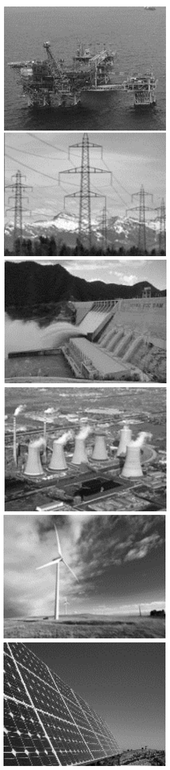
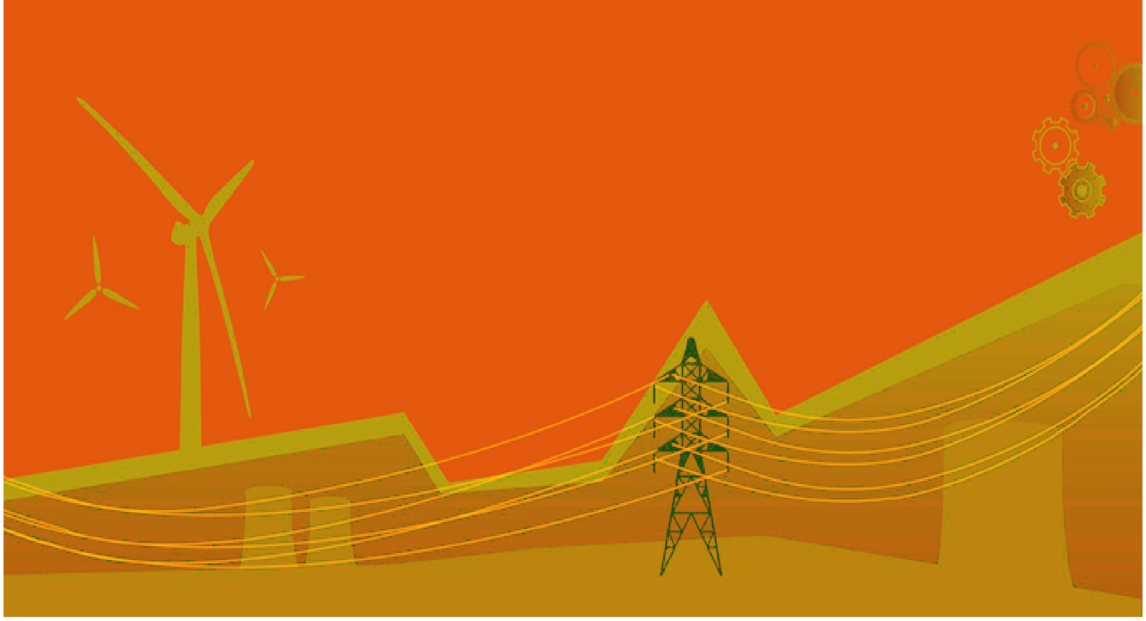
The Government of the Republic of the Union of Myanmar

National Energy Management Committee



Myanmar Energy Master Plan



December 2015

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Foreword

Myanmar's successful transformation into a democratic nation in 2010, opened the new development horizons in political arena and economic arena of the country. Since then, Myanmar is performing proactively and moving forward with the ultimate goal of achieving an "All-inclusive Sustainable Development".

Under the effective reform processes undertaken by the Government of the Republic of the Union of Myanmar, positive improvements have been evident in the economic performance of the country during the last five year. The country is also achieving the rapid economic growth and it is now a priority to sustain this development state by enabling access to sustainable and reliable energy supply.

Therefore, the Government of the Republic of the Union of Myanmar instituted the National Energy Management Committee (NEMC) on 9 January 2013 with the view of being a multi-ministerial coordinating body to comprehensively address all energy related issues in Myanmar. Since then, NEMC takes the leading role and the committee is implementing its priority duties and functions to ensure the development of energy sector, including the power subsector.

Under the Patronage of the Vice President of Myanmar, the committee is chaired by the Union Minister for Energy and the membership of the Union Ministers from energy related ministries and Senior Officials from two non-government organisations strengthen the structure of the committee.

After its establishment, NEMC encountered the urgent need of comprehensive energy policy and the committee initiated the formulation of draft National Energy Policy based on the current situation analysis of each energy subsector provided by energy concerned ministries. At the same time, Ministry of Energy received the technical assistance TA-8244 from the Asian Development Bank and two energy sector experts prepared the draft version of Myanmar's Energy Sector Policy 2013.

And then NEMC prepared the comprehensive energy policy paper based on two draft policy papers. After two years of close cooperation with relevant stakeholders, NEMC successfully accomplished the first mission to set up the policy framework for energy sector and the National Energy Policy was adopted on 6 January 2015. On the other hand, NEMC launched the Energy Master Plan Formulation Processes in 2014 under the Technical Assistance TA-8356 provided under the Japan Fund for Poverty Reduction and administered by the Asian Development Bank

During the planning process, international and national experts conducted several consultations with government agencies, private sector, international and non-international government organisations, civil society organisations and local communities in order to access the actual ground condition and to improve the data quality. Therefore, the Energy Master Plan sheds a good insight into Myanmar energy sector with information on locally available energy resources, history of energy sector transformation and consumption patterns and projections of future energy needs.

The Myanmar Energy Master Plan also provides the supply strategies through viable energy mix scenarios to secure the stable and reliable energy supply in the long term view. Moreover, this master plan is developed to ensure the efficient use of energy resources, to create effective investment environment, to employ innovative technologies and to minimize the environment and social impacts.

In summary, the Myanmar Energy Master Plan prioritises the long term benefit of the country by ensuring sustainable energy sector development and conserving the environment sustainably. The planning process is also designed to ensure the integration of Global and ASEAN commitments in Myanmar Energy Master Plan. Therefore, we hope that Myanmar Energy Master Plan can provide the strategic supports and inspirations to the Government of the Republic of the Union of Myanmar in adopting national strategies for sustainable and reliable energy supply, ultimately complementing to United Nation's Sustainable Development Goals of 2015.

In this regard, we express our profound gratitude to the Government of Japan and the Asian Development Bank for their support and dedication to this study. We also appreciate the international and national experts, government agencies, development partners, all the stakeholders and concerned persons for their genuine efforts, invaluable supports and contributions for the successful formulation of Myanmar Energy Master Plan.

National Energy Management Committee

AUTHORS

Michael Emmerton
Stuart Thorncraft
Sakari Oksanen
U Myint Soe
Kyi Kyi Hlaing
Yi Yi Thein
U Myat Khin

Project Number: TA No. 8356-MYA

FINAL REPORT

MYANMAR ENERGY MASTER PLAN

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Prepared for

The Asian Development Bank

and

The Myanmar Ministry of Energy

Prepared by

IES Intelligent Energy Systems

in association with

MMIC MYANMAR INTERNATIONAL CONSULTANTS

STRUCTURE OF ENERGY MASTER PLAN

1. The Energy Master Plan (EMP) has been structured to present a story that starts with Myanmar's economy and growth assumptions, a review of the historical outcomes for Myanmar's energy sector and an assessment of Myanmar's supply options. It then sets out the assumptions that underpin a number of projections of energy demand from 2014 to 2035. Together this forms the basis of a set of supply expansion plans that have been determined for five scenarios considered to span the range of cases considered plausible and possible at this time. The outcomes of each scenario, including their investment costs, risk profiles and other performance metrics are used to rank and prioritise each scenario and enable us to arrive at a final overall investment strategy in energy sector infrastructure for the country, which – following industry consultation – will form the basis of our final recommendations. We conclude the EMP with a number of recommendations for institutional arrangements that could be adopted in Myanmar to support integrated energy planning in Myanmar into the future.

2. As such, the EMP has been structured in the following way:

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Chapter D: Demand Forecasts

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- Vol. 2 Liquid and Gaseous Fuels Strategy
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EXECUTIVE SUMMARY

1. Intelligent Energy Systems Pty Ltd (IES) in association with Myanmar International Consultants Co. Ltd. (MMIC) were contracted by the Asian Development Bank (ADB) to undertake the following Technical Assistance (TA) project: "TA-8356 MYA: Institutional Strengthening of National Energy Committee in Energy Policy and Planning – 1 Energy Master Plan Consultant (46389-001)". The key objective of the TA project was to prepare a Long-Term Energy Master Plan for the energy sector of Myanmar.

2. A national Energy Master Plan (EMP) defines a long-term optimal fuel supply mix taking into account a country's primary resource endowments. The EMP is guided by the principles of long-term cost effectiveness, environmental responsibility and security of energy supply.

3. The EMP has been prepared from a strategic perspective requiring that all concerned Ministries align to a common energy development plan based on an understanding of fundamental economic development needs. According to government policy preference the EMP predicts that Myanmar's energy sector will be require an investment of between USD 30 to 40 billion over a 15 to 20 year period. The outlook for the supply of natural gas in particular is uncertain and the EMP recognizes a potential constraint in the next decade. In an environment where there are technology choices and resource constraints a strategic approach is needed to decide the best use of energy in support of national development goals.

A. Economic Development of Myanmar

4. In 2014, Myanmar stands at the beginning stages of the development of a market economy. A privatization program is in place and the Myanmar Government is actively encouraging foreign investment in all sectors of the economy. Market sentiment is, by many accounts, running high as foreign investors explore the possibilities. Whilst Myanmar's State Economic Enterprises continue to play a dominant role in the economy, supplying intermediate and final products to local markets, foreign investors with international market reach can be expected to seek opportunities to supply international markets with commodities and products that they can produce in Myanmar to international standards and with healthy profit margins. If experience elsewhere is a guide, foreign investors will aim to leverage Myanmar's factor endowments; low cost educated labour in particular may be of interest to industrialists bringing capital to Myanmar. On the other hand Myanmar's business leaders consistently report in the social media that skilled labour is in short supply in Myanmar. The implication is that, in addition to capital formation, the achievement of Myanmar's development goals will require significant human resource development. The re-deployment of labour between sectors of the economy is likely to be a major challenge.

A. **Primary Sector.** As the primary sector employs some 60-70% of the active workforce, there is a consensus amongst international agencies, such as the Livelihoods and Food Security Trust Fund and USAID, that Myanmar's prosperity will be tied to the productivity of agricultural land and agricultural labour for the coming decades. A reputable study, conducted jointly between Myanmar's Yezin Agricultural University and the University of Kassel (Germany) concluded that land productivity can be improved significantly through increased use of fertilizers and improved water management[1]. A USAID-funded agricultural strategy diagnostic study[2] conducted in 2013 concluded that "all of these impediments [to the performance of the agriculture sector] can be remedied through good policies,

[1] A Survey of Myanmar Rice Production and Constraints; Naing, Kingsbury et al, 2008
[2] A Strategic Agricultural Sector and Food Security Diagnostic for Myanmar; USAID/MDRI/CESD, July 2013

institutional reforms and key public investments". Chief amongst the USAID team's observations was the importance of food security. Higher yields of crops would serve both food security and export needs; however, in an environment where it is reported that poor households spend 70% of their income on food, and there is a large population of landless poor, there is clearly a case to approach agricultural reform with some caution. Furthermore the economic growth of the secondary and tertiary sectors will potentially result in a competition for primary sector labour resources, with implications for food production.

The contribution of fisheries, livestock and forestry to primary sector GDP was reported by the Central Statistics Organisation of Myanmar to be 32% in 2013, following a period of several years of strong growth in the export of fish products. Since 2008 there have been concerns raised over the future of seafood exports due to over-fishing, particularly in the case of shrimp, but nevertheless fishing sector GDP growth has continued to 2013. In forestry, there have been reports tabled in the public domain that indicate that the quality of exported teak has fallen over the last decade with adverse impact on export revenues. Furthermore, that land clearing and illegal logging is resulting in an unacceptable rate of deforestation of upwards of 1% per annum.

The Myanmar Government has responded to these concerns with a Millennium Development Goal (MDG) target to increase forest coverage from 48.3 percent in 2010 to 68 percent in 2020[3]. It is interesting to note that none of the discussion papers, published during the last decade by forestry expert groups, has drawn a link between deforestation and the use of firewood and charcoal, except in the case of the delta region where it has been reported that the mangrove forests have been severely impacted by harvesting for charcoal production. As in other countries the forestry sector is challenged by the need to balance economic and environmental interests.

B. **Secondary Sector.** The prospect for economic growth led by industrialization appears to be mixed. In mining, Myanmar is endowed with a wide variety of mineral deposits. However, the proven reserves are relatively small by comparison to those of countries that currently dominate each mineral market. Moreover, Myanmar's large mineral deposits are located in remote areas of the country where there is currently no rail or road infrastructure. In the case of mineral processing, the production of iron and steel, copper concentrate, tin and tungsten concentrate is well established in Myanmar. Mineral processing in Myanmar is undertaken at the mine-mouth and production levels are dictated by local market demand. Given the scale of mining in Myanmar, it seems likely that minerals processing will continue to develop to service local market demands. Companies with established footholds in Myanmar's mining industry will continue to lead the way through small-scale mining ventures. It follows that over the long-term the mining industry is likely to grow at a modest pace.

One of the unusual features of Myanmar's heavy industry sector is the dominance of the cement industry in the use of energy; this reflects the local nature of the existing industry structure. In the power, oil and gas subsector, Myanmar's willingness to sell oil and gas to its near neighbours impacts GDP growth in two ways, firstly in terms of royalties, taxes and employment and secondly in terms of the oil and gas that is secured from international investors for the purposes of local consumption. Where foreign investors develop oil and gas fields for export, it is only the allocation of the energy carriers reserved for national energy supply that are of direct relevance to national energy planning. Given that a significant proportion of the gas being produced in Myanmar is being sold internationally, there is clearly a need to consider how electricity production can be increased economically with available resources and how it will be best to supply petroleum products to address local production to serve growing demand. Strong growth is expected in the power and gas

[3] Myanmar Comprehensive Development Vision, Chapter 5, p9

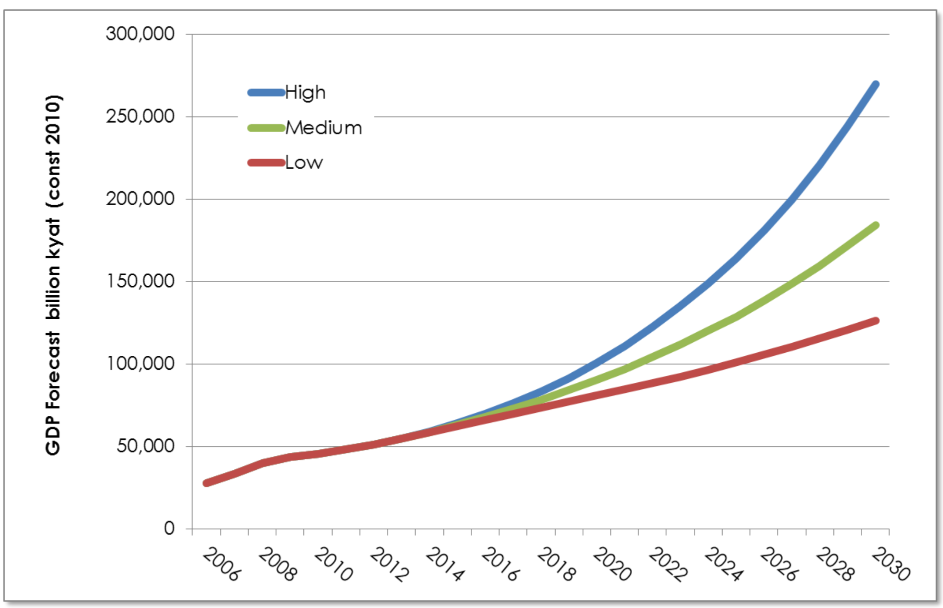
subsectors, albeit dependent on an injection of substantial foreign direct investment (FDI).

The construction sector will need copper wire; bricks; glass and cement (aluminium products will continue to be imported); clearly the production of these products will rely on energy intensive local industries that in turn will rely on stable energy supplies. In manufacturing, growth can be expected to continue steadily, with the notable prospect of rapid growth in the Ready-Made Garments (RMG) industry. Overall it appears that the growth of the secondary sector observed during the last decade will continue, albeit with potential for acceleration in the coming decades, as multi-national corporations (MNC's) invest in the sector.

C. **Tertiary Sector.** Economic growth in the services sector is partly a consequence of economic growth in the primary and secondary sectors of the economy. Services sector growth is sensitive to international trading; export activity requires financial services, trading and logistics services. Retail activity, including the restaurant trade, will continue to grow in line with population growth and growing income. Tourism and eco-tourism will grow largely independent of the other sectors of the economy; in time tourists can be expected to demand services that depend on reliable energy, communication and transport infrastructure. The hotel trade will benefit from increasing visitor arrivals for both tourism and business purposes.

5. Strong economic growth is anticipated by the Asian Development Bank in all sectors of the economy[4]. Compound annual growth rate projections range from 4.8% to 9.5% with a most likely growth scenario of 7.1%. This most likely growth scenario was also the official target of the government at the time of preparation of the EMP. If this most likely growth rate is achieved it will mean that Myanmar will have exceeded the economic performance of most Asian developing countries (with the exception of People's Republic of China (PRC) which has recorded a growth of 9.5% for a 15 year period).

Figure E1: Myanmar GDP Projection: 2006 to 2030



Source: Consultant, ADB Economic & Research Policy Unit (August 2014)

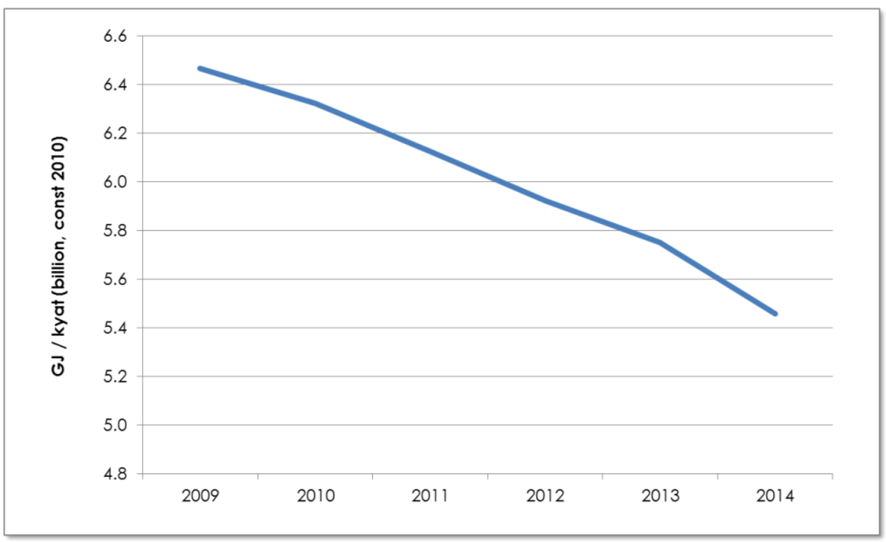
[4] Myanmar Unlocking the Potential, ADB (August 2014)

6. Economic growth will require resources – capital, labour and energy supply. For the purpose of energy planning, it is assumed that capital formation will support the achievement of GDP growth under any scenario that is envisaged. In the case of labour and energy supply however, it is necessary to quantify the relationship between agricultural sector labour productivity and energy use to understand the potential for labour to be released from the primary sector to supply the secondary and tertiary sectors to support growth.

7. Myanmar's labour work force is expected to grow at a modest rate of 2.3% to 2020, falling to 1.2% thereafter[5]. High growth in all sectors of Myanmar's economy could be expected to lead to a competition for scarce labour. Myanmar's business leaders consistently report that there is a shortage of skilled labour and so it appears that the competition for labour will increase. Such competition is the reason that rural populations decline in industrializing nations when higher wages are offered by industry. In other countries, the release of agricultural labour to industry has been accompanied with increasing levels of farm mechanization and therefore energy consumption. Farm mechanization is essential to the maintenance of food security.

8. Energy intensity, a measure of energy input per unit of GDP, typically increases during the transition from a developing to middle income status. In fact, Myanmar's energy intensity trend of recent years has shown a decline; however, this appears to reflect the impact of gas sales on GDP because gas production, transport and sales, in itself, is not an energy intensive activity.

Figure E2: Myanmar Energy Intensity (2009 to 2014)



Source: Consultant, World Bank Development Indicators 2014

9. The growth assumptions which formed the basis for energy planning were as follows:

A. A compound annual GDP growth rate of 7.1%

B. A population growth rate of 1%

C. An increase in food production for local and export consumption, from 3.7 to 5.2 tons per hectare

D. An electrification access ratio rising from about 31% in 2014 to 87% by 2030

E. A target compound annual growth rate in passenger and freight services demand of 3.7% and 3.5% respectively (2012 to 2030) requiring adequate refined oil products,

[5] Myanmar Comprehensive Development Vision (2013); Appendix_Growth prospects

and

F. A target energy efficiency improvement in rural areas, evidenced through an environment of sustainable use of forest resources, maintaining total firewood consumption at around 17 million tons per annum despite a growing population.

B. Final Energy Consumption

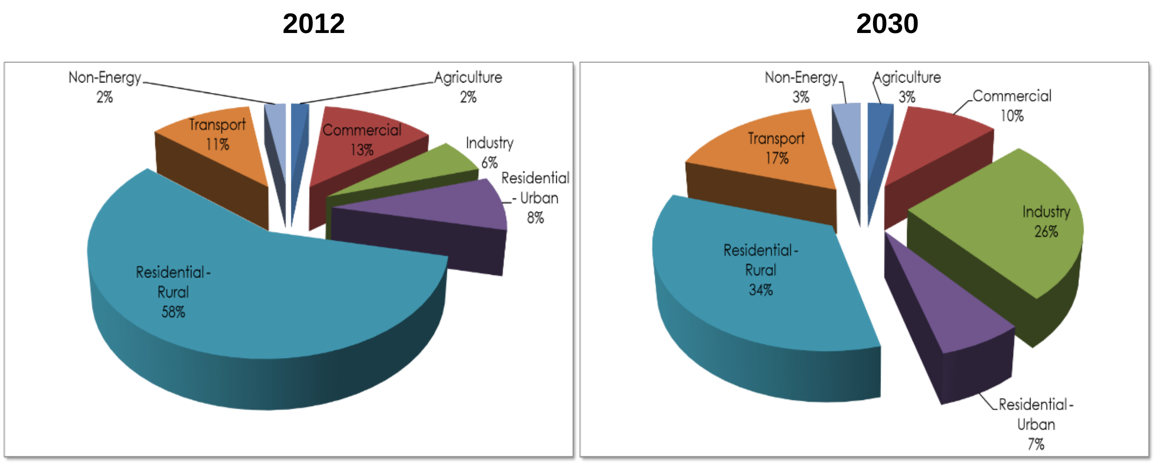
10. A breakdown of the estimated final energy consumption (FEC) in 2012 is given by Figure E2. This chart shows the relative consumption of each economic sector and the household sector. Total FEC is estimated to have been 12.2 mtoe in 2012. At 66% of FEC, the residential sector was the largest energy consumer, due to the use of fuel wood for cooking.

11. The FEC forecast for Myanmar is forecast to rise from 12.2 mtoe in 2012, to 21.9 mtoe by 2030, at a compound annual growth rate of 3.0%. The increase reflects GDP growth, population growth and the impact of rural electrification.

12. A breakdown of the estimated FEC in 2030 is given by Figure E3. It can be seen from Figure E3 that the industry and transport sectors grow significantly, reducing the proportion of FEC of the residential sector. Nevertheless the residential sector remains the largest energy consumer by virtue of the large population and dependence on low efficiency cooking using fuel wood.

13. With regard to rural electrification, experience in other countries shows that access does not necessarily result in subscription. The ADB instructed that electricity forecasts should be based on an assumption of 87% electrification by 2030. This accords to a specific average household consumption of around 800 kWh per household by 2030.

Figure E3: Final Energy Consumption



Sources: Ministries of Myanmar, Consultant estimates based on EMP surveys

14. Consumption benchmark data were developed from a 1,000 household survey, an energy-intensive industry survey covering all large enterprises, and a Small-to-Medium Enterprise (SME) survey of some 100 premises including restaurants, hotels and business associations. This information was used to estimate the specific consumption associated with the drivers of energy use in each sector. Household (HH) energy consumption, on kgoe per HH basis, compares well with international benchmarks[6] and was used for the purpose of HH energy projection.

[6] EarthTrends (http://earthtrends.wri.org) Searchable Database Provided by the World Resources Institute (http://www.wri.org): Energy and Resources – Energy Consumption: Residential energy consumption per capita

Table E4: Final Energy Consumption

	2009	2012	2015	2018	2021	2024	2027	2030
Urban HH Cooking[1]	519.6	516.2	484.9	455.2	426.6	398.8	372.7	324.7
Urban HH Lighting[2]	2.1	2.2	2.1	2.1	2.0	2.1	2.2	2.1
Urban HH TV / Entertainment[3]	0.1	0.1	0.2	0.3	0.4	0.5	0.5	0.6
Urban HH Other[4]	8.6	29.9	24.3	29.0	34.6	38.0	54.2	112.8
Urban HH Total	*530.4*	*548.4*	*511.6*	*486.6*	*463.6*	*439.4*	*429.6*	*440.3*
Rural HH Cooking[5]	615.6	604.7	594.1	583.5	567.4	540.5	514.8	486.0
Rural HH Lighting[6]	2.1	2.1	2.1	2.1	2.0	2.0	1.9	1.8
Rural HH TV / Entertainment[7]	0.1	0.1	0.2	0.2	0.3	0.4	0.4	0.5
Rural HH Other[8]	2.6	5.7	5.7	7.4	9.8	13.1	19.7	35.3
Rural HH Total	*620.3*	*612.6*	*602.0*	*593.3*	*579.6*	*556.0*	*536.9*	*523.7*
Average Urban & Rural (wtd)	*607.6*	*603.5*	*588.6*	*576.7*	*560.7*	*536.1*	*517.7*	*508.1*

Notes: 1. Use of commercial fuels continues. 2. Candles and wick lamps replaced. 3. Leisure hours increasing. 4. Air-conditioning, refrigeration, fans, other. 5. Increase in line with population rise. 6. Firewood displaced by electricity. 7. Candles and wick lamps replaced. 7. Leisure hours increasing. 8. Refrigeration, fans, other, cottage industry.

Table E5: Total Final Energy Consumption (TFEC, mtoe)

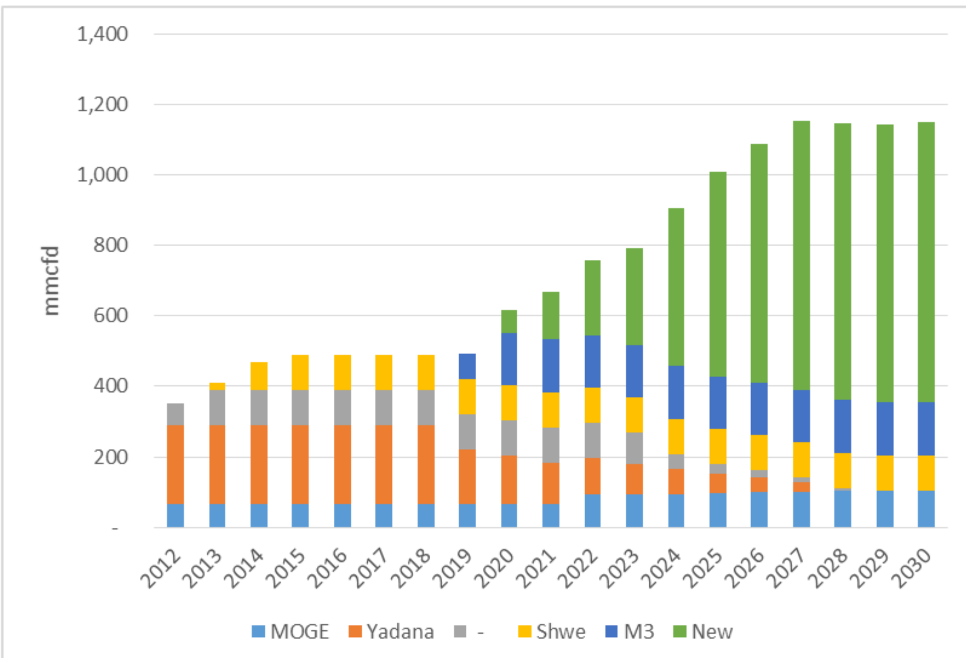
	2012	2015	2018	2021	2024	2027	2030
TFC	12.6	14.2	15.3	16.5	17.9	19.6	21.9
Coal	0.1	0.1	0.2	0.2	0.3	0.4	0.6
Oil	2.5	3.4	3.6	4.0	4.4	4.9	5.5
Gas	0.6	0.9	1.2	1.5	2.0	2.5	3.2
Electricity	0.7	1.0	1.3	1.8	2.4	3.2	4.3
Biomass Type II	8.8	8.9	9.0	9.0	8.8	8.6	8.4
Shares (%)							
Coal	0.6	0.8	1.1	1.4	1.7	2.1	2.5
Oil	19.3	23.9	23.7	23.9	24.5	24.8	25.0
Gas	5.0	6.2	7.7	9.3	11.0	12.7	14.4
Electricity	5.5	6.7	8.7	10.9	13.5	16.4	19.6
Biomass Type II	69.6	62.3	58.8	54.5	49.2	43.9	38.5
TOTAL INDUSTRY	0.7	1.2	1.7	2.4	3.3	4.3	5.7
Coal	0.07	0.11	0.16	0.23	0.31	0.42	0.55
Oil	0.06	0.09	0.11	0.14	0.18	0.22	0.28
Gas	0.29	0.48	0.71	1.01	1.38	1.85	2.44
Electricity	0.28	0.47	0.71	1.01	1.38	1.85	2.43
Biomass Type II	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Shares (%)							
Coal	10.7	9.5	9.5	9.5	9.6	9.7	9.7
Oil	8.1	7.9	6.7	6.0	5.5	5.1	4.9
Gas	41.6	41.3	41.9	42.3	42.5	42.6	42.8

	2012	2015	2018	2021	2024	2027	2030
Electricity	39.6	41.3	41.9	42.2	42.4	42.6	42.7
Biomass Type II	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TRANSPORT	1.4	2.3	2.3	2.5	2.8	3.2	3.7
TOTAL OTHER SECTOR	10.54	10.86	11.25	11.61	11.82	12.08	12.51
Coal	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Oil	0.99	1.09	1.20	1.32	1.42	1.47	1.51
Gas	0.31	0.37	0.44	0.51	0.57	0.64	0.70
Electricity	0.42	0.49	0.62	0.79	1.03	1.37	1.86
Biomass Type II	8.82	8.90	9.00	8.99	8.80	8.61	8.43
Shares (%)							
Coal	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Oil	9.4	10.1	10.7	11.4	12.0	12.1	12.1
Gas	2.9	3.4	3.9	4.4	4.8	5.3	5.6
Electricity	4.0	4.5	5.5	6.8	8.7	11.3	14.9
Biomass Type II	83.7	82.0	79.9	77.5	74.4	71.3	67.4

C. Primary Energy Resources

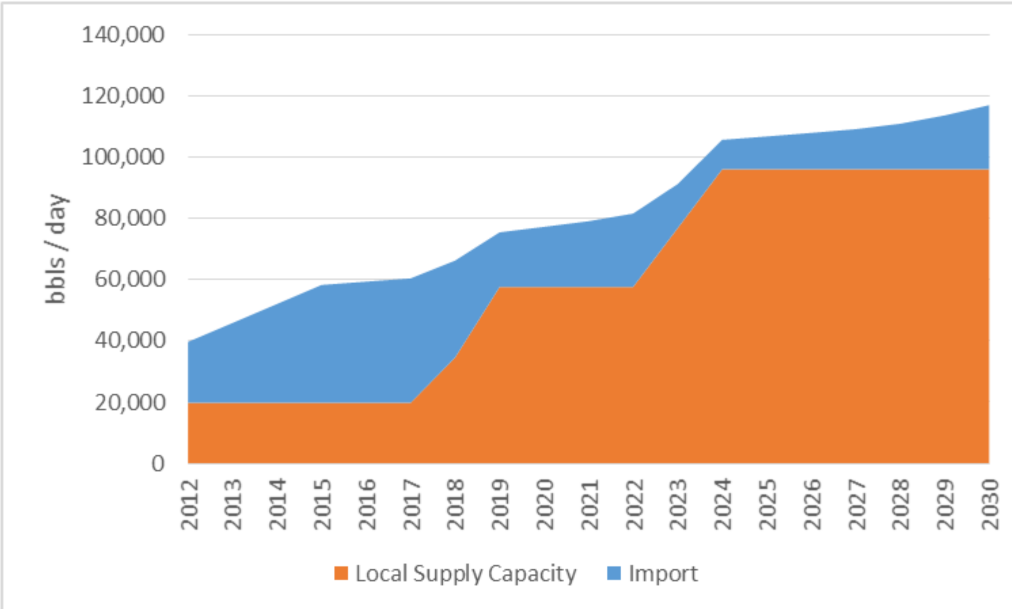
15. The Republic of the Union of Myanmar possesses large resources of natural gas. It plays a significant role in the country's energy mix: in recent years natural gas accounted for 45% of the total primary energy production. At home the natural gas was mainly used for electricity production and industrial purposes, whereas the largest part of the gas produced in Myanmar was given for export. Myanmar's proven petroleum gas reserve lies between 6 and 32 times the energy value of proven oil reserves, according to whether the Ministry of Energy or US Energy assessments are correct. Pending further discoveries of oil, it is only Myanmar's petroleum gas that can be considered to be a strategic resource – it is in demand internationally, whereas locally gas could potentially be allocated to pharmaceutical and chemical industry processes, to fertilizer production, to the production of refined petroleum products, to power production, for passenger vehicles, and as a cooking fuel as economic development takes place. In recent years the Government has considered the possibility to establish an LNG terminal to supplement indigenous natural gas supplies.

Figure E6: Projection for Gas Supply (JICA 2014)



16. In the case of oil, the first step in defining the strategy for liquid fuels is to identify what should be done with the country's existing refinery capacity. Three small refineries are currently in operation in Myanmar, but all three are old and their operating efficiency is low. Even if the Myanmar Petroleum Enterprise decides to upgrade at least one of the existing refineries, the throughput will not be sufficient to cover the increasing demand; hence the strategy for liquid fuels must be based on construction of new capacity and / or by importing. Myanmar has the right to use 50 000 bbl/day of the transfer capacity of the Sino-Burma pipeline, which could be used as a feedstock for a potential new refinery. For the imports there are initial plans for a new import terminal, which could at a later stage support a new local refinery. However, it is believed that a small scale coastal refinery may not be economically feasible under the competitive pressure from large, world class refineries in the Middle East, India and Southeast Asia. Locating a refinery inland, adjacent to the pipeline, could result in a competitive advantage as production would be close to consumption which would in turn reduce transportation costs.

Figure E7: Oil Production Local vs. Import (physical)



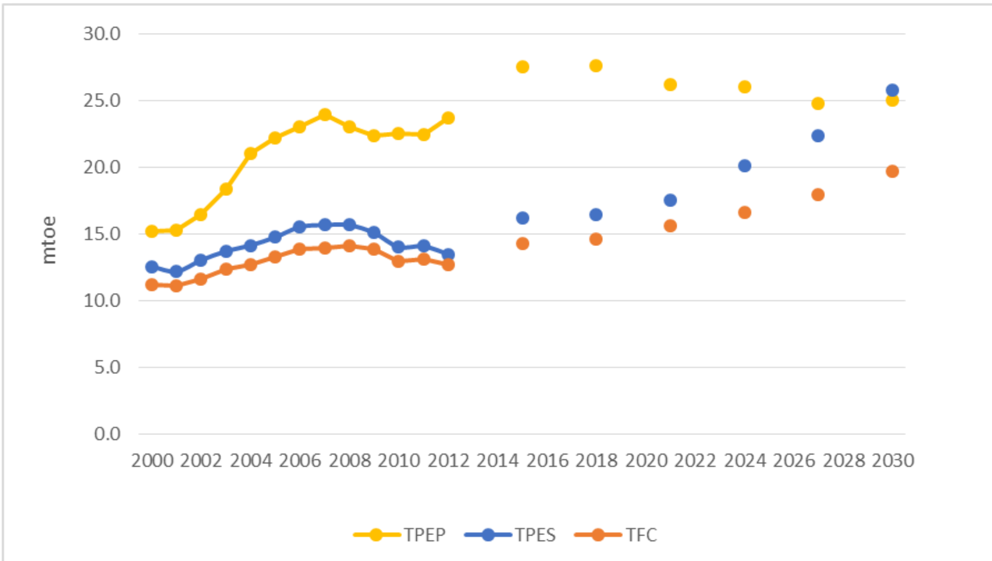
17. In the case of coal, the Consultant has assumed that all coal used to power large coal-fired plants (in coastal locations) will be imported bituminous coal of high calorific value. Industrial need for coal will be met mainly with indigenous coal.

18. In the case of fuelwood, the Consultant has assumed that primary energy production is equivalent to primary secondary energy production. There was insufficient data available to quantify fuelwood losses arising between forests and distribution centres. Furthermore the conversion losses associated with the burning of fuelwood has not been accounted for in the energy balance – such losses are important from an energy efficiency standpoint, but from an energy balance perspective they occur within consumer premises and are therefore ignored.

D. Total Energy Production Outlook

19. Total Primary Energy Supply (TPES) and Total Energy Production (TPEP) is forecast as shown by Figure E8. It can be observed that local production capacity (TPES) rises to create a healthy margin over TFEC. TPEP falls as gas production and export reduces to the point where Myanmar becomes a net importer of energy (slightly).

Figure E8: Total Supply & Demand Outlook



Sources: 2000 – 2012 IEA, MoE; 2013 – 2030 Consultant estimate

20. Figures E9 and E10 show the change in fuel mix composition for TPES from 2015 to 2030. It can be seen clearly that the composition of the fuel mix could change dramatically over a 15 year period, due in particular to the growth in electricity displacing the use of fuelwood for household cooking in rural areas. Other changes are related to the growth in demand for passenger and freight services. Also the increased use of coal for power production after 2020.

Figure E9: TPES – Fuel Mix 2015

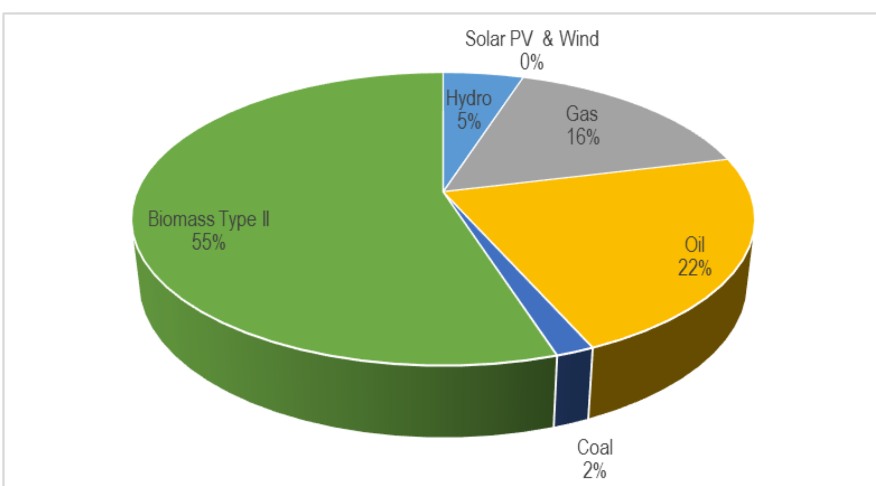
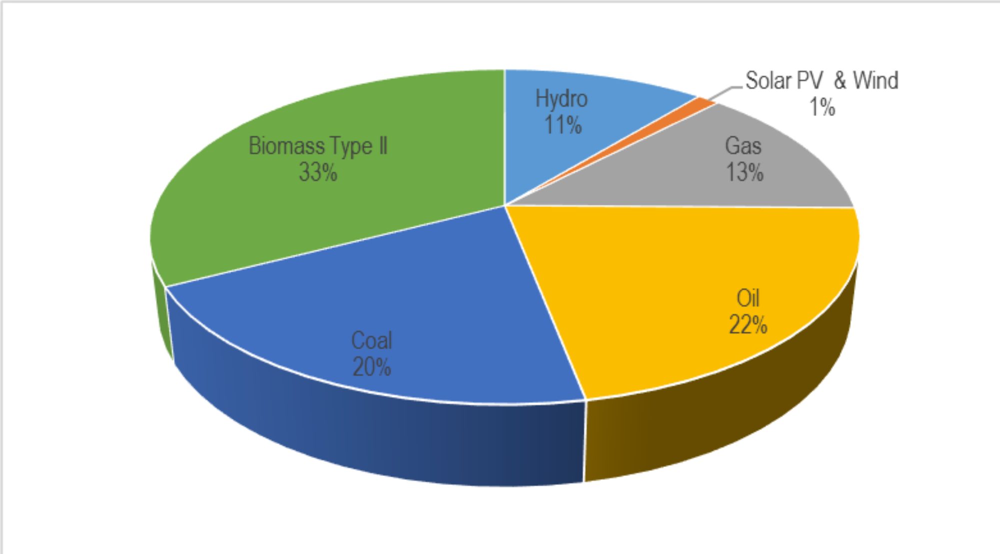


Figure E10: TPES – Fuel Mix 2030

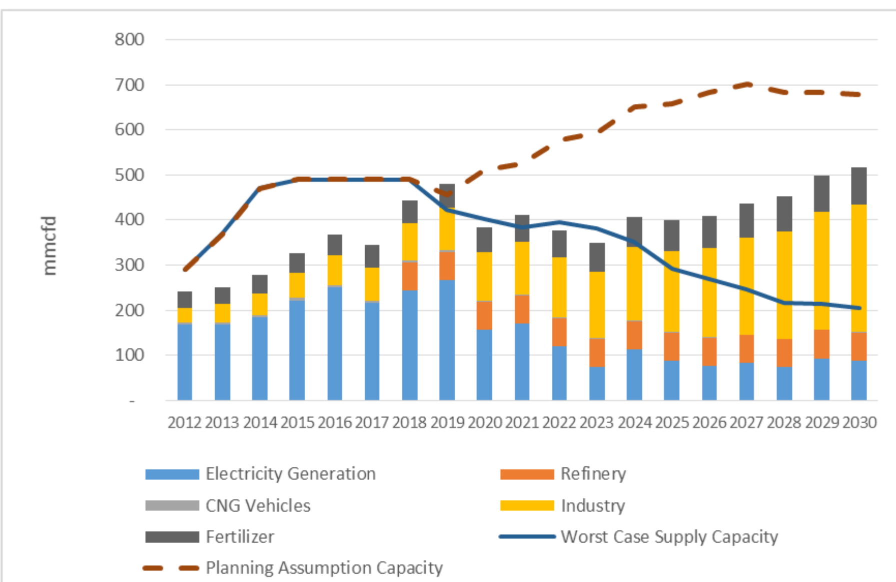


Sources: 2000 – 2012 IEA, MoE; 2013 – 2030 Consultant estimate

21. It has been assumed that a local oil refinery will be constructed by 2019. The capacity will initially be 50 000 bpd. The projection for refined oil products suggests that additional capacity of 50 000 bpd will be required by 2024. Nevertheless in most years it will be necessary to import gasoline and diesel fuels. It has been assumed that LPG will be totally imported from 2020.

22. The projection for gas supply – demand shows that the outlook is tight. Figure E11 shows projected demands for gas, a worst-case gas supply outlook and a more optimistic gas supply outlook. The projection shows that the M3 gas field will be needed to meet demand. If there is any delay to the development of the field it could result in a sustained supply shortfall from 2018.

Figure E11: Projections for Natural Gas Supply & Demand by Sector



23. There is an opportunity to manage the risks that natural gas supplies do not develop as anticipated. If required, fuel imports can be used to supplement the supply to the transportation and agriculture sectors to release the capacity required to serve the industry and power sectors. Nevertheless, ahead of the development of firm supplies of natural gas, it is considered as a prudent practice to minimize the use of natural gas in the power sector in favour of allocation to industry.

Table E12: Gas Supply Risk Mitigation circa 2019

	MMCF	MMCFD	Comment
Refinery	22,630	62	Hydro-cracking refinery needs hydrogen and usually powered with natural gas power plant
Power	81,030	222	EMP estimate
Fertilizer	20,552	56	Standard-run production plant 1 725 mtpd
Industry	38,623	106	EMP estimate
Total	~165,000	~548	
Available gas	~150,000	~411	Yadana, Yetagun, Shwe, Zawtika
Potential to Reduce Gas Consumption			
Refinery	(7,500)	(21)	Power the refinery using liquid fuels (30 – 40 MW)
Power sector	(30,250)	(83)	Increase hydropower, gas / oil plant
Fertilizer	(10,000)	(27)	Import fertilizer
Total	(50,000)	(137)	

24. The refinery design can be modified to minimize gas consumption. In principle the use of gas for power generation could be replaced by oil or storage hydropower capacity for deployment at times of peak demand. A fertilizer plant appears to be uneconomic and gas could be saved by importing urea. These measures have been assumed ahead of the development of an LNG terminal because the cost of LNG will be high and market acceptance may therefore be low.

25. Table E13 provides a projection for Myanmar's electricity output shares in terms of fuel consumption to 2030. It can be seen that the composition of electricity output could change significantly with a reduced dependence on hydropower and increased dependence on coal.

Table E13: Electricity Demand & Transformation Losses

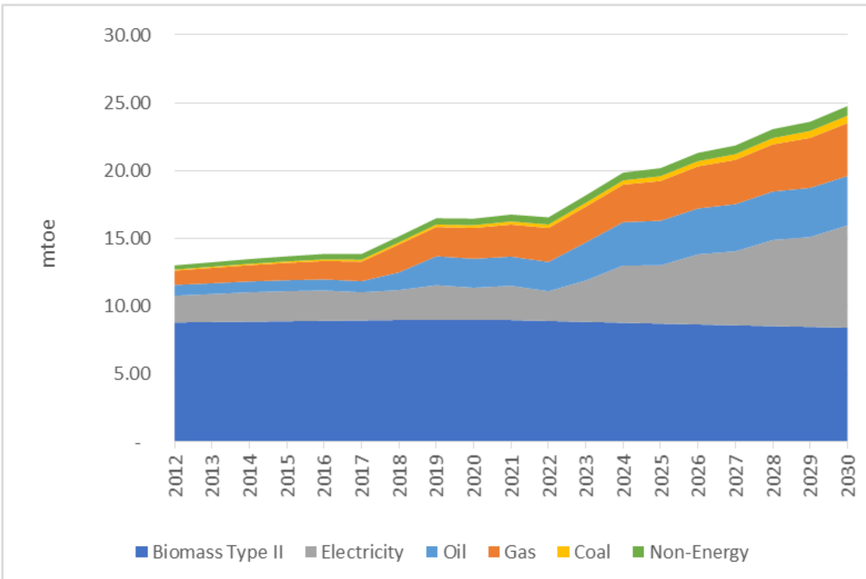
	2012	2015	2018	2021	2024	2027	2030
INPUT (mtoe)	1.97	2.22	2.21	2.52	4.22	5.45	7.54
OUTPUT Electricity (GWh)	10,364	14,398	19,446	25,763	33,904	44,238	57,654
Electricity output shares (%)							
Hydro	69.7%	65.0%	56.5%	74.1%	64.0%	65.7%	57.1%
Solar PV	0.0%	0.0%	0.0%	0.0%	0.0%	2.0%	5.2%
Wind	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Natural gas	28.1%	33.4%	38.9%	22.4%	12.7%	8.3%	8.2%
Oil	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Coal	2.2%	1.6%	4.6%	3.4%	23.3%	24.0%	29.5%

	2012	2015	2018	2021	2024	2027	2030
TOTAL LOSSES (mtoe) of which:							
Electricity generation	0.37	0.52	0.98	0.76	1.70	2.07	3.21
T&D losses	0.19	0.24	0.30	0.36	0.42	0.50	0.58
Total	0.56	0.76	1.27	1.12	2.12	2.57	3.79
Electricity generation[1]	18.6%	23.5%	44.1%	30.1%	40.3%	38.0%	42.6%
T&D losses	9.6%	10.8%	13.4%	14.1%	10.0%	9.2%	7.7%
Total	28.2%	34.3%	57.6%	44.2%	50.4%	47.2%	50.3%

Note: 1. Projection based on ADICA electricity expansion plan, which is attached in Appendix 4.

26. Table E14 is given in chart form by Figure E8. It can be seen that as a result of rural electrification, the use of biomass type II (fuelwood) falls with time. The growth in electricity in particular replaces the need to produce and consume fuelwood thereby easing pressure on Myanmar's forests. Oil, gas and coal production requirements increase with economic development.

Figure E14: TPES – Total Primary Energy Supply Forecast (mtoe)



27. The production of all other fuels gradually increases over time as the population grows and the economy further develops.

Table E15: Compound Annual Growth Rate Projections – TPES

Fuel	CAGR	Comment
Total Primary Energy Supply	3.4%	
Secondary Conversion Efficiency	4.2%	Average fuel conversion loss not including losses in consumer's premises
Import	-1.3%	
TFEC	3.0%	
Total Primary Energy Supply Composition		

Fuel	CAGR	Comment
Electricity	7.6%	Rural electrification
Oil	8.9%	Vehicle ownership and freight
Gas	7.3%	Power production and industrial growth
Coal	10.9%	Power production
Biomass Type II	-0.3%	Rural electrification replaces fuelwood

28. The physical forecasts for Total Primary Energy Supply are given by the following charts:

Figure E16: Oil TPES Forecast (bblsd)

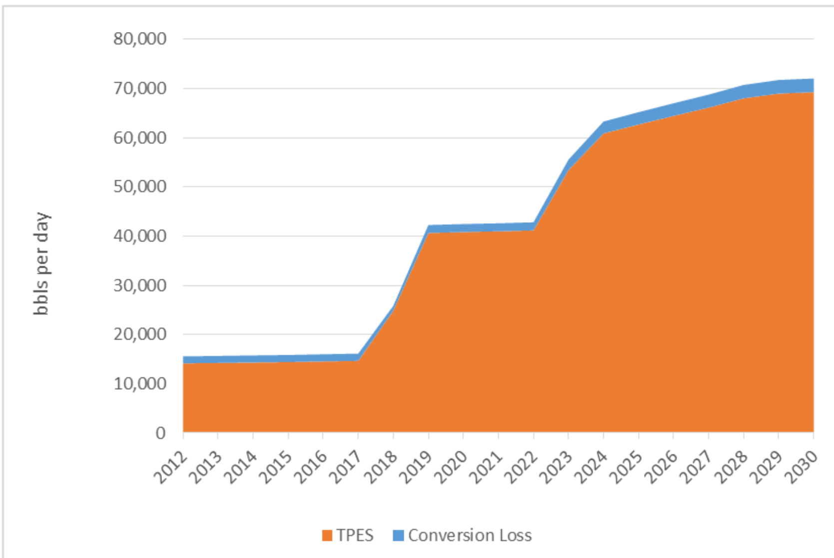


Figure E17: Natural Gas TPES Forecast (mmcfd)

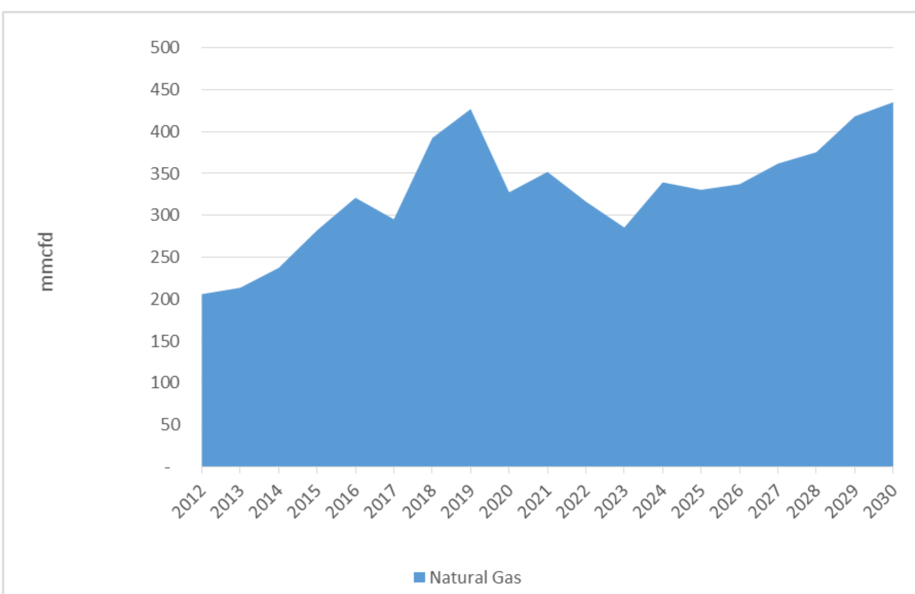


Figure E18: Coal TPES Forecast (tons per annum)

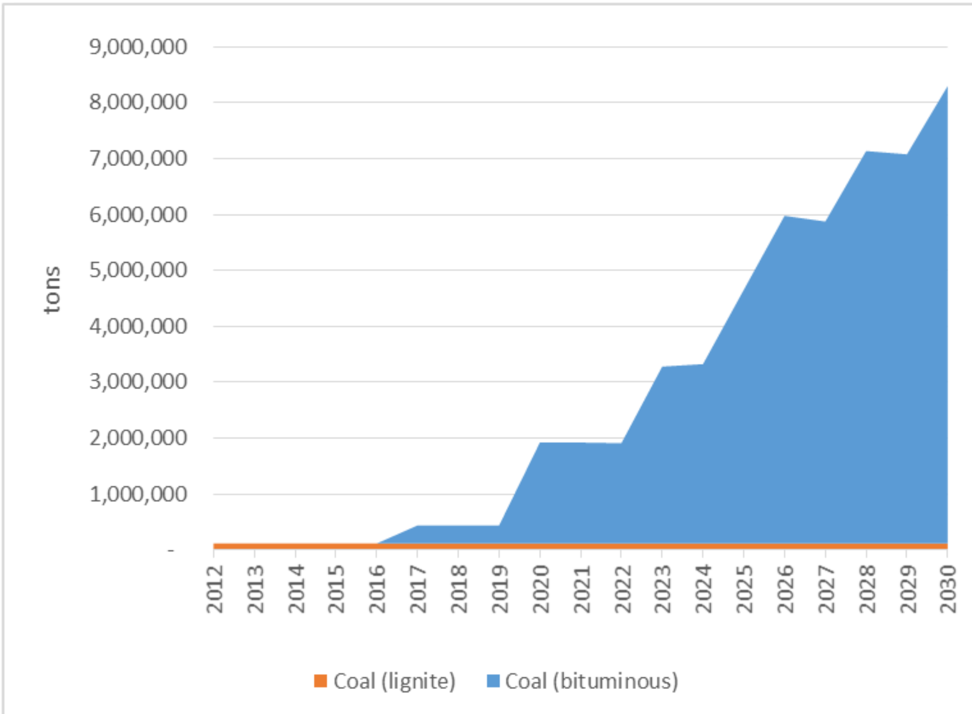


Figure E19: Fuelwood TPES Forecast (tons per annum)

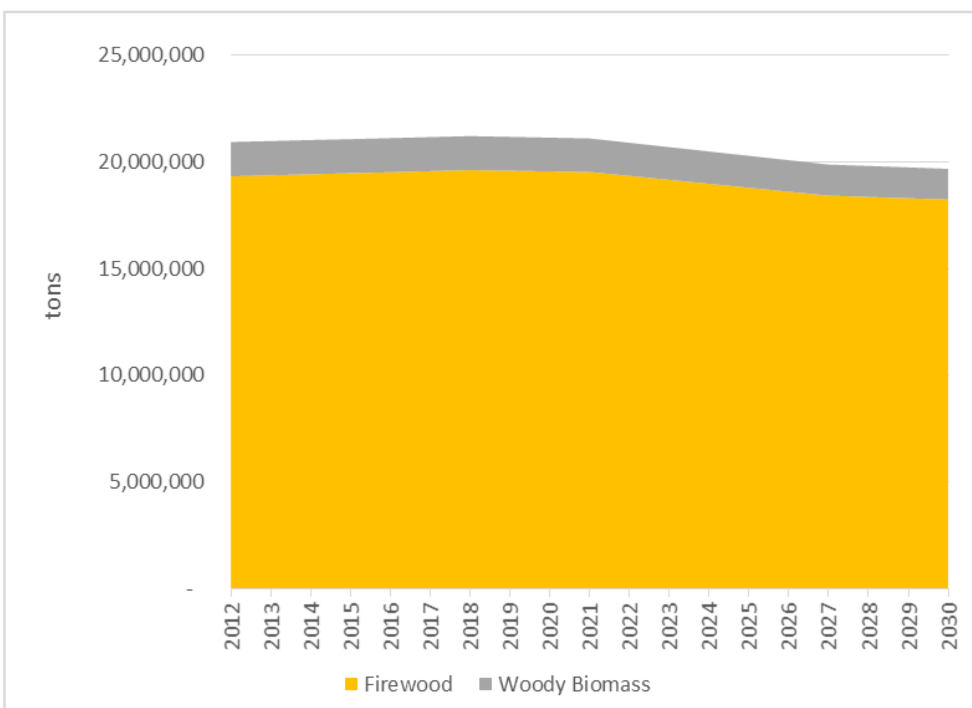


Figure E20: Electricity TPES Forecast (GWh)

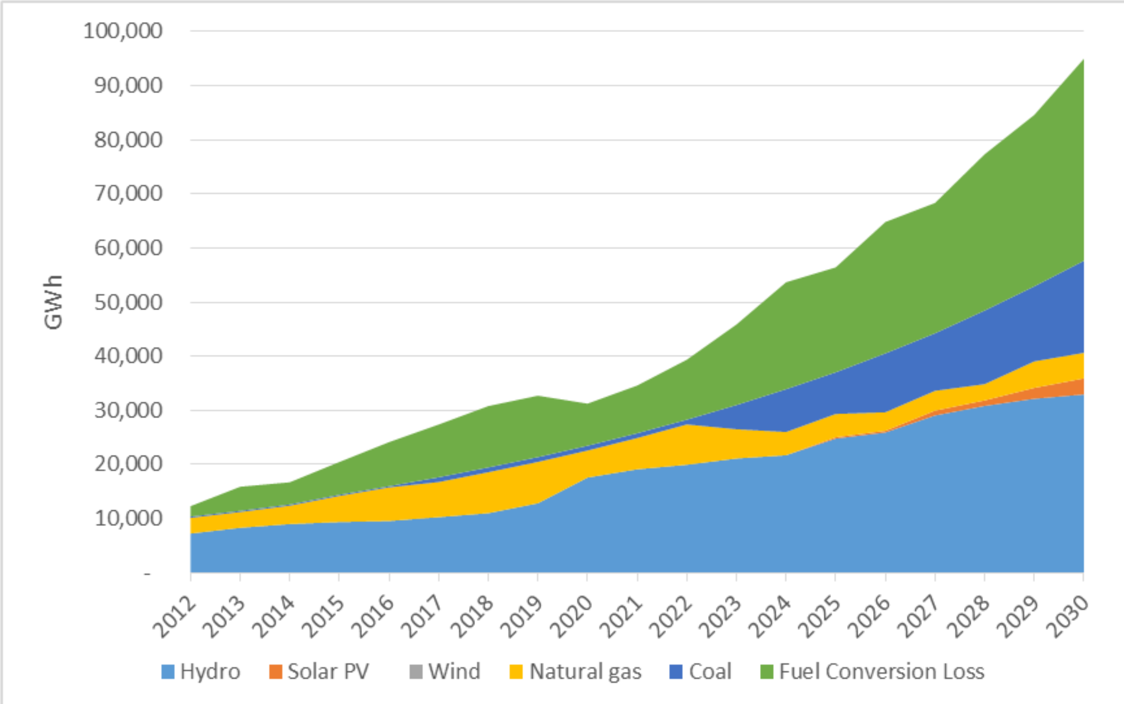
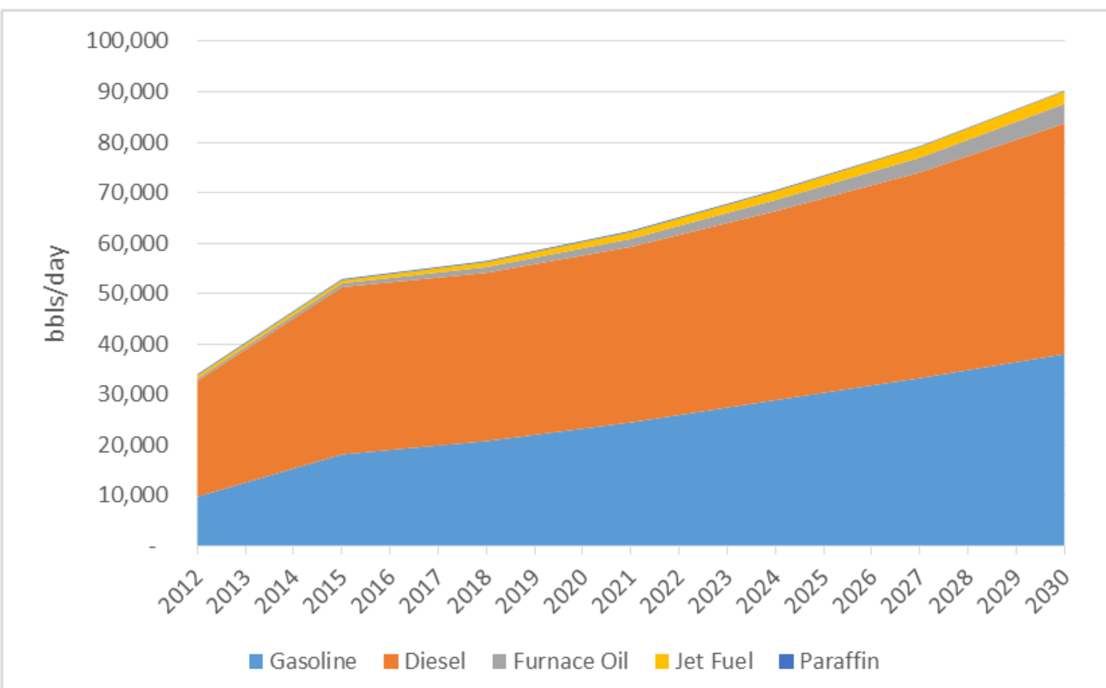


Figure E21: Refined Oil Products TPES Forecast (bblsd)



Source: Consultant's analysis

29. Table E22 and Table E22 provides an Energy Balance projection for Myanmar to 2030. This Energy Balance projection is based on the abovementioned projections for TFEC and TPES. In the case of exports, it is only Myanmar's allowance of Saudi crude oil that appears in the Energy Balance. Gas exports to Thailand and PRC appear in the energy balance because the gas is produced in Myanmar. Hydropower electricity produced by Chinese merchant hydropower plants, and exported directly to PRC, is not included in the Energy Balance.

Table E22: Energy Balance Projection to 2030 (mtoe)

	2012	2015	2018	2021	2024	2027	2030
TOTAL PRODUCTION	23.7	27.5	27.7	26.3	26.4	24.9	25.1
Hydro	0.7	0.8	0.9	1.6	1.9	2.5	2.8
Solar PV & Wind	0.0	0.0	0.0	0.0	0.0	0.1	0.3
Gas	13.0	16.6	15.7	12.8	11.3	9.1	8.5
Oil	1.0	1.0	1.5	2.2	3.5	3.6	3.6
Coal	0.2	0.3	0.5	0.7	0.8	1.1	1.3
Biomass Type II	8.8	8.9	9.0	9.0	8.8	8.6	8.4
TOTAL NET IMPORTS	-10.2	-11.3	-11.2	-8.7	-6.2	-2.5	0.8
Hydro Exports	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Imports	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Net Imports	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Natural Gas Exports	11.9	13.9	13.9	11.1	9.5	7.0	5.9
Imports	0.0	0.0	0.4	0.5	0.6	0.6	0.7
Net Imports	-11.9	-13.9	-13.5	-10.6	-9.0	-6.3	-5.2
Oil Exports	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Imports	1.7	2.6	2.3	1.9	1.0	1.4	2.0
Net Imports	1.7	2.6	2.3	1.9	1.0	1.4	2.0
Coal Exports	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Imports	0.0	0.0	0.0	0.0	1.7	2.4	4.0
Net Imports	0.0	0.0	0.0	0.0	1.7	2.4	4.0
TOTAL STOCK CHANGES	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TOTAL SUPPLY (TPES)	13.5	16.2	16.5	17.6	20.2	22.4	25.8
Hydro	0.7	0.8	0.9	1.6	1.9	2.5	2.8
Solar PV & Wind	0.0	0.0	0.0	0.0	0.0	0.1	0.3
Gas	1.1	2.6	2.2	2.2	2.4	2.7	3.4
Oil	2.6	3.6	3.8	4.0	4.5	5.0	5.6
Coal	0.2	0.3	0.5	0.7	2.6	3.5	5.3

	2012	2015	2018	2021	2024	2027	2030
Biomass Type II	8.8	8.9	9.0	9.0	8.8	8.6	8.4
Electricity trade	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shares (%)							
Hydro	4.9	5.0	5.7	9.4	9.3	11.1	11.0
Solar PV & Wind	0.0	0.0	0.0	0.0	0.0	0.4	1.2
Gas	8.4	16.2	13.5	12.5	11.8	12.3	13.0
Oil	19.5	22.2	22.9	23.1	22.5	22.4	21.7
Coal	1.6	1.7	3.3	3.8	12.8	15.4	20.4
Biomass Type II	65.5	54.9	54.6	51.2	43.7	38.4	32.6
Electricity trade	0.0	0.0	0.0	0.0	0.0	0.0	0.0

30. The Energy Balance predicts that Myanmar will become a net importer of energy (slightly) by 2030 if no new gas fields export gas abroad. As mentioned the projection assumes that the M3 field will be indefinitely delayed; this is due to the recent change in government policy in Thailand and the weak international market for oil and gas.

E. Myanmar Energy Sector Key Performance Indicators

31. A projection of key performance indicators for Myanmar's energy sector is provided as Table E23. It can be seen that per capita consumption and total primary energy supply are expected to increase as the economy develops and as rural electrification takes place.

Table E23: Key Performance Indicators

	2012	2015	2018	2021	2024	2027	2030
GDP (billion 2010 US$)	52.2	64.5	79.8	98.8	122.4	151.6	187.9
Population[7] (millions)	61.0	63.5	65.4	67.4	69.4	71.5	73.7
TPES/GDP	0.26	0.25	0.21	0.18	0.16	0.15	0.14
Energy production/TPES	1.76	1.70	1.68	1.50	1.29	1.11	0.97
Per capita TPES	0.22	0.26	0.25	0.26	0.29	0.31	0.35
Oil supply/GDP	0.05	0.06	0.05	0.04	0.04	0.03	0.03
TFEC/GDP	0.24	0.22	0.19	0.17	0.15	0.13	0.12
Per capita TFEC	0.21	0.22	0.23	0.24	0.26	0.27	0.30
Energy–related CO2 emissions	5.8	8.7	11.5	12.5	16.4	19.5	24.9
CO2 Emissions (Million tons)							

[7] Note that the population forecast of this study was conducted using pre-consensus population statistics. Afterwards, the impact of the change in population was examined, which appeared not significant to energy demand forecasts because the historical demand forecasts that are driven by population were calibrated against reported energy consumption. The effect of reducing the historical population statistics means that the historical per capita energy rates increase. When these new energy consumption rates are applied to the (lower) projections for population using the census 2014 figures as a base, the change to the total energy consumption was not affected significantly.

Electricity	0.66	1.05	1.83	1.47	3.56	4.36	6.74
Gas (excludes electricity production)	1.45	2.08	3.92	4.78	5.85	7.14	8.75
Transport	3.65	5.54	5.77	6.26	7.01	8.05	9.43

F. Investment Plan

32. It is recommended that the Myanmar Government consider the following energy supply options:-

A. To develop a small, low complexity inland oil refinery that is powered by residual heavy distillates and a small coal-fired power plant using Myanmar coal. The strategic advantage of this approach is that a low complexity refinery does not require a supply of natural gas. The sizing of the refinery at 50,000 bpd is consistent with Myanmar's quota of Arab heavy sour oil, furthermore, the liquid fuel demand of the transport sector requires a balanced production of gasoline and diesel fuel which leads to efficient refinery operation. The economic feasibility of this proposal is largely based on the inland location of the refinery (at the pipeline) with associated low cost to transport fuel to consumers. Intangible benefits relate to the tradition to refining in Myanmar through the three existing refineries; refining provides the domestic industry sector with added depth, supporting the existence of a downstream industry. On the other hand a small refinery will no supply all of Myanmar's highly refined petroleum product needs – while the transport and industry sector needs can be satisfied, imports of diesel fuel will be required to meet the demands of agriculture up to 25% of total by 2030.

B. To develop a power generation supply with a gas plant capacity of not more than 15% in 2030. On this basis, the total annual gas consumption by the power subsector would be very modest, in 2020, 83 MMCFD and in 2030 only 96 MMCFD. The existing (and under construction / development) capacity for gas based power will be about 1 700 MW within a few years, which will consume over 300 MMCFD when simultaneously in operation. As reserve capacity needs increase to 2030, and if gas would be used to meet this capacity need, then total gas consumption could reach some 1 000 MMCFD. This requirement for gas may not be able to be met through a future domestic gas quota but could instead be met by imported LNG or by light fuel oils. However, the cost of LNG exceeds 18 $/MMBtu whereas the subsidised price to the current gas fired plants in Myanmar is around 7.5 $/MMBtu for domestic consumers and 11-12 $/MMBtu for industry. This cost difference means that LNG would be a very expensive solution for the country (whether LNG is used by the power subsector or by industry). Therefore it is clear that it is preferable to use light fuel oils to fuel reserve capacity plant. LNG imports can be considered again nearer to the time when the current gas supply contracts expire, if it is feasible to negotiate for a higher quota of domestic consumption. In the meantime, new gas fields may be discovered.

C. To rely primarily on electricity as a substitute for fuel wood used for cooking, in line with the national electrification plan objectives, rather than LP gas; and

D. Biogas, bioethanol and biodiesel can have a place in the rural energy mix with appropriate policy incentives. Electricity production using engines fuelled by biogas is limited to areas with cattle herds but in these areas it is both practicable and economical. In the transport sector a 10:90 mix of bioethanol and gasoline will reduce CO2 and other noxious emissions; biodiesel produced from jathropha is a potential substitute fuel for use by agricultural machinery in the medium to long-term.

33. The investment required in the energy sector is estimated as follows:

A. The capital cost of the oil refinery is estimated to be $1.2 billion; and

B. The capital investment in the selected power sector portfolio ranges between $11 and $17 billion (current cost basis) according to government policy preference; the levelized cost of electricity ranges between 4 – 5 USc/kWh

34. The following are the key barriers identified in attracting investment in Myanmar's energy sector:

A. There is competition for private sector investment. Key expectations are: (i) tariffs must be cost-reflective; (ii) tariffs must ensure adequate returns on investments; (iii) the law must protect private assets; and (iv) there must be transparency through mechanisms such as auctions. It is recommended that the government ensure that a legal and regulatory framework is in place that meets international standards, the private sector will be more likely to participate if risks are minimized with the establishment of legal rights and privileges that are enforceable

B. Environmental standards must be in place and a capability developed to monitor and report compliance in a transparent manner. It is recommended that the government continue to develop consultative mechanisms with civil society and environmental groups

C. Social acceptance of large hydropower schemes and gas pipelines has diminished in recent years by perceived rent seeking behaviour by project developers – local residents claim they receive no direct benefits from energy development projects. The future of hydropower development in particular will be tied to the success of developing greater social acceptance. It is recommended that the government explore the opportunities for local residents to share the benefits of energy developments.

G. Institutional Arrangements

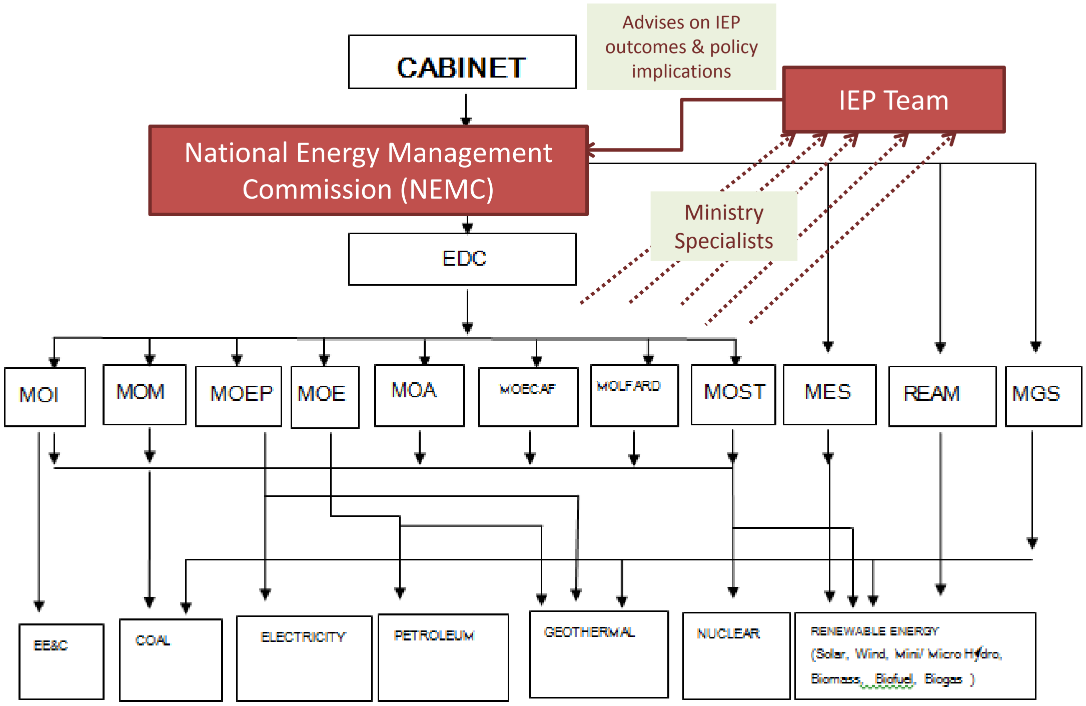
35. The present governance structure and supporting National Energy Policy provides the foundation for an Integrated Energy Planning process. However, a number of enhancements to the organisational structure are recommended to allow it to become more effective. The following enhancements to the existing structure are recommended:

A. Establish a permanent and specialist IEP team within the existing governance structure at NEMC.

B. Allocate the roles and duties of the concerned IEP team, the Ministries and NEMC in a way that can support the IEP process.

36. NEMC itself could be thought of as more of a Planning Commission and the NEMC working level staff as an Energy Planning team, for example, an "Energy Wing" of the Planning Commission. This is a common structure implemented in other countries. The concept is illustrated in Figure E24, where we have introduced the IEP Team to the current structure in Myanmar.

Figure E24: IEP Team



37. Shown in the diagram is the concept of the ministry specialist advisors, who feed into the IEP Team critical information relevant to the ministries that each represents. In essence the Ministry specialists would be responsible for the following duties:

A. Provide macroeconomic policy options;

B. Provide strategic development plans for economic sectors;

C. Provide primary resource assessments;

D. Develop roadmaps (pipelines, storage depots, roads, railway lines, power plant sites);

E. Evaluate energy supply technologies; and

F. Report on energy statistics for consolidation to the IEP Team.

38. The IEP Team would be responsible for the key activities associated with the IEP process:

A. Definition of policy and socio-economic issues;

B. Definition of regulations;

C. Compilation of Energy Statistics;

D. Definition of planning criteria and targets;

E. Selection of Primary Resource & Technology options (screening curves);

F. Performance of Integrated Energy Modelling;

G. Development of financing & tariff strategies; and

H. Industry & Public Consultation.

39. And finally, NEMC taking the form of a Planning Commission, would be responsible for:

A. Ratification of projections of estimated future energy needs in support of macroeconomic and socio-economic requirements;

B. Recommend preferred energy supply options in light of:-

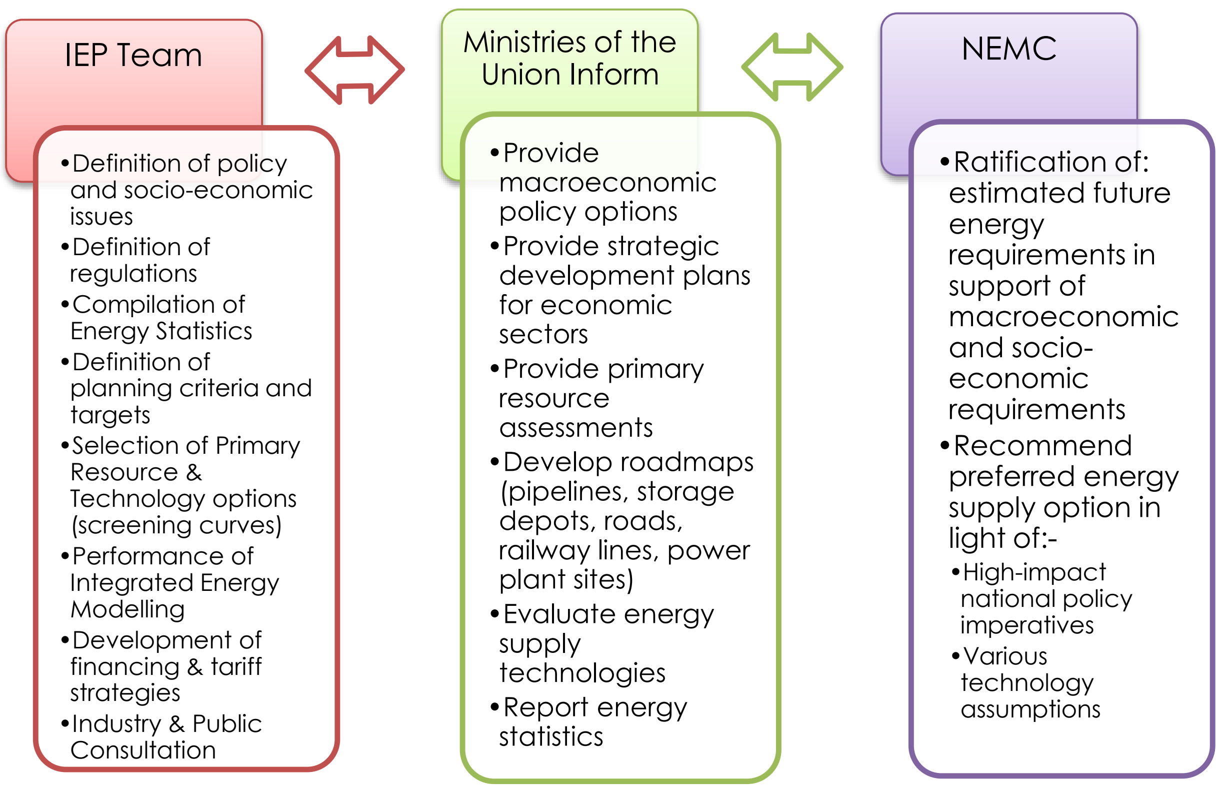
i. High-impact national policy imperatives

ii. Various technology assumptions

C. Recommend energy policy to support the preferred path.

40. The delineation in responsibilities between the IEP Team, Ministry Specialists and NEMC is illustrated in Figure E25.

Figure E25: Responsibilities of the IEP Team, Ministries and NEMC



Project Number: TA No. 8356-MYA

FINAL REPORT

MYANMAR ENERGY MASTER PLAN

Prepared for

The Asian Development Bank

and

The Myanmar Ministry of Energy

Prepared by

Intelligent Energy Systems

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ABBREVIATIONS

ADB	–	Asian Development Bank
ADBI	–	Asian Development Bank Institute
ASEAN	–	Association of South-East Asian Nations
CSO	–	Central Statistics Organisation
DUT	–	Dalian University of Technology
ERIA	–	Economic Research Institute for ASEAN
ESCAP	–	Economic & Social Commission for Asia & the Pacific
FDI	–	Foreign Direct Investment
GDP	–	Gross Domestic Product
GoM	–	Government of the Republic of the Union of Myanmar
HH	–	Household
IMF	–	International Monetary Fund
IEA	–	International Energy Agency
LIFT	–	Livelihoods and Food Security Trust Fund
JICA	–	Japan International Cooperation Agency
MCDV	–	Myanmar Comprehensive Development Vision
MDG	–	Millennium Development Goals
MNC	–	Multi-National Corporation
MoE	–	Ministry of Energy
MoF	–	Ministry of Finance
NPED	–	Ministry of National Planning & Economic Development
NPV	–	Net Present Value
PRC	–	People's Republic of China
RMG	–	Ready-Made Garments
TFP	–	Total Factor Productivity
UN	–	United Nations
UNDP	–	United Nations Development Programme
USAID	–	United States Agency for International Development

UNITS OF MEASURE

GJ	–	Gigajoule (one thousand megajoules)
kJ	–	Kilojoule
kWh	–	Kilowatt-hour
MJ	–	Megajoule
MWh	–	Megawatt-hour
MWel	–	Megawatt electric
PJ	–	Petajoule
TJ	–	Terajoule

WEIGHTS AND MEASURES

GW (giga watt)	–	1,000,000,000 calories
GJ (giga joules)	–	1,000,000,000 joules
GW (giga watt)	–	1,000,000,000 watts
kVA (kilovolt-ampere)	–	1,000 volt-amperes
kW (kilowatt)	–	1,000 watts
kWh (kilowatt-hour)	–	1,000 watts-hour
MW (megawatt)	–	1,000,000 watts
W (watt)	–	unit of active power

CONVERSION FACTORS

1 GCal	=	4.19 GJ
1 BTU	=	1.05506 kJ
1 Gcal	=	1.1615 MWh = 4.19 GJ
1 GJ	=	0.278 MWh = 0.239 Gcal
1 MW	=	0.86 Gcal = 3.6 GJ

NOTE

In this report, “$” refers to US dollars.

CONTENTS

I. INTRODUCTION

A. General

1. A long-term economic growth forecast is an essential input to an Energy Masterplan. There is no doubt amongst the academic community that in the developed world energy and GDP growth are highly dependent. In the developing world, the relationship also applies but the results of reputable studies show that GDP growth leads energy growth, contrary to the situation in the developed world where energy growth leads GDP growth. As Myanmar is a developing country, then energy planning should be based on a target for GDP growth. The country's historical energy intensity – the efficiency measure of a unit of energy needed for a unit of economic growth – can be expected to change slowly because the factors of production of the economy tends to change slowly. Accordingly the anticipated rate of GDP growth and value-added contribution of each of the primary, secondary and tertiary sectors of the economy, and the likely trend in energy intensity can be used to forecast energy consumption growth.

2. In 2014, Myanmar stands at the beginning stages of the development of a market economy. A privatization program is in place and the Myanmar Government is actively encouraging foreign investment in all sectors of the economy. Market sentiment is, by many accounts, running high as foreign investors explore the possibilities. Whilst Myanmar's State Economic Enterprises continue to play a dominant role in the economy, supplying intermediate and final products to local markets, foreign investors with international market reach can be expected to seek opportunities to supply international markets with commodities and products that they can produce in Myanmar to international standards and with healthy profit margins. If experience elsewhere is a guide, foreign investors will aim to leverage Myanmar's factor endowments; low cost educated labour in particular may be of interest to industrialists bringing capital to Myanmar. On the other hand Myanmar's business leaders consistently report in the social media that skilled labour is in short supply in Myanmar. The implication is that, in addition to capital formation, the achievement of Myanmar's development goals will require significant human resource development. The re-deployment of labour between sectors of the economy is likely to be a major challenge.

A. **Primary Sector.** As the primary sector employs some 60-70% of the active workforce, there is a consensus amongst international agencies, such as LIFT and USAID, that Myanmar's prosperity will be tied to the productivity of agricultural land and agricultural labour for the coming decades. A reputable study, conducted jointly between Myanmar's Yezin Agricultural University and the University of Kassel (Germany) concluded that land productivity can be improved significantly through increased use of fertilizers and improved water management[1]. A USAID-funded agricultural strategy diagnostic study[2] conducted in 2013 concluded that "all of these impediments [to the performance of the agriculture sector] can be remedied through good policies, institutional reforms and key public investments". Chief amongst the USAID team's observations was the importance of food security. Higher yields of crops would serve both food security and export needs; however, in an environment where it is reported that poor households spend 70% of their income on food, and there is a large population of landless poor, there is clearly a case to approach agricultural reform with some caution. Furthermore the economic growth of the secondary and tertiary sectors will potentially result in a competition for primary sector labour resources, with implications for food production. The contribution of fisheries, livestock and forestry to primary sector GDP was reported by

[1] A Survey of Myanmar Rice Production and Constraints; Naing, Kingsbury et al, 2008
[2] A Strategic Agricultural Sector and Food Security Diagnostic for Myanmar; USAID/MDRI/CESD, July 2013

the Central Statistics Organisation of Myanmar (CSO) to be 32% in 2013, following a period of several years of strong growth in the export of fish products. Since 2008 there have been concerns raised over the future of seafood exports due to over-fishing, particularly in the case of shrimp, but nevertheless fishing sector GDP growth has continued to 2013. In forestry, there have been reports tabled in the public domain that indicate that the quality of exported teak has fallen over the last decade with adverse impact on export revenues. Furthermore, that land clearing and illegal logging is resulting in an unacceptable rate of deforestation of upwards of 1% per annum. The Myanmar Government has responded to these concerns with a Millennium Development Goal (MDG) target to increase forest coverage from 48.3 percent in 2010 to 68 percent in 2020[3]. It is interesting to note that none of the discussion papers published during the last decade by forestry expert groups has drawn a link between deforestation and the use of firewood and charcoal, except in the case of the delta region where it has been reported that the mangrove forests have been severely impacted by harvesting for charcoal production. As in other countries the forestry sector is challenged by the need to balance economic and environmental interests.

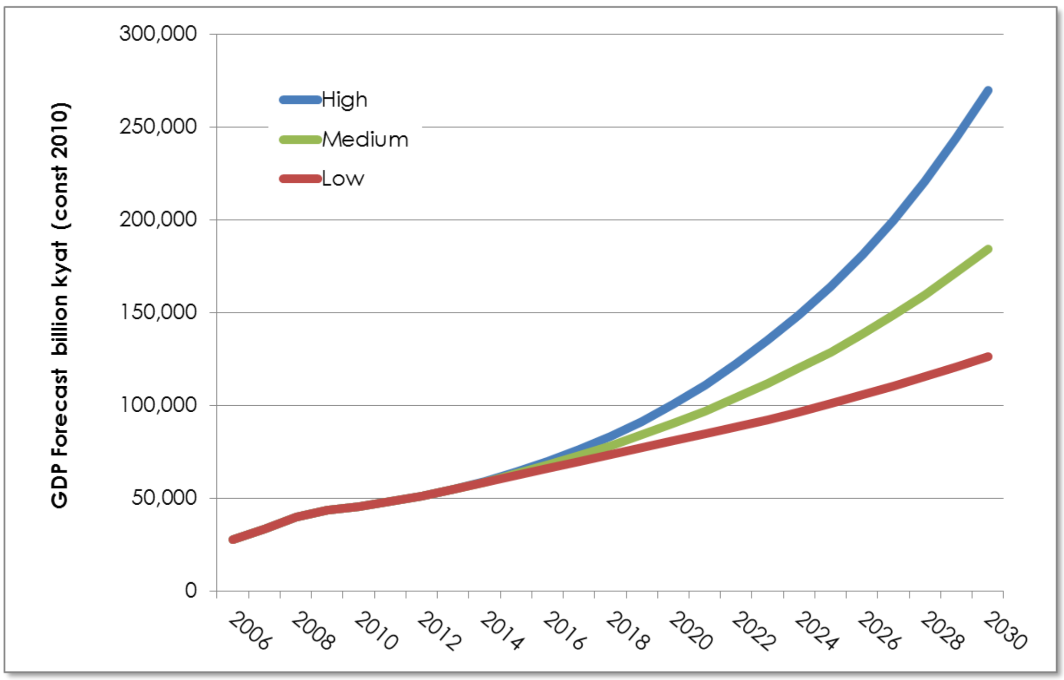
B. **Secondary Sector.** The prospect for economic growth led by industrialization appears to be mixed. In mining, Myanmar is endowed with a wide variety of mineral deposits. However, the proven reserves are relatively small by comparison to those of countries that currently dominate each mineral market. Moreover, Myanmar's large mineral deposits are located in remote areas of the country where there is currently no rail or road infrastructure. In the case of mineral processing, the production of iron and steel, copper concentrate, tin and tungsten concentrate is well established in Myanmar. Mineral processing in Myanmar is undertaken at the mine-mouth and production levels are dictated by local market demand. Given the scale of mining in Myanmar, it seems likely that minerals processing will continue to develop to service local market demands. Companies with established footholds in Myanmar's mining industry will continue to lead the way through small-scale mining ventures. It follows that over the long-term the mining industry is likely to grow at a modest pace. One of the unusual features of Myanmar's heavy industry sector is the dominance of the cement industry in the use of energy; this reflects the local nature of the existing industry structure. In the power, oil and gas sector, Myanmar's willingness to sell oil and gas to its near neighbours impacts GDP growth in two ways, firstly in terms of royalties, taxes and employment and secondly in terms of the oil and gas that is secured from international investors for the purposes of local consumption. Where foreign investors develop oil and gas fields for export, it is only the allocation of the energy carriers reserved for national energy supply that are of direct relevance to national energy planning. Given that a significant proportion of the oil and gas being produced in Myanmar is being sold internationally, there is clearly a need to consider how electricity production can be increased economically with available resources and how it will be best to supply petroleum products to address local production to serve growing demand. Strong growth is expected in the power and gas sector, albeit dependent on an injection of substantial foreign direct investment (FDI). The construction sector will need copper wire; bricks; glass and cement (aluminium products will continue to be imported); clearly the production of these products will rely on energy intensive local industries that in turn will rely on stable energy supplies. In manufacturing, growth can be expected to continue steadily, with the notable prospect of rapid growth in the Ready-Made Garments (RMG) industry. Overall it appears that the growth of the secondary sector observed during the last decade will continue, albeit with potential for acceleration in the coming decades as multi-national corporations (MNC's) invest in the sector.

[3] Myanmar Comprehensive Development Vision, Chapter 5, p9

C. **Tertiary Sector.** Economic growth in the services sector is partly a consequence of economic growth in the primary and secondary sectors of the economy. Services sector growth is sensitive to international trading; export activity requires financial services, trading and logistics services. Retail activity, including the restaurant trade, will continue to grow in line with population growth and growing income. Tourism and eco-tourism will grow largely independent of the other sectors of the economy; in time tourists can be expected to demand services that depend on reliable energy, communication and transport infrastructure. The hotel trade will benefit from increasing visitor arrivals for both tourism and business purposes.

3. Strong economic growth is anticipated by the Asian Development Bank in all sectors of the economy. Compound annual growth rate projections range from 4.8% to 9.5% with a most likely growth scenario of 7.1%. If this most likely growth rate is achieved it will mean that Myanmar will have exceeded the economic performance of most Asian developing countries (with the exception of People's Republic of China (PRC) which has recorded a growth of 9.5% for a 15 year period).

Figure I-1: Myanmar GDP Projection: 2006 to 2030



Source: Consultant, ADB Economic & Research Policy Unit (August 2014)

4. Economic growth will require resources – capital, labour and energy supply. For the purpose of energy planning, it is assumed that capital formation will support the achievement of GDP growth under any scenario that is envisaged. In the case of labour and energy supply however, it is necessary to quantify the relationship between agricultural sector labour productivity and energy use to understand the potential for labour to be released from the primary sector to supply the secondary and tertiary sectors.

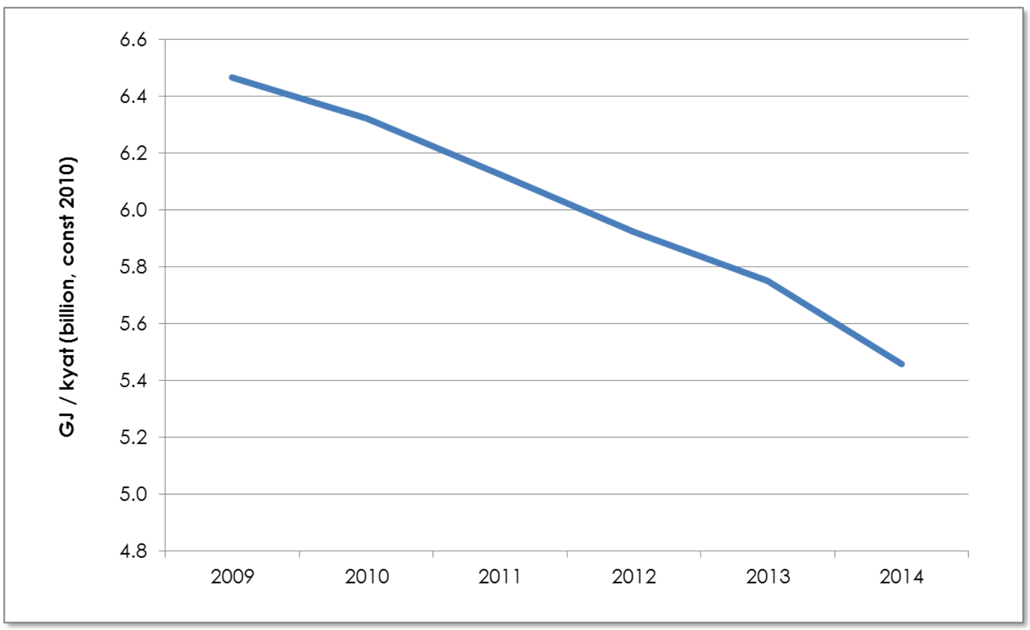
5. Myanmar's labour work force is expected to grow at a modest rate of 2.3% to 2020, falling to 1.2% thereafter[4]. High growth in all sectors of Myanmar's economy could be expected to lead to a

[4] Myanmar Comprehensive Development Vision (2013); Appendix_Growth prospects

competition for scarce labour. Myanmar's business leaders consistently report that there is a shortage of skilled labour and so it appears that the competition for labour will increase. Such competition is the reason that rural populations decline in industrializing nations when higher wages are offered by industry. In other countries, the release of agricultural labour to industry has been accompanied with increasing levels of farm mechanization and therefore energy consumption. Farm mechanization is essential to the maintenance of food security.

6. With economic growth Myanmar's energy needs will also grow. Myanmar's energy intensity can be expected to increase as economic reform takes place and traditional labour-based activities are impacted by technology. There is strong evidence that energy consumption follows 'GDP' in developing countries[5]. An econometric analysis of 80 countries, using time series data drawn from the World Bank's Development Indicators, found that GDP growth precedes energy growth. In the transitional phase from developing to middle income country status, traditional activities result in the accumulation of wealth that is later channelled into investment in energy infrastructure. In the longer term the nature of economic activity changes to become highly energy dependent; additional energy must be provided before further economic growth can take place. Energy intensity, a measure of energy input per unit of GDP, typically increases during the transition from a developing to middle income status. In fact, Myanmar's energy intensity trend of recent years has shown a decline; however, this appears to reflect the impact of gas sales on GDP because gas production and sales is not an energy intensive activity.

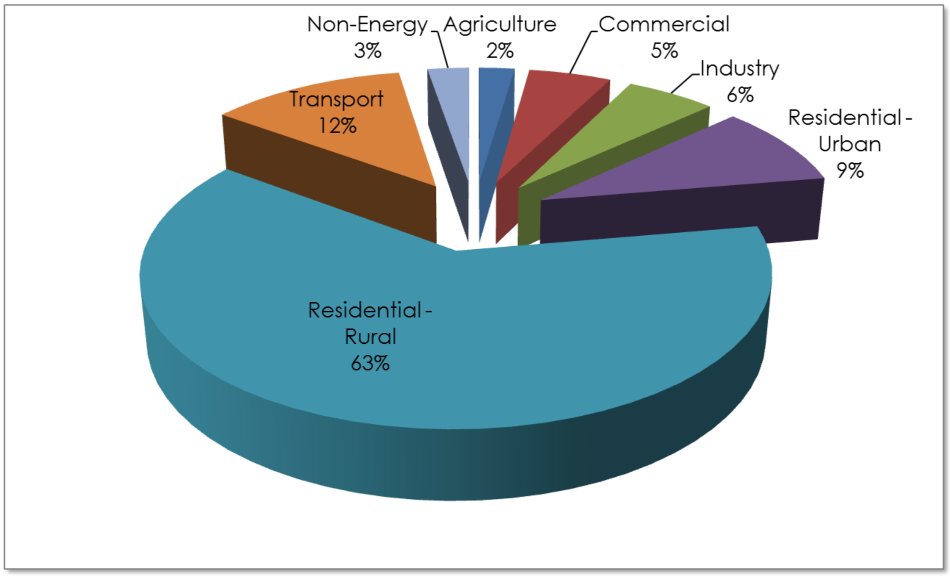
Figure I-2: Myanmar Energy Intensity (2009 to 2014)



Source: Consultant, World Bank Development Indicators 2014

[5] Energy Consumption and Economic Growth: A Panel Co-integration Analysis for Developing Countries (2012); Adhikari, Chen, Dalian University of Technology (DUT)

Figure I-3: Final Energy Consumption 2012-13



Sources: Ministries of Myanmar, Consultant estimates based on EMP surveys

7. As economic development takes place it can be expected that the share of final energy consumption taken up by rural households will reduce significantly. In 2012, the residential rural household share was around 63% as shown above in Figure I-3.

B. Quality of Historical Data

8. Users of socio-economic data in Myanmar raise regular questions about the reliability and accuracy of historical records. A review by Ware and Clark (2009) states that, "Accurate statistical data for Myanmar is lacking, and what is available is of questionable validity. This is the result of several factors including the government having limited control over parts of the territory, limited resources for data gathering and analysis, and data being manipulated for internal and external consumption." The United Nation's regional Economic and Social Commission for Asia and the Pacific similarly concludes that Myanmar stands out as having the least capacity in ASEAN "to produce reliable and timely data even for the most basic statistics" (ESCAP 2007).

9. Confidence in the population statistic has been low. As an indication of the uncertainty involved in the population statistic, the World Bank considered that the population was 53.5 million in 2012, whereas the ADB estimated that the population was 61.0 million, a discrepancy of some 20%. The ADB estimate was in line with the Central Statistics Office official estimate. The Government Population & Housing Census released in August 2014, determined the total population to be 50.4 million on the night of 29 March 2014.

10. In the case of GDP, according to the UNDP (2011), Kumagai, et al (2012), there are three statistical times series for GDP, namely the official series A, official series B and the 'night-time lights' series. The ADB's statistical series has been adopted for the Energy Masterplan, with cross-references against the IMF statistical series.

11. Energy planning relies heavily on quality historical data as a guide to the future. The ADB Consultant has found that Myanmar's available energy production statistics are of good quality.

However, there is very limited data pertaining to energy consumption of the rural household sector. The sector accounts for an estimated 70% of Myanmar's total energy consumption[6] due to the use of woody biomass for domestic hot water and meal preparation. In the past three years efforts have been made by international organizations to survey the rural farm and household sector to establish baseline planning data. The Livelihoods and Food Security Trust Fund (LIFT) completed a baseline survey of 4,000 households[7] in 2012. The LIFT survey included questions concerning cooking and lighting use against income strata and is a key source of information for energy planning for the rural sector. Other studies of note concerning the rural sector are those conducted by MercyCorps in 2011 and 2012[8]. Extending on the scope of these studies, the Energy Masterplan scope has included a household energy survey of 1,000 rural and urban households.

12. Overall, the accuracy of statistics means that energy forecasts could be under- or over-stated. The planning principle adopted for this Energy Masterplan is to use the statistics that lead to the highest energy forecasts. This principle will result in a conservative approach to planning of the energy demand and supply needs which is considered preferable to understating such needs by relying on the low end of statistical ranges.

C. Geography and Geology of the Union of Myanmar

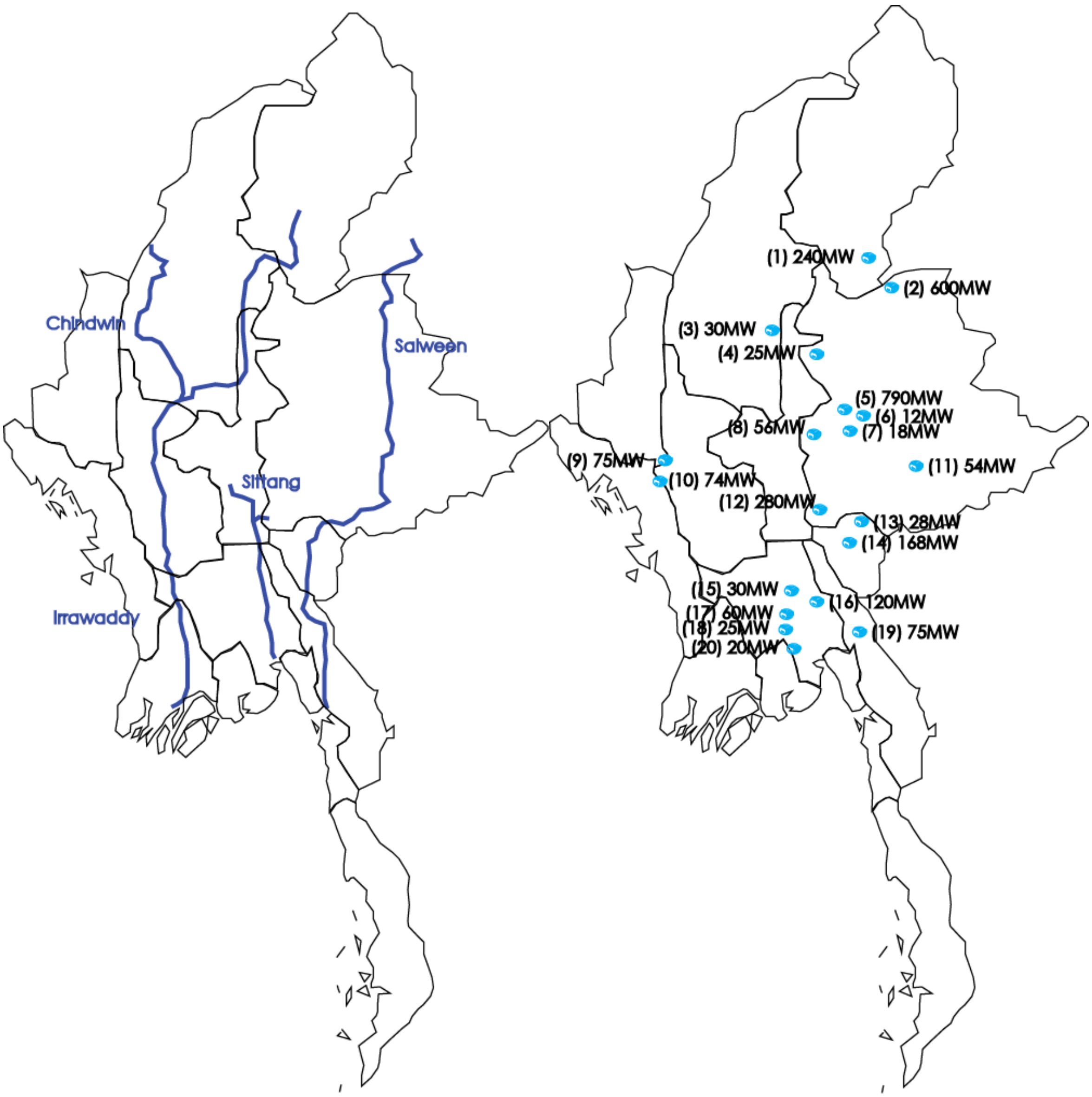
13. Myanmar is a large country, with a land area of 676,577 square kilometres (km^2). The country shares borders with Bangladesh, the PRC, India, the Lao People's Democratic Republic (Lao PDR), and Thailand; it also has a 2,800-kilometer (km) coastline along the eastern side of the Bay of Bengal.

14. There are three distinct climatic regions, a mountainous region, a central dry region and a coastal / delta region. The mountainous region covers the north and west of the country, bordering India, and is characterized by high mountains (up to 5,800 meters above sea level), dense forest, and uplands. To the east is the Shan Plateau consisting of rolling hills and uplands at an elevation of about 2,000 meters. The population density in the mountainous region and the Shan Plateau is low, consisting largely of ethnic minorities. Both regions are characterized by low levels of development, poor infrastructure, and poor communications. The central dry region has the lowest annual rainfall, an extended dry season and infertile, sandy soils. Nonetheless, it has the second-highest population density in Myanmar. The delta region is a vast fertile area that is at the confluence of three major river systems: the Ayeyarwaddy[9], the Sittaung, and the Thanlwin. The delta region has the highest population density, highest land productivity, moderately high rainfall and a generally flat topography. It is an excellent environment for agriculture, especially rice production.[10] Yangon, the country's largest city and commercial capital, is located in the delta region. The coastal region runs along the eastern side of the Bay of Bengal and the Andaman Sea, bordering Thailand. The southern portion of this region has the highest annual rainfall (exceeding 4,000 millimetres per annum) and is highly suitable for growing perennial crops such as coconut, oil palm, and rubber. In addition to extensive land and forest resources, the country has abundant water resources. Five major rivers flow through the country, providing for irrigation and hydropower generation, as depicted below in Figure I-4. It can be seen that the hydropower plants are located in creeks and tributaries of the major rivers. Myanmar is also richly endowed with oil, gas and a variety of mineral deposits throughout the country, as shown below

[6] Refer Energy Masterplan Volume III Rural HH Cooking
[7] LIFT Baseline Survey Report - July 2012
[8] MercyCorps: Myanmar Energy Poverty Survey – 2011; Myanmar Household Energy Market Assessment - Aug 2012
[9] The Ayeyarwady, along with its major tributary, the Chindwin, drains 58% of the country's territory
[10] Some 50% of Myanmar's rice cultivation and production is in the three Delta Region divisions of Ayeyarwady, Bago, and Yangon. The Ayeyarwady division alone accounts for 25% of rice production

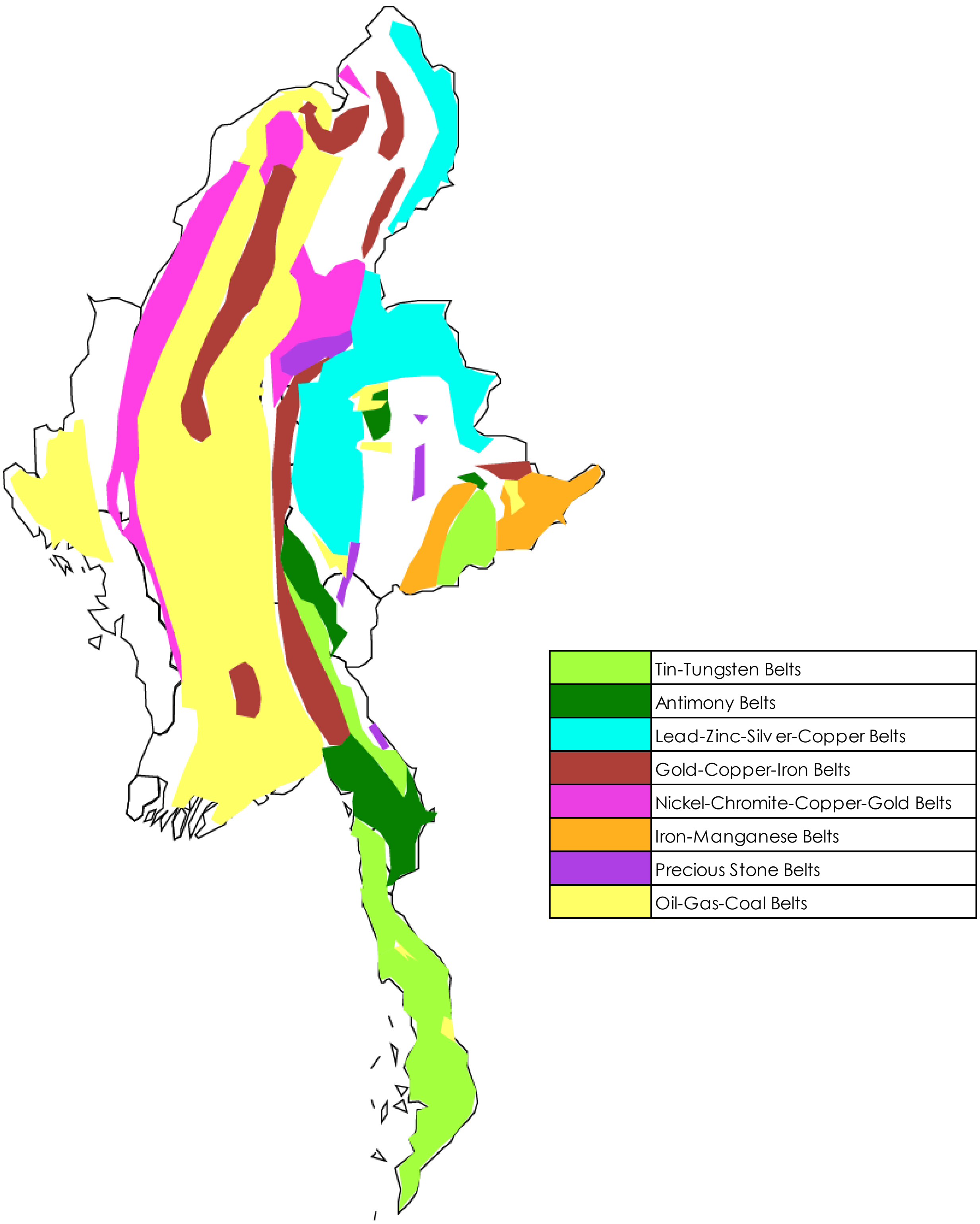
by mapping of the mineral belts in Figure I-5.

Figure I-4: Major Rivers & Existing Major Hydropower Schemes in the Union of Myanmar



(1)	Depein	(5)	Yeywa	(9)	Mone Chaung	(13)	Baluchaung (1)	(17)	Kun Chaung
(2)	Shweli (1)	(6)	Zawgyi (2)	(10)	Kyeeon Kyeewa	(14)	Baluchaung (2)	(18)	Yenwe
(3)	Thaphanseik	(7)	Zawgyi (1)	(11)	Keng Tawng	(15)	Kabaung	(19)	Shwegyin
(4)	Sedawgyi	(8)	Kinda	(12)	Paunglaung	(16)	Thauk Ye Khat	(20)	Zaungtu

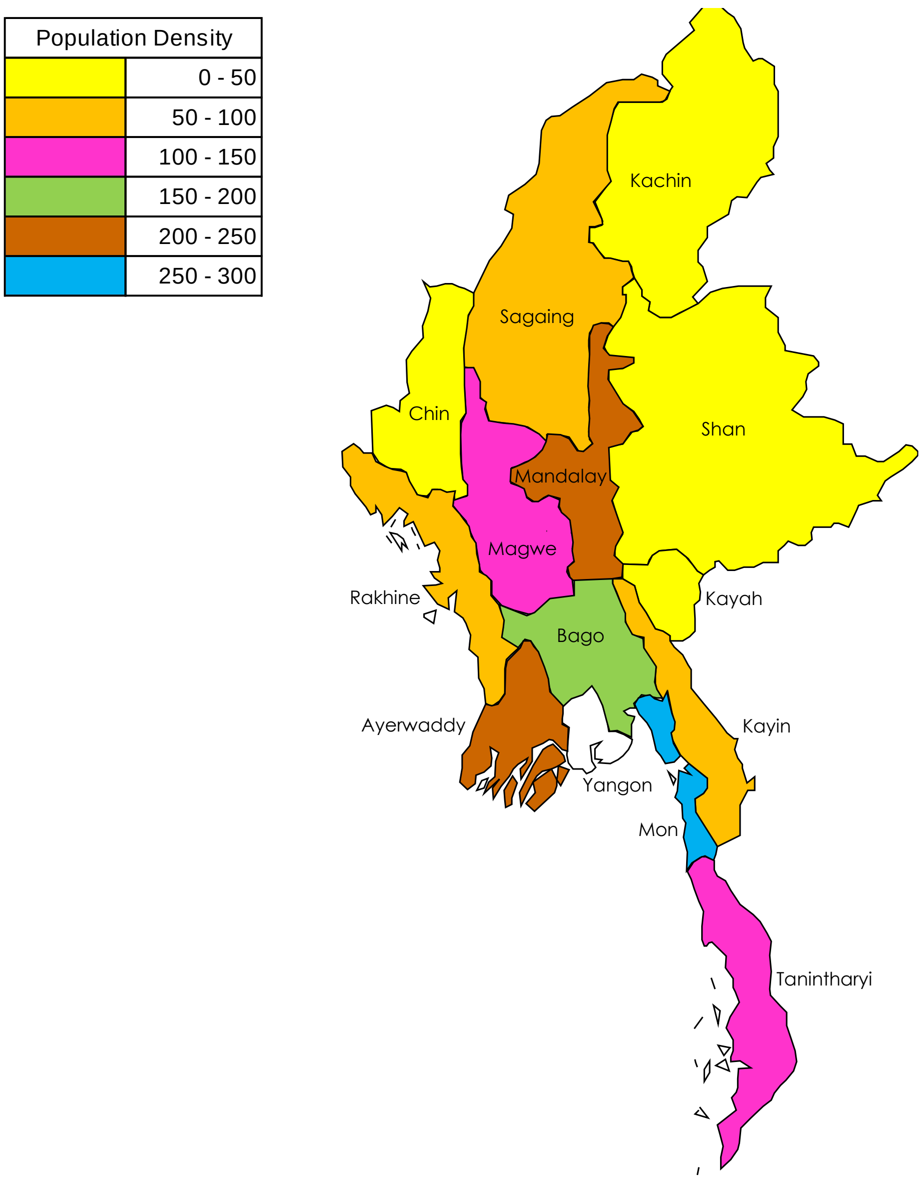
Figure I-5: Myanmar's Mineral Belts



D. Union of Myanmar Demographics

15. The Myanmar nation is administered as a total of 14 States and Regions. The Regions can be described as ethnically predominantly Burman (Bamar), while the States are ethnic minority-dominant. Yangon has the largest population. Outside Yangon, Ayerwaddy has the largest population followed closely by Mandalay. Kayah State has the smallest population. In terms of land area, Shan State is the largest and Yangon Region is the smallest. Consequently, Shan State and Yangon Region have the lowest and highest density of population respectively as shown below in Figure I-6. The population density has been computed using the ADB population statistic for 2012.

Figure I-6: Myanmar Population Density (2012; per sq km)



II. MACROECONOMIC PERFORMANCE

E. Main Trade Indicators

16. Myanmar's trade in 2013 led to a total turnover of US $303 million, of which exports accounted for US $7 241 million and imports for US $ 6 938 million. Exports accounted for 21.1% of GDP in FY 2013. Myanmar has traditionally experienced a positive trade balance, with the value of exports exceeding that of imports, but in early 2014 the IMF forecast the development of a negative trade balance in coming years. Myanmar's main trade indicators and the IMF forecast are shown in Table II-1 and Figure II-2. The impact of the global recession of 2008 is apparent in the 2009 and 2010 export figures with recovery happening thereafter.

Table II-1: Myanmar: Main Trade Indicators: FY 2008 – 2015

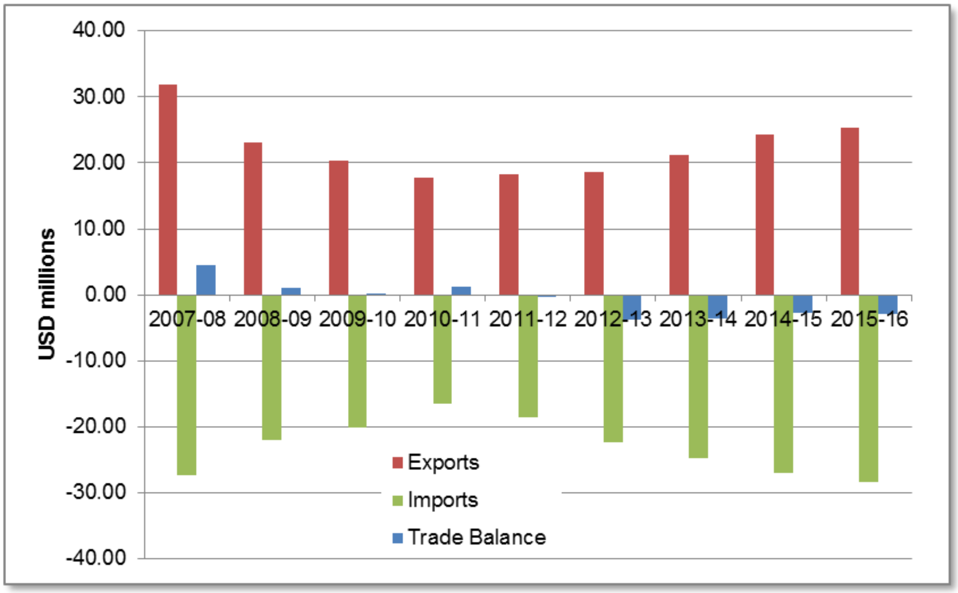
	2008-09	2009-10	2010-11	2011-12	2012-13	2013-14	2014-15	2015-16
GDP (current kyat billion)	28 778	32 351	39 847	43 368	47 851	54 434	62 572	72 075
GDP (US$ million)	31 367	35 225	49 600	56 200	55 800	56 400	60 300	64 800
Exports (current kyat billion)	9 199	8 076	7 093	7 252	7 412	8 448	9 683	10 121
Exports (US$ million)	7 241	7 139	8 829	10 228	10 379	11 957	14 653	16 459
Exports as % of GDP	23.1%	20.3%	17.8%	18.2%	18.6%	21.2%	24.3%	25.4%
Imports (current kyat billion)	-8 814	-7 994	-6 575	-7 412	-8 926	-9 882	-10 799	-11 317
Imports (US $ million)	-6 938	-7 067	-8 184	-10 453	-12 499	-13 987	-16 341	-18 403
Imports as % of GDP	-22.1%	-20.1%	-16.5%	-18.6%	-22.4%	-24.8%	-27.1%	-28.4%
Trade turnover (current kyat billion)	385	81	518	-159	-1 514	-1 434	-1 116	-1 195
Trade turnover (US$ million)	303	72	645	-225	-2 120	-2 030	-1 688	-1 944

Source: IMF

F. Main Export Goods and Destinations

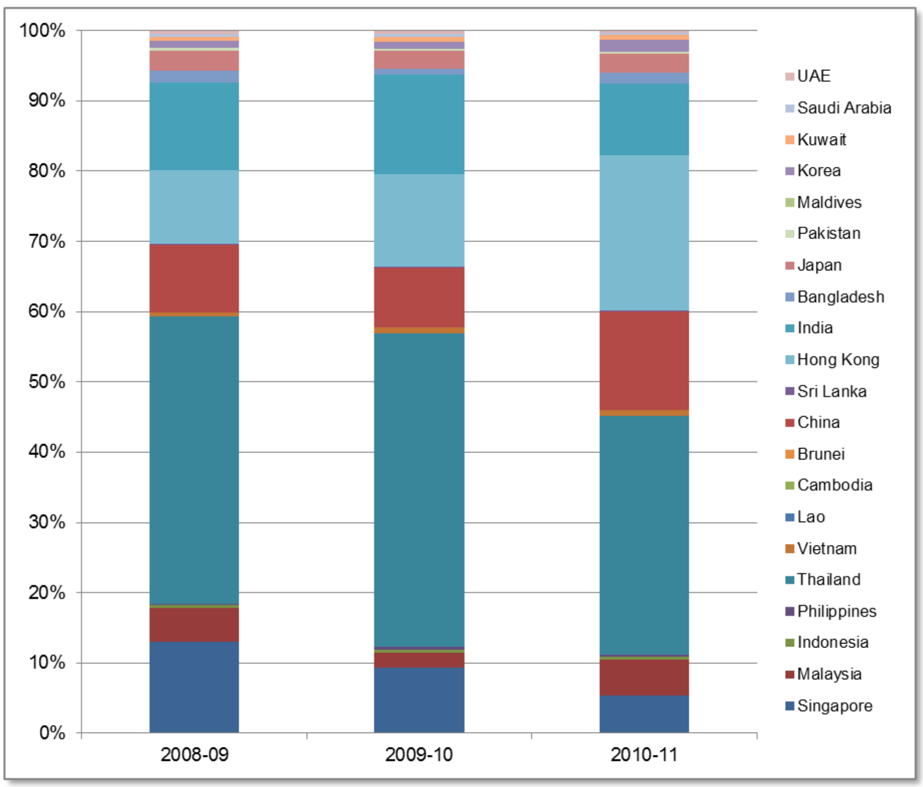
17. Myanmar's export sector has been dominated by the sale of gas to Thailand and PRC as can be inferred from Figure II-3 below. Together with gas, agricultural and fish products, and precious minerals make up a significant share of exports. The trend in exports appears to be steady, with the exception of a sudden increase in the export of precious minerals in 2010.

Figure II-2: Myanmar: Main Trade Indicators: FY 2007 – FY 2015



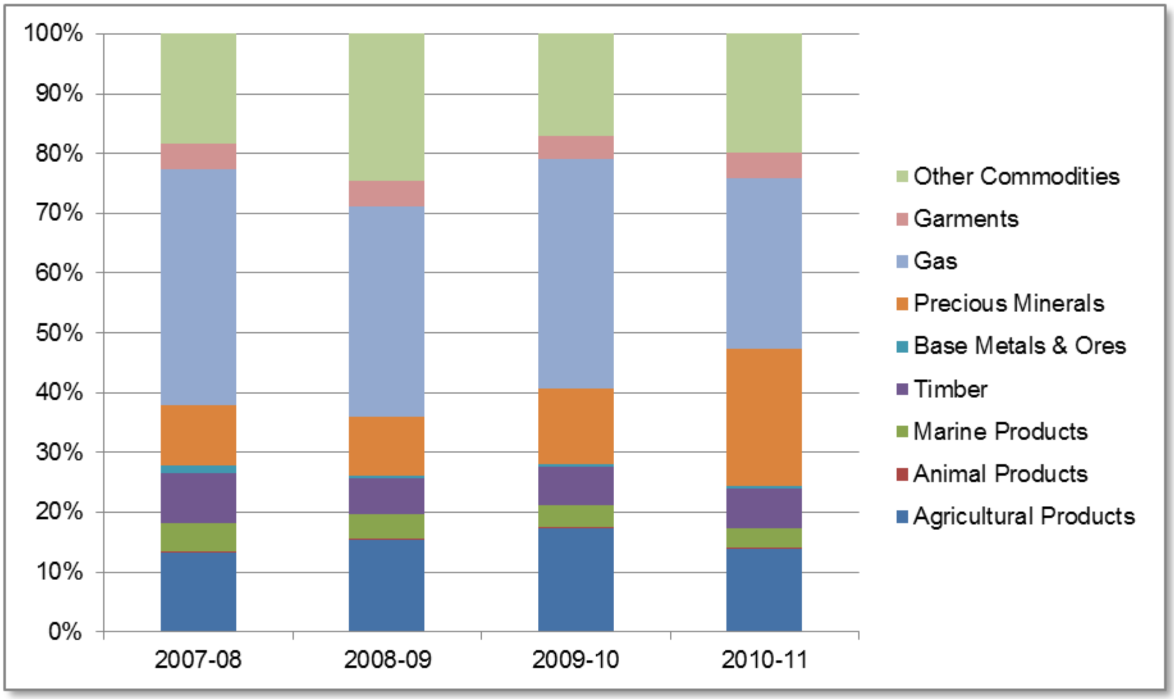
Source: IMF

Figure II-3: Myanmar's Exports by Destination: FY 2008 – FY 2010 (% of total exports)



Source: Central Statistics Office of Myanmar; data tables provided in Annex

Figure II-4: Exports by Main Commodity: FY 2007 – FY 2010 (% of total exports)



Source: National Statistics Office of Myanmar; data provided in Annex

18. Myanmar's exports account for 25% of total GDP and the IMF expects the percentage to increase in the coming years. The majority of export trade is dominated by relatively few commodities and by a few trading partners, namely Thailand, PRC and increasingly by Hong Kong. Myanmar's exports are therefore dependent on a few products and a few importers. However, with long-term gas and oil contracts with PRC and Thailand, the exposure to a few major trading partners is modest and suggests that the risks to GDP from a sudden cessation of trading by a major partner would at worst be unpleasant in its effects.

G. Main Imported Goods and Sources

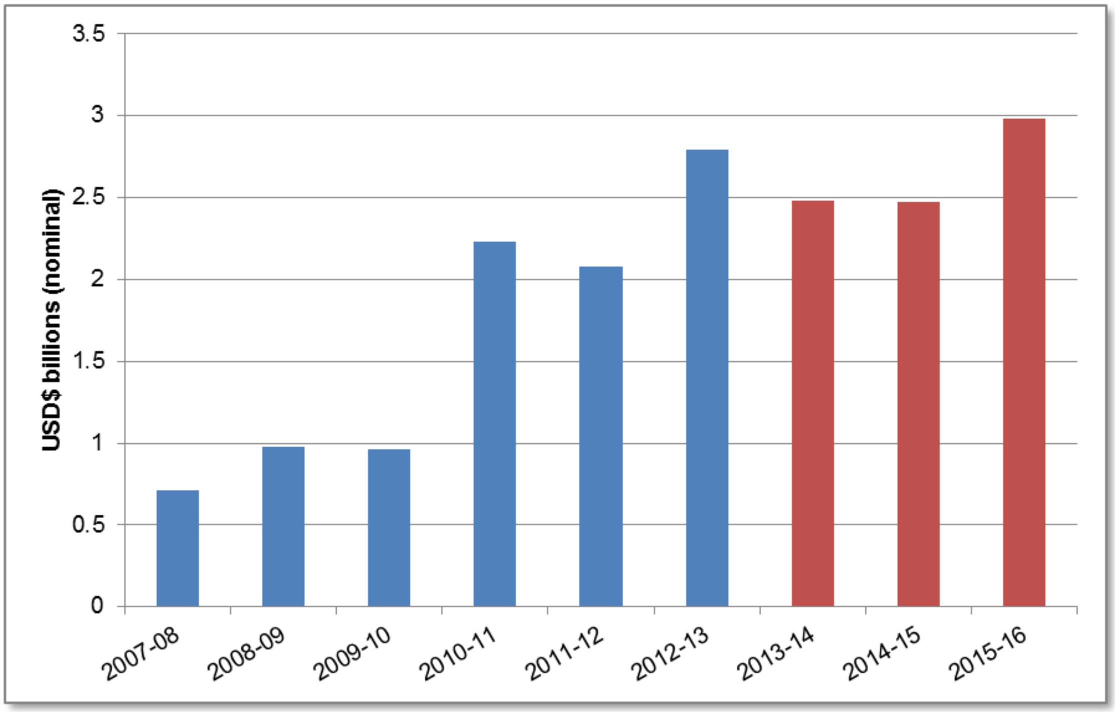
19. Myanmar's imports are sourced mainly from Asia, from a large number of trading partners. Within South-East Asia the largest trading partner is Singapore. From the rest of Asia, the largest trading partner is PRC. The main import commodities, by $ value, are fertilizers and machinery (motor vehicles).

H. Foreign Direct Investment

20. A key factor in both recent and expected rises in GDP is the surge in foreign direct investment inflows to the Myanmar economy. In FY 2007, Myanmar attracted just over US$0.5 billion of foreign investment. By FY 2013 the figure had risen to around US$2.75 billion, with the IMF expecting that the level of FDI will sustain and increase in the coming years as shown in Figure II-5. Figure II-6 shows the relationship of these levels of foreign direct investment as a percentage of real GDP over the period 2000 - 2012.

21. A foreign direct investment inflow of the magnitude experienced to date, and particularly during 2011-2012, presents the forecaster with a problem. As these inflows are essentially an inorganic injection of funds into the economy over a relatively short period (2-3 years), they are by their nature out of the normal pattern of growth projections and trends.

Figure II-5: FDI Inflows FY 2007 – FY 2015 (US$ billion)

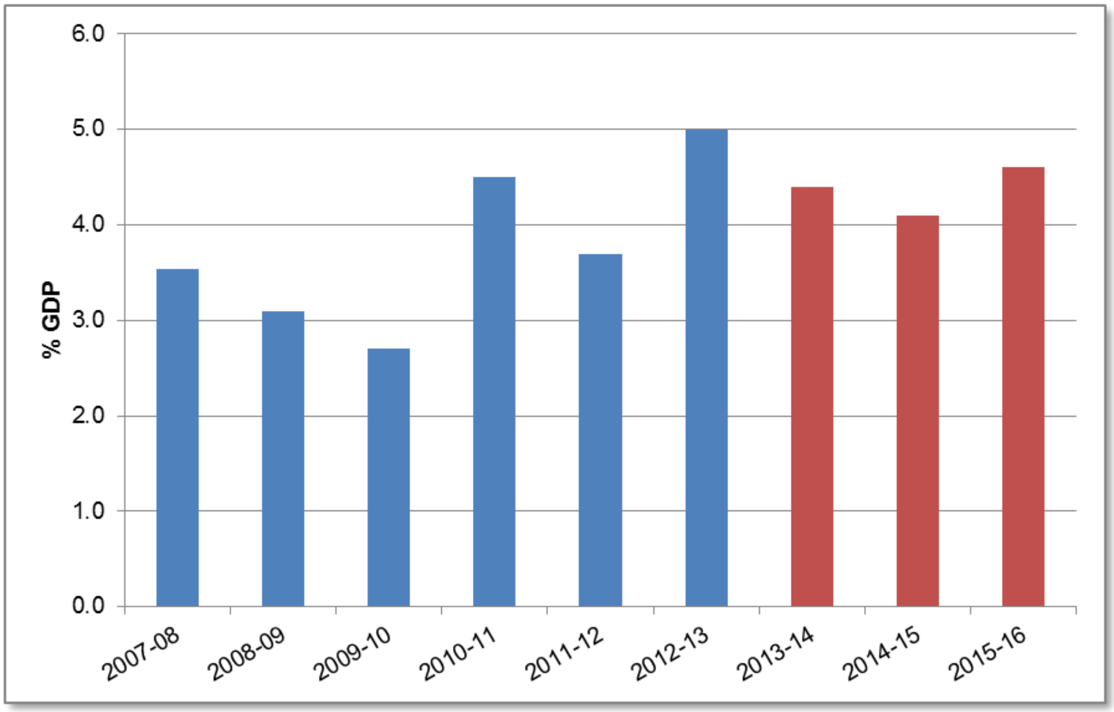


Source: IMF

22. The full economic implications these inflows are likely to be magnified to some degree due to the so-called 'Multiplier Effect'[11]. FDI inflows are distortions to more usual growth patterns, albeit productive distortions, nevertheless any GDP forecast that is made from 2013 is unlikely to fully incorporate the full implications of the FDI inflows because the full extent of these inflows (the size and duration) is not yet known. A forecast that is made and is predicated on say a US$3 billion inflow in the base year, will lead to significantly different outcomes than one that is made on the basis of say a US$1 billion inflow during the same year. The growth trajectories for each case will yield different outcomes by the end of the forecast period. On the other hand, the FDI level has been of the order of a modest 5% of GDP as shown in Figure II-6. The IMF believes that FDI will stay at the 5% level for the foreseeable future, bearing in mind inflationary effects that would occur if FDI was to increase significantly. For the purpose of energy planning it is assumed that FDI will contribute to growth according to a 'business-as-usual' scenario throughout the planning horizon.

[11] An increase in spending (e.g. FDI or increased government spending) produces a larger increase in income.

Figure II-6: FDI as a Percentage of Real GDP 2000 – 2012



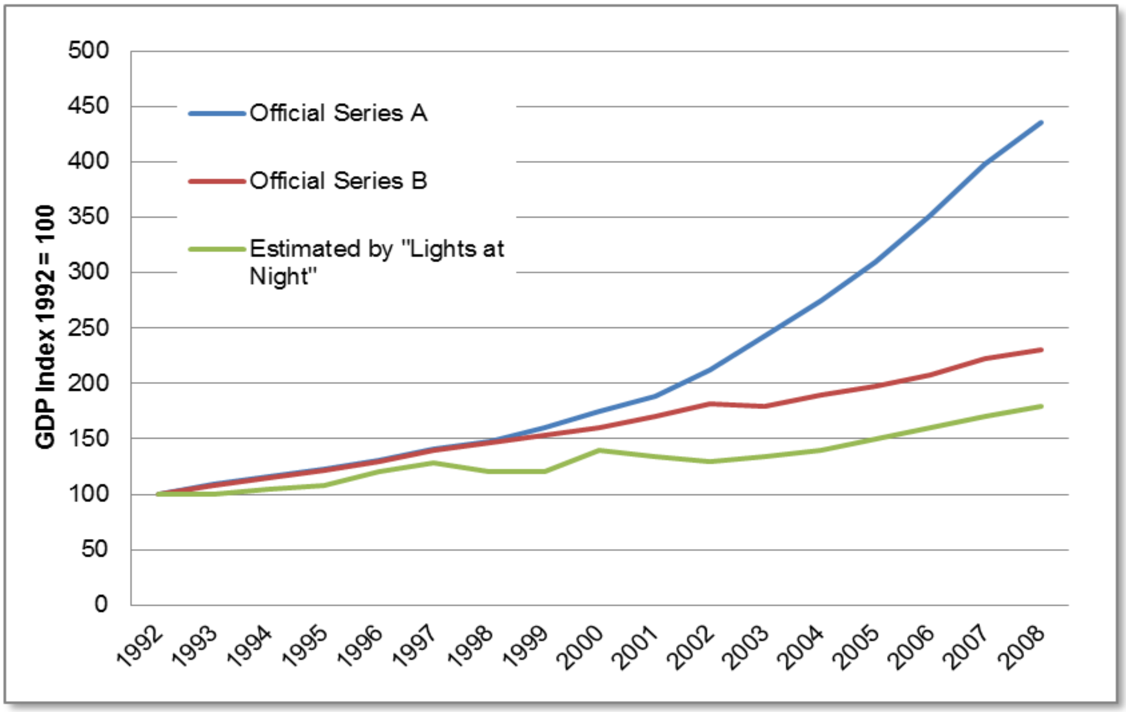
Source: IMF

I. Gross Domestic Product (GDP)

23. According to official GDP statistics compiled and published by the Myanmar Government, Myanmar achieved double digit growth for the twelve consecutive years from FY 1999 to FY 2010. There is however considerable difference of opinion regarding this statistic. There are several published series of GDP statistics that exhibit a wide range (1) the official series A, compiled and published by Myanmar government, (2) the official series B, estimated by the UNDP (2011) based on the official series A but adjusted for the strong controls on the exchange rate, and (3) an estimate based on a satellite images of lights at night by Kumagai, et al (2012). These series are shown below in Figure II-7.

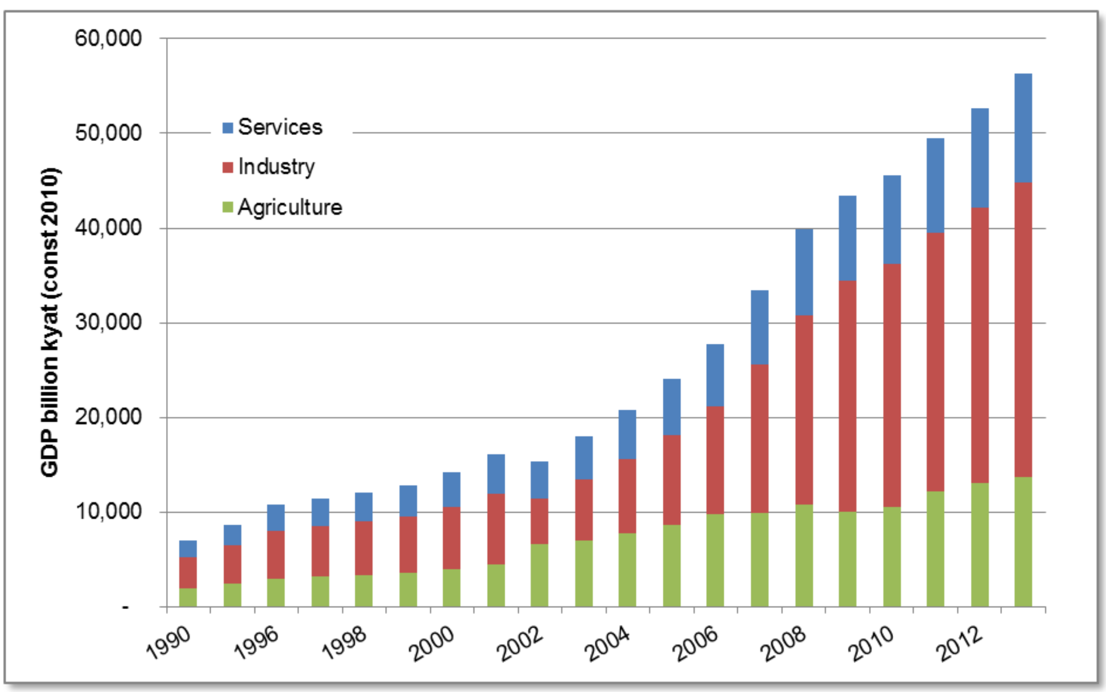
24. The MCDV states that it is difficult to judge which of the series reflects reality. Series (1) and (2) suggest over-reporting against the official statistics. Notwithstanding the doubts expressed in relation to the accuracy of the historical GDP series, the ADB GDP statistical series is adopted as a basis for energy planning. In line with the current practice of the Myanmar Government, the ADB series has been converted to a constant 2010 base as shown in Figure II-8; GDP evidences strong growth in the secondary sector.

Figure II-7: Myanmar's GDP



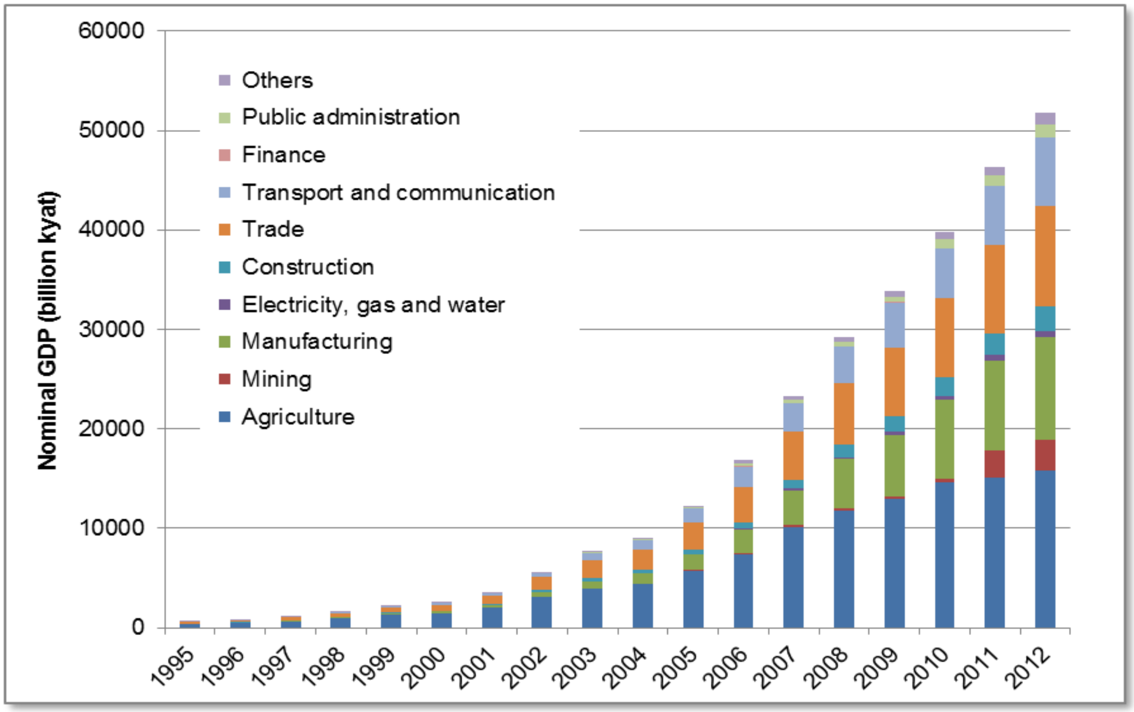
Source: Myanmar Comprehensive Development Vision

Figure II-8: Myanmar's GDP by Sector



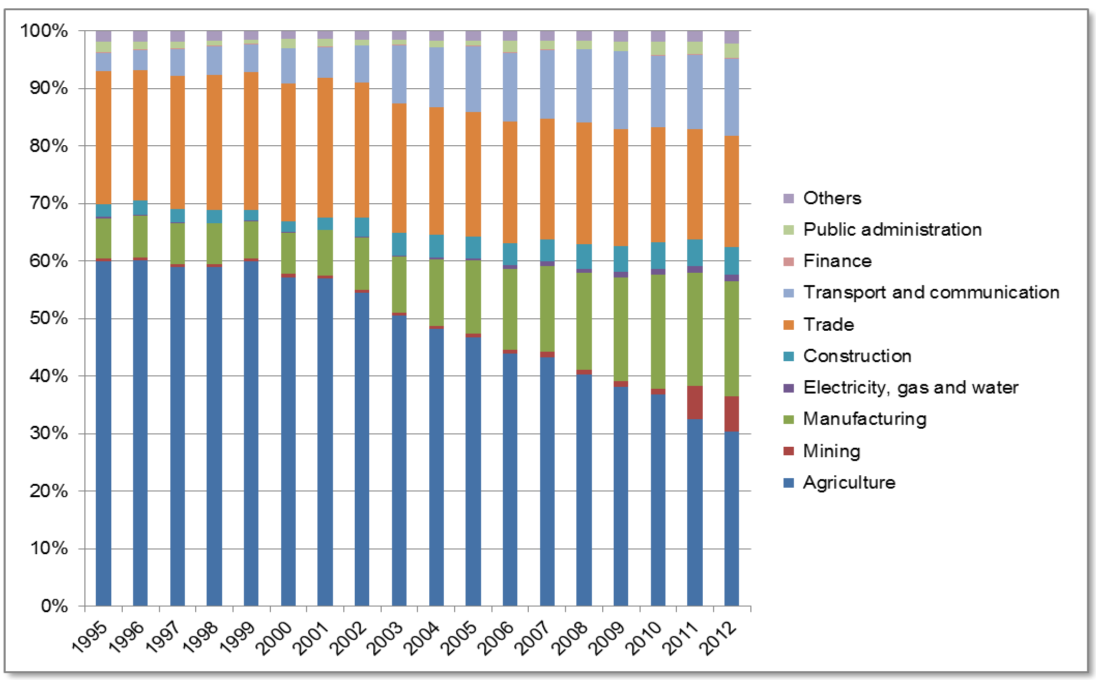
Source: Asian Development Bank; statistics provided in Annex

Figure II-9: Myanmar's GDP by Sector



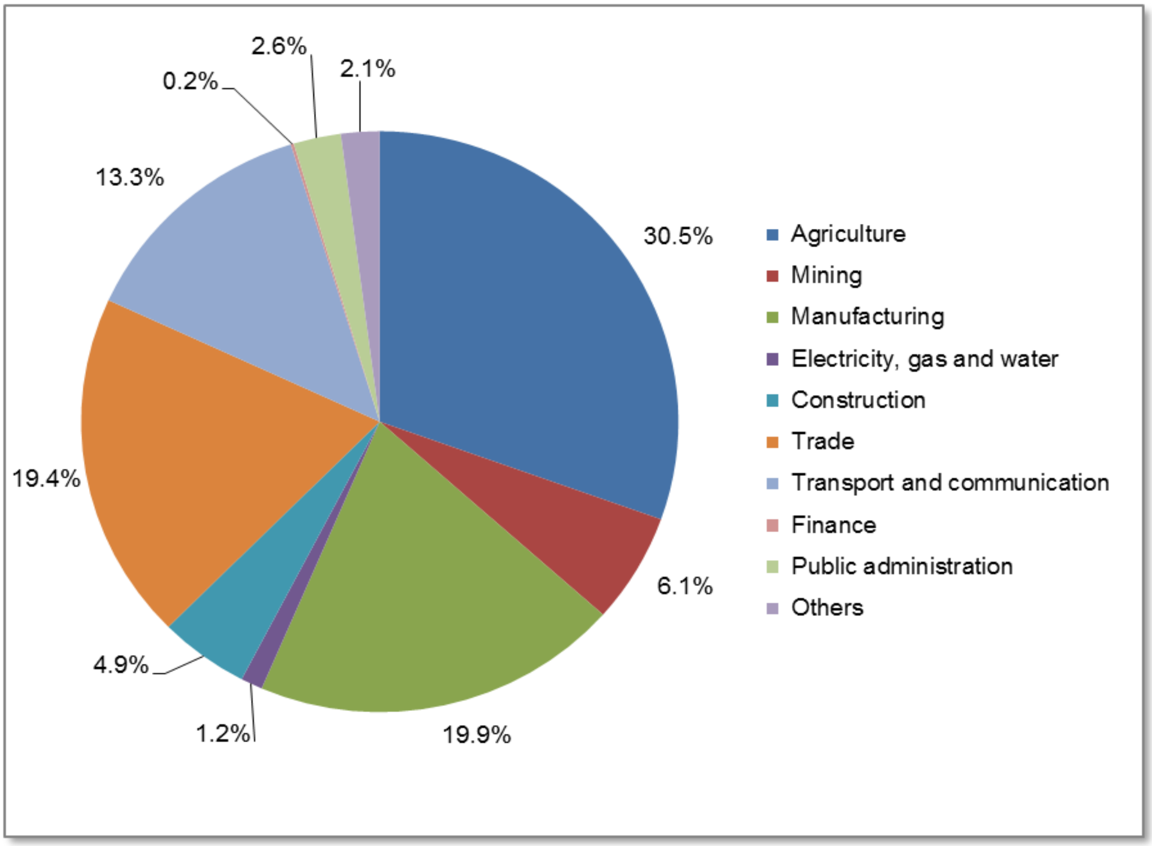
Source: Asian Development Bank; statistics provided in Annex

Figure II-10: Myanmar's GDP by Sector (% basis)



Source: Asian Development Bank; statistics provided in Annex

Figure II-11: Myanmar's GDP by Composition (2012)



Source: Asian Development Bank; statistics provided in Annex

25. The historical GDP statistical series used for the Energy Masterplan was taken as the ADB's Economic Indicator series; the ADB statistics most closely match the Official Series A statistics of the Government. In the course of establishing relationships between energy consumption statistics and GDP statistics it was found that the ADB's GDP statistics gave strong correlations against the energy statistics.

26. Figure II-9, Figure II-10 and Figure II-11 above show that the primary sector, comprising Agriculture/Horticulture, Fisheries, Livestock and Forestry provided the largest single contribution to GDP. This sector was followed by the sub-sectors of Manufacturing, Trade and Transport & Communication making up a total of 52.3% of GDP. When combined with the primary sector contribution, the total was 82.8%, with the remaining sub-sectors making a relatively small contribution on individual basis.

III. ECONOMIC ASSUMPTIONS

J. Introduction

27. A fundamental requirement of energy planning is a GDP growth forecast. This is particularly the case for developing countries where there is strong evidence that final energy consumption follows 'GDP'[12]. As Myanmar is a developing country, then energy planning should be based on a GDP growth target.

28. In principle GDP can be maximized through the optimal allocation of national resources. In practice this means ensuring that each sector of the economy is supplied with the resources, viz a viz capital, labour and energy supplies, required for achievement of the expected growth of the sector. When resources are constrained, GDP growth of the primary, secondary and tertiary sectors of the economy may result in a competition for the resources that are available. It is observed in developing countries that such competition can result in a declining rural population as the industry and services sectors offer higher wages than those available to agricultural workers. This issue is considered as a planning issue within the context of food security.

29. GDP can be used to compute an indirect measure of household income. Household income growth drives the growth in consumer spending, notably for private passenger cars, and is a useful measure for energy forecasting. Time series data for household income is not available suggesting the need for a proxy measure. A suitable proxy measure is considered as the cost of firewood for areas outside of Yangon Division and urban Mandalay, and the cost of firewood and charcoal in the case of Yangon and Mandalay.

30. The allocation of labour to each sector of the economy is a function of population and population growth. The population growth and workforce growth and sectoral allocations are therefore important settings in planning for future energy consumption.

K. GDP Forecast

31. The Ministry of National Planning and Economic Development provided the Consultant with a projection of Gross Domestic Product. Low and High projections were set by the Asian Development Bank according to the findings of a Country Diagnostic Study released by the ADB's Economic Research & Policy Unit in August 2014. The growth forecasts are summarized in Table III-1.

Table III-1: GDP Scenario Growth Rates by Sector (CAGR)

	Low	Medium	High
Primary	3.7%	4.1%	4.6%
Secondary	5.4%	8.2%	10.9%
Tertiary	4.1%	6.4%	8.6%
Total	4.8%	7.1%	9.5%

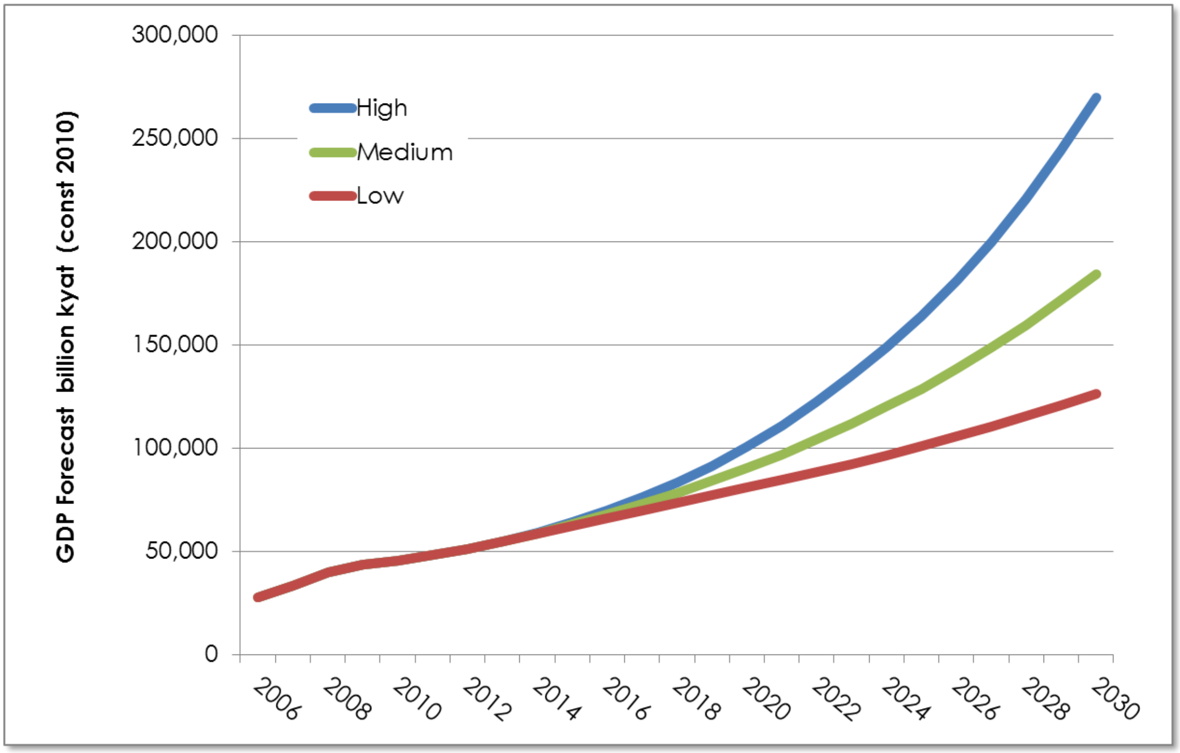
Source: ADB

32. A chart of the consolidated GDP sector forecasts provides an indication of the divergence of the

[12] Energy Consumption and Economic Growth: A Panel Co-integration Analysis for Developing Countries (2012); Adhikari, Chen, Dalian University of Technology (DUT)

three growth scenarios about the median trajectory. The details of the consolidated forecast are provided in the Annex to this report.

Figure III-2: GDP Forecast



Source: Consultant

L. Food Security

33. In Myanmar the prospect of a declining rural population raises food security concerns. The MCDV anticipates that agricultural labour will decline, but also that the primary sector will continue to be a significant employer and of central importance to Myanmar for many years to come.

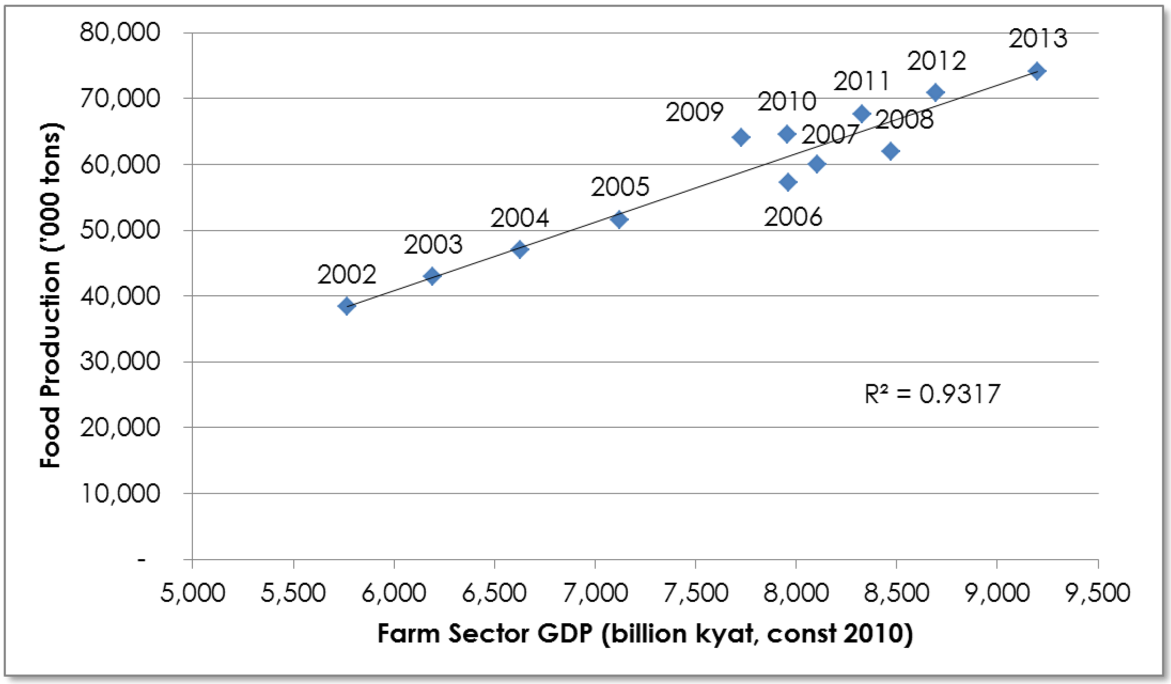
34. In the face of a declining agricultural labour force, food security can be addressed by setting a 'stretch' target for food production for the farm sector. The achievement of the target will require energy inputs (diesel, electricity) and non-energy inputs (seeds, fertilizer, pesticide, water) to support increased productivity of land and labour. An increase in the productivity of land requires high quality seed, fertilizer and water, whereas labour productivity depends primarily on mechanization (tractors, power tillers). These issues are addressed in detail in Volume III – Primary Sector Demand Forecasts, according to the following process:-

1. Relationships were established for the agricultural sector by regressing historical crop production (thousand tons), estimated motive energy[13] (MJ) and estimated agricultural labour on the agriculture contribution to primary sector GDP;

[13] Motive Energy is defined here as the total 'horsepower' of human labour, draft animals, tractors and power tillers.

2. A target crop production of 5.2 tons per hectare was set based on international benchmarks. Agricultural sector GDP forecasts were developed according to the time taken to achieve the crop production target. The chosen lag periods define Low, Medium and High agricultural sector GDP growth scenarios. Agriculture sector labour needs were then determined;
3. Relationships were established for the Industry and Services sectors by regressing labour against GDP; and
4. The total labour requirements, including that of the farm sector, determined in Step 2, were compared to the estimated total available labour force projection. In the cases where a labour deficit was found, farm labour was 'released' to the Industry and Services sectors, with the reduction met by increasing farm mechanization.

Figure III-3: Rice Production & GDP: 2002 – 2013



Source: CSO, ADB Economic Indicators

35. Various indicators were calculated for the GDP growth forecasts; measures of the social impact of growth (rate of workforce change, farm size, urban population growth, rural population decline); measures of the primary sector performance (food production / food security); and measures of energy intensity.

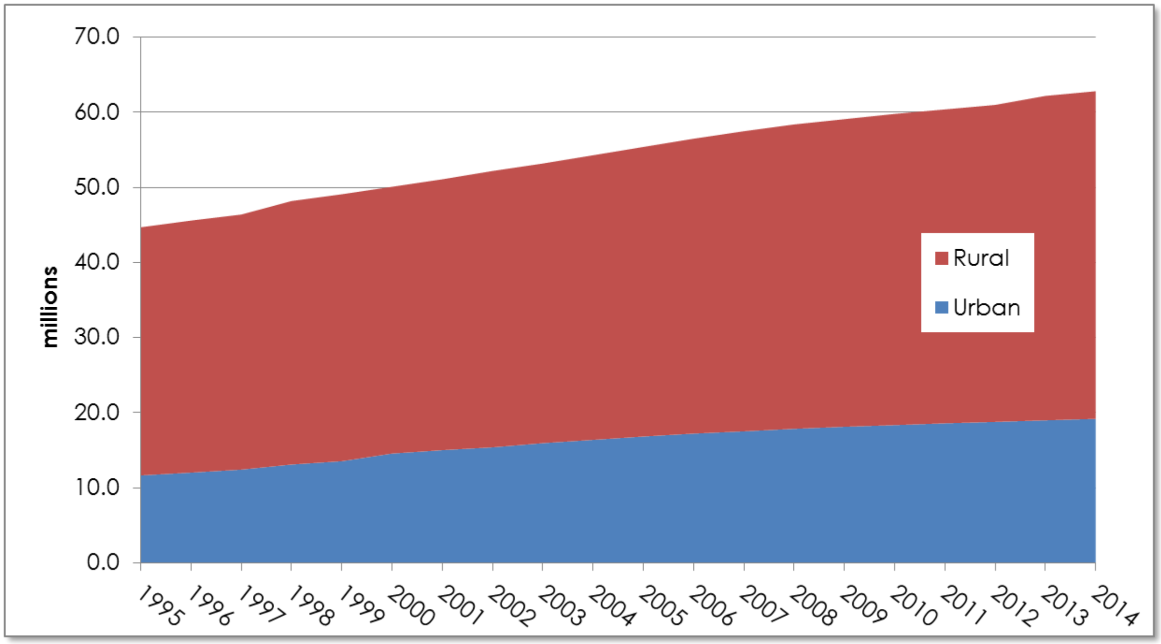
M. Population Forecasts

36. The historical population growth trend shown in Figure III-4 has been used to calibrate energy consumption and for the purpose of forecasting.[14] This time series is drawn from the ADB's Economic

[14] Note that this forecast was conducted using pre-consensus population statistics, which determined the total population to be 50.4 million on 29 March 2014. Afterwards, the impact of the change in population was examined, which appeared not significant to energy demand forecasts because the historical demand forecasts that are driven by population were calibrated against reported energy consumption. The effect of reducing the historical population

Indicators. The compound annual growth rates of the urban and rural populations, from 1995 to 2012, compute at 1.7% and 1.0% respectively.

Figure III-4: Myanmar Population: Urban / Rural Breakdown: 1995 – 2012



Source: CSO, ADB 2012; statistics provided in Annex

37. A population estimate by State and Region, based on data available from the CSO and Myanmar Ministry of Health, is shown in Table III-5. The Consultant's estimate suggests that the urban and rural populations are respectively 16% and 84% of the total.

Table III-5: Myanmar States / Region Population Spread: 2012

State / Region	Urban		Rural		Total	
Ayeyarwaddy Region	496,874	5%	7,708,126	15%	8,205,000	13%
Bago Region	511,162	5%	5,613,838	11%	6,125,000	10%
Chin State	19,517	0%	551,483	1%	571,000	1%
Kachin State	133,940	1%	1,482,060	3%	1,616,000	3%
Kayah State	48,888	1%	316,112	1%	365,000	1%
Kayin State	54,155	1%	1,800,845	4%	1,855,000	3%
Magway Region	434,635	4%	5,295,365	10%	5,730,000	9%
Mandalay Region	1,456,856	15%	5,966,144	12%	7,423,000	12%
Mon State	452,916	5%	2,740,084	5%	3,193,000	5%

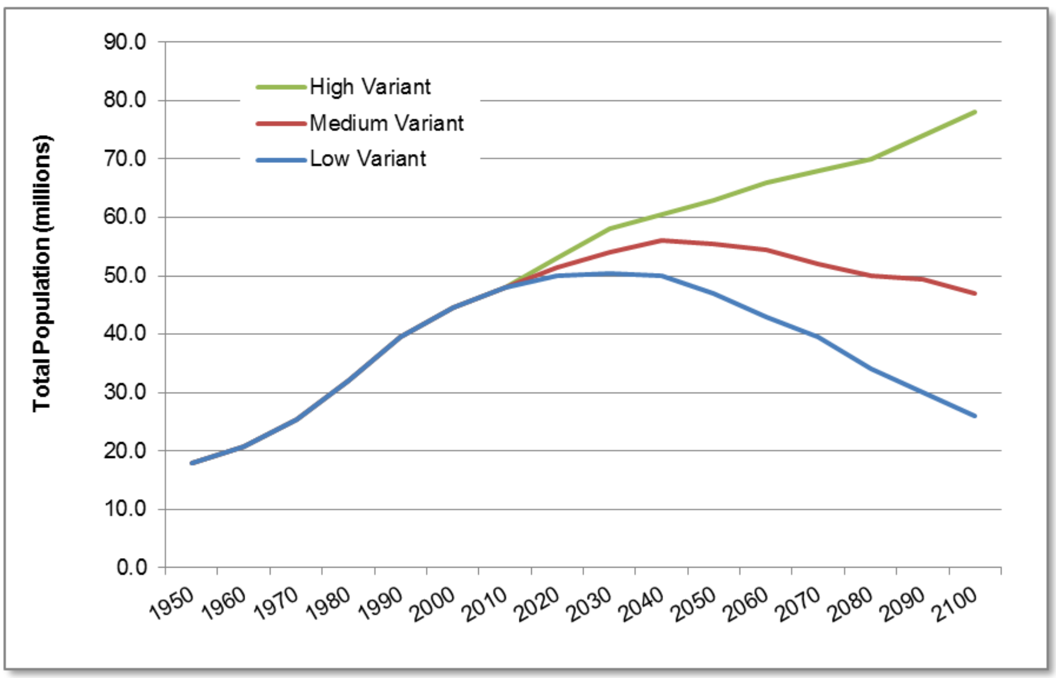
statistics means that the historical per capita energy rates increase. When these new energy consumption rates are applied to the (lower) projections for population using the census 2014 figures as a base, the change to the total energy consumption was not affected significantly.

State / Region	Urban		Rural		Total	
Naypyitaw	170,588	2%	993,412	2%	1,164,000	2%
Rakhine State	261,878	3%	3,108,122	6%	3,370,000	6%
Sagaing Region	447,275	5%	6,206,725	12%	6,654,000	11%
Shan State	432,119	4%	5,347,881	10%	5,780,000	9%
Tanintharyi Region	213,102	2%	1,541,898	3%	1,755,000	3%
Yangon	4,548,320	47%	2,621,680	5%	7,170,000	12%
Total	9,682,227	100%	51,293,773	100%	60,976,000	100%

Source: CSO (Totals); Department of Health Planning, Ministry of Health, Myanmar, 2011 (Urban – adjusted to 2012); Consultant (Rural)

38. In July 2012, the United Nations Population Division published a population growth forecast for Myanmar. The forecasts, depicted in Figure III-6 and Table III-7, show a very wide range of growth potential to 2100. It can be surmised from the chart that the UN Population Division considers that there could be increasing urbanization with industrialization with shrinking family size, or a continued growth trend in the population with average family size maintained.

Figure III-6: Myanmar Population Forecast: 1950 – 2100



Source: Projections based on a 2010 revision of WPP by UN Population Division (July 2012); data provided in Annex

39. For the planning horizon of the Energy Masterplan, from 2014 to 2030, the population forecasts span a range of + / - 10% about the median forecast. These ranges translate into the per annum growth rates shown in Table III-7. A population growth rate of 1% is assumed as a conservative estimate for the purpose of energy planning.

Table III-7: Myanmar Population Growth Rates: 2010 – 2040

	Low	Medium	High
Per Annum	0.1%	0.6%	0.9%

Source: 2010 revision of WPP by UN Population Division (July 2012

40. The population demographic can be expected to change according to the rate at which the industrial and services sectors grow. Table III-8 and Table III-9 provide estimates of the population spread between urban and rural areas under the GDP growth scenarios. The estimates are based on the historical relationship between the labour workforce and GDP of each sector.

Table III-8: Forecast Urban / Rural Population by GDP Growth (millions)

		2013	2015	2020	2025	2030
Low	rural	43.2	44.3	48.7	52.7	53.6
	urban	19.0	19.2	18.0	17.4	20.1
Medium	rural	43.2	44.6	49.8	49.0	47.7
	urban	19.0	18.9	16.9	21.0	26.0
High	rural	43.2	45.1	47.4	42.7	33.0
	urban	19.0	18.4	19.3	27.4	40.6

Sources: Consultant

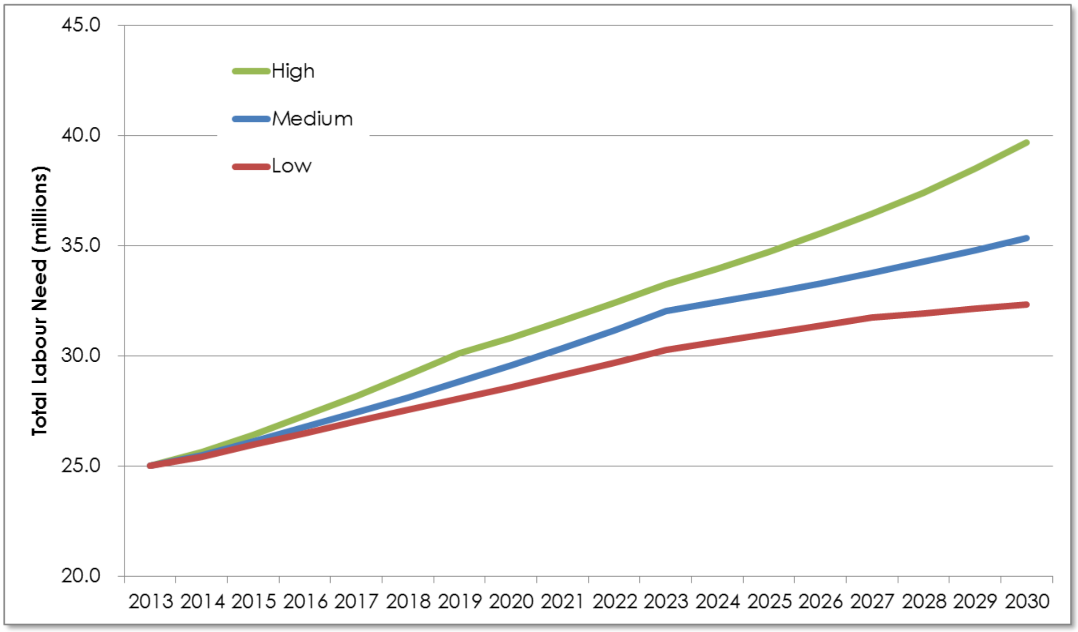
Table III-9: Forecast Urban / Rural Population % by GDP Growth

		2013	2015	2020	2025	2030
Low	% rural	69.5%	69.8%	73.0%	75.1%	72.8%
	% urban	30.5%	30.2%	27.0%	24.9%	27.2%
Medium	% rural	69.5%	70.3%	74.6%	70.0%	64.7%
	% urban	30.5%	29.7%	25.4%	30.0%	35.3%
High	% rural	69.5%	71.0%	71.0%	60.9%	44.9%
	% urban	30.5%	29.0%	29.0%	39.1%	55.1%

Sources: Consultant

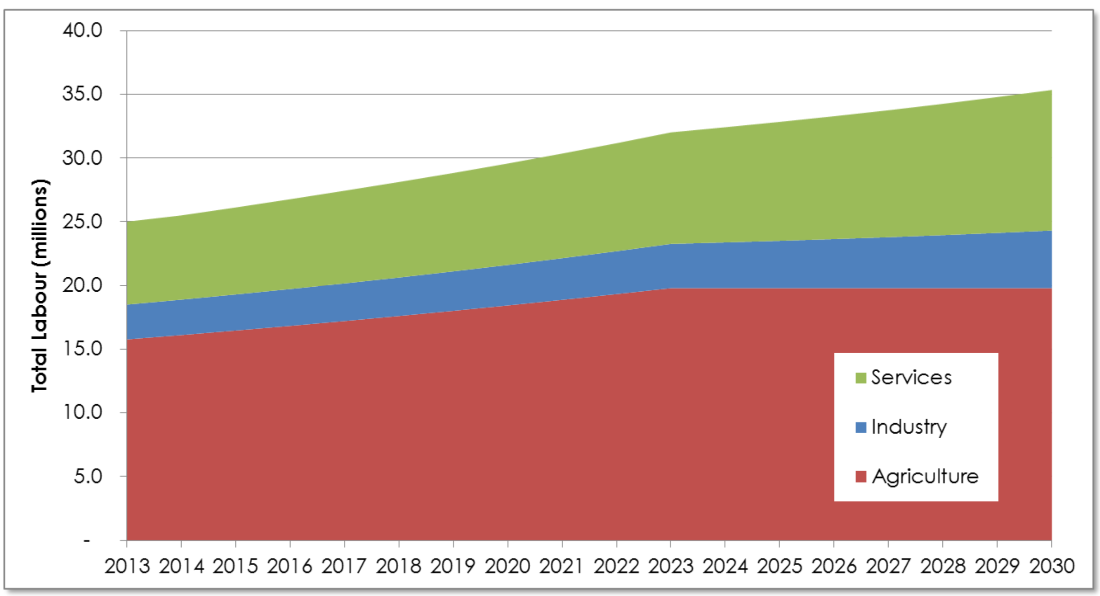
41. The labour workforce projections and deficit, corresponding to the above demographic tables, are shown as Figure III-10, Figure III-11 and Figure III-12.

Figure III-10: Workforce Requirement by Scenario: 2013 - 2030



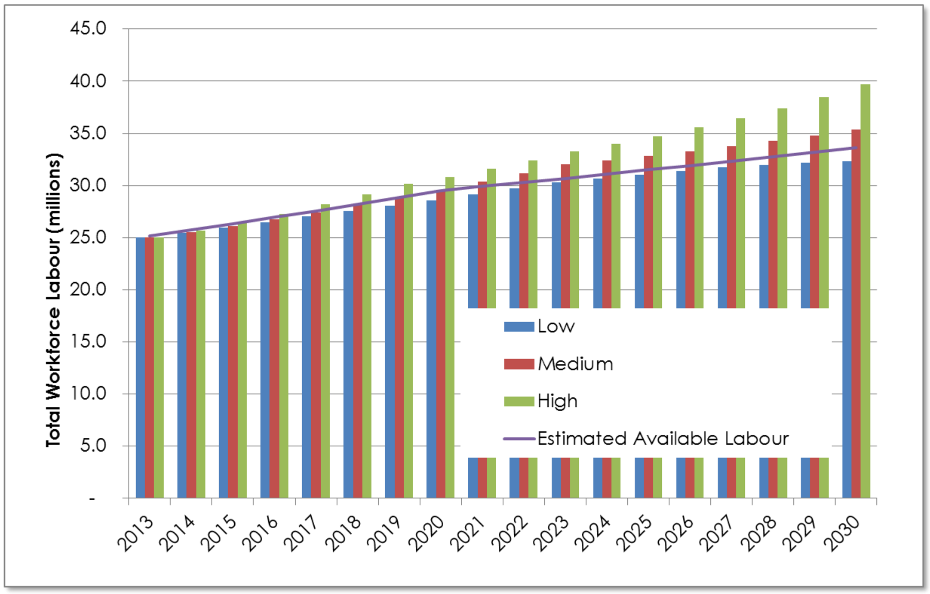
Source: Consultant

Figure III-11: Workforce Requirement (medium growth): 2013- 2030



Source: Consultant

Figure III-12: Labour Workforce Deficit Projections: 2013 - 2030

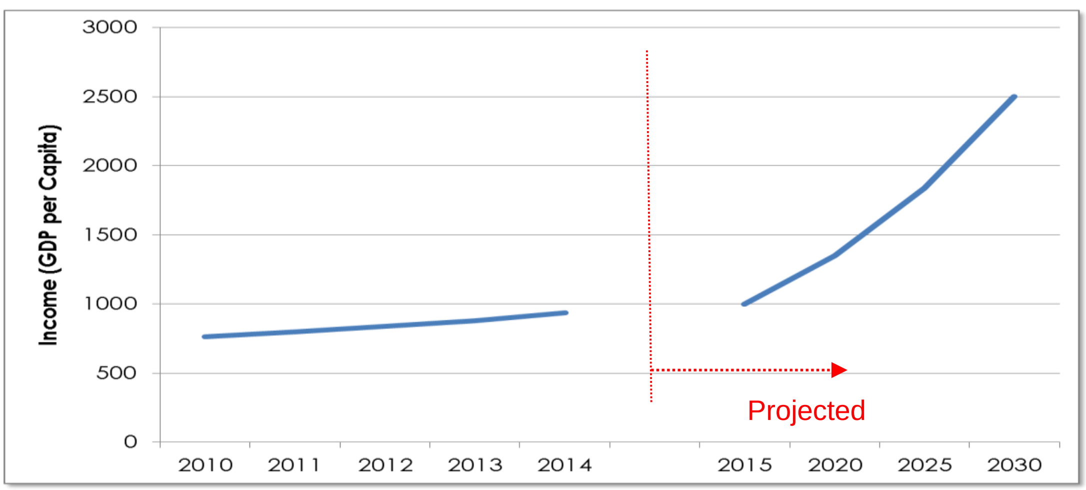


Source: Consultant

N. Per Capita GDP

42. Per capita GDP – calculated as the total GDP divided by the total population – is commonly used as an indicator of standard of living. Although not a measure of personal income, a higher per capita GDP is generally interpreted as an indication of a country's higher standard of living as compared to a lower value. The compound annual growth rate projection for GDP per capita is 6.1%.

Figure III-13: GDP per Capita

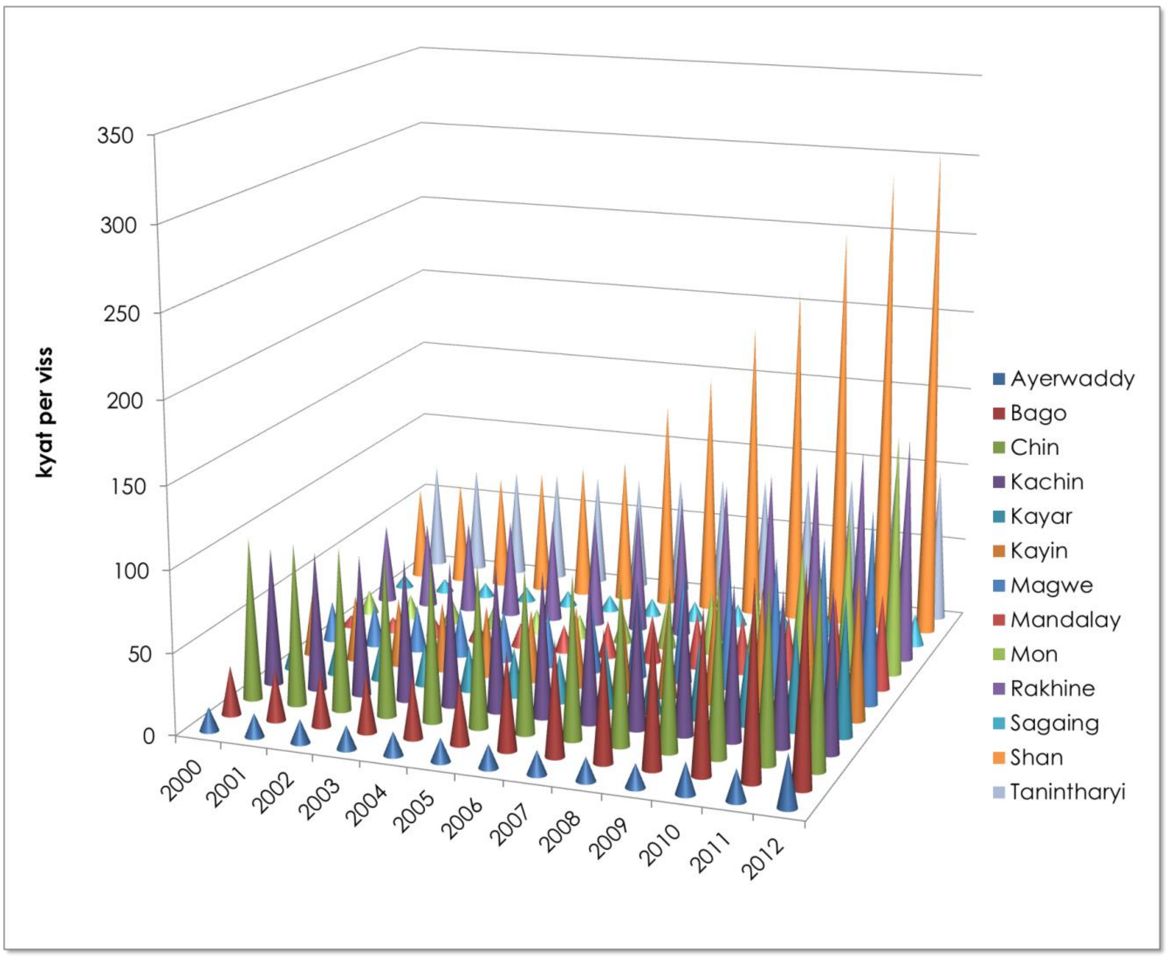


Source: Historical Data (1980- 2010), ADB; Projected Values (2010-2030), ADB

O. Household Income

43. Household income survey data is not available. A reasonable proxy measure for household income is the price of firewood sold commercially through markets around the country. Firewood is an essential Time series data for firewood prices by State and Region was obtained from the Ministry of Environment, Conservation & Forestry. As can be seen from Figure III-14, the data shows that in the hilly areas of Myanmar, where firewood is plentiful, the rate of growth of firewood prices has been relatively low. In the dry areas of Myanmar, prices have risen at a much greater rate. On average the compound average growth rate of the price of firewood has been steady at around 10%. This rate indicates that average real household incomes, outside of Yangon Division and urban Mandalay, have been rising at a similar rate; if not the price of firewood would soon have escalated beyond the ability of households to pay.

Figure III-14: Price of Firewood: 2000 to 2012



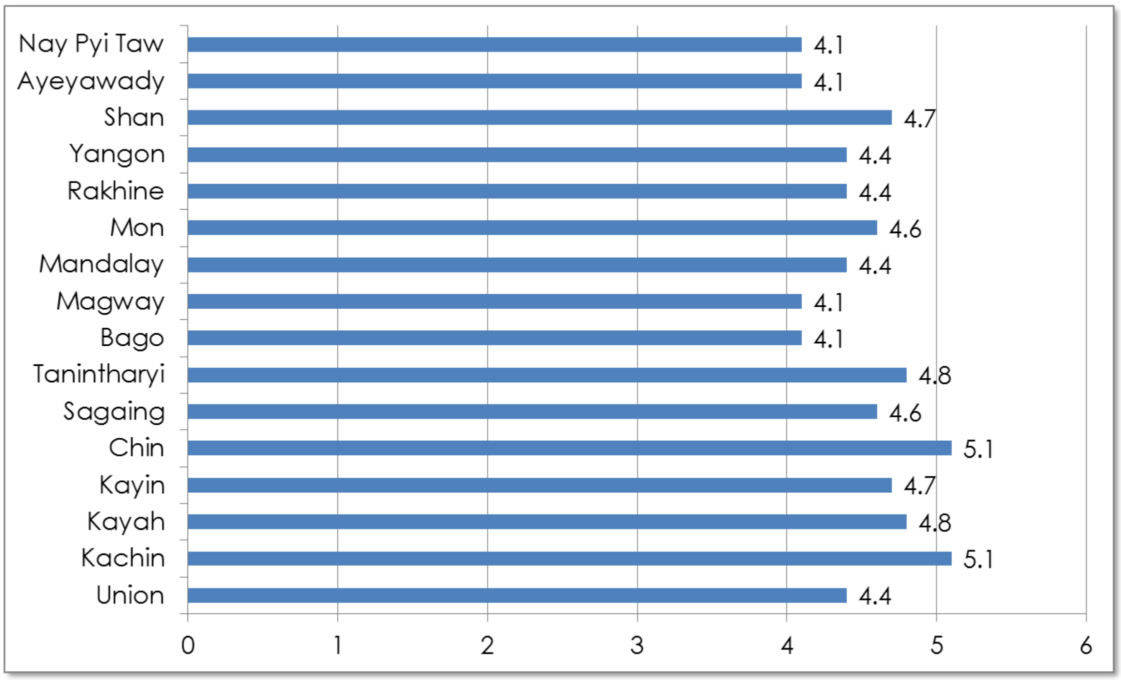
Source: MoECAF

P. Household Counts

44. As energy demand in the residential sector is best estimated for households rather than individuals, the projected number of households is used to estimate future final energy demand for the residential sector. Furthermore, the projected number of households connected to the grid provides a basis for estimating future electricity demand; while the projected number of households not connected to the grid provides a basis for estimating demand for other energy carriers other than electricity in households. A combination of population growth and changes in the average household size determines the total number of households in the future.

45. The number, size and structure of households in Myanmar do not appear to have undergone any significant change since 1995. The Myanmar Population & Household Census results indicate an average household size of 4.4 persons at the national level as shown in Figure III-15.

Figure III-15: Average Size of Households by State/Region



Source: Preliminary Census

46. The average household size is highest in Kachin and Chin States at 5.1. The lowest household sizes were observed in Nay Pyi Taw, Bago, Magwe and Ayerwaddy at 4.1, respectively. The authors of the Preliminary Population & Household Census report stated that "There is no significant variation in average household size between urban and rural areas. For example, one would have expected that Yangon Region, being predominantly urban, would record a low household size, but the average household size is 4.4, the same as the national average."

Q. Percentage of Households with Grid Connection

47. Universal access to modern forms of clean energy is a strategic objective of the Government of Myanmar. Electrification is a cornerstone of social development and has been proven to positively

contribute to developmental goals. MoEP reported that around 950,000 grid connections were made between 2008 and 2012.

Table III-16: New Connections: 2008 to 2012

	2008	2009	2010	2011	2012
Ayeyarwaddy Region	10,993	6,838	8,750	7,602	9,140
Bago Region	60,825	16,801	7,902	11,937	16,984
Chin State	993	1,142	808	542	347
Kachin State	6,316	9,757	5,100	4,907	5,857
Kayah State	2,368	895	524	1,060	1,209
Kayin State	4,640	746	1,424	2,225	2,161
Magway Region	22,582	12,483	5,237	4,741	6,527
Mandalay Region	55,678	22,331	13,923	14,894	31,233
Mon State	22,441	12,907	6,709	6,692	8,383
Naypyitaw	24,018	2,745	19,595	9,837	12,789
Rakhine State	3,200	1,705	1,709	1,722	2,443
Sagaing Region	33,733	11,166	10,328	6,988	14,731
Shan State	22,913	19,037	16,211	16,767	25,355
Tanintharyi Region	340	138	504	395	262
Yangon Division	67,992	28,324	30,976	35,630	57,012
Total	341,040	149,024	131,710	127,950	196,445

Source: MoEP

48. According to MoEP statistics collected in 2014, the percentage of households connected to the grid at the start of 2014 was 19%.

49. The percentage of households connected to the grid is expected to grow to an estimated 95% by 2030. The percentage of households is not expected to reach 100% due to technical constraints and the high cost of infrastructure required to reach to the remotest areas of the country. Nevertheless universal access to electricity is expected to be accomplished through the implementation of off-grid solutions and non-grid solar home systems.

Table III-11: HH's with Grid Connection

	Total HH's	% Grid Electrified	HH Grid Electrified
Ayeyarwaddy	1,941,899	4%	149,949
Bago Region	1,449,620	7%	256,870
Chin State	108,642	8%	13,710
Kachin State	307,470	7%	62,342
Kayah State	73,788	17%	21,896
Kayin State	382,982	5%	33,010
Magway Region	1,356,134	5%	136,881
Mandalay Region	1,564,256	13%	410,605
Mon State	673,555	6%	116,329
Naypyitaw	275,487	0%	86,288
Rakhine State	743,206	3%	33,227
Sagaing Region	1,403,644	6%	219,151
Shan State	1,193,334	7%	233,056
Tanintharyi Region	354,787	5%	18,930
Yangon Division	1,789,736	49%	949,925
Total	14,233,196		2,742,169
% Grid Electrified			19%

Source: MoEP, Consultant Estimate

Annexes

ANNEX 1: GDP by SUB-SECTOR: 1995 – 2012 (Source: ADB)

	1995	1996	1997	1998	1999	2000	2001	2002	2003
Total	1,692.9	1,802.0	1,906.1	2,017.8	2,238.6	2,538.1	2,842.3	3,184.1	3,624.9
Agriculture	714.0	760.0	803.9	851.0	944.1	1,070.4	1,588.3	1,684.1	1,881.2
Mining	40.5	43.1	45.6	48.3	53.6	60.7	15.8	20.5	22.3
Manufacturing	172.2	183.3	193.8	205.2	227.7	258.1	222.8	286.8	350.0
Electricity, gas and water	18.6	19.8	20.9	22.1	24.6	27.8	3.2	3.9	4.5
Construction	79.3	84.4	89.3	94.6	104.9	118.9	59.6	95.6	114.5
Trade	352.8	375.5	397.2	420.5	466.5	528.9	678.9	750.3	849.9
Transport and communication	114.8	122.2	129.2	136.8	151.8	172.1	184.1	237.4	284.0
Finance	35.4	37.7	39.9	42.2	46.9	53.1	3.3	4.8	5.3
Public administration	101.3	107.8	114.0	120.7	133.9	151.8	44.7	50.7	56.2
Others	64.1	68.3	72.2	76.4	84.8	96.2	41.6	50.0	57.0

	2004	2005	2006	2007	2008	2009	2010	2011	2012
Total	4,116.6	4,675.2	13,893.4	15,559.4	17,155.1	18,964.9	20,792.1	42,004.6	45,209.6
Agriculture	2,087.8	2,340.0	6,290.3	6,789.9	7,170.2	7,569.8	7,923.7	14,562.6	14,847.0
Mining	25.2	33.2	98.8	104.8	119.6	133.3	143.4	401.2	374.2
Manufacturing	436.4	532.2	1,919.9	2,326.0	2,750.7	3,269.5	3,938.8	8,754.6	9,488.9
Electricity, gas and water	4.8	5.7	30.5	31.9	35.5	41.8	53.5	444.0	480.6
Construction	130.0	144.3	531.9	623.4	736.3	837.6	942.7	2,004.8	2,191.9
Trade	958.7	1,074.3	3,009.8	3,357.6	3,680.2	4,043.0	4,460.0	8,341.2	8,754.9
Transport and communication	337.2	392.4	1,652.8	1,922.9	2,211.7	2,569.9	2,756.5	5,577.6	6,853.6
Finance	6.7	10.2	12.0	14.2	17.6	23.0	31.6	78.0	109.2
Public administration	64.5	69.9	122.7	133.7	143.9	154.3	178.9	989.0	1,130.5
Others	65.3	73.1	224.6	255.0	289.5	322.8	363.0	851.6	978.8

ANNEX 2: MACRO-ECONOMIC INDICATORS: IMF (INCLUDING SHORT TERM PROJECTIONS to FY 2017)

	2007-08	2008-09	2009-10	2010-11	2011-12	2012-13	2013-14	2014-15	2015-16	2016-17	2017-18
GDP Growth (real)	12	10.3	10.6	10.4							
Staff working estimates of real GDP	5.5	3.6	5.1	5.3	5.5	6.3	6.5	6.6	6.7	6.8	6.9
Agriculture	8	3.4	4.7	4.4	4.4	4.2	4.9	5	5.3	5.4	5.4
Industry	21.8	3	5	6.3	6.5	7.2	7.2	7.2	7.2	7.6	7.6
Services	12.9	4.2	5.8	6.1	6.3	8.5	8	8.1	8.1	8.1	8.1
Inflation (CPI, end of period)	28.8	9.2	7.1	8.9	5	6.1	5.3	5	5	5	5
Exchange rate	1156	917	918	861	822	828					
FDI forecast millions US	715	976	963	969	1992	2325	1811	2050	2600	3000	3350

Source: IMF

ANNEX 3: UN POPULATION PROJECTIONS FOR MYANMAR (US$ millions)

	1950	1960	1970	1980	1990	2000	2010	2020	2030	2040	2050	2060	2070	2080	2090	2100
Low	18.0	20.8	25.5	32.0	39.5	44.5	48.0	50.0	50.5	50.0	47.0	43.0	39.5	34.0	30.0	26.0
Medium	18.0	20.8	25.5	32.0	39.5	44.5	48.0	51.5	54.0	56.0	55.5	54.5	52.0	50.0	49.5	47.0
High	18.0	20.8	25.5	32.0	39.5	44.5	48.0	53.0	58.0	60.5	63.0	66.0	68.0	70.0	74.0	78.0

Source: UN Population Division

ANNEX 4: BREAKDOWN OF URBAN-RURAL POPULATION 1997 – 2012

	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Rural	34.0	35.1	35.5	35.5	36.1	36.8	37.2	37.9	38.6	39.3	40.0	40.5	41.0	41.4	41.8	42.2
Urban	12.4	13.1	13.6	14.6	15.0	15.4	16.0	16.4	16.8	17.2	17.5	17.9	18.1	18.4	18.6	18.8
Total	46.4	48.2	49.1	50.1	51.1	52.2	53.2	54.3	55.4	56.5	57.5	58.4	59.1	59.8	60.4	61.0

Source: ADB

ANNEX 5: MYANMAR: MAIN TRADING PARTNERS: EXPORT FY 2008 – FY 2010 (US$ millions)

	2008-09	2009-10	2010-11
Singapore	832.75	670.41	456.99
Malaysia	311.69	152.61	437.80
Indonesia	28.45	37.43	41.11
Philippines	8.99	27.21	22.30
Thailand	2631.23	3215.68	2905.18
Vietnam	39.58	54.75	67.03
Lao	0.04	0.00	0.02
Cambodia	-	-	0.04
Brunei	0.98	0.75	0.37
PRC	617.67	617.16	1203.56
Sri Lanka	7.19	9.37	1.44
Hong Kong	673.43	947.70	1894.69
India	803.83	1013.14	871.59
Bangladesh	110.76	69.34	125.03
Japan	183.50	177.35	237.43
Pakistan	29.64	20.47	19.56
Maldives	-	-	-
Korea	63.22	75.58	148.39
Kuwait	30.97	53.96	54.16
Saudi Arabia	24.89	25.70	26.54
UAE	35.38	34.88	32.45
Total	6434.19	7203.49	8545.68

Source: Central Statistics Office of Myanmar

ANNEX 6: MYANMAR: MAIN TRADING PARTNERS: IMPORT FY 2008 – FY 2010 (US$ millions)

	2008-09	2009-10	2010-11
South-East Asia	2 042.50	1 922.14	2 840.60
Rest of Asia	1 787.90	2 001.26	3 015.94
Middle East	23.10	45.39	142.14
Americas	538.17	26.36	82.68
North-West Europe	98.42	101.93	186.37
Southern Europe	11.53	8.36	38.13
Eastern Europe	9.12	8.57	10.91
Africa	2.47	5.77	3.27
Oceania	29.11	59.19	88.71
Total	4 542.32	4 178.97	6 408.75

Source: Central Statistics Office of Myanmar

ANNEX 7: MAIN GOODS AND COMMODITIES TRADED: EXPORTS FY 2007 – FY 2010 (US$ millions)

	2007-08	2008-09	2009-10	2010-11
Agricultural Products	852	1 047	1 320	1 228
Animal Products	4	5	7	13
Marine Products	301	276	277	287
Timber	539	411	494	594
Base Metals & Ores	86	32	33	42
Precious Minerals	646	671	949	2 028
Gas	2 521	2 385	2 927	2 523
Garments	283	292	283	379
Other Commodities	1 170	1 660	1 297	1 767
Total	6 402	6 779	7 587	8 861

Source: Central Statistics Office of Myanmar

ANNEX 8: MAIN GOODS AND COMMODITIES TRADED: IMPORTS FY 2008 – FY 2010 (US$ millions)

	2008-09	2009-10	2010-11
Milk, Condensed & Evaporated	36.8	41.7	37.9
Edible Vegetable Oils	295.4	178.9	202.4
Dyeing, tanning, colouring	7.8	9.6	12.4
Chemicals	33.3	45.1	48.8
Pharmaceuticals	124.6	146.2	180.9
Manufactured Fertilizers	2.3	11.0	14.9
Cotton fabrics	33.8	25.9	23.8
Fabrics of artificial	150.0	143.0	207.5
Paper, paperboard	71.9	58.3	70.3
Rubber manufactures	47.4	64.3	61.0
Cement	26.9	57.3	140.4
Refined mineral oil	585.6	673.5	1 390.7
Scientific instrument	33.9	26.7	48.5
Base metals and	333.6	365.3	552.9
Machinery non-electric	1 328.2	899.7	1 201.2
Electrical machinery	174.0	179.1	347.8
Other	46.4	36.9	61.5

Source: Central Statistics Office of Myanmar

ANNEX 9: Myanmar GDP Growth Forecast by Sector (2014 – 2030): LOW SCENARIO

		2014	2015	2016	2017	2018	2019	2020	2021	2022
Agriculture	billion kyat const 2010	12,535	12,979	13,437	13,912	14,402	14,909	15,433	15,975	16,536
Industry		33,550	36,132	38,385	40,779	43,323	45,800	48,180	50,684	53,318
Services		12,335	13,322	14,223	15,036	15,739	16,393	17,075	17,785	18,432
Total	billion kyat const 2010	58,421	62,433	66,045	69,727	73,464	77,102	80,689	84,445	88,286
	growth %	6.8%	6.9%	5.8%	5.6%	5.4%	5.0%	4.7%	4.7%	4.5%
GDP per Capita	thousand kyat	939	994	1,041	1,088	1,135	1,179	1,222	1,266	1,311

		2023	2024	2025	2026	2027	2028	2029	2030
Agriculture	billion kyat const 2010	17,114	17,718	18,340	19,162	20,017	20,817	21,650	22,516
Industry		56,090	59,005	62,072	65,298	68,691	72,262	76,017	79,968
Services		19,103	19,798	20,415	21,052	21,708	22,385	23,083	23,683
Total	billion kyat const 2010	92,307	96,521	100,826	105,511	110,416	115,464	120,751	126,168
	%	4.6%	4.6%	4.5%	4.6%	4.6%	4.6%	4.6%	4.5%
GDP per Capita	thousand kyat	1,357	1,405	1,453	1,505	1,560	1,615	1,672	1,730

Source: Consultant

ANNEX 10: Myanmar GDP Growth Forecast by Sector (2014 – 2030): MEDIUM SCENARIO

		2014	2015	2016	2017	2018	2019	2020	2021	2022
Agriculture	billion kyat const 2010	12,677	13,268	13,879	14,511	15,165	15,841	16,509	17,206	17,933
Industry		33,656	36,474	39,431	42,680	46,310	50,248	54,524	59,306	64,508
Services		12,376	13,453	14,570	15,685	16,773	17,893	19,087	20,348	21,641
Total	billion kyat const 2010	58,709	63,195	67,880	72,876	78,247	83,982	90,120	96,861	104,081
	%	7.3%	7.6%	7.4%	7.4%	7.4%	7.3%	7.3%	7.5%	7.5%
GDP per Capita	thousand kyat	944	1,006	1,070	1,137	1,209	1,285	1,365	1,452	1,545

		2023	2024	2025	2026	2027	2028	2029	2030
Agriculture	billion kyat const 2010	18,601	19,301	20,025	20,875	21,758	22,628	23,533	24,475
Industry		70,123	76,228	82,813	89,968	97,741	106,186	115,360	125,326
Services		23,000	24,446	25,902	27,429	29,027	30,719	32,509	34,319
Total	billion kyat const 2010	111,724	119,974	128,741	138,272	148,526	159,533	171,402	184,120
	%	7.3%	7.4%	7.3%	7.4%	7.4%	7.4%	7.4%	7.4%
GDP per Capita	thousand kyat	1,642	1,746	1,855	1,973	2,098	2,231	2,374	2,524

Source: Consultant

ANNEX 11: Myanmar GDP Growth Forecast by Sector (2014 – 2030): HIGH SCENARIO

		2014	2015	2016	2017	2018	2019	2020	2021	2022
Agriculture	billion kyat const 2010	12,820	13,560	14,330	15,129	15,959	16,820	17,649	18,519	19,434
Industry		33,761	36,817	40,492	44,639	49,446	55,031	61,535	69,131	77,665
Services		12,416	13,584	14,922	16,353	17,856	19,498	21,290	23,219	25,323
Total	billion kyat const 2010	58,997	63,962	69,744	76,121	83,262	91,349	100,474	110,870	122,422
	Total GDP Growth %	7.8%	8.4%	9.0%	9.1%	9.4%	9.7%	10.0%	10.3%	10.4%
GDP per Capita	thousand kyat	949	1,018	1,099	1,188	1,286	1,397	1,522	1,663	1,818

		2023	2024	2025	2026	2027	2028	2029	2030
Agriculture	billion kyat const 2010	20,201	21,009	21,849	22,723	23,632	24,578	25,561	26,583
Industry		87,150	97,794	109,609	122,852	137,695	154,331	172,977	193,876
Services		27,585	30,048	32,692	35,525	38,558	41,849	45,422	49,299
Total	billion kyat const 2010	134,936	148,851	164,151	181,101	199,885	220,758	243,960	269,758
	Total GDP Growth %	10.2%	10.3%	10.3%	10.3%	10.4%	10.4%	10.5%	10.6%
GDP per Capita	thousand kyat	1,984	2,166	2,365	2,584	2,824	3,088	3,378	3,699

Source: Consultant

ANNEX 12: Myanmar Labour Forecast (2014 – 2022): ALL SECTORS

		2014	2015	2016	2017	2018	2019	2020	2021	2022
LOW GDP	billion kyat const 2010	58,421	62,433	66,045	69,727	73,464	77,102	80,689	84,445	88,286
	growth %	6.8%	6.9%	5.8%	5.6%	5.4%	5.0%	4.7%	4.7%	4.5%
Total Labour Need	Millions	25.4	26.0	26.5	27.0	27.5	28.1	28.6	29.1	29.7
Available Labour	Millions	25.8	26.4	27.0	27.6	28.2	28.9	29.5	29.9	30.3
Labour Deficit	%	-1.3%	-1.4%	-1.7%	-2.0%	-2.4%	-2.8%	-3.2%	-2.6%	-2.0%
Farm Labour Quota	Millions	16.1	16.3	16.7	17.0	17.3	17.6	18.0	18.3	18.7
MEDIUM GDP	billion kyat const 2010	58,709	63,195	67,880	72,876	78,247	83,982	90,120	96,861	104,081
	growth %	7.3%	7.6%	7.4%	7.4%	7.4%	7.3%	7.3%	7.5%	7.5%
Total Labour Need	Millions	25.5	26.1	26.8	27.4	28.1	28.8	29.6	30.4	31.2
Available Labour	Millions	25.8	26.4	27.0	27.6	28.2	28.9	29.5	29.9	30.3
Labour Deficit	%	-1.0%	-0.9%	-0.7%	-0.5%	-0.3%	-0.1%	0.1%	1.5%	2.9%
Farm Labour Quota	Millions	16.1	16.5	16.8	17.2	17.6	18.0	18.4	18.3	18.2
HIGH GDP	billion kyat const 2010	58,997	63,962	69,744	76,121	83,262	91,349	100,474	110,870	122,422
	growth %	7.8%	8.4%	9.0%	9.1%	9.4%	9.7%	10.0%	10.3%	10.4%
Total Labour Need	Millions	25.6	26.4	27.3	28.2	29.1	30.1	30.8	31.6	32.4
Available Labour	Millions	25.8	26.4	27.0	27.6	28.2	28.9	29.5	29.9	30.3
Labour Deficit	%	-0.5%	0.3%	1.2%	2.2%	3.2%	4.4%	4.4%	5.6%	6.9%
Farm Labour Quota	Millions	16.2	16.6	16.8	17.0	17.2	17.3	17.5	17.2	16.9

Sources: Consultant

Myanmar Labour Forecast (2023 – 2030): ALL SECTORS

		2023	2024	2025	2026	2027	2028	2029	2030
LOW GDP	billion kyat const 2010	92,307	96,521	100,826	105,511	110,416	115,464	120,751	126,168
	growth %	4.6%	4.6%	4.5%	4.6%	4.6%	4.6%	4.6%	4.5%
Total Labour Need	millions	30.3	30.6	31.0	31.4	31.7	31.9	32.1	32.3
Available Labour	millions	30.7	31.1	31.5	31.9	32.3	32.7	33.2	33.6
Labour Deficit	%	-1.4%	-1.5%	-1.6%	-1.7%	-1.8%	-2.5%	-3.1%	-3.7%
Farm Labour Quota	millions	19.1	19.3	19.4	19.6	19.8	19.8	19.8	19.8
MEDIUM GDP	billion kyat const 2010	111,724	119,974	128,741	138,272	148,526	159,533	171,402	184,120
	growth %	7.3%	7.4%	7.3%	7.4%	7.4%	7.4%	7.4%	7.4%
Total Labour Need	millions	32.0	32.4	32.8	33.3	33.8	34.3	34.8	35.4
Available Labour	millions	30.7	31.1	31.5	31.9	32.3	32.7	33.2	33.6
Labour Deficit	%	4.3%	4.3%	4.3%	4.3%	4.4%	4.6%	4.9%	5.2%
Farm Labour Quota	millions	18.1	18.1	18.1	18.1	18.0	17.9	17.8	17.6
HIGH GDP	billion kyat const 2010	134,936	148,851	164,151	181,101	199,885	220,758	243,960	269,758
	growth %	10.2%	10.3%	10.3%	10.3%	10.4%	10.4%	10.5%	10.6%
Total Labour Need	millions	33.3	34.0	34.7	35.5	36.4	37.4	38.5	39.7
Available Labour	millions	30.7	31.1	31.5	31.9	32.3	32.7	33.2	33.6
Labour Deficit	%	8.4%	9.2%	10.2%	11.4%	12.7%	14.3%	16.1%	18.1%
Farm Labour Quota	millions	16.6	16.2	15.8	15.2	14.6	13.9	13.1	12.2

Sources: Consultant

Project Number: TA No. 8356-MYA

FINAL REPORT

HISTORICAL ENERGY BALANCES

Prepared for

The Asian Development Bank

and

The Myanmar Ministry of Energy

Prepared by:

IES Intelligent Energy Systems

in association with:

MMIC MYANMAR INTERNATIONAL CONSULTANTS

ABBREVIATIONS

ADB	–	Asian Development Bank
ASEAN	–	Association of South-East Asian Nations
CSO	–	Central Statistics Organisation
GCV	–	Gross Calorific Value
HH	–	Household
IEA	–	International Energy Agency
MOE	–	Ministry of Energy
MOECAF	–	Ministry of Environment, Conservation and Forestry
MOEP	–	Ministry of Electric Power
MOGE	–	Myanma Oil and Gas Enterprise
MPPE	–	Myanma Petroleum Products Enterprise
LNG	–	Liquefied Natural Gas
LPG	–	Liquefied Petroleum Gas
SBP	–	Special Boiling Point

UNITS OF MEASURE

bbl	–	barrel
bbl/d	–	barrel per day
cf	–	(standard) cubic foot
GJ	–	Gigajoule (one thousand megajoules)
kJ	–	Kilojoule
kWh	–	Kilowatt-hour
MJ	–	Megajoule
MWh	–	Megawatt-hour
MWel	–	Megawatt electric
PJ	–	Petajoule
TJ	–	Terajoule
toe	–	Tonne of oil equivalent
ton	–	Metric ton

WEIGHTS AND MEASURES

Ccf	–	100 cubic feet
GW (giga watt)	–	1,000,000,000 calories
GJ (giga joules)	–	1,000,000,000 joules
GW (giga watt)	–	1,000,000,000 watts
ktoe	–	1,000 tonnes of oil equivalent
kVA (kilovolt-ampere)	–	1,000 volt-amperes
kW (kilowatt)	–	1,000 watts
kWh (kilowatt-hour)	–	1,000 watts-hour
MMcf	–	1,000,000 cubic feet
MMcfd	–	1,000,000 cubic feet per day
Tcf	–	1,000,000,000 cubic feet

Mtoe	–	1,000,000 tonnes of oil equivalent
MW (megawatt)	–	1,000,000 watts
W (watt)	–	unit of active power
'000 ton	–	1,000 ton
kton	–	1,000 ton

CONVERSION FACTORS

1 GCal	=	4.19 GJ
1 BTU	=	1.05506 kJ
1 Gcal	=	1.1615 MWh = 4.19 GJ
1 GJ	=	0.278 MWh = 0.239 Gcal
1 MW	=	0.86 Gcal = 3.6 GJ
1 toe	=	11.63 MWh
1 toe	=	41.87 GJ
1 toe	=	39,683,205.411 BTU

CONTENTS

I. SUMMARY

A. Introduction

1. Myanmar is well-endowed with domestic energy sources, particularly natural gas and the potential to generate hydroelectricity. Bordering People's Republic of China (PRC), India, Thailand and Bangladesh the country is also strategically located to countries that have large combined and individual energy needs. Not unsurprisingly, Myanmar finds itself in a situation where it exports a large fraction of the total primary energy it produces. In the recent past, Myanmar has experienced increased demand for energy services from industrial, commercial and residential sectors, placing pressure on the existing energy infrastructure to support growth. As a consequence of low electricity access levels, fuel wood plays a significant role in satisfying the final consumption at the household level both in urban and rural areas.

2. The purpose of this report is to set out a historical energy balance for Myanmar in order to provide information on the trends in primary energy supply and final end use energy consumption over the last 13 years. This provides a baseline for projecting Myanmar's energy sector as part of the expansion plans that we later develop within the Energy Master Plan (EMP).

3. The report has been based on data collected from the Government of the Republic of the Union of Myanmar ministries as part of ADB Technical Assistance (TA) project 8536. The energy balances have been developed in isolation from other energy balances for the country that have been published, for example, by the International Energy Agency (IEA) and internally by the Ministry of Energy (MOE) Energy Planning Department. The report provides a statement of the raw "physical" data that was collected and the calorific value assumptions that have been applied to the physical data to derive the energy balance. In this way, alternative calorific value assumptions or conventions can be applied to the physicals presented to arrive at an alternative energy balance. Notwithstanding some gaps and issues in terms of categorisation in the data sets, we present the Total Primary Energy Production (TPEP), Total Primary Energy Supply (TPES) and Total Final Energy Consumption (TFEC) in a number of statistical tables in this report.

B. Approach to Energy Balance

4. A model for Myanmar's energy sector is illustrated in Figure I-1. This illustrates the key components and transformation processes of Myanmar's energy industry. It also sets out the main categories for primary, secondary and tertiary sectors that we have adopted for use in both historical analysis as well as later, in our projections. This conceptual model is useful to have in mind as we work through different aspects of the energy balance; importantly, we can see a distinction between primary energy supply and the secondary sector – where primary energy resources are transformed into different energy products or different forms of energy through to their various end uses.

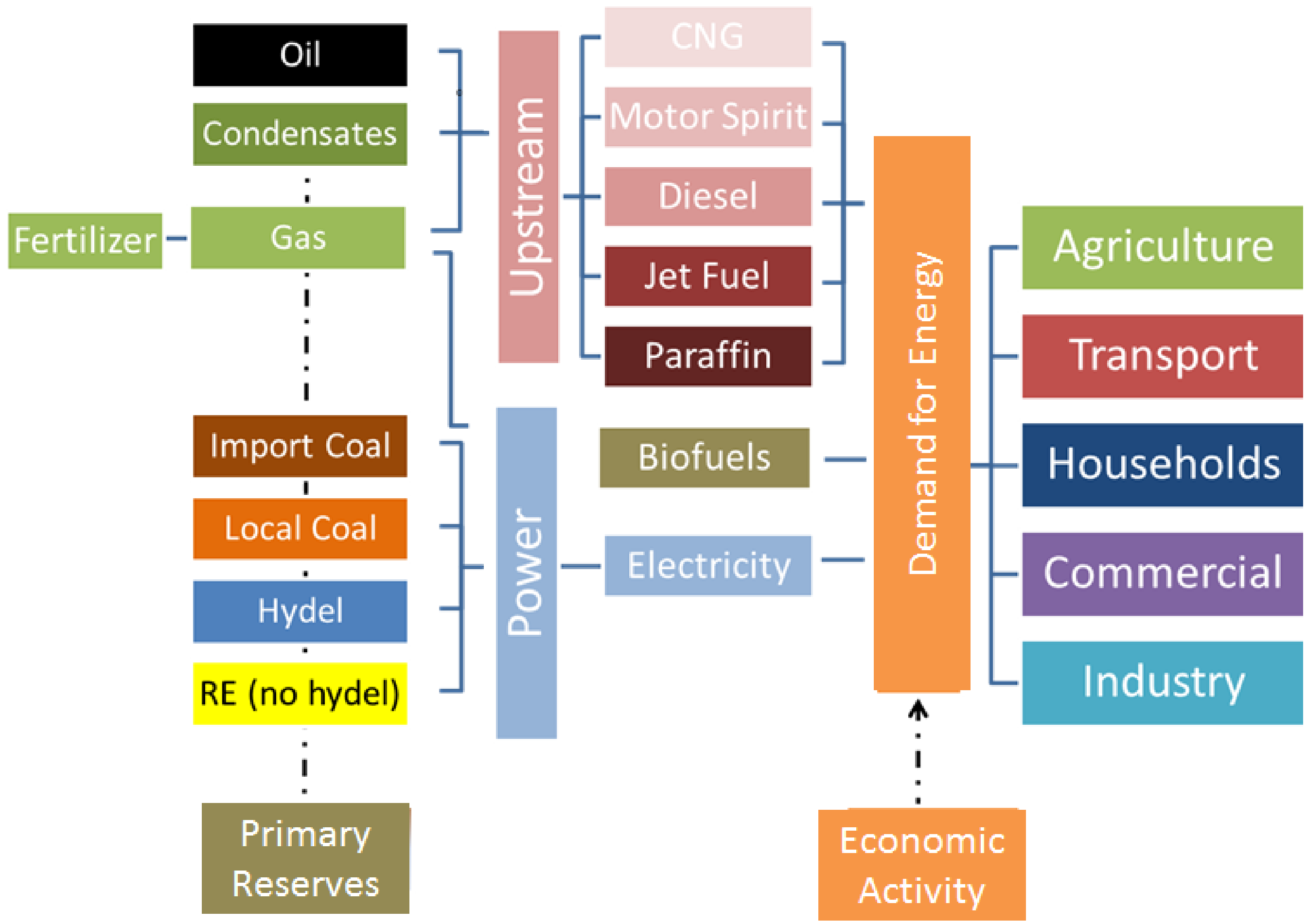
5. An Energy Balance is essentially a process that seeks to account for the flow of energy from the supply side, through transformation processes and onto end-use energy consumption without double counting and with reference to measurements taken of energy stocks, conversions and consumption statistics. Historical Energy Balances are an important step in developing an integrated energy plan as it enables not only trends to be identified but also the interrelationship between different energy forms to be assessed and mapped out.

6. Accurate information on energy stocks, energy supply and consumption is crucial in the development of an Energy Balance. For the Energy Balance work presented in this chapter data

was collected on the primary, secondary and tertiary sectors from the Ministries and Central Statistics Organisation (CSO). Separately, surveys and other estimates have been conducted as a way of reconciling discrepancies and/or inconsistencies in the information collected. A final issue encountered was non-uniform categorisation of energy consumption.

7. This report presents the Historical Energy Balances for Myanmar and in doing so consolidates the information that was collected.

Figure I-1: Model of Myanmar's Energy Sector



C. Total Primary Energy Production (TPEP)

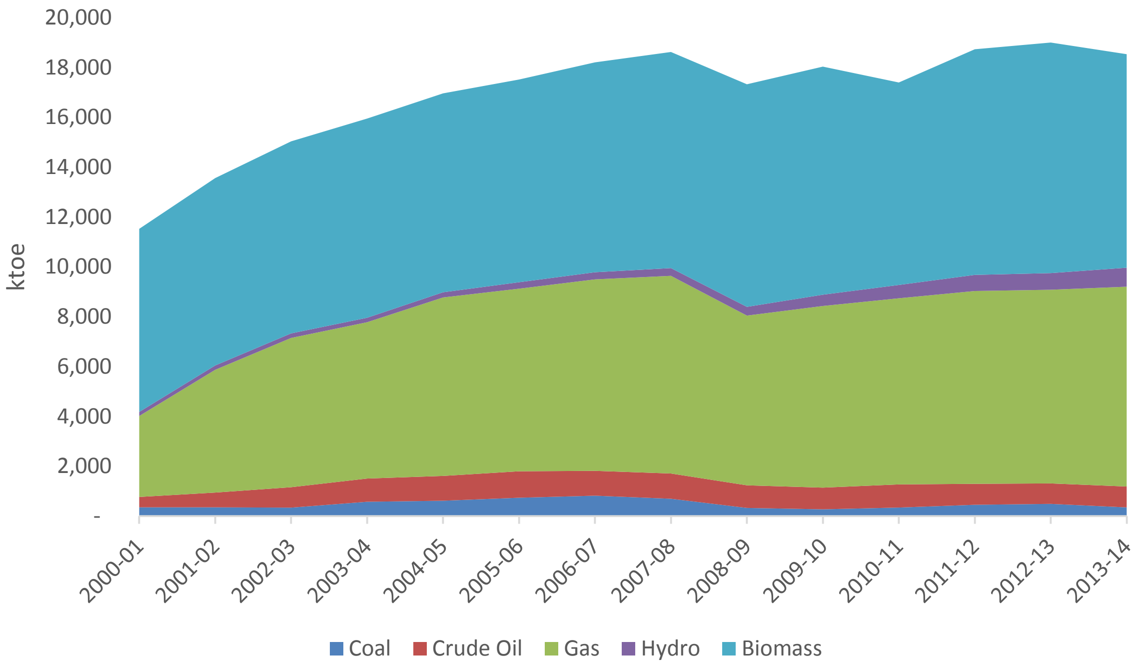
8. TPEP by definition is the total domestic production for a country by the type of energy carrier.

9. Figure I-2 plots the Myanmar's domestic TPEP for 14 years from 2000 to 2014. This demonstrates Myanmar domestically produces a total of 18.53 Mtoe of primary energy with biomass, gas, crude oil (5%), coal and hydro being the main constituents. As Figure I-3 illustrates biomass makes up some 46% of the total domestic primary energy production, 43% is natural gas, crude oil 5%, and the remainder consisting of hydro and coal. Figure I-4 and Figure I-5 show primary energy production as separate line charts in order to make the trends for each commodity type clear.

10. Over the period shown, Myanmar's aggregated primary energy production increased by an average of 3.9% annually, from 11.53 Mtoe to 18.53 Mtoe. Gas production experienced rapid growth between 2000 and 2006 with an overall increase of 2.5 times in volume; since then the production stabilised at about 7.5 Mtoe annually. Biomass production has grown by 20% over the period from 2000 to 2013. Hydro power generation, while a relatively minor component of Myanmar's overall primary energy sector, had steady growth with a fourfold increase over the analysed period, to reach 761 Mtoe in 2013. Coal production experienced a peak in 2006/07 at more than 825 Mtoe but has subsequently decreased.

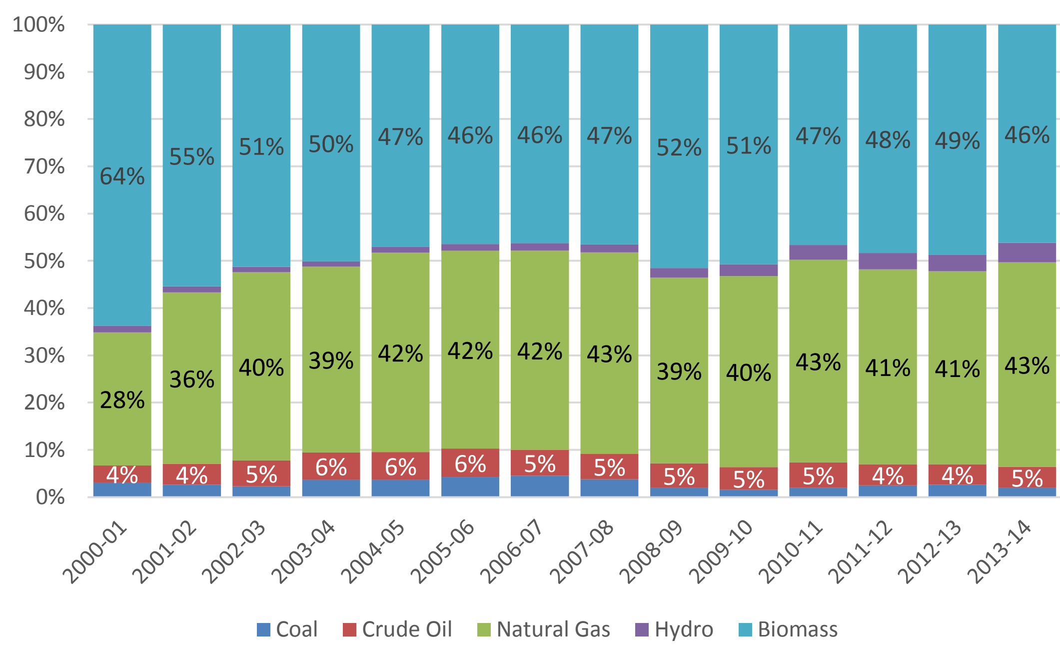
11. Table I-6 sets out the TPEP statistics in energy-units of ktoe. Note that in this report we have used the calorific value assumptions that are provided in section VII. We also provide data on the physicals to allow the reader to apply an alternative set of calorific value assumptions to the data should they wish to do so.

Figure I-2: Myanmar Total Primary Energy Production



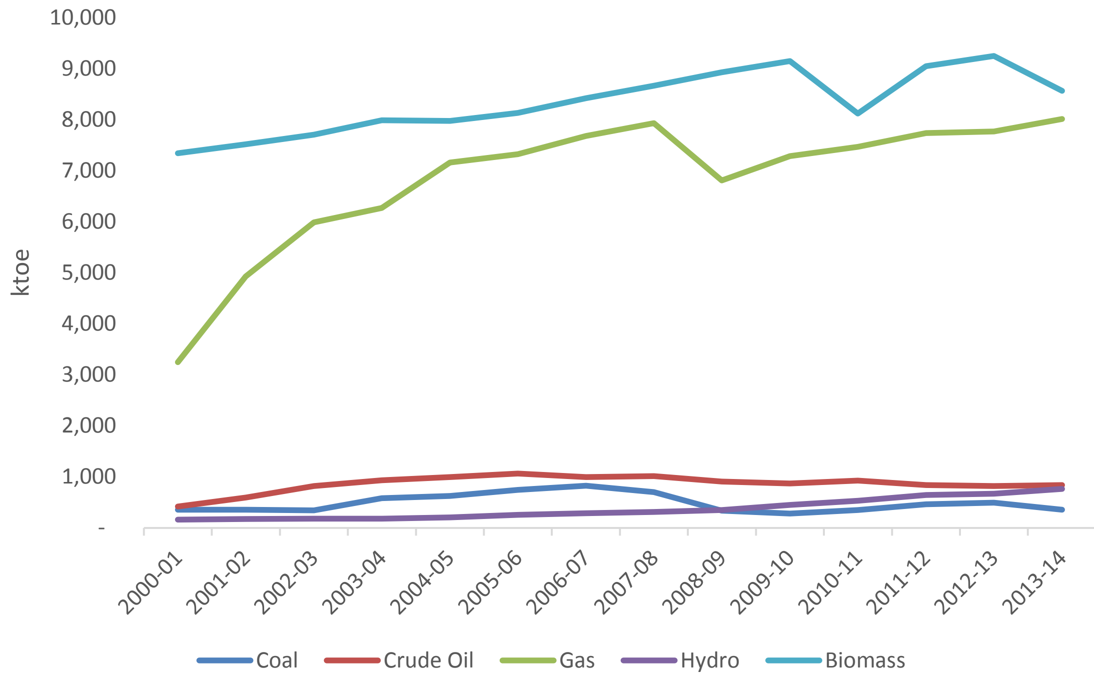
Source: Consultant's estimate based on data of MOE, MOEP, MOGE, MPPE, MOECAF, and CSO

Figure I-3: Myanmar Composition of Primary Energy Production as Percentages



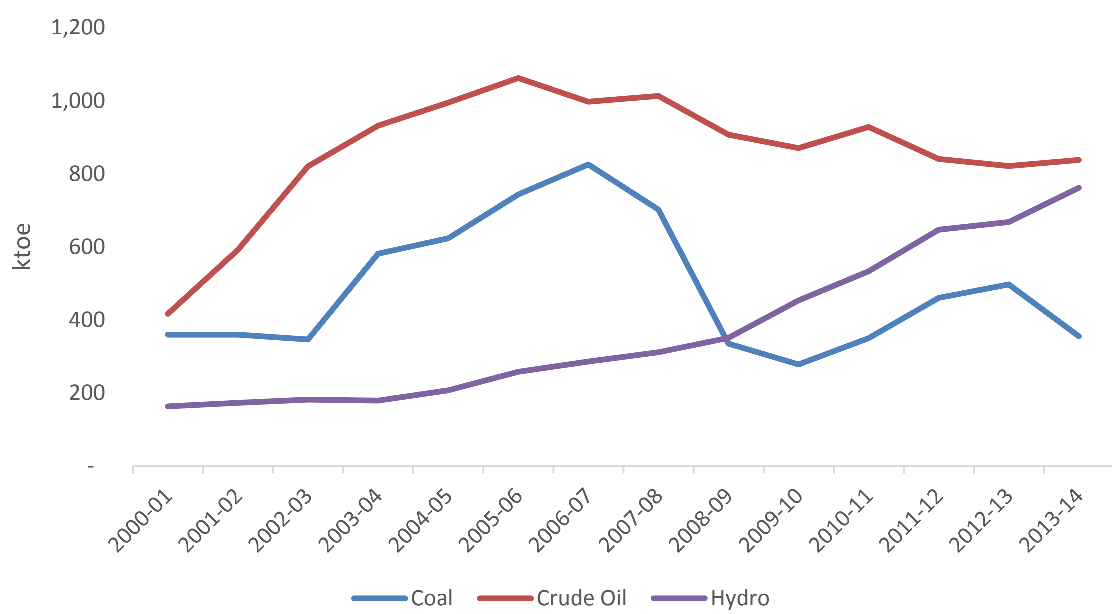
Source: Consultant's estimate based on data of MOE, MOEP, MOGE, MPPE, MOECAF, and CSO

Figure I-4: Myanmar Primary Energy Production by Commodity Type



Source: Consultant's estimate based on data of MOE, MOEP, MOGE, MPPE, MOECAF, and CSO

Figure I-5: Myanmar Primary Energy Production for Selected Commodities



Source: Consultant's estimate based on data of MOE, MOEP, MOGE, MPPE, MOECAFF, and CSO

Table I-6: Total Primary Energy Production (TPEP) Statistics

Unit: ktoe	00-01	01-02	02-03	03-04	04-05	05-06	06-07	07-08	08-09	09-10	10-11	11-12	12-13	13-14
Coal														
Production	359	359	346	581	623	743	825	702	334	278	349	460	496	355
Import	-	-	-	-	-	-	-	-	-	-	-	30	5	-
Export	158	209	173	291	315	246	203	90	17	12	-	10	13	21
Stock Change	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Crude Oil														
Production	416	591	820	931	994	1,061	997	1,013	907	870	928	840	821	838
Import	647	538	470	-	-	-	-	-	-	-	-	-	-	-
Export	-	167	168	-	57	163	111	142	-	94	-	-	140	236
Stock Change	-	34	-19	15	-12	5	-39	7	-15	37	7	-25	28	3
Gas														
Production	3,246	4,925	5,987	6,270	7,159	7,324	7,679	7,928	6,807	7,285	7,466	7,734	7,768	8,014
Import	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Export	2,090	3,947	4,806	4,952	5,746	5,998	6,338	6,496	5,330	6,079	5,946	5,934	5,888	6,059
Hydro														
Production	163	173	182	178	207	258	285	311	350	453	533	646	668	761
Biomass														
Production	7,344	7,515	7,703	7,990	7,978	8,130	8,418	8,667	8,927	9,148	8,121	9,049	9,247	8,564
Totals														
TPEP Total	**11,527**	**13,562**	**15,037**	**15,951**	**16,961**	**17,516**	**18,204**	**18,620**	**17,325**	**18,034**	**17,397**	**18,730**	**19,000**	**18,532**
Annual Growth Rate (%)		17.7%	10.9%	6.1%	6.3%	3.3%	3.9%	2.3%	-7.0%	4.1%	-3.5%	7.7%	1.4%	-2.5%
CAGR (00-01 to 13-14) (%)														3.4%

D. Total Primary Energy Supply (TPES)

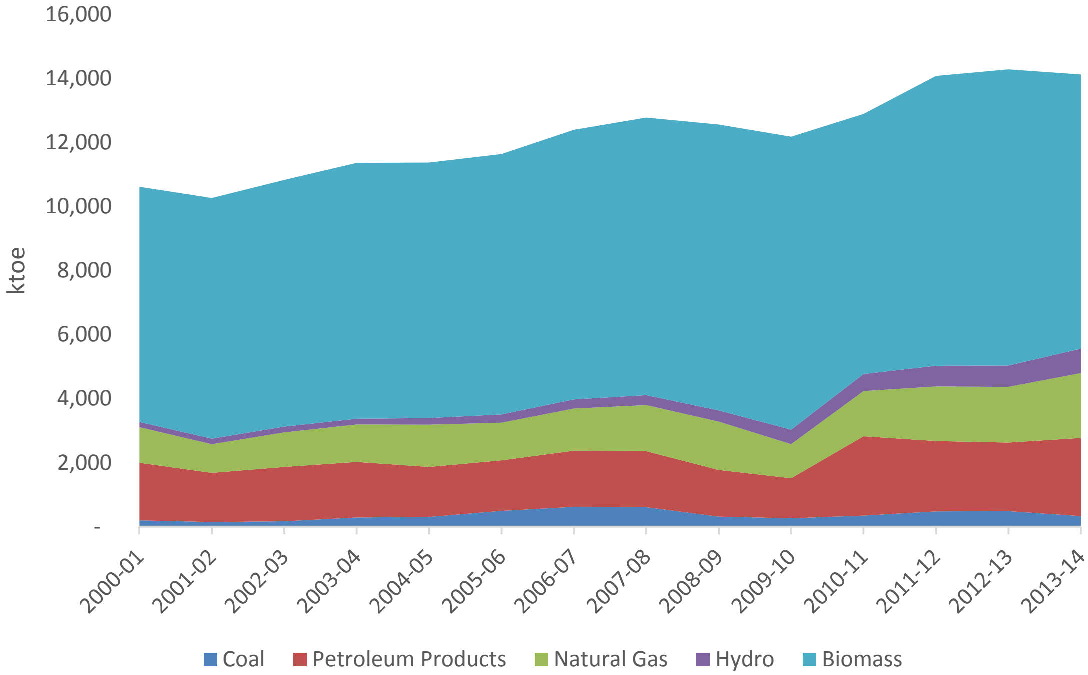
12. TPES by definition is the total amount of primary energy supply to a country net of any imports, exports and/or stock changes.

13. Figure I-7 plots Myanmar's TPES in energy units. This shows the country's Total Primary Energy Supply (TPES) in 2014 was 14.12 Mtoe, around 76% of TPEP. The country's primary energy supply consists of coal, oil, gas, hydropower and biomass. As illustrated in Figure I-8, biomass makes up 61%, gas 14%, petroleum products 17%, hydro 5% and coal 3%. Figure I-9 and Figure I-10 show primary energy production as separate line charts in order to make the trends for each commodity type clear.

14. Clearly in the TPES, natural gas is much less dominant in the TPES as the majority of gas produced is exported. Petroleum products have trended up in the last 5 years with an increase in imported diesel. The majority of the biomass is fuel wood with charcoal being the other main source. Further details behind each element of the TPES are discussed in later sections.

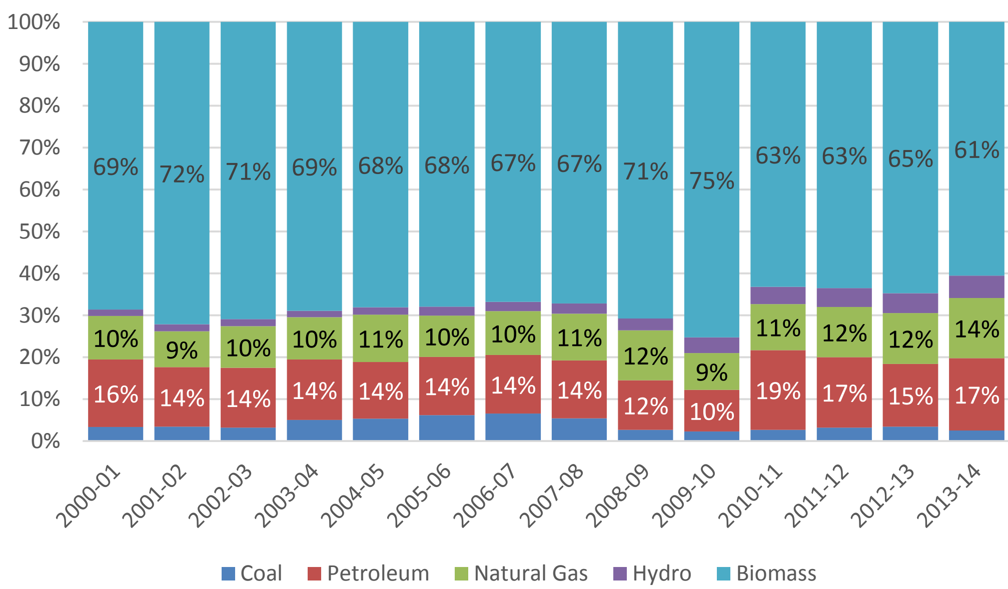
15. Table I-11 sets out the TPES statistics in energy-units of ktoe. Note that in this report we have used the calorific value assumptions that are provided in section VII. We also provide data on the physicals to allow the reader to apply an alternative set of calorific value assumptions to the data should they wish to do so.

Figure I-7: Myanmar Total Primary Energy Supply



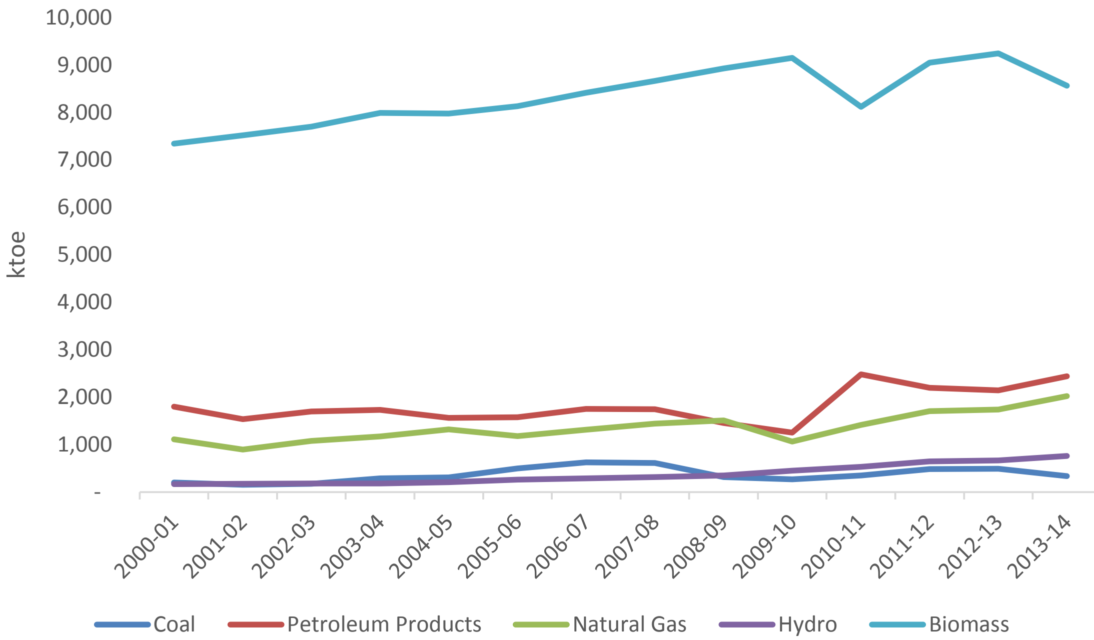
Source: Consultant's estimate based on data of MOE, MOEP, MOGE, MPPE, MOECAF, and CSO

Figure I-8: Myanmar Total Primary Energy Supply as Percentages



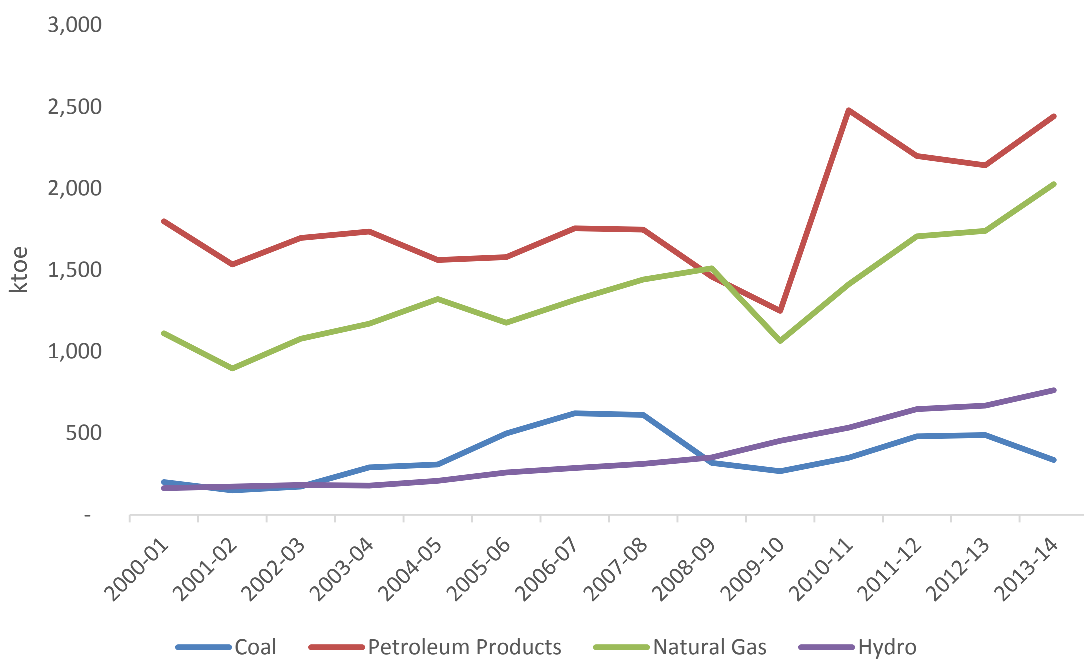
Source: Consultant's estimate based on data of MOE, MOEP, MOGE, MPPE, MOECAF, and CSO

Figure I-9: Myanmar Total Primary Energy Supply by Commodity Type



Source: Consultant's estimate based on data of MOE, MOEP, MOGE, MPPE, MOECAF, and CSO

Figure I-10: Myanmar Total Primary Energy Supply for Selected Commodities



Source: Consultant's estimate based on data of MOE, MOEP, MOGE, MPPE, MOECAF, and CSO

Table I-11: Total Primary Energy Supply (TPES) Statistics

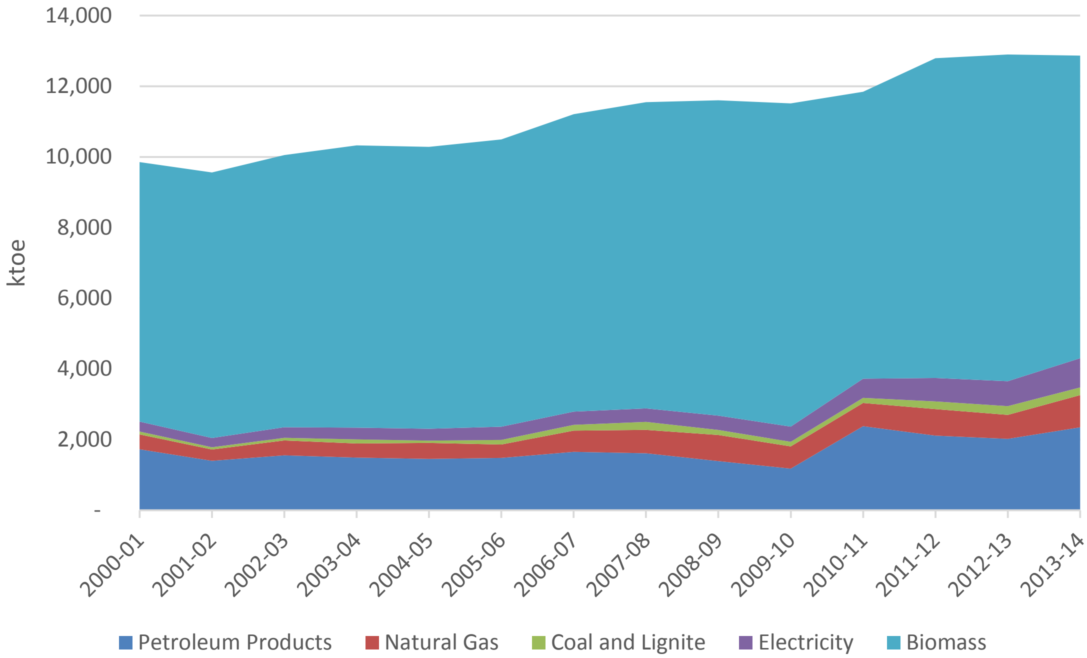
Unit: ktoe	**00-01**	**01-02**	**02-03**	**03-04**	**04-05**	**05-06**	**06-07**	**07-08**	**08-09**	**09-10**	**10-11**	**11-12**	**12-13**	**13-14**
Coal	359	359	346	581	623	743	825	702	334	278	349	460	496	355
Petroleum	968	878	1,069	996	893	830	902	832	784	704	813	845	680	526
Natural Gas	3,246	4,925	5,987	6,270	7,159	7,324	7,679	7,928	6,807	7,285	7,466	7,734	7,768	8,014
Hydro	163	173	182	178	207	258	285	311	350	453	533	646	668	761
Biomass	7,344	7,515	7,703	7,990	7,978	8,130	8,418	8,667	8,927	9,148	8,121	9,049	9,247	8,564
Total	**10,617**	**10,266**	**10,830**	**11,363**	**11,373**	**11,639**	**12,395**	**12,777**	**12,560**	**12,181**	**12,891**	**14,078**	**14,283**	**14,124**
Annual Growth Rate (%)		-3.3%	5.5%	4.9%	0.1%	2.3%	6.5%	3.1%	-1.7%	-3.0%	5.8%	9.2%	1.5%	-1.1%
CAGR (00-01 to 13-14) (%)														2.1%

E. Total Final Energy Consumption (TFEC)

16. Figure I-16 sets out the historical Total Final Energy Consumption (TFEC) for Myanmar. This show the country consumed a total amount of 14 Mtoe of fuels in 2013. Figure I-17 illustrates sectors' contribution in the total consumption for each year. The residential sector is the largest energy end user, responsible for 75% of total consumption. It is followed by the industrial sector (9%), transport sector (8%) and others (6%). Energy consumption by the commercial and agricultural sectors makes up the remaining 2%.

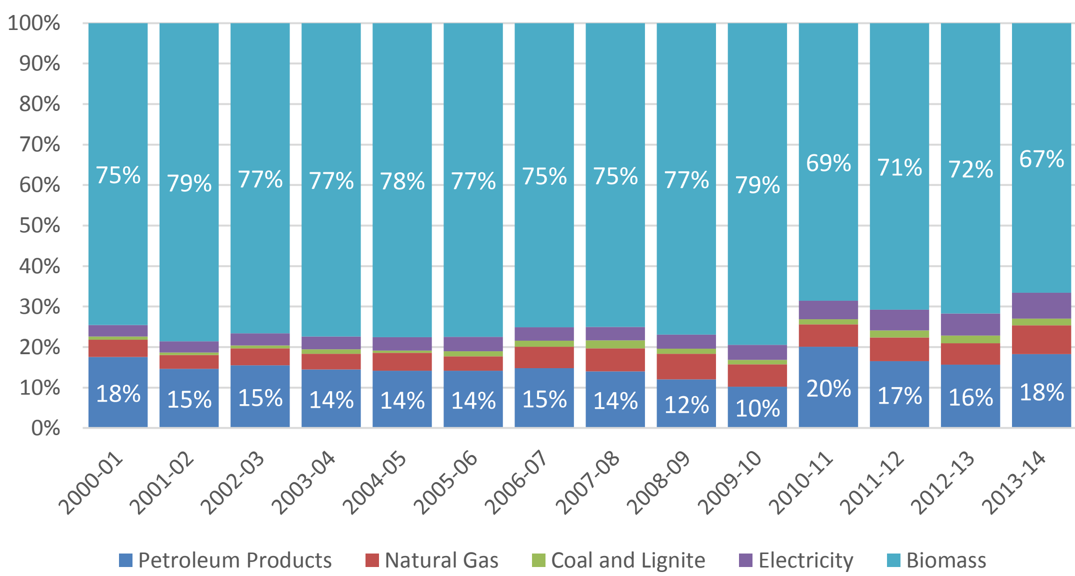
17. Overall, Myanmar's TFEC increased between 2000 and 2013 by an average of 2.3% annually, from 11 Mtoe to 14.3 Mtoe. As illustrated in Figure I-18 and Figure I-19 which show the TFEC by each major end-use category, over this period energy consumption by the industrial has doubled, the consumption by the commercial sector grew three times as much, whereas energy use in transport sector has not increased generally. Residential consumption increased only by 1.3% annually; nonetheless, it remains by far the largest consumer of energy due to exclusive use of biomass (fuel wood and charcoal).

Figure I-12: Myanmar Total Final Energy Consumption (TFEC) by Sector



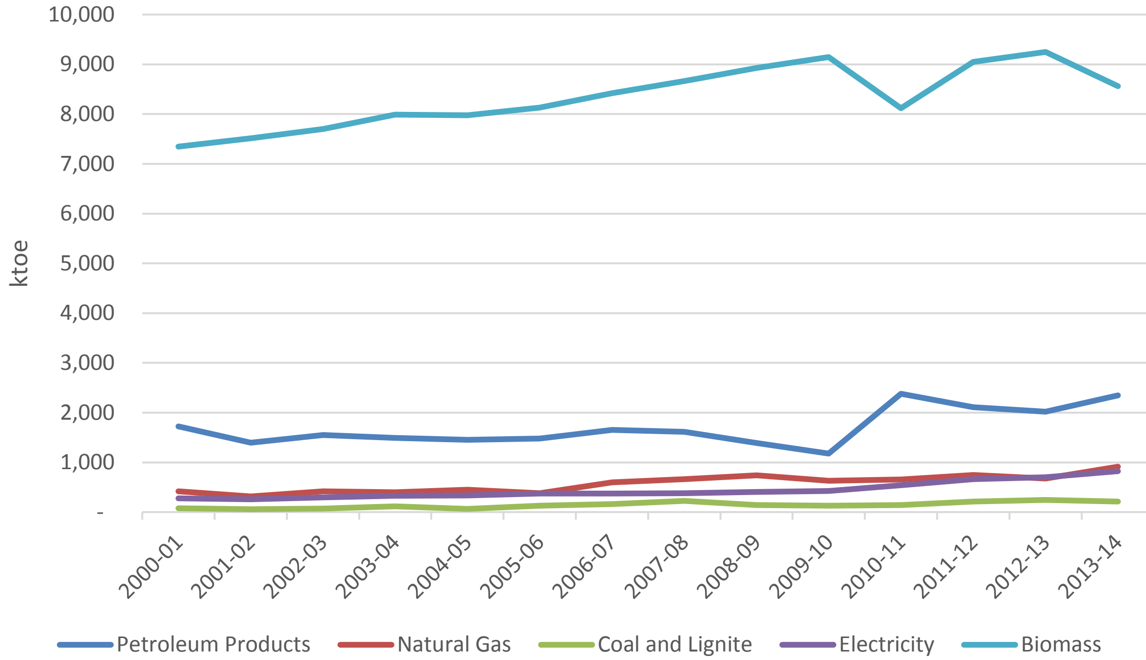
Source: Consultant's estimate based on data of MOE, MOEP, MOGE, MPPE, MOECAF, and CSO

Figure I-13: Myanmar Total Final Energy Consumption as Percentages



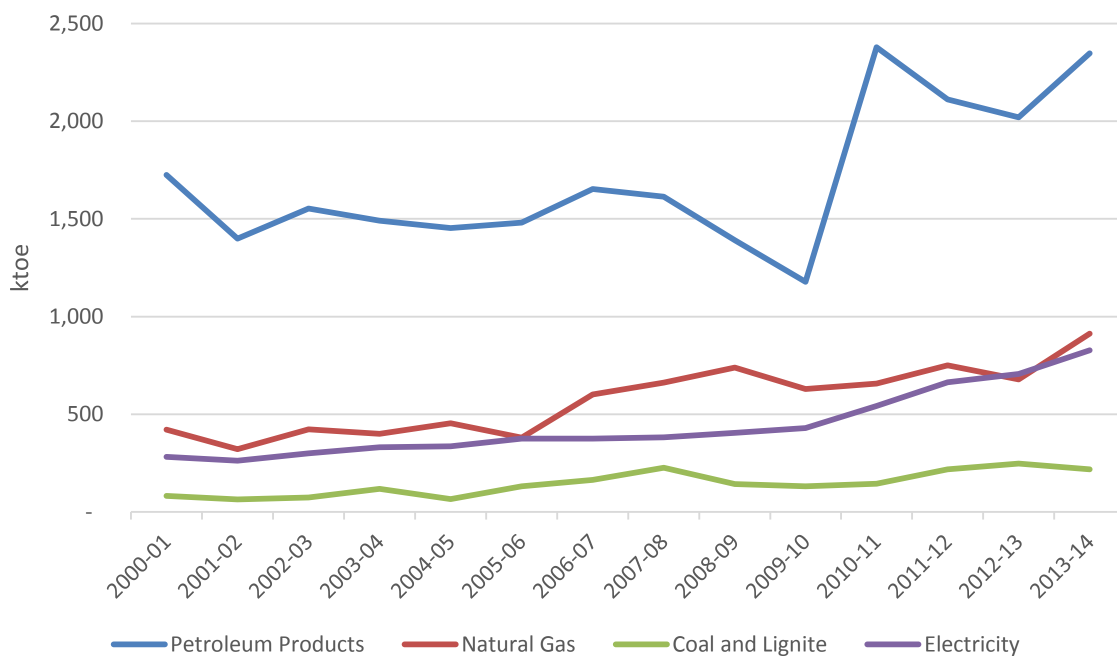
Source: Consultant's estimate based on data of MOE, MOEP, MOGE, MPPE, MOECAF, and CSO

Figure I-14: Myanmar TFEC by Energy Carrier



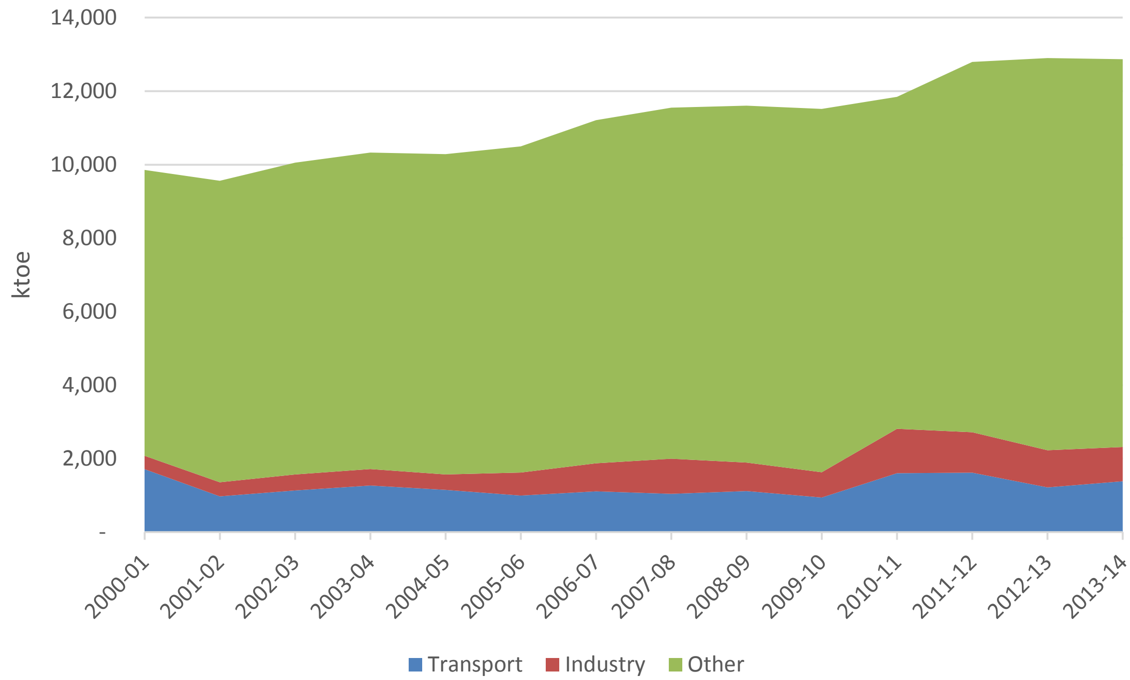
Source: Consultant's estimate based on data of MOE, MOEP, MOGE, MPPE, MOECAF, and CSO

Figure I-15: Myanmar TFEC by Selected Energy Carriers



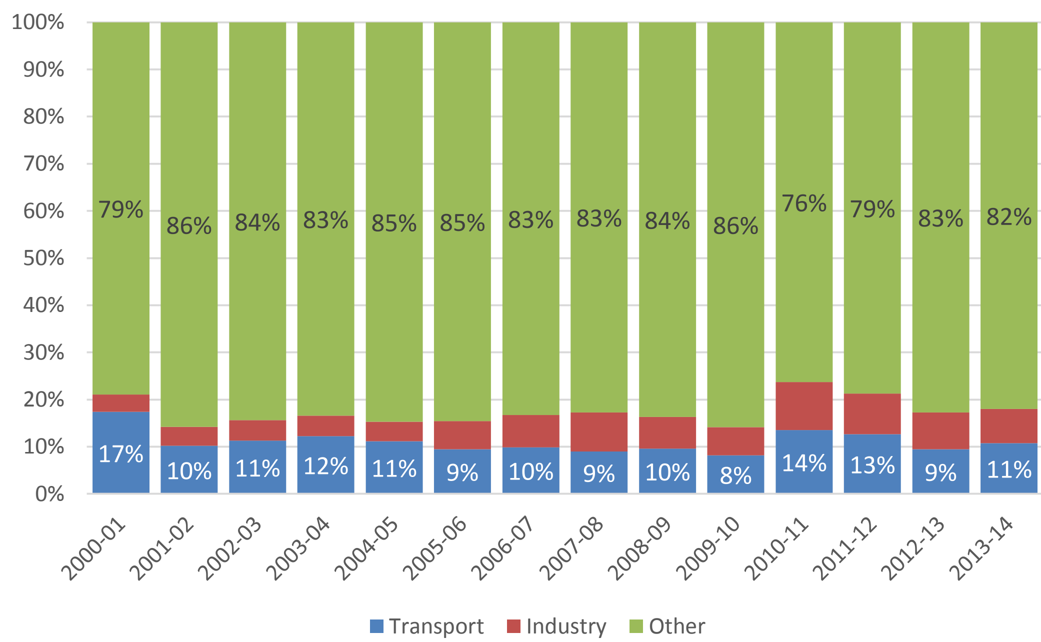
Source: Consultant's estimate based on data of MOE, MOEP, MOGE, MPPE, MOECAF, and CSO

Figure I-16: Myanmar Total Final Energy Consumption (TFEC) by Sector



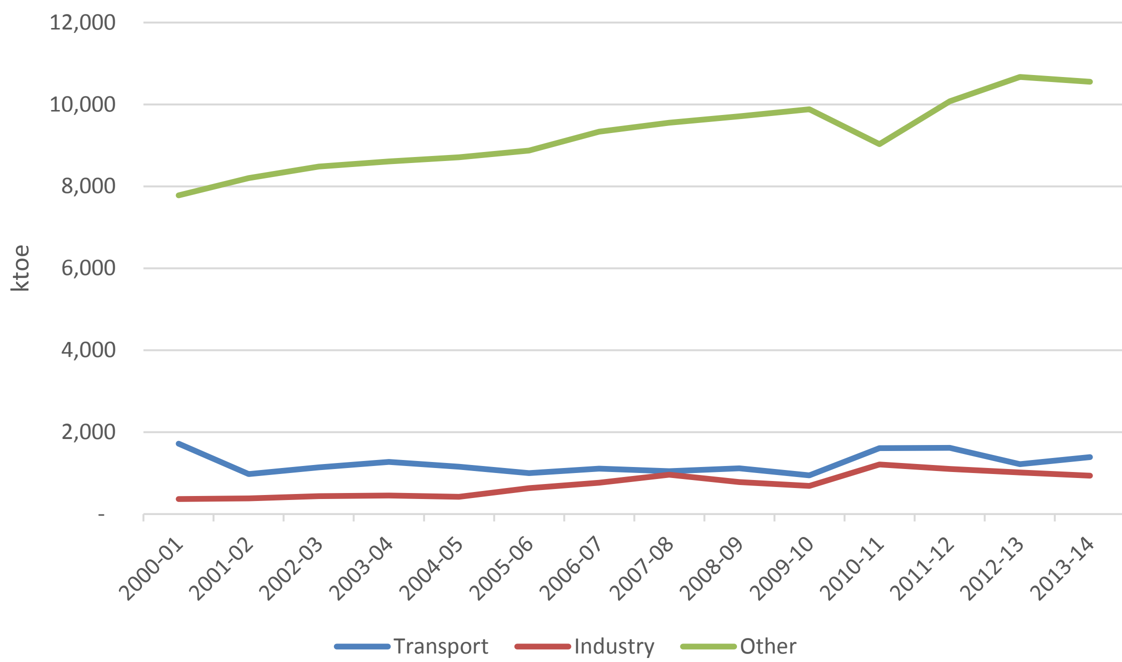
Source: Consultant's estimate based on data of MOE, MOEP, MOGE, MPPE, MOECAF, and CSO

Figure I-17: Myanmar Total Final Energy Consumption for 2013



Source: Consultant's estimate based on data of MOE, MOEP, MOGE, MPPE, MOECAF, and CSO

Figure I-18: Myanmar Total Final Energy Consumption for 2013



Source: Consultant's estimate based on data of MOE, MOEP, MOGE, MPPE, MOF, and CSO

Figure I-19: Myanmar Total Final Energy Consumption for 2013

Source: Consultant's estimate based on data of MOE, MOEP, MOGE, MPPE, MOF, and CSO

F. Summary of Sector Level Observations

18. Solid Fuels (Coal):

A. Coal exports have decreased significantly in the last five years, whereas the domestic demand has averaged 593 kton/y over the last 5 years, down from a peak of 889 kton/y in 2007/08.

B. Coal for electricity generation was 31 kton in 2013/14, down on the 303 kton in the year prior. Coal for electricity in 2013/14 corresponded to 26% of Myanmar's total demand for coal, compared to 40% in the year prior.

C. Industry was the next largest coal end user to the electricity sector, accounting for about 56% of total domestic coal consumption in 2013/14. Cement production is responsible for the majority (69% in 2013/14) within the industrial category.

19. Petroleum:

A. Myanmar crude oil production has generally decreased over the last decade from a peak of 8 billion bbl/y in 2005 to just over 6 billion bbl/y by 2013. Most all of the crude oil that Myanmar produces is delivered to the country's oil refineries to produce petroleum products, although in the last two years (2012/13 and 2013/14) Myanmar has exported 17% and 28% of its domestically produced crude oil.

B. Myanmar has become a net importer of petroleum products as a consequence of increased domestic demand for petroleum products in the recent past combined with limited oil refining facilities. The production from three ageing refineries is observed to be significantly below design capacity (at around 50% of rated capacity on average) and has generally been following a downward production trend – for instance, some 1,033 Mt (1,069 ktoe) of petroleum products in 2002/03 compared to some 506 Mt (526 ktoe) in 2013/14.

C. Domestic production of petroleum products satisfies only 22% of the total domestic demand of around 2.3 million tons (2.4 Mtoe). The remaining demand is presently being met by importing products, with a sharp rise in petroleum product imports over the last five years from some 1.2 million tons in 2009/10 (1.3 Mtoe) to 2.4 million tons (2.4 Mtoe).

D. Major petroleum products consumed in Myanmar are gas/diesel oil, motor gasoline and jet kerosene. Gas and diesel oil constitutes some 59% of petroleum demand, followed by 24% motor gasoline and 5% jet kerosene. The imported segment of gas and diesel oil is dominant, accounting for 87% over the last three years (2011/12 to 2013/14). Similarly, around 58% of the motor gasoline in Myanmar is imported.

E. The transport sector is the largest end user of petroleum products. In 2013/14 it consumed 1,038 ktoe out of a total of 2,348 ktoe, or 44% of the country's final petroleum consumption.

20. Natural Gas:

A. Myanmar's natural gas production has been consistent from year to year over the last decade with an annual production levels averaging around 450,000 MMcf (7,500 ktoe) per year. Around 75% to 80% of Myanmar's domestically produced natural gas is exported to Thailand and more recently PRC.

B. Domestically, Myanmar's electricity sector accounts for around 55% to 60% of natural gas consumption. Other major gas users are the government-owned factories (20%), fertiliser plants (7.9%), a compressed natural gas facility (7.2%), and LPG production (0.9%).

C. The statistical differences between the calculated and observed gas supply to Myanmar were observed to be reasonably significant in the commodity balances over the last 10 years with discrepancies averaging some 6%.

21. Electricity:

A. Electricity supply in Myanmar is dominated by hydro. The hydro total install capacity has more than doubled since 2008 to reach 3,004 MW in 2013/13, representing more than 70% of the total installed capacity. However, hydro generation availability is seasonal and faces limits. The second largest mode of electricity production is gas turbines, accounting for some 19% of system's total installed capacity and around 23% by generation in 2013/14.

B. Transmission and distribution losses are high Myanmar but have decreased from 35% in 2000/01 to 20% in 2013/14 or some 2,416 GWh against 12,104 GWh of gross production in 2013.

C. Electricity consumption has increased rapidly in the last five years at an annual average growth rate of 15.8%. Industrial, residential and commercial sectors are the major end users of electricity in descending order. The industrial sector has had an annual average growth rate of 16.4% over the last 5 years, followed by 12.6% in the commercial sector and 7.8% in the residential sector.

22. Biomass:

A. Some 8.6 Mtoe of biomass is produced and consumed in the residential sector. Currently, fuelwood plays a very significant role in household energy consumption as there are only a few other affordable energy options available.

G. Energy Balance Table and Myanmar Energy Flow Diagram

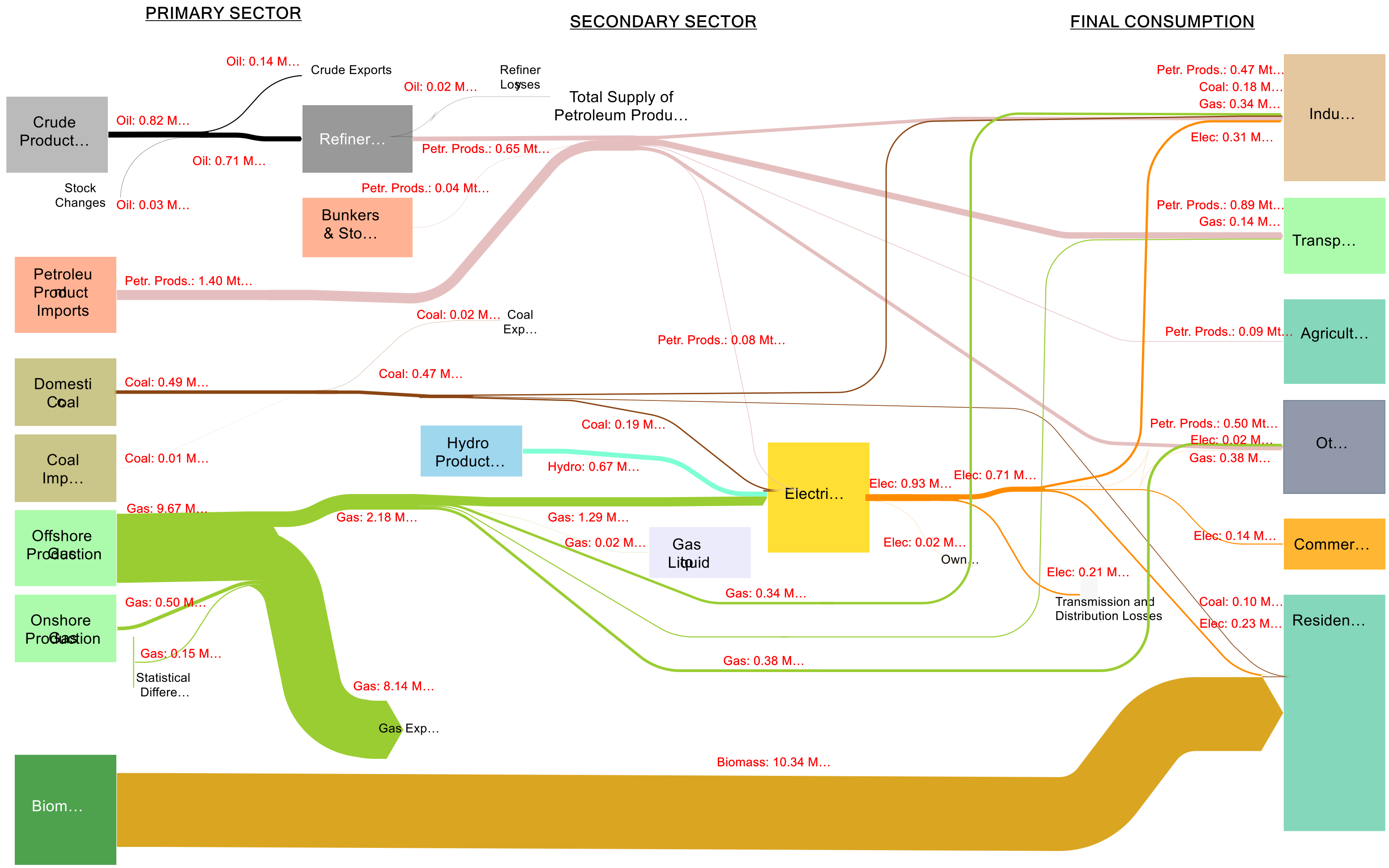
23. A simplified energy balance table for Myanmar for the year 2013/14 in energy units is provided in Table I-20. This provides a snapshot of energy flows in the country based on the information and data that the Consultant has been able to collect and assemble.

24. A corresponding energy flow diagram otherwise called a "Sankey Diagram" for Myanmar is presented in Figure I-21. This can be directly related to the modelled Myanmar's energy sector of Figure I-1 to provide an immediate appreciation of the current state of Myanmar's energy industry and the relative energy situation between the different subsectors.

Table I-20: Energy Balance Table for 2013/14

Supply & Consumption	Coal	Crude Oil	Petroleum Products	Natural Gas	Hydro	Biomass	Electricity	Total
Production	355	838		8,014	761	8,564		**18,532**
Imports			1,922					**1,922**
Exports	-21	-236		-6,059				**-6,316**
Stock Changes	-	3						**3**
TPES	**334**	**606**	**1,922**	**1,955**	**761**	**8,564**		**14,142**
Statistical Error	-34	-42	-8	-69				**-153**
Electricity Generation	-83		-63	-1,080	-761		1,056	-931
Other Transformation				-9				-9
Oil Refineries		-552	526					-25
Losses		-12					-223	-234
TFEC	**217**		**2,348**	**912**		**8,564**	**827**	**12,867**
Transport	-		1,038	345				1,384
Industry	181		390	129			232	932
Other (Commercial, Residential, Others)	36		919	437		8,564	594	10,551

Figure I-21: Overall Myanmar Energy Flow Diagram for 2013/14



Source: Consultant's estimates

II. SOLID FUELS

H. Summary

25. This section presents statistics on supply and demand for coal in Myanmar. The commodity balance is provided in Table II-11. Table **II-1** provides a simplified summary of historical coal production and coal consumption.

26. An energy flow chart for coal is provided for 2012/13 in Figure II-10. This shows the flow of coal from production and exports through to consumption. The energy flow chart simplifies the figures that are found in the commodity balance for coal in Table II-11. It illustrates the flow of coal from the point at which it becomes available from home production or imports (on the left) to the eventual final use of coal (on the right).

I. Coal Production, Trade & Reserves

27. The production and consumption of coal was insignificant in the past due to the remoteness of coal reserves and the lack of sufficient investment for exploitation, The Myanmar Mines Law of 1994 allowed private sector participation in the mining industry. The efforts of seven companies operating under large-scale mining permits have yielded an increase in coal production since 2001.

28. Statistics for coal production and total consumption are provided in Table II-1, which shows the production of coal, domestic consumption, exports and imports. Most of the coal produced is of sub-bituminous coal, although a small proportion (about 7% in 2012/13) is Lignite.

Table II-1: Myanmar Coal Production and Total Consumption 2000/01 to 2013/14

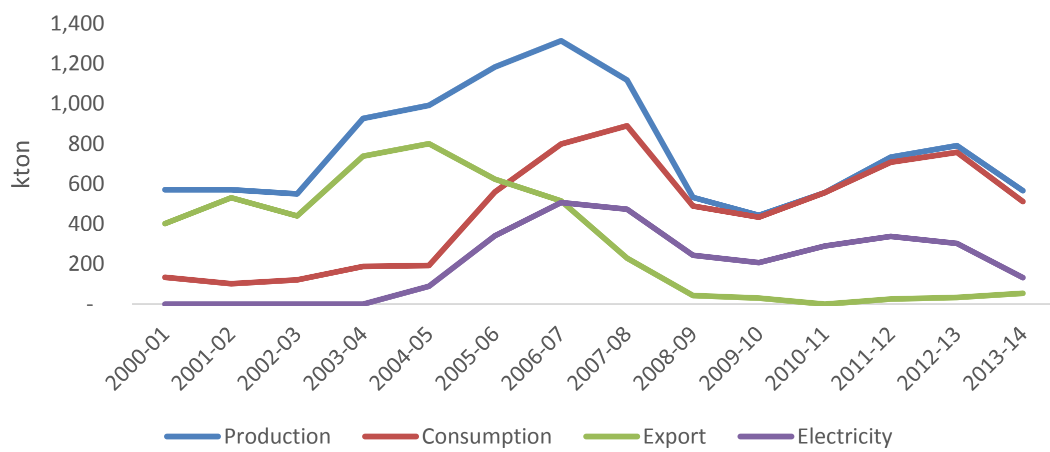
Unit: '000 ton

Year	Production	Consumption	Export	Import
2000-01	571	133	402	
2001-02	571	102	531	
2002-03	550	120	440	
2003-04	925	188	737	
2004-05	992	192	800	
2005-06	1,183	559	623	
2006-07	1,314	798	515	
2007-08	1,117	889	229	
2008-09	532	489	43	
2009-10	443	433	30	
2010-11	556	556	-	
2011-12	733	708	25	47
2012-13	790	757	34	8
2013-14	565	512	53	

Source: Ministry of Mining (MOM)

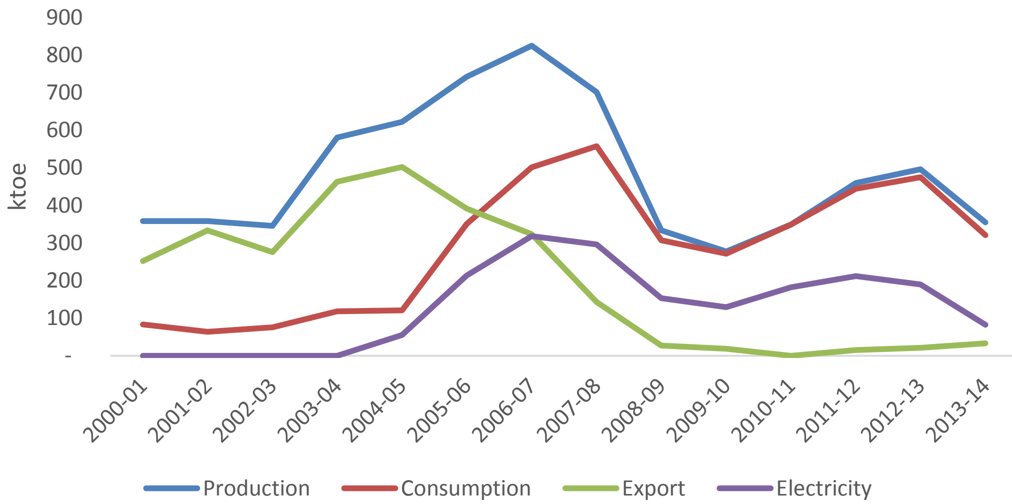
29. Figure II-2, Figure II-3 show coal production, consumption, exports, and also coal usage by the Tigyit Power Station which started operation in late 2004. There has been a trend away from exporting coal. Importing coal essentially not a significant feature of Myanmar's coal industry. Exports have historically been to Thailand and PRC.

Figure II-2: Myanmar Coal Production & Consumption 2000/01 to 2012/13 (ktons)



Source: Ministry of Mining (MOM)

Figure II-3: Myanmar Coal Production & Consumption 2000/01 to 2012/13 (ktoe)



Source: Ministry of Mining (MOM)

30. There are 16 major coal deposits the country, located along the Ayeyarwady and Chindwin river basins, and in the south. A summary of Proven, Positive, Possible and Potential coal deposits are listed in Table II-4. According to the size of their proven reserves, there are eight locations that can be considered as 'strategic' reserves in Myanmar. Notwithstanding location, strategic reserves are of sufficient size to support coal-fired power generation.

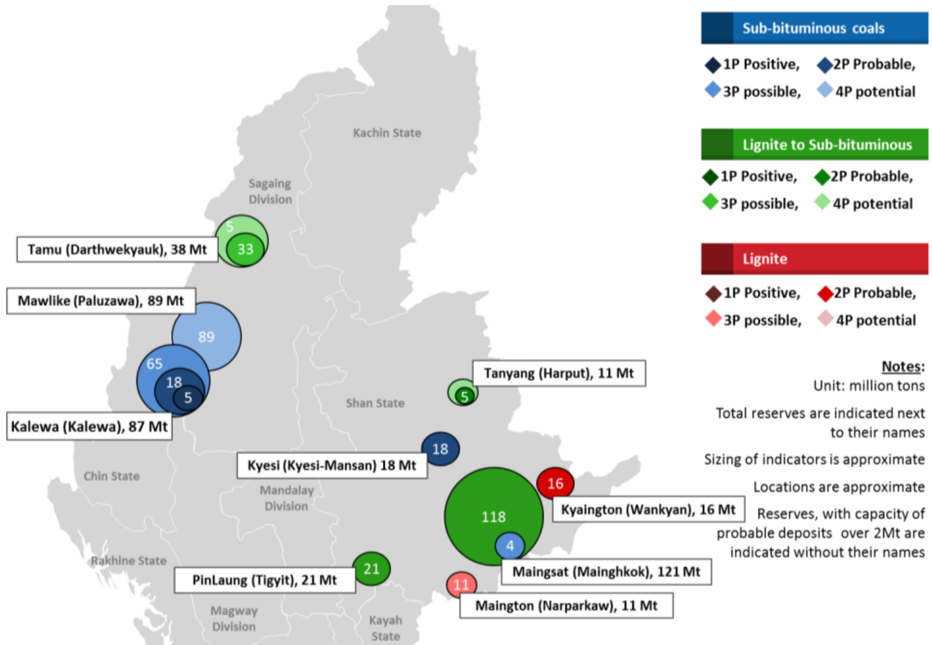
Table II-4: Myanmar Coal Reserves

	Coal Mine	Location	State / District	Proven Reserves	Coal Grade
				mtons	
1	Mainghkok	Maingsat	Shan (East)	117.70	Lignite (mostly)
2	Paluzawa	Mawleik	Sagaing	89.00	Sub-bituminous
3	Kalewa	Kalewa	Sagaing	87.78	Sub-bituminous
4	Dathwegyauk	Tamu	Sagaing	33.00	Sub-bituminous
5	Tigyit	Pinlaung	Shan	20.70	Lignite
6	Kehsi Mahsam	Kehsi Mahsam	Shan	18.00	Sub-bituminous
7	Wankyan	Kyaington	Shan (East)	16.66	Lignite
8	Narparkaw	Mainton	Shan (East)	10.93	Lignite
9	Maw Taung	Taninthayi	Taninthayi	3.60	Sub-bituminous
10	Namma	Lashio	Shan	2.80	Lignite
11	Theindaw / Kawmabyin	Taninthayi	Taninthayi	2.00	Sub-bituminous
12	Sam Laung (Sam Lau)	Tibaw	Shan	1.60	Lignite
13	Mahu Taung	Kani	Sagaing	0.80	Lignite
14	Kyauktaga	Natmauk	Magwe	0.54	Sub-bituminous
15	Myeni	Paung	Magwe	0.25	Sub-bituminous
16	Inbyin	Kalaw	Shan	0.22	Sub-bituminous
17	Lweje	Moemauk	Kachin	0.20	Lignite
18	Thinbaung	Khin Oo	Sagaing	0.08	Lignite
19	Kyobin	Kawlin	Sagaing	0.03	Sub-bituminous
			Total	405.89	

Source: Ministry of Mining (MOM)

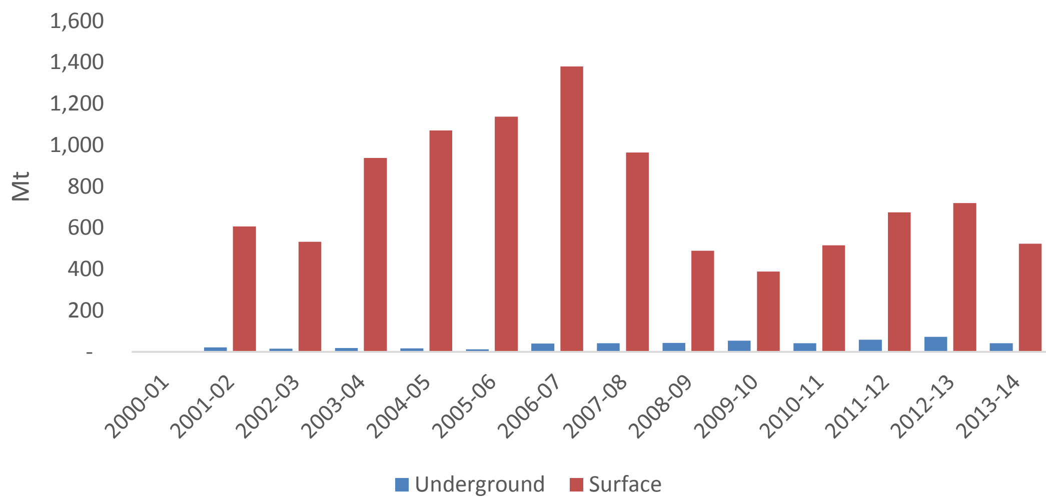
31. The locations of coal reserves in Myanmar with capacity exceeding 10 Mt are shown in Figure II-5. It can be seen that the unexploited reserves are located in remote locations of the country; the locations are also at considerable distances from the established rail network.

Figure II-5: Locations of Coal Reserves of Myanmar with Total Capacity over 10 Mt



Source: Ministry of Mining (MOM)

Figure II-6: Myanmar Coal Production – By Mine Type 2001/02 to 2012/13



Source: Ministry of Mining (MOM)

J. Coal Consumption

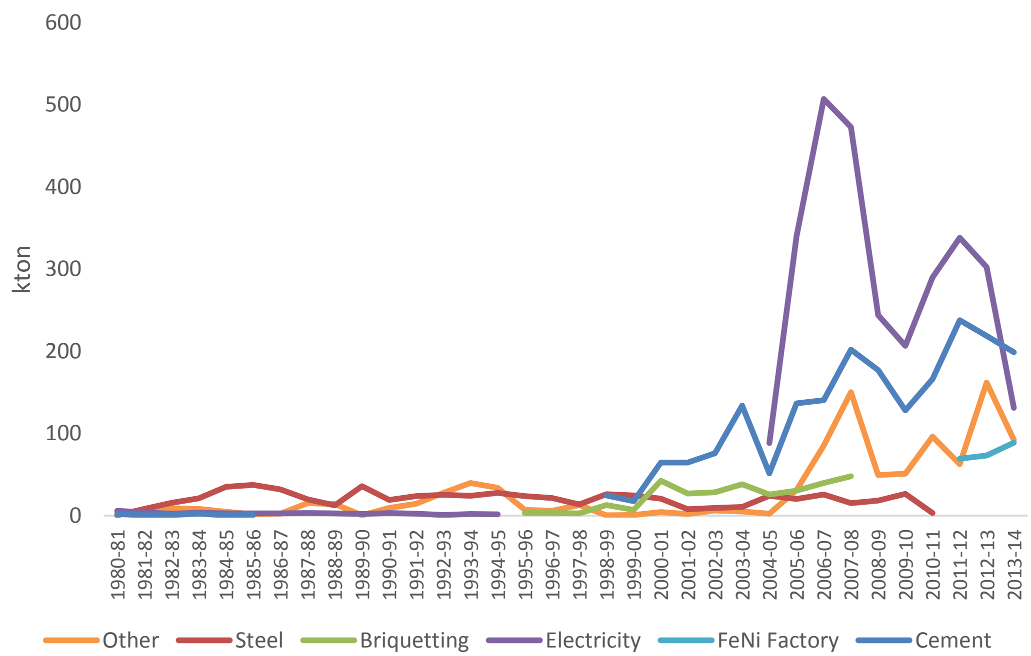
32. Coal consumption statistics are set out in Table II-7. Figure II-8 and Figure II-9 show the trends in domestic coal consumption in Myanmar for the period from 2000/01 to 2013/14. Coal is used in domestic industries and a small amount is exported. Several coal-fired cement plants are in operation in the coal mining area, and in Shan State. Domestic coal consumption in Myanmar has seen a general increase over the last 10 years, which has been driven by increased use in the construction and cement industry and also increased use of coal in the residential sector for cooking.

Table II-7: Myanmar Coal Consumption Statistics 2000/01 to 2013/14

Unit: '000 ton

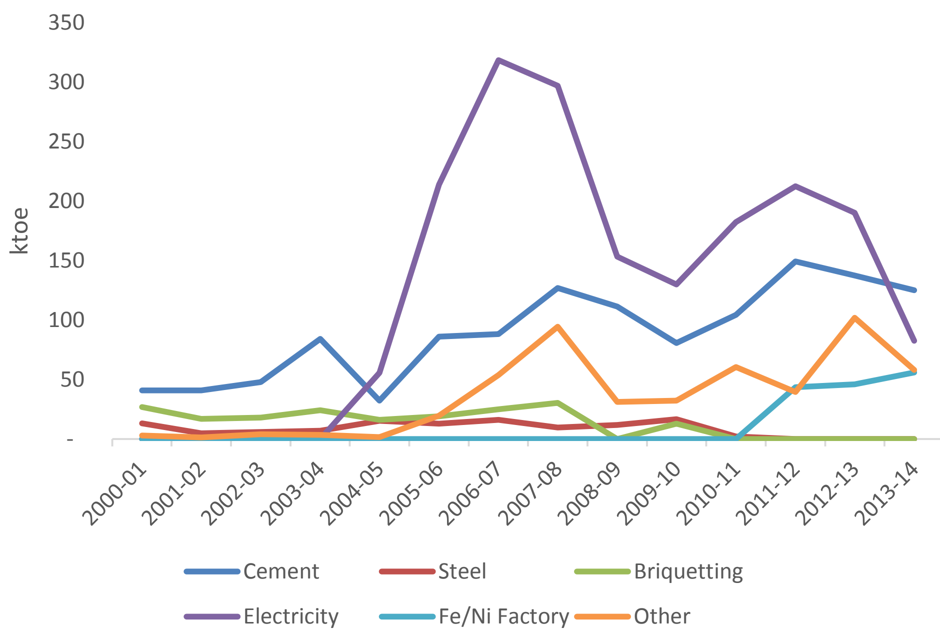
Year	Cement	Steel	Briquetting	Electricity	Iron & Nickle Factory	Others
2000-01	65	21	43			4
2001-02	65	8	27			2
2002-03	76	9	29			6
2003-04	134	11	38			5
2004-05	51	24	26	89		2
2005-06	137	20	30	340		31
2006-07	141	26	40	507		85
2007-08	202	15	48	473		150
2008-09	177	19		244		50
2009-10	128	27	20	207		51
2010-11	166	3		290		96
2011-12	238			338	69	63
2012-13	219			303	73	162
2013-14	199			131	89	92

Figure II-8: Myanmar Coal Consumption 1980 to 2014 (kton)



Source: Ministry of Mines (MOM)

Figure II-9: Myanmar Coal Consumption 2000/01 to 2013/14 (ktoe)



Source: Ministry of Mines (MOM)

K. Coal Energy Flow Diagram

33. Figure II-10 is a coal energy flow chart for 2013 showing the flows of coal from production and imports through to consumption. The flow chart simplifies the figures that are found in the commodity balance for coal. It illustrates the flow of coal from the point at which it becomes available from home production or imports (on the left) to the eventual final use of coal (on the right).

L. Coal Commodity Balance Statistics

34. Statistics on supply and demand for coal in Myanmar are provided in Table II-11 and Table II-12 for the period from 2000/01 to 2012/13. Refer to section VII for the calorific value assumption that was applied.

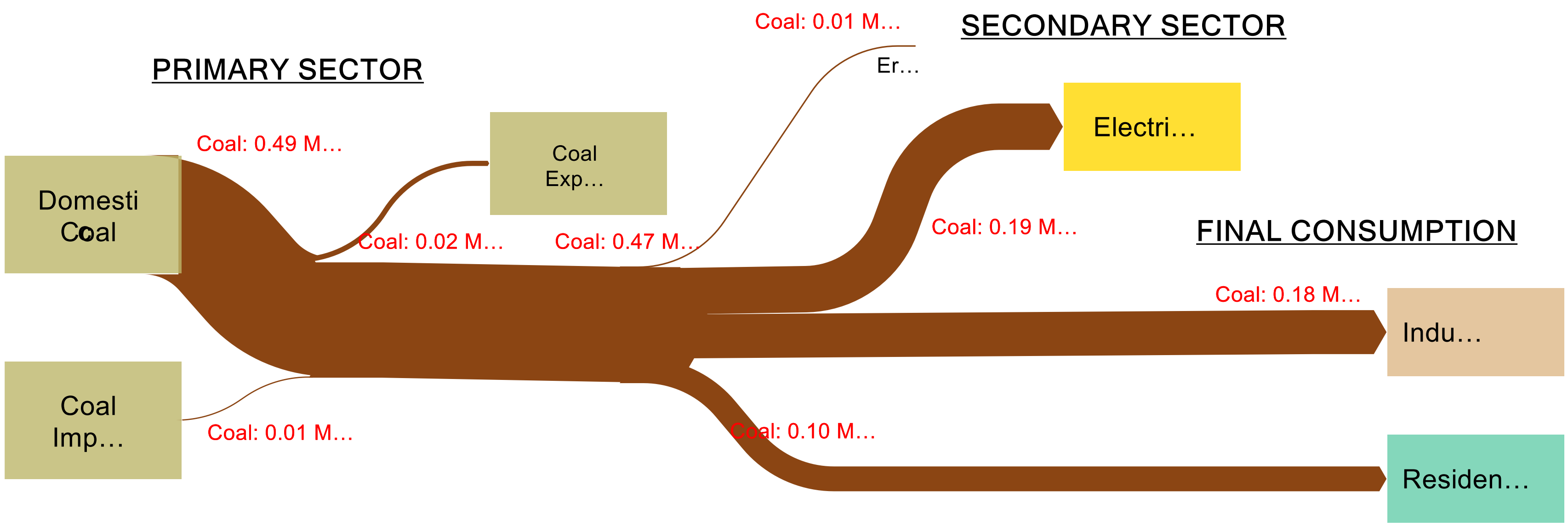
M. Coal Sector Observations

35. Coal exports have decreased significantly in the last five years, whereas the domestic demand has averaged 593 kton/y over the last 5 years, down from a peak of 889 kton/y in 2007/08.

36. Coal for electricity generation was 131 kton in 2013/14, down on the 303 kton in the year prior. Coal for electricity in 2013/14 corresponded to 26% of Myanmar's total demand for coal, compared to 40% in the year prior.

37. Industry was the next largest coal end user to the electricity sector, accounting for about 56% of total domestic coal consumption in 2013/14. Cement production is responsible for the majority (69% in 2013/14) within the industrial category.

Figure II-10: Myanmar Coal Energy Flow Diagram for 2012/13



Sources: Consultants' Analysis

Table II-11: Myanmar Commodity Balance: Coal from 2000/01 to 2013/14 ('000 ton)

Unit: '000 ton	00-01	01-02	02-03	03-04	04-05	05-06	06-07	07-08	08-09	09-10	10-11	11-12	12-13	13-14
Total production	571	571	550	925	992	1,183	1,314	1,117	532	443	556	733	790	565
Underground		21	15	19	17	13	39	41	43	54	41	59	72	42
Surface		606	532	938	1,071	,137	1,381	964	489	389	514	674	719	523
Statistical Difference		-56	-3	-31	-96	-32	-106	-113						
Imports												47	8	
Exports	402	531	440	737	800	623	515	229	43	30		25	34	53
Domestic Supply	169	40	110	188	192	559	798	889	489	413	556	708	757	512
Statistical Difference	37	-62	-10							-20				
Total Final Consumption	133	102	120	188	192	559	798	889	489	433	556	708	757	512
Transformation					89	340	507	473	244	207	290	338	303	131
Electricity					89	340	507	473	244	207	290	338	303	131
Total Final Consumption	133	102	120	188	103	219	291	416	245	226	266	370	454	380
Industry sector	128	99	114	183	101	188	206	266	196	175	170	307	292	288
Cement	65	65	76	134	51	137	141	202	177	128	166	238	219	199
Steel	21	8	9	11	24	20	26	15	19	27	3			
Briquetting	43	27	29	38	26	30	40	48		20				
Fe/Ni Factory												69	73	89
Other Sector	4	2	6	5	2	31	85	150	50	51	96	63	162	92
Commercial & public														

Unit: '000 ton	00-01	01-02	02-03	03-04	04-05	05-06	06-07	07-08	08-09	09-10	10-11	11-12	12-13	13-14
Residential														
Agriculture														
Fishing														
Transport														
Other	4	2	6	5	2	31	85	150	50	51	96	63	162	92

Source: MOM, Consultant's analysis

Table II-12: Myanmar Commodity Balance: Coal from 2000/01 to 2013/14 (ktoe)

Unit: ktoe	00-01	01-02	02-03	03-04	04-05	05-06	06-07	07-08	08-09	09-10	10-11	11-12	12-13	13-14
Total production	359	359	346	581	623	743	825	702	334	278	349	460	496	355
Underground		13	9	12	11	8	25	26	27	34	26	37	45	26
Surface		381	334	589	672	714	867	605	307	244	323	423	451	328
Statistical Difference		-35	2	-20	-60	20	-67	71						
Imports												30	5	
Exports	252	334	276	463	502	391	324	144	27	19	-	15	21	34
Domestic Supply	106	25	69	118	121	351	501	558	307	259	349	445	475	321
Statistical Difference	23	-39	-6							-13				
Total Final Consumption	83	64	76	118	121	351	501	558	307	272	349	445	475	321
Transformation					56	214	318	297	153	130	182	212	190	83
Electricity					56	214	318	297	153	130	182	212	190	83
Total Final Consumption	83	64	76	118	65	137	183	261	154	142	167	232	285	239
Industry sector	81	62	72	115	63	118	129	167	123	110	106	193	183	181
Cement	41	41	48	84	32	86	88	127	111	81	104	149	137	125
Steel	13	5	6	7	15	13	16	10	12	17	2			
Briquetting	27	17	18	24	16	19	25	30		13				
Fe/Ni Factory												44	46	56
Other Sector	3	1	4	3	2	20	54	94	31	32	60	40	102	58
Commercial & public														

Unit: ktoe	00-01	01-02	02-03	03-04	04-05	05-06	06-07	07-08	08-09	09-10	10-11	11-12	12-13	13-14
Residential														
Agriculture														
Fishing														
Transport														
Other	3	1	4	3	2	20	54	94	31	32	60	40	102	58

Source: MOM, Consultant's analysis

III. PETROLEUM

N. Summary

38. This section provides statistics on the supply and demand of crude oil and petroleum products in Myanmar. We firstly discuss the supply and demand of primary crude oil, and feedstocks. We then provide coverage of the overall supply, transformation and end use consumption of petroleum products.

39. Table III-15 and Table III-16 set out the Myanmar's crude oil production and refinery intake statistics for the period from 2000/01 to 2013/14.

40. Table III-17 and Table III-18 provide statistics on the total supply of petroleum products (including both products that are produced by Myanmar's oil refineries and those that are imported to the country) for the period from 2000/01 to 2013/14.

41. Table III-19 and Table III-20 set out the statistics on the consumption of petroleum products in Myanmar for the period from 2000/01 to 2013/14.

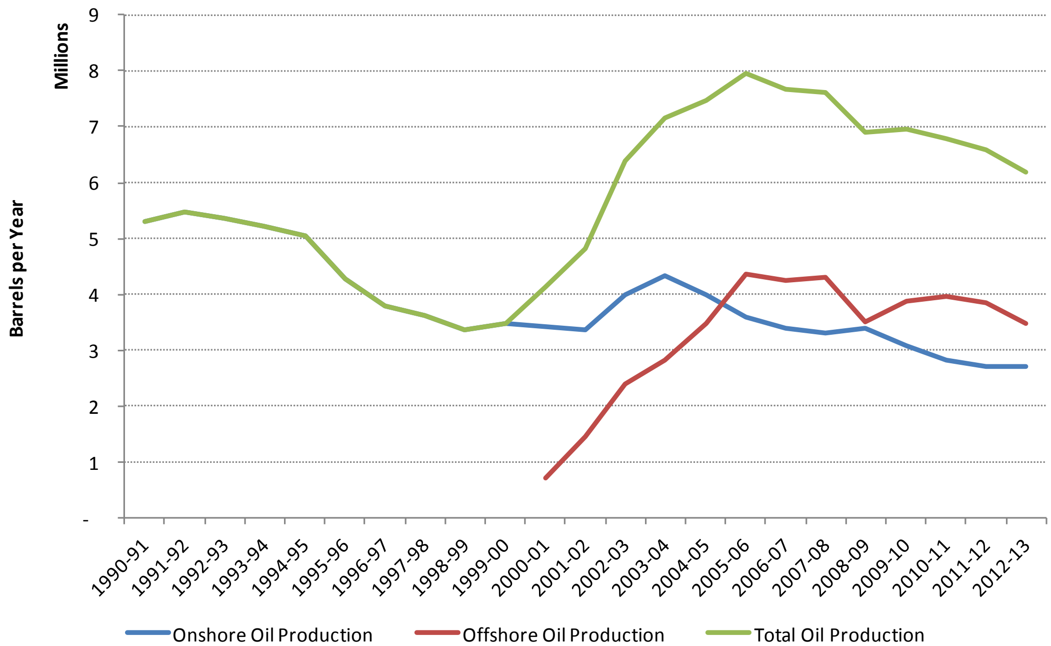
42. Additional tables and charts in this section provide further information on Myanmar's petroleum sector including a brief discussion of Myanmar's refinery facilities.

43. Finally, an energy flow chart to illustrate the movement of crude oil, refinery feedstocks and petroleum products in Myanmar is presented in Figure III-14 for the year 2012/13. This provides a snapshot of the present state of Myanmar's petroleum sector and shows how Myanmar is effectively a net importer of oil as a consequence of increased demand for petroleum products in the recent past combined with a limited oil refining capacity.

O. Primary Oil

44. Figure III-1 illustrates the main trend in crude oil production in Myanmar since 1990. The country produces crude oil and condensates from the onshore Salin basin and as of 2000, from the offshore Yetagun field. This trend shows that from 2005 to 2013, total crude oil production has generally trended downward from a peak of approx. 21,000 bbl/d in 2005 to approx. 17,000 bbl/d in 2012. The chart also shows a general decline in onshore production over the last decade.

Figure III-1: Myanmar Oil Production 1990/91 to 2012/13



Source: MOGE

P. Petroleum Products

45. Some 84% of the oil that Myanmar produced in 2012/13 was directed to the country's oil refineries to produce petroleum products, the rest was exported. Myanmar has three refineries, which are summarised in Table III-2. Despite a sharp increase in demand for certain refined petroleum products, the refineries are currently operating at below their rated capacities. Myanmar's limited refining capacities have therefore been insufficient to satisfy domestic demand and the country imports petroleum products to meet the demand and it is thus a net oil importer.

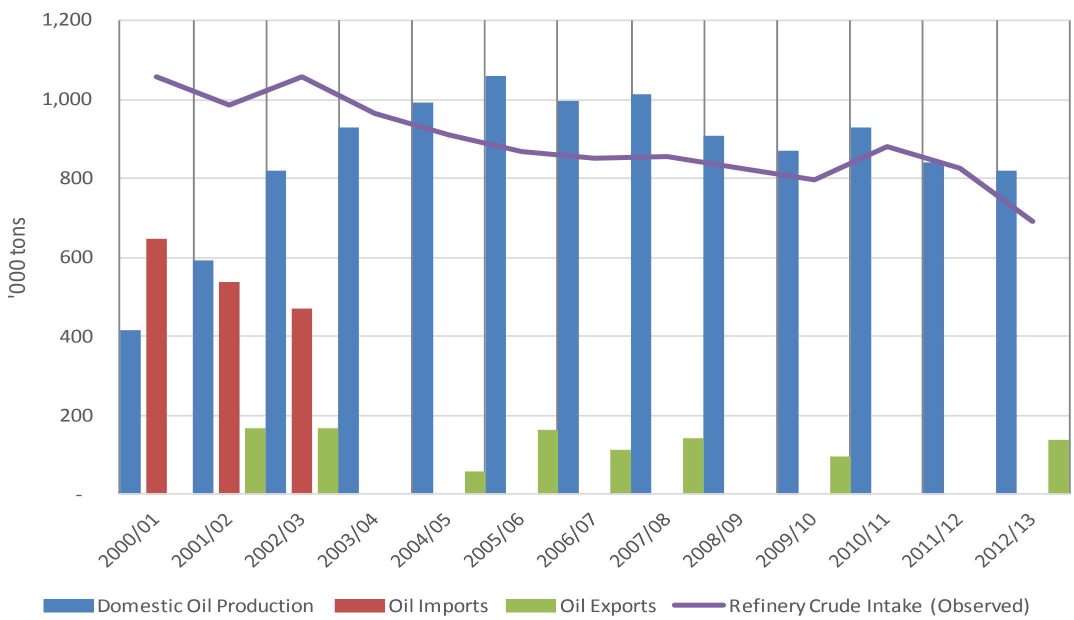
46. Figure III-3 shows Myanmar's overall oil production and overall refinery input. Figure III-4 illustrates the level of refinery output against the refinery capacity over time. This demonstrates the extent to which the existing refineries in Myanmar are underutilised.

Table III-2: Myanmar's Refineries

Refinery	Year in Operation	Design Capacity (bbl/d)	Actual Output (bbl/d – 2013)	Main Products Produced
Thanbayakan (Mann)	1982	25,000	8,600	Naptha, gasoline, diesel, petroleum, coke
Thanlyin	1963 (extended in 1980)	20,000	11,400	Naptha, LPG
Chauk	1954	6,000	2,000	Naptha, wax
Total		**51,000**	**22,000**	

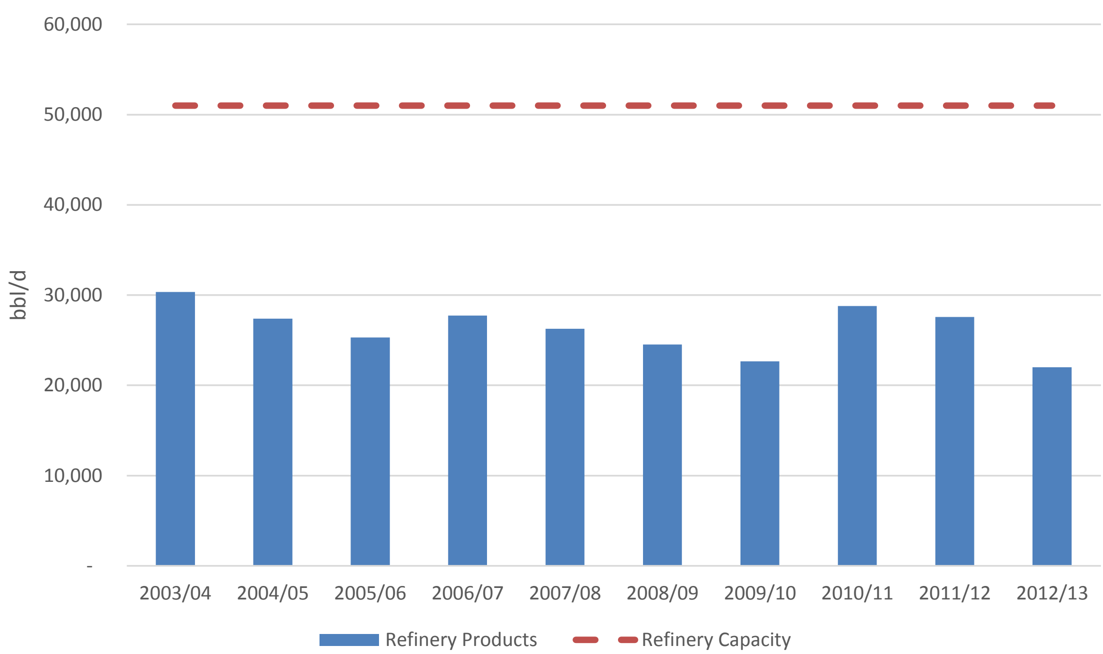
Source: MOGE, ADB

Figure III-3: Myanmar Oil Production and Refinery Input



Source: MOGE

Figure III-4: Myanmar Refinery Capacity and Petroleum Product Output



Source: MOE, MOGE

47. Table III-19 and Table III-20 set out detailed statistics on total domestic supply, transformation and petroleum product end use.

48. Figure III-6 and Figure III-7 respectively show the domestic production of petroleum products and imported petroleum products. Figure III-8 and Figure III-9 are the corresponding energy equivalents. Figure III-10 and Figure III-11 show the total supply of petroleum products to Myanmar, respectively in physical units (thousands of metric tons) and energy units (ktoe).

Figure III-5: Location of Myanmar Oil Refineries

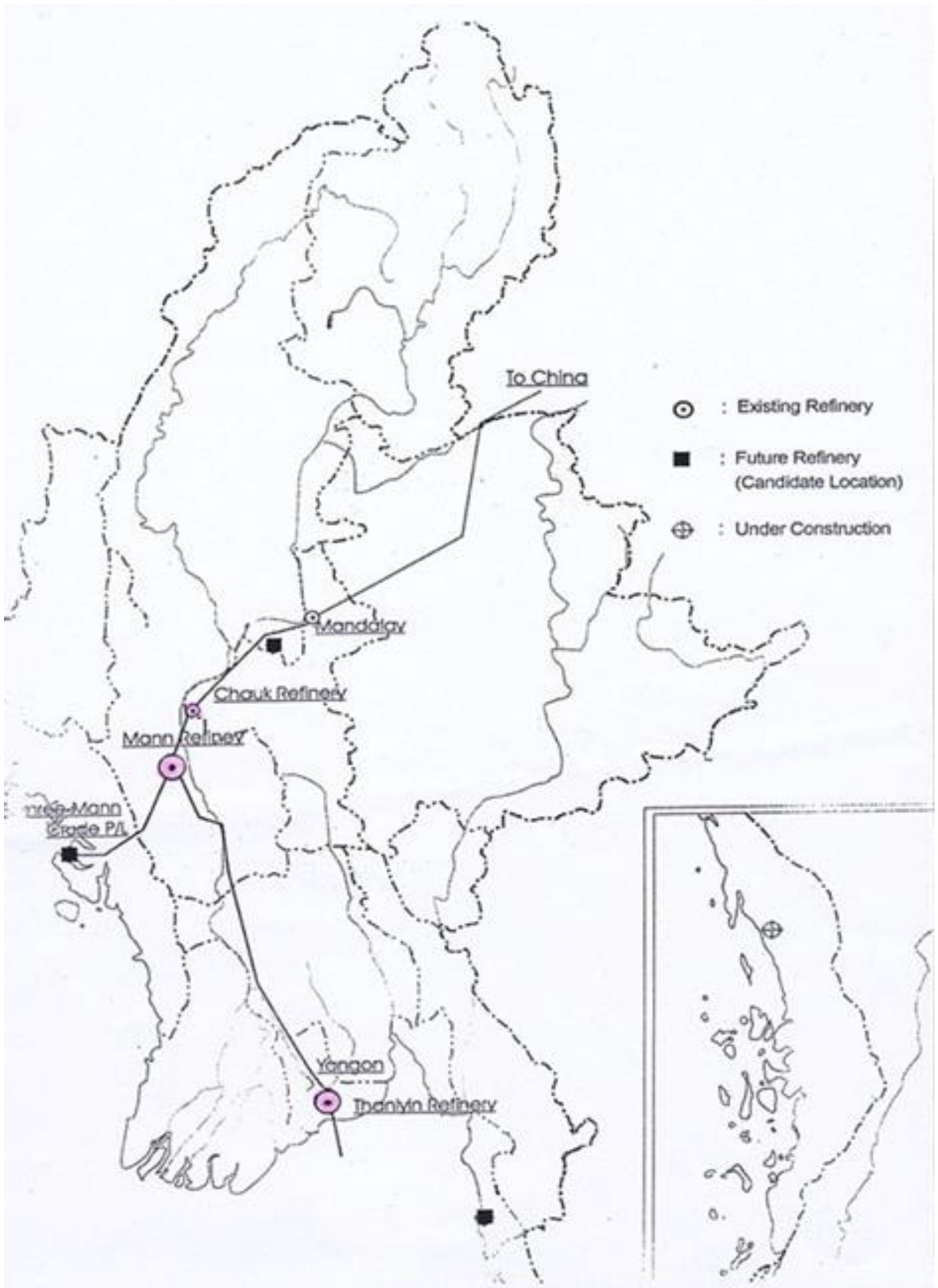
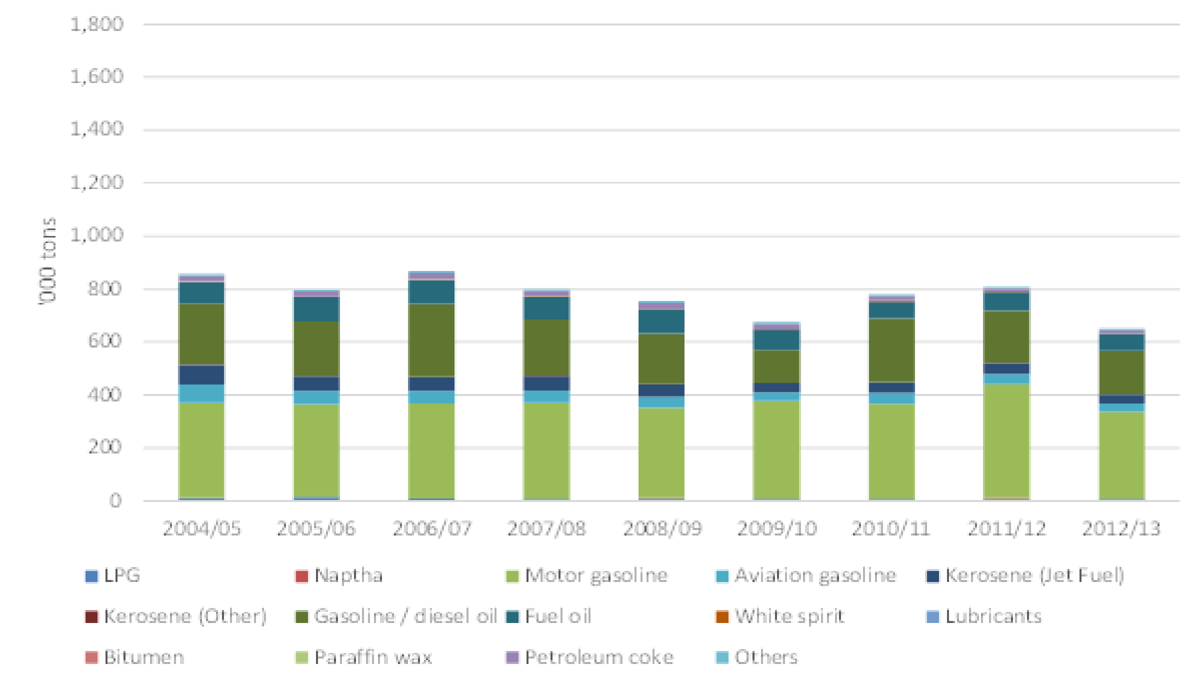
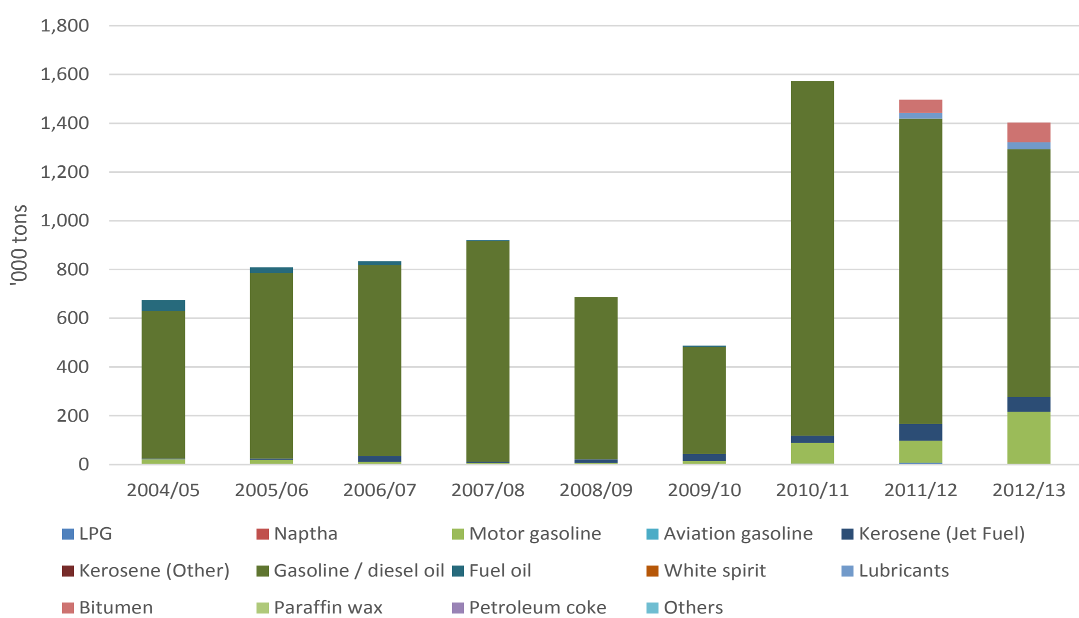


Figure III-6: Myanmar Petroleum Products Produced ('000 ton)



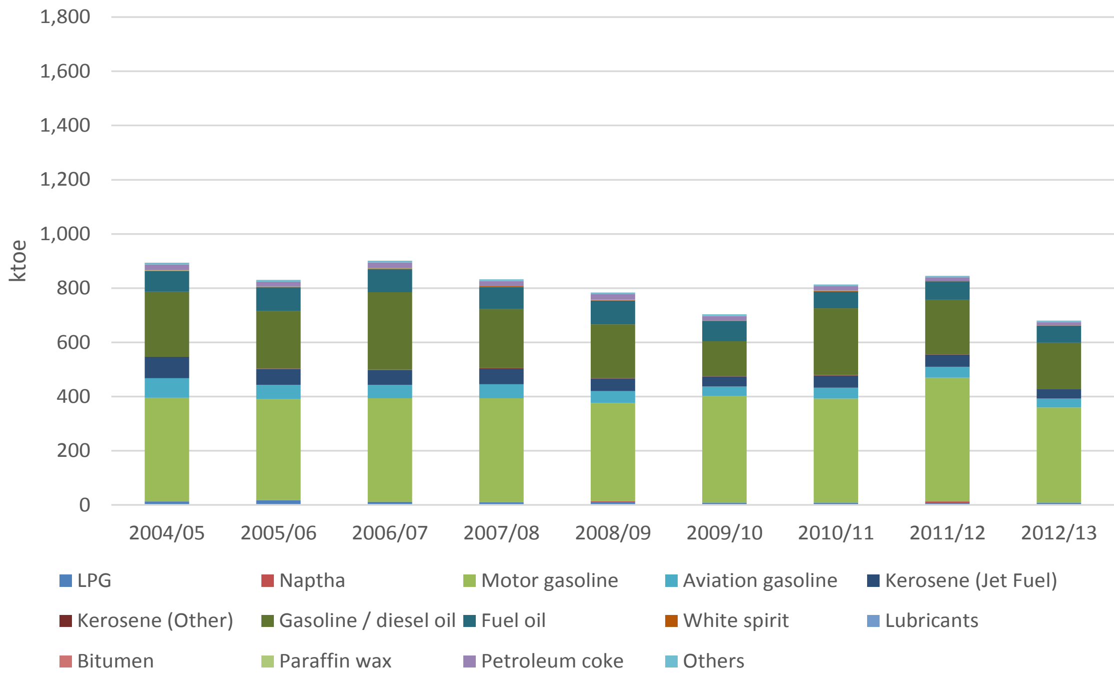
Sources: MOE, MPPE, CSO

Figure III-7: Myanmar Petroleum Products Imported ('000 ton)



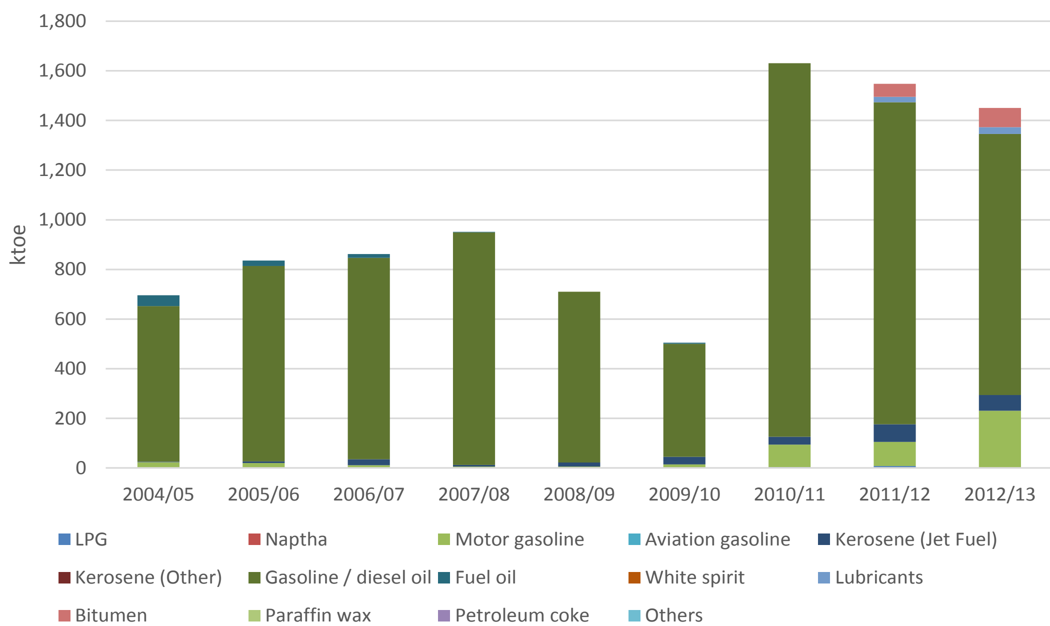
Sources: MOE, MPPE, CSO

Figure III-8: Myanmar Petroleum Products Produced (ktoe)



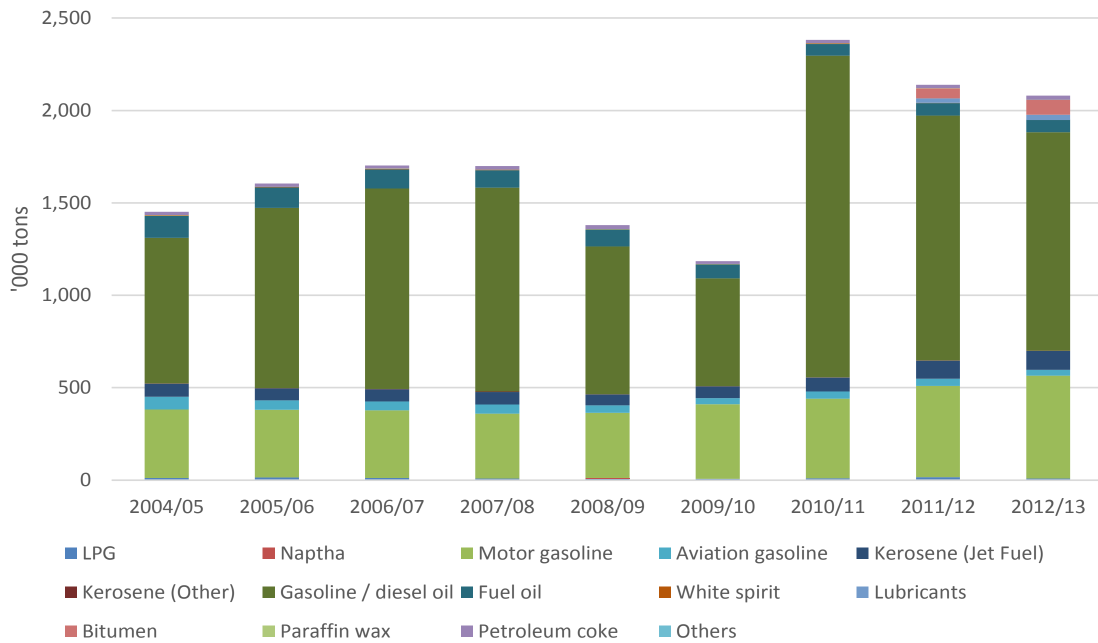
Sources: MOE, MPPE, CSO

Figure III-9: Myanmar Petroleum Products Imported (ktoe)



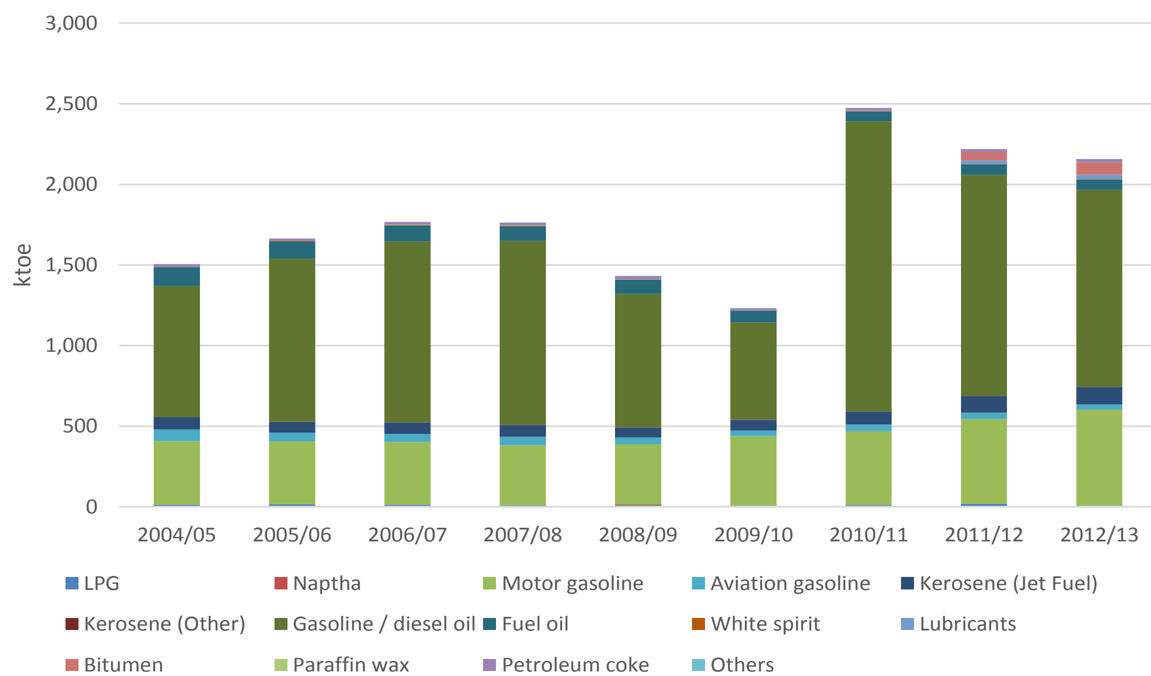
Sources: MOE, MPPE, CSO

Figure III-10: Myanmar Petroleum Total Product Supply ('000 ton)



Sources: MOE, MPPE, CSO

Figure III-11: Myanmar Petroleum Total Product Supply (ktoe)

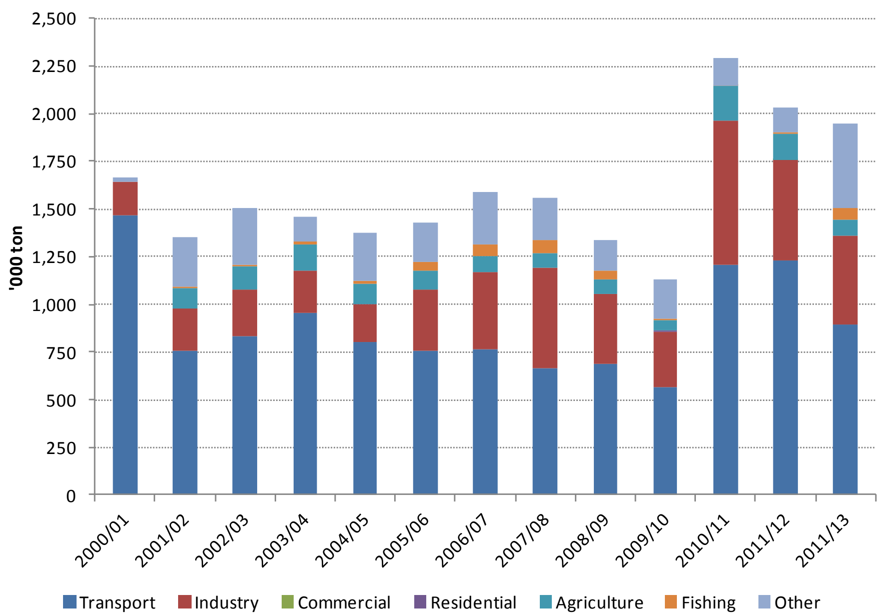


Sources: MOE, MPPE, CSO

Q. Petroleum Product Final Consumption

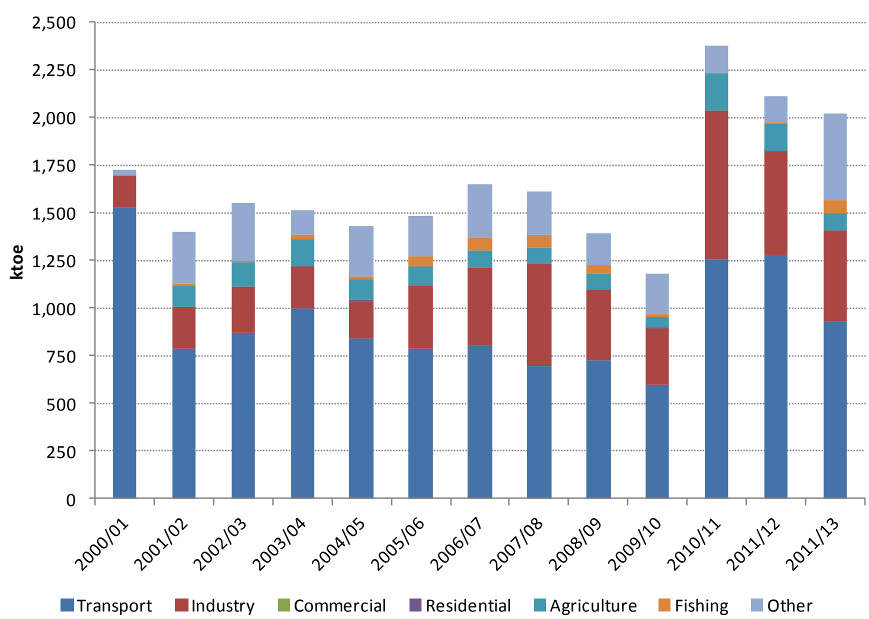
49. The charts presented in Figure III-12 and Figure III-13 illustrate in physical and energy terms the final energy consumption of petroleum products in Myanmar.

Figure III-12: Myanmar Petroleum Product End Use ('000 tons)



Sources: MOE, MPPE, CSO

Figure III-13: Myanmar Petroleum Product End Use (ktoe)



Sources: MOE, MPPE, CSO

R. Petroleum Energy Flow Diagram

50. Figure III-14 provides an overall energy flow diagram for Myanmar's petroleum sector. This provides a snapshot of the current state of Myanmar's petroleum sector as of 2012/13. It illustrates that Myanmar is currently a net importer of oil – a consequence of increased demand for petroleum products in the recent past combined with a limited oil refining capacity.

S. Primary Oil and Petroleum Commodity Balance Statistics

51. Table III-15 and Table III-16 set out the Myanmar's crude oil production and refinery intake statistics for the period from 2000/01 to 2013/14.

52. Table III-17 and Table III-18 provide statistics on the total supply to Myanmar of petroleum products (including both products that are produced by Myanmar's oil refineries and those that are imported to the country) for the period from 2000/01 to 2013/14.

53. Table III-19 and Table III-20 set out the statistics on the consumption of petroleum products in Myanmar for the period from 2000/01 to 2013/14.

T. Petroleum Sector Observations

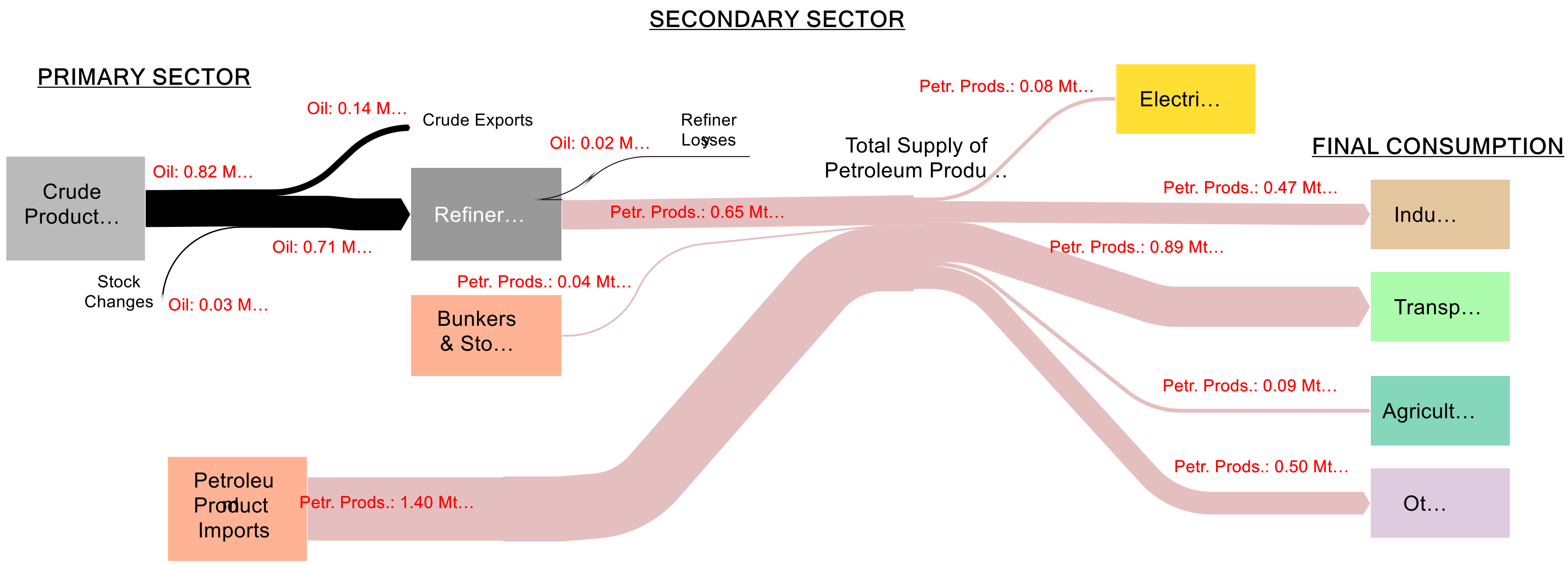
54. Myanmar crude oil production has generally decreased over the last decade from a peak of 8 billion bbl/y in 2005 to just over 6 billion bbl/y by 2013. Most all of the crude oil that Myanmar produces is delivered to the country's oil refineries for production of petroleum products, although in the last two years (2012/13 and 2013/14) Myanmar has exported 17% and 28% of its domestically produced crude oil.

55. Myanmar has become a net importer of petroleum products as a consequence of increased domestic demand for petroleum products in the recent past combined with limited oil refining facilities. The production from three ageing refineries is observed to be significantly below design capacity (at around 50% of rated capacity on average) and has generally been following a downward production trend – for instance, some 1,033 Mt (1,069 ktoe) of petroleum products in 2002/03 compared to some 506 Mt (526 ktoe) in 2013/14.

56. Major petroleum products consumed in Myanmar are gas/diesel oil, motor gasoline and jet kerosene. Gas and diesel oil constitutes some 59% of petroleum demand in Myanmar, followed by 24% motor gasoline and 5% jet kerosene. The imported segment of gas and diesel oil is dominant accounting for 87% over the last three years (2011/12 to 2013/14). Similarly, around 58% of the motor gasoline in Myanmar is imported.

57. The transport sector is the largest end user of petroleum products. In 2013/14 it consumed 1,038 ktoe out of a total of 2,348 ktoe, or 44% of the country's final petroleum consumption.

Figure III-14: Myanmar Petroleum Energy Flow Diagram 2012/13



Sources: Consultants' Analysis

Table III-15: Myanmar oil Production and Refinery Intake 2000/01 to 2013/14 (Physicals)

Unit: '000 ton	**00-01**	**01-02**	**02-03**	**03-04**	**04-05**	**05-06**	**06-07**	**07-08**	**08-09**	**09-10**	**10-11**	**11-12**	**12-13**	**13-14**
Crude oil														
Indigenous Production	416	591	820	931	994	1,061	997	1,013	907	870	928	840	821	838
From Other Sources														
from coal														
from gas														
Products Transferred														
Imports	647	538	470											
Exports		167	168		57	163	111	142		94			140	236
Direct Use (includes transfers to consumption)														
Stock Changes (+ or -)		34	-19	15	-12	5	-39	7	-15	37	7	-25	28	3
REFINERY INTAKE (Calc.)	**1,063**	**996**	**1,104**	**947**	**924**	**903**	**846**	**878**	**892**	**814**	**935**	**815**	**709**	**606**
Statistical Differences (+ or -)	6	10	48	-19	15	36	-6	20	67	16	52	-12	20	54
REFINERY INTAKE (Observed)	**1,057**	**986**	**1,056**	**965**	**909**	**867**	**852**	**857**	**825**	**798**	**882**	**827**	**690**	**552**
Refinery Losses		10					6	13	49	-388		8	20	12
Total stocks on national territory:														
Stock at:														
Opening		76	41	60	45	57	52	92	85	100	63	63	54	27
Closing		41	60	45	57	52	92	85	100	63	56	88	27	24

Sources: MOE, MPPE, CSO 2014

Table III-16: Myanmar oil Production and Refinery Intake 2000/01 to 2013/14 (ktoe)

Unit: '000 ton	**00-01**	**01-02**	**02-03**	**03-04**	**04-05**	**05-06**	**06-07**	**07-08**	**08-09**	**09-10**	**10-11**	**11-12**	**12-13**	**13-14**
Crude oil														
Indigenous Production	416	591	820	931	994	1,061	997	1,013	907	870	928	840	821	838
From Other Sources														
from coal														
from gas														
Products Transferred														
Imports	647	538	470											
Exports		167	168		57	163	111	142		94			140	236
Direct Use (includes transfers to consumption)														
Stock Changes (+ or -)	-	34	-19	15	-12	5	-39	7	-15	37	7	-25	28	3
REFINERY INTAKE (Calc.)	**1,063**	**996**	**1,104**	**947**	**924**	**903**	**846**	**878**	**892**	**814**	**935**	**815**	**709**	606
Statistical Differences (+ or -)	6	10	48	-19	15	36	-6	20	67	16	52	-12	20	54
REFINERY INTAKE (Observed)	**1,057**	**986**	**1,056**	**965**	**909**	**867**	**852**	**857**	**825**	**798**	**882**	**827**	**690**	552
Refinery Losses														
Total stocks on national territory:														
Stock at:														
Opening		76	41	60	45	57	52	92	85	100	63	63	54	27
Closing		41	60	45	57	52	92	85	100	63	56	88	27	24

Sources: MOE, MPPE, CSO 2014

Table III-17: Myanmar Total Primary Energy Supply of Petroleum Products 2000/01 – 2013/14 (Physicals)

Unit: '000 ton	00-01	01-02	02-03	03-04	04-05	05-06	06-07	07-08	08-09	09-10	10-11	11-12	12-13	13-14
LPG	14	15	15	15	11	15	11	8	8	7	10	16	7	19
Naphtha														
Motor Gasoline	335	306	322	369	369	369	366	352	359	404	431	494	536	548
Aviation Gasoline	59	65	65	71	68	50	47	49	41	33	39	38	30	24
Kerosene Type Jet Fuel	62	67	72	78	70	63	67	60	59	61	75	97	103	119
Kerosene	2	1	2	1	1	1	1	2	1	1	2	1	-	0
Gas/Diesel Oil	1,070	857	989	977	851	905	1,084	1,106	814	591	1,743	1,325	1,187	1,401
Fuel Oil	134	114	122	124	106	89	86	78	87	80	58	42	65	35
White Spirit SBP	3	3	3	4	2	2	3	3	3	2	3	2	1	
Lubricants	3	4	1									23	28	41
Bitumen												54	81	114
Paraffin Waxes	10	2	2	2	2	1	1	1	1	1	1	1	1	37
Petroleum Coke	37	36	34	25	18	17	17	19	21	15	19	19	22	11
Other Products	7	12	12	6	7	6	7	6	7	6	6	5	5	5

Sources: MOE, MPPE, CSO 2014

Table III-18: Myanmar Total Primary Energy Supply of Petroleum Products 2000/01 – 2013/14 (ktoe)

Unit: ktoe	00-01	01-02	02-03	03-04	04-05	05-06	06-07	07-08	08-09	09-10	10-11	11-12	12-13	13-14
LPG	16	17	17	17	13	17	13	9	9	8	12	18	8	16
Naphtha									4					
Motor Gasoline	357	326	343	393	393	393	390	375	383	430	459	526	571	357
Aviation Gasoline	62	69	69	75	71	53	50	52	43	35	41	40	32	62
Kerosene Type Jet Fuel	65	70	76	82	73	66	70	63	63	64	79	102	109	65
Kerosene	3	1	2	2	1	1	1	2	1	1	2	1	-	3
Gas/Diesel Oil	1,107	886	1,023	1,011	880	936	1,121	1,144	841	611	1,803	1,370	1,227	1,107
Fuel Oil	129	110	117	119	102	86	83	75	83	76	56	40	62	129
White Spirit SBP	2	3	3	3	2	2	3	3	3	2	3	2	1	2
Lubricants	3	3	1									22	27	3
Bitumen												52	78	
Paraffin Waxes	10	2	2	2	2	1	1	1	1	1	1	1	1	10
Petroleum Coke	36	35	33	24	17	16	16	18	20	15	18	18	21	36
Other Products	7	11	11	6	6	6	6	6	6	6	6	5	5	7

Sources: MOE, MPPE, CSO 2014

Table III-19: Myanmar Petroleum Product Consumption 2000/01 – 2013/14 (Physicals)

Unit: '000 ton	00-01	01-02	02-03	03-04	04-05	05-06	06-07	07-08	08-09	09-10	10-11	11-12	12-13	13-14
Transport														
LPG	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Naphtha	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Motor Gasoline	335	269	284	360	325	306	321	308	316	360	350	442	469	451
Aviation Gasoline	-	0	0	0	0	0	-	-	0	0	0	0	-	0
Kerosene Type Jet Fuel	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Kerosene	62	67	72	78	70	63	67	-	59	61	75	97	103	119
Gas/Diesel Oil	-	-	-	0	-	0	0	-	-	-	-	-	-	-
Fuel Oil	1,069	409	472	511	406	380	371	352	313	146	781	594	210	273
White Spirit SBP	-	5	5	4	4	5	5	5	1	1	0	0	0	1
Lubricants	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Bitumen	-	4	1	-	-	-	-	-	-	-	-	23	28	41
Paraffin Waxes	-	-	-	-	-	-	-	-	-	-	-	54	81	114
Petroleum Coke	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Other Products	-	-	-	-	-	-	-	-	-	-	-	19	-	-
Industry														
LPG	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Naphtha	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Motor Gasoline	-	4	4	5	5	5	5	5	5	6	47	7	8	12
Aviation Gasoline	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Kerosene Type Jet Fuel	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Kerosene	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Gas/Diesel Oil	-	-	0	0	0	0	0	-	0	0	-	-	-	-
Fuel Oil	-	108	124	107	120	238	338	475	291	227	659	501	408	347

Unit: '000 ton	00-01	01-02	02-03	03-04	04-05	05-06	06-07	07-08	08-09	09-10	10-11	11-12	12-13	13-14
White Spirit SBP	134	69	74	64	66	62	55	42	47	40	27	17	31	8
Lubricants	2	3	3	2	4	2	3	3	3	2	3	2	1	-
Bitumen	3	-	-	-	-	-	-	-	-	-	-	-	-	-
Paraffin Waxes	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Petroleum Coke	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Other Products	37	36	34	18	25	17	-	-	21	15	19	-	22	11
Other														
LPG	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Naphtha	14	15	15	15	11	15	11	8	8	7	10	16	7	19
Motor Gasoline	-	32	33	3	38	58	39	38	38	38	34	45	59	84
Aviation Gasoline	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Kerosene Type Jet Fuel	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Kerosene	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Gas/Diesel Oil	2	1	1	1	1	1	1	-	1	1	2	1	-	0
Fuel Oil	-	294	339	231	291	252	332	269	197	188	253	192	489	721
White Spirit SBP	-	35	37	35	32	23	26	31	39	39	30	25	34	26
Lubricants	-	-	-	-	-	-	-	-	-	-	-	-	-	0
Bitumen	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Paraffin Waxes	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Petroleum Coke	10	2	2	2	2	1	1	1	1	1	1	1	1	37
Other Products	-	-	-	-	-	-	17	19	-	-	-	-	-	-

Sources: MOE, MPPE, CSO 2014

Table III-20: Myanmar Petroleum Product Consumption 2000/01 – 2013/14 (ktoe)

Unit: ktoe	00-01	01-02	02-03	03-04	04-05	05-06	06-07	07-08	08-09	09-10	10-11	11-12	12-13	13-14
Transport														
LPG	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Naphtha	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Motor Gasoline	356	287	303	383	346	325	342	328	336	383	372	471	499	481
Aviation Gasoline	-	0	0	0	0	0	-	-	0	0	0	0	-	0
Kerosene Type Jet Fuel	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Kerosene	65	70	76	82	73	66	70	-	63	64	79	102	109	125
Gas/Diesel Oil	-	-	-	0	-	0	0	-	-	-	-	-	-	-
Fuel Oil	1,105	423	489	529	420	393	384	365	324	151	808	614	217	283
White Spirit SBP	-	4	5	4	4	4	4	5	1	1	0	0	0	1
Lubricants	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Bitumen	-	3	1	-	-	-	-	-	-	-	-	22	27	39
Paraffin Waxes	-	-	-	-	-	-	-	-	-	-	-	52	78	110
Petroleum Coke	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Other Products	-	-	-	-	-	-	-	-	-	-	-	18	-	-
Industry														
LPG	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Naphtha	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Motor Gasoline	-	4	5	5	5	5	5	5	5	6	51	7	9	12
Aviation Gasoline	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Kerosene Type Jet Fuel	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Kerosene	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Gas/Diesel Oil	-	-	0	0	0	0	0	-	0	0	-	-	-	-
Fuel Oil	-	111	129	111	124	246	349	491	301	235	682	518	422	359

Unit: ktoe	00-01	01-02	02-03	03-04	04-05	05-06	06-07	07-08	08-09	09-10	10-11	11-12	12-13	13-14
White Spirit SBP	129	66	71	62	63	59	53	40	45	39	26	16	29	8
Lubricants	2	3	3	2	3	2	3	3	3	2	3	2	1	-
Bitumen	3	-	-	-	-	-	-	-	-	-	-	-	-	-
Paraffin Waxes	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Petroleum Coke	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Other Products	36	35	33	17	24	16	-	-	20	15	18	-	21	11
Other														
LPG	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Naphtha	16	17	17	17	13	17	13	9	9	8	12	18	8	22
Motor Gasoline	-	34	35	4	41	62	42	41	41	41	36	48	62	90
Aviation Gasoline	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Kerosene Type Jet Fuel	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Kerosene	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Gas/Diesel Oil	3	1	1	1	1	1	1	-	1	1	2	1	-	0
Fuel Oil	-	304	350	239	301	261	344	278	204	195	261	199	506	746
White Spirit SBP	-	33	36	33	31	22	25	30	37	37	29	24	33	25
Lubricants	-	-	-	-	-	-	-	-	-	-	-	-	-	0
Bitumen	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Paraffin Waxes	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Petroleum Coke	10	2	2	2	2	1	1	1	1	1	1	1	1	36
Other Products	-	-	-	-	-	-	16	18	-	-	-	-	-	-

Sources: MOE, MPPE, CSO 2014

IV. NATURAL GAS

U. Summary

58. This section presents statistics on supply and demand for natural gas in Myanmar. Natural gas commodity balances are provided in Table IV-21 and Table IV-22. Additional tables and charts in this section supplement these statistics to provide further detail on Myanmar's gas sector.

59. An energy flow chart to illustrate the movement of gas in Myanmar is provided in Figure IV-20 for the year 2013/14. This illustrates how most of the natural gas produced by Myanmar is exported, with Thailand being the main export destination as of 2013/14, followed by PRC.

V. Onshore Natural Gas Production

60. Table IV-1 and Table IV-2 provide onshore natural gas production statistics by onshore field for years 2012/13 and 2013/14. Figure IV-3 shows for the year 2013/14 the breakdown in onshore production by field. Figure IV-4 plots the historical onshore production of natural gas for the period from 2000/01 to 2013/14 with breakdowns by onshore gas field provided in the last two years. The broad trend is that production from onshore gas fields has declined over the last decade.

Table IV-1: Onshore Natural Gas Production by Field (2012/13)

Onshore Gas Production for 2012-2013

No.	Gas Field	Production	Sale	Own use	Total Used	Flare	Pack	Unpack
		MMcf	MMcf	MMcf	MMcf	MMcf	MMcf	MMcf
1	KKT	3,823.7	3,633.6	93.5	3,727.1		37.0	
2	LPD	155.4	82.5	80.3	162.8	0.2	7.7	15.3
3	AYD	737.1	357.0	380.3	737.4		0.6	0.8
4	TGT	1,994.9	1,854.0	111.3	1,965.3	1.1	37.4	8.5
5	CHK	73.7	29.8	44.0	73.7			
6	YNG	116.2	9.2	107.0	116.2			
7	MANN	853.6	442.2	411.4	853.6			
8	TSB	115.2	102.4	12.4	114.9	0.4		
9	KNI	85.9	87.1	1.9	88.9			
10	PEPI	149.6	144.1	5.4	149.6			
11	DHP	0.2		0.2	0.2			
12	PYAY	57.4	20.4	36.9	57.3	0.1		
13	PYAYE	149.9	149.9		149.9			
14	MAG	40.5	3.3	37.2	40.5			
15	SPT	15.8		13.9	13.9	0.7	0.5	
16	NDN	10,817.3	10,600.4	210.1	10,810.4	12.7		4.4
17	MUB	428.0	426.1		426.1	1.6		
18	APK (ZALON)	2,968.1	2,755.2	212.0	2,967.2	1.0	8.7	
19	APK (TAIKEGYI)	51.7	51.5		51.5	0.2		
	TOTAL	**22,634.5**	**20,748.7**	**1,757.8**	**22,506.5**	**18.1**	**91.9**	**29.1**

Table IV-2: Onshore Natural Gas Production by Field (2013/14)

Onshore Gas Production for 2013-14								
No.	**Gas Field**	**Production MMcf**	**Sale MMcf**	**Own Used MMcf**	**Total Used MMcf**	**Flare MMcf**	**Pack MMcf**	**Unpack MMcf**
1	KKT	4,586.1	4,481.0	128.4	4,609.4	0.3	23.6	
2	LPD	89.4	39.0	61.1	100.0	-	10.7	-
3	AYD	652.0	321.1	330.9	652.0		-	-
4	TGT	1,810.6	1,691.9	136.1	1,828.1	-	17.0	8.5
5	CHK	73.7	29.1	44.6	73.7			
6	YNG	109.7	7.3	102.4	109.7			
7	MANN	758.5	330.1	428.4	758.5			
8	TSB	568.8	493.1	12.4	505.5	63.3		
9	KNI	76.1	74.2	1.4	75.6	0.4		
10	PEPI	104.9	102.7	2.1	104.9			
11	DHP	0.4		0.4	0.4			
12	PYAY	36.9	-	36.9	36.9	-		
13	PYAYE	82.4	82.4		82.4			
14	MAG	40.5	3.5	37.0	40.5			
15	SPT	14.6	-	14.6	14.6	-	-	
16	NDN	7,500.5	7,312.8	270.8	7,583.5	12.9	72.1	-
17	MUB	2,897.6	2,864.0		2,864.0	26.0		
18	APK (ZALON)	2,178.6	1,956.0	222.2	2,178.2	-	1.0	
19	APK (TAIKEGYI)	237.2	237.2		237.2	-		
	TOTAL	**21,818.5**	**20,025.5**	**1,829.9**	**21,855.3**	**103.0**	**124.4**	**8.5**

Figure IV-3: Onshore Natural Gas Production Shares by Field in 2013/14

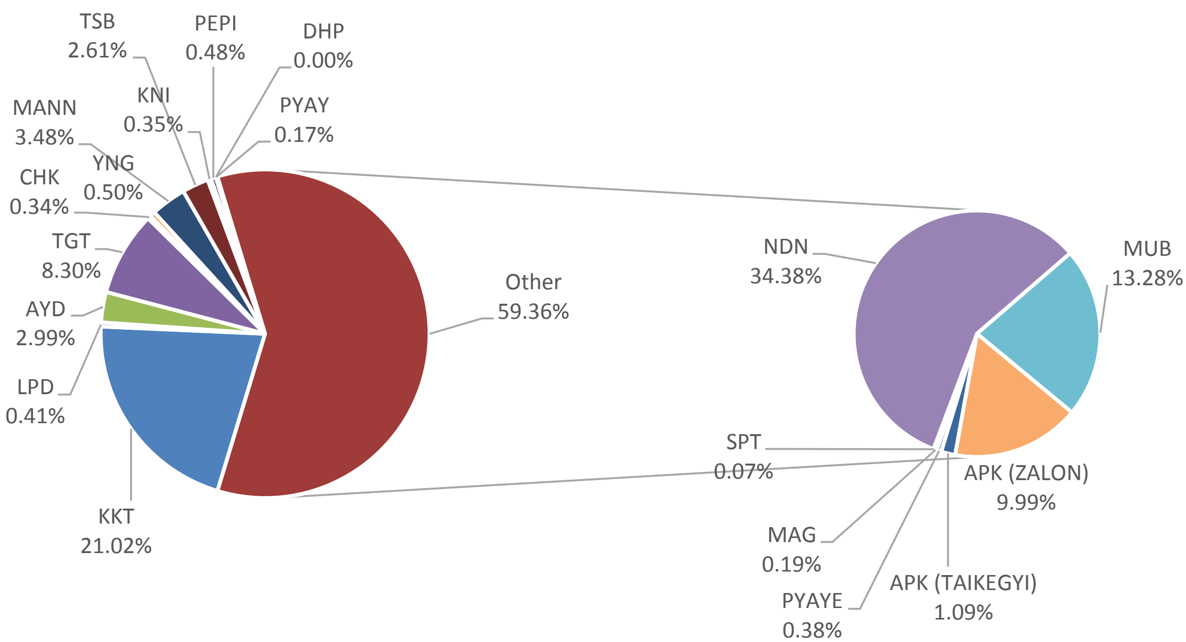
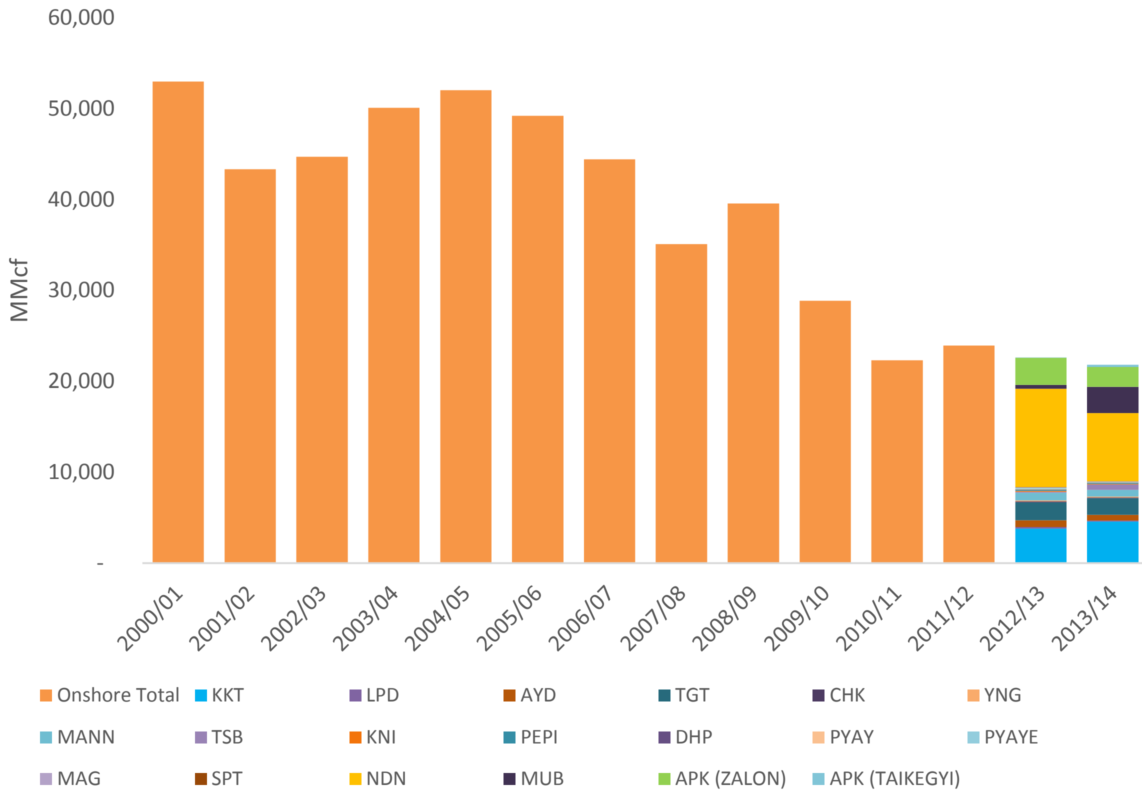


Figure IV-4: Onshore Natural Gas Production 200/01 to 2013/14



W. Offshore Natural Gas Production

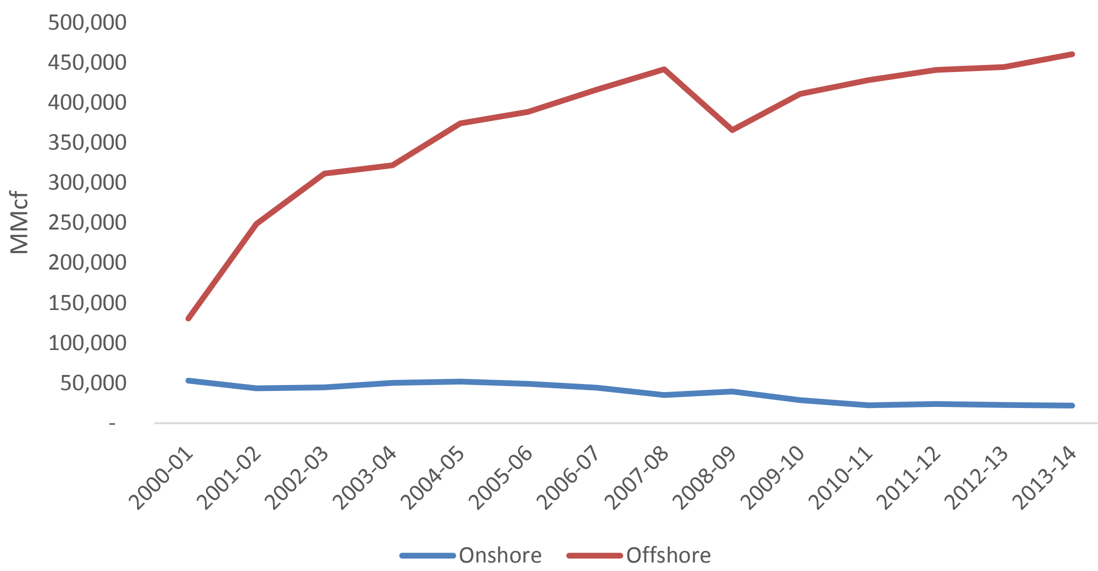
61. Figure IV-5 plots Myanmar's gas production showing the onshore and offshore production. It demonstrates how offshore production with production from the offshore fields has become a key component of Myanmar's gas sector since the year 2000. Yadana and Yetagun are the two major offshore gas fields that have been supplying natural gas. Production from the Shwe field commenced in July 2013 and Zawtika was scheduled to commence in 2014. The combined production from Shwe and Zawtika is expected to be around 200 MMcfd by 2015.

62. The vast majority of natural gas produced in Myanmar is for export. As of 2012/13, most was to Thailand, however production from Shwe from July 2013 means that PRC has also become a significant export destination for Myanmar's gas. In 2012/13, the export volume was 362 MMcf of the 453 MMcf produced.

63. Production from the Shwe field which was discovered in 2004 is achieved through an overland pipeline from Myanmar to Kunming, Yunnan Province, as illustrated in Figure IV-6. The pipeline has a capacity of about 500 MMcfd, with a possible expansion to 1,200 MMcfd. More detailed statistics on the production by field is provided in Table IV-7 and Table IV-8.

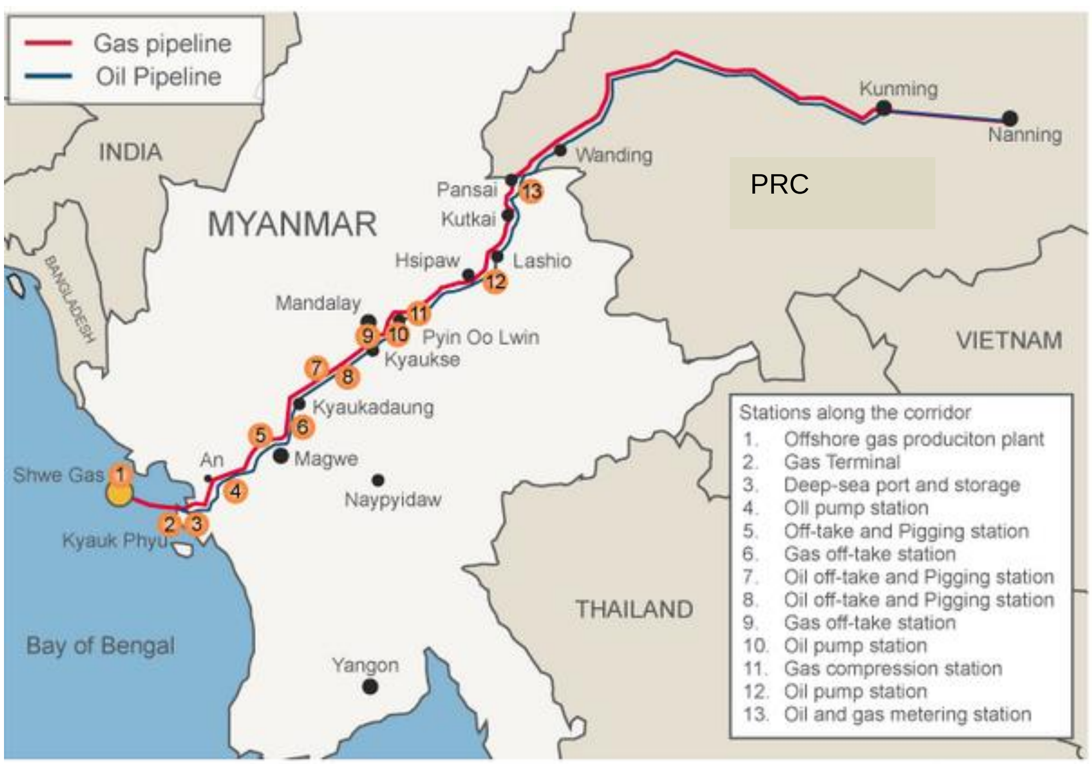
64. Figure IV-9 shows the breakdown of gas production by major field in Myanmar while Figure IV-10 plots annual production by major field for the period 2000/01 to 2013/14.

Figure IV-5: Myanmar's Onshore and Offshore Natural Gas Production



Sources: MOGE, CSO, 2014

Figure IV-6: Oil and gas export pipelines from Myanmar to PRC



Source: Reuters International 2013

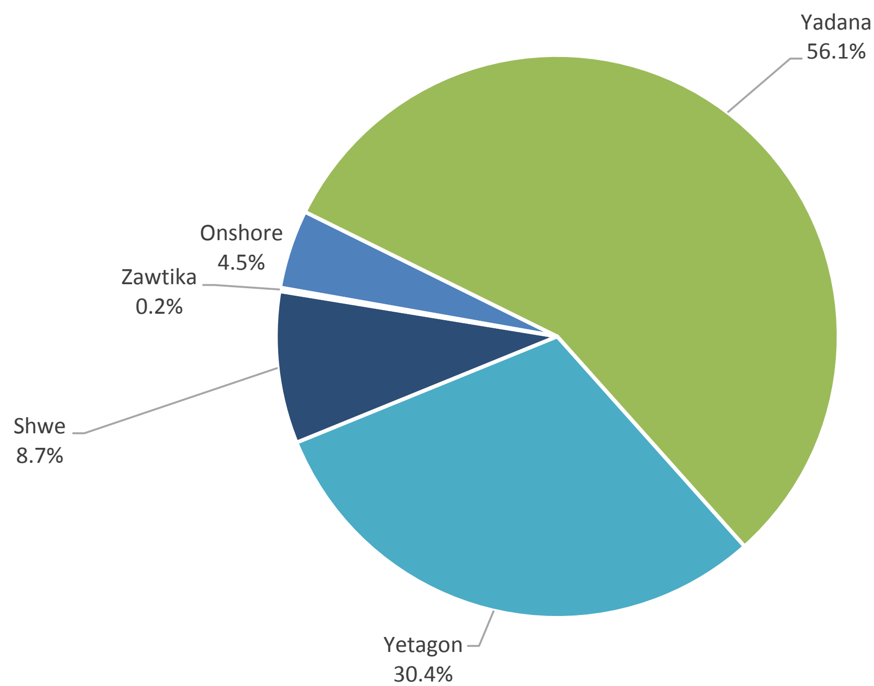
Table IV-7: Onshore and Offshore Natural Gas Production 2011/12 to 2013/14

Onshore & Offshore Gas Production (2011/12 to 2013/14)									
Period	Gas Field	Production	Sales			Own Use	Vent/Flare	Line Pack	Unpack
			Export	Domestic	Total				
		MMcf	MMcf	MMcf	MMcf	MMcf	MMcf	MMcf	MMcf
2011-12	Onshore	23,948		21,058	21,058	2,840	53	1,344	
	Yadana	287,385	218,336	66,460	284,796	2,190	458	306	368
	Yetagon	153,602	146,649		146,649	2,616	109	4,227	
	Total	**464,935**	**364,985**	**87,518**	**452,503**	**7,646**	**620**	**5,878**	**368**
2012-13	Onshore	22,635		13,833	13,833	391	16	92	29
	Yadana	288,931	217,333	67,728	285,060	2,897	485	3,382	-
	Yetagon	155,439	144,823		144,823	4,397	1,940	4,278	
	Total	**467,005**	**362,156**	**81,561**	**443,717**	**7,686**	**2,442**	**7,752**	**29**
2013-14	Onshore	21,819		12,370	12,370	350	39	124	8
	Yadana	270,579	197,826	69,411	267,237	2,851	451	-	-
	Yetagon	146,814	137,823		137,823	4,530	421	4,041	
	Shwe	42,079	37,041	531	37,571	1,249	3,045		
	Zawtika	986		618	618	45	11		
	Total	**482,276**	**372,690**	**82,929**	**455,619**	**9,025**	**3,967**	**4,165**	**8**

Table IV-8: Natural Gas Total Production Statistics 2011/12 to 2013/14

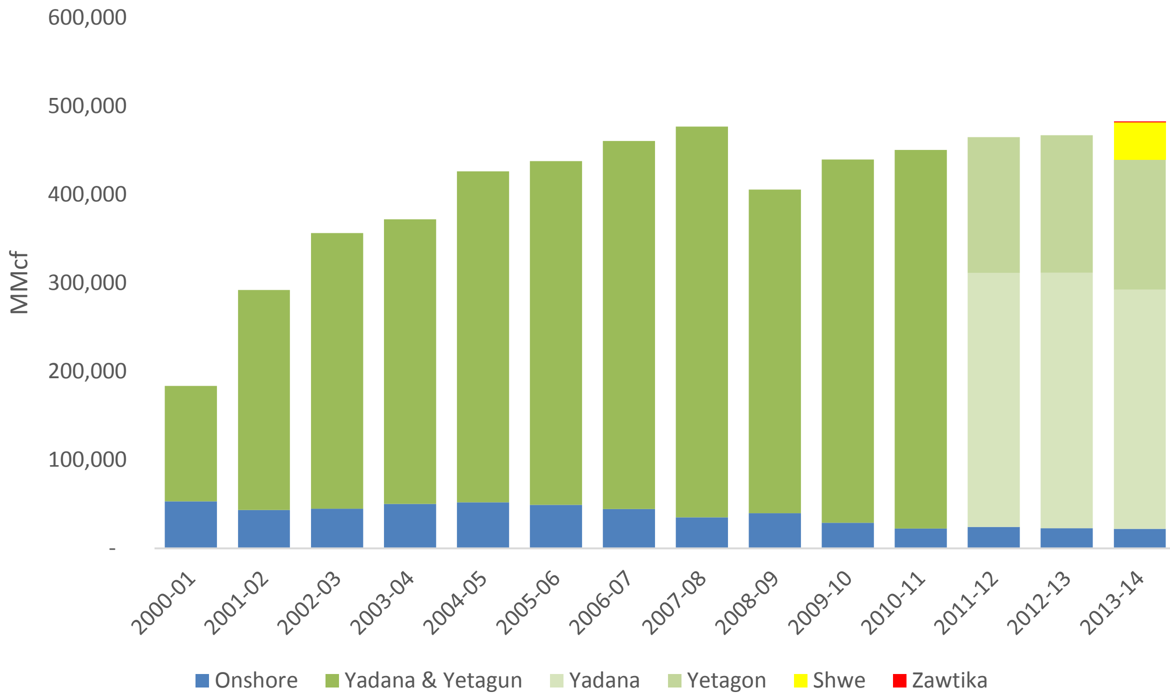
Total Production Statistics								
	Production	Exports	Domestic	Total	Own Use	Vent/Flare	Line Pack	Unpack
2011-12	464,935	364,985	87,518	452,503	7,646	620	5,878	368
2012-13	467,005	362,156	81,561	443,717	7,686	2,442	7,752	29
2013-14	482,276	372,690	82,929	455,619	9,025	3,967	4,165	8

Figure IV-9: Shares of Myanmar's Natural Gas Production for the year 2013/14



Sources: MOGE, CSO

Figure IV-10: Natural Gas Production by Major Field for 2000-01 to 2013-14



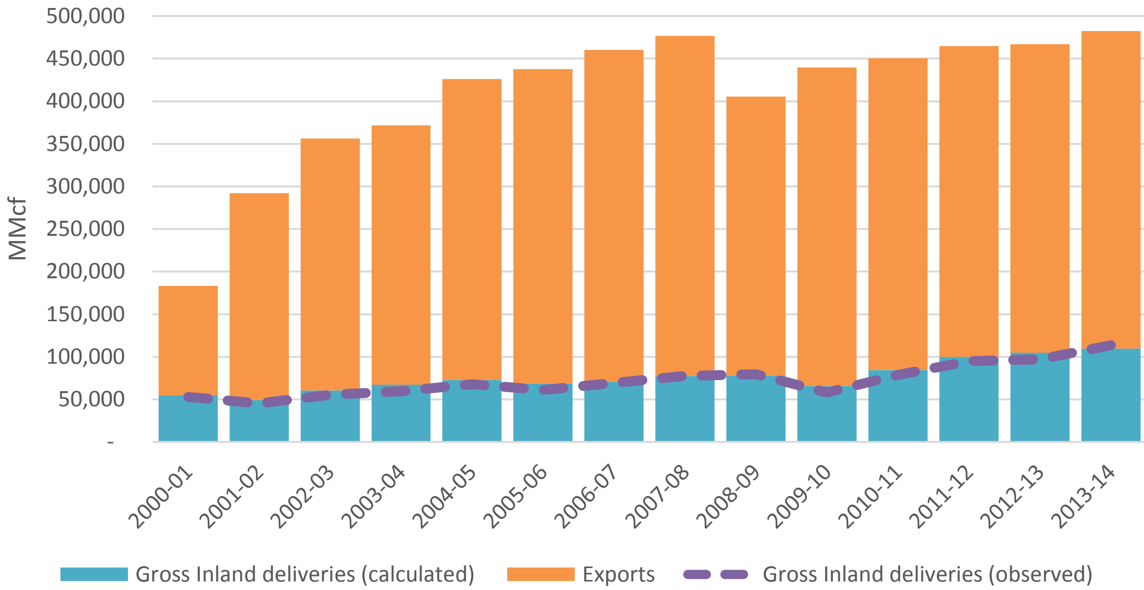
Sources: MOGE, CSO

X. Natural Gas Total Primary Energy Production and Total Primary Energy Supply

65. Figure IV-11 and Figure IV-12 respectively plot the primary supply of natural gas in Myanmar in physical units and in energy terms.

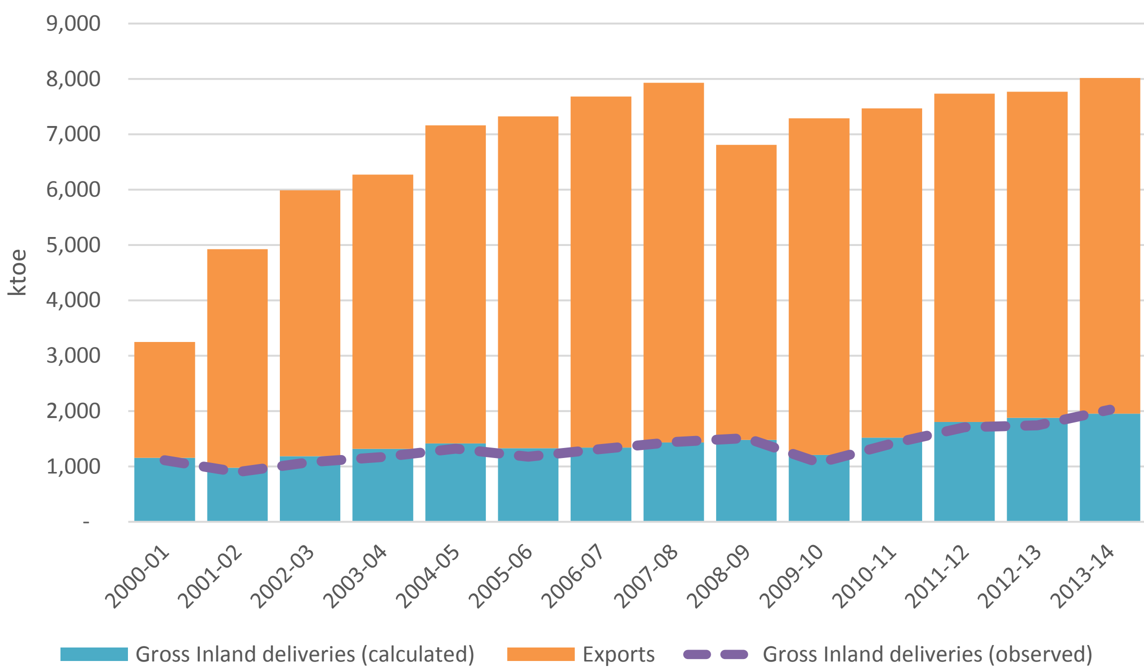
66. Annual domestic supply of natural gas has stabilised at about 2 thousand ktoe in the last two years. The observed supplies though were slightly higher, by 4% to 7% due to statistical differences.

Figure IV-11: Myanmar Natural Gas Production (MMcf)



Sources: MOGE, CSO

Figure IV-12: Myanmar Natural Gas Production (ktoe)



Sources: MOGE, CSO

Y. Natural Gas Transformation

67. Around 55% to 60% of Myanmar's domestic supply of natural gas is used for electricity generation.

68. Table IV-13 shows natural gas used for power generation with breakdowns by generator, and where the gas has been sourced from (onshore vs. offshore). This breakdown is shown for 2012/13 and 2013/14.

69. Figure IV-14 plots the natural gas used in the power subsector. This shows a ramp up in the use of gas for power generation over the last three years, a consequence of Myanmar needing to satisfy a high rate of electricity demand growth in the recent past.

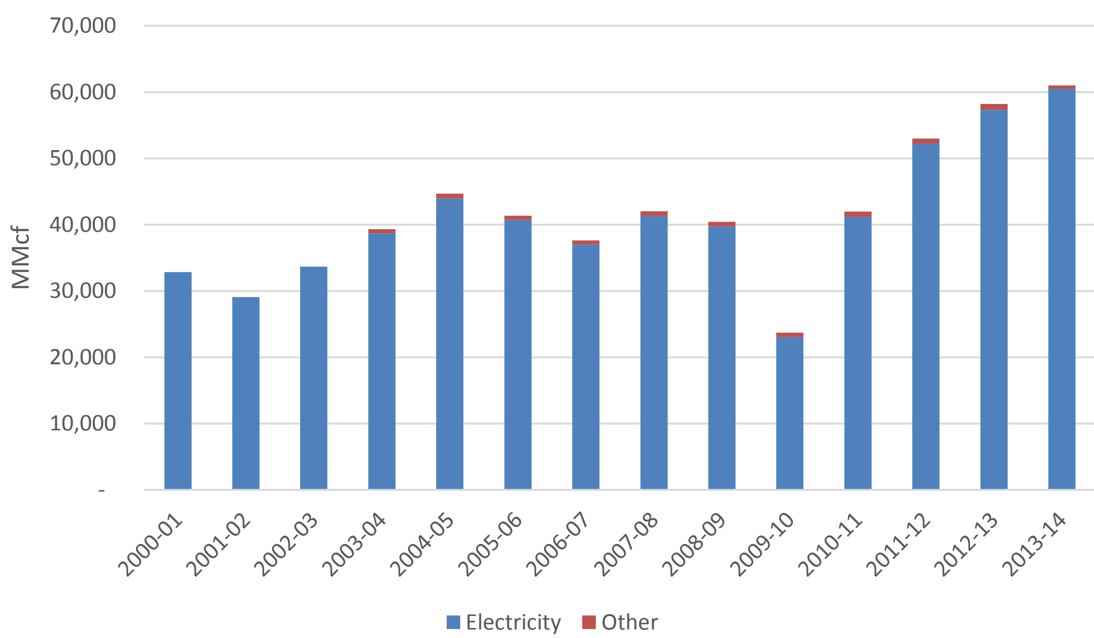
70. Figure IV-15 and Figure IV-16 plot the overall amounts of natural gas for electricity generation and other energy transformation processes.

Table IV-13: Gas for Power Generation 2012/13 and 2013/14

Gas for Power Generation (2012/13 and 2013/14)							
No.	Generator	2012-13			2013-14		
		Onshore	Offshore	Total	Onshore	Offshore	Total
		MMcf	MMcf	MMcf	MMcf	MMcf	MMcf
1	Kyun Chaung GT	2,788		2,788	3,707		3,707
2	Shwe Daung GT		5,371	5,371		3,838	3,838
3	Myan Aung GT	10	2,229	2,238	-	2,336	2,336
4	Ywama GT		6,140	6,140		9,194	9,194
5	Thaketa GT		9,555	9,555		8,956	8,956
6	Ahlone GT		11,307	11,307		13,609	13,609
7	Hlawga GT	113	11,856	11,970	563	10,789	11,352
8	Thaton Turbine (Old)		2,240	2,240		2,717	2,717
9	Thaton Turbine (New)		4,910	4,910		4,077	4,077
10	Ngantae GT		813	813		696	696
11	Kyaukphyu					82	82
12	Kyaukse GEG					1	1
	Total	**2,911**	**54,421**	**57,333**	**4,270**	**56,293**	**60,563**

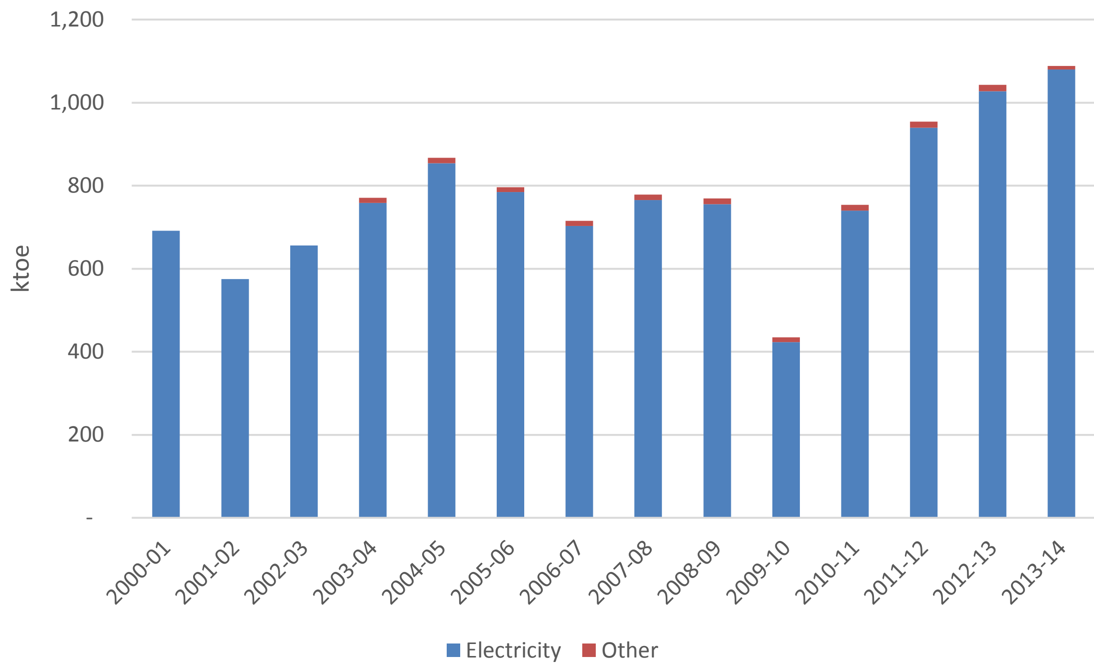
Figure IV-14: Myanmar Natural Gas used in Power Generation 2000-01 to 2013-14

Figure IV-15: Myanmar Natural Gas Transformation (MMcf)



Sources: MOGE, CSO

Figure IV-16: Myanmar Natural Gas Transformation (ktoe)



Sources: MOGE, CSO

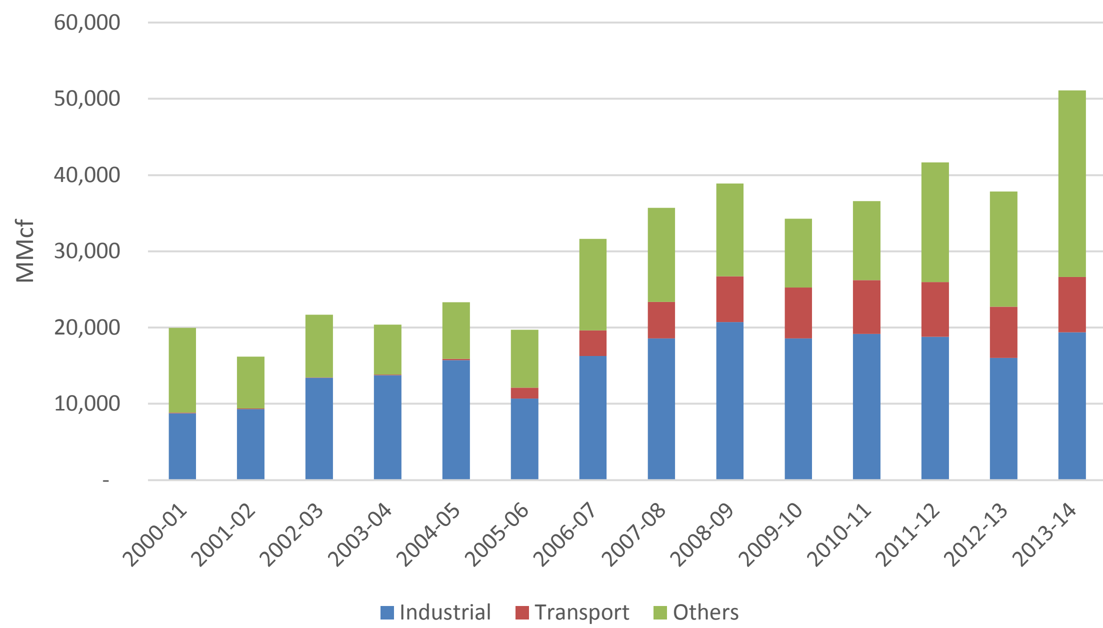
Z. Natural Gas Consumption

71. Figure IV-18 and Figure IV-19 show natural gas consumption. Industry is the largest single sector in terms of gas uses. Its share in total final consumption was more than 50% until 2011 but has then decreased, to about 40% by 2013. Within the industrial sector, fertilizer plants are the largest natural gas users, responsible for roughly a fourth of all sector consumption.

Table IV-17: Gas Consumption by Major Facilities 2012/13 and 2013/14

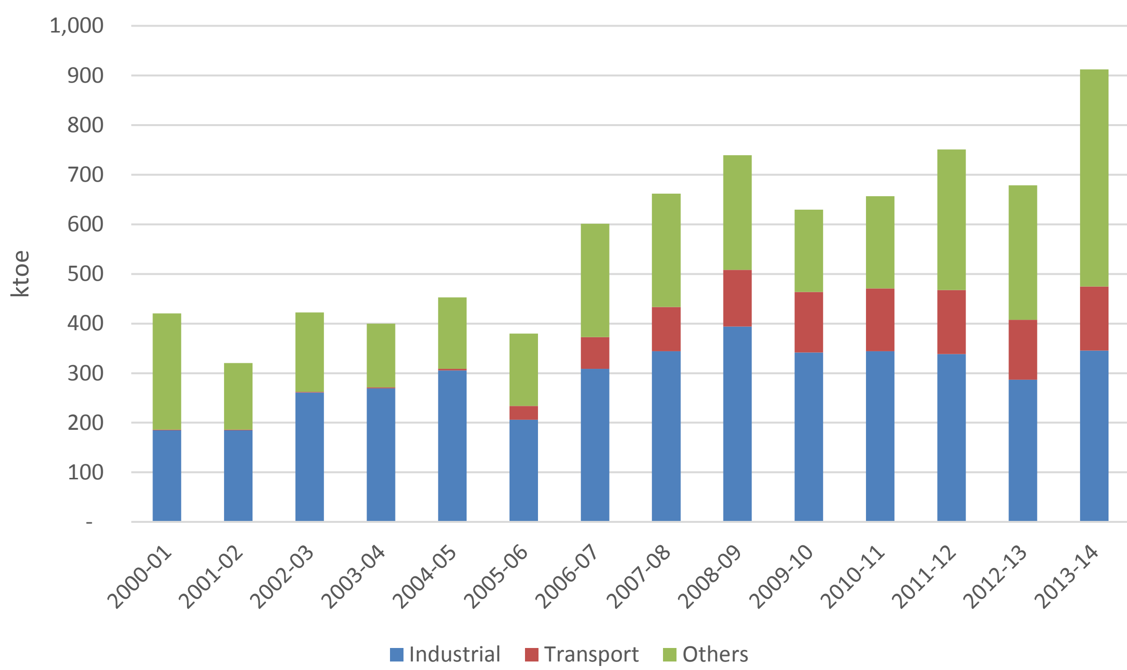
Gas for Fertlizer Plants, Refineries, LPG, and CNG Stations (2012/13 and 2013/14)							
No.	Factory Name	2012-13			2013-14		
		Onshore	Offshore	Total	Onshore	Offshore	Total
		MMcf	MMcf	MMcf	MMcf	MMcf	MMcf
1	Kyun Chaung Fertilizer Plan	0		0	1		1
2	Sale Fertilizer Plant	1,281		1,281	991		991
3	Myangdakar Fertilizer Plant	3,764		3,764	3,156		3,156
4	Kangyidaung Fertilizer Plan	2,861		2,861	1,978		1,978
5	Kyawzwa Fertilizer Plant			-			-
	Total	**7,906**		**7,906**	**6,126**		**6,126**
6	Thanlyin Refinery		1,256	1,256		826	826
7	Chauk Refinery	378		378	390		390
8	Thanbayagan Refinery	347		347	665		665
	Total	**724**	**1,256**	**1,980**	**1,054**	**826**	**1,881**
9	Minbu LPG Plant	426		426	317		317
10	Kyun Chung LPG Plant	102		102	13		13
11	Nyaundone LPG Plant	333		333	153		153
	Total	**861**	**-**	**861**	**483**	**-**	**483**
12	CNG Stations	6,425	300	6,725	6,046	1,208	7,254
	Total	15,916	1,556	17,472	13,710	2,034	15,744

Figure IV-18: Myanmar Natural Gas Consumption (MMcf)



Sources: MOGE, CSO

Figure IV-19: Myanmar Natural Gas Consumption (ktoe)



Sources: MOGE, CSO

AA. Natural Gas Energy Flow Diagram

72. Figure IV-20**Figure II-10** provides an overall energy flow diagram for Myanmar's natural gas sector as of 2012/13. It demonstrates how Myanmar exports a significant portion of the natural gas it produces.

BB. Natural Gas Commodity Balance Statistics

73. Table IV-21 and Table IV-22 set out the statistics for the natural gas commodity balances in units of MMcf and ktoe. Refer to section VII for information on the gross calorific value (higher heating value) conversion factor that has been applied to convert from MMcf to ktoe.

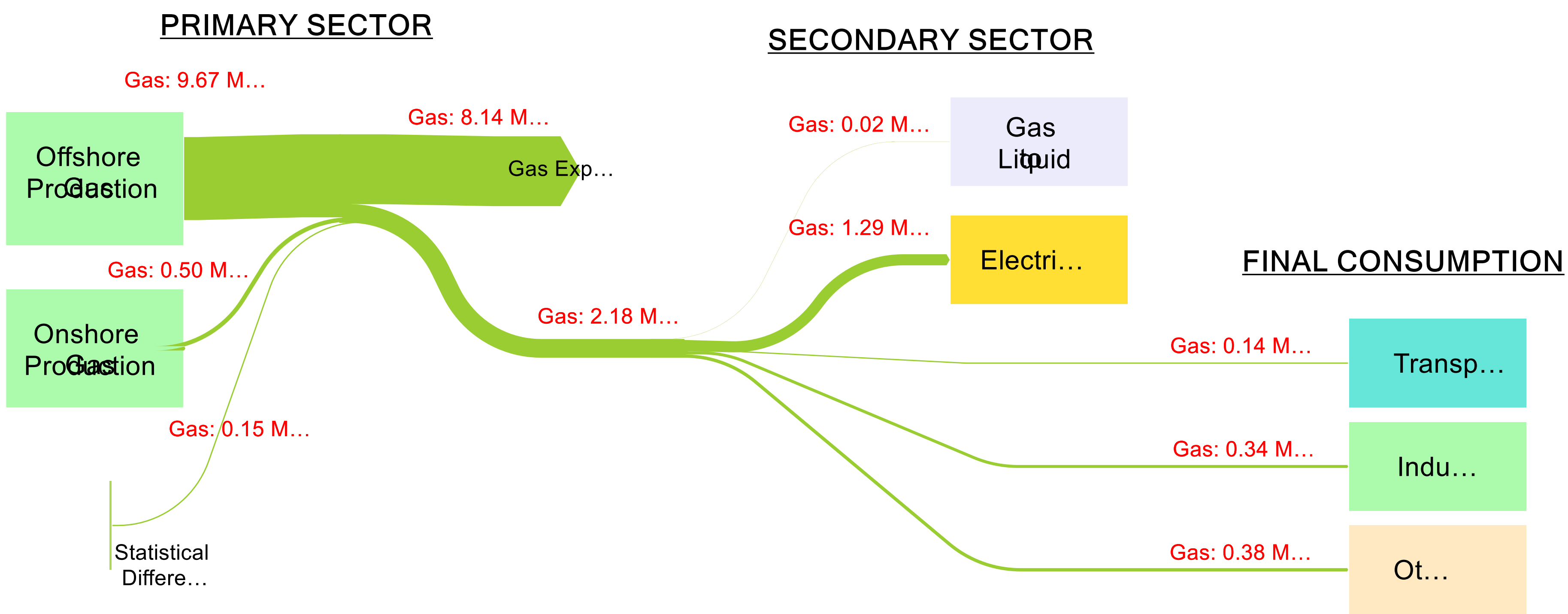
CC. Natural Gas Observations

74. Myanmar's natural gas production has been consistent from year to year over the last decade with an annual production level averaging around 450,000 MMcf (7,500 ktoe) per year. Around 75% to 80% of Myanmar's domestically produced natural gas is exported to Thailand and more recently PRC.

75. Domestically, Myanmar's electricity sector accounts for around 55% to 60% of natural gas consumption. Other major gas users are the government-owned factories (20%), fertiliser plants (7.9%), a compressed natural gas facility (7.2%), and LPG production (0.9%).

76. The statistical differences between the calculated and observed gas supply to Myanmar were observed to be reasonably significant in the commodity balances over the last 10 years with discrepancies averaging some 6%.

Figure IV-20: Myanmar Natural Gas: Energy Flow Diagram for 2012/13



Sources: Consultants' Analysis

Table IV-21: Myanmar Commodity Balance: Natural Gas 2000/01 to 2013/14 (MMcf)

Unit: '000 ton	00-01	01-02	02-03	03-04	04-05	05-06	06-07	07-08	08-09	09-10	10-11	11-12	12-13	13-14
Production	183,421	292,174	356,248	371,811	426,171	437,729	460,442	476,829	405,521	439,615	450,379	464,935	467,005	482,276
Imports	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Exports	128,530	242,787	295,598	304,600	353,408	368,913	389,827	399,562	327,802	373,873	365,709	364,985	362,156	372,663
Stock Changes (+ or -)	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Gross Inland deliveries (calculated)	54,891	49,387	60,650	67,212	72,763	68,816	70,615	77,267	77,719	65,742	84,671	99,950	104,848	109,614
Statistical Differences (+ or -)	2,108	4,136	5,290	7,513	4,776	7,794	1,330	-458	-1,618	7,740	6,102	5,282	7,825	-3,870
Gross Inland deliveries (observed)	52,783	45,251	55,361	59,699	67,987	61,022	69,285	77,725	79,337	58,002	78,569	94,668	97,024	113,483
Transform														
Total transform	**32,826**	**29,066**	**33,689**	**39,329**	**44,668**	**41,325**	**37,646**	**42,014**	**40,447**	**23,705**	**41,985**	**52,988**	**58,194**	**61,046**
Electricity	32,826	29,066	33,689	38,693	43,958	40,716	37,009	41,281	39,747	23,047	41,226	2,196	57,333	60,563
Other	-	-	-	636	710	609	637	733	700	658	759	793	861	483
Total Final Consumption	**19,957**	**16,185**	**21,672**	**20,370**	**23,320**	**19,697**	**31,639**	**35,711**	**38,890**	**34,297**	**36,584**	**41,680**	**37,857**	**51,118**
Industrial	8,768	9,323	13,400	13,754	15,742	10,694	16,262	18,570	20,734	18,599	19,160	18,799	16,010	19,364
Fertilizer Plant	3,942	3,296	4,588	6,462	4,335	4,837	5,139	5,617	5,332	2,796	2,818	6,816	7,906	6,126
Other Industry	4,826	6,027	8,812	7,292	11,407	5,857	11,123	12,953	15,402	15,803	16,342	11,983	8,104	13,238
Transport	74	73	9	74	150	1,440	3,357	4,813	6,006	6,664	7,040	7,165	6,725	7,254
Others	11,115	6,790	8,203	6,542	7,427	7,564	12,019	12,329	12,150	9,034	10,384	15,716	15,122	24,500

Sources: MOE, MOGE, Consultant's analysis

Table IV-22: Myanmar Commodity Balance: Natural Gas 2000/01 to 2013/14 (ktoe)

Unit: ktoe	00-01	01-02	02-03	03-04	04-05	05-06	06-07	07-08	08-09	09-10	10-11	11-12	12-13	13-14
Production	3,246	4,925	5,987	6,270	7,159	7,324	7,679	7,928	6,807	7,285	7,466	7,734	7,768	8,014
Imports	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Exports	2,090	3,947	4,806	4,952	5,746	5,998	6,338	6,496	5,330	6,079	5,946	5,934	5,888	6,059
Stock Changes (+ or -)	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Gross Inland deliveries (calculated)	1,156	977	1,181	1,318	1,413	1,326	1,341	1,432	1,478	1,207	1,520	1,800	1,879	1,955
Statistical Differences (+ or -)	44	82	103	147	93	150	25	-8	-31	142	110	95	140	-69
Gross Inland deliveries (observed)	1,112	896	1,078	1,171	1,320	1,176	1,316	1,441	1,508	1,065	1,411	1,705	1,739	2,024
Transform														
Total transform	**691**	**575**	**656**	**771**	**868**	**796**	**715**	**779**	**769**	**435**	**754**	**954**	**1,043**	**1,089**
Electricity	691	575	656	759	854	85	703	765	756	423	740	940	1,028	1,080
Other	-	-	-	12	14	12	12	14	13	12	14	14	15	9
Total Final Consumption	**420**	**320**	**422**	**399**	**453**	**380**	**601**	**662**	**739**	**630**	**657**	**751**	**679**	**912**
Industrial	185	185	261	270	306	206	309	344	394	341	344	339	287	345
Fertilizer Plant	83	65	89	127	84	93	98	104	101	51	51	123	142	109
Other Industry	102	119	172	143	222	113	211	240	293	290	293	216	145	236
Transport	2	1	1	1	3	28	64	89	114	122	126	129	121	129
Others	234	134	160	128	144	146	228	229	231	166	186	283	271	437

Sources: MOE, MOGE, Consultant's analysis

V. ELECTRICITY

DD. Summary

77. This chapter presents statistics on electricity from generation to end-use consumption in Myanmar.

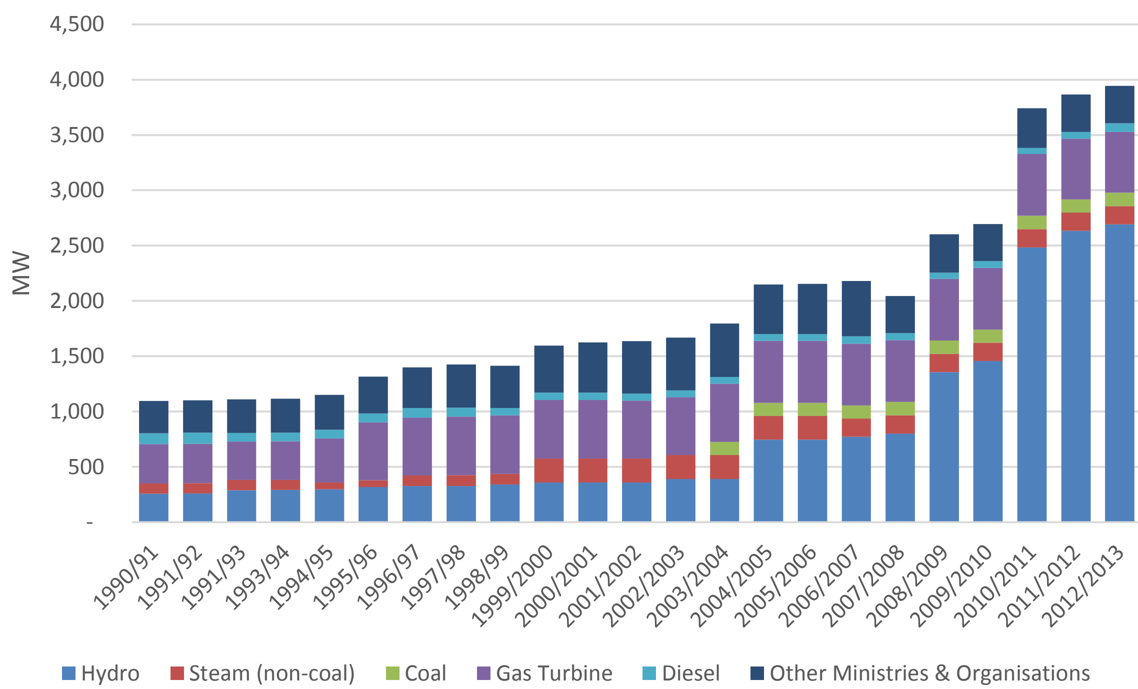
78. An energy flow chart to illustrate Myanmar's electricity sector is provided in Figure V-12 for the year 2012/13. This directly demonstrates the dominant roles of hydro and gas in electricity industry.

79. Commodity balances for electricity are provided in Table V-13 and Table V-14. This section also sets out a number of additional tables and charts for generation capacity, map of the transmission system and plots of primary energy input to the electricity sector.

EE. Electricity Capacity

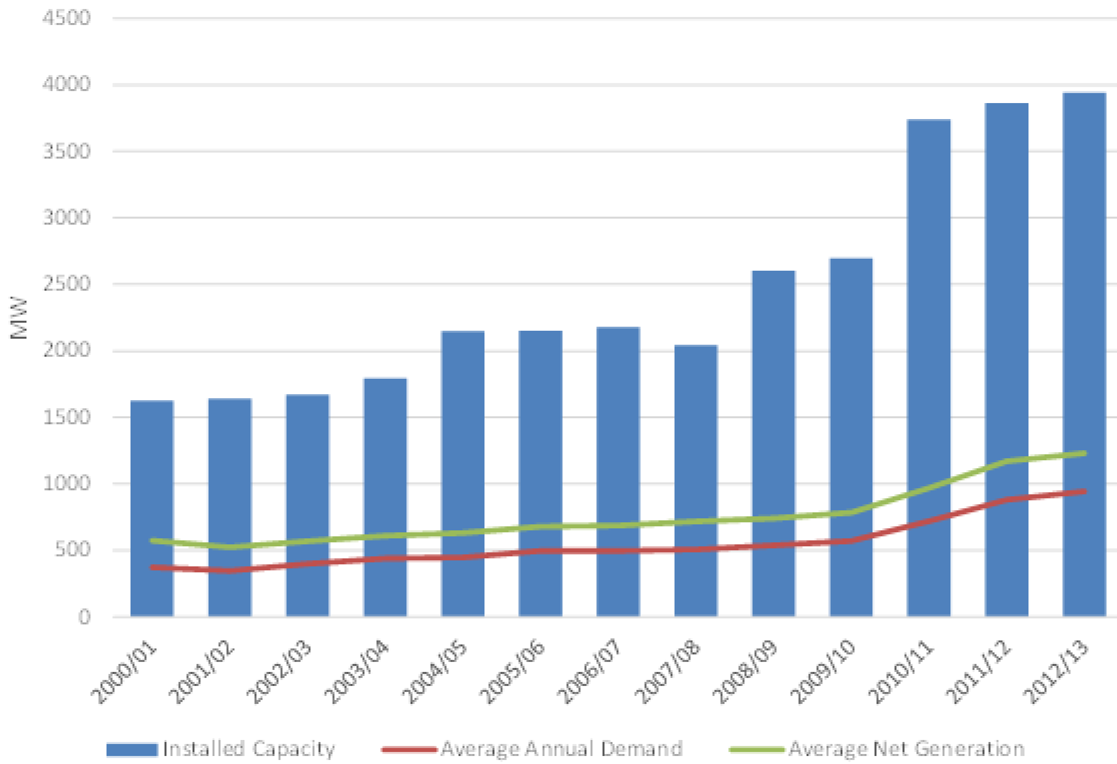
80. Figure V-1 plots generation installed capacity from 1990/91 through to 2012/13. This shows that Myanmar has seen almost a doubling in hydro generation from 2008 to 2011 with the commissioning of several large hydro projects: Shweli-1 (600 MW), Yeywa (790 MW) and Dapein-1 (240 MW). Figure V-2 sets out the profile of installed capacity, annual average gross generation and the annual average demand level.

Figure V-1: Myanmar Installed Generation Capacity (MW)



Sources: Ministry of Electric Power (MOEP)

Figure V-2: Gross Generation, Net Generation and Demand (MW)

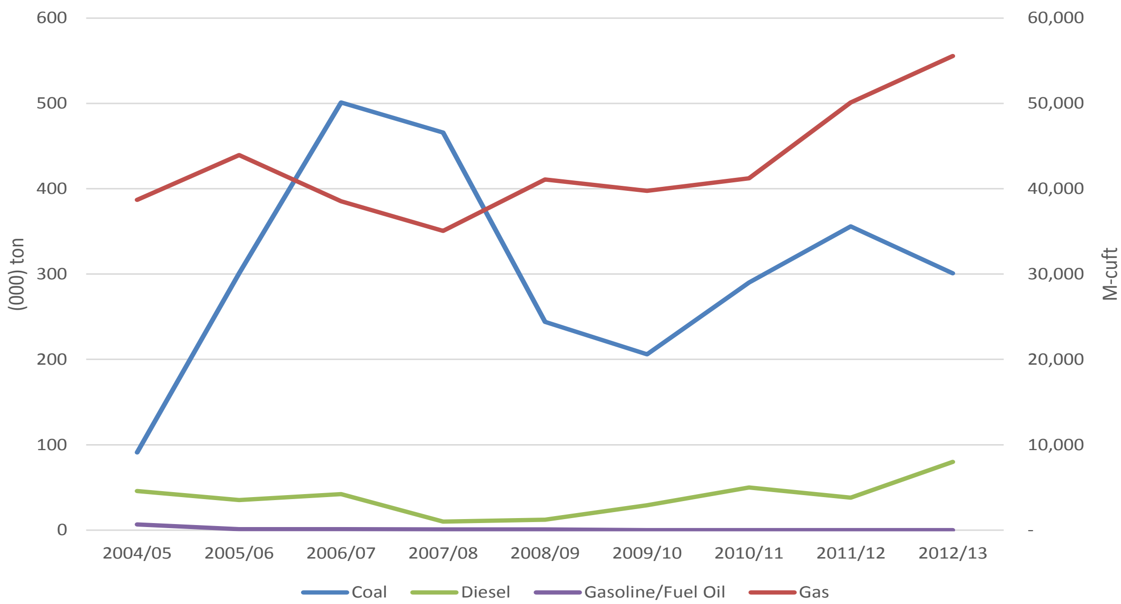


Source: MOEP

FF. Electricity Primary Energy Consumption

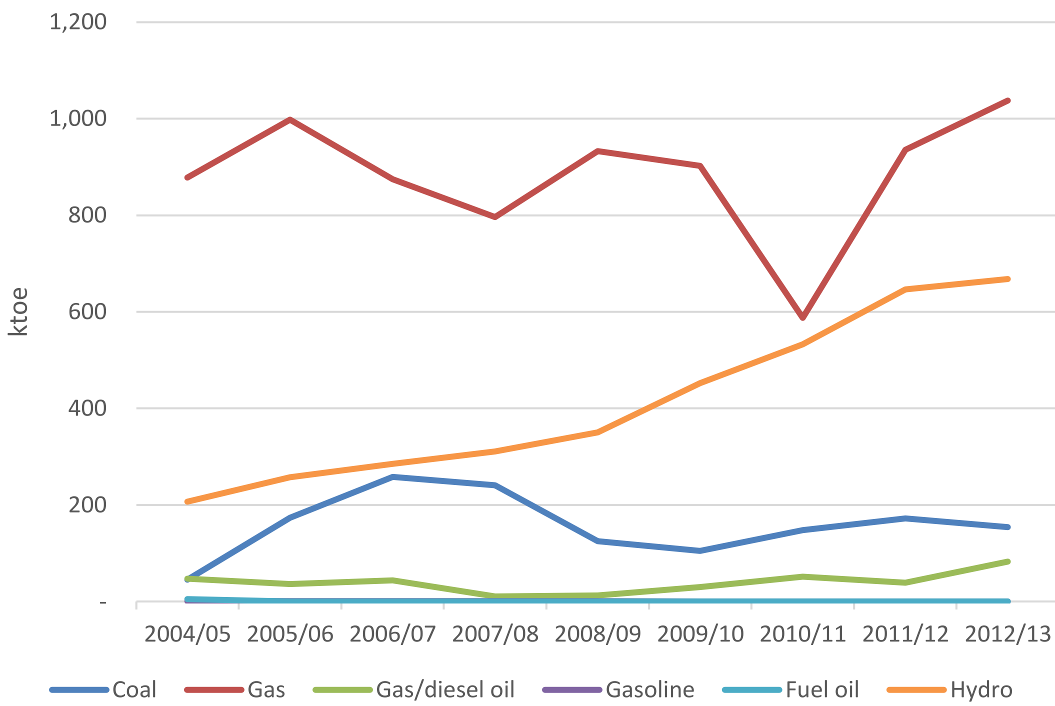
81. Figure V-3 and Figure V-4 illustrate historical uses of different primary fuels for electricity generation in physical and ktoe units respectively. These show natural gas is a major fuel for producing power in Myanmar and use of hydro resources has been rising, which is explained by the commissioning of more hydro power plants in the country.

Figure V-3: Primary Fuels Use for Generation (physical units)



Sources: MOEP, Consultant's estimates

Figure V-4: Primary Fuels Use for Generation (ktoe)



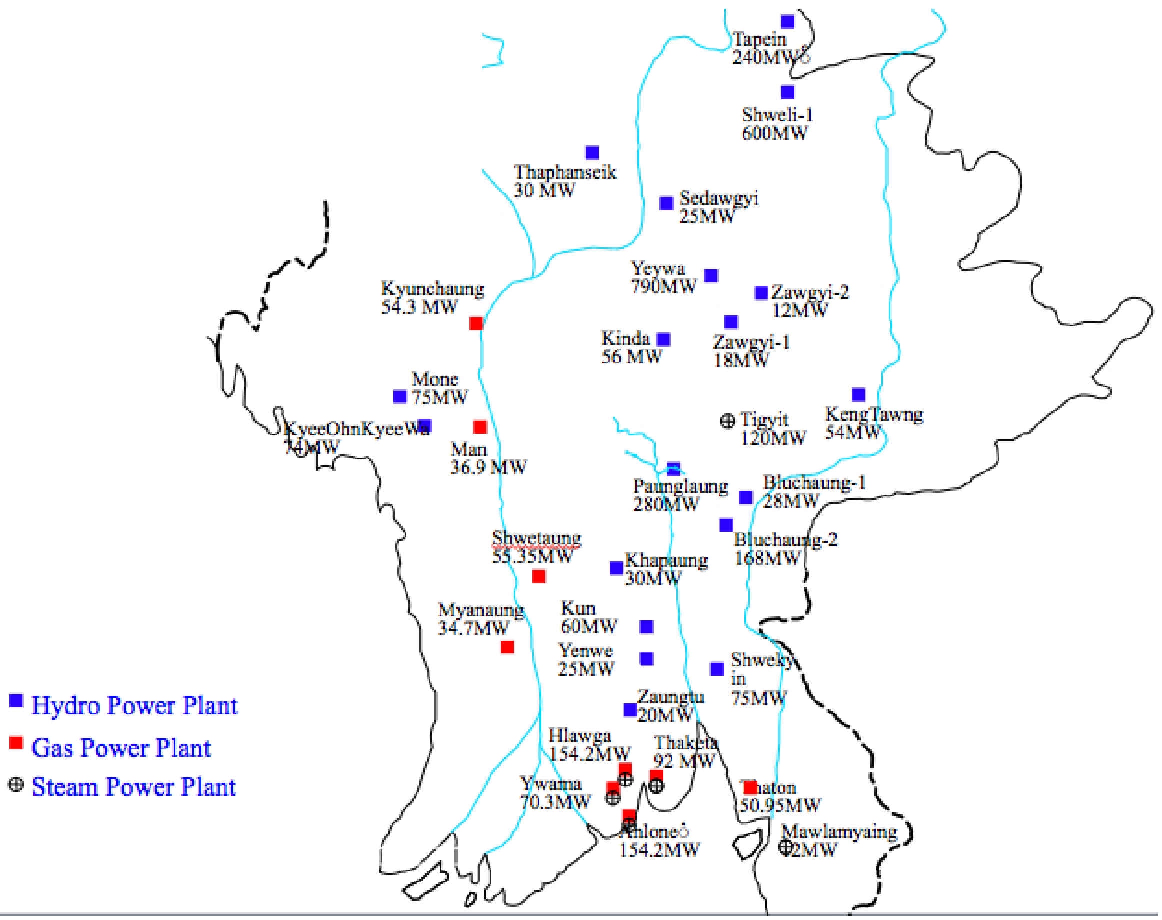
Sources: MOEP, Consultant's estimates

GG. Electricity Supply

82. Myanmar's main sources of generation are hydro, gas and coal powered plant. Figure V-5 shows a map of Myanmar with the locations of main generators in country.

83. Figure V-6 and Figure V-7 respectively plot generation by physical (GWh) units and on an equivalent energy basis (ktoe). Resembling the situation in primary resource supply, hydro and gas are the two main power generation technologies, contributing nearly 93% of the aggregated electricity production. Among these two technologies, hydro is by far the largest single mode, accounting for more than 70% of the generation mix. Remaining electricity is generated from coal, non-coal steam, diesel and some other sources.

Figure V-5: Myanmar Map of Generation Plant

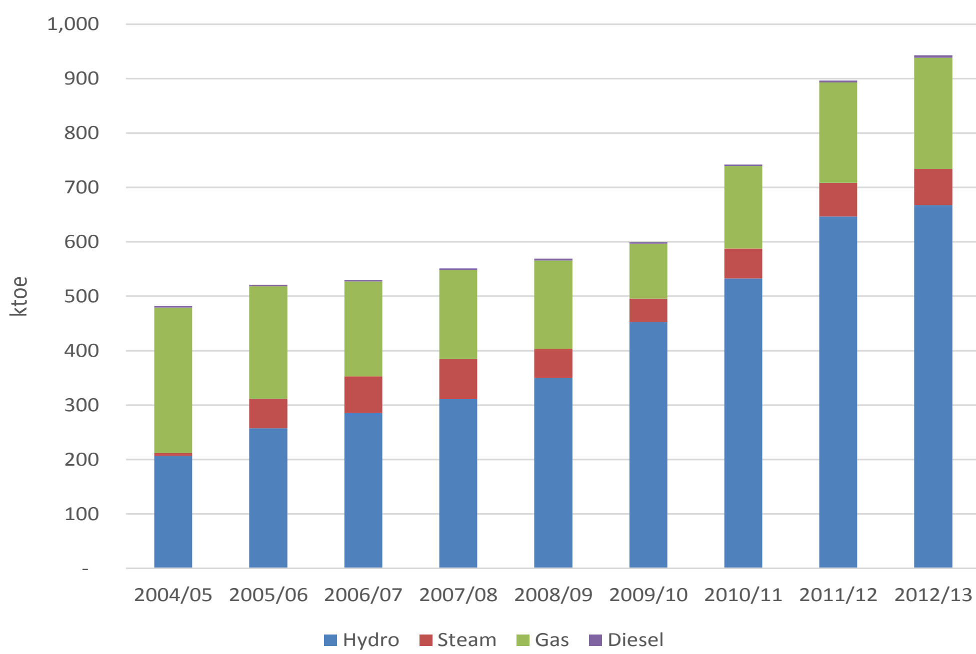


Source: MOEP

Figure V-6: Gross Generation by Type (GWh)

Sources: MOEP

Figure V-7: Gross Generation by Type (ktoe)



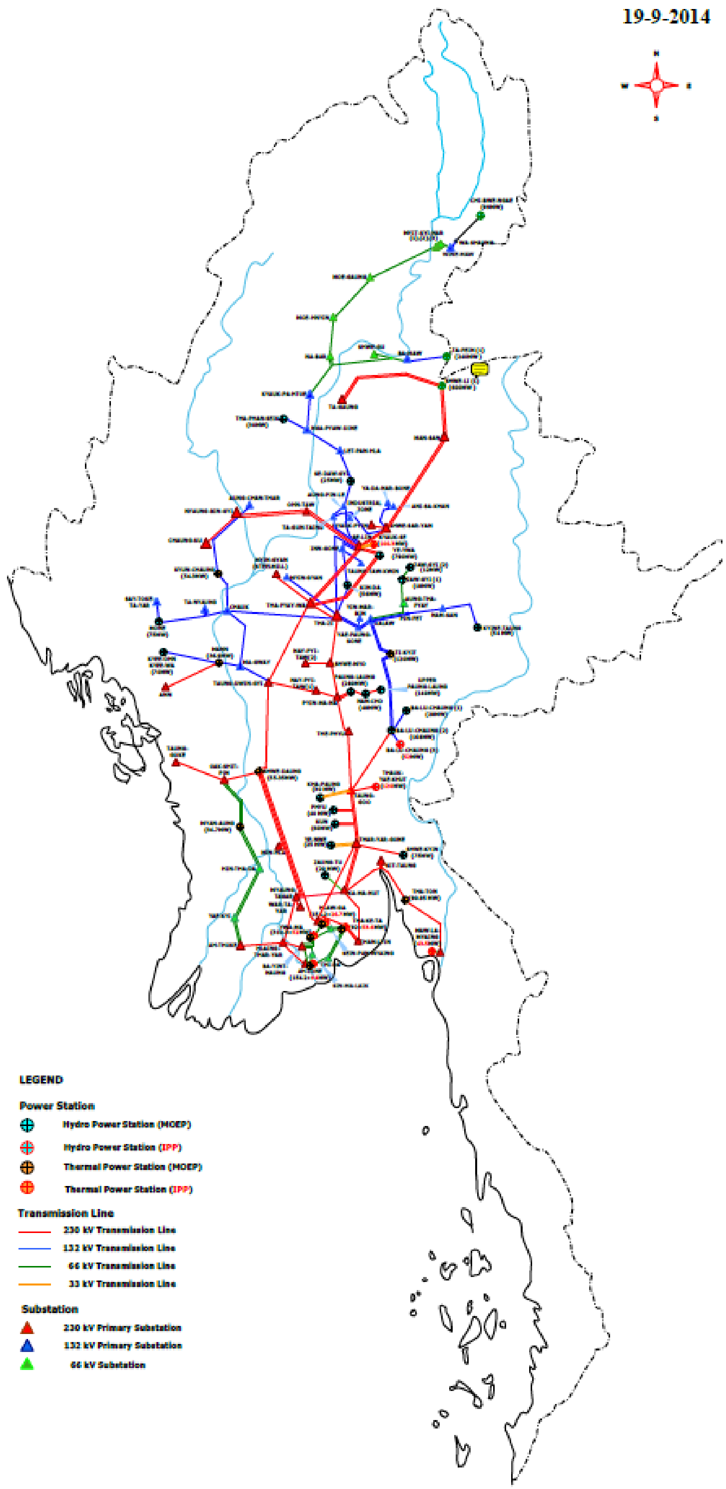
Sources: MOEP

HH. Electricity Transmission and Distribution System

84. Figure V-8 provides a diagram of Myanmar's national grid, including the 33kV, 66 kV, 132 kV and 220 kV transmission system which has evolved to be concentrated around the major load centres, and to convey electrical energy from the more remotely located generation sources in the north and south.

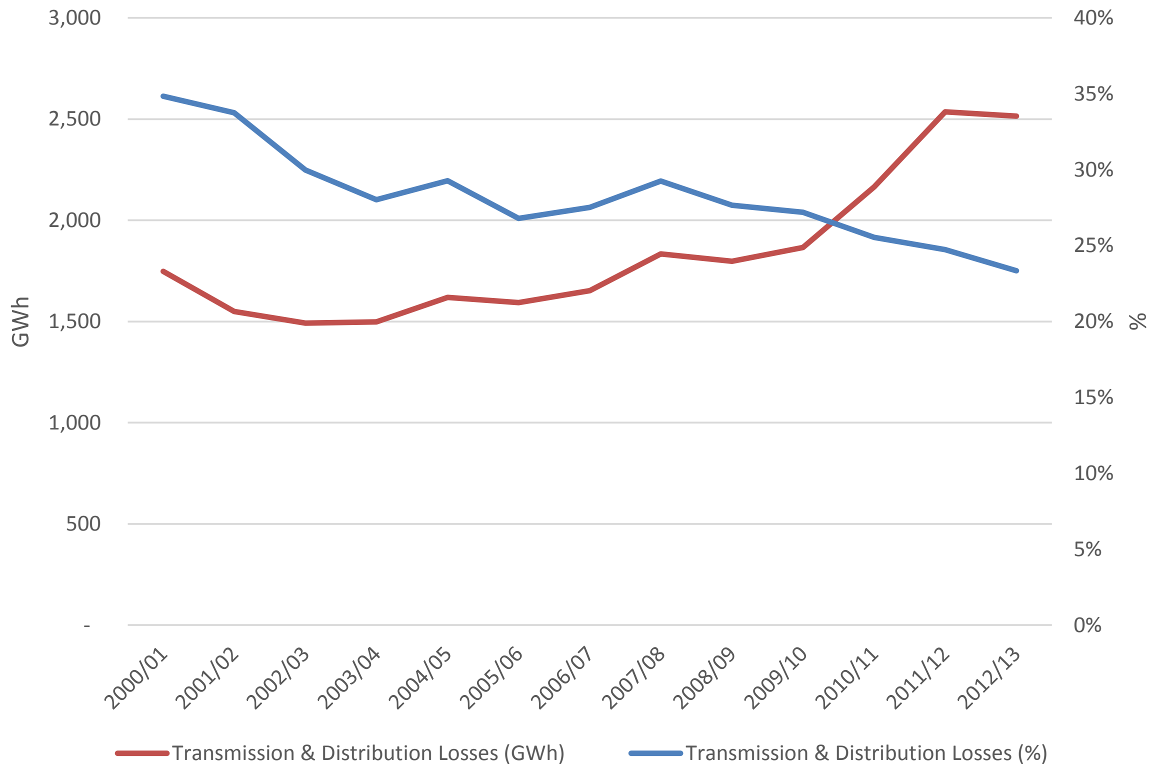
85. Figure V-9 shows transmission and distribution losses over time, which have generally decreased from nearly 35% in 2000 to 25% in 2013.

Figure V-8: Myanmar National Grid



Source: Global Energy Network Institute

Figure V-9: Transmission and Distribution Losses

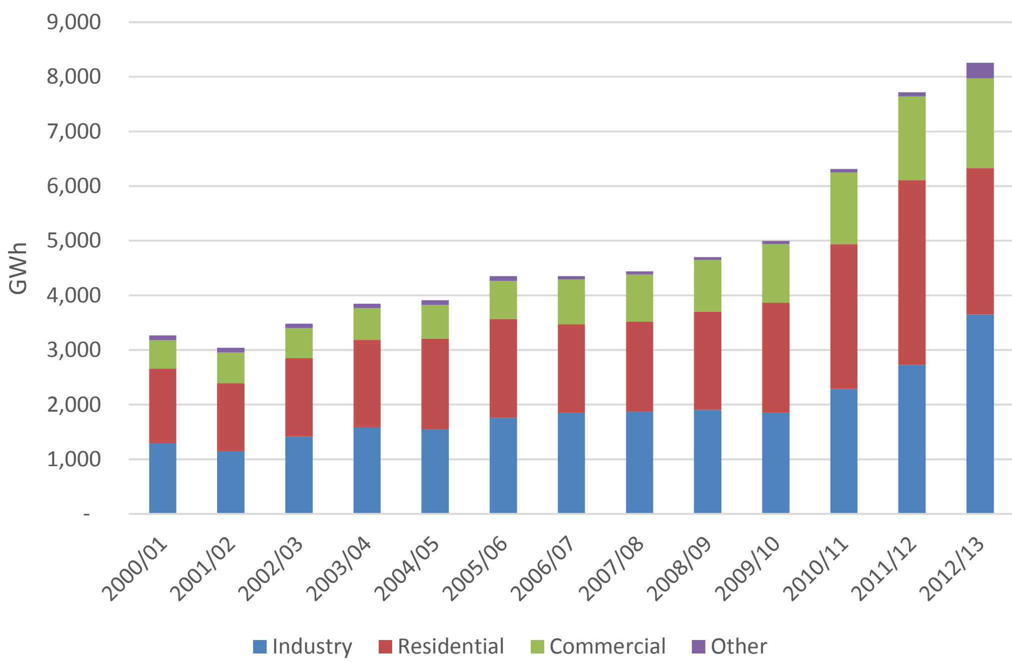


Sources: MOEP

II. Electricity Consumption

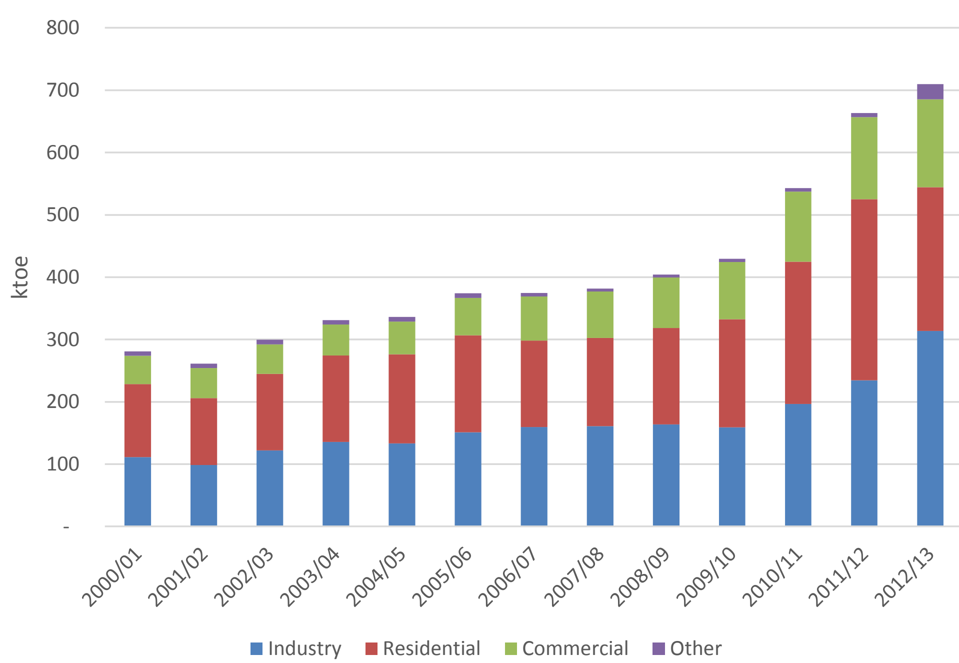
86. Figure V-10 and Figure V-11 show the final consumption by the end use categories in physicals and in energy equivalent terms. The main electricity end users are the industrial, residential and commercial/service sectors. Their shares in the 2012/13 total final consumption were 44%, 32% and 20% respectively.

Figure V-10: Myanmar Electricity Consumption (GWh)



Sources: MOEP

Figure V-11: Myanmar Electricity Consumption (ktoe)



Sources: MOEP

JJ. Electricity Energy Flow Diagram

87. Figure V-12 provides an overall energy flow diagram for Myanmar's electricity industry based on 2012/13 information.

KK. Electricity Commodity Balance Statistics

88. Table V-13 and Table V-14 provide detailed statistics on the electricity sector in the form of commodity balances.

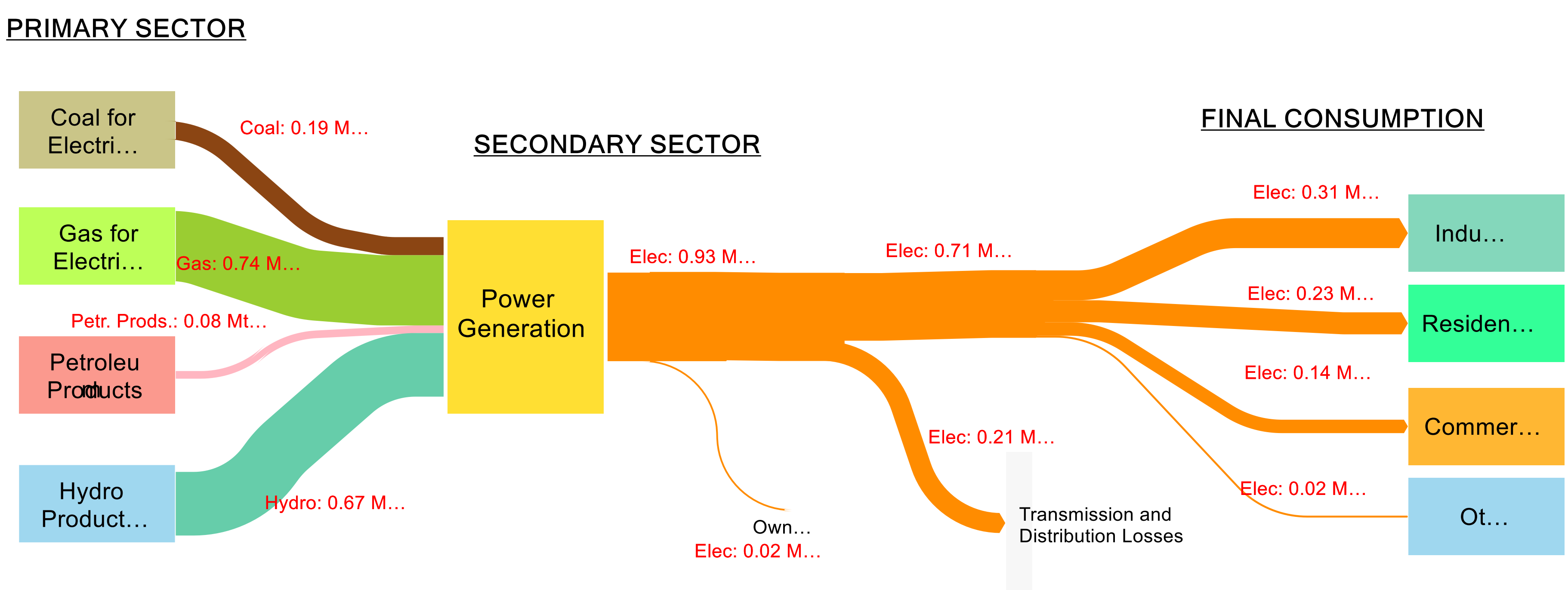
LL. Electricity Sector Observations

89. Electricity supply in Myanmar sector is dominated by hydro. The hydro total install capacity has doubled since 2008 to reach 2,693 MW in 2012/13, representing over two thirds of the total installed capacity. However, hydro generation availability is seasonal and therefore limited. The second largest mode of electricity production is gas turbines, accounting for 14% of system's total by capacity and 22% by generation.

90. Transmission and distribution losses are high in Myanmar but have generally decreased from 35% in 2000 to 25% in 2013, which equalled to 2,515 GWh against 10,965 GWh of gross production.

91. Electricity consumption has increased significantly in the last five years at an annual average growth rate of 13.6%. Industrial, residential and commercial sectors are the major end users of electricity in descending order. The industrial sector has been observed to have annual average growth rate of 15.1% over the last 5 years, followed by 13.8% in the commercial sector and 11.9% in the residential sector.

Figure V-12: Myanmar Electricity: Energy Flow Diagram for 2012/13



Sources: Consultants' Analysis

Table V-13: Myanmar Commodity Balance: Electricity 2000/01 to 2012/14 (GWh)

Unit: GWh	**00-01**	**01-02**	**02-03**	**03-04**	**04-05**	**05-06**	**06-07**	**07-08**	**08-09**	**09-10**	**10-11**	**11-12**	**12-13**	**13-14**
Gross Production	**5,118**	**4,689**	**5,068**	**5,426**	**5,608**	**6,061**	**6,163**	**6,409**	**6,622**	**6,971**	**8,633**	**10,424**	**10,965**	**12,278**
Hydro	1,892	2,008	2,111	2,075	2,408	2,997	3,320	3,618	4,071	5,263	6,196	7,518	7,766	8,854
Steam	662				60	632	786	855	614	505	640	724	771	569
Gas	2,528	2,650	2,928	3,320	3,107	2,398	2,025	1,901	1,897	1,173	1,763	2,144	2,377	2,794
Diesel	36	31	29	31	33	34	32	34	40	30	33	38	51	61
Own use by site	102	99	92	78	80	81	82	138	153	115	148	160	186	174
Net Production	5,016	4,590	4,976	5,348	5,528	5,980	6,081	6,270	6,468	6,856	8,485	10,264	10,779	12,104
Imports														
Exports														
Overall Power Supplied	5,016	4,590	4,976	5,348	5,528	5,980	6,081	6,270	6,468	6,856	8,485	10,264	10,779	12,104
(Before tx/dx losses etc.)														
Tx & Dx Losses	1,748	1,550	1,492	1,498	1,619	1,630	1,727	1,822	1,767	1,856	2,158	2,548	2,524	2,416
Total Consumption (calc.)	3,268	3,041	3,484	3,850	3,909	4,353	4,355	4,438	4,701	4,993	6,312	7,717	8,255	9,688
Statistical differences		1				-2	1	1					-48	-76
Total consumption (obs.)	3,268	3,042	3,484	3,850	3,909	4,351	4,356	4,439	4,701	4,993	6,312	7,717	8,207	9,613
Residential	1,295	1,148	1,417	1,577	1,549	1,756	1,854	1,872	1,904	1,850	2,287	2,727	2,628	2,699
Transport														
Industrial	1,361	1,245	1,431	1,612	1,662	1,811	1,614	1,647	1,799	2,015	2,653	3,381	3,655	3,764
Commercial and Public Services	527	564	552	578	613	695	827	864	945	1,071	1,306	1,532	1,643	1,692
Other	85	85	84	83	85	89	61	56	53	57	66	77	281	1,458

Source: MOEP, Consultant's analysis

Table V-14: Myanmar Commodity Balance: Electricity 2000/01 to 2012/14 (ktoe)

Unit: ktoe	00-01	01-02	02-03	03-04	04-05	05-06	06-07	07-08	08-09	09-10	10-11	11-12	12-13	13-14
Gross Production	**440**	**403**	**436**	**467**	**482**	**521**	**530**	**551**	**569**	**599**	**742**	**896**	**943**	**1,056**
Hydro	163	173	182	178	207	258	285	311	350	453	533	646	668	761
Steam	57				5	54	68	74	53	43	55	62	66	49
Gas	217	228	252	285	267	206	174	163	163	101	152	184	204	240
Diesel	3	3	2	3	3	3	3	3	3	3	3	3	4	5
Own use by site	9	8	8	7	7	7	7	12	13	10	13	14	16	15
Net Production	431	395	428	460	475	514	523	539	556	590	730	883	927	1,041
Imports														
Exports														
Overall Power Supplied	431	395	428	460	475	514	523	539	556	590	730	883	927	1,041
(Before tx/dx losses etc.)														
Tx & Dx Losses	150	133	128	129	139	140	149	157	152	160	186	219	217	208
Total Consumption (calc.)	281	261	300	331	336	374	374	382	404	429	543	664	710	833
Statistical differences													-4	-7
Total consumption (obs.)	281	262	300	331	336	374	375	382	404	429	543	664	706	827
Residential	111	99	122	136	133	151	159	161	164	159	197	234	226	232
Transport														
Industrial	117	107	123	139	143	156	139	142	155	173	228	291	314	324
Commercial and Public Services	45	48	47	50	53	60	71	74	81	92	112	132	141	146
Other	7	7	7	7	7	8	5	5	5	5	6	7	24	125

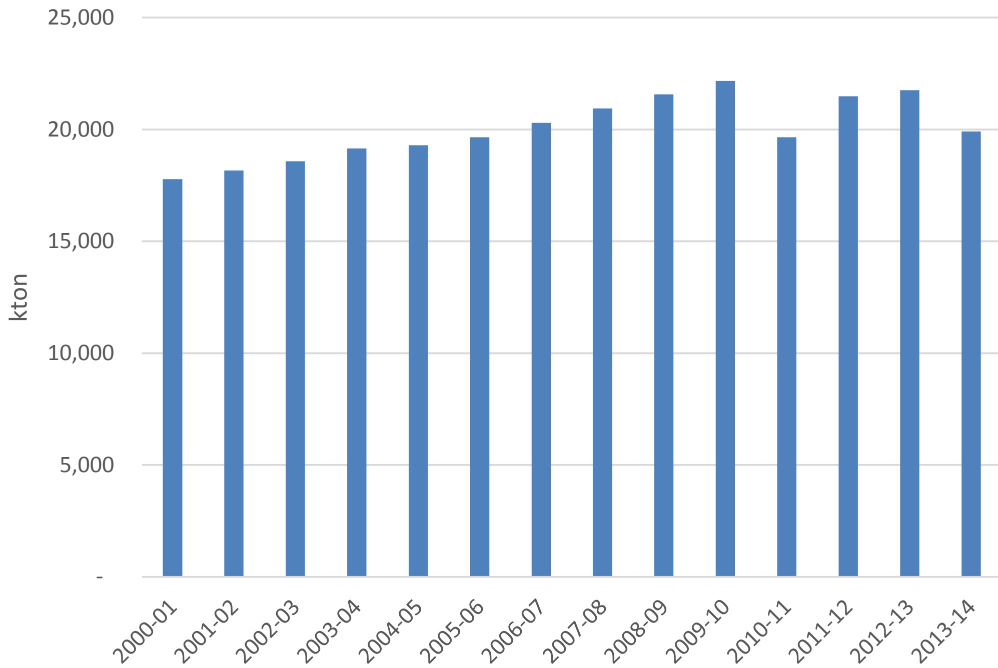
Source: MOEP, Consultant's analysis

VI. BIOMASS

92. Biomass has historically played a major role in satisfying end use energy consumption in Myanmar's residential sector. This chapter provides statistics on biomass. In particular, production statistics are given in Table VI-5 and Table VI-6.

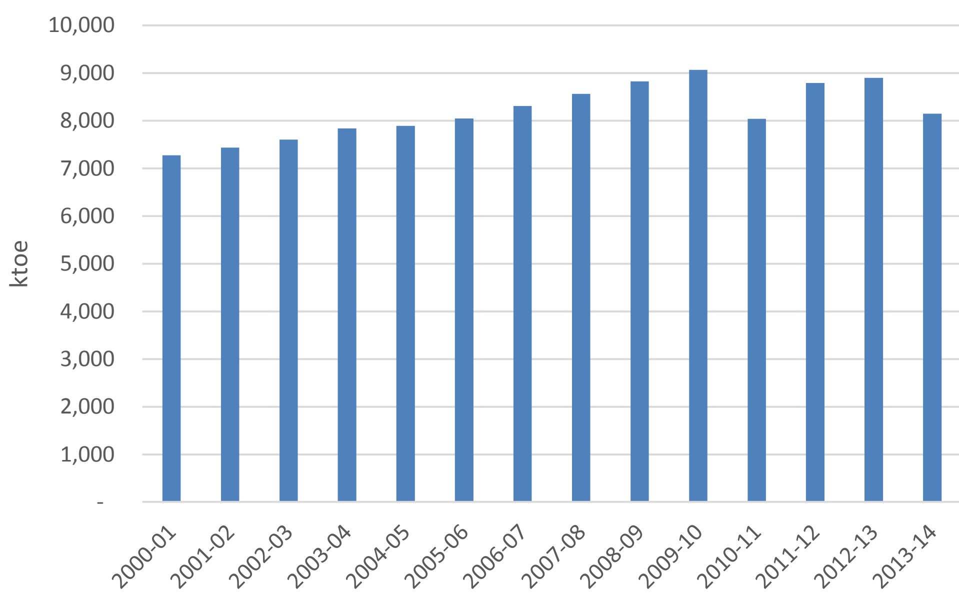
93. All end-use consumption of biomass is in the residential sector. In terms of equivalent caloric values the use of fuel wood dominates final energy consumption in Myanmar. For example in 2012/13, there was about 9,000 ktoe of fuel wood, compared to just 231 ktoe of electricity consumed by the residential sector.

Figure VI-1: Myanmar Fuel Wood Production (physical units)



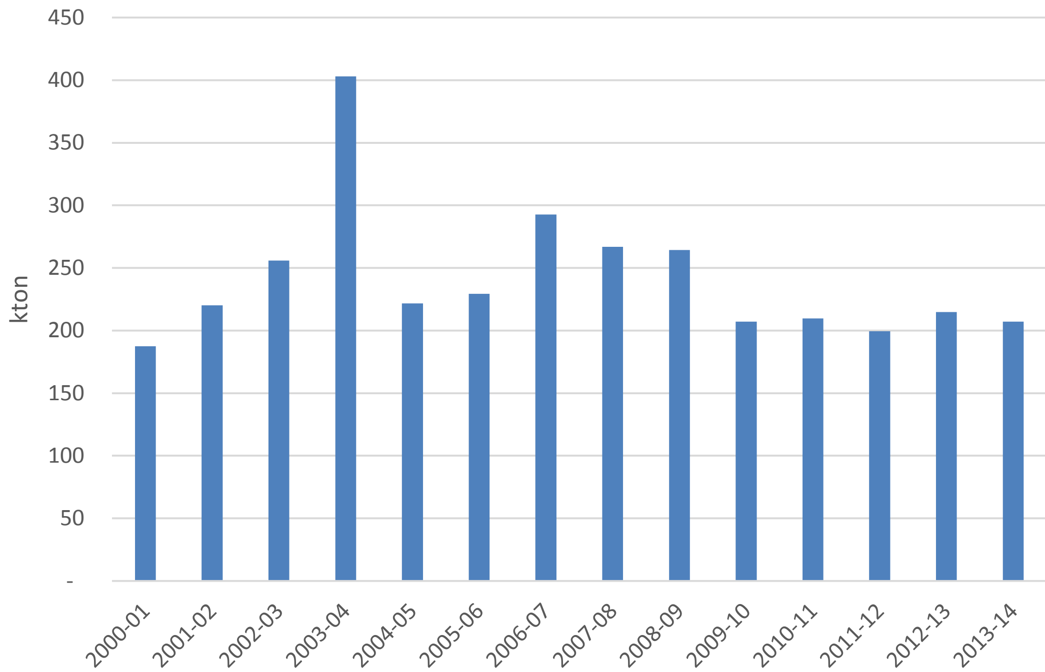
Source: MOECAF

Figure VI-2: Myanmar Fuel Wood Production (ktoe)



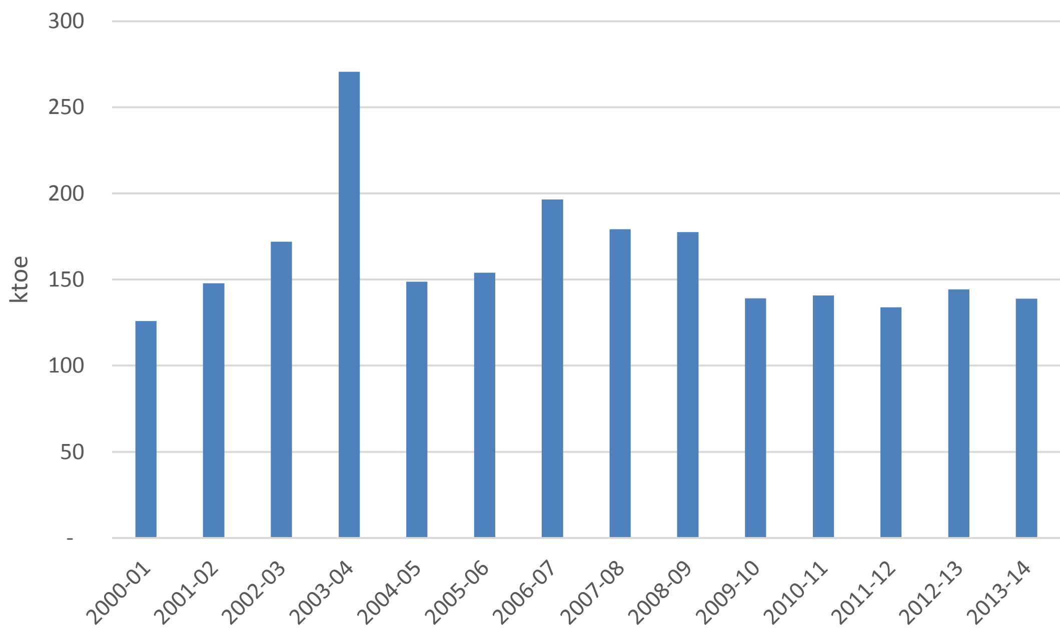
Source: MOECAF

Figure VI-3: Myanmar Charcoal Production (physical units)



Source: MOECAF

Figure VI-4: Myanmar Charcoal Production (ktoe)



Source: MOECAF

Table VI-5: Myanmar Commodity Balance: Biomass 2000/01 to 2012/13 (000' tons)

		00-01	01-02	02-03	03-04	04-05	05-06	06-07	07-08	08-09	09-10	10-11	11-12	12-13	13-14
Fuel Wood & Waste	kton	17,775	18,162	18,586	19,150	19,291	19,657	20,300	20,932	21,570	22,165	19,651	21,483	21,750	19,906
Bagasse	kton												417	604	775
Charcoal	Kton	187	220	256	403	222	229	293	267	264	207	210	199	215	207
Biogas	10^{10} kcal											0.50	0.52	0.55	0.52
Consumption:															
Residential															
Fuel wood & waste	kton	17,775	18,162	18,586	19,150	19,291	19,657	20,300	20,932	21,570	22,165	19,651	21,483	21,750	19,906
Bagasse	kton												417	604	775
Charcoal	Kton	187	220	256	403	222	229	293	267	264	207	210	199	215	207
Biogas	10^{10} kcal											0.50	0.52	0.55	0.52

Source: MOECAF

Table VI-6: Myanmar Commodity Balance: Biomass 2000/01 to 2012/13 (ktoe)

Unit: ktoe		**00-01**	**01-02**	**02-03**	**03-04**	**04-05**	**05-06**	**06-07**	**07-08**	**08-09**	**09-10**	**10-11**	**11-12**	**12-13**	**13-14**
Fuel Wood & Waste		7,272	7,431	7,604	7,835	7,892	8,042	8,305	8,564	8,825	9,068	8,040	8,789	8,899	8,144
Bagasse													183	265	340
Charcoal		72	85	98	155	85	88	113	103	102	80	81	77	83	80
Biogas												0.50	0.52	0.55	0.52
Total production		**7,344**	**7,515**	**7,703**	**7,990**	**7,978**	**8,130**	**8,418**	**8,667**	**8,927**	**9,148**	**8,121**	**9,049**	**9,247**	**8,564**
Consumption:															
Residential		7,344	7,515	7,703	7,990	7,978	8,130	8,418	8,667	8,927	9,148	8,121	9,049	9,247	8,564
Fuel wood & waste		7,272	7,431	7,604	7,835	7,892	8,042	8,305	8,564	8,825	9,068	8,040	8,789	8,899	8,144
Bagasse													183	265	340
Charcoal		72	85	98	155	85	88	113	103	102	80	81	77	83	80
Biogas												0.50	0.52	0.55	0.52

Source: MOECAF

VII. NOTES ON CONVERSION FACTORS

94. Energy Balances require conversions from physical units (metric tons, barrels, imperial gallons etc.) to a consistent energy basis, typically tonnes of equivalent oil (toe). In order to do this assumptions around the calorific value of different fuels are required. In this section, we lay out the assumptions that underpin the energy balance work presented in this chapter.

95. Table VII-1 lists the conversion factors that we have used to convert from the physical units to tonnes of oil equivalent for the purpose of overall energy balances.

Table VII-1: Summary of Conversion Factors

Commodity	Physical Unit	Conversion to ktoe factor
Domestic coal	'000 ton	0.628
Crude oil	'000 ton	1.000
LPG	'000 ton	1.075
Naptha	'000 ton	1.065
Motor gasoline	'000 ton	1.053
Aviation gasoline	'000 ton	1.056
Kerosene	'000 ton	1.034
Gasoline / diesel oil	'000 ton	0.960
Fuel oil	'000 ton	0.960
White spirit (SBP)	'000 ton	0.960
Lubricants	'000 ton	0.960
Bitumen	'000 ton	0.960
Paraffin wax	'000 ton	0.960
Petroleum coke	'000 ton	0.960
Natural Gas (offshore)	toe/scf	2.2834 x 10^-5
Natural Gas (onshore)	toe/scf	1.6258 x 10^-5
Electricity	GWh	0.0860
Bagasse	'000 ton	0.4386
Fuelwood	'000 ton	0.4091
Charcoal	'000 ton	0.7356

Project Number: TA No. 8356-MYA

FINAL REPORT

ENERGY RESOURCE INVENTORY

Prepared for

The Asian Development Bank

and

The Myanmar Ministry of Energy

Prepared by

Intelligent Energy Systems

in association with

MYANMAR INTERNATIONAL CONSULTANTS

ABBREVIATIONS

ADB	-	Asian Development Bank
AFOC	-	Asian Forum of Coal
ASEAN	-	Association of Southeast Asian Nations
CAPEX	-	Capital Expenditure
CCS	-	Carbon Capture and Storage
CFBC	-	Circulating Fluidized Bed Combustion
CNG	-	Compressed Natural Gas
CSO	-	Central Statistics Organisation
CSP	-	Concentrating Solar Plant
DRD	-	Department of Rural Development
EIA	-	Environmental Impact Analysis
EMP	-	Energy Master Plan
EPC	-	Engineering Procurement Construction
ESE	-	Electricity Supply Enterprise
FOB	-	Free On Board
FSRU	-	Floating Storage Regasification Unit
GCV	-	Gross Calorific Value
GDP	-	Gross Domestic Product
GoM	-	Government of the Republic of the Union of Myanmar
HHV	-	Higher Heating Value
IDC	-	Interest During Construction
IGCC	-	Integrated Gasification Combined Cycle
IOR	-	Improved Petroleum Recovery
JCOAL	-	Japan Coal Energy Centre
JICA	-	Japan International Cooperation Agency
LCOE	-	Levelized Cost of Energy (or Electricity)
LNG	-	Liquefied Natural Gas
MEPE	-	Myanmar Electric Power Enterprise
MES	-	Myanmar Engineering Society
META	-	Model for Electricity Technology Assessment
MOAI	-	Ministry of Agriculture and Irrigation
MOE	-	Ministry of Energy
MOECF	-	Ministry of Environmental Conservation and Forestry
MOEP	-	Ministry of Electric Power
MOGE	-	Myanmar Oil and Gas Enterprise
MOI	-	Ministry of Industry

MOLFRD	-	Ministry of Livestock, Fisheries and Rural Development
MOST	-	Ministry of Science and Technology
NCEA	-	National Commission for Environmental Affairs
NCV	-	Net Calorific Value
NEMC	-	National Energy Management Committee
NG	-	Natural Gas
O&M	-	Operation and Maintenance
OPEX	-	Operational Expenditure
PC	-	Pulverized Coal Combustion
PCC	-	Performance Compensation Contract
PP	-	Power Plant
PSC	-	Production Sharing Contract
PV	-	Photovoltaic
RSF	-	Reactivation of Suspended Fields
SC	-	Supercritical
TA	-	Technical Assistance
USC	-	Ultra Supercritical

UNITS OF MEASURE

IG	-	Imperial Gallon
km	-	Kilometre
l	-	Litre
gal	-	Gallon
cfd	-	Cubic Feet per Day
MW	-	Megawatt
Btu	-	British Thermal Unit
Passenger-km	-	Passenger-Kilometre
Ton-km	-	Metric Ton-Kilometre
TOE, toe	-	Tonne of Oil Equivalent
BCF, bcf	-	Billion Cubic Feet

WEIGHTS AND MEASURES

1 ha	=	2.47105 acre
1 km^2	=	100 ha

CONVERSION FACTORS

1 litre	=	0.22 Imperial Gallon
1 km	=	0.62137 mile
1 TOE	=	11.63 MWh

CONTENTS

ANNEXES

FOREWORD

1. Under the Technical Assistance (TA) package 8356 for Institutional Strengthening of the National Energy Management Committee (NEMC) in Energy Policy and Planning, a team of international consultants and national consultants (the Consultant) have been engaged by the Asian Development Bank (ADB) and Ministry of Energy (MOE) to prepare a 20-year Energy Master Plan (EMP) for Myanmar, including energy demand forecasts, an assessment of energy supply options, determination of investment requirements, and recommending supporting legal and institutional arrangements to support the EMP.

2. A number of discussion papers were issued as the Interim Report of the TA, which focused on taking a stock of Myanmar's energy demand and how it is currently satisfied. Models were created to calibrate the demand development with the past and present drivers of the energy use in various sectors. Reports were issued for rural households and their lighting and cooking needs, and the transport sectors. Simultaneously, the Consultant has developed assumptions on long-term socioeconomic and demographic development in Myanmar and consequent top-down forecasts consistent with the bottom-up demand analysis. Scenarios for future energy demand are linked to forecast production of goods and services (GDP), demographics and regional development, lifestyle changes and increasing incomes and mobility.

3. The next stage in the planning exercise is to examine the current energy supply system in Myanmar. This report describes the primary energy basis on which the future energy supply can be built in Myanmar. It summarizes the information available on the available primary energy resources in the country and identifies constraints with respect of their utilization. Constraints may include issues such as how much of the available resources have already been allocated for other purposes, for example to which extent natural gas or hydropower capacity is available for domestic needs after existing commitments to supply energy for exports are fulfilled; what is the social and environmental cost, and public acceptance of harnessing hydropower resources; or whether or not domestic coal is suitable for large scale thermal power generation given its quality and location of mines.

4. Part II of this report covers natural gas resources; Part III focuses on coal related issues; Part IV is about renewable energy resources such as solar, wind, biomass / biogas and biofuel; and Part V discusses hydropower potential.

I. OIL

A. Myanmar's Oil Resources

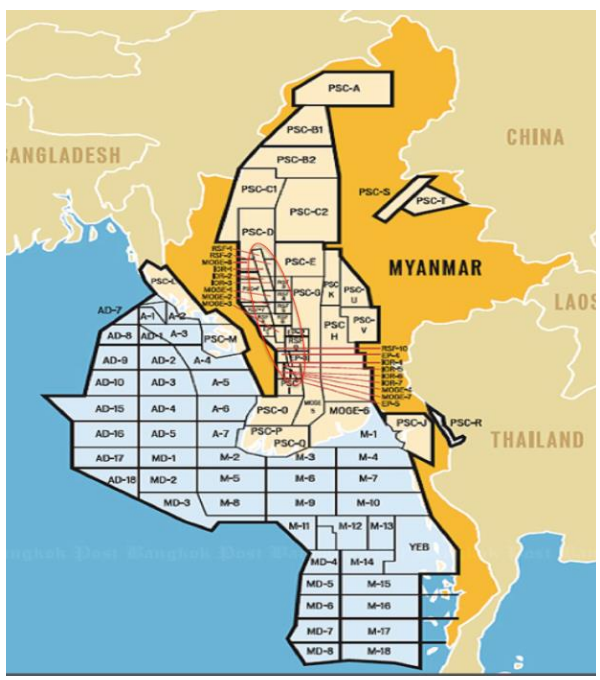
5. Globally, the Union of Myanmar does not have significant oil oil resources and production is relatively small. According to Myanmar's Ministry of Energy (MoE), the country's proven oil reserves (Offshore and Onshore) are 459 million barrels (mmbbl). In the past few years Myanmar has produced approximately 20,000 barrels of oil per day (BOPD); clearly Myanmar's proven oil reserves provide the possibility for a significant increase in oil production.

6. The domestic demand for refined petroleum based transportation fuels has evidenced strong growth due to growing passenger and freight services. In the last few years Myanmar's oil production has accounted for only 45% of the oil products consumed in Myanmar, with the balance of consumption provided by imports.

7. Myanmar has 10 operating onshore oil fields that are all located in the middle of the country close to the rivers of Ayeyarwady and Chindwin. The approximate total crude oil production is 8000 bbl/day of which the Mann oil field located in the central basin 550 kilometres north of Yangon produces around 1700 bbl/day. Figure I-1 below presents on overview of Myanmar's oil and gas production zones.

8. The Yetagun field is the only offshore condensate producing gas field in Myanmar. Yetagun's condensate production accounts for approximately 90% of all condensate produced in Myanmar. The total condensate production in Myanmar is around 12,000 bbl/day. There has been active development in the natural gas sector, which can be expected to be seen as an increase in the condensate production in the coming years.

Figure I-1: Myanmar's Onshore Oil & Gas Production Zones



B. Oil Refining Capacity

9. The Myanmar Petroleum Enterprise (MPE) operates three refineries with a total oil processing capacity of 51,000 bbl/d. The refineries use a blend of domestic crude oil from onshore fields and condensates from the Yetagun offshore gas field.

10. Of the existing three refineries in Myanmar, Thanbayakan is the largest with a capacity of 25,000 bbl/d followed by Thanlyin refinery at 20,000 bbl/d. With a capacity of 6000 bbl/d, Chauk refinery is the smallest refinery in Myanmar. Thanbyakan refinery processes mostly local crude oil but it is also capable of processing condensate from the Yetagun offshore gas field. In addition to a topping unit Thanbyakan has a small reforming unit for the production of high octane gasoline, a hydro-treater and naphtha hydro-desulphuriser for sulphur content reduction, and a delayed coker for deeper oil processing. Thanlyin refinery processes mostly condensate from the Yetagun offshore gas field and produces mostly naptha. Thanlyin refinery lacks the capability to refine oil into transport sector fuels. Chauk refinery is located inland and it processes crude oil coming down from a pipeline from Yenangyaung. Chauk refinery produces mainly waxes and other non-energy oil products.

11. All of the refineries are relatively old and their operating efficiency is low. The refining capabilities of Thanlyin and Chauk in particular, fall well short of modern standards. All refineries are operating at a refining capacity that is less than 45% of design capacity. The total quantity of refined oil is estimated to be approximately 22,000 bbl/d. Design capacities as well as estimated factual outputs of the three refineries are presented in Table I-1.

Table I-1: Design Capacity, Actual Output and Main Products

Refinery	Design Capacity (bbl/d)	Actual Output (bbl/d)	Main Products
Thanbayakan	25 000	8 600	Naphtha, Gasoline, Diesel, Petroleum coke
Thanlyin	20 000	11 400	Naphtha, LPG
Chauk	6 000	2 000	Naphtha, Wax

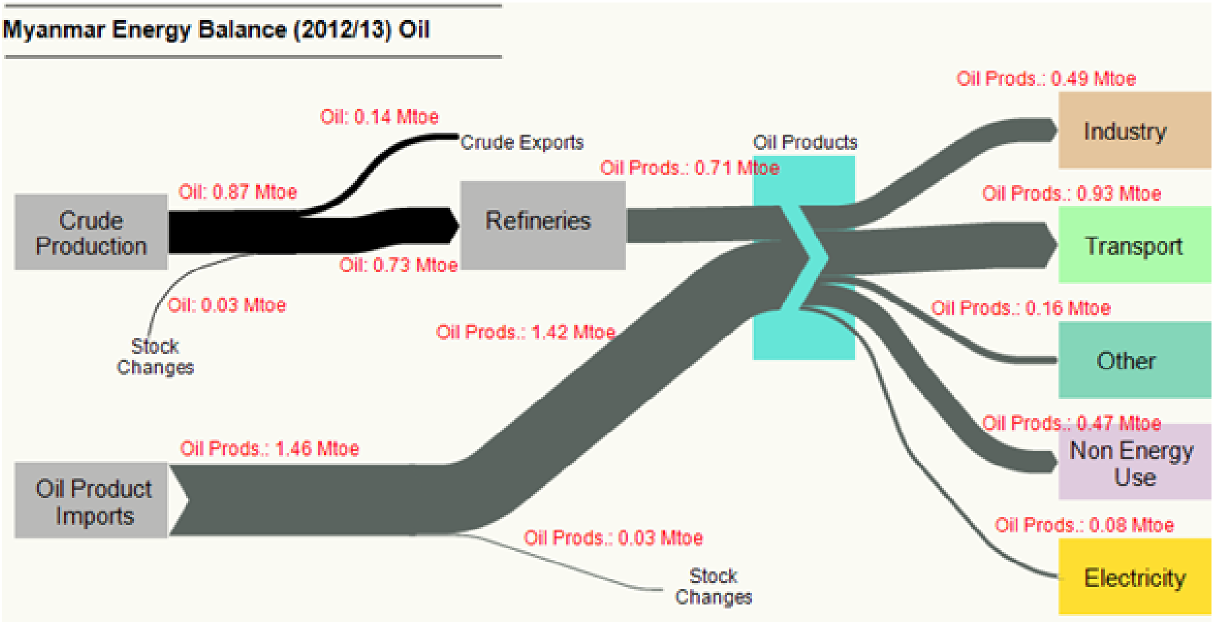
Source: MPE

C. Oil Consumption

12. Myanmar's oil consumption in 2012 – 2013 was approximately 42,000 bbl / day or 2.13 million tons of oil equivalent (mtoe) per year. Oil consumption per capita in Myanmar is almost 20 times lower compared to neighbouring Thailand. If Myanmar's economy continues to grow at the expected annual rate of 7 – 8%[1], oil consumption could reach 1.5 to 2 times the current level within the next ten years. Considering the current production capacity, increasing oil consumption could only be covered by importing more refined petroleum products. Figure I-2 illustrates Myanmar's energy balance with regards to petroleum based fuels clearly depicting the production deficit in the country as the difference between oil product imports and refined oil products.

[1] http://www.adb.org/countries/myanmar/economy

Figure I-2: Myanmar Energy Balance (2012/2013) Oil



(Note: have detailed breakdowns by products and use in industry, but drawn in aggregate)

Source: Consultant

13. **Oil Product Consumption.** The transport sector is the largest single oil consuming sector in Myanmar accounting for 43% of total oil consumption. Other significant oil consumers are industry (23%) and non-energy use (22%). Diesel is currently the most used transportation fuel as presented in Table II-2. Gasoline is the second significant transport fuel expected to become the most used transportation fuel towards the end of 2010s. Natural gas is used in small quantities mostly for public transport. Due to the growing number of private vehicle the demand for gasoline and diesel is expected to grow by 150% within the next two decades.

D. Upstream and Downstream Development Possibilities

14. **Crude Oil and Condensate Production Perspectives.** It is noted that reports of proven natural gas and oil reserves show some discrepancies. According to MoE, Myanmar holds proven natural gas reserves of 470 billion cubic meters. On energy basis the proven oil reserves of 459 MMbbl are almost six times smaller than the natural gas reserves. Table I-2 provides MoE's breakdown of the proven and probable oil reserves of Myanmar.

Table I-2: Myanmar's Oil Production and Proven Reserves

Crude Resources (mmbbl)	Onshore	Offshore	Total
Proven	104	355	459
Probable	355	45	400
Production (bbl/day)	**Onshore**	**Offshore**	**Total**
Crude Oil	8 000	0	8 000
Condensate	1 200	10 800	12 000

Source: MOE

15. According to the U.S. Energy Information Administration (EIA) Myanmar's proven oil reserves are only 50 MMBL and natural gas reserves 286 billion cubic meters. On the basis of the EIA's data the natural gas reserves would be energy wise approximately 32 times larger than the oil reserves. Regardless of the level of proven oil reserves, it is clear that Myanmar holds significant natural gas reserves; these reserves must be taken into consideration when developing a hydrocarbon strategy for Myanmar. The natural gas component in the fuel balance becomes even more important for Myanmar if the EIA's data is correct. If this is the case and oil production continues at the current level (20 000 bbl/day) Myanmar will run out of oil within seven years. On the other hand, if the MoE estimates are correct, there is potential for a significant increase in oil production.

16. To determine the degree to which the production of oil based products in Myanmar can be based on local feedstock, it is recommended that a process is started to take stock of the oil reserves of the country once more, to ensure that future decisions are based on reliable information.

17. Aside from the local oil reserves, another source of crude oil that is available to Myanmar is Arabian oil transported by the Sino-Burma pipeline, which is under construction and 75% completed at the time of this report (September 2014); Myanmar has negotiated a contractual right to take 50 000 bbl/day. The location of the pipeline is presented in Figure I-3.

Figure I-3: Location of the Sino-Burma pipeline

E. Development Possibilities in the Oil Refining Sector

18. **Current Condition.** The maximum design capacity of MEP's existing three refineries is still insufficient to satisfy the increasing demand for transportation fuels. Thanlyin refinery does not have delayed coking, catalytic cracking or hydrocracking units for large scale diesel and gasoline production. Thanbayakan refinery has more advanced refining technology but its production capacity is nevertheless considerably less than the transportation fuel demand. Chauk refinery is very small and has only nominal capabilities to produce transportation fuels.

19. In a scenario in which Myanmar's oil refining industry would be modernized, the current equipment of Thanlyin and Chauk refineries would be very unlikely to add significant value. In theory, the Thanbayakan refinery could be modernized by taking advantage of the existing equipment, but this would likely require extensive inspections and costly engineering work. Even if the modernization of Thanbayakan refinery turned out to be feasible a significant part of the demand for transportation fuels would still need to be covered by additional means – either by importing the amount corresponding to the production deficit or by a new refinery.

II. NATURAL GAS

A. Introduction

20. The Republic of the Union of Myanmar possesses large resources of natural gas (NG). It plays a significant role in the country's energy mix: in recent years natural gas accounted for 45% of the total primary energy production and was mainly used for electricity production and industrial purposes. The largest part of the gas produced in Myanmar is currently intended for exports. In 2013, export of gas valued 3.6 billion USD accounting 40% of Myanmar exports.2 The economic growth outlook for Myanmar is strongly linked to the expected increase of gas exports. There are contracts for future gas exports to People's Republic of China (PRC) already in place, as well as development of gas fired power plants. In the short run gas shortages are expected and thus the key issue for energy system expansion planning is the availability of domestic gas supply for power generation, industries and other uses.

B. Natural Gas Reserves

21. There are 17 geological sedimentary basins identified in Myanmar, of which six have been thoroughly explored: Rakhine, Moattama, and Tanintharyi offshore basins, and Central Myanmar, Pyay Embayment, and Ayeyarwaddy Delta onshore basins. The other basins have been examined to some extent or not examined at all (Figure II-2 below).

22. Myanmar possesses both onshore and offshore gas resources. There are various estimates of the gas resources of Myanmar, however all sources follow the same pattern of larger offshore resources as compared to the onshore resources. The estimates provided in the ADB report and in the Draft Electricity Masterplan[3] (JICA) report are presented in Table II-1. These sources refer to Ministry of Energy estimates for different years, thus further on more fresh estimates on the proven gas resources will be considered. The estimates of Energy Planning Department (2012) and Myanmar Oil and Gas Enterprise are considerably more optimistic than those shown in Table II-1, at around 60 TCF of probable offshore natural gas resources.

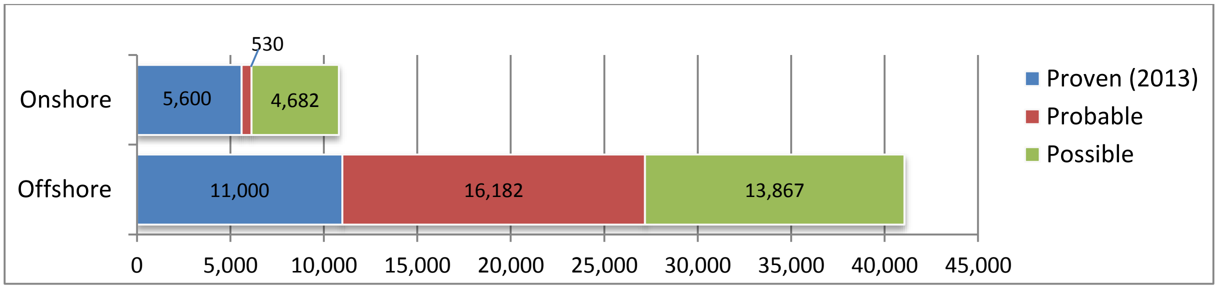
Table II-1: Recoverable Gas Resources of Myanmar Provided by JICA and ADB (in BCF)

Region	JICA (MOE 2013)	ADB (MOE 2011)			Total
	Proven	Proven	Probable	Possible	
Offshore	11,000	11,400	16,182	13,867	41,049
Onshore	5,600	394	530	4,682	10,812
Total	16,600	11,794	16,712	18,549	51,862

Source: ADB report referring to the Ministry of Energy (2011), JICA draft final report referring to the MOE 2013

[2] Estimated by ADB, accessible at http://www.adb.org/countries/myanmar/economy
[3] The Project for Formulation on The National Electricity Master Plan in The Republic of the Union of Myanmar, Draft Final Report (2), prepared for Japan International Cooperation Agency by NEWJEC Inc. and the Kansai Electric Power Co Inc, July 2014

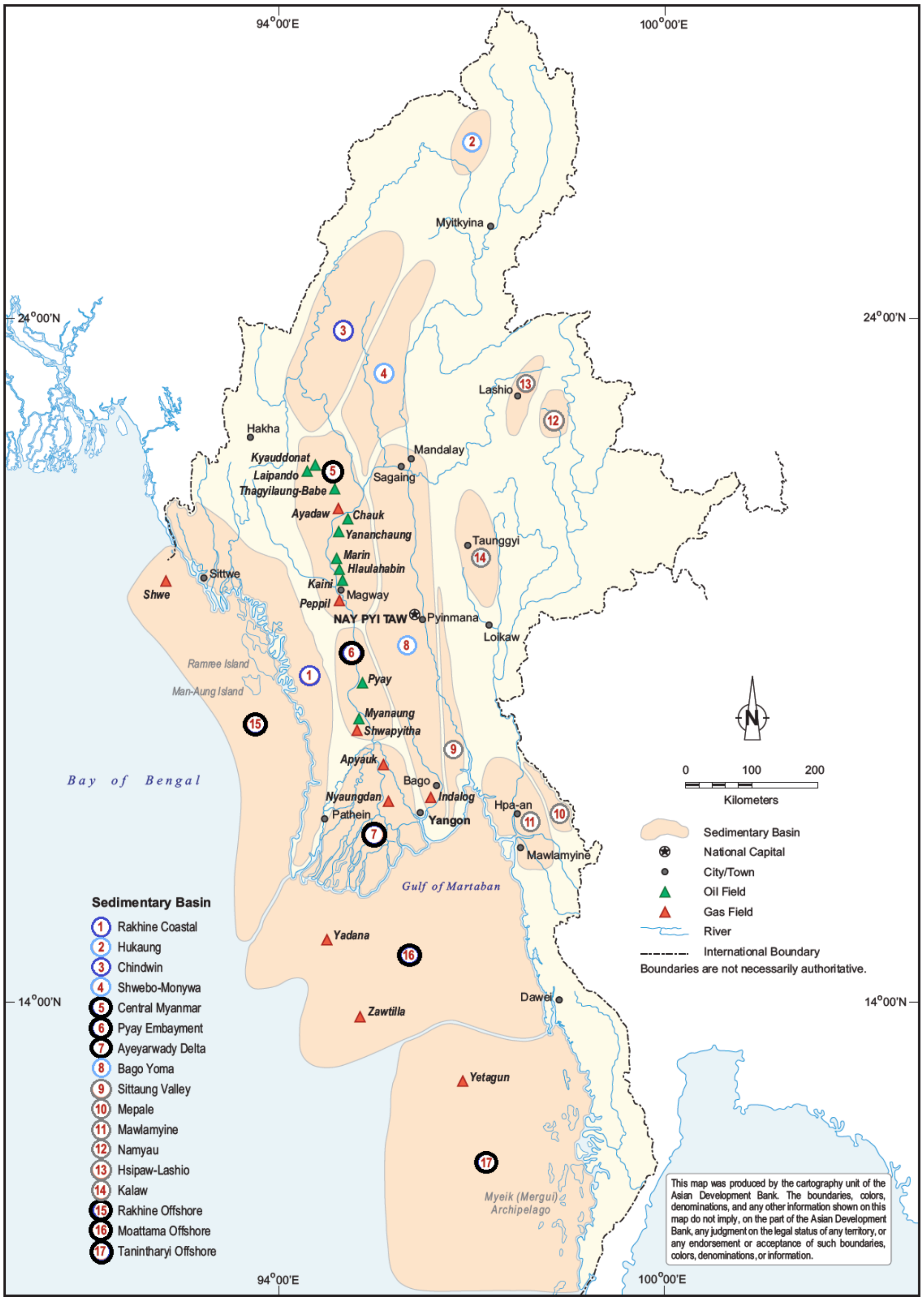
Figure II-1: Graphic Presentation of Gas Resources of Myanmar (in BCF)



Source: Ministry of Energy 2011 and 2013.

Figure II-2: Location of Gas Fields in Sedimentary Basins of Myanmar

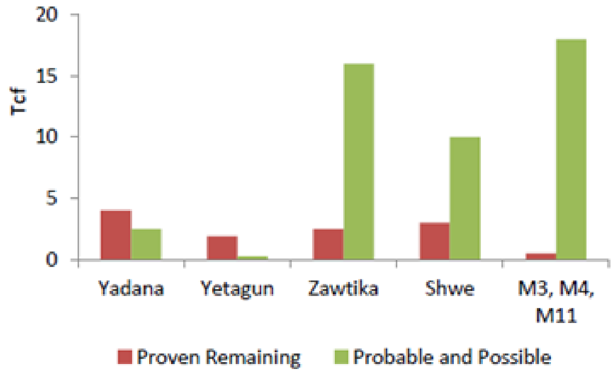
Marked with black thoroughly explored basins; blue – explored to some extent; pale blue – very little explored; grey – not yet explored basins



Source: ADB referring to the Ministry of Energy, 2011

23. Data on resource estimates per each field is limited. There are, however, estimates for the four offshore fields and three blocks provided by Myanmar Oil and Gas Enterprise (MOGE).

Figure II-3: Recoverable Gas Resources of Operating Fields



Source: Myanmar Oil and Gas Enterprise, 2013

24. Properties of Myanmar gas are presented in the Table II-2. Heating value of offshore gases is lower due to content of inert gases (N_2, CO_2). This is especially true for Yadana filed with gas of nearly 25 mole% of N_2 and 70 mole% of methane and resulting heating value of 26 900 kJ/m^3. IEA[4] estimates Average* Gross Calorific Value of Natural Gas in Myanmar to be 39 269 kJ/m^3.

Table II-2: Myanmar Offshore and Onshore Gas Properties

Field Name	Offshore			Onshore	
	YADANA	ZAWTIKA	SHWE	NDN	AYD
Component	*MOLE %*	*MOLE %*	*MOLE %*	*MOLE %*	*MOLE %*
Methane	69.880	91.786	97.0	91.20	99.28
Ethane	1.011	0.401	0	6.40	0
Propane	0.169	0.111	0	1.12	0.11
I-Butane	0.018	0.035	0	0.57	0.10
N-Butane	0.028	0.021	0	0.29	0
I-Pentane	0.007	0.010	0	0.26	0.05
N-Pentane	0.004	0.007	0	0.16	0.02
Neo-Pentane	0.002				0.01
Hexane					0
Hexane &>	0.021	0.031	0.08	0	0.22
N2	24.727	7.357	0	0	0
CO2	4.130		2.5	0	0.21
			0.5		
H2O	0.0011		0.0011	0	

[4] IEA, NATURAL GAS INFORMATION (2012 edition)

Field Name	Offshore			Onshore	
	YADANA	ZAWTIKA	SHWE	NDN	AYD
H2S	0.0021		0.0001	0	
	100	100	100	100	100
GCV(BTU/SCF)[5]	**722.70**	**944.80**	**987.77**	**1007.00**	**1026.49**
GCV (kJ/m^3)	**26,909**	**35,179**	**36,778**	**37,495**	**38,220**

Source: JICA draft final report referring to the MOE

C. Production Activities and Related Infrastructure

25. For the purpose of managing exploration and drilling activities, the territory of Myanmar is divided into production blocks. There are 53 onshore and 51 offshore blocks located in deep and shallow waters. Contractually the blocks may be of three types: (i) exploration/production EP/Production Sharing Contract (PSC); (ii) improved petroleum recovery IOR or performance compensation contract (PCC); (iii) reactivation of suspended fields RSF. Map of the blocks is provided in the Figure II-4 below.

26. The blocks are available for foreign investment. According to MOGE, the 29 contracts have been signed with 14 foreign companies for 30 offshore blocks; three shallow water blocks ad 19 deep water blocks were available for exploration and investment in 2011. As for onshore blocks, 12 contracts were signed with 9 foreign companies by 2011; some of the onshore blocks were intended to be open for additional investment opportunities. The MOE estimates to have 20 offshore blocks operating by 9 companies, and 17 onshore blocks operating by 12 companies.

27. Five onshore gas fields are operating and there are currently no onshore gas fields suspended or under test. As for offshore fields, four of them are operating, one gas field (M-3) is under preparation and one gas field (A-6) is appraised. Status of some of the gas fields is presented in the Table II-3. As it is seen, gas from the offshore gas fields is intended mostly for exports.

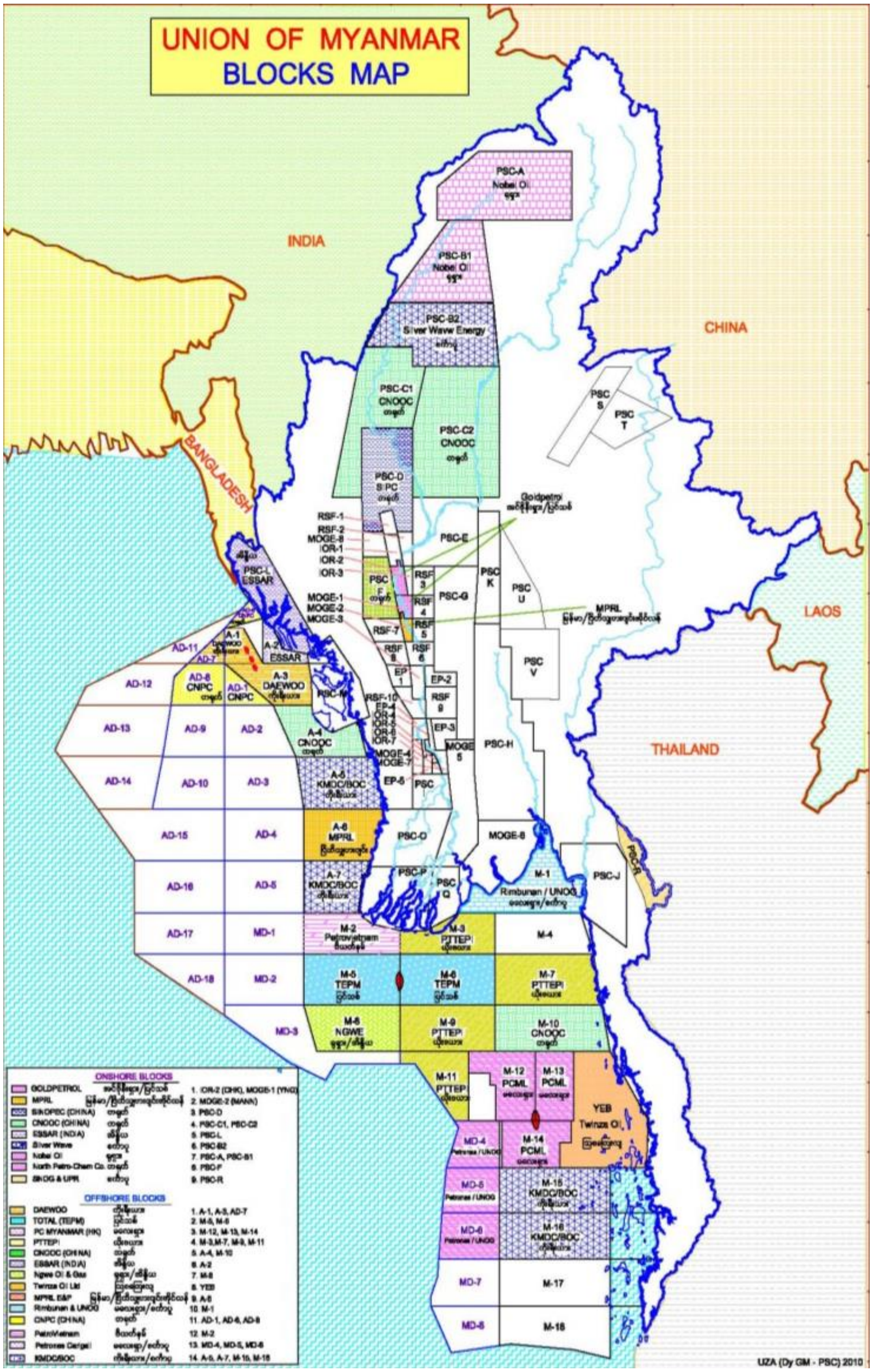
Table II-3: Status of Key Operating Offshore Gas Fields in Myanmar

Phase	Gas Field	2P reserves (TCF)	Block	Main Developer	Export	Domestic supply
Existing	Yadana	6.9	M-5, M-6	Total	Thailand	20%
	Yetagun	4.2	M-12, M-13, M-14	Petronas	Thailand	0
Ongoing	Shwe	5.4	A-1, A-3	Daewoo	PRC	20%
	Zawtika	1.8	M-9	PTTEPI	Thailand	20%
	M3	1.6	M-3	PTTEPI	Thailand	100%

Source: JICA referring to MOE 2012

[5] GCV: Gross Caloric Value, Same meaning as HHV (higher heating value)

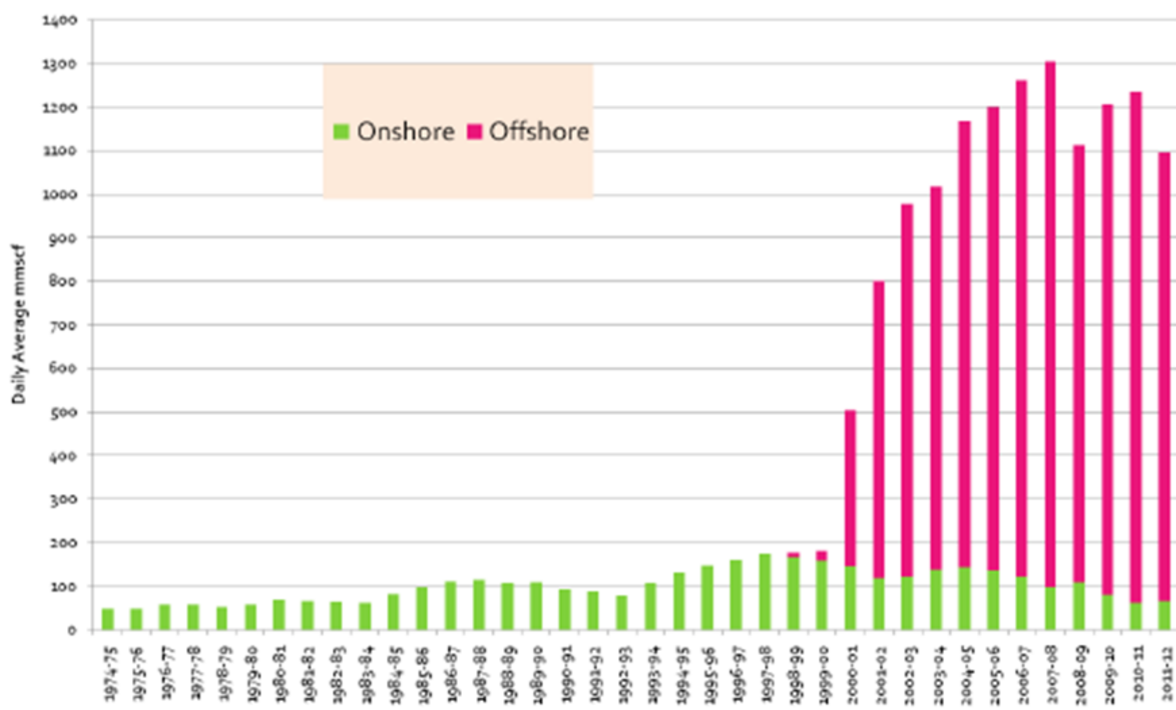
Figure II-4: Myanmar Blocks Map



Source: MOGE 2011

28. Production of gas in Myanmar grew substantially since year 2000 when offshore technologies became of wide use. Since then, the production of gas increase in some six times, and most of it is produced offshore and for exports (Figure II-5). The forecasts estimate some 20% growth in the offshore gas production over next ten years, assuming some of the fields to reduce production, and the other to start its operations.

Figure II-5: Natural Gas Production History in Myanmar



Source: MOE 2013

29. As of 2012, Yetagun and Yadana were the main gas producing fields. Yadana exports some 565 mmscfd to Thailand, and 150 mmscfd is available for domestic use. Yetagun exports 460 mmscfd to Thailand. Zawtika (M-9 and part of M-11) exports 240 mmscfd to Thailand and 60 mmscfd is for domestic use. Fields under exploration are M-3, M-11, PSC-G, EP-2. Generally, onshore gas resources are considered for domestic supply, whereas offshore fields have mainly operated for exports.

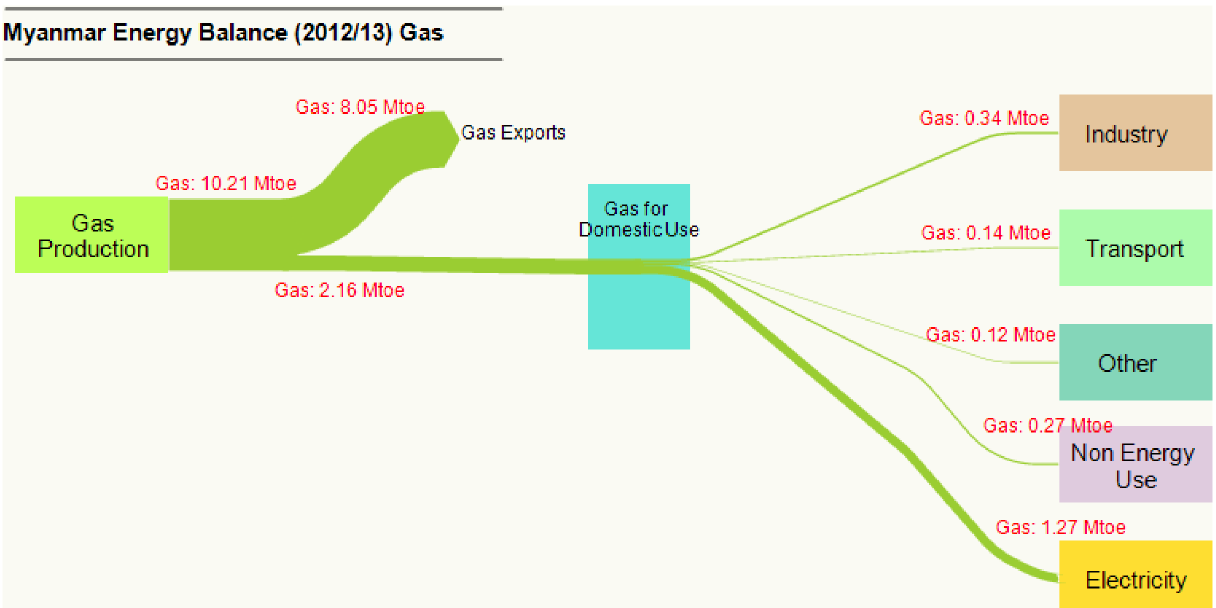
30. Myanmar possesses a developed gas transmission system. About 4,500 km of gas pipelines have been constructed onshore and 700 km offshore. It is planned to further extend and enlarge diameters of the pipeline network. There are two international gas pipe lines from Myanmar: one to Thailand and another one to PRC. A list of gas pipelines and their properties are listed in the Annex 1 on page 207.

31. Export pipelines are newer and of considerably better condition compering to domestic pipelines. They are of better design and maintained to the standards, and also possess corrosion prevention system and SCADA system. Domestic pipelines were built following lover standards and have suffered from inadequate maintenance. There are planned activities on rehabilitation of existing pipelines as well as construction of new ones.

D. Gas Consumption and Export

32. Most of the produced natural gas in Myanmar (87% in 2010[6]) is intended for exports, while the remaining 13% is utilized for domestic use (Figure II-6). Largest part of domestically utilized gas is used for power production: 40% in 2010 according to IEA, and already 60% in 2012 according to MOE. There is substantial pressure to increase the share of domestic use of gas for electricity generation as there is need to balancing firm power capacity to supplement hydropower, and the hydropower schemes do not develop in pace with the growing demand. The remaining part of gas is consumed for industrial purposes (fertilizer production), as well as for transportation and other needs.

Figure II-6: Balance of Natural Gas in Myanmar, 2012/2013

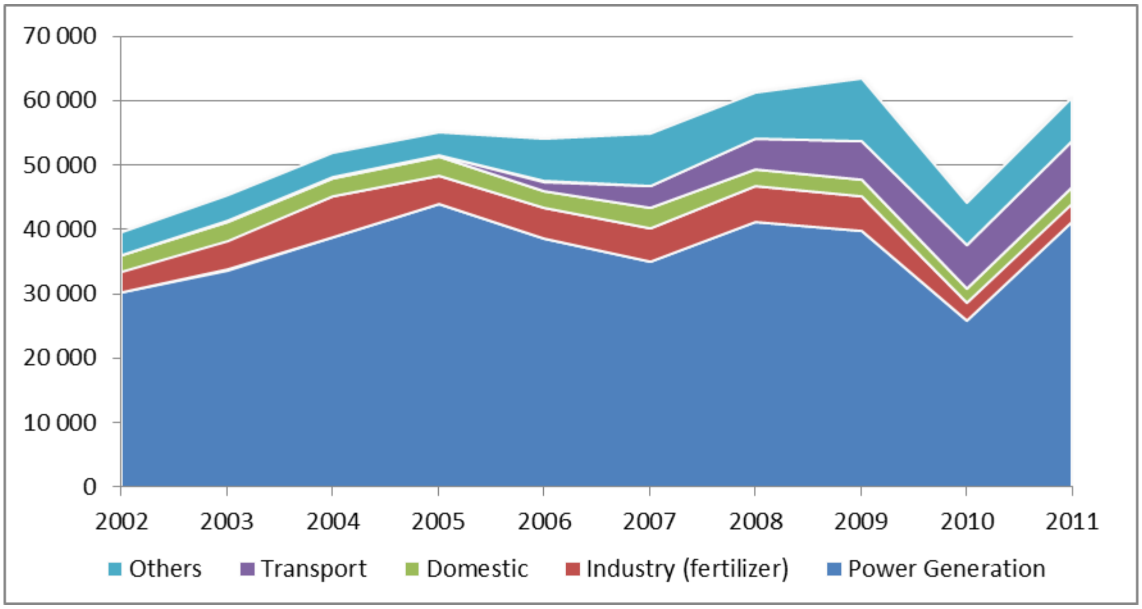


Source: Consultant

33. Overview of domestic gas consumption in Myanmar is presented in Figure III-8 below. It is seen that a large share of gas consumed for power production is a historical pattern for Myanmar. Share of gas for industries and fertilizer production tends to decrease over years while use of gas in transport sector (as Compressed Natural Gas CNG) is slowly increasing. Reasons behind drop of gas consumption in 2010 in the statistics remain unclear to the consultant at the current stage.

[6] According to IEA

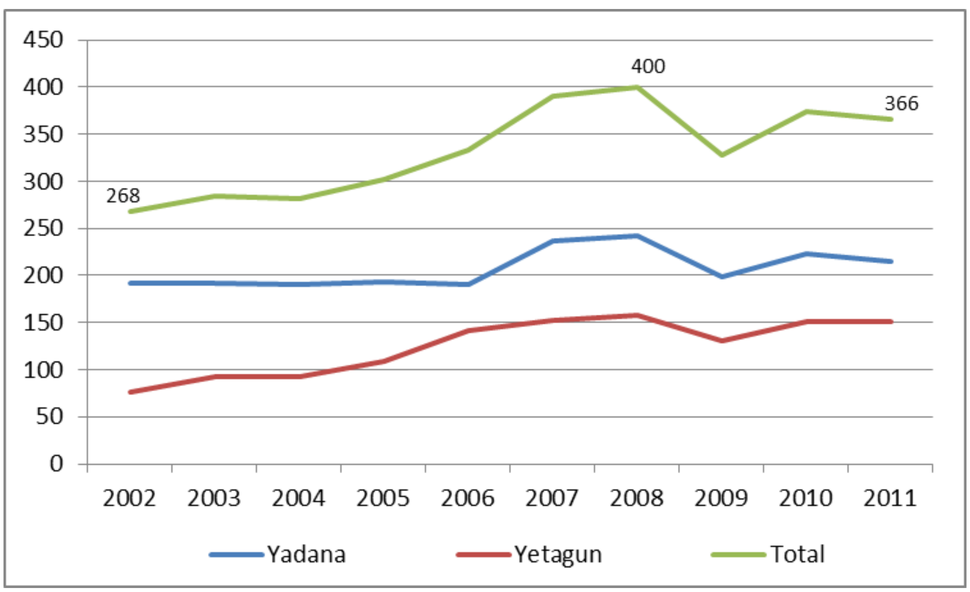
Figure II-7. Domestic Consumption of Gas in Myanmar, 2002-2011 (in MMCF)



Source: ADB referring to MOE

34. Export of gas plays significant role in Myanmar economy. As mentioned earlier, it accounts up to 40% of the country's overall export. Myanmar takes the 16th place in the world and the 2nd in the Asia Pacific region by its gas export.

Figure II-8: Export of Piped Natural Gas from Myanmar (in BCF)



Source: ADB referring to the MOE.

35. Korean, Chinese and Indian consortiums, on basis of memorandum of understanding (MOU) with the Government of Myanmar of 2008, have developed the sale and transport of natural gas from the offshore blocks A-1 and A-3 (see Figure II-4). In combination, the A-1 and A-3 fields called as Shwe and the associated pipelines in Myanmar and to PRC have started operation in 2014. Shwe gas fields are expected to produce a total of 500 mmcfd, of which 400 mmcfd will be transported to PRC and 100 mmcfd will be kept for domestic use.

E. Natural Gas for Power Production

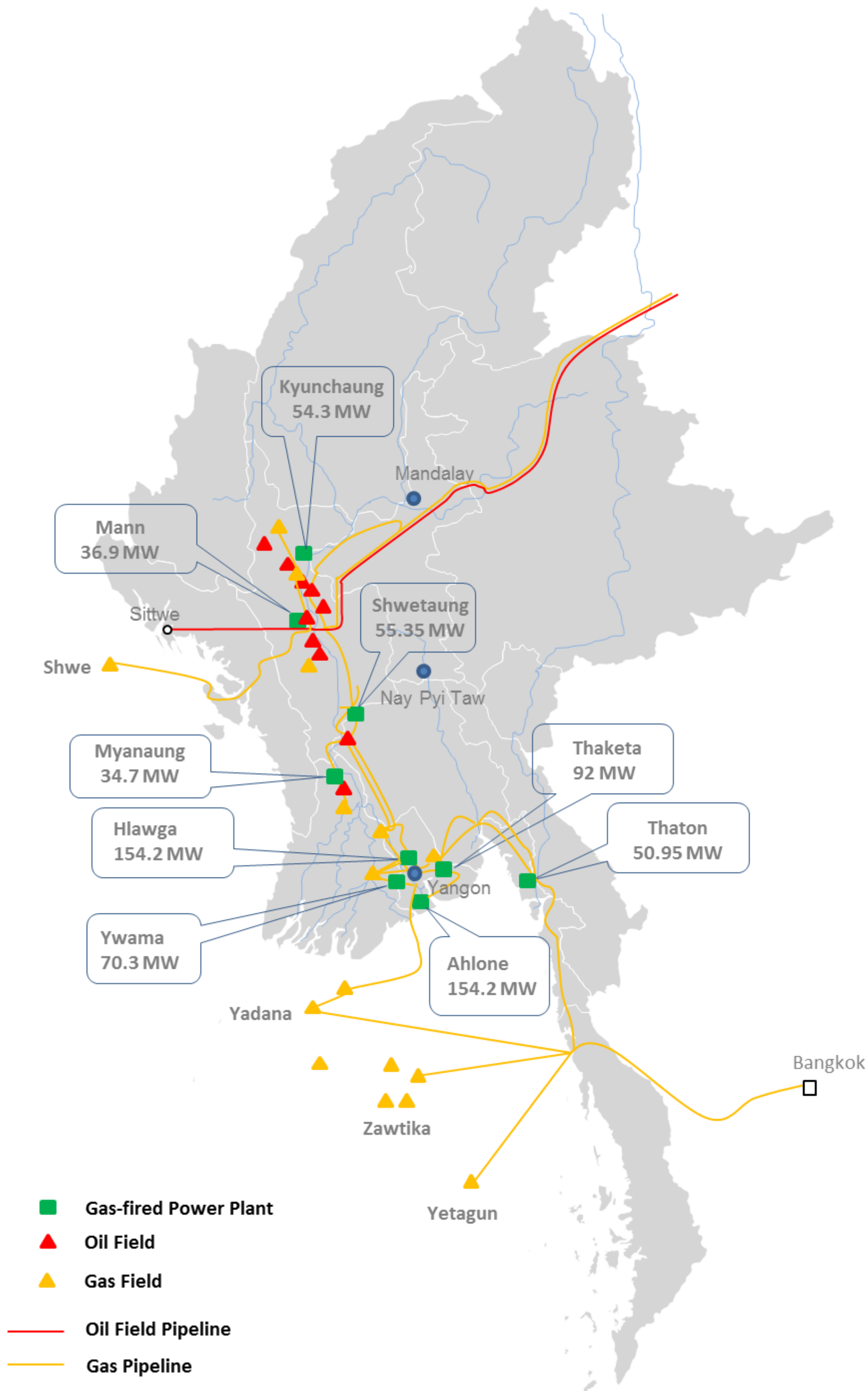
36. Myanmar produces some 30% of its power from natural gas. The currently operating gas-fired power plants are presented in Figure II-9 below. There are plans and on-going activities for the rehabilitation of existing power plants (Table II-4). The rehabilitation would provide for an increase in generation. Altogether, the available natural gas based electricity generation capacity stands at around 700 MW in 2014. Many of the plants are relatively small.

Table II-4: Existing Power Plants and Plans for Their Rehabilitation

Name		Current nameplate		Actual capacity (2013)		2014 additions	
		GTCC	GT/GE	GTCC	GT/GE	GTCC	GT/GE
	Region	MW	MW	MW	MW	2014	2014
Existing							
Hlawga	Yangon	154.2		88			
Yawama	Yangon	70.3		50			
Ahlone	Yangon	154.2		76			
Tharkayta	Yangon	92		86			
Thaton	Mon		50.95		35		
Kyunchaung	Magwe		54.3		24,5		
Mawlamyaing (STs)	Mon		12		3		
Myanaung	Ayeyarwady		34.7		12		
Mann	Magwe		36.9		0		
Shwedaung	Bago		55.35		20,5		
New installations							
Hlawga (Zeya)	Yangon		54.55		26		28.55
Ywama (MSP)	Yangon		52		52		
Ywama (EGAT)	Yangon		240			240	
Ahlone Toyo-Thai	Yangon		82		82		
Ahlone	Yangon		39			39	
Thaketa	Yangon		53.6		53,6		9
Thaton	Mon					106	-35
Actual capacity GTCC		**470.7**		**300**		**385**	
Actual capacity GT/GE			**765.35**		**308.6**		**37.55**

Source: Draft Electricity Master Plan report (2014) referring to interviews with TPD, updates by MOEP (March 2015)

Figure II-9: Location of Existing Gas Fields, Pipelines and Gas-Fired Power Plants



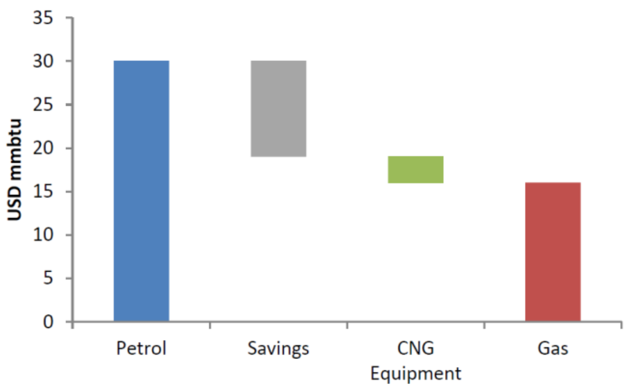
Source: Consultant based on JICA,MOE, JOGMEC and JEPIC data

F. Gas for Transportation

37. The CNG/NGV Converting Programme was initiated in 1985. During the initial phase five CNG filling stations were constructed and 587 buses converted from petrol to NGVs. The programme was reactivated in 2004, and by 2012 year 45 CNG filling stations were constructed: 40 in the Yangon city, 2 in the Mandalay city, 2 in Yenangyang oil field and 1 in Chauk oil field. Currently more than 27600 passenger cars were converted from petrol/diesel to NGVs. In recent years approximately 10% of Myanmar domestic gas supply was utilized by the transportation sector.

38. The Lantau Group estimated basic economics for the NGVs conversion project and arrived to a conclusion that it does not require subsidies if the domestic petrol price is set in line with the 'world prices'. Summary of their estimations are presented in the Figure II-10 below. The programme continues with high momentum. The filling stations are considered to be installed along the existing domestic pipeline. 2 mmcf of offshore gas and 20 mmcf onshore gas is considered for supply of the CNG Programme. However, as it seems that gas shortage will be likely, it may be advantageous to pause this programme until the gas supply is secured.

Figure II-10: NGVs Conversion Economics



High Level NGV Conversion Economics	
Petrol	
Real Levelised Retail Petrol USD/mmbtu	30.0
Calorific Value of Petrol btu/litre	33,000
Real Levelised Petrol USD/litre	1.0
NGV	
Levelised NGV USD/mmbtu	19.0
Calorific Value of NGV btu/kilogramme	50,000
Levelised NGV USD/kilogram me	1.0
Fuel Saving	
Petrol less NGV USD/mmbtu	11.0
Petrol less NGV USD/litre	0.4
Breakeven Calculation	
Fuel Use in Kilometres/litre	14
Saving USD/kilometre	0.03
Average Cost to Convert Car to NGV (USD)	1,500
Breakeven kilometres	58,000
Source : TLG	

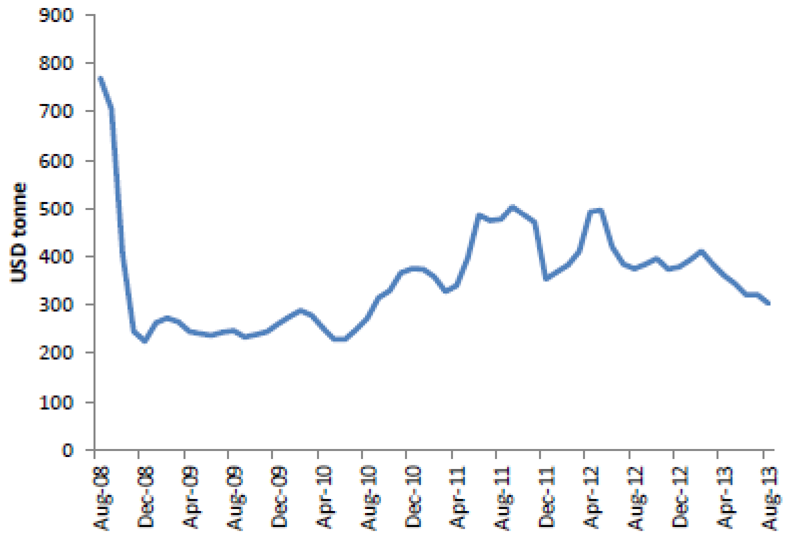
Source: The Lantau Group, 2013

G. Gas for Fertilizers

39. Ammonia plants produce some 90% of fertilizers used worldwide. The main ingredient for the production is natural gas. There is an increased interest to this linked to the currently low prices for natural gas. However, the urea prices did not recover after the financial crisis of 2008/9 to anywhere near the 2008 levels even though some recovery in LNG prices could be observed. This indicates certain de-linking between the input and output prices and therefore higher risks.

40. Myanmar operates five fertilizer plants that utilize ammonia 1 340 MTD and Urea 2 012 MTD. There is an initiative for an energy-efficient urea fertilizer plant at Kyawzwa.

Figure II-11: Urea Price Estimations



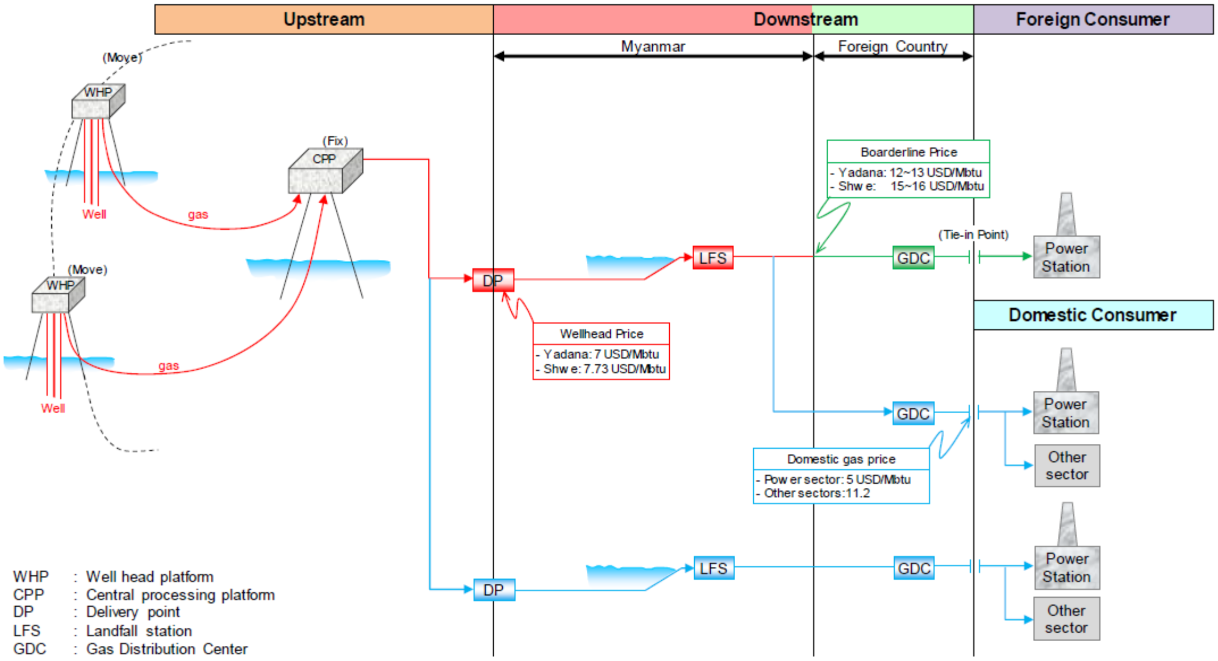
Source: The Lantau Group referring to the World Bank

41. In past, low prices and availability of natural gas created a fruitful environment for fertilizers production in Myanmar. But, as mentioned above, the current contracts for gas exports and high-priority use off natural gas for power generation go ahead of planned fertilizer production. Under foreseen shortage of gas feasibility of fertilizers production needs to be re-considered, as well as alternatives of gas supply to fertilizer plants carefully evaluated.

H. Gas Price and Cost Estimates for Gas Based Power

42. A gas contract system is well established in Myanmar. The developer agrees a Product Sharing Contract (PSC) with the Government of Myanmar, Gas Transportation Agreement (GTA) with the gas pipeline operator in Myanmar, and makes a Gas Purchase Sales Agreement (GPSA) with the foreign distributor. As for the domestic market, domestic gas pipelines are owned by the MOGE (Myanmar Oil and Gas Enterprise), and gas prices are determined by a Presidential Decree. Thus, there are no GTAs and GPSAs for the domestic market. The schematic presentation of the system can be found in the Figure II-12 below.

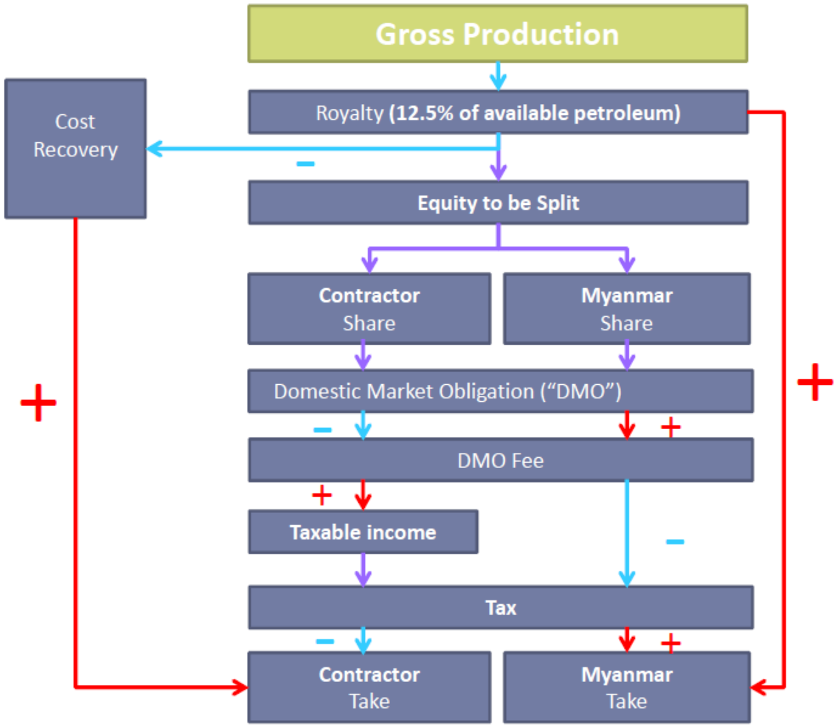
Figure II-12: Gas Contract System and Gas Prices in Myanmar



Source: JICA

43. There are three types of the PSC in Myanmar: (i) for onshore blocks, (ii) for shallow water offshore blocks, and (iii) for deep water offshore blocks. While having minor differences in details, the main features (e.g. exploration period) of the three types of PSCs remain the same and are presented in the Figure II-13 below. For all PSCs royalty tax is 12.5% of available petroleum. The production split is inversely proportional to the capacity of production, the MOGE part varies from 55% to 90%. There is a developed system of production bonuses, depending on the production, from 0.5 MMUSD to 6 MMUSD for onshore, and up to 10 MMUSD offshore. The domestic requirement for gas is 25%. The Contractor receives three years of Tax Holiday, after which pays 30% tax on Contractor's net profit. Other fees include 0.5% of Contractor's share of profit petroleum for Research and Development, as well as contributions to the training fund as 25 000 USD annually during the exploration period, and 50 000 USD per year during production for onshore, and double of the amount for offshore.

Figure II-13: Myanmar Product Sharing Contract (PSC) Calculation



Source: Charltons

44. The prices for gas in Myanmar are briefly shown in the Figure II-12 above. Although gas prices of Yadana are 7 USD/MMbtu (Wellhead) and 12..13 USD/MMbtu (Borderline[7]), gas is sold to MOEP at 5 USD/MMbtu, thus subsidised by the Presidential Decree. Other sectors than the power sector pay 11.2 USD/MMbtu without a subsidy. However MOE has filed price-up from 5 USD/MMbtu to 7.5 USD/MMbtu. If approved, MOE will apply to price-up till 11.2 USD/MMbtu in 2015. The Shwe gas price is 7.73 USD/MMbtu (Wellhead) and 15-16 USD/MMbtu (Borderline). For comparison, the LNG price after bidding was established at the level of 18 USD/MMbtu and the export price to Thailand in 2013 was 10.3 USD/MMbtu in average as per Central Statistical Office (CSO) monthly statistical report.

I. Summary

45. Myanmar possesses large reserves of natural gas. The estimates vary from 52 to 60 TCF of 3P reserves. The largest identified reserves are located offshore, however not all sectors with pre-identified gas resources have been well-studied. Heating value of offshore gas is generally lower comparing to onshore gas due to containment of inert gasses.

46. The daily average production of gas in Myanmar is about 1100 mmscf, with its larger share being produced offshore. The government of Myanmar allows foreign investment into gas explorations activities. Gas fields are interconnected with gas pipelines. Gas pipelines for domestic use are of significantly worse condition comparing to gas pipelines intended for exports.

[7] Borderline price is a Wellhead price plus a Gas transportation price in Myanmar

47. 83% of the gas produced in Myanmar is currently exported to Thailand. Export of gas to PRC has recently started from the Shwe gas field.

48. The rest of the gas is utilized internally, mainly for power production, but also for transportation, industrial parks and fertilizers industry. There is roughly 0.8 GW of installed capacity of gas fired PPs in Myanmar, however their actual capacity is only one third of that. There are plans for rehabilitation of existing power plants, as well as plans to construct new gas fired PPs to achieve total installed capacity of 4 GW. Besides, there is a programme on conversion of petrol cars into NGVs. Some 27 600 cars have been converted so far, and 45 filling stations constructed along the gas pipeline system.

49. The Government of Myanmar subsidises gas price for power production, bringing it down to 5 USD/MMbtu from the borderline price of 12-13 USD/MMbtu (Yadana) and 15-16 USD/MMbtu (Shwe). MOE has initiated an increase of gas price to 7.5 USD/MMbtu, and if approved it will apply it to 11.2 USD/MMbtu. The study assumes international reference prices for natural gas as a proxy for the economic value of Myanmar's domestic gas.

III. COAL RESOURCES

J. Introduction

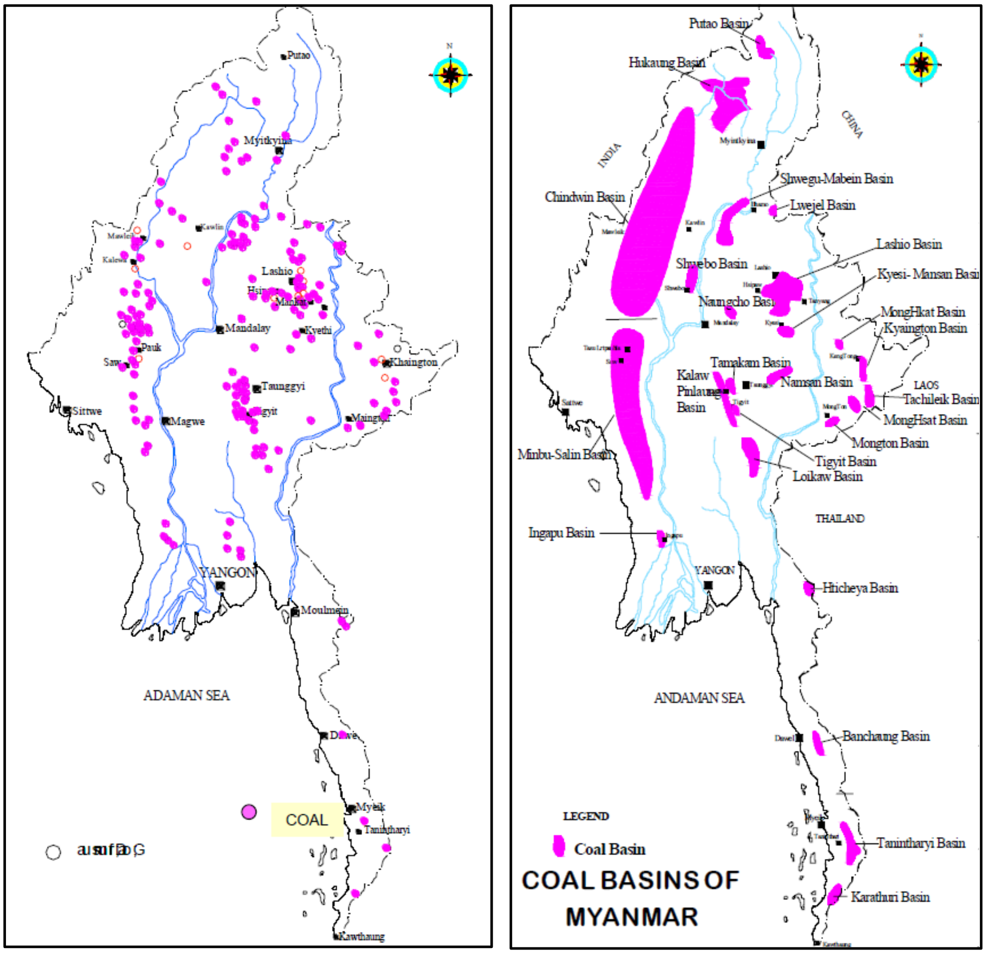
50. The Republic of the Union of Myanmar possesses relatively large reserves of coal; however this remains of a minor importance for the country's energy mix. Share of coal in the primary energy supply in 2011 accounted 2.9%, and 9% in the electricity generation mix[8]. Low share of coal has its historical prerequisites, as well as can be related to low quality of coal reserves and obsolete technologies remaining in use. Still, there are government initiatives on deployment of coal mining and increase of coal share in the energy mix of Myanmar.

K. Coal Resources

51. Most recent geological investigations identified over 500 coal occurrences in Myanmar. The deposits are spread over the country, with some more occurrences in the Northern Myanmar in basins of rivers Chindwin and Ayeyarwaddy (Figure III-1). Most of the coal resources were deposited during the Tertiary period. The Mesozoic coal deposits occur in a localized area of the Shan State (Central East Myanmar). Jurassic coals occur mainly in the Southern Shan State.

[8] Source: International Energy Agency, balances for Myanmar for 2011, accessible at http://www.iea.org/countries/non-membercountries/myanmar/

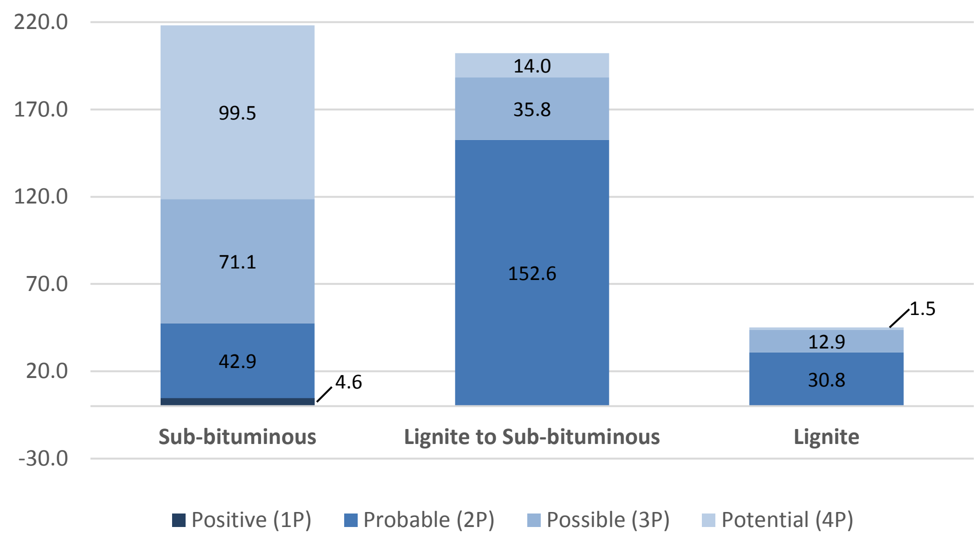
Figure III-1: Distribution of Coal Occurrences (Left) and Coal Basing (Right) in Myanmar



Source: Department of Geological Survey and Mineral Exploration of Myanmar

52. Over 200 deposits were estimated in reserves, 34 of them being of greater importance. The overall capacity of reserves is 466 million tons, divided into categories by degree of their yield probability. Myanmar operates 218 million tons of sub-bituminous coal reserves, however, only one fifth of them are of high degree of probability (1P and 2P). Lignite to sub-bituminous coal reserves amount to 202 million tons, and 75% of them are probable (2P). Lignite coals amount to 45 million tons with 69% of them being probable (2P). The overall capacity of coal reserves with indication of probabilities is presented in Figure III-2 below.

Figure III-2: Coal Reserves of Myanmar by Grade, million tons



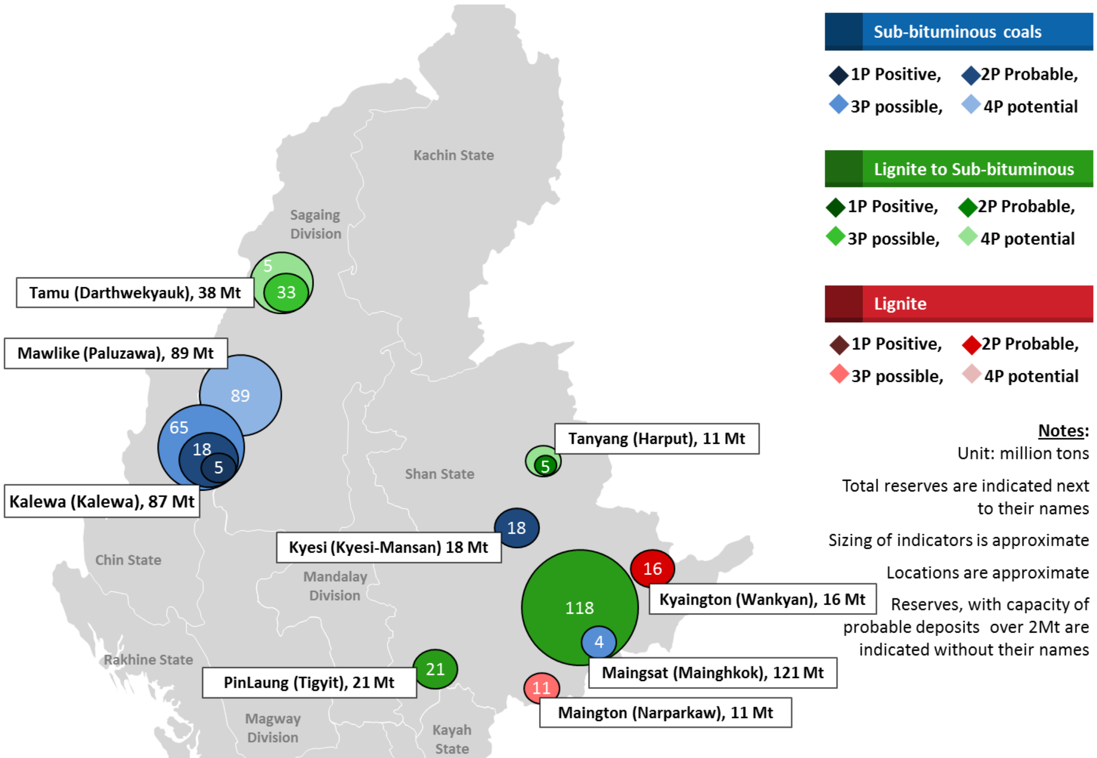
Source: Myanmar Ministry of Mines

53. Largest coal reserves[9] are noted in Sagaing division and Shan state – North-West and Central East of Myanmar accordingly (see Figure III-3 below). The largest coal reserve is Maingsat with a capacity of 118 Mtons of probable lignite to sub-bituminous and 4 Mtons of possible sub-bituminous coals. These deposits are located some 400 km to East from the Tigyit power plant with its own capacities being lignite to sub-bituminous coals of 21 Mtons. The largest deposit of sub-bituminous coals is at Kalewa with total capacity of 87 Mtons, 5 Mtons of which are positive, 18 Mtons are probable and 65 Mtons are possible. Southern part of Myanmar (Tanintharyi Division) has limited coal deposits – 8.6 Mtons of lignite to sub-bituminous coals from four various deposit locations. Capacities of 33 Myanmar coal deposits are presented in the Annexes at the end of this report.

54. Quality of Myanmar coals is not too high, but they are suitable as fuel for coal-fired boilers due to low contaminant of sulphur (<3%) and ash (average value is 16%, of largest reserves varies between 1% and 15%). On the other hand, they have propensity of spontaneous combustion due to high moisture content (average is 16%, maximum reaches 40%) and high volatility (the average is 47% however volatility of Shan coals rises as high as to 97%). Thus it is required to pay special attention to coal transportation and storage systems. Fix carbon value of Myanmar coals varies from 15% to 53% with average 35%. Average calorific value is 5 200 kcal/kg. Kalewa and Tamu coals have calorific values comparable to bituminous coals suitable for any standard coal combustion technologies of modern power plants. Overview of calorific values of coals is presented in Figure III-4 below. Detailed data on chemical composition of various deposits may be found in Annex 4.

[9] The largest considered to be coal reserves with total capacity over 10 million tons

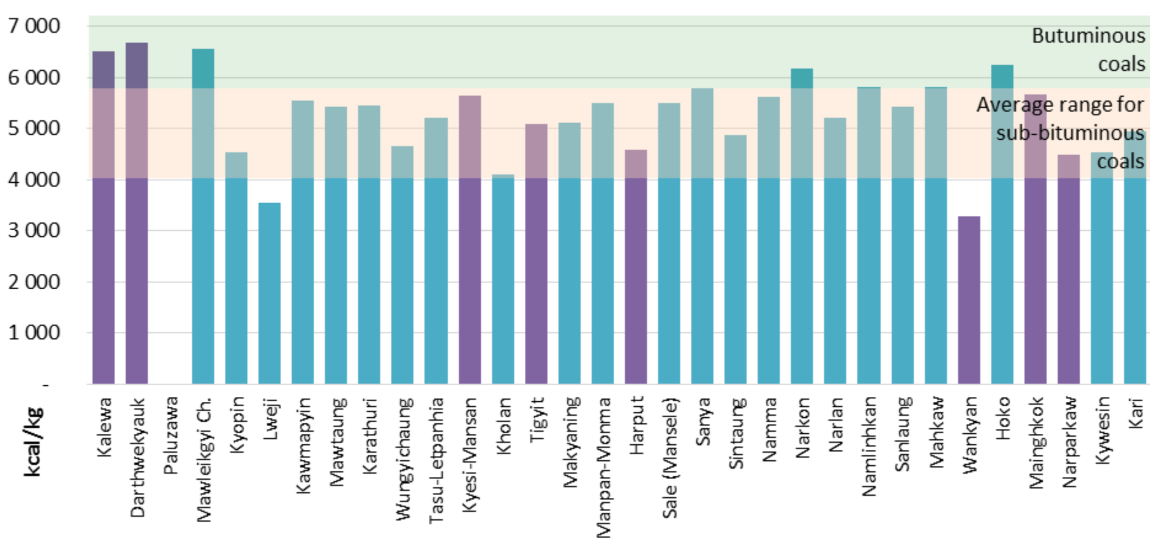
Figure III-3: Locations of Coal Reserves of Myanmar with Total Capacity over 10 Mt



Source: Myanmar Ministry of Mines

Figure III-4: Calorific Values of Myanmar Coal Deposits (kcal/kg).

Coal reserves with total capacity over 10 Mtons are marked with violet



Source: Myanmar Ministry of Mines(based on chemical analysis)

L. Existing Coal Mining Activities

55. Coal mining activities in Myanmar started already during Myanmar Monarchy in the middle of the 19th century with average annual coal production of 2,400 ton. Then, during the 58 years of British Colony Myanmar annually produced on average 2,600 ton. From 1949 to 1988 while Parliament Democracy Myanmar was producing 13,500 ton coal annually. During period of SPDC (1988 to 2009) the production reached over 500,000 ton annually.

56. Peak of coal production (1.3 million ton) was in 2006/07. The lowest drop up to 387 thousand ton was in 2009/10 after change of political system from APDC to the Republic. A large part of produced coal (81% at its maximum in 2004/05) was exported to PRC and Thailand. But the export was significantly reduced after production stopped from Maw Taung coal mines. Currently there is no import of coal to Myanmar, however the government has already announced zero import tax for it and some of the planned power plans consider importing coal from Indonesia.

57. Most of the coal in Myanmar is produced at open-surface mines. Production from underground mines remains low; however it has been growing since 2006 (Figure III-5).

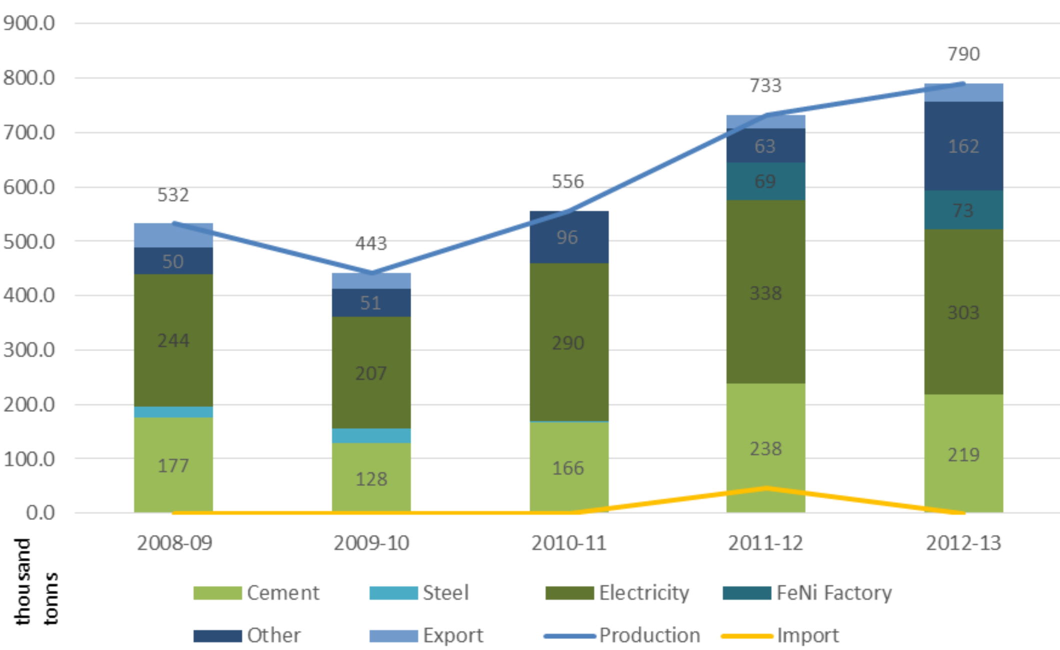
Figure III-5: Coal Production by Mine Type for Years 2000 to 2013 (thousand ton)

Source: Source: Mining (3), Ministry of Mining

58. Myanmar Consumption of coal in the early 2000s was split between predominant export and internal use mainly for industrial purposes. This was considerably changed after the Tigyit PP started its operation in 2005. Since then, export of coal accounts no more than 10%, and power production consumes some 30-50% of the annually produced coal. Recent data on coal consumption (Figure III-6) shows that the main consumers of coal in Myanmar are electricity generation (Tigyit PP) and cement industries. Minor consumption of steel industry phased out in recent years, while FeNi Factory increased its demands for coal. Consumption by households is assumed to represent some 5% of the total consumption. In recent years, export and import of coal have been insignificant.

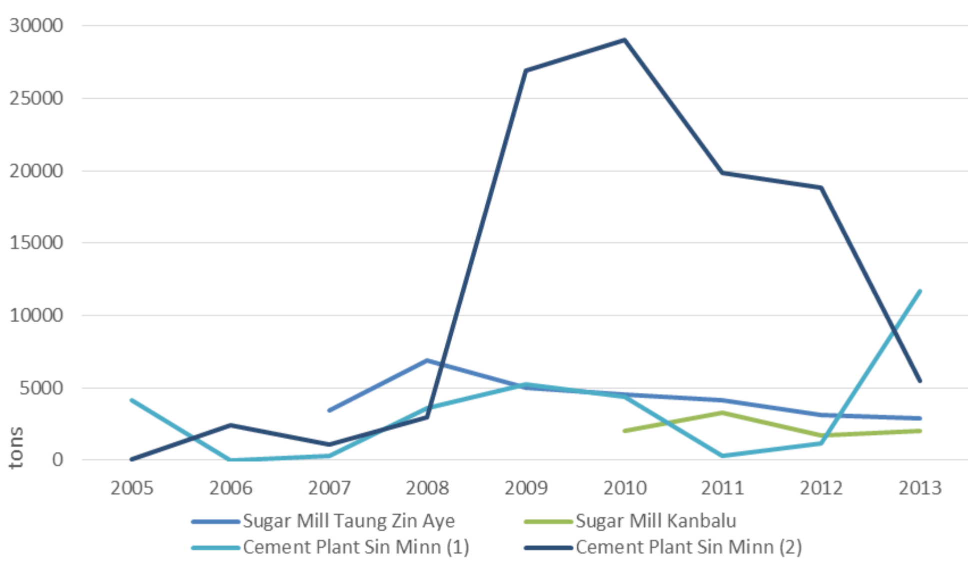
59. Coal consumption of two sugar mills and cement plants are presented in Figure III-7. Data for other industrial enterprises that consume coal is unavailable.

Figure III-6: Overall Coal Production and Consumption in Myanmar, 2008 to 2013



Source: No (3) Mining Enterprise

Figure III-7: Coal Consumption of Some Industrial Companies Which Reported Consumption to the Ministry of Mines



Source: Ministry of Mines

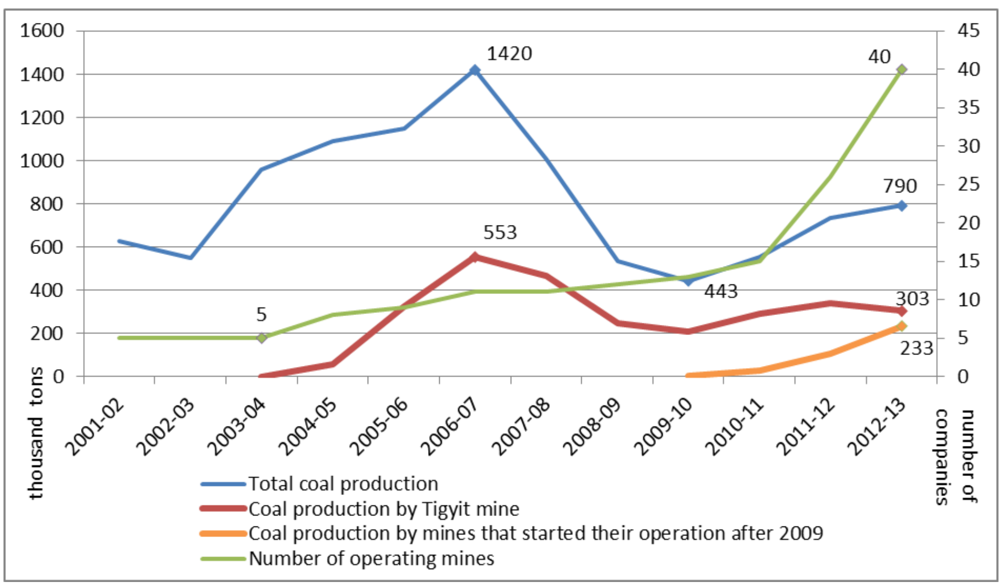
60. Ministry of Mines (MOM) is responsible for the formulation of the mining policy and exploration and extraction of coal. There are two departments and three enterprises within MOM. The exploration permits are issued to private companies in accordance to the Myanmar Mines Law. Depending on reserves, large and small mining permits are issued to mining companies. The main objectives of MOM include: (a) improved data on coal balances; (b) increased coal share in total energy mix; (c) control of pollution; (d) lead for international cooperation on coal; (e) implementing Myanmar's role under ASEAN Plan of Action for Energy Cooperation. The government plays key role in obtaining clean coal technologies and bringing them to the sector.

61. The state owned No.3 Mining Enterprise is responsible for coal production in Myanmar. The production sharing contact (PSC) system is practiced in which 100% of investment is borne by the private companies and the agreed split ratio is used for shared production between the two parties. The usual ratio is 30% for government and 70% for private contractor. After privatization of Kalewa and Namma in 2010 there is no more coal production by state sector only. The No.3 Mining Enterprise remains responsible for the supervision of private mines.

62. In 2010, a Coal Mining Group was formed out of 13 mining companies to develop mining activities in the Sagaing region in a more efficient and profitable manner. The region suffers from poor infrastructure thus one of the main objectives of the group is to construct a road on a cost-sharing basis to the mining area. Currently MOM has reported that six of the 19 private companies are in production, while many of the remaining mines are still in the development stage.

63. The Kalewa, Namma, Lejel, Samlong and Maw Taung are the oldest mines in Myanmar. Up to 2005 Maw Taung was the largest mine in Myanmar with annual production over 600 thousand ton. With the Tigyit PP coming on-line in 2004/05 the mine in the vicinity of the power plant took the lead in the coal production and remains having it up to now. In recent years a number of new private mines were opened; over last ten years their number grew from 5 to 40. Contribution from young rather small-scale mines grows with their increasing number, and now adds up to some 30% of annual coal production in Myanmar (Figure III-8). Please refer to Annex 5 for detailed data on coal production by mines in Myanmar.

Figure III-8: Total Coal Production in Myanmar vs. Number of Private Mines



Source: JICA referring to No(3) Mining Enterprise; DGSE

64. Myanmar participates in Association of Southeast Asian Nations (ASEAN) that released Plan of Action for Energy Cooperation and Asian Forum on Coal (AFOC). In 2000, Myanmar formed National Committee for AFOC, chaired by Deputy Minister for Mines. The overall objectives of the committee are increase of regional cooperation and exchange of clean technologies.

65. According to the 30 years governmental plan prepared in 2006-2007, coal production was expected to increase by 40% annually in order to meet growing demand for coal. The growth of demand was seen to be linked to: (i) growing demand in pyro-metallurgical industry; (ii) plans to construct new coal-fired power plants, part of generated electricity of close to the border power plans is considered for export; (iii) replacement of firewood with coal in order to prevent deforestation. Whilst not all expected development has taken place until today, the identified key drivers of coal demand remain valid for Myanmar. However, the forecast growth path of output from expected 2.3 million tons in 2015-16 to about 5.6 million tons 2030-31 does not seem realistic today (2014) as in the short and medium term the staring level production of 2012-13 was only 790,000 tons, thus substantially lower than anticipated in the plan.

66. A notable increase in coal production capacities in Myanmar is expected to take place in the nearest future with the completion of development of eight mines of the Coal Mining Group in the Sagaing Region. The output target for the Coal Mining Group by 2030 is 5 million tons, fulfilling demand of cement manufacturers, new power plants and Chinese ferro-nickel production. Mine Khoke with the largest reserves in Myanmar plans to start its operation in 2014.

M. Current Coal Fired Power Assets

67. There is one coal-fired power plant operating in Myanmar. It is located 40 km to South-East from Kalaw city in the Shan State. The plant was built with the support of Chinese experts in 2004-2005, with use of Japanese modern technology enabling more efficient use of lignite coal. The plant is operated by the Ministry of Electric Power (MOEP). It is planned that 640 thousand ton of coal will be supplied to this power plant.

68. The installed capacity is 120 MW (2x60 MW), however the actual firm available capacity of the power plant is estimated as low as 27 MW. In 2013, consultants from JICA[10] in assessing Myanmar's existing power generation capacity concluded that this drop is mainly caused by inadequate maintenance of the power station. Additionally, real calorific value of the coal (7050 Btu/b) is below the calorific value considered by boiler manufacturer (7200 Btu/b), but this is considered not as a major factor behind the output degradation.

69. JICA study team also identified a number of environmental issues associated with the plant: (i) not working flue gas desulfurization; (ii) no monitoring for NOx, SOx and dust from the stack. Also, it was noted that the height of stack was shortened from 150 m to 80 m to reduce time of the construction. According to JICA, neighbouring residents have no complains about the environmental conditions of the Tigyit station. However, NGO's have raised some concerns, such as that research of Pa-Oh Youth Organization (PYO) in 2010 identified a number of complains of the local people related to water pollution and piles of coal waste located in a close proximity to the village. Besides, it identified some social issues to be reviewed: acquisition of farm land and related income issues, poor compensation approaches, limitation on farming linked to operation of the conveyor, insufficient healthcare approaches for workers at the station.

[10] The Draft Myanmar National Electricity Masterplan by Newjec Inc. and the Kansai Electric Power Co., Inc. financed by Japan International Cooperation Agency (JICA), 2013-2014

Table III-1: Coal Power Plant at Tigyit

	Unit	2008	2009	2010	2011	2012	2013
Installed Capacity	MW	120	120	120	120	120	120
Available Firm Capacity	MW	27	27	27	27	27	27
Total Generation	MWh	331,277	217,406	351,509	379,040	266,907	161,160
Station Own-Use	MWh	56,986	37,576	59,559	69,734	58,923	39,727
	%	17%	17%	17%	18%	22%	25%
Net generation	MWh	274,291	179,829	291,950	309,306	207,984	121,433
Capacity factor	%	31%	21%	33%	36%	25%	15%
Total annual Coal consumption	ton	267,535	263,364	436,445	377,961	461,160	153,770

Source: MOEP.

Note: Data on coal consumption of the Tigyit PP presented here differs from the data on coal consumption for power generation provided above by the MOM.

70. Considering degradation of equipment of the Tigyit PP caused by inadequate maintenance, a rehabilitation plan has been developed and submitted to the Minister of MOEP.

71. As to the Tigyit coal mine, it is located approximately 3 km away from the power plant. It is an open surface mine of 2.7 km^2. The coal is transported by truck and belt conveyor. The mine serves mainly for the power station thus the coal production is linked to demands of the Tigyit PP. The expected service life of the mine is 27 years.

N. Cost Estimates

Coal Prices

72. The cost of coal, which would be representative in this study, can be estimated using world market prices. The extra coal outputs from local mines and demand for coal inputs due to planned domestic coal-fired power generation facilities will have a direct or indirect effect on international coal trade. Importing coal represents an alternative to domestic production for the power generation companies, and the local mining companies have an opportunity to sell their production to export instead of supplying local consumers. Therefore, from the economic analysis perspective, the value of coal, whether locally produced or imported can be chosen for the study by taking reference from international coal markets applicable to Myanmar.

73. Whilst this is applicable for most coal-fired power plant projects that are in pipeline for Myanmar, some small-scale mine mouth power plants might represent an exception from the above principle. If there is no real market available other than a mine-mouth power plant for a mine due to constrains such as poor quality of coal, difficult access or high transportation distance, then in such case the cost of coal could be based on the mining, processing, local transportation and handling, all estimated in economic prices.

74. Economic prices are exclusive of taxes. The coal mining industry in Myanmar is subject to 3% of royalty, 5% of commercial and 2% of income taxes which are applied by MOM. Zero import tax for coal has been already announced by Government.

75. In domestic market, coal has been traded at prices ranging from US$ 7 to US$ 40 per ton for

low quality and high quality coal respectively. The JICA study based on data from HPGE (Hydropower Generation Enterprise) as of August 2013 and the report of JCOAL (Japan Coal Energy Centre) (January 2013) reported the following reference prices of local coal. Coal prices were unified in USD at exchange rate of 1 USD=975 Kyats.

Table III-2: Reference Prices for Locally Traded Coal

JCOAL Report	**Location**	**Heating Value (kcal/kg)**	**FOB (US$/ton)**	**Transportation (US$/ton)**	**CIF (US$/ton)**	**Remarks**
	Kalewa	6,111	41 ~ 51	17 ~ 22	58 ~ 73 at Mandalay	Transportation fees are different by dry and rainy seasons
	Lasio 1	5,789	37 ~ 47	21	58 ~ 68 at Mandalay	
	Lasio 2	5,429	36	15	51 at Mandalay	
By HPGE	Tygit	3,920			31	for Mine Mouth Power Station

Source: JICA study

76. The average calorific value of Myanmar coal is reported to be around 5 200 kcal/kg whilst the largest coal deposits have higher values, mines in Kalewa and Tamu townships have calorific values of 6,516 and 5,662 kcal/kg respectively. The reference price is therefore taken from sub-bituminous coal imported from Australia.

77. The Newcastle 5,500 NAR (Net Calorific value in kcal/kg) has become an increasingly important grade of Australian coal and its daily assessment reflects the tradable, repeatable spot market price for coal in Asia-Pacific region. As of July-August 2014 the FOB prices of Newcastle 5,500 kcal/kg NAR thermal coal with typical ash of 20% have been at around $60 per ton.

78. As of July 2014, cost of dry bulk freight from Australia to East India in panamax type vessels is around US$ 17 per ton whereas cost from Kalimantan to East India is around US$ 11 per ton. On as-delivered basis, the price of Newcastle 5,500 kcal/kg NAR thermal coal has been approximately US$ 70 per ton in ports in Southern PRC and US$ 75 to 77 per ton when delivered to ports in Eastern coast of India. On this basis, the as-delivered price for Myanmar is fixed at US$ 75 including FOB price, the costs of sea born transport, receipt and handling at a coastal location of a power plant with its own jetty.

79. The costs of bituminous coal and lignite are not in direct relation of their calorific values to the reference coal of 5,500 kcal/kg. The current levels of FOB prices of bituminous coal and lignite have been estimated at 78 US$/ton and 30 US$/ton, respectively, as follows:

Table III-3: Assumed Cost of Coal

Type	NCV (kcal/kg)	Cost US$/ton
Bituminous	6,000	93
Sub-bituminous	5,500	75
Lignite	3,500	45

Source: Consultant's analysis based on FOB prices as of September 2014

80. The JICA consultants observed the high price differences of the CIF price of imported coal to domestic coal and recommended studies of the construction of the mine-mouth coal-fired plants and/or coal-fired plants in Mandalay Area in future subject to the improvement of infrastructure on bulk coal transportation to Mandalay Area and construction of the transmission lines to the national grid. The option of having mine-mouth power plants inland is indeed worthy of further studies but the constraints of transport infrastructure are significant.

IV. RENEWABLE ENERGY

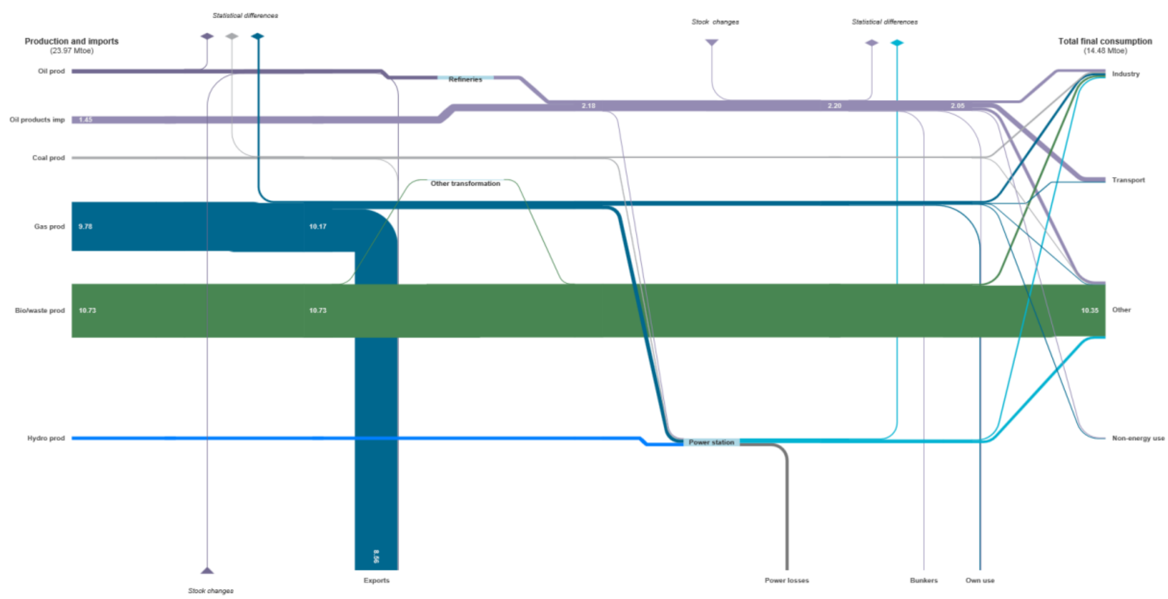
O. Introduction

81. Myanmar has significant oil, gas and some coal reserves, however currently it heavily relies on traditional forms of energy resources primarily in the form of biofuels and waste that account for as high as 71% of its primary energy resources. Figure IV-1 shows that in 2012, the consumption level of biomass/waste products was 10.35 MTOE (120.4 TWh) out of a total requirement of 14.48 MTOE (168.4 TWh). It is also understood that Myanmar has at least 4,000 MW of wind, and several thousands of megawatts of solar PV potential[11]. Until now, renewable energy other than hydroelectricity projects has not been adopted in a significant way in Myanmar.

82. By 2020, it is planned to achieve the 15% - 20% share of renewable energy in the total installed capacity. Most of renewable energy sources other than large hydro will be used for rural electrification purposes. The overall responsibility to promote the rural electrification has been recently transferred from the Ministry of Industry (MOI) to the Ministry of Livestock, Fisheries and Rural Development (MOLFRD). Roles and responsibilities on renewable energy in Myanmar are presented in Annex 6.

[11] NEP (2013) noted that two Chinese companies have estimated 4,023 MW of wind potential in Myanmar. Discussion with MOE suggests potential for 1,000 MW

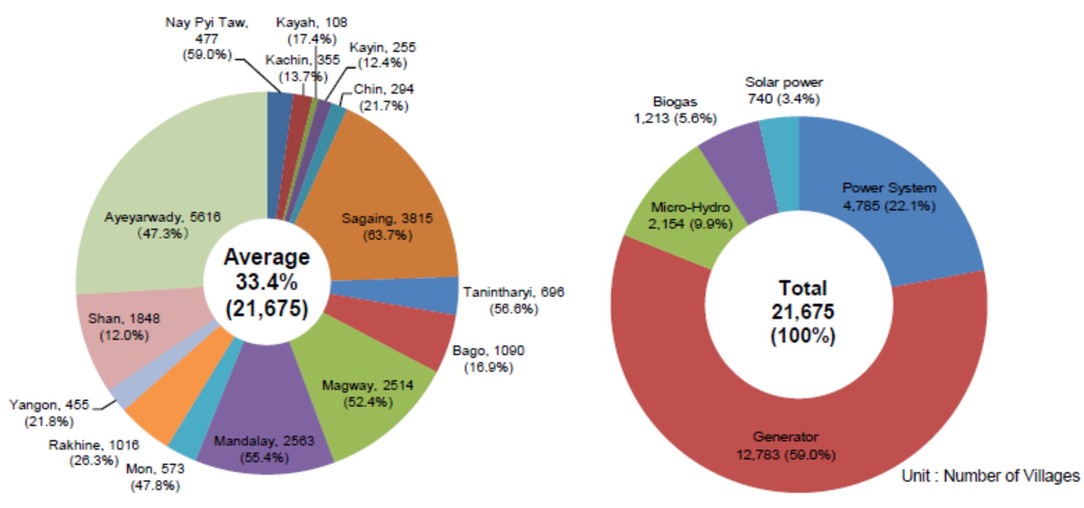
Figure IV-1: Myanmar Energy Balance (2012 data in MTOE)



Source: IEA website (http://www.iea.org/Sankey/index.html)

83. Nationwide average rural electrification rate is 33.4%. Area-wise electrification and its power sources for 2012 - 2013 are showed in Figure IV-2. As it can be seen, total share of renewable energy such as mini-hydro, solar and biogas in village electrification made up only 18.9% of the total. Main power source was local generation by mostly diesel engines. In the future, the share of renewable energy is planned to significantly increase, and various renewable off-grid power sources are among those preferred by the government.

Figure IV-2: . Area-wise Electrification and its Power Sources for 2012 - 2013



21,675: Actual Number of Electrification Villages until 2012-2013

Source: The Project for Formulation on the National Electricity Master Plan in The Republic of the Union of Myanmar. Draft Final Report. JICA et al., July 2014

84. The Ministry of Science and Technology (MOST) is currently pursuing to implement various rural electrification schemes focusing on the complete range of renewable energy option including solar energy, wind farms biomass bio energy, biomass thermo-chemical energy, and mini-hydro[12].

85. **Solar and wind energy**: MOST in coordination with the Mandalay Technological University has successfully tested 3 kW solar PV installations at six sites (i.e., 18 kW) but there has been no large-scale deployment of solar PV in the country. Similarly, MOST has installed wind turbines over 2008 - 2010 of 1.2-3.0 kW totalling 37.2 kW. MOEP's long term electricity plan includes 50 MW of solar to be developed in FY 2015 and 1,209 MW of wind by FY 2020[13].

86. **Biomass**: Biogas digesters with fixed domes have been identified as a technology with good potential in Myanmar to provide dual purpose of cooking gas and electricity, and to substitute for firewood. However, implemented biogas projects still fall well short of the biomass resources available in the country; further developments would require an enabling framework to be put in place for financing, implementation and maintenance of these projects.

87. **Biomass thermo-chemical energy** would use woodchip down draft gasifier to generate electricity for lighting purposes. Few pilot projects have been successful at several sites totalling up to 600 kW capacity installed over 2004 - 2009, but there has been no large-scale demonstration of the technology at this stage.

88. **Biofuel** can be used as an alternative fuel to reduce the dependence on import of liquid fuels. The Ministry of Energy issued specifications for biofuels and take responsibility for monitoring the distributed biofuels specifications. The Government pursues to reduce the CO_2 emission by increasing natural gas utilization in transport sector by converting gasoline, diesel and LPG vehicles to CNG vehicles and also using biofuels.

89. Also **geothermal** energy has been noted in the draft NEP 2013 as an option with "considerable potential for commercial development in Myanmar." A total of 93 sites have been identified, with 43 having been tested. Although the feasibility of generating electric power using geothermal resources has not been fully explored, this is currently under investigation and 200 MW of geothermal power has been included in MOEP's power development plan.

90. Myanmar has a complex **energy policy environment**. The Ministry of Industries, Science and Technology, and Agriculture are jointly entrusted with promoting renewable energy, and the Ministry of Environment Conservation and Forestry, and the Ministry of Agriculture and Irrigation deal with all biomass-related energy needs. This complicated structure of responsibilities sharing causes slow decision-making and approval processes and creates challenges for co-ordination of joint efforts done by the above authorities, as well as to conflicting or competing goals. For example, a hybrid solar-biomass facility would need the involvement of the Ministry of Environmental Conservation and Forestry (responsible for biomass and firewood), Ministry of Education (responsible for basic and applied research), the Ministry of Science and Technology (responsible for development of renewable power sources), and, if using direct combustion of biomass, the Ministry of Agriculture and Irrigation[14].

91. In addition to major institutional and legal framework regulating energy sector, some additional laws and norms have major direct impact on biomass and biofuel energy development. These include Forestry Law (1992), National Environmental Policy (1994), and National Sustainable Development Strategies (2009). The Renewable Energy Association of Myanmar (REAM), an NGO established in 1999, aims at increasing the living standards of rural people of Myanmar and to protect the

[12] MOST. 2013. Renewable Energy Research Activities – Current Situation Analysis. Myanmar
[13] MOEP, Power Development Plan, December 2013.
[14] Source: Accelerating Energy Access for All in Myanmar. UNDP, May 2013

environment through the promotion of the renewable energy applications.

92. Development of biomass, firewood and biofuel is challenged by environmental issues such as protection of the permanent forest area by reducing deforestation rate and increasing protected area system. Environmental issues related to energy are regulated by the Environmental Conservation Committee and the Ministry of Environment Conservation and Forestry, as well as through the Environmental Law.

93. Importance of the environmental issues related the use of biomass and general development of the country's energy sector is proved by the fact that in terms of greenhouse gas emissions related to change in land use and deforestation, Myanmar ranks third in the world, coming after Indonesia and Brazil. However, use or biomass can significantly help in fighting energy poverty.

P. Solar Energy

94. The GOM has a policy to support to the utilization of renewable energy and private investment in the electricity sector. The draft Power Generation Development Plan (PGDP) proposed by JICA financed electricity sector master plan study sets a target of renewables of solar, wind, biomass and geothermal to be developed by 2,000 MW, which is equivalent to 10% of the power supply capacity at 2030 as assumed in the draft document.

95. The GOM has a policy to support to the utilization of renewable energy and private investment in the electricity sector. Solar energy utilization by grid-connected photovoltaic technology (PV) has shown a remarkable worldwide progress. PV technology is increasingly cost competitive, no major performance degradation has been found in the large PV systems within the limited period of such installations, its maintenance needs are low and the power output is relatively predictable. PV technology therefore constitutes a low-risk investment which appeals to investors and private sector financiers. As to expansion planning, it has important assets such as a short lead time, flexibility as to locations, and good ability to respond to power regulation in the day time. In Myanmar, PV technology provides electricity at the time of daily morning/mid-day peak, and thus provides an opportunity to shift hydropower reserves for serving the evening peak. With all the above issues in mind, PV technology has been identified as a prospective element in Myanmar's future energy mix.

96. Photovoltaic technology converts incident solar radiation directly into electricity. The output is proportional to the radiation intensity, so the solar production can be calculated from the radiation data. The location within the northern tropical zone endows Myanmar with a high level of radiation. There is a seasonal reduction in radiation levels due to cloudiness during the monsoon rains. The Solar Energy Research Laboratory Thailand suggests Myanmar´s solar level at par with Thailand and above that of Laos and Cambodia. For comparison, Central Europe with a very active PV industry reaches only about 60% of these values.

97. Annexes 7 and 8 show the regional variation of solar radiation over the year. High monthly averages on a horizontal surface are 6.64 kWh/m²d, lowest values 3.27 (corresponding to 23.9 and 11.7 MJ/m²d). These values can be levelised with a suitable inclination angle. The national average is 17.61 MJ/m^{2}d and annual generation of 748.3 MW/m^{2}a. The PV electricity generation output is computed with a standard PV design program. Example results are for Myitkyina 1532 kWh/kWp output generation, or for Mandalay 1716 kWh/kWp, corresponding to 6178 MJ/kWp. The resource is abundant, and the utilization of solar resource in Myanmar can only be constrained by the cost competitiveness and the intermittent nature of generation output[15].

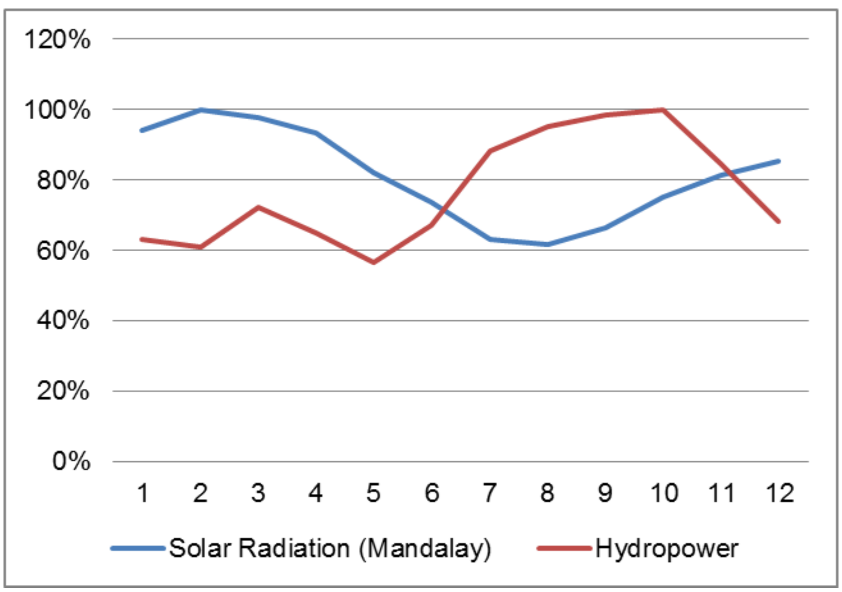
[15] These statistics have been presented by Heinz W. Böhnke, Renewable Energy Adviser under ADB TA-8356 MYA

98. Solar energy is available relatively evenly through the year in Myanmar, and its seasonal variation is in beneficial phase shift with hydropower output. When hydropower generation is at its lowest, solar PV yield is at its highest, and vice versa. This is in stark contrast to Europe and North-America, where solar PV provides electricity at its highest during the season of lowest electricity demand.

99. The daily variation of solar PV production is also advantageous in Myanmar. PV generation fits well to the daily load pattern even though it cannot provide for the evening peak. Hydropower has such a significant role in Myanmar's power system, that its ability to regulate on the daily level counterbalances largely what is often elsewhere quoted as the disadvantage of solar PV technology. Most of the hydropower in Myanmar is able to regulate on daily level, and therefore energy savings for day-time PV production can be used in the evening by increasing correspondingly hydropower generation. This feature is particularly important in the dry season. During that period several hydropower plants are both capacity and energy constrained, and may limit their operation to only peak time of the day.

100. Figure IV-3 demonstrates the countering seasonal shifts of hydropower and solar radiation (Mandalay). The annual maximum solar irradiation is in February and the minimum in July-August. For hydropower, the annual maximum output is received in October, when the reservoirs are filled after the dry season by rains, which typically start in May-June. For both forms of electricity generation, the difference between the annual monthly maximum and minimum is about 40%.

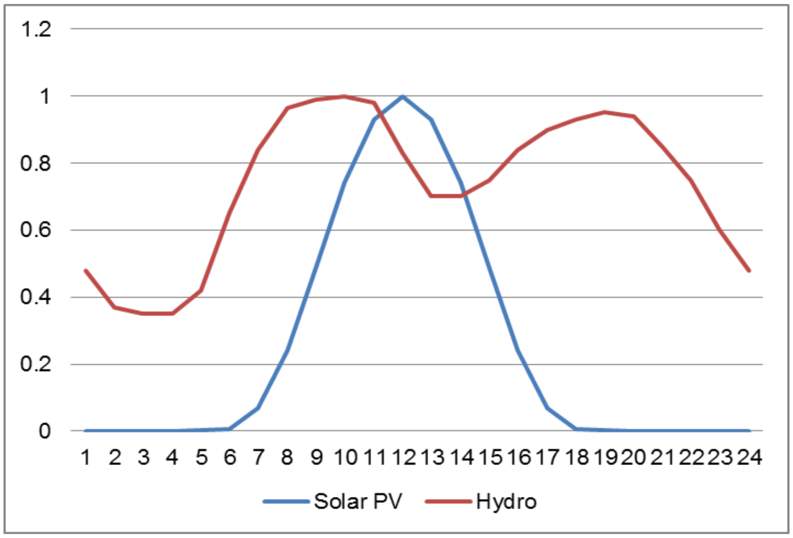
Figure IV-3: Seasonal Variation of Solar Energy vs Hydropower
(Monthly Output as % of that of the Highest Month)



Source: Consultant's analysis

101. As to the daily variation, solar PV power would contribute favourably to serving the day time high load, and hydropower capacity can be used to shift the corresponding energy generated by PV power to a time, which may be more critical during dry season, such as the evening peak.

Figure IV-4: Daily Variation of Solar Energy vs Hydropower (Output as % of that of the Highest Hour)



Source: Consultant's analysis

Q. Wind Energy

102. Myanmar has significant resources of wind energy. Government documents quote an estimated 365 TWh as the technical potential per year. Average wind speeds are the highest in the north most of the Kachin State, in the western coasts of the Chin State and the Rakhine State, and coastal areas of the Tanitharyi Region. The monthly average wind speeds at 50 m above surface are around 4 m/s in the best locations; however site specific optimization can naturally identify even better local conditions. Average wind speeds are presented in Annex 9.

103. Wind energy development is yet at the experimental and research phase in Myanmar. The evaluation of wind energy resources using modern systems has been conducted since 1998, led by the Myanmar Scientific and Technological Research Department and the Department of Meteorology and Hydrology. Other institutions have also conducted research and development on wind energy, including the Department of Physics at Yangon University and the Department of Electric Power (DEP) and the MOEP. This research was in cooperation with the New Energy and Industrial Technology Development Organization (NEDO) of Japan, which has constructed meteorological observation stations in Central and Lower Myanmar. Further, NEDO has assisted in installing wind and solar measuring equipment at several sites, to collect data and to conduct feasibility studies for wind-solar power hybrid systems.

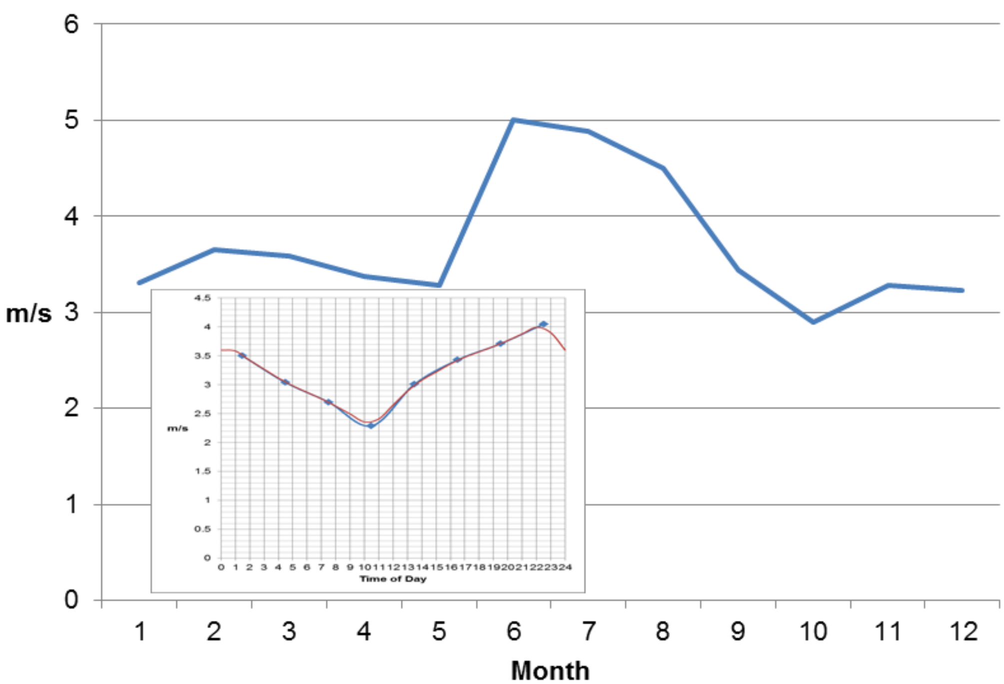
104. There are some wind turbines operational in Myanmar, including at the Technological University (Kyaukse), Shwetharlyoug Mountain in Kyaukse Township, the Government Technical High School (Ahmar) in Ayeyarwaddy region, and Dattaw Mountain in Kyaukse Township. It was perfectly utilized for lighting purpose in the township's monastery. Up to September 2011, 15-foot wind turbine (3 kW) of axial-type permanent magnet generator has been constructed and tested at the Shwetharlyoug Mountain. Three wind turbines of 1 to 3 kW has been installed under the Ministry of Science and Technology, and one of 500 kVA under organisations of Ministry of Industry. Overall

capacity is estimated at 519 kW[16].

105. For systemic point of view, wind energy is slightly less predictable and with a more unfavourable daily variation pattern than solar PV power when reflected against a typical load curve. Wind speeds are at their highest when the wet season starts from June to August. As to the daily pattern, wind power typically coincides well with the evening peak but the daily minimum seems to be during the morning peak hours. In this respect, solar and wind seem to complement each other. The monthly and daily variation of wind speeds is illustrated in the following graph.

106. As for renewable energy development, MOEP is in charge of solar and wind power project with IPP development. Currently (2014) there are two foreign companies with several developments in the country. Under their respective memorandums of understanding from 2011 with the Ministry, a Thai (Gunkul Engineering Public Co., Ltd) and PRC Three Gorges Corporation (CTG) company are carrying out feasibility analysis of building wind farms in several locations. The Gunkul Engineering Public Co., Ltd has seven sites in the Mon and Kayin States and in Tahintharyin Region, which would produce 1,000 MW and in Shan and in Kayah States, which would produce 1,930 MW. The PRC's Three Gorges Corporation (CTG) company is studying locations in the Chin State, Rakhine State, Ayeyarwaddy Region and Yangon Region to the capacity of 1,102 MW.

Figure IV-5: Monthly and Daily (Small Graph) Variation of Wind Energy[17]



Source: NASA

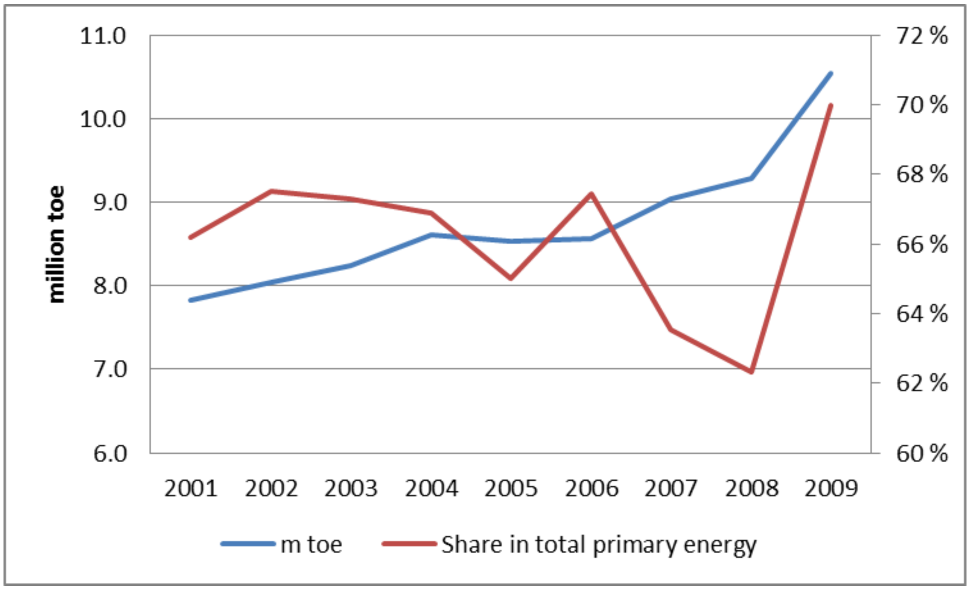
[16] Energy Sector Initial Assessment, ADB 2012
[17] Monthly average wind speed at 50 m above surface of earth (m/s) by NASA; typical location in Myanmar

R. Biomass

107. Myanmar has significant biomass and biogas potential: ca. 50% of total land area (33.5 million ha) is covered with forests, with available annual sustainable yield of wood-based fuels being 19.12 million cubic tons. Biomass energy is also provided through 18.56 million acre (7.5 million ha) of land generating residues, by-products, or direct feedstock[18].

108. **Firewood and charcoal** are the main bioenergy resources. Firewood is used for heating and cooking purposes by 76% of total Myanmar population both in urban and rural areas. Charcoal accounts to only 4% - 5% of total firewood consumption and is mainly used in urban areas. Total biomass (wood) energy supply in Myanmar for 2001 – 2009 is presented in the figure below.

Figure IV-6: Role of Biomass (Wood) in Total Primary Energy Supply



Source: Accelerating Energy Access for All in Myanmar. UNDP, May 2013

109. The woody biomass consumption estimate for rural households in 2012 was around 8 MTOE (out of total biomass consumption of 10.35 MTOE); the Consultant's respective baseline forecast for 2030 is about 9.3 MTOE. According to preliminary assessments, high electrification scenario may decrease woody biomass consumption of rural households to approximately 7.3 MTOE.

110. Myanmar's forest policy is currently designed to promote forest conservation and efficient use and management of forest resources. The policy is based on six principles: protection, sustainability, basic needs, efficiency, public awareness, and participation. In 2002, the Ministry of Forestry announced a long-term (to 2030) National Forestry Master Plan, including bio-energy. Despite an increasing population, firewood is forecast to decrease, reflecting greater reliance on energy efficient stoves and alternative energy sources (hydropower, natural gas). It is estimated that by 2030, firewood would account for less than half of the total primary energy. The firewood supply forecast is shown in the table below.

[18] Source: Myanmar: Country Assessment on Biofuels and Renewable Energy. Greater Mekong Subregion Economic Cooperation Program, March 2009

Table IV-1: Forecast Supply of Firewood as per the National Forestry Master Plan

	2002		2030	
Source	million m3	%	million m3	%
Plantations	1.06	3.4%	1.26	4.2%
Non-forest land	7.89	25.0%	7.44	25.0%
Community forests	0.06	0.2%	7.44	25.0%
Natural forests	22.54	71.4%	13.63	45.8%
Total	**31.55**	**100.0%**	**29.77**	**100.0%**

Source: Myanmar Energy Sector Initial Assessment. ADB, October 2012

111. A large share of firewood and charcoal production is linked to sawmilling, as offcuts and sawdust are used as a fuel. However, the shares of collecting wood directly as firewood and/or from commercial millers are not known to the Consultant. With this link, there is the continuing risk that heavy dependency on firewood and charcoal lead to depletion of the country's forests, and consequently also to increase of prices. Thus, the average price for firewood in Yangon increased by a factor of eight during the period of 1988 – 1997, and it further quadrupled from 1998 to 2004. The prices for charcoal increased by a factor of six between 1997 and 1998, and increased further by tripling from 1998 to 2004. Governmental efforts to reduce demand for firewood and charcoal through introduction of alternatives such as briquettes and fuel sticks (made from paddy husk, sawdust, charcoal dust or petroleum coke) have been so far insufficient.

112. **Rice** dominates the domestic agricultural sector. Each year, 21.6 million tons of rice husk from milling could create 4 million metric tons of fuel, or together with abundant bagasse from sugarcane production and sugar processing, it could be converted to energy at biomass power plants.

113. According to estimates of the Myanmar Engineering Society in 2012, the country possesses significant potential for **lumber waste, bagasse, molasses, and livestock waste**. These findings are presented in the table below.

Table IV-2: Biomass Energy Resources in Myanmar

Type	Quantity, tons per year
Lumber waste	1 500 000
Bagasse	2 176 000
Molasses	240 000
Livestock waste	34 421 000

Source: Accelerating Energy Access for All in Myanmar. UNDP, May 2013

114. Myanmar has 103 million heads of livestock (cows), particularly in its central regions. On average, one medium-sized animal produces 10 kg of dung per day, which is enough to produce 0.5 m^3 of **biogas** in an anaerobic digester. Over the past 10 years, about 152 community-based biogas digesters and associated power plants have been built, mostly in Mandalay, Sagaing, Magway and in the Northern Shan State. The digesters vary in capacity (25 – 100 m^3) and electricity output (5 – 25 kW). In addition to biogas, these digesters produce organic fertilizers which can be used in organic farming and fishery. In 2002, in a pilot project with a 50 m^3 fixed dome biogas tank, the tank unit cost was ca. 7 000 USD. Annex 10 summarizes the biogas energy projects in Myanmar.

115. **Biomass thermo-chemical energy** for power generation has relied mainly on paddy husk and bagasse, also sawdust can be used. To generate 100 kVA of electricity, a gasifier consumes nine baskets of rice husk per hour. Improved rice husk gasifiers can generate more than 1 MW of electricity. Research is on-going for development of woodchip and other forms of small-scale gasifiers capable to produce 30 – 50 kW of electricity for rural villages. Biomass gasification projects for rice husk and woodchips are presented in the Annex 11.

S. Biofuels

116. Biofuels considered for potential production in Myanmar include the following:

- Bioethanol – a substitute for gasoline produced from sugar- and starch-based crops such as sugarcane, cassava, paddy rice, or maize;
- Ethanol or gasohol – a gasoline blend referred to as anhydrous alcohol (at least 99.96%) blended with gasoline at a specified blended ratio;
- Biodiesel – a diesel fuel obtained from non-edible oil plants (e.g. jatropha, rubber seeds) and edible oilseed crops (e.g. palm oil, coconut, rapeseed, soybean) through a chemical reaction process;
- Biodiesel blend – biodiesel blended with diesel at a specified blended ratio.

117. Initially, the Government's energy plan assumed that gasoline would be gradually substituted with bioethanol (95% ethanol) to meet energy demand at the rural community level, and with gasohol at the national level. Diesel was planned to be substituted with a diesel-blend (from 5% to 20% of jatropha oil) at the community level, and biodiesel at the national level.

118. Myanmar has already cultivated ca. 2 million ha of jatropha, and also grows maize, cassava, sweet sorghum and sugarcane, each of them could be used for producing of biofuels. By 2015, the Government has had an ambitious plan to plant further 2.8 million ha of jatropha plants, producing 700 million gallons (ca. 2.6 million cubic meter) of diesel by that time. However, possibility to achieve this target is vulnerable to low yield from jatropha seeds.

119. Since Myanmar has experienced oversupply of sugar which led to decrease of sugar prices, this creates an opportunity for **bioethanol** production. Several private companies engaged in sugar production have already been active in this area. Sugar-to-ethanol conversion rate suggested by the MOE was 90 kg of sugar per 60 litres of bioethanol.

120. The first **gasohol** plant in Myanmar (with capacity of 500 gallons of 99.5% ethanol per day) was established in 2000. That time it was not economic as the cost of production (3000 MMK/gallon, ca. 792 MMK/litre) was twice higher than the gasoline price controlled by the Government. When the gasoline price sharply increased in August 2007 (from 330 MMK/litre to 549.9 MMK/litre), there was a renewed interest in the factory which was then transferred from the public Myanmar Sugarcane Enterprise to private ownership.

121. Since 2002, the Myanmar Chemical Engineers Group (MCE) has constructed four plants for 99.5% ethanol in Mandalay, Sagaing and Bago; their total capacity is 1.95 million gals/year[19]. The Myanmar Economic Cooperation has built two large bioethanol plants with combined capacity of 1.8 million gals/year[20]. Commercial production at these plants started in 2008. A private company Great Wall has also built an ethanol plant (3 700 gals/day) based on sugarcane, there was a plan to build a plant using cassava. Major bio-ethanol production facilities are listed in the table below.

Table IV-3: Major Bio-Ethanol Production Facilities in Myanmar

Plant Name	Capacity, gals/day
Ethanol distillery No 2 Sugar Mill (MCE)	500
Kantbalu Distillery (MCE)	3 000
Taungsinaye (MCE)	3 000
Mattaya Distillery (MCE)	15 000
MaungKone	37 500
Pyinhtaunglay	45 000
Total	**104 000**

Source: Presentation Material for Regional Workshop on GMS Country Experience in Achieving Performance Target. MOEP 1, MOE, MOI, August 2012

122. Myanmar transport sector experiences a quick growth, and **biodiesel** could be an attractive fuel option for the country. Domestic biodiesel production would allow reducing Myanmar's dependence on imported fuels.

123. As mentioned earlier, in Myanmar, biodiesel can be produced from a number of raw materials including crude palm oil and jatropha curcas oil; research and development works for biodiesel production are still on-going. There are several pilot plants using jatropha which was selected as raw material for biodiesel production because of its high oil content (36% - 38%), as well as due to existing experience of using it for biodiesel production in Indonesia, India and Africa. A small demonstration plant which needs six hours to refine 100 litres of jatropha crude oil to 97 litres of refined biodiesel may cost ca. 50 000 USD.

124. Oil content of different land races of jatropha curcas is presented in Annex 12. Jatropha production in Myanmar in 2010 – 2011 is presented in Annex 13.

125. Despite the ambitious start of jatropha-based biodiesel production project in 2005, its implementation faced numerous constraints such as difficulty in dissemination of technology, lack of capacity, presence of pest and diseases, problems during post-harvest, ownership issues, and marketing and processing concerns[21]. Since domestic fuel supply should have been increased without endangering food security, jatropha had to be cultivated in areas which were not suitable for edible species (such as on roadsides and under shades). As a result, low nutrient value, lack of fertilizers, narrow spacing and lack of systematic pruning resulted in only marginal yields.

[19] Source: Myanmar Energy Sector Initial Assessment. ADB, October 2012
[20] Source: Myanmar Energy Sector Initial Assessment. ADB, October 2012
[21] Source: Myanmar Energy Sector Initial Assessment. ADB, October 2012

V. HYDROPOWER

T. Introduction

126. Electricity generation in hydropower plants remains the backbone of Myanmar's power supply system. Hydropower is a logical solution to the country's growing electricity demand. Not only that Myanmar's geography and climate provide substantial hydropower development potential, hydropower as an energy conversion technology delivers one of the best conversion efficiencies of all known energy sources. It necessitates fairly high initial capital investment, but has a long life and low operation and maintenance costs.

127. Hydropower is renewable, and when developed responsibly, it offers significant potential for carbon emissions reductions and possibilities to address social needs of local communities in terms of rural electrification, irrigation, flood control and fresh water supply. On the other hand, environmental and social issues may also affect negatively hydropower deployment opportunities. If not developed responsibly, hydropower construction causes adverse impacts of methane emissions from reservoirs sites, poor water quality, altered flow regimes, barriers to fish migration, loss of biological diversity, and population resettlements. The impacts of hydropower are highly site specific. The challenge of Myanmar is to establish modern, environment science based planning with stakeholder consultations to support environmental and social sustainability of future projects.

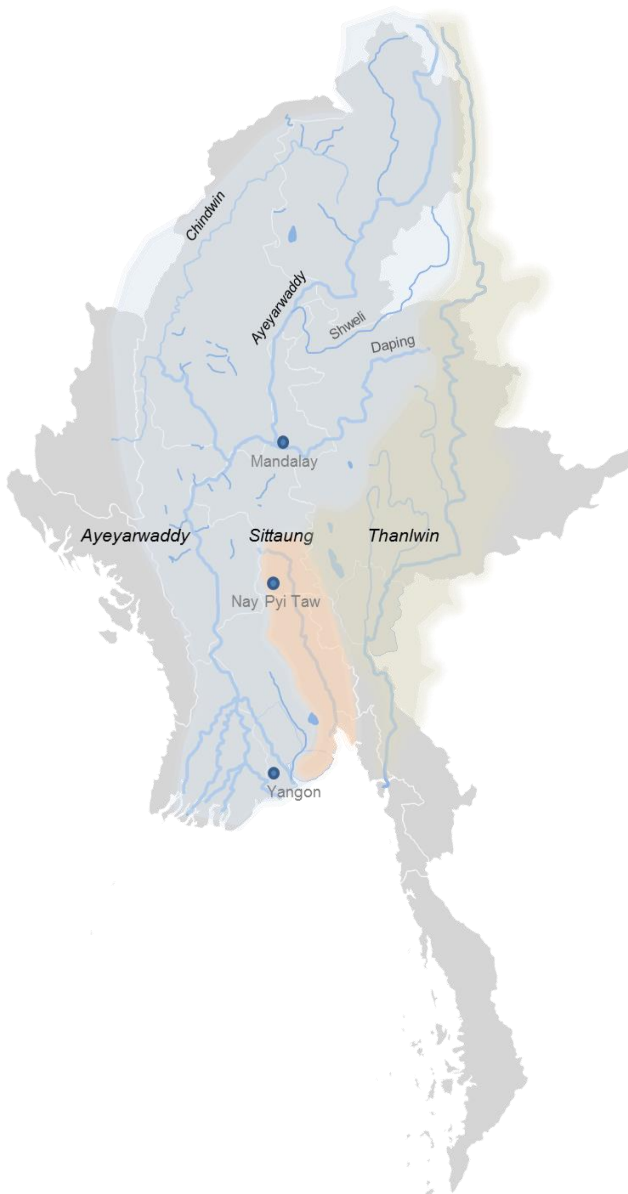
128. There are three distinct climatic profiles in Myanmar. One is formed by two mountainous regions, one in the west and the other one in the east of the country. The western mountainous region runs from the north-west of the country, bordering India, towards south and is characterized by mountains up to 5,800 meters above sea level, dense forest, and uplands. The eastern highlands is the Shan Plateau consisting of rolling hills and uplands at an elevation of about 2,000 meters, bordering PRC and Thailand in the east. The second climatic profile is in the country's central dry region surrounded by highlands and mountains in east, north and west. The third includes the coastal areas and the delta region through which the country's main river Ayeyarwaddy empties to the Andalan Sea. The delta region and central dry valley regions have the highest population densities and consequently highest electricity demand. Myanmar's largest city Yangon is located in the delta, whereas capital city Nay Pyi Taw and the second largest city Mandalay are in the central valley area.

129. The mountainous regions in the east, north and west of the country provide the necessary elevations for hydropower development. There are three major rivers, Ayeyarwaddy, Sittaung and Thanlwin, flowing through the country that provide for irrigation and hydropower generation (see Figure V-1). The largest river system, Ayeyarwaddy has a major tributary Chindwin, which is sometimes counted as an independent river system. There are no power plants constructed to the main rivers themselves, for various reasons, including that they are important transportation routes and that they run to a large extent through valleys with relatively small elevation differences. Their tributaries, however, gather the rainfall from the mountains and hills and provide the steepest creeks for hydropower construction.

130. Rainfall in Myanmar is highly seasonal. Most of the rainfall comes to the coastal and delta areas where there are limited or no possibilities to develop hydropower due to flat geography. The main sources of water are therefore Tibetan glaciers for Ayeyarwaddy and Thanlwin rivers; western mountain strip for Chindwin river and its tributaries; mountainous border area between Myanmar and PRC for upstream and mid-stream Ayeyarwaddy; and eastern Shan highlands for both Thanlwin and Ayerarwaddy rivers.

131. The rainfall is four times higher in coastal and delta regions, reaching 1,200 to 1,500 mm in the months from June to August, than in the rest of the country where the peak monthly rainfall is 200 to 300 mm. An exception is upstreams of Ayeyarwaddy in Kachin State where the monthly rainfall is around 600 mm in June. Generally the monsoon rains start in April and end in November. This causes hydropower generation to be seasonal unless water discharge can be regulated by having water reservoirs upstream of power stations. Selected rainfall data is shown in Appendix 15.

Figure V-1: Myanmar's Main River Systems



Source: Consultant's analysis

132. The **Ayeyarwady River** runs from north to south and empties through the delta into the Indian Ocean. The river was traditionally an important channel for trade and transport, a navigable way to

Mandalay and even further. The river headwaters are in the north partly on the Chinese side in Tibet mountain glaciers and partly in northern highlands from where the Mali and the Mai rivers feed it. Around 90% of the total drainage area is in Myanmar and covers around two fifths of the country's surface area. There is statistical evidence based on the earliest data from 19th century that the discharges from the sources to the Ayeyarwady River have been on decrease. The Shweli and Daping rivers are important tributaries, both running from west, and Shweli being a trans-border river with PRC. Daping joins Ayeyarwaddy River close to Mandalay.

133. The **Chindwin River** runs in western Myanmar, just inside the Indian border. For most part, the river flows in Sagaing Division. It has its origin in Kachin State where it is formed by a network of headstreams including the Tanai, the Tawan, and the Taron rivers. More south the main tributaries, the Uyu and the Myittha Rivers, join the Chindwin River. The confluence of the Chindwin and the Ayeyarwady rivers is at Myingyan in northern Mandalay Division, some 85 km from the city of Mandalay.

Table V-1: Myanmar's Major River Basins

	River	Length km	Basin Area sq km^2	Average Discharge (m^3/s)	Major sources and tributaries
1	Ayeyarwady	2,170	413,710	13,000	Tibet, Kachin State Tributaries Mali, Mai, Shweli, Daping Chindwin
1b	Chindwin	1,207	115,300	4,000	Rivers Tanai, Tabye, Tawan, Taro in Kachin Tributaries Uyu, Mu and Myittha
2	Sittaung	420	48,100	1,659	Bago mountains and Shan Plateau Tributaries Paunglaung, Thaunkyegat, Yenwe
3	Thanlwin	2,815	324,000	4,978	Tibet glaciers, Yunnan Shan and Kayan States Main tributary: Moei

Sources: Generally consistent hydrological data on Myanmar rivers is not well available. The above is partly based on MOAI presentation[22] and partly on public domain data collected by the Consultant.

134. **The Sittaung River** originates from the edge of the Shan Plateau and flows south 420 km and discharges to the Gulf of Martaban of the Andaman Sea. The broad Sittaung River valley lies between the forested Bago Mountains on the west and the steep Shan Plateau on the east. Main transport routes by road and railway from Yangon to the capital Nay Pyi Taw and further to Mandalay are in this valley. The Sittaug River despite being the smallest of the four river basins, holds a substantial number of Myanmar's hydropower plants which is logical given its nearness to the centre of electric

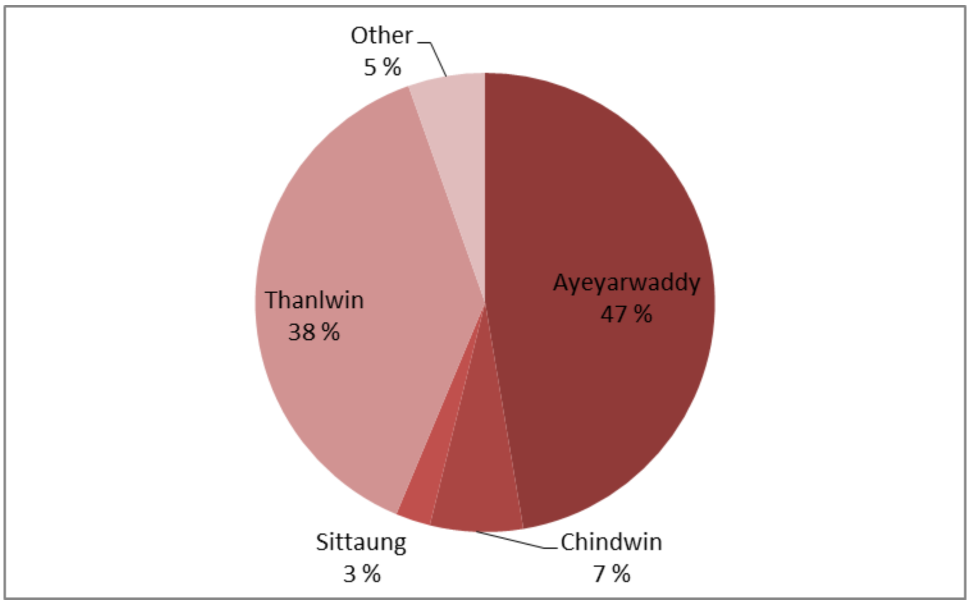
[22] Water Quality Management at River Basin of Myanmar. Presentation by Director Hydrology Branch of Irrigation Department, Ministry of Agriculture and Irrigation, 21st September, 2011.

load as well as irrigation and fresh water needs of the relatively highly populated area.

135. **The Thanlwin (Salween) River** is the longest river of the four main rivers. From the edges of Tibetan mountains the river runs in southern Yunnan province of PRC and arrives to the Shan plateau of Myanmar. In southern Shan, it is joined by its tributaries Pang, Hsim, and Teng. The river flows as a border river between Myanmar and Thailand, crosses Kayah and Kayin States until it reaches the river mouth located at Mawlamyaing coastal town in Mon State where the river descends to the Andaman Sea.

136. The overall hydropower potential in Myanmar is estimated at about 108 GW, of which slightly less than 3 GW is currently developed for production. During the recent years, the list of sites potential for development and their priority orders within it have changed. Some locations previously considered prospective for hydropower development have been considered environmentally too sensitive. Ministry of Electric Power (MOEP) presented in February 2013 generation expansion plan for the long term, which lists 58 projects with a total capacity of 45,344 MW at various stages for development. This amount and the underlying projects are considered in this study as the available hydropower potential for electricity system expansion[23].

Figure V-2: Hydropower Potential by River System



Source: Consultant's analysis based on MOEP data

137. Whilst the existing hydropower capacity has been built largely to the middle reaches of the Ayeyarwady and to the Sittaung river systems, the largest exploitable capacity is in the upstreams of the Ayeyarwady River and in the main stream of Thanlwin river. Potential in other river systems outside the major river basins include those in the rivers flowing in the eastern border area of Shan State and to some prospects in the coastal strip of western and southern Myanmar.

U. Existing Hydropower Plants

138. The installed capacity of hydropower plants in Myanmar totals 3,005 MW in June 2014. This

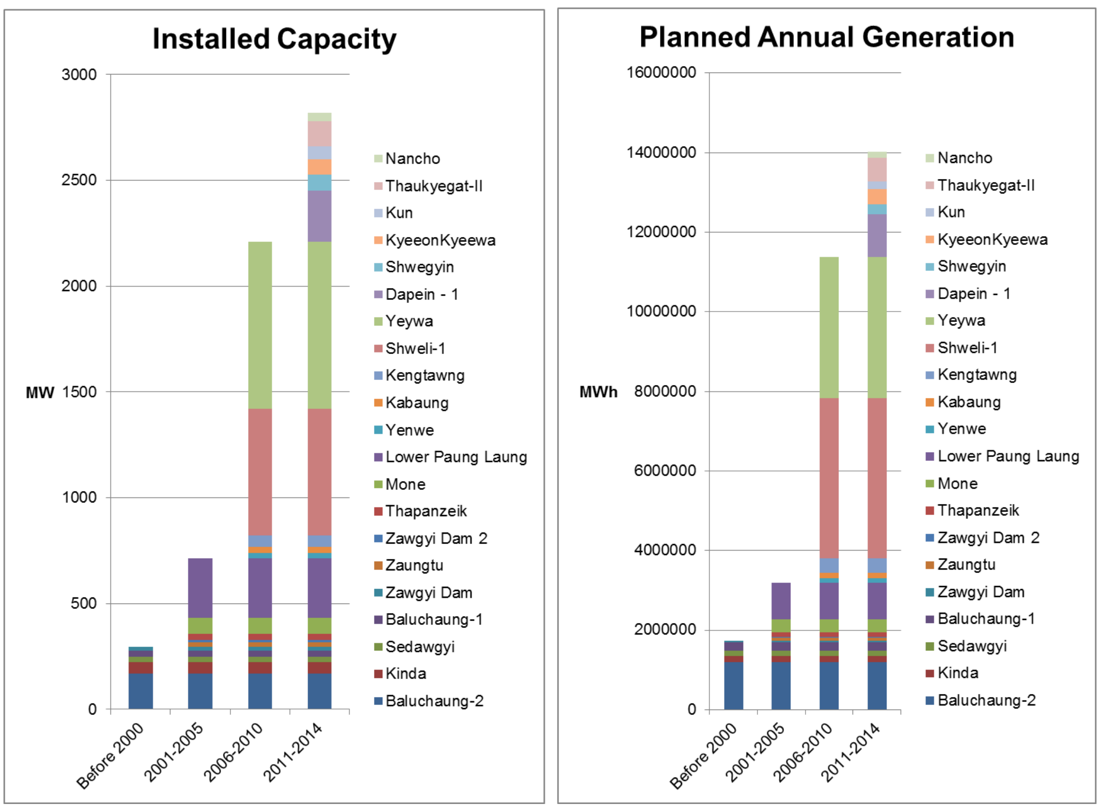
[23] Present & Future Power Sector Development in Myanmar, Ministry of Electric Power, 27 February 2013

includes 23 hydropower plants of installed capacity higher than 10 MW, and some 40 mini and micro hydropower plants of 34 MW in total capacity. The hydropower plants have been listed in Appendices II and III respectively. The planned annual hydropower generation totals to 14,956.8 GWh (excluding mini hydro). Twelve of the operating plants are within the Ayeyarwaddy river system, seven within the Sittaung river system and three within the Thanlwin river system. None of the currently operating plants are built to the main rivers but to their tributaries. The available capacity of Chipwenge plant of 99 MW, located in Kachin and commissioned in 2013, is limited to only 15 MW temporarily until a 330 kV power line will be constructed to the region, which is expected to take place during 2018-2020.

139. The development of hydropower begun in the 1954 with the construction of Baluchaung-2 in central-east Myanmar about 420 km north of Yangon. The plant was commissioned in 1960. It has an installed capacity of 84 MW. The plant was designed for an annual generation of 595 gigawatt-hours (GWh) to supply Yangon and, in 1963, Mandalay. The second stage was commissioned in 1974, also with 84 MW capacity and providing an additional 595 GWh.

140. In 2005, the 280 MW Paunglaung Hydropower Plant, about 20 km east of the new capital, Nay Pyi Taw, was commissioned. The hydropower development took a major leap during the consequent period from 2006 to 2010 as two major hydropower plants came on-line. Shweli-1 of 600 MW and Yeywa of 790 MW in installed capacity were commissioned in 2009 and 2010, respectively. They together represent 49% of Myanmar's installed hydropower capacity.

Figure V-3: Development of Hydropower in Myanmar



Sources: MOEP, MOE

Note: Part of planned annual generation is for export

141. Almost half of the number of hydropower developments in Myanmar is multipurpose schemes, in which provision of irrigation services plays important role. It permits the dry-season cropping of maize, peanuts, sesame, wheat, cotton, millet, and other dry crops. The installed capacities of the plants associated with irrigation dams are typically not high. Kinda (56 MW), Mone (75 MW), Paunglaung (280 MW), Sedawgyi (25 MW), Thapainzeik (30 MW), Yenwe (25 MW), Kyeeon Kyeewa (74 MW), Zaungtu-2 (12 MW) and Zawgyi (30 MW) plants are installed to large dams for irrigation. Their total electric capacity is 597 MW.

142. In cases of multipurpose schemes, the dams and reservoirs are managed and water rights owned by the Ministry of Agriculture and Irrigation (MOAI). Their operational pattern follows the irrigation needs in particular during exceptional years when water levels are either too low or too high. Thapanzeik is the largest multipurpose scheme in Myanmar and has one of the largest dams in Southeast Asia. It provides year-round water to an irrigated area of over 2,000 square kilometres (0.5 million acres) and has therefore substantially boosted agricultural production of the area. On the other hand, among the above mentioned plant the acreage for irrigated farming is rather low for Mone (75 MW) and Paunglaung (280 MW), which therefore are effectively running for electricity generation. Whilst MOEP is tasked with hydropower development, MOAI may also appear as a developer of hydropower facilities, when they are connected to irrigation. Kyeeon Kyeewa 74 MW plant is owned by MoAI.

143. With fiscal constraints for large scale hydropower developments, the government has recently entered into Joint Venture arrangements with foreign investors for selected projects. As to the Shewli-1 hydropower plant, the agreement with the PRC investor is that three of its six generating units will provide power to the Myanmar grid. Of the total generated electricity, 50% will be provided at no cost to Myanmar and an additional 15%, if required, will be provided at cost. MOEP records indicate that 49% of the electricity generated by the power plant since 2008, operating at about 75% of its potential capacity, has been transmitted to the Myanmar grid.

144. For the Dapein-1 hydropower plant (240 MW), also being developed by the PRC investors, 100% of the generated electricity can be made available to the Myanmar central grid and 10% of the generated electricity will be free power as royalty. In combination, the two plants will augment domestic supply by 324 MW. Similar ownership and power dispatch structures are also planned for many future projects included in the MOEP's power system expansion plans.

145. Government has also supported Build-Own-Transfer (BOT) structure in hydropower sector. Thaukyegat-2 (120 MW) and Chipwenge (99 MW) projects, both commissioned in 2013, have been funded by either foreign or local private sector under such schemes. Various Public-Private-Parnership (PPP) models are under consideration for further development of Shweli scheme.

146. Small hydropower projects have been built for border area development. According to Asian Development Bank's (ADB) Energy Sector Initial Assessment of 2012, since 2007 some 26 micro- and 9 mini-hydropower power projects have been developed by MOEP with installed capacity ranging from 24 kilowatts (kW) to 5,000 kW. These projects have included those for border areas, aimed at improving the social and economic conditions of poor rural households and remote communities. These mini-hydropower projects also facilitate cottage industries and enhance agricultural productivity through improved irrigation.

147. Village-scale hydropower projects range from primitive wooden wheel types to a variety of small modern turbine systems. Research on micro-hydropower plants, led by Ministry of Science and Technology (MOST), includes the design and construction of different types of turbines and synchronous generators for micro-hydropower plants.

V. Institutional and Legal Setting

148. The key institution for hydropower planning is MOEP who have responsibility for hydropower planning, construction and operation of hydropower plants. As mentioned above, in cases of multipurpose schemes, the dams and reservoirs are managed and water rights owned by the MOAI. The MOAI together with the Ministry of Livestock, Fisheries and Rural Development (MOLFRD) have broader responsibility for policy issues related to land tenure and land-use reform. The Department of Meteorology and Hydrology under the Ministry of Transport (MOT) is responsible for measurements, monitoring and assessment of rivers.

149. In recent years, the government has endeavoured to improve inter-ministerial co-operation by the establishment of special commissions to ensure coordination in planning and execution of multi-sector projects and projects with widespread societal impacts. The National Energy Management Commission (NEMC) was established in 2013 with a view to comprehensively address all energy demand and supply related issues. NEMC will have a major role in determining to which extent hydropower will be developed to cover the country's increasing electricity demand. NEMC has its patronage with the Vice President of Myanmar and its Chairman being the Union Minister for Energy.

150. The National Commission for Environmental Affairs (NCEA) was established in 1990. Following several institutional rearrangements as to its host organisation during the years it is today chaired by the Ministry of Environmental Conservation and Forestry (MOECF). The NCEA's responsibilities include ensuring sustainable use of natural resources, promoting environmentally sound practices in economic life, nature and environmental conservation and offering guidelines for environmental management, and international cooperation in its field. The NCEA with its limited enforcement capacity has, however, not developed to a strong safeguarding body to ensure that environmental issues are adequately addressed in decision making, but sector limitations still affect issues such as forest degradation or water resources management.

151. The key legislation with respect to hydropower development include the following acts:

- Conservation of Water Resources and Rivers Law (2006)
- Environmental Law (2012)
- Land Acquisition Act (1894)
- Vacant, Fallow, Virgin Lands Management Law (2012)
- Farmland Law (2012)
- Foreign Investment Law (2012)
- Environmental Conservation Rules (2014)

152. The people's awareness of and concerns over environmental and social impacts of large scale developments has increased in Myanmar during recent years, and a lot of public attention has been paid particularly to hydropower development. A number of NGOs, associations, religious groups and ethnically based associations take today active role in monitoring whether projects are planned and implemented considering protection of environment, mitigation of impacts, benefit-sharing, compensation, labour issues and human rights.

153. The legal framework is considered by many analysts and consultants still as too weak to enable sustainable hydropower development in the future without risk of major socio-political and ethnic controversies. Under the new laws on farmland tenure and fallow lands management, the farmers still lack land tenure security. MOAI may confiscate lands demarcated as wastelands from subsistence farmers without compensation. The small farmers ability to influence and challenge land

classification in cases where lands are cultivated with traditional manner is limited. The Environmental Law has been criticised of too low penalties as compared to the economic interest of developers in large scale projects.

154. The environmental law did not yet require environmental impact analysis (EIA) to be carried out systematically and by independent agencies and consultants, and NCEA did not have authority to commission them. There were no formalized, regulation based process of public consultations with local communities and hearings of interest groups. However, the Environmental Conservation Rules (2014) indicated requirement of conducting EIAs prior to proposed projects are approved.

W. Energy Contribution and Availability of Hydropower

155. Electricity system planning should include a probabilistic analysis of hydropower capacity by extracting a series of overlapping short-term river discharge sequences directly from the historical records, which includes the extreme droughts, and then simulating reservoir operations over this interval for each sequence. However, for master planning purposes modelling of individual plants and reservoirs is not necessary, and possible within the overall scope of this study, whilst it is still of utmost importance to understand the frequency and impact to the total electricity generation of extreme dry seasons.

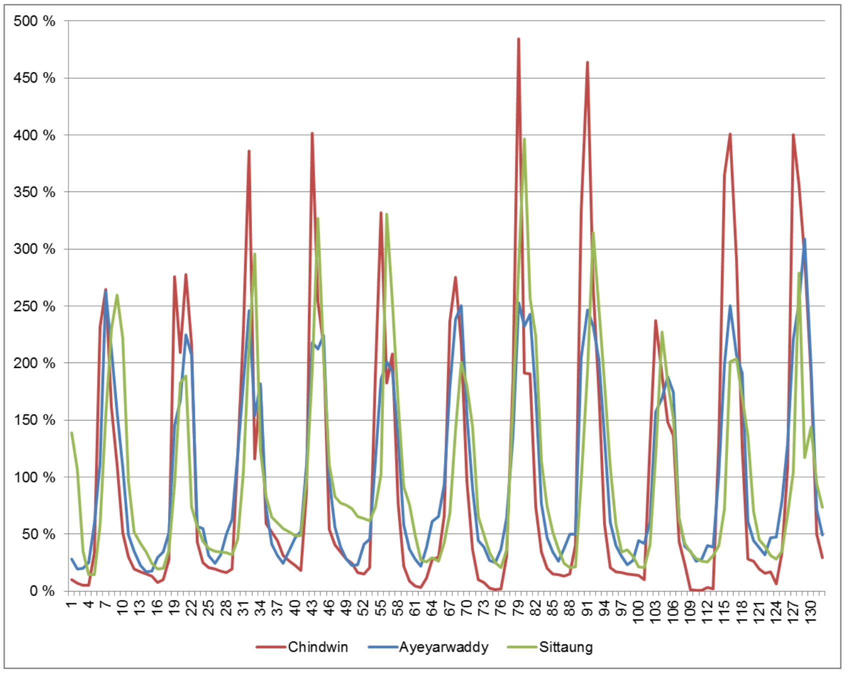
156. Dependable hydropower capacity is typically defined deterministically as the capacity available in the worst drought on record. Most modelling approaches today, however, take into account all historical hydrological years, whether they are dry, average or wet. A Monte Carlo simulation model can be used to generate synthetic discharge data that preserve the statistical properties of the historical river discharges including extreme droughts and floods.

157. Whilst some hydrological data has been available to the Consultant, needed technical data on major plants and reservoirs and statistics on coincident historical hydropower generation have not been available. Therefore the key assumptions on hydropower in electricity system expansion planning are deduced here based on both professional judgement and analysis of empirical data.

158. Dependable capacities for operational plants as of 2011 have been given by ADB Initial Energy Sector Initial Assessment, in Appendices Table A5.2. However, the basis of determining the given numbers has not been defined. Some figures on the table do not seem to match the criterion of dependable minimum capacity defined as representing worst drought on record. The concept of ‘firm capacity’ is also used in many consultant reports of Myanmar electricity sector, including the above mentioned. However, in most sources and government presentations it is calculated as the average annual capacity resulting from the designed annual electricity generation of the plant. Such ‘firm capacity’ is not dependable capacity firmly available during a drought, which is chosen to be the basis of calculations of supply deficit on selected probability level.

159. Furthermore, data on the water reservoirs and water release cycles of Myanmar hydropower plants remain to be collected. Based on available data, it seems for most plants the cycle is relatively short, for instance, storing water at night for daytime power generation. Such “run-of-river” plants have relatively low dams and high correlation of electricity generation to natural river discharge. For Myanmar, the storage capacity extending for about six months from wet season to dry season would be most essential. It would also be beneficial if some projects could operate on multi-year cycles carrying over water in a wet year to offset the effects of dry years.

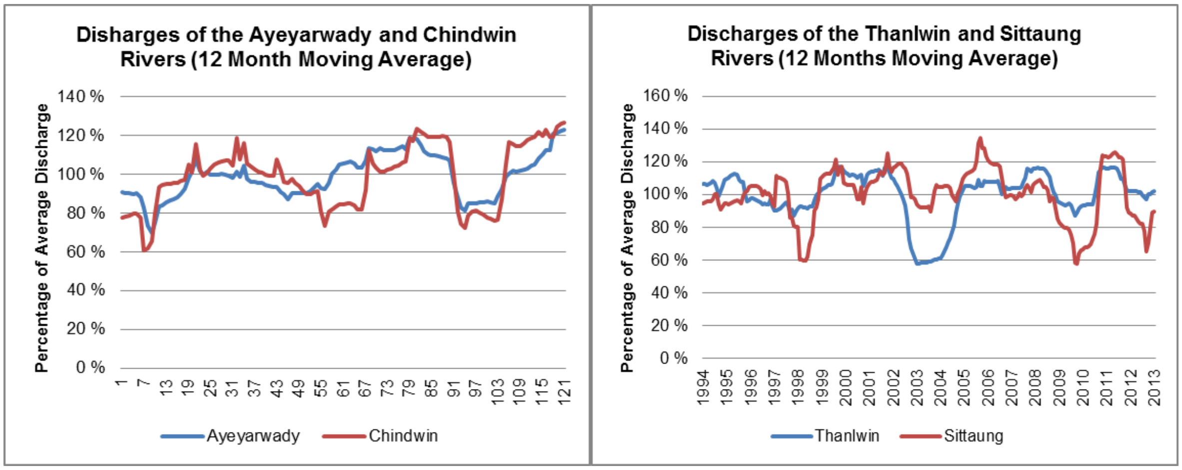
Figure V-4: Seasonal Pattern of River Discharges in Myanmar (Monthly Discharges as Percentage of the Long-Term Average)



Source: The Global Runoff Data Centre (GRDC), 50068 Koblenz, Germany. The monitoring stations are located upstream of the Chindwin and Sittaung rivers, and in Mandalay region for the Ayeyarwaddy River.

160. The seasonal variation of Myanmar river discharges is very sharp and the difference between dry and wet season is distinct as seen on Figure V-4. The impact of monsoon is most significant for the Ayeyarwady, Chindwin and Sittaung rivers, whereas the Thanlwin river, which has its sources in the Chinese side of border up to Tibetan heights, has slightly different discharge profile. The 12 month moving average river discharges from 1994 to 2014 of the Sittaung and Thanlwin rivers are shown in Figure V-5.

Figure V-5: Long-Term Discharge Variation of Myanmar's Main Rivers



Source: The Global Runoff Data Centre (GRDC), 50068 Koblenz, Germany for the Chindwin and Ayeyarwady rivers. Myanmar Ministry of Transport, Department of Meteorology and Hydrology for the Thanlwin and Sittaung rivers (data series 1994-2013).

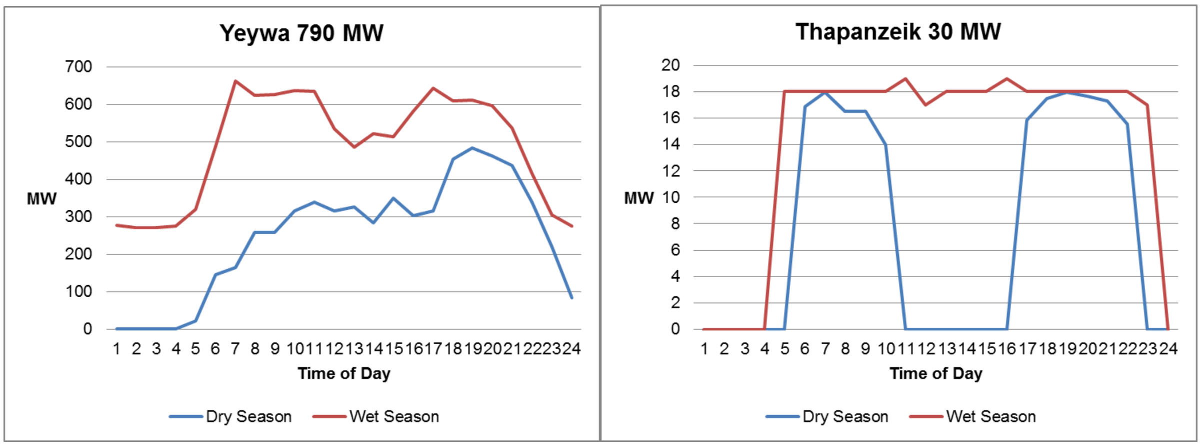
161. Some observations relevant to the availability of Myanmar's hydropower capacity to serve the peak and to the dimensioning of the needed capacity reserve can be drawn from the hydrological data as follows:

- The phenomenon of a relative drought can be seen in both data samples of the above figure. As a large river, the Ayeyarwady has the smallest variation in annual discharges as its 12-month month moving average discharge varies only between approximately 80% and 120% of the long-term average.
- The rivers Chindwin, Sittaung and Thanlwin, all seem to have annual variation between approximately 60% and 120% of the long-term average. The likelihood of annual discharge minimum of 60% seems to be about 10%. In the data of the Chindwin river, such dry year occurs once in the 11 year sample. The second data set covering 20 years from 1994 to 2013 on the Thanlwin and Sittaung rivers indicates two consequent dry years (2003-2004) for the Thanlwin river, and two for the Sittaung river (years 1998 and 2010), again indicating approximately 10% likelihood for such event.
- In the long-term, diversification of the hydropower capacity over the three main river basins seems a reasonable strategy for Myanmar. The correlations in annual river discharges between the Chindwin, Sittaung and Thanlwin rivers seem to be small, which provides higher energy availability and dependable capacity in all-country level than if the correlations were high. Correlation between annual (12 month moving average) discharges of Chindwin and Sittaung rivers is only 27%, and correlation of the Sittaung River and Thanlwin River 12-month moving average discharges is 35%. These results confirm the visual observation from the above graph that the extreme dry years are not necessarily simultaneous between the river systems whilst it can also be observed that a drought in one does not coincide with high discharges in another.

162. The critical time in Myanmar's electricity system is the end of dry season, which normally happens in April. The water reservoirs of plants with storage are then at their lowest levels. The low

levels of water reservoirs cause the hydropower system be constrained both for serving the daily peak demand and for providing base load energy. Some plants may have water reservoirs to serve only one peak per day (morning or evening peak) and with some, the overall reservoir levels are low so that plants cannot reach their design capacity as the available head is lower than the design value. There are plants, which are able to provide some base load, such as Balungchaung 2 and Shweli, but other plants are more constrained. The following two graphs illustrate how Yeywa is energy constrained during dry season. In the case of Thapanzeik plant an operating regime is illustrated, where water is reserved for only day time operation. During dry season it too is highly energy constrained but maintains the peaking capacity at the same level as in the wet season. In both cases typical dry season available capacity is substantially lower than the installed capacity.

Figure V-6: Examples of Energy and Capacity Availability during Wet and Dry Season



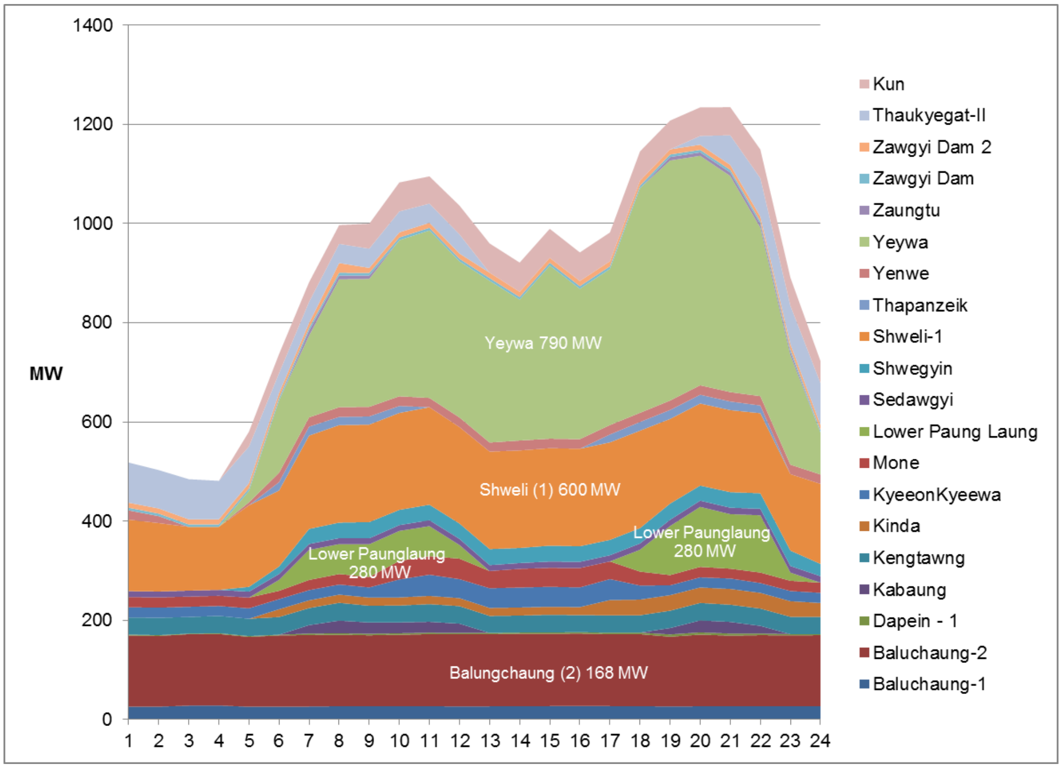
Source: Consultant's analysis

163. A typical daily production profile of hydropower during dry season is shown in Figure V-7. The key plants contributing to providing base load are Balungchaung 2, Shweli and Yeywa. Lower Paunglaung plays important role in serving the morning and evening peak loads.

164. The draft National Electricity System Masterplan issued in 2014 by Japanese International Cooperation Agency (JICA) and prepared by Newjec Inc. and the Kansai Electric Power Co., Inc chose the planning criterion by assuming the dry season power supply from hydroelectric plants decreases 30% compared to wet season production. Hence it was assumed that wet season capacity represents 70% and dry season capacity 50% of the installed capacity.

165. Expansion planning under this Energy Master Plan (EMP) is based on a fixed capacity constrain and generation profile of hydropower in Myanmar. The dispatch model will need to assume (i) the available capacity by month, (ii) the profile of daily output of hydropower during dry season and wet season, and (iii) the available hydro energy per month. The generation profiles and constrains are set on grounds of the features of the current capacity. They are assumed to remain unchanged to the future also for the new capacity.

Figure V-7: Typical Structure of Hydropower Generation during Dry Season

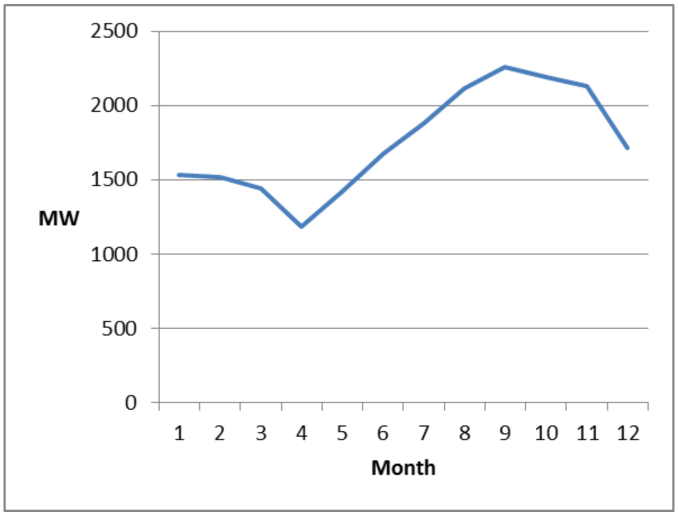


Source: Consultant's analysis

166. The available maximum capacity is assumed from the JICA study to be 50% of the installed capacity. This assumption is considered valid through the planning period until 2035 and represent a normal year. It is realized, however, that this assumption should be tested. The reservoir and plant operations, and consequently available capacity during day time in April should be simulated over an interval during which the annual river discharges would average about 60% of their normal level representing around 10% likelihood of drought (in relative terms).

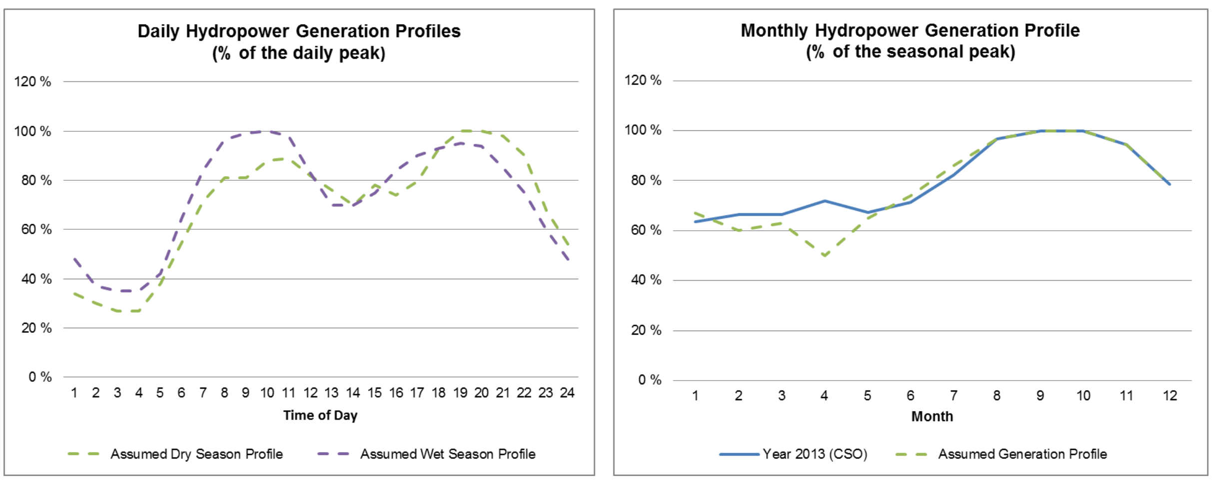
167. The overall available capacity is assumed to have monthly profile as shown in Figure V-8. The minimum is set to April and the maximum to September. The maximum available capacity is assumed to develop gradually between the maximum and minimum, because of time needed to fill up the reservoirs, and the gradual lowering of the reservoir levels after the rainy season.

Figure V-8: The Assumed Monthly Maximum Available Capacity (2013)



168. Assumptions for the monthly and daily generation profiles are given in Figure V-9. They are based on the data set given by MOEP including estimates for typical generation output during dry and wet season, plant by plant for all hydropower stations in Myanmar. Minor adjustments have been made for the purpose of gathering the peaks and minimum loads more accurately in the dispatch model. The monthly generation profile follows the realized 2012 and 2013 monthly profiles in broad terms. Minor adjustments were made which were considered necessary to make the profile more representative of an average for long term, such as that April as the driest month in the end of dry season was set to be the lowest in energy yield.

Figure V-9: Assumed Typical Hydropower Generation Profiles



Source: Consultant's analysis

X. Cross-Border Co-operation in Hydropower Development

169. Myanmar has been actively developing foreign cooperation in hydropower development. The recent shift towards an economic reform in Myanmar further supports regional cooperation as new legislation and free trade agreements offer economic opportunities for foreign investors. The authorities have taken steps to unify the multiple exchange rates, to prepare a new national development plan and to pass a foreign investment law that will offer tax breaks to investors and to setup businesses without the need for local partners. In addition, the increased development assistance and reduced sanctions have raised hopes for renewed economic opportunity.

170. Myanmar is located between the geographic and political regions of South and Southeast Asia and PRC. With demand on electric power in PRC and throughout South and Southeast Asia on the rise, as well as the need to encourage 'clean' energy options, hydropower is becoming an increasingly popular alternative to more environmentally harmful energy forms. The differences in energy endowments, level of development and energy consumption needs have driven the region to push for resource sharing and interconnecting resulting in an increasing focus on energy trade and cross-border hydropower development. The existence of the regional cooperation initiatives, the Greater Mekong Subregion (GMS), the Bay of Bengal Initiative for Multi-Sectoral Technical and Economic Cooperation (BIMSTEC) and the Association of Southeast Asian Nations (ASEAN), further boosts this development, as they all emphasise energy as one of the priority areas of cooperation.

171. The neighbouring countries, India, Bangladesh, PRC and Thailand, are potential cooperation partners for hydropower schemes and importers of the planned new hydropower capacity. Both India and PRC, though investing heavily on domestic hydropower, are also interested in importing to their large power market where demand growth constantly exceeds the supply growth. PRC and India also seek strong bilateral relations with Myanmar to ensure continuous access to resources and to maintain a major role in the region's energy market.

172. For PRC, Myanmar is also an important southwest link to Bangladesh and India. India's eastern states form nearly a third of its population while being amongst the most underdeveloped areas and could benefit from cooperation with Myanmar, ASEAN and BIMSTEC. Furthermore, many of Myanmar's neighbours have ambitious electrification targets. For instance, the Government of Bangladesh has set a target to electrify the whole country by 2020. Thailand's interest in Myanmar's resources is a combined result of the depletion of domestic resources, pressure to diversify electricity sources, electricity demand growth, resource availability in Myanmar, and rising environmental awareness in Thailand.

173. Neighbouring countries' increasing interest and dependence on imported energy has led to numerous plans for exploiting Myanmar's hydropower resources, within the technical and economical limits, and to export this power to Thailand, PRC, India and Bangladesh. It has been observed that PRC is the most important partner for Myanmar when it comes to financial, political and technical support for hydropower development. According to some estimates at least 45 Chinese corporations have been involved in approximately 63 hydropower projects in Myanmar, including some related substation and transmission line projects.

174. Plans for dams on the Thanlwin, Ayeyarwady and Shweli Rivers with financial and construction support from PRC are estimated to be between a combined capacity of 20,000 MW and of almost 40,000 MW, although current confirmed projects are of a combined capacity of only a couple of thousand megawatts. Thailand's interests in Myanmar's hydropower target the potential of the Thanlwin and Tanintharyi river basins in the eastern part of the country, whereas possible Indian projects would be located in the Chindwin river on the western border region. The status of these projects is currently unknown, as due to Myanmar's continued political instabilities as well as

environmental and social considerations some of the cooperative schemes have been postponed and cancelled.

175. Myanmar has potential to be the energy bridge between South and Southeast Asian energy systems, while hydropower could foster regional development and a safer energy future for Myanmar and the neighbouring countries. Increased cooperation between PRC and South and Southeast Asian countries can result in enhanced economic and political opportunities: technology transfer and human resource development; diversification of energy forms and lowering cost of energy; strengthening of smaller exporting economies; optimisation of the management of water resources, and; reduction of supply costs. Economic integration can also create mutual trust and understanding. Meanwhile, a long-term process of regional cooperation effort calls for harmonisation of energy policies and promotion of a legal and regulatory framework favourable for regional trade. An integrated regional hydropower development plan, which would comprehensively support sustainable regional energy cooperation and ensure shared benefits and responsibilities to all the cooperative partners, is needed.

Y. Environmental and Social Safeguards

176. While hydropower brings numerous economic, technical and financial benefits, also significant negative social and environmental impacts are predicted. Many of the proposed dams remain non-researched or under-researched, making it particularly difficult to assess the exact impacts of the projects. Another complicating factor in estimating the impacts of the dams is the uncertainty over which dams will be built and their configuration and construction sequence. As numerous plans on large mainstream hydropower projects have been introduced, increasing number of concerns have been raised by different environmental and human rights groups on the environmental, social and political impacts of the hydropower projects.

177. A preliminary EIA conducted by an environmental group on the planned dam cascade in the upper Ayeyarwady basin, commissioning of which has not yet been confirmed, finds that potential multiple impacts from dam building on biodiversity, wildlife species, aquatic ecology, subsistence fishing, rice cultivation and local livelihoods can be anticipated. The planned hydropower projects on the Thanlwin River are expected to seriously affect the ecological conditions by flooding vast areas and changing the river flows in the downstream reaches, including the delta, causing salt intrusion. An extensive damming scheme would also affect the future sediment flux, which could impact the densely populated delta regions, where sedimentation and seasonal flooding are important for rice growing. In terms of energy and food ‘security, the rivers form a particularly critical resource. Unfortunately, the two forms of security seem not to be complementary, but largely contradictory: increasing energy security through large-scale hydropower could radically reduce the food security. Based on impact assessments done on the dams in Mekong, the construction of mainstream dams will affect fish biodiversity in Myanmar, with cumulative fish loss and reduction of capture fisheries. Fisheries are the fifth largest earner of foreign exchange and fish is also a major part of the diet in Myanmar.

178. Further, the foreign-owned hydropower development potentially threatens national sovereignty over water resources. While hydropower infrastructure can improve flood control in the wet season and benefit irrigation during the dry season, communities living in the vicinity of the hydropower site may remain without electricity and have other elements of their security, such as food, water or livelihood, undermined. Meanwhile, the adverse social and environmental impacts are disproportionately burdening the rural ethnic communities in the immediate watersheds, while the energy importing countries receive many of the positive political and economic impacts.

179. Based on the guidelines by the World Commission on Dams, when assessing the needs for water and energy services, the plans for water and energy development need to reflect the local and

national needs adequately as well as the needs and priorities between and within sectors. In this context, grid electrification of the rural communities close to the hydropower sites should be given high priority in the grid expansion plans, and such measure should be an integral part of social impact mitigation. To gather acceptance to further hydropower development, new hydropower plants should not be built without villages around the site and reservoir, which are impacted by the scheme, to be electrified by the grid in the event the electrification has not taken place earlier. Suitable criteria for such electrification should be developed.

180. As a specific sensitivity in Myanmar, hydropower development can lead to conflicts between ethnic minorities and the dam developers, since many of the planned dam sites are located in the ethnic minority areas. Some human rights organisations have listed abuses such as forced seizures of land, submersion of villages as well as large areas of forests and arable lands, displacements, inappropriate resettlement, forced labour, disregard for local people's rights and the loss of ethnic sovereignty over natural resources. Many people are directly dependant on land and water resources for their livelihoods, with impacts on natural systems directly linking to their social and economic wellbeing, while lacking secured access to them.

181. Despite these numerous concerns, it is believed that the impacts of the planned dams can be mitigated making further hydropower development in the country possible. However, impact should be appropriately assessed, the developers should develop monetary and non-monetary benefit sharing schemes with the local communities, and generally more effort and financial resources should be allocated to mitigation.

182. Based on experience from the Mekong river, where number assessments have been made on the extensive dam development plans, it is recommended that the impact assessments should be holistic and comparative, instead of sectoral approaches looking at impacts separately on water flows, fisheries, livelihoods and economy. Sectoral assessments should be complemented with broader, cumulative assessments looking at the combined impacts of all known hydropower development plans to result in an impact range that would provide a more coherent picture of the expected social, economic, and environmental impacts. Further, transparency and inclusiveness are particularly important as the decisions relate to complex systems and can lead to high economic and social gains and costs.

183. Rapid changes such as development projects, which outpace institutional capacity to absorb them, can create stress on socio-economic and geopolitical systems. The responsibility of the foreign investors and financiers needs to be emphasised in countries like Myanmar lacking to some degree own institutional strength to address these issues. Sometimes companies conducting feasibility studies for dams simultaneously serve as financiers, builders and regulators of hydropower projects resulting in a blurring of lines between these roles. The sheer number of public and private actors involved in Myanmar's hydropower industry raises transparency and accountability issues due to the multiplicity of players involved.

184. Environmental conservation rules enacted in August 2014 indicated requirement to conduct pre-project EIA for proposed projects. Environmental Conservation Department of MOECF undertakes reviews of the hydropower project proposal from the environmental point of view and they also review the EIA reports submitted by contractors. Thus the environmental and social standards and practices employed by the investors themselves are extremely relevant in the host country. The contractual agreements under which the companies operate abroad determine the nature and scope of the company's involvement. Equitable contracts should play an important role in ensuring appropriate sharing of benefits and responsibilities. According to the guidelines by World Commission on Dams, the agreements should be verified to have mechanisms in place for benefit-sharing, mitigation, compensation, development and compliance measures.

185. Appropriate planning and management coupled with analysis of social and environmental impacts would ensure that development is premised on shared benefits and sustainability. Concerted effort is necessary to assess benefits, costs and uncertainties of the development plans, in order to maximize their sustainability and equality for all riparian people.

Z. Cost Analysis

186. Hydropower is a capital intensive technology and requires long lead times for development and construction. It is also very engineering- and design intensive. Before financing can be secured, substantial effort needs to be put on site surveying, feasibility analysis, planning, preliminary civil engineering design, environmental and social impact analysis, planning of resettlement measures, fish, water quality and biodiversity mitigation, and analysing ways to preserve historical and archaeological sites. Therefore lead times for hydro power schemes can easily vary from two to up to 13 years and even more and the owner's development cost prior to construction may represent up to a quarter of the total cost of a hydropower scheme.

187. The construction costs for new hydropower plants are unique and site specific. The costs can be roughly considered in two major areas. The first area is the civil works, which dominate in the cost structure of a hydropower plant. The works include dam and reservoir construction, tunnelling and canals, powerhouse construction, site infrastructure and grid connection. The second component, electro-mechanical equipment, is mature technology and its cost correlates relatively strictly with the capacity of the hydropower plant. The electro-mechanical equipment account normally not more than 15-25% of the total cost of the scheme,

188. A typical estimation of the construction costs requires detailed physical dimensions of the major civil components, which depend on the hydrological characteristics of the river affecting the dam structure, safety requirements and spill capacities, site and its terrain, and access road and electrical connections. The needs of the power system determine whether the plant is designed for base load supply, middle load, peaking and whether the plant will contribute to system regulation and frequency control. The optimum MW/MWh ratio will be established and the characteristics of electro-mechanical equipment, such as with how many generating units and of which capacity, the plant will be equipped.

189. The usual means of estimating construction costs is a bottom-up approach, where using the physical parameters and "cost of construction" factors, such as specific costs ($/m^3) for material volumes – e.g. for building the dam, costs for each main component are estimated separately, and finally summed up.

190. In the context of EMP, there is no opportunity to carry out a bottom-up cost estimation exercise for candidate projects of future hydropower capacity expansion. Cost estimates should be developed, which are sufficiently justified to be used for expansion planning but which can be applied without going to the details of the plant design and construction. Therefore a short statistical analysis was carried out on the total costs of past hydropower developments in Myanmar thinking that the costs of future plants would follow essentially the same trajectory.

191. The cost information on Myanmar's hydropower plants was made available by MOEP in original currencies and in nominal values. Construction costs were then adjusted to reflect 2014 level. The cost data was assumed to represent the year of average between the year of starting construction and starting operation. The costs were brought forward using CPI indices in Myanmar and for the USA. Only power plants commissioned in the 2000's were considered including 15 plants. The cost data of 6 projects under construction was separately analysed.

192. The weighted average specific capital expenditure (weights by installed capacities) for the existing plants was about 1,400 $/kW. The average of large plants of over 250 MW including Dapein, Shweli, Lower Paunglaung and Yeywa, was 1,200 $/kW. For the rest of plants the average cost was about 1,900 $/kWh. Costs of Kun and Zaungtu hydropower stations stood out from the rest as relatively high. Among the power plants under construction, Thahtay and Upper Paunglaung have clearly higher than average costs, driven by unique cost features behind the higher costs.

193. Hydropower construction in Myanmar has taken place largely by Chinese construction companies, equipment suppliers and design institutes. Several surveys on the costs of power plants clearly indicate that the massive hydropower construction in Brazil, PRC and India has led to lower investment costs as compared to hydropower construction costs in high-income countries. As each of these five countries puts tens of power plants (and in PRC close to one hundred) in operation every year, it means that their domestic market supports a large number of contractors, builders, designers and equipment suppliers tuned to implement hydropower projects efficiently in a very competitive domestic marketplace and worldwide. Another important factor is the low cost of labour in these countries. It should be noted briefly, however, that the higher cost of hydropower outside the developing country context is not simply attributable to source of technology and cost of labour. The best hydropower sites have already been developed in the industrialized countries or they been protected from construction, hence the most costly sites remain, whereas in the mentioned five large emerging economies and many developing countries there are still many hydrologically valuable sites available for development.

194. A World Bank study from 1991[24] analysed hydropower costs using regression analysis and having (i) the size of the facility, (ii) hydraulic head, (iii) type of projects (impoundment, diversion, expansion etc.), (iv) dam characteristics and (v) remoteness of the location, as variable parameters. The study concluded that regression models capturing the number of megawatts, hydraulic head of impoundment projects, or the height of the dam for a diversion scheme of expansion, predicted with a high degree of accuracy and confidence the total costs of hydropower projects and recommended such models be used in project screening by the bank.

195. Regression formula capturing the installed capacity, design head and construction time were tested with the result that the cost profile of Myanmar hydropower stations is stable and can be largely explained only by the size of the project (in installed megawatts). Therefore using flat specific costs $/kW separately for small and medium sized projects and large projects, is well justified. However, the average capital expenditure (CAPEX) of projects is forecast to increase. It is believed that currently on-going economic reform in Myanmar and the country's opening to international markets will cause the supplier base of future plants be wider than before when Chinese companies represented vast majority of supply. With project developers from Thailand and other countries, financing sources will also be more diversified and project financing will increasingly reflect opportunity costs in international markets. Again, the environmental and social standards and practices employed by the investors are believed to be enhanced. With these developments, the specific capital costs are assumed at 1,700 $/kW and 2,800 $/kW for small and medium sized projects, the threshold being at 250 MW in installed capacity.

196. The duration of construction clearly proved to have an impact to the construction costs, but the factors behind lengthened construction periods could not be identified, and therefore this parameter is not useful for predicting costs of construction of the planned new facilities in Myanmar. The construction times in the 2000's were from 2 to 10 years whereas the estimated construction times for the capacity currently under construction vary from 8 to 13 years. However, the overall average of the

[24] Understanding the Costs and Schedules of the World Bank Supported Hydroelectric Projects, the World Bank, Energy Series Paper No. 31, July 1990

sample of currently operational projects of 7 years is assumed in this study for future capacity.

197. The analysis of the World Bank indicated that less construction time, not more was required in remote areas. The remoteness of the site is associated with less schedule slip. The hypothesis presented was that it was associated with less relocation, less interface with the implementation of the project by local governmental authorities and greater labour stability and productivity.

198. As to the operation and maintenance expenditure (OPEX), the MOEP data of operational costs indicates that the average OPEX is 5,600 kyat/MWh, equal to 5.7 $/MWh, which includes both fixed and variable costs. When expressed as percentage of investment cost per kW per year, the cost is on average 1.2% of CAPEX. Costs have been adjusted to 2014 level and calculated as weighted average using installed capacities as weights. The EMP uses cost estimates expressed as $/MWh for existing capacity, and estimates expressed as $/kW for new capacity.

199. International Renewable Energy Agency reports[25] that typical values range from 1% to 4%. The IEA assumes 2.2% for large hydropower and 3% for smaller projects, with global average of around 2.5%. The low level of OPEX in Myanmar is largely due to low cost of labour. Therefore escalation of costs is assumed from 1.2% to the global average of 2.5% by 2035.

200. The cost assumptions are summarized below:

Table V-2: Cost Assumptions for Hydropower Expansion Planning

Plant Type Example	CAPEX US$/kW	Fixed O&M % of CAPEX
Small and Medium Size	2800	1.2% - 2.5%
Large Hydro	1700	1.2% -2.5%

Source: Consultant's analysis based on various sources

[25] Renewable Energy Technologies: Cost Analysis Series Volume 1, Issue 3/5 Hydropower, June 2012

ANNEXES

ANNEX 1 Myanmar Gas Pipelines

A. Pipeline Installation between 1963 and 1988

Sr. No	Description	Year Built	Nominal Diameter (inch)	Length (mile)	Transported comodity
1	Mann-Thanlyin	1979	10	279.50	Oil
2	Chauk-Sale	1969	8	13.30	Gas
3	Ayadaw-Lanywa	1983	10	23.00	Gas
4	Chauk-Lanywa	1980	6	1.00	Gas
5	Pyayay-Thayet	1979	6	7.50	Gas
6	Myanaung-Shwepyitha	1977	10	13.70	Gas
7	Myanaung-Kyankhin	1975	8	13.50	Gas
8	Myanaung-Kyankhin	1986	10	0.64	Gas
			8	2.64	Gas
			6	6.75	Gas
9	Kyankhin-Htantabin-Saketha	1985	10	8.64	Gas
			8	0.64	Gas
10	Pyay-Shwetaung	1981	10	22.00	Gas
11	Shwetaung-Kyawzwar	1984	10	29.00	Gas
12	Payagon-Ywama	1985	10	54.00	Gas
13	Ywama-Shwepyitha(Yangon)	1986	10	2.50	Gas
14	Shwepyitha-Toegyaunggalay	1986	10	4.50	Gas
			14	4.00	Gas
15	Toegyaunggalay-Thanlyin	1986	14	2.50	Gas
			10	6.50	Gas
			6	4.00	Gas
16	South Dagon-Thaketa	1987	10	4.00	Gas
17	Toegyaunggalay-Sittaung	1988	10	56.50	Gas
			8	9.50	Gas
			6	0.75	Gas
Total				570.56	

Source: MOGE

B. Pipeline Installation after 1988

Sr. No	Description	Year Built	Nominal Diameter (inch)	Length (mile)	Transported comodity
1	Pyay-Saketha	1994	10	9.50	Gas
2	Apyauk-Okkan	1995	10	12.25	Gas
3	Apyauk-Shwepyitha(Yangon)	1992	10	24.00	Gas
4	Shwepyitha-Hlawga	1995	10	2.52	Gas
5	Apyauk-Shwepyitha	1994	14	41.15	Gas
6	Popehlawsu-Ywama	1998	14	9.40	Gas
7	Popehlawsu-Alon	1994	10	4.75	Gas
		2002	10	5.17	Gas
8	Toegyaunggalay-Sittaung	1998	10	58.82	Gas
			14	5.38	Gas
			8	0.75	Gas
9	Sittaung-Thahton	1994	10	47.28	Gas
			10	0.98	Gas
			8	22.13	Gas
		2003	10	22.77	Gas
10	Thahton-Myainggalay	1994	6	16.70	Gas
11	Ywama-Hmawbi brick factory	1994	6	4.00	Gas
12	Kyaukkwet-Ayadaw	1997	10	44.52	Gas
13	Indaing-Payonsu	1997	14	5.22	Gas
14	Kanni-Lanywa	1997	10	58.86	Gas
			14	17.03	Gas
15	Kyawzwa-Kyaukswegyo	1998	8	6.88	Gas
			4	0.80	Gas
16	Letpando-Ayadaw	1998	8	30.31	Oil
			6	16.70	Oil
17	Letpando-Kyaukkwet	1998	14	7.95	Gas
			10	0.75	Gas
18	Apyauk-Pyay	1999	14	90.00	Gas

19	Pyay-Titut	1999	14	37.00	Gas
20	Nyaungdon-Hlaingthaya	2000	10	28.08	Gas
			8	4.32	Gas
21	Titut-Sakha	2000	14	212.76	Gas
22	Sakha-Paleik	2000	10	59.67	Gas
23	Paleik-Kyaukse CS-1	2000	10	22.40	Gas
24	Kyaukse CS-1 to 2	2002	10	1.83	Gas
	Kyaukse CS-2 to Cement Mill		10	0.30	Gas
25	PLC(TOTAL)-GRS(MOGE)	2001	6	0.48	Gas
			14	1.67	Gas
26	Kanbauk-Myainggalay	2001	20	180.22	Gas
			14	0.68	Gas
27	Myainggalay cement mill (new)	2001	10	2.26	Gas
28	Myainggalay cement mill (old)	2001	14	2.97	Gas
29	Thargyitaung-Kamma	2001	10	6.16	Oil
30	Thargyitaung-Kamma	2001	10	4.57	Gas
31	Nyaungdon-LPG Plant	2001	10	3.22	Gas
32	Ayadaw-LPG Plant	2001	10	1.40	Gas
33	Myainggalay-Thahton	2002	14	14.2	Gas
			10	1.86	Gas
34	Nyaungdon-Myogyaung	2002	10	27.18	Gas
35	Nyaungdon-Myogyaung-2	2003	10	28.4	Gas
36	Sabe-Ayadaw	2003	10	7.345	Gas
	Total Length			1215.55	

Source: MOGE

ANNEX 2 JICA Gas Supply and Demand Forecasts

Gas Supply and Demand Forecast 2013/14 ~ 2014/15 as of July 2013

Location			COD	Output (MW)		New Output (MW)			Required Gas Aomunt for Existing	As of 2013.0		Newly Required Gas			Gas Source
				Existing	Additional	2013-2014	2014-2015	2015-2016		Gas supply (MMSCFD)	Gas shortage (MMSCFD)	2013-2014	2014-2015	2015-2016	
Local	Kyungchung	Existing	1974	54.30					18.00	9.92	8.08				Onshore
	Mann	Existing	1980	36.90					12.00	0.00	12.00				
	Shwedaung	Existing	1984	55.35					27.00	14.35	12.65				Yadana→Shwe→Yadana?
	Mawlamyaing	Existing	1980	12.00					4.00	2.17	1.83				Yadana→Zawtika (2014)
		Myanmar Lighting	2014.04		100.00		100.00						21.00		
			2015.10		130.00			130.00						29.00	
	Myanaung	Existing	1975/1984	34.70					9.00	6.00	3.00				Yadana
	Thaton	Existing	1985/2001	50.95					25.00	22.34	2.66				Yadana→Zawtika (2014)
Yangon	Hlawga	Existing GT/ST	1996/1999	154.20					39.00	33.80	5.20				Yadana
		Zeya	2013.05 (26MW) 2014.02 (28.55W)		54.55	54.55						15.86			
		Hydrolancang (China)	2014.11		243.00		243.00						53.50		LNG
		Hydrolancang (China)	2015.05		243.00			243.00						53.50	
	Ywama	Existing GT/ST	1980/2004	70.30					28.00	24.64	3.36				Yadana
		MSP	2013.07		52.00	52.00						16.57			
		EGAT	2014.02		240.00	240.00						80.00			
	Ahlone	Existing GT/ST	1995/1999	154.20					39.00	30.60	8.40				Yadana
		Toyo-Thai	2013.06		82.00	82.00						29.80			
			2014.09		39.00		39.00								
	Thaketa	Existing GT/ST	1990/1997	92.00					29.00	28.03	0.97				Yadana
		CIC	2013.07		53.60	53.60						15.00			
		BKB(Korea)	2015.02		167.00		167.00						40.00		LNG
			2016.01		336.00			336.00						40.00	
		UREC(China)	2014.12		127.00		127.00						30.00		
			2016.03		386.00			386.00						89.00	
New	Kyaukphyu	MOEP	2014.12		100.00		100.00						20.00		Shwe
	Kanpouk	Dawei Power Utilities	2015.03		175.00		175.00						50.00		Yadana
			2016.02		350.00			350.00						50.00	
Total				**714.90**	**2,878.15**	**482.15**	**951.00**	**1,445.00**	**230.00**	**171.85**	**58.15**	**157.23**	**214.50**	**261.50**	
				3,593.05		**2,878.15**									

Existing On-going Future

	2013-2014	2014-2015	2015-2016
Total Gas Supply Amount (MMSCFD)	271.85	271.85	271.85
Total Gas Required Amount (MMSCFD)	387.23	601.73	863.23
Total Gas Shortage Amount (MMSCFD)	115.38	329.88	591.38

Additional gas of 100MMSCFD will be supplied on Jan. 2014.

ANNEX 3 Coal Resource Estimates

No.	Location	Township	State	Total capacity. million tons	Capacity by reserves type. million tons				Category
					1P-Positive	2P-Probable	3P-Possible	4P-Potential	
1	**Mainghtok**	Maingsat	Shan (East)	**121.4**		117.7			Lignite to Sub-bituminous
							3.7		Sub-bituminous
2	**Paluzawa**	Mawlike	Sagaing	**89.0**				89.0	Sub-bituminous
3	**Kalewa**	Kalewa	Sagaing	**87.8**	4.6				Sub-bituminous
						17.8			Sub-bituminous
							65.3		Sub-bituminous
4	**Darthwekyauk**	Tamu	Sagaing	**38.0**			33.0		Lignite to Sub-bituminous
								5.0	Lignite to Sub-bituminous
5	**Tigyit**	PinLaung	Shan (South)	**20.7**		20.7			Lignite to Sub-bituminous
6	**Kyesi-Mansan**	Kyesi-Mansan	Shan	**18.1**		18.1			Sub-bituminous
7	**Wankyan (Namiap)**	Kyaington	Shan (East)	**16.7**		16.7			Lignite
8	**Harput**	Tanyang	Shan (North)	**11.2**		5.2			Lignite to Sub-bituminous
							0.5		Lignite to Sub-bituminous
								5.5	Lignite to Sub-bituminous
9	**Narparkaw**	Maington	Shan (East)	**10.9**			10.9		Lignite
10	**Manpan-Monma**	Tanyang	Shan (North)	**7.2**		3.4			Sub-bituminous
								3.8	Sub-bituminous
11	**Sintaung**	Lashio	Shan (North)	**6.5**		5.8			Lignite
							0.7		Lignite
12	**Namma**	Lashio	Shan (North)	**6.5**		2.8			Sub-bituminous
								3.7	Sub-bituminous
13	**Mawtaung**	Tanintharyi	Tanintharyi	**4.8**		1.8			Lignite to Sub-bituminous
							1.8		Lignite to Sub-bituminous

							1.2	Lignite to Sub-bituminous
14	**Kholan**	Namsam	Shan (South)	**3.5**	3.5			Lignite
15	**Narkon**	Lashio	Shan (North)	**2.7**	0.7			Lignite
						1.0		Lignite
							0.9	Lignite
16	**Kyopin**	kawlin	Sagaing	**2.2**	2.2			Lignite to Sub-bituminous
17	**Kawmapyin**	Tanintharyi	Tanintharyi	**2.0**	2.0			Lignite to Sub-bituminous
18	**Sanlaung**	Thipaw	Shan (North)	**1.9**	1.9			Lignite to Sub-bituminous
19	**Narlan**	Lashio	Shan (North)	**1.6**	1.6			Lignite
20	**Karathuri**	Bokpyin	Tanintharyi	**1.5**			1.5	Sub-bituminous
21	**Kywesin**	Ingapu	Ayeyawadi	**1.5**			1.5	Sub-bituminous
22	**Sale (Mansele)**	Lashio	Shan (North)	**1.4**		0.1		Lignite to Sub-bituminous
							1.2	Lignite to Sub-bituminous
23	**Mahkaw**	Thipaw	Shan (North)	**1.3**	1.0			Lignite to Sub-bituminous
							0.3	Lignite to Sub-bituminous
24	**Hoko**	Kyaington	Shan (East)	**1.2**	1.2			Lignite
25	**Mankyaung**	Tanyang	Shan (North)	**1.1**		1.1		Sub-bituminous
26	**Tasu-Letpanhia**	Pauk	Magwe	**1.0**	1.0			Lignite
27	**Sanya**	Lashio	Shan (North)	**0.97**	0.05			Lignite to Sub-bituminous
						0.07		Lignite to Sub-bituminous
							0.85	Lignite to Sub-bituminous
28	**Namlinhkan**	Lashio	Shan (North)	**0.94**	0.05			Lignite
					0.34			Lignite
							0.55	Lignite
29	**Mawleikgyi Ch.**	Mawklike	Sagaing	**0.81**		0.81		Sub-bituminous
30	**Wungyichaung**	Seikphyu	Magwe	**0.81**	0.81			Sub-bituminous
31	**Banchaung**	Dawe	Tanintharyi	**0.28**		0.28		Lignite to Sub-bituminous

32	**Kyasakan-Minpalaung**	Ywangan	Shan (South)	**0.22**		0.22	Sub-bituminous
33	**Lweji**	Bamoh	Kachin	**0.20**		0.20	Lignite
			Total	**465.7**			

Source: Myanmar Ministry of Mines

ANNEX 4 Chemical Composition of Coal Deposits

Coal reserves with total capacity over 10 Mtons are marked with **bold**.

No.	Location			Chemical Analysis				
	Region	Township	State	Fix Carbon %	Volatile %	Moisture %	Ash %	Calorific Value kcal/kg
1	**Kalewa**	**Kalewa**	**Sagaing**	**52.5**	**38.6**	**9.7**	**8.9**	**6 515**
2	**Darthwekyauk**	**Tamu**	**Sagaing**	**50.0**			**1.0**	**6 671**
3	**Paluzawa**	**Mawlike**	**Sagaing**	**41.5**	**45.3**			
4	Mawleikgyi Ch.	Mawklike	Sagaing	49.7	43.9	8.6	6.4	6 560
5	Kyopin	kawlin	Sagaing	31.0	34.4	8.3	34.4	4 544
6	Lweji	Bamoh	Kachin	17.7	38.9	14.4	43.5	3 556
7	Kawmapyin	Tanintharyi	Tanintharyi	36.7	34.8	5.5	21.8	5 546
8	Mawtaung	Tanintharyi	Tanintharyi	43.7				5 423
9	Karathuri	Bokpyin	Tanintharyi	37.6				5 454
10	Wungyichaung	Seikphyu	Magwe	31.7	41.8		26.4	4 650
11	Tasu-Letpanhia	Pauk	Magwe	34.6	48.4		16.9	5 197
12	**Kyesi-Mansan**	**Kyesi**	**Shan (South)**	**35.6**	**49.0**	**13.3**	**15.4**	**5 644**
13	Kholan	Namsan	Shan (South)	14.8	56.3	21.3	28.9	4 089
14	**Tigyit**	**Pinlaung**	**Shan (South)**	**33.8**	**34.4**	**18.5**	**13.3**	**5 097**
15	Makyaning	Tayang	Shan (North)	26.9	50.9	12.7	22.3	5 107
16	Manpan-Monma	Tayang	Shan (North)	35.6	55.0	19.5	9.3	5 498
17	**Harput**	**Tayang**	**Shan (North)**	**27.6**	**56.3**	**28.4**	**13.2**	**4 583**
18	Sale (Mansele)	Lashio	Shan (North)	33.0	54.0	16.0	13.0	5 493
19	Sanya	Lashio	Shan (North)	35.5	58.3	17.8	6.2	5 793
20	Sintaung	Lashio	Shan (North)	33.7	97.0	28.3	9.3	4 875
21	Namma	Lashio	Shan (North)	34.5	44.3	8.6	20.7	5 605
22	Narkon	Lashio	Shan (North)	38.0	59.5	16.0	2.5	6 160
23	Narlan	Lashio	Shan (North)	33.4	41.8	16.6	17.1	5 209
24	Namlinhkan	Lashio	Shan (North)	35.7	53.0	13.3	11.3	5 804
25	Sanlaung	Thipaw	Shan (North)	30.5	51.4	12.2	18.1	5 433
26	Mahkaw	Thipaw	Shan (North)	35.3	61.3	19.9	6.4	5 798
27	**Wankyan**	**Kyaington**	**Shan (East)**	**23.0**	**23.0**	**40.0**	**8.5**	**3 274**
28	Hoko	Kyaington	Shan (East)	44.5	56.5		15.4	6 245
29	**Mainghkok**	**Maingsat**	**Shan (East)**	**45.0**			**1.9**	**5 662**
30	**Narparkaw**	**Maington**	**Shan (East)**	**27.0**	**29.1**		**15.1**	**4 472**
31	Kywesin	Ingapu	Ayeyawadi	41.1	18.2	1.2	40.7	4 538
32	Kari	Dawei	Taninthayi	42.3	48.8		9.5	4 939

Source: Myanmar Ministry of Mines

ANNEX 5 Coal Production by Mine

Note:

- *Production from Kalewa and Namma mines were under privatization since 2011.*
- *Mine of Maw Taung belongs to military since 2009.*

Unit: ton

No.	Coal Mine; Company Name	2001/02	2002/03	2003/04	2004/05	2005/06	2006/07	2007/08	2008/09	2009/10	2010/11	2011/12	2012/13
1	Kalewa; No.(3) Mining Enterprise	13 808	11 773	17 091	15 002	12 250	7 870	6 016	6 012	8 946	2 000		
2	Namma; No.(3) Mining Enterprise	30 200	40 000	55 000	55 000	55 400	42 800	25 000	12 600	17 601	1 300		
3	Lwejel; Arawaddy Myit Phya Co.. Ltd.	7 000	3 200	1 700	2 400	700				30 000		4 500	
4	Samlong (Large Scale); Triple 'A' Cement International Co.. Ltd.	44 731	60 800	111 000	119 400	67 800	100 000	72 000	60 000	48 000	46 000	92 884	85 965
5	Maw Taung; Myanma Economic Corporation	531 248	431 375	771 819	799 878	623 295	515 206	228 592	43 085				
6	Ti-gyit; Edin Energy Natural Resources Development Co.. Ltd.				58 095	324 906	553 089	466 136	244 136	206 549	290 097	338 120	302 598
7	Ma Khaw; UE Export Import Co.. Ltd.				3 232	6 768	12 320	35 801	15 025	28 400	5 130	6 500	12 000
8	Paluzawa; Tun Thwin Mining Co.. Ltd.					30 000	87 050	20 250	10 245	15 096	20 065	15 915	22 237
9	Samlong (Small Scale); Triple 'A' Cement International Co.. Ltd.				35 000	28 912	61 521	60 000	40 000	27 000	36 092	25 889	13 066
10	Na-Shan; Ming Htet Co.. Ltd.						2 000	22 440	25 000	9 800	39 000	24 639	5 653
11	Mapan/Mongma; Ming Htet Co.. Ltd.						31 500	35 000	37 000	15 100	39 000	54 286	31 737
12	Kongbaung/Nakon; Ngweyi Pale Mining Co.. Ltd.						6 550	33 450	37 090	30 040	38 940	55 145	81 500
13	Kaung Pon Chaung; Ngweyi Pale Mining Co.. Ltd.											300	6 950
14	Maipar; Ngweyi Pale Mining Co.. Ltd.												
15	Maw Leik Kyi Chaung; Geo Asia Industry and Mining Co.. Ltd.								2 200	5 000	12 000	11 116	2 430
16	Dah Thway Kyauk; Yangon City Development Committee												6 500
17	Mine Khoke; Myanma Economic Corporation												
18	Ban Chaung; May Flower Mining Enterprise Ltd.(1+2+3)											20 000	33 700
19	Ban Chaung; May Flower Mining Enterprise Ltd. (4+5+6)												
20	Kywe Tayar Taung; Myanmar Naing Mining Group Co.. Ltd.												

No.	Coal Mine; Company Name	2001/02	2002/03	2003/04	2004/05	2005/06	2006/07	2007/08	2008/09	2009/10	2010/11	2011/12	2012/13
21	Kyak Sakhan; Yangon City Development Committee												31 000
22	Kayauk Ohn Chaung; Myanma Economic Corporation									1 137	24 407	39 366	14 724
23	Dah Thway Kyauk & Pazun Seik; Dagon Mining Co.. Ltd.											1 000	4 430
24	Nang Tang; Tun Kywel Paw Co.. Ltd.											2 016	1 880
25	Kyun Pin Pyant; Tun Kyawe Paw Co.. Ltd												
26	Thantaung Kywin; Shwe Ohn Pwint Co.. Ltd.											800	1 250
27	Paluzawa; Shwe Taung Mining Co.. Ltd.												13 623
28	Dah Thway Kyauk; G4 Mining Co.. Ltd.												500
29	Miinpalaung; G4 Mining Co.. Ltd.												300
30	Wah-Ye Chaung; Max Myanmar Co.. Ltd.											17 400	9 821
31	Three Small Scale; Dragon Cement Co.. Ltd.										1 012	3 551	942
32	Pinlong; Mega Strength Co.. Ltd.										278	71	73
33	Kyak Sakhan; Thukha Panthu Co.. Ltd.										472		1 075
34	Sintaung; UE Export Import Co.. Ltd.											12 500	13 000
35	Kyak Sakhan; Young Investment Group Industry Co.. Ltd.												
36	Dah Thway Kyauk; Young Investment Group Industry Co.. Ltd.												
37	Thit Chauk & Labin Chaung; Hoo International Industry Group. Ltd.												2 100
38	Harput; Ruby Garden Mining Co.. Ltd.											2 420	27 680
39	Maw Ku; Geo Asia Industry and Mining Co.. Ltd.											1 000	2 430
40	Hein Latt; Yuzana Cement Industrial Co.. Ltd.												
41	Nan Pan Moon Chaung; Mandalay Distribution and Mining. Ltd.											900	20 400
42	Loon Taung; Myanmar Kauntoun Industry												
43	Kholan; Min Anawyahta Group Co.. Ltd.												
44	Na-ngwe; Ngweyi Pale Mining Co.. Ltd.											500	6 700
45	Mahu Taung; Shwe Innwa Mining & Industry Co.. Ltd.											800	1 200

No.	Coal Mine; Company Name	2001/02	2002/03	2003/04	2004/05	2005/06	2006/07	2007/08	2008/09	2009/10	2010/11	2011/12	2012/13
46	Pharse & Matpaing; Shan Yoma Goal & Product Co.. Ltd.											900	3 900
47	Kyauk Sak; Thunder Lion Mining Co.. Ltd.												3 000
48	Shwe Chaung; Lu Paung Sak Su Way Mining Co.. Ltd.												800
49	Makar; Kanbawza Industry Group Co.. Ltd.												21 000
50	Kantote; Pothar Mining Co..Ltd												1 260
51	Shan Tut; YaungNi Mining Co..Ltd												480
52	Kyat Sakhan; Thukha Panthu Co.. Ltd.												2 300
53	Naungtaya/Tigyit; Big Power Co..Ltd												110
54	Kantote; Soe Yadana Oo Co..Ltd.												120
55	Thanpayar kaing; Myint Myat Chan Aye Mining Co..Ltd.												
56	NaungLai; Tiger Horn Co..Ltd.												
57	Ohmyaytwin; Zabuthit Mining Co..Ltd.												
58	Kantote; Ingyin Taung Co..Ltd.												
59	Ngaw Taung; Nyeinchan Seinphyarmyay Kabar Co..Ltd.												
60	Ohmyaytwin; Myanmar AhtutAhteik Mining Co..Ltd.												
61	Kaung Ai; Ahlinthit Year Mining Co..Ltd.												
62	Kone Paung; Shan Yoma Goal & Product Co.. Ltd.												
	TOTAL	**626 987**	**547 148**	**956 610**	**1 088 007**	**1 150 031**	**1 419 906**	**1 004 685**	**532 393**	**442 669**	**555 793**	**732 518**	**790 434**

Source: JICA referring to No.(3) Mining Enterprise; DGSE

ANNEX 6 Roles and Responsibilities on Renewable Energy in Myanmar

Type of Energy	Research & Education	Production				
		Off-Grid/Mini-Grid			On-Grid	
		Central Government	Local Government	Private Company	Central Government	Private Company
Solar Power	MOST	MOI*2, DRD*3	○	○	MOEP*3	○
Mini-Hydro	MOST	MOAI, MOI*2, DRD*3, MOEP*1	○	○	-	-
Wind Power	MOST	MOI*2	○	○	MOEP*3	○
Biogas	MOST	MOST	○	-	-	-
Biofuel (Jetropha, etc.)	MOST	MOST	○	-	-	-
Biomass (Rice husk, Refuse, etc.)	MOST	MOST, MOI*2, DRD*3	○	○	-	-
(Diesel/GE)	-	ESE/MOI*2	○	○	MOEP	○
Geothermal Power	-	-	-	-	MOEP*3	○
Tidal Power	MES	Under study stage				

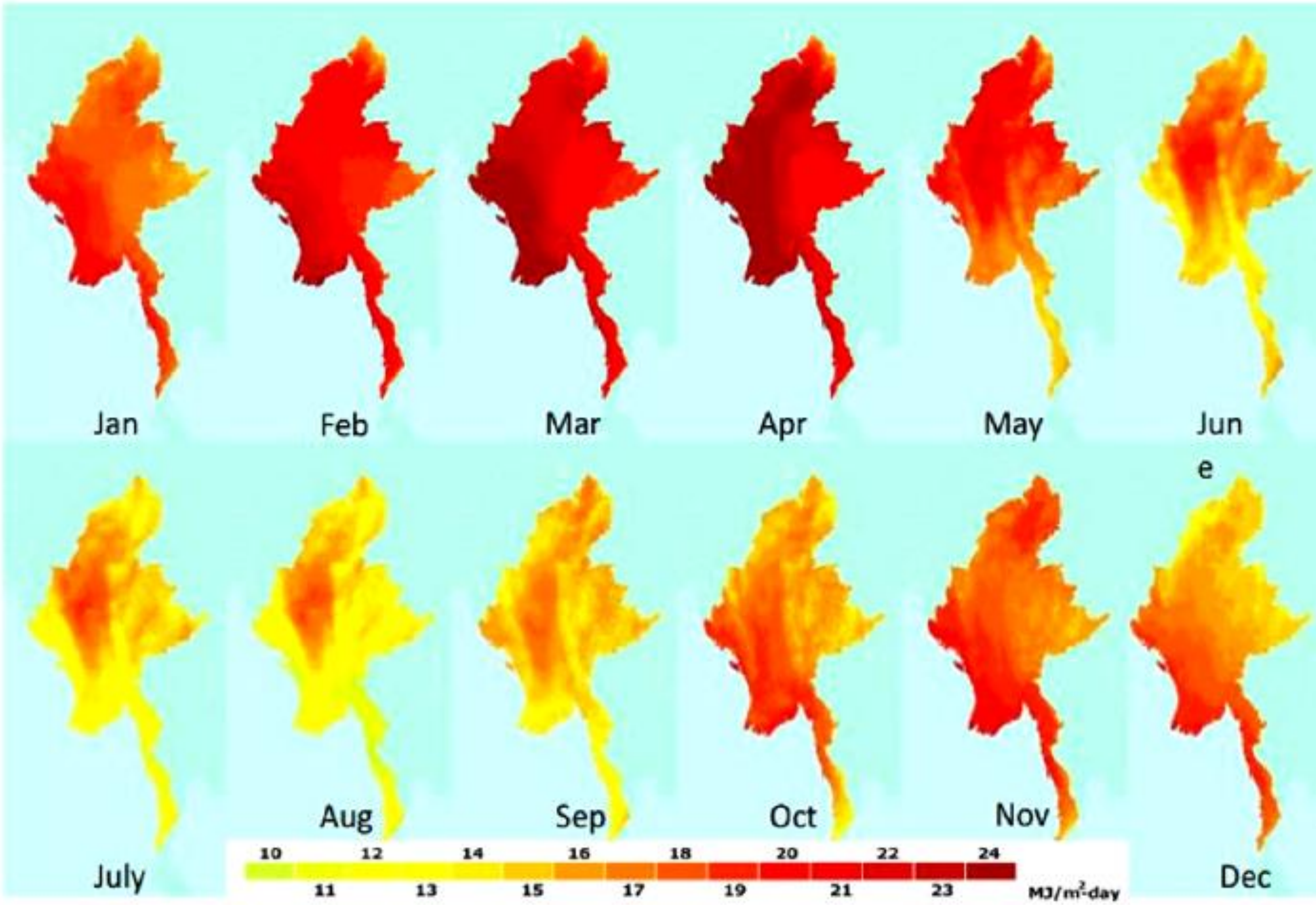
*1 Transfer to Local Government, *2MOI sells equipment, *3Tendering for Investors

Source: The Project for Formulation on the National Electricity Master Plan in The Republic of the Union of Myanmar. Draft Final Report. JICA et al., July 2014

ANNEX 7 Annual Monthly Average Radiation Incident on Equator-Pointed Surface (kWh/m²/day)

Lat \ Long	93	94	95	96	97	98	99	100	101
28	4.95	4.46	4.31	4.32	4.6	4.78	5.37	5.46	5.28
27	4.21	4.23	4.49	4.42	4.21	4.31	4.79	5.29	5.26
26	4.97	4.86	4.61	4.37	4.5	4.57	4.82	5.2	5.24
25	4.92	4.91	4.62	4.63	4.8	4.76	4.94	5.11	5.17
24	4.96	4.76	4.75	4.76	4.93	4.87	4.92	4.86	4.87
23	5.11	4.74	4.92	5.05	5	4.92	4.96	4.88	4.8
22	5.13	4.94	5.19	5.21	5.08	5.08	5.03	4.93	4.84
21	5.17	5.06	[illegible]	[illegible]	5.27	5.22	5.18	4.95	4.88
20	[illegible]	5.14	[illegible]	5.45	[illegible]	5.33	5.18	5.04	4.95
19	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	5.33	5.11	5.13	4.97
18	5.37	5.23	5.24	5.33	[illegible]	5.22	5.2	5.15	5.05
17	5.43	[illegible]	5.07	5.13	5.09	5.03	[illegible]	5.29	5.09
16	5.45	5.23	[illegible]	4.93	[illegible]	4.97	4.98	5.39	5.08
15	5.48	5.42	5.24	5.1	5.05	[illegible]	4.93	5.38	5.3
14	5.48	5.42	5.31	5.2	5.19	[illegible]	5.03	5.34	5.15
13	5.45	5.43	5.3	5.18	5.16	5.04	4.78	5.27	5.08
12	5.44	5.4	5.27	5.19	5.19	[illegible]	4.71	5.4	5.37
11	5.38	5.33	5.27	5.22	5.24	5.2	4.68	5.49	5.37
10	5.33	5.3	5.28	5.28	5.31	5.12	4.7	5.4	5.22
							Coding		
	>4	4.25	4.5	4.75	5	5.25	Radiation kWh/m²/d		

ANNEX 8 Average Monthly Radiation on Horizontal Surface (MJ / m²/d) (3.6 MJ/kWh)
Showing the Regional Variation of Solar Profile over the Year



Source: Photovoltaic Power Generation Myanmar, Working Paper by Heinz - W . Böhnke , Renewable Energy Adviser ADB TA-8356 MYA

ANNEX 9 Monthly Average Wind Speed at 50 m above Surface of Earth (m/s)

Lat	93	94	95	96	97	98	99	100	101
28	5.28	4.28	3.89	4.08	4.28	4.13	3.89	2.80	3.56
27	4.20	3.21	2.82	3.04	3.25	3.47	3.68	2.68	2.48
26	3.11	2.79	2.71	2.87	3.04	3.29	3.54	2.56	2.25
25	2.52	2.58	2.68	2.86	2.96	3.15	3.33	2.25	2.20
24	2.45	2.59	2.73	2.87	3.02	3.04	3.07	3.06	2.03
23	2.54	2.65	2.79	2.87	2.95	2.92	2.89	2.88	2.90
22	2.80	2.76	2.74	2.79	2.75	2.77	2.79	[illegible]	2.81
21	3.34	3.03	2.85	2.82	2.79	2.78	2.78	2.78	2.78
20	4.14	3.44	3.08	3.07	3.07	2.96	2.86	2.80	2.80
19	4.68	3.75	3.25	3.16	3.07	3.04	3.01	2.96	2.91
18	4.95	3.98	3.35	3.08	2.81	3.01	3.22	3.25	3.10
17	4.96	3.92	3.39	3.06	2.61	2.94	3.15	3.10	2.85
16	4.72	3.61	3.08	3.02	3.16	2.78	2.80	2.52	2.14
15	4.87	3.96	3.57	3.68	3.80	3.38	2.75	2.27	2.13
14	5.41	4.98	4.77	4.77	4.77	3.69	3.01	2.65	2.80
13	5.78	5.62	5.48	5.38	5.38	4.24	3.40	3.04	2.35
12	6.00	5.86	5.69	5.51	5.33	4.62	3.92	3.55	3.51
11	6.11	5.98	5.81	5.59	5.38	4.90	4.44	4.14	4.00
10	6.12	5.99	5.83	5.63	5.43	5.30	4.96	4.80	4.72
							Code		
	>3	3.3	3.6	3.9	4.2	>4.5	Wind m/s		

ANNEX 10 Biogas Energy Projects in Myanmar

Digester Size (m^3)	Location	Type	Date Started	Purpose/Objective	No. of Biogas Plant (No.)
50	Naypyidaw Division	Fixed Dome Type	2003	Electricity	6
10			2009	Electricity, Cooking and Lighting	5
8			2008	Cooking and Lighting	8
35			2012	Demonstration	1
15			2012	Demonstration	2
100	Mandalay Division		2008	Electricity	1
50			2002		102
35			2009		4
25			2009		2
8			2009	Cooking and Lighting	3
50	Sagaing		2004	Electricity	23
15			2010		1
10			2009	Cooking and Lighting	1
50	Magway		2004	Electricity	8
25			2009		1
50	Shan State (N)		2005		1
25	Shan State (E)		2009		1
10			2009		1
60	Shan Stage (S)		2010	Cooking	1
25			2009	Electricity	1
50	Kayah		2009		1
15	Kachin		2010		2
5			2010	Cooking and Lighting	1
10	Ayeyarwady		2009	Electricity	2
10	Mon		2012	Pumping	1
35	Yangon		2012	Electricity	1
35	Rakhine		2012	Electricity	1
8	Shan State (E)		2012	Cooking and Lighting	1
Total					**183**

Source: MOST, June 2012

Source: The Project for Formulation on the National Electricity Master Plan in The Republic of the Union of Myanmar. Draft Final Report. JICA et al., July 2014

ANNEX 11 Biomass Gasification Projects for Rice Husk and Woodchips in Myanmar

A. Biomass Gasification Projects (rice husk)

No.	Location	No. of Village	Quantity of plant
1	Chin State	3	3 sets (8 kW Gasifier)
2	Mandalay Division	1	1 set
Total		**4**	**4 sets**

Source: MOI, Dec. 2012

B. Pilot Plants of Woodchip Down-Draft Gasifier

Location	Capacity (kW)	Date started	Cost (US$)
Prawn Hatchery (Ge Wa, Taung Koat Township, Rakhine State)	30	2004	7,500
Technological University (Htarwel)	50	2009	9,400
Technological High School (Gantgaw)	50	2009	7,800
Mel Zel Village, Loi Kor Township, Kayah State	50	2009	9,400
Technical High School (Putao)	50	2009	9,400
Technological University (Mawlamyaing)	50	2009	9,400
No(1) Motorcar Industry Department, Yangon, MOI (2)	50	2009	9,400
Gasifier Project, Renewable Energy Department, Technological University (Kyause)	50	2009	9,400

Source: MOST, 2010

Source: The Project for Formulation on the National Electricity Master Plan in The Republic of the Union of Myanmar. Draft Final Report. JICA et al., July 2014

ANNEX 12 Oil Content of Different Land Races of Jatropha Curcas

Sr	Land Race	Division/ State	Oil Content %	Sr	Land Race	Division/ State	Oil Content %
1	Kyaukpandaung	Mandalay	23.87	26	Kyinpontaung	Magwe	34.99
2	Kyaukcheck	Mandalay	24.91				
3	Leiway	Mandalay	27.62	27	Watphyuye	Southern Shan	38.34
4	Yelepauk	Mandalay	28.40	28	Naunglay	Southern Shan	35.41
5	Myaingyang	Mandalay	31.41	29	Pinngyo	Southern Shan	34.15
6	Nyaungoo	Mandalay	37.32	30	Nantse	Southern Shan	32.71
7	Tatgone	Mandalay	40.04	31	Sarlaein	Southern Shan	37.04
8	Nyaunglaybin	Mandalay	31.92	32	Banyinn	Southern Shan	36.19
9	Pyawbwe	Mandalay	38.06	33	Sesai	Southern Shan	40.70
10	Zeebwar	Mandalay	41.50	34	Pinmhyie	Southern Shan	30.55
11	Mile 57/4	Mandalay	35.73	35	Kyuneywa	Southern Shan	25.99
12	Kyatpyityar	Mandalay	38.91	36	Pinyintaw	Southern Shan	33.17
13	Nwgahtoegyi	Mandalay	35.35	37	Nyaunggone	Southern Shan	28.65
14	6 mile	Mandalay	23.01	38	Latpanpin	Southern Shan	23.48
15	**Shawphyu**	**Mandalay**	**42.39**	39	Yongtaung	Southern Shan	20.84
16	Kyauktadar	Mandalay	31.59	40	Mintaipin	Southern Shan	35.90
				41	**Banyin farm**	**Southern Shan**	**41.27**
17	**Watkya**	**Magwe**	**43.87**	42	Taunggyi	Southern Shan	39.06
18	Yenangkyaung 36	Magwe	39.16	43	Nammalat	Northern Shan	36.23
19	Magwe	Magwe	35.56				
20	Gyaycho	Magwe	30.73	44	**TaungNgyu**	**Eastern Bago**	**46.41**
21	Payapyo	Magwe	37.25	45	lapandan	Western Bago	38.70
22	Tamanntaw	Magwe	35.99				
23	Watmasaut	Magwe	35.79	46	Africa	Exotic	35.73
24	Mindone	Magwe	32.80	47	Thailand	Exotic	37.55
25	Yesagyo	Magwe	41.56	48	Laos	Exotic	39.54
				49	Thai	Exotic	**43.40**
				50	Indonesia	Exotic	35.54

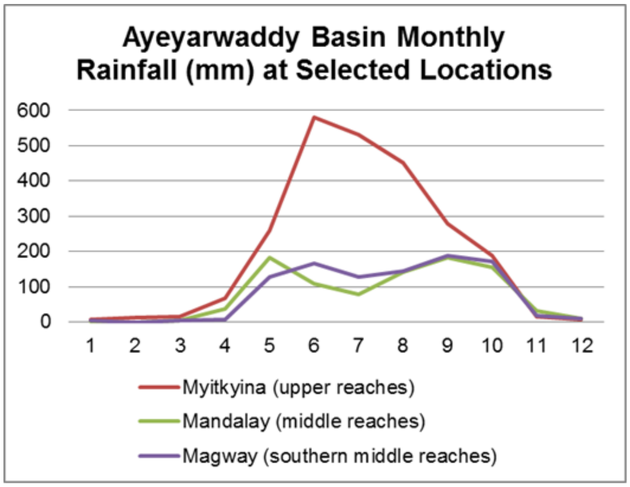
Source: Myanmar: Country Assessment on Biofuels and Renewable Energy. Greater Mekong Subregion Economic Cooperation Program, March 2009

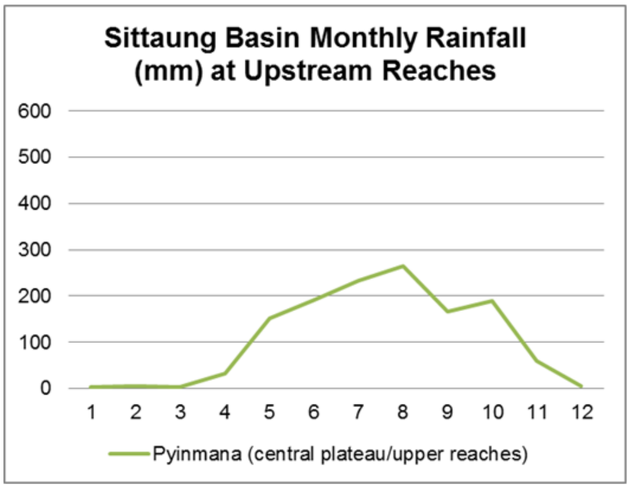
ANNEX 13 Jatropha Production in Myanmar in 2010 – 2011

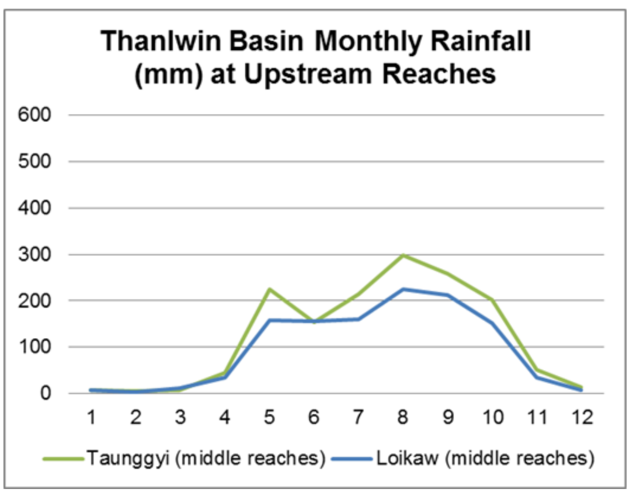
State /Region	Sown area (,000ha)	Harvested (,000ha)	Yield (MT/ha)	Production (MT)	State /Region	Sown area (,000ha)	Harvested (,000ha)	Yield (MT/ha)	Production (MT)
Kachin	135	1.5	0.03	40	Mandalay	217	3.0	0.07	210
Kayah	120	2.4	0.12	274	Mon	67	0.3	0.06	16
Kayin	95	1.3	0.15	203	Rakhine	43	1.2	0.06	69
Chin	81	0.2	0.05	10	Yangon	34	0.5	0.05	26
Sagaing	208	9.9	0.07	734	Shan (S)	190	9.7	0.10	998
Taninthar-yi	9	1.5	0.06	81	Shan (N)	198	11.2	0.02	203
Bago (E)	113	1.8	0.04	66	Shan (E)	49	2.9	0.07	260
Bago (W)	90	0.6	0.03	16	Ayeyar-wady	188	1.4	0.06	91
Magwe	324	27.2	0.08	2201	Total	2127	78	0.07	5498

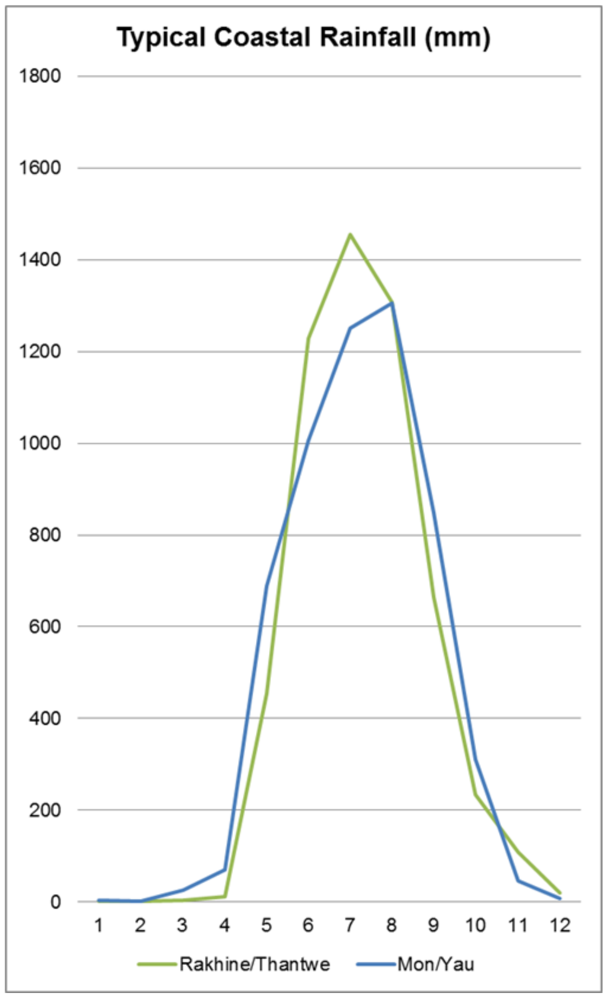
Source: Presentation Material for Regional Workshop on GMS Country Experience in Achieving Performance Target. MOEP 1, MOE, MOI, August 2012

ANNEX 14 Basin and Coastal Monthly Rainfalls in Myanmar









ANNEX 15 Hydropower Resources in Myanmar

A. Large Hydropower Plants

HYDROPOWER PLANTS OF MYANMAR OF OVER 10 MW INSTALLED CAPACITY - IN OPERATION

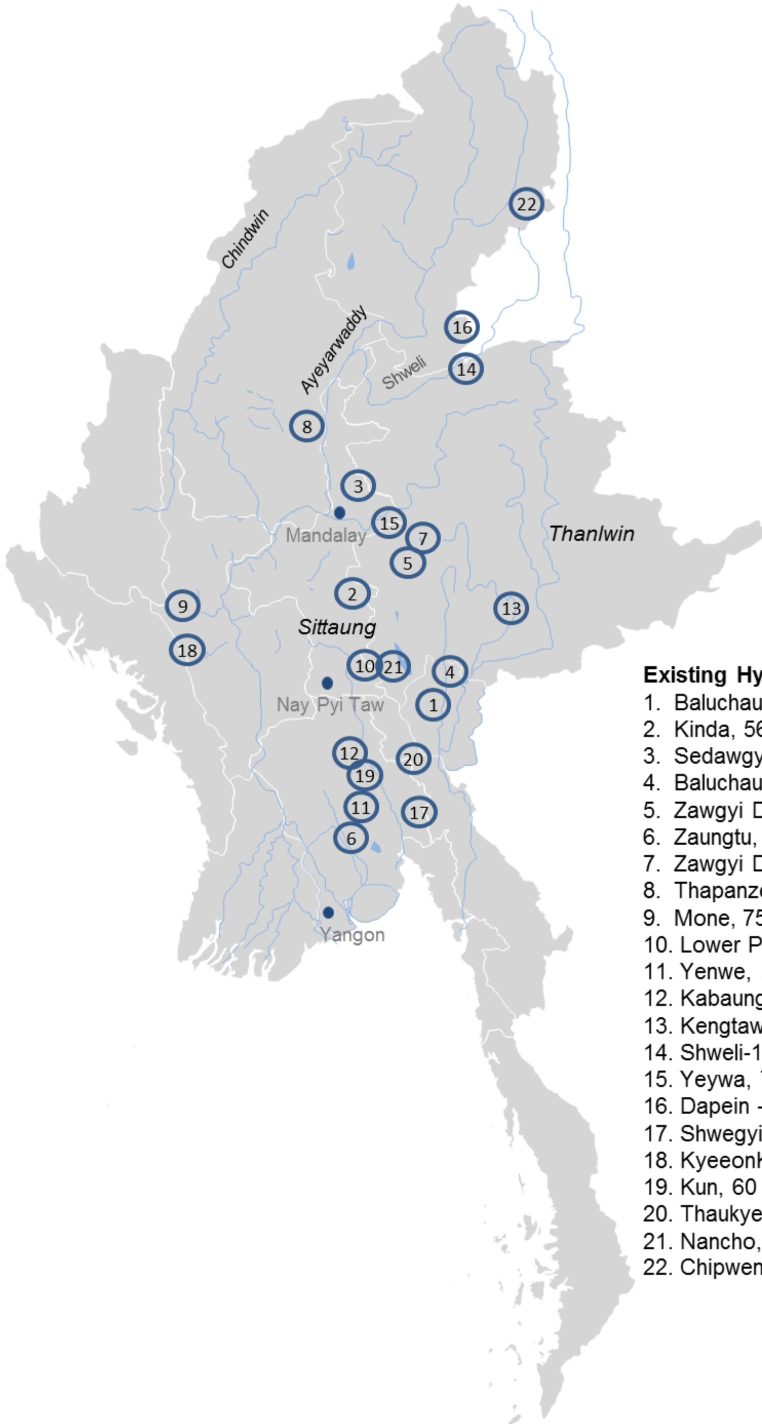
	Hydro Power Plant			Installed capacity		Capacity	Firm	Design values		Production (MWh/a)		On-line	Location		Turbine	
				Total	Unit	Myanmar	Capacity	Head	Discharge	Planned	in 2013					
No	Name of the plant	Info sheet link	Owner	MW	MW	MW	MW	ft	cft/s	MWh/a	MWh/a	Year	Town	State/region	Manufacturer	Type
1	Baluchaung-2	Paunglaung-2	Ministry of Electric Power	168	28	168	155	1388	1 680	1 190 000	982 539	1960/74	Loikaw	Kayah	HITACHI	PELTON
2	Kinda	Kinda	Ministry of Electric Power	56	28	56	21	184	3 952	165 000	42 899	1985	Myittha	Mandalay	RIVA	FRANCIS
3	Sedawgyi	Sedawgyi	Ministry of Electric Power	25	12.5	25	20	93	3 185	134 000	99 860	1989	Madayar	Mandalay	TOSHIBA	KAPLAN
4	Baluchaung-1	Baluchaung-1	Ministry of Electric Power	28	14	28	26	229	1 680	200 000	184 333	1992	Loikaw	Kayah		FRANCIS
5	Zawgyi Dam	Zawgyi-1	Ministry of Electric Power	18	6	18	4	384	656	35 000	76 150	1995	Yutsawle	Shan	SFECO	FRANCIS
6	Zaungtu	Zaungtu	Ministry of Electric Power	20	10	20	9	90	3 078	76 000	58 405	2000	Teikkyi	Bago	YUNNAN	KAPLAN
7	Zawgyi Dam 2	Zawgyi-2	Ministry of Electric Power	12	6	12	3	107	1 740	30 000	34 037	2000	Yutsawle	Shan		
8	Thapanzeik	Thaphanseik	Ministry of Electric Power	30	10	30	13	62	6 684	117 200	64 551	2002	Khunglha	Sagaing	CHINA	KAPLAN
9	Mone	Mone Chaung	Ministry of Electric Power	75	25	75	38	125	6 030	330 000	243 044	2004	Sidoktaya	Magway	CHINA	FRANCIS
10	Lower Paung Laung	Paunglaung	Ministry of Electric Power	280	70	280	104	340	10 807	911 000	581 847	2005	Zayarthin	Naypyitaw	YUNNAN	FRANCIS
11	Yenwe	Yenwe	Ministry of Electric Power	25	12.5	25	14	187	1 766	123 000	72 341	2007	Kyaukdaga	Bago	CNEEC	FRANCIS
12	Kabaung	Kabaung	Ministry of Electric Power	30	15	30	13	152	2 790	120 000	65 833	2008	Oatdwin	Bago	CNEEC	FRANCIS
13	Kengtawng	Keng Tawng	Ministry of Electric Power	54	18	54	43	427	1 800	377 600	350 280	2009	Mone	Shan	YUNNAN	FRANCIS
14	Shweli-1	Shweli-1	JV Shweli River Power Station Co	600	100	300	175	981	7 972	4 022 000	1 993 963	2009	Namkhan	Shan	YUNNAN	FRANCIS
15	Yeywa	Yeywa	Ministry of Electric Power	790	197.5	790	175	299	29 680	3 550 000	2 560 440	2010	Kyaukse	Mandalay	CNEEC	FRANCIS/V
16	Dapein-1	Dapein-1	JV with China Datang Overseas Investment	240	60	24	30	225	13 631	1 065 000	10 456	2011	Moemauk	Kachin	TIANBAO	FRANCIS
17	Shwegyin	Shwegyin	Ministry of Electric Power	75	18.75	75	51	136	7 600	262 000	224 635	2011	Shwegyin	Bago		FRANCIS/V
18	KyeeonKyeewa	Kyeeon Kyeewa	Ministry of Agriculture and Irrigation	74	37	74	42	113	4 296	370 000	268 560	2012	Pwintbyu	Magway		
19	Kun	Kun	Ministry of Electric Power	60	20	60	18	270	2 331	190 000	208 129	2012	Phyu	Bago	TAH	FRANCIS
20	Thauk Ye Khat-2	Thauk Ye Khat-2	BOT	120	40	120	32	269	7 468	604 000	343 836	2013	Taungoo	Phyu		FRANCIS
21	Nancho		Ministry of Electric Power	40	20	40		328	1 674	152 000	n/a	2014	Pyinmana	Mandalay		
22	Chipwenge		BOT	99	33	15				65 000	n/a	2014	Chipwenge	Kachin		

		Total MW	Capacity Myanmar MW		
Totals	Installed Capacity as of 2014	2 919	2 319	2919	
	Installed Capacity as of 2013	2 660	2 144	3	13 267 800 MWh
	Dry Season availability (May)	1210	45 %	of installed capacity	1515 MW - Yearly average (design value)
	Wet Season Availability (Sep)	1897	71 %	of installed capacity	

B. Small Hydropower Plants

SMALL HYDROPOWER PLANTS OF MYANMAR			
		Installed capacity	On-line
No	Name of the plant	MW	year
1	WATWON	0.51	1933
2	DAUNG VA	0.4	1984
3	ZALUI	0.4	1984
4	ZINKYAIK	0.198	1984
5	NGALSIP VA	1	1986
6	TATKYI	2	1987
7	PUTAO	0.16	1987
8	MYITNGE	0.15	1987
9	NAMKHAM	0.3	1988
10	MUSE	0.192	1988
11	HPASAUNG	0.108	1988
12	HPAPUN	0.064	1988
13	PALETWA	0.05	1988
14	MOGOK	4	1989
15	HOPIN GALANGCHAI	1.26	1991
16	NAMLAT	0.48	1991
17	KATTALU	0.15	1991
18	NAMSHAN	0.15	1991
19	SELU	0.012	1991
20	PARKYETHAW	0.3	1992
21	NAMLAUNG CHAUNG	0.2	1992
22	YETAGUN CHAUNG I	0.192	1992
23	MAING LAR	0.06	1992
24	MONGLA	0.03	1992
25	SALA SHAN	0.024	1992
26	KYUKOK	0.3	1993
27	DOBE	0.055	1993
28	NAM YAO	4	1994
29	NAM WOP	3	1994
30	LAIVA	0.6	1994
31	NAMKHAM HKA	5	1995
32	NAMSAUNG NGAUNG	4	1995
33	ZI CHAUNG	1.26	1996
34	NAMSAUNG CHAUNG	0.5	1996
35	CHE CHAUNG	0.4	1997
36	TUI SAUNG	0.2	1997
37	LAHE	0.05	1997
38	ZAWGYI MINI	0.03	2000
39	PATHI CHAUNG	2	2006

C. Map of Existing Power Plants



Existing Hydropower Plants

1. Baluchaung-2, 168 MW
2. Kinda, 56 MW
3. Sedawgyi, 25 MW
4. Baluchaung-1, 28 MW
5. Zawgyi Dam, 18 MW
6. Zaungtu, 20 MW
7. Zawgyi Dam 2, 12 MW
8. Thapanzeik, 30 MW
9. Mone, 75 MW
10. Lower Paung Laung, 280 MW
11. Yenwe, 25 MW
12. Kabaung, 30 MW
13. Kengtawng, 54 MW
14. Shweli-1, 600 MW
15. Yeywa, 790 MW
16. Dapein – 1, 240 MW
17. Shwegyin, 75 MW
18. KyeeonKyeewa, 74 MW
19. Kun, 60 MW
20. Thaukyegat-II, 120 MW
21. Nancho, 40 MW
22. Chipwenge, 99 MW

Source: Consultant

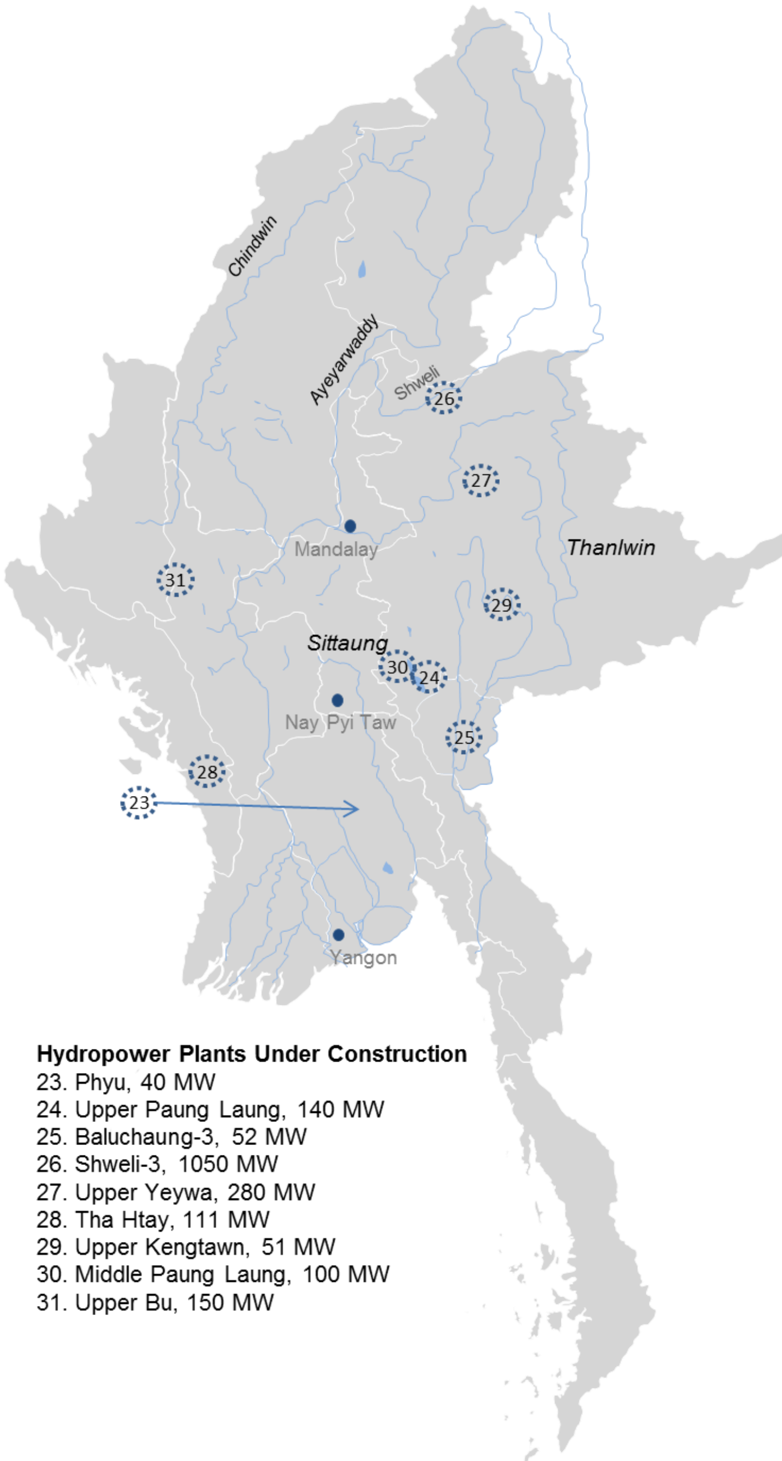
D. Planned Hydropower Plants

FUTURE HYDRO POWER PLANTS IN MYANMAR

	No	Name of the plant	Owner	Installed capacity Total MW	Installed capacity Unit MW	For Myanmar MW	Design values Head ft	Design values Discharge cft/s	Planned production MWh/a	Anticipated construction period Start Year	Anticipated construction period End Year	Anticipated construction period Duration Months	Location Town	Location State
Plants under construction	1	Phyu	Ministry of Electric Power	40	20	40	377	2540	120 000	2002	2015	156	Phyu	Bago
	2	Upper Paung Laung	Ministry of Electric Power	140	70	140	260	7060	454 000	2005	2015	120	Pyinmana	Mandalay
	3	Baluchaung (3)	BOT	52	26	52	398	1800	334 000	2008	2015	84	Loikaw	Kayah
	4	Shweli (3)	Ministry of Electric Power	1050	210	1050	338	39735	3 400 000	2011	2020	108	Moemate	Shan
	5	Upper Yeywa	Ministry of Electric Power	280	70	280	230	8830	1 409 000	2011	2019	96	Kyaukme	Shan
	6	Tha Htay	Ministry of Electric Power	111	37	111	205	7420	386 000	2006	2019	156	Thandwe	Rakhine
	7	Upper Keng Tawng	Ministry of Electric Power	51	17	51	150	5298	267 000	2009	2018	108	Keng Tawng	Shan
	8	Middle Paung Laung	Ministry of Electric Power	100	50	100	180	7770	500 000	2015	2019	48	Pyinmana	Mandalay
	9	Dee Doke		66	22	66	30		297 600		2020		Kyaukse	Mandalay
	10	Mong Wa	BOT	50		50			183 960		2020		Minewa	Shan
	11	Ngot Chaung	BOT	16.6		17			61 075		2020		Nyaung shwe	Shan
	12	Upper Bu	Ministry of Agriculture and I	150	75	150	276	6000	334 000	2007	2020		Sidoktaya	Magway
	13	Kaingkan	Ministry of Agriculture and I	6		6			22 075		2020		Kaingkan	Shan
	14	Upper Baluchaung	BOT	30.4		30	725	565	134 600	2011	2020		Nyaungshe	Shan
		Sub-total		2143		2143			7 903 310					
2021-2025	15	Middle Yeywa	Ministry of Electric Power	320		320			1 438 080		2023			Shan
	16	Bawgata	Ministry of Electric Power	160		160	1900	1230	500 000		2021		Kyaukgyi	Bago
	17	Upper Thanlwin (Kunlong)	JV	1400		700	177	116780	7 142 000		2025	75	Kunlong	Shan
	18	Naopha	JV	1200	200	600	148	105942	6 182 000		2025	75	Larshio	Shan
	19	Mantong	JV	225	75	225	279	10876	992 000		2022	49	Larshio	Shan
	20	Dapein (2)	JV	140	70	84	136	13434	641 700		2021	33	Bhamo	Kachin
	21	Shweli (2)	JV	520	130	260	361	18578	2 814 000		2022	57	Namkan	Kachin
		Sub-total 2021-2025		3965		2349			19 709 780					
2026-2030	1	Nam Tamhpak	JV	200		100								
	2	Gaw Lan	JV	100		50								
	3	Hkan Kawn	JV	160		80								
	4	Lawngdin	JV	600		300								
	5	Tongxingqiao	JV	340	170	170	853	5150	1 695 000			45	Tsawlaw	Kachin
	6	Keng Tong	JV	128		64								
	7	Wan Ta Pin	JV	33		17								
	8	So Lue	JV	160		80								
	9	Keng Yang	JV	40		20								
	10	He Kou	JV	100		50								
	11	Nam Kha	JV	200		100								
	12	Namtu (Hsipaw)	BOT	100		50								
	13	Mong Young		45		22								
	14	Dun Ban		130		65								
	15	Nam Li		165		82								
	16	Nam Khot		50		25								
	17	Taninthayi		600		600								
	18	Upper Sedawgyi	Ministry of Agriculture and Irrigation	64		64								
	19													
Sub-total 2026-2030			Installed capacity subtotal	3215		1939								
Anticipated installed capacity 2031				9323		6431								

Source: Consultant's analysis

E. Location of Hydropower Plants under Construction



Source: Consultant's analysis

F. Typical Power Generation by Season

DAILY PRODUCTION, DRY SEASON DAY (MW)																								
hours	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Baluchaung-2	143.4	142.7	144.3	144.2	141.0	143.7	144.2	144.1	143.3	144.3	145.5	145.5	145.5	146.0	146.0	146.0	145.0	145.3	140.7	144.6	142.4	143.5	143.0	143.3
Kinda	0.0	0.0	0.0	0.0	0.0	15.7	15.7	16.4	16.5	16.3	16.5	16.2	16.2	16.2	16.1	16.3	30.7	31.5	31.4	31.1	31.8	31.6	31.5	28.0
Sedawgyi	11.9	12.0	12.0	12.0	12.1	11.9	12.0	12.0	12.0	11.7	11.9	12.3	11.9	11.6	12.7	12.6	12.5	12.7	12.6	12.6	13.0	13.2	13.4	13.2
Baluchaung-1	25.8	25.7	27.7	28.1	25.5	25.7	26.0	26.6	26.4	26.4	26.5	26.3	26.4	26.6	26.8	27.1	26.8	26.7	26.1	26.5	26.6	26.5	26.5	26.6
Zawgyi Dam	5.2	5.2	5.1	5.0	5.1	5.3	5.4	5.6	5.4	5.4	5.3	5.3	5.4	5.3	5.4	5.4	5.3	5.1	5.2	5.1	5.3	5.1	5.1	5.1
Zaungtu	0.0	0.0	0.0	0.0	0.0	0.0	10.0	7.7	6.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7.1	6.9	7.0	7.4	7.0	0.0
Zawgyi Dam 2	10.3	10.3	10.4	10.3	10.5	9.7	10.3	19.4	10.3	10.3	10.1	10.5	10.9	10.4	10.1	10.4	10.2	10.1	10.3	10.5	9.9	10.1	10.2	10.2
Thapanzeik	0.0	0.0	0.0	0.0	0.0	16.9	18.0	16.5	16.5	14.0	0.0	0.0	0.0	0.0	0.0	0.0	15.9	17.5	18.0	17.7	17.3	15.6	0.0	0.0
Mone	20.7	20.7	20.7	20.7	21.6	16.7	20.7	21.1	21.1	37.4	37.4	41.4	34.8	37.8	38.3	39.2	35.6	28.2	20.7	21.1	19.8	21.1	20.7	20.4
Lower Paung Laung	0.0	0.0	0.0	0.0	0.0	22.0	60.5	60.5	66.0	60.5	60.5	27.5	0.0	0.0	0.0	0.0	0.0	44.0	99.0	121.0	110.0	115.5	16.5	0.0
Yenwe	18.7	14.0	0.0	0.0	6.2	18.9	18.7	19.6	19.4	19.6	18.7	19.4	18.3	20.2	19.1	19.4	19.1	18.5	19.1	19.1	18.9	18.9	19.1	18.9
Kabaung	0.0	0.0	0.0	0.0	0.0	0.0	17.2	25.4	22.8	22.0	22.0	18.8	0.0	0.0	0.0	0.0	0.0	0.0	12.9	24.1	23.4	15.5	0.0	0.0
Kengtawng	34.7	35.0	33.7	35.0	35.0	35.6	34.3	36.0	33.7	34.0	35.6	35.3	34.3	34.3	35.8	34.3	35.3	35.0	35.0	35.3	34.7	35.0	35.0	35.0
Shweli-1	144.3	138.0	128.3	127.3	164.6	153.2	188.4	196.7	196.7	195.6	196.7	194.6	196.7	196.7	196.7	196.7	196.7	196.7	170.8	165.6	165.6	161.4	154.2	161.5
Yeywa	0.0	0.0	0.0	0.0	23.0	145.9	165.1	258.0	258.0	314.9	337.9	314.9	326.4	284.2	349.4	303.3	314.9	453.1	484.0	462.9	436.0	339.8	220.8	84.5
Dapein-1	1.9	1.6	1.0	1.6	1.5	1.4	2.9	3.1	3.1	3.0	2.9	2.5	2.5	2.6	2.5	2.9	3.0	3.2	4.6	4.5	4.3	3.2	2.5	2.0
Shwegyin	0.0	0.0	0.0	0.0	9.6	15.2	30.4	31.4	32.7	30.7	31.4	31.0	32.3	30.4	32.0	31.4	31.0	31.0	32.7	30.4	31.4	31.4	31.0	24.8
KyeeonKyeewa	20.5	20.5	20.5	19.8	21.1	20.5	20.5	20.5	20.5	36.3	42.9	38.3	39.6	40.3	40.3	39.6	42.2	28.4	19.8	20.5	21.1	19.8	20.5	20.5
Kun	0.0	0.0	0.0	0.0	29.9	38.7	39.6	37.8	50.2	58.5	55.0	58.1	59.0	59.0	58.5	57.6	58.1	59.0	58.1	57.6	56.8	57.6	56.8	44.4
Thauk Ye Khat-2	81.0	77.4	81.0	77.4	73.9	39.7	42.2	38.7	38.7	42.2	38.7	38.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	17.6	59.8	77.4	77.4	84.5
Total:	**518.1**	**502.9**	**484.5**	**481.3**	**580.5**	**736.8**	**881.9**	**997.1**	**999.8**	**1083.2**	**1095.5**	**1036.5**	**960.1**	**921.5**	**989.7**	**942.0**	**982.2**	**1145.7**	**1208.0**	**1234.6**	**1235.1**	**1149.6**	**891.2**	**722.7**

DAILY PRODUCTION, WET SEASON DAY (MW)																								
hours	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Baluchaung-2	68.9	76.4	63.9	64.0	68.1	70.0	71.1	70.1	73.7	68.4	64.9	52.8	50.1	48.3	48.8	57.1	58.3	58.7	58.5	59.2	58.8	57.3	49.4	46.6
Kinda	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Sedawgyi	14.5	14.6	14.6	14.3	14.4	14.3	14.6	14.3	14.3	14.2	14.6	14.4	14.5	14.4	14.3	14.6	14.4	14.3	14.6	14.3	14.6	14.3	14.4	14.2
Baluchaung-1	8.1	8.1	8.1	8.2	8.0	8.2	8.1	7.6	7.1	7.2	7.1	7.3	7.0	7.1	7.3	7.3	7.4	7.1	7.2	7.2	7.5	7.2	9.3	9.1
Zawgyi Dam	9.9	9.4	9.1	8.5	9.8	15.7	17.3	17.3	15.4	16.7	17.3	17.4	17.3	17.5	17.5	17.4	17.3	17.4	17.8	17.5	17.4	17.4	17.3	13.2
Zaungtu	17.6	17.4	16.7	16.9	16.9	16.4	18.5	17.6	17.6	17.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	16.5	17.3	15.3	18.0
Zawgyi Dam 2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Thapanzeik	0.0	0.0	0.0	0.0	18.0	18.0	18.0	18.0	18.0	18.0	19.0	17.0	18.0	18.0	18.0	19.0	18.0	18.0	18.0	18.0	18.0	18.0	17.0	0.0
Mone	57.2	36.1	22.9	22.4	21.6	21.6	23.3	36.1	54.1	65.6	60.7	63.8	61.6	61.6	62.9	64.7	62.5	64.2	67.3	66.0	61.6	65.1	67.3	64.7
Lower Paung Laung	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Yenwe	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Kabaung	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Kengtawng	35.0	35.0	34.3	34.7	34.3	35.0	34.7	34.3	35.3	34.3	34.7	34.7	35.0	34.7	34.7	34.3	38.6	33.6	34.3	33.7	35.0	34.0	33.7	33.7
Shweli-1	177.0	154.0	142.8	162.5	181.1	192.5	195.6	192.5	193.5	189.4	193.5	189.4	147.0	132.5	159.4	191.5	173.5	195.6	198.7	195.6	192.2	195.6	196.7	186.3
Yeywa	278.3	270.7	270.6	274.4	320.5	487.4	662.3	624.0	625.9	637.4	635.5	533.7	485.7	522.2	512.6	581.8	643.2	608.6	610.5	597.1	535.6	416.5	305.2	274.5
Dapein-1	2.3	2.7	2.2	2.2	2.5	3.5	4.4	4.4	4.4	4.1	3.4	3.3	3.0	3.0	3.2	3.7	4.2	4.2	4.9	4.7	3.8	3.3	2.5	2.1
Shwegyin	0.0	0.0	0.0	0.0	0.0	0.0	21.1	35.0	37.3	33.0	33.7	33.3	31.7	30.4	19.1	17.2	17.5	17.2	17.5	17.2	17.2	17.8	17.2	4.0
KyeeonKyeewa	70.0	71.3	70.6	71.3	71.3	71.3	70.0	70.0	72.6	70.6	70.6	70.6	70.6	72.6	70.0	70.0	70.0	71.3	70.6	71.3	70.6	73.3	78.6	78.6
Kun	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Thauk Ye Khat-2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	35.2	38.7	42.2	38.7	38.7	0.0	0.0	0.0	0.0	0.0	38.7	38.7	42.2	38.4	38.4	21.1	0.0
Total:	**738.724**	**695.618**	**655.818**	**679.218**	**766.454**	**953.788**	**1158.943**	**1176.214**	**1207.983**	**1218.607**	**1193.649**	**1076.403**	**941.378**	**962.162**	**967.764**	**1078.353**	**1124.768**	**1148.871**	**1158.608**	**1143.868**	**1087.284**	**975.498**	**844.948**	**744.838**

Source: MOEP

G. Monthly Production by Plant in 2013

MONTHLY PRODUCTION 2013 (MWh)												
months	1	2	3	4	5	6	7	8	9	10	11	12
Baluchaung-2	106 714	96 299	105 334	103 835	103 546	101 108	99 686	61 662	39 945	44 396	50 794	89 830
Kinda	0	4 569	11 144	10 077	0	0	0	0	2 413	2 437	11 117	2 216
Sedawgyi	3 789	3 527	7 846	8 964	7 087	7 668	4 941	8 898	16 205	11 104	13 485	6 345
Baluchaung-1	19 667	17 758	19 440	19 154	19 180	18 675	18 464	11 533	7 684	8 420	9 815	16 260
Zawgyi Dam	478	4 027	3 942	3 377	3 771	5 580	5 547	9 953	9 767	10 675	8 953	6 632
Zaungtu	988	887	1 524	1 339	729	5 732	9 893	12 011	11 528	8 432	5 174	1 114
Zawgyi Dam 2	1 350	2 983	6 434	6 162	4 093	4 514	240	0	1 162	1 810	3 936	2 082
Thapanzeik	155	1 943	5 491	5 059	4 139	4 506	7 506	5 632	7 395	7 844	15 308	59
Mone	14 747	15 747	14 703	9 962	4 044	9 860	17 500	37 378	44 124	43 254	24 994	8 978
Lower Paung Laung	40 981	36 597	25 905	39 754	30 399	33 369	35 283	69 328	66 902	72 589	72 809	68 096
Yenwe	6 369	8 214	10 467	11 689	11 860	12 190	10 824	616	99	148	0	0
Kabaung	6 862	6 565	6 826	8 860	12 514	14 165	8 049	320	149	256	201	1 619
Kengtawng	31 443	26 773	25 638	22 928	24 001	26 751	34 336	27 800	25 870	33 728	36 827	38 217
Shweli-1	170 702	142 250	151 571	166 408	213 955	188 347	212 437	145 344	132 205	143 487	155 622	183 139
Yeywa	168 411	154 643	165 896	160 808	103 916	127 657	155 199	326 099	324 526	344 190	316 047	323 431
Dapein-1	0	0	0	456	1 765	2 287	2 265	2 337	2 348	2 199	2 143	2 240
Shwegyin	17 476	19 720	18 852	22 079	15 563	11 120	18 530	23 599	29 295	31 212	14 056	5 845
KyeeonKyeewa	16 287	15 542	18 375	13 537	10 219	14 786	16 825	37 367	41 228	45 772	30 334	8 738
Kun Chaung	19 169	24 211	32 064	37 806	35 092	23 955	10 633	856	129	2 308	14 578	7 967
Thauk Ye Khat-2	0	13 974	27 769	33 025	23 355	13 380	22 436	31 599	60 780	54 183	33 739	34 725

Source: MOEP

Project Number: TA No. 8356-MYA

FINAL REPORT

MYANMAR ENERGY MASTER PLAN

DEMAND FORECASTS

Prepared for

The Asian Development Bank

and

The Myanmar Ministry of Energy

Prepared by

Intelligent Energy Systems

in association with

MYANMAR INTERNATIONAL CONSULTANTS

Project Number: TA No. 8356-MYA

FINAL REPORT

ENERGY FORECASTS

AGRICULTURE SECTOR

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MYANMAR
INTERNATIONAL
CONSULTANTS

ABBREVIATIONS

ADB	–	Asian Development Bank
ADBI	–	Asian Development Bank Institute
ANRE	–	Agriculture & Natural Resources
ASEAN	–	Association of South-East Asian Nations
CSO	–	Central Statistics Organisation
DTW	–	Deep Tube-Well
FDI	–	Foreign Direct Investment
GDP	–	Gross Domestic Product
GoM	–	Government of the Republic of the Union of Myanmar
HH	–	Household
IMF	–	International Monetary Fund
IEA	–	International Energy Agency
LIFT	–	Livelihoods and Food Security Trust Fund
JICA	–	Japan International Cooperation Agency
MCDV	–	Myanmar Comprehensive Development Vision
MDG	–	Millennium Development Goals
MNC	–	Multi-National Corporation
MoAI	–	Ministry of Agriculture & Irrigation
MoE	–	Ministry of Energy
STW	–	Shallow Tube-Well
TFP	–	Total Factor Productivity
UN	–	United Nations
UNDP	–	United Nations Development Programme
USAID	–	United States Agency for International Development

UNITS OF MEASURE

FEC	–	Final Energy Consumption
GJ	–	Gigajoule (one thousand megajoules)
kJ	–	Kilojoule
kWh	–	Kilowatt-hour
MJ	–	Megajoule
MWh	–	Megawatt-hour
MWel	–	Megawatt electric
PJ	–	Petajoule
TJ	–	Terajoule

WEIGHTS AND MEASURES

GW (giga watt)	–	1,000,000,000 calories
GJ (giga joules)	–	1,000,000,000 joules
GW (giga watt)	–	1,000,000,000 watts
kVA (kilovolt-ampere)	–	1,000 volt-amperes
kW (kilowatt)	–	1,000 watts
kWh (kilowatt-hour)	–	1,000 watts-hour
MW (megawatt)	–	1,000,000 watts
W (watt)	–	unit of active power

CONVERSION FACTORS

1 GCal	=	4.19 GJ
1 BTU	=	1.05506 kJ
1 Gcal	=	1.1615 MWh = 4.19 GJ
1 GJ	=	0.278 MWh = 0.239 Gcal
1 MW	=	0.86 Gcal = 3.6 GJ

NOTE

In this report, “$” refers to US dollars.

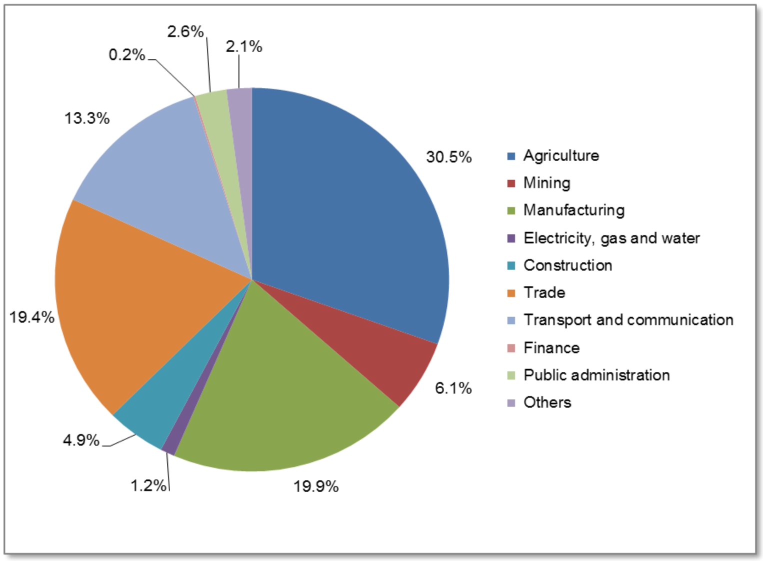
CONTENTS

I. SUMMARY

A. Introduction

1. In 2012 the agriculture sector of Myanmar's economy sector contributed around 30% of GDP. The contribution has declined since the 90's as other sectors have grown at a faster rate.

Figure I-1: Myanmar's GDP by Composition (2012)



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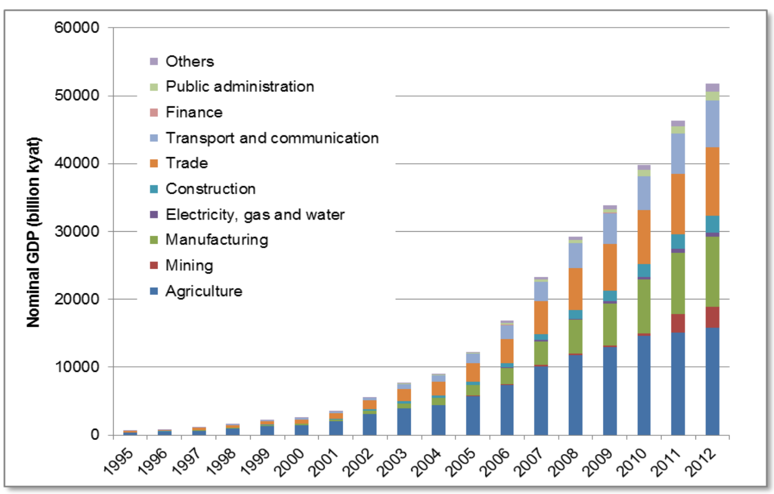
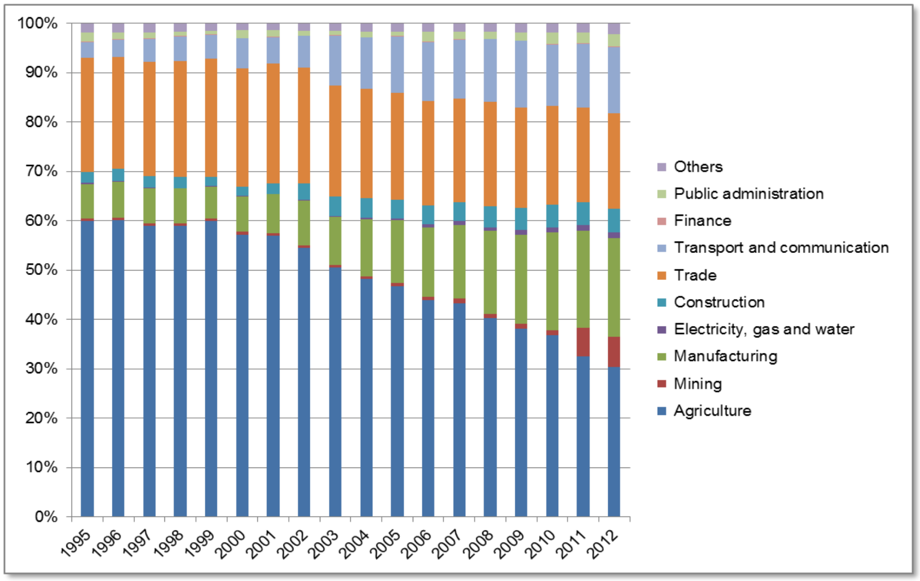
Source: Asian Development Bank

Figure I-2: Myanmar's GDP by Sector



Source: Asian Development Bank

Figure I-3: Myanmar's GDP by Sector (% basis)

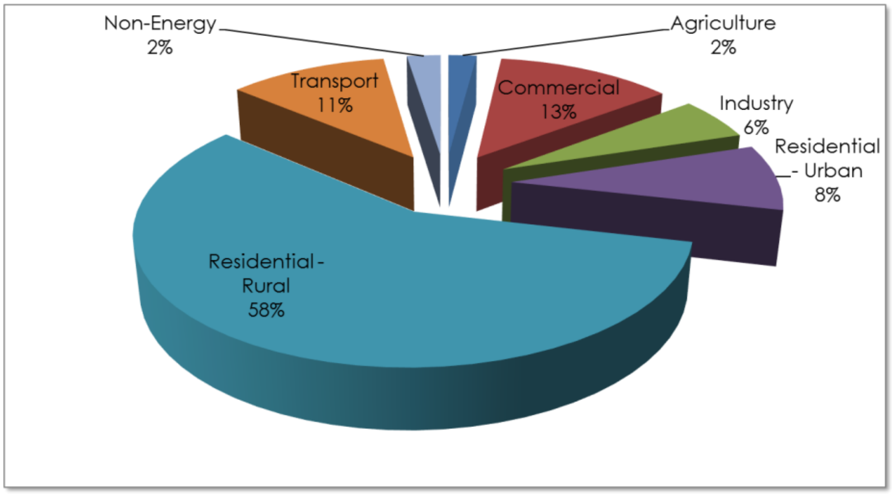


Source: Asian Development Bank

2. The sub-sector GDP contribution of the agriculture sector is estimated to be farming (18%); fisheries and livestock (9%); and forestry (3%). Whilst the farm sector GDP contribution appears at a modest 18%, in 2012 it is estimated that the agriculture sector employed around 63% of the total labour workforce, of which 36% was found in the farm sector.

3. In contrast, the agriculture sector final energy consumption (FEC) is a relatively small part of the overall final energy consumption of Myanmar. In 2012 the FEC of agriculture was only 2% of total FEC. This reflects the need for more motive power for farms and more powered irrigation.

Figure I-4: Final Energy Consumption: 2012



Sources: Ministries of Myanmar, Consultant estimates based on EMP surveys

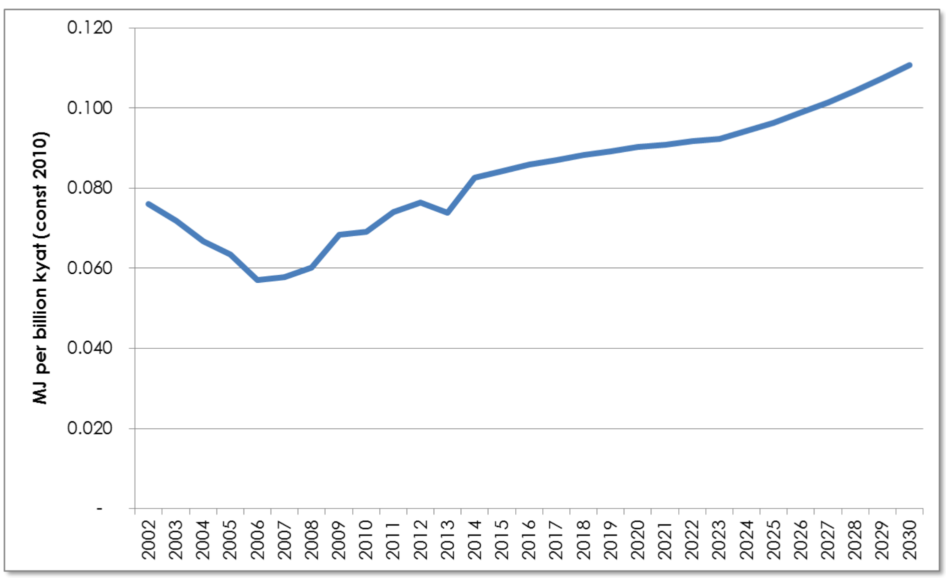
B. Sector Energy Use

4. Whilst total agriculture final energy consumption is small, the farm sector is the dominant energy user.

- Livestock energy use is associated with village water pumping;
- Off-shore fishing vessels are diesel powered but fuel consumption is negligible;
- On-shore fishing – the energy use of prawn pond fisheries has been captured under the commercial sector but is again negligible;
- Forestry energy use mainly concerns electric saw mills. In Myanmar hauling of logs is carried out by elephants;
- The farm sector uses significant energy to power irrigation pumps; these pumps include river pumps and tube-wells, both electric and diesel fuelled. Energy is also required for motive power in the form of tractors and power tillers.

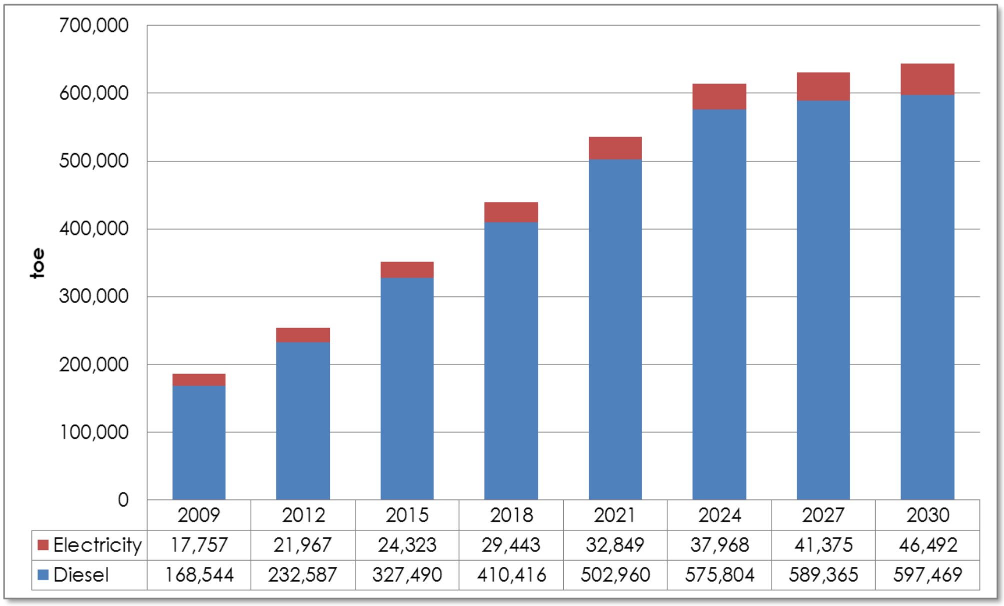
5. The relationship between Agriculture sector GDP and Agriculture sector energy is the energy intensity of the Agriculture sector. It is calculated as a unit of energy needed per unit of farm GDP. The relationship between energy intensity and economic development has the following pattern in agriculture - in the initial stage, where agriculture is more conventional, human and animal muscle power plays a significant role; energy intensity is lower and productivity is also low. In the second stage, the initial phase of the modernization of agriculture, energy intensity increases because of the application of chemical fertilizer, pesticides, and from motive power. In the third stage, energy intensity decreases due to increased efficiency of farm productivity, through modern technology and efficient utilization of various forms of energy. Myanmar is in the second stage transition in agriculture.

Figure I-5: Agriculture Sector Energy Intensity



Sources: Consultant

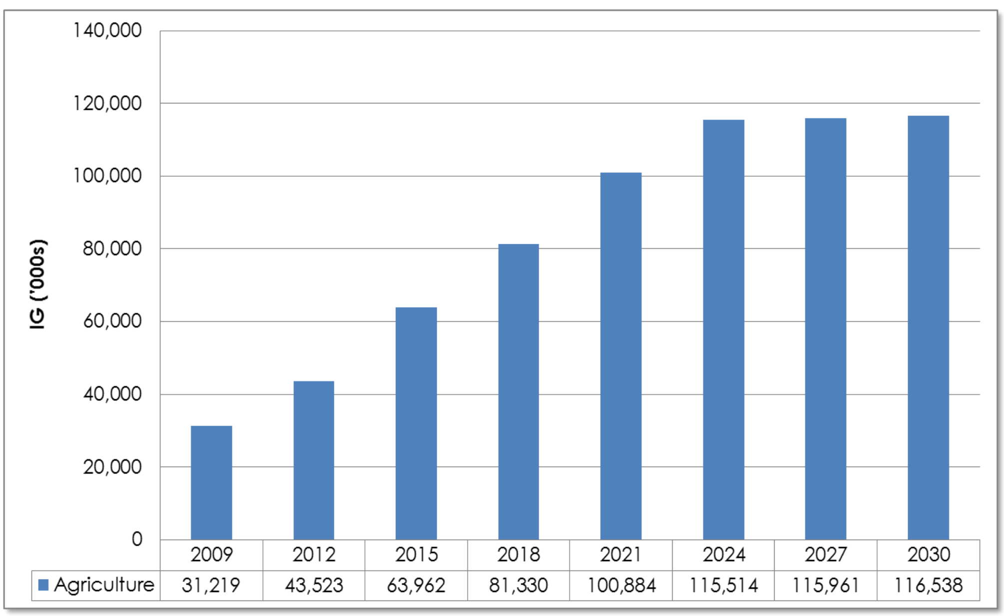
Figure I-6: Agriculture Sector Final Energy Consumption



Sources: Consultant

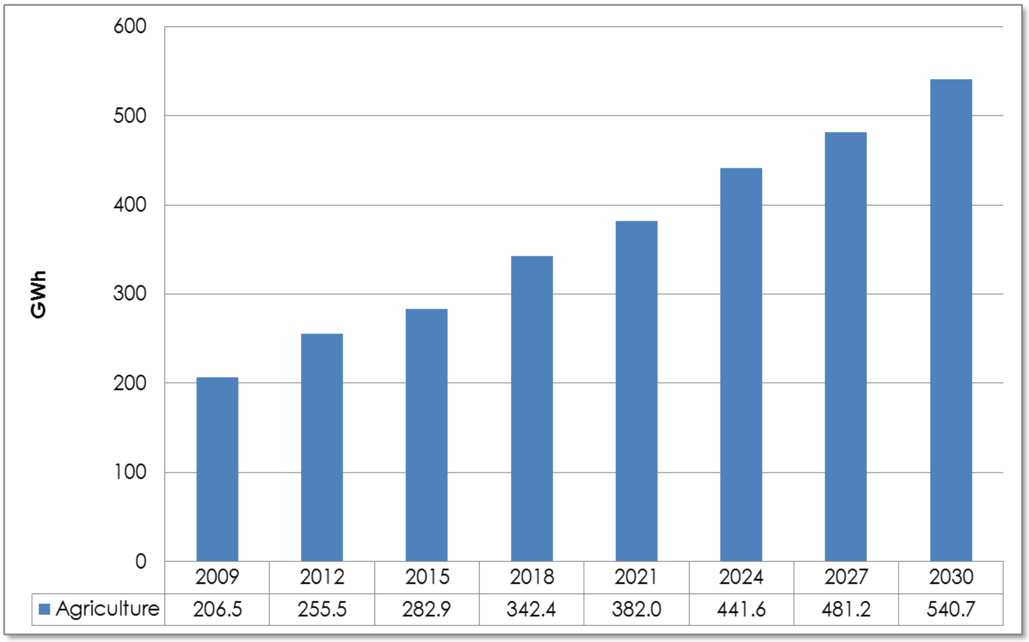
6. The estimated Agriculture Sector final energy consumption shows a rising trend from just under 0.2 mtoe in 2009 to 0.63 mtoe in 2030. The corresponding energy carrier demands, for diesel and electricity fuels, are shown in Figure I-7 and Figure I-8.

Figure I-7: Final Diesel (HSD) Fuel Consumption



Sources: Consultant

Figure I-8: Final Electricity Consumption



Sources: Consultant

II. AGRICULTURE SECTOR

C. Introduction

7. The Agriculture sector includes farming and horticulture, livestock, fisheries and forestry. Agriculture produces a wide range of crops. The principal crops include:-

i. Rice, grown on around 8.2 million hectares;
ii. Beans and pulses, which have recently become major export crops and are grown on around 4.2 million hectares;
iii. Oilseeds (especially in the Central Dry Zone), grown on 1.7 million ha; production is insufficient to meet national demand and around 200 000 tons of palm oil are imported annually;
iv. Vegetables and chilies, grown on about 0.8 million ha, principally in highland areas; and
v. Other crops, including maize, cotton, rubber, sugarcane, and tropical fruit crops.

8. The Livestock sub-sector includes cattle, buffalo, swine, and poultry. Livestock production represents a considerable portion of household income and capital, accounting for around 7.5% of overall GDP. Most rural households raise livestock, thereby contributing significantly to household protein (meat, eggs, and milk). Livestock also contributes to agriculture GDP through sale of by-products such as hides and leather. Almost all livestock is raised in household backyards

although there is some commercial production near major cities. Livestock numbers have changed little for the past decade, except for the poultry population, which has tripled.

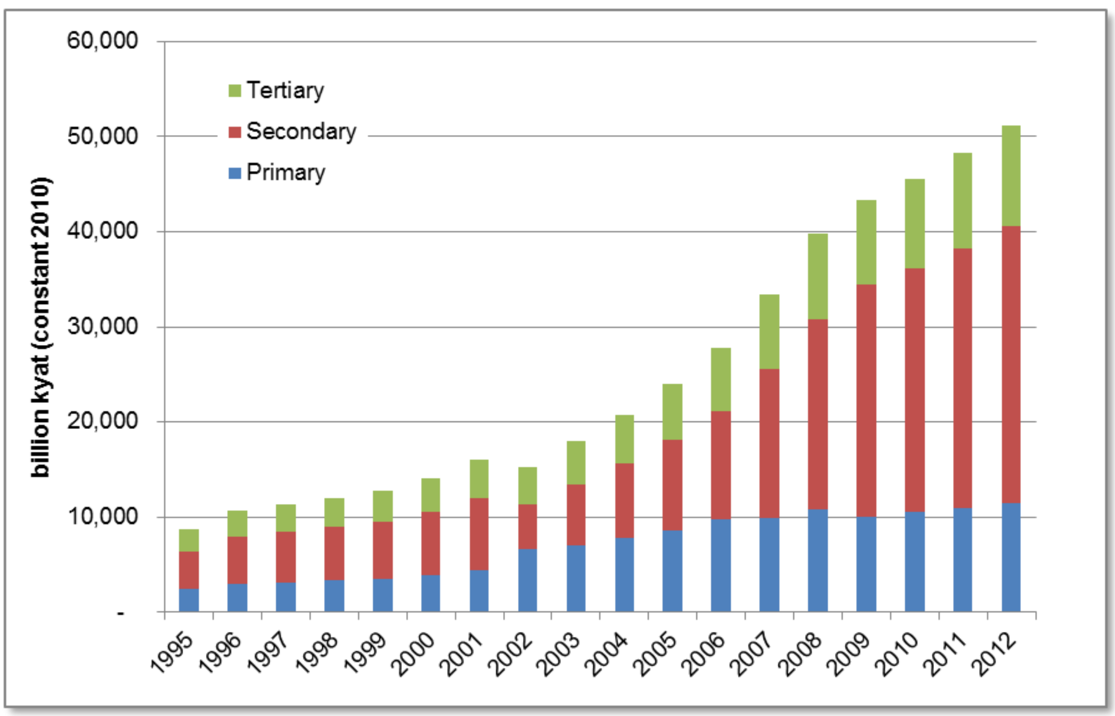
9. The Fisheries sub-sector relies on the country's abundant water resources. There are substantial fisheries in the major rivers, the 1 900 km of coastline, and the 500 000 ha of mangrove swamps. There is considerable potential for aquaculture development in the low-lying river delta areas in the south and centre of the country. Fisheries production almost tripled between 1998 and 2009, mainly due to aquaculture development. Fish and shrimp have become major export items.

10. The Forestry sub-sector is built on one of the largest forest reserves in Southeast Asia. Around 50% of the total land area of Myanmar is heavily forested or unsuitable for agriculture, being mountainous or deforested hill slopes. As well as being a major economic resource, this huge forest reserve, much of which is closed, provides an important component of biodiversity, ecological preservation, and environmental sustainability within Southeast Asia. Teak and hardwood logging is undertaken on a quota basis. Firewood and charcoal supplies are mainly by-products of logging and, with the exception of the mangrove forests found in the coastal / delta areas, generally not associated with deforestation.

D. Key Statistics for the Agriculture Sector

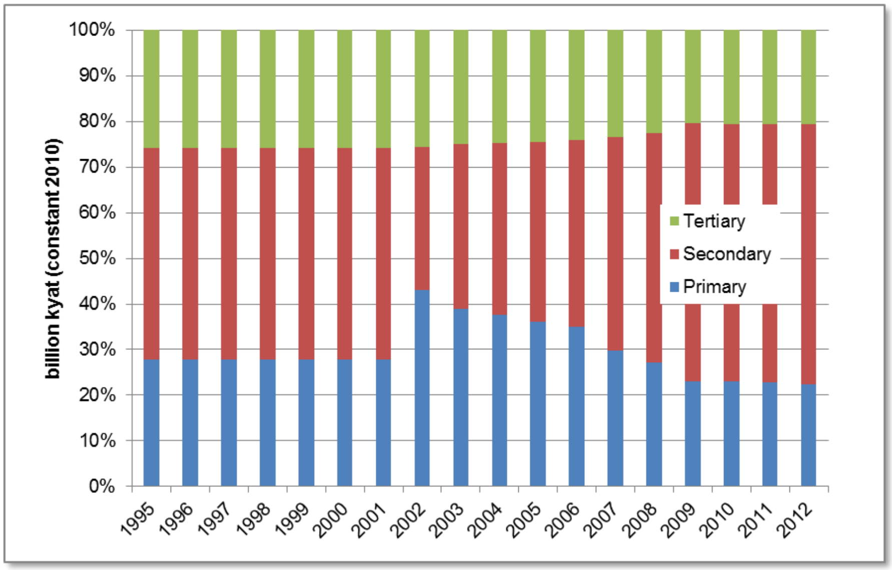
11. The prosperity of Myanmar is heavily dependent on the primary sector. The sector contributed 15,753 billion kyats in 2012. The GDP of the sector has grown steadily since 1995 as shown in Figure II-1.

Figure II-1: Primary Sector GDP



Sources: ADB

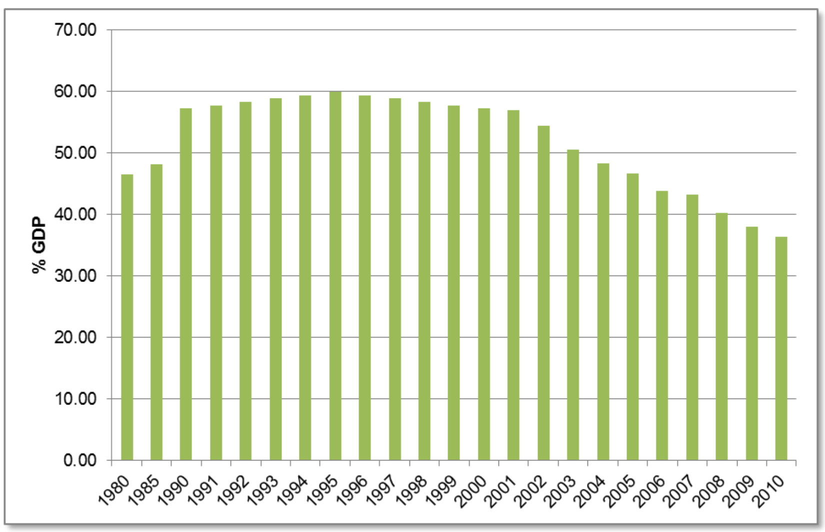
Figure II-2: GDP Composition by %



Sources: ADB

12. The primary sector Value-Added measure of performance (as % of GDP) has followed a steadily declining trend since 2000 as shown in Figure II-3. The reason that the workforce has increased but 'value-added' has reduced is likely to be because farm mechanization is low and farming is therefore labour intensive. Farming practices are largely of a traditional nature, relying heavily on human and draft power.

Figure II-3: Primary Sector Value-Added as % GDP



Sources: World Bank Development Indicators

13. In 2012, the agriculture sector employed around 56% of the active labour force in Myanmar or 15.0 million. The labour force is reported to have grown by 1.9% since 1995 as shown in Figure II-6 below.

Table II-4: Agriculture Sector Workforce (millions)

1995	1996	1997	1998	1999	2000	2001	2002	2003
10.7	10.9	10.2	10.5	10.4	10.5	11.0	12.6	12.7
2004	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**
13.3	13.8	14.5	14.5	14.8	14.2	14.5	14.7	15.0

Sources: ADB, Ministry of Industry, Consultant

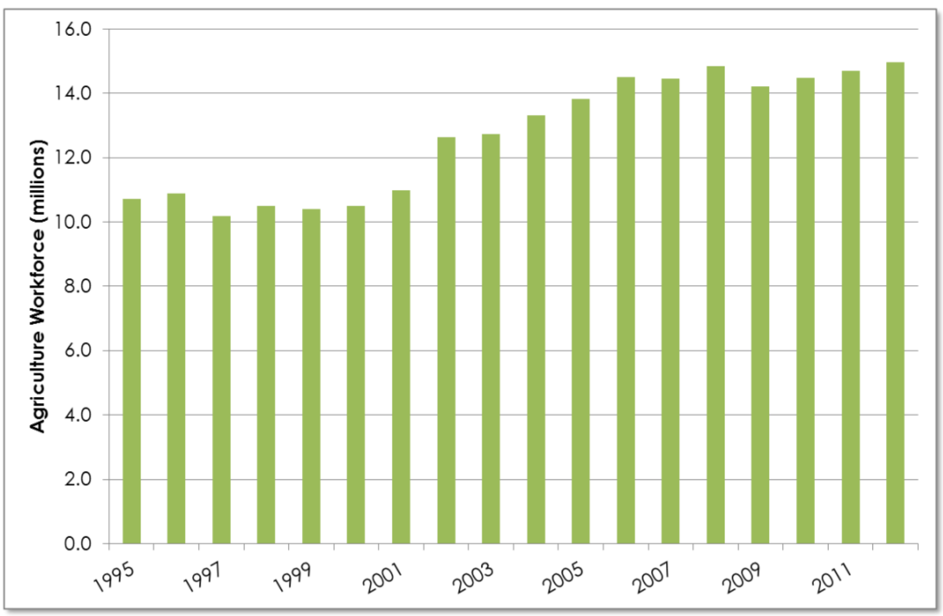
14. In 2012, the farm sector employed around 80% of the Agriculture sector labour (est. 19.5 million), or 50% of the active labour force (est. 31.1 million). The farm labour force is estimated to have grown by an average of 2% since 2002 as shown in Table II-5.

Table II-5: Estimated Farm Workforce (millions)

	2004	2005	2006	2007	2008	2009	2010	2011	2012
Farm	10.6	11.1	11.6	11.6	11.9	11.4	11.6	11.8	12.0

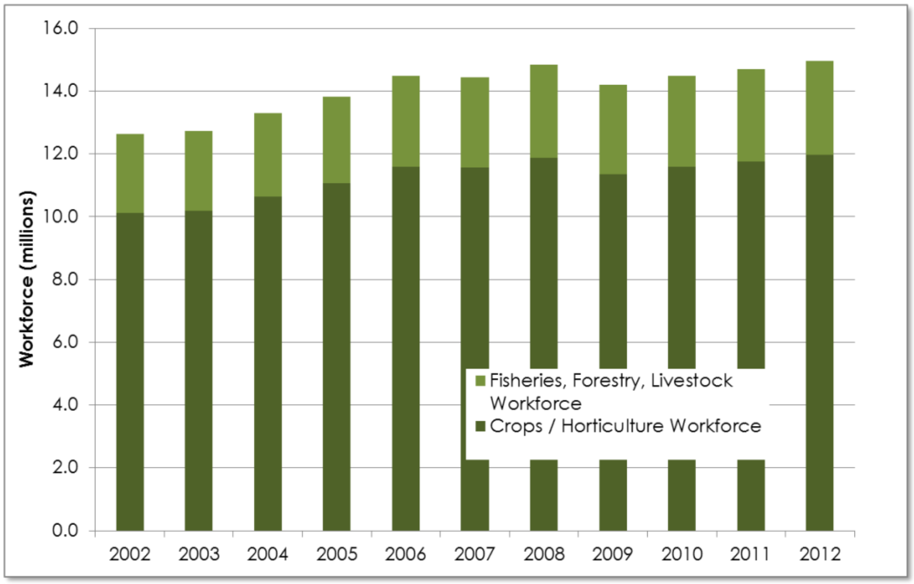
Sources: Consultant; refer also Volume II: Economic Outlook

Figure II-6: Agriculture Sector Workforce



Sources: Consultant

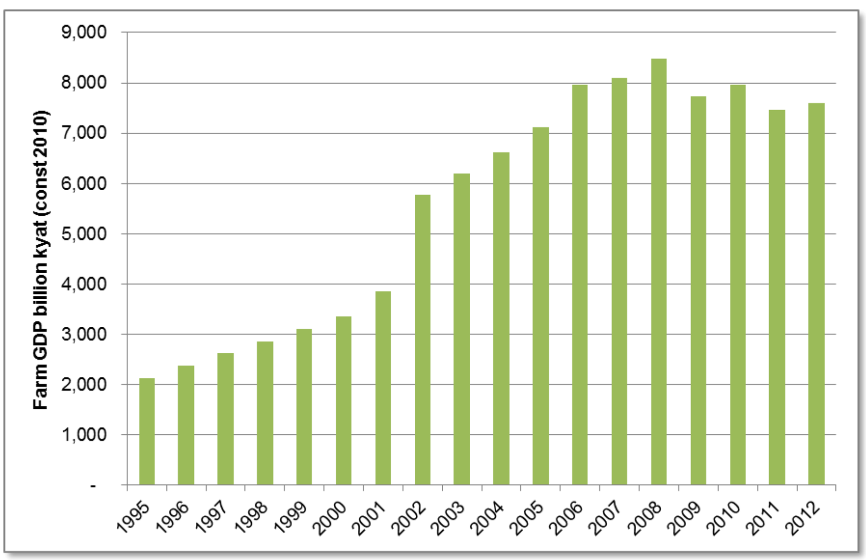
Figure II-7: Estimated Farm Labour on Agriculture Sector Workforce (FY 2005 – 2012)



Sources: ADB, Ministry of Industry, CSO

15. Agriculture sector GDP has steadily increased in real terms from FY 1995 to FY 2008, only to fall in recent years as shown in Figure II-8. The step change reported in FY 2002 is possibly a result of the lifting of economic sanctions by the United States, a result of over-reporting, or both. The impact of Cyclone Nargis in 2008 and the global economic crisis can be seen in Figure II-8 in FY 2009; it is also apparent that by FY 2012 the farm sector had not fully recovered. Nevertheless a long term trend in farm sector GDP growth is apparent.

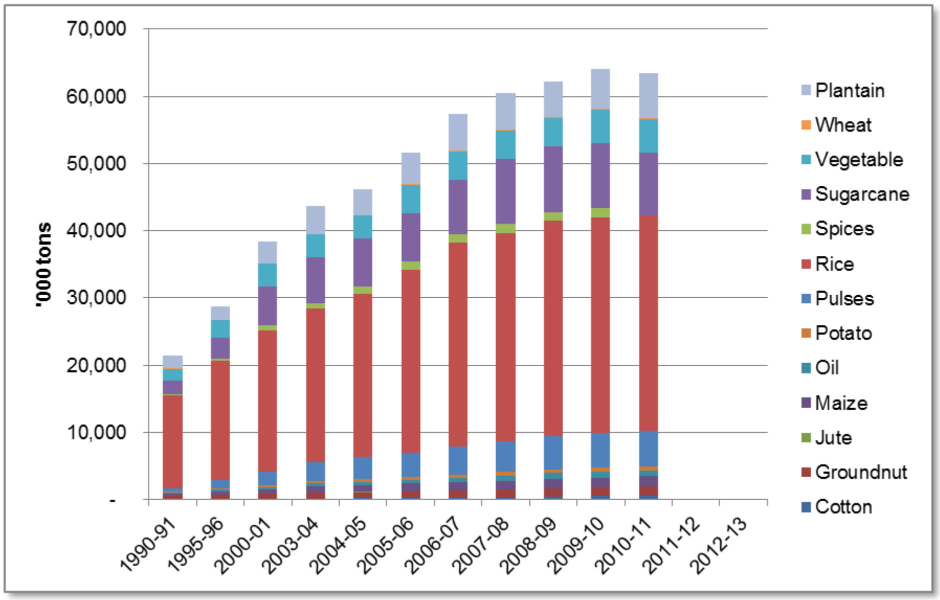
Figure II-8: Agriculture GDP billion kyat (constant 2010)



Sources: ADB

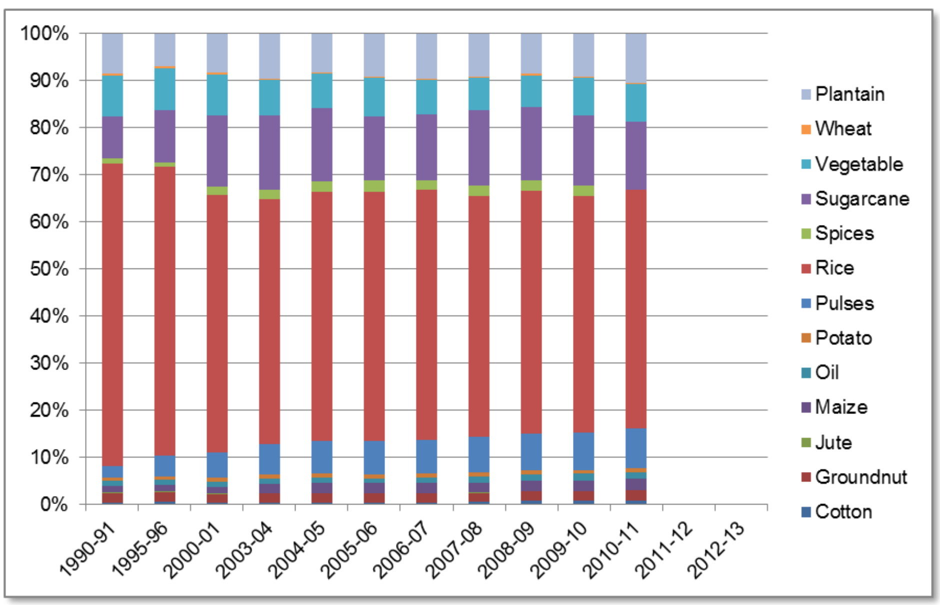
16. Crop production by weight increased by an average 10% during the period 1990 to 2010, as shown in Figure II-9. Rice production accounted for 51% of food production by weight in 2010, followed by sugarcane at 15%, plaintain at 10% and pulses at 8%, as shown in Figure II-10.

Figure II-9: Crop Production (tons)



Sources: Central Statistics Office of Myanmar

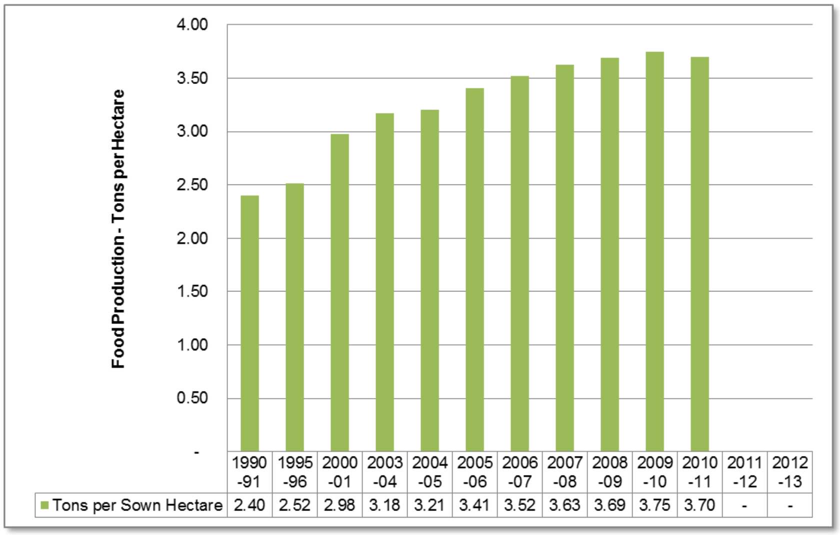
Figure II-10: Crop Production (tons) by %



Sources: Central Statistics Office of Myanmar

17. Land productivity, as measured by crop production per net hectare[1], has steadily increased since 1990, appearing to have stagnated since 2008. The stagnation in rice yields was noted by Naing / Kingsbury[2].

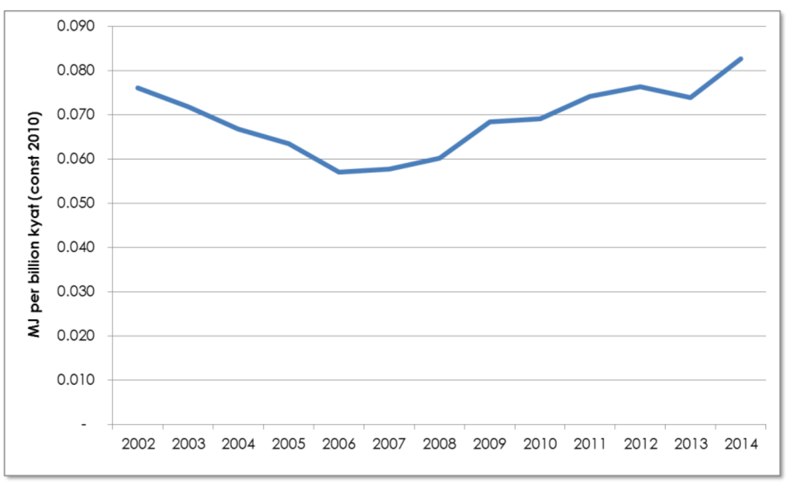
Figure II-11: Land Productivity (tons food per net hectare)



Sources: CSO; 2011 and 2012 data in abeyance

18. According to modelling of farm sector energy end-use, the energy intensity of the Agriculture sector has shown a consistently rising trend since 2007. This trend is consistent with rising agricultural food production and yields.

Figure II-12: Agriculture Sector Energy Intensity



Sources: Consultant

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[1] A net hectare is a measure of sown hectares on basis of land-use; sown hectares may be greater than net hectares due to double- and triple-cropping

[2] Naing/Kassel, A Survey of Myanmar Rice Production and Constraints – Yezin Agricultural University & University of Kassel, 2008

E. Farm Sector Analyses

19. In 2013 University of Michigan and Myanmar Development Resource Institute experts, working on behalf of USAID[3], reported that the imposition by many countries of deep economic sanctions in the late 1980s had clearly hampered development of Myanmar's ANRE[4] sector. They stated that "in the nearly three decades following imposition of the sanctions, Myanmar lost most access to international investment and assistance. Consequently, the development of Myanmar's ANRE sector has lagged greatly behind its potential". Furthermore that "all of these impediments [to the performance of the agriculture sector] can be remedied through good policies, institutional reforms and key public investments".

20. In practice the potential for the growth of farm GDP depends on the starting position of crop yields, the rate at which increased crop yields can be achieved, and a ready market for sale of crops at prices that return a profit margin. The rate at which crop yields can be increased also depends on land and labour productivity.

21. Land productivity depends mainly on the following factors:-

- Total sown hectares (includes cropping frequency);
- Seed quality;
- Fertilizer (nitrogen);
- Pesticide; and
- Water (irrigation).

22. Labour productivity depends on farm mechanization which involves the use of tractors, power tillers and harvesting equipment.

23. **Sown Hectares.** In 2009 the potential net sown hectares was reported to be 17.1 million hectares compared to the actual net sown area of 12.3 million hectares. As shown in Table II-13 the category of 'waste land' equates to 5.4 million hectares which is approximately the difference between 17.1 and 12.3 million hectares.

[3] A Strategic Agricultural Sector and Food Security Diagnostic for Myanmar; USAID/MDRI/CESD, July 2013
[4] Agriculture and Nature Resources

Table II-13: Land Use in Myanmar (2009)

	Hectares (million)	%
Net Sown Land	12.3	18%
Waste Land	5.4	8%
Forest Land	33.5	50%
Other Land	16.5	24%
Total	67.7	100%

Sources: MoAI, CSO

24. The statistics indicate that there is scope to increase net sown hectares by converting waste land to farm land. However, according to the MCDV "the expansion of agricultural land is becoming technically more difficult and financially more costly." Consequently for energy planning purposes it is assumed that, for the planning horizon to 2035, cultivable waste other than fallows will not be less than 5% of the of the total land area.

Table II-14: Cultivable Land Use Projection (million hectares)

2014	2015	2016	2017	2018	2019	2020	2021
13.76	14.08	14.40	14.73	15.07	15.42	15.77	16.14
2022	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**
16.51	16.89	16.89	16.89	16.89	16.89	16.89	16.89

Sources: Consultant

25. **Seed.** Naing/Kingsbury reported that "most farmers in both Upper and Lower Myanmar sowed seed from their own harvest or from neighbouring farms, rather than purchasing seed as recommended from the Myanmar Agriculture Service. Respondents mentioned that due to poor transportation and communication infrastructures, certified seeds of improved rice varieties were often unobtainable. As a result, a considerable amount of varietal degeneration was found in all areas of rice cultivation surveyed, likely the result of farmers using seeds from their own harvest for extended time periods". Furthermore, Naing/Kingsbury recommended that "The seed production sector should be strengthened to supply quality seeds at affordable prices to farmers throughout the country. In addition, farmers should be trained to carefully select and manage their own seed production fields". While seed quality is not linked directly to energy use, nevertheless food production will be affected and energy consumption will therefore be affected indirectly. For the purpose of energy planning it is simply assumed that seed quality will be improved sufficiently that a food production target of 5.2 tons per hectare can be achieved, thereby matching Vietnam's level of food production – refer Section E below for more details.

26. **Fertilizer / Pesticide.** Fertilizer use, as reported by the Central Statistics Organization, has varied considerably since 1990. The kg per hectare fertilizer load appears to have fallen considerably, well below the levels observed in other developing countries.

Table II-15: Fertilizer Use (Urea)

	1990-91	1995-96	2000-01	2003-04	2004-05	2005-06	2006-07
000 tons	151 565	369 481	264 171	196 240	112 150	117 620	136 120
GJ / hectare	1.03	1.96	1.24	0.86	0.47	0.47	0.51
kg per hectare	16.98	32.30	20.50	14.26	7.79	7.76	8.36
	2007-08	**2008-09**	**2009-10**	**2010-11**	**2011-12**	**2012-13**	**2013-14**
000 tons	76 870	105 700	168 660				
GJ / hectare	0.28	0.38	0.60				
kg per hectare	4.61	6.27	9.88				

Sources: CSO

27. According to Naing / Kingsbury there is considerable scope to increase land productivity by increasing the application of nitrogen fertilizer up to 80 kg per hectare from the current low level. Their survey and field trials, conducted in 2008, found that mean yields were increased by 36% with suitable fertilizer loads.

28. Fertilizer can be imported or manufactured in Myanmar. The manufacture of fertilizer (urea) requires natural gas. An economic evaluation of these options is discussed in further detail under the gas strategy section of the Energy Masterplan.

29. Pesticide use has also varied considerably since 1990. According to Naing / Kingsbury the use of pesticides cannot be justified in Myanmar. Their survey and field research found that the overall incidence of insect pests was very low and they concluded as follows “it appears that most pesticide applications are unnecessary or counterproductive. Insecticides usually have a higher human toxicity than fungicides and herbicides, and when considering the rudimentary understanding of pesticides and pesticide safety expressed by respondents, the potential for health hazards are real. In view of their high cost and the associated health hazards especially when not applied with the proper precautions, any recommendation for their use appears unwise”. Therefore for energy planning, no allowance has been made for pesticide use.

Table II-16: Pesticide Use (tons per sown hectare)

	1990-91	1995-96	2000-01	2003-04	2004-05	2005-06	2006-07
Imperial Gallons	43 900	166 868	17 523	27 297	36 788	11 566	33 414
GJ / hectare	0.002	0.001	0.000	0.000	0.000	0.000	0.000
	2007-08	**2008-09**	**2009-10**	**2010-11**	**2011-12**	**2012-13**	**2013-14**
Imperial Gallons	518 000	621 934	660 051				
GJ / hectare	0.006	0.006	0.006				

Sources: CSO

30. **Water (Irrigation).** Naing / Kingsbury concluded that “Water management has to be improved to allow a more efficient management of the resource at the farm level”. They referred to the higher yields of rice in the Mandalay region as follows “Reported and measured rice yields were generally higher in Upper Myanmar than in Lower Myanmar, likely the result of higher radiation and favourable socioeconomic conditions. The Mandalay Division of Upper Myanmar for example, enjoys a climate particularly suited to rice production, and access to year round irrigation water allows for the

cultivation of three crops per year. In addition, spatial proximity to urban markets directly correlates with higher profits than what is obtainable to farmers in other regions. This additional income allows for the purchase and use of additional inputs to further enhance yields". Therefore, for energy planning, allowance has been made for enhanced and more reliable irrigation.

31. The Ministry of Agriculture and Irrigation maintains a network of river pumping stations. In 2013-14 it was reported by MoAI that 22.4% of the main pumping stations were powered by diesel engines while the remainder are powered by electric motors. MoAI has an objective to replace the diesel engines with electric motors where a national grid supply is available. The average river pump size is 1 MVA. The total electrical capacity of the prime movers as at end 2013-14 is shown in the following table:-

Table II-17: Inventory: River Pumping Stations (2013)

	Pumping Stations	**Beneficial Area**	**Capacity**
State/Region	**count**	**acres**	**MVA**
Sagaing Region	62	206 385	130.0
Mandalay Region	83	172 961	123.8
Magway Region	55	100 706	67.4
Bago Region	61	64 340	19.3
Yangon Region	33	63 955	9.2
Ayeyarwaddy Region	29	67 627	14.8
Kayar State	3	4 732	1.5
Kayin State	7	9 100	1.7
Mon State	7	41 900	21.8
Shan State	8	5 780	5.1
Kachin State	5	2 100	0.8
Rakhine State	4	800	0.3
Tanintharyi Region	11	2 100	0.8
Chin State	0	0	0.0
Total	368	742 486	396.3

Sources: MoAI

32. Farmers use deep and shallow tubewells, and low lift pumps for irrigation purposes. MoAI reported that half of the tubewells are powered by diesel fuel and half by electric pumps.

Table II-18: Inventory: Farm Tubewells

	2008-09	**2009-10**	**2010-11**	**2011-12**	**2012-13**	**2013-14**
DTW - Diesel	4,526	5,028	5,587	6,208	6,898	7,587
DTW - Electric	3,017	3,352	3,725	4,139	4,598	5,058
STW - Diesel	12,319	13,688	15,209	16,899	18,777	20,654
STW - Electric	5,280	5,866	6,518	7,242	8,047	8,852
Total	25,142	27,935	31,039	34,488	38,320	42,152

Sources: MoAI; Consultant

33. In many villages drinking water is provided from deep and shallow tubewells. These village water supplies are also powered by diesel and electric motors. As was the case for tubewells used for agriculture, it is reported by MoAI that the inventory of diesel engines and electric motors is evenly split at 50%.

Table II-19: Inventory: Domestic Water Supply: 2013

	Deep	Shallow	Total	Beneficial Population
Kachin	17	655	672	141,000
Kayah	58	177	235	60,645
Kayin	49	20	69	34,230
Sagaing	2,826	1,830	4,656	2,178,275
Bago	2,491	8,638	11,129	3,878,680
Magwe	2,650	1,877	4,527	2,062,818
Mandalay	3,486	1,105	4,591	2,418,255
Mon	176	45	221	113,900
Rakhine	15	786	801	151,845
Yangon	1,971	3,930	5,901	2,259,515
Shan	213	102	315	147,900
Ayeyarwaddy	771	4,481	5,252	1,519,855
Total	14,723	23,646	38,369	14,966,918

Sources: MoAI publication

Table II-20: Inventory: Tubewells for Village Drinking Water Suppy

	2008-09	2009-10	2010-11	2011-12	2012-13	2013-14
DTW - Diesel	9,660	10,733	11,926	13,251	14,723	16,195
DTW - Electric	6,440	7,155	7,950	8,834	9,815	10,797
STW - Diesel	6,352	7,058	7,842	8,713	9,681	10,650
STW - Electric	2,722	3,025	3,361	3,734	4,149	4,564
Total	25,174	27,971	31,079	34,532	38,369	42,206

Sources: MoAI; Consultant

34. **Farm Mechanization.** The Ministry of Agriculture and Irrigation reported the number of tractors and power tillers according to Table II-21. As a point of reference, this level of mechanization is similar to that of Bangladesh, where the sown hectares in 2005 were 15 million hectares and the tractor inventory was reported to be 12 500 units. The Myanmar Government reported 15 million sown hectares in 2005 and a tractor inventory of 11 000 units.

Table II-21: Inventory: Farm Machinery

	1990-91	1995-96	2002-03	2003-04	2004-05	2005-06	2006-07
Tractors	10 000	9 000	11 000	11 000	11 000	11 000	11 000
Power Tillers	5 000	17 000	70 862	82 566	85 800	97 000	109 000
	2007-08	**2008-09**	**2009-10**	**2010-11**	**2011-12**	**2012-13**	**2013-14**
Tractors	11 000	11 000	11 000	11 000	11 000	12 000	13 000
Power Tillers	118 000	138 000	148 000	160 000	197 000	218 000	230 000

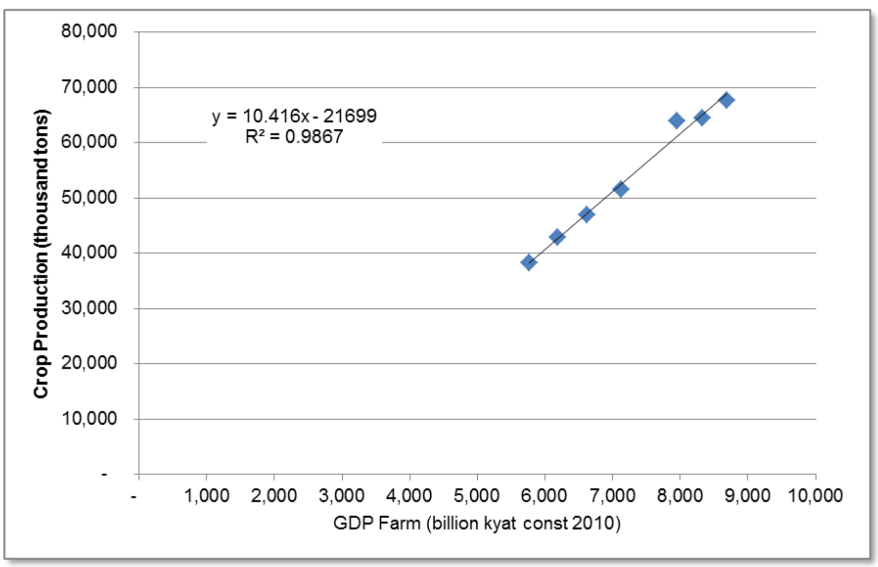
Sources: MoAI

35. The above statistics and inventories are summarized in Table II-26 below. The historical data reveals three relationships that are important for forecasting the energy needs of the farm sector. These relationships are:-

1. The relationship between food production and farm GDP;
2. The relationship between farm labour and farm GDP; and
3. The relationship between motive energy (human, animal, tractor, power tiller) and farm GDP.

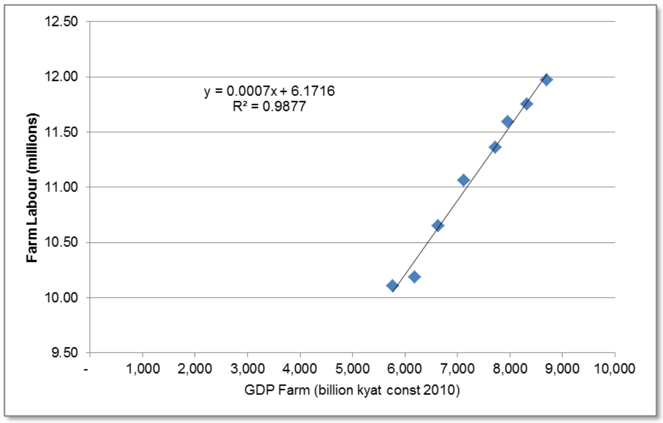
36. These relationships are charted below as Figure II-22 to Figure II-24. In each case the data relationships for FY 2007, 2008 and 2009 were found to lie on a lower trajectory, suggesting that GDP data reported at the time of Cyclone Giri and the global financial crisis was overstated. In any case these data points were omitted from the analysis as outliers. For the remaining data points it can be seen that the relationships are consistently linear, with high correlation. Therefore, these relationships were used to estimate farm labour, motive energy requirements and anticipated crop production for a chosen agricultural GDP trajectory.

Figure II-22: Food Production vs. Farm GDP (1995 – 2013)



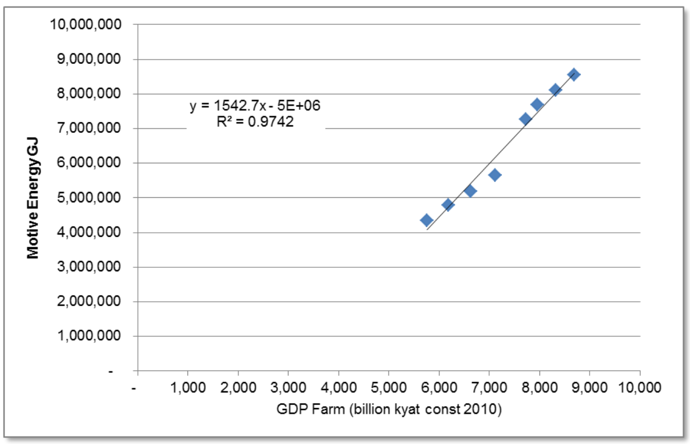
Sources: Consultant

Figure II-23: Farm Workforce vs. Farm GDP (1995 – 2013)



Sources: Consultant

Figure II-24: Motive Energy vs. Farm GDP (1995 – 2013)



Sources: Consultant

37. In the agriculture sector, motive energy, the total physical (human and draft animal) and mechanical energy (powered farm machinery), has been estimated for the period 2002 to 2013 on GJ per hectare basis. Commercial energy (irrigation) is not included in the motive energy category. The level of estimated motive energy is consistent with the levels reported in other countries, e.g. in Bangladesh where agricultural conditions are similar and benchmarks provided a validation of the estimates.

Table II-25: Estimated Motive Energy (GJ per hectare)

2002	2003	2004	2005	2006	2007
0.34	0.35	0.36	0.37	0.38	0.40
2008	**2009**	**2010**	**2011**	**2012**	**2013**
0.41	0.43	0.44	0.45	0.46	0.49

Sources: Consultant

Table II-26: Crop Farm Sector Statistics (2003 – 2013)

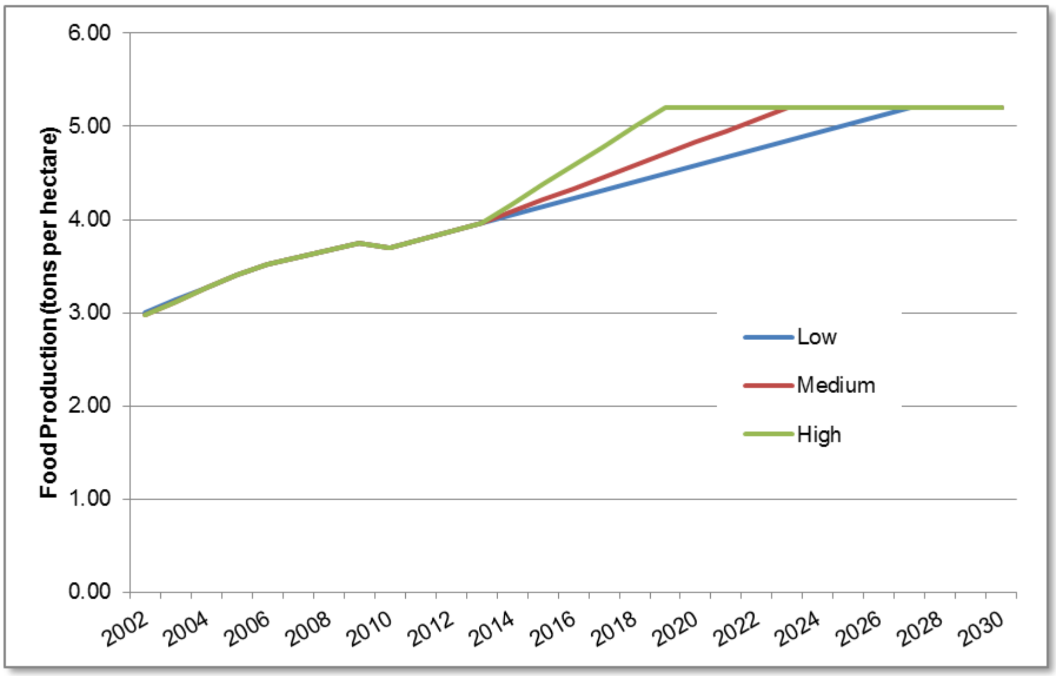
		2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Food Production	'000 tons	42,935	46,956	51,607	57,294	59,975	61,889	64,028	64,583	67,690	70,860	74,140
Farm GDP	billion kyat const 2010	6,193	6,628	7,125	7,961	8,103	8,471	7,730	7,955	8,330	8,697	9,201
	% growth	7.4%	7.0%	7.5%	11.7%	1.8%	4.5%	-8.8%	2.9%	4.7%	4.4%	5.8%
Farm Workforce	Millions	10.2	10.6	11.1	11.6	11.6	11.9	11.4	11.6	11.8	12.0	12.6
Farm Labour Productivity	GDP per worker '000	608	622	644	686	701	713	680	686	709	726	730
Sown Hectares	'000	13,761	14,390	15,151	16,277	16,675	16,848	17,074	17,467	17,868	18,279	18,700
Land Productivity	tons per hectare	3.1	3.3	3.4	3.5	3.6	3.7	3.8	3.7	3.8	3.9	4.0
Tractors	Count	11,000	11,000	11,000	11,000	11,000	11,000	11,000	11,000	12,000	13,000	13,000
Power Tillers	Count	82,566	85,800	97,000	109,000	118,000	138,000	148,000	160,000	197,000	218,000	227,489
Est. Motive Energy	PJ	4,781	5,186	5,650	6,258	6,639	6,971	7,272	7,682	8,105	8,417	9,195

Sources: GDP – ADB, Food Production, Net Hectares – CSO, Motive Energy – Consultant Estimate, Farm Workforce – ADB & Consultant Estimate, Tractors/Power Tillers – CSO and LIFT (2012)

F. Farm Sector Energy Demand Projections

38. Energy projections are based on an assumption that farm sector output, measured as food tons per hectare, will grow according to the trajectories shown in Figure II-27. These growth scenarios are based on a target rice production of an average of 5.2 tons of food per hectare, matching the reported performance of Vietnam's paddy fields. The improvement in productivity of Vietnam, shown in Figure II-28, reveals that Vietnam passed the level of Myanmar's current agricultural productivity in 2000, achieving a rice yield of 5.2 tons per hectare after eight years of continuous gains.

Figure II-27: Agriculture Sector Productivity Assumption (tons per hectare)

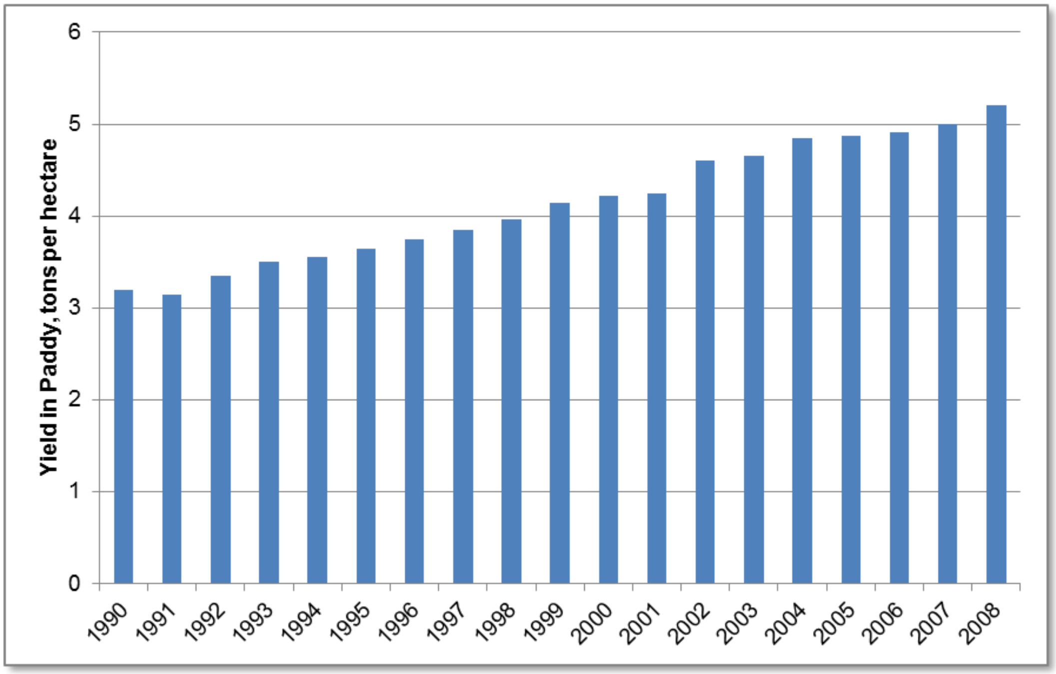


Sources: Consultant

39. The low growth case is based on the assumption that the 5.2 tons per hectare target can be achieved by 2027 (a 12 year period). The Medium scenario assumes target achievement by 2023 (8 years), and the High scenario by 2019 (5 years). These target years are based on considerations of food security, economy-wide GDP growth, economy-wide employment needs and farm mechanization.

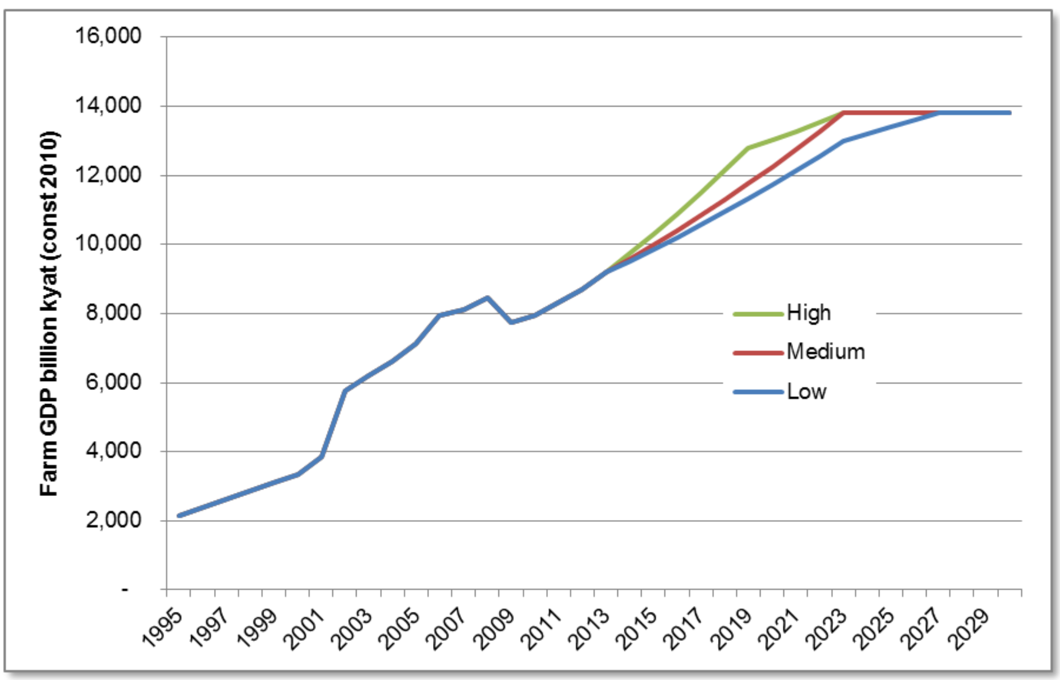
40. Achievement of the targeted level of food production will be accompanied by GDP growth. This growth has been estimated based on the observed historical relationship between food production and GDP growth in Myanmar. The Low growth scenario loosely follows the growth trajectory reported before FY 2003, the year that US economic sanctions were imposed. The High growth trajectory follows the trend reported from FY 2003 to FY 2008, at which point the global economic crisis appears to have impacted Myanmar's economic performance as shown in Figure II-29.

Figure II-28: Paddy Production in Vietnam



Sources: General Statistics Office Vietnam

Figure II-29: Agriculture Sector GDP



Sources: Consultant; refer also Volume I: Economic Outlook

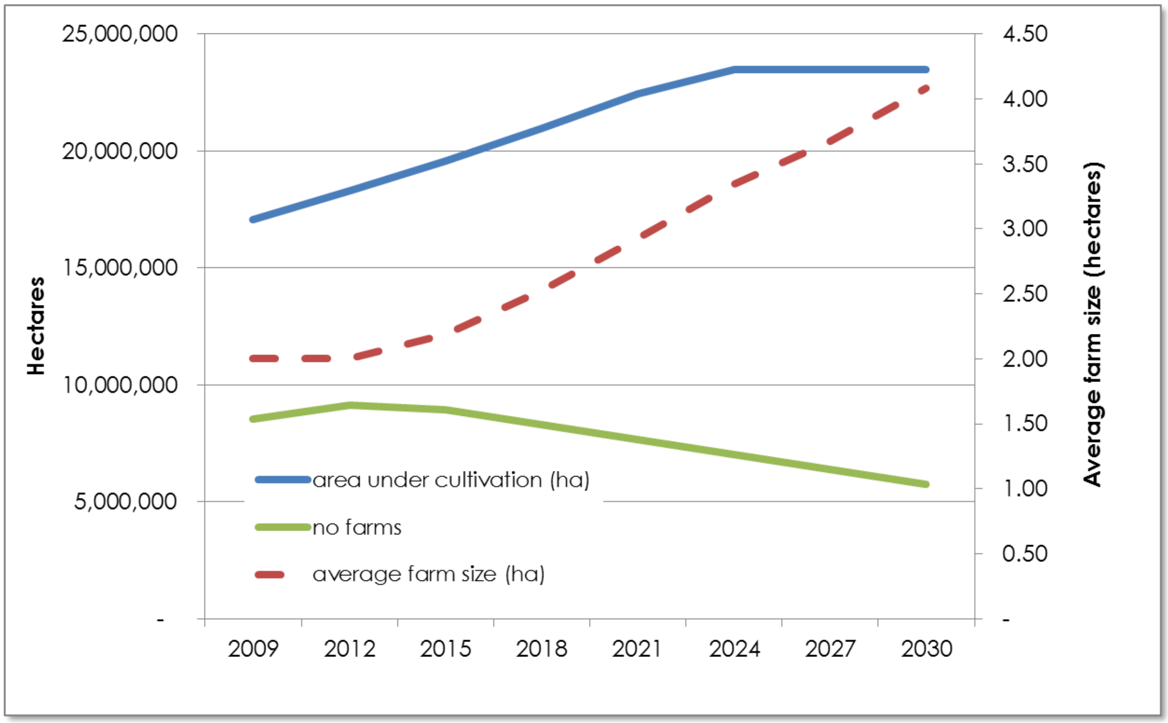
G. Farm Sector Energy Modelling

41. Long-term farm GDP growth rate scenarios have different resource needs for physical and mechanical energy and non-energy inputs such as fertilizer and seed. The total energetic efficiency of farming is the defined by the relationship between the total output energy of farm product in the form of different kinds of crops such as rice, pulses, wheat, maize, jute, oil seeds, vegetable, potato, sugarcane, spices, cotton and groundnut, and their residues, and the input energy required to produce crops and their residues. Input energy can be restricted to consideration of 1) only the commercial energy input; or 2) the total energy input including commercial energy and solar energy input. In the second approach, the aim is to determine the efficiency of converting solar energy by agriculture as it increases through the additional input of all forms of energy; human, draft animal, machinery, fertilizer, manure, pesticide, commercial fuels (petroleum and electricity), as well as from water and seeds. In both cases the over-arching aim is to determine the minimum energy requirement for maximum agricultural production from cultivated land.

42. Method 1) is selected for farm sector energy demand projections. The calculation of energy demand is based on the farm energy forecasting model depicted in Figure II-32. The model is used to determine the commercial energy input to the farm sector as power required for village water supplies, farm mechanization and for irrigation. The model requires projections of the demand for services translated into an inventory of tractor units and irrigation pumps of various kinds. Non-energy fertilizer, which requires a supply of natural gas, is dealt with under the Industry Sector; however the irrigation required so that water can work together with fertilizer to boost crop yields is dealt with directly in the farm model.

43. A key consideration concerning the future demand for farm services is the land expected to be under cultivation and the average farm size. The following chart shows the projected land productivity associated with the rice production targets mentioned above:-

Figure II-30: Land Productivity Projection



Sources: Consultant

44. The total land under cultivation impacts the total requirement for motive power, for irrigation water and fertilizer. Farms of small size, say 2 hectares are not well suited to large, more efficient tractors, due to uneven surface levels between farms and inadequate turning circle.

45. In the case of motive power, the key input variable submitted to the model is a forecast of available farm labour (both human and draft animal). The need for motive energy from machinery is determined by the model as the net difference between total energy needs and available physical energy (human and draft animal) that is available. The key working assumptions are as follows:-

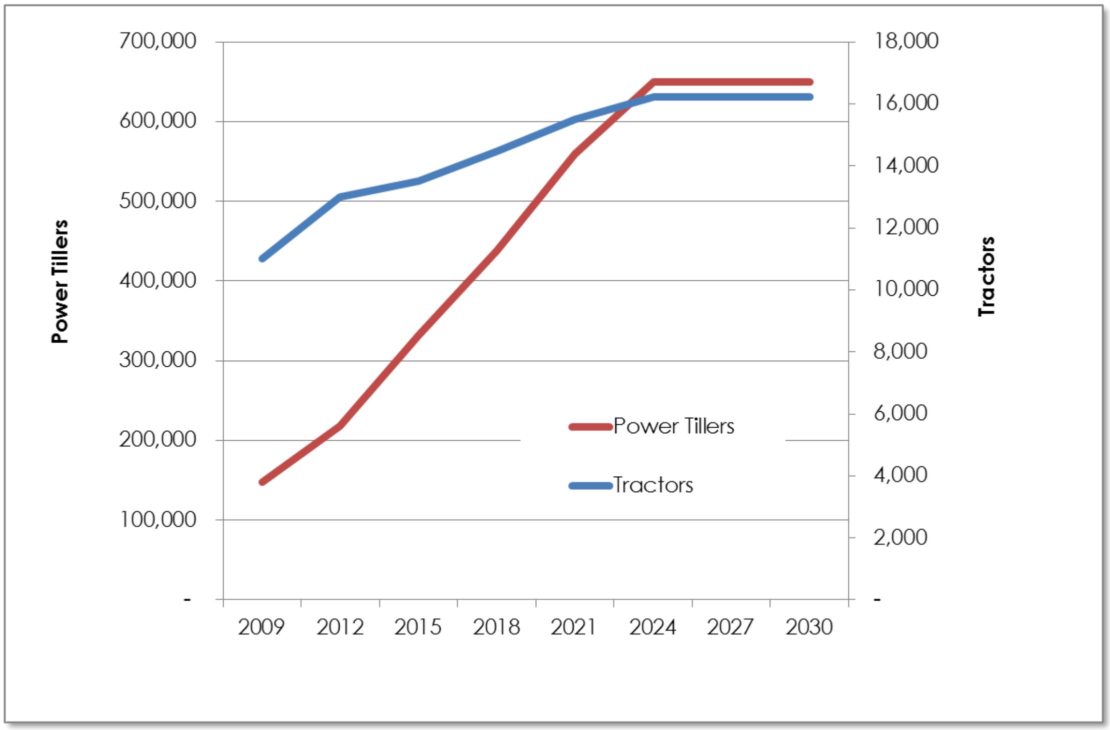
- The energy supplied by human labour has been calculated on the basis that a human can deliver an average of 0.5 horsepower throughout an average 8 hour working day. To estimate the gross energy input to the farm sector as labour, the working day of a farm worker is considered as 207 days per year.

- The average working hours of an animal in agriculture is considered to be 360 hours per year. In Myanmar it is typical for farmers to use draft animals for up to 2 hours in the morning before the sun raises high in the sky and before the ambient temperature becomes too hot for animals to work.

- The total diesel energy input to agriculture is calculated from the petroleum consumed only by tractors and power tillers. Few harvesters are in use in Myanmar and they have been ignored in the energy calculations. From field investigations, it is known that a 50-hp tractor consumes 5 litres of diesel per hour and its average use on the field is 1 140 hours per year. A 10-hp power tiller consumes 1.75 litres of diesel per hour with an 80% loading capacity and its average use on the field is assumed to be 720 hours per year.

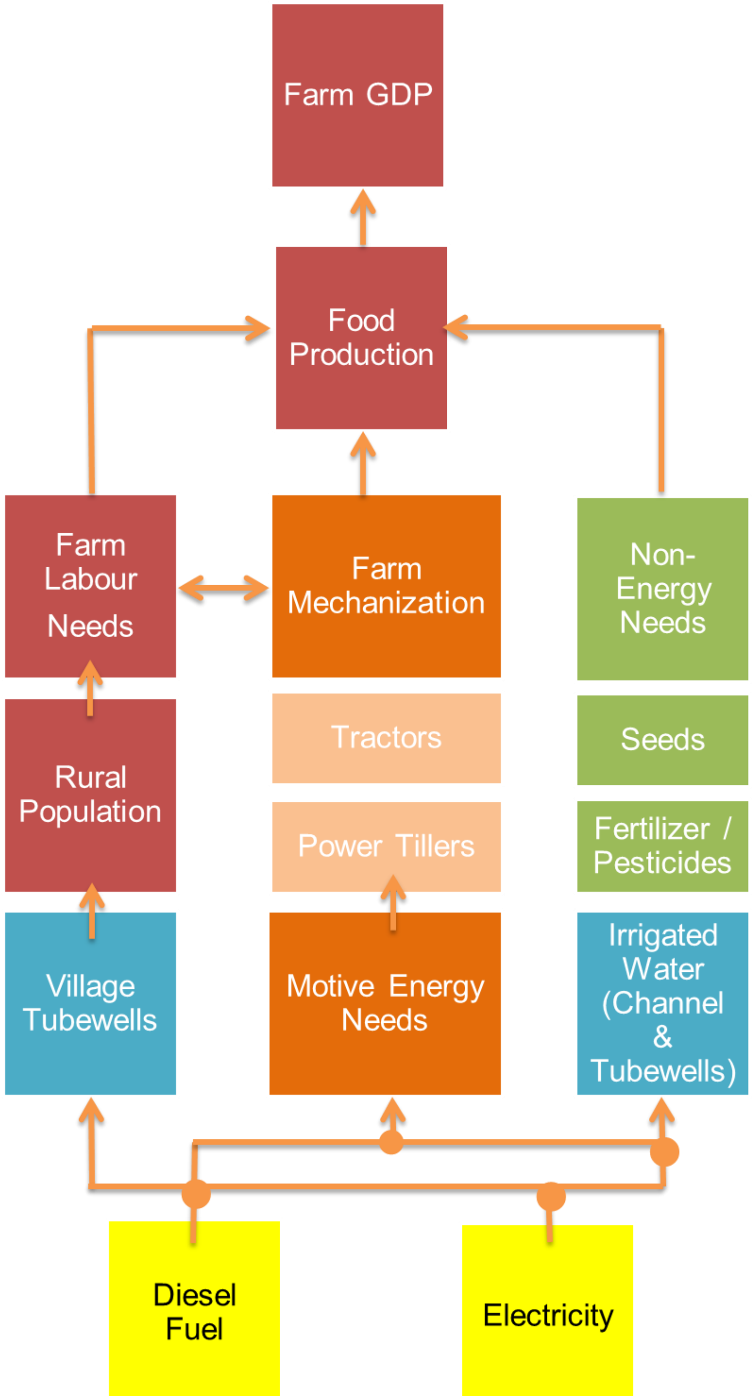
46. Model projections for the tractor inventory (small and large tractors) are shown in Figure II-31 for the medium growth trajectory.

Figure II-31: Motive Power Projections



Sources: Consultant

Figure II-32: Farm Energy Forecasting Model



Source: Consultant

47. In the case of irrigation power, it has been assumed that for irrigation and village water supply, a deep tube-well consumes 1 388 kWh electricity per hectare, whereas shallow tube-wells and low lift pumps consume 266 litres of diesel per hectare. Main river pumping stations are equipped with large capacity pumps. The average capacity of these pumps is 1 MVA. The projected growth of the farm tube-well inventory is shown in Figure II-33.

Figure II-33: Farm Tube-well Inventory Projection

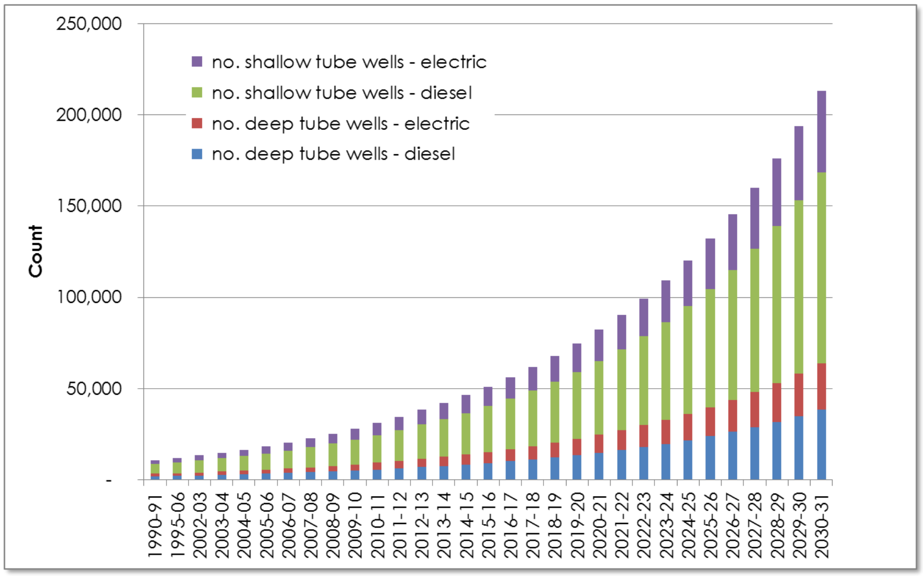
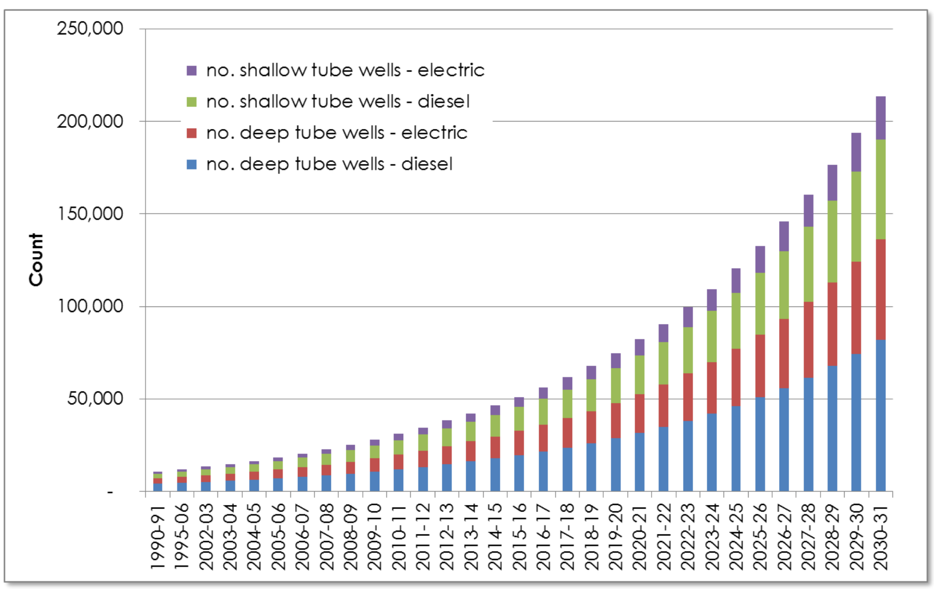


Figure II-34: Village Water Supply Tube-well Inventory Projection



Sources: Consultant

48. The projected inventory of river pumps is shown in Figure II-35 and Figure II-36 by count and by electric capacity (MVA) respectively. The inventory is based on the beneficial areas to receive irrigation. The fuel consumption projection of river pumps recognizes an intention on the part of MoAI to steadily replace diesel pumps with electric pumps. The projected inventory has been determined in conjunction with MoAI irrigation specialists and will see the percentage of diesel-powered pumps fall from 54% in 2014 to 12% in 2030.

Figure II-35: River Pumping Station Count Projection

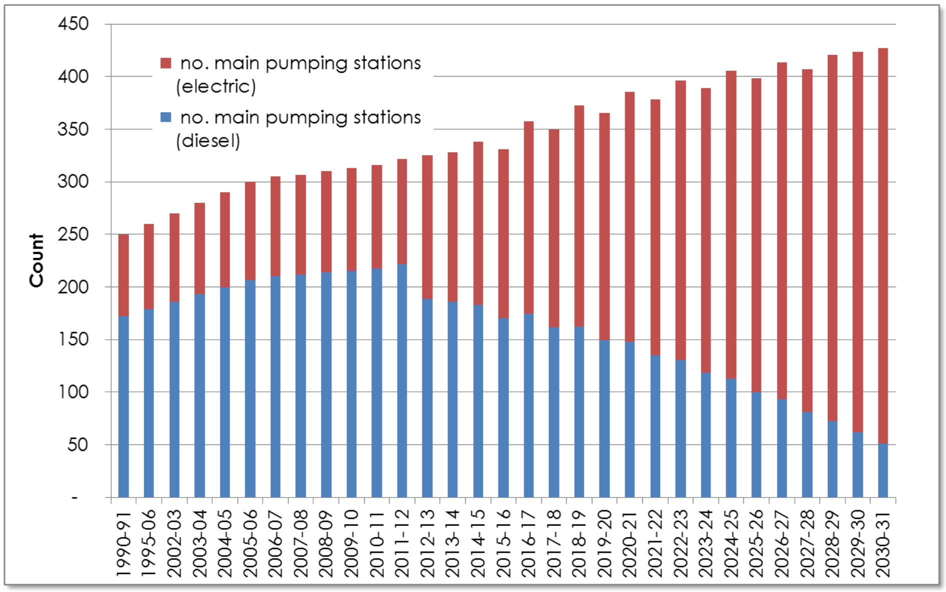
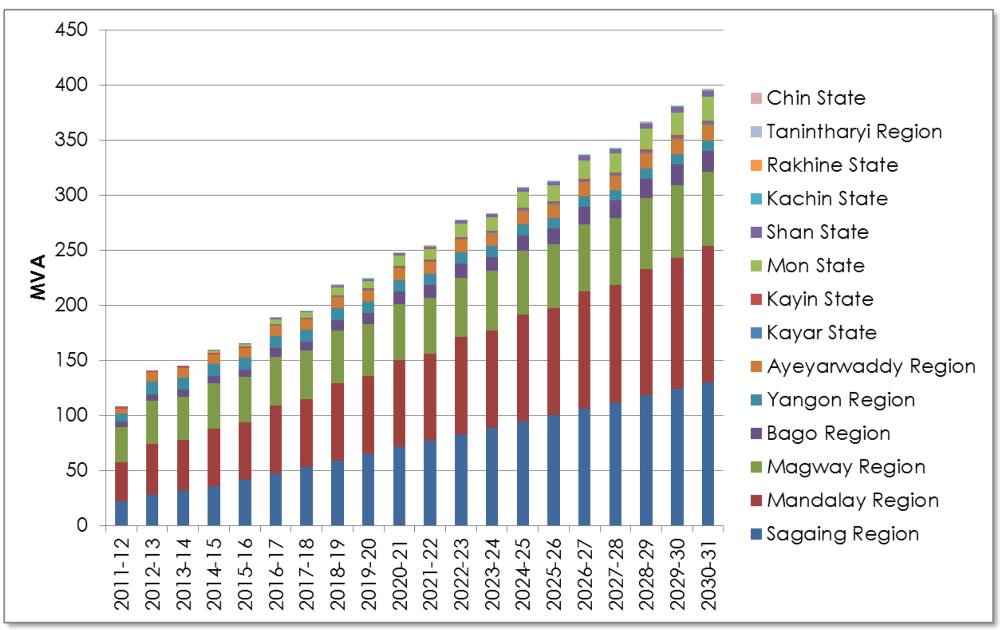


Figure II-36: River Pumping Station Capacity Projection



Sources: Consultant

H. Agriculture Sector Final Energy Consumption

49. The estimates for diesel fuel and electricity consumption, total final energy consumption and energy intensity of the Agriculture sector follow in chart form. The detailed results of the modelling are given as Table II-41 to Table II-43.

Figure II-37: Diesel (HSD) Fuel Consumption

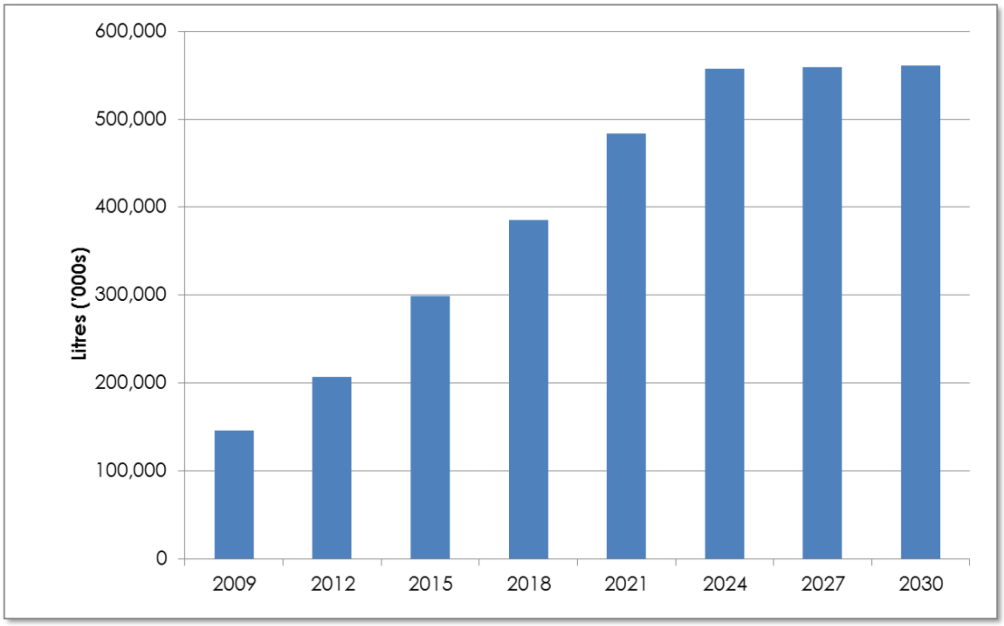
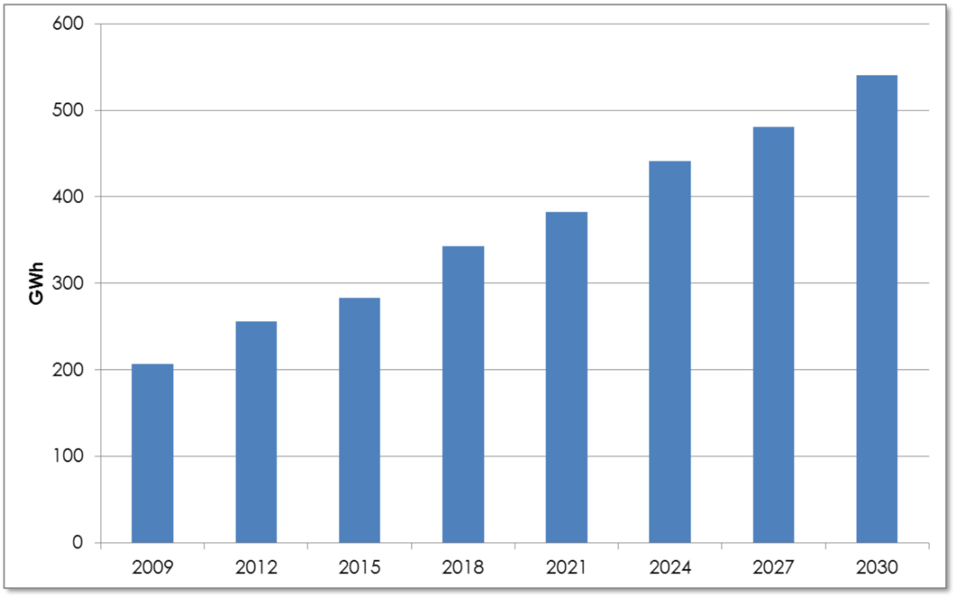
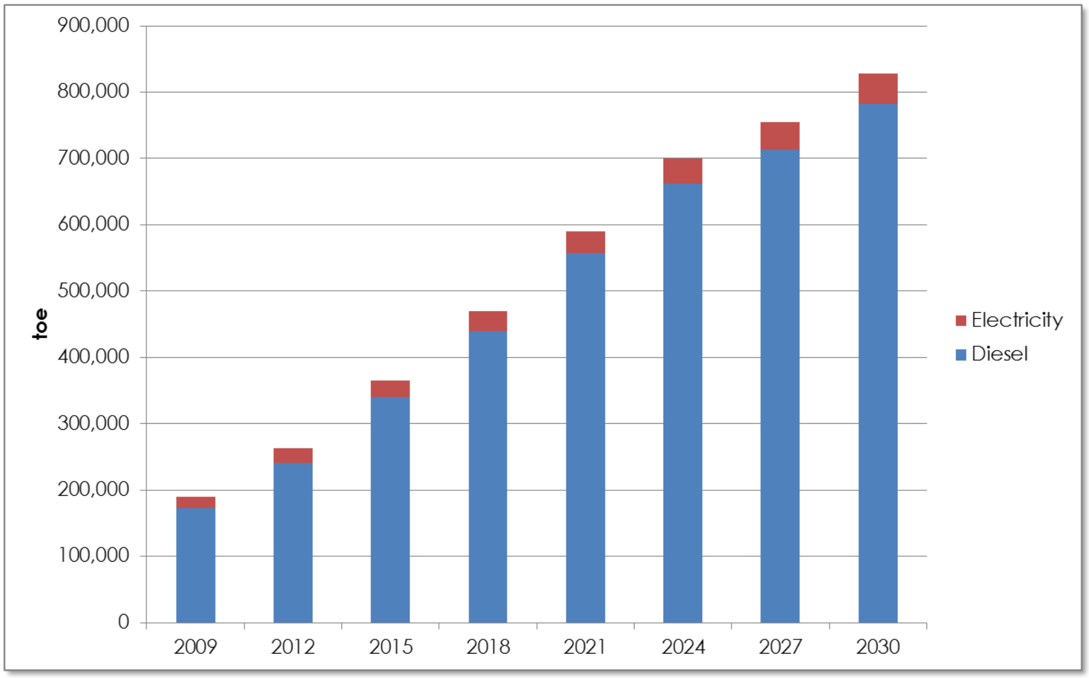


Figure II-38: Estimated Electricity Consumption



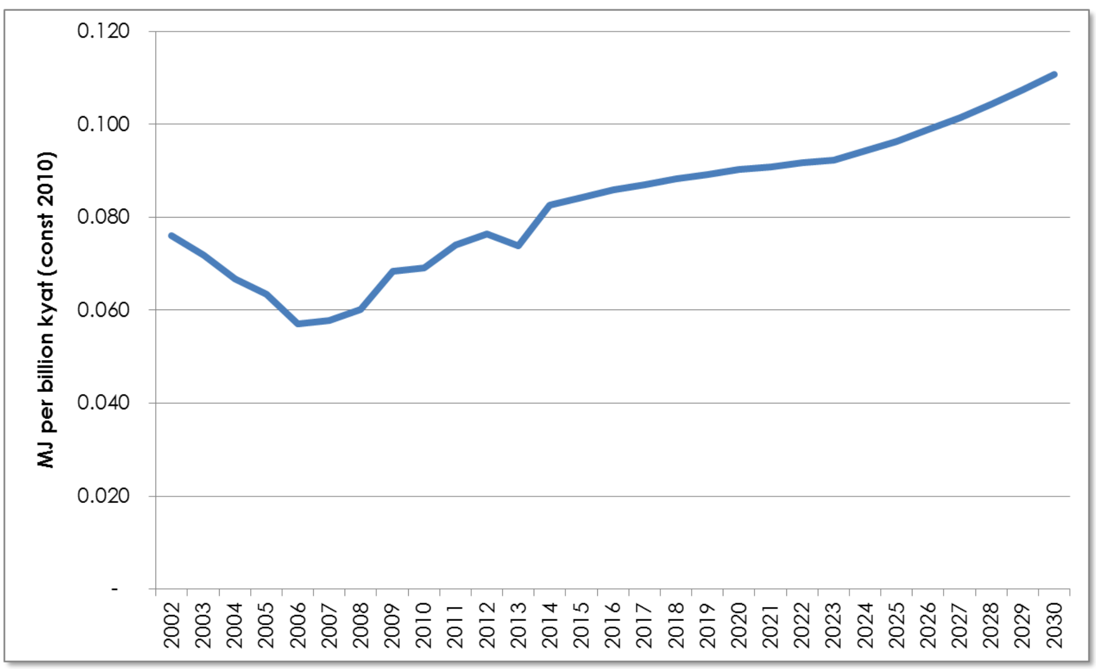
Sources: Consultant

Figure II-39: Agriculture Sector Final Energy Consumption



Sources: Consultant

Figure II-40: Agriculture Sector Energy Intensity



Sources: Consultant

Table II-41: Crop Farm Sector Statistics (2014 – 2035): LOW Scenario

		2014	2015	2016	2017	2018	2019	2020	2021	2022
Food Production	'000 tons	77,533	81,043	84,673	88,428	92,310	96,325	100,475	104,765	109,199
Farm GDP	billion kyat const 2010	12,535	12,979	13,437	13,912	14,402	14,909	15,433	15,975	16,536
	% Growth	5.0%	5.0%	5.0%	5.0%	5.0%	5.0%	5.0%	4.0%	3.0%
Farm Workforce	Millions	12.8	13.1	13.3	13.6	13.8	14.1	14.4	14.7	15.0
Net Hectares	‘000	13,763	14,079	14,403	14,734	15,073	15,420	15,774	16,137	16,508
Sown Hectares	‘000	19,130	19,570	20,020	20,481	20,952	21,434	21,926	22,431	22,947
Land Productivity	tons per hectare	4.1	4.1	4.2	4.3	4.4	4.5	4.6	4.7	4.8
Tractors	Count	13,000	13,000	13,211	13,514	13,825	14,143	14,469	14,801	15,142
Power Tillers	Count	293,115	319,730	347,229	375,721	405,236	435,806	467,465	500,312	534,312
Est. Motive Energy	TJ	9,697	10,217	10,755	11,311	11,886	12,480	13,095	13,730	14,387

Sources: Consultant

Crop Farm Sector Projections (2014 – 2035): LOW Scenario

		2023	2024	2025	2026	2027	2028	2029	2030
Food Production	'000 tons	113,782	115,853	117,925	119,996	122,067	122,067	122,067	122,067
Farm GDP	billion kyat const 2010	17,114	17,718	18,340	19,162	20,017	20,817	21,650	22,516
	% Growth	2.0%	2.0%	2.0%	2.0%	2.0%	2.0%	2.0%	2.0%
Farm Workforce	millions	15.3	15.4	15.6	15.7	15.8	15.8	15.8	15.8
Net Hectares	‘000	16,888	16,888	16,888	16,888	16,888	16,888	16,888	16,888
Sown Hectares	‘000	23,474	23,474	23,474	23,474	23,474	23,474	23,474	23,474
Land Productivity	tons per hectare	4.8	4.9	5.0	5.1	5.2	5.2	5.2	5.2
Tractors	count	16,211	16,211	16,211	16,211	16,211	16,211	16,211	16,211
Power Tillers	count	569,502	588,718	607,935	627,152	646,369	646,902	647,435	647,969
Est. Motive Energy	TJ	15,066	15,373	15,679	15,986	16,293	16,293	16,293	16,293

Sources: Consultant

Table II-42: Crop Farm Sector Projections (2014 – 2035): MEDIUM Scenario

		2014	2015	2016	2017	2018	2019	2020	2021	2022
Food Production	'000 tons	78,208	82,424	86,793	91,319	96,008	100,864	105,892	111,098	116,488
Farm GDP	billion kyat const 2010	12,677	13,268	13,879	14,511	15,165	15,841	16,509	17,206	17,933
	% Growth	4.7%	4.7%	4.6%	4.6%	4.5%	4.5%	4.2%	4.2%	4.2%
Farm Workforce	millions	12.9	13.2	13.5	13.8	14.1	14.4	14.7	15.1	15.5
Net Hectares	'000	13,763	14,079	14,403	14,734	15,073	15,420	15,774	16,137	16,508
Sown Hectares	'000	19,130	19,570	20,020	20,481	20,952	21,434	21,926	22,431	22,947
Land Productivity	tons per hectare	4.1	4.2	4.3	4.5	4.6	4.7	4.8	5.0	5.1
Tractors	count	299,205	332,191	366,350	401,802	438,587	476,748	516,499	559,151	603,407
Power Tillers	count	298,750	346,382	395,877	447,398	501,017	556,836	572,547	590,190	608,091
Est. Motive Energy	TJ	9,797	10,422	11,069	11,739	12,433	13,153	13,897	14,668	15,467

Sources: Consultant

Crop Farm Sector Statistics (2014 – 2035): MEDIUM Scenario

		2023	2024	2025	2026	2027	2028	2029	2030
Food Production	'000 tons	122,067	122,067	122,067	122,067	122,067	122,067	122,067	122,067
Farm GDP	billion kyat const 2010	18,601	19,301	20,025	20,875	21,758	22,628	23,533	24,475
	% Growth	3.7%	3.8%	3.8%	4.2%	4.2%	4.0%	4.0%	4.0%
Farm Workforce	millions	15.8	15.8	15.8	15.8	15.8	15.8	15.8	15.8
Net Hectares	'000	16,888	16,888	16,888	16,888	16,888	16,888	16,888	16,888
Sown Hectares	'000	23,474	23,474	23,474	23,474	23,474	23,474	23,474	23,474
Land Productivity	tons per hectare	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2
Tractors	count	16,211	16,211	16,211	16,211	16,211	16,211	16,211	16,211
Power Tillers	count	649,344	649,910	650,500	651,165	651,912	652,760	653,718	654,727
Est. Motive Energy	TJ	16,293	16,293	16,293	16,293	16,293	16,293	16,293	16,293

Sources: Consultant

Table II-43: Crop Farm Sector Statistics (2014 – 2035): HIGH Scenario

		2014	2015	2016	2017	2018	2019	2020	2021	2022
Food Production	'000 tons	79,783	85,647	91,739	98,066	104,635	111,454	114,018	116,640	119,323
Farm GDP	billion kyat const 2010	12,820	13,560	14,330	15,129	15,959	16,820	17,649	18,519	19,434
	% Growth	5.9%	5.8%	5.7%	5.6%	5.5%	5.4%	4.9%	4.9%	4.9%
Farm Workforce	millions	13.0	13.4	13.8	14.2	14.7	15.1	15.3	15.5	15.6
Net Hectares	'000	13,763	14,079	14,403	14,734	15,073	15,420	15,774	16,137	16,508
Sown Hectares	'000	19,130	19,570	20,020	20,481	20,952	21,434	21,926	22,431	22,947
Land Productivity	tons per hectare	4.2	4.4	4.6	4.8	5.0	5.2	5.2	5.2	5.2
Tractors	count	13,211	13,514	13,825	14,143	14,469	14,801	15,142	15,490	15,846
Power Tillers	count	313,416	361,540	412,188	464,956	519,910	577,178	594,665	613,897	633,733
Est. Motive Energy	TJ	10,030	10,899	11,801	12,738	13,711	14,721	15,101	15,489	15,887

Sources: Consultant

Crop Farm Sector Statistics (2014 – 2035): HIGH Scenario

		2023	2024	2025	2026	2027	2028	2029	2030
Food Production	'000 tons	122,067	122,067	122,067	122,067	122,067	122,067	122,067	122,067
Farm GDP	billion kyat const 2010	20,201	21,009	21,849	22,723	23,632	24,578	25,561	26,583
	% Growth	3.9%	4.0%	4.0%	4.0%	4.0%	4.0%	4.0%	4.0%
Farm Workforce	millions	15.8	15.8	15.8	15.8	15.8	15.8	15.8	15.8
Net Hectares	'000	16,888	16,888	16,888	16,888	16,888	16,888	16,888	16,888
Sown Hectares	'000	23,474	23,474	23,474	23,474	23,474	23,474	23,474	23,474
Land Productivity	tons per hectare	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2
Tractors	count	16,211	16,211	16,211	16,211	16,211	16,211	16,211	16,211
Power Tillers	count	654,167	655,860	657,760	659,892	662,276	664,973	668,015	671,440
Est. Motive Energy	TJ	16,293	16,293	16,293	16,293	16,293	16,293	16,293	16,293

Sources: Consultant

Annex: Agriculture – Food Production Statistics

Food Production Statistics

1990 - 91

	Production	Energy Co-efficient	Energy Output	Sown acres	Sown hectares	Food Production	Energy Output per hectare
	'000 ton	MJ/kg	TJ	'000s	'000s	ton/ha	GJ / ha
Cotton	61	11.8	723	387	160	0.38	4.52
Groundnut	465	23.8	11 057	1 369	566	0.82	19.52
Jute	24	16.91	406	92	38	0.63	10.66
Maize	309	15.1	4 658	793	328	0.94	14.20
Oil	221	22.72	5 010	3312	1370	0.16	3.66
Potato	134	4.06	545	36	15	9.01	36.58
Pulses	515	15.1	7 769	2 164	895	0.57	8.68
Rice	13 748	14.7	202 100	12 220	5 056	2.72	39.97
Spices	237	0.8	190	252	104	2.28	1.82
Sugarcane	1 931	2.0	3 861	118	49	39.55	79.09
Vegetable	1 830	0.88	1 610	343	142	12.90	11.35
Wheat	122	14.7	1 786	370	153	0.79	11.67
Plantain	1 798	5.56	9 997	116	48	37.46	208.30
Total	21 393		249 713	21 572	8 925	**2.40**	27.98

1995 – 96

	Production	Energy Co-efficient	Energy Output	Sown acres	Sown hectares	Food Production	Energy Output per hectare
	'000 ton	MJ/kg	TJ	'000s	'000s	ton/ha	GJ / ha
Cotton	162	11.8	1,916	937	388	0.42	4.94
Groundnut	583	23.8	13,885	1303	539	1.08	25.76
Jute	43	16.91	720	124	51	0.83	14.04
Maize	418	15.1	6,306	982	406	1.03	15.52
Oil	307	22.72	6,975	3197	1323	0.23	5.27
Potato	184	4.06	748	48	20	9.28	37.66
Pulses	1,287	15.1	19,432	4690	1940	0.66	10.01
Rice	17,670	14.7	259,743	15166	6275	2.82	41.40
Spices	257	0.8	206	253	105	2.46	1.97
Sugarcane	3,199	2.0	6,398	165	68	46.86	93.73
Vegetable	2,586	0.88	2,276	445	184	14.05	12.36
Wheat	77	14.7	1,127	229	95	0.81	11.90
Plantain	2,013	5.56	11,194	113	47	43.06	239.42
Total	28,787		330,927	27,652	11,441	**2.52**	28.93

2000 - 01

	Production	Energy Co-efficient	Energy Output	Sown acres	Sown hectares	Food Production	Energy Output per hectare
	'000 ton	MJ/kg	TJ	'000s	'000s	ton/ha	GJ / ha
Cotton	150	11.8	1,774	801	331	0.45	5.35
Groundnut	720	23.8	17,124	1458	603	1.19	28.39
Jute	41	16.91	697	111	46	0.90	15.17
Maize	525	15.1	7,929	1156	478	1.10	16.58
Oil	406	22.72	9,218	3436	1422	0.29	6.48
Potato	314	4.06	1,273	72	30	10.53	42.74
Pulses	2,057	15.1	31,062	6555	2712	0.76	11.45
Rice	20,987	14.7	308,507	15713	6501	3.23	47.46
Spices	720	0.8	576	440	182	3.95	3.16
Sugarcane	5,801	2.0	11,601	343	142	40.87	81.75
Vegetable	3,343	0.88	2,942	733	303	11.02	9.70
Wheat	92	14.7	1,354	198	82	1.12	16.53
Plantain	3,200	5.56	17,792	125	52	61.88	344.03
Total	38,355		411,848	31,141	12,884	**2.98**	31.97

2003 - 04

	Production	Energy Co-efficient	Energy Output	Sown acres	Sown hectares	Food Production	Energy Output per hectare
	'000 ton	MJ/kg	TJ	'000s	'000s	ton/ha	GJ / ha
Cotton	156	11.8	1,835	721	298	0.52	6.15
Groundnut	864	23.8	20,556	1617	669	1.29	30.73
Jute	26	16.91	435	80	33	0.78	13.13
Maize	866	15.1	13,080	1274	527	1.64	24.81
Oil	475	22.72	10,794	3573	1478	0.32	7.30
Potato	397	4.06	1,610	81	34	11.83	48.05
Pulses	2,812	15.1	42,460	7571	3132	0.90	13.56
Rice	22,770	14.7	334,722	16168	6689	3.40	50.04
Spices	899	0.8	719	469	194	4.63	3.71
Sugarcane	6,804	2.0	13,609	373	154	44.09	88.18
Vegetable	3,343	0.88	2,942	952	394	8.49	7.47
Wheat	122	14.7	1,799	235	97	1.26	18.51
Plantain	4,166	5.56	23,165	147	61	68.50	380.88
Total	43,700		467,725	33,261	13,761	**3.18**	33.99

2004 - 05

	Production	Energy Co-efficient	Energy Output	Sown acres	Sown hectares	Food Production	Energy Output per hectare
	'000 ton	MJ/kg	TJ	'000s	'000s	ton/ha	GJ / ha
Cotton	191	11.8	2,259	756	313	0.61	7.22
Groundnut	931	23.8	22,163	1690	699	1.33	31.70
Jute	17	16.91	291	67	28	0.62	10.49
Maize	949	15.1	14,327	1291	534	1.78	26.82
Oil	517	22.72	11,735	3662	1515	0.34	7.75
Potato	449	4.06	1,824	86	36	12.63	51.27
Pulses	3,219	15.1	48,611	7935	3283	0.98	14.81
Rice	24,361	14.7	358,105	16946	7011	3.47	51.08
Spices	1,040	0.8	832	532	220	4.72	3.78
Sugarcane	7,195	2.0	14,390	361	149	48.17	96.34
Vegetable	3,343	0.88	2,942	1036	429	7.80	6.86
Wheat	150	14.7	2,205	266	110	1.36	20.04
Plantain	3,761	5.56	20,914	152	63	59.81	332.55
Total	46,124		500,597	34,780	14,390	**3.21**	34.79

2005 - 06

	Production	Energy Co-efficient	Energy Output	Sown acres	Sown hectares	Food Production	Energy Output per hectare
	'000 ton	MJ/kg	TJ	'000s	'000s	ton/ha	GJ / ha
Cotton	232	11.8	2,736	820	339	0.68	8.07
Groundnut	1,023	23.8	24,345	1805	747	1.37	32.60
Jute	15	16.91	247	56	23	0.63	10.66
Maize	1,112	15.1	16,794	1419	587	1.89	28.61
Oil	489	22.72	11,110	3296	1364	0.36	8.15
Potato	471	4.06	1,911	86	36	13.23	53.71
Pulses	3,653	15.1	55,160	8455	3498	1.04	15.77
Rice	27,246	14.7	400,513	18259	7554	3.61	53.02
Spices	1,254	0.8	1,003	562	233	5.39	4.31
Sugarcane	7,073	2.0	14,146	330	137	51.80	103.61
Vegetable	4,193	0.88	3,690	1094	453	9.26	8.15
Wheat	156	14.7	2,296	277	115	1.36	20.04
Plantain	4,692	5.56	26,085	160	66	70.87	394.05
Total	51,607		560,037	36,619	15,151	**3.41**	36.96

2006 - 07

	Production	Energy Co-efficient	Energy Output	Sown acres	Sown hectares	Food Production	Energy Output per hectare
	'000 ton	MJ/kg	TJ	'000s	'000s	ton/ha	GJ / ha
Cotton	264	11.8	3,115	873	361	0.73	8.62
Groundnut	1,088	23.8	25,892	1867	772	1.41	33.52
Jute	9	16.91	157	31	13	0.73	12.26
Maize	1,221	15.1	18,433	1398	578	2.11	31.87
Oil	671	22.72	15,238	3563	1474	0.45	10.34
Potato	508	4.06	2,064	90	37	13.65	55.43
Pulses	4,103	15.1	61,955	9016	3730	1.10	16.61
Rice	30,435	14.7	447,395	20076	8306	3.66	53.86
Spices	1,186	0.8	949	533	221	5.38	4.30
Sugarcane	8,039	2.0	16,078	369	153	52.66	105.31
Vegetable	4,193	0.88	3,690	1132	468	8.95	7.88
Wheat	140	14.7	2,061	227	94	1.49	21.94
Plantain	5,503	5.56	30,595	166	69	80.12	445.47
Total	57,360		627,622	39,341	16,277	**3.52**	38.56

2007 - 08

	Production	Energy Co-efficient	Energy Output	Sown acres	Sown hectares	Food Production	Energy Output per hectare
	'000 ton	MJ/kg	TJ	'000s	'000s	ton/ha	GJ / ha
Cotton	303	11.8	3,579	909	376	0.81	9.52
Groundnut	1,202	23.8	28,612	2014	833	1.44	34.34
Jute	3	16.91	56	14	6	0.57	9.63
Maize	1,316	15.1	19,870	1358	562	2.34	35.37
Oil	767	22.72	17,435	3768	1559	0.49	11.18
Potato	521	4.06	2,116	91	38	13.85	56.21
Pulses	4,632	15.1	69,948	9581	3964	1.17	17.65
Rice	30,954	14.7	455,025	19990	8271	3.74	55.02
Spices	1,324	0.8	1,059	565	234	5.66	4.53
Sugarcane	9,678	2.0	19,355	417	173	56.09	112.19
Vegetable	4,193	0.88	3,690	1189	492	8.52	7.50
Wheat	155	14.7	2,283	243	101	1.54	22.71
Plantain	5,460	5.56	30,357	165	68	79.98	444.68
Total	60,509		653,386	40,304	16,675	**3.63**	39.18

2008 - 09

	Production	Energy Co-efficient	Energy Output	Sown acres	Sown hectares	Food Production	Energy Output per hectare
	'000 ton	MJ/kg	TJ	'000s	'000s	ton/ha	GJ / ha
Cotton	446	11.8	5,257	908	376	1.19	13.99
Groundnut	1,284	23.8	30,564	2086	863	1.49	35.41
Jute	1	16.91	17	9	4	0.27	4.54
Maize	1,375	15.1	20,758	1389	575	2.39	36.12
Oil	849	22.72	19,282	3928	1625	0.52	11.86
Potato	549	4.06	2,227	93	38	14.26	57.88
Pulses	4,916	15.1	74,230	9677	4004	1.23	18.54
Rice	32,059	14.7	471,260	20001	8275	3.87	56.95
Spices	1,325	0.8	1,060	554	229	5.78	4.63
Sugarcane	9,744	2.0	19,488	408	169	57.72	115.45
Vegetable	4,193	0.88	3,690	1255	519	8.08	7.11
Wheat	170	14.7	2,505	246	102	1.67	24.61
Plantain	5,328	5.56	29,622	168	70	76.65	426.16
Total	62,237		679,960	40,722	16,848	**3.69**	40.36

2009 - 10

	Production	Energy Co-efficient	Energy Output	Sown acres	Sown hectares	Food Production	Energy Output per hectare
	'000 ton	MJ/kg	TJ	'000s	'000s	ton/ha	GJ / ha
Cotton	515	11.8	6,073	888	367	1.40	16.53
Groundnut	1,341	23.8	31,904	2141	886	1.51	36.02
Jute	1	16.91	22	9	4	0.35	5.90
Maize	1,436	15.1	21,678	1450	600	2.39	36.13
Oil	875	22.72	19,887	4115	1703	0.51	11.68
Potato	554	4.06	2,251	94	39	14.26	57.88
Pulses	5,132	15.1	77,486	9935	4110	1.25	18.85
Rice	32,166	14.7	472,837	19933	8247	3.90	57.33
Spices	1,420	0.8	1,136	575	238	5.97	4.78
Sugarcane	9,562	2.0	19,124	396	164	58.36	116.72
Vegetable	5,043	0.88	4,438	1297	537	9.40	8.27
Wheat	179	14.7	2,634	256	106	1.69	24.87
Plantain	5,825	5.56	32,389	179	74	78.66	437.34
Total	64,049		691,859	41,268	17,074	**3.75**	40.52

2010 - 11

	Production	Energy Co-efficient	Energy Output	Sown acres	Sown hectares	Food Production	Energy Output per hectare
	'000 ton	MJ/kg	TJ	'000s	'000s	ton/ha	GJ / ha
Cotton	541	11.8	6,385	867	359	1.51	17.80
Groundnut	1,370	23.8	32,608	2168	897	1.53	36.35
Jute	2	16.91	30	8	3	0.54	9.20
Maize	1,567	15.1	23,662	1508	624	2.51	37.92
Oil	875	22.72	19,869	4007	1658	0.53	11.98
Potato	564	4.06	2,288	96	40	14.19	57.61
Pulses	5,370	15.1	81,093	10197	4219	1.27	19.22
Rice	32,065	14.7	471,357	19885	8227	3.90	57.29
Spices	7	0.8	6	566	234	0.03	0.02
Sugarcane	9,250	2.0	18,499	374	155	59.78	119.55
Vegetable	5,043	0.88	4,438	1339	554	9.10	8.01
Wheat	181	14.7	2,661	251	104	1.74	25.62
Plantain	6,580	5.56	36,583	187	77	85.04	472.84
Total	63,414		699,478	41,453	17,151	**3.70**	40.78

Project Number: TA No. 8356-MYA

FINAL REPORT

ENERGY FORECASTS

INDUSTRY SECTOR

Prepared for

The Asian Development Bank

and

The Myanmar Ministry of Energy

Prepared by

Intelligent Energy Systems

in association with

MYANMAR INTERNATIONAL CONSULTANTS

ABBREVIATIONS

ADB	–	Asian Development Bank
CSO	–	Central Statistics Organisation
ESE	–	Electricity Supply Enterprise
FEC	–	Final Energy Consumption
GDP	–	Gross Domestic Product
GoM	–	Government of the Republic of the Union of Myanmar
MoE	–	Ministry of Energy
YESC	–	Yangon Electricity Supply Corporation

UNITS OF MEASURE

IG	–	Imperial Gallon
km	–	Kilometre
l	–	Litre
Passenger-km	–	Passenger-Kilometre
Ton-km	–	Metric Ton-Kilometre

CONVERSION FACTORS

1 litre	=	0.22 Imperial Gallon
1 km	=	0.62137 mile

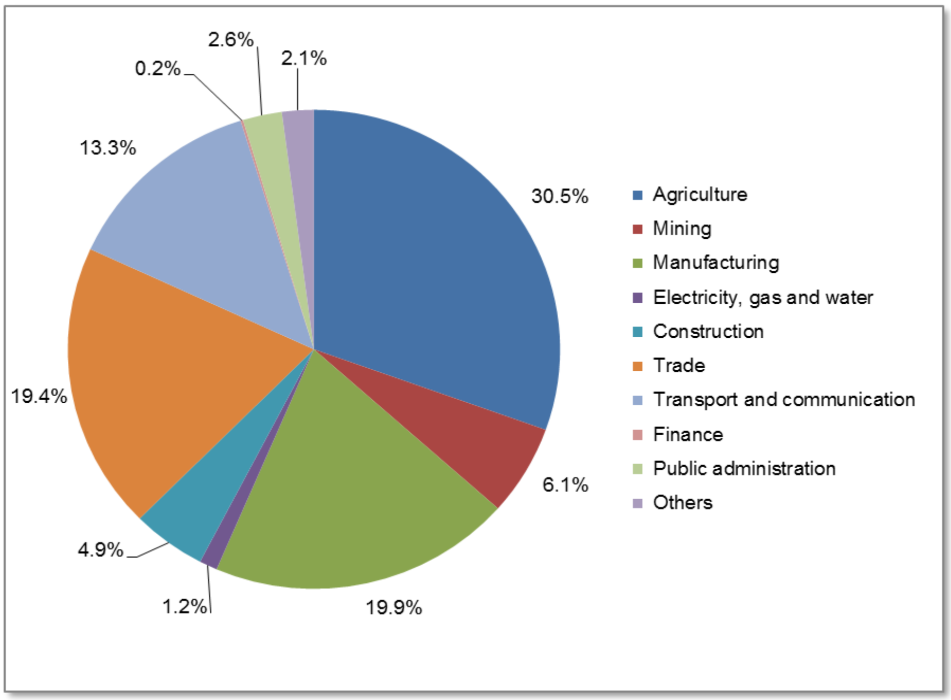
CONTENTS

I. SUMMARY

A. Introduction

1. The Industry sector includes Minerals Extraction (Mining), Minerals Processing, Construction, Power and Gas and Manufacturing. In 2012, the contribution of the Industry sector to GDP was 32.1%.

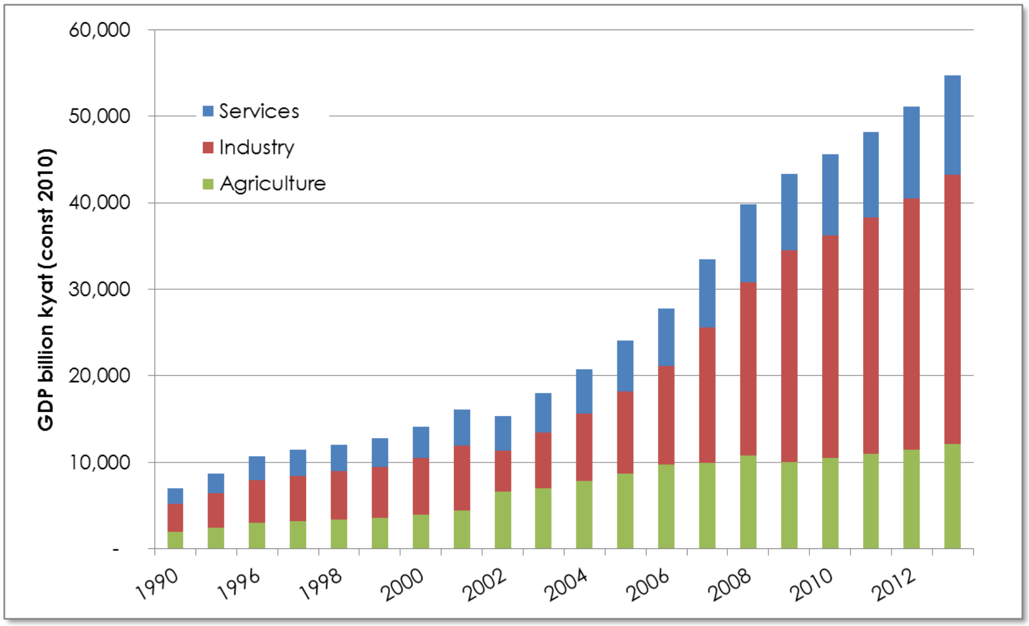
Figure I-1: Myanmar's GDP by Composition (2012)



Source: ADB

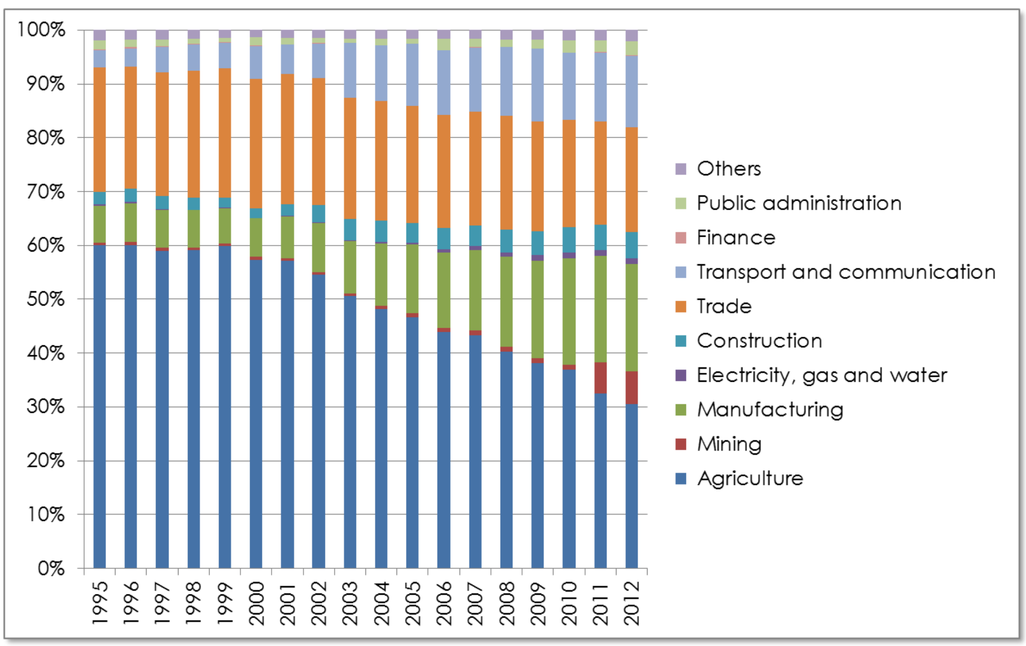
2. Industry sector GDP contribution has been steadily increasing; the historical compound annual growth rate of Myanmar's Industry sector GDP for the period 2004 to 2012 was reported to be 16.4%. The composition of GDP shows that the contribution of the Industry sector has been increasing steadily as a result of Government efforts to industrialize the nation.

Figure I-2: GDP by Sector



Source: ADB

Figure I-3: GDP Contribution by Sector



Source: ADB

3. **Mining –** Minerals extraction in Myanmar is mainly concerned with the extraction of non-ferrous metals, ferrous metal, precious metal, industrial minerals, Jade and Gems. In FY2012 it was reported by the Ministry of Mines that there were 1 297 small scale mines and 148 large scale

mines. Small scale mines have increased six-fold in the last decade; this growth indicates that many of Myanmar's mineral deposits are small, with relatively low ore grade and concentration, and suited to small scale mining operation. Of the large mines the most notable are the Kyauk Pa Hto gold mine, the Takaung Taung ferro-nickel mine, the Monywa open-pit copper mine, the Namma coal mine, the Bawdwin lead mine, the HsiPaw gypsum mine and the Phakant Jade mine. Whilst Myanmar's mineral wealth holds the promise of continued earnings growth, in excess of 15%, it also seems likely that much mining activity will be carried out by established players in the mining field, producing for local market needs.

4. **Construction –** An increase of around one million households is expected in the next 30 years; in Yangon an annual growth rate of 25 000 housing units and housing plots is expected. This is proposed to be implemented through:-

- Densification of unpopulated residential areas, Upgrading of Housing Estates: upgrading of government owned and public housing estates and densification through additional stories in upgrading projects;
- Old Satellite Town Redevelopment: with the location of South Okkalapa, North Okkalapa and Thaketa townships becoming central, efficient utilization of existing buildings and increase of building storeys to achieve densification;
- New Satellite Town Redevelopment: Densification through mid-rise housing estate development in unpopulated wards of Dagon Newtown, Shwe Pyithar and Hlaing Thayar townships; and
- Water Front Development: Urban regeneration and land readjustment in Botahtaung, near Botahtaung Pagoda, Dawbon (Pazundaung Creek), Dagon Seikkan and Thaketa.

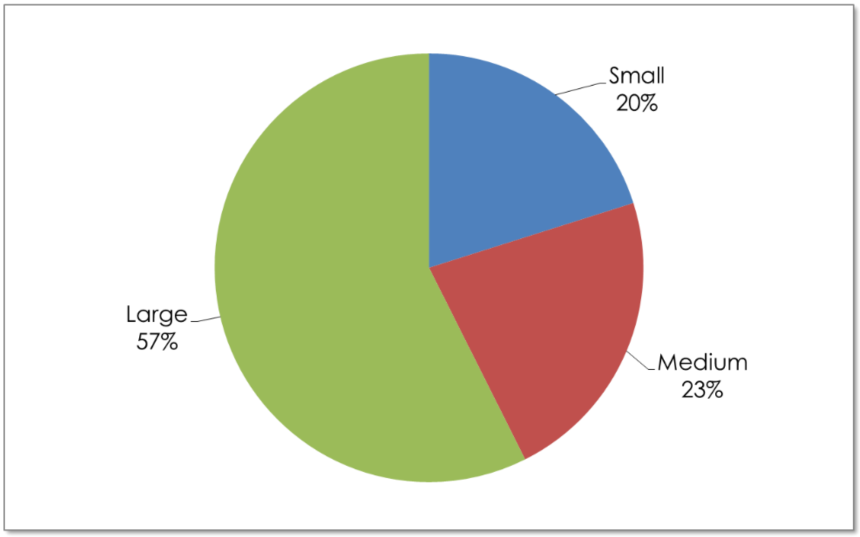
5. Much construction is also expected in the form of industrial parks, office buildings and hotels, to cater for the needs of business and tourists respectively. Construction in itself is not a heavy user of energy but construction does depend on the products produced by energy intensive industries including steel, bricks, glass and cement.

6. **Power & Gas –** the most important driver for growth in the past decade has been offshore natural gas production for export coming on stream. Natural gas has become by far the most important export and has attracted large volumes of FDI. The energy sector plays a critical role in the sustained development of a country. In FY2012, $3.6 billion worth of natural gas was exported, making it the largest export commodity, and extraction from new gas fields, which is expected soon, has been forecast by the Ministry of Energy to provide additional export revenues of about $2.7 billion per year. In the medium to long term, the exploration of other offshore plots and largely unexplored onshore resources has the potential to further develop the sector. The economic potential is large for oil and gas exploration and production in deep water blocks. These reserves are largely untapped, offering considerable potential for discoveries of more resource. In the context of Industry sector energy use, the power and gas sub-sector is a net producer rather than a consumer. Consequently this sub-sector is dealt with by other sections of the Energy Masterplan report.

7. **Manufacturing** – In 2014 there were around 10 000 factories in operation employing a workforce of 180 000. These factories are mostly found in eighteen Industrial Zones (IZ) spread across the country. The Government plans to increase the number of IZ's to further support industrial development through clustering of industry. According to Kudo in 2012, "the combined value of the industrial products is less than USD 1 billion, contributing only 10% to the total exports or 20% of total private exports"[1]. It is anticipated that the creation of new IZ's, supported by changes to legislation and regulation, will see industry grow strongly.

[1] New Government's Initiative for Industrial Development in Myanmar; Aug Min & Toshihiro Kudo, 2012

Figure I-4: Industry Sector Structure by Count



Source: Ministry of Industry[2]

8. In the case of Manufacturing, in comparison to international standards the large Industry sector is of a relatively small scale, falling into a Medium Enterprise category. Nevertheless from the point of view of energy forecasting, energy intensive industries currently operating in Myanmar fall into the categories of ferrous metals (iron, steel), non-ferrous metals, non-metallic minerals (glass, bricks, cement) and food (sugar).

9. The remaining industries in Myanmar fall under a Small to Medium Enterprise (SME) category. The SME sector includes Electronics, Plastic Goods, Garments, Footwear, Fisheries, Food Products (including ice storage) and Automotive Industries. Of these industries, past successes in the Ready-Made Garments industry suggests a significant opportunity to re-capture international market share.

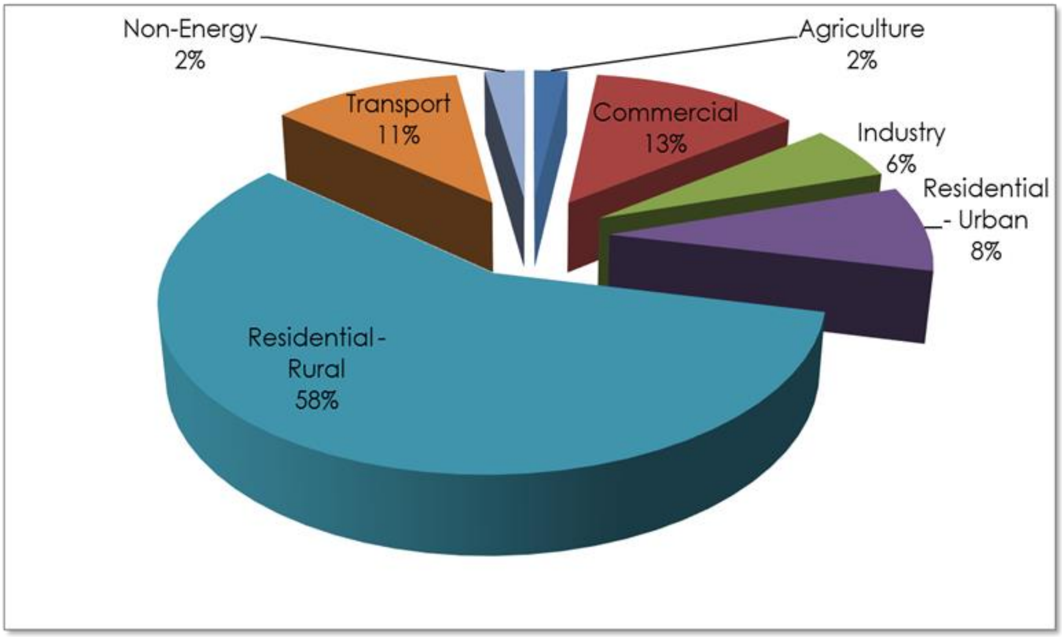
B. Final Energy Consumption (FEC)

10. The final energy consumption of the total Industry sector is estimated to have been 6% of total in 2012-13 as shown below in Figure I-5. The final energy consumption (FEC) of the total industry segment in 2012-13, comprising the large industry and SME segments, is estimated to have been 0.701 mtoe.

11. The breakdown of the energy intensive industry FEC of 0.398 mtoe was determined by survey and computation as shown in Figure I-6. The FEC of the SME segment is estimated to have been 0.303 mtoe in 2012-13. Consumption survey of 50 SME's was undertaken to determine energy end-use; it was found that the majority of the surveyed firms were consumers of electricity and diesel fuel. The diesel fuel use was found to be mainly related to the use of standby diesel generators.

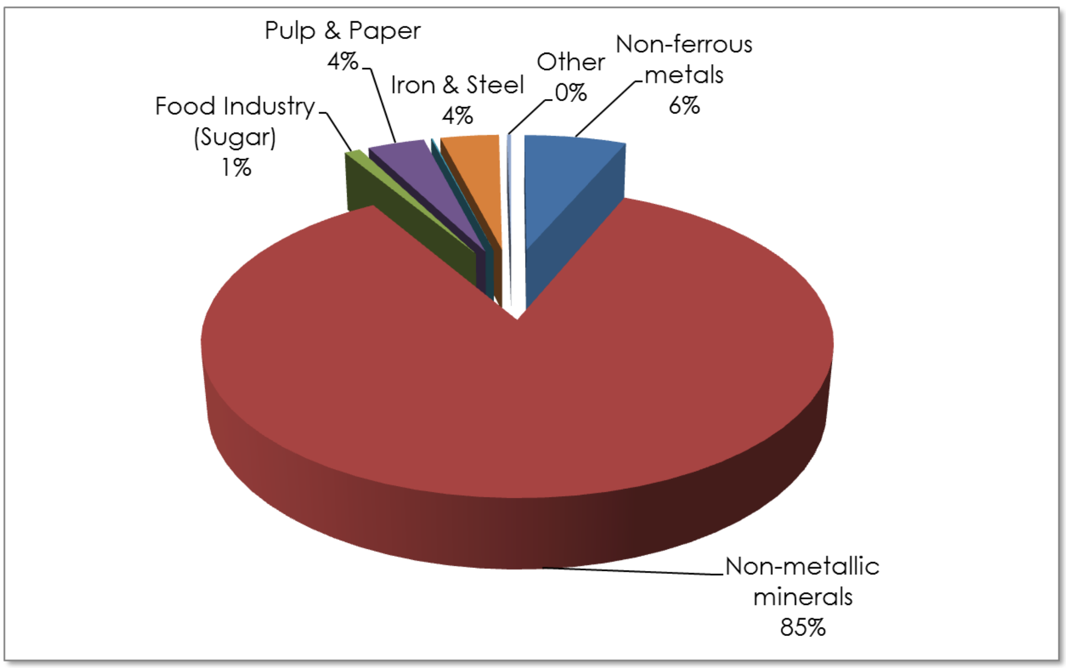
[2] Small industry is categorised as 3 to 25HP; medium 26 to 50HP; large greater than 50HP

Figure I-5: Final Energy Consumption 2012-13



Source: Consultants' analysis

Figure I-6: Large Industry FEC: 2012 - 13 (0.398 mtoe)

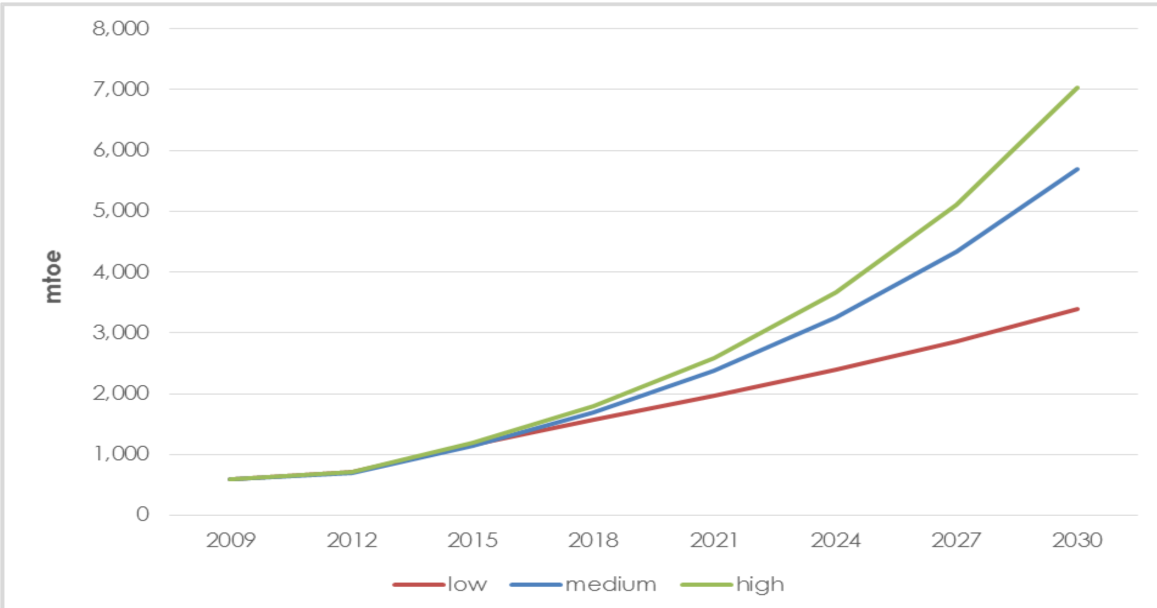


Source: Consultants' analysis

12. Final energy consumption forecasts were prepared for three growth cases. The planning assumptions were based on electricity growth as a proxy for industry growth. The production of industrial products, particularly metal products, is related directly to the amount of energy consumed by the sector. The growth cases were developed independently for each of the heavy and light industrial sectors.

13. The final energy consumption (FEC) forecast for the industry sector is shown in Figure I-7. In the case of the medium forecast, the compound annual growth rate from 2012 to 2030 is 11.6%.

Figure I-7: Industry Sector FEC Forecasts (mtoe)

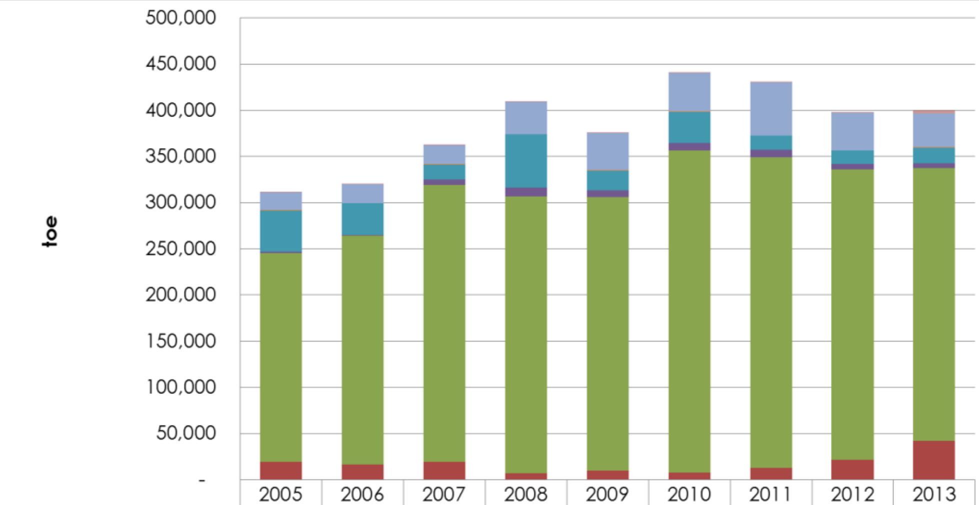


Sources: Consultant

C. Final Energy Consumption Forecasts – Medium Case

14. The following charts provide detail of the final energy consumption forecasts for the medium case planning assumptions. The FEC forecast for the energy-intensive industry sector is given as Figure I-8. The FEC forecast for the industry sector as a whole is given as Figure I-9 and Figure I-10 without and with fertilizer. Table I-11 and Table I-12 give the forecast of physical energy use by fuel carrier, for energy-intensive industry and the SME sector respectively.

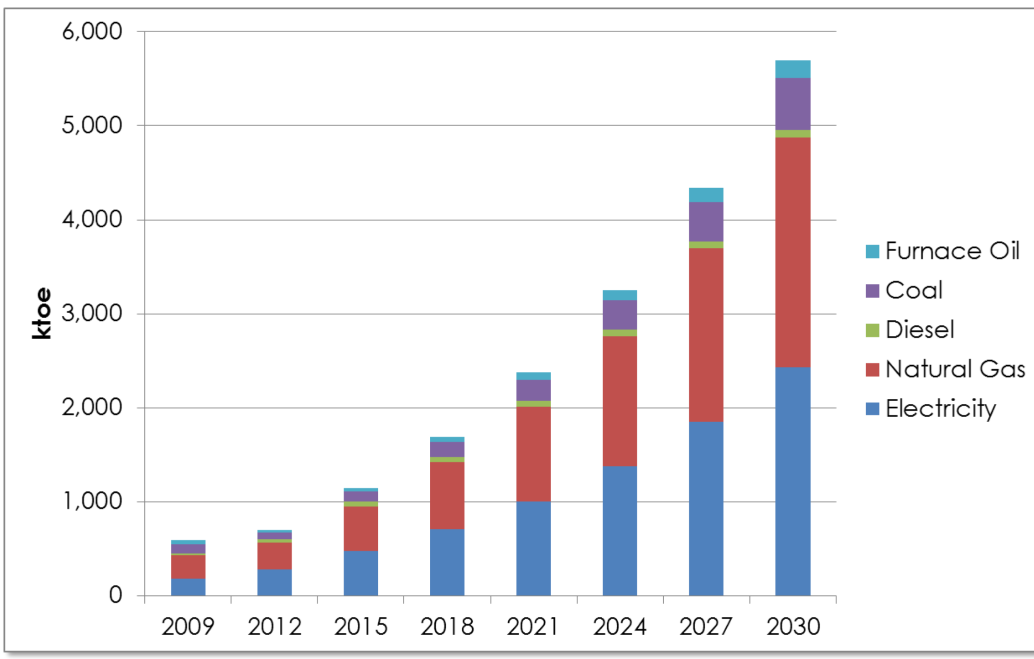
Figure I-8: Energy-Intensive Industry Sector FEC Forecast (toe)



	2005	2006	2007	2008	2009	2010	2011	2012	2013
Iron & Steel	277	431	545	507	1,064	562	617	556	2,533
Chem / Petrochem	19,445	20,398	20,463	35,377	40,425	41,736	57,942	40,528	36,954
Pulp & Paper	141	163	151	174	271	374	357	345	355
Food	45,195	34,442	16,490	57,203	21,401	33,667	15,421	14,682	16,965
Food	939	493	5,484	10,100	7,078	8,124	7,439	5,894	5,612
Non-metallic minerals	226,263	248,073	299,980	299,458	296,155	348,727	337,020	314,491	294,808
Non-ferrous metals	19,243	16,345	19,411	7,040	10,022	7,920	12,481	21,286	42,302

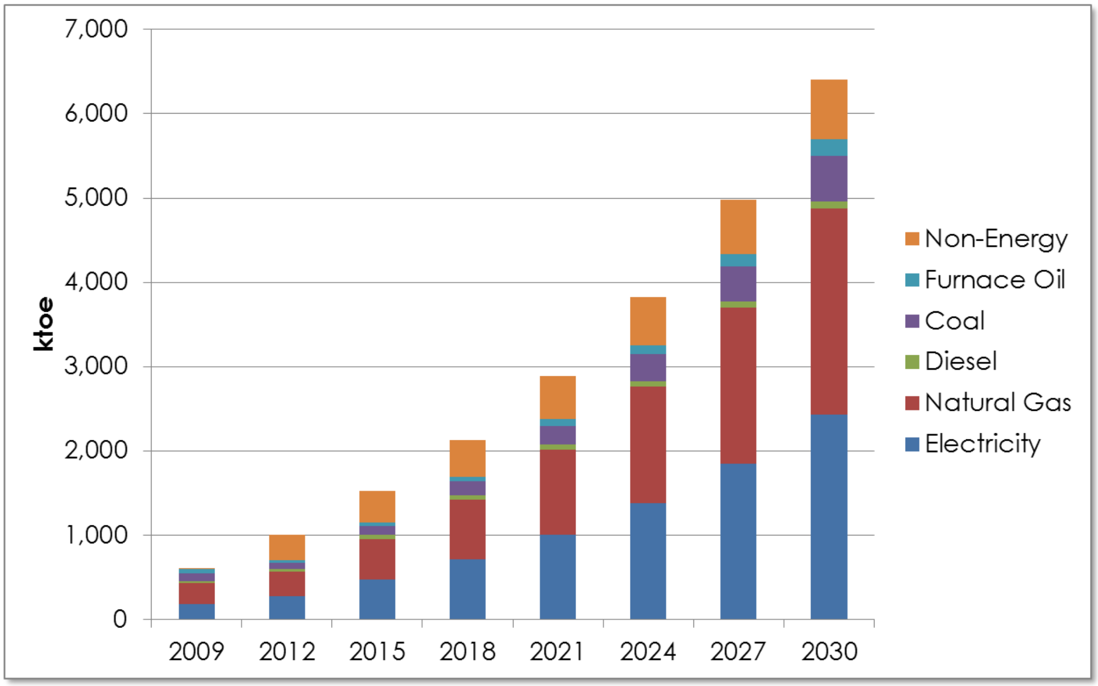
Sources: Consultant

Figure I-9: FEC Energy Carriers (without fertilizer) (ktoe)



Sources: Consultant

Figure I-10: FEC Energy Carriers (with fertilizer) (ktoe)



Sources: Consultant

Table I-11: Heavy Industry: Energy Carrier Projections (physical)

		2009	2012	2015	2018	2021	2024	2027	2030
Electricity	GWh	318	379	663	990	1 403	1 927	2 578	3 397
Natural Gas	Tons	212 681	247 546	403 668	602 926	854 279	1 173 641	1 569 684	2 068 738
Diesel[3]	IG '000s	1	3	9	10	12	13	15	18
Coal	Tons	64 469	49 929	78 456	117 183	166 035	228 105	305 079	402 073
Furnace Oil	IG	9 116	5 385	8 210	12 263	17 375	23 870	31 925	42 075

Sources: EMP Industry Sector Survey, Consultant

Table I-12: SME Sector: Energy Carrier Projections (physical)

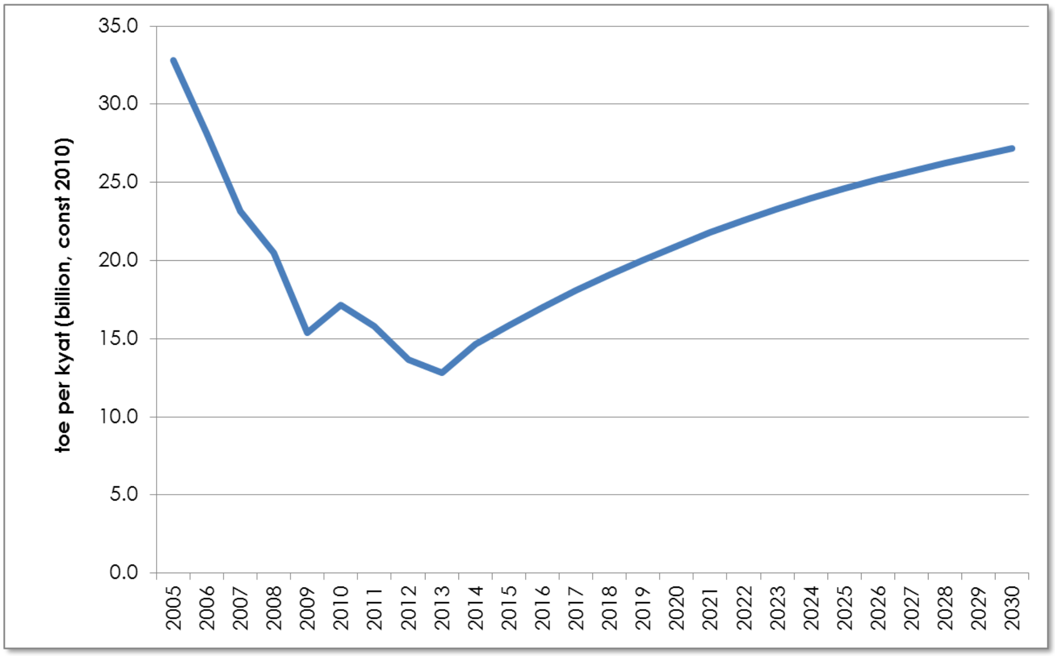
		2009	2012	2015	2018	2021	2024	2027	2030
Electricity	GWh	1 778	2 852	4 861	7 261	10 288	14 133	18 903	24 913
Diesel	IG '000s	3 786	3 276	2 767	2 258	1 748	1 239	729	220
Coal	tons	53,564	41,484	56,866	82,625	116,061	160,666	216,142	282,297

Sources: EMP Industry Sector Survey, Consultant

[3] Diesel consumption also accounted for in the Transport sector forecast for registered on-road vehicles

15. A forecast of the energy intensity of the Industry sector is given as Figure I-13. The trend in recent years suggests that the efficiency of the Industry sector has been increasing at a rapid rate. The projection for energy intensity shows an increasing trend that is to be expected as the industry sector develops strongly.

Figure I-13: Energy Intensity of Industry Sector – Medium Growth



Sources: Consultant

II. ENERGY PLANNING

D. Energy-Intensive Industry

16. The energy consumption of the heavy industry sector is determined according to 1) the types of energy carriers that support a manufacturing process, 2) the amount of physical product demanded by the market, and 3) an energy consumption rate related to the nature of the manufacturing process.

17. The energy carriers and energy consumption measures considered are shown in the following tables by sector:-

Table II-1: Energy Carriers by Segment

Economic Sector	Sub-Sectors	Sub-Sectors Included	Energy Carriers Considered
Manufacturing	Iron & Steel	Iron, Steel	Electricity, Coal, Natural Gas
	Non-Ferrous metals	Copper , (Tin and Zinc not significant in energy use)	Electricity, Coal, Natural Gas
	Non-Metallic minerals	Bricks, Glass, Cement	Electricity, Coal, Natural Gas
	Pulp & Paper		Electricity, Gas
	Food Processing	Sugar	Electricity, Gas
	Other manufacturing	Chemicals, Food processing, Electronics, Plastics, Machinery, Textiles, Wood and Wood Products, Transport Equipment & Repair	Electricity, Coal, Natural Gas, Diesel
Mining & Quarrying	N/A	N/A	
Construction	N/A	N/A	
Power & Gas	N/A	N/A	

Sources: Consultant

18. The historical production and fuel consumption of the energy-intensive industry sector was determined by a survey, after which a conversion was made to establish a GJ per ton basis as shown in Table II-3 below.

Table II-2: Energy Intensive Sector Historical Production

	Steel	Non-Ferrous Metal	Non-Metallic Minerals			Food	Pulp & Paper
	Steel[4]	Copper	Cement	Bricks	Glass	Sugar	Paper
Year	tons	tons	Tons	Tons	tons	Tons	tons
2005	62 080	811 074	1 101 450	22 341	113 898	35 943	121 261
2006	70 058	684 735	1 259 692	27 910	9 349	38 588	91 701
2007	70 605	807 672	1 477 744	35 594	72 649	87 775	43 287
2008	90 808	297 782	1 411 317	34 544	114 315	184 088	155 838
2009	93 908	417 437	1 303 885	37 138	117 914	108 867	56 062
2010	84 281	333 265	1 569 841	57 402	115 935	107 019	96 416
2011	129 584	521 819	1 577 133	76 375	37 030	83 089	43 561
2012	102 264	890 926	1 442 156	15 678	4 478	72 588	37 583
2013	89 114	1 768 785	1 461 283	19 492	6 948	63 862	46 805
2014	62 080	811 074	1 101 450	22 341	113 898	35 943	121 261

Sources: EMP Industry Survey conducted by Consultant

Table II-3: Myanmar Energy Efficiency Rates

Industry	GJ / ton
Steel	5
Copper	93
Cement	6
Bricks	15
Glass	3
Sugar	2
Paper	15

Sources: EMP Industry Survey conducted by Consultant

19. The forecast of final energy consumption for the heavy industry segment of the Industry sector was undertaken according to the following process:-

1. Electricity consumption is common to all sub-sectors of the heavy industry;
2. Historical electricity industrial sales are known, according to the records of YESC and ESE, and projections were made for industrial electricity sales to heavy industry (and to the SME segment) according to the historical relationship between Industry sector GDP and electricity consumption;
3. The forms of energy used for each of the heavy industry sub-sector production

[4] Crude and fabricated steel tons

processes were scaled in line with the electricity forecasts; and

4. A GJ per ton metric was used to establish the expected production of each industry sub-sector as tons of production.

E. Small to Medium Enterprise

20. The energy consumption of the heavy industry sector was determined by converting the diesel fuel consumption into units of electricity (kWh). In the latter case, an SME survey was conducted to determine fuel consumption by energy carrier. It was determined that SME's use electricity and diesel fuel. The diesel fuel use was analysed to determine the average diesel fuel consumption per SME, then related to the average electricity use; the energy ratio was extrapolated to the total SME sector according to commercial sector and light industry sector electricity sales reported by YESC and ESE. The SME survey covered 50 enterprises in total, selected to encompass the full range of SME types.

Table II-4: SME Survey Set

	Factory	Company
1	Cement	Triple "A" Cement International Co; Ltd
2	Gas Factory (Oxygen)	
3	Metal Industry (Lead 99%)	Yangon Metal Industry Co: Ltd
4	Edible Oil	Yangon Pure Ground Nut Oil
5	Edible Oil	Ngwe Thazin Min
6	Edible Oil	First Top Co., Ltd. – Myanmar
7	Edible Oil	Yuzana Palm Oil Refinery
8	PP Bags	Diamond Dragon Co; Ltd
9	Bag & Penang (LDPE,HDPE,PP)	Asia World Industries Ltd
10	Bag & Penang (LDPE,HDPE,PP)	Hmwe Plastic Bag
11	Plastic Bottle (PE,PP,PVC)	Asia Star Plastic
12	Instant Noddle (Shin Shin)	Cho Cho Co.Ltd
13	Instant Noddle (Yun Yun)	Yathar Cho Industry
14	CABLE,PVC Wire	Golden Lion Wire Co;Ltd
15	Transformer, Capacitor Bank	Soe Electric & Machinery Co.Ltd
16	Cold Storage	Golden sea cold storage& processing plant
17	Cold Storage	Ngwe Pinlel Livestock Breeding & Fisheries
18	Ice Factory	Ice Mountain
19	Cold Storage	ANAWAR HLWAM Company Limited
20	Ice Factory	Linn Ice Factory
21	Ice Factory	Dagon Kyaw Cube Ice
22	Corrugated Paper Boxes & Cartons	Ngwe Pinlel (Hlaing Tharyar)
23	Corrugated Paper Boxes & Cartons	Deco-Land

	Factory	Company
24	Garment Factory	A1
25	Garment Factory	Opal Int'l Co., Ltd
26	Texile Factory	Panda Group of Companies
27	Garment Factory	Rising White Tiger
28	Lead Battery	Proven Technology Industry
29	Drinking water (Alpine)	Loi Hein
30	Drinking water	Five Stars (Lucky)
31	Flour Mill	U Kyu Family Grains & Manufacturing
32	Flour Mill	Sun Flower
33	Rice mill	Ok
34	Rice mill	Golden Lace
35	Rice mill	Ayeyar Hinthar Trading Co., Ltd
36	Rice mill	Gold Delta
37	Rice mill	Hlaing Nady Chan Myae
38	Dairy Plant	Tun Dairy Plant
39	Soft Drink	100% (Power C)
40	Soft Drink (Ve Ve)	Green Circle Co; Ltd
41	Soft Drink (Blue Mountain)	Loi Hein
42	Wood Industry	National Wood Industry Co., Ltd
43	Bakery & Confectionery	A & T
44	Bakery & Confectionery	Myanmar Mason Industry (Goodmorning)
45	Bakery & Confectionery	J' Donuts
46	Bakery & Confectionery	Shwe Pu Zun
47	Soap & Detergent Powder	E- Lan
48	Soap & Detergent Powder	United Pacific (Oki)
49	Soap & Detergent Powder	First Top Group Co., Ltd.
50	Calcium Carbonate Plant	Crown Calcium Carbonate

Sources: EMP Industry Survey conducted by Consultant

III. ENERGY-INTENSIVE INDUSTRY

F. Steel & Iron

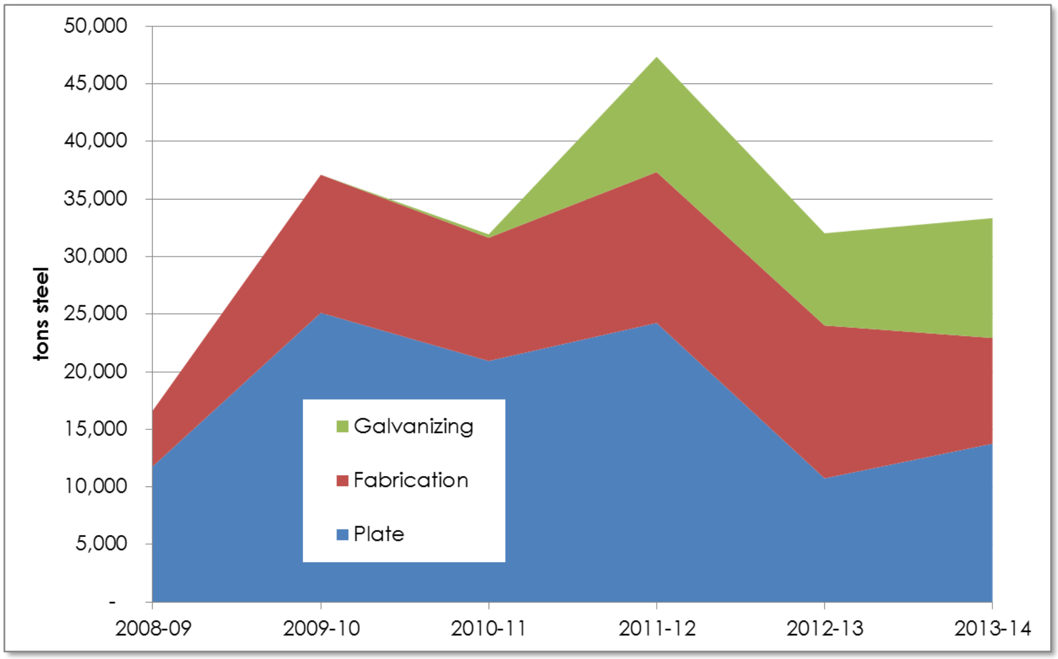
21. Myanmar has three rich iron deposits. The first deposit is in Pyin Oo Lwin (Kyadwinyay) with three million tons of iron ore. The second deposit is in Pinpet on the border between Taunggyi and Hopong townships, with 70 million tons of iron ore. The third is in Kathaingtaung with 230 million tons of iron ore.

22. There are five steel plants in Myanmar designed to convert iron ore to steel, or to use steel billets or scrap steel for fabrication of steel parts.

- The no. 1 Steel Plant, in Bago Division, processes iron ore, beginning production in 1999 at an annual production rate of 150,000 to 200,000 tons;
- The no. 2 Steel Plant (Myaungdagar) was established in Yangon Division in 1997; the plant can produce various sizes of billets for shipbuilding, as well as steel plates, H beams, I beams, girders, and trusses. The plant has a Mild Steel Plate Rolling Mill, Steel Structure Fabrication facilities, and Galvanizing facilities;
- The no. 3 Steel Plant (Ywama) produces deformed bars, round bars, wire coils and angle iron. The plant has an Electric Arc Furnace, a Ladle Refining Furnace and a Continuous Casting Machine;
- The no. 4 Steel Plant (Myingyan) and no. 5 Steel Plant (Pinpet) are designed to produce billets and slabs for the other steel plants. The no. 4 Steel Plant (Myingyan) produces steel billets from pig iron for the no. 1 Steel Plant, and steel slabs for the no. 2 Steel Plant. The ship dismantling workshop (Thilawa) began operation in 2002 to provide steel scraps to the no.4 Steel Plant; and
- The no. 5 Steel Plant reported no production.

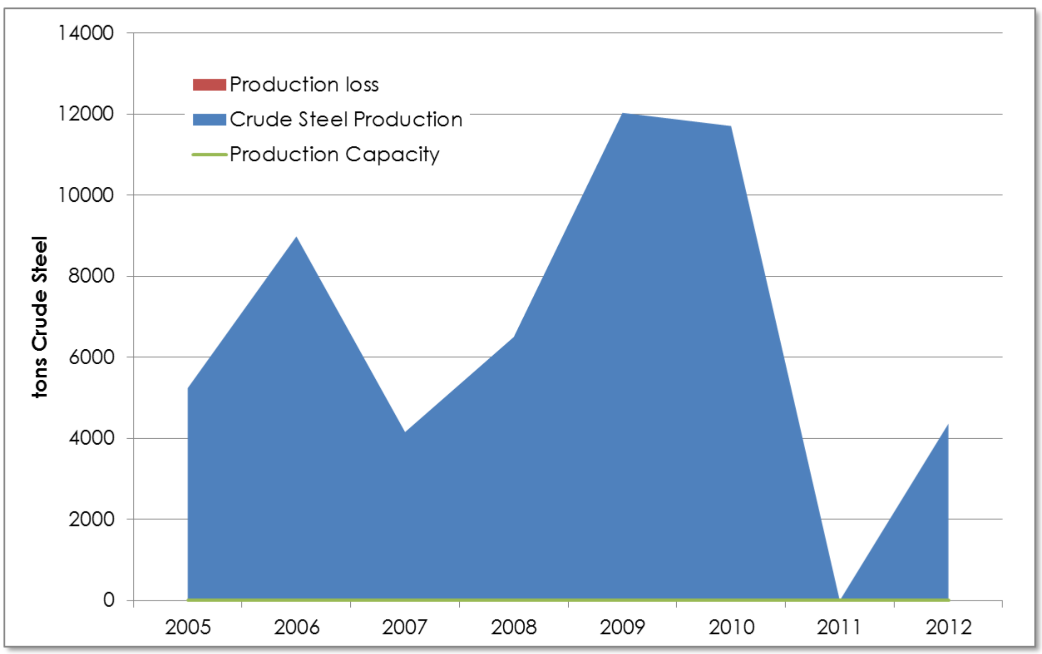
23. The production of the steel plants was established by survey. Steel Plant no. 1 reported an annual production of 40 000 tons of sponge iron, 7 000 tons of pig iron and 25 000 tons of liquid steel over the last decade. The production of Steel Plants no. 2 and 3 are given in Figure III-1 and Figure III-2.

Figure III-1: Steel Production: Steel Plant no. 2



Sources: Industry Sector Survey, Consultant

Figure III-2: Steel Production: Steel Plant no. 3



Sources: Industry Sector Survey, Consultant

24. The total production of crude and fabricated steel is given by Table III-3. The total market demand for iron and steel is estimated to be around 1,000,000 tonnes per annum. However in recent years the maximum production was reported at 130 000 tonnes. Crude steel production from iron ore has been 25 000 tons. Myanmar imports around 600 000 tonnes of steel from Thailand, South Korea, India and the People's Republic of China. Myanmar's import of billet, was reported to be 117,000 tonnes in the first ten months of 2011, double the volume in the same period in 2010 (SEAISI, 2012).

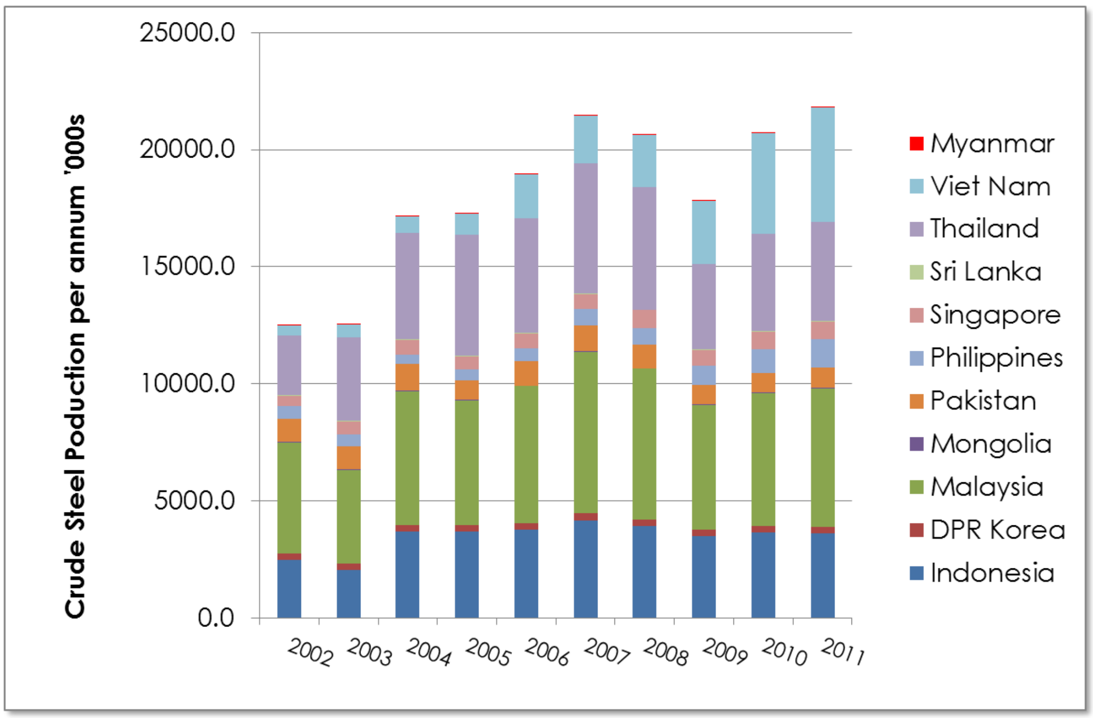
Table III-3: Total Steel Production (Crude & Fabricated Steel)

	2005	2006	2007	2008	2009	2010	2011	2012	2013
Steel	62,080	70,058	70,605	90,808	93,908	84,281	129,584	102,264	89,114

Sources: Industry Sector Survey, Consultant

25. By Asian country standards the production of crude steel has been very small as shown in Figure III-4. Anecdotal evidence suggests that Myanmar's cost to produce crude steel is uncompetitive compared to imports from PRC.

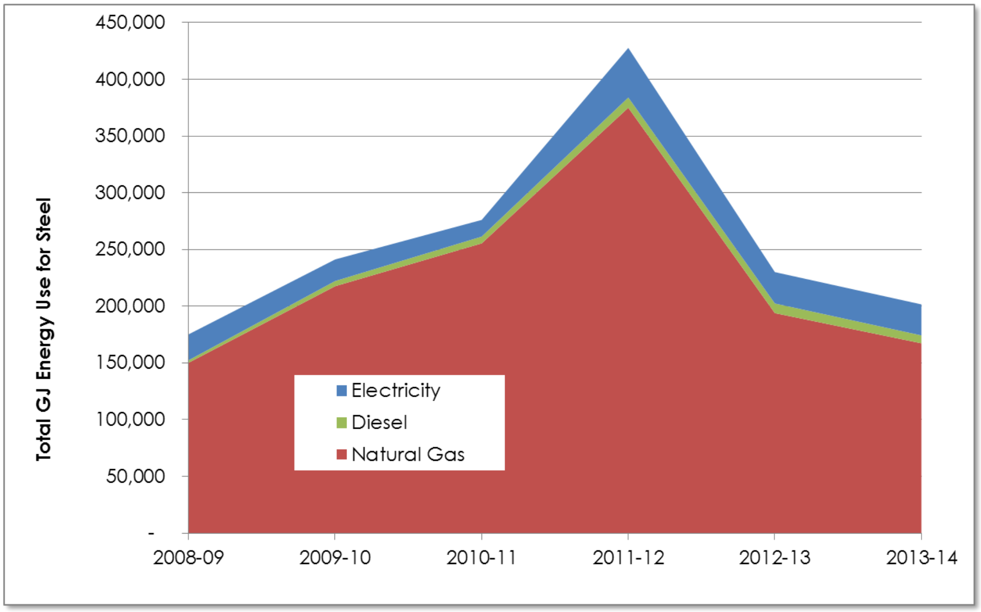
Figure III-4: Crude Steel Production in Asia (excluding PRC)



Sources: Steel Statistical Yearbook 2012

26. Figure III-5 shows the energy consumption of the no 2 Steel Plant by energy carrier. This and the consumption of the other steel plants were used to establish the average energy use, according to their production of crude steel.

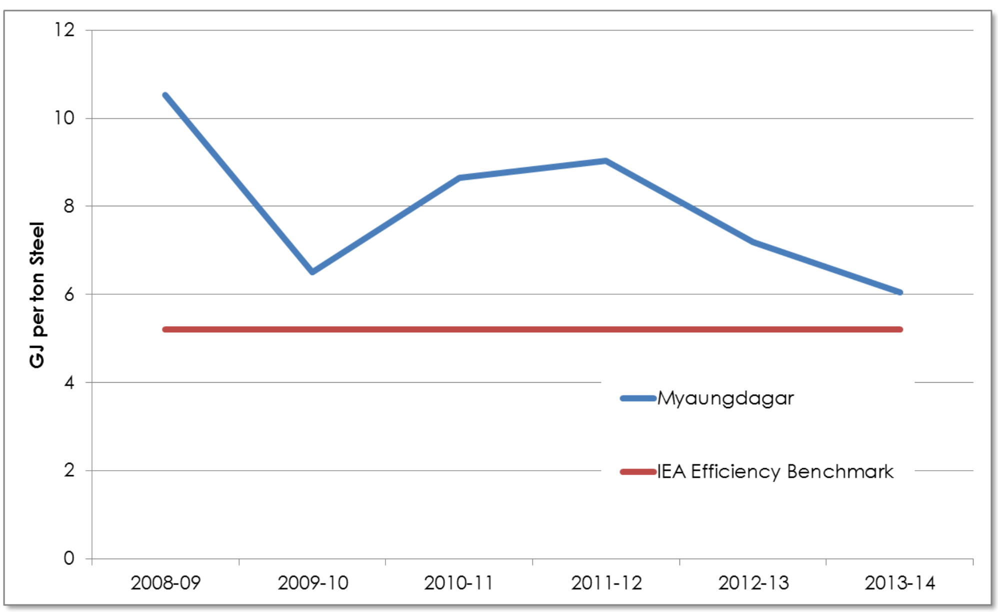
Figure III-5: Energy Consumption of no. 2 Steel Plant by Carrier



Sources: EMP Industry Survey

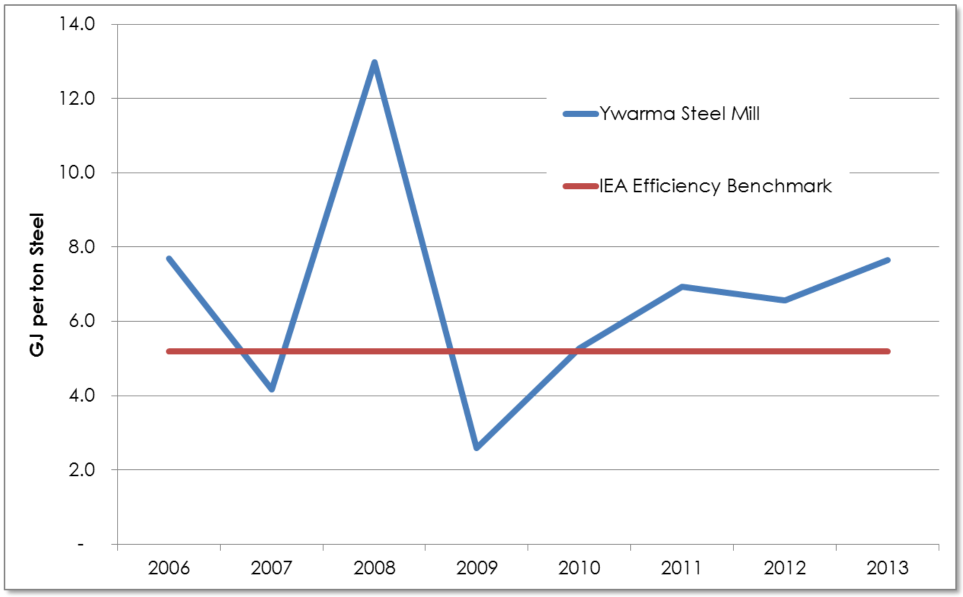
27. The average energy consumption of the iron and steel sub-sector in recent years is estimated to have been around 5 GJ per ton. This has been determined from the EMP survey of Myanmar's steel plants.

Figure III-6: Energy Efficiency of no. 2 Steel Plant



Sources: EMP Industry Survey

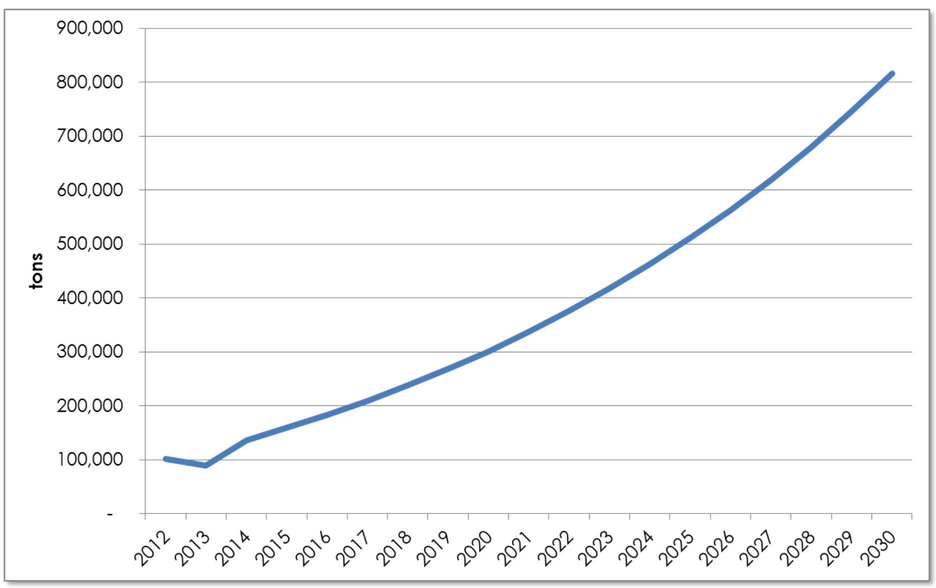
Figure III-7: Energy Efficiency of no. 3 Steel Plant



Sources: EMP Industry Survey

28. Energy consumption has been forecast according to expected industry sector GDP growth after which the corresponding crude steel production has been computed by way of simple division by 5 GJ per ton. This is a conservative estimate that nevertheless assumes that reliable energy supplies will support Myanmar's crude steel production at a cost that is competitive with imports.

Figure III-8: Crude Steel Production Forecast



Sources: Consultant

G. Non-Ferrous Metals

29. Myanmar has two rich copper bearing deposits in Sabetaung and Letpadaung. The ore grade quality is of world class. Copper is mined at Sabetaung, Sabetaung South and Kyisintaung. Letpadaung is due to commence operation in 2015 and facility construction is currently underway.

Figure III-9: Copper Mineral Resources

Mine	Mineral	Mining Process	Ore Resources	Mineral Resources	Run of Mine Grade/ Quality
			'000 tons	'000 tons	
Shangalon	Copper	Open Pit		9,000	0.23%
Kyesin Taung	Copper	Open Pit		66,500	0.22% to 0.3%
SabeTaung	Copper	Open Pit	600,000	27,860	0.31%
Letpadaung	Copper	Open Pit		577,000	0.44%
Bawdwin	Copper	Open Pit		2,500	0.87%

Sources: Ministry of Mines

30. Copper mineral extraction is made using an open pit mining technique. Considerable quantities of diesel fuel are used to fuel the trucks and excavators used in the mine.

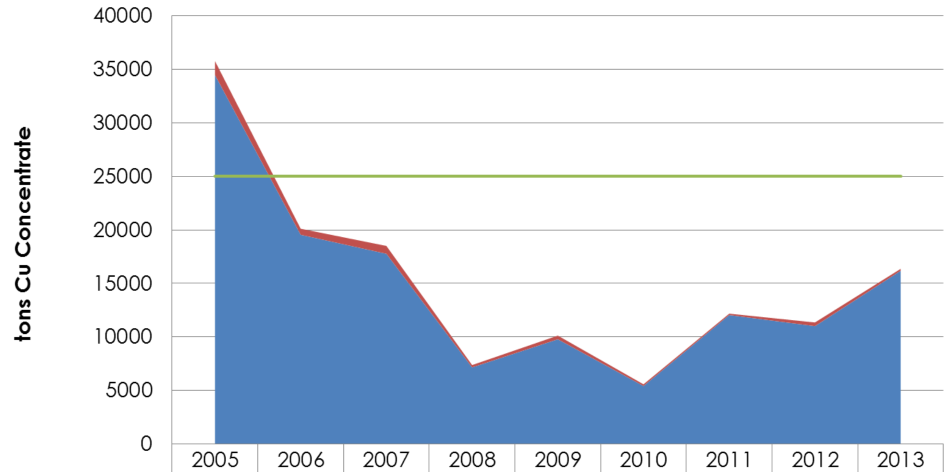
31. The copper is processed using an electro-winning process:-

- Heap leaching to dissolve the valuable copper from the chalcocite ore;
- Solvent extraction to purify and concentrate the copper solution generated by leaching; and
- Electro-winning to plate the copper as high-grade cathodes.

32. The electro-winning process is energy intensive. According to the EMP energy-intensive industry survey, the average energy consumption of the iron and steel sub-sector in recent years is estimated to have been around 93 GJ per ton.

33. The copper production of the Monywa copper mine was established by survey. The company reported an annual production of around 16 000 tons of copper concentrate in 2013.

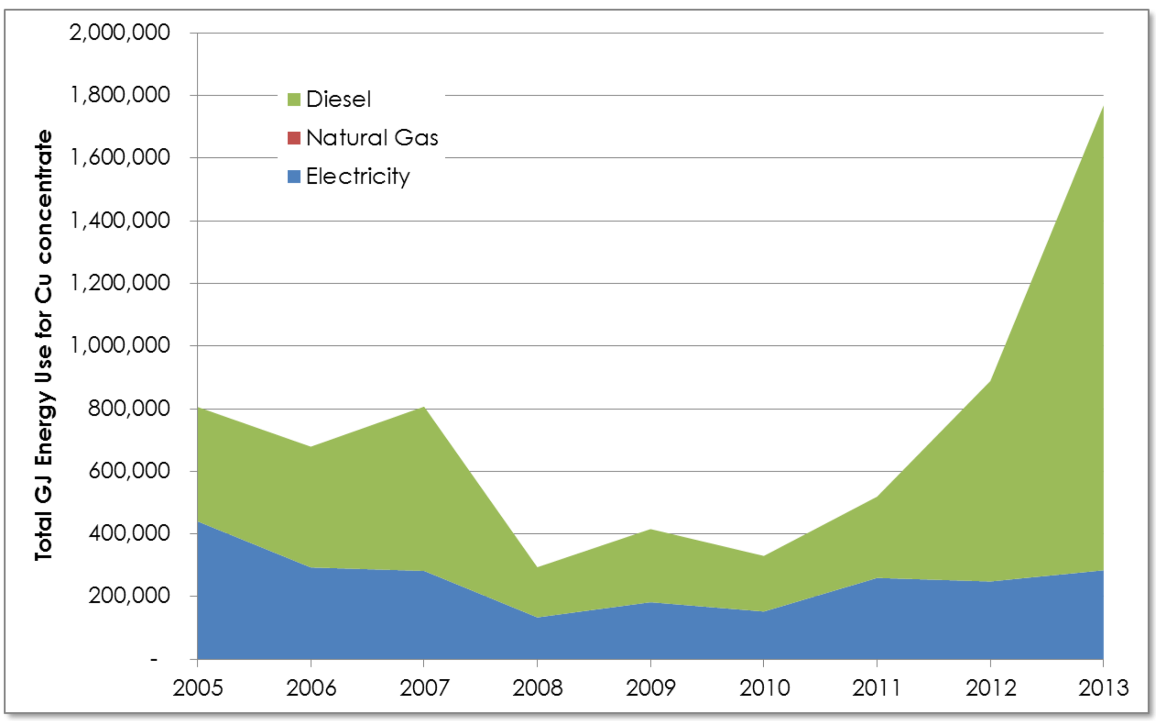
Figure III-10: Copper Concentrate Production (tons)



	2005	2006	2007	2008	2009	2010	2011	2012	2013
Production loss	1305	564	733	219	343	160	132	343	183
Copper Cathode Production (>99.99%)	34479	19554	17778	7159	9789	5420	12053	11017	16188
Production Capacity	25000	25000	25000	25000	25000	25000	25000	25000	25000

Sources: Industry Sector Survey, Consultant

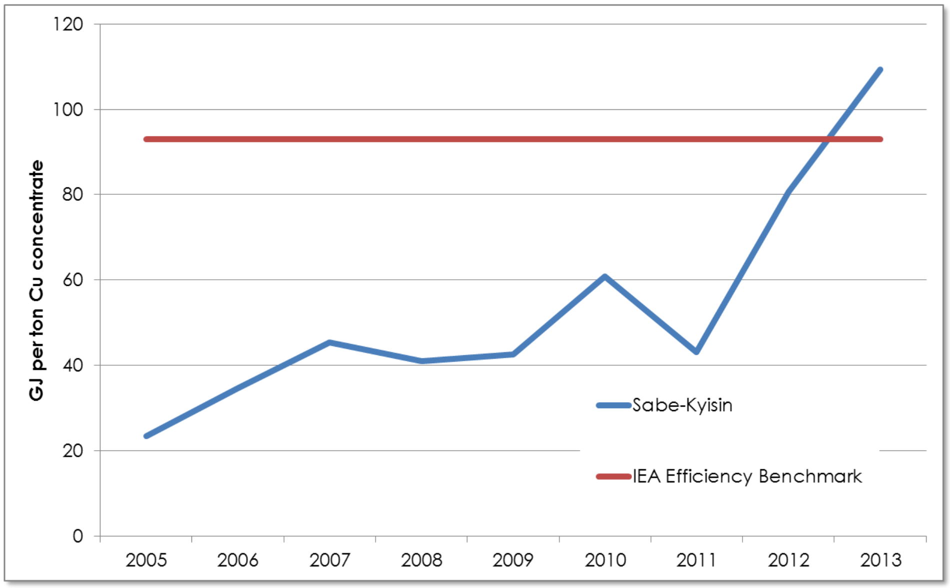
Figure III-11: Energy End-Use per ton: Copper Concentrate



Sources: Industry Sector Survey, Consultant

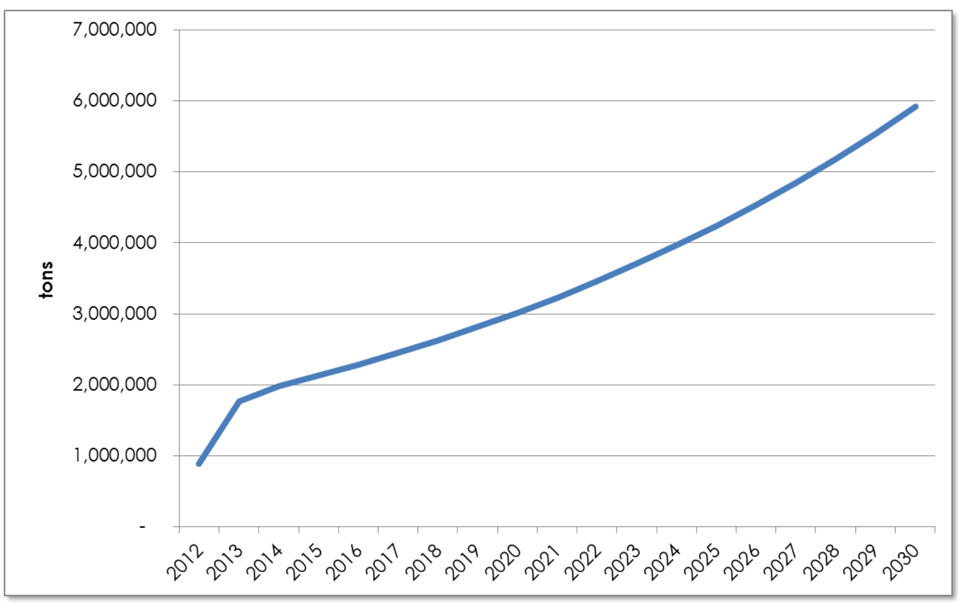
34. The average energy consumption of the copper concentrate production in recent years is estimated to have been around the IEA benchmark of 93 GJ per ton. The energy consumption forecast for copper is made according to expected industry sector GDP growth after which the corresponding steel production was computed by way of simple division by 93 GJ per ton.

Figure III-12: Energy Efficiency at Sabetaung Copper



Sources: Consultant

Figure III-13: Copper Concentrate Production Forecast



Sources: Consultant

H. Non-Metallic Minerals

35. A survey of the non-metallic mineral industry sector was undertaken comprising six cement factories (wet and dry type), two brick factories and two glass factories.

Table III-14: Non-Metallic Mineral Survey

Cement Plant	Kyangin
	Thayet
	Kyaukse
	Sin Minn – 1
	Sin Minn – 2
	Sin Minn – 3
Brick Factory	Danyingone
	Aung Lan
Glass Factory	Pathein
	Thanlyn

Sources: EMP Industry Survey

1. Cement

36. It is understood that the cement industry has a total installed capacity around 17 000 tonne per day, but due to a low production yield Myanmar produced 2.8 million tonnes per annum in 2012. The Government sector production has been reported by the CSO at around 22% of total production. It is understood that Myanmar's cement production falls short of demand with the shortfall made up mainly by imports from Thailand.

Table III-15: Government Cement Production (tons)

2000	2003	2004	2005	2006	2007	2008	2010
418 923	582 908	533 475	547 068	576 589	611 353	690 750	637 264

Sources: CSO

37. The EMP industry survey sought data from the largest cement producers, totalling around 1.1 million ton in 2012, or less than half of total production.

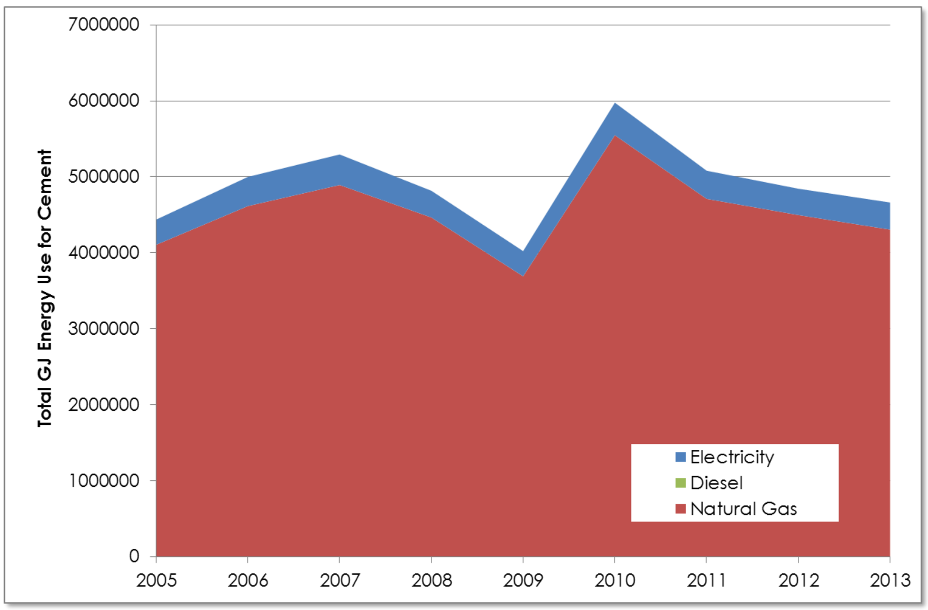
Table III-16: Cement Production tons

	2005	2006	2007	2008	2009	2010	2011	2012	2013
Kyangin	3,149	3,422	4,028	3,856	3,392	3,145	3,667	2,703	2,947
Thayet	108,972	143,550	126,090	192,600	138,456	85,500	124,020	131,000	108,439
Kyaukse	103,926	94,639	63,163	85,050	110,410	84,500	66,915	66,450	87,125
Sin Minn – 1	64,826	82,324	79,807	94,375	89,780	90,336	56,424	50,425	43,311
Sin Minn – 2	92,866	98,285	138,504	127,471	125,151	103,310	47,663	33,508	39,877
Pa-An	811,141	837,567	924,725	801,813	728,157	1,073,161	925,183	784,544	850,203
Total	1,184,880	1,259,787	1,336,317	1,305,165	1,195,346	1,439,952	1,223,872	1,068,630	1,131,902

Sources: EMP Industry Survey

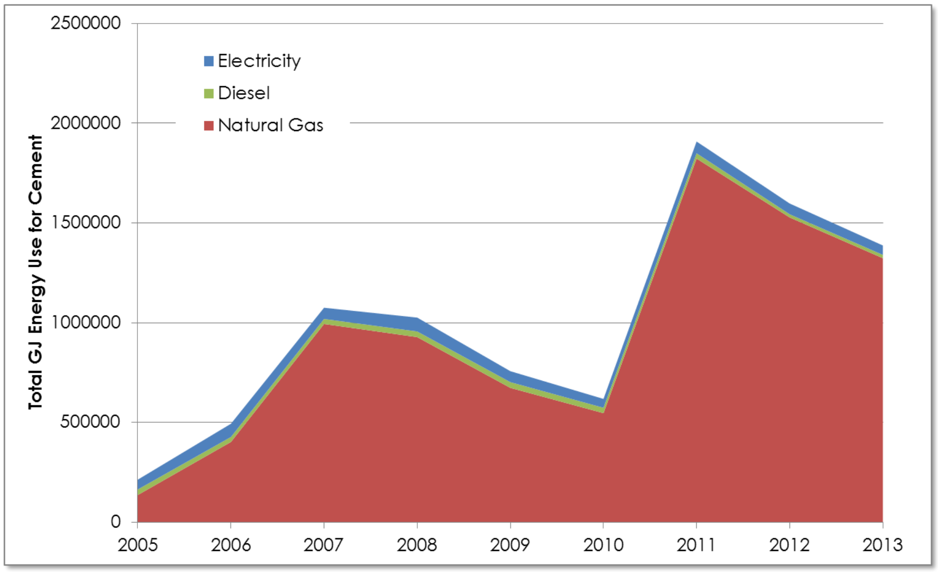
38. The large cement mills use natural gas as their primary fuel as shown by Figure III-17.

Figure III-17: Cement Production: Pa-An



Sources: Industry Sector Survey, Consultant

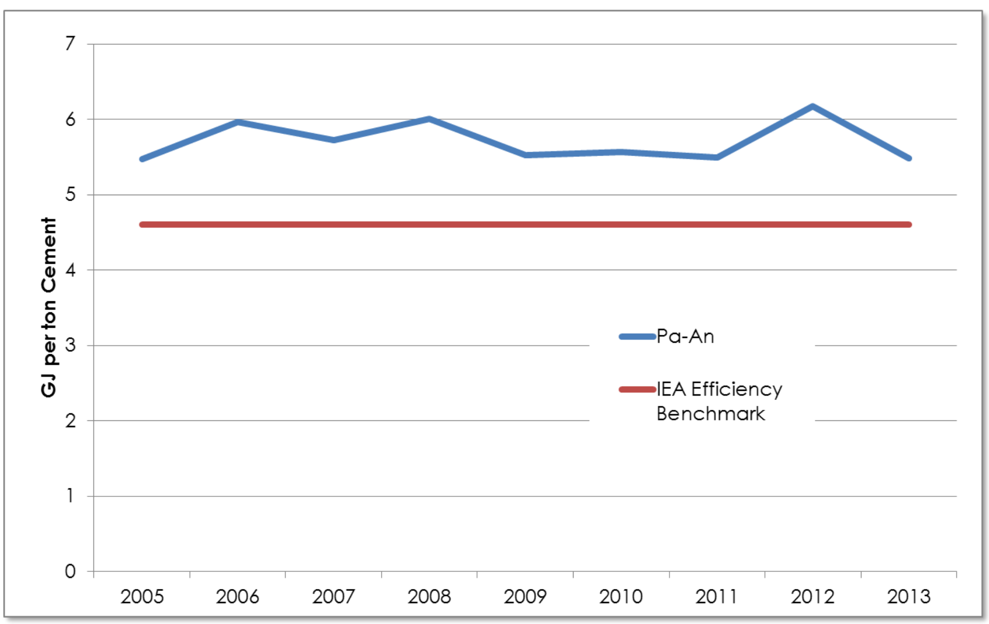
Figure III-18: Cement Production: Thayet



Sources: Industry Sector Survey, Consultant

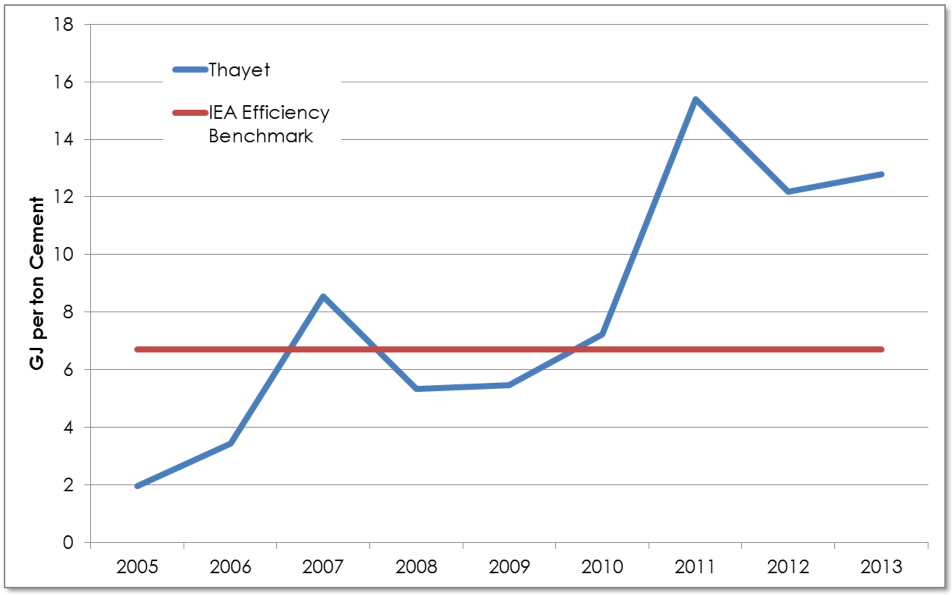
39. Fuel use and cement production was used to calculate the GJ per ton for cement production, which was found to average 6 GJ per ton (wet and dry kilns).

Figure III-19: Energy Efficiency at Pa-An



Sources: Consultant

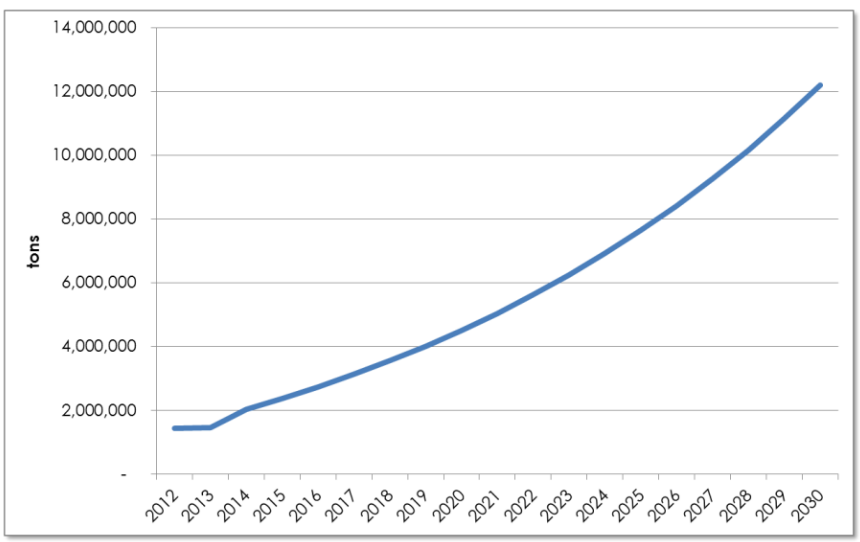
Figure III-20: Energy Efficiency at Thayet



Sources: Consultant

40. A study (LVT, 2013) considered that cement production will reach to 5.5 mtpa by 2015, however using the industry survey data to make a projection according to Industry sector GDP yields the forecast of Figure III-21. This projection has been based on the expected energy requirement to produce cement adjusted for Industry sector GDP growth after which the corresponding cement production has been computed by way of simple division by 6 GJ per ton.

Figure III-21: Cement Production Forecast (tons)



Sources: Consultant

2. Bricks

41. In Asia, the brick industry uses coal, heavy fuel oil, gas, and petroleum coke as a source of heat; biomass is also sometimes used such as rice husk, paddy husks, saw dust and firewood (e.g. Sri Lanka and Vietnam). In larger brickworks, electricity is utilized by electric motors for the preparation of raw materials through milling and pressing as well as blowers for the drying and firing process.

42. Total Government sector brick production in Myanmar was reported by the CSO at 140,000 tons in 2010. A brickworks was surveyed, Danyingone, as representative of a large brickworks. The reported production was 128,020 tons in 2010. However, according to CSO statistics and Danyingone's report, brick production appears to have been declining since 2007.

Table III-22: CSO-Reported Brick Production

	2000	2003	2004	2005	2006	2007	2008	2010
'000s	66 575	82 600	76 997	72 325	70 858	76 223	52 536	47 317
tons	195 809	242 941	226 462	212 721	208 406	224 185	154 518	139 168

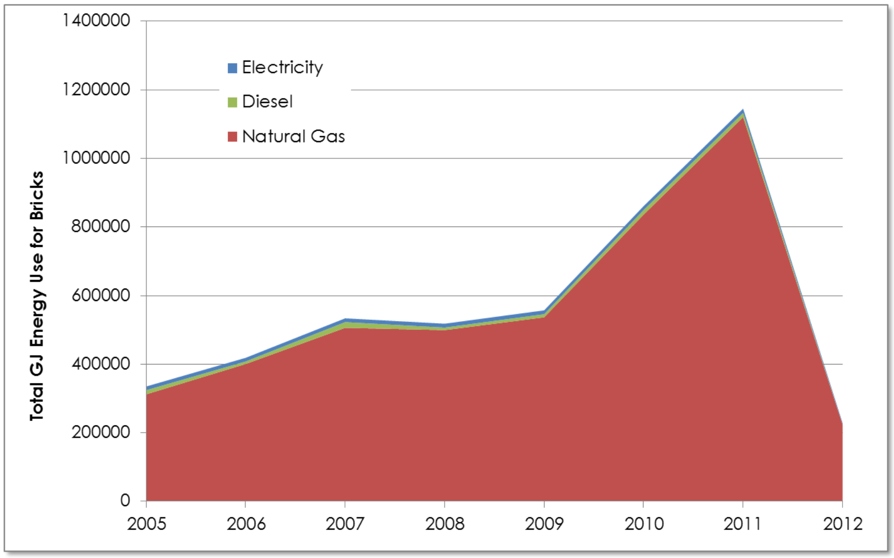
Table III-23: Brick Production (tons)

	2000	2005	2006	2007	2008	2009	2010	2011	2012
Danyingone	122 864	142 496	151 518	169 467	125 024	139 169	128 020	95 994	21 600

Sources: EMP Industry Survey

43. Danyingone reported the use of natural gas as a primary fuel.

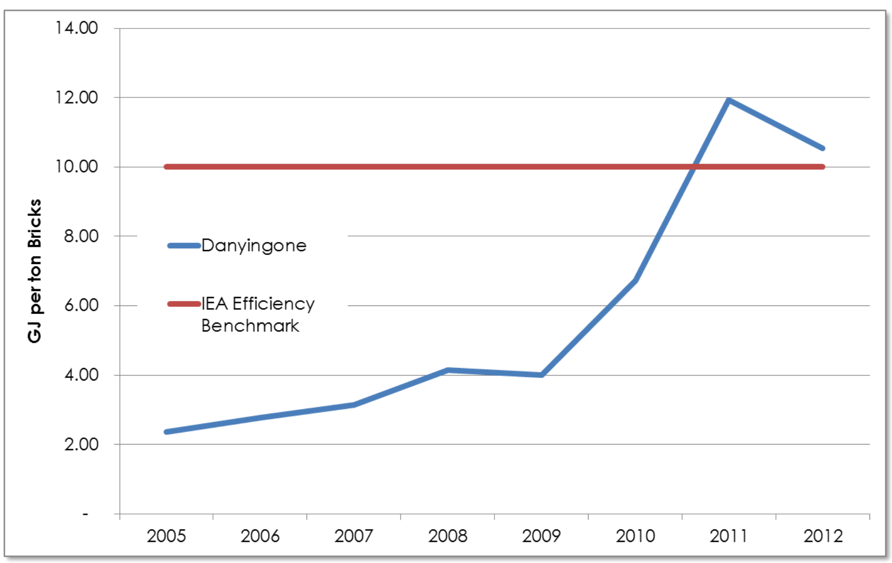
Figure III-24: Energy End-Use: Danyingone



Sources: Industry Sector Survey, Consultant

44. The average energy consumption of brick production in recent years is estimated to have been around the IEA benchmark of 10 GJ per ton. The energy consumption forecast for bricks is made according to expected industry sector GDP growth after which the corresponding steel production was computed by way of simple division by 10 GJ per ton.

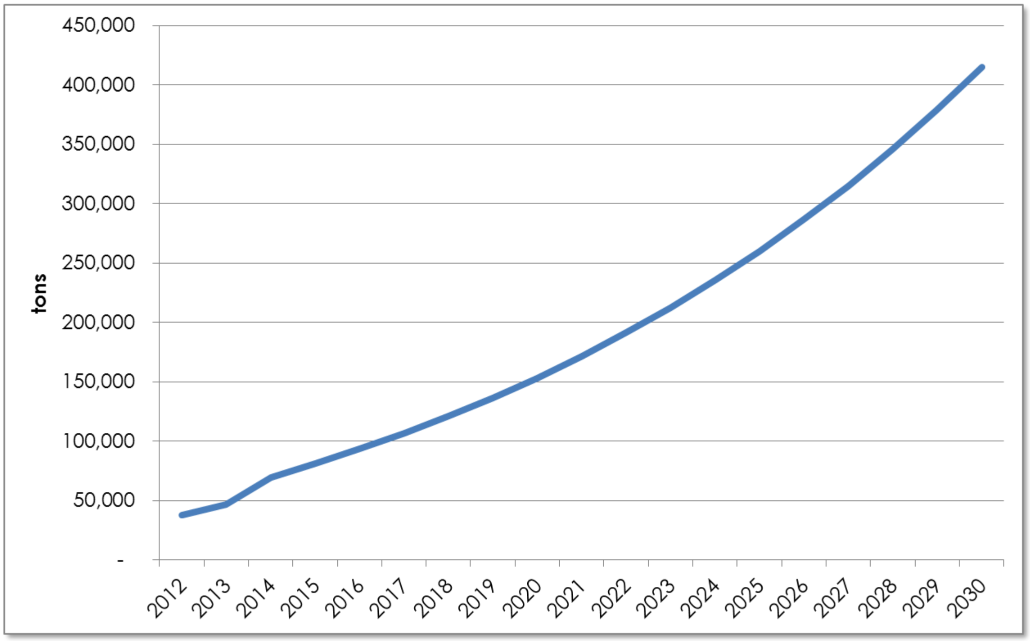
Figure III-25: Energy Efficiency at Danyingone



Sources: Consultant

45. The energy consumption for brick making has been forecast according to the expected Industry sector GDP growth after which the corresponding brick production was computed by way of simple division by 10 GJ per ton.

Figure III-26: Bricks Forecast (tons)



Sources: Consultant

3. Glass

46. Two large glass factories were surveyed as representative of large glassworks. The reported production totalled 15,345 tons in 2013. There were no CSO statistics cited for glass production. It appears that for these two plants glass production has remained steady since 2005.

Figure III-27: Glass Production (tons)

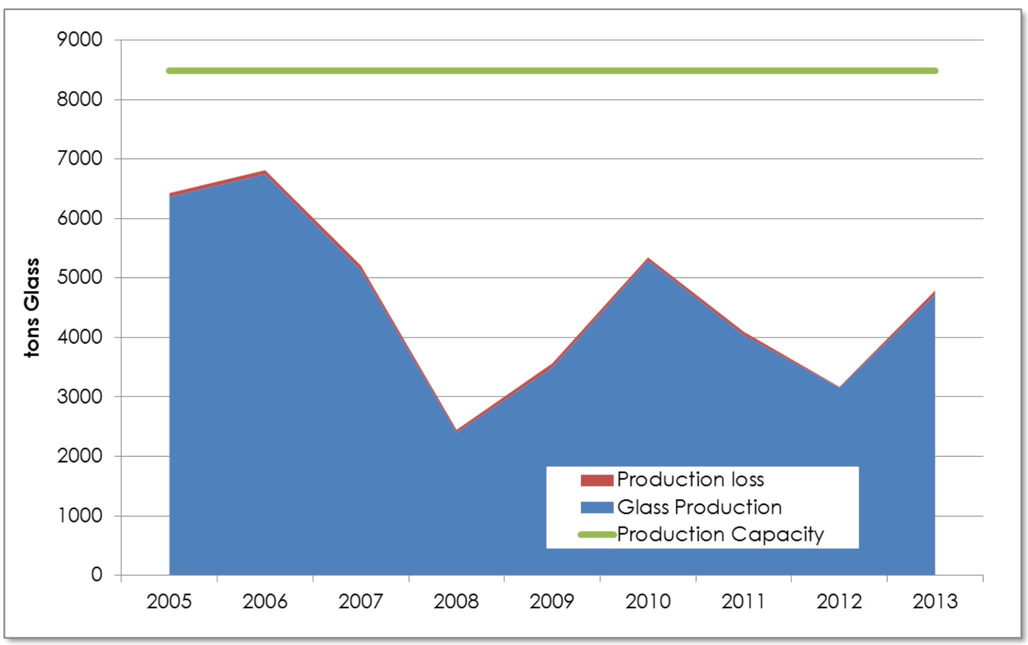
	2005	2006	2007	2008	2009	2010	2011	2012	2013
Pathein	10,236	5,863	-	5,775	10,964	10,602	10,051	7,077	-
Thanlyn	4,748	3,263	4,463	6,364	6,746	5,133	2,400	3,495	5,294
Total	15,277	14,531	14,699	12,227	6,746	10,908	13,364	14,097	15,345

Sources: EMP Industry Survey

Figure III-28: Glass Production: Pathein

Sources: Industry Sector Survey, Consultant

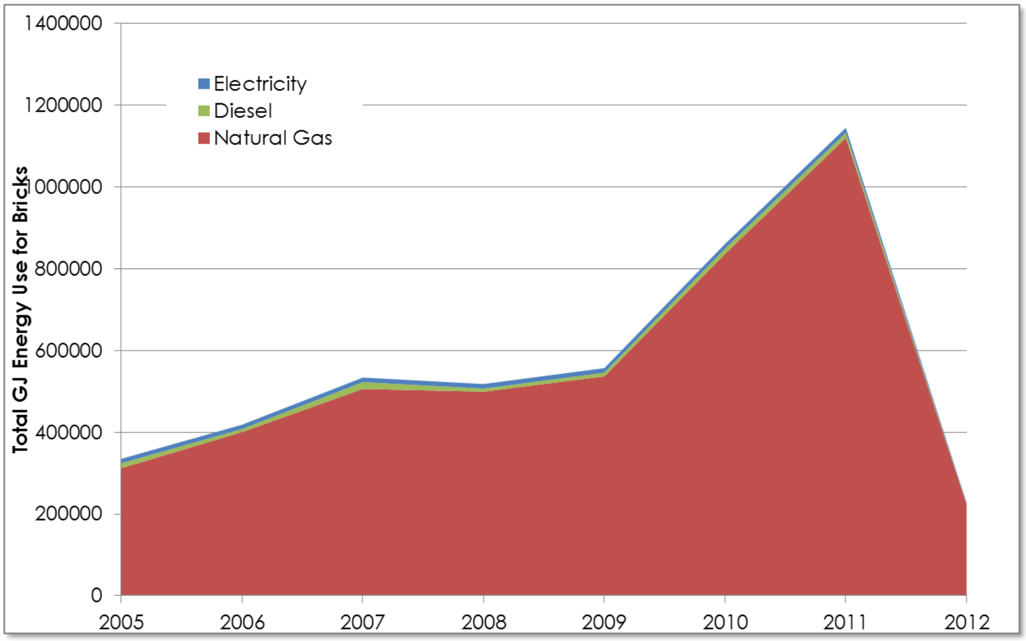
Figure III-29: Glass Production: Thanlyn



Sources: Industry Sector Survey, Consultant

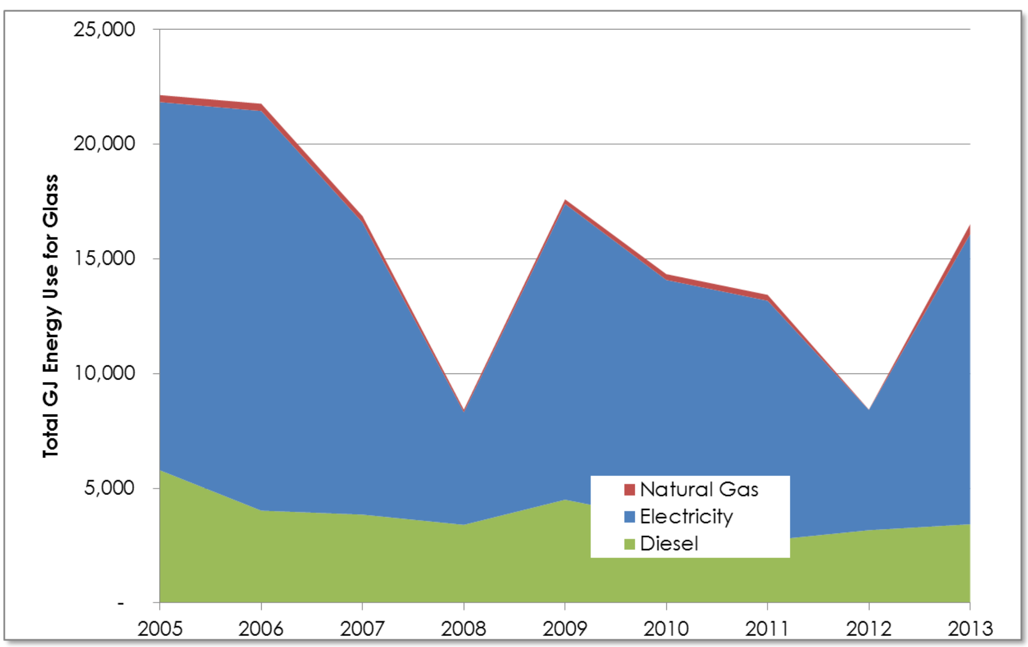
47. Pathein depends on natural gas and and Thanlyn on electricity as their primary fuel supply as shown by the following charts:-

Figure III-30: Energy End-Use: Pathein



Sources: Industry Sector Survey, Consultant

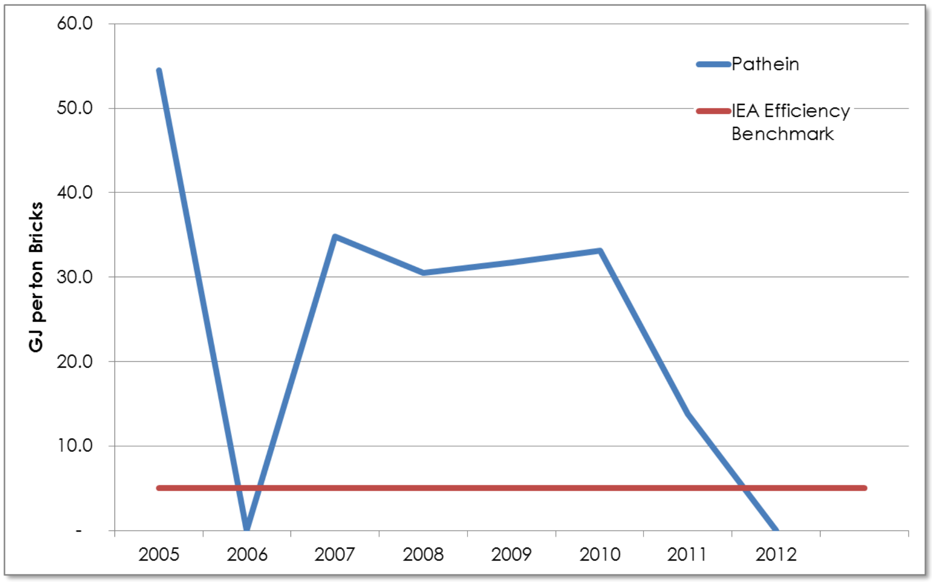
Figure III-31: Energy End-Use: Thanlyn



Sources: Industry Sector Survey, Consultant

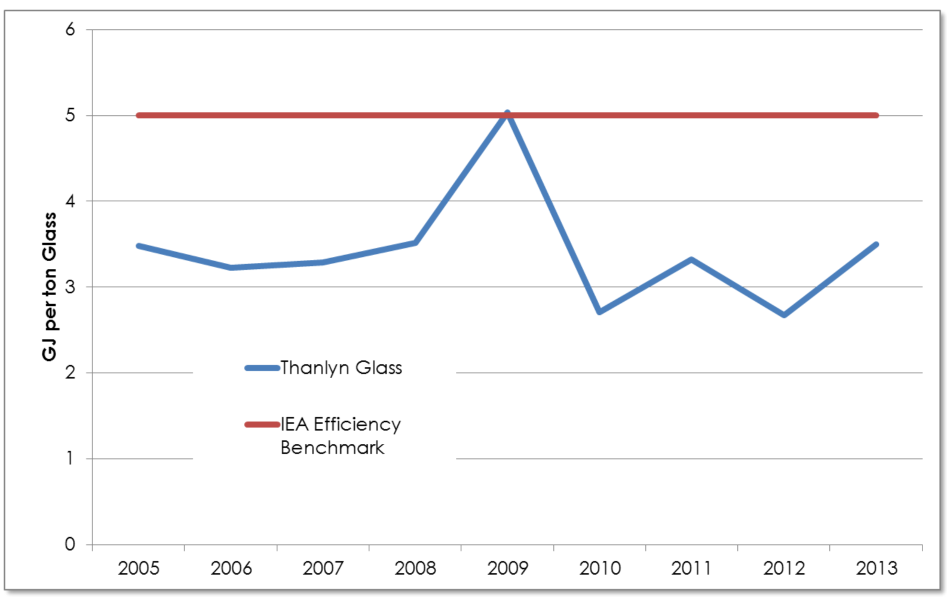
48. The average energy consumption for glass making at Pathein and Thanlyn is computed to average 6 GJ per ton, around the IEA energy efficiency benchmark for brick making. The energy consumption forecast for bricks is made according to expected industry sector GDP growth after which the corresponding steel production was computed by way of simple division by 6 GJ per ton.

Figure III-32: Energy Efficiency at Pathein



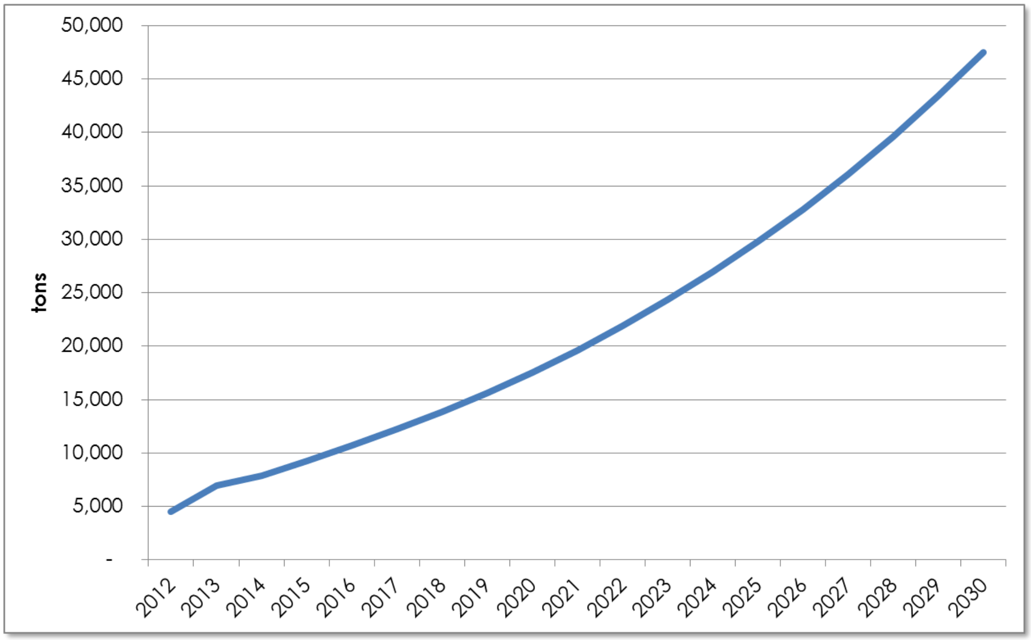
Sources: Consultant

Figure III-33: Energy Efficiency at Thanlyn



Sources: Consultant

Figure III-34: Glass Production Forecast (tons)



Sources: Consultant

I. Food - Sugar

49. Small and medium enterprise (SMEs) sugar producers dominate the sugar business in Myanmar, estimated to account for more than 60% of total output in 2006-07. The remaining production was by state-owned producers.

Table III-35: Sugar Production

	2002	2003	2004	2005	2006	Growth
State-owned	88,852	64,701	82,897	71,450	92,598	1%
Private	127,199	141,779	129,382	154,314	159,963	5%
Total	216,051	206,480	212,279	225,764	252,561	3%

Sources: Kudo T and San Thein, 2008

50. The EMP survey included seven sugar and ethanol producers. The total reported production of sugar from these large producers is given below as Table III-37. The total quantity reported by these producers in 2005 and 2006 is a small portion of the total sugar production in the country reported in Table III-35. This is because of the many small producers in operation in addition to the large operators.

Table III-36: Sugar Mill Survey Set

Mill Type	Mill
Sugar Mill	Zayyawaddy
	Belin
	TZ Aye
	Kan Hla
	Dahatkone
Sugar Mill - Ethanol & Sugar	Kanbalu
Ethanol (Sugar Mill)	Taung Zin Aye

Sources: EMP Survey

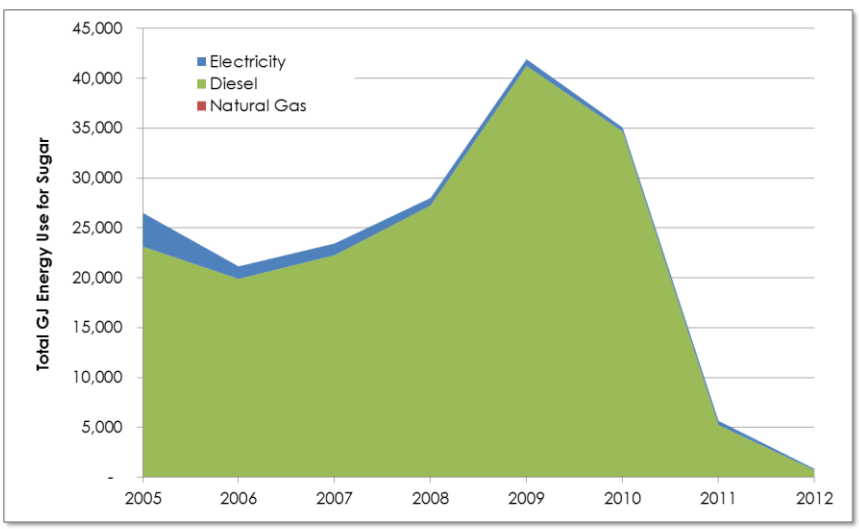
Table III-37: Surveyed Sugar Mill Production

	2000	2005	2006	2007	2008	2009	2010	2011	2012	2013
Zayyawaddy	3,263	1,517	1,307	1,892	754	-	344	-	-	6,400
Belin	3,867	869	1,021	1,523	1,533	830	1,093	718	-	-
TZ Aye	5,128	5,092	7,316	6,998	5,992	5,618	3,498	3,346	7,343	6,791
Kan Hla	-	-	-	-	-	198	2,836	6,004	16,173	19,019
Dahatkone	3,726	3,644	5,029	1,586	328	2,721	1,244	1,496	4,891	6,949
Total	15,984	11,121	14,673	11,999	8,607	9,367	9,015	11,563	28,407	39,159

Sources: EMP Survey

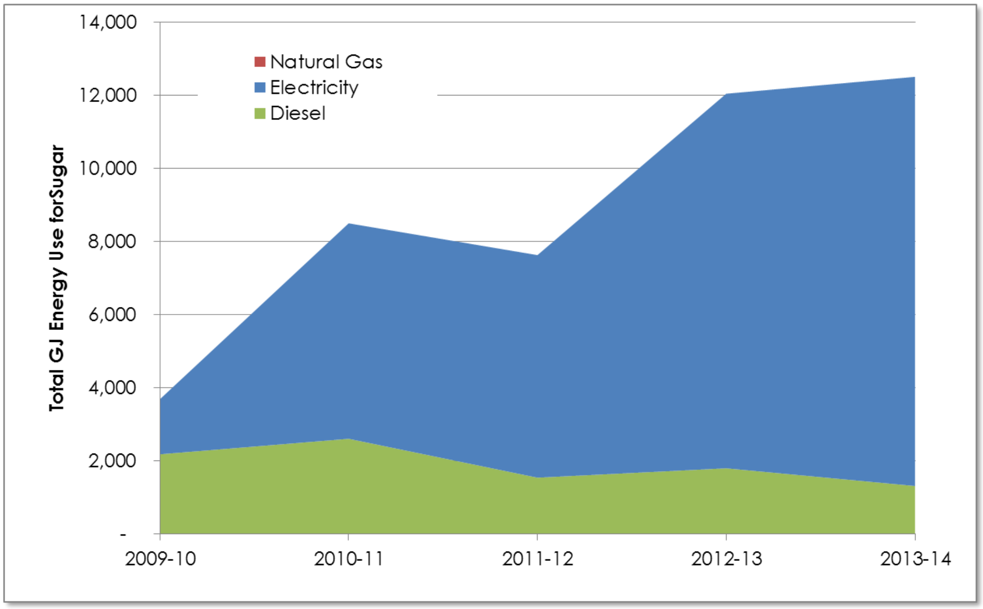
51. The large sugar mills reported heavy use of diesel fuel as their primary fuel for heat production as shown by Figure III-38.

Figure III-38: Energy End-Use – Belin



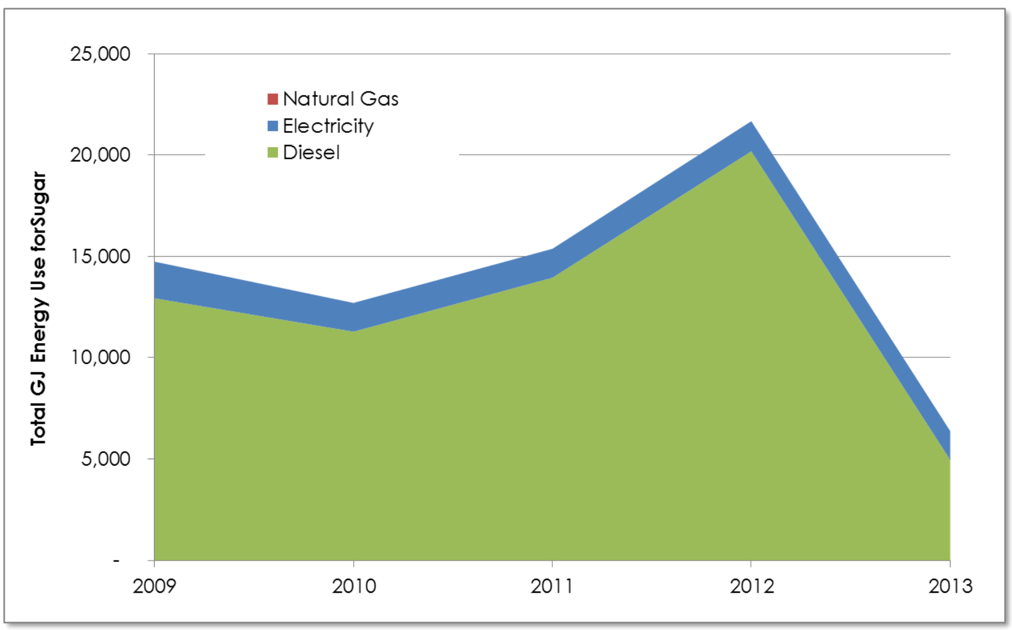
Sources: Consultant

Figure III-39: Energy End-Use – Kan Hla



Sources: Consultant

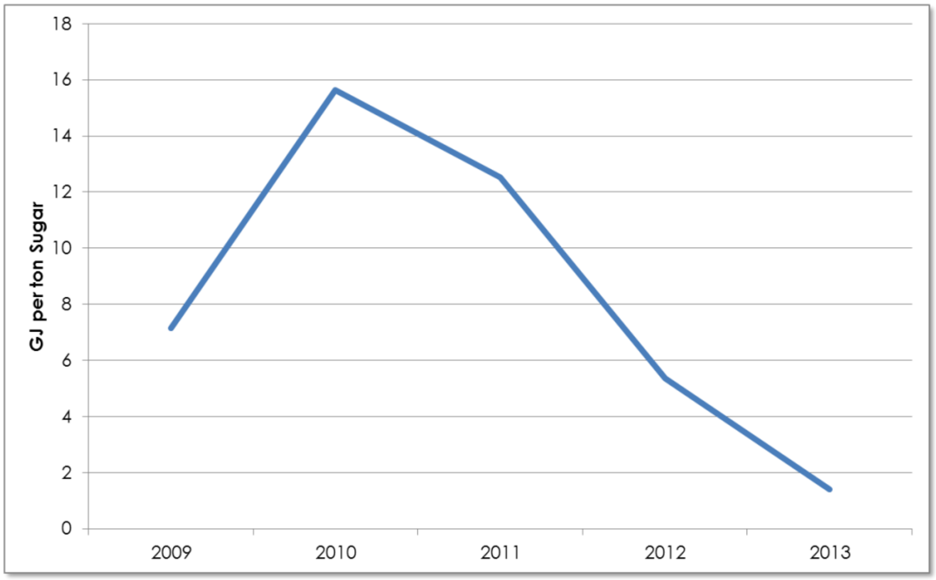
Figure III-40: Energy End-Use – Dahatkone



Sources: Consultant

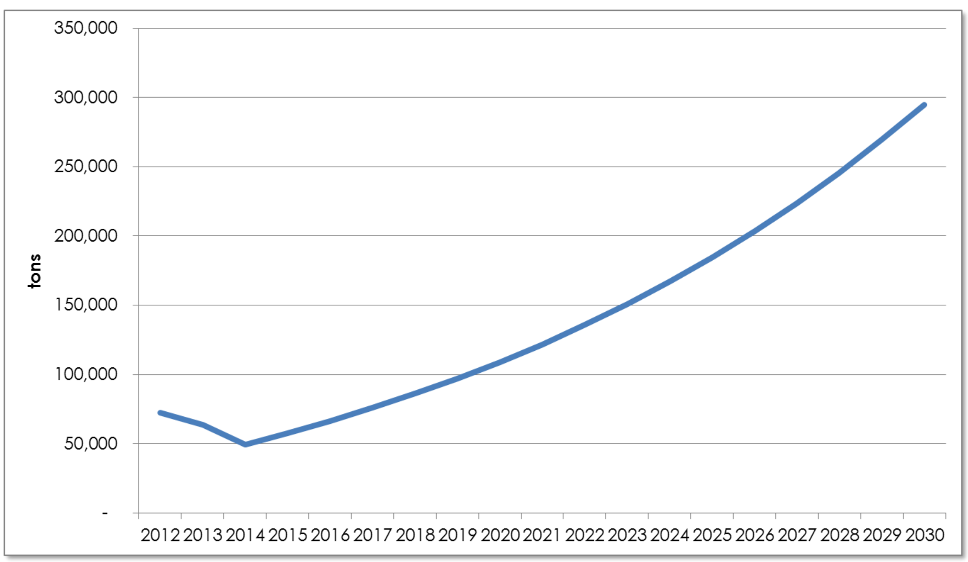
52. The average energy consumption of sugar production in recent years was found to have varied considerably. The energy consumption has been forecast according to expected industry sector GDP growth after which the corresponding sugar production was computed by way of simple division by 2 GJ per ton.

Figure III-41: Energy Efficiency of Sugar Production



Sources: Consultant

Figure III-42: Sugar Production Forecast



Sources: Consultant

J. Pulp & Paper

53. The EMP survey included three pulp and paper producers.

Table III-43: Pulp & Paper Mills in Survey

Paper Mill	Paleik
	Tharpaung
	Sittoung

Sources: EMP Survey

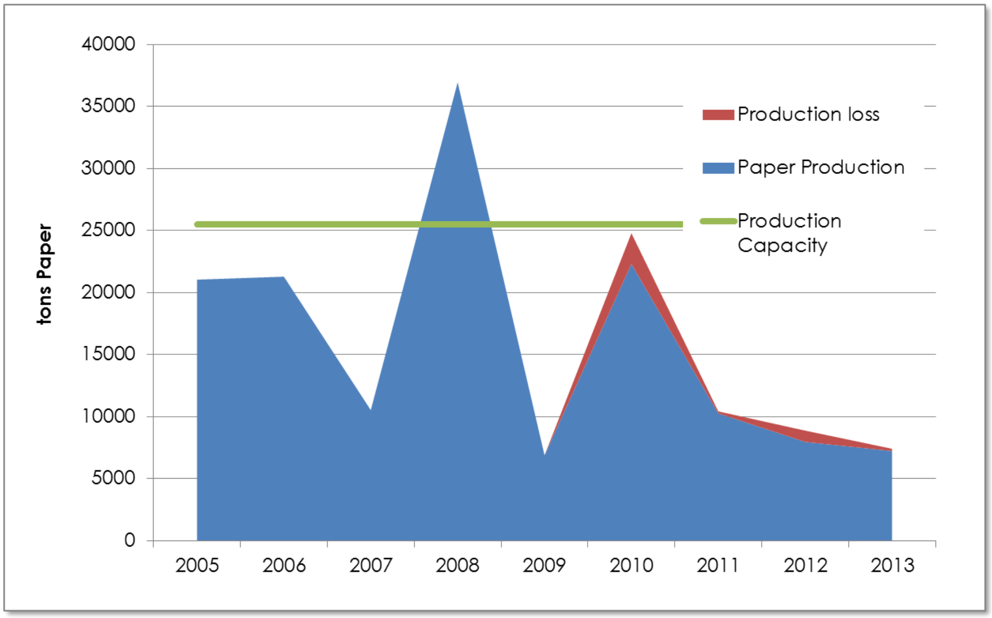
54. In Myanmar, non-wood materials are widely used in the pulp and paper industry, particularly the cellulose fibre of bamboo. Tharpaung in Myanmar's south-western Ayeyarwaddy division uses bamboo for pulp and paper production. Tharpaung has the largest installed capacity and is reported to be capable of producing 200 ton of pulp and paper per day. It is understood that three-quarters of production is bound for export. Combining this with a reported estimated annual production of 25 000 ton from state-run factories, and 27 000 ton of privately-owned factories, the installed capacity is understood to be 60 000 ton annually. This overall capacity is understood to meet only 40% of the total demand in the country. On the other hand, the reported total production by three large mills in 2013 is very low.

Table III-44: Pulp & Paper Mill Production

	2005	2006	2007	2008	2009	2010	2011	2012	2013
Paleik	5,200	5,413	4,097	2,314	3,212	3,474	3,355	1,006	-
Tharpaung	21,039	21,281	10,523	36,946	6,878	22,301	10,258	7,961	7,224
Sittoung	5,653	7,573	5,411	6,104	3,940	3,376	3,651	-	-
Total	31,892	34,266	20,031	45,364	14,031	29,151	17,264	8,967	7,224

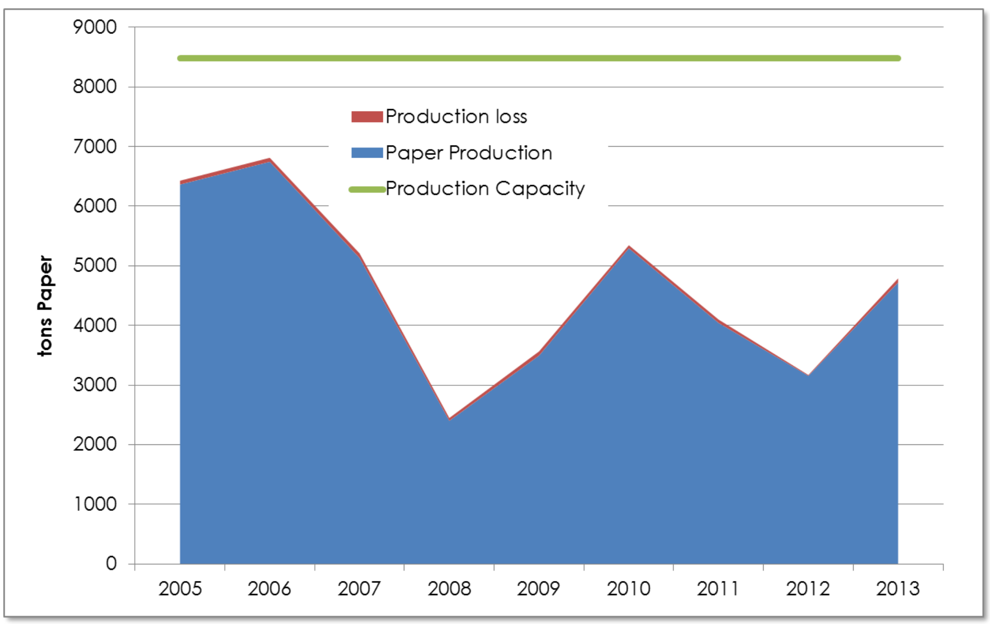
Sources: EMP Survey

Figure III-45: Pulp & Paper Production – Tharpaung



Sources: Industry Sector Survey, Consultant

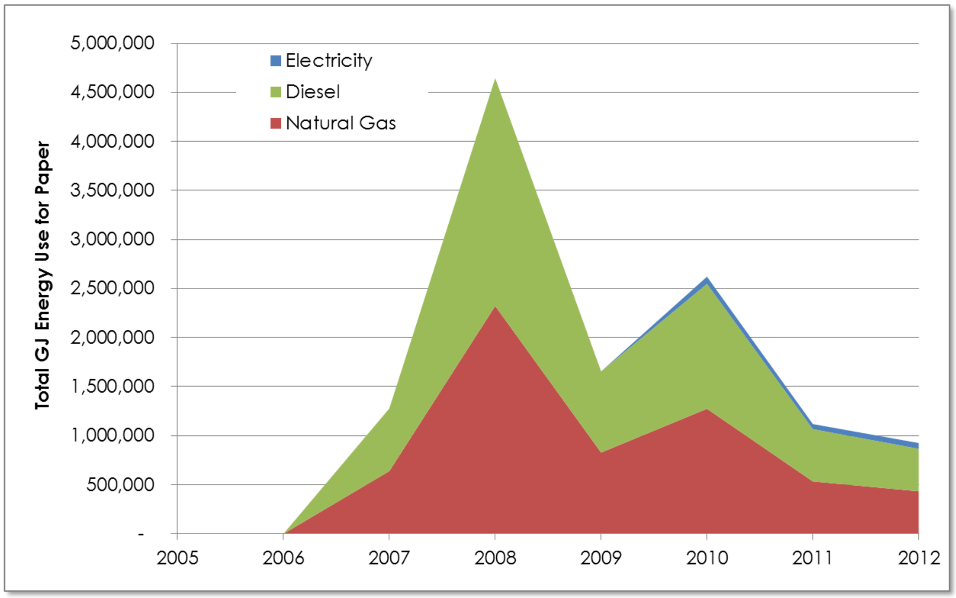
Figure III-46: Pulp & Paper Production – Paleik



Sources: Industry Sector Survey, Consultant

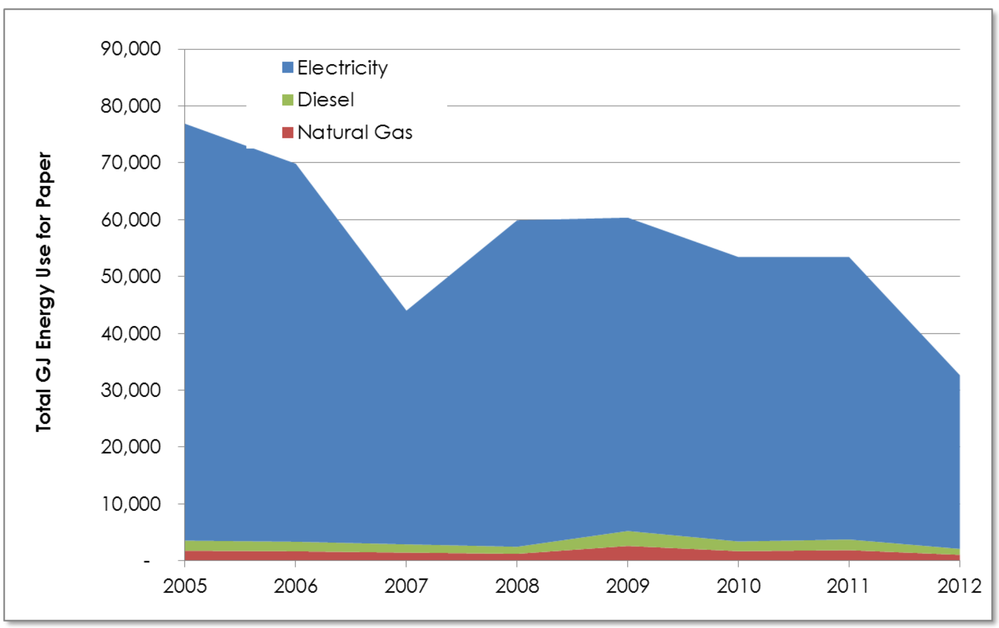
55. The Tharpaung and Paleik mills reported fuel consumption mixes as follows:-

Figure III-47: Energy End-Use: Tharpaung



Sources: Industry Sector Survey, Consultant

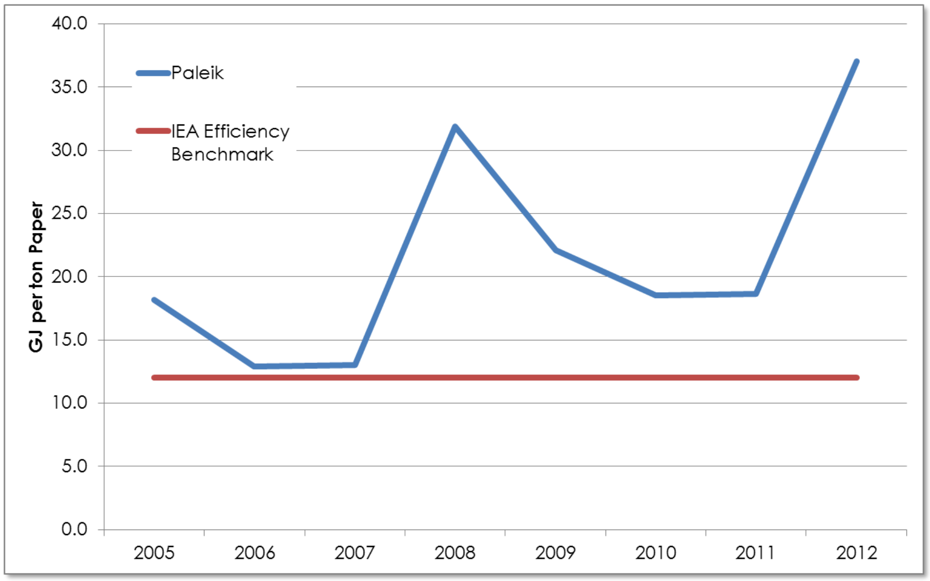
Figure III-48: Energy End-Use: Paleik



Sources: Industry Sector Survey, Consultant

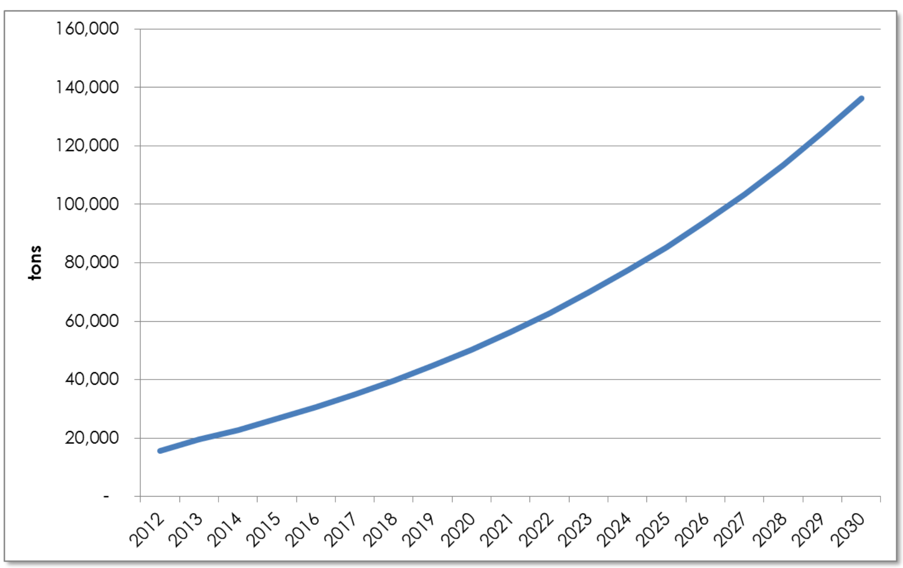
56. The average energy consumption of paper production in recent years has varied considerably amongst the surveyed mills. The Tharpaung consumption data appears to be over-stated. The energy consumption has been forecast according to expected industry sector GDP growth after which the corresponding paper production was computed by way of simple division by 15 GJ per ton.

Figure III-49: Energy Efficiency at Paleik



Sources: Consultant

Figure III-50: Pulp & Paper Forecast (tons)



Sources: Consultant

IV. SMALL TO MEDIUM ENTERPRISE

K. Historical SME End-Use Statistics

57. Industrial sales statistics were obtained from YESC and ESE (GWh). Heavy industry was determined as 12% of the total energy sales in 2012. Diesel consumption was determined to be around 6.5% of total energy sales in energy terms, i.e. diesel consumption reported from the EMP SME survey was equivalent to 6.5% of electricity sales on average. The historical electricity sales are given as Table IV-1.

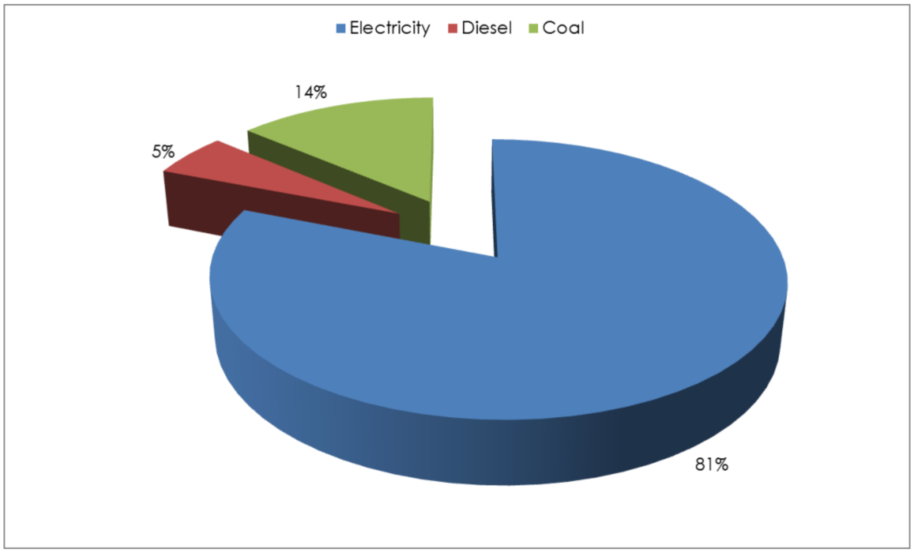
Table IV-1: Industrial Electricity Sales

	2007	2008	2009	2010	2011	2012
Ayeyarwaddy Region	54.6	63.5	65.3	62.0	122.8	156.4
Bago Region	125.0	127.0	143.9	162.5	180.5	193.0
Chin State	0.0	0.0	0.0	0.5	0.8	0.7
Kachin State	1.9	2.7	2.3	3.3	5.9	6.0
Kayah State	4.3	4.3	4.7	4.6	5.2	7.0
Kayin State	127.0	138.1	124.2	121.6	148.9	138.0
Magway Region	383.0	354.7	387.6	328.1	280.6	286.4
Mandalay Region	474.0	396.9	428.2	484.1	571.4	664.5
Mon State	47.9	37.0	51.7	45.3	58.4	70.0
Naypyitaw	0.0	89.7	129.7	169.7	250.5	313.6
Rakhine State	0.0	0.0	0.0	0.0	0.0	0.1
Sagaing Region	135.8	132.6	72.4	124.5	115.2	147.9
Shan State	26.5	38.6	47.8	73.1	91.3	119.5
Tanintharyi Region	0.1	0.1	0.1	0.1	0.1	0.1
Yangon Division	555.6	592.8	637.9	820.7	1,093.4	1,128.0

Sources: YESC, ESE

58. The EMP Industry survey determined the end-us of the sector by energy carrier. The total end-use of the SME sector in 2012 is estimated to be 303 ktoe.

Figure IV-2: SME End-Use Breakdown by Energy Carrier (303 ktoe)



Sources: Industry Sector Survey, Consultant

L. SME Sector FEC Forecasts

59. SME sector forecasts were developed according to anticipated industry sector growth. The electricity forecasts were developed from the customer and energy sales statistics provided by YESC and ESE. The energy forecasts were determined as follows:-

Table IV-2: SME Electricity End-Use Breakdown (ktoe)

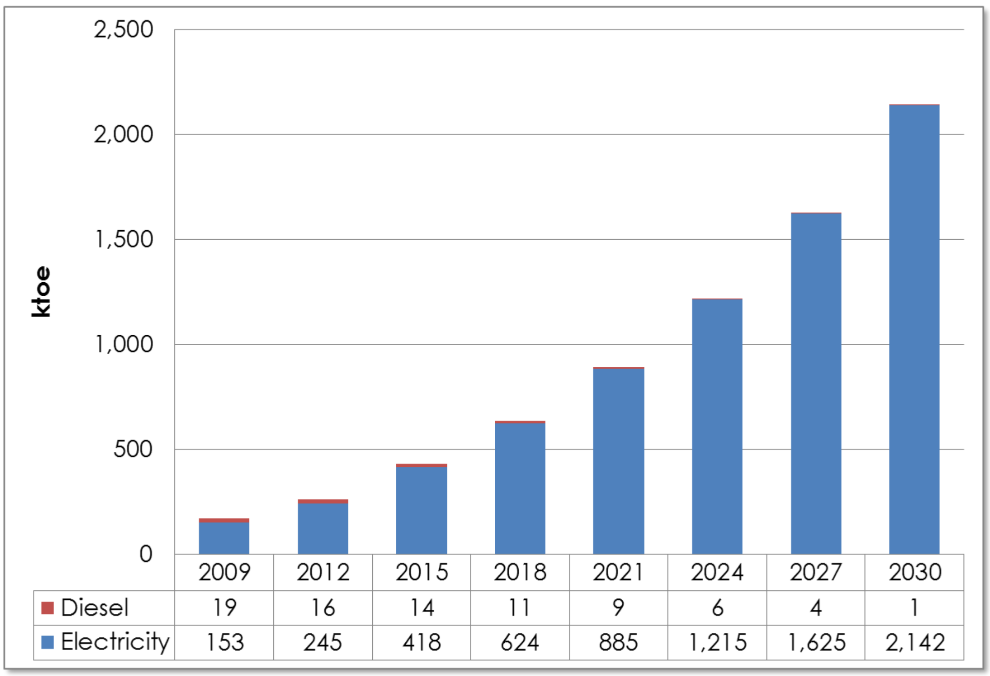
	2009	2012	2015	2018	2021	2024	2027	2030
Ayeyarwaddy Region	5.6	13.4	21.8	34.6	50.6	70.8	95.7	126.8
Bago Region	12.4	16.6	21.3	27.9	36.0	46.3	58.9	74.6
Chin State	0.0	0.1	0.1	0.1	0.1	0.1	0.2	0.2
Kachin State	0.2	0.5	1.0	1.6	2.2	3.1	4.2	5.5
Kayah State	0.4	0.6	1.0	1.3	1.8	2.5	3.2	4.2
Kayin State	10.7	11.9	11.9	12.3	12.9	13.6	14.4	15.5
Magway Region	33.3	24.6	26.7	26.6	26.4	25.9	25.0	23.6
Mandalay Region	36.8	57.1	77.5	107.2	144.3	191.2	248.9	321.2
Mon State	4.4	6.0	8.9	13.3	18.9	25.9	34.5	45.4
Naypyitaw	11.1	27.0	45.1	70.5	102.4	142.7	192.8	255.7
Rakhine State	0.0	0.0	0.0	0.1	0.1	0.2	0.3	0.4
Sagaing Region	6.2	12.7	25.3	40.8	60.2	84.6	114.4	151.4
Shan State	4.1	10.3	17.7	26.9	38.4	52.9	70.9	93.4

	2009	2012	2015	2018	2021	2024	2027	2030
Tanintharyi Region	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.2
Yangon Division	54.8	97.0	216.6	346.3	510.8	721.1	983.5	1,316.1
Total	180.2	277.8	475.0	709.4	1,005.2	1,381.0	1,847.0	2,434.2
Light Industry	152.9	245.3	418.0	624.3	884.6	1,215.3	1,625.3	2,142.1
Heavy Industry	27.3	32.6	57.0	85.1	120.6	165.7	221.6	292.1

Sources: Industry Sector Survey, Consultant

60. The light industry (SME) energy component shown above has been maintained at 88% of total industry energy to 2030. The SME energy forecast by fuel carrier is as follows:-

Figure IV-3: SME FEC Electricity Forecast



Sources: Consultant

Table IV-3: SME Energy Carrier FEC Forecast (physical quantities)

		2009	2012	2015	2018	2021	2024	2027	2030
Electricity	GWh	1,778	2,852	4,861	7,261	10,288	14,133	18,903	24,913
Diesel	IG '000s	3,786	3,276	2,767	2,258	1,748	1,239	729	220
Coal	Tons	53,564	41,484	56,866	82,625	116,061	160,666	216,142	282,297

Sources: Consultant

V. SUMMARY FEC FORECASTS

Table V-1: Energy Intensive Industry FEC Forecast (ktoe)

	2009	2012	2015	2018	2021	2024	2027	2030
Electricity	27	33	57	85	121	166	222	292
Natural Gas	251	292	476	710	1,006	1,383	1,849	2,437
Diesel	6	15	39	45	52	61	70	81
Coal	43	33	52	78	111	152	203	268
Furnace Oil	42	25	38	57	81	111	148	195
Total	369	398	662	976	1,371	1,872	2,493	3,274

Sources: Consultant

Table V-2: SME Sector FEC Forecast (ktoe)

	2009	2012	2015	2018	2021	2024	2027	2030
Electricity	153	245	418	624	885	1,215	1,625	2,142
Diesel	19	16	14	11	9	6	4	1
Coal	54	41	57	83	116	161	216	282
Total	225	303	489	718	1,009	1,382	1,845	2,425

Sources: Consultant

Table V-3: Total Industry FEC Forecast (ktoe, without fertilizer)

	2009	2012	2015	2018	2021	2024	2027	2030
Electricity	180	278	475	709	1,005	1,381	1,847	2,434
Natural Gas	251	292	476	710	1,006	1,383	1,849	2,437
Diesel	24	32	53	56	61	67	74	82
Coal	97	75	109	161	227	313	420	550
Furnace Oil	42	25	38	57	81	111	148	195
Total	594	701	1,151	1,694	2,380	3,254	4,338	5,699

Sources: Consultant

Table V-4: Total Industry FEC Forecast (ktoe, with fertilizer)

	2009	2012	2015	2018	2021	2024	2027	2030
Electricity	180	278	475	709	1,005	1,381	1,847	2,434
Natural Gas	251	292	476	710	1,006	1,383	1,849	2,437
Diesel	24	32	53	56	61	67	74	82
Coal	97	75	109	161	227	313	420	550
Furnace Oil	42	25	38	57	81	111	148	195
Non-Energy	10	306	372	439	505	571	638	704
Total	604	1,007	1,523	2,133	2,885	3,825	4,975	6,403

Sources: Consultant

Table V-5: Energy-Intensive Industry Sector

Energy Carrier FEC Forecast (physical quantities)

		2009	2012	2015	2018	2021	2024	2027	2030
Electricity	GWh	318	379	663	990	1,403	1,927	2,578	3,397
Natural Gas	Tons	212,681	247,546	403,668	602,926	854,279	1,173,641	1,569,684	2,068,738
Diesel	IG '000s	1	3	9	10	12	13	15	18
Coal	Tons	64,469	49,929	78,456	117,183	166,035	228,105	305,079	402,073
Furnace Oil	IG	9,116	5,385	8,210	12,263	17,375	23,870	31,925	42,075

Sources: Consultant

Table V-6: SME Sector FEC Forecast (physical quantities)

		2009	2012	2015	2018	2021	2024	2027	2030
Electricity	GWh	1,778	2,852	4,861	7,261	10,288	14,133	18,903	24,913
Diesel	IG '000s	3,786	3,276	2,767	2,258	1,748	1,239	729	220
Coal	Tons	53,564	41,484	56,866	82,625	116,061	160,666	216,142	282,297

Sources: Consultant

Table V-7: Total Industry FEC Forecast (physical quantities, without fertilizer)

		2009	2012	2015	2018	2021	2024	2027	2030
Electricity	GWh	2,095	3,231	5,524	8,251	11,690	16,061	21,480	28,310
Natural Gas	Tons	212,681	247,546	403,668	602,926	854,279	1,173,641	1,569,684	2,068,738
Diesel	IG '000s	3,787	3,280	2,776	2,268	1,760	1,252	745	238
Coal	Tons	64,469	49,929	78,456	117,183	166,035	228,105	305,079	402,073
Furnace Oil	IG	9,116	5,385	8,210	12,263	17,375	23,870	31,925	42,075

Sources: Consultant

Table V-8: Non-Energy (fertilizer) FEC Forecast (physical quantities)

		2009	2012	2015	2018	2021	2024	2027	2030
Fertilizer	ktoe	10	306	372	439	505	571	638	704
	GJ	418,201	12,817,185	15,593,500	18,369,814	21,146,129	23,922,443	26,698,758	29,475,072
	tons	12,486	382,667	465,555	548,444	631,333	714,222	797,111	880,000

Sources: Consultant

Table V-9: Total Industry FEC Forecast (physical quantities, with fertilizer)

		2009	2012	2015	2018	2021	2024	2027	2030
Electricity	GWh	2,095	3,231	5,524	8,251	11,690	16,061	21,480	28,310
Natural Gas	Tons	212,681	247,546	403,668	602,926	854,279	1,173,641	1,569,684	2,068,738
Diesel	IG '000s	3,787	3,280	2,776	2,268	1,760	1,252	745	238
Coal	tons	64,469	49,929	78,456	117,183	166,035	228,105	305,079	402,073
Furnace Oil	IG	9,116	5,385	8,210	12,263	17,375	23,870	31,925	42,075
Non-Energy	tons	378	11,583	14,092	16,602	19,111	21,620	24,129	26,638

Sources: Consultant

Project Number: TA No. 8356-MYA

FINAL REPORT

ENERGY FORECASTS

COMMERCE & PUBLIC SERVICES SECTOR

Prepared for

The Asian Development Bank

and

The Myanmar Ministry of Energy

Prepared by

IES
Intelligent Energy Systems

in association with

MMIC
MYANMAR
INTERNATIONAL
CONSULTANTS

ABBREVIATIONS

ADB	–	Asian Development Bank
CSO	–	Central Statistics Organisation
ESE	–	Electricity Supply Enterprise
FEC	–	Final Energy Consumption
GDP	–	Gross Domestic Product
GoM	–	Government of the Republic of the Union of Myanmar
MoE	–	Ministry of Energy
YESC	–	Yangon Electricity Supply Corporation

UNITS OF MEASURE

IG	–	Imperial Gallon
km	–	Kilometre
l	–	Litre
Passenger-km	–	Passenger-Kilometre
Ton-km	–	Metric Ton-Kilometre

WEIGHTS AND MEASURES

–

CONVERSION FACTORS

1 litre	=	0.22 Imperial Gallon
1 km	=	0.62137 mile

CONTENTS

I. SUMMARY

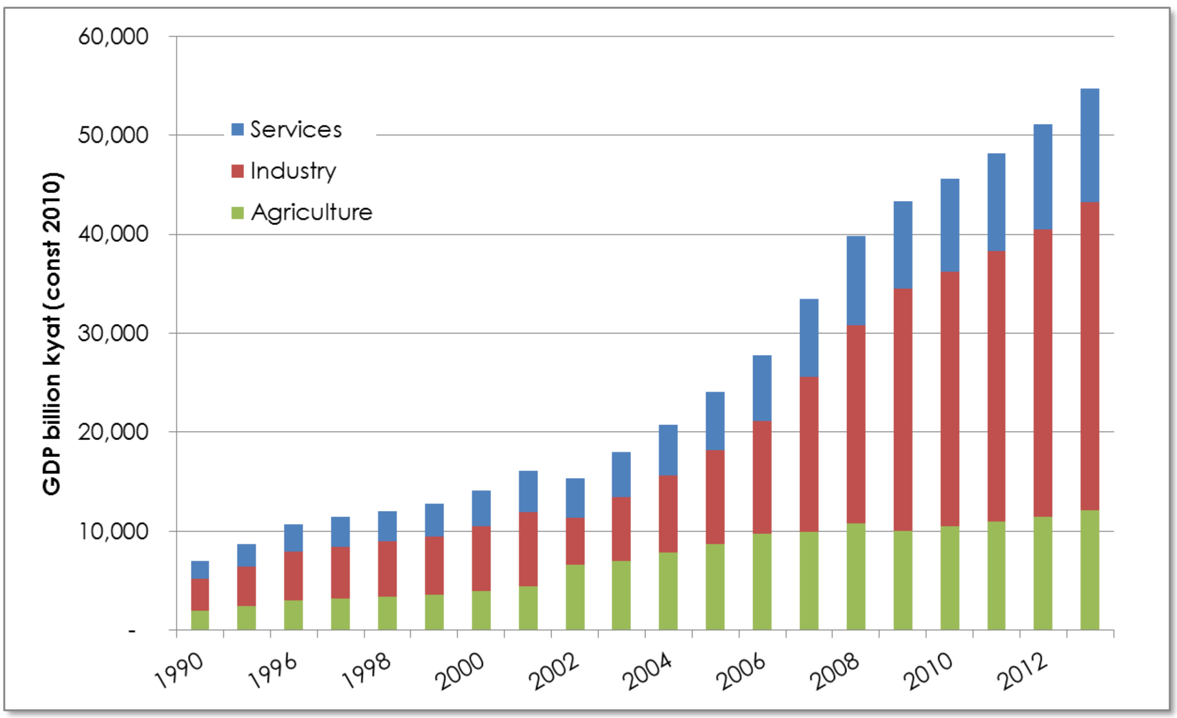
A. Introduction

1. The Commerce and Public Services sector includes wholesale and retail, public services, financial and business services, hospitality, education, entertainment, information and communication. The sector excludes commercial transport.

2. In practice the sector segmentation has been segmented as restaurants, hotels, traditional and modern retail, private and Government office accommodation. This segmentation is further divided between Yangon and the areas outside of Yangon, designated hereafter as 'Yangon' and 'Outside Yangon'.

3. The historical GDP of the commercial sector has shown a compound annual growth rate of 8.8% between 2004 and 2012. It must be noted that this sectoral growth forecast includes a contribution from the transport sector. There is a dependency because the commercial sector needs transport services.

Figure I-1: GDP Growth Rates by Sector



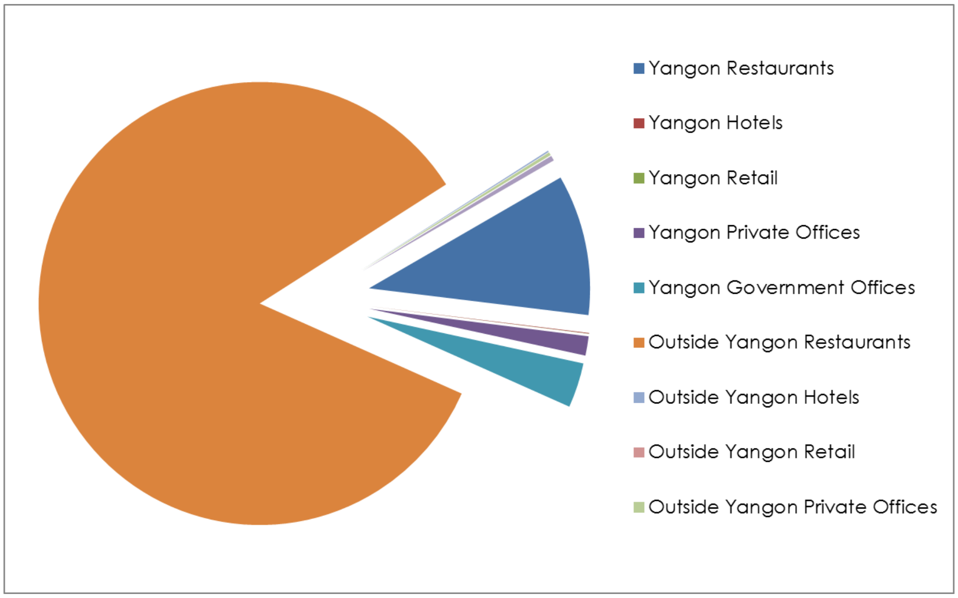
Source: ADB

B. Final Energy Consumption Forecasts

4. Forecasts of the stocks of premises and energy benchmarks relating economic activity and

energy carrier use were determined by survey and final energy consumption of the sector in 2012-13 was computed as a baseline.

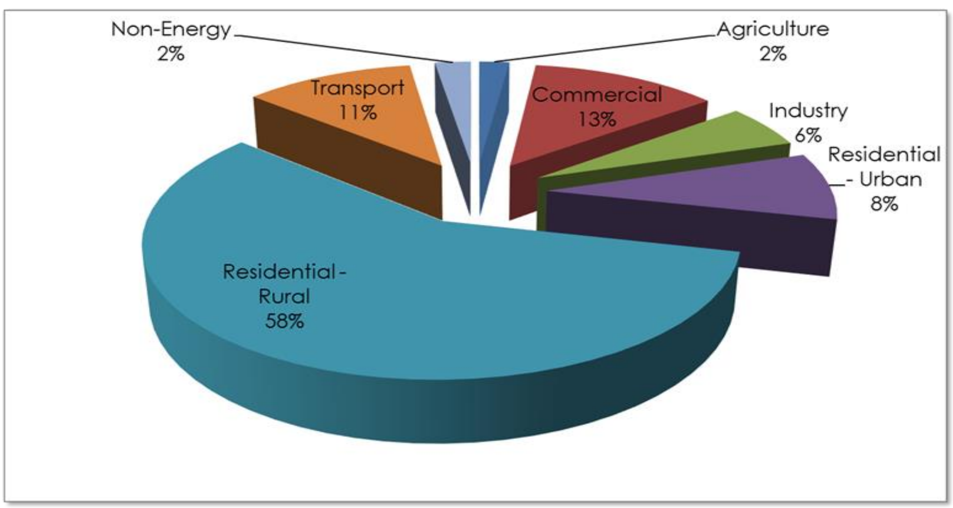
Figure I-2: Final Energy Consumption: 2012 - 13 (1.59 mtoe)



Source: Consultant's analysis[1]

5. The final energy consumption (FEC) of the sector is estimated to have been 13% of total FEC in 2012-13.

Figure I-3: Final Energy Consumption 2012-13



Source: Consultant's analysis

[1] Unless otherwise noted unattributed figures in this report are based on Consultant estimates.

6. Final energy consumption forecasts were prepared for three cases. The expected counts and floor space projections for restaurants, hotels, retail stores, government and private offices were forecast according to their historical relationship between GDP, and the low, medium and high GDP forecasts established in the Economic Outlook report.

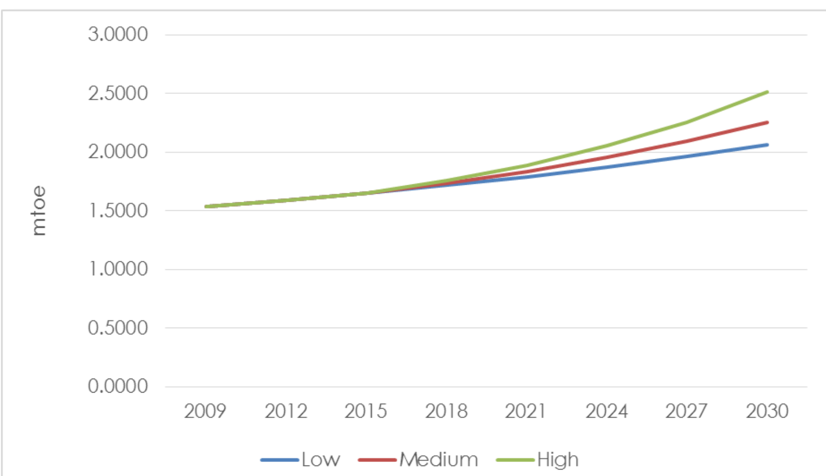
Table I-4: Commercial Sector Planning Assumptions

		Restaurants	Hotel Rooms	Retail	Govt Offices	Private Offices
Low	Yangon	-1.1%	3.9%	-20.7%	3.0%	12.6%
	Outside Yangon	1.0%	5.9%	-1.1%	12.6%	12.0%
	Total	0.8%	5.4%	-6.0%	5.2%	12.3%
Medium	Yangon	4.5%	9.2%	-0.4%	3.0%	11.7%
	Outside Yangon	1.0%	8.5%	4.5%	12.4%	11.0%
	Total	1.5%	8.7%	2.3%	5.1%	11.3%
High	Yangon	8.3%	12.9%	5.2%	3.0%	10.0%
	Outside Yangon	1.0%	11.0%	8.3%	12.1%	9.3%
	Total	2.3%	11.6%	6.8%	5.0%	9.6%

Sources: Consultant

7. The FEC forecast for the commercial sector is shown in Figure I-6. In the case of the medium forecast, the compound annual growth rate from 2012 to 2030 is 1.9%. This growth rate reflects a variety of energy consumption drivers relevant to each segment of the sector.

Figure I-5: Commercial Sector FEC Forecasts (mtoe)



Sources: Consultant's analysis

C. Final Energy Consumption Forecasts – Medium Case

8. The following charts provide detail of the final energy consumption forecasts for the medium growth case:-

Figure I-6: Commerce & Public Services Sector Final Energy Consumption (mtoe)

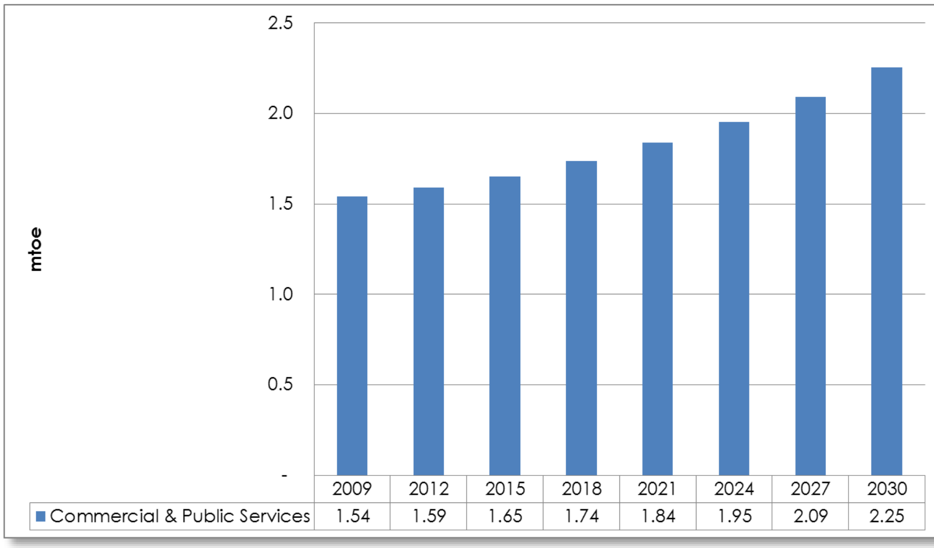
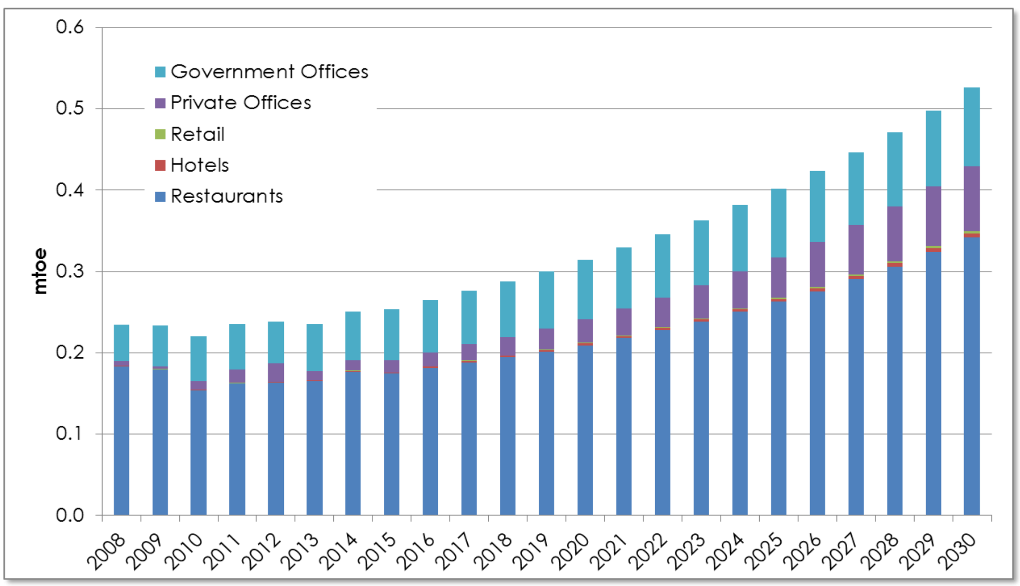
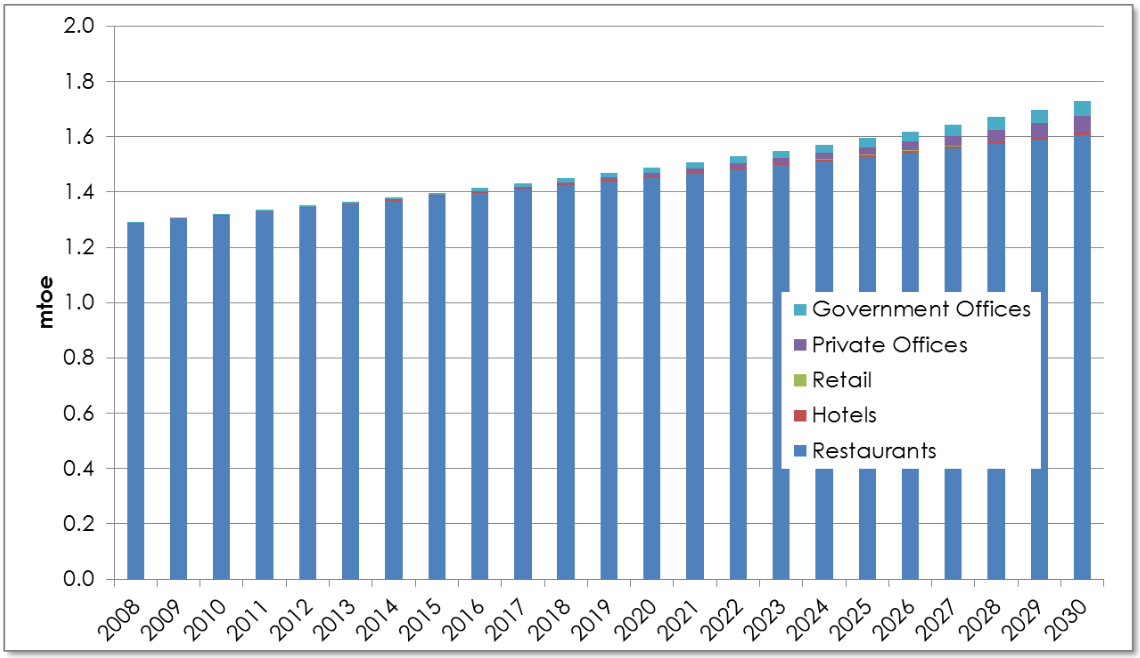


Figure I-7: Yangon - Commerce & Public Services Sector FEC



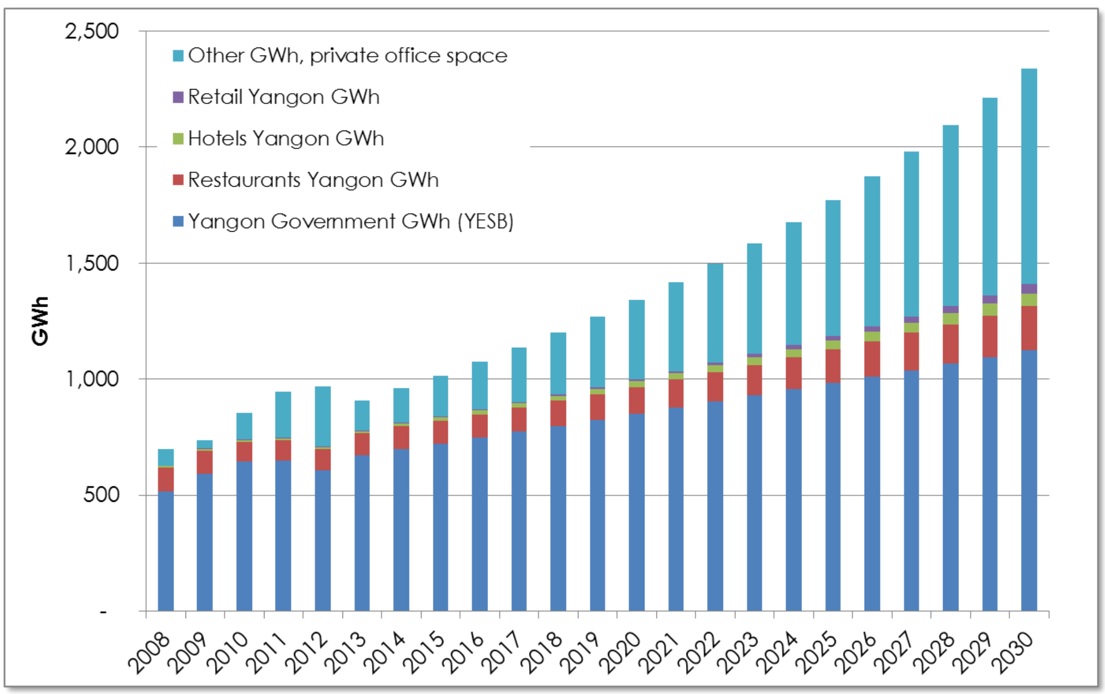
Source: Consultant's analysis

Figure I-8: Outside Yangon - Commerce & Public Services Sector FEC



Source: Consultant's analysis

Figure I-9: Yangon – Electricity Consumption Forecast



Sources: Consultant's anlaysis

Figure I-10: Outside Yangon – Electricity Consumption Forecasts

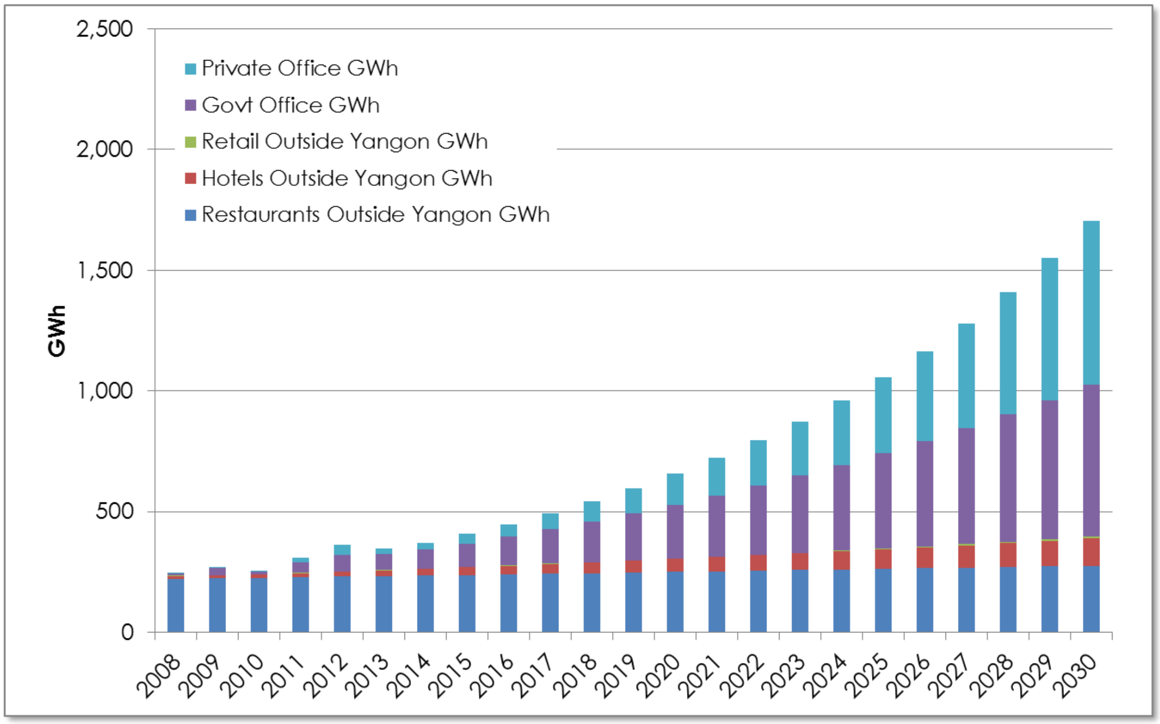
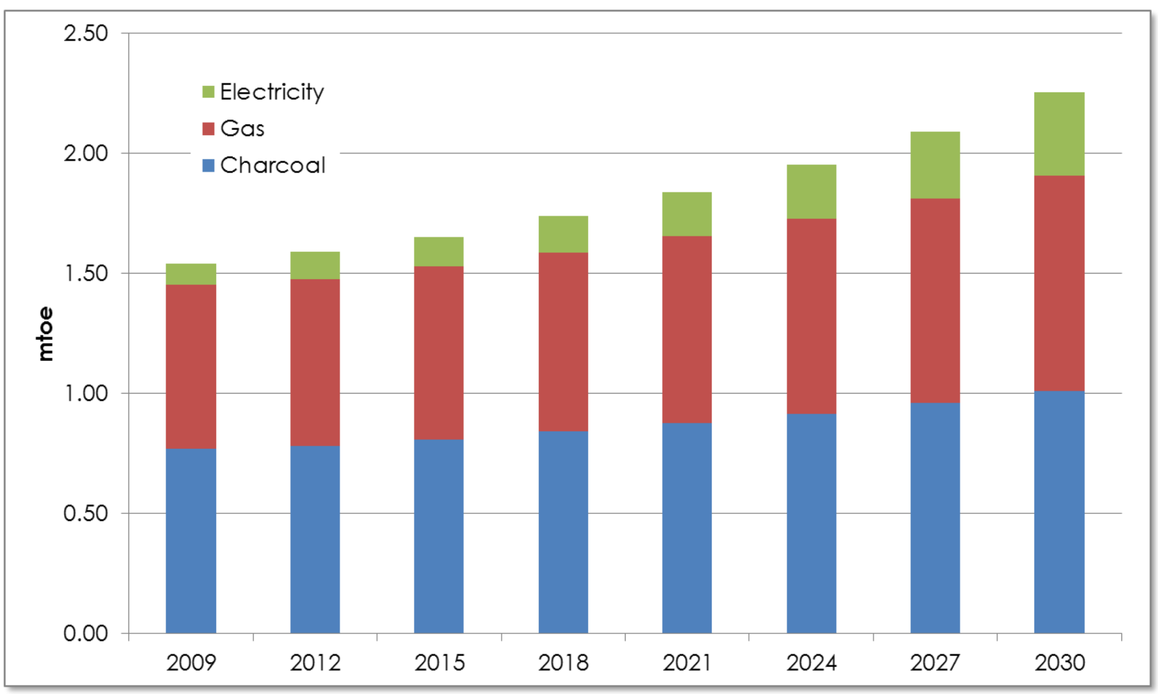


Figure I-11: FEC Energy Carriers (mtoe)



Sources: Consultant's analysis

Table I-12: Energy Carrier Projections (physical)

	Restaurants			Hotels	Retail	Govt Offices	Private Offices
	GWh	tons LPG	tons Charcoal	GWh	GWh	GWh	GWh
2009	324	735,556	1,078,066	22	2	618	44
2012	322	747,907	1,096,168	28	3	676	302
2015	335	773,593	1,133,816	45	5	820	217
2018	353	804,264	1,178,768	65	9	965	351
2021	374	837,242	1,227,103	86	13	1,128	539
2024	400	874,891	1,282,283	110	20	1,311	796
2027	430	916,876	1,343,818	137	31	1,518	1,144
2030	466	965,205	1,414,651	169	47	1,751	1,610

Sources: Medium growth planning assumptions, EMP Commercial Sector Survey, Consultant

II. ENERGY PLANNING

D. Planning Approach

9. The energy consumption of the commerce and public services sector segments is determined as the product of 1) the types of energy carriers in use within each segment, 2) an energy consumption benchmark related to the nature of the economic activity being undertaken within each segment, and 3) the stock of 'premises' within the segment,

10. The energy carriers and energy consumption measures considered are shown in the following tables by sector:

Table II-1: Energy Carriers by Segment

Economic Sector	Energy Demand Sector	Sub-Sectors	Energy Carriers Considered
Trade	Restaurants	Yangon, Outside Yangon	Electricity, Charcoal & Gas
Trade	Hotels	Yangon, Outside Yangon	Electricity, Furnace Oil
Trade	Traditional Retail	Yangon, Outside Yangon	Electricity
Trade	Modern Retail	Yangon	Electricity
Services	Private Office Space	Yangon, Outside Yangon	Electricity
Administration	Government Offices	Yangon, Outside Yangon	Electricity

Table II-2: Energy Consumption Measures

Segment	End-Use	Energy Carriers	Measure
Restaurants	Cooking	Electricity; Charcoal; LPGas	kWh/kg/kg per square metre of table
Hotels	Lighting; Air-conditioning; Television	Electricity	kWh per room per night
Traditional Retail	Lighting	Electricity	kWh per square metre of retail space
Modern Retail	Lighting, Air-conditioning	Electricity	kWh per square metre of retail space
Private Office Space	Lighting, Air-conditioning	Electricity	kWh per square metre of office space
Government Offices	Lighting, Air-conditioning	Electricity	kWh per square metre of office space

Sources: Consultant's analysis

E. Historical Stock of Premises

11. The historical stock of restaurants was determined from various representative bodies:

Table II-3: Restaurant Stocks

	Yangon Restaurants	Nay Pi Taw Restaurants	Remark
2008	8835	707	
2009	8636	813	
2010	7432	858	
2011	7815	923	
2012	7883	871	
2013	7974	860	
2014	6391	509	To 3rd. week 9/14

Sources: Yangon Restaurant Association, Nay Pi Taw Development Committee

Table II-4: Myanmar Hotel Stocks

Year	No.	Room
2004	595	18 533
2005	603	19 040
2006	604	19 506
2007	609	19 655
2008	624	20 418
2009	631	20 942
2010	677	22 373
2011	731	25 002
2012	787	28 291
2013	923	34 834
2014	1048	40 574

Sources: Yangon Hotel Association

Table II-5: Myanmar Hotel Stocks by State/Region

Region/State	2010		2011		2012		2013		2014 (Aug)	
	No.	Room	No.	Room	No.	Room	No.	Room	No.	Room
Yangon	181	7658	187	7934	204	8915	232	11175	271	12530
Mandalay	195	6291	219	7861	234	8636	287	10995	321	13429
Bago	33	770	33	770	36	879	37	926	42	1034
Sagaing	10	223	10	242	12	298	16	462	19	629
Tahintharyi	9	484	11	570	11	598	14	695	20	985
Ayeyarwaddy	39	1456	43	1565	46	1824	53	2081	54	2254
Magway	7	101	11	173	13	244	17	347	18	415
Kachin	16	423	18	495	18	495	21	607	21	607
Kayar	3	44	5	98	6	109	7	135	7	135
Kayin	7	172	7	172	7	172	7	180	9	284
Chin	–	–	–	–	–	–	–	–	–	–
Mon	18	444	19	478	21	652	28	980	36	1261
Rakhine	25	735	27	791	30	933	35	1104	36	1132
Shan	134	3572	141	3853	149	4536	169	5147	194	5879
Total	**677**	**22373**	**731**	**25002**	**787**	**28291**	**923**	**34834**	**1048**	**40574**

Sources: Yangon Hotel Association, Nay Pi Taw Development Committee

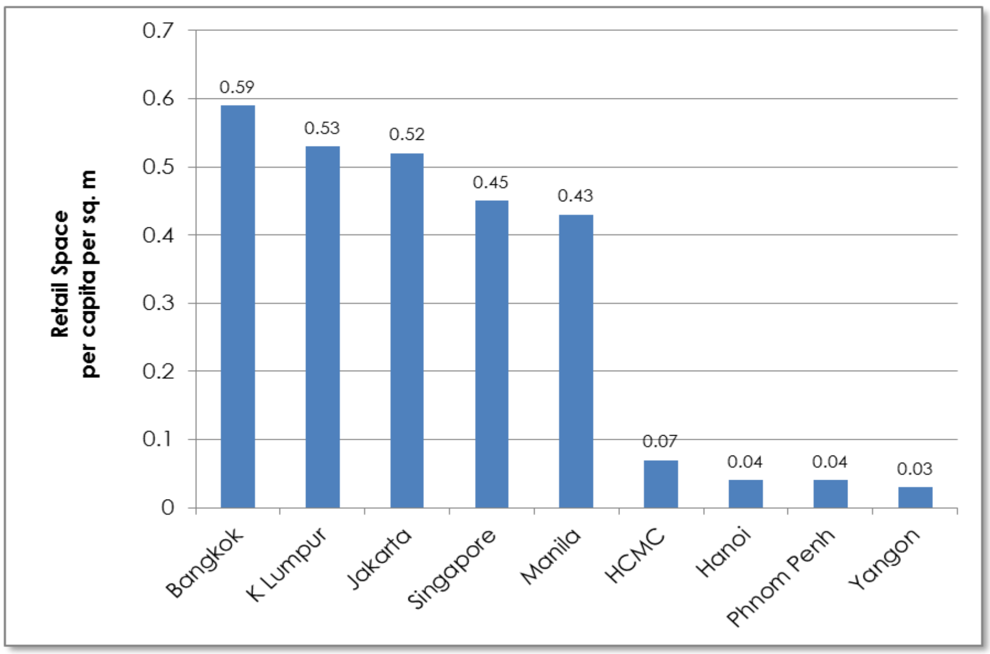
12. Modern retail space in Yangon is very limited by comparison to other large Asian cities such as Bangkok, Kuala Lumpur, Jakarta and Singapore. Modern retail space is reported to be only 10%

of total retail space in Yangon, with the remainder made up by traditional retail space. The historical time series for modern retail space on per capita basis is given by Figure II-7.

13. Historical data pertaining to retail space in and outside of Yangon is given by Table II-8 and Table II-9. Modern retail is found predominantly in Yangon; the modern retail in Mandalay and Nay Pi Taw is very small compared to traditional retail. A modern retail outlet is considered to be on average 3.6 times larger in area than a traditional retail outlet.

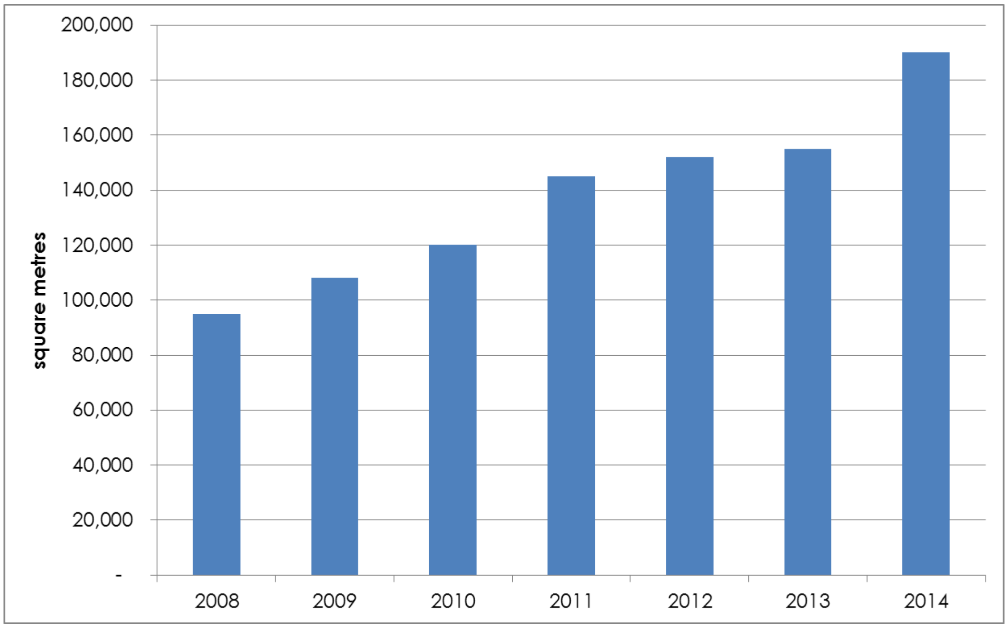
14. The stock of office space, both private and Government, was estimated based on electricity sales of YESC and ESE using a benchmark kWh consumption per square metre. The use of this method shows that the ratio of private to Government office space is currently low, as can be seen from Table II-10 below.

Figure II-6: Retail Space per Capita in Yangon



Sources: NCRA Research, 2014

Figure II-7: Modern Retail Space in Yangon (sq.m)



Sources: NCRA Research, 2014

Table II-8: Stock of Retail Outlets

	Myanmar Retail Outlets	Traditional Retail Outlets	Modern Retail Outlets
2008	11 780	2 281	664
2009	11 515	2 124	754
2010	9 909	1 639	838
2011	10 420	1 592	1 013
2012	10 511	1 566	1 062
2013	10 632	1 575	1 083
2014	11 362	1 513	1 327

Sources: NCRA Research (22014), Consultant

Table II-9: Traditional Retail Space (sq.m)

	Outside Yangon			Yangon		
	Trad Retail Outlets	Traditional Retail sq m per outlet	Trad Retail sq m	Trad Retail Outlets	Traditional Retail sq m per outlet	Trad Retail sq m
2008	2 079	40	83 159	866	40	34 641
2009	2 032	40	81 286	847	40	33 861
2010	1 749	40	69 953	729	40	29 140
2011	1 839	40	73 558	766	40	30 642
2012	1 855	40	74 198	773	40	30 909
2013	1 876	40	75 054	782	40	31 266
2014	2 005	40	80 206	835	40	33 412

Table II-10: Stock of Office Space (sq. m)

	Outside Yangon			Yangon		
	Sq m Private Office	Sq m Govt Office	Private on Government Office Space	Sq m Private Office	Sq m Govt Office	Private on Government Office Space
2008	104 766	77 581	35%	490 558	3 684 151	13%
2009	247 170	198 015	25%	262 940	4 218 076	6%
2010	98 246	74 014	33%	828 816	4 601 539	18%
2011	456 868	313 315	46%	1 403 670	4 622 762	30%
2012	787 923	493 243	60%	1 862 085	4 336 746	43%
2013	629 739	466 806	35%	924 221	4 808 622	19%
2014	755 608	549 192	38%	1 059 159	4 984 674	21%

Source: Consultant's analysis

F. Energy Consumption Measures

15. Energy consumption measures were determined by end-use survey of Myanmar commercial and public service premises. Energy data was surveyed from restaurants, hotels, retail and office premises and energy consumption measures computed. The measures were compared to developing country benchmarks.

Table II-11: Restaurant Energy Benchmarks

	Average table sq. m per restaurant	Annual kWh per sq. m of tables	Monthly kg LPG per sq. m table	Monthly kg Charcoal per sq. m table
Yangon	35	334	24	35
Outside Yangon	35	100	24	35

Sources: EMP Commercial Sector Survey, Consultant

Table II-12: Hotel Energy Benchmarks

	Annual kWh per room
Yangon	1 000
Outside Yangon	1 000

Sources: EMP Commercial Sector Survey, Consultant

Table II-13: Traditional Retail Energy Benchmarks

	Annual kWh per outlet (2014)
Yangon	600
Outside Yangon	600

Sources: EMP Commercial Sector Survey, Consultant

Table II-14: Modern Retail Energy Benchmarks

	Annual kWh per outlet
Yangon	2 170

Sources: EMP Commercial Sector Survey, Consultant

Table II-15: Private & Government Office Energy Benchmarks

	Annual kWh per sq m
Yangon	140
Outside Yangon	140

Sources: EMP Commercial Sector Survey, Consultant

III. FINAL ENERGY CONSUMPTION FORECASTS

G. Restaurants

16. Restaurants were surveyed for energy consumption covering electricity, charcoal and gas usage. An extract of the survey results is shown here:-

Table III-1: Restaurant End-Use

	No of Tables	Average Size per Table (Square metres)	Average Fuel Consumption per month	
			LPG (Kg)	Charcoal (Kg)
1	47	0.634	–	1190
2	44	0.658	147	768
3	41	0.774	372	797
4	63	0.557	1960	735
5	47	0.557	980	735
6	12	0.557	653	245
7	42	1.115	1715	2980
8	27	1.115	531	1641
9	26	1.115	670	1223
10	29	1.115	555	1551
11	70	1.825	4083	817
12	33	2.208	1225	735
13	etc			

Sources: EMP Commercial Sector Survey, Consultant

17. The stock of restaurants is forecast according to the historical relationship between commercial sector GDP and population growth. The relationship between these variables is of weak explanatory power in the case of restaurants in Yangon the correlation co-efficient is 0.60; outside of Yangon the correlation co-efficient is 0.87. In spite of the uncertainty the forecasts have been adopted on the basis of best available information.

Figure III-2: Restaurant Stock Forecasts - Yangon

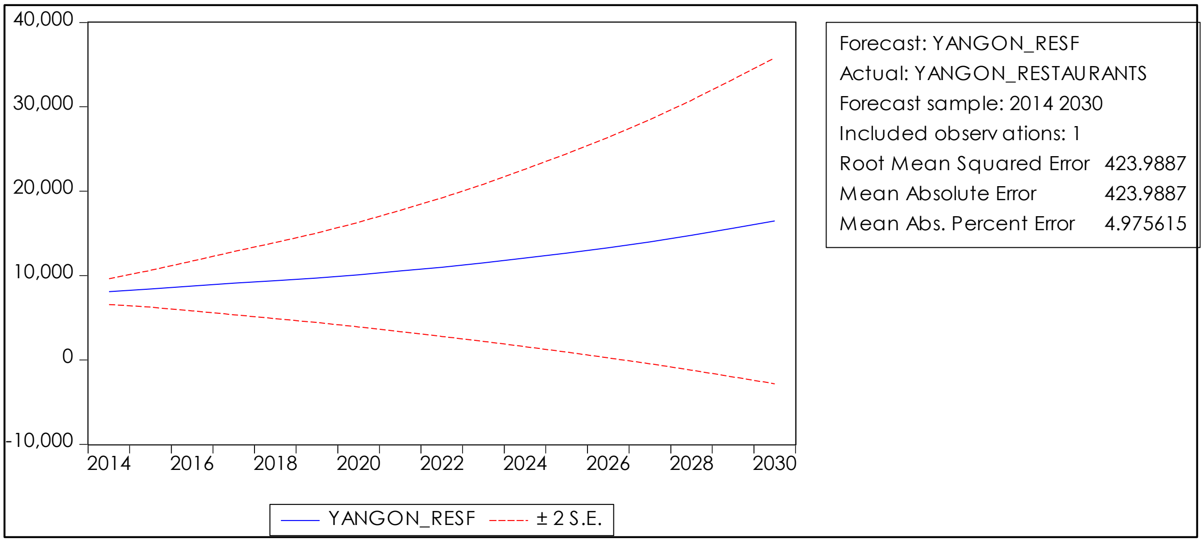
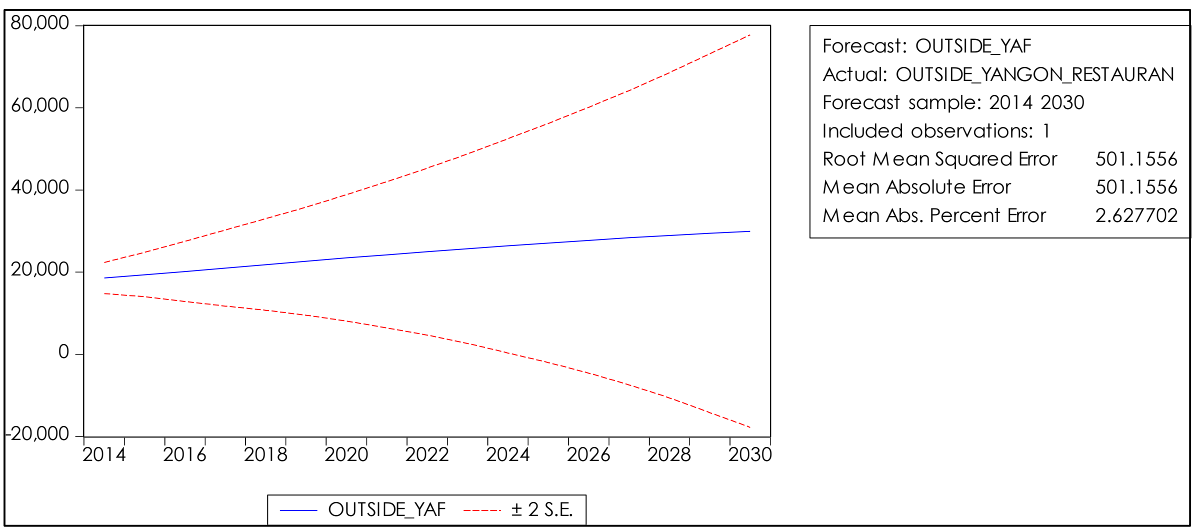


Figure III-3: Restaurant Stock Forecasts – Outside Yangon



Sources: EMP Commercial Sector Survey, Consultant

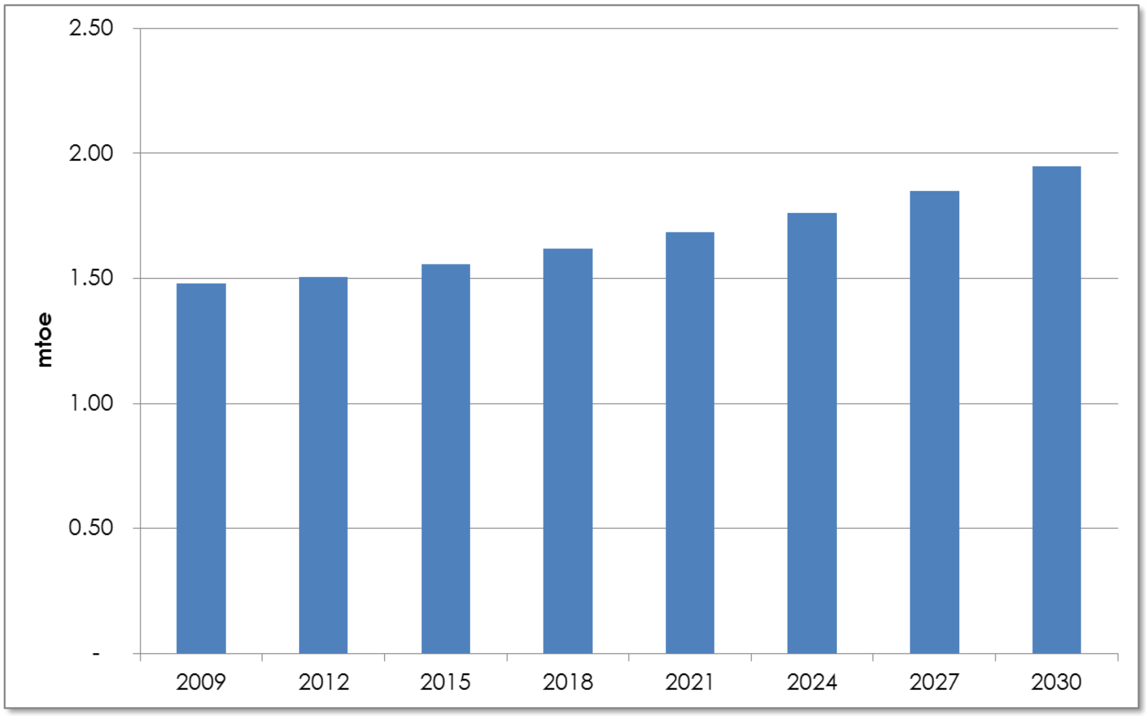
Table III-4: Restaurant Stock Forecasts

	Yangon Restaurants	Yangon Restaurants per '000	Outside Yangon Restaurants	Outside Yangon Restaurants per '000
2008	8 835	1.31	12 013	0.28
2009	8 636	1.27	12 290	0.28
2010	7 432	1.08	14 281	0.28
2011	7 815	1.12	16 812	0.32
2012	7 883	1.12	17 133	0.32
2013	7 974	1.12	16 882	0.32
2014	8 521	1.19	19 072	0.35
2015	8 411	1.16	19 375	0.36
2016	8 753	1.20	20 166	0.37
2017	9 086	1.23	20 975	0.38
2018	9 389	1.26	21 821	0.39
2019	9 714	1.29	22 659	0.40
2020	10 098	1.33	23 459	0.41
2021	10 535	1.37	24 225	0.42
2022	10 993	1.42	24 986	0.43
2023	11 504	1.47	25 714	0.44
2024	12 084	1.53	26 396	0.44
2025	12 666	1.58	27 087	0.45
2026	13 304	1.65	27 743	0.46
2027	13 999	1.72	28 365	0.46
2028	14 769	1.79	28 935	0.47
2029	15 619	1.88	29 450	0.47
2030	16 479	1.96	29 969	0.48

Sources: EMP Commercial Sector Survey, Consultant

18. Using the stock of restaurants in Table III-4, and the restaurant energy benchmarks in Table II-11, gives the following forecast for the final energy consumption of the restaurant sector:-

Figure III-5: FEC Forecast: Restaurants



Sources: Consultant's analysis

19. The associated physical energy forecasts are as follows:-

Table III-6: Restaurants Energy Carrier Projections (physical)

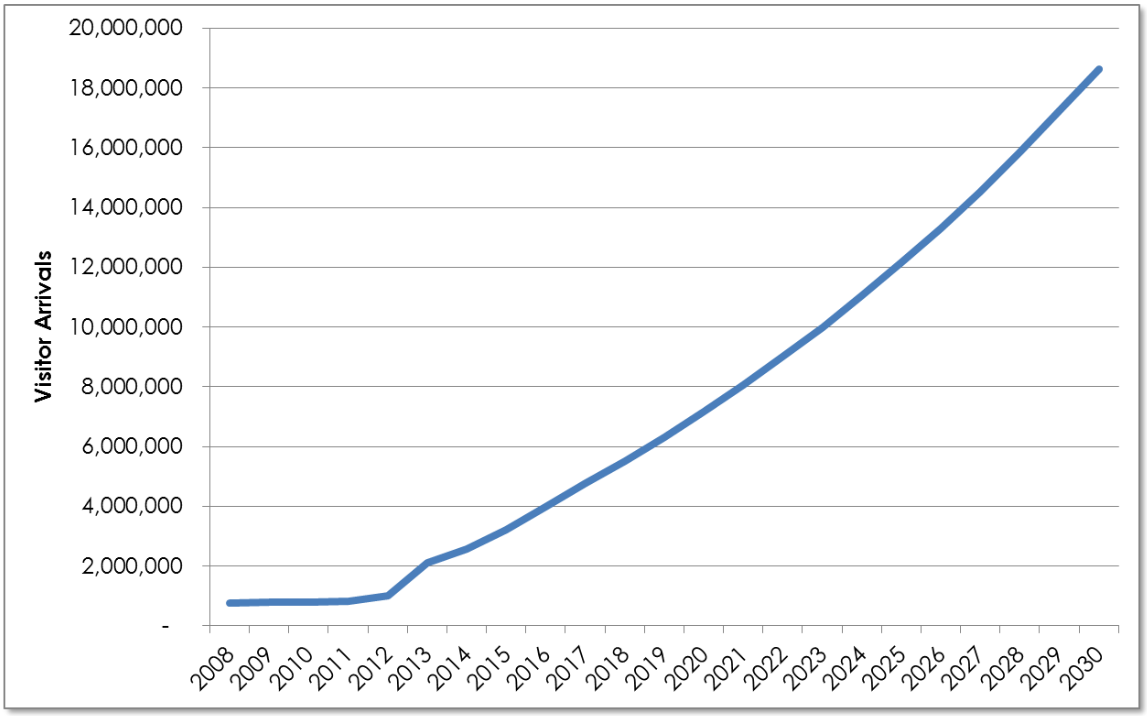
	Restaurants		
	GWh	tons LPG	tons Charcoal
2009	324	735 556	1 078 066
2012	322	747 907	1 096 168
2015	335	773 593	1 133 816
2018	353	804 264	1 178 768
2021	374	837 242	1 227 103
2024	400	874 891	1 282 283
2027	430	916 876	1 343 818
2030	466	965 205	1 414 651

Sources: EMP Commercial Sector Survey, Consultant

H. Hotels

20. Visitor arrivals are a driver of hotel development and can be constrained by the availability of hotel rooms. Visitor arrivals are forecast according to the commercial sector GDP and the availability of Yangon hotel rooms. The correlation co-efficient is 0.91.

Figure III-7: Visitor Arrival Forecast



Sources: EMP Commercial Sector Survey, Consultant

21. The stock of hotels is forecast according to the historical relationship between commercial sector GDP and international visitor arrivals. While there will be patronage of hotels by the local population, it is considered that international visitors are the main driver for hotel development. The relationship between these variables is of good explanatory power in the case of hotel rooms in Yangon, the correlation co-efficient is 0.82; the relationship is very strong in the case of hotel rooms outside of Yangon with a correlation co-efficient of 0.99.

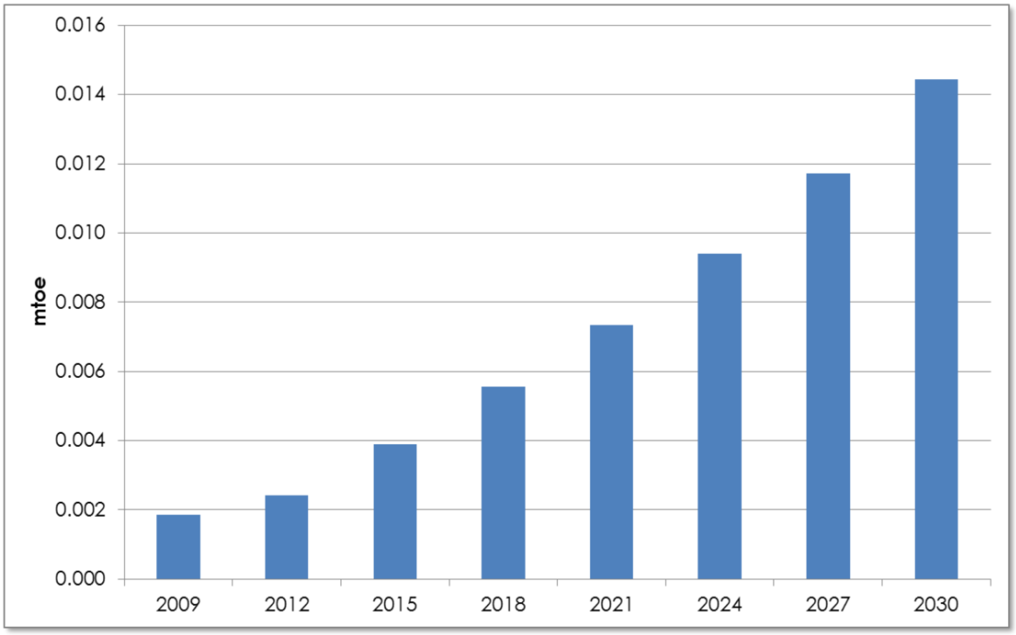
Table III-8: Hotel Room Stock Forecasts

	Yangon Hotel Rooms	Outside Yangon Hotel Rooms	Visitor Arrivals (forecast)
2008	8 835	12 384	755 000
2009	8 636	12 670	780 000
2010	7 432	14 715	800 000
2011	7 815	17 068	820 000
2012	9 108	19 376	1 000 000
2013	8 903	23 659	2 100 000
2014	7 658	28 044	2 555 519
2015	7 934	31 408	3 205 403
2016	8 915	35 836	3 990 850
2017	11 175	40 262	4 771 326
2018	12 530	44 597	5 522 675
2019	14 063	49 050	6 301 786
2020	16 121	53 771	7 150 030
2021	18 161	58 734	8 060 095
2022	20 108	63 810	8 996 531
2023	22 137	69 130	9 995 343
2024	24 374	74 756	11 073 513
2025	26 795	80 427	12 159 373
2026	29 293	86 350	13 309 399
2027	31 978	92 532	14 525 638
2028	34 901	99 047	15 828 523
2029	37 844	105 915	17 223 261
2030	40 979	112 859	18 633 811

Sources: EMP Commercial Sector Survey, Consultant

22. Using the stock of hotels in Table II-8, and the hotel energy benchmarks in Table II-12, gives the following forecast for the final energy consumption of the hotel sector:-

Figure III-9: FEC Forecast: Hotels



Sources: Consultant's analysis

23. The associated physical energy forecasts are as follows:-

Table III-10: Hotels Energy Carrier Projections (physical)

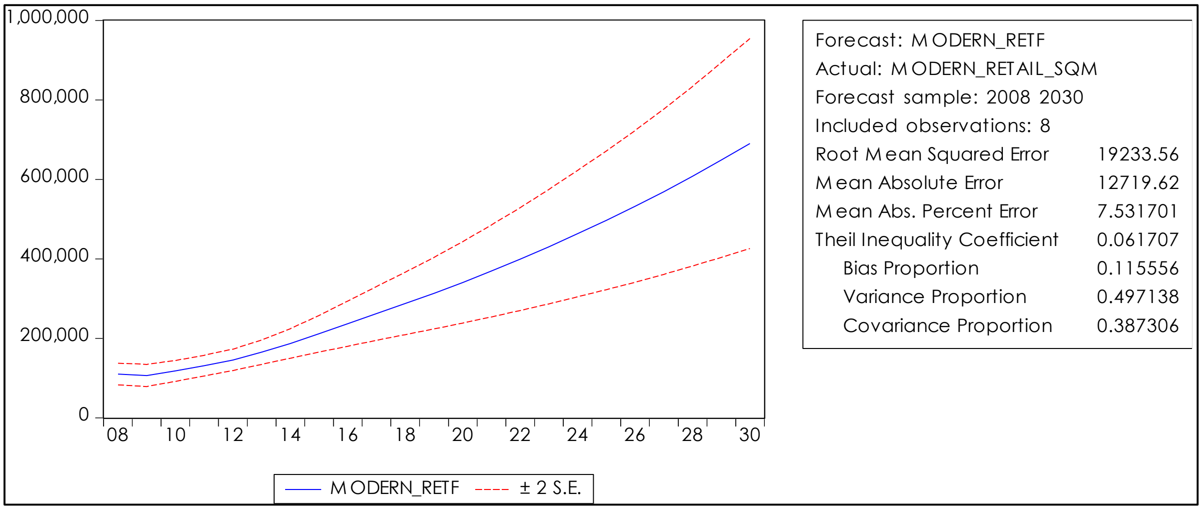
	Yangon Hotels	Outside Yangon Hotels
	GWh	GWh
2009	8.9	12.4
2012	8.9	19.4
2015	14.1	31.4
2018	20.1	44.6
2021	26.8	58.7
2024	34.9	74.8
2027	44.3	92.5
2030	55.7	112.9

Sources: Consultant's analysis

I. Retail Space

24. Modern retail space is forecast according to commercial sector GDP. The correlation co-efficient between historical modern retail space and commercial sector GDP is reasonably strong at 0.82. Using this relationship the forecast for modern retail space in Yangon follows:-

Figure III-11: Modern Retail Space Stock Forecasts



Source: Consultant's analysis

25. It has been assumed that modern retail space outside of Yangon will remain at very low levels as traditional retail space dominates during the planning horizon to 2030. There is and will be further modern retail developments outside Yangon, notably in Mandalay and Nay Pi Taw, but such development will not significantly affect total electricity consumption for the retail sector outside of Yangon; the electricity consumption of modern retail spaces is captured in the overall commercial electricity forecasts. The stock forecasts used for the purpose of estimating electricity consumption are as follows:-

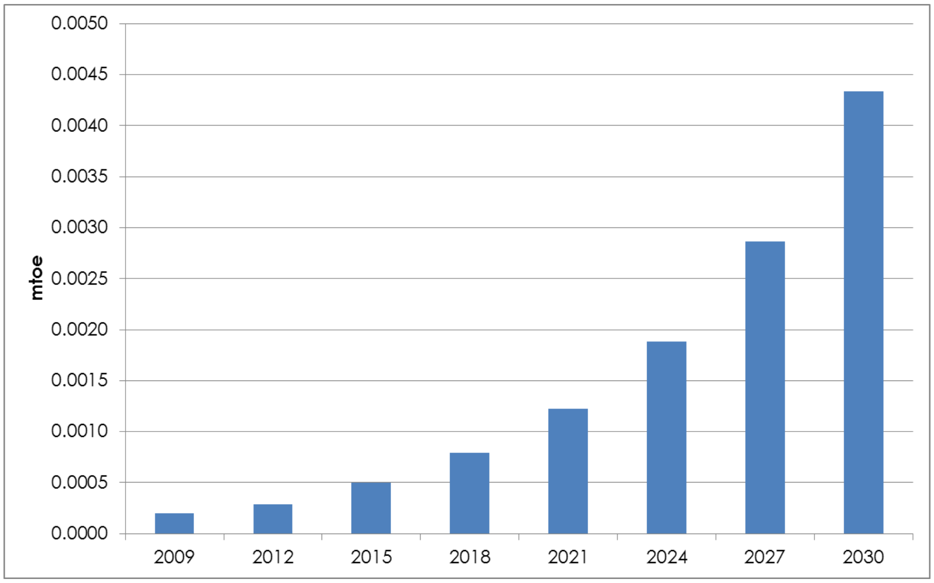
Table III-12: Retail Space Stock Forecasts (sq. m)

	Yangon Modern	Yangon Traditional	Outside Yangon
2008	95 000	34 641	83 159
2009	108 000	33 861	81 286
2010	120 000	29 140	69 953
2011	145 000	30 642	73 558
2012	152 000	30 909	74 198
2013	155 000	31 266	75 054
2014	190 000	33 412	80 206
2015	211 214	32 978	79 166
2016	236 851	34 319	82 384
2017	262 439	35 627	85 524
2018	287 405	36 814	88 375
2019	313 102	38 087	91 430
2020	340 514	39 594	95 047
2021	369 469	41 308	99 163
2022	399 124	43 102	103 469
2023	430 335	45 105	108 278
2024	463 508	47 379	113 736
2025	496 940	49 664	119 222
2026	531 973	52 165	125 224
2027	568 657	54 888	131 761
2028	607 478	57 907	139 008
2029	648 562	61 240	147 011
2030	690 101	64 614	155 110

Source: Consultant's analysis

26. Using the stock of modern and traditional retail space and energy benchmarks gives the following forecast for the final energy consumption of the traditional retail sector:-

Figure III-13: FEC Forecast: Retail



Sources: Consultant's analysis

27. The associated physical energy forecasts are as follows:-

Table III-14: Retail Sector Energy Carrier Projections (physical)

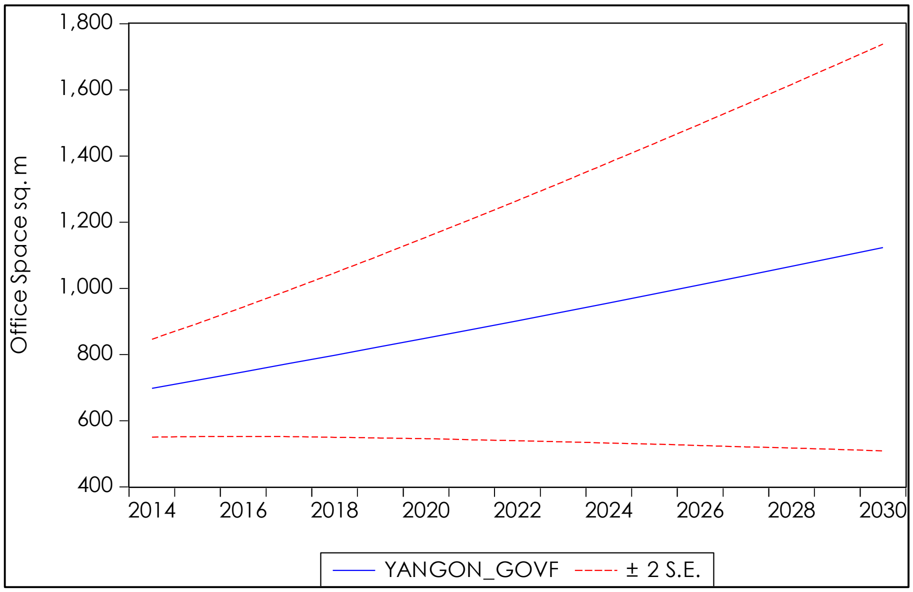
	Yangon Retail	Outside Yangon Retail
	GWh	GWh
2009	1.46	0.84
2012	2.38	0.96
2015	4.00	1.30
2018	6.68	1.82
2021	10.67	2.58
2024	16.72	3.72
2027	25.70	5.43
2030	39.18	8.05

Sources: Consultant's analysis

J. Government Office Space

28. Government office space has been forecast according to Government kWh electricity sales records from which trends in consumption were established. It was determined that Government office space is weakly correlated with population. Nevertheless the relationship was used to forecast Government office space.

Figure III-15: FEC Forecast: Retail



Sources: Consultant's analysis

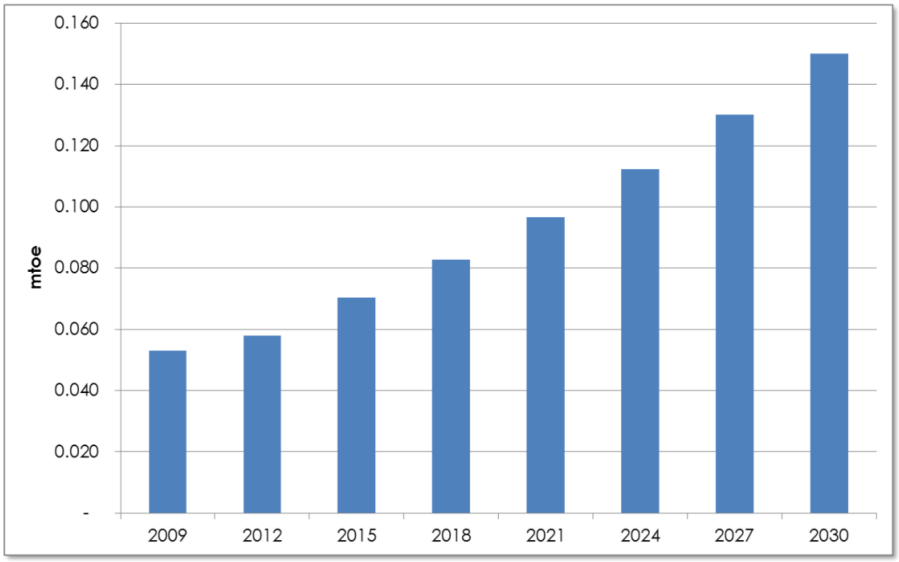
Table III-16: Forecast: Government Office Space

	Yangon	Outside Yangon
2009	4 218 076	77 581
2012	4 336 746	313 315
2015	5 160 726	549 192
2018	5 699 514	1 015 308
2021	6 254 629	1 586 822
2024	6 826 564	2 278 561
2027	7 415 829	3 111 434
2030	8 022 950	4 108 280

Sources: Consultant's analysis

29. Using the stock of Government office space in Table III-16, and the energy benchmarks in Table II-15 gives the following forecast for the final energy consumption of the Government office sector:

Figure III-17: FEC Forecast: Government Office Space



Sources: Consultant's analysis

30. The associated physical energy forecasts are as follows:

Table III-18: Govt Office Space Energy Carrier Projections (physical)

	Yangon Government Offices	Outside Yangon Government Offices
	GWh	GWh
2009	515.8	27.7
2012	607.1	69.1
2015	722.5	97.6
2018	797.9	167.1
2021	875.6	252.4
2024	955.7	355.5
2027	1 038.2	479.4
2030	1 123.2	627.5

Sources: Consultant's anlaysis

K. Private Office Space

31. Private office space has been forecast initially as reconciliation against total commercial energy sales reported by YESC and ESE, then validated by comparison to Government office space.

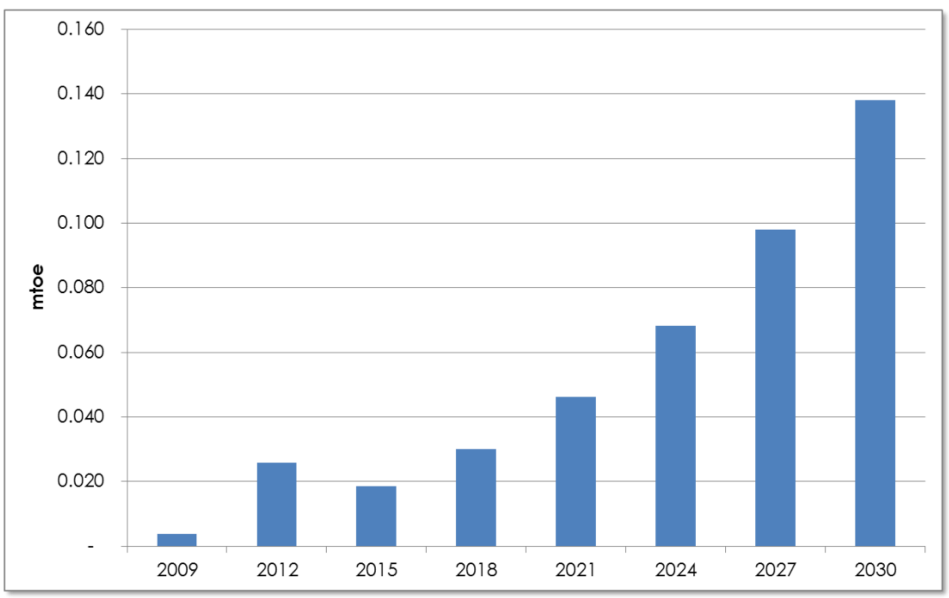
Table III-19: Forecast: Private Office Space (sq. m)

	Yangon	Outside Yangon
2009	262 940	104 766
2012	1 862 085	456 868
2015	1 269 314	755 608
2018	1 904 906	1 491 118
2021	2 735 851	2 504 394
2024	3 774 811	3 886 711
2027	5 070 123	5 764 629
2030	6 649 718	8 302 788

Sources: Consultant's analysis

32. Using the stock of private off space in Table III-19, and the energy benchmarks in Table II-15 gives the following forecast for the final energy consumption of the private office sector:-

Figure III-20: FEC Forecast: Private Office Space



Sources: Consultant's analysis

33. The associated physical energy forecasts are as follows:-

Table III-21: Private Office Space Energy Carrier Projections (physical)

	Yangon Private Offices	Outside Yangon Private Offices
	GWh	GWh
2009	36.8	6.9
2012	260.7	64.0
2015	177.7	105.8
2018	266.7	208.8
2021	383.0	350.6
2024	528.5	544.1
2027	709.8	807.0
2030	931.0	1 162.4

Sources: Consultant's analysis

Project Number: TA No. 8356-MYA

FINAL REPORT

ENERGY FORECASTS

TRANSPORT SECTOR

Prepared for

The Asian Development Bank

and

The Myanmar Ministry of Energy

Prepared by

IES

Intelligent Energy Systems

in association with

MMIC

MYANMAR INTERNATIONAL CONSULTANTS

ABBREVIATIONS

ADB	–	Asian Development Bank
CSO	–	Central Statistics Organisation
GDP	–	Gross Domestic Product
GoM	–	Government of the Republic of the Union of Myanmar
MoE	–	Ministry of Energy

UNITS OF MEASURE

IG	–	Imperial Gallon
km	–	Kilometre
l	–	Litre
Passenger-km	–	Passenger-Kilometre
Ton-km	–	Metric Ton-Kilometre

CONVERSION FACTORS

1 litre	=	0.22 Imperial Gallon
1 km	=	0.62 mile

CONTENTS

I. SUMMARY

A. Introduction

1. The transport sector is a large consumer of energy in Myanmar and vital for economic development. Currently the transport sector consumes around 12% of final energy, all of which is in the form of liquid fuels. As the population increases and incomes rise, so the demand for private passenger vehicles will increase; similarly, rising Gross Domestic Product (GDP) will drive the demand for freight transport. Fuel supply interruptions are costly to the economy and careful long-term planning is required to ensure that there is sufficient infrastructure to support the efficient functioning and growth of the transport sector into the future.

2. Long-term planning requires an accurate depiction of the current demand for passenger and freight transport in different transport modes. It also requires projections of future demand for passenger and freight transport, and a translation of demand for transport into a demand for fuel and infrastructure requirements. With these aims in mind a transport supply-demand model was developed to answer the following questions:-

- What are the medium to long-term trends in demand for passenger and freight transportation under the envisaged economic Cases?
- What is the resulting demand for liquid fuels under these Cases?
- What are the emissions associated with each of the Cases?

3. The transport supply-demand model comprises a number of models which, when combined, are used to answer these and other questions around the likely future energy and infrastructure requirements of the transport sector and its major influences in terms of both energy and emissions. The future energy demand of the transport sector has been calculated in terms of services performed ('useful' energy) as well as the amount of energy supplied ('final' energy). This allows analysis of the substitution between alternative energy forms and modes, as well as an appraisal of the evolution of the technological improvements in vehicles.

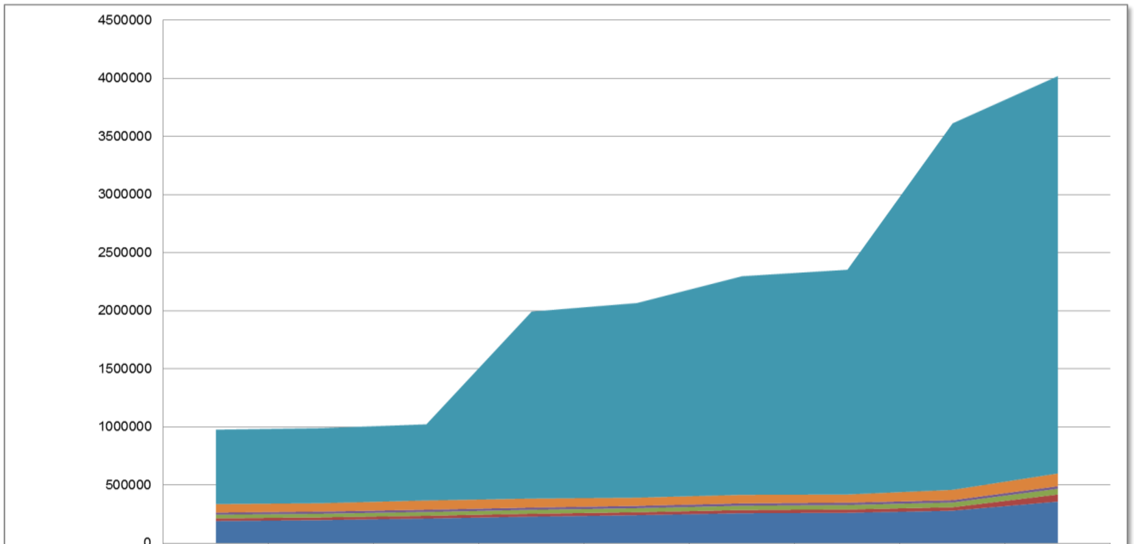
4. A number of modelling techniques have been combined for estimating the current and future vehicle parc[1] and the associated energy demand. The transport supply-demand model comprises four modules: a vehicle parc module; a time budget module; a freight demand module; and a fuel demand module. In future the model could be further enhanced with the use of a computable general equilibrium model to forecast the change in household income over time.

5. The data needed to populate transport sector models is sparse in Myanmar, and it has been necessary to make a broad range of input assumptions. The vehicle parc model was developed to fill knowledge gaps around passenger vehicle usage patterns in Myanmar. The model provides a picture of the baseline vehicle parc and its activity, disaggregated by vehicle class and technology. Ideally, due to the nature and spatial distribution of the demand for fuels by the transport sector, the vehicle parc model should be developed and calibrated at a provincial (State / District) scale. However, as the transport demand model embraces a broad range of assumptions with regard to national demand patterns, the vehicle parc model has been prepared at a national level. At this time the disaggregation

[1] The parc is a term used to describe the stock of active vehicles

to State/District level will not increase the accuracy or change the conclusions of the model in a material sense. It should however be noted that the majority of passenger cars are found in Yangon whereas motorcycles are only found outside Yangon due to a ban in force in Yangon.

Figure I-1: Myanmar Registered Vehicle Statistics



	2005-06	2006-07	2007-08	2008-09	2009-10	2010-11	2011-12	2012-13	2013-14
Two Wheeler	640313	645683	654741	1608772	1674246	1880986	1933673	3153201	3418918
Other	73199	71714	79618	77328	70933	73284	70265	89405	110062
Bus	17985	18614	19390	19576	19837	20717	20065	19522	21043
Truck (heavy duty)	31235	31951	33038	33659	34702	36355	38053	41075	49760
Truck (light duty)	23247	23472	23866	24870	25596	27623	29173	29478	60945
Passenger car	192543	200132	213719	230153	242525	259712	263046	281575	359772

Source: Road Transport Administration Department & CSO Myanmar

6. With reference to Figure I-1, the large increase in passenger car and motorcycle stocks is a result of an easing of Government policy with regard to imports and taxes.

7. The vehicle parc model draws on estimates of scrapping curves, vehicle sales, annual vehicle mileage for each vehicle class and decay of mileage as vehicles age. In order to calibrate the vehicle parc model against known fuel usage, the evolution of vehicle fuel efficiency over the lifetime of the vehicle is included in the model. The primary sources of data for the vehicle parc model were the Road Transport Administration Department and the Central Statistics Organization of Myanmar. Various other assessments by institutions were available from which statistics and other salient facts were extracted. International benchmarks were used for calibration, giving due regard to the particular characteristics of Myanmar. Base year technology penetration, fuel economy and vehicle mileage are validated outputs of the vehicle parc model.

8. Energy demand in the transport sector is driven by the distance travelled and the energy required for each passenger or ton-mile travelled. Average fuel economy is influenced by several variables: for instance, the fuel economy of vehicles decreases with age, but new cars are becoming more efficient and tend to cover higher annual mileages than older vehicles. Efficiency improvements occur due to technology becoming more efficient, in particular due to reductions in vehicle mass and engine capacity. Significant improvements in vehicle efficiency are still possible for new vehicles; an estimated annual improvement of 1% was adopted for the model, based on studies in the United Kingdom and elsewhere.

9. Vehicle occupancy and load factor assumptions are critical for calculating passenger-miles and freight ton-miles travelled. An estimate of vehicle occupancy rates was provided by the Road Transport Administration Department and these rates were compared to international benchmarks for developing countries. Accordingly, it has been assumed that passenger vehicles have an average occupancy of 1.4 passengers, and diesel bus' 25 passengers. Light commercial vehicles (LCVs) were assumed to have a load carrying capacity of 1 ton and 2 tons for gasoline and diesel LCVs respectively. Transport planners typically classify a vehicle with a carrying capacity of 2.5 tons as an MCV, and because there are no vehicles of this size in the parc, this category was assigned a zero stock. Heavy commercial vehicles (HCVs) were assumed to have an average carrying capacity of 13 tons on advice from Road Transport Administration Department. However, it should be noted that the actual freight tons carried on average is determined by the transport demand model calibration. It was found that average loads are around 25% of maximum carrying capacity.

10. Annual vehicle mileage can vary markedly from vehicle to vehicle and moreover tends to decline as the vehicle ages. In this regard estimates of average mileage for vehicles in their first year of operation and for all operating vehicles are useful indicators of activity. The vehicle parc model estimates that on average passenger cars (gasoline) travel 20 000 kilometres per year and heavy commercial vehicles travel around 45 000 kilometres per year with new vehicles, on average, travelling over 70 000 kilometres in their first year. Similarly, the average vehicle mileage estimated for light commercial vehicles was around 18 000 kilometres with new vehicles, on average, travelling 25 000 kilometres in their first year of operation. These estimates are one of the major uncertainties in the vehicle parc model. Passenger car mileage estimates in particular have a large effect on the model calibration due to a high modal share, and the confidence in the model would be further enhanced if reliable data was available.

B. Calibrated Energy Demand Model Results

11. The model-generated activity data for passenger and freight transport is shown in Table I-2 and Table I-3. In general the calibrated vehicle parc model (passenger-km and ton-km) aligns well with reported passenger-miles where such statistics were available from the Road Transport Administration Department.

Table I-2: Modelled Passenger Transport Use for Myanmar (2012)

		Total Vehicles	Vehicle-km	Activity	Modal Share
Modality	**Fuel**	**no.**	**billion veh-km**	**billion pass-km**	**% of pass-km**
Passenger Vehicle (public and private passenger cars and diesel buses)	Gasoline	176 459	2.60	3.64	13%
	CNG	17 286	0.35	0.49	2%
	Diesel	115 106	1.68	14.31	52%
Motorcycle	Gasoline	3 153 201	3.72	4.83	18%
Rail	Diesel	405	n.a.	3.92	14%
Waterways	Diesel	5 200	n.a.	0.34	1%

Source: Consultant

Table I-3: Modelled Freight Transport Use for Myanmar (2012)

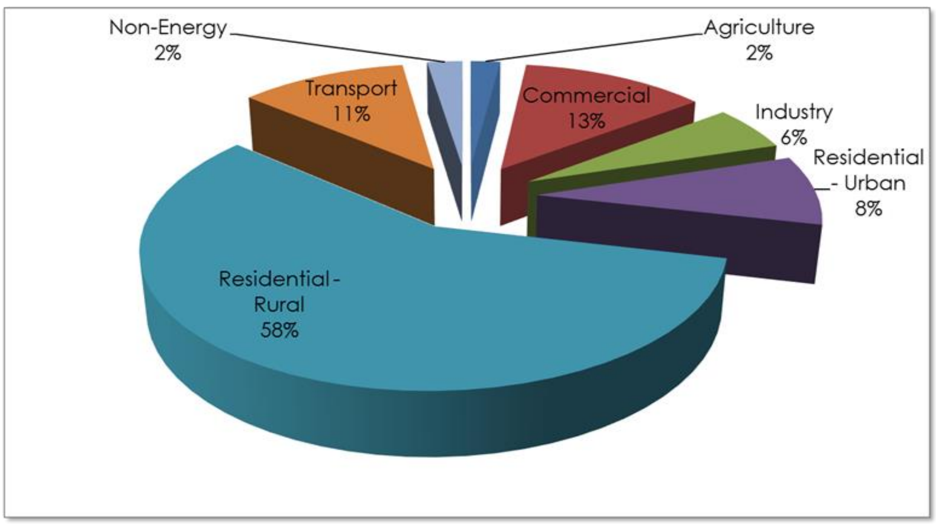
		Total Vehicles	Freight	Activity	Modal Share
Modality	**Fuel**	**no.**	**billion veh-km**	**billion ton-km**	**% of ton-km**
Heavy Commercial Vehicles	Diesel	41 075	1.77	5.76	81%
Light Commercial Vehicles	Gasoline & Diesel	53 730	0.96	0.38	5%
Rail	Diesel	405	n.a.	0.61	9%
Waterways	Diesel	5 200	n.a.	0.34	5%
Air	Jet Fuel (ATF)	tbc	n.a.	0.00	0%

Source: Consultant

C. Final Energy Consumption Forecasts

12. The final energy consumption (FEC) of the transport sector is estimated to have been 11% of total FEC in 2012-13.

Figure I-4: Final Energy Consumption 2012-13

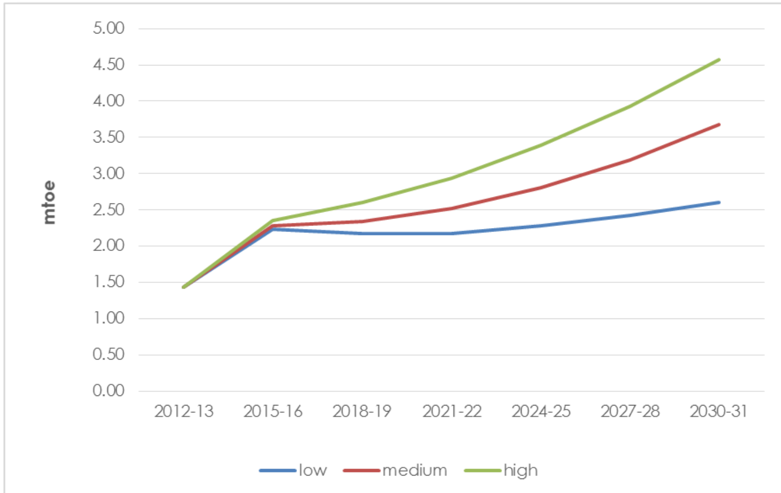


Sources: Consultant

13. Final energy consumption forecasts were prepared for three GDP growth cases. The main driver of transport services demand is GDP per capita in the case of passenger services and GDP of the economy in the case of freight services. Regression of the historical demand for transport services and GDP was undertaken and the strong correlations used to predict the future demand according to GDP projections (low / medium / high).

14. The FEC forecast for the transport sector is shown in Figure I-5. In the case of the medium forecast, the compound annual growth rate from 2012 to 2030 is 5.2%.

Figure I-5: Transport Sector FEC Forecasts (mtoe)



Sources: Consultant

D. Transport Energy Efficiency

15. A reference case was prepared based on the medium GDP growth forecast. Transport energy consumption was forecast according to a 'business-as-usual' case, i.e. no significant shifts in transport efficiency, no fuel substitution or other major changes were entertained. The projected demand for passenger and freight services are given in Figure I-6 and Figure I-7 below, for passenger and freight vehicles respectively.

Figure I-6: Passenger-km Demand Projections

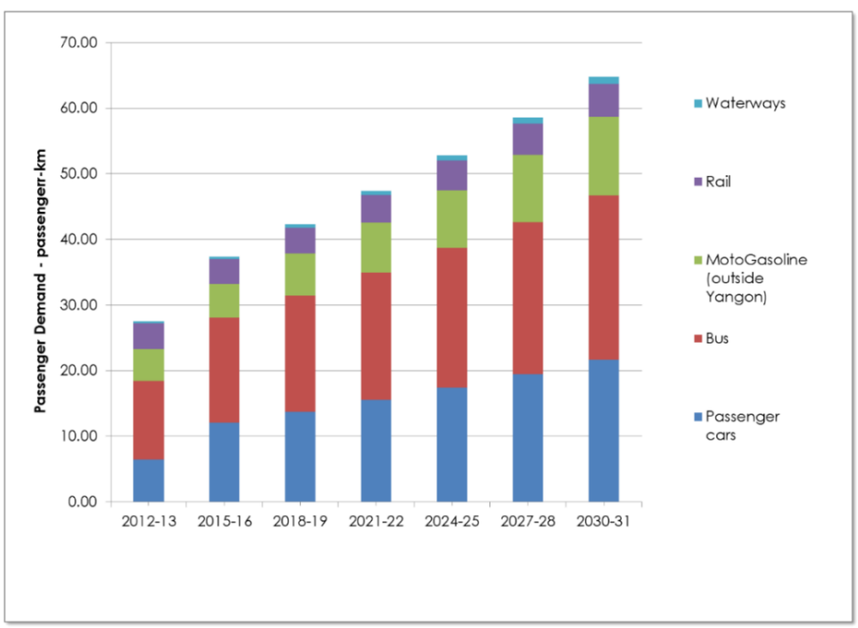
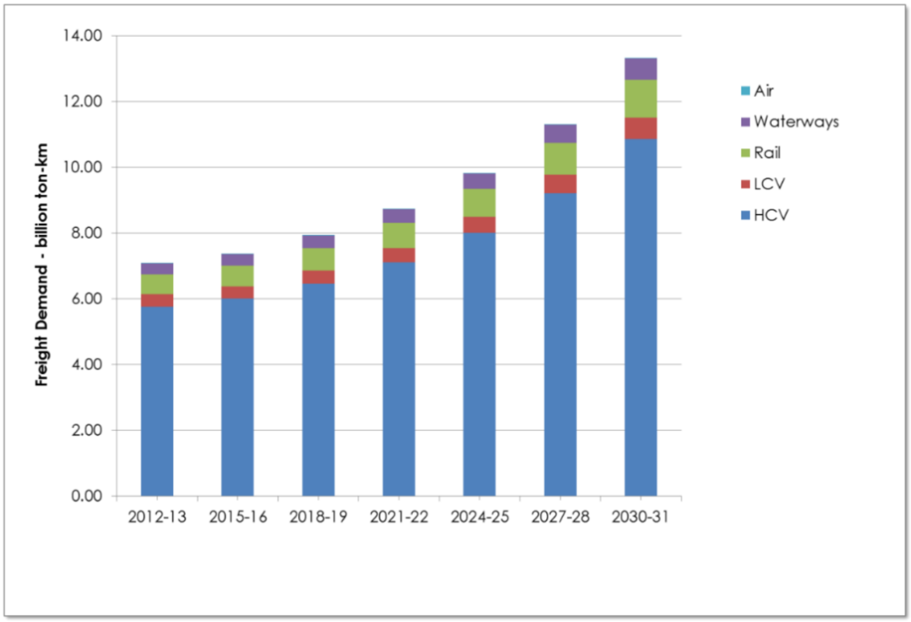


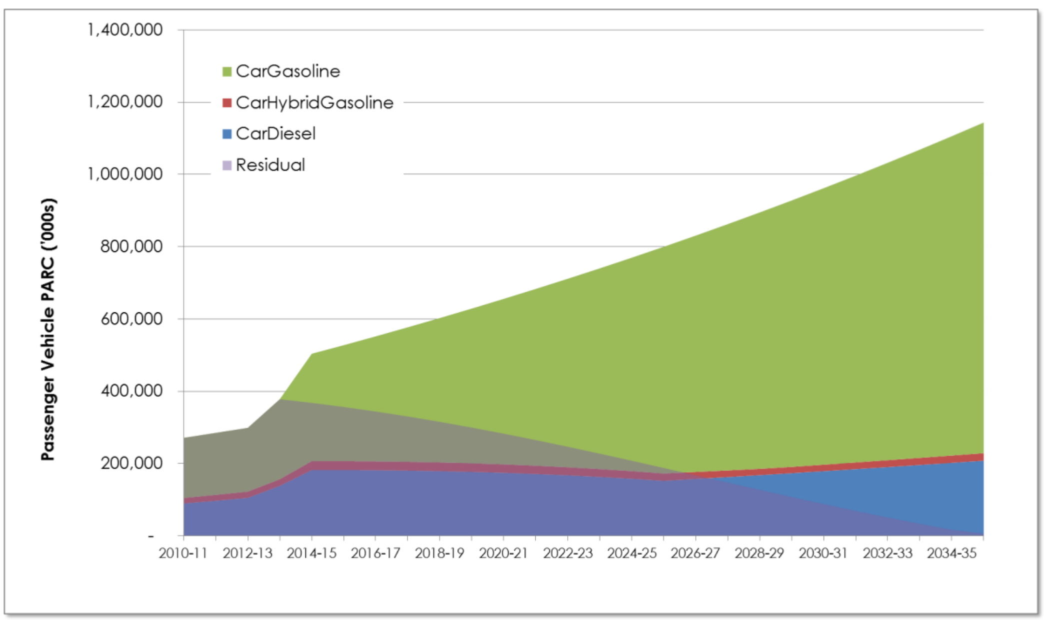
Figure I-7: Freight ton-km Demand Projections



Source: Consultant

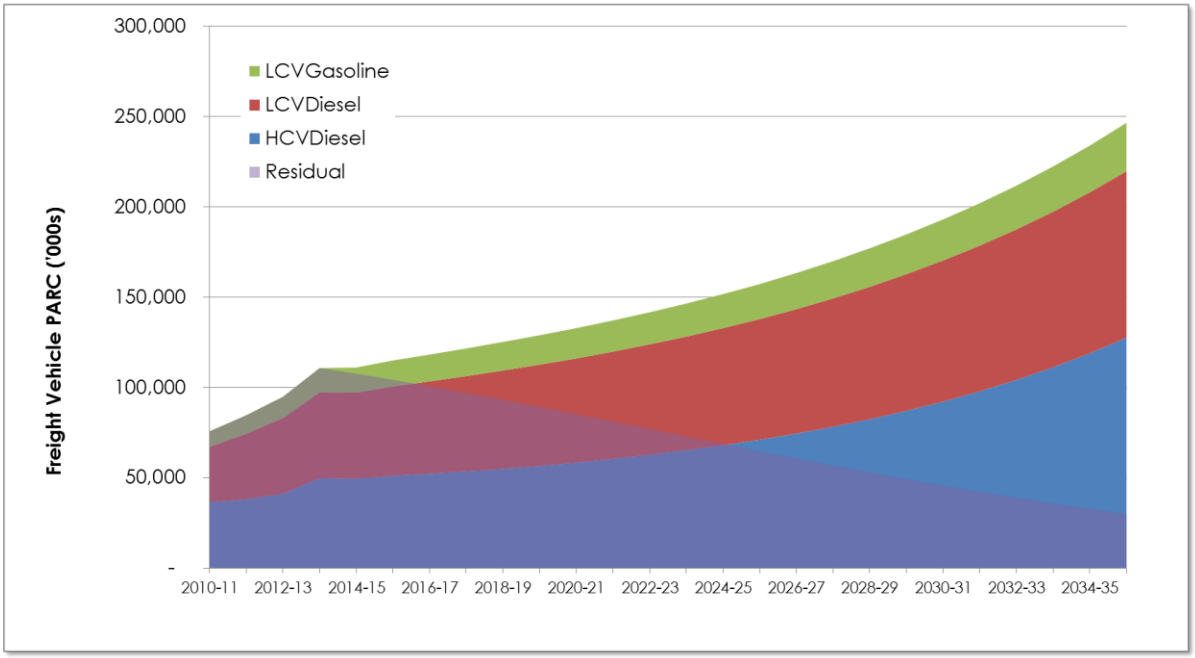
16. The projected vehicle parc is shown in Figure I-8 and Figure I-9 for passenger and freight vehicles respectively. The charts show the 'residual' vehicle count as scrapping of the vehicles on the road in 2013-14 takes place.

Figure I-8: Passenger Vehicle Projections



Source: Consultant

Figure I-9: Freight Vehicle Projections



Source: Consultant

17. An alternative low CO_2 Case was also prepared by making adjustments to the reference case. Specific changes were as follows:-

- Vehicle fuel efficiency was assumed to increase at a rate of 2% per annum (instead of 1%); and
- Bioethanol was assumed to be introduced in 2020, mixed with gasoline in proportion to 10: 90 (gasoline at 90%), and increasing on pro-rata basis to 20:80 by 2030.

18. No changes were made to freight services supply and the alternative Case remains the same as the reference Case.

19. The projected fuel sales and energy consumption for the reference and alternative case are presented in the following tables:

Table I-10: Total Fuel Sales Projection

	Reference						
	2012-13	**2015-16**	**2018-19**	**2021-22**	**2024-25**	**2027-28**	**2030-31**
Gasoline (IG - 000's)	138,568	262,495	313,401	373,072	437,381	485,485	519,767
Bioethanol (IG - 000's)	-	-	-	-	-	-	-
Diesel (IG - 000's)	192,351	283,269	268,451	259,578	264,090	291,511	338,510
Natural Gas (cub m - 000's)	37,326	52,971	43,164	35,197	27,509	19,751	20,839
Jet Fuel (IG '000s)	9,211	9,250	14,800	20,350	25,900	31,450	37,000
	Alternative Case						
	2012-13	**2015-16**	**2018-19**	**2021-22**	**2024-25**	**2027-28**	**2030-31**
Gasoline (IG - 000's)	138,568	262,451	313,243	335,738	382,597	413,114	437,354
Bioethanol (IG - 000's)	-	-	-	37,082	54,487	72,024	84,832
Diesel (IG - 000's)	192,351	283,137	267,838	258,468	262,703	290,054	337,020
Natural Gas (cub m - 000's)	37,326	52,969	43,154	35,156	27,439	19,655	11,409
Jet Fuel (IG '000s)	9,211	9,250	14,800	20,350	25,900	31,450	37,000

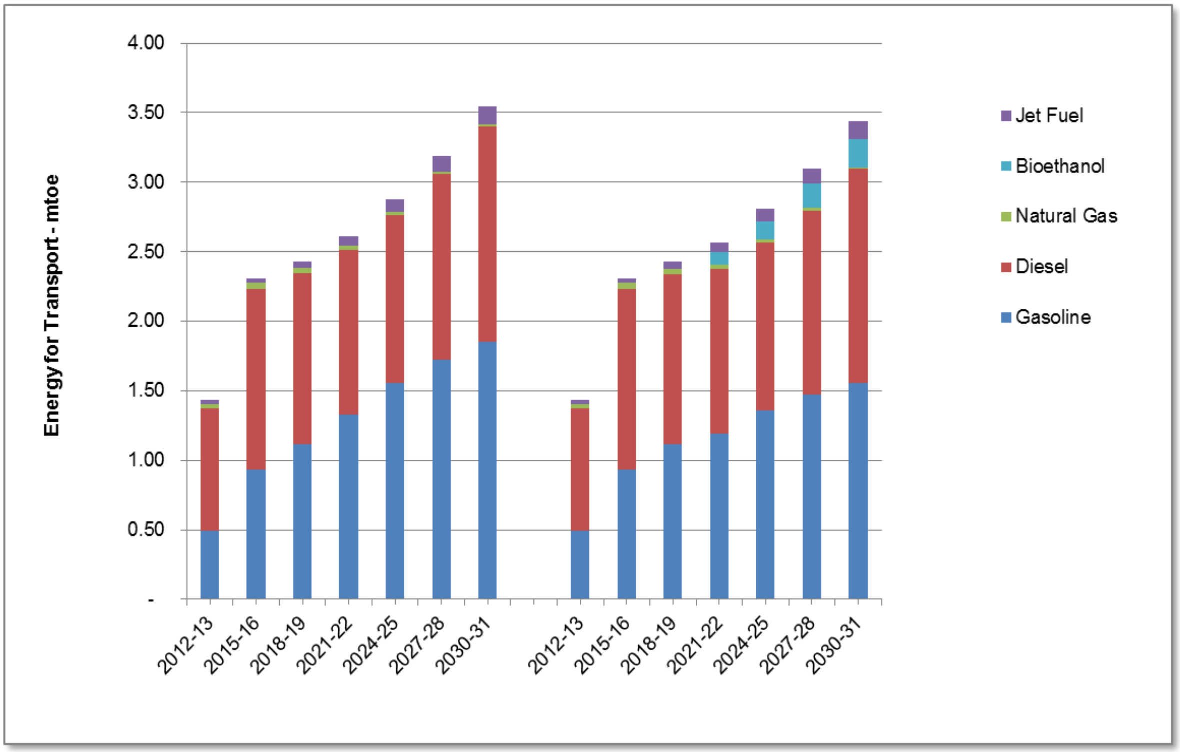
Source: Consultant

Table I-11: Energy for Transport (mtoe)

	Reference							**Alternative Case**						
	2012	**2015**	**2018**	**2021**	**2024**	**2027**	**2030**	**2012**	**2015**	**2018**	**2021**	**2024**	**2027**	**2030**
Gasoline	0.49	0.93	1.11	1.33	1.56	1.73	1.85	0.49	0.93	1.11	1.19	1.36	1.47	1.55
Bioethanol	-	-	-	-	-	-	-	-	-	-	0.09	0.13	0.17	0.21
Diesel	0.88	1.30	1.23	1.19	1.21	1.33	1.55	0.88	1.30	1.23	1.18	1.20	1.33	1.54
Natural Gas	0.03	0.05	0.04	0.03	0.02	0.02	0.02	0.03	0.05	0.04	0.03	0.02	0.02	0.01
Jet Fuel (ATF)	0.03	0.03	0.05	0.07	0.09	0.11	0.13	0.03	0.03	0.05	0.07	0.09	0.11	0.13
Total	1.44	2.31	2.43	2.61	2.88	3.18	3.54	1.44	2.31	2.43	2.57	2.81	3.09	3.44

Source: Consultant

Figure I-12: Energy for Transport



Source: Consultant

II. TRANSPORTATION ENERGY PLANNING

E. Background

20. The energy consumption of the transport sector in Myanmar is large, reported to total around 12% of total final consumption (TFC) in the national energy balance[2]. All of this energy demand is in the form of liquid fuels, which itself is the bulk of the national liquid fuel demand. The evolution of transport demand is very uncertain but has large implications for infrastructure requirements.

21. A successful and productive economy is founded not only on a reliable energy supply for current needs but also on the ability of that supply to respond sustainably to changing needs. Due to the reliance on liquid fuels for transport, disruptions to liquid fuels supply to the transport sector can have large economic impacts. Ensuring that such disruptions do not occur requires that the appropriate strategy is in place, to develop refineries, to import liquid fuels or to adopt a hybrid approach.

22. The energy infrastructure required to meet liquid fuel needs, and transport liquid fuels from the point of supply to the point of demand involves large investments and long lead-times. In addition, the choice of primary energy and the transformation process can have substantial impacts on society and the environment. Investment decisions must therefore be informed by planning processes, such as a national integrated energy plan. A key part of such a plan concerns the transportation sector.

23. A first step in the planning process is to develop an understanding of the current demand for mobility of passengers and freight in the economy and the drivers of mobility in the transport sector and how these will evolve over time. The need for mobility is not something that can be directly measured or observed and therefore requires estimation based on a number of observable variables, for instance how much people are driving and the quantity of goods being moved around in the current economic environment or how many vehicles are on the road/rail network.

24. Whilst statistics have been reported over the years, the use of a calibrated model of the vehicle fleet and its characteristics, often called a 'vehicle parc model', is an essential support to energy planning. The parc model can be used to characterise liquid fuel consumption in the transport sector in Myanmar. The model developed for this Energy Masterplan development includes both passenger and freight transport, and different transport modes, and is calibrated at a national level. The objective is to characterize liquid fuels demand in the transport sector, and to support the development of projections of demand for passenger and freight transport in Myanmar's transport sector in order to inform decisions related to infrastructure planning such as the capacity and location of refineries and pipelines. Very broadly, the modelling approach follows two steps; firstly available historic data is used to develop a picture of the 'base' year use of energy for transport, by fuel and mode. Secondly, demand for passenger and freight transport is projected into the future under different plausible Cases.

F. Overview of Transport in Myanmar

25. In Myanmar, owning a private vehicle is still out of the income range of many people. The per capita GDP in 2013 computes to be US$920[3]. The mass public relies on public transportation as their

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[2] IEA Energy Balance for Myanmar (2012)

[3] Adopting GDP reported by IMF for 2013-14 (IMF Country Report 14/91 – March 2014) and ADB population estimate

primary means to commute within the cities and provinces. Otherwise the majority of passenger vehicles are found in the major cities where the quality of the road network is good. Motorcycles, a popular form of transport in Myanmar, are banned in Yangon city and Mandalay has developed with the highest density of motorcycles. In the past, the bus fleet in Myanmar was very old, mostly left over Chevy C15 trucks from World War II that were converted into passenger buses. With the recent urbanisation and modernisation of Myanmar, these buses have been banned from Yangon and are gradually being replaced with modern buses. Year 2011-12 saw a drop in the number of registered buses due to the fact that many were submitted for the old car substitution program. Most of the buses in Myanmar have been converted to run on compressed natural gas (CNG) in order to save government expenditure in importing fuel for domestic use. Recent bus imports have been from Korea and Japan. As Yangon plans to be a mega-city (population of more than 10 million) by the year 2030, and more people from the rural provinces move to the cities, the demand for public transportation will continue to increase.

26. In the commercial transport sector, trucks are currently being used by the extractive industries, notably for logging and mining. Myanmar's extractive industries are the sectors that have seen the most foreign direct investment, with an associated heavy increase in the use of trucks. In the past, old Hino trucks were a common site on the streets of Myanmar but these are gradually being phased out by modern hauling vehicles. As the country becomes more industrialised this increased demand for trucks will continue. Trucks will continue to be essential for hauling containers and cargos as more factories and production bases are set up in the country. Today road trucks dominate the transport of general goods and their net annual utilization is estimated to have reached 7.4 billion ton-km in 2013-14. Much of the freight is between ports and city destinations as is evidenced by container trucks. In the absence of the export of bulk goods, particularly iron ore and coal, the rail freight industry takes a relatively small of freight demand in Myanmar. The model indicates that freight haulage by rail has actually contracted by 0.1 billion ton-km per annum over the last 10 years to 0.61 billion ton-km in 2012-13.

27. While the stock of road vehicles will surely increase in the next 20 years, the use of rapid transit busses and rail offer the prospect of relief from the inevitable traffic congestion that is increasingly reported as a growing a problem in Yangon. Current registrations of vehicles are reported by the Myanmar CSO. The aggregate statistics for the distribution of vehicles in the provinces in Myanmar were shown above in Figure I-1. In 1995, Myanmar had a registered motorisation level of around 7 vehicles per thousand people; by 2013 the level had risen to 70.

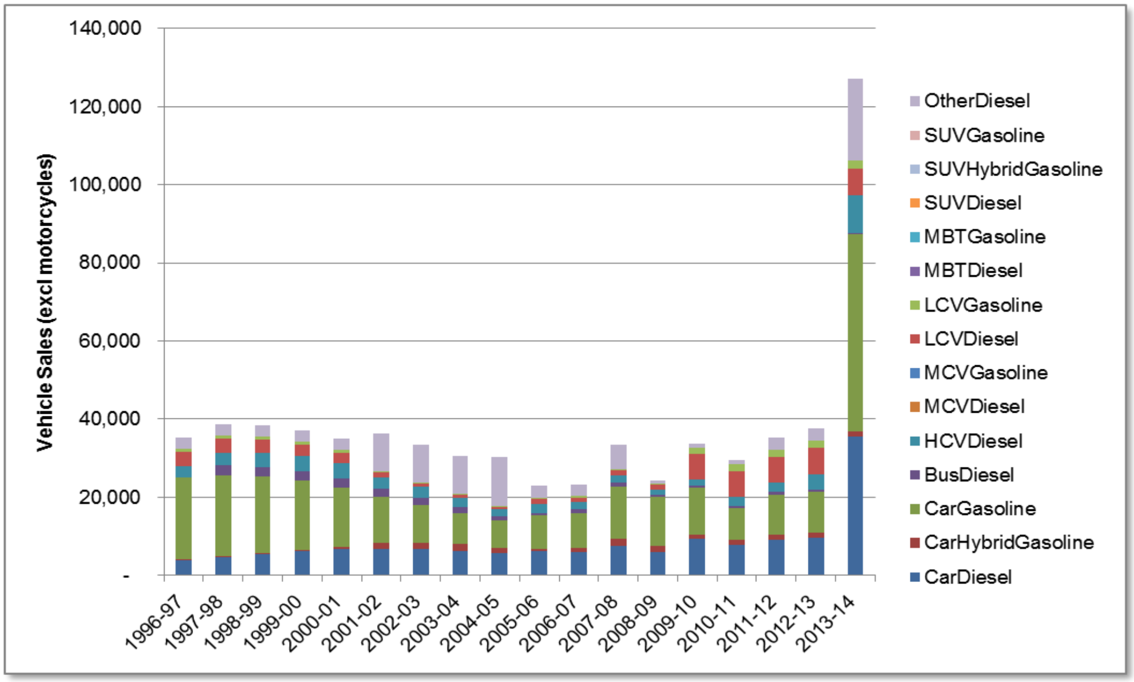
Table II-1: Motorization of Myanmar's Provinces (February 2013)

State /	Private	Truck	Truck (Heavy	Passenger	Motorcycles	Trawlergi	Heavy
Yangon,	252,518	22,162	23,351	14,078	1,051,444	9,878	466
NPT &	89%	74%	56%	73%	33%	29%	58%
Other	31,923	7,964	18,694	5,231	2,146,836	24,738	332
	11%	26%	44%	27%	67%	71%	42%

Source: Myanma Railway

28. Vehicle sales of passenger cars and motorcycles increased markedly in 2013 due to the Government reducing restrictions on import and vehicle taxes. Vehicle sales appear to have dropped with the global recession in 2009 but have quickly risen again.

Figure II-2: Model-Estimated Vehicle Sales (1995 - 2013)



Source: Road Transport Administration Department; CSO: to be validated

29. In line with the above vehicle sales growth, the last decade has seen steady growth in diesel passenger cars as a fraction of the passenger car fleet, thus emulating trends in Europe.

30. The average diesel car fraction of the passenger car fleet in the European Union (EU) grew from 25% in 2001 to 41% in 2007, led by France, Austria and Luxembourg with diesel car fractions of over 50% in 2007 (Eurostat, 2012). In 2013-14, dieselization of the Myanmar fleet has reached 41% of estimated new vehicle sales.

31. Growth in transport demand in Myanmar is largely a result of both population growth and economic growth, however there are other factors which characterize the growth of energy demand that are included in the vehicle parc model, such as the ratio of vehicles using diesel and petrol, long freight haulage distances and high road freight demand. Other factors which translate transport demand into fuel consumption, such as the age of the vehicle fleet which impacts energy efficiency, are also included in the model.

G. Modelling Transport Demand

32. There are several approaches that could be used to model transport sector demand. International transport research centres tend to favour a bottom-up approach where the objective is fuel consumption and energy analysis. A bottom up approach is a disaggregated analysis of the transportation system as a provider of energy services. The calculation of energy demand in terms of services performed ('useful' energy) as opposed to the amount of energy supplied ('final' energy), offers a better understanding of the substitution between alternative energy forms, as well as an appraisal of the effect that evolution of the technological improvements has on demand. Such insights are essential in developing energy policy.

33. In a bottom-up approach, energy consumption by the transport sector is directly driven by two factors: vehicle-km travelled, and conversion efficiency of the vehicle (whether a road, rail, waterway or air vehicle).

34. The vehicle-kms travelled are in turn driven by the needs of society and the economy to move people and goods from place to place. Conversion efficiency depends mostly on the underlying technology, i.e. the type of vehicle, fuel and vintage that makes up the vehicle parc, and to some degree the patterns of utilisation of that technology. It is useful to treat passenger transport and freight transport separately, as the need for mobility by people and goods have different drivers and technologies.

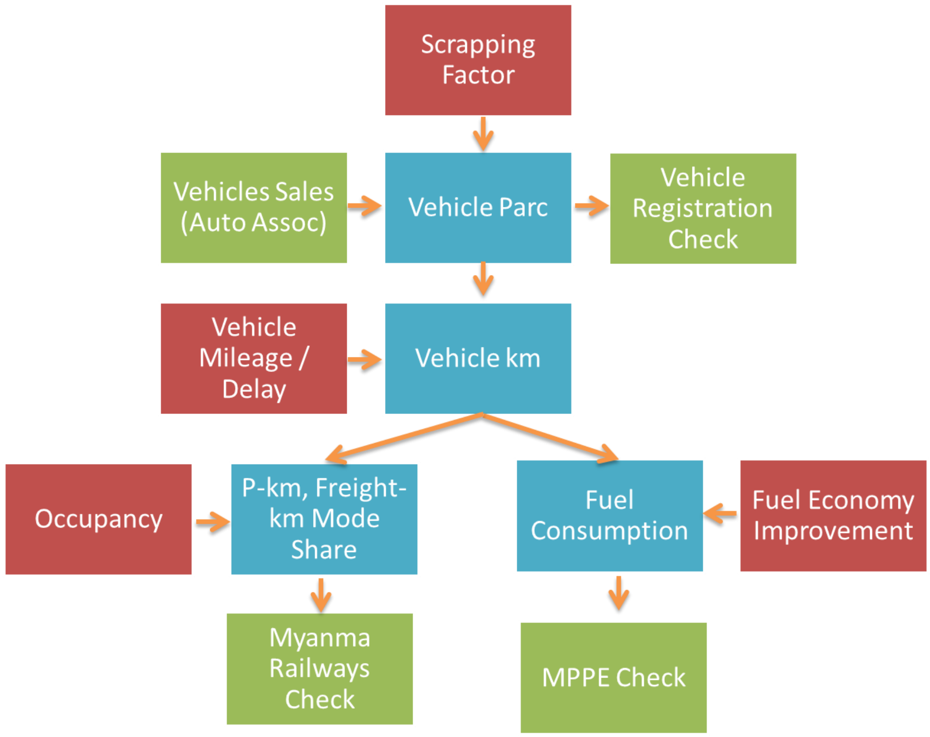
35. The major economic and policy drivers are similar for both the road and rail transport modes and the outcome of the system; fuel consumption is the direct result of vehicle km travelled and vehicle fuel efficiency in both cases.

36. Several distinct elements are included in the calibrated vehicle parc model used for transport demand planning. These are the distance travelled per vehicle, the total kilometres travelled, fuel consumption, fuel efficiency, the total vehicle fleet, and the average age of vehicles. Certain factors affecting the vehicle-km travelled and fuel-distance efficiency, for instance traffic congestion, are difficult to quantify as they are not well understood due to the limited availability of data. To accommodate such unknown influences the model is calibrated by adjusting the variables until the output matches the known fuel sales data. Once calibrated, it is reasonably certain that the model returns realistic estimates of the number of operating vehicles and their annual distance travelled, notwithstanding the accuracy of the reported statistics. However, by making an informed assumption regarding the average occupancies of different vehicle types it is feasible to estimate total private travel demand and international benchmark comparisons also shed light on the reasonableness of the model outputs.

H. Model Structure & Calibration

37. A schematic representation of the vehicle parc model and its inputs (red boxes) is shown in Figure II-3. Each of the checkpoints (green boxes) is a Myanmar organization. The outputs of the model (blue boxes) are computed by the model algorithms.

Figure II-3: Transport Demand Model Structure



Source: Consultant

38. Given the gaps in knowledge around vehicle utilisation in Myanmar, the model had to be calibrated with care, testing the plausibility of all assumptions. To this end it was decided to calibrate the model over the period from 1995 to 2012, the latter year becoming the base year. This approach gives some reassurance that the model's sensitivity to assumptions is unlikely to cause any unrealistic divergence in the results. In essence, the calibration involves iterating the most uncertain variables like annual mileage and fuel economy until the model predicts the observed fuel sales for the calibration years. Clearly, if errors are large, given reasonable values for these variables relative to available empirical data, there would be something structurally wrong with the model and therefore these iterations require a careful assessment at each step.

39. The vehicle parc model was calibrated for both passenger and freight vehicles for Myanmar as a whole. The set-up and calibration of the critical variables defining the utilisation of vehicles and their efficiency in the model proceeded as follows:

1. Historic vehicle sales data for cars, buses and commercial vehicles was used along with scrapping curves to derive an estimate of the stock of vehicles of different vehicle types, the sum of stock by type was compared with the statistics reported from the Road Transport Administration Department registration database for calibration purposes.

2. Vehicle mileage estimates were calculated for both passenger and freight vehicles, assuming that the annual mileage travelled by vehicles decays as they age.

3. Fuel demand was calculated by multiplying the kilometres travelled, the vehicle technology fuel efficiency and the number of vehicles in the vehicle technology segment as shown in the equation below. The technology segment fuel demands were summed to yield the

vehicle parc demand and compared to the recorded fuel sales for calibration purposes.

$$D_{f,k} = \sum_{j=yr1}^{j=k} \sum_{i=1}^{i=C} N_{i,j} FC_{i,j} VKT_{i,j}$$

Df,k = Demand for fuel fin year k

Ni,j = The number of vehicles in technology segment i with model year j (yr1 being the first model year), where technologies numbered 1 to C all use fuel f

FCi,j = Estimated fuel consumption for technology segment i with model year j

VKTi,j = Vehicle kilometres travelled per vehicle in technology segment i with model year j

4. The fuel demand was calibrated to match the known fuel sales data by first getting broad agreement by scaling the kilometres travelled per vehicle and then fine tuning with adjustments to the fuel economy assumptions.

I. Data and Assumptions

40. Developing transport sector models and projecting demand into the future is challenging in the Myanmar context because there is doubt regarding the validity of statistical data on vehicle utilisation as well as a paucity of detailed input data. With respect to the latter point, assumptions had to be made on the vehicle scrapping factors, vehicle mileage and occupancy, and fuel economy inputs. The vehicle parc model developed required disaggregated data on the current vehicle population, efficiency and utilisation for both passenger and freight transport.

41. Data on the total registered vehicle population in Myanmar is captured by the Road Transport Administration Department and reported publicly by the Myanmar CSO. The standard vehicle classification used for reporting is relatively simple. While the classification has served Myanmar well for many years, there will come a time in the near future when it will be sensible for the classification to be expanded to provide a clearer picture of consumer demand patterns. For now, the classification chosen for transportation energy modelling was aligned to Myanmar's existing classification. Some additional vehicle classes were included in the model, but the vehicle stocks for these categories were recorded as null, namely items 6, 7, 10, 11, 12, 13 and 14 in Table II-4.

Table II-4: Vehicle Classes & Nomenclature in the Model

Item	Vehicle Types	Fuel Type	Model ID*
1	Passenger car	Diesel	CarDiesel
2	Passenger car	Gasoline	CarHybridGasoline
3	Passenger car	Gasoline	CarGasoline
4	Bus	Diesel	BusDiesel
5	Heavy Commercial Vehicle	Diesel	HCVDiesel
6	Medium Commercial Vehicle	Diesel	MCVDiesel
7	Medium Commercial Vehicle	Gasoline	MCVGasoline
8	Light Commercial Vehicle	Diesel	LCVDiesel
9	Light Commercial Vehicle	Gasoline	LCVGasoline
10	Minibus Taxi	Diesel	MBTDiesel
11	Minibus Taxi	Gasoline	MBTGasoline
12	Sport Utility Vehicle	Diesel	SUVDiesel
13	Sport Utility Vehicle	Gasoline	SUVHybridGasoline
14	Sport Utility Vehicle	Gasoline	SUVGasoline
15	Motorcycle	Gasoline	MotoGasoline
16	3 Wheel, Trawlergi	Diesel	OtherDiesel
* These model IDs are used in all charts and tables			

Source: Consultant

42. Estimates of freight utilisation in ton-km for have been available in the public domain through the annually publications of the Central Statistics Office. These estimates extend from public bus and taxis, to rail, waterways and air. (Estimates of the demand for road passenger transport in passenger-km are not published).

43. In order to check the model calibration, data on fuel sales is useful. Aggregate fuel consumption by the transport sector was captured by questionnaire from all institutional or company owners of transport fleets. This approach necessarily omitted passenger cars in public ownership and the long haul freight industry.

44. The fuel demand calculation and model calibration process required a number of assumptions to populate the three variables in the fuel demand equation Df,k, i.e. N the number of vehicles, VKT, their mileage and FC their fuel economy. The assumptions required are:-

- A vintage profile derived from realistic scrapping curves;
- An assessment of annual vehicle mileage for each vehicle class and the rate at which this decays as the vehicle ages; and
- Estimates of the fuel economy of each vehicle class and how it is changing with time.

J. Vintage Profile

45. To project the energy consumption of a vehicle parc and how it may evolve over time, a vintage profile of the current vehicle parc was established. This is important, as newer vehicles have better fuel economy and higher vehicle mileage than older vehicles. Moreover, as newer vehicles enter the parc and older ones are driven less and are scrapped, the average fuel economy of the parc changes.

46. The rate at which vehicles have been scrapped was defined in the model by scrapping curves which estimate the probability of a vehicle surviving as a function of its age. This allows us to convert historical sales data into stock data. The Weibull cumulative distribution function, shown below, was used for this purpose.

If: x = age of the vehicle

f(x) = the probability of the vehicle remaining operational

α = a constant

β = a constant

$$f(x) = e^{-(\frac{x}{\beta})^\wedge\alpha}$$

47. Multiplying the total sales of a vehicle type in a particular year (vintage) by the appropriate scrapping factor on the curve will yield the probable population in a future base year. Thus a historical sales data can be converted to an approximation of stock in the vehicle parc for given year by substituting the result of the equation describing the probability of a vehicle being scrapped, into the following equation:-.

If: Y_S = the year of sale

Y_P = the year for which the vehicle park is being characterized

V_P = the stock of vehicles in the vehicle parc in year Y_P sold in year Y_S

V_S = the number of vehicles sold in year Y_S

$$f(Yp - Ys)$$

= the function estimating the probability of the vehicle being scrapped

$$Vp = f(Yp - Ys).Vs$$

48. The scrapping curves were calibrated by iterating the parameters for the scrapping curves until a target population was reached. The iteration proceeded in a chained manner, starting from a base year and continuing year to year until the annual sales data assumption for each consecutive year resulted in a match with the aggregated total vehicle population data from the Road Transport Administration Department for that year, starting from a base year of 1995-96. The Weibull constants used for the vehicle parc model, and the average age of vehicle categories in the 1995-96 calibration year, are presented in Table II-5. The model calculates the average age for each successive year.

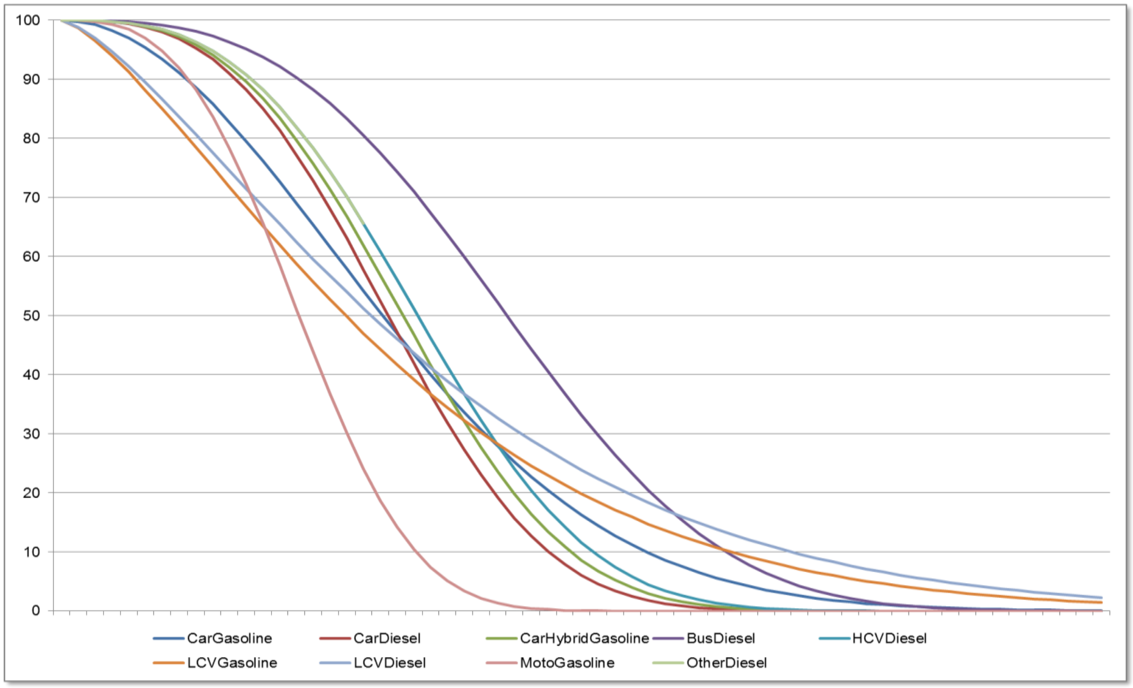
Table II-5: Weibull Scrapping Curve Parameters for the Parc

	Vehicle Types	Fuel Type	Model ID	Beta	Alpha	Average Age
1	Passenger car	Diesel	CarDiesel	22	3.0	8.0
2	Passenger car	Gasoline	CarHybridGasoline	23	3.0	5.0
3	Passenger car	Gasoline	CarGasoline	23	2.0	10.0
4	Bus	Diesel	BusDiesel	30	3.0	15.0
5	Heavy Commercial Vehicle	Diesel	HCVDiesel	24	3.0	10.0
6	Medium Commercial Vehicle	Diesel	MCVDiesel	Not Used		
7	Medium Commercial Vehicle	Gasoline	MCVGasoline	Not Used		
8	Light Commercial Vehicle	Diesel	LCVDiesel	24	1.4	8.0
9	Light Commercial Vehicle	Gasoline	LCVGasoline	22	1.4	12.0
10	Minibus Taxi	Diesel	MBTDiesel	Not Used		
11	Minibus Taxi	Gasoline	MBTGasoline	Not Used		
12	Sport Utility Vehicle	Diesel	SUVDiesel	Not Used		
13	Sport Utility Vehicle	Gasoline	SUVHybridGasoline	Not Used		
14	Sport Utility Vehicle	Gasoline	SUVGasoline	Not Used		
15	Motorcycle	Gasoline	MotoGasoline	16	3.0	5
16	3 Wheel, Trawlergi	Diesel	OtherDiesel	24	3.0	5

Source: Consultant

49. There is a wide range of average ages between vehicle classes; the established vehicle classes such as gasoline cars, LCVs and HCVs have average ages at 10 or more years. The scrapping curve for each vehicle class in the model, plotted using the Weibull coefficients in Table II-5, is shown in Figure II-6.

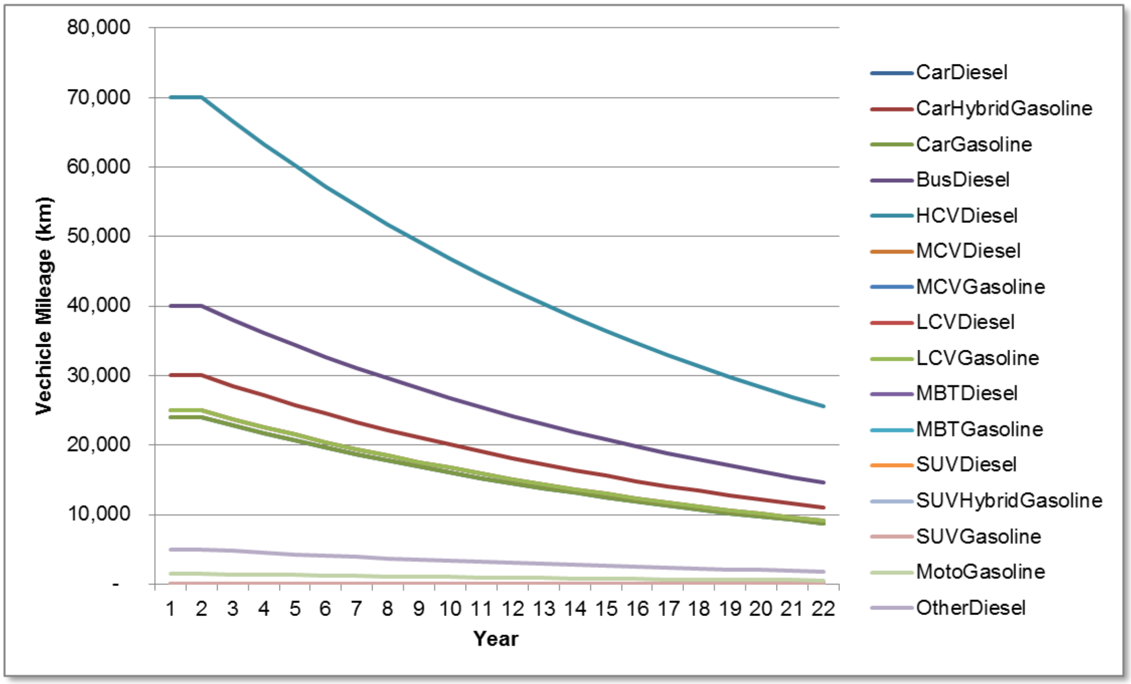
Figure II-6: Base Year Scrapping Curves for Vehicles in the Parc



K. Vehicle Mileage

50. The process of developing mileage assumptions for the model, that would be both plausible and allow for the calibration of model fuel demand with fuel sales, requires an assumption around the initial annual mileage of ‘new vehicle’ annual mileage. The assumed ‘new vehicle’ mileage was based on national and international literature. The annual mileage of vehicles has been observed to, on average, decay steadily from this initial value for each year of operation. The United States’ EPA MOBILE 6 transport model assumes a constant rate of decay compounding annually that is specific to vehicle type (Jackson, 2001) as shown in Figure II-7. In general (buses being the exception), the rate of decay assigned is higher for vehicles with a higher initial mileage, heavy truck mileage for example decays at 10.9% per annum while for light-duty vehicles the default rate in Mobile 6 is 4.9% annual decay in annual mileage per annum.

Figure II-7: Vehicle Mileage Decay with Vehicle Age



Source: Consultant

51. Lacking even rudimentary mileage accumulation data for Myanmar, a value of 4.9% was used as the rate of mileage decay for the Myanmar vehicle parc model across all vehicles classes. The rate of decay combined with the assumption of an initial 'new vehicle' mileage, and the age profile of the model parc resulting from the scrapping assumptions discussed above, results in an estimate of average annual mileage for each vehicle class. Clearly, if recent vehicle sales have been low then this will reduce the average mileage of that class because older vehicles which cover less mileage contribute disproportionately. After model calibration, these assumptions resulted in average mileages for the model vehicle classes that are reasonably consistent with previous studies and local and foreign data as shown in Table II-8.

Table II-8: New Vehicle Mileage (km) by Vehicle Class (2013)

	Vehicle Types	Fuel Type	Model ID*	New Vehicle Mileage	Average Mileage of Stock 2013
1	Passenger car	Diesel	CarDiesel	24 000	16 935
2	Passenger car	Gasoline	CarHybridGasoline	30 000	19 809
3	Passenger car	Gasoline	CarGasoline	24 000	15 825
4	Bus	Diesel	BusDiesel	40 000	21 832
5	Heavy Commercial Vehicle	Diesel	HCVDiesel	70 000	45 471
6	Medium Commercial Vehicle	Diesel	MCVDiesel	Not Used	
7	Medium Commercial Vehicle	Gasoline	MCVGasoline	Not Used	

	Vehicle Types	Fuel Type	Model ID*	New Vehicle Mileage	Average Mileage of Stock 2013
8	Light Commercial Vehicle	Diesel	LCVDiesel	25 000	17 873
9	Light Commercial Vehicle	Gasoline	LCVGasoline	25 000	18 077
10	Minibus Taxi	Diesel	MBTDiesel	Not Used	
11	Minibus Taxi	Gasoline	MBTGasoline	Not Used	
12	Sport Utility Vehicle	Diesel	SUVDiesel	Not Used	
13	Sport Utility Vehicle	Gasoline	SUVHybridGasoline	Not Used	
14	Sport Utility Vehicle	Gasoline	SUVGasoline	Not Used	
15	Motorcycle	Gasoline	MotoGasoline	1 500	1 148
16	3 Wheel, Trawlergi	Diesel	OtherDiesel	5 000	3 253

Source: Consultant

L. Fuel Economy

52. The projection of fuel economies for each vehicle class and year is generated by assuming a 1% annual improvement in fuel economy of new vehicles according to the aggregate manufacturer's data available for representative car models in each vehicle class. Average vehicle fuel economy is a factor of several variables, as vehicles age the efficiency decreases, but the fuel economy of new vehicles tends to improve over time. This is the result not only of technology becoming more efficient but also because regulation is reducing vehicle mass and engine capacity.

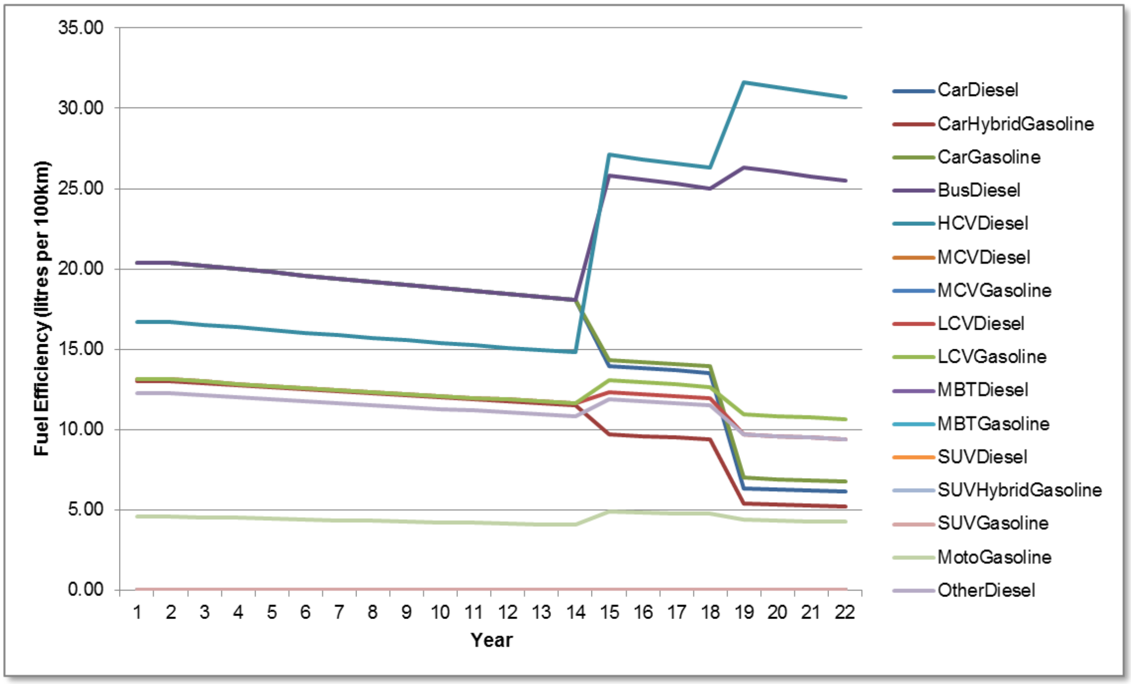
53. The Myanmar vehicle parc is dominated by models from Japan, so a higher annual improvement could be expected, but given the slower rate of scrapping in Myanmar, a scrapping rate of 1% was chosen for new vehicles in 2013 as a reasonable historical improvement rate in the absence of local reliable data. This assumption is also supported by a British study (Kwon, 2006), which suggests that new passenger vehicles and light commercial vehicles had an improved vehicle efficiency of 0.9% per annum between 1979 and 2000 in Britain.

54. Data for the fuel economy improvement of heavy-duty vehicles over the calibration period was not found and therefore an assumption of 1% was applied to these vehicle classes as well. The resulting historical fuel economy trajectory for the vehicles classes in the model is presented in Figure II-9. Given the blanket 1% assumption, the fuel economy of all vehicle classes will increase into the future by around 22% over a 20 year period.

55. Ordinarily for calibration purposes a 1% rate of improvement would also be used for modelling, but in Myanmar this figure is inappropriate. The quality of vehicles is known to be poor, and there have some step changes in the evolution of fuel economy driven by forced retirements of vehicles as a result of Government policy. The Road Transport Administration Department offered an expert opinion regarding the current efficiency of the vehicles active in the vehicle parc as shown in Table II-10. The figures were used to deduce a rate of improvement of fuel economy for the parc, validated as part of the process of matching fuel consumption and production.

56. In Figure II-9 the fuel economy data for some technologies are extrapolated back to before those technologies entered the market, gasoline hybrid SUVs for instance, but this does not affect the model because no stock of these vehicles exists.

Figure II-9: Assumed Historical Evolution of Vehicle Fuel Economy in the Model



Source: Consultant

57. The calibration process involved first adjusting the initial annual mileage assumption to the final values shown above in Table II-8, and then adjusting the fuel economy estimates until a good match was obtained between the data for historical fuel sales to the transport sector and the fuel demand of the vehicle parc model. The average fuel economy of the parc compared to typical new vehicle assumptions and to the Road Transport Administration Department opinions are shown in the following table:-

Table II-10: Calibrated Model Fuel Economy (l/100km) by Vehicle Class

Model ID	New Vehicle Fuel Economy	Average Fuel Economy of Stock*	Average Fuel Economy of Stock by Model
CarDiesel	7.5	31.4	18.3
CarHybridGasoline	6.4	11.3	10.6
CarGasoline	8.3	31.4	17.4
BusDiesel	31.2	31.4	22.2
HCVDiesel	37.5	25.7	19.2
MCVDiesel	Not Used		
MCVGasoline	Not Used		
LCVDiesel	11.5	20.2	12.3

Model ID	New Vehicle Fuel Economy	Average Fuel Economy of Stock*	Average Fuel Economy of Stock by Model
LCVGasoline	13.0	20.2	12.5
MBTDiesel	Not Used		
MBTGasoline	Not Used		
SUVDiesel	Not Used		
SUVHybridGasoline	Not Used		
SUVGasoline	Not Used		
MotoGasoline	5.2	7.1	4.4
OtherDiesel	11.5	18.8	11.5

*Source: *Road Transport Administration Department; Consultant*

58. Less data was available to guide the assumptions for vehicle occupancy and load factor which are critical for calculating the demand for passenger-km and ton-km respectively in the model. Again the Road Transport Administration Department provided an opinion of the occupancy and load factor for different passenger and freight modes and these figures were adopted for the transport demand model.

59. The final occupancy and load factors selected for the model are shown in the following table:-

Table II-11: Model Occupancy & Load Factor (2013-14)

	Vehicle Types	Fuel Type	Model ID	Units	Occupancy or Load Factor
1	Passenger car	Diesel	CarDiesel	pass/veh	1.4
2	Passenger car	Gasoline	CARHybridGasoline	pass/veh	1.4
3	Passenger car	Gasoline	CarGasoline	pass/veh	1.4
4	Bus	Diesel	BusDiesel	pass/veh	25
5	Heavy Commercial Vehicle	Diesel	HCVDiesel	ton/veh	13.0
6	Medium Commercial Vehicle	Diesel	MCVDiesel	Not Used	
7	Medium Commercial Vehicle	Gasoline	MCVGasoline	Not Used	
8	Light Commercial Vehicle	Diesel	LCVDiesel	ton/veh	2.0
9	Light Commercial Vehicle	Gasoline	LCVGasoline	ton/veh	1.0
10	Minibus Taxi	Diesel	MBTDiesel	Not Used	
11	Minibus Taxi	Gasoline	MBTGasoline	Not Used	
12	Sport Utility Vehicle	Diesel	SUVDiesel	Not Used	
13	Sport Utility Vehicle	Gasoline	SUVHybridGasoline	Not Used	
14	Sport Utility Vehicle	Gasoline	SUVGasoline	Not Used	

	Vehicle Types	Fuel Type	Model ID	Units	Occupancy or Load Factor
15	Motorcycle	Gasoline	MotoGasoline	pass/veh	1.3
16	3 Wheel, Trawlergi	Diesel	OtherDiesel	ton/veh	0.2

Source: Consultant

M. Calibration Results

60. Aside from the results of the fuel demand calibration which validate the model, the model generated some interesting aggregate statistics allowing for the profiling of the Myanmar vehicle parc by vehicle class fraction, shown in Table II-12, and the share of fuel type, shown in Table II-13.

Table II-12: Vehicle Class as % of Total Road Vehicle (2013-14)

	Count	%
CarDiesel	138,447	3.4%
CarHybridGasoline	18,324	0.5%
CarGasoline	221,325	5.5%
BusDiesel	21,043	0.5%
HCVDiesel	49,760	1.2%
MCVDiesel	-	
MCVGasoline	-	
LCVDiesel	47,537	1.2%
LCVGasoline	13,408	0.3%
MBTDiesel	-	-
MBTGasoline	-	-
SUVDiesel	-	-
SUVHybridGasoline	-	-
SUVGasoline	-	-
MotoGasoline	3,418,918	85.0%
OtherDiesel	91,738	2.3%
TOTAL	4,020,500	100.0%

Source: Consultant; note where entries are blank, the vehicle class was not modelled

Table II-13: Split of Vehicle Types by Fuel (2005-06 to 2013-14)

	2005-06	2006-07	2007-08	2008-09	2009-10	2010-11	2011-12	2012-13	2013-14
Diesel Vehicles	19.4%	19.7%	20.4%	10.8%	11.0%	10.6%	11.0%	7.7%	8.7%
Gasoline Vehicles	79.5%	79.1%	78.4%	88.5%	88.3%	88.8%	88.4%	91.8%	90.9%
CNG Vehicles	1.2%	1.2%	1.3%	0.7%	0.7%	0.7%	0.7%	0.5%	0.5%

Source: Consultant; note that gasoline vehicles include motorcycles

61. The model generated total vehicle-km which, when combined with assumptions of occupancy and load factor as discussed above, enables the calculation of demand for passenger-km by passenger transport modality and freight ton-km by freight modality. The historical demand for passenger services in billion passenger-km is shown on the following table:-

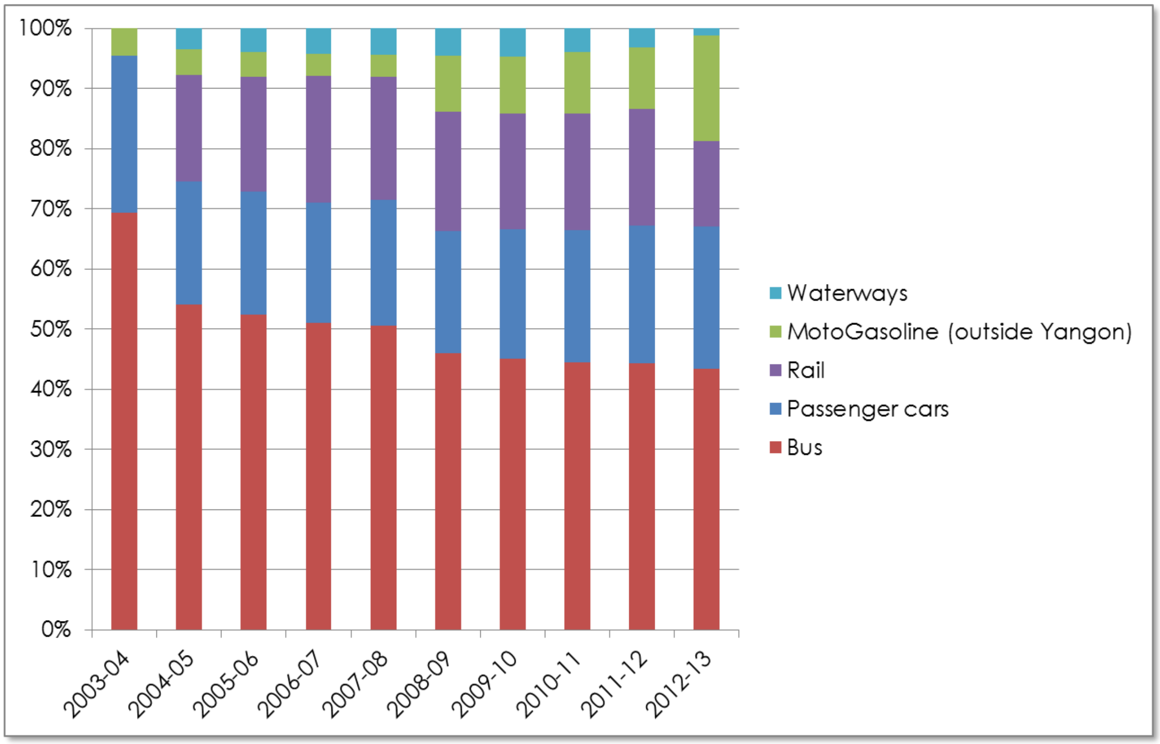
Table II-14: Passenger Services Historical Demand (billion pass-km)

	2005-06	2006-07	2007-08	2008-09	2009-10	2010-11	2011-12	2012-13	2013-14
Cars	4.9	5.0	5.3	5.6	5.9	6.0	6.3	6.5	8.7
Bus	12.5	12.7	13.0	12.6	12.4	12.2	12.1	12.0	11.5
Motos	1.0	0.9	0.9	2.6	2.6	2.8	2.8	4.8	5.1
Rail	4.6	5.2	5.3	5.5	5.3	5.3	5.3	3.9	3.6
Waterways	0.9	1.0	1.2	1.3	1.3	1.1	0.9	0.3	0.3
Total	23.8	24.9	25.7	27.5	27.4	27.5	27.2	27.5	29.2
Airways	0.2	0.1	0.1	0.1	0.1	0.1	0.2	0.2	0.2

Source: Consultant

62. The table above is also presented as a modal split for passenger freight transport, on billion passenger-km basis, is shown in Figure II-15. There is a heavy dependence on bus transportation, related to the affordability of passenger cars.

Figure II-15: Modal Split of Passenger Transport (billion pass-km)



Source: Consultant

63. The historical demand for freight services in billion ton-km is shown by the following table:-

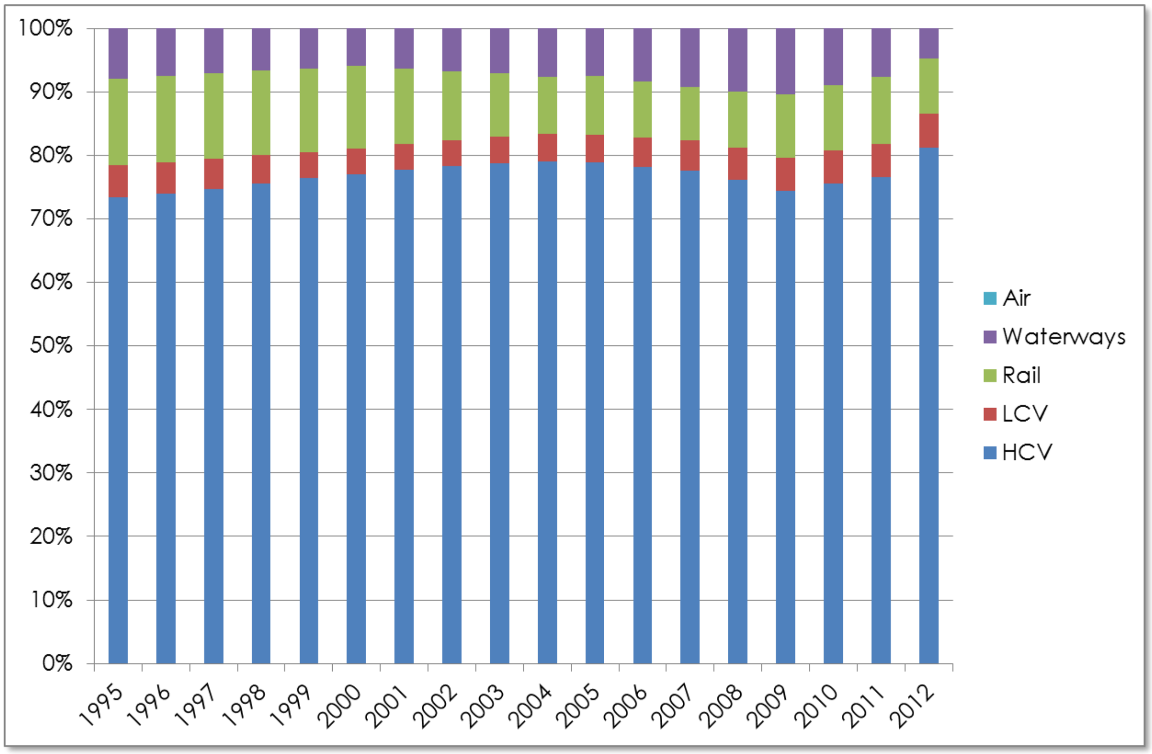
Table II-16: Freight Services Historical Demand (billion ton-km)

	2005-06	2006-07	2007-08	2008-09	2009-10	2010-11	2011-12	2012-13	2013-14
HCV	4.9	4.9	5.0	5.0	5.0	5.2	5.3	5.8	5.9
LCV	0.3	0.3	0.3	0.3	0.3	0.4	0.4	0.4	0.4
Railway	0.6	0.6	0.5	0.6	0.7	0.7	0.7	0.6	0.6
Waterways	0.5	0.5	0.6	0.6	0.7	0.6	0.5	0.3	0.3
Air	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Source: Consultant's estimate

64. The corresponding modal split for the freight sector is shown in Figure II-17. The split shows a heavy dependence on heavy freight vehicles. This feature is related to the role that rail is currently playing in the freight services market. It has been reported in the press in recent times that heavy freight vehicles are causing congestion in Yangon, as they move goods from the port locations.

Figure II-17: Modal Split of Freight Transport (billion ton-km)



Source: Consultant

65. The most important validation is a comparison of the model fuel demand with actual fuel sales for the calibration years. The validation of the demand model requires data on fuel sales specific to each of the passenger and freight transport sectors.

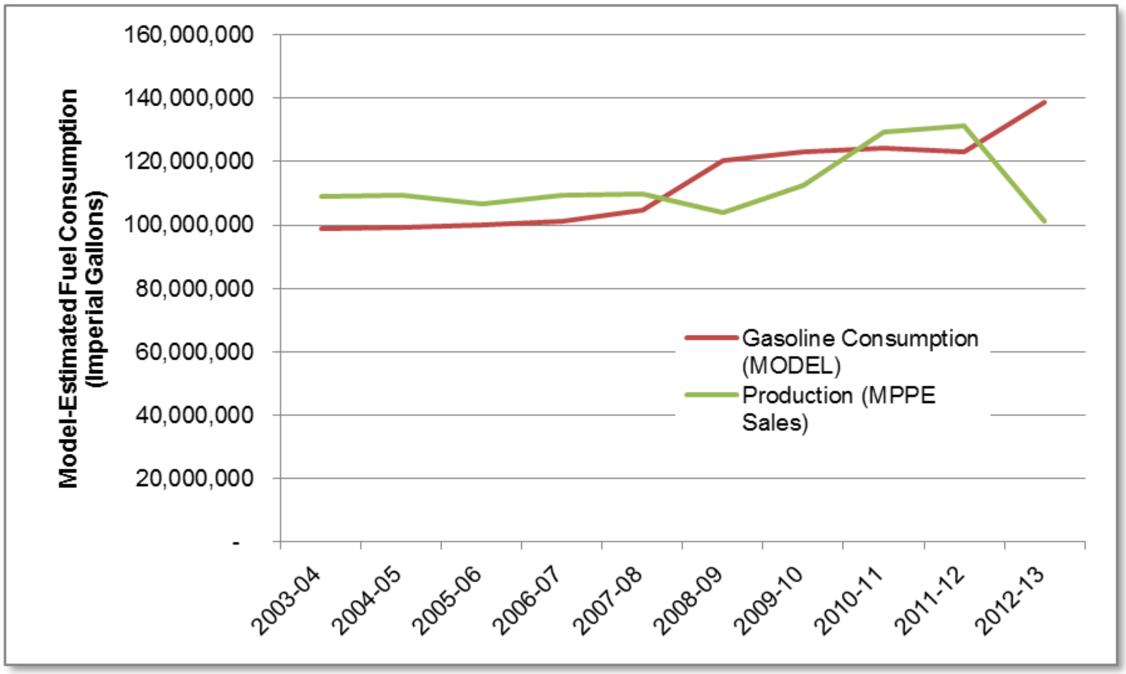
66. Gasoline statistics are shown in Table II-18 and Figure II-19, the gasoline use in recent years is in good agreement with the model. The calibration of diesel production and consumption is complicated by the fact that diesel fuel is consumed across multiple sectors. Moreover, large volumes of diesel fuel have been imported in recent years. An HSD balance has been constructed for the economic and household sectors that indicates that the transport sector diesel consumption determined by the transport model lies within the expected bounds. Table **II-21** below provides the reconciliation which shows a 2% gap between reported HSD consumption and modelled consumption.

Table II-18: Gasoline Statistics '000's IG: 2008 – 2013

	2008-09	2009-10	2010-11	2011-12	2012-13
Gasoline Consumption	120,261	123,168	124,305	123,281	138,568
Gasoline Production	103,853	112,615	129,290	131,162	101,220

Source: Production – CSO, MPPE; Consumption: Consultant

Figure II-19: Gasoline Statistics



Source: Consultant, CSO Myanmar Productions Statistics

Table II-20: Diesel Fuel (HSD) – IG '000's: 2005 - 2013

	Transport Sector HSD	Total HSD	Diesel on Total
	IG '000's	IG '000's	%
2005	133,783	169,821	79%
2006	136,182	175,013	78%
2007	143,374	184,538	78%
2008	146,998	192,493	76%
2009	157,897	206,068	77%
2010	168,159	219,282	77%
2011	179,614	238,743	75%
2012	192,351	256,619	75%
2013	243,736	310,725	78%

Source: Consultant

Table II-21: Diesel Fuel – thousands IG (2008 - 2013)

	HSD Local Production & Imports	Consultant's Estimate
2005	119,354	169,821
2006	246,290	175,013
2007	129,843	184,538
2008	162,944	192,493
2009	160,692	206,068
2010	346,559	219,282
2011	328,935	238,743
2012	227,822	256,619
2013	276,623	310,725
Total	1,999,062	1,953,300

Source: Consultant

III. TRANSPORTATION ENERGY FORECAST

N. Background

67. The last century has seen exceptionally rapid growth in the human population and its demand for resource, particularly energy. It might be argued that this rate of change results from the availability of cheap and accessible energy. Clearly, predicting future consumption patterns, particularly in the context of climate change and the diminishing abundance of oil, is a very challenging task. In building up the components of a model, the developer will typically look for patterns or consistencies in the behaviour of the critical aspects of the system to which the outcomes are most sensitive. Aspects of transport systems investigated in the development of this model include:

- The evolution of the number of vehicles per capita, called motorization (vehicles/1000 people) with changing income per capita;
- The total time people spend travelling per day, called the Travel Time Budget (TTB); and
- The future improvement of the energy conversion efficiency of vehicles, termed as the fuel economy, due to technological change, environmental regulations and possible sharp increases in oil price. Large improvements in fuel economy are possible with current technology by manufacturing smaller and less powerful cars.

68. Future energy demand is highly dependent on the number of vehicles, how much they are driven and their energy conversion efficiencies and some literature dealing with these issues are referenced during the course of developing transport energy forecasts. The future energy demand of the transport sector was calculated in terms of services performed ("useful" energy) as opposed to amount of energy supplied ("final" energy). This allows analysis of the substitution between alternative energy forms, as well as an appraisal of the evolution of the technological improvements in vehicles.

69. The baseline for transport energy services was established as described above with a careful calibration of the vehicle parc model. The baseline provides a foundation from which to project future fuel demand by the transport sector when augmented with the following key assumptions:

- Projected total passenger and commercial vehicle sales;
- The percentage of different technology types within those sales. In the case of passenger vehicles these would include gasoline, diesel, CNG / hybrid gasoline cars. In future hybrid diesel, natural gas, fuel cell and electric vehicles may also become important;
- The projected fuel economy of the technology types; and
- The evolution of annual vehicle km travelled due to growing cities and possible growing affluence.

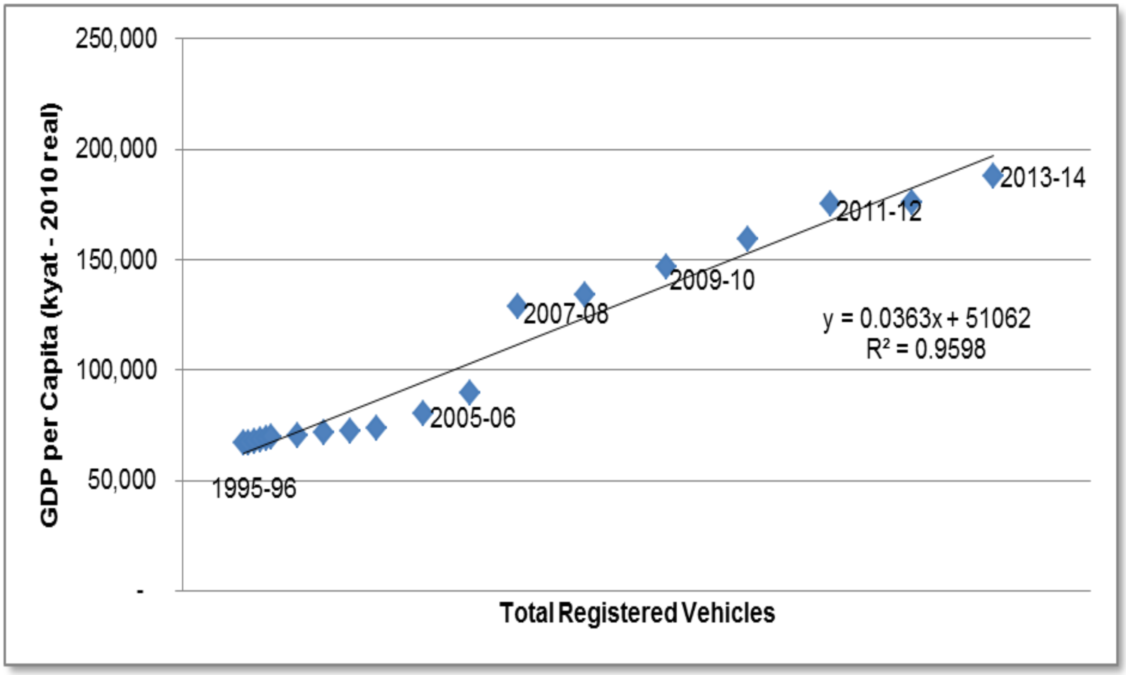
70. The base year technology penetration rates, fuel economies and vehicle mileages are validated outputs from the vehicle parc model. Two steps were then used to project energy demand:-

- Using population and GDP-driven demand for mobility is projected for different modes and transport classes; and.
- Given projected demand for mobility for each mode, a mix of technologies is established to meet this demand, based on techno-economic criteria.

O. Motorisation

71. The relationship between motorisation (vehicles per 1000 population), particularly passenger car motorisation, and GDP/capita is well documented. In general motorisation increases more or less linearly with GDP/capita until saturating and is thus usually modelled with an s-shaped Gompertz curve. However, in Myanmar saturation is a distant expectation and a linear relationship is assumed as shown in Figure III-1.

Figure III-1: GDP per Capita versus Total Registered Vehicles



Source: Consultant

P. Passenger Services Demand

72. Passenger services demand is specified in passenger-kilometres or passenger-miles. The statistic 'passenger-miles' is reported by the CSO on annual basis for each of the passenger transport sectors. This demand is determined by the time-travel budget of the population, i.e. the amount of time each person spends travelling each day. In this regard there is an observation of particular relevance, viz a viz, the time spent travelling, across the population, does not vary. The observed rule is that people spent on average 1.1 hours per day travelling, irrespective of income strata. This means that the demand can be projected according to observed trends in travel time and population growth.

73. The supply of passenger km is a more difficult to forecast. The choice between public and private transport depends on access and effectiveness of the services, whether private vehicle, mass transit bus or light rail. As mentioned above, it is observed that passenger vehicle ownership rises with household income. However, robust modelling of household income requires an economic model (CGE model) and this is not available to the Consultant at this time. In the absence of an economic model, GDP per capita has been used as a proxy measure. The following chart shows the straight line

relationship between GDP per capita (constant 2010) and vehicle stocks; a useful relationship in transport demand forecasting.

74. Other factors that affect the supply of transport service are the reported state of the road network and the impact of congestion. Average travel speeds tend to reduce with city size and may act as a deterrent to private vehicle ownership if public transport offers a speedier alternative for daily commuters. As Myanmar's industrial and services sectors grow, it is likely that the urban population will increase at a faster rate than the rural population creating added pressure on the road network.

75. Taking these factors into account, passenger services demand for road transport has been determined as the product of the average kilometres travelled per hour, the travel time budget of 1.1 hours per day, 300 days travel per year and the number of travelling passengers. The transport model determined the average speed of passenger cars in 2012 to be around 40km per hour. The passenger services demand forecast has been based on a projection of the number of passengers, and according to an allocation to passenger transport mode. The allocation can be adjusted, allowing for alternative transport energy projections. In the case of rail and waterways travel, passenger services are of a relatively long distance nature by comparison to intra-city transport and the demand has been forecast based on historical trend.

Q. Freight Services Demand

76. Freight ton-km demand is determined by economic activity, particularly in the industry sectors of mining and construction where heavy haulage is required. The relationship between GDP and freight ton-km is an important indicator for forecasting.

77. The supply of freight ton-km is also influenced by Government policy, e.g. in relation to rail over road. In Myanmar, integration into the ASEAN road network would increase road freight transport. Increased import and export trading activities via sea routes will rely on land container freight haulage to and from ports. Freight transport services demand has been forecast based on GDP growth.

R. Reference & Alternative Case

78. A reference case forecast has been prepared as described above. The reference case is a 'business-as-usual' case. No significant shifts in transport efficiency, no fuel substitution or other major changes are considered.

79. An alternative low CO2 case has been prepared by making the following adjustments to the reference case. No changes have been made to the freight services supply and the alternative Case remains the same as the reference case. Specific changes are as follows:-

- Vehicle fuel efficiency is assumed to increase at a rate of 2% per annum (instead of 1%); and
- Bioethanol is introduced in 2020, mixed with gasoline in proportion to 10: 90 (gasoline at 90%), and increasing on pro-rata basis to 20:80 by 2030.

S. Transport Services & Fuel Forecasts

80. The forecasts are presented in the following order:-

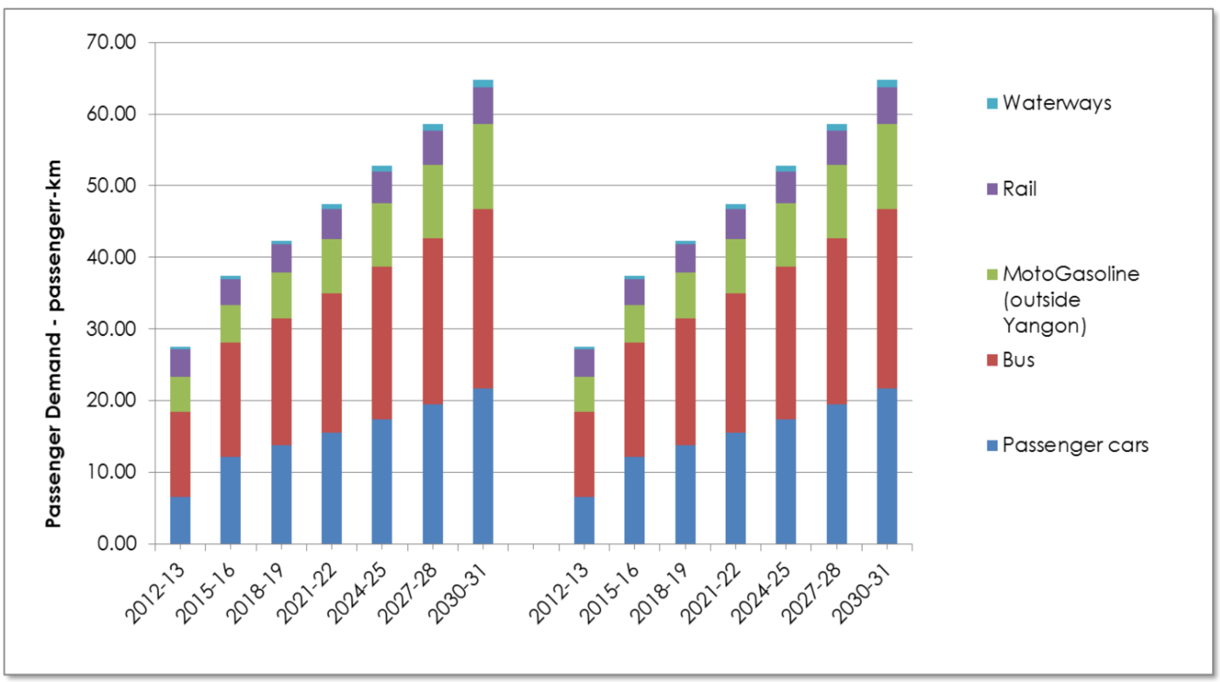
- Passenger services demand forecast;
- Passenger vehicle-km forecast;
- Passenger services supply forecast by mode;
- Freight services demand forecast;
- Freight vehicle-km forecast;
- Freight vehicle forecast by mode;
- Vehicle sales projections;
- Vehicle PARC projections;
- Average vehicle fuel economy;
- Fuel sales projections;
- CO2 emissions (million tons per annum); and
- CO2 intensity (emissions per transport services)

Table III-2: Passenger Services Demand Forecast

	Reference							Alternative Case						
	2012	2015	2018	2021	2024	2027	2030	2012	2015	2018	2021	2024	2027	2030
	Annual passenger travel demand projections (bill pass-km)													
Passenger cars	6.5	12.1	13.8	15.5	17.4	19.4	21.7	6.5	12.1	13.8	15.5	17.4	19.4	21.6
Bus	12.0	16.0	17.7	19.5	21.3	23.2	25.1	12.0	16.0	17.7	19.5	21.3	23.2	25.1
Motorcycles	4.8	5.2	6.4	7.5	8.8	10.3	11.9	4.8	5.2	6.4	7.5	8.8	10.3	11.9
Rail	3.9	3.7	4.0	4.2	4.5	4.8	5.0	3.9	3.7	4.0	4.2	4.5	4.8	5.0
Waterways	0.3	0.4	0.5	0.7	0.8	0.9	1.1	0.3	0.4	0.5	0.7	0.8	0.9	1.1
Total	27.5	37.4	42.3	47.4	52.8	58.6	64.8	27.5	37.4	42.3	47.4	52.8	58.6	64.8
	Annual passenger road vehicle-km projections (bill veh-km)													
Passenger cars	4.6	9.0	9.6	10.4	11.4	12.6	13.9	4.6	9.0	9.6	10.4	11.4	12.6	13.9
Bus	0.5	0.7	0.8	0.8	0.9	0.9	1.0	0.5	0.7	0.8	0.8	0.9	0.9	1.0
Motorcycles	3.7	4.4	5.1	5.9	6.8	8.0	9.3	3.7	4.4	5.1	5.9	6.8	8.0	9.3

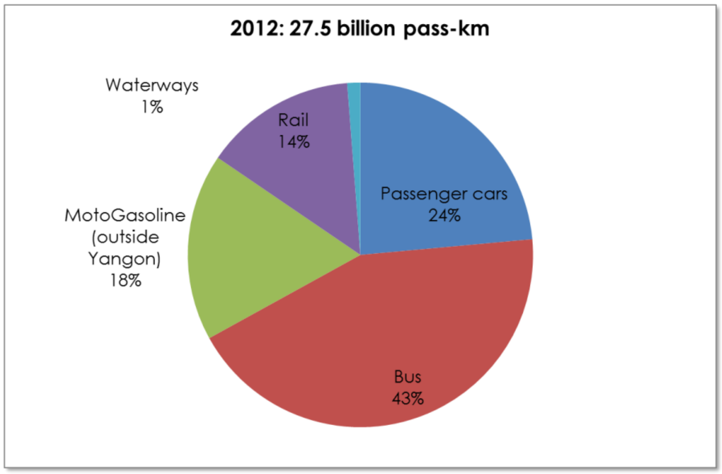
Source: Consultant

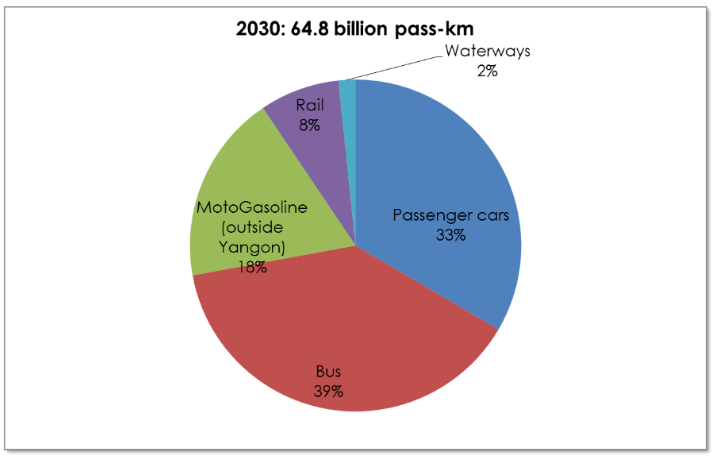
Figure III-3: Projection of Passenger Transport Demand (p-km) by Mode

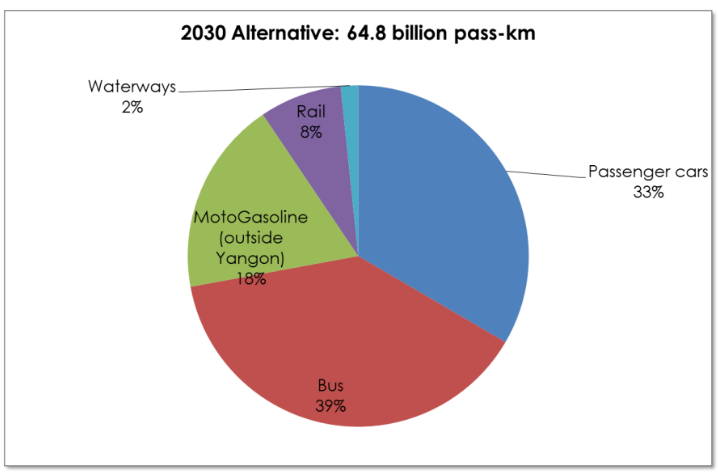


Source: Consultant

Figure III-4: Share of Passenger-km







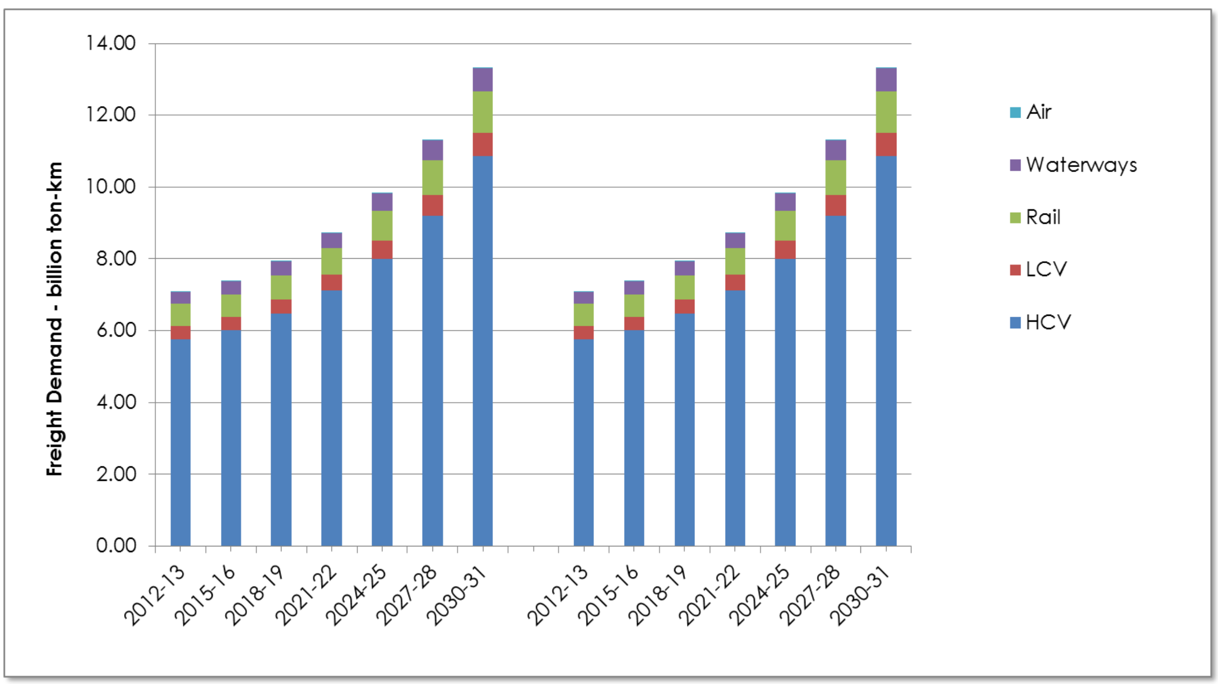
Source: Consultant

Table III-5: Freight Services Demand Forecast

	Reference Case							Alternative Case						
	2012	**2015**	**2018**	**2021**	**2024**	**2027**	**2030**	**2012**	**2015**	**2018**	**2021**	**2024**	**2027**	**2030**
			Annual freight demand projections (bill ton-km)											
HCV	5.8	6.0	6.5	7.1	8.0	9.2	10.9	5.8	6.0	6.5	7.1	8.0	9.2	10.9
LCV	0.4	0.4	0.4	0.4	0.5	0.6	0.7	0.4	0.4	0.4	0.4	0.5	0.6	0.7
Rail	0.6	0.6	0.7	0.8	0.9	1.0	1.2	0.6	0.6	0.7	0.8	0.9	1.0	1.2
Waterways	0.3	0.4	0.4	0.4	0.5	0.5	0.6	0.3	0.4	0.4	0.4	0.5	0.5	0.6
Air	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	7.1	7.4	7.9	8.7	9.8	11.3	13.3	7.1	7.4	7.9	8.7	9.8	11.3	13.3
			Annual road freight vehicle-km projections (bil veh-km)											
HCV	1.77	2.20	2.26	2.47	2.81	3.3	4.0	1.77	2.18	2.25	2.44	2.78	3.25	3.91
LCV	0.96	1.08	1.12	1.17	1.24	1.3	1.5	0.96	1.08	1.12	1.17	1.24	1.33	1.45

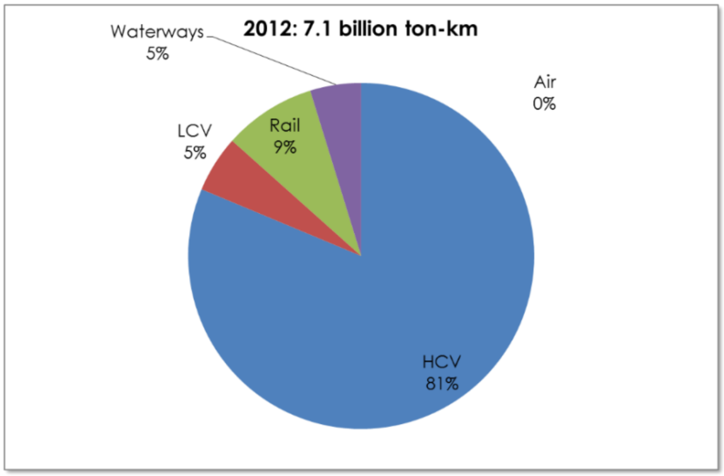
Source: Consultant

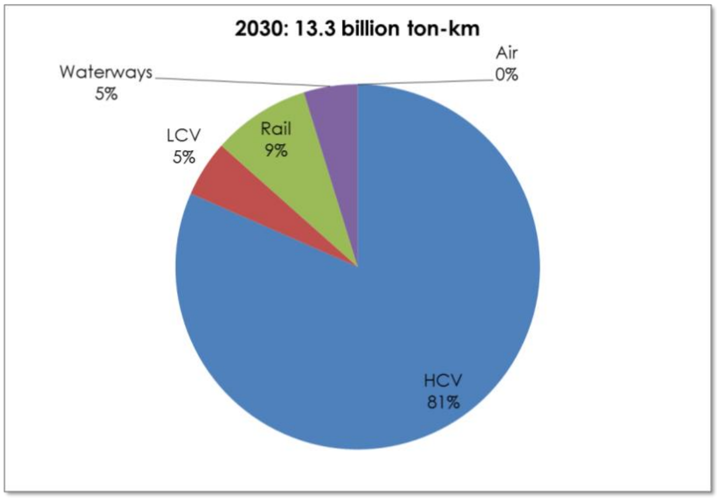
Figure III-6: Projection of Freight Transport Demand (ton-km) by Mode

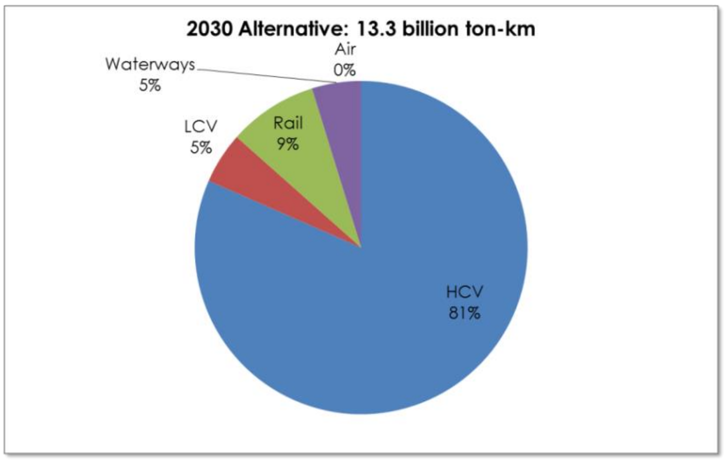


Source: Consultant

Figure III-7: Share of Freight ton-km







Source: Consultant

Table III-8: Vehicle Sales Projections

	Reference						
	2012	2015	2018	2021	2024	2027	2030
Passenger car	21,369	33,929	39,850	46,432	53,170	59,648	65,304
Motorcycle	1,263,967	411,458	453,323	534,669	651,343	768,537	843,635
Bus	662	1,416	1,594	1,786	1,980	2,162	2,324
Heavy Commercial Vehicle	3,821	2,751	2,971	3,989	5,002	6,214	7,787
Light Commercial Vehicle	8,583	4,300	4,555	4,915	5,474	6,121	6,623
3 Wheel, Trawlergi	3,316	7,380	9,220	11,280	13,519	15,935	18,577
Total	1,280,348	427,306	471,663	556,639	677,318	798,970	878,945

	Alternative Case						
	2012	2015	2018	2021	2024	2027	2030
Passenger car	21,369	33,929	39,850	46,432	53,170	59,648	65,290
Motorcycle	1,263,967	411,458	453,323	534,669	651,343	768,537	843,635
Bus	662	1,416	1,594	1,786	1,980	2,162	2,324
Heavy Commercial Vehicle	3,821	2,751	2,971	3,989	5,002	6,214	7,787
Light Commercial Vehicle	8,583	4,300	4,555	4,915	5,474	6,121	6,623
3 Wheel, Trawlergi	3,316	7,380	9,220	11,280	13,519	15,935	18,577
Total	1,301,717	461,235	511,513	603,071	730,489	858,618	944,235

Source: Consultant

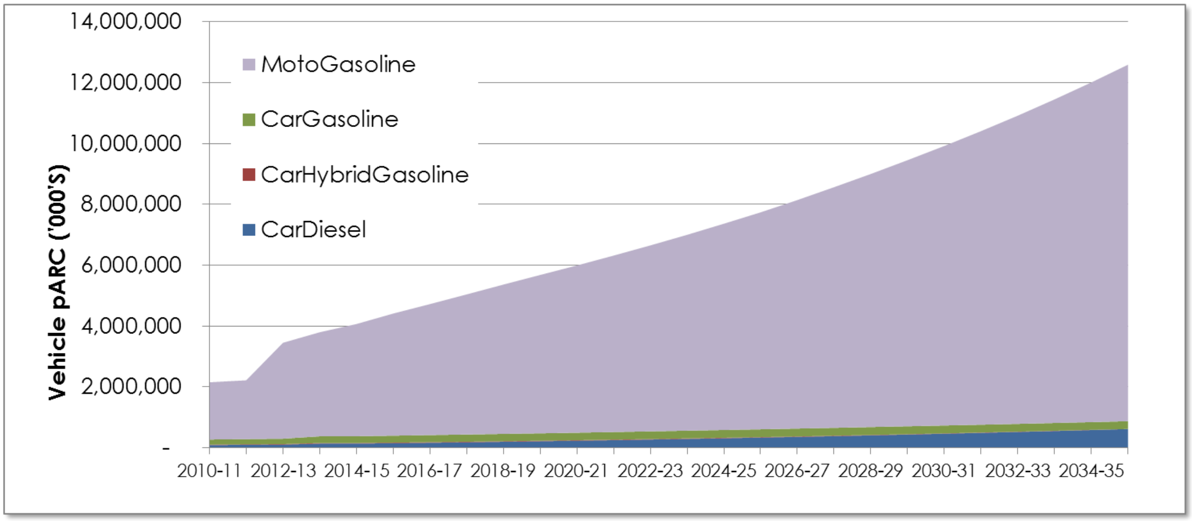
Table III-9: Vehicle PARC

	Reference						
	2012	2015	2018	2021	2024	2027	2030
Passenger car	298,861	527,670	602,653	194,234	769,640	862,448	961,958
Motorcycle	3,153,201	4,012,298	4,907,778	5,799,181	6,779,526	7,907,553	9,186,215
Bus	21,051	29,279	32,464	35,728	39,070	42,490	45,986
Heavy Commercial Vehicle	41,075	51,024	54,882	60,401	67,994	78,195	92,163
Light Commercial Vehicle	53,730	63,907	70,303	76,671	83,673	91,731	100,864
3 Wheel, Trawlergi	72,119	99,443	117,745	139,542	165,503	196,423	233,249
Total	3,640,037	4,783,622	5,785,826	6,305,756	7,905,406	9,178,840	10,620,436

	Alternative Case						
	2012	2015	2018	2021	2024	2027	2030
Passenger car	298,861	527,670	602,653	194,234	769,640	862,448	961,935
Motorcycle	3,153,201	4,012,298	4,907,778	5,799,181	6,779,526	7,907,553	9,186,215
Bus	21,051	29,279	32,464	35,728	39,070	42,490	45,986
Heavy Commercial Vehicle	41,075	51,024	54,882	60,401	67,994	78,195	92,163
Light Commercial Vehicle	53,730	63,907	70,303	76,671	83,673	91,731	100,864
3 Wheel, Trawlergi	72,119	99,443	117,745	139,542	165,503	196,423	233,249
Total	3,640,037	4,783,622	5,785,826	6,305,756	7,905,406	9,178,840	10,620,413

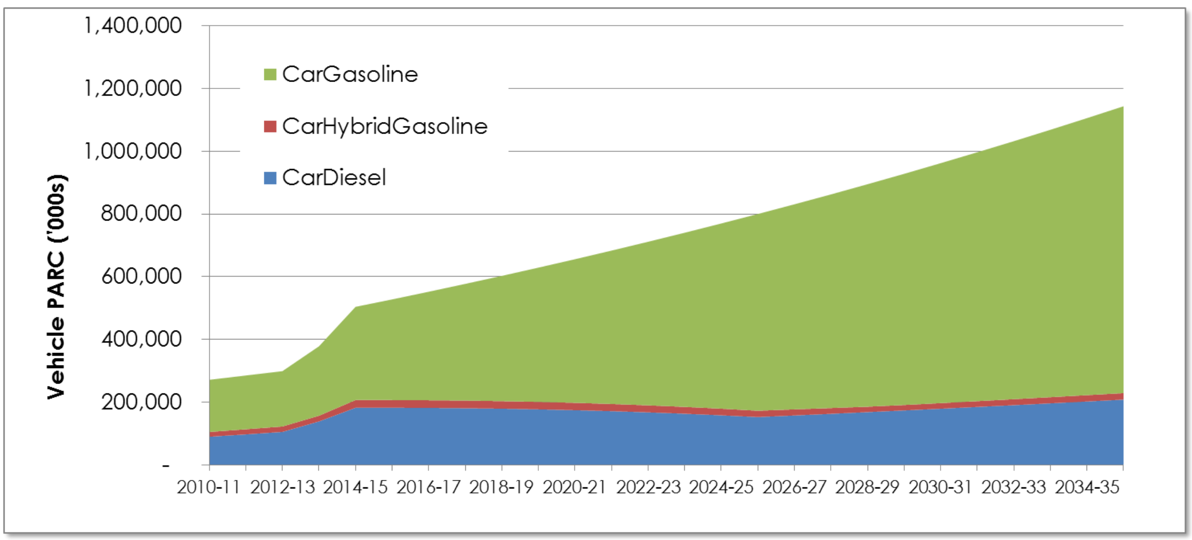
Source: Consultant

Figure III-10: Vehicle PARC (All Passenger Vehicles)



Source: Consultant

Figure III-11: Vehicle PARC (excluding motorcycles)



Source: Consultant

Table III-12: Average Passenger Vehicle Fuel Economy (litres per 100km)

	Reference							Alternative Case						
	2012	2015	2018	2021	2024	2027	2030	2012	2015	2018	2021	2024	2027	2030
Gasoline cars	16.9	18.0	18.1	18.1	18.0	17.7	17.1	16.9	18.0	18.0	18.1	18.0	17.7	17.1
CNG cars*	10.7	10.6	9.9	9.4	8.8	7.9	8.0	10.7	10.6	9.9	9.4	8.8	7.9	6.4
Diesel cars	18.0	18.3	17.4	16.6	15.0	14.9	15.1	18.0	18.3	17.4	16.6	15.0	14.9	15.1
Gasoline motos	4.4	4.4	4.3	4.4	4.4	4.4	4.4	4.4	4.4	4.3	4.4	4.4	4.4	4.4
Diesel bus	21.8	21.6	21.4	20.8	20.3	21.3	21.3	21.8	21.6	21.3	20.6	20.1	21.1	21.1

Source: Consultant

Table III-13: Average Freight Vehicle Fuel Economy (litres per 100km)

	Reference							Alternative Case						
	2012	2015	2018	2021	2024	2027	2030	2012	2015	2018	2021	2024	2027	2030
Diesel HCV	19.5	19.6	19.5	18.9	19.8	18.96	18.6	19.5	19.6	19.4	18.8	19.7	18.8	18.5
Diesel LCV	12.4	12.1	12.0	12.0	12.0	11.78	11.8	12.4	12.1	12.0	12.0	12.0	11.7	11.7
Gasoline LCV	12.5	12.3	12.2	12.2	12.3	12.13	12.1	12.5	12.3	12.2	12.2	12.3	12.1	12.1

Source: Consultant

Table III-14: Total Fuel Sales Projection

	Reference						
	2012	2015	2018	2021	2024	2027	2030
Gasoline (IG - 000's)	138,568	262,495	313,401	373,072	437,381	485,485	519,767
Bioethanol (IG - 000's)	-	-	-	-	-	-	-
Diesel (IG - 000's)	192,351	283,269	268,451	259,578	264,090	291,511	338,510
Natural Gas (cub m - 000's)	37,326	52,971	43,164	35,197	27,509	19,751	20,839
Jet Fuel (IG '000s)	9,211	9,250	14,800	20,350	25,900	31,450	37,000
	Alternative Case						
	2012	**2015**	**2018**	**2021**	**2024**	**2027**	**2030**
Gasoline (IG - 000's)	138,568	262,451	313,243	335,738	382,597	413,114	437,354
Bioethanol (IG - 000's)	-	-	-	37,082	54,487	72,024	84,832
Diesel (IG - 000's)	192,350	283,137	267,838	258,468	262,703	290,054	337,020
Natural Gas (cub m - 000's)	37,325	52,969	43,154	35,156	27,439	19,655	11,409
Jet Fuel (IG '000s)	9,211	9,250	14,800	20,350	25,900	31,450	37,000

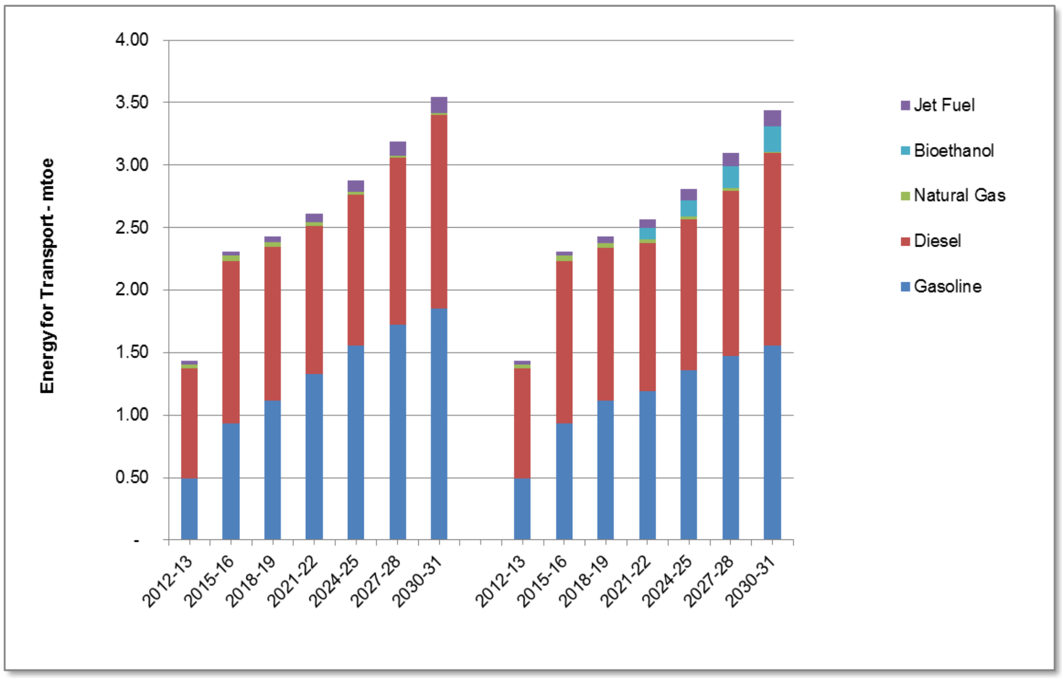
Source: Consultant

Table III-15: Energy for Transport (mtoe)

	Reference							Alternative Case						
	2012	2015	2018	2021	2024	2027	2030	2012	2015	2018	2021	2024	2027	2030
Gasoline	0.49	0.93	1.11	1.33	1.56	1.73	1.85	0.49	0.93	1.11	1.19	1.36	1.47	1.55
Bioethanol	-	-	-	-	-	-	-	-	-	-	0.09	0.13	0.17	0.21
Diesel	0.88	1.30	1.23	1.19	1.21	1.33	1.55	0.88	1.30	1.23	1.18	1.20	1.33	1.54
Natural Gas	0.03	0.05	0.04	0.03	0.02	0.02	0.02	0.03	0.05	0.04	0.03	0.02	0.02	0.01
Jet Fuel (ATF)	0.03	0.03	0.05	0.07	0.09	0.11	0.13	0.03	0.03	0.05	0.07	0.09	0.11	0.13
Total	1.44	2.31	2.43	2.61	2.88	3.18	3.54	1.44	2.31	2.43	2.57	2.81	3.09	3.44

Source: Consultant

Figure III-16: Energy for Transport



Source: Consultant

Table III-17: CO2 Emissions (mtons)

	Reference							Alternative Case						
	2012	2015	2018	2021	2024	2027	2030	2012	2015	2018	2021	2024	2027	2030
Passenger cars	1.57	2.89	3.13	3.43	3.78	4.20	4.66	1.57	2.89		3.20	3.51	3.89	3.99
Public bus	0.34	0.51	0.53	0.57	0.60	0.65	0.70	0.34	0.51	0.53	0.57	0.60	0.65	0.70
Freight	1.74	2.14	2.22	2.41	2.73	3.17	3.77	1.74	2.14	2.22	2.41	2.73	3.17	3.77
Total	3.65	5.60	5.95	6.48	7.19	8.10	9.23	3.65	5.53	2.75	6.17	6.84	7.71	8.46

Table III-18: CO2 Intensity

	Reference							Alternative Case						
	2012	2015	2018	2021	2024	2027	2030	2012	2015	2018	2021	2024	2027	2030
Passenger cars (g CO2 per p-km)	92	112	107	104	103	103	103	92	112	107	98	96	96	89
Freight (g CO2 per ton-km)	274	319	306	301	302	306	310	274	319	306	301	302	306	310

Source: Consultant

Project Number: TA No. 8356-MYA

FINAL REPORT

ENERGY FORECASTS

HOUSEHOLD SECTOR

Prepared for

The Asian Development Bank

and

The Myanmar Ministry of Energy

Prepared by

IES

Intelligent Energy Systems

in association with

MMIC

MYANMAR INTERNATIONAL CONSULTANTS

ABBREVIATIONS

ADB	–	Asian Development Bank
CSO	–	Central Statistics Organisation
FES	–	Fuel Efficient Stove
GDP	–	Gross Domestic Product
GoM	–	Government of the Republic of the Union of Myanmar
MoE	–	Ministry of Energy

UNITS OF MEASURE

toe	–	tons of oil equivalent
ton	–	metric ton
kg	–	kilogram
KJ	–	kilojoule
ks	–	Kyat
MJ	–	megajoule

WEIGHTS AND MEASURES

ktoe	–	1000 toe
MJ	–	1000 kilojoue
kg	–	1000 gram
KJ	–	1000 joule
ton	–	1000 kg

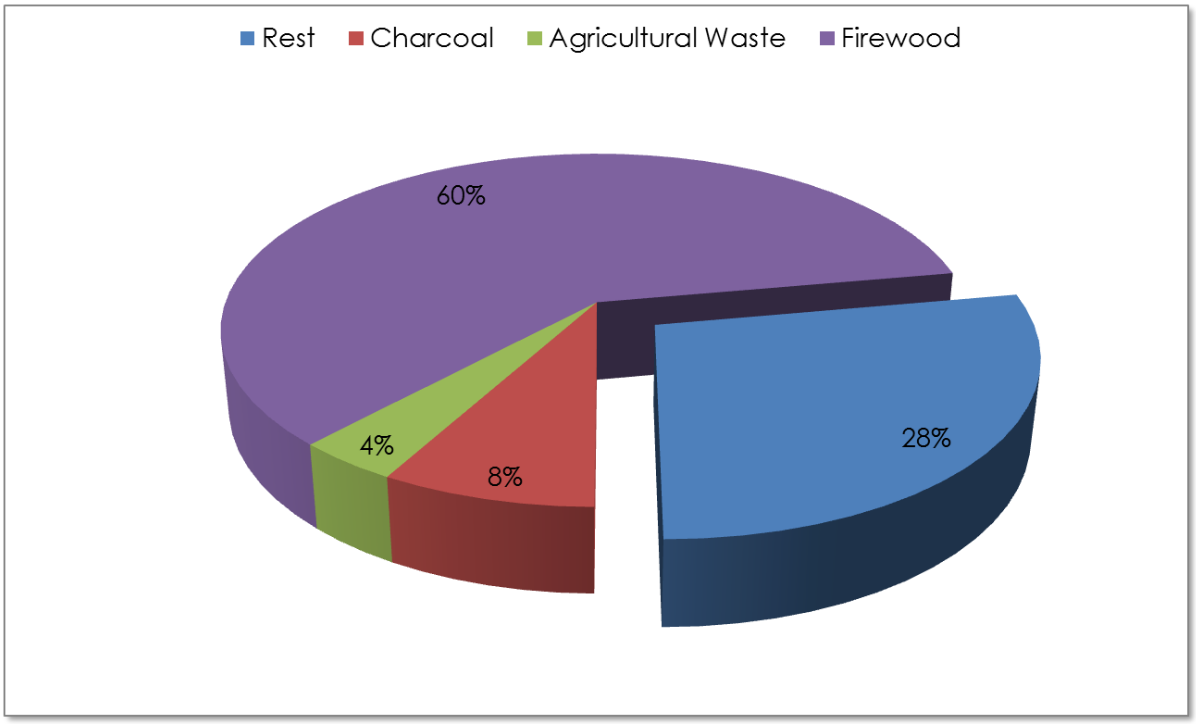
CONTENTS

I. SUMMARY

A. Introduction

1. Household energy accounts for by far the largest consumption of energy in Myanmar due to the large rural population and the daily cooking cycle. Cooking relies on woody biomass as the most important national energy source. In 2013, cooking demand met by biomass sources— firewood, charcoal, agricultural waste, wood waste, and animal dung—amounted to around 72% of total final energy consumed.

Figure I-1: Cooking Fuels: 2013-14

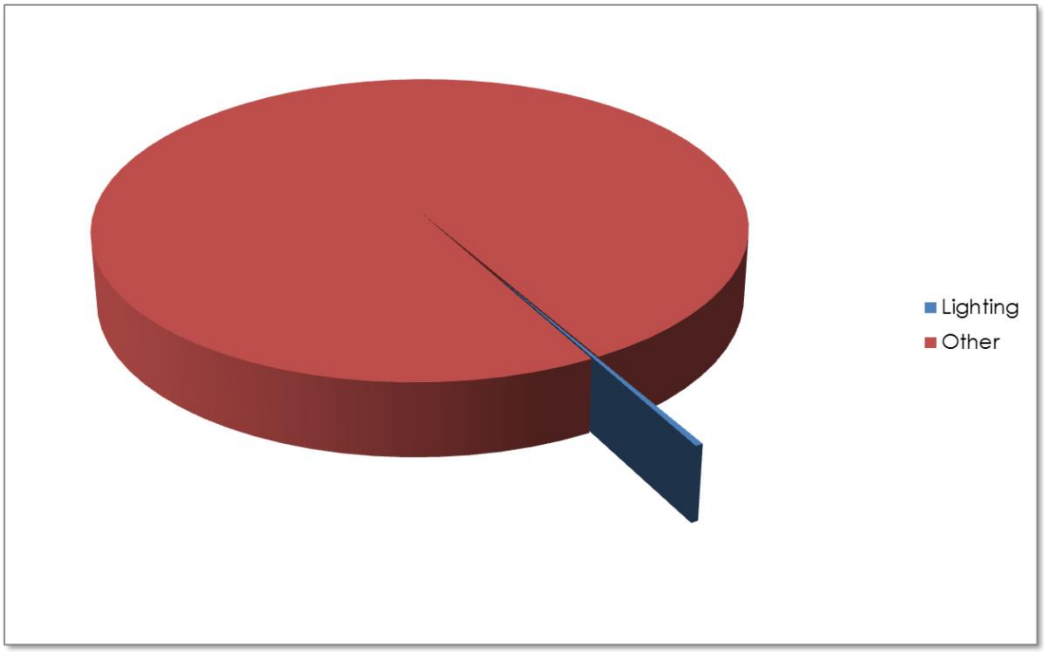


Sources: Consultant

2. In Yangon and urban Mandalay commercial fuels are in use for cooking; electricity, LPGas and charcoal are in common use. Outside of these urban areas, traditional fuels are mainly used along with electricity where it is available.

3. Rural household lighting accounts for a relatively low consumption of the total household energy consumption at less than 1%. Energy used for household cooking dominates household energy consumption. The demand for lighting services is met by on-grid and off-grid sources—by candles, wick lamps, fluorescent bulbs, LED / battery lighting systems, and solar lighting systems. Households without access to electricity, and those with the lowest incomes, rely mainly on candles, oil wick lamps and LED DC lighting.

Figure I-2: Lighting Energy Use: 2012



Sources: Consultant

4. The use of non-commercial fuels in the villages occurs because rural villagers have a very low and sporadic cash income and this poses two problems:-

(i) It limits their fuel options

Poor villagers are able to buy only small amounts of fuel when money is available to do so. This means that fuels that can be purchased in small amounts at low cost will be most viable. It also means that the cheapest fuel will usually be sought, regardless of the harmful health effects that come with the burning of woody biomass.

(ii) There is a limited expendable income to buy appliances

Energy using appliances often require significant capital outlay relative to the household income. A particular consequence is that if electricity or LPGas becomes available, many households will not be able to use these fuels for cooking because of a lack of electrical appliances.

5. Compared to wealthier, electrified households, low income households (mainly rural but also many peri-urban) suffer high levels of harmful emissions by burning wood, woody biomass, charcoal, diesel oil and paraffin. Emissions from these fuels are highly concentrated and slow moving. The use of open fires in the household can also be the cause of accidents that result in injury or death. Electricity and gas are relatively cleans fuel for households, notwithstanding that gas is more hazardous than electricity.

6. Long-term planning requires an accurate depiction of the current household demand for energy on which to base projections of future demand. The EMP household survey, conducted throughout 2014, has provided household end-use data suitable for establishing baseline energy use in 2014.

7. An important planning issue is the potential for fuel substitution over the long-term. The ADB

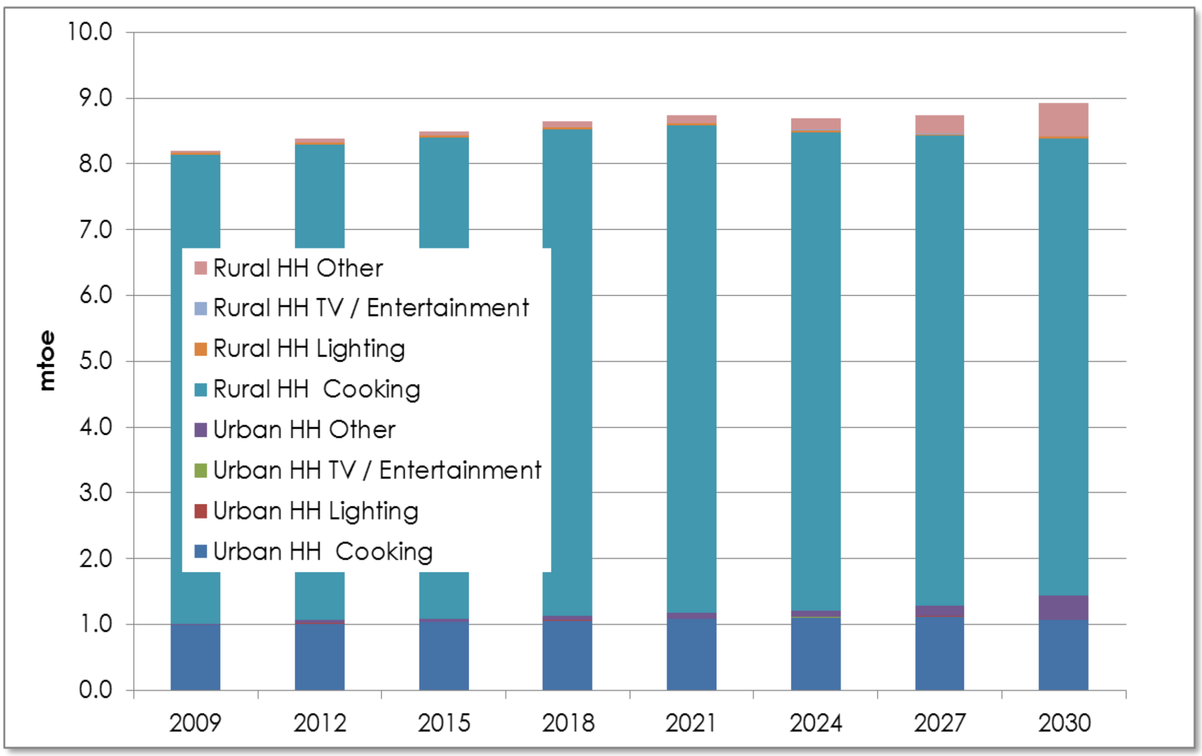
supports a 100% rural electrification program and household energy demand has been projected with the programme in mind. In the case of cooking, electricity access would provide an opportunity for the use of rice cookers. In the case of lighting, electricity access would allow households to switch from candles, diesel oil lamps and battery lighting to electric lights. Care has been taken to ensure that the household electricity use projected in this household sector report, is fully consistent with the State/Region 'top-down' electricity forecasts developed from historical electricity sales data.

B. Household Sector Final Energy Consumption Forecasts

8. The EMP household survey has revealed that the patterns of fuel use for cooking divide into a 'Yangon Division / urban Mandalay' and 'Other' segmentation. For consistency the same segmentation has been used for lighting, TV/entertainment and other energy consumption (cooling services). These segments are hereafter referred to as the 'Urban' and 'Rural' segments.

9. The household sector energy projections are provided as Figure I-3 . The details are given in Table I-4.

Figure I-3: Final Energy Consumption by Household Segment



Sources: Consultant

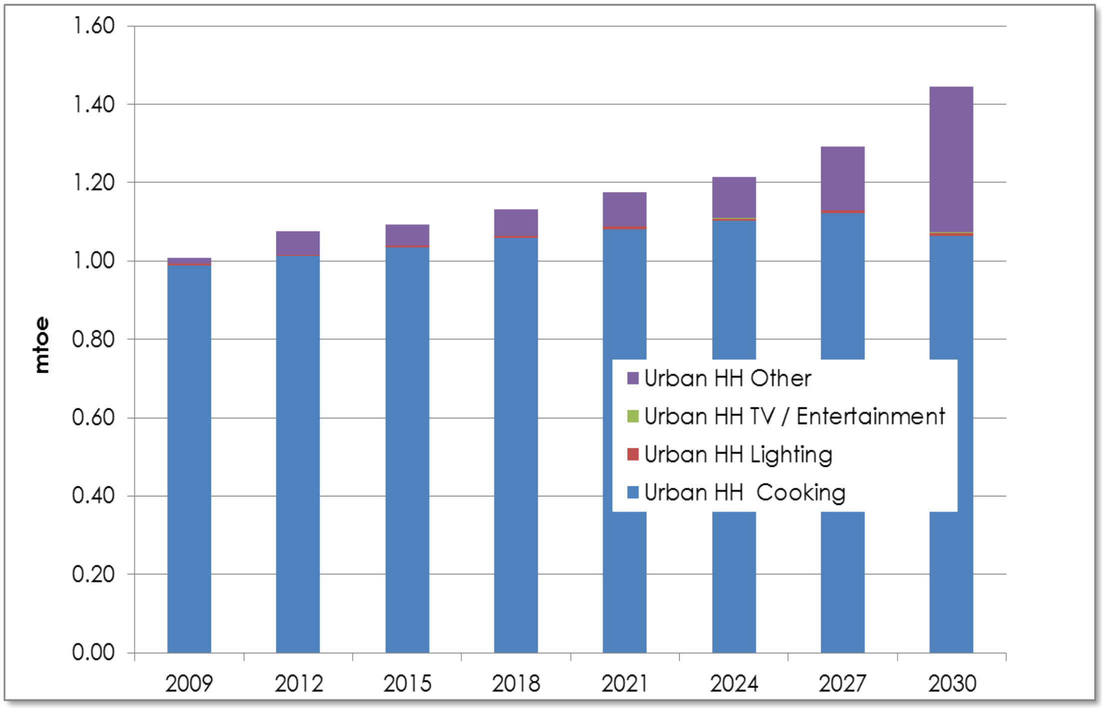
10. Figure I-5 and Figure I-6 provide separate views of final energy consumption for Urban households and Rural households respectively. Table I-7 provides the final energy consumption for electricity only. Table I-8 provides the final energy consumption on a toe per household basis. The toe per capita estimates are consistent with international benchmarks. Figure I-9 to Figure I-15 provide the projections of household fuel carrier consumption (in physical terms).

Table I-4: Household Sector (mtoe)

	2009	2012	2015	2018	2021	2024	2027	2030	CAGR	Comment
Urban HH Cooking	0.9885	1.0121	1.0358	1.0594	1.0819	1.1019	1.1220	1.0651	0.2%	Use of commercial fuels continues
Urban HH Lighting	0.0040	0.0043	0.0046	0.0049	0.0052	0.0059	0.0065	0.0070	2.8%	Candles and wick lamps replaced
Urban HH TV / Entertainment	0.0002	0.0003	0.0005	0.0008	0.0010	0.0013	0.0017	0.0021	9.4%	Leisure hours increasing
Urban HH Other	0.0163	0.0585	0.0519	0.0674	0.0877	0.1050	0.1632	0.3699	13.1%	Air-conditioning, refrigeration, fans, other
Urban HH Total	*1.0090*	*1.0752*	*1.0928*	*1.1325*	*1.1757*	*1.2141*	*1.2934*	*1.4441*	*1.9%*	Increase in line with population rise
Rural HH Cooking	7.1287	7.2167	7.3046	7.3925	7.4056	7.2689	7.1323	6.9382	-0.3%	Firewood displaced by electricity
Rural HH Lighting	0.0239	0.0246	0.0253	0.0260	0.0267	0.0267	0.0266	0.0255	0.1%	Candles and wick lamps replaced
Rural HH TV / Entertainment	0.0009	0.0010	0.0020	0.0030	0.0040	0.0050	0.0060	0.0076	8.8%	Leisure hours increasing
Rural HH Other	0.0297	0.0682	0.0705	0.0941	0.1281	0.1762	0.2735	0.5037	13.1%	Refrigeration, fans, other, cottage industry
Rural HH Total	*7.1832*	*7.3105*	*7.4024*	*7.5156*	*7.5644*	*7.4767*	*7.4384*	*7.4751*	*0.1%*	Efficiency with increased population
Total Urban & Rural	*8.1923*	*8.3857*	*8.4952*	*8.6481*	*8.7401*	*8.6909*	*8.7318*	*8.9192*	*0.3%*	Energy efficiency with increasing population
% Electricity	1.8%	3.4%	4.0%	5.1%	6.6%	8.8%	12.0%	16.4%		

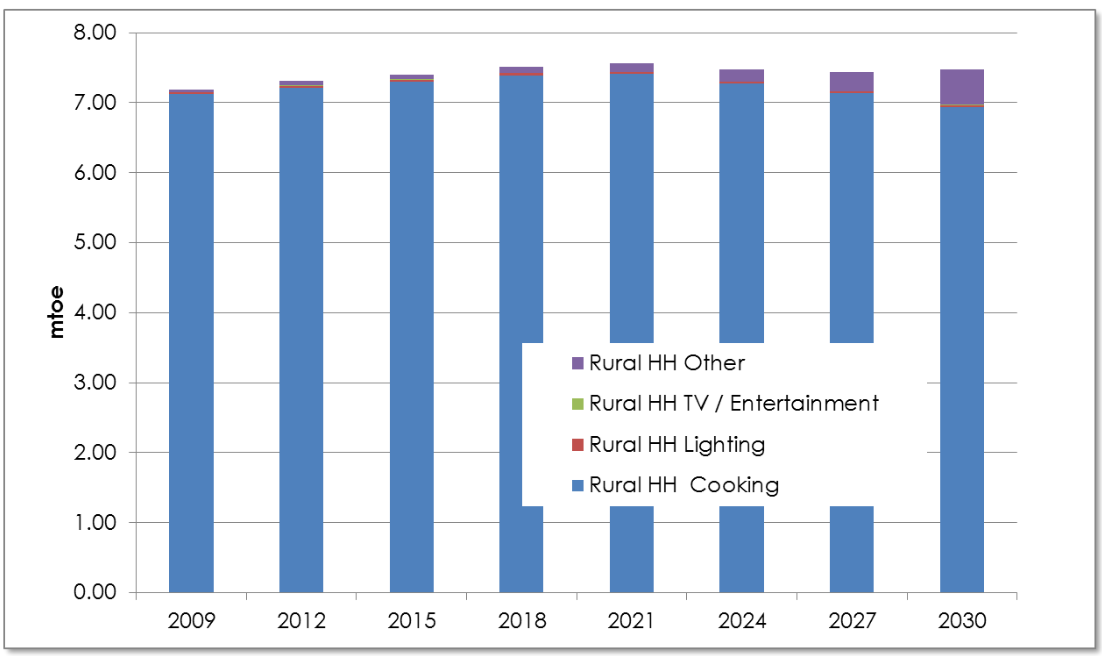
Sources: Consultant

Figure I-5: Urban Household Sector (mtoe)



Sources: Consultant

Figure I-6: Rural Household Sector (mtoe)



Sources: Consultant

Table I-7: Household Sector Electricity Only (mtoe)

	2009	2012	2015	2018	2021	2024	2027	2030	CAGR
Urban HH Cooking	0.0662	0.0905	0.1148	0.1391	0.1768	0.2414	0.3060	0.2905	6.2%
Urban HH Lighting	0.0016	0.0019	0.0021	0.0024	0.0027	0.0037	0.0047	0.0055	6.3%
Urban HH TV / Entertainment	0.0002	0.0003	0.0005	0.0008	0.0010	0.0013	0.0017	0.0021	9.4%
Urban HH Other	0.0163	0.0585	0.0519	0.0674	0.0877	0.1050	0.1632	0.3699	13.1%
Urban HH Total	*0.0844*	*0.1512*	*0.1694*	*0.2097*	*0.2682*	*0.3514*	*0.4755*	*0.6680*	*9.1%*
Rural HH Cooking	0.0285	0.0612	0.0940	0.1267	0.1673	0.2235	0.2798	0.2721	7.1%
Rural HH Lighting	0.0052	0.0057	0.0062	0.0067	0.0072	0.0091	0.0111	0.0128	4.9%
Rural HH TV / Entertainment	0.0009	0.0010	0.0020	0.0030	0.0040	0.0050	0.0060	0.0076	8.8%
Rural HH Other	0.0297	0.0682	0.0705	0.0941	0.1281	0.1762	0.2735	0.5037	13.1%
Rural HH Total	*0.0643*	*0.1362*	*0.1727*	*0.2305*	*0.3066*	*0.4138*	*0.5703*	*0.7964*	*10.2%*
Total Urban & Rural	*0.1488*	*0.2874*	*0.3421*	*0.4402*	*0.5747*	*0.7652*	*1.0458*	*1.4644*	*9.7%*

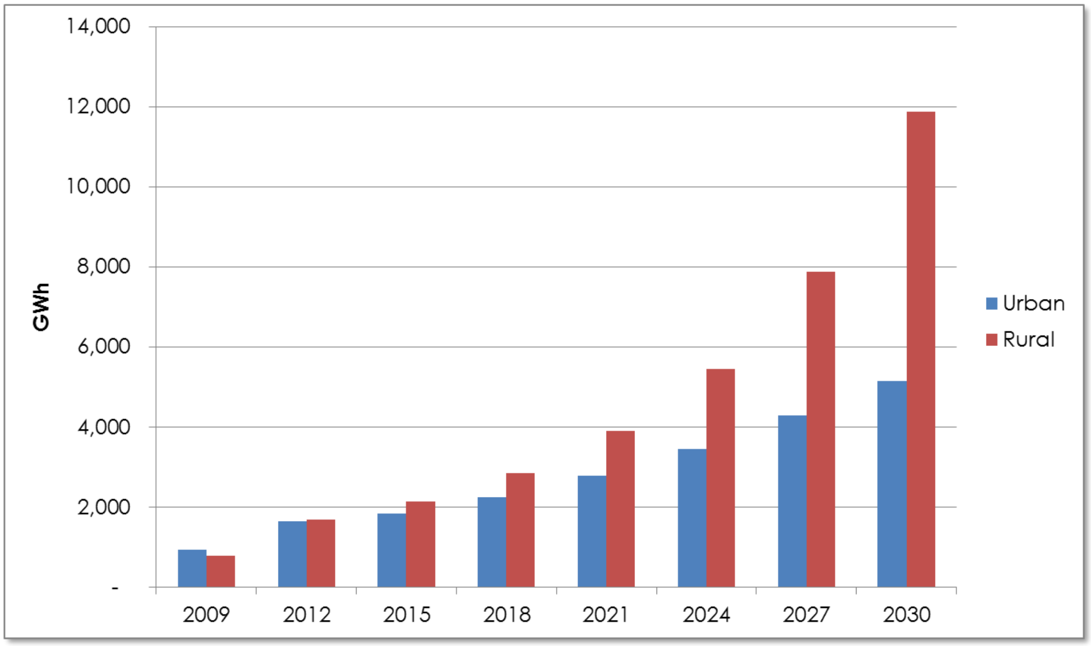
Sources: Consultant

Table I-8: Household Sector Energy (toe per household)

	2009	2012	2015	2018	2021	2024	2027	2030
Urban HH Cooking	0.5196	0.5162	0.4849	0.4552	0.4266	0.3988	0.3727	0.3247
Urban HH Lighting	0.0021	0.0022	0.0021	0.0021	0.0020	0.0021	0.0022	0.0021
Urban HH TV / Entertainment	0.0001	0.0001	0.0002	0.0003	0.0004	0.0005	0.0005	0.0006
Urban HH Other	0.0086	0.0299	0.0243	0.0290	0.0346	0.0380	0.0542	0.1128
Urban HH Total	*0.5304*	*0.5484*	*0.5116*	*0.4866*	*0.4636*	*0.4394*	*0.4296*	*0.4403*
Rural HH Cooking	0.6156	0.6047	0.5941	0.5835	0.5674	0.5405	0.5148	0.4860
Rural HH Lighting	0.0021	0.0021	0.0021	0.0021	0.0020	0.0020	0.0019	0.0018
Rural HH TV / Entertainment	0.0001	0.0001	0.0002	0.0002	0.0003	0.0004	0.0004	0.0005
Rural HH Other	0.0026	0.0057	0.0057	0.0074	0.0098	0.0131	0.0197	0.0353
Rural HH Total	*0.6203*	*0.6126*	*0.6020*	*0.5933*	*0.5796*	*0.5560*	*0.5369*	*0.5237*
Average Urban & Rural (wtd)	*0.6076*	*0.6035*	*0.5886*	*0.5767*	*0.5607*	*0.5361*	*0.5177*	*0.5081*

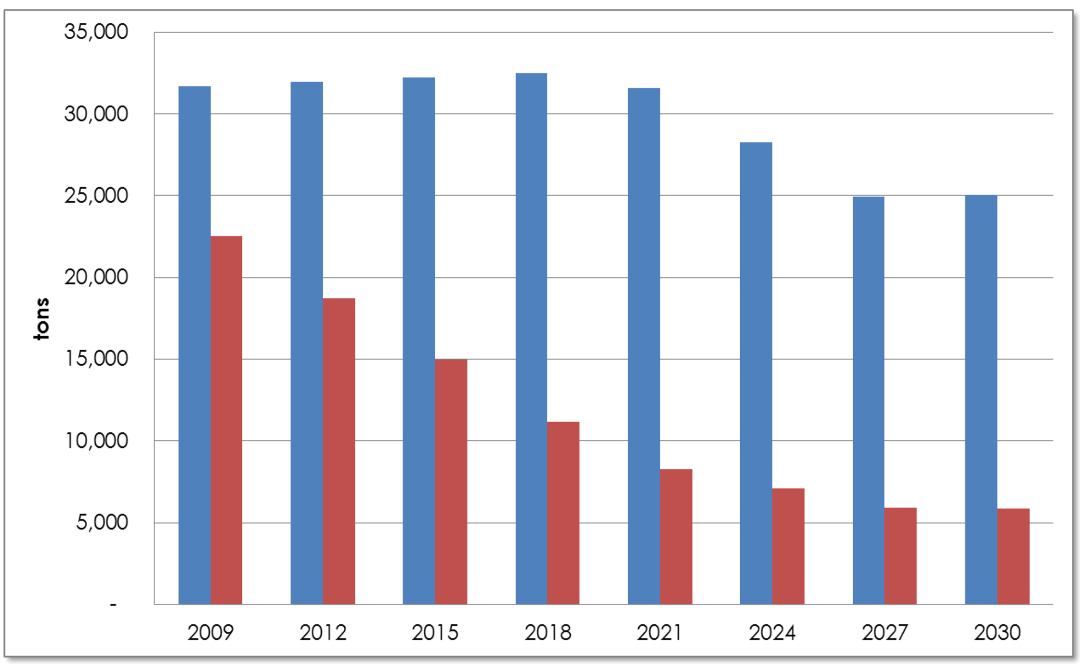
Sources: Consultant

Figure I-9: Household Sector – Electricity (GWh)



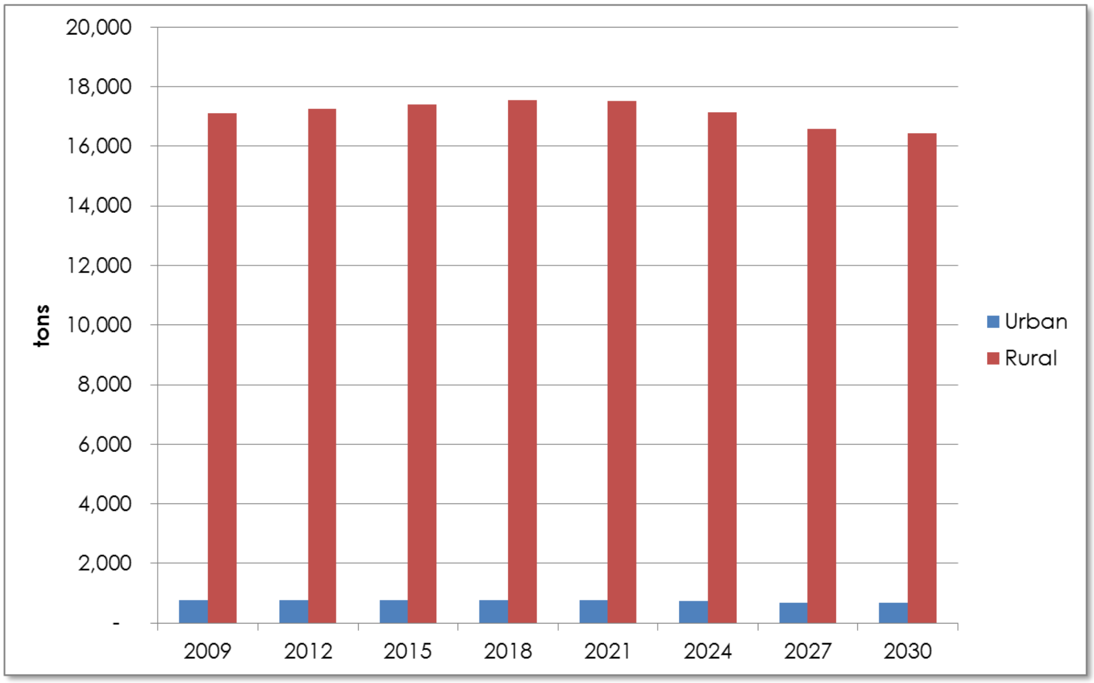
Sources: Consultant

Figure I-10: Household Sector – LPG (tons)



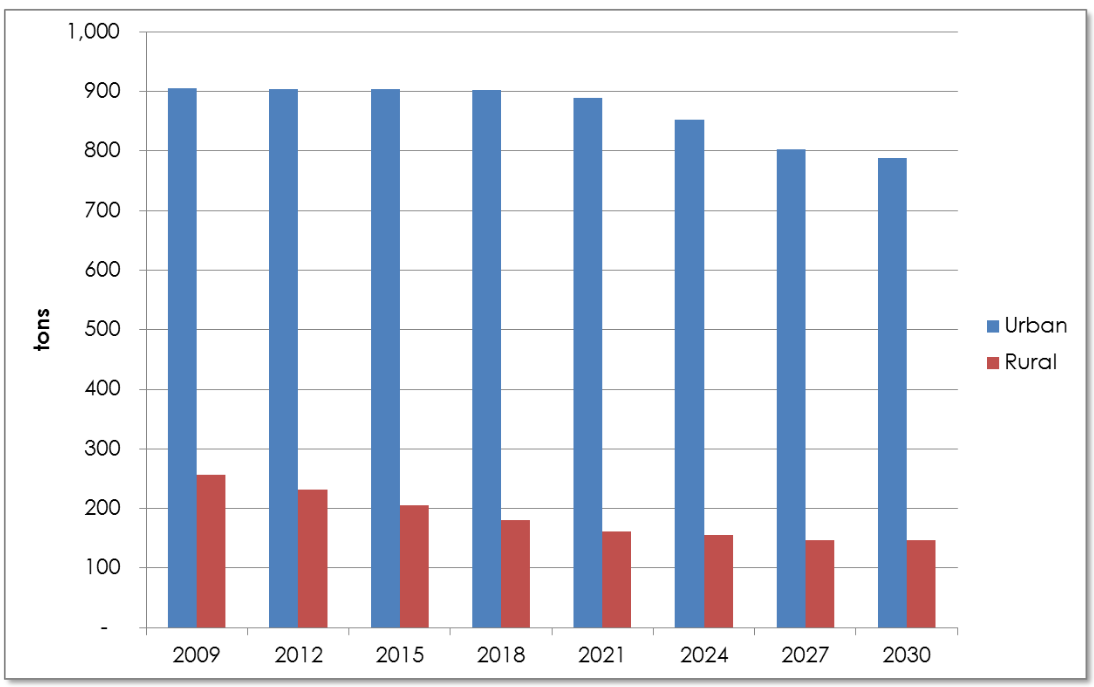
Sources: Consultant

Figure I-11: Household Sector – Firewood (tons)



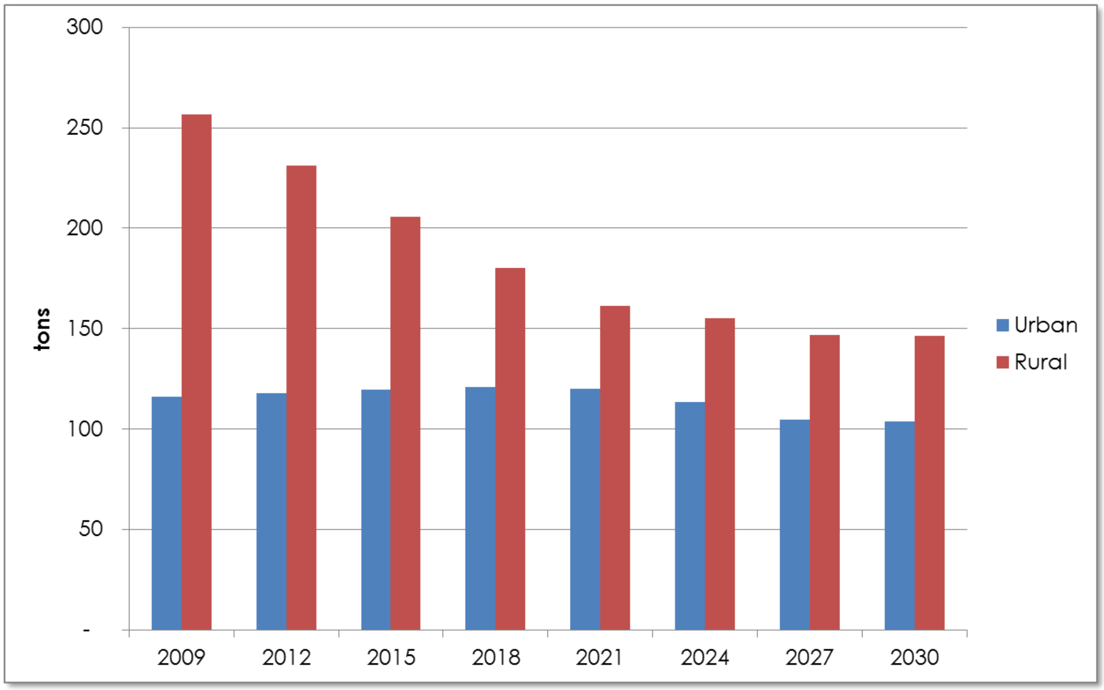
Sources: Consultant

Figure I-12: Household Sector – Biomass (tons)



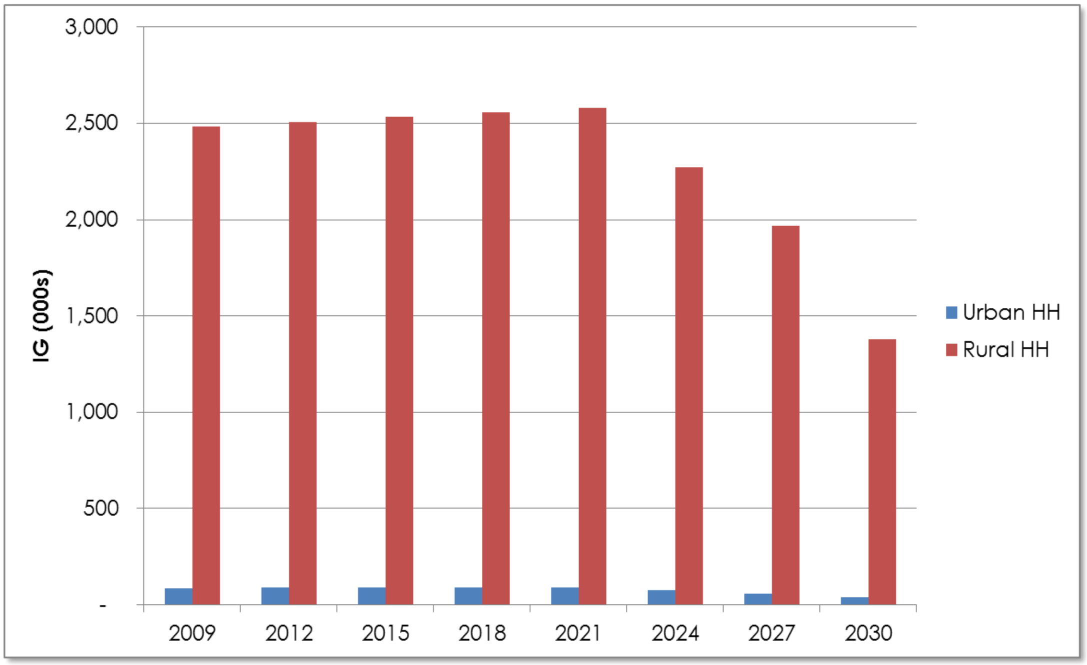
Sources: ADB, Consultant

Figure I-13: Household Sector – Charcoal (tons)



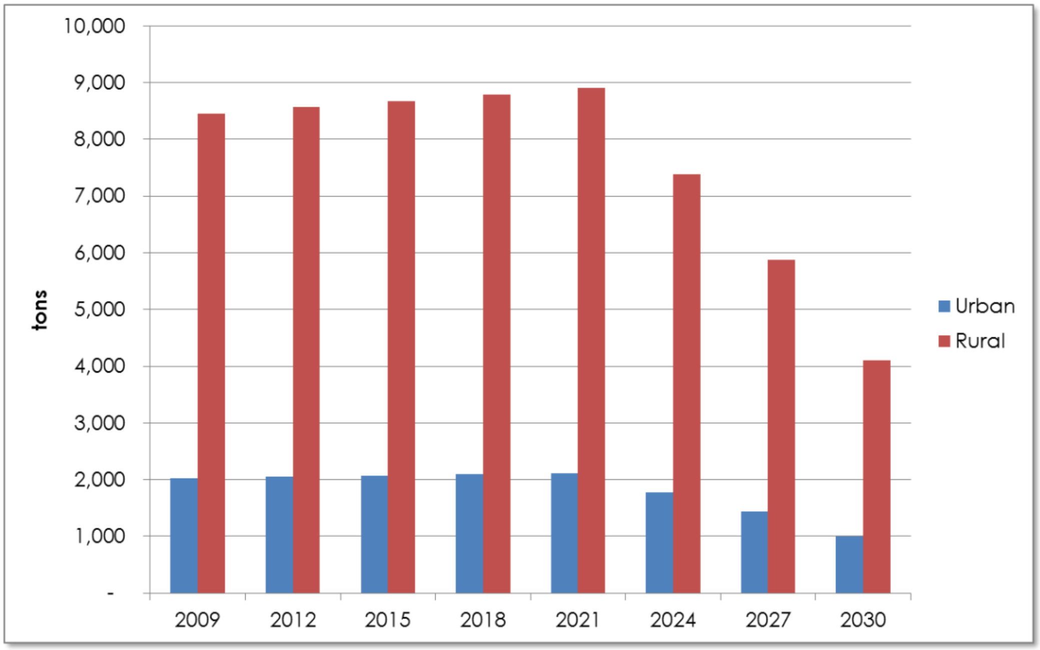
Sources: Consultant

Figure I-14: Household Sector – Diesel Oil (IG 000s)



Sources: Consultant

Figure I-15: Household Sector – Paraffin Wax (tons)



Sources: Consultant

II. PLANNING CONSIDERATIONS

C. EMP HH Survey

11. The data concerning household energy use for cooking and heating water has been sparse until recent years. MercyCorps has undertaken surveys of rural households that provide insights into the patterns of energy use for household cooking, water heating and lighting. The focus of the MercyCorps studies was on the use and barriers to the introduction of fuel efficient stoves (FES). A survey of food security was conducted in 2012 by the Livelihoods for Food Security Trust (LIFT). The survey covered 4,000 rural households in poverty-stricken areas and captured high level information concerning fuel use for cooking by fuel zone and by income decile.

12. Whilst previous surveys provide a useful starting point for energy planning, the LIFT survey did not extend to end-use patterns or urban households, and so a household survey was designed and conducted under the aegis of the Energy Masterplan. The design of the EMP household survey was shaped by the insights gained from the LIFT survey but has specifically tackled the question of household end-use.

13. The EMP HH survey revealed that the fuels used for cooking are predominantly commercial fuels in the Yangon Division and the urban area of Mandalay. Outside of these areas, cooking fuel use was found to be fairly uniform and predominantly fuel wood. Fuel wood includes fire wood and woody biomass in the form of agricultural waste used mainly as a supplementary fuel. On a dry weight basis, agricultural waste accounts for around 7% of the wood fuel used for cooking by rural households. These fuel use patterns are revealed by 'fuel heatmaps' developed from the HH survey data:-

Figure II-1: Yangon Division – Cooking Appliance Use by Surveyed Towns

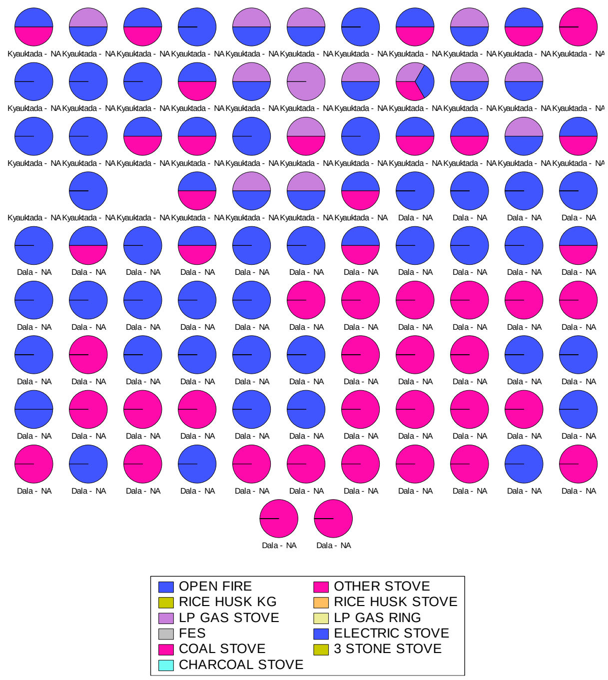
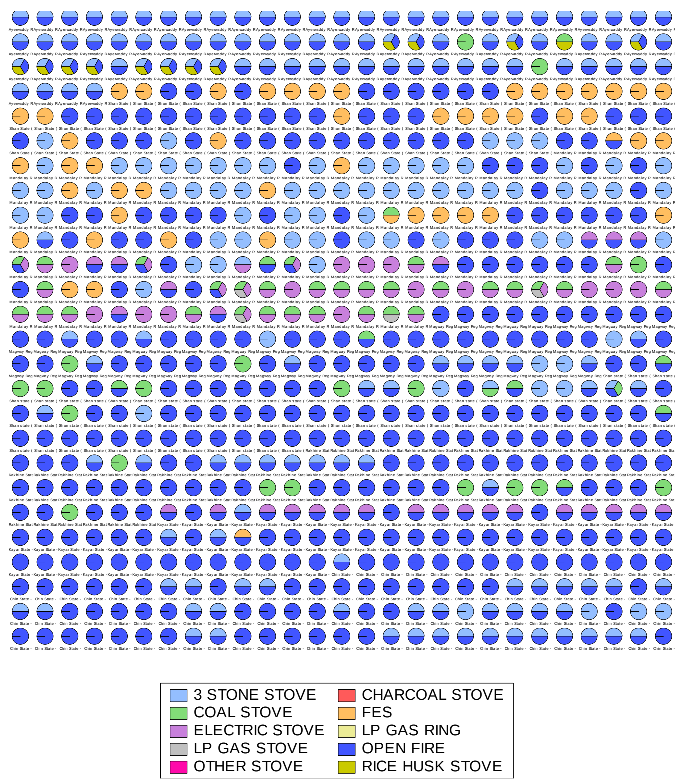


Figure II-2: Outside Yangon – Cooking Appliance by State / District Towns



Sources: EMP HH Survey

14. The heat maps provide a striking illustration of the difference between the cooking habits of Yangon and urban Mandalay residents and residents elsewhere in Myanmar. The colours represent a different cooking technology / fuel and from the difference in colours it can be seen that there is a vast difference between urban and rural cooking habits. It is apparent from Figure II-1 that electricity, LPGas and charcoal are the dominant fuels in the Yangon Division where households are relatively affluent and commercial fuels are available. Moveover, Figure II-2 shows that electricity, LPGas and charcoal are also the dominant fuels in urban Mandalay. Outside of urban Mandalay the pattern of end-use is fairly homogenous; open fires were found to be the most common means used for cooking. These patterns of fuel use for cooking mean that it is logical to segment fuel estimates for cooking according to a 'Yangon Division / urban Mandalay' and 'Other' split. Hereafter these segments are referred to as the 'Urban' and 'Rural' segments.

D. Fuel Zone Population

15. The energy consumption estimate for the household sector is significantly affected by the demographic of the population because the available fuels for cooking vary according to the temperate zones of the country. A spread of the household population is shown in Figure II-8 below, characterized by agricultural zones1. These agricultural zones coincide with 'fuel zones' defined in the LIFT study as the 'hilly zone', the 'dry zone' and the 'coastal/ delta' zone. LIFT also defined a 'Giri zone' as a zone that has a unique fuel status due to the long lasting effects of cyclone Nargis. The hilly zone corresponds to the yellow shaded areas in Figure II-8, the dry zone to the green shaded area, and the coastal/delta zone to the brown shaded areas. The Giri zone is the smaller of the two brown-shaded areas to the north-west. The household population breakdown is shown in Table II-3, segmented by the fuel zones.

Table II-3: Estimated Population by Fuel Zone (millions)

	Total	Rural	Urban
Hilly	15.7	15.7	0
Dry	21.4	19.9	1.5
Delta/Coastal	22.5	15.3	7.2
Giri	1.5	1.5	0
Total	61.1	52.5	8.6

Sources: ADB, USAID, Consultant

16. The fuel zone population and income data from the LIFT study of 2012 (4,000 household sample) supports an estimate of the population by fuel zone and income for both Urban and Rural areas.

Table II-4: Estimated Urban Population by Fuel Zone & Income Deciles: 2012

	Hilly	Dry	Delta/Coastal	Giri
Less than Ks 25,000	-	40,560	152,770	-
Ks 25,001-50,000	-	99,331	694,594	-

[1] "A Strategic Agricultural Sector and Food Security Diagnostic for Myanmar prepared for prepared for USAID/Burma by the University of Michigan and the Myanmar Development Resource Institute's Center for Economic and Social Development"; July 2013

	Hilly	Dry	Delta/Coastal	Giri
Ks 50,001-75,000	-	80,293	346,278	-
Ks 75,001-100,000	-	58,357	179,250	-
Ks 100,001-150,000	-	23,591	128,327	-
Ks 150,001-200,000	-	13,658	50,923	-
Ks 200,001-250,000	-	4,139	20,369	-
Ks 250,001-300,000	-	4,553	18,332	-
Over Ks 300,000	-	6,622	38,702	-
Total	-	331,104	1,629,545	-

Sources: Consultant

Table II-5: Estimated Rural Population by Fuel Zone & Income Deciles: 2012

	Hilly	Dry	Delta/Coastal	Giri
Less than Ks 25,000	513,387	555,085	326,151	65,665
Ks 25,001-50,000	1,374,985	1,359,392	1,482,899	123,937
Ks 50,001-75,000	785,706	1,098,842	739,275	76,972
Ks 75,001-100,000	410,710	798,643	382,684	56,533
Ks 100,001-150,000	232,140	322,856	273,967	19,569
Ks 150,001-200,000	124,999	186,916	108,717	2,609
Ks 200,001-250,000	49,107	56,641	43,487	1,305
Ks 250,001-300,000	44,642	62,305	39,138	-
Over Ks 300,000	40,178	90,626	82,625	1,305
Total	3,575,855	4,531,308	3,478,943	347,894

Sources: Consultant

E. Fuel Substitution

17. Fuel substitution is driven by economic considerations. A comparison of the fuel costs of different cooking fuels reveals that on average basis the lowest energy cost fuel is biogas, followed by firewood and electricity[2]. Charcoal and LPGas are currently considerably more expensive.

[2] The electricity tariff rate is taken from the World Bank National Electrification Plan report; 7 July 2014.

Table II-6: Cooking Fuel Economic Comparison

Fuel	Wood vs Grid	Charcoal	Biogas	LP Gas	Grid	Private Gen
Unit of Sale	kg	kg	kg	kg	kWh	kWh
End Use	cooking	cooking	cooking	cooking	Elec	Elec
Price (kyat)	55	150	186	1280	40	50
Gross Energy Content (MJ)	15	27	43	49	3.6	3.6
Conversion	30%	30%	78%	78%	90%	90%
Useful Energy Cost (kyat/kWh)	44	67	20	121	44	55
Useful Energy Cost (USD/ kWh)	0.046	0.07	0.02	0.13	0.046	0.06

Sources: Consultant

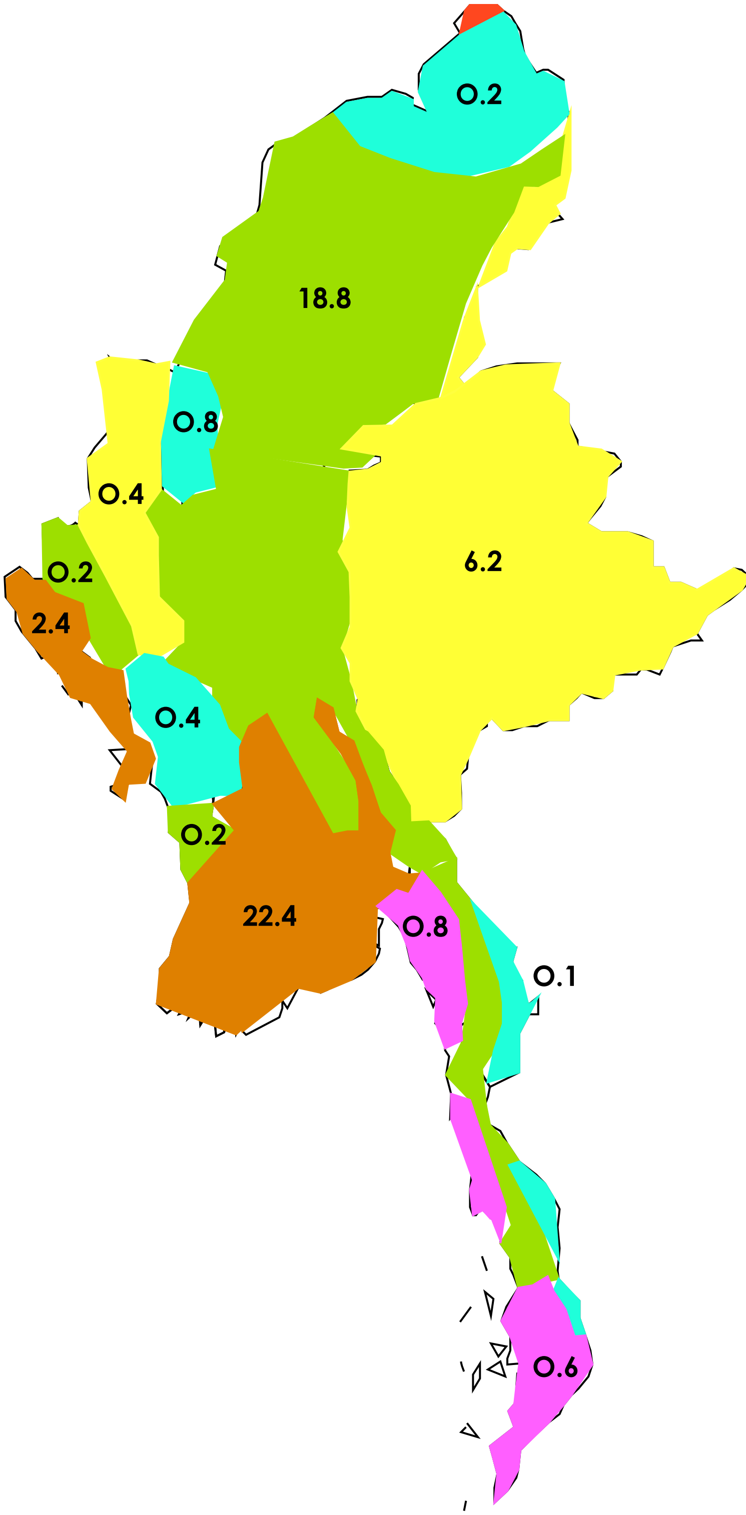
18. In the case of lighting, grid electricity is clearly the most economic choice if grid access is available. The relative attractiveness of electricity means that significant weight should be given to fuel substitution by electricity, consistent with a 100% national electrification plan.

Table II-7: Lighting Energy Economic Comparison

Fuel	Grid	Private Gen	Diesel	Car Batts	Candles	Dry Batteries	Solar PV
Unit of Sale	kWh	kWh	litre	80Ah	pkt	2 x D	kWh
End Use	Elec	Elec	lighting	lighting	lighting	lighting	lighting
Price (kyat)	40	50	1300	133	150	25	150
Gross Energy Content (MJ)	3.6	3.6	45	2.8	20.7	0.04	n.a.
Conversion	90%	90%	11%	100%	2%	100%	n.a.
Useful Energy Cost (kyat/kWh)	44	55	945	171	1304	2250	150
Useful Energy Cost (USD/ kWh)	0.046	0.06	0.98	0.18	1.36	2.34	0.16

Sources: Consultant

Figure II-8: Myanmar's Rural Population by Agriculture (Fuel) Zone



Farming System & Population (millions)

	Lowland Rice (24.8)
	Upland Intensive Mixed (19.2)
	Highland Extensive Mixed (6.5)
	Tree Crop Mixed (1.4)
	Sparse Forest (1.5)
	Pastoral

Sources: ADB, Myanmar CSO, USAID/MDRI/CESD

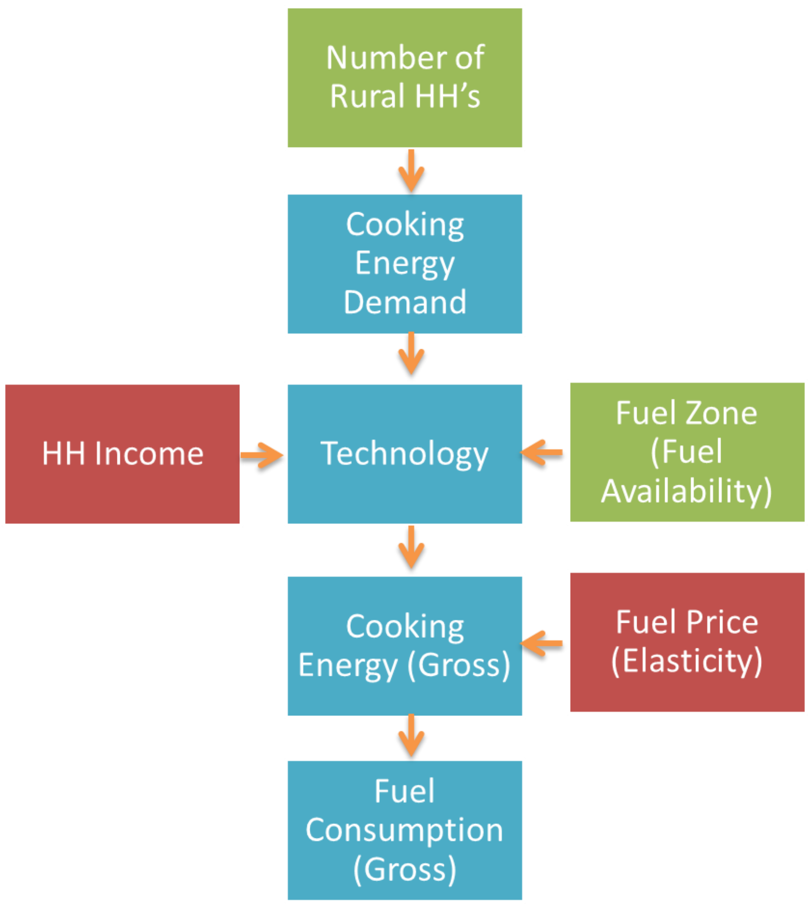
III. RURAL HOUSEHOLD COOKING

F. Cooking Energy Model

19. The modelling of household cooking energy demand depends on a variety of assumptions. The key assumptions are the quantities of fuels used in the daily cooking cycle today, and into the future; the calorific values of fuels in use or expected to be in use; the penetration of cooking appliances according to household income deciles; and the efficiencies of energy conversion by the technologies (useful to final energy).

20. A schematic representation of a household cooking model is shown in Figure III-1. Cost factors influencing energy consumption are shown (red boxes). Inputs of the model are based on the abovementioned assumptions (green boxes). The outputs of the model (blue boxes) are computed by the model algorithms.

Figure III-1: Rural HH Cooking Energy Model Structure



Sources: Consultant

21. To apply the household cooking model requires a cooking appliance classification as shown in Table III-2.

Table III-2: Cooking Appliances & Fuel Type

Item	Cooking Appliance	Fuel Type
1	Open Fire / 3 stone stove	Woody biomass
2	Fuel Efficient Stove	Woody biomass
3	Charcoal Stove	Charcoal
4	Rice Husk Stove	Rice Husks
5	Electric Stove	Electricity
6	Gas Ring	LPG

22. The cooking model requires an inventory of cooking appliances. The Energy Masterplan household survey results were used to establish such an inventory for Urban and Rural areas. These results were then combined with LIFT household survey results to develop estimates of the inventory by income deciles and by fuel zone. Table III-3 and Table III-4 shows the inventory as at 2012, according to the % of common appliances over the total inventory population.

Table III-3: Urban HH Cooking Appliance Inventory by Income (% basis)

Income Decile	Hilly	Dry	Delta/Coastal	Giri
3 stone / open fire		62%	73%	
FES		8%	0%	
Charcoal Stove		12%	12%	
Rice Husk Stove		0%	3%	
Electric		18%	12%	

Table III-4: Rural HH Cooking Appliance Inventory by Income (% basis)

Income Decile	Hilly	Dry	Delta/Coastal	Giri
3 stone / open fire	85%	62%	73%	73%
FES	7%	8%	0%	0%
Charcoal Stove	3%	12%	12%	12%
Rice Husk Stove	0%	0%	3%	3%
Electric	5%	18%	12%	12%

Sources: Consultant' analysis

23. The cooking model also requires knowledge of the daily cooking cycle fuel / energy use. The EMP household survey was used to determine the daily cooking cycle fuel use for Urban and Rural households in 2014. The amount of fuel used for cooking was reported by households in each fuel zone and found to vary between the fuel zones as shown in Table III-5 and Table III-6 respectively.

Table III-5: Urban HH Annual Cook Cycle by Fuel Type

		3 stone / open fire	FES	Charcoal Stove	Rice Husk Stove	Electric	LPG Stove
Hilly	dry mton	-	-	-	-	-	
	MJ	-	-	-	-	-	
Dry	dry mton	2.04	1.43	0.52	0.61	614.41	768
	MJ	31,249	42,891	7,121	2,199	9,400	76,800
Delta / Coastal / Giri	dry mton	1.50	1.05	1.20	0.61	737.29	768
	MJ	22,950	31,500	16,497	2,199	11,281	76,800

Table III-6: Rural HH Annual Cook Cycle by Main Fuel Type

		3 stone / open fire	FES	Charcoal Stove	Rice Husk Stove	Electric	LPG Stove
Hilly	dry mton	1.64	1.15	0.26	0.61	224.00	365
	MJ	25,153	34,524	3,643	2,199	3,427	36,500
Dry	dry mton	2.40	1.68	0.52	0.61	224.00	365
	MJ	36,720	50,400	7,121	2,199	3,427	36,500
Delta / Coastal / Giri	dry mton	1.02	0.71	0.26	0.61	224.00	365
	MJ	15,606	21,420	3,643	2,199	3,427	36,500

Sources: EMP HH Survey, Consultant

24. The energy estimates (MJ) appearing in these tables were based on the gross calorific values of cooking fuels as listed in Table III-7.

Table III-7: Gross Calorific Values of Energy Carriers

Fuel wood		
3 stone stove (firewood)	15.3	MJ / kg
FES (firewood)	15.3	MJ / kg
Charcoal	30	MJ / kg
Agricultural Residue		
Pigeon Pea Stalk	18.6	MJ / kg
Cotton Stalk	18.1	MJ / kg
Sesame Stalk	19.1	MJ / kg
Coconut or Palm leaves	18.3	MJ / kg
Rice Husk	13.8	MJ / kg
Sawdust	18.1	MJ / kg
Bamboo	19.5	MJ / kg
Other		
LPG Gas	100	MJ / m3
Biogas (digester)	24.9	MJ / m3
Electricity	3.6	MJ/ kWh

Sources: UK Digest of Energy Statistics, Agriculture Research Institutes

G. Cooking Energy Demand Model Calibration

25. The assumptions outlined in the preceding section, along with population estimates, were used to generate baseline cooking fuel and energy use estimates by fuel zone and by income decile. Fuel stacks were developed on energy consumption basis to test the validity of the model.

26. Figure III-9 shows that the penetration of commercial fuels in the higher income deciles in the urban areas is significant compared to the penetration in rural areas that is shown in Figure III-10.

27. The cooking energy measured in toe per household is 0.52 per Urban household and 0.60 per Rural household. These figures show the expected relative difference and compare well to international benchmarks for rural cooking energy consumption.

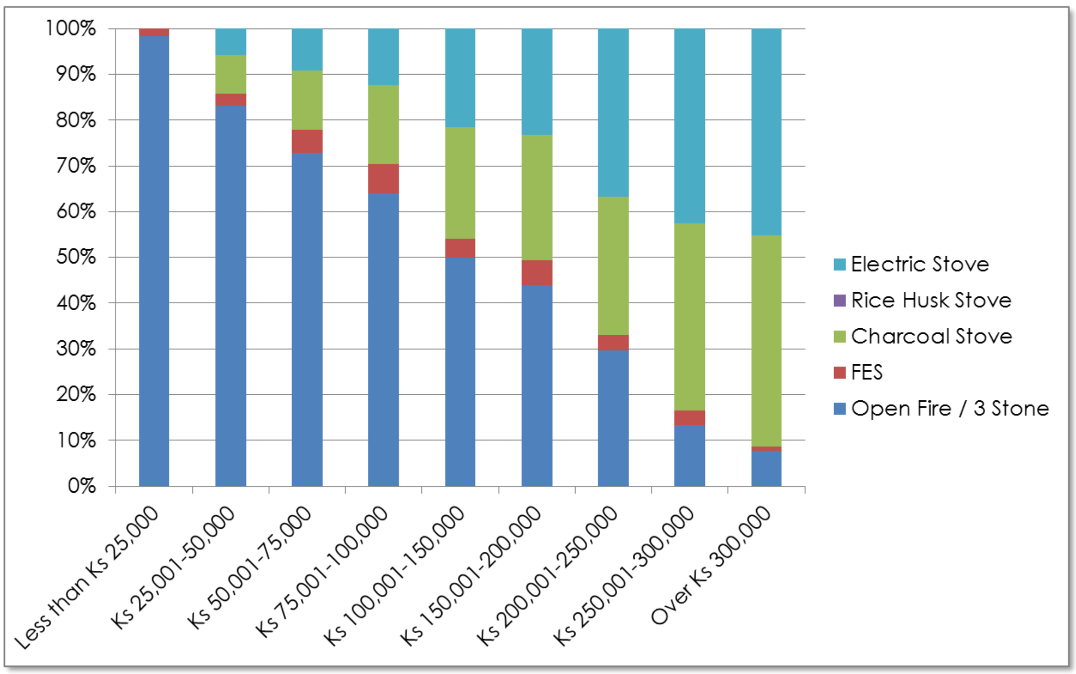
28. Estimates of the household cooking final energy consumption (FEC) in 2012-13 are given in the following table:

Table III-8: Household Cooking FEC by Fuel Zone: 2012-13

	Urban	Rural
	ktoe	ktoe
Hilly Zone	-	2,203
Dry Zone	242	3,714
Coastal/Delta Zone	770	1,178
Giri Zone	-	122
Total	1,012	7,217

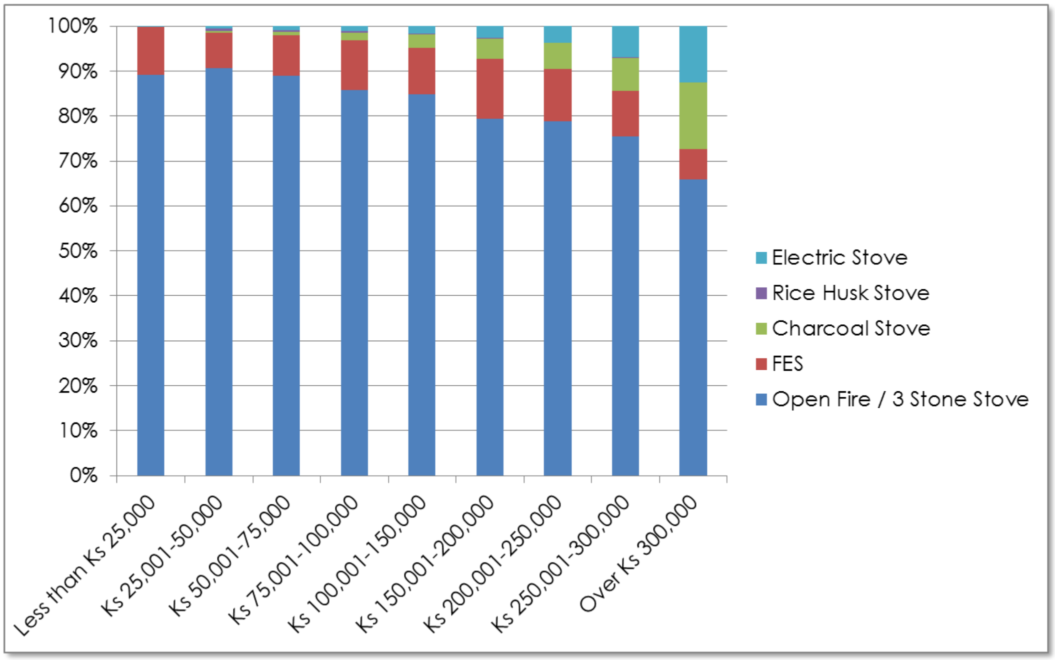
Sources: Consultant

Figure III-9: Urban HH Cooking Fuel Stack (% Energy Use)



Sources: Consultant

Figure III-10: Rural HH Cooking Fuel Stack (% Energy Use)



Sources: Consultant

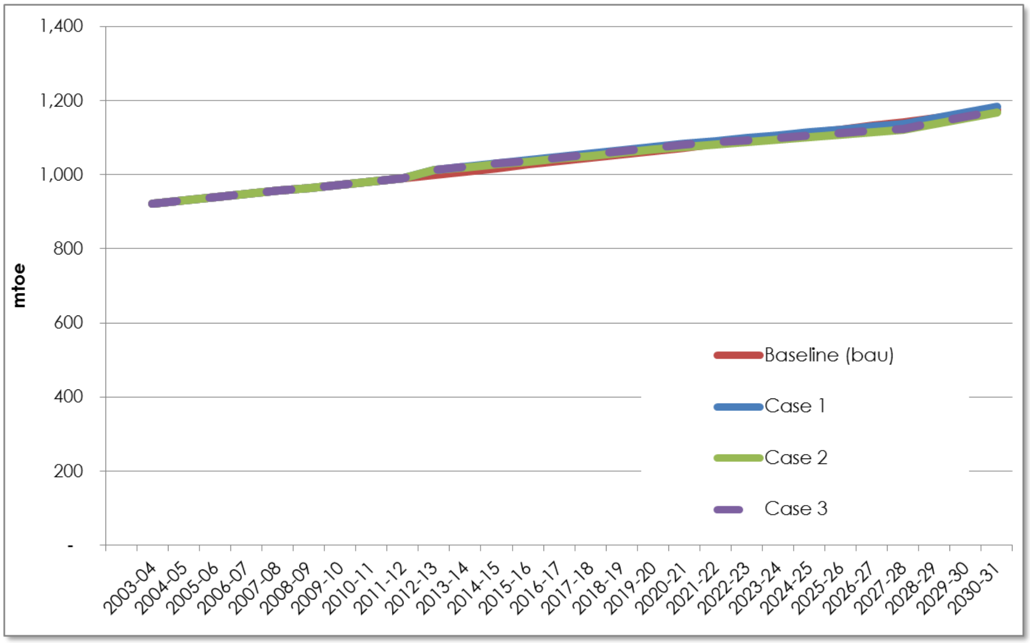
H. Final Energy Consumption Projections for HH Cooking

29. The projection of the final energy consumption for household cooking was made from the baseline year of 2012-13. The projections take into account the rate at which household income increases over time, the change in population and the impact of grid electrification. More specifically assumptions common to all planning cases were 1) the rate of income growth was assumed to be 4% real on long-term basis, and 2) the population growth was assumed at a fixed rate of 1% per annum.

30. A reference case assumed no change to the basic pattern of cooking fuel and appliance use, i.e. electricity grid subscription was taken to grow at the historical rate. Three cases were modelled according to national rural electrification targets as follows:-

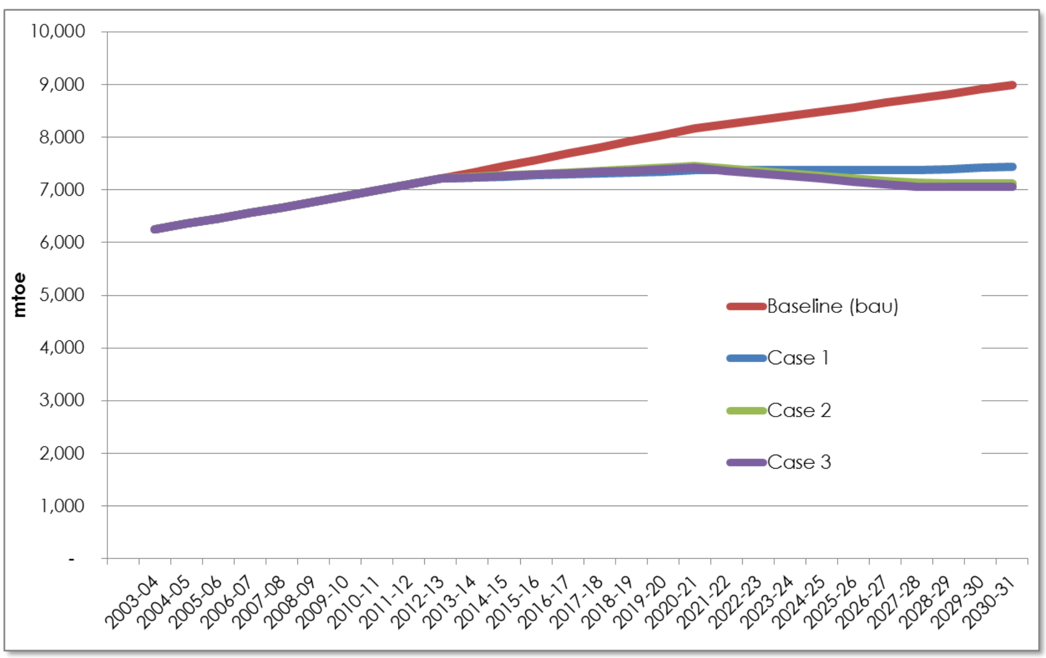
1. Assumption 81% grid electrification is reached by 2030;
2. Assumption 87% grid electrification is reached by 2030; and
3. Assumption 96% grid electrification is reached by 2030.

Figure III-11: Urban HH Cooking Final Energy Use



Sources: Consultant

Figure III-12: Rural HH Cooking Final Energy Use



Sources: Consultant

31. The HH cooking model demonstrates that the Urban household projections are not greatly affected by electrification. This is to be expected as electrification is already advanced in the Urban area. The final energy consumption grows in line with the population. The Rural household projections show a reduction in energy consumption compared to a business as usual case. The difference in electrification between each case is not so marked that there is a substantial difference in energy efficiency between the cases.

Table III-13: HH Cooking FEC Projections (mtoe) (Case 2)

	2012	2015	2018	2021	2024	2027	2030	CAGR
3 stone	6.701	6.742	6.783	6.746	6.554	6.362	6.173	-0.6%
FES	0.668	0.692	0.716	0.726	0.706	0.686	0.667	-0.2%
Charcoal Stove	0.194	0.187	0.180	0.173	0.163	0.153	0.146	-1.6%
Rice Husk Stove	0.025	0.017	0.010	0.006	0.006	0.005	0.005	-8.0%
Electric Stove	0.152	0.209	0.266	0.344	0.465	0.586	0.563	6.6%
LPG Stove	0.042	0.037	0.032	0.028	0.025	0.021	0.020	-4.0%
Biogas Stove	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.0%
Pigeon Pea Stalk	0.217	0.221	0.224	0.225	0.219	0.213	0.207	-0.4%
Cotton Stalk	0.043	0.043	0.044	0.044	0.043	0.042	0.041	-0.4%
Sesame Stalk	0.117	0.119	0.121	0.121	0.118	0.115	0.112	-0.4%
Coconut or Palm leaves	0.053	0.054	0.055	0.055	0.054	0.052	0.051	-0.4%
Sawdust	0.006	0.007	0.007	0.007	0.007	0.006	0.006	-0.4%
Bamboo	0.012	0.012	0.012	0.012	0.012	0.012	0.011	-0.4%
Total	8.229	8.340	8.452	8.487	8.371	8.254	8.003	-0.3%

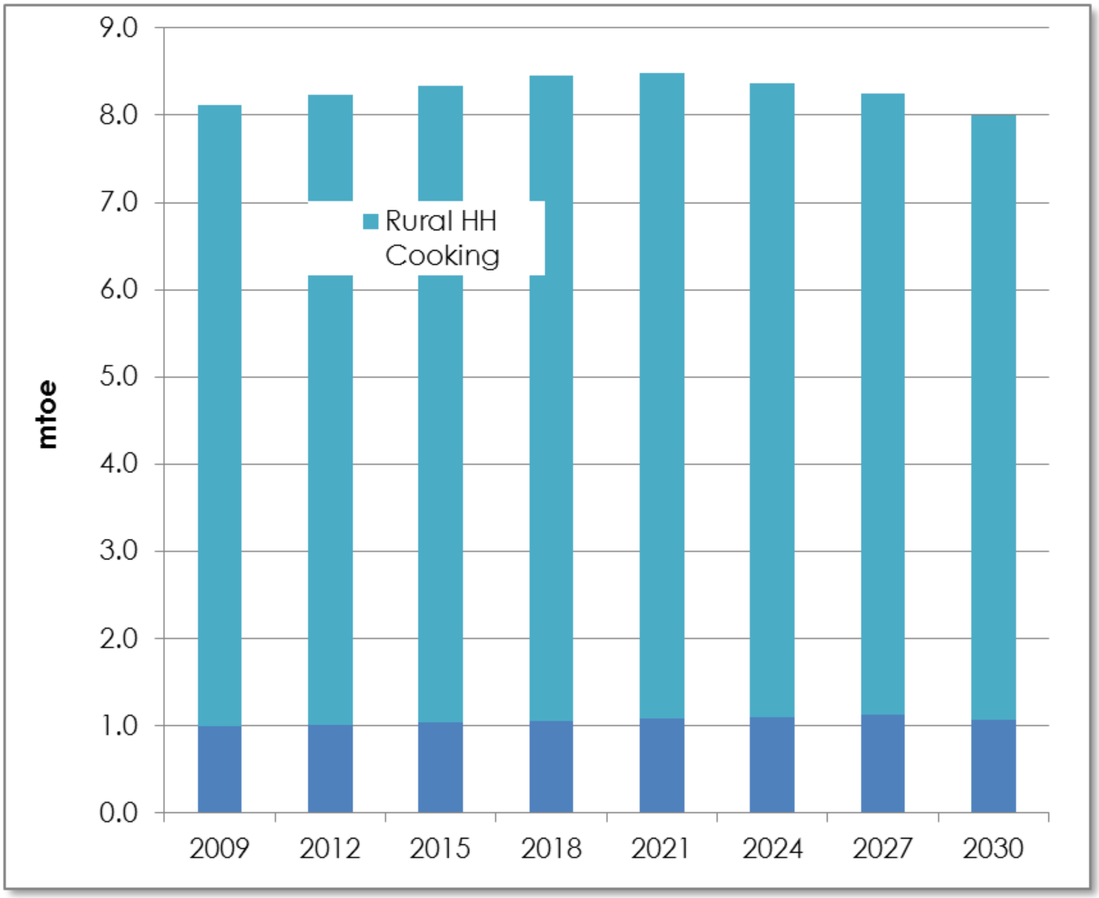
Sources: Consultant

Table III-14: Cooking Fuel Carrier Projections (physical) (Case 2)

		2012	2015	2018	2021	2024	2027	2030	CAGR
3 stone	tons	2,034,814	2,027,474	1,995,111	1,912,701	1,802,822	1,767,864	1,732,905	-1.0%
FES	tons	52,160	52,563	52,503	51,517	50,203	50,160	50,116	-0.3%
Charcoal Stove	tons	363,590	368,649	365,336	345,282	318,542	315,475	312,407	-1.1%
Rice Husk Stove	tons	204	122	67	65	63	61	60	-4.8%
Electric Stove	GWh	573	730	931	1,221	1,608	1,898	2,187	7.3%
LPG Stove	mcm	15	14	12	11	9	9	9	-2.8%
Biogas Stove	tons	0	0	0	0	0	0	0	0.0%
Pigeon Pea Stalk	tons	13,811	13,834	13,757	13,478	13,106	13,047	12,987	-0.4%
Cotton Stalk	tons	2,786	2,791	2,776	2,719	2,644	2,632	2,620	-0.4%
Sesame Stalk	tons	7,269	7,281	7,240	7,094	6,898	6,867	6,835	-0.4%
Coconut / Palm	tons	3,453	3,459	3,439	3,370	3,277	3,262	3,247	-0.4%
Sawdust	tons	424	425	422	414	402	401	399	-0.4%
Bamboo	tons	727	728	724	709	690	687	684	-0.4%

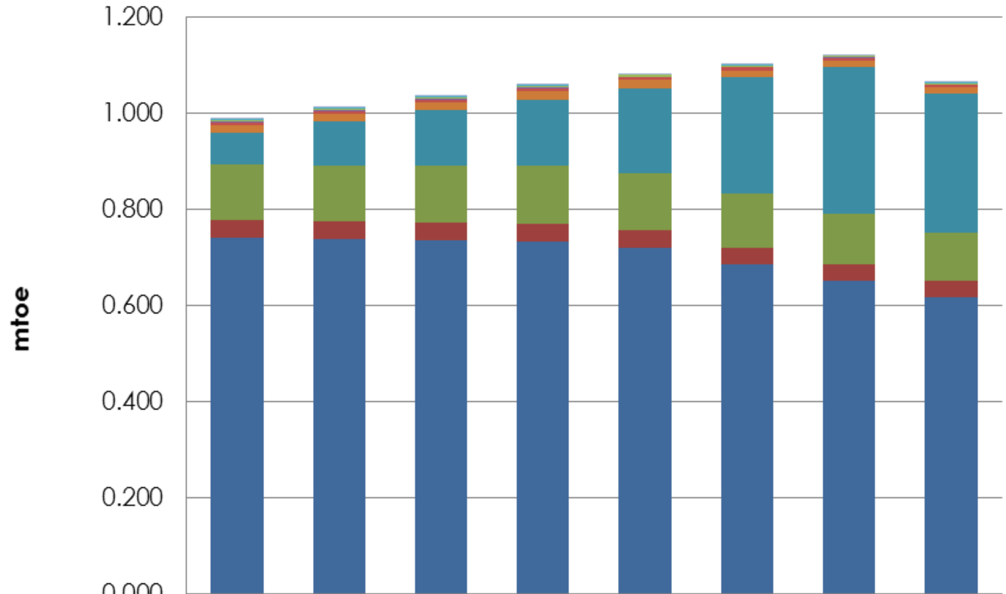
Sources: Consultant

Figure III-15: Final Energy Use Projections for Household Cooking (Case 2)



Sources: ADB Consultant

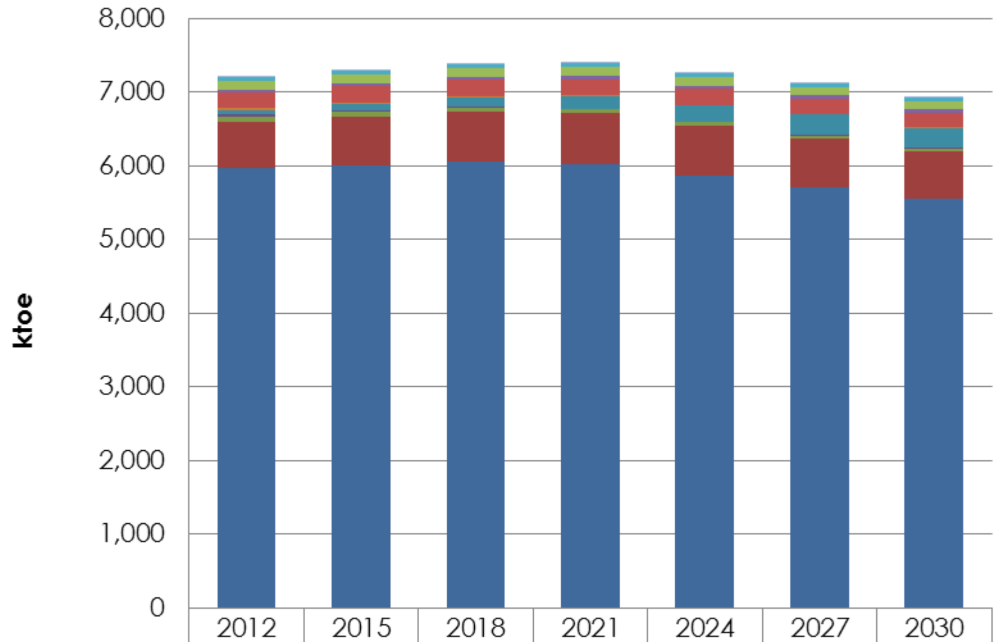
Figure III-16: Urban HH Cooking Energy Carrier Projections to 2030 (Case 2)



	2009	2012	2015	2018	2021	2024	2027	2030
Bamboo	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Sawdust	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Coconut or Palm leaves	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Sesame Stalk	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003
Cotton Stalk	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Pigeon Pea Stalk	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.005
Biogas Stove	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
LPG Stove	0.017	0.017	0.018	0.018	0.017	0.015	0.014	0.013
Electric Stove	0.066	0.091	0.115	0.139	0.177	0.241	0.306	0.291
Rice Husk Stove	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Charcoal Stove	0.116	0.118	0.119	0.121	0.120	0.112	0.105	0.099
FES	0.036	0.036	0.037	0.037	0.037	0.036	0.035	0.033
3 stone	0.741	0.738	0.735	0.733	0.719	0.685	0.651	0.618

Sources: Consultant

Figure III-17: Rural HH Cooking Energy Carrier Projections to 2030 (Case 2)



	2012	2015	2018	2021	2024	2027	2030
Bamboo	11.6	11.8	12.0	12.1	11.8	11.5	11.1
Sawdust	6.3	6.4	6.5	6.5	6.4	6.2	6.0
Coconut or Palm leaves	51.9	52.8	53.7	53.8	52.5	51.1	49.7
Sesame Stalk	114.1	116.0	118.0	118.3	115.3	112.3	109.2
Cotton Stalk	41.4	42.2	42.9	43.0	41.9	40.8	39.7
Pigeon Pea Stalk	211.1	214.7	218.4	218.9	213.3	207.7	202.1
Biogas Stove	0.0	0.0	0.0	0.0	0.0	0.0	0.0
LPG Stove	24.2	19.4	14.5	10.7	9.2	7.7	7.5
Electric Stove	61.2	94.0	126.7	167.3	223.5	279.8	272.1
Rice Husk Stove	24.5	17.5	10.5	5.7	5.6	5.4	5.3
Charcoal Stove	75.9	67.6	59.3	52.9	50.6	48.2	46.9
FES	631.4	655.4	679.4	689.1	670.1	651.1	633.4
3 stone	5,962.8	6,006.7	6,050.6	6,027.2	5,868.9	5,710.6	5,555.2

Sources: Consultant

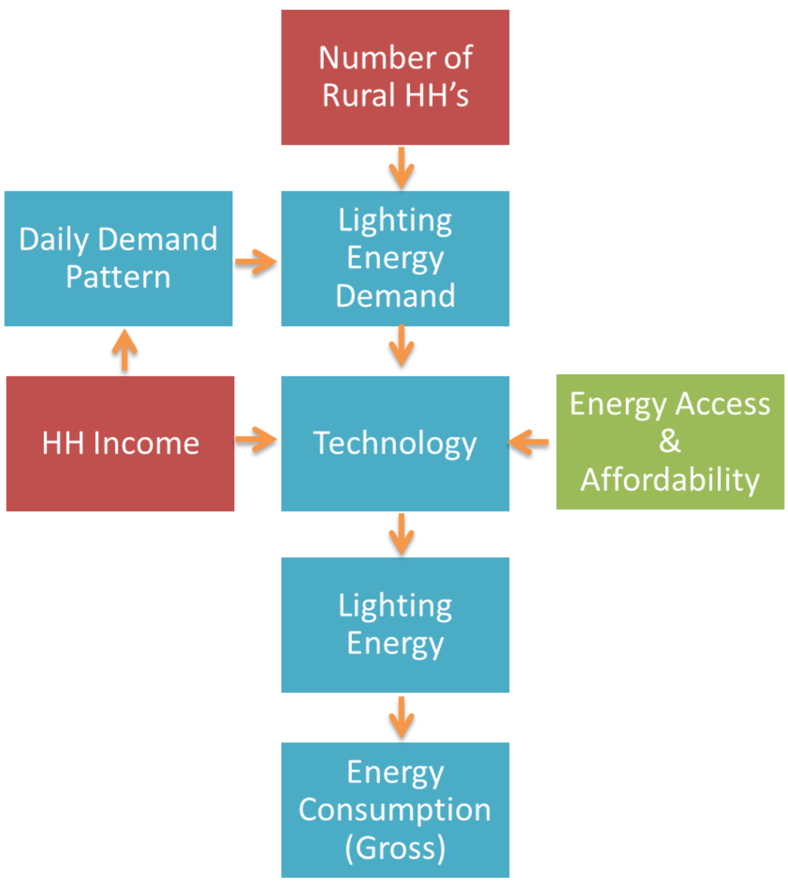
IV. HOUSEHOLD LIGHTING

I. Lighting Energy Model

32. Several distinct elements are included in the rural household lighting model used for energy demand planning. These are the fuels known to be available and in use today or expected to be in use in the future, the calorific values of said fuels, the lighting technologies, the energy used by technology, rural household income deciles by fuel zone and by population, the rural household populations by fuel zone and the average family size. Furthermore where technologies / fuels are known to be absent from a particular fuel zone, and likely to remain so, they are excluded from the model for that zone.

33. A schematic representation of the rural household lighting model and its inputs (green boxes) is shown in Figure IV-1. Factors influencing energy consumption are shown as drivers (red boxes). The outputs of the model (blue boxes) are computed by the model algorithms.

Figure IV-1: Household Lighting Energy Model Structure



Sources: International Planning Agencies, ADB Consultant

34. To apply the household cooking model requires a cooking appliance classification as shown in Table IV-2.

Table IV-2: Lighting Appliance

Item	Cooking Technology	Energy Supply	Model ID*
1	Battery / LED 1W	Battery	BL
2	Candle	Paraffin	C
3	Compact Fluorescent 20W	Electricity	CFL
4	Wick Lamp	Diesel	D
5	Fluorescent 10W	Electricity	F
6	Incandescent 20W	Electricity	I
7	Wick Lamp	Paraffin	P
8	Solar Battery Lantern 15W	Sun / Battery	SHS1
9	Solar Battery Lantern 20W	Sun / Battery	SHS2
* These technology IDs are used in all charts and tables			

Sources: Consultant

35. The lighting model requires an inventory of cooking appliances. The Energy Masterplan household survey results were used to establish such an inventory for Urban and Rural areas. These results were then combined with LIFT household survey results to develop estimates of the inventory by income deciles and by fuel zone. Table IV-3 and Table IV-4 shows the inventory as at 2012, according to the % of common appliances over the total inventory population.

Table IV-3: Urban Lighting Appliance Counts

	Electric Lights			Lamp	Candles	Others
	Fluoro	Incandescent	CFL	Diesel Oil	Paraffin	Battery LED
Less than Ks 25,000	24,028	5,875	5,875	2,853	72,750	11,395
Ks 25,001-50,000	130,149	35,597	44,496	10,671	280,513	46,712
Ks 50,001-75,000	100,911	31,054	44,362	7,845	167,649	29,717
Ks 75,001-100,000	86,300	29,204	45,632	5,314	98,097	15,036
Ks 100,001-150,000	62,644	22,147	36,912	2,078	68,407	10,807
Ks 150,001-200,000	35,805	13,210	25,686	1,337	12,047	5,217
Ks 200,001-250,000	15,531	6,631	13,262	573	4,821	897
Ks 250,001-300,000	10,650	5,231	10,700	390	6,461	2,418
Over Ks 300,000	30,724	17,599	35,931	434	137,807	1,515
	496,743	166,548	262,856	31,497	848,551	123,714

Source: EMP HH Survey, LIFT 2012

Table IV-4: Rural Lighting Appliance Counts

	Electric Lights			Lamp	Candles	Others
	Fluoro	Incandescent	CFL	Diesel Oil	Paraffin	Battery LED
Less than Ks 25,000	73,367	40,267	32,467	130,289	391,806	150,448
Ks 25,001-50,000	281,062	127,855	102,168	456,426	1,025,784	417,195
Ks 50,001-75,000	243,659	130,679	97,994	190,911	732,140	278,715
Ks 75,001-100,000	219,014	118,142	92,901	86,423	476,670	138,699
Ks 100,001-150,000	124,114	63,752	44,950	38,698	269,695	69,548
Ks 150,001-200,000	88,709	52,490	35,445	16,355	61,030	38,519
Ks 200,001-250,000	39,256	24,271	14,306	8,456	21,378	6,003
Ks 250,001-300,000	30,693	18,533	11,111	4,811	27,915	15,364
Over Ks 300,000	72,083	32,213	21,162	5,752	399,659	6,528
	1,171,958	608,200	452,505	938,121	3,406,078	1,121,021

Source: EMP HH Survey, LIFT 2012

36. The Energy Masterplan household survey results were used to establish the hours of use of lighting appliances in Urban and Rural areas. Again the results were then combined with LIFT household survey results to develop estimates of the daily hours of use of lighting by income deciles.

Table IV-5: Household Lighting Appliance Daily Hours of Use

Income Decile	Hours of Use per Day
Less than Ks 25,000	2.76
Ks 25,001-50,000	3.25
Ks 50,001-75,000	3.43
Ks 75,001-100,000	3.51
Ks 100,001-150,000	4.04
Ks 150,001-200,000	4.32
Ks 200,001-250,000	4.51
Ks 250,001-300,000	5.25
Over Ks 300,000	5.75

Source: EMP HH Survey

37. The power and consumption of energy carriers supplying lighting are provided in Table IV-6.

Table IV-6: Power / Consumption of Energy Carriers

Fuel / Technology Characteristics				
BL	1	Watt	3600	kJ per kWh
C	2.25	gms per hour	42.0	kJ per gram
CFL	20	Watt	3600	kJ per kWh
D	10	ml per hour	38.0	kJ per ml
F	10	Watt	3600	kJ per kWh
I	20	Watt	3600	kJ per kWh
P	10	ml per hour	37.2	kJ per ml
SHS1	15	Watts	3600	kJ per kWh
SHS2	20	Watts	3600	kJ per kWh

Sources: UK Digest of Energy Statistics, Agriculture Research Institutes

J. Lighting Energy Demand Model Calibration

38. The assumptions outlined in the preceding section, along with population estimates, were used to generate baseline cooking fuel and energy use estimates by fuel zone and by income decile. Fuel stacks were developed on energy consumption basis to test the validity of the model.

39. Figure IV-8 shows that the penetration of commercial fuels in the higher income deciles in the urban areas is far more significant compared to the penetration in rural areas that is shown in Figure IV-9.

40. The lighting energy measured in toe per household is 0.0021 per Urban household and 0.0022 per Rural household. As a result of energy poverty, the total lighting energy consumption in 2012-13 is most certainly insufficient to meet a minimum level of illumination required for task-based lighting such as reading. A typical Western standard for illumination for reading is 300 lux, whereas the average illumination level in the majority of Myanmar rural households is of the order of 10 lux. As a matter of energy policy the target demand for lighting services should be set according to a minimum standard of illumination. A suitable long-term intermediate illumination target for rural households in Myanmar is 160 lux. This level of illumination can be met with a 1 watt LED lamp fitted with a polycarbonate lens or by grid-connected lighting.

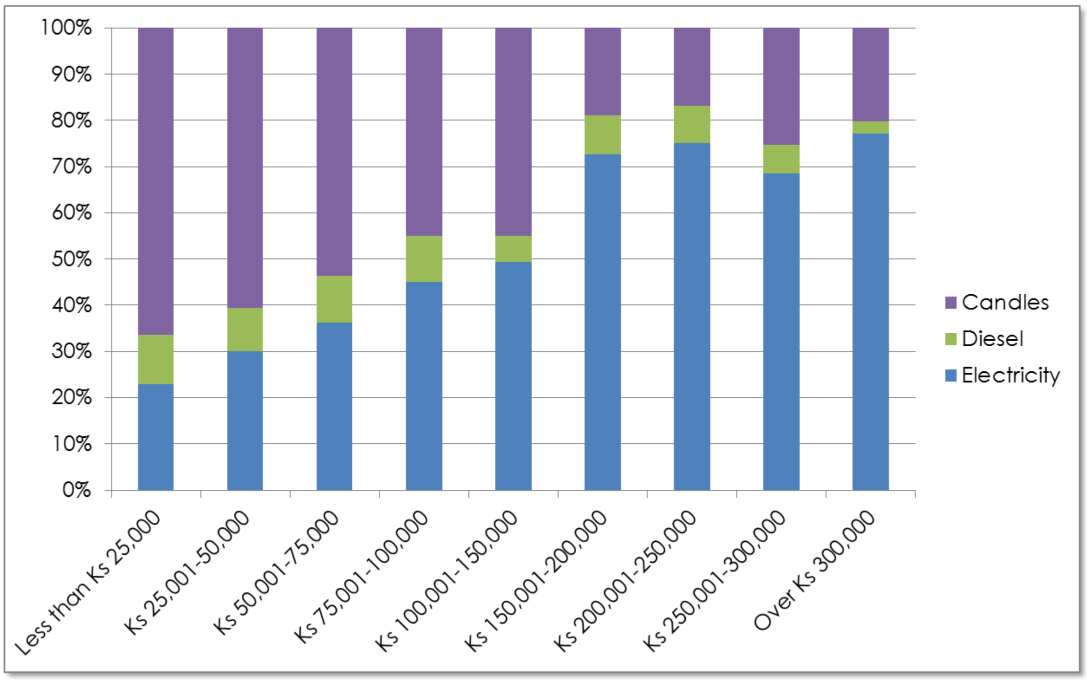
41. Estimates of the household lighting final energy consumption (FEC) in 2012-13 are given in the following table:-

Table IV-7: HH Lighting Final Energy Use by Fuel Zone

	Urban	Rural
	ktoe	ktoe
Hilly Zone	-	7.5
Dry Zone	0.9	8.2
Coastal/Delta Zone	3.3	8.9
Total	4.3	24.6

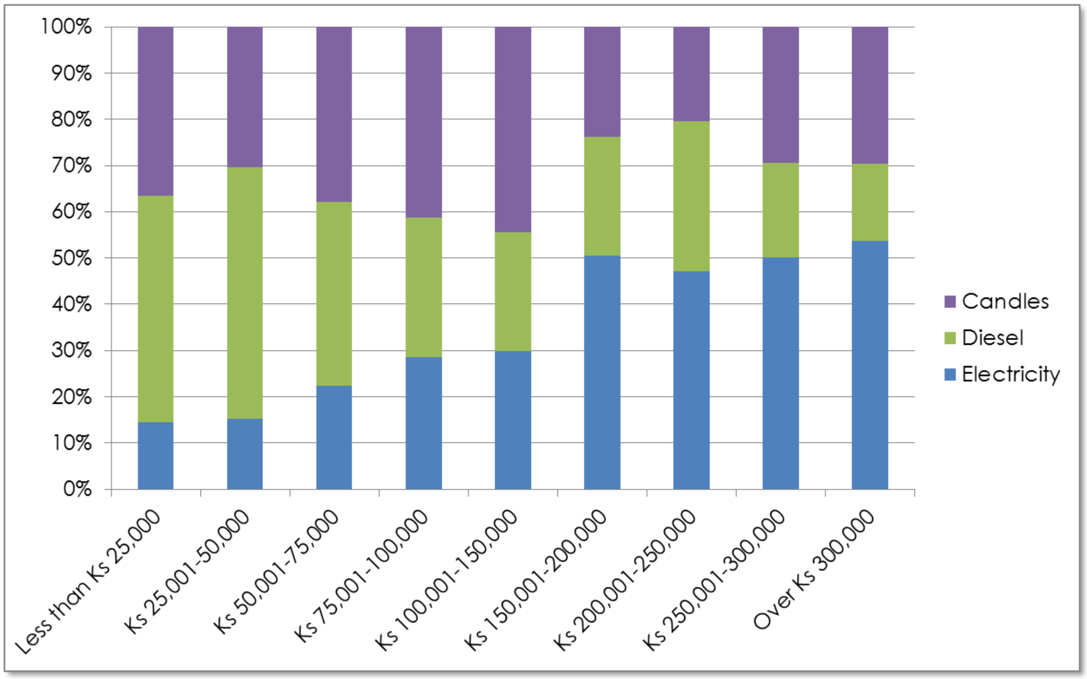
Sources: Consultant

Figure IV-8: Modelled Urban HH Lighting Fuel Stack (Final Energy)



Sources: Consultant

Figure IV-9: Modelled Rural HH Lighting Fuel Stack (Final Energy)



Sources: Consultant

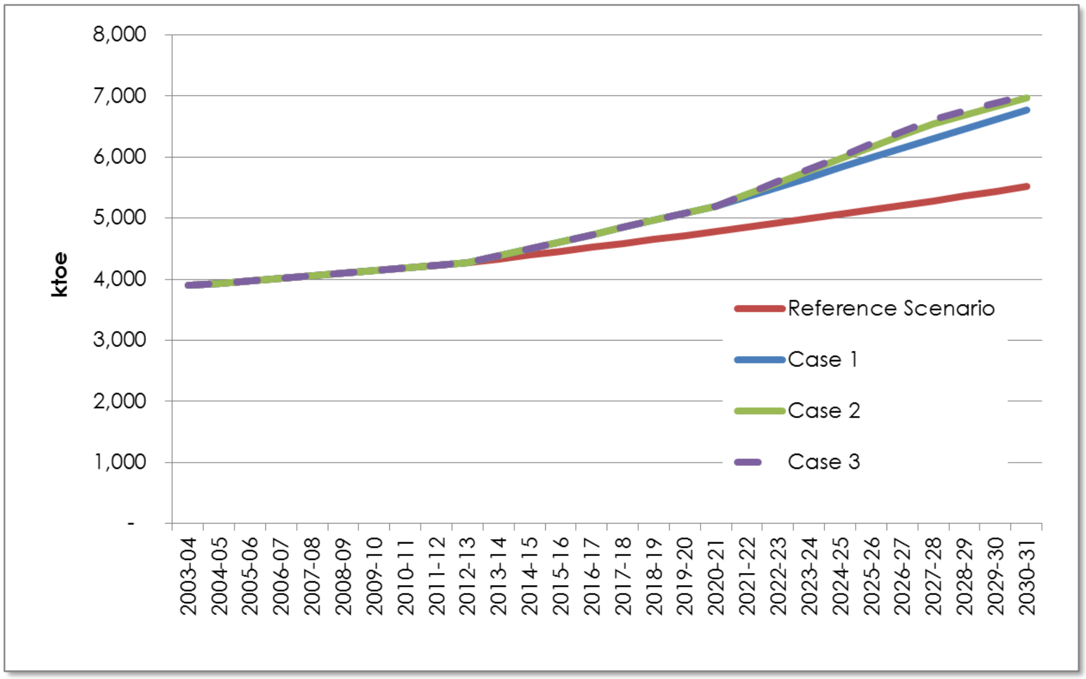
K. Final Energy Consumption Projections for HH Lighting

42. The projection of the final energy consumption for household lighting was made from the baseline year of 2012-13. The projections take into account the rate at which household income increases over time, the change in population and the impact of grid electrification. More specifically assumptions common to all planning cases were 1) the rate of income growth was assumed to be 4% real on long-term basis, and 2) the population growth was assumed at a fixed rate of 1% per annum.

43. A reference case assumed no change to the basic pattern of lighting fuel and appliance use, i.e. electricity grid subscription was taken to grow at the historical rate. Three alternative cases were also defined according to national rural electrification targets as follows:-

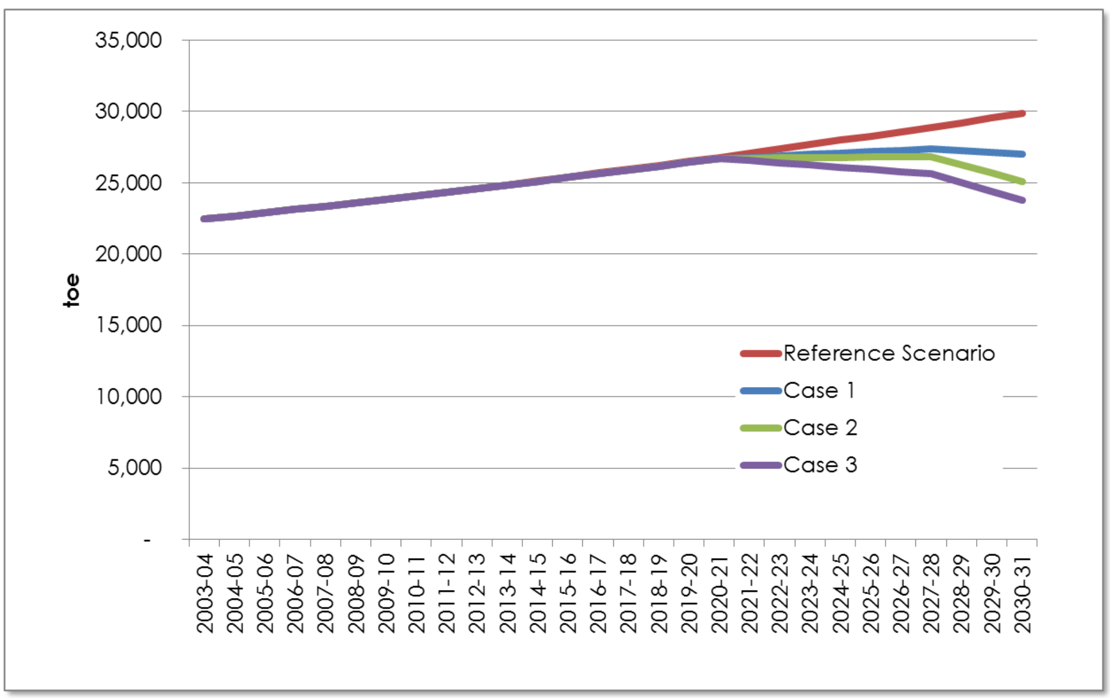
1. Assumption 81% grid electrification is reached by 2030;
2. Assumption 87% grid electrification is reached by 2030; and
3. Assumption 96% grid electrification is reached by 2030.

Figure IV-10: Urban HH Lighting Final Energy Use



Sources: Consultant

Figure IV-11: Rural HH Lighting Final Energy Use



Sources: Consultant

44. The Urban lighting cases 1 to 3 show an increased energy consumption trajectory compared to the business as usual case. This is due to an accelerated electrification rate and population growth. The energy efficiency of lighting in the Rural sector improves as candles and oil lamps are replaced by grid lighting. The greater the extent of rural electrification, the greater the extent of the efficiency gain, despite the increasing population.

Table IV-12: Urban HH Lighting FEC Projections (mtoe) (Case 2)

	2009	2012	2015	2018	2021	2024	2027	2030	CAGR
Electricity	0.00160	0.00185	0.00214	0.00243	0.00271	0.00368	0.00465	0.00553	6.3%
Diesel	0.00036	0.00036	0.00037	0.00037	0.00037	0.00033	0.00029	0.00021	-3.9%
Candles	0.00203	0.00205	0.00207	0.00209	0.00211	0.00186	0.00161	0.00124	-3.4%
Total	0.0040	0.0043	0.0046	0.0049	0.0052	0.0059	0.0065	0.0070	2.8%

Sources: Consultant

Table IV-13: Rural HH Lighting FEC Projections (mtoe) (Case 2)

	2009	2012	2015	2018	2021	2024	2027	2030	CAGR
Electricity	0.0052	0.0057	0.00618	0.00668	0.00717	0.00912	0.01106	0.01284	4.9%
Diesel	0.0102	0.0103	0.01042	0.01052	0.01062	0.00983	0.00905	0.00730	-2.4%
Candles	0.0085	0.0086	0.00868	0.00879	0.00890	0.00770	0.00650	0.00538	-3.2%
Total	0.0239	0.0246	0.0253	0.0260	0.0267	0.0267	0.0266	0.0255	0.1%

Sources: Consultant

Table IV-14: Urban Lighting Fuel Carrier Projections (physical) (Case 2)

		2012	2015	2018	2021	2024	2027	2030	CAGR
Electricity	GWh	21.6	25.0	28.3	31.6	43.0	54.3	64.5	6.3%
Diesel	litres	399,382	404,126	408,870	413,614	364,797	315,980	227,724	-3.8%
Candles	tons	2,050	2,070	2,090	2,110	1,861	1,611	1,241	-3.4%

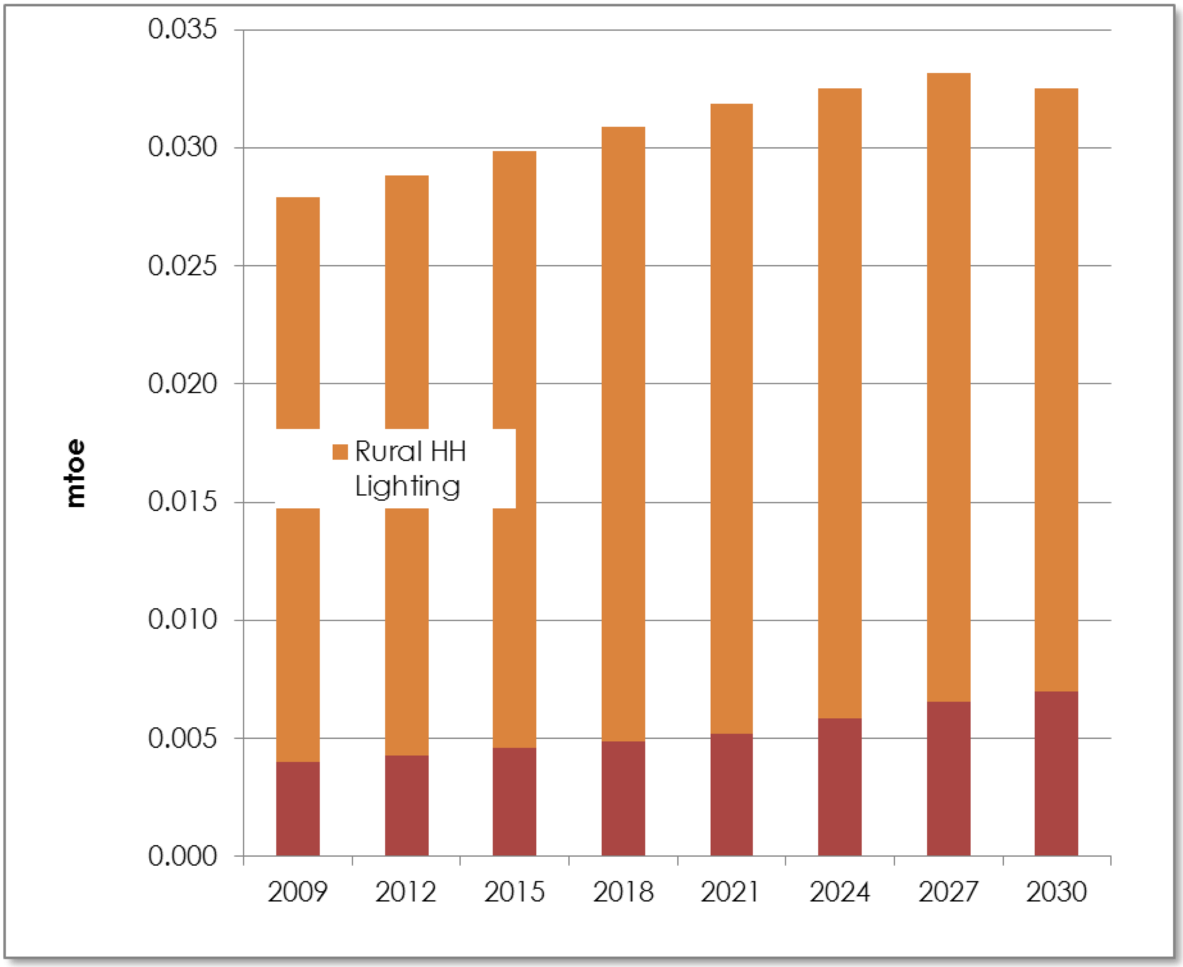
Sources: Consultant

Table IV-15: Rural Lighting Fuel Carrier Projections (physical) (Case 2)

		2012	2015	2018	2021	2024	2027	2030	CAGR
Electricity	GWh	66.4	72.1	77.9	83.7	106.4	129.1	149.9	4.9%
Diesel	litres	11,404,846	11,515,774	11,626,703	11,737,632	10,869,991	10,002,351	8,063,712	-2.4%
Candles	tons	8,565.2	8,678.4	8,791.7	8,905.0	7,702.7	6,500.4	5,381.2	-3.2%

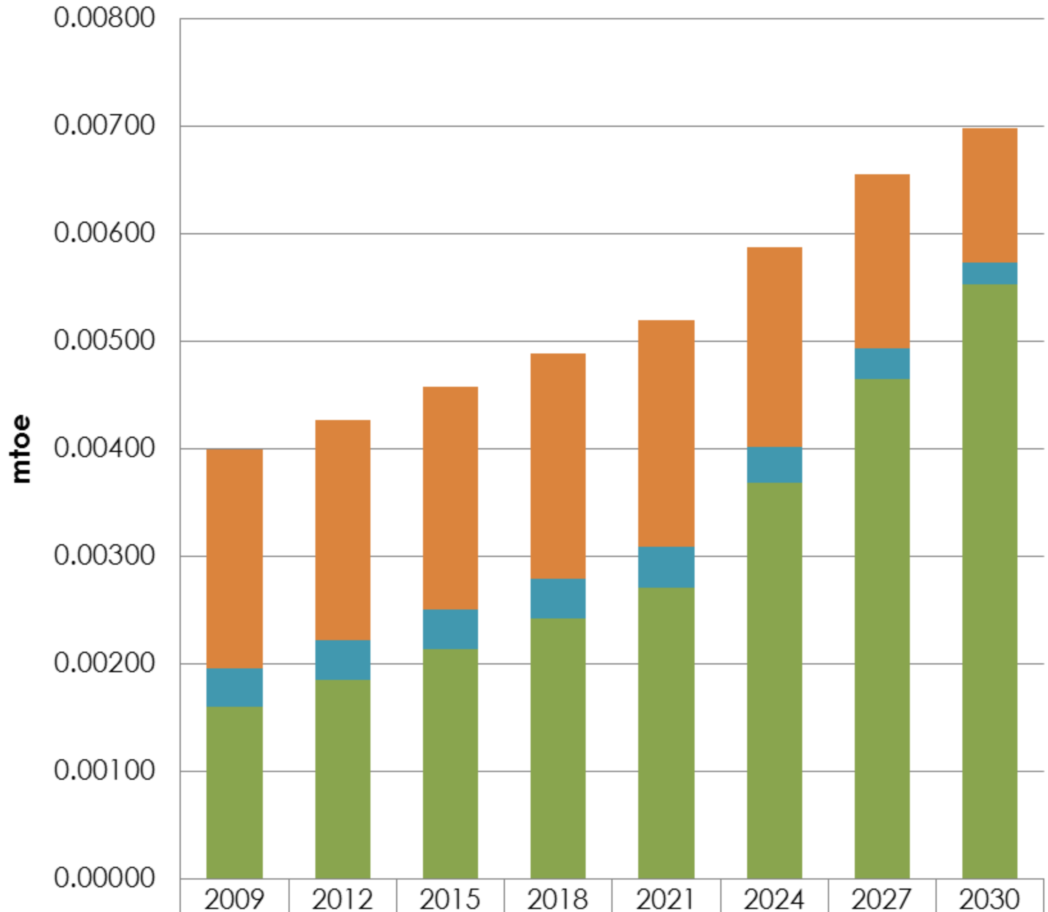
Sources: Consultant

Figure IV-16: Final Energy Use Projections for Household HH Lighting (Case 2)



Sources: ADB Consultant

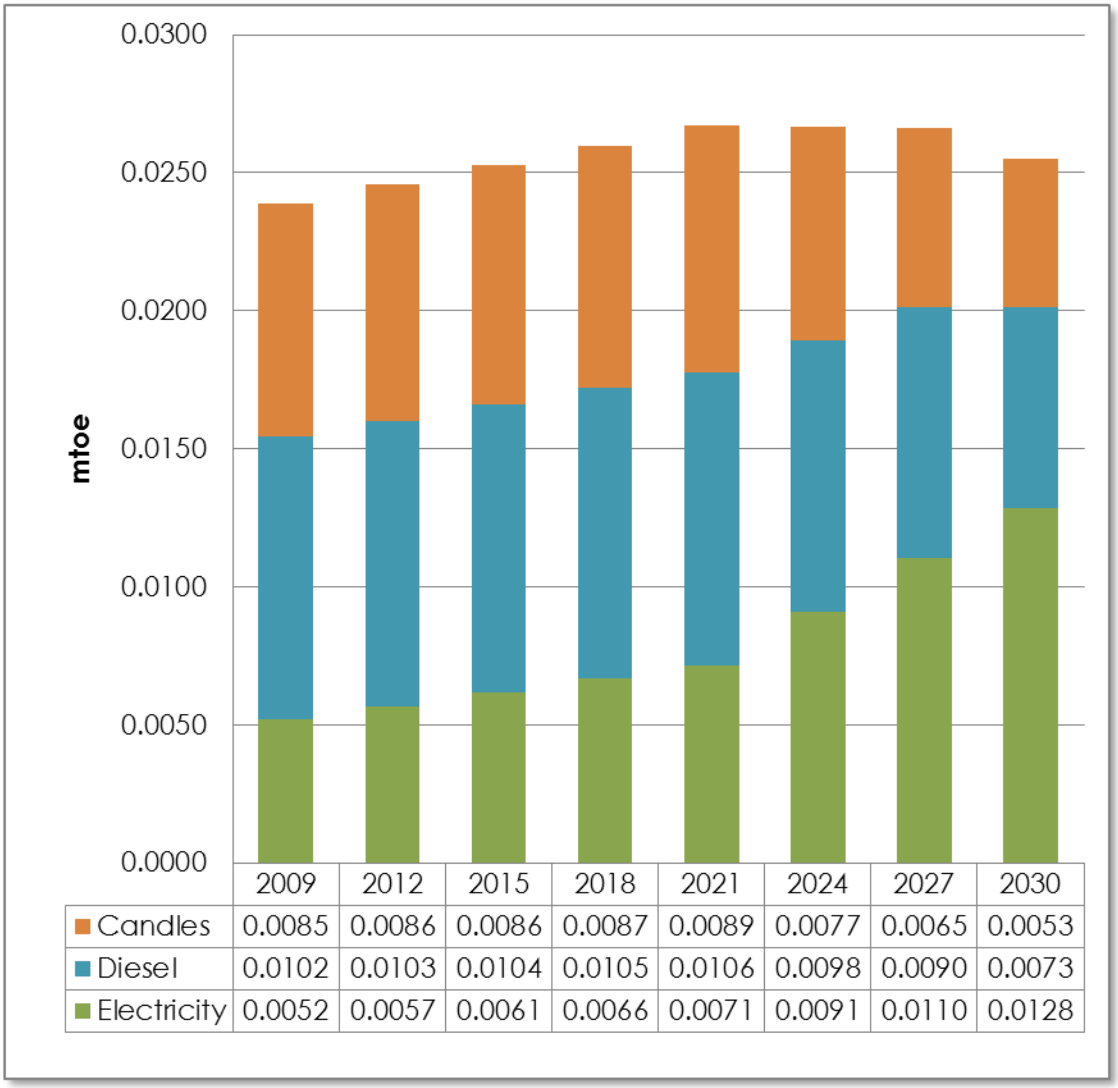
Figure IV-17: Urban HH Lighting Energy Carrier Projections to 2030 (Case 2)



	2009	2012	2015	2018	2021	2024	2027	2030
Candles	0.00203	0.00205	0.00207	0.00209	0.00211	0.00186	0.00161	0.00124
Diesel	0.00036	0.00036	0.00037	0.00037	0.00037	0.00033	0.00029	0.00021
Electricity	0.00160	0.00185	0.00214	0.00243	0.00271	0.00368	0.00465	0.00553

Sources: Consultant

Figure IV-18: Rural HH Lighting Energy Carrier Projections to 2030 (Case 2)



	2009	2012	2015	2018	2021	2024	2027	2030
Candles	0.0085	0.0086	0.0086	0.0087	0.0089	0.0077	0.0065	0.0053
Diesel	0.0102	0.0103	0.0104	0.0105	0.0106	0.0098	0.0090	0.0073
Electricity	0.0052	0.0057	0.0061	0.0066	0.0071	0.0091	0.0110	0.0128

Sources: Consultant

V. OTHER HOUSEHOLD ENERGY USE

L. Introduction

45. Other household energy use falls into two categories – TV / entertainment and Cooling Services. TV / Entertainment end-use has been modelled using a similar approach to that used for household lighting. Cooling services includes cooling fans, air-conditioning and refrigeration. Due to paucity of data, cooling service end-use has been modelled as a net energy consumption where the net represents the difference between the total residential electricity consumption reported by YESB and ESE, and the total residential electricity use estimated for cooking, lighting and TV / entertainment. In this way there is consistency maintained between the 'bottom-up' electricity end-use estimates and the top-down electricity sales. The net energy consumption is validated by computing the equivalent cooling service given by the average net electricity consumption per Urban and Rural household, and by comparison of the toe per household between segments and across segments, particularly between lighting and cooling services.

M. TV / Entertainment

46. The estimate of energy consumption of TV / Entertainment category requires an inventory of appliances. The Energy Masterplan household survey results were used to establish such an inventory for Urban and Rural areas. These results were then combined with LIFT household survey results to develop estimates of the inventory by income deciles and by fuel zone. Table IV-3 shows the inventory as at 2012, according to the % of common appliances over the total inventory population.

Table V-1: TV / Entertainment Appliance Counts

	Urban	Rural
Less than Ks 25,000	81,376	14,798
Ks 25,001-50,000	87,935	20,622
Ks 50,001-75,000	129,751	27,628
Ks 75,001-100,000	141,177	19,595
Ks 100,001-150,000	240,045	22,629
Ks 150,001-200,000	156,638	41,880
Ks 200,001-250,000	315,360	53,136
Ks 250,001-300,000	291,834	67,523
Over Ks 300,000	300,001	63,614
	1,744,116	331,426

Source: EMP HH Survey, LIFT 2012

47. The Energy Masterplan household survey results were used to establish the hours spent watching TV (on appliance basis) in Urban and Rural areas. Again the results were combined with LIFT household survey results to develop estimates of the daily hours of use of lighting by income deciles.

Table V-2: Household Lighting Appliance Daily Hours of Use

Income Decile	Hours of Use per Day
Less than Ks 25,000	1.5
Ks 25,001-50,000	2
Ks 50,001-75,000	2.5
Ks 75,001-100,000	2.5
Ks 100,001-150,000	3
Ks 150,001-200,000	3
Ks 200,001-250,000	3
Ks 250,001-300,000	3
Over Ks 300,000	3

Source: EMP HH Survey

48. The power rating of a typical TV / entertainment system was determined to be 80W. Estimates of the household lighting final energy consumption (FEC) in 2012-13 are given in the following table:-

Table V-3: Final Energy Use by Fuel Zone

	Urban	Rural
	GWh	GWh
Hilly Zone	-	5.415
Dry Zone	0.466	4.899
Coastal/Delta Zone	2.686	12.088
Total	3.152	22.402

Sources: Consultant

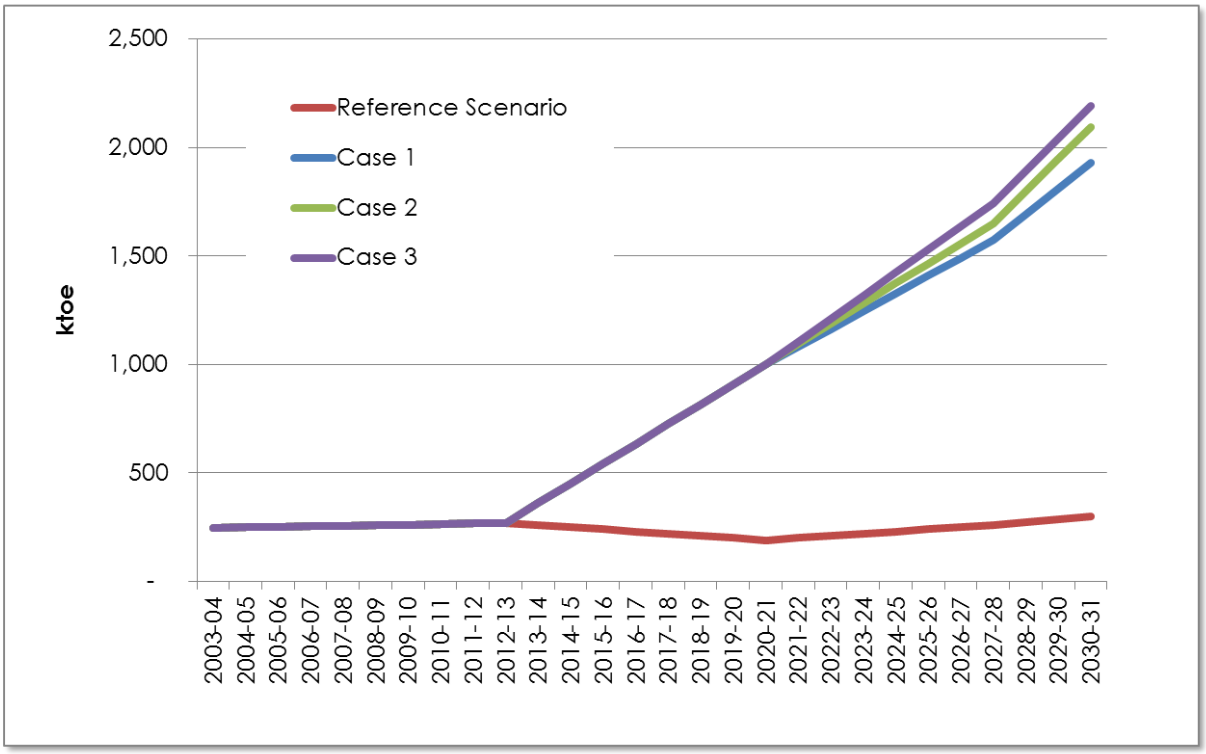
N. Final Energy Consumption Projections for HH Lighting

49. The projection of the final energy consumption for household lighting was made from the baseline year of 2012-13. The projections take into account the rate at which household income increases over time, the change in population and the impact of grid electrification. More specifically assumptions common to all planning cases were 1) the rate of income growth was assumed to be 4% real on long-term basis, and 2) the population growth was assumed at a fixed rate of 1% per annum.

50. A reference case assumed no change to the basic pattern of lighting fuel and appliance use, i.e. electricity grid subscription was taken to grow at the historical rate. Three alternative cases were also defined according to national rural electrification targets as follows:-

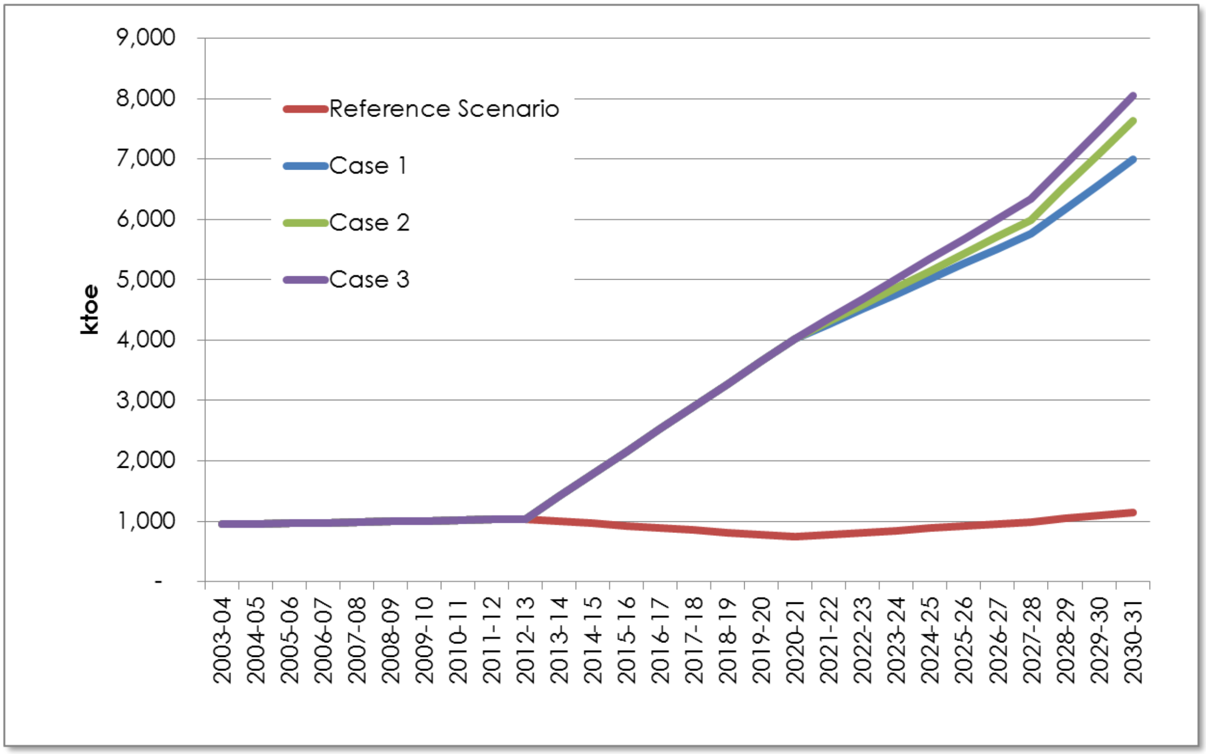
1. Assumption 81% grid electrification is reached by 2030;
2. Assumption 87% grid electrification is reached by 2030; and
3. Assumption 96% grid electrification is reached by 2030.

Figure V-4: Urban HH TV / Entertainment Final Energy Use



Sources: Consultant

Figure V-5: Rural HH TV / Entertainment Final Energy Use



Sources: Consultant

51. The Urban and Rural cases 1 to 3 show an increased energy consumption trajectory compared to the business as usual case. This is due to an accelerated electrification rate and population growth.

Table V-6: Urban HH TV / Ent FEC Projections (mtoe) (Case 2)

	2009	2012	2015	2018	2021	2024	2027	2030	CAGR
Electricity mtoe	0.00023	0.00027	0.00051	0.00076	0.00100	0.00133	0.00165	0.00209	9.4%
Electricity GWh	5.1	6.0	8.8	11.7	15.5	19.3	24.4	29.5	8.1%

Sources: Consultant

Table V-7: Rural HH TV / Ent FEC Projections (mtoe) (Case 2)

	2009	2012	2015	2018	2021	2024	2027	2030	CAGR
Electricity mtoe	0.0009	0.0010	0.0020	0.0030	0.0040	0.0050	0.0060	0.0076	8.8%
Electricity GWh	10.3	12.1	23.7	35.3	46.9	58.4	69.9	89.1	8.8%

Sources: Consultant

O. Other Energy Consumption Projections (Cooling Services)

52. The electricity sales consumption data reported by YESB and ESE were reconciled to the total electricity consumption estimates for household cooking, lighting and TV / Entertainment in 2012-13. The reconciliations were carried out separately for Urban and for Rural segments. The net energy estimate and forecasts for the 'Other' energy category are provided in the following tables. The toe per household for the Other category (average basis) is of the same order as for lighting in the Rural segment suggesting that the predominant form of cooling is electric fans. In the Urban segment the toe per household for the Other category is a factor of four greater. These comparisons are a reasonable validation of the estimates. The forecast shows a convergence between the Urban and Rural segments as rural electrification proceeds to a 100% target.

Table V-8: Household Sector Electricity Only (mtoe)

	2009	2012	2015	2018	2021	2024	2027	2030	CAGR
Urban HH Other	0.0163	0.0585	0.0519	0.0674	0.0877	0.1050	0.1632	0.3699	13.1%
Rural HH Other	0.0297	0.0682	0.0705	0.0941	0.1281	0.1762	0.2735	0.5037	13.1%

Sources: Consultant

Table V-9: Household Sector Energy (toe per household)

	2009	2012	2015	2018	2021	2024	2027	2030
Urban HH Other	0.0086	0.0299	0.0243	0.0290	0.0346	0.0380	0.0542	0.1128
Rural HH Other	0.0026	0.0057	0.0057	0.0074	0.0098	0.0131	0.0197	0.0353

Sources: Consultant

Project Number: TA No. 8356-MYA

FINAL REPORT

MYANMAR ENERGY MASTER PLAN

LONG-TERM OPTIMAL FUEL MIX

Prepared for

The Asian Development Bank

and

The Myanmar Ministry of Energy

Prepared by

IES
Intelligent Energy Systems

in association with

MMIC
MYANMAR
INTERNATIONAL
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FINAL REPORT

CONSOLIDATED DEMAND FORECASTS

(BIOMASS, LIQUID FUELS, ELECTRICITY)

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INTERNATIONAL
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ABBREVIATIONS

ADB	–	Asian Development Bank
CSO	–	Central Statistics Organisation
ESE	–	Electricity Supply Enterprise
FEC	–	Final Energy Consumption
GDP	–	Gross Domestic Product
GoM	–	Government of the Republic of the Union of Myanmar
MoE	–	Ministry of Energy
YESC	–	Yangon Electricity Supply Corporation

UNITS OF MEASURE

IG	–	Imperial Gallon
km	–	Kilometre
l	–	Litre
mtoe	–	Million tons of oil equivalent
Passenger-km	–	Passenger-Kilometre
Ton-km	–	Metric Ton-Kilometre

CONVERSION FACTORS

1 litre	=	0.22 Imperial Gallon
1 km	=	0.62137 mile

NOTE

In this report, “$” refers to US dollars.

CONTENTS

I. SUMMARY

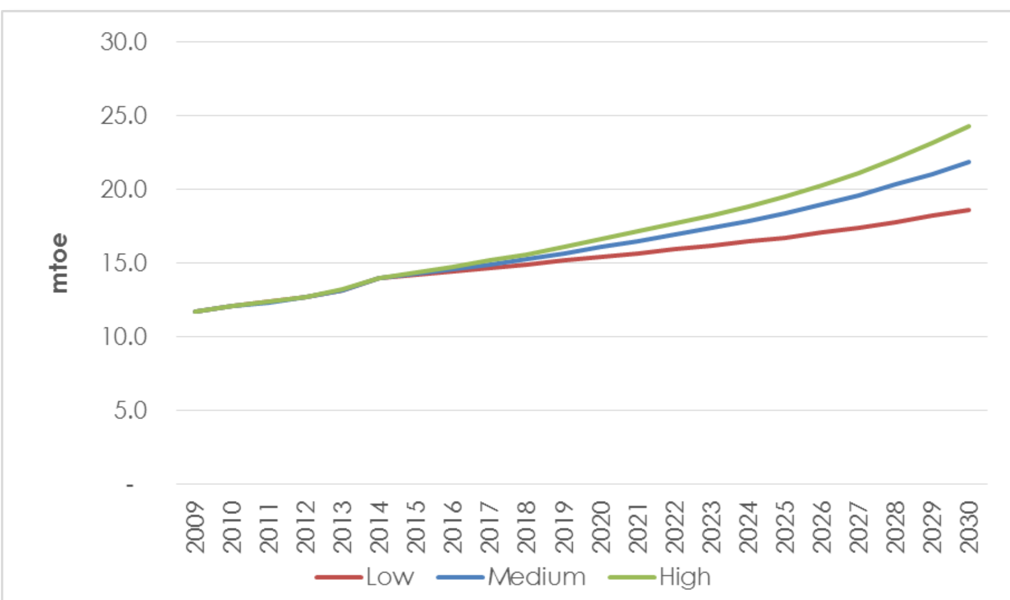
A. Introduction

1. This summary report presents the aggregate demand projections for biomass, solid fuels, liquid fuels and electricity for Myanmar. The demand projection for biomass is given according to the forecasts developed for household and economic sectors using firewood, charcoal and woody biomass. Solid fuel is primarily coal and is an aggregation of the forecasts for the energy-intensive and SME industry sectors. Liquid fuel forecasts represent an aggregation of demands of the economic and household sectors. In the case of electricity the demand projections are presented in this report as 'top-down' forecasts for Yangon Division and the fourteen States and Regions that collectively make up the countryside areas of Myanmar. Residential, commercial, light industry and heavy industry electricity consumption energy forecasts have been forecast separately. A reconciliation process was undertaken to ensure that the aggregated electricity consumption forecast is fully consistent with the individual electricity consumption forecasts presented in the Agriculture, Industry, Commerce & Public Services and Household sector reports of this Energy Masterplan.

B. Final Energy Consumption Projection for Myanmar

2. The aggregate final energy consumption (FEC) forecast for Myanmar is given in Figure I-1. In the case of the medium growth final energy consumption is forecast to rise at a compound annual growth rate of 3.0% from 2012 to 2030, from 12.7 mtoe to 21.9 mtoe.

Figure I-1: Myanmar: Final Energy Consumption Projection to 2030

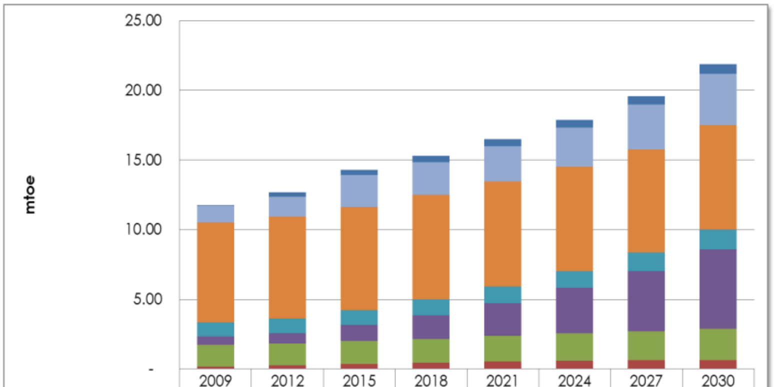


Source: Consultants' analysis

3. The low, medium and high growth cases in Figure I-1 correspond to a) GDP growth of 4.8%, 7.1% and 9.5% respectively, and b) electrification ratios of 80%, 87% and 86% respectively.

4. Figure I-2 to Figure I-5 provide a detailed breakdown of FEC for the medium demand growth forecast by sector and by energy carrier. Given the dominance of household cooking energy consumption, Figure I-4 shows the FEC projection without the household sector.

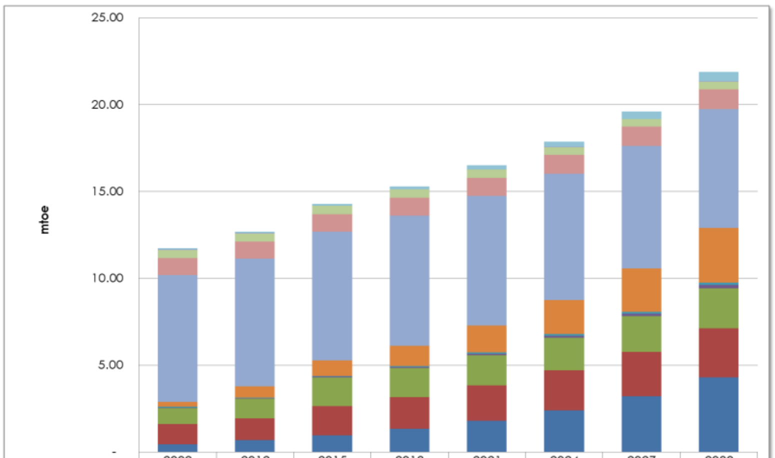
Figure I-2: Myanmar: Final Energy Consumption Projection (Medium)



	2009	2012	2015	2018	2021	2024	2027	2030
Non-Energy	0.01	0.31	0.37	0.44	0.51	0.57	0.64	0.70
Transport	1.22	1.44	2.28	2.34	2.52	2.81	3.19	3.68
Residential - Rural	7.18	7.31	7.40	7.52	7.56	7.48	7.44	7.48
Residential - Urban	1.01	1.08	1.09	1.13	1.18	1.21	1.29	1.44
Industry	0.59	0.70	1.15	1.69	2.38	3.25	4.34	5.70
Commercial	1.54	1.59	1.65	1.74	1.84	1.95	2.09	2.25
Agriculture	0.19	0.25	0.34	0.43	0.52	0.60	0.62	0.63

Source: Consultants' analysis

Figure I-3: Myanmar: FEC Projection by Energy Carrier (medium)

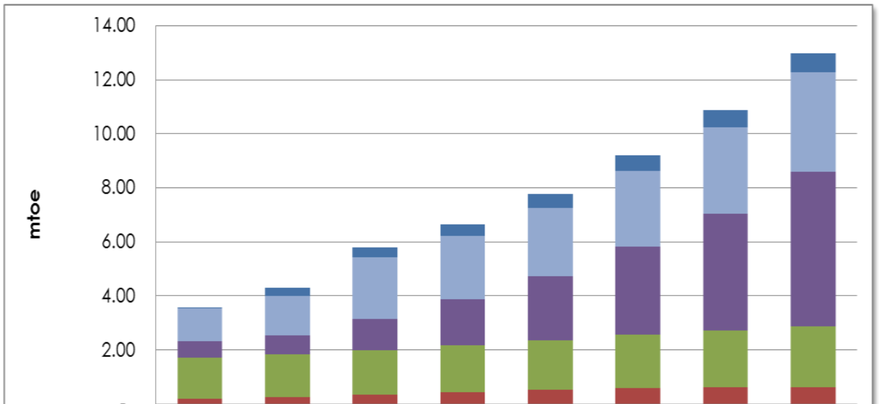


	2009	2012	2015	2018	2021	2024	2027	2030
Coal	0.10	0.07	0.11	0.16	0.23	0.31	0.42	0.55
Paraffin	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Woody Biomass	0.47	0.47	0.47	0.47	0.47	0.46	0.45	0.43
Charcoal	0.97	0.98	1.00	1.02	1.05	1.08	1.11	1.16
Firewood	7.30	7.37	7.43	7.50	7.47	7.26	7.05	6.84
Gas	0.29	0.63	0.89	1.18	1.54	1.97	2.50	3.15
ATF	0.03	0.03	0.03	0.05	0.07	0.09	0.11	0.13
Furnace Oil	0.04	0.03	0.04	0.06	0.08	0.11	0.15	0.20
HSD	0.93	1.16	1.67	1.68	1.75	1.89	2.05	2.30
Motor Spirit	1.17	1.23	1.67	1.83	2.04	2.29	2.55	2.83
Electricity	0.43	0.70	0.96	1.33	1.80	2.41	3.21	4.29

Source: Consultants' analysis

5. The FEC forecast, excluding the household sector is given as Figure I-4. Energy is forecast to rise at a compound annual growth rate of 6.2% from 2012 to 2030, from 4.3 mtoe to 13.0 mtoe.

Figure I-4: Myanmar: FEC Projection (excluding HH's, medium)

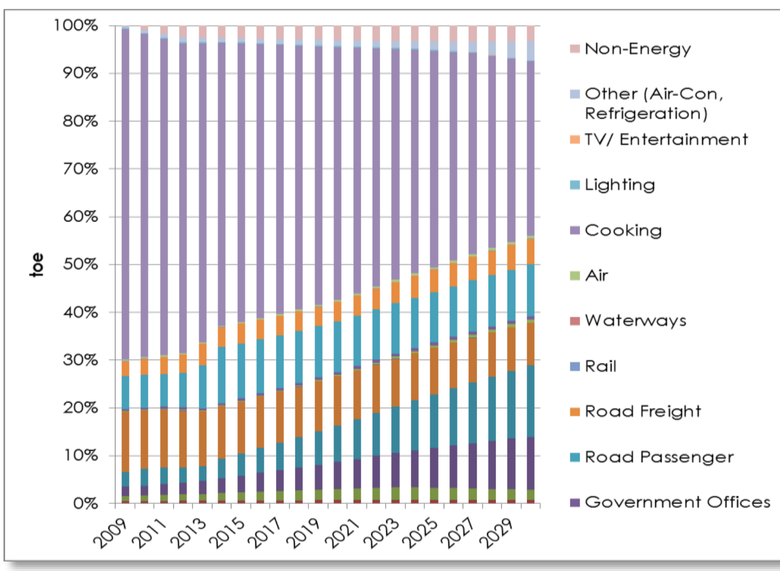


	2009	2012	2015	2018	2021	2024	2027	2030
Non-Energy	0.01	0.31	0.37	0.44	0.51	0.57	0.64	0.70
Transport	1.22	1.44	2.28	2.34	2.52	2.81	3.19	3.68
Industry	0.59	0.70	1.15	1.69	2.38	3.25	4.34	5.70
Commercial	1.54	1.59	1.65	1.74	1.84	1.95	2.09	2.25
Agriculture	0.19	0.25	0.34	0.43	0.52	0.60	0.62	0.63

Source: Consultants' analysis

6. The FEC forecast is given by sub-sector contributions as follows, illustrating the dominance of household cooking but also the reduction assuming an electrification ratio of 87% by 2030.

Figure I-5: Myanmar: FEC Projection Contribution by Sub-Sectors (medium)



Source: Consultants' analysis

C. Energy Intensity & Elasticity Projection for Myanmar

7. The energy intensity projection for Myanmar is given as Figure I-6; this projection includes only the economic sectors, the household sector is excluded, and the projection is for the medium GDP growth scenario. The elasticity of electricity consumption is given as Figure I-7.

Figure I-6: Myanmar: Energy Intensity Projection

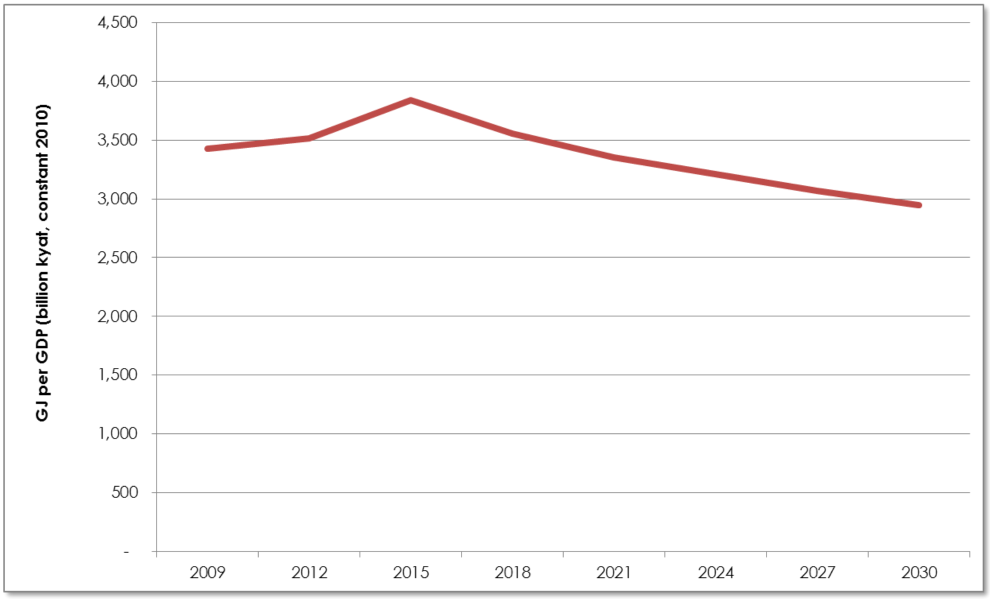
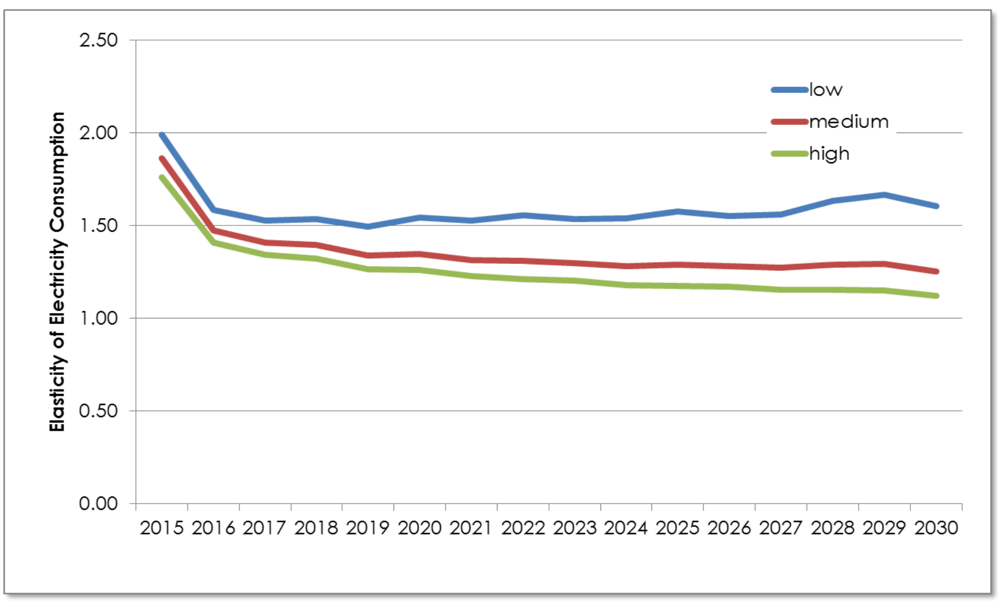


Figure I-7: Myanmar: Elasticity Electricity Consumption



Source: Consultants' analysis

II. FEC FORECASTS BY SECTOR

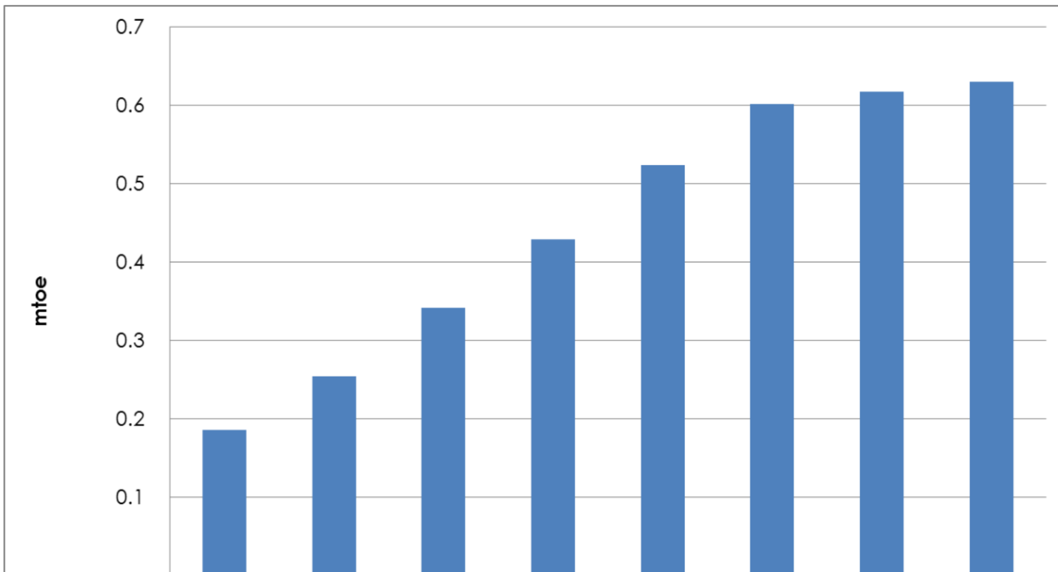
D. Introduction

8. Sector FEC forecasts follow for the medium demand growth case. Forecasts are given for the Agriculture, Industry, Commercial & Public Services, Transport and Household sectors.

E. Agriculture

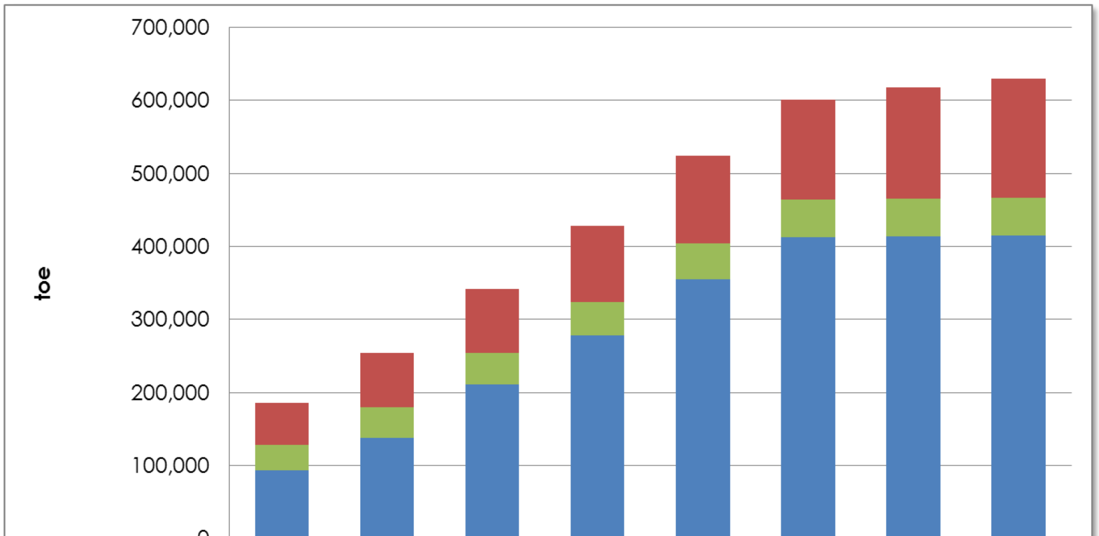
9. The FEC forecast for Myanmar's Agriculture sector are given as a set of charts. Figure II-1 shows that the FEC of Agriculture is forecast to grow at a compound annual rate of 5.0%.

Figure II-1: FEC Projection: Agriculture



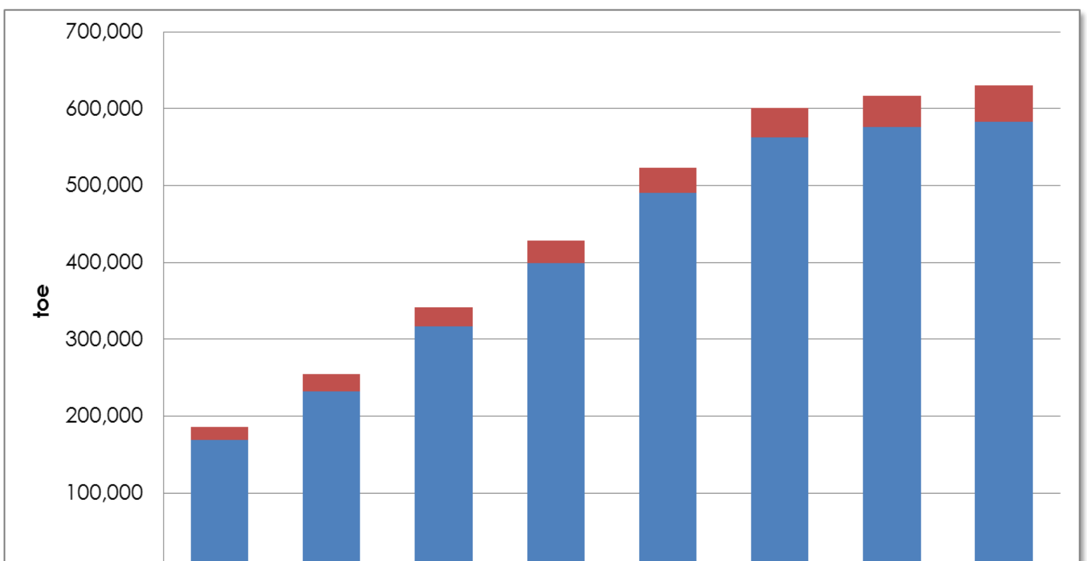
	2009	2012	2015	2018	2021	2024	2027	2030
Agriculture	0.19	0.25	0.34	0.43	0.52	0.60	0.62	0.63

Figure II-2: FEC by Modality: Agriculture



	2009	2012	2015	2018	2021	2024	2027	2030
Water Pumping	57,505	75,000	87,937	104,331	119,609	137,216	152,341	163,181
Tractors	34,896	41,240	42,872	45,899	49,140	51,426	51,426	51,426
Power Tillers	93,901	138,314	210,764	278,268	354,763	412,346	413,616	415,402

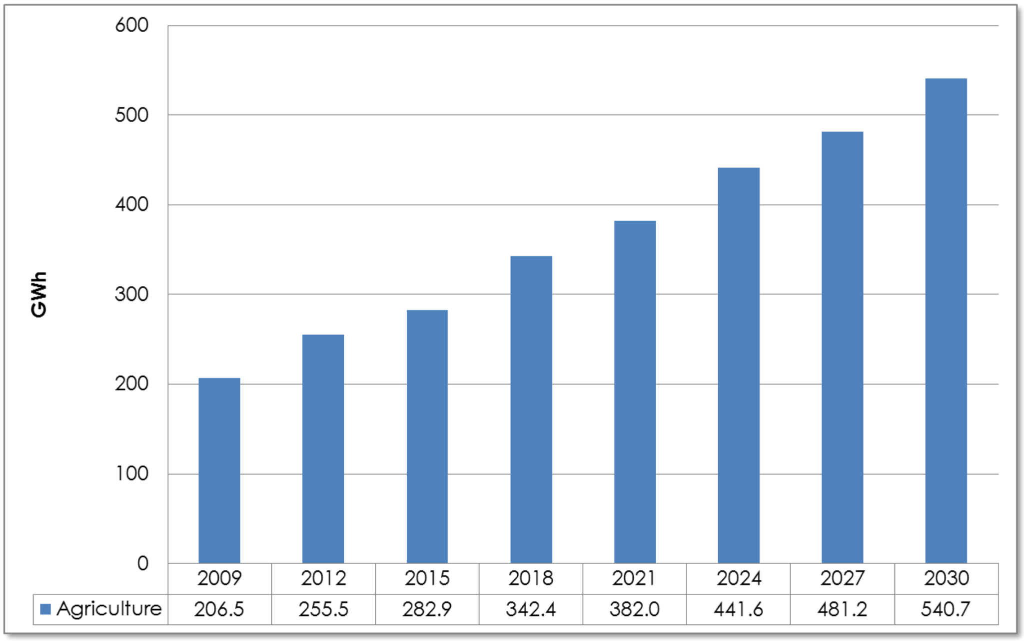
Figure II-3: FEC by Energy Carrier: Agriculture



	2009	2012	2015	2018	2021	2024	2027	2030
Electricity	17,757	21,967	24,323	29,443	32,849	37,968	41,375	46,492
Diesel	168,544	232,587	317,250	399,055	490,662	563,019	576,008	583,518

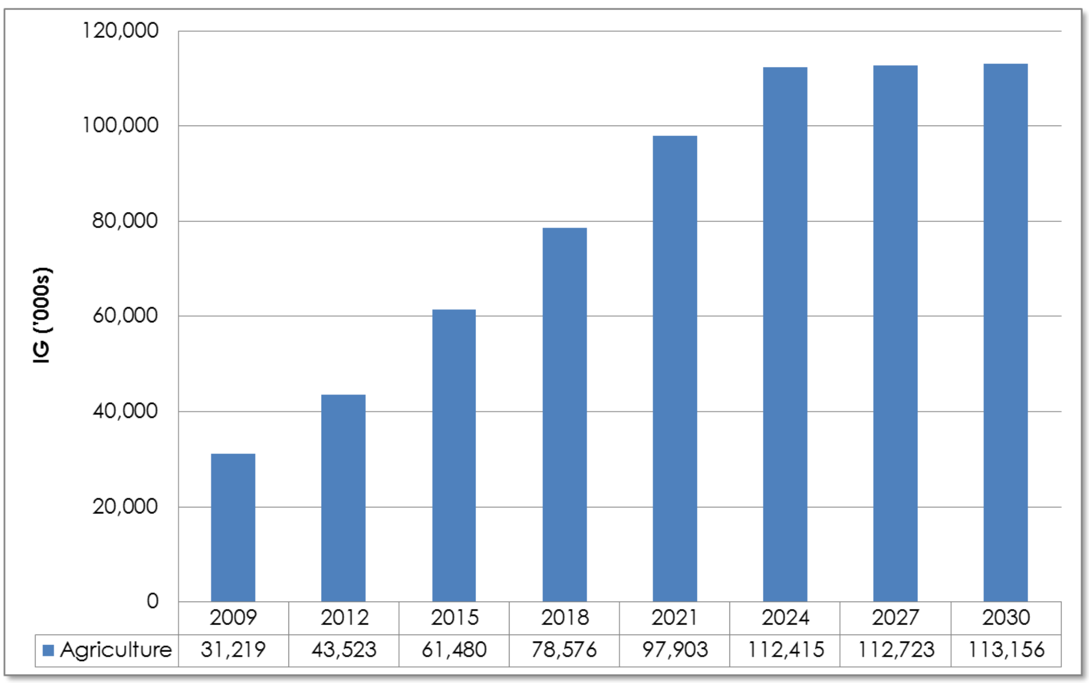
Source: Consultants' analysis

Figure II-4: FEC by Energy Carrier: Electricity, Agriculture



Source: Consultants' analysis

Figure II-5: FEC by Energy Carrier: Diesel, Agriculture

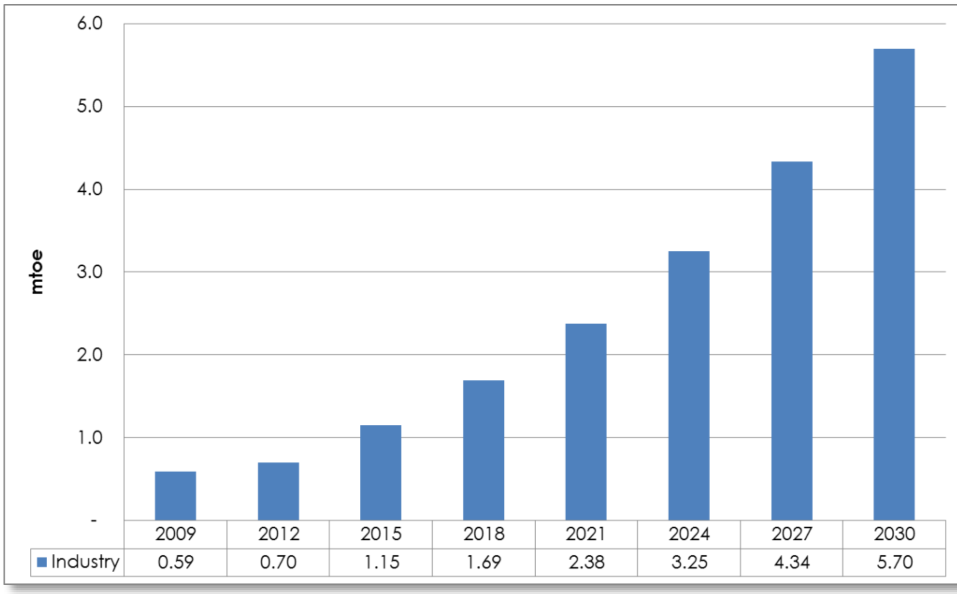


Source: Consultants' analysis

F. Industry

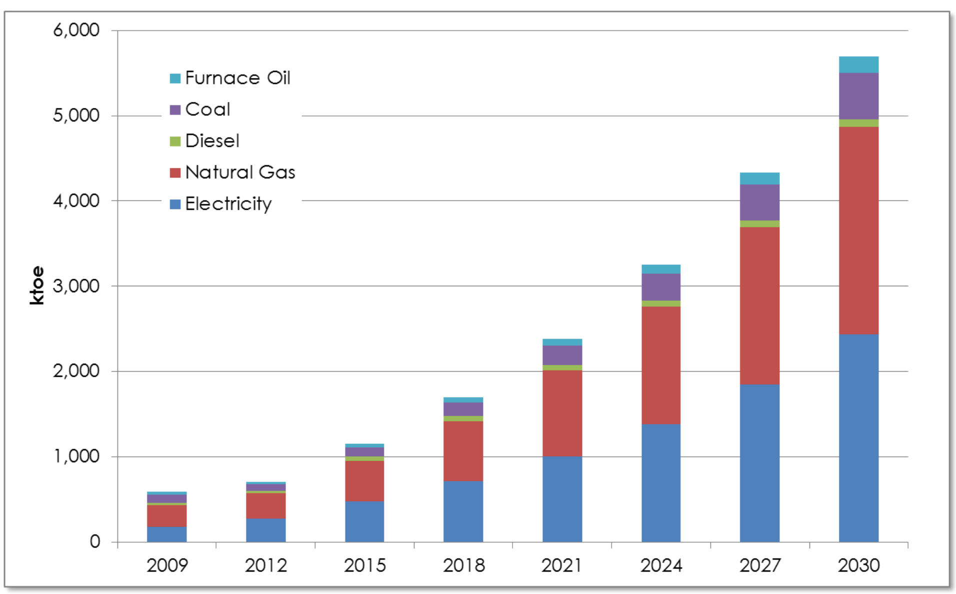
10. The FEC forecast for Myanmar's Industry sector is given by the charts and tables that follow. Figure II-6 shows that the Industry FEC is forecast to rise at a compound annual growth rate of 11.6% from 2012 to 2030.

Figure II-6: FEC Projection: Industry (excluding fertilizer)



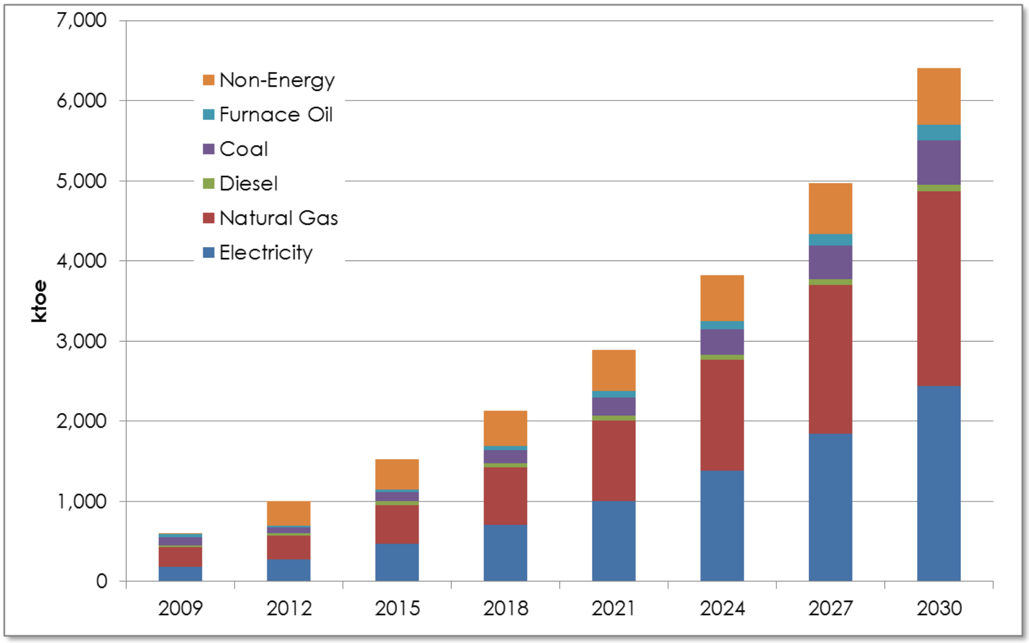
Source: Consultants' analysis

Figure II-7: FEC by Energy Carrier: Industry (excluding fertilizer)



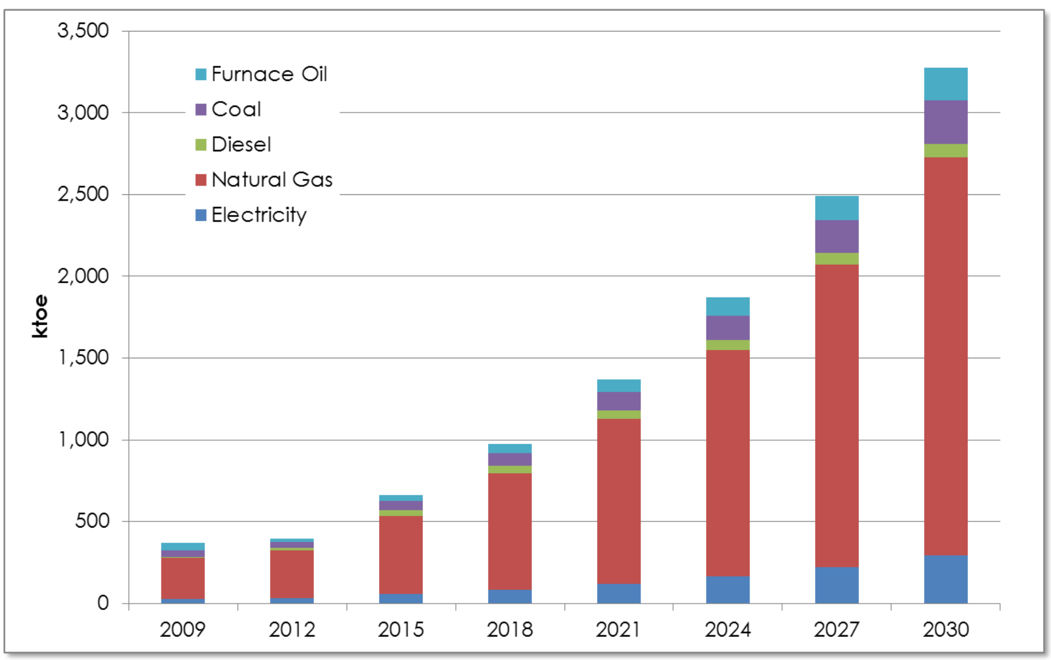
Source: Consultants' analysis

Figure II-8: FEC by Energy Carrier: Industry (including fertilizer)



Source: Consultants' analysis

Figure II-9: FEC Projection: Energy-Intensive Industry



Source: Consultants' analysis

Table II-10: FEC by Energy Carrier: Energy-Intensive Industry

		2009	2012	2015	2018	2021	2024	2027	2030
Electricity	GWh	318	379	663	990	1,403	1,927	2,578	3,397
Natural Gas	tons	212,681	247,546	403,668	602,926	854,279	1,173,641	1,569,684	2,068,738
Diesel[1]	IG '000s	1	3	9	10	12	13	15	18
Coal	tons	64,469	49,929	78,456	117,183	166,035	228,105	305,079	402,073
Furnace Oil	IG	9,116	5,385	8,210	12,263	17,375	23,870	31,925	42,075

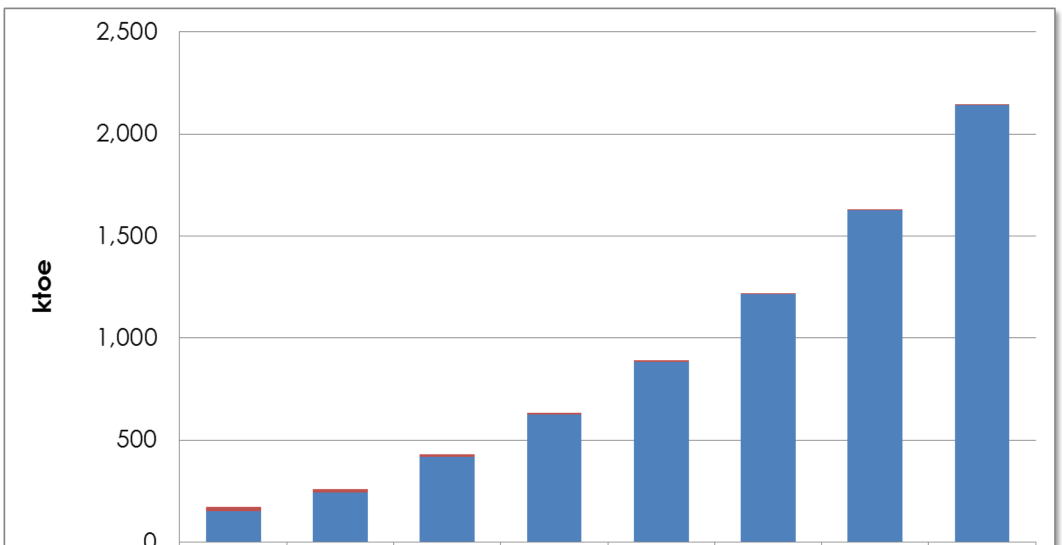
Source: Consultants' analysis

Table II-11: FEC by Energy Carrier: SME

		2009	2012	2015	2018	2021	2024	2027	2030
Electricity	GWh	1,778	2,852	4,861	7,261	10,288	14,133	18,903	24,913
Diesel	IG '000s	3,786	3,276	2,767	2,258	1,748	1,239	729	220

Source: Consultants' analysis

Figure II-12: FEC Projection: Small to Medium Enterprise



	2009	2012	2015	2018	2021	2024	2027	2030
Diesel	19	16	14	11	9	6	4	1
Electricity	153	245	418	624	885	1,215	1,625	2,142

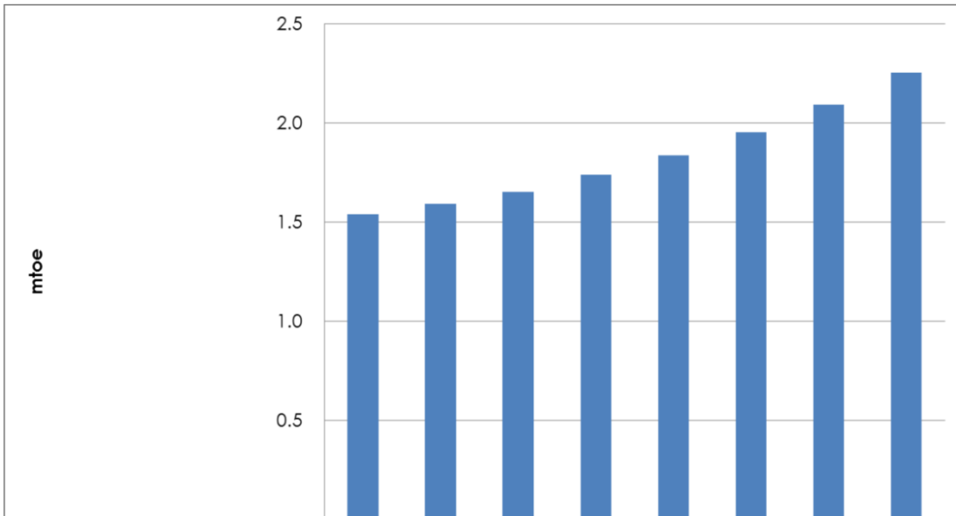
Source: Consultants' analysis

[1] Diesel consumption for transport use associated with industry activity is included in the Transport sector forecasts

G. Commercial & Public Services

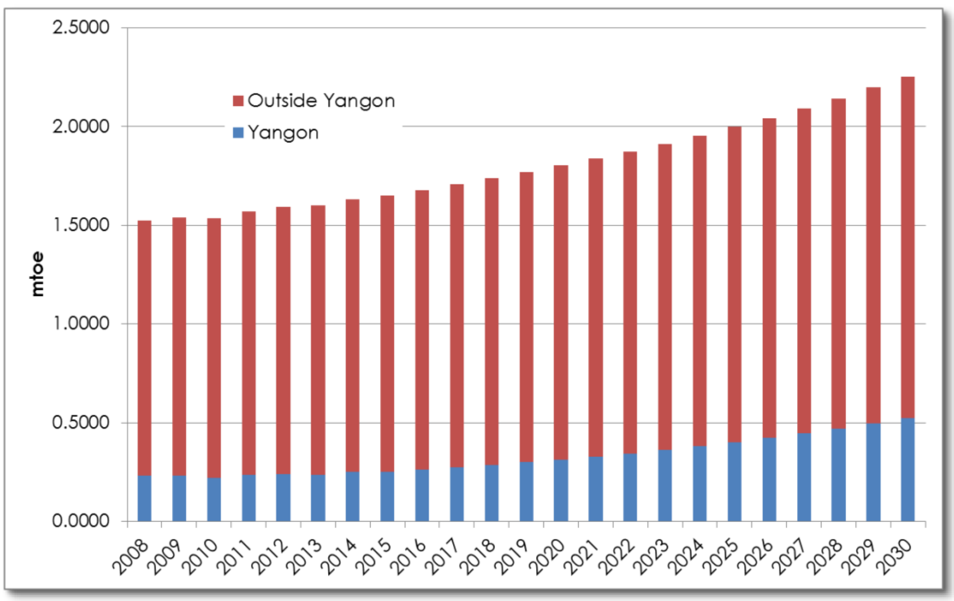
11. The FEC forecasts for Myanmar's Commercial & Public Services sector are given as a set of charts. Figure II-13 shows that the FEC of Commercial & Public Services is forecast to grow at a compound annual rate of 2.1%.

Figure II-13: FEC Projection: Commercial & Public Services



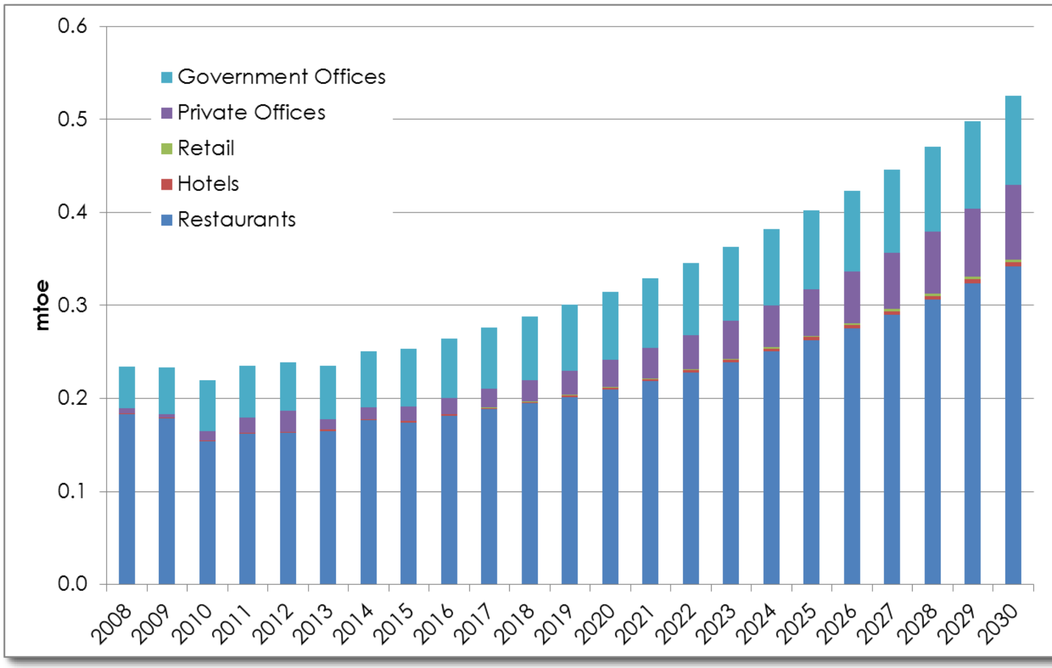
	2009	2012	2015	2018	2021	2024	2027	2030
Commercial & Public Services	1.54	1.59	1.65	1.74	1.84	1.95	2.09	2.25

Figure II-14: FEC Projection: Commercial & Public Services



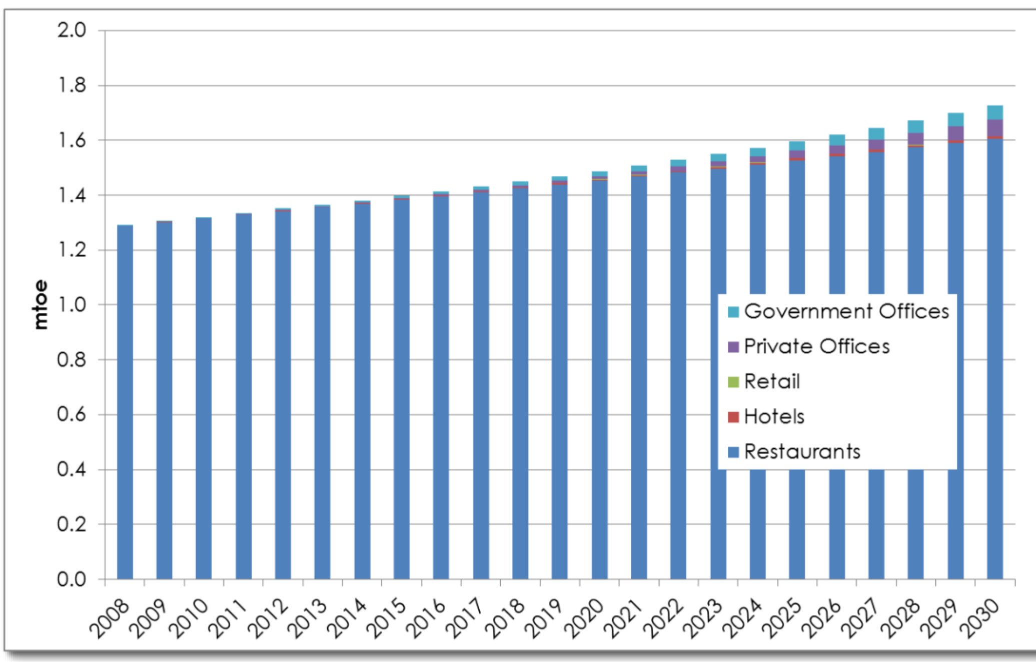
Source: Consultants' analysis

Figure II-15: FEC: Commercial & Public Services by Sub-Sector: Yangon



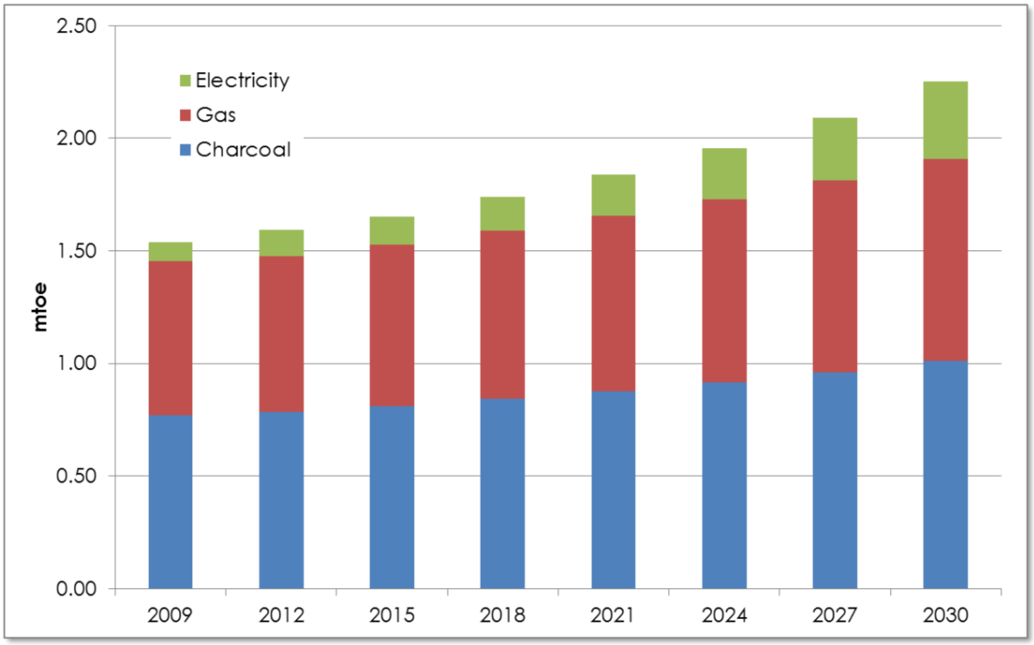
Source: Consultants' analysis

Figure II-16: FEC: Commercial & Public Services by Sub-Sector: Outside Yangon



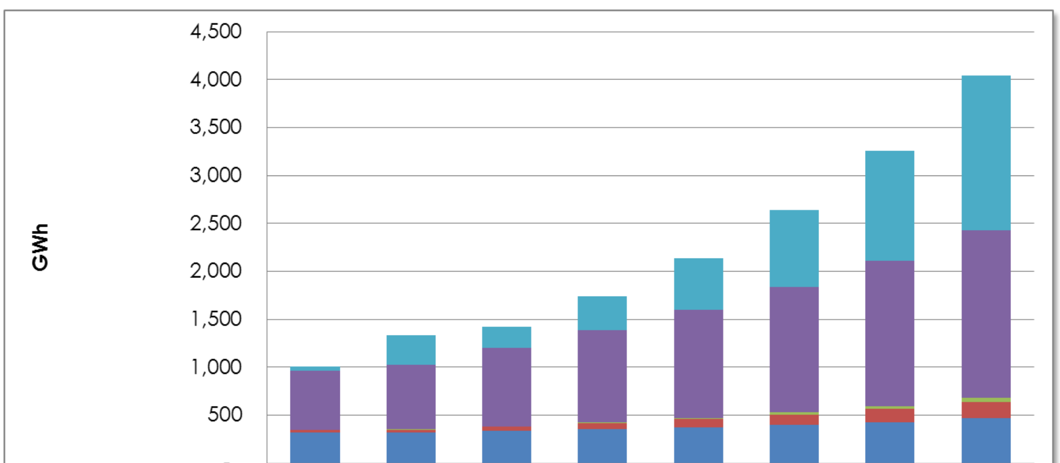
Source: Consultants' analysis

Figure II-17: FEC by Energy Carrier: Public & Commercial Services



Source: Consultants' analysis

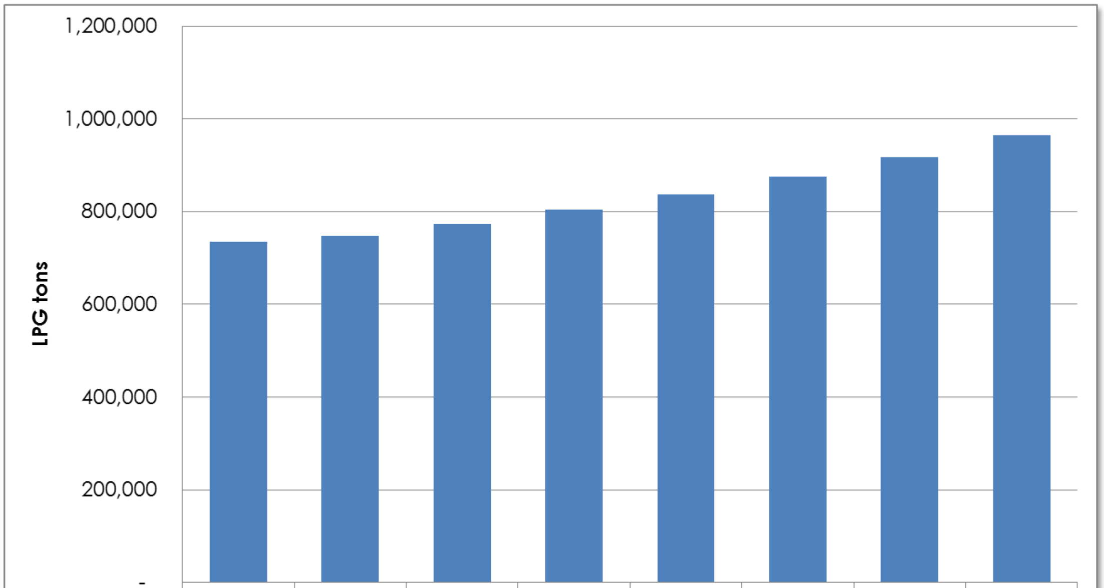
Figure II-18: FEC by Energy Carrier: Public & Commercial Services, Electricity



	2009	2012	2015	2018	2021	2024	2027	2030
Private Offices GWh	44	302	217	351	539	796	1,144	1,610
Gov't Offices GWh	618	676	820	965	1,128	1,311	1,518	1,751
Retail GWh	2	3	5	9	13	20	31	47
Hotels GWh	22	28	45	65	86	110	137	169
Restuarants GWh	324	322	335	353	374	400	430	466

Source: Consultants' analysis

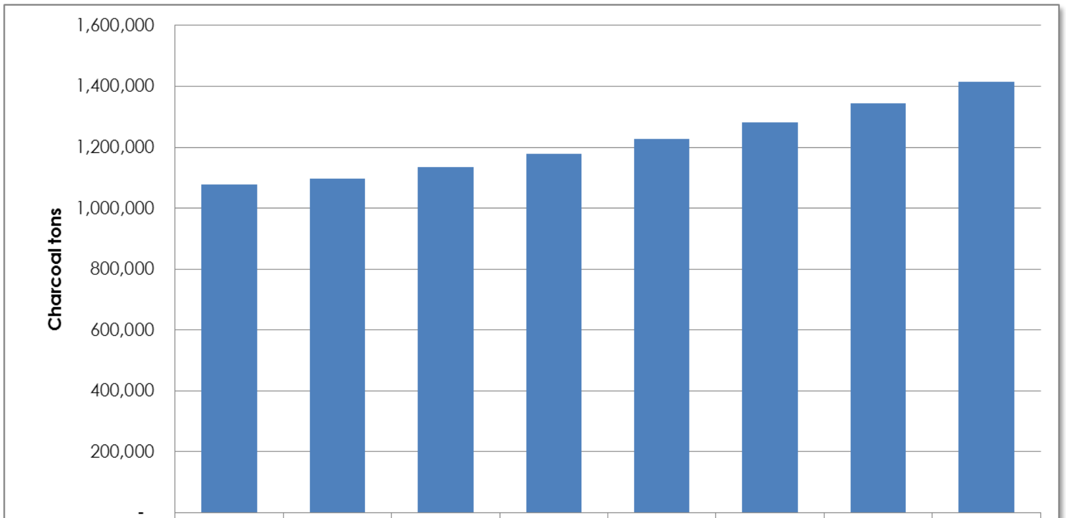
Figure II-19: FEC by Energy Carrier: Public & Commercial Services, LPGas



	2009	2012	2015	2018	2021	2024	2027	2030
Restaurants	735,556	747,907	773,593	804,264	837,242	874,891	916,876	965,205

Source: Consultants' analysis

Figure II-20: FEC by Energy Carrier: Public & Commercial Services, Charcoal



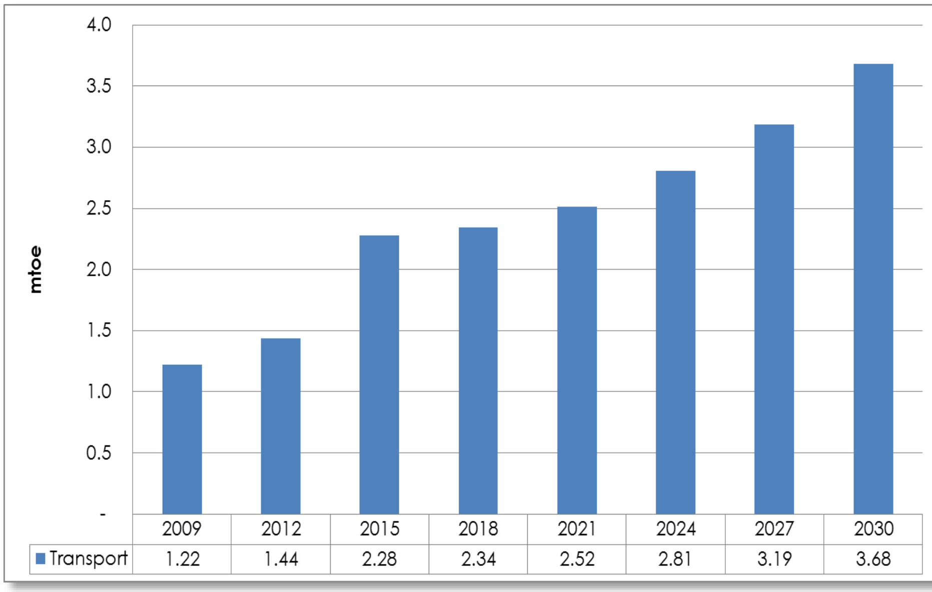
	2009	2012	2015	2018	2021	2024	2027	2030
Restaurants	1,078,066	1,096,168	1,133,816	1,178,768	1,227,103	1,282,283	1,343,818	1,414,651

Source: Consultants' analysis

H. Transport

12. The FEC forecasts for Myanmar's Transport Services sector are given as a set of charts. Figure II-13 shows that the FEC of Transport is forecast to grow at a compound annual rate of 15%.

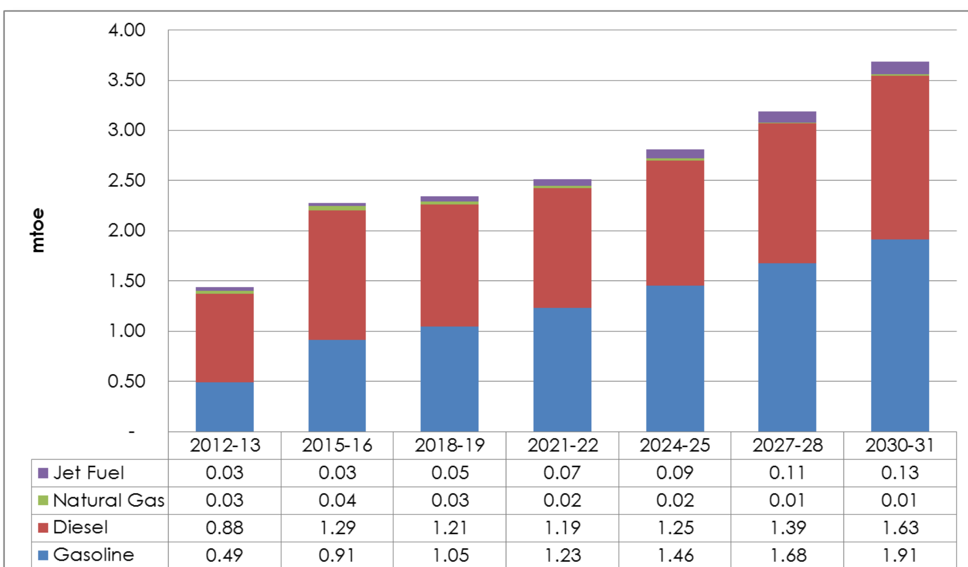
Figure II-21: FEC Projection: Transport



	2009	2012	2015	2018	2021	2024	2027	2030
Transport	1.22	1.44	2.28	2.34	2.52	2.81	3.19	3.68

Source: Consultants' analysis

Figure II-22: FEC Projection by Energy Carrier: Transport



	2012-13	2015-16	2018-19	2021-22	2024-25	2027-28	2030-31
Jet Fuel	0.03	0.03	0.05	0.07	0.09	0.11	0.13
Natural Gas	0.03	0.04	0.03	0.02	0.02	0.01	0.01
Diesel	0.88	1.29	1.21	1.19	1.25	1.39	1.63
Gasoline	0.49	0.91	1.05	1.23	1.46	1.68	1.91

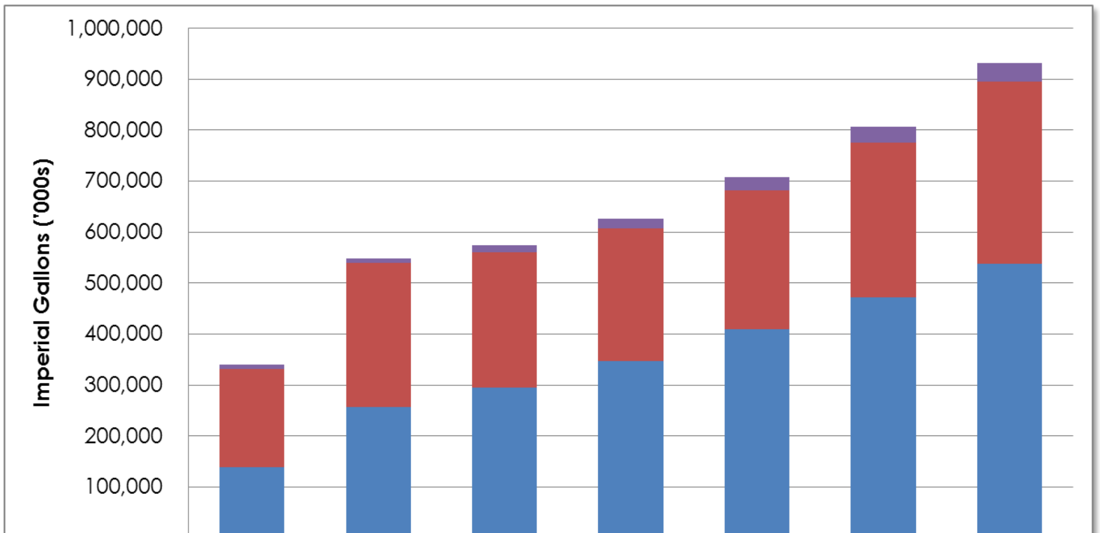
Source: Consultants' analysis

Table II-23: FEC by Energy Carrier Physicals: Transport

	Reference						
	2012	2015	2018	2021	2024	2027	2030
Gasoline (IG - 000's)	138,568	257,110	294,565	346,927	409,364	471,405	538,565
Bioethanol (IG - 000's)	-	-	-	-	-	-	-
Diesel (IG - 000's)	192,351	281,645	265,174	259,770	272,469	304,403	355,854
Natural Gas (cub m - 000's)	37,326	51,621	38,749	29,061	20,825	13,694	14,591
Jet Fuel (IG '000s)	9,211	9,250	14,800	20,350	25,900	31,450	37,000

Source: Consultants' analysis

Figure II-24: FEC by Energy Carrier Physicals: Transport



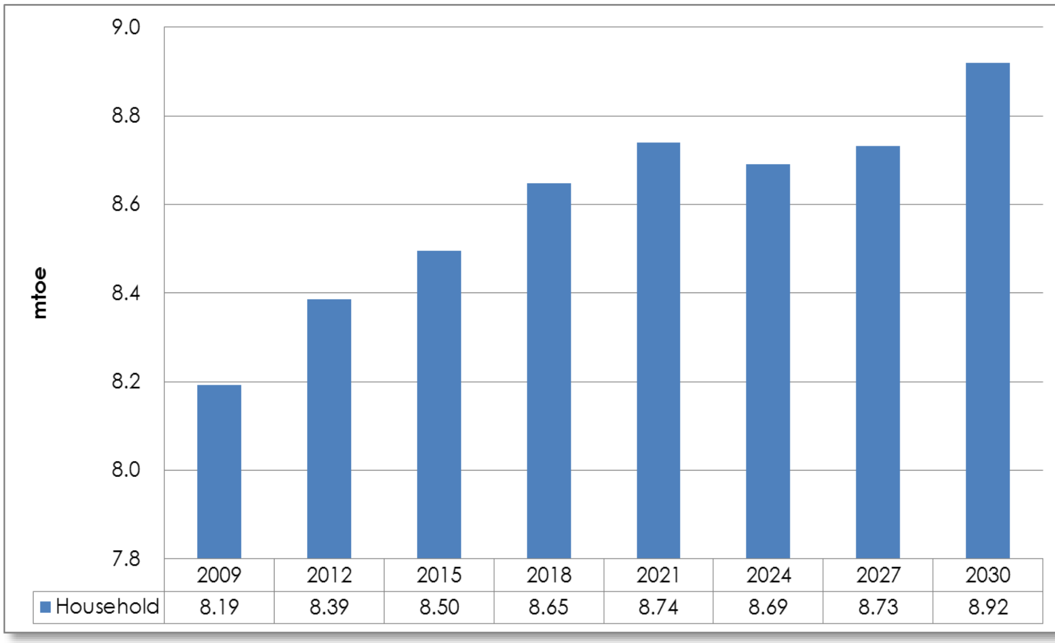
	2012-13	2015-16	2018-19	2021-22	2024-25	2027-28	2030-31
Jet Fuel	9,211	9,250	14,800	20,350	25,900	31,450	37,000
Diesel	192,351	281,645	265,174	259,770	272,469	304,403	355,854
Gasoline	138,568	257,110	294,565	346,927	409,364	471,405	538,565

Source: Consultants' analysis

I. Households

13. The FEC forecasts for Myanmar's Household sector are given as a set of charts. Figure II-25 shows that the FEC of Households is forecast to grow at a compound annual rate of 0.4%.

Figure II-25: FEC Projection: Households



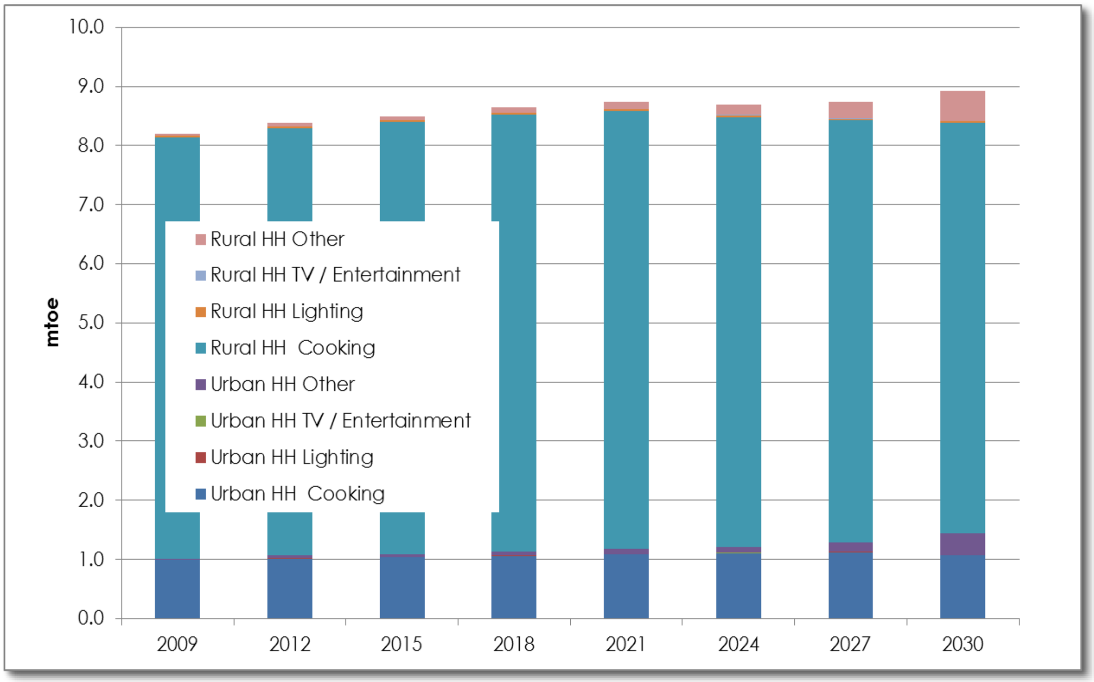
Source: Consultants' analysis

Table II-26: Household FEC by Sub-Sector

	2009	2012	2015	2018	2021	2024	2027	2030	CAGR
Urban HH Cooking	0.9885	1.0121	1.0358	1.0594	1.0819	1.1019	1.1220	1.0651	0.2%
Urban HH Lighting	0.0040	0.0043	0.0046	0.0049	0.0052	0.0059	0.0065	0.0070	2.8%
Urban HH TV / Entertainment	0.0002	0.0003	0.0005	0.0008	0.0010	0.0013	0.0017	0.0021	9.4%
Urban HH Other	0.0163	0.0585	0.0519	0.0674	0.0877	0.1050	0.1632	0.3699	13.1%
Urban HH Total	*1.0090*	*1.0752*	*1.0928*	*1.1325*	*1.1757*	*1.2141*	*1.2934*	*1.4441*	*1.9%*
Rural HH Cooking	7.1287	7.2167	7.3046	7.3925	7.4056	7.2689	7.1323	6.9382	-0.3%
Rural HH Lighting	0.0239	0.0246	0.0253	0.0260	0.0267	0.0267	0.0266	0.0255	0.1%
Rural HH TV / Entertainment	0.0009	0.0010	0.0020	0.0030	0.0040	0.0050	0.0060	0.0076	8.8%
Rural HH Other	0.0297	0.0682	0.0705	0.0941	0.1281	0.1762	0.2735	0.5037	13.1%
Rural HH Total	*7.1832*	*7.3105*	*7.4024*	*7.5156*	*7.5644*	*7.4767*	*7.4384*	*7.4751*	*0.1%*
Total Urban & Rural	*8.1923*	*8.3857*	*8.4952*	*8.6481*	*8.7401*	*8.6909*	*8.7318*	*8.9192*	*0.3%*
% Electricity	1.8%	3.4%	4.0%	5.1%	6.6%	8.8%	12.0%	16.4%	

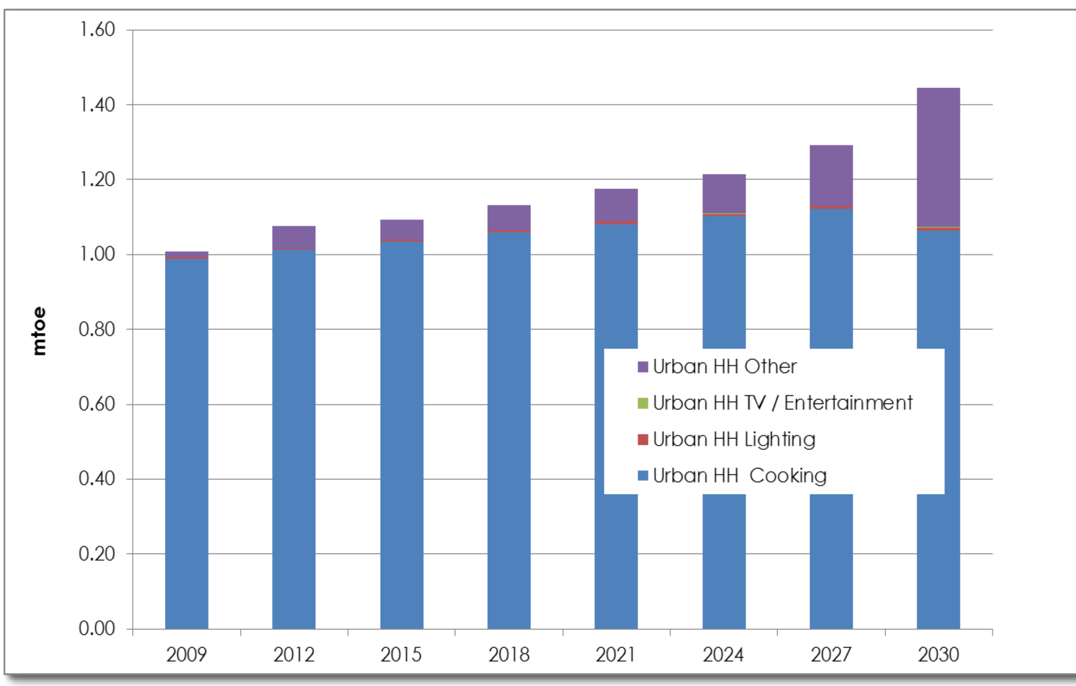
Source: Consultants' analysis

Figure II-27: FEC Projection by End-Use: All Households



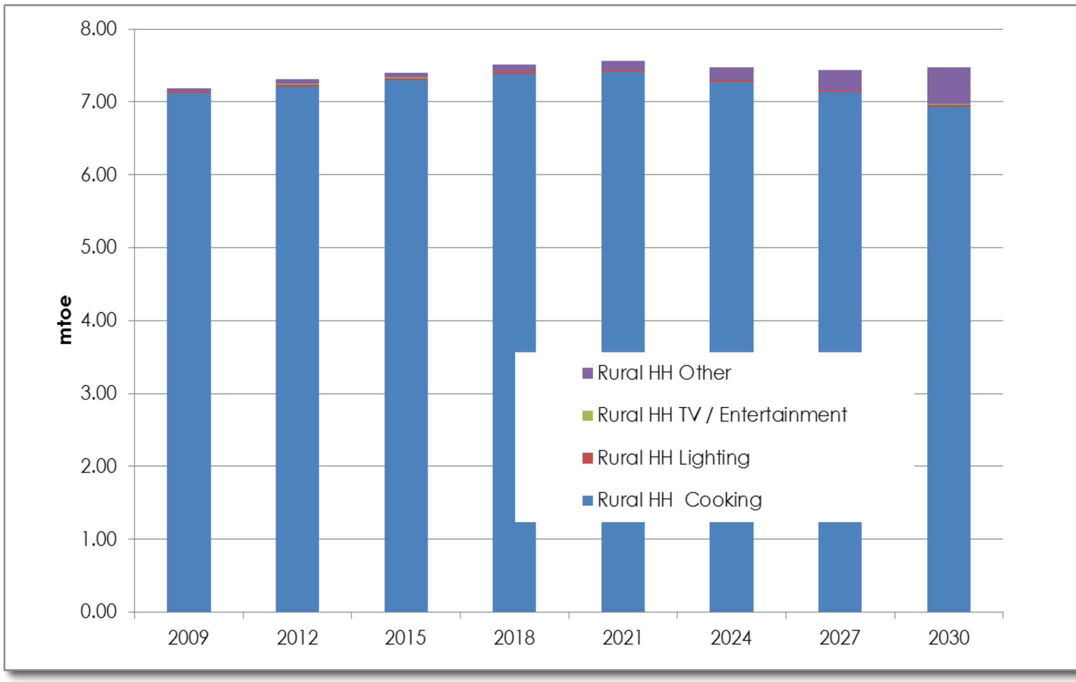
Source: Consultants' analysis

Figure II-28: FEC Projection by End-Use: Urban Households



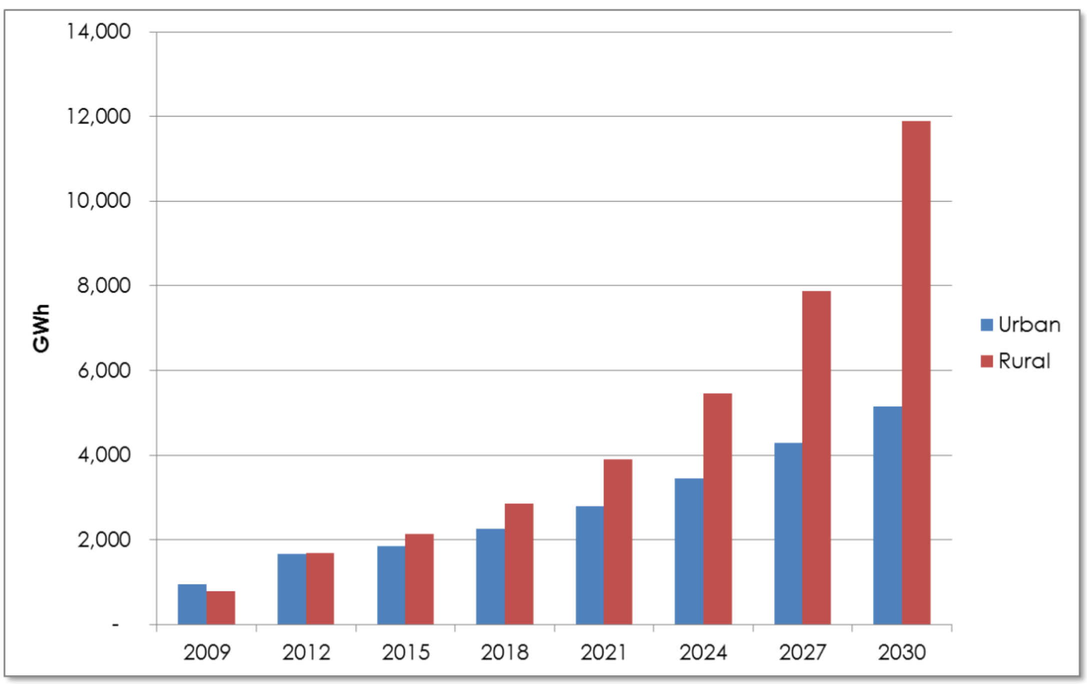
Source: Consultants' analysis

Figure II-29: FEC Projection by End-Use: Rural Households



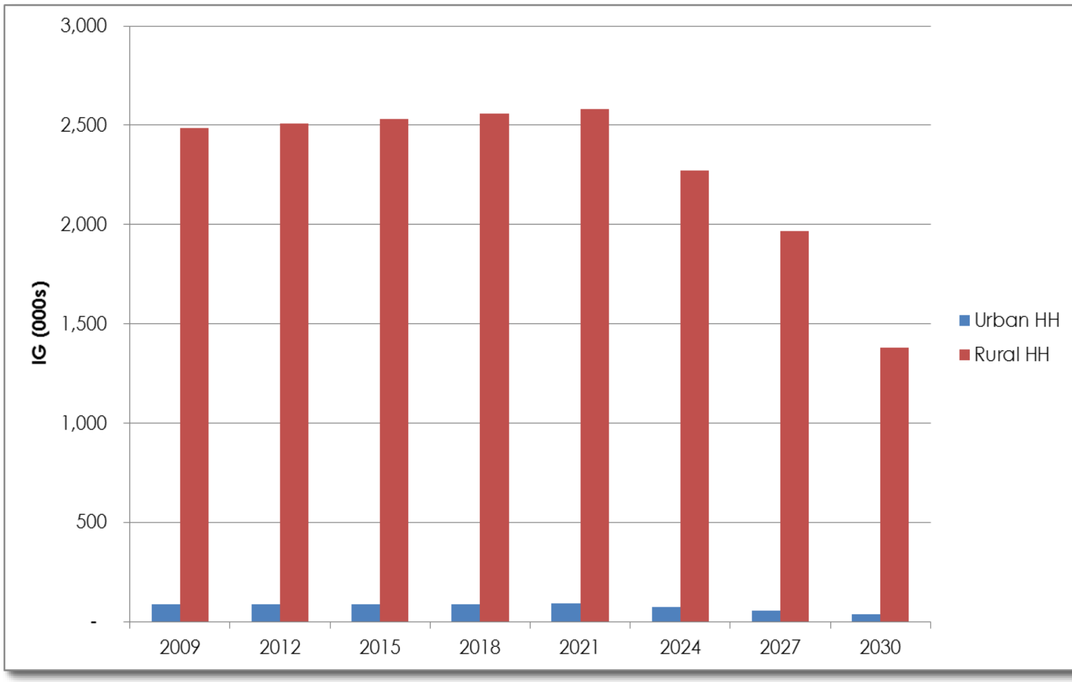
Source: Consultants' analysis

Figure II-30: FEC Projection by Energy Carrier: Households, Electricity



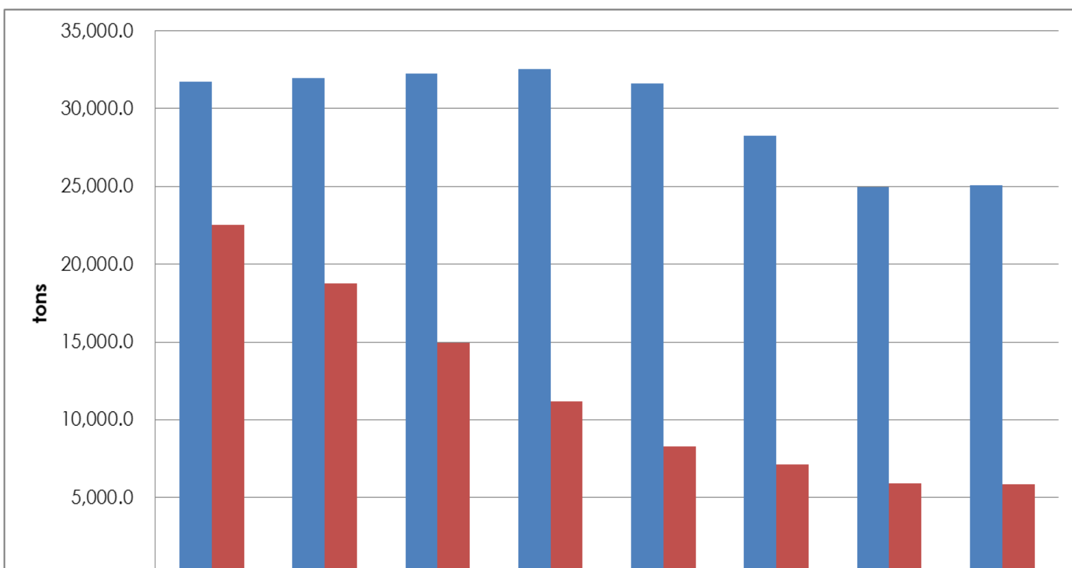
Source: Consultants' analysis

Figure II-31: FEC Projection by Energy Carrier: Households, Diesel



Source: Consultants' analysis

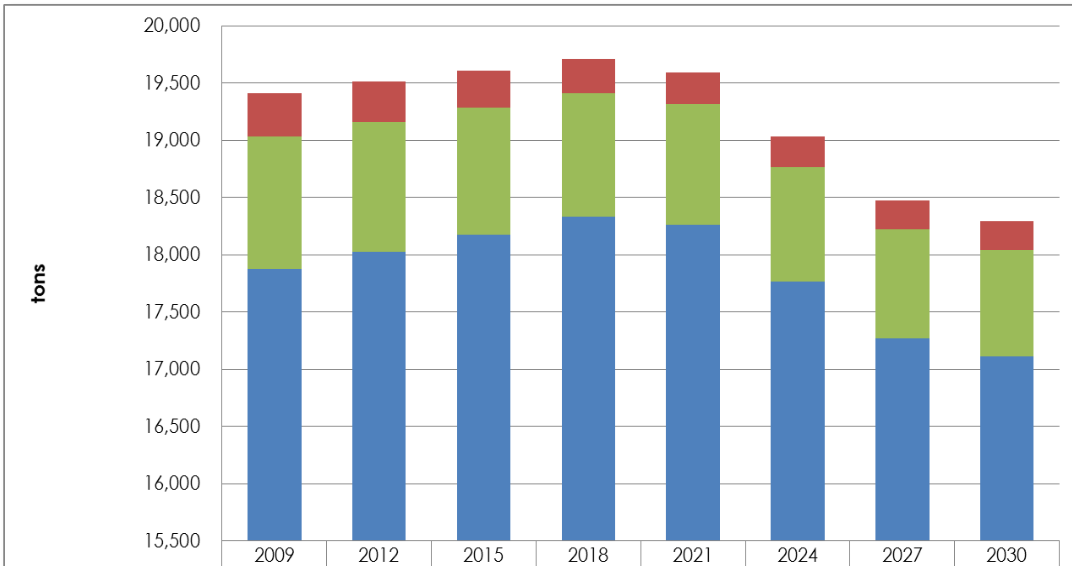
Figure II-32: FEC Projection by Energy Carrier: Households, LP Gas



	2009	2012	2015	2018	2021	2024	2027	2030
Urban HH	31,714.9	31,983.9	32,252.8	32,521.7	31,595.7	28,279.6	24,963.6	25,049.3
Rural HH	22,506.8	18,736.0	14,965.2	11,194.3	8,288.1	7,111.1	5,934.1	5,840.6

Source: Consultants' analysis

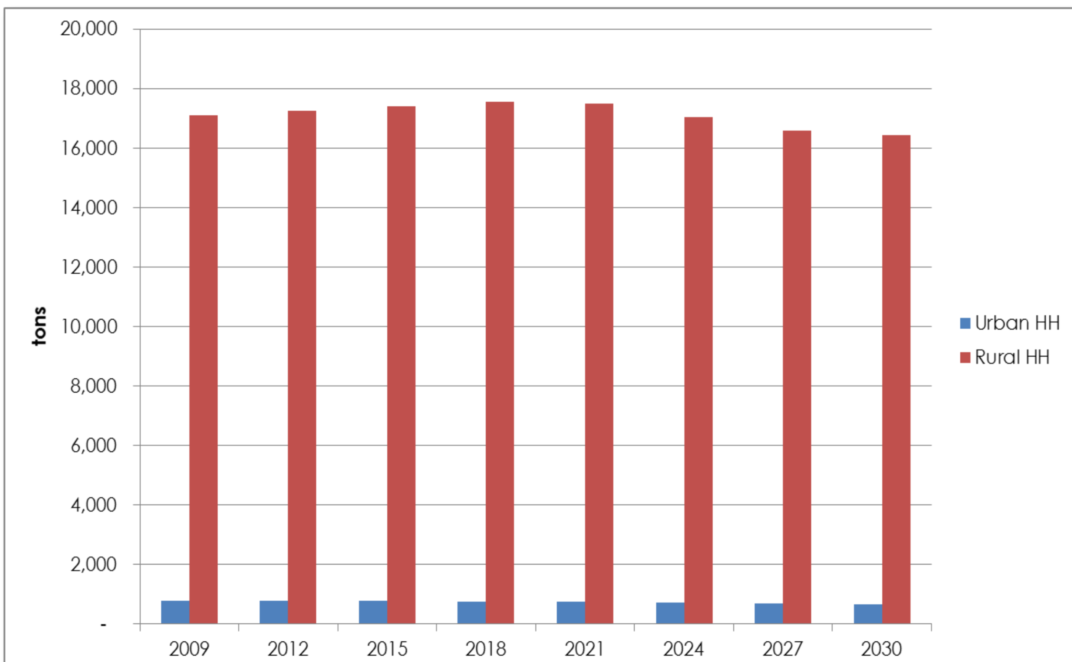
Figure II-33: FEC Projection by Energy Carrier: All Households, Biomass



	2009	2012	2015	2018	2021	2024	2027	2030
Charcoal	373	349	325	301	281	266	251	250
Agricultural Waste	1,161	1,135	1,109	1,083	1,049	999	949	935
Firewood	17,875	18,027	18,178	18,330	18,266	17,770	17,274	17,111

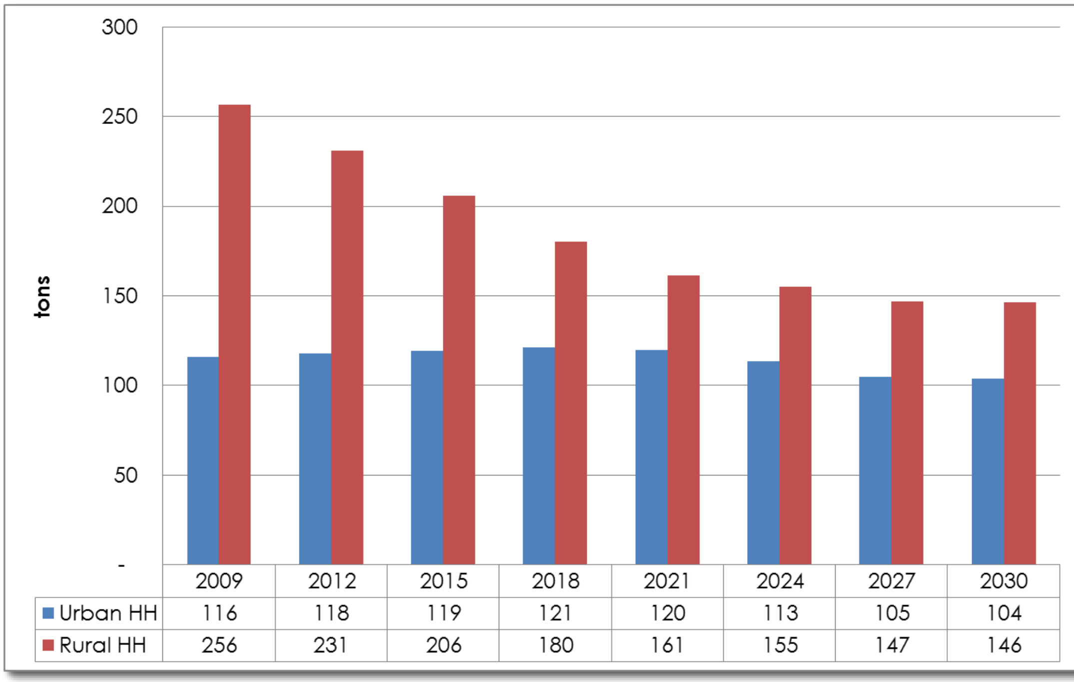
Source: Consultants' analysis

Figure II-34: FEC Projection by Energy Carrier: All Households, Firewood



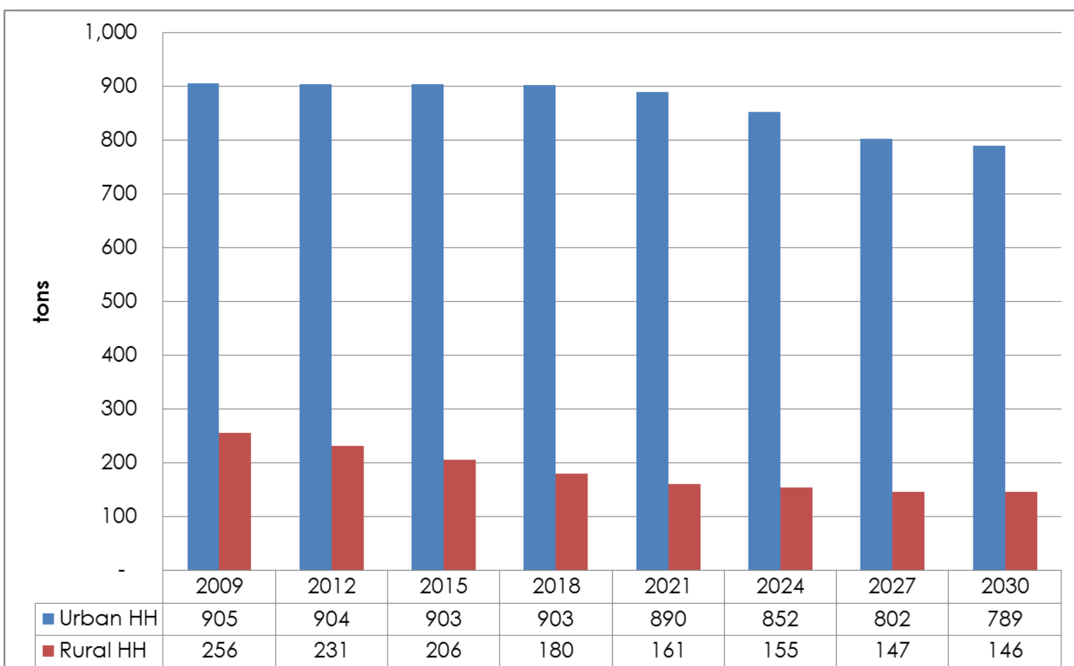
Source: Consultants' analysis

Figure II-35: FEC Projection by Energy Carrier: All Households, Charcoal



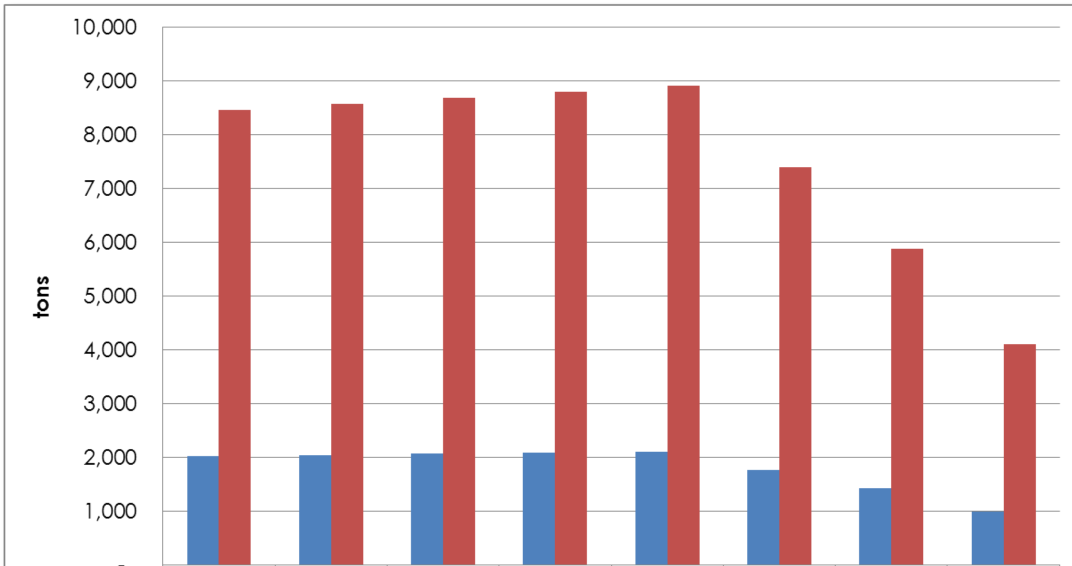
Source: Consultants' analysis

Figure II-36: FEC Projection by Energy Carrier: All Households, Agricultural Waste



Source: Consultants' analysis

Figure II-37: FEC Projection by Energy Carrier: All Households, Paraffin Wax



	2009	2012	2015	2018	2021	2024	2027	2030
Urban HH	2,030	2,050	2,070	2,090	2,110	1,772	1,434	999
Rural HH	8,452	8,565	8,678	8,792	8,905	7,390	5,875	4,100

Source: Consultants' analysis

III. CONSOLIDATED FORECASTS BY ENERGY CARRIER

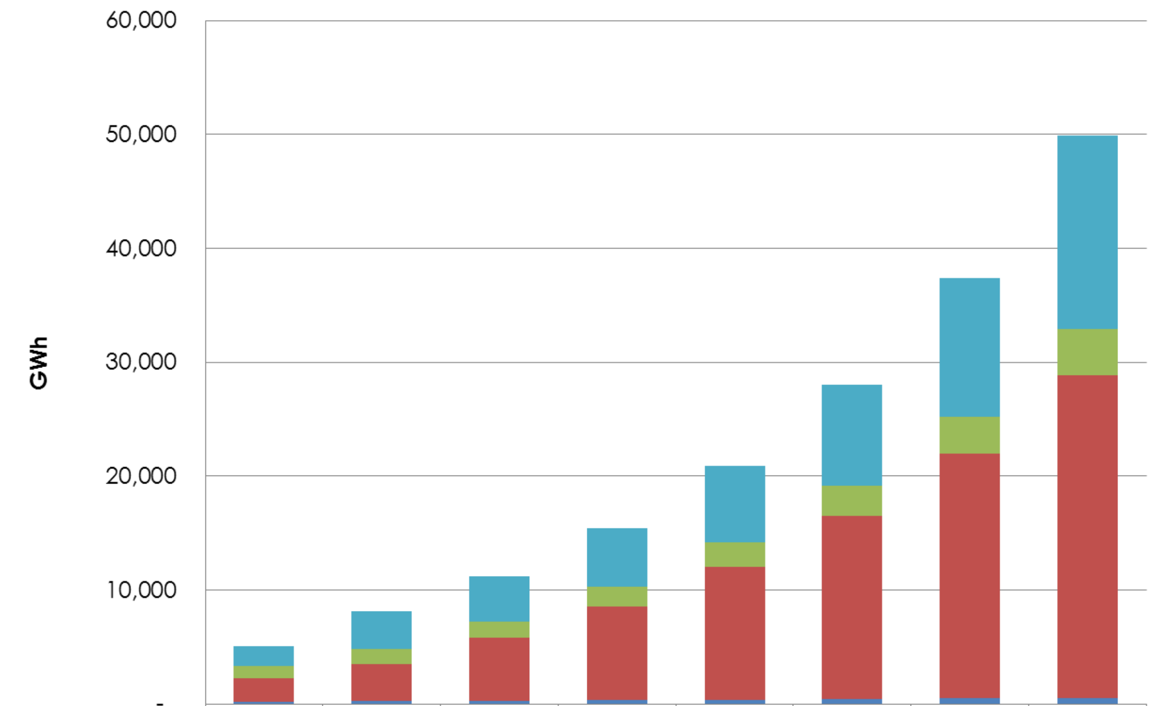
J. Introduction

14. A consolidation of the fuel forecasts, given in the previous section by sector, is given by chart in each of the following sub-sections. These consolidated forecasts represent the total energy carrier demand forecasts for the energy sector of Myanmar to 2030, according to the medium demand growth case.

K. Electricity

15. A consolidation of the electricity forecasts given in the previous section are given as Figure III-1. Historical electricity sales data was gathered from YESC and ESE and used to forecast electricity consumption using a top-down' forecasting method, taking into account the national electrification program. The 'top-down' forecasts and the 'bottom-up' forecasts given in Section II were reconciled. The details of the 'top-down' forecasts are given in Section IV.

Figure III-1: Electricity Forecast (GWh): Total

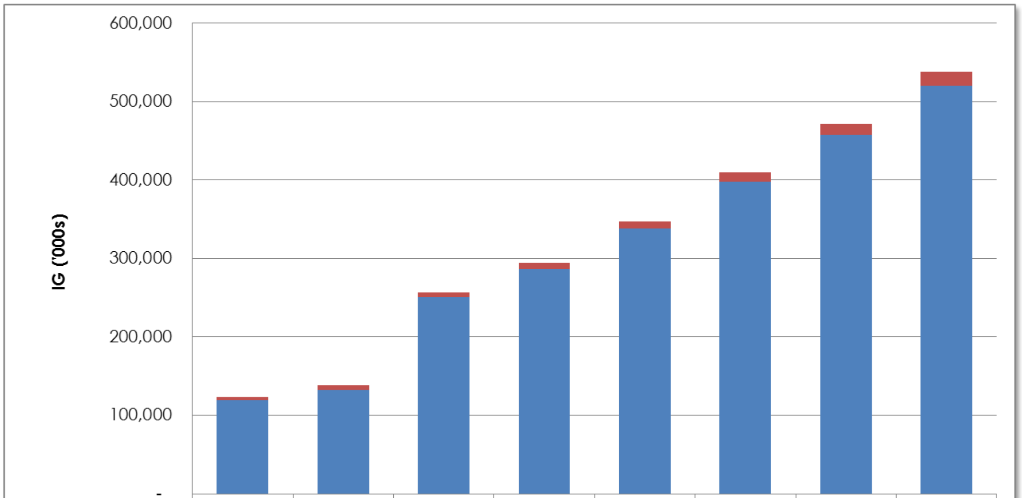


	2009	2012	2015	2018	2021	2024	2027	2030
Household	1,730	3,342	3,979	5,119	6,684	8,900	12,163	17,030
Commercial	1,009	1,332	1,423	1,742	2,140	2,637	3,259	4,043
Industry	2,095	3,231	5,524	8,251	11,690	16,061	21,480	28,310
Agriculture	207	255	283	342	382	442	481	541

Source: Consultants' analysis

L. Motor Spirit

Figure III-2: Motor Spirit Forecast (IG '000s)

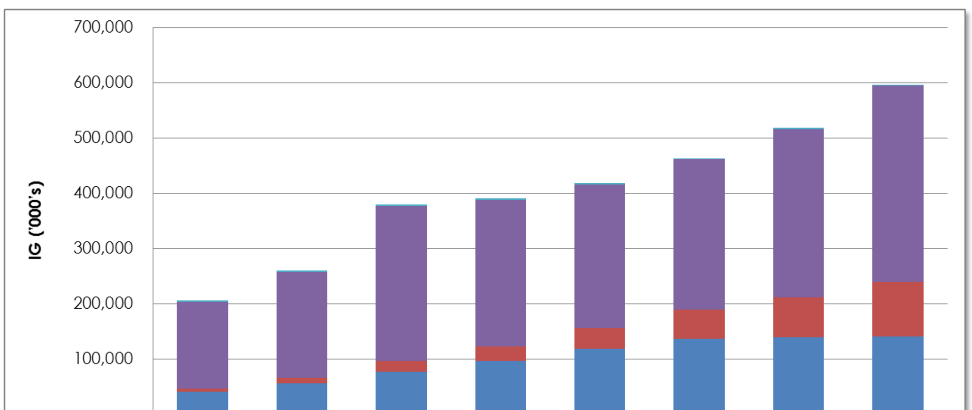


	2009	2012	2015	2018	2021	2024	2027	2030
Road Freight	3,390	5,908	6,818	7,618	9,145	11,356	14,216	18,275
Road Passenger	119,778	132,660	250,291	286,947	337,782	398,009	457,189	520,290

Source: Consultants' analysis

M. Diesel

Figure III-3: Diesel (HSD) Forecast (IG '000s)

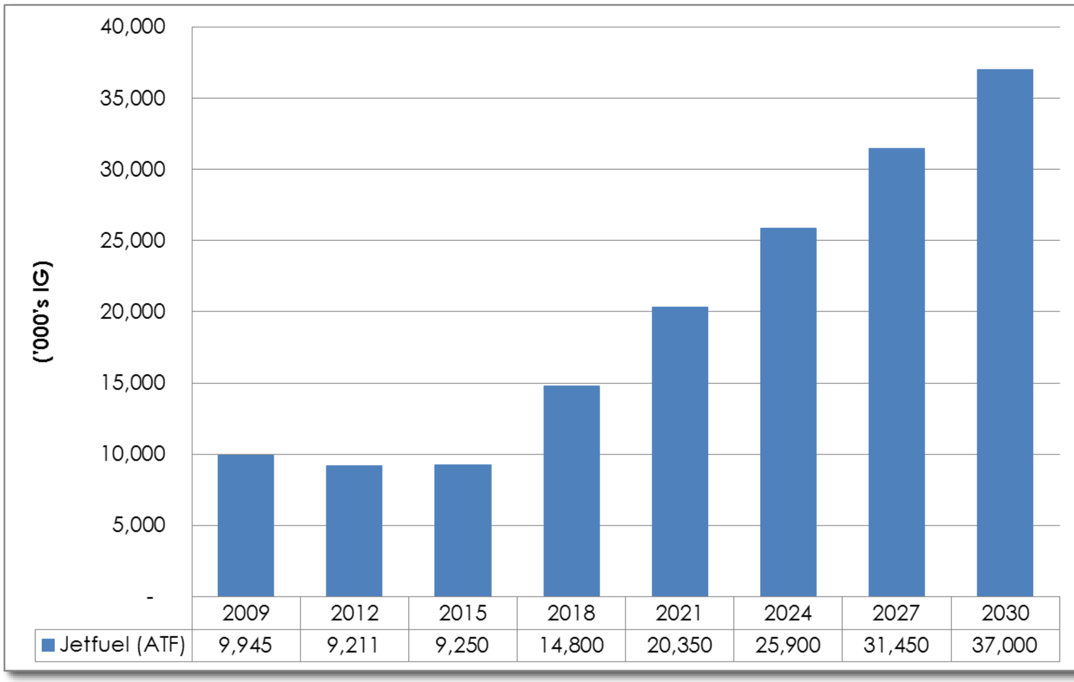


	2009	2012	2015	2018	2021	2024	2027	2030
Household	2,577	2,597	2,622	2,648	2,673	2,349	2,024	1,418
Transport	157,897	192,351	281,645	265,174	259,770	272,469	304,403	355,854
Commercial	-	-	-	-	-	-	-	-
Industry	5,014	9,323	18,913	26,575	37,442	52,275	71,844	98,059
Agriculture	40,854	56,378	76,900	96,728	118,933	136,472	139,621	141,441

Source: Consultants' analysis

N. Jet Fuel

Figure III-4: Jet Fuel (ATF) Forecast (IG '000s)



Source: Consultants' analysis

O. Liquid Gas

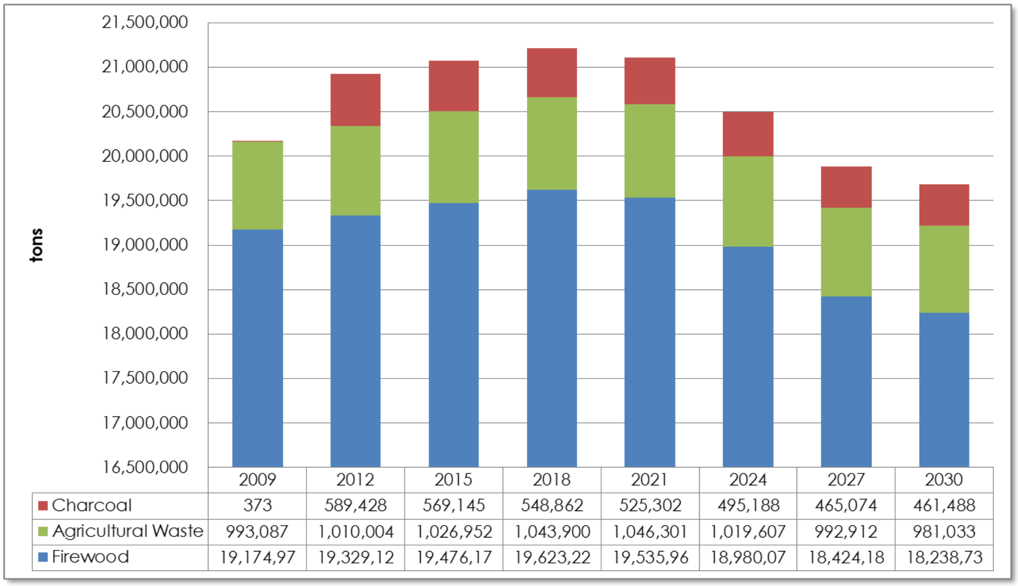
Table III-5: Gas Forecast (tons)

	Heavy Industry	Restaurants	Road Passenger	Urban HH	Rural HH	Fertilizer	Total
2009	212,681	324	16,908	31,715	22,507	12,486	296,620
2012	247,546	322	18,947	31,984	18,736	382,667	700,201
2015	403,668	335	26,889	32,253	14,965	465,555	943,666
2018	602,926	353	21,911	32,522	11,194	548,444	1,217,351
2021	854,279	374	17,866	31,596	8,288	631,333	1,543,737
2024	1,173,641	400	13,964	28,280	7,111	714,222	1,937,617
2027	1,569,684	430	10,026	24,964	5,934	797,111	2,408,148
2030	2,068,738	466	10,578	25,049	5,841	880,000	2,990,673

Source: Consultants' analysis

P. Woody Biomass

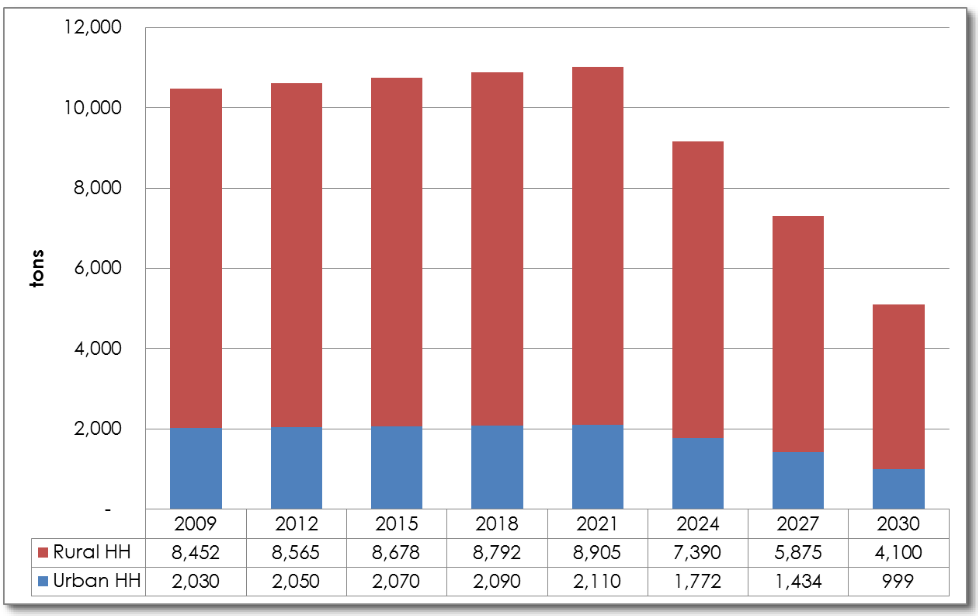
Figure III-6: Woody Biomass Forecast (tons)



Source: Consultants' analysis

Q. Paraffin Wax (Candles)

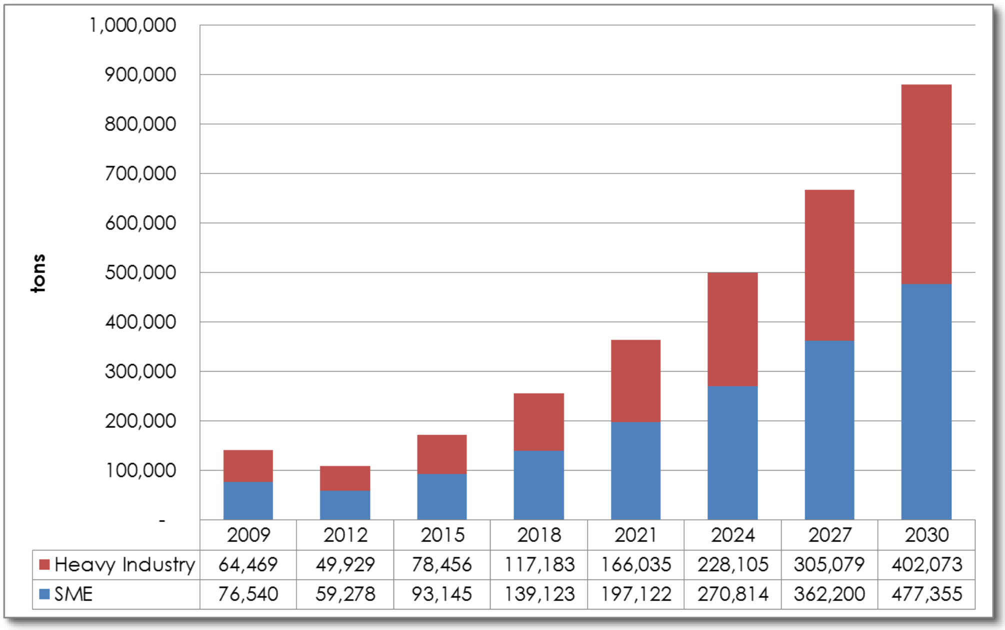
Figure III-7: Paraffin Wax Forecast (tons)



Source: Consultants' analysis

R. Coal

Figure III-8: Coal Forecast (tons)



	2009	2012	2015	2018	2021	2024	2027	2030
Heavy Industry	64,469	49,929	78,456	117,183	166,035	228,105	305,079	402,073
SME	76,540	59,278	93,145	139,123	197,122	270,814	362,200	477,355

Source: Consultants' analysis

IV. ELECTRICITY FORECAST (TOP – DOWN RECONCILIATION)

T. Introduction

16. Electricity consumption forecasts were presented in the previous section as a summary of ‘bottom-up’ forecasts for each economic sector. These ‘bottom-up’ forecasts have been reconciled to ‘top-down’ load forecasts developed by forecasting electricity sales from historical statistics gathered from MoEP and shaped by GDP sector growth. The reconciled ‘top-down’ forecasts are presented in this section of the report.

17. In the case of the household sector the plan for national electrification was taken into account. National electrification targets were targeted as low case – 80%, medium case – 87% and high case – 96%; to be achieved by 2030. Top-down electricity forecasts were then prepared as follows:

1. Historical consumption and demand trends were examined and modelled by State and Region; the model was calibrated so that estimated demand (including losses) matched with demand reported by MoEP for each State and Region;
2. Electricity consumption was forecast for each State and Region according to national electrification targets, per consumer energy consumption (kWh per customer) and GDP growth across residential, commercial and industrial consumer categories; and
3. The individual sector estimates were aggregated on State and Region basis and for Myanmar as a whole.

18. No allowance has been made for large developments such as the Dawei industrial zone / port development, or for large mines. In these cases it is usual for a developer or a mine owner to construct a captive power plant.

U. Planning Assumptions

19. Planning assumptions extend to electricity losses, energy consumption trends and economic

Table IV-1: Distribution Losses - Yangon (2013)

<table>
<tr><th></th><th></th><th>2009</th><th>2010</th><th>2011</th><th>2012</th><th>2013</th></tr>
<tr><td colspan="7">Eastern District</td></tr>
<tr><td>Technical loss</td><td>%</td><td rowspan="2">23.0</td><td rowspan="2">20.67</td><td rowspan="2">19.56</td><td rowspan="2">17.99</td><td rowspan="2">20.46</td></tr>
<tr><td>Non-technical loss</td><td>%</td></tr>
<tr><td colspan="7">Western District</td></tr>
<tr><td>Technical loss</td><td>%</td><td rowspan="2">20.7</td><td rowspan="2">19.98</td><td rowspan="2">19.16</td><td rowspan="2">17.72</td><td rowspan="2">18.97</td></tr>
<tr><td>Non-technical loss</td><td>%</td></tr>
<tr><td colspan="7">Southern District</td></tr>
<tr><td>Technical loss</td><td>%</td><td rowspan="2">20.65</td><td rowspan="2">20.23</td><td rowspan="2">19.65</td><td rowspan="2">17.26</td><td rowspan="2">19.01</td></tr>
<tr><td>Non-technical loss</td><td>%</td></tr>
</table>

		2009	2010	2011	2012	2013
Northern District						
Technical loss	%	29.41	25.28	23.95	25.98	26.63
Non-technical loss	%					

Table IV-2: Distribution Losses – States & Regions

		2006	2007	2008	2009	2010	2011	2012	2013
Technical Loss									
Kachin State	%		10	10	10	11	11	12	12
Kayar State	%		23	23	10	10	22	12	16
Kayin State	%		9	9	9.5	9.5	10	11.5	11
Chin State	%		3	3	3	3	3	3	3
Mon State	%		22.12	16.24	15.39	14.35	20.65	23.24	22.21
Rakhine State	%		0.9	0.5	0.45	0.45	0.45	0.4	0.3
Shan State	%		11.09	25.73	25.85	34.03	33.09	34.78	34.11
Sagaing Region	%		20.19	21.45	20.15	23.45	22	18.35	15.14
Magway Region	%		1.8	2.8	1.8	3.1	4.3	8.7	8.9
Mandalay Region	%		17.13	17.78	18.61	23.5	28.8	32.18	32.24
Bago Region	%		27.7	28.5	31.58	27.33	27.84	26.47	24.32
Tanintharyi Region	%								
Ayeyarwaddy Region	%		21	20	19	19	18	18	18
Naypyitaw	%		6.9	6.6	6	5.4	3.732	3.03	2
Non-Technical Loss									
Kachin State	%			10.53	8.93	8.59	9.71	9.14	6.2
Kayar State	%		12	10	4	5	9	7	5
Kayin State	%		4	4.5	4.5	4.5	4.5	4.12	5
Chin State	%		2	2	2	2	2	2	2
Mon State	%		9.48	6.96	6.59	6.15	8.84	9.96	9.48
Rakhine State	%								
Shan State	%		7.01	6.9	7.23	10.67	8.64	9.22	9.46
Sagaing Region	%		12.51	12.51	7	7.5	6.12	6	5.5
Magway Region	%		7.07	8.26	5.6	7.61	7.55	5.59	7.46
Mandalay Region	%		12.51	12.63	12.68	13.12	12.11	10.57	10.31
Bago Region	%		20.04	20.48	19.89	19.01	18.98	21.96	20.02
Tanintharyi Region	%								

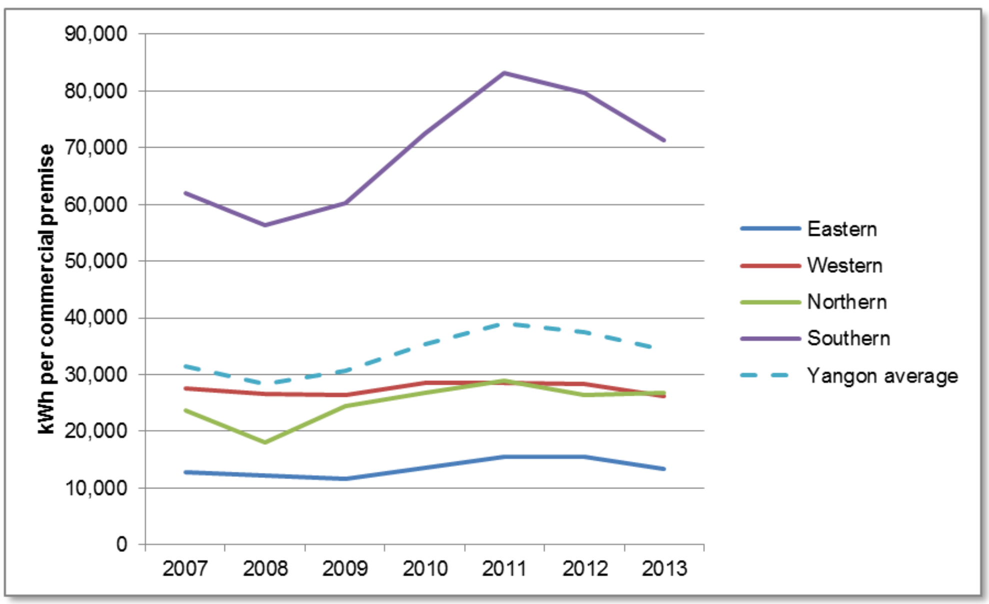
		2006	2007	2008	2009	2010	2011	2012	2013
Ayeyarwaddy Region	%		13	12	11	10	9	9	9
Naypyitaw	%		6.9	6.9	6.8	6.01	4	4.2	2.55

Sources: MoEP

V. Energy Consumption Trends

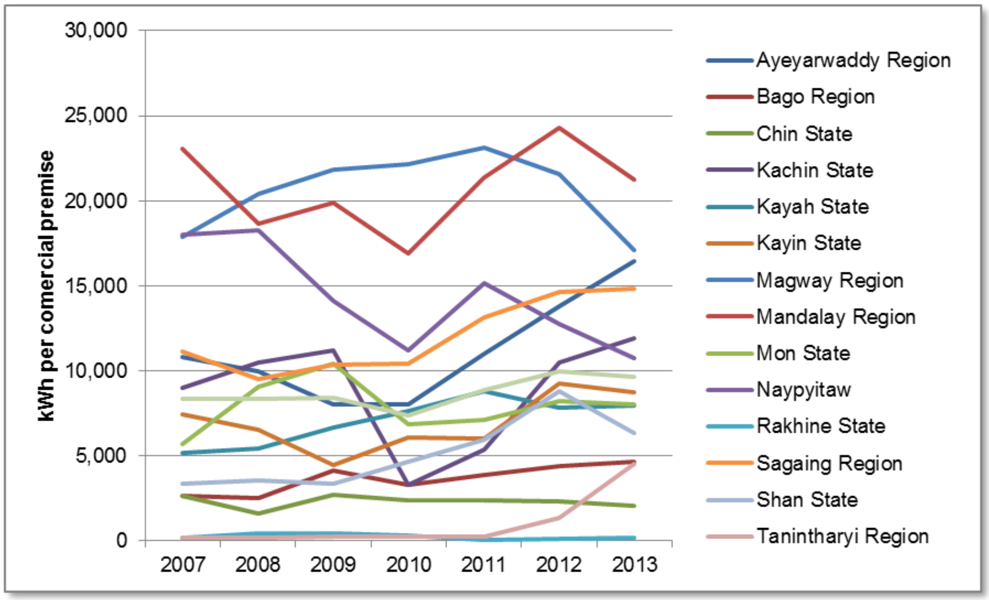
20. Energy consumption trends are observed as a change to the customer's annual consumption of power. In the case of electricity, kWh per consumer is the measure of electricity consumption. Figure IV-3 and Figure IV present the electricity consumption per consumer for the Commercial & Light Industrial segment in Yangon Division and by State / Regions. The kWh per consumer growth trend for the Yangon commercial and light industrial segment shows an average growth of 2%. The kWh per consumer growth trend for the States / Regions in aggregate has averaged 3%.

Figure IV-3: Yangon C&I kWh per Customer



Sources: Consultants' estimate

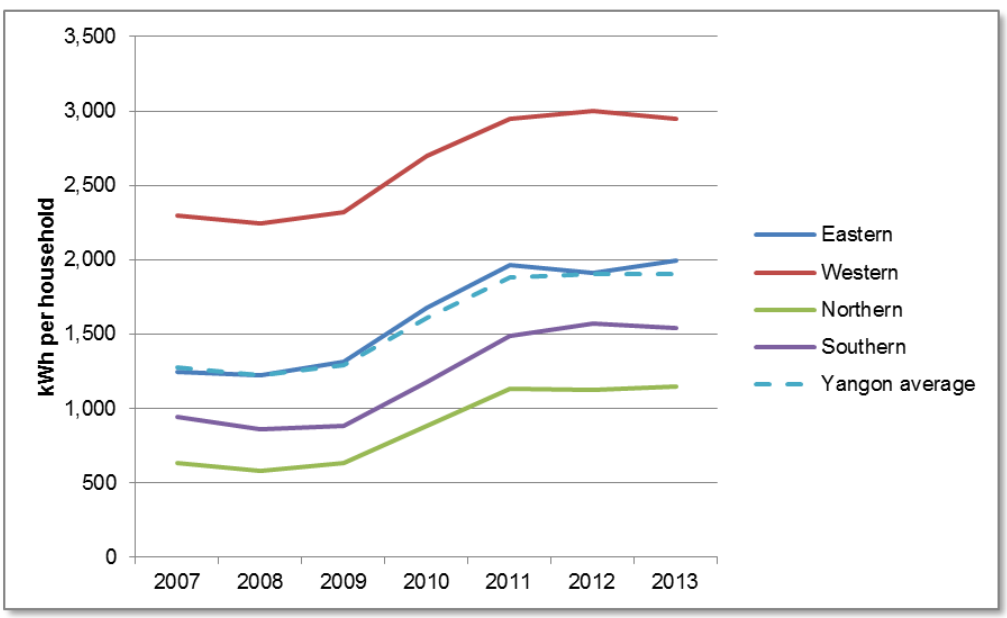
Figure IV-4: State / Region C & I kWh per Customer



Sources: Consultants' estimate

21. Figure IV-5 and Figure IV-6 present the electricity consumption per consumer for the residential segment in Yangon Division and by State / Regions.

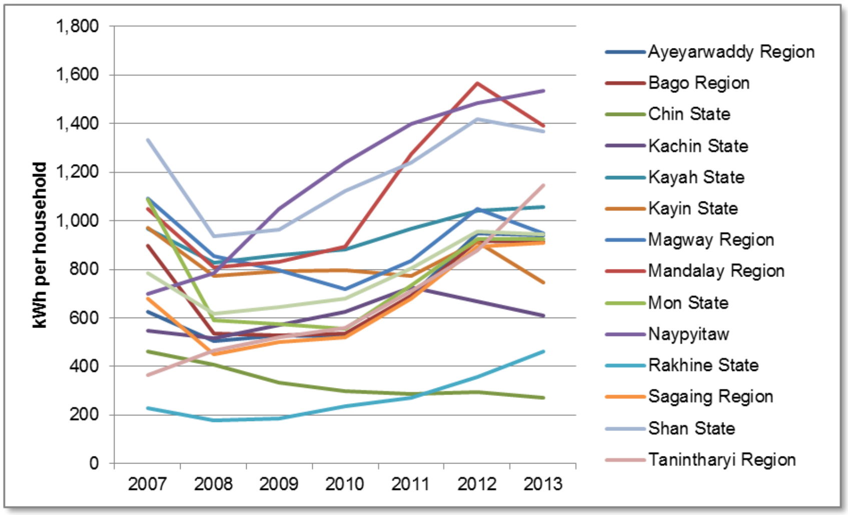
Figure IV-5: Yangon Residential kWh per Customer



Sources: Consultants' estimate

22. The kWh per consumer growth trend for the Yangon residential segment shows an average growth of 7.4%. The kWh per consumer growth trend for the States / Regions in aggregate has averaged 4%.

Figure IV-6: State / Region Residential kWh per Customer

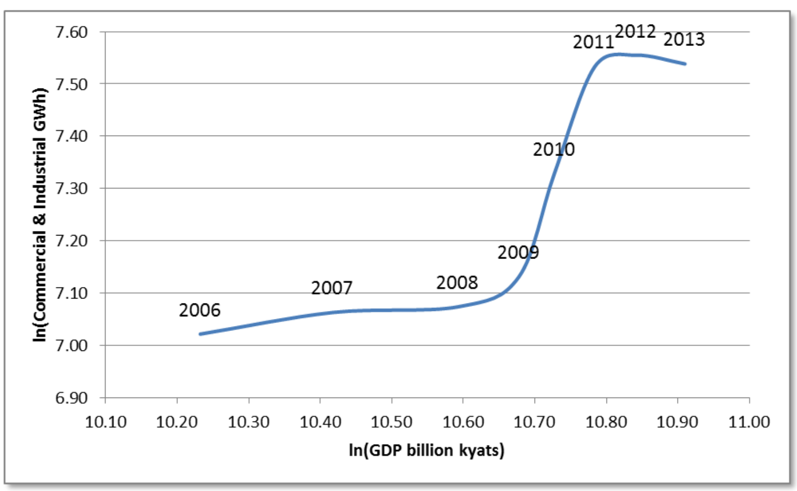


Sources: Consultants' estimate

W. Economic Trends

23. It is observed that in the non-oil producing countries, GDP and the growth in non-residential electricity consumption are strongly correlated. The relationship between the natural logarithm of GDP and the natural logarithm of GWh consumption is typically linear. Figure IV-7 shows that the relationship of non-residential electricity consumption and GDP in Myanmar has not been linear and is therefore unsuitable as an input to forecasting.

Figure IV-7: Myanmar – log (GWh Consumption) vs. log (GDP)



Sources: Consultants' estimate

X. Baseline Energy Consumption

24. Baseline energy data for each State / Region was collected from YESC and ESE. The data was analyzed and a summary is presented in Table IV-8 for FY2013.

Table IV-8: Baseline Energy Sales by State / Region: 2013

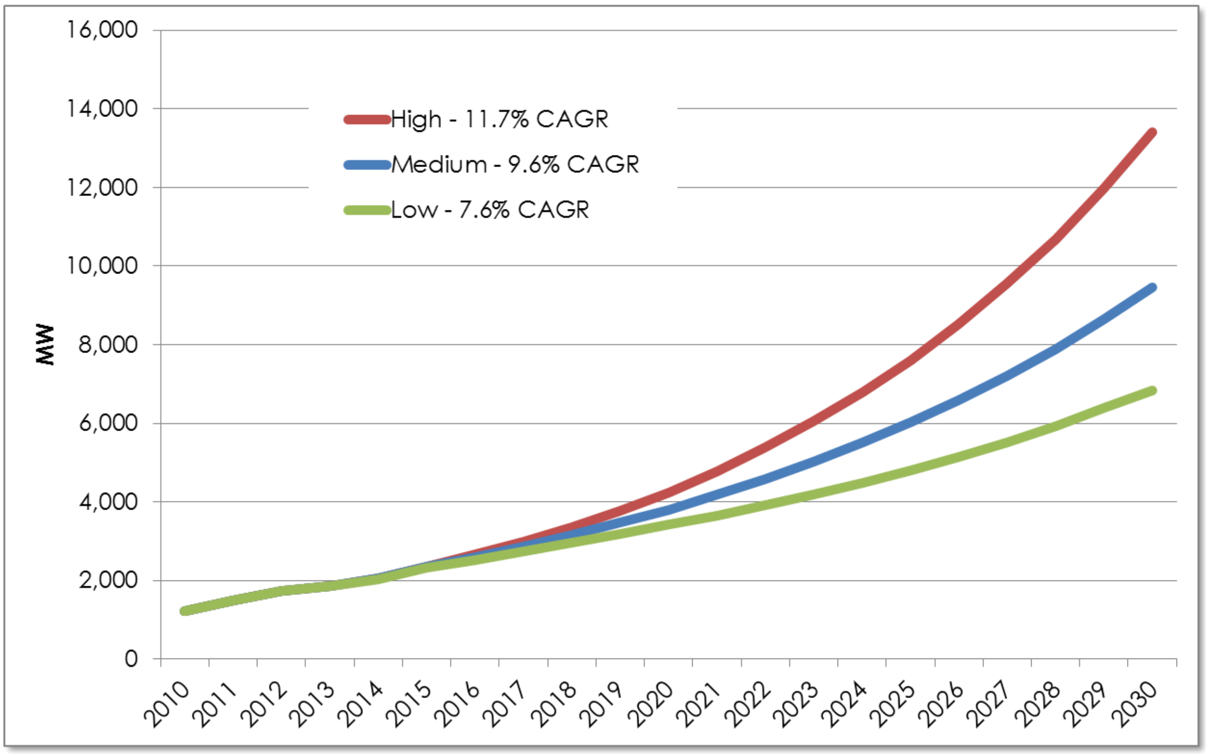
State / Region	Grid-Electrified Residential Customers	Peak Demand MW	Average kWh per HH	Average kWpeak per HH	Note
Ayerwaddy Region	136,021	92	941	0.24	
Bago Region	236,773	140	913	0.20	
Chin State	12,963	4	271	0.34	No supply by ESE
Kachin State	57,555	24	609	0.30	
Kayar State	20,081	10	1,058	0.27	
Kayin State	30,774	15	748	0.19	
Magway Region	126,931	112	948	0.27	
Mandalay Region	372,812	462	1,393	0.48	
Mon State	107,718	49	925	0.20	
Nay Pi Taw	77,425	106	1,534	0.30	
Rakhine State	32,347	13	461	0.31	No supply by ESE
Sagaing Region	191,984	101	908	0.21	
Shan State	207,933	110	1,369	0.35	
Tanintharyi Region	18,610	67	1,148	1.00	
Yangon	921,462	1,096	1,907	0.55	
Total	2,551,389	2,401			
Average Yangon, Mandalay & NPT			1,611	0.45	
Average Other			858	0.33	

Sources: Consultants' estimate

Y. Myanmar Consolidated Electricity Forecasts

25. The medium growth case forecast for Myanmar shows an expected growth of peak demand MW from the current level of 2 100 MW to around 9 500 MW by 2030. This case calls for an average annual addition of generation capacity of around 440 MW from now to year 2030. The growth projections can also be understood in terms of the average kWh / capita growth; from 200 to 800 kWh per capita by 2030.

Figure IV-9: Myanmar Grid Electricity Growth Forecast



Source: Consultants' analysis; includes T&D losses

Table IV-10: Average kWh / Capita Growth

	kWh per Capita		
	Low	Medium	High
2010	125	125	125
2015	225	227	230
2020	316	352	393
2025	423	530	670
2030	573	793	1,124

Source: Consultants' analysis; includes T&D losses

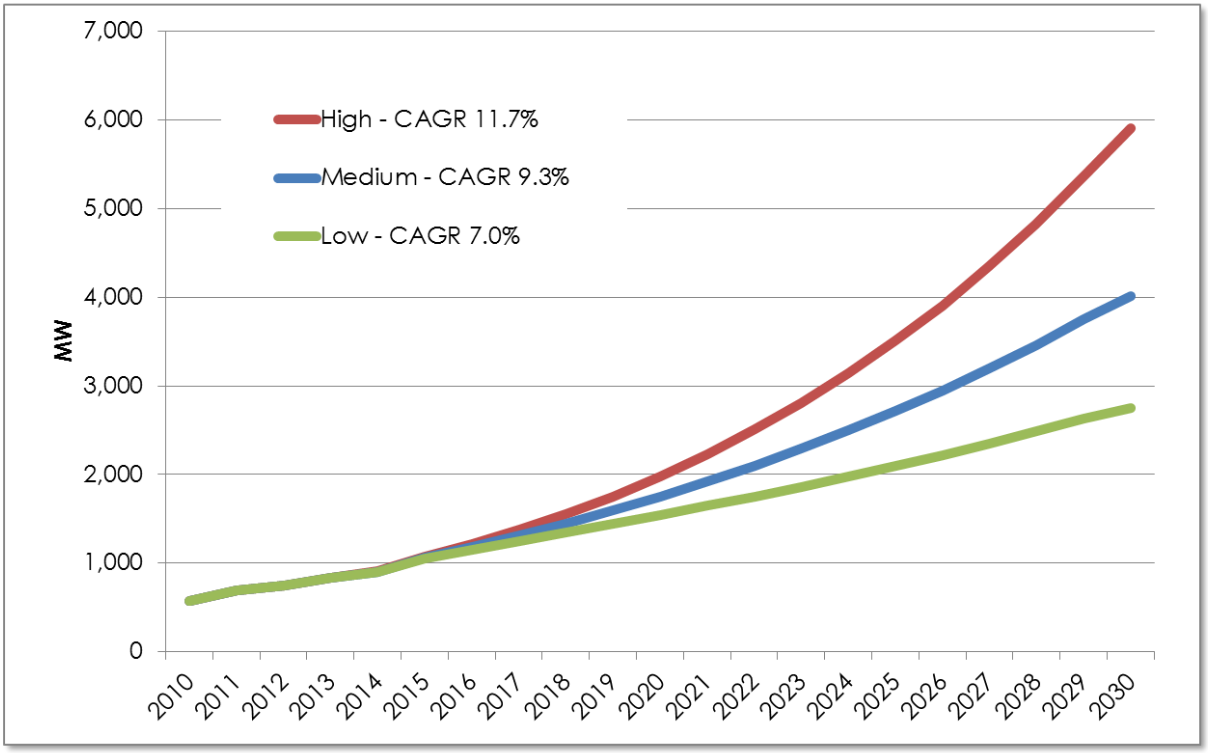
Table IV-11: Myanmar Grid Electricity Growth Forecast

	Low			Medium			High		
	MW	GWh	AGR MW	MW	GWh	AGR MW	MW	GWh	AGR MW
2010	1,221	7,318		1,221	7,318		1,221	7,318	
2011	1,490	8,927	22.0%	1,490	8,927	21.98%	1,490	8,927	22.0%
2012	1,730	10,364	16.1%	1,730	10,364	16.09%	1,730	10,364	16.1%
2013	1,853	10,388	7.1%	1,853	10,388	7.13%	1,853	10,388	7.1%
2014	2,036	12,200	9.9%	2,045	12,255	10.39%	2,055	12,311	10.9%
2015	2,314	13,866	13.7%	2,336	14,000	14.24%	2,359	14,136	14.8%
2016	2,526	15,137	9.2%	2,592	15,531	10.94%	2,660	15,937	12.7%
2017	2,741	16,425	8.5%	2,861	17,143	10.38%	2,986	17,894	12.3%
2018	2,967	17,775	8.2%	3,155	18,906	10.28%	3,356	20,111	12.4%
2019	3,186	19,092	7.4%	3,465	20,762	9.82%	3,769	22,585	12.3%
2020	3,415	20,463	7.2%	3,806	22,805	9.84%	4,244	25,431	12.6%
2021	3,658	21,917	7.1%	4,180	25,047	9.83%	4,784	28,662	12.7%
2022	3,917	23,468	7.1%	4,588	27,491	9.76%	5,387	32,280	12.6%
2023	4,190	25,108	7.0%	5,026	30,112	9.54%	6,050	36,250	12.3%
2024	4,485	26,872	7.0%	5,501	32,962	9.46%	6,786	40,660	12.2%
2025	4,800	28,762	7.0%	6,019	36,064	9.41%	7,606	45,574	12.1%
2026	5,146	30,835	7.2%	6,589	39,481	9.47%	8,525	51,078	12.1%
2027	5,519	33,070	7.2%	7,211	43,205	9.43%	9,547	57,203	12.0%
2028	5,932	35,541	7.5%	7,900	47,334	9.56%	10,698	64,099	12.1%
2029	6,384	38,252	7.6%	8,661	51,892	9.63%	11,990	71,843	12.1%
2030	6,843	41,002	7.2%	9,465	56,715	9.29%	13,410	80,353	11.8%
CAGR 2014-2030	7.6%	7.6%		9.6%	9.6%		11.7%	11.7%	
Average MW added p.a.	255			439			738		

Source: Consultants' analysis; includes T&D losses

26. The medium growth case forecast for Yangon shows an expected growth of peak demand MW from the current level of 950 MW to around 4 000 MW in 2030. This case calls for an average annual addition of generation capacity of around 200 MW from now to year 2030. The growth projections can also be understood in terms of the average kWh / capita growth; from 900 to 3000 kWh per capita by 2030.

Figure IV-12: Yangon Grid Electricity Growth Forecast



Source: Consultants' analysis; includes T&D losses

Table IV-13: Average kWh / Capita Growth

	kWh per Capita		
	Low	Medium	High
2010	526	526	526
2015	916	927	937
2020	1,280	1,450	1,637
2025	1,653	2,141	2,766
2030	2,061	3,013	4,434

Source: Consultants' analysis; includes T&D losses

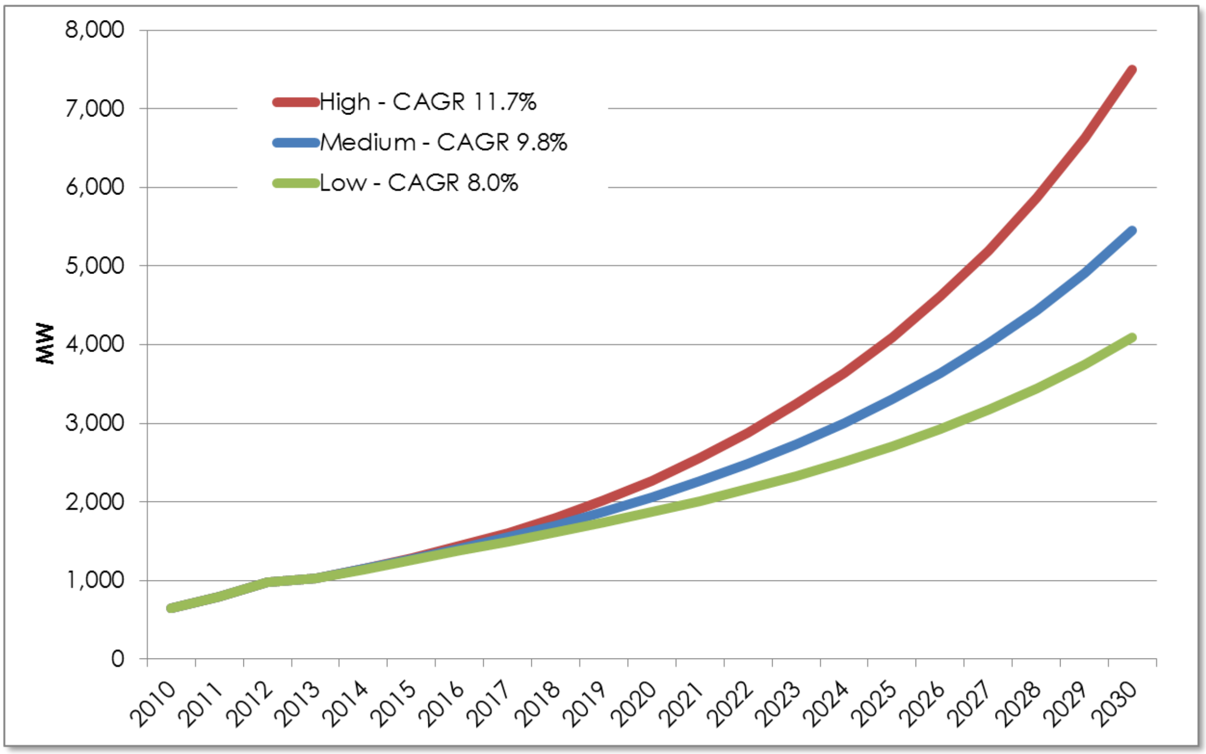
Table IV-14: Yangon Electricity Growth Forecast

	Low			Medium			High		
	MW	GWh	AGR MW	MW	GWh	AGR MW	MW	GWh	AGR MW
2010	573	3,624		573	3,624		573	3,624	
2011	691	4,368	20.53%	691	4,368	20.53%	691	4,368	20.53%
2012	746	4,727	7.96%	746	4,727	7.96%	746	4,727	7.96%
2013	831	4,660	11.43%	831	4,660	11.43%	831	4,660	11.43%
2014	895	5,642	7.62%	901	5,680	8.34%	907	5,719	9.08%
2015	1,052	6,637	17.62%	1,064	6,712	18.17%	1,076	6,789	18.71%
2016	1,149	7,249	9.22%	1,184	7,471	11.30%	1,220	7,696	13.36%
2017	1,248	7,872	8.60%	1,312	8,276	10.78%	1,378	8,691	12.94%
2018	1,349	8,506	8.05%	1,449	9,137	10.41%	1,554	9,800	12.76%
2019	1,447	9,126	7.29%	1,594	10,053	10.02%	1,752	11,049	12.74%
2020	1,544	9,741	6.74%	1,749	11,034	9.75%	1,975	12,459	12.76%
2021	1,647	10,386	6.62%	1,919	12,103	9.69%	2,228	14,052	12.79%
2022	1,752	11,049	6.38%	2,100	13,242	9.41%	2,506	15,807	12.49%
2023	1,862	11,744	6.29%	2,292	14,454	9.16%	2,810	17,721	12.11%
2024	1,978	12,473	6.21%	2,498	15,754	8.99%	3,144	19,829	11.89%
2025	2,097	13,223	6.01%	2,715	17,127	8.72%	3,508	22,125	11.58%
2026	2,221	14,010	5.95%	2,948	18,595	8.57%	3,908	24,645	11.39%
2027	2,352	14,837	5.90%	3,197	20,164	8.44%	4,346	27,413	11.23%
2028	2,490	15,705	5.85%	3,464	21,846	8.34%	4,829	30,459	11.11%
2029	2,635	16,617	5.81%	3,749	23,647	8.24%	5,361	33,813	11.01%
2030	2,748	17,329	4.29%	4,017	25,335	7.14%	5,910	37,278	10.25%
CAGR 2014-2030	7.0%	7.0%		9.3%	9.3%		11.7%	11.7%	
Average MW added p.a.	103			198			343		

Source: Consultants' analysis; includes T&D losses

27. The medium growth case forecast for the States and Regions, excluding Yangon, shows an expected growth of peak demand MW from the current level of 1 150 MW to around 5 450 MW in 2030. This case calls for an average annual addition of generation capacity of around 240 MW from now to year 2030. The growth projections can also be understood in terms of the average kWh / capita growth; from 130 to 500 kWh per capita by 2030.

Figure IV-15: ESE Grid Electricity Growth Forecast



Source: Consultants' analysis; includes T&D losses

Table IV-16: Average kWh / Capita Growth

	kWh per Capita		
	Low	Medium	High
2010	71	71	71
2015	133	134	135
2020	188	206	227
2025	259	315	391
2030	375	497	683

Source: Consultants' analysis; includes T&D losses

Table IV-17: ESE Electricity Growth Forecast

	Low			Medium			High		
	MW	GWh	AGR MW	MW	GWh	AGR MW	MW	GWh	AGR MW
2010	648	3,694		648	3,694		648	3,694	
2011	799	4,559	23.27%	799	4,559	23.27%	799	4,559	23.27%
2012	984	5,636	23.12%	984	5,636	23.12%	984	5,636	23.12%
2013	1,022	5,728	3.86%	1,022	5,728	3.86%	1,022	5,728	3.86%
2014	1,141	6,557	11.73%	1,145	6,575	12.05%	1,148	6,592	12.36%
2015	1,262	7,229	10.55%	1,272	7,287	11.14%	1,283	7,347	11.76%
2016	1,377	7,888	9.11%	1,408	8,060	10.64%	1,440	8,241	12.21%
2017	1,493	8,552	8.43%	1,549	8,868	10.05%	1,608	9,202	11.72%
2018	1,618	9,269	8.37%	1,707	9,769	10.17%	1,803	10,311	12.08%
2019	1,739	9,966	7.51%	1,871	10,709	9.65%	2,018	11,537	11.93%
2020	1,871	10,721	7.54%	2,057	11,771	9.91%	2,269	12,972	12.46%
2021	2,011	11,530	7.51%	2,261	12,944	9.95%	2,556	14,610	12.63%
2022	2,165	12,419	7.65%	2,489	14,249	10.05%	2,881	16,473	12.73%
2023	2,328	13,365	7.56%	2,734	15,658	9.86%	3,240	18,529	12.47%
2024	2,507	14,399	7.68%	3,003	17,209	9.86%	3,642	20,832	12.40%
2025	2,704	15,539	7.84%	3,304	18,938	9.99%	4,098	23,449	12.52%
2026	2,925	16,825	8.18%	3,641	20,886	10.21%	4,617	26,432	12.66%
2027	3,167	18,233	8.27%	4,014	23,040	10.23%	5,200	29,790	12.64%
2028	3,441	19,836	8.68%	4,436	25,488	10.53%	5,868	33,639	12.84%
2029	3,749	21,635	8.95%	4,911	28,246	10.71%	6,629	38,030	12.96%
2030	4,095	23,673	9.23%	5,448	31,380	10.94%	7,500	43,075	13.14%
CAGR 2014-2030	8.0%	8.0%		9.8%	9.8%		11.7%	11.7%	
Average MW added p.a.	152			241			395		

Source: Consultants' analysis

Z. National Electrification

28. The current status of electrification and connection rates in 2014 was reported by MoEP. The national electrification goals were used to project the status of electrification by State and Region in 2030. New connection rates were estimated for the period from 2014 to 2030, taking into account household growth. The status of electrification is estimated for 2030.

Table IV-18: Status of Electrification - 2014

	HH 2014	% Grid Electrified	HH Grid Electrified	New Connection Rates p.a. 2014
Ayeyarwaddy	2,025,306	7%	149,949	13,928
Bago Region	1,511,883	17%	256,870	20,097
Chin State	113,308	12%	13,710	747
Kachin State	320,677	19%	62,342	4,787
Kayah State	76,957	28%	21,896	1,815
Kayin State	399,431	8%	33,010	2,236
Magway Region	1,414,382	10%	136,881	9,950
Mandalay Region	1,738,036	24%	410,605	37,793
Mon State	702,485	17%	116,329	8,611
Naypyitaw	287,319	30%	86,288	8,863
Rakhine State	775,128	4%	33,227	880
Sagaing Region	1,463,932	15%	219,151	27,167
Shan State	1,244,589	19%	233,056	25,123
Tanintharyi Region	370,026	5%	18,930	320
Yangon Division	1,789,736	53%	949,925	60,000
Total	14,233,196		2,742,169	222,317
			19%	

Sources: MoEP, Consultant

Table IV-19: New Connection Rates – (Medium Electrification – 87%)

	2014	2015	2018	2021	2024	2027	2030
Ayeyarwaddy Region	13,928	16,714	29,251	52,513	94,273	169,243	303,831
Bago Region	20,097	22,107	33,667	51,706	79,408	121,954	187,294
Chin State	747	896	1,510	2,418	3,872	6,200	9,927
Kachin State	4,787	5,266	7,155	10,133	14,349	20,320	28,775
Kayah State	1,815	1,906	2,190	2,477	2,803	3,171	3,587
Kayin State	2,236	2,684	4,911	10,077	20,680	42,438	87,088
Magway Region	9,950	11,939	20,801	36,835	65,231	115,515	204,563

	2014	2015	2018	2021	2024	2027	2030
Mandalay Region	37,793	39,682	49,619	72,386	105,601	154,056	224,745
Mon State	8,611	9,042	12,018	21,061	36,909	64,680	113,348
Naypyitaw	8,863	9,306	11,743	13,316	15,100	17,124	19,418
Rakhine State	880	1,056	2,217	6,868	21,279	65,925	204,249
Sagaing Region	27,167	29,883	39,865	53,424	71,595	95,946	128,579
Shan State	25,123	27,635	34,235	36,740	39,428	42,313	45,409
Tanintharyi Region	320	384	835	2,872	9,878	33,982	116,902
Yangon Division	60,000	64,897	82,119	103,911	131,487	166,380	97,324
Total	224,331	245,413	334,153	478,759	713,917	1,121,274	1,777,070
Yr on Yr Rate of Increase	-	9.4%	11.9%	13.2%	14.8%	17.0%	12.9%

Sources: Consultant

Table IV-20: Status of Electrification in 2030 (Medium Electrification – 87%)

	HH 2030	% Grid Electrified 2030 at 2014 connection rates	HH Grid Electrified with current connection rates	HH not grid electrified
Ayeyarwaddy	2,228,735	80%	1,789,563	439,172
Bago Region	1,663,742	91%	1,519,004	144,738
Chin State	124,689	61%	76,437	48,252
Kachin State	352,886	81%	284,371	68,515
Kayah State	84,687	76%	64,774	19,913
Kayin State	439,551	99%	433,357	6,194
Magway Region	1,556,447	81%	1,260,613	295,834
Mandalay Region	2,205,543	94%	2,065,902	139,641
Mon State	773,045	97%	750,955	22,090
Naypyitaw	316,179	100%	315,819	360
Rakhine State	852,984	80%	682,615	170,369
Sagaing Region	1,610,974	81%	1,312,087	298,887
Shan State	1,369,600	61%	839,086	530,514
Tanintharyi Region	407,192	90%	365,000	42,192
Yangon Division	2,867,737	99%	2,831,660	36,077
Total	16,853,991		14,591,243	2,262,748
			87%	13%

Sources: Consultant

APPENDIX: Myanmar State and Region Electricity Demand Growth

AYERWADDY REGION

1. Ayerwaddy occupies the delta region of the Ayerwaddy River (Irrawaddy River). It is bordered by Bago Region to the north, Bago Region and Yangon Region to the east, and the Bay of Bengal to the south and west. It is contiguous with the Rakhine State in the northwest. The Region is heavily forested and wood products are an important component of the economy. The principal crop of Ayerwaddy is rice, and the region is called the "granary of Burma." In addition to rice, other crops include maize, sesame, groundnut, sunflower, beans, pulses and jute. Fisheries are also important; the Region produces fish, prawn, fish-paste, dry fish, dry prawn and fish sauce.

2. Ayerwaddy Region also has considerable tourist potential. The city of Pathein has numerous historic sights and temples. Outside Pathein are the beach resorts of Chaungtha Beach and the lake resort of Inye Lake. Inye Lake is well known for fishery as the major supplier of fresh water fish. However, hotel and transportation infrastructure is still very poorly developed.

Residential Connections Forecast

3. In the last six years the reported new connection rate has been high at an average of 9%; the rate appears to reflect the low electrification rate.

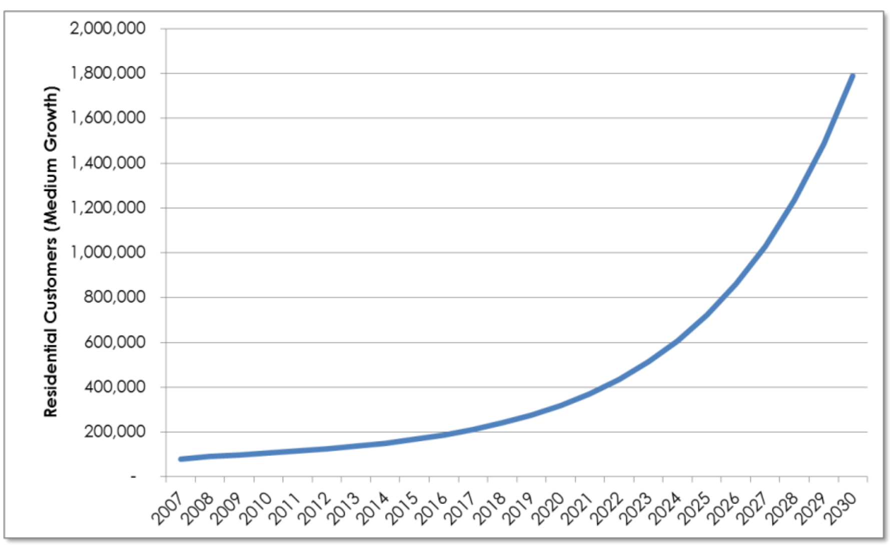
Table IV-21: National Grid Supply Connections to 2013

	2008	2009	2010	2011	2012	2013
Total	91 029	97 867	106 617	114 219	123 359	136 021
Growth (new connections p.a.)	10,993	6,838	8,750	7,602	9,140	12,662
Growth %	14%	8%	9%	7%	8%	10%

Sources: MoEP

4. The forecast growth of residential grid supply connections is shown in Figure IV-22 for the 87% national electrification goal.

Figure IV-22: Growth of Residential Connections

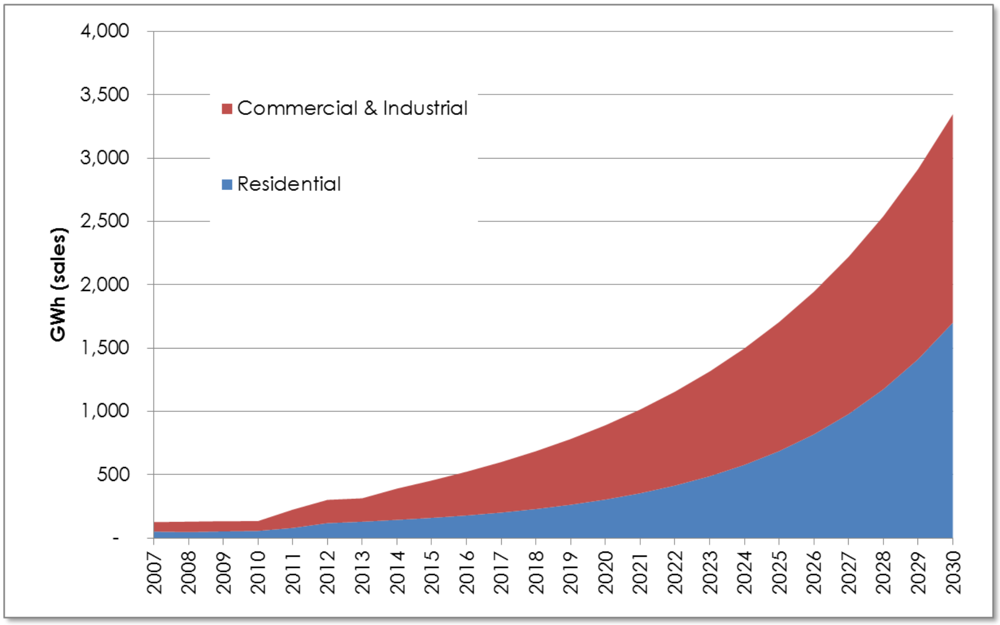


Sources: Consultant

Electricity Forecasts

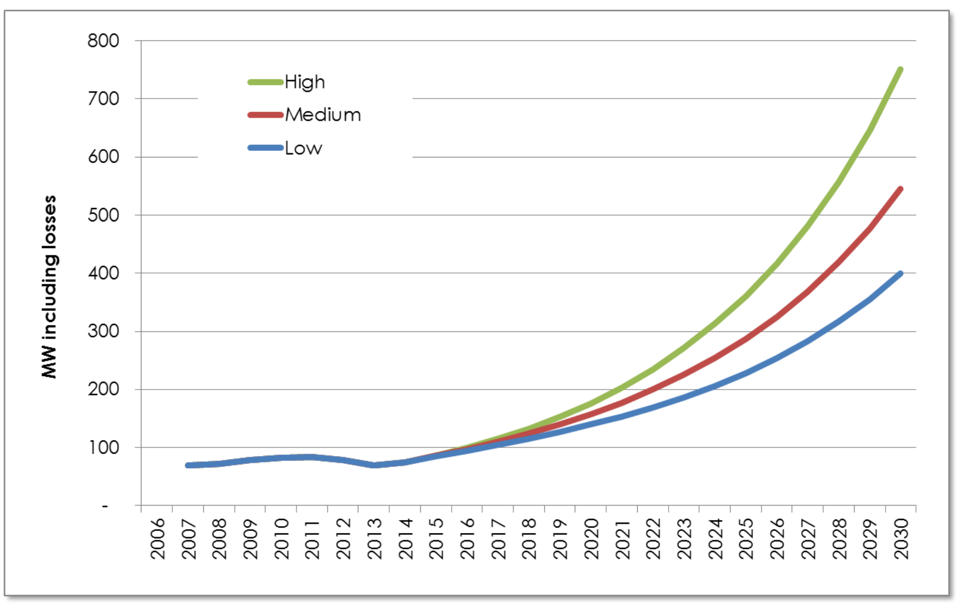
5. The average kWh per residential customer increased from 506 in 2008 to 940 in 2013. Commercial and light industrial consumption is reported by MoEP at average16 500 kWh per customer. There were no industrial customers of 2 MVA or above reported.

Figure IV-23: Forecast Electricity Consumption Growth



Sources: Including losses; Consultant

Figure IV-24: Forecast Electricity Demand Growth



Sources: Consultant; includes losses

BAGO REGION

6. Bago Region is located in the southern central part of the country. It is bordered by Magway Region and Mandalay Region to the north; Kayin State, Mon State and the Gulf of Martaban to the east; Yangon Region to the south and Ayerwaddy Region and Rakhine State to the west.

7. The regional economy is strongly dependent on the timber trade. Taungoo, in the northern end of the Bago Region, is bordered by mountain ranges, home to teak and other hardwoods. Another natural resource is petroleum. The major crop is rice which occupies over two-thirds of the available agricultural land. Other major crops include betel nut, sugarcane, maize, groundnut, sesamum, sunflower, beans and pulses, cotton, jute, rubber, tobacco, tapioca, banana, Nipa palm and toddy. Industry includes fisheries, salt, ceramics, sugar, paper, plywood, distilleries and monosodium glutamate.

8. Bago has a small livestock breeding and fisheries sector, and a small industrial sector. In 2005 it had over 4 million farm animals; nearly 3 000 acres (12 km^2) of fish and prawn farms; and about 3 000 private factories and about 100 state owned factories.

Residential Connections Forecast

9. In the last six years, the reported new connection rate has been high at an average of 16%. This rate appears to have resulted in the relatively high electrification rate of 54%. This rate suggests that Bago Region citizens are relatively wealthy due to the diverse nature of economic activity including a degree of industrialization.

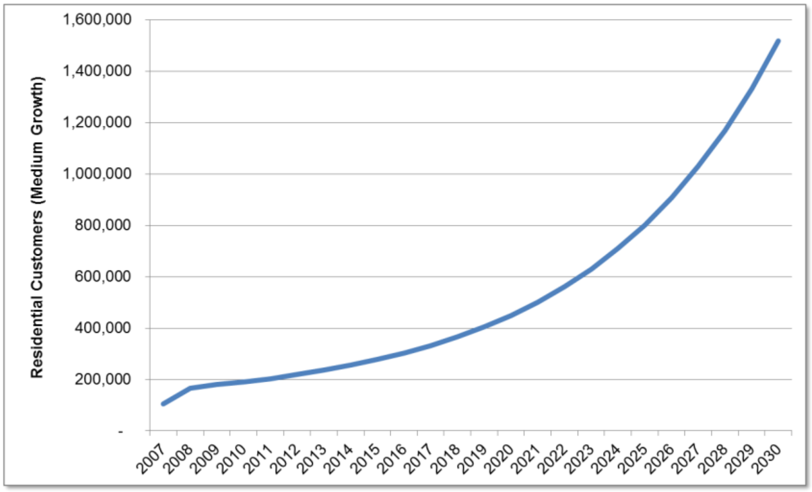
Table IV-25: National Grid Supply Connections to 2013

	2008	2009	2010	2011	2012	2013
Total	164 879	181 680	189 582	201 519	218 503	236 773
Growth (new connections p.a.)	16 801	7 902	11 937	16 984	18 270	20 000
Growth %	58%	10%	4%	6%	8%	8%

Sources: MoEP

10. The forecast growth of residential grid supply connections is shown in Figure IV-26 for the 87% national electrification goal.

Figure IV-26: Growth of Residential Connections



Sources: Consultant

Electricity Forecasts

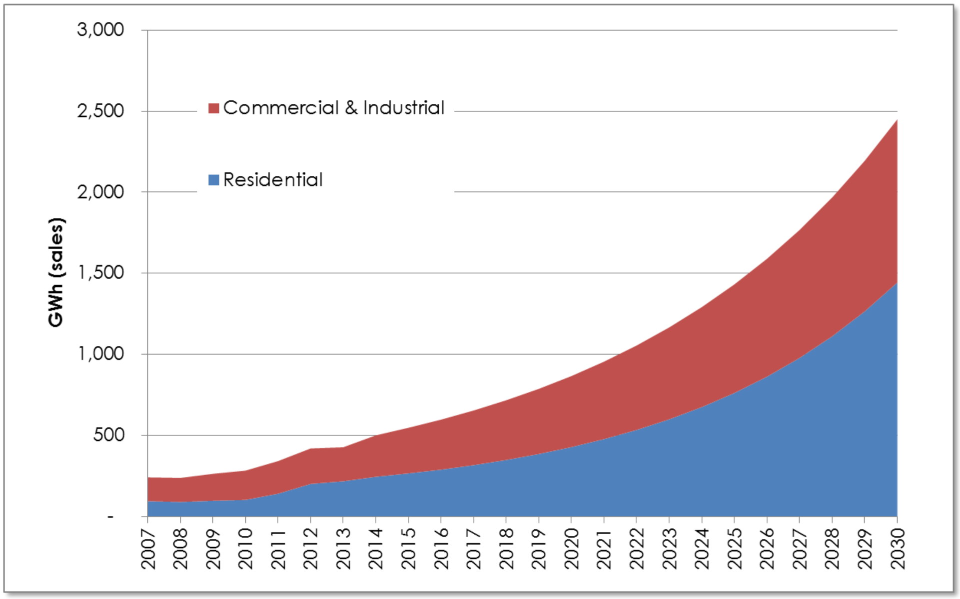
11. The average kWh per residential customer has increased from 540 in 2008 to 910 in 2013. Commercial and light industrial consumption is reported by MoEP at 4 700 kWh per customer. The following industrial customers of 2 MVA or above were reported to be active in 2013.

Table IV-27: Bago Industrial Customers (2013)

Customer	Load MVA	Supply Voltage kV	Type of Business
Chin Su	3	33/11	Plywood
Inn lay	3	33/11	Shoes
Myan Star	3	33/11	Ready-Made Garments(RMG)
Daw Yone Shwin	3	33/11	Ready Made Garments(RMG)
Dawoo	2.5	33/11	Plywood
Pyay Industrial Zone	5	66/11	Machinery Food processing Rice/Oil Ice mill
Shwedaing Textiles Machinery	10	66/11	Textiles
Nawaday Sugar Mill	2	33/11	Food processing
Nyaung Cha Tauk Steel Mill	20	66/6.6	Iron and steel
Procelan	5	33/11	Porcelain

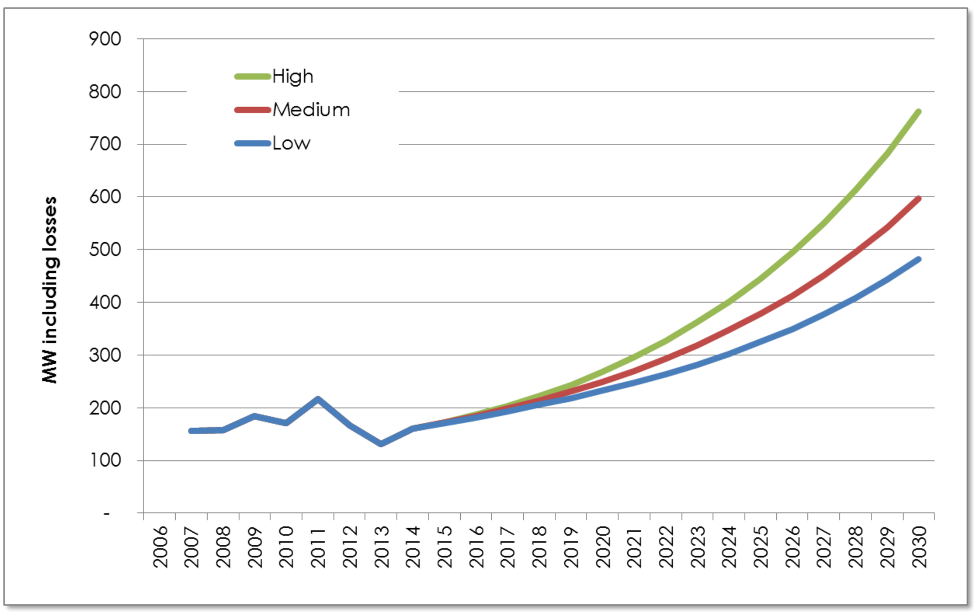
Sources: MoEP

Figure IV-28: Forecast Electricity Consumption Growth



Sources: Excluding losses; Consultant

Figure IV-29: Forecast Electricity Demand Growth



Sources: Consultant; includes losses

CHIN STATE

12. Chin State is located in the western part of the country. The State is bordered by Rakhine State in the south, Bangladesh in the south-west, Sagaing Division and Magwe Division in the east, the Indian state of Manipur in the north and the Indian state of Mizoram in the west. Chin has been restricted to visitors but it is reported that tourism may provide an opportunity in future.

Residential Connections Forecast

13. In the last six years the reported new connection rate has been high at an average of 7% although the rate has declined in recent years. The residential electrification rate of 10% appears to have been mainly achieved in recent years.

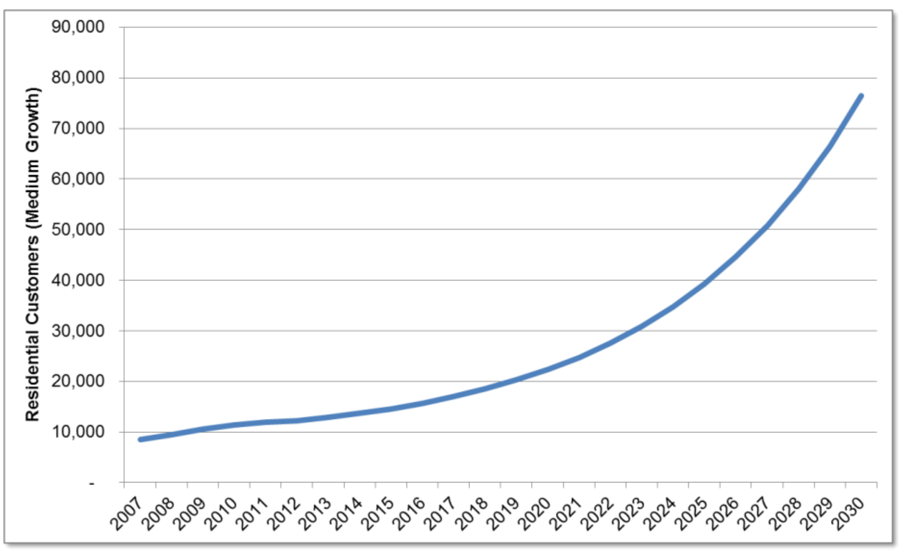
Table IV-30: National Grid Supply Connections to 2013

	2008	2009	2010	2011	2012	2013
Total	9 445	10 587	11 395	11 937	12 284	12 963
Growth (new connections p.a.)	1 142	808	542	347	679	600
Growth %	12%	12%	8%	5%	3%	6%

Sources: MoEP

14. The forecast growth of residential grid supply connections is shown as Figure IV-31 for the 87% national electrification goal.

Figure IV-31: Growth of Residential Connections

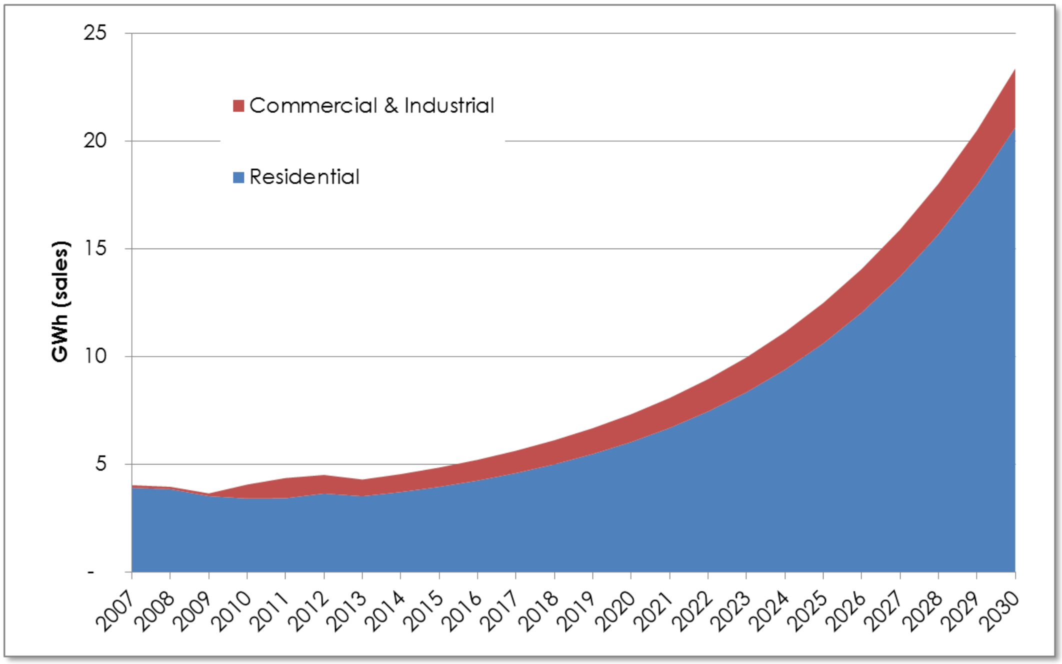


Sources: Consultant

Electricity Forecasts

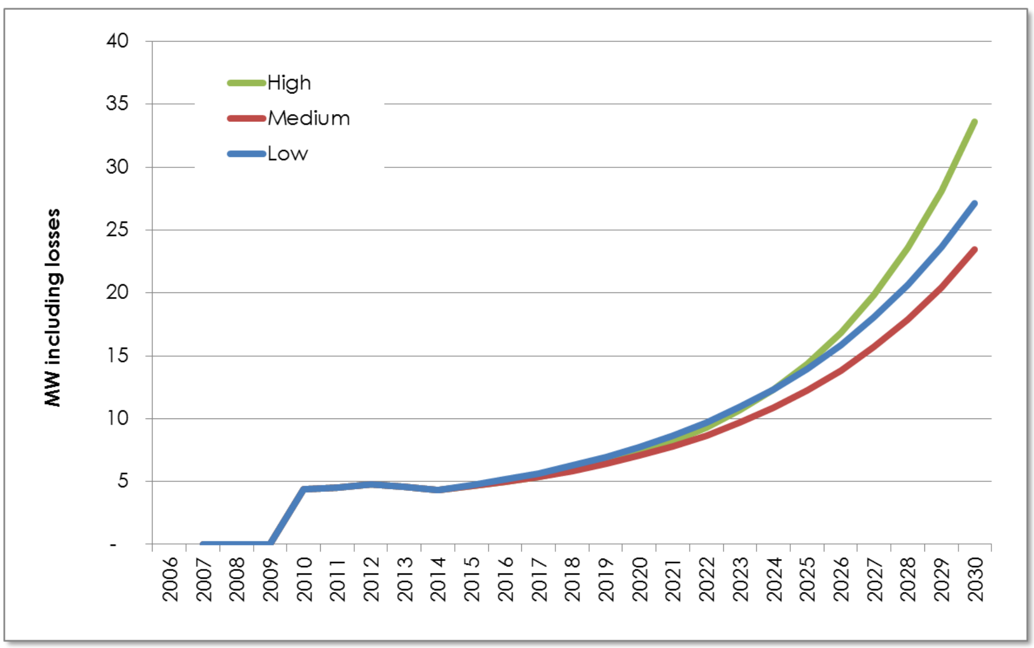
15. The average kWh per residential customer has fallen from 400 in 2008 to 270 in 2013 suggesting a declining population or hardship. Commercial and light industrial consumption is reported by MoEP at 2 000 kWh per customer. There were no industrial customers of 2 MVA or above reported.

Figure IV-32: Forecast Electricity Consumption Growth



Sources: Excluding losses; Consultant

Figure IV-33: Forecast Electricity Demand Growth



Sources: Consultant; includes losses

KACHIN STATE

16. Kachin State is the northernmost state of Myanmar. It is bordered by China to the north and east; Shan State to the south; and Sagaing Region and India to the west. The economy of Kachin State is predominantly agricultural. The main products include rice, teak and sugar cane. Mineral products include gold and jade. Kachin has deep economic ties with China which is the largest trading partner and chief investor in development projects in the region. However, recently the Myitsone hydro-electric power plant was cancelled amid protests over relocation of around 15 000 local residents.

Residential Connections Forecast

17. In the last six years, the reported new connection rate has been high at an average of 18%. The residential electrification rate of 15% appears to have been mainly achieved in recent years.

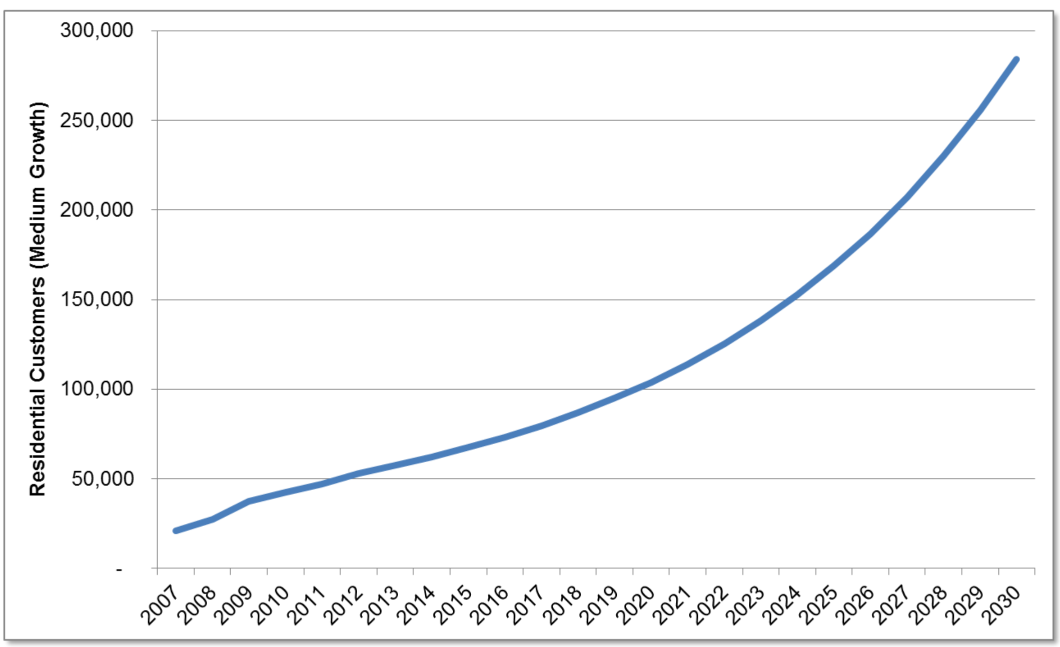
Table IV-34: National Grid Supply Connections to 2013

	2008	2009	2010	2011	2012	2013
Total	27 582	37 339	42 439	47 346	53 203	57 555
Growth (new connections p.a.)	9 757	5 100	4 907	5 857	4 352	4 400
Growth %	30%	35%	14%	12%	12%	8%

Sources: MoEP

18. The forecast growth of residential grid supply connections is shown in Figure IV-35 for the 87% national electrification goal.

Figure IV-35: Growth of Residential Connections

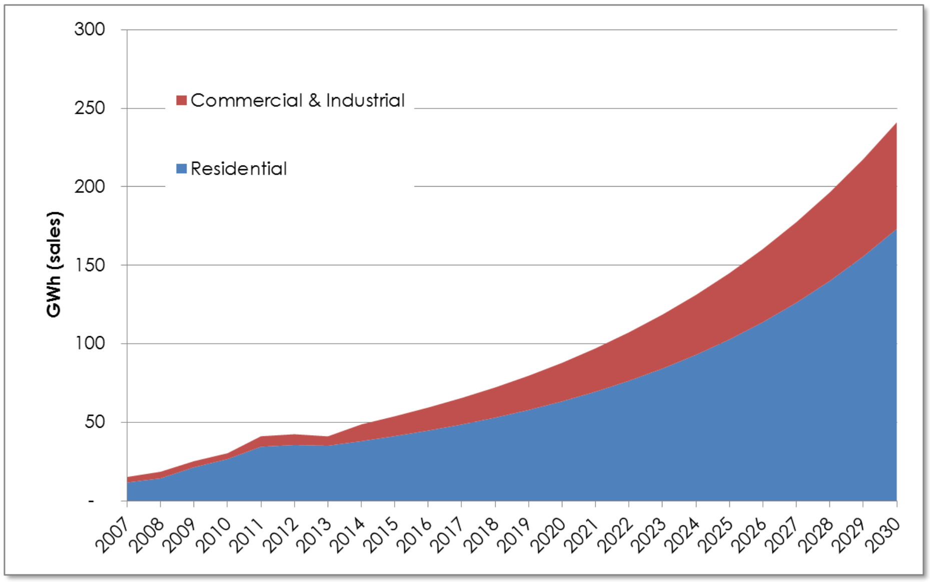


Sources: Consultant

Electricity Forecasts

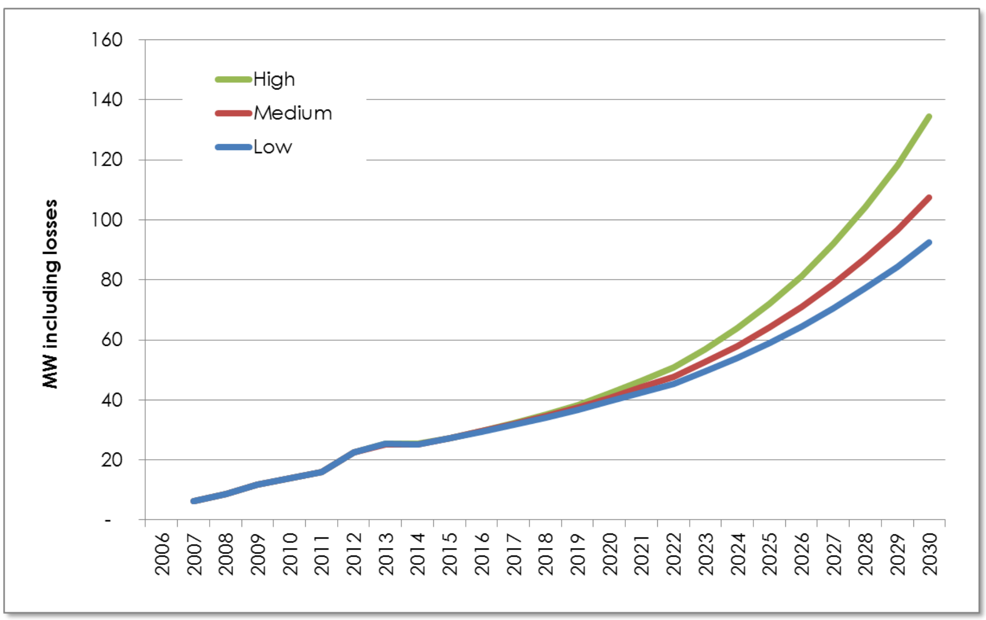
19. The average kWh per residential customer has increased from 500 in 2008 to 600 in 2013. Commercial and light industrial consumption is reported by MoEP at an average 12 000 kWh per customer. There were no industrial customers of 2 MVA or above reported.

Figure IV-36: Forecast Electricity Consumption Growth to 2035



Sources: Excluding losses; Consultant

Figure IV-37: Forecast Electricity Demand Growth



Sources: Consultant; includes losses

KAYAR STATE

20. Kayar State is situated in eastern Myanmar; it is bounded on the north by Shan State, on the east by Thailand's Mae Hong Son Province, and on the south and west by Kayin State.

21. Kayah State has a primarily extraction-based economy. The main crop is rice, mostly irrigated, with other important crops including millet, maize, sesame, groundnut, garlic and vegetables. Mineral products include alabaster, tin and tungsten. Valuable woods such as teak and pine were once produced, but the forests have largely been stripped bare by illegal logging. The hydroelectric power plant at Lawpita Falls outside of Loikaw is of strategic importance, as it supplies over 20% of Myanmar's total electrical power. Kayah State has theoretical tourist potential, if the political situation is resolved. The state has rugged mountains, river streams, lakes and waterfalls; however, transport and communication are difficult.

Residential Connections Forecast

22. In the last six years the reported new connection rate has been high at an average of 9%. This rate appears to have supported the achievement of a moderately high residential electrification rate of 40%.

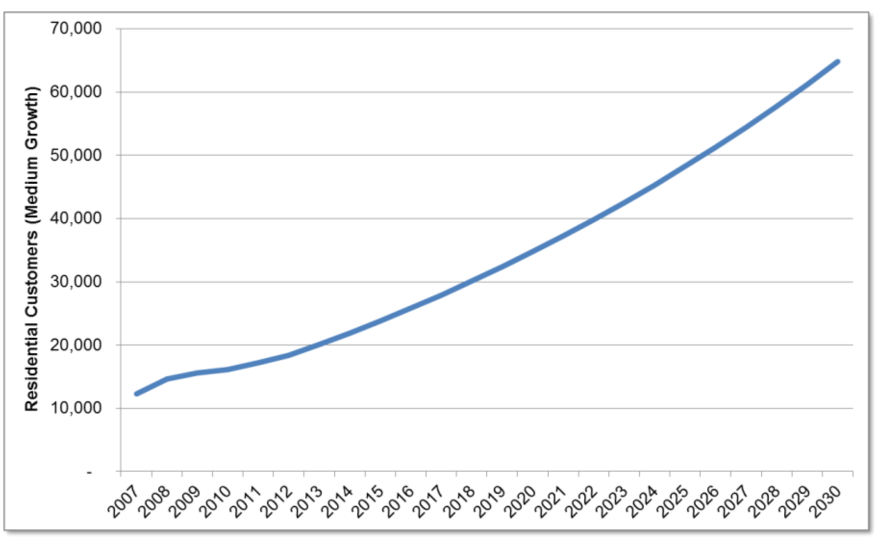
Table IV-38: National Grid Supply Connections to 2013

	2008	2009	2010	2011	2012	2013
Total	14 664	15 559	16 083	17 143	18 352	20 081
Growth (new connections p.a.)	895	524	1 060	1 209	1 729	1 500
Growth %	19%	6%	3%	7%	7%	9%

Sources: MoEP

23. The forecast growth of residential grid supply connections is shown in Figure IV-39 for the 87% national electrification goal.

Figure IV-39: Growth of Residential Connections

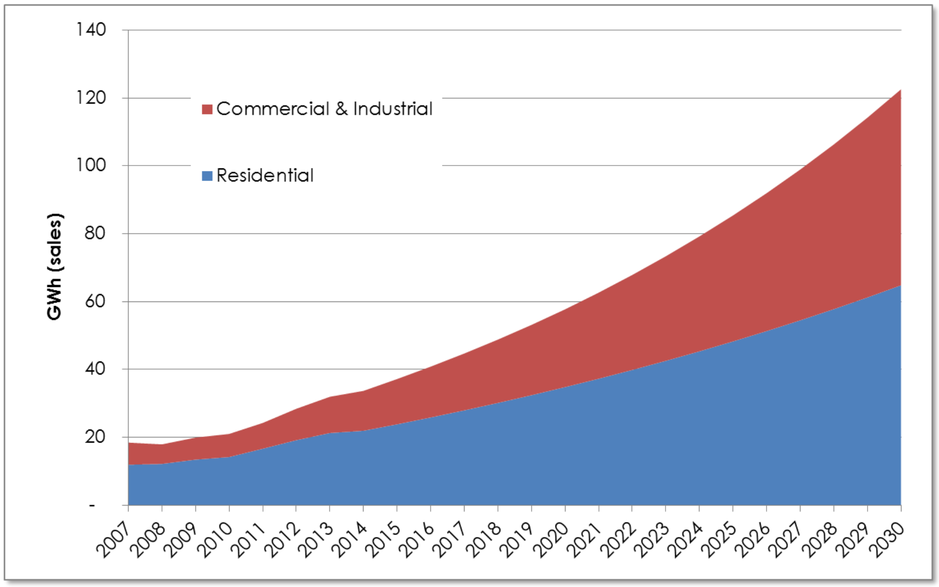


Sources: Consultant

Electricity Forecasts

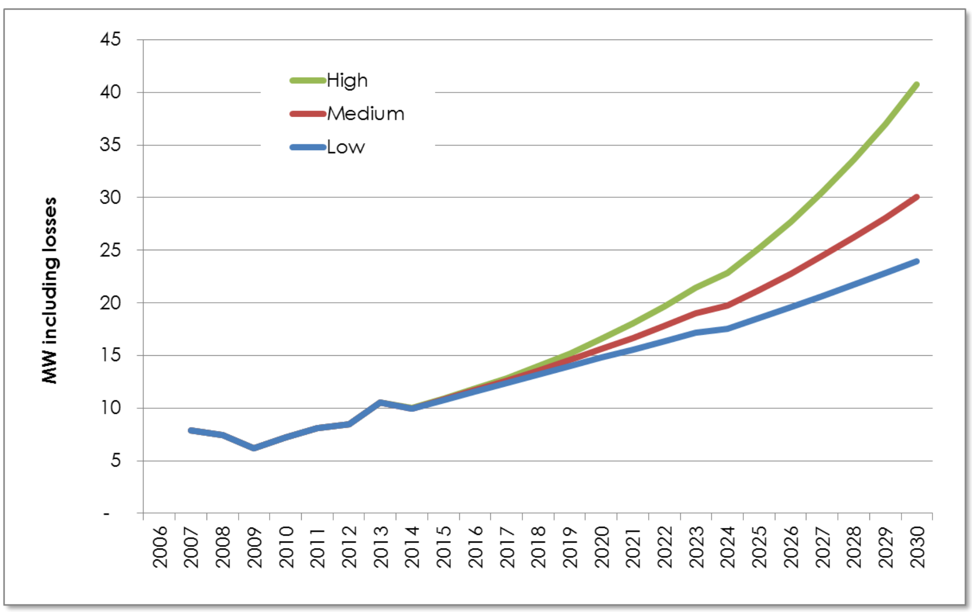
24. The average kWh per residential customer has increased from 830 in 2008 to 1 030 in 2013. Commercial and light industrial consumption is reported by MoEP at 8 000 kWh per customer. There were no industrial customers of 2 MVA or above reported.

Figure IV-40: Forecast Electricity Consumption Growth



Sources: Excluding losses; Consultant

Figure IV-41: Forecast Electricity Demand Growth



Sources: Consultant; includes losses

KAYIN STATE

25. Kayin State is mountainous with the Dawna Range running along the state in a NNW - SSE direction. The southern end of the Karen Hills is to the northwest. The State is bordered by Mae Hong Son Tak and Kanchanaburi provinces of Thailand to the east; Mon State and Bago Region to the west and south; and Mandalay Region Shan State and Kayah State to the north.

Residential Connections Forecast

26. In the last six years the reported new connection rate has been high at an average of 10%. This rate appears to reflect the low residential electrification rate of 8%.

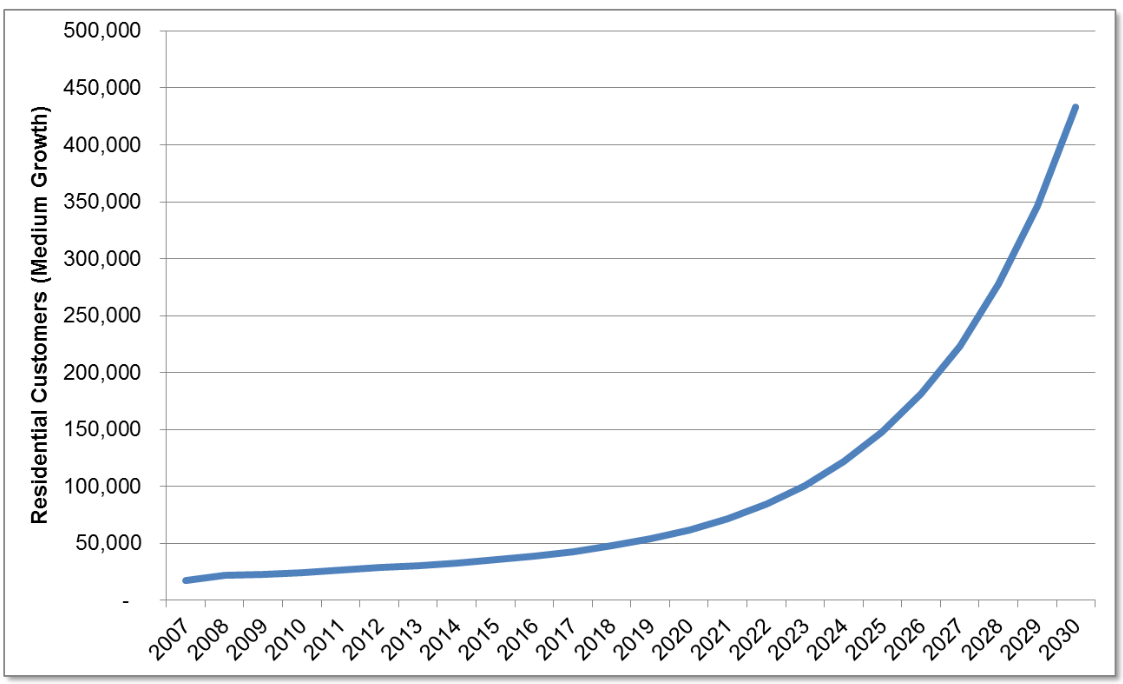
Table IV-42: National Grid Supply Connections to 2013

	2008	2009	2010	2011	2012	2013
Total	22 185	22 931	24 355	26 580	28 741	30 774
Growth (new connections p.a.)	746	1 424	2 225	2 161	2 033	2 000
Growth %	26%	3%	6%	9%	8%	7%

Sources: MoEP

27. The forecast growth of residential grid supply connections is shown as Figure IV-43 for the 87% national electrification goal.

Figure IV-43: Forecast Growth of Residential Connections



Sources: Consultant

Electricity Forecasts

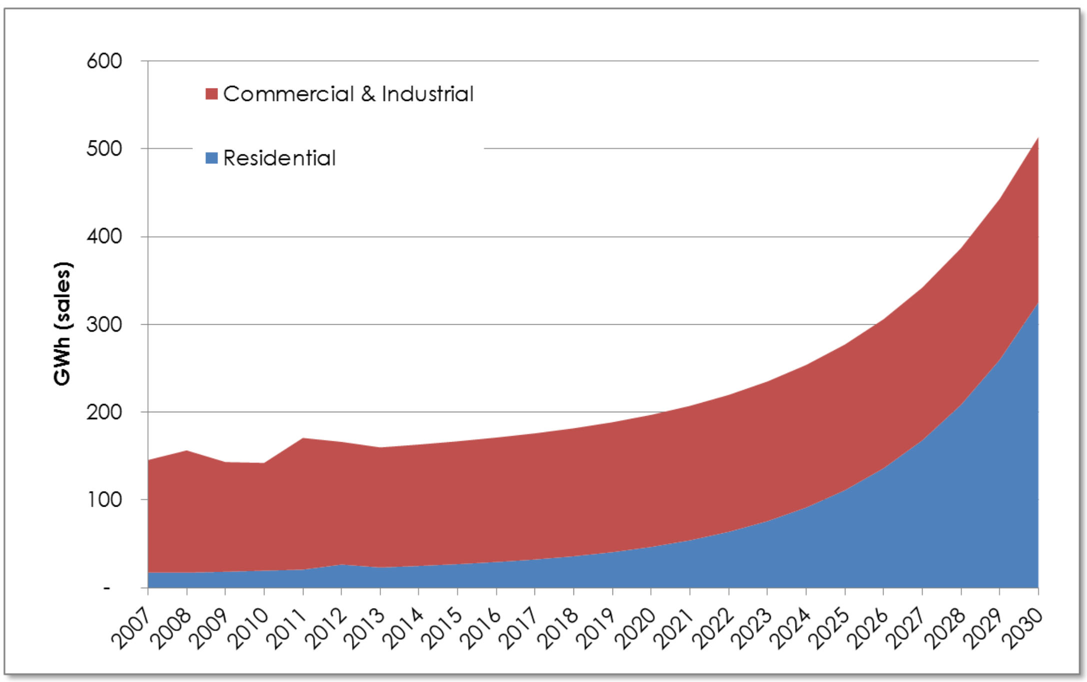
28. The average kWh per residential customer has remained steady from 2008 to 2013 at around 750. Commercial and light industrial consumption is reported by MoEP at 8 700 kWh per customer. There following industrial customers of 2 MVA or above were reported to be active in 2013.

Table IV-44: Kayin Industrial Customers (2013)

Customer	Load	Supply Voltage	Type of Business
	MVA	kV	
Tan 4000 Industrial(Myaing Kalay)	35	66	Cement
Tan 900 Industrial(Myaing Kalay)	15	66	Cement
Tan 900 Industrial(Myaing Kalay)	10.5	33	Cement

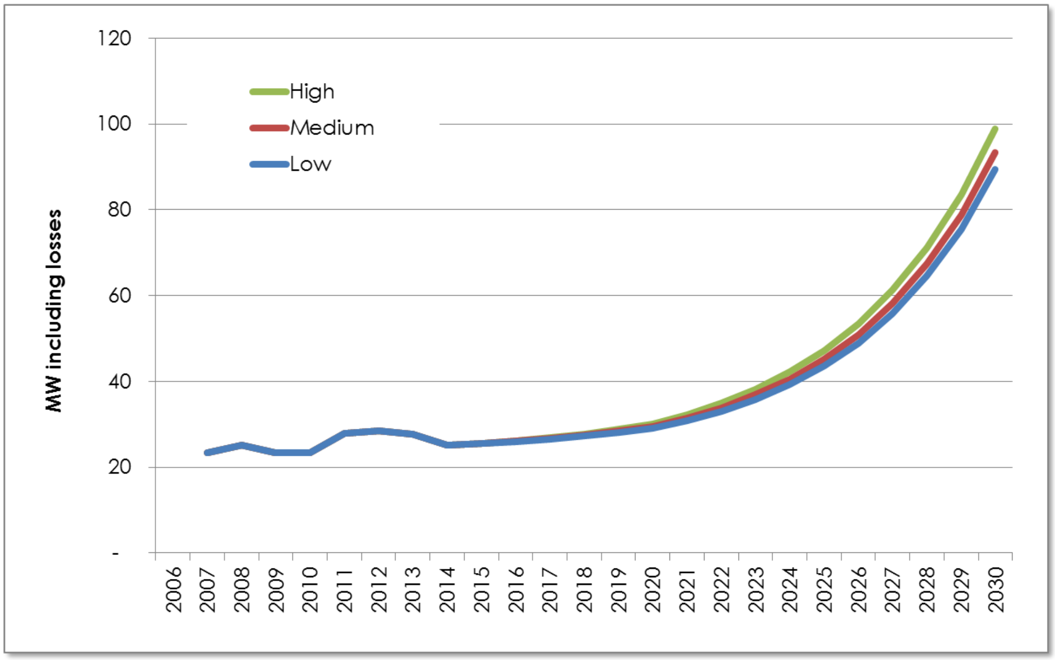
Sources: MoEP

Figure IV-45: Forecast Electricity Consumption Growth to 2035



Source: Excluding losses; Consultant

Figure IV-46: Forecast Electricity Demand Growth



Sources: Consultant; includes losses

MAGWE REGION

29. Magwe is located in the central part of Myanmar. The principal product of Magwe Region is petroleum; the region produces most of Myanmar's oil and natural gas. The oil fields located in the Magwe Region are the Mann, Yenangyaung, Chauk, Kyauk-khwet, Letpando and Ayadaw oil fields. Petroleum is produced and Magwe is referred to as the 'oil pot of Myanmar'.

30. Other industries include cement, cotton weaving, tobacco, iron and bronze. The major agricultural crops are sesamum and groundnut. Other crops grown are rice, millet, maize, sunflower, beans and pulses, tobacco, toddy, chili, onions and potatoes. Famous products of Magwe Region include: Thanaka (Limonia acidissima) and Phangar (Chebulic myorobalan) fruit. Magwe Region also produces a large quantity of edible oil. Magwe has almost no tourist industry.

Residential Connections Forecast

31. In the last six years the reported new connection rate has been high at an average of 12%. This rate appears to reflect the achievement of the residential electrification rate of 10%.

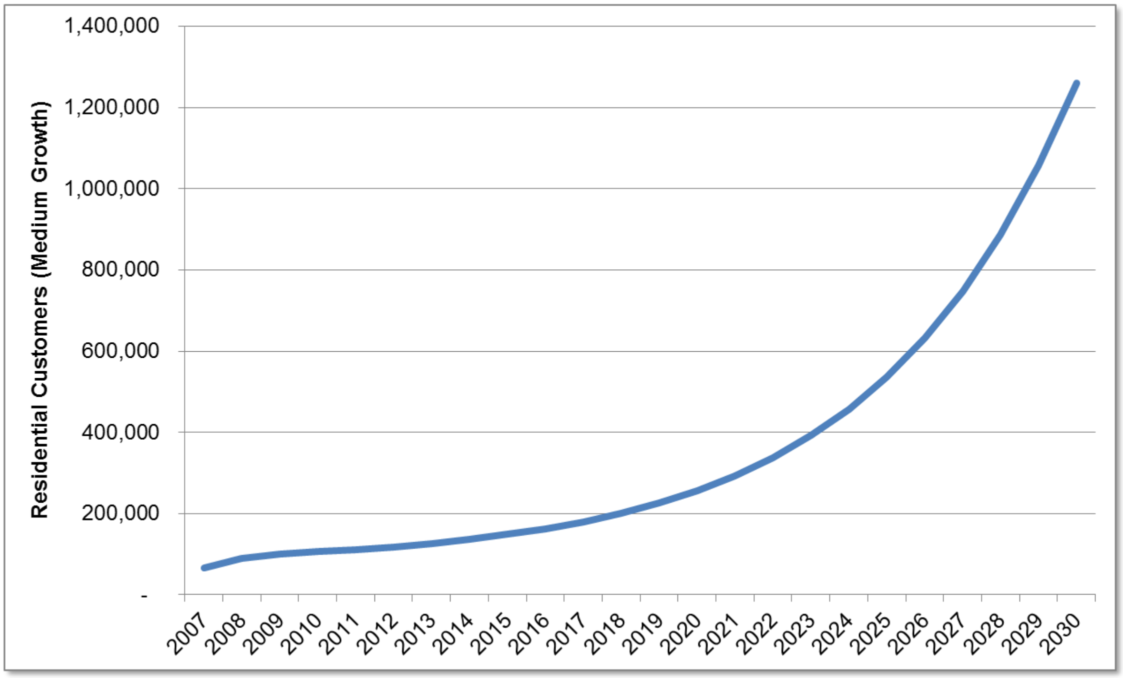
Table IV-47: National Grid Supply Connections to 2013

	2008	2009	2010	2011	2012	2013
Total	88 898	101 381	106 618	111 359	117 886	126 931
Growth (new connections p.a.)	12 483	5 237	4 741	6 527	9 045	10 000
Growth %	34%	14%	5%	4%	6%	8%

Sources: MoEP

32. The forecast growth of residential grid supply connections is shown as Figure IV-48 for the 87% national electrification goal.

Figure IV-48: Growth of Residential Connections



Sources: Consultant

Electricity Forecasts

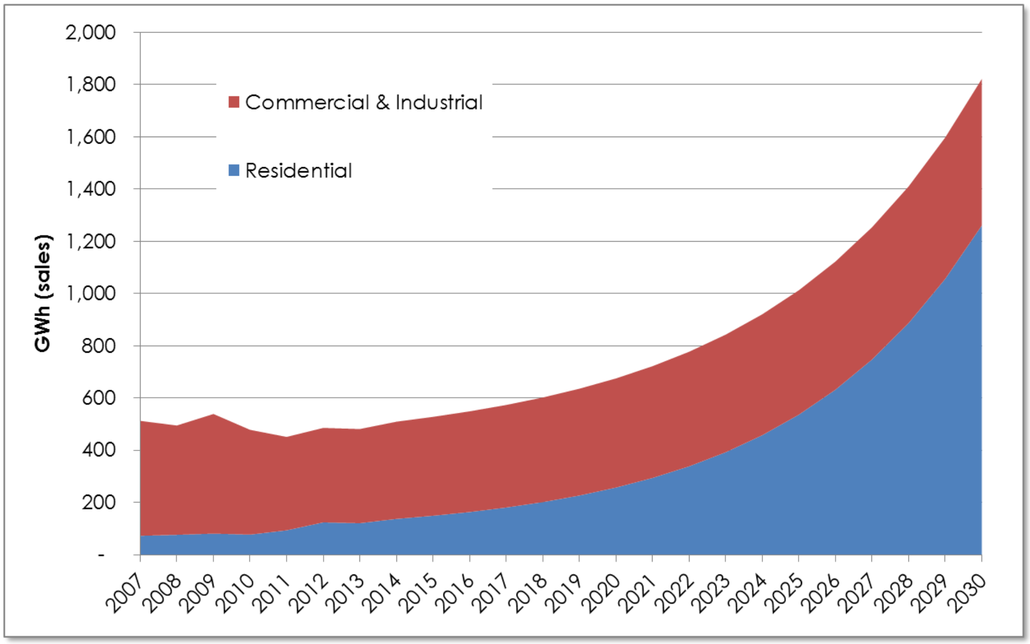
33. The average kWh per residential customer has increased from 850 in 2008 to 950 in 2013. Commercial and light industrial consumption is reported by MoEP at 17 000 kWh per customer. The following industrial customers of 2 MVA or above were reported to be active in 2013.

Table IV-49: Magwe Industrial Customers (2013)

Customer	Load MVA	Supply Voltage kV	Type of Business
Tan 4000 Industrial(Myaing Kalay)	35	66	Cement
Tan 900 Industrial(Myaing Kalay)	15	66	Cement
Tan 900 Industrial(Myaing Kalay)	10.5	33	Cement

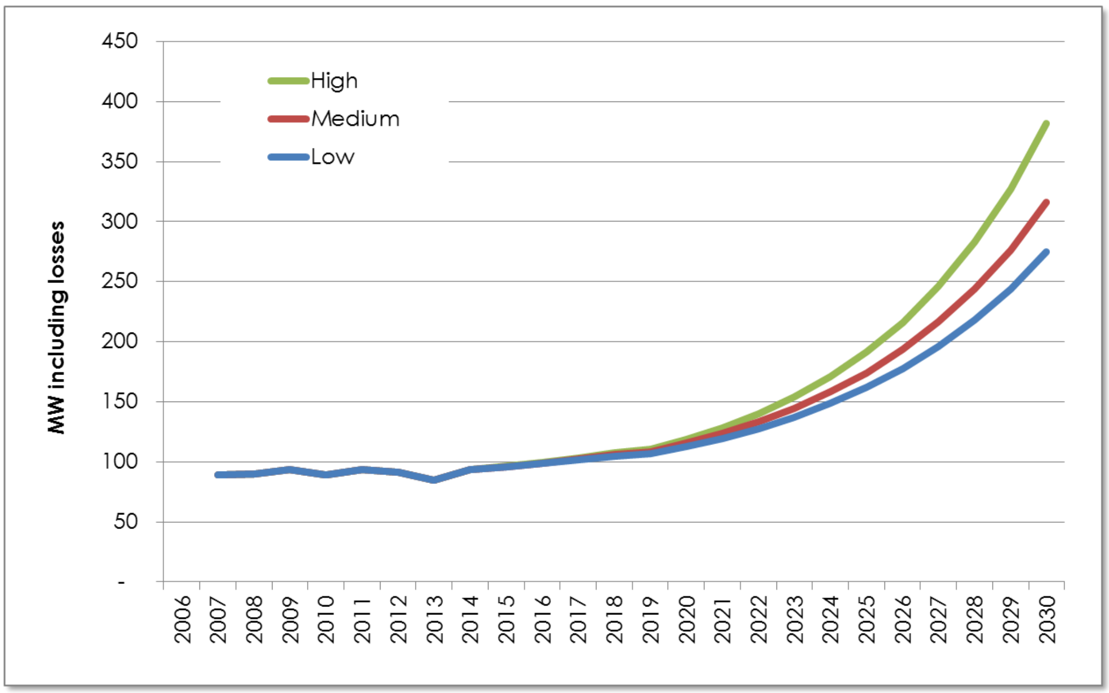
Sources: MoEP

Figure IV-50: Forecast Electricity Consumption Growth



Sources: Excluding losses; Consultant

Figure IV-51: Forecast Electricity Demand Growth



Sources: Consultant; includes losses

MANDALAY REGION

34. Mandalay is located in the center of the country, bordering Sagaing Region and Magway Region to the west, Shan State to the east, and Bago Region and Kayin State to the south. The regional capital is Mandalay. The national capital of Naypyidaw is found in the south of the region.

35. Agriculture is the primary economic activity. The primary crops grown within Mandalay Region are rice, wheat, maize, peanut, sesame, cotton, legumes, tobacco, chilli and vegetables. Industry, including alcohol breweries, textile factories, sugar mills and gem mines also exist. Tourism forms a substantial part of Mandalay Region's economy, as the region contains many historical sites including Mandalay, Amarapura, Bagan, Pyin U Lwin, Mount Popa and Ava. Hardwoods such as teak and thanaka are also harvested.

Residential Connections Forecast

36. In the last six years the reported new connection rate has been high at an average of 11%. This rate appears to have supported the achievement of the residential electrification rate of 11%.

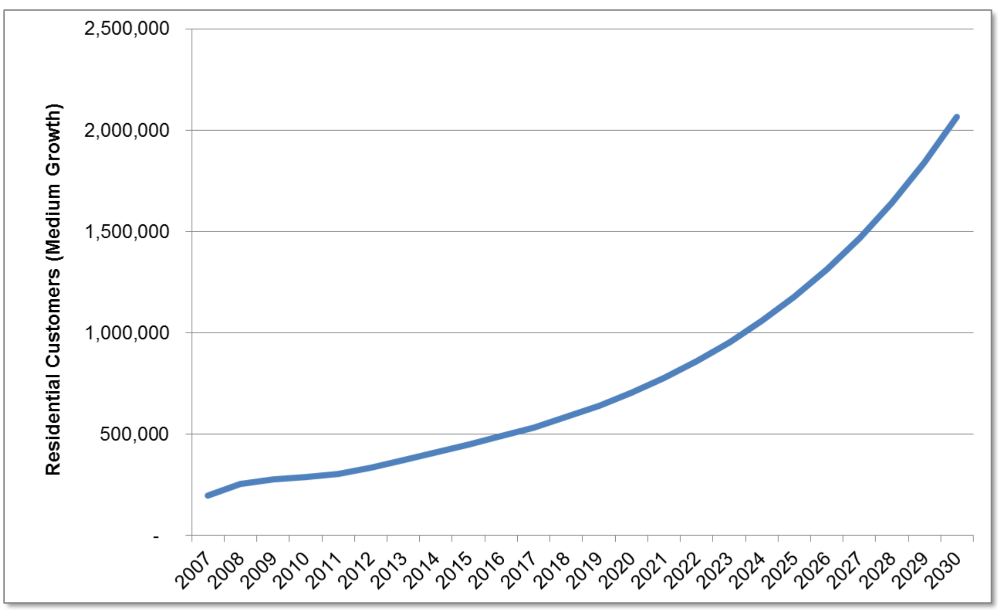
Table IV-52: National Grid Supply Connections to 2013

	2008	2009	2010	2011	2012	2013
Total	254 438	276 769	290 692	305 586	336 819	372 812
Growth (new connections p.a.)	22 331	13 923	14 894	31 233	35 993	36 000
Growth %	28%	9%	5%	5%	10%	11%

Sources: MoEP

37. The forecast growth of residential grid supply connections is shown as Figure IV-53 for the 87% national electrification goal.

Figure IV-53: Growth of Residential Connections



Sources: Consultant

Electricity Forecasts

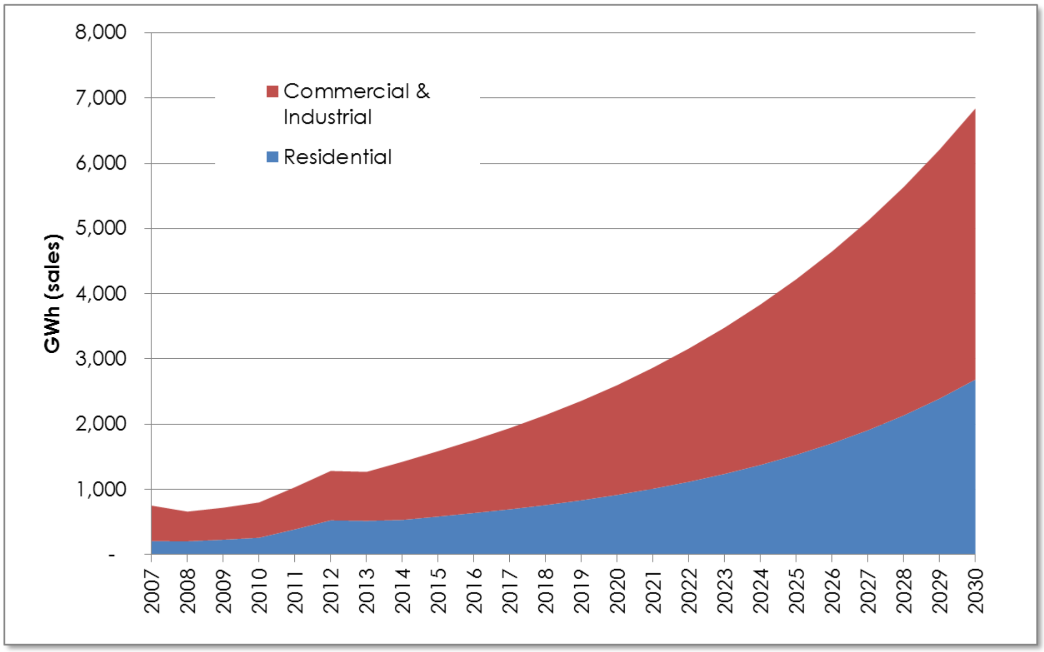
38. The average kWh per residential customer has increased from 800 in 2008 to 1 400 in 2013. Commercial and light industrial consumption is reported by MoEP at 21 200 kWh per customer. The following industrial customers of 2 MVA or above were reported to be active in 2013.

Table IV-54: Mandalay Large Industrial Customers (2013)

Customer	Load	Supply Voltage	Type of Business
	MVA	kV	
Daw San Kyu	2.5	33/0.4	Food processing
U Htun Naing	3	33/0.4	Textiles
U Maung Soe	3	33/0.4	Iron and steel
U Myint Aung	3	33/0.4	Iron and steel
Daw Khin Tidar Win	2	11/0.75	Iron and steel
U Sein Win	3	33/0.4	Other
Aung Myint Shaing Co. Ltd	5	33/11	Iron and steel
103 Wood Factory	5	33/11	Other
AAA Cement Factory	10	33/6.3	Cement
Myanmar Elephant Cement Factory	3.15	33/10	Cement
Steel Mill	85	33/10	Iron and steel
Steel Mill	4	33/10	Iron and steel
Vest Mill	2	33/10	Textiles
Petrol	0.16	33/10	Petrol
Pozolan	10	33/10	Pozolan
Shwe Taung	16	33/10	Textiles
Max Myanmar	6.3	33/10	Cement
Iron and Steel Factory	35.9	33/10	Iron and steel
Pharmaceutical Factory	5	33/10	Phamacutical

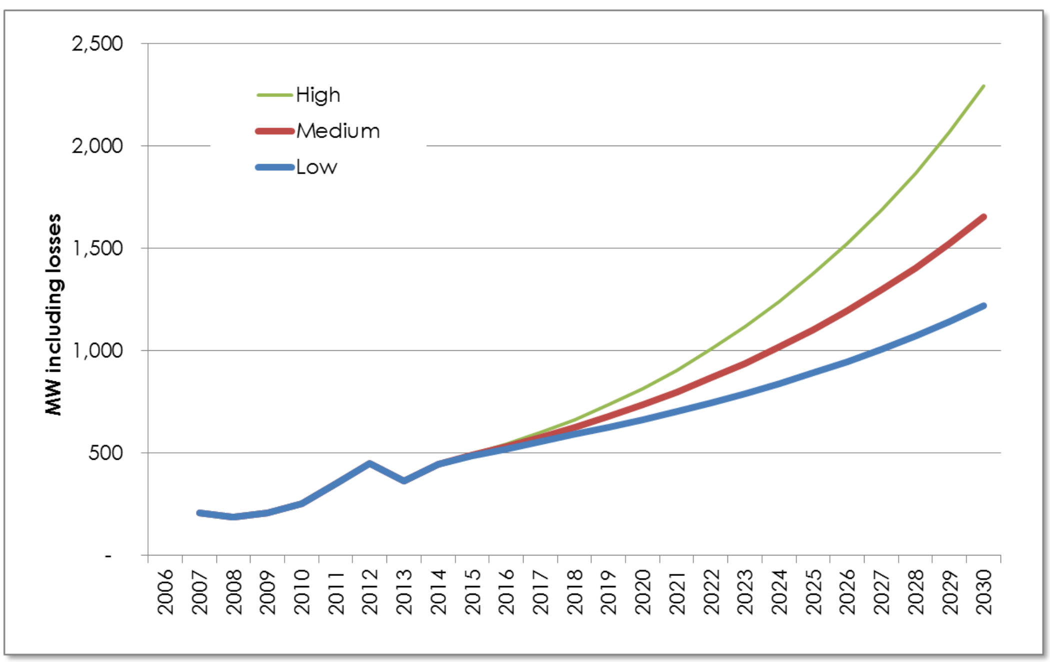
Sources: MoEP

Figure IV-55: Forecast Electricity Consumption Growth



Sources: Excluding losses; Consultant

Figure IV-56: Forecast Electricity Demand Growth



Sources: Consultant; includes losses

MON STATE

39. Mon State is located between Kayin State on the east, the Andaman Sea on the west, Bago Region on the north and Tanintharyi Region on the south, and has a short border with Thailand's Kanchanaburi Province at its south-eastern tip.

40. Mon State has a cultivated area of nearly 4.5 million acres, mostly under rice. The major secondary crop is rubber. Orchards and rubber plantations are found in the mountainous areas while coastal fishing and related industries such as production of dried fish, fish sauce and agar-agar are in southern part. Other industries include betel nut production, paper, sugar and rubber tires. Thaton has a major factory (Burmese Ka-Sa-La) of rubber products run by the Ministry of Industry. Forests cover approximately half of the area and timber production is one of the major contributors to the economy. Minerals extracted from the area include salt, antimony and granite. Natural resources such as forest products, and onshore and offshore mineral resources, are exploited only by top Myanmar military leaders and foreign companies. The Yadana Gas project pipelines pass through Mon State.

Residential Connections Forecast

41. In the last six years the reported new connection rate has been high at an average of 18% and does not appear to reflect the low residential electrification rate of 8%.

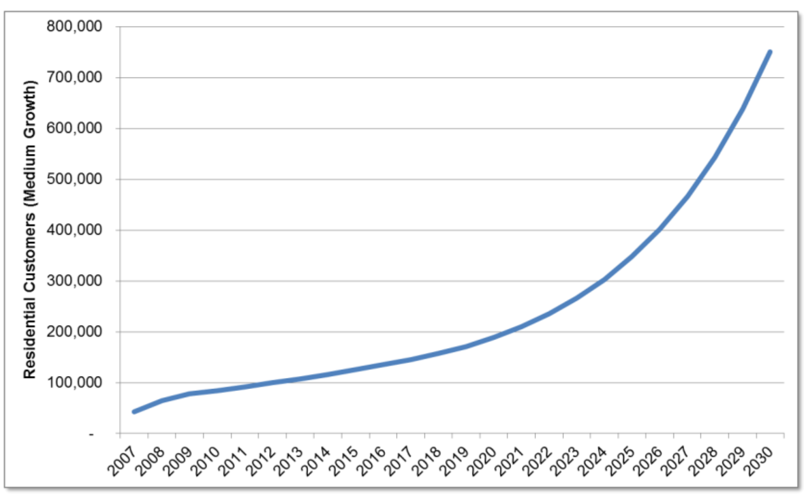
Table IV-57: National Grid Supply Connections to 2013

	2008	2009	2010	2011	2012	2013
Total	64 826	77 733	84 442	91 134	99 517	107 718
Growth (new connections p.a.)	12 907	6 709	6 692	8 383	8 201	8 000
Growth %	53%	20%	9%	8%	9%	8%

Sources: MoEP

42. The forecast growth of residential grid supply connections is shown as Figure IV-58 for the 87% national electrification goal.

Figure IV-58: Growth of Residential Connections



Sources: Consultant

Electricity Forecasts

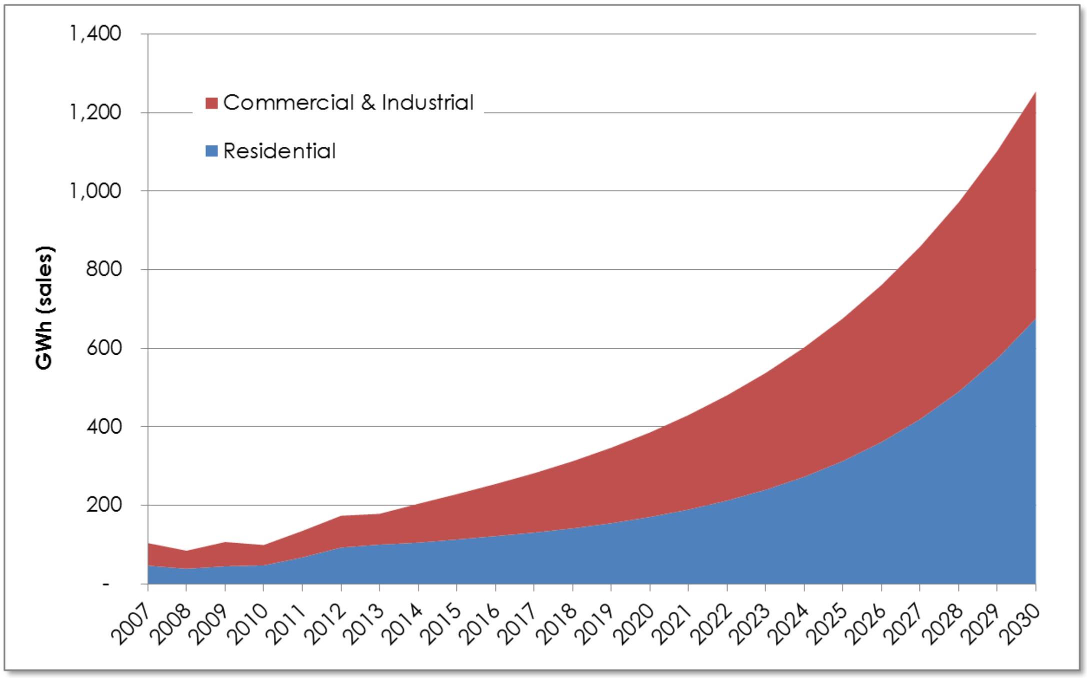
43. The average kWh per residential customer has increased from 590 in 2008 to 920 in 2013. Commercial and light industrial consumption is reported by MoEP at 8 000 kWh per customer. The following industrial customers of 2 MVA or above were reported to be active in 2013.

Table IV-59: Mon Large Industrial Customers (2013)

Customer	Load	Supply Voltage	Type of Business
	MVA	kV	
U Nyi Nyi Htwe	2	11	Iron and steel

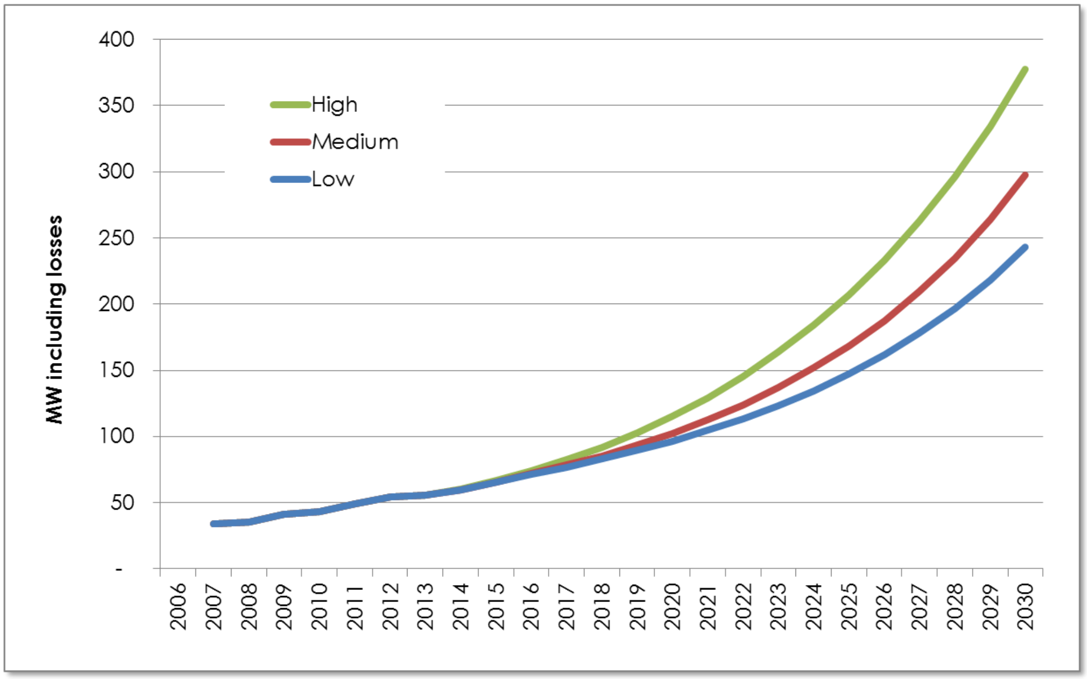
Sources: MoEP

Figure IV-60: Forecast Electricity Consumption Growth



Sources: Excluding losses; Consultant

Figure IV-61: Forecast Electricity Demand Growth



Sources: Consultant; includes losses

NAY PYI TAW

44. Nay Pyi Taw is the capital city of Myanmar. It is located in the southern part of the Mandalay region.

Residential Connections Forecast

45. In the last six years the reported new connection rate has been high at an average of 28%. This rate appears to have supported the achievement of a high electrification rate of 37%.

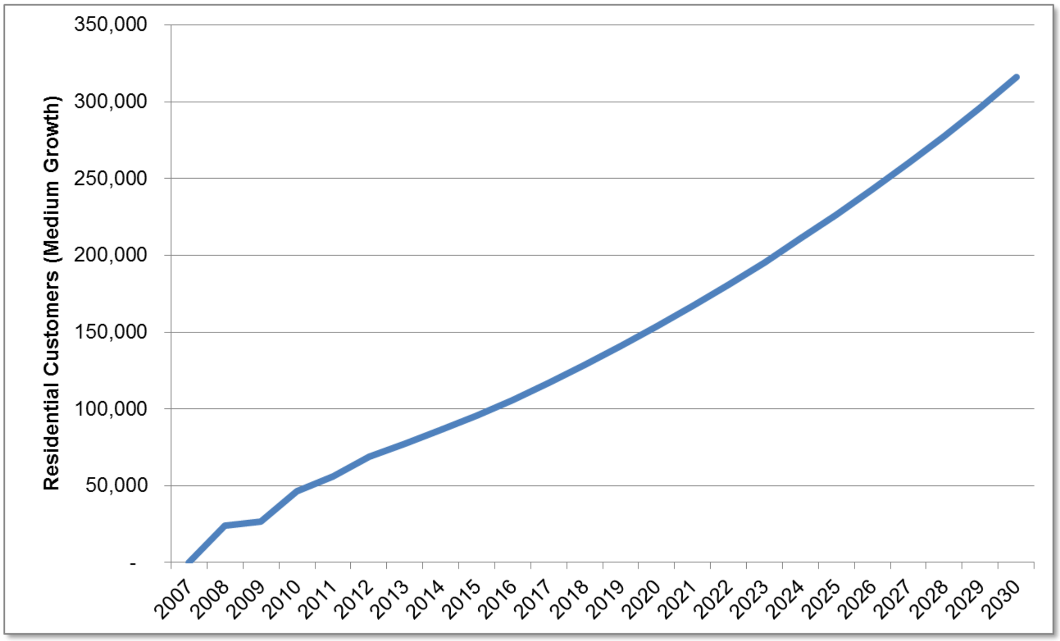
Table IV-62: National Grid Supply Connections to 2013

	2008	2009	2010	2011	2012	2013
Total	24 018	26 763	46 358	56 195	68 984	77 425
Growth (new connections p.a.)	2 745	19 595	9 837	12 789	8 441	8 500
Growth %	11%	73%	21%	23%	12%	11%

Sources: MoEP

46. The forecast growth of residential grid supply connections is shown as Figure IV-63 for the 87% national electrification goal.

Figure IV-63: Growth of Residential Connections



Sources: Consultant

Electricity Forecasts

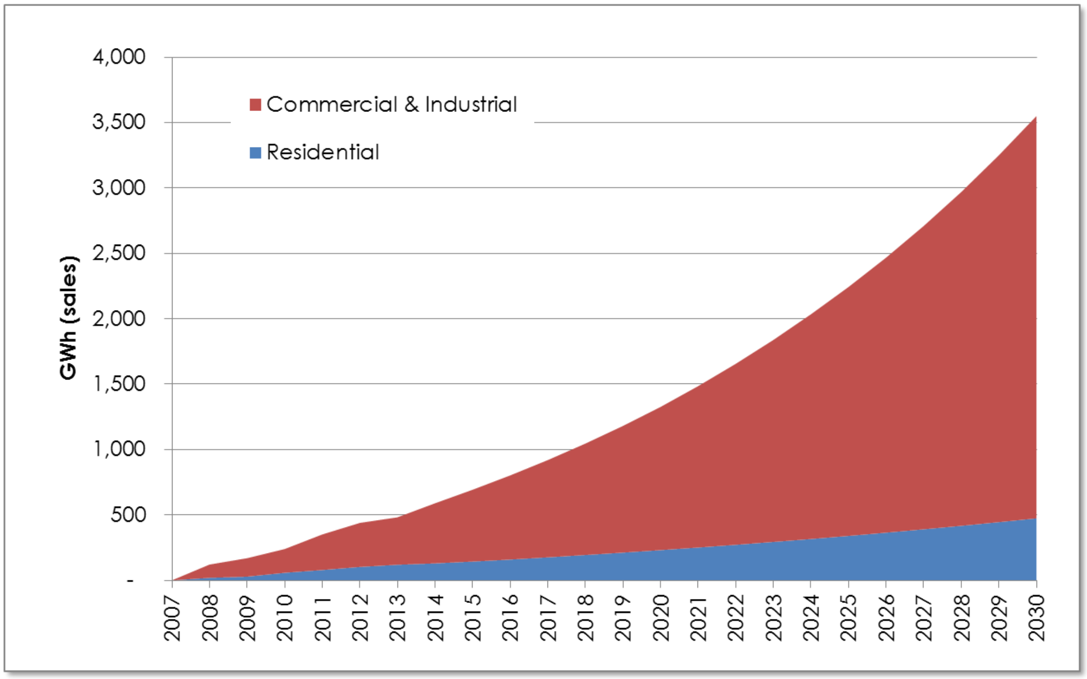
47. The average kWh per residential customer has increased from 780 in 2008 to 1 530 in 2013. Commercial and light industrial consumption is reported by MoEP at 10 800 kWh per customer. The following industrial customers of 2 MVA or above were reported to be active in 2013.

Table IV-64: Nay Pyi Taw Large Industrial Customers (2013)

Customer	Load	Supply Voltage	Type of Business
	MVA	kV	
Max Myanmar Cement	6.3	33	Cement
Naypyitaw Sipin Cement	6.3	33	Cement
Naypyitaw (Brick)	5	33	Other

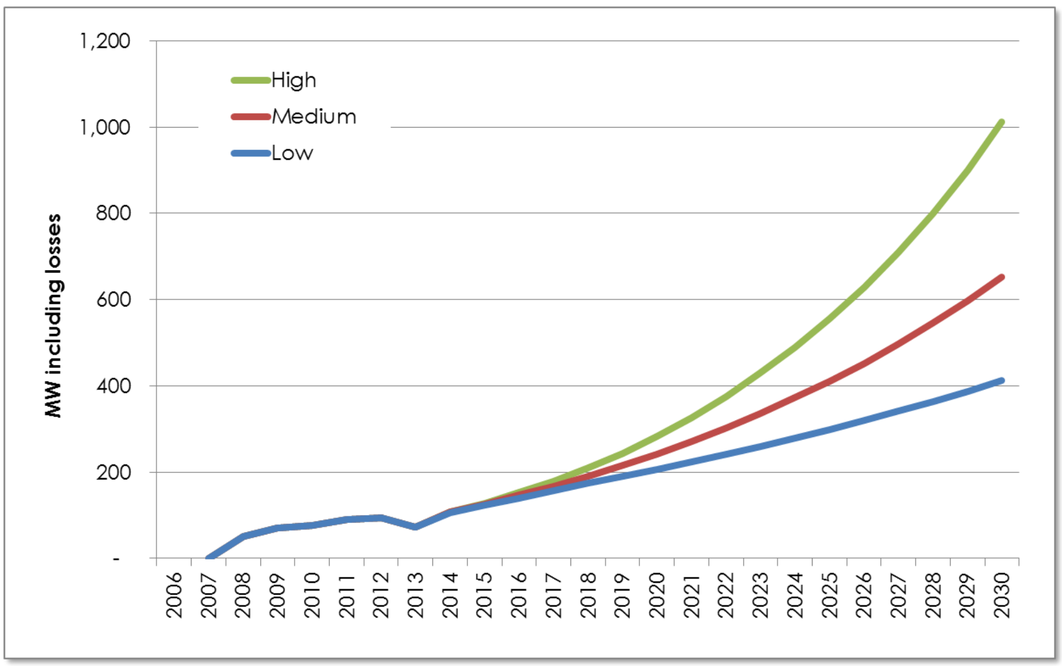
Sources: MoEP

Figure IV-65: Forecast Electricity Consumption Growth



Sources: Excluding losses; Consultant

Figure IV-66: Forecast Electricity Demand Growth



Sources: Consultant; includes losses

RAKHINE STATE

48. Rakhine State is situated on the western coast; it is bordered by Chin State in the north, Magway Region, Bago Region and Ayeyarwady Region in the east, the Bay of Bengal to the west, and the Chittagong Division of Bangladesh to the north.

49. Rice is the main crop in the region, occupying around 85% of the total agricultural land. Coconut and nipa palm plantations are also important. Fishing is a major industry, with most of the catch transported to Yangon, but some is also exported. Wood products such as timber, bamboo and fuel wood are extracted from the mountains. Small amounts of inferior-grade crude oil are produced from primitive, shallow, hand-dug wells, but there is yet unexplored potential for petroleum and natural gas production.

50. Tourism is slowly being developed. The ruins of the ancient royal town Mrauk U and the beach resorts of Ngapali are the major attractions for foreign visitors.

Residential Connections Forecast

51. In the last six years new connection rate has been high at an average of 8%. This relatively low rate, with decline in recent years, appears to reflect the residential electrification rate of 3%.

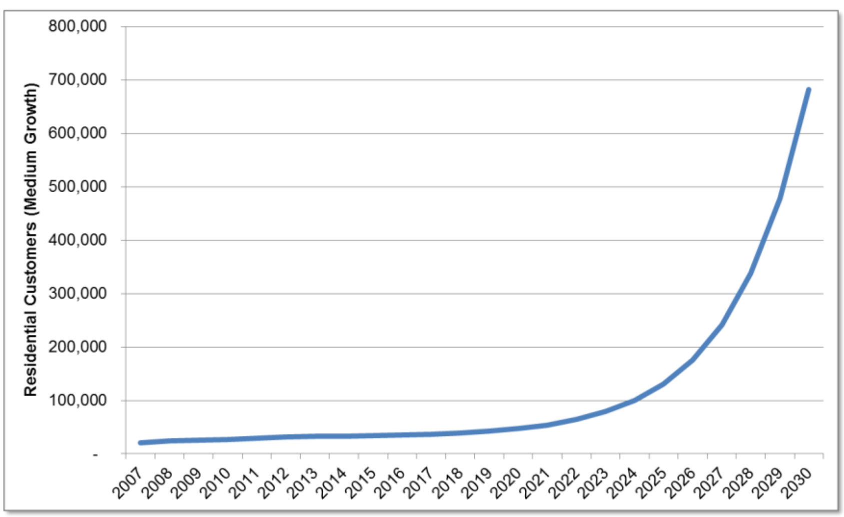
Table IV-67: National Grid Supply Connections to 2013

	2008	2009	2010	2011	2012	2013
Total	23 968	25 673	27 382	29 104	31 547	32 347
Growth (new connections p.a.)	1 705	1 709	1 722	2 443	800	2 000
Growth %	15%	7%	7%	6%	8%	3%

Sources: MoEP

52. The forecast growth of residential grid supply connections is shown in Figure IV-68 for the 87% national electrification goal.

Figure IV-68: Growth of Residential Connections

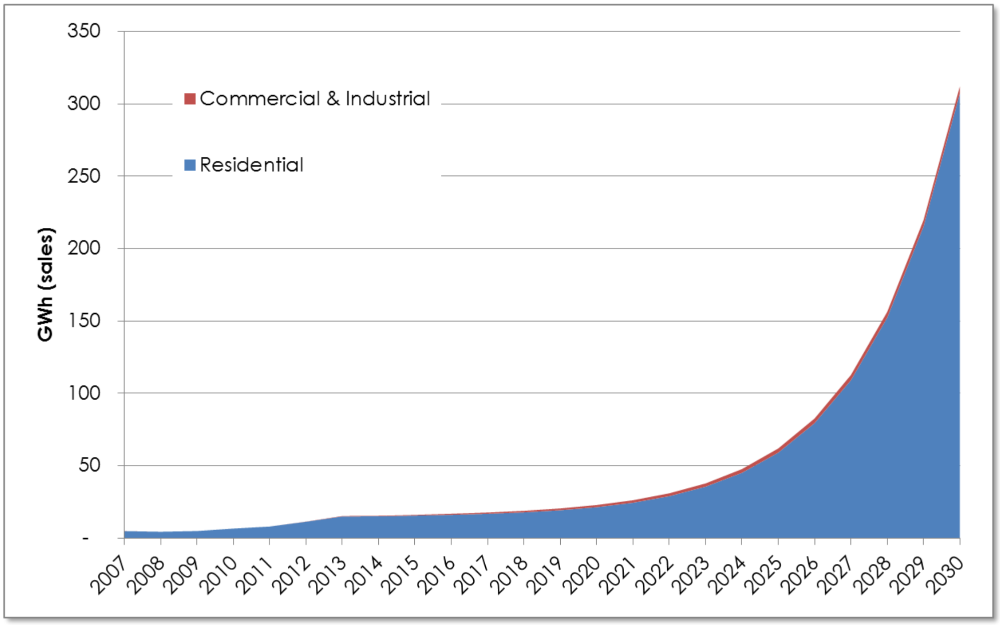


Sources: Consultant

Electricity Forecasts

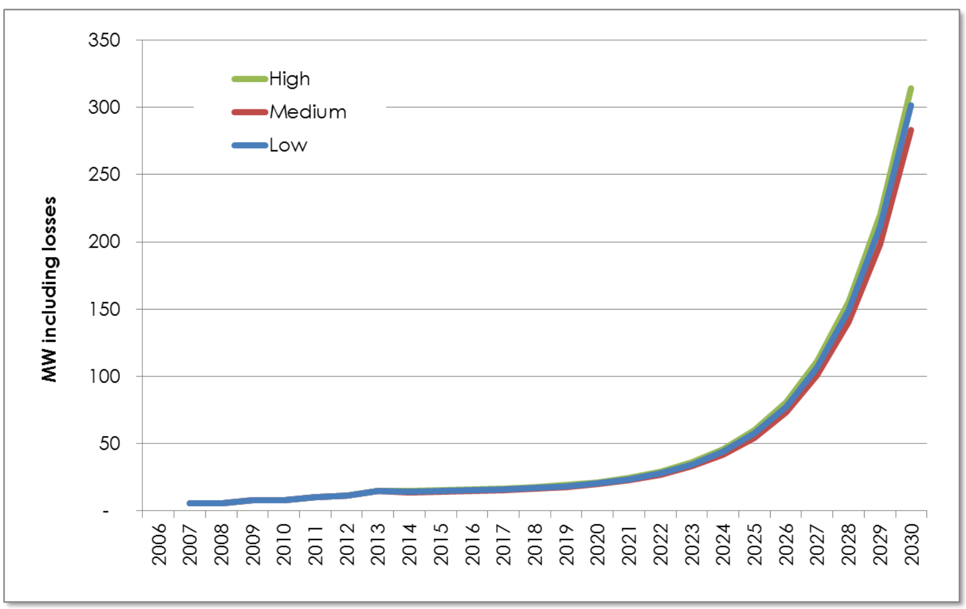
53. The average kWh per residential customer has increased from 180 in 2008 to 460 in 2013. Commercial and light industrial consumption is reported by MoEP at a very low 190 kWh per customer. There were no industrial customers of 2 MVA or above reported.

Figure IV-69: Forecast Electricity Consumption Growth



Sources Excluding losses; Consultant

Figure IV-70: Forecast Electricity Demand Growth



Sources: Consultant; includes losses

SAGAING REGION

54. Sagaing Region is located in the north-western part of Myanmar. It is bordered by India's Nagaland and Manipur States to the north, Kachin State, Shan State and Mandalay Region to the east, Mandalay Region and Magwe Region to the south, with the Ayerwaddy River forming a greater part of its eastern and also southern boundary, and Chin State and India to the west.

55. Agriculture is the main economic activity with rice occupying most of the arable ground. Other crops include wheat, sesame, peanut, pulses, cotton and tobacco. Sagaing is Myanmar's leading producer of wheat, contributing more than 80% of the country's total production. Forestry is important in the wetter upper regions along the Chindwin River, with teak and other hardwoods extracted. Important minerals include gold, coal, salt and small amounts of petroleum. Industry includes textiles, copper refining, gold smelting and a diesel engine plant. The Region has many rice mills, edible oil mills, saw mills, cotton mills and mechanized weaving factories. Local industry includes earthen pots, silverware, bronze-wares, iron-wares and lacquerware.

Residential Connections Forecast

56. In the last six years the reported new connection rate has been high at an average of 14%. This rate appears to reflect the residential electrification rate of 15%.

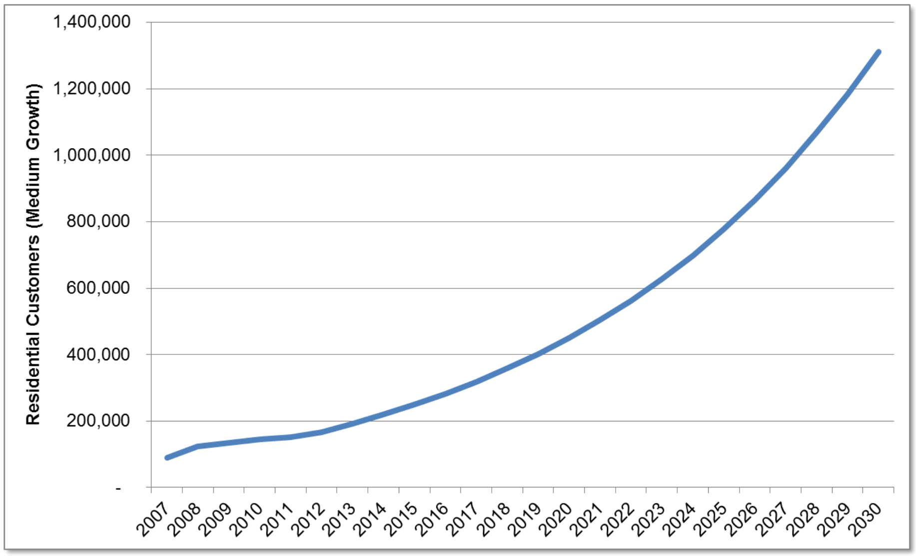
Table IV-71: National Grid Supply Connections to 2013

	2008	2009	2010	2011	2012	2013
Total	124 074	135 240	145 568	152 556	167 287	191 984
Growth (new connections p.a.)	11 166	10 328	6 988	14 731	24 697	20 000
Growth %	37%	9%	8%	5%	10%	15%

Sources: MoEP

57. The forecast growth of residential grid supply connections is shown in Figure IV-72.

Figure IV-72: Growth of Residential Connections



Sources: Consultant

Electricity Forecasts

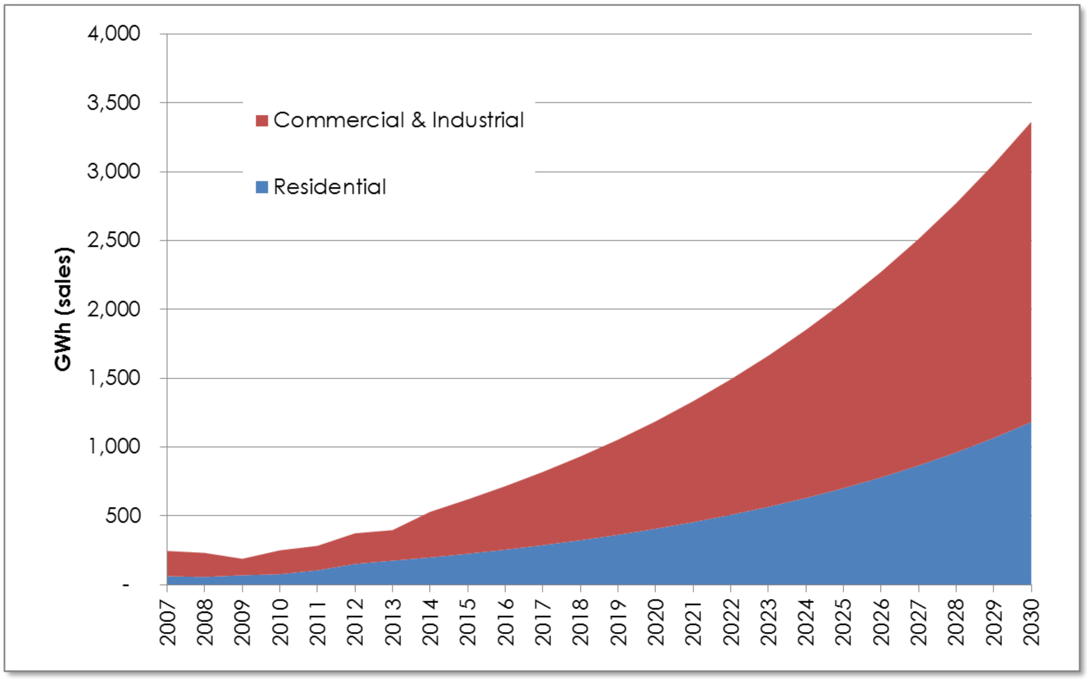
58. The average kWh per residential customer has increased from 450 in 2008 to 910 in 2013. Commercial and light industrial consumption is reported by MoEP at 14 800 kWh per customer. The following industrial customers of 2 MVA or above were reported to be active in 2013.

Table IV-73: Sagaing Large Industrial Customers (2013)

Customer	Load	Supply Voltage	Type of Business
	MVA	kV	
Iron and steel	5	33/11	Iron and steel
Other	2	33/11	Other
Chemicals	2x10	33/11	Chemicals
Chemicals	3.15	33/10	Chemicals
Iron and steel	2	33/11	Iron and steel

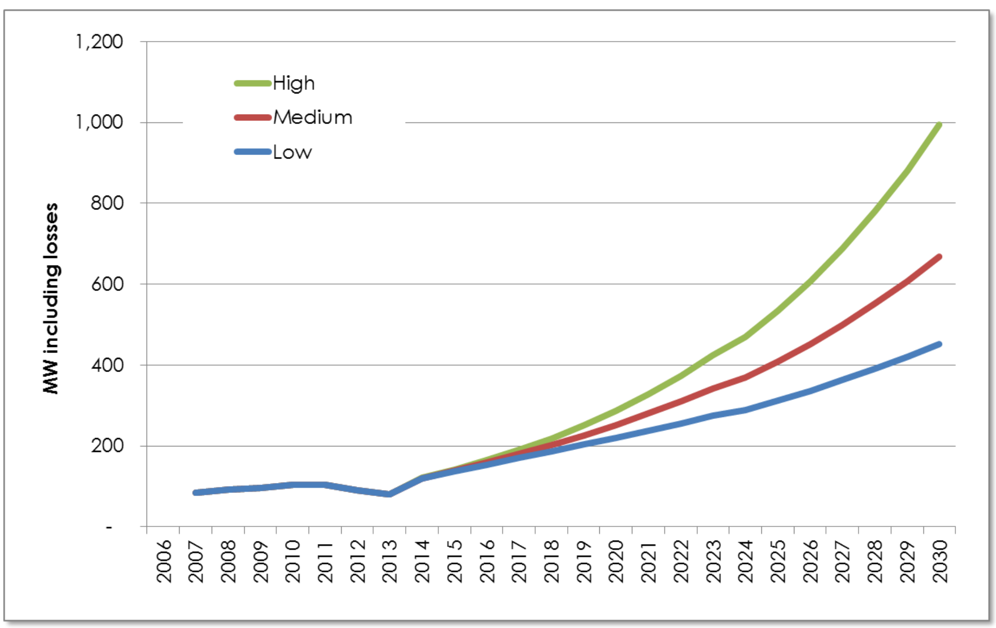
Sources: MoEP

Figure IV-74: Forecast Electricity Consumption Growth



Sources: Excluding losses; Consultant

Figure IV-75: Forecast Electricity Demand Growth



Sources: Consultant; includes losses

SHAN STATE

59. Shan State borders China to the north, Laos to the east, Thailand to the south, and five

administrative divisions of Myanmar to the west.

60. Silver, lead and zinc are mined, notably at the Bawdwin mine, and there are smelters at Namtu. Teak is extracted from the local forests. Rice and all sorts of fresh fruit and vegetables are grown due to the temperate but sunny climate. Shan State is part of the Golden Triangle, an area in which much of the world's opium and heroin are illegally produced.

61. There are border trading centres along the Shan State border and neighbour countries. Muse, the largest border trading centre along the Myanmar China border and Tachileik and another important trading centre between Myanmar and Thailand. The China-Myanmar oil and gas pipelines pass through the northern part of Shan State.

Residential Connections Forecast

62. In the last six years the reported new connection rate has been high at an average of 16%. This rate appears to have supported the achievement of a residential electrification rate at 23%.

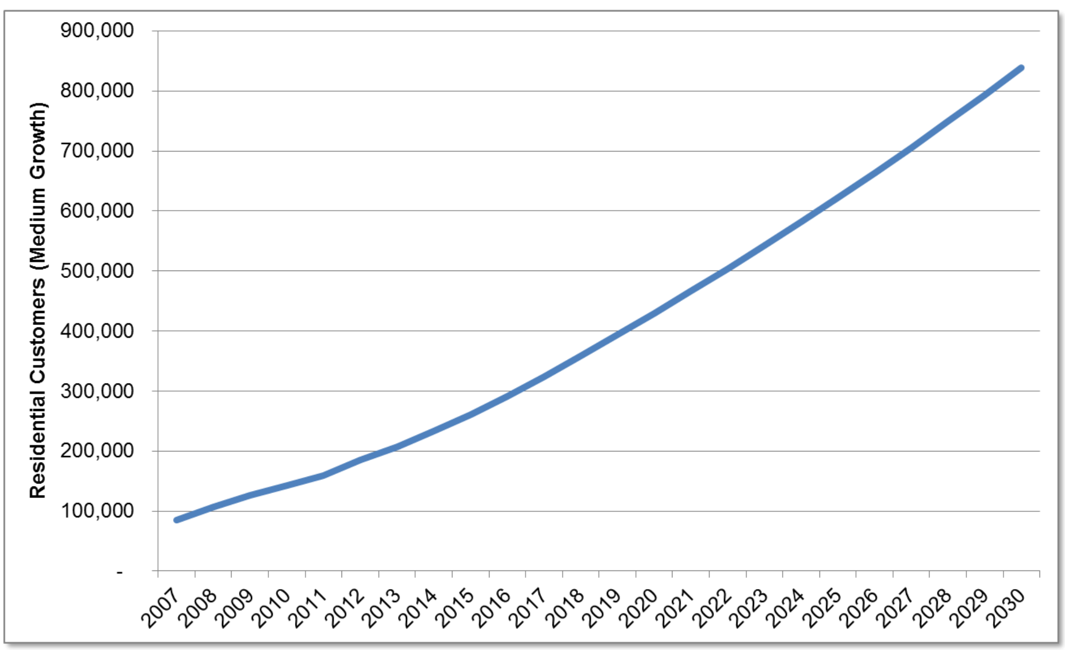
Table IV-76: National Grid Supply Connections to 2013

	2008	2009	2010	2011	2012	2013
Total	107 724	126 761	142 972	159 739	185 094	207 933
Growth (new connections p.a.)	19 037	16 211	16 767	25 355	22 839	23 000
Growth %	27%	18%	13%	12%	16%	12%

Sources: MoEP

63. The forecast growth of residential grid supply connections is shown as Figure IV-77 for the 87% national electrification goal:

Figure IV-77: Growth of Residential Connections



Sources: Consultant

Electricity Forecasts

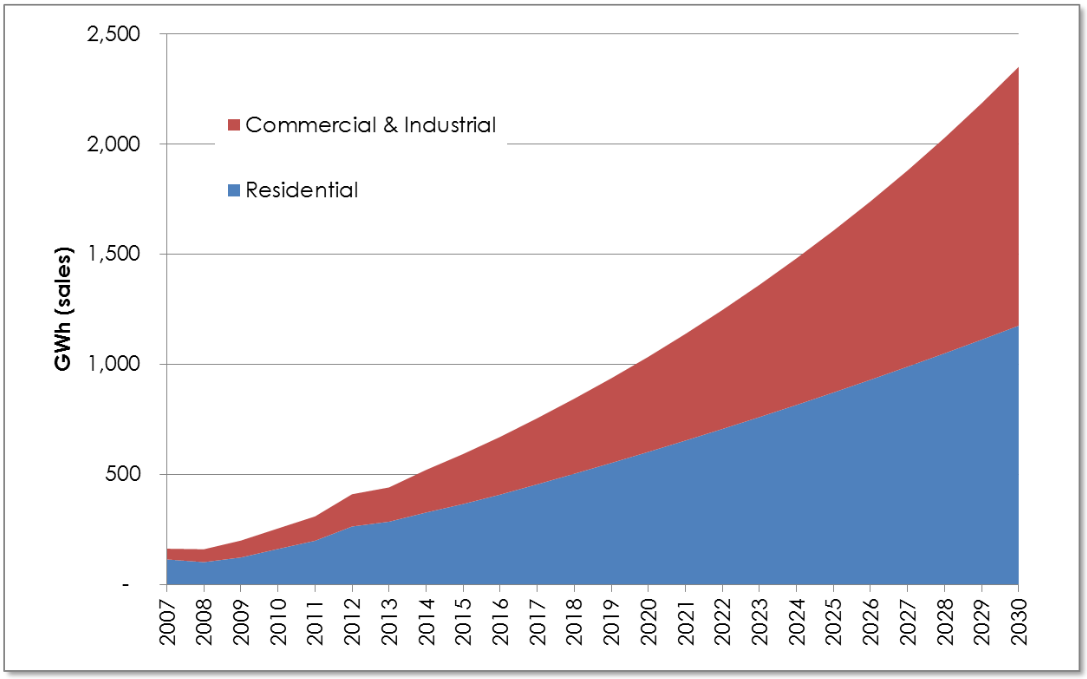
64. The average kWh per residential customer has increased from 940 in 2008 to 1 370 in 2013. Commercial and light industrial consumption is reported by MoEP at 6 360 kWh per customer. The following industrial customers of 2 MVA or above were reported to be active in 2013:

Table IV-78: Shan Large Industrial Customers (2013)

Customer	Load	Supply Voltage	Type of Business
	MVA	kV	
Ayetharyar(Iron Company)	5	66	Iron and steel
Tigyit(charcoal)	5	33	Charcoal
Dragon Cement	6.3	66	Cement
Pinprick Steel	2	33	Steel
Pinprick Steel	4	33	Steel
Khaungtawe Innarriye	5	33	Recycle Project

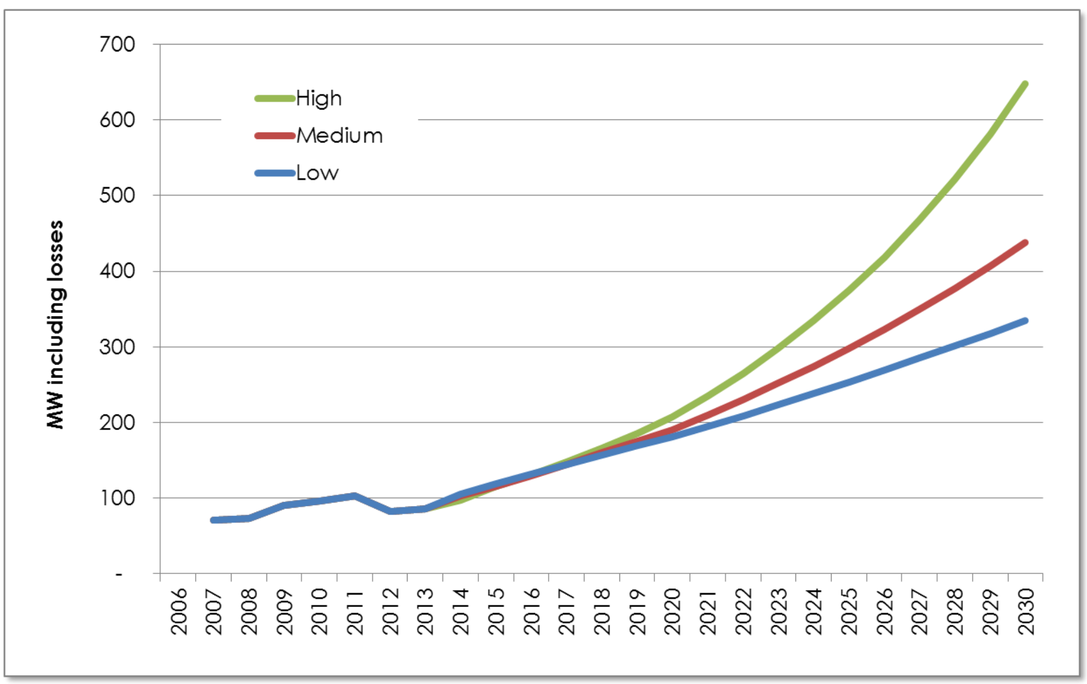
Sources: MoEP

Figure IV-79: Forecast Electricity Consumption Growth



Sources: Excluding losses; Consultant

Figure IV-80: Forecast Electricity Demand Growth



Sources: Consultant; includes losses

TANINTHARYI REGION

65. Tanintharyi Region covers a long narrow southern part of the country on the Kra Isthmus. It borders the Andaman Sea to the west and the Tenasserim Hills beyond which lies Thailand to the east. To the north is the Mon State. There are many islands off the coast the large Mergui Archipelago in the southern and central coastal areas and the smaller Moscos Islands off the northern shores. The capital of the division is Dawei (Tavoy).

Residential Connections Forecast

66. In the last six years the reported new connection rate has been low at an average of 1%. This rate appears to reflect the low population.

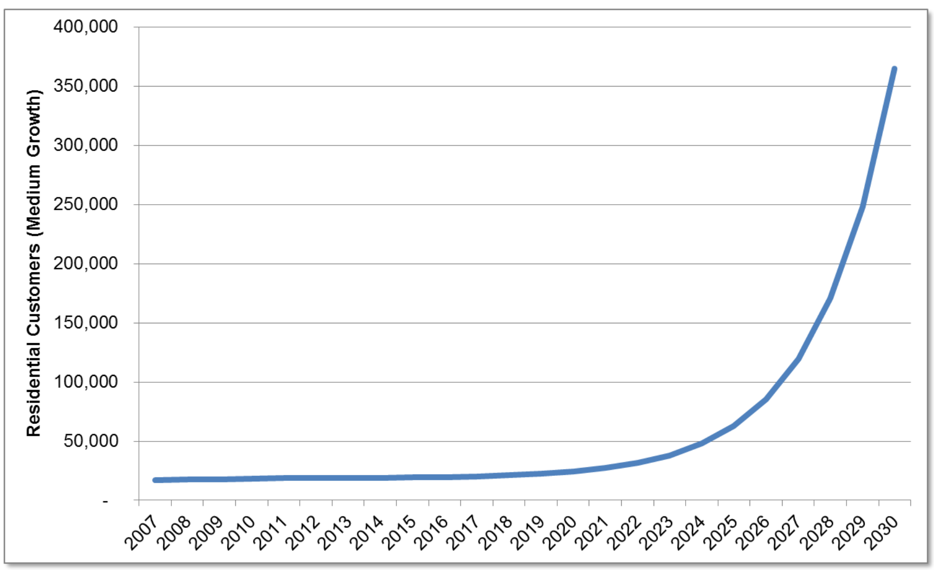
Table IV-81: National Grid Supply Connections to 2013

	2008	2009	2010	2011	2012	2013
Total	17 609	17 747	18 251	18 646	18 908	18 610
Growth (new connections p.a.)	138	504	395	262	(298)	300
Growth %	2%	1%	3%	2%	1%	-2%

Sources: MoEP

67. The forecast growth of residential grid supply connections is shown as Figure IV-82 for the 87% national electrification goal.

Figure IV-82: Growth of Residential Connections

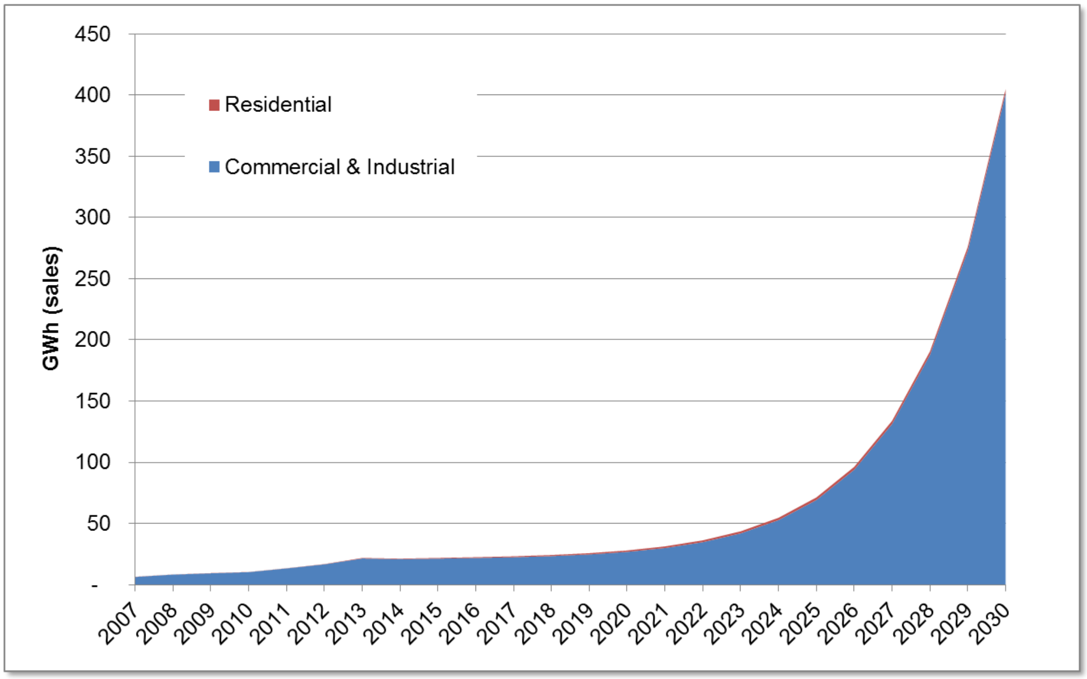


Sources: Consultant

Electricity Forecasts

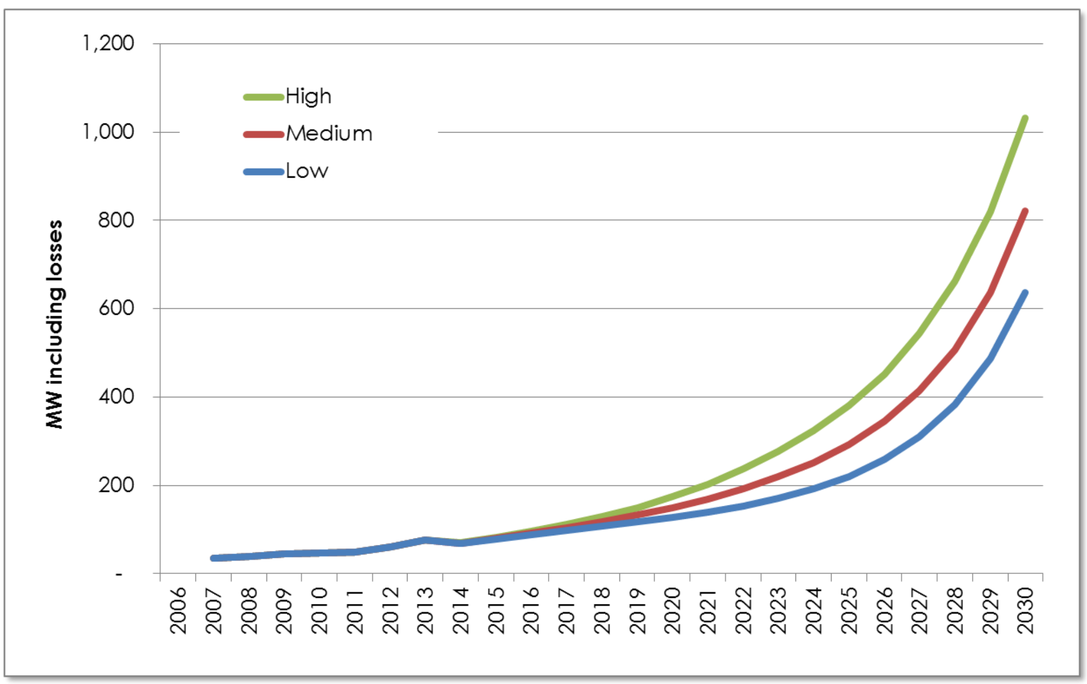
68. The average kWh per residential customer has increased from 460 in 2008 to 1 150 in 2013. Commercial and light industrial consumption is reported by MoEP at an average 4 530 kWh per customer. There were no industrial customers of 2 MVA or above reported.

Figure IV-83: Forecast Electricity Consumption Growth



Sources Excluding losses; Consultant

Figure IV-84: Forecast Electricity Demand Growth



Sources: Consultant; includes losses

YANGON

69. Yangon is the country's main centre for trade, industry, real estate, media, entertainment and tourism. The city of Yangon alone represents about one fifth of the national economy. According to official statistics for FY 2010–2011, the size of the economy of Yangon Region was 8.93 trillion kyats, or 23% of the national GDP.

70. The city is Lower Burma's main trading hub for all kinds of merchandise – from basic food stuffs to used cars although commerce continues to be hampered by the city's severely underdeveloped banking industry and communications infrastructure. Bayinnaung Market is the largest wholesale centre in the country for rice, beans and pulses, and other agricultural commodities. Much of the country's legal imports and exports go through Thilawa Port, the largest and busiest port in Burma. There is also a great deal of informal trade, especially in street markets that exist alongside street platforms of Downtown Yangon's townships.

71. Manufacturing accounts for a sizable share of employment. At least 14 light industrial zones ring Yangon, directly employing over 150,000 workers in 4,300 factories in early 2010. The city is the centre of country's garment industry which exported US$292 million in 2008/9 fiscal year. More than 80 % of factory workers in Yangon work on a day-to-day basis. Most are young women between 15 and 27 years of age who come from the countryside in search of a better life. The manufacturing sector suffers from both structural problems (e.g. chronic power shortages) and political problems (e.g. economic sanctions). In 2008, Yangon's 2500 factories alone needed about 120 MW of power; yet, the entire city received only about 250 MW of the 530 MW needed. Chronic power shortages limit the factories' operating hours between 8 am and 6 pm.

72. Tourism represents a major source of foreign currency for the city although by Southeast Asian standards the actual number of foreign visitors to Yangon has always been quite low. The number of visitors dipped even further following the Saffron Revolution and Cyclone Nargis. The recent improvement in the country's political climate has attracted an increasing number of businessmen and tourists. It is estimated that between 300 000 to 400 000 visitors went through Yangon International in 2011. However, after years of underinvestment, Yangon's modest hotel infrastructure—only 3 000 of the total 8 000 hotel rooms in Yangon are "suitable for tourists"—is already bursting at seams, and will need to be expanded to handle additional visitors. As part of an urban development strategy, a hotel zone has been planned in Yangon's outskirts, encompassing government- and military-owned land in Mingaladon, Hlegu and Htaukkyant Townships.

Residential Connections Forecast

73. In the last six years the residential new connection rate is reported to have averaged 8%.

Table IV-85: National Grid Supply Connections to 2013

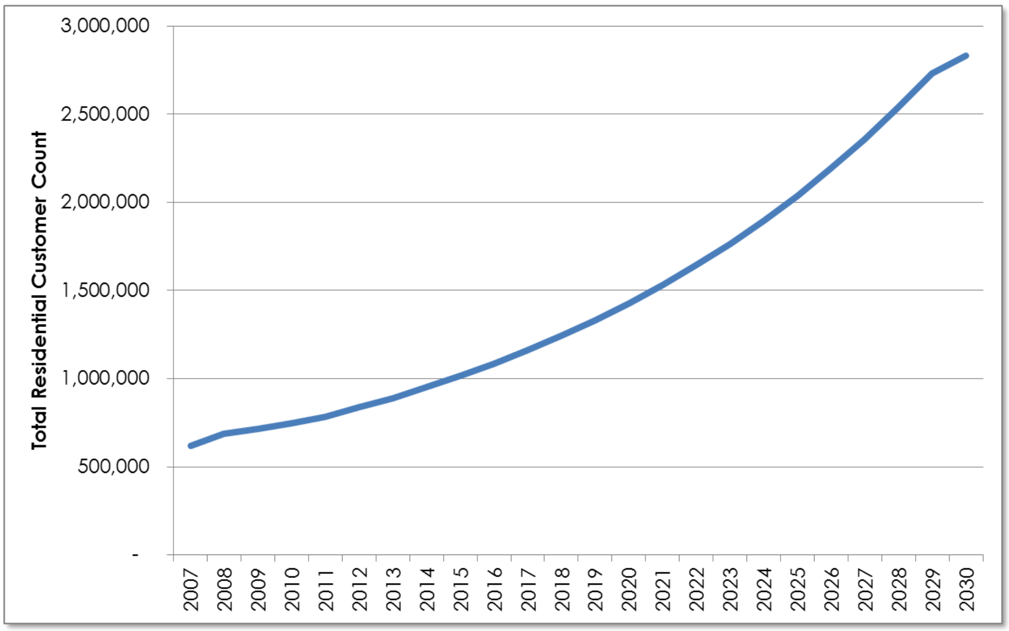
	2006	2007	2008	2009	2010	2011	2012	2013
Eastern	274 298	313 761	330 641	339 184	349 894	361 610	378 876	393 235
Western	159 723	171 009	182 911	190 852	198 532	204 699	213 508	222 626
Northern	26 335	38 823	51 342	54 597	59 331	64 714	73 941	81 917
Southern	77 065	119 555	149 795	159 301	167 747	180 085	202 390	223 684
Total	537 421	643 148	714 689	743 934	775 504	811 108	868 715	921 462
Growth (new connections p.a.)		105 727	71 541	29 245	31 570	35 604	57 607	52 747

Growth %		20%	11%	4%	4%	5%	7%	6%

Sources: MoEP

74. The forecast growth of residential grid supply connections is shown in Figure IV-86.

Figure IV-86: Forecast Growth of Residential Connections



Sources: Consultant

75. The average kWh per residential customer has increased from 800 in 2008 to 1 900 in 2013. For the purpose of forecasting residential consumption it has been assumed that this average consumption will be maintained for the period of the planning horizon.

Commercial Sector Consumption Forecast

76. In the last six years the commercial consumer new connection rate has been reported at an average of 8%. Average commercial consumer consumption was reported by MoEP at 33 340 kWh per customer.

Table IV-87: Commercial Consumers to 2013

	2006	2007	2008	2009	2010	2011	2012	2013
Eastern	8 812	8 866	9 049	9 206	9 248	9 548	9 852	10 003
Western	8 293	8 407	8 498	8 568	8 538	8 557	8 643	8 659
Northern	1 382	1 149	1 199	1 161	1 168	1 200	1 230	1 247
Southern	3 902	3 872	4 068	4 137	4 153	4 195	4 417	4 631
Total	22 389	22 294	22 814	23 072	23 107	23 500	24 142	24 540
Growth %		-0.4%	2.3%	1.1%	0.2%	1.7%	2.7%	1.6%

Sources: MoEP

Table IV-88: kWh per Commercial Consumers to 2013

	2006	2007	2008	2009	2010	2011	2012	2013	Average
Eastern	14 093	12 802	12 136	11 686	13 611	15 446	15 498	13 331	13 575
Western	29 708	27 478	26 674	26 405	28 561	28 508	28 363	26 136	27 729
Northern	18 261	23 708	18 065	24 526	26 707	28 910	26 355	26 856	24 174
Southern	57 737	62 070	56 420	60 255	72 430	83 245	79 689	71 246	67 886

Sources: MoEP

Light Industry Sector Consumption Forecast

77. In the last six years the light industry consumer new connection rate has been reported at an average of 11%. Average light industry consumer consumption was reported by MoEP at 33 340 kWh per customer.

Table IV-89: Light Industry Consumers to 2013

	2006	2007	2008	2009	2010	2011	2012	2013
Eastern	529	603	660	707	772	831	924	1 049
Western	97	108	115	134	145	202	243	266
Northern	1 011	1 151	1 297	1 388	1 533	1 651	1 884	2 069
Southern	27	35	41	55	60	68	75	88
Total	1 664	1 897	2 113	2 284	2 510	2 752	3 126	3 472
Growth %		14%	11%	8%	10%	10%	14%	11%

Sources: MoEP

Table IV-90: kWh per Light Industry Consumers to 2013

	2006	2007	2008	2009	2010	2011	2012	2013	Average
Eastern	187 812	193 791	178 772	140 352	176 461	221 321	194 286	146 568	179 920
Western	176 911	144 731	134 696	133 668	197 436	220 693	280 617	283 806	196 570
Northern	195 691	204 250	206 639	225 442	260 799	334 975	277 267	282 442	248 438
Southern	173 018	153 064	165 285	167 436	184 547	226 244	274 398	243 544	198 442

Sources: MoEP

Bulk Power (Heavy Industry) Sector Consumption Forecast

78. In the last six years the bulk power consumer new connection rate has been reported at an average of 11%. Average bulk power consumer consumption was reported by MoEP at 200 000 kWh per customer.

Table IV-91: Bulk Power Consumers to 2013

	2006	2007	2008	2009	2010	2011	2012	2013
Eastern	129	138	157	164	187	206	228	254
Western	333	377	411	438	485	541	585	662
Northern	194	192	198	204	223	245	272	314
Southern	21	31	29	36	48	68	111	151
Total	677	738	795	842	943	1 060	1 196	1 381
Growth %		9%	8%	6%	12%	12%	13%	15%

Sources: MoEP

Table IV-92: kWh per Bulk Power Consumers to 2013

	2006	2007	2008	2009	2010	2011	2012	2013	Average
Eastern	350 644	320 278	278 843	276 272	295 739	321 849	322 757	264 295	303 835
Western	362 664	330 974	306 009	313 585	337 979	341 183	368 353	311 341	334 011
Northern	66 699	64 256	65 599	69 092	102 109	164 156	154 755	124 966	101 454
Southern	66 108	45 109	67 896	51 898	62 804	79 488	55 644	53 512	60 307

Sources: MoEP

Yangon Industrial Zones

79. Yangon has 18 established industrial zones (IZ's) with another 3 under consideration. These zones represent a significant part of the daily Yangon load. The rate of electricity demand growth has been analysed and Gompertz saturation curves developed to describe the anticipated growth of the IZ's until 2035 (both existing and planned).

Table IV-93: Yangon Industrial Zones (status end 2012)

	District	IZ Name	Start Year	Total Acre	Industrial Acres	Operating	Not Operating	Under Construction
1	East	Dagon Seikkan	1997	1 209	440	102	14	7
2	East	East Dagon	2000	784	146	45	49	98
3	East	North Okkalapa	1998	110	110	94	23	13
4	East	Shwelinban	2002	1 100	209	85		
5	East	South Dagon (1)	1992	475	475	136	35	

6	East	South Dagon (2)	1996	215		773	330	170
7	East	South Dagon (3)	2000	53		1 509		
8	East	South Okkalapa	2000	35	35	70	6	
9	East	Thaketa	1999	200	73	90		
10	West	No industrial zones	1996			659		
11	North	Hlaing Thar Yar (1 2 3 4 6 7)	1995	1 401	1 088	518	43	32
12	North	Hlaing Thar Yar - 5	1996	223		170		65
13	North	Shwe Pyi Thar (1)	1990	336	310	132		
14	North	Shwe Pyi Thar (2 3 4)	1998	987	764	108	65	42
15	North	Shwepaykkan	1998	95	95	244		3
16	North	Yangon Industrial Zone	2000	903	903	31	23	34
17	South	Thilawar	2000	433		3	6	2
18	South	Than Lyan/Kyauk Tan	1996			76		

Sources: MoI

Figure IV-94: Yangon Industrial Zones Saturation Load Curve

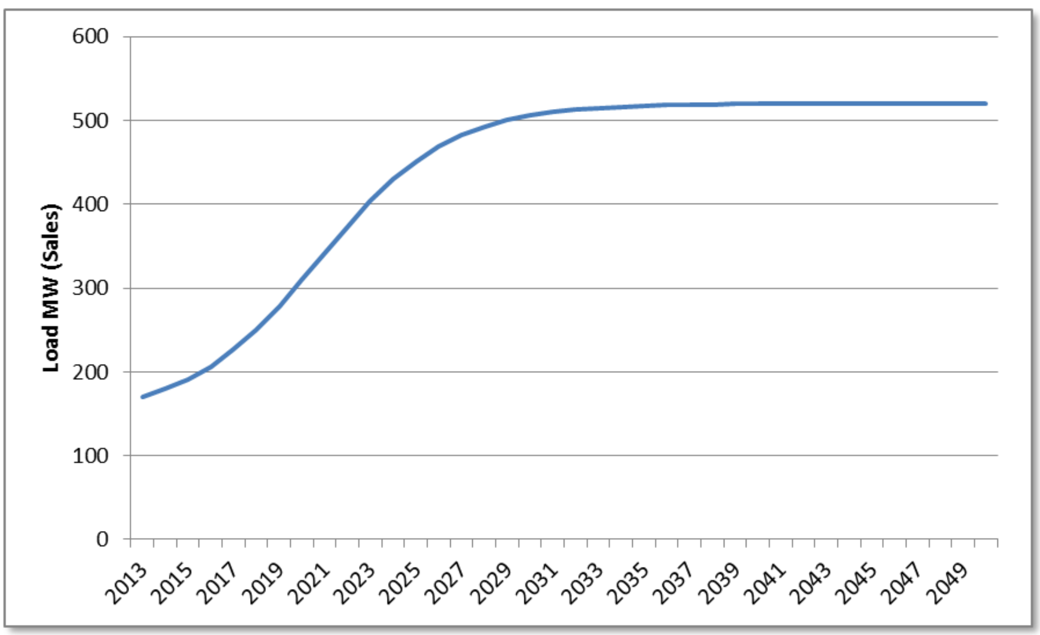


Table IV-95: Yangon Industrial Zones (status end 2012)

	MVA Substation	MW	Sq. km	Year	Yrs operation	Avge MW growth per year	Average kW per factory	Years of growth remaining	kVA per ind acre
Dagon Port	30	8.99	4.89	1997	16	0.56	88	37	68
East Dagon	25	7.08	2.7	2000	13	0.54	157	33	171
North Okkalarpa	10	4.8		1998	15	0.32	51	16	91
Shwe Lin Pan	35	12.9	8.03	2002	11	1.17	152	19	167
South Dagon	100	18.1	1.39	1994	19	0.95	7	86	211
South Okkalarpa	10	2.3	0.14	2000	13	0.18	33	44	286
Thaketa	10	2.25	0.51	1999	14	0.16	25	48	137
Hlaing Thar Yar	75	42.1	30.04	1995	18	2.34	61	14	69
Shwe Pyi Thar	55	21.2	7.35	1996	17	1.25	88	27	177
Shwe Pauk Kan	25	5.21	0.39	1998	15	0.35	21	57	263
Yangon Industrial	20	4.5	3.65	2000	13	0.35	145	45	22
Min Ga Lar Don	5	2.75	0.9	1996	17	0.16	36	14	
Pyin Ma Pin	10	2.5	2.25						
War Ta Yar	10	1.8	4.56						
Myaung Ta Gar	100	32.3	3.85						

Sources: Consultant

80. The saturation curve shown in Figure IV-94 represents an aggregated load demand curve. Saturation growth curves were developed for each IZ according to the load in 2013 and the substation capacity supplying the IZ. The individual saturation curves were summated to determine the total IZ load forecast. However this load does not represent the total heavy industrial load as industry also operates outside the IZ's.

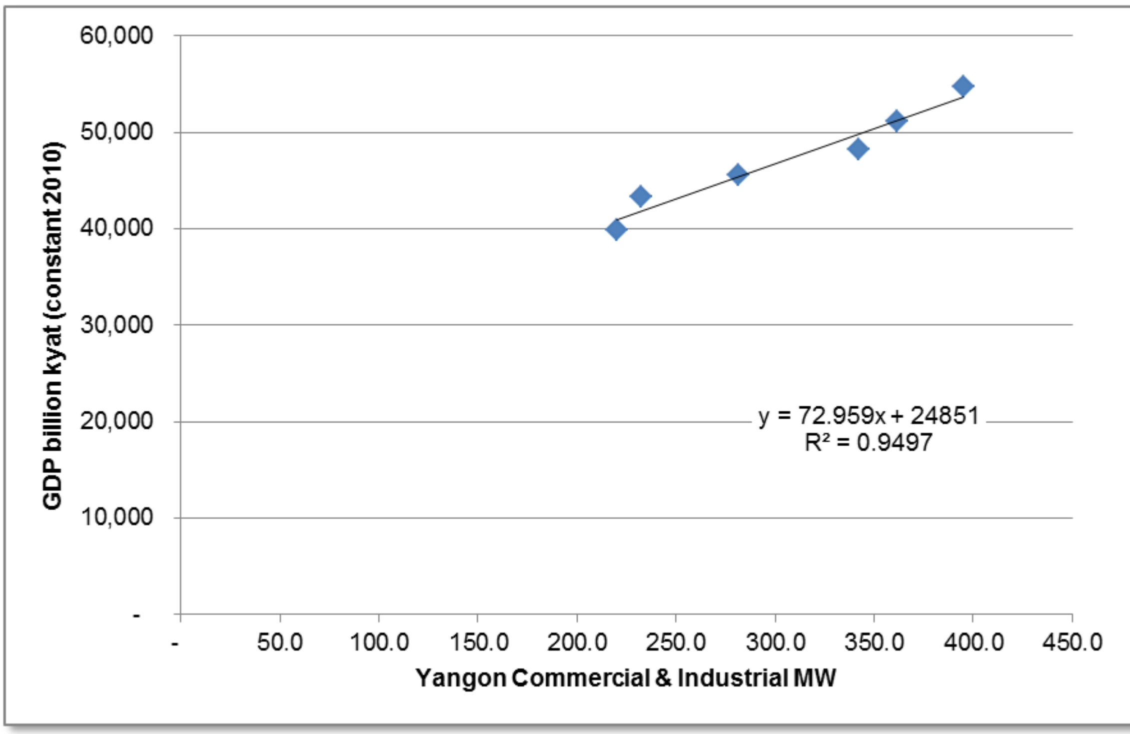
Total Demand Projection for Yangon

81. The approach used to project total demand was as follows.

1. The residential load was forecast based on customer growth and a constant kWh per customer assumption of 1 900kWh per consumer;

2. Total commercial and industrial load GWh was projected by the use of linear regression on Myanmar GDP. The load included in the regression included light and heavy industry including the load of the IZ's;

Figure IV-96: Regression – GDP versus C&I MW



82. These two energy forecasts were summed and the IZ load determined by the saturation curve method was then subtracted to determine a 'public load' forecast (in the manner that YESC reports load). Using this approach all end-use sector energy was forecasted and finally aggregated.

Project Number: TA No. 8356-MYA

FINAL REPORT
LIQUID & GASEOUS FUEL STRATEGY

Prepared for

The Asian Development Bank

and

The Myanmar Ministry of Energy

Prepared by

IES Intelligent Energy Systems

in association with

MMIC MYANMAR INTERNATIONAL CONSULTANTS

ABBREVIATIONS

ADB	–	Asian Development Bank
ASEAN	–	Association of Southeast Asian Nations
CSO	–	Central Statistics Organisation
EIA	–	U.S. Energy Information Administration
FAO	–	Food and Agriculture Organization
FAME	–	Fatty Acid Methyl Ester
GDP	–	Gross Domestic Product
GoM	–	Government of the Republic of the Union of Myanmar
LNG	–	Liquefied Natural Gas
MOE	–	Ministry of Energy
MPE	–	Myanmar Petroleum Enterprise
PRC	–	People’s Republic of China
USD	–	United States Dollar

UNITS OF MEASURE

IG	–	Imperial Gallon
km	–	Kilometre
l	–	Litre
mcm	–	Million Cubic Meters
bbl	–	Barrels
bcm	–	Billion Cubic Meters
boe	–	Barrels of Oil Equivalent
bopd	–	Barrels of Oil Per Day
mmbbl	–	Million Barrels
mtoe	–	Million tons of Oil Equivalent

CONVERSION FACTORS

1 litre	=	0.22 Imperial Gallon
1 km	=	0.62137 mile
1 barrel	=	159 litres or 35 imperial gallons
1 ha	=	2.47105 acre
1 km^2	=	100 ha

CONTENTS

I. LIQUID & GASEOUS FUEL STRATEGY

A. Introduction

1. Myanmar's economy is expected to grow at a rate of 7.1%, which will result in an increase in the demand for liquid fuels – a demand which is currently covered mainly with imported hydrocarbons. Covering the liquid fuel needs of a growing economy with imports would negatively affect Myanmar's trade balance in the future – identification of local alternatives is therefore wise. Some possibilities for initiating local production of liquid and gaseous fuels are presented in this report.

2. The Republic of the Union of Myanmar possesses large resources of natural gas. It plays a significant role in the country's energy mix: in recent years natural gas accounted for 45% of the total primary energy production. At home the natural gas was mainly used for electricity production and industrial purposes, whereas the largest part of the gas produced in Myanmar was given for export. Myanmar's proven petroleum gas reserve lies between 6 and 32 times the energy value of proven oil reserves, according to whether the Ministry of Energy or US Energy assessments are correct. Pending further discoveries of oil, it is only Myanmar's petroleum gas that can be considered to be a strategic resource – it is in demand internationally, whereas locally gas could potentially be allocated to pharmaceutical and chemical industry processes, to fertilizer production, to the production of refined petroleum products, to power production, for passenger vehicles, and as a cooking fuel as economic development takes place. In recent years the Government has considered the possibility to establish an LNG terminal to supplement indigenous natural gas supplies.

3. Biodiesel / bioethanol production in Myanmar is currently limited to only a few production facilities. Existing bioethanol facilities have more or less stopped production due to lack of subsidies and no information indicating new facilities being under construction was found. Only pilot scale biodiesel facilities have been built in Myanmar, which are producing small amounts of biodiesel for use by agricultural machinery. Approximately ten years ago Myanmar began an ambitious biofuel implementation program with a plan to plant a total of 3.5 million hectares of jatropha curcas trees. The program was unsuccessful failing to live up to the expectations of making Myanmar self-sufficient as far as the demand for diesel goes. The estimated yield of the jatropha trees planted as part of the program is not available, but considering that several reports have claimed that jatropha plantations covered an area of approximately 2 million hectares, the trees seem to have offered a significant source of non-edible oil that could be used for the production of biodiesel

B. Liquid & Gaseous Fuel Strategy

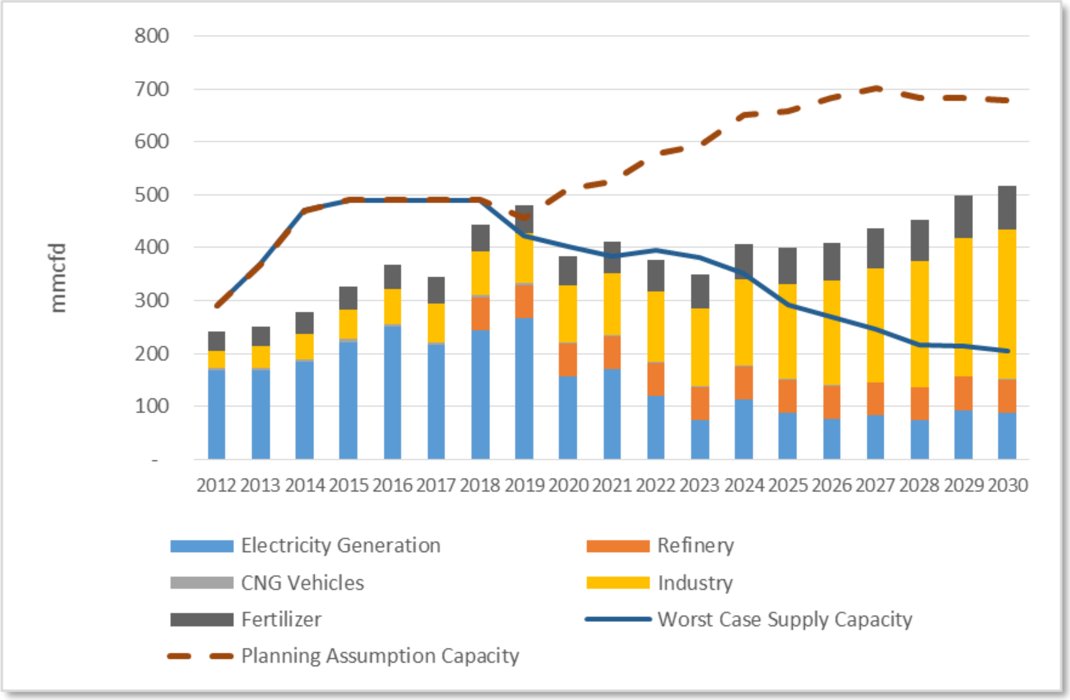
4. **Refined Oil Products.** The first step in defining the strategy for liquid fuels is to identify what should be done with the country's existing refinery capacity. Three small refineries are currently in operation in Myanmar, but all three are old and their operating efficiency is low. Even if The Myanmar Petroleum Enterprise decides to upgrade at least one of the existing refineries, the throughput will not be sufficient to cover the increasing demand; hence the strategy for liquid fuels must be based on construction of new capacity and / or by importing. For the imports there are initial plans for a new import terminal, which could at a later stage support a new local refinery. However, it is believed that a small scale coastal refinery may not be economically feasible under the competitive pressure from large, world class refineries in the Middle East, India and Southeast Asia.

5. Myanmar has the right to use 50 000 bbl/day of the transfer capacity of the Sino-Burma pipeline, which could be used as a feedstock for a potential new refinery. Locating a refinery inland, adjacent to the pipeline, could result in a competitive advantage as production would be close to consumption which would in turn reduce transportation costs.

6. Accordingly it is recommended to undertake a detailed feasibility study for a new inland oil refinery. The concept is based on the development of a small, low complexity inland oil refinery that is powered by residual heavy distillates (supplemented by a small coal-fired power plant using Myanmar coal). The strategic advantage of this approach is that a low complexity refinery does not require a supply of natural gas. The sizing of the refinery at 50,000 bpd is consistent with Myanmar's quota of Arab heavy sour oil, furthermore, the liquid fuel demand of the transport sector requires a balanced production of gasoline and diesel fuel which leads to efficient refinery operation. The economic feasibility of this proposal is largely based on the inland location of the refinery (at the pipeline) with associated low cost to transport fuel to consumers. Intangible benefits relate to the tradition of refining in Myanmar through the three existing refineries; refining provides the domestic industry sector with added depth, supporting the existence of a downstream industry. On the other hand a small refinery will no supply all of Myanmar's highly refined petroleum product needs – while the transport and industry sector needs can be satisfied, imports of diesel fuel will be required to meet the demands of agriculture up to 25% of total by 2030.

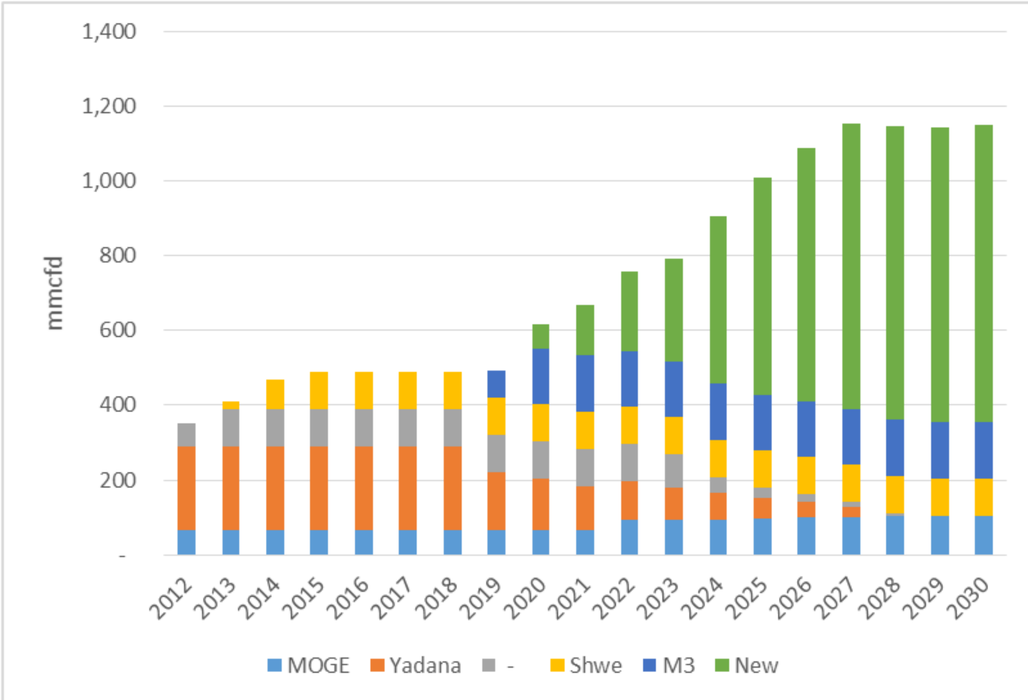
7. **Natural Gas.** The projection for gas supply – demand shows that the outlook is tight. The following supply – demand projection shows that the M3 gas field will be needed to meet demand. If there is any delay to the development of the field would result in a sustained supply shortfall from 2018.

Figure I-1: Projections for Natural Gas Supply & Demand by Sector



Source: Consultant's analysis

Figure I-2: Projection for Gas Supply (JICA 2014)



Source: JICA (2014)

8. There is an opportunity to manage the risks that natural gas supplies do not develop as anticipated. If required, fuel imports can be used to supplement the supply to the transportation and agriculture sectors to release the capacity required to serve the industry and power sectors. Nevertheless, ahead of the development of firm supplies of natural gas, it is considered as a prudent practice to minimize the use of natural gas in the power sector in favor of allocation to industry.

9. Moreover a local refinery can be designed to minimize gas consumption. Power at peak times could be provided by additional storage hydropower or gas / oil plants mainly powered by oil to conserve gas. A fertilizer plant appears to be uneconomic and gas will be saved by importing urea. An LNG terminal would deliver gas at international prices but would be expensive for Myanmar, particularly for the power sector. Moreover the development of an LNG terminal would take at least 5 years. In the recent past it was considered that the M3 field would commence operation in 2019 but recent developments in Thailand and the depressed international prices for oil and gas is expected to result in an indefinite delay. It is recommended that the development of an LNG terminal is considered in conjunction with the timing of the M3 field, and in the meantime a detailed study of industry need for gas is undertaken complete with a Willingness-to-Pay assessment to establish the viability of high-price LNG imports (and therefore the viability of an LNG terminal).

10. In summary, gas could be reserved for industry and the power sector. Other demands could be met by alternative means. The decision to pursue alternatives, such as an LNG terminal, can be decided as a matter of government policy as the natural gas supply – demand balance unfolds in the coming years.

11. **Biofuels.** In future diesel and gasoline production could be supplemented by production of biodiesel from oily plants and of bioethanol from starchy crops. Considering the large surface area

and good growing conditions in Myanmar, liquid fuels produced from renewable feedstock could play a significant role in the supply of transportation fuels.

12. Other crops could also be utilized for the production of biodiesel, but the first step recommended to be taken is to identify the current state of the planted jatropha trees and the means that are available for improving the yield from these trees. Afterwards the focus should be shifted on harvesting methods and defining how the seeds are best processed into biodiesel and whether this should be conducted in large facilities or on a community level.

13. Use of bioethanol should also be considered. Sugarcane, whether used as whole or only in the form of molasses seems to present the most cost-effective way of producing bioethanol utilizing first generation production technology. The concept of blend wall, meaning in essence that approximately 10 % bioethanol can be blended with gasoline without the need for updating the vehicle fleet is coming less important as flex-fuel vehicles, either new one or retrofits, have proved a low-cost solution to pursue consumer side interest in bioethanol fuel.

14. Both biodiesel and bioethanol seem economically feasible for Myanmar. A biofuel policy with set mixing targets for 2020 and 2030 is recommended. Assuming a 10 % target for both diesel and gasoline by 2020, and 20 % target by 2030, transport de-carbonisation case can be developed. Alternative scenarios are discussed in this report, namely a base case, a small inland refinery case, and domestic biofuel case, and their impacts to the supply side of liquid fuels until 2030 in Myanmar.

II. PETROLEUM FUELS

C. Introduction

15. Myanmar's liquid fuel production capacity is insufficient for satisfying the growing demand for liquid fuels in the transportation sector. However, increased dependence on imported petroleum products poses a risk to national fuel security and is a burden on the nation's trade balance.

16. The expansion of a local refinery has been under consideration of the government. The cost and benefits of such an expansion are discussed in detail. The possibility to supplement the current oil based liquid fuel system with biodiesel and bioethanol to satisfy transport demands is also discussed. However, the demand for liquid fuels outside of the transport and industry sectors is not considered. The agriculture sector demand for diesel is expected to grow, to support farm mechanization, but this demand is relatively uncertain compared to that of the transport and industry sectors. Again, biodiesel and bioethanol could be attractive alternatives to petroleum products for agriculture, due to the close proximity of the feedstock, otherwise the agriculture sector could be supplied by imported fuels until the trend towards agricultural mechanization is better established.

17. A concept for increasing Myanmar's oil refining capacity is introduced. The concept is based on a relatively small inland refinery with feedstock sourced from the Sino-Burma pipeline. The expected competitive advantage of the refinery against some of the large scale refineries located at Southeast Asia lies in its inland location, which minimizes the costs related to transportation of the refined products to the local inland market. The size of the refinery is dictated by the quota of 50 000 barrels per day (bbl/day) Myanmar has for the Sino-Burma pipeline. The concept of an inland refinery based on crude in the Sino-Burma pipeline has been criticized for its choice of crude, which is ultimately determined by the Chinese off-taker. Local crude is of different quality, and can be

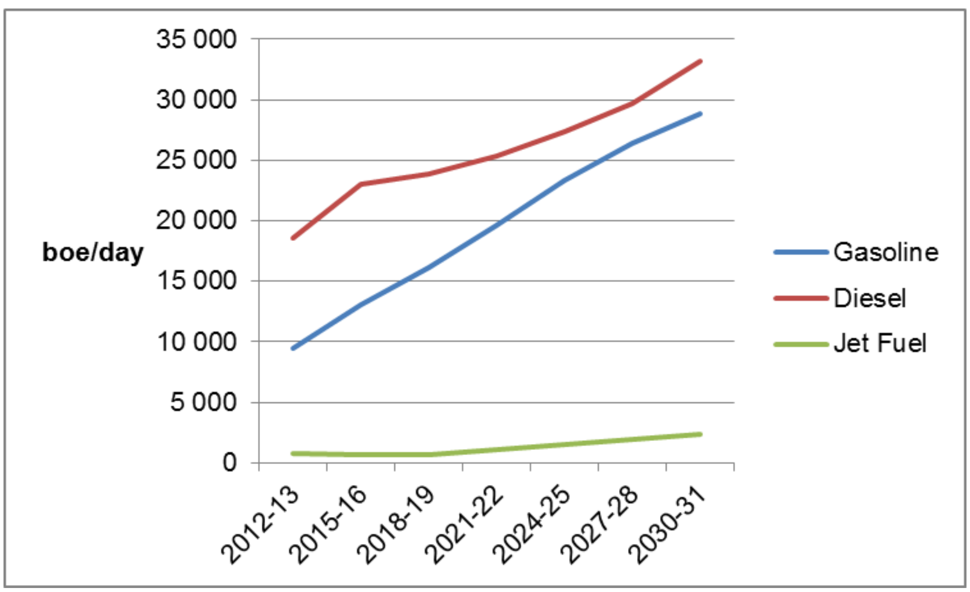
utilized only partly in the contemplated concept. Therefore, an alternative idea of having crude receiving terminal at the coastal area of Myanmar, and a possible local refinery at a later stage attached to it, which would be able to process a mixture of imported and domestically sourced crude oil. Whilst an import terminal may be needed for Myanmar's continuing need to import petroleum products, it is believed that it would be difficult for a finery of relatively modest capacity in international standards to find competitive advantage against new Middle Eastern, Indian and Southeast Asian refineries, many of which represent large scale, cost competitive refinery concepts and latest technology, but there could be a clear location based advantage for an inland refinery, which, however, needs to be proven by thorough feasibility analysis.

Table II-1: Myanmar Petroleum Fuel Sales Projection (in boe/day)

Fuel	2012-13	2015-16	2018-19	2021-22	2024-25	2027-28	2030-31
Gasoline	9 424	13 042	16 129	19 648	23 298	26 394	28 877
Diesel	18 580	22 980	23 900	25 379	27 406	29 684	33 148
Jet Fuel	744	689	692	1 108	1 523	1 938	2 353
Total	28 748	36 711	40 721	46 135	52 227	58 016	64 378

18. Information presented in Table II-1 is also presented in Figure II-2 to highlight the expected increase in demand for liquid fuels in Myanmar.

Figure II-2: Demand of Petroleum Fuels in Myanmar



19. Considering that the combined demand for diesel and gasoline in Myanmar is currently about 30 000 bbl/day (not including illegal imports), and that only the Thanbyakan refinery is capable of producing diesel and gasoline at 10 000 bbl combined per day, without a significant increase in

local refining capacity Myanmar will become increasingly dependent on imported petroleum products with attendant fuel security concerns.

20. So as to further elaborate the issues surrounding fuel security, the Consultant has developed a new oil refinery concept for Myanmar, the merits of which concept, however, need to be analysed by a more comprehensive feasibility analysis. The concept is discussed in the following sections.

21. **Options for Oil Refinery Investment.** Three options have been identified for development of the oil refinery sector in Myanmar. The identified options are:-

1. To invest in a small inland refinery by the Sino-Burma pipeline to cover the growing need for transportation fuels at the inland market;
2. To invest in a medium sized refinery to cover the need for transportation fuels in the whole country;
3. To invest in oil refining sector and build a globally competitive oil refinery producing high quality liquid transportation fuels to cover the domestic demand and to be exported to the Asia Pacific petroleum product markets.

22. **Small Size Refinery.** Out of the three identified alternatives, the first one seems most attractive. It could be realized by lowest capital investment and its inland location would offer competitive advantage as both the feedstock from the Sino-Burma pipeline as well as the target market would be in the close proximity of the refinery. A small refinery size would also fit well with Myanmar's quota of 50 000 bbl/day from the Sino-Burma pipeline.

23. **Middle and Large Size Refinery.** Due to Myanmar's limited oil quota (50 000 bbl/day) to the Sino-Burma oil pipeline, middle or large size refinery cannot be considered to be built inland. A coastal refinery would not have the advantage of being in the middle of the country where there is direct access to the transportation fuel market of Myanmar's second largest city Mandalay. Middle and large size refineries would need significant quantities of natural gas for cracking of heavy distillates as the demands for refinery residues and heavy products are not expected to experience large scale growth. As the availability of natural gas is unclear, building a middle or large sized refinery might require constructing an unloading terminal for liquefied natural gas (LNG). An LNG terminal would not only significantly increase the investment cost but due to the high LNG price at the Asia Pacific market, it would also increase the refinery's operating costs remarkably. A middle size refinery could be an attractive proposition in the event that domestic natural gas production was to grow, or other sources of natural gas could be secured below the market price for LNG. However, according to what is known at the present time, both middle and large size refineries appear to be unattractive under the current circumstances; therefore this report only develops the option of investing in a small scale refinery.

D. Investment in a Small Size Refinery

24. A small size refinery would enjoy a competitive advantage against refineries located in neighbouring countries, such as the new Paradip Refinery in India. The advantage would be gained in the lower transportation cost of both the feedstock and of the refined products to consumers More than half of Myanmar's population lives in landlocked states and regions and of the 12 major cities only four – Sittwe, Yangon, Pathein and Mawlamyaing – have direct access to or are located very close to the sea (see Table II-3 and Figure II-4). If transportation fuels were also in future mostly imported e.g. from the Paradip Refinery, it would be necessary to unload fuel at the major port cities, then to transport by road, river barge or by rail to the landlocked regions and cities.

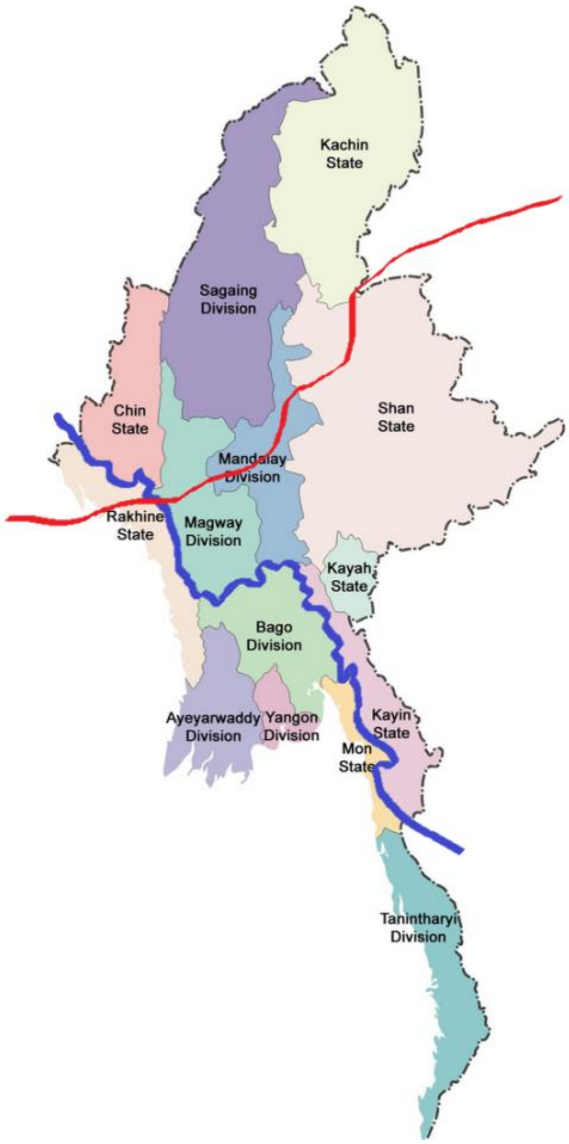
25. The refinery would mostly use the Arab Heavy Blend (Heavy, Sour) available from the Sino-Burma pipeline as a feedstock, supplemented by small quantities of the local heavy sweet crude sourced from local onshore oil fields. Freight costs and quality differences between the condensate produced at the offshore oil and gas fields and the Arab Heavy Blend suggest that it could be more cost-effective to export the condensate to neighbouring coastal refineries than transporting it to a domestic inland refinery.

26. The sea freight cost for supplying the fuel from Paradip Refinery to coastal cities like Sittwe and Yangon would be approximately 1.5 – 2.5 $ per barrel. Furthermore, the freight cost for transporting the fuel from Sittwe e.g. to Mandalay Region would add another 2.5 – 3.5 $ per barrel. If production is located in close proximity to consumption, a significant competitive advantage would be gained according to reduced freight costs. Another item that must be considered is the economy of scale. A large refinery such as Paradip (300 000 bbl/day) benefits from reduced operating costs. The difference in operating costs between a large scale and a small scale refinery is around 1 – 2 $ per barrel depending on the complexity of the smaller refinery.

Table II-3: Population Spread in Myanmar

Name	Location	Landlocked	Population
Ayerwaddy Region	Lower	No	6,663,000
Bago Region	Lower	No	5,099,000
Chin State	West	Yes	480,000
Kachin State	North	Yes	1,270,000
Kayah State	East	Yes	259,000
Kayin State	South	Yes	1,431,377
Magway Region	Central	Yes	4,464,000
Mandalay Region	Central	Yes	7,627,000
Mon State	South	No	2,466,000
Rakhine State	West	No	2,744,000
Shan State	East	Yes	4,851,000
Sagaing Region	North	Yes	5,300,000
Tanintharyi Region	South	No	1,356,000
Yangon Region	Lower	No	5,560,000
Naypyidaw Union Territory	Central	Yes	925,000
		Total	**50,495,377**
		Landlocked Regions	**26,607,377**

Figure II-4: The Sino-Burma Pipeline[1]



27. Three different scenarios for the estimated freight costs are shown in Table II-5. The scenarios are chosen based on the distance of the demand from the inland refinery (short, medium and long distance). As can be seen from Table II-5, a small inland refinery would face serious competition when it comes to the transportation fuel market of Myanmar's coastal cities. Yangon International Airport would for example most likely continue to import jet fuel even in the case a small domestic refinery was built.

28. Note that the freight cost of crude oil from the Middle East to the deep water port at Kyaukpyu

[1] Landlocked and coastal regions are indicated with a purple colour, the approximate location of the Sino-Burma pipeline with red.

were not taken into account in calculations presented in Table II-5; it was assumed that the freight cost of crude oil would be approximately the same to all refineries in neighbour countries.

Table II-5: Freight Cost Comparison[2]

All figures in $ per boe	Average Distribution Cost of Transportation Fuels to Inland Consumers			Average Distribution Cost of Transportation Fuels to Consumers at Coastal Regions			Pipeline Transportation Cost of Crude Oil in Myanmar
	Truck & Rail	**Sea**	**Total**	**Truck & Rail**	**Sea**	**Total**	**Total**
Large Neighboring Coastal Refinery	$2.50	$1.50	$4.00	$1.00	$1.50	$2.50	$0.00
	$3.25	$2.00	$5.25	$1.75	$2.00	$3.75	$0.00
	$4.00	$2.50	$6.50	$2.50	$2.50	$5.00	$0.00
Small Domestic Refinery in Mandalay	$1.00	$0.00	$1.00	$2.50	$0.00	$2.50	$0.30
	$1.75	$0.00	$1.75	$3.25	$0.00	$3.25	$0.60
	$2.50	$0.00	$2.50	$4.00	$0.00	$4.00	$0.90
Distribution Cost Difference	**To Inland Consumers**			**To Consumers at Coastal Cities**			
	$2.70			-$0.30			
	$2.90			-$0.10			
	$3.10			$0.10			

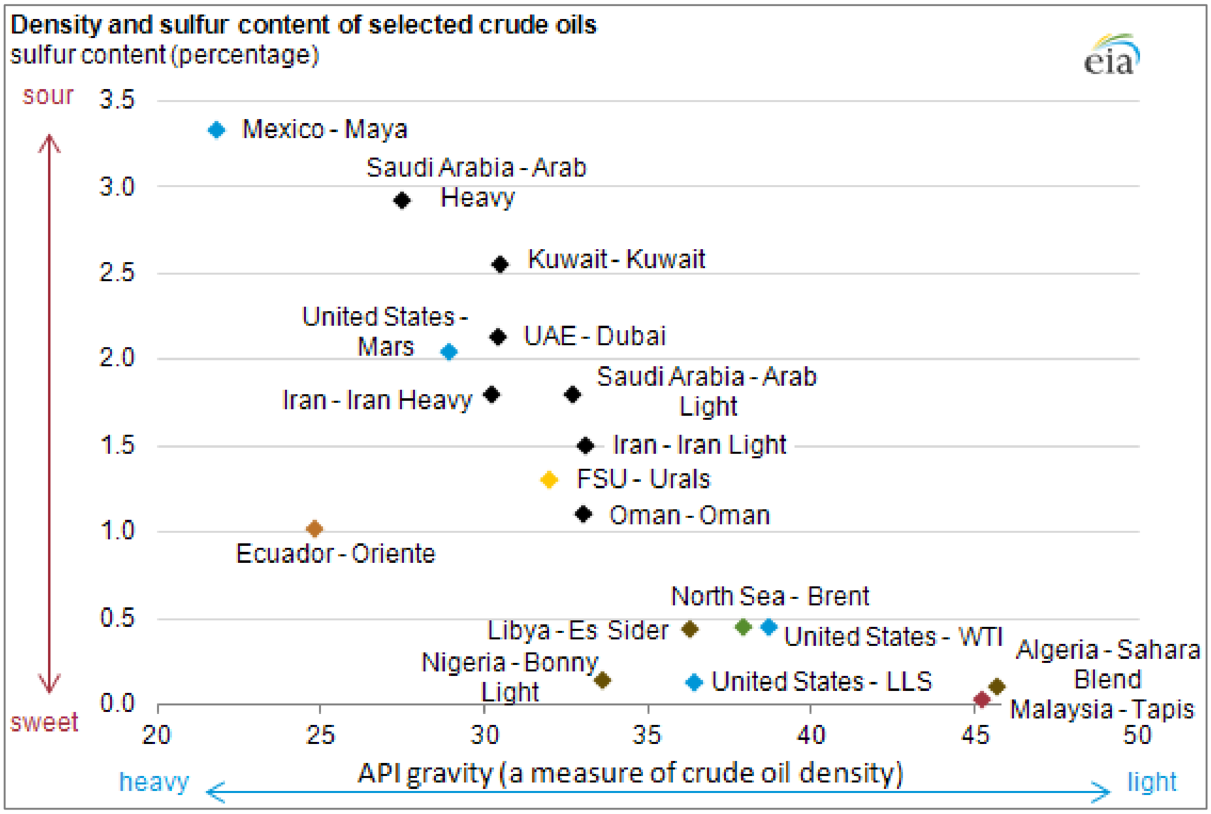
29. According to Table II-5, a small domestic inland refinery would have a clear freight cost advantage against its competitors in Myanmar's inland transportation fuel markets. Based on the population spread presented in Table II-3, inland transport fuel sales can be assumed to account for approximately 60 % of the total sales. According to the demand prognosis (Table II-1) Myanmar's total gasoline, diesel and jet fuel consumption in 2030 would be around 81 000 boe/day and assuming that consumption would increase evenly in inland and coastal regions, the total inland consumption in 2030 would be 48 500 boe/day.

[2] The table presents three cases: best, average and worse depending on the distance between the inland refinery and the point of demand – the reduction in revenue in pipeline tariff is assumed to be $0.3 for the best case and $0.9 for the worst case.

30. One of the main uncertainties of the presented small inland refinery business case is the tariff revenue that Myanmar gets for transporting oil to the People's Republic of China (PRC) along the Sino-Burma pipeline. In the calculation presented in Table II-5 it was presumed that PRC pays Myanmar a transportation fee for each barrel they receive and that the operating margin Myanmar receives for oil transportation would be 0.3 $, 0.6 $ or 0.9 $ per barrel. The pipeline transportation tariff rate could have a major impact on the profitability of the refinery since oil used at the refinery would reduce the income from oil transport to PRC.

31. In addition to the competitive advantage that an inland refinery could have against other refineries it is important to understand the total refinery margin. Refine margin is the difference in total price of the products that a refinery sells minus the price of the feedstock. The total operating margin per barrel is calculated by deducting the operational costs from the refining margin. In general a more complex refinery has a higher refining margin and a higher investment cost. More complex refineries are capable of using cheaper heavier oil blends with higher sulphur content whereas simpler refineries have to buy lighter oil blends with lower sulphur content. The most common crude oil blends and their characteristics are shown in the Figure II-6.

Figure II-6: Characteristics of Crude Oil Blend



Source: EIA (2014)

32. There are numerous variations for how the oil refining process could be designed. Each oil refining process has different functions and yield profiles which directly affect the refining and operating margins. One way of simplifying numerous different oil refinery processes is to sort them into four generalized categories according to their process complexity as presented in Table II-7.

Table II-7: Generalized Process Complexity Categories

Process Complexity	Category	Feedstock
High	Deep Conversion	Heavy Sour
Intermediate	Hydrocracking	Heavy Sour
Elementary	Catalytic Cracking	70 % Light, Sweet & 30 % Heavy, Sweet
Low	Hydro-skimming, Topping	Light, Sweet

33. Since the goal is to achieve maximum production of high quality transportation fuels, and the main feedstock is assumed to be heavy and sour (Arab Heavy) from the Sino-Burma pipeline, for a satisfactory refining margin to be achieved a small inland refinery must have intermediate or high process complexity. A hydrocracking refinery using heavy and sour feedstock produces significantly more middle distillates (diesel and jet fuel) than a catalytic cracking refinery.

34. An example of the product slate received from different refinery configurations is shown in Table II-8. It should be emphasized that today's modern hydrocracking and deep conversion refineries are relatively flexible giving the refiners control over the proportion of middle and light distillates that are produced. In Table II-9, the differences in the product slate are converted into sales according to the average market prices at New York and Rotterdam between October 1, 2013 and September 30, 2014. It can be seen that with crude prices of the same period exceeding 100 $/bbl hydro-skimming and catalytic cracking type of refineries are not feasible, and many of such types have not been developed anymore except under special circumstances.

35. It has to be noted that the prices of the residue and heavy products have significant differences depending on their location. Furthermore, the refinery configurations given in Table II-8 and Table II-9 have been generalized and the exact product slate in the residue and heavy products category is also depended on the exact production line configuration of the refinery within the given generalized refinery configurations. For example a deep conversion refinery can have a fluid coking unit that, as a residue, produces low energy content gas that cannot be sold outside the refinery but can easily be burned in process furnaces. Alternatively a refinery can have a delayed coking unit that produces coal-like petroleum coke as a residue that can either be sold or used in a circulated fluidized bed boiler for refinery's steam and electricity production.

Table II-8: Examples of the Product Slates by Refinery Configuration

Product	Hydro skimming	Catalytic Cracking	Hydrocracking	Deep Conversion
Gases (Propane, Butane etc.)	3 %	2 %	2 %	2 %
Light Distillates	14 %	32 %	18 %	18 %
Middle Distillates	29 %	27 %	58 %	65 %
Heavy Products	27 %	19 %	14 %	11 %
Residue	27 %	18 %	8 %	4 %

Table II-9: Example of Oil Product Sales by Refinery Configuration

(USD per refiner barrel)

Product	Hydro skimming	Catalytic Cracking	Hydrocracking	Deep Conversion
Gases (Propane, Butane etc.)	$1.39	$0.92	$0.92	$0.92
Light Distillates	$16.35	$37.37	$21.02	$21.02
Middle Distillates	$35.57	$33.12	$71.14	$79.72
Heavy Products	$19.74	$13.89	$10.23	$8.04
Residue	$12.29	$8.19	$3.64	$1.82
Total Price per Barrel of Oil	**$85.33**	**$93.49**	**$106.96**	**$111.53**

36. An oil refinery consumes a significant amount of energy in process furnaces and in form of steam and electricity. In addition to energy consumption, a hydrocracking process requires also significant quantities of hydrogen. The lack of natural gas for domestic consumption in Myanmar means that the refinery's energy supply and production configuration cannot be standard, as natural gas is often the main source for steam and electricity generation and in most cases it is also the most important source of the hydrogen used by the hydrocracking unit. For the small inland refinery, the energy supply could be based on a combination of coal, refinery residue and petroleum coke from the delayed coking unit. The investment cost of a combined heat and power plant burning solid fuel with a high sulphur content, would be significantly higher than the cost to build an ordinary combined cycle gas turbine power plant, but the power plant investment could be made in co-operation with a local power generation company and the power plant could in addition to the refinery's energy needs also generate electricity to the national power grid.

37. For a hydrocracking unit with capacity between 15,000 and 20,000 barrels per day about 45,000 – 60,000 cubic meters of natural gas per day would be needed for hydrogen production. The exact amount of natural gas consumption depends on the feedstock and the desired product slate.

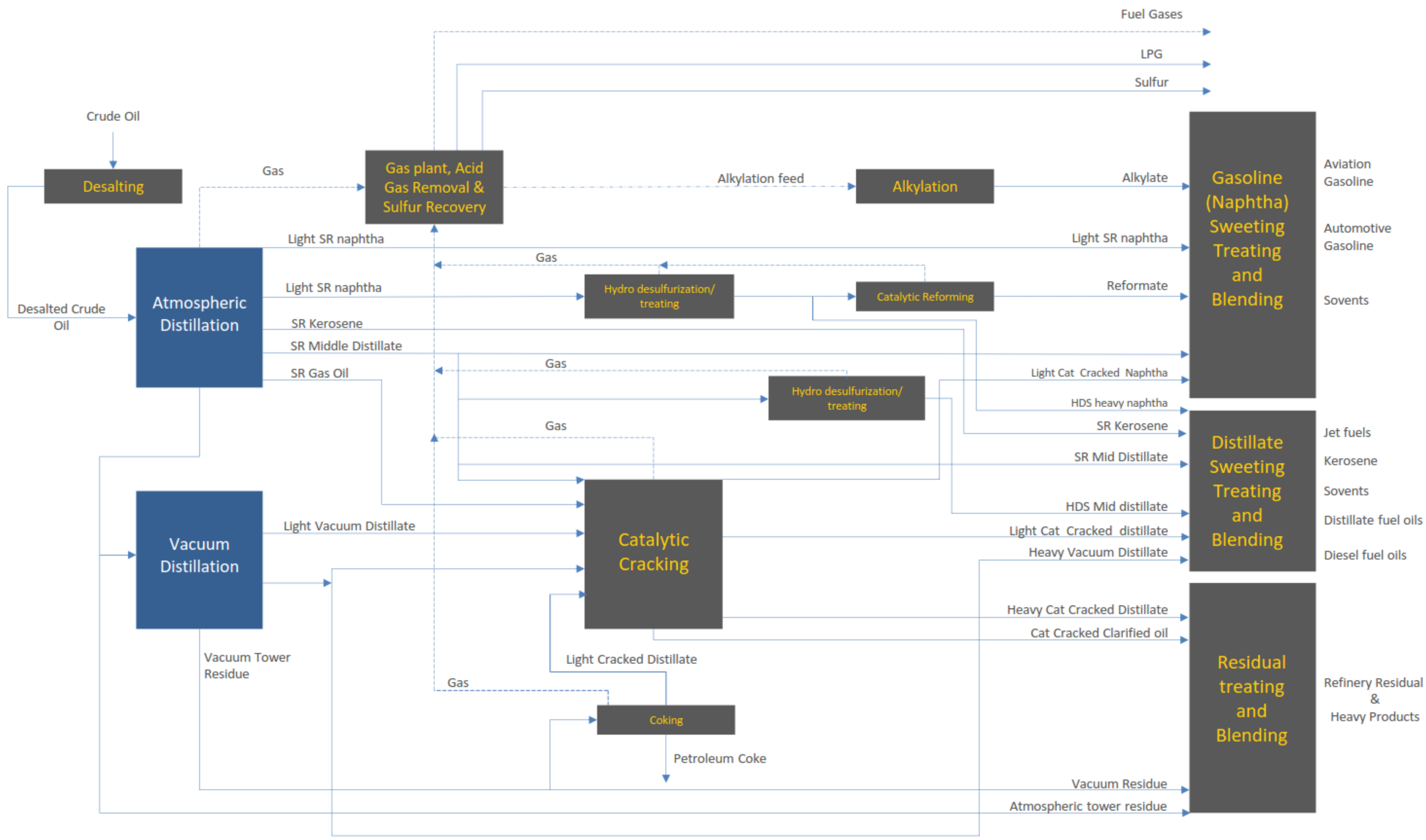
Production of light distillates such as gasoline requires more hydrogen than the production of middle distillates such as jet fuel, diesel and heating oil. Since it is unlikely that there is enough natural gas for a hydrocracking unit, the ideal configuration of a small inland refinery could be based on a catalytic cracking design with a delayed coking or vis-breaking unit. In principle this configuration could operate without any natural gas, instead steam and electricity could be produced by using the refinery residues, coal and petroleum coke. A refinery with catalytic cracking and delayed coking configuration (no hydrocracking) would produce more low value refinery residue and heavy products but the deficit in natural gas supply means that the demand for the refinery residue and heavy products would be stable.

38. An example of the potential production capacity of a refinery designed to use Arab heavy sour oil, is presented in Table II-10. A process schematic of the envisaged refinery is given as Figure II-11.

Table II-10: Refinery Process Capacity

Production Unit	Capacity (bbl/day)
Atmospheric Distillation	50 000 – 60 000
Vacuum Distillation	20 000 – 25 000
Delayed Coker or Visbreaker	8 000 – 9 000
Fluid Catalytic Cracker	20 000 – 25 000
Naphtha Hydrotreater	10 000 – 14 000
Catalytic Reformer	10 000 – 14 000
Kero/Jet Reformer	4 000 – 5 000
Diesel Hydrotreater	10 000 – 12 000
Alkylation Unit	5 500 – 7 000
Isomerizer	8 000 – 10 000

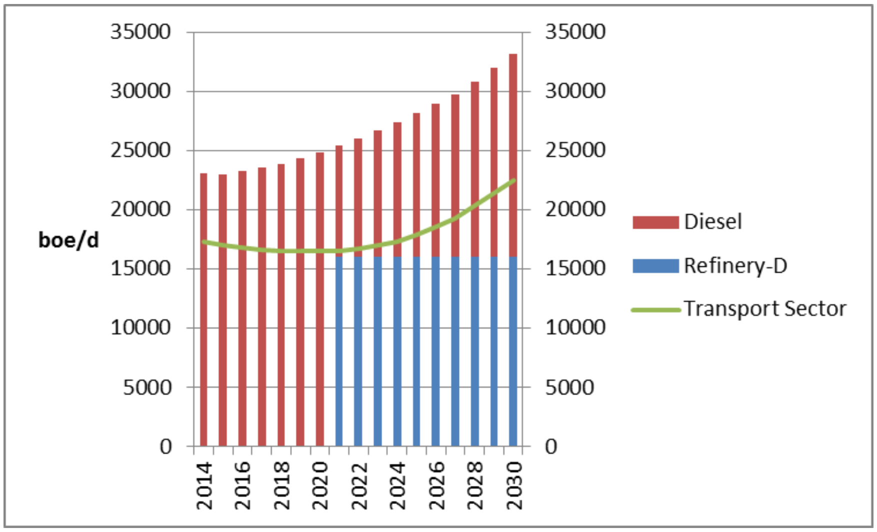
Figure II-11: Schematic of Concept Refinery Process



39. Due to the high share of residue and heavy products produced by a catalytic cracking refinery, the optimal throughput capacity could be more than 50 000 barrels per day. A feedstock capacity of 50 000 barrels per day would yield approximately 35 000 boe per day in transportation fuels even if in addition to the catalytic cracking unit a delayed coking or vis-breaking unit were to be added. Additionally, refinery downtime would reduce the total yield by 8 – 10 % which means that the total transportation fuel output would be about 20 % lower than the predicted inland consumption in 2030 (40 500 boe per day). However, due to the relatively low refinery complexity and the possibility for outsourcing the steam and electricity production, the total investment cost of the small inland refinery with catalytic cracking and delayed coking or vis-breaking could be under 1 200 million US dollars even if the feedstock capacity were to be slightly increased.

40. Figure II-12 and Figure II-13 present the total production of diesel and gasoline compared to the estimated demand (as presented in Table II-3). The demand presented is the estimated total demand, so it can be assumed that part of the local production deficit will be balanced by imports especially to the coastal regions. Figure II-12 shows the diesel demand of the transport sector by a green line. As all of the gasoline demand is for transport sector, one can observe from the graphs that the conceptual 50 000 bbl/d refinery would cover most of domestic transport sector fuel demand. If liquid biofuels were to be introduced to the supply portfolio, Myanmar could achieve almost full fuel independence for at least the first years of refinery operation.

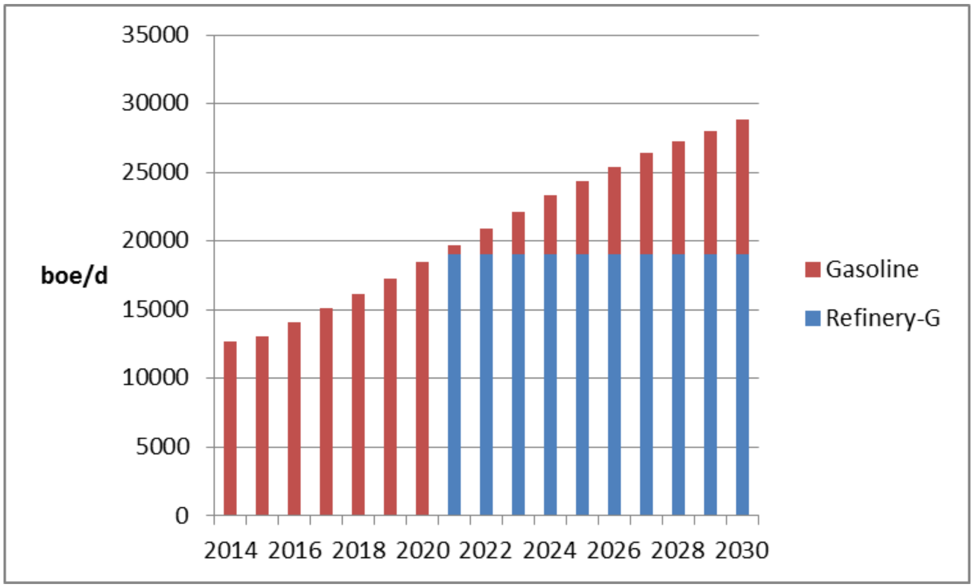
Figure II-12: Estimated Diesel Demand & Production



Source: Consultant's analysis

41. In the future, once the technologies for producing renewable transportation fuels in the form of biodiesel and bioethanol become more advanced and therefore more cost competitive, the production of the new refinery can be supplemented with a construction of both biodiesel as well as bioethanol production facilities to further improve Myanmar's supply security. The size of the facilities producing renewable transportation fuels should be determined, once the final configuration of the small refinery is known. Considering the current demand forecasts, there seems to be a larger need for a facility producing bioethanol that could be blended with gasoline to reduce the supply deficit. It would be wise to locate the possible biodiesel and bioethanol production facilities closer to coastal regions to achieve a good nationwide balance between supply and demand. Biodiesel and bioethanol are discussed in more detail in Section VII.

Figure II-13: Estimated Gasoline Demand & Production



Source: Consultant's analysis

42. **Feasibility of the Small Inland Refinery.** The feasibility of an investment in a small inland refinery is mainly dependent on the heavy product consumption and energy supply of the envisaged inland refinery, as well as future investments in oil refineries in neighboring countries. Even though the small inland refinery will benefit from lower freight costs and from the relatively low price of the Arab Heavy Blend oil, the refinery complexity will remain moderate until a cost effective natural gas supply can be made available. Energy supply (steam and electricity) often accounts up to 40 % of the refinery's operating expenses and so the cost of the energy supply largely determines the net benefits case.

43. The most effective way to organize the energy supply of the refinery would be a large scale power plant based on circulated fluidized bed boiler that would be able to utilize refinery residues and coal and, in addition to supplying energy to the refinery, could sell electricity to the grid.

44. Feasibility is also affected by the development of competition from the refineries producing in neighbouring countries and willing to sell to Myanmar. This risk appears to be small. Apart from the Paradip Refinery in India, which is expected to start operation in 2015, there are no new large scale refineries under construction. It is anticipated that the Paradip Refinery's production will be mostly sold at the Indian domestic transportation fuel market.

E. Conclusion

45. Myanmar's economy is expected to grow at a rate of 7.1%, which will result in an increase in the demand for liquid fuels – a demand which is currently covered mainly with imported hydrocarbons. Covering the liquid fuel needs of the growing economy with imports would negatively affect Myanmar's trade balance in the future – identification of local alternatives is therefore wise. Some possibilities for initiating local production of both fossil and renewable based liquid fuels were presented in this report.

46. The first step in defining the strategy for liquid fuels is to identify what should be done with the

country's existing refinery capacity. Three small refineries are currently in operation in Myanmar, but all three are old and their operating efficiency is low. Even if The Myanmar Petroleum Enterprise decides to upgrade at least one of the existing refineries, the throughput will not be sufficient to cover the increasing demand; hence the strategy for liquid fuels must be based on construction of new capacity and / or by importing. For the imports there are initial plans for a new import terminal, which could at a later stage support a new local refinery. However, it is believed that a small scale coastal refinery may not be economically feasible under the competitive pressure from large, world class refineries in the Middle East, India and Southeast Asia.

47. Myanmar has the right to use 50 000 bbl/day of the transfer capacity of the Sino-Burma pipeline, which could be used as a feedstock for a potential new refinery. Locating the refinery inland, adjacent to the pipeline, could result in a competitive advantage as production would be close to consumption which would in turn reduce transportation costs. According it is recommended to undertake a detailed feasibility study for a new refinery.

III. NATURAL GAS

F. Introduction

48. Myanmar's natural gas is in demand internationally whereas locally, Myanmar's natural gas could potentially be allocated to fertilizer production, as a fuel for the production of refined petroleum products, to industry, to the power sector. LPG could also be produced and used as a cooking fuel.

49. At the present time Myanmar's proven reserves of gas are insufficient to meet the projected demands of all sectors of the economy. Given the relationship between GDP growth and natural gas supply, it is considered that Myanmar's natural gas should be allocated to export, to fertilizer production and to industry.

G. Power Sector Consumption

50. There is a role for gas in power generation, potentially supplemented by liquid fuels. The existing (and under construction/development) capacity for gas based power will be about 1 700 MW within a few years, which would consume over 200 MMCFD when simultaneously in operation. Given the relative uncertainty surrounding hydropower development with storage capacity, as reserve capacity needs increase to 2030, and if gas would be used to meet this capacity need, then total gas consumption could reach as high as 1 000 MMCFD. This requirement for gas may not be able to be met through a future domestic gas quota but could instead be met by imported LNG or by light fuel oils. However, the cost of LNG exceeds 18 $/MMBtu and this means that LNG would be a very expensive solution for power generation. In principle however, power generation could comprise a gas plant capacity of less than 10% in 2030 if light fuel oil was used to fuel fast-acting reserve capacity plant. In this case, the total annual gas consumption by the power sector would be very modest; in 2020 only 18 BCF and in 2030 only 31 BCF. When the existing gas contracts governing domestic quotas expire it may be feasible to negotiate for a higher quota, or new gas fields may be discovered, but in the meantime, it is considered prudent to plan the expansion of the power sector to minimize the consumption of gas to ensure that industry needs are met.

H. Refinery

51. A 50 000 bblpd hydro-cracking refinery would require around 10 000 MMCF of natural gas to produce hydrogen and to power the refinery. This gas requirement can be much reduced by using an alternative refinery design that does not require hydrogen, and one that is powered using heavy distillates.

52. The oil supplied to the refinery will have fractions that are gaseous (condensates) and gas will be produced, some of which can be used for power production and some which can be sold to consumers for profit. Table III-1 provides an estimate of the quantities of refined oil products that would be produced by a vis-breaking 50 000 bblpd refinery, expressed in energy terms. Table III-2 provides an estimate of the gas and residue fuels that could be used to power a vis-breaking refinery, along with the residual quantities that could be sold to consumers. The residues are of sufficient quantity to power a 100 MW power plant; the residues could be stored and called upon to power reserve gas / oil plant, or the refinery power plant could be over-sized and the additional 100 MW capacity could be used to supply consumers living in the vicinity of the refinery.

Table III-1: Energy Content of Refined Oil Products (50 000 bbld)

Product	Share	Thermal Value	Total Energy Content (MJ/Day)
Gases	2%	50	6,439,500
Light Distillates	37%	46	110,308,635
Middle Distillates	29%	42	79,180,092
Heavy Products	17%	37	40,723,398
Residue	15%	35	33,807,375
		Total	270,459,000

Table III-2: Vis-breaking Refinery Power Production

Fuel	Used for Energy Production (MJ/Day)	Sold to Consumers (MJ/Day)	Used for Energy Production (barrels per day)	Sold to Consumers (barrels per day)
Gas	3,219,750	3,219,750	450	450
Residue	7,511,130	26,296,245	1,250	4,375

I. Fertilizer

53. As discussed in the Agriculture Sector demand report, the use of fertilizer in Myanmar has fallen to around 10 kg per hectare. Agricultural experts Naing and Kingsbury found that a fertilizer load of 80 kg per hectare produced significantly increased yields of all major crops including rice.

54. A standard production run for a modern fertilizer plant is 1 725 metric tons per day. This equates to around 600 000 tons of fertilizer per annum. Myanmar has around 17 million hectares which means that the standard production run output would provide for around 35 kg per hectare. For the purpose of evaluation of the economics of a standard fertilizer plant, a urea production equivalent to 35 kg per hectare has been assumed. A 70 – 80 kg per hectare production could be achieved with two standard run fertilizer plants, each located in the north and south of the country.

55. Table III-3 presents an outline calculation for a standard run fertilizer plant. The plant would produce 1 000 mt of ammonia per day before adding water for conversion to 1 725 mt of urea. The natural gas requirement would be 31 mmcfd or 10 200 mmcf per annum. The investment cost would be $ 1.2 billion.

Table III-3: Conceptual Fertilizer Plant (Ammonia / Urea)

	Plant Capacity
	1 725 mtpd
Urea	595 000 t/a
Gas	10 200 mmcf/a
Investment Cost	1 200 MUSD
O&M	2.5% of capital cost

56. An economic evaluation has been conducted with the objective of determining the price of natural gas that would result in a competitive cost for locally-produced urea. The economic discounting rate (real) has been assumed as 6 % and the life of the fertilizer plant as 20 years.

57. The economic evaluation shows that the price of natural gas would need to be set at no more than $ 6 per MMBtu if a local fertilizer plant was to be cost competitive against an international price for urea of around $ 350 per mt. The gas price appears to be too low if an economic value of $ 18 per MMBtu is considered as an opportunity cost, or if the government's current subsidized price of $ 11.2 per MMBtu is considered. Therefore it is assumed that fertilizer would be imported rather than manufactured locally.

J. Industry, Commercial, Household Sector

58. Industry uses natural gas for processes that require fine control of heat, e.g. petrochemical production. The commercial sector uses LPG for cooking, primarily in restaurants. There is also production required for household use for cooking. LPG is being imported and could continue to be imported while natural gas is in short supply and demanded by industry.

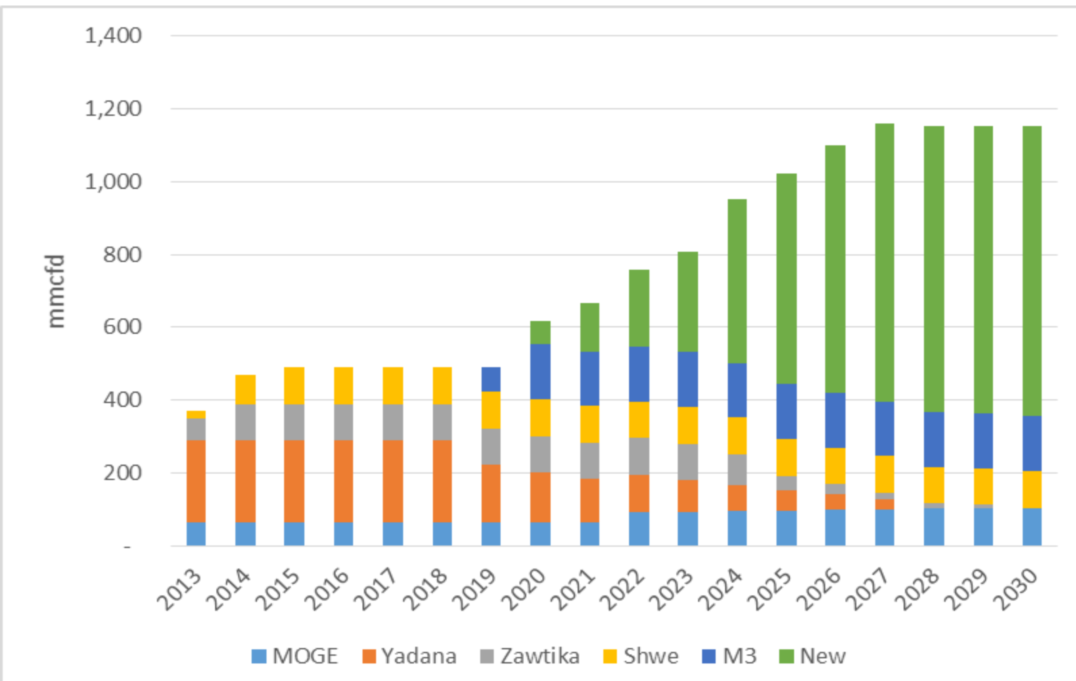
K. Natural Gas Supply – Demand Balance

59. The natural gas supply-demand balance takes into account the estimated production of the operation gas fields, based on domestic needs, and known and likely development of new gas fields.

60. The Aung Thein Kha (M3) field has been planned to start production in 2019. However, in early 2015, the new Thai government indicated that Thailand's dependence on Myanmar for natural gas has reached a comfortable limit and further purchases may not be in Thailand's strategic interest. This announcement, coupled with depressed international prices for oil and gas, has led to public announcements by PTT Thailand that the development of the M3 field may be indefinitely delayed. The production of other new fields are speculative, e.g. the announced find of an Indian company in Block A6 (Phyithar discovery) was not accompanied by an estimate for the commencement operation date.

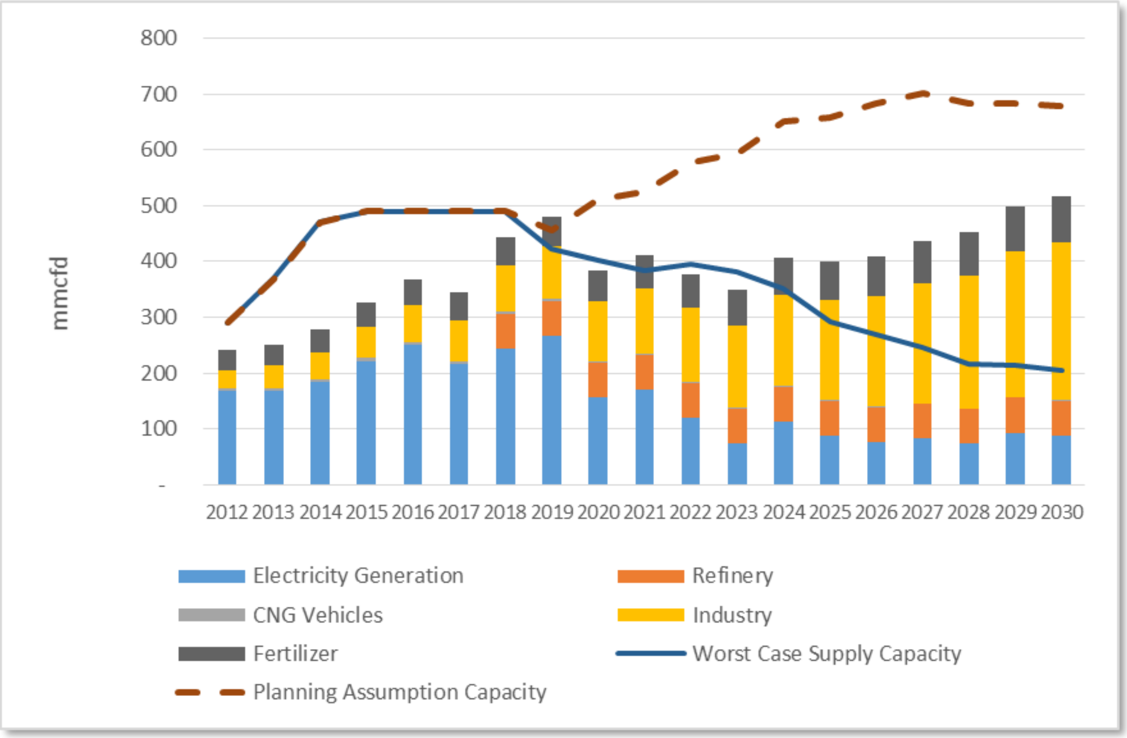
61. Figure III-1 presents a gas supply – demand balance projection developed by JICA under their Electricity Masterplan. The projection includes the M3 field and other fields identified by JICA in the course of their study in 2014.

Figure III-1: Projection for Gas Supply (JICA 2014)



Source: JICA 2014

Figure III-2: Projections for Natural Gas Supply & Allocation



Source: JICA 2014, Consultant's analysis

62. Figure III-2 provides a projection according to the worst case where the M3 and other fields are indefinitely delayed. The planning assumption capacity trajectory represents a capacity half way between JICA's projection in Figure III-1 and the worst case trajectory. The sector demands are based on the electricity growth scenario developed in ADICAs Electricity Expansion plan and the refinery development of Section II above. Fertilizer production need for gas is included to understand the relationship between demand and available capacity. Whilst the planning assumption capacity trajectory could be considered as likely, in practice it is considered prudent to minimize gas consumption. This issue is further discussed below in terms of risk mitigation.

63. Unless natural gas development and consumption is managed through policy means, there is a real potential for significant shortages of gas within 10 years. In the past MOE has negotiated with gas suppliers from Thailand for additional gas supply to Myanmar. Also, as a separate development, MOEP has explored the possibility to purchase LNG. The principal options available therefore include demand-side measures, such as limiting gas supply to sectors outside power generation sector, or giving the industry sector high priority and the power sector priority for peaking generation needs. Policy measures could be used to shift from gas to liquid fuels in these sectors.

64. On the supply side, there is a relatively high certainty of new, feasible gas finds, although their timing is uncertain, as well as the possibility to import gas as LNG. It has been reported that Yadana gas field operator has claimed ability to sell additional gas, but the offer is of course subject to commercial negotiation. Careful assessment of the issue and evaluation of various measures is needed in order to find an optimal way forward. However, planners for electricity system expansion cannot consider any new gas-based power plants to be built prior to 2020 – and even thereafter; inclusion of any substantial amount of gas-based power capacity should be subject to identifying

new sources of gas, either from physical gas fields or through re-negotiating some of the gas export deals currently in force with the neighbouring countries.

Table III-4: Natural Gas – Supply & Demand Balance (MMCFD)

65.	2013	2014	2015	2016	2017	2018	2019	2020	2021
Supply									
MOGE	65	65	65	65	65	65	65	65	65
Yadana	225	225	225	225	225	225	225	157	137
Zawtika	-	60	100	100	100	100	100	100	100
Shwe	-	20	80	100	100	100	100	100	100
M3	-	-	-	-	-	-	-	70	150
New	-	-	-	-	-	-	-	-	66
Total	290	370	470	490	490	490	490	492	618
Demand									
Electricity Generation	168	184	214	241	200	221	222	96	112
Refinery	-	-	-	-	-	62	62	62	62
CNG Vehicles	4	5	5	5	4	4	4	3	3
Industry	41	48	55	65	74	83	94	106	117
Fertilizer	38	41	43	46	49	51	54	56	59
Total	252	278	318	356	327	421	436	324	353

	2022	2023	2024	2025	2026	2027	2028	2029	2030
Supply									
MOGE	92	94	95	97	99	101	102	104	105
Yadana	104	87	70	54	43	26	-	-	-
Zawtika	100	100	87	42	28	19	14	9	-
Shwe	100	100	100	100	100	100	100	100	100
M3	150	150	150	150	150	150	150	150	150
New	211	275	448	580	678	763	786	790	797
Total	757	806	950	1,023	1,098	1,159	1,152	1,153	1,152
Demand									
Electricity Generation	149	105	83	83	66	71	58	99	96
Refinery	62	62	62	62	62	62	62	62	62
CNG Vehicles	3	2	2	2	2	1	1	1	1
Industry	132	147	161	179	197	216	238	261	284
Fertilizer	61	64	67	69	72	74	77	79	82
Total	407	380	375	395	399	424	437	503	526

66. **LNG.** With regard to the identified shortage of natural gas in the short run, MOEP has deliberated a Feasibility Study on the LNG receiving facilities in Myanmar, which was completed in March 2014. The study suggested location of the Floating Storage Regasification Units (FSRU) 80 km to south from the Yangon estuary where the sea depth is around 15m (satisfactory for the LNG carrier). There are three alternatives of gas pipeline landfall location; all consider gas as receiving terminal the South Dagon Junction. MOGE plans to extend the gas pipeline from South Dagon Junction to Thilawa SEZ. The purchase of the LNG was considered from LNG portfolio suppliers.

67. Specifications of the considered facilities were as follows:

- FSRU storage capacity: 173,000 m^3
- Regasification capacity: 120 mmscfd x 4 units (1 unit is spare)
- Gas pipeline length: 80 km (offshore), 50 km (onshore)
- Size of gas pipeline: 24 inch
- Design of jetty: Cross jetty
- Expected timing: 53 months from the design to LNG supply, including EPC 33 months

68. The feasibility study estimated the required capital costs of the facility as follows:

- FSRU: 278 MUSD
- Jetty: 82 MUSD
- Offshore gas pipelines: 154 MUSD
- Consulting fee: 15 MUSD
- Interest during construction, etc.: 69 MUSD
- Tax: 25.2 MUSD
- Total: 624 MUSD

69. Financial analysis of the project showed good results with expected LNG price of 14 USD/MMbtu. The expected electricity tariff with LNG fuel were set at 11.3 c/kWh, which together with LNG facility cost of 0.8 c/kWh, would have resulted in electricity generation cost of 12.1 c/kWh.

70. Before the feasibility study, the MOEP had already started activities on the LNG development and related infrastructure. A tender invitation was announced in 2013 with a specification of 150 to 200 mmscfd of LNG supplied before March 2014, and 500-600 mmcfd after 2014 for the next 5 to 10 years period. In August 2013 MOEP selected 14 bidders qualified for the LNG purchase. YESB (Yangon Electricity Supply Board) has evaluated them and submitted the report to MOEP, which was further submitted to NEMC (National Energy Management Committee). NEMC has since then suspended the evaluation reports. The main challenge with the LNG project was considered the selection of the location of the FSRU. A commercial offer has also been submitted thereafter to the government, which indicated a price of approximately 18 $/mmbtu for the gas supplied from the LNG facility.

71. Realization of the LNG project is not clear at the moment. If there is a decision to realize this project, it will take a few years until its commissioned and the LNG supply begun. Also upgrade and rehabilitation of GT to GTCC requires some years for implementation. Therefore the use of liquid fuel such as light oil, crude oil and heavy fuel oil, rather than natural gas, will be needed by any thermal capacity that is developed in Myanmar to meet the short term power demand. The LNG options would be an expensive one for the electricity generation sector, and it would require

approximately five years to develop to production, and therefore other solutions should be identified and firmed up if gas based power generation is proposed.

L. Natural Gas Supply Risk Mitigation Strategy

72. There is an opportunity to manage the risks that natural gas supplies does not develop as anticipated. If required, fuel substitution can first be made in the transportation and agriculture sectors to release the capacity required to serve the industry and power sectors. However, the decision to develop these sectors may come ahead of the development of firm supplies of natural gas, in which case it can be considered as a prudent practice to minimize the use of natural gas in the power sector and for fertilizer production in favor of allocation to industry.

Table III-5: Gas Supply Risk Mitigation circa 2019

	MMCF	MMCFD	Comment
Refinery	22,630	62	Hydro-cracking refinery needs hydrogen and usually powered with natural gas power plant
Power	81,030	222	EMP estimate
Fertilizer	20,552	56	Standard-run production plant 1 725 mtpd
Industry	38,623	106	EMP estimate
Total	~165,000	~548	
Available gas	~150,000	~411	Yadana, Yetagun, Shwe, Zawtika
		Potential to Reduce Gas Consumption	
Refinery	(7,500)	(21)	Power the refinery using liquid fuels (30 – 40 MW)
Power sector	(30,250)	(83)	Increase hydropower, gas / oil plant
Fertilizer	(10,000)	(27)	Import fertilizer
Total	(50,000)	(137)	

Source: Consultant's analysis

73. Clearly the gas supply – demand outlook is tight. However, the refinery design can be modified to minimize gas consumption. In principle the use of gas for power generation could be replaced by oil or storage hydropower capacity for deployment at times of peak demand. A fertilizer plant appears to be uneconomic and gas could be saved by importing urea. The M3 gas field will ease the situation considerably, through an increase in capacity, however the delay in the development of the field means that a prudent approach is indicated.

74. In summary, gas could be reserved for industry and the power sector. Other demands could be met by alternative means. The decision to pursue alternatives can be decided as a matter of government policy as the natural gas supply – demand balance unfolds in the coming years.

IV. Biofuels

M. Introduction

75. Increasing use of biofuel in diesel engines is tried and tested in many markets including in Myanmar. Most current passenger cars and truck diesel vehicles are today B7 capable. The compatibility of large engines and heavy-duty vehicles with higher blends is better than for light duty vehicles. It has been estimated that about 80 % of the trucks can run safely on B30. Therefore the introduction of 5 to 10 % of biodiesel does not require specific actions or issues to be resolved but fuel suppliers can increase the level of biodiesel (Fatty Acid Methyl Ester – FAME in accordance with international EN 14214 standard, or so called advanced biodiesels with properties almost

76. Biofuel consumption is a key indicator in many countries of the deployment of renewable energy in the transport sector. Fuel ethanol already accounts for nearly 10 % of the gasoline market in the USA and a major share in Brazil. Current European fuel standards allow up to 7 volume% in diesel fuel (the most common type of biodiesel, B7) and 10 volume% of ethanol (E10).

77. Biofuel consumption is a key indicator in many countries of the deployment of renewable energy in the transport sector. Fuel ethanol already accounts for nearly 10 % of the gasoline market in the USA and a major share in Brazil. Current European fuel standards allow up to 7 volume% in diesel fuel (the most common type of biodiesel, B7) and 10 volume% of ethanol (E10).

78. Myanmar is well positioned to adopt progressive policies towards renewable fuels. The country is endowed by suitable natural resources and has already entered into several experiments for domestic biofuels production. At the same time new technologies have been developed allowing the country to step in to applying the second generation refining technologies, which allow a wider range of feedstock especially for ethanol production. At the same time car manufacturers around the world are increasingly adapting their products to allow use of higher mixing ratios of biofuels.

79. Biofuels considered for potential production in Myanmar include the following:-

a) Biodiesel – a diesel fuel obtained from non-edible oil plants (e.g. jatropha, rubber seeds and edible oilseed crops (palm oil, coconut, rapeseed and soybean), through a chemical reaction process. Like bioethanol, also biodiesel can be used as a fuel either alone or blended with petroleum diesel (e.g. B20 consists of 20 % biodiesel and 80 % petroleum diesel);

b) Bioethanol – a substitute for gasoline produced from sugar- and starch-based crops such as sugarcane, cassava, paddy rice, or maize. Bioethanol could be used as a fuel either alone or blended with gasoline (e.g. E10 consists of 10 % ethanol and 90 % gasoline).

80. About ten years ago the Government of Myanmar introduced a biofuel implementation program with an aim to minimize the country's dependence on imported liquid fuels. The program was based on an ambitious plan of mass cultivating approximately 200 000 ha of jatropha curcas in each state and division. The program included plans for blending bioethanol with conventional gasoline, for establishing small scale processing plants in rural areas, and for implementing projects on biofuel production with the assistance of the FAO and ASEAN countries.

81. However, as there are currently no facilities capable of producing biodiesel or bioethanol in large scale and to the extent outlined by the Government of Myanmar at the time the biofuel implementation program was initiated, then it seems fair to conclude that the biofuel implementation

program has thus far been unsuccessful.

82. It is understood that the cornerstone of the biofuel implementation plan – cultivation of jatropha – failed due to poor planning and execution, and as the planted jatropha plants did not deliver the yields expected, the ambitious biodiesel program was eventually discarded by the Myanmar Government. Today the production of biodiesel is limited to local level facilities producing biodiesel mainly to be used by agricultural machinery.

83. For the time being, no support scheme has been identified for the production of biodiesel or bioethanol, which seemingly directly reflects the lack of new initiatives by the private sector.

84. Despite the unsuccessful implementation of the biofuel program, which is not rare because the global experience of domestic biofuel schemes is rather mixed, it should be kept in mind that Myanmar holds significant potential for liquid biofuels and they should therefore not be excluded from country's energy mix. It is recommended that the lessons learned from the biofuel program and from the cultivation of jatropha trees are thoroughly reviewed and taken into consideration in any possible future project.

85. The following two sections, present more information regarding biodiesel and bioethanol, including some indicative calculations related to the investment cost for selected production facility configurations and consequent pre-feasibilities of domestic biofuel production.

N. Biodiesel

86. Increasing use of biofuel in diesel engines is tried and tested in many markets including in Myanmar. Most current passenger cars and truck diesel vehicles are today B7 capable. The compatibility of large engines and heavy-duty vehicles with higher blends is better than for light duty vehicles. It has been estimated that about 80 % of the trucks can run safely on B30. Therefore the introduction of 5 to 10 % of biodiesel does not require specific actions or issues to be resolved but fuel suppliers can increase the level of biodiesel (Fatty Acid Methyl Ester – FAME in accordance with international EN 14214 standard, or so called advanced biodiesels with properties almost equal to petroleum diesel) without causing vehicle compatibility problems or requiring modifications to fuel distribution, and without significant consumer involvement.

87. Biodiesel can be produced from a myriad of different plants that can be roughly divided into edible and non-edible crops. The use of edible crops for biodiesel production is controversial, as this could impact food prices and in some cases also worsen mal-nutrition in developing countries. Edible crops that could be considered for biodiesel production include oil palm, coconut, groundnut, soybean, sesame etc. Some non-edible crops that could be considered for biodiesel production include jatropha curcas, castor oil plant and rubber trees. So called third generation sources of biodiesel such as algae are currently under development. This paper focuses mainly on the use of jatropha seeds for production of biodiesel due to the fact that the number of jatropha trees in Myanmar is assumed to be significant as a result of the national effort to plant jatropha trees between 2006 and 2008.

88. Jatropha growing has potentially many benefits. It can be intercropped with many other cash crops such as coffee, sugarcane and vegetables with the Jatropha offering both fertilizer and protection against livestock. Jatropha needs at least 600 mm of rain annually to thrive but it can survive three years of drought by dropping its leaves. Jatropha is excellent at preventing soil erosion, and the leaves it drops act as a soil enriching mulch.

89. The oil content of jatropha seeds is between 36 and 38 %. The plant starts to bear fruit in 4 – 5 years after planting and economic yields start from the fifth year. The seeds of jatropha are

non-edible and therefore production of biodiesel from jatropha seeds does not limit country's food production capacity assuming jatropha is farmed on a land unsuited for farming of edible crops. It should however be emphasized that, as with every plant crop, the quality of the farmland, the amount of sunshine hours and irrigation define the annual yield. If grown on non-arable land, the annual yield from jatropha trees can be assumed to be between 0 and 2.2 t/ha[3] (0 – 800 kg/acre). Table II-9 presents an estimation of yields for jatropha trees of different age.

Table IV-1: Yield Estimation for Jatropha Trees of Different Age

Plant Age (years)	Seed Yield (kg/acre)	Oil Yield (gallons/acre)
1 – 2	32	1.6
2 – 3	280	14
3 – 4	600	29
4 – 5	800	40
5 – onward	1 000 – 1 200	50 – 60

Source: Myanmar Industrial Crops Development Enterprise, Ministry of Agriculture and Irrigation. The source indicates that seed yield for plats aged 4 – 5 years would be 4 800 kg/acre, which is assumed to be a mistake.

90. As at October 2012, Myanmar had reportedly cultivated around 2 million ha of jatropha4. These numbers should however be interpreted with a level of caution as several reports have highlighted that a significant portion of the jatropha seedlings planted under the biofuel program between 2006 and 2008 have failed to grow into seed-bearing trees. Assuming that the total cultivation area of two million hectares mentioned in several reports is correct, the biodiesel production potential from jatropha trees alone assuming a conservative biodiesel yield of 20 gallons per acre can be calculated to be:

a. 2 000 000 ha = 4 941 932 acres
b. 20 gallons/acre x 4 941 932 acres = 98 838 640 gallons

91. The estimated biodiesel production capacity potential of 100 million gallons could, if utilized, cover a significant portion of Myanmar's diesel demand. However, as mentioned above, it is unclear if the conservative yield estimation of 20 gallons per acre reflects the actual yield from the jatropha trees planted under the biofuel implementation program. Whatever the current yield, 2 million hectares represents a significant cultivation area and if the jatropha trees planted were well tended in the future the annual harvest could become large enough to cover a relatively large part of the diesel demand especially at a rural community level.

92. It is understood that there are no large scale production facilities currently in operation or under construction, in Myanmar. The following jatropha processing pilot facilities were at one time in operation but it is unclear whether or not these plants are still in operation:-

a. Pilot production in Yangon (Myanmar Industrial Crops Development Enterprise, Ministry of Agriculture), output 100 gls/day;
b. Pilot jatropha crude oil expeller and processing plant, Hline Tet Farm, Myanmar Agricultural Service, Mandalay Division. The small demonstration plant needs six

[3] Ouwens et al. Position paper on Jatropha curcas State of the Art, small and large scale project development
[4] Source: Myanmar Energy Sector Initial Assessment. ADB, October 2012

hours to refine 100 liters of jatropha crude oil to 97 liters of refined biodiesel and cost ca. 50,000 USD;

c. North-eastern Military Command, Lashio, Shan State; refines 240 gals of jatropha crude oil per day. Estimated cost was 10 million kyats (circa 2008); and
d. Jatropha and Rubber Plantation in Man Pan Project (Hill 5), Lashio, Shan State.

93. Table IV-2 presents an outline calculation for two different sized jatropha based biodiesel production facilities assuming oil content of 37 % in the jatropha seeds, a yield extraction efficiency of 92 % and a loss of 2 % in the trans-esterification process. The press cake that is a by-product of the oil extraction process could be used for the production of the process steam needed for the process.

Table IV-2: Conceptual Jatropha Based Biodiesel Refinery

	Plant Capacity	
	10 000 t/a	100 000 t/a
Biodiesel	3 336 t/a	33 359 t/a
Steam	5 000 MWh/a	50 000 MWh/a
Electricity	1 000 MWh/a	10 000 MWh/a
Investment Cost	1.5 MUSD	8.0 MUSD

94. Assuming Myanmar adopted an objective of increasing use of biofuels so that diesel fuel sold in the country consisted on average of 20 % biodiesel and 80 % petroleum diesel, the impacts of such policy can be estimated as follows:-

- The cost of jatropha seeds is the single most important cost factor in jatropha based biodiesel production representing 75 to 90 % of the production cost. There is no direct cost reference from Myanmar available to the Consultant, but international references from Africa, India and South-East Asia indicate that the price paid to the farmers have ranged between 120 to 170 $/ton whilst the price of the output oil ranges from 400 to 700 $/ton (September 2014). Feedstock cost of 170 $/ton (146,000 Kyat/ton) is therefore assumed.
- The cost of steam generation is estimated only based on the capital cost of a solid-fuel boiler plant at 12 $/MWh(th) (11,700 Kyat/MWh(th)) and electricity purchase price at 95 $/MWh (93 Kyat/kWh, representing economic long run marginal cost including generation and T&D). The operating costs are estimated at 3 % and 2.5 % of CAPEX for the smaller and larger facility, respectively.
- The economic cost of petroleum diesel is assumed on basis on international fuel prices. For estimation purposes the diesel cost is set at 0.73 $/liter corresponding approximately to crude price of 100 $/bbl. The current pump price of diesel in Myanmar including transport and distributions cost is about 0.91 $/liter (890 Kyat/liter, 4,154/Kyat/gallon).
- Petroleum diesel has net heat value of 42 MJ/kg, density of 0.8 kg/liter, and CO_2 emission factor of 73.6 g/MJ, i.e. 2.51 kg/liter.
- Economic discounting rate (real) is assumed at 6 % and life of the refinery at 20 years.

95. With these assumptions for the two above plant capacities the cost of domestic biodiesel is in the range of 0.47 and 0.5 $/liter (584 to 628 $/ton), on average 0.48 $/liter. Therefore blending ratio of 20 % would results in net savings of 0.25 $ per liter of diesel. Having B20 policy would

subsequently result in savings of $713 million calculated as a present value of the annual costs for 15 years until 2030. For the most part this saving would also contribute to the national trade balance as much of the transport fuels are is currently imported. Totally 11.9 million tons of CO2 emissions would be reduced. If valued at 30 $/ton of CO2 further economic savings of $ 357 million can be achieved.

96. B20 policy would result in the increase of biodiesel demand from 290 to 413 million litres, ie. 64 to 91 million gallons from year 2016 to 2030. This would require correspondingly that the about 2 million hectares (4.9 million acres), which was targeted in the mid-2000's, would need to be brought again under active jatropha cultivation by 2030.

97. The above calculation is only for demonstrating that policy encouraging production and use of biodiesel remains desirable and seems economically and technically feasible for Myanmar. The calculation itself is highly sensitive to (i) feedstock price and (ii) reference price of petroleum diesel. Furthermore, the mixing policy would cause some economic cost on the consumer side, which is difficult to quantify, such as slightly increased operation and maintenance cost of the vehicle fleet in the event shift to B20 level be rapid and based on existing engines and fuel qualities. However, technological development work of car manufacturers is addressing these maintenance issues and selecting new materials more suited to biodiesel use than the current ones. Fast development is happening also on the production side, where different second and third generation biodiesel production methods are already entering the business.

98. The referenced diesel price corresponds roughly to crude price of 100 $ per barrel. With prices of 70 $ and 130 $ per barrel, the referenced international diesel price could be estimated at 0.51 and 0.95 $/liter respectively. With the lower level, the refinery price of biodiesel would roughly match the international diesel cost, whereas with the higher level, the present value of savings in the country's fuel bill until 2030 would increase to $1.3 billion.

99. As mentioned earlier, international experience on developing jatropha based biofuel businesses is mixed, and many pilot schemes have failed. Assuming seed yield of 1 to 1.2 tons per acre, one acre generates 150 to 180 dollars annual income to the farmer per acre. As the sown land of most Myanmar farmers is 5 acres and less, introducing a less-income generating crops, such as jatropha, among the traditional cash crops, which provide substantially higher income, would be difficult. For jatropha cultivation, large scale specialized private agricultural companies, who also have an interest in the upstream side of the business, in production and selling biodiesel, would probably provide a more suited business model than small farmer or community based cultivation. Large private corporations should, however, address the problems encountered in the past with land allocation practices. Biofuels are still contested in many countries due to uncertainties surrounding positive environmental and social benefits, concerns about potentially negative impacts, and the manner with which land is acquired for these projects.

100. As significant amounts of jatropha trees have already been planted around Myanmar, it is recommended that it is considered, how the seeds of the jatropha trees could best be used for biodiesel production. If nothing is done, it seems possible that the significant national push for promoting the jatropha has been in vain and the planted trees might wither away. A recommended first step would be to identify the current state of the planted jatropha trees, the most suitable regions for cultivating jatropha, and the means that are available for improving the yield from the planted trees. Afterwards the focus should be shifted to harvesting methods and defining how the seeds are best processed into biodiesel and whether this should be conducted in large facilities or on a community level. Private sector driven and environmentally and socially sustainable business model for jatropha cultivation and processing should be developed.

O. Bioethanol

101. The drive towards sustainable economy has caused the governments around the world introduce ambitious policies and mandatory targets for renewable fuels. This has brought ethanol to the fuel markets. The US and Brazil together represent around 90 % of the ethanol produced and consumed in the world. In Brazil, ethanol can be used as a standalone biofuel in over half of the country's light vehicle fleet. This is because of the widespread introduction of flex-fuel cars, which can run on either gasoline or ethanol or any mixture of the both. The additional price of a flex-fuel-vehicle currently ranges from zero to about $ 2,000 per vehicle depending on the manufacturer and model. This would allow the consumer side also in Myanmar follow the extending provision of ethanol.

102. Currently, commercial bioethanol is produced by first generation (1G) technology from sugars found in arable crops, which can easily be extracted using conventional technology. The second generation (2G) technologies use non-food ligno-cellulosic biomasses such as bamboo and are on the threshold of commercialization. First generation sources of bioethanol in Myanmar include crops such as sugarcane, cassava, maize, sweet potato, yam, sorghum and rice. Second generation bioethanol could be produced from non-food parts of crops already under cultivation such as stems, leaves and husks of maize and sugarcane as well as stems, leaves and husks of non-food crops such as jatropha.

103. First generation bioethanol is produced by fermenting plant-derived sugars to ethanol in processes similar to those used for making alcoholic beverages such as wine. Second generation bioethanol production is more complicated; as an example the sugars in ligno-cellulosic biomasses are locked within a fibrous matrix and are therefore not readily available for extraction. An important consideration related to the use of bioethanol blended with gasoline is the so-called “blend wall” i.e. blending more that 10 % of ethanol with gasoline requires the use of flex-fuel vehicles as car manufacturers are claiming that blends higher than 10 % have the potential to damage conventional vehicle engines. However, as mentioned earlier and by referencing Brazil experience, the flex-fuel vehicle is already today in the market allowing up to 85 % ethanol content. Modifications to fuel distribution infrastructure could also be needed if more than 10 % of bioethanol is blended into gasoline as RE85 or similar ethanol products would need to be provided dedicated pumps.

104. The current production capacity of bioethanol in Myanmar is based on first generation biomass, especially sugarcane and maize. In the future, production of bioethanol utilizing the second generation technology for extraction of bioethanol e.g. from the non-oily parts of the jatropha tree could be considered assuming the technology becomes more accessible.

105. Since 2002, the Myanmar Chemical Engineers Group (MCE) has constructed four plants for 99.5 % ethanol production in Mandalay, Sagaing and Bago; their total capacity is 1.95 million gallons/year5. The Myanmar Economic Cooperation has furthermore built two large bioethanol plants with combined capacity of 1.8 million gallons/year[6]. Commercial production started at these plants in 2008. A private company Great Wall Food Stuff Industry has also built an ethanol plant (3 700 gals/day) based on sugarcane.

106. The Consultant has not come across any information indicating that any bioethanol production facilities have been established since 2008. Furthermore, the Consultant has discovered that the existing facilities are no longer producing bioethanol due to lack of legal support and subsidies.

[5] Source: Myanmar Energy Sector Initial Assessment. ADB, October 2012
[6] Source: Myanmar Energy Sector Initial Assessment. ADB, October 2012

107. As to maize based ethanol production, in Table IV-3 below, an outline calculation is presented for two different size bioethanol production facilities with an assumed moisture content of 13.5 %, starch content of 70 % of dry matter and ethanol yield of 50 % of the inherent starch. Similar or slightly higher yields could be expected if polished rice was used instead of maize.

Table IV-3: Conceptual Maize Based Ethanol Refinery

	Plant Capacity	
	100 000 t/a	200 000 t/a
Ethanol production	30 275 t/a	60 550 t/a
	8.4 Million gallons/a	16.9 Million gallons/a
Fodder production (10 % moisture)	34 000 t/a	68 000 t/a
Steam	55 000 MWh/a	110 000 MWh/a
Drying, steam/gas	45 000 MWh/a	90 000 MWh/a
Electricity	15 000 MWh/a	30 000 MWh/a
Investment costs	40 MUSD	60 MUSD

108. Cassava could also be considered as a suitable feedstock for bioethanol production due to its high starch content. The following Table IV-4 presents an outline calculation for two different size production facilities based on cassava assuming a dry matter content of 25 %, starch content of 80 % of the dry matter and finally ethanol yield of 50 % of the inherent starch in cassava.

Table IV-4: Conceptual Cassava Based Ethanol Refinery

	Plant Capacity	
	200 000 t/a	400 000 t/a
Ethanol production	20 000 t/a	40 000 t/a
	5.6 Million gallons/a	11.1 Million gallons/a
Steam	25 000 MWh/a	50 000 MWh/a
Electricity	8 000 MWh/a	15 000 MWh/a
Investment costs	20 MUSD	35 MUSD

109. A similar outline calculation as presented for maize and for cassava is presented for two facility sizes for both molasses as well as for sugarcane (sugarcane juice + molasses) in in Table IV-5 and Table IV-6 below. For calculation on molasses a sucrose content of 50 % and ethanol from sucrose efficiency of 50 % are assumed.

Table IV-5: Conceptual Molasses Based Ethanol Refinery

	Plant Capacity	
	50 000 t/a	100 000 t/a
Ethanol production	12 500 t/a	25 000 t/a
	3.5 Million gallons/a	7.0 Million gallons/a
Steam	15 000 MWh/a	30 000 MWh/a
Electricity	3 000 MWh/a	6 000 MWh/a

Investment costs	8 MUSD	12 MUSD

Table IV-6: Conceptual Sugarcane Based Ethanol Refinery

	Plant Capacity	
	300 000 t/a	1 000 000 t/a
Ethanol production	15 500 t/a	51 000 t/a
	4.3 Million gallons/a	14.3 Million gallons/a
Steam	15 000 MWh/a	50 000 MWh/a
Electricity	4 000 MWh/a	12 000 MWh/a
Investment costs	12 MUSD	25 MUSD

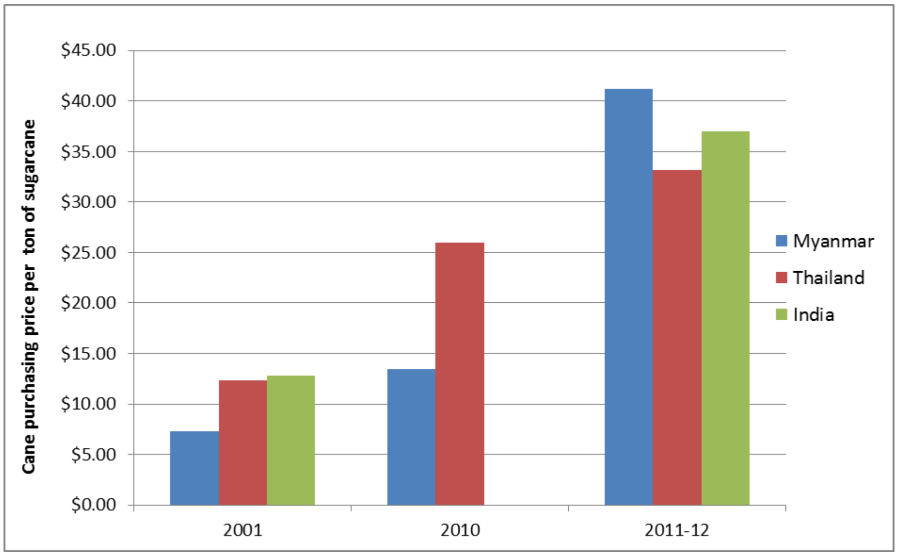
110. If sugarcane was to be used, process steam and electricity could be generated by combustion bagasse, which is a byproduct of the sugarcane production. In the future, bagasse could also be used as a feedstock for bioethanol production in a second generation bioethanol plant. As can be seen from the tables above, sugarcane can be considered as the most advantageous feedstock for the production of first generation bioethanol in Myanmar, especially on a larger scale. As with all first generation biofuels, if the production capacity of sugarcane based bioethanol is increased, it must be ensured that this does not result in shortages in food supply.

111. It is also recommended to study the ongoing second generation bioethanol projects (1 in Brazil, 1 in Italy, 3 in the USA). If a cost-competitive way for producing bioethanol from ligno-cellulosic materials becomes available, Myanmar could base its bioethanol production on more sustainable feedstocks such as maize and jatropha stover.

112. Assuming Myanmar adopted objective of shifting to a mixing standard so that all gasoline sold in the country would be replaced totally by gasohol consisting of 10 % ethanol and 90 % regular gasoline, the impacts of such policy are estimated in the following by reviewing two feedstock as an example, (i) sugarcane and (ii) maize.

113. The cost of feedstock is again the most important cost factor. At the moment, the sugar industry in Myanmar has experienced rapidly rising feedstock cost. Whilst sugarcane ton was sold at 13,500 kyat in 2007-2008, it was sold at 30,000 kyat in 2012-2013 (31 $/ton). The current level may not sustain as the sugar mills compete against globally competitive prices. There are 18 sugar mills in the country and all of them have a capacity at or below 2,000 tons of cane per day (TCD) whereas a competitive facility size can be estimated at around 10,000 TCD. The two fuel refineries of Table IV-6 represent approximately 1000 and 3000 TCD capacities.

Figure IV-1: Cane Intake Prices as Compared to Thailand and India



Source: Sun Thein, Myanmar Agriculture Sector at a Glance and its Evolution: Opportunities and Challenges, paper presented to "Investing in Sustainable Agriculture in Myanmar" Yangon, July 2014

114. Maize is an internationally traded commodity. International maize price averaged about 194 $/ton (IMF Commodity Prices) during the second and third quarters of 2014. Farmers in India sell maize at around 134 $/ton (800-840 rupees per 100 kg). Therefore, the reference price is set for the calculation at 150 $/ton (146,000 Kyat/ton).

115. The reference price for gasoline corresponding to about 100 $/bbl of crude oil price, is 0.68 $/liter. The current pump price of gasoline in Myanmar is about 1.08 $/liter (1,050 Kyat/liter, 4,770 Kyat/gallon). International ethanol prices, e.g. as quoted in Chicago or Rotterdam, vary more regionally than prices of petroleum products. The international reference price for ethanol is assumed at 0.71 $/liter, which roughly represents an average of Chicago and Rotterdam price levels.

116. Gasoline and ethanol have different fuel properties and therefore a 10 % renewable target would correspond to a volume consumption, which is not divided 90/10 in liters as in E10. Gasoline has net heating value of 42.4 MJ/kg and density of 0.75 kg/liter. Its CO_2 emission factor is 73.6 g/MJ equal to 2.33 kg/liter. Ethanol has net heating value of 27.0 MJ/kg, density of 0.79 kg/liter, and no CO_2 emissions if feedstock is cultivated sustainably and/or provided from excess production.

117. The 10 % mixing ratio here is assumed in terms of fuel heating value. Because ethanol has lower heating value, mixing results in higher volume of fuel consumed than without mixing. However, several studies have shown that due to higher octane value of ethanol, this relationship is not directly proportional to heating values only, but some fuel volume is saved because of efficiency gains in vehicle engine combustion due to ethanol's octane value. When these relationships are summed up, a 10 % mixing ratio is estimated to result to a liter of regular gasoline to be replaced by 4.1 % higher volume of gasohol. With 10 % renewable energy target, the mix therefore has 85.8 % gasoline and 14.2 % ethanol when expressed in liters.

118. The maize based plant concepts provide ethanol costs of 0.53 $/liter whereas sugarcane based refining produces ethanol at 0.55 to 0.58 $/liter, both below the international reference prices

for gasoline and ethanol.[7] Because resulting ethanol prices are near to each other, 0.56 $/liter is assumed as the common price for locally produced ethanol. The contemplated biofuel policy would therefore result in a small net cost of $123 million to the economy calculated as a present value of the annual costs for 15 years until 2030. Totally 5.9 million tons of CO_2 emissions would be reduced. The implicit cost of CO_2 reduction would be 38 $/ton. Changes to the net impact to the economy remain small even if the crude price assumptions are let to change ± 30 $/bbl.

119. The results of bioethanol policy would be more modest than those of biodiesel policy. Production of domestic biodiesel seems already now more economical that diesel imports, whereas local ethanol is of slightly higher cost than gasoline. It should also be noted that the underlying demand forecast for gasoline is less than that for diesel and the assumed blending ratio is smaller.

120. The 10 % renewable energy in gasoline policy would result to some 286 million liters (63 million gallons) of ethanol consumed in 2030, which, if all would be produced from sugarcane, would require 4.4 million tons of sugarcane to be delivered for biofuel production. Today the total sown acres for sugarcane are 180,000 hectares with an average yield of 6.58 tons per hectare.[8] Therefore 670,000 hectares would be needed for biofuels if fuel ethanol production depended solely on sugarcane. This calls for having a wider feedstock base and introduction of second generation ethanol production technologies, which can utilize agricultural waste such as leaves and stalks of maize, excess bagasse and ordinary straw from rice and wheat farming.

P. Conclusion

121. In future diesel and gasoline production could be supplemented by production of biodiesel from oily plants and of bioethanol from starchy crops. Considering the large surface area and good growing conditions in Myanmar, liquid fuels produced from renewable feedstock could play a significant role in the supply of transportation fuels.

122. Biodiesel / bioethanol production in Myanmar is currently limited to only a few production facilities. Existing bioethanol facilities have more or less stopped production due to lack of subsidies and no information indicating new facilities being under construction was found. Only pilot scale biodiesel facilities have been built in Myanmar, which are producing small amounts of biodiesel for use by agricultural machinery.

123. Approximately ten years ago Myanmar began an ambitious biofuel implementation program with a plan to plant a total of 3.5 million hectares of jatropha curcas trees. The program was unsuccessful failing to live up to the expectations of making Myanmar self-sufficient as far as the demand for diesel goes. It is unclear, what is the estimated yield of the jatropha trees planted as part of the program, but considering that several reports have claimed that jatropha plantations cover an area of approximately 2 million hectares, the trees seem to offer a significant source of non-edible oil that could be used for the production of biodiesel. Other crops could also be utilized for the production of biodiesel, but the first step recommended to be taken is to identify the current state of the planted jatropha trees and the means that are available for improving the yield from these trees. Afterwards the focus should be shifted on harvesting methods and defining how the seeds are best processed into biodiesel and whether this should be conducted in large facilities or on a community level.

[7] It is understood that there exists business cases where an ethanol refinery would have revenues from side products such as fodder for animal feed. It is further realized that with second generation technologies ethanol can be produced from side products and agriwaste at very low feedstock price. These aspects were ignored for the simplicity of calculating the example.

8 Crop Summary in Myanmar, by Issares Thumrongthunyawong, www.bangkokbank.com.

124. Use of bioethanol should also be considered. Sugarcane, whether used as whole or only in the form of molasses seems to present the most cost-effective way of producing bioethanol utilizing first generation production technology. The concept of blend wall, meaning in essence that approximately 10 % bioethanol can be blended with gasoline without the need for updating the vehicle fleet is coming less important as flex-fuel vehicles, either new one or retrofits, have proved a low-cost solution to pursue consumer side interest in bioethanol fuel.

125. Both biodiesel and bioethanol seem economically feasible for Myanmar. A biofuel policy with set mixing targets for 2020 and 2030 is recommended. Assuming a 10 % target for both diesel and gasoline by 2020, and 20 % target by 2030, transport de-carbonisation case can be developed. Table IV-7 below summarizes cases discussed in this report, namely base case, a small inland refinery case, and domestic biofuel case, and their impacts to the supply side of liquid fuels until 2030 in Myanmar.

Table IV-7: Liquid Fuels under Different De-Carbonization Regimes

ktoe	Gasoline					Diesel					Renewables
Year	Demand	Refinery	Decarbonization Case			Demand	Refinery	Decarbonization Case			Share
			Gasoline	Ethanol	Total			Diesel	Biodiesel	Total	%
2014	644	0	644	0	644	1169	0	1169	0	1169	0 %
2015	661	0	661	0	661	1165	0	1165	0	1165	0 %
2016	714	0	698	14	712	1181	0	1157	24	1181	2 %
2017	766	0	733	30	763	1196	0	1149	48	1196	4 %
2018	818	0	774	41	815	1212	0	1139	73	1212	6 %
2019	877	0	802	70	872	1237	0	1138	99	1237	8 %
2020	937	0	837	93	930	1262	0	1136	126	1262	10 %
2021	996	964	879	109	988	1287	871	1145	142	1287	11 %
2022	1058	964	923	126	1049	1321	871	1163	159	1321	12 %
2023	1120	964	965	144	1109	1356	871	1179	176	1356	13 %
2024	1181	964	1006	164	1169	1390	871	1195	195	1390	14 %
2025	1234	964	1037	183	1220	1428	871	1214	214	1428	15 %
2026	1286	964	1068	203	1271	1467	871	1232	235	1467	16 %
2027	1338	964	1097	225	1322	1505	871	1249	256	1505	17 %
2028	1380	964	1132	232	1363	1564	871	1282	281	1564	18 %
2029	1422	964	1151	253	1404	1622	871	1314	308	1622	19 %
2030	1464	964	1170	274	1444	1681	871	1345	336	1681	20 %

Source: Consultant

Project Number: TA No. 8356-MYA

FINAL REPORT
ELECTRICITY STRATEGY

Prepared for

The Asian Development Bank

and

The Myanmar Ministry of Energy

Prepared by

IES
Intelligent Energy Systems

in association with

MMIC
MYANMAR
INTERNATIONAL
CONSULTANTS

ABBREVIATIONS

ADB	–	Asian Development Bank
BBL	–	Barrel
BOPD	–	Barrels of Oil per Day
CFB	–	Circulating Fluidized Bed
CHP	–	Combined Heat Power
CO_2	–	Carbon Dioxide
CPI	–	Consumer Price Index
CSO	–	Central Statistics Organisation
EHV	–	Extra High Voltage
EIA	–	U.S. Energy Information Administration
EUR	–	European currency unit EURO
FAO	–	Food and Agriculture Organization
GDP	–	Gross Domestic Product
GHG	–	Greenhouse Gases
GoM	–	Government of the Republic of the Union of Myanmar
IDC	–	Interest during construction
LCOE	–	Levelized Cost of Energy
LNG	–	Liquefied Natural Gas
MOE	–	Ministry of Energy
MOEP	–	Ministry of Electric Power
MPE	–	Myanmar Petroleum Enterprise
NOx	–	Nitrogen Oxides
O&M	–	Operation and Maintenance
PPA	–	Power Purchase Agreement
PV	–	Photovoltaic
SOx	–	Sulfur Oxides
USD	–	United States Dollar
VAT	–	Value Added Tax

UNITS OF MEASURE

kWh	-	Kilowatt-hour
MWh	-	Megawatt-hour
MWel	-	Megawatt electric
MWth	-	Megawatt thermal
kJ	-	Kilojoule

GJ	-	Gigajoule (one thousand megajoules)
PJ	-	Petajoule (1000 GJ)
TJ	-	Terajoule (1000 PJ)

CONVERSION FACTORS

1 GCal	=	4.19 GJ
1 BTU	=	1.05506 kJ
1 Gcal	=	1.1615 MWh = 4.19 GJ = 1.75 steam tons/hour
1 GJ	=	0.278 MWh = 0.239 Gcal = 0.42 steam tons/hour
1 MW	=	0.86 Gcal/hour = 3.6 GJ = 1.52 steam tons/hour

CONTENTS

I. SUMMARY

A. Electricity Development Strategy

1. The optimal long-term fuel mix of Myanmar is determined to a significant extent by the fuel mix of the electricity generation sector. The selection of a fuel mix that is most suitable for electricity generation in Myanmar is shaped by the economic value of fuels available to Myanmar, the competition for fuels outside of the electricity sector, and the cost to convert fuels to electricity.

2. These factors are particularly relevant to the consideration of Myanmar's proven natural gas resource. The gas is in demand internationally whereas locally, Myanmar's gas could potentially be allocated to fertilizer production, to the production of refined petroleum products, to industry, to fuel passenger vehicles (CNG), to the power sector, or as a cooking fuel. At the present time Myanmar's proven reserves of gas are insufficient to meet the projected demands of all sectors of the economy. Given a basic analysis of the relationship between GDP growth and natural gas supply, it is considered that Myanmar's natural gas should be allocated to export and to industry. Economic analysis suggests that it would be economical to import fertilizer rather than to produce fertilizer locally. Other needs, including power sector needs, can instead be met by liquid fuels.

3. In principle, power generation could comprise a gas plant capacity of less than 10% in 2030. In this case, the total annual gas consumption by the power sector would be very modest; in 2020 only 18 BCF and in 2030 only 31 BCF. The existing (and under construction/development) capacity for gas based power will be about 1 700 MW within a few years, which will consume over 300 MMCFD when simultaneously in operation. As reserve capacity needs increase to 2030, and if gas would be used to meet this capacity need, then total gas consumption could reach to around 1 000 MMCFD. This requirement for gas may not be able to be met through a future domestic gas quota but could instead be met by imported LNG or by light fuel oils. On the other hand the cost of LNG exceeds 18 $/MMBtu whereas the subsidized price to the current gas fired plants in Myanmar is around 5 $/MMBtu for domestic consumers and 11-12 $/MMBtu for industries. This cost difference means that LNG would be a very expensive solution for the country (whether LNG is used by the power sector or by industry). Therefore it is clear that it is preferable to use light fuel oil to fuel fast-acting reserve capacity plant. LNG imports can be considered again nearer to the time when the current gas supply contracts expire, if it is feasible to negotiate for a higher quota for domestic consumption. In the meantime new gas fields may be discovered.

4. A set of alternative long-term fuel mixes have been examined in detail, each with a low dependence on natural gas. Concerns regarding seasonal variation in hydropower output have been addressed by analysing in detail and by modelling hydropower generation profiles on a conservative basis, on hourly and monthly basis. The cost of each fuel mix has been estimated, according to the optimal use of power generation technologies as they apply in Myanmar. These technologies extend from hydropower, to thermal and renewable energy forms of power generation. Whilst the focus of the EMP is on the optimal long-term fuel mix, it has been necessary to undertake generation sector expansion planning to quantify the cost of the fuel mix and also to take into account the practicability of implementing the optimal fuel mix strategy.

II. INTRODUCTION

B. Optimal Fuel Mix Selection

5. The selection of a fuel mix that is most suitable for electricity generation in Myanmar is shaped by the economic value of fuels available to Myanmar, the competition for fuels outside of the electricity sector, and the cost to convert fuels to electricity.

6. The fuels considered for electricity generation are hydropower, gas, coal, wind, solar PV and fuel oil.

a) **Gas.** Myanmar's future gas reserves are uncertain and care must be taken to make the most efficient use of gas for the purpose of power generation.

b) **Coal.** Myanmar's coal reserves are small in quantity and of poor calorific value. Therefore it is assumed that, for efficiency of conversion of coal to electricity, sub-bituminous coal would need to be imported.

c) **Oil.** It is not a preferred practice to use oil for power production. However, the use of heavy and light fuel oil can be economic when used to fuel reserve power plant. Such oil is stored adjacent to gas / oil engines that are used under emergency conditions. If a local refinery is established the heavy distillates that have no other use could be used for this purpose.

d) **Type I Renewables.** Myanmar has abundant hydropower resources. Myanmar's solar energy and wind resources are suitable for grid-connected large-scale electricity generation.

7. Electricity technology costs and efficiency of fuel conversion is considered in detail in this report. Cost and performance assumptions are based on the Consultants' extensive experience of Asian power plant costs and performance[1].

8. Optimization of a generation portfolio is a modern practice that relies on economic dispatching principles. The EMP is based on hourly economic dispatch, allowing for detailed modelling to 288 time periods. This level of granularity is important to capture the variable characteristics of the generation profiles of seasonal hydropower and intermittent renewable energy. A key planning criterion for electricity expansion planning is related to the security of the electricity system. Security is determined by the reserve capacity (spinning reserve or standby). Up until the 1990's reserve capacity was mostly set on a deterministic basis as a % of installed capacity. Economists were dissatisfied with this approach as the spare capacity could not be valued economic terms. With the advent of advanced computer tools, it became feasible to compute the Loss of Load Probability (LOLP). The associated Expected Unserved Energy could then be valued in strict economic terms and compared to the cost to find the trade-off point between security and cost. However, the LOLP approach is problematic in a hydro-dominated system where the impact of water limitations can far outweigh power plant unit failures. Accordingly for the EMP the reserve margin was set on a deterministic basis, allowing for the seasonal variations in hydropower output based on best available hydrological data and climate change projections.

[1] The Consultants' have previously worked with Poyry (China, Singapore, Thailand) and Parsons Brinckerhoff Asia (PB Power HK and PB Power Singapore) and have extensive experience in costing power plant developments in Asia and internationally.

III. Supply Side Options

9. The following section considers power plant development by fuel type. Fuel price projections are developed and presented. Finally, classical screening curves are developed for all technology options deemed suitable for Myanmar over the period of the planning horizon. Screening curves provide a hi-level appreciation of the relationship between costs and capacity factors of different technologies. Such appreciation supports the development of a range of potential planting schedules based on policy considerations.

C. Gas.

10. There are plans for construction of new gas power plants at various stages of development. If all planned projects are completed, the installed capacity of gas PPs will increase to 4,148 MW. If rehabilitation plans are successfully implemented, the available capacity of gas fired PPs would be 4,514MW.

Table III-1: Proposed Gas Fired Power Plants in Myanmar and Their Development Status

Station	Capacity (MW)	Type	Contraction		
Hlawga	541	GE	Local/ IPP	Phase 1	MOA/PPA
				Phase 2	MOA
			JV/IPP	Phase 1	MOU
				Phase 2	MOU
Ywama	292	52 GE + 240 GT	Local/IPP		MOA/PPA
Ahlone	121	82 GT + 39 ST	Local/IPP	Phase 1	MOA/PPA
				Phase 2	MOA/PPA
Thaketa	1,070	GE	Local/IPP		MOA/PPA
			JV/IPP	Phase 1	MOA
				Phase 2	MOA
			JV/IPP	Phase 1	MOU
				Phase 2	MOU
Mawlamyaing	200	GTCC	Local/ IPP	Phase 1	MOA/PPA
				Phase 2	MOA/PPA
Kanpouk (New)	525		Local/IPP or JV/IPP	Phase 1	MOU
				Phase 2	MOU
Ayeyarwaddy/ Yangon	500	GT	JV/IPP		MOU
Additional information:					
Kyaukphyu (new)	50	GT	**JICA assumption*		

Station	Capacity (MW)	Type	Contraction
Myin Guam	250	GTCC	*JICA assumption*
Kyause	100	GE, rental	*JICA assumption*
Hlaingtharyar	500		
TOTAL	**4,148**	**MW**	

Source: JICA report (2014)

11. The capital cost of a turnkey (EPC) delivery for a gas combustion plant significantly depends on the power plant capacity, its location, and delivery terms. Thus, a recent (2014) feasibility study carried out by the consultant for a location in Kazakhstan provided with CAPEX level of about 1,500 USD/kW for a 210 MW CCGT plant. On the other hand, a study carried out by PA Consulting Group for Singapore in 2010 defined CAPEX for a 423 MW CCGT plant to be only 850 USD/kW (890 USD/kW if adjusted by inflation to 2014). This notable difference is mainly explained by the equipment manufacture location (delivery to Kazakhstan would have been done from Europe), long transportation distances, transportation means involved (both by sea and then on-land in case of Kazakhstan), as well as by associated technical and country risks.

12. The CAPEX assumptions used for the current analysis for Myanmar take into consideration higher capacity of the considered CCGT units (650 MW) but also include project contingency which altogether leads to an estimated cost of 918 USD/kW for a power plant operating with 80 % capacity factor. The fixed operating cost is assumed at 1.8 % of CAPEX, and variable operating costs (other than fuel costs) being 0.59 USc/kWh. Lead time for a CCGT plant is assumed to be 2.5 years.

13. Costs for an open cycle gas combustion turbine are assumed to be 486 USD/kW (CAPEX including contingency), 1.2 % of total CAPEX for fixed operating costs, and 0.99 USc/kWh for variable operating costs (other than fuel costs). Open cycle gas power plant capacity factor in this study is 10 % (assuming that this power plant provides with capacity to cover peak loads). Lead time is assumed to be 1.5 years.

14. For both CCGT and open cycle power plants, low OPEX reflects low labour costs in Myanmar. Life time for the both types of gas power plants is set at 25 years.

D. Coal.

15. Myanmar possesses large coal reserves (230 million ton probable and 120 million ton possible). The largest reserves are in Kalewa region and central east of Myanmar (Maingsat). Coals are accessible for extraction but due to road conditions could be difficulties for their further transportation. Projects for infrastructure improvement are ongoing thus this factor may be mitigated in the future. However, the currently identified domestic coal resources are not sufficient for developing coal-based electricity generation capacities in thousands of megawatts as a 1000 MW coal fired base load plant would consume over its life around 90 to 100 million tons.

16. Myanmar coals are not of high quality and possess low calorific values (3 200 to 6 700 kcal/kg); however their low sulphur contaminant allows using them for power production. Modern technologies allow more efficient utilization of low-quality coals' potential.

17. A 300 MW coal-fired power unit would consume around 1 to 1.3 million tons of coal annually (depending on type of plant and calorific value of coal). Therefore, over the life of 30 years the coal supply amounts to 30 to 39 million tons. The largest coal reserve currently listed is Maingsat in Shan

State with a capacity of 118 Mtons of probable lignite to sub-bituminous and 4 Mtons of possible sub-bituminous coals. The largest deposit of sub-bituminous coals is at Kalewa in Southern Sagaing Division with total capacity of 87 Mtons, 5 Mtons of which are positive, 18 Mtons are probable and 65 Mtons are possible. These reserves do not suffice for large scale power development, for example in the range of 1,000 MW supercritical power units, currently typical in the People's Republic of China (the PRC). Therefore the development of coal based power should be carried out in synchrony with the mining development so that capacities of mine mouth plants are properly dimensioned to match the proven and probable resources.

18. There are indicators that environmental and social approaches in developing new coal-fired power plants projects are not completely adequate. More attention shall be paid to these issues while developing future power plants. Three types of coal-fired power units have been selected as representative for Myanmar's future coal capacity, namely 600 MW supercritical, 150 MW circulating fluidized bed, and 50 MW pulverized coal fired unit. Cost and operational parameters have been defined for these three representative units for further analysis and expansion planning.

19. At the present time Myanmar operates only one coal-fired power plant at Tigyit. The plant is of 120 MW installed capacity but operates at only 27 MW due to inadequate maintenance. The plans for its rehabilitation have not yet been approved. Data on plans for new coal-fired PPs is somewhat undefined. MOM and MEP have announced three projects with total installed capacity 876 MW (Kalewa, Yangon and Tanintharyi).

20. MoM and MoEP have announced three projects with total installed capacity 876 MW (Kalewa, Yangon and Tanintharyi). The JICA 2014 study, referring to Hydropower Generation Enterprise, provides information for 11 projects with a total capacity of 15 GW. All projects were expected to be developed by the private sector by both domestic and foreign investors. Some projects included a provision that 50 % of the generated electricity would be exported to neighbouring countries.

- Yangon PP (270 MW) in 2013;
- Kalewa PP (600 MW) in 2014;
- Tanintharyi (6MW) in 2015.

21. In 2014 JICA, referring to an interview with the Hydropower Generation Enterprise[2] (HPGE), concluded that plans for expansion of the coal sector were wider – see Table III-2 for details and Figure III-1 for schematic representation of locations of the planned generation projects.

Table III-2: Candidate Projects of Coal-Fired PPs

NN	Location	Planned capacity	MOU signed
Yangon Region			
1	Htan Ta Bin Township, Near Kukowa River	2 x 135 MW (1st Phase) 2 x 135 MW (or) 1 x 300 MW (2nd Phase)	11.2.2010
2	Kyun Gyan Gon Township, Thoung Khon Village	2 x 150 MW (1st Phase) 2 x 300 MW (2nd Phase)	24.8.2012

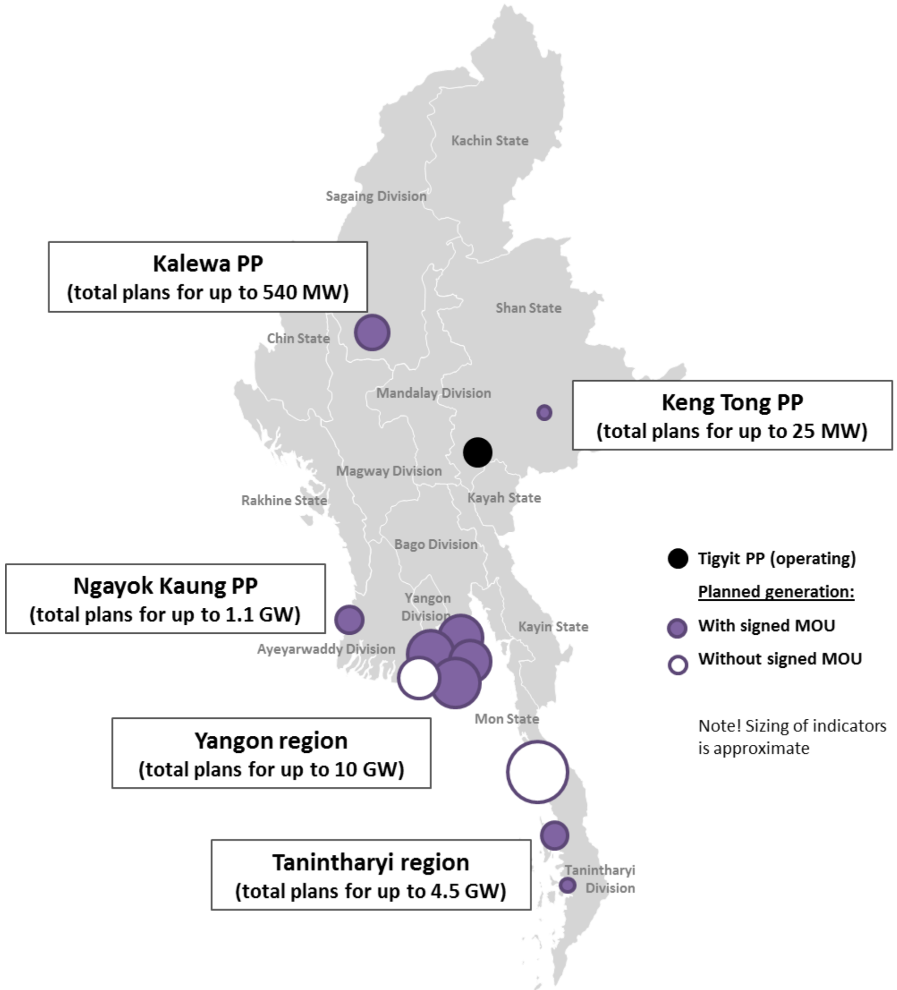
[2] Scope of work of the Hydropower Generation Enterprise also includes coal-fired thermal generation

NN	Location	Planned capacity	MOU signed
		2 x 600 MW (3rd Phase)	
3	Thilawa Industrial Zone	650~1200 MW (1st Phase) 1200~2000 MW (2nd Phase) 3000 MW (3rd Phase)	21.3.2013
4	Kyauk Tan Township, Chaungwa Village	2 x 250 MW	8.10.2013
5	Htan Ta Bin Township, Shwe Lin Ban Industrial Zone	1 x 350 MW (1st Phase) Total 1,050 MW	no - at the MOU proposal stage
Sagaing Region			
6	Kale District, Kalewa Township	2 x 135 MW (1st Phase) 2 x 135 MW (2nd Phase)	27.5.2010
Tanintharyi Region			
7	Myeik Township, Lotlot Village	1 x 50 MW	27.7.2012
8	Kawthaung District, Bokpyin Township, Manawlone	1 x 250 MW (1st Phase) 1 x 250 MW (2nd Phase)	21.9.2012
9	Dawei Special Economic Zone	1 x 400 MW (1st Phase) 2 x 1800 MW(2nd Phase)	no - at the MOU proposal stage
Ayeyarwady Region			
10	Ngayok Kaung	2 x 270 MW (or) 2 x 300 MW	11.4.2013
Shan State			
11	Keng Tong	25 MW	1.10.2013

Source: JICA report, 2013

22. Whilst many proposed projects in have large units at a later stage, the first phases of proposed plants call for 25 MW, 50 MW, 135 MW, 250 MW, 300 MW and 400 MW units to be built.

Figure III-1: Locations of New Coal-Fired Generation



Source: JICA report, 2013

23. The major coal based technologies that are available today globally at various stages of development include (i) conventional pulverized coal combustion (PC), (ii) circulating fluidized bed combustion (CFB), (iii) supercritical (SC) and ultra-supercritical (USC) PC combustion, and (iv) integrated gasification combined cycle (IGCC). There are also add-on technologies that can be combined with some or all of the mentioned technologies to improve environmental performance of coal combustion. Among them are carbon capture and storage (CCS) technologies either as a retrofit to running power plants or as part of the new ones. CSS technologies have not yet been commercialized.

24. There is limited experience of coal fired units in Myanmar's power industry, and there is not a large scale for coal-based power foreseen in Myanmar, it is believed the choice of technologies can be limited to PC, SC, USC and CFB technologies. IGCC technology, whilst already demonstrated in several plants, is not yet fully commercial and competitive in comparison to PC technology. Not only that the capital cost of IGCC technology is high, the technology is perceived to involve unquantifiable operating risks. Furthermore, the advances in PC combustion through substantial efficiency gains achieved with SC and USC technologies have overall reduced interest in IGCC technology.

25. USC and SC plants are already commercially available, cost effective, and there is rapidly accumulating worldwide operational experience of them. Steam parameters of typical sub-critical power plants are 150 to 180 bar pressure and 540 to 565 ºC temperature; SC plants operate at around 245 bar pressure and 540 to 570 ºC temperatures, and USC plants have temperatures of around 600 ºC or higher. Supercritical pressure is reached at 221 bar, above which level water/steam reaches a state where there is no distinction between liquid and gaseous state. Consequently the boiler does not need to separate steam from water and the substance is heated in a once-through process.

26. The design efficiencies of USC plants are between 39% and 46%. This stands in an apparent contrast with the typical efficiencies of 30% to 37% of the conventional PC and CFBC technologies. However, it should be noted that the SC and USC technologies have not yet been designed for high ash and low grade coal. Therefore, large SC and USC plants can be an option primarily for large IPPs on the coast depending on imported bituminous or higher NCV sub-bituminous coal.

27. CFBC technology is mature and offers many benefits in Myanmar conditions. Compared to traditional PC technology, CFBC is less sensitive to coal quality variation, allows mixing various kinds of coals, and provides opportunity to low-cost solution for the reduction of SO2 and NOx emissions. It is believed that for Myanmar, CFBC technology is commendable in the unit capacity range below 300 MW.

28. These considerations lead to the emergence of three types of coal-fired power units as more fitting with Myanmar's future coal capacity, namely 600 MW supercritical, 150 MW circulating fluidized bed, and 50 MW pulverized coal fired unit. Cost and operational parameters are defined in this report for these three representative units for further analysis and expansion planning.

29. The 600 MW SC unit represents future IPPs which are planned on the coast to serve both exports and domestic demand and rely on imported coal. The 150 MW CFBC unit represents a typical coal fired unit whether mine-mouth combusting low-quality lignite or IPP on the coast which is built in multitude of stages of 150 MW and uses either imported or locally produced coal. The 50 MW PC represents a typical mine-mouth unit designed for a designated coal.

30. The capital costs assumed here range from 1300 $/kW to 2300 $/kW from the largest 600 MW SC plant to the smallest PC unit of 50 MW. The plant own use of electricity has been estimated to range from 7 % and 8 % to 10%, and plant efficiencies from 41 %, 35 % and 33 %, respectively from largest unit to the smallest.

31. It should be noted that the plant capital costs vary significantly country-by-country. The cost levels are considerably lower in the PRC than those in OECD countries including Japan and Korea. IEA data from 2010 collected for SC and USC plants, so called overnight costs, which exclude construction time interest, and were expressed in 2008 US dollars calculated on the net capacities, ranged from 800 $/kW to 3,500 $/kW whilst the median cost was at around 2,100 $/kW. The costs in the Chinese domestic market were between 600 $/kW and 700 $/kW.

32. The cost estimates chosen here are clearly higher than the costs in China but lower than the median costs reported by IEA in 2010. The cost levels provided by mainly Chinese EPC contractors in South-East Asia have been used as a reference. There is no economy of scale in the domestic market of Myanmar and each project should be considered a stand-alone site. Even though some plants would be of standard design, Myanmar will face a local first-of-kind phenomenon, whereby project faces risks as to experience of local contractors and labour. With not many large projects to construct annually in Myanmar, there are no major domestic contractors experienced in implementing large subcontracts for power projects.

33. With the above issues in mind, this study assumes gradually increasing unit costs over the planning period. The first power plants in the expansion plan are assumed to have lower specific costs than the later units of the same kind due to real-term increase of relevant raw material prices and labour costs.

34. Key assumptions pertaining to the power plant costs are summarized as follows:

Table III-3: Power Plant Cost Assumptions for Expansion Planning

Plant Type Example	Efficiency	CAPEX US$/kW	Fixed O&M % of CAPEX	Variable O&M USc/kWh	Typical Fuel
Supercritical 600 MW	41 %	1,300	2.0 %	0.31	Bituminous
Fluidized-Bed 150 MW	35 %	1,800	2.5 %	0.33	Sub-bituminous
Pulverized Coal 50 MW	33 %	2,300	3.0 %	0.35	Lignite

E. Oil.

35. The reserve plant could be fuelled by fuel oil. The engines would be capable of accepting gas or oil fuel. The cost of the engines would be the same as for gas engines and were discussed above under the Gas section.

F. Type 1 Renewables - Hydropower.

36. The hydropower plants, which are currently under construction, are listed in Table III-4. All plants in the list are planned to be commissioned by end of financial year 2020/21. Out of the total capacity of 2,143 MW, 1,994 MW (93 %) are developed by MOEP or MOAI.

37. Overall, there is a major uncertainty with respect to project development and the timing of the plant commissioning. During recent years, several projects, which have started construction, have progressed slowly because of either financial or technical difficulties encountered during the project. Construction times have extended from the typical 4 to 8 years so that many projects, now under construction, have anticipated construction periods up to 13 years.

38. As of July 2014, among the listed projects, the largest one, Shweli 3 of 1,050 MW, has not yet secured full financing although work on site has commenced with infrastructure and civil works. Debt financing from overseas remains open. Progress of civil works on Upper Kengtawng project has been impacted by fiscal limitations. Financing for Middle Paunglaung 100 MW project has not yet been closed. Technical concepts for the Tha Htay 111 MW project in Western Myanmar were changed during construction, which caused delay in the project schedule.

Table III-4: Hydropower Project by Investment Category 2014-2020

Station Name	Location	Capacity	Energy	Construction Period (Year)	
		MW	MWh	Start	On-line
		Investments by MOEP			
Phyu	Bago	40	120,000	2001	2015
Upper Paunglaung	Mandalay	140	454,000	2004	2015

Station Name	Location	Capacity	Energy	Construction Period (Year)	
		MW	MWh	Start	On-line
Upper Kengtawng	Shan	51	267,000	2008	2018
Upper Yeywa	Shan	280	1,409,000	2010	2019
Thahtay	Rakhine	111	386,000	2005	2019
Middle Paunglaung	Mandalay	100	500,000	2014	2019
Shweli 3	Mandalay	1,050	3,400,000	2010	2020
Dee Doke	Mandalay	66	297,600		2020*)
Sub-total		***1,838***	***6,833,600***		
		Investments by MOAI			
Upper Bu	Magway	150	334,000	2006	2016 *)
Kaingkan	Shan	6	22,000*)		2016 *)
Sub-total		***156***	***354,000***		
		Domestic entrepreneurs on BOT basis			
Baluchaung 3	Kayah	52	334,000	2008	2015
Upper Baluchaung	Shan	30	135,000	2010	2017
Ngot Chaung	Shan	17	63,000*)		2020*)
Mong Wa	Shan	50	184,000*)		2020*)
Sub-total		***149***	***716,000***		
TOTAL		**2,143**	***7,903,600***		

**) Data not available. Consultant's estimates for planning purposes. Energy by uniform capacity factor of 42%*

39. In 2012, MOEP completed an assessment of hydropower opportunities which indicated that there are as many as 92 potential sites for hydropower development, each having capacity greater than 10 MW. The MOE Energy Statistics Review of 2013 indicated that these hydro sites have been grouped into 60 potential hydro projects including 10 projects that are in various stages of development. Similarly as many as 210 sites for small and medium size plants each with capacity of less than 10 MW with a total potential installed capacity of 231 MW have been identified.

40. About 46 GW of new hydro capacities were planned until 2030 and beyond. Unlike earlier, when most of the existing plants as well of those currently under construction, belonged to MOEP or MOAI, major part of plants in the list for long-term development are planned to be built under a JV/BOT arrangement by foreign investors and domestic private entrepreneurs.

41. During recent years private and foreign project developments in Myanmar have become subject to higher level of scrutiny by the public and media, and even direct opposition by various interest groups and stake holders. A large Myitsone dam project in Kachin state was suspended in 2011 and is today considered as cancelled. It was part of agreements signed in 2007 with Chinese companies about their participation in the development of seven major hydropower projects on the confluence of the Ayeyarwaddy River and the Mali and the Mai Rivers in Kachin State. The total capacity of these developments is 13,360 MW. Two other projects from the 2012 list of MOEP (Mawlaik, 520 MW and Belin 280 MW) have also been cancelled.

42. The draft National Electricity System Masterplan issued in 2014 by JICA includes a thorough review of the hydropower prospects and their status as of June 2013. The JICA study highlighted some potential concerns over the environmental and social impacts related to large dams. The study therefore outlined two scenarios, in which large hydropower developments were minimized and replaced by coal and gas fired power station respectively, and in both scenarios by increasing amount of small and medium size hydropower.

43. EMP Consultant requested MOEP to list prospective projects for future expansion. MOEP's list of preferred hydropower opportunities are shown in Table III-5. This list of projects is used in the continuation as the base hydropower option for expansion planning.

Table III-5: Hydropower Prospects in 2021-2025 and 2026-2030

Station Name	Location	Installed Capacity	Myanmar Capacity	Estimated Annual Energy	Developer's Status
	State/Region	MW	MW	MWh	
		Years 2021-2025			
Middle Yeywa	Shan	320	320	1,438,080*)	MOEP
Bawgata	Bago	160	160	500 000	MOEP
Upper Thanlwin (Kunlong)	Shan	1400	700	7,142,000	JV
Naopha	Shan	1200	600	6,182,000	JV
Mantong	Shan	225	225	992,000	JV
Dapein (2)	Kachin	140	84	641,700	JV
Shweli (2)	Shan	520	260	2,814,000	JV
Sub-total		**3,965**	***2,349***	***19,709,780***	
		Years 2026-2030			
Nam Tamhpak	Kachin	200	100		JV
Gaw Lan	Kachin	100	50		JV
Hkan Kawn	Kachin	160	80		JV
Lawngdin	Kachin	600	300		JV
Tongxingqiao	Kachin	340	170		JV
Keng Tong	Shan	128	64		JV
Wan Tan Pin	Shan	33	17		JV
So Lue	Shan	160	80		JV
Keng Yang	Shan	40	20		JV
He Kou	Shan	100	50		JV
Nan Kha	Shan	200	100		JV
Namtu (Hsipaw)	Shan	100	50		BOT
Mong Young	Shan	45	22		not specified

Station Name	Location	Installed Capacity	Myanmar Capacity	Estimated Annual Energy	Developer's Status
	State/Region	MW	MW	MWh	
Dun Ban	Shan	130	65		not specified
Nam Li	Shan	165	82		not specified
Nam Khot	Shan	50	25		not specified
Taninthayi	Taninthayi	600	600		not specified
Upper Sedawgyi	Mandalay	64	64		MOAI
Sub-total		***3,215***	***1,939***		***716,000***
TOTAL (2021-2030)		***7,180***	***4,288***		***7,903,600***

**) Estimated CF 51% **) Estimated CF 42%*

44. The hydropower expansion plan excludes a number of projects included in the previous plans. The excluded projects are listed below. Many of those are large projects, which would involve mainstream dams in Myanmar's major rives and are therefore more environmentally and socially sensitive than those listed above. No projects in the Chindwin river system are included. The exclusion of some projects, however, is not an indication that this study would have regarded them not-feasible or environmentally or socially controversial. The prospects should be considered to remain in the pipeline for the case the demand growth necessitates and government strategy calls for more hydropower to be developed. Should there be need to re-prioritize projects, their economic and social merits should be independently weighed against their possibly negative social and environmental impacts.

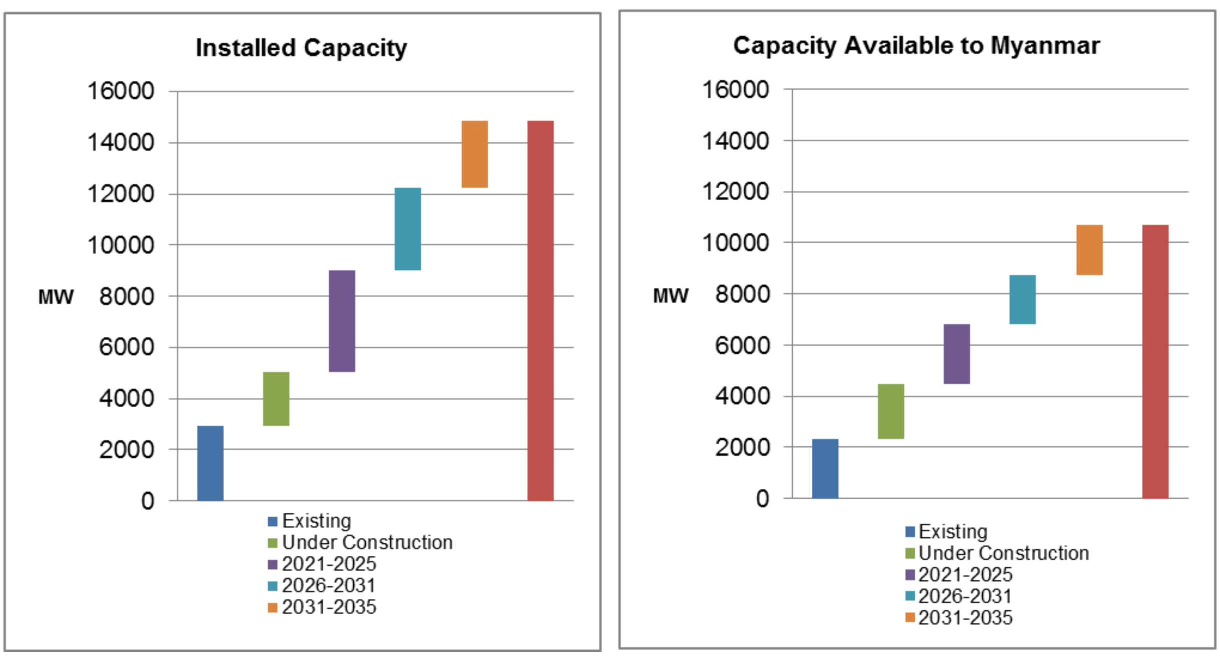
Table III-6: Large Hydropower Prospects

	No	Name of the plant	Owner	Installed	
				Total	Myanmar
				MW	MW
Very Large Projects	1	Chipwi	JV, JVA	6000	1700
	2	Wutsok	JV, JVA	1800	900
	3	Kaunglangphu	JV, MOA	2700	1350
	4	Renam (Yenam)	JV, MOA	1200	600
	5	Hpizaw (Pisa)	JV, MOA	2000	1000
	6	Laza	JV, JVA	1900	950
	7	Upper Thanlwin (Mongton)	JV, MOA	7110	3555
	8	Hutgyi	JV, MOA	1360	680
	9	Yawathit (Thanlwin)	JV, MOA	4000	2000
		Sub-Total Large		**28070**	**12735**
Small and Mediu	1	Wu Zhongzhe	JV, MOA	60	30
	2	Sinedin	JV, MOA	76.5	38.25

No	Name of the plant	Owner	Installed	
			Total	Myanmar
			MW	MW
3	Lemro (Laymyo)	JV, MOA	600	300
4	Lemro 2	JV, MOA	90	45
5	Htu Kyan (Tuzhing)	JV, MOA	105	52.5
6	Hseng Ne	JV, MOA	45	22.5
7	The Hkwa	JV, MOA	150	75
8	Palaung	JV, MOA	105	52.5
9	Bewlake	JV, MOA	180	90
10	Manipur	JV, MOA	380	190
	Sub-Total Others		**1791.5**	**895.75**

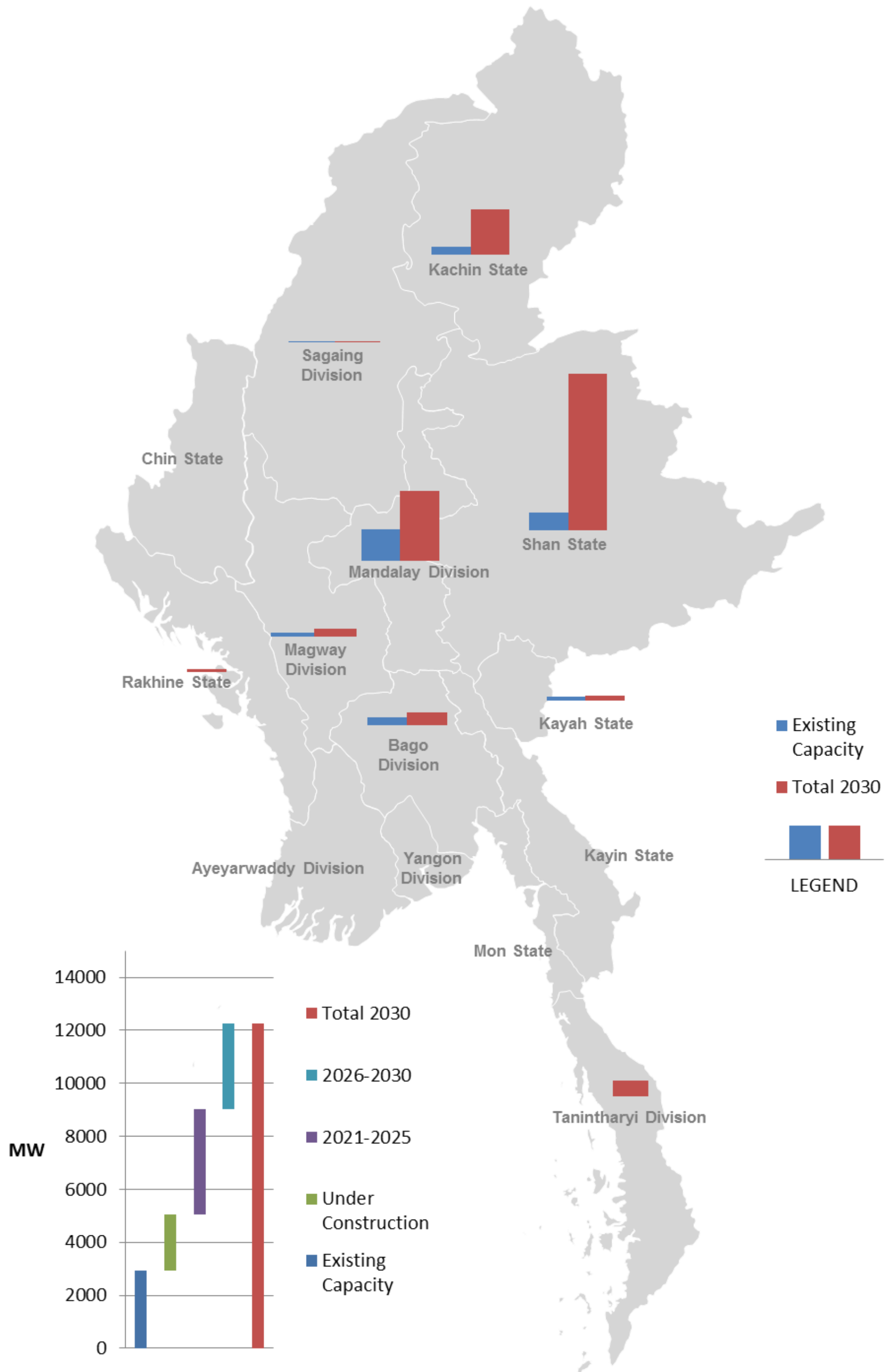
45. The base case for expansion plan has total installed capacity of 14,842 MW in 2035. The installed capacity to Myanmar, after the assumed 50 % export share of IPPs with foreign investments has been extracted, is 10,690 MW. Major part of the new hydropower schemes are located in the Shan State and include that electricity is exported to Thailand or China. Most new schemes in the Kachin State are developed in partnerships with Chinese companies. Major hydropower schemes not having an assumed export obligation include Shweli 3 (1,050 MW), which is under construction, Middle Yeywa (320 MW) and Mangton (225 MW) in the Shan State, Bawgata (160 MW) in the Bago Division, and Taninthayi (600 MW) in the South of Myanmar.

Figure III-2: Base Case Hydropower Expansion (Installed Capacity) until 2035



Source: Consultant's Analysis

Figure III-3: Base Case Hydropower Expansion (Installed Capacity) until 2030



Source: Consultant's Analysis

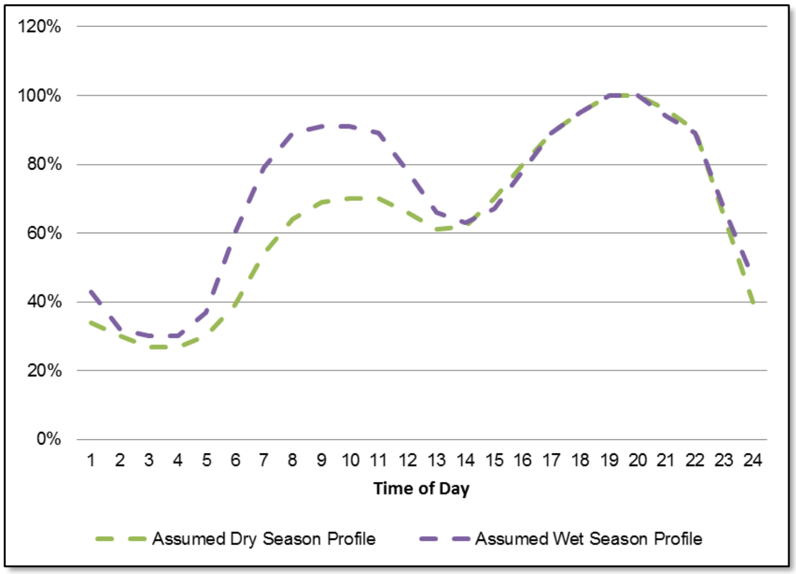
46. The availability of hydropower capacity was considered carefully in light of MoEP concerns regarding the constraints on hydropower in the dry season. Seasonal production of each plant, capacity factors and available hydrological data were considered in establishing hourly, daily and monthly production profiles. Moreover the impact of solar PV resources in supporting storage of water during the day time in reservoir schemes, particularly in the dry season, was considered. The hydropower profiles developed for the purpose of expansion planning are shown for the wet and dry seasons in the following table and figures:

Table III-7: Daily Production Profiles by Season

	DRY	% of max		WET	% of max		May/Dec
	DAILY	Adjusted	Share %	DAILY	Adjusted	Share %	average
1	42%	34%	2.2 %	61%	43%	2.5 %	2.4 %
2	41%	30%	2.0 %	57%	32%	1.9 %	1.9 %
3	39%	27%	1.8 %	54%	30%	1.8 %	1.8 %
4	39%	27%	1.8 %	56%	30%	1.8 %	1.8 %
5	47%	30%	2.0 %	63%	37%	2.2 %	2.1 %
6	60%	39%	2.6 %	78%	60%	3.5 %	3.0 %
7	71%	54%	3.5 %	95%	79%	4.6 %	4.1 %
8	81%	64%	4.2 %	97%	89%	5.2 %	4.7 %
9	81%	69%	4.5 %	99%	91%	5.3 %	4.9 %
10	88%	70%	4.6 %	100%	91%	5.3 %	5.0 %
11	89%	70%	4.6 %	98%	89%	5.2 %	4.9 %
12	84%	66%	4.3 %	88%	78%	4.6 %	4.4 %
13	78%	61%	4.0 %	77%	66%	3.9 %	3.9 %
14	75%	62%	4.1 %	79%	63%	3.7 %	3.9 %
15	80%	70%	4.6 %	79%	67%	3.9 %	4.3 %
16	76%	80%	5.2 %	88%	78%	4.6 %	4.9 %
17	80%	89%	5.8 %	92%	89%	5.2 %	5.5 %
18	93%	95%	6.2 %	94%	95%	5.6 %	5.9 %
19	98%	100%	6.5 %	95%	100%	5.9 %	6.2 %
20	100%	100%	6.5 %	94%	100%	5.9 %	6.2 %
21	100%	96%	6.3 %	89%	94%	5.5 %	5.9 %
22	93%	90%	5.9 %	80%	89%	5.2 %	5.6 %
23	72%	65%	4.3 %	69%	67%	3.9 %	4.1 %
24	59%	40%	2.6 %	61%	47%	2.8 %	2.7 %

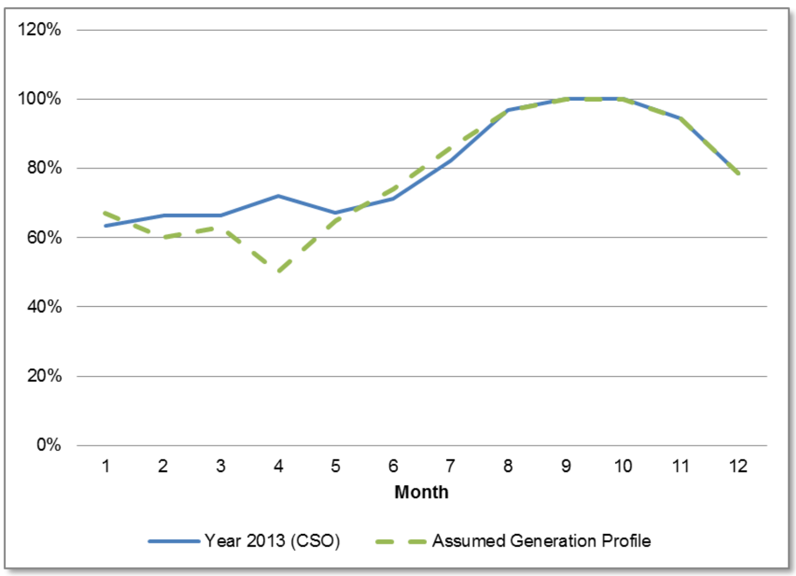
Source: MoEP (per datapack issued by the Consultant)

Figure III-4: Daily Hydropower Generation Profiles (% of the Daily Peak Demand MW)



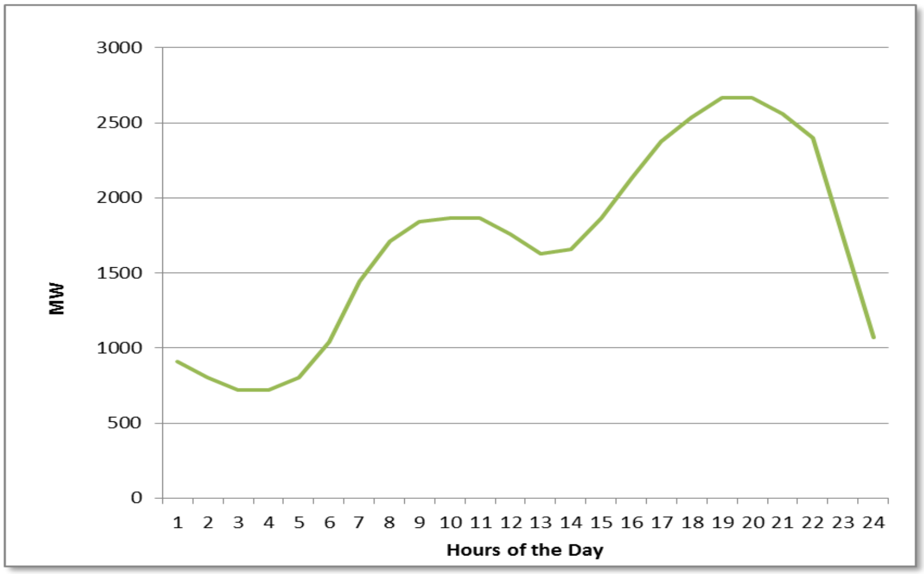
Source: Consultant's analyses of existing HPPs and hydrological data

Figure III-5: Monthly Hydropower Generation Profiles (% of the Season Peak Demand MW)



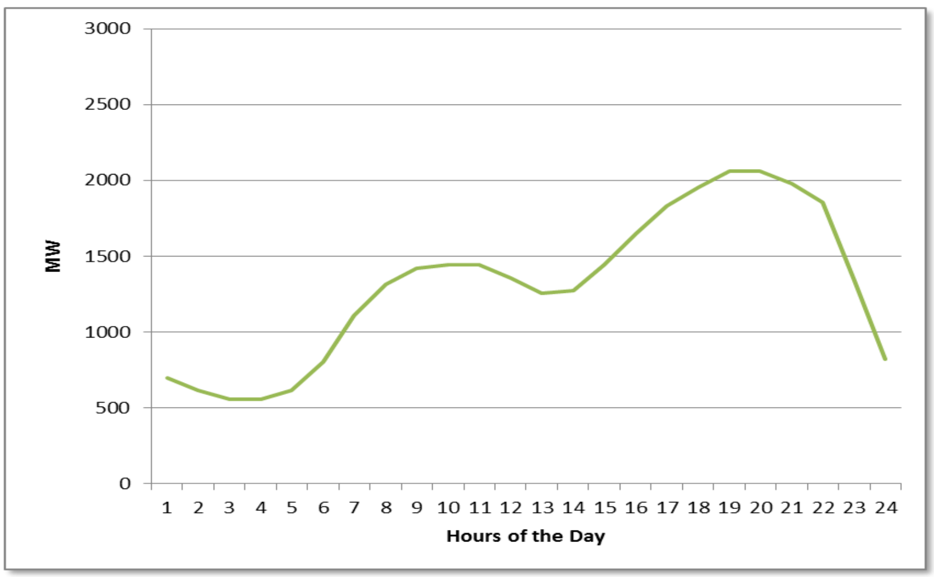
Source: Consultant's calibration against reported HPP production (CSO 2013)

Figure III-6: Monthly Hydropower Generation Profile – January (Wet Season)



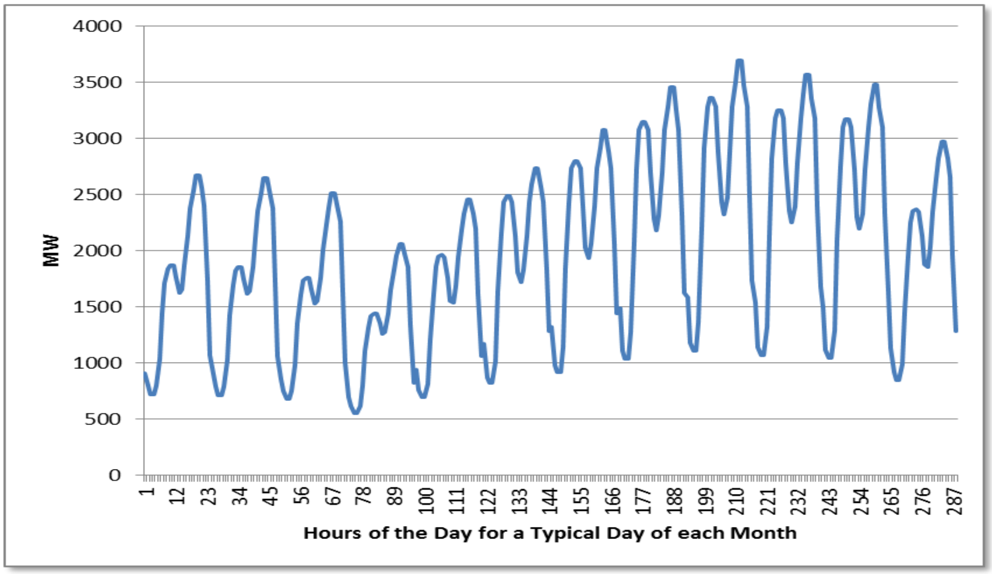
Source: Consultant's model

Figure III-7: Monthly Hydropower Generation Profile – April (Dry Season)



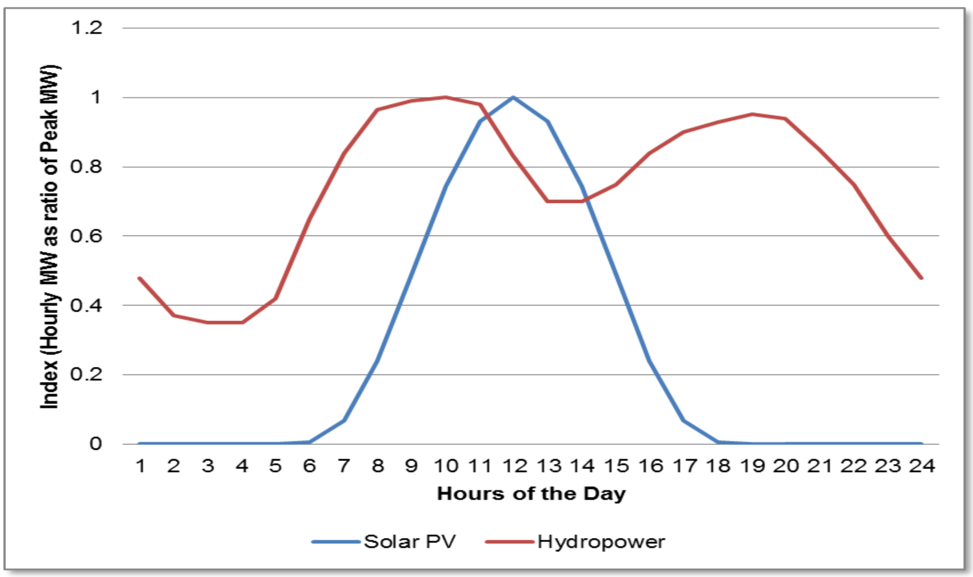
Source: Consultant's model

Figure III-8: Annual Hydropower Generation Profile (Typical Day for each Month)



Source: Consultant's model

Figure III-9: Solar Power & Hydropower Balancing Potential



Source: Consultant's model

G. Type 1 Renewables - Solar PV

47. The PV technology in utility-level applications can be divided to classes roughly by two important technical parameters. One is whether the project uses crystalline-silicon (c-SI) modules or amorphous Si thin film modules. The second dimension is whether or not the modules are mounted at a fixed-tilt or on a tracking system. Due to mass production and fierce competition typical residential

PV systems based on crystalline-silicon (c-SI) modules challenge well the amorphous Si thin film modules, which used to be more common and economical in earlier utility scale applications from 2005 to 2010. The system costs have since then converged.

48. As to the tracking system, it represents an additional cost but provides a higher energy yield. One-axis tracking, although it increases capital costs by 10 % to 20 %, can be economically attractive because of the increase in energy-production (20 % to 30 % more kWh/kW/year in areas with a good solar resource).3

49. A recent study by Lawrence Berkeley National Laboratory in the USA gathered cost and price data for 202 utility-scale (i.e. ground-mounted and larger than 2 MW) solar projects in the USA totalling more than 1,735 MWAC, of which 194 representing 1,544 MWAC consisted of PV projects.[4] Important observations were made on recent cost trends. The clear convergence in the average price of c-Si and thin-film projects was observed. The development is due to declined price of silicon combined with global excess of c-Si module manufacturing capacity. The economies of scale appear to diminish considerably when the system capacity goes beyond 5-10 MW. Overall, the system prices had fallen from around 5,600 $/kW of the period of 2007-2009 to 3,900 $/kWh on average for projects completed in 2012. Anecdotal evidence was given about cost reductions continuing to 2013-2014 to the extent that a large US project had reported an installed price of 2,030 $/kW to the regulator.

50. The operation and maintenance (O&M) costs reported in the USA appear to be in the range of 20 to 40 $/kW, or 10-20 $/MWh. These represent approximately 0.5 % to 1 % of the installed capital cost annually. The O&M costs are related to module cleaning, panel repairs and replacements, vegetation control, maintenance of mounting structures, and maintenance of the power system covering inverters, transformers, switchgear, internal wiring and grid connection. Part of the maintenance is labour intensive and therefore lower costs can be assumed in Myanmar than the US reference.

51. A Memorandum of Understanding was recently signed between MOEP and US investors of a solar PV project to Myanmar. The project consists of two 150 MW facilities, one in Nabuai and the other in Wundwin, both locations in Mandalay Region. The published project cost is 480 m$, equal to 1,600 $/kW. The targeted commissioning of the project is in 2016. Also a Thai company has been pursuing a 50 MW solar power plant in Minbu in Magway Region.

52. The cost assumptions made here are 2,100 $/kW for a solar PV plant operating on average at 20 % capacity factor. The capacity factor is highly site and project technology specific, including whether or not the project uses tracking devices. The operation cost is assumed at 0.4 % of CAPEX reflecting low labour cost of Myanmar.

53. Another solar power technology is Concentrated Solar Power (CSP) that uses mirrors to focus sunlight to either vertical pipes (parabolic troughs) or to a single point tank (solar tower), in which heat transfer fluid, typically water or oil, is heated and led further to evaporate steam for an ordinary thermal power process. This technology allows heat storage and scale, which is suitable for utility operations, typically from 50 to 100 MW. There are competing technological development lines for CSP including parabolic trough, tower systems, linear Fresnel and dish Stirling.

54. A CSP plant with the heat storage provides the benefit of higher dispatchability than a PV plant,

[3] IRENA Cost Analysis Series 4/5, Solar Photovoltaics, International Renewable Energy Agency, 2012

[4] Utility-Scale Solar 2012, An Empirical Analysis of Project Cost, Performance, and Pricing Trends in the United States, Authors: Mark Bolinger and Samantha Weaver, Lawrence Berkeley National Laboratory, the USA, September 2013

albeit at higher capital costs typically over 5,000 $/kW. With thermal storages CSP plants can extend power supply to the evening hours, which are often also peak hours of the system. However, as Myanmar's power system is dominated by hydropower, this feature is of lesser importance. As mentioned earlier, hydropower can be used for hourly-level regulation so that the energy supplied by solar systems during day-time can be effectively stored by the hydropower system and utilized in the evening. Therefore, CSP technology is not considered prospective in Myanmar over the planning period of this study.

H. Type 1 Renewables - Wind

55. Global wind power has also seen a substantial reduction in initial capital costs of wind farms. There has been continuous up scaling in the unit sizes of wind turbines so that the current standard in many European markets seems to be around 3 MW. Another major factor in cost reductions has been that Chinese and Indian turbine manufacturers have consolidated their place in the international market place. Around half of the wind turbine cost is in the installation and farm infrastructure. They include grid connection costs, farm internal power network, track and crane pad, foundation survey, design and ground works. In these areas, the low cost of labour has some significance to the costs. In this study, grid-connected wind onshore in about 100 MW class will be assumed to operate at a capacity factor of 30 %, and the CAPEX is assumed at 1,360 $/kW, OPEX at 0.8 % of CAPEX annually and the project lead time in two years.

I. Fuel Price Projections

Table III-8: Base Fuel Costs and Prices Used for Expansion Planning

Fuel type	Unit	Value	Date & Source
Crude oil	US$/bbl	108.01	June 2014, Crude oil, Dubai (WB Commodities Price
	Kyat/bbl	105,202	Data (the Pink Sheet))
Diesel	US$/l	0.82	META method: crude oil price x 120%
	Kyat/gal	3,631	
Fuel oil	US$/kl	441.59	META method: crude oil price x 65%
	Kyat/gal	1,955	
Gasoline	US$/l	1.30	India, 14.7.2014
	Kyat/gal	5,756	http://www.globalpetrolprices.com/India/gasoline_prices/
Natural Gas	US$/mmbtu	10.62	Consultant conversion from June 2014, Natural Gas,
	Kyat/mmbtu	10,344	LNG Japan (WB Commodities Price Data (the Pink Sheet)) considering LNG gasification, regasification and transport.
Coal - lignite	US$/ton	45	Consultant
	Kyat/ton	43,830	
Coal -	US$/ton	75	Platts, Coal Trader International
Sub-bituminous	Kyat/ton	73,050	Consultant
Coal - Bituminous	US$/ton	93	Consultant

Fuel type	Unit	Value	Date & Source
	Kyat/ton	90,582	
Biomass	US$/ton Kyat/ton	82.88 80,725	India, Biomass Briquettes Fuel (Sawdust, Cane Waste) as per 18.7.2014, http://www.biomassbriquettesystems.com/listings Reference firewood 250 Kyat per viss i.e. 1.63293 kg, equivalent of 157 US$/ton,
Average electricity price	US$/kWh Kyat/kWh	0.09 88	Myanmar: average over the range of 0.08 - 0.10 $/kWh "The Rise of Distributed Power" by Brandon Owens, 2014, GE Company

56. Assumed heating values for fuels are typical for the region where Myanmar is located and are presented in the table below.

Table III-9: Heating Value of Fuels, kJ per unit

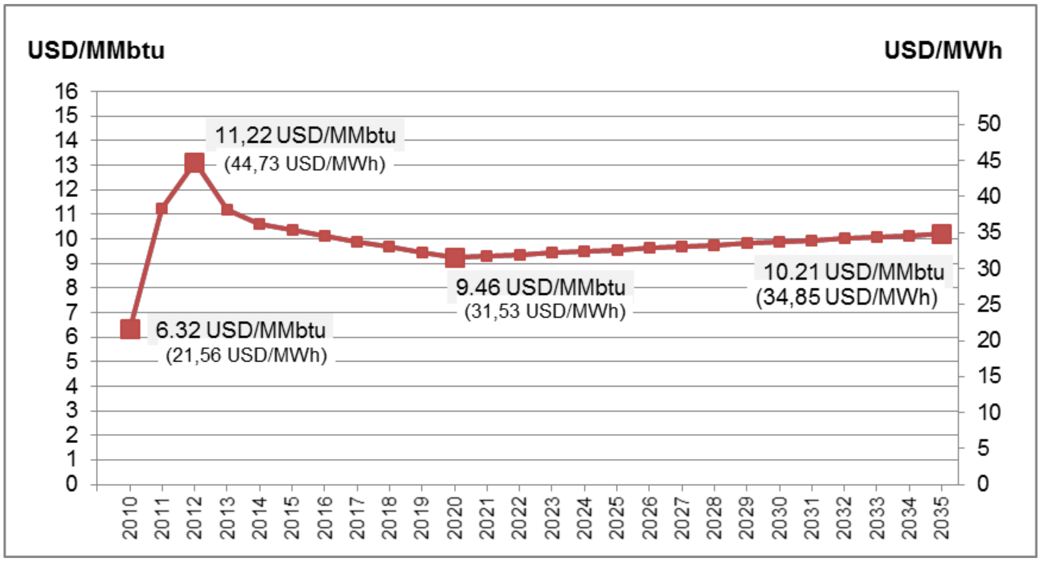
	Unit	Heating value
Crude oil	MJ/l	38.50
Diesel	MJ/l	35.80
Fuel oil	MJ/l	38.90
Gasoline	MJ/l	32.10
Natural Gas	MJ/m^3	37.26
Coal – lignite	MJ/ton	14,655
Coal - Sub-bituminous	MJ/ton	23,029
Coal – Bituminous	MJ/ton	25,122
Biomass	MJ/ton	13,500

Source: Consultant's assumption based on various sources

57. Growth rates for fuel prices are based on Current Policies Scenario forecast in World Energy Outlook 2013 prepared by the International Energy Agency (IEA). It is assumed that crude oil and coal prices will continue to grow over the following 11 years, while natural gas price will decline during the next 6 years but thereafter the prices would start to moderately recover (see the table below). Electricity price is expected to grow over the whole forecast horizon.

58. The assumed gas price has been based on the Japan Liquefied Natural Gas Import Price (Ycharts 2010 to 2013), with subtraction of 5 USD/MMbtu for LNG gasification, regasification and transport costs that are not relevant for Myanmar's domestic gas consumers. This reference price is used as a proxy of the economic value of domestic gas and it reflects well the realized export prices of the same periods. The gas price forecast from 2014 to 2030 has been based on the IEA forecasts (on reduction of the gas price by 13 % till 2020, and its further recovery at 3.4 % during every five years). The base gas price and results of the forecasts are presented in the Figure III-10 below in two units for reader's convenience.

Figure III-10: Natural Gas Price Forecast for Myanmar



Source: Japan Liquefied Natural Gas Import Price (Ycharts 2010-2013), IEA, consultant's calculations

59. IEA sees that coal demand trends diverge across regions. Growth in coal production over 2011-2035 comes mainly from non-OECD countries, with India, Indonesia and China accounting for 90 % of incremental coal output. Whilst the three countries are all major producers, they are also the large consumers with India and China using vast majority of own coal domestically. Australia is the principal OECD country with higher production, and therefore price references have been sought from Australian coal which is traded throughout South-East Asian region. Coal resources will not be a constraint for many decades, yet the cost of supply is likely to increase moderately in real terms as a result of rising mining and transportation costs as well as forecast tightening supply/demand balance. The Current Policies Scenario of IEA does not reflect any measures which would limit the use of coal, other than those measures and policy trends that are already visible.

60. Whilst the New Policies Scenario has coal prices to grow in real terms approximately 10 % from the current levels to 2035, the so called 450 Scenario, which is most determined with respect of climate change mitigation efforts, sees 25 % reduction in coal prices under the pressure of declining demand. It is considered here, however, that the Current Policies Scenario, which extends the currently prevailing global trends, and has an in-built assumption of increased coal consumption which causes increasing prices, is a conservative assumption for a country that would depend on coal imports, if it were to decide to enter the path of building substantial amounts of coal based electricity generation capacity. The reference is made to this scenario only as a matter of prudency, and the choice does not in any way reflect the Consultant's views on desired future development.

Table III-10: Forecast Fuel and Electricity Real Price (2014) Changes (Over the Previous 5 Years)

Fuel/Electricity	2020	2025
Crude oil	10.10 %	5.80 %
Natural Gas	-13.00 %	3.40 %
Coal (Australian)	6.90 %	3.90 %
Off-peak electricity from the grid	10.00 %	10.00 %

Source: Consultant's analysis

J. Technology Screening

61. For the purpose of technology screening curve analysis, selected generation assets were divided into two groups, so-called large and small power plants. This division is somewhat relative and is not always based on installed capacities scale but rather on what can be considered "large" or "small" for a particular generation technology.

62. The screening curves presented in the following figures reflect range of capacity factors assumed to be realistic for the selected power generation technologies. Solid part of each screening curve represents a highly probable ("guaranteed") capacity factor range, while dashed part of the curve represents less probable capacity factor still achievable under given technologic and economic conditions.

63. Large scale power plants cover large oil/gas and coal combustion plants, as well as large hydro and on-shore wind. All selected large-scale power plants except the solar PV can assume construction of both transmission and distribution facilities, including 220 kV overhead double circuit lines and 220/132kV substations. The table below contains main features of the considered large power plants.

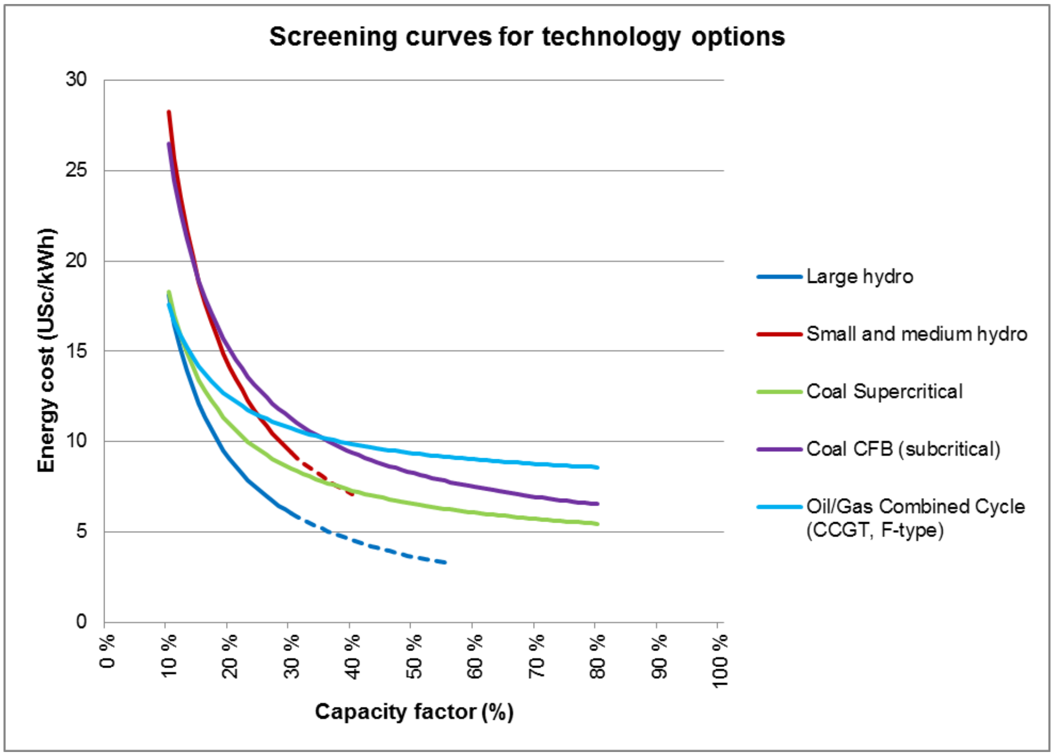
64. The following graphs show the estimated levelised costs of main large scale power generation options as a function of capacity factor. The large scale hydro, on the lower level, and the small & medium size hydro on the higher level, can be considered to represent a range for hydropower costs as there is a major uncertainty, and case by case dependence on site specific conditions, of hydro project capital costs. Whilst large scale hydropower delivers the lowest LCOE, supercritical coal based power reaches the same level if it is run as base load plant with annual capacity factor exceeding 80 %.

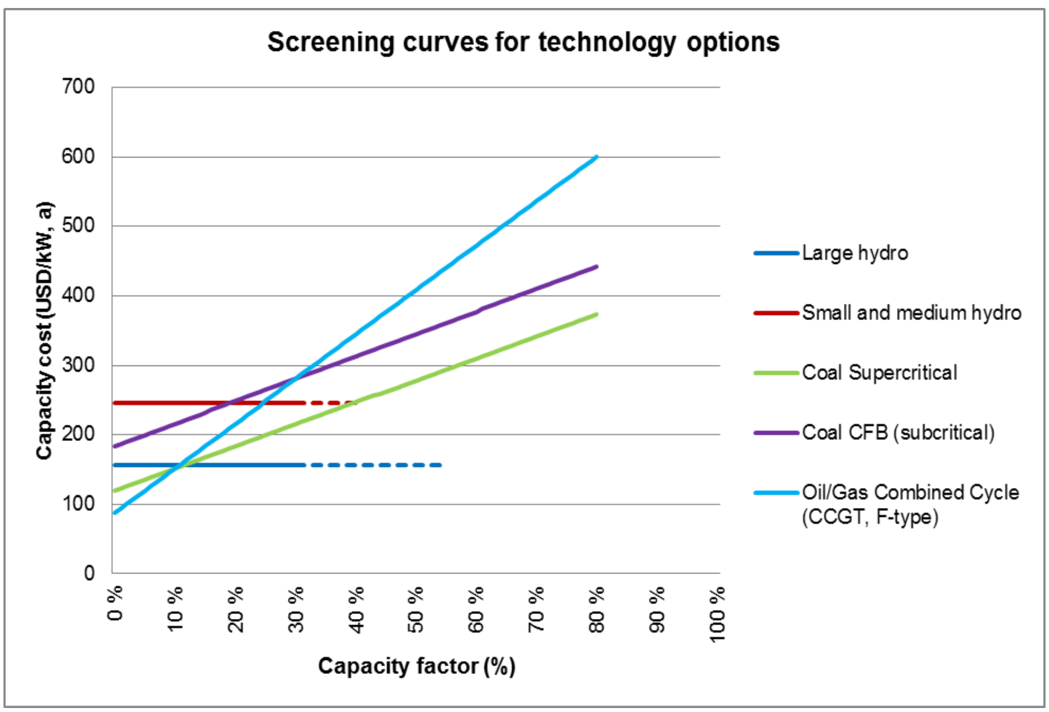
Table III-11: Main Features of Selected Large-Scale Power Plants

	Installed capacity	Capacity factor	Life time	CAPEX overnight cost	Fixed O&M cost	Variable O&M cost	Lead time
	MW	%	a	US$/kW	% of CAPEX	USc/kWh	A
Oil/Gas Combustion Turbine (F-type)	250	10 %	25	486	1.2 %	0.99	1.5
Oil/Gas Combined Cycle (CCGT, F-type	650	80 %	25	918 (*)	1.8 %	0.59	2.5
Coal Supercritical	600	80 %	30	1,300	2.0 %	0.31	3
Coal CFB (subcritical)	150	80 %	30	1,800	2.5 %	0.33	2
Coal PC (subcritical)	50	80 %	30	2,300	3.0 %	0.35	2
Solar PV (large)	50	20 %	25	2,100	0.4 %		1
Wind onshore (large)	100	30 %	20	1,360	0.8%		2
Small and medium hydro	100	50 %	70	2,800	1.2 %		7
Large hydro	600	50 %	70	1,700	1.2 %		9

(*) PA Consulting Group, September 2010 (Singapore costs adjusted to the price level of 2014); estimate for a 423 MW CCGT F-type power unit

Figure III-11: Screening Large Scale Conventional Power Plants

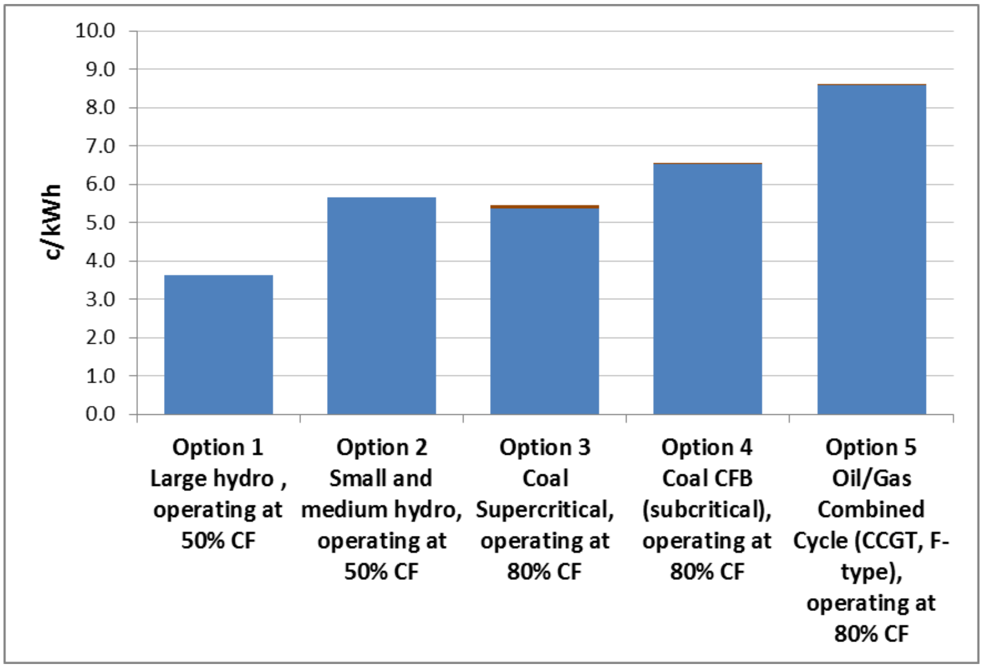




Source: Consultant's analysis

65. The LCOE of generation is the lowest with large scale hydro (3.62 c/kWh), but the cost is also dependent on capacity factor (assumed here at 50 %) and capital cost (1,700 $/kW). The costs of coal based power vary rather little as the higher CAPEX and OPEX of smaller CFB and PC plants is offset by correspondingly lower cost of lignite and sub-bituminous coal versus bituminous coal of supercritical large coal plant. With the current value of natural gas, assumed here to the level of gas exported to Thailand, gas-firing base load is not feasible compared to hydro and coal. The F-class GTCC plant selected as representative of gas combined cycle technology delivers LCOE of 8.58 c/kWh.

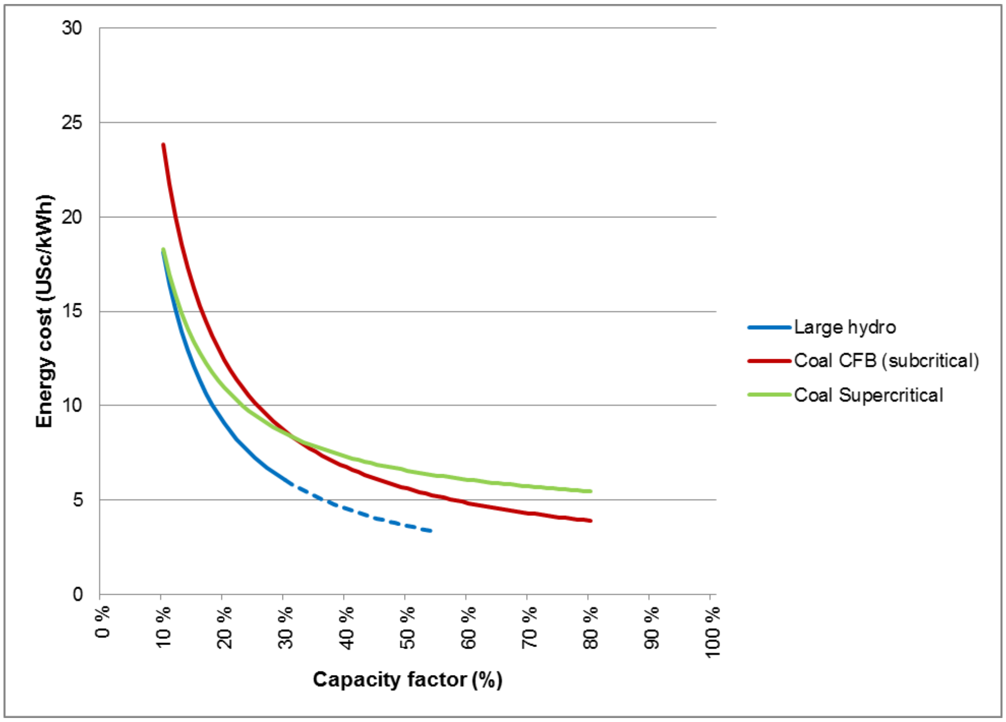
Figure III-12: Generation LCOE of Large Scale Conventional Power Plants



Source: Consultant's analysis

66. The underlying assumptions for all coal fired technologies above was use of imported coal, which is largely justified. However, there is domestic coal available albeit not in very large amounts supporting large scale mine-mouth power plants. Whilst the cost of imported coal is set here to vary between 40 $ and 90 $/ton, is can be assumed that cost of mine-mouth generation could be based on coal prices varying between 10 and 20 $/ton, depending on coal quality. With such low level of coal cost, mine-mouth power generation seems feasible, especially, if the mine and its associated facilities would consume major part of generated power whereby there would be less marginal need to strengthen electricity transmission and substation systems. The following graph compares the costs of large scale hydro and bituminous coal power plant to small-medium scale lignite fired power plants.

Figure III-13: Lignite-Fired Mine Mouth Power Station, Large Scale Hydro & Coal-fired Power Plant (Imported Coal)



Source: Consultant's analysis

67. Transmission and distribution makes up an important part of the total cost of the power supply system, but the cost impact can be only roughly estimated in a screening analysis, and such is inevitably based on averages for illustration only rather than actual costs, which are highly site specific. A logical location for a gas turbine peaking plant is close to the load centre and in the vicinity of major transmission lines, and therefore this production type is estimated to have the smallest requirement for transmission development. These power plants are used only periodically, short periods at a time and their site areas are limited so that suitable sites are usually not difficult to identify insofar as noise abatement issues are adequately considered. Large thermal plants (coal and CCGT) are assumed to be located in coastal locations in Myanmar, not in immediate vicinity of major population centres, but optimized to be not too far from the transmission system and source of fuel (coal by sea and gas pipeline). Location of a large coal fired plant has specific requirements related to access to seaborne transportation of coal and the construction of jetty.

68. Longest transmission distances can be expected for wind and hydropower. Likely locations for wind are in the South of Myanmar and not very near to the major transmission lines. Hydropower sites in the Shan State and the Kachin State, may be remote from the perspective of current national load centre, but once hydropower construction in these region starts, several plants are planned to the same area and to the same river system, sometimes in cascades, so that the share attributable to one single plant of the transmission system development remains limited. The modelled capacity for photovoltaic power is 5 MW, which is already a large plant of that type, but in reality it is possible that PV will be developed in even larger units if sparsely inhabited land is available and taken into use, and panels are clustered to form a large single entity up to tens of megawatts requiring HV transmission. Therefore 30 km of 132 kV line has also been assumed for PV of 100 MW capacity.

69. Assumptions for the transmission system of the various types of large scale power plants in the META model are as presented in the following table.

Table III-12: Assumptions for T&D Facilities Associated with Power Plants

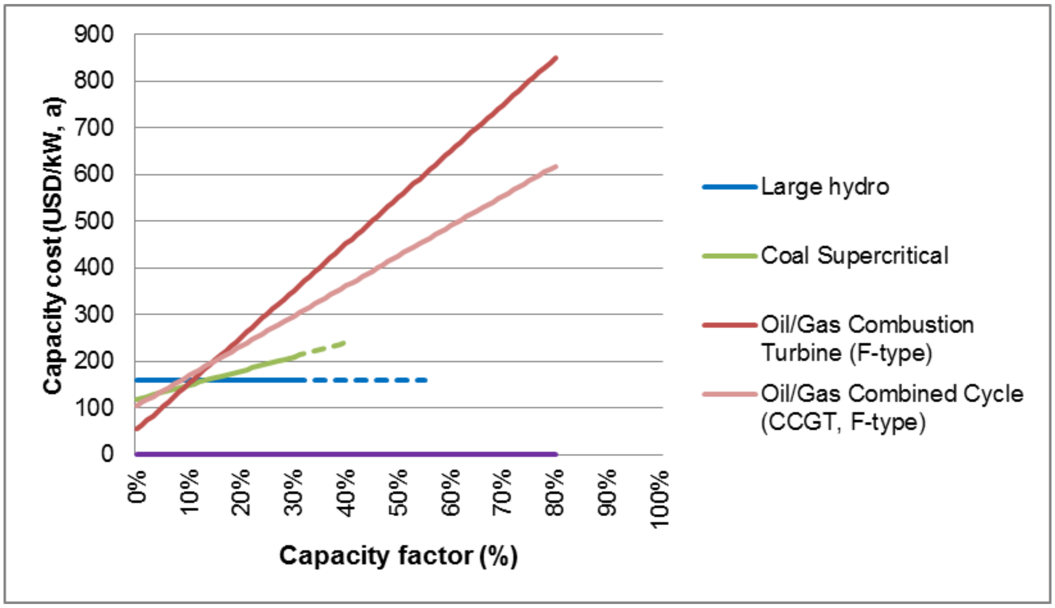
	Installed capacity	Capacity factor	400 kV	220 kV	132 kV	440/220 kV substation	220/132 kV substation
	MW	%	km	km	km	no	No
Oil/Gas Combustion Turbine (F-type)	250	10 %		10			1
Oil/Gas Combined Cycle (CCGT, F-type	650	80 %	30			1	
Coal Supercritical	600	80 %	30			1	
Coal CFB (subcritical)	150	80 %		50			
Coal PC (subcritical)	50	80 %			50		1
Solar PV (large)	50	20 %			50		1
Wind onshore (large)	100	30 %			50		1
Small and medium hydro	100	50 %		50		1	
Large hydro	600	50 %	50			1	

Source: META model

70. The inclusion of the transmission and distribution cost does not have an impact on the ranking order of generation technologies. The distribution cost of the delivered energy is the same for all options, and it also has the highest share within all T&D costs. The distribution cost is 3.18 c/kWh. High voltage (HV) transmission and substation costs are minor, only 0.07c/kWh and 0.07 c/kWh, respectively, for large hydro. The share of HV transmission and substation is so small, about 4 % of the LCOE that despite minor differences in those between different plant options, they will not differentiate various generation types.

71. One possible policy option for Myanmar is to develop strongly a hydropower based power supply system. However, with hydropower, large 'extra' capacity is needed for peaking purposes. Hydropower is highly capital intensive and it would not be rational to build hydro capacity to such level that every peak could be covered considering rare adverse hydrological events and droughts. The following screening curve shows that gas turbine peaking power is the least cost option up to the capacity factor of around 10 % representing about 900 operational hours a year in average. Open cycle gas turbine is of low CAPEX – high OPEX type. It seems reasonable to include this technology option in system expansion planning when hydropower provides the base and medium load.

Figure III-14: Open Cycle Gas Turbine as Part of the System

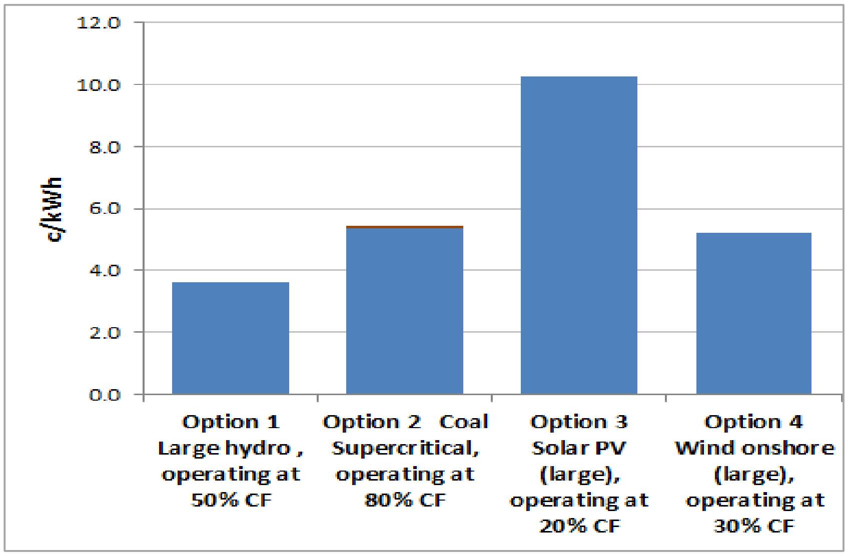


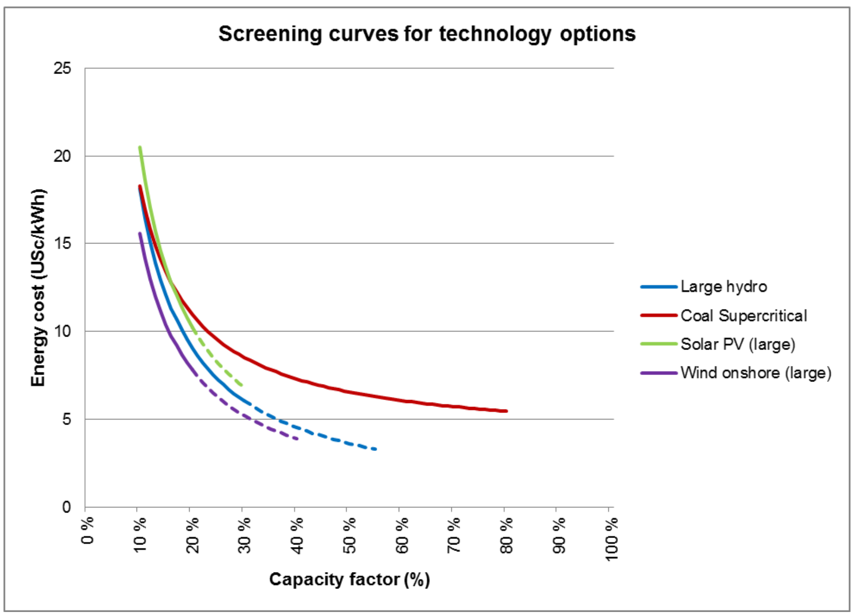
Source: Consultant's analysis

72. Since 2010, the costs of both solar PV and wind technologies have declined significantly with increasing numbers of installations globally. One of the main contributing factors to PV power generation growth has been the sharp reduction in the cost of crystalline silicon PV modules. Their prices have fallen by more than 65 % in the past three years to less than 1,000 $/kW. Whilst the worldwide cumulative installed capacity of wind still exceed that of solar PV, in 2013, for the first time, solar installations exceeded wind albeit by a narrow margin. The massive investments in wind energy installations in China and India have caused these countries to develop own design capability and manufacturing base for wind turbines bringing competition in technology to a new level.

73. With the given assumptions the LCOE of PV technology is 10.24 c/kWh. LCOE of wind energy is 5.2 c/kWh, almost equal to that of coal fired power. For the solar PV, technology improvement over years (annual 2% decrease of CAPEX) has been taken into consideration in META.

Figure III-15: Large Scale Conventional Power Plants vs Wind and Solar PV





Source: Consultant's analysis

74. Small-scale island power plants do not assume construction of any transmission infrastructure but their downside is poorer service quality, which means that some technologies can provide electricity to consumers only part time of the day, and that electricity supply is dependent on natural forces (river discharge, wind, solar). With the exception of a small diesel generator, all selected small-scale technologies below are based on renewable energy. The main features of the considered small power plants are presented in the following table.

Table III-13: Main Features of Selected Small-Scale Power Plants

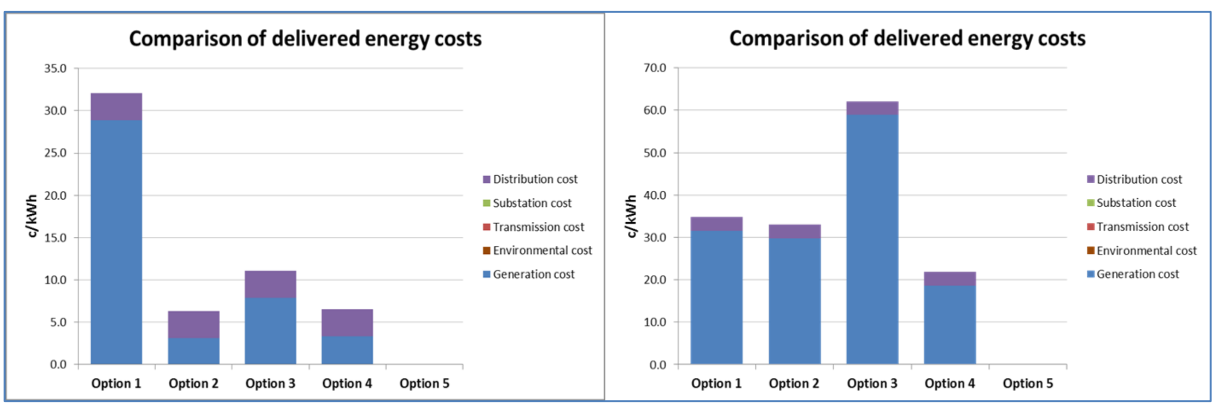
	Installed capacity	Capacity factor	Life time	CAPEX	Fixed O&M cost	Variable O&M cost	Lead time
	MW	%	a	US$/kW	% of CAPEX	USc/kWh	A
Diesel generator (small) (option 1, graph 1)	5	10 %	20	391	6.5%	2.7	0.5
Biogas, Landfill gas (option 2, graph 1)	5	80 %	20	1,088	8.1%		0.5
Micro hydro (option 3, graph 1)	0.1	30 %	30	2,108	0.8%		0.5
Mini hydro (option 4, graph 1)	5	45 %	30	1,316	0.8%		1
Solar PV (mini) (option 1, graph 2)	0.0003	20 %	25	5,681	0.2%		0.5
Wind onshore (micro) (option 2, graph 2)	0.0003	30 %	20	7,162	0.3%		0.5
PV-wind hybrid (micro) (option 3, graph 2)	0.0003	25 %	20	11,804	0.1%		1
Pico hydro (mini) (option 4, graph 2)	0.001	30 %	15	3,564	0.8%		1

Source: Consultant's analysis

75. As can be seen from the figures below, major share of delivered energy costs for small power plants consists of generation costs. Solar PV, and especially PV-wind hybrid plants have significantly higher unit delivered energy costs when compared to other selected options. Diesel and onshore wind unit costs are almost equal. Biogas and mini hydro are the most attractive. It is worth noticing that these power plants also have significantly higher installed capacity when compared to the most expensive options (respectively 5 MW vs. not more than 0.1 MW).

Figure III-16: Delivered Energy Costs, Small Power Plants

Graph 1 **Graph 2**

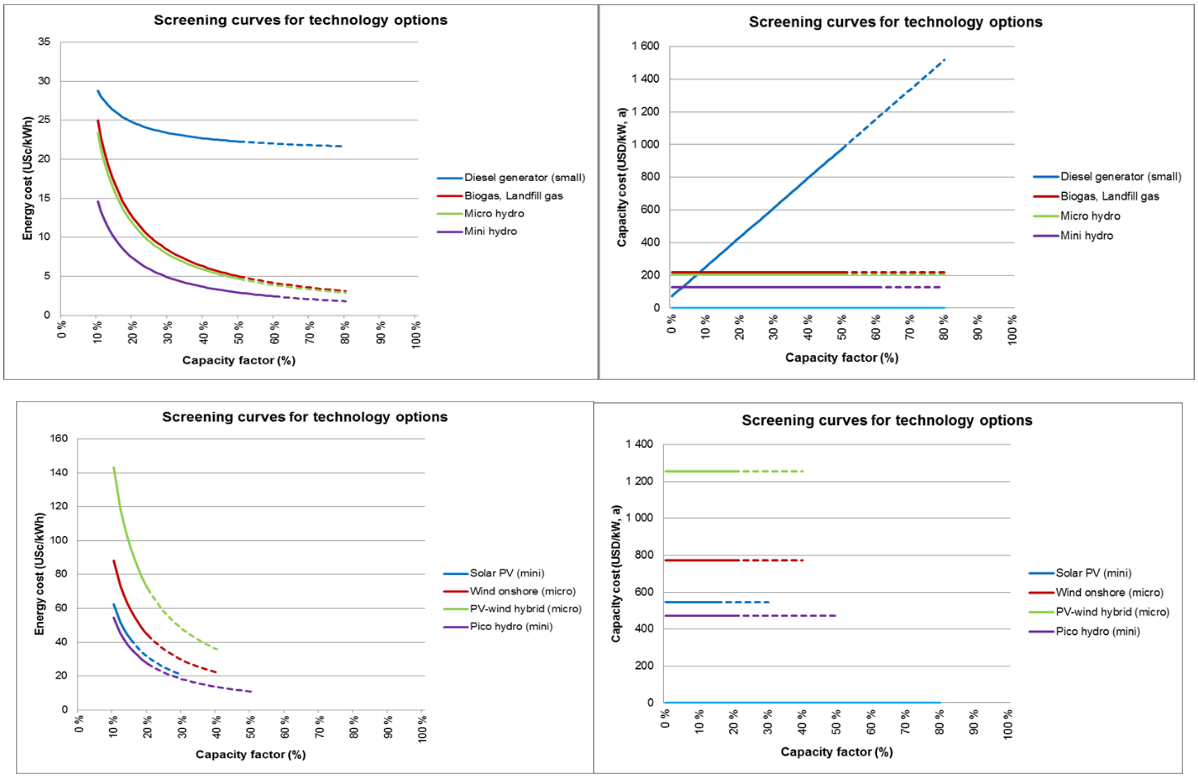


Source: Consultant's analysis

76. Graph 1 above represents the costs of small-scale units suitable for a village level system; whereas Graph 2 shows costs of systems designed more for individual households. The screening curve analysis for small-scale power plants indicates that under given conditions, a micro PV-wind hybrid plant is the most expensive generation option. Even a small diesel plant is less expensive until its capacity factor starts to exceed 70%. The least expensive generation options in this group are mini hydro, micro hydro and landfill biogas (the last two having practically similar unit costs). Pico hydro

mini and mini solar PV have mid-level unit costs. Onshore micro wind starts to be more attractive than e.g. diesel power only if its capacity factor exceeds 40%.

Figure III-17: Screening Curves, Small Power Plants



Source: Consultant's analysis

77. A screening curve method based on the Model for Electricity Technology Assessment (META) was applied for generic analysis and illustration of the costs of various electricity generation technologies in Myanmar. The analysis gave the following guidance:

- Myanmar's power sector today relies heavily on hydropower. Hydropower is likely to provide the least-cost option for further system expansion.
- Next in cost-based ranking order come large scale coal-fired power and wind energy. The underlying assumption for coal power plants was that they are built on the coast and depend on imported coal sourced from Australia or Indonesia.
- The LCoE of small scale mine-mouth coal fired power is 1.5 - 2.5 c/kWh higher than that of large scale coal when lignite is valued at word market prices whereas if lignite is valued at domestic cost at mines, it would be 1.0 - 1.5 c/kWh cheaper, but still higher than the LCoE of large hydropower.
- Of the new forms of renewable energy, wind energy is currently most cost-competitive and feasible for utility-scale application.
- Because Myanmar has the opportunity to sell natural gas to her neighbouring countries, natural gas was valued at market prices valid in South-East Asia. At such fuel cost, power generation of in CCGT plants is relatively costly and not feasible on economic grounds for Myanmar.

- Open-cycle gas turbines provide a low capital cost alternative to build fast-reacting capacity for serving the peak loads. Such plants are feasible and should be dimensioned so that their annual capacity factor is approximately 10 %.

IV. POWER SUBSECTOR EXPANSION

K. Introduction

78. Commercial energy planning software such as MARKAL / TIMES and MESSAGE has the functionality to produce a power section expansion with acceptable accuracy for long-term planning purpose. However, due to the concerns on historical data, bespoke planning models emulating MARKAL / TIMES methodology were used to model the economic and household sectors. In the case of power sector expansion, ADICA used software WASP (in Appendix 4) and the Consultant used an optimization model.[5] The Consultant's optimization model used a deterministic approach, a pseudo-reserve margin was set at 15% of demand, and alternative long-term fuel mixes were examined using a least-cost hourly dispatch optimization technique. The methodology and approach is explained in more detail in Appendix A.

79. Five expansion cases were defined based on a practical consideration of available resources, recent policy direction and the advice of the Ministry of Electric Power. The five cases were chosen to represent the widest possible spread of fuel mixes. The definitions of the five cases are given in Table IV-1. Capacity planting schedules were developed for each case and the portfolios were dispatched according to marginal cost considerations with a variable operating cost merit order as follows – solar PV, wind, large hydropower, small hydropower small, gas and coal.

Table IV-1: Fuel Mix Cases

Case	Name	Description
Case 1	Planned Hydro / Coal	Includes all committed and planned hydro, existing coal and gas fired generation, committed 300 MW solar PV starting from 2016, and moderate large coal expansion starting from 2026
Case 2	Balanced (Hydro / Coal / Solar PV)	Same as the Base Case but with less planned hydro displaced by a balance of large thermal resources and solar PV resource (the solar PV balances the hydropower)
Case 3	Maximum Hydro	Same as the Base Case but with maximum dependence on hydropower (including existing, committed and planned resources – the latter to the maximum technically-feasible) and no new thermal capacity
Case 4	Maximum Coal	Same as the Base Case but without planned hydro (only existing and committed) and with large scale coal-fired power development
Case 5	Maximum Solar PV / Wind	Same as the Base Case but with large scale solar PV and wind development

[5] The model was based on a public domain OpenSolver using the Open Source, COIN-OR CBC optimization engine, designed to rapidly solve large Linear and Integer problems

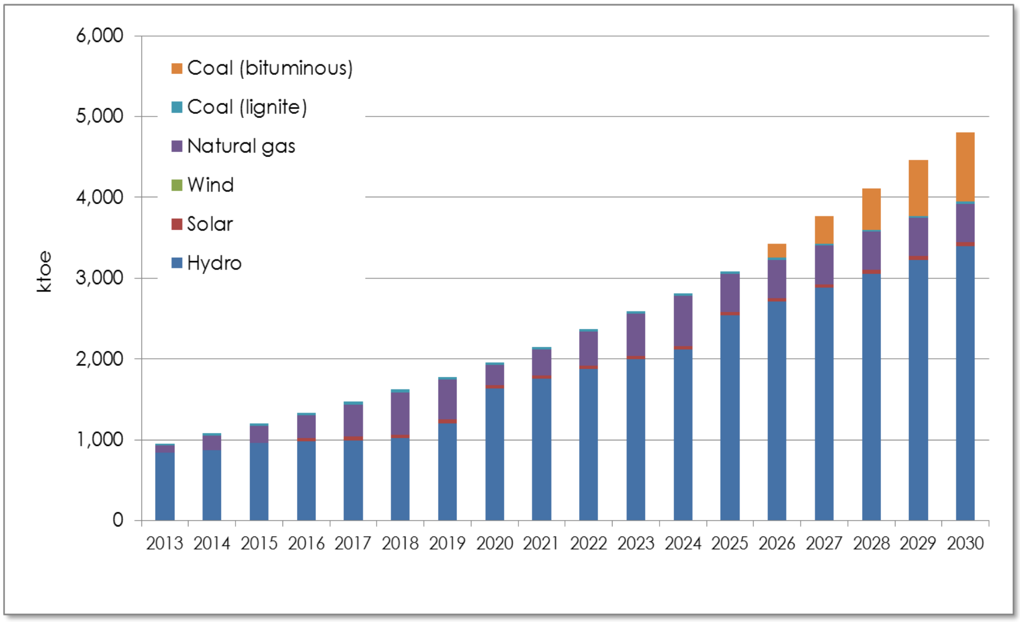
80. In mid-2015, the ADB commissioned ADICA[6] to develop a least-cost power subsector expansion using probabilistic expansion planning techniques (WASP software). ADICA set a minimum reserve margin of 20% and settled on different planning assumptions. As the ADICA report did not quantify energy conversion losses, the least-cost capacity expansion plan produced by WASP was modelled by the EMP team to determine the energy content of the fuel and the energy conversion losses based on EMP fuel calorific values and conversion efficiency factors.

L. Electricity Fuel Mix & Conversion Efficiency (TPES)

81. The following charts provide the outputs for the five fuel mix cases. In each case, a pair of charts represents the primary energy fuel use and the useful energy and energy conversion losses respectively. In all cases the projections are for the medium electricity growth case defined in the Consolidated Demand Forecasts report of this EMP.

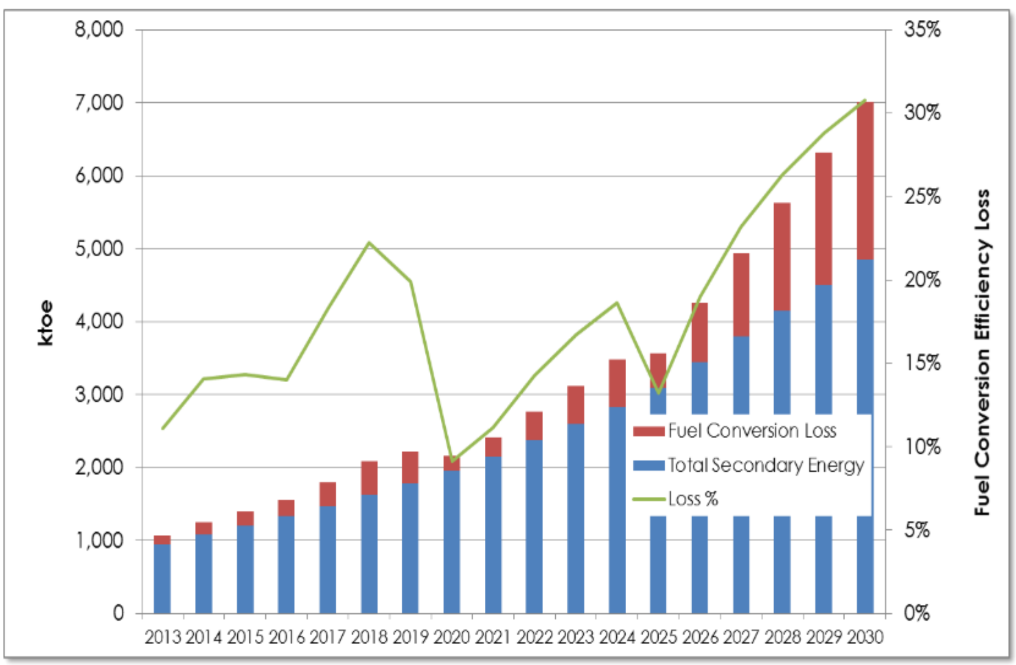
[6] NATIONAL POWER EXPANSION PLAN; prepared by ADICA using the Wien Automatic System Planning software (WASP-IV). The expansion plan is based on the EMP 'medium' electricity demand forecast

Figure IV-1: Case 1 – Planned Hydropower / Coal



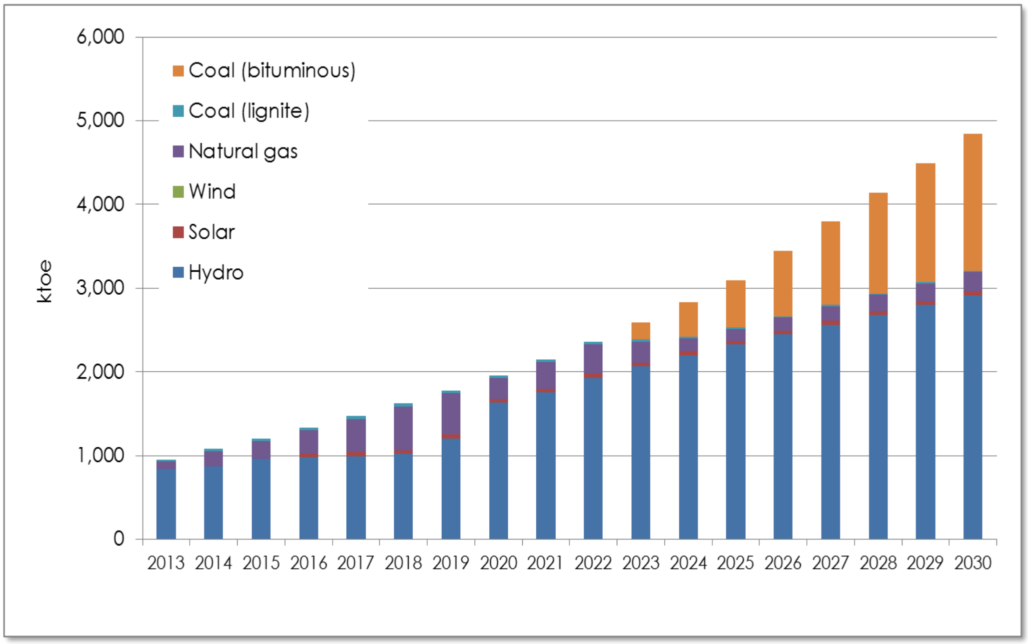
Source: Consultant's analysis

Figure IV-2: Case 1 – Energy Conversion Loss



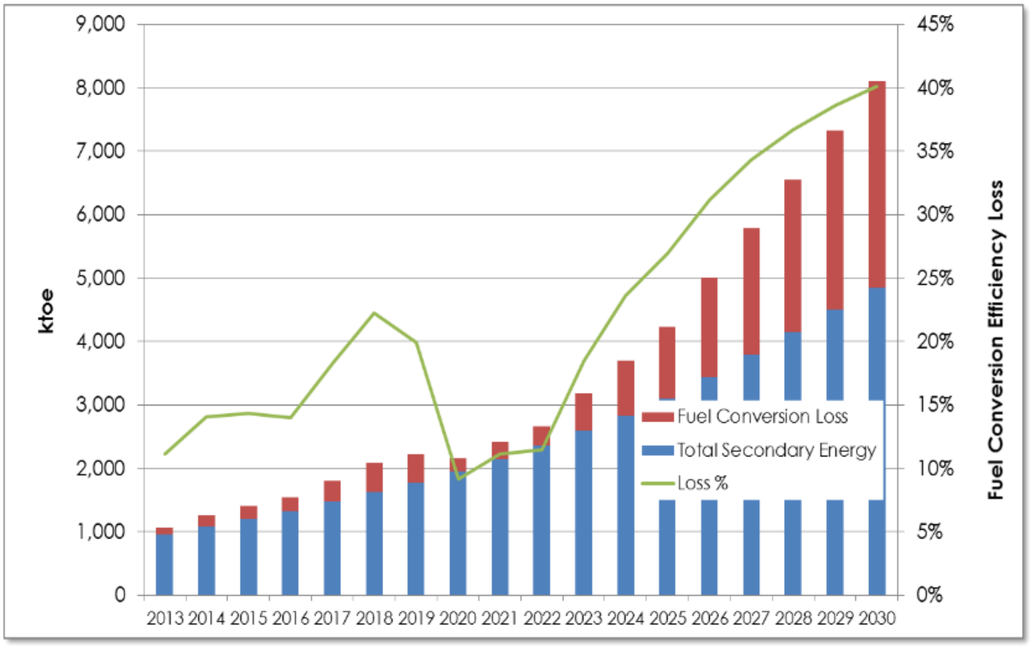
Source: Consultant's analysis

Figure IV-3: Case 2 – Balanced (Hydro / Coal / Solar PV)



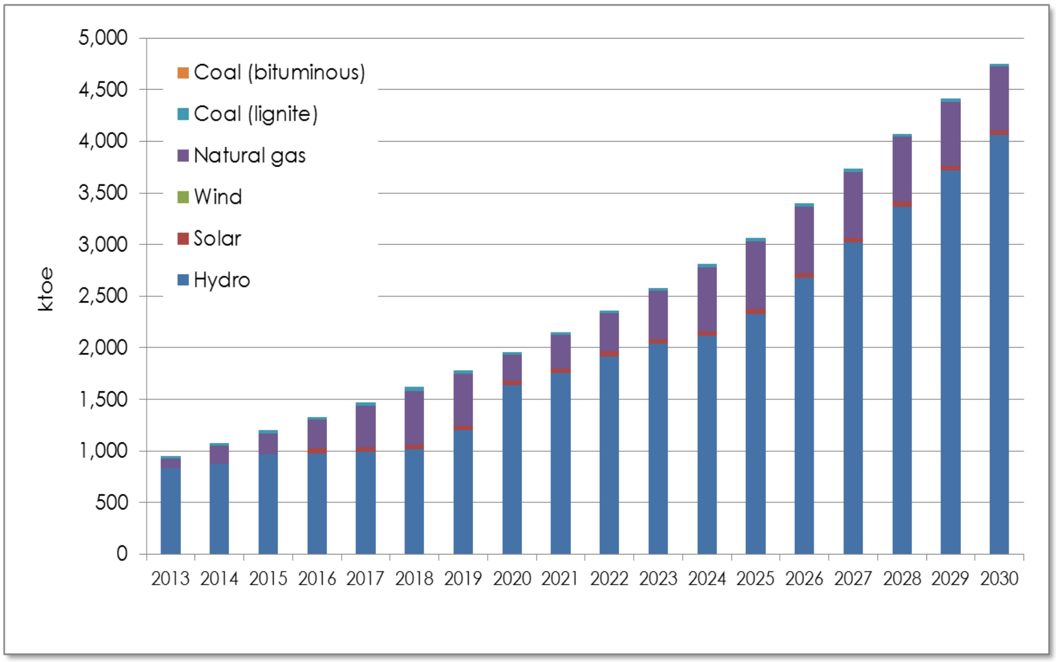
Source: Consultant's analysis

Figure IV-4: Case 2 – Energy Conversion Loss



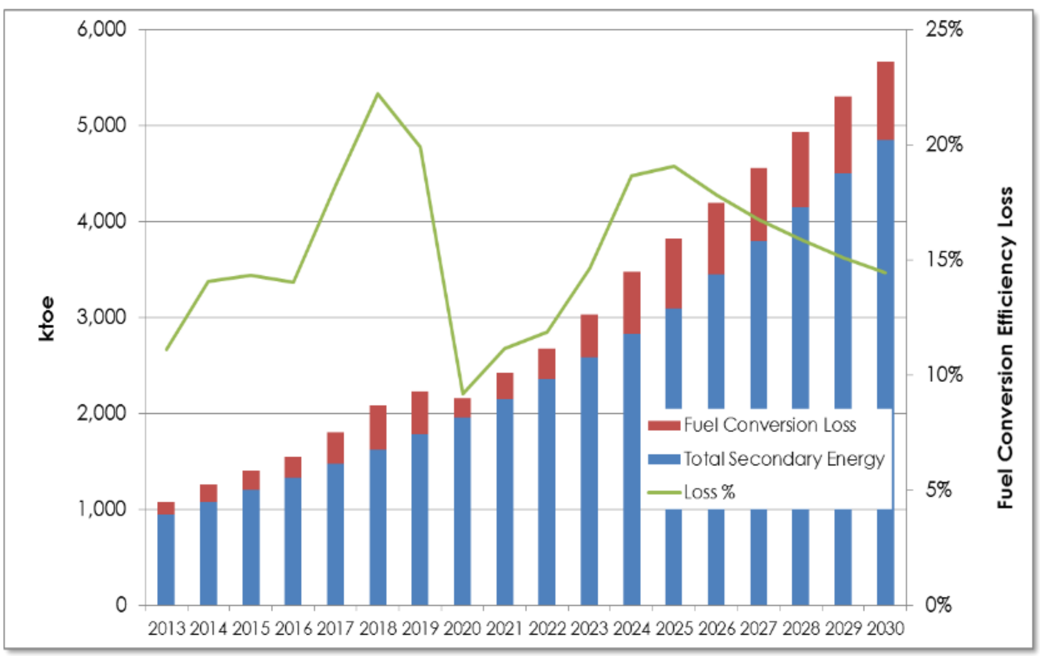
Source: Consultant's analysis

Figure IV-5: Case 3 – Large Hydropower



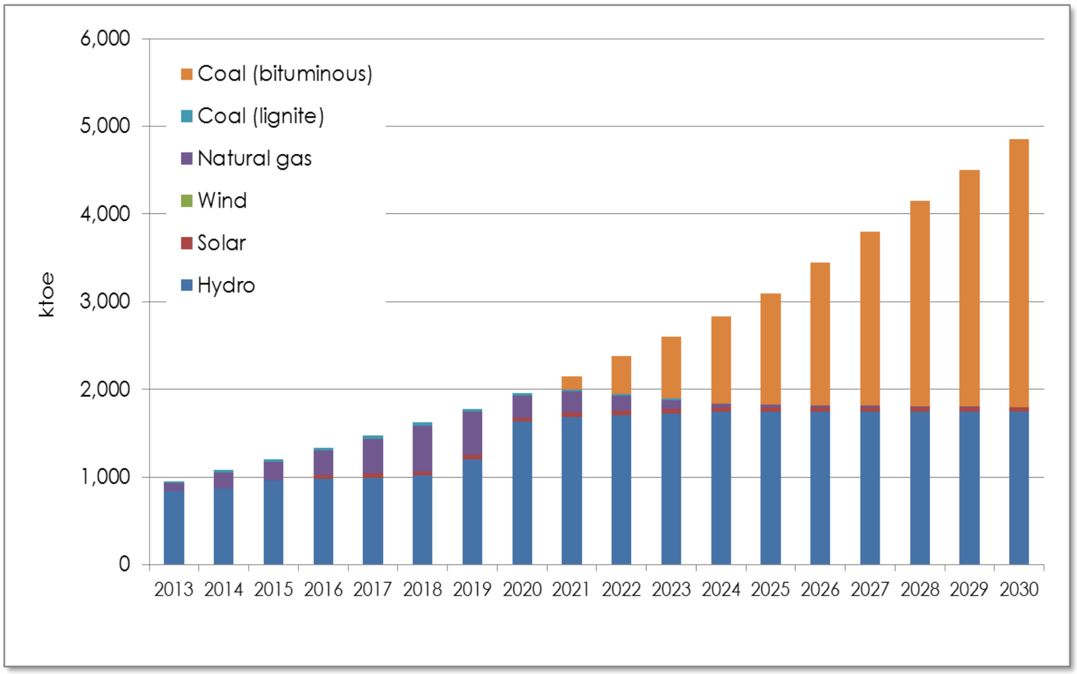
Source: Consultant's analysis

Figure IV-6: Case 3 – Energy Conversion Loss



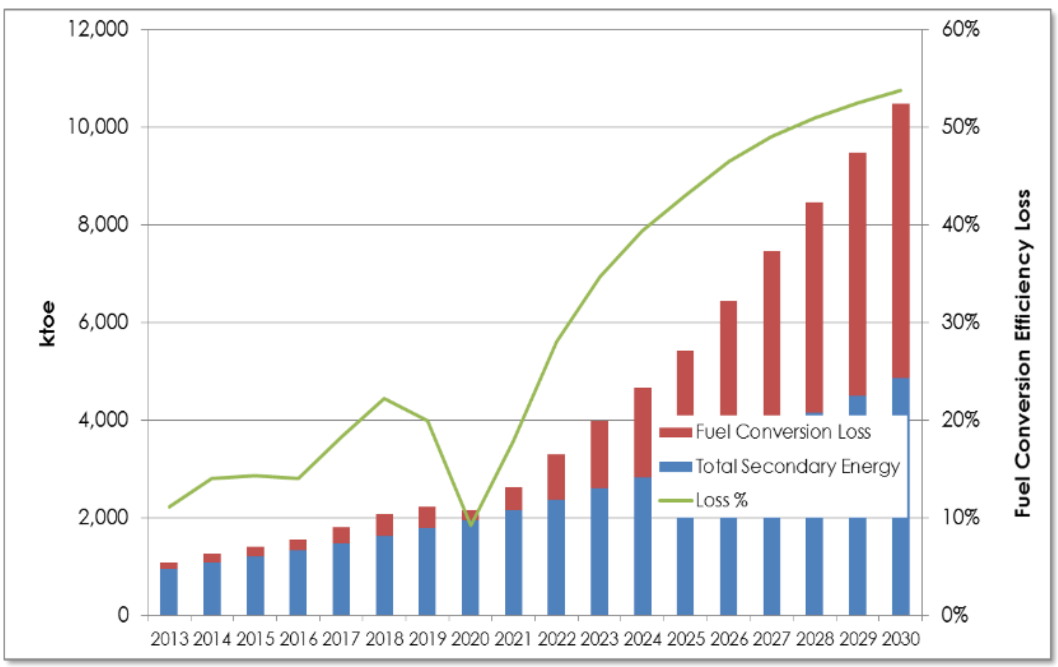
Source: Consultant's analysis

Figure IV-7: Case 4 – Large Coal



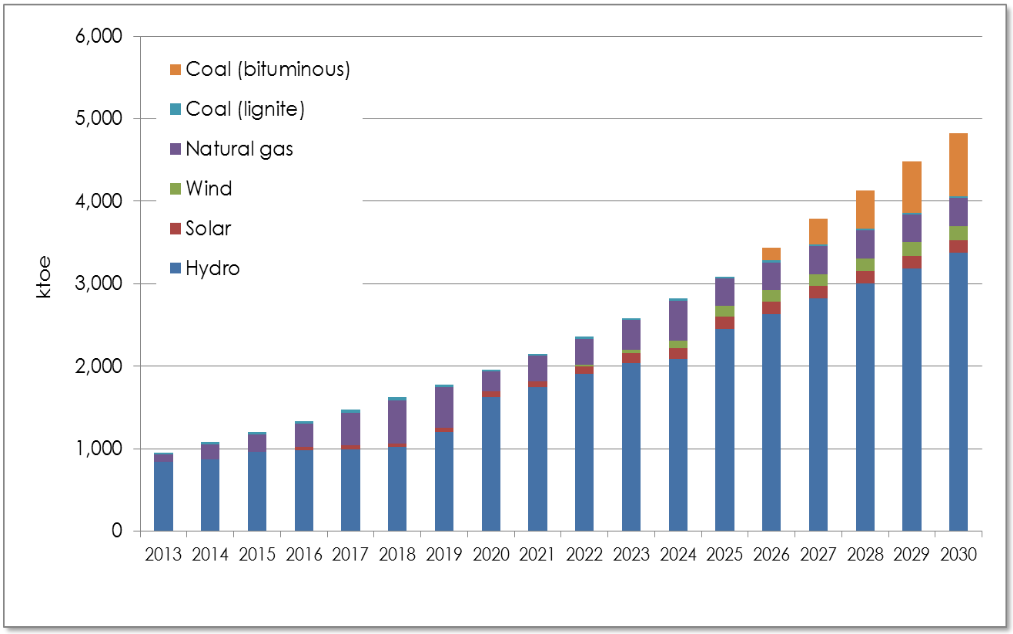
Source: Consultant's analysis

Figure IV-8: Case 4 – Energy Conversion Loss



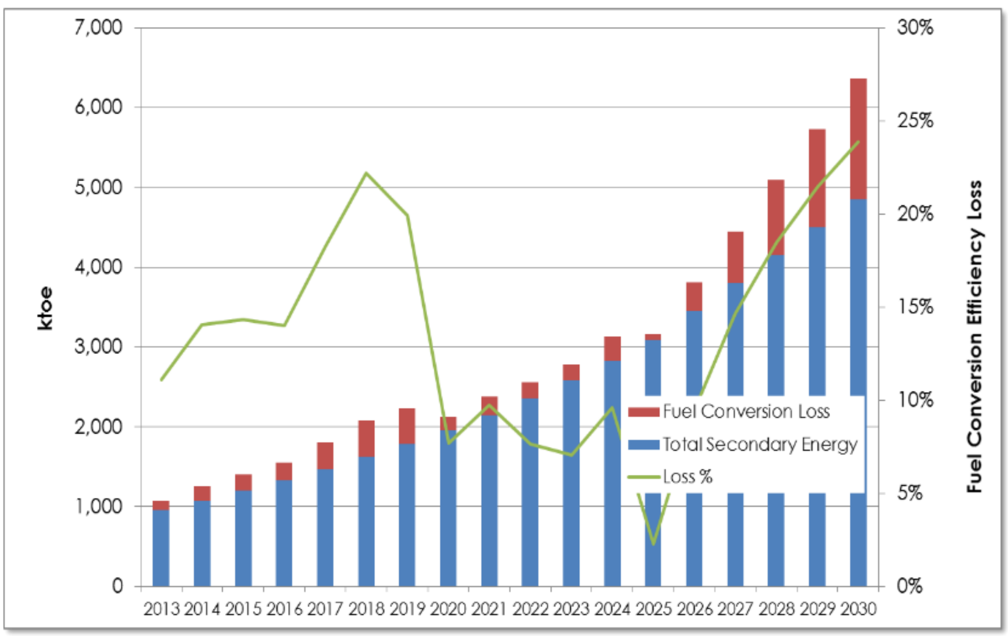
Source: Consultant's analysis

Figure IV-9: Case 5 – Large Solar PV / Wind



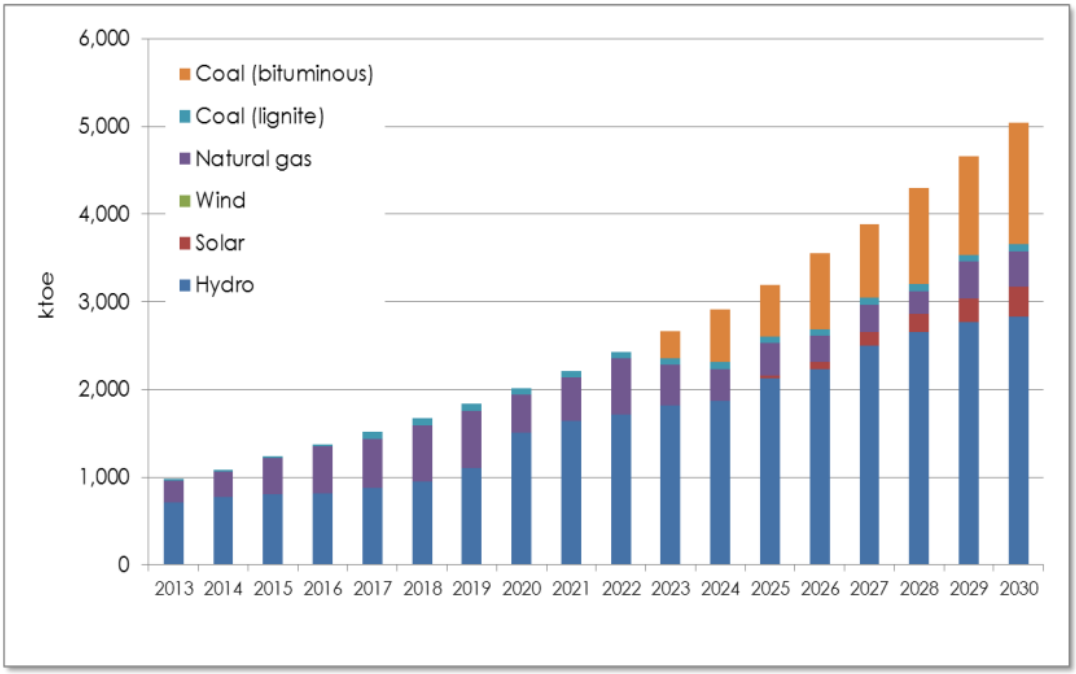
Source: Consultant's analysis

Figure IV-10: Case 5 – Energy Conversion Loss



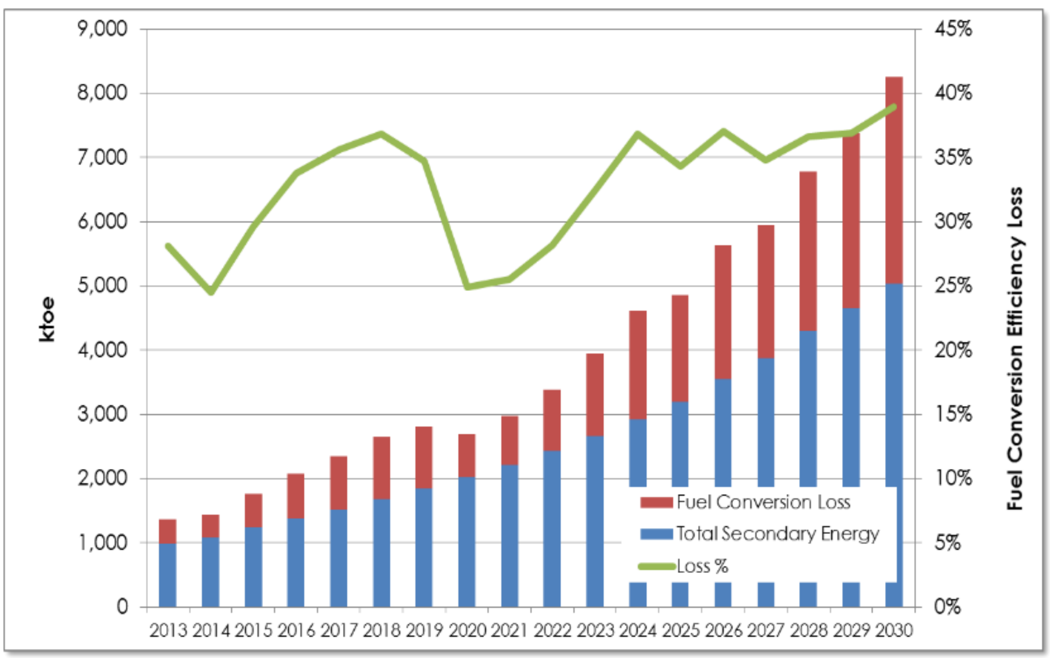
Source: Consultant's analysis

Figure IV-11: ADICA Least-Cost



Source: ADICA 2015

Figure IV-12: ADICA – Energy Conversion Loss



Source: ADICA 2015

82. The preceding charts show that if fossil fuel use and energy efficiency (thermal losses) were considered as the key determinants of an optimal expansion plan then Case 3 would be the optimal expansion due to the large amount of hydropower capacity. The lowest efficiency expansion is Case 4 due to a high dependence on coal. The expansion plan defined by ADICA shows a fuel consumption and energy conversion efficiency falling between Case 3 and Case 4. The ADICA case is stated by ADICA as the least-cost expansion; given current technology costs, there is an evident trade-off between cost and thermal efficiency.

M. Portfolio Analyses (5 Cases)

83. Table IV-2 provides a summary of key performance indicators, for the 5 cases examined by the EMP team. The planning horizon spans from 2015 to 2035; 20 years is the minimum planning horizon considered acceptable for a Present Value comparison given that power plants are long-lived assets. ADICA did not provide an expansion plan to 2035 and cost assumptions differed, and so the ADICA expansion plan was not included in the portfolio analyses.

Table IV-2: Summary of Portfolio Analyses (2015-2035)

	CASE 1 Base	CASE 2 Balanced	CASE 3 Max Hydro	CASE 4 Max Coal	CASE 5 Max Solar PV / Wind
PV ($ billion) - no CO2 costs	19.2	18.5	20.4	19.9	17.8
LCoE (USc/kWh) - no CO2 costs	4.87	4.69	5.17	5.05	4.51
Annual CAPEX ($ million) (*)	1 563	1 394	1 980	1 165	1 569
CO2 (million tons)	167	240	74	444	134
CO2 cost ($ million)	1 440	2 073	632	3 835	1 159
Other pollution ($ million)	136	236	35	476	119
LCoE (USc/kWh) incl. CO2 costs	5.23	5.22	5.33	6.02	5.75

(*) Annual average for 2015-2030

N. Policy-Adjusted Expansion Plan

84. Raw performance scores were determined by a Portfolio Analysis Model (refer Appendix A) for the Financial, Environmental, Diversity and Project Development Risk policy factors. The following table provides a summary of the raw scores:-

Table IV-3: Raw Performance Scores for each Case

Case	Name	CO2, Sox and Nox Emissions Cost (in 2030)	Normalised PV cost of plan	Dependence (% Gas-fired Generation Sent Out on Total in 2030)	Risk factor Associated with Projects
1	Planned Hydro / Coal	680.8	1.149	10.8%	4.43
2	Balanced Hydro / Coal / Solar PV	1089.8	1.051	4.9%	4.61
3	Maximum Hydro	**435.3**	1.329	14.8%	4.33
4	Maximum Coal	1958.3	**1.000**	**0.1%**	**5.14**
5	Maximum Solar PV / Wind	469.5	1.100	7.5%	4.07

Source: Consultant's analysis

85. Partial value functions were used to normalize the raw scores (refer Appendix A for the functions). This step was carried out by normalizing the raw performance scores above across the partial value function range. Table IV-4 provides the normalized scores (with 100 being the best score, and 0 being the worst).

Table IV-4: Partial Value Function Normalized Scores

Case	Name	CO2 Emissions	Cost of Plan	Diversity	Risk Factor
1	Planned Hydro / Coal	94	66	46	96
2	Balanced Hydro / Coal / Solar PV	76	90	90	94
3	Maximum Hydro	100	3	0	97
4	Maximum Coal	0	100	100	82
5	Maximum Solar PV / Wind	98	79	74	100

Source: Consultant's analysis

86. The normalized scores shown in Table IV-4 were weighted by policy weights to produce the final 'policy-weighted value' scores for each case.

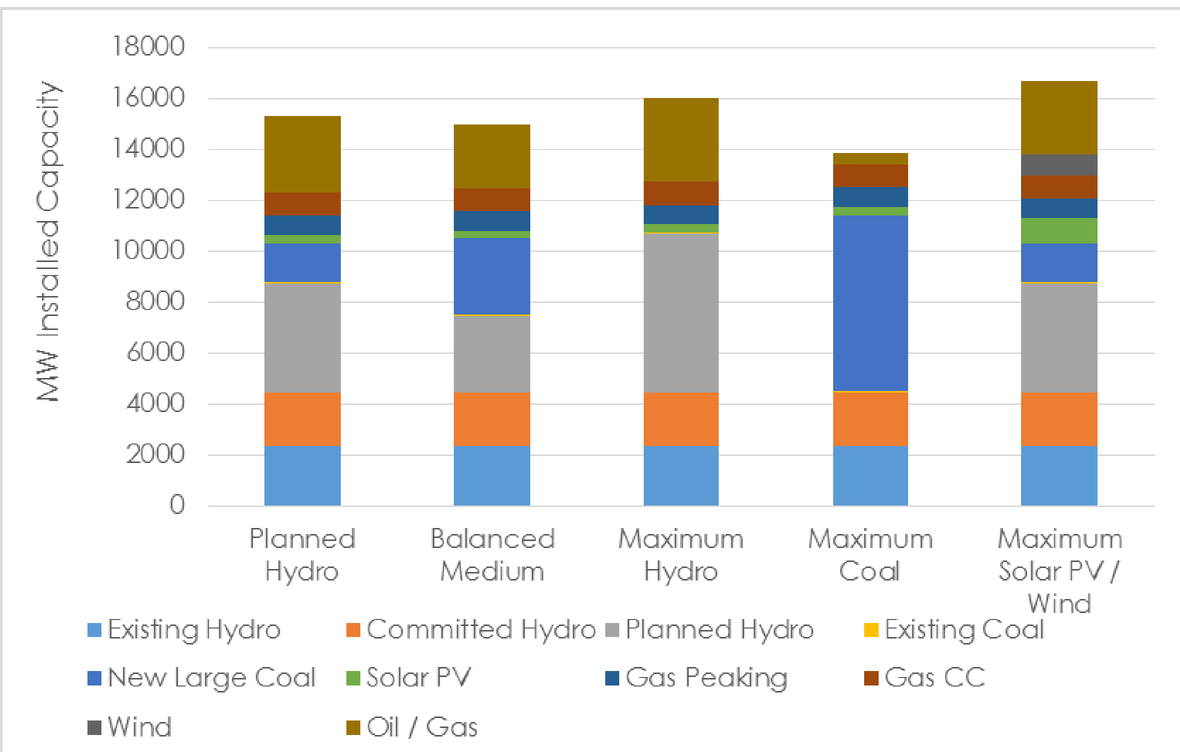
Table IV-5: Final Policy-Weighted Value Scores

Case	Name	CO2	Cost of	Diversity	Risk	Total
1	Planned Hydro / Coal	18.8	33.0	11.4	4.8	68.1
2	Balanced Hydro / Coal /	15.3	45.1	22.4	4.7	**87.5**
3	Maximum Hydro	20.0	2	-	4.9	26.4
4	Maximum Coal	-	50.0	25.0	4.1	79.1
5	Maximum Solar PV /	19.7	39.4	18.5	5.0	82.6
	Policy Weights	20%	50%	25%	5%	

Source: Consultant's analysis

87. Thus, from a multi-criteria decision analysis, when policy considerations are taken into account, it is found that Case 2 – the balanced portfolio is the most attractive option. The capacity mix for each case is shown for year 2030 by Figure IV-13.

Figure IV-13: Installed Capacity by Plan (MW) in 2030



Source: Consultant's analysis

88. Figure IV-15 to Figure IV-34 provide for all Cases, including a high electricity demand Case 2, the optimal fuel mix for the resources deployed, the planting schedule by annual MW, and the cumulative and annual investment requirements. In addition the composition of installed capacity is

given for Case 2 (medium growth) for years 2015, 2020 and 2030. A summary of the planting schedules are given here to 2030 for the medium electricity growth case:-

Table IV-6: Planting Schedule Summary – Case 1

	2020		2025		2030	
	MW	%	MW	%	MW	%
Hydro	4,462	61%	6,811	65%	8,751	57%
Coal	60	1%	60	1%	1,560	10%
Gas	1,670	23%	1,670	16%	1,670	11%
Solar PV / Wind	300	4%	300	3%	300	2%
Oil / Gas	850	12%	1,700	16%	3,000	20%
Total	7,342		10,541		15,281	

Source: Consultant's analysis

Table IV-7: Planting Schedule Summary – Case 2

	2020		2025		2030	
	MW	%	MW	%	MW	%
Hydro	4,462	61%	6,065	60%	7,450	50%
Coal	60	1%	1,260	12%	3,060	20%
Gas	1,670	23%	1,670	16%	1,670	11%
Solar PV / Wind	300	4%	300	3%	300	2%
Oil / Gas	850	12%	850	8%	2,500	17%
Total	7,342		10,145		14,980	

Source: Consultant's analysis

Table IV-8: Planting Schedule Summary – Case 3

	2020		2025		2030	
	MW	%	MW	%	MW	%
Hydro	4,462	61%	5,990	60%	10,691	67%
Coal	60	1%	60	1%	60	0%
Gas	1,670	23%	1,670	17%	1,670	10%
Solar PV / Wind	300	4%	300	3%	300	2%
Oil / Gas	850	12%	2,000	20%	3,300	21%
Total	7,342		10,020		16,021	

Source: Consultant's analysis

Table IV-9: Planting Schedule Summary – Case 4

	2020		2025		2030	
	MW	%	MW	%	MW	%
Hydro	4,462	66%	4,462	47%	4,462	32%
Coal	60	1%	2,760	29%	6,960	50%
Gas	1,670	25%	1,670	18%	1,670	12%
Solar PV / Wind	300	4%	300	3%	300	2%
Oil / Gas	300	4%	350	4%	450	3%
Total	6,792		9,542		13,842	

Source: Consultant's analysis

Table IV-10: Planting Schedule Summary – Case 5

	2020		2025		2030	
	MW	%	MW	%	MW	%
Hydro	4,462	64%	6,811	59%	8,751	52%
Coal	60	1%	60	1%	1,560	9%
Gas	1,670	24%	1,670	14%	1,670	10%
Solar PV / Wind	450	6%	1,600	14%	1,800	11%
Oil / Gas	300	4%	1,400	12%	2,900	17%
Total	6,942		11,541		16,681	

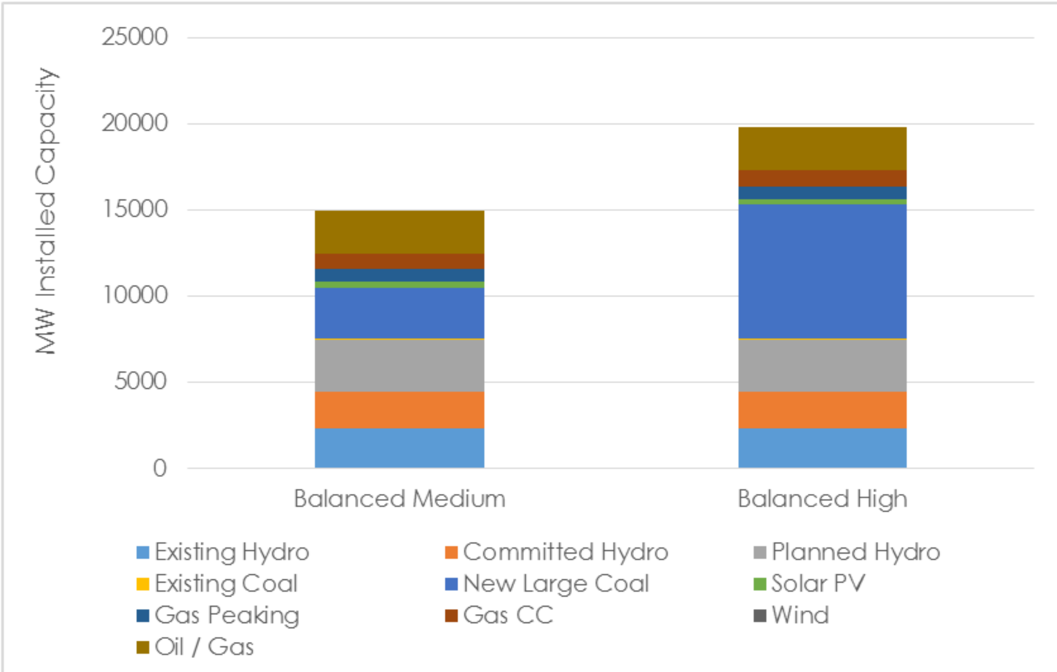
Source: Consultant's analysis

O. Long-Run Marginal Cost

89. Case 2 was run against a high electricity growth scenario wherein the electricity growth was that provided in the Consolidated Demand Forecasts report of this EMP. Figure IV-14 shows a comparison between the installed capacity in 2030 for the medium growth and high growth cases.

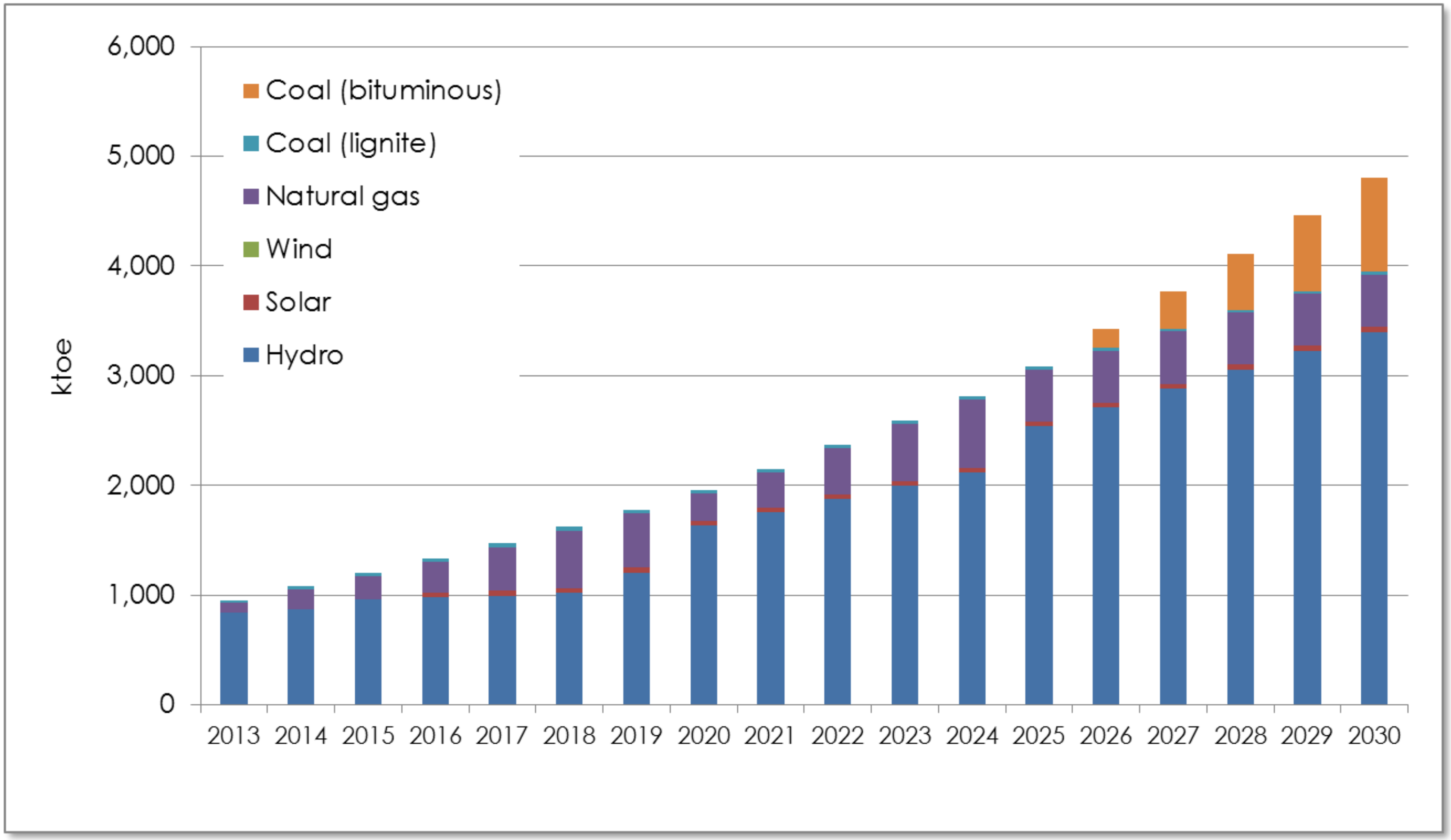
90. Using Case 2 as the basis for computation, comparing the incremental investment and capacity needs for the medium- and high-growth Case 2, the long-run marginal cost (2015 to 2030) is computed to be $ 1 200 per kW. If the out-turn growth was in line with the high growth case, the total additional Capex from 2015 to 2030 would be $ 6 B (real terms) or $ 400 M per annum.

Figure IV-14: Installed Capacity for Case 2 Medium & High Growth (MW) in 2030



Source: Consultant's analysis

Figure IV-15: Long-Term Fuel Mix – Case 1 (Planned Hydro / Coal)[7]



[7] Source of Figures IV-15 to IV-34, and Tables IV-11 to IV-16 is: Consultant's Analysis.

Table IV-11: Long-Term Expansion – Case 1 (Planned Hydro / Coal)

		Group 1	Group 2	Group 3	Group 4	Group 7	Group 8	Group 9	Group 10	Group 11	Group 12
	Installed Capacity	Existing Hydro	Committed Hydro	Planned Hydro	Existing Coal	New Large Thermal	Solar PV	Existing Gas Peaking	Existing Gas CC	Wind	Reserve & Peaking
Year	MW	MW	MW	MW	MW	MW	MW	MW	MW	MW	MW
2013	3083	2144			60			229	300		350
2014	3499	2319			60			303	767		50
2015	3881	2319	232		60			303	767		200
2016	4481	2319	232		60		300	503	767		300
2017	4781	2319	232		60		300	503	767		600
2018	5182	2319	283		60		300	703	767		750
2019	5773	2319	774		60		300	703	767		850
2020	6942	2319	2143		60		300	903	767		850
2021	7486	2319	2143	244	60		300	903	767		600
2022	8371	2319	2143	729	60		300	903	767		967
2023	9291	2319	2143	1049	60		300	903	767		1333
2024	10091	2319	2143	1049	60		300	903	767		1700
2025	11541	2319	2143	2349	60		300	903	767		1700
2026	12449	2319	2143	2737	60	180	300	903	767		1960
2027	13357	2319	2143	3125	60	360	300	903	767		2220
2028	14265	2319	2143	3513	60	540	300	903	767		2480
2029	15173	2319	2143	3901	60	720	300	903	767		2740
2030	16681	2319	2143	4289	60	1500	300	903	767		3000

Figure IV-16: Cumulative Investment Profile – Case 1 (Planned Hydro / Coal)

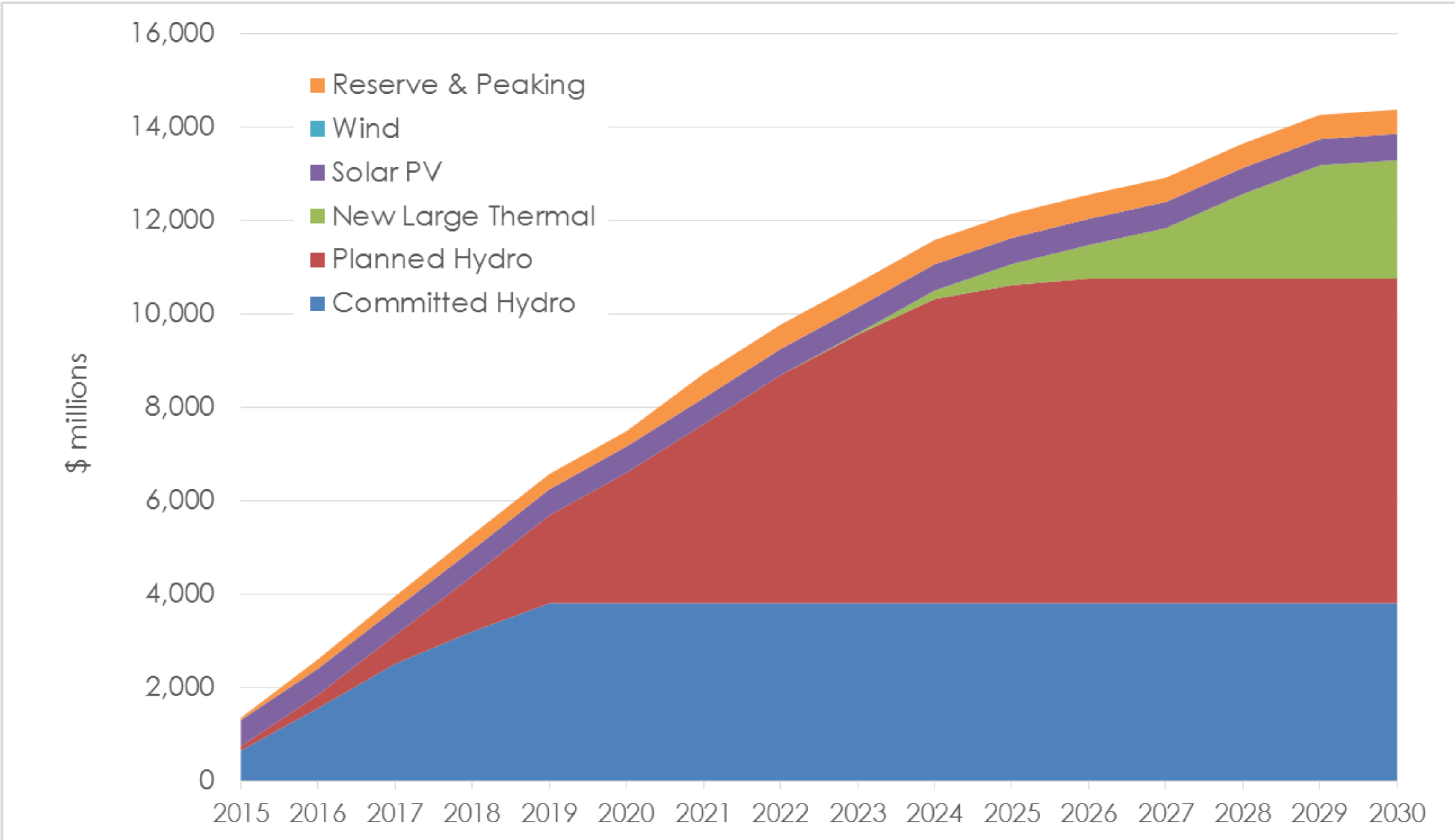


Figure IV-17: Annual Investment Profile – Case 1 (Planned Hydro / Coal)

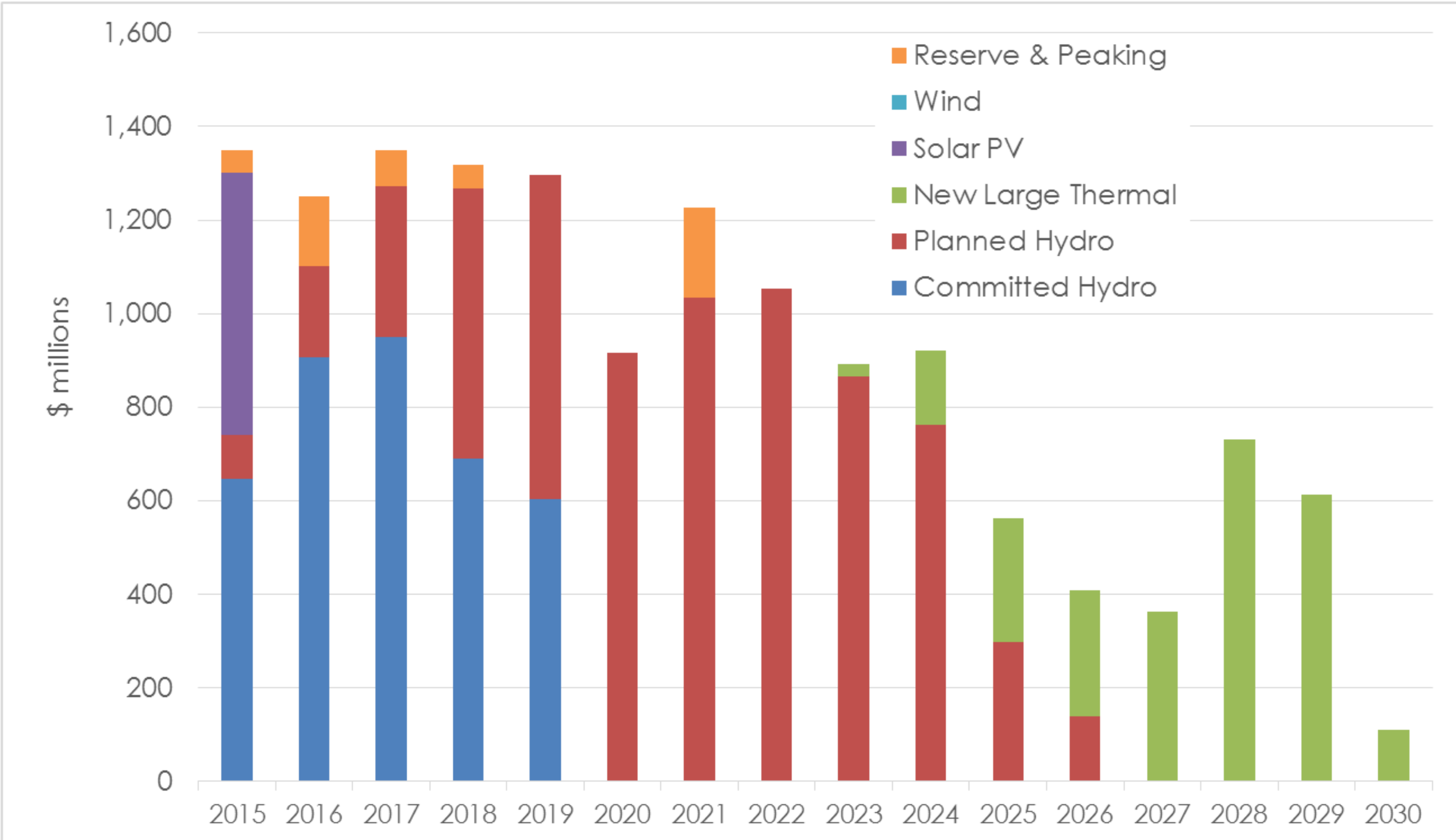


Figure IV-18: OPTIMAL Long-Term Fuel Mix – Case 2 (Balanced Hydro / Coal / Solar PV)

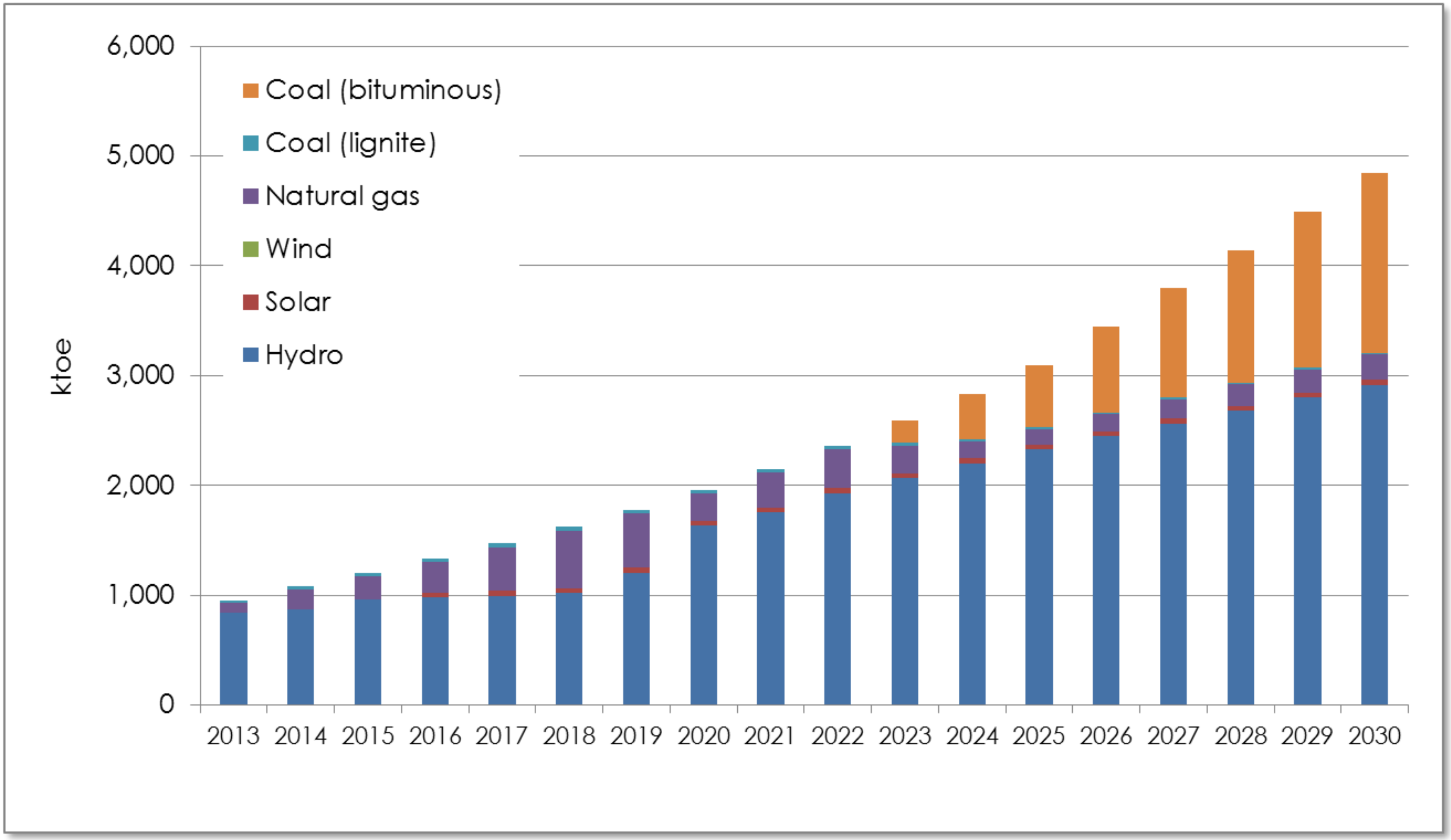


Table IV-12: OPTIMAL Long-Term Expansion – Case 2 (Balanced Hydro / Coal / Solar PV)

		Group 1	Group 2	Group 3	Group 4	Group 7	Group 8	Group 9	Group 10	Group 11	Group 12
	Installed Capacity	Existing Hydro	Committed Hydro	Planned Hydro	Existing Coal	New Large Thermal	Solar PV	Existing Gas Peaking	Existing Gas CC	Wind	Reserve & Peaking
Year	MW	MW	MW	MW	MW	MW	MW	MW	MW	MW	MW
2013	3083	2144			60			229	300		*350*
2014	3499	2319			60			303	767		50
2015	3881	2319	232		60			303	767		200
2016	4481	2319	232		60		300	503	767		300
2017	4781	2319	232		60		300	503	767		600
2018	5182	2319	283		60		300	703	767		750
2019	5773	2319	774		60		300	703	767		850
2020	7342	2319	2143		60		300	903	767		850
2021	7586	2319	2143	244	60		300	903	767		850
2022	8071	2319	2143	729	60		300	903	767		850
2023	8631	2319	2143	1049	60	240	300	903	767		850
2024	9568	2319	2143	1326	60	900	300	903	767		850
2025	10145	2319	2143	1603	60	1200	300	903	767		850
2026	10752	2319	2143	1880	60	1200	300	903	767		1180
2027	11359	2319	2143	2157	60	1200	300	903	767		1510
2028	11966	2319	2143	2434	60	1200	300	903	767		1840
2029	12573	2319	2143	2711	60	1200	300	903	767		2170
2030	14980	2319	2143	2988	60	3000	300	903	767		2500

Figure IV-19: Installed Capacity 2015 – Case 2

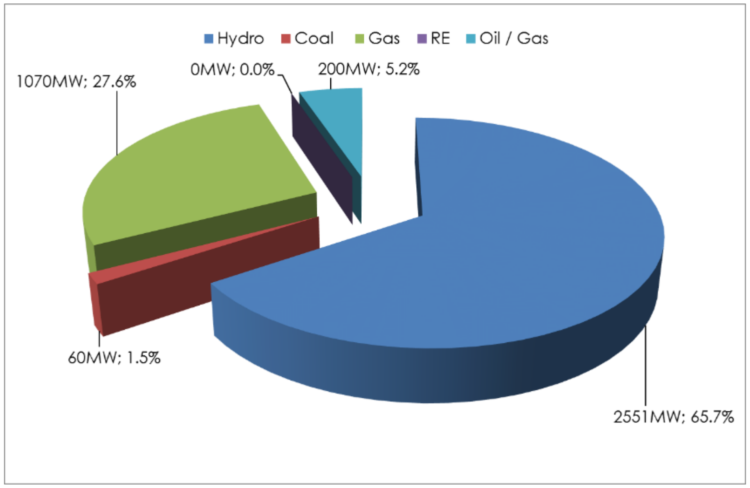


Figure IV-20: Installed Capacity 2020 – Case 2

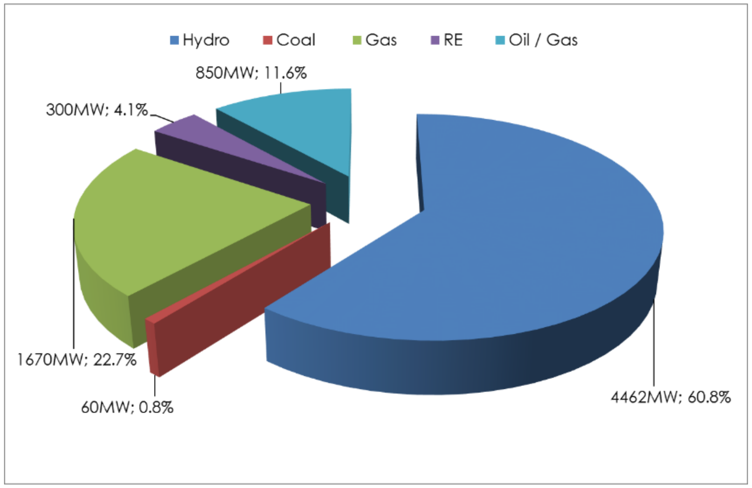


Figure IV-21: Installed Capacity 2030 – Case 2

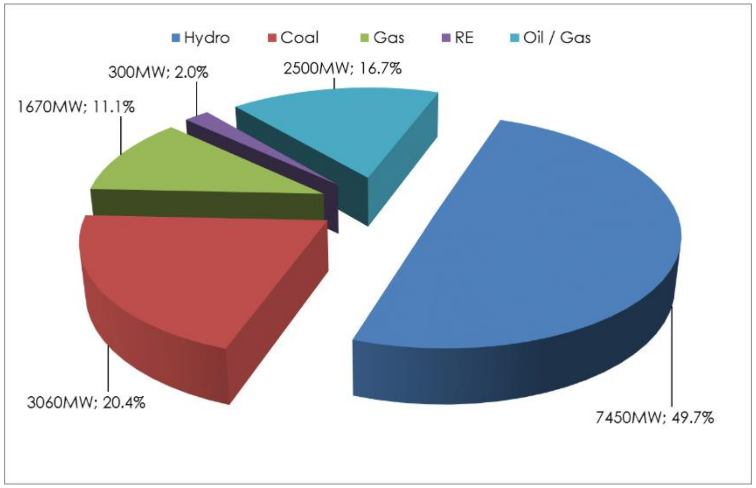


Figure IV-22: Cumulative Investment Profile – Case 2 (Balanced Hydro / Coal / Solar PV)

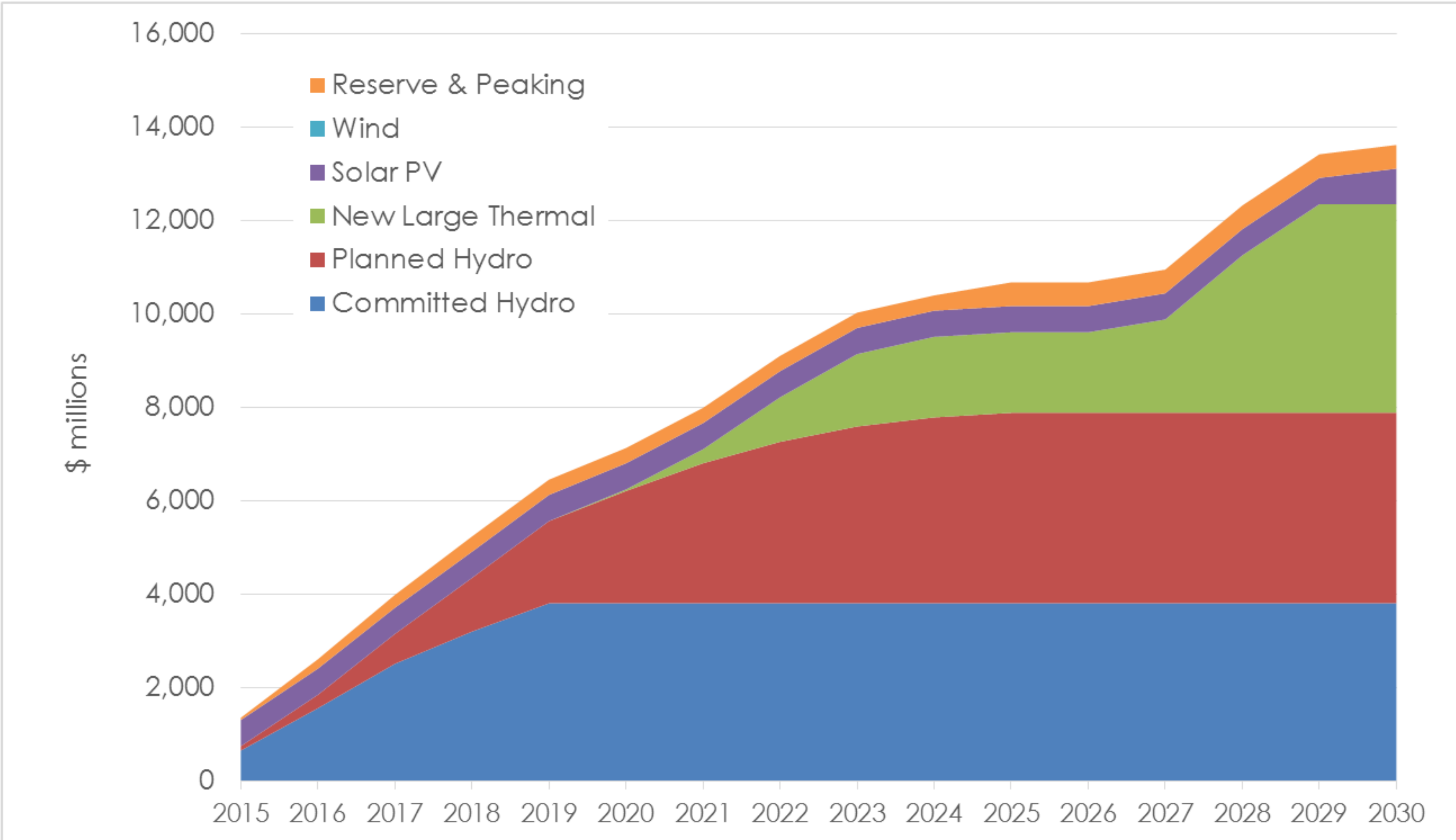


Figure IV-23: Annual Investment Profile – Case 2 (Balanced Hydro / Coal / Solar PV)

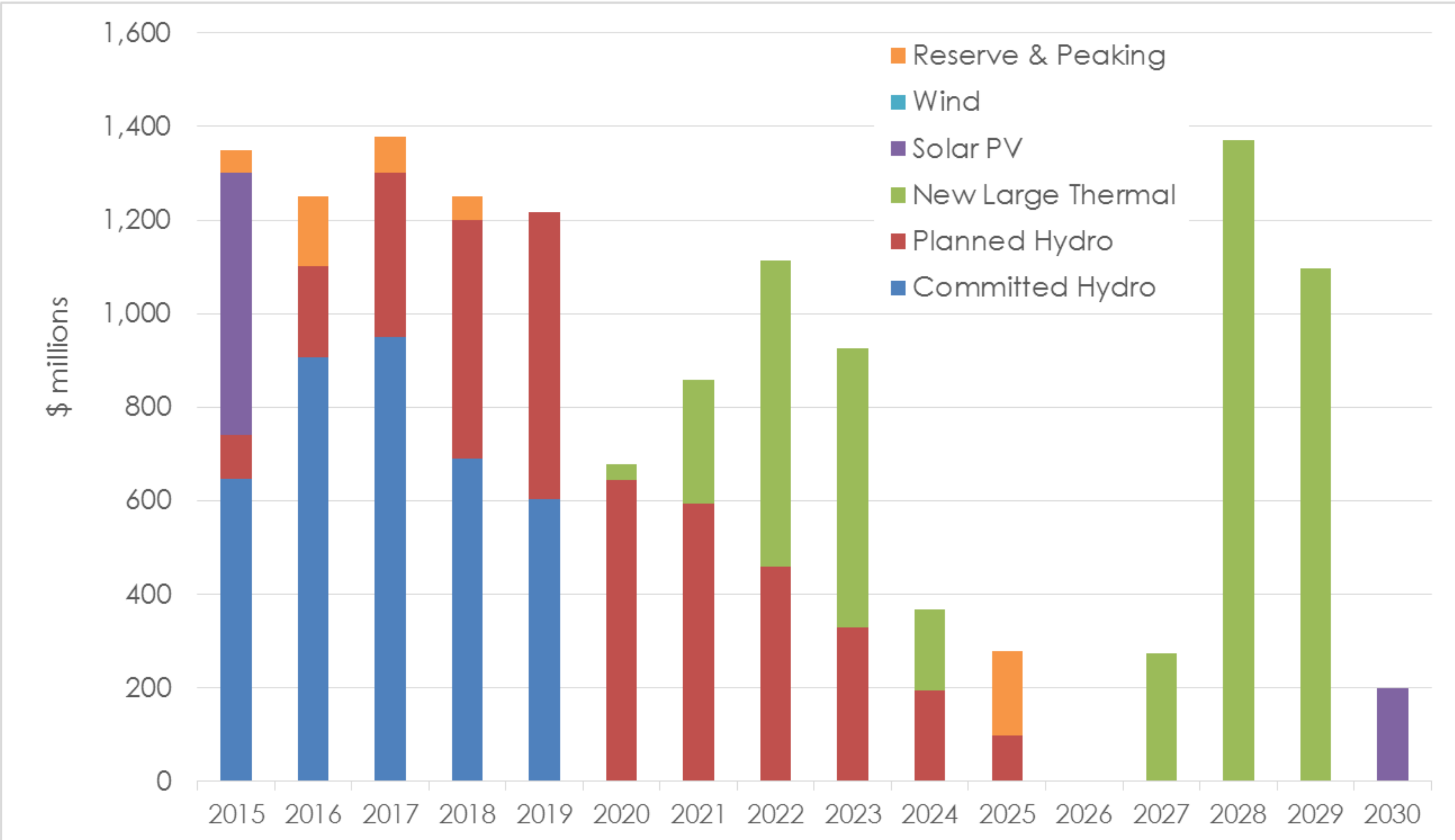


Figure IV-24: Long-Term Fuel Mix – Case 3 (Max Hydro)

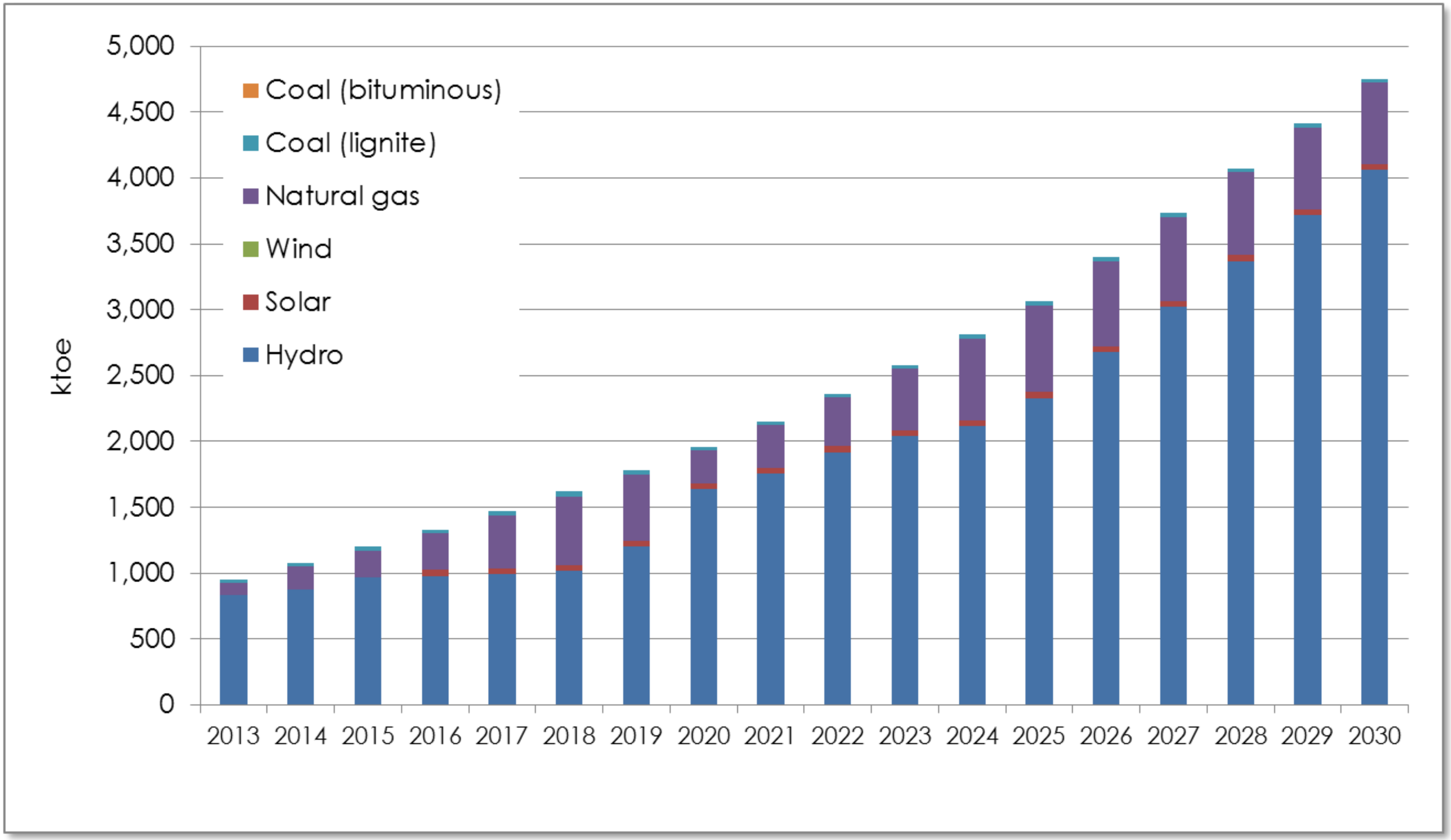


Table IV-13: Long-Term Expansion – Case 3 (Max Hydro)

		Group 1	Group 2	Group 3	Group 4	Group 7	Group 8	Group 9	Group 10	Group 11	Group 12
	Installed Capacity	Existing Hydro	Committed Hydro	Planned Hydro	Existing Coal	New Large Thermal	Solar PV	Existing Gas Peaking	Existing Gas CC	Wind	Reserve & Peaking
Year	MW	MW	MW	MW	MW	MW	MW	MW	MW	MW	MW
2013	3083	2144			60			229	300		*350*
2014	3499	2319			60			303	767		50
2015	3881	2319	232		60			303	767		200
2016	4481	2319	232		60		300	503	767		300
2017	4781	2319	232		60		300	503	767		600
2018	5182	2319	283		60		300	703	767		750
2019	5773	2319	774		60		300	703	767		850
2020	7342	2319	2143		60		300	903	767		850
2021	7325	2319	2143	233	60		300	903	767		600
2022	7943	2319	2143	651	60		300	903	767		800
2023	8568	2319	2143	826	60		300	903	767		1250
2024	9192	2319	2143	1000	60		300	903	767		1700
2025	10020	2319	2143	1528	60		300	903	767		2000
2026	11220	2319	2143	2468	60		300	903	767		2260
2027	12420	2319	2143	3408	60		300	903	767		2520
2028	13621	2319	2143	4349	60		300	903	767		2780
2029	14821	2319	2143	5289	60		300	903	767		3040
2030	16021	2319	2143	6229	60		300	903	767		3300

Figure IV-25: Cumulative Investment Profile – Case 3 (Max Hydro)

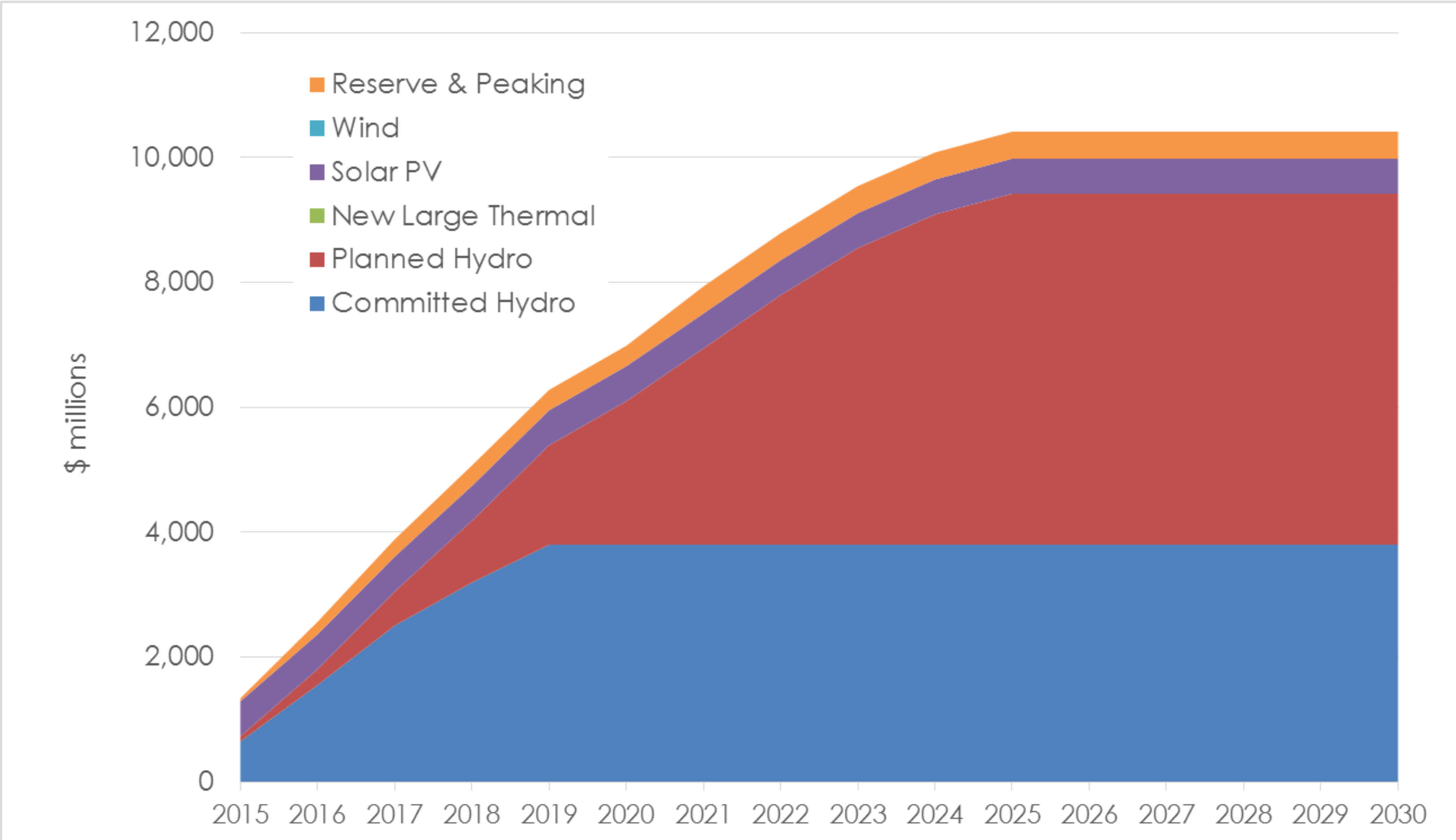


Figure IV-26: Annual Investment Profile – Case 3 (Max Hydro)

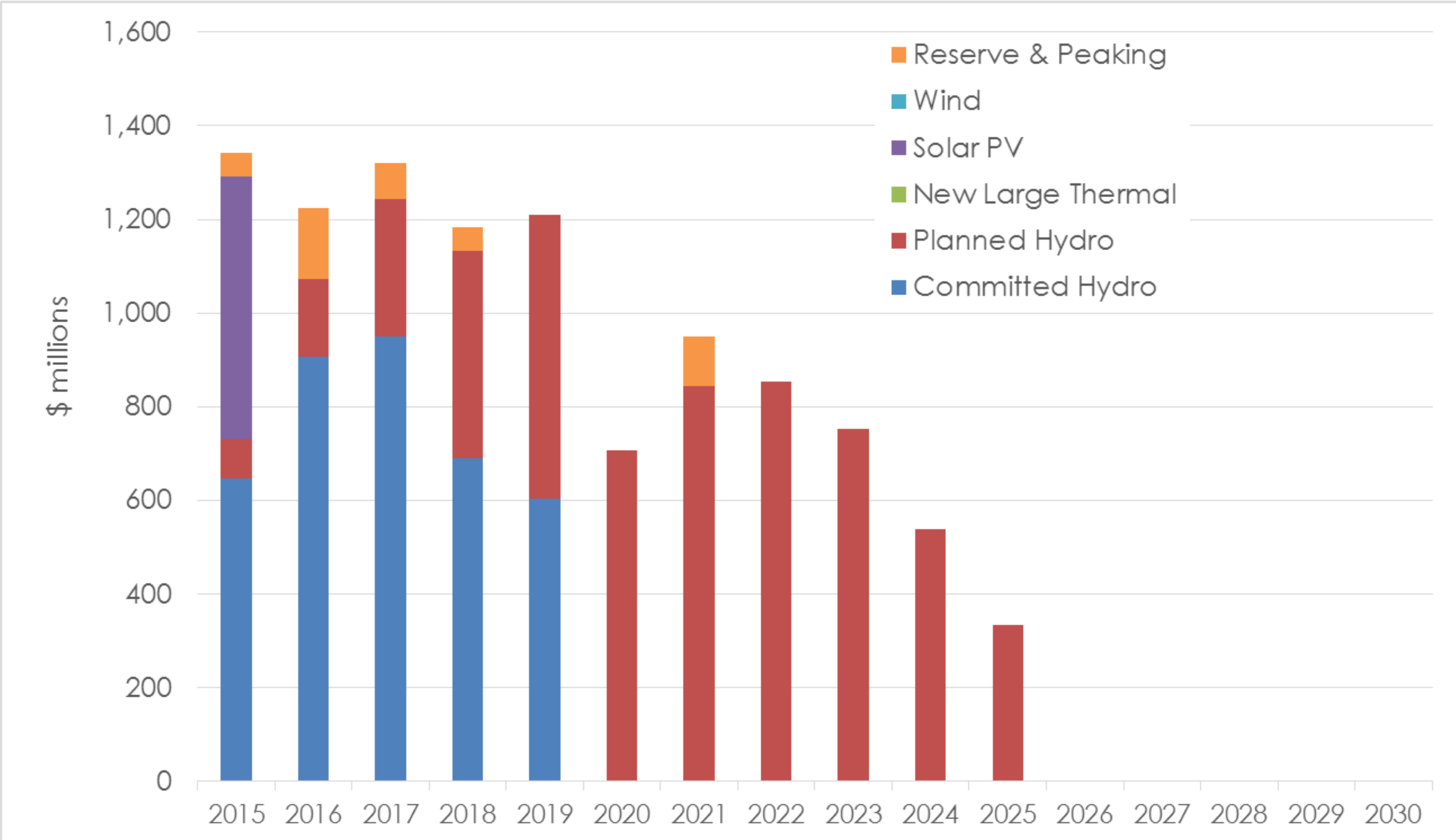


Figure IV-27: Long-Term Fuel Mix – Case 4 (Max Coal)

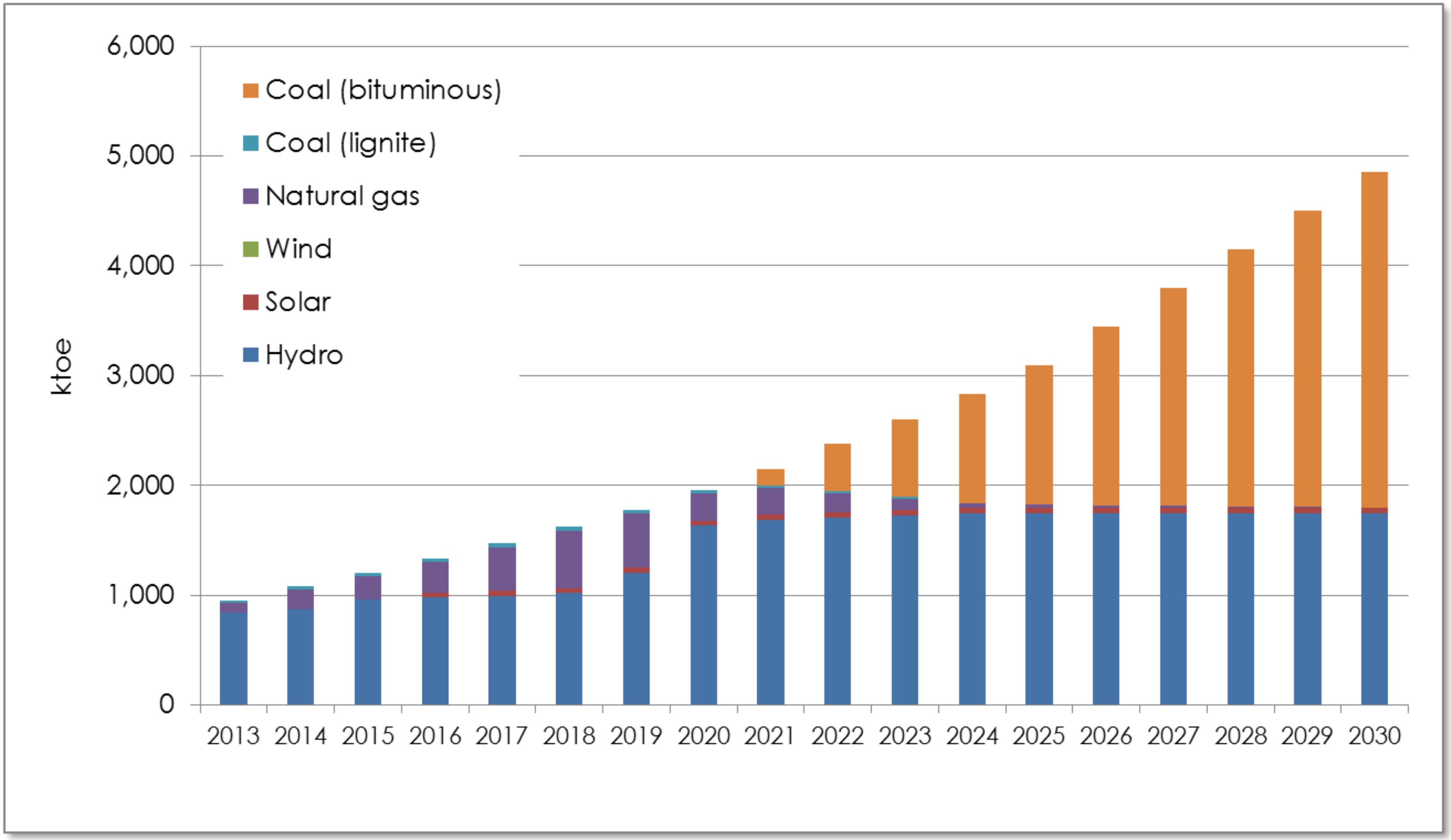


Table IV-14: Long-Term Expansion – Case 4 (Max Coal)

		Group 1	Group 2	Group 3	Group 4	Group 7	Group 8	Group 9	Group 10	Group 11	Group 12
	Installed Capacity	Existing Hydro	Committed Hydro	Planned Hydro	Existing Coal	New Large Thermal	Solar PV	Existing Gas Peaking	Existing Gas CC	Wind	Reserve & Peaking
Year	MW	MW	MW	MW	MW	MW	MW	MW	MW	MW	MW
2013	3083	2144			60			229	300		*350*
2014	3499	2319			60			303	767		50
2015	3881	2319	232		60			303	767		200
2016	4481	2319	232		60		300	503	767		300
2017	4781	2319	232		60		300	503	767		600
2018	5182	2319	283		60		300	703	767		750
2019	5773	2319	774		60		300	703	767		850
2020	6792	2319	2143		60		300	903	767		300
2021	7242	2319	2143		60	300	300	903	767		450
2022	7732	2319	2143		60	840	300	903	767		400
2023	8222	2319	2143		60	1380	300	903	767		350
2024	8892	2319	2143		60	2100	300	903	767		300
2025	9542	2319	2143		60	2700	300	903	767		350
2026	10342	2319	2143		60	3480	300	903	767		370
2027	11142	2319	2143		60	4260	300	903	767		390
2028	11942	2319	2143		60	5040	300	903	767		410
2029	12742	2319	2143		60	5820	300	903	767		430
2030	13842	2319	2143		60	6900	300	903	767		450

Figure IV-28: Cumulative Investment Profile – Case 4 (Max Coal)

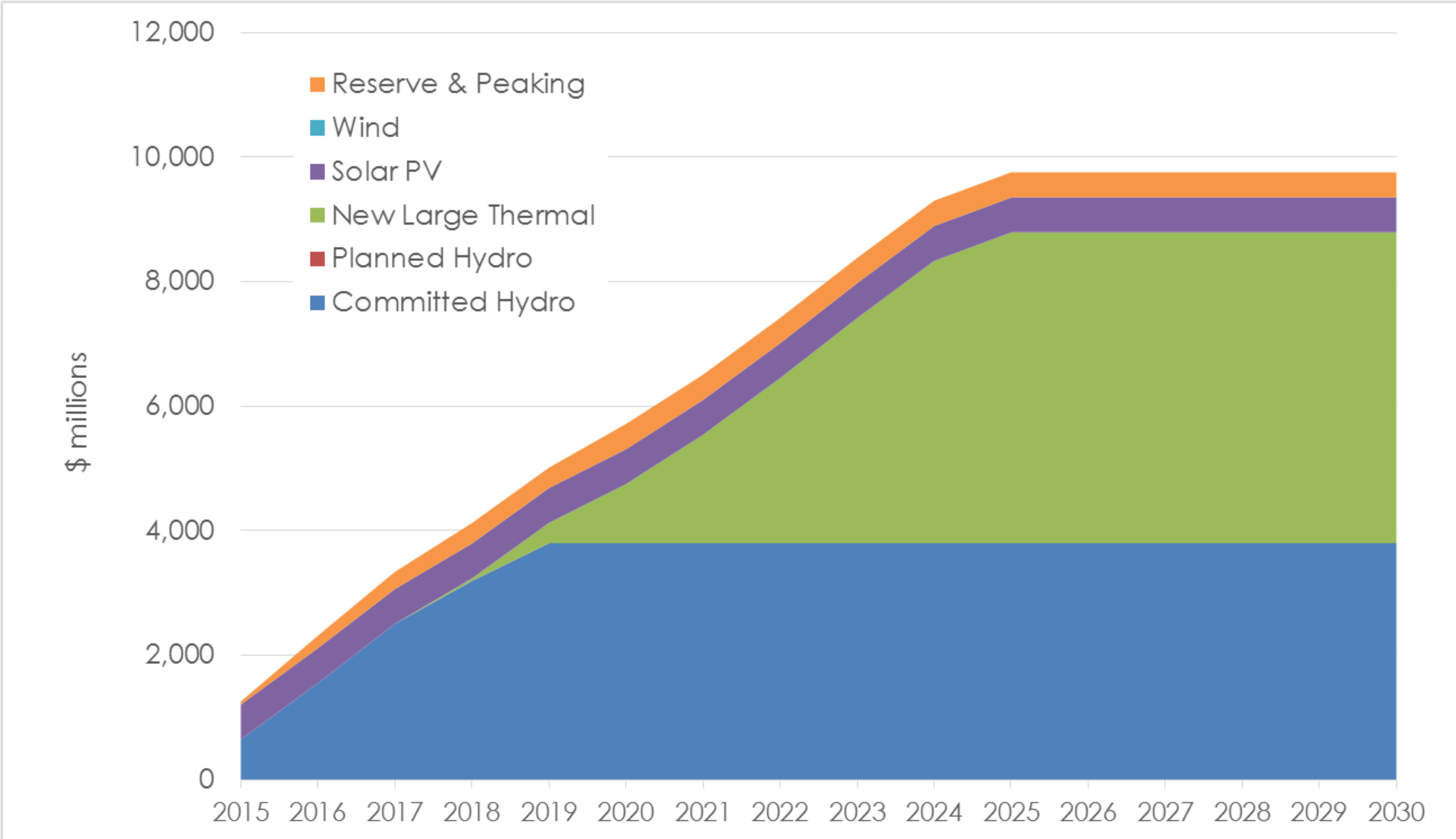


Figure IV-29: Annual Investment Profile – Case 4 (Max Coal)

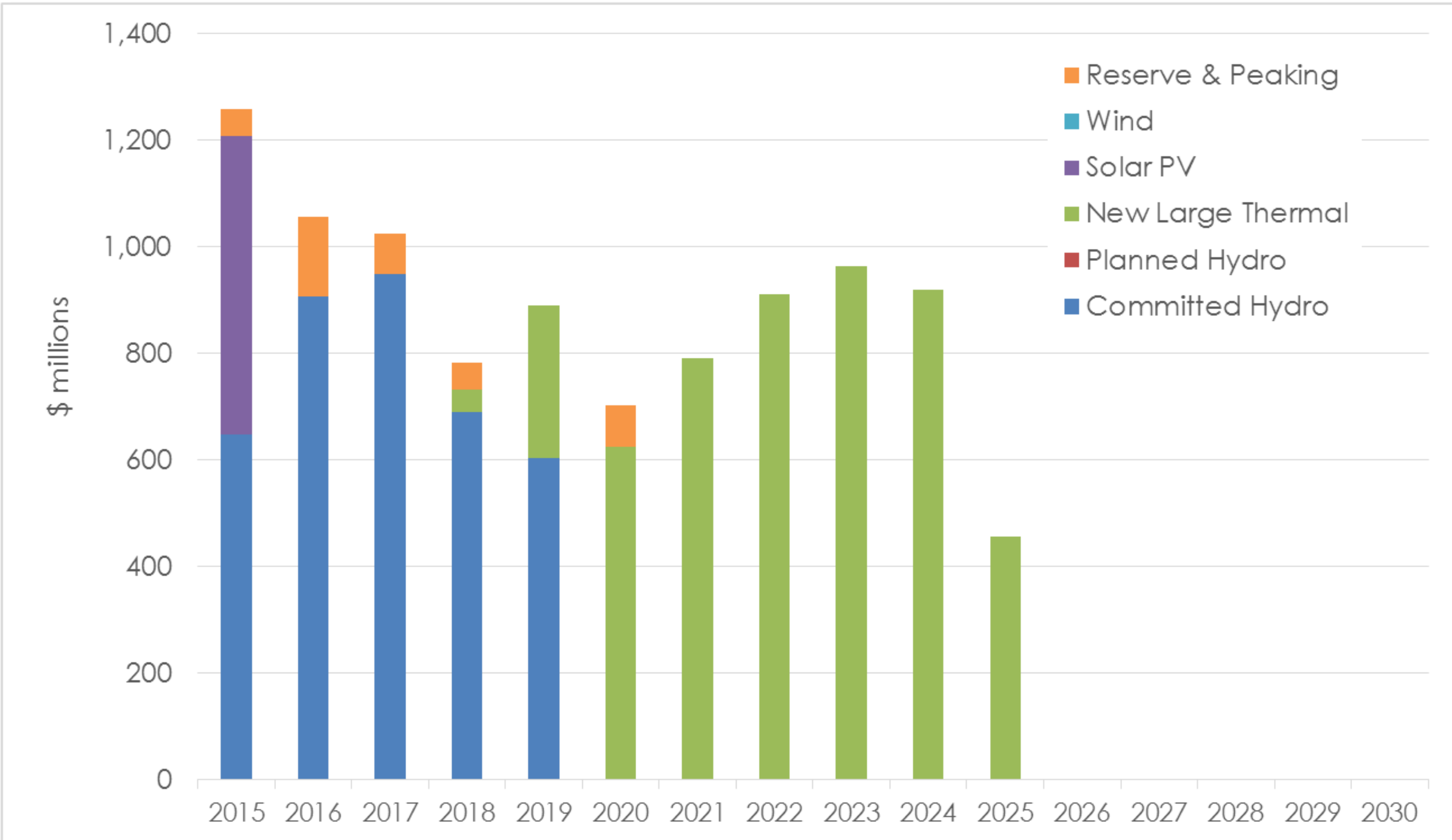


Figure IV-30: Long-Term Fuel Mix – Case 5 (Max Solar PV / Wind)

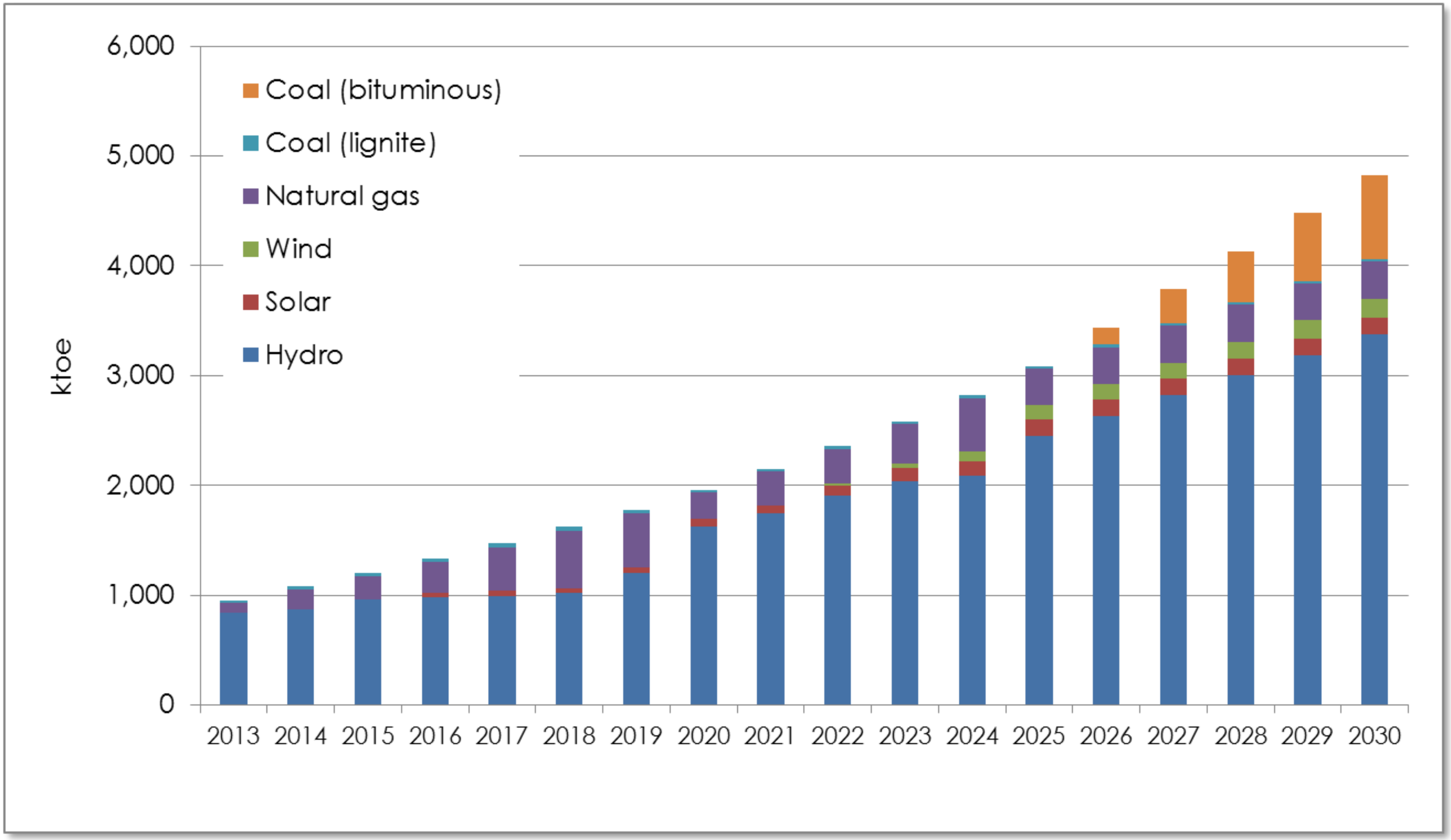


Table IV-15: Long-Term Expansion – Case 5 (Max Solar PV / Wind)

		Group 1	Group 2	Group 3	Group 4	Group 7	Group 8	Group 9	Group 10	Group 11	Group 12
	Installed Capacity	Existing Hydro	Committed Hydro	Planned Hydro	Existing Coal	New Large Thermal	Solar PV	Existing Gas Peaking	Existing Gas CC	Wind	Reserve & Peaking
Year	MW	MW	MW	MW	MW	MW	MW	MW	MW	MW	MW
2013	3083	2144			60			229	300		*350*
2014	3499	2319			60			303	767		50
2015	3881	2319	232		60			303	767		200
2016	4481	2319	232		60		300	503	767		300
2017	4781	2319	232		60		300	503	767		600
2018	5182	2319	283		60		300	703	767		750
2019	5773	2319	774		60		300	703	767		850
2020	6942	2319	2143		60		450	903	767		300
2021	7486	2319	2143	244	60		450	903	767		600
2022	8371	2319	2143	729	60		600	903	767	100	750
2023	9291	2319	2143	1049	60		800	903	767	200	1050
2024	10091	2319	2143	1049	60		900	903	767	400	1550
2025	11541	2319	2143	2349	60		1000	903	767	600	1400
2026	12449	2319	2143	2737	60	180	1000	903	767	640	1700
2027	13357	2319	2143	3125	60	360	1000	903	767	680	2000
2028	14265	2319	2143	3513	60	540	1000	903	767	720	2300
2029	15173	2319	2143	3901	60	720	1000	903	767	760	2600
2030	16681	2319	2143	4289	60	1500	1000	903	767	800	2900

Figure IV-31: Cumulative Investment Profile – Case 5 (Max Solar PV / Wind)

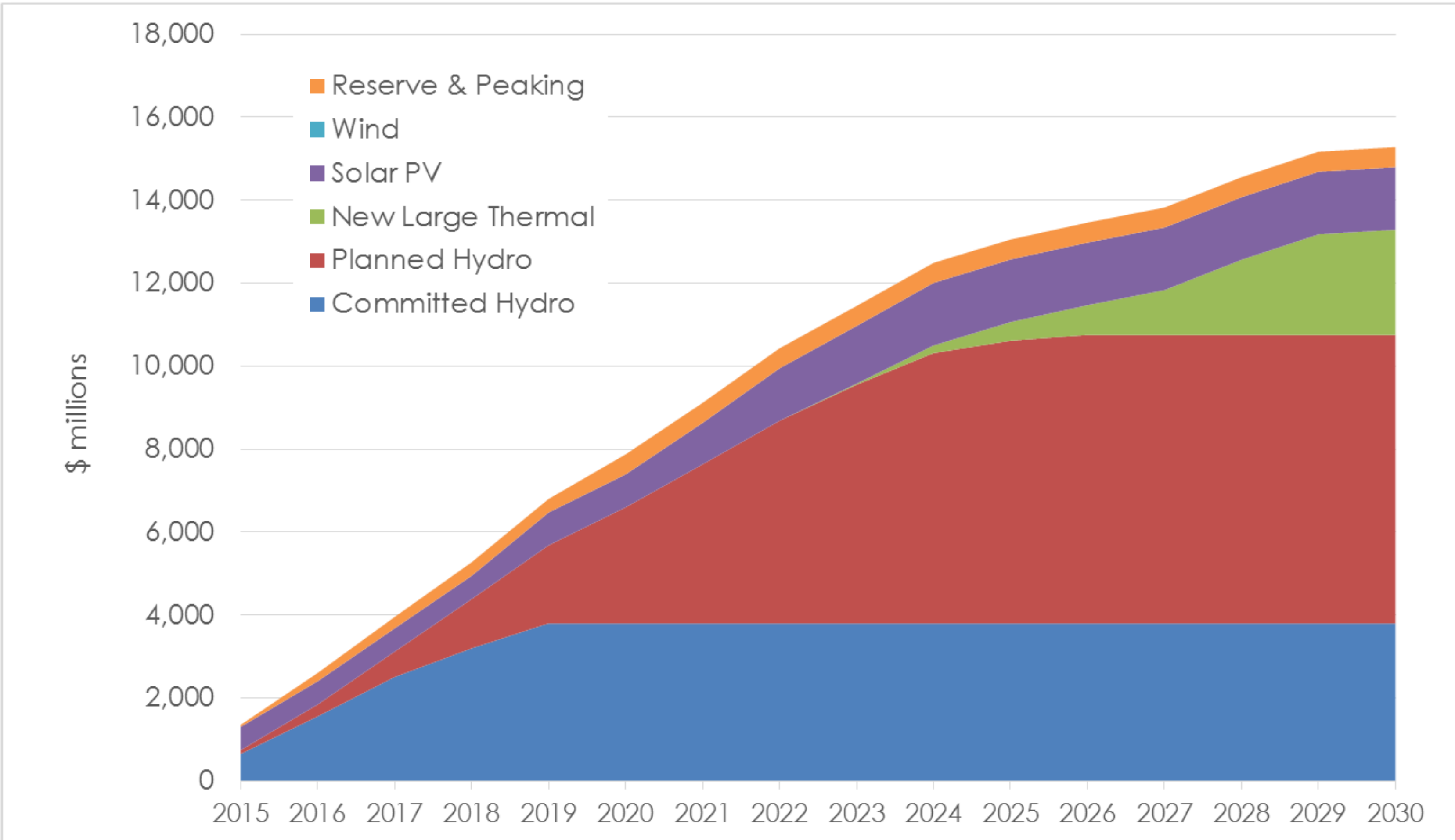


Figure IV-32: Annual Investment Profile – Case 5 (Max Solar PV / Wind)

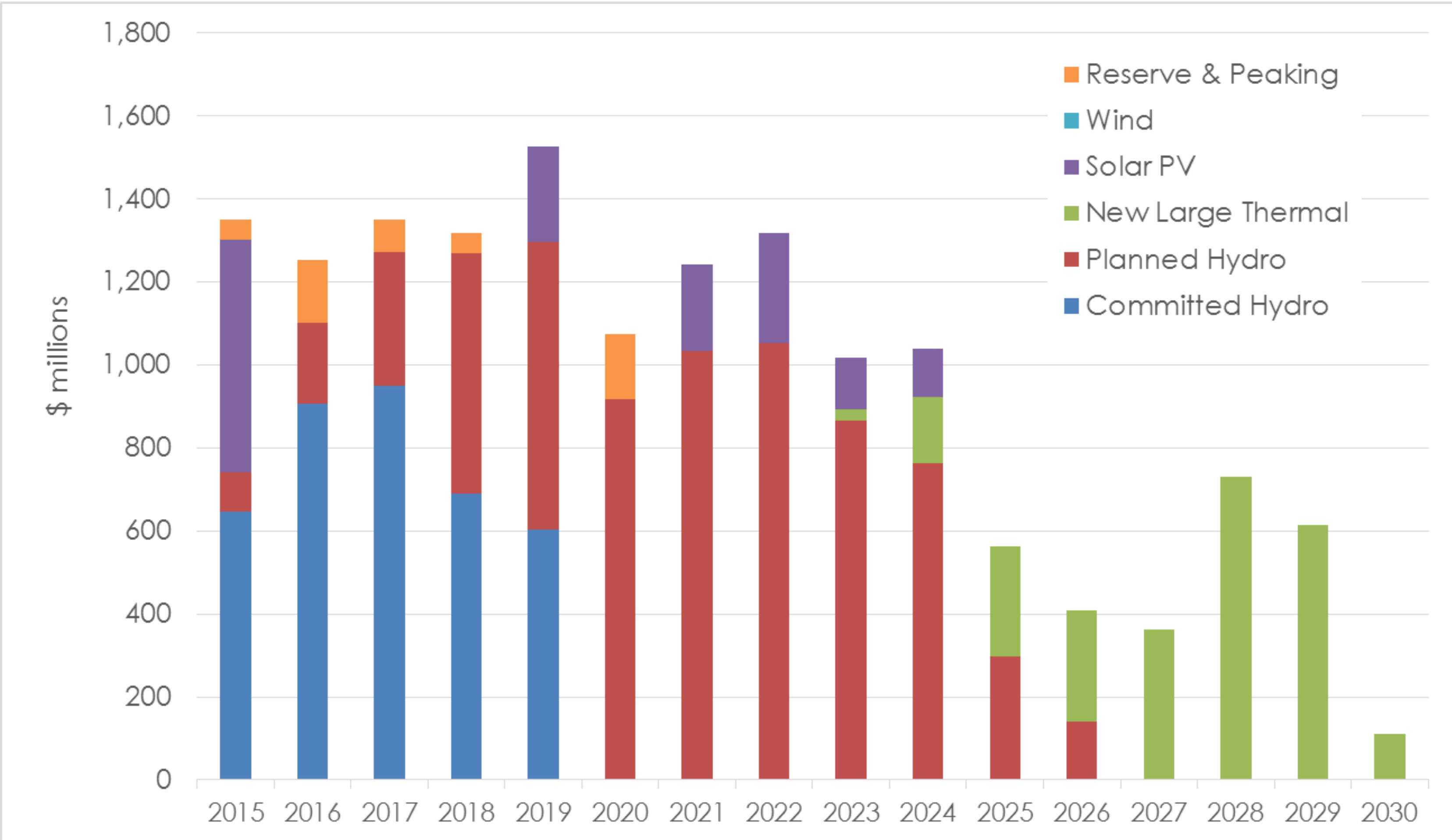


Table IV-16: Long-Term Expansion – Case 2 HIGH GROWTH

		Group 1	Group 2	Group 3	Group 4	Group 7	Group 8	Group 9	Group 10	Group 11	Group 12
	Installed Capacity	Existing Hydro	Committed Hydro	Planned Hydro	Existing Coal	New Large Thermal	Solar PV	Existing Gas Peaking	Existing Gas CC	Wind	Reserve & Peaking
Year	MW	MW	MW	MW	MW	MW	MW	MW	MW	MW	MW
2013	3083	2144			60	0	0	229	300		*350*
2014	3499	2319			60	0	0	303	767		50
2015	3931	2319	232		60	0	0	303	767		250
2016	4581	2319	232		60	0	300	503	767		400
2017	4931	2319	232		60	0	300	503	767		750
2018	5382	2319	283		60	0	300	703	767		950
2019	6123	2319	774		60	0	300	703	767		1200
2020	7342	2319	2143		60	0	300	903	767		850
2021	8036	2319	2143	244	60	450	300	903	767		850
2022	8971	2319	2143	729	60	900	300	903	767		850
2023	9951	2319	2143	1049	60	1560	300	903	767		850
2024	11068	2319	2143	1326	60	2400	300	903	767		850
2025	12245	2319	2143	1603	60	3300	300	903	767		850
2026	13812	2319	2143	1880	60	4260	300	903	767		1180
2027	15379	2319	2143	2157	60	5220	300	903	767		1510
2028	16946	2319	2143	2434	60	6180	300	903	767		1840
2029	18513	2319	2143	2711	60	7140	300	903	767		2170
2030	19780	2319	2143	2988	60	7800	300	903	767		2500

Figure IV-33: Cumulative Investment Profile – Case 2 HIGH GROWTH

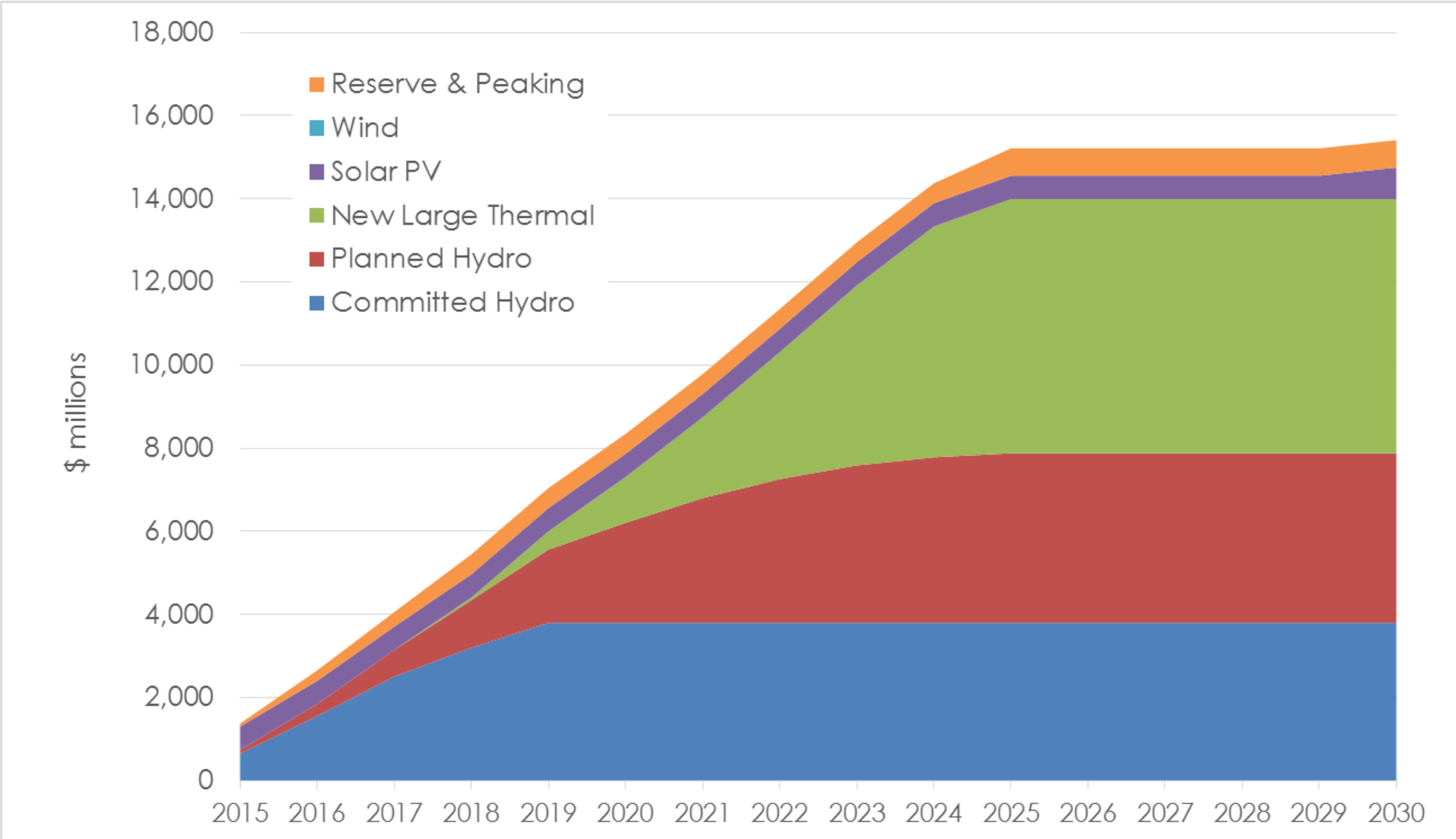
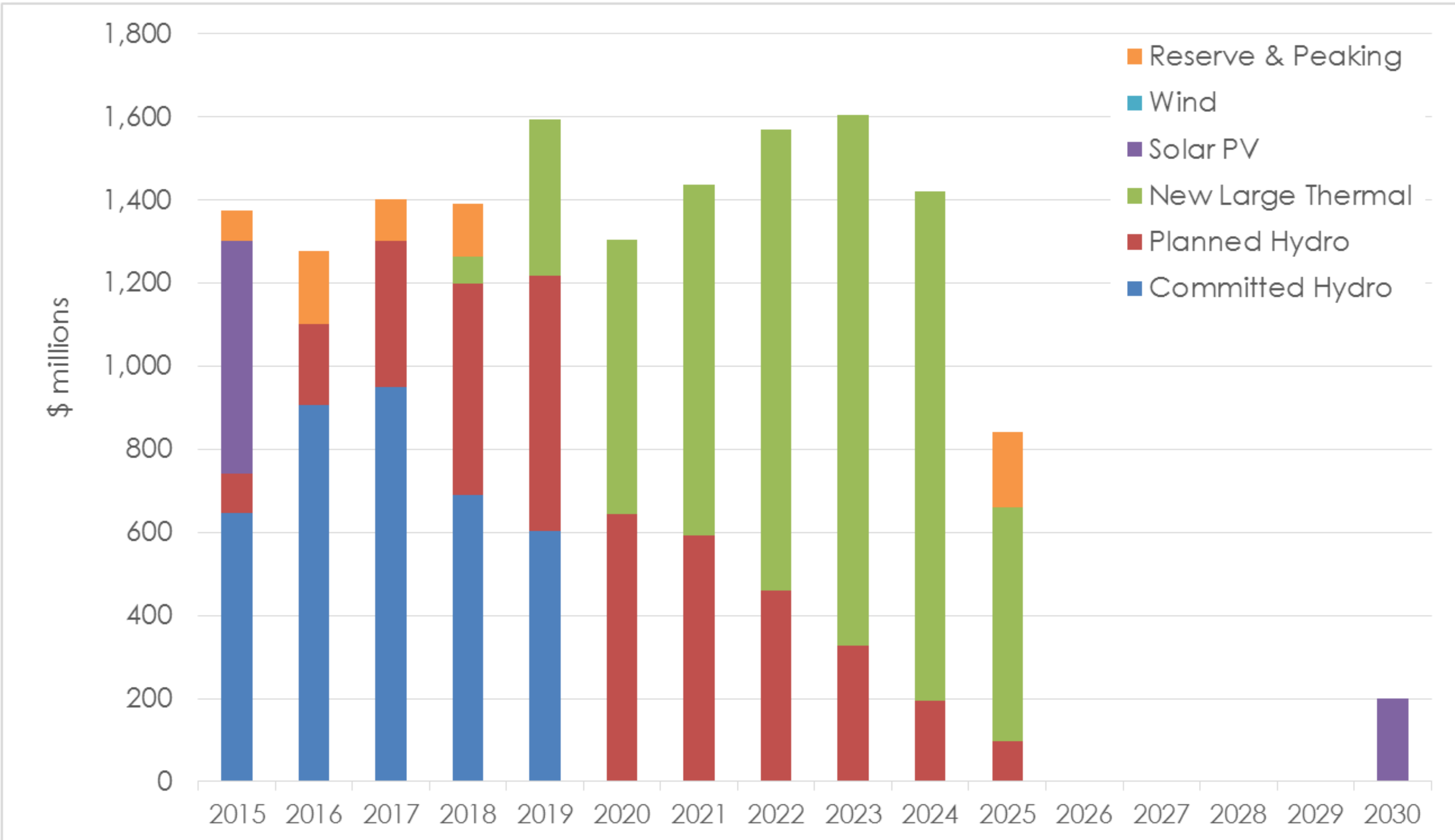


Figure IV-34: Annual Investment Profile – Case 2 HIGH GROWTH



APPENDIX A: Methodology & Approach for EMP Expansion Planning

Long-Term Fuel Mix Optimization Model

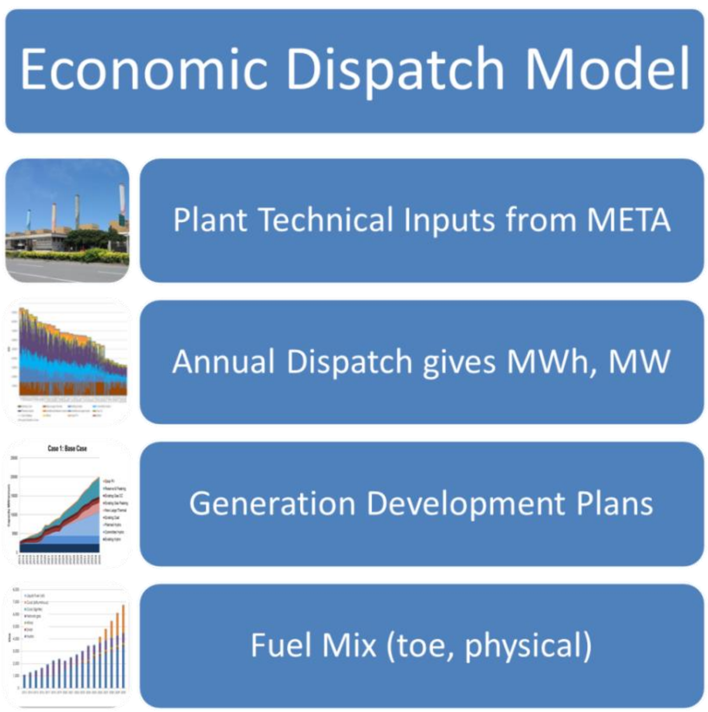
An optimization model was used to identify the optimal long-term fuel mix. The model comprises three modules: 1) An Economic Dispatch Model; 2) A Portfolio Analysis Model; and 3) a Portfolio Prioritization & Ranking Model (a Multi-Criteria Decision Model).

Economic Dispatch Model

The Economic Dispatch Model takes technical inputs for power plants (as energy pools) and computes the optimal plant dispatch that minimizes fuel costs. Fuel cost optimization is determined primarily by heat rate considerations. However, the maximum capacity available from each pool acts as a constraint. The model produces the generated MWh and reports the peak MW produced by each energy type.

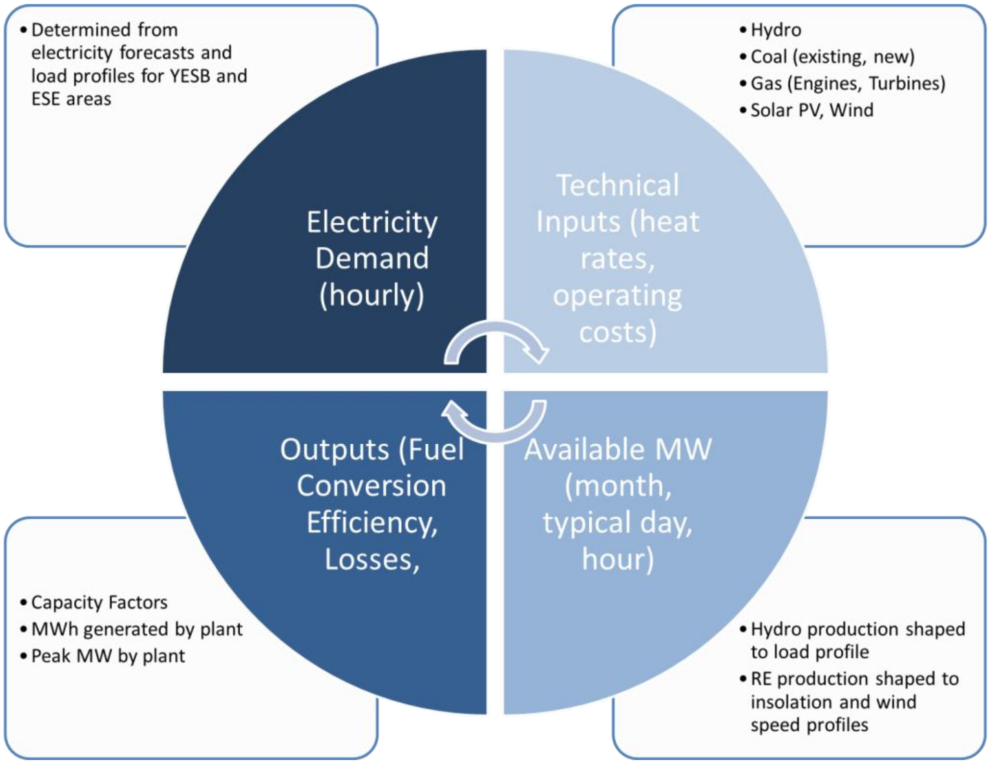
The schema of the Economic Dispatch model is shown by Figure A1 and A2:

Figure A1: Economic Dispatch Model



Source: Consultant

Figure A2: Economic Dispatch Modeling Process



Source: Consultant's analysis

Portfolio Analysis Model

The Portfolio Analysis Model computes the Levelized Cost of Energy (LCoE) for a portfolio of generation assets. The levelised cost of energy (LCoE) is the total discounted unit cost of power generation over the asset lifetime, and includes CAPEX, fixed and variable O&M costs, fuel costs, and the option to include environmental costs.

The capital investment (CAPEX) for each generation asset type has been determined as the 'overnight' capital costs which include costs of equipment, construction, installation and engineering, but excludes interest during construction (IDC). IDC is calculated as a separate cost item and is based on a predetermined cost of debt.

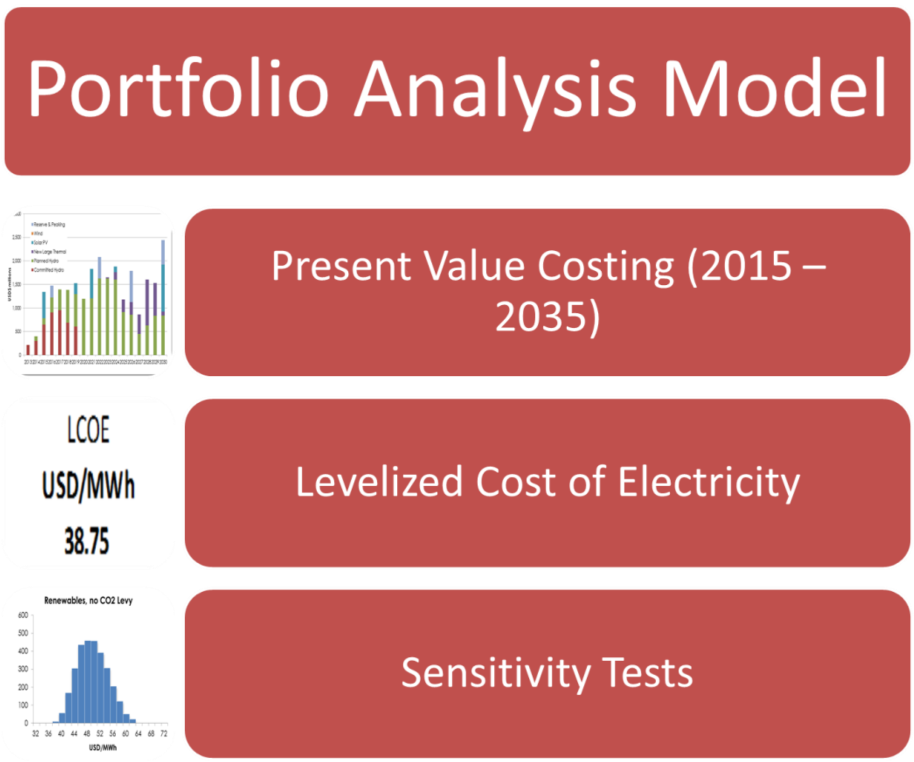
The Model calculates CAPEX, fixed and variable O&M costs as well as decommissioning costs based on initial values for the base year (2014) and respective profiles over the calculation horizon. The CAPEX profile takes into consideration both price escalation reflecting changes in raw material and labour costs over the period, as well as change of unit CAPEX costs related to generation unit size. Fixed O&M and decommissioning costs are defined as shares of the CAPEX.

The Model supports evaluation of three CO2 price scenarios: zero levy, flat price of 30 USD/ton, and price increase over the calculation time horizon (from 8.07 USD/ton in 2014 to 30 USD/ton in 2035). The price increase scenario is used for final ranking of the portfolios according to their LCoE levels.

The Model supports the evaluation of asset portfolio investment using a deterministic approach based on the most likely expenditure and price values, or by including uncertainties related to price and cost levels and their future developments. This is achieved by introducing additional expert-based estimates of possible minimum and maximum boundaries for unit CAPEX and fuel growth rates. The expected CAPEX and price values are estimated using Monte Carlo simulation for beta-binomial (PERT) distribution.

The Model calculates the present value of total portfolio costs at 4%, 6% and 8% real discount rates. Real prices of 2014 are used throughout the whole calculation chain (both for the input and output data).

Figure A3: Portfolio Analysis Model



Source: Consultant's analysis

It has been assumed that 40% of the total investment program expenditures will be financed with equity, the cost of equity being equal to 10%. The remainder is assumed to be financed with long-term loans, the cost of debt being 3.3%. This rate is also used for calculating IDC.

Base year values for CAPEX, OPEX, fuel prices and discrete fuel price change rates for each 5-year period over the calculation horizon are based on the Model for Electricity Technology Assessments (META)[8]. Using the META data, the portfolio evaluation model calculates smoothed price curves for crude oil, natural gas, bituminous and sub-bituminous coal, and lignite fuels.

Assumptions for unit CAPEX and fuel price change rates used for deterministic and probabilistic

[8] For description of META and of CAPEX, OPEX and price assumptions used, see the Primary Energy & Technology Options Report

evaluation are presented in the tables below. The US dollar is the base currency of the portfolio evaluation model. All input and output costs and prices are expressed in real US dollar terms for 2014.

Table A1: Unit CAPEX (USD/kWh)

Plant Type	Most Likely		
	Min	META	Max
Existing Hydro		2 000	
Committed Hydro	1 500	2 800	4 000
Planned Hydro	1 000	2 000	4 000
Existing Coal		2 300	
New Large Thermal	1 000	1 300	2 200
Solar PV	1 700	2 100	2 500
Existing Gas Peaking		486	
Existing Gas CC	600	918	1 300
Wind	1 000	1 360	2 000
Reserve & Peaking		486	

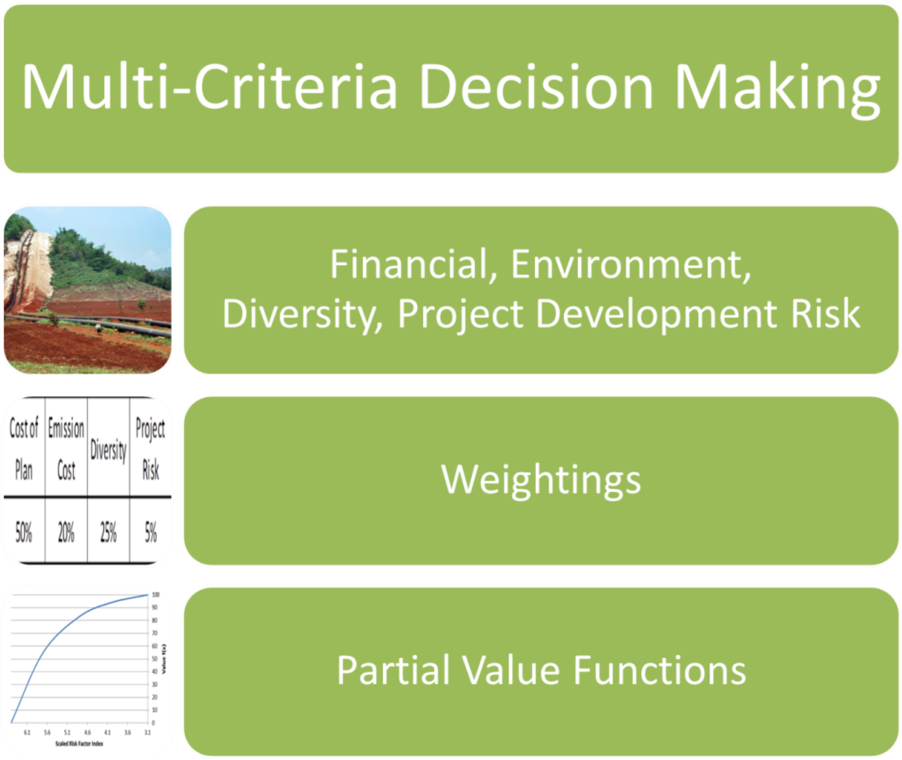
Table A2: Fuel Price Change Assumptions

Fuel prices	Most Likely		
	Min	META	Max
Coal price growth			
2014-2020	5.9 %	6.9 %	7.9 %
2020-2025	2.9 %	3.9 %	4.9 %
2025-2030	2.9 %	3.9 %	4.9 %
2030-2035	2.9 %	3.9 %	4.9 %
Gas price growth			
2014-2020	-14.0 %	-13.0 %	-12.0 %
2020-2025	2.4 %	3.4 %	4.4 %
2025-2030	2.4 %	3.4 %	4.4 %
2030-2035	2.4 %	3.4 %	4.4 %
Oil price growth			
2014-2020	9.1 %	10.1 %	11.1 %
2020-2025	4.8 %	5.8 %	6.8 %
2025-2030	4.8 %	5.8 %	6.8 %
2030-2035	4.8 %	5.8 %	6.8 %

Portfolio Prioritization & Ranking Model

A Multi-criteria Decision Making process has been used to prioritize and rank the alternative cases. Prioritization is applied according to weighted policy objectives. The policy performance is scored and partial value functions applied to normalize the scores.

Figure A4: Portfolio Prioritization & Ranking Model



Source: Consultant's analysis

For the purpose of scoring the cases, the performance measures are as follows:-

- The cost of the plan is determined as the present value total operating cost. This cost is normalised by indexing against the cost of the lowest cost plan.
- The emissions factor is determined as the total cost of CO2, Nox, Sox and particulates.
- Dependence on gas is determined as the installed capacity of gas-fuelled plant as a percentage of the total installed capacity.
- Project development risk is scored for each case, weighted by the MW of installed capacity for the generation technologies employed.

Some further elaboration of project development risks is necessary. One of the key risks relates to the learning curve associated with the use of a new technology in a new environment. An obvious example is the introduction of large solar PV farms in Myanmar. Such risks would be further elevated if two technologies were to be introduced at the same time, e.g. solar PV farms and large wind farms.

The following table provides a risk assessment of project risk factors including the scores associated with various technology choices, where the scoring is related to the use of the technology in Myanmar.

Table A3: Project Development Risk Factors

	CFB Coal 300MW	Wind Farm	Small Hydro	Large Hydro	Solar PV Farm	Gas CCGT	Gas Engine	Coal Supercritical
Confidence in Cost Assumptions	0	0	1	2	0	0	0	1
Confidence in Technology	0	0	0	0	0	0	0	0
Confidence in Timing	2	0	2	3	0	1	1	3
Confidence in Reliability	0	0	0	0	0	0	0	0
Safety Concerns	0	0	0	0	0	0	0	0
Resource Concerns	0	2	0	0	0	3	3	2
TOTAL	2	2	3	5	0	4	4	6

Sources: Consultants' analysis

The raw scores determined as the abovementioned performance measures, cannot be added directly as the policy factors are of different nature. The raw scores are weighted by policy weighting factors as follows:-

- Cost of plan – Weighting 50%;
- Emissions – Weighting 20%;
- Diversification (dependence on gas) – Weighting 25%; and
- Project Development Risk – Weighting 5%.

Again the weighted scores cannot be added directly. It is first required to normalize the weighted scores using a 'value preference' approach. The values are determined separately for each policy factor and normalized using partial value functions.

The weighting of the project development risk factors by MW of installed capacity is given for each case as follows:

Table A4: Risk Factor Scores

Risk rating			
Projects	**R**	**Rationale**	**Scoring**
No risk project	0	High confidence in cost assumptions	
		High confidence in technology	
		High confidence in timing	
		High confidence in reliability	
		Minimal safety concerns	
		No resource concerns	
CFB Coal 300MW	2	Moderate confidence in cost assumptions	0
		Moderate confidence in technology	0
		Moderate confidence in timing	2
		High confidence in reliability	0

Risk rating			
Projects	**R**	**Rationale**	**Scoring**
		Minimal safety concerns	0
		Moderate resource concerns: water	0
Wind Farm	2	Confidence in cost assumptions	0
		Low confidence in technology	0
		Fair confidence in timing	0
		Low confidence in reliability: typhoons in Myanmar	0
		Minimal safety concerns	0
		Low resource concerns: wind speed	2
Small Hydro	3	Confidence in cost assumptions	1
		High confidence in technology	0
		Confidence in timing	2
		Poor confidence in reliability: history in Myanmar	0
		Minimal safety concerns	0
		Moderate resource concerns: water	0
Large Hydro	5	Low confidence in cost assumptions	2
		High confidence in technology	0
		Moderate confidence in timing	3
		Moderate confidence in reliability	0
		Minimal safety concerns	0
		Moderate resource concerns: water	0
Solar PV Farm	0	Moderate confidence in cost assumptions	0
		High confidence in technology	0
		Moderate confidence in timing	0
		High confidence in reliability	0
		Minimal safety concerns	0
		No resource concerns	0
Gas CCGT	4	Low confidence in cost assumptions	0
		High confidence in technology	0
		Moderate confidence in timing	1
		High confidence in reliability	0
		Minimal safety concerns	0
		Moderate resource concerns: water	3
Gas Engine	4	High confidence in cost assumptions	0
		High confidence in technology	0

Risk rating			
Projects	**R**	**Rationale**	**Scoring**
		Moderate confidence in timing	1
		High confidence in reliability	0
		Minimal safety concerns	0
		Moderate resource concerns: water	3
Coal Supercritical	6	High confidence in cost assumptions	1
		High confidence in technology	0
		Moderate confidence in timing	3
		High confidence in reliability	0
		Moderate safety concerns: Ash, Dust	0
		Moderate resource concerns: water	2

Source: Consultant's analysis

Table A5: Weighted Risk Factors for Each Case

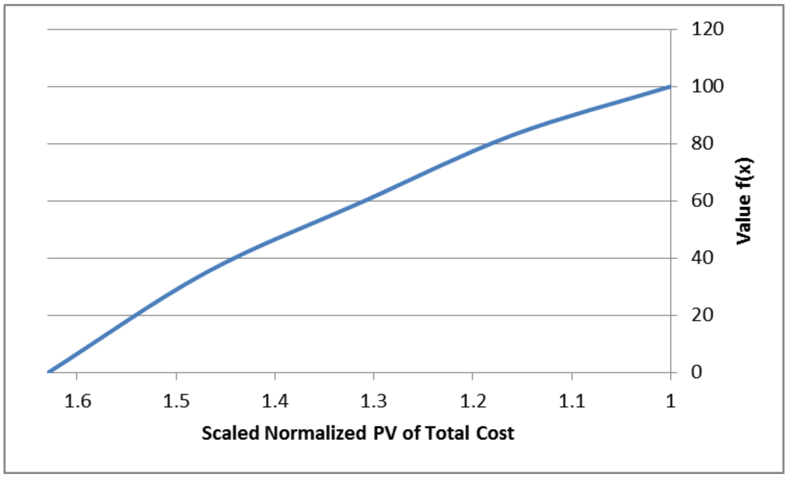
	Risk rating				
Case	**Plan**	**R**	**Projects**	**New Capacity by 2030**	**Scoring**
1	Planned Hydropower	4.4	CFB Coal 300MW	300	2.0
			Wind Farm		2.0
			Small Hydro	1,442	3.0
			Large Hydro	5,766	5.0
			Solar PV Farm	300	0.0
			Gas CCGT	3,800	4.0
			Gas Engine		4.0
			Coal Supercritical	1,560	6.0
2	Balanced	4.6	CFB Coal 300MW	300	2.0
			Wind Farm		2.0
			Small Hydro	1,026	3.0
			Large Hydro	4,105	5.0
			Solar PV Farm	300	0.0
			Gas CCGT	2,500	4.0
			Gas Engine		4.0
			Coal Supercritical	2,700	6.0
3	Maximum Hydro	4.3	CFB Coal 300MW		2.0
			Wind Farm		2.0
			Small Hydro	1,975	3.0
			Large Hydro	7,899	5.0
			Solar PV Farm	300	0.0
			Gas CCGT	3,940	4.0

	Risk rating				
Case	**Plan**	**R**	**Projects**	**New Capacity by 2030**	**Scoring**
			Gas Engine		4.0
			Coal Supercritical		6.0
4	Maximum Coal	5.1	CFB Coal 300MW	900	2.0
			Wind Farm		2.0
			Small Hydro	429	3.0
			Large Hydro	1,714	5.0
			Solar PV Farm	300	0.0
			Gas CCGT	850	4.0
			Gas Engine		4.0
			Coal Supercritical	7,560	6.0
5	Maximum Solar PV / Wind	4.1	CFB Coal 300MW	300	2.0
			Wind Farm	750	2.0
			Small Hydro	1,209	3.0
			Large Hydro	4,835	5.0
			Solar PV Farm	1,000	0.0
			Gas CCGT	3,050	4.0
			Gas Engine		4.0
			Coal Supercritical	1,680	6.0

Source: Consultant's analysis

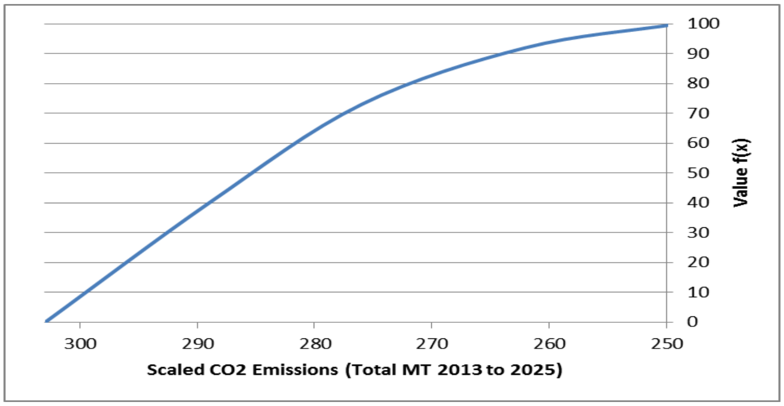
Partial value functions are based on prior experience of the Consultant; they were developed using preference testing techniques with an audience of energy professionals. The partial value functions are given by the following curves:

Figure A5: Cost Value Curve



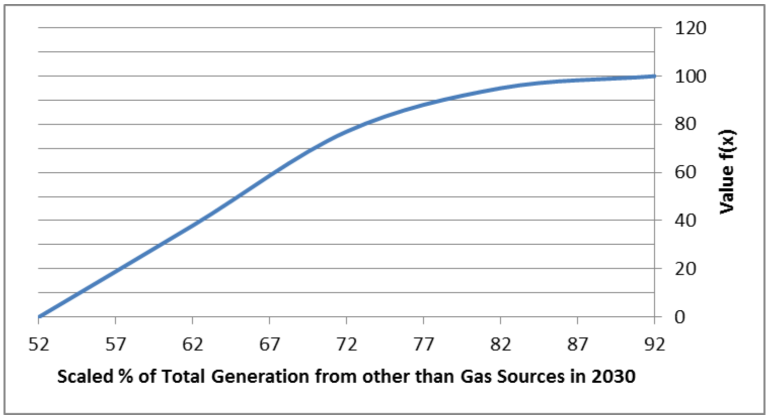
Source: Consultant

Figure A6: Emissions Value Curve



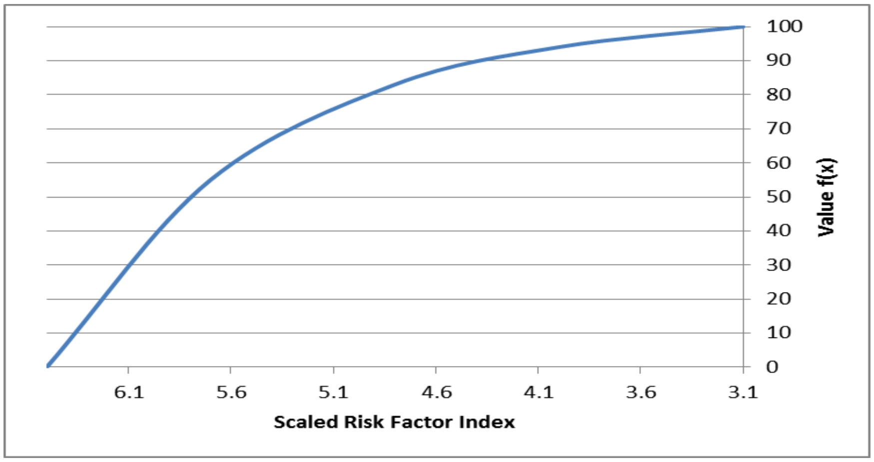
Source: Consultant

Figure A7: Diversity Value Curve



Source: Consultant

Figure A8: Risk Value Curve



Source: Consultant

Project Number: TA No. 8356-MYA

FINAL REPORT
ENERGY SUPPLY OUTLOOK

Prepared for

The Asian Development Bank

and

The Myanmar Ministry of Energy

Prepared by

IES
Intelligent Energy Systems

in association with

MMIC
MYANMAR
INTERNATIONAL
CONSULTANTS

ABBREVIATIONS

ADB	–	Asian Development Bank
ASEAN	–	Association of Southeast Asian Nations
CSO	–	Central Statistics Organisation
EIA	–	U.S. Energy Information Administration
FAO	–	Food and Agriculture Organization
FAME	–	Fatty Acid Methyl Ester
GDP	–	Gross Domestic Product
GoM	–	Government of the Republic of the Union of Myanmar
LNG	–	Liquefied Natural Gas
MOE	–	Ministry of Energy
MPE	–	Myanmar Petroleum Enterprise
TFEC	–	Total Final Energy Consumption
TPEP	–	Total Primary Energy Production
TPES	–	Total Primary Energy Supply
USD	–	United States Dollar

UNITS OF MEASURE

IG	–	Imperial Gallon
km	–	Kilometre
l	–	Litre
mcm	–	Million Cubic Meters
bbl	–	Barrels
bcm	–	Billion Cubic Meters
boe	–	Barrels of Oil Equivalent
bopd	–	Barrels of Oil Per Day
mmbbl	–	Million Barrels
mtoe	–	Million tons of Oil Equivalent

CONVERSION FACTORS

1 litre	=	0.22 Imperial Gallon
1 km	=	0.62137 mile
1 barrel	=	159 litres or 35 imperial gallons
1 ha	=	2.47105 acre
1 km^2	=	100 ha

CONTENTS

I. SUMMARY

A. Introduction

1. The EMP includes projections for Total Primary Energy Production (TPEP), Total Primary Energy Supply (TPES) and for Total Final Energy Consumption (TFEC)[1].

- The TFEC is the Total Final Energy Consumption. This represents the consumption by end-use sectors, agriculture, transport, industry, commerce / government and residential.
- The TPES is the Total Primary Energy Supply. This represents the TFEC plus the addition of locally supplied energy.
- The TPEP is the Total Primary Energy Production. This represents the TPES plus the addition of energy exports less energy imports.

2. Whilst care has been taken to develop an historical energy balance and to make projections using the 2012 balance as a baseline, it must be noted that projections are by their nature speculative. They represent one possible future amongst many. Therefore it is most important to define assumptions regarding sources of energy in the future since any deficit in the local energy supply capacity would made up by import. In this regard the key assumptions to note are:

- All electricity needs can be met by local power plants, however bituminous coals would be imported for all new power plants[2]
- A local oil refinery of 50 000 bopd will commence operation in 2019
- The M3 field will be delayed indefinitely, with no new fields commencing operation during the planning horizon
- Fertilizer will be imported from 2018 (consistent with the Liquid & Gaseous Fuel Strategy report); and
- LPG will be fully imported from 2018 (consistent with the Liquid & Gaseous Fuel Strategy report)
- Biofuels are potentially viable but not considered for substitution during the energy outlook period

B. Energy Balance Projection to 2030

3. Table I-1 to Table I-2 is given as an Energy Balance projection for Myanmar to 2030. This Energy Balance projection is based on the abovementioned assumptions. Moreover, because Saudi Arabian crude oil is transported across the country, with an allowance of 50 000 bopd provided to Myanmar, it is only the allowance that appears in the Energy Balance. Unlike oil exports, gas exports to Thailand and China appear in the energy balance because the gas is produced in Myanmar. Finally hydropower electricity produced by Chinese merchant hydropower plants, and exported directly to China, is not included in the Energy Balance.

4. The Energy Balance predicts that Myanmar will become a net importer of energy (slightly) by 2030 if no new gas fields export gas abroad. As mentioned the projection assumes that the M3 field will be indefinitely delayed; this is due to the recent change in government policy in Thailand and the weak international market for oil and gas.

[1] 3. The formulation used for the development of energy projections and Energy Balance is that of the IEA. The rules regarding the classification of forms of energy is given by the IEA's Energy Statistics Manual (2005).
[2] By instruction of ADB

Table I-1: Supply Projection to 2030 (mtoe)

	2012	2015	2018	2021	2024	2027	2030
TOTAL PRODUCTION	23.7	27.5	27.7	26.3	26.4	24.9	25.1
Hydro	0.7	0.8	0.9	1.6	1.9	2.5	2.8
Solar PV & Wind	0.0	0.0	0.0	0.0	0.0	0.1	0.3
Gas	13.0	16.6	15.7	12.8	11.3	9.1	8.5
Oil	1.0	1.0	1.5	2.2	3.5	3.6	3.6
Coal[1]	0.2	0.3	0.5	0.7	0.8	1.1	1.3
Biomass Type II[2]	8.8	8.9	9.0	9.0	8.8	8.6	8.4
TOTAL NET IMPORTS	-10.2	-11.3	-11.2	-8.7	-6.2	-2.5	0.8
Hydro Exports	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Imports	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Net Imports	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Natural Gas Exports	11.9	13.9	13.9	11.1	9.5	7.0	5.9
Imports[4]	0.0	0.0	0.4	0.5	0.6	0.6	0.7
Net Imports	-11.9	-13.9	-13.5	-10.6	-9.0	-6.3	-5.2
Oil Exports	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Imports	1.7	2.6	2.3	1.9	1.0	1.4	2.0
Net Imports	1.7	2.6	2.3	1.9	1.0	1.4	2.0
Coal Exports	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Imports	0.0	0.0	0.0	0.0	1.7	2.4	4.0
Net Imports	0.0	0.0	0.0	0.0	1.7	2.4	4.0
TOTAL STOCK CHANGES	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TOTAL SUPPLY (TPES)	13.5	16.2	16.5	17.6	20.2	22.4	25.8
Hydro	0.7	0.8	0.9	1.6	1.9	2.5	2.8
Solar PV & Wind	0.0	0.0	0.0	0.0	0.0	0.1	0.3
Gas	1.1	2.6	2.2	2.2	2.4	2.7	3.4
Oil	2.6	3.6	3.8	4.0	4.5	5.0	5.6
Coal	0.2	0.3	0.5	0.7	2.6	3.5	5.3
Biomass Type II	8.8	8.9	9.0	9.0	8.8	8.6	8.4
Electricity trade[3]	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shares (%)							

	2012	2015	2018	2021	2024	2027	2030
Hydro	4.9	5.0	5.7	9.4	9.3	11.1	11.0
Solar PV & Wind	0.0	0.0	0.0	0.0	0.0	0.4	1.2
Gas	8.4	16.2	13.5	12.5	11.8	12.3	13.0
Oil	19.5	22.2	22.9	23.1	22.5	22.4	21.7
Coal	1.6	1.7	3.3	3.8	12.8	15.4	20.4
Biomass Type II	65.5	54.9	54.6	51.2	43.7	38.4	32.6
Electricity trade	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Source: Consultant's analysis

Table I-2: Electricity Demand & Transformation Losses

	2012	2015	2018	2021	2024	2027	2030
INPUT (mtoe)	1.97	2.22	2.21	2.52	4.22	5.45	7.54
OUTPUT Electricity (GWh)	10,364	14,398	19,446	25,763	33,904	44,238	57,654
Electricity output shares (%)							
Hydro	69.7%	65.0%	56.5%	74.1%	64.0%	65.7%	57.1%
Solar PV	0.0%	0.0%	0.0%	0.0%	0.0%	2.0%	5.2%
Wind	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Natural gas	28.1%	33.4%	38.9%	22.4%	12.7%	8.3%	8.2%
Oil	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Coal	2.2%	1.6%	4.6%	3.4%	23.3%	24.0%	29.5%
TOTAL LOSSES (mtoe) of which:							
Electricity generation	0.37	0.52	0.98	0.76	1.70	2.07	3.21
T&D losses	0.19	0.24	0.30	0.36	0.42	0.50	0.58
Total	0.56	0.76	1.27	1.12	2.12	2.57	3.79
Electricity generation[8]	18.6%	23.5%	44.1%	30.1%	40.3%	38.0%	42.6%
T&D losses	9.6%	10.8%	13.4%	14.1%	10.0%	9.2%	7.7%
Total	28.2%	34.3%	57.6%	44.2%	50.4%	47.2%	50.3%

Source: Consultant's analysis

Table I-3: Total Final Energy Consumption (TFEC, mtoe)

	2012	2015	2018	2021	2024	2027	2030
TFC	12.6	14.2	15.3	16.5	17.9	19.6	21.9
Coal[1]	0.1	0.1	0.2	0.2	0.3	0.4	0.6
Oil	2.5	3.4	3.6	4.0	4.4	4.9	5.5
Gas	0.6	0.9	1.2	1.5	2.0	2.5	3.2
Electricity	0.7	1.0	1.3	1.8	2.4	3.2	4.3

	2012	2015	2018	2021	2024	2027	2030
Biomass Type II[2]	8.8	8.9	9.0	9.0	8.8	8.6	8.4
Shares (%)							
Coal	0.6	0.8	1.1	1.4	1.7	2.1	2.5
Oil	19.3	23.9	23.7	23.9	24.5	24.8	25.0
Gas	5.0	6.2	7.7	9.3	11.0	12.7	14.4
Electricity	5.5	6.7	8.7	10.9	13.5	16.4	19.6
Biomass Type II	69.6	62.3	58.8	54.5	49.2	43.9	38.5
TOTAL INDUSTRY	0.7	1.2	1.7	2.4	3.3	4.3	5.7
Coal[1]	0.07	0.11	0.16	0.23	0.31	0.42	0.55
Oil	0.06	0.09	0.11	0.14	0.18	0.22	0.28
Gas	0.29	0.48	0.71	1.01	1.38	1.85	2.44
Electricity	0.28	0.47	0.71	1.01	1.38	1.85	2.43
Biomass Type II[2]	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Shares (%)							
Coal	10.7	9.5	9.5	9.5	9.6	9.7	9.7
Oil	8.1	7.9	6.7	6.0	5.5	5.1	4.9
Gas	41.6	41.3	41.9	42.3	42.5	42.6	42.8
Electricity	39.6	41.3	41.9	42.2	42.4	42.6	42.7
Biomass Type II	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TRANSPORT[5]	1.4	2.3	2.3	2.5	2.8	3.2	3.7
TOTAL OTHER SECTOR[6]	10.54	10.86	11.25	11.61	11.82	12.08	12.51
Coal[1]	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Oil	0.99	1.09	1.20	1.32	1.42	1.47	1.51
Gas	0.31	0.37	0.44	0.51	0.57	0.64	0.70
Electricity	0.42	0.49	0.62	0.79	1.03	1.37	1.86
Biomass Type II[2]	8.82	8.90	9.00	8.99	8.80	8.61	8.43
Shares (%)							
Coal	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Oil	9.4	10.1	10.7	11.4	12.0	12.1	12.1
Gas	2.9	3.4	3.9	4.4	4.8	5.3	5.6
Electricity	4.0	4.5	5.5	6.8	8.7	11.3	14.9
Biomass Type II	83.7	82.0	79.9	77.5	74.4	71.3	67.4

Source: Consultant's analysis

Table I-4: Key Performance Indicators

	2012	2015	2018	2021	2024	2027	2030
GDP (billion 2010 US$)	52.2	64.5	79.8	98.8	122.4	151.6	187.9
Population (millions)	61.0	63.5	65.4	67.4	69.4	71.5	73.7
TPES/GDP[9]	0.26	0.24	0.21	0.18	0.17	0.15	0.14
Energy production/TPES	1.76	1.72	1.66	1.49	1.29	1.10	0.97
Per capita TPES[10]	0.22	0.25	0.26	0.27	0.29	0.32	0.36
Oil supply/GDP[9]	0.05	0.06	0.05	0.04	0.04	0.03	0.03
TFEC/GDP[9]	0.24	0.22	0.19	0.17	0.15	0.13	0.12
Per capita TFEC[10]	0.21	0.22	0.23	0.24	0.26	0.27	0.30
Energy–related CO2 emissions[11]	5.8	8.7	11.5	12.5	16.4	19.5	24.9
CO2 Emissions (Million tons)							
Electricity	0.66	1.05	1.83	1.47	3.56	4.36	6.74
Gas (excludes electricity production)	1.45	2.08	3.92	4.78	5.85	7.14	8.75
Transport	3.65	5.54	5.77	6.26	7.01	8.05	9.43

Source: Consultant's analysis

Footnotes to all EB tables above

1 Includes lignite and bituminous coal

2 Comprises solid biomass.

3 Total supply of electricity represents net trade. A negative number indicates that exports are greater than imports.

4 Includes non-energy use. (Note: Assumed that fertilizer will be imported after 2018).

5 Includes no non-oil fuels.

6 Includes residential, commercial & government and agricultural sectors.

7 Inputs to electricity generation refers to gross energy inputs to electricity plants. Output refers only to net electricity generation.

8 Losses arising in the production of electricity at public utilities. For non-fossil-fuel electricity generation, losses are zero.

9 Toe per thousand US dollars at 2010 prices and exchange rates.

10 Toe per person.

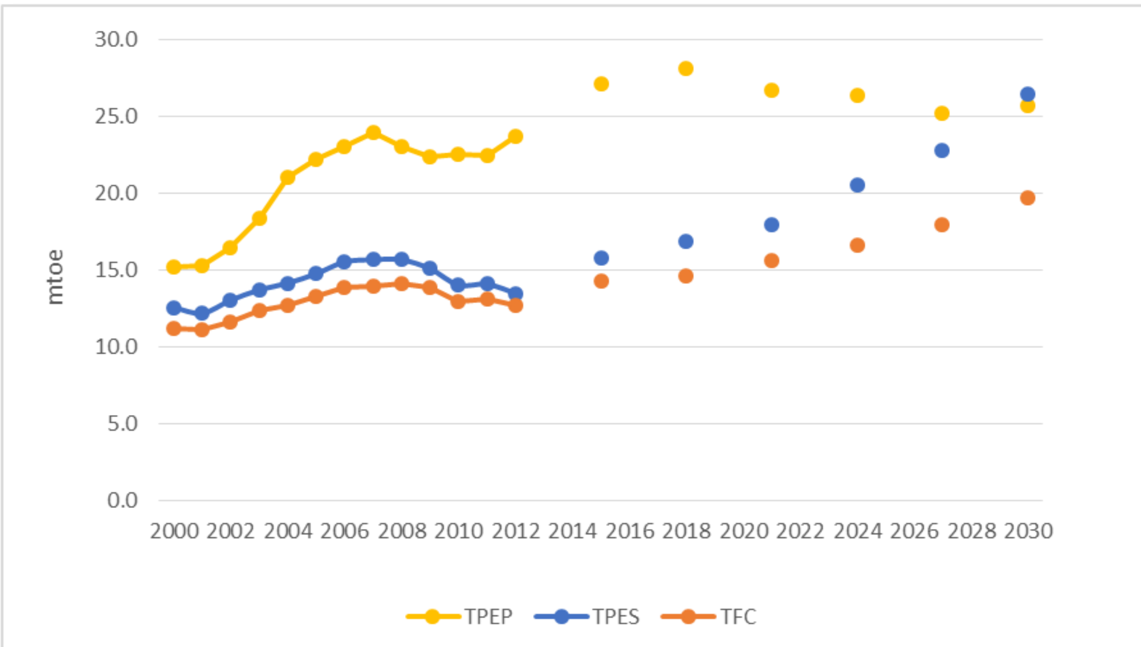
11 "Energy related CO2 emissions" specifically means CO2 from the combustion of the fossil fuel components of TPES (i.e. coal and coal products, crude oil and derived products and natural gas), while CO2 emissions from the remaining components of TPES (i.e. electricity from hydro, other renewables and nuclear) are zero. Emissions from the combustion of biomass-derived fuels are not included, in accordance with the IPCC greenhouse gas inventory methodology. TPES, by definition, excludes international marine bunkers. Units in million tons (Mtons).

C. Total Supply & Demand Outlook

5. An Energy Balance was constructed from the EMP using a bottom up method. Surveys were used to capture energy consumption and production data in as rigorous a manner as possible. The Energy Balance was projected on a three-year basis from 2012 to 2030.

6. The forecast is shown by Figure I-1. The forecast matches with the energy projections presented as Table I-1 to Table I-4. It can be observed that local production capacity (TPES) rises to create a healthy margin over TFEC. TPEP falls as gas production and export reduces to the point where Myanmar becomes a net importer of energy (slightly).

Figure I-1: Total Supply & Demand Outlook



Source: Consultant's analysis

7. Figure I-2 and Figure I-3 show the fuel mix composition for the TPES in 2015 and 2030. It can be seen clearly that the composition of the fuel mix could change dramatically over a 15 year period, due in particular to the growth in electricity displacing the use of fuelwood for household cooking in rural areas. Other changes are related to the growth in demand for passenger and freight services. Also the increased use of coal for power production after 2020.

Figure I-2: TPES – Energy Mix 2014

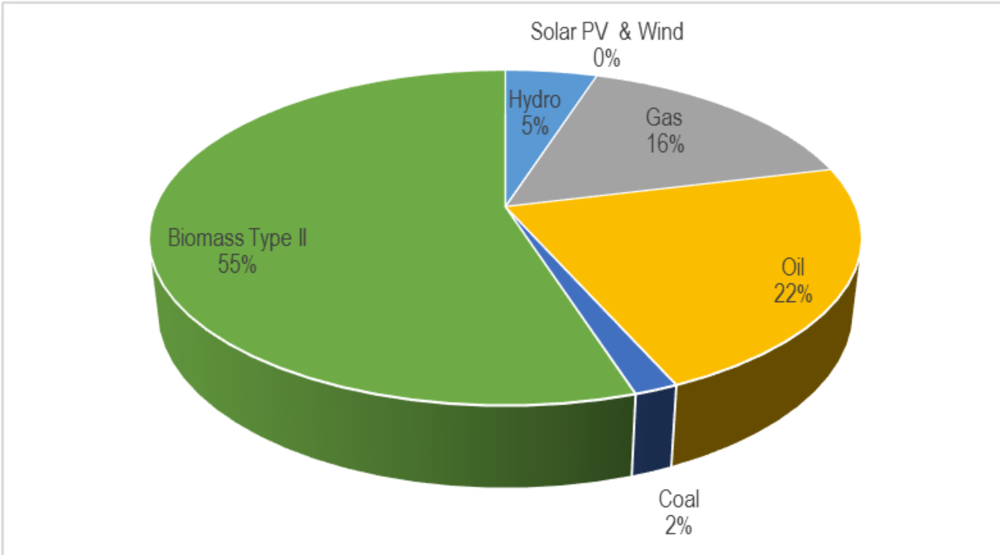
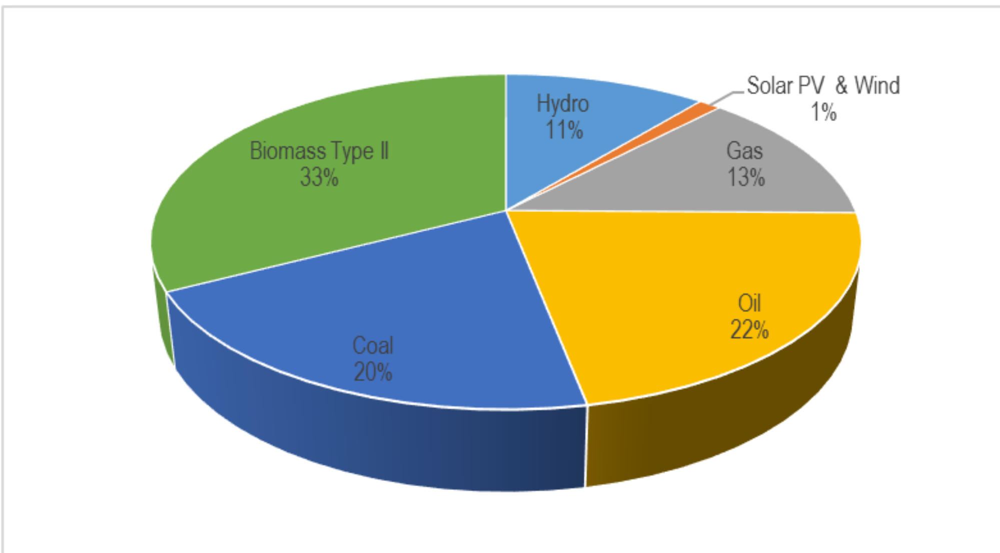


Figure I-3: TPES – Energy Mix 2030



Source: Consultant's analysis

8. The sections that follow describe first the Total Primary Energy Production outlook before proceeding to the Primary Energy Supply outlook. The fundamental driver of the production and supply outlook is Total Final Energy Consumption. The forecasts for Total Final Energy Consumption were developed in detail in the EMP Consolidated Demand forecasts report.

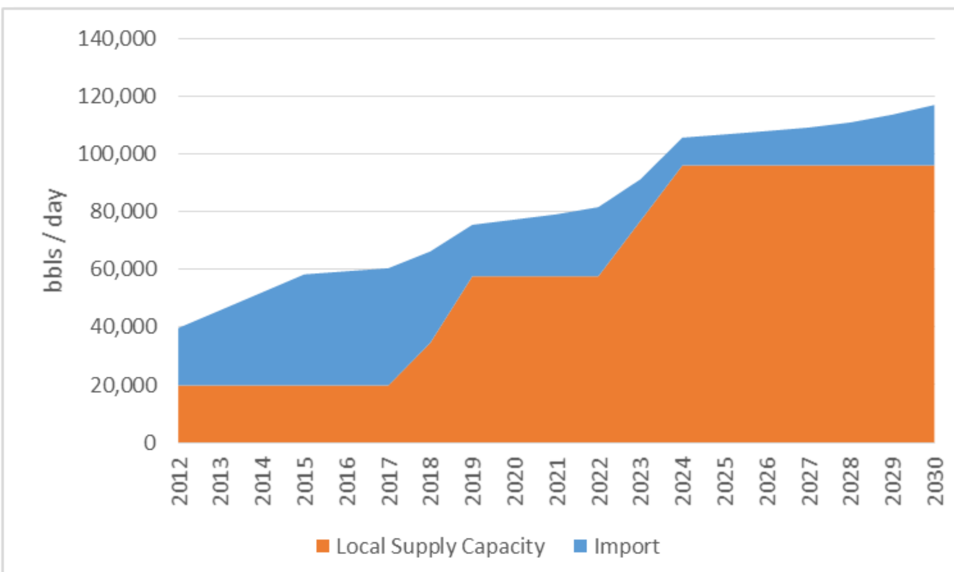
D. Total Primary Energy Production (TPEP)

9. In the case of electricity, the Consultant has assumed that all local electricity needs will be met by local power plants. Electricity that is currently produced by hydropower schemes dedicated for export to China is not considered as part of an IEA energy balance since Myanmar neither produces nor consumes any part of the plant output. It has been assumed that no further electricity export will take place during the planning period to 2030, in other words it has been assumed that Myanmar will not build large hydropower schemes or any other power plants specifically for electricity trade.

10. Under the optimal expansion, defined by the ADB as the ADICA electricity expansion in the Electricity Strategy report, electricity output shares would change in favour of coal, i.e. the electricity asset portfolio would become more balanced in terms of the fuel mix. The dominance of hydropower would reduce to around 57% from its current level of 65%. The dependence on natural gas will also reduce as expected when gas is used to meet peak demand. Electricity losses will increase as load increases and as coal-fired power plants are introduced. The conversion efficiency of large coal plants is of the order of 43% and so conversion losses increase in proportion to the amount of coal used for electricity generation. The increase can be mitigated to some extent if T&D losses can be reduced.

11. In the case of oil, the Consultant has assumed that a local refinery will be constructed by 2019. The capacity will initially be 50 000 bpd. The projection for refined oil products suggests that additional capacity of 50 000 bpd will be required by 2024. Nevertheless in most years it will be necessary to import oil. It has been assumed that LPG will be totally imported from 2020.

Figure I-4: Oil Production Local vs. Import (physical)



Source: Consultant's analysis

12. In the case of natural gas the Consultant has assumed that the M3 field will be indefinitely delayed and no new gas fields will commence operation during the period of the planning horizon. This represents a worst case scenario with a tight gas supply – demand outlook. However, as was discussed in the Liquid & Gaseous Fuel Strategy report there is an opportunity to manage the risks that natural gas supplies does not develop as anticipated.

Table I-5: Gas Supply Risk Mitigation circa 2019

	MMCF	MMCFD	Comment
Refinery	22,630	62	Hydro-cracking refinery needs hydrogen and usually powered with natural gas power plant
Power	81,030	222	EMP estimate
Fertilizer	20,552	56	Standard-run production plant 1 725 mtpd
Industry	38,623	106	EMP estimate
Total	~165,000	~548	
Available gas	~150,000	~411	Yadana, Yetagun, Shwe, Zawtika
		Potential to Reduce Gas Consumption	
Refinery	(7,500)	(21)	Power the refinery using liquid fuels (30 – 40 MW)
Power sector	(30,250)	(83)	Increase hydropower, gas / oil plant
Fertilizer	(10,000)	(27)	Import fertilizer
Total	(50,000)	(137)	

Source: Consultant's analysis

13. The refinery design can be modified to minimize gas consumption. In principle the use of gas for power generation could be replaced by oil or storage hydropower capacity for deployment at times of peak demand. A fertilizer plant appears to be uneconomic and gas could be saved by importing urea. These measures have been assumed ahead of the development of an LNG terminal because the cost of LNG will be high and market acceptance may therefore be low.

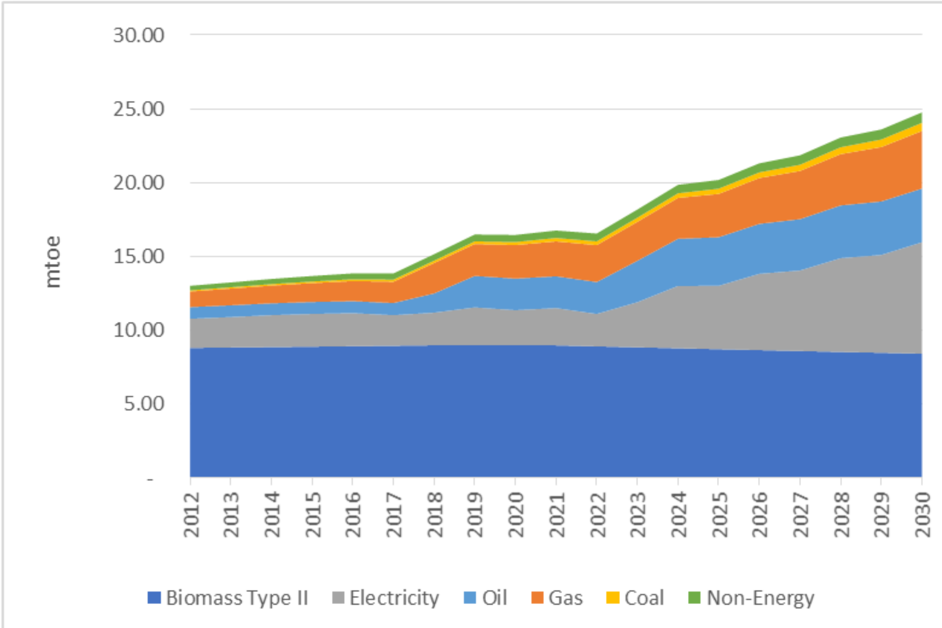
14. In the case of coal, the Consultant has assumed that all coal used to power large coal-fired plants (in coastal locations) will be imported bituminous coal of high calorific value. Industrial need for coal will be met mainly with indigenous coal.

15. In the case of fuelwood, the Consultant has assumed that primary energy production is equivalent to primary secondary energy production. There was insufficient data available to quantify fuelwood losses arising between forests and distribution centres. Furthermore the conversion losses associated with the burning of fuelwood has not been accounted for in the energy balance – such losses are important from an energy efficiency standpoint, but from an energy balance perspective they occur within consumer premises and are therefore ignored.

E. Total Primary Energy Supply (TPES)

16. The primary energy forecast for Myanmar is given by Figure I-5. It can be seen that as a result of rural electrification, the use of biomass type II falls with time. The growth in electricity in particular replaces the need to produce and consume fuelwood thereby easing pressure on Myanmar's forests. Oil, gas and coal production requirements increase with economic development.

Figure I-5: TPES – Total Primary Energy Supply Forecast (mtoe)



Source: Consultant's analysis

17. The production of all other fuels gradually increases over time as the population grows and the economy further develops. The corresponding compound annual growth rates are given in Table I-6.

Table I-6: Compound Annual Growth Rate Projections – TPES

Fuel	CAGR	Comment
Total Energy	3.4%	
Secondary Conversion Efficiency	4.2%	Average fuel conversion loss not including losses in consumer's premises
Import	-1.3%	
TFEC	3.0%	
Total Primary Energy Supply		
Electricity	7.6%	Rural electrification
Oil	8.9%	Vehicle ownership and freight
Gas	7.3%	Power production
Coal	10.9%	Power production
Biomass Type II	-0.3%	Rural electrification replaces fuelwood

Source: Consultant's analysis

18. The primary energy forecast for Myanmar's oil is given by Figure I-6. It can be seen that over time, oil production must increase to supply the transport and industry sectors. The corresponding compound annual growth rates are given in Table I-7.

Figure I-6: Oil TPES Forecast (toe)

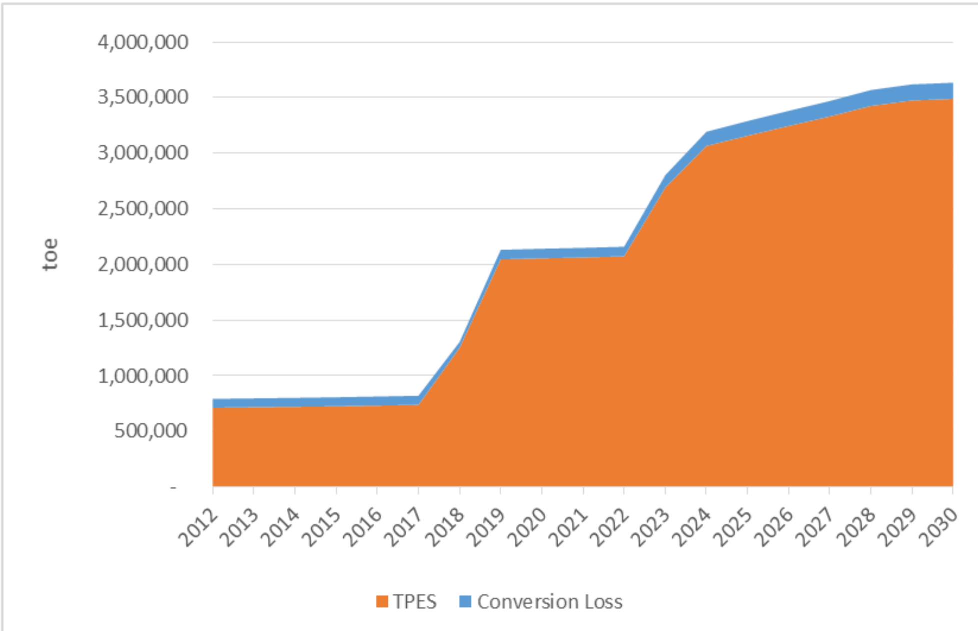
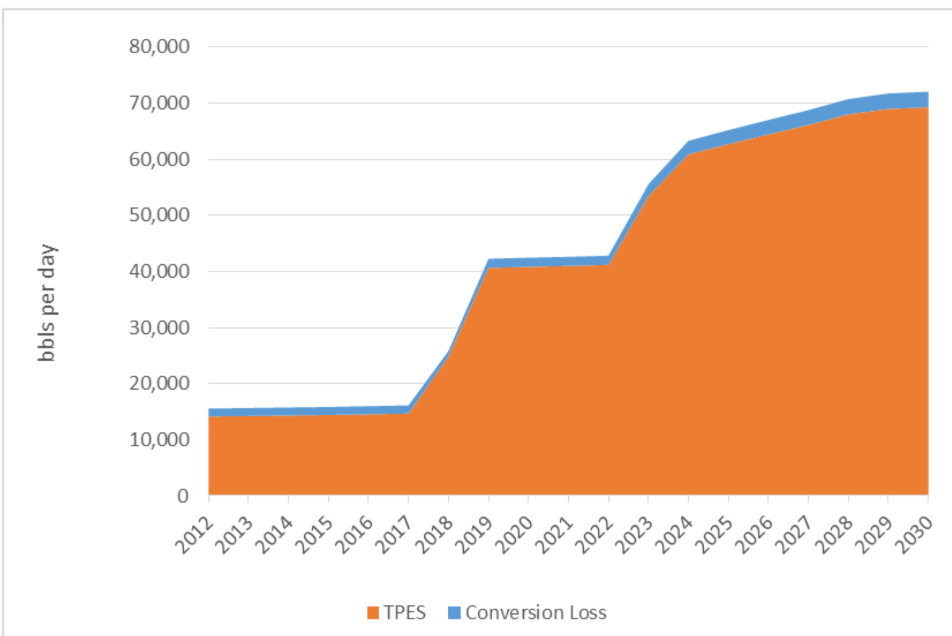


Figure I-7: Oil TPES Forecast (physical)



Source: Consultant's analysis

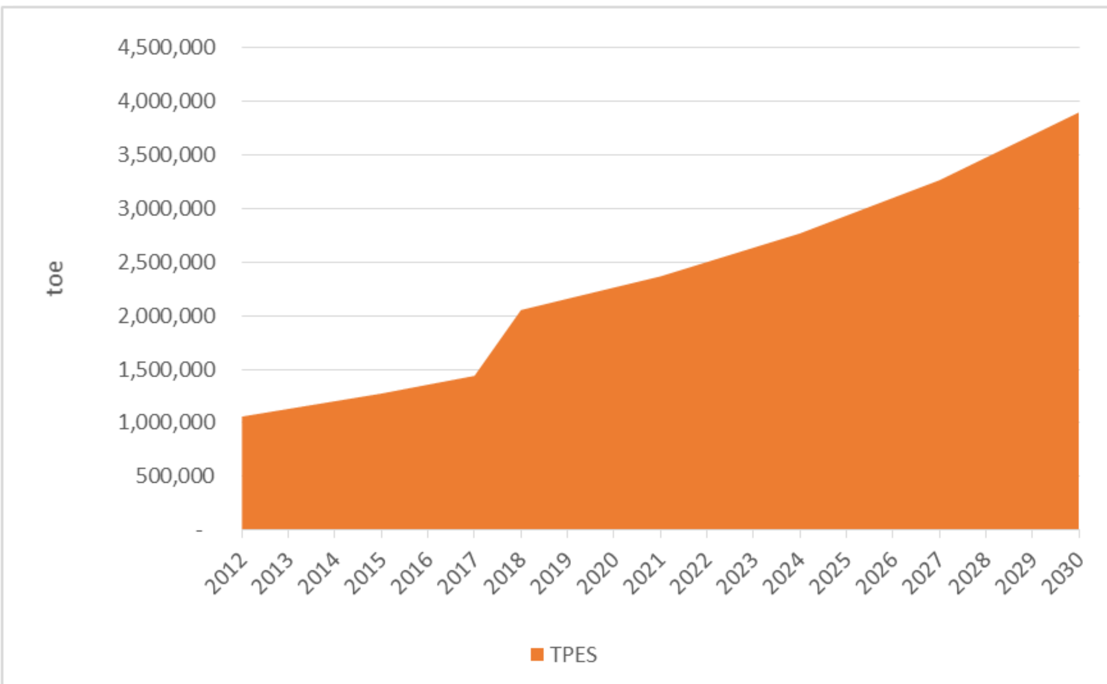
Table I-7: Compound Annual Growth Rate Projections – Oil

Fuel	CAGR	Comment
Total Oil Production	8.9%	Increasing due to economic growth
Fuel Conversion Loss	3.5%	Reducing with new refinery
Oil Product Demand	4.7%	TFEC

Source: Consultant's analysis

19. The primary energy forecast for Myanmar's natural gas is given by Figure I-8. It can be seen that total gas production is required to increase over time, mainly due to industrial demand. The production allocation by sector is given as Figure I-9. The corresponding compound annual growth rates are given in Table I-8.

Figure I-8: Natural Gas TPES Forecast (toe)



Source: Consultant's analysis

Figure I-9: Natural Gas - Primary Energy Demand by Sector (MMCFD)

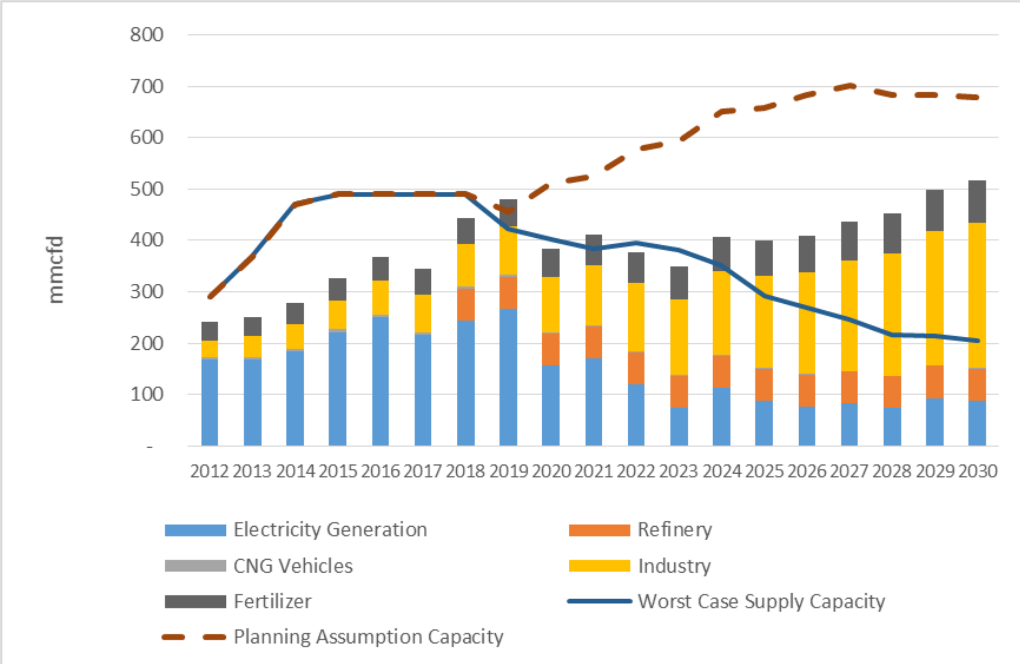
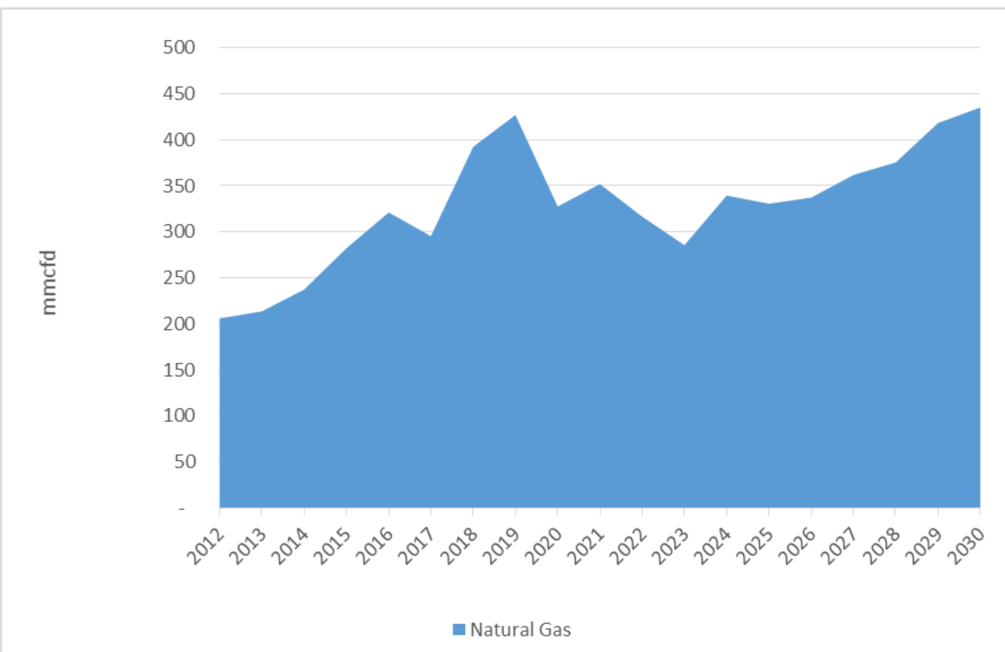


Figure I-10: Natural Gas TPES Forecast (physical)



Source: Consultant's analysis

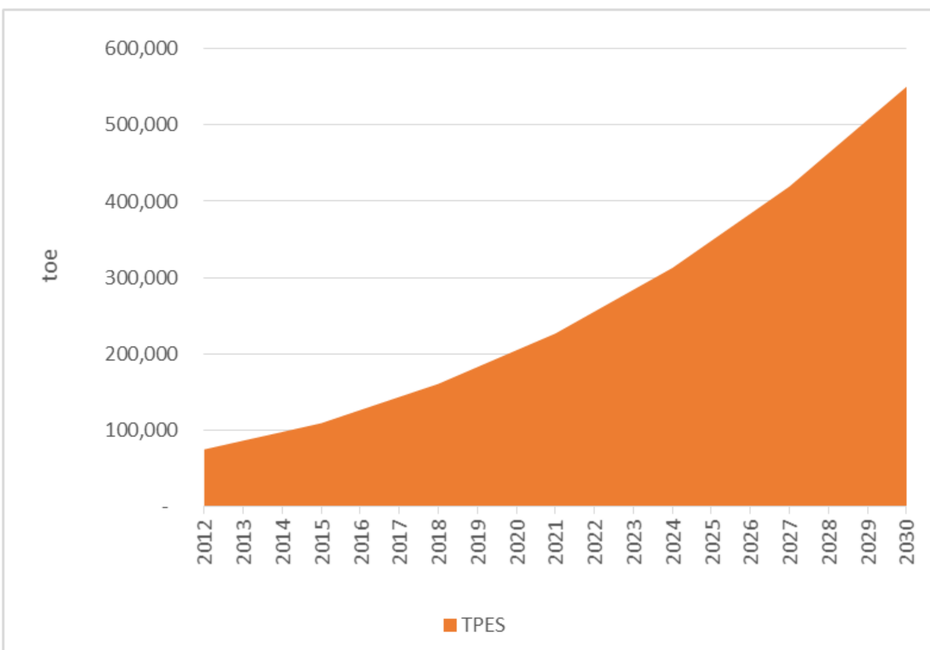
Table I-8: Compound Annual Growth Rate Projections – Gas

Fuel	CAGR	Comment
Total Gas Production	7.3%	Increasing mainly due to industry consumption
Fuel Conversion Loss	7.3%	Increasing as gas increases in supply mix
Net Production	7.3%	TFEC
Electricity Generation	-10.5%	Decreasing as gas decreases in supply mix
Refinery	0.0%	Excluded due to recommendation to power the refinery with distillate
Fertilizer	4.5%	Included but noting that economics of fertilizer production does not appear to be positive for Myanmar
Transport	-6.2%	Reducing as CNG is reduced
Industrial	11.4%	Strongly increasing due to economic growth

Source: Consultant's analysis

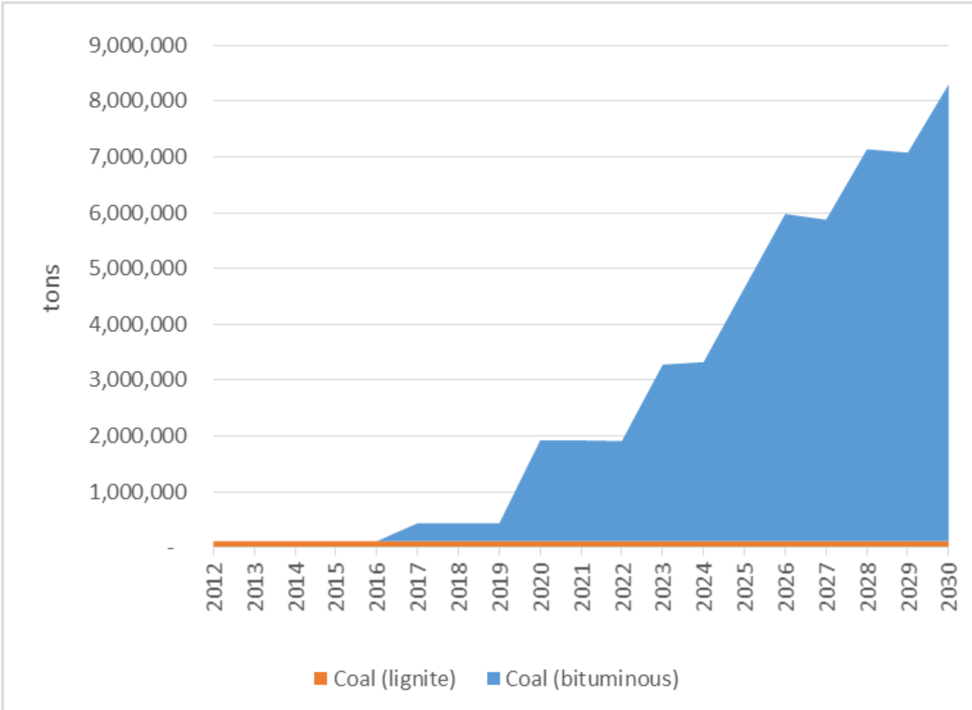
20. The primary energy forecast for Myanmar's industrial coal use is given by Figure I-11. It can be seen that the coal requirement increases strongly with time. The corresponding compound annual growth rates are given in Table I-9. Figure I-12 shows the coal consumption projection to meet the industrial and power generation sector needs.

Figure I-11: Coal TPES Forecast (toe)



Source: Consultant's analysis

Figure I-12: Coal TPES Forecast (physical)



Source: Consultant's analysis

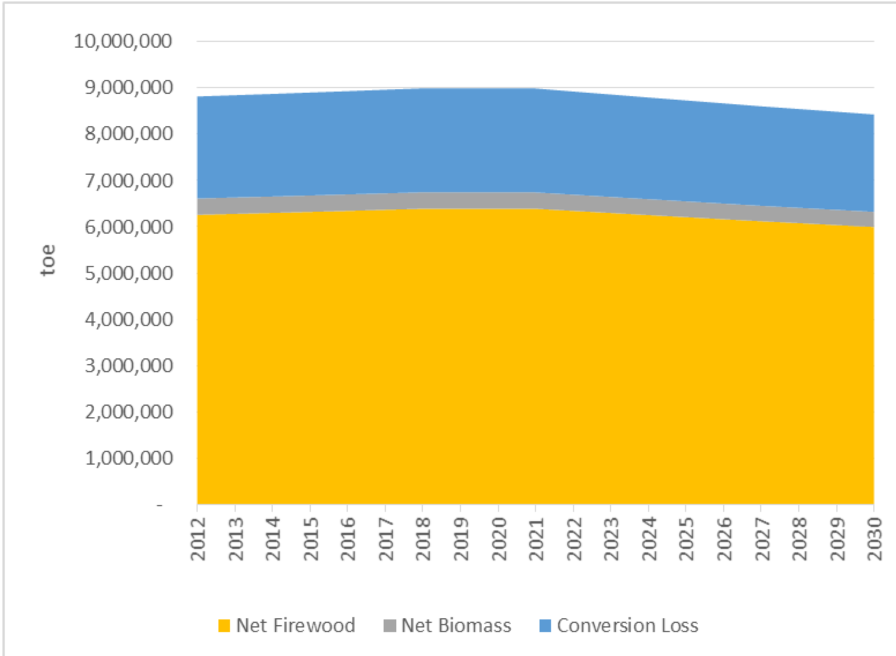
Table I-9: Compound Annual Growth Rate Projections – Coal

Fuel	CAGR	Comment
Total Coal Production	10.9%	Increasing due to power production
Fuel Conversion Loss	0.0%	No losses accounted for in coal winning and transport
Net Production	10.9%	TFEC
Electricity Generation	25.5%	Increasing due to increasing coal in supply mix
Industry	10.9%	Increasing with economic growth

Source: Consultant's analysis

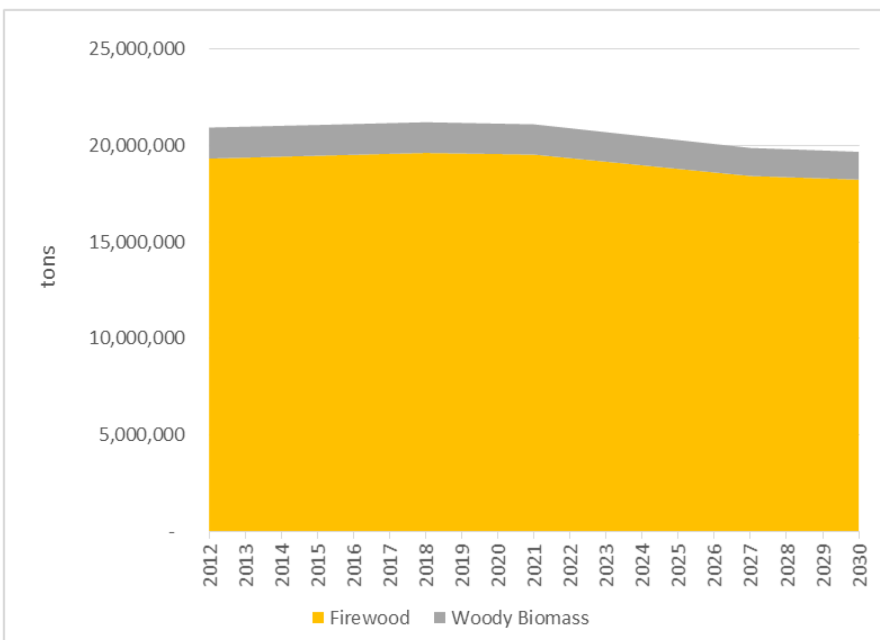
21. The primary energy forecast for Myanmar's Type II biofuel (fuel woods including firewood, charcoal and woody biomass) is given by Figure I-13. It can be seen that as a result of rural electrification, the use of fuelwood falls with time. This growth pattern is based on an assumption that the delivered price of electricity in rural areas will be sufficiently low that electricity substitutes widely for the use of fuelwood for cooking. The corresponding compound annual growth rates are given in Table I-10.

Figure I-13: Fuelwood TPES Forecast (toe)



Source: Consultant's analysis

Figure I-14: Fuelwood TPES Forecast (physical)



Source: Consultant's analysis

Table I-10: Compound Annual Growth Rate Projections - Fuelwood

Fuel	CAGR	Comment
Total Fuelwood Production	-0.3%	Reducing due to substitution with electric cooking
Fuel Conversion Loss	-0.3%	Reducing due to substitution with electric cooking
Net Production	-0.3%	TFEC
Firewood (Cooking)	-0.3%	Reducing due to substitution with electric cooking
Woody biomass (Cooking)	-0.3%	Reducing due to substitution with electric cooking

Source: Consultant's analysis

F. Secondary Energy

22. The secondary energy forms considered are electricity and refined oil products. The secondary energy is equivalent to primary energy net of conversion losses. However, conversion losses in consumer's premises are not included in the projections.

23. The energy forecast for electricity for Myanmar is given by Figure I-15. It can be seen that as a result of rural electrification, electricity use increases substantially. The growth in electricity replaces the need to produce and consume fuelwood thereby easing pressure on Myanmar's forests. The production of by all forms of generation gradually increases over time as the population grows and the economy further develops. The corresponding compound annual growth rates are given in Table I-11.

Figure I-15: Electricity TPES Forecast (toe)

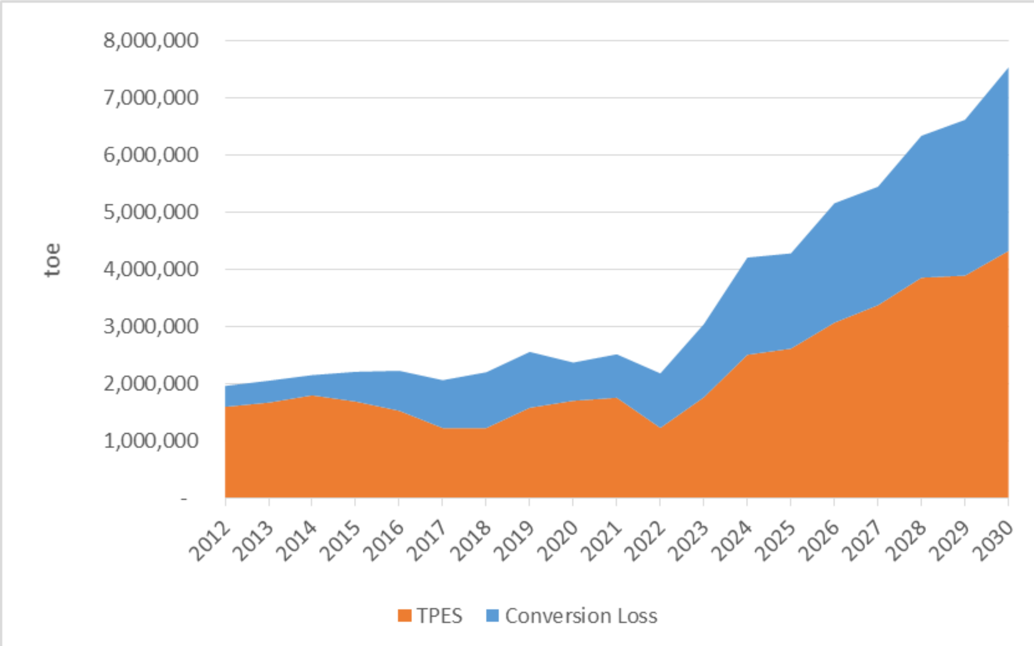
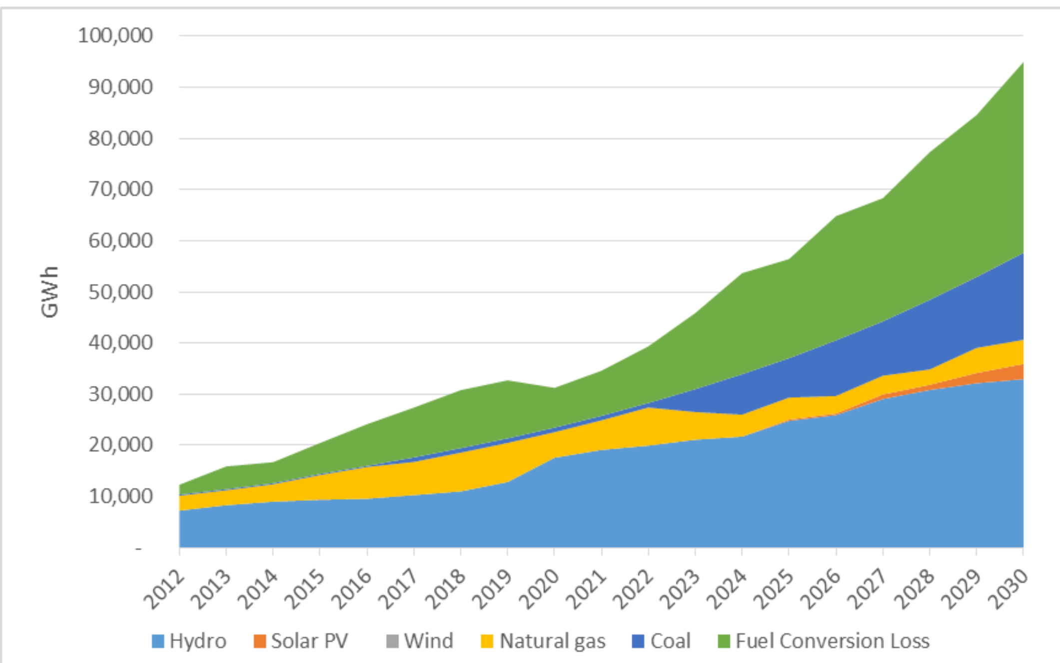


Figure I-16: Electricity TPES Forecast (physical)



Source: Consultant's analysis

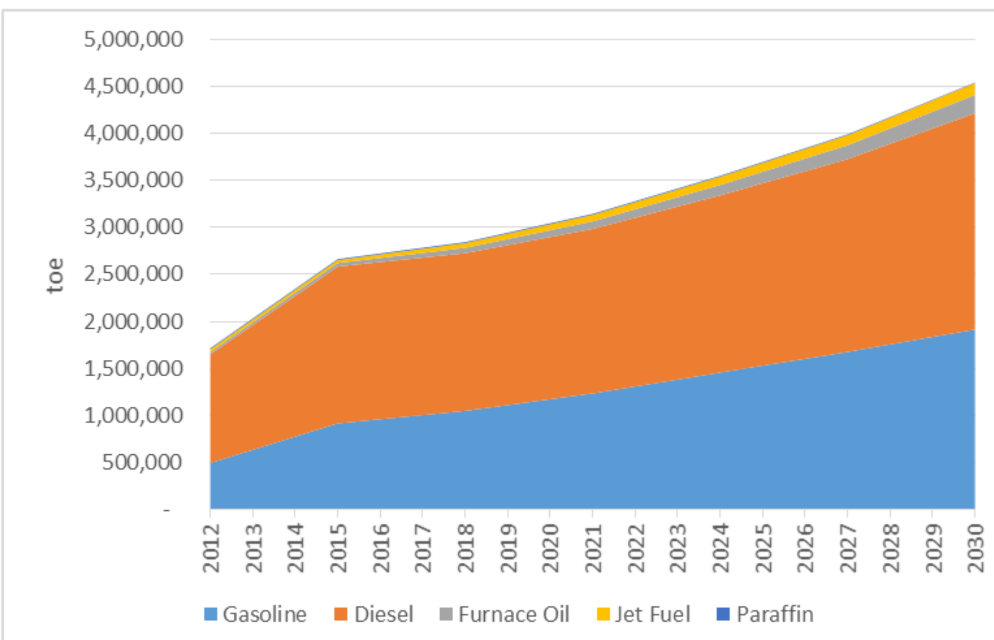
Table I-11: Compound Annual Growth Rate Projections – Electricity

Fuel	CAGR	Comment
Total Electricity Production	7.6%	Strong growth due to rural electrification
Fuel Conversion Loss	12.5%	Increasing due to thermal power
Net Total Energy	5.6%	TFEC rate
Hydropower	8.1%	Increasing due to MoEP programme
Solar PV	n.a.	Enters in 2015
Wind	0.0%	Not included
Gas	-10.5%	Increase to 2022, then declines as coal-fired power and hydropower increases
Coal	25%	Increasing strongly due to thermal power

Source: Growth rates projections based on ADICA – see EMP Electricity Strategy report

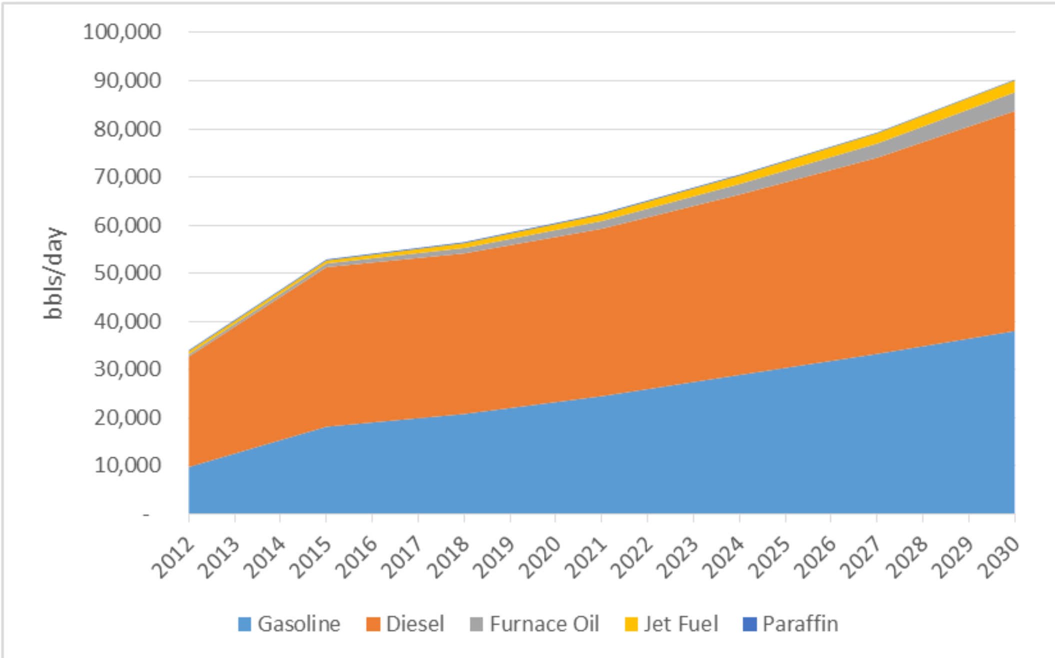
24. The secondary energy forecast for refined oil products is given by Figure I-17. It can be seen that the production of refined oil products increases strongly as demand grows due to economic development. The efficiency of the oil refining sector will increase with a new refinery. If one refinery of 50 000 bopd is built, then imports will be required above this limit. The corresponding compound annual growth rates are given in Table I-12.

Figure I-17: Refined Oil Products TPES Forecast (toe)



Source: Consultant's analysis

Figure I-18: Refined Oil Products TPES Forecast (physicals)



Source: Consultant's analysis

Table I-12: Compound Annual Growth Rate Projections – Refinery

Fuel	CAGR	Comment
Total Oil Production	8.9%	Increasing due to economic growth
Fuel Conversion Loss	3.5%	Reducing with new refinery
Oil Product Demand	4.7%	TFEC
Gasoline	6.5%	Increasing due to economic growth
Diesel	3.2%	ditto
Furnace Oil	11.1%	ditto
Jet Fuel	8.2%	ditto
Paraffin	-2.8%	Reducing due to substitution of paraffin with electricity for lighting
LPG	1.2%	Increasing slowly mainly due to restaurant use; assumed that LPG will not penetrate households due to electrification programme

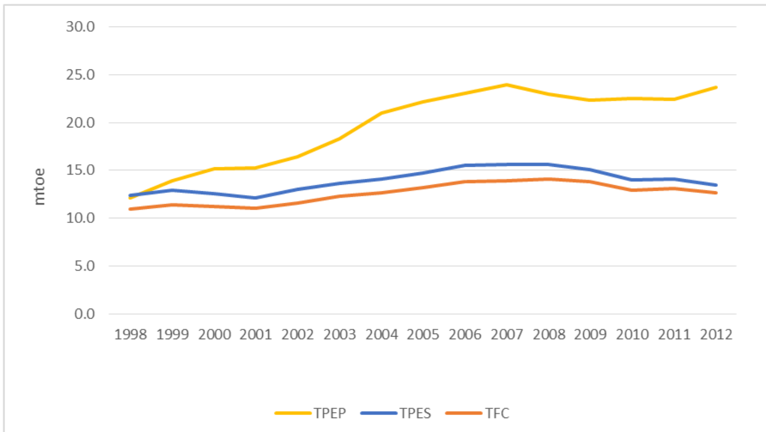
Source: Consultant's analysis

II. IEA ENERGY BALANCE RECONCILIATION

G. Historical Trend

26. The IEA has tracked Myanmar's Energy Balance since at least 1998. The Consultant understands that the Energy Balance has been formulated each year based on reports provided by the Ministry of Energy. Figure II-1 shows the reported trend in TPEP, TPES and TFEC for the years 2000 to 2011.

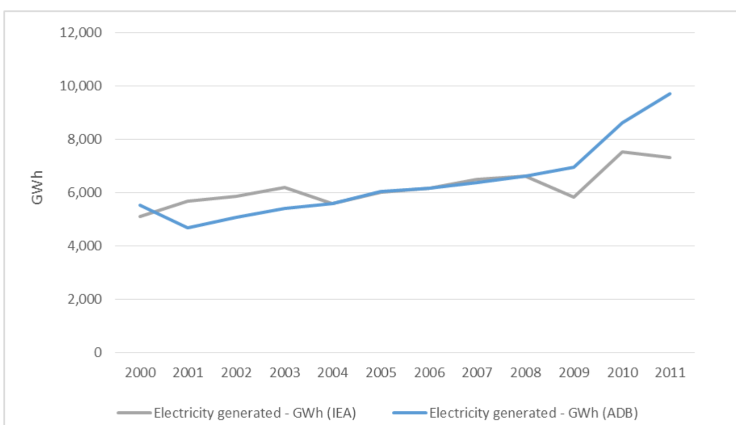
Figure II-1: Historical IEA Energy Balance



Source: Consultant's analysis

27. In addition a comparison has been prepared showing the sent-out electricity generation reported by the IEA and by the ADB. There are clearly some discrepancies, most notably in the last few years.

Figure II-2: Historical Electricity Generation (IEA, ADB)

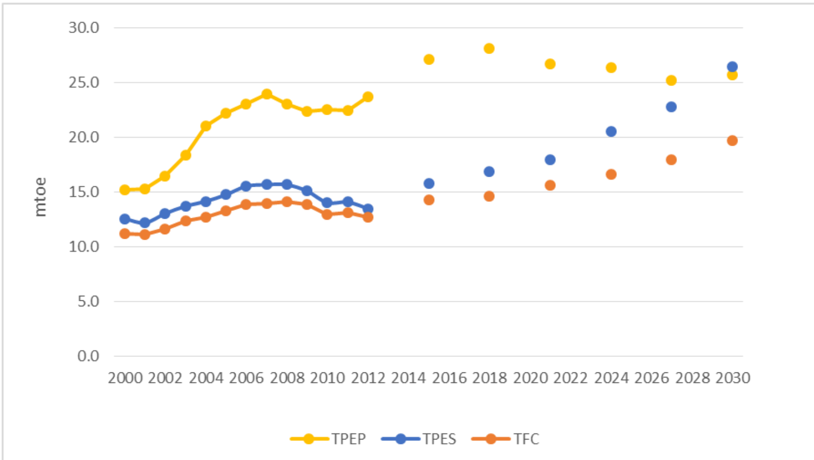


Source: Consultant's analysis

28. An Energy Balance was constructed from the EMP using a bottom up method. Surveys were used to capture energy consumption and production data in as rigorous a manner as possible. The Energy Balance was projected on a three-year basis from 2012 to 2030.

29. The forecast is shown by Figure II-3. The forecast matches with the energy projections presented as Table I-1 to Table I-4. It can be observed that local production capacity (TPES) rises to create a healthy margin over TFEC. TPEP falls as gas production and export reduces.

Figure II-3: Energy Balance Projection to 2030

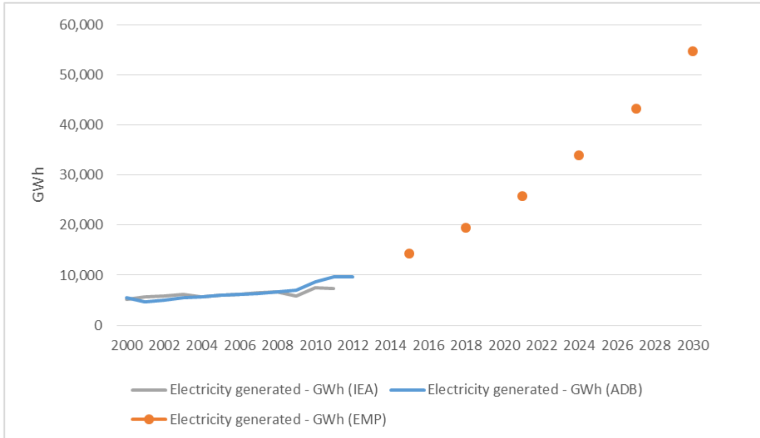


Source: Consultant's analysis

30. It can be seen from Figure II-3 that the IEA Energy Balance and EMP Energy Balance show a smooth extrapolation across the 2012 boundary point. The full set of Energy Balance tables for years 2012, then 2015, 2018, 2021, 2024, 2027 and 2030 is provided as Appendix A to this report. The Energy Balance tables are provided in IEA format.

31. Sent-out electricity generation has also been forecast and is shown here against the historical figures. It can be seen that electricity generation rises at a substantial rate due to anticipated rural electrification. It can also be seen that the projection is smoothly in line with the historical figures reported by the IEA and the ADB. The noticeable fall in the growth rate of electricity in 2021 is due to the introduction of a large hydropower plant with associated reduction in conversion losses.

Figure II-4: Energy Balance Projection to 2030



Source: Consultant's analysis

III. ELECTRICITY

H. Electricity – Total Primary Energy Production

32. The Consultant has assumed that all local electricity needs will be met by local power plants. Electricity that is currently produced by hydropower schemes dedicated for export to China is not considered as part of an IEA energy balance since Myanmar neither produces nor consumes any part of the plant output. It has been assumed that no further electricity export will take place during the planning period to 2030, in other words it has been assumed that Myanmar will not build large hydropower schemes or any other power plants specifically for electricity trade.

Table III-1: Electricity Demand & Transformation Losses

	2012	2015	2018	2021	2024	2027	2030
INPUT (mtoe)	1.97	2.22	2.21	2.52	4.22	5.45	7.54
OUTPUT Electricity (GWh)	10,364	14,398	19,446	25,763	33,904	44,238	57,654
Electricity output shares (%)							
Hydro	69.7%	65.0%	56.5%	74.1%	64.0%	65.7%	57.1%
Solar PV	0.0%	0.0%	0.0%	0.0%	0.0%	2.0%	5.2%
Wind	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Natural gas	28.1%	33.4%	38.9%	22.4%	12.7%	8.3%	8.2%
Oil	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Coal	2.2%	1.6%	4.6%	3.4%	23.3%	24.0%	29.5%

TOTAL LOSSES (mtoe) of which:

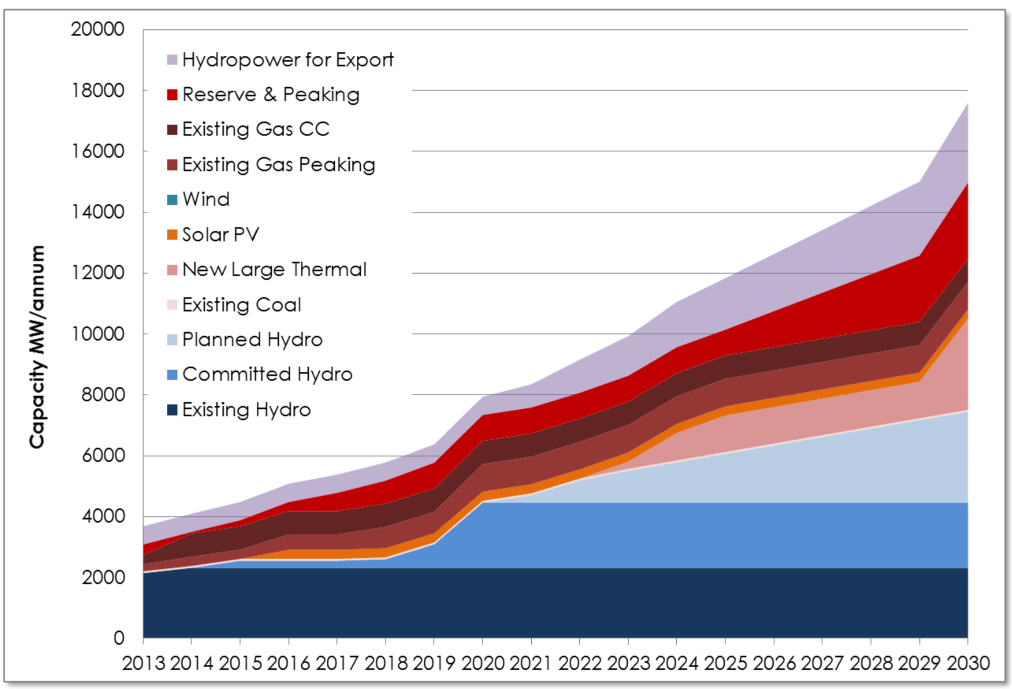
Electricity generation	0.37	0.52	0.98	0.76	1.70	2.07	3.21
T&D losses	0.19	0.24	0.30	0.36	0.42	0.50	0.58
Total	0.56	0.76	1.27	1.12	2.12	2.57	3.79
Electricity generation[8]	18.6%	23.5%	44.1%	30.1%	40.3%	38.0%	42.6%
T&D losses	9.6%	10.8%	13.4%	14.1%	10.0%	9.2%	7.7%
Total	28.2%	34.3%	57.6%	44.2%	50.4%	47.2%	50.3%

Source: Consultant's analysis

33. Under the optimal expansion, defined as the ADICA expansion, electricity output shares would change in favour of coal, i.e. the electricity asset portfolio would become more balanced in terms of the fuel mix. The dominance of hydropower would reduce to around 56% from its current level of 72%. The dependence on natural gas will also reduce as expected when gas is used to meet peak demand. Electricity losses will increase as load increases and as coal-fired power plants are introduced. The conversion efficiency of large coal plants is of the order of 43% and so conversion losses increase in proportion to the amount of coal used for electricity generation. The increase can be mitigated to some extent if T&D losses can be reduced.

34. The export capacity of hydropower was not quantified in ADICA's expansion plan. The capacity is given for Case 2 in Figure III-1. However, the associated energy has not been included in the Energy Balance since the plants are owned by Chinese and supply China.

Figure III-1: EMP Case 2 – Hydropower Export to 2030

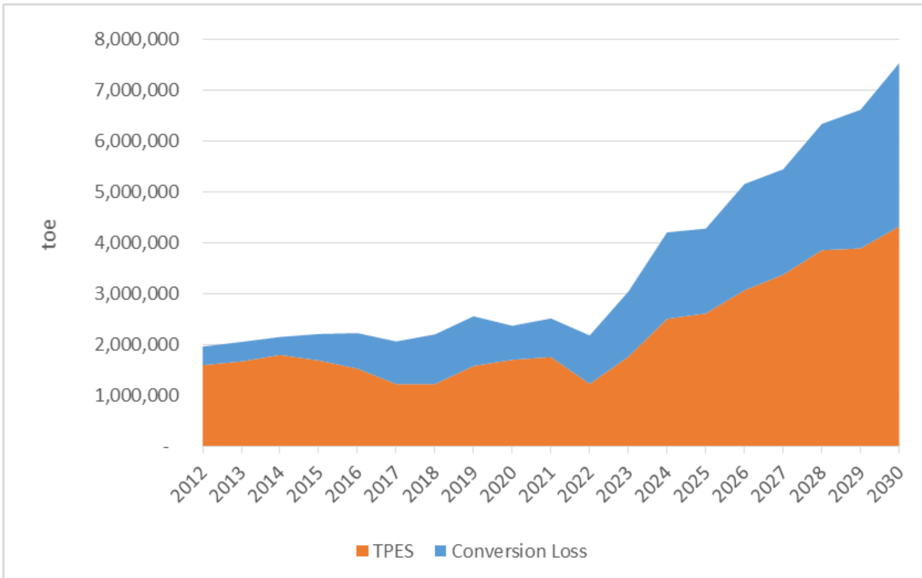


Source: Consultant's analysis

I. Electricity – Total Primary Energy Supply Outlook

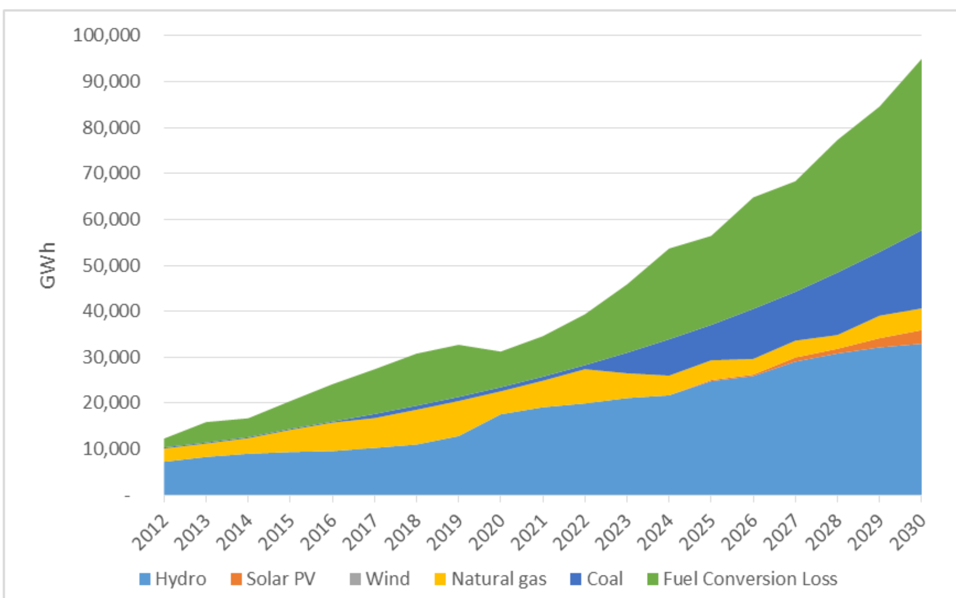
35. The Consultant has determined the TPES for electricity for the ADICA expansion as follows:

Figure III-2: Electricity TPES Forecast (toe)



Source: EMP Consultant forecast

Figure III-3: Electricity TPES Forecast (physical)



Source: Consultant's analysis

36. The compound annual growth rates of electricity production are given between 2013 and 2030 unless otherwise noted.

Table III-2: Compound Annual Growth Rate Projections – Electricity

Fuel	CAGR	Comment
Total Electricity Production	7.6%	Strong growth due to rural electrification
Fuel Conversion Loss	12.5%	Increasing due to thermal power
Net Total Energy	5.6%	TFEC rate
Hydropower	8.1%	Increasing due to MoEP programme
Solar PV	n.a.	Enters in 2015
Wind	0.0%	Not included
Gas	-10.5%	Increase to 2022, then declines as coal-fired power and hydropower increases
Coal	25%	Increasing strongly due to thermal power

Source: Consultant's analysis

37. The energy projection for forecast electricity production, that matches Figure III-3, is given here as Table III-3 for convenience.

Table III-3: Electricity TPES Forecast (ktoe)

	Total	Hydro	Solar PV	Wind	Natural gas	Oil	Coal (lignite)	Coal (bituminous)	Fuel Conversion Loss	Loss	Sent Out Electricity
	ktoe	ktoe	ktoe	ktoe	ktoe	ktoe	ktoe	ktoe	ktoe	%	ktoe
2012	1,972	621	0	0	1295	0	55	-	366	19%	1,606
2013	2,063	712	0	0	1295	0	55	-	383	19%	1,680
2014	2,160	772	0	0	1332	0	55	-	352	16%	1,808
2015	2,219	805	0	0	1359	0	55	-	520	23%	1,698
2016	2,237	821	0	0	1361	0	55	-	700	31%	1,537
2017	2,073	882	0	0	971	0	57	162	837	40%	1,235
2018	2,210	945	0	0	1046	0	57	162	975	44%	1,235
2019	2,566	1,103	0	0	1244	0	57	162	977	38%	1,589
2020	2,380	1,511	0	0	653	0	13	204	669	28%	1,711
2021	2,524	1,643	0	0	665	0	13	204	759	30%	1,765
2022	2,190	1,715	0	0	257	0	13	205	953	43%	1,237

	Total	Hydro	Solar PV	Wind	Natural gas	Oil	Coal (lignite)	Coal (bituminous)	Fuel Conversion Loss	Loss	Sent Out Electricity
	ktoe	ktoe	ktoe	ktoe	ktoe	ktoe	ktoe	ktoe	ktoe	%	ktoe
2023	3,053	1,815	0	0	138	0	38	1,062	1,280	42%	1,773
2024	4,215	1,866	0	0	405	0	67	1,877	1,699	40%	2,516
2025	4,289	2,130	27	0	237	0	46	1,849	1,667	39%	2,623
2026	5,165	2,227	34	0	226	0	51	2,626	2,088	40%	3,077
2027	5,455	2,498	95	0	250	0	51	2,561	2,071	38%	3,383
2028	6,346	2,650	109	0	241	0	53	3,292	2,482	39%	3,863
2029	6,624	2,764	211	0	238	0	55	3,355	2,723	41%	3,900
2030	7,542	2,832	314	0	216	0	57	4,122	3,210	43%	4,332

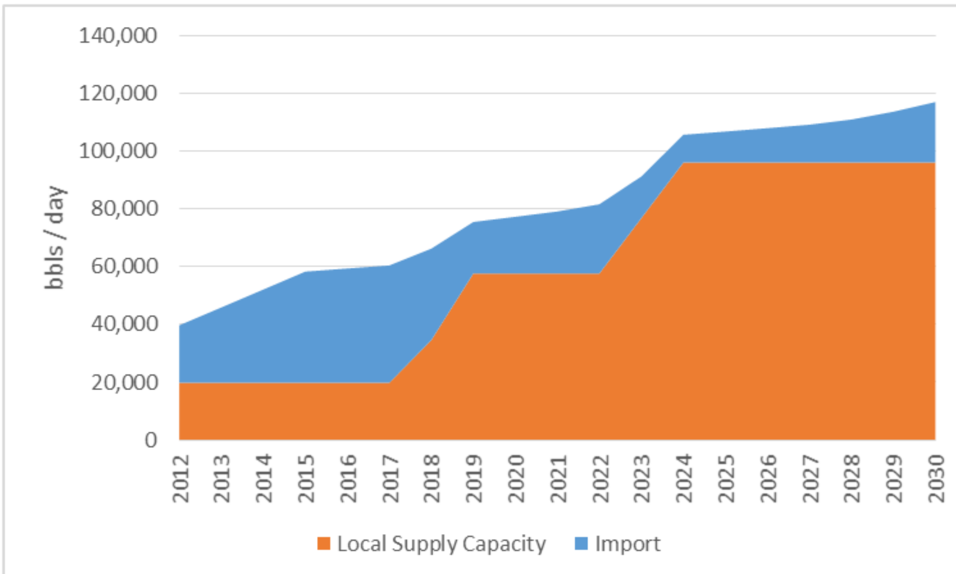
Source: Consultant's analysis

IV. OIL & REFINED OIL PRODUCTS

J. Oil – Total Primary Energy Production

38. The Consultant has assumed that a local refinery will be constructed by 2019. The capacity will initially be 50 000 bpd. The projection for refined oil products suggests that additional capacity of 50 000 bpd will be required by 2024. Nevertheless in most years it will be necessary to import oil.

Figure IV-1: Oil Production Local vs. Import (physical)



Source: Consultant's analysis

K. Oil – Total Primary Energy Supply Outlook

39. The primary energy supply requirements of oil has been forecast in terms of tons of oil, barrels per day and imperial gallons per annum. The results are given in the following charts and table.

Figure IV-2: Oil TPES Forecast (toe)

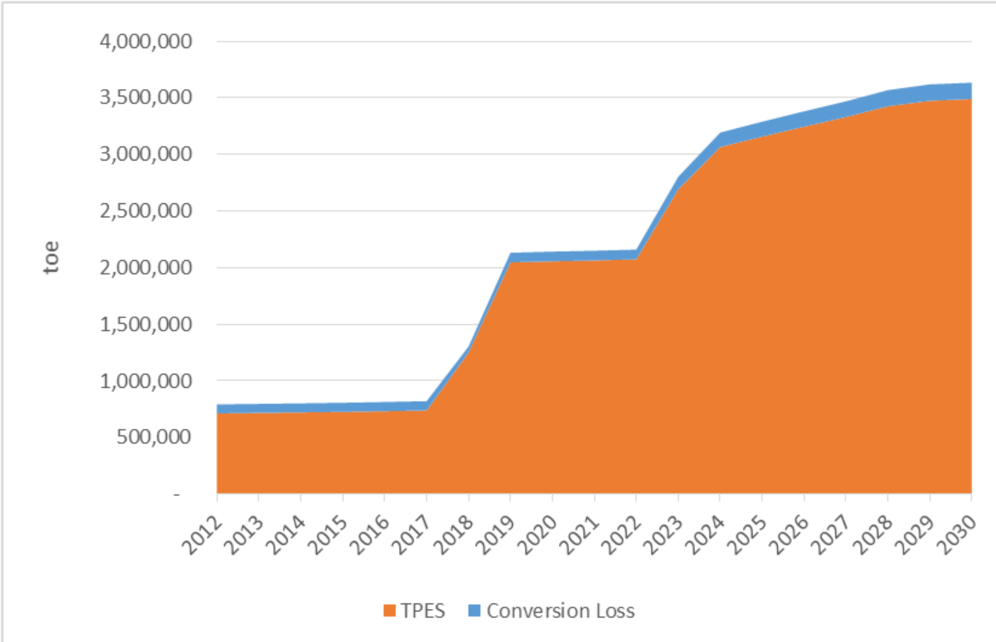
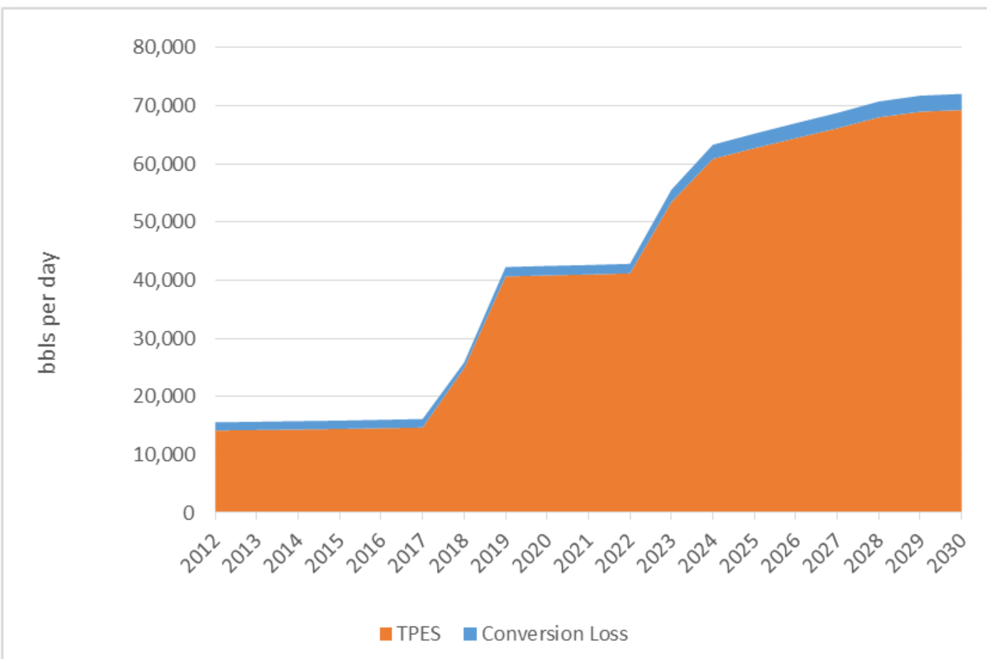


Figure IV-3: Oil TPES Forecast (physical)



Source: Consultant's analysis

40. The compound annual growth rates for oil production are given between 2013 and 2030 unless otherwise noted.

Table IV-1: Compound Annual Growth Rate Projections (2013 to 2030)

Fuel	CAGR	Comment
Total Oil Production	8.9%	Increasing due to economic growth
Fuel Conversion Loss	3.5%	Reducing with new refinery
Oil Product Demand	4.7%	TFEC
Gasoline	6.5%	Increasing due to economic growth
Diesel	3.2%	ditto
Furnace Oil	11.1%	ditto
Jet Fuel	8.2%	ditto
Paraffin	-2.8%	Reducing due to substitution of paraffin with electricity for lighting
LPG	1.2%	Increasing slowly mainly due to restaurant use; assumed that LPG will not penetrate households due to electrification programme

Source: Consultant's analysis

Table IV-2: Oil & Gas Condensates TPES Forecast (ktoe)

	Total Primary Energy	Conversion Efficiency	Loss	Total	Gasoline	Diesel	Furnace Oil	Jet Fuel	Paraffin	LPG
	ktoe	ktoe	%	ktoe	ktoe	ktoe	ktoe	ktoe	ktoe	ktoe
2012	583	58	10%	525	302	236	20	16	8	78
2013	587	59	10%	587	302	236	24	16	8	78
2014	590	59	10%	590	302	236	28	16	8	78
2015	594	59	10%	594	302	236	31	16	8	78
2016	599	60	4%	599	302	236	36	16	8	78
2017	604	60	4%	604	302	236	41	16	8	78
2018	1,023	41	4%	1,023	527	413	47	28	9	78
2019	1,674	67	4%	1,674	878	688	53	46	9	78
2020	1,681	67	4%	1,681	878	688	59	47	9	-
2021	1,688	68	4%	1,688	878	688	66	47	9	-
2022	1,696	68	4%	1,696	878	688	74	47	9	-
2023	2,201	88	4%	2,201	1,129	917	82	63	8	-
2024	2,507	100	4%	2,507	1,190	1,146	91	72	8	-
2025	2,582	103	4%	2,582	1,250	1,146	101	77	7	-

	Total Primary Energy	Conversion Efficiency	Loss	Total	Gasoline	Diesel	Furnace Oil	Jet Fuel	Paraffin	LPG
2026	2,654	106	4%	2,654	1,310	1,146	111	79	7	-
2027	2,724	109	4%	2,724	1,370	1,146	121	79	7	-
2028	2,801	112	4%	2,801	1,435	1,146	134	79	6	-
2029	2,841	114	4%	2,841	1,463	1,146	147	79	6	-
2030	2,853	114	4%	2,853	1,463	1,146	160	79	5	-

Source: Consultant's analysis

Table IV-3: Oil TPES Forecast (bbl per day)

	Total Primary Energy	Conversion Efficiency	Loss	Total	Gasoline	Diesel	Furnace Oil	Jet Fuel	Paraffin
	bbl/day	bbl/day	%	bbl/day	bbl/day	bbl/day	bbl/day	bbl/day	bbl/day
2013	14,158	1,416	10%	12,743	7,326	5,742	496	396	198
2014	14,245	1,425	10%	14,245	7,326	5,742	583	396	198
2015	14,332	1,433	10%	14,332	7,326	5,742	670	396	198
2016	14,419	1,442	10%	14,419	7,326	5,742	757	396	198
2017	14,543	1,454	10%	14,543	7,326	5,742	881	396	198
2018	14,668	1,467	10%	14,668	7,326	5,742	1,006	396	198
2019	24,847	994	4%	24,847	12,787	10,022	1,130	691	216
2020	40,646	1,626	4%	40,646	21,312	16,704	1,288	1,125	217
2021	40,830	1,633	4%	40,830	21,312	16,704	1,445	1,152	218
2022	40,988	1,640	4%	40,988	21,312	16,704	1,602	1,152	219
2023	41,178	1,647	4%	41,178	21,312	16,704	1,801	1,152	209
2024	53,437	2,137	4%	53,437	27,428	22,272	2,001	1,536	199
2025	60,878	2,435	4%	60,878	28,897	27,840	2,200	1,750	190
2026	62,701	2,508	4%	62,701	30,357	27,840	2,448	1,875	180
2027	64,443	2,578	4%	64,443	31,817	27,840	2,696	1,920	171
2028	66,141	2,646	4%	66,141	33,277	27,840	2,943	1,920	161
2029	68,023	2,721	4%	68,023	34,857	27,840	3,255	1,920	151
2030	68,988	2,760	4%	68,988	35,520	27,840	3,567	1,920	141

Source: Consultant's analysis

Table IV-4: Oil TPES Forecast (IG '000's)

	Total Primary Energy	Conversion Efficiency	Loss	Total	Gasoline	Diesel	Furnace Oil	Jet Fuel	Paraffin
	IG '000s	IG '000s	%	IG '000s	IG '000s	IG '000s	IG '000s	IG '000s	IG '000s
2012	147,771	14,777	-90%	132,993	76,461	59,929	5,181	4,133	2,067
2013	148,676	14,868	10%	148,676	76,461	59,929	6,087	4,133	2,067
2014	149,582	14,958	10%	149,582	76,461	59,929	6,993	4,133	2,067
2015	150,488	15,049	10%	150,488	76,461	59,929	7,899	4,133	2,067
2016	151,788	15,179	10%	151,788	76,461	59,929	9,199	4,133	2,067
2017	153,088	15,309	10%	153,088	76,461	59,929	10,499	4,133	2,067
2018	259,329	10,373	4%	259,329	133,459	104,603	11,798	7,214	2,255
2019	424,215	16,969	4%	424,215	222,432	174,338	13,438	11,743	2,264
2020	426,144	17,046	4%	426,144	222,432	174,338	15,077	12,023	2,273
2021	427,793	17,112	4%	427,793	222,432	174,338	16,717	12,023	2,283
2022	429,776	17,191	4%	429,776	222,432	174,338	18,800	12,023	2,182
2023	557,714	22,309	4%	557,714	286,267	232,451	20,883	16,031	2,082
2024	635,379	25,415	4%	635,379	301,600	290,564	22,966	18,267	1,982
2025	654,403	26,176	4%	654,403	316,836	290,564	25,549	19,572	1,882
2026	672,589	26,904	4%	672,589	332,073	290,564	28,133	20,039	1,781
2027	690,308	27,612	4%	690,308	347,309	290,564	30,716	20,039	1,681
2028	709,954	28,398	4%	709,954	363,802	290,564	33,971	20,039	1,578
2029	720,024	28,801	4%	720,024	370,719	290,564	37,226	20,039	1,475
2030	723,176	28,927	4%	723,176	370,719	290,564	40,482	20,039	1,372

Source: Consultant's analysis

V. NATURAL GAS

L. Natural Gas – Total Primary Energy Production

41. The Consultant has assumed that the M3 field will be indefinitely delayed and no new gas fields will commence operation during the period of the planning horizon. This represents a worst case scenario with a tight gas supply – demand outlook. However, as was discussed in the Liquid & Gaseous Fuel Strategy report there is an opportunity to manage the risks that natural gas supplies does not develop as anticipated.

Table V-1: Gas Supply Risk Mitigation circa 2019

	MMCF	MMCFD	Comment
Refinery	22,630	62	Hydro-cracking refinery needs hydrogen and usually powered with natural gas power plant
Power	81,030	222	EMP estimate
Fertilizer	20,552	56	Standard-run production plant 1 725 mtpd
Industry	38,623	106	EMP estimate
Total	~165,000	~548	
Available gas	~150,000	~411	Yadana, Yetagun, Shwe, Zawtika
Potential to Reduce Gas Consumption			
Refinery	(7,500)	(21)	Power the refinery using liquid fuels (30 – 40 MW)
Power sector	(30,250)	(83)	Increase hydropower, gas / oil plant
Fertilizer	(10,000)	(27)	Import fertilizer
Total	(50,000)	(137)	

Source: Consultant's analysis

42. The refinery design can be modified to minimize gas consumption. In principle the use of gas for power generation could be replaced by oil or storage hydropower capacity for deployment at times of peak demand. A fertilizer plant appears to be uneconomic and gas could be saved by importing urea. These measures have been assumed ahead of the development of an LNG terminal because the cost of LNG will be high and market acceptance may therefore be low.

M. Natural Gas – Primary Energy Supply Outlook

43. Natural gas production requirements are expected to rise significantly mainly due to industrial sector demand. The compound annual growth rates of Table V-2 show this clearly.

Figure V-1: Natural Gas TPES Forecast (toe) (excl. electricity)

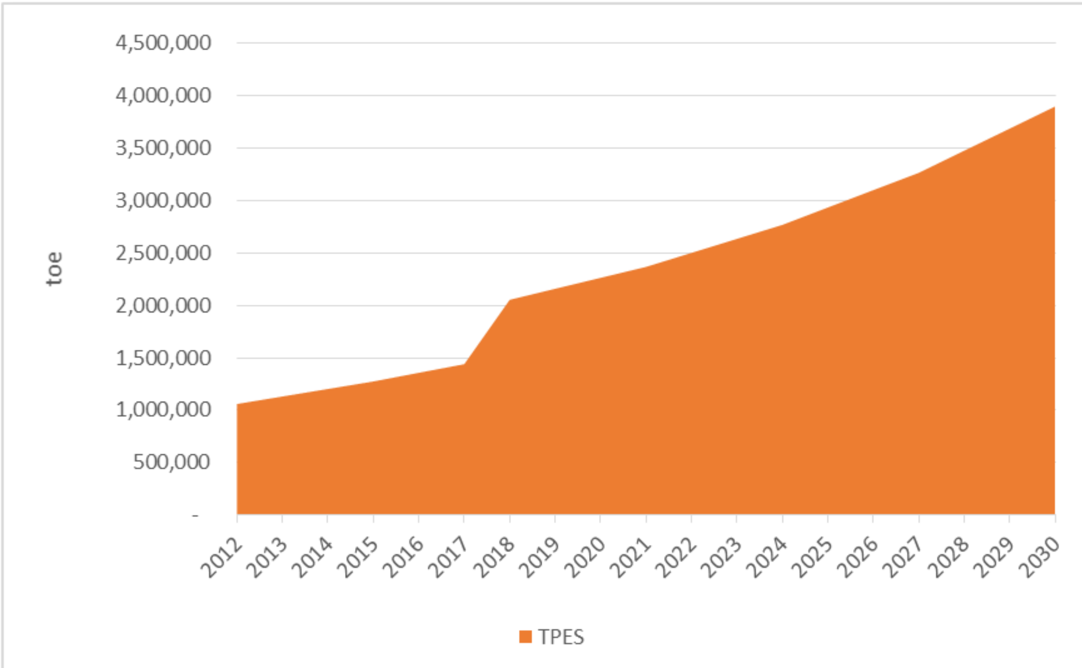
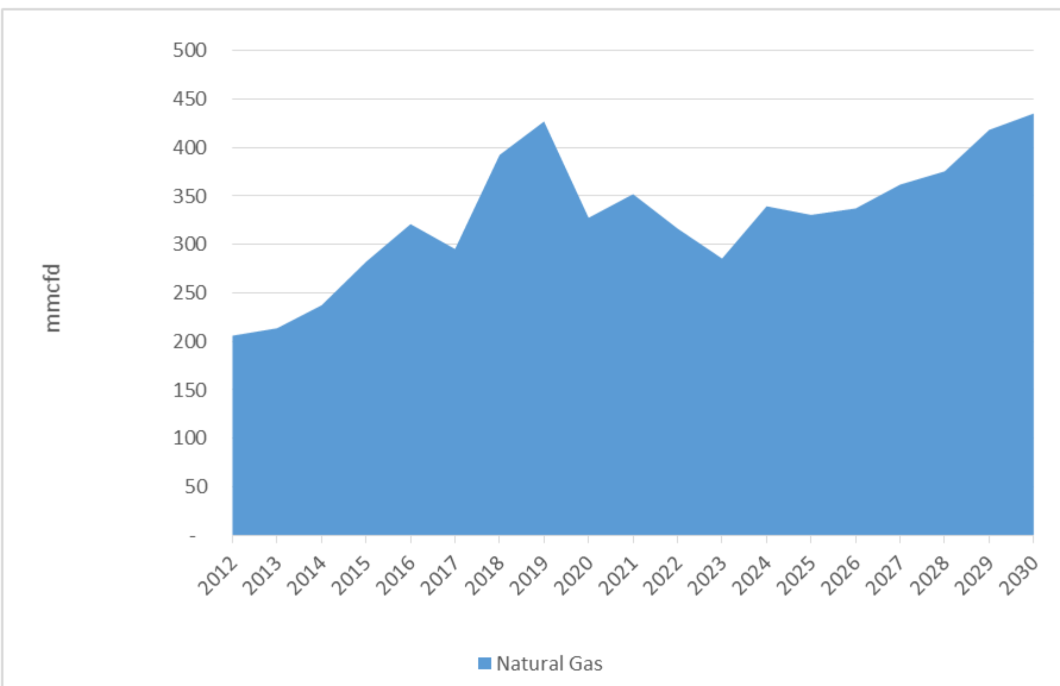


Figure V-2: Natural Gas TPES Forecast (physical) (incl. electricity)



Source: Consultant's analysis

44. The compound annual growth rates for gas production are given between 2013 and 2030 unless otherwise noted.

Table V-2: Compound Annual Growth Rate Projections (2013 to 2030)

Fuel	CAGR	Comment
Total Gas Production	7.3%	Increasing mainly due to industry consumption
Fuel Conversion Loss	7.3%	Increasing as gas increases in supply mix
Net Production	7.3%	TFEC
Electricity Generation	-10.5%	Decreasing as gas decreases in supply mix
Refinery	0.0%	Excluded due to recommendation to power the refinery with distillate
Fertilizer	4.5%	Included but noting that economics of fertilizer production does not appear to be positive for Myanmar
Transport	-6.2%	Reducing as CNG is reduced
Industrial	11.4%	Strongly increasing due to economic growth

Source: Consultant's analysis

45. The energy projection for forecast natural gas production, that matches Figure V-2, is given here as a table for convenience:

Table V-3: Natural Gas TPES Forecast (toe)

	Total Primary Energy	Conversion Efficiency	Loss	Total with Electricity	Electricity Generation	Refinery	Transport	Industrial
	toe	toe	%	toe	toe	toe	toe	toe
2012	324,642		0%	324,642	1,295,429	-	31,738	291,609
2013	389,998	-	0%	389,998	1,295,429	-	35,789	352,913
2014	455,391	-	0%	455,391	1,332,382	-	39,841	414,217
2015	520,773	-	0%	520,773	1,358,717	-	43,893	475,521
2016	595,369	-	0%	595,369	1,360,866	-	40,244	553,763
2017	669,573	-	0%	669,573	971,245	-	36,596	632,005
2018	1,276,046	-	0%	1,276,046	1,046,338	531,805	32,948	710,247
2019	1,372,196	-	0%	1,372,196	1,243,894	531,805	30,202	808,945
2020	1,467,557	-	0%	1,467,557	652,517	531,805	27,456	907,643
2021	1,563,521	-	0%	1,563,521	664,559	531,805	24,710	1,006,341
2022	1,686,182	-	0%	1,686,182	257,080	531,805	22,376	1,131,744
2023	1,809,131	-	0%	1,809,131	137,745	531,805	20,042	1,257,146
2024	1,932,466	-	0%	1,932,466	405,005	531,805	17,707	1,382,549

	Total Primary Energy	Conversion Efficiency	Loss	Total with Electricity	Electricity Generation	Refinery	Transport	Industrial
2025	2,085,790	-	0%	2,085,790	236,889	531,805	15,686	1,538,062
2026	2,239,271	-	0%	2,239,271	226,188	531,805	13,665	1,693,575
2027	2,392,787	-	0%	2,392,787	250,089	531,805	11,644	1,849,088
2028	2,588,994	-	0%	2,588,994	241,454	531,805	11,898	2,045,050
2029	2,785,207	-	0%	2,785,207	238,151	531,805	12,152	2,241,012
2030	2,981,401	-	0%	2,981,401	215,911	531,805	12,407	2,436,974

Source: Consultant's analysis

Table V-4: Natural Gas TPES Forecast (MMCF)

	Total Primary Energy	Conversion Efficiency	Loss	Total with Electricity	Electricity Generation	Refinery	Transport	Industrial
	mmcf	mmcf	%	mmcf	mmcf	mmcf	mmcf	mmcf
2012	75,189	-	0%	75,189	61,432	-	1,351	12,409
2013	77,970	-	0%	77,970	61,432	-	1,523	15,018
2014	86,628	-	0%	86,628	67,307	-	1,695	17,626
2015	102,987	-	0%	102,987	78,221	-	1,868	20,235
2016	117,184	-	0%	117,184	87,962	-	1,713	23,564
2017	107,802	-	0%	107,802	73,022	-	1,557	26,894
2018	143,242	-	0%	143,242	80,633	22,630	1,402	30,223
2019	155,830	-	0%	155,830	81,079	22,630	1,285	34,423
2020	119,580	-	0%	119,580	35,114	22,630	1,168	38,623
2021	128,482	-	0%	128,482	40,892	22,630	1,052	42,823
2022	115,505	-	0%	115,505	54,384	22,630	952	48,159
2023	104,244	-	0%	104,244	38,284	22,630	853	53,496
2024	123,898	-	0%	123,898	30,168	22,630	754	58,832
2025	120,648	-	0%	120,648	30,254	22,630	668	65,449
2026	123,092	-	0%	123,092	24,059	22,630	581	72,067
2027	132,069	-	0%	132,069	25,880	22,630	495	78,685
2028	137,060	-	0%	137,060	21,221	22,630	506	87,023
2029	152,673	-	0%	152,673	36,204	22,630	517	95,362
2030	158,833	-	0%	158,833	35,101	22,630	528	103,701

Table V-5: Natural Gas TPES Forecast (MMCFD)

	Total Primary Energy	Conversion Efficiency	Loss	Total with Electricity	Electricity Generation	Refinery	Transport	Industrial
	mmcfd	mmcfd	%	mmcfd	mmcfd	mmcfd	mmcfd	mmcfd
2012	206	-	0%	206	168	-	4	34
2013	214	-	0%	214	168	-	4	41
2014	237	-	0%	237	184	-	5	48
2015	282	-	0%	282	214	-	5	55
2016	321	-	0%	321	241	-	5	65
2017	295	-	0%	295	200	-	4	74
2018	392	-	0%	392	221	62	4	83
2019	427	-	0%	427	222	62	4	94
2020	328	-	0%	328	96	62	3	106
2021	352	-	0%	352	112	62	3	117
2022	316	-	0%	316	149	62	3	132
2023	286	-	0%	286	105	62	2	147
2024	339	-	0%	339	83	62	2	161
2025	331	-	0%	331	83	62	2	179
2026	337	-	0%	337	66	62	2	197
2027	362	-	0%	362	71	62	1	216
2028	376	-	0%	376	58	62	1	238
2029	418	-	0%	418	99	62	1	261
2030	435	-	0%	435	96	62	1	284

Source: Consultant's analysis

VI. COAL

N. Introduction

46. Myanmar possesses large coal reserves (230 million ton probable and 120 million ton possible). The largest reserves are in Kalewa region and central east of Myanmar (Maingsat). Coals are accessible for extraction but due to road conditions could be difficulties for their further transportation. Projects for infrastructure improvement are ongoing thus this factor may be mitigated in the future. However, the currently identified domestic coal resources are not sufficient for developing coal-based electricity generation capacities in thousands of megawatts as a 1000 MW coal fired base load plant would consume over its life around 90 to 100 million tons.

47. In 2013 Myanmar produced 790 thousand tons of coal and the production is likely to grow in the future. The government estimates production growth at 40% annually till 2030 in order to meet the growing demand. The growth of demand for coal in Myanmar can be linked to: (i) growing demand in pyro-metallurgical industry; (ii) plans to construct new coal-fired power plants; (iii) replacement of firewood with coal in order to prevent deforestation.

48. Myanmar coals are not of high quality and possess low calorific values (3200 to 6700 kcal/kg); however their low sulphur contaminant allows using them for power production. Modern technologies allow more efficient utilization of low-quality coals' potential.

O. Power

49. At present Myanmar operates only one coal-fired power plant at Tigyit. The plant is of 120 MW installed capacity but operates only 27 MW due to inadequate maintenance. The plans for its rehabilitation have not yet been approved.

50. Data on plans for new coal-fired PPs is somewhat undefined. MOM and MEP have announced three projects with total installed capacity 876 MW (Kalewa, Yangon and Tanintharyi). JICA study referring to Hydropower Generation Enterprise provide information of about 11 projects with a total capacity of 15 GW. All projects are developed by the private sector by both domestic and foreign investors. Some projects include that 50 % of the generated electricity will be exported to neighbouring countries.

51. There are indicators that environmental and social approaches in developing new coal-fired power plants projects are not completely adequate. More attention shall be paid to these issues while developing future power plants. Three types of coal-fired power units have been selected as representative for Myanmar's future coal capacity, namely 600 MW supercritical, 150 MW circulating fluidized bed, and 50 MW pulverized coal fired unit. Cost and operational parameters have been defined for these three representative units for further analysis and expansion planning.

52. Apart from limitations due to available infrastructure, another issue to be considered is the rather limited capacity of the mines. A 300 MW coal-fired power unit would consume around 1 to 1.3 million tons of coal annually (depending on type of plant and calorific value of coal). Therefore, over the life of 30 years the coal supply amounts to 30 to 39 million tons. The largest coal reserve currently listed is Maingsat in Shan State with a capacity of 118 Mtons of probable lignite to sub-bituminous and 4 Mtons of possible sub-bituminous coals. The largest deposit of sub-bituminous coals is at Kalewa in

Southern Sagaing Division with total capacity of 87 Mtons, 5 Mtons of which are positive, 18 Mtons are probable and 65 Mtons are possible. These reserves do not suffice for large scale power development, for example in the range of 1,000 MW supercritical power units, currently typical in the People's Republic of China (the PRC). Therefore the development of coal based power should be carried out in synchrony with the mining development so that capacities of mine mouth plants are properly dimensioned to match the proven and probable resources.

53. The power generation sector supply requirement for coal was defined by the ADICA power sector expansion as follows:-

P. Industry Sector

54. The industry sector demands raw coal for industrial furnace applications. This may be phased out in time if more gas is available to industry.

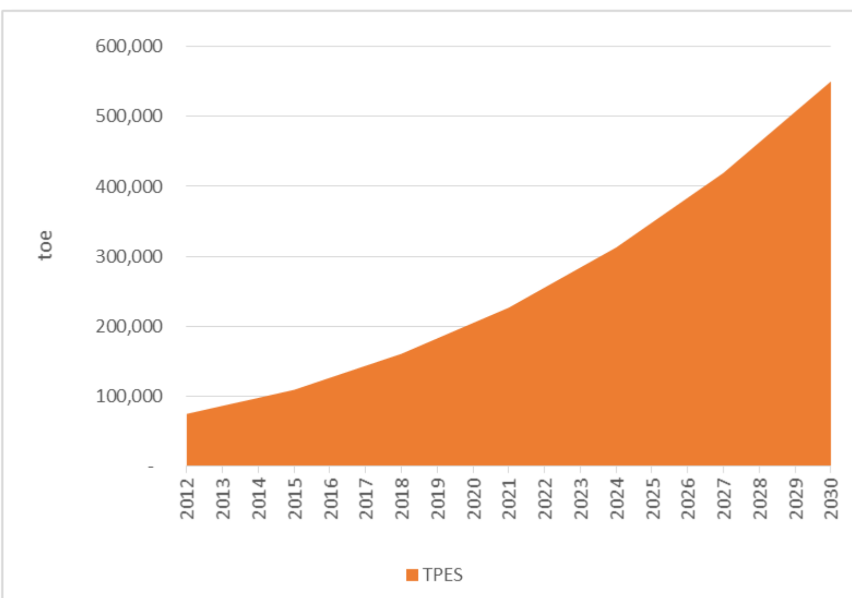
Q. Coal – Total Primary Energy Production

55. The Consultant has assumed that all coal used to power large coal-fired plants (in coastal locations) will be imported bituminous coal of high calorific value. Industrial need for coal will be met mainly with indigenous coal.

R. Coal – Primary Energy Supply Outlook

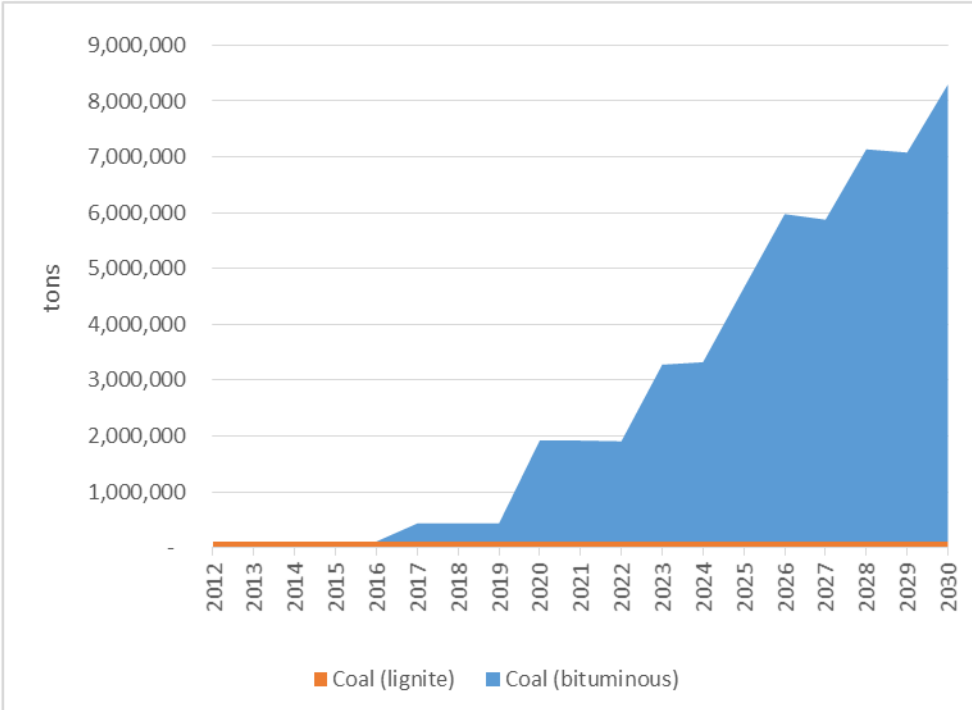
56. Coal production requirements are expected to rise significantly mainly due to power generation demand. However, it is anticipated the sub-bituminous coal will be imported. The compound annual growth rates of Table VI-1 show this clearly.

Figure VI-1: Coal TPES Forecast (toe) (excl. electricity)



Source: Consultant's analysis

Figure VI-2: Coal TPES Forecast (physical) (incl. electricity)



Source: Consultant's analysis

57. The compound annual growth rates for coal production are given between 2013 and 2030 unless otherwise noted.

Table VI-1: Compound Annual Growth Rate Projections (2013 to 2030)

Fuel	CAGR	Comment
Total Coal Production	10.9%	Increasing due to power production
Fuel Conversion Loss	0.0%	No losses accounted for in coal winning and transport
Net Production	10.9%	TFEC
Electricity Generation	25.5%	Increasing due to increasing coal in supply mix
Industry	10.9%	Increasing with economic growth

Source: Consultant's analysis

Table VI-2: Coal TPES Forecast (toe)

	Total Primary Energy	Fuel Conversion Loss	Loss	Total	Industrial
	toe	toe	%	toe	toe
2012	74,770		0%	74,770	74,770
2013	86,237		0%	86,237	86,237
2014	97,703	-	0%	97,703	97,703
2015	109,169	-	0%	109,169	109,169
2016	126,362	-	0%	126,362	126,362
2017	143,554	-	0%	143,554	143,554
2018	160,746	-	0%	160,746	160,746
2019	182,748	-	0%	182,748	182,748
2020	204,750	-	0%	204,750	204,750
2021	226,751	-	0%	226,751	226,751
2022	255,413	-	0%	255,413	255,413
2023	284,074	-	0%	284,074	284,074
2024	312,736	-	0%	312,736	312,736
2025	348,333	-	0%	348,333	348,333
2026	383,931	-	0%	383,931	383,931
2027	419,528	-	0%	419,528	419,528
2028	463,134	-	0%	463,134	463,134
2029	506,740	-	0%	506,740	506,740
2030	550,346	-	0%	550,346	550,346

Source: Consultant's analysis

Table VI-3: Coal TPES Forecast (tons)

	Total Primary Energy	Fuel Conversion Loss	Loss	Total	Industrial
	tons	tons	%	tons	tons
2012	49,929	-	0%	49,929	49,929
2013	45,849	-	0%	45,849	45,849
2014	66,951	-	0%	66,951	66,951
2015	78,456	-	0%	78,456	78,456
2016	90,451	-	0%	90,451	90,451
2017	103,294	-	0%	103,294	103,294

	Total Primary Energy	Fuel Conversion Loss	Loss	Total	Industrial
	tons	tons	%	tons	tons
2018	117,183	-	0%	117,183	117,183
2019	132,073	-	0%	132,073	132,073
2020	148,182	-	0%	148,182	148,182
2021	166,035	-	0%	166,035	166,035
2022	185,213	-	0%	185,213	185,213
2023	205,806	-	0%	205,806	205,806
2024	228,105	-	0%	228,105	228,105
2025	251,827	-	0%	251,827	251,827
2026	277,434	-	0%	277,434	277,434
2027	305,079	-	0%	305,079	305,079
2028	334,986	-	0%	334,986	334,986
2029	367,342	-	0%	367,342	367,342
2030	402,073	-	0%	402,073	402,073

Source: Consultant's analysis

VII. RENEWABLES (TYPE II)

S. Introduction

58. Type I renewables include hydropower, solar power and wind power. These renewables were discussed in the electricity production section above. Type II renewables include biomass and biofuels. Solid biomass in the form of fuelwood and woody agricultural residues is the most used fuel in Myanmar by far, due to the dominance of the fuel in household cooking in rural areas.

59. Biofuels have been trialed in Myanmar with poor results. The production of bioethanol and biodiesel is discussed further, albeit there is sufficient uncertainty that these fuels have not been included in the energy projections.

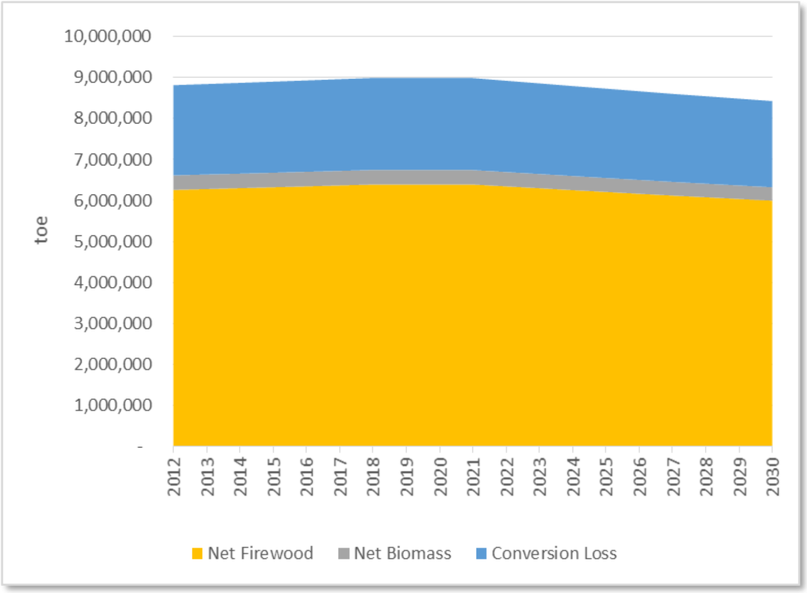
T. Fuelwood – Total Primary Energy Production

60. The Consultant has assumed that primary energy production is equivalent to primary secondary energy production. There was insufficient data available to quantify fuelwood losses arising between forests and distribution centres. Furthermore the conversion losses associated with the burning of fuelwood has not been accounted for in the energy balance – such losses are important from an energy efficiency standpoint, but from an energy balance perspective they occur within consumer premises and are therefore ignored.

U. Fuelwood – Primary Energy Supply Outlook

61. The projection for fuelwood is shown in Figure VII-1. The chart shows a significant decline in fuelwood production needs, easing pressure on Myanmar's forests. The reduction is due to the substitution of fuelwood by electricity for the purpose of household cooking.

Figure VII-1: Fuelwood TPES Forecast (toe)



Source: Consultant's analysis

Figure VII-2: Fuelwood TPES Forecast (toe)

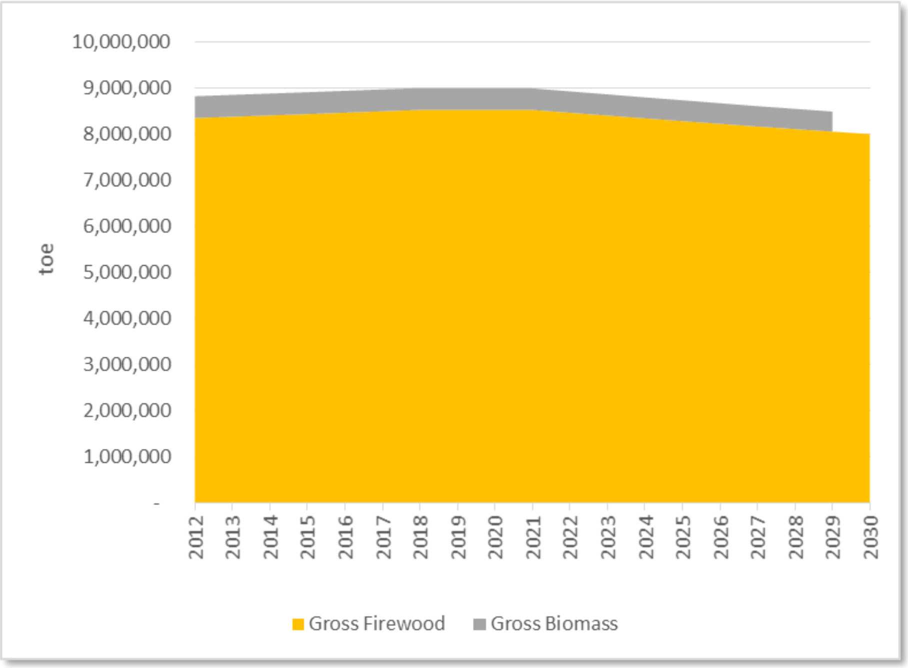
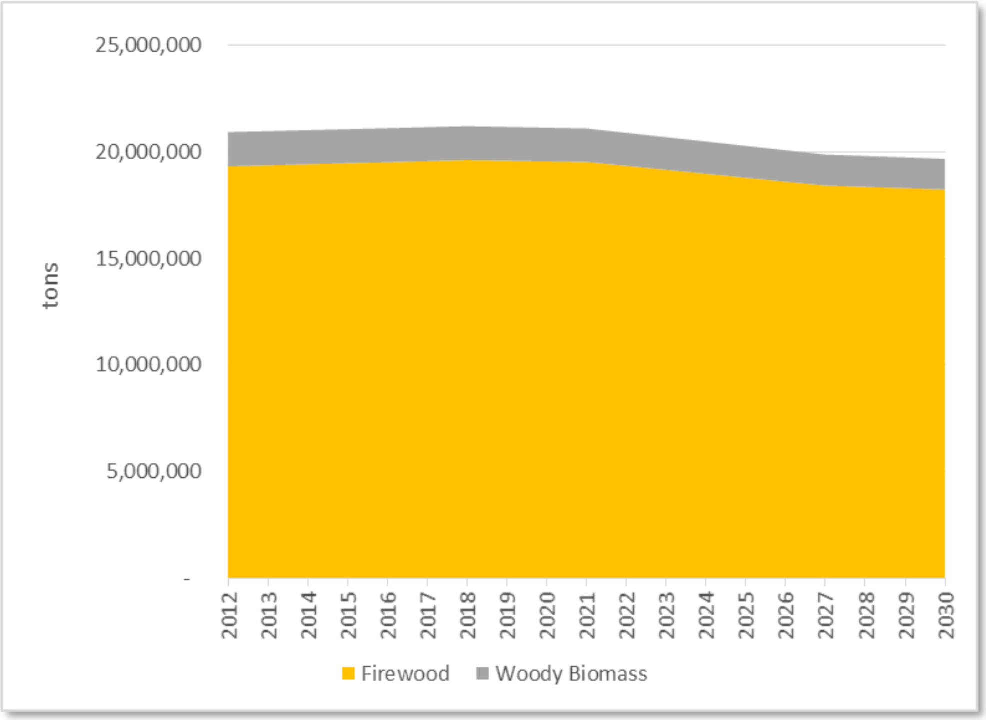


Figure VII-3: Fuelwood TPES Forecast (physical)



Source: Consultant's analysis

62. The compound annual growth rates for fuelwood production are given between 2013 and 2030 unless otherwise noted.

Table VII-1: Compound Annual Growth Rate Projections (2013 to 2030)

Fuel	CAGR	Comment
Total Fuelwood Energy Supply	-0.3%	Reducing due to substitution with electric cooking
Net Production	-0.3%	TFEC considered as TPES
Firewood (Cooking)	-0.3%	
Woody biomass (Cooking)	-0.3%	

Source: Consultant's analysis

63. The total energy supply projection for fuelwood, that matches Figure VII-2, is given here as a table for convenience:

Table VII-2: Fuelwood TPES Forecast (toe)

	Total Primary Energy Supply	Conversion Efficiency	Loss	Gross Firewood	Net Firewood	Gross Biomass	Net Biomass
	toe	toe	%	toe	toe	toe	toe
2013	8,847,089	-	0%	8,373,737	6,280,303	473,352	118,338
2014	8,875,819	-	0%	8,402,298	6,301,723	473,521	118,380
2015	8,904,548	-	0%	8,430,858	6,323,144	473,689	118,422
2016	8,935,016	-	0%	8,461,158	6,345,869	473,858	118,465
2017	8,965,485	-	0%	8,491,458	6,368,593	474,027	118,507
2018	8,995,953	-	0%	8,521,757	6,391,318	474,196	118,549
2019	8,994,627	-	0%	8,521,654	6,391,241	472,973	118,243
2020	8,993,301	-	0%	8,521,551	6,391,163	471,750	117,938
2021	8,991,975	-	0%	8,521,448	6,391,086	470,527	117,632
2022	8,927,078	-	0%	8,460,557	6,345,418	466,522	116,630
2023	8,862,182	-	0%	8,399,666	6,299,750	462,516	115,629
2024	8,797,286	-	0%	8,338,776	6,254,082	458,510	114,628
2025	8,733,902	-	0%	8,279,398	6,209,548	454,504	113,626
2026	8,670,519	-	0%	8,220,020	6,165,015	450,499	112,625
2027	8,607,136	-	0%	8,160,643	6,120,482	446,493	111,623
2028	8,548,363	-	0%	8,106,010	6,079,507	442,353	110,588
2029	8,489,589	-	0%	8,051,377	6,038,533	438,212	109,553
2030	8,430,816	-	0%	7,996,744	5,997,558	434,072	108,518

Source: Consultant's analysis

Table VII-3: Fuelwood TPES Forecast (tons)

	Total Primary Energy Supply	Conversion Efficiency	Loss	Gross Firewood	Gross Biomass
	tons	tons	%	tons	tons
2013	20,983,536	-	0%	19,378,139	1,605,397
2014	21,027,903	-	0%	19,427,157	1,600,747
2015	21,072,271	-	0%	19,476,175	1,596,097
2016	21,120,178	-	0%	19,525,193	1,594,985
2017	21,168,084	-	0%	19,574,211	1,593,873
2018	21,215,991	-	0%	19,623,229	1,592,762
2019	21,179,850	-	0%	19,594,141	1,585,709
2020	21,143,710	-	0%	19,565,054	1,578,656
2021	21,107,570	-	0%	19,535,967	1,571,603
2022	20,903,336	-	0%	19,350,669	1,552,667
2023	20,699,102	-	0%	19,165,372	1,533,730
2024	20,494,868	-	0%	18,980,074	1,514,794
2025	20,290,635	-	0%	18,794,776	1,495,858
2026	20,086,401	-	0%	18,609,479	1,476,922
2027	19,882,167	-	0%	18,424,181	1,457,986
2028	19,815,196	-	0%	18,362,365	1,452,831
2029	19,748,226	-	0%	18,300,549	1,447,676
2030	19,681,255	-	0%	18,238,734	1,442,521

Source: Consultant's analysis

Appendix A – IEA Energy Balance Tables (2012 to 2030)

2012

	Thousand tonnes of oil equivalent										
SUPPLY AND CONSUMPTION	**Coal & peat**	**Crude oil**	**Oil products**	**Natural Gas**	**Nuclear**	**Hydro**	**Geotherm. solar etc.**	**Biofuels & waste**	**Electricity**	**Heat**	**Total**
Production	219	879	82	13005		664	0	8818			23668
Imports			1669								1669
Exports				-11880							-11880
Intl. marine bunkers											
Intl. aviation bunkers											
Stock changes											
TPES	**219**	**879**	**1751**	**1125**		**664**		**8818**			**13458**
Electricity and CHP plants	-144		-2	-190		-664			804		-196
Oil refineries		-792	713								-79
Other transformation		-87	-12	-306							-405
TFC	**75**		**2451**	**629**				**8818**	**701**		**12675**
INDUSTRY	**75**		**57**	**292**					**278**		**701**
Iron and steel				8					5		
Chemical and petrochemical									0.3		
Non-metallic minerals	13			272					15		301
Other/non-specified	61		57	11					257		386
TRANSPORT			**1404**	**32**							**1436**
Domestic aviation			31								31
Road			1368	32							1400
Other/non-specified			5								5
OTHER			**990**					**8818**	**423**		**10232**
Residential			63					8035	287		8386
Comm. and public services			694					783	114		1592
Agriculture/forestry			233						22		255
Other/non-specified											
NON-ENERGY USE				**306**							**306**
				Electricity and Heat Output							
Electricity generated - GWh	703		16	1917		7728					10364

2015

		Thousand tonnes of oil equivalent									
SUPPLY AND CONSUMPTION	**Coal & peat**	**Crude oil**	**Oil products**	**Natural Gas**	**Nuclear**	**Hydro**	**Geotherm. solar etc.**	**Biofuels & waste**	**Electricity**	**Heat**	**Total**
Production	273	894	80	16561		805		8905			27518
Imports			2625								2625
Exports				-13938							-13938
Intl. marine bunkers											
Intl. aviation bunkers											
Stock changes											
TPES	**273**	**894**	**2705**	**2623**		**805**		**8905**			**16205**
Electricity and CHP plants	-164		0	-1359		-805			1698		-629
Oil refineries		-807	726								-81
Other transformation		-87	-12	-372							-471
TFC	**109**		**3420**	**892**				**8905**	**963**		**14289**
INDUSTRY	**109**		**91**	**476**					**475**		**1151**
Iron and steel				11					8		
Chemical and petrochemical									1		
Non-metallic minerals				438					27		465
Other/non-specified	109		91	26					440		666
TRANSPORT			**2235**	**44**							**2278**
Domestic aviation			31								31
Road			2199	44							2243
Other/non-specified			4								4
OTHER			**1094**					**8905**	**488**		**10487**
Residential			58					8,095	342		8495
Comm. and public services			718					810	122		1650
Agriculture/forestry			317						24		342
Other/non-specified											
NON-ENERGY USE				**372**							**372**
Electricity and Heat Output											
Electricity generated - GWh	224		0	4815		9359					14398

2018

	Thousand tonnes of oil equivalent										
SUPPLY AND CONSUMPTION	**Coal & peat**	**Crude oil**	**Oil products**	**Natural Gas**	**Nuclear**	**Hydro**	**Geotherm. solar etc.**	**Biofuels & waste**	**Electricity**	**Heat**	**Total**
Production	540	1391	79	15728		945	0	8996			27679
Imports			2306	439							2744
Exports				-13938							-13938
Intl. marine bunkers											
Intl. aviation bunkers											
Stock changes											
TPES	**540**	**1391**	**2385**	**2228**		**945**	**0**	**8996**			**16485**
Electricity and CHP plants	-380		0	-1046		-945	0		1235		-1136
Oil refineries		-1304	1251								-52
Other transformation		-87	-12								-99
TFC	**161**		**3624**	**1182**				**8996**	**1328**		**15292**
INDUSTRY	**161**		**113**	**710**					**709**		**1694**
Iron and steel				17					12		
Chemical and petrochemical									1		
Non-metallic minerals				655					40		695
Other/non-specified	161		113	39					657		970
TRANSPORT			**2311**	**33**							**2344**
Domestic aviation			50								50
Road			2256	33							2289
Other/non-specified			5								5
OTHER			**1200**	**0**				**8996**	**619**		**10815**
Residential			54					8,154	440		8648
Comm. and public services			747					842	149		1738
Agriculture/forestry			399						29		428
Other/non-specified											
NON-ENERGY USE				439							**439**
				Electricity and Heat Output							
Electricity generated - GWh	891		0	7568		10987					19446

2021

		Thousand tonnes of oil equivalent									
SUPPLY AND CONSUMPTION	**Coal & peat**	**Crude oil**	**Oil products**	**Natural Gas**	**Nuclear**	**Hydro**	**Geotherm. solar etc.**	**Biofuels & waste**	**Electricity**	**Heat**	**Total**
Production	670	2150	1	12805		1643	0	8992			26262
Imports			1898	505							2403
Exports				-11110							-11110
Intl. marine bunkers											
Intl. aviation bunkers											
Stock changes											
TPES	**670**	**2150**	**1899**	**2201**		**1643**	**0**	**8992**			**17555**
Electricity and CHP plants	-443			-665		-1643	0		1765		-985
Oil refineries		-2150	2064								-86
Other transformation			-12								-12
TFC	**227**		**3951**	**1536**				**8992**	**1796**		**16502**
INDUSTRY	**227**		**142**	**1006**					**1005**		**2380**
Iron and steel				24					16		
Chemical and petrochemical									1		
Non-metallic minerals				928					57		984
Other/non-specified	227		142	55					931		1354
TRANSPORT			**2492**	**25**							**2516**
Domestic aviation			69								69
Road			2417	25							2442
Other/non-specified			5								5
OTHER			**1318**	**0**				**8992**	**791**		**11101**
Residential			50					8,115	575		8740
Comm. and public services			777					877	184		1837
Agriculture/forestry			491						33		524
Other/non-specified											
NON-ENERGY USE				505							**505**
					Electricity and Heat Output						
Electricity generated - GWh	882		0	5780		19101					25763

2024

		Thousand tonnes of oil equivalent									
SUPPLY AND CONSUMPTION	**Coal & peat**	**Crude oil**	**Oil products**	**Natural Gas**	**Nuclear**	**Hydro**	**Geotherm. solar etc.**	**Biofuels & waste**	**Electricity**	**Heat**	**Total**
Production	843	3541	2	11340		1866	0	8797			26390
Imports	1726		998	571							3296
Exports				-9535							-9535
Intl. marine bunkers											
Intl. aviation bunkers											
Stock changes											
TPES	**2570**	**3541**	**1000**	**2377**		**1866**	**0**	**8797**			**20151**
Electricity and CHP plants	-2257		0	-405		-1866	0		2516		-2012
Oil refineries		-3541	3400								-142
Other transformation		0	-12								-12
TFC	**313**		**4388**	**1972**				**8797**	**2410**		**17880**
INDUSTRY	**313**		**178**	**1383**					**1381**		**3254**
Iron and steel				33					22		
Chemical and petrochemical									2		
Non-metallic minerals				1274					78		1352
Other/non-specified	313		178	75					1279		1844
TRANSPORT			**2791**	**18**							**2808**
Domestic aviation			88								88
Road			2697	18							2714
Other/non-specified			6								6
OTHER			**1420**	**0**				**8797**	**1029**		**11246**
Residential			44					7,881	765		8691
Comm. and public services			812					916	226		1954
Agriculture/forestry			563						38		601
Other/non-specified											
NON-ENERGY USE				571							**571**
					Electricity and Heat Output						
Electricity generated - GWh	7912		0	4290		21702					33904

2027

		Thousand tonnes of oil equivalent									
SUPPLY AND CONSUMPTION	**Coal & peat**	**Crude oil**	**Oil products**	**Natural Gas**	**Nuclear**	**Hydro**	**Geotherm. solar etc.**	**Biofuels & waste**	**Electricity**	**Heat**	**Total**
Production	1057	3588	4	9071		2498	95	8607			24920
Imports	2394		1428	638							4459
Exports				-6961							-6961
Intl. marine bunkers											
Intl. aviation bunkers											
Stock changes											
TPES	**3450**	**3588**	**1432**	**2749**		**2498**	**95**	**8607**			**22419**
Electricity and CHP plants	-3031		0	-250		-2498	-95		3383		-2491
Oil refineries		-3588	3444								-144
Other transformation		0	-12								-12
TFC	**420**		**4864**	**2498**				**8607**	**3214**		**19603**
INDUSTRY	**420**		**222**	**1849**					**1847**		**4338**
Iron and steel				44					30		
Chemical and petrochemical									2		
Non-metallic minerals				1704					104		1809
Other/non-specified	420		222	101					1710		2453
TRANSPORT			**3176**	**12**							**3188**
Domestic aviation			107								107
Road			3063	12							3075
Other/non-specified			6								6
OTHER			**1466**	**0**				**8607**	**1367**		**11440**
Residential			39					7,647	1,046		8732
Comm. and public services			851					960	280		2091
Agriculture/forestry			576						41		617
Other/non-specified											
NON-ENERGY USE				638							**638**
				Electricity and Heat Output							
Electricity generated - GWh	10627		0	3661		29049					43337

2030

		Thousand tonnes of oil equivalent									
SUPPLY AND CONSUMPTION	**Coal & peat**	**Crude oil**	**Oil products**	**Natural Gas**	**Nuclear**	**Hydro**	**Geotherm. solar etc.**	**Biofuels & waste**	**Electricity**	**Heat**	**Total**
Production	1318	3635	5	8541		2832	314	8431			25077
Imports	3962		1978	704							6644
Exports				-5876							-5876
Intl. marine bunkers											
Intl. aviation bunkers											
Stock changes											
TPES	**5280**	**3635**	**1984**	**3369**		**2832**	**314**	**8431**			**25846**
Electricity and CHP plants	-4730		0	-216		-2832	-314		4332		-3760
Oil refineries		-3635	3490								-145
Other transformation			-12								-12
TFC	**550**		**5461**	**3153**				**8431**	**4292**		**21888**
INDUSTRY	**550**		**278**	**2437**					**2434**		**5699**
Iron and steel				58					40		97
Chemical and petrochemical									3		3
Non-metallic minerals				2246					138		2384
Other/non-specified	550		278	133					2254		3215
TRANSPORT			**3669**	**12**							**3682**
Domestic aviation			126								126
Road			3537	12							3549
Other/non-specified			7								7
OTHER			**1514**	**0**				**8431**	**1858**		**11803**
Residential			34					7,420	1,464		8919
Comm. and public services			896					1,010	347		2254
Agriculture/forestry			584						46		630
Other/non-specified											
NON-ENERGY USE				704							**704**
					Electricity and Heat Output						
Electricity generated - GWh	17010		0	4735		32932					54677

Project Number: TA No. 8356-MYA

FINAL REPORT

INSTITUTIONAL ARRANGEMENTS TO SUPPORT ENERGY MASTER PLANNING

Prepared for

The Asian Development Bank

and

The Myanmar Ministry of Energy

Prepared by

IES
Intelligent Energy Systems

in association with

MMIC
MYANMAR
INTERNATIONAL
CONSULTANTS

ABBREVIATIONS

ADB	–	Asian Development Bank
BOT	–	Build Operate Transfer
DSM	–	Demand Side Management
EEG	–	Energy Expert Group
EGAT	–	Electricity Generating Authority of Thailand
EMP	–	Energy Master Plan
EPD	–	Energy Planning Department
EPPO	–	Energy Policy and Planning Office (Thailand)
ESI	–	Energy Saving Initiative (Australia)
GDE	–	General Directorate on Energy (Vietnam)
IEP	–	Integrated Energy Planning
IPP	–	Independent Power Producer
LNG	–	Liquefied Natural Gas
LPG	–	Liquefied Petroleum Gas
LRES	–	Large-scale Renewable Energy Scheme (Australia)
MES	–	Myanmar Engineering Society
MOA	–	Ministry of Agriculture
MGS	–	Myanmar Geoscience Society
MOECAF	–	Ministry of Environment, Conservation and Forestry
MOE	–	Ministry of Energy
MOEP	–	Ministry of Electric Power
MOGE	–	Myanmar Oil and Gas Enterprise
MOI	–	Ministry of Industry
MOIT	–	Ministry of Industry and Trade (Vietnam)
MOLFRD	–	Ministry of Livestock, Fisheries and Rural Development
MOM	–	Ministry of Mines
MOST	–	Ministry of Science and Technology
MPE	–	Myanmar Petrochemical Enterprise
MPPE	–	Myanmar Petroleum Products Enterprise
NEC	–	National Energy Policy Council (Thailand)
NEMC	–	National Energy Management Committee
NESA	–	National Energy Security Assessment (Australia)
NTNDP	–	National Transmission Development Plan (Australia)
PPC	–	Pakistan Planning Commission
PMO	–	Prime Minister’s Office (Vietnam)
RET	–	Renewable Energy Target (Australia)
REAM	–	Renewable Energy Association Myanmar
SPP	–	Small Power Producer
SRES	–	Small-scale Renewable Energy Scheme (Australia)

CONTENTS

I. SUMMARY

1. An important aspect of any Energy Master Plan (EMP) is to ensure that the process is supported by an appropriate institutional framework. Establishing such a framework is key to the long-term viability of the EMP as it is necessary to monitor, update and refine the EMP over time.

2. The formation of the National Energy Committee (NEMC) represents a commitment to the concept of integrated energy planning. Integrated Energy Planning (IEP) takes into account plans relating to transport, agriculture, electricity, industry, petroleum, water supply, trade, macroeconomic infrastructure development, housing, air quality management, greenhouse gas mitigation within the energy sector and integrated development plans of local and provincial authorities. The IEP needs to inform and be informed by plans across all sectors (primary, secondary and tertiary) whose plans impact on or are impacted by the EMP.

3. This report discusses the key concepts of IEP including benefits and barriers for establishing a set of institutional arrangements that can support it on an ongoing basis. The report identifies a number of critical factors in the implementation of an EMP process.

4. We review the present governance structure in place for Myanmar's energy sector and draw upon international experience before commenting on:

- Institutional and regulatory impediments to collecting energy information and preparing the long-term outlook, and
- Improvements necessary in the institutional and regulatory framework to support the function of integrated energy planning in the Ministry of Energy (MOE).

5. For completeness, we also present the outcomes of a review of the approaches taken for the implementation of IEP in a number of selected countries with a view to identifying and benefiting from the experience gained and lessons learned.

6. Our recommendations are made for the three facets of the IEP process:

- Organisational structure and allocation of responsibilities.
- Defining of the IEP / EMP process within the recommended organisational structure.
- Human capacity requirements.

7. We discuss the key recommendations of each in turn.

IEP organisational structure and allocation of responsibilities

8. We recommend establishing of a permanent and specialist IEP team within the existing governance structure at NEMC, and allocating the roles and duties of the concerned IEP team, the ministries and NEMC in a way that can support the IEP process.

9. The ministries will be represented by ministry specialist advisors who will feed into the IEP team critical information relevant to the ministries that each present. The ministerial provisions of information could include macroeconomic policy options, sectoral strategic development plans and primary resource assessments.

10. The IEP team would be responsible for the key activities within the IEP process such as compilation of energy statistics, definition of planning criteria and targets, and performance of Integrated Energy Modelling.

11. The IEP team can be structured as a specialised energy planning entity with a director of energy planning, an energy planning division, an energy statistics division, and a ministry advisory team (ministry specialists).

12. NEMC, as a Planning Commission, would be responsible for ratification of projections of estimated future energy needs in support of macroeconomic and socio-economic requirements, and recommend energy policy to support the preferred path.

IEP / EMP process

13. The IEP / EMP is recommended to be carried out on a 5 year cycle. Typical components of any IEP implementation should include data collection; data compilation, analysis and statistical reporting; energy demand forecasting; energy supply forecasting; developing an overall strategy; and monitoring and evaluation.

Human capacity requirements

14. The IEP team are required to have a set of specific skills to undertake the different components in the energy planning task. The team members should have knowledge and practical expertise to autonomously complete undertakings in energy statistics, energy demand forecasting, and energy supply modelling. The energy modellers perform a crucial part of the task and are expected to possess multidiscipline expertise covering engineering, economics and finance.

II. INTEGRATED ENERGY PLANNING

A. Integrated Energy Planning Process

1. An EMP must be based on sound research on the national energy consumption trends, existing and potential energy supplies, energy prices, supply and demand-side technologies, population growth, environmental and social impacts, and political situation of a country. It is critical to understand the importance that IEP enables informed decisions to be made in terms of energy policy; robust research into the present context and assessing numerous scenarios allows for more informed and robust decision-making.

2. The basic features of integrated energy planning are similar to those of the current energy planning and environmental planning practices, including integrated assessment, life-cycle assessment and integrated resource planning. However, IEP is unique because it mainly focuses on issues relating to energy extraction, transportation, transmission, distribution and use. The planning can be multifaceted, including economic, environmental, social or institutional aspects.

3. IEP is the methodology for developing a roadmap to both satisfy the energy needs of a nation as well as to stimulate the development of economic activity. These are defined and outlined by the EMP. IEP must deal with issues relating to the supply, transformation, transport, storage of and demand for energy in a way that accounts for:-

- Security of supply;
- Economically available energy resources;
- Affordability;
- Universal access to energy;
- Social equity;
- Employment;
- Environment;
- International commitments;
- Consumer protection; and
- Contribution of energy supply to socioeconomic development.

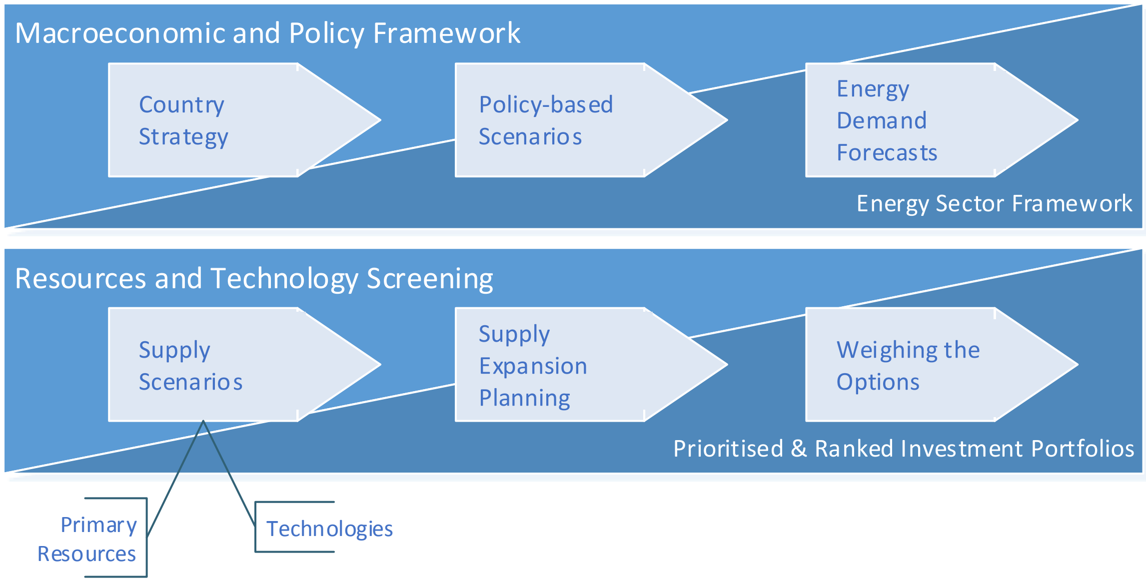
4. The IEP approach differs from strategic supply planning because it includes not only the costs incurred by the individual/organisation, but also societal costs and other externalities, such as environmental impact mitigation necessitated by some resource choices.

5. It involves making an integrated assessment of supply and demand-side options of increasing energy services, whilst attempting to minimise all costs subject to a set of assumptions made over the planning horizon. The end result – the EMP, is a flexible plan that allows for uncertainty and adjustment in response to changing circumstances.

B. Stages and Implementation of IEP

6. An approach to IEP is illustrated in Figure II-1.

Figure II-1: Integrated Energy Planning Process



Source: Consultant

7. The following are the main stages of the IEP process:-

A. Macroeconomic and policy framework – a clear specification of the country's objectives and economic policies;

B. Energy forecasts – developing energy forecasts into the future based on assessments of the energy requirements attributable to different end-users – industrial, commercial, residential sector, agriculture sector and transport sector.

C. Supply side technologies and resources – developing estimates of primary energy resource potentials, and feasible energy supply-side technology options;

D. Supply-side expansion planning and costing – determine the costing of the supply side expansion options and develop a sequence of investments that can best satisfy projected energy requirements, usually a least-cost approach is preferred (subject to various constraints that reflect the physical limits of the energy conversion chain and policy objectives); and

E. Multi-criteria scenario assessment – which involves ranking a set of EMP scenarios based on a set of criteria that are reflective of priorities suitable for the country. This type of approach is appropriate when one attempts to satisfy multiple objectives, as is the case in the EMP.

C. Critical Issues for an IEP Framework to Address

8. The IEP process needs to inform and be informed by plans for specific subsectors. It also

needs to be aligned with the broader strategic and economic direction of the country. With this, comes the potential for there to be some overlaps and/or inconsistencies between an EMP and the plans developed by other government agencies. For example, “master plans” and/or “roadmaps” for the economy, industry, power, gas and oil, electrification, transport, forestry and agriculture, renewable energy, energy efficiency, coal, greenhouse gas mitigation and others, are often developed in isolation.

9. An IEP also needs to be designed as a process that can support continuous refinement and adaption. While EMP scenarios can be devised to span a range of scenarios to overcome uncertainty, invariably, new issues emerge, unforeseen events evolve and lessons are learned. The IEP must therefore be institutionalised and implemented in such a way that it can be updated and evolve over time.

10. Importantly in the fast-changing landscape of energy technology, IEP needs to be technologically neutral, provide equal treatment of demand-side options including end-use efficiency improvements and demand-side management (DSM) and supply side options. This means that deferred or avoided end-use energy consumption needs to be recognised.

11. The IEP must be supported by an organisational structure that is able to accommodate diverse, yet specialised capability that can collectively undertake.

12. Issues that need to be addressed as part of IEP implementation and development of the associated institutional arrangements needs to address:-

A. Defining objectives and scopes for each of formal planning study that avoid overlap.

B. Defining interfaces or formal processes of data exchange between planning studies. For example, submission of data or key policy parameters by one entity for use in the IEP process and/or the use of IEP outputs as an input into other planning processes.

C. Setting in place an appropriate organisational structure that enables the IEP to be informed by the specialist knowledge across all subsectors it seeks to coordinate.

D. Introduce processes to identify and rectify inconsistencies between and/or to seek consistency between certain assumptions.

E. Process that enables some level of refinement.

F. Setting some level of precedence and/or ordering between plans.

G. Incorporating a process to support change and also updating.

H. Staffing the agency responsible for IEP with people who have the capacity and knowledge to undertake the different components of the IEP.

III. REVIEW OF INTERNATIONAL EXPERIENCE IN IEP

13. This section provides a review of the energy planning frameworks implemented in a number of selected countries. We have reviewed these frameworks in order to identify the aspects that have work well and identify any useful organisational structures that could be applied to the Myanmar context.

D. Thailand

Institutional arrangements for energy policy and planning

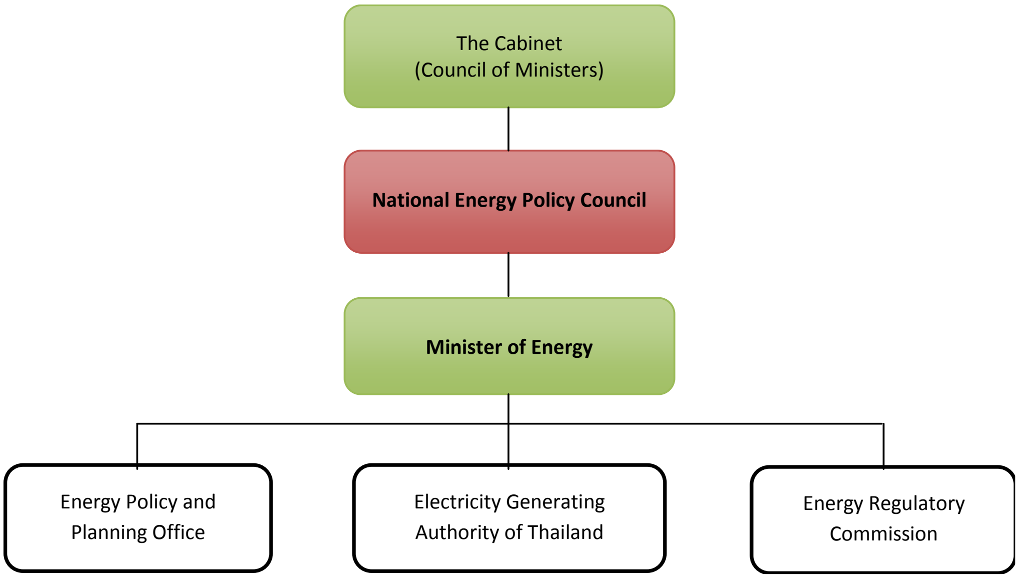
14. The highest authority in terms of energy policy in Thailand is the National Energy Policy Council (NEPC) which sits directly under the Cabinet and the Prime Minister.

15. NEPC has the following powers and duties:

- To submit the National Energy Policy and the National Management and Development Plan to the Council of Ministers Development Plan to the Council of Ministers;
- To lay down rules and conditions for prescribing the price of energy in accordance with the National Energy Policy and the National Energy Management and Development Plan;
- To monitor, supervise, coordinate, support and expedite the operations of all committees with the powers and duties related to energy, government agencies, state enterprises and the private sector related to energy, ensuring their operations are in accordance with the National Energy Policy and the National Management and Development Plan;
- To evaluate the results of the implementation of the National Energy Policy and the National Management and Development Plan; and
- To perform other functions as entrusted by the Prime Minister or the Council of Ministers.

16. Administratively placed under the NEPC, the Ministry of Energy Ministry of energy is responsible for implementing the mission in providing, developing, and managing energy suitably and effectively for sustainable economic and social development. The MOE entrusts the planning and regulating functions to subordinate agencies including the Energy Policy and Planning Office (EPPO), the Electricity Generating Authority of Thailand (EGAT) and the Energy Regulatory Commission. Figure III-1 below depicts an institutional hierarchy in relation to policy and planning decision making in Thailand's energy sector.

Figure III-1: Thailand Energy Policy and Planning Institutional Hierarchy



Source: Consultant

Energy Policy and Planning Office (EPPO)

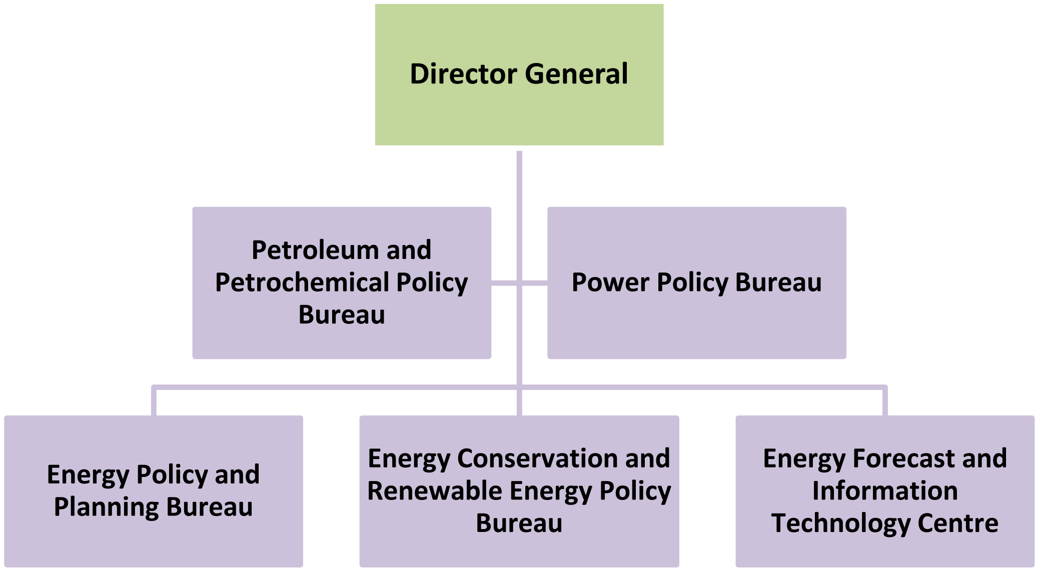
17. EPPO is a pivotal agency in the formulation and administration of energy policies and planning for the national sustainability. This agency has a mission to study, to analyse the policies and energy management and development plans of the country, to coordinate, monitor and evaluate the implementation and outcomes pursuant to energy policies and energy plans. EPPO has the following responsibilities:

- Recommend energy policies and integrate/review energy management plans of the country;
- Recommend national strategies for energy conservation and alternative energy promotion;
- Recommend measures to solve and prevent oil shortage in both short and long terms;
- Supervise, monitor and evaluate the effectiveness of national energy policy and energy management plans;
- Administer the information and communication technology with regard to energy issues of the country; and
- Enhance EPPO to become a strategic organisation.

18. One of EPPO key functions is to formulate energy policies and administer energy planning of the country.

19. EPPO has five key divisions: (1) Petroleum and Petrochemical Policy Bureau, (2) Power Policy Bureau, (3) Energy Policy and Planning Bureau, (4) Energy Conservation and (5) Renewable Energy Policy Bureau and Energy Forecast and Information Technology Centre (Figure III-2).

Figure III-2: EPPO Organisational Structure



Source: Consultant

EGAT

20. EGAT's main responsibilities are:-

- Power production. EGAT is a government-owned power producer owning and operating power plants with a total installed capacity over 15,000 MW, or about 46% of the entire generation system;
- Owner and operator of Thailand's high voltage transmission network.
- Undertake the role of single buyer in Thailand's "Single Buyer" electricity supply model. Specific responsibilities are: (1) purchasing bulk electricity from private power producers and neighbouring countries, and (2) selling wholesale electric energy to two distributing authorities and a small number of direct industrial customers as well as neighbouring utilities.

Energy Regulatory Commission

21. The responsibilities of the Energy Regulatory Commission are:

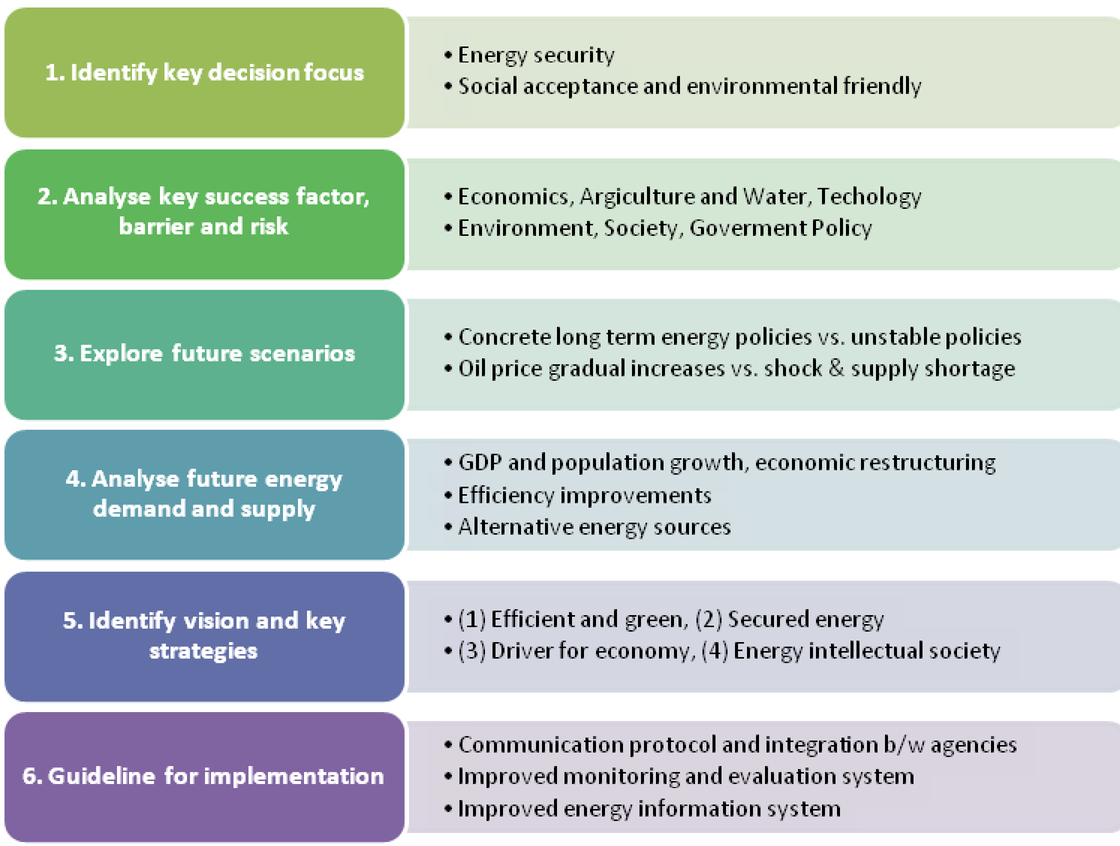
- Regulate electricity tariffs;
- Administer licencing schemes for energy activities (electricity and gas licences);
- Approval of power purchase agreements; and
- Providing a platform to management disputes.

The Energy Master Planning Process

22. EPPO has been administering the development of the first national energy master plan for the

period 2015-2035. The energy master plan is intended to integrate a number of other plans, including: Power Development Plan, the forecasts of the country's oil and gas consumption, the Energy Efficiency Development Plan and the Alternative (Renewable) Energy Development Plan. The energy master planning process in Thailand involves the six steps that are shown in Figure III-3.

Figure III-3: Thailand Energy Master Planning Process



Source: EPPO

Thailand Power Development Plan

23. The national Power Development Plan is developed by EGAT within the framework of the Ministry of Energy's policies. EGAT, which also manages and operates the state-owned generation and transmission assets, formulated the last such plan for the period of 2010-2030, known as PDP 2010. Compared to the previous PDP 2007, PDP 2010 had a greater focus on renewable energy integration.

24. The plan was first approved by the NEPC and the Cabinet in November, 2010. Following the Fukushima incident in Japan, the plan has been twice revised, as Thailand's approach to harnessing nuclear energy had to be revisited. The third and current (as of March 2013) revision was approved by the Cabinet in June, 2012. The plans have been used to guide planning and construction of EGAT's new power plants, power purchases from independent power producers (IPPs), small power

producers (SPPs) and neighbouring countries, as well as transmission system development to accommodate these new power capacities.

25. The main strategies that the PDP 2010 focused on were:-

- Security and adequacy of the power system, following the policies of the Ministry of Energy on environmental concerns;
- Promotion of energy efficiency and renewable energy to be in line with the Energy Efficiency Development Plan ("EEDP 2011-2030") and the Alternative Energy Development Plan ("AEDP 2012-2021"); and
- Promotion of cogeneration systems for efficient electricity generation.

E. Pakistan

Ministries Governing the Energy Sector

26. In Pakistan, two ministries oversee different parts of the country's energy industry. The Ministry of Water and Power is responsible for policies in electricity sector including alternative and renewable energy. The Ministry of Petroleum and Natural Resources is in charge of the oil, gas and coal sectors.

Planning Commission

27. The Pakistan Planning Commission (PPC) is a government agency attached to the Ministry of Planning, Development and Reform. The Prime Minister is the Chairman of Planning Commission which apart from the minister as Deputy Chairman, comprises of nine Members including Secretary, Planning & Development Division / Member Coordination, Chief Economist, Director, Pakistan Institute of Development Economics, Executive Director, Implementation and Monitoring, and Members for Social Sectors, Science and Technology, Energy, Infrastructure, and Food and Agriculture.

28. The strategies of PPC are:-

- Preparing the National Plan and review and evaluating its implementation;
- Formulating annual development plans;
- Monitoring and evaluating implementation of major development projects and programs;
- Stimulating preparation of sound projects in regions and sectors lacking adequate portfolio;
- Continuously evaluating the economic situation and coordinate economic policies; and
- Organising research and analytical studies for economic decision making.

Energy Expert Groups for Integrated Energy Plan

29. The Economic Advisory Council was set up by the Government of Pakistan under the umbrella of the Ministry for Finance, and mandated an Energy Expert Group (EEG) to prepare an Integrated Energy Plan which would provide a short, medium and long term strategy. The EEG is chaired by a member of the Economic Advisory Council and has representatives who hold senior management positions at energy companies.

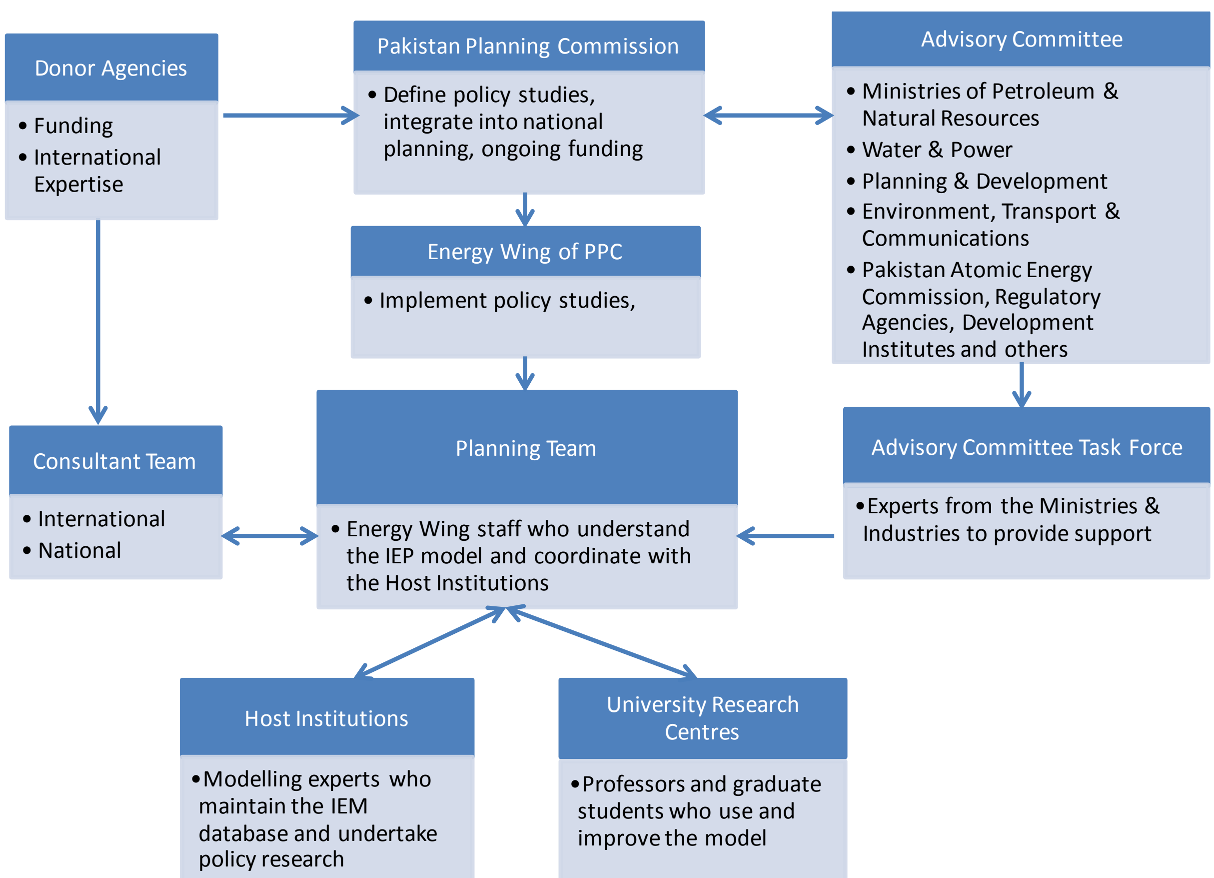
30. In March 2009 the EEG developed the first integrated energy plan for the period 2009-2022.

The purpose of the integrated energy plan is to provide a roadmap for Pakistan to achieve greater energy self-sufficiency by pursuing policies that are sustainable, provide for energy security and conservation, and are environmentally friendly. The practical goal is to meet the demand for energy needs of all sectors in a sustainable manner at competitive prices with a greater reliance on indigenous resources. A focus group was set up under the EEG to undertake the task of collating, digesting, integrating and articulating the work of the various sectoral study groups which included:-

- Exploration and production;
- Natural gas and LNG;
- Oil (including refining, OMC, liquefied petroleum gas, and ethanol);
- Power (hydro, thermal, transmission and distribution);
- Coal;
- Alternative and renewable (wind, solar, mini-hydro, biomass, biodiesel); and
- Nuclear.

31. The energy planning structure in Pakistan is illustrated in Figure III-4

Figure III-4: Energy Planning Functions in Pakistan



Source: Consultant

Recommendation on the Creation of National Energy Authority

32. As part of the integrated energy plan, the EEG recommended the creation of a National Energy Authority for streamlining decision making and planning processes in Pakistan's Energy sector. This recommendation was primarily based on the view of the Asian Development Bank (ADB) that there appeared to be confusion about the proper decision making authorities in terms of additional generation capacity (one example). The two main ministries related to energy, Water and Power, and Petroleum and Natural Resources do not necessarily have a collective and integrated country, regional or world view. For an integrated approach on energy, a single Ministry/Authority would be needed to address this issue.

33. To date, the recommendation to create a National Energy Authority has not been implemented.

The Integrated Energy Model

34. In 2011, the Asian Development Bank (ADB) provided a technical assistance (TA) to Pakistan's Planning Commission to assist the Government of Pakistan in developing an integrated energy system planning model for the entire sector. This so called Integrated Energy Model (IEM) would encompass resource supplies, refineries and power plants, transmission and distributions systems for fuels and electricity and the end-use devices. The IEM objective is to assess the impacts of various options and strategies for meeting the country's future energy needs in an optimal manner.

35. The IEM followed the same planning structure as depicted in Figure III-4. The international consultant selected for this TA was International Resources Group. Domestic agencies who took part in the planning team for the IEM development included:

- The Planning Commission;
- Global Change Impact Studies Centre;
- Hydrocarbon Development Institute of Pakistan;
- National Transport Research Centre;
- Pakistan Atomic Energy Commission;
- Pakistan Electric and Power Company;
- Pakistan Institute of Engineering and Applied Sciences;
- Pakistan Institute of Development Economics;
- University of Engineering and Technology, Lahore; and
- University of Engineering and Technology, Taxila.

36. The IEM employed the MARKAL/TIMES modelling framework. In particular, it utilised the TIME model generator, which is the successor to the MARKAL framework, and the VErsatile Data Analyst (VEDA).

37. The Pakistan IEM reference Scenario produced the following results for the year 2030:

- 82,000 MW of new power generation capacity to be added;
- Four-times increase in electricity generation from 94,000 GWh to 410,000 GWh; and
- Three-times increase in consumption of high value petroleum products from 6.2 Mtoe to 18 Mtoe.

38. As part in the IEM, recommendations were made for establishing an institutional structure for a sustainable implementation of IEM MARKAL/TIMES modelling capacity in future. The

recommendations included:

- Create of a dedicated Planning Unit overseen by the Planning Commission to manage and coordinate modelling activities in Pakistan;
- Recruit highly capable individuals to the Planning Unit who have an engineering or economics background;
- Set up the model at several different institutions where it is likely to be used (e.g. agencies participating in the IEM planning team);
- Produce annual or biannual energy outlook report;
- Establish at network of data providers from different sectors that can provide information for model updates; and
- Maintain the Advisory Committee Task Force.

F. Vietnam

Sector Policy and Planning Process

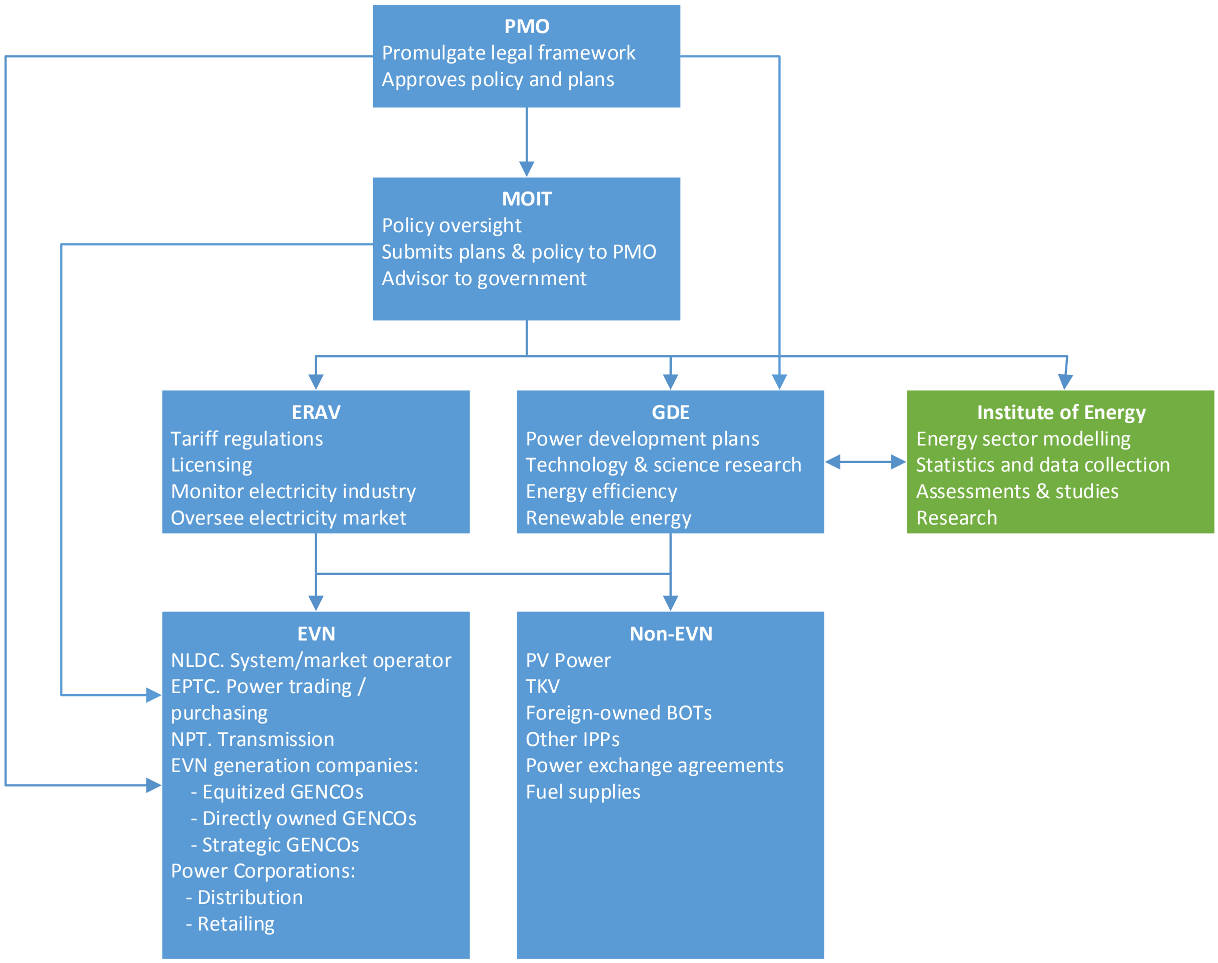
39. The Ministry of Industry and Trade (MOIT) is the government body for energy policy and planning. MOIT is responsible for overseeing all aspects of Vietnam's energy sector including electricity, new and renewable energy, coal, and the oil and gas industry. Specifically, MOIT is responsible for formulating and submitting to the Government draft laws, decrees and policies; preparing and submitting to the Government, or the Prime Minister for approval, overall development strategies and master plans; promulgating circulars, decisions, directives and other documents on state management and regulation for the listed sectors and fields. Under the current organisational structure, the MOIT’s functions of energy policy making and planning are effectively carried out by the General Directorate of Energy (GDE).

40. GDE was established in September 2011 to carry out the function of advising and assisting the MOIT to execute the tasks of state management over the energy sector. GDE is responsible for drafting laws and degrees, preparing and evaluating development strategies and national master plans. In particular, GDE oversees the execution of approved electricity development master plans, and is heavily involved in negotiations with Build Operate Transfer (BOT), and IPP investors for approval of new power generation projects. GDE is responsible for national energy planning and energy policy, but they are not involved in the day-to-day management of Vietnam’s energy industry. There have been discussions that a separate ministry for energy could be created from GDE in the coming years.

41. In relation to energy planning, GDE/MOIT prepares separate national development plans (also called master plans) for the power, coal and petroleum sectors. The current power master plan (number 7) was developed in 2011 for the period 2011–2020. The coal master plan was developed in early 2012 for same period, and the petroleum plan was approved in 2011 for a period until 2015. The plans are updated as required, for example, power master plan 7 was updated in 2013.

42. Figure III-5 illustrates the governance structure of Vietnam’s electricity industry showing in particular the responsibilities between GDE, MOIT and the Prime Minister Office (PMO) in the planning process. The planning for coal and petroleum industries shall follow the same procedure, i.e. the plan being prepared by GDE and proposed by MOIT to PMO for approval. The Institute of Energy is a specialist group that supports the GDE, and in particular provides statistical and modelling services in support of developing Vietnam’s Power Master Plan (PMP).

Figure III-5: Governance Structure of Vietnam's Energy Industry



Source: Consultant based on ERAV and EVN

Vietnam Power Master Plan (PMP)

43. The PMP is developed every 10 years for the following 10 year period with outlook to further 10 subsequent years. The PMP is also subject to a midterm revision which occurs 5 years after the start of each PMP.

44. The PMP shall include the following main contents:

- Current status of the power sector and the implementation of the previous PMP;
- National socio-economic background;
- Electricity demand forecast;
- Primary energy availability for power generation;
- Renewable energy generation;
- Planned generation projects;

- Planned transmission projects;
- Regional interconnections;
- Rural electrification;
- Financing options for the planned power projects;
- Environmental impact;
- Land use impact;
- Economic assessment of the PMP (including the evaluation LRMC and electricity tariffs);
- Implementation plan.

45. GDE shall prepare the general proposal, select and engage a capable consultant to prepare the PMP, and carry out the appraisal of the plan prepared by the consultant.

46. The Vietnam Institute of Energy is a dedicated entity (under MOIT) that has continually been involved in the preparation of Vietnam's PMPs. They have established energy planning expertise, adequate planning tools and a network of updated industry data and information required for the PMP modelling.

47. The current PMP (number 7) for the 2011-2020 period with the vision to 2030, which was approved on 21 July 2011, has strong emphasis on energy security, energy efficiency, renewable energy and power market development. It sets out six key directions and four specific targets for the Vietnam's power sector.

48. The six directions of the current PMP:-

A. Integrate the development of the power sector into socio-economic development and ensure sufficient supply of electricity for the national economic and social activities.

B. Supplement the efficient use of domestic energy resources with reasonable levels of imported electricity and fuels, diversify the primary energy resources for power generation and promote fuel conservation to ensure energy security in the future.

C. Gradually improve the quality of electricity supply and electricity services, adjust the electricity tariffs in accordance with market-based mechanisms to encourage investment and the efficient use of electricity.

D. Develop the power sector in parallel with safeguards of natural resources, ecosystems and the environment.

E. Create a competitive power market by diversifying forms of electricity investment and trading. The State shall maintain monopoly only over the power transmission network for the security of the national energy system.

F. Develop the power sector based on reasonable and efficient use of primary energy resources in each region and continue rural electrification to ensure sufficient supply of electricity to the entire country.

49. Specific targets of the current PMP:

A. Increase the aggregate electricity production (including import) from 200 billion kWh by 2015 to 350 billion kWh by 2020 and 700 billion kWh by 2030.

B. Increase the proportion of renewable energy in the total electricity production from the present 3.5% to 4.5% in 2020 and 6% in 2030.

C. Reduce the average energy intensity elasticity (the ratio between the growth rate of energy consumption and the growth rate of GDP in the same period) from the current 2.0 to 1.5 in 2015 and 1.0 in 2020.

D. Promote rural electrification programs in remote areas and islands so that most of the rural households will have access to electricity by 2020.

Coal Sector Development Plan

50. The current Vietnam Coal Sector Development Plan was approved in January 2012 and is the first of its kind in the country. It contains development visions and objectives, and specific plans for the coal sector for a period until 2010 with outlook to 2030.

51. The main content of the current coal development plan is:-

- Development visions for the sector;
- Development objectives for exploration and production;
- Coal demand forecast;
- Total coal reserves and prioritising;
- Exploration plan;
- Production and processing plan;
- Coal transportation plan;
- Coal export and import plan;
- Facility planning for coal export and import;
- Financial requirements;
- Policy recommendations; and
- Implementation plan.

52. The Coal Sector Development Plan provides a development vision as follows:-

A. Develop the sector with rational production and use of coal, and with the priority to meet the domestic demand and contribute to supporting national energy security. Gradually reduce coal export and limit it only to the types of coal that are not used by local consumers.

B. Promote exploration and assessing activities to ensure there are reliable and adequate coal resources for the sector sustainable, long-term growth and for meeting the future demands.

C. Diversify the financing sources with the state-owned enterprises retaining dominating roles, and implement market-based mechanisms for coal trading.

D. Develop the coal sector in parallel with safeguards of natural resources, ecosystems and the environment.

53. It also sets out the following targets for the sector:-

A. Specific exploration timelines for each coal basin; and

B. Production targets set at 58 million tons by 2015, 65 million tons by 2020, 70 million tons by 2025 and 75 million tons by 2030.

Petroleum Sector Development Plan

54. The current Vietnam Petroleum Sector Development Plan was approved in March 2011 and is the first of its kind in the country. It contains development visions, objectives and directions for the petroleum sector for a period until 2015 with outlook to 2025.

55. The main contents of the current petroleum development plan include:-

- Development visions for the sector;
- Development objectives for exploration and production;
- Development directions for exploration and production;
- Development directions for the gas pipe network;
- Development directions for LPG terminals;
- Trading and pricing mechanisms;
- Financial requirements;
- Policy recommendations; and
- Implementation plan.

56. The development vision arising from the Petroleum Sector Development Plan is:-

A. The state maintains the leading role in investing into the petroleum sector infrastructure;

B. Develop the sector with rational exploitation and use of natural resources, increasing import to ensure sustainable energy supply in future;

C. Promote investments into natural gas processing and refining activities, reduce LPG share in the total petroleum import;

D. Effectively utilise the existing infrastructure such as pipelines, terminals and processing facilities;

E. Develop the gas consumption market with state regulation; gradually integrate into regional and international markets.

57. Development objectives:

A. Natural gas production to achieve 14 billion cubic meters in 2015 and 19 billion cubic meters in 2015; and

B. LPG production to achieve 2 million tons in 2015 and 4 million tons in 2015.

Integrated Energy Planning

58. The development strategy for the energy sector to the year 2020 with a vision to 2050 was approved by the Prime Minister in 2007. The strategy outlined broad development objectives of the energy subsectors including electricity, coal and petroleum. It also set out the MOIT responsibility for preparing the energy sector development plan and development plans for the individual subsectors.

59. Nevertheless, in Vietnam, developing a single IEP process has not been done. Coordination between plans is largely achieved by simply setting a broad set of development objectives for each subsector. For the electricity, coal and petroleum sectors, these objectives largely shape the formal planning that is carried out.

G. Australia

Energy Sector Management

60. The energy sector in Australia is under the management of the Australian Federal Government and the state governments. The federal government is responsible for making national policies and regulations while the jurisdictions manage their state-bound energy resources and infrastructure.

61. The federal overseeing body for energy is the Department of Industry (formerly, the Department of Resources, Energy and Tourism). Another essential agency is the Standing Council on Energy and Resources (SCER) which is attached to the Council of Australian Governments (COAG). SCER coordinates the national energy policy among the states and is responsible for pursuing priority issues of national significance in the energy and resources sectors and progressing the key reform elements. SCER specific duties include:

- Progress consistent upstream petroleum administration and regulation standards;
- Address issues affecting investment in resources exploration and development;
- Develop a nationally consistent approach to clean energy technology;
- Promote efficiency and investment in generation and networks;
- Build on Australia's resilience to energy supply shocks.

Energy Sector Planning Overview

62. Since Australia has liberalised its energy markets, the planning practice was made to a minimum. There is no such a centralised planning process for development of energy industries as could have been witnessed in other developing countries. Instead, most investment decisions have been taken by businesses purely based on market circumstances. Nevertheless, the government does carry out the overall Australia's Energy Resource Assessment and National Energy Security Assessment, as well as different initiatives and plans for targeted areas such as National Strategy on Energy Efficiency, Energy Savings Initiative (ESI) and Renewable Energy Target (RET).

63. Recent developments may suggest there is a trend back to a more consolidated and centralised approach of managing the energy policy and planning issues. In particular, since 2013 the National Transmission Network Development Plan has been commenced for the electricity market. A mandatory petroleum data reporting regime is now being drafted for the petroleum sector, and the government is also in the process of preparing the first Energy White Paper dubbed as an integrated approach to Australia's energy policy.

Australia's Energy Resource Assessment

64. On 1 March 2010, the former Minister for Resources and Energy released the first edition of the Australian Energy Resource Assessment. The assessment, undertaken by Geoscience Australia (GA) and the Australian Bureau for Agriculture and Resource Economics (ABARE) provides a national prospectus of Australia's energy resources. For the first time it brings together a comprehensive understanding of the country rich energy resource endowment, integrating geoscience and long term economic energy outlooks with common terms and definitions.

65. The assessment examines identified and potential capacities from both non-renewable (coal, uranium and increasingly gas) and renewable energy resources (wind, geothermal, solar and

bioenergy). It also considers the factors likely to influence Australia's energy future in a low-carbon economy to 2030. The next edition of the assessment is expected to be released soon.

National Energy Security Assessment

66. In 2011 the former department of Resources, Energy and Tourism released the National Energy Security Assessment (NESA) which considers the key influences on the supply of energy in Australia in the short, medium and long terms covering the period 2011–2035. The NESA identifies key strategic energy security issues in the liquid fuels, natural gas and electricity sectors currently, and those likely to impact the level of energy security. The assessment collates and analyses available information and provides an assessment of energy security. The assessment considers how the identified strategic issues could affect adequacy, reliability and affordability in each of the energy sectors.

67. In 2012, the department commissioned two additional reports to further examine issues identified in the 2011 NESA.

National Strategy on Energy Efficiency

68. In July 2009, the COAG approved the comprehensive, 10-year National Strategy on Energy Efficiency (NSEE), to accelerate energy efficiency improvements and deliver cost-effective energy efficiency gains across all sectors of the Australian economy. The NSEE aims to streamline roles and responsibilities across government by providing a nationally consistent and coordinated approach to energy efficiency.

69. The NSEE was updated in July 2010.

Energy Savings Initiative

70. The Energy Savings Initiative Working Group released their information paper in July 2013. The Australian Government committed to do further work to investigate the merits of a national ESI. ESI is a market-based approach for driving economy-wide improvements in energy efficiency. It would place a requirement on obligated parties (typically energy retailers) to find and implement energy savings in households and businesses. An ESI would help energy consumers to save money by encouraging the identification and take-up of energy efficient technologies.

Renewable Energy Target

71. The Renewable Energy Target (RET) scheme is designed to ensure that 20 per cent of Australia's electricity comes from renewable sources by 2020. The RET scheme is helping to transform our electricity generation mix to cleaner and more diverse sources and supporting growth and employment in the renewable energy sector.

72. Since January 2011 the RET scheme has operated in two parts: the Small-scale Renewable Energy Scheme (SRES) and the Large-scale Renewable Energy Target (LRET).

73. Large-scale Renewable Energy Target:

- The LRET creates a financial incentive for the establishment or expansion of renewable energy power stations, such as wind and solar farms or hydro-electric power stations. It does this by legislating demand for Large-scale Generation Certificates (LGCs). One LGC can be created for each megawatt-hour of eligible renewable electricity produced by an accredited renewable power station. LGCs can be sold to entities (mainly electricity retailers) who surrender them annually to the Clean Energy Regulator to demonstrate their compliance with the RET scheme's annual targets. The revenue earned by the power station for the sale of LGCs is additional to that received for the sale of the electricity generated.

- The LRET includes legislated annual targets which will require significant investment in new renewable energy generation capacity in coming years. The large-scale targets ramp up until 2020 when the target will be 41,000 GWh of renewable electricity generation.

74. Small-scale Renewable Energy Scheme:

- The SRES creates a financial incentive for households, small businesses and community groups to install eligible small-scale renewable energy systems such as solar water heaters, heat pumps, solar photovoltaic (PV) systems, small-scale wind systems, or small-scale hydro systems. It does this by legislating demand for Small-scale Technology Certificates (STCs). STCs are created for these systems at the time of installation, according to the amount of electricity they are expected to produce or displace in the future. For example, the SRES allows eligible solar PV systems to create, at the time of installation, STCs equivalent to 15 years of expected system output.
- The RET scheme is currently under the review as to whether the objective to deliver 41,000 GWhand small solar generation by 2020 is still appropriate.

National Transmission Network Development Plan

75. The purpose of the National Transmission Network Development Plan (NTNDP) is to facilitate the development of an efficient national electricity network that considers potential transmission and generation investments. The NTNDP provides an independent, strategic view of the efficient development of the National Electricity Market (NEM) transmission network over a 25-year planning horizon. It is focused on large-scale electricity generation and the main transmission networks that connect this generation to population and industrial centres.

76. The first NTNDP was prepared by the Australian Energy Market Operator (AEMO) using information available at 1 November 2013; however the impact of changes after this date has been assessed where practical. The plan contains a consolidated list of projects for the Transmission Network Service Providers (TNSP) in Australia.

Mandatory petroleum data reporting regime

77. On 25 January 2013, the then Minister for Resources and Energy announced the Australian Government's decision to develop and implement a mandatory petroleum data reporting regime. Mandatory reporting will improve the quality and coverage of data on the production, sale, stock holding and trade of petroleum across the Australian supply chain.

78. On 20 May 2013, a discussion paper was released to facilitate the first stage of consultation with stakeholders on the design and implementation of the regime. The main objectives of the discussion paper are to:

- identify the data and data reporters required to develop a precise and comprehensive petroleum dataset for Australia;

- determine whether existing regulatory activities and/or the business data systems developed for them could separately or collectively be used as part of the mandatory petroleum data reporting regime; and
- facilitate future government data requirements in a manner which minimises the regulatory burden on reporting entities.

79. Further stakeholder consultation is being undertaken to facilitate the development of the mandatory petroleum data reporting regime.

Australia's Energy White Paper

80. Referred to as an integrated approach to energy policy, the Australia's Energy White Paper will set out a coherent and integrated approach to energy policy to reduce cost pressure on households and businesses, improve Australia's international competitiveness and grow the export base and economic prosperity. It will consider Australia's supply and use of energy resources, including how increases in new energy sources can meet demand. The Energy White Paper will also look at regulatory reform to put downward pressure on prices and improve energy efficiency.

81. The Department of Industry is leading the development of the Energy White Paper with advice from an Expert Reference Panel. There are three stages in the development of the White Paper:

- The Issues Paper, which provides an overview of the identified issues of interest to the Government.
- The Green Paper, which will draw on submissions to the Issues Paper and assess the issues and policy approaches.
- The White Paper, which will draw on submissions to the Green Paper and present the Government's strategic direction and policy commitments.

82. The first Australia's Energy White Paper is expected to be released in December 2014.

H. Lessons from Review of International Practices for Myanmar IEP

83. It is important to have a streamlined set-up of the governmental authorities/agencies who are involved in policy making and planning for the energy sector. The planning functions of each authority should be clearly spelt to avoid being overlapped, and it is desirable that there is a single minister with sufficient mandate and resources to oversee the entire planning matter. Such an arrangement is helpful for achieving better coordination of efforts and more efficient management and utilisation of energy data.

84. Key to successful planning is to set out detailed procedure, timing, scope and contents of the planning activities. It will reduce the time spent and help to coherently address the planning objectives. While energy planning horizons are normally medium to long terms, there should be a timeframe for updates and revisions to accommodate changes in the underlining circumstances during the planned term.

85. It is beneficial to have a dedicated institution for energy plan preparation. Energy planning requires specific, multidiscipline expertise and a continuously updated bank of data about the industry and the wider economy. A specialised energy planner would be the best venue to consolidate needed expertise and manage an updated planning database. The examples of dedicated energy planners are the Institute of Energy for preparing PMPs in Vietnam and an recommended Planning Unit for implementing IEM in Pakistan.

86. More integrated approaches have been used, whether this is for planning an individual sector or the entire energy industry. The power sector development plans, for example, have become more comprehensive in countries by incorporating considerations of renewable and alternative energy sources, accounting for primary energy sectors such as oil, gas and coal, and considering linkages with other parts including land use and water supply.

87. Having a holistic development plan for the entire energy industry is on agenda for all countries under the above review. Although there have been different levels of planning details and actual realisation, the countries will likely look at implementing full integrated energy sector planning in future. The advantage of producing one energy plan in a single is to achieve more efficient allocation of natural resources, avoid counterproductive nexus effects and make the industry growth more sustainable and resilient with better environmental considerations.

88. It is noted that in cases with developed energy markets, with Australia being an example, despite many investment decisions in the industry being shifted from a planning-driven process to a market-driven approach, centralised planning processes are still maintained for strategic and/or regulated areas such as the power transmission networks and “backbone” infrastructure. The Government also periodically conducts assessments of national energy resources and the implications for energy security. In addition, the introduction of the Energy White Paper in Australia suggests a recent trend towards having a higher level of consolidation of energy planning activities. Thus, market liberalisation, as has occurred in the energy space does not necessarily mean the role of coordinated energy planning becomes diminished; in fact, this remains a key tool for coordination of planning both regulated or government elements of the energy industry with those areas that are driven more by market-based investment decisions. This is critical for assessing and providing some assurance for national energy security.

IV. CURRENT ENERGY PLANNING ARRANGMENETS IN MYANMAR

I. Energy Sector Governance in Myanmar: Current Situation

89. Regarded as an enabler for economic activity in the country, Myanmar's energy sector has received significant attention in recent years. In January 2013, the government established NEMC with a view of being a multi-ministerial coordinating body to comprehensively address all energy demand and supply related issues.

90. NEMC has its Patron being the Vice President of Myanmar and its Chairman being the Union Minister for Energy. NEMC primary function is to provide administrative functions for all energy policy and planning matters. In addition, the government also constituted Energy Development Committee (EDC) to support the activities of NEMC.

The present governance structure of Myanmar's energy sector is set out in

91. Figure IV-1. This illustrates the relationship between NEMC, EDC and other entities that influence Myanmar's energy industry.

92. The following are the entities referenced in the diagram:

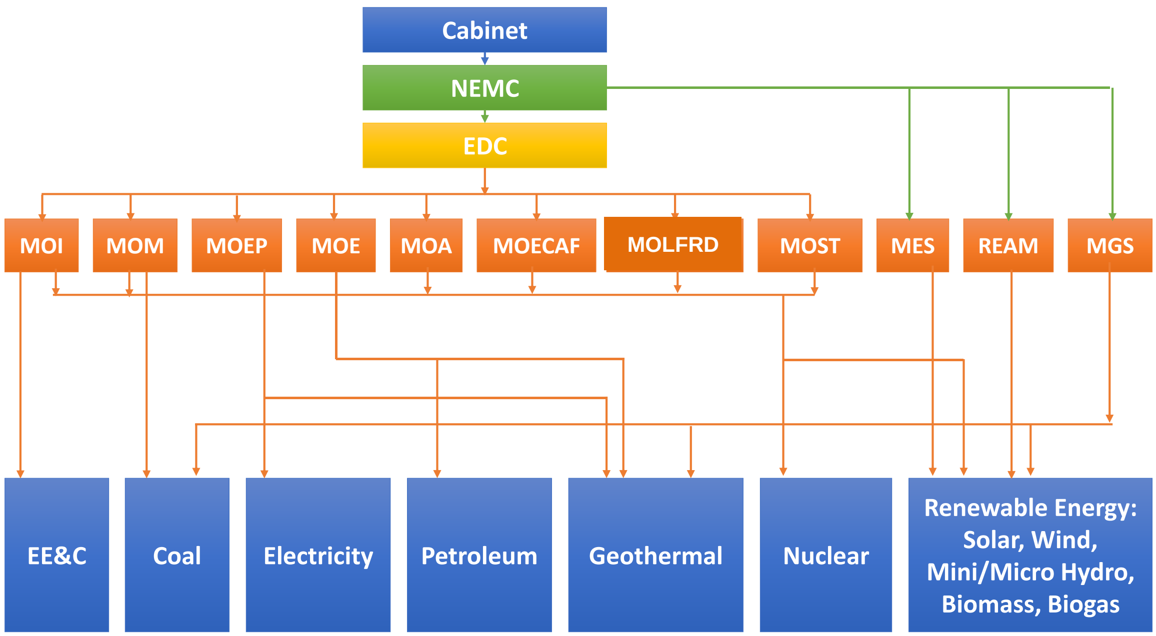
- NEMC National Energy Management Committee;
- EDC Energy Development Committee;
- MOI Ministry of Industry – energy efficiency and conservation (EE&C), nuclear power, renewable energy (RE);
- MOM Ministry of Mines – coal;
- MOEP Ministry of Electric Power – electricity sector and geothermal sector ;
- MOA Ministry of Agriculture – mini-hydro;
- MOE Ministry of Energy – oil and gas, petroleum industry, and geothermal;
- MOECAF Ministry of Environment, Conservation and Forestry – fuel wood and biomass;
- MOLFRD: Ministry of Livestock, Fisheries and Rural Development;
- MOST: Ministry of Science and Technology – nuclear, renewable energy, nuclear power, biomass, wind and solar;
- MES: Myanmar Engineering Society – renewable energy;
- REAM: Renewable Energy Association Myanmar – renewable energy; and
- MGS: Myanmar Geoscience Society – renewable energy, geothermal and coal.

93. Other critical entities in Myanmar's energy sector, not illustrated in the diagram include:

- MOGE: Myanmar Oil and Gas Enterprise, who is concerned with the commercial management of Myanmar's oil and gas resources;

- MPPE: Myanmar Petroleum Products Enterprise, concerned with the commercial management of Myanmar's petroleum sector; and
- MPE: Myanmar Petrochemical Enterprise, who is concerned with the commercial management of Myanmar's petrochemical industry.

Figure IV-1: Governance of Myanmar's Energy Sector[1]



Source: Consultant

J. Duties and Functions of NEMC

94. The duties and functions of NEMC are formally defined in Myanmar's National Energy Policy. In summary the 22 duties and functions fall into the following broad categories[2]:

A. Policy:

i. Formulate National Energy Policy based on energy demand and supply.

ii. Coordinate with the Privatization Commission and Myanmar Investment Commission to adjust the ratio between state-owned and private-owned sectors through privatization.

B. Regulatory:

i. Formulate energy regulations for implementation of energy development of the state.

[1] "The Republic of the Union of Myanmar- National Energy Management Committee: National Energy Policy" (Draft, 2013) ("Draft NEP, 2013")
[2] "The Republic of the Union of Myanmar- National Energy Management Committee: National Energy Policy" (Draft, 2013) ("Draft NEP, 2013")

C. Energy Statistics:

i. Supervise the facts and figures on energy for ensuring qualified and accurate statistics.

D. Energy Planning:

i. For development of electrical sector, to fulfil the current requirements by laying down short-term plans.

ii. Lay down long-term plans based on sustainable development of industrial sector of the State and GDP to be able to meet increased demand for electricity.

iii. To generate electricity with the use of coal as in many other countries as there has been greater demand for electricity and to use Clean Coal Technology (CCT) aimed at placing emphasis on environmental conservation

iv. Strive for generating electricity based on regional and topographical conditions with the use of solar power, hydro power, wind power, geothermal, biomass and bio-fuel to be able to meet the public demand for electricity.

v. Formulate necessary measures for adequate supply of energy for development of industrial sector.

vi. Take systematic measures in laying down development plans to be able to cover three sectors as energy, industrial and electrical sectors are mutually dependent.

vii. Prioritize and supervise oil and gas, and other natural resources to be able to meet domestic demands.

viii. Carry out oil & gas production through local and foreign investments in accordance with international regulations.

ix. Sell out value-added petrochemical products rather than raw materials.

x. Coordinate natural gas and electricity generation in order to meet urea fertilizer demand of the agriculture sector by planning production target.

E. Energy Security:

i. Enforce an energy sufficiency ambition in industry, transport and household sectors and minimise energy wastage.

ii. To adopt a National Energy Security Strategy that envisages the future generations, apart from the current energy issues.

F. Technology Research:

i. Conduct necessary assessment to participate in civil nuclear energy activities in ASEAN.

G. Environment:

i. Conduct environmental impact and social impact assessments of the region ahead of implementation and raise community awareness for the people who live in affected project areas.

H. Finance & Economics:

i. Adopt convenient pricing policy for both consumers and investors depending on international prices.

ii. Invite foreign and local investments for the energy sector development and increase FDI in accordance with international norms.

I. Administration

i. To make arrangement for drafting necessary law, rules and regulations to be able to implement in accordance with the National Energy Policy and National Energy Security Strategy

ii. Engage with members of the President Office, Natural Resources and Environmental Conservation Committee and the Mineral and Natural Resources Affairs Committee.

K. Comments on the present state

95. The duties and functions NEMC as formally defined can be placed within the context of an IEP process. The present governance structure and supporting National Energy Policy provides a foundation for an EMP process, however a number of enhancements are required in order for it to become a well-functioning process.

96. However, the roles and responsibilities at the working level need to be strengthened in order to enable NEMC to achieve its overarching objectives. NEMC could be considered to be analogous to a planning commission, while the NEMC working level staff could be responsible for essentially undertaking energy planning.

97. As illustrated in Figure IV-1 responsibilities are spread over many different ministries for different components of Myanmar's energy sector. This is a considerable impediment to developing a holistic and coherent IEP / EMP process as to information transfers and synchronisation of the inputs/outputs between the EMP and many other ministerial planning works.

98. A number of other planning processes have been established in Myanmar by the different ministries for particular subsectors of the energy industry. Among others, there is a Power Master Plan (PMP), a Forestry Master Plan (FMP), a Transport Plan, and short and long term plans for the oil and gas sector. Thus the relationship between an IEP process and these other plans needs to be carefully developed and considered as part of enhancing Myanmar's institutional arrangements for an IEP process.

V. INSTITUTIONAL ARRANGEMENTS TO SUPPORT IEP IN MYANMAR

99. The previous sections have set out the issues that an IEP process needs to address, reviewed the arrangements in several comparator countries, and reviewed and critiqued the arrangements presently in place in Myanmar. We can leverage these insights to make some recommendations to enhance Myanmar's current arrangements to better support an IEP / EMP process.

100. In particular, we have organised a number of options and recommendations in the following way:

A. Organisational structure and allocation of responsibilities.

B. Definition of IEP / EMP process and how it is managed within the organisational structure that we recommend.

C. Human capacity requirements.

D. Software tools and training considerations.

L. Organisational Structure

101. Figure IV-1 combined with the roles and duties of NEMC defined in the National Energy Policy provide a reasonable foundation for a coordinated approach to energy planning. However, the following are the two key enhancements to the existing structure that we recommended:

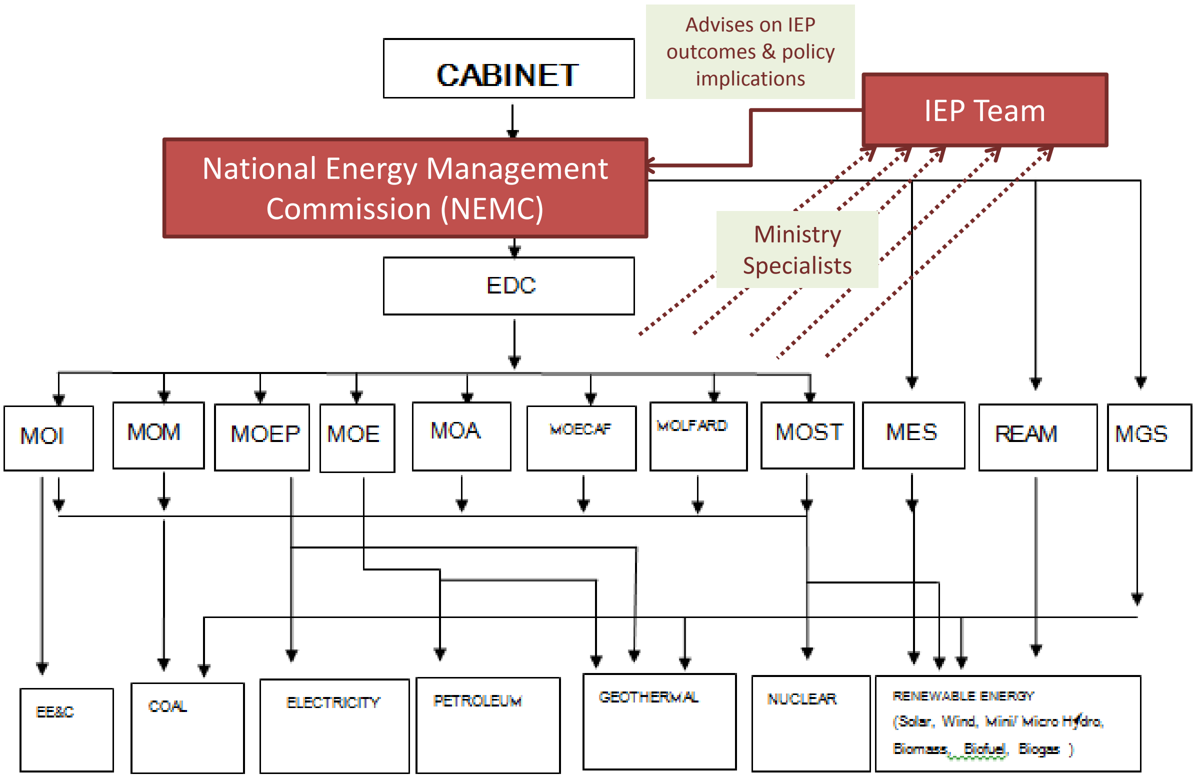
A. Establish a permanent and specialist IEP team within the existing governance structure at NEMC.

B. Allocate the roles and duties of the concerned IEP team, the Ministries and NEMC in a way that can support the IEP process.

Concept of IEP Team and Allocation of Duties for the Purpose of IEP

102. NEMC itself could be thought of as more of a Planning Commission and the NEMC working level staff as an Energy Planning team, for example, an "Energy Wing" of the Planning Commission. This is a common structure implemented in other countries. The concept is illustrated in Figure V-1, where we have introduced the IEP Team to the current structure in Myanmar.

Figure V-1: IEP Team



Source: Consultant

103. Shown in the diagram is the concept of the ministry specialist advisors, who feed into the IEP Team critical information relevant to the ministries that each represents. In essence the Ministry specialists would be responsible for the following duties:

A. Provide macroeconomic policy options;

B. Provide strategic development plans for economic sectors;

C. Provide primary resource assessments;

D. Develop roadmaps (pipelines, storage depots, roads, railway lines, power plant sites);

E. Evaluate energy supply technologies; and

F. Report on energy statistics for consolidation to the IEP Team.

104. The IEP Team would be responsible for the key activities associated with the IEP process:

A. Definition of policy and socio-economic issues;

B. Definition of regulations;

C. Compilation of Energy Statistics;

D. Definition of planning criteria and targets;

E. Selection of Primary Resource & Technology options (screening curves);

F. Performance of Integrated Energy Modelling;

G. Development of financing & tariff strategies; and

H. Industry & Public Consultation.

105. And finally, NEMC taking the form of a Planning Commission, would be responsible for:

A. Ratification of projections of estimated future energy needs in support of macroeconomic and socio-economic requirements;

B. Recommend preferred energy supply options in light of:-

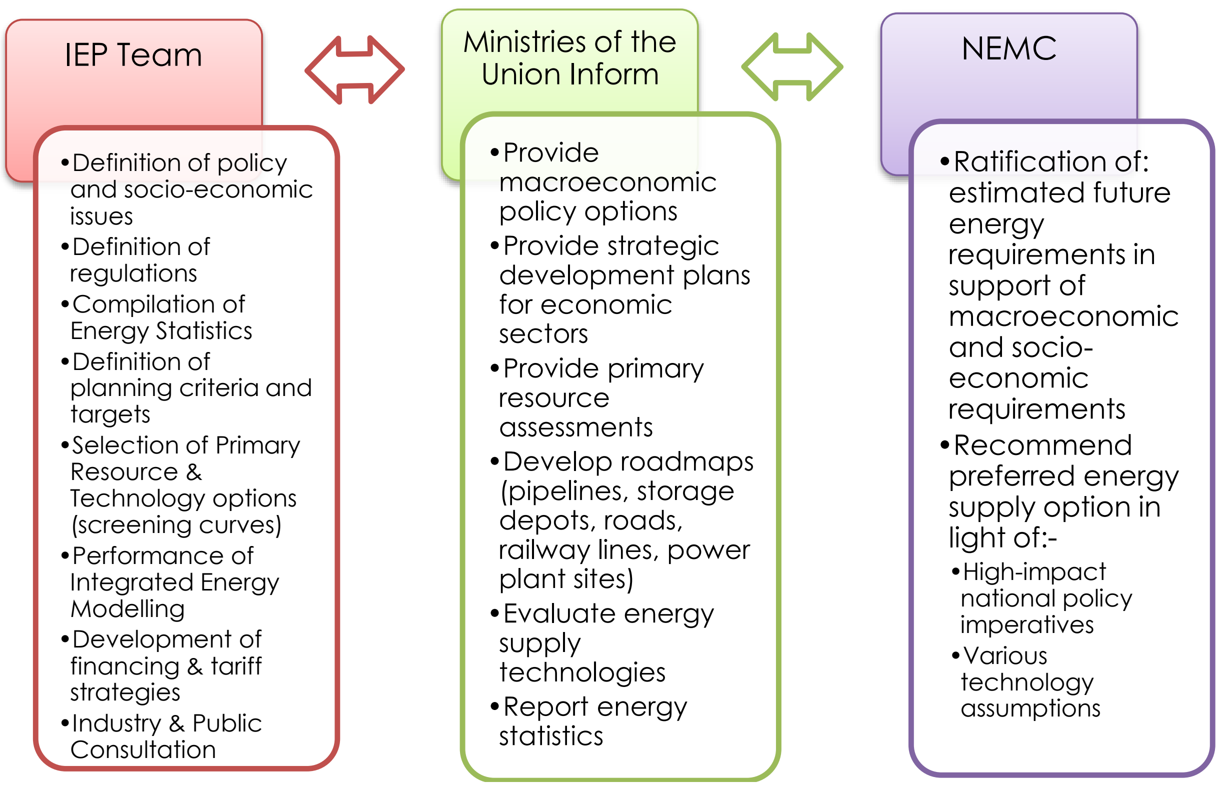
i. High-impact national policy imperatives

ii. Various technology assumptions

C. Recommend energy policy to support the preferred path.

106. The delineation in responsibilities between the IEP Team, Ministry Specialists and NEMC is illustrated in Figure V-2.

Figure V-2: Responsibilities of the IEP Team, Ministries and NEMC



Source: Consultant

IEP Team Structure

107. The IEP Team itself can be structured as a specialised energy planning entity, with a structure such as that illustrated in Figure V-3.

108. The roles within the IEP Team would be:

A. **Director General**. The Director General would be responsible for delivering the Integrated Energy Plan to the NEMC. The Director would identify policy issues and make recommendations on policy options for NEMC's consideration. These could form the basis of policy-based expansion scenarios in accordance with national economic growth aspirations, international obligations and other criteria. The expansion scenarios could be modelled by energy planners and subsequently assessed for its suitability. It would then ultimately lead to a final recommendation to be made to NEMC.

B. **Ministry Specialist Advisors**. The ministry specialist advisors are needed to contribute as advisors to the IEP in respect of (1) primary resource development, specifically to advise the projected economic value of local fuels, (2) consumption patterns, (3) supply technology selection based on field experience and capability, and (4) provision of energy statistics to the energy statistics team. Development partners could play the role of specialist advisors to assist the Director General in relation to energy planning and energy policy.

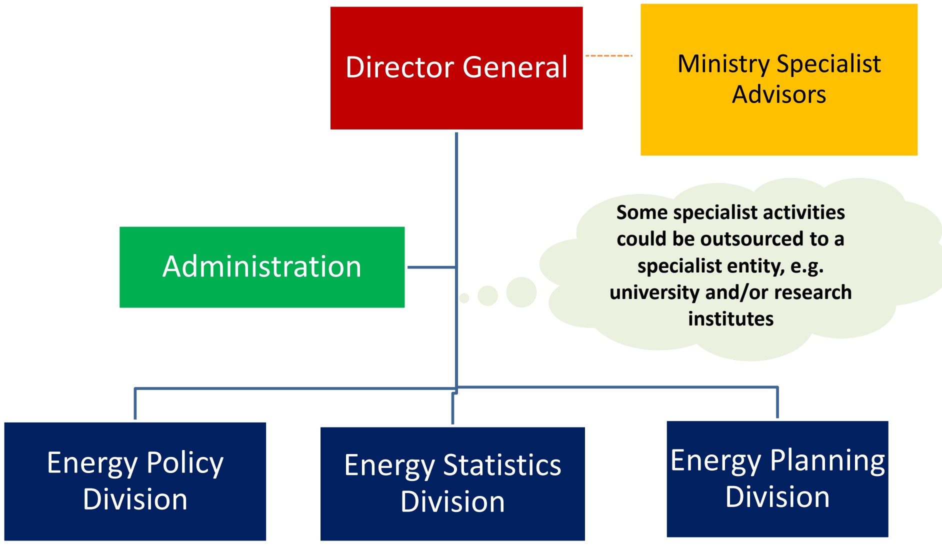
C. **Energy Policy Division**. Develop high-level scenarios in accordance with national development plan and strategic policy etc. Develop policy implications of the IEP. Conduct energy demand forecast through modelling specialists.

D. **Energy Statistics Division**. The energy statistics team is responsible for maintaining an energy statistics digest on an annual basis, by sector (for example, solid fuel, petroleum, gas, renewables, electricity etc.) The team would also be responsible for developing demand and supply statistics to the demand and supply modelling specialists within the energy modelling team.

E. **Energy Planning Division**. The energy planning team could be structured so that it comprises: (1) a demand modelling specialist capability, to consolidate energy demand forecasts by Primary, Secondary and Tertiary sectors, (2) a supply modelling specialist capability to develop policy-based expansion plans, and (3) an economist / financial capability to cost supply expansion plans and to undertake tariff analysis. Another role of the energy planning team would be to monitor the progress of previously developed plans, and identify and improve the IEP process over time, so that over time it can become more aligned with outcomes to date as well as reflective of emerging issues. Note that some functions of the energy planning team described here could be outsourced to specialist institutions.

F. **Outsourcing of specialist activities**. It may make sense for certain functions to be outsourced to specialist entities, such as institutions or universities. For example, other entities could perform energy consumption surveys, they could perform analysis and diagnosis of pilot projects to enhance energy efficiency or renewable energy, or they could take a larger role, such as performing least cost energy planning, which would mean that the energy planning division would take on more of a role of oversighting the modelling and planning rather than being directly responsible for it.

Figure V-3: IEP Team Structure



Source: Consultant

M. IEP Process

109. The EMP is typically repeated on a cycle of 5 years.

110. The main aspects of any IEP implementation includes the following:-

A. Data collection. A strategy needs to be put into place to support the routine collection and reporting of. While data uncertainty can never be completely eliminated, the need for verification and validation is important as it ultimately informs the IEP process of trends in energy supply and energy demand. Furthermore, a process to recognise and set in motion a process for obtaining any missing data is required – for example, designing targeted surveys or legislating mandatory declarations of stocks and inventory for commercial enterprise. Tools such as spreadsheets and databases are required to support this.

B. Compilation, analysis and statistical reporting on data. Data will necessarily be fragmented across different agencies who are concerned with different subsets of the energy conversion chain (gas, oil, electricity, commerce, industry, etc.). The data needs to be transformed to develop a holistic picture of the energy situation. This may require analytics and/or reconciliation processes to eliminate gaps. Analysis of this kind enables one to identify any emerging trends in energy supply and demand, which in turn is necessary for use in the development or calibration of forecasting models.

C. Energy demand forecasting. The IEP requires as a key input projections of energy demand for all key sectors: industry, commerce, residential, agriculture, transport and others. These need to be consistent with an underlying set of economic scenarios. The IEP may involve developing a set of independent forecasts or leveraging externally developed forecasts[3]. Other dimensions to this include the issue of energy efficiency

[3] For example, individual ministries or government agencies may have established processes or models in place, or

and energy access. Models to support the development of energy demand forecasts are essential.

D. Energy supply forecasting. Issues to be addressed include estimates of primary energy resources, existing and planned infrastructure, options for development, cost of developing primary energy resources, fuel costs, operational expenditure, capital costs, assessments of conventional and emerging technologies, and costs of developing them etc. Again, a database and basic supply option cost models support this process.

E. Developing an overall strategy. A process to translate the projections and modelling results into a meaningful set of recommendations. The demand and supply analysis will require consideration of a range of scenarios that need to eventually be used to guide key decisions on policy and a concrete set of implementation plans or roadmaps for each of the main subsectors.

F. Monitoring and evaluation. Finally, the progress, and effectiveness of any IEP needs to be checked. This process is one of comparing actual outcomes to those that had been planned, identifying areas of discrepancy and making refinements to the IEP process to better address these issues on a go-forward basis.

111. It may be possible to streamline some aspects of the preparation of the EMP so that some aspects are updated more frequently than others.

N. Relationship between EMP and Other Planning Processes

112. Figure V-4 conceptually illustrates the linkage between the EMP and other planning or policy processes in Myanmar[4]. This highlights the need for coordination between the different planning processes and also the potential for there to be interface issues; the boundaries between the EMP and other planning processes must be carefully defined and managed.

113. A number of the ministries already have in place their own forward-looking process, in particular:

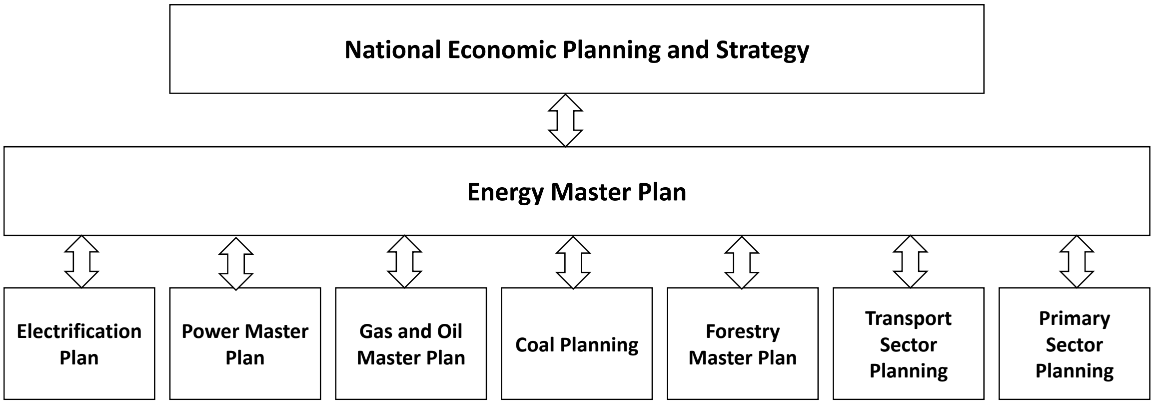
- MOEP – 20-year Power Master Plan;
- MOGE – 30-year plan that is updated as required, and a 20-year oil and gas plan;
- MOECAF – Forestry Master Plan; and
- Most of the other ministries also have in place planning processes.

114. The IEP process is intended to provide an integrated implementation of the individual subsectors. A key issue is the relationship between EMP and other ministry-level plans. Ideally the top-down and bottom-up assessments will be consistent, although this can't always be guaranteed. In this context, the EMP is defining the broad parameters or a broad space that then needs to be filled in with the details by the concerned ministry.

115. For instance, for the power sector, the EMP provides the broad direction, but it does not provide a detailed consideration of transmission and distribution investments, this is an issue for MOEP to address. For other sectors, the situation is similar.

they could be independently developed as part of a centrally coordinated EMP framework.
[4] In fact, it could be any country.

Figure V-4: Energy Master Plan Relationship to other Planning Processes



Source: Consultant

O. Human Capacity

116. The previous sections set out an organisational structure and procedure for successfully implementing the IEP. As discussed, functionality falls into four (4) main categories that can be either common across all the Phases or embedded within one Phase. These categories are:

- Co-ordination & program management;
- Demand side assessment;
- Supply side assessment; and
- Statistics.

117. The skill sets required to undertake these critical functions are discussed in the subsections that follow. We have detailed the total skill sets required to complete the tasks that fall within the categories outlined. It is envisaged that these skill sets would reside within multiple individuals who are in the IEP Team structure that was set out earlier. It is unlikely that one individual could either (a) undertake the work required within the timeframe provided, or (b) have sufficient diversity in expertise across all areas to undertake the work to a sufficiently high standard.

118. All the members of this team must have good communication skills particularly with regards to coordination with ministries, and the production of documents for circulation amongst ministries. The ability to engage and collaborate with stakeholders at all levels of this team is very important.

Energy statistics

119. Energy statistics involves initial data gathering as well as the measurement and monitoring of the success of the prior period EMP. This area requires people qualified in mathematics, statistics and/or econometrics.

120. Energy statisticians specialise in the compilation verification and dissemination of information on all aspects of energy including its production transformation and consumption of all fuels renewables emergency reporting system energy efficiency indicators CO2 emissions and energy prices and taxes done managers are responsible for receiving reviewing and importing data submissions from ministries and other sources into last computerised databases.

121. The statisticians check for completeness correct calculations internal consistence consistency accuracy and consistency with definitions. Often this will entail proactively investigating and helping to resolve anomalies in collaboration with ministries.

122. Data managers and statisticians also play a key role in helping design and implement computer macros used in the preparation of the EMP.

123. These team members should have a university degree in a topic relevant to either energy, computer programming or statistics. They should have experience in the basic use databases and computer software.

124. Members of the statistics team must have the ability to work accurately, to pay attention to detail, and work to deadlines. They also must have the ability to deal simultaneously with a wide variety of tasks and to organise the work efficiently.

125. At least one or two of the members of this team must have good communication skills particularly with regards to coordination with ministries, and the production of documents for circulation amongst ministries.

126. Subsets of the skills required to undertake this function would include data collection and analysis, the ability to perform an energy balance and experience in conducting surveys on energy use and consumption.

Energy demand forecasting

127. Energy demand forecasting is a specialised skill area.

128. The senior in charge of the energy forecasting group should be responsible for the delivery of all energy forecast across various energy sources. These sources include coal, electricity, gas, petroleum and biomass.

129. The senior requires a team that is capable of undertaking statistical and mathematical modelling to develop both short and long-term energy forecasts. The team are also required to develop technical solutions to problems that impact energy demand.

130. Relevant tertiary qualifications in statistics, mathematics, econometrics, science, engineering or economics will be useful in this role. At least one or two members must have an understanding of the workings and impacts (on demand forecasts) of demand management and energy efficiency.

131. In addition, strong programming and data management skills as well as experience in statistical or mathematical modelling and database development are important.

132. Due to the scope and importance of the function of this team, members must have the ability to take ownership of pieces of analytical work.

133. The team members should have an interest in macroeconomic modelling and forecasting and a keen interest in real world economic issues and policy developments.

134. At least one or two of the members of this team must have good communication skills particularly with regards to coordination with ministries, and the production of documents for circulation amongst ministries. The ability to engage and collaborate with stakeholders at all levels of this team is important.

Energy supply modelling

135. A large proportion of the functionality that is required of this team lies in their ability to undertake research. Research into processes and trends that are emerging in the technology or conversion market that is being assessed, as well as the external environment that may affect all the future supply options.

136. The team as a whole must have the capacity to develop solutions and organise a complex workflow.

137. At least one or two of the members of this team must have good communication skills particularly with regards to coordination with ministries, and the production of documents for circulation amongst ministries. The ability to engage and collaborate with stakeholders at all levels of this team are important

138. This team could be divided into two types of groups: (a) engineering group, and (b) financial group.

Energy supply modelling: engineering group

139. The engineering group would be concerned more with technology assessments and supply options for its applicability in energy extraction or conversion within an energy system. Across multiple streams there need to be specialists with backgrounds in engineering for coal, gas, electricity, renewables, petroleum, demand management & energy efficiency. Within these categories an understanding of the following is required:

- Technology assessments;
- Renewable energy / non-conventional technologies; and
- Primary energy resource assessments.

140. The members within the engineering group should have experience in some (or all) of those areas combined with strong communication skills, and the ability to research. As a whole, the team must have the ability to undertake analytical thinking and to take a logical, defensible approach to resolution of problems.

Energy supply modelling: economics and financial group

141. The economics group would need to be responsible for costing models for the supply chain, assessing value of expansion options, fuel sources, capital costs and so on. The team would need to be able to understand and develop:

- costing models;
- expansion models;
- macro-economic outlooks;
- cost-benefit analysis; and
- tariffs / pricing analysis.

142. Therefore there is a requirement for a group within the supply modelling team that understand the costing of different types of technology, and the capacity to forecast changes in technology costs over time (technology curve).

143. Ideally the staff engaged in this area would have some level of exposure to energy specific analysis, costing structures, and event forecasts. Team members should have considerable experience in working with and developing applied macroeconomic models, combined with excellent macro-modelling and macro-econometric skills.

Comments on Training Areas

144. Figure V-5 sets out possible areas of training and capacity building which provides coverage of all key areas and topics that the energy planning team requires.

Figure V-5: Possible Areas of Training and Capacity Building

1a	Energy demand forecasting techniques (theory, electricity with electrification targets)
1b	Energy demand forecasting applied (practice using Excel, demonstration of e-Views, discussion of MAED)
2a	Load / production profile development theory (capacity factors, load factors etc.)
2b	Load / production profile development applied (practice, discussion of MAED)
3a	Screening curve theory (electricity)
3b	Screening curve (practice)
4a	Economic dispatch theory
4b	Economic dispatch applied (practice solving a number of problems of increasing degrees of sophistication, the final one to be electricity expansion)
5a	Portfolio costing theory
5b	Portfolio costing applied (focus on the economic / financial evaluation principles – NPV, IRR, payback etc.)
6a	Energy balance theory
6b	Energy balance practice

Source: Consultant

P. Models and Tools to Support Energy Planning

145. The following are specialist energy planning tools that could be considered:

A. MAED = Model for the Analysis of Energy Demand

B. MESSAGE = Model for Energy Supply System Alternatives and their General Environmental impacts

C. MARKAL/TIMES with ANSWER or VEDA (as user interfaces) = Market Allocation

D. LEAP = Long-range Energy Alternatives Planning system

E. WASP = Wien Automated System Planning

F. EViews = Regression / statistical modelling

G. eSankey = Sankey Diagram Visualisation software suitable for visualisation of energy flows

146. A summary of these tools is provided in Figure V-6.

Figure V-6: Summary of Energy Planning Tools

Tool	**Developer**	**Scope**	**Method**	**Suitable?**
MAED	IAEA	Integrated Energy / Environment Analysis	Physical accounting, simulation	Yes, for demand (need MESSAGE for supply)
MESSAGE	IAEA	Final and useful energy supply	Optimization	Yes, for supply (need MAED for demand)
MARKAL / TIMES	ETSAP	Integrated Energy / Environment Analysis	Optimization	Yes, for demand & supply
LEAP	SEI	Integrated Energy / Environment Analysis	Physical accounting, simulation, optimization	Yes, but not as flexible as others
WASP	IAEA	Electricity sector	Simulation and optimization	No, electricity planning focus
EViews	his	Generic statistical modelling tools	Statistical models	Useful
eSankey!	ifu Hamburg	Generic Sankey diagram generator	Provides tools to make drawing easy	Useful but not essential

Source: Consultant's analysis

Project Number: TA No. 8356-MYA

FINAL REPORT

MYANMAR ENERGY MASTER PLAN

APPENDICES

Prepared for

The Asian Development Bank

and

The Myanmar Ministry of Energy

Prepared by

IES
Intelligent Energy Systems

in association with

MMIC
MYANMAR
INTERNATIONAL
CONSULTANTS

December 2015

Project Number: TA No. 8356-MYA

FINAL REPORT

APPENDIX 1:
TERMS OF REFERENCE

Prepared for

The Asian Development Bank

and

The Myanmar Ministry of Energy

Prepared by

Intelligent Energy Systems

in association with

MYANMAR INTERNATIONAL CONSULTANTS

ABBREVIATIONS

ADB	–	Asian Development Bank
IES	–	Intelligent Energy Systems Pty Ltd
MMIC	–	Myanmar International Consultants
NEMC	–	National Energy Management Committee
TA	–	Technical Assistance
TOR	–	Terms of Reference

CONTENTS

I. INTRODUCTION

1. Intelligent Energy Systems Pty Ltd (IES) in association with Myanmar International Consultants Co. Ltd. (MMIC) were contracted by the Asian Development Bank (ADB) to undertake the following Technical Assistance (TA) project: “TA-8356 MYA: Institutional Strengthening of National Energy Committee in Energy Policy and Planning – 1 Energy Master Plan Consultant (46389-001)”. The project objectives are to: (1) provide technical assistance and institutional strengthening to the National Energy Management Committee (NEMC) in Energy Policy and Planning, and (2) to prepare a 20-year Myanmar Long-Term Energy Master Plan for the energy sector of Myanmar.

2. The detailed terms of reference (TOR) for the project as specified by ADB is reproduced in Section II.

II. PROJECT TERMS OF REFERENCE

A. Scope of Work

3. Under the technical assistance for Institutional Strengthening of NEMC in Energy Policy and Planning, a team of consultants will be engaged to prepare a 20-year energy master plan for Myanmar, including an energy demand forecast, supply options, investment requirements, and legal and institutional arrangements. To strengthen the abilities of NEMC and the EDC to prepare an energy policy, a renewable energy development strategy, and an energy efficiency policy in coordination with seven concerned ministries, three (3) international and four (4) national experts were engaged. The project team will be required to prepare several reports, set up systems and procedures, implement a variety of capacity development activities, and monitor project implementation.

B. Long-Term Energy Master Plan

4. A team of international and national consultants from a consulting firm will be engaged to prepare the 20-year energy master plan. This will be done in accordance with the Asian Development Bank (ADB) Guidelines on the Use of Consultants (2010, as amended from time to time). The work will require about 18 person-months of international consulting services and 20 person-months of national consulting services. A team of experts comprising an energy statistician, an energy planner, and an energy economist will be engaged from a consulting firm that has expertise in energy demand and market analysis, demand projections, assessing supply options to meet energy demand, investment requirements, and legal and institutional arrangements.

5. The energy statisticians (international, 6 person-months; national, 12 person months) will undertake the following activities:

(i) Consolidate the existing fragmented energy statistics and planning studies and reports for the energy sector from the seven concerned ministries, including the Ministry of Energy (oil and gas sectors); the Ministry of Electric Power (power sector); the Ministry of Mines (coal development); the Ministry of Agriculture and Irrigation (biofuels, and micro-hydro for irrigation purposes); the Ministry of Science and Technology (renewable energy); the Ministry of Environmental Conservation and Forestry (fuelwood, climate change, and environmental safeguards requirements); and the Ministry of Industry (energy efficiency).

(ii) Collect and compile energy statistics and energy outlooks prepared by the International Energy Agency, ADB, the Association of Southeast Asian Nations, and other development partners.

(iii) Conduct the surveys on the use of energy in various sectors.

(iv) Review existing energy data and develop an energy balance for 2000 – 2012 for Myanmar, adapting the methodology used by the Asia-Pacific Economic Cooperation forum in its Energy Demand and Supply Outlook, including overall energy balances, as an input to energy projection.

(v) Develop the manual or tool kit for preparing a primary energy consumption and energy balance table.

(vi) Train staff from concerned ministries on the developed manual or tool kit and will develop a capacity development plan.

6. The energy planners (international, 5 person-months; national, 4 person-months) will undertake the following activities:

(i) Develop a common methodology for energy demand and supply analysis and make demand projections for each primary energy and each sector based on the developed energy balance for the next 20 years. These projections will take into account projections for gross domestic product, population and other economic indicators in close consultation with the Ministry of National Planning and Economic Development and research institutions.

(ii) Assess the supply potential of primary energy sources in Myanmar such as biomass, coal, oil, gas, hydro, and renewable energy.

(iii) Assess the technical feasibility of primary energy supply options in close consultations with the energy economist.

(iv) Recommend least-cost options for delivering the energy supply required to meet the energy demand, in close consultation with the energy economist.

(v) Train staff from the concerned ministries on the developing common methodology and develop the capacity development plan.

(vi) Design, organize, facilitate, and document public discussions with a range of stakeholders, including civil society, and ensure that these discussions follow ADB models of good practice for consultation.

7. The Energy Economists (international, 7 person-months; national, 4 person-months will undertake the following activities:

(i) Assess the economic feasibility of primary energy supply options in close consultations with the energy planner.

(ii) Recommend least-cost options for delivering the energy supply required to meet energy demand, also in close consultation with the energy planner.

(iii) Assess the availability of financial resources from domestic and international bilateral, multilateral, and private sector sources to meet investment needs, and develop a financing plan to implement the long-term planning.

(iv) Suggest the financing modality, including public – private partnerships.

(v) Identify the institutional and regulatory impediments to collecting energy information and preparing the long-term outlook.

(vi) Determine the improvements necessary in the institutional and regulatory framework to support the function of energy planning in the Ministry of Energy (MOE).

(vii) Supervise and organize the necessary workshops and seminars and conduct the necessary training and capacity building on energy balance and planning, including a capacity development implementation program.

8. The consultants will prepare an inception report within 1 month, an interim report within 6 months, and a draft final report within 11 months from the commencement of consulting services. For each report, the consultants will organize a workshop to enhance staff skills in energy planning from the concerned ministries.

C. Variations to Scope of Work

The following variations to the scope of work were initiated by ADB:

9. ADB separately engaged a Consultant to undertake a power expansion plan. IES was instructed to follow this expansion plan as the electricity sector strategy for Myanmar and to not consider independently developed views or cost estimates for the electricity sector.

10. The ADB expansion plan is to be included as an appendix to the Energy Master Plan (EMP) final report.

11. The long-term energy plan was to be determined to 2030 in order to facilitate comparison to other studies and work. In the report it is only necessary to provide projections on outcomes for a 15-year period from 2015 to 2030.

12. Only a single medium-case energy supply outlook is to be developed.

Project Number: TA No. 8356-MYA

FINAL REPORT

APPENDIX 2:
NOTES ON ENERGY PLANNING

Prepared for

The Asian Development Bank

and

The Myanmar Ministry of Energy

Prepared by

IES
Intelligent Energy Systems

in association with

MMIC
MYANMAR
INTERNATIONAL
CONSULTANTS

ABBREVIATIONS

ADB	–	Asian Development Bank
APERC	–	Asia Pacific Energy Research Centre
ASEAN	–	Association of South East Asian Nations
EMP	–	Energy Master Plan
GDP	–	Gross Domestic Product
MOAI	–	Ministry of Agriculture & Irrigation
MOE	–	Ministry of Energy
MOEP	–	Ministry of Electric Power
RE	–	Renewable Energy

CONTENTS

NOTES ON ENERGY PLANNING

A. Introduction

1. Strategic energy sector planning requires the use of formal methods that ensure transparency, comprehensiveness, consistency between subsectors and reproducibility. As least-cost strategies are to be identified for each scenario considered in this project, the tools used for energy planning must be capable of optimization. Also, the tools must be suited for the size of the energy systems of the country and must lend itself to integration of country results to study all aspects of energy substitution.

2. The key considerations involved in selection of energy planning tools are as follows:-

- The planning horizon;
- The focus on short versus medium and long-term need;
- The confidence in historical data describing the economy and the energy industry;
- The need to take into account regional issues versus national issues; regional issues are usually significant when an energy system is small and there are one or two large load centres and many regional load centres at various stages of development;
- The maturity of the energy sector and the degree to which fuel substitution is evidenced; in particular the role that natural gas plays, within the context of the economy, is a critical issue; and
- The suitability of the planning tools for transfer to energy planning staff in the responsible Ministries.

3. The Consultant has worked to a planning horizon spanning the years 2014 to 2035. This planning horizon of slightly more than 20 years is relatively short. Given the social reforms that are taking place in Myanmar, and the uncertainty surrounding the economic growth outlook, a 20 year planning horizon is considered to be the longest period for a meaningful energy planning study.

4. In regards to the energy needs of Myanmar, it is clear that the focus is on the short to medium-term. The current shortfall in electricity supply and declining on-shore production of liquid fuels point to the need for near-term action.

5. Confidence in historical performance data is somewhat mixed. There is no shortage of literature in the public domain, wherein consultants and analysts have questioned the accuracy of economic and technical data reported by the Government of Myanmar. Whilst the experience of the ADB Consultant has been generally positive with regard to data accuracy, nevertheless the confidence is considerably less than is the case for transition and OECD-economy countries.

6. Myanmar's energy system is small and characterized by the very large load centre of Yangon, a moderate size centre of Mandalay, and a range of State/Region centres at different levels of development. Myanmar is a long country, from south to north, with marked differences in topology and climate. As a result there are three agricultural zones and three fuel zones to consider. Energy planning from a national perspective only will not deal adequately with this mixed presentation;

some level of disaggregation to regional level is needed.

7. Myanmar's energy system is relatively immature when compared to those of developed world countries. This is not a comment on the maturity of the energy technologies in use; rather it highlights the shortage of gas available for domestic use. In the coming years, gas supplies might be expected to increase and so the potential for fuel substitution. This means that energy planning tools must be able to evaluate the optimal use of gas across the economy.

8. Energy planning tools come with various levels of sophistication. It is understood that energy planning staff in the Ministries have had exposure to a moderately sophisticated energy planning package called LEAP. It is understood that the planning staff involved came away with the opinion that it was too soon to apply such a model in Myanmar. The lack of reliable data in particular was a concern, along with general concerns regarding the lack of transparency with such a model.

9. With reference to the key considerations outlined above as bullet points, and the ensuing discussion points, the Consultant considers that the best approach to energy modelling is a bottom-up optimization / accounting approach applied at regional level. Considering the energy planning tools that are applied consistently throughout the world, and their characteristics, this leads to the conclusion that individual economic sector models are most appropriate for Myanmar at the present time. The tools and their characteristics are tabled as follows:-

Table 0-1: Energy Modelling Tools

Approach	Space	Sector	Time	Examples	Suitability for developing countries
Top down simulation	Global, national	Macro-Economy, Energy	Long term (20+ years)	AIM, SGM2, I/O models	4
Bottom up optimization	National	Energy	Long term (20+ years)	MARKAL / TIMES	3
Bottom up accounting	National, regional	Energy	Long term (20+ years)	LEAP	2
Bottom up optimization / accounting	National, regional, local	Energy	Medium term (20 years), short term	Sector models (e.g. agriculture, transport, industry, household, etc)	1

Source: Consultant

10. There are advantages and disadvantages in using sector models for energy planning

- Sector models better facilitate training in the concepts involved in sector planning as the models are transparent;
- Sector models are weak when it comes to modelling fuel substitution effects; however in Myanmar the key issue is the use of gas and the allocation can be readily tested by

sector, notably the diversion of gas for fertilizer and / or CNG-fuelled vehicles, versus the savings that could be gained if the gas is instead used for power generation; and

- The sector model approach supports the use of a long-term planning tool, such as LEAP or MARKAL / TIMES, because the accurate calibration of sector energy consumption against historical fuel production/imports will ultimately provide a high level of confidence in historical data; this confidence is a pre-requisite for setting parameters within the more sophisticated planning packages. In future such multi-criteria optimisation models could be developed for Yangon Division and the rest of the country, or for north and south partitions of the country.

11. A final comment regarding the MARKAL / TIMES planning package is that the power of the software is fully released when consumer price behaviour is included in the model. At the present time there is insufficient knowledge of consumer behaviour to support such an approach, particularly in the rural sector. A possible evolution would be to develop a simple MARKAL / TIMES model for a typical rural village. This model could later be integrated into a national model thereby ensuring that energy consumption of the country is correctly characterized at the consumer end.

B. Myanmar Energy Planning Model

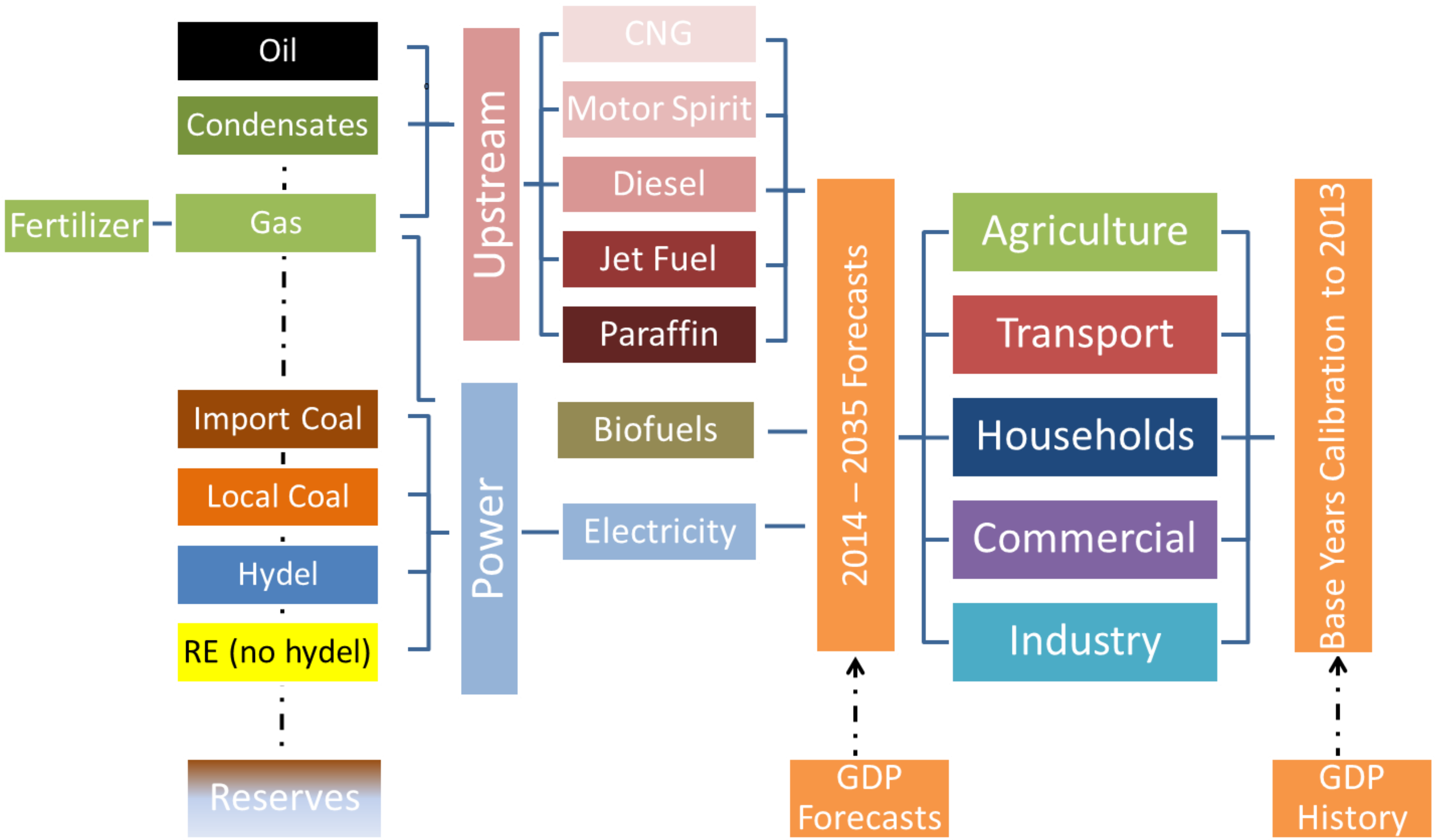
12. The energy planning model developed to support the development of Myanmar's Energy Masterplan is based on a modular approach. The model comprises separate demand side and supply side components as shown in Figure 0-2.

13. On the demand side, the economic and household sectors are modelled as separate modules. Each of these modules contains bottom-up and top-down historical data used for calibration purposes. Forecasts are developed within each module according to the economic or other relevant growth drivers, e.g. GDP per capita.

14. On the supply side, the optimization of electricity supply is performed according to economic despatch principles. This is because electricity cannot be stored and supply and demand must be balanced at all times according to economic least-cost supply principles (for a given supply scenario). In the case of liquid fuels the petroleum product requirement is expressed in the form of a refinery slate. The least cost supply of petroleum products is determined by a conventional economic evaluation of alternatives, including off-shore and on-shore oil purchase, on-shore refining, import of petroleum products. Total upstream energy costs are determined simply according to volumes supplied and price rates for each petroleum product.

15. Gas supply is modelled by constraining the supply of gas to relevant individual sectors.

Figure 0-2: Integrated Energy Planning Model for Myanmar



Source: Consultant

16. Further details of the energy planning modules are discussed in the sections that follow. At the time of preparation of these notes, the GDP growth and demand-side models were fully complete. Not shown in Figure 0-2 is an electricity forecast module. Electricity forecasts are prepared in a single module according to consumer class (residential, commercial, light industrial, industrial, Government and agriculture) then disaggregated by household, commercial and industry sectors where other energy forms are added to account for the total energy consumption of the sector (e.g. diesel, wood fuel, etc).

17. Some further minor development may be required to apply the electricity economic dispatch model to the Myanmar system; at this time it is not decided whether the economic dispatch modelling will be undertaken separately for Yangon Division and the southernmost portion of the country, on a fully integrated national basis, or both if a particular expansion scenario of interest should require it.

C. GDP Growth Module

18. The GDP growth model is based on an overall target growth rate for the economy, and disaggregated targets for individual sectors viz a viz, the primary, secondary and tertiary sectors. The model also forecasts manpower needs by sector as well as specifically for the agriculture sub-sector. These forecasts are used in the consideration of farm mechanization. The details are provided in the Economic Outlook report.

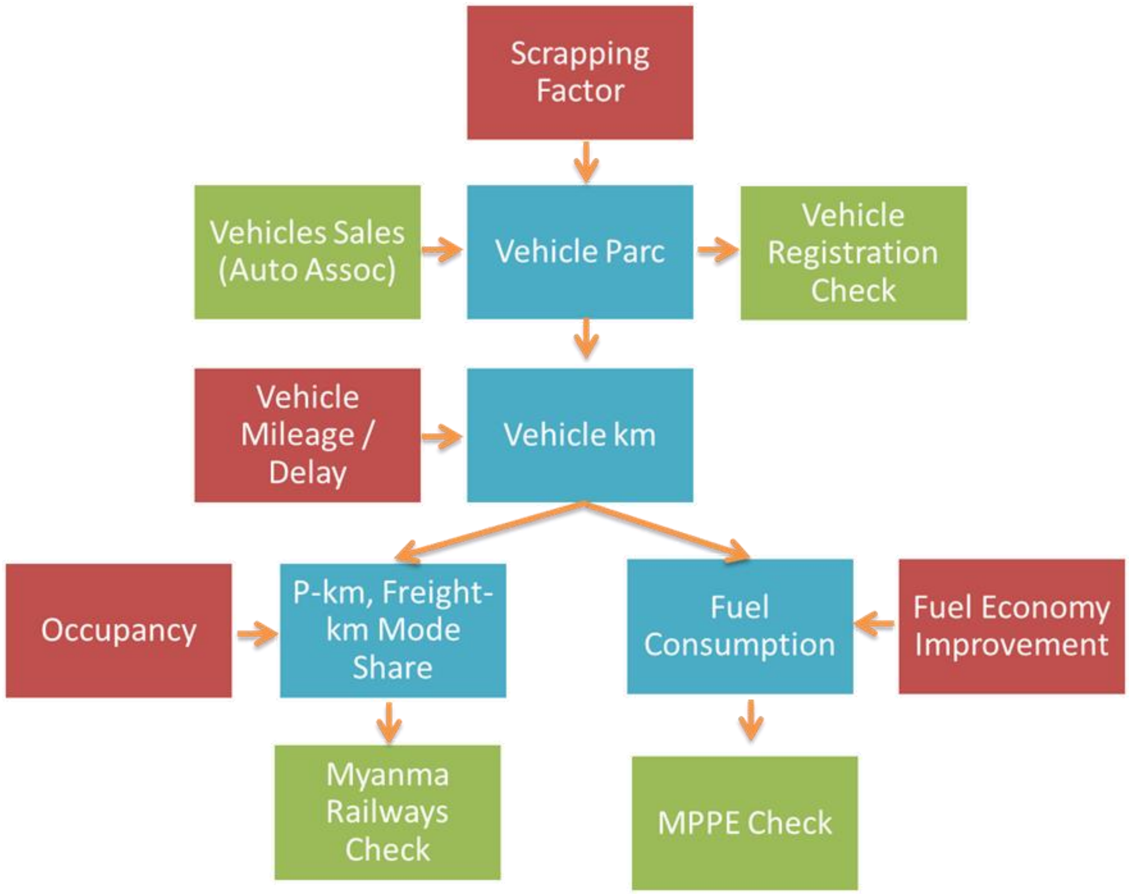
D. Transport Module

19. There are several approaches that could be used to model transport sector demand. International transport research centres tend to favour a bottom-up approach where the objective is fuel consumption and energy analysis. A bottom up approach is a disaggregated analysis of the transportation system as a provider of energy services. The calculation of energy demand in terms of services performed ('useful' energy) as opposed to the amount of energy supplied ('final' energy), offers a better understanding of the substitution between alternative energy forms, as well as an appraisal of the effect that evolution of the technological improvements has on demand. Such insights are essential in developing energy policy.

20. In a bottom-up approach, energy consumption by the transport sector is directly driven by two factors: vehicle-km travelled, and conversion efficiency of the vehicle (whether a road, rail, waterway or air vehicle). Vehicle-kms travelled are in turn driven by the needs of society and the economy to move people and goods from place to place. Conversion efficiency depends mostly on the underlying technology, i.e. the type of vehicle, fuel and vintage that makes up the vehicle 'parc'[1], and to some degree the patterns of utilisation of that technology. It is a best practice to treat passenger transport and freight transport separately, as the need for mobility by people and goods have different drivers and technologies.

[1] The vehicle 'parc' is a term used to describe the total number of active vehicles on the road

Figure 0-3: Transport Planning Module



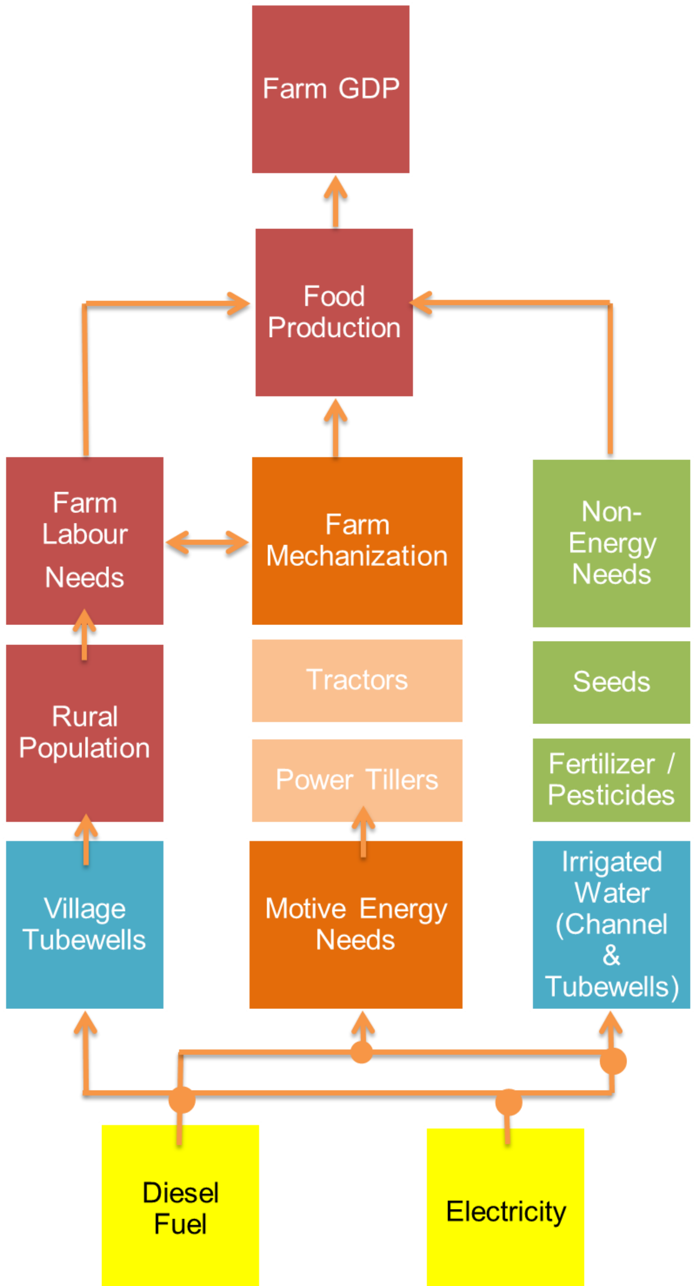
Source: Consultant

E. Agriculture Module

21. The calculation of agriculture sector energy demand is based on the farm energy forecasting model depicted in Figure 0-4 below. The model determines the total commercial energy requirement (for irrigation), and the total mechanization energy requirement (tractors and other machinery). Furthermore the model determines the efficiency of converting solar energy by agriculture as it increases through the additional input of energy from humans, animals, machinery, fertilizer, manure, pesticide, irrigation fuel (petroleum and electricity), as well as from water and seeds. The details are provided in the Primary Sector Demand Forecast report.

22. The agriculture sector requires fertilizer, and the option exists to manufacture on-shore or to import. The production of urea requires gas as a fuel supply and as a feedstock. The agriculture module is designed such that a change in fertilizer load per hectare can be accounted for in the sector energy balance and in terms of GDP impact. This means that as the gas supply allocation to the agriculture sector is varied the net benefit can be assessed in terms of farm sector GDP contribution. The economic benefits can then be understood in relation to the cost saving associated with local fertilizer production (usually fertilizer imports are more costly).

Figure 0-4: Agriculture Sector Energy Planning Module



Source: Consultant

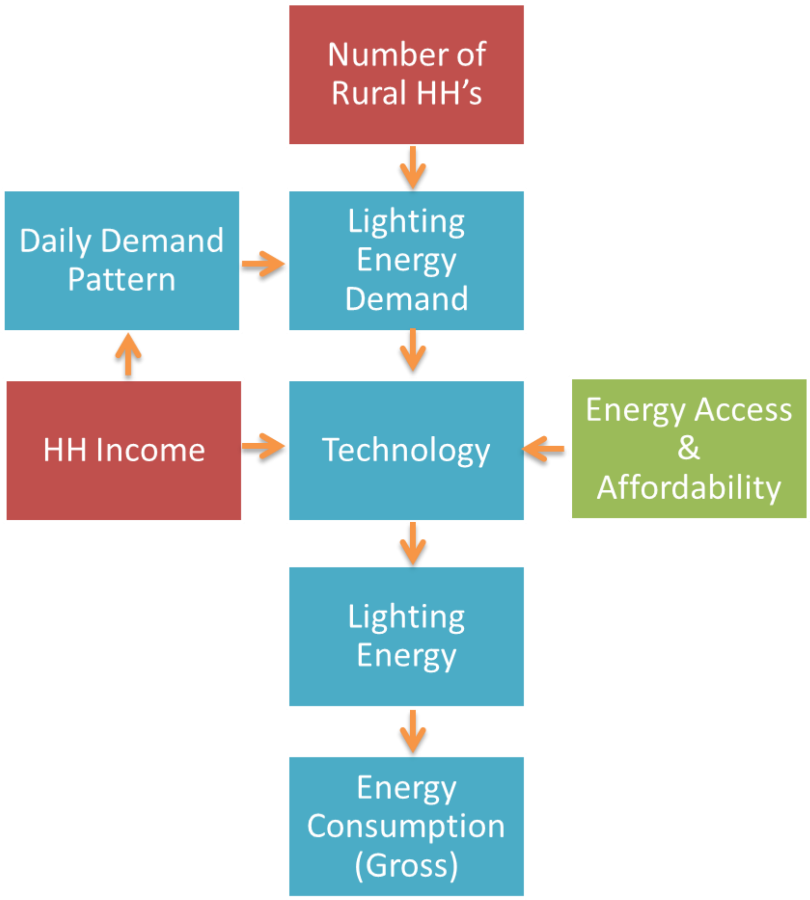
F. Rural HH Lighting Module

23. Rural household lighting energy analysis is concerned with the determination of the existing stock of lighting appliances in use by household income bracket. End-use behaviour is established by survey. When both the stock and usage are known, the household lux (illumination per square

metre) can be estimated. Household lux is a measure of the demand for lighting services.

24. The demand for lighting services can be met in different ways, and a model is required to forecast the optimal supply from standpoint of lux and total cost of ownership. Once the trade-offs are understood an energy policy can be developed. The form of the lighting module is as follows:-

Figure 0-5: Rural HH Lighting Energy Planning Module

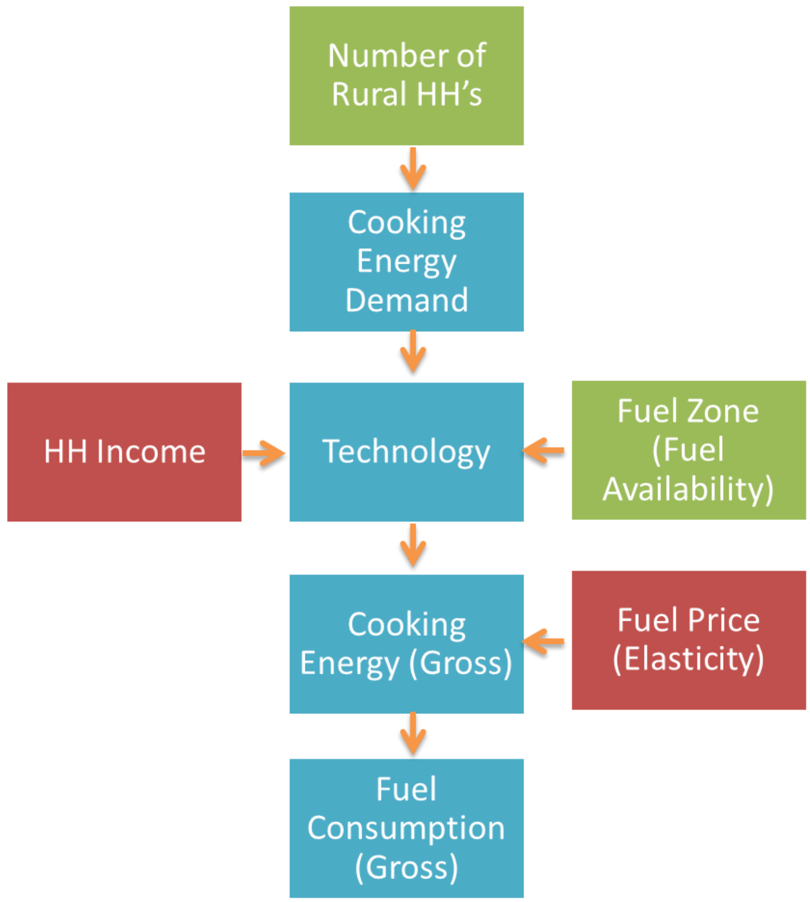


Source: Consultant

G. Rural HH Cooking Module

25. The same principles apply to rural HH cooking energy as described above for lighting, with final cooking energy substituting for lux. The form of the cooking energy module is as follows:-

Figure 0-6: Rural HH Cooking Energy Planning Module



Source: Consultant

H. Electricity Forecasts

26. Electricity forecasts are produced based on bottom-up and top-down forecasting methods.

27. For bottom-up forecasting there are typically five methods that can be applied 1) Land-based, 2) Customer-based, 3) Percentage growth, 4) Trend-method, and 5) Geo-spatial based approach. In practice a combination of these techniques is usually necessary.

28. For top-down forecasting the typical method is econometric regression

29. For the Energy Masterplan, the bottom-up methods used are 2), 3) and 4). The details are described in the Electricity Forecast report. Further details will be provided as part of knowledge

transfer as appropriate to the level of knowledge of Ministry staff participating in training.

30. In summary however, the key features of the forecasting model are as follows:-

- kWh per consumer type is used as a basic indicator;
- Population growth and kWh per household are used for residential forecasts
- Commercial and light industrial forecasts were based on trending + known developments;
- Industrial zone growth was based on Gompertz curves (using Monte Carlo techniques); and
- Regression methods and measured demand data were used for validation.

I. Electricity Supply Optimization

31. For an Energy Masterplan it is important to formulate policy-driven supply portfolio alternatives and to compare them on a net present cost basis. This requires basic economic dispatch modelling to forecast individual plant output, and a financial evaluation model that handles capital investment (including disbursement profiles for new plants), and the forecast production, to determine levelized costs of energy for the portfolio. For a policy-driven expansion planning, a prioritization and ranking criteria model is also required to weight and score each expansion alternative according to a set of agreed criteria, including a net present cost criterion.

32. MoEP is using the software package WASP for electricity supply expansion planning. WASP is a software tool that contains an economic dispatch optimization engine and this tool can be used to test supply expansion alternatives. However, in the interests of time, the Consultant will carry out a basic economic dispatch modelling using a bespoke modelling tool. The bespoke model is not a commercial model and will not be provided. However, the theory of economic dispatch optimization can be given as part of training if required. The financial evaluation model will be provided in the form of an Excel spreadsheet. Unlike WASP, this model is open and transparent and will support training in economic evaluation for a power system if required. The prioritization and ranking model will also be provided with familiarization training as required.

33. It is envisaged that in future the updating of the expansion plan could be carried out using WASP to generate the production outputs of a given portfolio of interest. The production figures could be submitted to the financial evaluation model or the financial calculations of WASP could be used for the purpose of policy-based prioritization and ranking.

J. Petroleum Products Supply Optimization

34. The petroleum products supply optimization is modelled using standard economic evaluation techniques to determine the optimal supply option from amongst on- and off-shore options.

35. The determination of on-shore refinery costs and refinery product prices, for a given demand slate, is a specialized task undertaken by only a handful of international firms. For a simple refinery structure, benchmark costs can be used without loss of accuracy.

Project Number: TA No. 8356-MYA

FINAL REPORT

APPENDIX 3: HOUSEHOLD ENERGY CONSUMPTION SURVEY

Prepared for

The Asian Development Bank

and

The Myanmar Ministry of Energy

Prepared by

IES Intelligent Energy Systems

in association with

MMIC MYANMAR INTERNATIONAL CONSULTANTS

ABBREVIATIONS

ADB	–	Asian Development Bank
CSO	–	Central Statistics Organisation
EMP	–	Energy Master Plan
FES	–	Fuel Efficient Stove
HH	–	Household
LIFT	–	The Livelihoods for Food Security Trust
NEMC	–	National Energy Management Committee
TA	–	Technical Assistance

CONTENTS

I. INTRODUCTION

1. As part of TA-8356, the Terms of Reference (TOR) requires the Consultant to “conduct the surveys on the use of energy in various sectors”. It is understood from the inception phase that the energy surveys were to focus on end-use energy consumption, which is consistent with the MOE’s perspective that end use energy consumption data has the greatest level of uncertainty.

2. The energy consumption surveys have the intent of enhancing our understanding of energy consumption trends in Myanmar, which in turn will enhance the level of confidence in the quality of the data that is used to inform the energy demand forecasts that underpin the Energy Master Plan (EMP). The surveys should also assist in being able to develop more accurate historical energy balances, which become the baseline for the energy sector projections.

3. Following an assessment of data availability with in the ministries, other previous survey work in Myanmar and a general consideration of where the energy survey work could best assist this project, the Consultant recommended in the Inception Report that the main focus areas of the energy consumption surveys be in the following areas:

- Rural and urban household (HH) energy consumption;
- Private industry energy consumption; and
- Commercial sector energy consumption.

4. Of the three areas identified above, the rural and urban HH energy surveys were identified to be the highest priority since they correspond the area for which the least amount of information is available. Furthermore, surveys of this nature take considerable time to plan and execute. Hence the focus of survey work during the initial stages of the project has been to focus on executing a rural and urban HH energy survey. The purpose of this discussion paper is to describe the present state of the urban and rural household survey work that is being undertaken.

5. This paper has been organised as follows:

- Section II provides a preliminary review of other survey work, the intent is to leverage any insights from previous work and understand the nature of any publicly available data sets that offer insights into rural and urban HH energy consumption trends in Myanmar;
- Section III then sets out the methodology that we have adopted for the HH energy consumption survey. Because this is a work in progress, we briefly touch upon the present state of field work execution;
- Appendix A provides a copy of the HH energy survey that was used; and
- Appendix B provides relevant supporting data from a previously conducted study.

6. It should be noted that this paper contains preliminary findings for discussion. At the time of writing the HH energy consumption surveys were ongoing and thus we can only present the data that was provided by the energy survey team as of 1 June 2014. We expect to be able to provide a far more comprehensive presentation of HH energy consumption trends at the draft report stage.

II. REVIEW OF PREVIOUS SURVEYS IN MYANMAR

A. Previous Work

7. A number of surveys have been recently undertaken in Myanmar that provides insight into energy consumption trends. It is important to briefly review the nature and scope of these surveys as the household survey that we have conducted can be thought to essentially complement these surveys and enhance our overall understanding of present energy consumption trends in Myanmar.

8. Two recent and relevant surveys that have been undertaken include: (i) The Livelihoods for Fuel Security Trust (LIFT) baseline survey, a joint funding effort by multiple donors[1] conducted in 2012 to provide a comprehensive assessment of rural households in general[2], and (ii) a MercyCorps Poverty Survey, which focused on the issue of Fuel Efficient Stoves (FES), and was conducted in 2011.

B. LIFT Baseline Survey

9. LIFT baseline survey's objective was to gain a better understanding of trends in the rural households of Myanmar. The Livelihoods for Food Security Trust (LIFT) conducted a survey covering 4,000 rural households to seek information concerning fuel use for cooking and lighting by residence zone and income deciles.

10. Methodology. The surveyed locations included the Hilly, Dry and Delta/Coastal agro-ecological zones of Myanmar. Four thousand households were chosen from 252 villages with probability proportional to their number of households. Specifically, eight-hundred households were randomly selected from each zone (coastal/delta, hilly and dry) 800 from Rakhine (Giri-affected areas), and 800 as a control. By income, the respondents were grouped into deciles (10 categories), ranging from earning less than Ks 25,000 to over Ks 300,000 per household per month.

11. Summary of key findings:

- Overall, only 7% of the sample households were connected to the electricity grid; ranging from maximum of 16% of households in the Hilly Zone to less than 1% of households in the Giri-affected areas. Similarly households from the Hilly Zone were most likely to be connected to a village generator (15.6%) or have their own generator (3.8%). By contrast households in Giri-affected areas were most likely to use candles for lighting (55%) and households in the Delta/Coastal Zone most likely to use a kerosene or oil lamp (60%). Households in the Dry Zone were the second most connected to the grid (11%) but most likely to share a generator with other households (11%).
- Á it can be expected, access to electricity either from the grid or generators (other than village generators) was correlated with level of household average monthly income. In general, the larger the household average monthly income the more likely the household

[1] The donors are Australia, Denmark, the European Union, the Netherlands, New Zealand, Sweden, Switzerland and the United Kingdom.

[2] Livelihoods and Food Security Trust (LIFT), "Baseline Survey Results", July 2012. Accessible at: http://www.lift-fund.net/downloads/LIFT%20Baseline%20Survey%20Report%20-%20July%202012.pdf.

had electricity from the grid, had its own generator or shared a generator with other households. Conversely the poorer the household the more likely it used candles or lamps for lighting.

- Sources of cooking fuel were similar between regions with a very high reliance on fuel wood. The use of fuel wood ranged from a low of 90% of households in the Delta/Coastal Zone to a high of 99% of households in Giri-affected areas.
- Firewood collection and sale was an important source of income for poor households. In some cases especially the Giri-affected villages the community had to travel long distances to collect fuel wood. These results suggest that community forestry, agroforestry and fuel efficient stoves may be important areas for support in some locations.

12. Appendix B has tabulated a number of extracts from the LIFT baseline survey.

C. MercyCorps Energy Poverty Survey (2011)

13. MercyCorps Energy Poverty Survey objective: The Energy Poverty Survey was conducted with a focus to analyse village households' energy consumption and a market for FES's.

14. Methodology: The samples were taken for 396 households from 18 villages (22 HHs each) in 22 village tracts of Laputta Township.

15. Results: The main findings of the survey are summarised for cooking, firewood collection and lighting in the following paragraphs.

16. Cooking:

- The majority of households (88%) use wood, either with open fire or "three-stone" method (69%) or with a fuel efficient stove (19%) for cooking and heating water. 10% use plain rice husk (not compressed into bricks). Other fuel types used by some households are charcoal (1%) and electricity grid (1%).
- The most preferred type of fuel for cooking is wood with FES (42% of total respondent households), followed by wood with open fire (22%), electricity grid (18%), charcoal (11%), and rice husk (5%).
- The reasons, stated by the households, for preferring wood-burning FES are as follows: (i) Convenient and easy to use, (ii) Wood is easier to buy and more affordable than charcoal, (iii) FES are less of a fire hazard and are safer for children, (iv) FES can reduce deforestation

17. Firewood collection:

- Overall, 61% of wood-fuel is purchased and 38% is collected. Significantly, 43% of the respondents buy 100% of firewood because there is no longer any wood collector in the household. An average of 233 hours per year is spent by a household for collecting the firework.

- Households get the firewood mainly from state land resources (reserve areas) (49%) and personal forest resources (29%). Some get it from community forest resources (12%) and privately held forest resources (4%).

18. Household Lighting:

- The majority of households (56%) use diesel lamps, followed by 29% using power from the electricity grid as the main fuel sources for lighting. Other fuel types used by some households are candle (9%), and battery (6%).
- The most preferred type of fuel for lighting is electricity grid (55% of total respondent households), followed by diesel lamps (25%), and battery-powered lamps (18%). The rest prefer solar (1%) and candle (0.3%).
- The common reasons, stated by the households, for preferring the electricity grid, diesel and battery are as follows: (i) Good quality lighting power, (ii) More affordable, (iii) Convenient and easy to use, (iv) Can use anytime, (v) More suitable for business and income generating work, (vi) Reduced fire hazard, (v) Can use for any social activities and (vi) Can use for education (studying at night)
- Households can afford an average of 3.8 hours of light per night although they would like 5 hours on average.

III. URBAN AND RURAL HOUSEHOLD ENERGY CONSUMTPION SURVEY DESIGN

D. Broad Design Parameters

19. A key constraint in undertaking the rural and urban HH energy consumption survey is time and budget. As noted, we have identified, collected and compiled as much of the relevant existing data sets that we have been able to locate, but we observe that they are not necessarily complete from a holistic energy consumption perspective; for example, electricity consumption data will not include other fuel inputs, similarly, the central statistics office data does not necessarily provide the type of coverage that would be ideal.

20. As such we need to complement the collection of existing data exercise with surveys that target the gaps in our knowledge and/or that can in some way confirm or enhance the quality of the data that already exists. For the rural and urban HH energy consumption survey, we have attempted to fill that gap. However, it should be noted that a key practical constraint that had to be satisfied in the design was being limited to 700 HH surveys. Furthermore, the level of detail in the surveys themselves needs to be carefully managed so that they can be quickly completed “on the fly”. Another important consideration is to ensure adequate coverage of different income brackets and trends within the different “fuel zones” of Myanmar.

21. In consultation with the national consultants who have a firmer grasp on what can be achieved and what areas can be readily accessed, we have arrived at the survey approach that is documented in Table III-1. Note that some of the regions can be covered with minimal barriers owing to the fact that the local government or community leaders already have experience in having surveys conducted their regions / townships. Other regions are more problematic as the local

government may oppose having the survey issued or may wish to have control over the questions asked. As such Table III-1 is essentially a "compromise" between all of the factors that have had to be taken into account in the design of the HH energy consumption.

Table III-1: Summary of Urban and Rural Household Energy Consumption Survey Approach

Region	No. of HHs	General Purpose Consumption (kWh)	Electrification Rate (%)	kWh / HH	Regional access?	Type and No. of Surveys Planned
Ayeyarwaddy	1,335,968	116,522	9%	267	Yes	Rural / 60
Rakhine	527,654	29,650	6%	285	Yes	Rural / 60
Sagaing	862,616	154,404	18%	640	No	-
Mon	340,971	92,945	27%	672	Yes	Rural / 60
Shan (south)	382,428	94,596	25%	678	Yes	Rural / 60
Bago (east)	556,540	124,615	22%	705	No	-
Tanintharyi	207,153	18,659	9%	709	No	-
Magway	770,123	113,214	15%	716	Yes	Rural / 60
Shan (north)	326,799	53,461	16%	721	Yes	Rural / 60
Kachin	217,309	48,094	22%	757	No	-
Kayar	47,514	17,396	37%	823	Yes	Rural / 60
Bago (west)	448,323	80,662	18%	929	No	-
Kayin	221,825	27,171	12%	954	Yes	Rural / 60
Shan (east)	131,549	19,637	15%	1,219	No	-
Naypyitaw	116,995	60,660	52%	1,247	No	-
Mandalay	1,060,762	311,876	29%	1,294	Yes	Urban & Rural / 80
Yangon	1,270,090	801,949	63%	1,757	Yes	Urban & Rural / 80
Chin	81,055	12,001	15%	2,293	Yes	Rural / 60
Total	**8,905,674**	**2,177,512**	**24%**	**1,219**	**No**	**Total / 700**

Source: Consultant

E. Household Energy Questionnaire Design

22. The questionnaire for the household energy consumption survey was designed with consideration of the results of the previous surveys by LIFT and MercyCorps. The focus was to gather information on fuel end-user patterns, which could supplement the previous findings in establishing an estimate of energy consumption by rural households.

23. The survey questionnaire consists of 14 parts (A to N), in detail as follows:

A. Household information: to gather information about the location and type of household including the size of the house and the number of occupants.

B. Household income and expenses: Covers the monthly income, expenses on different energy needs and the other household expenditure.

C. Household appliances: Information about appliances by purpose and fuel used, and the respondent's preference in terms of appliances' importance.

D. Energy uses – Cooking: Types of coking ovens, daily cooking duration, cooking fuel types, and quantity of fuel used in month.

E. Energy uses – Lighting: Types of lighting appliances, the time and duration of use, and main fuel sources.

F. Energy uses – Water heating: Types of appliances, duration of use and main fuel sources.

G. Total non-electricity fuel consumption: Information about quantities of different non-electricity types of fuel used by the household each month.

H. Electricity supply: Whether the household is connected to the power grid and (if yes) what purposes the electricity is used for.

I. Past energy usage: To compare the consumption between this and the last year.

J. Fuel source and usage: For enquiring whether the household pays for the fuel they need or gets any of it for free, purchases from market or gets the fuel delivered by someone else, what is the form of payment and how often it is made?

K. Generators: Information about whether the household has a generator and the features of the generator if they own one, including the fuel type and quantity consumed.

L. Motor vehicles: Whether the household has a vehicle, vehicle type and fuel type, quantity of fuel consumed, and how it is obtained.

M. Agriculture energy: Types of equipment and fuel used for farming activities.

N. Solar power: Whether the household has a solar panel installed.

24. A complete copy of the HH energy consumption is provided in Appendix A.

F. Approach to Survey Fieldwork

25. Prior to undertaking HH energy consumption survey the following was undertaken:

- The MOE provided an endorsement letter for the survey work and to also explain how the energy consumption results will feed into a process of national energy planning;
- An advocacy process then was required for each local / regional authority to get their buy-in and endorsement; and
- A survey team was formed and the national consultant leading the HH energy survey undertook a series of workshops to explain the survey forms and concepts. This is to

ensure that the energy survey team members fully understand the questions and to explain how to obtain the answers from those that are being surveyed.

26. The survey team has then travelled to the different regions listed in Table III-1 to conduct their fieldwork. For each region the process was as follows:

- The survey team met with the community leader and village volunteers for a consultation workshop, which involved explaining survey content and its objectives, which is extremely important to ensuring buy-in from the community leader – in general, it was explained that the survey is intended for national planning purposes and the community leader supported the initiative. An illustration of this occurring in the Ngaputaw Township, Ayeyarwaddy is illustrated in Figure III-1.
- The community leader then assisted the survey team in terms of the HH selection process in order to maximise the coverage of different income levels. Furthermore, volunteers within the community would be recruited to facilitate the survey team in conducting their field work. An illustration of this is given in Figure III-2.
- A basic strategy was devised to then carry out the HH survey in the village for the sample of HHs.
- The approach to taking the surveys was then generally perform a combination of door-to-door surveys or selected HH occupants were invited to a temporary office to come and fill out the survey. An example is illustrated in Figure III-3.
- Finally those completing the survey were provided with a small gift, as illustrated in Figure III-4.

27. The remaining part in the process is then for the survey team to compile the results of the surveys into spreadsheets to enable data analysis.

G. Actual numbers of surveyed regions and households

28. In total, 967 surveys were conducted in 11 regions across Myanmar. Table III-2 lists the regions and townships where the surveys took place; it also shows the number of surveyed households in each location. Geographical spread of the surveyed areas is showed in Figure III-5.

Table III-2: Summary of Urban and Rural Household Energy Consumption Survey Approach

No	Region	Township	Number of Surveyed HHs
1	Ayeyarwaddy Region	Ngaputaw	85
2	Magway Region	Magway	61
3	Mandalay Region	Kyaukpadaung / Mandalay	184
4	Yangon Region	Kyauktada / Dala	101
5	Shan state (North)	Thein Ni	69
6	Shan State (South)	Pekon	72
7	Kayah State	Demoso	61
8	Rakhine State	Taunggup	75
9	Chin State	Palatwa	95
10	Mon State	Chaung Sone	78
11	Kayin State	Hlaing Bwae	86
Total			**967**

Source: Consultant

Figure III-1: Meeting with community leader in Ngaputaw Township, Ayeyarwaddy

Source: Consultant's Energy Survey Team

Figure III-2: Training and workshop with volunteers in Ngaputaw Township, Ayeyarwaddy

Source: Consultant's Energy Survey Team

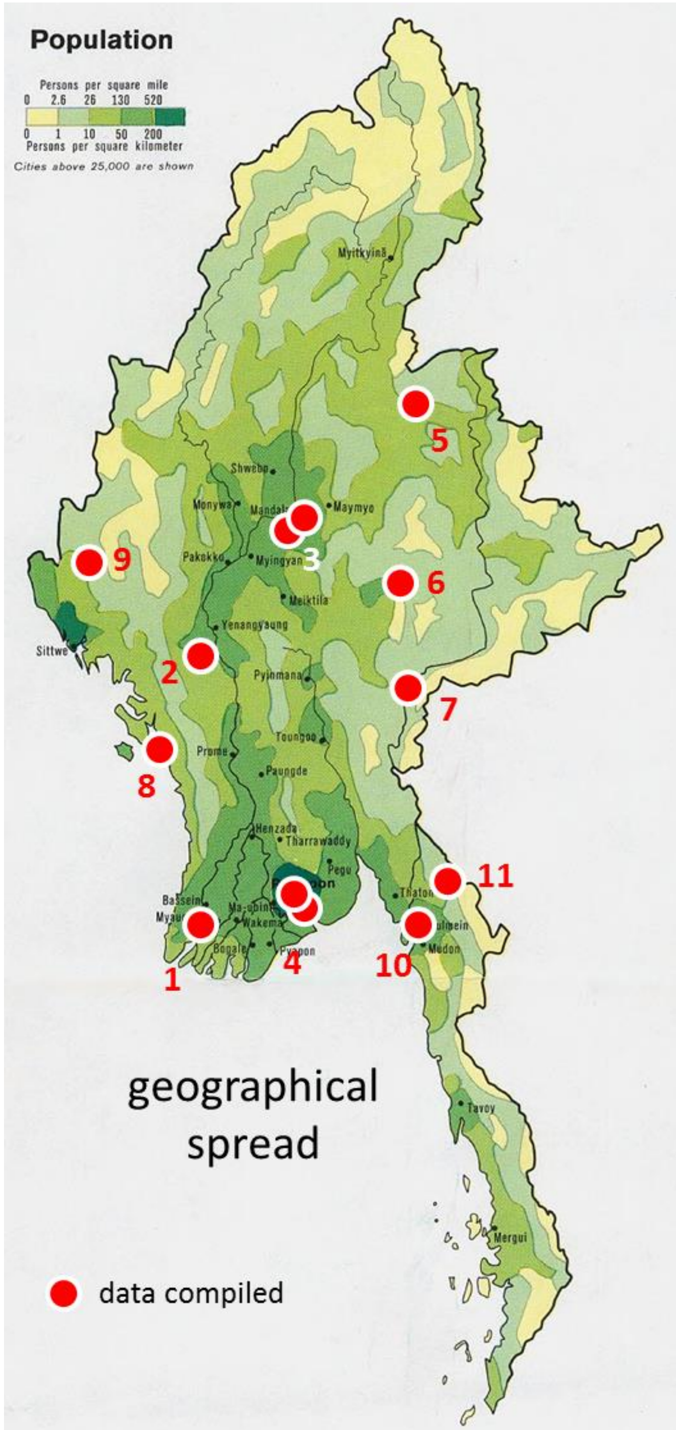
Figure III-3: Conducting the Survey in Ngaputaw Township, Ayeyarwaddy

Source: Consultant's Energy Survey Team

Figure III-4: Conducting the Survey in Ngaputaw Township, Ayeyarwaddy

Source: Consultant's Energy Survey Team

Figure III-5: Geographical Spread of the Surveyed Areas



Source: Consultant analysis

Appendix A:

Household Energy Consumption Survey

ADB – TA-8356 Energy Master Plan

Household Energy Consumption Survey

Purpose of this survey

The Ministry of Energy (MOE) is conducting a household energy survey in order to gain a better understanding of energy consumption patterns in Myanmar households. This survey is intended to collect data on the types and quantities of energy consumed in households in Myanmar. This information will be used by the MOE for the purpose of enhancing energy planning, with the longer-term objective being to enhance energy access in the country.

Your participation is important

This survey is conducted under the authority of the Ministry of Energy. However, completion of the survey is voluntary. The use of this survey will enhance the Ministry of Energy's understanding of household energy consumption and will assist in planning Myanmar's future energy needs, which is in the national interest.

Completion of the survey

Please complete this survey and return it to the person that issued it.

Details of person completing this survey

	Township
	Address / location of household
	Phone no.

Details of person issuing this survey

	Person issuing survey form
	Phone no.

Cover Page

A) Household Information

A1) Location of House: ☐

A2) Type of house location (tick one):

☐ City ☐ Town ☐ Village

☐ Farm ☐ Other, please specify:

☐

A3) Number of occupants: ☐ Number of people

A4) Number of rooms in house: ☐ Number of rooms

A5) Type of home (tick one):

☐ Single family detached house (a free standing house)

☐ Single family attached house (attached to one or more houses)

☐ An apartment building with a total of 2 to 4 units

☐ An apartment building with 5 or more units

☐ Other, please specify:

☐

A6) Area of property (floor space): ☐ ☐ Units of measure (Example: meters squared)

B) Household Income and Expenses

B1) Total Monthly Income: ______ Kyat

B2) Monthly Expenses:

(please tick those that are relevant and give the monthly spend)

Tick	Item	Monthly Spend	
	Electricity		Kyat
	LP gas		Kyat
	Batteries		Kyat
	Fuel Wood		Kyat
	Candles		Kyat
	Coal		Kyat
	Charcoal		Kyat
	Kerosene		Kyat
	Paraffin		Kyat
	Rice Husk		Kyat
	Petrol		Kyat
	Diesel		Kyat
	All other monthly expenditure		Kyat
	Total monthly household expenditure		Kyat

) **Household Income and Expenses**

C1) What are the main types of household appliances that you have and what are they used for?

	Cooking	Lighting	Space Cooling	Water Heating	Television	Refrigeration	Pumping	Other (please specify)
Electricity								
LP gas								
Paraffin								
Candles								
Torches								
Batteries								
Rice Husk								
Generator								
Other (please specify)								

C) Household Income and Expenses (cont.)

C2) Rank the appliances listed below in order of importance to you.

	Tick if you have the appliance	Rank the appliance in order from 1 (most important) to 9 (least important)
Lighting		
Water Heating (example: kettle)		
Rice Cooker		
Microwave Oven		
Toaster		
Refrigerator		
Freezer		
Radio		
Air Conditioner		
Pump		
Television		

D) Energy Uses: Cooking

D1) What of the type of oven used for cooking?

- ☐ 3 stone stove
- ☐ Fuel efficient stove
- ☐ Wood fire
- ☐ Coal stove
- ☐ Electric stove
- ☐ Rice husk stove
- ☐ LPG stove
- ☐ Charcoal stove
- ☐ Other, specify: ______

D2) How many hours per day do you use your stove/fire? ______ Hours

D3) What fuel do you use for cooking? ______

D4) How much of this fuel is used per month? ______ Quantity of fuel/month

E) Energy Uses: Lighting

E1) List the type of appliances used for lighting and their number

Tick Item:	Approx. Number:	Tick Item:	Approx. Number:
☐ Lantern		☐ Lp Gas Light	
☐ Incandescent light		☐ Candles	
☐ Fluorescent light		☐ Torch	
☐ LED lighting		☐ Other (please explain):	
☐ Compact Fluorescent Lamp (CFL)			

E2) How many hours a day are your lights turned on? ____________

E3) What is the main fuel used for lighting?

☐ LP gas ☐ Electricity ☐ Fire Wood ☐ Batteries

☐ Dung ☐ Kerosene ☐ Paraffin ☐ Candles

☐ Other – please explain: ____________

E4) Reason for using this fuel? ____________

E5) What hours of the day are the lights usually turned on?

____________ hours

☐ am to ☐ am

☐ pm to ☐ pm

F) Energy Uses: Water Heating (for washing)

F1) Type of appliance used for water heating?

☐ LP gas cooker ☐ Wick stove ☐ Pressure stove ☐ Electric stove

☐ Coal/wood stove ☐ Other – please specify ______

F2) What is the main fuel used for water heating?

☐ LP gas ☐ Electricity ☐ Fire Wood ☐ Dung ☐ Rice husk

☐ Other – please explain: ______

F3) How many hours a day do you use appliances for water heating? ______ Hours

G) Total Fuel (Non-Electricity) Consumption

G1) Provide information on how much fuel is used each month by specifying the type of fuel and what quantities of those fuels you use.

Type of Fuel	Tick if used	Quantity used	Unit	Specify, if other
LP Gas				
Fire wood				
Dung				
Kerosene				
Paraffin				
Candles				
Coal				
Charcoal				
Rise Husk				
Petrol				
Diesel				
Other				

G2) Compare consumption between winter and summer

Energy consumption is
- ☐ More in winter (or cold days) than in summer (or hot days)
- ☐ The same in winter (cold days) compared to summer (hot days)

H) Electricity Supply

H1) Is the house electrified? ☐ Yes ☐ No

H2) If yes, for how long? ☐ Years

H3) What is the electricity used for?

☐ Cooking ☐ Water heating for washing ☐ Space cooling ☐ Black & White TV

☐ Ironing ☐ Water heating (kettle) ☐ Colour TV ☐ Incandescent lights

☐ Candescent lights ☐ LED lighting ☐ Compact Fluorescent Lights (CFLs)

☐ Other – specify: ☐

I) Past Energy Usage

I1) This time last year, what was the household income? ☐ Kyat per month

I2) This time last year, what was your monthly fuel bill? ☐ Kyat per month

I3) Did you spend about the same amount on fuel last year as you do now? ☐ Yes ☐ No

I4) Do you use the same fuels now as you did last year? ☐ ☐

I5) If not, which fuels did you use this time last year?

☐ Paraffin ☐ Dung ☐ Fuel wood ☐ LP Gas ☐ Kerosene

☐ Candles ☐ Coal ☐ Rice husk ☐ Charcoal

☐ Other - specify ☐

J) Fuel Source and Usage

J1) I buy all the fuel I use ☐ ` Yes ☐ No

J2) Where do you buy your fuel?

- [ ] Someone delivers to home
- [ ] Purchase from market
- [ ] Other – please specify: ______

J3) From how many suppliers do you buy your fuel?

- [ ] Always the same supplier
- [ ] I purchase from: [ ] Suppliers (enter number)

J4) I get some of the fuel for free

- [ ] Yes
- [ ] No

J5) If you get some fuel for free please specify what and how much:

	Tick	Quantity	Unit	Specify (if other)
LP Gas				
Fire Wood				
Dung				
Kerosene				
Paraffin				
Candles				
Rise Hush				
Other				

J6) How do you pay for the fuel?

- [ ] In cash each time I buy
- [ ] In cash at the end of the week
- [ ] In cash at the end of the month
- [ ] In cash advance at the start of the month
- [ ] By cheque, credit card in advance
- [ ] By cheque, credit card at the end of the month
- [ ] In kind (in exchange for something else)
- [ ] Other, specify: ______

J7) What happens if you can't pay for your fuel?

- [ ] Supplier gives credit
- [ ] Supplier gives loan
- [ ] Obtain fuel from another supplier
- [ ] Borrow money from friends/relatives
- [ ] Borrow fuel from friends/relatives
- [ ] Avoid use of fuel
- [ ] Other, specify: ______

K) Generators

K1) Does the household have one or more generators? ☐ Yes ☐ No

IF "NO" THEN PLEASE SKIP THE REMAINING QUESTIONS ON THIS PAGE

K2) How many hours a day does the generator operate? ☐ pm/am to ☐ pm/am

If operating also in other hours, specify: ☐ pm/am to ☐ pm/am

☐ pm/am to ☐ pm/am

K3) What is the generator capacity? ☐ HP OR ☐ kVA

K4) What fuel does the generator use?

☐ Petrol ☐ Diesel ☐ LPG ☐ Other

K5) How many litres of fuel does the generator use each month?

☐ Petrol ☐ Diesel ☐ LPG ☐ Other

K6) How much does the fuel cost per litre? ☐ Kyat

L) Motor Vehicles

L1) Does the household have a vehicle? ☐ Yes ☐ No

IF "NO" THEN PLEASE SKIP THE REMAINING QUESTIONS ON THIS PAGE

L2) Vehicle type(s)

Tick Items:	Number:
☐ Mini Bus	☐
☐ Car - Sedan	☐
☐ Car - Wagon	☐
☐ 2-wheel	☐
☐ 3-wheel	☐
☐ Other	Details: ☐

L3) What is the main fuel used in your vehicle? ☐ Petrol ☐ Diesel ☐ LPG

Other – please explain: ☐

L4) I buy all the fuel I use ☐ Yes ☐ No

L5) Where do you buy your fuel? ☐ Someone delivers to home ☐ Purchase from market

☐ Other – please specify: ☐

L6) From how many suppliers do you buy your fuel? ☐ Always the same supplier

☐ I purchase from: ☐ Suppliers (enter number)

L) Motor Vehicles (cont.)

L7) I get some of the fuel for free ☐ Yes ☐ No

L8) If you get some fuel for free please specify what and how much:

	Tick	Quantity	Unit	Specify (if other)
Petrol				
Diesel				
LPG				
CNG				
Bio-diesel				
Bio-ethanol				
Other				

L9) How do you pay for the fuel?

- ☐ In cash each time I buy
- ☐ In cash at the end of the week
- ☐ In cash at the end of the month
- ☐ In cash advance at the start of the month
- ☐ By cheque, credit card in advance
- ☐ By cheque, credit card at the end of the month
- ☐ In kind (in exchange for something else)
- ☐ Other, specify:

L10) What happens if you can't pay for your fuel?

- ☐ Supplier gives credit
- ☐ Supplier gives loan
- ☐ Obtain fuel from another supplier
- ☐ Borrow money from friends/relatives
- ☐ Borrow fuel from friends/relatives
- ☐ Avoid use of fuel
- ☐ Other, specify:

M) Agricultural Energy

M1) Is the property part of an agricultural area or farm? ☐ Yes ☐ No

IF "NO" THEN PLEASE SKIP THE REMAINING QUESTIONS ON THIS PAGE

M2) Area of farm ☐ ☐ Unit (example: meter squared)

M3) What crops do you grow?

Crop type	Area used

M4) What livestock do you keep?

Livestock Type	Number of Animals

M5) Is there heavy equipment used on the farm? ☐ Yes ☐ No

M6) Specify equipment:

Equipment Type	Powered by? (e.g. petrol, diesel, wind)

M7) Irrigation

a) Do you own a portable diesel or petrol engine for pumping water? ☐ Yes ☐ No

b) What is its horsepower? ☐

c) On average how many hour in the engine used each day? ☐

M) Agricultural Energy (cont.)

M8) Provide information on how much fuel is used on your farm each month by specifying the types of fuels and what quantities of those fuels you use:

Type of Fuel	Tick if used	Enter quantity that is used	Unit (Kg, litre, number, etc.)	Specify, if other
LP Gas				
Petrol				
Diesel				
Other #1				
Other #2				

M9) What was your monthly fuel bill for farm equipment this time last year? Kyat per month

M10) Did you spend about the same amount of fuel last year as you do now? Yes No

M11) If not, what is your fuel bill for farm equipment this year? Kyat per month

M12) If not, which fuel did you use this time last year?

Paraffin	Dung	Fuel wood	LP Gas	Kerosene
Candles	Coal	Rice husk	Charcoal	Petrol
Diesel	Other, specify:			

N) Solar Power

N1)	**Does the household have a solar panel for electricity?**	Yes	No
	IF "NO" THEN PLEASE SKIP THE REMAINING QUESTIONS ON THIS PAGE		
N2)	**How many solar panels?**		
N3)	**If you know the size (in Watts) pf the solar panel please specify:**		
N4)	**Approximate cost per solar panel**	Kyat	

Appendix B:

LIFT Baseline Survey Extracts

Table III-3: Frequency of Household Energy Sources for Lighting, by Region[3]

Source	Hilly	Dry	Delta / coastal
Electricity from the grid	16%	11%	4%
Village generator	16%	9%	1%
Own generator	4%	1%	3%
Shared generator*	6%	11%	6%
Lamp (kerosene/oil)	16%	2%	60%
Candle	24%	18%	16%
Other	19%	48%	10%

** Shared generator with other households*

Table III-4: Frequency of Household Sources of Energy for Lighting, by Income Level[4]

Monthly household income range (Ks)	Electricity from grid	Village generator	Own generator	Shared generator	Lamp (kerosene / oil)	Candle	Other
Less than 25,000	4%	7%	0%	2%	31%	33%	23%
25,001-50,000	5%	7%	1%	4%	34%	27%	23%
50,001-75,000	6%	8%	1%	8%	24%	27%	26%
75,001-100,000	10%	8%	3%	13%	18%	26%	22%
100,001-150,000	15%	3%	3%	15%	15%	26%	24%
150,001-200,000	17%	8%	10%	15%	14%	11%	26%
200,001-250,000	24%	20%	5%	12%	17%	10%	12%
250,001-300,000	23%	9%	9%	6%	11%	11%	31%
Over 300,000	29%	7%	19%	16%	9%	10%	10%
Don't know / nil response	10%	0%	0%	5%	14%	43%	29%

[3] Extracted from LIFT Baseline Survey 2012 – Table 121, p. 71.
[4] Extracted from LIFT Baseline Survey 2012 – Table 122, p. 72.

Figure III-6: Plot of Household Energy Sources for Lighting, by Region

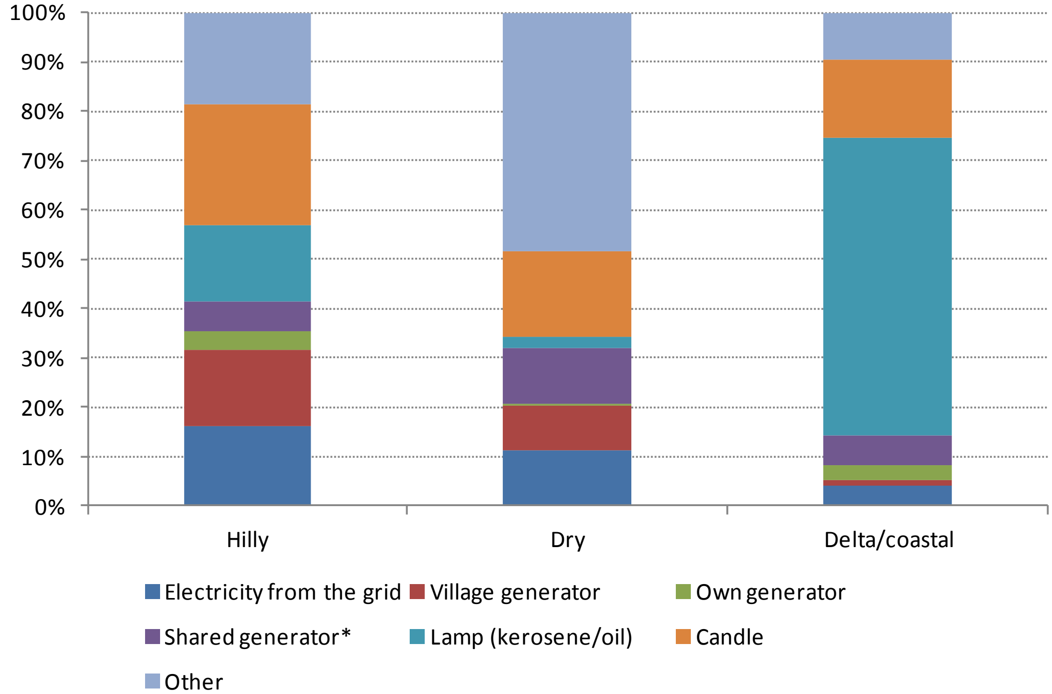


Figure III-7: Plot of Household Sources of Energy for Lighting, by Income Level

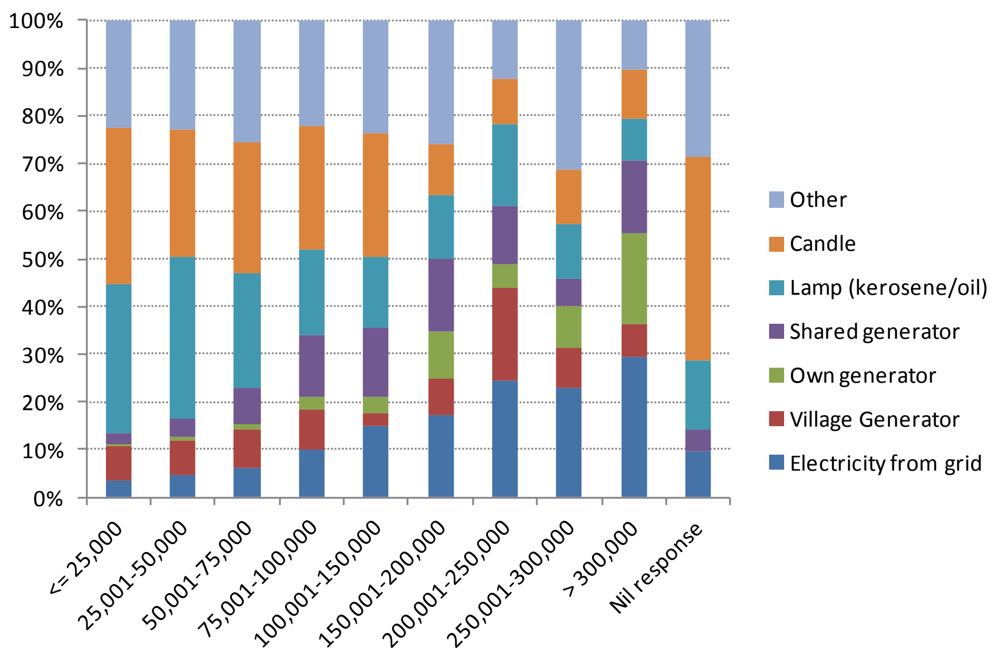
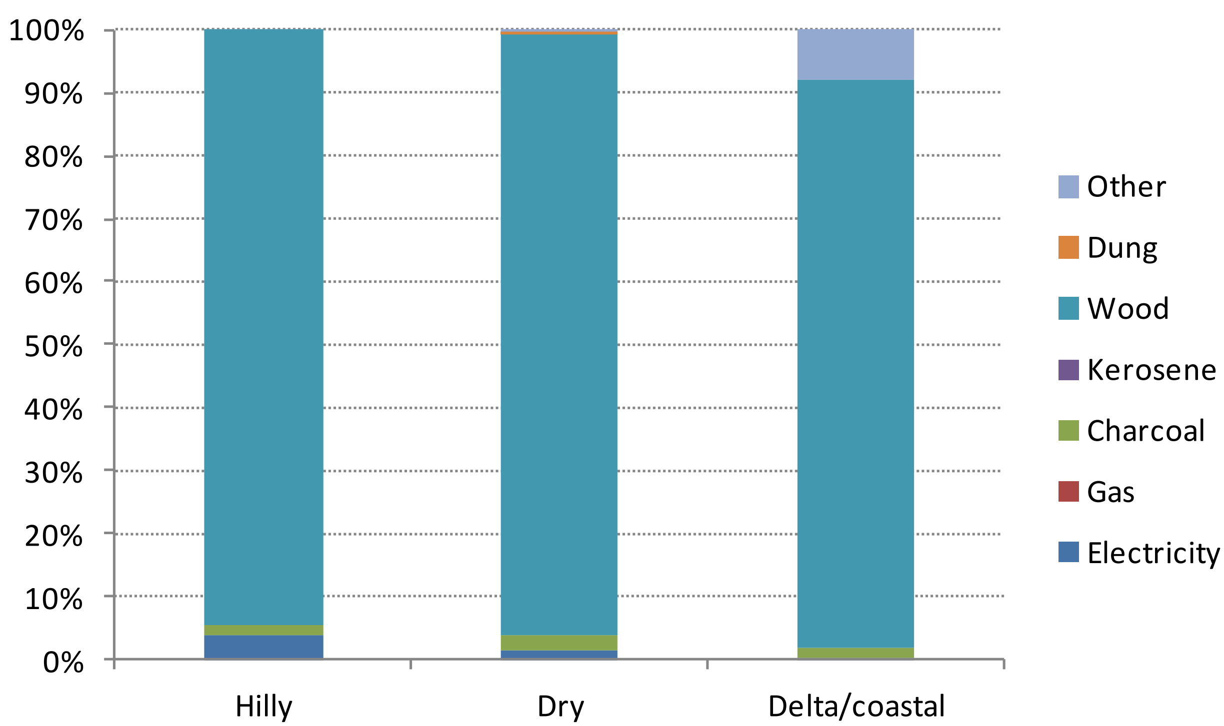


Table III-5: Statistics on Rural Household Cooking, by Region[5]

Frequency of Energy Source for Cooking			
Source	**Hilly**	**Dry**	**Delta / coastal**
Electricity from the grid	4%	1%	0%
Village generator	0%	0%	0%
Own generator	1%	2%	2%
Shared generator*	0%	0%	0%
Lamp (kerosene/oil)	95%	96%	90%
Candle	0%	1%	0%
Other	0%	0%	8%
Frequency of Rural Households using Fuel Efficient Wood Stoves			
Percentage of households using Fuel Efficient Wood Stoves	9%	13%	14%

Figure III-8: Plot of Household Energy Sources for Cooking, by Region



[5] Extracted from LIFT Baseline Survey 2012 – Table 123a and Table 123b, p. 72.

Project Number: TA No. 8356-MYA

FINAL REPORT

APPENDIX 4:
NATIONAL POWER EXPANSION PLAN

Prepared for

The Asian Development Bank

and

The Myanmar Ministry of Energy

Prepared by

IES
Intelligent Energy Systems

in association with

MMIC
MYANMAR
INTERNATIONAL
CONSULTANTS

I. DISCLAIMER

1. This chapter reproduces the report from a separate study on Myanmar's power sector for which ADB engaged the services of ADICA. IES was not involved in scoping, executing or in any stakeholder consultations in this study. IES takes no responsibility for the accuracy, sources of material used and will not be liable in any way for any of its findings. Where necessary we have drawn on the findings of the power sector study in the body of the energy master plan report with references to this appendix.

Project Number: TA No. 8356-MYA

NATIONAL POWER EXPANSION PLAN

A study conducted for The Asian Development Bank and The Myanmar Ministry of Energy

Prepared by

ADICA®
"The Ultimate in Strategic Analysis"

16 October 2015

AUTHORS

Bruce P. Hamilton
John Irving
U. Soe Myint

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TABLE OF CONTENTS

I. INTRODUCTION

A. BACKGROUND

1. During the **6th Electric Power Sector Working Group Meeting** organized in Nay Pyi Taw, on 23rd February 2015, key government participants and development partners (DPs) discussed recent activities in the energy and power sector. In his opening remarks, Deputy Minister H.E. U Aung Than Oo stressed the need for consistency in concurrent energy and power sector master plans being formulated for relevant Myanmar Government agencies[1] with Asian Development Bank (ADB), Japan International Cooperation Agency (JICA), and World Bank Group (WBG) support, including:

a) Myanmar Energy Master Plan (EMP) – ADB
b) National Electricity Master Plan (NEMP) – JICA
c) Myanmar National Electricity Plan – WBG

2. ADB's EMP study has completed energy surveys and data collection, historical energy balances, primary energy resource assessments, and energy demand forecasts. The remaining chapters of the EMP concern recommendations on supply options and investment requirements in the power sector as well as finalization of total primary energy supply forecasts and the final energy balance reflecting fuel requirements identified from the optimal generation expansion plan.

3. As JICA's NEMP study finalized generation expansion plans using the Wien Automation System Planning model (WASP IV) for a high growth case[2], ADB decided and MOE/NEMC agreed to complete the remaining chapter using WASP IV to analyze a medium growth case[3], to provide robust results and ensure consistency between the EMP and NEMP studies.

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[1] The relevant Myanmar Government agencies include: MOE (Ministry of Energy); MOEP (Ministry of Electric Power); NEMC (National Energy Management Committee)

[2] In the NEMP study, a macro and top-down approach is applied to project electric power demand growth rate by multiplying elasticity and GDP growth rate. The elasticity of 1.4 is used based on its analysis of the average elasticity during 2002-2010 and GDP growth rate for 2013-2030 is assumed as (i) for a high growth case, 8.7% which is the growth rate of 2011-2012, and (ii) for a low growth case, 6.4% based on IMF Economic Outlook. As a result, peak demand in 2030 is projected as 14.5 GW for its high growth case and 9.1 GW for its low growth case. The NEMP study analyzed the high growth case as a base case for preparing power expansion plan.

[3] In the EMP study, a micro and bottom-up approach is applied to project electric power demand by examining historical consumption and demand trends of households, commercial, agriculture, and industrial sectors for each of the 14 states and regions of Myanmar. Electricity consumption drivers are for (i) households: cooking , lighting, water heating, TV / entertainment and cooling services; (ii) commercial: restaurants, hotels, retail space, office space, (iii) agriculture: tractors, power tillers, harvesters, irrigation pumps, and (iv) industry: production of steel, non-metallic minerals (bricks, cement, glass), non-metallic metals (copper, zinc, tin), food (sugar), electronics, plastics, ice storage, food processing, automotive parts, footwear and garments. GDP growth rate for 2013-2030 is assumed as (i) for a high growth case, 9.5% which is the highest growth rate forecasted from ADB's Country Diagnostic Study (CDS, 2014), (ii) for a medium growth scenario, 7.1% which is the government growth forecast, and (iii) for a low growth scenario, 4.8% which is the lowest growth rate forecasted from ADB's CDS. As a result,

B. OBJECTIVES

4. The objective of this study is to apply the WASP IV model in identifying an optimum generation expansion plan for the Myanmar power sector, and determine the associated system costs, fuel requirements, and environmental emissions under the EMP's medium growth case.

5. Study assumptions are to be consistent with the NEMP, while making adjustments based on additional information and insights provided by relevant Myanmar Government agencies, DPs, and project personnel.

6. The ADB consultants for this engagement are tasked with: (i) Assembling all required data for executing WASP IV in consultation with the MOEP and JICA consultants; (ii) Developing plausible generation expansion scenarios in consultation with the MOE, MOEP, NEMC and ADB; (iii) Executing WASP IV to identify the optimum generation expansion plan under the EMP's medium growth case; and (iv) Drafting this chapter on the National Power Expansion Plan as part of the EMP report.

II. MODELING APPROACH

C. DESCRIPTION OF THE WASP MODEL

7. WASP is an optimization model for examining medium- to long-term development options for electrical generating systems. The International Atomic Energy Agency (IAEA) distributes and maintains this model, which is the public domain's most frequently used program for expansion planning of electrical generating systems.

8. The latest version of the model, called WASP IV, is designed to find the economically optimal generation expansion policy for an electric utility system. It utilizes *probabilistic estimation* of system production costs, unserved energy cost, and reliability, a *linear programming technique* for determining optimum dispatch policy satisfying exogenous constraints on environmental emissions, fuel availability and electricity generation by groups of plants, and the *dynamic programming method of optimization* for comparing the costs of alternative system expansion policies.

9. WASP IV permits finding the optimal expansion plan for a power generating system over a period of up to thirty years, within constraints given by the planner. The optimum solution is evaluated in terms of minimum discounted total costs. Each possible sequence of power unit additions that meets the specified constraints is evaluated by means of a cost function (i.e., the "objective function") represented by the following equation:

peak demand in 2030 is projected as 13.4 GW for a high growth case, 9.5 GW for a medium growth case, and 6.8 GW for a low growth case. The EMP study is using the medium growth case as a base case for estimating fuel requirements from all sectors including power sector.

$$B_j = \sum_{t=1}^{T} [\, \bar{I}_{j,t} - \bar{S}_{j,t} + \bar{L}_{j,t} + \bar{F}_{j,t} + \bar{M}_{j,t} + \bar{O}_{j,t} \,]$$

Where:

I is the depreciable capital investment costs
S is the salvage value of investment costs
L is the non-depreciable capital investment costs
F is the fuel costs
M is the non-fuel operation and maintenance costs
O is the cost of the energy-not-served

10. WASP IV comprises the following eight modules.

11. **LOADSY** (Load System Description): Processes information describing the peak loads and load duration curves for up to 30 years. The objective of LOADSY is to prepare all the demand information needed by subsequent modules.

12. **FIXSYS** (Fixed System Description): Processes information describing the existing generating system. This includes performance and cost characteristics of all generating units in the system at the start of the study period and a list of retirements and "fixed" additions to the system. Fixed additions are power plants already committed and not subject to change.

13. **VARSYS** (Variable System Description): Processes information describing the various generating units to be considered as candidates for expanding the generating system.

14. **CONGEN** (Configuration Generator): Calculates all possible year-to-year combinations of expansion candidate additions that satisfy certain input constraints and that, in combination with the existing system, can adequately meet the electricity demand.

15. **MERSIM** (Merge and Simulate): Considers all configurations put forward by CONGEN and uses probabilistic simulation of system operation to calculate the associated production costs, unserved energy, and system reliability for each configuration. The module also calculates plant loading orders and maintenance schedules.

16. **DYNPRO** (Dynamic Programming Optimization): Determines the optimum expansion plan as based on previously derived operating costs along with input information on capital cost, economic parameters, unserved energy cost, and system reliability constraints.

17. **REMERSIM** (Re-MERSIM): Simulates the configurations contained in the optimized solution. By providing a detailed output of the simulation, REMERSIM allows the user to analyze particular components of the production-cost calculation, such as unit-by-unit capacity factors and fuel requirements for each season and hydroelectric condition.

18. **REPROBAT** (Report Writer of WASP): Writes a report summarizing the results for the optimum power system expansion plan.

III. STUDY PARAMETERS

D. Reference Information

19. In the process of defining study assumptions, the ADB consultants reviewed technical information available in the documents listed below.

- *Myanmar Energy Sector Assessment, Strategy and Roadmap*, ADB, Mar 2015
- *Institutional Strengthening of National Energy Management Committee in Energy Policy and Planning*, ADB TA-8356 MYA, 2015
- *The Project for Formulation of the National Electricity Master Plan in the Republic of the Union of Myanmar*, Newjec Final Report (for MOEP), JICA, Dec 2014
- WBG Comments on Myanmar National Electricity Master Plan, Oct 2014
- *Myanmar Energy Master Plan*, Intelligent Energy Systems/Myanmar International Consultants (IES/MIC) Draft Report (for NEMC), ADB TA 8316 MYA, Dec 2014
- *Myanmar National Electricity Plan*, Earth Institute, Columbia University & Castalia Strategic Advisors report (for MOEP), World Bank TA, Oct 2014
- *Preparing the Power Transmission and Distribution Improvement*, Project Final Report by Fichtner, ADB - TA 8342 MYA, Oct 2014
- *Capacity Building Support for Project Identification*, Final Report by SMEC, Aug 2014

20. The first five documents include referenced planning reports, along with issues raised by others relating to the overall energy and power planning process. The last three reports provide information more relevant to transmission planning issues. Additional data relevant to the study was provided by MOEP and Newjec.

E. Study Period

21. Consistent with the NEMP, the reference case and all sensitivity analyses performed in this study span a period of 18 years from 2013 through 2030.

F. Discount Rate

22. Consistent with NEMP study assumptions, this study uses a discount rate of 10% in the present worth discounting of costs to the reference year of 2013.

G. Reserve Margin

23. Reserve Margin and Loss of Load Probability (LOLP) are common approaches for introducing reliability into system planning. The Asia Pacific Energy Research Centre (APERC) reports while

Peninsular Malaysia and Singapore require a 30 percent reserve margin, other areas in the region define reliable service as maintaining an LOLP no greater than 1 day per year.[4]

24. System reserve margin is a reliability criteria used in WASP IV. When simulating system operations in each year, WASP IV identifies the "critical period" as the period of the year for which the difference between corresponding available generating capacity and peak demand has the smallest value. For a configuration of unit additions to satisfy the reserve margin constraint, the installed capacity in the critical period must lie between the given minimum and maximum reserve margins above the peak demand in the critical period of the year.

25. A minimum reserve margin of 20% is applied in this study. As countries in the region typically use a value between 15% to 30% for planning purposes, sensitivity analyses should be performed to evaluate the costs and benefits of a more or less stringent reserve margin constraint.

H. Cost of Energy Not Served

26. Energy not Served (ENS) is the amount of energy required by the system, which cannot be supplied by the generating equipment existing in the system. WASP IV computes ENS in GWh.

27. The planner can specify a cost of unserved energy (CUE) in US$/kWh representing the average loss to the economy due to unsupplied electrical energy. Approaches for estimating CUE include the *production loss method* – relating the value of lost production to the loss of power supply, the *captive generation method* – estimating the extra cost incurred by consumers that must rely on alternative or back-up power generation, and the *willingness to pay method* – determining a value based on surveys of consumer's willingness to pay for a reliable and uninterrupted electricity supply.

28. In the absence of reference evaluations of estimated outage costs to consumers in Myanmar, the ADB consultant chose to remain consistent with the NEMP and apply a CUE of 1.0 US$/kWh in this study. In comparison, a survey of the production loss for twelve major industries in Bangladesh reports the associated average cost of unplanned outages at 0.83 US$/kWh.[5]

I. Loss of Load Probability

29. LOLP is defined as the percentage of time during which the system load exceeds the available generating capacity of the system. For example, a cumulative failure duration of one (1) day per year has a corresponding LOLP of 0.274%.

30. As noted in a recent ADB study report, the security and reliability requirements in Lao PDR specify a maximum cumulative failure duration for the generating system of 5.5 days/year, while

[4] **Electric Power Grid Interconnections in the APEC Region**, APERC, 2004
[5] **Energy Strategy Approach Paper Annexes**, Sustainable Development Network, WBG, Oct 2009

planning criteria in Thailand call for LOLP not more than 24 hours per year.[6] The planning criteria adopted by the Korea Power Exchange (KPX) calls for a maximum LOLP of 12 hours per year.[7]

31. This study specifies a maximum system LOLP of 24 hours per year to be met beginning in 2025.

IV. ELECTRICITY DEMAND

J. DEMAND FORECAST

32. As part of the EMP, IES/MMI prepared an electricity demand forecast using a "bottom-up" approach for agriculture, industry, transport and household power and energy demand. The report examines energy trends by region and by customer class and aggregates the results, including system losses, to provide one consolidated electricity demand forecast for the country. The EMP postulates three demand forecasts: high (11.7% CAGR), medium (9.6% CAGR) and low (7.6%CAGR).

33. The medium demand forecast used in this study is displayed in Table 1. Under this forecast the country's electricity demand is expected to grow from 1,853 MW in 2013 to 9,465 MW in 2030. The annual energy generation requirement grows in line with demand to reach 58,336 GWh in 2030.

Table 1: EMP Medium Demand Forecast [8]

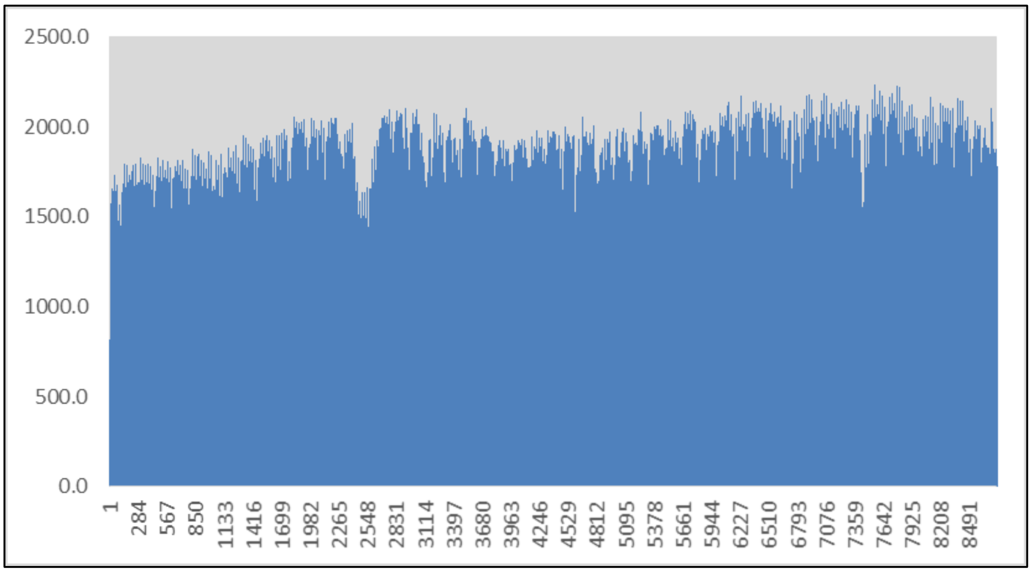
Year	Peak Load		Generation	
	MW	AGR	GWh	AGR
2013	1,853		11,421	
2014	2,045	10.36%	12,604	10.36%
2015	2,336	14.23%	14,398	14.23%
2016	2,592	10.96%	15,975	10.96%
2017	2,861	10.38%	17,633	10.38%
2018	3,155	10.28%	19,445	10.28%
2019	3,465	9.83%	21,356	9.83%
2020	3,806	9.84%	23,458	9.84%
2021	4,180	9.83%	25,763	9.83%
2022	4,588	9.76%	28,278	9.76%
2023	5,026	9.55%	30,977	9.55%
2024	5,501	9.45%	33,905	9.45%
2025	6,019	9.42%	37,097	9.42%
2026	6,589	9.47%	40,610	9.47%
2027	7,211	9.44%	44,444	9.44%
2028	7,900	9.55%	48,691	9.55%
2029	8,661	9.63%	53,381	9.63%
2030	9,465	9.28%	58,336	9.28%

[6] **Final Technical Report on Harmonization Study for ASEAN Power Grid**, ADB TA 7893 REG, Sep 2013
[7] **The 5thBasic Plan for Long-term Electricity Supply and Demand (2010-2024)**, KPX, 2010
[8] IES/MIC, **Myanmar Energy Master Plan**, ADB TA 8316 MYA, Dec 2014

K. Seasonal Load Characteristics

34. In order to better capture the variability in system load characteristics and hydro power plant operations, the ADB consultant developed the EMP WASP IV database enable the model to operate with 12 periods per year.

35. At the advice of staff of the MOEP National Control Center, hourly systems loads for 2014, as represented in Figure 1, were used to define seasonal load characteristics as input to the EMP power expansion study.



Source: MOEP

Figure 1: 2014 Hourly System Loads

36. The PRELOAD program was used to read in the 8760 values of hourly system load and create representative period load duration curves and peak load ratios required as input to WASP. The computed period peak load ratios are displayed in Table 2.

Table 2: Period Peak Load Ratios

Period	1	2	3	4	5	6	7	8	9	10	11	12
Peak Load Ratio	0.82	0.87	0.92	0.94	0.94	0.89	0.92	0.94	0.97	0.98	1.00	0.97

Source: Consultant, MOEP Hourly Loads 2014

V. EXISTING GENERATING SYSTEM

37. In 2013, Myanmar produced 11,681 GWh of electricity, the bulk of which was from hydropower (73%), followed by gas-fired (25%) and coal-fired (2%) generation. (source: MOEP)

38. As of March 2013, actual installed capacity for Myanmar is 2,259 MW of hydropower, 363 MW of gas power plants, and one 30 MW coal power plant. (source: JICA Study Team)

39. Though in 2013 the installed capacity provides a %70 reserve margin over annual peak load, system reserve drops significantly in the dry season when hydropower plants receive insufficient water to generate at full capacity.

L. THERMAL POWER PLANTS

40. Existing gas-fired plants depend on domestic supply from the Yadana, Zawtika, and Shwe gas fields. As noted in Table 3, up to 261 bbtud (billion British Thermal Units per day) of gas is currently allocated to the power sector. This maximum volume is not expected to be increased until commissioning of the new gas field of M-3 in 2019. Imported gas and high speed diesel is considered for use in satisfying potential near term supply shortages.

Table 3: Domestic Gas Supply for Electricity through 2018 (bbtud)

Year	2013	2014	2015	2016	2017	2018
Supply for Electricity	201	248	261	261	261	261

Source: Newjec, NEMP 2014

41. The allocation of domestic gas supply to the power sector is expected to increase following commissioning of the new gas field of M-3 in 2019.

Table 4: Domestic Gas Supply for Electricity after Commissioning of M-3 Gas Field (bbtud)

Year	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Supply for Electricity	272	309	302	311	306	291	259	246	235	221	219	215

Source: Newjec, NEMP 2014

42. As the NEMP reports Yadana gas has a substantially lower heating value than gas from the other fields, the EMP power expansion plan includes a separate category of fuel type for Yadana gas.

43. This study uses the fuel characteristics listed in Table 5 and operational characteristics for existing thermal power plants (TPPs) in Table 6, both of which are consistent with assumptions for the NEMP.

Table 5: Thermal Fuel Types

Type	Description	Fuel Cost ($/mmbtu)	Heat Value
1	COAL	domestic 1.93 imported 4.26	5000 (kcal/kg)
2	Yadana NGAS	11.19	6099 (kcal/m^3)
3	NATURAL GAS	11.19	8581 (kcal/m^3)
4	High Speed Diesel	19.40	10146 (kcal/kg)
5	SOLAR		
6	WIND		

Source: Consultant, Newjec NEMP 2014

Table 6: Characteristics of Existing Thermal Power Plants

Thermal Plant Type	Number of Units	Min. Operationg Level	Max Generating Capacity	Heat Rate	Fuel Cost	Fuel Type	Spinning Reserve	Forced Outage	Scheduled Maintenance	Maintenance Class Size	Fixed O&M	Variable O&M
		(MW)	(MW)	(kcal/kWh)	(c/million kcal)		(%)	(%)	(Day)	(MW)	($/kW-month)	($/MWh)
GT	1	48	95	4504	4442	3	0	7	37	95	1.9	2
GTCC	1	136	271	4389	4442	2	0	7	37	275	2.3	1
COAL	1	15	30	2545	765	1	0	7	32	60	2.5	2
GT2	0	29	93	4463	4442	3	0	7	37	394	1.9	2
GTCC	0	216	481	2182	4442	2	0	7	37	449	2.3	1
COAL	0	60	120	2450	765	1	0	7	32	120	2.5	2
GEHD	0	25	50	1886	7696	4	0	7	37	50	1.9	2

Source: Consultant, Newjec NEMP 2014

44. Rehabilitations to enhance the operating efficiency of several existing gas- and coal-fired power plants are scheduled to be completed by 2017.

M. HYDRO POWER PLANTS

45. With support of the MOEP National Control Center and Department of Electric Power (DEP), ADB consultants received detailed data on historical operations of existing hydro power plants in Myanmar, including: hydro power plant (HPP) classification, available installed capacity, energy storage capacity, and monthly generation and average capacity.

46. MOEP classifies HPPs in the following categories:

(i) HPPs not related to reservoir
(ii) HPPs to be operated at accord of the Irrigation Department
(iii) HPPs to be operated by Reservoir water.

47. The EMP WASP IV database is defined with the following two hydro types:

- Type HYD1 includes HPPs of category (i) or (ii) (i.e., run-of-river or irrigation controlled)
- Type HYD2 includes HPPs of category (iii) (i.e., reservoir storage).

48. Characteristics for existing HPPs are displayed in Table 7. Based on these values, HPPs of type HYD1 have an average capacity factor of 58%, while the average for HPPs of type HYD2 is 36%. The average capacity factor for the combined set of existing HPPs is 42%.

49. In addition to the 2,259 MW of installed hydropower capacity in 2013, 165 MW is added with the Phu Chuang, Nancho, Baluhaung-3, and Chipwinge-1 HPPs are commissioned in 2014, and 66 MW with commissioning of Chipwinge-2 in 2015.

Table 7: Characteristics of Existing Hydropower Plants

WASP Hydro Type	Sr.	Hydro Category	Name of Hydroelectric Power Station	Installed Capacity	Start of Operation	Actual available Capacity	Storage Capacity	Montly Generation (GWh) in 2013											
		Storage Irrigation Run-of-River		(MW)	Year	(MW)	(GWh)	1	2	3	4	5	6	7	8	9	10	11	12
HYD2	1	S	Ba Luchang No.1	28	1992	28	28	19.7	17.8	19.4	19.2	19.2	18.7	18.5	11.5	7.7	8.4	9.8	16.3
HYD2	2	S	Ba Luchang No.2	168	1974	168		106.7	96.3	105.3	103.8	103.5	101.1	99.7	61.7	39.9	44.4	50.8	89.8
HYD1	3	I	Kinda	56	1985	56		0.0	4.6	11.1	10.1	0.0	0.0	0.0	0.0	2.4	2.4	11.1	2.2
HYD1	4	I	Sedawgyi	25	1989	25		3.8	3.5	7.8	9.0	7.1	7.7	4.9	8.9	16.2	11.1	13.5	6.3
HYD1	5	R	Zawgyi No1	18	1995	18		4.8	4.0	3.9	3.4	3.8	5.6	5.5	10.0	9.8	10.7	9.0	6.6
HYD1	6	I	Zawgyi No2	12	1998	12		1.3	3.0	6.4	6.2	4.1	4.5	0.2	0.0	1.2	1.8	3.9	2.1
HYD2	7	S	Zaungtu	20	2000	20	20	1.0	0.9	1.5	1.3	0.7	5.7	9.9	12.0	11.5	8.4	5.2	1.1
HYD1	8	I	Thapanseik	30	2002	30		0.2	1.9	5.5	5.1	4.1	4.5	7.5	5.6	7.4	7.8	15.3	0.1
HYD2	9	S	Mone	75	2004	75	75	14.7	15.7	14.7	10.0	4.0	9.9	17.5	37.4	44.1	43.3	25.0	9.0
HYD2	10	S	Paunglaung	280	2005	280	280	41.0	36.6	25.9	39.8	30.4	33.4	35.3	69.3	66.9	72.6	72.8	68.1
HYD2	11	S	Yenwe	25	2007	25	25	6.4	8.2	10.5	11.7	11.9	12.2	10.8	0.6	0.1	0.1	0.0	0.0
HYD2	12	S	Kabaung	30	2008	30	30	6.9	6.6	6.8	8.9	12.5	14.2	8.0	0.3	0.1	0.3	0.2	1.6
HYD1	13	R	Shweli	600	2008	300		170.7	142.3	151.6	166.4	214.0	188.3	212.4	145.3	132.2	143.5	155.6	183.1
HYD1	14	R	Keng Tong	54	2008	54		31.4	26.8	25.6	22.9	24.0	26.8	34.3	27.8	25.9	33.7	36.8	38.2
HYD2	15	S	Yeywa	790	2010	790	790	168.4	154.6	165.9	160.8	103.9	127.7	155.2	326.1	324.5	344.2	316.0	232.4
HYD2	16	S	Shwegyin	75	2011	75	75	17.5	19.7	18.9	22.1	15.6	11.1	18.5	23.6	29.3	31.2	14.1	5.8
HYD1	17	R	Dapein No.1	240	2011	19		0.0	0.0	0.0	0.5	1.8	2.3	2.3	2.3	2.3	2.2	2.1	2.2
HYD2	18	S	Kun	60	2012	60	60	19.2	24.2	32.1	37.8	35.1	24.0	10.6	0.9	0.2	2.3	14.6	8.0
HYD1	19	I	Kyee On Kyee Wa	74	2012	74		16.3	15.5	18.4	13.5	10.2	14.8	16.8	37.4	41.2	45.8	30.3	8.7
HYD2	20	S	Thauk Ye Khat	120	2013	120	120	24.8	13.1	16.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10.0	12.3
2013	HYD1	R & I				588	0	229	202	230	237	269	254	284	237	239	259	278	250
	HYD2	S				1,671	1,503	426	394	418	415	337	358	384	543	524	555	518	444
	TOTAL					2,259	1,503	655	595	648	652	606	612	668	781	763	814	796	694
	A		Phu Chaung	40	2014	40	0												
	B		Nancho	40	2014	40	0												
	C		Baluhaung - 3	52	2014	52	0												
	8		Chipwinge-1	33	2014	33	0												
2014	HYD1	R & I				165	0	74	60	55	81	56	42	76	35	42	64	56	55
	8		Chipwinge-2	66	2018	66	0												
2018	HYD1	R & I				66	0	18	20	27	14	18	19	2	25	37	24	32	19

Source: Consultant, MOEP Operations Statistics 2014

VI. CANDIDATE PLANTS FOR FUTURE SYSTEM EXPANSION

50. Given the abundant energy resources in Myanmar, the EMP power expansion study considered a range of generation options, including: hydro, fossil fuel based thermal, wind and solar power. A large number of factors including cost of development, operation and maintenance costs, technical operational characteristics, impact on system reliability, and environmental effects were evaluated in order to consider the suitability of these candidates for system expansion.

N. THERMAL POWER PLANTS

51. The operational characteristics for candidate thermal power plants in Table 8 are consistent with assumptions in the NEMP. This includes equipping new Gas Engine and Gas Turbine plants to run on either gas or high speed diesel.

Table 8: Candidate Thermal Power Plant – Operational Characteristics

Thermal	Min. Operating Level	Max Generating Capacity	Heat Rate	Fuel Cost	Fuel Type	Spinning Reserve	Forced Outage	Schedule Maintenance	Maintenance Class Size	Fixed O&M	Variable O&M
	(MW)	(MW)	(kcal/kWh)	(c/million kcal)		(%)	(%)	(Day)	(MW)	($/kW-month)	($/MWh)
GT-N	25	50	2765	natural gas 4442 diesel oil 7696	3 or 4	0	7	37	50	1.9	2.0
GTCN	125	250	1700	4442	3	0	7	37	250	2.3	1.0
GE-N	25	50	1886	natural gas 4442 diesel oil 7696	3 or 4	6	7	37	50	1.9	2.0
COAN	250	500	2000	1690	1	0	7	32	250	2.5	2.0

Source: Consultant, Newjec NEMP 2014

52. An effort was made to harmonize capital cost assumptions between the EMP and NEMP with additional advice from the WBG. The capital cost for Gas Engine and Coal-fired plants are from the NEMP, while the value for Gas Turbine Combined Cycle (GTCC) is from IES. In addition, the capital cost for Gas Turbines was reduced from the original NEMP value in response to comment from the WBG. Thermal power plant capital cost assumptions for this study are presented in Table 9.

Table 9: Candidate Thermal Power Plant – Capital Cost

Thermal	Capital Cost	Plant Life	Construction Time
	(2013 US$/kW)	years	years
GT	653	25	2.5
GTCC	918	25	3.5
GE	890	25	2.5
COAL	2,222	25	5

Source: Consultant, Newjec NEMP 2014, IES EMP 2015, and WBG review

53. Air pollutant emission rates in Table 10 were obtained from the referenced generation technology document prepared by Black & Veatch[9] and are used in this study.

Table 10: Thermal Power Plant – Emission Rates

Thermal	Emission Rate (lb/mmbtu)			
	SO_2	NO_x	PM10	CO_2
GT	0.0002	0.033	0.006	117
GTCC	0.0002	0.0073	0.0058	117
COAL	0.055	0.05	0.011	215

Source: Black & Veatch, NREL Technology Review 2012

O. HYDRO POWER PLANTS

54. As noted in the NEMP, Myanmar has over 100 GW of hydroelectric reserves.

55. Newjec staff consulted with MOEP to identify a list of thirty-eight (38) candidate HPPs for the NEMP, along with the associated installed capacity, first possible year of operation, and prioritized sequence of hydro developments considering distribution of HPPs with respect to load centers and transmission, economic, social and other factors. This same set of 38 HPPs, with a total available capacity for Myanmar of 6,328 MW, are included as candidates in the EMP power expansion study.

56. With support of the MOEP DEP and Department of Hydroelectric Power Planning (DHPP), ADB consultants developed representative values of monthly generation, average available capacity, and energy storage capacity (where applicable) for candidate HPPs. Operational and cost parameters for these candidates are listed in Table 11.

57. Consistent with NEMP assumptions, due to limited availability of information on the estimated cost of HPP candidates, an average value of $2,000 US$/MW developed by Newjec in consultation with MOEP applies to all HPP candidates in the EMP power expansion study.

[9] Black & Veatch, **Cost and Performance Data for Power Generation Technologies**, National Renewable Energy Laboratory, 2012

Table 11: Candidate HPP – Operational and Cost Parameters

Sr.	Hydro Type	HPP Name in WASP	Name of Hydroelectric Power Station	Location Region/State	Overnight Capital Cost (mUS$/MW)	Available Capacity (MW)	Monthly Generation (GWh)											
							1	2	3	4	5	6	7	8	9	10	11	12
E		UPAU	Upper Paunglaung	Bago	2,000	140	42	40	46	46	43	40	34	45	51	51	49	37
P		DAPO	Dapain (only supply)	Kachin	2,000	101	31	29	33	33	31	29	24	33	37	36	36	27
37		MOWA	Mong Wa	Shan (S)	2,000	50	15	14	16	17	15	14	12	16	18	18	18	13
H		UKEN	Upper Kengtawng	Shan St (S)	2,000	51	15	15	17	17	16	15	12	16	18	18	18	14
O		NGOT	Ngotchaung		2,000	16.6	5	5	5	5	5	5	4	5	6	6	6	4
Q		PROJ	Projects		2,000	79	24	23	26	26	24	23	19	25	29	29	28	21
D		UBAL	Upper Baluchaung	Bago	2,000	30.4	9	9	10	10	9	9	7	10	11	11	11	8
G		THAH	Thahtay	Rakhine St	2,000	111	34	32	36	37	34	32	27	36	40	40	39	29
I		UYEY	Upper Yeywa	Shan St (N)	2,000	280	85	80	92	92	86	81	67	90	101	101	99	74
M		MPAU	Middle Paunglaung	Mandalay	2,000	100	30	29	33	33	31	29	24	32	36	36	35	26
R		DEED	Dee Doke		2,000	66	20	19	22	22	20	19	16	21	24	24	23	17
J	HYD2	SHW3	Shweli - 3	Shan St (N)	2,000	1,050	318	299	345	347	324	303	253	339	379	379	371	278
L		UBU	Upper Bu	Magway	2,000	150	45	43	49	50	46	43	36	48	54	54	53	40
S		KKHA	Keng Kham		2,000	6	2	2	2	2	2	2	1	2	2	2	2	2
9		DAP2	Dapein - 2	Kachin	2,000	84	25	24	28	28	26	24	20	27	30	30	30	22
T		MYEY	Middle Yeywa	Bago	2,000	320	97	91	105	106	99	92	77	103	116	115	113	85
U		USED	Upper Sedawgyi		2,000	64	19	18	21	21	20	18	15	21	23	23	23	17
K		BAWG	Bawgata	Bago	2,000	160	48	46	53	53	49	46	38	52	58	58	57	42
10		GAWL	Gawlan	Kachin	2,000	50	15	14	16	17	15	14	12	16	18	18	18	13
33	HYD2	SHW2	Shweli - 2	Shan (N)	2,000	260	79	74	85	86	80	75	63	84	94	94	92	69
34		KTON	Keng Tong	Shan (S)	2,000	64	19	18	21	21	20	18	15	21	23	23	23	17
35		WATA	Wan Ta Pin	Shan (S)	2,000	17	5	5	5	5	5	5	4	5	6	6	6	4
36		SOLU	So Lue	Shan (S)	2,000	80	24	23	26	26	25	23	19	26	29	29	28	21
15	HYD2	UTHA	Upper Thanliwn (Kunlong)	Shan (N)	2,000	700	212	200	230	231	216	202	168	226	253	253	247	185
40	HYD2	NKHA	Nam Kha	Shan (S)	2,000	100	30	29	33	33	31	29	24	32	36	36	35	26
38		KYAN	Keng Yang	Shan (S)	2,000	20	6	6	7	7	6	6	5	6	7	7	7	5
39		HEKU	He Kou	Shan (S)	2,000	50	15	14	16	17	15	14	12	16	18	18	18	13
20	HYD2	TANI	Taninthayi	Taninthayi	2,000	300	91	86	99	99	93	87	72	97	108	108	106	79
12		HKAN	Hkan Kawn	Kachin	2,000	80	24	23	26	26	25	23	19	26	29	29	28	21
16,17	HYD2	NAMA	Naopha, Mantong	Shan (N)	2,000	713	216	203	234	235	220	206	171	230	257	257	252	189
13		TONG	Tongxinqiao	Kachin	2,000	170	51	48	56	56	52	49	41	55	61	61	60	45
14		LAWN	Lawngdin	Kachin	2,000	300	91	86	99	99	93	87	72	97	108	108	106	79
46	HYD2	DUBA	Dun Ban		2,000	130	39	37	43	43	40	38	31	42	47	47	46	34
48		NKHO	Nam Khot		2,000	25	8	7	8	8	8	7	6	8	9	9	9	7
42		NATA	Nam Tamhpak (Kachin)	Kachin	2,000	100	30	29	33	33	31	29	24	32	36	36	35	26
44		NATU	Namtu		2,000	100	30	29	33	33	31	29	24	32	36	36	35	26
45		MOYO	Mong Young		2,000	45	14	13	15	15	14	13	11	15	16	16	16	12
47	HYD2	NALI	Nam Li		2,000	165	50	47	54	54	51	48	40	53	60	60	58	44

Source: Consultant, MOEP Operations Statistics 2014, and Newjec NEMP 2014

P. RENEWABLE GENERATION OPTIONS

58. With estimated reserves of 365 TWh/year from wind and 52,000 TWh/year from solar[10] and the strong emphasis renewable energy receives in the National Energy Policy Myanmar, this study investigated the viability of large-scale renewable energy projects by evaluating wind and solar energy candidate projects in the context of the least-cost generation expansion plan.

59. IES consultants analyzed wind speed and solar irradiation estimates in order to understand geographical dispersion of RE potential in the country. As illustrated in Figures 2 & 3, the analysis suggests that: (i) solar is better located with respect to the transmission system and distance to major load centres, and (ii) wind potential is generally in less favorable locations further away from existing transmission.

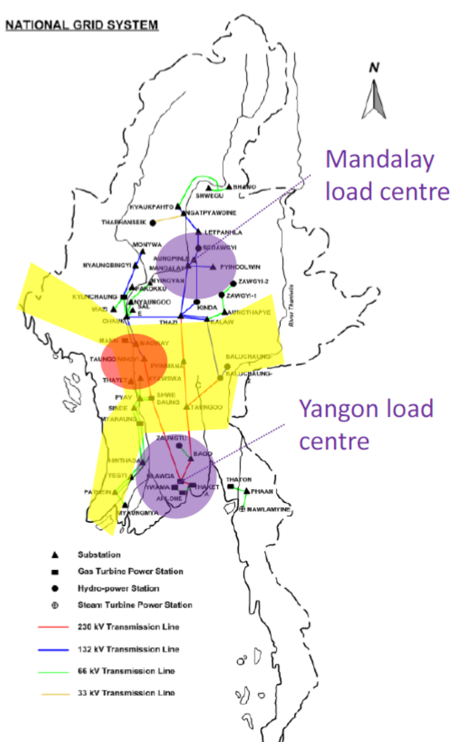


Figure 2: Areas with High Solar Potential

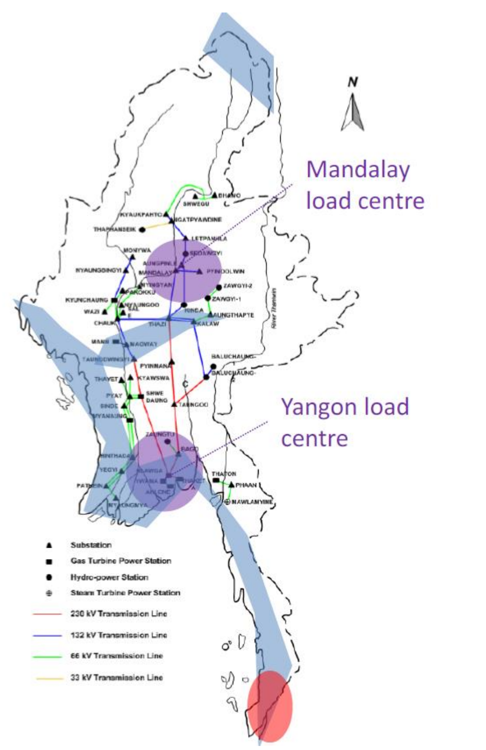


Figure 3: Areas with Significant Wind Potential

Source: IES, EMP 2015

60. ADB undertook a study on renewable energy potential in Myanmar.[11] This assessment, study and roadmap effort developed estimates of full-load hours of generation for solar PV and wind energy converters at different sites throughout the country. Study results were used to estimate annual forced outage rates for renewable candidates in the EMP power expansion plan.

[10] Source: MOE (2013), ADB (2012) and Japan Electric Power Information Center (2012) documents.
[11] H.-W. Boehnke, **ASR Report**, TA-8356 Myanmar 2014

Table 12: Estimated Annual Outage Rate for Solar PV in Myanmar

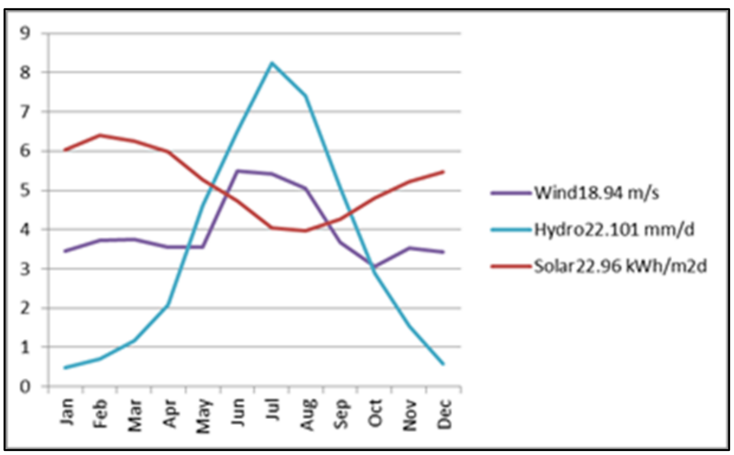
Location	Myitkyina	Mandalay	Magwey	Sittwey	Yangon	Dawei
G kWh/m²d	4.507	5.048	5.138	4.736	4.694	4.844
E kWh/kWp	**1532**	1716	1746	1610	1596	1647
Outage Rate (%)	82.5	80.4	80.1	81.6	81.8	81.2

Source: H.-W. Boehnke, ASR Report, ADB TA-8356 Myanmar 2014

61. Based on the outage rate estimates for a variety of sites listed in Table 12, the EMP power expansion study assumes an average annual forced outage rate of 81.3% for solar PV candidates.

62. According to members of the ADB ASR study team, global wind data suggests Myanmar has a few sites where wind speed reaches 6 m/s. For these sites, an estimate of available power was developed assuming wind energy converter operating at a height of 50m. Based on results of this analysis, the EMP power expansions study assumes an average annual forced outage rate of 71.4% for wind candidates.

63. Another interesting observation from the renewable energy study, as illustrated in Figure 4, is that the strong seasonal variations of solar, wind, and hydro energy potential complement each other over the year.



Source: Consultant, IES EMP 2015

Figure 4: Season Variation of Solar, Wind and Hydro

64. While the WASP IV model was originally designed to analyze conventional thermal and hydroelectric generation options, planners have employed a number of special unit representations to analyze renewables. The most common approach is to represent renewable generation candidates as thermal power plants, which enables the planner to: (i) analyze viability of solar and wind generation in an expansion plan without having to specify a predefined scenario, (ii) produce an accurately accounting of annual renewable generation (through specification of planned maintenance and force outage rate) and cost (through specification of capital cost and fixed O&M), and (iii) evaluate the impact of renewables on system reliability. Others have commented on the merits of this type of approach to

modeling renewable energy resources in long-term planning models, including the following quote from the referenced National Renewable Energy Laboratory (NREL) publication:

> *If time-of-day power delivery information is not available, modeling a time-dependent resource as a generating unit with constant capability and an appropriate forced outage rate may yield a reasonable approximation. The benefit of modeling the resource as a generating unit is that many utility planning models [such as WASP] have probabilistic algorithms for addressing generating unit unavailability attributable to random equipment failures. This feature could be used to reflect the uncertainty associated with renewable power delivery. In some models, [like WASP] unit unavailability is specified by a forced outage rate - the percentage of time that a unit is expected to be unavailable. Other models (notably those of a chronological nature) allow a user to model a unit's availability by specifying probability distributions for the time between outages and the time it may take to restore the unit to service. In renewable resource modeling, any of these availability features could be used to represent the renewable generation that would be curtailed because of equipment failure (usually a minor factor) or lack of wind or sunshine (the major factor that limits wind and solar resource generation).*[12]

65. For the EMP power expansion study, renewable energy options are represented with the operational characteristics listed in Table 13.

Table 13: Candidate Renewables – Operational Characteristics

Renewables	Min. Operationg Level	Max Generating Capacity	Heat Rate	Fuel Cost	Fuel Type	Spinning Reserve	Forced Outage	Scheduled Maintenance	Maintenance Class Size	Fixed O&M	Variable O&M
	(MW)	(MW)	(kcal/kWh)	(c/million kcal)		(%)	(%)	(Day)	(MW)	($/kW-month)	($/MWh)
SOLAR	1	50	0	0	5	0	81.3	10	50	2.0	0.0
WIND	1	100	0	0	6	0	71.4	10	50	3.3	0.0

Source: Consultant, H.-W. Boehnke ASR Report, ADB TA-8356 Myanmar 2014

66. When simulating system operation for a configuration of unit additions that includes a 50 MW solar PV candidate with a forced outage rate of 81.3%, the WASP IV model reflects that the PV candidate operates only 18.7% of the time. For the remainder of time, when the solar PV unit is not generating, the full system load must be satisfied by other units or result in increased cost of unserved energy and a higher loss of load probability.

67. Capital cost assumptions for candidate renewables are listed in Table 14. The estimated cost of 1.8 US$/W for solar PV in Myanmar is on advice of the WBG. As the cost of solar PV continues to decline due to learning curve and mass production effects, with reference to the Black & Veatch generation

[12] RCG/Hagler, Baily, Inc., **Modeling Renewable Energy Resources in Integrated Resource Planning**, NREL, 1994

technology report,[13] this study applied a scaling factor to reduce the cost of PV by 5.5% in 2020, and another 5.4% in 2025.

Table 14: Candidate Renewables – Capital Cost

Renewables	Capital Cost (2013 US$/kW)	Plant Life years	Construction Time years
SOLAR	1,800	20	2
WIND	1,782	20	2

Source: Consultant, WBG Review Comments and IES EMP 2015

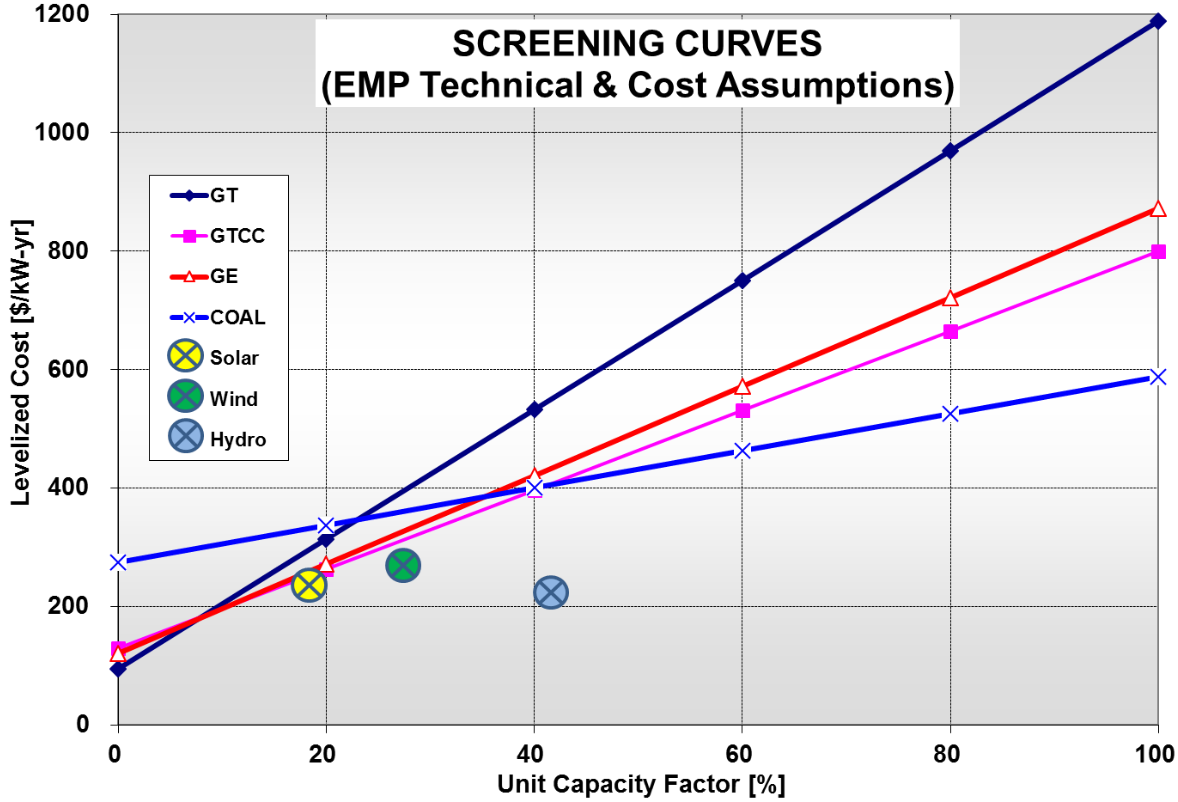
VII. POWER EXPANSION PLANNING PROCESS

Q. Preliminary Screening of Generation Options

68. A preliminary screening exercise was performed to chart the economic competitiveness of expansion candidates as a function of their technology utilization. This approach is used to develop initial insights into the relative competitiveness of generation options over a range of technical and cost assumptions before carrying out the expansion planning study.

69. The Screening Curve diagram in Figure 5 shows the levelized generation cost expressed in US$/kW-yr calculated at different capacity factors for all candidates using a discount rate of 10% and technical and cost parameters for described above. As an initial indication, the diagram points to hydro candidates (with average capacity factor of 42%) being most competitive, while solar appears more economic than wind. In comparing the dispatchable thermal power plants, Gas Turbine has an advantage when dispatched to operate at a low capacity factor, GTCC performs well within the capacity factor range of 10% to 35%, and COAL has an advantage over other thermal candidates for base load generation.

[13] Black & Veatch, **Cost and Performance Data for Power Generation Technologies**, NREL, 2012

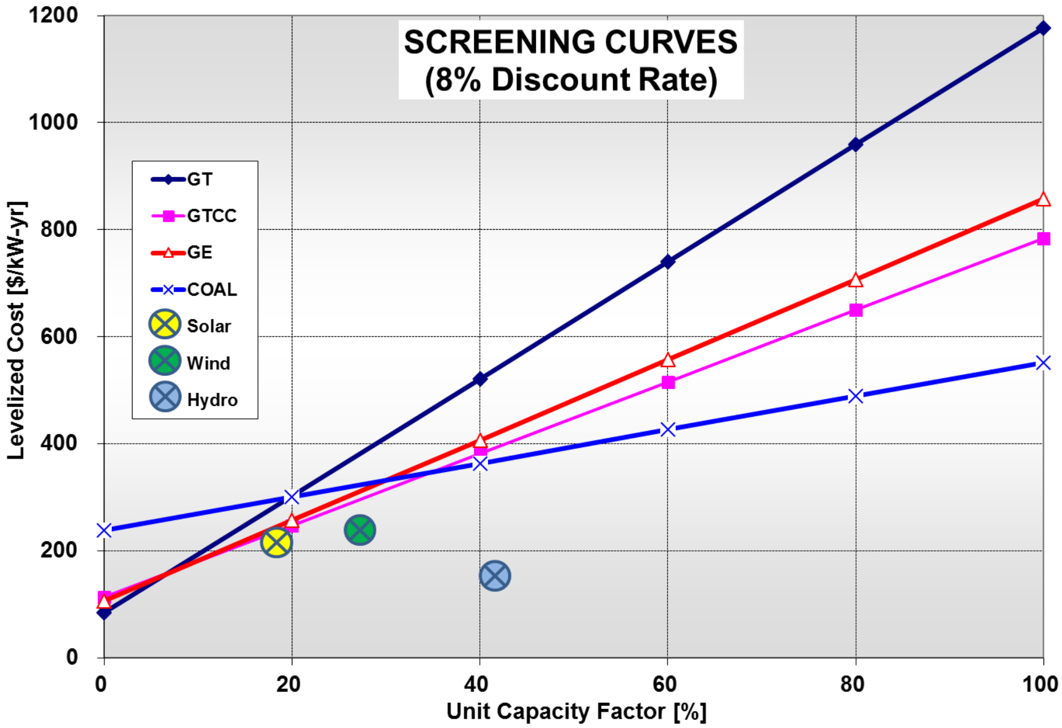


Source: Consultant

Figure 5: Screening Curves for Expansion Candidates - EMP Study Assumptions

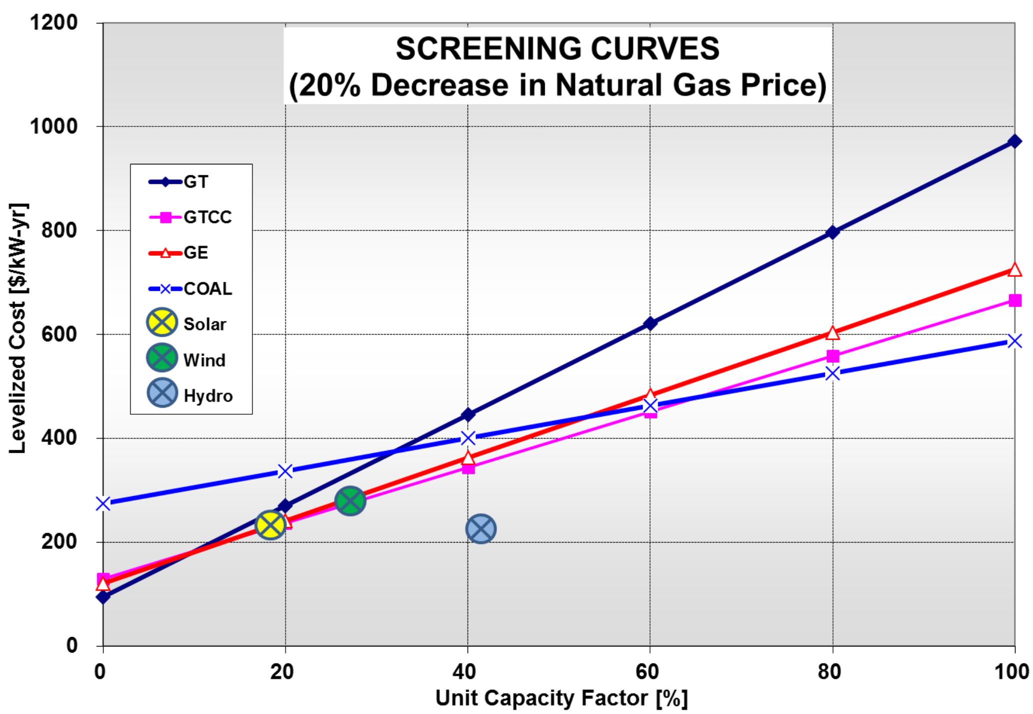
70. Note that screening curves provide a very rough estimate of candidate competitiveness and do not account for many factors, such as existing generation mix, price escalation, environmental constraints, forced outage rates, and system reliability.

71. The following diagrams illustrate the impact of reducing the discount rate to 8% (Figure 6), or decreasing natural gas price by 20% (Figure 7) on plant competitiveness.



Source: Consultant

Figure 6: Screening Curves for Expansion Candidates - Discount Rate of 8%



Source: Consultant

Figure 7: Screening Curves for Expansion Candidates - Natural Gas Price Decrease of 20%

R. BENCHMARKING MODEL SIMULATION VS SYSTEM OPERATIONS

72. After assembling the WASP IV database for the EMP power expansion study and running the model, a validity check was performed to compare the generation mix reported by the WASP simulation against actual system operations in 2013. WASP IV model simulated results are presented in Table 15 and actual system operation statistics received from MOEP are presented in Table 16.

Table 15: WASP IV Simulated Results (MWh)

	NEMC-EMP Myanmar Only		
Period	Hydro	Gas	Coal
1	655,000	148,000	20,400
2	596,000	243,200	20,400
3	648,000	282,500	20,400
4	652,000	292,300	20,400
5	606,000	359,100	20,400
6	612,000	337,400	20,400
7	668,000	286,500	-
8	780,000	169,800	20,400
9	763,000	215,500	20,400
10	814,000	173,200	20,400
11	796,000	163,300	20,400
12	694,000	242,100	20,400
Total	8,284,000	2,912,900	224,400
	11,421,300		

Source: Consultant

Table 16: Actual System Operations (MWh)

	MOEP Actual Including Export		
Month	Hydro	Gas	Coal
Jan	630,040	225,422	24,774
Feb	594,998	210,256	13,114
Mar	659,482	278,571	16,744
Apr	685,622	208,497	16,643
May	629,492	278,542	17,486
Jun	626,444	285,619	16,018
Jul	690,901	294,447	14,254
Aug	812,727	232,556	18,587
Sep	825,385	203,714	11,032
Oct	870,771	211,691	-
Nov	829,618	223,133	-
Dec	734,607	278,125	12,393
Total	8,590,086	2,930,573	161,045
	11,681,704		

Source: MOEP Operations Statistics

73. While recognizing that the actual system operation statistics include an amount of hydro generated electricity for exports and the WASP simulation focuses exclusively on electricity generation for Myanmar, there is a tight correlation between the seasonal generation mix for the simulated results and actual values.

74. In the WASP simulation for 2013, hydropower is dispatched with an average capacity factor of 44%, while coal plants averaged 85%, existing GTCC 81% and Gas Turbines 38%. In 2013, no additional generation was required from new GTCC power plants.

VIII. LEAST COST POWER SYSTEM EXPANSION PLAN

S. OPTIMUM POWER EXPANSION PLAN

75. This section presents model results for the least cost power expansion plan developed under the EMP's medium growth case and assumptions described above.

76. The capacity mix associated with the Myanmar power sector in 2013 is provided in Table 17. In contrast, the resulting capacity mix in 2030 for the least cost expansion plan is provided in Table 18.

Table 17: Actual Capacity Mix for Myanmar Power System in 2013

Plant Type	Installed Capacity in 2013	
	MW	%
Gas	866	27%
Coal	30	1%
Hydro	2259	72%
Renewables	0	0%
Total	3155	

Source: MOEP

Table 18: Least Cost Expansion Plan - Capacity Mix in 2030

Plant Type	Installed Capacity in 2030	
	MW	%
Gas	2374	15%
Coal	2620	16%
Hydro	8818	55%
Renewables	2300	14%
Total	16112	

Source: Consultant Analysis

77. The schedule of capacity additions for the least cost expansion plan is provided in Table 19. The timing of commercial operation for committed power plants through 2016 is according to the implementation schedule reported in the NEMP.

Table 19: Least Cost Strategy - Power Expansion Plan

Existing Plants	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Combined Cycle	271	271	271	271	481	481	481	481	481	481	481	481	481	481	481	481	481	481
Gas Turbine	95	95	95	95	93	93	93	93	93	93	93	93	93	93	93	93	93	93
Coal	30	30	30	30	120	120	120	120	120	120	120	120	120	120	120	120	120	120
Hydropower	2259	2424	2424	2424	2424	2490	2490	2490	2490	2490	2490	2490	2490	2490	2490	2490	2490	2490
Annual Fixed Capacity (MW):	2655	2820	2820	2820	3118	3184	3184	3184	3184	3184	3184	3184	3184	3184	3184	3184	3184	3184
Candidate Plants																		
Gas	500	400	450	350														100
Coal											500	500		500		500		500
Hydro			101	50	191	126	491	1266	410	224	310	161	820	50	1093	470	355	210
Solar													200	50	450	100	750	750
Wind																		
Annual Capacity Additions (MW):	500	400	551	400	191	126	491	1266	410	224	810	661	1020	600	1543	1070	1105	1560
Total Capacity Additions:	500	900	1451	1851	2042	2168	2659	3925	4335	4559	5369	6030	7050	7650	9193	10263	11368	12928
Total Supply Capacity	3155	3720	4271	4671	5160	5352	5843	7109	7519	7743	8553	9214	10234	10834	12377	13447	14552	16112
Renewable Capacity (MW)	0	0	0	0	0	0	0	0	0	0	0	0	200	250	700	800	1550	2300
Renewable % of Total Capacity	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	2.0%	2.3%	5.7%	5.9%	10.7%	14.3%

Source: Consultant Analysis

78. In the least cost expansion plan, all 6,328 MW of candidate hydropower projects is added over the period of study.

79. 2,500 MW of new coal-fired generation is added beginning with the first 500 MW unit in 2023.

80. In addition to the 1,700 MW of committed additions of new gas-fired generation through 2016, an additional 100 MW of Gas Turbines is brought online in the final year of the study.

81. Concerning renewables, no wind generators were selected in the least cost plan. However, after the second scheduled cost reduction takes effect in 2025, solar power becomes quite competitive and 2,300 MW is added to the system from 2025 to 2030.

82. The cumulative capacity (i.e., existing system plus new additions) by plant type for the least cost expansion strategy is displayed in Figure 8.

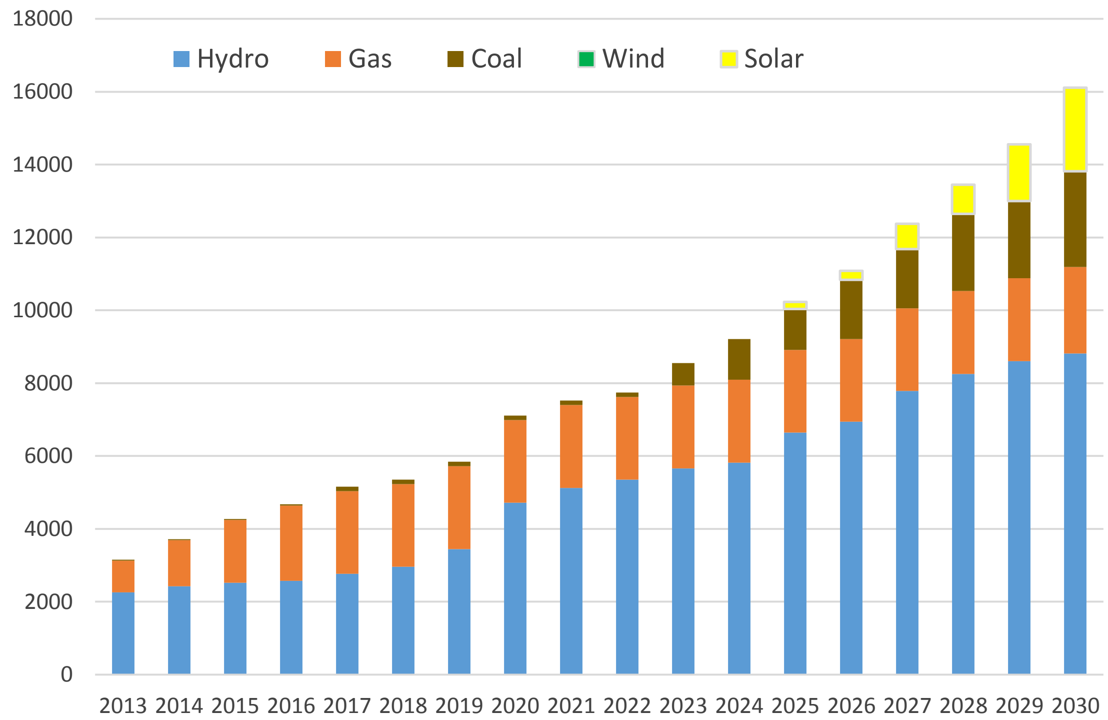


Figure 8: Least Cost Strategy - Cumulative Capacity (MW) by Plant Type

Source: Consultant Analysis

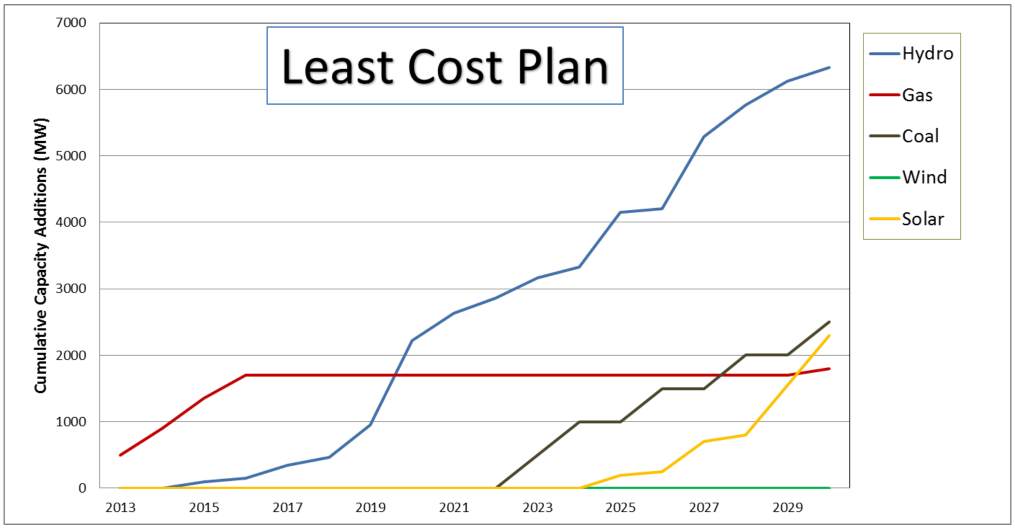
83. The schedule of hydro power plant additions for the least cost expansion plan is listed in Table 20. While all candidate HPPs are selected for construction in the optimum expansion plan, commissioning for 300 MW of potential additions is delayed past the HPP's first year of available operation.

Table 20: Least Cost Strategy – Schedule of Hydro Power Plant Additions

Sr.	HPP Name in WASP	First Year of Operation	Name of Hydroelectric Power Station	Location Region/State	Available Capacity (MW)
P	DAPO	2015	Dapain (only supply)	Kachin	101
37	MOWA	2016	Mong Wa	Shan (S)	50
E	UPAU	2017	Upper Paunglaung	Bago	140
H	UKEN	2017	Upper Kengtawng	Shan St (S)	51
O	NGOT	2018	Ngotchaung		16.6
Q	PROJ	2018	Projects		79
D	UBAL	2018	Upper Baluchaung	Bago	30.4
G	THAH	2019	Thahtay	Rakhine St	111
I	UYEY	2019	Upper Yeywa	Shan St (N)	280
M	MPAU	2019	Middle Paunglaung	Mandalay	100
R	DEED	2020	Dee Doke		66
J	SHW3	2020	Shweli - 3	Shan St (N)	1,050
L	UBU	2020	Upper Bu	Magway	150
S	KKHA	2021	Keng Kham		6
9	DAP2	2021	Dapein - 2	Kachin	84
T	MYEY	2021	Middle Yeywa	Bago	320
U	USED	2022	Upper Sedawgyi		64
K	BAWG	2022	Bawgata	Bago	160
10	GAWL	2023	Gawlan	Kachin	50
33	SHW2	2023	Shweli - 2	Shan (N)	260
34	KTON	2024	Keng Tong	Shan (S)	64
35	WATA	2024	Wan Ta Pin	Shan (S)	17
36	SOLU	2024	So Lue	Shan (S)	80
40	NKHA	2025	Nam Kha	Shan (S)	100
15	UTHA	2025	Upper Thanliwn (Kunlong)	Shan (N)	700
38	KYAN	2025	Keng Yang	Shan (S)	20
39	HEKU	2026	He Kou	Shan (S)	50
20	TANI	2027	Taninthayi	Taninthayi	300
12	HKAN	2027	Hkan Kawn	Kachin	80
16,17	NAMA	2027	Naopha, Mantong	Shan (N)	713
13	TONG	2028	Tongxinqiao	Kachin	170
14	LAWN	2028	Lawngdin	Kachin	300
46	DUBA	2029	Dun Ban		130
48	NKHO	2029	Nam Khot		25
44	NATU	2029	Namtu		100
42	NATA	2029	Nam Tamhpak (Kachin)	Kachin	100
45	MOYO	2030	Mong Young		45
47	NALI	2030	Nam Li		165

Source: Newjec NEMP 2014 and Consultant Analysis

84. In the least cost plan, by the year 2030, hydropower plants comprise approximately 55% of system installed capacity and 56% of annual generation. At the same time, installed capacity for solar nearly matches that of gas- and coal-fired power plants. The progression of capacity additions by plant type for the least cost expansion strategy is presented in Figure 9.



Source: Consultant Analysis

Figure 9: Least Cost Case - Cumulative Capacity Additions by Plant Type

85. Annual generation by plant fuel type is reported in Table 21.

Table 21: Least Cost Strategy – Annual Generation by Plant Type

Year	Hydro		Gas		Coal		Solar		Wind	
	GWh	%	GWh	%	GWh	%	GWh	%	GWh	%
2013	8,284	73%	2,913	26%	224	2%	0	0%		0%
2014	8,980	71%	3,400	27%	224	2%	0	0%		0%
2015	9,359	65%	4,815	33%	224	2%	0	0%		0%
2016	9,545	60%	6,207	39%	224	1%	0	0%		0%
2017	10,260	58%	6,483	37%	891	5%	0	0%		0%
2018	10,987	57%	7,568	39%	891	5%	0	0%		0%
2019	12,825	60%	7,641	36%	891	4%	0	0%		0%
2020	17,566	75%	5,007	21%	884	4%	0	0%		0%
2021	19,101	74%	5,780	22%	882	3%	0	0%		0%
2022	19,941	71%	7,450	26%	886	3%	0	0%		0%
2023	21,102	68%	5,397	17%	4,478	14%	0	0%		0%
2024	21,702	64%	4,290	13%	7,912	23%	0	0%		0%
2025	24,772	67%	4,296	12%	7,712	21%	317	1%		0%
2026	25,898	64%	3,420	8%	10,896	27%	397	1%		0%
2027	29,049	65%	3,661	8%	10,627	24%	1,106	2%		0%
2028	30,811	63%	2,997	6%	13,615	28%	1,267	3%		0%
2029	32,142	60%	4,901	9%	13,877	26%	2,458	5%		0%
2030	32,932	56%	4,735	8%	17,010	29%	3,655	6%		0%

Source: Consultant Analysis

86. With the amount of candidate hydro power projects limited to just over 6,300 MW, the share of hydro in the system capacity mix drops from 72% in 2013 to 55% in 2030. In line with the reducing share of hydro capacity, hydro generation is reduced from 73% in 2013 to 56% in 2030.

87. Gas-fired generation rises from 26% of total in 2013 to a high of 39% in 2018, then drops to just 8% of total electricity generation in 2030.

88. Although there is about an equal share of installed capacity for solar (14%), gas- (15%), and coal-fired (16%) power plants in 2030, their respective shares of total generation are far from equal with coal at 29%, gas 8%, and solar 6%.

T. FUEL REQUIREMENT AND EXPENDITURE

89. To meet increased demand for electricity over the period 2013 – 2030, consumption of coal, and natural gas in the power sector is expected to increase as elaborated in Table 22. Also noted is the associated fuel expenditures in current year (non-discounted) values.

Table 22: Least Cost Strategy – Fuel Consumption and Expenditure

Year	Coal		Gas	
	1000MT	US $ million	million m^3	US $ million
2013	114	4	1,740	509.3
2014	114	4	1,906	569.2
2015	114	4	2,215	686.9
2016	114	4	2,491	792.1
2017	436	17	2,068	649.4
2018	436	17	2,283	731.6
2019	436	17	2,296	736.5
2020	433	17	994	379.0
2021	432	17	1,158	439.7
2022	434	17	1,540	576.3
2023	1,871	138	1,084	411.6
2024	3,245	254	854	325.4
2025	3,164	247	857	326.2
2026	4,438	355	681	259.3
2027	4,330	346	733	278.6
2028	5,525	447	601	228.2
2029	5,630	456	1,025	380.8
2030	6,883	562	994	368.9

Source: Consultant Analysis

90. Table 23 shows the gas supply and demand balance until 2030. Annual gas consumption volumes reported above are converted to a daily gas volume basis in million cubic feet per day (MMcfd) and to a gas calorific value basis (in bbtud). These projections of fuel requirements were developed under the EMP's medium growth case and with the assumptions described in this report. The values listed for annual domestic gas supply for electricity were obtained from the NEMP.

Table 23: Least Cost Strategy – Gas Demand vs Supply for Electricity

Year	Gas Demand for Electricity		Gas Supply for Electricity
	MMcfd	bbtud	bbtud
2013	168.3	**124.7**	**201**
2014	184.4	**139.3**	**248**
2015	214.3	**168.1**	**261**
2016	241.0	**193.9**	**261**
2017	200.1	**159.0**	**261**
2018	220.9	**179.1**	**261**
2019	222.1	**180.3**	**272**
2020	96.2	**92.8**	**309**
2021	112.0	**107.6**	**302**
2022	149.0	**141.0**	**311**
2023	104.9	**100.7**	**306**
2024	82.7	**79.6**	**291**
2025	82.9	**79.8**	**259**
2026	65.9	**63.5**	**246**
2027	70.9	**68.2**	**235**
2028	58.1	**55.9**	**221**
2029	99.2	**93.2**	**219**
2030	96.2	**90.3**	**215**

Source: Consultant Analysis and Newjec NEMP 2014

91. Fuel requirements could increase under a higher forecast of demand. Information on power sector fuel requirements under such conditions, is elaborated in *The Project for Formulation of the National Electricity Master Plan in the Republic of the Union of Myanmar*, JICA, Dec 2014.

U. POWER DEVELOPMENT COST

92. To implement the EMP Reference Case Power Expansion Plan through 2030, the 2013 present worth of capital cost investment is approximately 10.5 billion US$ and O&M cost - including fuel cost – approximately 6.3 billion US$. Annual and cumulative discounted costs for the least cost plan are provided in Table 24.

Table 24: Least Cost Strategy – System Costs

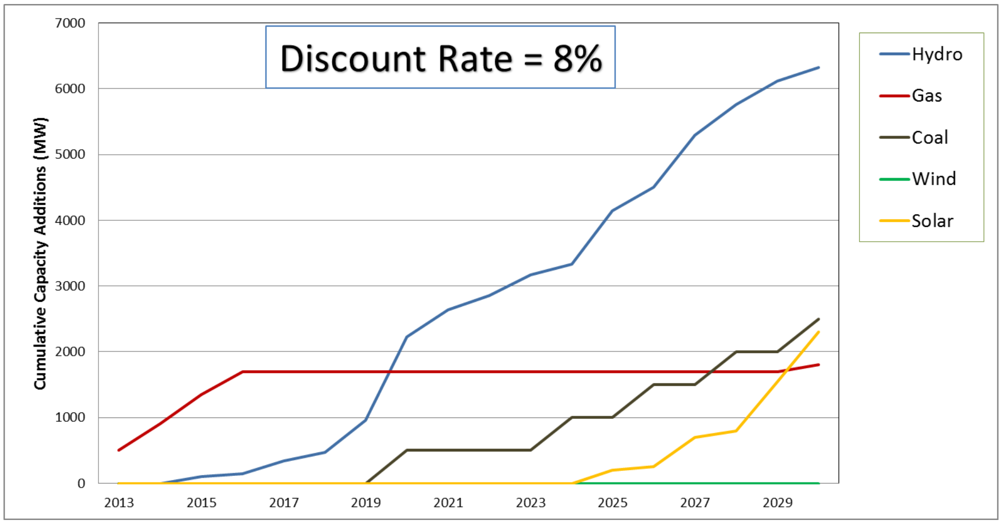
Year	Present Worth Cost of 2013 (K$)						LOLP
	Investment	Salvage	Operating	ENS	Total	Cumulative	
2013	447750	43193	529747	0	934,304	934,304	0
2014	364955	42437	543841	0	866,359	1,800,663	0
2015	577633	95479	597961	0	1,080,115	2,880,778	0
2016	371488	67079	626725	0	931,134	3,811,912	0
2017	337358	86702	492250	0	742,906	4,554,818	0
2018	202319	57370	497518	0	642,467	5,197,285	0
2019	716727	224176	456720	0	949,271	6,146,556	0
2020	1680017	579460	242759	0	1,343,316	7,489,872	0
2021	494619	188086	249267	0	555,800	8,045,672	0
2022	245665	102970	283401	0	426,096	8,471,768	0.001
2023	839197	361318	249663	0	727,542	9,199,310	0.001
2024	627856	297722	244182	2	574,318	9,773,628	0.002
2025	764621	422316	223178	10	565,493	10,339,121	0.005
2026	642136	381366	220639	15	481,424	10,820,545	0.007
2027	722096	483445	207245	51	445,947	11,266,492	0.019
2028	648417	476992	205838	73	377,336	11,643,828	0.026
2029	382266	310096	225382	751	298,303	11,942,131	0.224
2030	550771	495479	230694	877	286,863	12,228,994	0.269

Source: Consultant Analysis

V. EFFECTS OF DISCOUNT RATE ON LEAST COST PLAN

93. Sensitivity analysis was performed to evaluate the robustness of the identified least cost power expansion plan and assess the impact on the plan to changes in a number of key factors, including discount rate, potential schedule delays in commissioning of new hydropower plants, and environmental considerations.

94. To analyze the effects of discount rate on the least cost plan, planning studies were carried for discount rates of 8% and 5%. The sequences of plant additions for these cases are given in Figures 10 and 11.

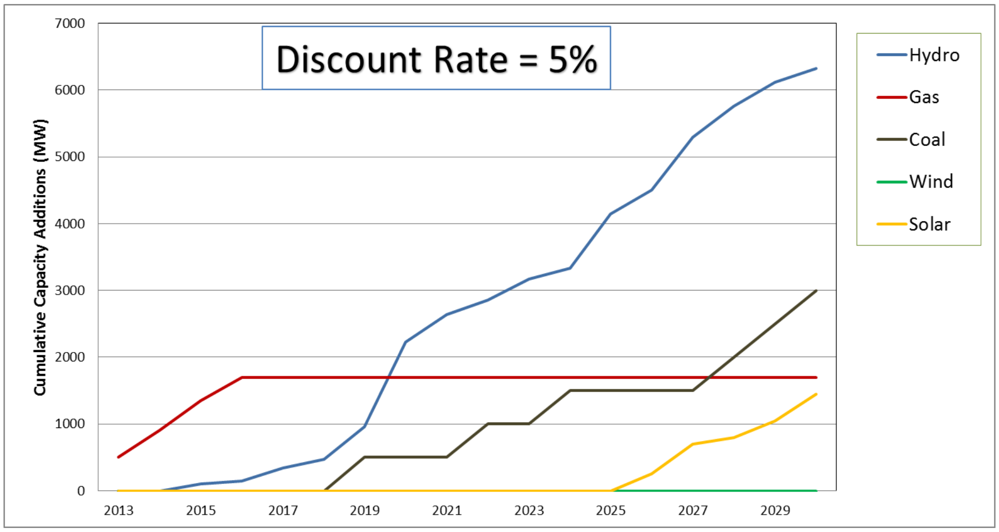


Source: Consultant Analysis

Figure 10: Sensitivity Analysis #1 – Discount Rate of 8%

95. Reducing the discount rate from 10% to 8% produces an expected result of accelerating the commission of capital intensive projects. All candidate hydropower plants are commissioned on their first year of availability and the timing of the first new coal unit moves forward from 2023 to 2020. The number and timing of candidate additions for gas, wind, and solar remains unchanged.

96. With a discount rate of 5%, the least cost plan once again commissions all candidate hydropower plants on their first year of availability. The timing of the first coal unit advances to 2019 and an extra unit is introduced bring the total amount of capacity added for coal to 3,000 MW. For the lower capital intensive candidates (e.g., solar and gas), the timing of new unit additions is delayed and number reduced.

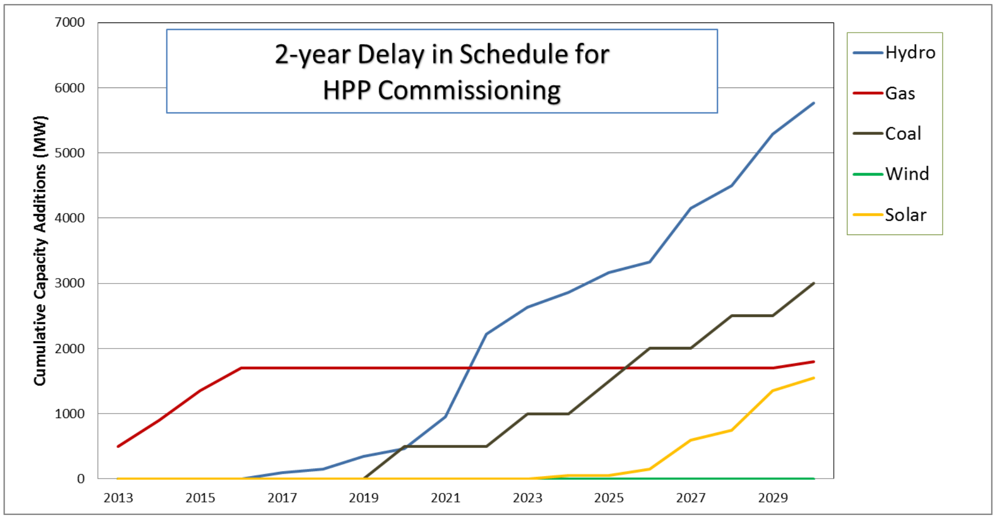


Source: Consultant Analysis

Figure 11: Sensitivity Analysis #2 – Discount Rate of 5%

W. Effects of HPP Schedule Delay on Least Cost Plan

97. To analyze the effect of delays in hydropower plant commissioning on the least cost plan and associated fuel requirements, the least cost plan was re-optimized after adjusting the schedule of candidate hydropower project additions to delay the first year of availability for each candidate by two years. This case assumes that no new hydro project can be added before 2017. The resulting sequences of plant additions is displayed in Figure 12 and associated fuel requirements listed in Table 25. HPP schedule delays result in increased levels of gas consumption through 2019 followed by construction of six 500 MW coal power plants with the first commissioned in 2020.



Source: Consultant Analysis

Figure 12: Sensitivity Analysis #3 – Delay in Schedule for Candidate HPPs

Table 25: Sensitivity Analysis #3 – Fuel Requirements with HPP Schedule Delay

Year	Fuel Requirements for Electricity				Gas Supply for Electricity
	Coal	Gas	Gas	Gas	
	ktonne	million m^3	MMcfd	bbtud	bbtud
2013	114.0	1739.6	168.3	124.7	201
2014	114.0	1905.9	184.4	139.3	248
2015	114.0	2290.1	221.6	175.1	261
2016	114.0	2602.7	251.8	204.3	261
2017	436.5	2247.4	217.4	175.7	261
2018	436.5	2519.9	243.8	201.2	261
2019	436.5	2760.7	267.1	223.6	272
2020	1920.9	1618.8	156.6	148.6	309
2021	1920.8	1754.6	169.8	158.9	302
2022	1909.0	1238.9	119.9	114.8	311
2023	3280.1	771.7	74.7	72.0	306
2024	3324.4	1180.6	114.2	108.5	291
2025	4655.1	902.9	87.4	83.6	259
2026	5977.4	787.7	76.2	73.1	246
2027	5876.5	856.4	82.9	79.0	235
2028	7137.5	761.3	73.7	70.4	221
2029	7079.6	967.0	93.6	88.4	219
2030	8300.6	905.0	87.6	82.4	215

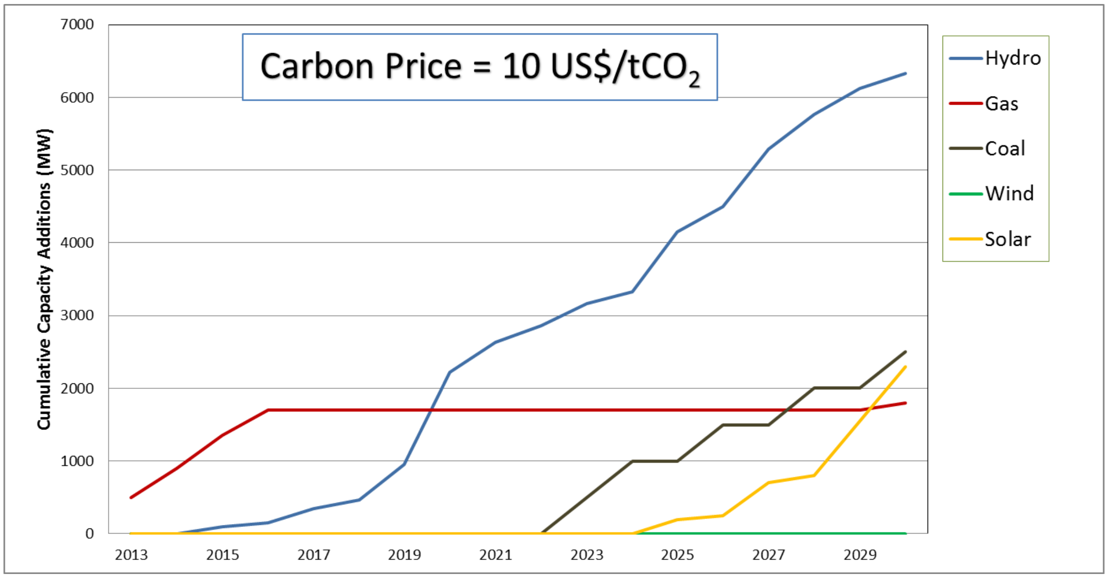
Source: Consultant Analysis and Newjec NEMP 2014

X. Effects of Environmental Considerations on Least Cost Plan

98. While this study focused on development of an economically optimal generation expansion strategy that satisfies specified reliability constraints, it is important to value both environmental protection and economic considerations in the development of an optimum solution.

99. One method of assigning a value to environmental protection, is through use of a carbon pricing mechanism. WBG's Carbon Pricing Watch 2015 brief notes the following recent carbon pricing developments: Beijing and Kazakhstan use a fee of 8 US$/t$CO_2$, Korea 9 US$/tCO_2, and France 15 US$/t$CO_2$.

100. To begin analyzing the effect of environmental considerations on the least cost plan, the expansion strategy was re-optimized using carbon pricing rates of 10 US$/t$CO_2$ and 15 US$/ t$CO_2$. The resulting sequences of plant additions are displayed in Figures 13 and 14.

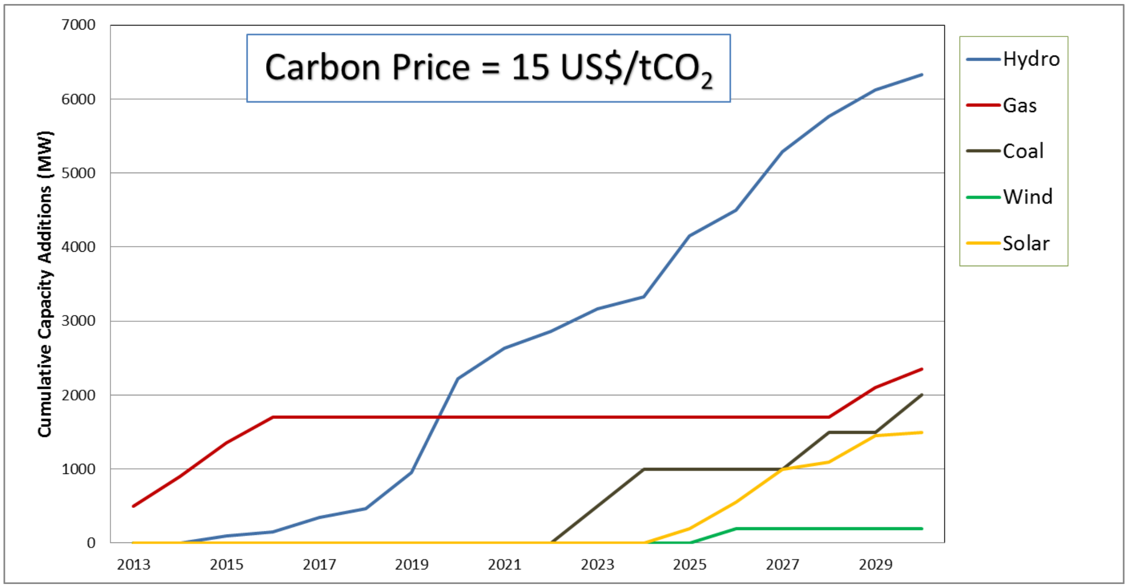


Source: Consultant Analysis

Figure 13: Sensitivity Analysis #4 – Carbon Price of 10 US$ per tonne CO_2

101. As illustrated in Figure 13, a carbon price of 10 US$/t$CO_2$ has little effect on the least cost expansion strategy. The schedule for commissioning of candidate hydropower plants is accelerated so that all HPPs are selected on their first year of availability. However, the number and timing of new unit additions remains unchanged for all other expansion candidates.

102. In contrast, Figure 14 illustrates that a carbon price of 15 US$/t$CO_2$ has a profound effect on the least cost expansion strategy. The schedule of new coal-fired units is delayed and number of units is reduced. As a substitute for coal, an additional 600 MW of gas-fired capacity is brought online, along with a total of 1500 MW of solar and 200 MW of wind.



Source: Consultant Analysis

Figure 14: Sensitivity Analysis #5– Carbon Price of 15 US$ per tonne CO_2

Y. Effects of Government Policy on Least Cost Plan

103. Upon reviewing the draft report of this power expansion study, responsible government agencies commented on the desire for increased diversification of energy sources in the national power expansion plan.

104. MOEP commented “it is necessary to develop diverse generation mix,” and NEMC noted “We suggest modification should be made to the proposed expansion plan because the dependency on the hydroelectricity is relatively high during the mid-term.”

105. NEMC provided further guidance noting “Although the expansion plan is based on least cost option, it still needs to encourage the renewable power generation. According to the discussion between MOEP and interested parties, it is also needed to consider the possible establishment of solar farms in the near future,” and “the timing of introducing coal power plant in the ADICA's power expansion plan should be reconsidered.”

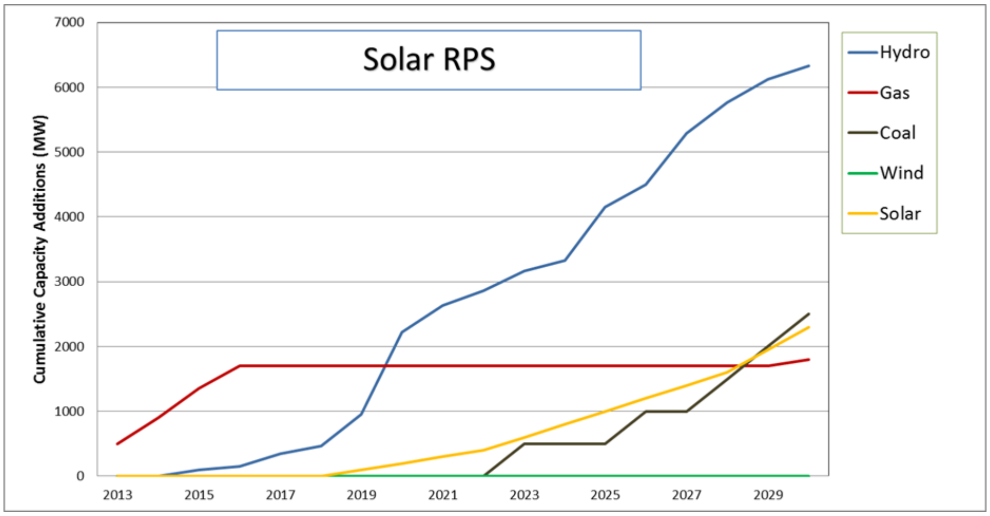
106. In response to the above comments, ADICA conducted additional sensitivity analyses to demonstrate how the WASP model can be used to evaluate the effect of potential government policies related to renewable energy integration and diversification of energy sources on the least cost expansion plan. The following three sensitivity cases were analyzed:

(i) Solar RPS: Establish a Renewable Portfolio Standard (RPS) setting a goal for 100 MW of new solar power integration each year from 2019 to 2022, 200 MW new solar added annually from 2023 to 2028. No RPS is needed in the last two years of the study when comparative economics of generation options results in higher levels of solar adoption.

(ii) Coal 2020: Consider potential government decision to advance timing of introducing new coal plants in the least cost plan by three years with first plant added in 2020.

(iii) Solar RPS + Coal 2020: Implement the Solar RPS and Coal 2020 policies in combination.

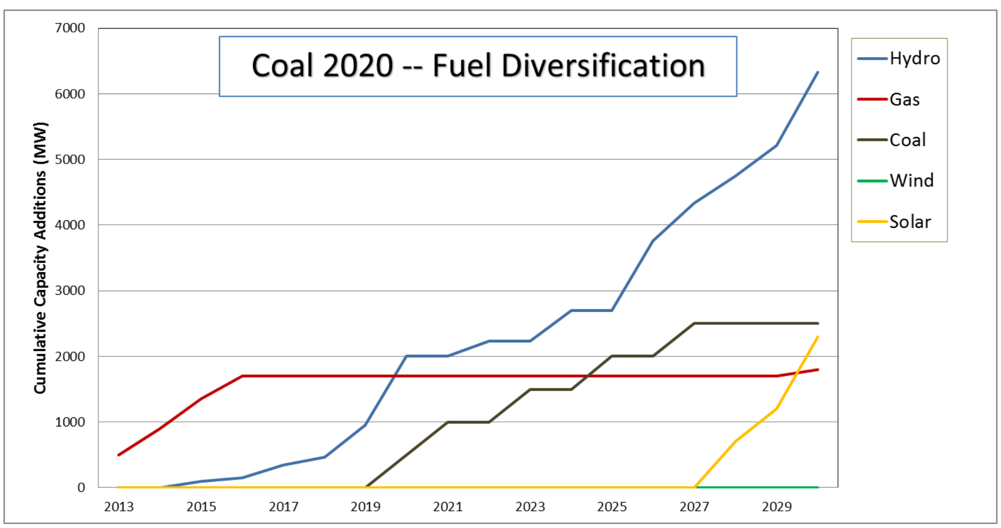
107. As illustrated in Figure 15, the impact of a Solar RPS policy as defined in 106.i is to delay the construction of the new coal-fired plants, and accelerate the construction of one hydro plant.



Source: Consultant Analysis

Figure 15: Sensitivity Analysis #6 – Solar RPS

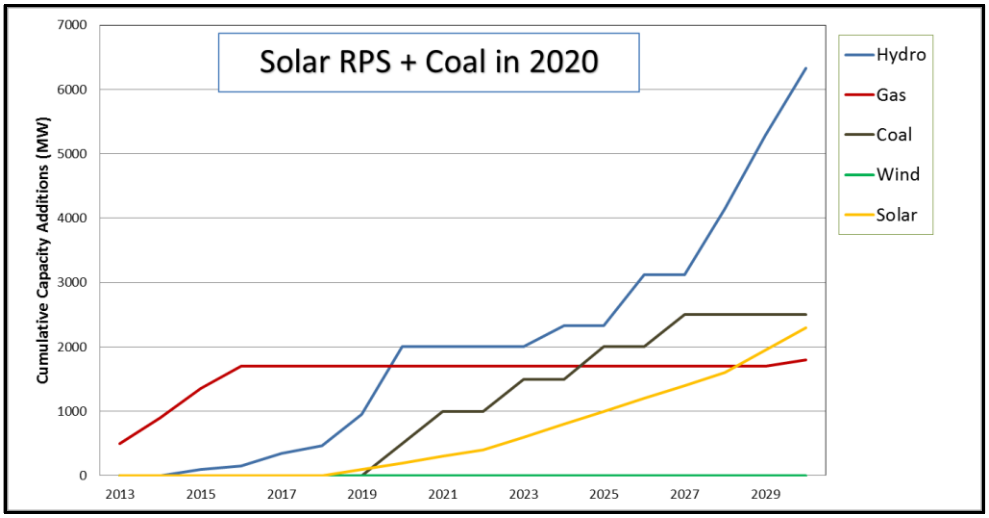
108. In contrast, Figure 16 illustrates the effect of a fuel diversification policy as defined in 106.ii, which delays the timing of new hydro and solar generation.



Source: Consultant Analysis

Figure 16: Sensitivity Analysis #7 – Coal 2020

109. The estimated effect of combining the RPS and fuel diversification policies is displayed in Figure 17, which shows a substantial reduction in the reliance on hydroelectricity in the mid-term.



Source: Consultant Analysis

Figure 17: Sensitivity Analysis #8 – Solar RPS + Coal 2020

110. As noted in Table 26, government policies can have a profound impact on the capacity mix and total cost associated with the national power expansion plan.

Table 26: Impact of RPS and Fuel Diversification Policy on Capacity Mix and Total Cost

Least Cost	2020		2025		2030	
	MW	%	MW	%	MW	%
Hydro	4,715	66	6,640	65	8,818	55
Gas	2,274	32	2,274	22	2,374	15
Coal	120	2	1,120	11	2,620	16
Solar	0	0	200	2	2,300	14
Present Worth of Cummulative Costs (2013$)				$12,228,994,000		
Solar RPS	**2020**		**2025**		**2030**	
	MW	%	MW	%	MW	%
Hydro	4,715	65	6,640	63	8,818	55
Gas	2,274	31	2,274	22	2,374	15
Coal	120	2	620	6	2,620	16
Solar	200	3	1,000	9	2,300	14
Present Worth of Cummulative Costs (2013$)				$12,396,110,000		
Coal 2020	**2020**		**2025**		**2030**	
	MW	%	MW	%	MW	%
Hydro	4,499	61	5,189	54	8,818	55
Gas	2,274	31	2,274	24	2,374	15
Coal	620	8	2,120	22	2,620	16
Solar	0	0	0	0	2,300	14
Present Worth of Cummulative Costs (2013$)				$12,359,010,000		
Solar RPS + Coal 2020	**2020**		**2025**		**2030**	
	MW	%	MW	%	MW	%
Hydro	4,499	59	4,825	47	8,818	55
Gas	2,274	30	2,274	22	2,374	15
Coal	620	8	2,120	21	2,620	16
Solar	200	3	1,000	10	2,300	14
Present Worth of Cummulative Costs (2013$)				$12,603,830,000		

Source: Consultant Analysis

Z. Comparing the Least Cost Strategy with Other Options

111. To identify an expansion strategy that best meets national goals for a sustainable, reliable, and competitive electricity supply, we recommend evaluating alternative expansion strategies with respect to key performance indicators, like the following:

a) *Sustainability* of an expansion strategy assessed in terms of air pollutant emissions over the study period and amount of renewable energy in the national capacity mix in 2030.

b) *Reliability* assessed in terms of system LOLP and security of energy supply in 2030.

c) *Competitiveness* of an expansion strategy assessed in terms of total discounted system cost over the study period, total revenue obtained from the placement of a value on CO_2 emissions, and the associated foreign fuel bill.

112. Summary results for the least cost plan displayed in Table 27 can be used in comparing this plan with alternative expansion strategies developed under a consistent set of assumptions.

Table 27: Summary Results of Least Cost Plan for Key Performance Indicators

GOALS	Key Performance Indicators		Units	Least Cost
Sustainable	Emissions over study period	CO_2	M tonnes	114.8
		SO_2	M tonnes	19.0
		NO_x	M tonnes	21.0
		PM10	M tonnes	5.8
	Renewable energy in system in 2030		%	14.3%
Reliability	Loss of Load Probability in 2030		%	0.269%
	Security of energy supply in terms of total fuel consumed over study period	Coal	k tonnes	38,152
		NGas	M m^3	25,520
Competitive	Total discounted system cost over study		k $	12,228,994
	Total discounted revenue from CO_2 fee		k $	-
	Foreign fuel bill		Qualitative	Lower NGas

Source: Consultant Analysis

113. Linking the comparison of alternative expansion strategies to key performance metrics highlights the costs and benefits of each option and provides useful information for decision making on power system expansion.

114. The following section highlights issues recommended for consideration in future transmission system planning.

IX. TRANSMISSION DEVELOPMENT

115. It is difficult to assess the corresponding transmission development plans to match the generation expansion plans for the medium growth case without estimates of individual substation load growth to perform detailed load flows of the power system. The EMP study provided regional demand estimates that could have been used to estimate substation loads but the study but did not perform the necessary load flows to establish transmission requirements. The EMP regional forecasts however showed that there would significantly higher growth outside Yangon which more closely matched the high load demand case.

116. For the forecast high case study, Newjec provided substation load estimates based on pro-rata growth rates assuming all regions would develop at the same rate. This indicated the total matching transmission investment would be $2.37b to 2020 and an additional $3.38 by 2030 for a total investment of $5.75b. Newjec included provision for a second 500kV line to be built in parallel with the 500kV line that is currently committed for completion by 2020. Newjec also considered other transmission arrangements for the high demand case necessary to evacuate large amounts of hydro power from northern areas of Myanmar to the southern load centres using an HVDC link. However, this would increase the total investment by a further $2.2b. Their analysis indicates that if it was possible to develop hydro resources faster than appears feasible at present, it would be necessary to look at alternative ways of staging the investments of the 500kV and HVDC lines to effect the north south power evacuation requirements to meet the medium growth case.

117. Separately the consultants Fichtner[14] prepared a transmission investment plan using pro-rata load growth estimates corresponding to the medium demand forecast. Their investment requirements to 2025, with provision for the ongoing 500kV line construction included, is summarized below and corresponds closely to the first stage of the Newjec estimates for transmission investments to 2020. Without more detailed analysis this combined investment program should therefore be considered a proxy for the investment needs for the medium forecast.

Table 28: Transmission Projects identified by Fichtner/MOEP [14]

Summary of Transmission Projects Identified By Fichtner/MOEP					
Priority Investments for 2017-2025	IPP	Transmission		S/S	Total
	MW	km	US$	US$	US$
Connection of Power Plants	5064	1022	554	339	893
Connection of new Areas NEM Project		975	365	187	552
500kV Backbone system (MOEP)		1795	1077	149	1226
Strengthening of Network		408	143	78	221
Total Transmission Investments		4200	2140	753	2892

[14] See ADB - TA 8342 MYA Preparing the Power Transmission and Distribution Improvement Project, Fichtner October 2014

118. Notably neither Newjec nor Fichtner considered the issues that can be expected to arise as a result of developing hydro projects on a shared basis with Yunnan and/or Thailand. As noted in Annex A, one solution is to operate a hybrid transmission interconnection arrangement using 500kV and HVDC systems connected in parallel with each other. This mode of operation will provide a continuous interconnection between all three parties that should increase flexibility and security of supplies to both systems. The proposed interconnection arrangement is adapted from one of the scenarios proposed in the 2014 MOEP-NEMP. It indicates that it may be feasible to build the HVDC line, in advance of the second 500kV line, to meet the base load. The proposal should be studied further when the NEMP masterplan is revised.

X. OBSERVATIONS AND RECOMMENDATIONS

119. This power planning study had as objective to apply the WASP IV model in identifying an economically optimum generation expansion plan under the EMP's medium growth case, and was successful in developing the reported least cost power expansion plan.

120. It is important to keep in mind that the role of the energy planner is not do develop “the plan” to be implemented. Rather, energy planning involves analysis of the energy system with the intent of providing decision makers information that will enable them to make informed judgments on strategies needed to meet current and future energy objectives.

121. This study provides useful information for decision making on energy development in Myanmar, including but not limited to the following observations:

a) The national power expansion plan designed to meet the EMP medium growth forecast of 9.6% CAGR on a least-cost basis shows hydroelectric and gas-fired generation playing a dominant role in meeting the countries electrical needs through 2021 – at which time coal, then renewables become viable candidates.

b) Under the least cost expansion plan, natural gas demand for electricity generation is not expected to exceed the NEMP-reported limit of domestic gas supply allocation for the power sector through 2030. Still, sufficient natural gas supply for power production is essential for reliable supply of electricity – particularly in the case of delays in HPP construction.

c) Based on the assumed technical and cost parameters for the EMP national power expansion plan, which are consistent with the NEMP, hydro power generation is the most economic supply option followed by coal. All thirty-eight hydropower candidates (totaling 6,328 MW), and 2,500 MW of coal-fired capacity are selected for construction in the least cost expansion plan. Reducing the discount rate below the value of 10% assumed in this study results in capital intensive coal and hydro candidates becoming even more competitive as compared with gas and solar.

d) In evaluating the potential role of coal-fired power plants in the least cost expansion plan, this study determined that, under the EMP medium growth forecast and assumptions listed in this report, new coal-fired generation is not economically justifiable before 2023. However, sensitivity analyses highlight that new coal could be required earlier in response to delayed commissioning of new hydro power plants or a reduction in the forecasted supply of natural gas available for electricity generation.

e) Sensitivity analysis related to hydro power plant commissioning points to a 2-year delay in the schedule of HPP additions resulting in increased levels of gas consumption through 2019 followed by construction of six 500 MW coal power plants with the first commissioned in 2020.

f) This study investigated the viability of large-scale renewable energy projects by evaluating wind and solar energy candidate projects in the context of the least cost generation expansion plan and identifies substantial potential for solar PV. Contributing factors include: (i) declining price of PV, (ii) renewable potential for solar being high in locations close to the grid and major load centres, (iii) Myanmar's largely hydro based system with significant spinning reserve capability, and (iv) the strong seasonal variations of solar and hydro energy potential in the country complement each other over the year.

g) While this study focuses on development of an economically optimal ("least cost") generation expansion plan that satisfies specified constraints on system reliability, it is important to value both environmental protection and economic considerations in development of an optimum strategy for the country. One method of assigning a value to environmental protection is through use of a carbon pricing mechanism. Results of sensitivity analyses point to a price of 15 US$/t$CO_2$ having a profound effect on the least cost expansion strategy – reducing the number of new coal-fired units, increasing gas-fired capacity by 600 MW over the least cost plan, and adding a total of 1,500 MW of solar and 200 MW of wind energy through 2030.

h) Sensitivity analyses further demonstrate that government policies related to renewable energy integration and diversification of energy sources can have a profound impact on the least cost power expansion plan and substantially reduce the reliance on hydroelectricity.

122. In the conduct of this study, a number of enhancements were made to the national WASP IV database and power system planning process. To maximize the benefits from this effort, we recommend that WASP IV training be provided to MOEP and NEMC staff through ongoing capacity building initiatives organized with the ADB and JICA.

123. As planning is a process, the power system expansion plan should be revised annually by MOEP according to updated information and assumptions related to energy demand, fuel prices and availability, government policies, etc. Suggested priority issues warranting further consideration in the next update of the national power expansion plan, include:

i) *Hydropower Development*: Due to limited availability of information on candidate hydro plants, the EMP expansion planning study used an average cost of new hydro developed by Newjec and applied aggregated characteristics of existing HPPs to develop initial estimates of seasonal operations for new hydro candidates. The ADB consultants agree with earlier comments by the WBG, that "a proper hydropower development study is needed to … optimize hydropower development." We note that a Norwegian effort over the next 18 months intends to upgrade MOEPs hydro data base and recommend that this effort also be deployed to capture information tailored to represent hydro capital cost and operational data for the WASP database. In parallel with the data collection effort, we recommend that MOEP consider complementing the current WASP-based planning with use of additional models that are able to capture the stochastic representation of hydropower that is lacking in WASP. For example, WASP is regularly run together with the VALORAGUA model (and others) for systems with a substantial amount of hydro.

j) *Natural Gas Price for the Power Sector*: The EMP expansion planning study assumed $11.2 per mmBTU as the price of natural gas to the power sector, which is the MOE-proposed gas price to MOEP and is consistent with the value used in the JICA-supported MOEP's NEMP. We note that WBG is carrying out a gas price study and suggest that results of this study will enhance understanding on appropriate economic value of gas in the country and should be reflected in future updates of the national power expansion plan.

k) *Demand Forecast and System Load Characteristics*: The current study defined seasonal load characteristics based on actual hourly loads in 2014 and uses the medium growth forecast of peak load and generation requirements developed in the EMP study. It is advised for MOEP to acquire and apply a tool such as the IAEA's Model for Analysis of Energy Demand (MAED) for forecasting electricity demand. MAED provides a systematic framework for mapping trends and anticipating change in energy needs corresponding to alternative scenarios for socioeconomic development and producing an associated hourly load forecast.

l) *Integrated Generation and Transmission System Planning:* Modeling the generation and transmission system in an integrated manner is more important in hydro-dominated power system because of significant investment cost of transmission connections between load centers and relatively remote hydropower plants. In addition, properly managed, hydro reservoir storage can deliver benefits in moderating seasonal variations in electricity supply due to changing water inflows and balancing hourly variability in generation from future renewable energy sources. It is recommended that MOEP should acquire suitable planning tools and build institutional capacity for developing an integrated generation and transmission plan for the country. Analyses to support the integrated plan should: (i) address short term system operation and stability issues at a higher level of detailed (e.g., hourly simulation) than is computationally possible with current long-term planning models, (ii) evaluate the value of hydro storage capacity in prioritizing the hydro development program, and (iii) identify transmission lines which are highest priority to support generation expansion and regional integration.

Annex A
Transmission Interconnection Strategy for Hydro Exports to GMS Countries

Transmission Interconnection Strategy for Hydro Exports to GMS Countries

Myanmar has considerable hydroelectric resources, some of which the Gov't wishes to develop to export power to its neighbours, notably China and Thailand. Some larger potential hydro sites located close to the borders with both countries have been identified as potential resources that could be developed on a shared basis. In particular, there are a group of hydro stations in northern Kachin state with an aggregate potential of 8835MW near the border with Yunnan, along with the proposed 7000MW Ta Sang[15] scheme in Shan State near the border with Thailand.

For some of the border projects, the Gov't envisages that a joint development agreement could be arranged so that up to 50% of the hydro power output could be evacuated to the major load centres in Yangon and Mandalay with the other 50% exported under a Power Purchase Agreement (PPA). Recently there has also been a suggestion that China may have excess hydro power in the short term and could be interested in exporting surplus power to Myanmar.

Since there are currently no plans to synchronise the three adjacent power systems of Yunnan, Thailand and Myanmar, it has been suggested that the busbars of the border hydro generating units should be separately synchronised the respective power systems in the border countries. This mode of operation will be difficult to operate safely and could cause system operational difficulties. Faults that occur on one or other of the transmission systems and will reduce the security and reliability of service from the hydro stations.

This paper therefore proposes that a feasible solution would be to operate a hybrid transmission interconnection arrangement using 500kV and HVDC systems connected in parallel with each other. This mode of operation will provide a continuous interconnection between all three parties that should increase flexibility and security of supplies to both systems. The proposed interconnection arrangement is adapted from one of the scenarios proposed in the 2014 MOEP-NEMP and will also provide the lowest cost means of supplying bulk power from the northern states to the southern load centres of Myanmar.

Myanmar National Electricity Master Plan MOEP-NEMP (JICA-NewJec)

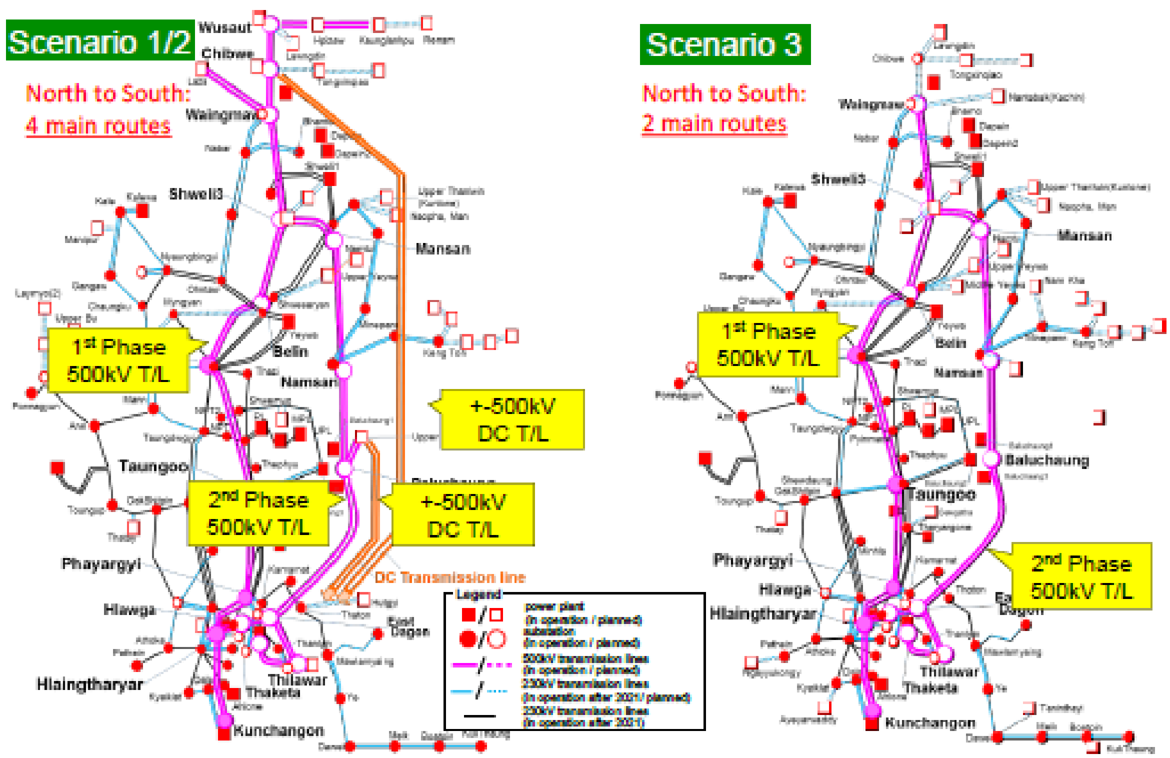
The MOEP-NEMP completed in December 2014 proposes various interconnection arrangements for evacuating hydro power from the north to the south of Myanmar assuming these projects would be developed to meet a high demand growth scenario. Two of the MOEP-NEMP proposed Scenarios (1/2) as shown below suggest the concept of building parallel 500kV and HVDC circuits are best suited to evaluate large amounts of hydro at least cost to Yangon. However, the NEMP does not indicate how the three power systems could be interconnected to maintain security and reliability of the respective networks. Nor does the plan suggest the order in which the transmission projects would be developed if demand grew more slowly – in accordance with a medium demand scenario.

Notably many of the proposed larger hydros in the MOEP-NEMP generation expansion plan (Yenan-1200MW, Kaungglanphu-2700MW, Pisa-2000MW, Wutsok-1880MW, Lawngdin plus three others-1055MW) are grouped together in the border area of the Kachin state. Some of these plants are

[15] https://en.wikipedia.org/wiki/TaSang_Dam

included in the WASP generation expansion scenarios based on the assumption that 50% of hydro output will be exported to China and 50% evacuated to Myanmar.

MOEP-NEMP Transmission proposals for Three Scenarios of Generation Expansion



Notably the transmission arrangements shown above indicate the Myanmar system will be synchronised with China although there are no such plans under consideration. An alternative proposal would be to synchronise all of northern hydro plants with China, and separate the two respective Mynamar and Chinese 500kV systems at the future Myitsone hydro (6000MW) project substation. To enable Myanmar to continuously evacuate its 50% share of hydro power from the future Kachin plants, as well as any surplus power from China, it would therefore be desirable to advance the building of the proposed HVDC line to Yangon (i.e. build it ahead of the proposed second 500kV line programmed in Scenario 1/2and 3). However, to simplify operations the 500kV and HVDC terminal should be at the Myitsone 500kV busbars (instead of Chibwe as shown above). At a future date when/if the huge 6000MW Myitsone hydro station is built it may be appropriate to consider installing an HVDC b/b facility interconnecting the station 500kV busbars.

Since the proposed bipolar HVDC line will be about 1100km[16] long, it would be significantly cheaper to build than an equivalent 500kV d/c line and would offer the advantage of providing increasing stability

[16] When comparing HVAC and HVDC the cost crossover where HVDC is much cheaper is about 400-700km depending on the volume of power transmitted: http://electrical-engineering-portal.com/analysing-the-costs-of-high-voltage-direct-current-hvdc-transmission

and security of supplies at the Yangon and Myitsone 500kV busbars. Moreover, the HVDC line can be designed so its capacity can be upgraded in (say) 1500MW stages (e.g. by changing from a monopolar to bipolar configuration, and/or by incrementally increasing terminal capacity and/or operating voltages from (say)±400kV to ±800kV). Because an HVDC line would operate in parallel to the underlying 500/230kV HVAC systems, it could be developed for private sector financing and/or operation on the basis a long term BOT contract with revenues based on agreed availability charges.

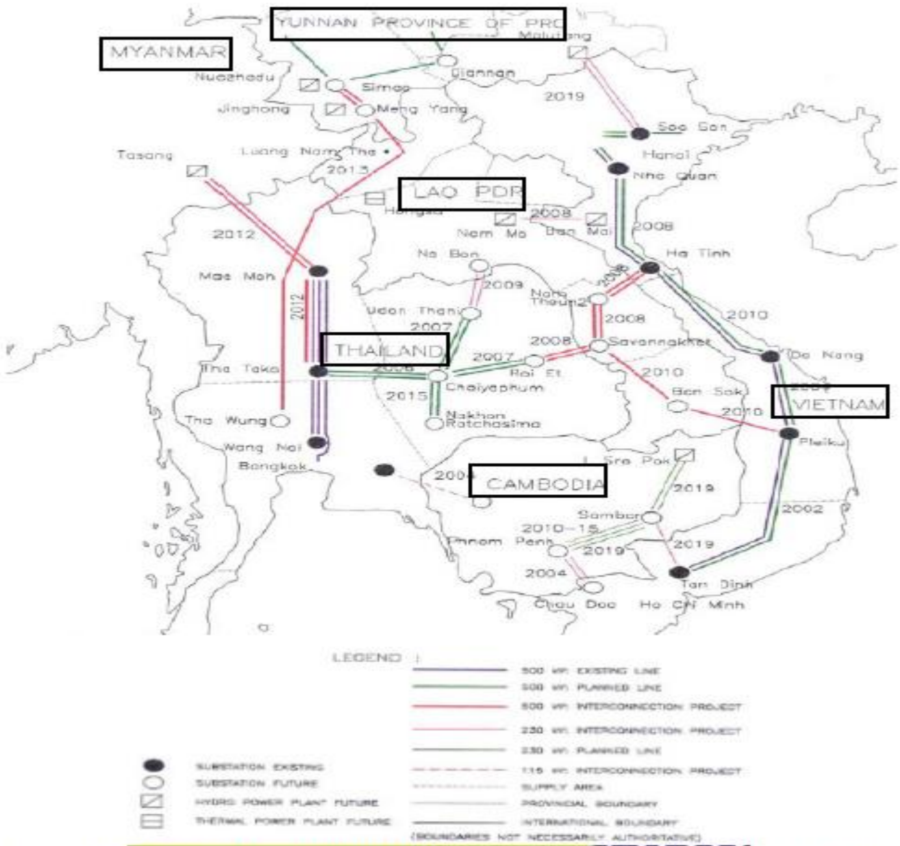
Proposals for Myanmar-GMS Interconnections

As a member of the Greater Mekong Subregion (GMS) Mynamar needs to consider ways in which its transmission export projects are compatible with GMS interconnection planning. As shown below a recent GMS Road Map includes a plan (a) to extend 500kV lines from Tha Wang S/S (substation) in Thailand to Meng Yang S/S and Simao S/S in Yunnan China- the latter will presumably be connected to the large HVDC terminal at the Chuxiong converter station[17]; and (b) to build a new 500KV line from Mae Moh S/S to Ta Sang S/S in Shan State. This arrangement however does not address or explain how the three currently asynchronous power systems will be interconnected – in fact it implies that Thailand, Myanmar and Yunnan will all be synchronised with each other[18]!

[17] The Yunnan-Guangdong project has a rated voltage of an ±800-kV dc, a capacity of 5,000 MW and a transmission distance of 1,418 km (881 miles). The main parts of the system are the Chuxiong converter station, the Suidong converter station, the dc transmission lines and electrodes at both ends

[18] This is probably the most important technical issue that needs resolution in the next five years. It is generally accepted that HVAC power systems must be synchronised to safely and optimally manage generation and power flows under various operational conditions.

Masterplan for GMS EHV Grid Integration (June 2013)



Source: "The GMS Road Map and Work Plan for Expanded Energy cooperation" (from materials presented at the second Subregional Forum).

Potential for HVDC Interconnections within GMS

Within the South East Asian subcontinent, most of the GMS cross border transmission proposals propose the use 500kV interconnections. While HVDC links are also proposed in a few situations this is largely because it is not practical to have long HVAC submarine cables (e.g. as required between Malaysia to Sumatera and Java-Sumatera). However, HVDC is increasingly being recognised as a suitable technology for interconnecting regional grids particularly where these are relatively small with long distances between main generation and load centres.

HDVC is indeed being used in both within China and India to link their various states together and to transfer large amounts of power over long distances. In this respect HVDC is much easier to control than HVAC and can link systems together without having to be concerned about local synchronisation issues. Unlike HVAC, HVDC links can be turned on/off, as power flows transferred up or down in response to system control instruction or as required by commercial load transfer requirements. There is clearly opportunity for ASEAN countries to make the technological leap beyond 500kV HVAC lines and consider the possibility using HVDC links for easily controllable power exchange within the GMS regions[19].

Notably even in the EU, where the UCTE operates a relatively tight 400kV networks, grid integration with the remoter EU systems (e.g. Scandinavian countries, UK, Eastern Europe) is being enhanced by a number of HVDC links. Moreover, there is considerable discussion within the EU about the need for a future HVDC grid overlay to facilitate power exchange between regions[20]: Part of this revived interest in HVDC is because the HVDC technology is increasingly being employed to integrate large intermittent offshore wind farm production into onshore HVAC grids. As a consequence, the limitations the older variety of HVDC (as used in the NZ HVDC link for the last 50 years) are being addressed using the versatility of modern electronic control systems[21].

[19] HVDC can be extended into neighbouring countries in much the same way as proposed for the WB funded CASA 1000 project linking Tajikistan, Afghanistan and Pakistan: http://www.casa-1000.org/

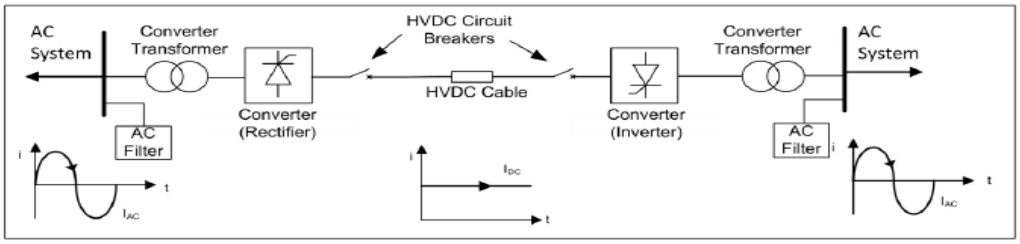
[20] https://en.wikipedia.org/wiki/Super_grid

[21] https://en.wikipedia.org/wiki/Intermittent_energy_source

Characteristics of HVDC Systems

For point-to-point transmission of bulk power over 500 km or more, HVDC transmission links can normally be built at a lower overall cost than conventional HVAC lines. Although HVDC transmission lines can be constructed at about 50% of the cost of an equivalent HVAC line, the cost of the necessary HVDC/HVAC converter stations are about $120/kW, compared with $20/kW for a conventional HVAC/HVAC substation.

Typical HVDC Interconnection Arrangements



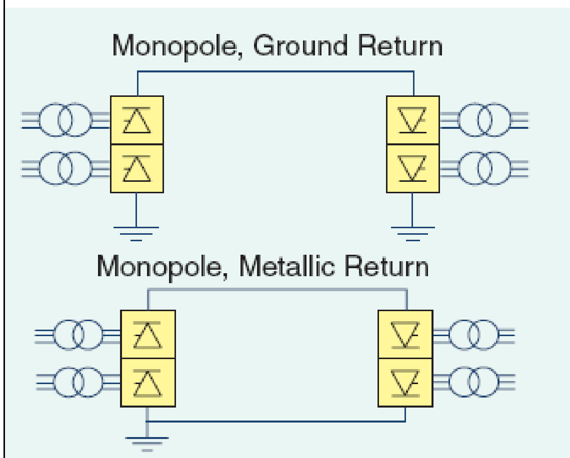
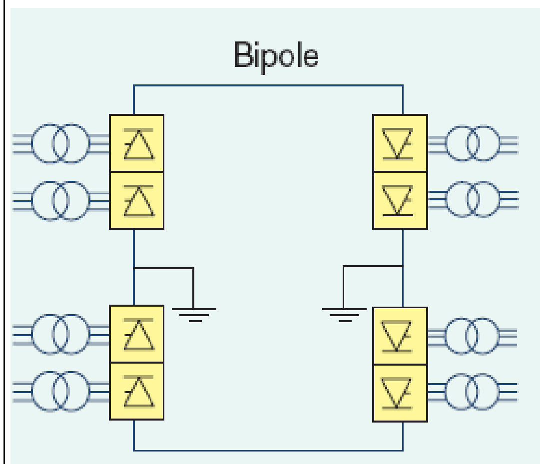
An HVDC interconnection for interconnecting asynchronous systems is sometimes effected with an HVDC back-to-back (b/b) facility, thereby enabling adjacent power systems to maintain their own system frequencies independently of the other. HVDC effectively enables two power systems to be interconnected without having to re-synchronize after every forced or planned disconnection. However, in considering an HVDC b/b facility, it is prudent to also consider building a long HVDC transmission interconnection instead to achieve the same objective at much lower cost. HVDC is also used in many countries, in parallel with HVAC systems, to improve system stability at both ends of the HVDC line as well as moving power more economically over long distances. In effect, HVDC can be designed to act as a very fast FACTS operating device designed to inject power into the HVAC system and counteract inherent instability problems.

Although HVDC technology has many years of operational experience,[22] new control systems have been developed recently which reduce cost and improve flexibility and performance. This is based on modern, newly developed voltage source converters (VSC[23]) with series-connected insulated gate bi-polar transistor (IGBT) valves controlled with pulse width modulation (PWM) that have already reached levels of 1,200 MW and ±500 kV. Notably, HVDC can also be built in stages to increase loading, as required. This can be done by first building the line for monopole operation, then later uprating to bipole operation – and, if necessary, uprating again using a higher operating voltage. Provided that the line is designed for its ultimate operating configuration (at little extra cost), the cost lies primarily in uprating the HVDC/HVAC terminals at each end of the lines.

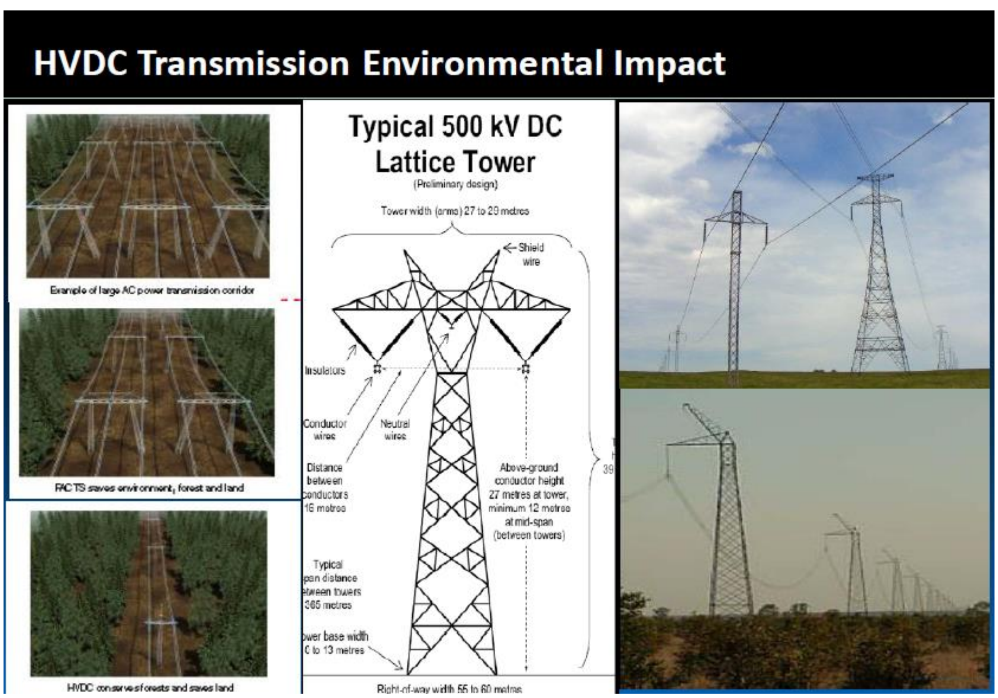
[22] HVDC was originally developed to supply large volumes of power over long distances. The first large-scale commercial project was installed in 1965 in New Zealand where a 600 MW HVDC line was built to carry power from the South Island 600 km to the North Island. This has operated very reliably for over 45 years and was recently upgraded to 1,400 MW. Over 200 HVDC systems have been built over the years. The longest HVDC link in the world is currently the 2,071 km ±800 kV, 6,400 MW link connecting Xiangjiaba Dam to Shanghai in the People's Republic of China.

[23] e.g., ABB's HVDC Light, Siemens HVDC Plus, Alstom's HVDC Maxsine.

Uprating HVDC Interconnection from Monopole to Bipole Configuration

HVDC Monopole Configurations	Monopole Uprated to Bipole Configuration
	

It is also important to note that HVDC lines have a much smaller environmental footprint than HVAC which is especially important for crossing mountainous forested areas as typically exist in Myanmar. The picture below (left) compares the ROW requirements for a typical 500kV triple and double circuity 500kV line with the equivalent capacity HVDC line (left-bottom). The pictures below (right) show the equivalent ROW requirements for two bipole lines (right-tope) and a monopole line with earth return (right-bottom).



HVDC versus HVAC Costs

It would be difficult to compare the cost of developing the HVAC and HVDC solutions without taking into account the stages of development of the hydro resources, the strategy for synchronisation between countries and the respective quantities of power planned to be exported over time to Myanmar, China and Thailand. It can be generally stated that for the distance involved (1100km) the unit costs associated with the transfer of about 2400MW of through an HVDC bipole system would be about 0.52 \$/MW.km compared with an HVAC solution of about 0.86 \$/MW.km[24].

The table below shows a comparison of the total investment cost might be expected to change for the transfer of up to 6000MW over distances of 320, 640and 1290km.

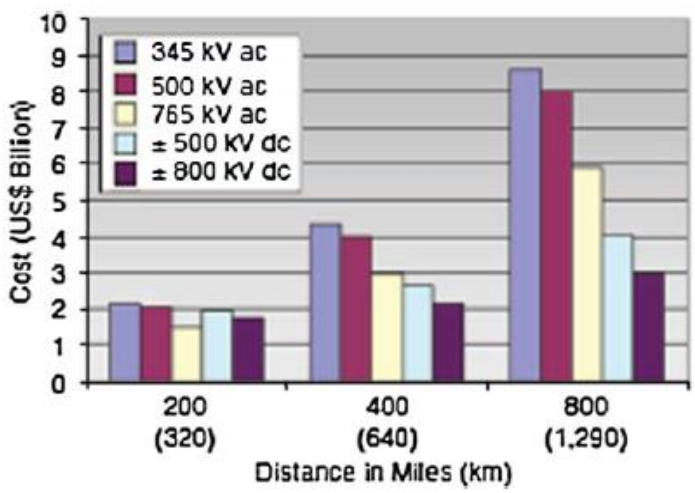
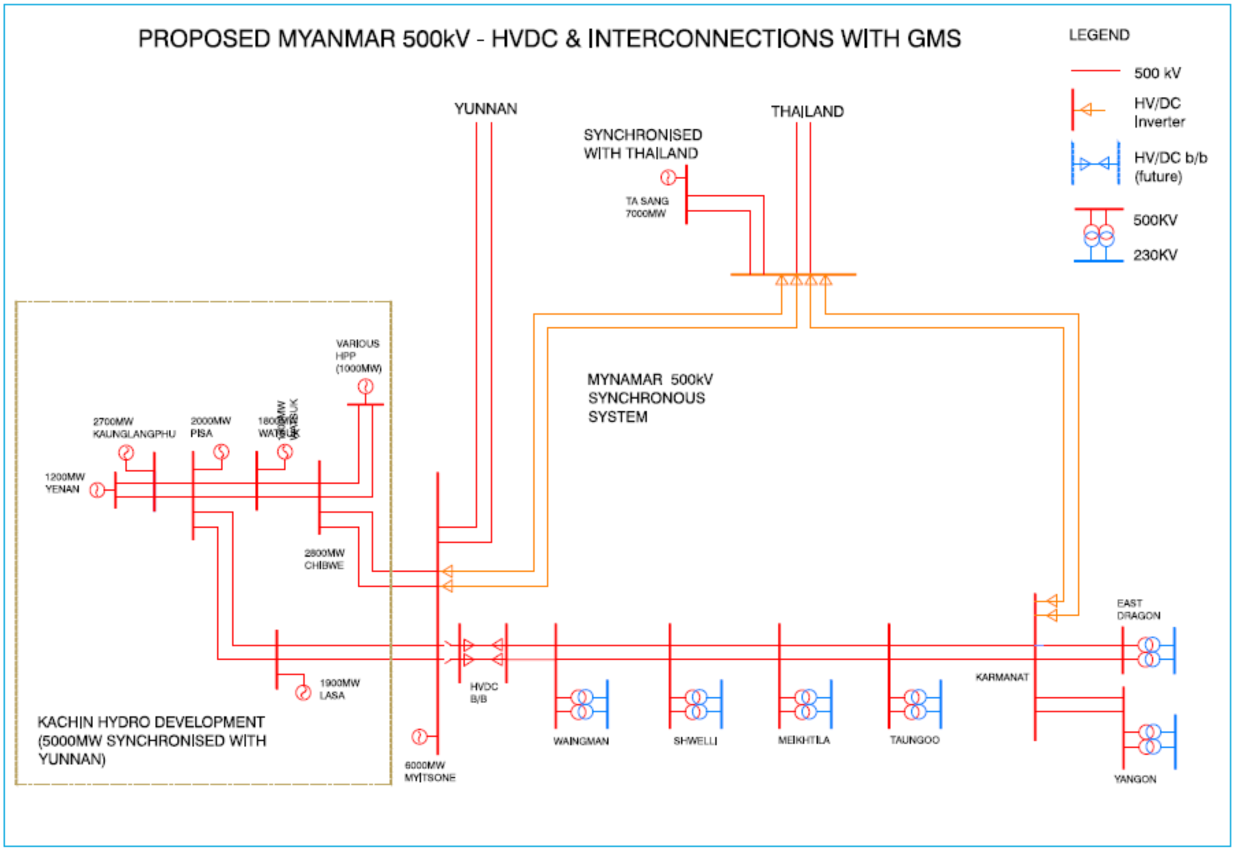


Fig. 9. HVDC and EHVAC investment cost comparisons for 6000 MW capacity.

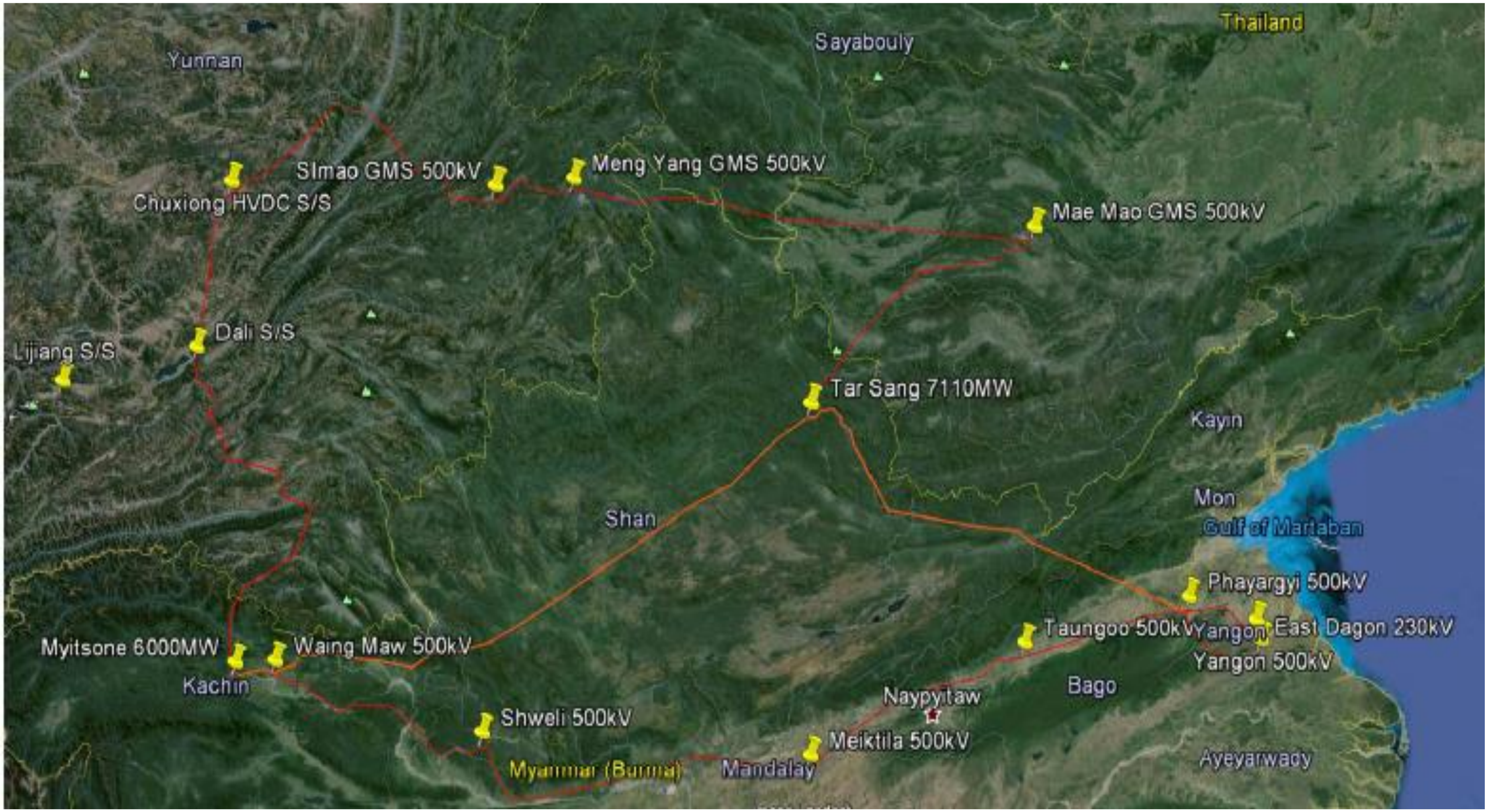
Proposed Interconnection Arrangement for Myanmar-Yunnan-Thailand

The proposed adaption of the MOEP-NEMP 500kV-HVDC arrangement is shown geographically over page and in the schematic diagram below. 500kV lines are shown in red, HVDC lines in orange. The geographic picture has utilized Google Earth design features to select possible routes along valleys or near existing roads. In the schematic drawing details of the Thailand and Yunnan substations connections, and cross border lines are not shown but could be inserted in the diagram when more information is available. The picture however shows the two areas of Myanmar that could be operated in synchronism with China and Thailand.

[24] The cost of power transferred under the different technologies is derived from Table xx of the paper: "A survey of transmission technologies for planning long distance bulk transmission overlay in US" James D. McCalley, Venkat Krishnan, 14 August 2013 The paper can be downloaded from ScienceDirect Electrical Power and Energy Systems: www.elsevier.com/locate/ijepes


PROPOSED MYANMAR 500kV - HVDC & INTERCONNECTIONS WITH GMS
LEGEND
500 kV
HV/DC Inverter
HV/DC b/b (future)
500KV
230KV
YUNNAN
THAILAND
SYNCHRONISED WITH THAILAND
TA SANG 7000MW
MYNAMAR 500kV SYNCHRONOUS SYSTEM
VARIOUS HPP (1000MW)
2700MW KAUNGLANGPHU
2000MW PISA
1200MW YENAN
2800MW CHIBWE
1900MW LASA
KACHIN HYDRO DEVELOPMENT (5000MW SYNCHRONISED WITH YUNNAN)
6000MW MYITSONE
HVDC B/B
WAINGMAN
SHWELLI
MEIKHTILA
TAUNGOO
KARMANAT
EAST DRAGON
YANGON

Google Earth Map of Possible Transmission Routes for Interconnecting Myanmar with GMS Countries (Thailand and Yunnan)



(Red line 500kV, Orange line HVDC, Yellow pointers show locations of main substation

Project Number: TA No. 8356-MYA

FINAL REPORT

APPENDIX 5: COMMENTS MATRIX

Prepared for

The Asian Development Bank

and

The Myanmar Ministry of Energy

Prepared by

Intelligent Energy Systems

in association with

MYANMAR INTERNATIONAL CONSULTANTS

ABBREVIATIONS

ADB	–	Asian Development Bank
IES	–	Intelligent Energy Systems Pty Ltd
MMIC	–	Myanmar International Consultants
NEMC	–	National Energy Management Committee
TA	–	Technical Assistance
TOR	–	Terms of Reference

CONTENTS

I. INTRODUCTION

1. The draft version of the Myanmar Energy Master Plan (EMP) report was submitted to ADB on 19 November 2014. It was subsequently issued by ADB to the Ministry of Energy on 19 December 2014.

2. On 26 March 2015, ADB provided the Consultant with comments from the concerned Myanmar ministries on the Draft EMP report.

3. It should be noted that the original concept was for IES to subsequently undertake consultations with each of the concerned ministries on the Draft EMP report findings and their feedback. However, circumstances did not allow this to occur. As such, the Final report has sought to address the comments raised by the concerned ministries as best as possible, but in the absence of any meaningful consultation with the concerned ministries. This means that in some cases we were not able to confirm or clarify the intent of some questions and also confirm / verify our understanding of additional data that was provided to IES by the concerned ministries as part of their feedback.

4. We have therefore taken a "best endeavours" approach to addressing the stakeholder comments but can't guarantee that we have adequately resolved all issues to the same level as would have occurred had IES been able to engage in consultations following the issuance of the draft report.

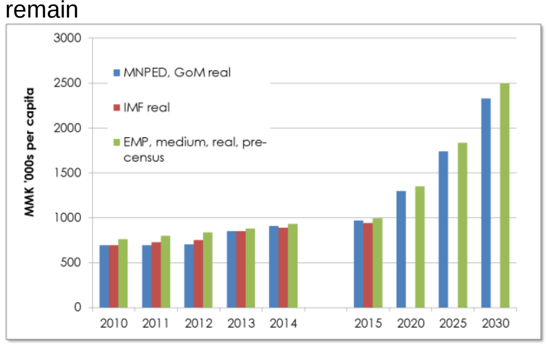
II. RESPONSES TO QUESTIONS FROM CONCERNED MINISTRIES

A. Responses to Comments from Ministry of Industry (MOI)

5. The Consultant's responses to the feedback and comments from the Ministry of Industry are set out in Table II-1.

Table II-1: Response to Ministry of Industry Comments

Comment	Response
For Chapter (D) Demand Forecast: Industry Sector:	
In paragraph of 6, although it is indicated that the earning form the export of natural gas in year 2012 is about 3.6 billion dollar but the cumulative contribution of Oil & Gas, Electricity and water in the total GDP is only 1.2%. So, it is needed to be consistent.	The 1.2% is based on constant price evaluation according to ADB statistics. ADB statistics give the GDP of Electricity, Gas and Water as 611 billion kyats in 2012 (current value) at an exchange rate of 660 kyats per USD$. This does not equate to $3.6 billion, rather it equates to ~$1 billion. It appears that the ADB include oil in the mining sector GDP (this will be checked with ADB). The figure of $3.6 billion includes a contribution from the mining sector; therefore the reference to oil in clause 6 is misplaced and will be revised.
The basic calculation, concept and methodology used for Industry Sector FEC forecast should be indicated.	The calculations, concept and methodology were planned to be explained as part of consultation or training process (or directly with Ministry of Industry representatives if preferred). The energy demand forecasts for the Industry Sector are amongst the most difficult given the wide range of activities involved.
In figure I.8: although the heading is "Energy-Intensive Industry Sector FEC Forecast" but the figure shows just only actual consumption data for the period of 2005 to 2013.	The heading has been corrected.
How figure I.7, I.9, I.10 and I.13 are related to each other and it should be explained. Additionally, it should also be explained how figure I.13 is created including its details calculation.	The details will be explained during upcoming training / appreciation workshop (or directly with Ministry of Industry representatives if preferred).
In the energy planning, only the manufacturing industry is taken into account under energy intensive industry category while the others, such as mining & quarrying, construction and power & gas sectors are eliminated due to the availability of its information. However, those sectors are	Mining and quarrying activities of significant scale were assumed to use captive power sources; while this is important for the energy balance it does not affect electricity expansion planning. It was mentioned that construction activities in themselves are not energy

Comment	Response
also developing and it is also needed to consider their influence on the energy consumption of industry sector.	intensive but the production of construction materials such as bricks, glass and cement require significant amounts of energy. The power and gas sector either provides its own captive power sources, e.g. supplying platforms/wells, or involves secondary transformation; the former is treated as captive power whereas the latter has been modelled and own-use has been included
Sources of reference are important for Table II-3.	The figures in Table II-3 were computed from the survey data provided by Myanmar industry. The figures are average figures for each of the industries mentioned. These points will be clarified with a note below the table.
It is indicated, energy efficiency of some selected Industries is higher than IEA efficiency benchmark but in the paragraph 10, it is also mentioned that the efficiency of the industry sector has been increasing rapidly in recent years.	Paragraph 10 refers to 'energy intensity', not energy efficiency. An increase in energy intensity, as shown in Figure I-13, is to be expected when an industrial sector grows; from an energy efficiency perspective it is not a positive development.
GDP forecast in the energy master plan should be in line with the forecast made by Ministry of National Planning and Economic Development.	The GDP forecast is in line with the MNPED forecast. Change to the population base to match with Census 2014 will affect the figures equally and the comparison will remain valid. 
For Chapter C: Primary Reserves and Technology Options Environmental conservation law is enacted on 8 August 2014 and the section 52, 53 and 54 of environmental conservation law indicates that it is needed to conduct the pre environmental impact assessment for the proposed projects. Currently, Environmental Conservation Department of Ministry of Environmental Conservation and Forestry is undertaking to review the hydropower projects proposals from the environmental point of view and they are also reviewing the environmental impact assessment reports submitted by contractors. Therefore, the following sentence from the paragraph 231 should be deleted "As mentioned above, the current environmental legislation does not require the commissioning of EIAs and thus the environmental and social standards and practices employed by the investors themselves are extremely relevant in the host country."	Noted and deleted from the report.
For Chapter B: Historical Energy Balance: The same graph is used in Figure VI-2 and Figure VI-3 and it should be corrected. Under those graphs, it should be denoted "MOECAF" as a source of information not "MOF" Abbreviation of MOECAF should be included	Noted and corrections have been made in Chapter B.
For Chapter E: Vol.1: Consolidated Demand Forecast: In figure III-6, the physical unit should be changed to "000' tons".	Agree and adjustments made.

B. Responses to Comments from Ministry of Mining (MOM)

6. The Consultant's responses to the feedback and comments from the Ministry of Mining are set out in Table II-2.

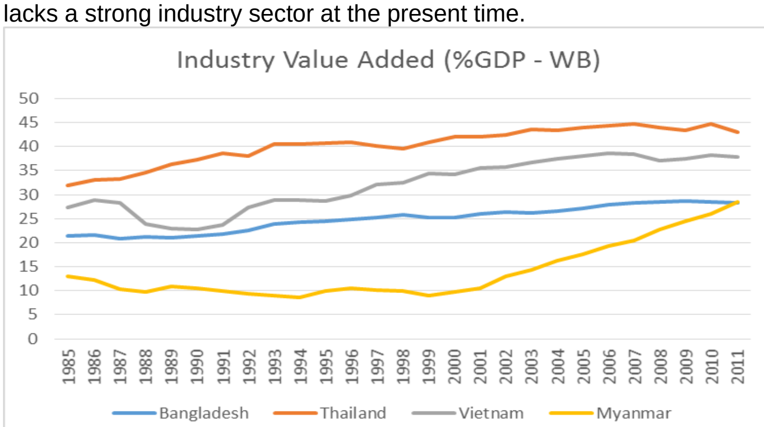
Table II-2: Response to Ministry of Mining Comments

Comment	Response
For Chapter B: Historical Energy Balance: Reserve Potential shown in Table II-4 includes Proven of Positive Ore Reserve (P1), Probable Ore Reserve (P2), Possible Ore Reserve (P3), and Potential Ore Reserve (P4). Among them, P3 and P4 are only potential reserve and the accuracy of coal reserve amount from P3 and P4 class coal mines is low. In the case of proven reserves, all the coal reserve cannot be extracted due to technical and other constraints such as the thickness, dip angle, overburden, groundwater.	This is noted, and some clarifying text added to the Energy Balance chapter.
Coal reserve identified in Table II -4 is not the remaining amount. Some coal mines, such as Maw Taung, San Laung, Namma and Kalaywa Coal mines cannot bear the same amount because those coal mines have been operating since many years ago. And most of the large coal deposits have already been handed over to private sector. Figure II-5 indicates the potential large coal deposits in Myanmar but it will be difficult for coal production due to steep coal bed dripping. Efficiency of conventional coal fired power plant is very low and high technology coal fired power plants have high efficiency but they need exported high class coal. On the other hand, environmental and social acceptance on coal fired power plants is very low in Myanmar. Therefore, high expectation should not be made to establish coal fired power plant.	As above, noted. Figure II-5 has been replaced by a more detailed overview of the locations of Myanmar's coal resources.
For Chapter C: Primary Reserves and Technology Options: In Table III-1, coal production forecast for 2015-2016 is 2316000 ton and it is about 4 times higher than 2013-2014 production. Increasing the coal production to 4 times depends on coal market and coal fired power plants.	This is noted and some text adjusted in the report.
For Chapter C: Primary Reserves and Technology Options: In paragraph 60, it is mentioned that the 80% of the coal production in 2004-2005 is exported to China and Thailand and coal export was significantly reduced after construction of Tigyit thermal power plant. Actually, coal export was reduced due to stop production from Maw Taung coal mines and it is not because of consumption of Tigyit thermal power plant.	This is noted at paragraph 60 revised.
For Chapter C: Primary Reserves and Technology Options: In paragraph 66, the update status of private sector participation in coal sector is that 6 companies are operating coal mines out of 19 companies.	This change has been reflected.

C. Responses to Comments from Ministry of Energy (MOE)

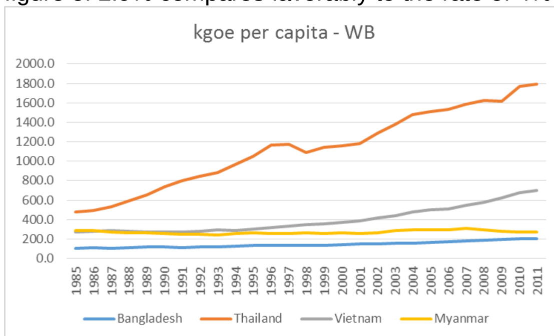
7. The Consultant's responses to the feedback and comments from the Ministry of Energy are set out in Table II-3.

Table II-3: Response to Ministry of Energy Comments

<table>
<tr><th>Comment</th><th>Response</th></tr>
<tr><td>Annual Growth Rate of 2.9% for Final Energy Consumption is too low as compare to the expected GDP growth rate of 7.1%. Its growth rate should be at least 5 or 6%.</td><td>
The following World Bank statistics for Thailand (THA), Vietnam (VNM), Bangladesh (BGD) show that the relationship between GDP growth and energy growth is correlated. The growth rate for energy is higher than the rate for GDP per capita. Myanmar's GDP per capita growth has not been published by the World Bank due to doubts on the statistics from 2000 to 2010 but most likely the growth rate for energy has been lower than for GDP per capita.
<table>
<tr><td colspan="2">CAGR for ktoe - period 1985 to 2011</td></tr>
<tr><td>THA</td><td>5.8%</td></tr>
<tr><td>VNM</td><td>5.0%</td></tr>
<tr><td>BGD</td><td>4.2%</td></tr>
<tr><td>MMR</td><td>0.9%</td></tr>
<tr><td colspan="2">CAGR for GDP per capita - period 1985 to 2011</td></tr>
<tr><td>THA</td><td>4.1%</td></tr>
<tr><td>VNM</td><td>4.7%</td></tr>
<tr><td>BGD</td><td>3.0%</td></tr>
<tr><td colspan="2">CAGR for kgoe per capita - period 1985 to 2011</td></tr>
<tr><td>THA</td><td>4.9%</td></tr>
<tr><td>VNM</td><td>3.5%</td></tr>
<tr><td>BGD</td><td>2.5%</td></tr>
<tr><td>MMR</td><td>-0.2%</td></tr>
</table>
The Consultant considers that the GDP and energy growth statistics of Thailand and Vietnam in particular are influenced heavily by energy-intensive industry growth; the growth in heavy industrial activity has resulted in relatively high energy growth rates.
The following chart for Industry Value Added includes a time series that is a composite of figures agreed by the World Bank (to 2000) and from other sources. Again the World Bank has not published figures post-2000 due to doubts regarding the statistics – it is considered that the rise in the Industry Value Added statistic since 2000 may not be significant – in other words that growth in the energy consumption of the industrial sector has been slow until recent times. The energy consumption and production statistics gathered from the public and private sector energy-intensive industries appears to support the likelihood that the Industry Value Added is low. Another way to consider this issue is to say that Myanmar is an agriculture + oil / gas economy that lacks a strong industry sector at the present time.


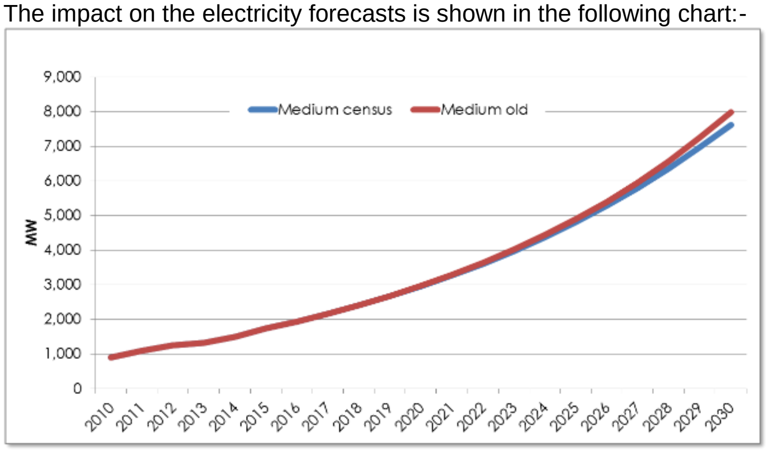
World Bank Indicators; Index Mundi
Myanmar's ktoe and kgoe per capita growth rates are recorded by the World Bank at 0.9% and -0.2% respectively. In this context, with a falling kgoe per capita rate over
</td></tr>
</table>

<table>
<tr><th>Comment</th><th>Response</th></tr>
<tr><td></td><td>the last decade, an energy growth rate of 2.9% represents a significant turn-around. The figure was derived using bottom-up estimates for each sector but from top-down perspective it is not inconsistent with an historical ktoe growth rate of 0.9%. The figure of 2.9% compares favorably to the rate of 4% experienced by Bangladesh.



World Bank Indicators

In any case the accuracy of the energy growth rate forecast is less important than the assumptions for the drivers of energy growth, e.g. the growth in passenger vehicles. So rather than focussing on the resultant energy growth rate it would be more helpful to understand if the assumptions for the drivers of energy growth are reasonable. In the meantime there does not appear to be a justification to arbitrarily change the 2.9% to a higher rate.</td></tr>
<tr><td>Expected population growth rate of 0.9% is acceptable. However, the size of country population used in the planning process should be based on the preliminary result of national census.</td><td>At the time of preparation of demand forecasts the results of the national census had not been validated. Since that time it is apparent that there is agreement between national and international experts that the population estimates determined by the census are robust. Therefore it is sensible to use the census results. In fact this approach was taken before the release of the draft EMP, but the ADB gave instructions to revert to the pre-census population for ease of comparison with other studies using the pre-census figures and so the higher population was used for demand forecasts and expansion planning.</td></tr>
<tr><td>Vehicle and income growth rates are also expected to change due to the new base line population.</td><td>The impact of the change in population is not as significant to energy demand forecasts as might be expected. This is because the historical demand forecasts that are driven by population, were calibrated against reported energy consumption (electricity, transport gasoline and diesel, and firewood). The effect of reducing the historical population statistics means that the historical per capita energy rates increase. When these new energy consumption rates are applied to the (lower) projections for population, using the census 2014 figures as a base, the change to the total energy consumption is not affected significantly.
The impact on the electricity forecasts is shown in the following chart:-



The ‘medium census’ forecast is based on the census population; the ‘medium old’ forecast is based on the ADB time series for the population. The difference in population assumption shows in the forecast after 2025. The Consultant considers that the difference in the forecast is not significant enough to require rework of the electricity expansion modelling.
The impact on transport energy is shown in the 2 charts in APPENDIX A.</td></tr>
</table>

Comment	Response
	The consumption rises because of the impact of GDP per capita, but again the impact is insignificant. The impact on agriculture has been checked, the difference is also insignificant. The impact on HH energy consumption has not been checked in detail. Here there are two conflicting drivers. If we were to assume fixed kgoe per capita figures for urban and rural HH's then a 15% reduction in population would result in an energy consumption reduction of 15%. Against this is that the census revealed that the urban population is higher than was assumed for the EMP (and the rural population is lower). Since urban energy consumption per HH is higher than for rural HH's, then from overall perspective it is expected that the change to the census population statistics will not result in a significant change to the total HH sector energy projection, however, the split of energy consumption between urban and rural HH will change and the change could be significant. The HH sector estimates will be reworked with the census population to verify these opinions.

D. Responses to Comments from Ministry of Rail Transportation (MORT)

8. The Consultant's responses to the feedback and comments from the Ministry of Rail Transportation are set out in Table II-4.

Table II-4: Response to Ministry of Rail Transportation

Comment	Response
For Chapter D: Demand Forecasts: Transport Sector All the expression of "Myanma Railways" should be replaced with "Road Transport Administration Department"	Noted and replacement made
Data are updated for the Figure I. 1, Table I-2, Table I-3, Table II-1, Table III-9. (See APPENDIX B.)	Noted and updated.

E. Responses to Comments from Ministry of Hotel and Tourism (MOHT)

9. The Consultant's responses to the feedback and comments from the Ministry of Rail Transportation are set out in Table II-5.

Table II-5: Response to Ministry of Hotel and Tourism

Comment	Response
For Chapter (D): ENERGY FORECASTS, COMMERCE & PUBLIC SERVICES SECTOR: Update the tables as discussed in APPENDIX C below.	All tables noted and updated.

F. Responses to Comments from Ministry of Electricity Power (MOEP)

10. The Consultant's responses to the feedback and comments from the Ministry of Electricity Power are set out in Table II-6.

Table II-6: Response to Ministry of Electric Power

Comment	Response
For Chapter (A) Economic Outlook, the caption of "Figure (1-4) should be changed into "Major River & Existing Hydro Power in the Union of Myanmar".	Noted, title has been changed.
For Chapter (B) Historical Energy Balance, In paragraph (74) Electricity Transmission and Distribution System, the voltage of Transmission line is" 230 kV". It is not "220 kV". Figure V-8: Myanmar National Grid map is updated in Annex (1). In paragraph (76), the amount of electricity consumption by industry, resident and commercial/services sectors in total final consumption are "32%, 44 % and 20% respectively."	This is noted and the information in the report updated accordingly.

Comment	Response
Table V-13 is updated in Annex (2).	
For "Chapter (C) Primary Reserve and Technology Option II. NATURAL GAS " Table II-5 is updated in Annex (3). In paragraph (71),the location of coal power plant is Kalaw city in the Shan State. It is not "Kalewa". Paragraph (142) should be replaced with "As for renewable energy development, MOEP is in charge of solar and wind power project with IPP development. Currently (2014) there are two foreign companies with several development in the country. Under their respective memorandums of understanding from 2011 with the ministry, a Thai (Gunkul Engineering Public Co., Ltd) and China Three Gorges Corporation (CTG) company are carrying out feasibility analysis of building wind farms in several locations. The Gunkul Engineering Public Co., Ltd has seven sites in the Mon and Kayin States and in Tahintharyin Region, which would produce 1,000 MW and in Shan and in Kayah States, which would produce 1930 MW. The China Three Gorges Corporation (CTG) company is studying locations in the Chin State, Rakhine State, Ayeyarwaddy Region and Yangon Region to the capacity of 1,102 MW." In paragraph (175) , the first four sentences should be replaced with "As of June 2014, the total installed capacity of hydropower plants in Myanmar was 3005 MW. This includes 23 hydropower plants of installed capacity higher than 10 MW, and some 40 mini and micro hydropower plants of 34 MW in total capacity. Detailed information on the hydropower plants is listed in Annex 15. The planned annual hydropower generation totals 14,956.8 GWh (excluding mini hydro)." In paragraph (182), the actual commissioning year of both Thaukyegat-2 and Chipwenge plants is 2013. It is not 2014. Paragraph (178) should be replaced with "Nearly half of the number of hydropower developments in Myanmar are multipurpose schemes, in which provision of irrigation services plays important role. It permits the dry- season cropping of maize, peanuts, sesame, wheat, cotton, millet, and other dry crops. The installed capacities of the plants associated with irrigation dams are typically not high. Kinda (56 MW), Mone (75MW),Paunglaung (280 MW), Sedawgyi (25 MW), Thapainzeik (30 MW), Yenwe (25 MW), Kyeeon Kyeewa (74 MW), Zaungtu (20 MW) and Zawgyi-2(12 MW) plants are installed to large dams for irrigation. Their total electric capacity is 597 MW." Paragraph (181) should be replaced with" For the Dapein-1 Hydropower plant (240 MW), also being developed by the PRC investors, 100% can be made available to the Myanmar central grid and 10% of the generated electricity will be free power as royalty."	All points noted and agreed, revisions have been made accordingly.
For Chapter (E) Vol-1 Final Energy Consumption Forecast IV.ELECTRICITY FORECAST (TOP - DOWN RECONCILIATION): Table IV-1: Distribution Losses - Yangon (2013) is updated as APPENDIX E.	The figures shown here in Table IV-1 were used for the demand forecasts but the figures in Table IV-1 in the report were not matching; they have now been updated in the report
Table IV-8: Baseline Energy Sales by State / Region: 2013 is updated in Annex (4).	Noted.
For the Analysis Results of Chapter(C) Primary Reserve and Technology Option, it is also suggested that the recommendation	The concept and methodology will be explained during a training session, or if preferred by way of a

Comment	Response
should include "To use different sources for electricity generation in the long term in order to bring the Energy Balance and for the short term, Combined Cycle Power Plant should be implemented only after the Open Cycle Plants are implemented. Concept and methodology used for Electricity Demand Forecast should be explained.	separate meeting with MoEP specialists.

G. Responses to Comments from Ministry of Energy (MOE) on Draft Final

Comment	Response
Supply Gas (3.4) at Table I-1 Supply Projection at Page No. 651, and Consumption Gas (4.1) at Table I-3 Energy Consumption at Page No. 653 are not the same. Supply gas is less than consumption gas.	*Two problems surfaced when looking at this issue. One was that LPG consumption was incorrectly gathered under the Natgas category when the IEA approach is to gather under Oil. It was noticed that light industry consumption was not gathered for some years in the IEA tables (from years 2021 to 2030). Corrections have been made, and the TFEC table and IEA tables revised.*
Table III-3 at Page No. 677: Coal (lignite) column is missing. 7,542 (Total Primary Energy) is not equal to the combination of 2,832 (Hydro), 314 (Solar PV), 216 (Natural Gas) and 57 (Coal bituminous).	*The fuel consumption figures were primary quantities and summed to the primary energy total, this has been clarified by re-arranging the columns in the table.*
LPG Column is missing at Table V-3 Natural Gas at Page No. 685 and Table V-4 Natural Gas at Page No. 686. Different units are used there.	*In first draft of the Energy Outlook report, LPG was accounted for under gas, but it was later remembered that, under IEA approach, LPG must be accounted for under Oil / Refined Petroleum, not under the Natural Gas category. In checking this issue it was noticed that Table V-5 included a column for LPG - this column has been removed.*
Figure I-3 TPES – Fuel Mix 2030 at Page No. 656 needs to be adjusted in percentage.	*This chart and Figure I-2 have been replaced.*
Table V-2: Compound Annual Growth Rate Projections at Page No. 685: "- 6.2 %" is mentioned under Transport. Actually, consumers prefer CNG as it is cheaper.	*A major barrier to widespread deployment of CNG is the availability of onshore gas; as such the assumptions was made that widespread use of CNG was limited and the view adopted was that we do not project increased CNG use. It would be possible to run a sensitivity of CNG consumption to understand the overall natural gas use if needed but best done by way of a demonstration in the development of a transport scenario, perhaps in a workshop setting.*
Table V-3: Natural Gas TPES Forecast (toe) at Page No. 685: Much are reduced under Electricity Consumption (2012-2014 were finished already.) compared to the previous report.	*This was the result of having to change our original gas consumptions figures over to those provided in the ADICA report. Unfortunately not all gas consumption projections in all tables and figures had been completely updated. We have fixed this and updated the figures.*
Fix the consistency between the following figures / tables: Figure I-3: Myanmar: FEC Projection by Energy Carrier (medium) from Consolidated Demand Forecasts Chapter Table I-1: Supply Projection to 2030 (mtoe) from	*This was related to a change in classification of LPG from the gas category to the oil category to be consistent with IEA categorisation – this was a late change that had not been reflected across all parts of the report. This is now fixed.*

Comment	Response
Energy Supply Outlook Chapter TableI-3: Total Final Energy Consumption (TFEC, mtoe) from Energy Supply Outlook Chapter	

Annexes

ANNEX A:

Original forecast using ADB population statistics

	Reference Case						
	2012-13	2015-16	2018-19	2021-22	2024-25	2027-28	2030-31
Gasoline	492.7	681.8	843.2	1,027.1	1,218.0	1,379.81	1,509.6
Bioethanol	-	-	-	-	-	-	-
Diesel	880.3	1,064.5	1,033.7	1,027.0	1,077.7	1,209.91	1,423.9
Natural Gas	31.7	29.9	24.4	20.4	16.3	12.74	8.9
Jet Fuel (ATF)	31.3	31.5	50.4	69.3	88.1	107.04	125.9
Total	1,436.1	1,807.7	1,951.7	2,143.8	2,400.1	2,709.50	3,068.3

Forecast based on census population

	Reference Case						
	2012-13	2015-16	2018-19	2021-22	2024-25	2027-28	2030-31
Gasoline	492.7	700.9	862.5	1,047.1	1,239.3	1,400.33	1,521.2
Bioethanol	-	-	-	-	-	-	-
Diesel	880.3	1,082.2	1,047.5	1,037.6	1,085.6	1,216.94	1,430.5
Natural Gas	31.7	31.1	25.3	21.0	16.7	12.94	15.0
Jet Fuel (ATF)	31.3	31.5	50.4	69.3	88.1	107.04	125.9
Total	1,436.1	1,845.7	1,985.7	2,175.0	2,429.7	2,737.25	3,092.6

ANNEX B:

Figure1-1: Myanmar Registered Vehicle Statistics

	05-06	06-07	07-08	08-09	09-10	10-11	11-12	12-13	13-14
Two wheeler	641777	646872	658997	1612423	1749083	1883958	1995505	3219213	3595474
Other	11307	11758	13008	13933	14514	15862	15693	18806	25730
Bus	18038	18857	19291	19683	19807	20944	19579	19812	22151
Truck(heavy duty)	31437	31990	33160	33928	35125	36820	38478	43881	52069
Truck(light duty)	23364	23392	24051	24929	26007	28068	29272	30665	72528
Passenger car	193940	202068	217018	233227	245921	265642	249561	292919	382774

Table I-2: Modelled Passenger Transport Use For Myanmar (2012)

		Total Vehicle
Modality	Fuel	No
Passenger Vehicle (Public And Private Passenger cars and diesel buses)	Gasoline	148073
	CNG	19431
	Diesel	221735

Table I-3: Model Freight Transport Use for Myanmar (2012)

		Total Vehicle
Modality	Fuel	No.
Heavy Commercial Vehicle	Diesel	38950
Light Commercial Vehicle	Gasoline	4385

Table II-1: Motorization of Myanmar's Provinces (February 2013)

State/ Region	Private Car	Truck (Light Duty)	Truck (Heavy Duty)	Passenger	Motorcycles
Other	38981	7981	18696	5248	2146877

Table III-9: Vehicle Parc

	2012
Passenger Car	281575
Bus	19522
Light Commercial Vehicle	29478
3 wheel Trawlergi	71082

ANNEX C:

Update data for table II.4 are as follow:

Year	No	Room
2004	591	19540
2005	594	19947
2006	594	20265
2007	599	20346
2008	619	21474
2009	631	21375
2010	677	22373
2011	731	25002
2012	787	28291
2013	923	34834
2014	1106	43243

Update data for table II-5 are as follow:

Sr. No	State / Region	2010 (Dec)		2011 (Dec)		2012 (Dec)		2013 (Dec)		2014 (Dec)	
		No.	Room	No.	Room	No.	Room	No.	Room	No.	Room
1	Yangon	181	7658	187	7934	204	8915	232	10175	287	13146
2	Mandalay	195	6291	219	7861	234	8636	287	11995	337	14475
3	Bago	33	770	33	770	36	879	37	926	43	1099
4	Sagaing	10	223	10	242	12	298	16	462	19	646
5	Tanintharyi	9	484	11	570	11	598	14	695	21	1005
6	Ayeyarwady	39	1456	43	1565	46	1824	53	2081	54	2254
7	Magway	7	101	11	173	13	244	17	347	21	471
8	Kachin	16	423	18	495	18	495	21	607	22	628
9	Kayah	3	44	5	98	6	109	7	135	8	175
10	Kayin	7	172	7	172	7	172	7	180	10	325
11	Chin	-	-	-	-	-	-	-	-	1	27
12	Mon	18	444	19	478	21	652	28	980	37	1300
13	Rekhine	25	735	27	791	30	933	35	1104	40	1250
14	Shan	134	3572	141	3853	149	4536	169	5147	206	6442
	Total	**677**	**22373**	**731**	**25002**	**787**	**28291**	**923**	**34834**	**1106**	**43243**

For Paragraph 73, the number of visitors arrival to Myanmar is provided as follow:

Visitors Arrival to Myanmar

Sr. No	Mean of Travelling	2011	2012	2013	2014
1	By Air	385732	588298	871153	1082140
2	By Water	131273	147139	226559	242217
3	By Land	299364	323558	946595	1757055
	Total	**816369**	**1058995**	**2044307**	**3081412**

Visitors Arrival through Yangon International Airport

Sr. No	Year	Person
1	2011	362810
2	2012	557462
3	2013	809100
4	2014	991208

ANNEX D:

		2009	2010	2011	2012	2013
Eastern District						
Technical loss	%	23.0	20.67	19.56	17.99	20.46
Non-technical loss	%					
Western District						
Technical loss	%	20.7	19.98	19.16	17.72	18.97
Non-technical loss	%					
Southern District						
Technical loss	%	29.41	25.28	23.95	25.98	26.63
Non-technical loss	%					
Northern District						
Technical loss	%	20.65	20.23	19.65	17.26	19.01
Non-technical loss	%					