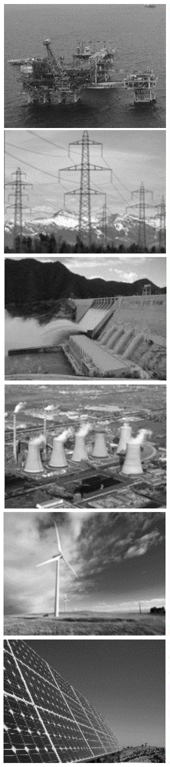
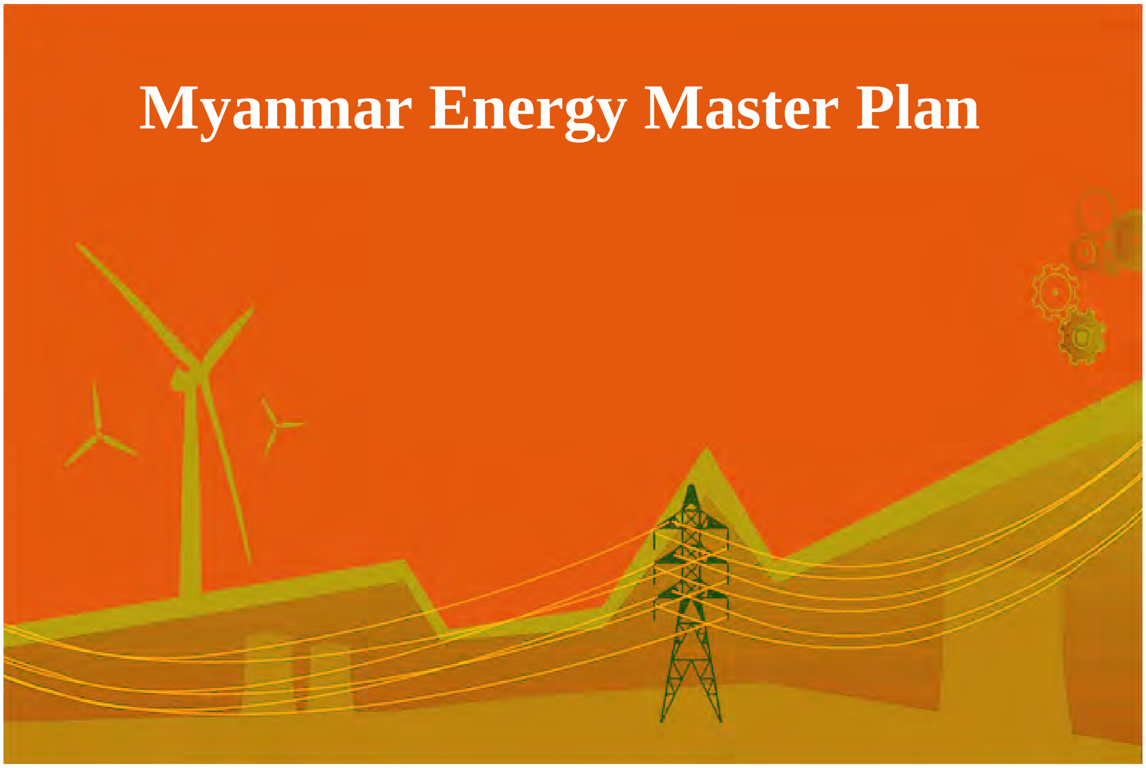
The Government of the Republic of the Union of Myanmar
National Energy Management Committee





Myanmar Energy Master Plan

ADB

IES Intelligent Energy Systems

MMIC
MYANMAR
INTERNATIONAL
CONSULTANTS

December 2015

MYANMAR ENERGY MASTER PLAN
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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

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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
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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 Industry Sector Report
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- Vol. 4 Transport Sector Report
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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,

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[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

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

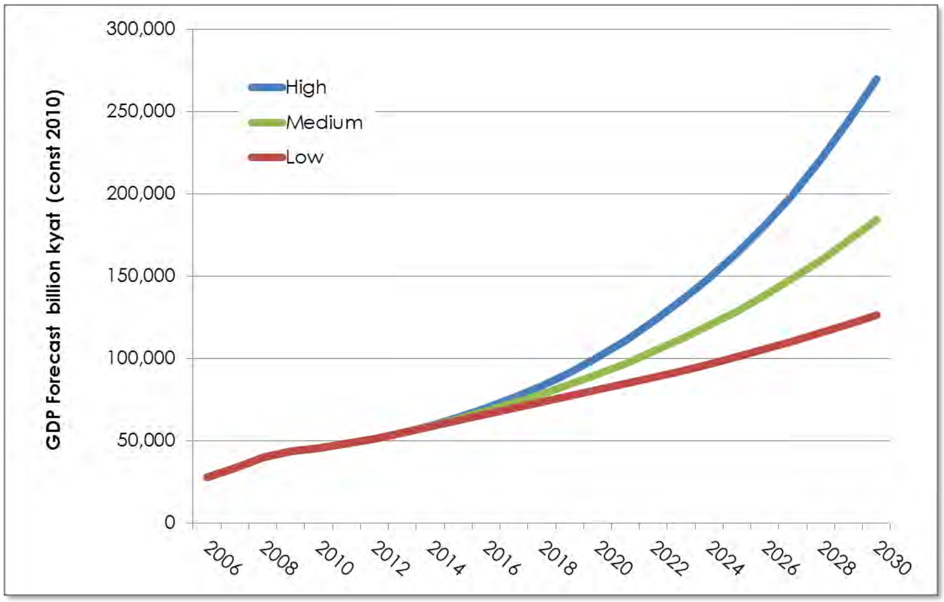
subsectors, albeit dependent on an injection of substantial foreign direct investment (FDI).

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)

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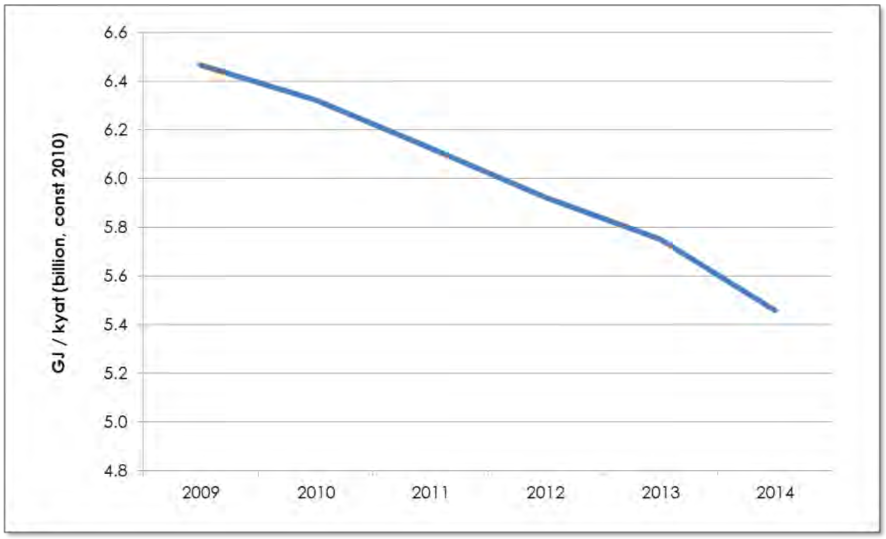
[4] Myanmar Unlocking the Potential, ADB (August 2014)

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,

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[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

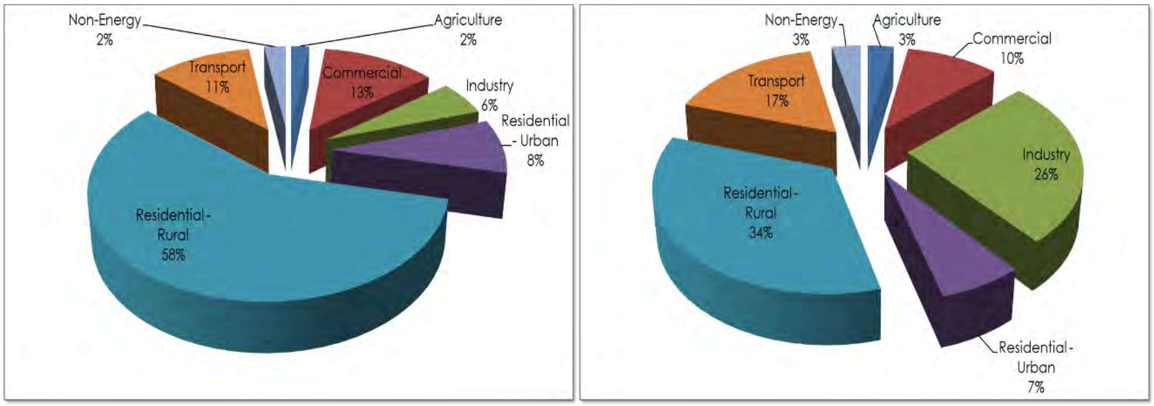
10. A breakdown of the estimated final energy consumption (FEC) in 2012 is given by Figure E2. This chart shows the relative consumption of each economic sector and the household sector. Total FEC is estimated to have been 12.2 mtoe in 2012. At 66% of FEC, the residential sector was the largest energy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



2012 **2030**

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.

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[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)

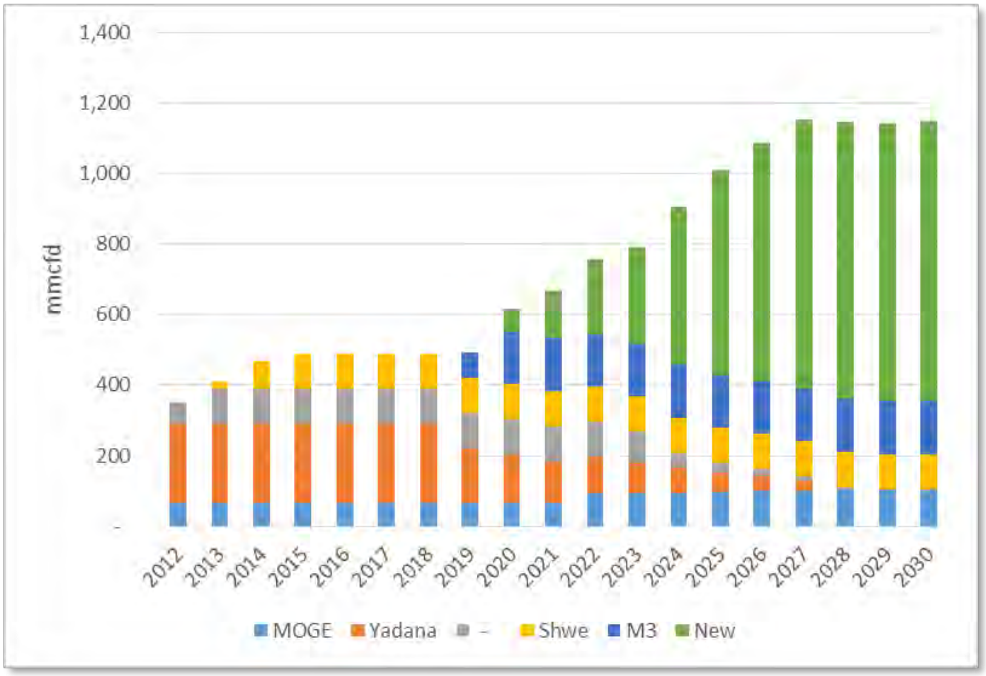
	2012	2015	2018	2021	2024	2027	2030
TFC	12.6	14.2	15.3	16.5	17.9	19.6	21.9
Coal	0.1	0.1	0.2	0.2	0.3	0.4	0.6
Oil	2.5	3.4	3.6	4.0	4.4	4.9	5.5
Gas	0.6	0.9	1.2	1.5	2.0	2.5	3.2
Electricity	0.7	1.0	1.3	1.8	2.4	3.2	4.3
Biomass Type II	8.8	8.9	9.0	9.0	8.8	8.6	8.4
Shares (%)							
Coal	0.6	0.8	1.1	1.4	1.7	2.1	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

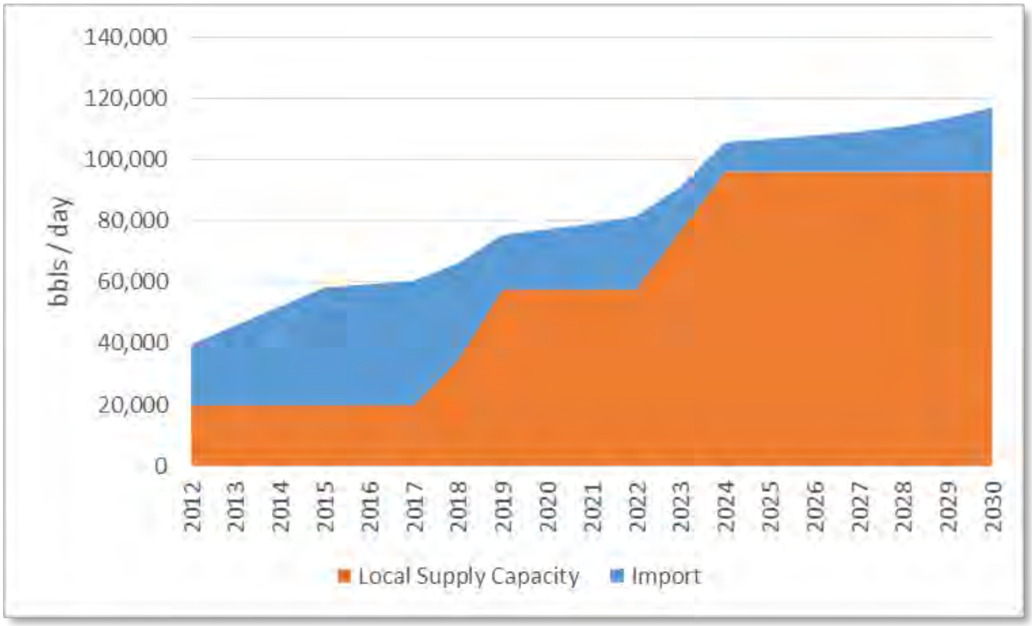
15. The Republic of the Union of Myanmar possesses large resources of natural gas. It plays a significant role in the country's energy mix: in recent years natural gas accounted for 45% of the total primary energy production. At home the natural gas was mainly used for electricity production and industrial 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)



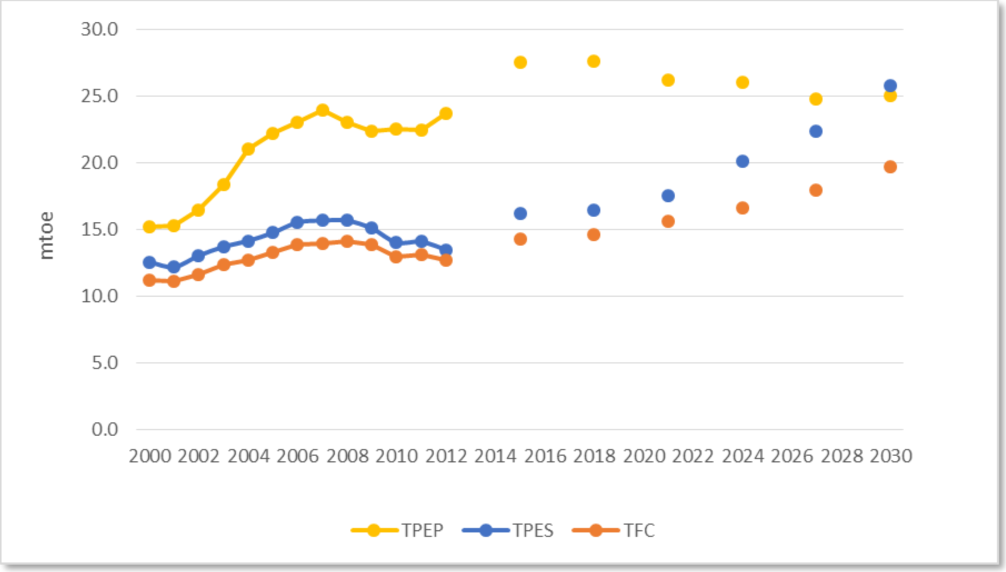
17. In the case of coal, the Consultant has assumed that all coal used to power large coal-fired plants (in coastal locations) will be imported bituminous coal of high calorific value. Industrial need for coal will be met mainly with indigenous coal.

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

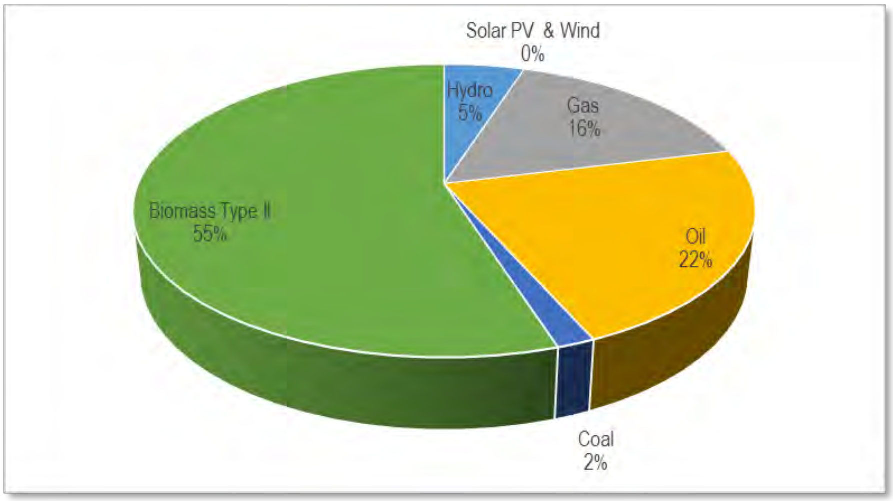
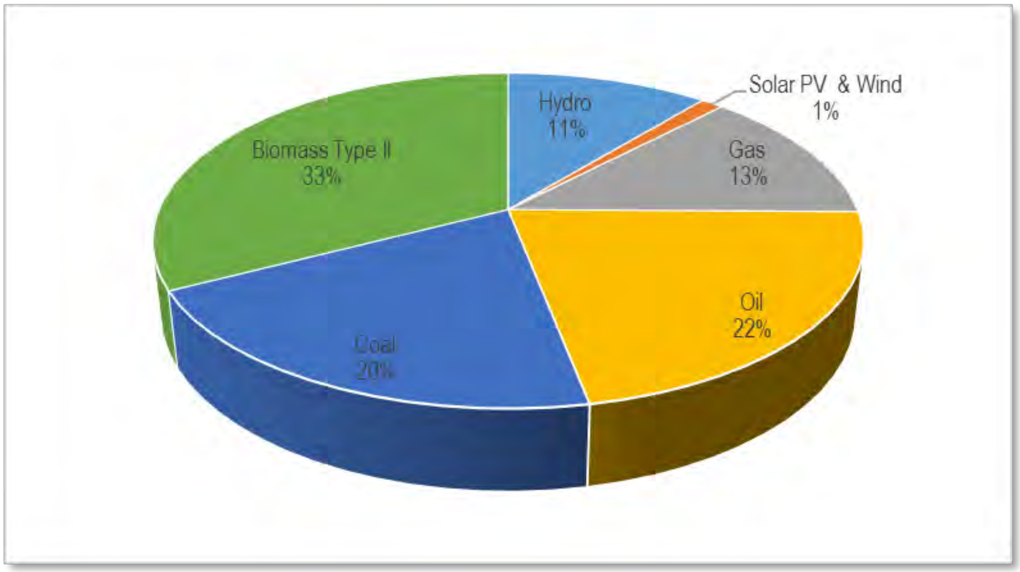


Figure E10: TPES – Fuel Mix 2030

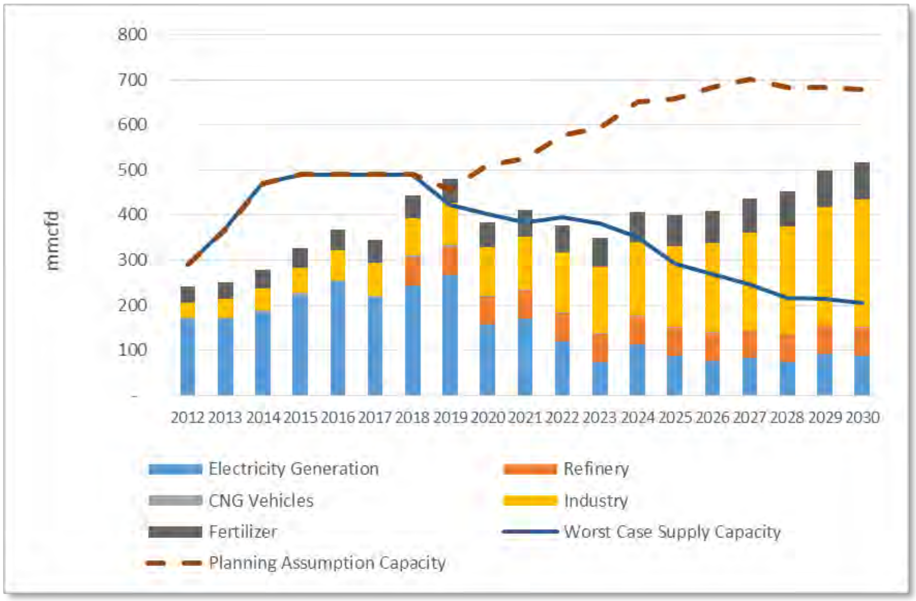


Sources: 2000 – 2012 IEA, MoE; 2013 – 2030 Consultant estimate

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

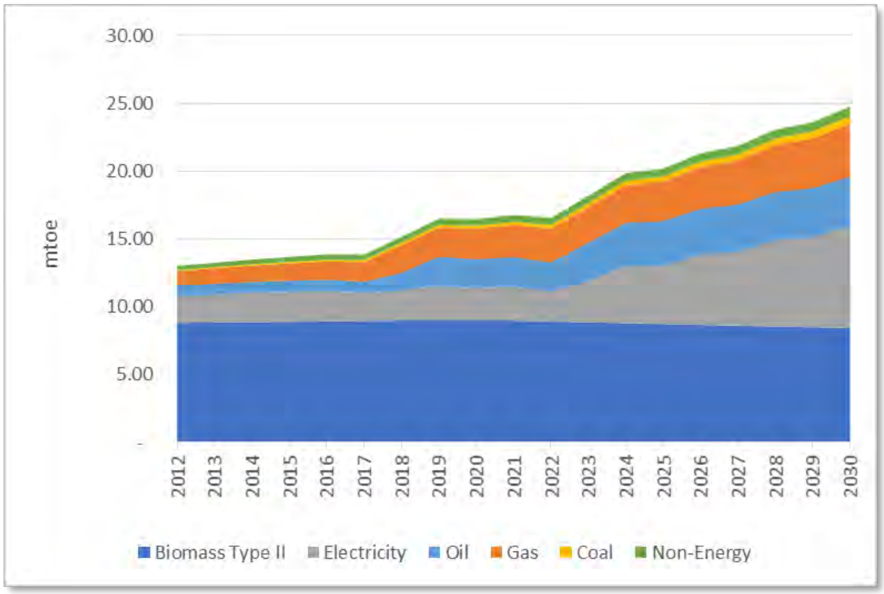
	2012	2015	2018	2021	2024	2027	2030
INPUT (mtoe)	1.97	2.22	2.21	2.52	4.22	5.45	7.54
OUTPUT Electricity (GWh)	10,364	14,398	19,446	25,763	33,904	44,238	57,654
Electricity output shares (%)							
Hydro	69.7%	65.0%	56.5%	74.1%	64.0%	65.7%	57.1%
Solar PV	0.0%	0.0%	0.0%	0.0%	0.0%	2.0%	5.2%
Wind	0.0%	0.0%	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)

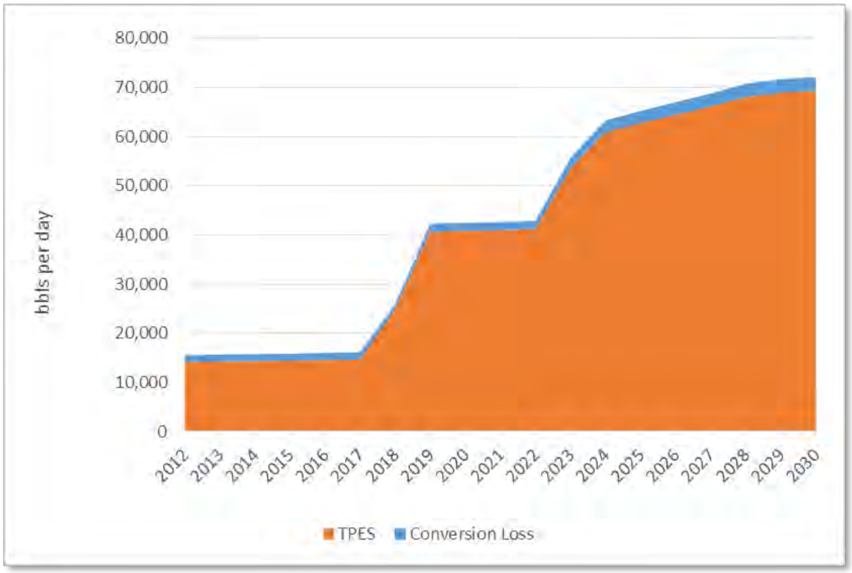


Figure E17: Natural Gas TPES Forecast (mmcfd)

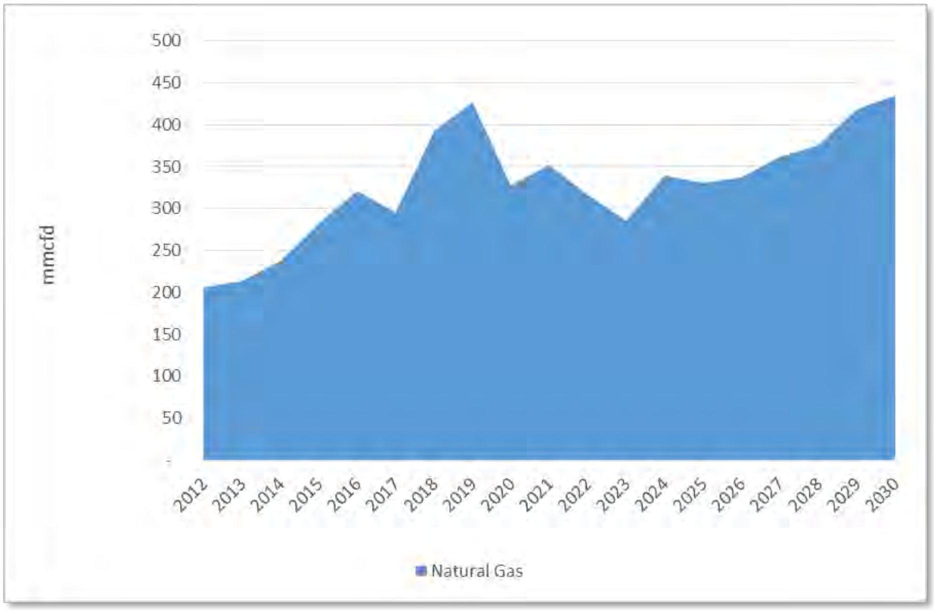


Figure E18: Coal TPES Forecast (tons per annum)

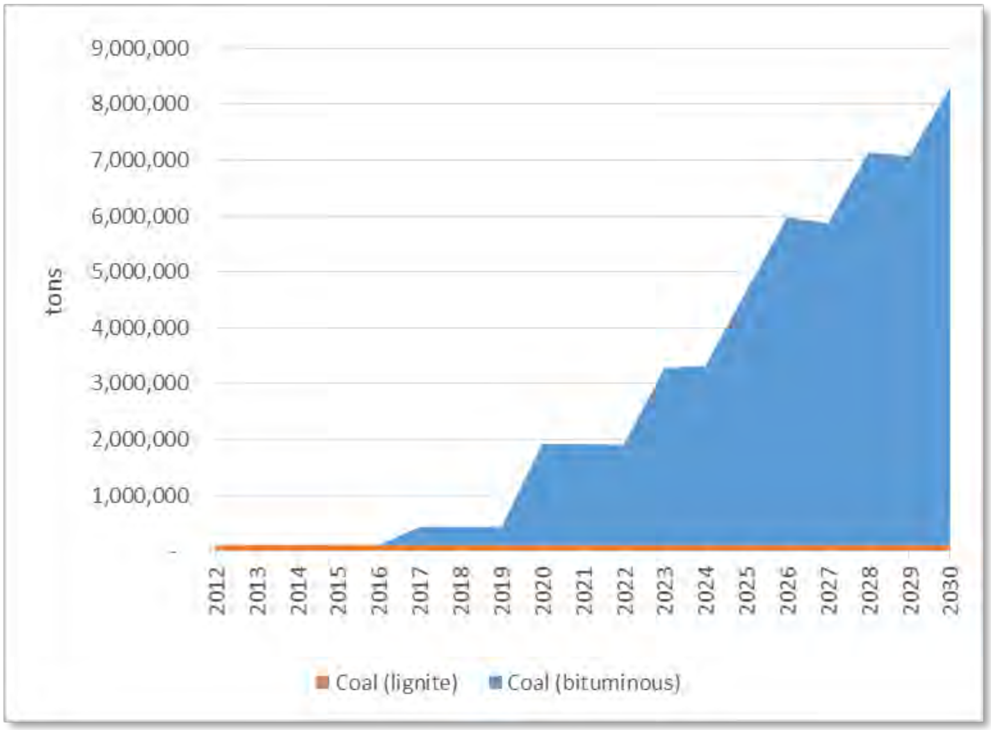


Figure E19: Fuelwood TPES Forecast (tons per annum)

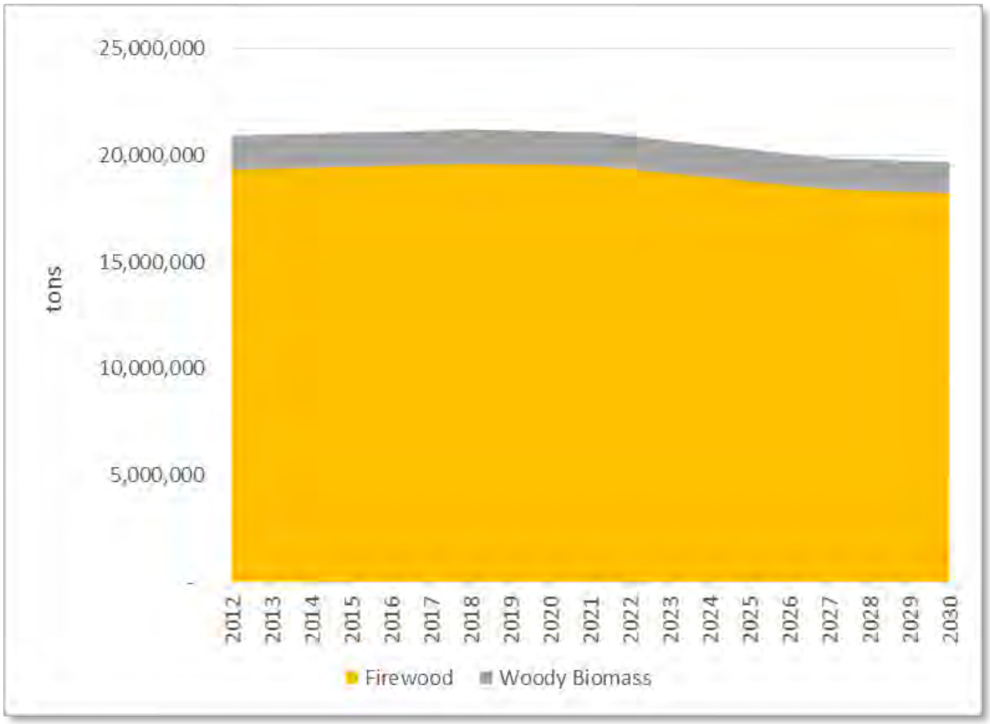


Figure E20: Electricity TPES Forecast (GWh)

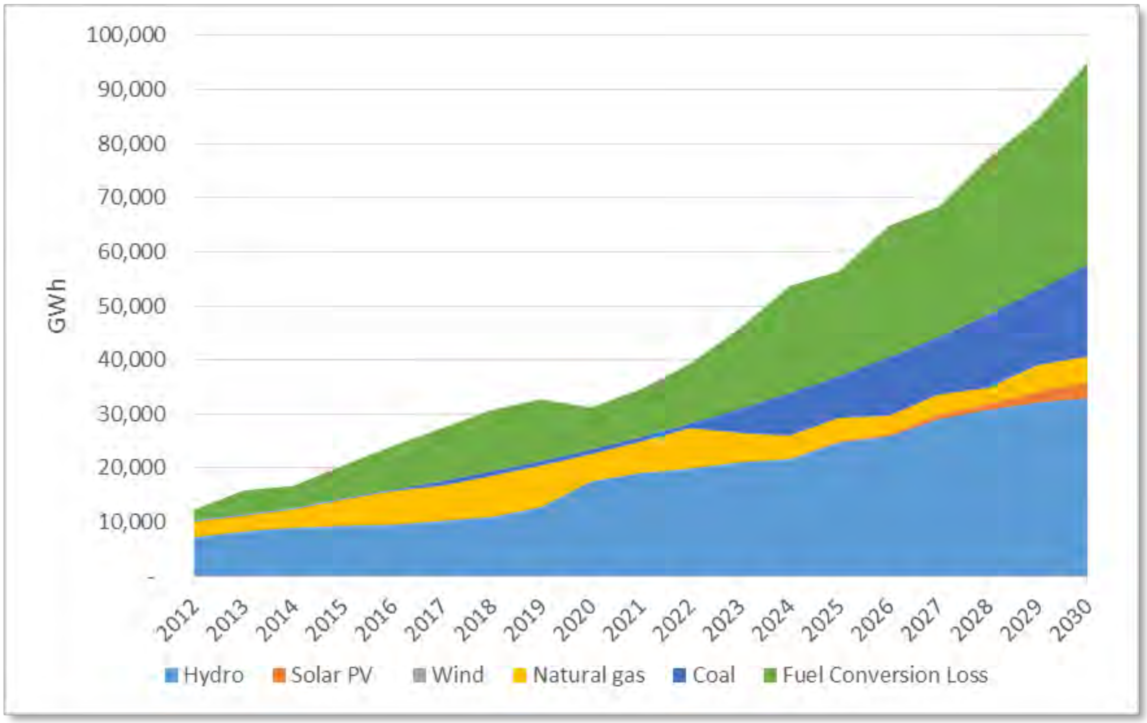
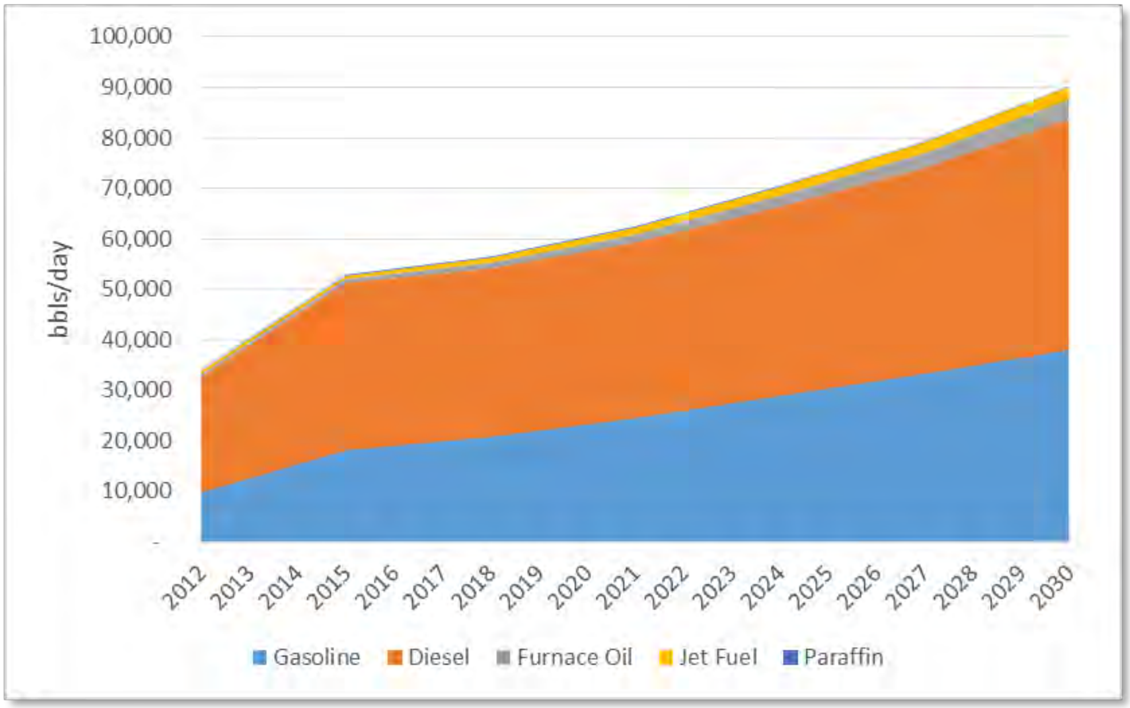


Figure E21: Refined Oil Products TPES Forecast (bblsd)



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)							

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[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

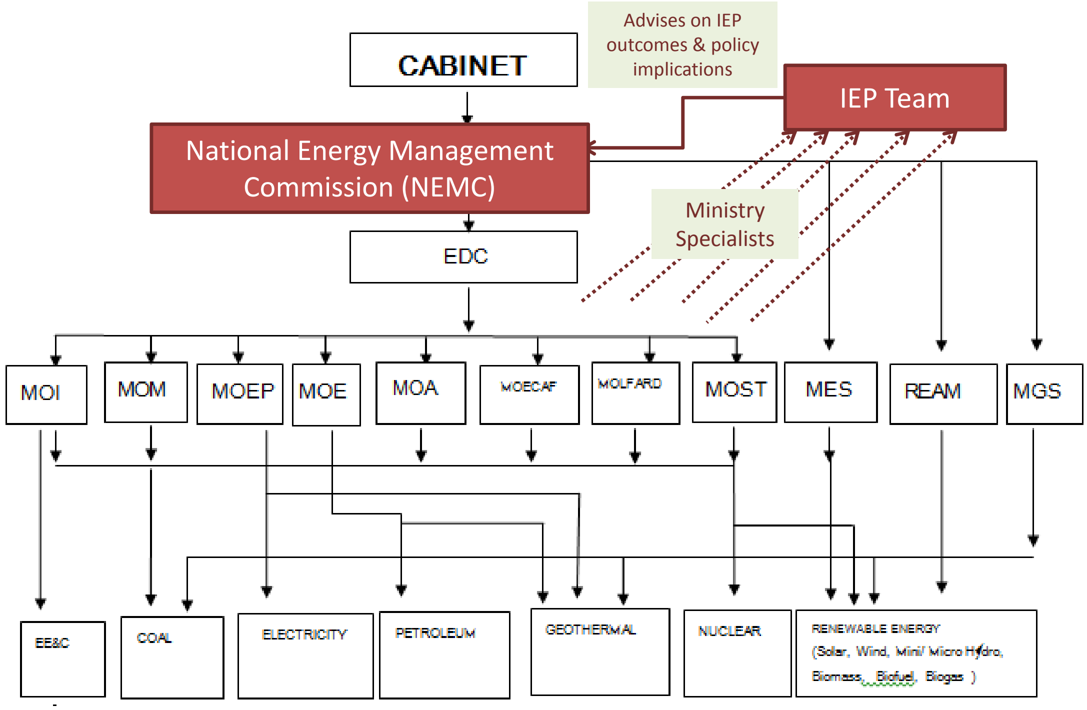
35. The present governance structure and supporting National Energy Policy provides the foundation for an Integrated Energy Planning process. However, a number of enhancements to the organisational structure are recommended to allow it to become more effective. The following enhancements to the existing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

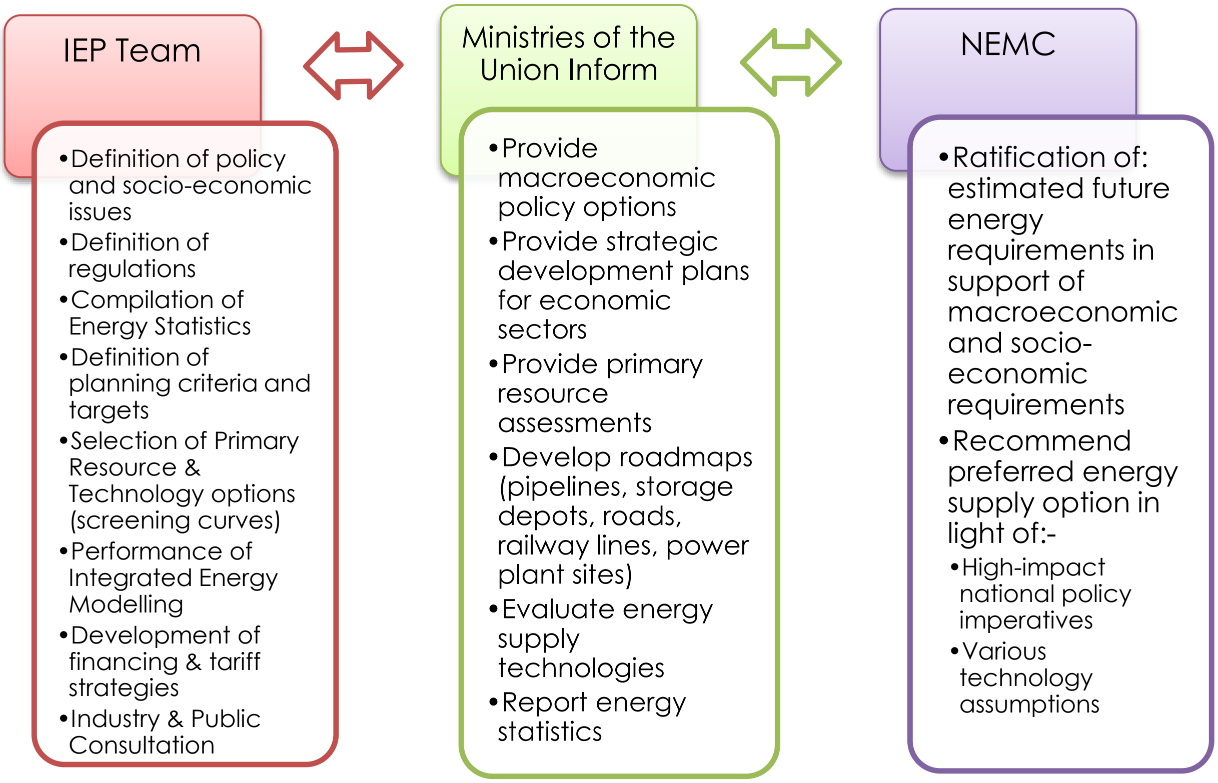
i. High-impact national policy imperatives

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



IEP Team

- Definition of policy and socio-economic issues
- Definition of regulations
- Compilation of Energy Statistics
- Definition of planning criteria and targets
- Selection of Primary Resource & Technology options (screening curves)
- Performance of Integrated Energy Modelling
- Development of financing & tariff strategies
- Industry & Public Consultation

Ministries of the Union Inform

- Provide macroeconomic policy options
- Provide strategic development plans for economic sectors
- Provide primary resource assessments
- Develop roadmaps (pipelines, storage depots, roads, railway lines, power plant sites)
- Evaluate energy supply technologies
- Report energy statistics

NEMC

- Ratification of: estimated future energy requirements in support of macroeconomic and socio-economic requirements
- Recommend preferred energy supply option in light of:-
  - High-impact national policy imperatives
  - Various technology assumptions

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

IES
Intelligent Energy Systems

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MMIC
MYANMAR
INTERNATIONAL
CONSULTANTS

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FINAL REPORT

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MYANMAR
INTERNATIONAL
CONSULTANTS

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

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[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.

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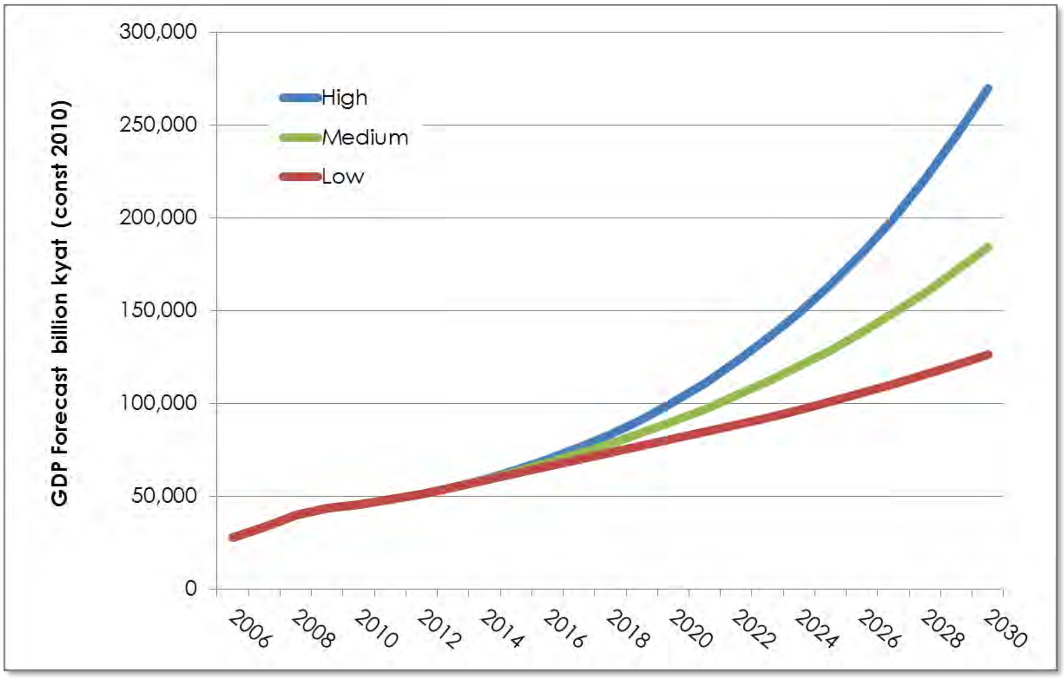
[3] Myanmar Comprehensive Development Vision, Chapter 5, p9

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

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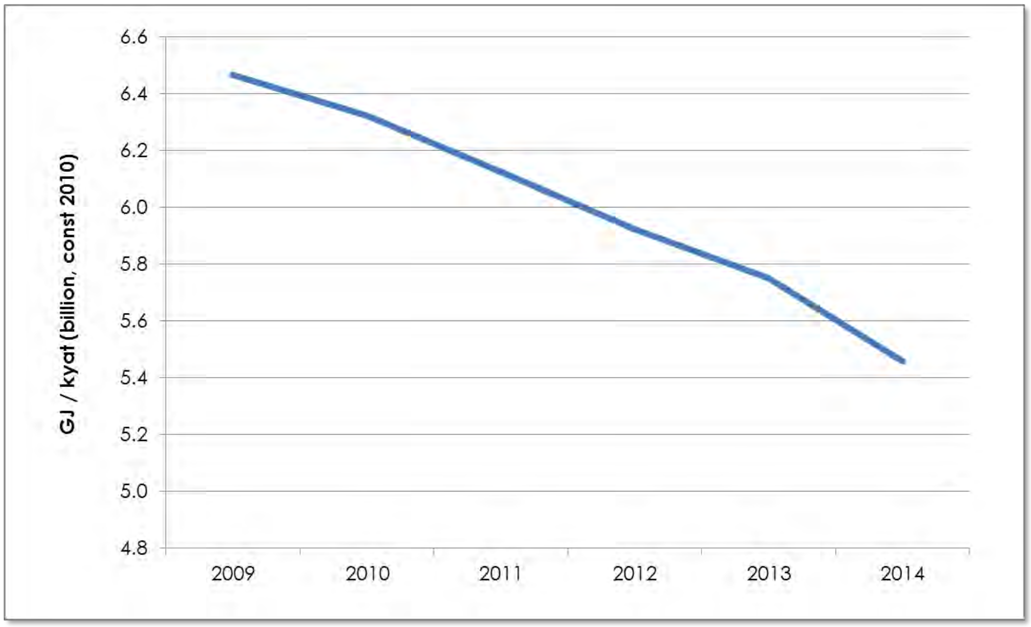
[4] Myanmar Comprehensive Development Vision (2013); Appendix_Growth prospects

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

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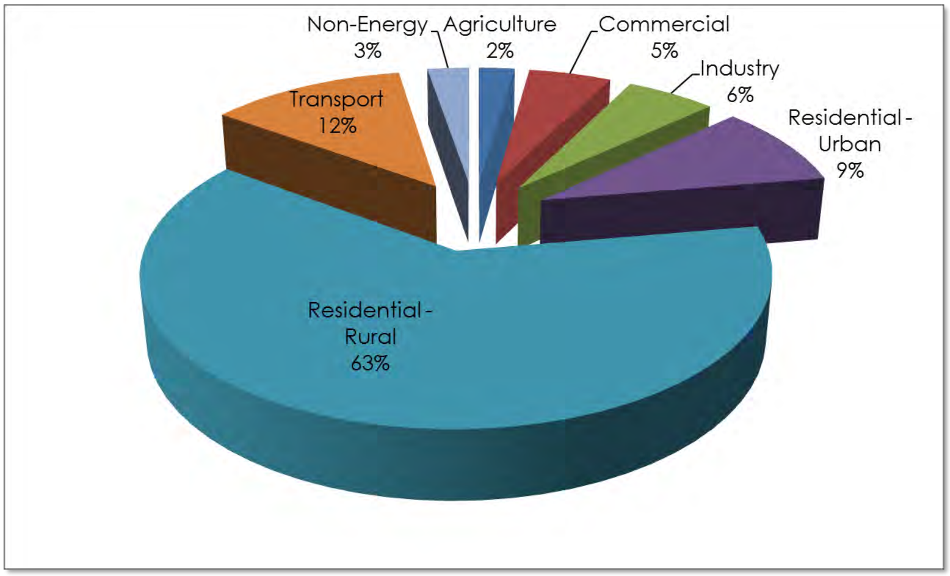
[5] Energy Consumption and Economic Growth: A Panel Co-integration Analysis for Developing Countries (2012); Adhikari, Chen, Dalian University of Technology (DUT)

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

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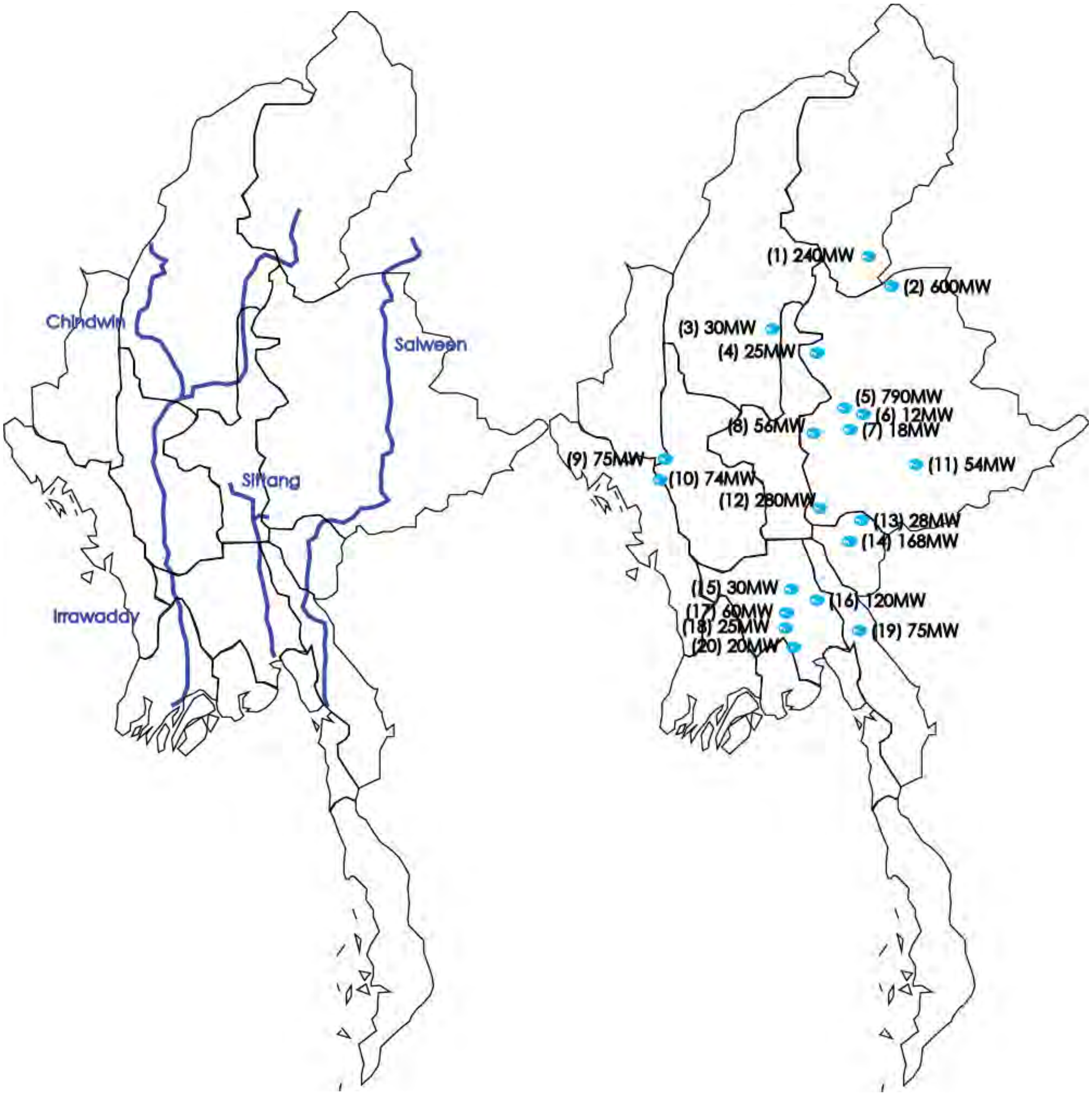
[6] Refer Energy Masterplan Volume III Rural HH Cooking
[7] LIFT Baseline Survey Report - July 2012
[8] MercyCorps: Myanmar Energy Poverty Survey – 2011; Myanmar Household Energy Market Assessment - Aug 2012
[9] The Ayeyarwady, along with its major tributary, the Chindwin, drains 58% of the country's 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

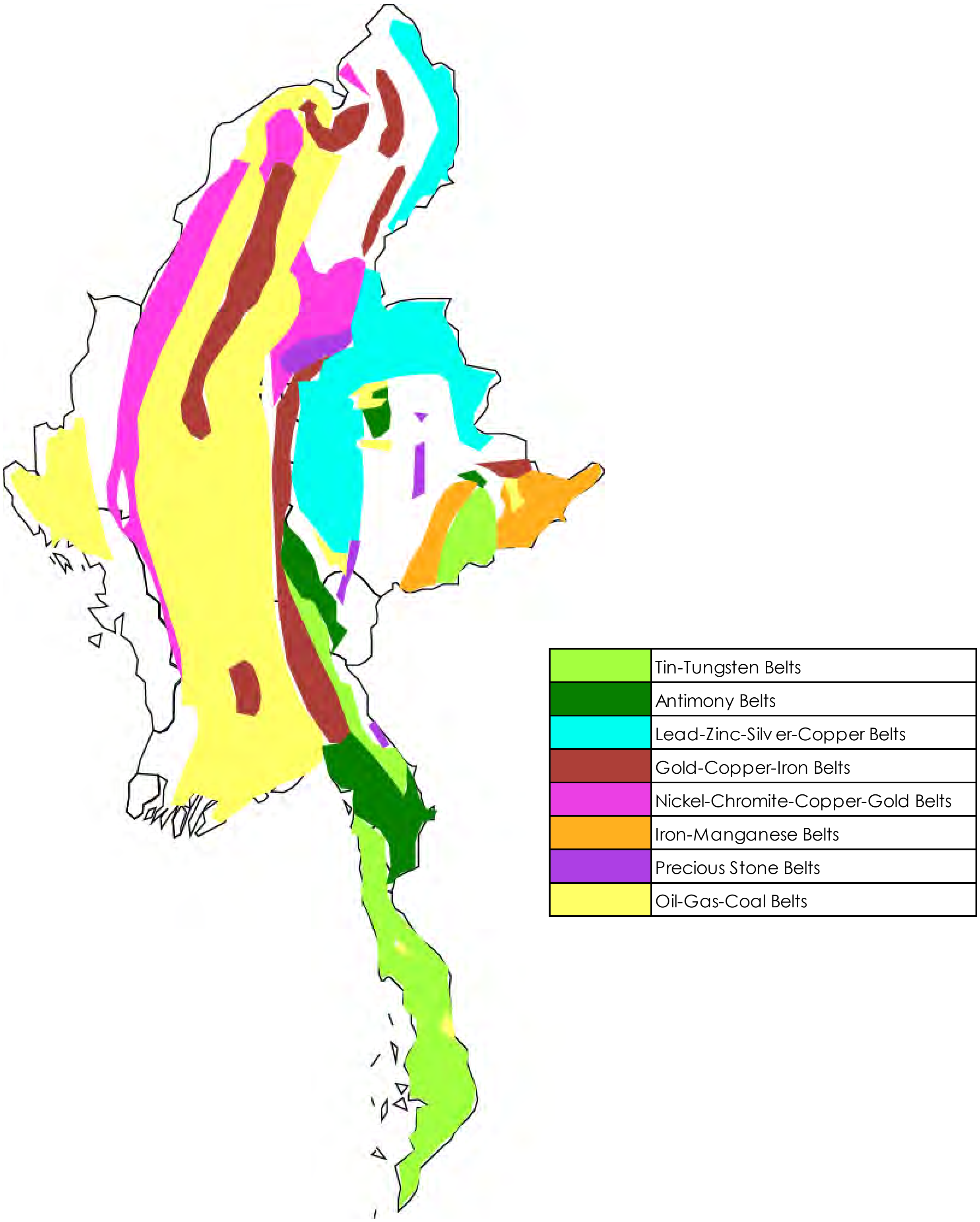
by mapping of the mineral belts in Figure I-5.

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

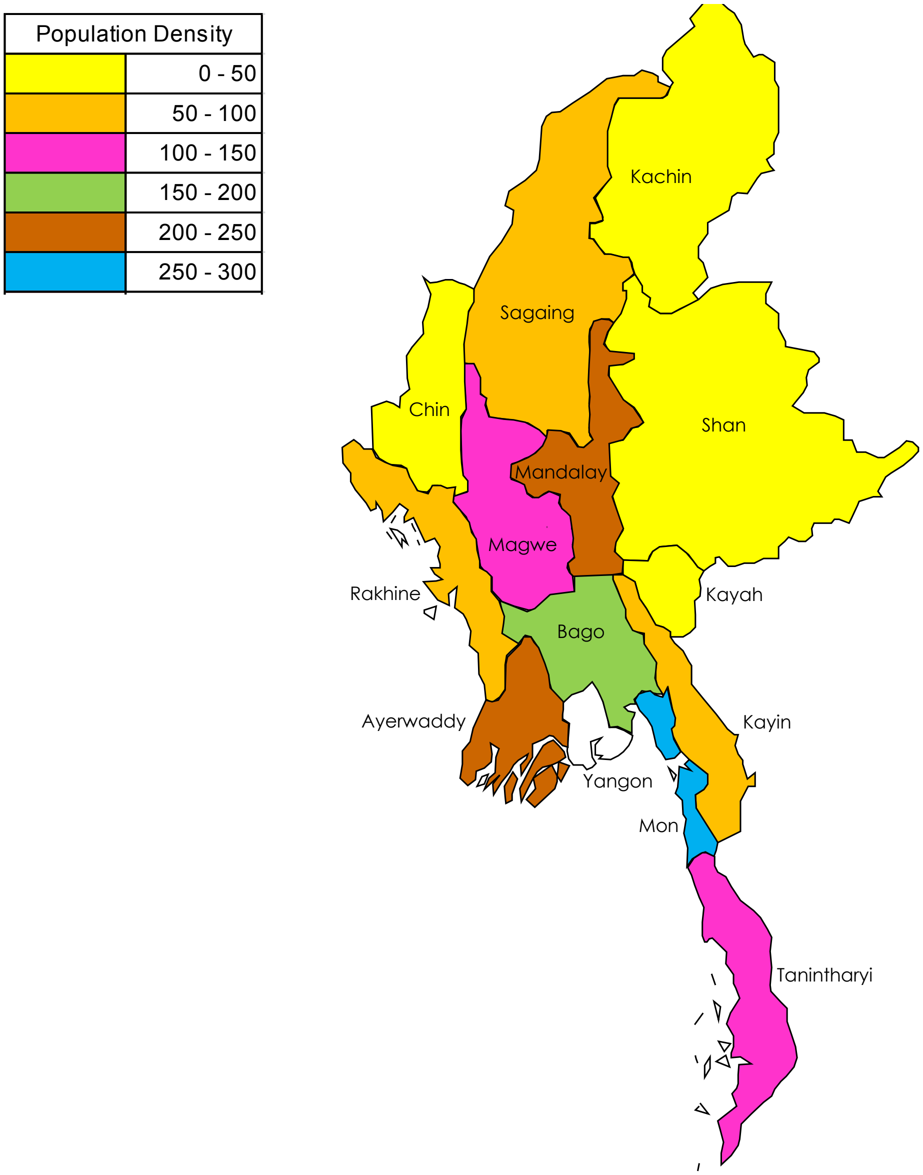
Figure I-5: Myanmar's Mineral Belts



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

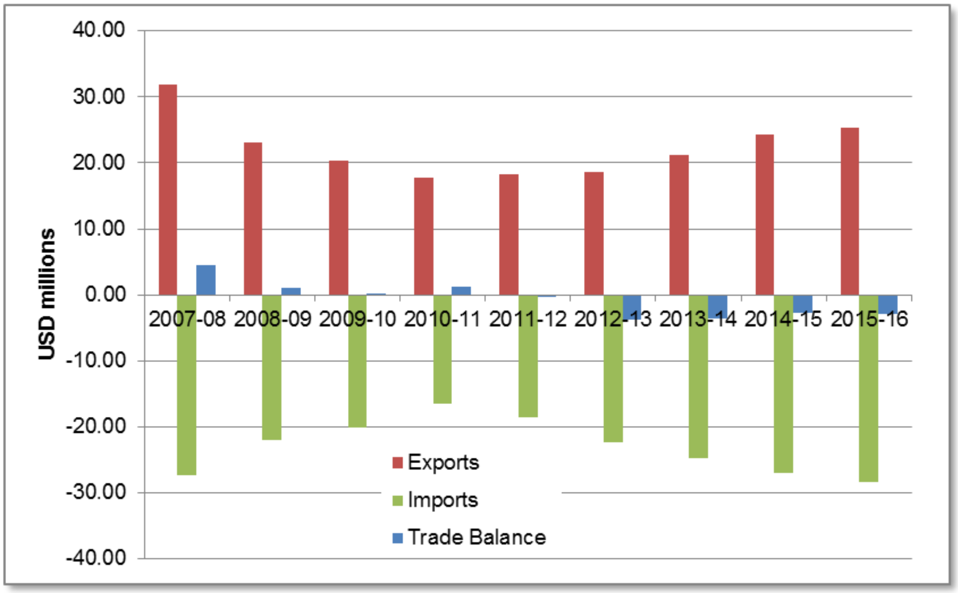
	2008-09	2009-10	2010-11	2011-12	2012-13	2013-14	2014-15	2015-16
GDP (current kyat billion)	28 778	32 351	39 847	43 368	47 851	54 434	62 572	72 075
GDP (US$ million)	31 367	35 225	49 600	56 200	55 800	56 400	60 300	64 800
Exports (current kyat billion)	9 199	8 076	7 093	7 252	7 412	8 448	9 683	10 121
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

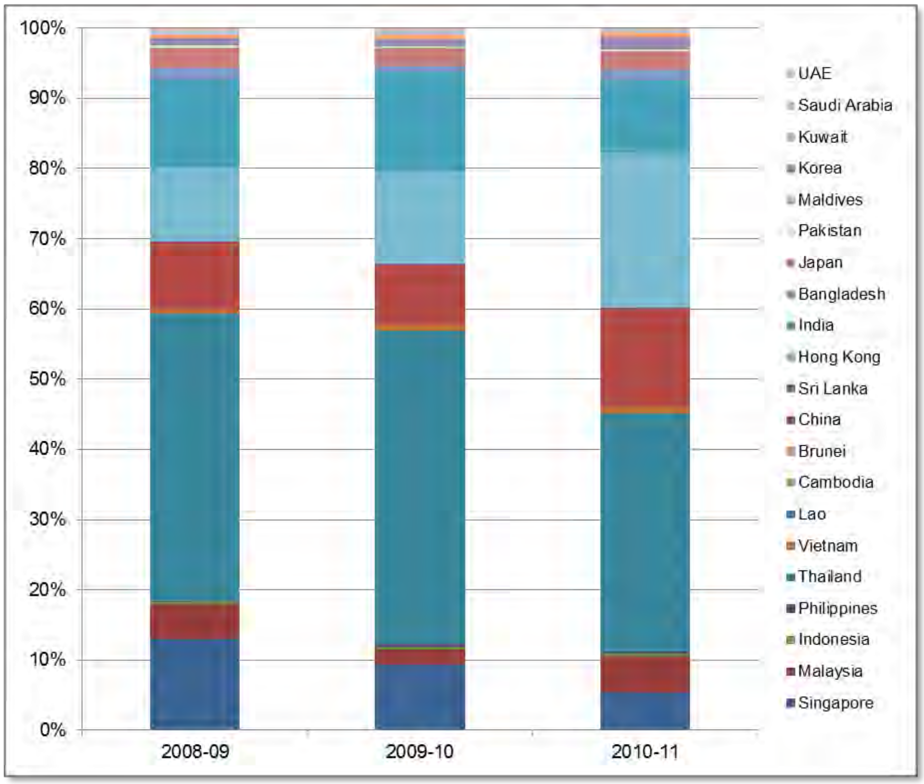
17. Myanmar's export sector has been dominated by the sale of gas to Thailand and PRC as can be inferred from Figure II-3 below. Together with gas, agricultural and fish products, and precious minerals make up a significant share of exports. The trend in exports appears to be steady, with the exception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

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



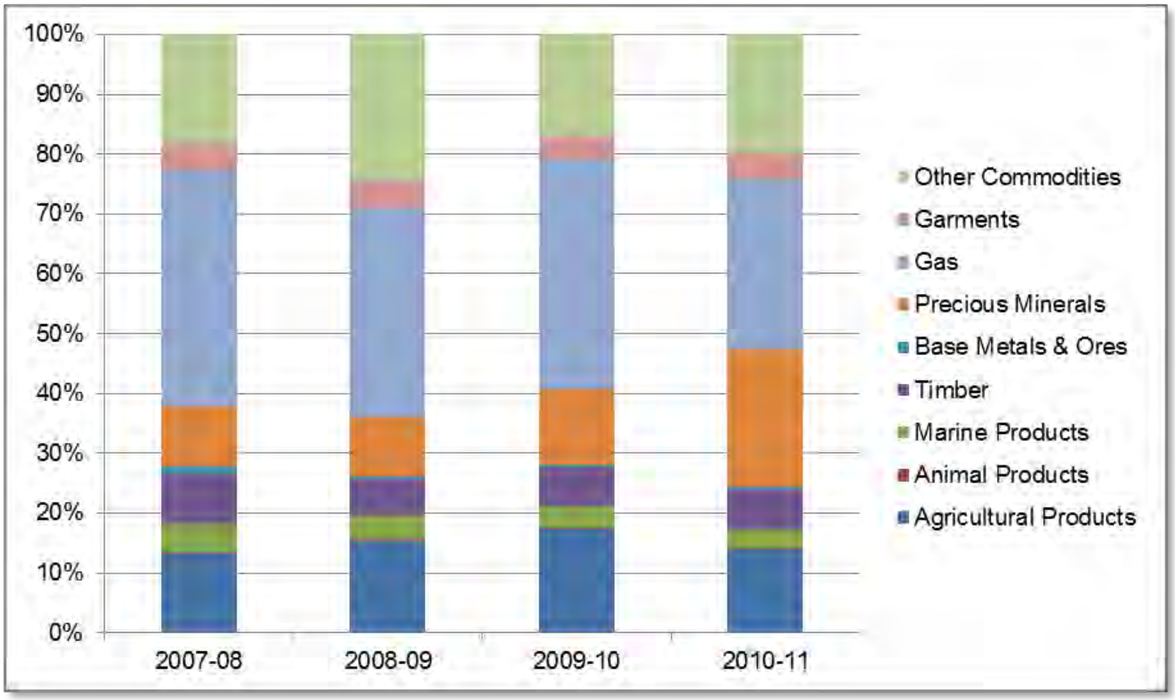
Source: IMF

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

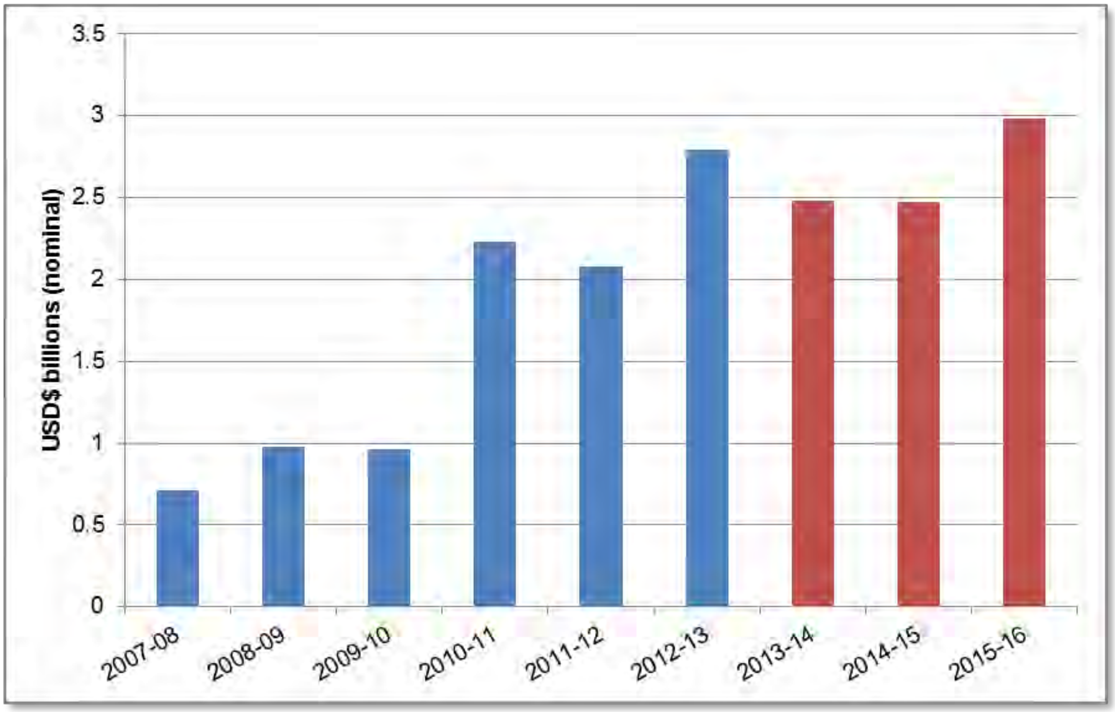
19. Myanmar's imports are sourced mainly from Asia, from a large number of trading partners. Within South-East Asia the largest trading partner is Singapore. From the rest of Asia, the largest trading partner is PRC. The main import commodities, by $ value, are fertilizers and machinery (motor vehicles).

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.

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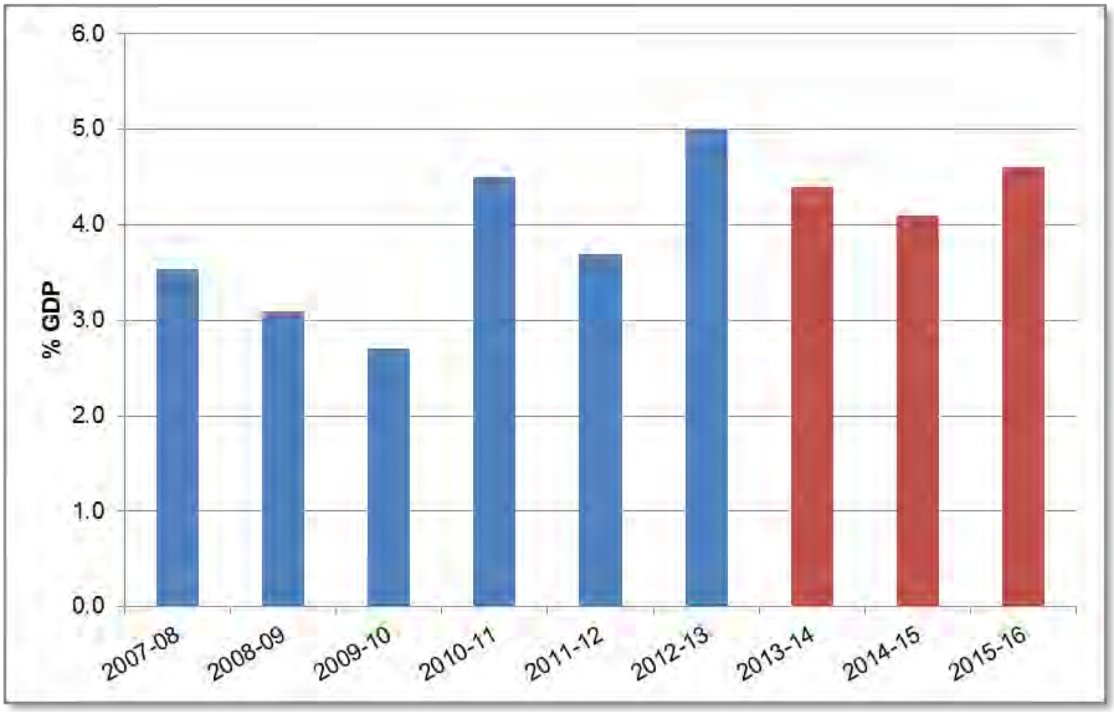
[11] An increase in spending (e.g. FDI or increased government spending) produces a larger increase in income.

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



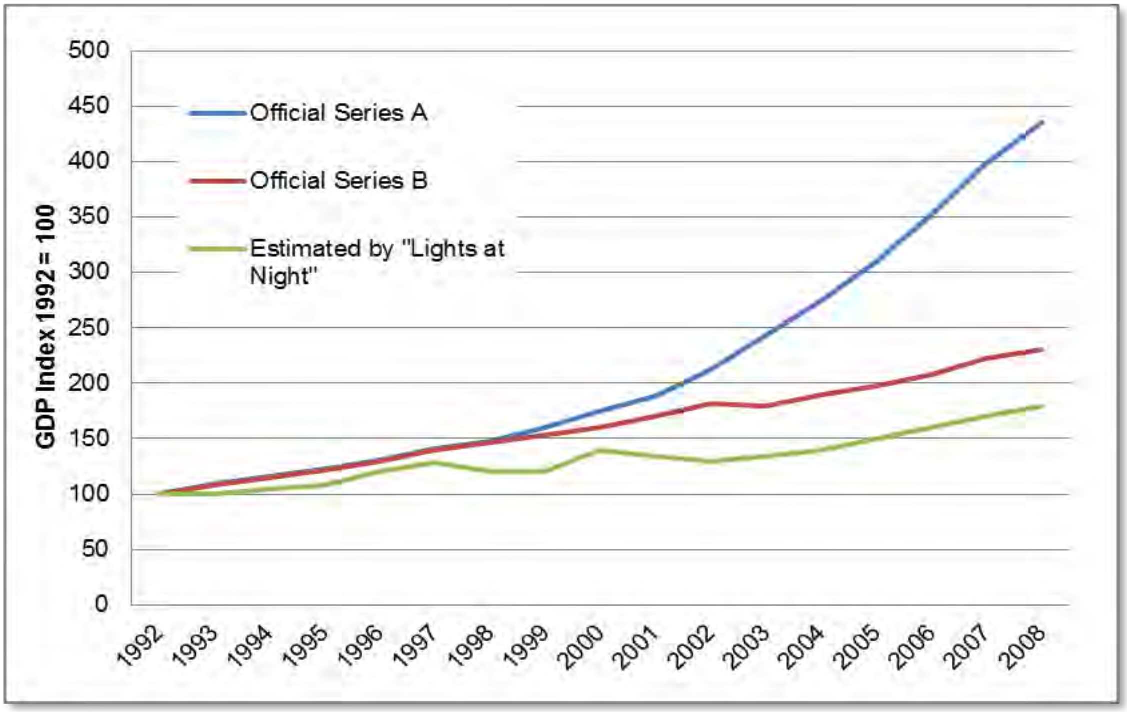
Source: IMF

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.

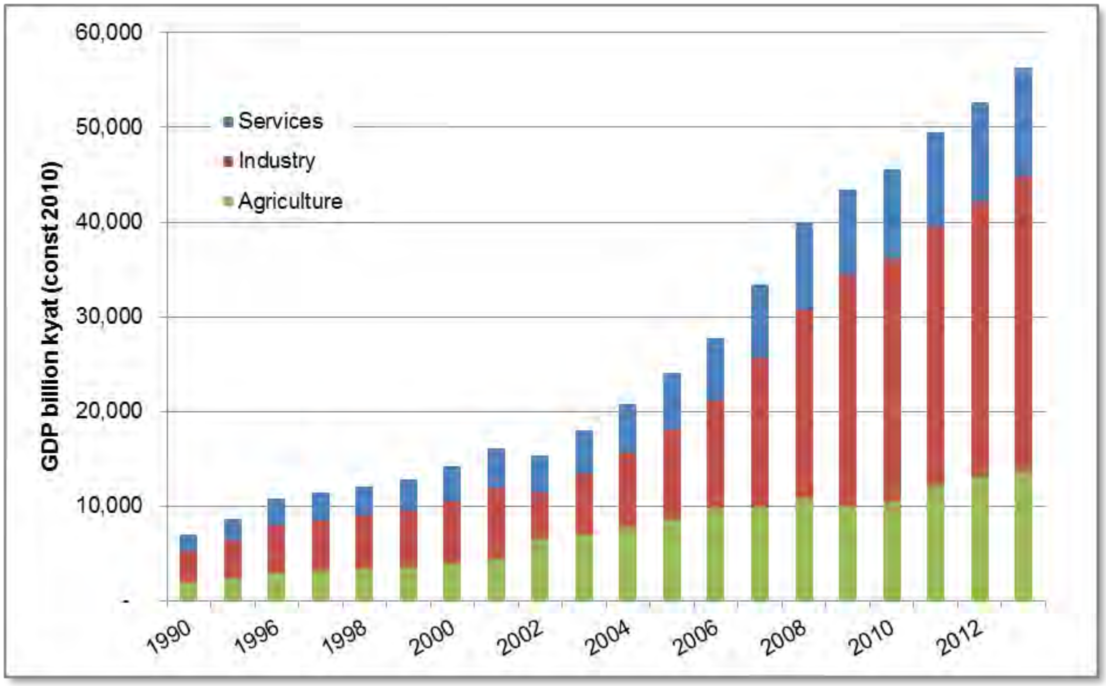
24. The MCDV states that it is difficult to judge which of the series reflects reality. Series (1) and (2) suggest over-reporting against the official statistics. Notwithstanding the doubts expressed in relation to the accuracy of the historical GDP series, the ADB GDP statistical series is adopted as 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



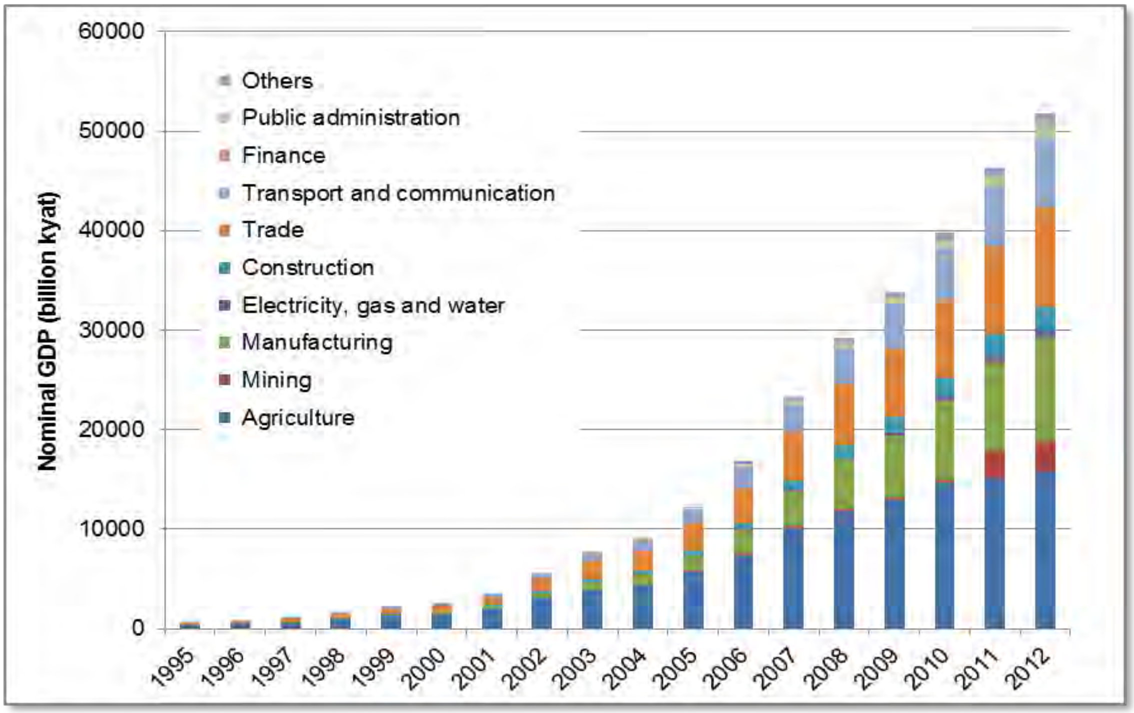
Source: Myanmar Comprehensive Development Vision

Figure II-8: Myanmar's GDP by Sector



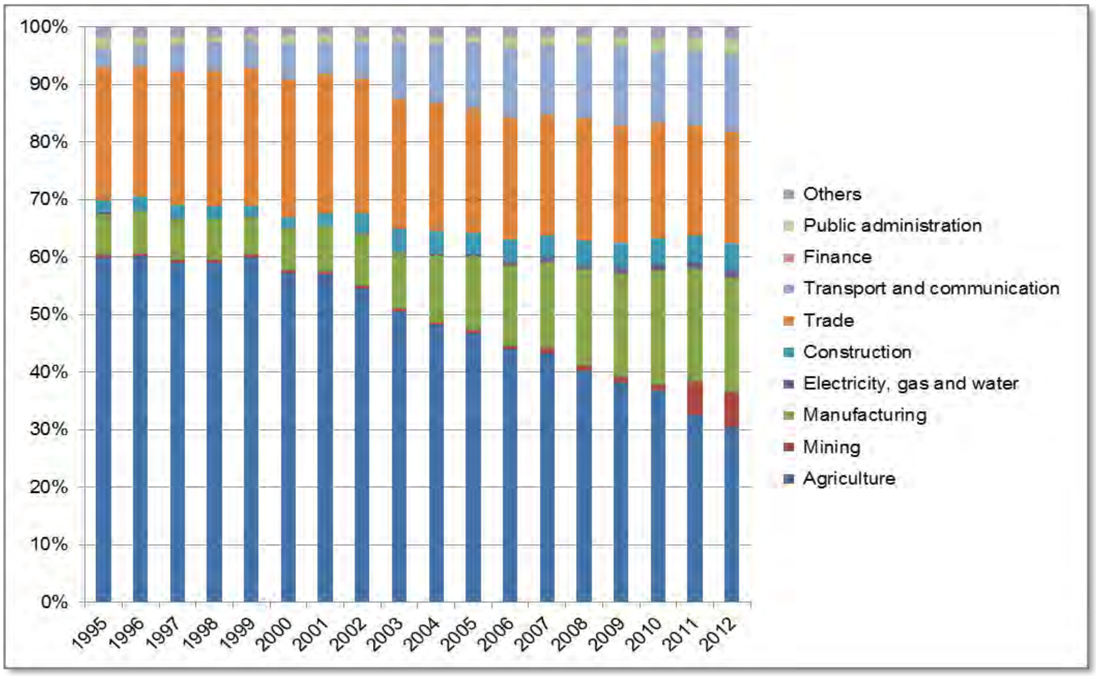
Source: Asian Development Bank; statistics provided in Annex

Figure II-9: Myanmar's GDP by Sector



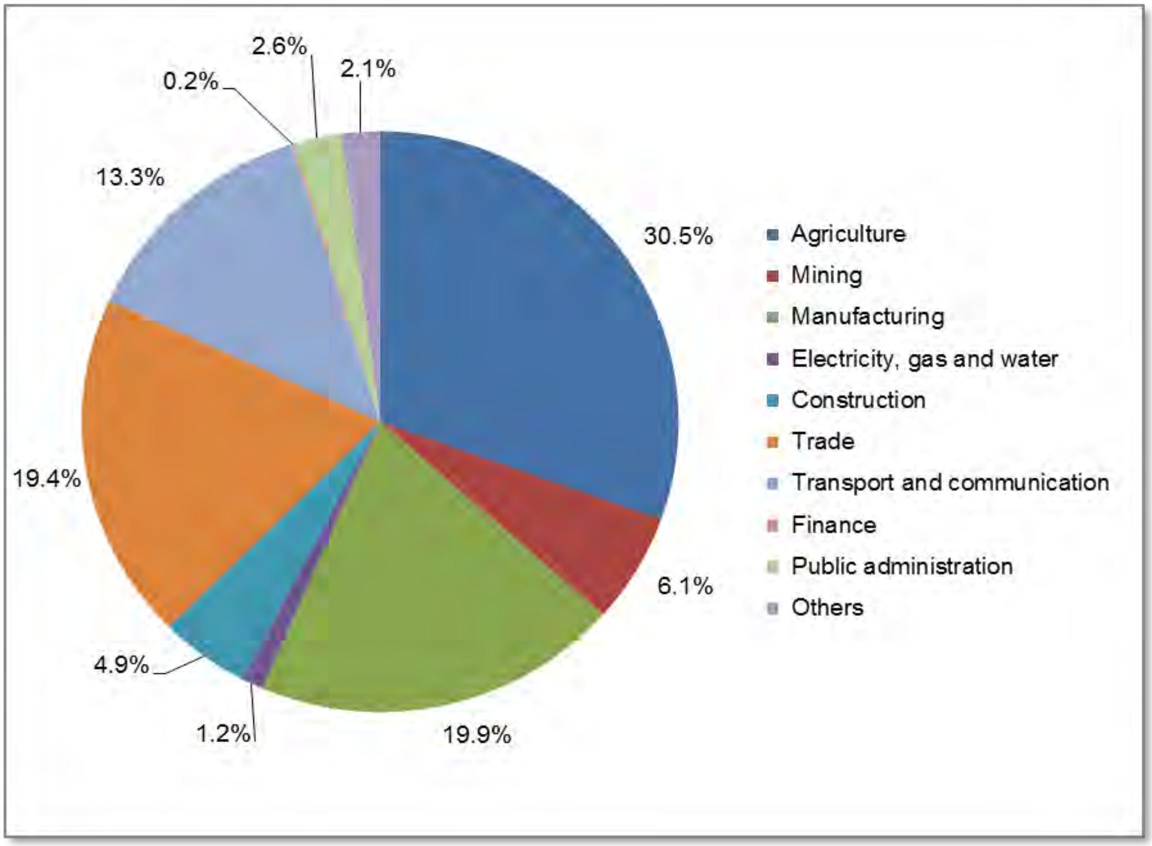
Source: Asian Development Bank; statistics provided in Annex

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

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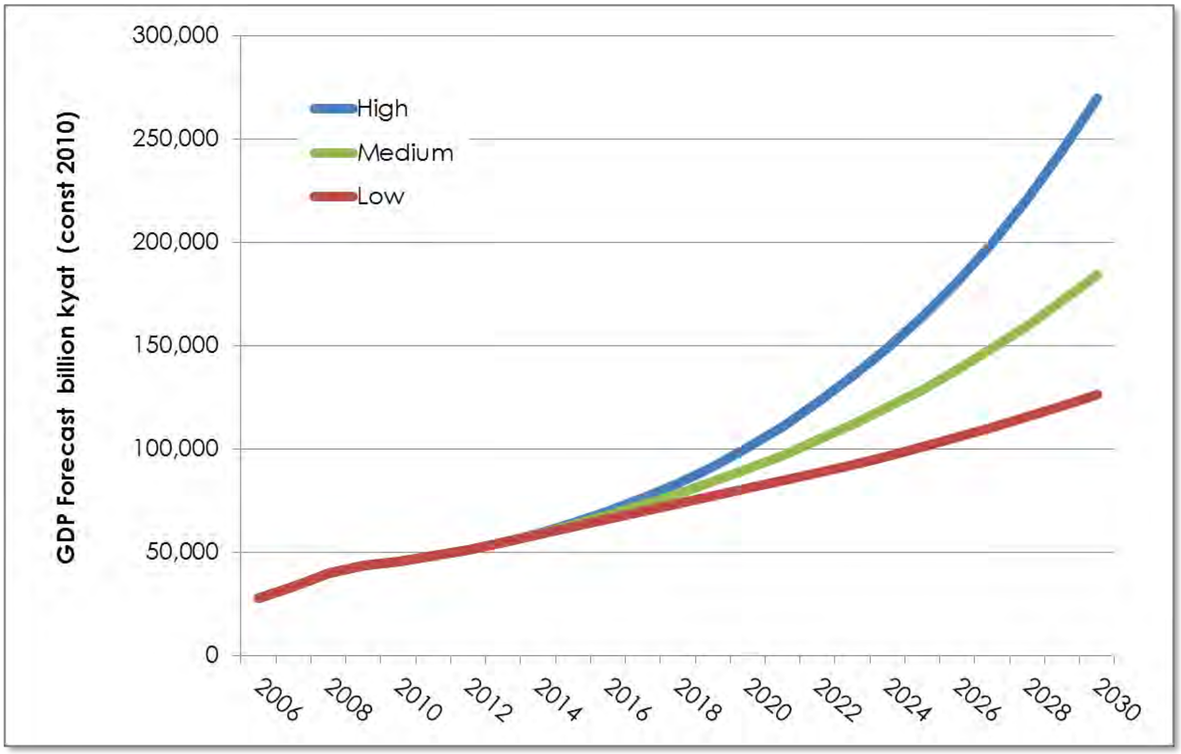
[12] Energy Consumption and Economic Growth: A Panel Co-integration Analysis for Developing Countries (2012); Adhikari, Chen, Dalian University of Technology (DUT)

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;

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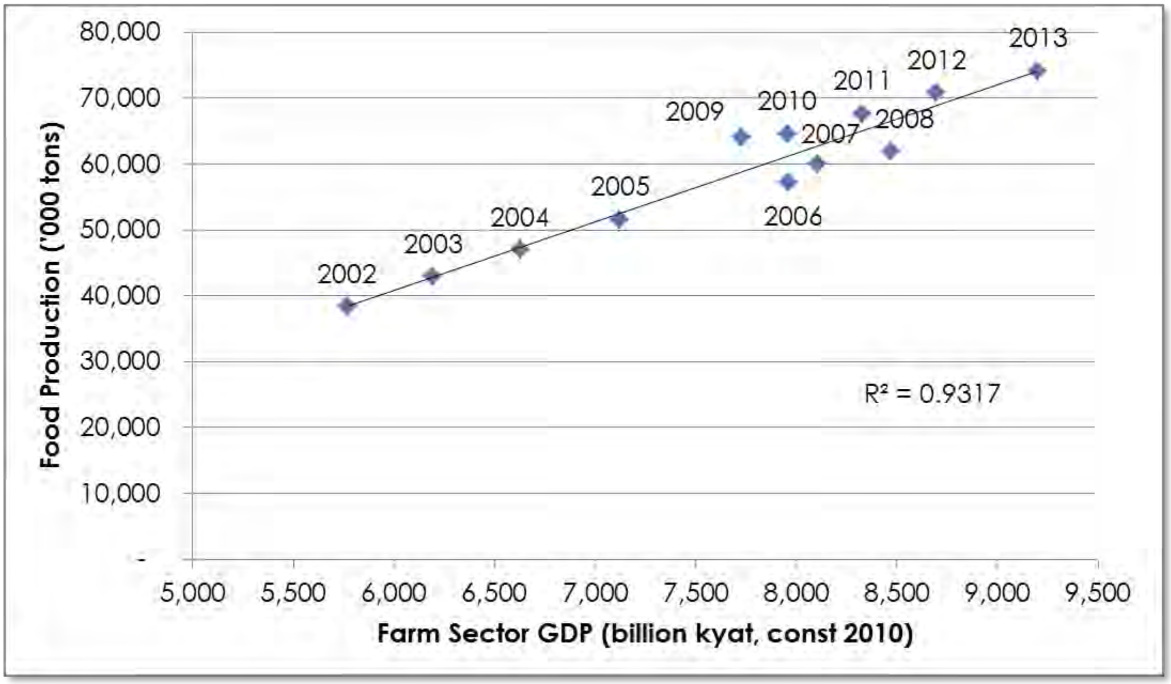
[13] Motive Energy is defined here as the total ‘horsepower’ of human labour, draft animals, tractors and power tillers.

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

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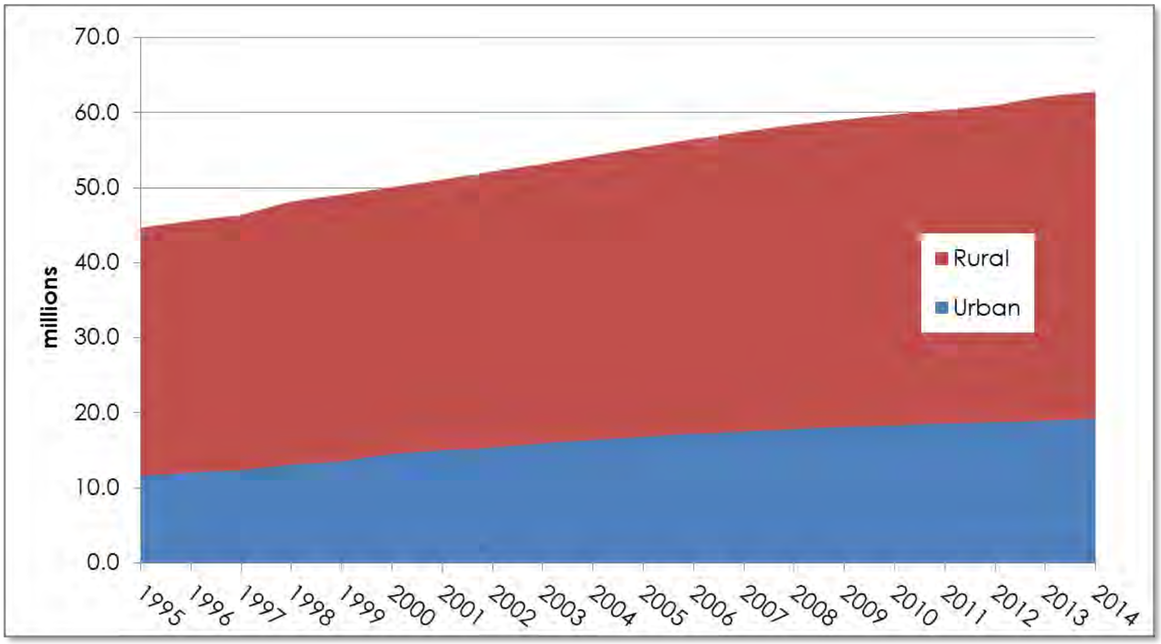
[14] Note that this forecast was conducted using pre-consensus population statistics, which determined the total population to be 50.4 million on 29 March 2014. Afterwards, the impact of the change in population was examined, which appeared not significant to energy demand forecasts because the historical 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%

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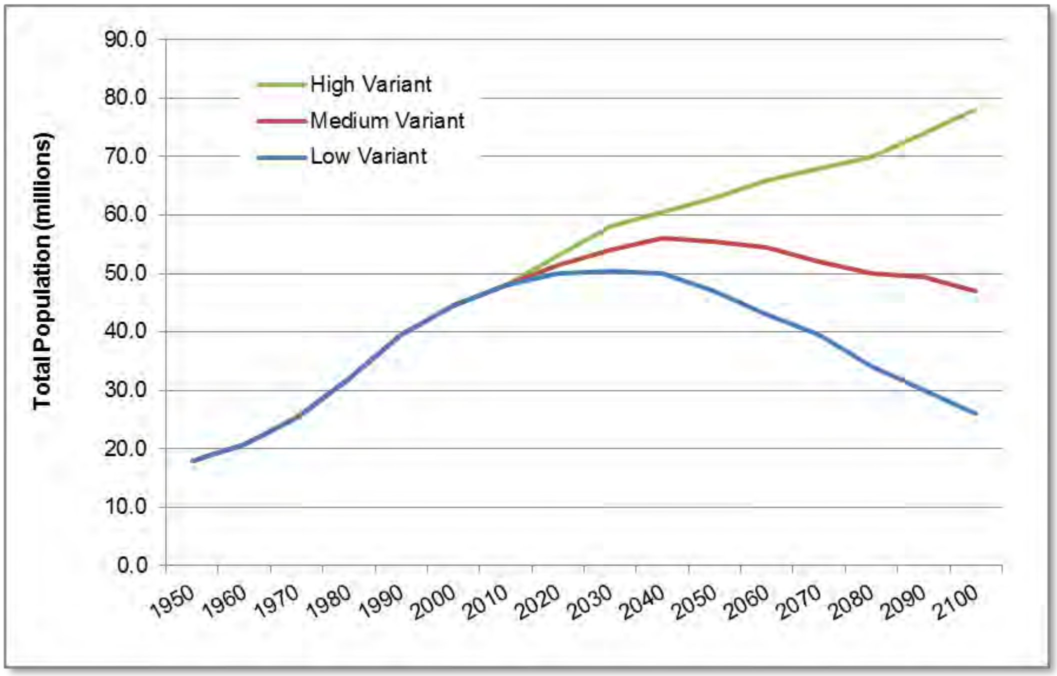
statistics means that the historical per capita energy rates increase. When these new energy consumption rates are applied to the (lower) projections for population using the census 2014 figures as a base, the change to the total energy consumption was not affected significantly.

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

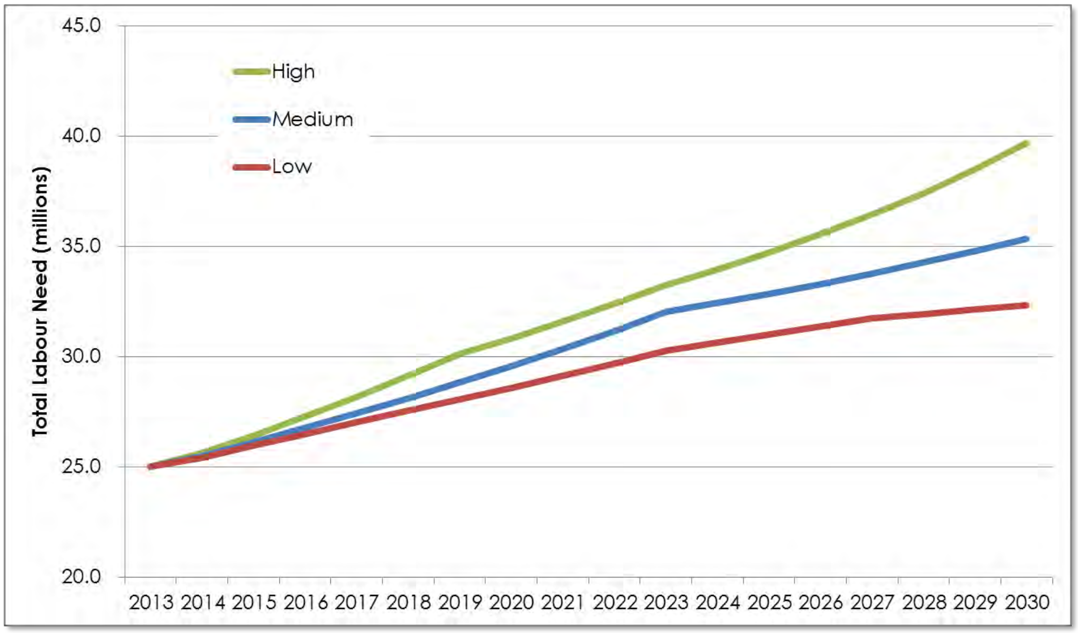
Table III-9: Forecast Urban / Rural Population % by GDP Growth

		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

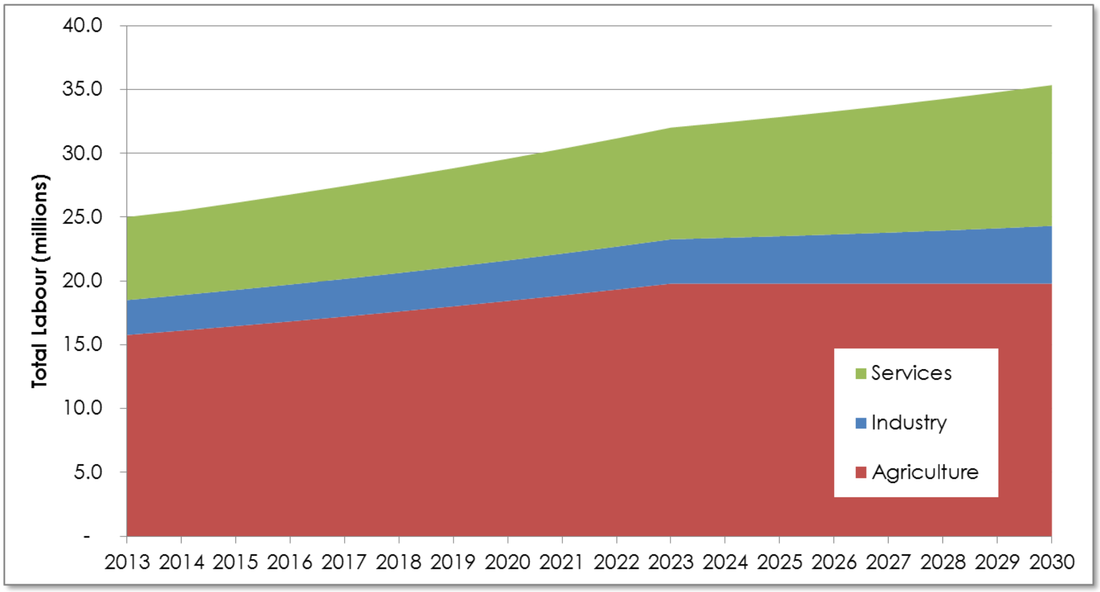
41. The labour workforce projections and deficit, corresponding to the above demographic tables, are shown as Figure III-10, Figure III-11 and Figure III-12.

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



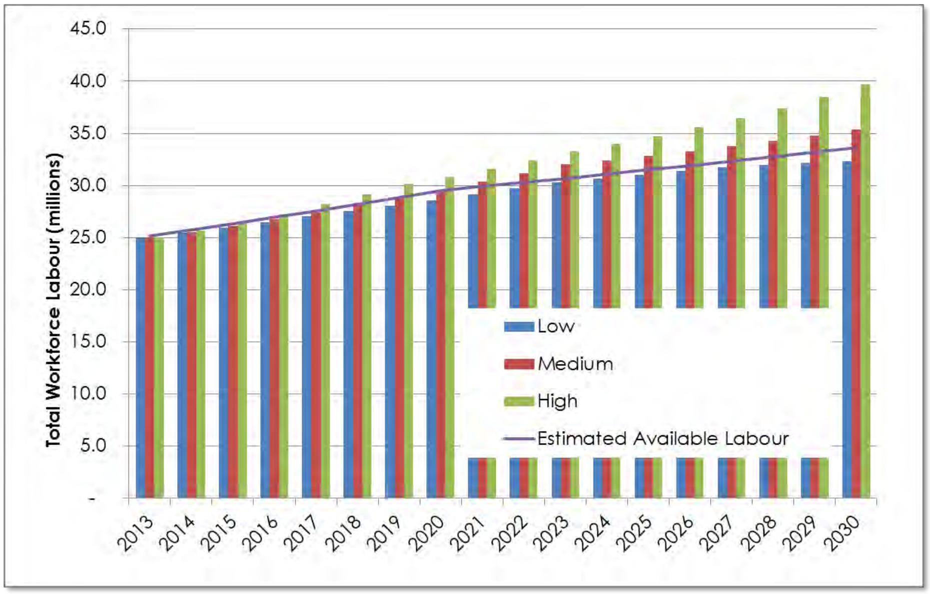
Source: Consultant

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



Source: Consultant

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

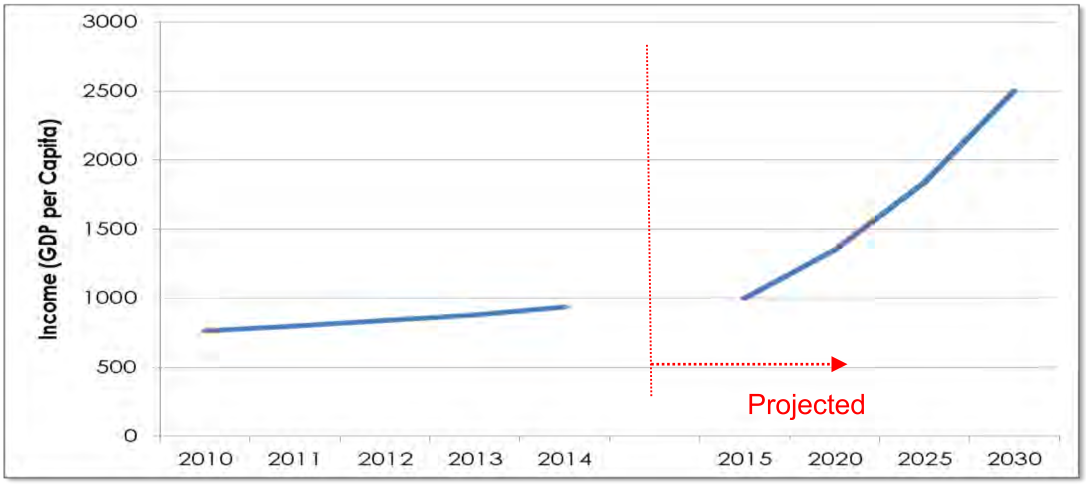


Source: Consultant

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

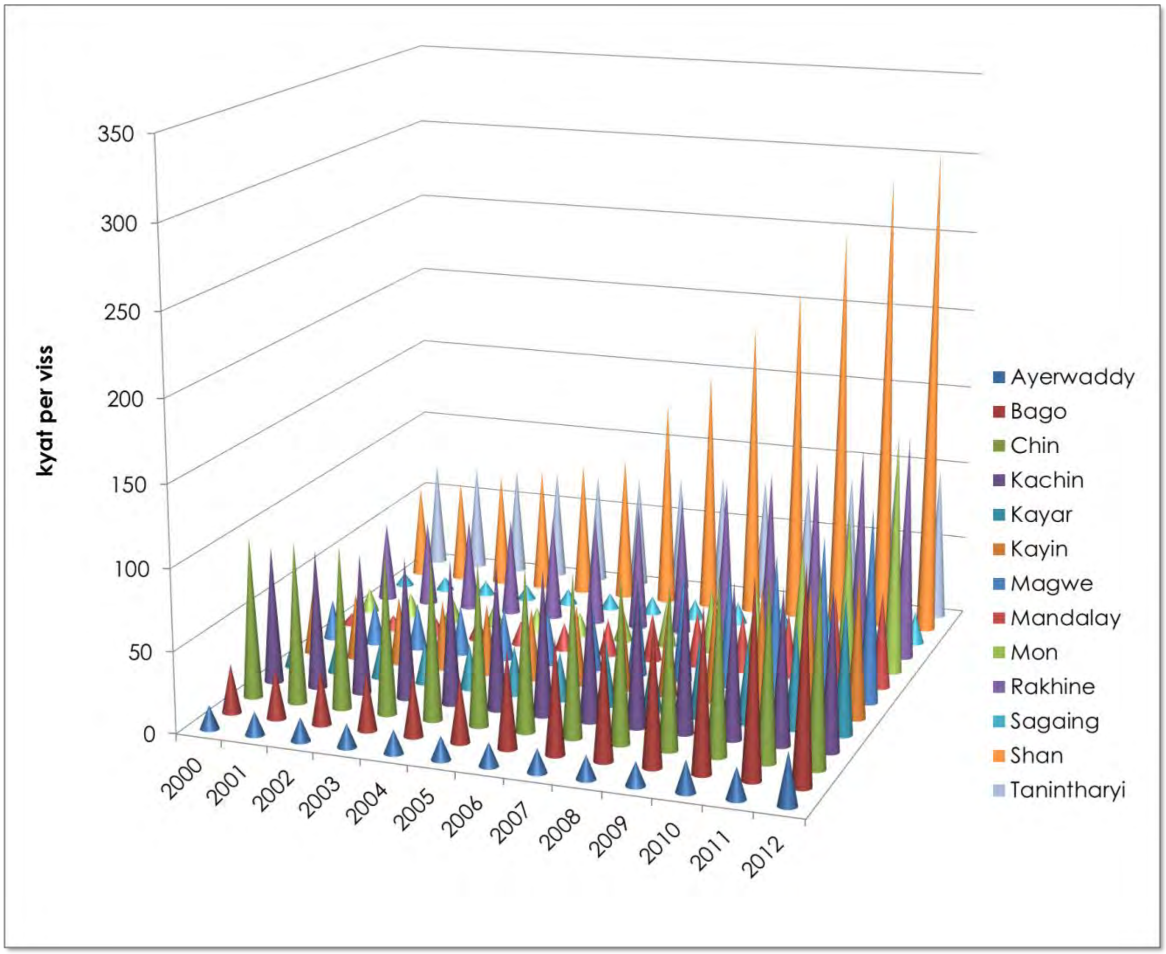


Source: Historical Data (1980- 2010), ADB; Projected Values (2010-2030), ADB

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



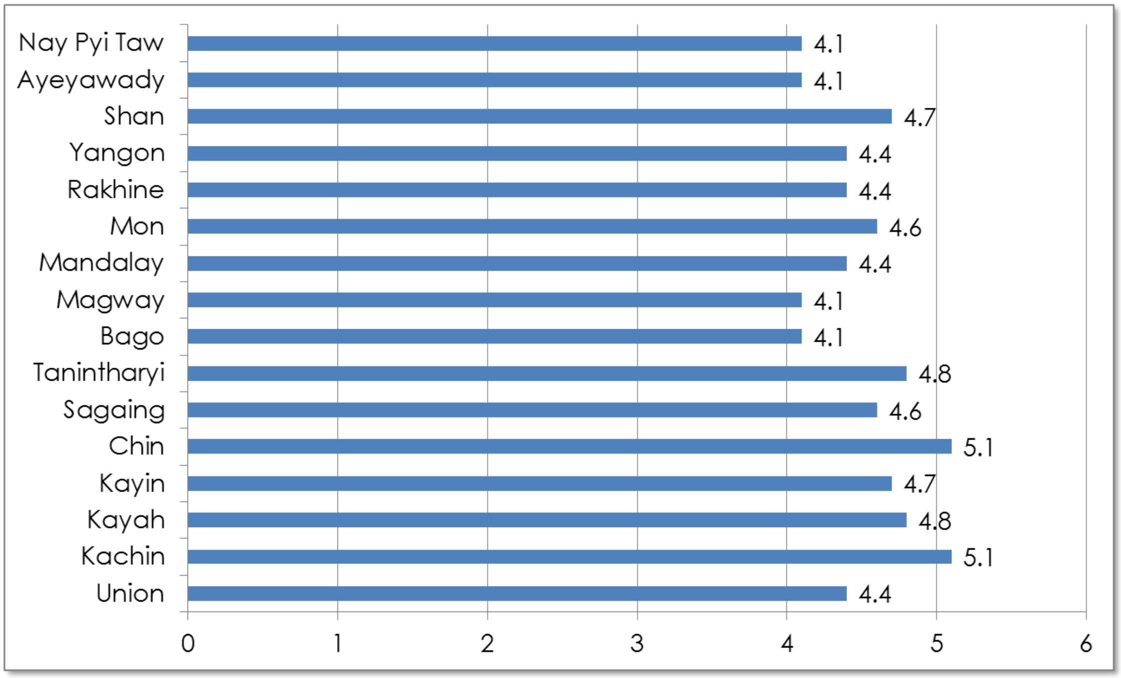
Source: MoECAF

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	2023	2024	2025	2026	2027	2028	2029	2030
Agriculture	billion kyat const 2010	12,820	13,560	14,330	15,129	15,959	16,820	17,649	18,519	19,434	20,201	21,009	21,849	22,723	23,632	24,578	25,561	26,583
Industry		33,761	36,817	40,492	44,639	49,446	55,031	61,535	69,131	77,665	87,150	97,794	109,609	122,852	137,695	154,331	172,977	193,876
Services		12,416	13,584	14,922	16,353	17,856	19,498	21,290	23,219	25,323	27,585	30,048	32,692	35,525	38,558	41,849	45,422	49,299
Total	billion kyat const 2010	58,997	63,962	69,744	76,121	83,262	91,349	100,474	110,870	122,422	134,936	148,851	164,151	181,101	199,885	220,758	243,960	269,758
	Total GDP Growth %	7.8%	8.4%	9.0%	9.1%	9.4%	9.7%	10.0%	10.3%	10.4%	10.2%	10.3%	10.3%	10.3%	10.4%	10.4%	10.5%	10.6%
GDP per Capita	thousand kyat	949	1,018	1,099	1,188	1,286	1,397	1,522	1,663	1,818	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.

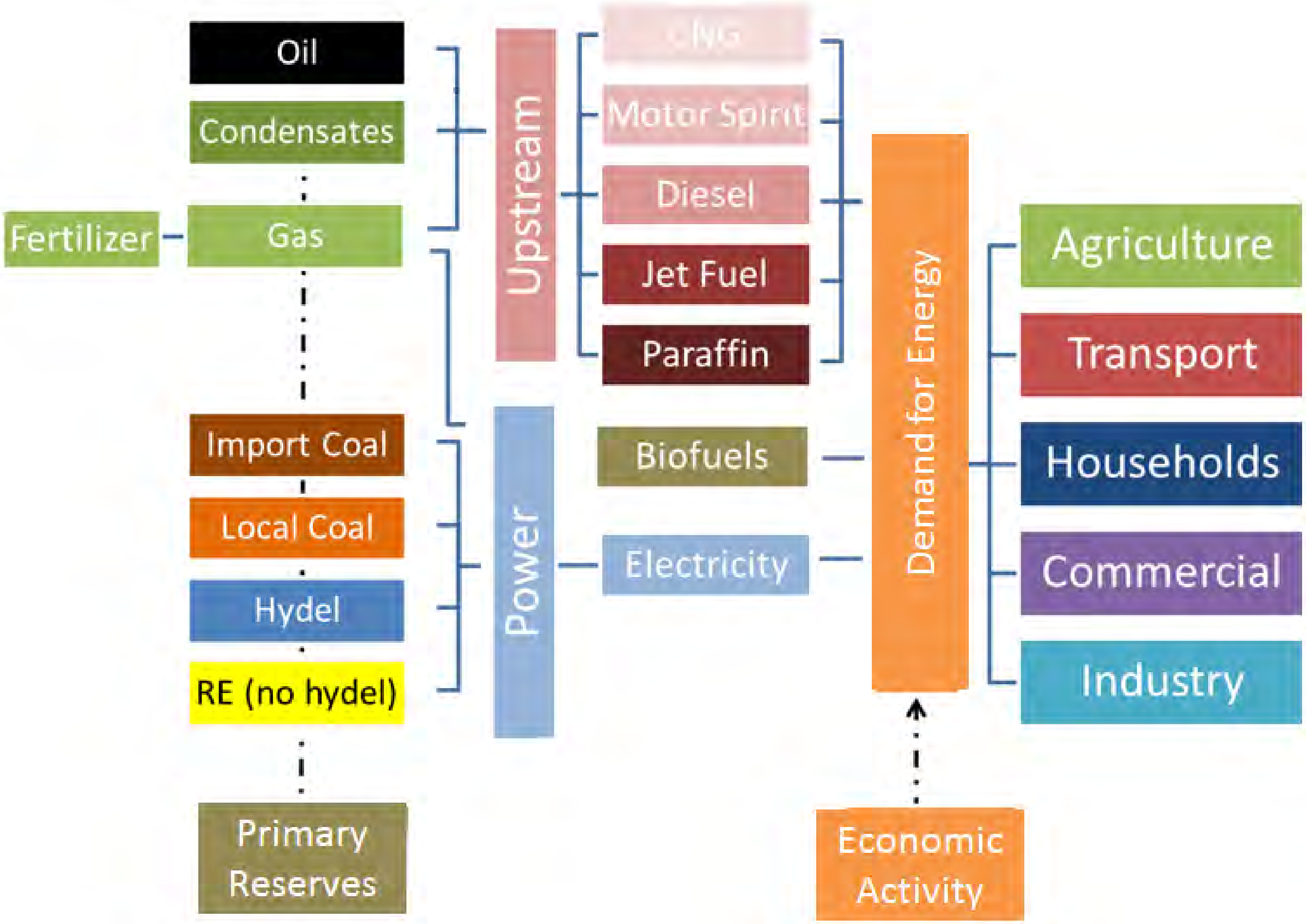
5. An Energy Balance is essentially a process that seeks to account for the flow of energy from the supply side, through transformation processes and onto end-use energy consumption without double counting and with reference to measurements taken of energy stocks, conversions and consumption statistics. 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)

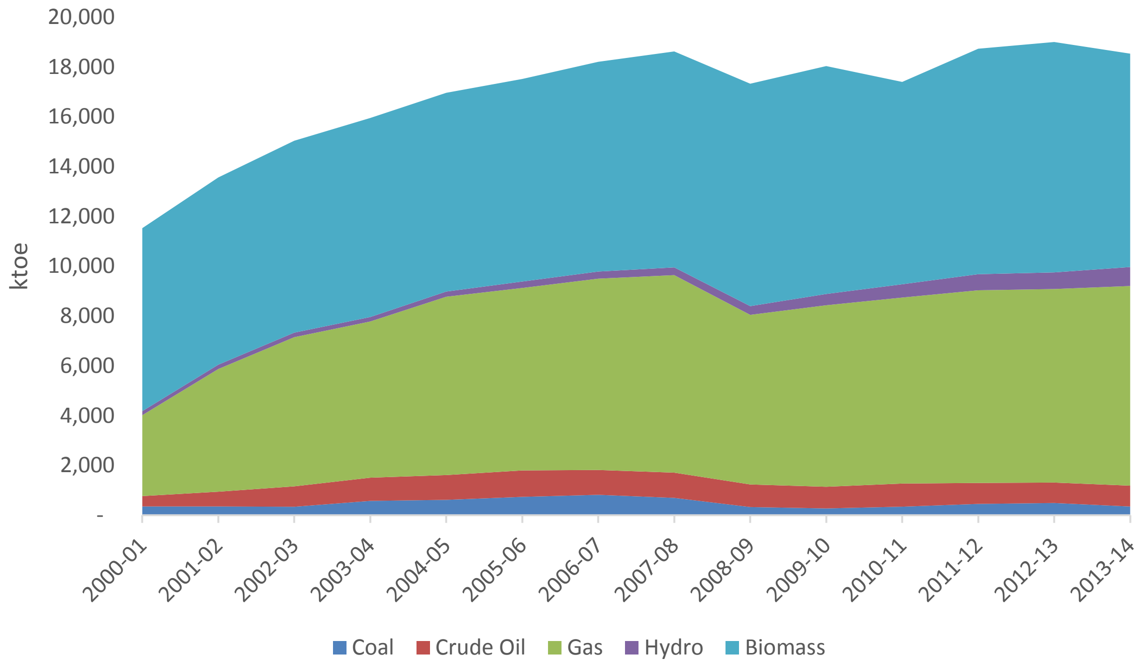
8. TPEP by definition is the total domestic production for a country by the type of energy carrier.

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.

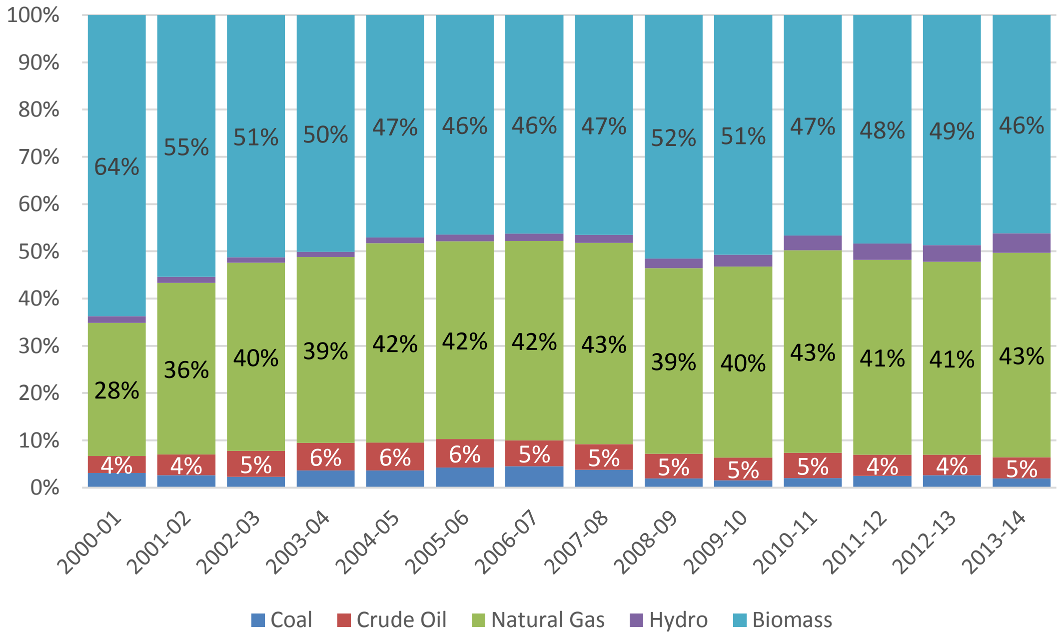
11. Table I-6 sets out the TPEP statistics in energy-units of ktoe. Note that in this report we have used the calorific value assumptions that are provided in section VII. We also provide data on the physicals to allow the reader to apply an alternative set of calorific value assumptions to the data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

Figure I-2: Myanmar Total Primary Energy Production



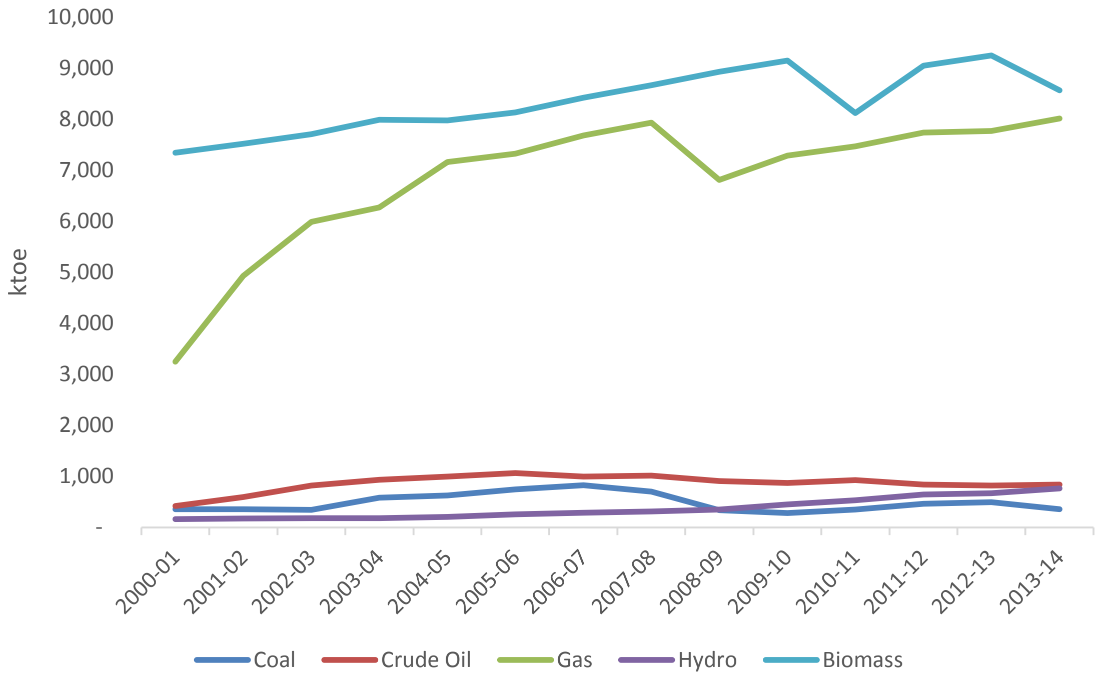
Source: Consultant's estimate based on data of MOE, MOEP, MOGE, MPPE, MOECAF, and CSO

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



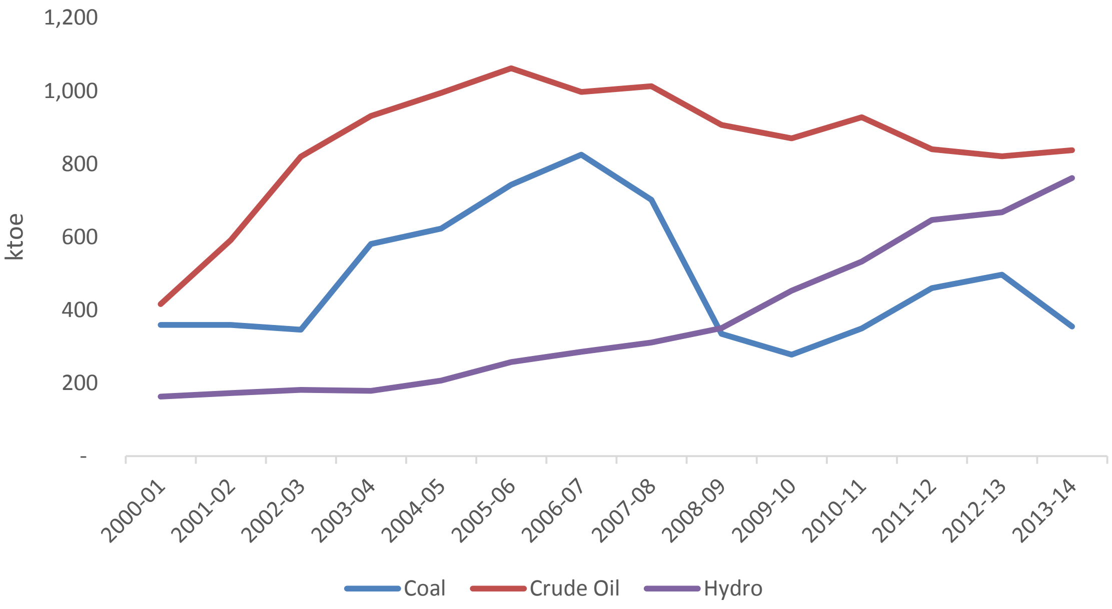
Source: Consultant's estimate based on data of MOE, MOEP, MOGE, MPPE, MOECAF, and CSO

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)

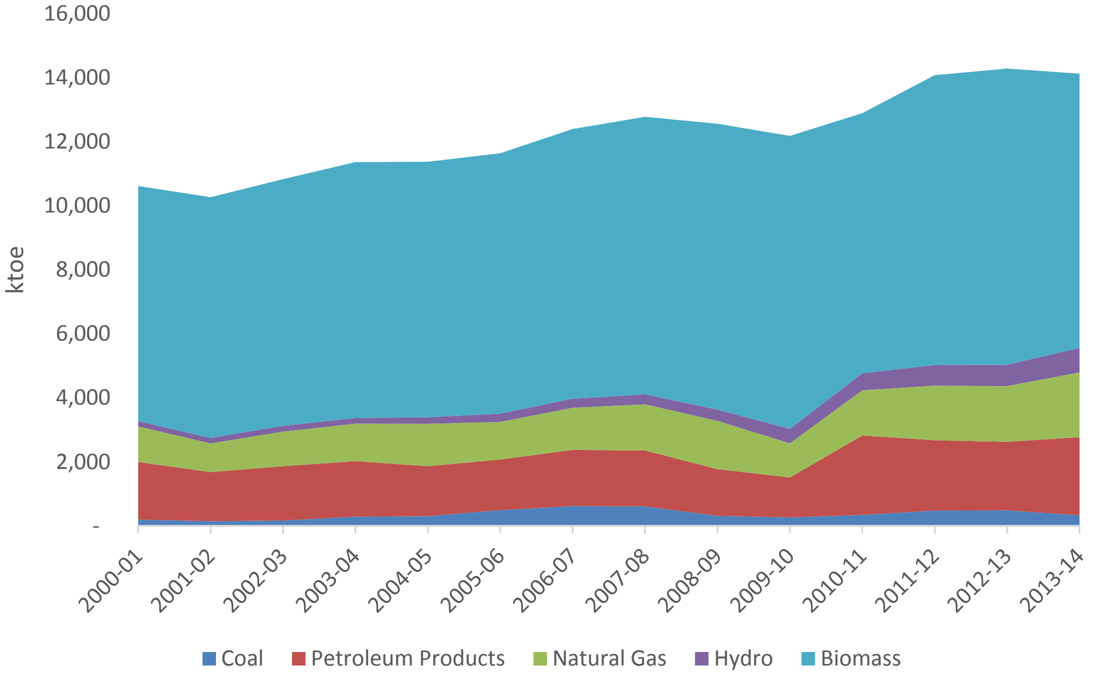
12. TPES by definition is the total amount of primary energy supply to a country net of any imports, exports and/or stock changes.

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.

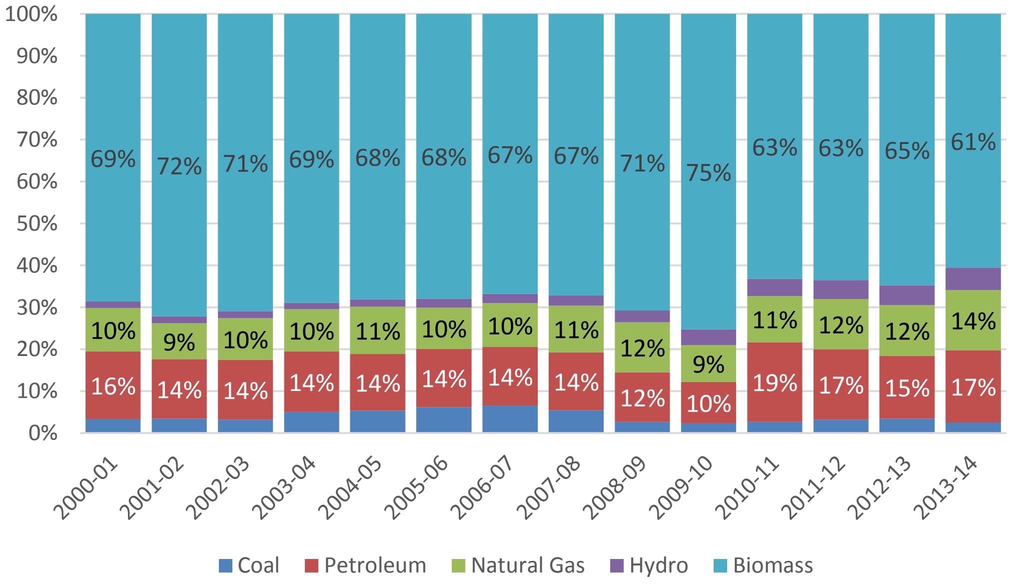
15. Table I-11 sets out the TPES statistics in energy-units of ktoe. Note that in this report we have used the calorific value assumptions that are provided in section VII. We also provide data on the physicals to allow the reader to apply an alternative set of calorific value assumptions to the data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

Figure I-7: Myanmar Total Primary Energy Supply



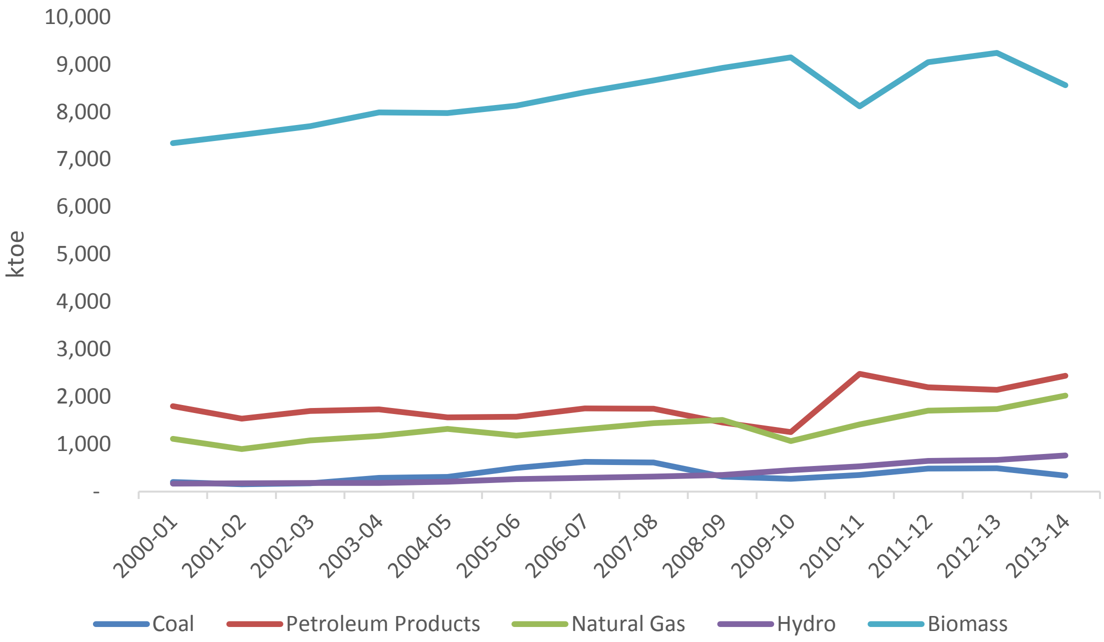
Source: Consultant's estimate based on data of MOE, MOEP, MOGE, MPPE, MOECAF, and CSO

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



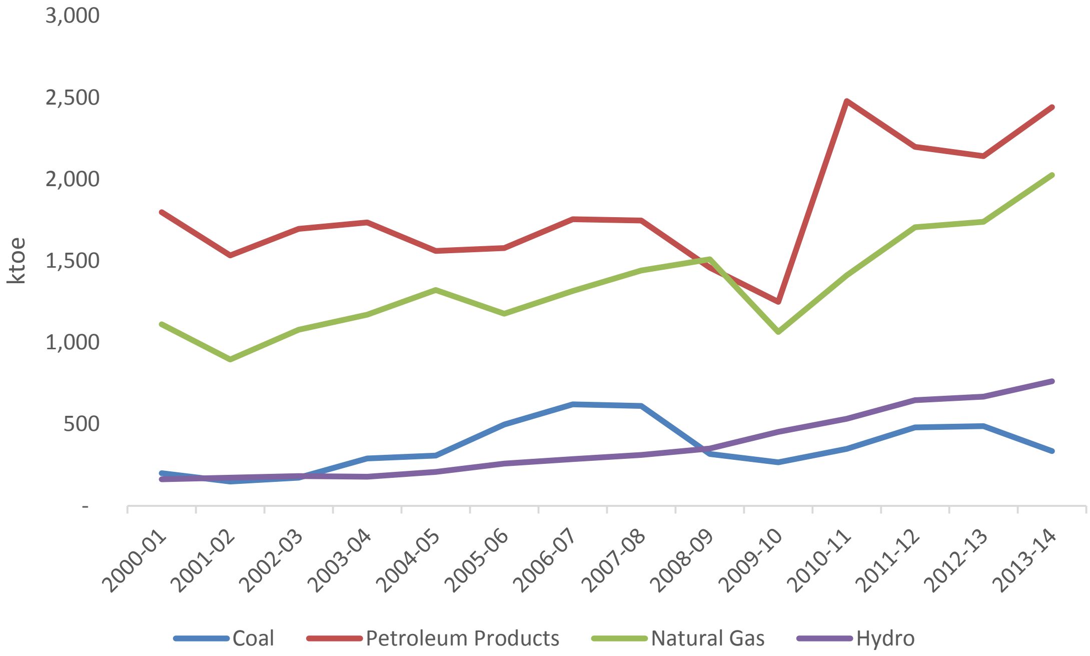
Source: Consultant's estimate based on data of MOE, MOEP, MOGE, MPPE, MOECAF, and CSO

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

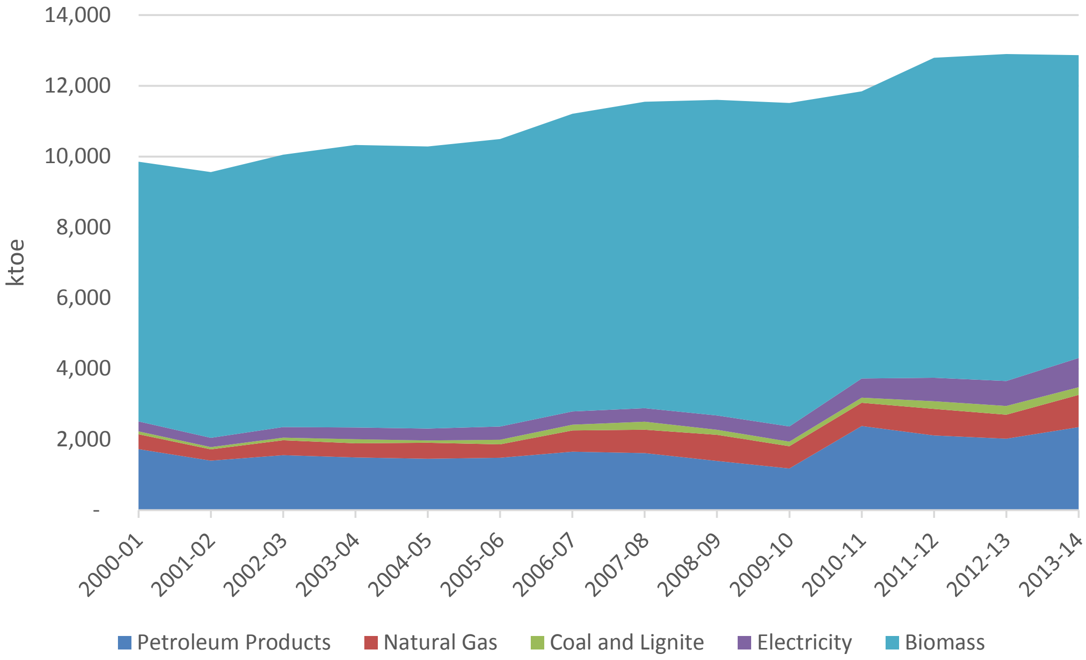
Unit: ktoe	**00-01**	**01-02**	**02-03**	**03-04**	**04-05**	**05-06**	**06-07**	**07-08**	**08-09**	**09-10**	**10-11**	**11-12**	**12-13**	**13-14**
Coal	359	359	346	581	623	743	825	702	334	278	349	460	496	355
Petroleum	968	878	1,069	996	893	830	902	832	784	704	813	845	680	526
Natural Gas	3,246	4,925	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%.

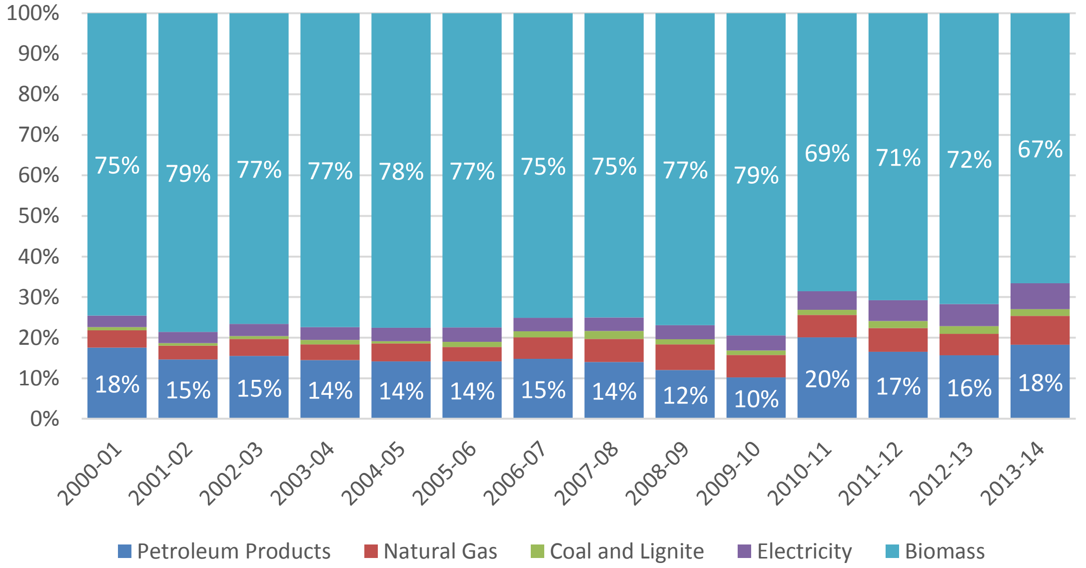
17. Overall, Myanmar's TFEC increased between 2000 and 2013 by an average of 2.3% annually, from 11 Mtoe to 14.3 Mtoe. As illustrated in Figure I-18 and Figure I-19 which show the TFEC by each major end-use category, over this period energy consumption by the industrial has doubled, the consumption by 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



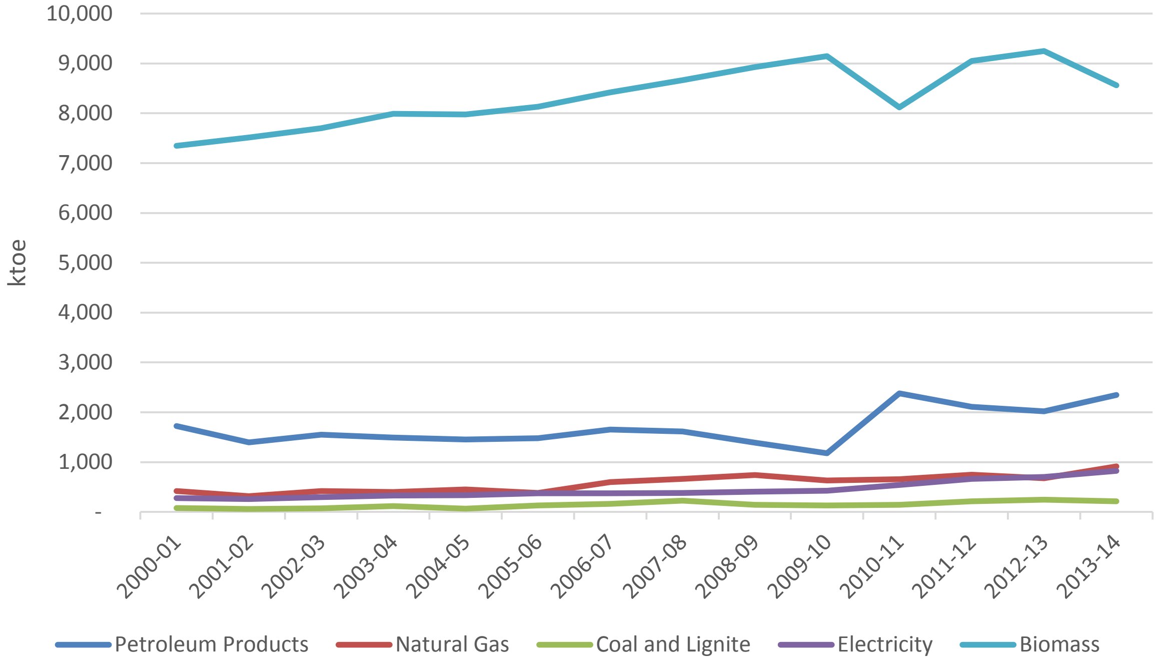
Source: Consultant's estimate based on data of MOE, MOEP, MOGE, MPPE, MOECAF, and CSO

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



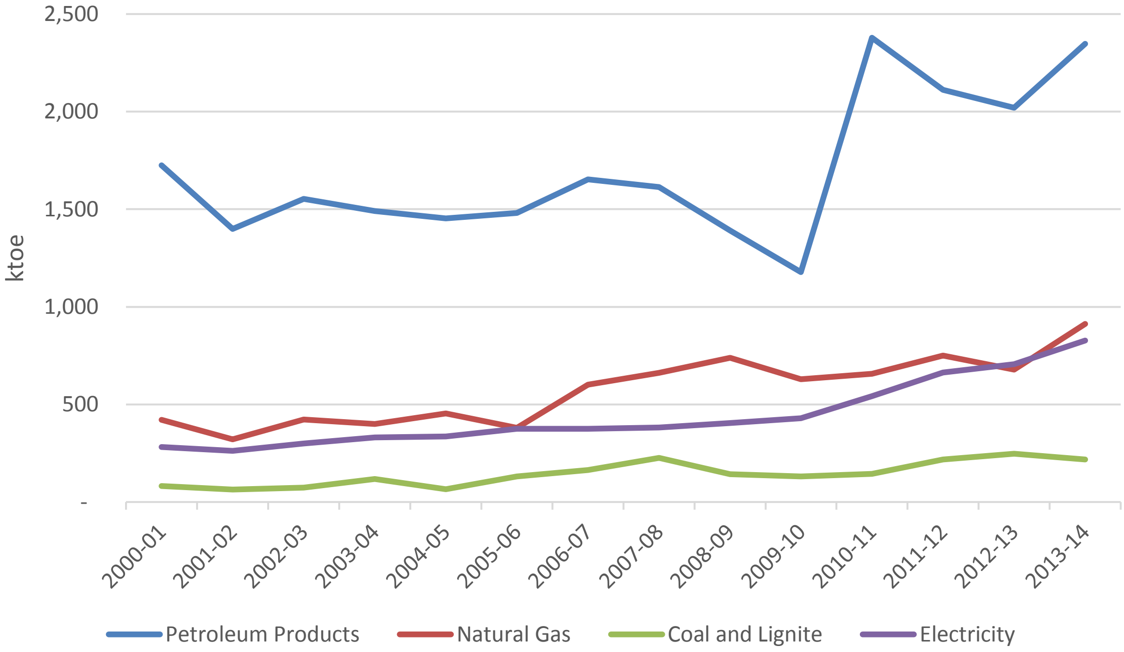
Source: Consultant's estimate based on data of MOE, MOEP, MOGE, MPPE, MOECAF, and CSO

Figure I-14: Myanmar TFEC by Energy Carrier



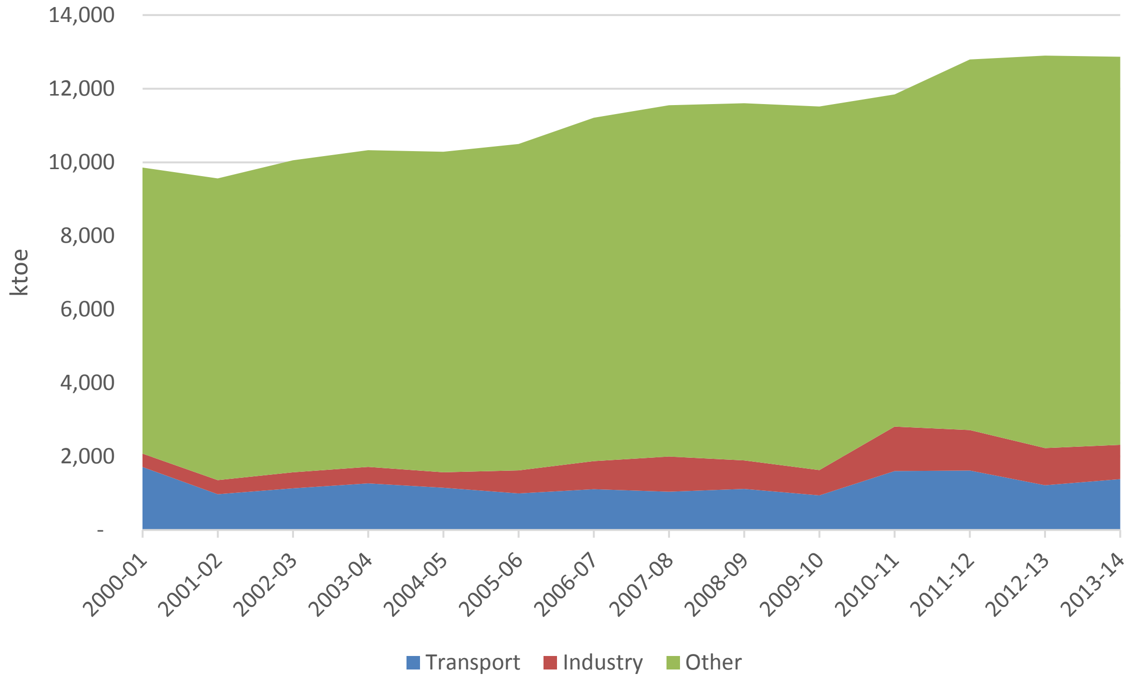
Source: Consultant's estimate based on data of MOE, MOEP, MOGE, MPPE, MOECAF, and CSO

Figure I-15: Myanmar TFEC by Selected Energy Carriers



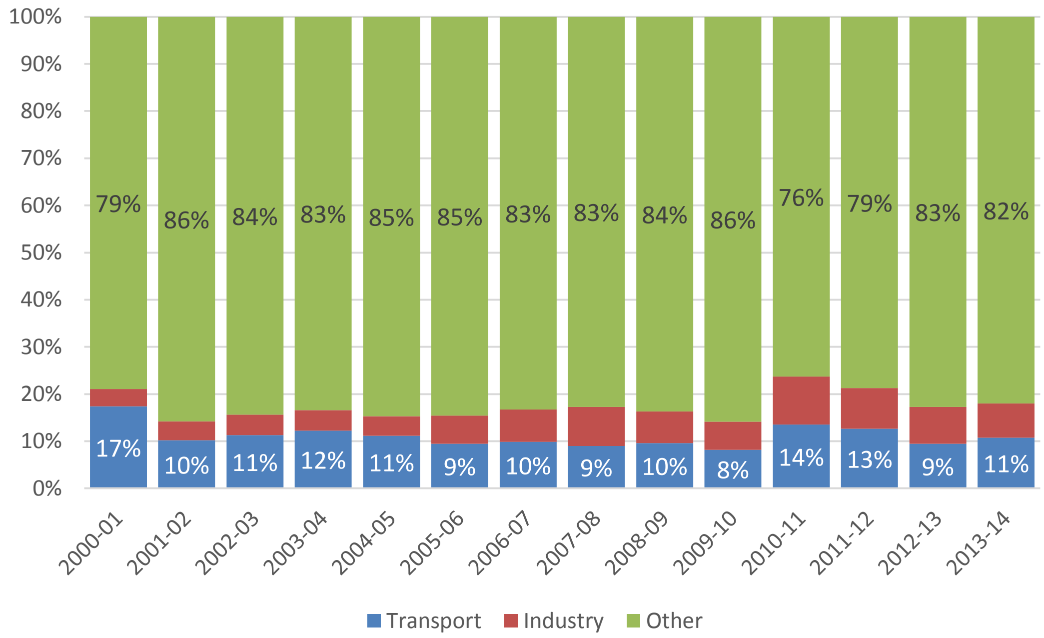
Source: Consultant's estimate based on data of MOE, MOEP, MOGE, MPPE, MOECAF, and CSO

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



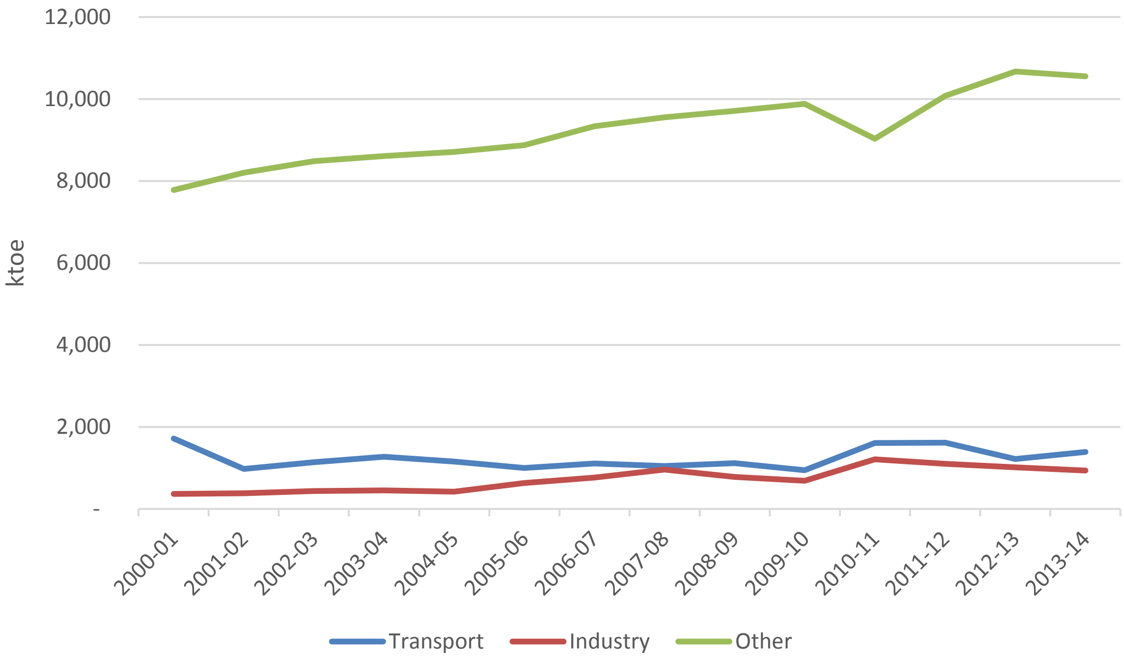
Source: Consultant's estimate based on data of MOE, MOEP, MOGE, MPPE, MOECAF, and CSO

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

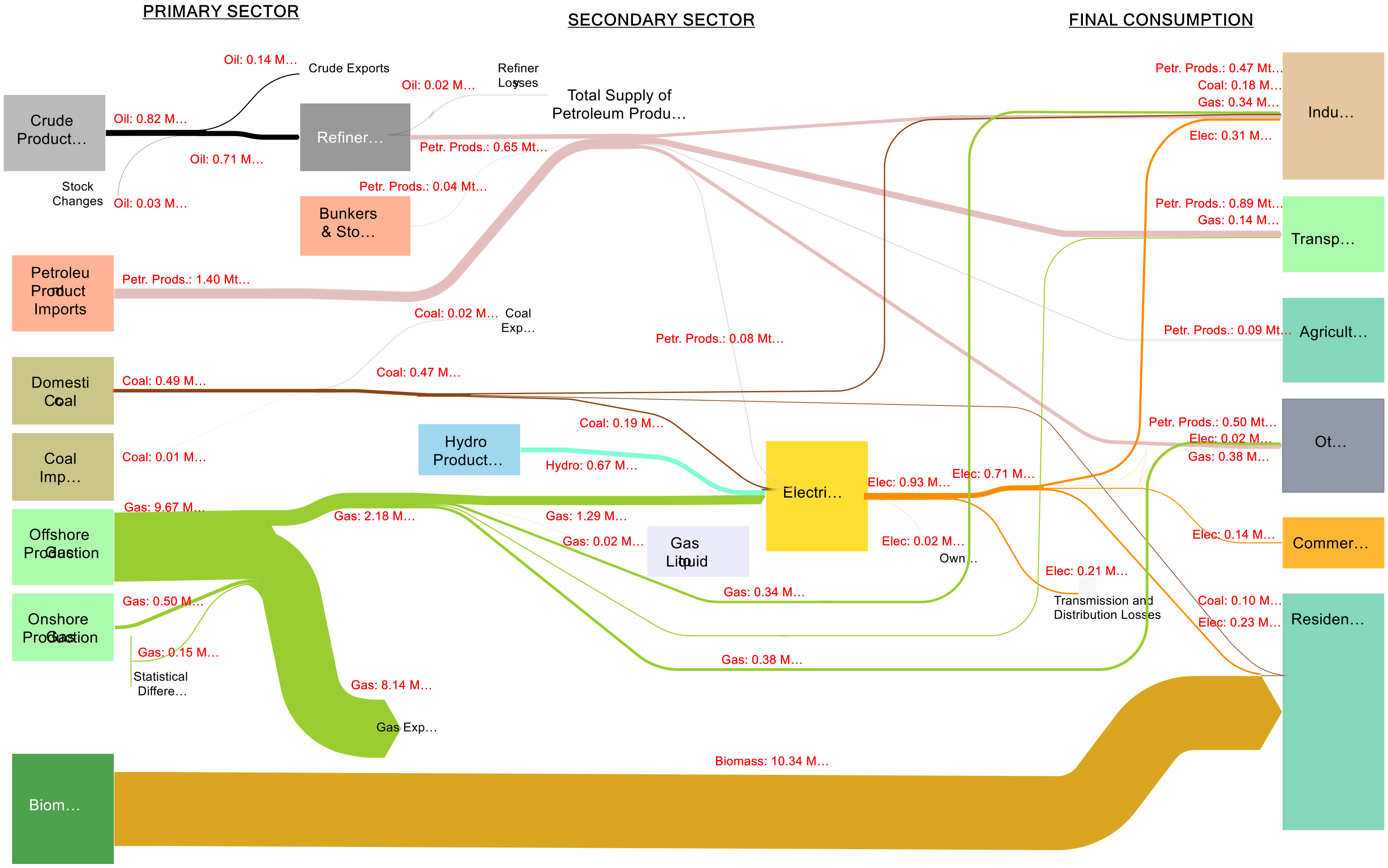
23. A simplified energy balance table for Myanmar for the year 2013/14 in energy units is provided in Table I-20. This provides a snapshot of energy flows in the country based on the information and data that the Consultant has been able to collect and assemble.

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

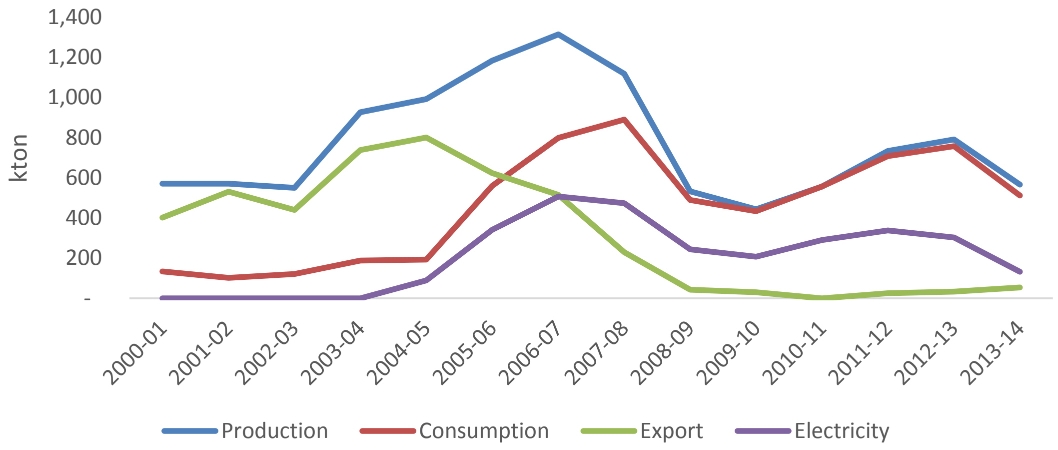
Unit: '000 ton

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)

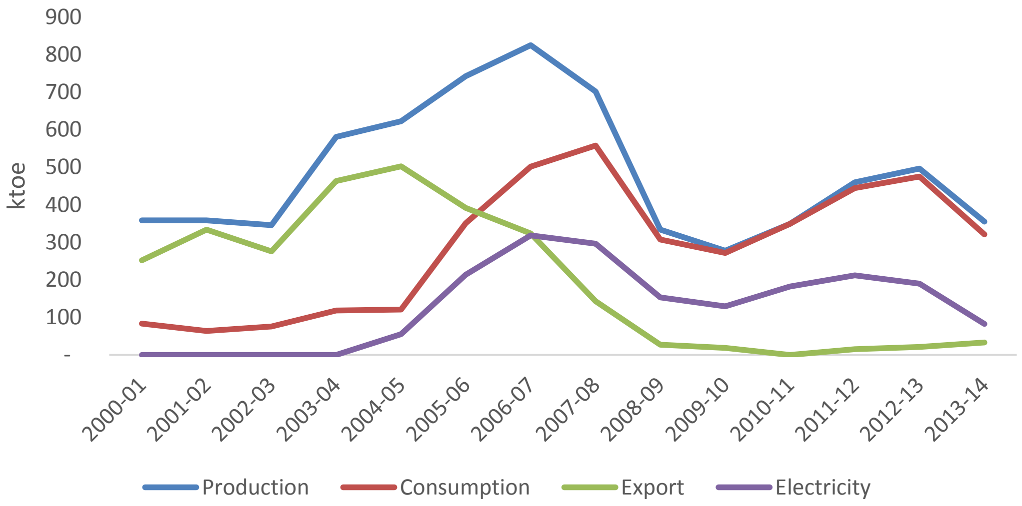
29. Figure II-2, Figure II-3 show coal production, consumption, exports, and also coal usage by the Tigyit Power Station which started operation in late 2004. There has been a trend away from exporting coal. Importing coal essentially not a significant feature of Myanmar's coal industry. Exports have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

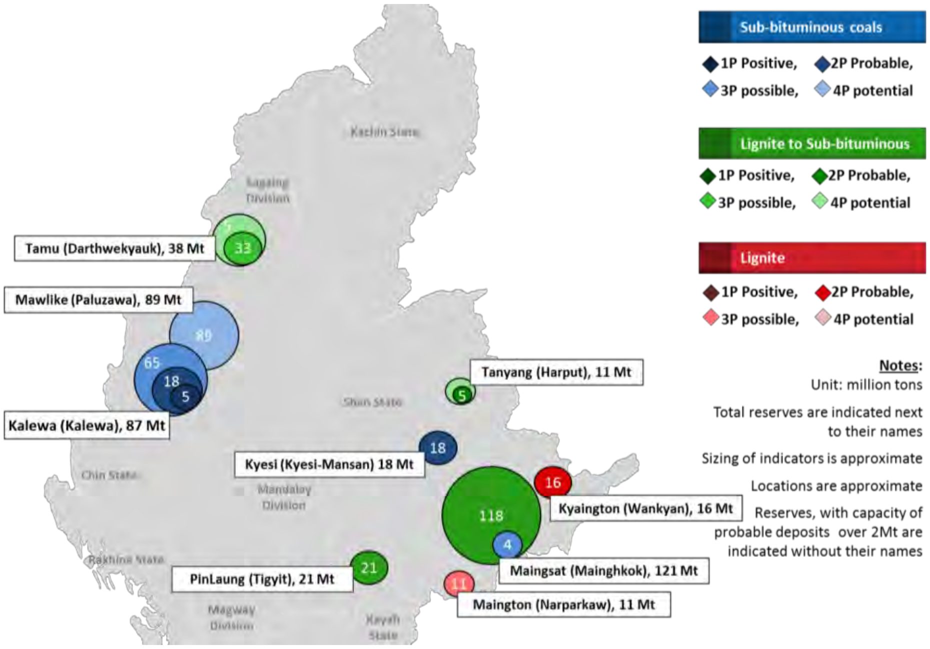
Table II-4: Myanmar Coal Reserves

	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.

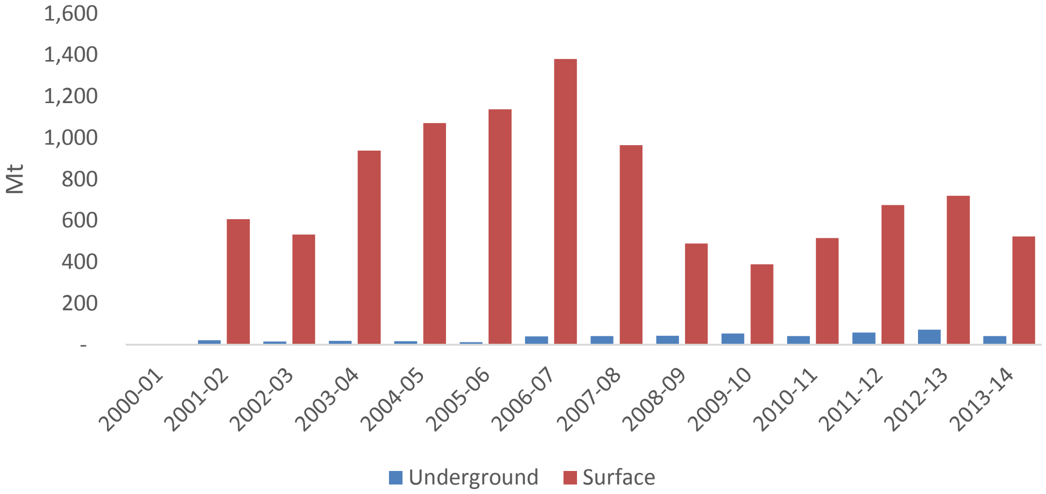
Figure II-5: Locations of Coal Reserves of Myanmar with Total Capacity over 10 Mt



Notes:
Unit: million tons
Total reserves are indicated next to their names
Sizing of indicators is approximate
Locations are approximate
Reserves, with capacity of probable deposits over 2Mt are indicated without their names

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

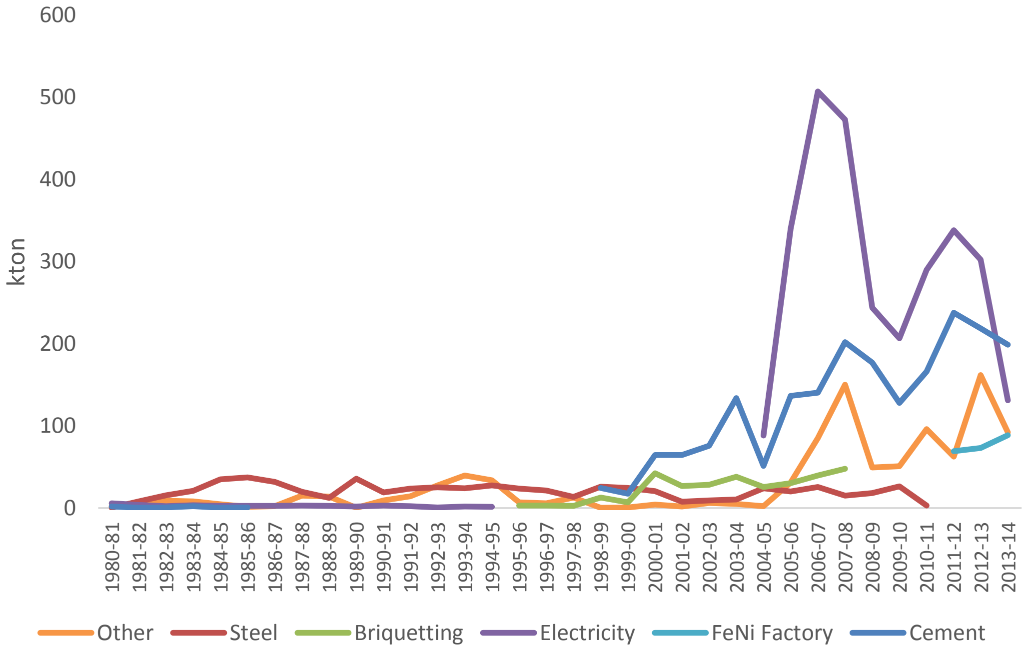
32. Coal consumption statistics are set out in Table II-7. Figure II-8 and Figure II-9 show the trends in domestic coal consumption in Myanmar for the period from 2000/01 to 2013/14. Coal is used in domestic industries and a small amount is exported. Several coal-fired cement plants are in operation 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

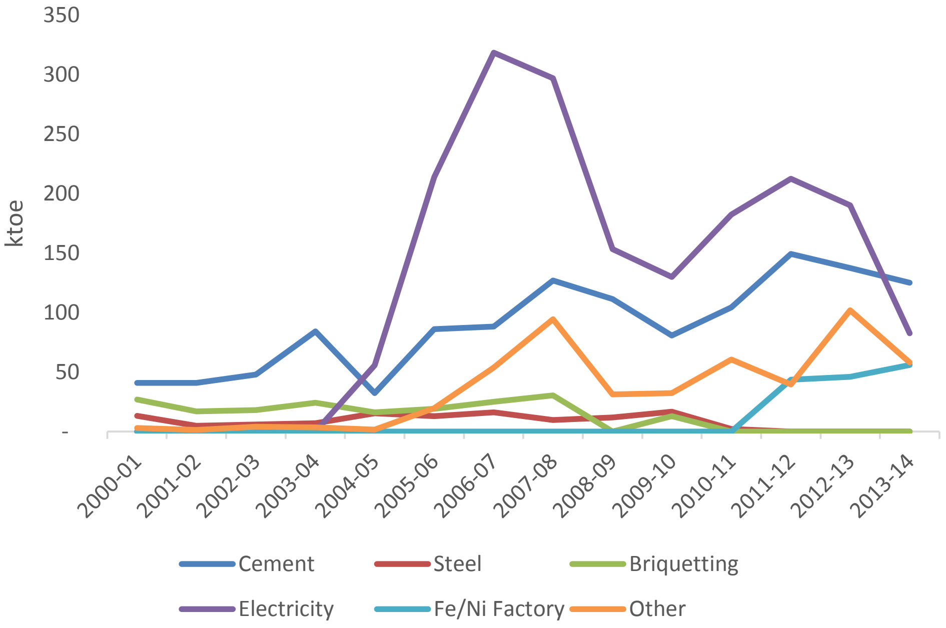
Year	Cement	Steel	Briquetting	Electricity	Iron & Nickle Factory	Others
2000-01	65	21	43			4
2001-02	65	8	27			2
2002-03	76	9	29			6
2003-04	134	11	38			5
2004-05	51	24	26	89		2
2005-06	137	20	30	340		31
2006-07	141	26	40	507		85
2007-08	202	15	48	473		150
2008-09	177	19		244		50
2009-10	128	27	20	207		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.

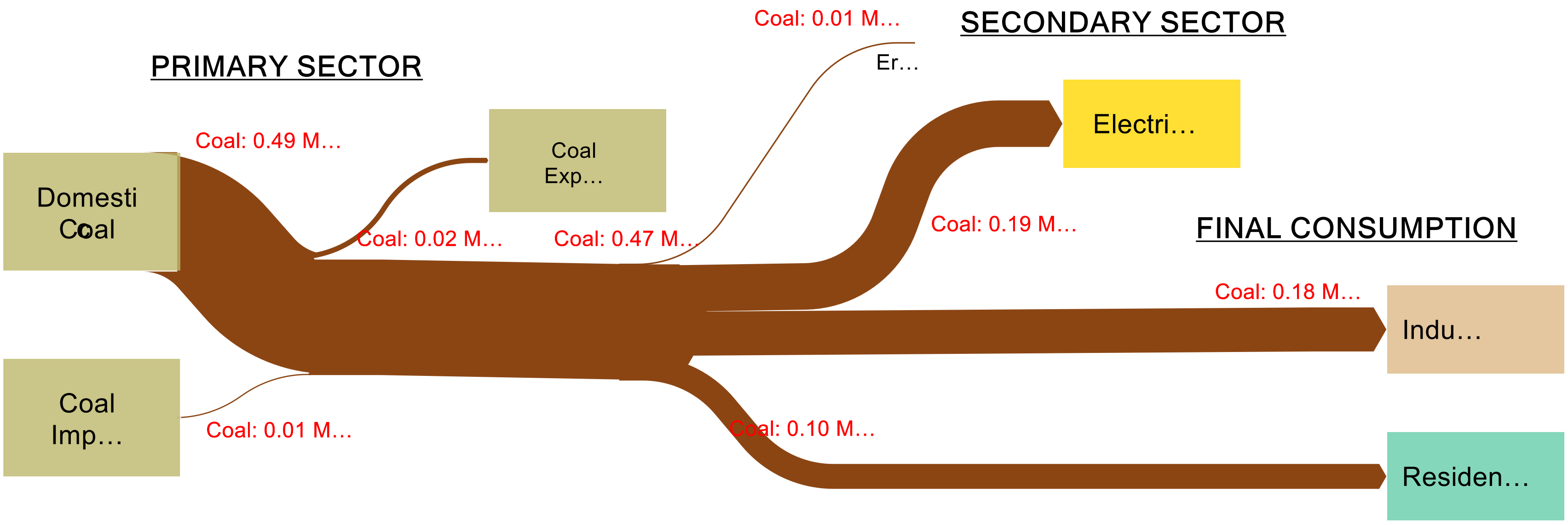
M. Coal Sector Observations

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.

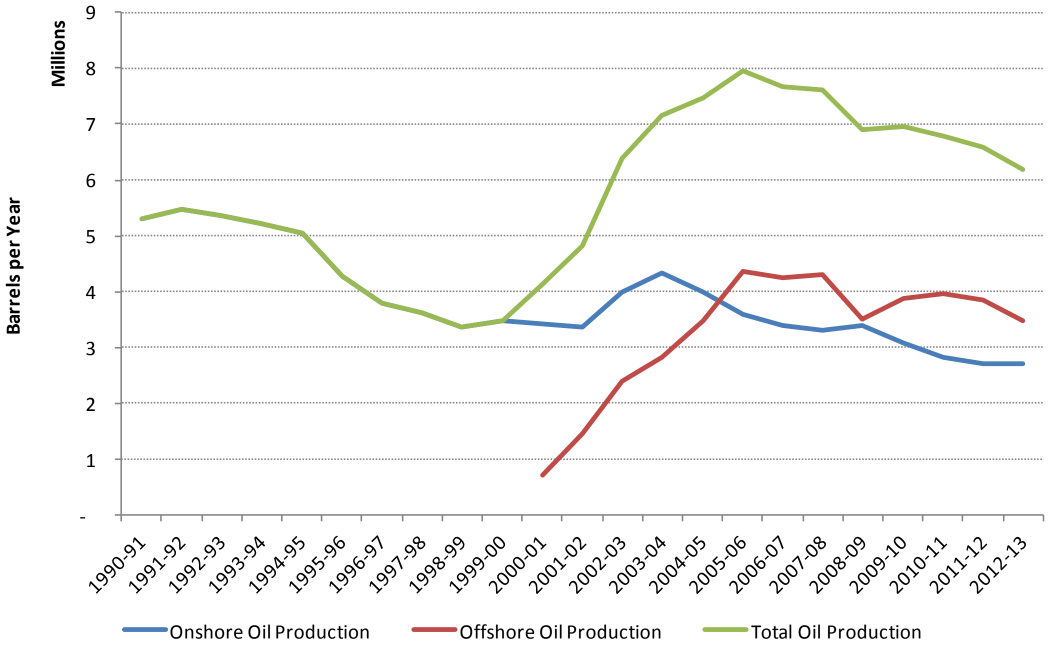
42. Additional tables and charts in this section provide further information on Myanmar's petroleum sector including a brief discussion of Myanmar's refinery facilities.

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.

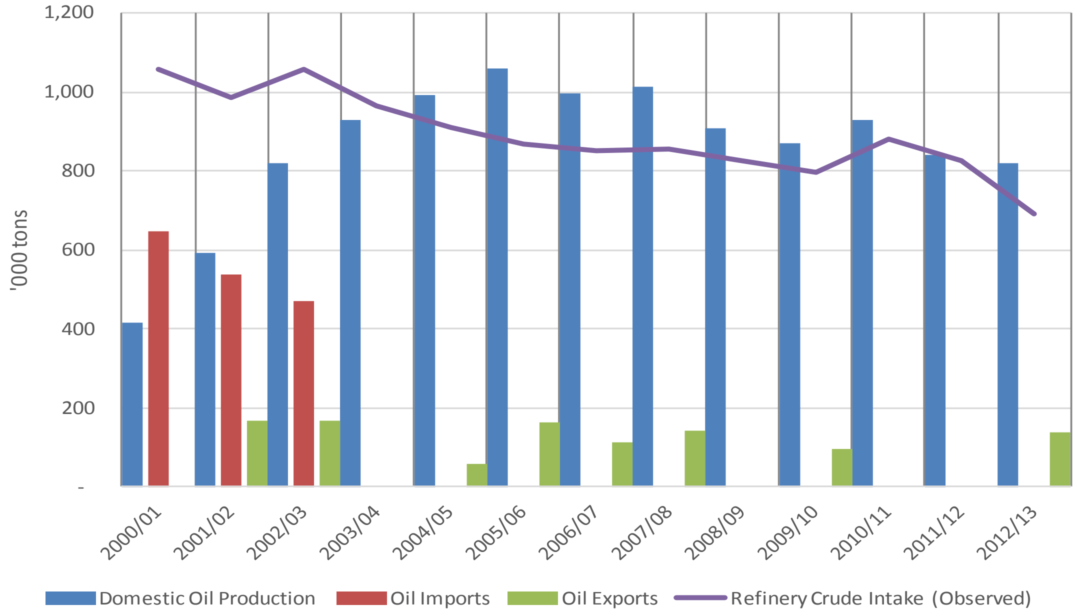
46. Figure III-3 shows Myanmar's overall oil production and overall refinery input. Figure III-4 illustrates the level of refinery output against the refinery capacity over time. This demonstrates the extent to which the existing refineries in Myanmar are underutilised.

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

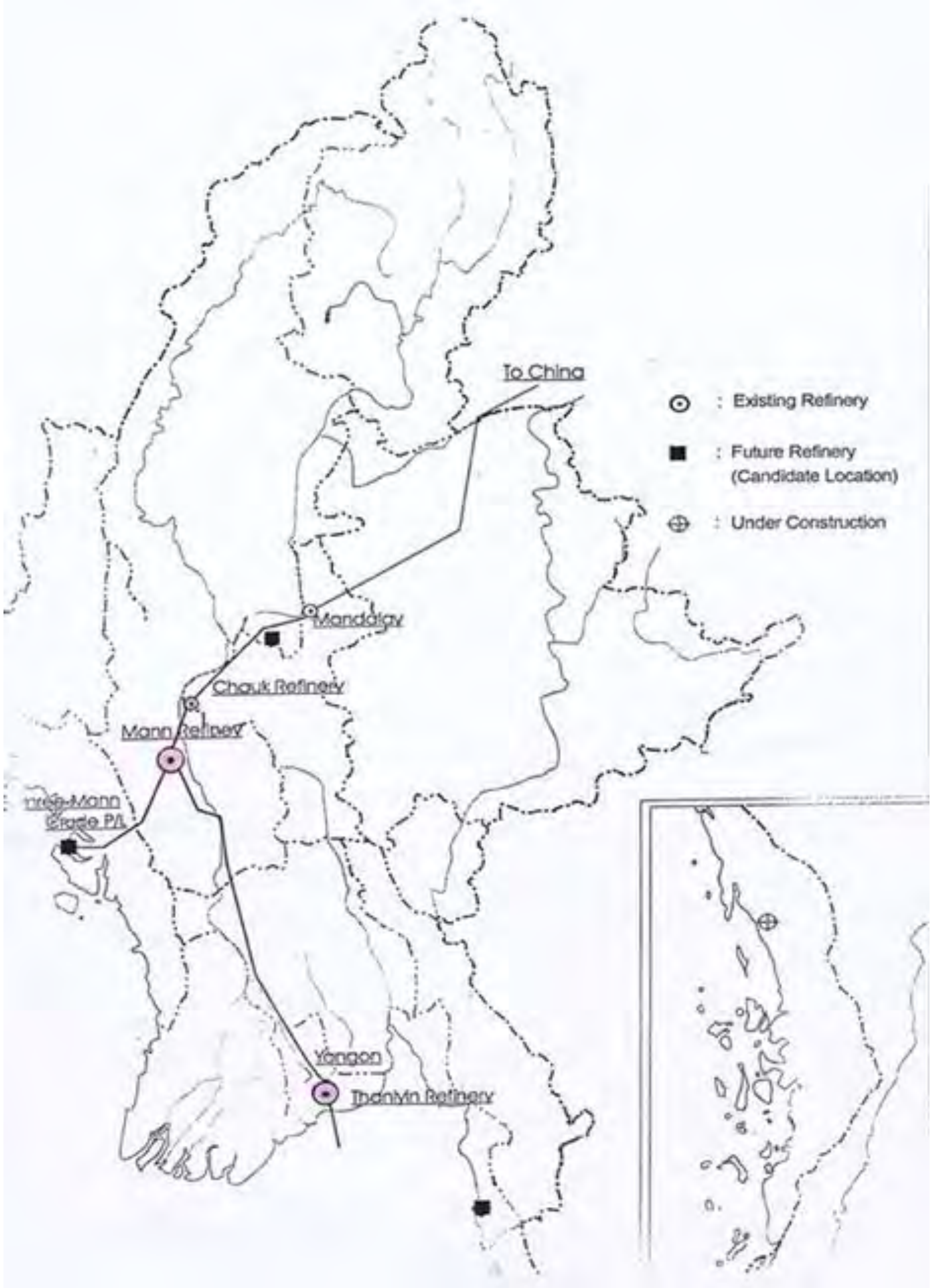
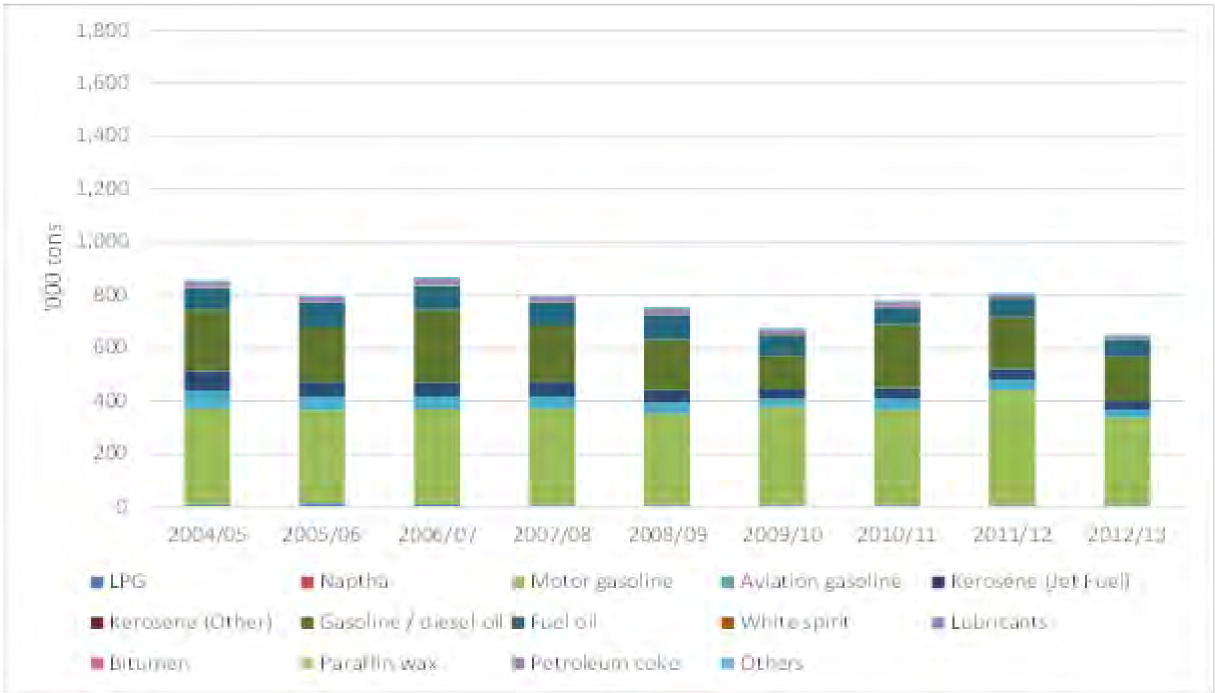
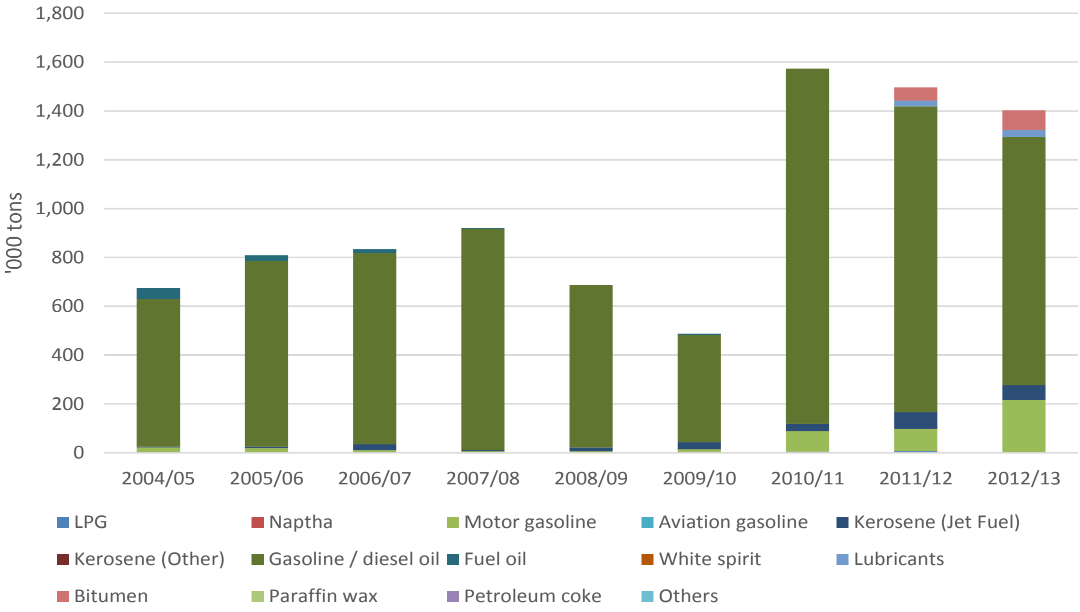


Figure III-6: Myanmar Petroleum Products Produced ('000 ton)



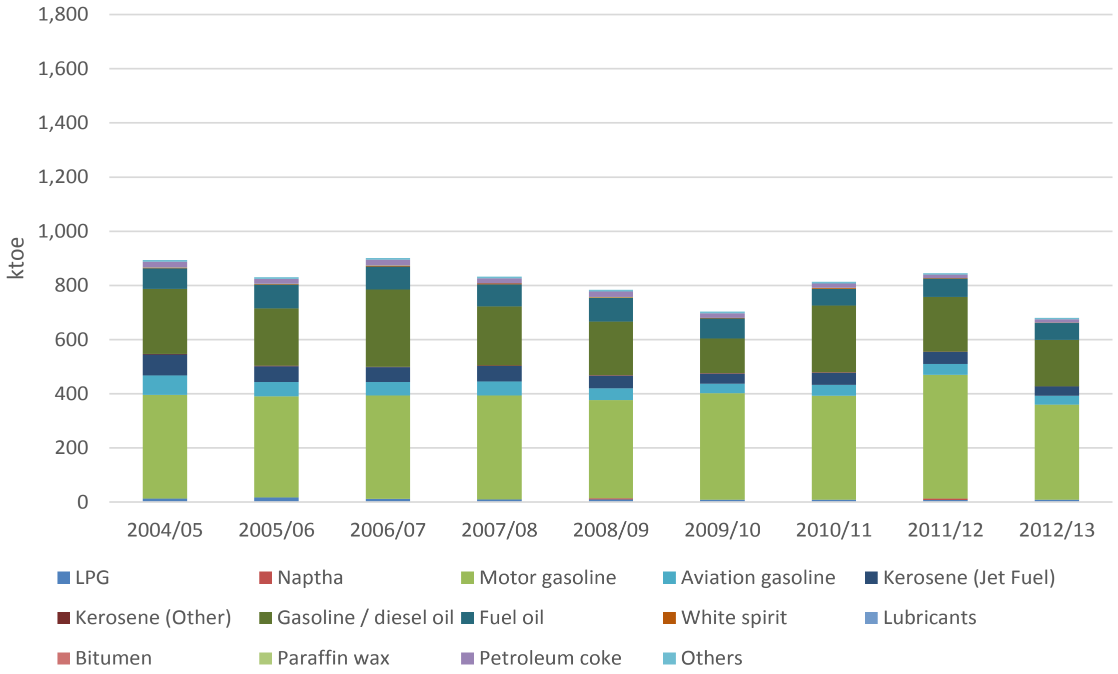
Sources: MOE, MPPE, CSO

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



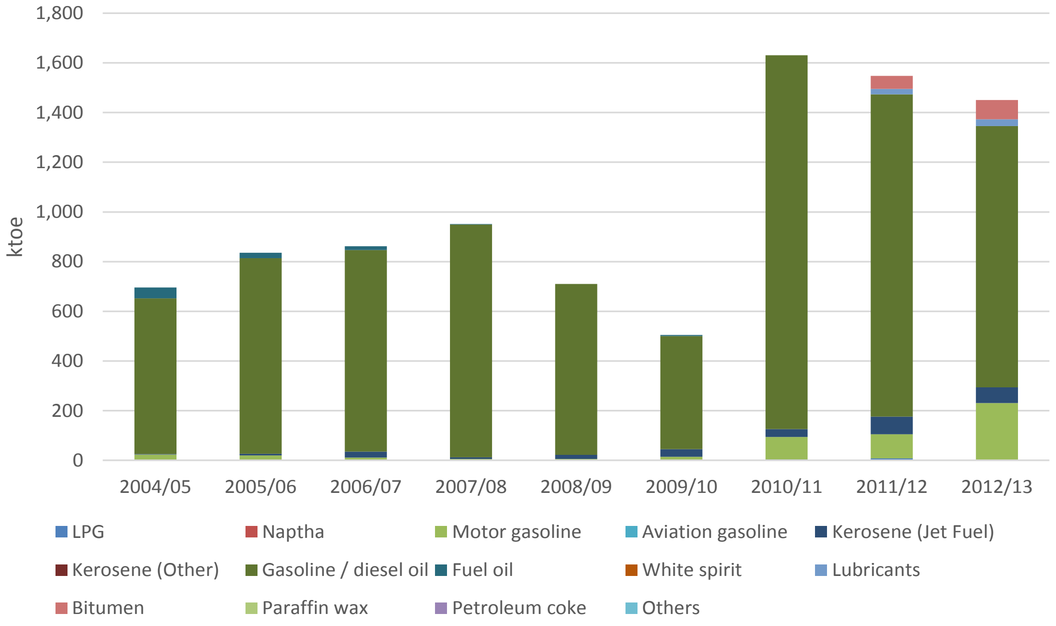
Sources: MOE, MPPE, CSO

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



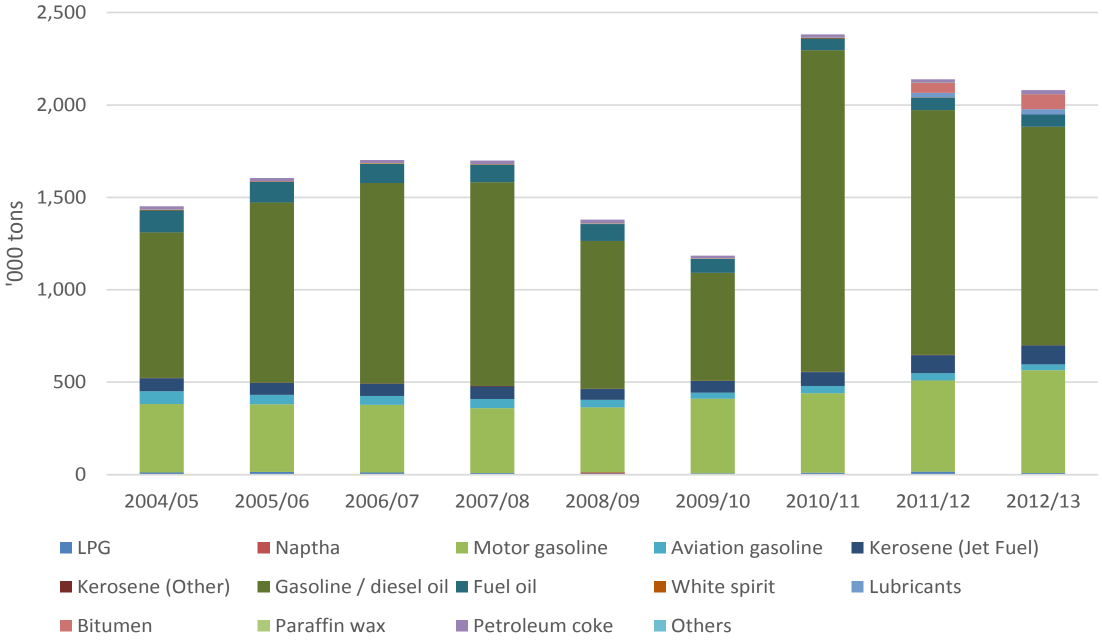
Sources: MOE, MPPE, CSO

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



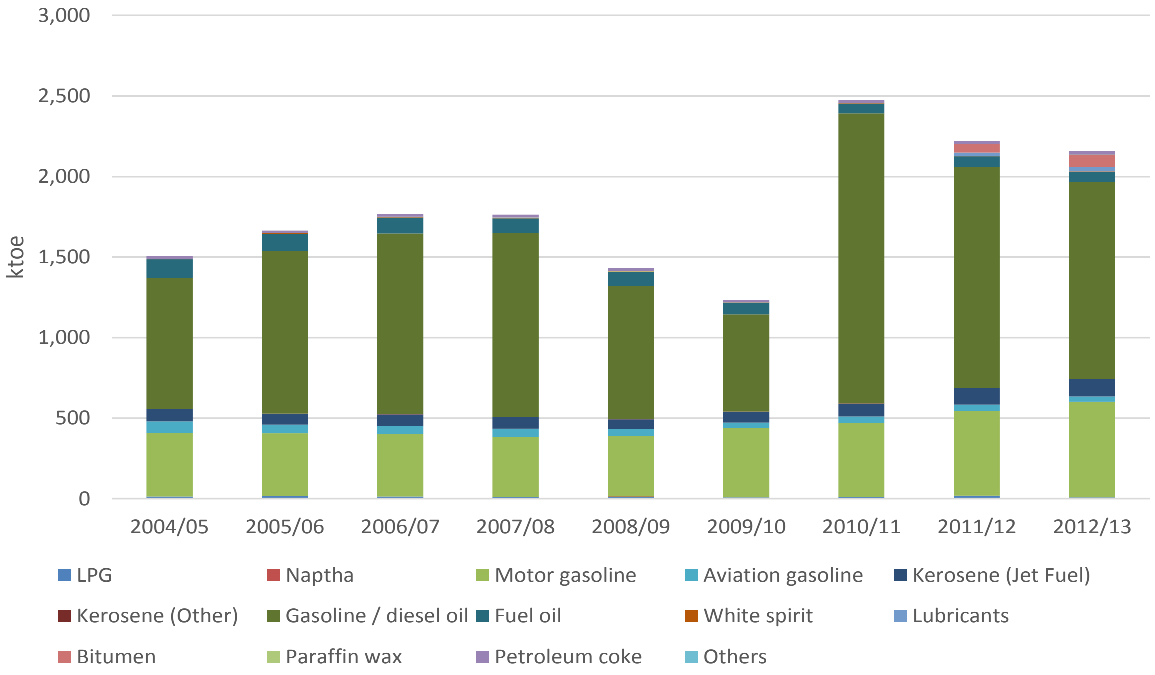
Sources: MOE, MPPE, CSO

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



Sources: MOE, MPPE, CSO

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

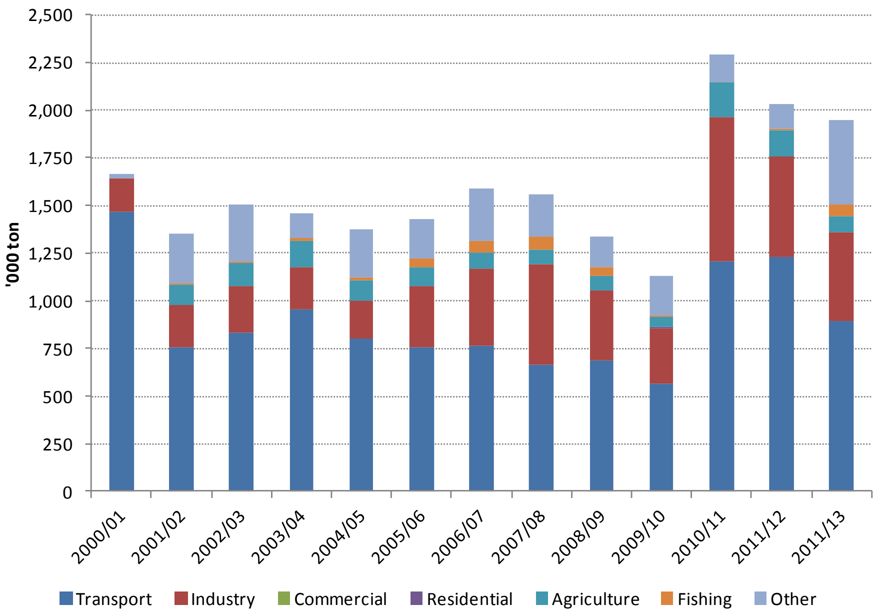


Sources: MOE, MPPE, CSO

Q. Petroleum Product Final Consumption

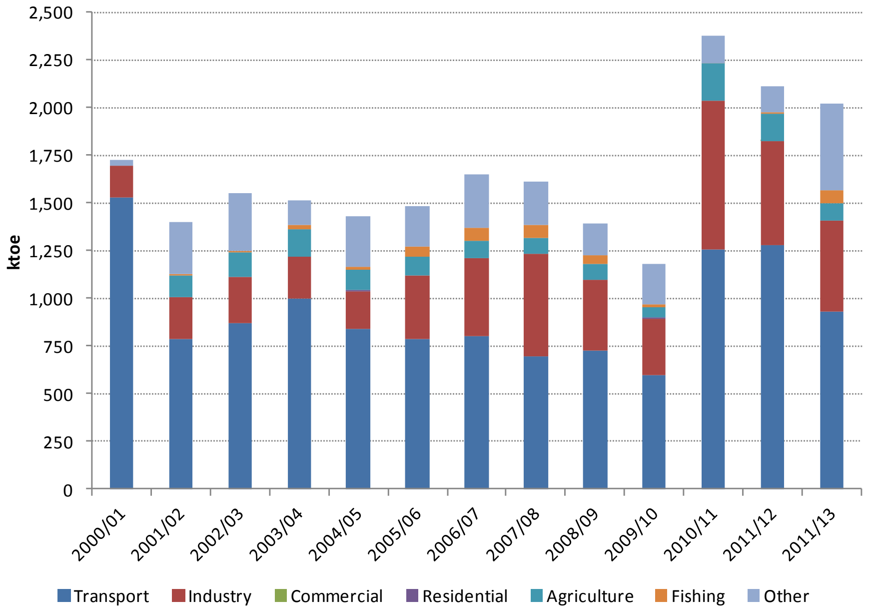
49. The charts presented in Figure III-12 and Figure III-13 illustrate in physical and energy terms the final energy consumption of petroleum products in Myanmar.

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

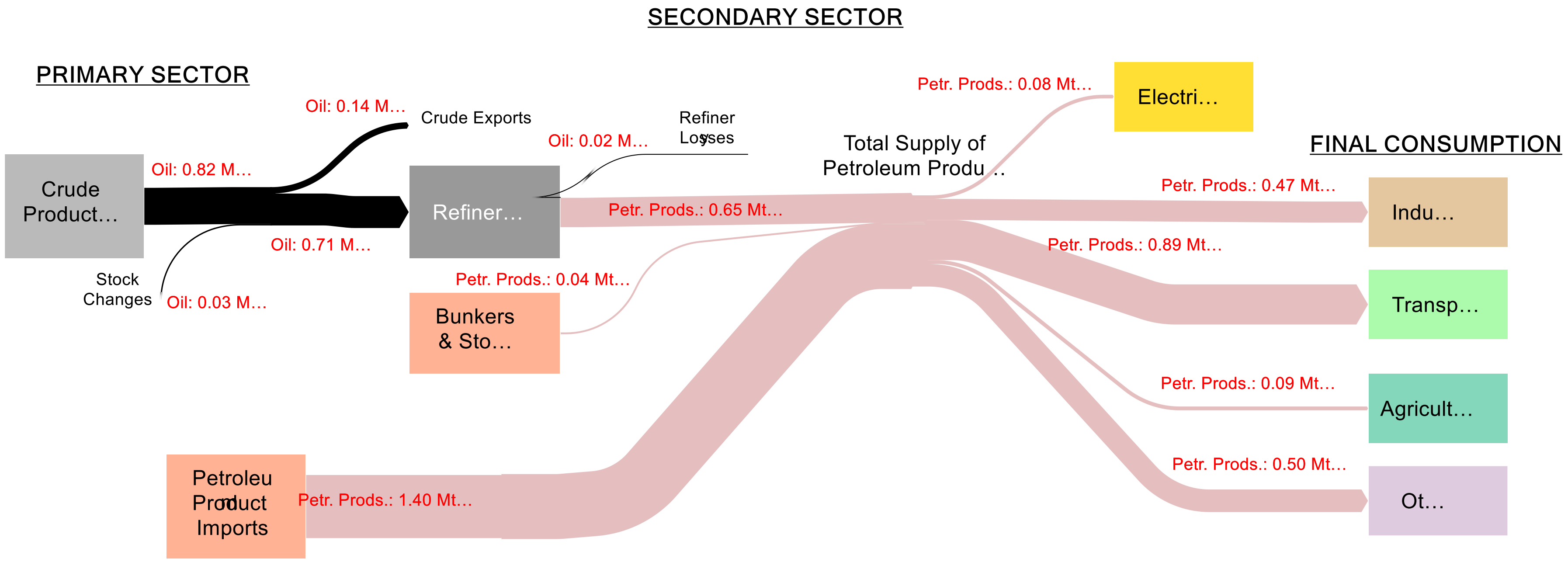
54. Myanmar crude oil production has generally decreased over the last decade from a peak of 8 billion bbl/y in 2005 to just over 6 billion bbl/y by 2013. Most all of the crude oil that Myanmar produces is delivered to the country's oil refineries for production of petroleum products, although in the 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
<u>Other</u>														
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	Sale	Own Used	Total Used	Flare	Pack	Unpack
		MMcf	MMcf	MMcf	MMcf	MMcf	MMcf	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

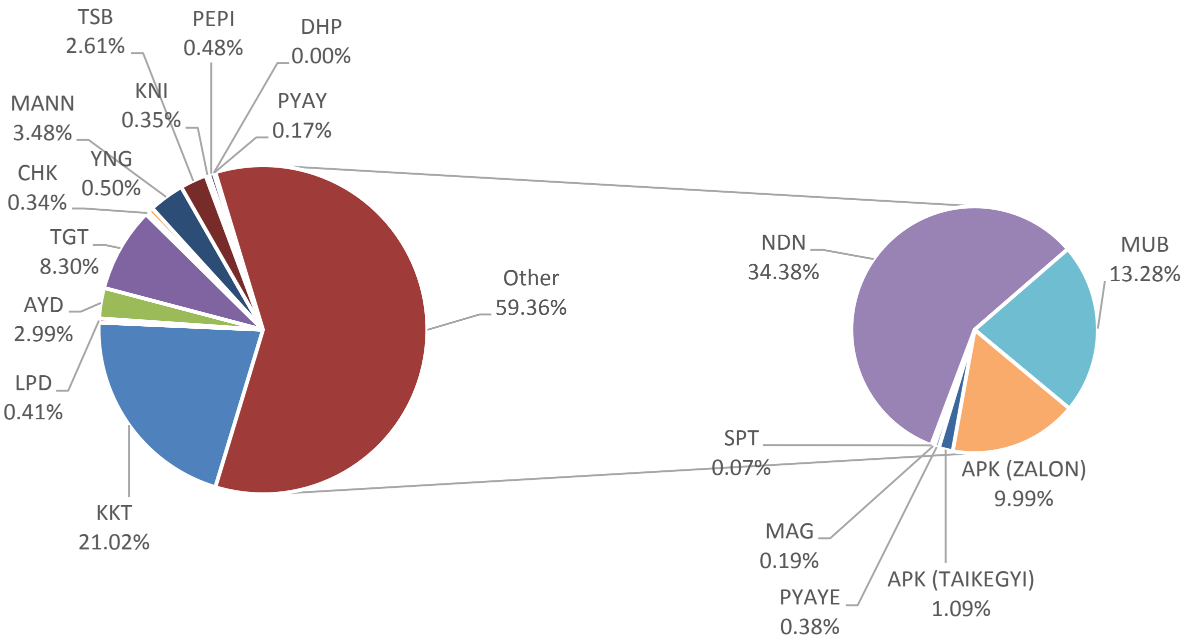
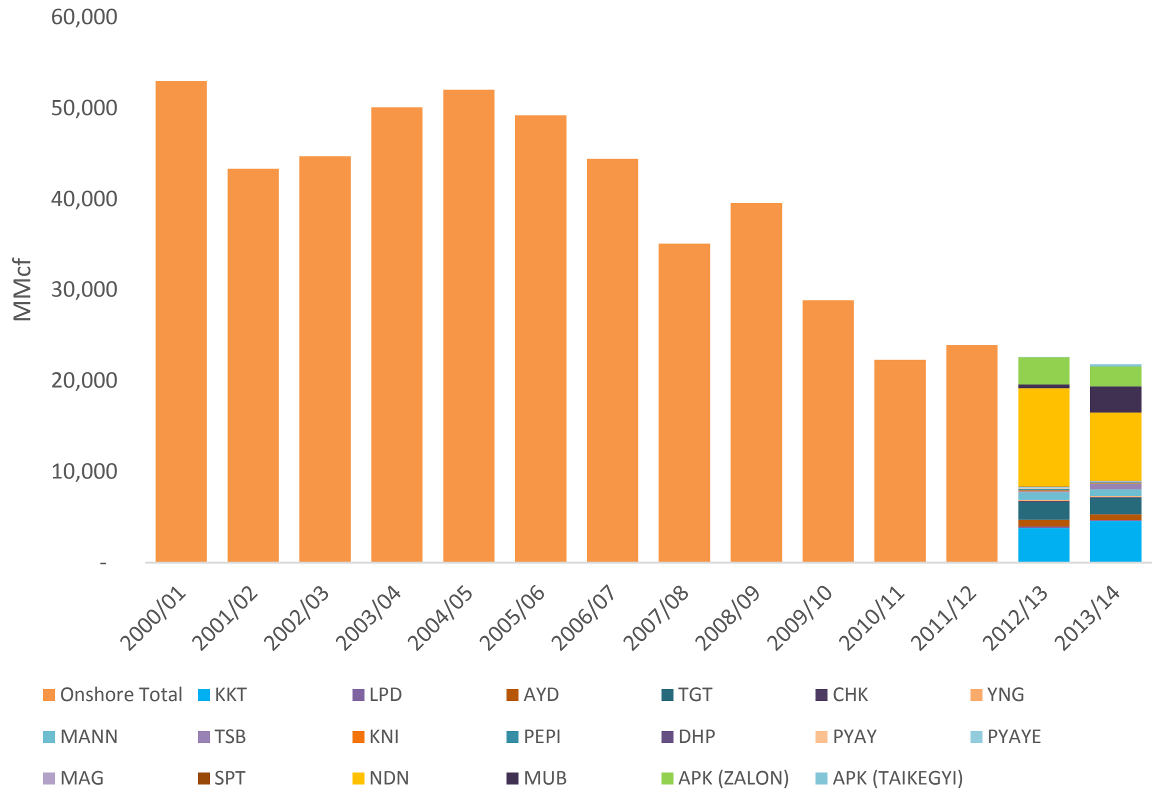


Figure IV-4: Onshore Natural Gas Production 200/01 to 2013/14



W. Offshore Natural Gas Production

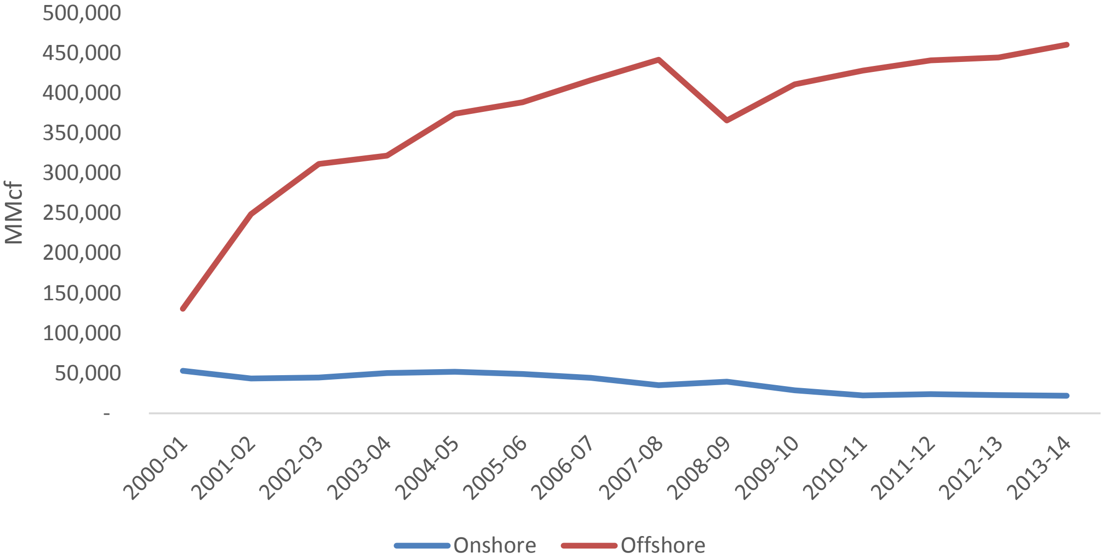
61. Figure IV-5 plots Myanmar's gas production showing the onshore and offshore production. It demonstrates how offshore production with production from the offshore fields has become a key component of Myanmar's gas sector since the year 2000. Yadana and Yetagun are the two major offshore gas fields 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)

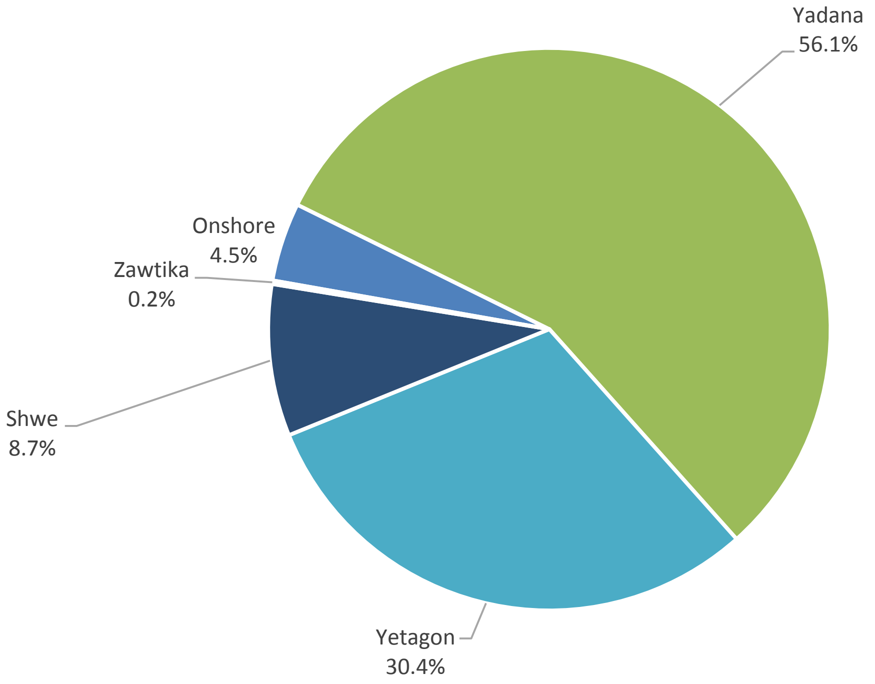
Period	Gas Field	Production	Sales			Own Use	Vent/Flare	Line Pack	Unpack
			Export	Domestic	Total				
		MMcf	MMcf	MMcf	MMcf	MMcf	MMcf	MMcf	MMcf
2011-12	Onshore	23,948		21,058	21,058	2,840	53	1,344	
	Yadana	287,385	218,336	66,460	284,796	2,190	458	306	368
	Yetagon	153,602	146,649		146,649	2,616	109	4,227	
	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

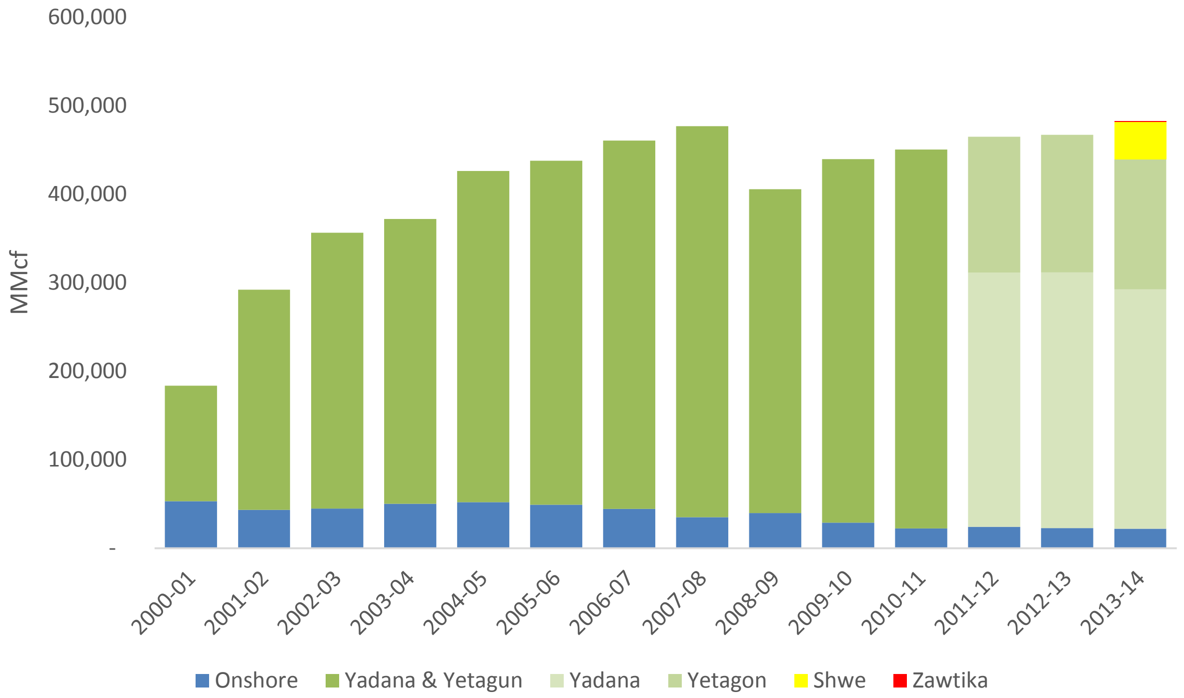
	Production	Exports	Domestic	Total	Own Use	Vent/Flare	Line Pack	Unpack
2011-12	464,935	364,985	87,518	452,503	7,646	620	5,878	368
2012-13	467,005	362,156	81,561	443,717	7,686	2,442	7,752	29
2013-14	482,276	372,690	82,929	455,619	9,025	3,967	4,165	8

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



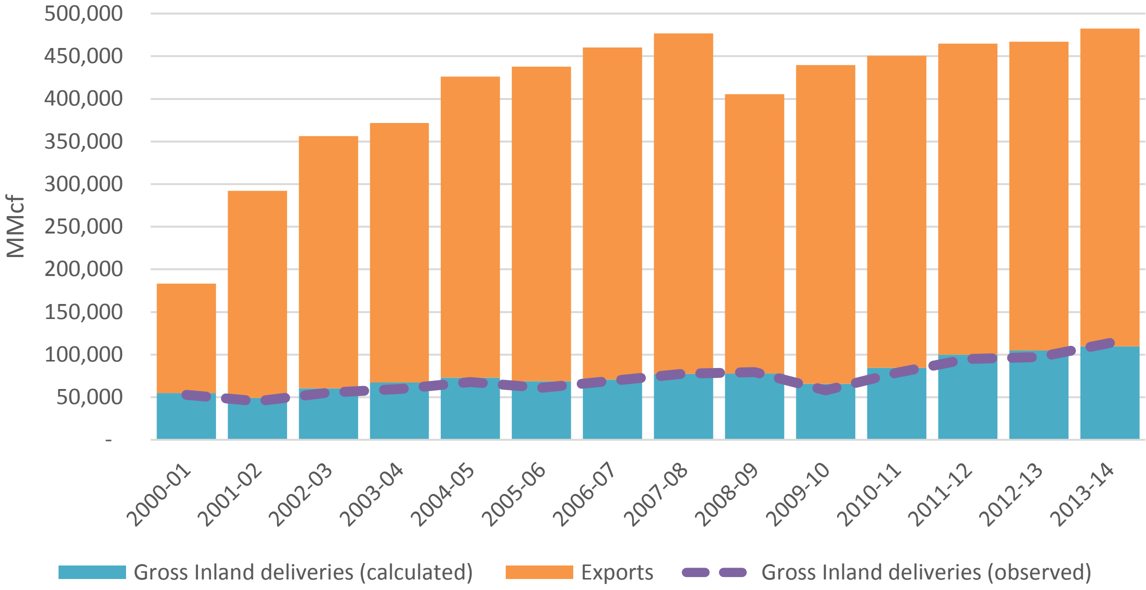
Sources: MOGE, CSO

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.

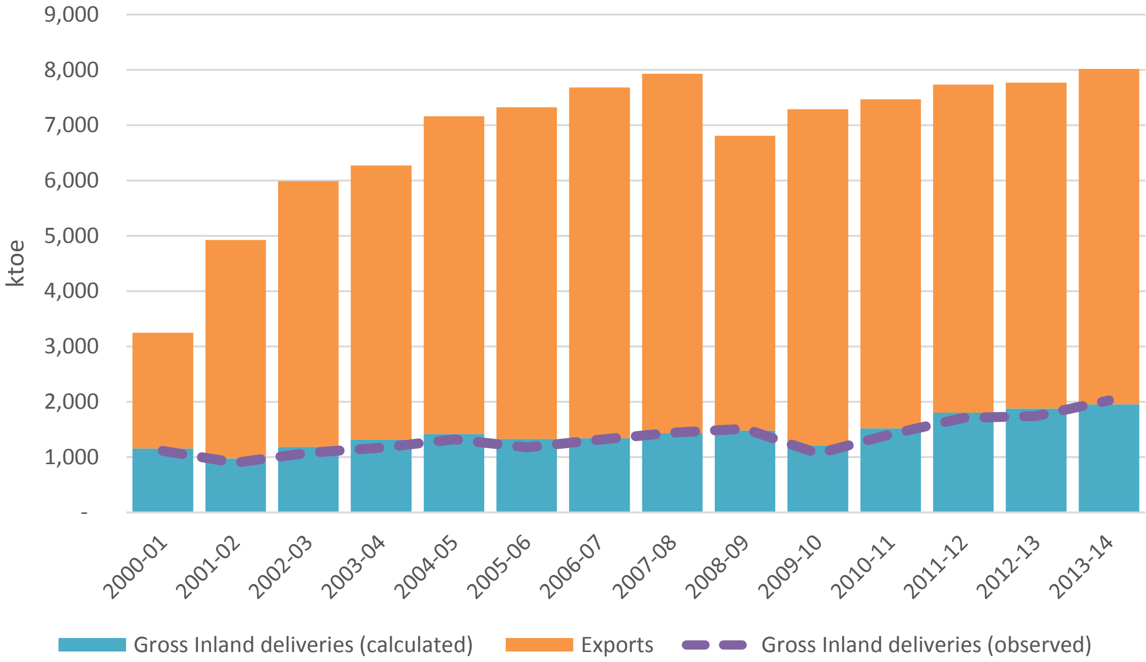
66. Annual domestic supply of natural gas has stabilised at about 2 thousand ktoe in the last two years. The observed supplies though were slightly higher, by 4% to 7% due to statistical differences.

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

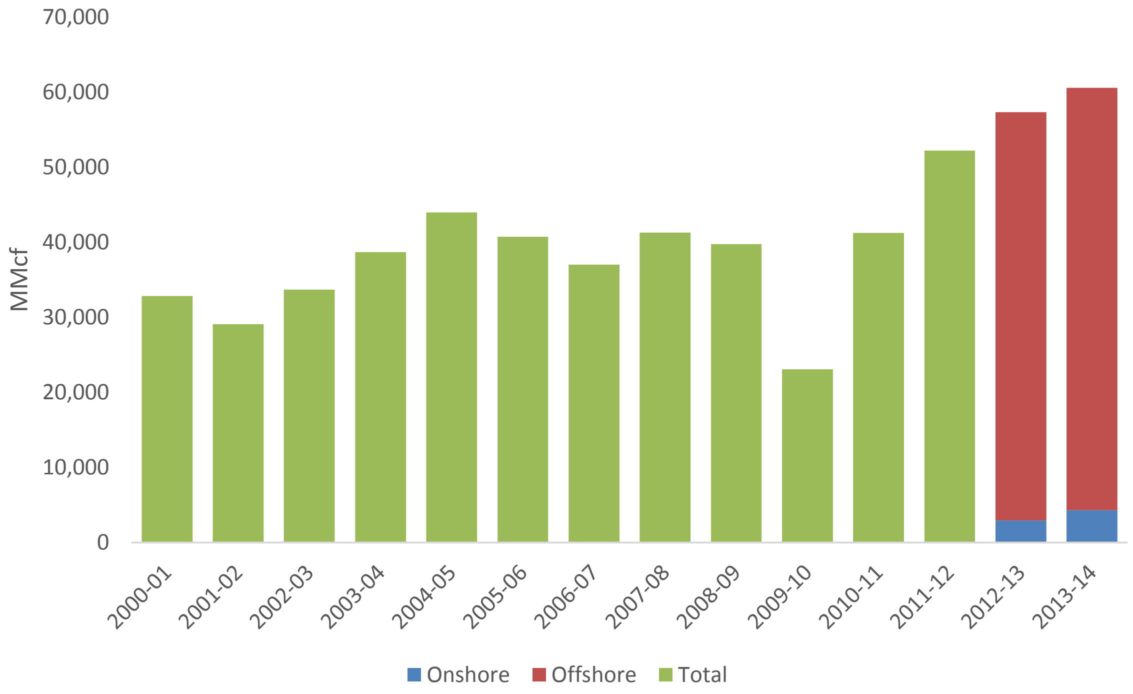
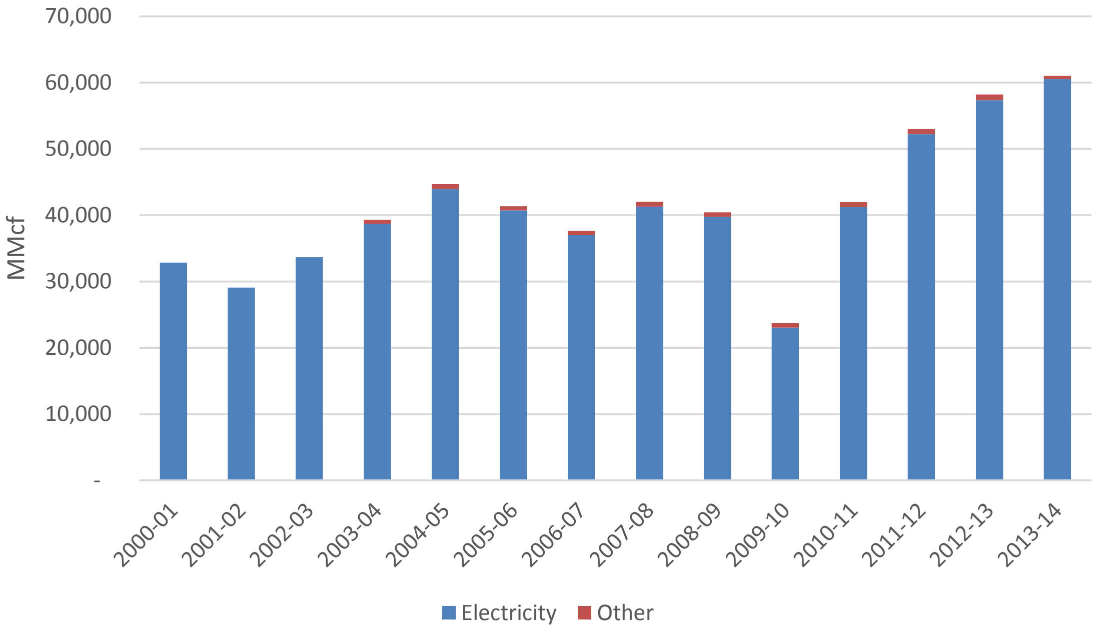
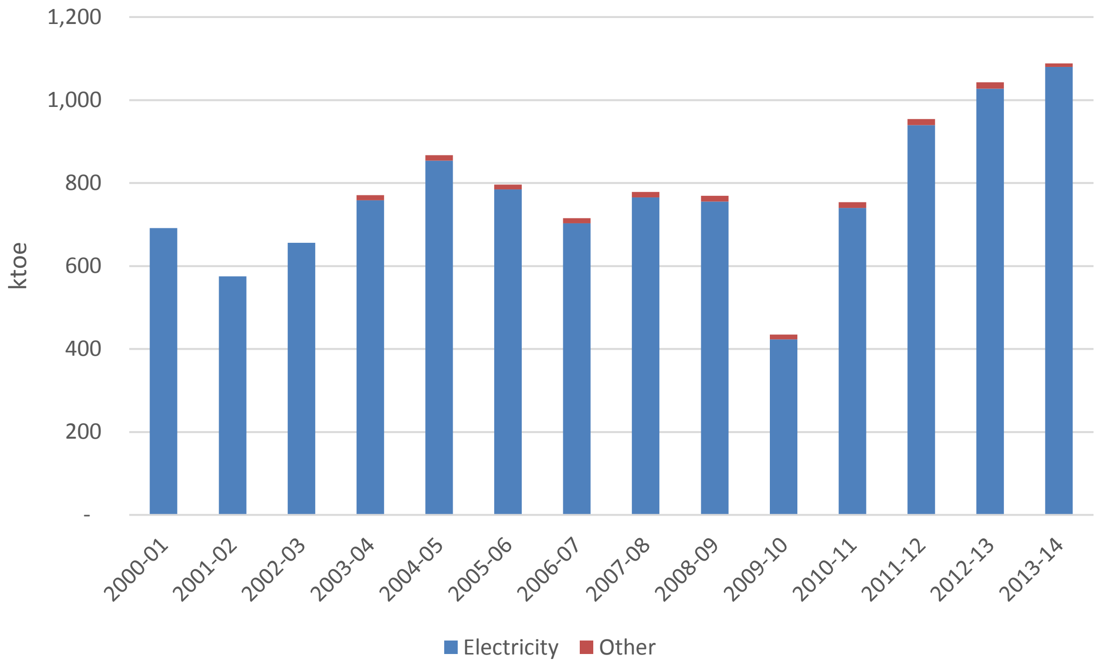


Figure IV-15: Myanmar Natural Gas Transformation (MMcf)



Sources: MOGE, CSO

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



Sources: MOGE, CSO

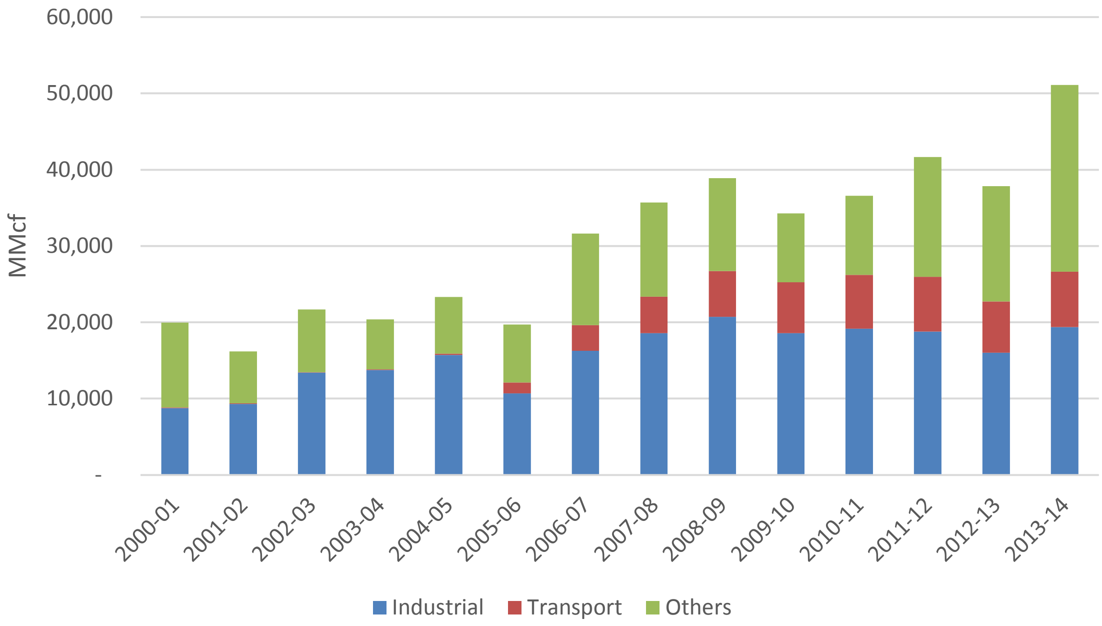
Z. Natural Gas Consumption

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

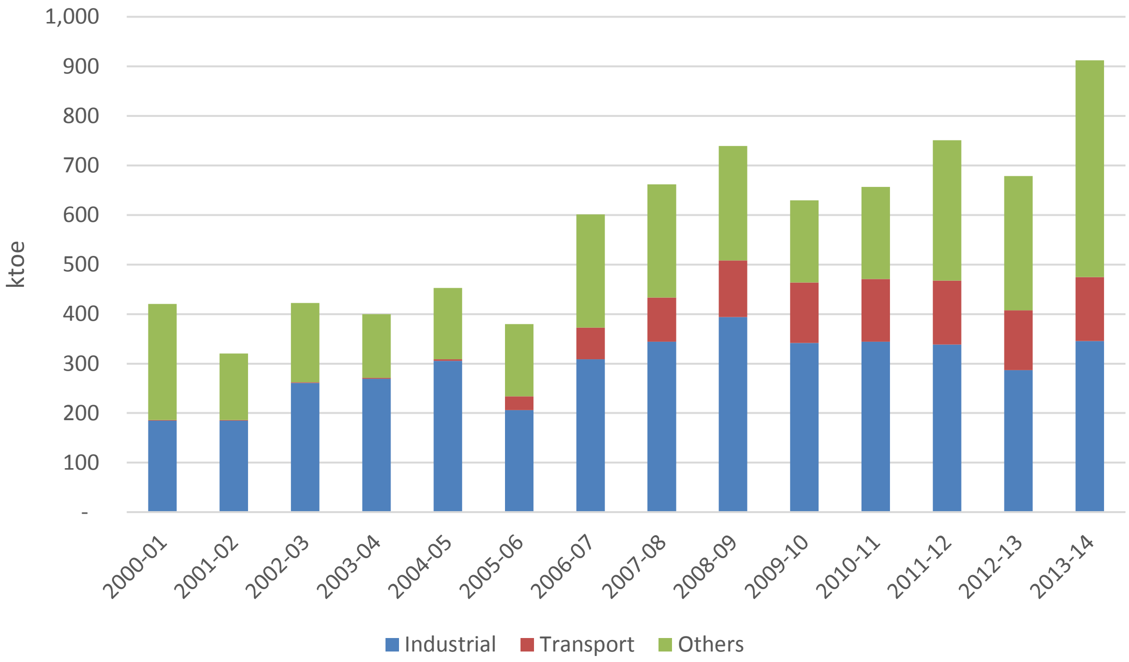
Gas for Fertlizer Plants, Refineries, LPG, and CNG Stations (2012/13 and 2013/14)							
No.	**Factory Name**	**2012-13**			**2013-14**		
		Onshore	**Offshore**	**Total**	**Onshore**	**Offshore**	**Total**
		MMcf	**MMcf**	**MMcf**	**MMcf**	**MMcf**	**MMcf**
1	Kyun Chaung Fertilizer Plan	0		0	1		1
2	Sale 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.

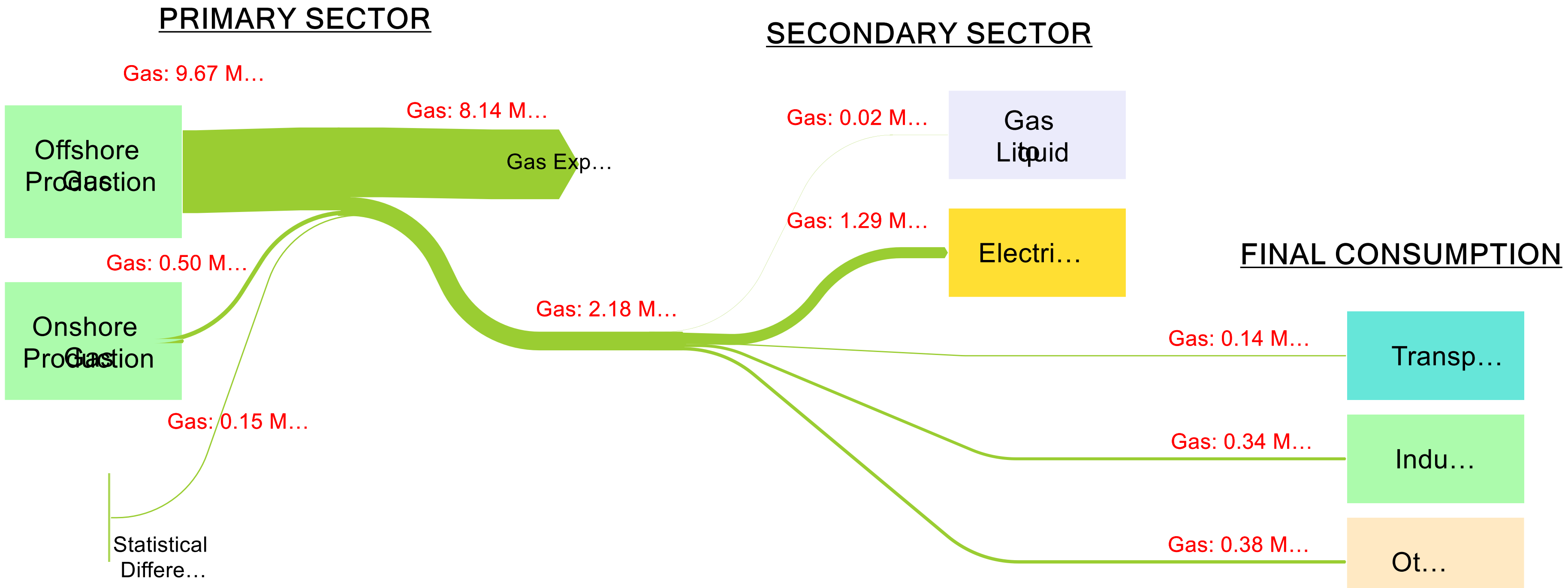
CC. Natural Gas Observations

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
<u>Transform</u>														
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
<u>Transform</u>														
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.

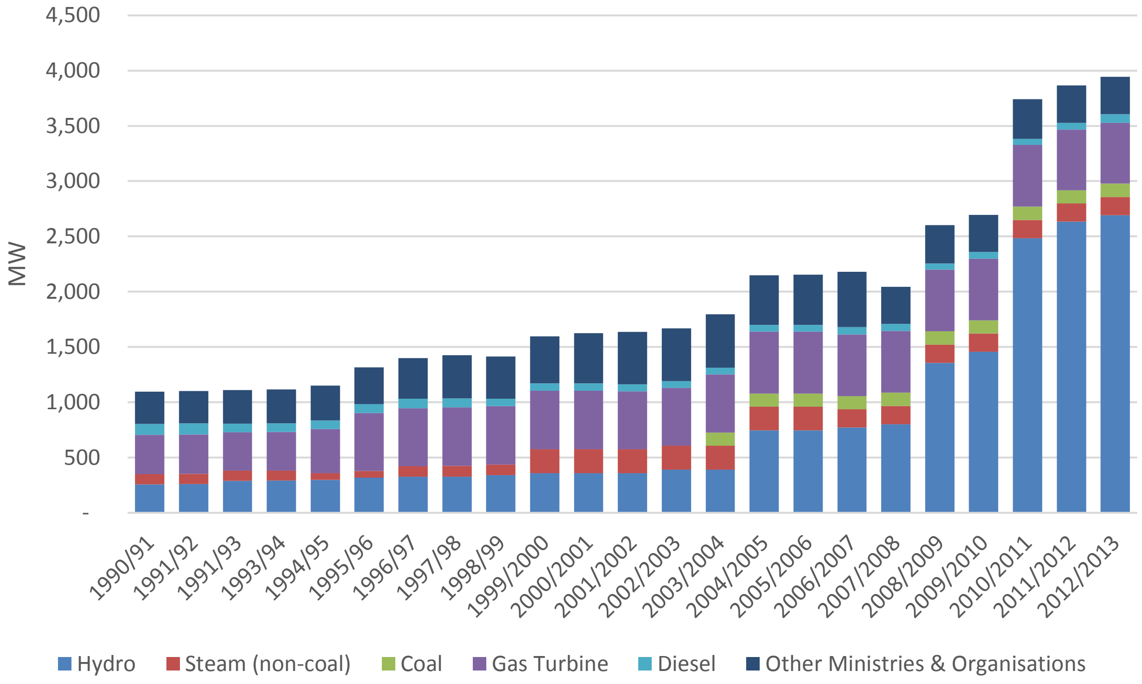
78. An energy flow chart to illustrate Myanmar's electricity sector is provided in Figure V-12 for the year 2012/13. This directly demonstrates the dominant roles of hydro and gas in electricity industry.

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

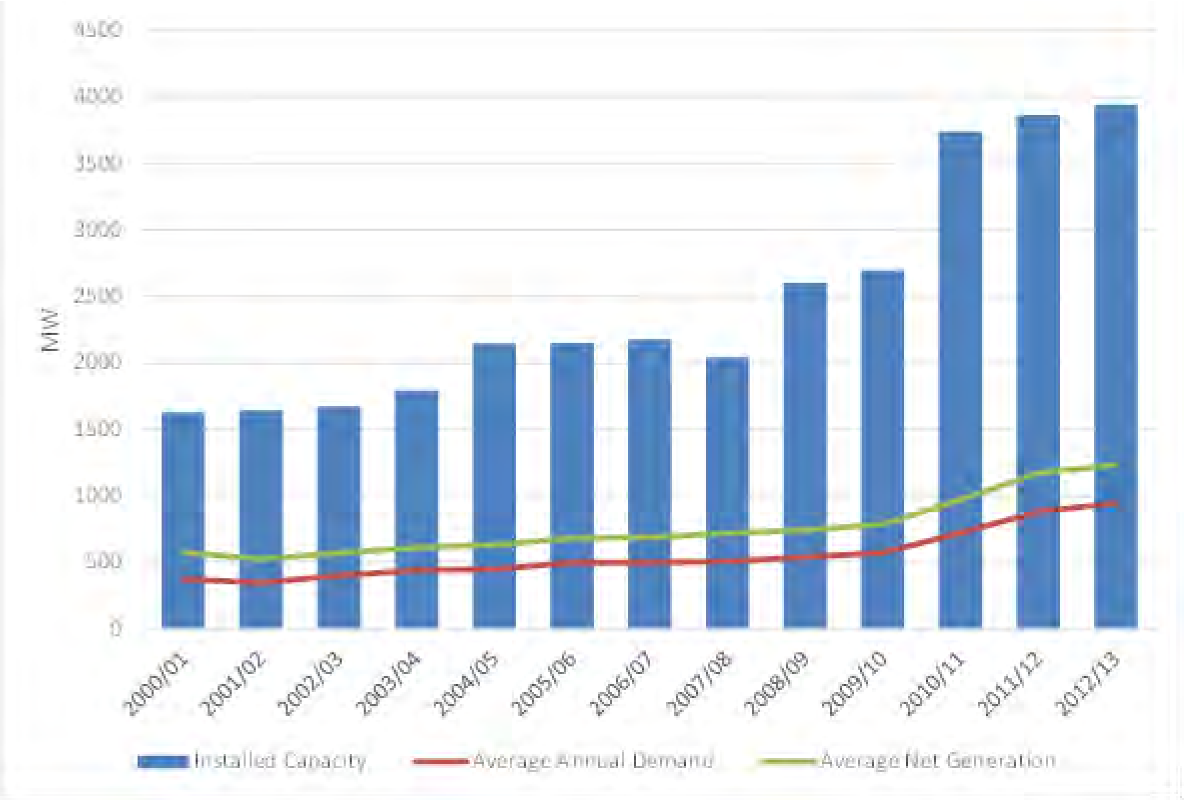
80. Figure V-1 plots generation installed capacity from 1990/91 through to 2012/13. This shows that Myanmar has seen almost a doubling in hydro generation from 2008 to 2011 with the commissioning of several large hydro projects: Shweli-1 (600 MW), Yeywa (790 MW) and Dapein-1 (240 MW). Figure V-2 sets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

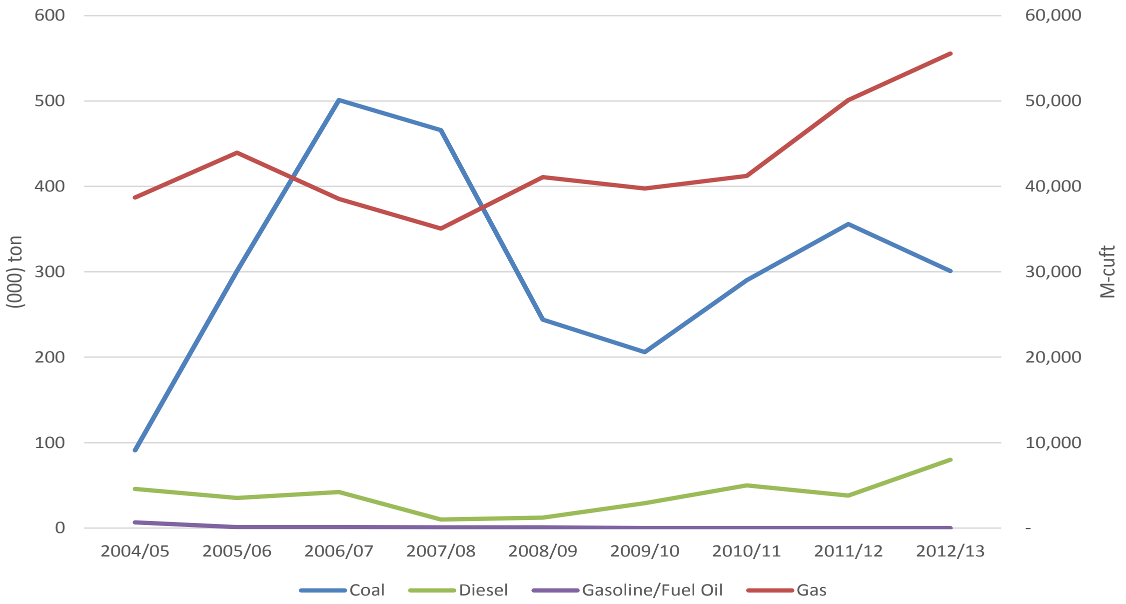


Source: MOEP

FF. Electricity Primary Energy Consumption

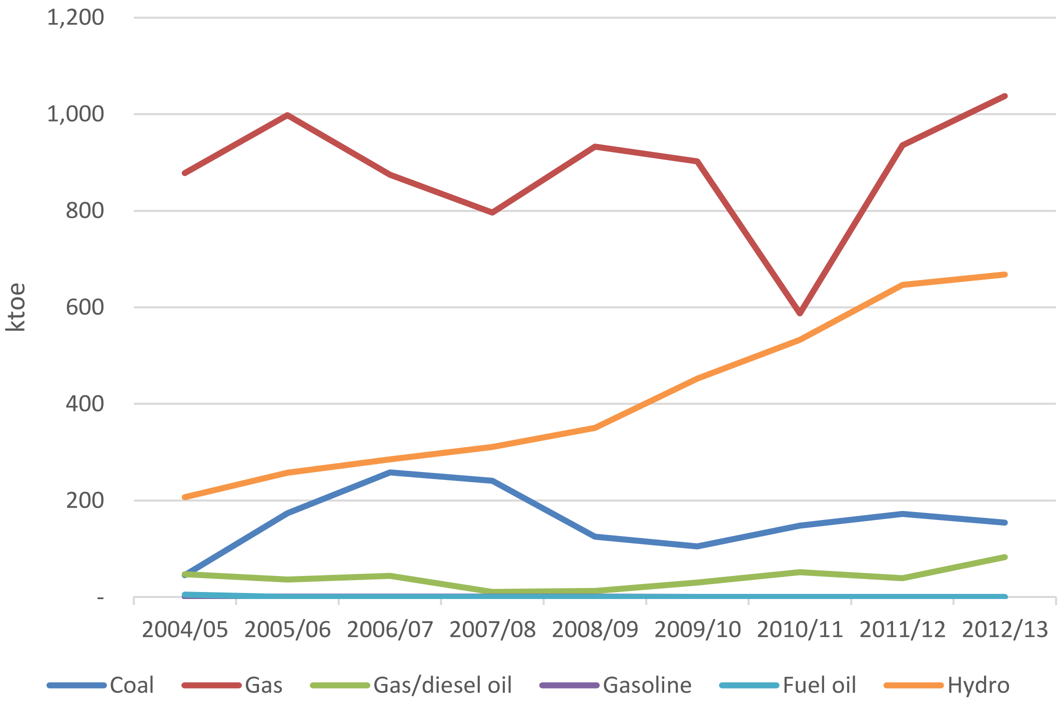
81. Figure V-3 and Figure V-4 illustrate historical uses of different primary fuels for electricity generation in physical and ktoe units respectively. These show natural gas is a major fuel for producing power in Myanmar and use of hydro resources has been rising, which is explained by the commissioning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



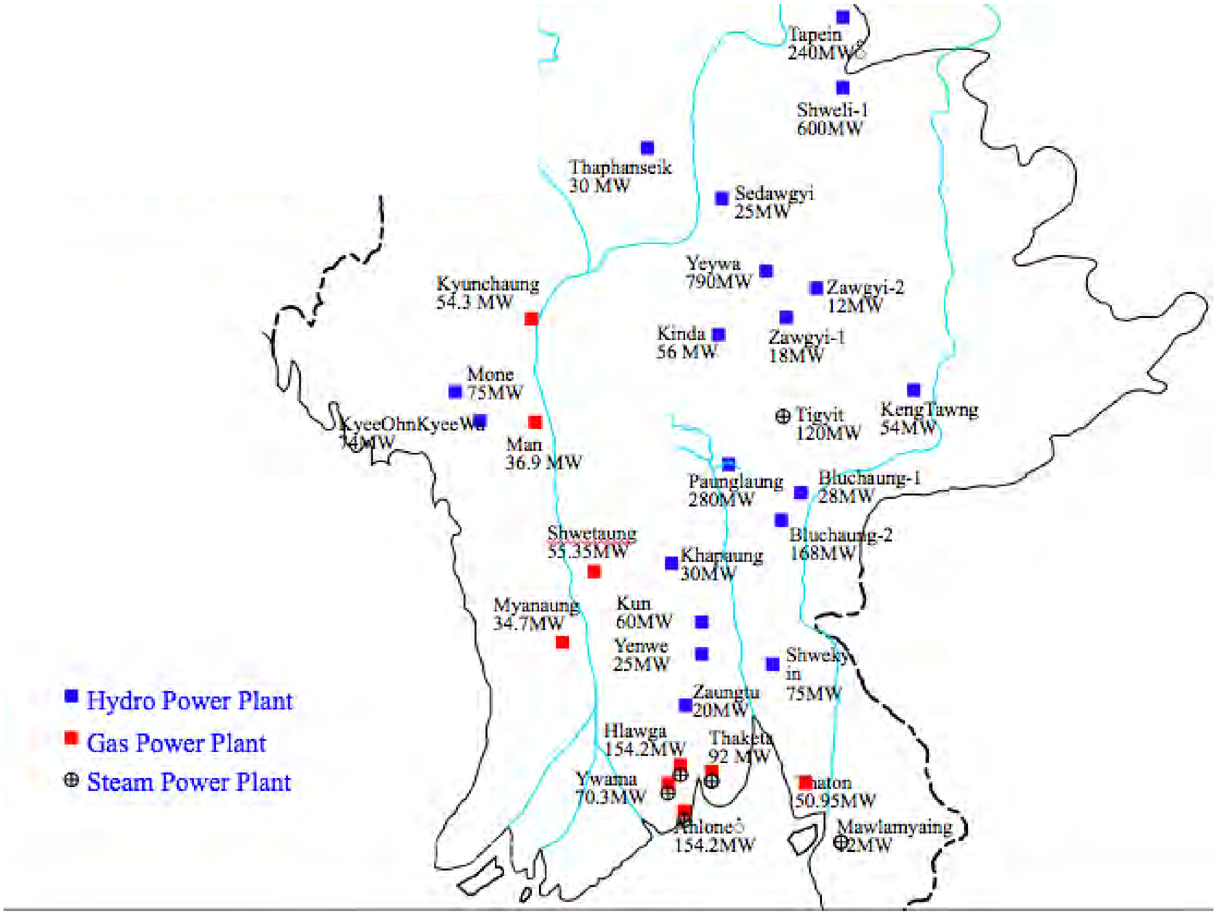
Sources: MOEP, Consultant's estimates

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

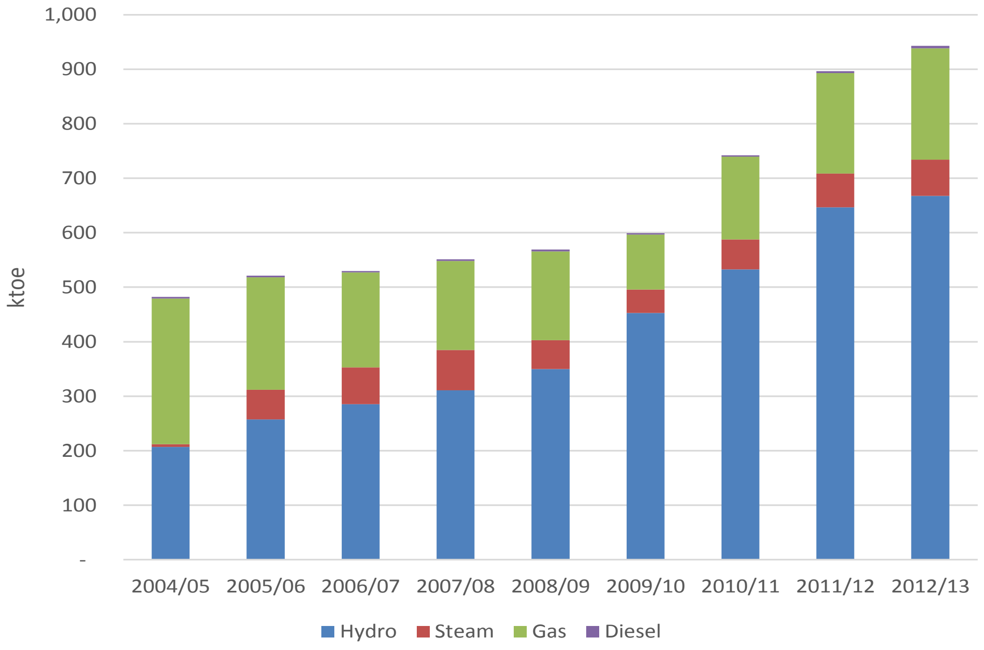


Source: MOEP

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

Sources: MOEP

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



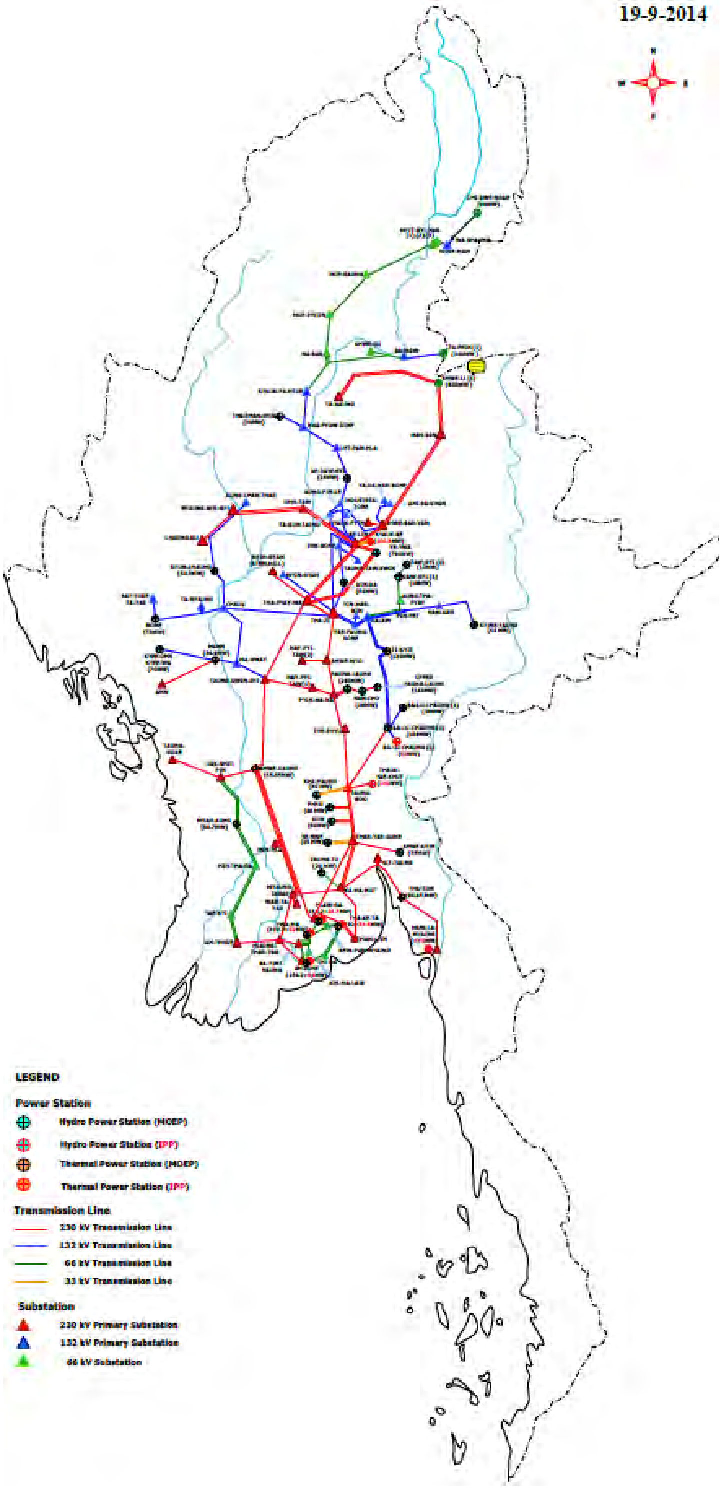
Sources: MOEP

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.

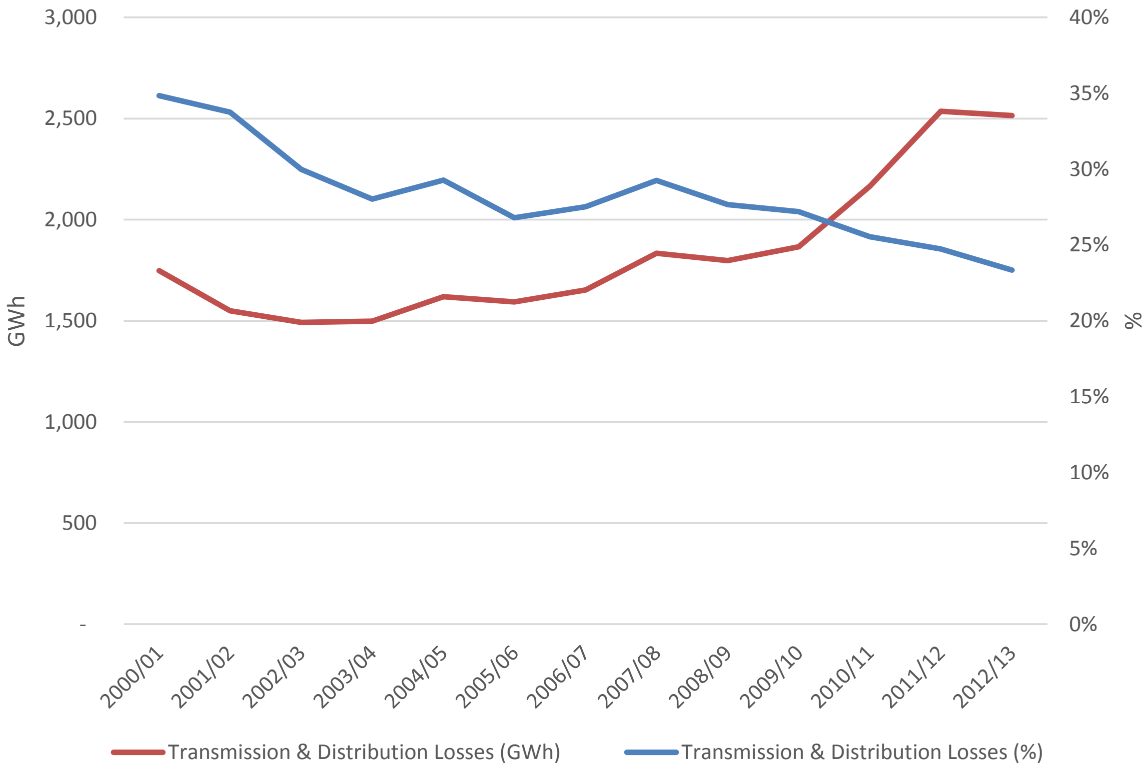
85. Figure V-9 shows transmission and distribution losses over time, which have generally decreased from nearly 35% in 2000 to 25% in 2013.

Figure V-8: Myanmar National Grid



Source: Global Energy Network Institute

Figure V-9: Transmission and Distribution Losses

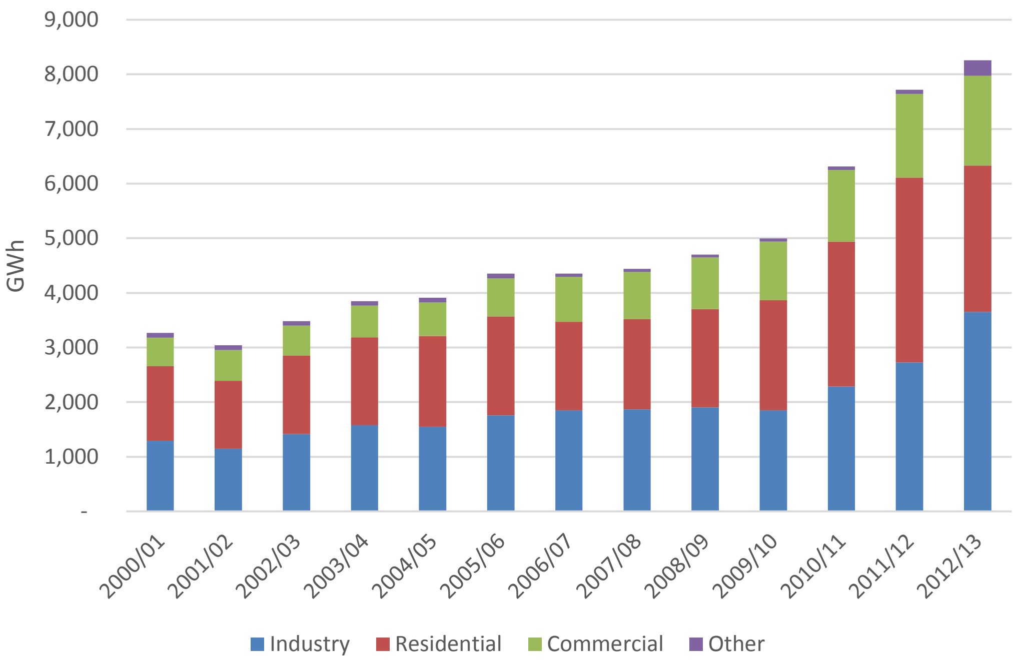


Sources: MOEP

II. Electricity Consumption

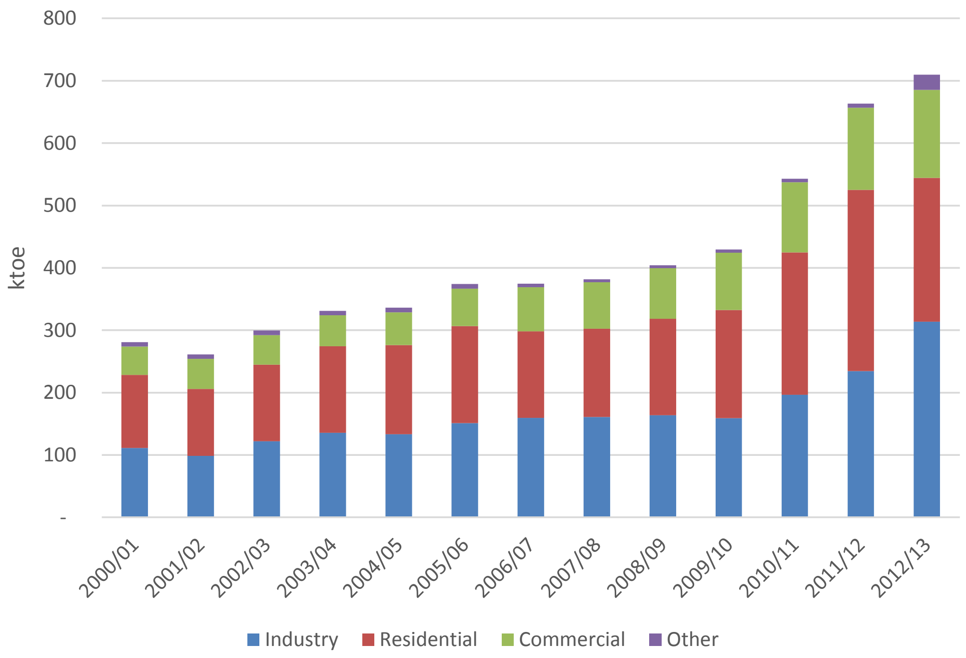
86. Figure V-10 and Figure V-11 show the final consumption by the end use categories in physicals and in energy equivalent terms. The main electricity end users are the industrial, residential and commercial/service sectors. Their shares in the 2012/13 total final consumption were 44%, 32% and 20% respectively.

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.

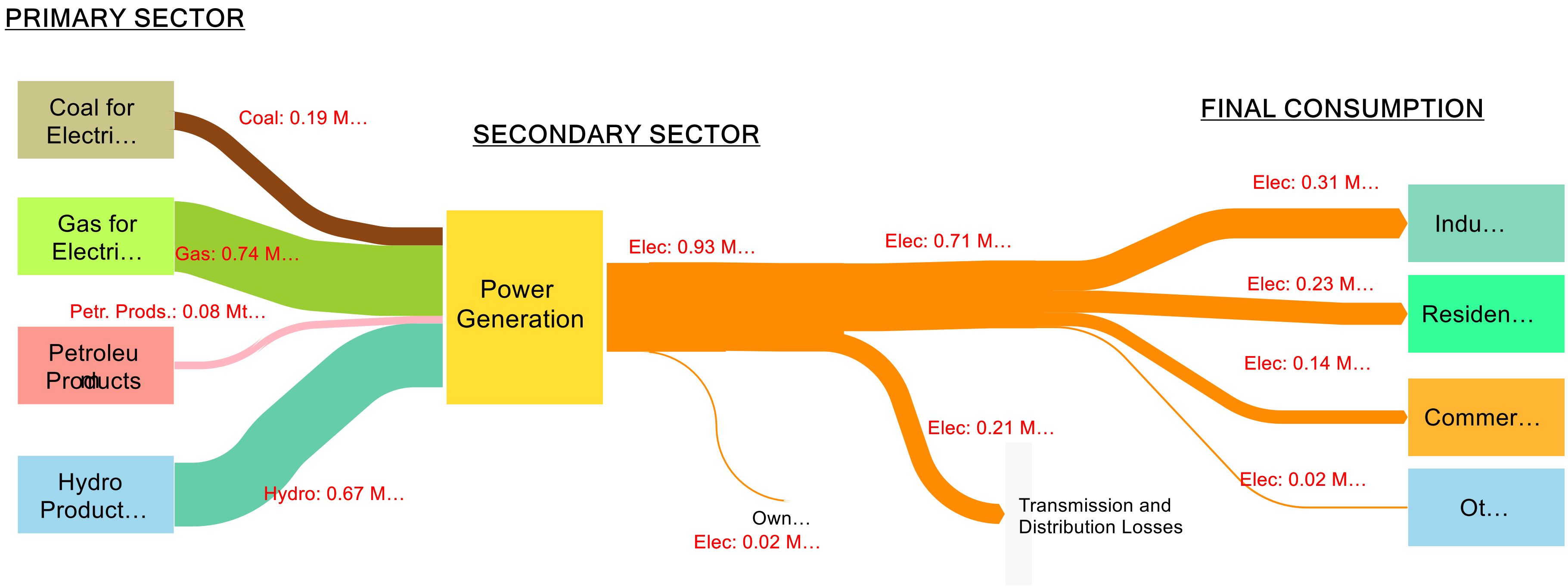
LL. Electricity Sector Observations

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

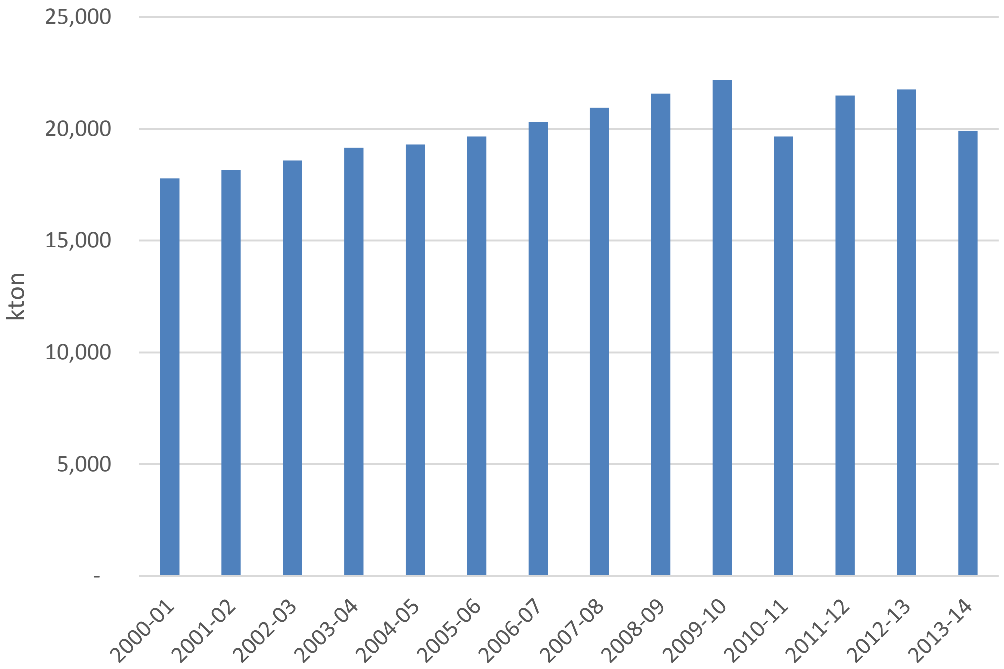
Source: MOEP, Consultant's analysis

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.

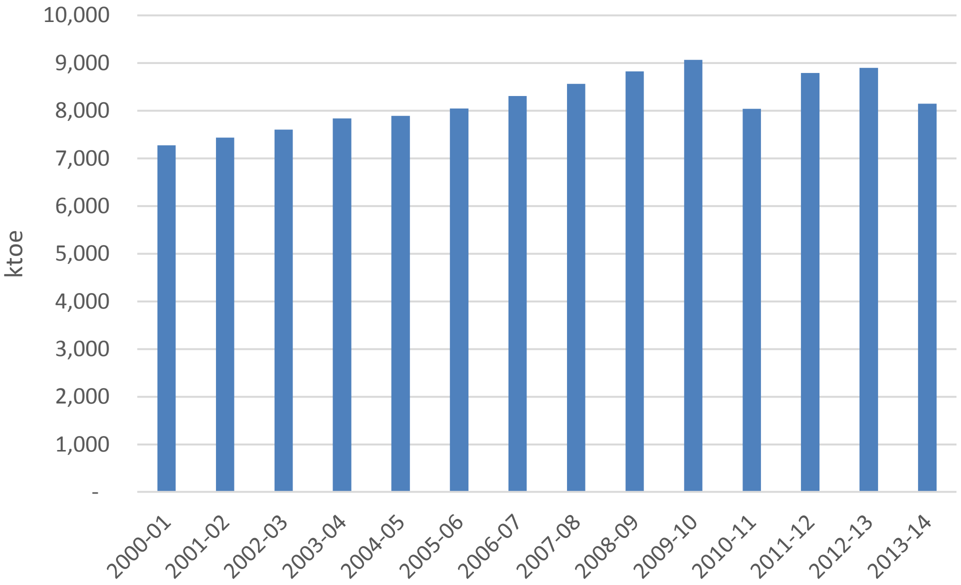
93. All end-use consumption of biomass is in the residential sector. In terms of equivalent caloric values the use of fuel wood dominates final energy consumption in Myanmar. For example in 2012/13, there was about 9,000 ktoe of fuel wood, compared to just 231 ktoe of electricity consumed by the residential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

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



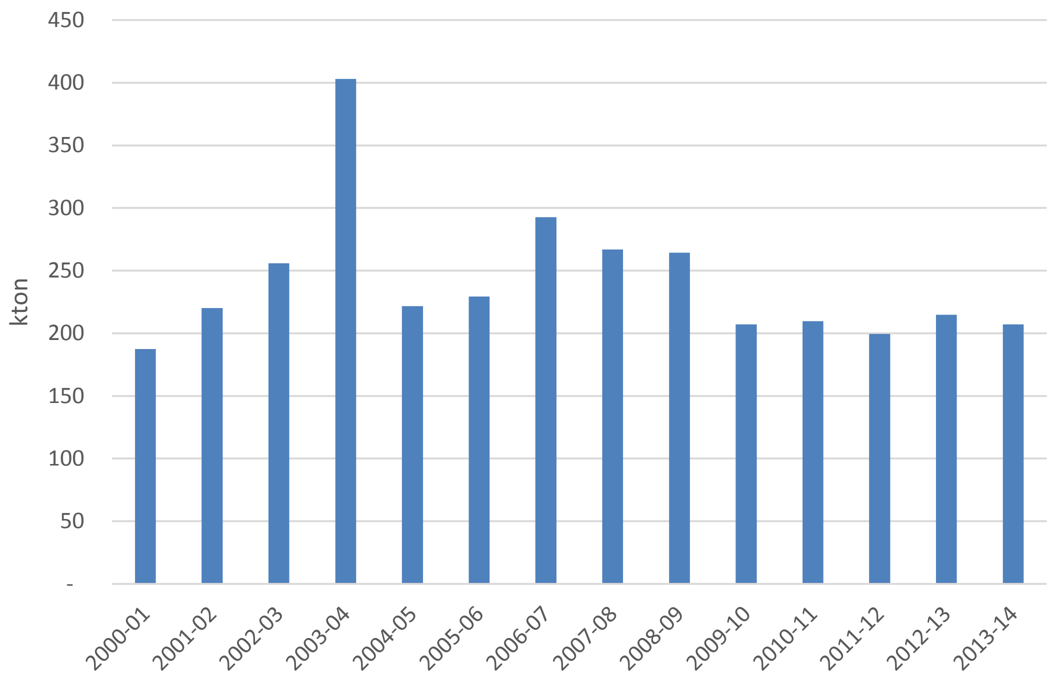
Source: MOECAF

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



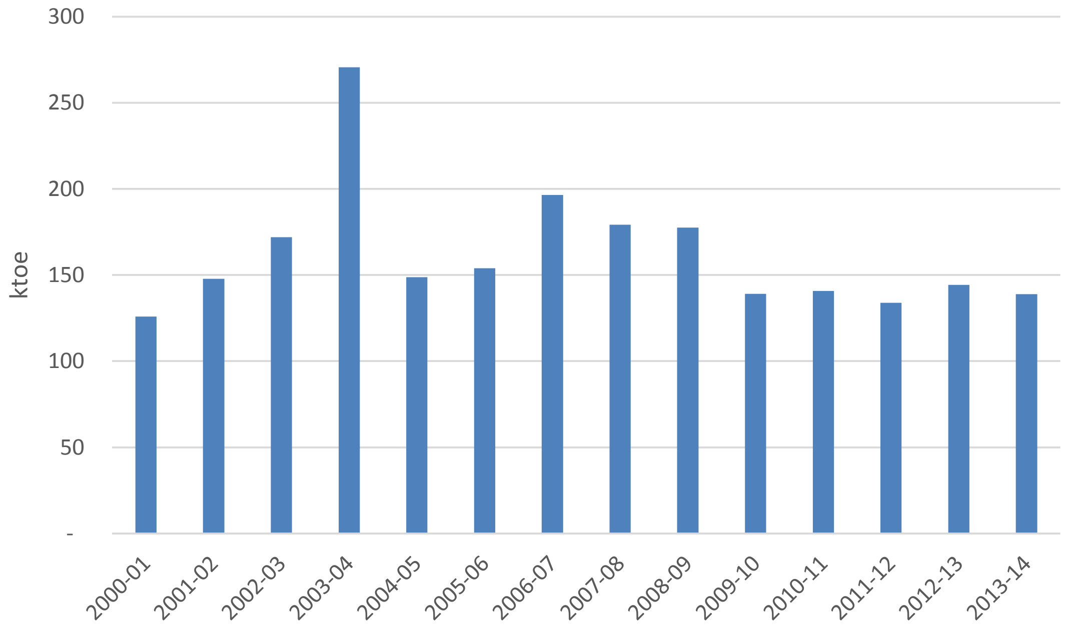
Source: MOECAF

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.

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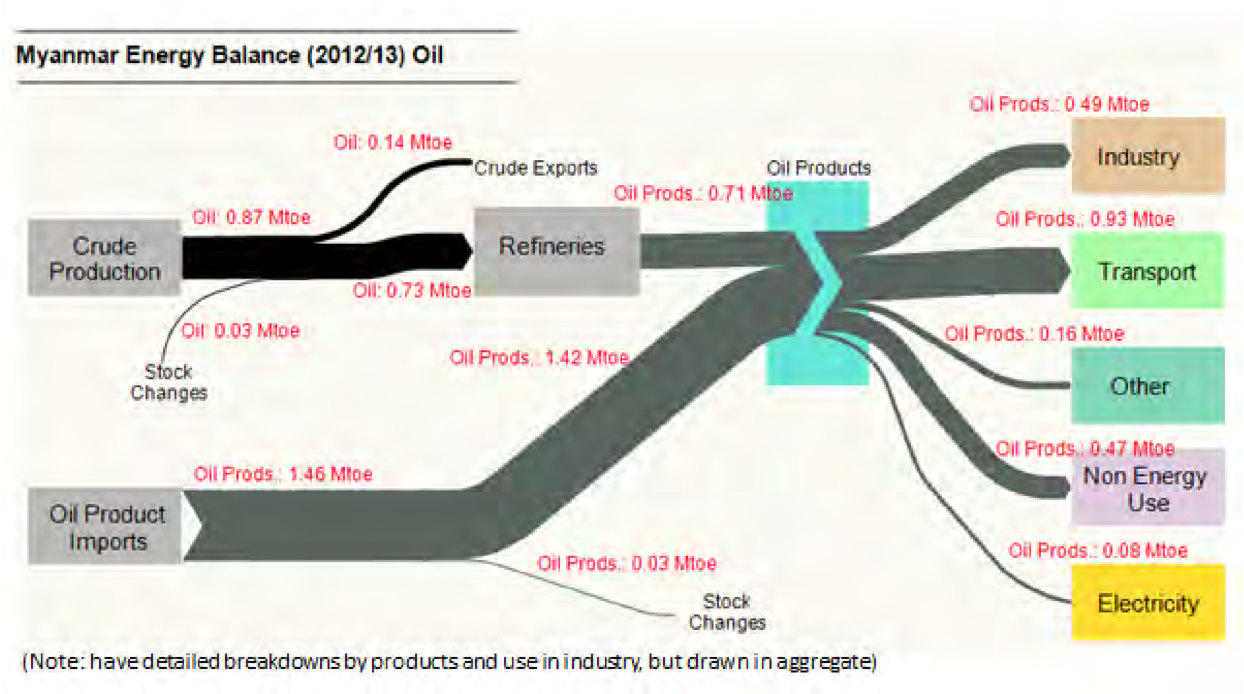
[1] http://www.adb.org/countries/myanmar/economy

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



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

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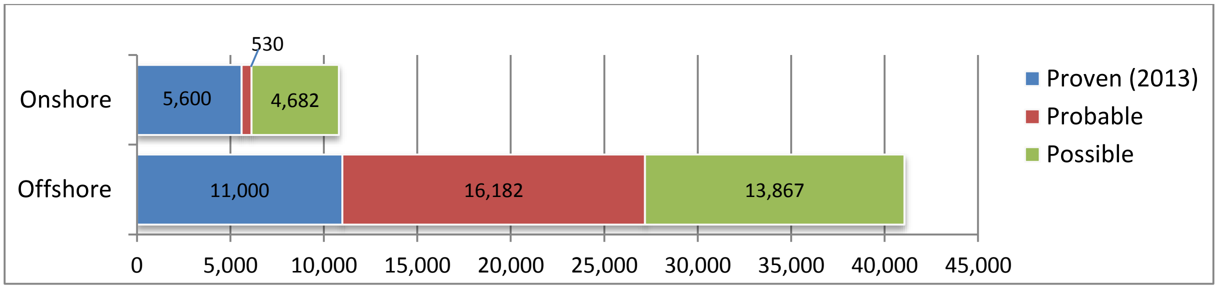
[2] Estimated by ADB, accessible at http://www.adb.org/countries/myanmar/economy

[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

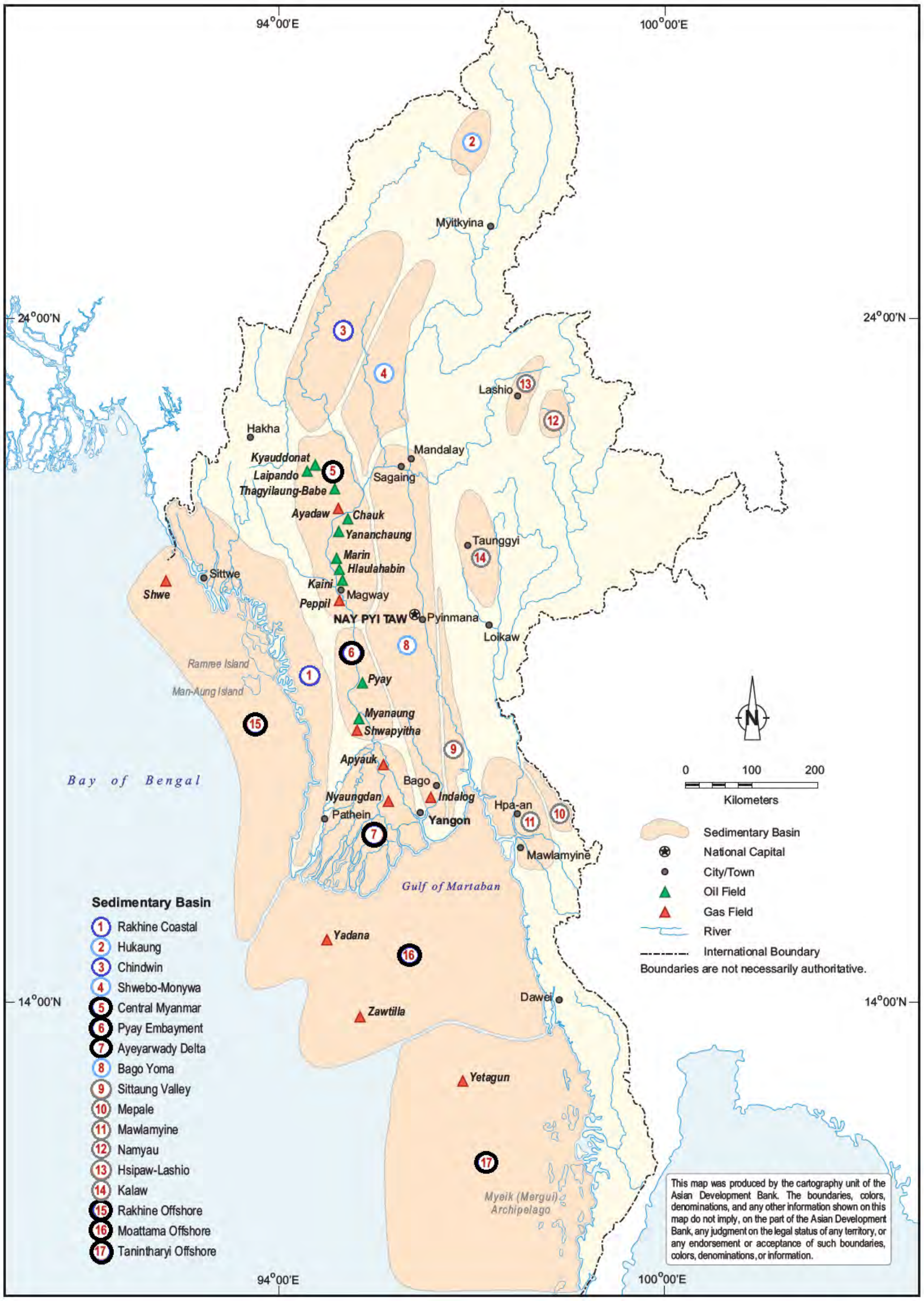
Figure II-1: Graphic Presentation of Gas Resources of Myanmar (in BCF)



Source: Ministry of Energy 2011 and 2013.

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

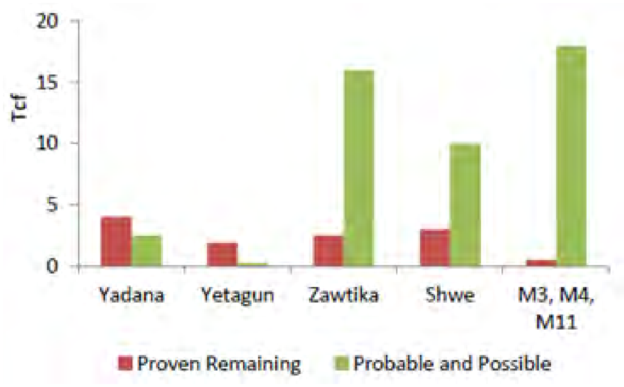
Marked with black thoroughly explored basins; blue – explored to some extent; pale blue – very little explored; grey – not yet explored basins



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	

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[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

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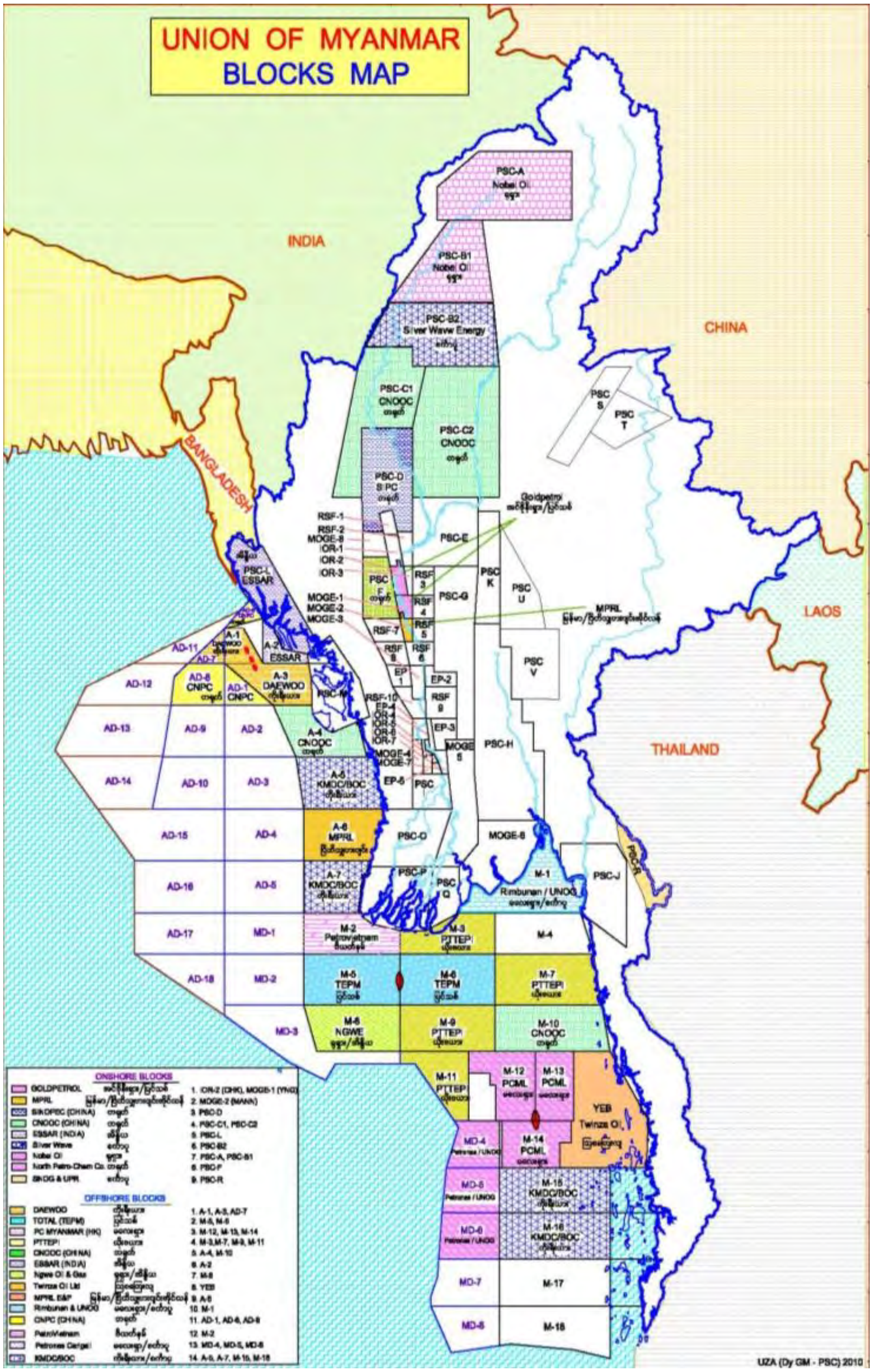
[5] GCV: Gross Caloric Value, Same meaning as HHV (higher heating value)

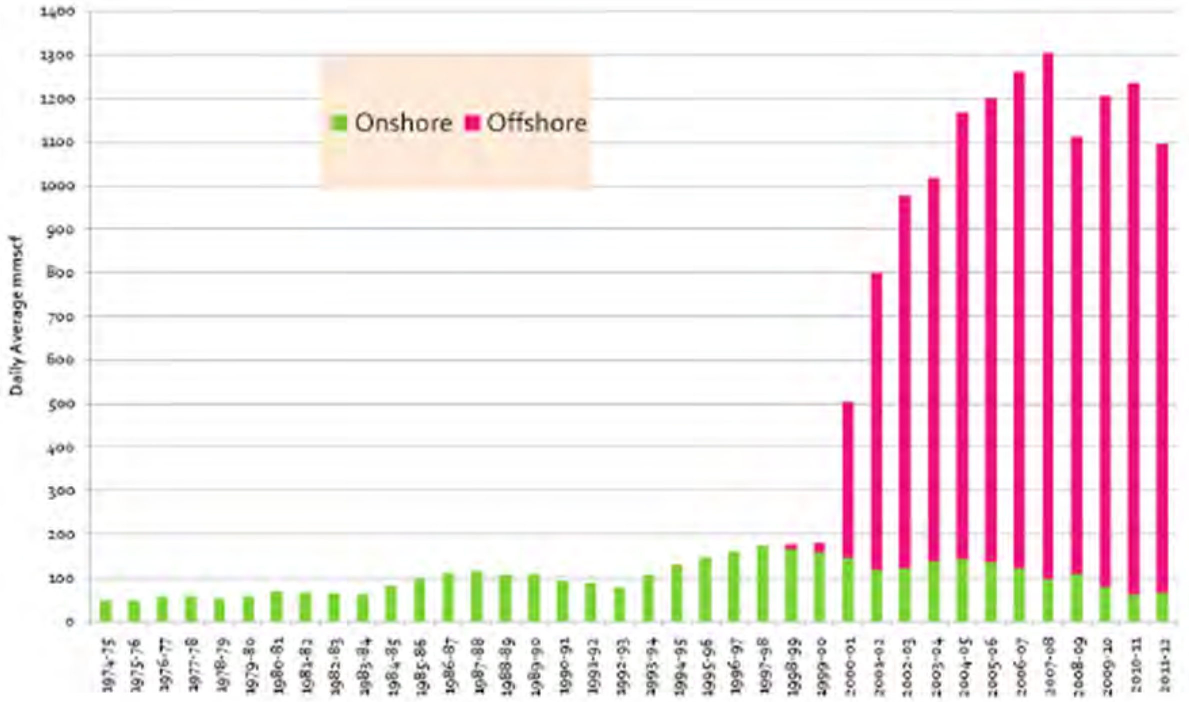
Figure II-4: Myanmar Blocks Map



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.

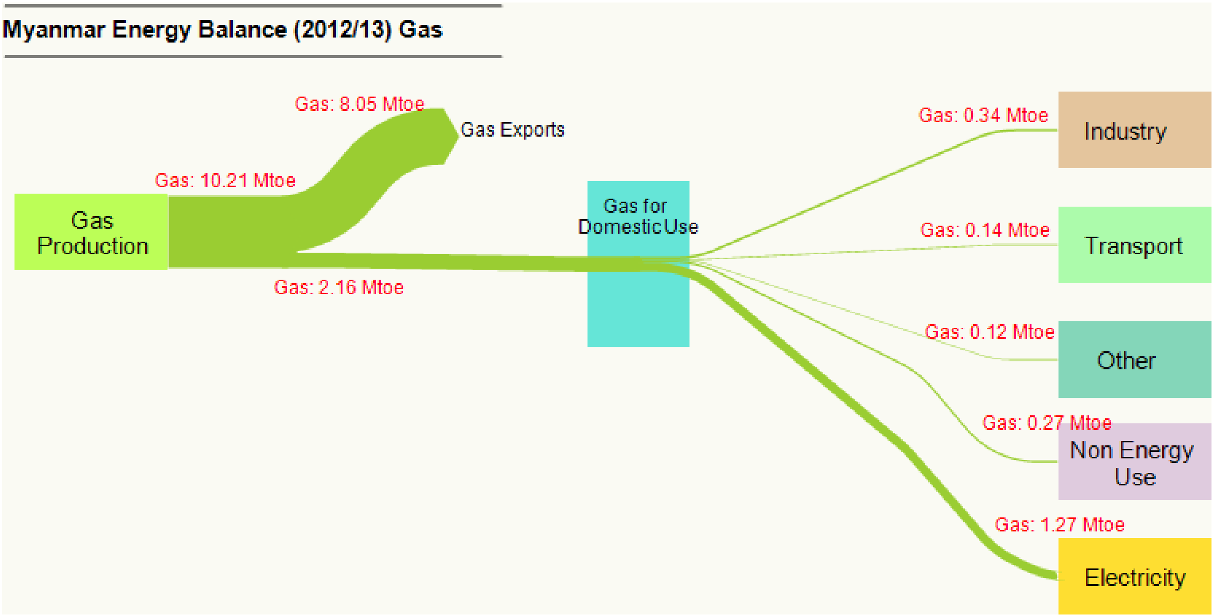
30. Myanmar possesses a developed gas transmission system. About 4,500 km of gas pipelines have been constructed onshore and 700 km offshore. It is planned to further extend and enlarge diameters of the pipeline network. There are two international gas pipe lines from Myanmar: one to Thailand and another 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.

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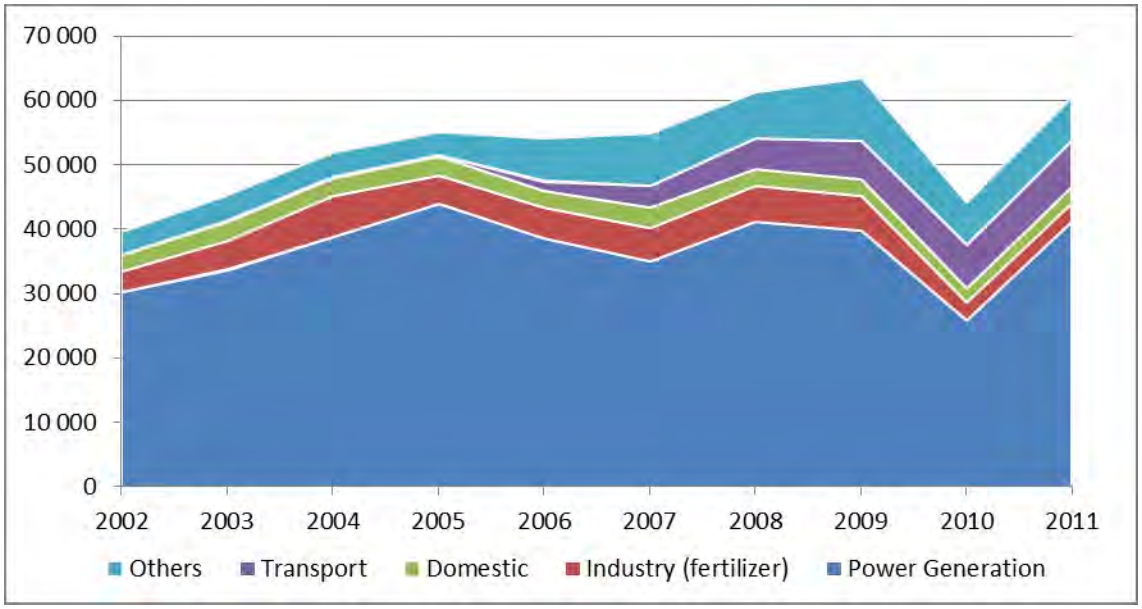
[6] According to IEA

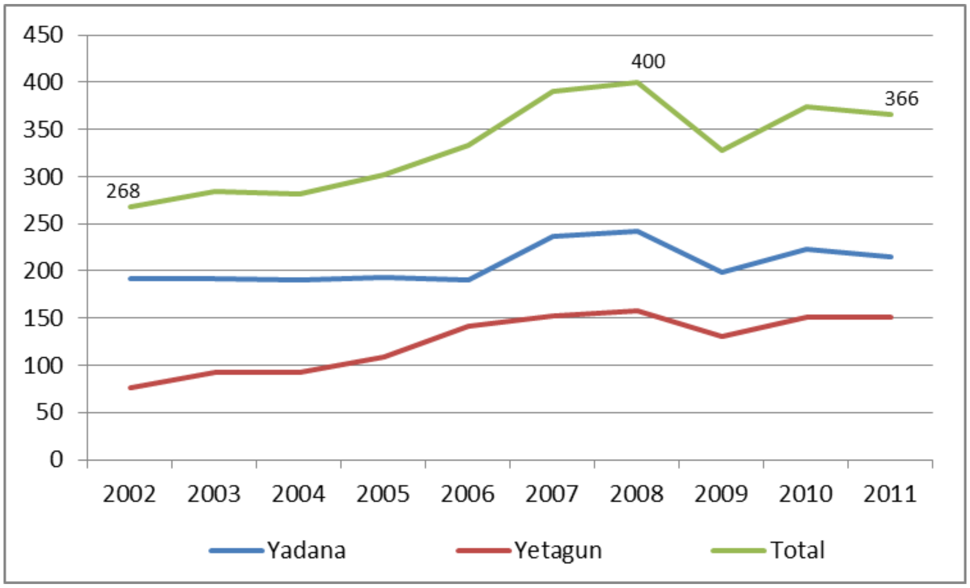
Figure II-7. Domestic Consumption of Gas in Myanmar, 2002-2011 (in MMCF)



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

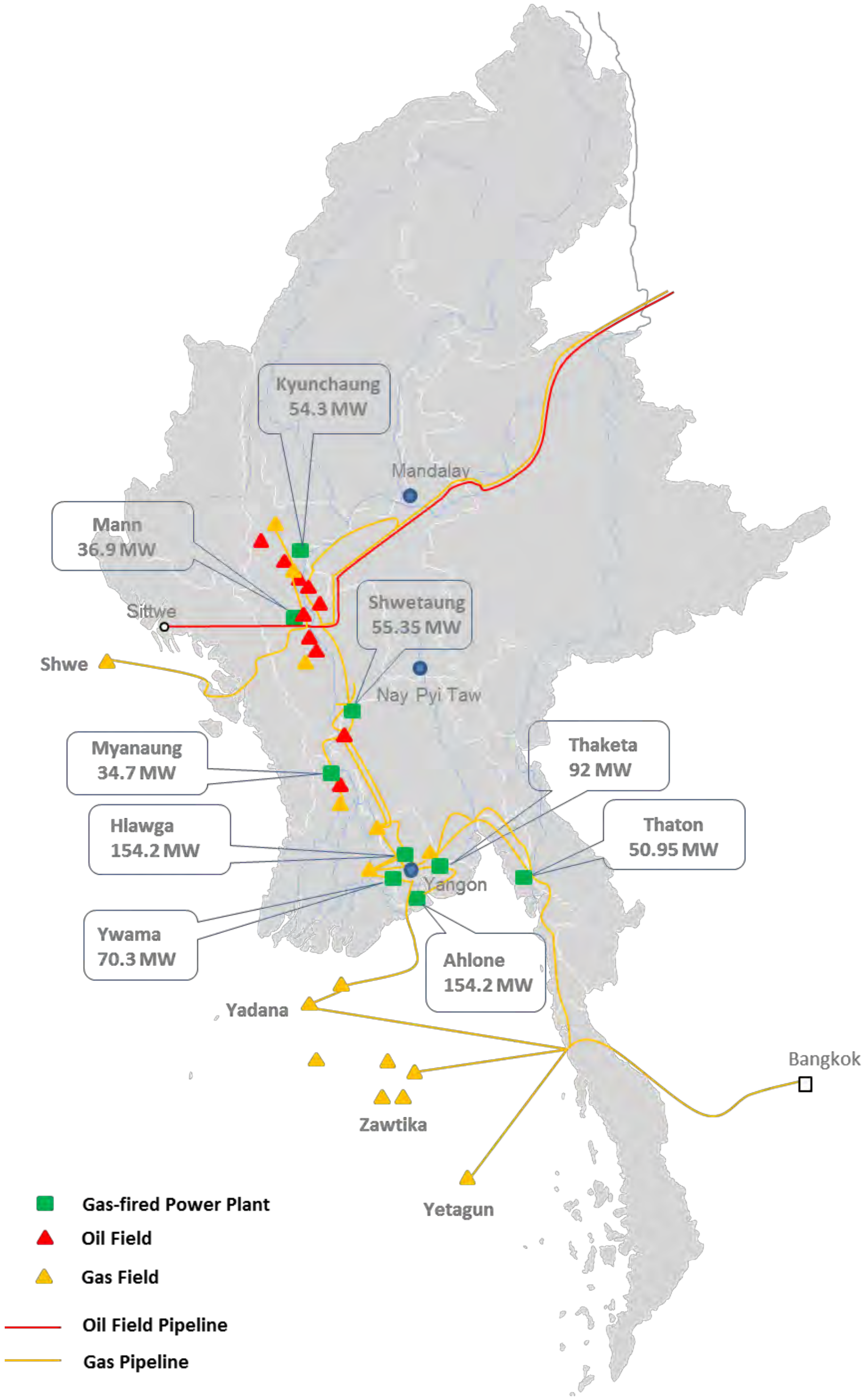
36. Myanmar produces some 30% of its power from natural gas. The currently operating gas-fired power plants are presented in Figure II-9 below. There are plans and on-going activities for the rehabilitation of existing power plants (Table II-4). The rehabilitation would provide for an increase in generation. 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



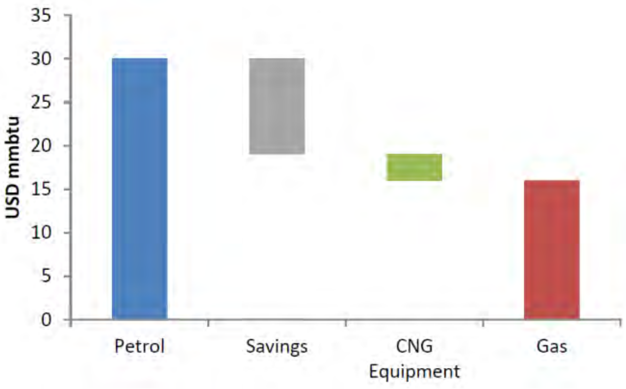
Source: Consultant based on JICA,MOE, JOGMEC and JEPIC data

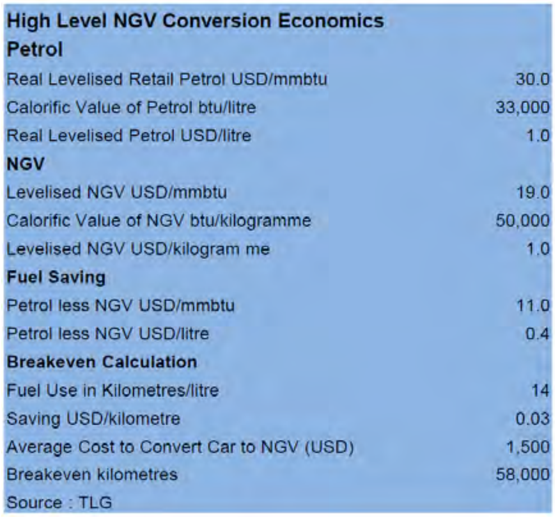
F. Gas for Transportation

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	

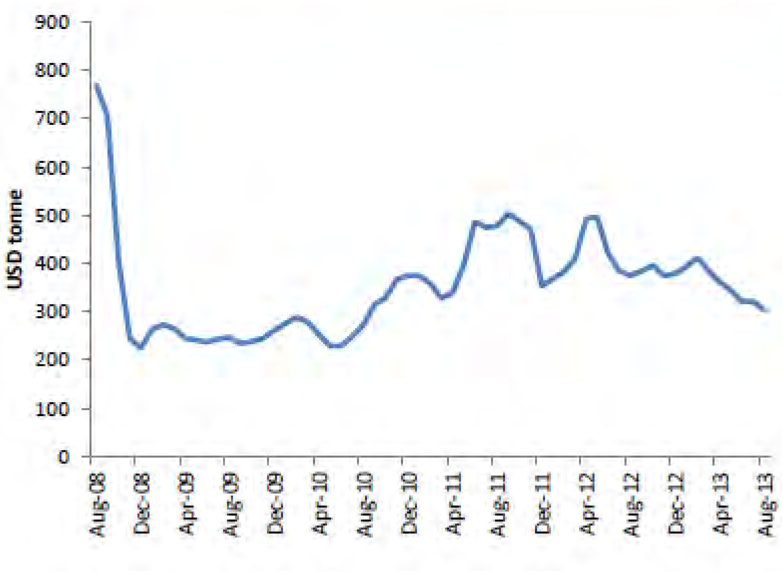
Source: The Lantau Group, 2013

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



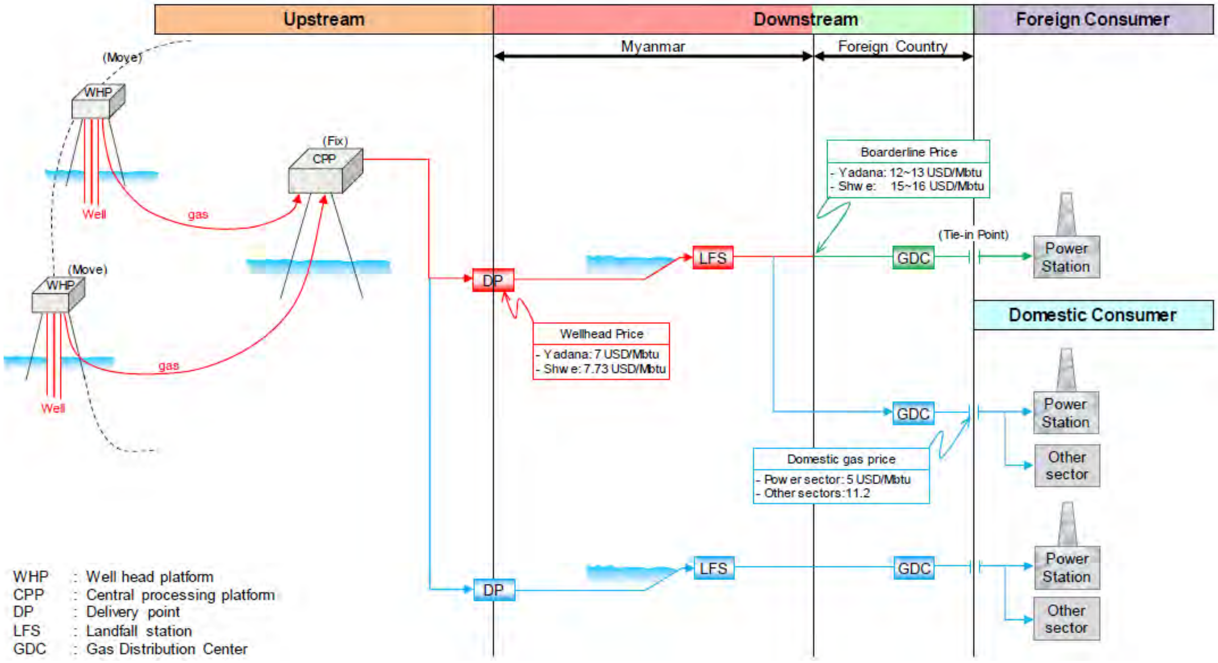
Source: The Lantau Group referring to the World Bank

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.

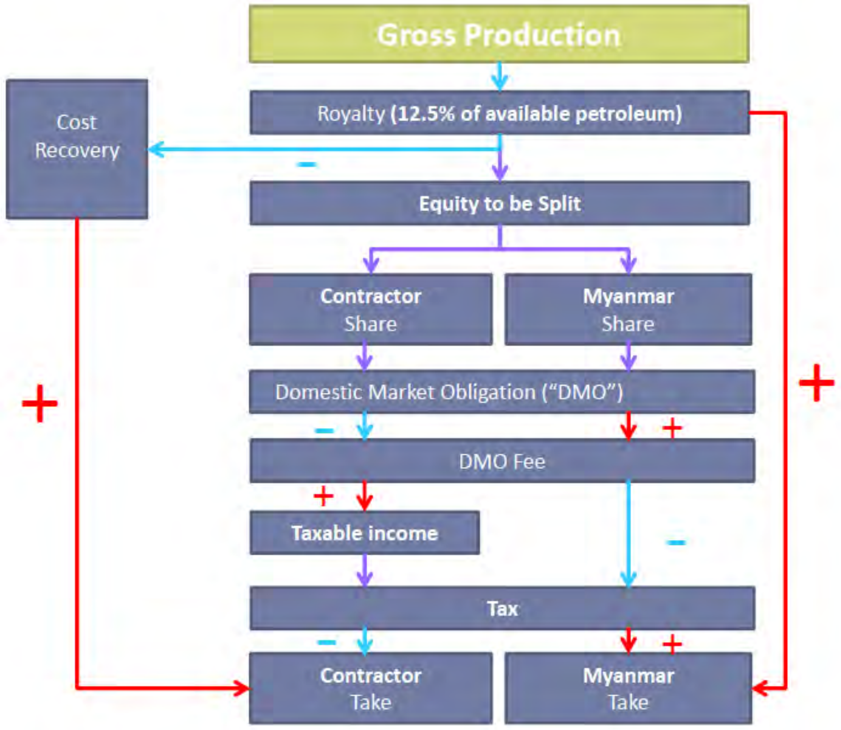
Figure II-12: Gas Contract System and Gas Prices in Myanmar



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.

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[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.

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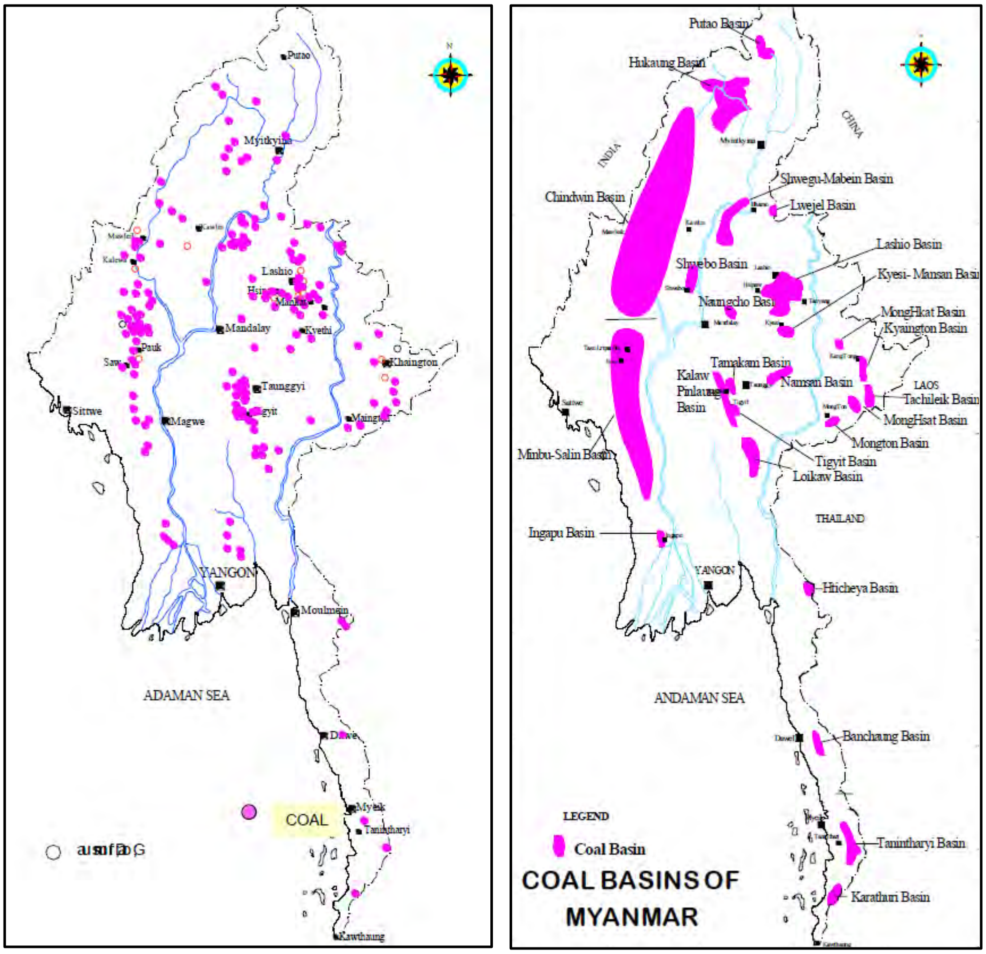
[8] Source: International Energy Agency, balances for Myanmar for 2011, accessible at http://www.iea.org/countries/non-membercountries/myanmar/

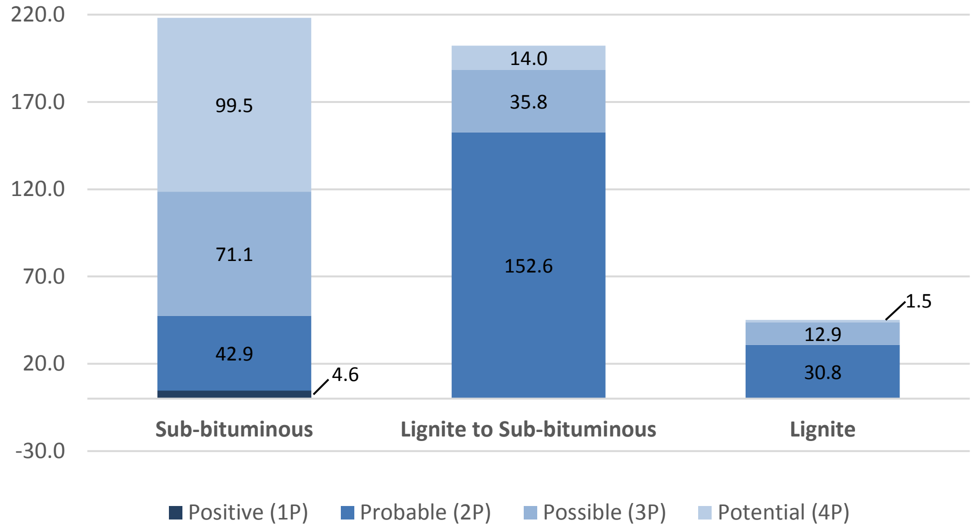
Figure III-1: Distribution of Coal Occurrences (Left) and Coal Basing (Right) in Myanmar



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.

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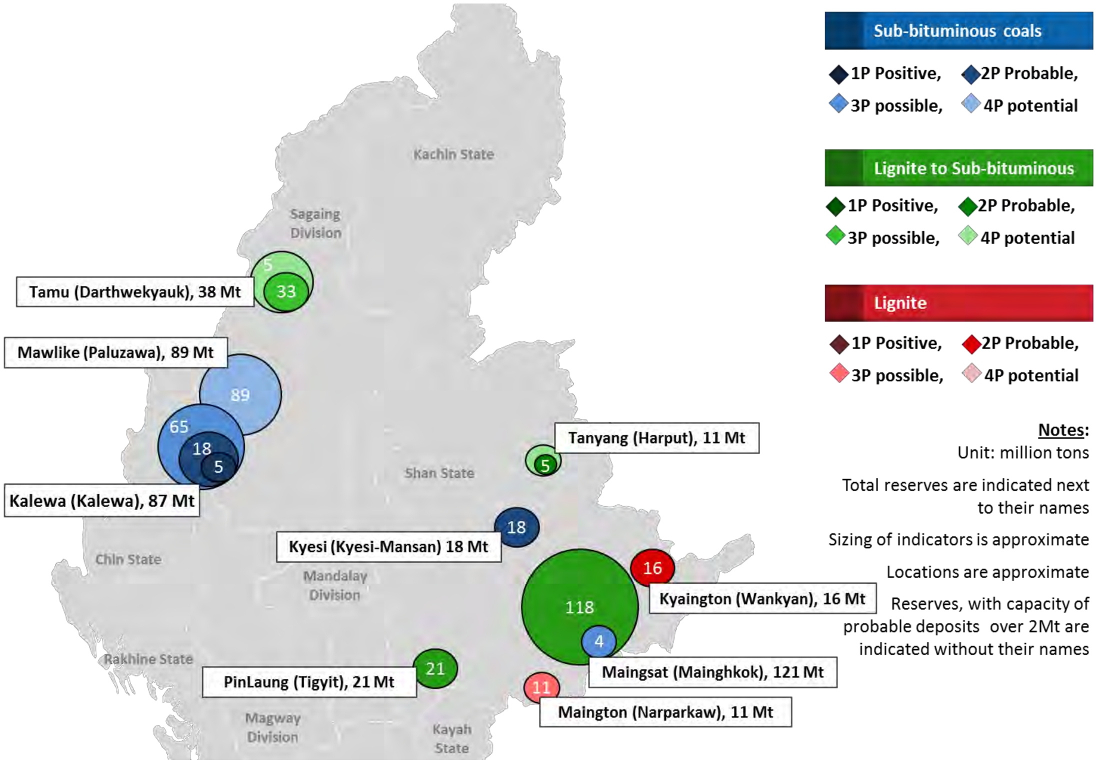
[9] The largest considered to be coal reserves with total capacity over 10 million tons

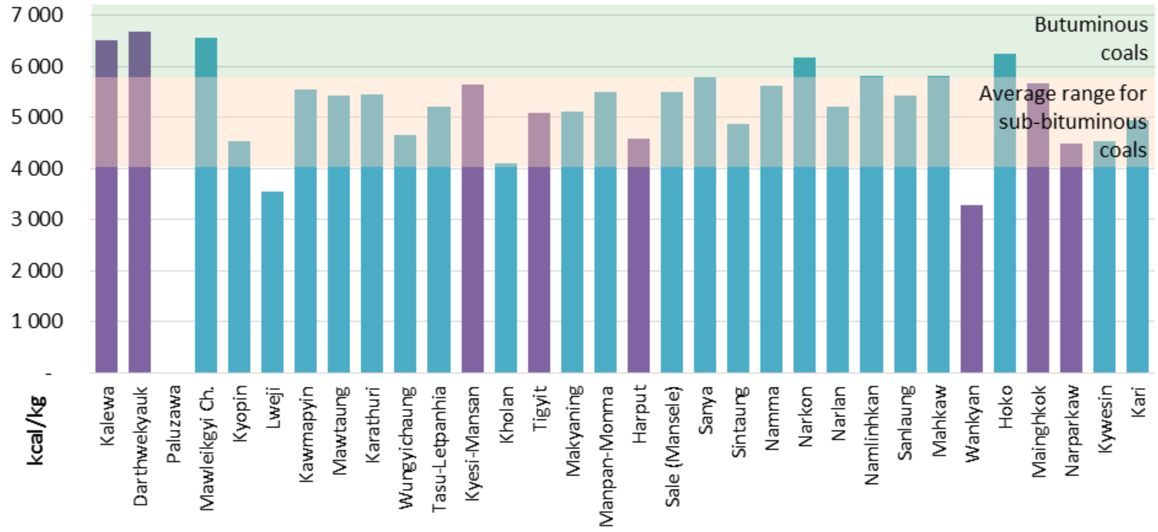
Figure III-3: Locations of Coal Reserves of Myanmar with Total Capacity over 10 Mt



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)

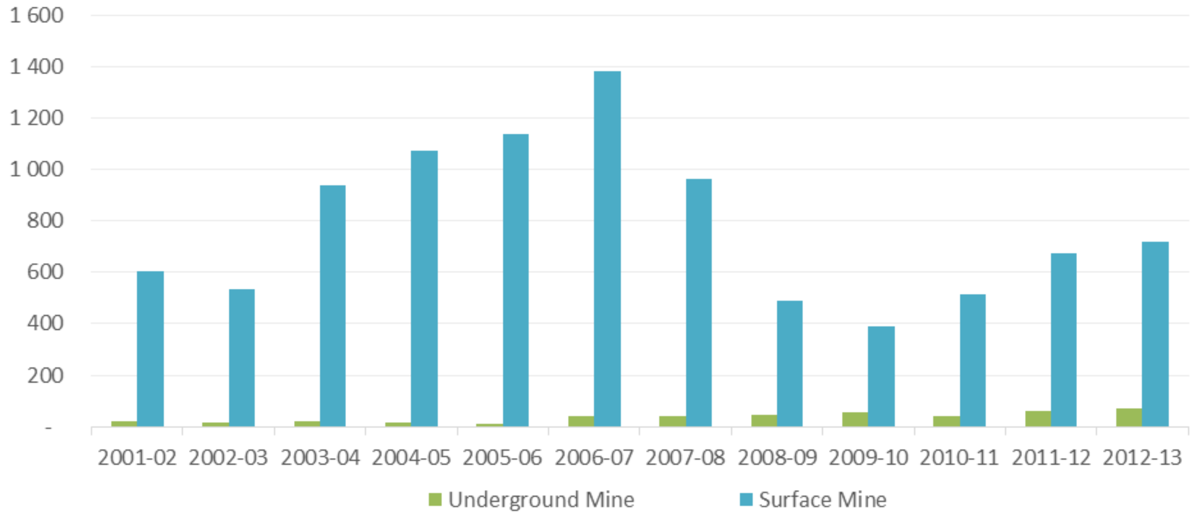
L. Existing Coal Mining Activities

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)

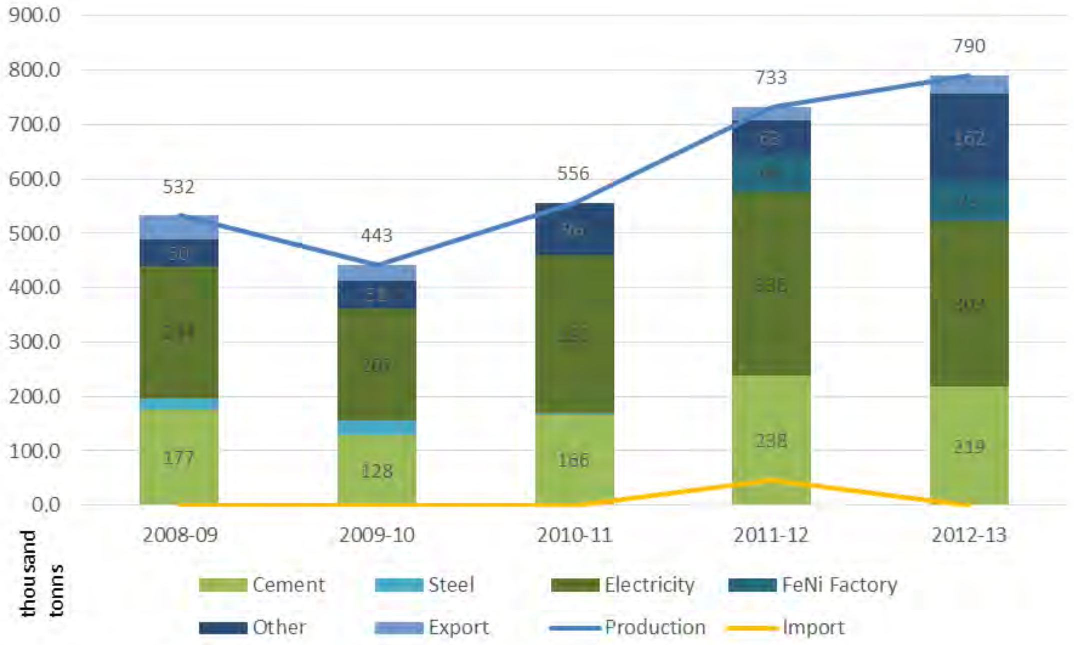


Source: Source: Mining (3), Ministry of Mining

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.

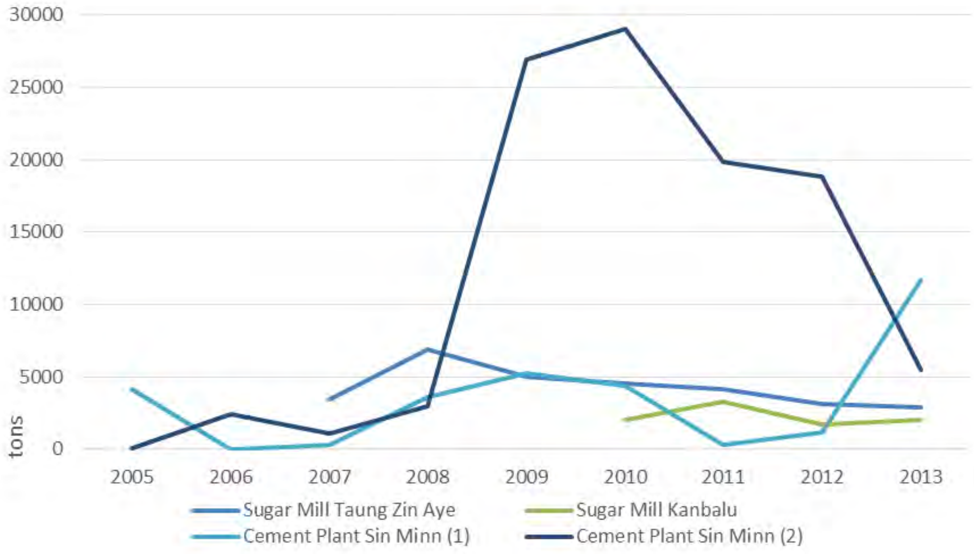
59. Coal consumption of two sugar mills and cement plants are presented in Figure III-7. Data for other industrial enterprises that consume coal is unavailable.

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

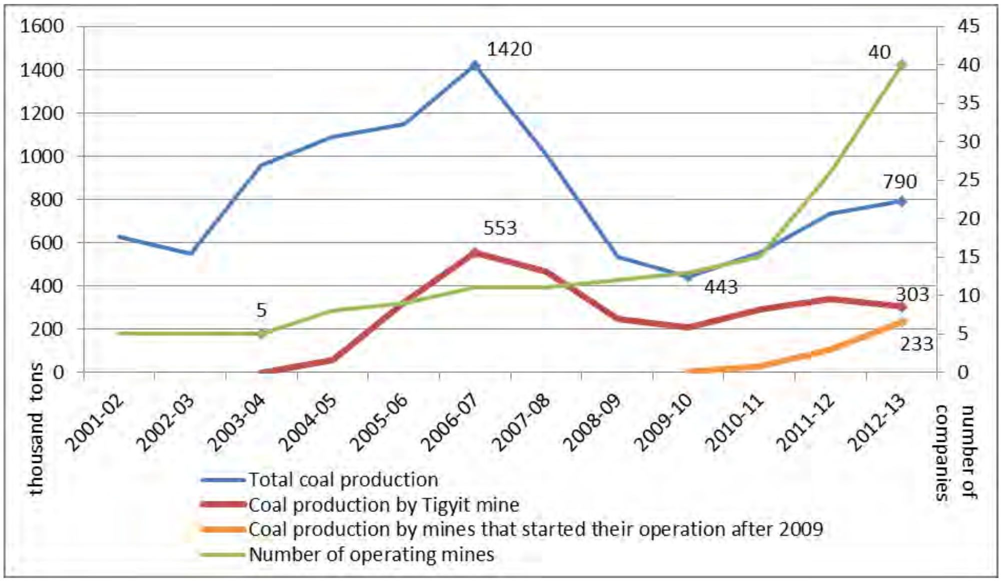
60. Ministry of Mines (MOM) is responsible for the formulation of the mining policy and exploration and extraction of coal. There are two departments and three enterprises within MOM. The exploration permits are issued to private companies in accordance to the Myanmar Mines Law. Depending on reserves, 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.

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[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.

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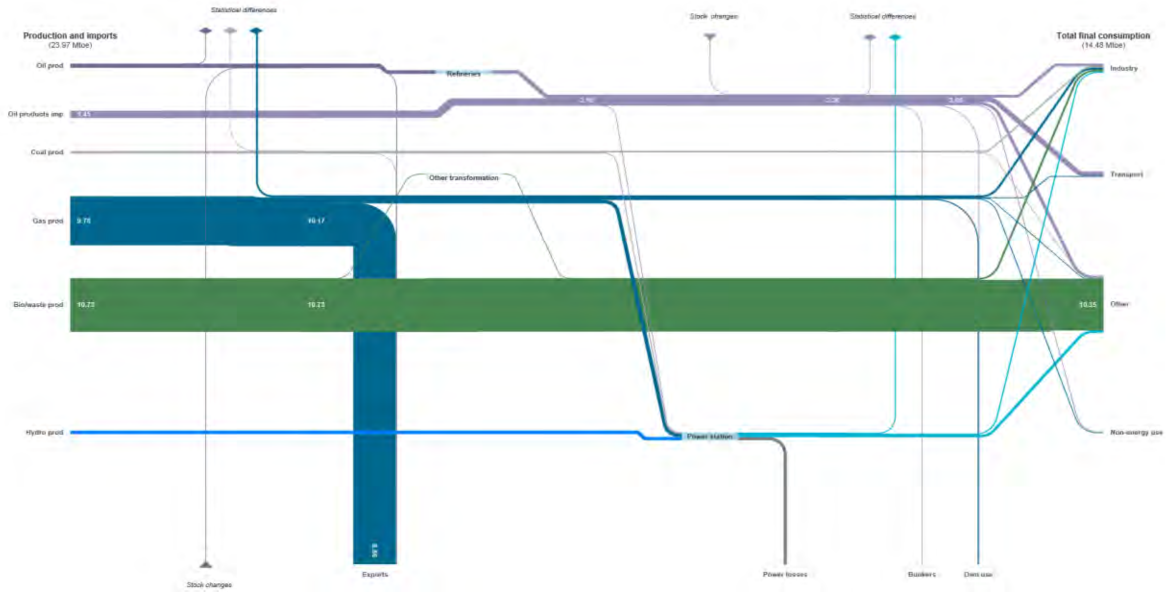
[11] NEP (2013) noted that two Chinese companies have estimated 4,023 MW of wind potential in Myanmar. Discussion with MOE suggests potential for 1,000 MW

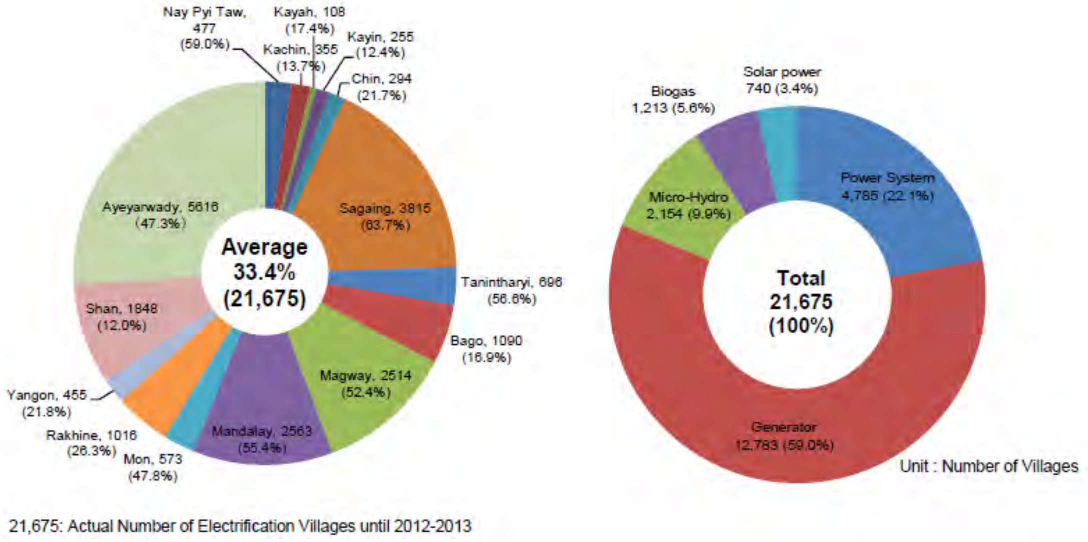
Figure IV-1: Myanmar Energy Balance (2012 data in MTOE)



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



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

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[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].

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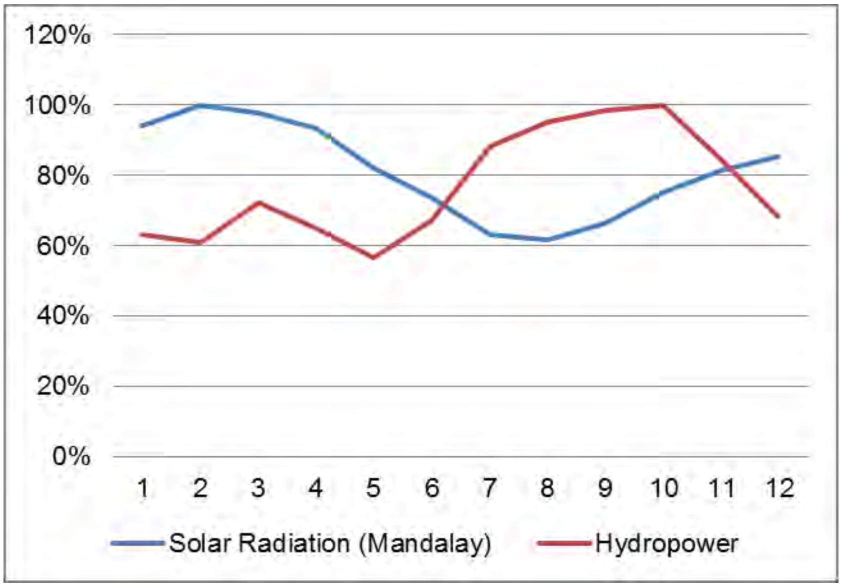
[15] These statistics have been presented by Heinz W. Böhnke, Renewable Energy Adviser under ADB TA-8356 MYA

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%.

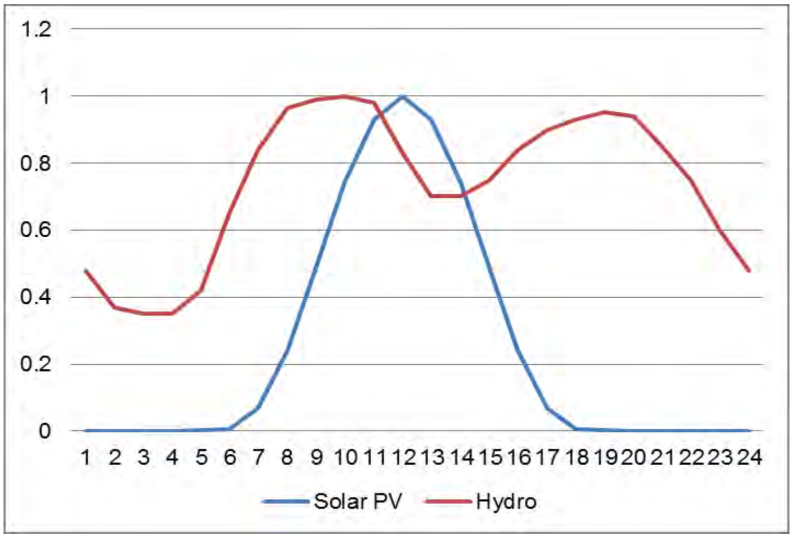
Figure IV-3: Seasonal Variation of Solar Energy vs Hydropower (Monthly Output as % of that of the Highest Month)



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.

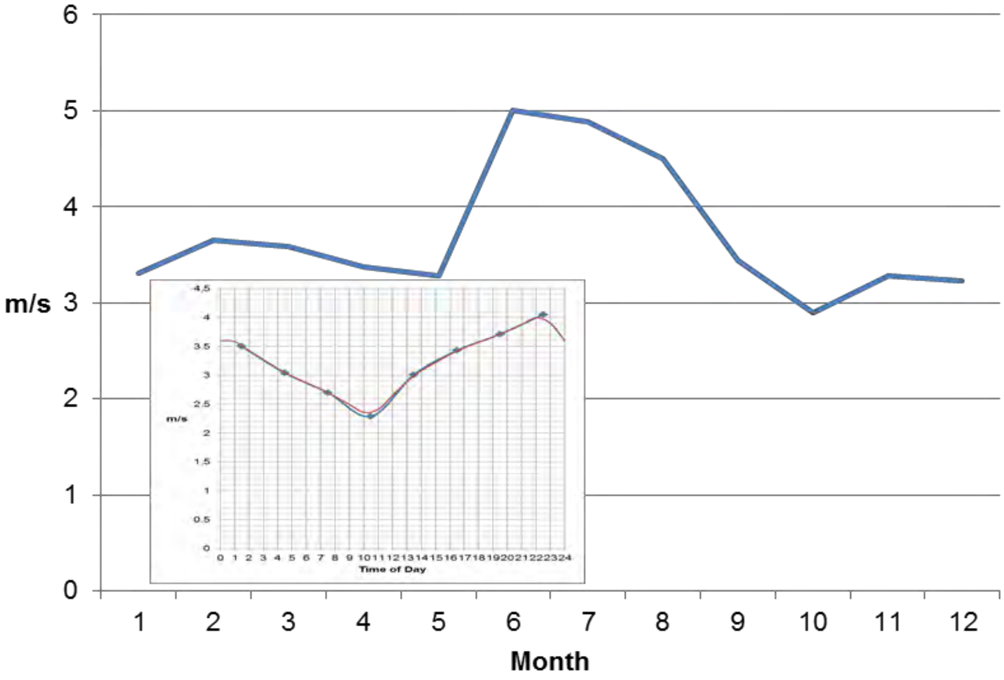
104. There are some wind turbines operational in Myanmar, including at the Technological University (Kyaukse), Shwetharlyoug Mountain in Kyaukse Township, the Government Technical High School (Ahmar) in Ayeyarwaddy region, and Dattaw Mountain in Kyaukse Township. It was perfectly utilized for lighting 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

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[16] Energy Sector Initial Assessment, ADB 2012

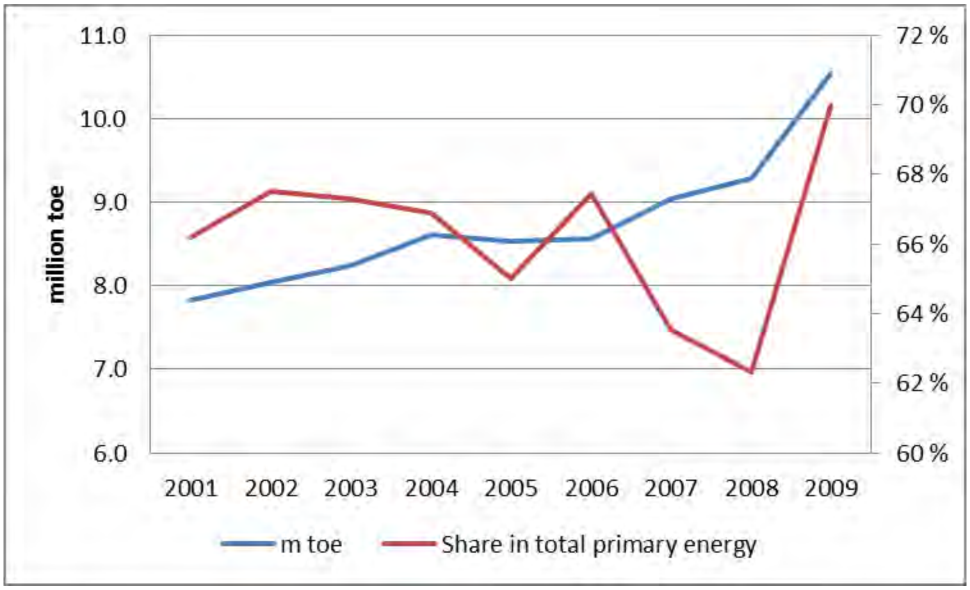
[17] Monthly average wind speed at 50 m above surface of earth (m/s) by NASA; typical location in Myanmar

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.

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[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.

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[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

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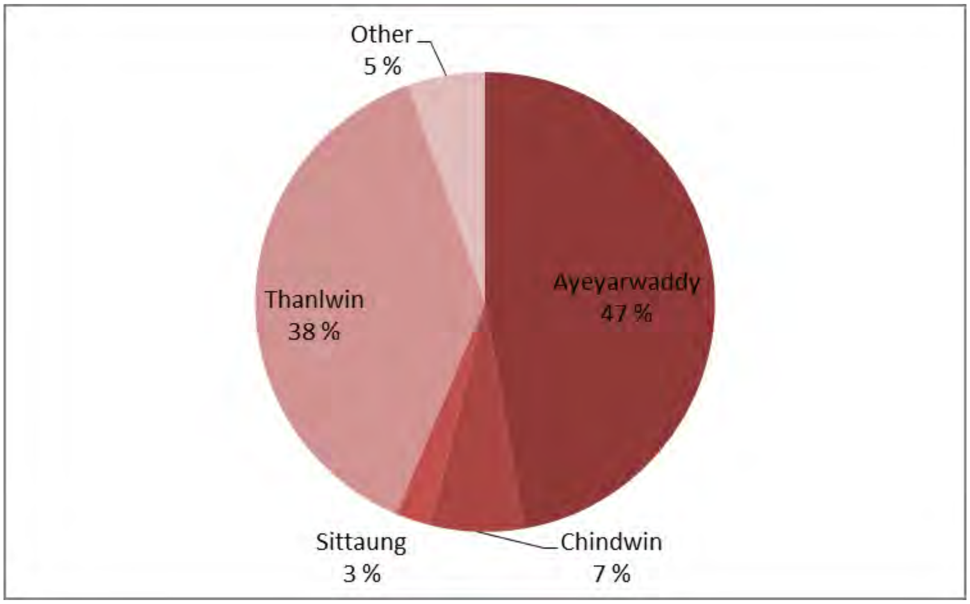
[22] Water Quality Management at River Basin of Myanmar. Presentation by Director Hydrology Branch of Irrigation Department, Ministry of Agriculture and Irrigation, 21st September, 2011.

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

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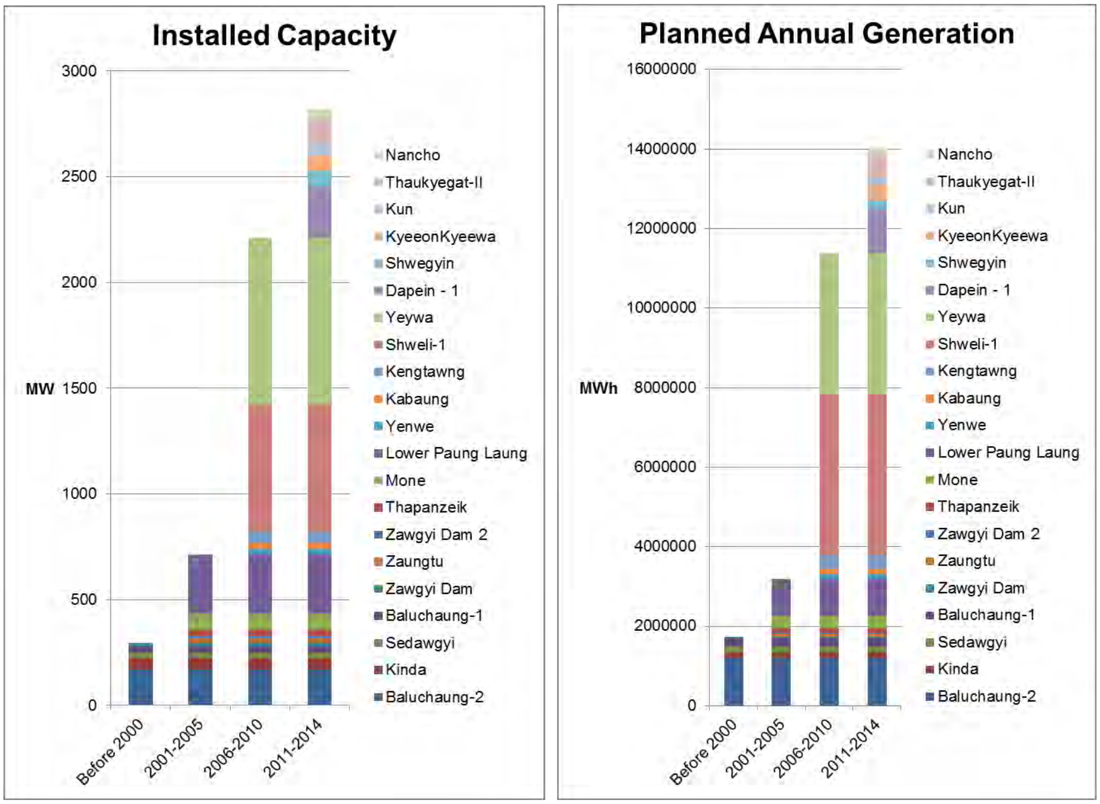
[23] Present & Future Power Sector Development in Myanmar, Ministry of Electric Power, 27 February 2013

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.

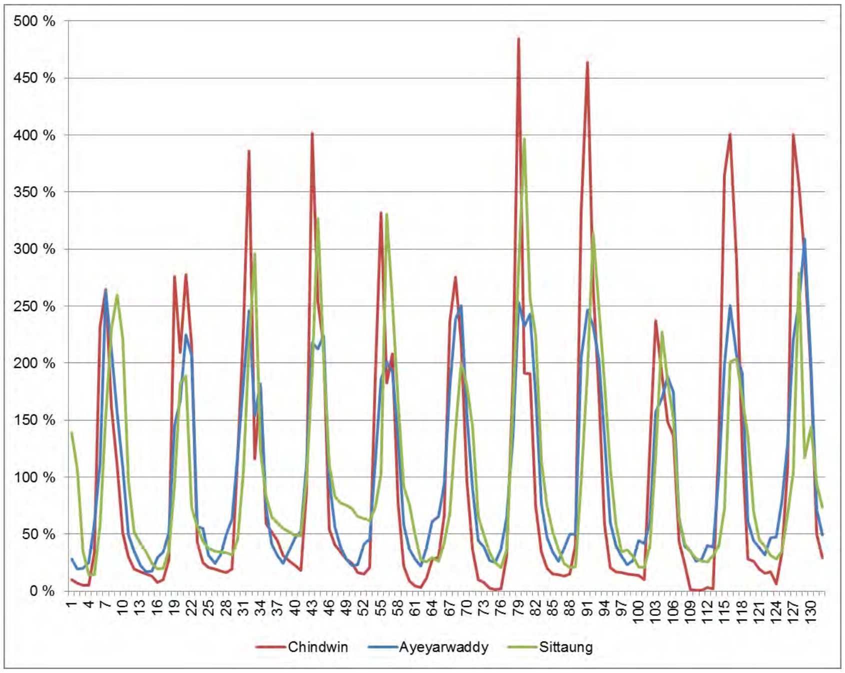
156. Dependable hydropower capacity is typically defined deterministically as the capacity available in the worst drought on record. Most modelling approaches today, however, take into account all historical hydrological years, whether they are dry, average or wet. A Monte Carlo simulation model can 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.

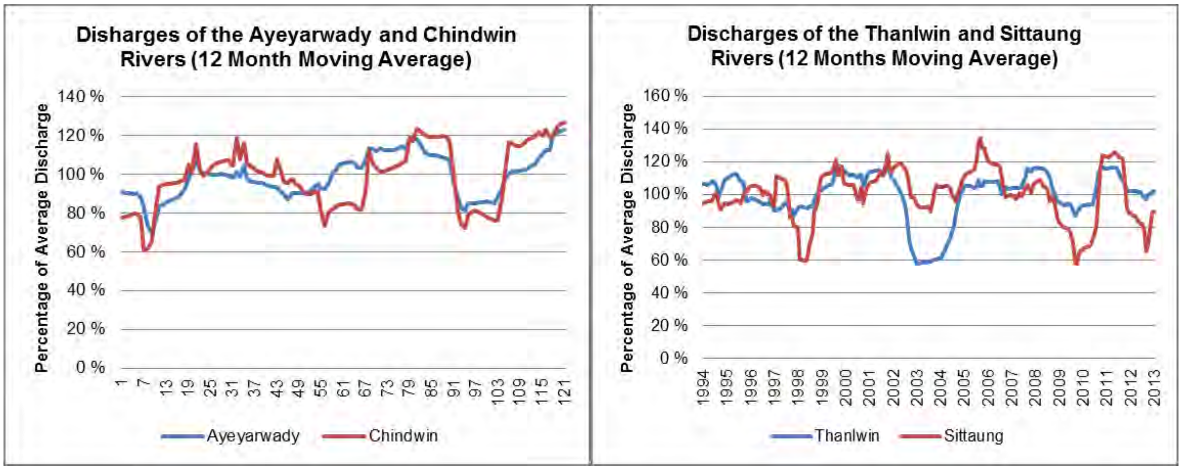
Figure V-4: Seasonal Pattern of River Discharges in Myanmar
(Monthly Discharges as Percentage of the Long-Term Average)



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).

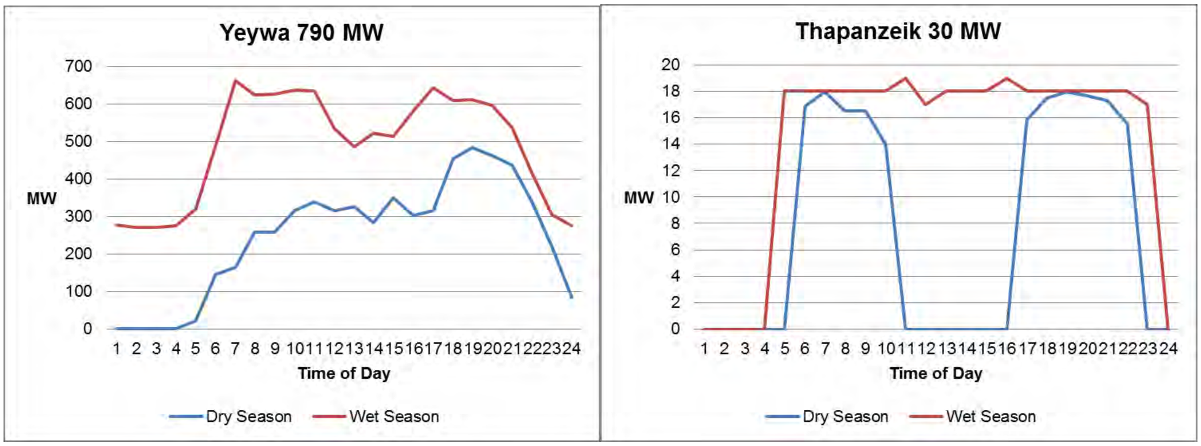
161. Some observations relevant to the availability of Myanmar's hydropower capacity to serve the peak and to the dimensioning of the needed capacity reserve can be drawn from the hydrological data as follows:

- 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



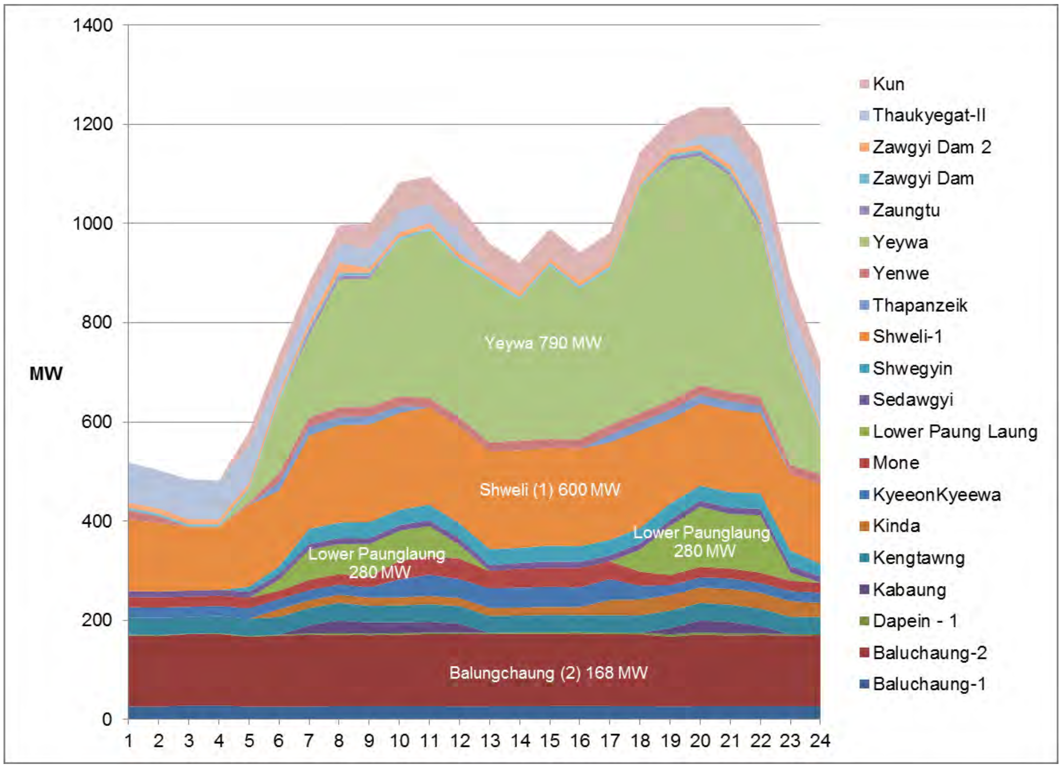
Source: Consultant's analysis

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

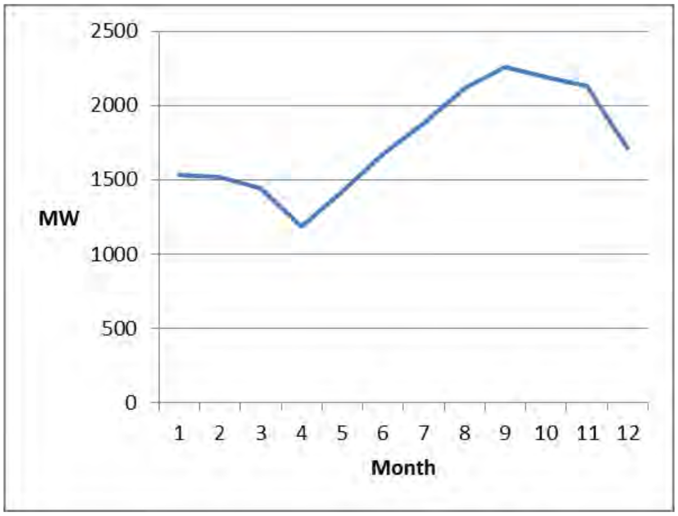


Source: Consultant's analysis

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).

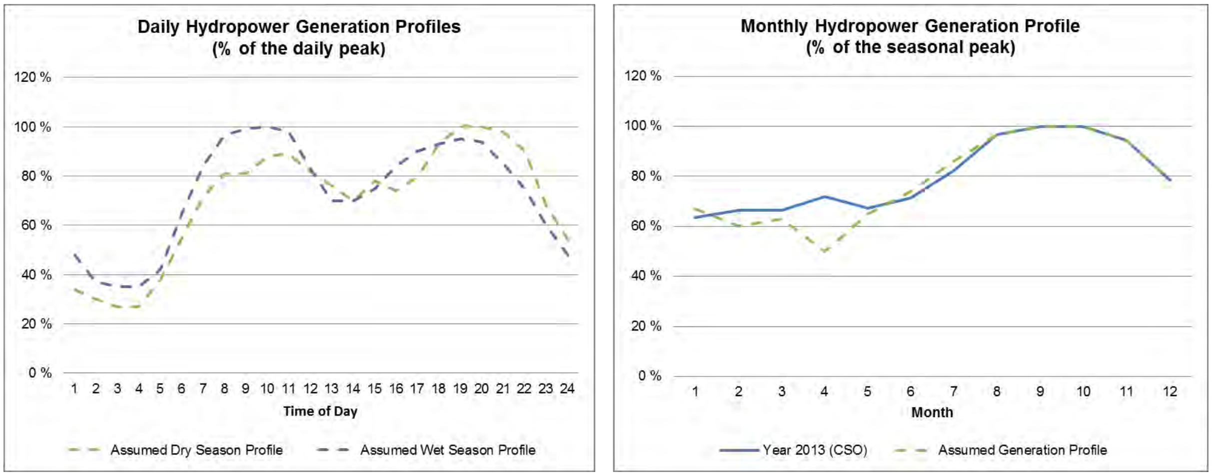
167. The overall available capacity is assumed to have monthly profile as shown in Figure V-8. The minimum is set to April and the maximum to September. The maximum available capacity is assumed to develop gradually between the maximum and minimum, because of time needed to fill up the reservoirs, and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

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[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

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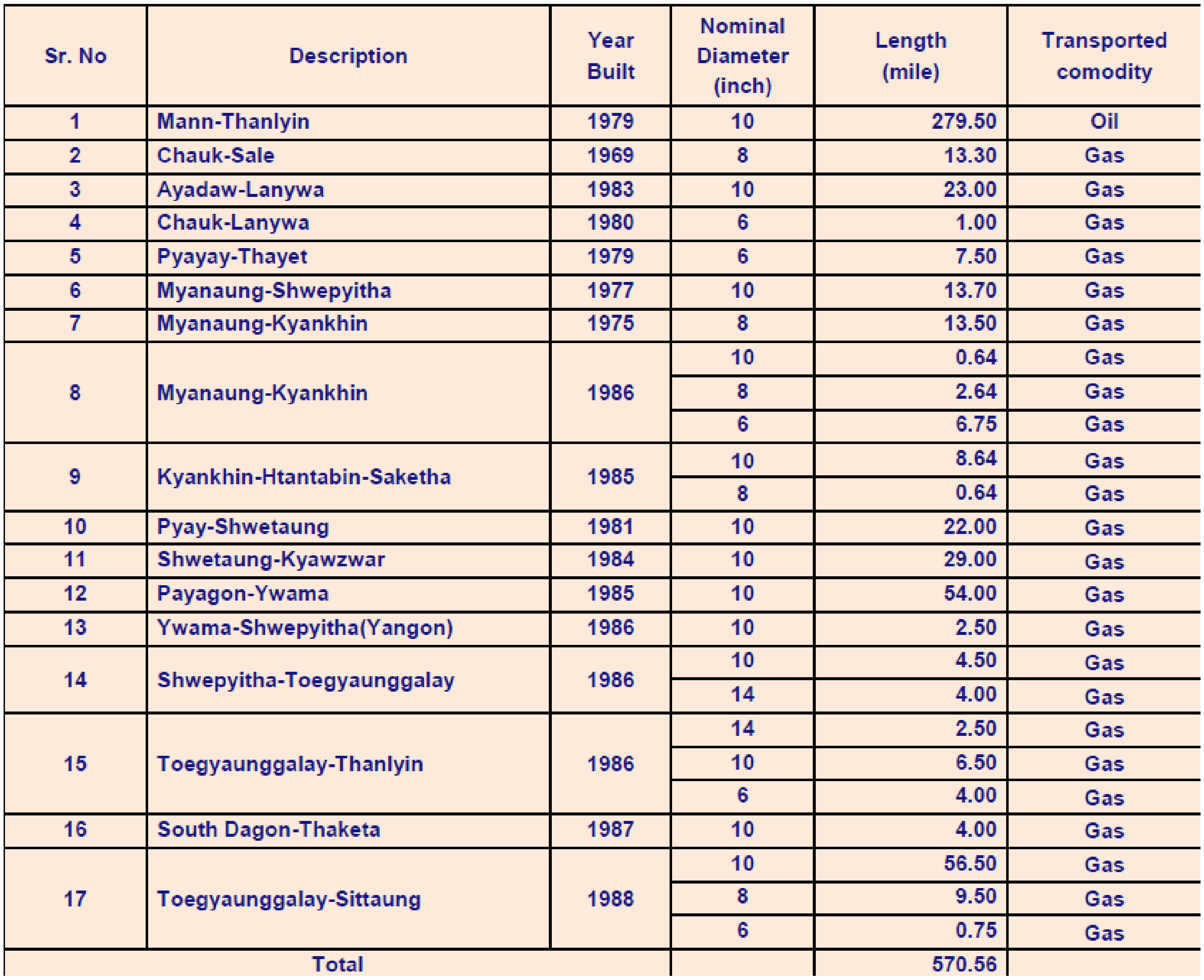
[25] Renewable Energy Technologies: Cost Analysis Series Volume 1, Issue 3/5 Hydropower, June 2012

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	Tanninthayi	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

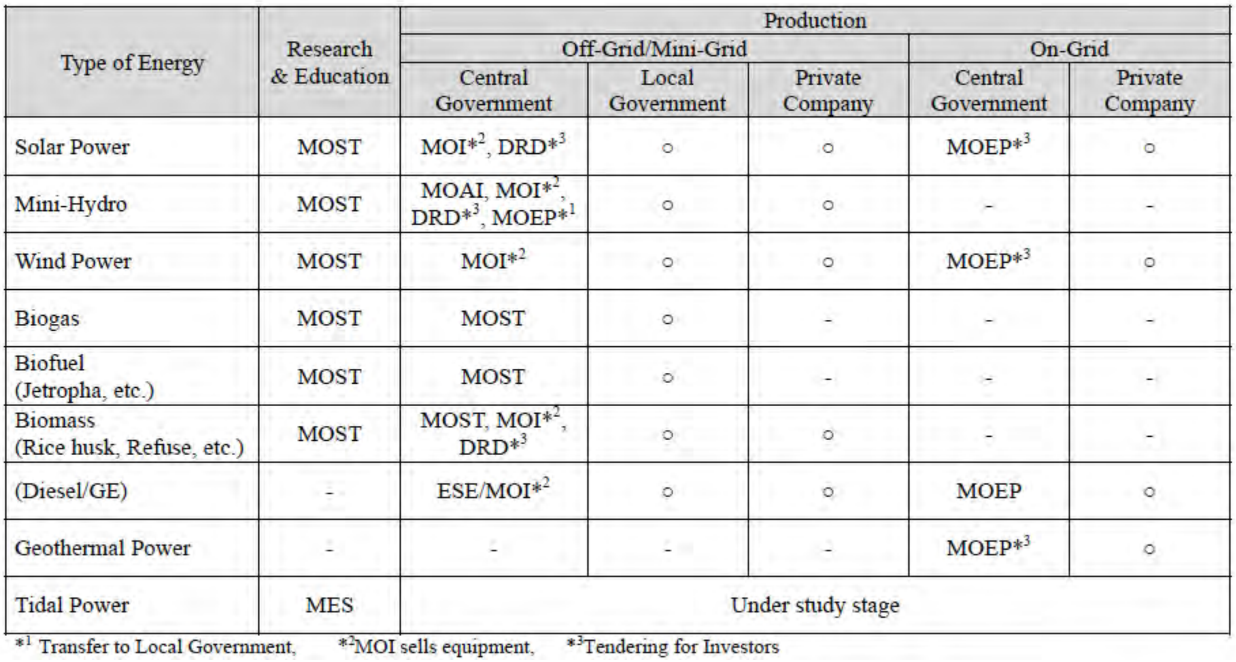
No.	Coal Mine; Company Name	2001/02	2002/03	2003/04	2004/05	2005/06	2006/07	2007/08	2008/09	2009/10	2010/11	2011/12	2012/13
1	Kalewa; No.(3) Mining Enterprise	13 808	11 773	17 091	15 002	12 250	7 870	6 016	6 012	8 946	2 000		
2	Namma; No.(3) Mining Enterprise	30 200	40 000	55 000	55 000	55 400	42 800	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

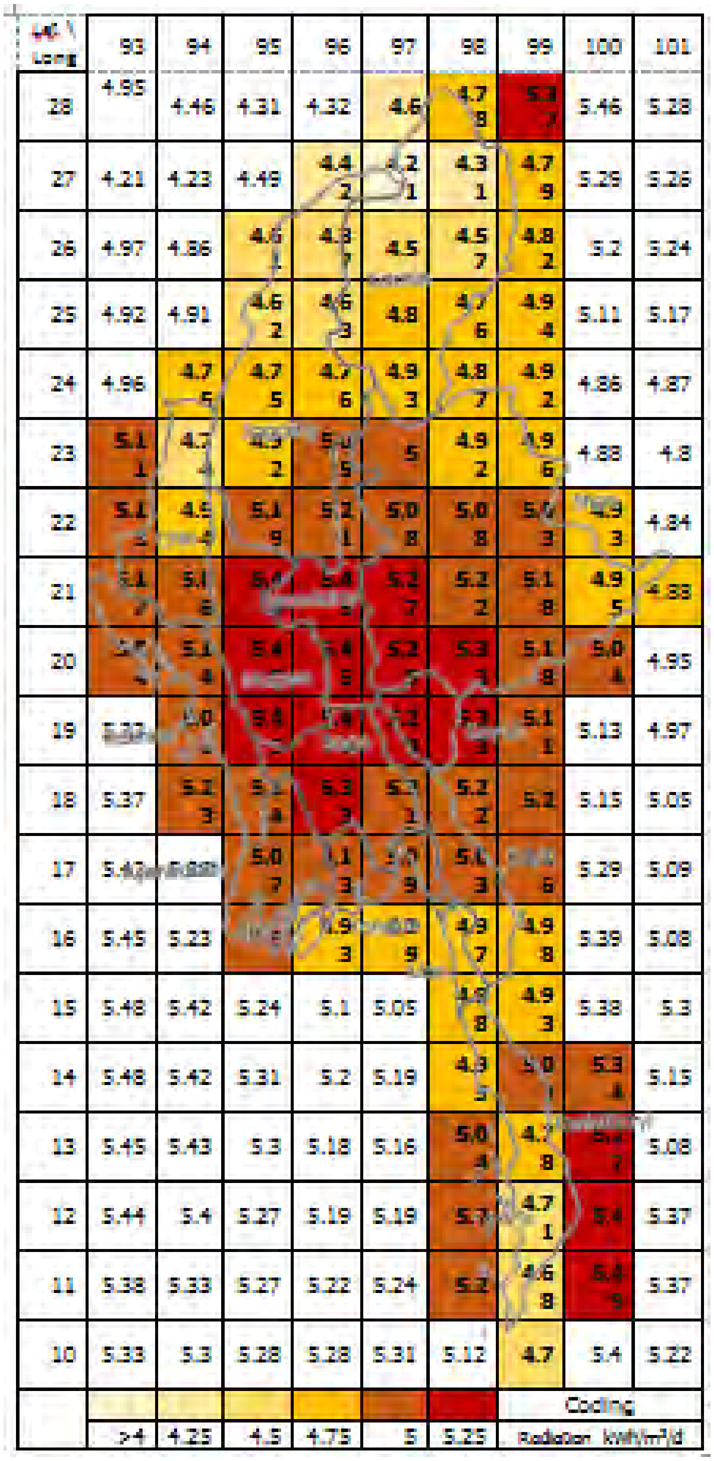


Type of Energy	Research & Education	Production				
		Off-Grid/Mini-Grid			On-Grid	
		Central Government	Local Government	Private Company	Central Government	Private Company
Solar Power	MOST	MOI*[2], DRD*[3]	○	○	MOEP*[3]	○
Mini-Hydro	MOST	MOAI, MOI*[2], DRD*[3], MOEP*[1]	○	○	-	-
Wind Power	MOST	MOI*[2]	○	○	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, *[2]MOI sells equipment, *[3]Tendering for Investors

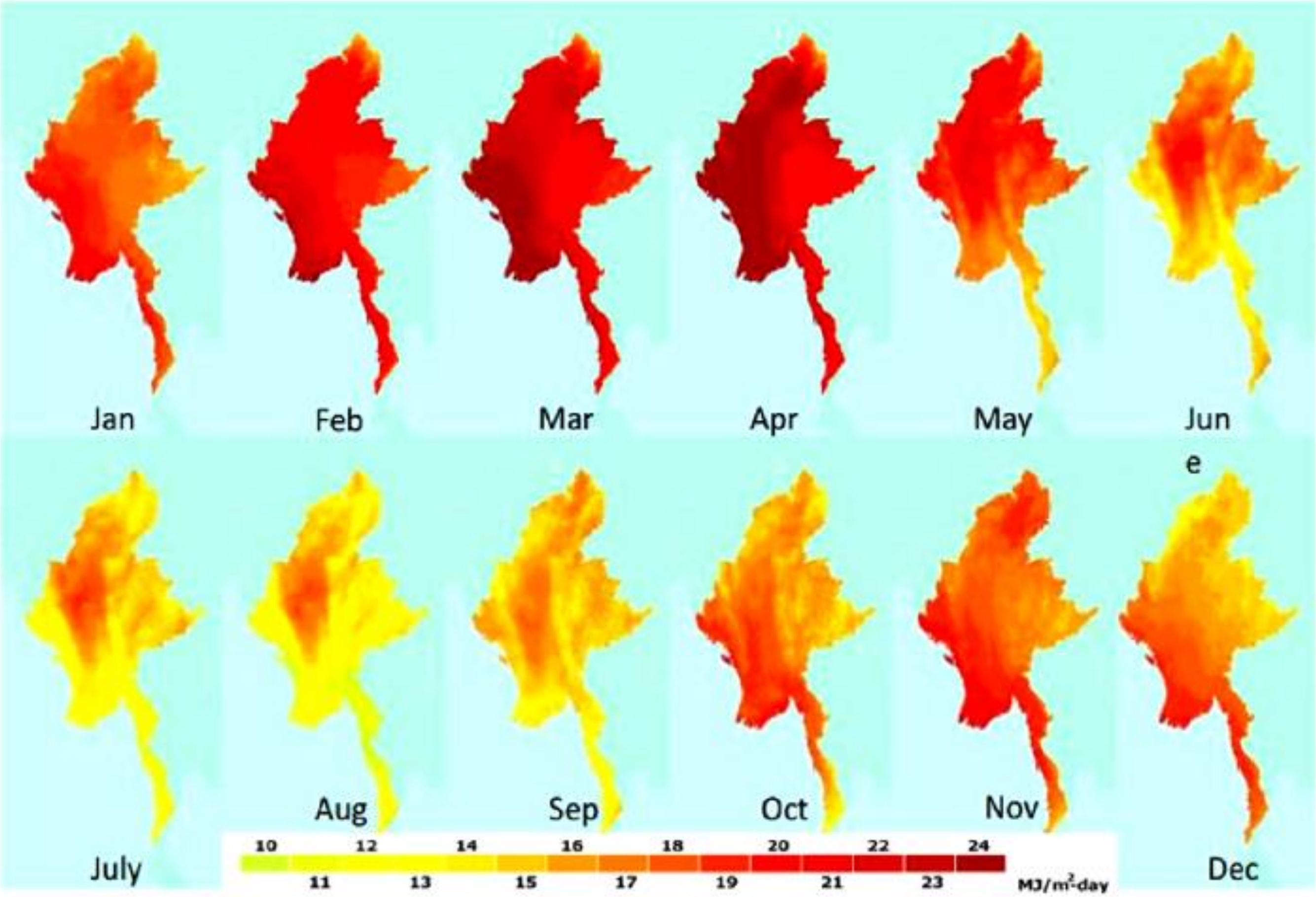
Source: The Project for Formulation on the National Electricity Master Plan in The Republic of the Union of Myanmar. Draft Final Report. JICA et al., July 2014

ANNEX 7 Annual Monthly Average Radiation Incident on Equator-Pointed Surface (kWh/m²/day)



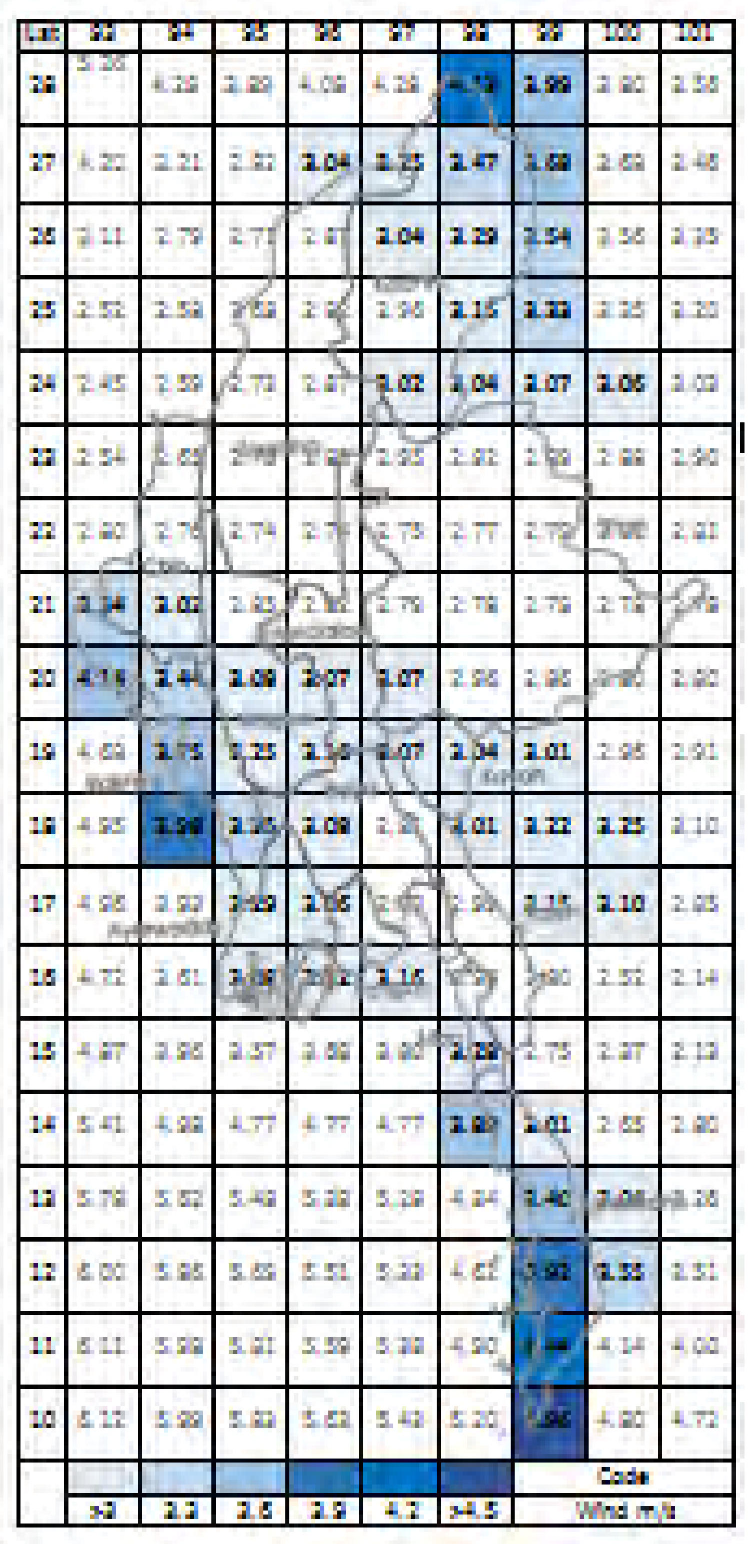
Lat \ Long	93	94	95	96	97	98	99	100	101
28	4.95	4.46	4.31	4.32	4.6	4.78	5.37	5.46	5.28
27	4.21	4.23	4.49	4.42	4.21	4.31	4.79	5.29	5.26
26	4.97	4.86	4.61	4.37	4.5	4.57	4.82	5.2	5.24
25	4.92	4.91	4.62	4.63	4.8	4.76	4.94	5.11	5.17
24	4.96	4.75	4.75	4.76	4.93	4.87	4.92	4.86	4.87
23	5.11	4.74	4.92	5.05	5	4.92	4.96	4.88	4.8
22	5.13	4.54	5.19	5.21	5.08	5.08	5.03	4.93	4.84
21	5.17	5.16	[illegible]	5.42	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	5.22	5.01	[illegible]	[illegible]	5.21	5.33	5.11	5.13	4.97
18	5.37	5.23	5.14	5.33	5.21	5.22	5.2	5.15	5.05
17	5.42	5.02	5.07	5.13	5.09	5.13	[illegible]	5.29	5.09
16	5.45	5.23	[illegible]	4.93	5.09	4.97	4.98	5.39	5.08
15	5.48	5.42	5.24	5.1	5.05	4.98	4.93	5.38	5.3
14	5.48	5.42	5.31	5.2	5.19	4.95	5.01	5.34	5.15
13	5.45	5.43	5.3	5.18	5.16	5.04	4.78	[illegible]	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 / m^2/d) (3.6 MJ/kWh) Showing the Regional Variation of Solar Profile over the Year



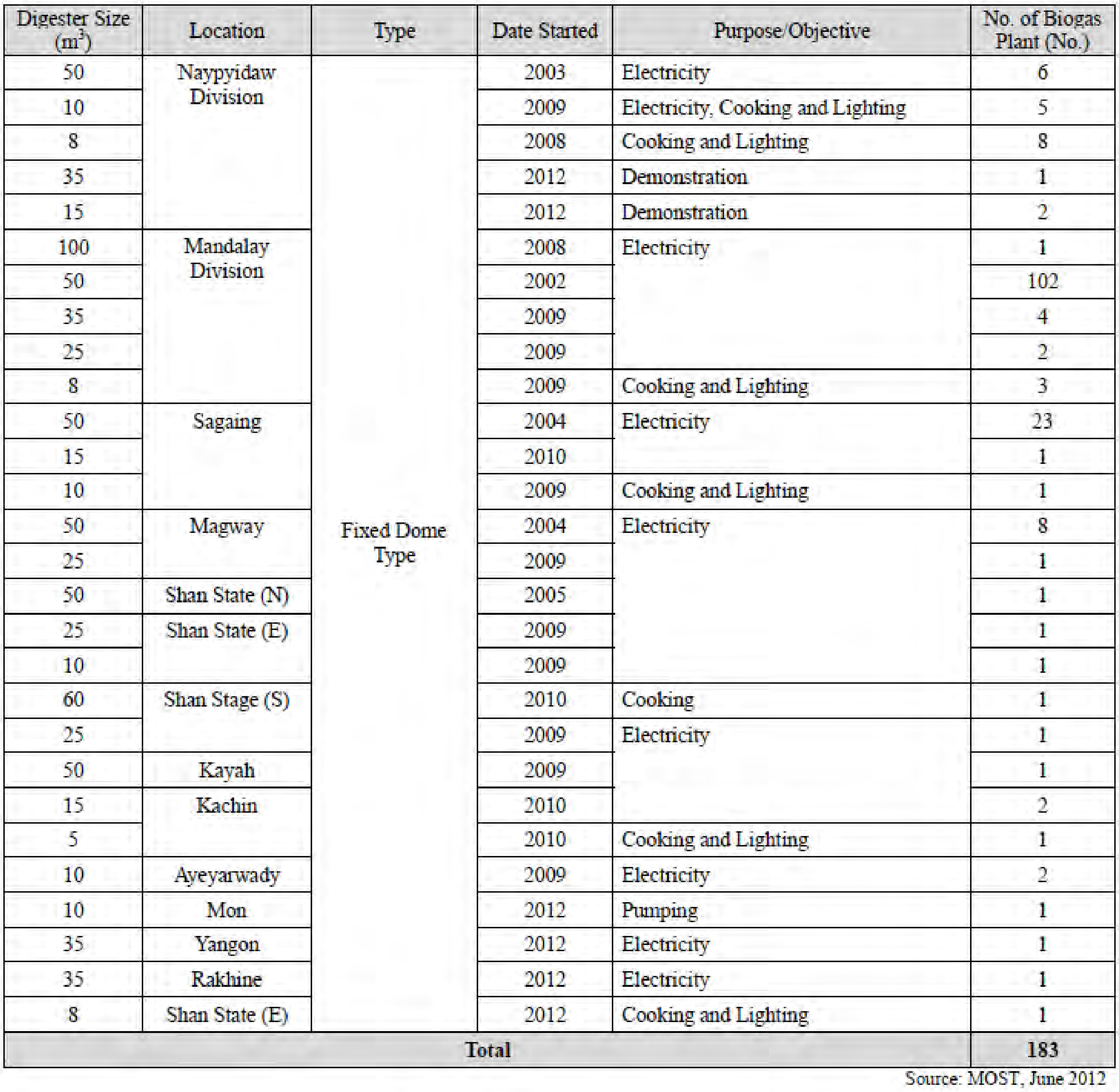
Source: Photovoltaic Power Generation Myanmar, Working Paper by Heinz - W . Böhnke , Renewable Energy Adviser ADB TA-8356 MYA

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	3.38	4.28	3.89	4.06	4.28	4.19	3.99	3.80	3.58
27	4.20	2.21	2.50	3.04	3.25	3.47	3.68	2.69	2.48
26	3.11	2.79	2.73	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	2.35	2.20
24	2.45	2.59	2.73	2.87	3.02	3.04	3.07	3.06	3.03
23	2.54	2.69	[illegible]	2.85	2.85	2.82	2.80	2.88	2.90
22	2.80	2.75	2.74	2.75	2.73	2.77	2.79	[illegible]	2.81
21	3.14	3.03	2.83	2.82	2.76	2.78	2.79	2.78	2.79
20	4.18	3.44	3.09	3.07	3.07	2.96	2.95	2.90	2.90
19	4.63	3.75	3.25	3.30	3.07	3.04	3.01	2.96	2.91
18	4.95	3.98	3.35	3.09	[illegible]	3.01	3.22	3.25	3.10
17	4.96	3.03	3.49	3.06	[illegible]	[illegible]	3.15	3.10	2.85
16	4.72	2.61	3.48	3.32	3.16	[illegible]	2.80	2.52	2.14
15	4.87	2.96	2.57	2.88	2.80	3.88	2.75	2.27	2.13
14	5.41	4.98	4.77	4.77	4.77	3.89	3.01	2.65	2.80
13	5.78	5.62	5.48	5.38	5.38	4.84	3.40	3.06	3.28
12	6.00	5.86	5.65	5.51	5.33	4.62	3.92	3.38	3.31
11	6.11	5.98	5.81	5.59	5.38	4.90	[illegible]	4.14	4.03
10	6.12	5.99	5.80	5.68	5.48	5.20	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



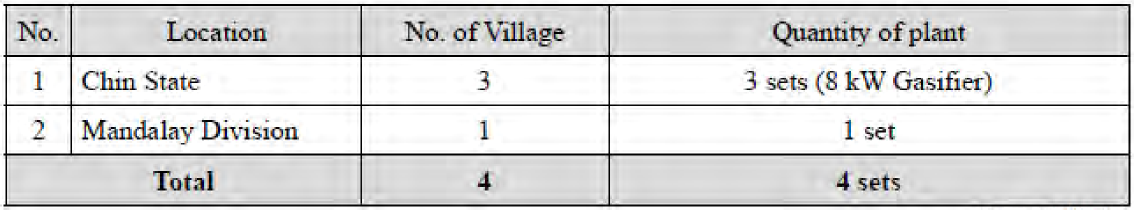
Digester Size (m^3)	Location	Type	Date Started	Purpose/Objective	No. of Biogas Plant (No.)
50	Naypyidaw Division	Fixed Dome Type	2003	Electricity	6
10			2009	Electricity, Cooking and Lighting	5
8			2008	Cooking and Lighting	8
35			2012	Demonstration	1
15			2012	Demonstration	2
100	Mandalay Division		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

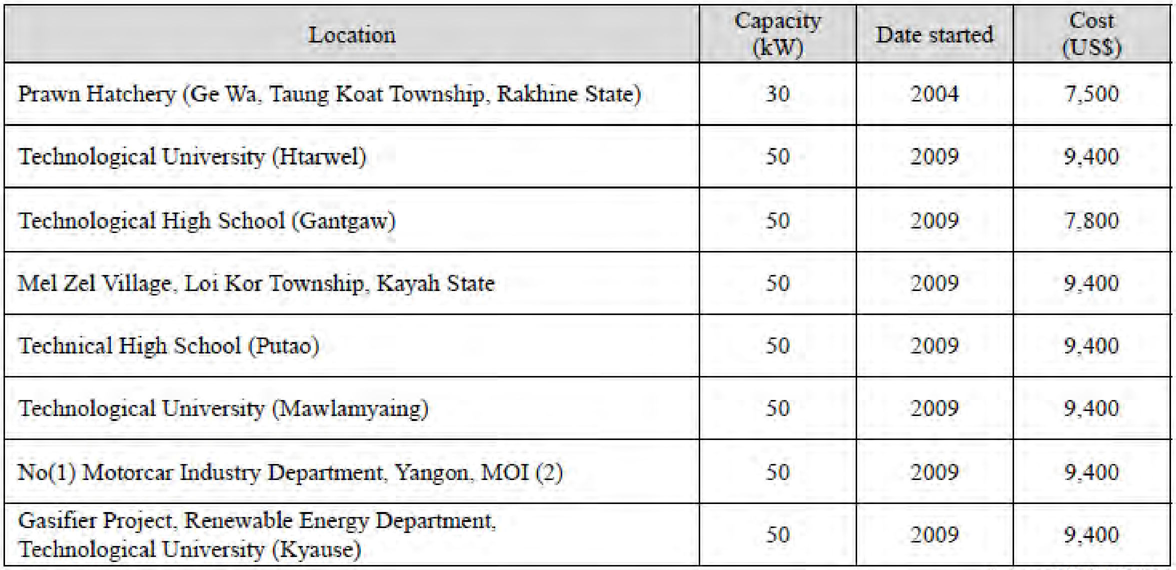
A. Biomass Gasification Projects (rice husk)



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

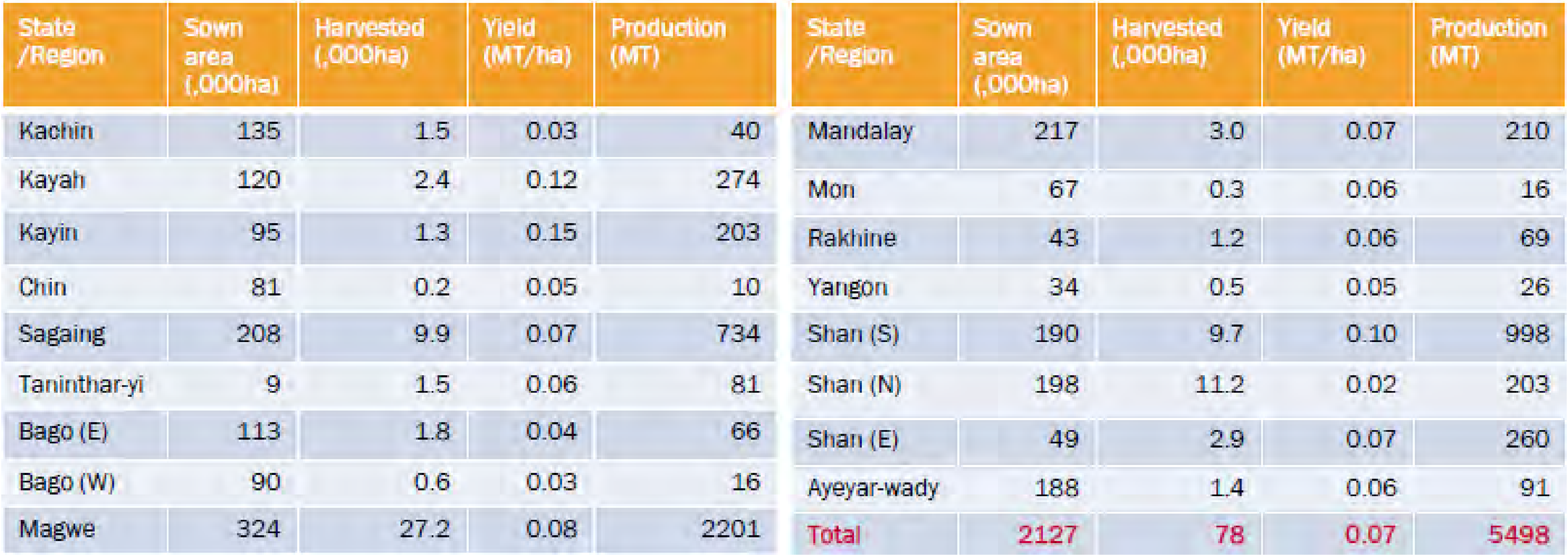
Source: The Project for Formulation on the National Electricity Master Plan in The Republic of the Union of Myanmar. Draft Final Report. JICA et al., July 2014

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	Iapandan	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

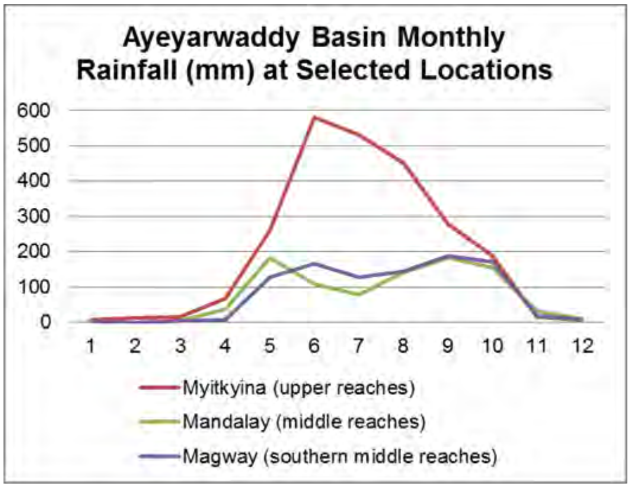
ANNEX 13 Jatropha Production in Myanmar in 2010 – 2011

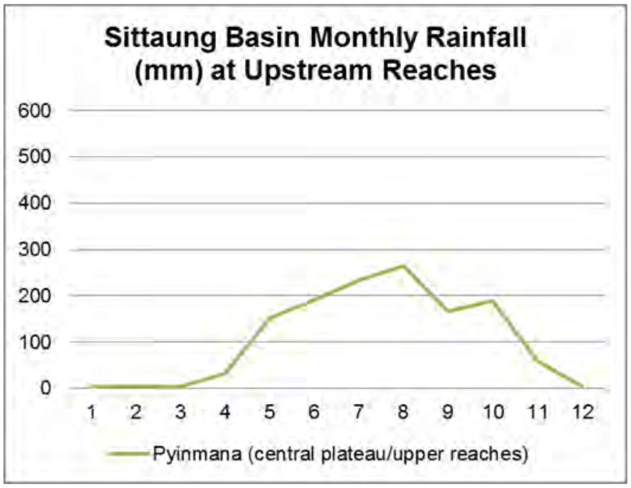


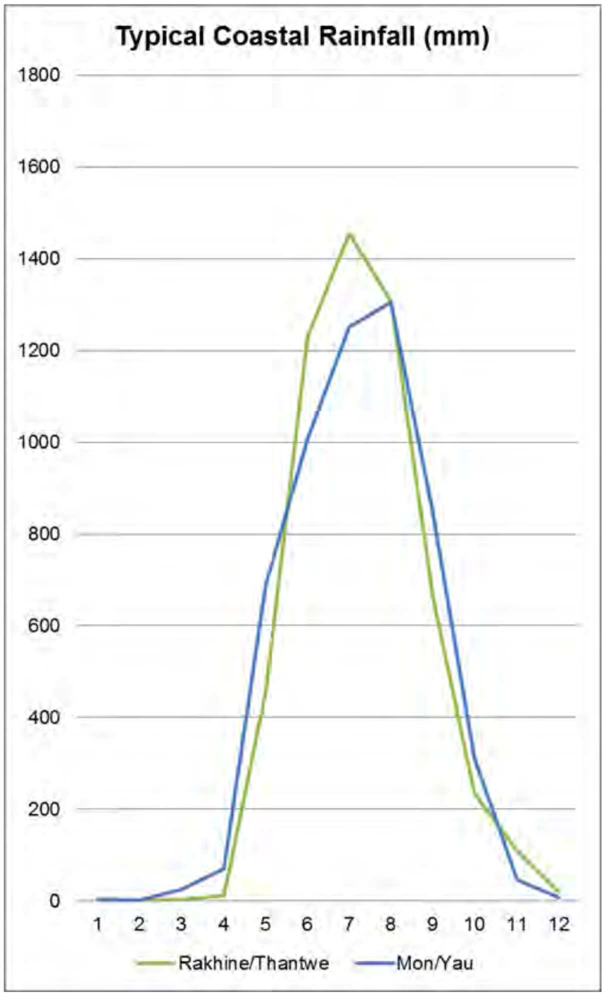
State /Region	Sown area (,000ha)	Harvested (,000ha)	Yield (MT/ha)	Production (MT)
Kachin	135	1.5	0.03	40
Kayah	120	2.4	0.12	274
Kayin	95	1.3	0.15	203
Chin	81	0.2	0.05	10
Sagaing	208	9.9	0.07	734
Taninthar-yi	9	1.5	0.06	81
Bago (E)	113	1.8	0.04	66
Bago (W)	90	0.6	0.03	16
Magwe	324	27.2	0.08	2201
Mandalay	217	3.0	0.07	210
Mon	67	0.3	0.06	16
Rakhine	43	1.2	0.06	69
Yangon	34	0.5	0.05	26
Shan (S)	190	9.7	0.10	998
Shan (N)	198	11.2	0.02	203
Shan (E)	49	2.9	0.07	260
Ayeyar-wady	188	1.4	0.06	91
Total	2127	78	0.07	5498

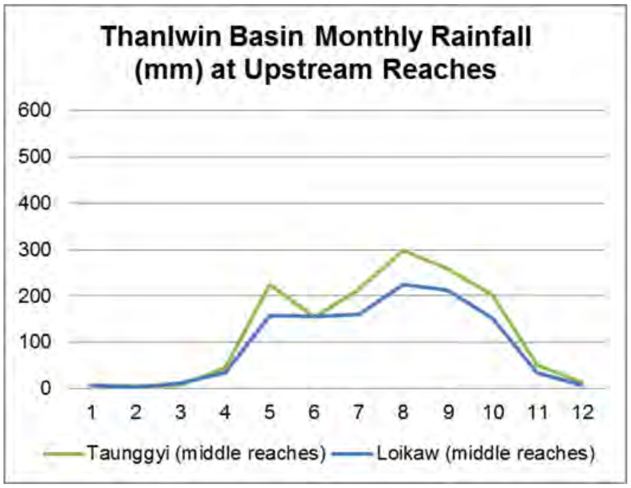
Source: Presentation Material for Regional Workshop on GMS Country Experience in Achieving Performance Target. MOEP 1, MOE, MOI, August 2012

ANNEX 14 Basin and Coastal Monthly Rainfalls in Myanmar


Ayeyarwaddy Basin Monthly Rainfall (mm) at Selected Locations


Sittaung Basin Monthly Rainfall (mm) at Upstream Reaches


Typical Coastal Rainfall (mm)


Thanlwin Basin Monthly Rainfall (mm) at Upstream Reaches

ANNEX 15 Hydropower Resources in Myanmar

A. Large Hydropower Plants

HYDROPOWER PLANTS OF MYANMAR OF OVER 10 MW INSTALLED CAPACITY - IN OPERATION

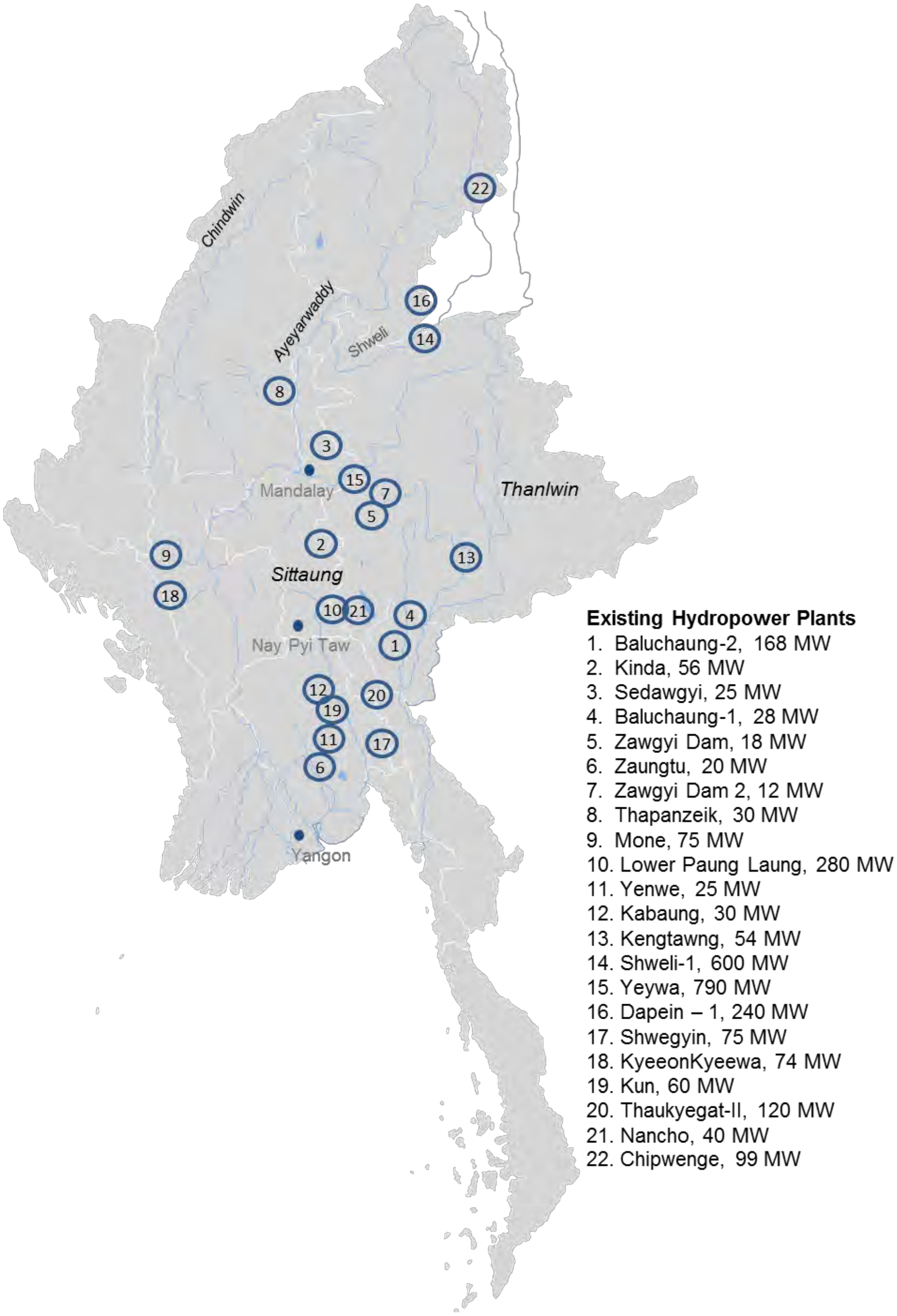
	Hydro Power Plant			Installed capacity		Capacity	Firm	Design values		Production (MWh/a)		On-line	Location		Turbine	
				Total	Unit	Myanmar	Capacity	Head	Discharge	Planned	in 2013					
No	**Name of the plant**	**Info sheet link**	**Owner**	**MW**	**MW**	**MW**	**MW**	**ft**	**cft/s**	**MWh/a**	**MWh/a**	**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		
		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

No	Name of the plant	Installed capacity MW	On-line 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 GALANGCHA	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 CHAUN	0.2	1992
22	YETAGUN CHAUNG	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 NGAUN	4	1995
33	ZI CHAUNG	1.26	1996
34	NAMSAUNG CHAUN	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

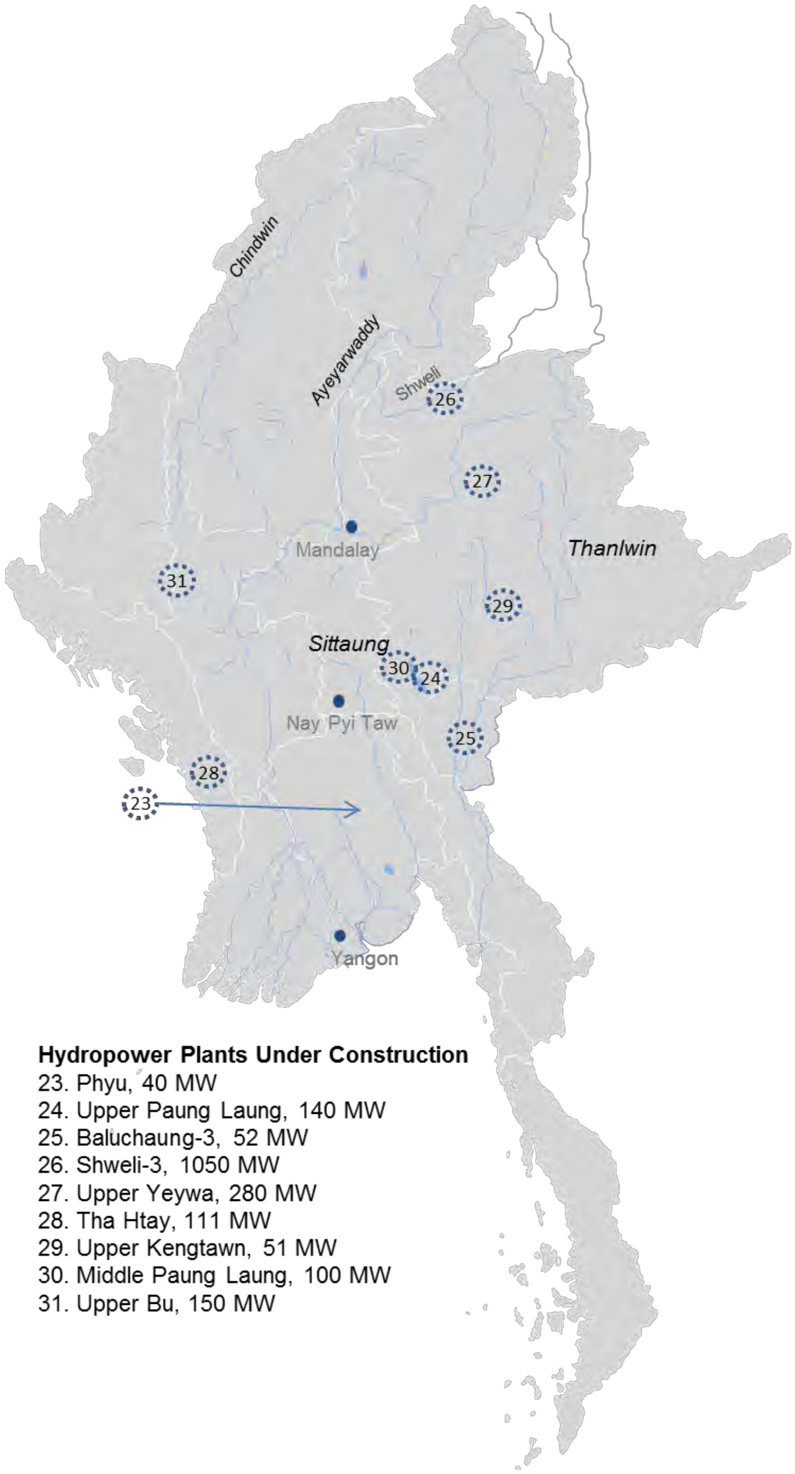
Source: Consultant

D. Planned Hydropower Plants

FUTURE HYDRO POWER PLANTS IN MYANMAR														
				Installed capacity		For	Design values		Planned	Anticipated construction period			Location	
				Total	Unit	Myanmar	Head	Discharge	production	Start	End	Duration		
	No	Name of the plant	Owner	MW	MW	MW	ft	cft/s	MWh/a	Year	Year	Months	Town	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



Hydropower Plants Under Construction
23. Phyu, 40 MW
24. Upper Paung Laung, 140 MW
25. Baluchaung-3, 52 MW
26. Shweli-3, 1050 MW
27. Upper Yeywa, 280 MW
28. Tha Htay, 111 MW
29. Upper Kengtawn, 51 MW
30. Middle Paung Laung, 100 MW
31. Upper Bu, 150 MW

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

IES
Intelligent Energy Systems

in association with

MMIC
MYANMAR
INTERNATIONAL
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FINAL REPORT

ENERGY FORECASTS

AGRICULTURE SECTOR

Prepared for

The Asian Development Bank

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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.

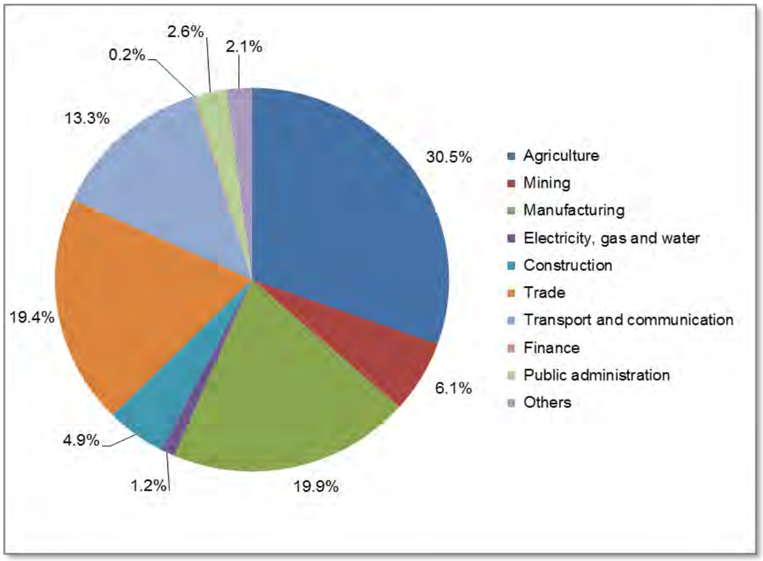
CONTENTS

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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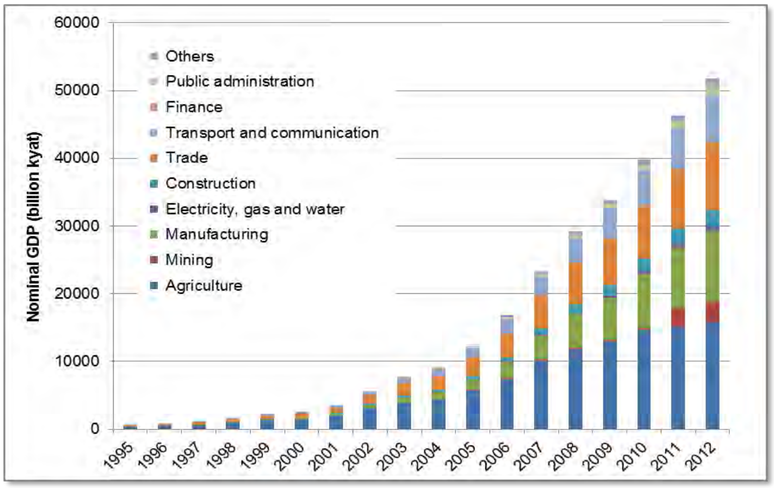
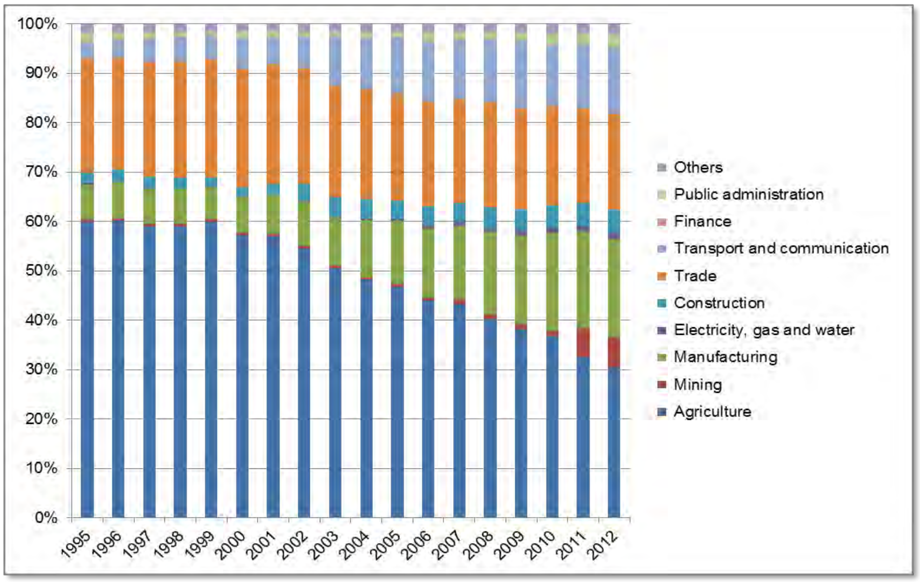
Source: Asian Development Bank

Figure I-2: Myanmar's GDP by Sector



Source: Asian Development Bank

Figure I-3: Myanmar's GDP by Sector (% basis)

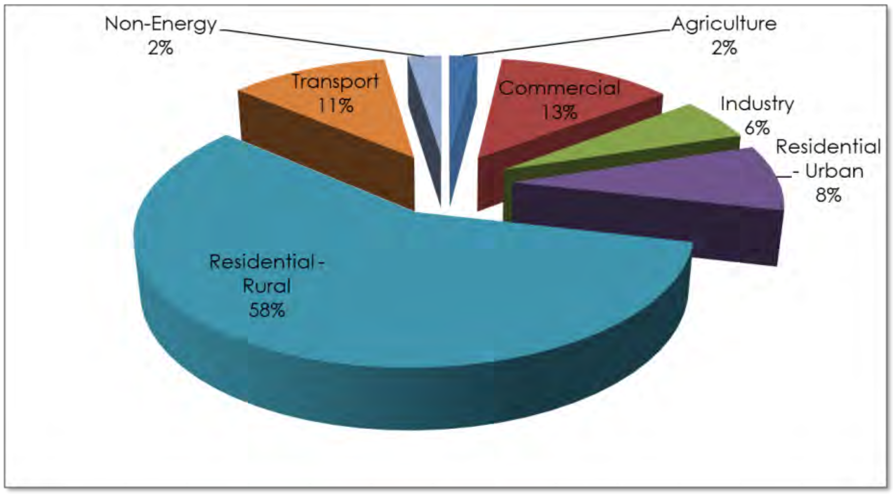


Source: Asian Development Bank

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

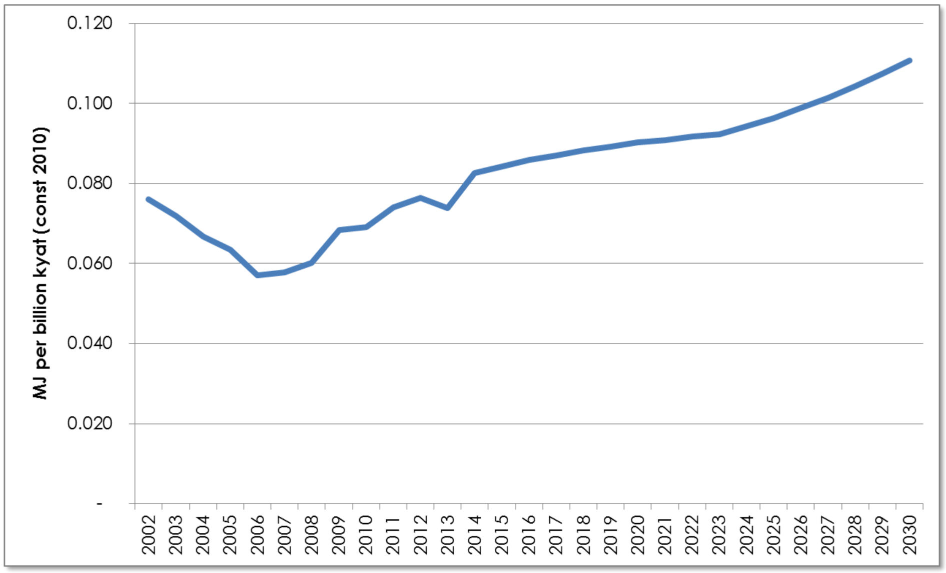
B. Sector Energy Use

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.

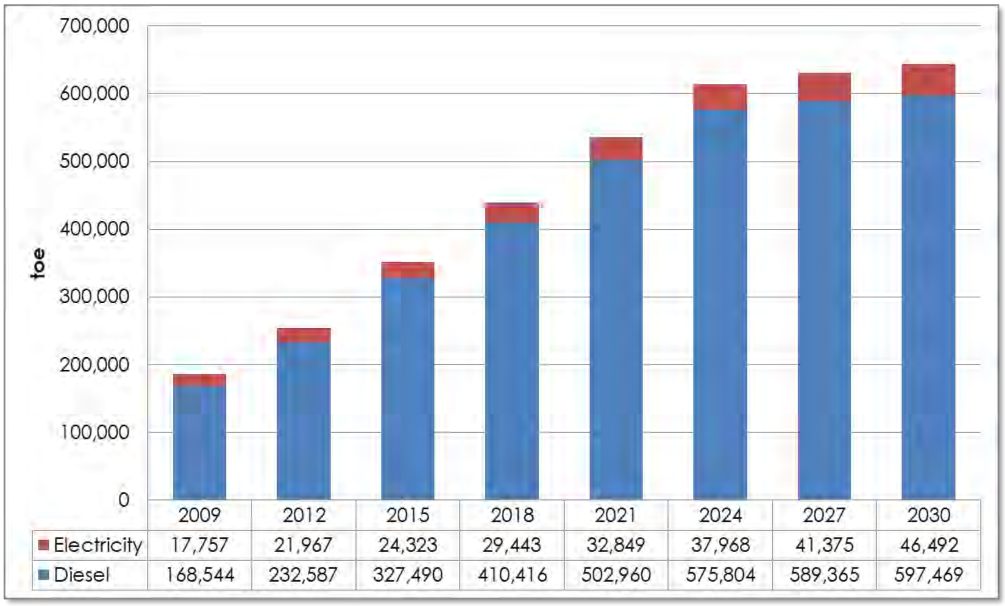
5. The relationship between Agriculture sector GDP and Agriculture sector energy is the energy intensity of the Agriculture sector. It is calculated as a unit of energy needed per unit of farm GDP. The relationship between energy intensity and economic development has the following pattern in agriculture - 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

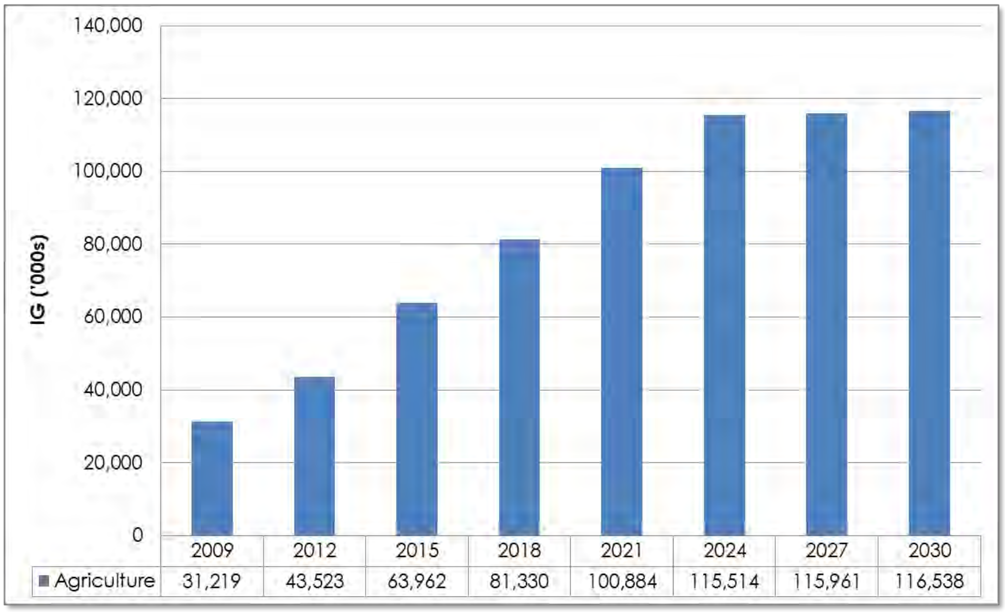


	2009	2012	2015	2018	2021	2024	2027	2030
🟥 Electricity	17,757	21,967	24,323	29,443	32,849	37,968	41,375	46,492
🟦 Diesel	168,544	232,587	327,490	410,416	502,960	575,804	589,365	597,469

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.

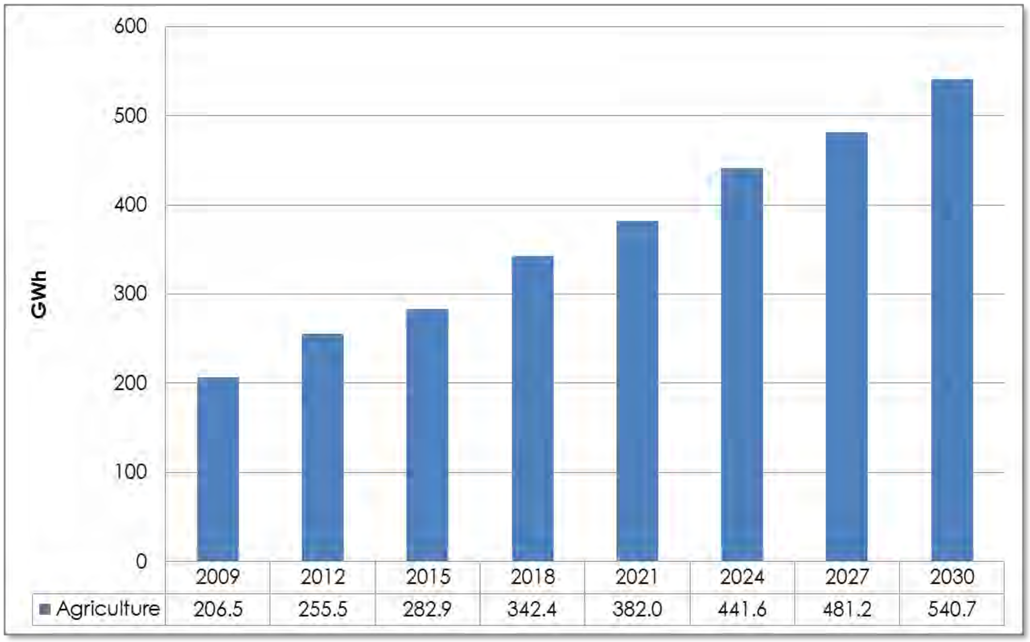
Figure I-7: Final Diesel (HSD) Fuel Consumption



	2009	2012	2015	2018	2021	2024	2027	2030
■ Agriculture	31,219	43,523	63,962	81,330	100,884	115,514	115,961	116,538

Sources: Consultant

Figure I-8: Final Electricity Consumption



	2009	2012	2015	2018	2021	2024	2027	2030
■ Agriculture	206.5	255.5	282.9	342.4	382.0	441.6	481.2	540.7

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.

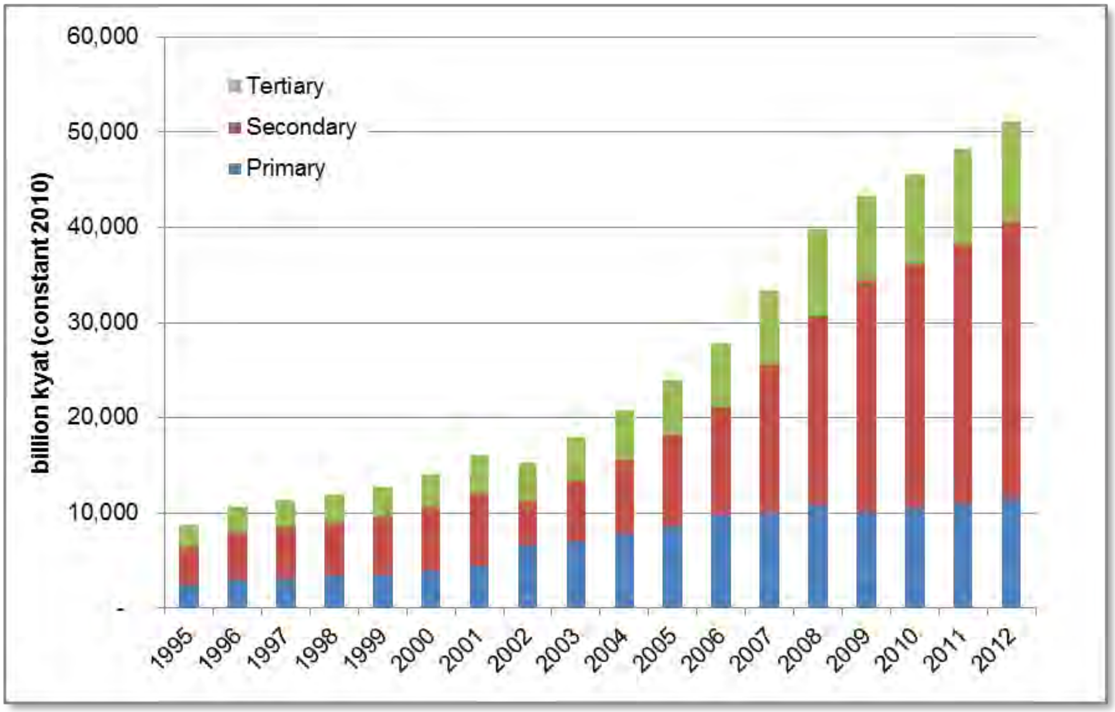
9. The Fisheries sub-sector relies on the country's abundant water resources. There are substantial fisheries in the major rivers, the 1 900 km of coastline, and the 500 000 ha of mangrove swamps. There is considerable potential for aquaculture development in the low-lying river delta areas in the south 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

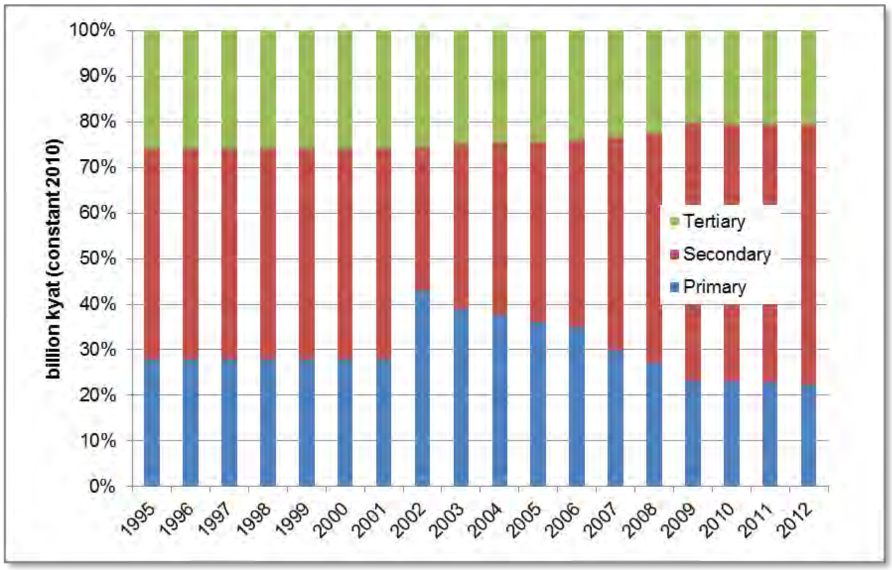
11. The prosperity of Myanmar is heavily dependent on the primary sector. The sector contributed 15,753 billion kyats in 2012. The GDP of the sector has grown steadily since 1995 as shown in Figure II-1.

Figure II-1: Primary Sector GDP



Sources: ADB

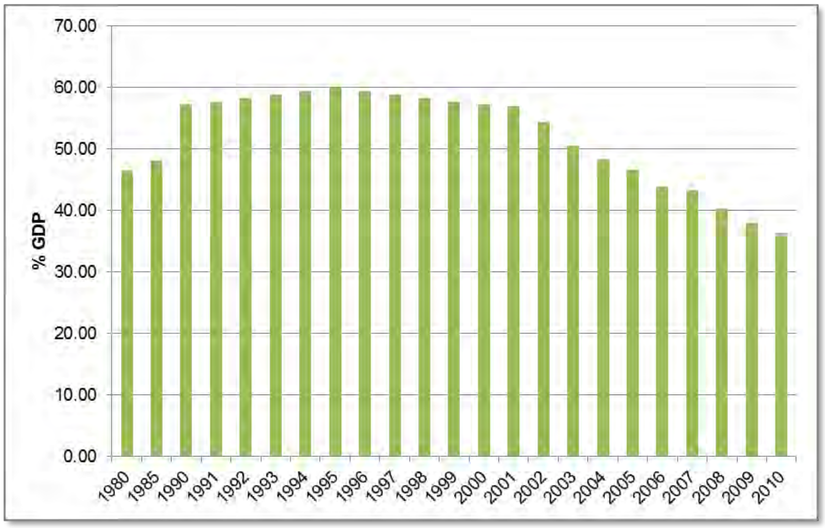
Figure II-2: GDP Composition by %



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

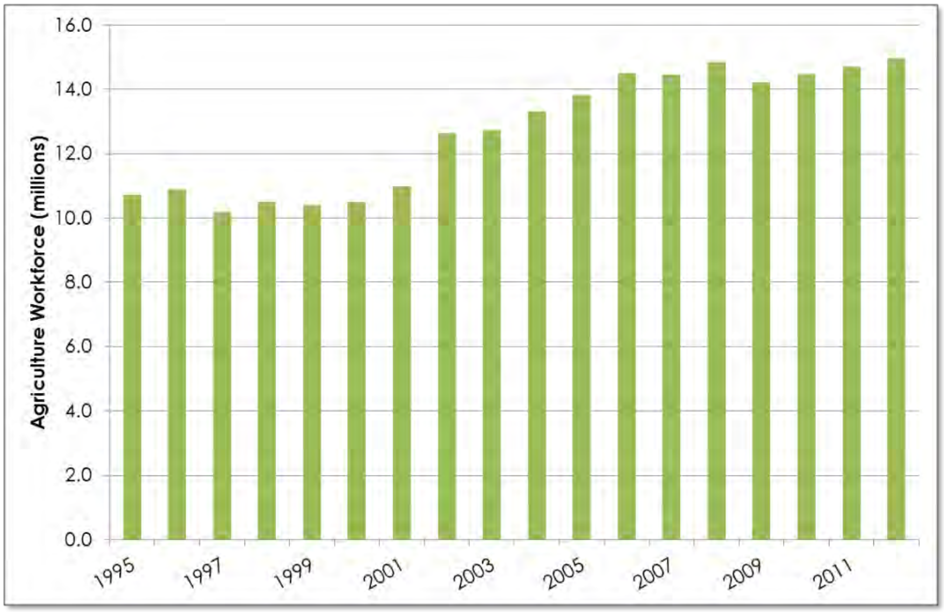
14. In 2012, the farm sector employed around 80% of the Agriculture sector labour (est. 19.5 million), or 50% of the active labour force (est. 31.1 million). The farm labour force is estimated to have grown by an average of 2% since 2002 as shown in Table II-5.

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

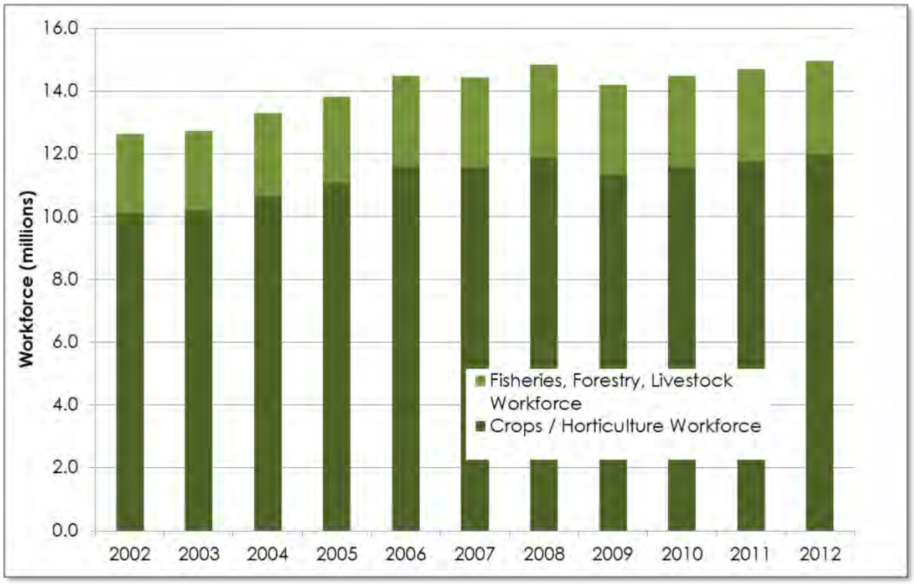
Sources: Consultant; refer also Volume II: Economic Outlook

Figure II-6: Agriculture Sector Workforce



Sources: Consultant

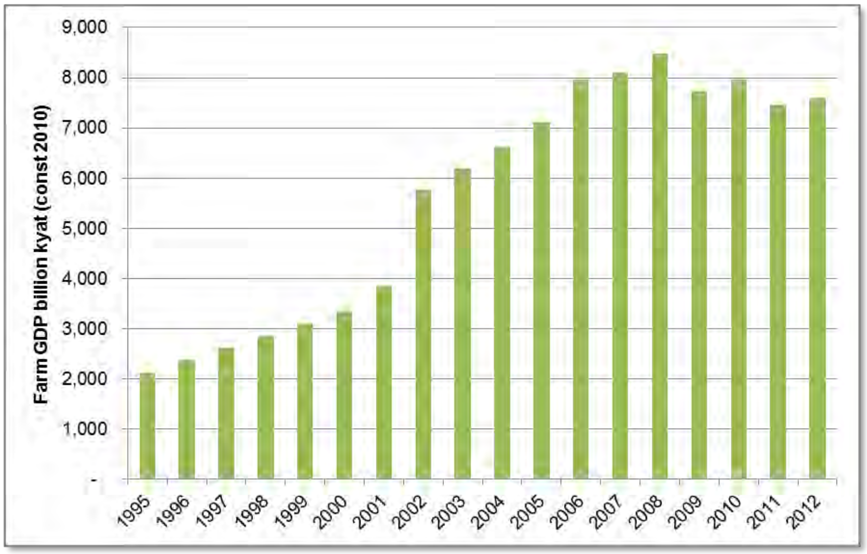
Figure II-7: Estimated Farm Labour on Agriculture Sector Workforce (FY 2005 – 2012)



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.

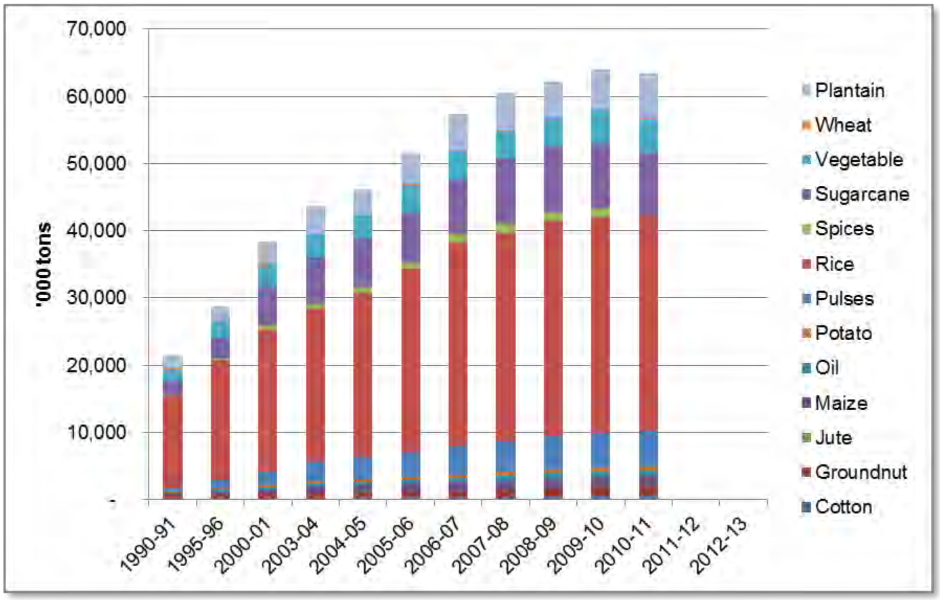
Figure II-8: Agriculture GDP billion kyat (constant 2010)



Sources: ADB

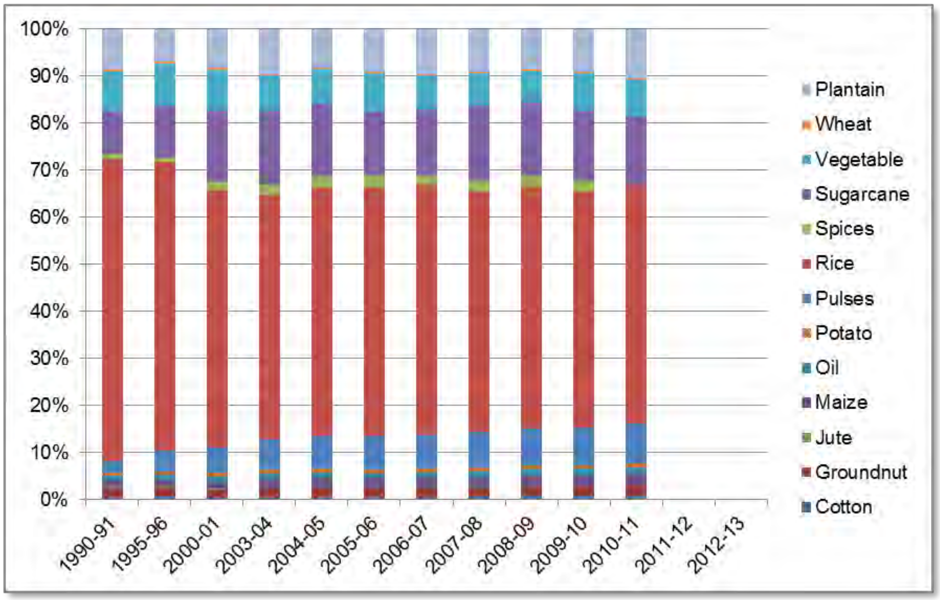
16. Crop production by weight increased by an average 10% during the period 1990 to 2010, as shown in Figure II-9. Rice production accounted for 51% of food production by weight in 2010, followed by sugarcane at 15%, plaintain at 10% and pulses at 8%, as shown in Figure II-10.

Figure II-9: Crop Production (tons)



Sources: Central Statistics Office of Myanmar

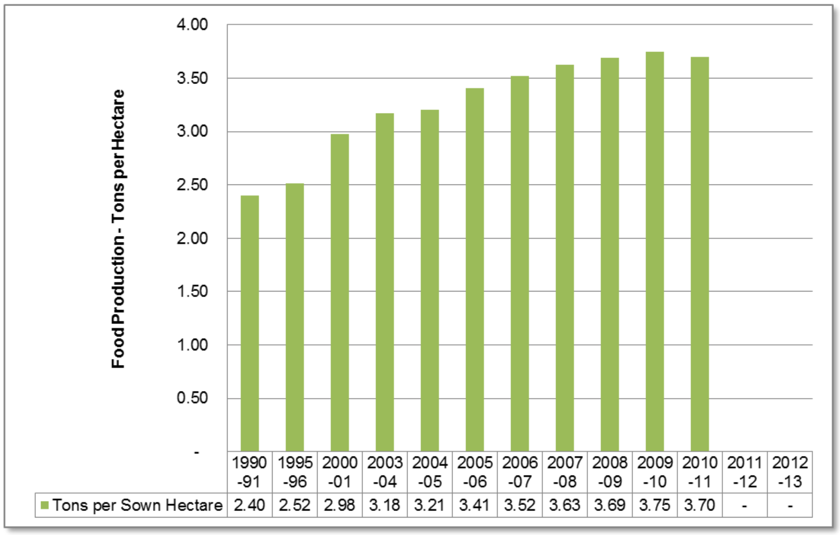
Figure II-10: Crop Production (tons) by %



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].

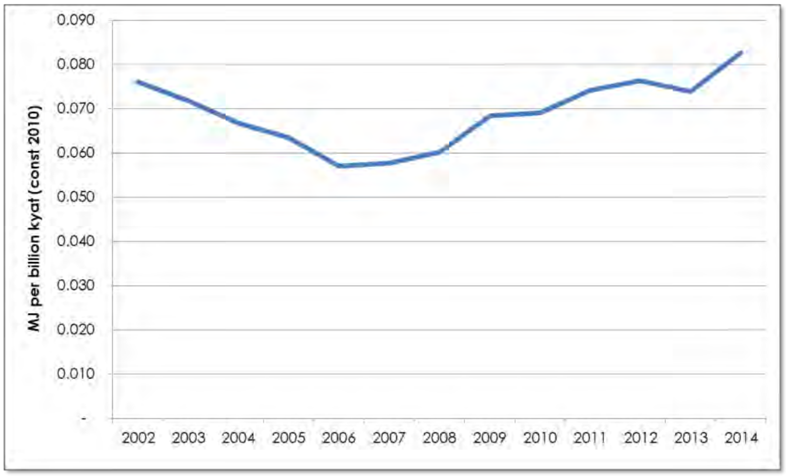
Figure II-11: Land Productivity (tons food per net hectare)



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

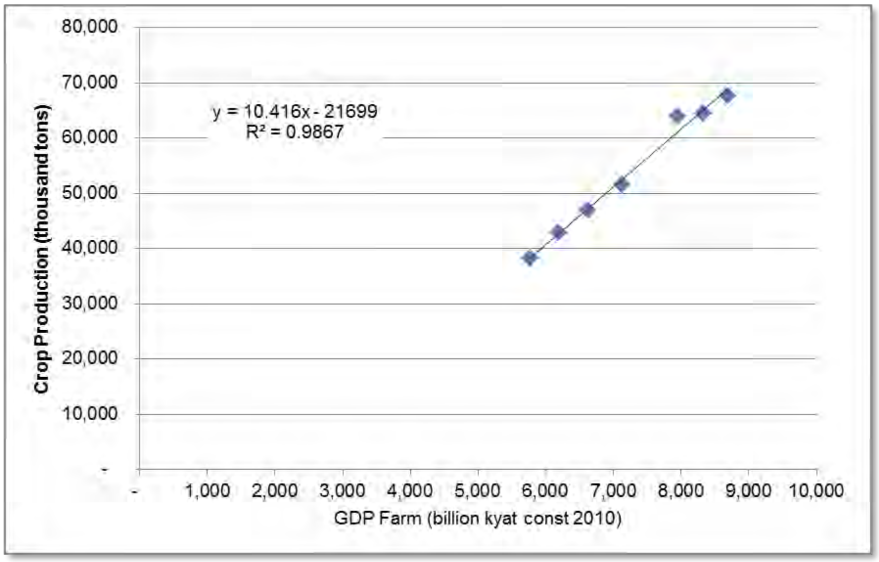
Sources: MoAI

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.

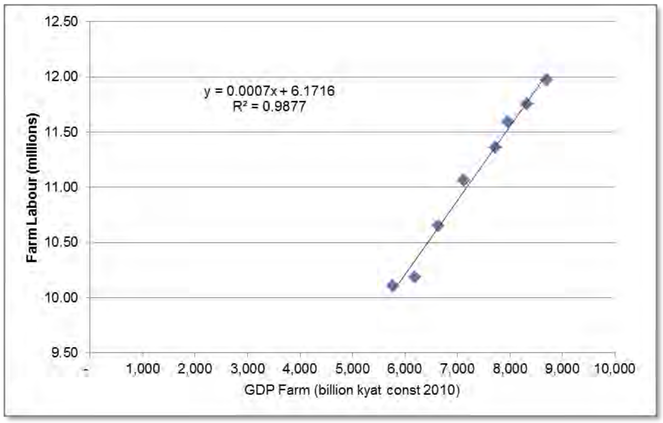
36. These relationships are charted below as Figure II-22 to Figure II-24. In each case the data relationships for FY 2007, 2008 and 2009 were found to lie on a lower trajectory, suggesting that GDP data reported at the time of Cyclone Giri and the global financial crisis was overstated. In any case 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)



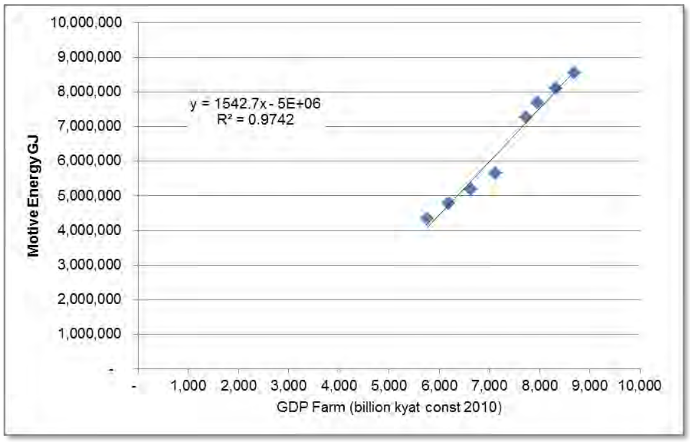
Sources: Consultant

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)

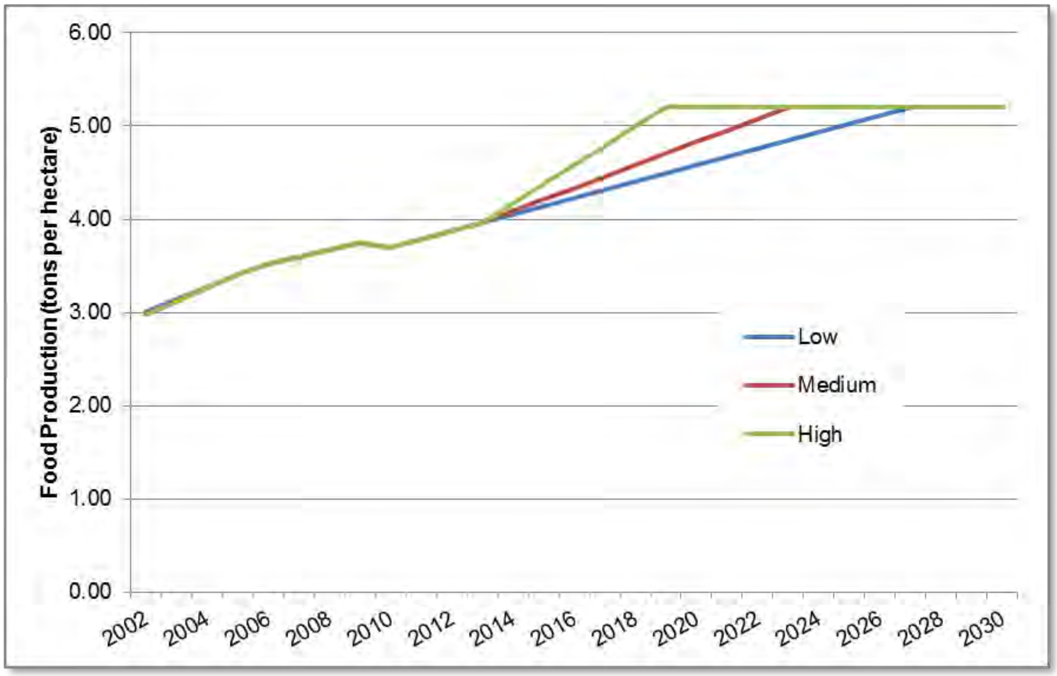
		2003	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**
Food Production	'000 tons	42,935	46,956	51,607	57,294	59,975	61,889	64,028	64,583	67,690	70,860	74,140
Farm GDP	billion kyat const 2010	6,193	6,628	7,125	7,961	8,103	8,471	7,730	7,955	8,330	8,697	9,201
	% growth	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)

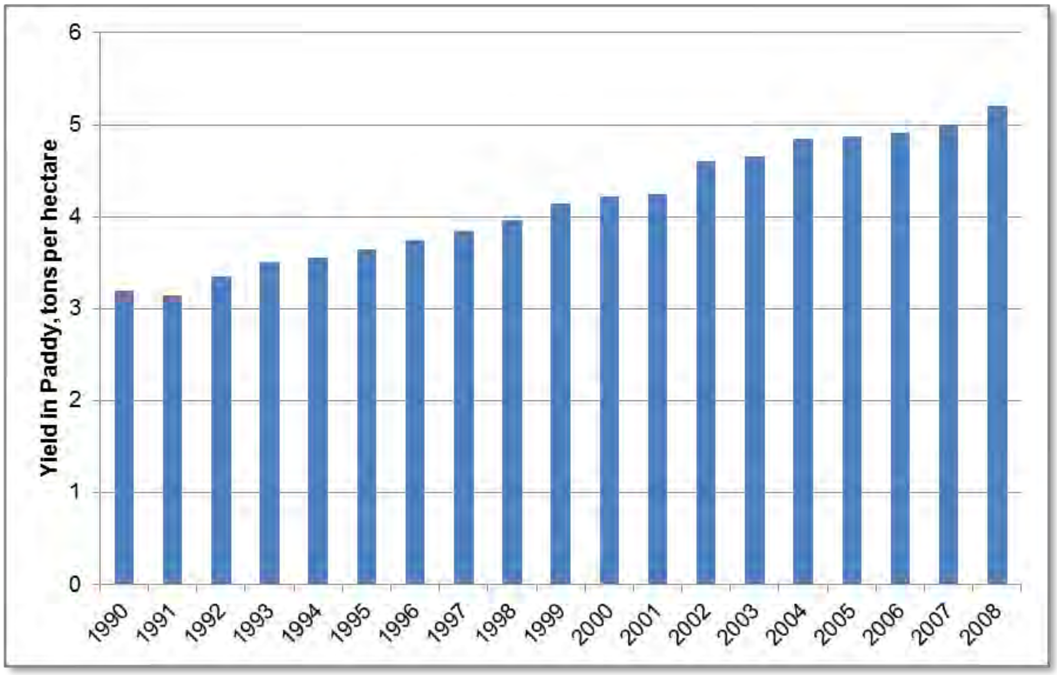


Sources: Consultant

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.

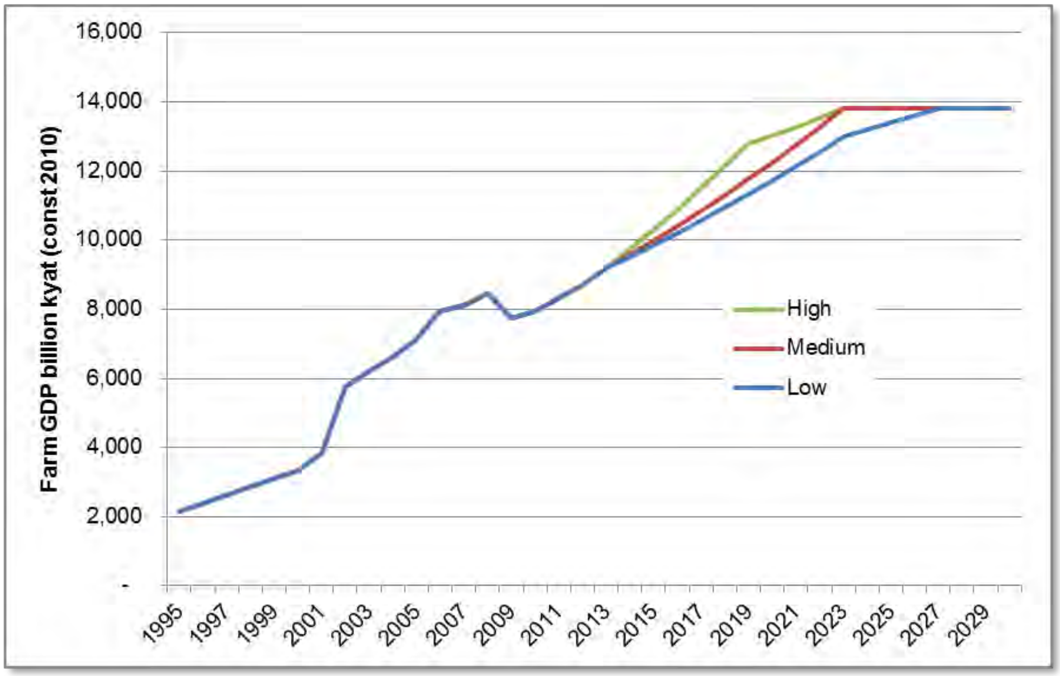
40. Achievement of the targeted level of food production will be accompanied by GDP growth. This growth has been estimated based on the observed historical relationship between food production and GDP growth in Myanmar. The Low growth scenario loosely follows the growth trajectory reported before FY 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

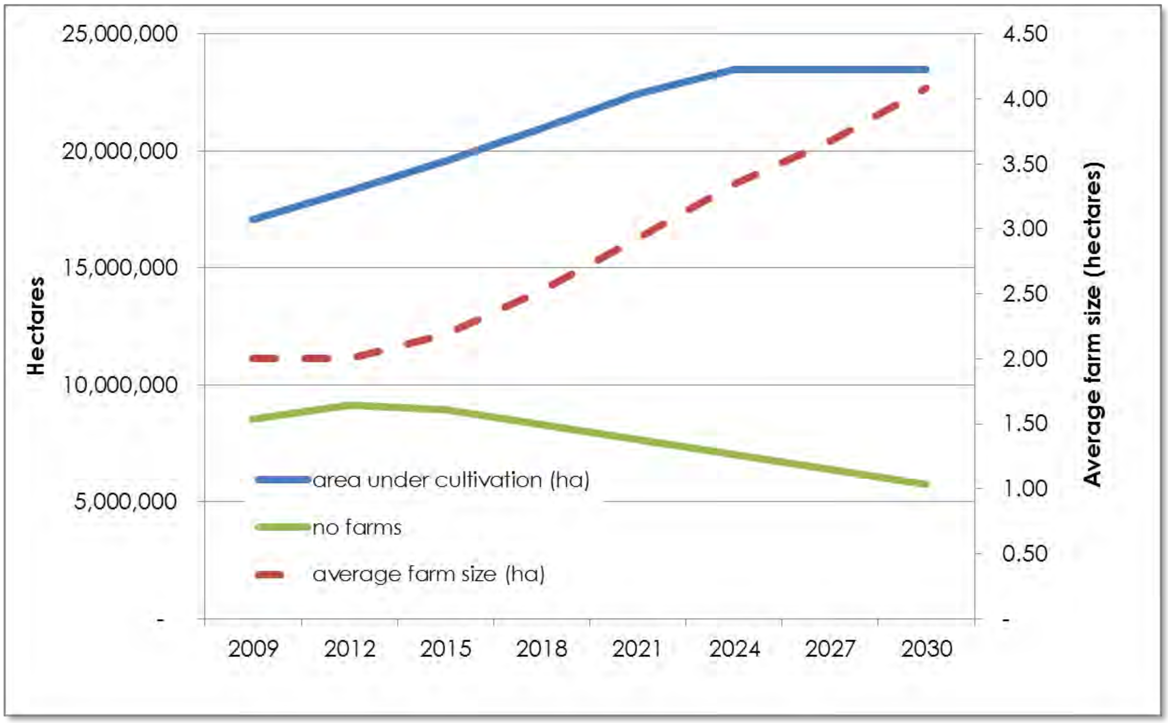
G. Farm Sector Energy Modelling

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

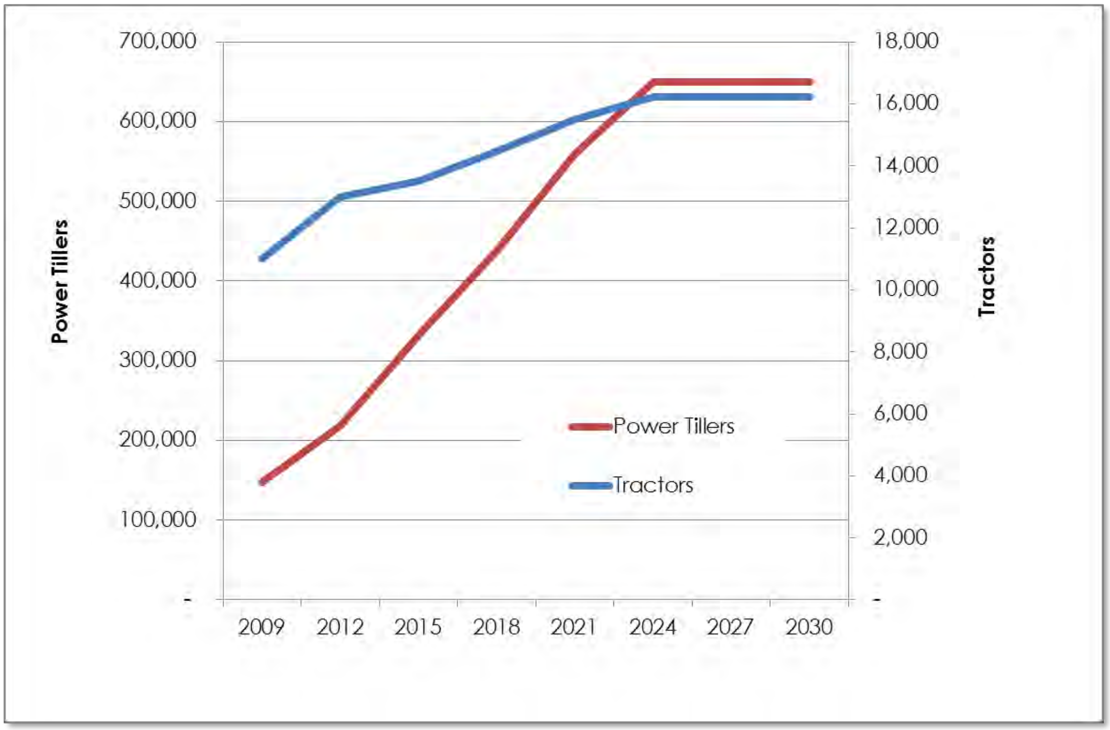
44. The total land under cultivation impacts the total requirement for motive power, for irrigation water and fertilizer. Farms of small size, say 2 hectares are not well suited to large, more efficient tractors, due to uneven surface levels between farms and inadequate turning circle.

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.

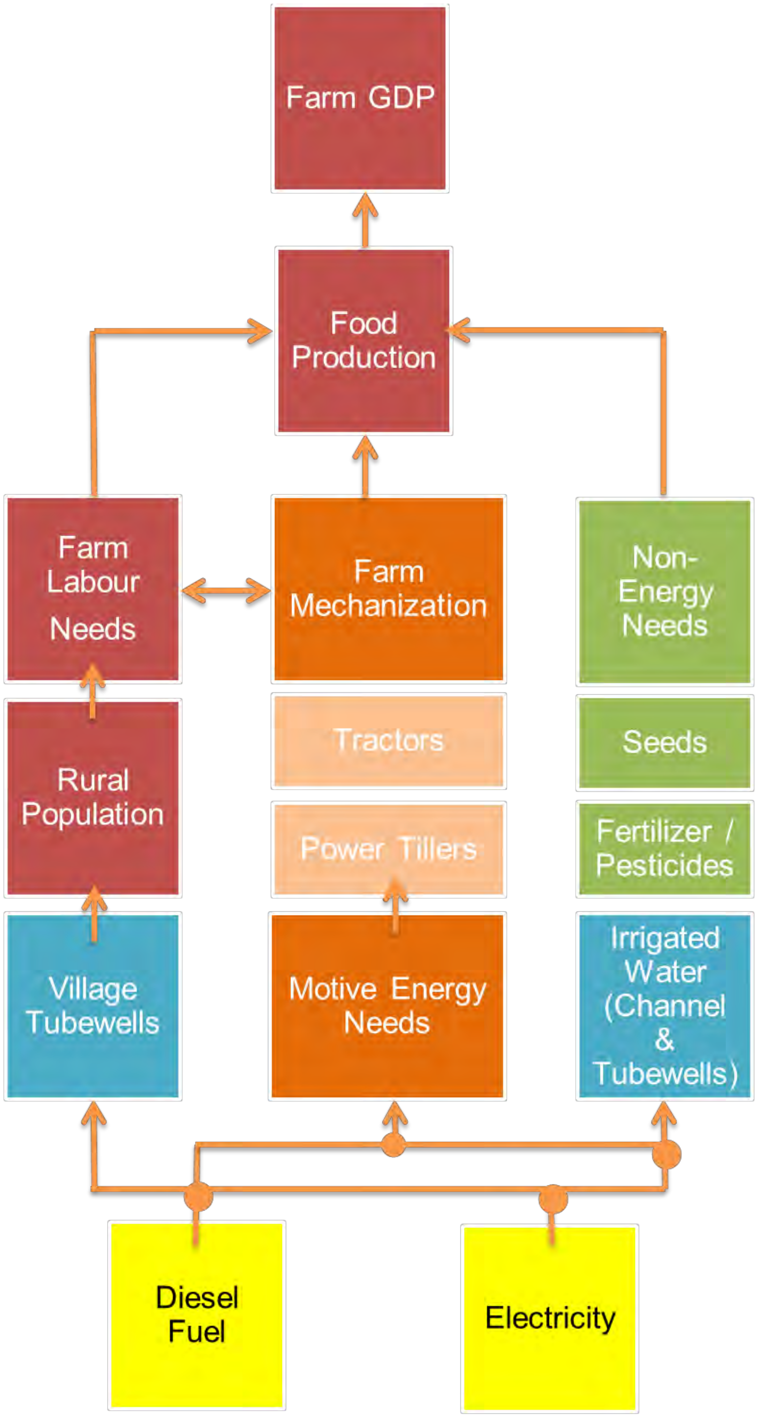
46. Model projections for the tractor inventory (small and large tractors) are shown in Figure II-31 for the medium growth trajectory.

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

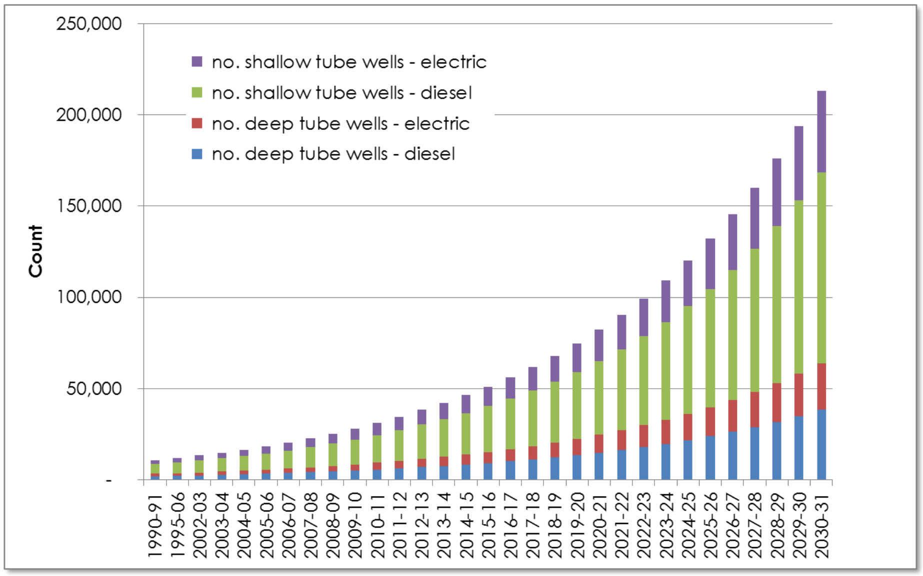
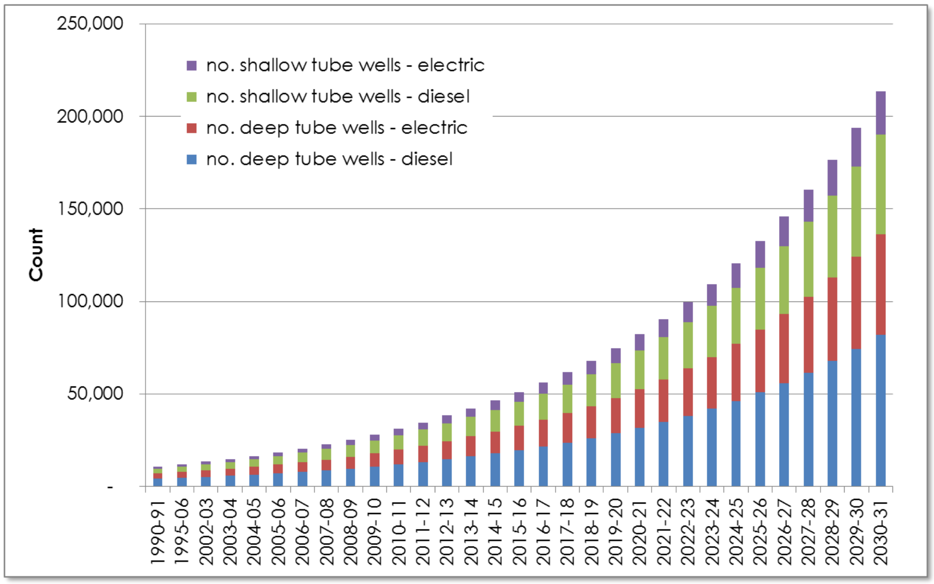


Figure II-34: Village Water Supply Tube-well Inventory Projection



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

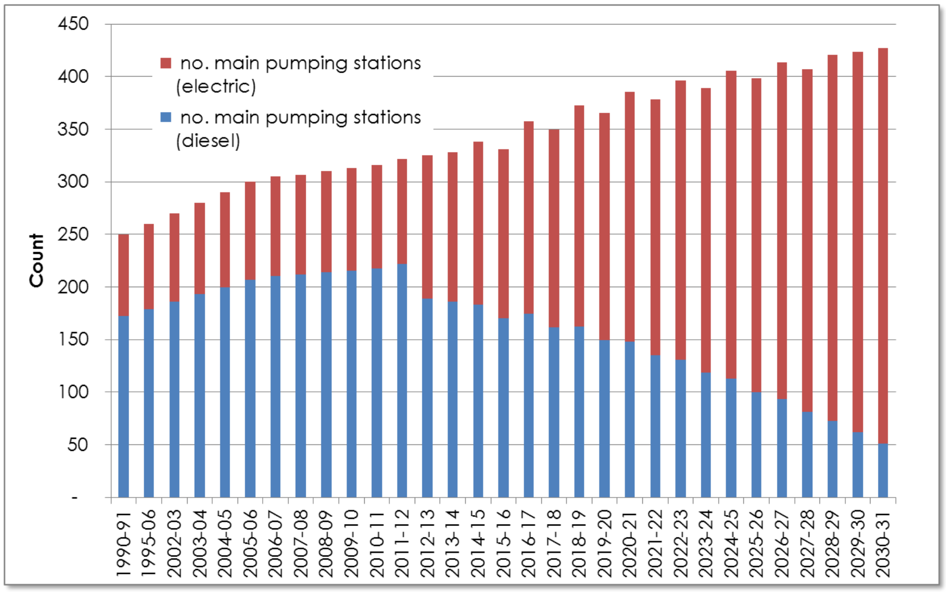
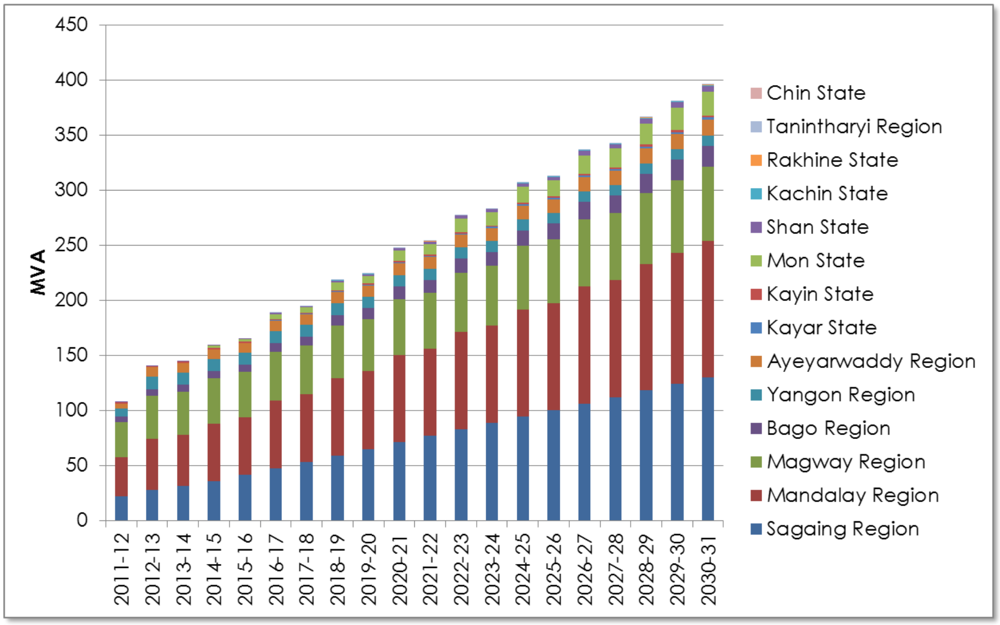


Figure II-36: River Pumping Station Capacity Projection



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

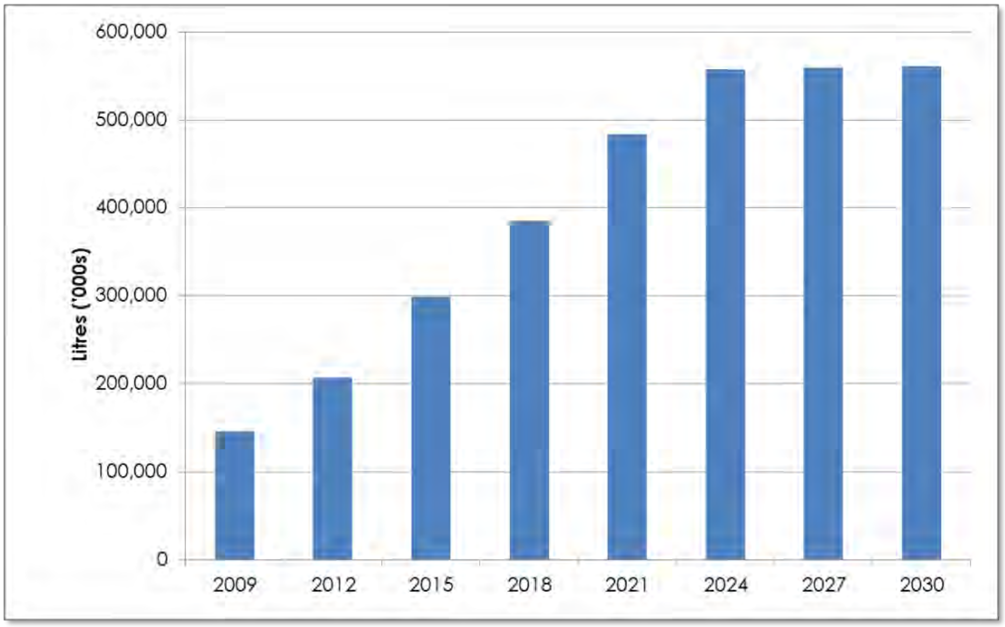
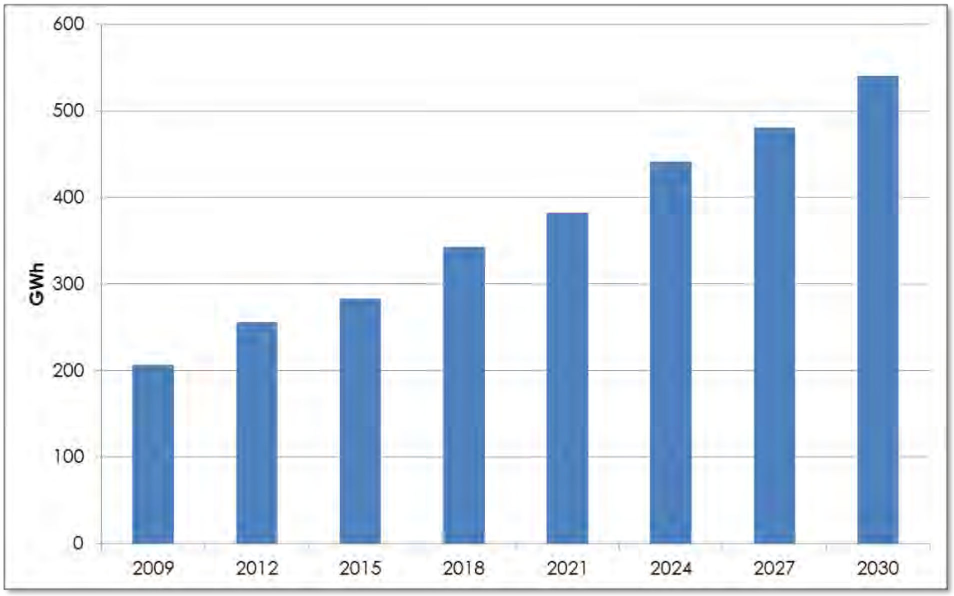
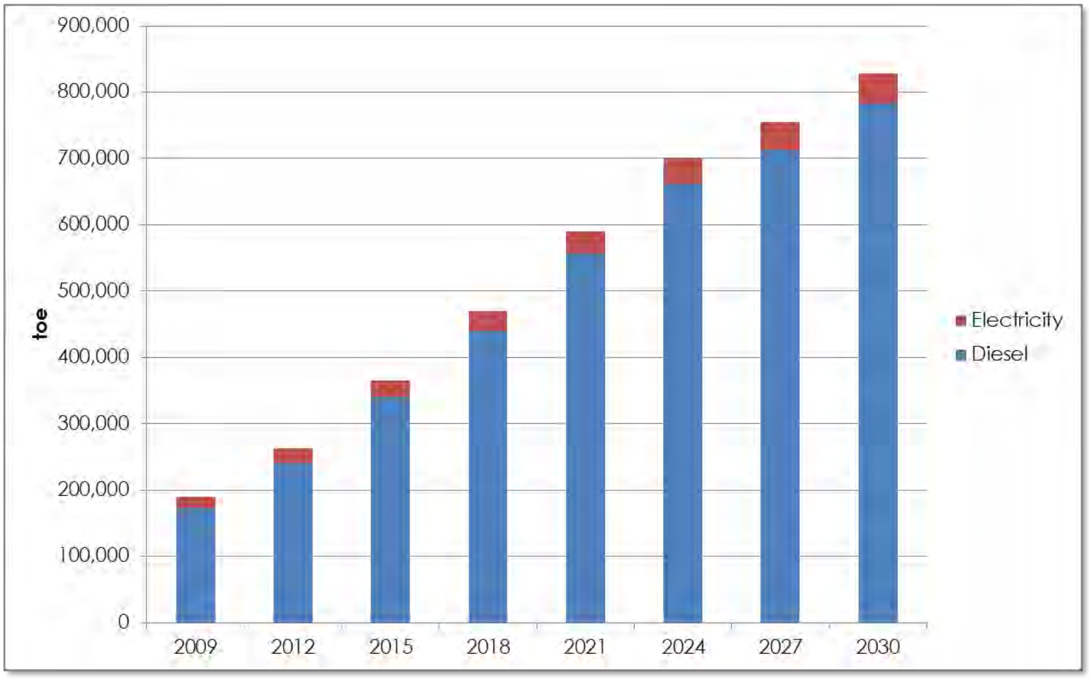


Figure II-38: Estimated Electricity Consumption



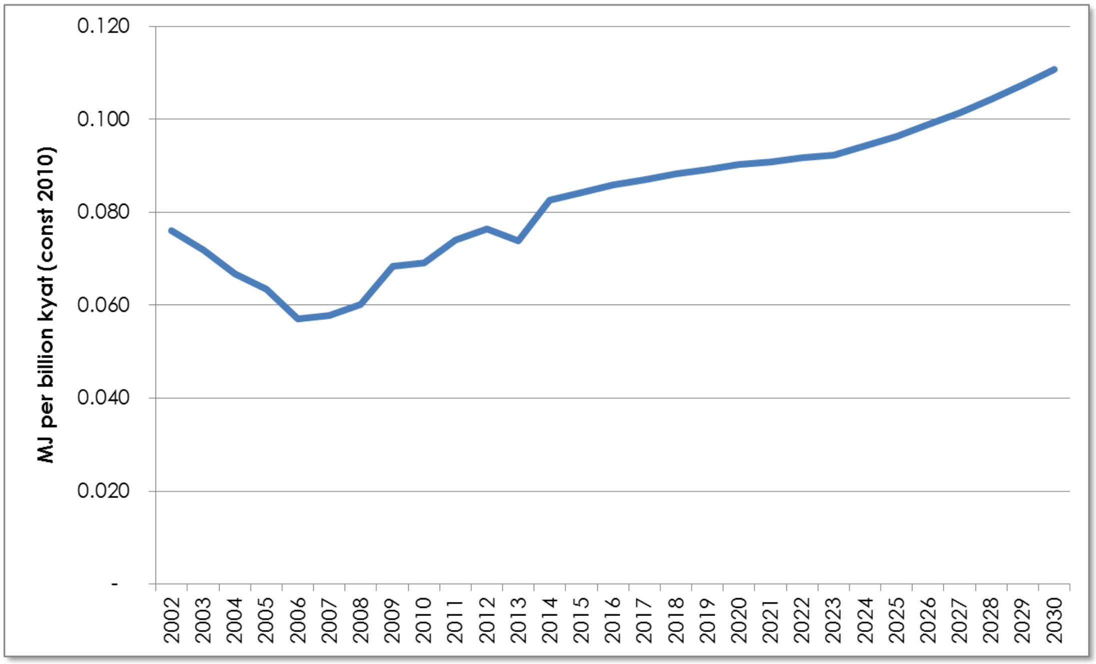
Sources: Consultant

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

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

CONVERSION FACTORS

1 litre = 0.22 Imperial Gallon
1 km = 0.62137 mile

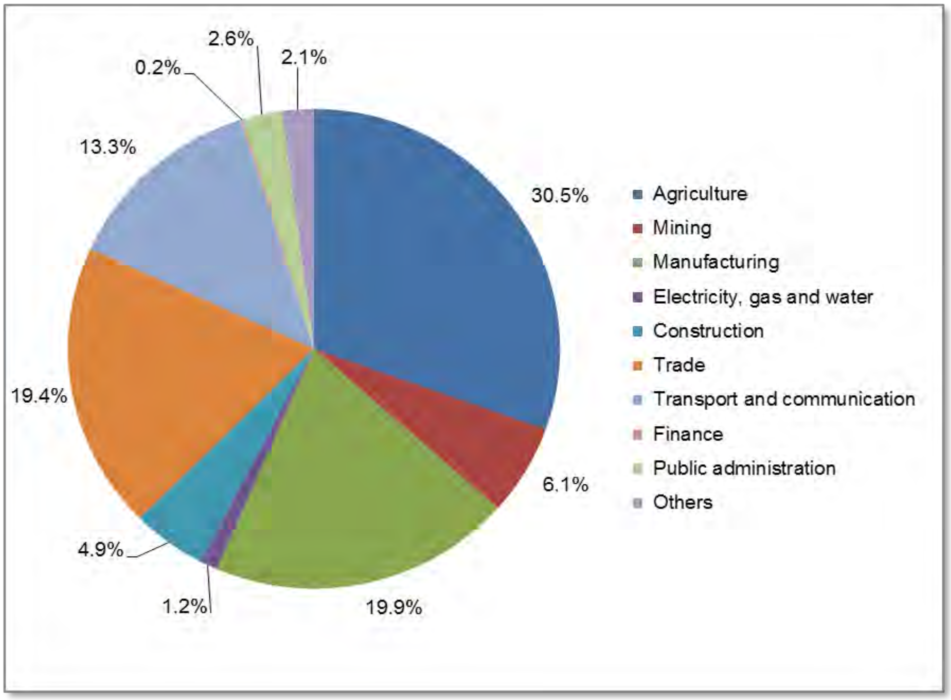
CONTENTS

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%.

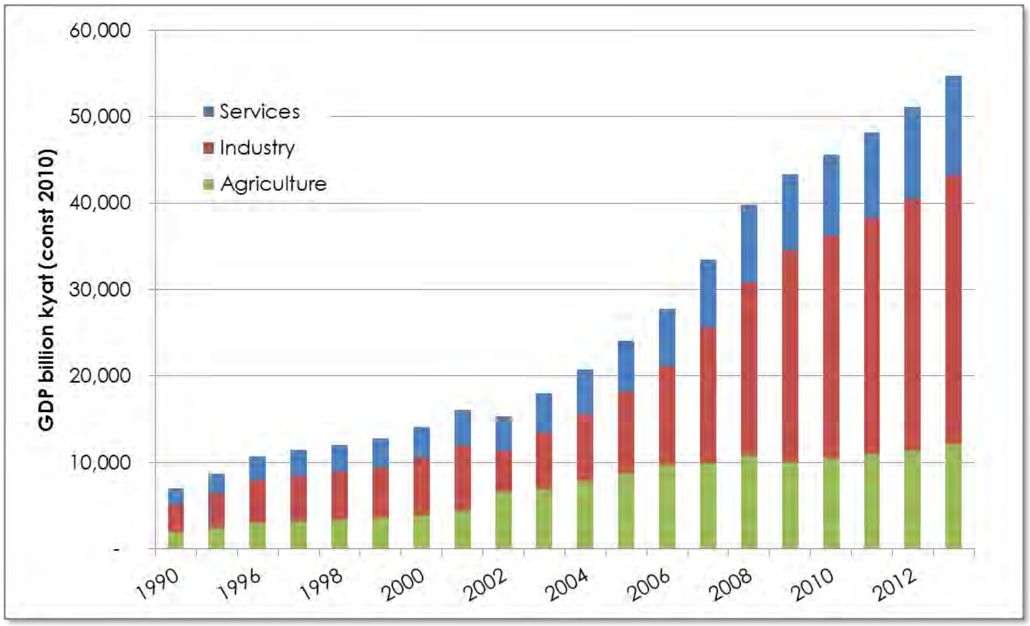
Figure I-1: Myanmar's GDP by Composition (2012)



Source: ADB

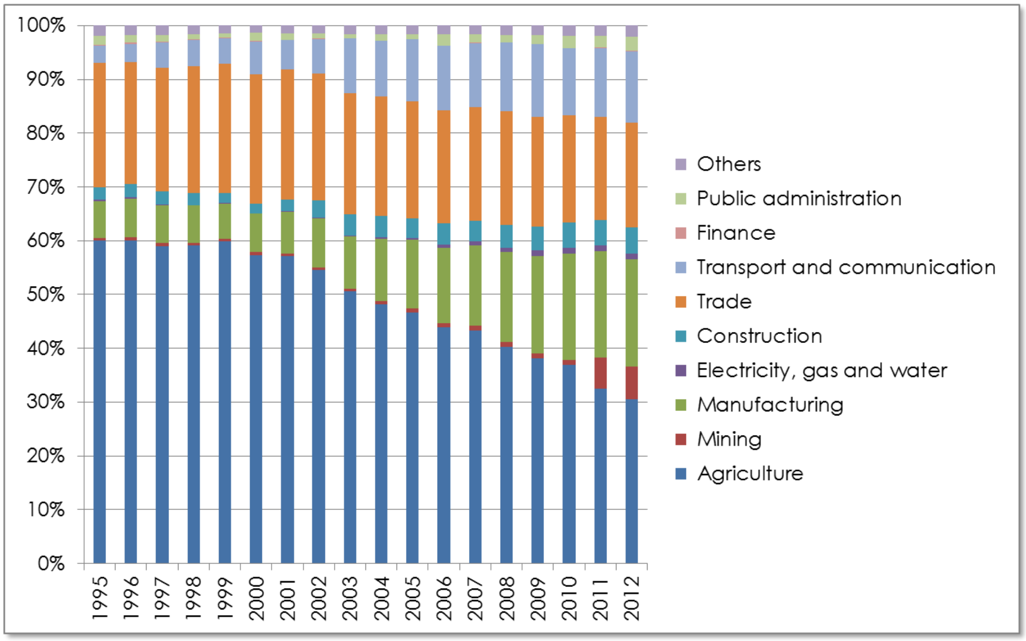
2. Industry sector GDP contribution has been steadily increasing; the historical compound annual growth rate of Myanmar's Industry sector GDP for the period 2004 to 2012 was reported to be 16.4%. The composition of GDP shows that the contribution of the Industry sector has been increasing steadily as 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.

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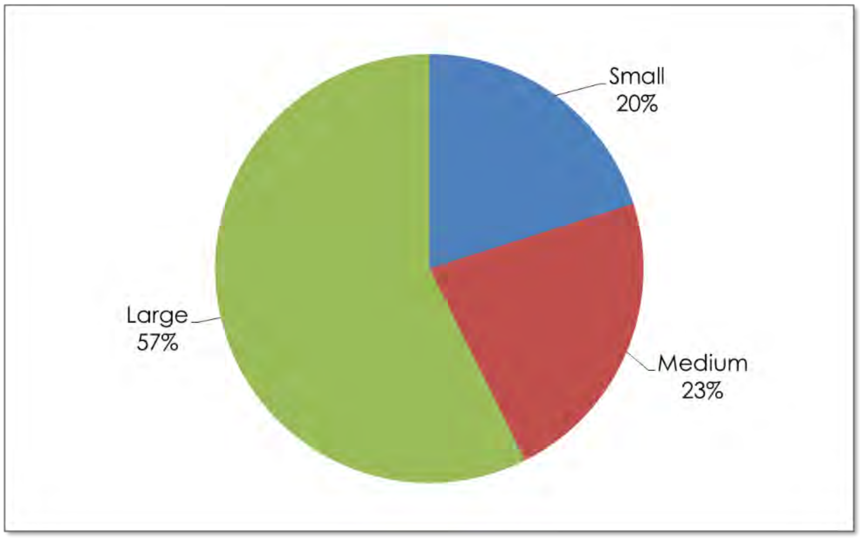
[1] New Government's Initiative for Industrial Development in Myanmar; Aug Min & Toshihiro Kudo, 2012

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.

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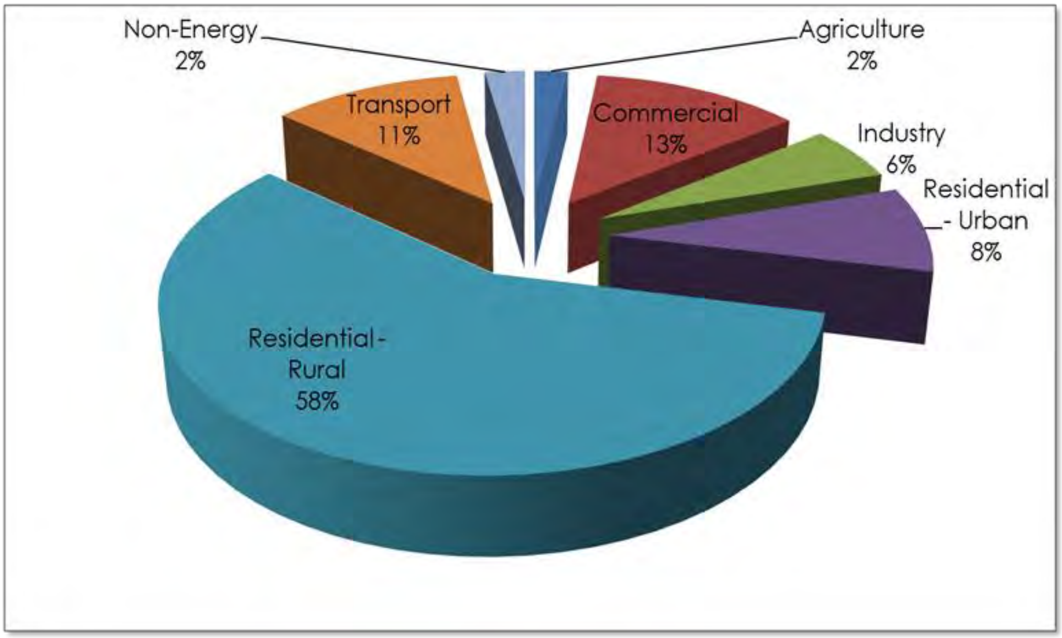
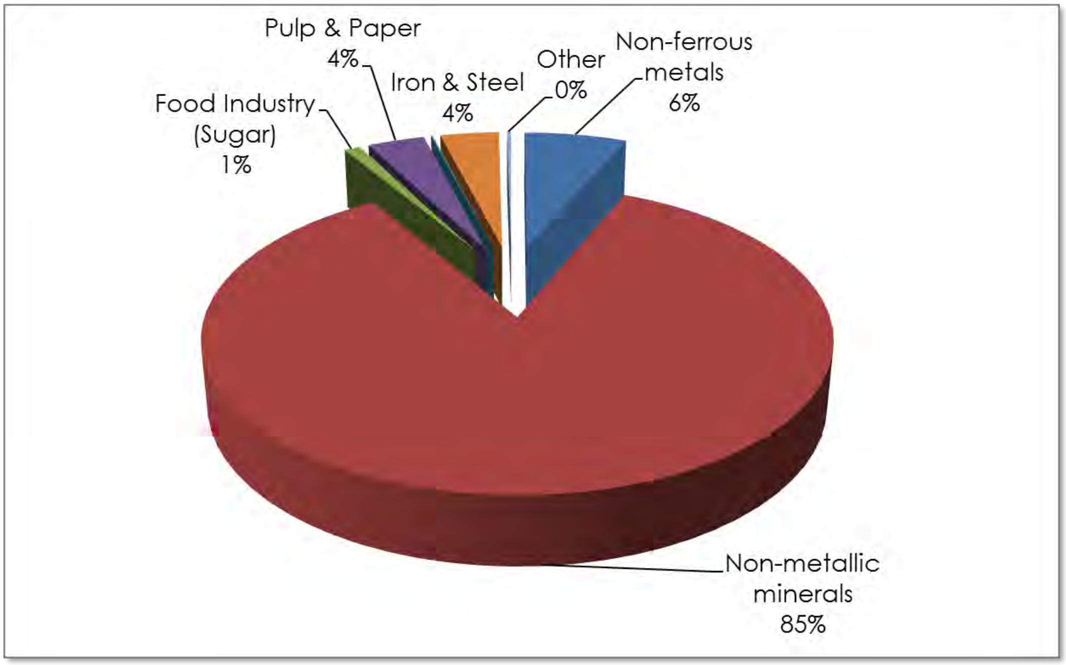
[2] Small industry is categorised as 3 to 25HP; medium 26 to 50HP; large greater than 50HP

Figure I-5: Final Energy Consumption 2012-13



Source: Consultants' analysis

Figure I-6: Large Industry FEC: 2012 - 13 (0.398 mtoe)

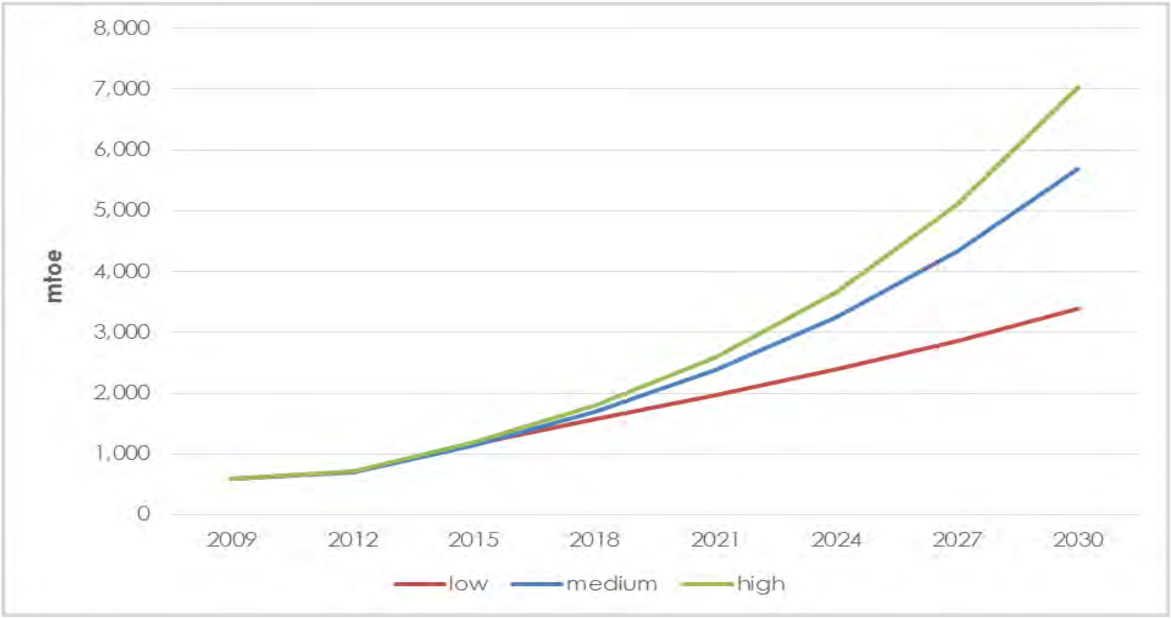


Source: Consultants' analysis

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)

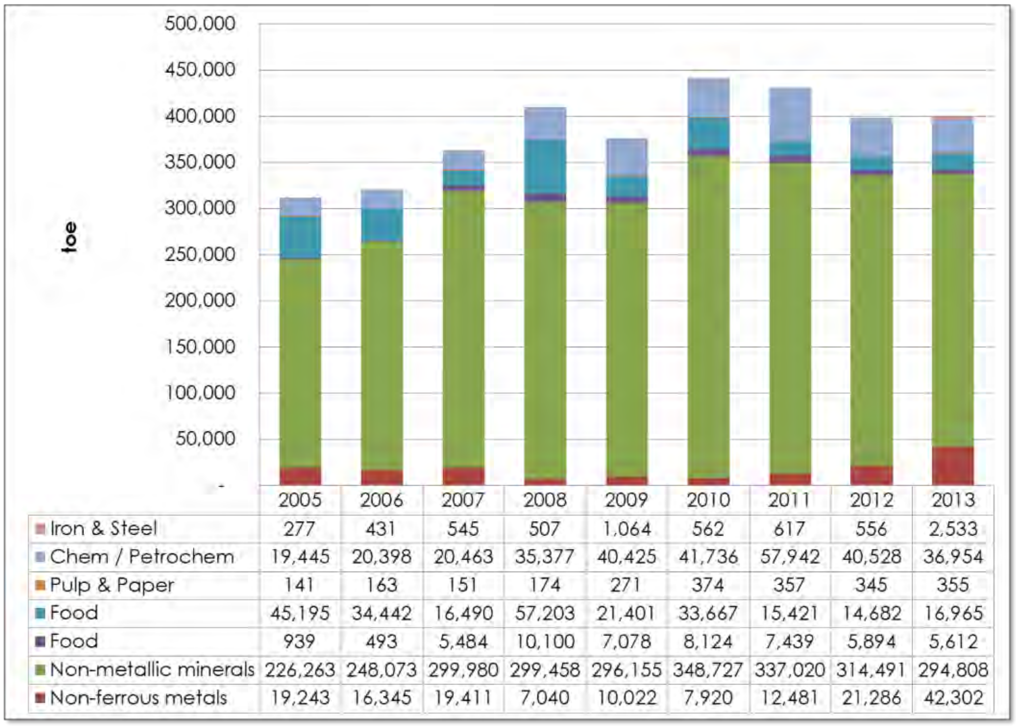


Sources: Consultant

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.

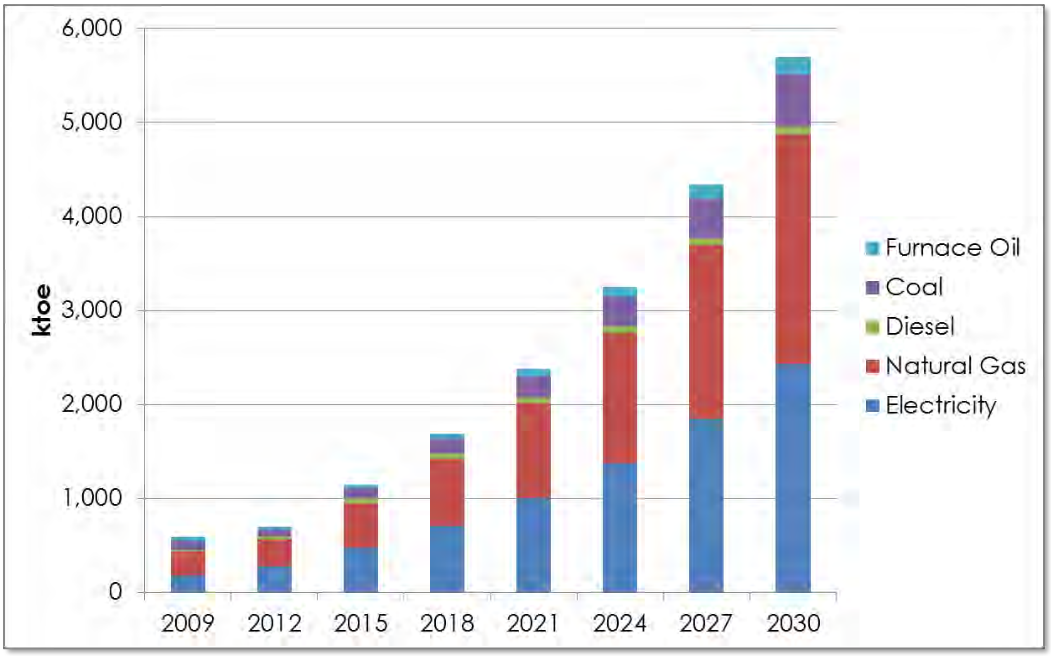
Figure I-8: Energy-Intensive Industry Sector FEC Forecast (toe)



	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

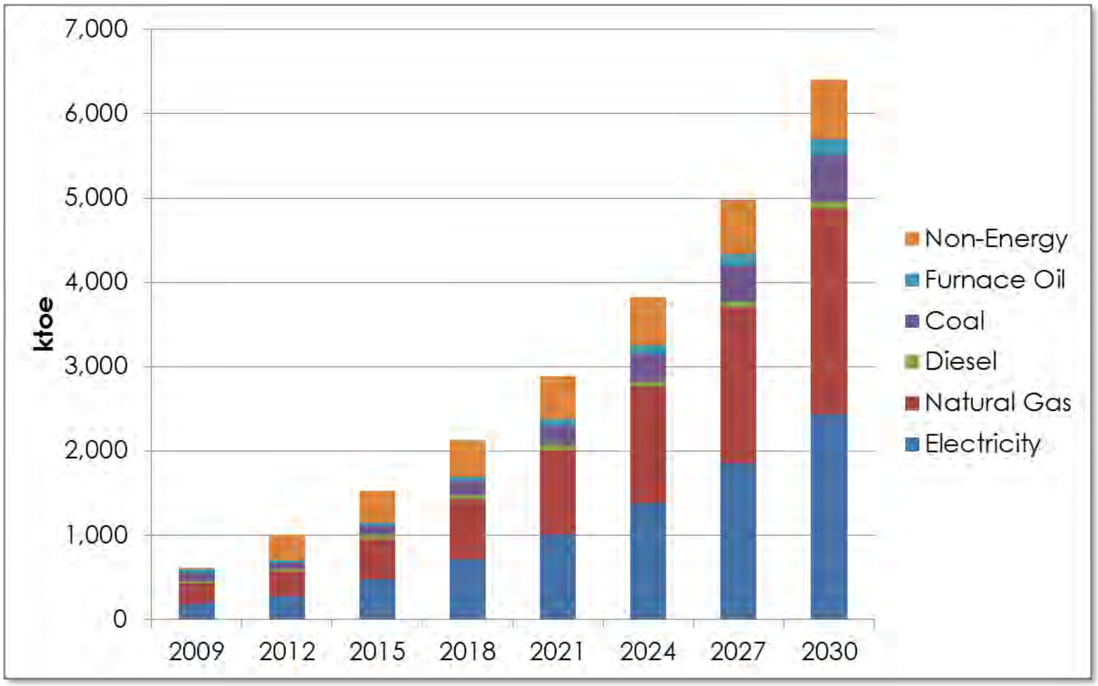
Sources: Consultant

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

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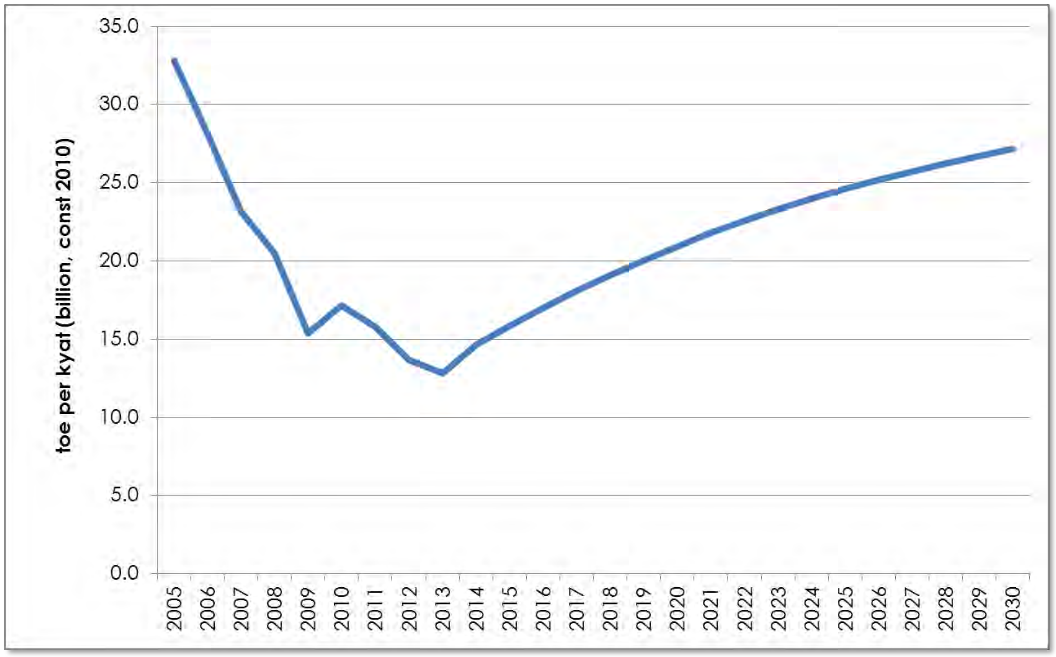
[3] Diesel consumption also accounted for in the Transport sector forecast for registered on-road vehicles

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

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[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

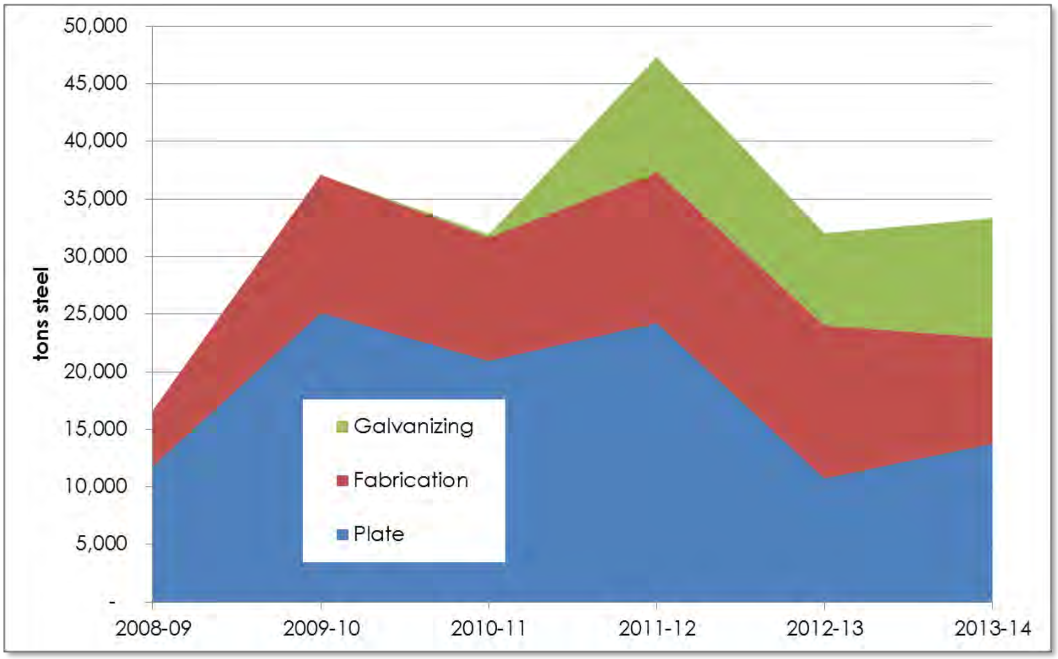
21. Myanmar has three rich iron deposits. The first deposit is in Pyin Oo Lwin (Kyadwinyay) with three million tons of iron ore. The second deposit is in Pinpet on the border between Taunggyi and Hopong townships, with 70 million tons of iron ore. The third is in Kathaingtaung with 230 million tons of 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.

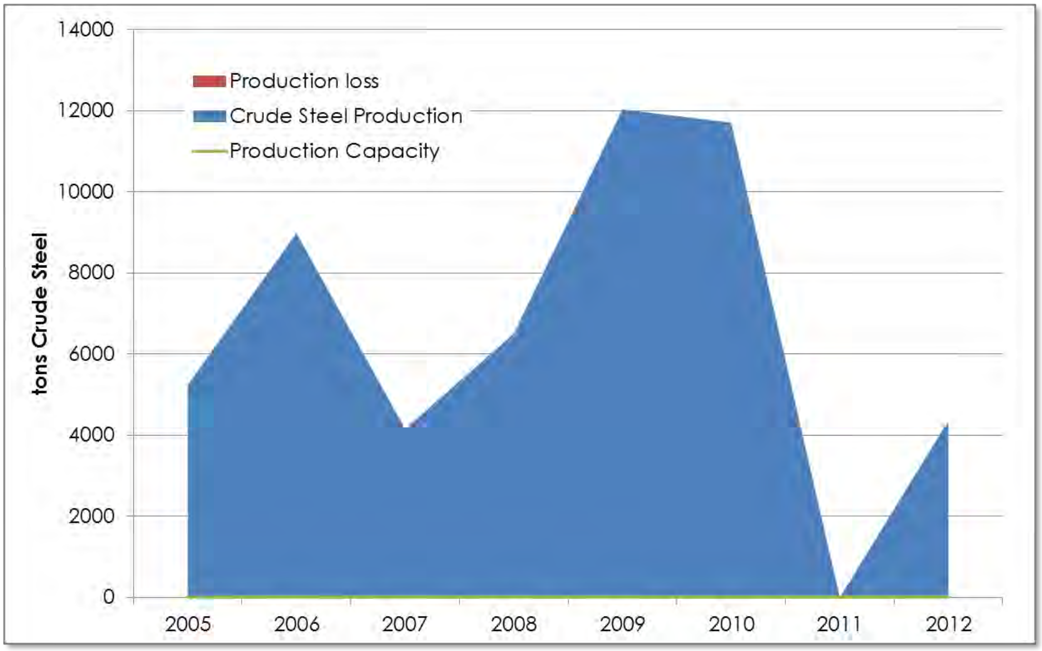
23. The production of the steel plants was established by survey. Steel Plant no. 1 reported an annual production of 40 000 tons of sponge iron, 7 000 tons of pig iron and 25 000 tons of liquid steel over the last decade. The production of Steel Plants no. 2 and 3 are given in Figure III-1 and Figure 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).

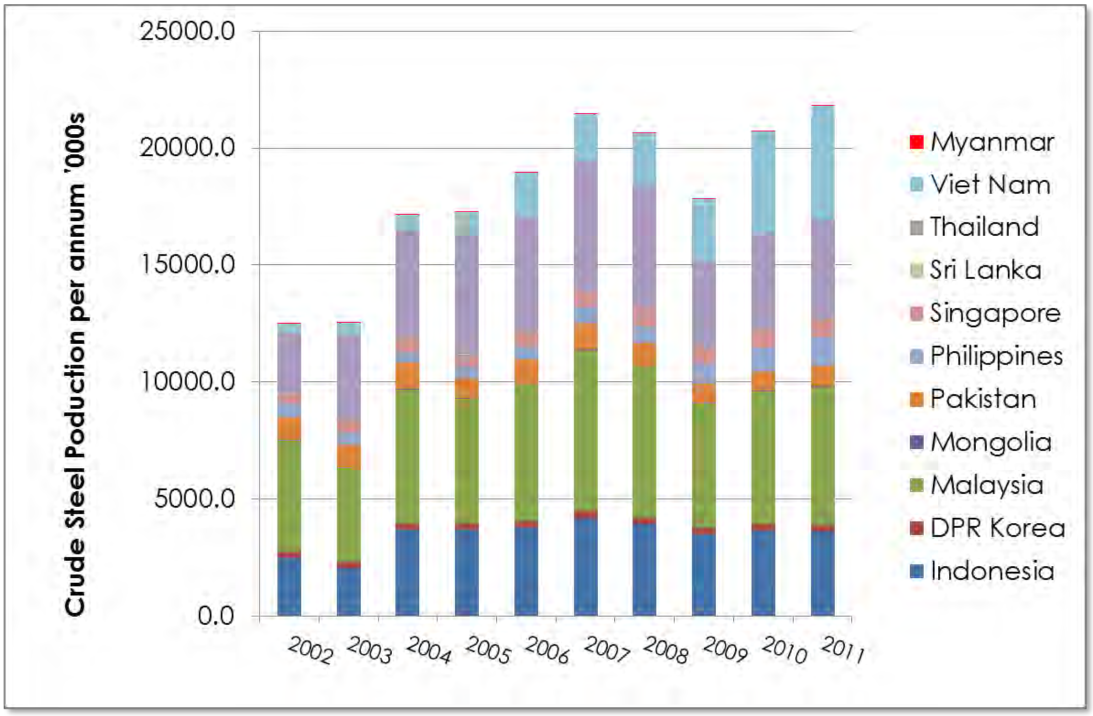
Table III-3: Total Steel Production (Crude & Fabricated Steel)

	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.

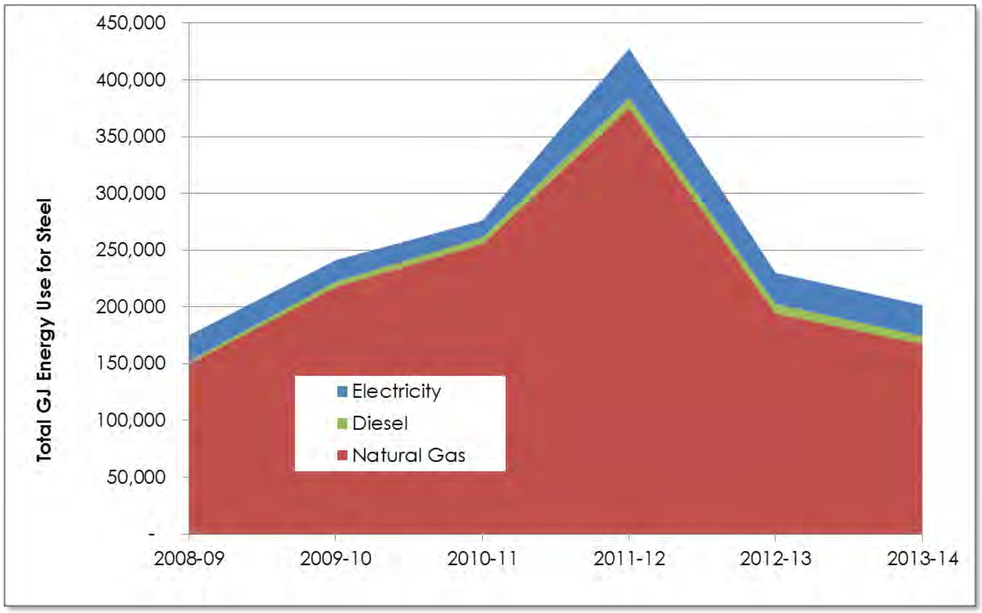
Figure III-4: Crude Steel Production in Asia (excluding PRC)



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.

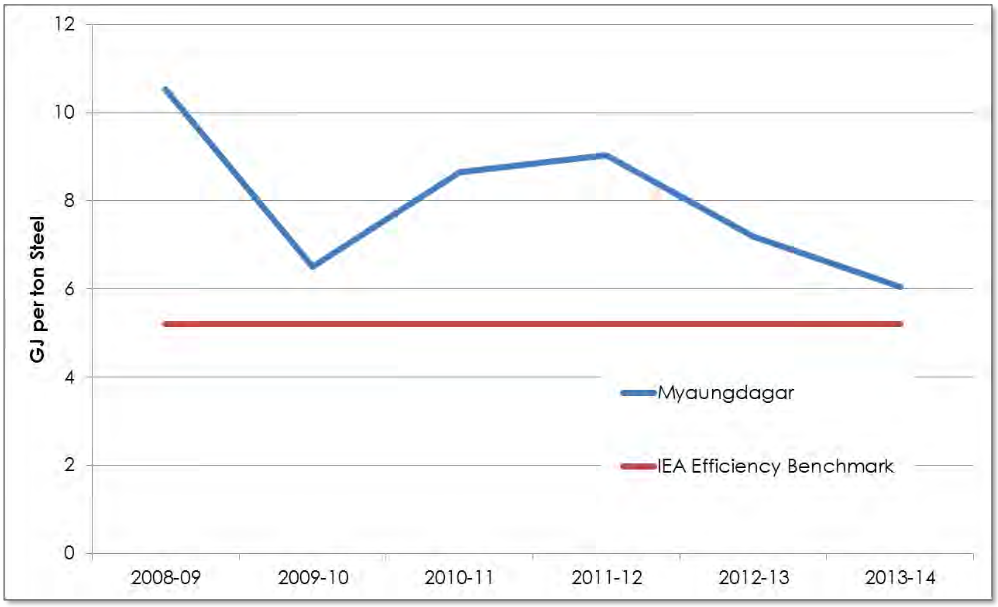
Figure III-5: Energy Consumption of no. 2 Steel Plant by Carrier



Sources: EMP Industry Survey

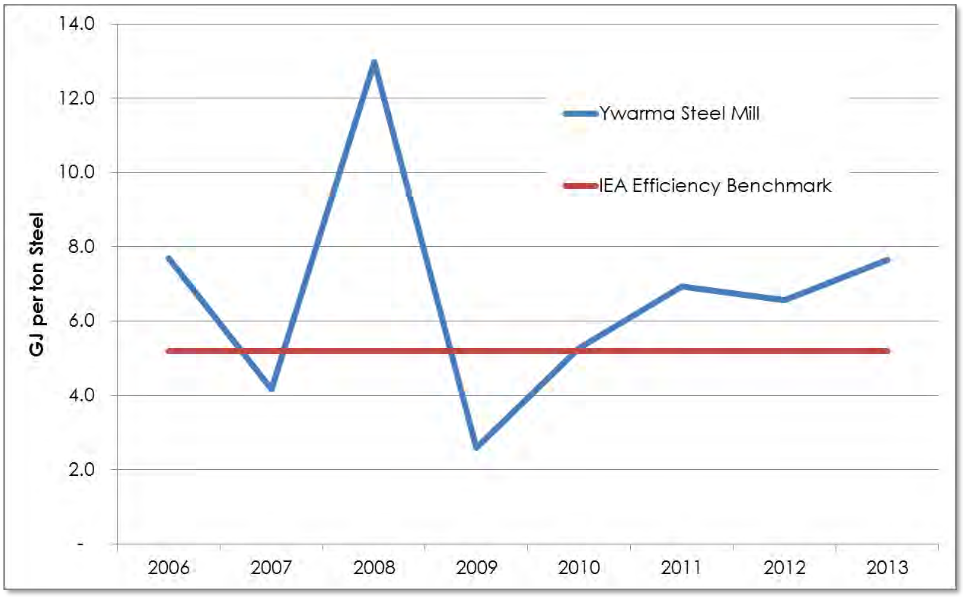
27. The average energy consumption of the iron and steel sub-sector in recent years is estimated to have been around 5 GJ per ton. This has been determined from the EMP survey of Myanmar's steel plants.

Figure III-6: Energy Efficiency of no. 2 Steel Plant



Sources: EMP Industry Survey

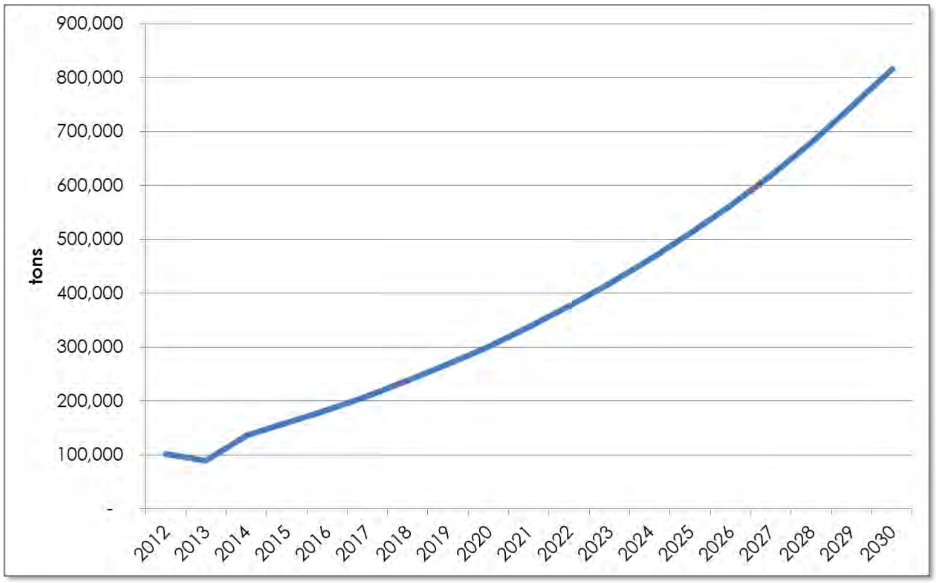
Figure III-7: Energy Efficiency of no. 3 Steel Plant



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.

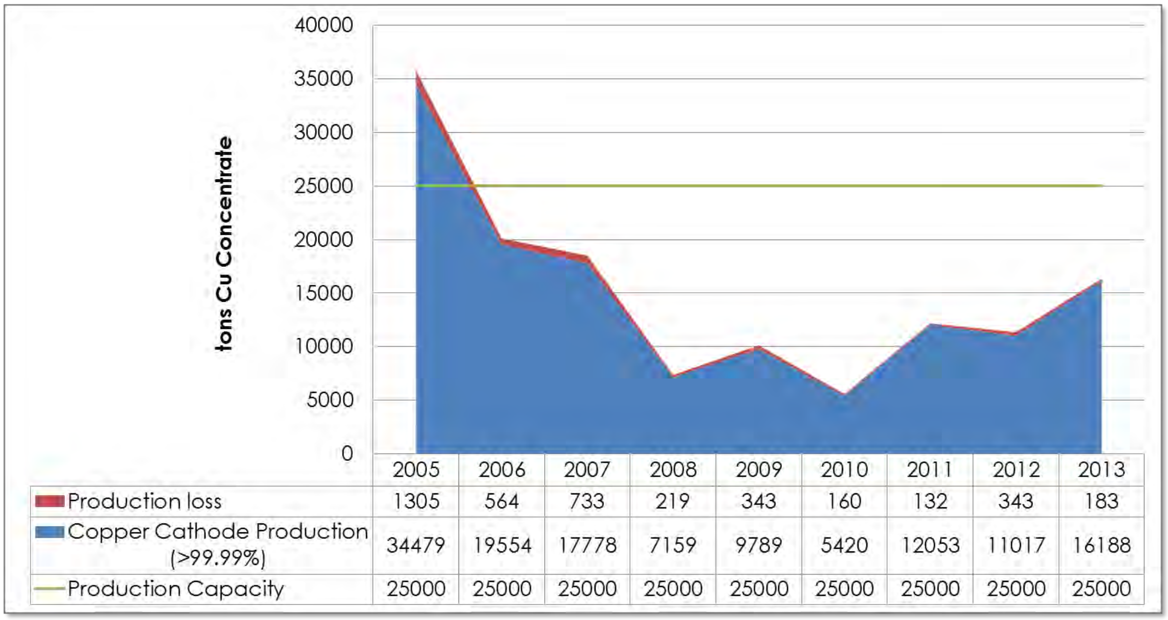
31. The copper is processed using an electro-winning process:-

- 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.

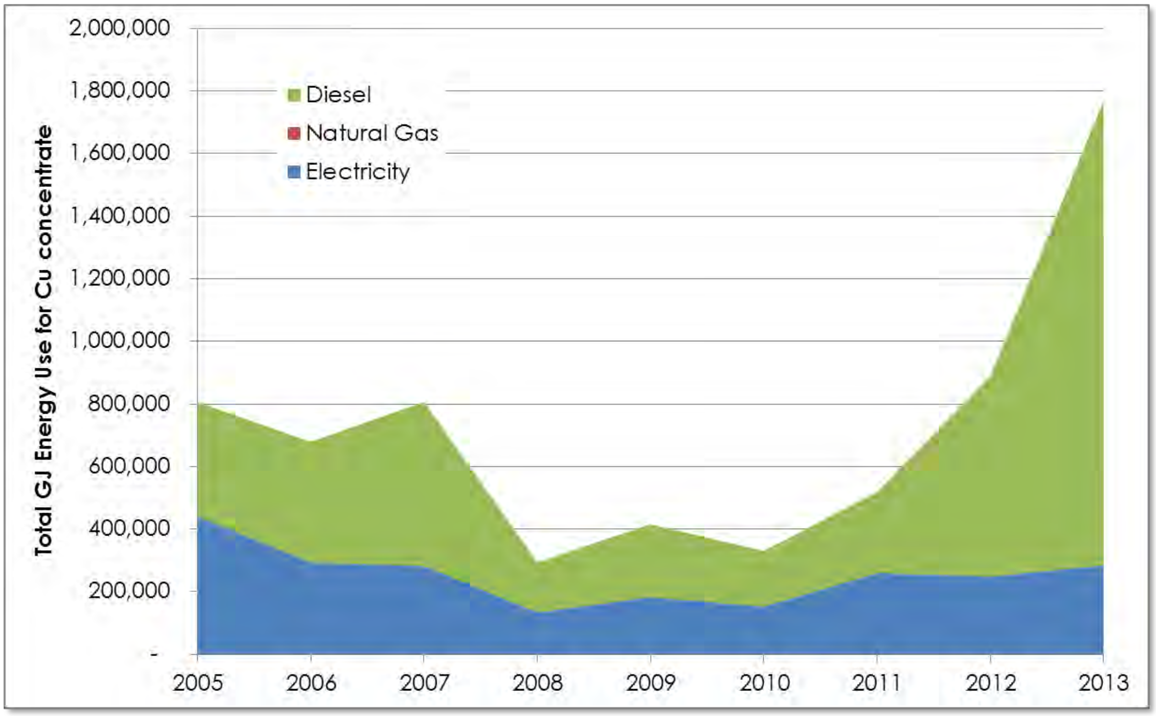
Figure III-10: Copper Concentrate Production (tons)



	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

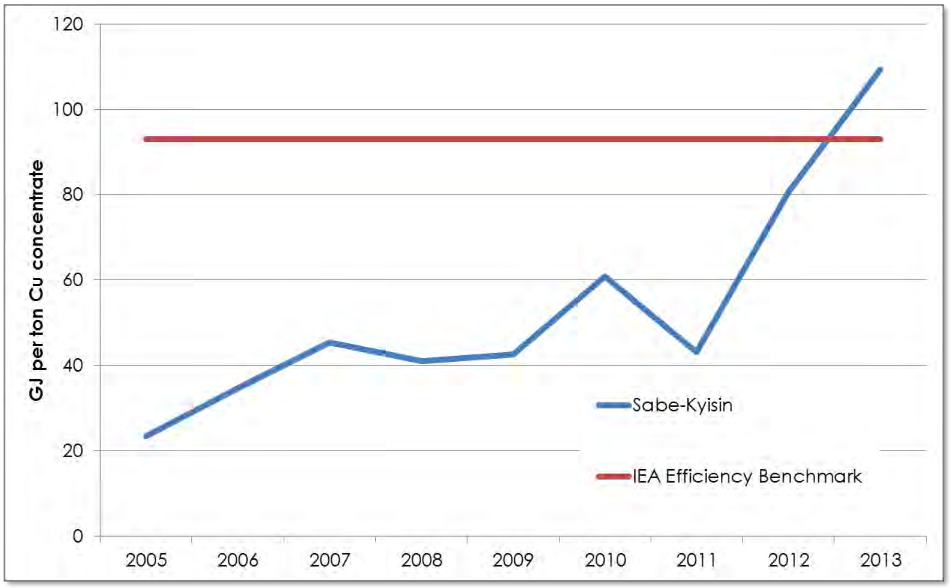
Figure III-11: Energy End-Use per ton: Copper Concentrate



Sources: Industry Sector Survey, Consultant

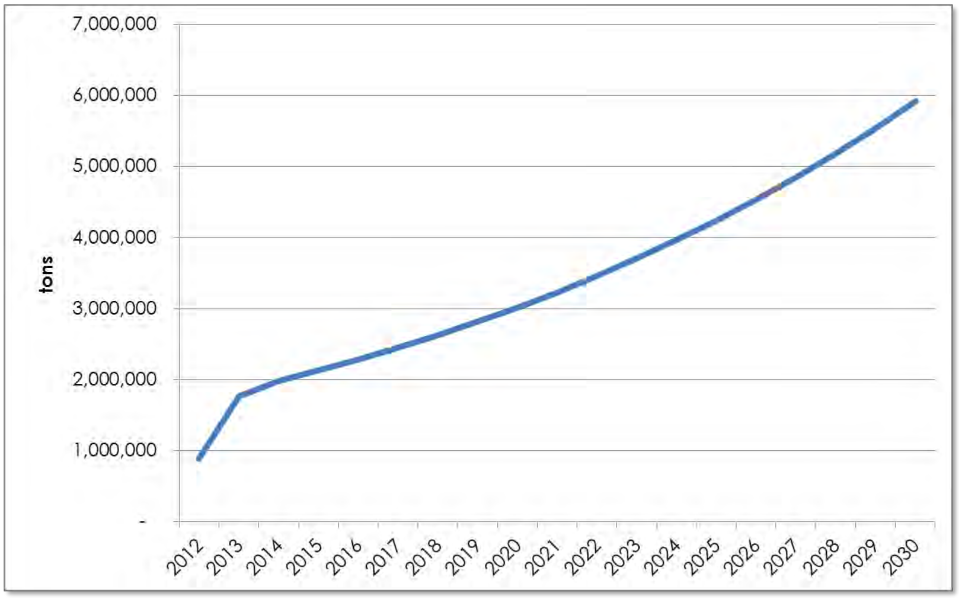
34. The average energy consumption of the copper concentrate production in recent years is estimated to have been around the IEA benchmark of 93 GJ per ton. The energy consumption forecast for copper is made according to expected industry sector GDP growth after which the corresponding steel production 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.

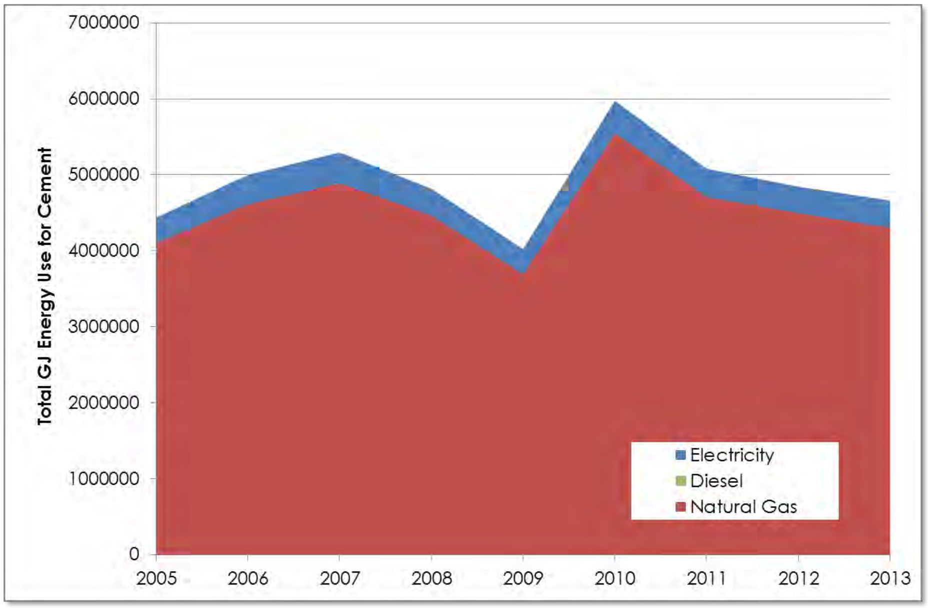
Table III-16: Cement Production tons

	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

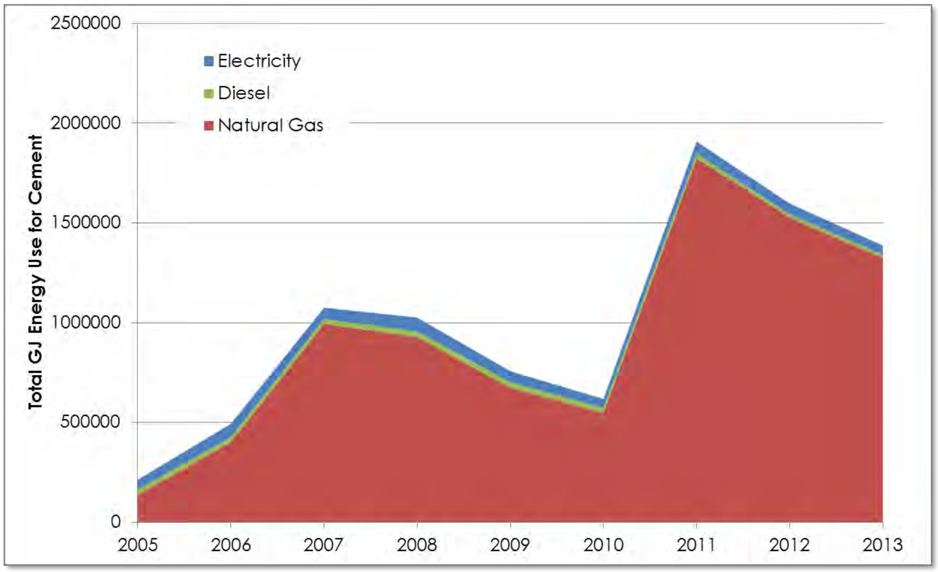
38. The large cement mills use natural gas as their primary fuel as shown by Figure III-17.

Figure III-17: Cement Production: Pa-An



Sources: Industry Sector Survey, Consultant

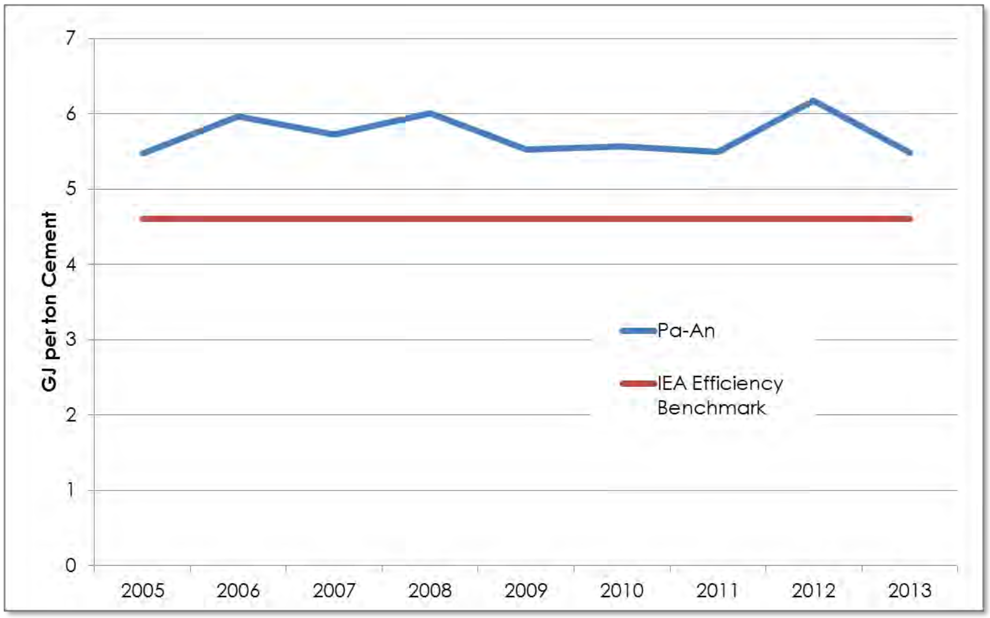
Figure III-18: Cement Production: Thayet



Sources: Industry Sector Survey, Consultant

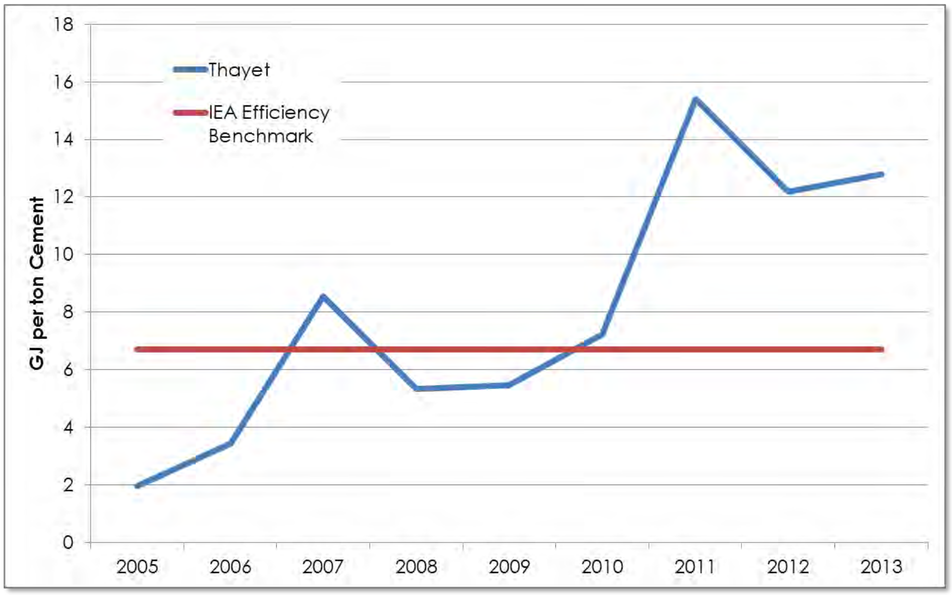
39. Fuel use and cement production was used to calculate the GJ per ton for cement production, which was found to average 6 GJ per ton (wet and dry kilns).

Figure III-19: Energy Efficiency at Pa-An



Sources: Consultant

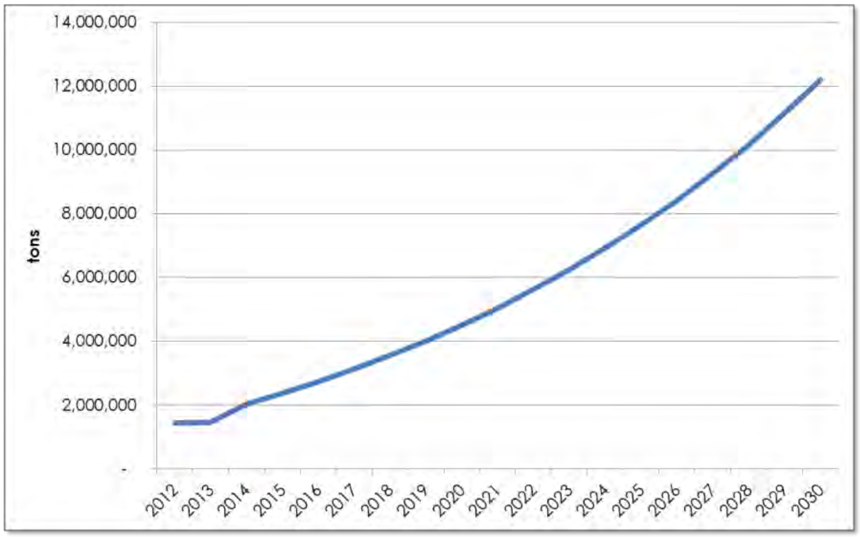
Figure III-20: Energy Efficiency at Thayet



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

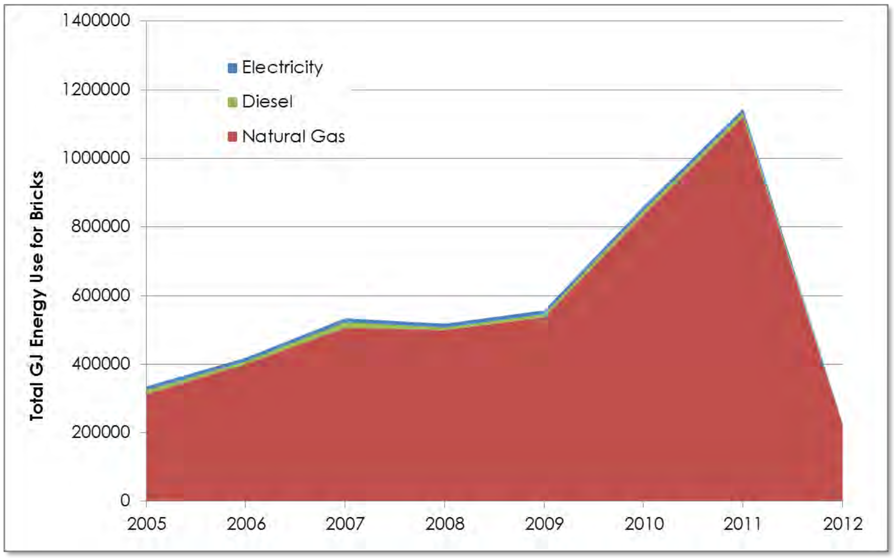
Table III-23: Brick Production (tons)

	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.

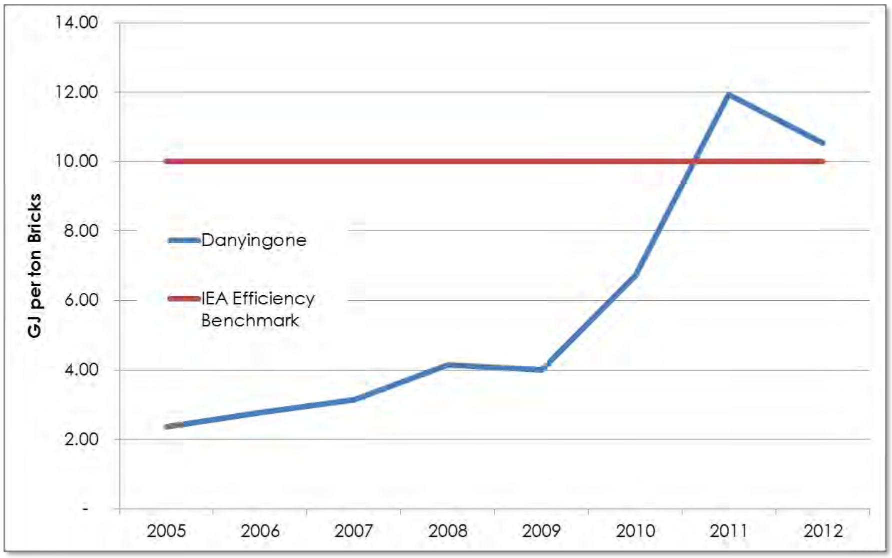
Figure III-24: Energy End-Use: Danyingone



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.

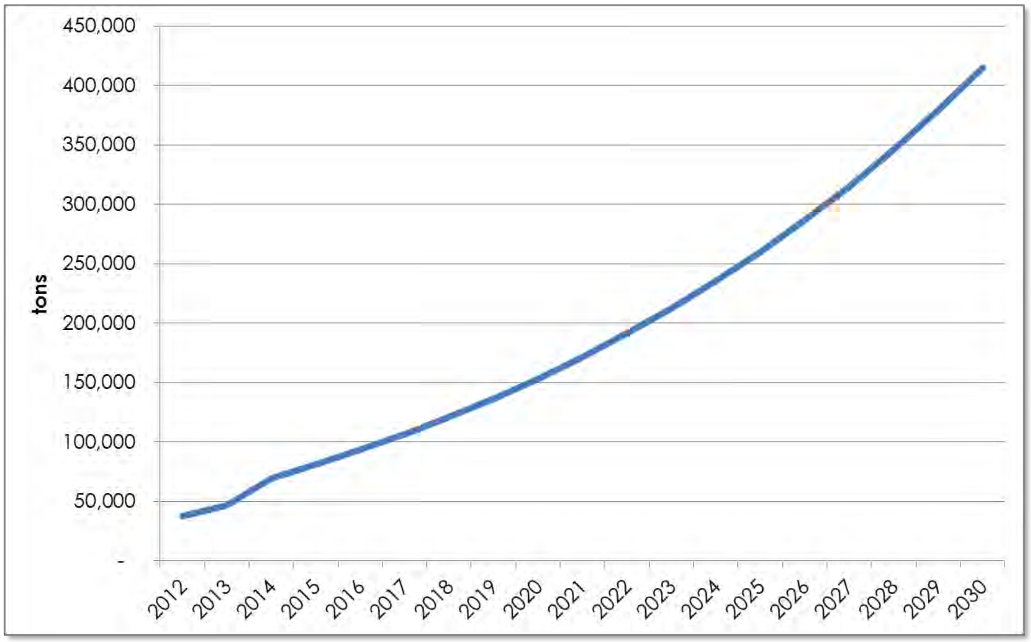
Figure III-25: Energy Efficiency at Danyingone



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

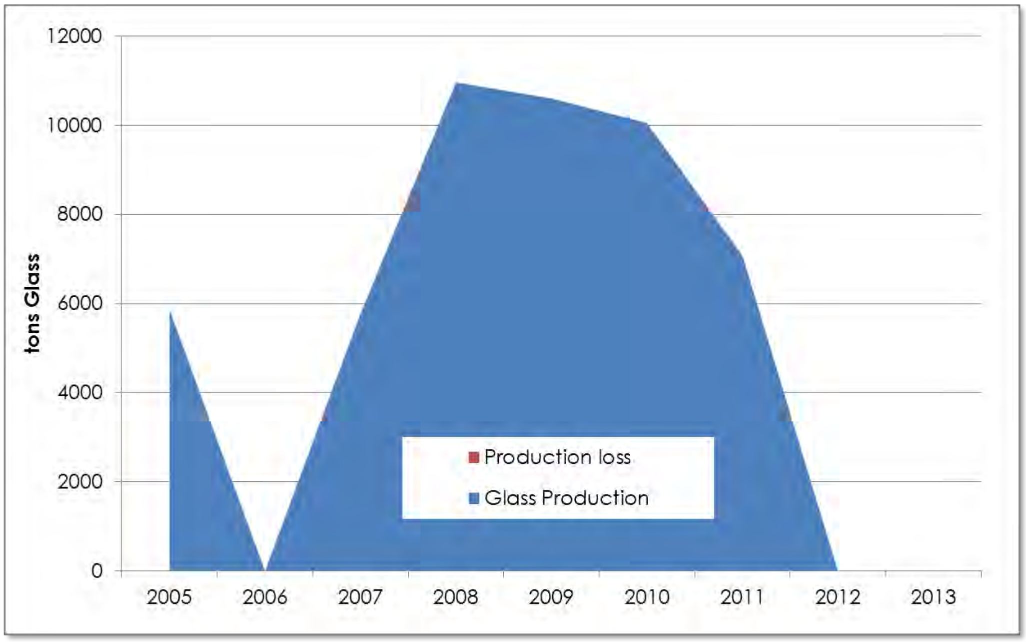
46. Two large glass factories were surveyed as representative of large glassworks. The reported production totalled 15,345 tons in 2013. There were no CSO statistics cited for glass production. It appears that for these two plants glass production has remained steady since 2005.

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

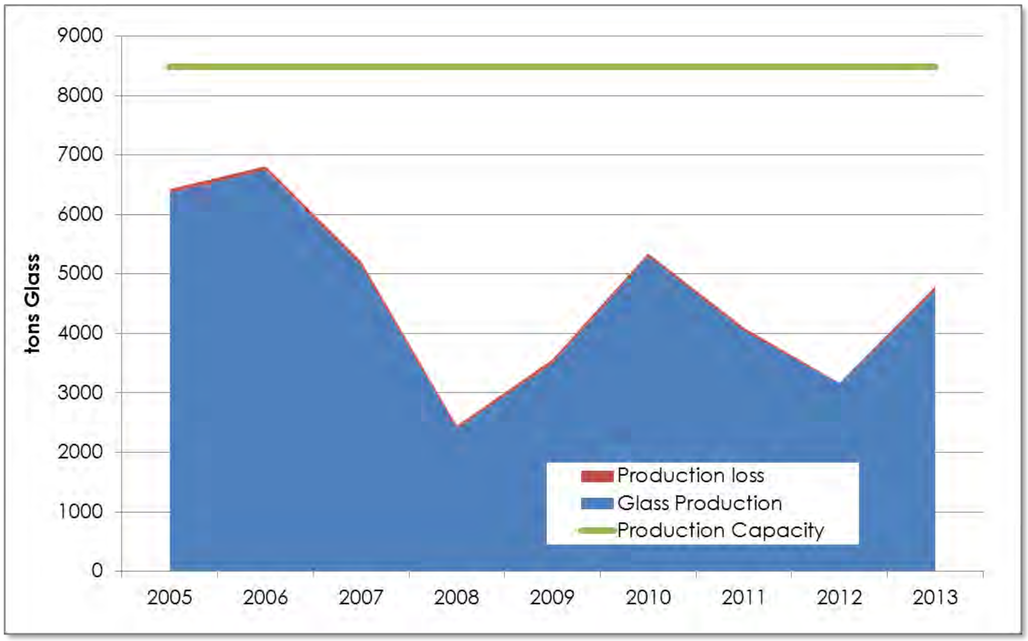
Sources: EMP Industry Survey

Figure III-28: Glass Production: Pathein



Sources: Industry Sector Survey, Consultant

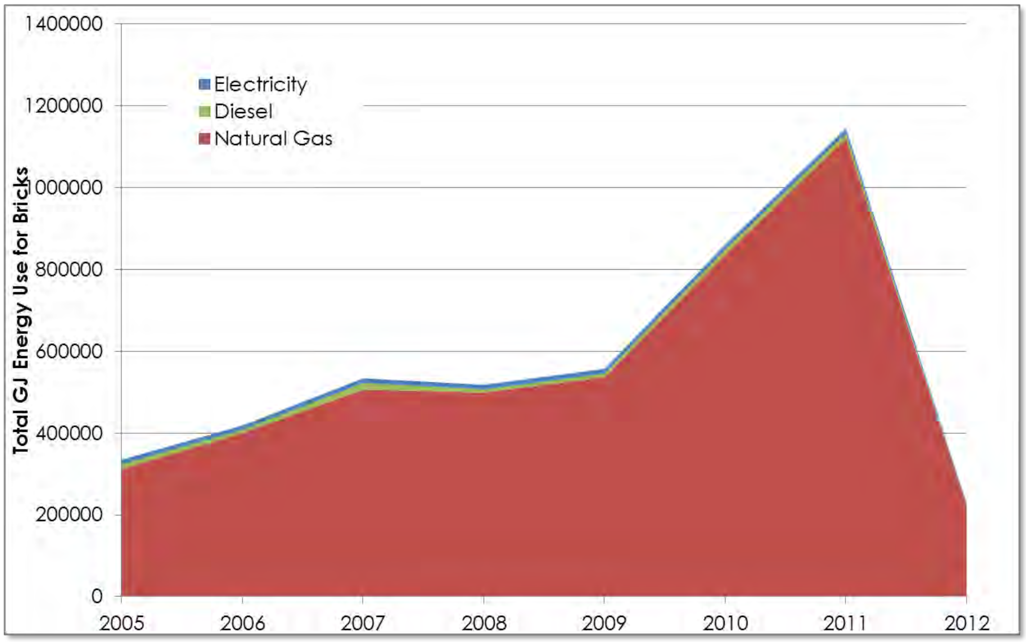
Figure III-29: Glass Production: Thanlyn



Sources: Industry Sector Survey, Consultant

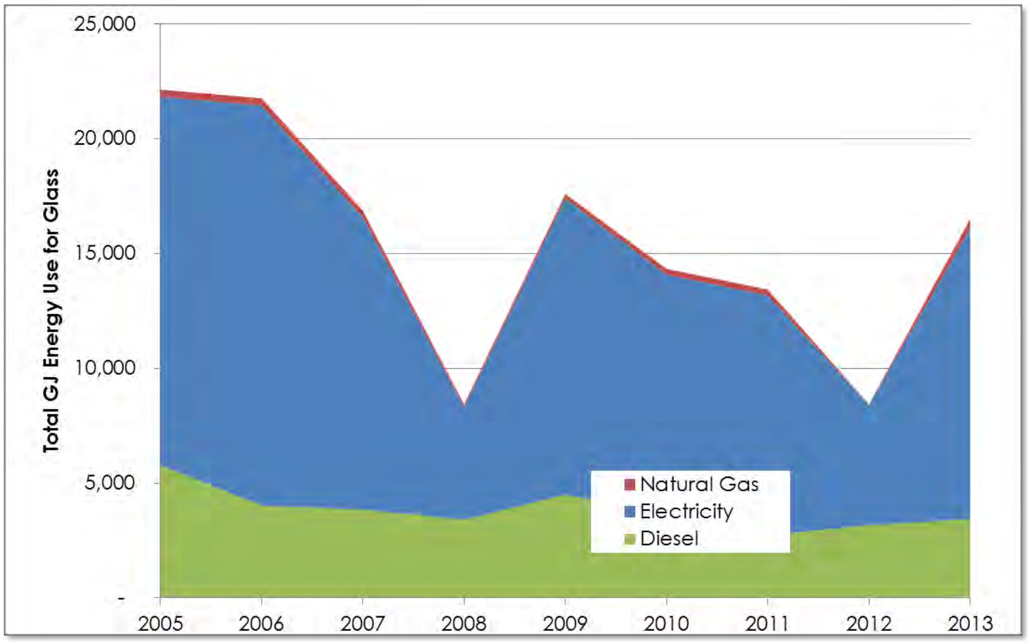
47. Pathein depends on natural gas and and Thanlyn on electricity as their primary fuel supply as shown by the following charts:-

Figure III-30: Energy End-Use: Pathein



Sources: Industry Sector Survey, Consultant

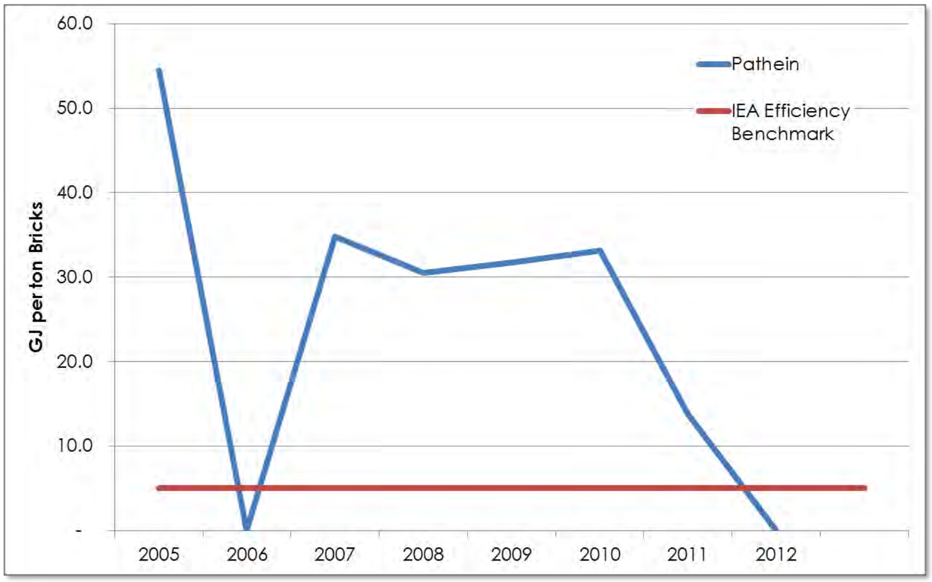
Figure III-31: Energy End-Use: Thanlyn



Sources: Industry Sector Survey, Consultant

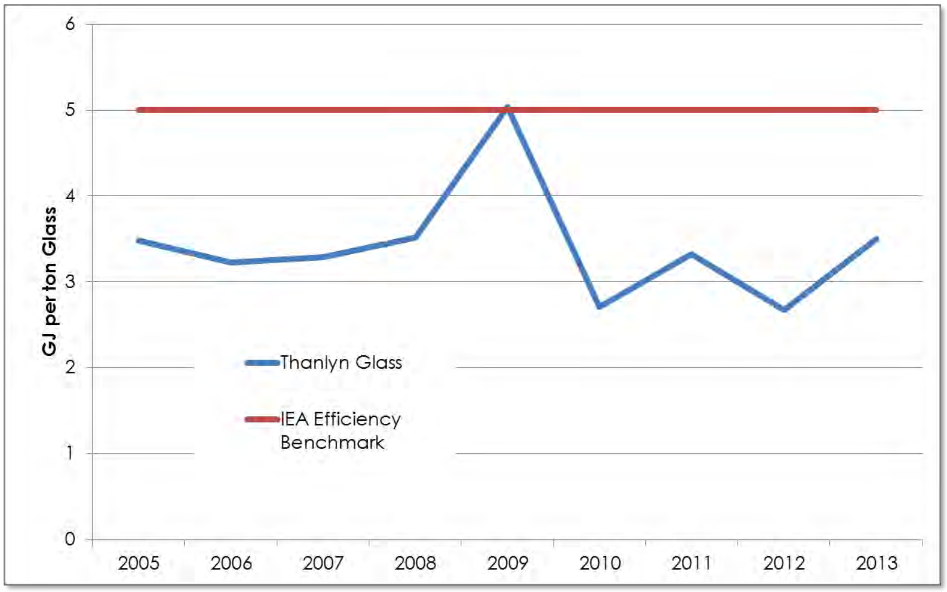
48. The average energy consumption for glass making at Pathein and Thanlyn is computed to average 6 GJ per ton, around the IEA energy efficiency benchmark for brick making. The energy consumption forecast for bricks is made according to expected industry sector GDP growth after which the corresponding steel production was computed by way of simple division by 6 GJ per ton.

Figure III-32: Energy Efficiency at Pathein



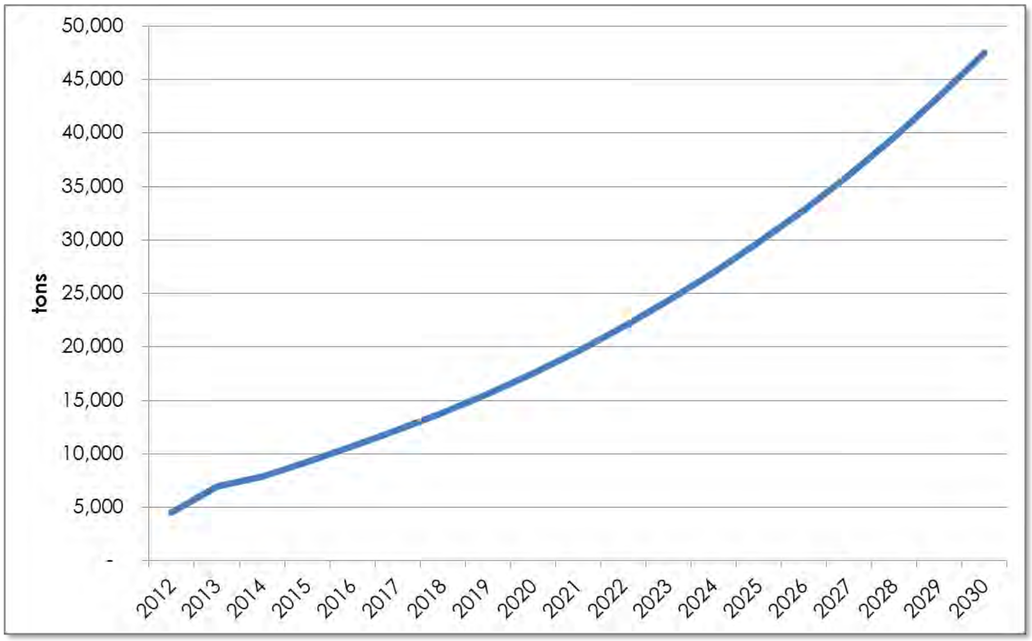
Sources: Consultant

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

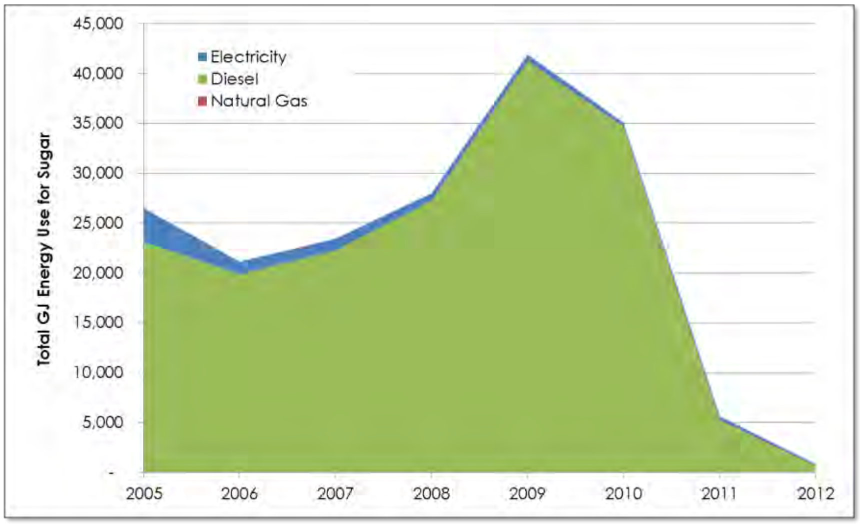
Table III-37: Surveyed Sugar Mill Production

	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

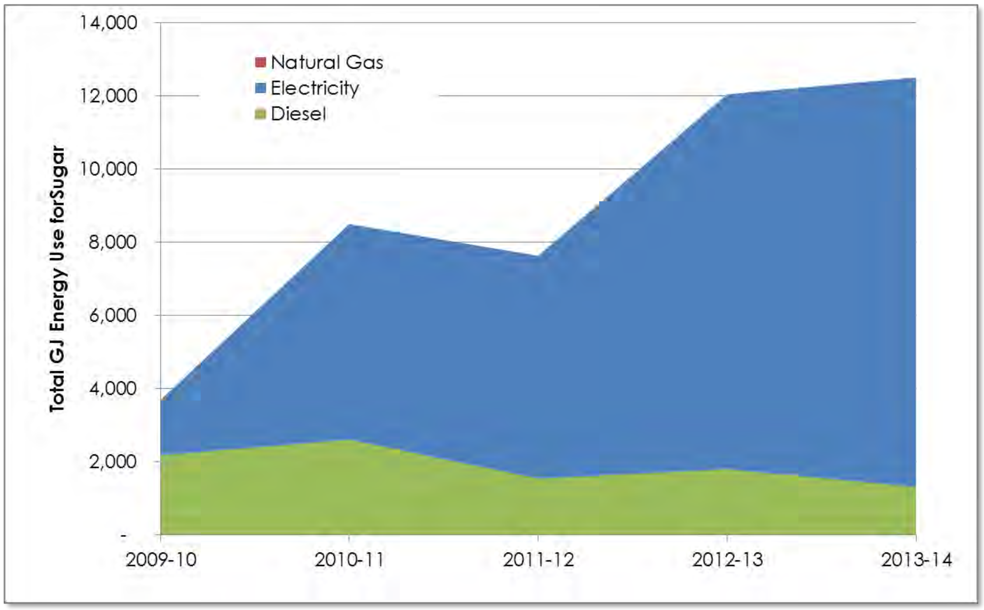
51. The large sugar mills reported heavy use of diesel fuel as their primary fuel for heat production as shown by Figure III-38.

Figure III-38: Energy End-Use – Belin



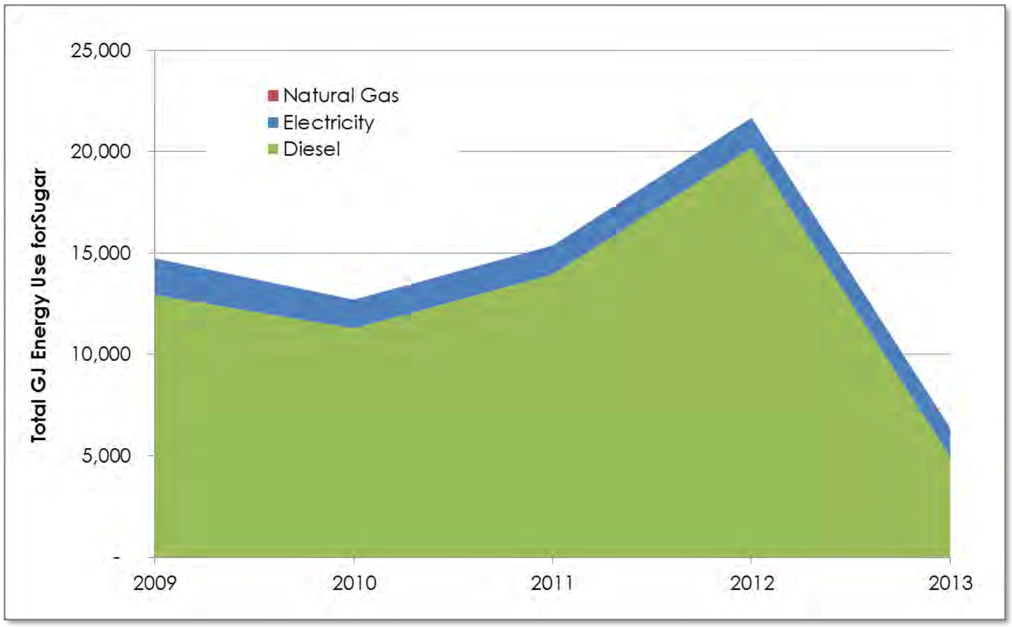
Sources: Consultant

Figure III-39: Energy End-Use – Kan Hla



Sources: Consultant

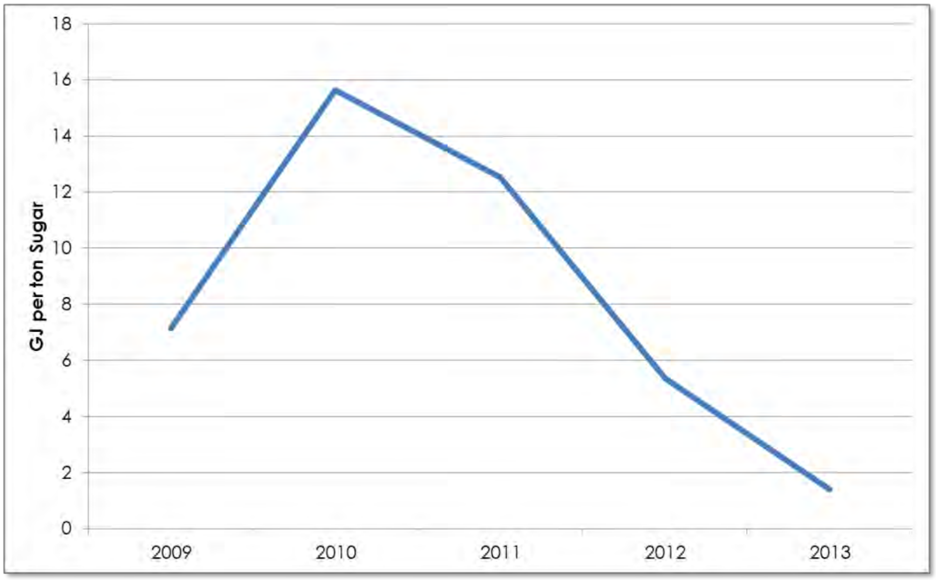
Figure III-40: Energy End-Use – Dahatkone



Sources: Consultant

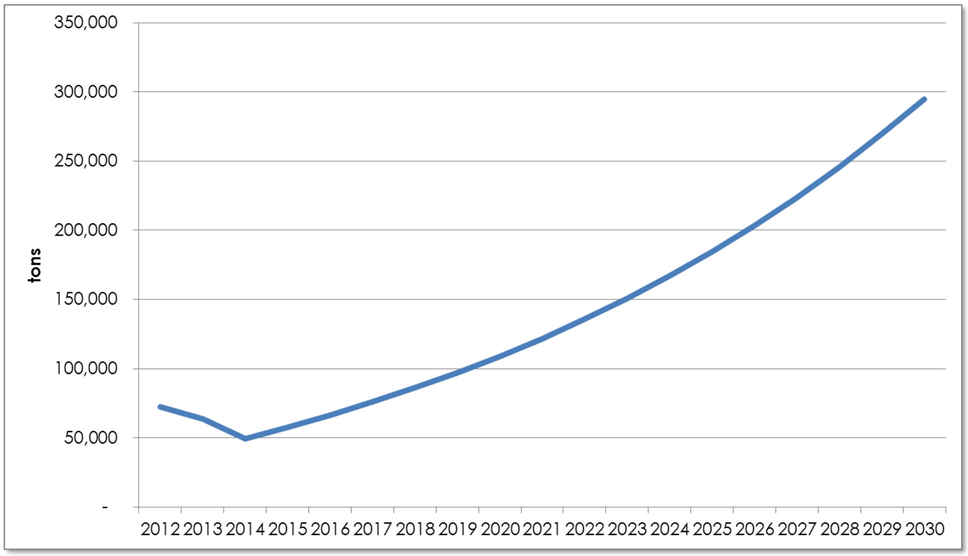
52. The average energy consumption of sugar production in recent years was found to have varied considerably. The energy consumption has been forecast according to expected industry sector GDP growth after which the corresponding sugar production was computed by way of simple division by 2 GJ per ton.

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

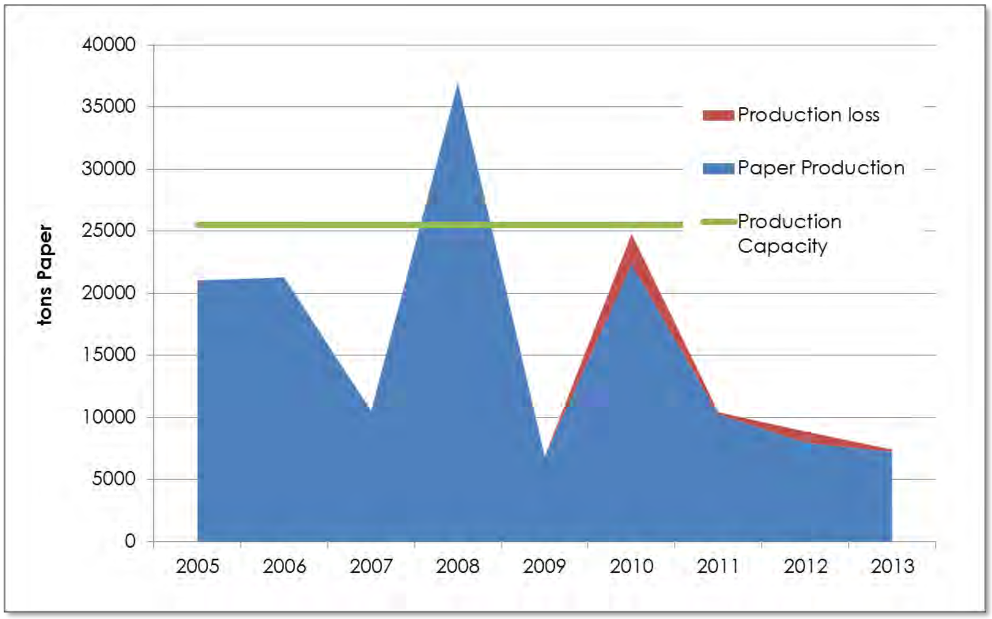
54. In Myanmar, non-wood materials are widely used in the pulp and paper industry, particularly the cellulose fibre of bamboo. Tharpaung in Myanmar's south-western Ayeyarwaddy division uses bamboo for pulp and paper production. Tharpaung has the largest installed capacity and is reported to be capable 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

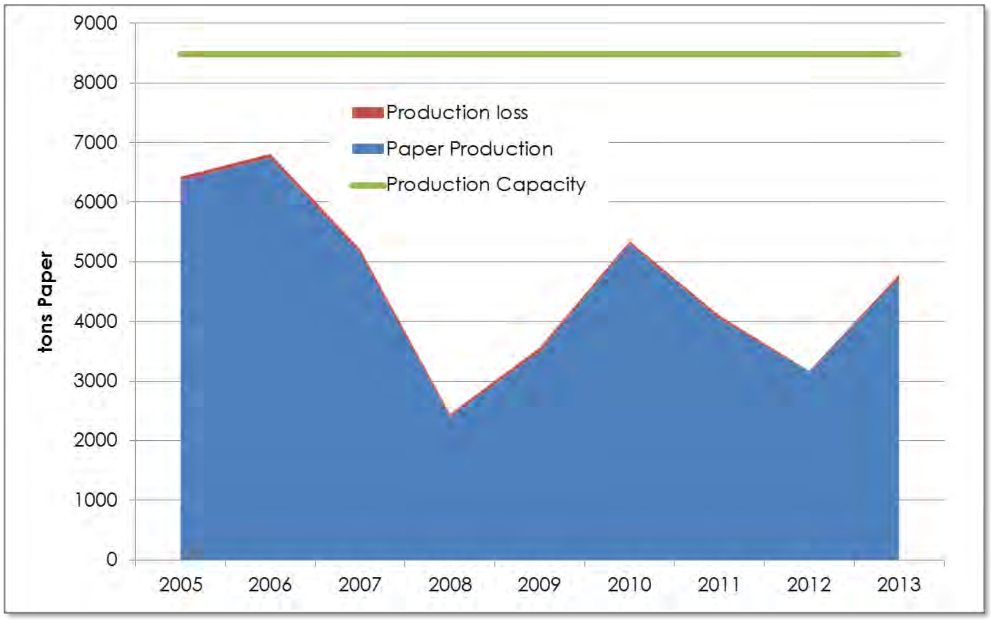
Sources: EMP Survey

Figure III-45: Pulp & Paper Production – Tharpaung



Sources: Industry Sector Survey, Consultant

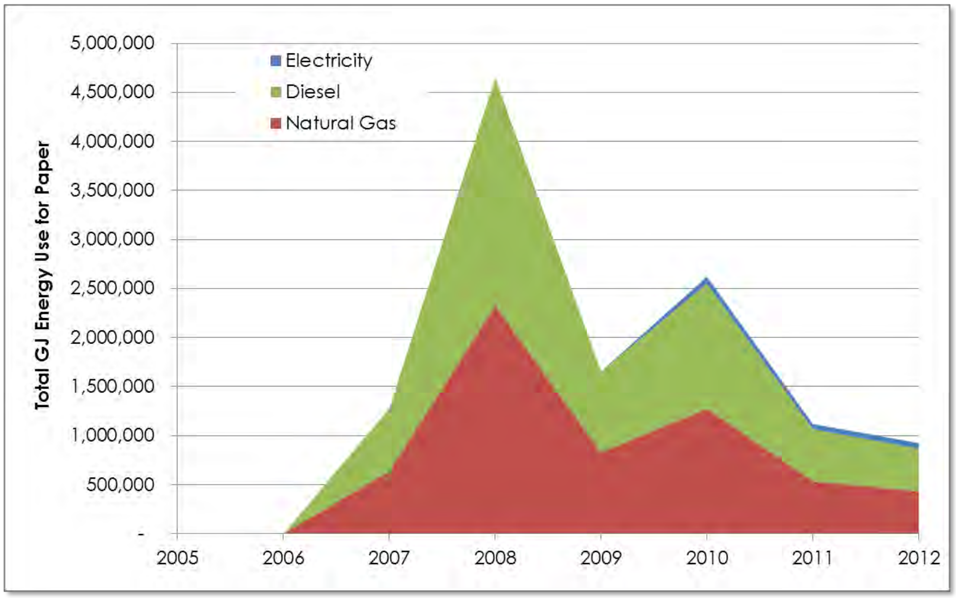
Figure III-46: Pulp & Paper Production – Paleik



Sources: Industry Sector Survey, Consultant

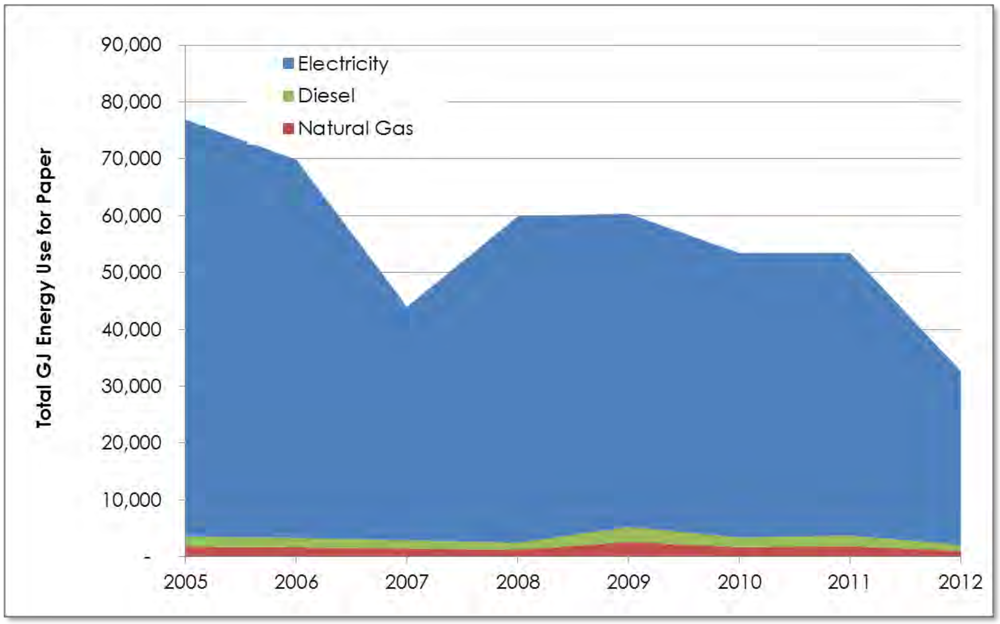
55. The Tharpaung and Paleik mills reported fuel consumption mixes as follows:-

Figure III-47: Energy End-Use: Tharpaung



Sources: Industry Sector Survey, Consultant

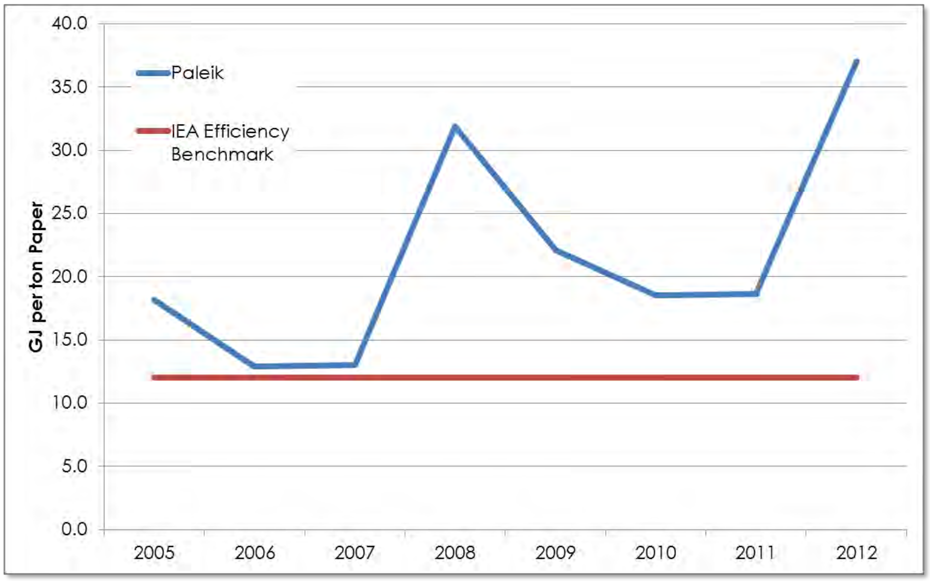
Figure III-48: Energy End-Use: Paleik



Sources: Industry Sector Survey, Consultant

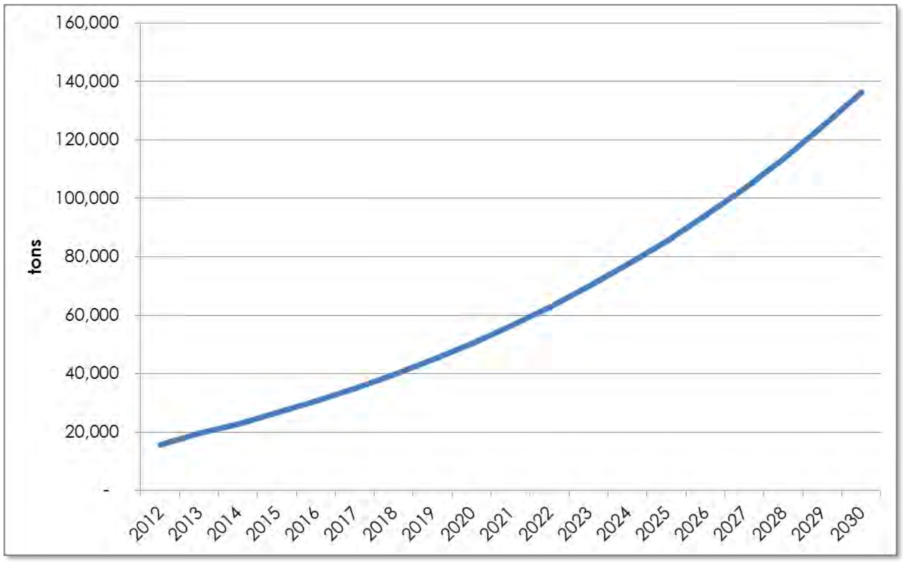
56. The average energy consumption of paper production in recent years has varied considerably amongst the surveyed mills. The Tharpaung consumption data appears to be over-stated. The energy consumption has been forecast according to expected industry sector GDP growth after which the corresponding 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.

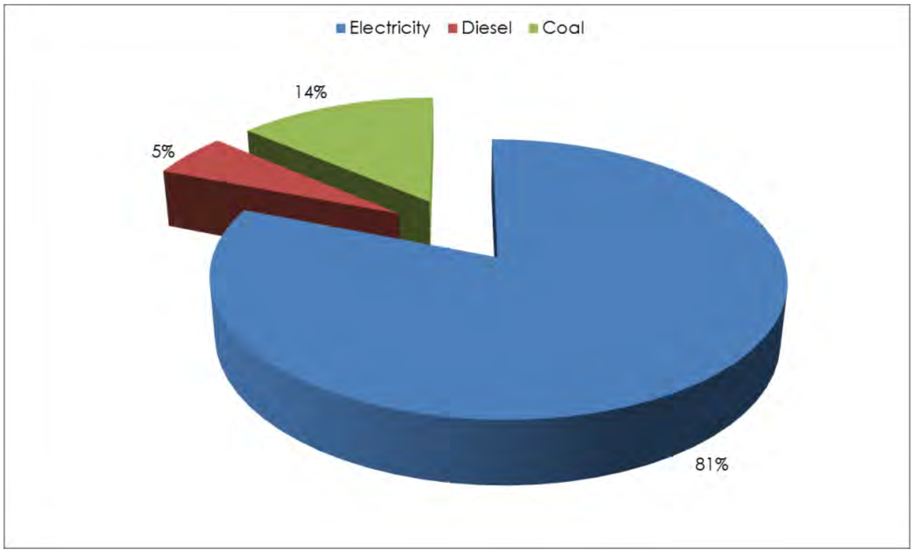
Table IV-1: Industrial Electricity Sales

	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)

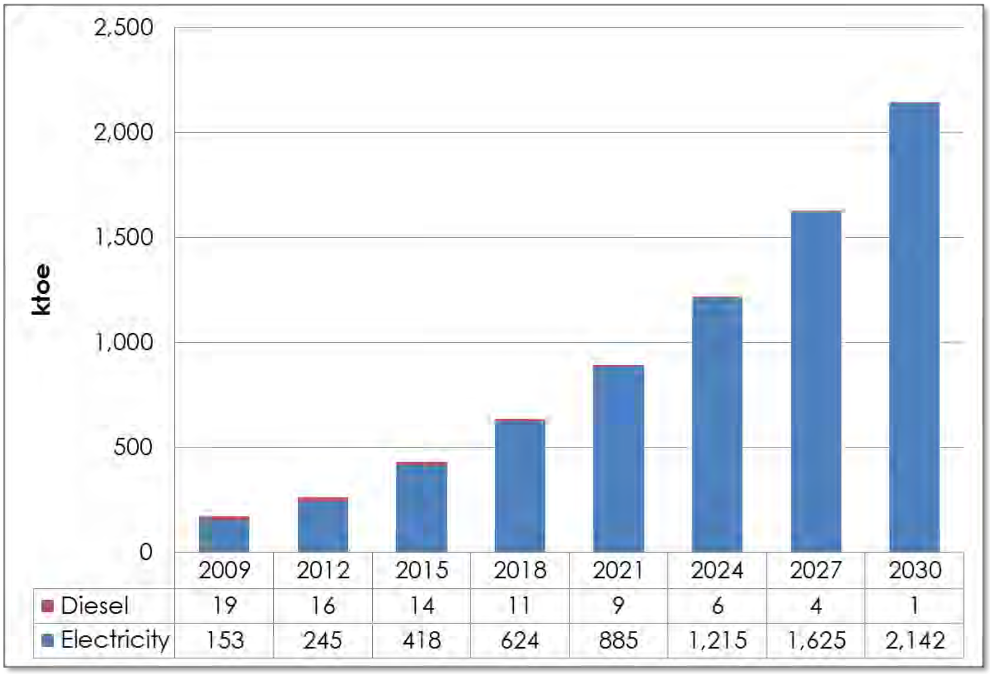
	2009	2012	2015	2018	2021	2024	2027	2030
Ayeyarwaddy Region	5.6	13.4	21.8	34.6	50.6	70.8	95.7	126.8
Bago Region	12.4	16.6	21.3	27.9	36.0	46.3	58.9	74.6
Chin State	0.0	0.1	0.1	0.1	0.1	0.1	0.2	0.2
Kachin State	0.2	0.5	1.0	1.6	2.2	3.1	4.2	5.5
Kayah State	0.4	0.6	1.0	1.3	1.8	2.5	3.2	4.2
Kayin State	10.7	11.9	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



	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

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

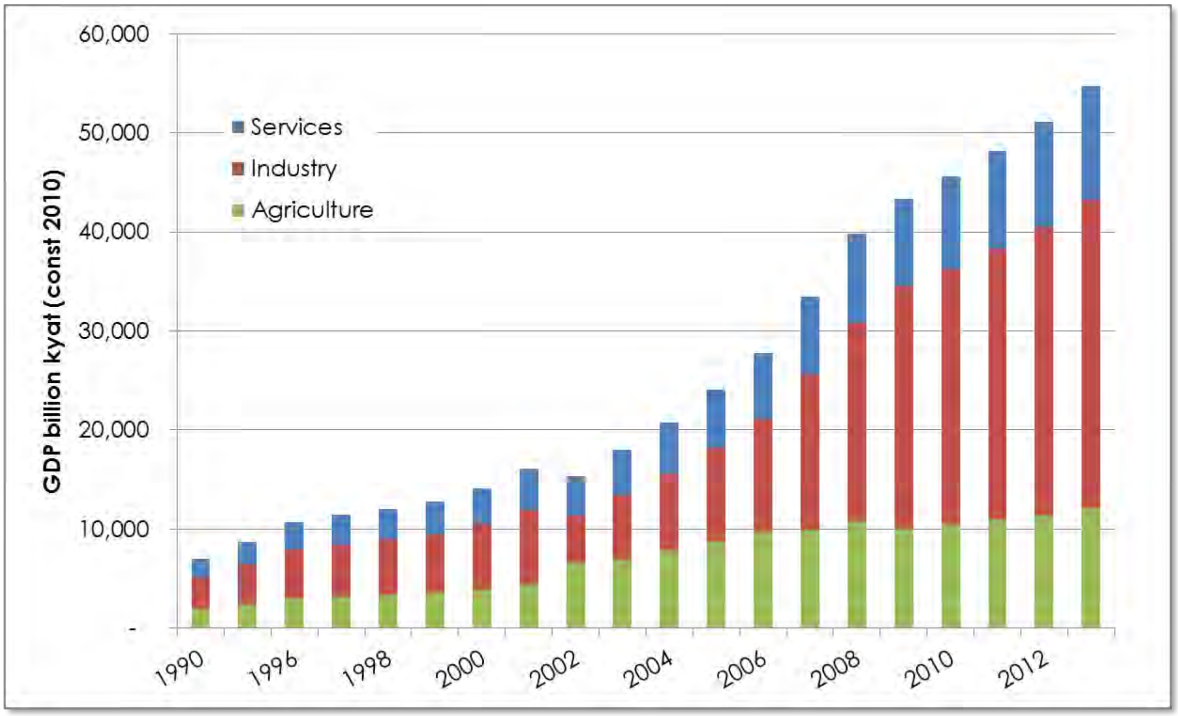
A. Introduction

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



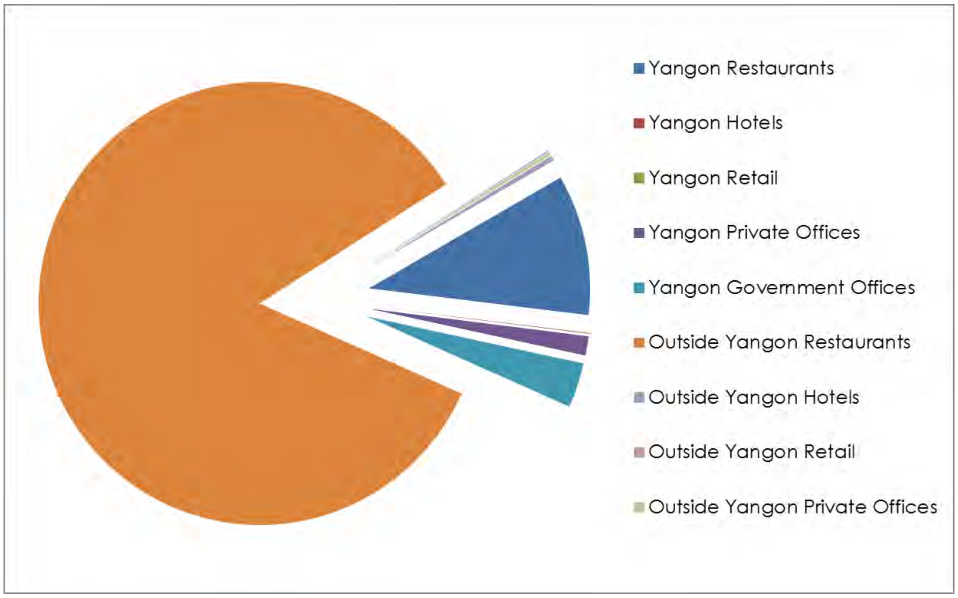
Source: ADB

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.

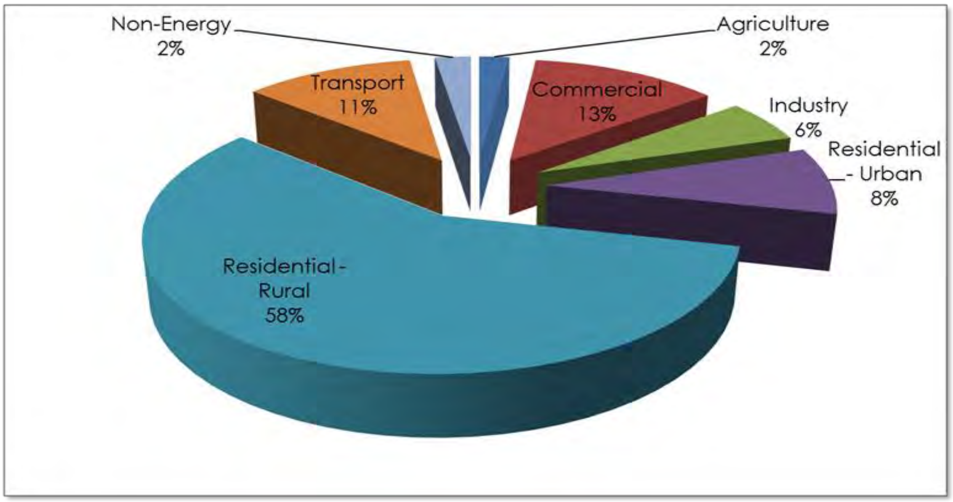
Figure I-2: Final Energy Consumption: 2012 - 13 (1.59 mtoe)



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

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[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.

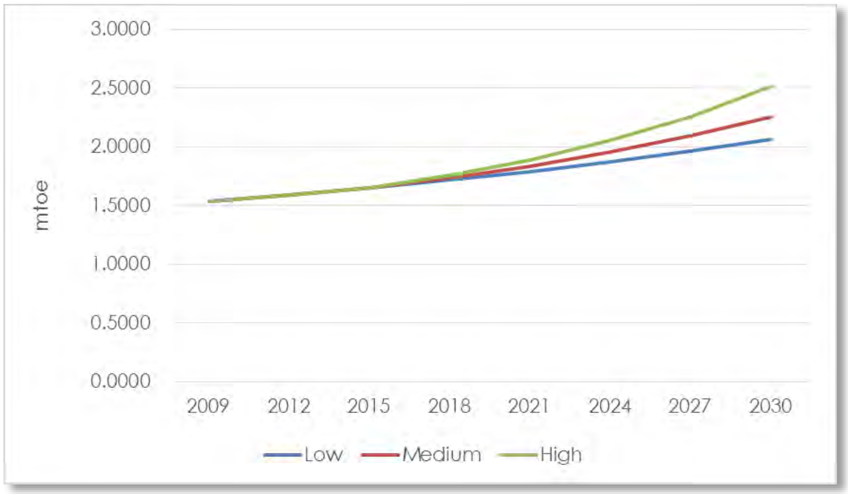
Table I-4: Commercial Sector Planning Assumptions

		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)

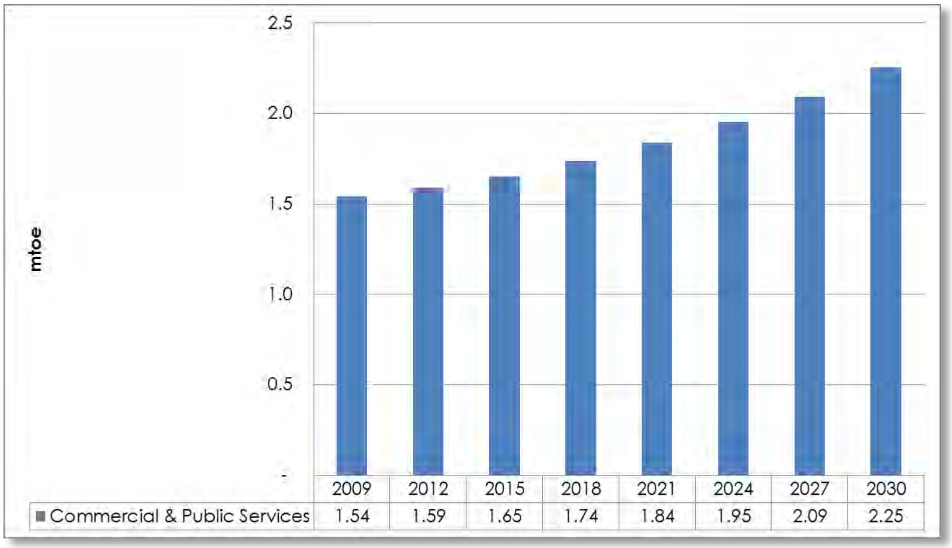
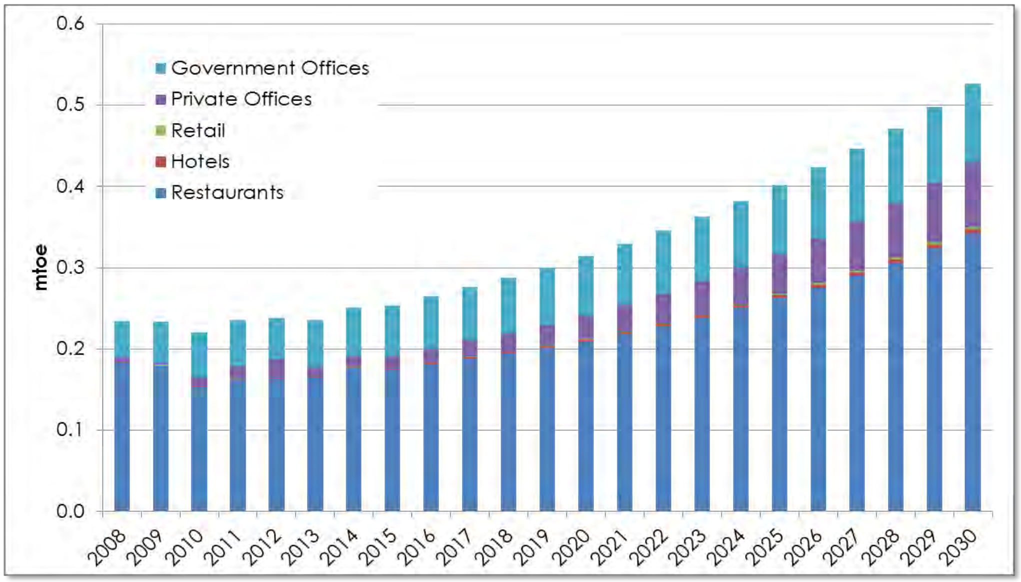
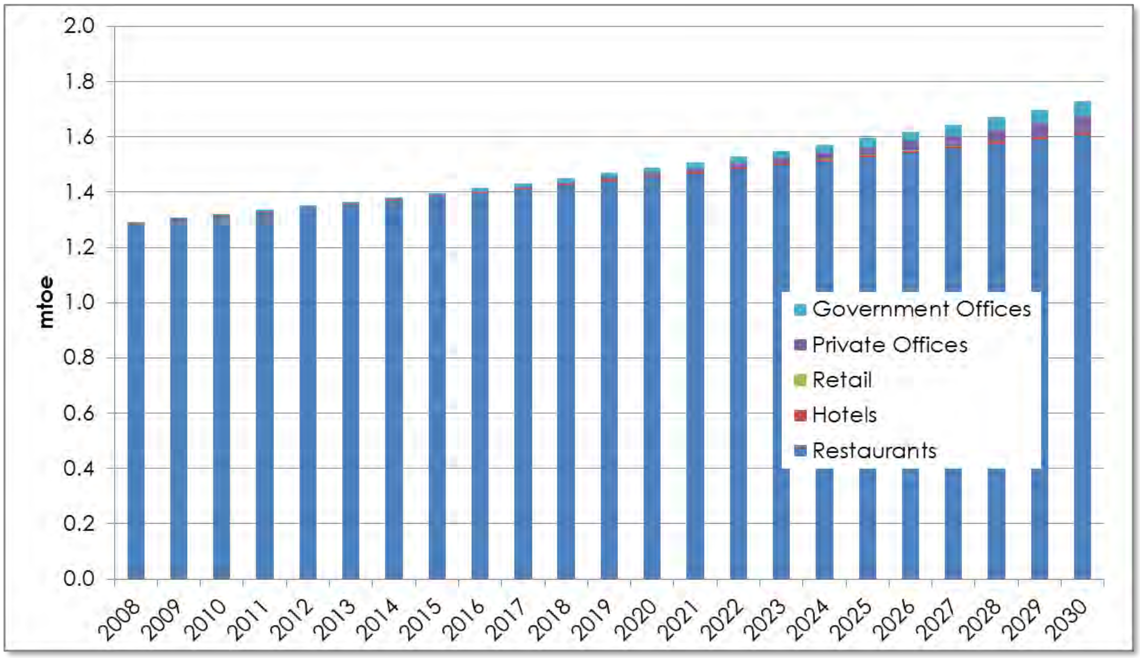


Figure I-7: Yangon - Commerce & Public Services Sector FEC



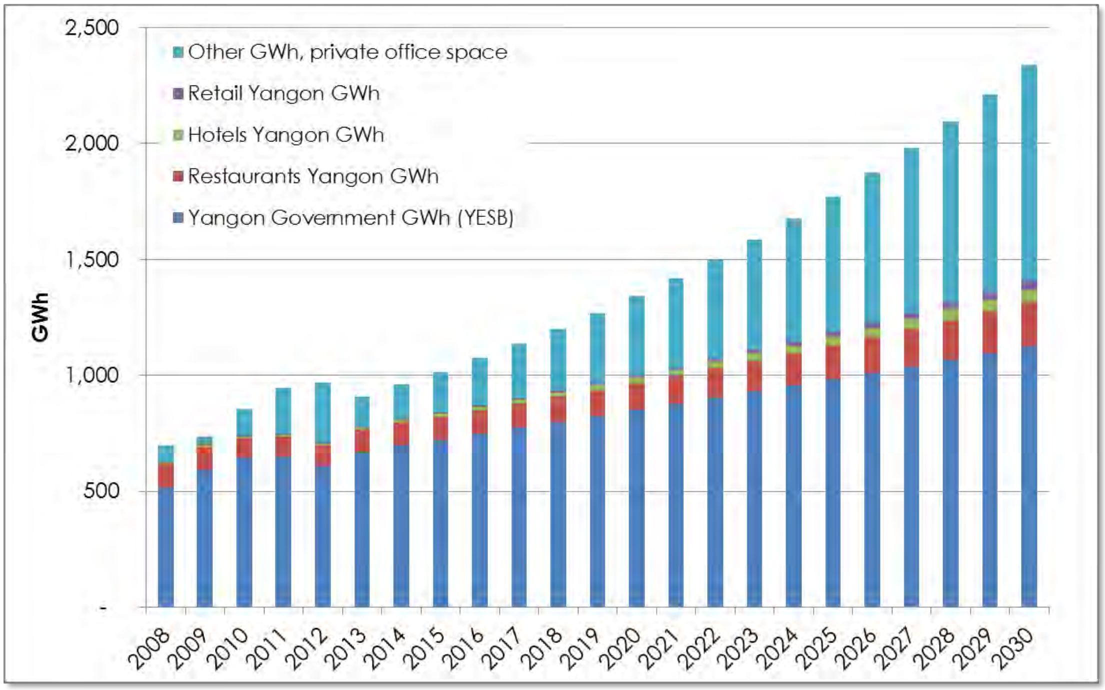
Source: Consultant's analysis

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

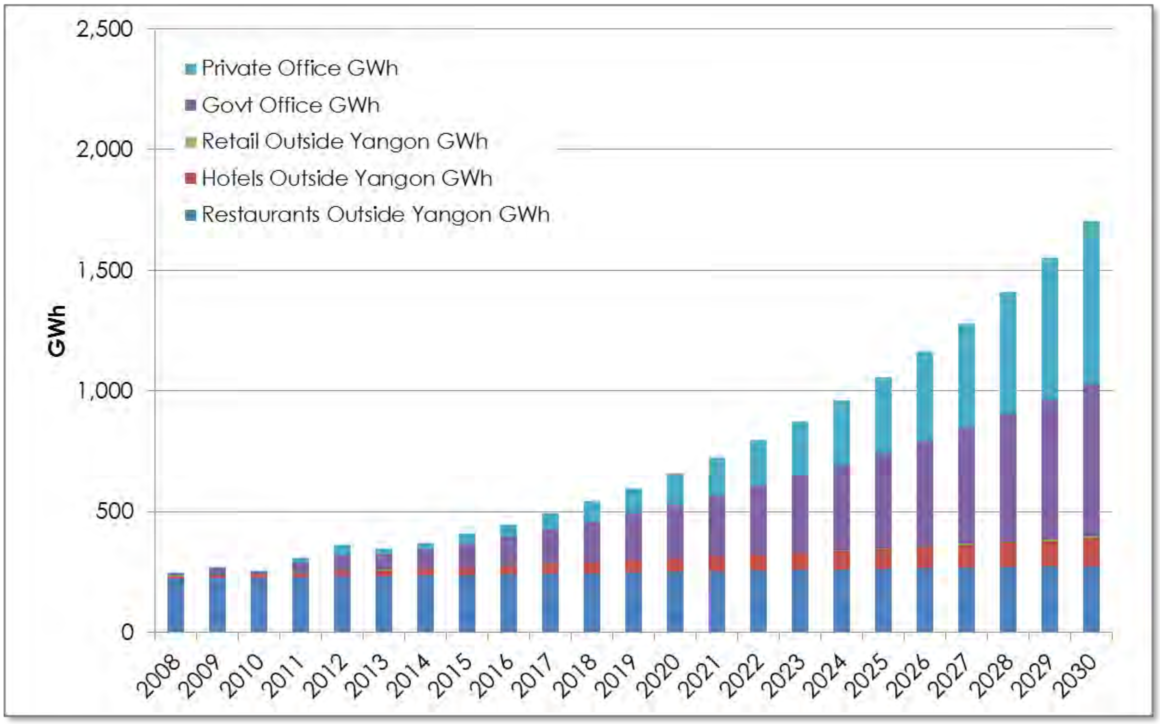
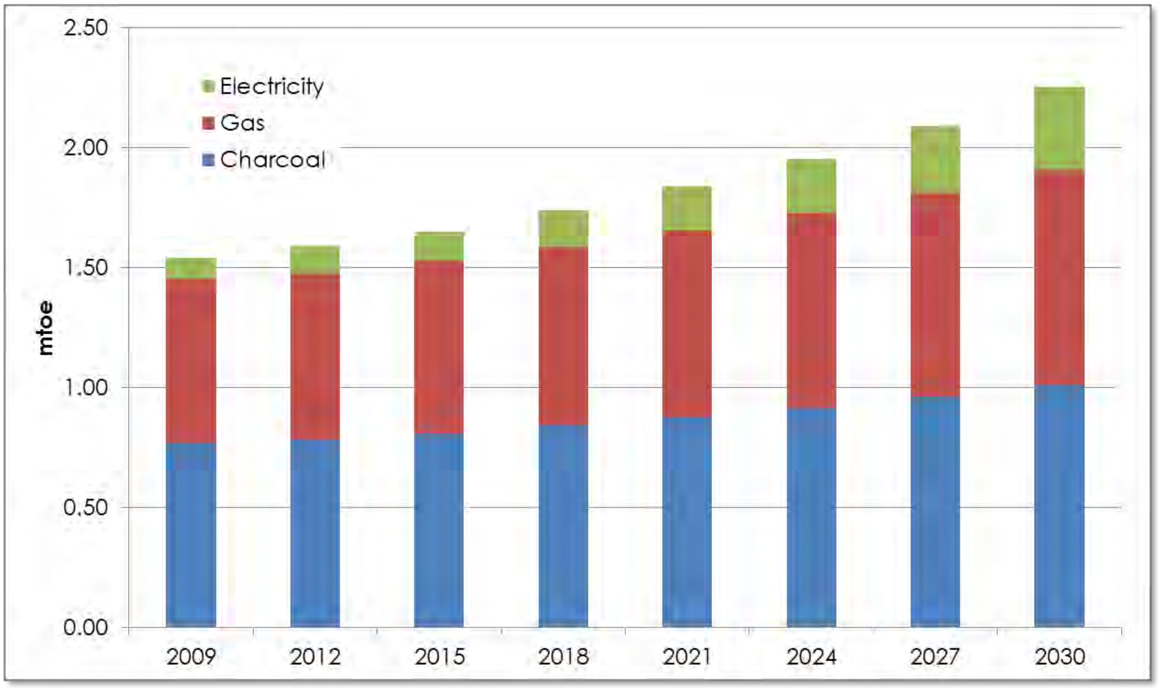


Figure I-11: FEC Energy Carriers (mtoe)



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

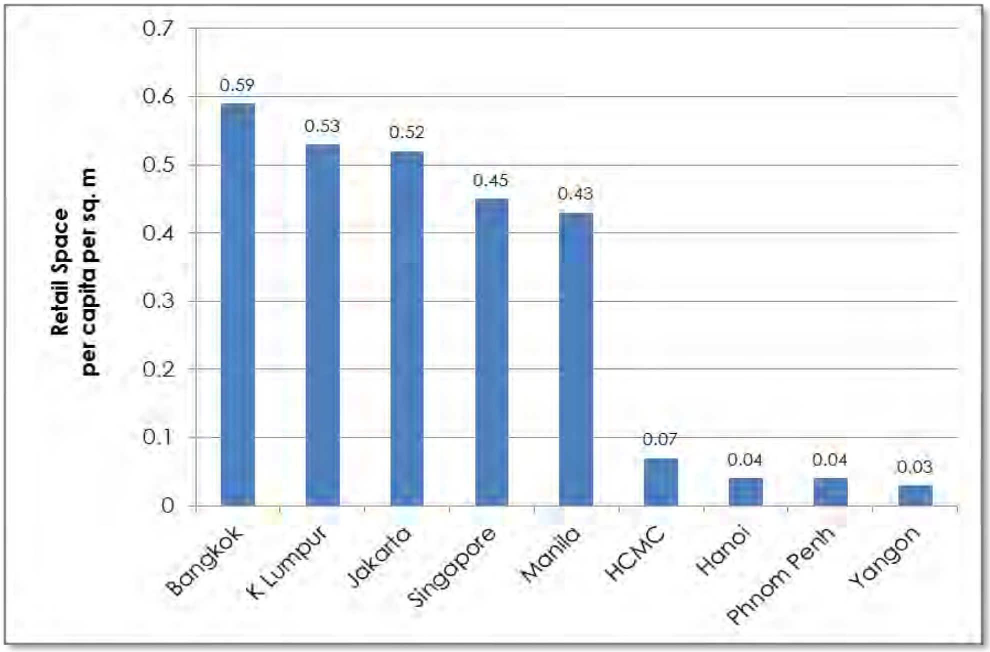
12. Modern retail space in Yangon is very limited by comparison to other large Asian cities such as Bangkok, Kuala Lumpur, Jakarta and Singapore. Modern retail space is reported to be only 10%

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.

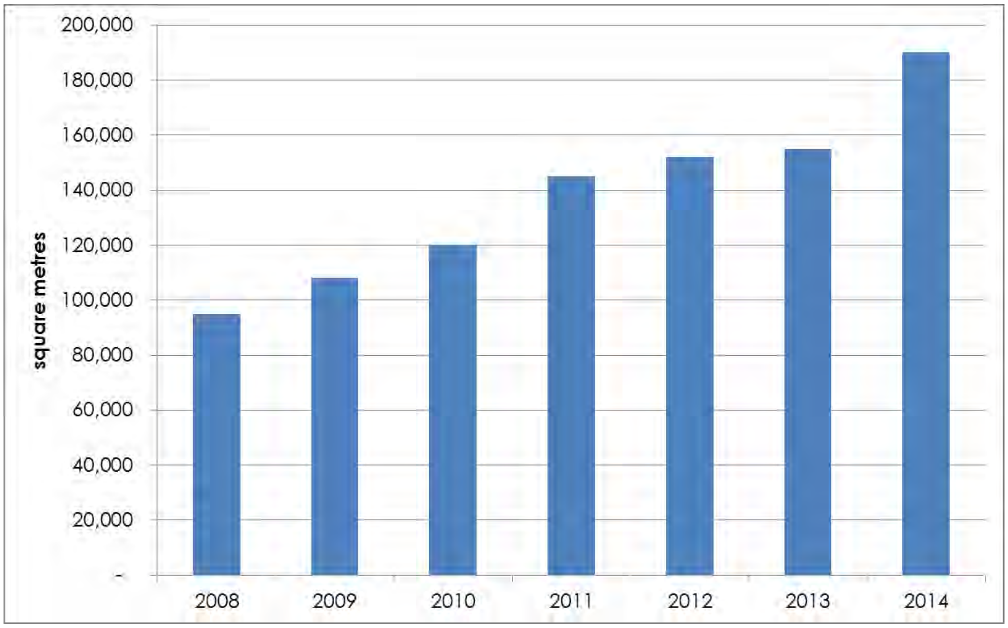
14. The stock of office space, both private and Government, was estimated based on electricity sales of YESC and ESE using a benchmark kWh consumption per square metre. The use of this method shows that the ratio of private to Government office space is currently low, as can be seen from Table II-10 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

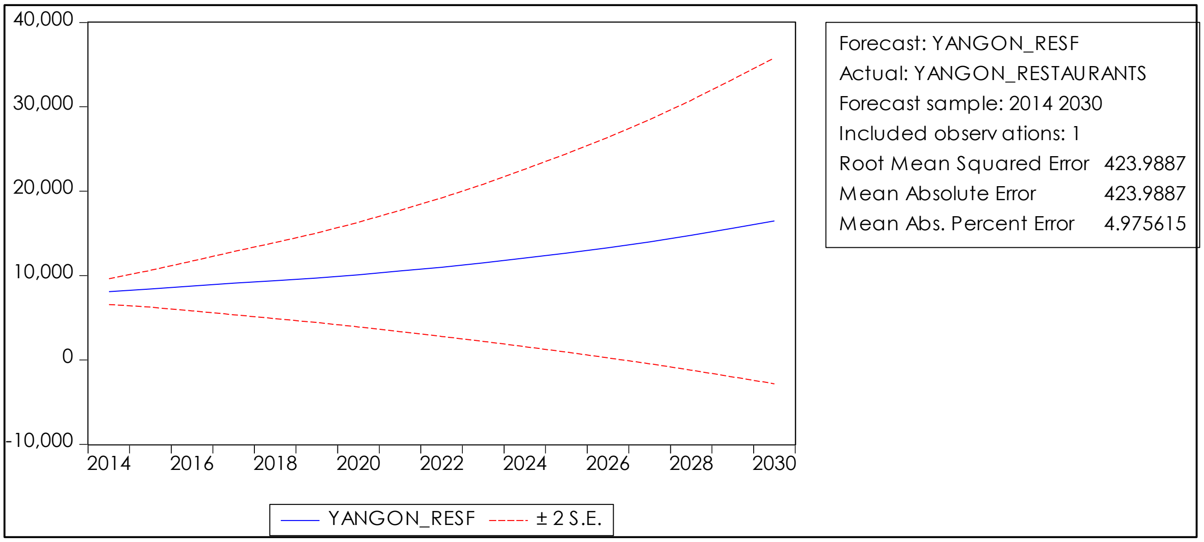
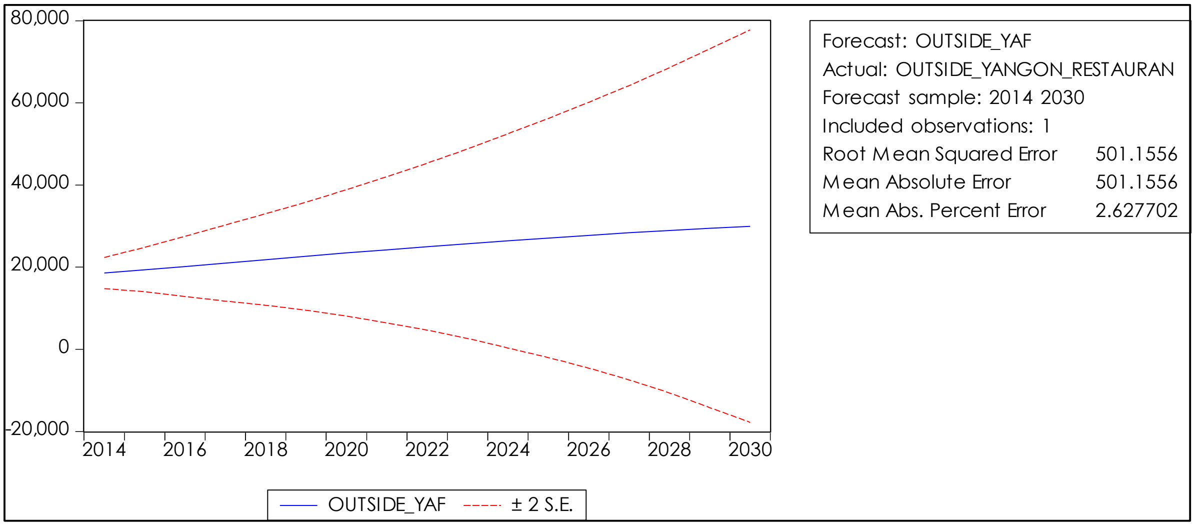


Figure III-3: Restaurant Stock Forecasts – Outside Yangon



Sources: EMP Commercial Sector Survey, Consultant

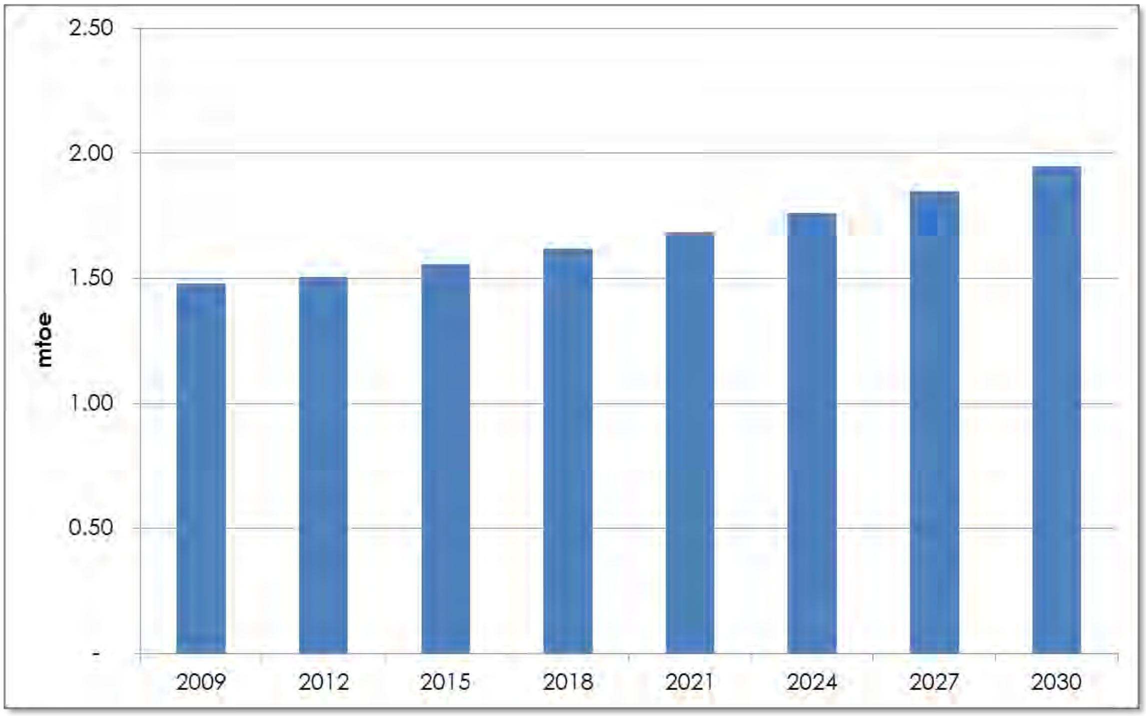
Table III-4: Restaurant Stock Forecasts

	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)

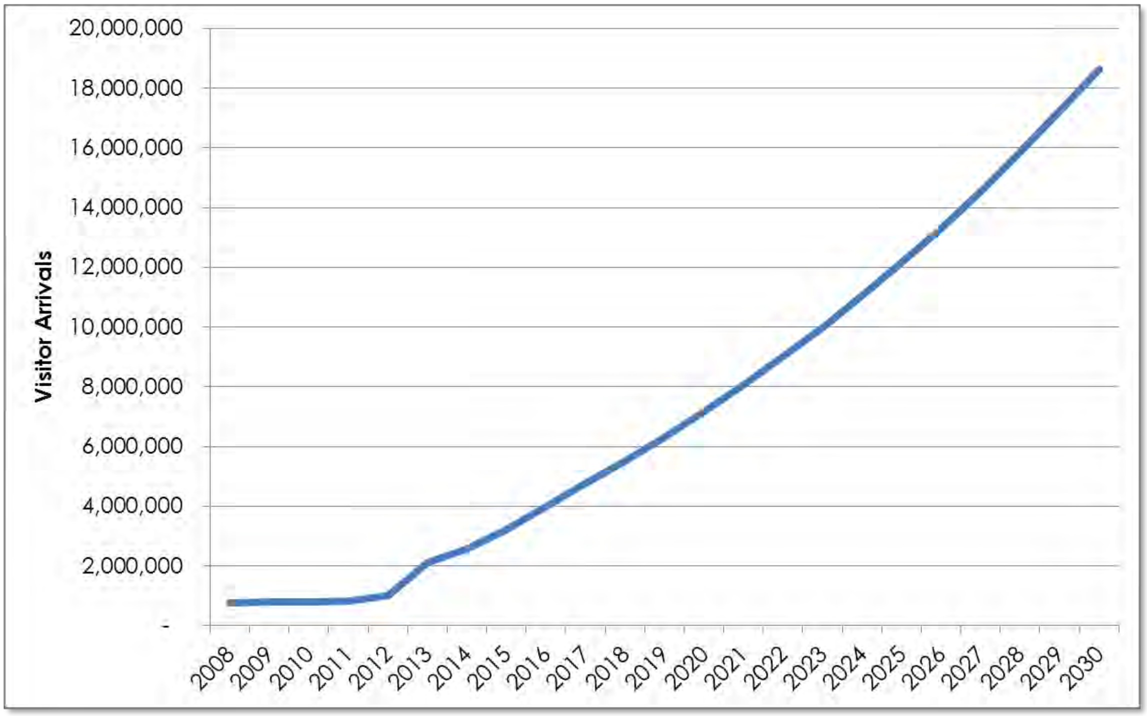
	Restaurants		
	GWh	tons LPG	tons Charcoal
2009	324	735 556	1 078 066
2012	322	747 907	1 096 168
2015	335	773 593	1 133 816
2018	353	804 264	1 178 768
2021	374	837 242	1 227 103
2024	400	874 891	1 282 283
2027	430	916 876	1 343 818
2030	466	965 205	1 414 651

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.

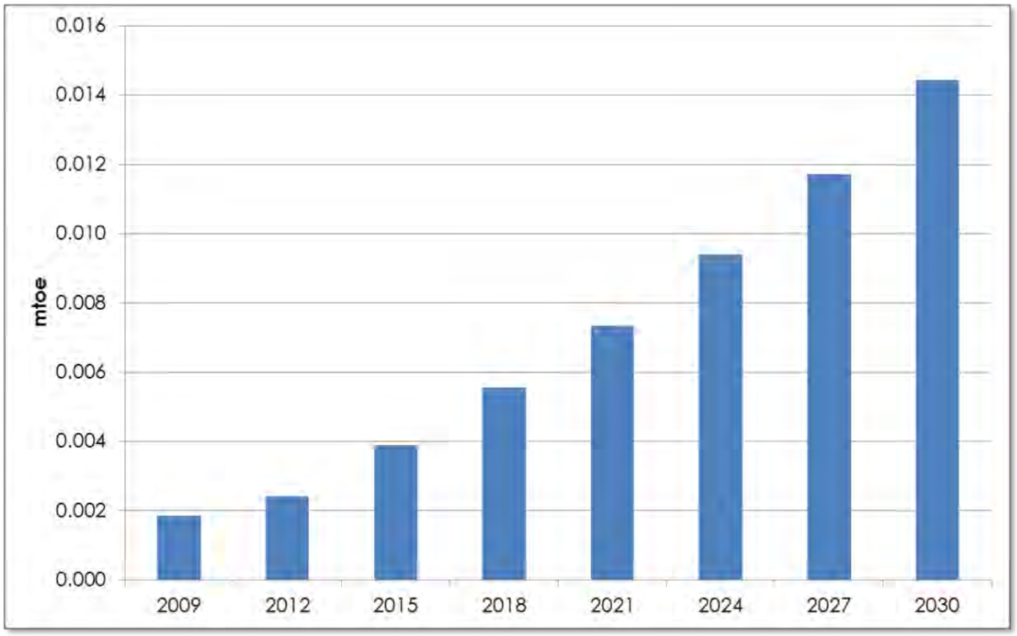
Table III-8: Hotel Room Stock Forecasts

	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)

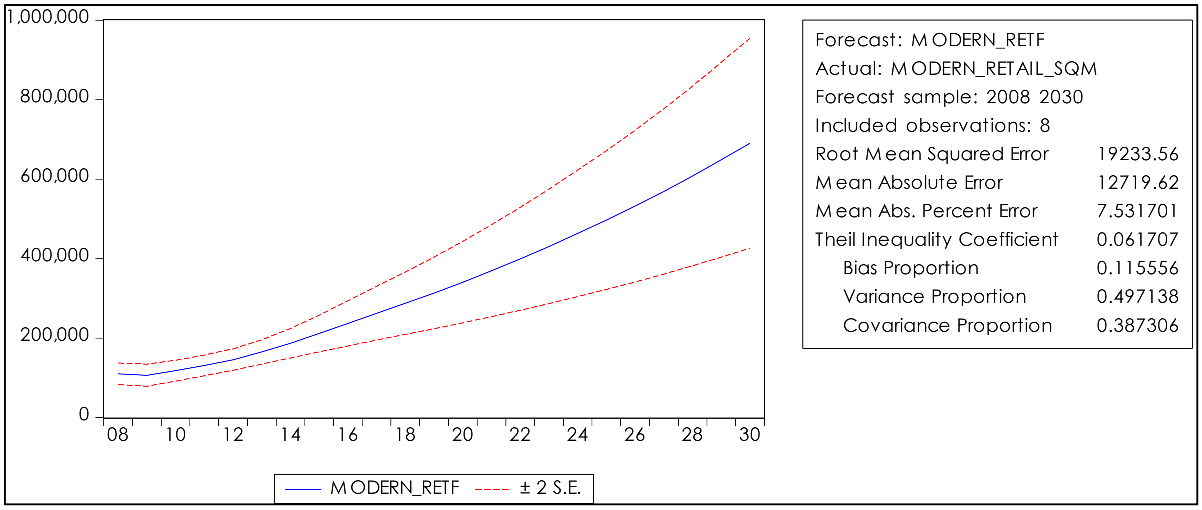
	Yangon Hotels	**Outside Yangon Hotels**
	GWh	**GWh**
2009	8.9	12.4
2012	8.9	19.4
2015	14.1	31.4
2018	20.1	44.6
2021	26.8	58.7
2024	34.9	74.8
2027	44.3	92.5
2030	55.7	112.9

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



Forecast: MODERN_RETF	
Actual: MODERN_RETAIL_SQM	
Forecast sample: 2008 2030	
Included observations: 8	
Root Mean Squared Error	19233.56
Mean Absolute Error	12719.62
Mean Abs. Percent Error	7.531701
Theil Inequality Coefficient	0.061707
Bias Proportion	0.115556
Variance Proportion	0.497138
Covariance Proportion	0.387306

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:-

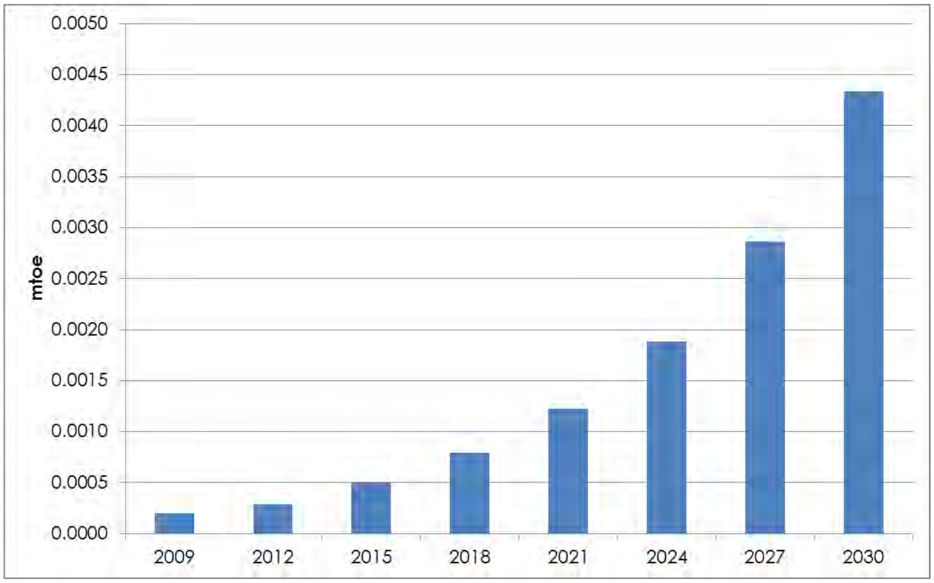
Table III-12: Retail Space Stock Forecasts (sq. m)

	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)

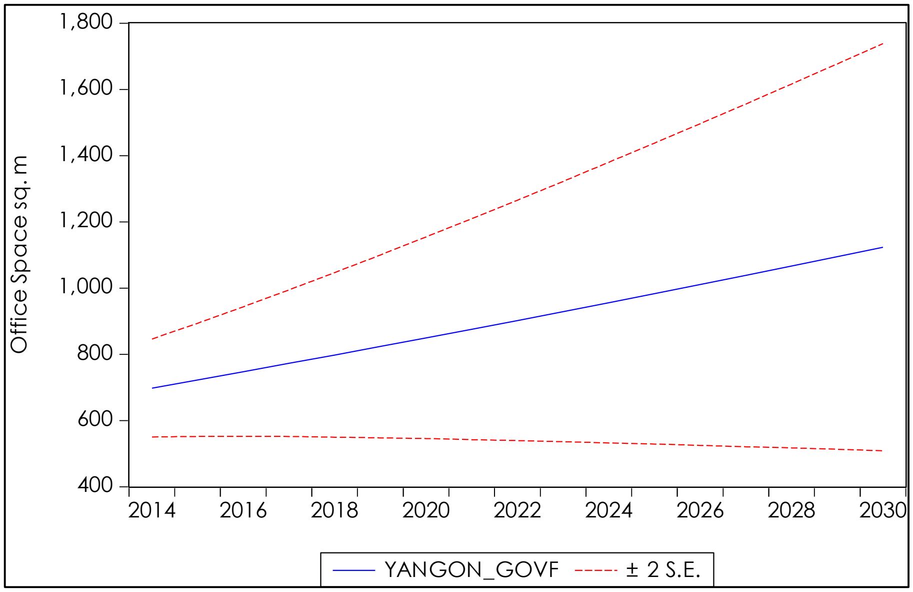
	Yangon Retail	Outside Yangon Retail
	GWh	GWh
2009	1.46	0.84
2012	2.38	0.96
2015	4.00	1.30
2018	6.68	1.82
2021	10.67	2.58
2024	16.72	3.72
2027	25.70	5.43
2030	39.18	8.05

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

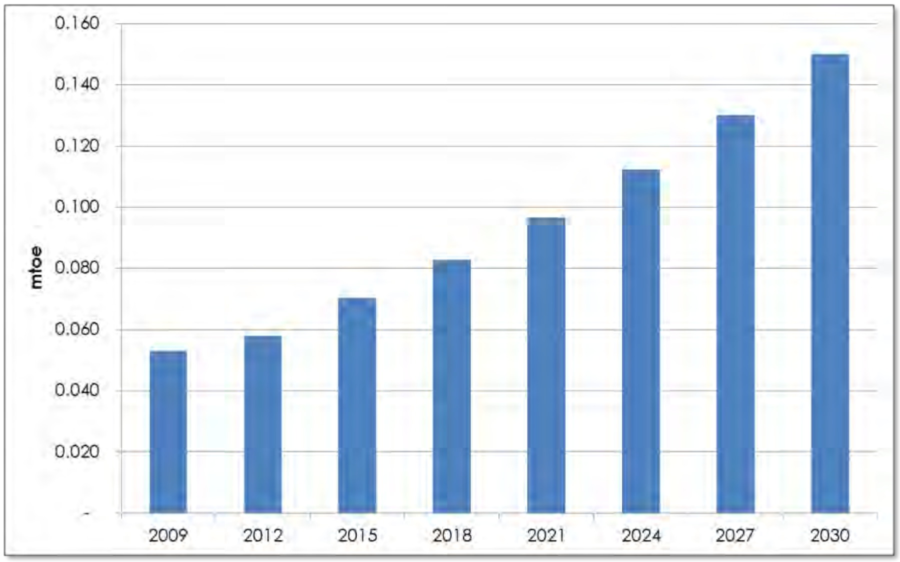
Table III-16: Forecast: Government Office Space

	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.

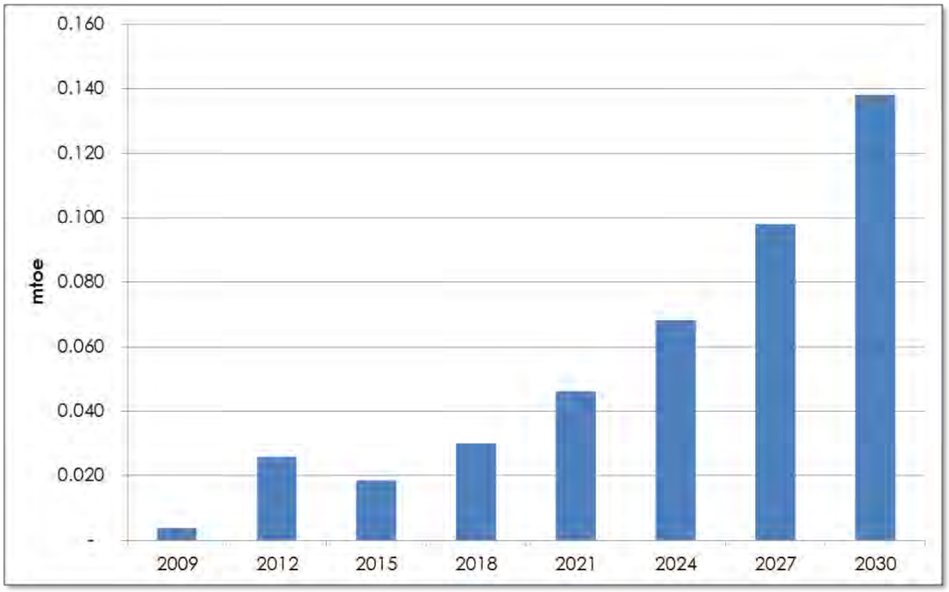
Table III-19: Forecast: Private Office Space (sq. m)

	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

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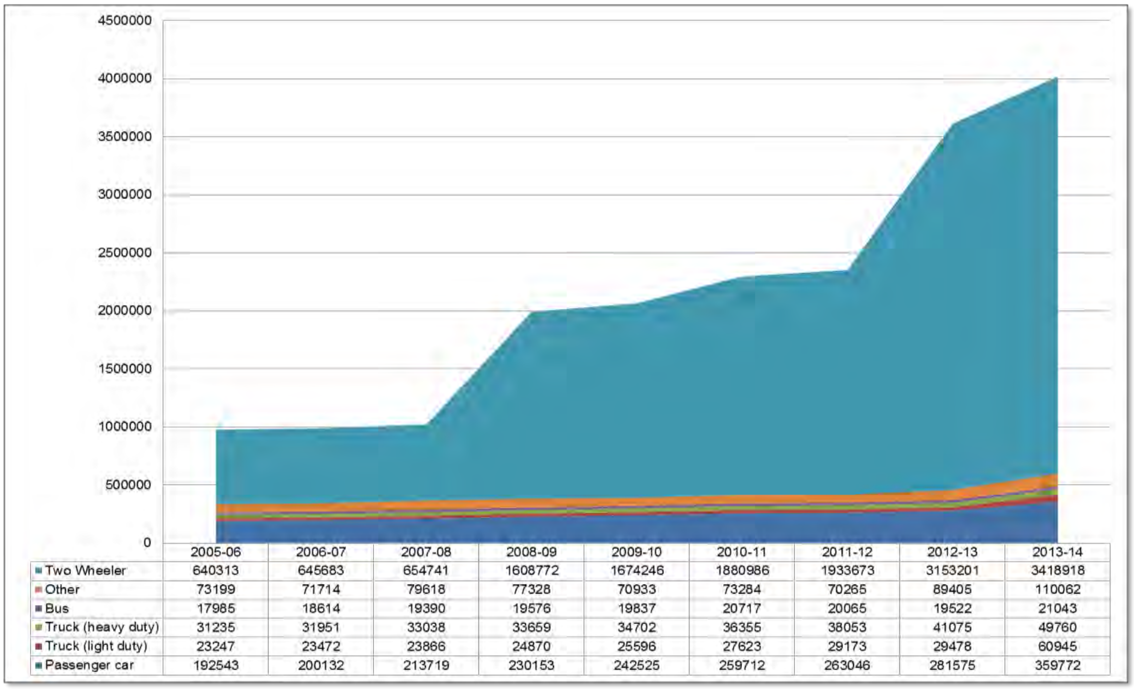
[1] The parc is a term used to describe the stock of active vehicles

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)

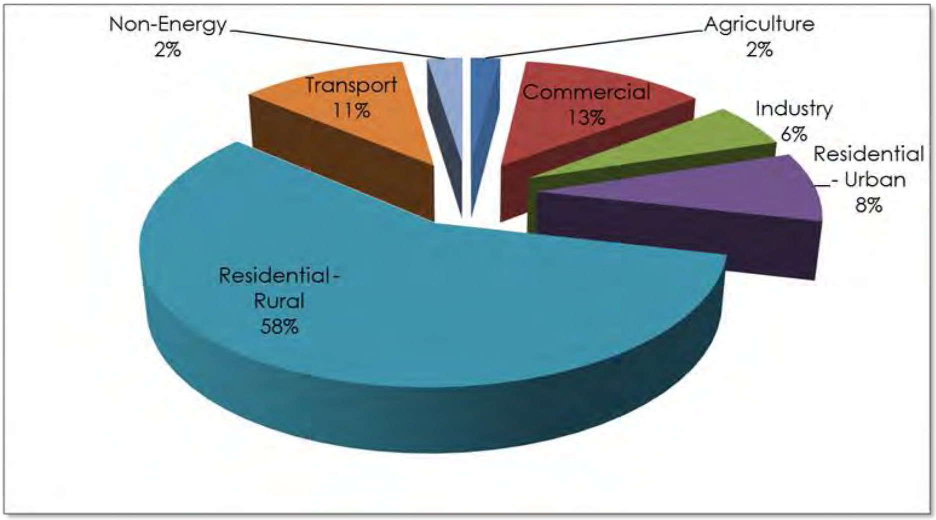
		Total Vehicles	Freight	Activity	Modal Share
Modality	**Fuel**	**no.**	**billion veh-km**	**billion ton-km**	**% of ton-km**
Heavy Commercial Vehicles	Diesel	41 075	1.77	5.76	81%
Light Commercial Vehicles	Gasoline & Diesel	53 730	0.96	0.38	5%
Rail	Diesel	405	n.a.	0.61	9%
Waterways	Diesel	5 200	n.a.	0.34	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

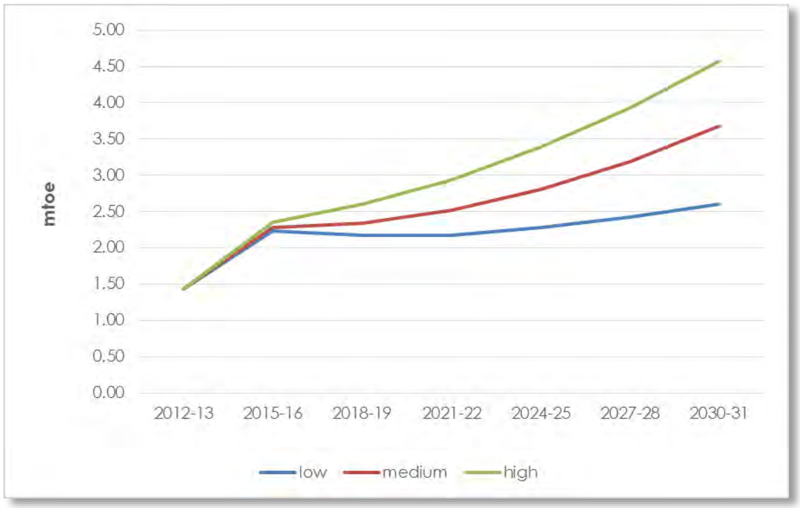


Sources: Consultant

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

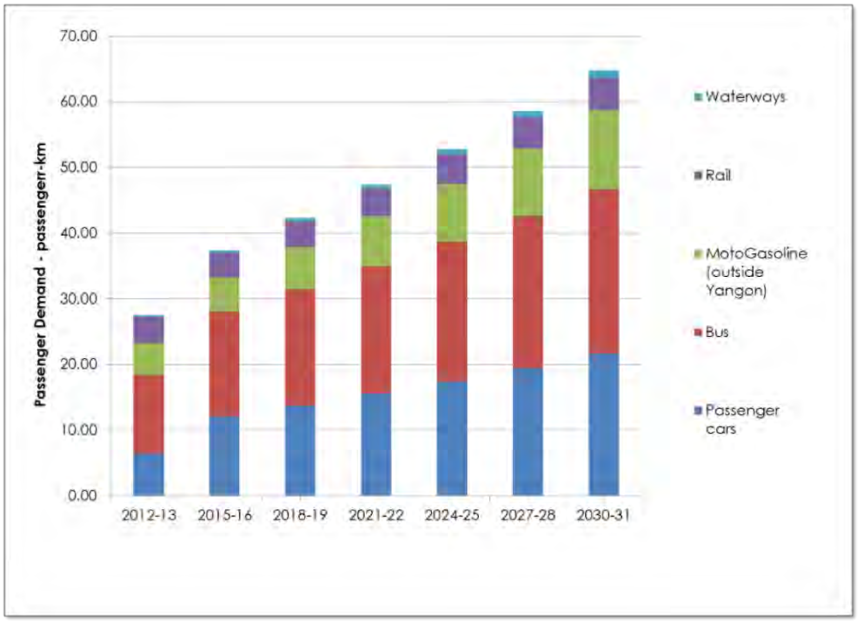
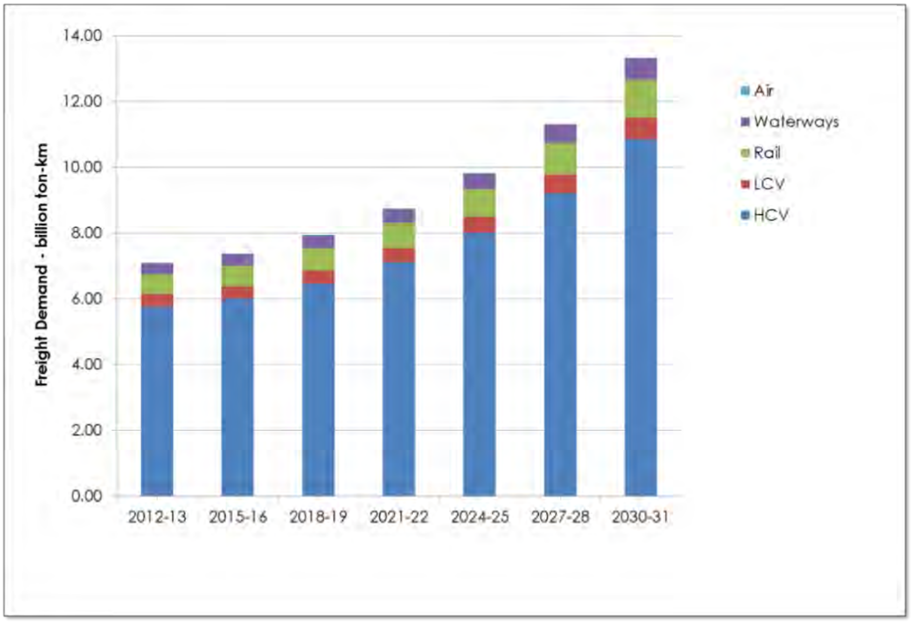


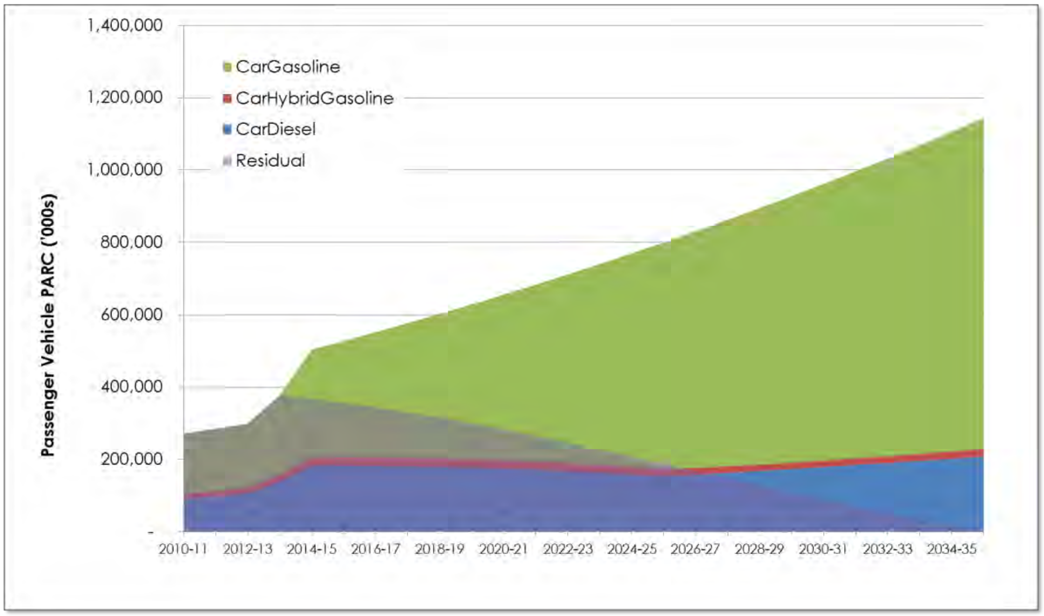
Figure I-7: Freight ton-km Demand Projections



Source: Consultant

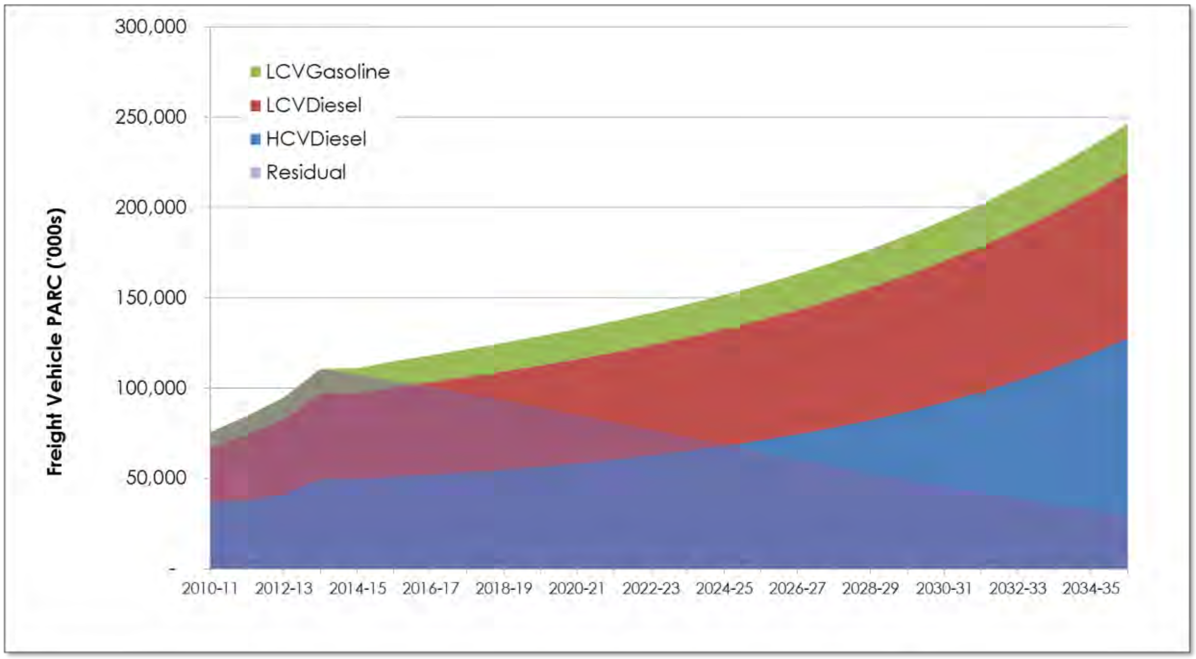
16. The projected vehicle parc is shown in Figure I-8 and Figure I-9 for passenger and freight vehicles respectively. The charts show the 'residual' vehicle count as scrapping of the vehicles on the road in 2013-14 takes place.

Figure I-8: Passenger Vehicle Projections



Source: Consultant

Figure I-9: Freight Vehicle Projections



Source: Consultant

17. An alternative low CO2 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

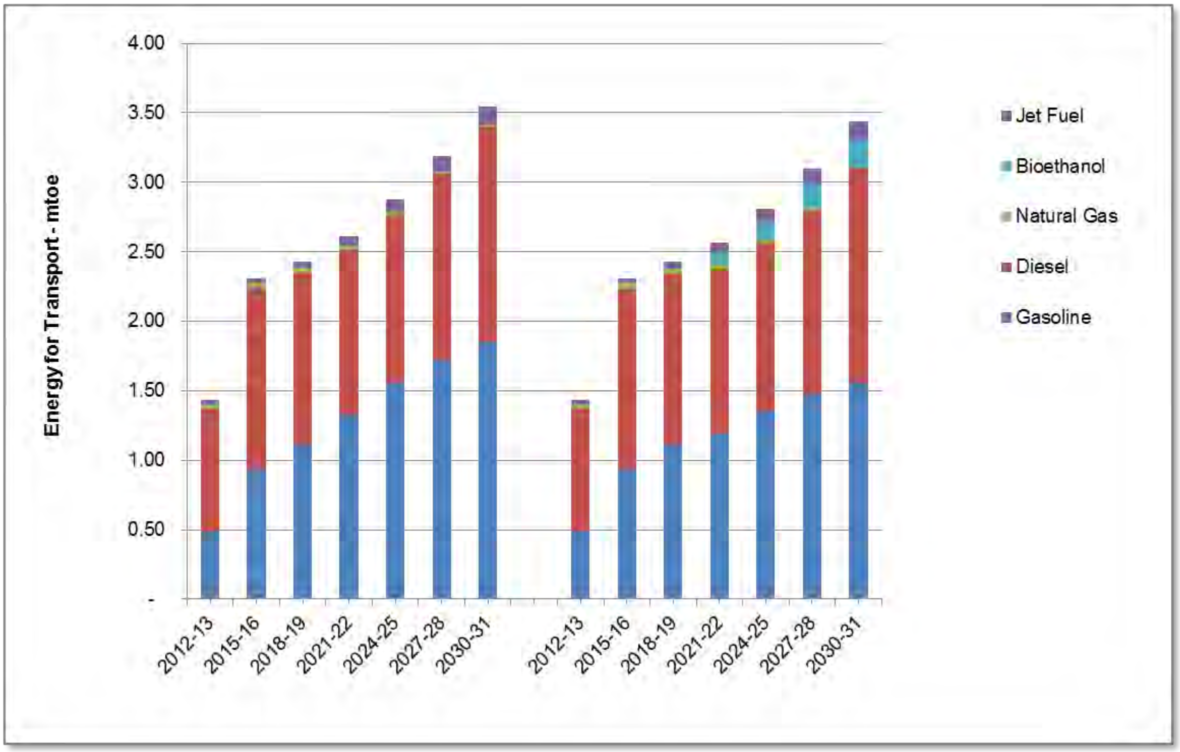
Source: Consultant

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.

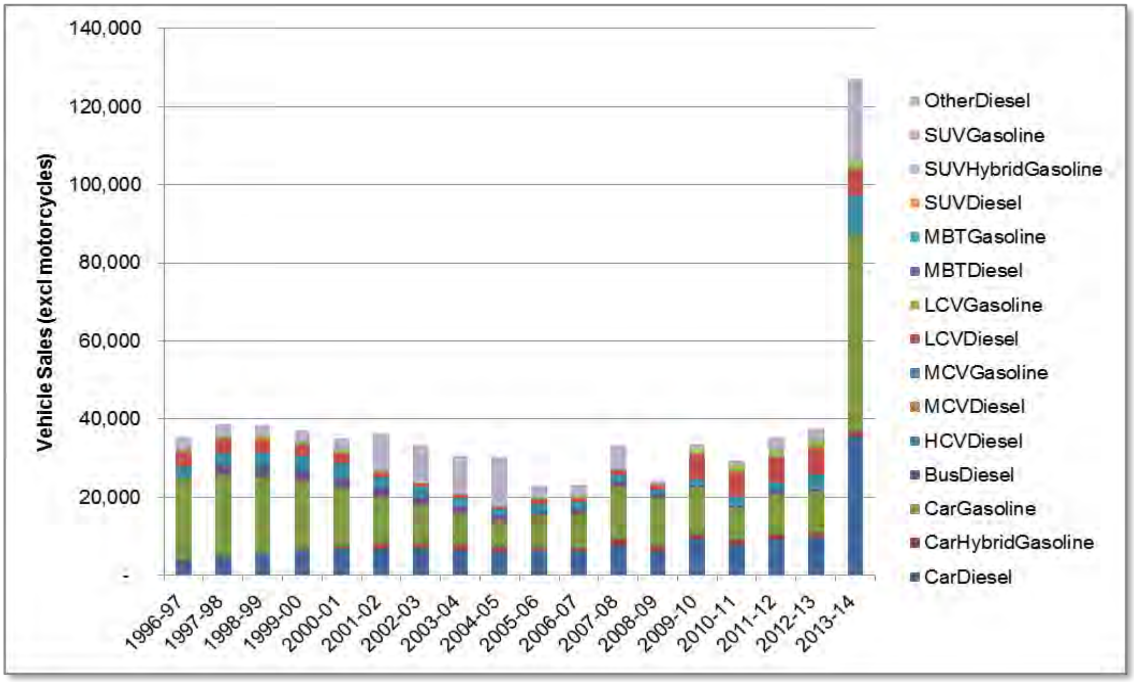
Table II-1: Motorization of Myanmar's Provinces (February 2013)

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.

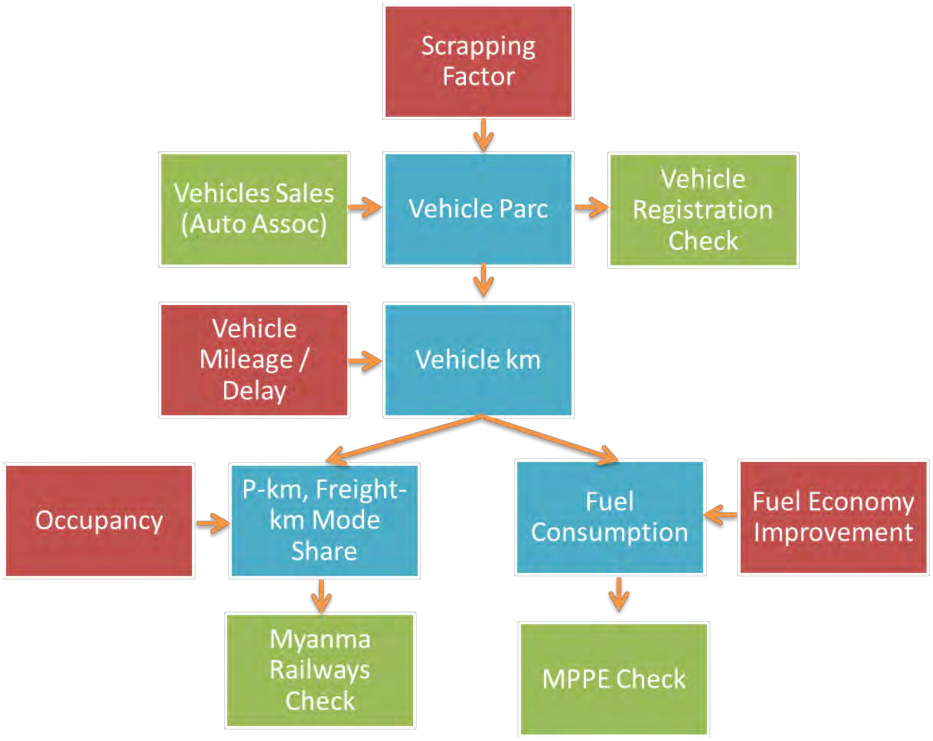
35. The major economic and policy drivers are similar for both the road and rail transport modes and the outcome of the system; fuel consumption is the direct result of vehicle km travelled and vehicle fuel efficiency in both cases.

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.

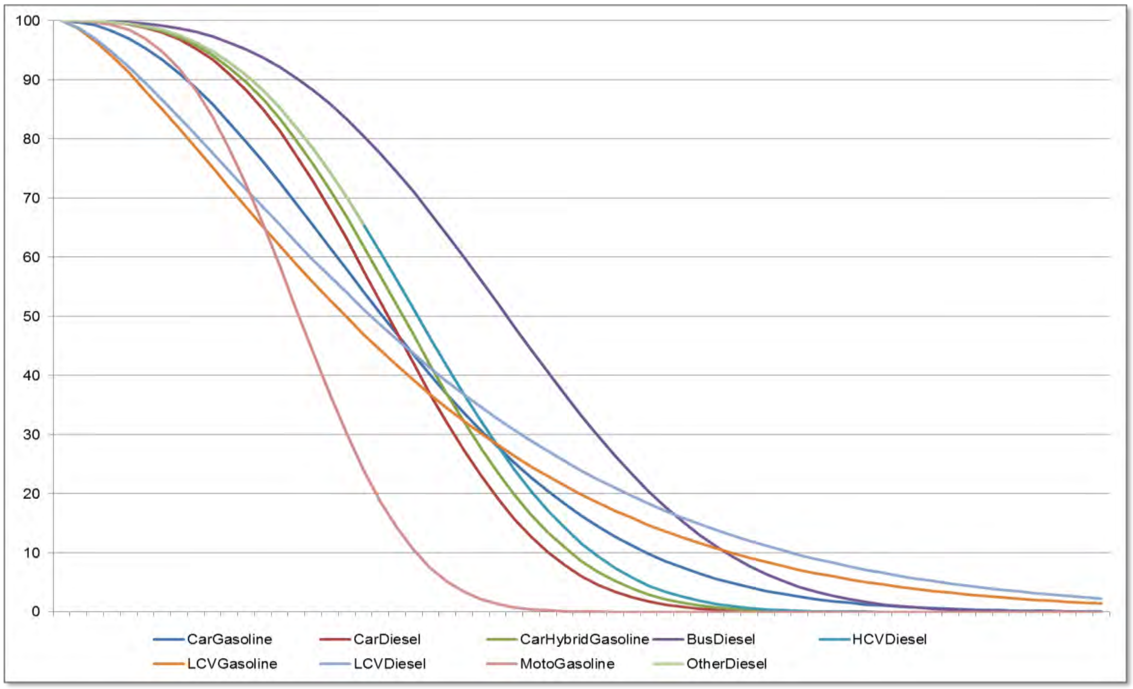
Table II-5: Weibull Scrapping Curve Parameters for the Parc

	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.

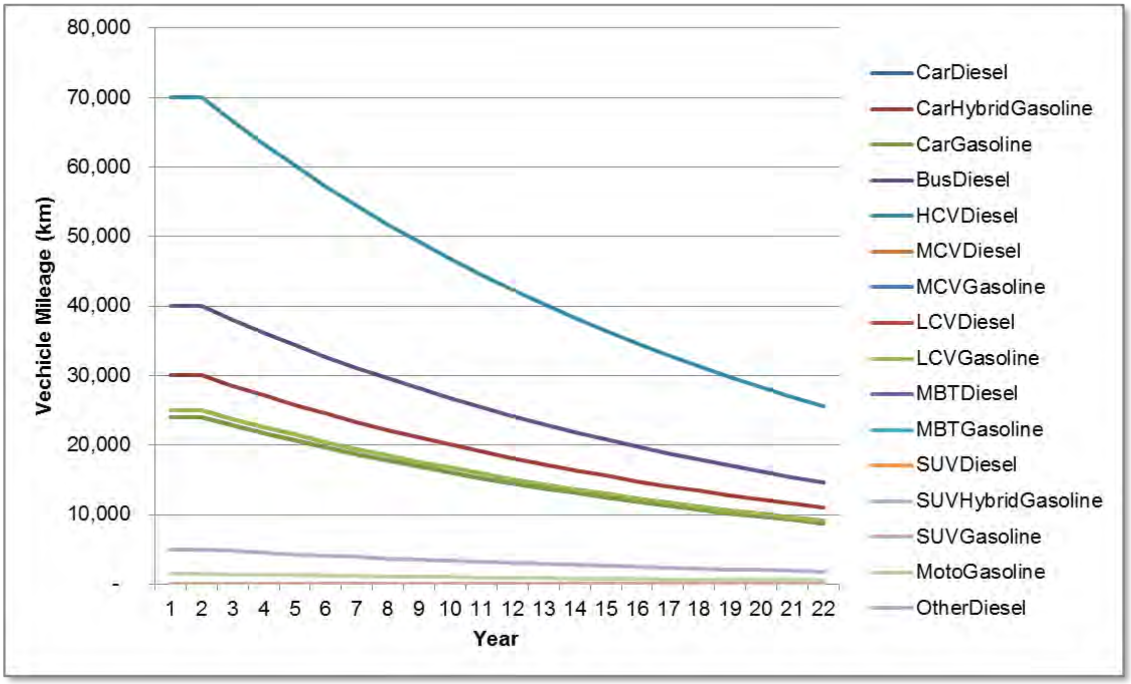
Figure II-6: Base Year Scrapping Curves for Vehicles in the Parc



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.

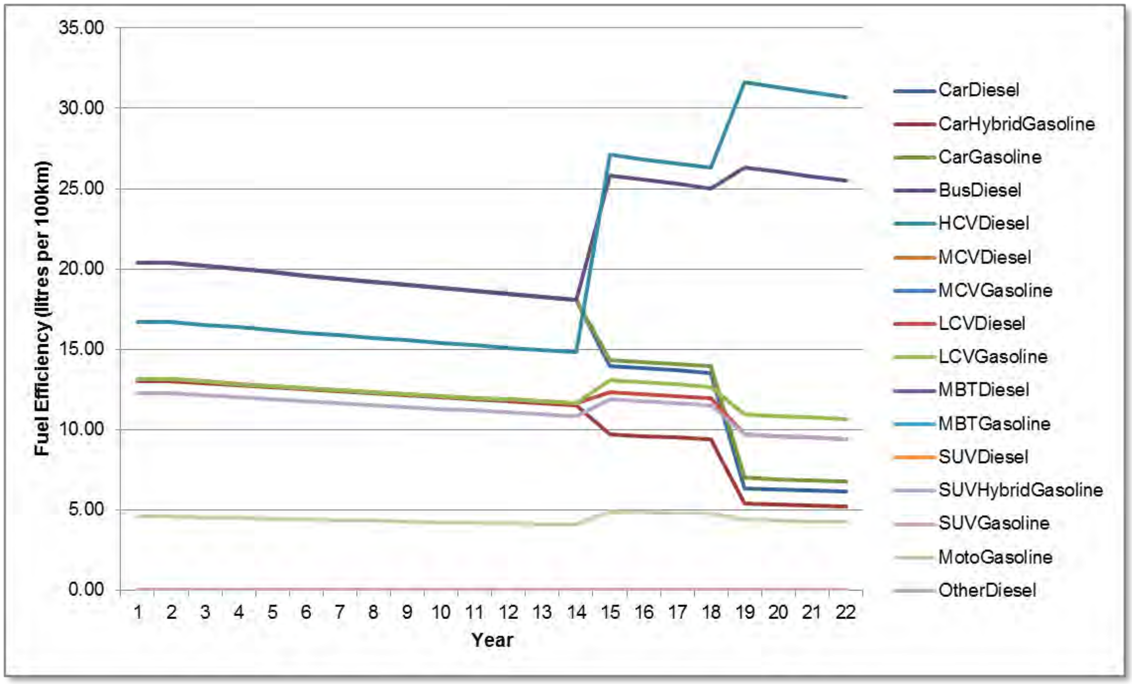
53. The Myanmar vehicle parc is dominated by models from Japan, so a higher annual improvement could be expected, but given the slower rate of scrapping in Myanmar, a scrapping rate of 1% was chosen for new vehicles in 2013 as a reasonable historical improvement rate in the absence of local reliable 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:-

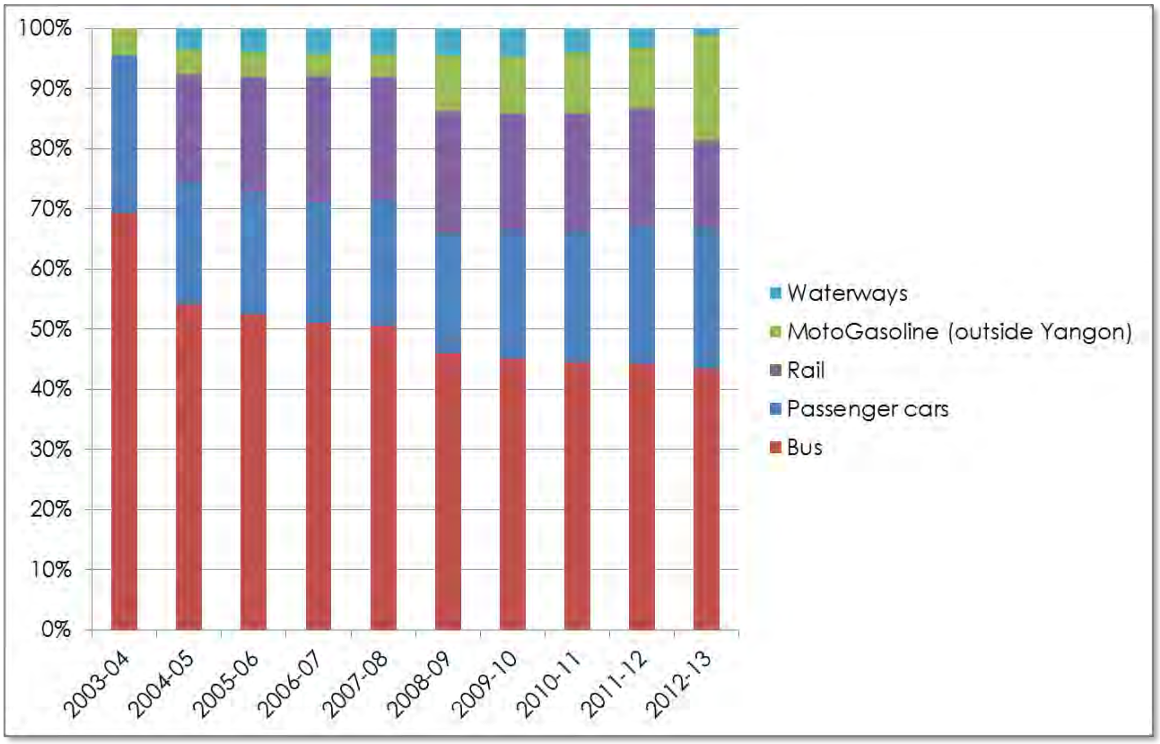
Table II-14: Passenger Services Historical Demand (billion pass-km)

	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:-

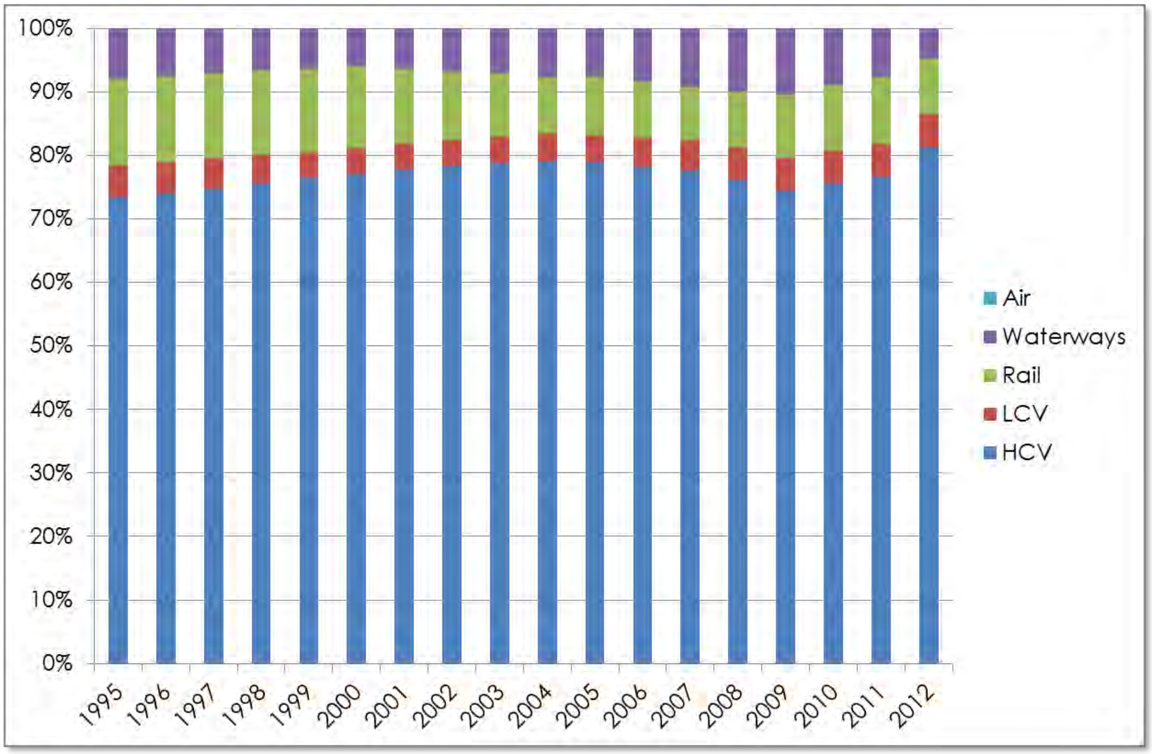
Table II-16: Freight Services Historical Demand (billion ton-km)

	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.

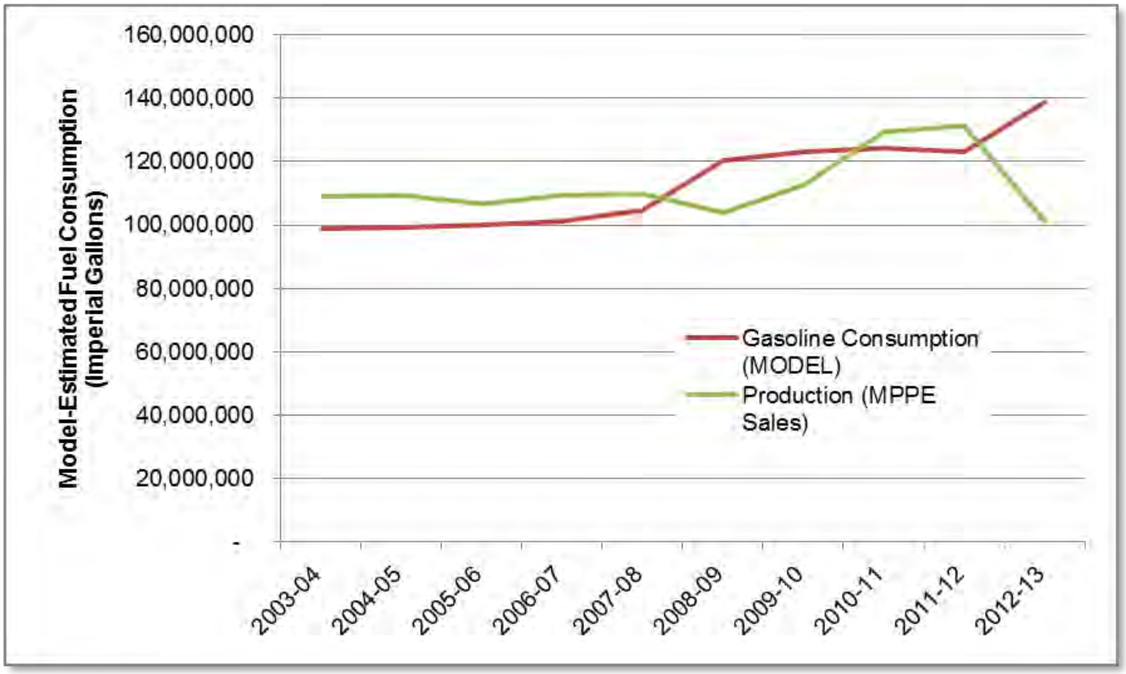
66. Gasoline statistics are shown in Table II-18 and Figure II-19, the gasoline use in recent years is in good agreement with the model. The calibration of diesel production and consumption is complicated by the fact that diesel fuel is consumed across multiple sectors. Moreover, large volumes of diesel 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.

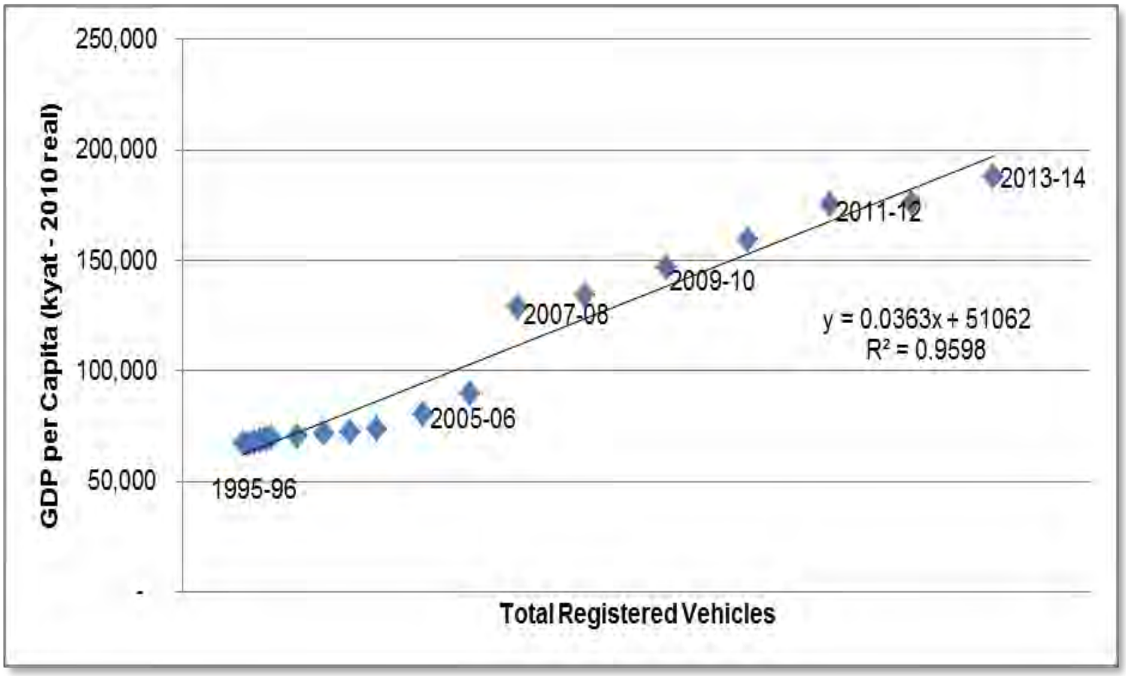
70. The base year technology penetration rates, fuel economies and vehicle mileages are validated outputs from the vehicle parc model. Two steps were then used to project energy demand:-

- 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:-

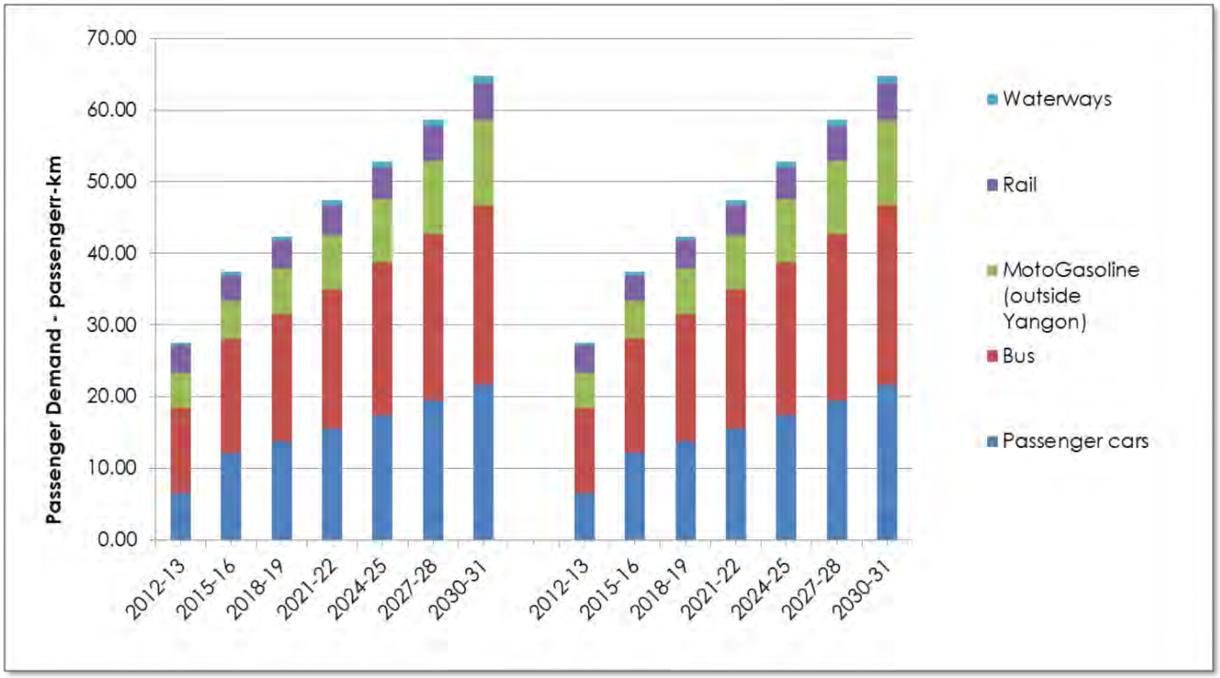
- Passenger services demand forecast;
- Passenger vehicle-km forecast;
- Passenger services supply forecast by mode;
- Freight services demand forecast;
- Freight vehicle-km forecast;
- Freight vehicle forecast by mode;
- Vehicle sales projections;
- Vehicle PARC projections;
- Average vehicle fuel economy;
- 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

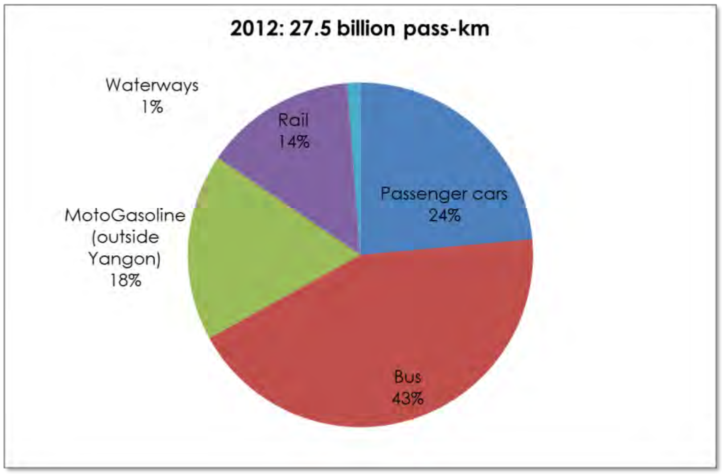
Source: Consultant

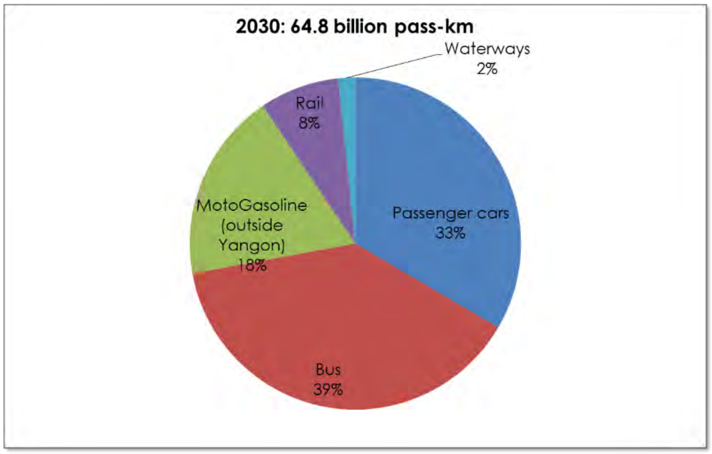
Figure III-3: Projection of Passenger Transport Demand (p-km) by Mode

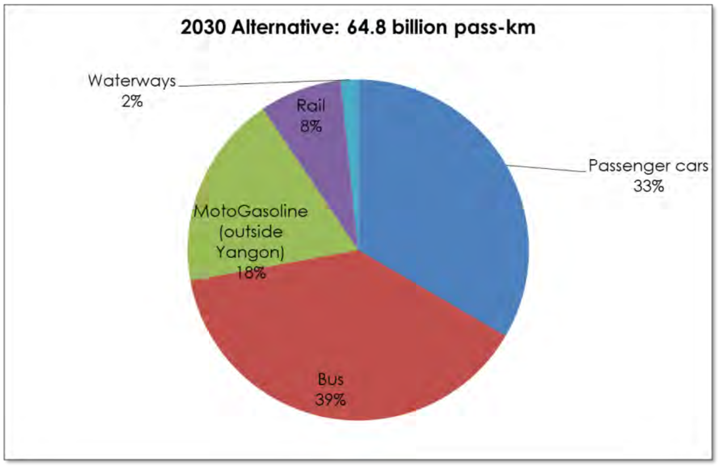


Source: Consultant

Figure III-4: Share of Passenger-km







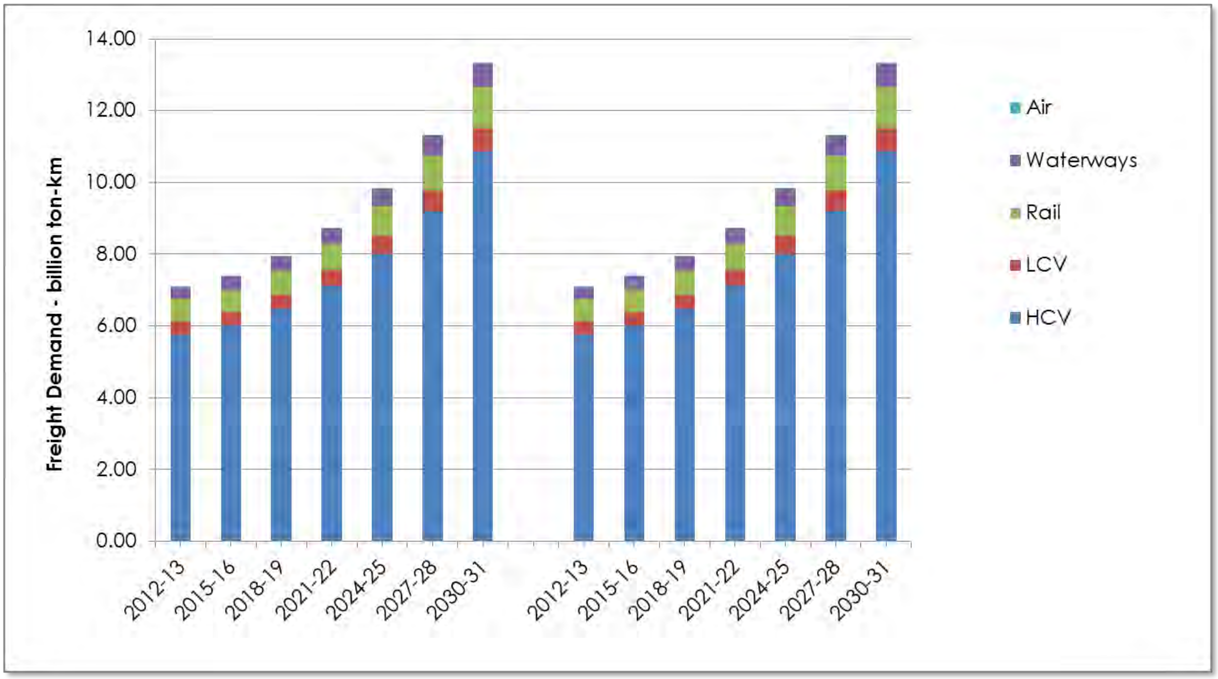
Source: Consultant

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

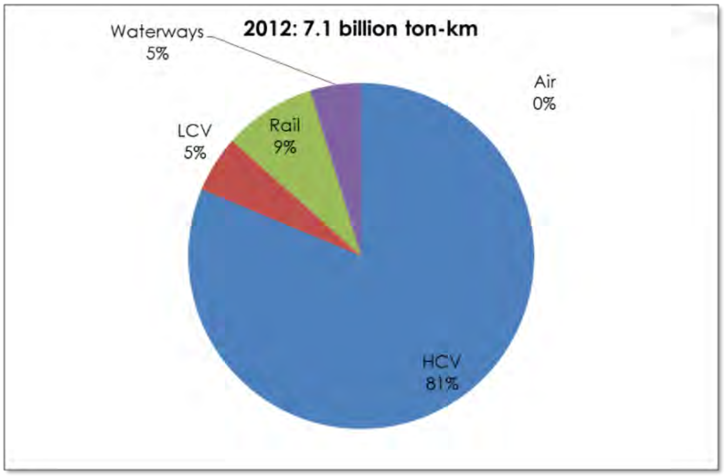
Source: Consultant

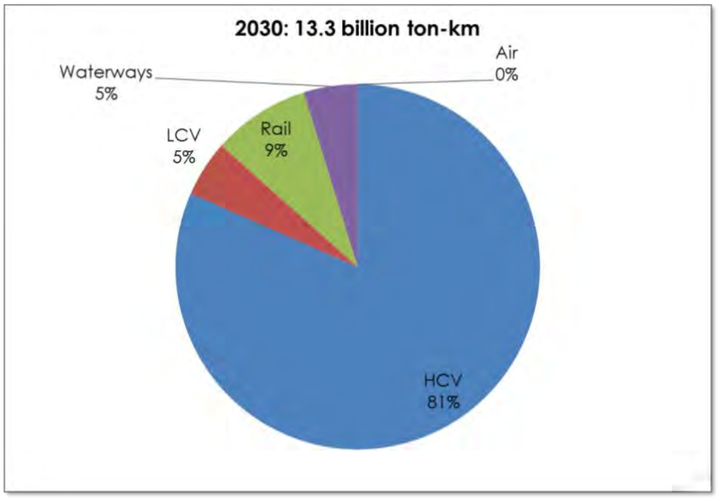
Figure III-6: Projection of Freight Transport Demand (ton-km) by Mode

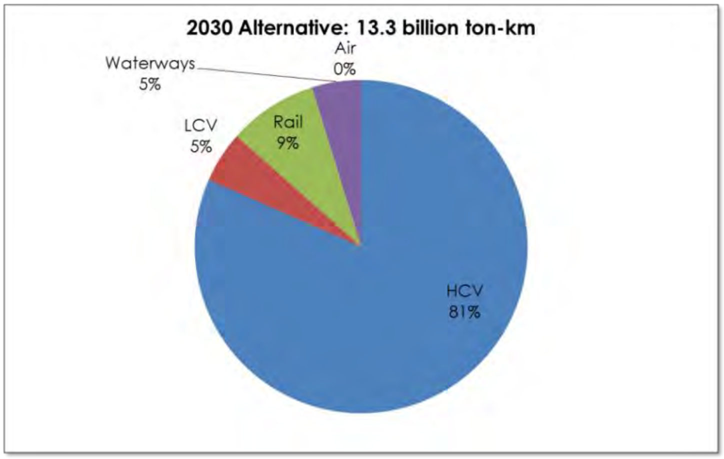


Source: Consultant

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