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Myanmar Energy Outlook 2040

Prepared by

Oil and Gas Planning Department, Ministry of Electricity and Energy of the Republic of the Union of Myanmar

Supported by

Economic Research Institute for ASEAN and East Asia

Myanmar Energy Outlook 2040

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Preface

The Republic of the Union of Myanmar has achieved remarkably high economic growth. Its average gross domestic product (GDP) growth rate was 6.9% in 2014–2018, one of the highest amongst the Association of Southeast Asian Nations (ASEAN) Member States during the same period. In 2018, Myanmar's real GDP per capita was US$1,326. Strong economic growth during 2014–2018 was accompanied by increased energy consumption in all sectors. The Ministry of Electricity and Energy, with technical and financial support from the Economic Research Institute for ASEAN and East Asia (ERIA), successfully launched the Myanmar Energy Outlook 2040 Project, which provides information about energy demand and supply up to 2040 in business-as-usual and alternative scenarios.

Myanmar is endowed with abundant, rich natural resources such as gas and hydropower, which, if fully developed, could meet most of the country's daily energy needs. Myanmar's energy policy aims to ensure energy independence by increasing national production of available primary energy resources through intensive exploration and development activities, including energy efficiency and conservation and promotion of renewable energy. Electricity is the main driver of economic development and Myanmar is taking steps to generate and distribute more power of greater volume, density, and reliability.

On behalf of the Ministry of Electricity and Energy, I express our gratitude for ERIA's technical and financial support for the Myanmar Energy Outlook 2040 Project. We will continue to consult ERIA as we build the energy database to support energy policies and planning.

I sincerely hope that this book will contribute to energy-related knowledge building and better solutions.

U Win Khaing

Union Minister

Ministry of Electricity and Energy, Myanmar

September 2020

Acknowledgement

I would like to acknowledge the Economic Research Institute of ASEAN and East Asia (ERIA) for funding and supporting the publication of *Myanmar Energy Outlook 2040*.

I would like to express my sincerest gratitude to the members of the working group of Myanmar Energy Outlook 2040 for their tireless efforts in the collection and updating of data, for their forecasts for 2040, and for the publication of the results. The working group consists of experts from the Oil and Gas Planning Department, Ministry of Electricity and Energy; and ERIA. Working group members have been contributing their time and expertise to the project after successfully launching *Myanmar Energy Statistics 2019*. I hope the energy outlook will help energy planners and policymakers prepare energy policies to meet growing energy demand and attract investment in sustainable power and energy-related infrastructure. I gratefully acknowledge other ministries and agencies for providing valuable data and information and for their cooperation on this project.

Special thanks go to Mr Shigeru Kimura of ERIA and his team for their excellent contribution to this project.

U Than Zaw

Permanent Secretary

Ministry of Electricity and Energy, Myanmar

September 2020

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Abbreviations

ASEAN	Association of Southeast Asian Nations
BAU	business as usual
CNG	compressed natural gas
CPI	consumer price index
CO_2	carbon dioxide
EEC	energy efficiency and conservation
GDP	gross domestic product
LEAP	Long-range Energy Alternative Planning System
LPG	liquefied petroleum gas
MOEE	Ministry of Electricity and Energy
Mt-c	million tons of carbon
Mtoe	million tons of oil equivalent
OGPD	Oil and Gas Planning Department
OLS	ordinary least squares
OOP	other petroleum products
PV	photovoltaic
TFEC	total final energy consumption
TPES	total primary energy supply
toe	tons of oil equivalent
TWh	terawatt hour

Executive Summary

After the publication of *Myanmar Energy Statistics 2019* (ERIA, 2019), which contains energy balance tables for 2000–2016 and analyses of energy demand and supply, the Economic Research Institute for ASEAN and East Asia (ERIA) continued to support the Oil and Gas Planning Department (OGPD), Ministry of Electricity and Energy (MOEE) to produce *Myanmar Energy Outlook 2040* based on *Myanmar Energy Statistics 2019*. ERIA provided training on the econometrics approach to OGPD, MOEE staff members. The approach consists of two parts: (i) estimation of energy demand formulas applying the ordinary least square method using *Myanmar Energy Statistics 2019,* and (ii) development of future simulation models that forecast future energy balance tables by 2040 under several macro assumptions such as growth rates of gross domestic product (GDP) and population.

GDP is an important assumption: energy demand is highly correlated with GDP historically and globally. We assume that current economic growth of Myanmar will continue until 2040, averaging 6.3%. Lowering the birth rate in the next 2 decades will require 0.7% average growth. The crude oil price will go up because of tight demand and supply, with the nominal price of US$185 in 2040. We included several energy development plans in the simulation models, such as installed capacity of solar photovoltaic (solar/PV) and hydropower plants.

Total final energy consumption (TFEC), which consists of industry, transport, commercial buildings, and residences, will increase 3.0% per year by 2040, much lower than GDP growth rate. Oil will increase 4.9% per year and electricity 7.0% by 2040. Biomass, however, will increase only 0.3% and will be almost flat until 2040. Thus, biomass will surely mitigate the TFEC growth rate.

Total primary energy supply (TPES) will increase at 3.5% per year by 2040, lower than GDP, for the same reason that TFEC will increase. TPES consists of coal, oil, gas, hydropower, renewable energy, and biomass. The major imported fuel is oil, but by 2040 all fossil fuels will depend on imports because domestic production of gas, for example, will decline. As a result, current import dependency (14% in 2016) will surely increase to 49%. Myanmar's energy supply security will be vulnerable. Therefore, the following policies are recommended:

(1) An energy efficiency and conservation policy, especially to mitigate electricity consumption, is the priority. Electricity consumption by commercial buildings is not large but new commercial buildings will increase rapidly all over Myanmar. The country will surely encourage businesses to apply energy efficiency schemes, such as the Green Building Index, in constructing new buildings.

(2) Myanmar is famous for producing natural gas and exporting large amounts of it to Thailand and China. But natural gas production is forecasted to decline. An option is to shift from natural gas power generation to coal, using domestic coal and applying clean coal technology.

(3) Biomass will phase out gradually, from 51% of total energy in 2016 to 24% in 2040, and the use of conventional energy such as oil and electricity will increase. Biomass should be used more, especially in rural areas, but so should an efficient biomass cooking stove.

(4) Hydropower is clean power and should be developed continuously, paying attention to environmental issues. Hydropower (especially during the rainy season) and solar/PV power (in the dry season) can complement each other.

Chapter 1

Introduction

The Economic Research Institute for ASEAN and East Asia (ERIA), in collaboration with the Oil and Gas Planning Department (OGPD), Ministry of Electricity and Energy (MOEE), published *Myanmar National Energy Statistics 2019*, which includes historical energy balance tables for 2000–2016. It is based on primary data and useful for analysing energy demand and supply historically.

To analyse future energy demand and supply, Myanmar needs energy outlook models. ERIA has regularly updated *Energy Outlook and Energy Saving Potential in East Asia,* which includes a chapter on Myanmar (published in 2019 but produced in 2017). The publication was the outcome of the Working Group of the Energy Outlook and Energy Saving Potentials of East Asia Summit (EAS), which used International Energy Agency energy balance tables to estimate energy demand formulas applying the ordinary least square method (OLS), and simulating future energy balance tables up to 2040 using the Long-range Energy Alternative Planning System (LEAP) and another software.

ERIA produced the Myanmar part of the EAS energy outlook on behalf of Myanmar because the Myanmar member of the working group lacked expertise in energy outlook modelling. ERIA suggested that the OGPD develop energy outlook models based on its national energy statistics in 2000–2016, not on International Energy Agency statistics in 2017, and build capacity in energy outlook modelling. As officially requested by the OGPD, ERIA started the Myanmar Energy Outlook Modelling Project. Through three working meetings and with ERIA's support, the OGPD successfully developed an energy outlook model, based on business as usual (BAU). The OGPD also conducted case studies: high and low gross domestic product (GDP), high crude oil price, and promotion of energy efficiency (EE) or renewable energy (RE). The working group meetings tackled the following:

(1) First meeting: Estimation of energy demand formulas applying OLS
(2) Second meeting: Development of future simulation model using LEAP
(3) Third meeting: Finalisation of BAU and case study results

This report describes the modelling process. Chapter 2 presents the main methodology used in producing the outlook, including the modelling work based on the use of the LEAP energy model. Chapter 3 introduces the data, which comprises mainly Myanmar national energy balance tables and socio-economic data. Chapter 4 explains how energy demand formulas from economic sectors are estimated and presents the formulas as well as the statistical values that demonstrate the estimates' reliability. Chapter 5 shows the main modelling assumptions. Chapter 6 presents the modelling results, which can be differentiated into the results of the BAU scenario and several alternative scenarios or case studies. Chapter 7 elaborates conclusions and a set of policy recommendations for the government.

Chapter 2
Methodology

1. Model Framework

Energy modelling involves the forecast of final energy consumption and the corresponding primary energy requirements or supply. Final energy consumption forecasts cover industry and transport, as well as 'others', which comprise agriculture, residential, commercial, and other sectors.

The energy outlook model was developed using the Long-range Energy Alternatives Planning System (LEAP)[1] software, an accounting system used to develop projections of energy balance tables based on final energy consumption and energy input and/or output in the transformation sector. Final energy consumption was forecasted using energy demand equations by the energy sector and future macroeconomic assumptions.

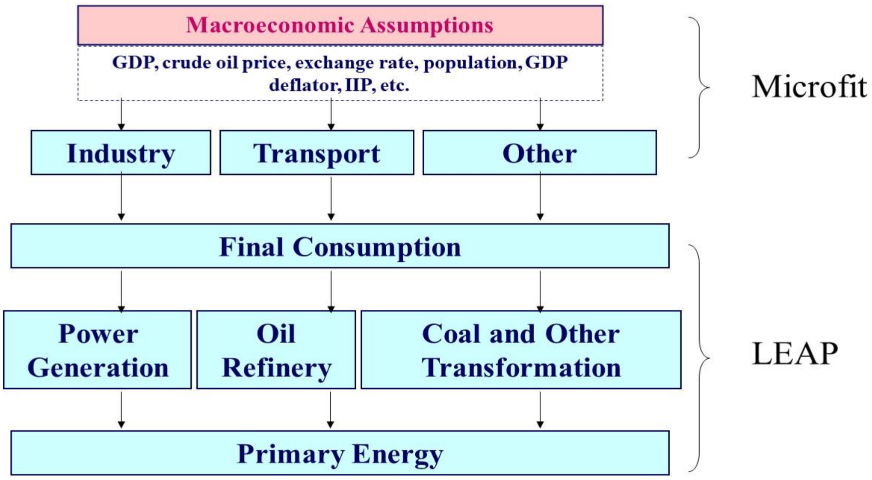
The energy demand equations are econometrically estimated using historical data, whilst future values are projected using the estimated energy demand equations under given explanatory variables. An econometric approach means that future demand will be heavily influenced by historical relations between socio-economic activities and energy demand. However, the supply of energy and new technologies is treated exogenously.

The ordinary least square (OLS) method is used to estimate energy demand functions. OLS is part of regression analysis and needs two types of historical data. One is energy data, which are national energy balance tables in 2000–2016 produced in 2018–2019 with ERIA's support, and the other is macroeconomic data such as population and gross domestic product (GDP) from the World Bank's World Development Indicators.

[1] An energy policy analysis and climate change mitigation assessment software developed at the Stockholm Environment Institute. For more information see LEAP, http://www.energycommunity.org/default.asp?action=47.

Figure 2.1 shows the model structure from final energy demand projection and forecast of transformation inputs and/or outputs to arrive at the primary energy requirements.

Figure 2.1. Structure of the Myanmar Energy Outlook Model

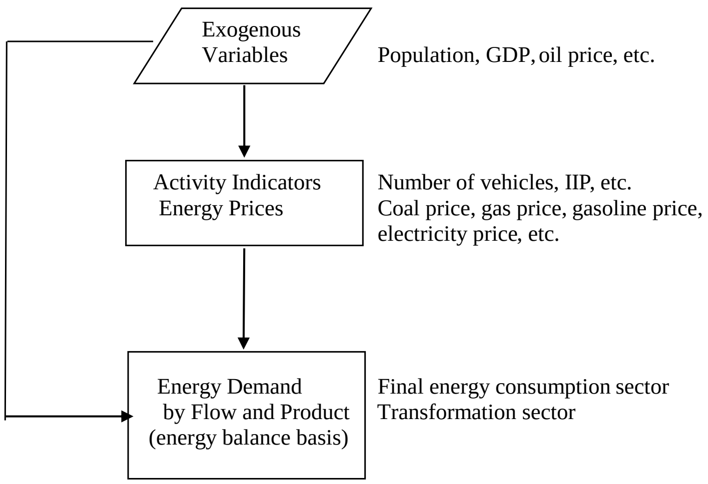


GDP = gross domestic product, IIP = index of industrial production, LEAP = Long-range Energy Alternatives Planning System.
Source: Author.

2. Estimating Demand Equation

Future energy demand for various energy sources is forecast using assumed future values of macroeconomic and activity indicators. The future values of these indicators were derived using historical data when they were enough for such analysis. The concept of estimating final energy demand equation is shown in Figure 2.2.

Figure 0.2. Process Flowchart of Myanmar Energy Outlook Model



GDP = gross domestic product, IIP = index of industrial production.
Source: Author.

In this process flowchart, energy demand is modelled as a function of activity such as income, industrial production, number of vehicles, number of households, number of appliances, and floor area of buildings. In the residential sector, for example, demand for electricity could be a function of number of households, disposable income, and penetration rate of electrical appliances. In the commercial sector, energy consumption could be driven by building floor area and GDP of service sector.

Such relationships amongst variables were derived using linear regression. The basic formulation is the following:

$$Energy\ demand\ (De) = f(Y, Pe/PGDP, De_{-1})$$

where,

Y: *Income (GDP, etc.)*

Pe: *Energy price (oil price, etc.)*

$PGDP$: *GDP` deflator (overall price, consumer price index, etc.)*

$Pe/PGDP$: *Relative variable*

De: *Energy demand (coal, oil, gas, and electricity)*

De_{-1}: *Lag variable (show habit)*

The regression analysis for the energy outlook was derived using OLS. The derived econometric equations were used in the LEAP model to estimate future energy demand based on growth assumptions of the activity (independent) variables such as GDP.

In cases where regression analysis is not applicable because of insufficient data or a failure to derive a statistically meaningful equation, appropriate growth assumptions were used to forecast future demand.

3. Forecasting Primary Energy Requirements

After future final energy demand is forecasted, the corresponding primary energy requirements need to be projected. Some of these primary energy requirements are the inputs to transformation to produce secondary fuels. Energy transformation involves electricity generation, oil refining, gas processing, charcoal making, and any other process that converts fuels from primary energy to secondary products.

Only the primary requirements for electricity generation were considered in the transformation sector. An oil refinery is being planned. Since no firm capacity was provided, the oil refinery was not included in this energy outlook.

Electricity in Myanmar is mainly produced by hydropower and gas power plants.

Myanmar also has coal, solar/PV, and biomass power plants. The electricity generation process in the model calculated the fuel requirement to produce electricity. The calculation of the primary energy requirements for electricity generation involves the following steps:

(1) Forecasting total electricity generation requirements. The total electricity generation requirement is greater than final electricity demand to cover the electricity consumption in the power stations and the expected losses in the transmission and distribution systems.

(2) Forecasting electricity generation capacity requirements, which involves two processes:

(a) Forecasting total capacity requirement, which is the capacity needed to meet peak demand. Total capacity requirement is peak demand plus assumed reserve margin, which is a percentage of peak demand. Reserve margin is the preferred amount of available capacity above peak demand to ensure that supply is not disrupted.

(b) Determining the power plants that should be added when total capacity of existing power plants cannot meet peak demand.

(3) Forecasting generation by each type of power plant. Generation by individual type of power plant in the energy model used the dispatch rule, which will meet annual demand for electricity as well as instantaneous demand for power in time slices of the year. Each power plant will be run (if necessary) up to the limit of its maximum capacity factor in each dispatch period.

4. Estimating Fuel Inputs

Finally, information on electricity generation together with conversion efficiency variables or the thermal efficiencies is used to calculate the input fuels required by power plants. This can be derived from the simple formula below:

$$Fuel\_Input_i = \frac{Electricity\_Generation_i}{Efficiency}$$

The unit of *Fuel_Input* and *Generation* is ktoe whilst that of *Efficiency* is a decimal number.

5. Case Studies and Scenarios

The outlook examined the business-as-usual (BAU) scenario, reflecting the country's current goals and action plans. BAU uses historical correlations of final energy consumption and economic activity from 2000 to 2016. The GDP growth rate is appropriate. It is used to estimate other drivers of energy demand such as GDP of the industrial sector, GDP per capita, and number of vehicles, amongst others. In view of the use of the regression analysis, future consumption trends will be similar to historical trends. Energy supply will be based on current government targets, as well.

The outlook examined the impact of changes in GDP, oil price, energy efficiency promotion, and renewable development. The details of these cases will be discussed in Chapter 5, on modelling assumptions.

Chapter 3

Data

Energy demand projections up to 2040 were implemented applying the econometrics approach wherever possible. Energy demand projections up to 2040 applied historical correlations of final energy consumption and economic activity from 2000 to 2016. Historical data consisted of energy data, socio-economic data, and energy price.

1. Energy Data

Historical energy demand data were taken from the Myanmar Energy Balance Table 2000–2016 (MOEE, 2019). The Oil and Gas Planning Department (OGPD), Ministry of Electricity and Energy (MOEE) compiled national energy statistics, which consisted of oil and gas data from the OGPD, and coal, electricity, and renewable energy data from other departments in the MOEE. Indigenous energy resources cover coal, oil, natural gas, hydropower, and biomass.

Table 3.1 shows historical energy data from 2000 to 2016 and Table is the energy balance table of 2016, which was used as the base year for the energy outlook.

For transport, final energy consumption was broken down into domestic aviation and road transport. In road transport, final consumption included consumption of other petroleum products, which were lubricants used in the vehicles.

Table 3.1. Myanmar Energy Data, 2000–2016 (ktoe)

			2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
International Aviation Bunkers		Jet Fuel	-18.0	-17.9	-14.9	-12.5	-16.8	-11.5	-14.0	-12.9	-12.9	-12.7	-18.8	-26.8	-35.6	-77.7	-83.5	-41.5	-88.7
		Total	-18.0	-17.9	-14.9	-12.5	-16.8	-11.5	-14.0	-12.9	-12.9	-12.7	-18.8	-26.8	-35.6	-77.7	-83.5	-41.5	-88.7
Total Final Energy Consumption		Hard Coal	59.9	45.9	54.3	84.9	46.7	98.8	131.4	187.7	144.2	102.2	181.8	166.9	170.8	168.1	289.8	266.5	407.3
		Briquette	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.8	1.5	2.1
		Motor Gasoline	353.9	285.3	300.6	380.3	343.6	323.2	339.9	326.0	333.9	380.9	369.9	467.6	495.7	477.5	783.7	1124.7	1331.2
		Jet Fuel	47.4	52.4	60.8	69.9	56.4	54.8	57.4	55.9	49.7	51.8	59.8	74.1	73.1	47.2	55.7	97.3	127.7
		Gas/Diesel Oil	1087.7	870.4	1006.4	993.8	863.2	918.5	1103.9	1125.2	822.8	597.5	1779.5	1348.5	1202.7	1420.0	1882.4	3165.9	2183.5
		Fuel Oil	47.2	41.5	116.9	139.7	115.0	107.8	100.4	90.7	88.4	72.5	60.8	65.9	63.5	52.7	47.9	46.9	79.8
		LPG	16.3	16.8	17.0	16.6	12.9	16.8	12.8	9.2	9.2	7.5	11.7	18.1	16.3	26.8	30.8	35.0	49.9
		Other Petroleum Products	46.4	38.0	34.2	25.8	18.1	17.5	17.8	18.3	20.9	16.0	19.6	92.1	122.7	195.1	309.3	290.6	432.1
		Natural Gas	397.8	250.2	352.7	339.8	390.6	298.2	545.0	636.8	750.9	620.9	674.6	836.4	572.6	654.2	573.3	498.2	429.7
		Electricity	281.0	261.5	299.6	331.1	336.2	374.3	374.5	381.7	404.3	429.4	542.8	662.2	710.2	827.1	969.6	1153.1	1321.4
		Biomass	6846.1	6975.6	7113.9	7218.9	7418.9	7556.9	7781.0	8038.6	8287.7	8543.3	8757.9	9379.5	9457.0	9192.7	9830.2	8917.6	8927.6
		Total	9183.7	8837.5	9356.4	9600.8	9601.6	9766.9	10464.0	10870.1	10912.0	10821.9	12458.3	13111.4	12884.7	13061.4	14773.4	15597.4	15292.3
Industry Sector	Industry Sector (Total)	Coal	59.9	45.9	54.3	84.9	46.7	98.8	131.4	187.7	144.2	102.2	181.8	166.9	170.8	168.1	289.8	266.5	407.3
		Petroleum Products	628.9	512.8	639.2	597.2	548.1	625.5	780.8	817.2	552.9	480.0	1003.8	818.3	1094.2	1261.3	1782.4	2790.9	2037.3
		Gas/Diesel Oil	562.3	450.0	521.3	468.8	445.8	528.6	689.1	731.3	467.4	411.3	940.8	700.4	951.3	1102.7	1524.8	2593.7	1754.4
		Fuel Oil	35.6	31.3	88.2	105.5	86.8	81.4	75.7	68.4	66.7	54.7	45.8	49.8	48.0	39.8	36.1	35.4	60.2
		Others	31.0	31.5	29.7	22.9	15.5	15.6	15.9	17.5	18.8	14.0	17.1	68.1	95.0	118.8	221.4	161.8	222.7
		Natural Gas	396.0	248.4	351.0	338.0	386.9	262.8	462.5	518.5	603.3	457.1	501.6	660.3	392.8	475.2	391.4	330.3	264.9
		Biomass	2053.8	2092.7	2134.2	2165.7	2225.7	2267.1	2334.3	2411.6	2486.3	2563.0	2627.2	2784.9	2795.3	2704.2	2886.0	2624.3	2633.1
		Electricity	111.4	98.7	121.9	135.6	133.2	151.1	159.4	161.0	163.8	159.1	196.7	233.1	331.0	349.2	453.7	354.4	400.0
		Total	3250.0	2998.4	3300.5	3321.4	3340.6	3405.3	3868.4	4096.0	3950.4	3761.3	4511.1	4663.6	4784.1	4958.1	5803.3	6366.4	5742.6
Transport Sector	Transport Sector (Total)	Petroleum Products	929.5	761.3	847.8	975.2	817.4	767.9	812.0	775.8	738.9	618.9	1268.3	1212.1	847.4	881.3	1254.3	1891.5	2065.3
		Motor Gasoline	353.9	285.1	300.6	380.3	343.6	323.2	339.9	326.0	333.9	380.8	369.8	467.5	495.7	477.5	783.6	1124.6	1331.1
		Jet Fuel	47.4	52.4	60.8	69.9	56.4	54.8	57.4	55.9	49.7	51.8	59.8	74.1	73.1	47.2	55.7	97.3	127.7
		Gas/Diesel Oil	525.4	420.4	485.1	525.0	417.4	389.9	414.8	393.9	355.4	186.2	838.7	648.0	251.4	317.3	357.6	572.2	429.1

			2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
		Other Petroleum Products	3.0	3.5	1.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	22.5	27.1	39.3	57.4	97.5	177.4
		Natural Gas	1.8	1.8	1.7	1.8	3.7	35.4	82.5	118.3	147.6	163.8	173.0	176.1	165.3	178.3	181.2	167.3	164.4
		Total	931.4	763.1	849.5	977.0	821.1	803.3	894.5	894.1	886.5	782.6	1441.3	1388.2	1012.7	1059.6	1435.5	2058.9	2229.7
	Domestic Air Transport	Petroleum Products	47.4	52.4	60.8	69.9	56.4	54.8	57.4	55.9	49.7	51.8	59.8	74.1	73.1	47.2	55.7	97.3	127.7
		Jet Fuel	47.4	52.4	60.8	69.9	56.4	54.8	57.4	55.9	49.7	51.8	59.8	74.1	73.1	47.2	55.7	97.3	127.7
		Total	47.4	52.4	60.8	69.9	56.4	54.8	57.4	55.9	49.7	51.8	59.8	74.1	73.1	47.2	55.7	97.3	127.7
	Road	Petroleum Products	882.2	708.9	787.1	905.3	761.0	713.1	721.0	687.8	655.3	531.1	1172.0	1099.8	738.2	797.5	1161.2	1757.6	1902.1
		Motor Gasoline	353.9	285.1	300.6	380.3	343.6	323.2	339.9	326.0	333.9	380.8	369.8	467.5	495.7	477.5	783.6	1124.6	1331.1
		Gas/Diesel Oil	525.4	420.4	485.1	525.0	417.4	389.9	381.2	361.9	321.4	150.2	802.2	609.8	215.4	280.7	320.2	535.6	393.5
		Other Petroleum Products	3.0	3.5	1.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	22.5	27.1	39.3	57.4	97.5	177.4
		Natural Gas	1.8	1.8	1.7	1.8	3.7	35.4	82.5	118.3	147.6	163.8	173.0	176.1	165.3	178.3	181.2	167.3	164.4
		Total	884.0	710.7	788.7	907.1	764.7	748.5	803.6	806.1	802.9	694.9	1345.0	1275.8	903.5	975.8	1342.4	1925.0	2066.5
	Rail	Diesel	0.0	0.0	0.0	0.0	0.0	0.0	33.6	32.0	33.9	36.0	36.5	38.3	36.1	36.6	37.4	36.6	35.5
		Total	0.0	0.0	0.0	0.0	0.0	0.0	33.6	32.0	33.9	36.0	36.5	38.3	36.1	36.6	37.4	36.6	35.5
Other Sector	Other Sector (Total)	Fuel Oil	11.6	10.2	28.7	34.3	28.2	26.5	24.6	22.2	21.7	17.8	14.9	16.2	15.6	12.9	11.8	11.5	19.6
		LPG	16.3	16.8	17.0	16.6	12.9	16.8	12.8	9.2	9.2	7.5	11.7	18.1	16.3	26.8	30.8	35.0	49.9
		Other Petroleum Products	12.5	3.2	3.2	2.9	2.6	1.9	1.9	0.9	2.2	2.0	2.5	1.6	0.6	37.0	30.5	31.5	32.1
		Natural Gas	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	14.5	0.6	0.7	0.5	0.4
		Biomass	4792.3	4882.9	4979.8	5053.2	5193.2	5289.8	5446.7	5627.0	5801.4	5980.3	6130.7	6594.6	6661.7	6488.5	6944.2	6293.3	6294.5
		Electricity	169.6	162.8	177.8	195.5	203.0	223.3	215.1	220.7	240.5	270.4	346.2	429.1	379.2	477.8	515.9	798.7	921.4
		Total	5002.3	5075.9	5206.4	5302.4	5439.9	5558.3	5701.1	5880.1	6075.0	6278.0	6506.0	7059.6	7088.0	7043.7	7533.8	7170.6	7317.9
	Commerce & Public Services	Fuel Oil	11.6	10.2	28.7	34.3	28.2	26.5	24.6	22.2	21.7	17.8	14.9	16.2	15.6	12.9	11.8	11.5	19.6
		Natural Gas	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	14.5	0.6	0.7	0.5	0.4
		Biomass	2053.8	2092.7	2134.2	2165.7	2225.7	2267.1	2334.3	2411.6	2486.3	2563.0	2627.2	2784.9	2795.3	2704.2	2886.0	2624.3	2633.1
		Electricity	45.3	48.5	47.5	49.7	52.7	59.8	71.1	74.3	81.3	92.1	112.3	131.7	141.3	145.5	150.9	215.5	260.0
		Total	2110.7	2151.3	2210.3	2249.7	2306.6	2353.3	2430.0	2508.1	2589.3	2672.9	2754.5	2932.8	2966.6	2863.3	3049.3	2863.7	2927.6
	Residential	Briquette	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.8	1.5	2.1
		LPG	16.3	16.8	17.0	16.6	12.9	16.8	12.8	9.2	9.2	7.5	11.7	18.1	16.3	26.8	30.8	23.2	35.5
		Biomass	2738.4	2790.2	2845.6	2887.5	2967.5	3022.8	3112.4	3215.5	3315.1	3417.3	3503.5	3809.7	3866.5	3784.4	4058.2	3669.1	3661.3

			2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
		Electricity	117.0	107.0	123.1	138.6	143.0	155.8	138.8	141.6	154.7	173.3	228.2	290.5	230.6	323.7	353.7	574.0	651.2
		Total	2871.8	2914.1	2985.7	3042.8	3123.4	3195.4	3264.0	3366.3	3479.0	3598.2	3743.4	4118.3	4113.4	4134.9	4443.5	4444.2	4444.8
	Non-specified Others	Other Petroleum Products	12.5	3.2	3.2	2.9	2.6	1.9	1.9	0.9	2.2	2.0	2.5	1.6	0.6	37.0	30.5	31.5	32.1
		Electricity	7.3	7.3	7.2	7.1	7.3	7.6	5.2	4.8	4.6	4.9	5.6	6.9	7.4	8.6	11.3	9.2	10.1
		Total	19.8	10.5	10.4	10.0	9.9	9.6	7.1	5.6	6.8	6.9	8.2	8.5	8.0	45.6	41.8	40.7	42.2

ktoe = thousand tons of oil equivalent, intl= international, LPG = liquefied petroleum gas, OOP = other petroleum product.

Source: Ministry of Electricity and Energy (2019).

Table 3.2. Myanmar Energy Balance Table, 2016 (ktoe)

	1. Coal	3. Crude Oil & NGL	4. Petroleum Products	4.1 Motor Gasoline	4.2 Naphtha	4.3 Jet Fuel	4.4 Kerosene	4.5 Gas/ Diesel Oil	4.6 Fuel Oil	4.7 LPG	4.9 Ethane	4.10 Other Petroleum Products	5. Gas	6. Hydro	8. Geothermal, Solar etc.	9. Others	10. Electricity	12. Total
1. Indigenous Production	209	607	11		4					7			16,466	1,043	1	9,069		27,406
2. Imports	208		3,966	1,154		201		2,151		35		424						4,174
3. Exports	-4	-146	-173					-173					-12,834				-205	-13,361
4. International Marine Bunkers			-1					-1										-1
13.1 International Aviation Bunkers			-89			-89												-89
5. Stock Changes		0	357	265	0	2		84	4	3		-2	-1					355
6. Total Primary Energy Supply	414	461	4,070	1,419	4	115		2,060	4	46		422	3,631	1,043	1	9,069	-205	18,484
7. Transfers				4	-4													
8. Total Transformation Sector	-7	-418	400	153		16	0	136	75	5		14	-2,747	-1,043	-1	-141	1,742	-2,213
8.1 Main Activity Producer	-5		-19					-19					-2,730	-1,043	-1		1,742	-2,056
8.4 Refineries		-418	419	153		16	0	155	75	5		14						0
8.5 Coal Transformation	-2																	0
9. Loss & Own Use			-5									-5	-431				-216	-652
10. Discrepancy	0	-43	-261	-245	0	-3		-13	0	-1		0	-23				0	-327
11. Total Final Energy Consumptions	407		4,204	1,331		128	0	2,183	80	50		432	430			8,928	1,321	15,292
12. Industry Sector	407		2,037					1,754	60			223	265			2,633	400	5,743
12.1 Iron and Steel	37												7					44
12.2 Chemical (incl. Petro-Chemical)													117					117
12.3 Non Ferrous Metals													2					2
12.4 Non Metallic Mineral Products	123												119					242
12.5 Transportation Equipment													0					0
12.6 Machinery													5					5
12.8 Food, Beverages and Tobacco													6					6
12.9 Pulp, Paper and Printing													0					0
12.1 Construction			215									215						215
12.1 Textiles and Leather													8					8
12.1 Non-specified Industry	247		1,823					1,754	60			8	2			2,633	400	5,104
13. Transport Sector			2,065	1,331		128		429				177	164					2,230
13.2 Domestic Air Transport			128			128												128
13.3 Road			1,902	1,331				394				177	164					2,066
13.4 Rail			36					36										36
14. Other Sector			102	0			0		20	50		32	0			6,294	921	7,320
14.1 Residential & Commercial			70						20	50			0			6,294	911	7,278
14.1.1 Commerce and Public Services			34						20	14			0			2,633	260	2,928
14.1.2 Residential			35							35						3,661	651	4,350
14.4 Non-specified Others			32	0			0					32					10	42
15. of which Non-Energy Use			424									424	105					529
16 Electricity Output in GWh	10	61											8,052	12,125	9	0		20,258

GWh = gigawatt hour, ktoe = thousand tons of oil equivalent, LPG = liquefied petroleum gas.
Source: Ministry of Electricity and Energy (2019).

In estimating the aviation fuel demand function, aviation fuel consumption is defined as domestic demand plus international aviation bunkers (aviation fuel for international flights). The international aviation bunkers in the energy balance table were reported as part of total primary energy supply and the absolute value was used in the summation.

'Others' are the commercial, services, residential, and agriculture sectors. Demand function was estimated for fuels consumed in each.

2. Macroeconomic Data

The economic indicators used in the energy outlook modelling were taken from the World Bank's World Development Indicators (World Bank, 2018): gross domestic product (GDP), major sectors gross value-added, GDP deflator, consumer price index (CPI), official exchange rate, total population, urban and rural population, and population in the largest city (Table 3.3).

Other economic indicators were used to estimate the final energy demand equation, but these data were obtained from national statistics.

3. International Crude Oil Price

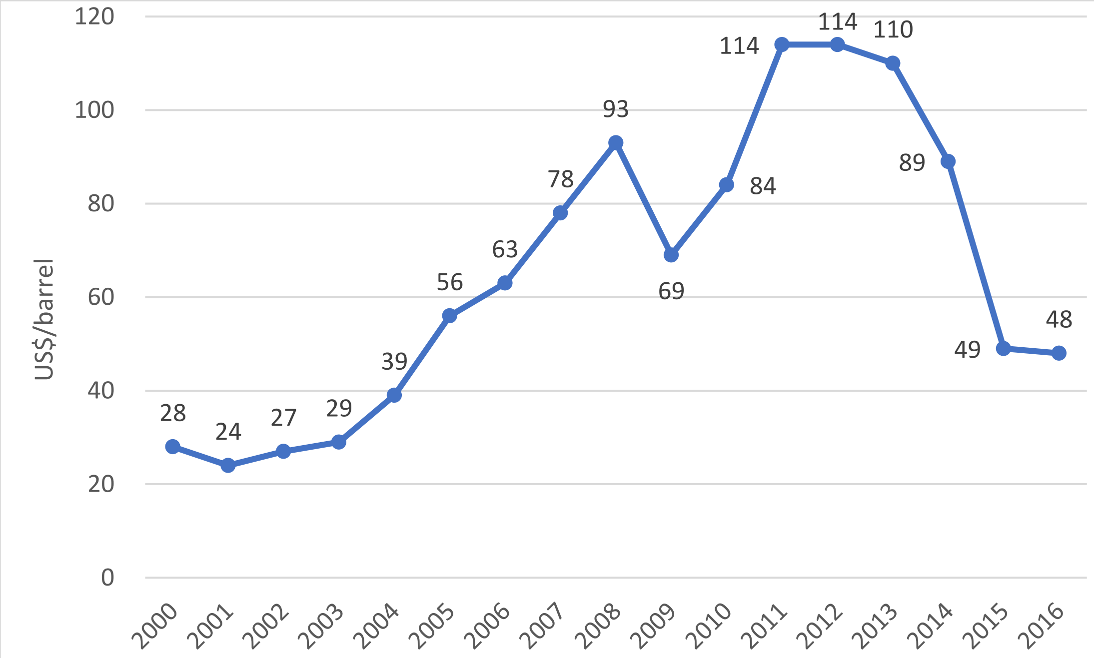
The international crude oil price in the outlook model used the imported price of Japan cost, insurance, and freight (CIF) as representing the world crude oil price. Historical crude oil price data were used for ERIA's energy outlook activity and for saving potential. Figure 3.1 shows the CIF crude oil price from 2000 to 2016.

Table 3.3. World Development Indicators, Myanmar, 2000–2016

Series Name	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Agriculture, value added (billion constant 2010 US$)	9.15	9.95	10.55	11.78	13.07	14.65	15.46	16.79	17.84	18.89	18.26	18.14	18.44	19.11	19.64	20.31	20.22
Agriculture, value added (trillion constant LCU)	7.35	7.99	8.47	9.46	10.50	11.76	12.41	13.48	14.32	15.16	14.66	14.56	14.81	15.35	15.77	16.31	16.23
Consumer price index (2010 = 100)	14.99	15.99	16.99	17.99	18.99	19.99	20.99	21.99	22.99	23.99	24.99	25.99	26.99	27.99	28.99	29.99	30.99
GDP (billion constant 2010 US$)	15.98	17.80	19.94	22.70	25.78	29.28	33.10	37.07	40.87	45.19	49.54	52.31	56.15	60.88	65.74	70.34	74.46
GDP (trillion constant LCU)	12.83	14.29	16.01	18.22	20.70	23.51	26.58	29.77	32.82	36.28	39.78	42.00	45.08	48.88	52.79	56.48	59.79
GDP deflator (base year varies by country)	19.89	24.83	35.14	42.34	43.87	52.27	63.41	78.40	89.07	93.42	100.00	110.25	113.71	118.68	123.64	128.75	133.41
Industry, value added (billion constant 2010 US$)	1.55	1.89	2.55	3.08	3.73	4.48	5.80	6.89	8.11	9.59	13.11	14.45	15.61	17.39	19.50	21.13	23.01
Industry, value added (trillion constant LCU)	1.24	1.52	2.05	2.47	3.00	3.60	4.65	5.53	6.51	7.70	10.53	11.60	12.53	13.96	15.66	16.96	18.48
Manufacturing, value added (billion constant 2010 US$)	1.15	1.40	1.80	2.19	2.73	3.33	4.24	5.12	6.11	7.25	9.84	10.90	11.81	12.94	14.16	15.56	17.01
Manufacturing, value added (trillion constant LCU)	0.92	1.12	1.44	1.76	2.19	2.68	3.40	4.11	4.91	5.82	7.90	8.75	9.48	10.39	11.37	12.50	13.66
Official exchange rate (LCU per US$, period average)	6.52	6.75	6.64	6.14	5.81	5.82	5.84	5.62	5.44	5.58	5.63	5.44	640.65	933.57	984.35	1162.62	1234.87
Population in largest city (million)	3.57	3.65	3.72	3.80	3.88	3.96	4.04	4.12	4.21	4.29	4.38	4.47	4.56	4.66	4.75	4.85	4.95
Population, total (million)	46.72	47.23	47.70	48.15	48.56	48.95	49.30	49.62	49.93	50.25	50.60	50.99	51.41	51.85	52.28	52.68	53.05
Rural population (million)	34.09	34.38	34.64	34.87	35.08	35.27	35.43	35.57	35.70	35.83	35.98	36.17	36.37	36.58	36.78	36.95	37.09
Services, etc., value added (billion constant 2010 US$)	5.85	6.68	7.37	8.28	9.32	10.13	11.52	12.82	14.06	15.18	18.17	19.72	22.09	24.37	26.60	28.90	31.24
Services, etc., value added (trillion constant LCU)	4.69	5.36	5.92	6.65	7.48	8.14	9.26	10.30	11.30	12.20	14.60	15.80	17.70	19.60	21.40	23.20	25.10
Urban population (million)	12.63	12.85	13.07	13.28	13.48	13.68	13.87	14.05	14.23	14.42	14.62	14.83	15.05	15.27	15.50	15.73	15.96

Source: World Bank, World Development Indicators. https://data.worldbank.org/country/myanmar?view=chart (accessed 24 October 2018).

Figure 3.1. Nominal Crude Oil Price (CIF Japan)



CIF = cost, insurance, and freight.
Source: Trade Statistics of Japan (2018).

4. National Data

In principle, national data should be used in estimating energy demand formulas. The World Bank's World Development Indicators data for Myanmar exclude the local energy price and other activity data that were relevant for estimating the energy demand equations.

4.1. Local Energy Price

Local energy prices included petroleum products (gasoline, diesel, LPG, amongst others); gas; electricity; and coal. Import CIF, CPI, and sales price were the basis for determining the domestic energy price. Local energy prices should be the relative price not the absolute price.

$$Energy\ demand\ (De) = f(Y, \mathbf{Pe/PGDP}, De_{-1})$$

where,

Y: Income (GDP, etc.)

Pe: Energy price (coal, petroleum products, gas and electricity price)

PGDP: GDP deflator (overall price, CPI, etc.)

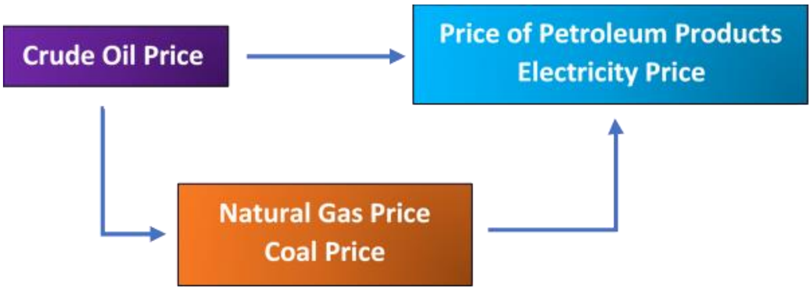
Pe/PGDP: Relative variable

De: Energy demand (coal, oil, gas, and electricity)

De_{-1}: Lag variable (show habit)

The international energy price can be used to explain the local energy price if the data are not available. Thus, the local energy price will be a function of the international energy price.

Figure 3.2. Estimating Local Energy Price



Source: Author.

Examples:

Motor gasoline price	*: MGprice = f(Poil/exr/pgdp, MGprice(-1))*
Electricity price	*: Eprice = f(DEprice/pgdp, Eprice(-1))*
Natural gas price	*: NGprice = f(DNGprice/pgdp, NGprice(-1))*
Poil	*: Crude oil price (US$/barrel, nominal)*
Exr	*: Exchange rate*
Pgdp	*: GDP deflator*
DEPrice	*: Domestic electricity price*
DNGPrice	*: Domestic natural gas price*

4.2. Local Activity Data

Local activity data that were commonly used in estimating the energy demand function of the final sectors were the following:

(1) Industry sector: Index of industrial production (IIP)
(2) Road sector: Number of vehicles (stock basis)
(3) Residential sector: Number of households
(4) Commercial sector: Number of buildings, floor area

These local activity data were usually explained by macro variables such as GDP.

Examples:

Index of industrial production : IIP = f(Industrial GDP, IIP(-1))

Number of cars : Ncar = f(GDP, Ncar(-1))

Floor area : Floor = f(commercial GDP, floor(-1))

Number of households : NHH = f(Population, NHH(-1))

Local activity data collected by the OGPD to estimate demand function for road transport was the number of vehicles (Table 3.4).

Table 3.4. Vehicle Statistics of Myanmar

	Passenger Car	Truck	Bus	Two-wheeler	Three-wheeler	Others	Total
2000	173.44	53.89	16.87	174.49	1.31	22.27	442.26
2001	174.65	53.54	17.55	171.18	1.17	31.40	449.50
2002	177.34	54.09	17.54	172.57	1.00	44.17	466.71
2003	183.33	52.15	17.78	174.50	0.96	54.33	483.05
2004	186.91	52.75	17.97	638.52	1.33	66.79	964.27
2005	193.94	54.80	18.04	641.78	2.37	68.36	979.29
2006	202.07	55.38	18.86	646.87	3.95	69.63	996.76
2007	217.02	57.21	19.29	659.00	5.64	74.68	1032.84
2008	233.23	58.86	19.68	1612.42	6.67	68.10	1998.96
2009	245.92	61.13	19.81	1749.08	8.88	62.59	2147.40
2010	265.64	64.89	20.94	1883.96	13.42	59.67	2308.52
2011	249.56	67.75	19.58	1955.51	18.00	53.35	2363.75
2012	292.92	74.55	19.81	3219.21	38.55	54.07	3699.11
2013	382.77	124.60	22.15	3595.47	51.40	61.29	4237.68
2014	429.49	193.56	26.75	4276.70	65.16	86.04	5077.70
2015	462.20	250.53	25.94	4631.11	74.27	97.32	5541.36
2016	512.14	322.53	26.80	5271.11	84.41	120.01	6337.00

Note: Others include ambulances, dump trucks, and trailers, amongst others.
Source: Oil and Gas Planning Department, Ministry of Electricity and Energy.

Chapter 4
Estimation of Energy Demand Formulas

Energy is an important commodity for developing the economy. As economic activities increase, demand for energy increases. Changes in energy prices directly influence energy consumption and economic growth. Rising energy prices bring an incentive to use energy sources more efficiently and conservatively, resulting in lower energy consumption. The increase in energy prices, however, leads to inflation because the cost of other goods increases and gross domestic product (GDP) decreases. Therefore, there is a direct link between energy consumption and socio-economic variables such as energy price and economic output (or GDP). Logically, an increase in GDP leads to an increase in energy consumption but, on the contrary, an increase in energy prices results in lower energy consumption.

This chapter focuses on the estimation of energy demand formulas based on historical data on energy consumption, socio-economic data, and activity indicators used to forecast energy demand until 2040.

1. Methodology

The demand function was estimated using the econometrics approach, which is a top-down approach linking the macroeconomic model and energy model.

In the econometrics approach, energy demand is modelled as a function of macroeconomic activities such as income (or GDP), relative prices amongst sources of energy, and energy consumption at previous period.

$$E = f(Y, Pe/CPI) \quad or \quad E = f(Y, Pe/CPI, E\text{-}1)$$

Where:

E : *Energy demand*
Y : *Income (or GDP)*
Pe : *Energy price*
CPI : *Consumer price index*
Pe/CPI : *Relative energy price over CPI*
E-1 : *Energy consumption at previous period*

The relationships amongst the above variables are derived using regression analysis software Microfit, which carries out econometrics analysis, estimating ordinary least squares (OLS) and testing equations, data processing, file management, graphic display, estimation, hypothesis testing, and forecasting using univariate and multivariate model specifications.

Future energy demand for various energy sources will be forecasted using the estimated formulas mentioned above with the assumed future values of the macroeconomic, energy price, and other activity indicators. However, not all energy consumption of the sectors could be estimated as a demand formula because of data limitations.

To estimate the energy demand formulas for economic activities in the industry, transport, commercial, and residential sectors, we disaggregate energy consumption by sector into type of energy, such as gas, petroleum products, electricity, and coal consumption, and then test the regression results for their relationship with GDP, energy prices, and other related indicators.

In cases where regression analysis is not applicable because of insufficient data or failure to derive a statistically effective equation, other exogenous approaches such as growth of GDP or share of percentage were applied.

2. Estimation of Energy Demand Formulas

2.1. Industry

Total energy consumption in industry is not broken down into subsectors. On the basis of fuel type, the total energy consumption each year from 2000 to 2016 is the sum of the different types of fuel: coal; electricity; natural gas; petroleum products (diesel and fuel oil); and others (fuelwood and charcoal, amongst others).

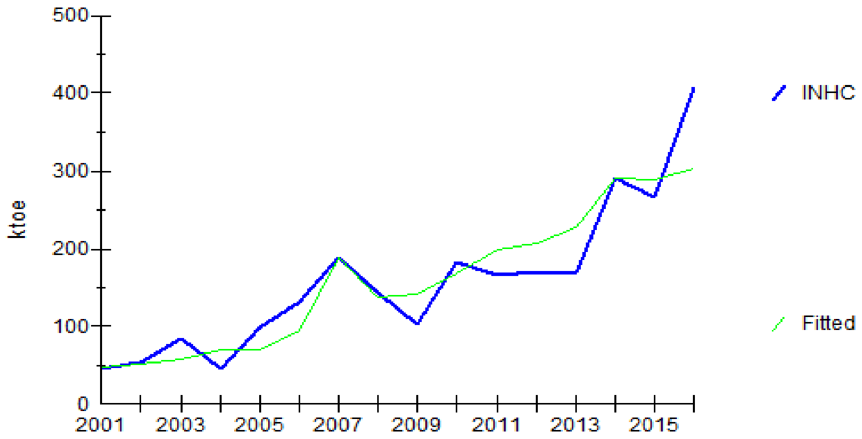
Based on available data, demand formulas have been estimated for the type of fuel, if applicable.

a) Sub-bituminous Coal Demand in Industry

Because of the limitation of national energy data, the domestic coal price for industry (wholesale price) was not available to use as an explanatory variable in the energy demand formula, so that the relative price of crude oil (RPOIL), defined as the price of crude oil (POILJ)/exchange rate (EXR)/GDP deflator (PGDP), instead of the domestic coal price was used to estimate the coal demand formula because the coal price was influenced by the international coal market, which was highly correlated to international crude oil prices. Sub-bituminous coal demand in the industry sector (INHC) was estimated using independent variables, including industrial GDP (shown as MMINGDP) and energy consumption of the previous year. The regression test was done with RPOIL, but the use of RPOIL is not applicable because of the positive sign of coefficient of RPOIL (which is irrational because sub-bituminous coal demand will increase when price increases). A dummy variable was used for 2007 and 2014 to improve the fitting of the formula. The result of the estimated demand equation is as follows:

$$INHC = 132.8113*CONSTANT + 0.1255E\text{-}4*MMINGDP + 0.20828*INHC(-1) - 74.9828*DUM07 - 41.8489*DUM14$$

For more details on the result of the regression analysis, see Table A-1 and Figure -1. **Plot of Actual and Fitted Values for Sub-bituminous Coal Demand in Industry, Myanmar**



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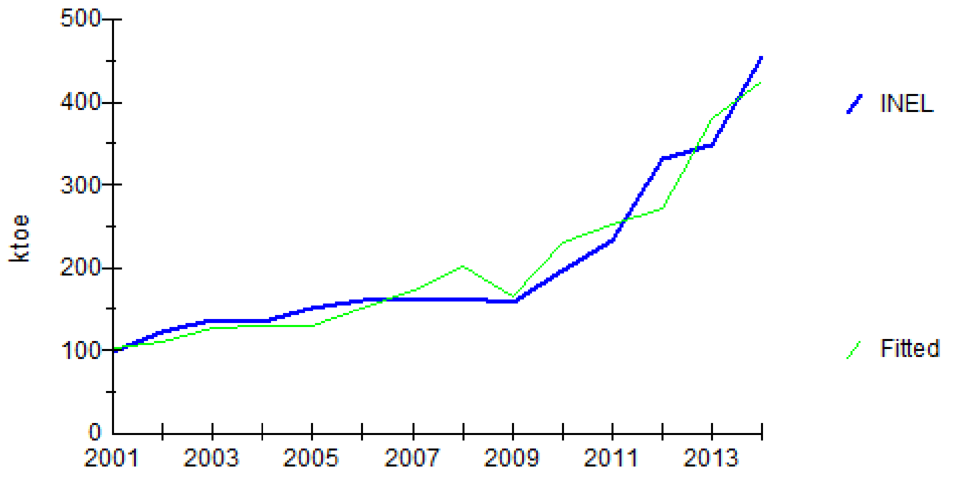
b) Electricity Demand in Industry

Due to limited national energy data, domestic electricity price for industry was not available as a price factor in the formula. Consequently, RPOIL was used instead of domestic electricity price because half of the power supply came from natural gas power plants, and the natural gas price is usually influenced by the international gas market, which is linked to international crude oil markets. Electricity demand in industry (INEL) was estimated using industrial GDP (shown as MMINGDP) and RPOIL as the independent variables. A dummy variable was used for 2009 and 2012. The result of the estimated demand equation is as follows:

$$INEL = 13.8777*CONSTANT + 0.2329E\text{-}4*MMINGDP - 0.040165*RPOIL + 75.1668*DUM0912$$

Details on the result of the regression analysis are in Table -2 and



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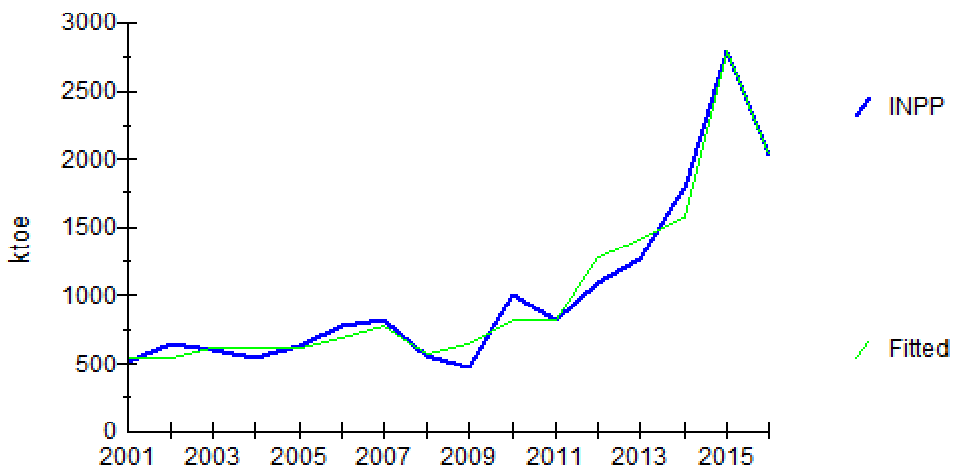
c) Demand for Petroleum Products in Industry

Petroleum products used in industry include diesel, fuel, and other oils. Diesel oil accounted for about 86% by 2016, fuel oil for 3%, and other oils for about 11%. Because of a data problem, diesel oil consumption in industry is estimated based on petroleum products and other fuels.

(1) Demand for petroleum products in industry (INPP) was estimated using independent variables such as industrial GDP (shown as MMINGDP), RPOIL, and energy consumption of the previous year. A dummy variable was included for 2008–2010, 2011, and 2015 to get a sound equation. The result of the estimated demand equation is

*INPP = 689.4636*CONSTANT + 0.6668E-4*MMINGDP - 0.095630*RPOIL+ 0.16475*INPP(-1) + 286.3320*DUM0810 + 432.2258*DUM11 -1020.0*DUM15*

The result of the regression analysis is in Table -3 and



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(2) Diesel demand in industry (INGD) could be estimated as follows:

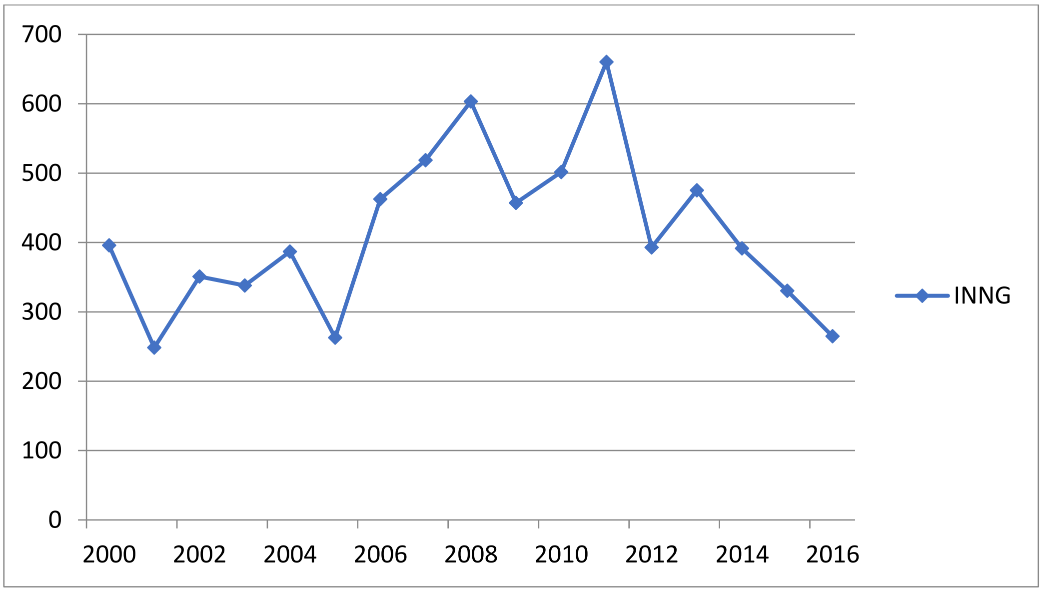
$$INGD = INPP\text{- } Fuel\ oil\ \text{-}\ Other\ oil$$

in which fuel oil and other oil demand account for a small share of total petroleum products with uncertain data, therefore we assume that the base year values (2016) will remain unchanged in the future.

d) Natural Gas Demand in Industry Sector

In the case of natural gas demand in industry (INNG), the data for 2000–2016 showed irregularity (Figure 4.1), so that the formula for INNG could not be estimated. Therefore, we assumed that INNG would keep the base year value (2016) unchanged for the future.

Figure 4.1. Natural Gas Consumption in Industry in Myanmar, 2000–2016



INNG = natural gas demand in industry.
Source: Myanmar Energy Statistics 2019.

e) Other Biomass Fuels

Other biomass fuels used in industry include fuelwood and charcoal, with the share of fuelwood at about 98.6% in 2016.

Biomass demand in industry (INBMS) is not affected by RPOIL and is not fit for regression analysis because of a data problem. Based on the historical data trend, biomass demand can be estimated to grow at 1% per year and each biomass fuel can be estimated based on the share of each fuel in the total as follows:

INBMS = Growth(1%)

Fuelwood = 0.986 INBMS*

*Charcoal = (1- 0.986) * INBMS*

2.2. Transport

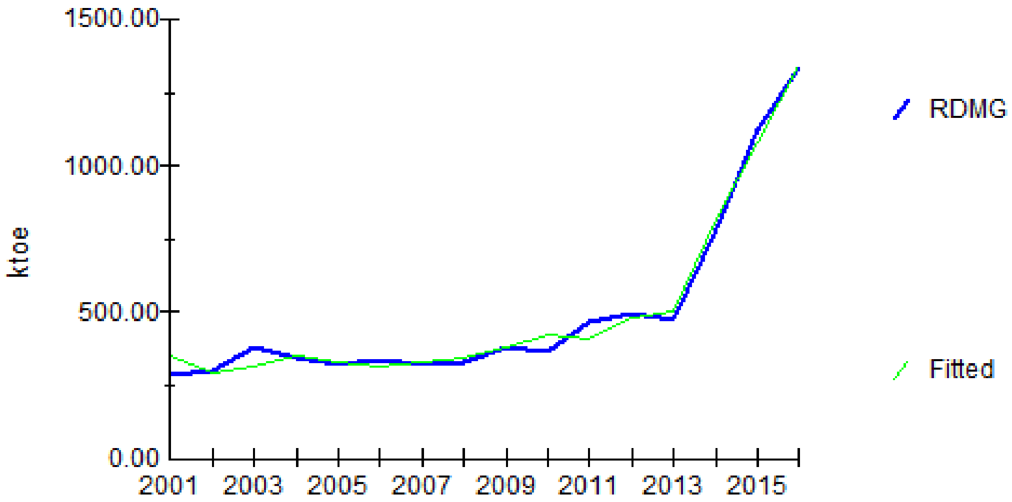
Total energy demand in transport is broken down by subsector, including air, road, and rail. Most fuel consumed by transport consists of oil products, including motor gasoline, diesel oil, lubricants (or non-energy petroleum products), and jet fuel. Motor gasoline, diesel oil, and lubricants are used by road transport, whilst jet fuel is used by aviation transport. A small part of compressed natural gas (CNG) is used for road transport.

a) Motor Gasoline Demand in Road Transport

Motor gasoline demand for road transport (RDMG) was estimated as a function of RPOIL, GDP (shown as MMGDP), and energy consumption in the previous year. A dummy variable was included for 2000–2013 to get a sound equation. The demand equation for RDMG is as follows:

*RDMG = 139.4596*CONSTANT - 0.097656*RPOIL + 0.1612E-5*MMGDP + 0.75141*RDMG(-1) + 305.1426*DUM0013*

The result of the regression analysis is shown in Table -4 and



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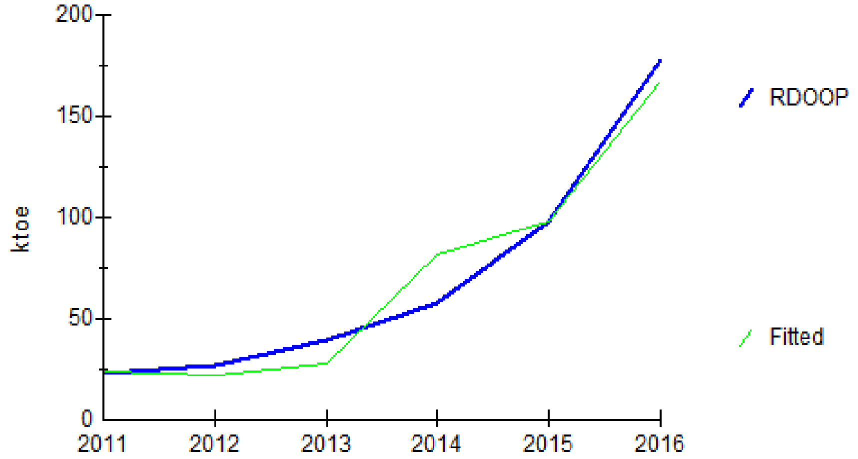
b) Lubricant Demand in Road Transport

Lubricant demand in road transport (shown as RDOOP) was estimated as a function of RPOIL and GDP (shown as MMGDP). The years for estimation were 2011–2016 to get a better equation. A dummy variable was included for 2015 to get a sound equation. The demand equation for RDOOP is as follows:

*RDOOP = -6.9320*CONSTANT - 0.22618*RPOIL + 0.3703E-5*MMGDP + 55.8092*DUM15*

The result of the regression analysis is shown in Table -5 and



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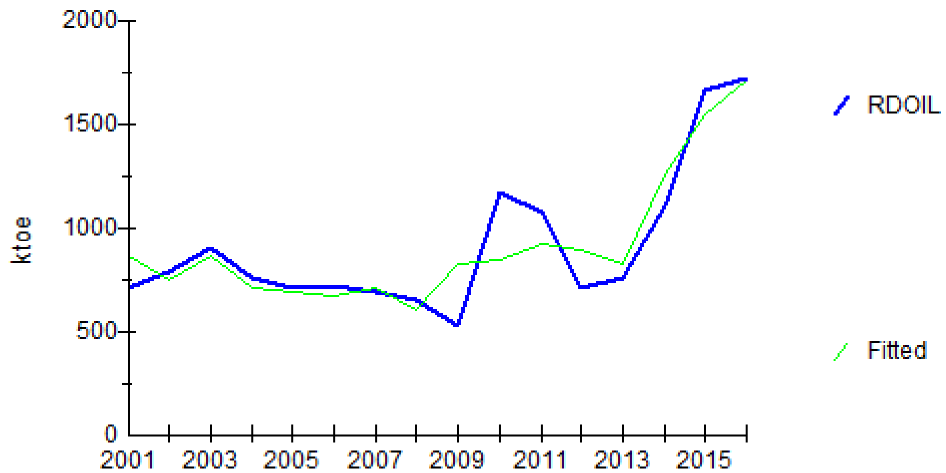
c) Demand for Oil Products in Road Transport

Demand for oil products in road transport (RDOIL) was estimated as a function of RPOIL, GDP (shown as MMGDP), and energy consumption in the previous year. A dummy variable was included for 2008–2013 to get a sound equation. The demand equation for RDOIL is as follows:

*RDOIL = 781.3236*CONSTANT - 0.69850*RPOIL + 0.1038E-4*MMGDP + 0.22108*RDOIL(-1) + 260.3233*DUM0813*

The result of the regression analysis is in Table -6 and



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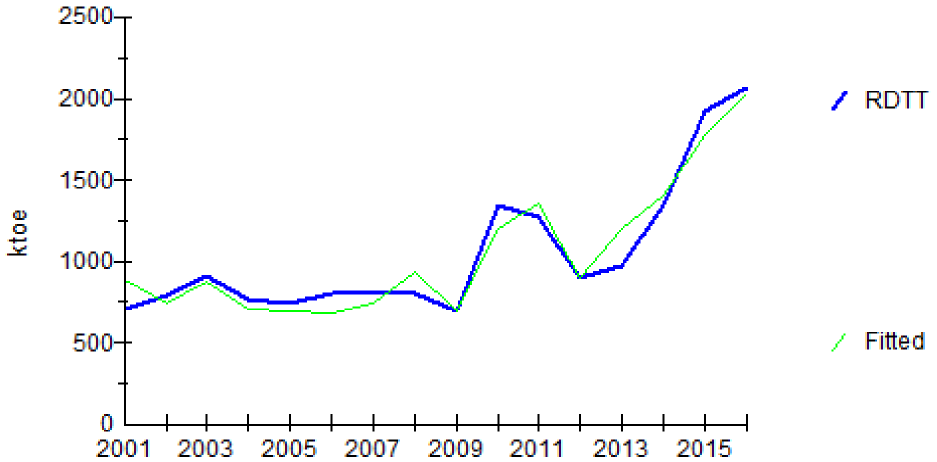
d) Total Energy Demand of Road Transport

Total energy demand of road transport (RDTT) was estimated as a function of GDP per capita (GDPC), RPOIL, and the energy consumption of the previous year. A dummy variable was included for 2009 and 2012. The demand equation for RDTT is as follows:

$$RDTT = 84.5159*CONSTANT + 625.7970*GDPC - 0.80750*RPOIL + 0.35481*RDTT(-1) + 504.9038*DUM09 + 416.8222*DUM12$$

The result of the regression analysis is shown in Table -7 and



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e) Other Fuels in Road Transport

We used regression analysis to test for other fuels in road transport, but because of the limitation of statistical data, other fuels such as CNG and diesel oil (DO) were estimated based on oil products and total energy demand for road transport:

$$RDCNG = RDTT - RDOIL$$

$$RDDO = RDOIL - Gasoline - Lubricants$$

The result of the calculation in the energy model showed that DO demand by 2040 is high, with an annual average growth rate of 6.4% in 2016–2040, which is higher than for GDP in the same period. Therefore, another exogenous approach is applied as follows:

$$RDDO = GrowthFromYear(2016, 5.55\%, 2025, 2.773\%)$$

f) Aviation Transport

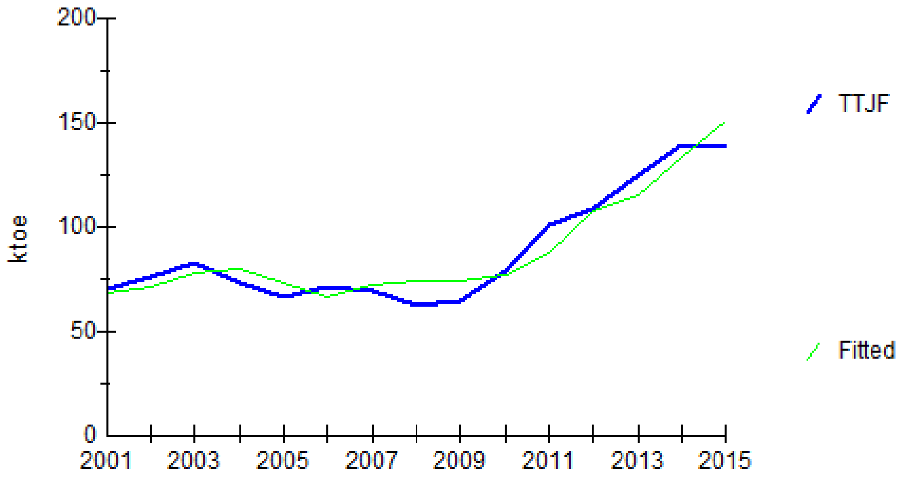
Aviation transport is international and domestic. Fuel demand for international aviation can be estimated based on total fuel demand for aviation transport and fuel demand for domestic aviation transport.

Total jet fuel demand of aviation transport (TTJF) was estimated using GDP (shown as

MMGDP), RPOIL, and jet fuel consumption of the previous year. The estimated result of energy demand formula for TTJF is as follows:

$$TTJF = 18.9831*CONSTANT + 0.2842E\text{-}6*MMGDP - 0.016262*RPOIL + 0.88702*TTJF(-1)$$

The result of the regression analysis is in Table -8 and



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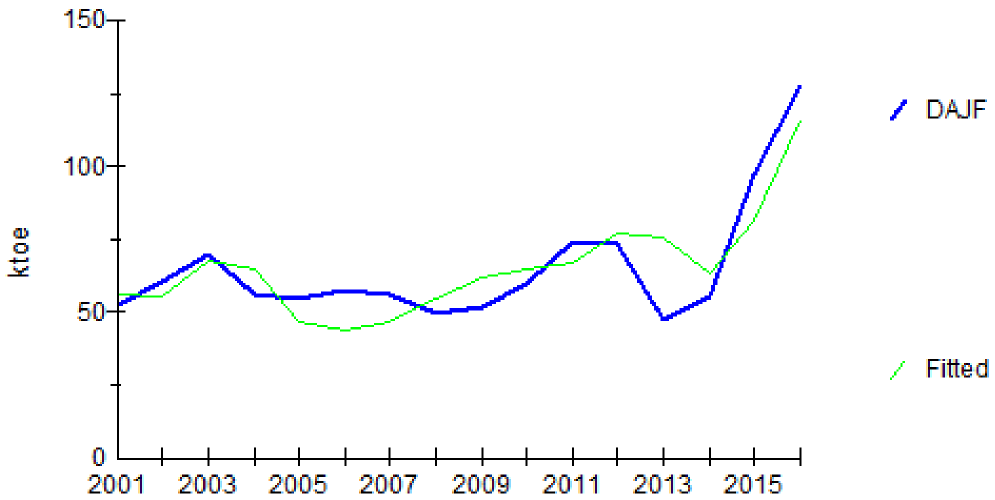
Jet fuel demand in domestic aviation transport (DAJF) was estimated as a function of GDP (shown as MMGDP), RPOIL, and the energy consumption of the previous year.

The demand equation for RDTT is as follows:

$$DAJF = 39.8634*CONSTANT - 0.041349*RPOIL + 0.2816E\text{-}6*MMGDP + 0.80633*DAJF(-1)$$

The result of the regression analysis is in Table -9 and



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2.3. Residential Sector

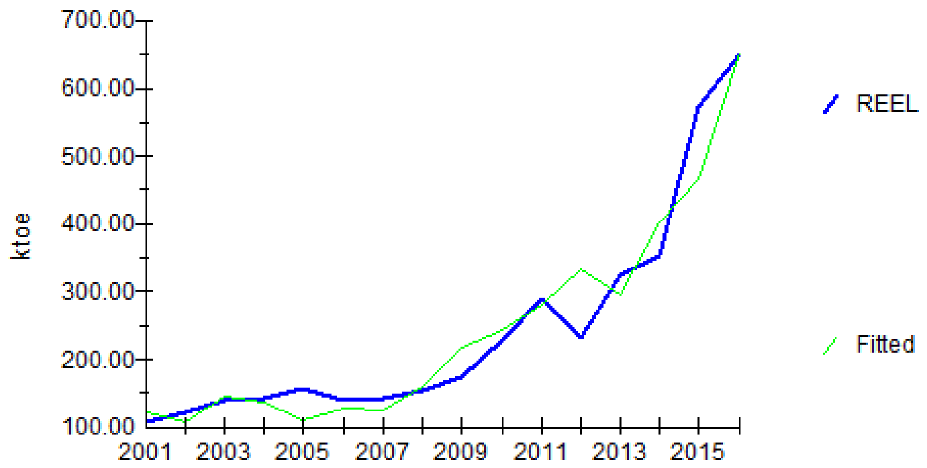
Energy used in the residential sector consists of electricity, liquefied petroleum gas (LPG), hard coal briquettes, and other fuel (biomass). Because of a data problem, hard coal briquettes and biomass are not fit for regression analysis; therefore, we suppose that demand for hard coal briquettes and biomass keeps their base year values (2016) unchanged for the future.

a) Electricity Demand in the Residential Sector

RPOIL was used as the price factor because of the national energy data limitation. Electricity demand in the residential sector (REEL) was estimated using independent variables, including GDP per capita (GDPC), RPOIL, and electricity consumption of the previous year. The result of the estimated demand equation is as follows:

$$REEL = 33.7965*CONSTANT + 0.1892E\text{-}3*GDPC - 0.11731*RPOIL + 0.80166*REEL(-1)$$

The result of the regression analysis is in Table -10 and



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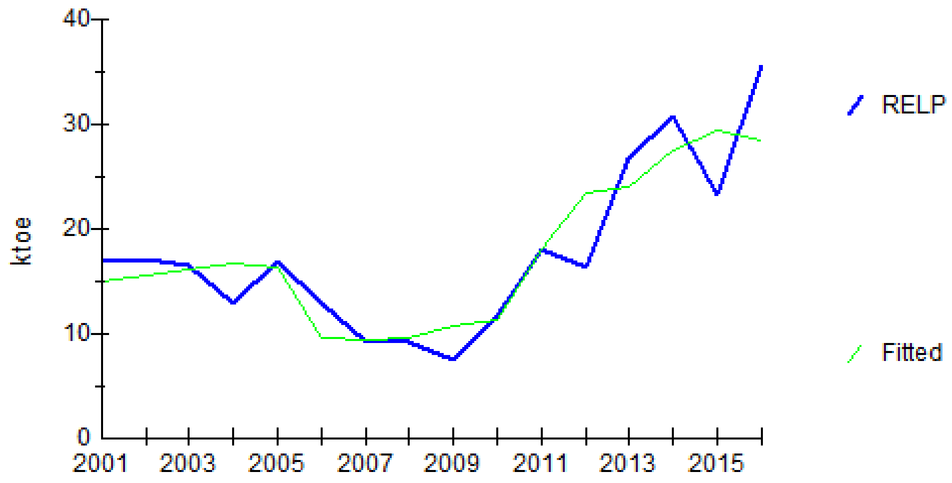
b) Liquefied Petroleum Gas Demand in the Residential Sector

LPG demand in the residential sector (RELP) was estimated using independent variables, including GDP per capita (GDPC), RPOIL, and LPG consumption of the previous year. A dummy variable was included for 2006–2010 and 2011 to improve the fitting of the equation.

The result of the estimated demand equation is as follows:

$$RELP = -4.7855*CONSTANT + 0.1449E\text{-}4*GDPC - 0.5858E\text{-}3*RPOIL + 0.23149*RELP(-1) + 8.6175*DUM0610 + 3.1833*DUM11$$

The result of the regression analysis is in Table -11 and



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2.4. Commercial Sector

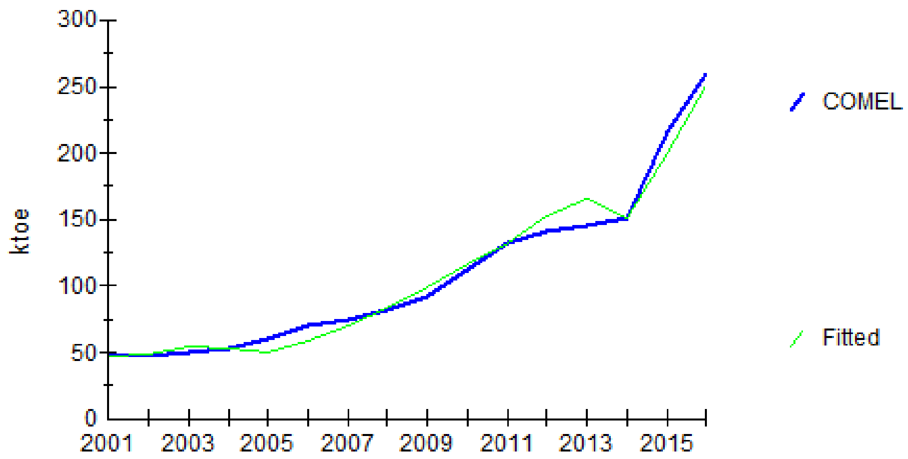
Energy used in the commercial sector consists of electricity, LPG, fuel oil, natural gas, and other biomass fuels (fuelwood and charcoal). Because of a data problem, regression analysis is applicable only for electricity, and exogenous approaches are used for the remaining fuels.

a) Electricity Demand in the Commercial Sector

RPOIL was used as a price factor because of the limitation of national energy data. Electricity demand in the commercial sector (CSEL) was estimated using independent variables such as commercial GDP (shown as MMCSGDP), RPOIL, and electricity consumption of the previous year. A dummy was used for 2014. The result of the estimated demand equation is as follows:

$$COMEL = -26.0884*CONSTANT + 0.4849E\text{-}5*MMCSGDP - 0.025305*RPOIL + 0.62662*COMEL(-1) + 31.6028*DUM14$$

The result of the regression analysis is in Table -12 and



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b) Biomass Demand in the Commercial Sector

Biomass demand in the commercial sector (COMBMS) is not affected by RPOIL and is not fit for regression analysis because of a data problem. Based on historical data, we can estimate the share of each fuel (fuelwood and charcoal) in total biomass fuels used in the commercial sector. Assuming that the share of each fuel is maintained in the coming years, we can estimate the demand of biomass fuels as follows:

COMBMS = Growth(0,1%)

COMCHC = COMCHCSH (-1) COMBMS*

COMFWD = (1- COMCHCSH(-1)) COMBMS*

Where:

COMCHC = Charcoal demand in the commercial sector

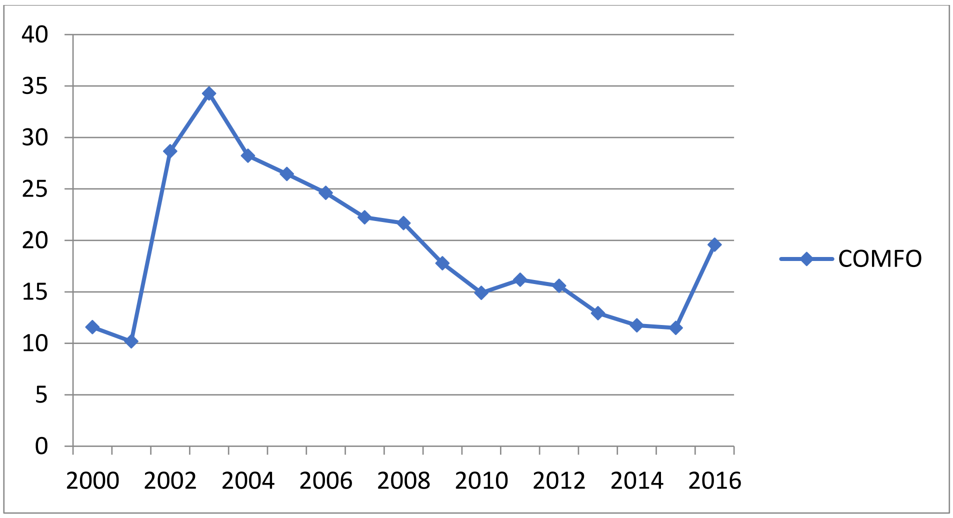
COMCHCSH = Charcoal share in the total biomass fuels

COMFWD = Fuelwood demand in the commercial sector

c) Fuel Oil Demand in the Commercial Sector

In the case of fuel oil in the commercial sector (COMFO), the data for 2000–2015 showed irregularity (Figure 4.2), so that the formula for diesel oil could not be estimated.

Figure 4.2. Fuel Oil Consumption in the Commercial Sector in Myanmar, 2000–2016



COMFO = commercial sector.
Source: Myanmar Energy Statistics 2019.

In this case, we assumed that fuel oil demand is maintained in the coming years as follows:

COMFO = COMFO(-1)

d) Liquefied Petroleum Gas and Natural Gas Demand in the Commercial Sector

LPG (COMLP) and natural gas (COMNG) have been used in the commercial sector for several years. Therefore, the regression analysis is not applicable because of insufficient data, and other exogenous approaches such as growth as commercial GDP (shown as MMCSGDP) were used as follows:

COMLP = GrowthAs(MMCSGDP)

COMLP = GrowthAs(MMCSGDP)

2.5. Other Key Variables

Aside from the main variables such as GDP, RPOIL, amongst others, other related key variables worked as the main drivers for energy demand projection, including GDP deflator or price index for GDP (PGDP) and sectoral GDP. However, these future variables are still lacking because of the limitation of data. Thus, in this study, these functions are estimated based on relationships amongst other related available variables by regression analysis.

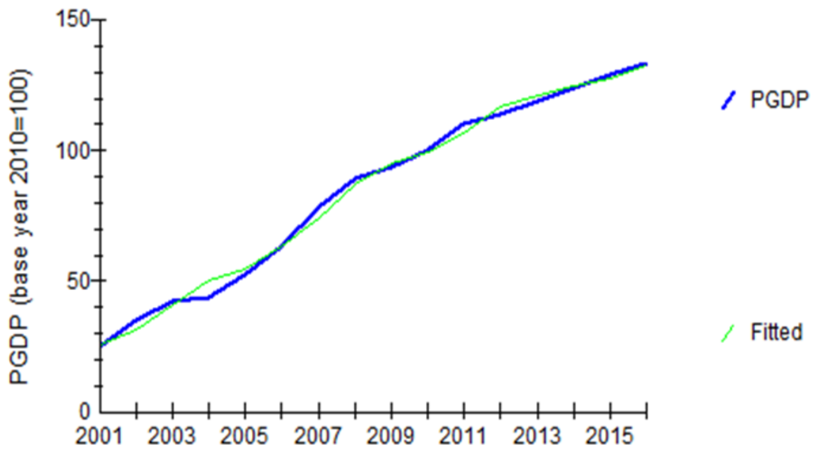
a) Gross Domestic Product Deflator

The crude oil price is clearly tied to economic activity and inflation. If the crude oil price increases, the consumer price index also increases. Therefore, GDP deflator (PGDP) was estimated as a function of (POILJ) and PGDP of the previous year as follows:

*PGDP = 2.1175*CONSTANT + 0.0084665*RPOIL + 0.97967*PGDP(-1)*

The result of the regression analysis is shown in PGDP = *2.1175*CONSTANT + 0.0084665*RPOIL + 0.97967*PGDP(-1)*

Table -13 and



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b) Industrial Gross Domestic Product

Industrial GDP (shown as MMINGDP) is the main component and contribution to GDP growth. Thus, MMINGDP was estimated as a function of GDP (shown as MMGDP) and MMINGDP of the previous year with the equation as follows:

$$MMINGDP = -1566795*CONSTANT + 0.14423*MMGDP + 0.67479*MMINGDP(-1)$$

The result of the regression analysis is in Table -14 and **Error! Reference source not found.**, Appendix.

c) Commercial Gross Domestic Product

Like industry GDP, commercial GDP (shown as MCSGDP) was estimated as a function of GDP and MCSGDP of the previous year. The estimated equation is as follows:

$$MCSGDP = -138528.5*CONSTANT + 0.085424*MMGDP + 0.86841*MCSGDP(-1)$$

The result of the regression analysis is in Table -15 and **Error! Reference source not found.**, Appendix.

Chapter 5
Model Assumptions

This chapter focuses on model assumptions for projecting future energy demand and greenhouse gas (GHG) emissions in the business-as-usual (BAU) scenario and other scenarios in the case studies. The assumptions used were based on future values of macroeconomic, energy price, and other activity indicators such as electricity generation technologies, as well as energy development policies.

1. Macroeconomic Assumptions

(1) Population. In 2016, Myanmar's population was 52.92 million and is projected to increase at an average annual rate of about 0.7%, reaching about 62.93 million in 2040. No difference in population is assumed between BAU and other scenarios in the case studies.

(2) Gross domestic product (GDP). Myanmar's GDP grew at an average annual rate of 11.1% during 2005–2010 and was slightly down to 7.3% during 2010–2015. GDP is assumed to grow at an average annual rate of 7.0% during 2016–2025, followed by 6.5% in 2025–2030, 6.0% in 2030–2035, and 5.5% in 2035–2040. These projections are used to develop the BAU scenario and provide a base for the scenario of GDP changes in the case studies.

The assumptions on the growth of GDP and population are in Table 5.1.

Table 5.1. Assumptions on Annual Average Growth of GDP and Population, Myanmar

Period	GDP Growth (%)	Population Growth (%)
2016–2025	7.0	0.9
2025–2030	6.5	0.8
2030–2035	6.0	0.6
2035-2040	5.5	0.6

GDP = gross domestic product.
Source: Author, based on consultation with relevant ministries.

2. Crude Oil Price

Future changes in crude oil prices remain highly uncertain. In this study, the crude oil price (Japan's average import price [nominal dollars per barrel]) is assumed to increase from US$48 a barrel in 2016 to US$76 a barrel in 2020, and from US$125 a barrel in 2030 to US$185 a barrel in 2040. These assumptions are used to develop the BAU scenario and provide a base for the scenarios of high and low oil prices in the case studies.

3. Electricity Generation Technologies

3.1. Electricity Generation Thermal Efficiency

Thermal efficiency of electricity generation reflects the amount of fuel required to generate a unit of electricity. Thermal efficiency was set exogenously based on historical data in electricity generation and future development trends.

The base year 2016 thermal efficiency by fuel type (coal and natural gas) was derived from the 2016 energy balance tables. The efficiency of the coal thermal power plant is only 17.2%, which is lower than the normal standard because domestic coal is of low quality and, while the power plant has a rated capacity of 120 megawatts (MW), it operates at only 40% capacity. The efficiency of coal power plants is assumed to stay unchanged because no coal power plants have been developed after 2019. The efficiency of natural gas power plants in 2016 was 25.5% and is expected to reach 38% by 2040 as additional power plants with advanced generation technologies become available.

3.2. Electricity Generation Fuel Mix

The energy mix used in electricity generation is an important input for the energy outlook because it is a key driver for primary energy demand and GHG emissions. The energy mix is an exogenous input to the model.

The main sources of electricity generation are hydropower and natural gas power plants. By 2016, total installed capacity reached 5,400 MW, with the share of hydro accounting for 60.3%; natural gas for 35.6%; and coal, diesel, and solar photovoltaic (solar/PV) for 4.1%.

Hydropower plants will still play a major role in the future. Natural gas, coal, and renewable energy (RE) capacity is assumed to increase, resulting in a lower share of hydropower in the total generation capacity mix. The future capacity expansion plan is based on existing development capacity and possible additional capacity until 2040. It is assumed that about 15,900 MW will be installed by 2030 and 24,550 MW by 2040.

4. Other Energy Development Policies

Myanmar does not have a comprehensive national energy policy setting out a systematic approach to energy planning, policy formulation, and sector development. The existing energy policy is generally aimed at ensuring energy independence by increasing national production of available primary energy resources through intensive exploration and development.

The national energy policy and sectoral development policies are summarised as follows:

(1) Implement short- and long-term comprehensive energy development plans based on systematically investigated data on potential energy resources that are feasible and can be practically exploited, considering minimum impact on the natural and social environments.

For electric power, implement the following:

- (a) Expand the national power grid to effectively utilise power generated from available energy resources such as hydropower, wind, solar/PV, thermal, and other alternative sources.
- (b) Generate and distribute electricity using advanced technologies, and boost and enhance private participation in regional distribution activities.
- (c) Conduct environmental and social impact assessments for power generation and transmission to minimise these impacts.

(2) Implement programmes on a wider scale, utilising RE resources such as wind, solar/PV, hydro, geothermal, and bioenergy for sustainable energy development. The objectives of the RE policy are the following:

- (a) Formulate a national RE policy, strategy, and road map based on international practices and in cooperation with ministries.
- (b) Improve research projects.
- (c) Train local practitioners and transfer technology to small and medium-sized enterprises.
- (d) Develop RE standards and provide testing services to the RE market.
- (e) Strengthen international cooperation and collaboration in the RE sector.

(3) Promote energy efficiency and energy conservation. The objective is to implement as a priority an energy efficiency and conservation (EEC) programme in accordance with Association of Southeast Asian Nations (ASEAN) targets. The energy policy framework aims to do the following:

- (a) Institute laws, rules, and regulations (legal framework) required to implement an EEC programme.

(b) Institute a dedicated department responsible for implementing an EEC programme.
(c) Conduct capacity-building programmes and awareness-raising campaigns to promote EEC.
(d) Implement EEC programmes in industry, commerce, and households.

5. Case Studies

The BAU scenario was developed based on the above assumptions, and its energy demand and supply were projected based on the relationship between energy consumption and macroeconomic indicators such as GDP, oil price, population, as well as energy development policies that promote EEC and RE development. But these assumptions include lots of uncertainty.

Case studies or sensitivity studies are effective ways to analyse uncertainty. Some case studies include changes in GDP, high oil price, additional energy efficiency promotion, and RE development, with the following assumptions:

(1) Changes in GDP. GDP annual growth rate is assumed to increase or decrease, with an additional ±3% at the end of 2035–2040 (compared with BAU) (Table 5.2).

Table 5.2. Changes in GDP Annual Growth Rate, Myanmar

Period	BAU	GDP Increasing 3%	GDP Decreasing 3%
2016–2025	7.0%	7.6%	6.4%
2025–2030	6.5%	7.9%	5.1%
2030–2035	6.0%	8.2%	3.8%
2035–2040	5.5%	8.5%	2.5%

BAU = business as usual, GDP = gross domestic product.
Source: Author.

(2) Changes in oil price. Crude oil price is assumed to increase from US$185 by 2040 in BAU to US$250 by 2040, or steeply decrease to US$20 by 2040 (Table 5.3).

Table 5.3. Changes in Oil Price, Myanmar (US$)

Scenario	2020	2030	2040
Business as usual	76	125	185
Oil price increasing	76	158	250
Oil price decreasing	76	43	20

Source: Author.

(3) Promotion of EEC. Total final energy consumption (TFEC) is assumed to reduce by 10% (case 1, EEC10) and 20% (case 2, EEC20) compared with BAU through EEC activities in 2040.

(4) RE development. The share of RE sources (solar/PV and wind) is assumed to reach 10% (case 1, RE10) and 20% (case 2, RE20) of total power capacity (compared with a negligible share in BAU) by 2040. These increases are assumed for replacing natural gas power plants.

The maximum capacity factor of wind plants is 40%, solar/PV power plants 15%, and natural gas power plants 52%. This means that about 3.5 MW of solar/PV power could be replaced by about 1 MW of natural gas power, with the same amount of power generation outputs.

Chapter 6

Assessment of Future Simulation Results

Several scenarios or cases were studied (Chapter 5). The base case is defined as the business-as-usual (BAU) scenario. The other case studies are gross domestic product (GDP), oil price, energy efficiency and conservation (EEC) promotion, and renewable energy (RE) development scenarios.

This chapter provides the results of the simulation runs for BAU and the other case studies.

1. Business-as-Usual Scenario

BAU is developed based on the assumptions that demand for energy will continue to increase based on historical trends and future growth of GDP, population, and oil price, in the absence of additional policies to promote EEC and RE. Table 6.1 and Table 6.2 use the base year (2016) and the projected 2040 energy balance table.

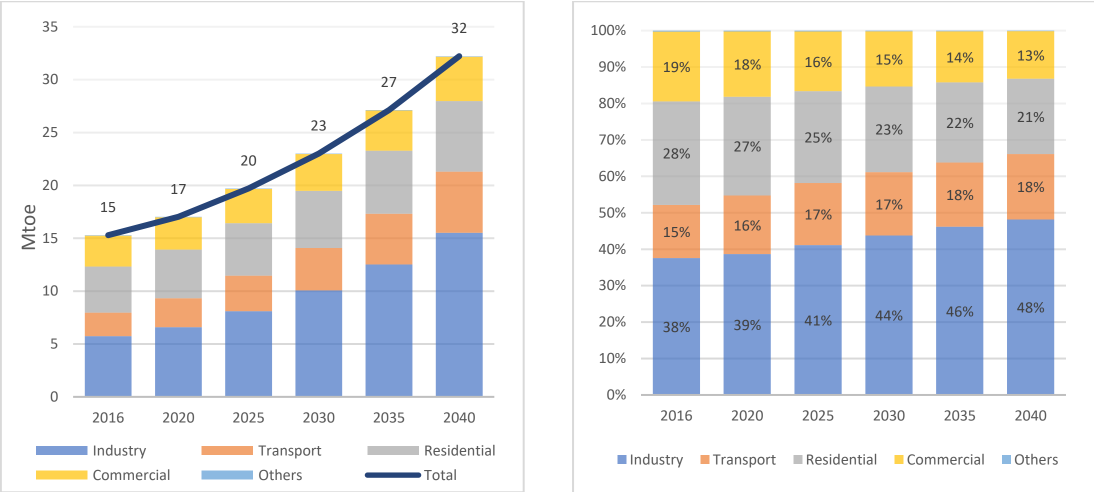
1.1. Final Energy Consumption

Total final energy consumption (TFEC) increased at an average rate of 3.1% per year, from 9.9 million tons of oil equivalent (Mtoe) in 2000 to 15 Mtoe in 2016. Given assumed economic and population growth, TFEC growth will continue but at a slightly slower rate of 3.0% per year during 2016–2040 in BAU (Figure 6.1).

TFEC growth slows down because of the assumption that future biomass consumption will remain as in 2016, as more people shift from biomass to oil and electricity, particularly in the residential sector. In 2000–2016, the biomass share was more than 85%. It will decline to 60% by 2040.

By sector, final energy consumption of industry in BAU will grow the fastest at an average rate of 4.2% per year. Most fuel consumed by industry was biomass in 2016 (46%). Assuming industry will use more efficient heating fuel, biomass will be replaced by diesel. By 2040, the share of biomass will be only 22% whilst diesel will reach 51%. The average annual growth rate of diesel consumption by industry will be 6.5% per year.

Figure 6.1. Total Final Energy Consumption by Sector, Myanmar



Mtoe = million tons of oil equivalent.
Source: Author.

Industry's electricity consumption will increase at a faster rate of 7.7% per year. Industry's coal consumption will grow at 5.1%, in line with the expansion of industries such as cement factories.

Transport's final energy consumption will grow more slowly than industry's, at an average rate of 4.0% per year. Most fuel consumed is for road transport (about 93%). Its fuel demand will grow at an average of 4.1% per year, slower than air transport's (4.6%). No significant growth is assumed for rail transport, so consumption will remain, on average, constant throughout the outlook period.

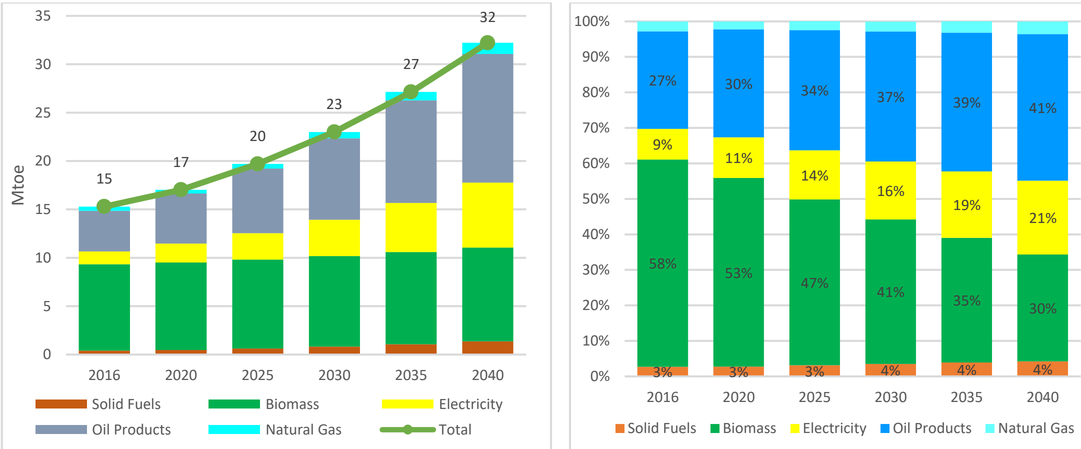
The residential sector's final energy consumption will grow slower, at an average annual rate of 1.8%, whilst the commercial sector's will grow at an average annual rate of 1.5%. Most growth in both sectors will be contributed by the rapid increase of electricity consumption: 6.4% per year for the residential sector and 7.3% for the commercial sector. Since more efficient cooking stoves and alternative fuels will be more available, LPG consumption is projected to increase at an average rate of 4.2% per year.

Demand for all fuels will continue to increase. Demand for electricity will increase the fastest, at an average rate of 7% per year from 1.3 Mtoe (15 terawatt hours [TWh]) in 2016 to almost 6.7 Mtoe (78 TWh) in 2040 (Figure 6.2). Although growing the fastest, electricity's share in the TFEC will not be dominant, increasing from about 9% in 2016 to 21% in 2040.

Biomass demand will have the highest share in the TFEC. Since biomass will experience slower growth (0.3% per year), its share in the TFEC will decline significantly, from 58% in 2016 to 30% in 2040. Oil will become dominant as the number of vehicles increases, industries expand, and more efficient stoves and alternatives are available for households. Demand for oil will increase at an average rate of 4.9% per year, with its share in the TFEC reaching 41% in 2040.

Demand for coal will grow faster than for oil, at 5.1% per year, but its share in total demand will still be about 4% since it is consumed only by industry. The share of natural gas will be slightly lower than that of coal in 2040 (3.6%) and demand will grow at 4.2% per year.

Figure 6.2. Total Final Energy Consumption by Fuel Type, Myanmar



Mtoe = million tons of oil equivalent.
Source: Author.

1.2. Power Generation

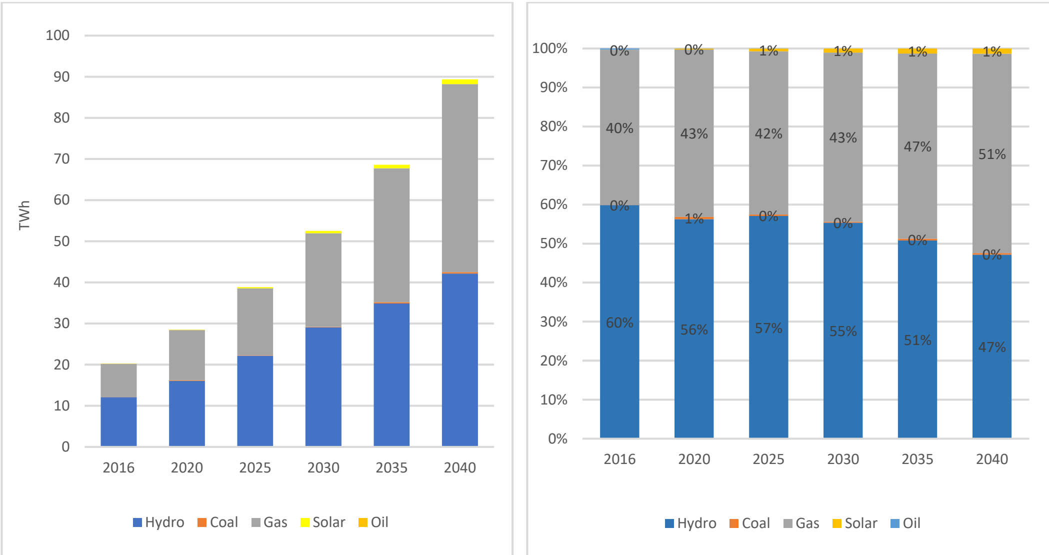
Power generation was mainly from natural gas before 2005. Total generation in 2000 was about 5 TWh and 62% of generation came from natural gas. Hydro's share in total production was only 37% and oil-based plants accounted for the rest. By 2016, power generation increased to 20.3 TWh, where hydropower generated 12.1 TWh (59.9%) and natural gas about 8 TWh (39.7%). The rest came from oil, coal, and solar photovoltaic (solar/PV) sources.

Most electricity produced will meet domestic demand, with no firm plan to export large amounts of electricity to neighbouring countries. Own use and losses (transmission and distribution) of electricity must be included in future electricity generation.

In BAU, power generation will increase to 89.4 TWh by 2040, growing at an average rate of 6.4% per year, slower than the 9% annual growth in 2000–2016 (Figure 6.3).

Capacity expansion of power plants was based on the current plan. Hydropower will still play a major role in future generation but with a declining share. By 2040, most electricity will come from natural gas (51%) and hydropower (47%). The average growth of electricity produced from natural gas will be 7.5% per year over the projection period, and from hydropower 5.3%.

Figure 6.3. Power Generation by Fuel Type, Myanmar



TWh = terawatt hour.
Source: Author.

The share of other renewable energy (RE) (solar/PV and wind) in total generation is about 1%, but its growth will be the fastest at an average rate of 22.3% per year. This rapid growth is in line with the national plan to increase the RE share in the power generation mix. Other generation will be from coal, with an average growth rate 16% per year.

1.3. Primary Energy Supply

The total primary energy supply (TPES) grew faster than the TFEC at about 3% per year, from around 11.1 Mtoe in 2000 to 17.7 Mtoe in 2016. Amongst the major energy sources, the fastest-growing fuel in 2000–2016 was coal, at 12.8% per year, mainly because of the rapid increase of coal use in industry, from 0.06 Mtoe in 2000 to 0.41 Mtoe in 2016.

Hydropower, the main supply for power generation, grew at an average rate of 10.2% per year in 2000–2016. Natural gas, another important fuel for power generation, grew at an average rate of 6.4% per year. Oil, the major supply for transport, grew at a slower rate of 6.1% per year, and biomass, the major supply for the residential sector, at an average rate of 1.6% per year.

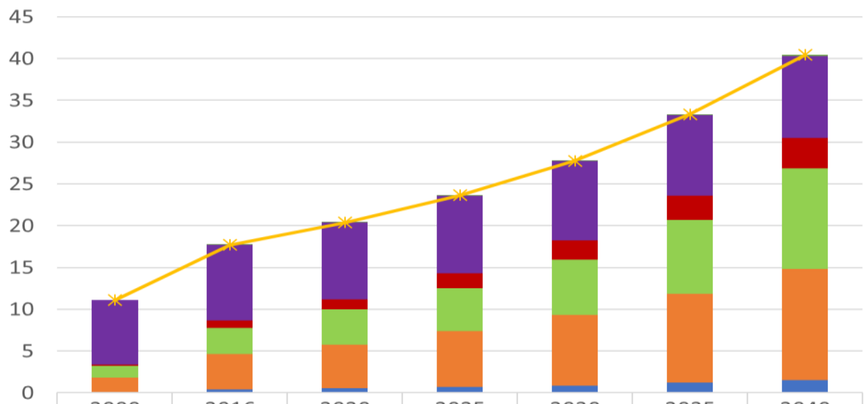
In BAU, the TPES is projected to increase faster than in the past, at an average annual rate of 3.5%, reaching about 40 Mtoe in 2040 (Figure 6.4). All fuel sources, except for RE (solar/PV and wind), will continue to increase but at a slower rate than in the past.

Coal is projected to grow at 5.6% per year, oil at 4.9%, and gas at 5.7%. The faster growth of natural gas is based on the rapid increase of its usage for power generation (7.5% per year). Coal, however, increased to meet industrial demand such as for cement plants.

Biomass sources will grow only at 0.3%, considering that more efficient biomass stoves for positive impact and alternative fuel such as LPG for negative impact will be available for household cooking needs.

Hydropower will increase at an average annual rate of 6.3% in 2016–2040, faster than fossil fuel. Solar/PV is projected to grow the fastest, at 22.3%, in line with the government programme to increase the RE share in the total mix of power generation.

Figure 6.4. Total Primary Energy Supply, Myanmar



	2000	2016	2020	2025	2030	2035	2040
Other Renewable	0.00	0.00	0.01	0.02	0.05	0.08	0.10
Biomass	7.73	9.07	9.19	9.34	9.50	9.67	9.84
Hydro	0.16	0.84	1.18	1.71	2.30	2.91	3.61
Natural Gas	1.35	3.16	4.27	5.19	6.62	8.87	12.03
Oil	1.79	4.22	5.19	6.67	8.42	10.61	13.31
Coal	0.06	0.41	0.55	0.69	0.87	1.21	1.54
Total	11.10	17.70	20.38	23.63	27.77	33.34	40.43

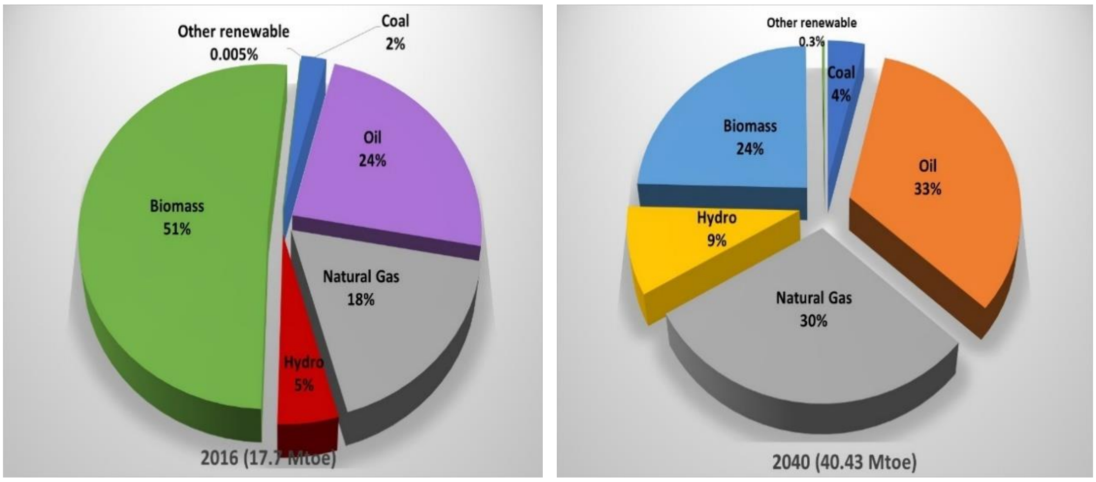
Mtoe = million tons of oil equivalent.
Source: Author.

Biomass had the highest share in the TPES in 2000–2016. The share, however, declined from about 69% in 2000 to 52% in 2016. The oil share remains the second highest in the TPES, increasing from 16% in 2000 to 31% in 2016. The natural gas share was 12% in 2000 and increased to 18% by 2016. The hydropower share was only 1.5% in 2000 but 5% by 2016. The coal share slightly increased from 0.5% in 2000 to 2.1% in 2016.

In BAU, the oil share in the TPES will be the highest in 2040 (33%) as passenger cars and industrial heating demand increase and more LPG is consumed by the residential and commercial sectors (Figure 6.5). Increased use of alternative fuel and more efficient stoves in the residential and commercial sector will slow the growth of biomass consumption, resulting in a lower share of biomass in the total TPES in 2040 (24%).

The increase of natural gas supply over the projected period will mainly be due to the expansion of natural gas power plants. The share of natural gas in the TPES will reach 30% in 2040. The hydropower share will increase to 9% by 2040 as demand for electricity increases. Other RE share will grow the fastest but their share in the TPES will remain small (0.3% in 2040).

Figure 6.5. Energy Mix of Total Primary Energy Supply, Myanmar



Mtoe = million tons of oil equivalent.
Source: Author.

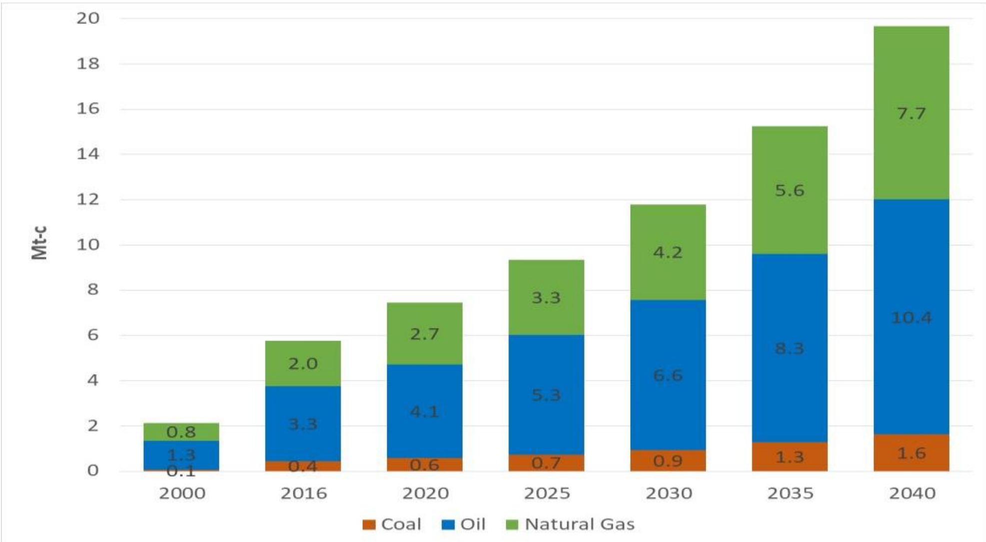
1.4. Carbon Dioxide Emissions

The major sources of carbon dioxide (CO_2) emissions are combustion of fossil fuels (coal, oil, and gas). In 2016, CO_2 emissions in Myanmar reached 5.8 million ton-c (in terms of carbon content) or about 21.1 million ton-CO_2. Most came from burning of oil, especially for transport. Total CO_2 emissions more than doubled in 2000–2016.

In BAU, total CO_2 emissions will reach almost 20 million ton-c by 2040, increasing at an average rate of 5.2% per year (Figure 6.6).

Oil combustion will still be the major source of CO_2 emissions since its share in the TPES will still be higher (33% in 2040) than that of coal and natural gas, but its share of CO_2 emissions will decrease from 56% in 2016 to 53% in 2040 because of the increasing use of natural gas in power generation and industries. Natural gas will account for 35% of CO_2 emissions in 2016 but 39% in 2040.

Figure 6.6. Total Carbon Dioxide Emissions, Myanmar



Mt-c = million tons of carbon.
Source: Author.

1.5. Energy Indicators

Energy indicators are often used to analyse a country's import dependency on energy, energy consumption per capita, energy consumption per GDP, as well as CO_2 emissions.

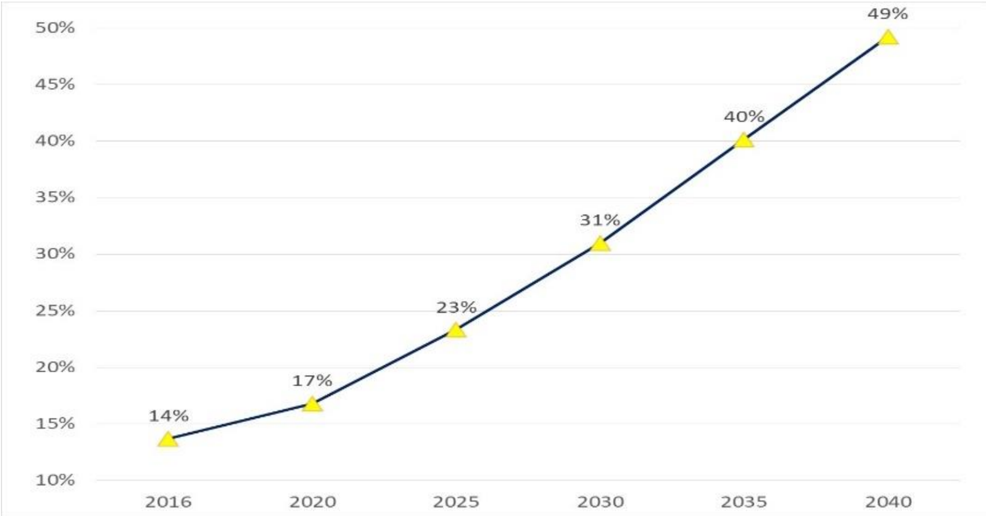
a) Import Dependency

Myanmar imported most of its petroleum product requirements and some coal. Import dependency is measured by dividing total energy imports by total energy production. Total production consists of oil, natural gas, coal, hydropower, biomass, solar/PV, and wind.

The import dependency ratio was 14% in 2016, an increase from 10% in 2000. In BAU, import dependency is projected to continue increasing and will reach 49% by 2040 (Figure 6.7). The increase in import dependency is due to the increase in consumption of oil products, particularly for transport. Introducing electric vehicles and improving public transportation can reduce oil imports.

Increasing demand for coal and natural gas for power generation also contributes to the high import dependency ratio in 2040. Further expanding hydro, solar/PV, and wind power capacity and increasing the use of domestic coal for power plants that apply clean coal technologies should further reduce import dependency.

Figure 6.7. Import Dependency, Myanmar



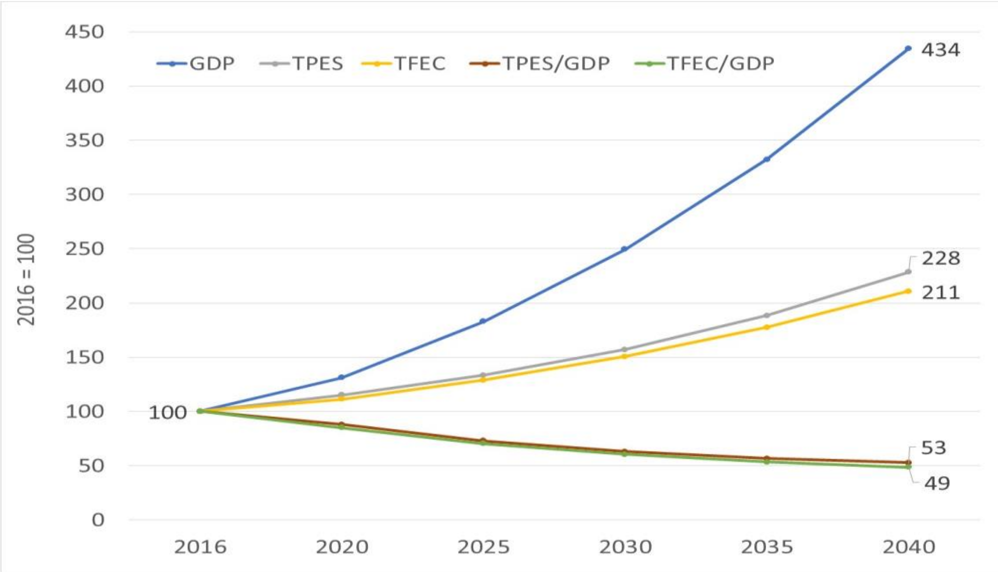
Source: Author.

b) Energy and Carbon Dioxide Emission Intensity

Energy intensity is the total primary energy supply or total final energy consumption (TPES or TFEC) divided by gross domestic product (GDP). GDP will grow at an average rate of 6.3% per year over the outlook period, whilst population will grow at 0.7% per year. Based on these assumptions, GDP in 2040 will be 4.3 times what it was in 2016, whilst the population will be 1.2 times larger. The TPES and TFEC will double in the next 24 years, indicating slower growth than that of GDP. Consequently, TPES and TFEC intensity will decline (Figure 6-8).

TPES intensity in BAU will decline at an average rate of 2.6% per year, from 238 to 125 tons of oil equivalent (toe)/million US dollars in 2016–2040. TFEC intensity will decline at a faster rate of 3.0% per year, from 205 to 100 toe/million US dollars. Declining energy intensities indicate relative improvement of energy consumption (primary and final) in all sectors. Primary and final energy intensity in BAU will improve by 53% and 49%, respectively, in 2040 compared with 2016. Improvement of intensities in BAU comes mainly from the remarkable dominance of biomass until 2040 and historical energy efficiency in 2000–2016.

Figure 6.8. Energy Indicators, Myanmar

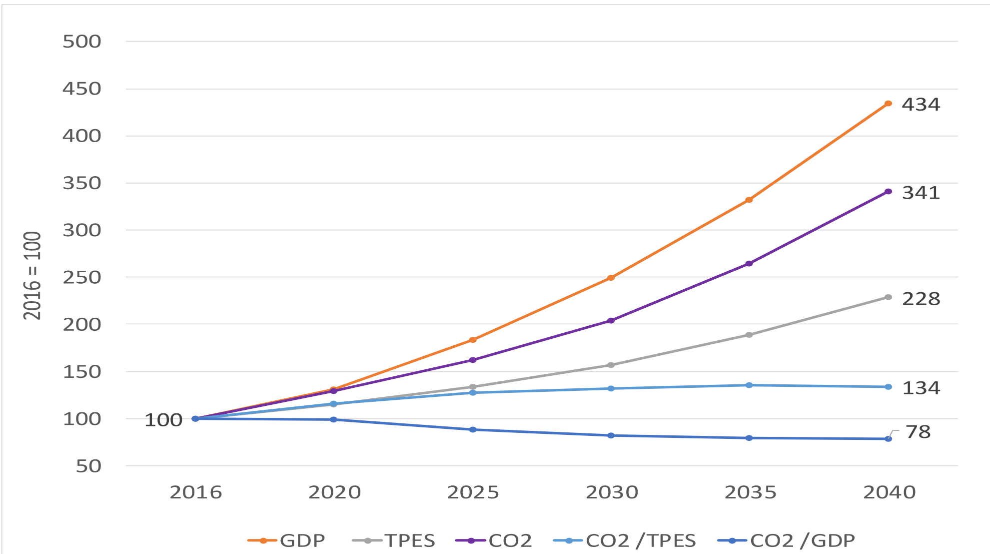


GDP = gross domestic product, TFEC = total final energy consumption, TPES = total primary energy supply.

Source: Author.

As with energy intensity, CO_2 intensity measures the ratio of GDP or the TPES to CO_2 emissions. In BAU, CO_2 emissions in 2040 will be 3.4 times the 2016 level, indicating slower growth than that of GDP. As a result, CO_2/GDP will decline by 0.8 times in 2040 (Figure 6.9). CO_2/GDP will decline at an average rate of 0.1% per year, from 77 ton-c/million US dollars in 2016 to 61 ton-c/million US dollars in 2040.

Figure 6.9. Carbon Dioxide Emissions Intensity, Myanmar



CO_2 = carbon dioxide, GDP = gross domestic product, TPES = total primary energy supply.

Source: Author.

CO_2/TPES will increase to 0.73 ton-c/toe by 2040 from 0.55 ton-c/toe in 2016 because the energy share will shift from low carbon energy (biomass and hydro) to fossil fuels (coal, oil, and gas).

2. Case Studies

The case studies being considered in this outlook are the following:

(1) **Changes in GDP.** GDP annual growth rate is assumed to increase by an additional 3% for the high case (GDPH) and decrease by 3% for the low case (GDPL) as compared with BAU.

(2) **Changes in oil price.** Crude oil price is assumed to increase from US$185 by 2040 in BAU to US$250 by 2040 in the high oil price (OILH) case or strongly decrease to US$20 by 2040 in the low oil price (OILL) case

(3) **EEC promotion.** The TFEC is assumed to reduce by 10% (EE10) and 20% (EE20) in 2040 compared with BAU because of EEC activities.

(4) **RE development.** Capacity from RE sources (solar/PV and wind) is assumed to be 10% (RE10) and 20% (RE20) higher in 2040 as compared with BAU. These additional increases are assumed for replacing gas-fired power plants.

Assumptions applied in the case studies are outlined in Chapter 5. The impacts of the different case studies will be compared with BAU.

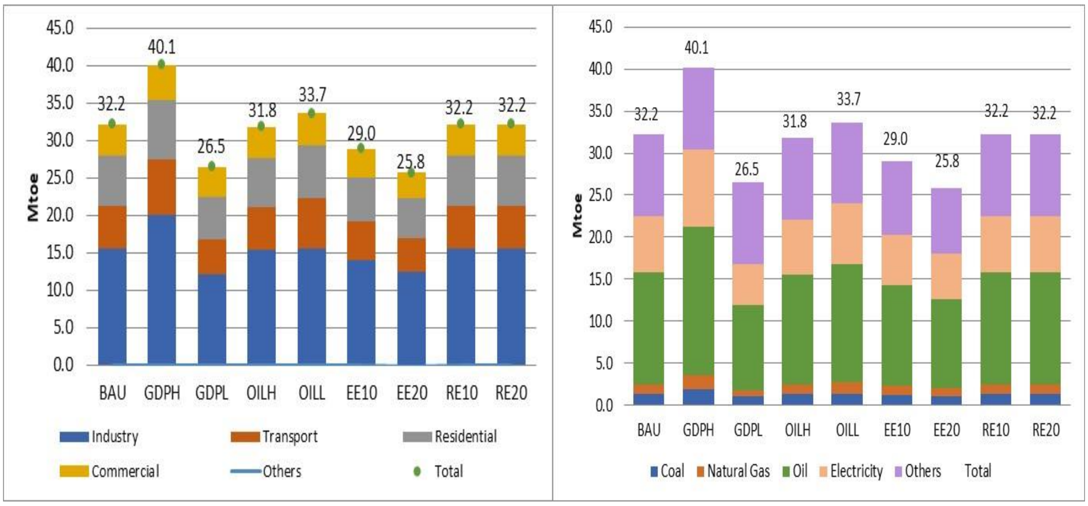
2.1. Final Energy Consumption

The projected TFEC in 2040 by sector and by fuel for the case studies as compared with BAU is shown in Figure 6.10. These scenarios are tentatively assumed for assessing the sensitivity of this outlook.

The TFEC for the case studies will be different than for BAU except for the RE development case studies. In RE10 and RE20, the TFEC will be the same as in BAU because the assumption is on the power generation side, not the demand side. In the RE case studies, the RE (solar/PV and wind) share in total generation capacity will increase to 10% (RE10) and 20% (RE20) in 2040. The assumption is that some of the gas power plants will be replaced by RE sources.

The TFEC of the GDPH will be higher than in BAU. GDP growth rate of 3% more than in BAU (GDPH) is an indicator of economic improvement. Stronger GDP growth will make the country more productive, see more people employed, increase income levels, and open investment opportunities. Consequently, more energy, especially commercial energy, will be consumed to support increasing economic activities. In GDPH, the TFEC in 2040 will be 40 Mtoe, which is 25% higher than in BAU.

Figure 6.10. Total Final Energy Consumption in 2040 by Case, Myanmar



BAU = business as usual, EE = energy efficiency, EE10 = 10% EE, EE20 = 20% EE, GDP = gross domestic product, GDPH =high GDP, GDPL = low GDP, OILH = high oil price, Mtoe = million tons of oil equivalent, OILL = low oil price, RE = renewable energy, RE10 =10% RE , RE20 =20% RE.
Source: Author.

The TFEC in OILL will also be higher but not as high as in GDPH because the biomass share in the TFEC will still be significant over the outlook period. The TFEC in OILL will reach around 34 Mtoe in 2040, or only 5% higher than in BAU.

The lower TFEC of the other cases (GDPL, OILH, EE10, and EE20) will be maximum in EE20. The TFEC of EE20 will reach 25.8 Mtoe in 2040, or 20% lower than BAU since EE20 is defined as reduction in all sectors by 20% in 2040. In EE10, the difference will be 10% (29 Mtoe).

The GDPL case, where GDP is growing slower than in BAU, resulted in a slowdown of economic activities and lower energy demand. The TFEC of GDPL will be 26.5 Mtoe or 18% lower than in BAU.

In GDPL, the reduction in different sectors is not the same. The reduction in the TFEC of industry will be the highest (22%), whilst for transport it will be 20%, residential sector 13%, commercial sector 8%, and ‘others’ 6%. Industry and transport are more sensitive to changes in GDP. The slowing down of the economy indicates lower industrial production, which impacts transport. Consequently, these sectors’ energy consumption will be reduced the most as compared with BAU.

In the residential and commercial sectors, most consumption is of biomass. Therefore, changes in GDP will not directly impact biomass consumption. Biomass consumption will increase in GDPL and decrease in GDPH.

In the higher crude oil price case (OILH), the TFEC in 2040 will only be 31.8 Mtoe, or 1.2% lower than BAU.

2.2. Power Generation

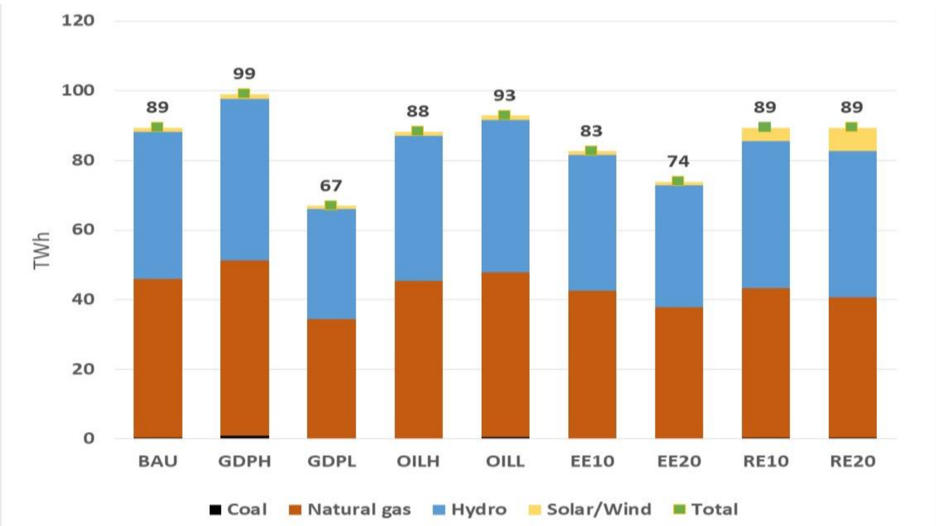
Electricity demand of the final energy consumption sector in case of GDPL will be 28% lower than in BAU. In EE10 and EE20, electricity consumption is only 10% and 20% lower than in BAU. Since own use and losses (distribution and transmission) are the same for all cases, then electricity generation will be the lowest in GDPL (Figure 6.11).

As in BAU, natural gas will be the major energy source for electricity generation in 2040 (51%) for all cases except RE10 and RE20, where the hydropower share in total generation will be 47% in 2040.

In RE10 and RE20, renewable (solar/PV and wind) capacity is assumed to be 10% and 20% higher than in BAU. Substitution is assumed only for natural gas plants. As a result, the generation from gas plants in RE10 will be 6% and in RE20 12% lower than in BAU. The share of natural gas in total generation of electricity will be 48% in RE10 and 45% in RE20. The gas share in RE10 will still be higher than the hydropower share (47%), whilst in RE20, hydropower will be dominant.

Generation from RE plants (solar/PV and wind) was 1.2 TWh in BAU. In RE10, generated electricity reached 3.9 TWh and in RE20 6.6 TWh in 2040.

Figure 6.11. Comparison of Scenarios to Electricity Generation by 2040, Myanmar



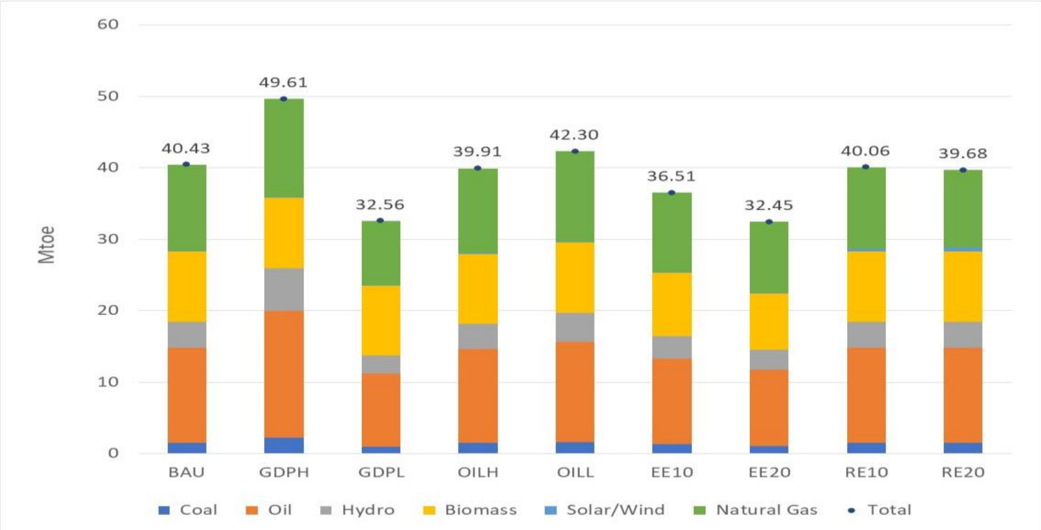
BAU = business as usual, EE = energy efficiency, EE10 = 10% EE, EE20 = 20% EE, GDP = gross domestic product, GDPH =high GDP, GDPL = low GDP, OILH = high oil price, OILL = low oil price, RE = renewable energy, RE10 =10% RE , RE20 =20% RE ,TWh = terawatt hour.
Source: Author.

2.3. Primary Energy Supply

A 3% increment of GDP (GDPH case) indicates economic growth and an increase in demand for energy. As a result, the TPES in 2040 will be 23% higher than in BAU (Figure 6.12). This increase will mainly come from increased electricity demand because of higher GDP. Coal supply will be 47% and oil supply 33% higher than in BAU, particularly because of increased industry and transport activities.

In a reverse situation, where GDP growth declined by 3% (GDPL), economic activities will be slower than in BAU. Consequently, supply of different sources of energy will be lower in GDPL. Biomass supply in GDPL will be only 0.3% lower than in BAU. Coal supply will be 35%, hydropower 30%, and natural gas 26% lower in GDPL, whilst oil will decrease by 24%, resulting in an overall decrease of the TPES by 19%.

Figure 6.12. Comparison of Scenarios with Total Primary Energy Supply by 2040, Myanmar



BAU = business as usual, EE = energy efficiency, EE10 = 10% EE, EE20 = 20% EE, GDP = gross domestic product, GDPH =high GDP, GDPL = low GDP, Mtoe = million tons of oil equivalent, OILH = high oil price, OILL = low oil price, RE = renewable energy, RE10 =10% RE , RE20 =20% RE.
Source: Author.

Changes in oil price will impact the TPES but not as significantly as changes in GDP. In OILH, the TPES will be 1.3% lower than in BAU, whilst in OILL, the TPES will increase by almost 5%.

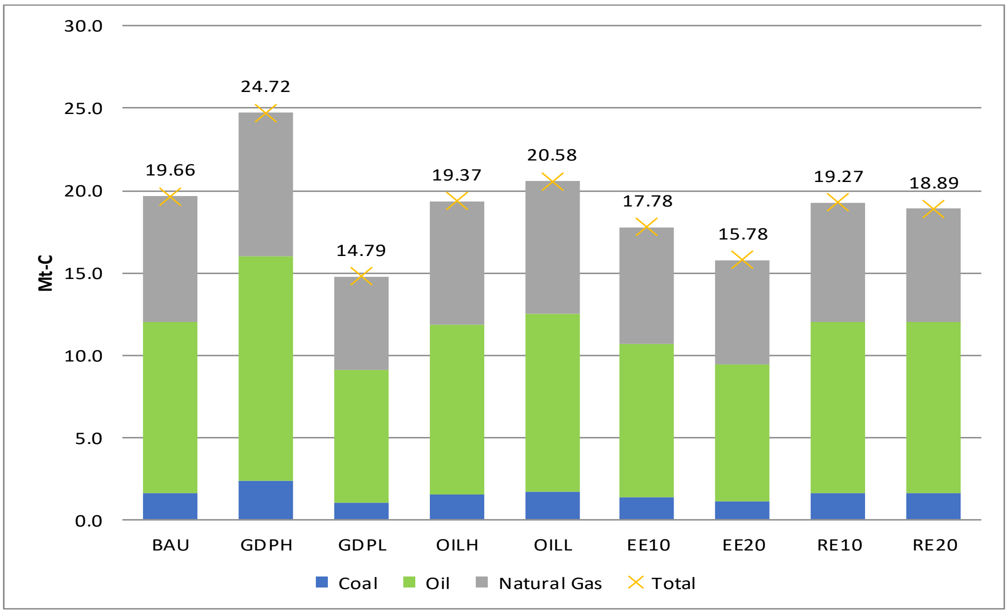
The TPES will be the smallest in EE20 as a result of implementing 20% EE policy in the final energy sectors. The TPES of RE10 and RE20 will impact only natural gas and RE supply (solar/PV and wind) as these cases only substitute natural gas with solar/PV and wind energy (increase 10% and 20%). Natural gas supply will be 5% lower in RE10 whilst solar/PV and wind supply will be 3.2 times higher. In RE20, natural gas supply will be 10% lower than in BAU whilst solar/PV and wind supply will be 5.6 times higher.

Both RE10 and RE20 will result in a lower TPES in 2040 than in BAU because solar/PV and wind power plants have 100% efficiency, and natural gas power plants only 55%. So, increasing the share of solar/PV and wind sources in total electricity production as substitutes for natural gas-fired power plants (RE10 and RE20) will reduce natural gas input compared with BAU and, thus, lower the TPES.

2.4. Carbon Dioxide Emission Reduction

The CO_2 emissions in BAU will reach 19.7 Mt-c by 2040, 3.4 times more than it was in 2016. GDPH will increase coal, oil, and natural gas supply as compared with BAU, resulting in higher CO_2 emissions. Total CO_2 emissions in GDPH will be 24.7 Mt-c by 2040, which is 26% higher than in BAU (Figure 6.13). CO_2 emissions will also be higher in OILL, but only by 5%.

Figure 6.13. Carbon Dioxide Emissions by Case, Myanmar



BAU = business as usual, EE = energy efficiency, EE10 = 10% EE , EE20 = 20% EE, GDP = gross domestic product, GDPH =high GDP , GDPL = low GDP, Mt-c =million tons-c, OILH = high oil price , OILL = low oil price, RE = renewable energy, RE10 =10% RE , RE20 =20% RE .

Source: Author.

Table 6.1. Energy Balance Table 2016, Business as Usual, Myanmar

Energy Balance for Myanmar Scenario: BAU, Year: 2016, Units: Million Tonnes of Oil Equivalent	Coal	Natural Gas	Crude Oil	Hydropower	Renewables	Biomass	Electricity	Oil Products	Total
Production	0.21	16.47	0.61	1.04	0.001	9.07	-	-	27.39
Imports	0.21	0.16	-	-	-	-	-	3.98	4.35
Exports	-0.004	-13.47	-0.19	-	-	-0.00	-0.21	-0.17	-14.05
Total Primary Supply	0.41	3.16	0.42	1.04	0.001	9.07	-0.21	3.80	17.70
coal production	-	-	-	-	-	-	-	-	-
crude oil production	-	-	-	-	-	-	-	-	-
Natural Gas Production	-	-	-	-	-	-	-	-	-
Charcoal Processing	-	-	-	-	-	-0.14	-	-	-0.14
Refinery	-	-	-0.42	-	-	-	-	0.42	-
Electricity generation	-0.00	-2.73	-	-1.04	-0.00	-	1.74	-0.02	-2.05
Loss and own use	-	-	-	-	-	-	-0.22	-	-0.22
Total Transformation	-0.00	-2.73	-0.42	-1.04	-0.00	-0.14	1.53	0.40	-2.41
Industry	0.41	0.26	-	-	-	2.63	0.40	2.04	5.74
Transport	-	0.16	-	-	-	-	-	2.07	2.23
Residential	0.00	-	-	-	-	3.66	0.65	0.04	4.35
Commercial	-	0.00	-	-	-	2.63	0.26	0.03	2.93
Others	-	-	-	-	-	-	0.01	0.03	0.04
Total Demand	0.41	0.43	-	-	-	8.93	1.32	4.20	15.29

BAU = business as usual.

Source: Author.

Table 6.2. Energy Balance Table 2040, Business as Usual, Myanmar

Energy Balance Myanmar Scenario: BAU, Year: 2040, Units: Million Tonnes of Oil Equivalent	Coal	Natural Gas	Crude Oil	Hydropower	Renewables	Biomass	Electricity	Oil Products	Total
Production	0.70	8.01	0.67	3.62	0.10	9.84	-	-	22.95
Imports	0.84	9.02	-	-	-	-	0.19	13.07	23.12
Exports	-	-5.00	-0.25	-	-	-	-0.21	-0.17	-5.63
Total Primary Supply	1.54	12.03	0.42	3.62	0.10	9.84	-0.01	12.89	40.43
coal production	-	-	-	-	-	-	-	-	-
crude oil production	-	-	-	-	-	-	-	-	-
Natural Gas Production	-	-	-	-	-	-	-	-	-
Charcoal Processing	-	-	-	-	-	-0.14	-	-	-0.14
Refinery	-	-	-0.42	-	-	-	-	0.42	-
Electricity generation	-0.18	-10.88	-	-3.62	-0.10	-	7.68	-	-7.10
Loss and own use	-	-	-	-	-	-	-0.98	-	-0.98
Total Transformation	-0.18	-10.88	-0.42	-3.62	-0.10	-0.14	6.71	0.42	-8.22
Industry	1.36	0.26	-	-	-	3.34	2.36	8.20	15.52
Transport	-	0.88	-	-	-	-	-	4.90	5.78
Residential	0.00	-	-	-	-	3.66	2.91	0.09	6.67
Commercial	-	0.00	-	-	-	2.70	1.41	0.09	4.20
Others	-	-	-	-	-	-	0.02	0.03	0.05
Total Demand	1.36	1.15	-	-	-	9.70	6.70	13.31	32.22

BAU = business as usual.

Source: Author.

Chapter 7

Conclusions and Policy Recommendations

Total final energy consumption (TFEC) will increase at an average rate of 3.0% per year in 2016–2040. Consumption by industry will grow the fastest (4.2%), followed by transport (4.0%), the residential sector (1.8%), and the commercial sector (1.5%). Low growth in the residential and commercial sectors will be due to flat growth of biomass consumption (0.3%) as liquefied petroleum gas (LPG) and more efficient biomass stoves become more available. Electricity will grow the fastest at 7.0%, followed by coal at 5.1%, oil at 4.9%, and natural gas at 4.2%.

Electricity production will increase to 89.4 TWh by 2040 from 20.3 TWh in 2016 at an average rate of 6.4% per year. The share of hydropower will decline from 60% in 2016 to 47% in 2040. The share of natural gas will increase from 40% in 2016 to 51% in 2040, with coal accounting for 1% and solar/PV for 1% in 2040.

Total primary energy supply (TPES) will reach 40 Mtoe in 2040, increasing at an average rate of 3.5% per year from 2016. Hydropower sources will increase at an average rate of 6.3% per year over the projection period. Gas supply will be important in power generation as well as transport and industry, with an average growth rate of 5.7% per year. Oil will grow at an average rate of 4.9% per year, mainly to meet road transport demand. As a result, biomass share will rapidly decline from 51% in 2016 to 24% in 2040, and other energy sources will increase their share: coal (2%–4%), oil (24%–33%), natural gas (18%–30%), and hydropower (5%–9%).

Import dependency, defined as imported energy/(TPES+export) will worsen from 14% in 2016 to 49% in 2040 because of a large increase in oil imports for transport and natural gas imports for power generation.

Because of the increase in the TPES, especially oil and natural gas, CO_2 emissions will also increase from 5.8 million carbon tons (Mt-C) in 2016 to 19.7 Mt-C in 2040. CO_2/TPES will worsen from 0.32 t-C/toe in 2016 to 0.49 t-C/toe in 2040 because the share of biomass and hydropower will be reduced from 56% in 2016 to 33% in 2040. Thus, CO_2 emissions will surely increase.

The TPES per GDP (energy intensity) will improve from 238 toe/million US dollars in 2016 to 125 toe/million US dollars in 2040 (52%). This improvement will come from the gap between GDP growth rate (6.3% in 2016–2020) and TPES growth rate (3.5%). The gap is caused by flat growth of biomass because the growth of other energy sources shows a similar trend in GDP: coal (5.6%), oil (4.9%), natural gas (5.7%), and hydropower (6.3%).

The case studies have the following implications:

(1) Change in GDP (plus or minus) remarkably affects energy demand. If GDP changes by 1%, energy demand increases or decreases by about 5%–7%. Energy demand will surely increase if Myanmar achieves high economic growth. GDP is highly sensitive to energy demand.

(2) The international crude oil price seems not to affect energy demand largely because most energy supply is domestic, such as natural gas and hydro, which are not affected by the international oil price. Oil demand is surely affected by change in international oil price but oil share in 2040 will be just 33%.

(3) Energy efficiency policy will surely help reduce energy TFEC and TPES as well as CO_2 emissions. The effect is the same as a change in GDP.

(4) The RE promotion scenario does not affect energy consumption but surely contributes to reducing CO_2 emissions, although not by much. Even if Myanmar increases the share of solar/PV capacity to 10% and 20%, its capacity factor is only 12%–15%, so that power generation by solar/PV is not as much as by baseload power such as coal and natural gas. To reduce CO_2 emissions using solar/PV, Myanmar needs an ambitious RE target of more than 50% of capacity basis.

(5) Important energy policies are the following:

    (a) Promote energy efficiency and conservation through an energy efficiency policy or sub-decree to curb energy demand.

    (b) Increase domestic energy such as hydropower, solar/PV, and local coal to maintain energy supply security.

    (c) Although biomass might be phased out of the energy market because of the shift to more convenient fuels, continuous use of biomass is an option to curb fossil fuel demand.

References

Asian Development Bank (2015), *National Energy Efficiency and Conservation Policy, Strategy and Roadmap for Myanmar.* Consultant’s report. Manila (TA 8356-MYA).

Economic Research Institute for ASEAN and East Asia (ERIA) (2017), *Natural Gas Master Plan for Myanmar*. Jakarta: ERIA

Ministry of Electricity and Energy (Myanmar) and ERIA (2019), *Myanmar Energy Statistics 2019.* Jakarta: ERIA.

Myint, Tin Zaw (2019), ‘Myanmar Country Report’, in *Energy Outlook and Energy Saving Potential in East Asia 2019.* Jakarta: ERIA, pp.219–42. http://www.eria.org/uploads/media/21.Energy_Outlook_and_Energy_Saving_Potential_2019_Chapter_12_Myanmar_Country_Report.pdf (accessed 18 December 2019).

World Bank. *World Development Indicators*. https://data.worldbank.org/country/myanmar?view=chart (accessed 24 October 2018).

Appendix

Results of Microfit Regression Analysis

1. Industry Sector

1.1. Sub-bituminous Coal Demand

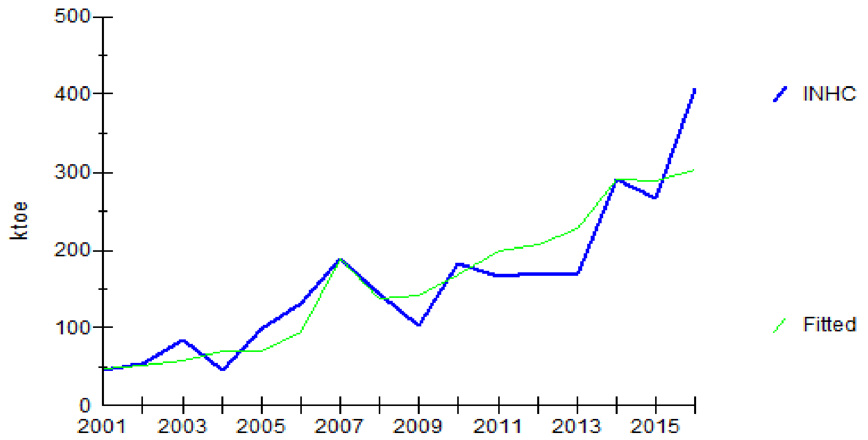
*INHC = 132.8113*CONSTANT + 0.1255E-4*MMINGDP + 0.20828*INHC(-1) - 74.9828*DUM07 - 41.8489*DUM14*

Table A-1. Ordinary Least Squares Estimation for Sub-bituminous Coal Demand, Myanmar

```
*******************************************************************************
 Dependent variable is INHC
 16 observations used for estimation from 2001 to 2016
*******************************************************************************
 Regressor              Coefficient       Standard Error         T-Ratio[Prob]
 CONSTANT                 132.8113            70.9335             1.8723[.088]
 MMINGDP                  .1255E-4           .5090E-5             2.4648[.031]
 INHC(-1)                   .20828             .37067             .56191[.585]
 DUM07                    -74.9828            48.4243            -1.5485[.150]
 DUM14                    -41.8489            54.2911            -.77082[.457]
*******************************************************************************
 R-Squared                     .84126   R-Bar-Squared                   .78354
 S.E. of Regression           45.2088   F-stat.    F(  4,  11)   14.5741[.000]
 Mean of Dependent Variable  159.2080   S.D. of Dependent Variable     97.1700
 Residual Sum of Squares      22482.2   Equation Log-likelihood       -80.6861
 Akaike Info. Criterion      -85.6861   Schwarz Bayesian Criterion    -87.6176
 DW-statistic                  1.5665   Durbin's h-statistic           *NONE*
*******************************************************************************
```

DUM07 = dummy variable for 2007, DUM14 = dummy variable for 2014, INHC = sub-bituminous coal demand in industry, INHC(-1) = sub-bituminous coal demand in industry in the previous year, MMINGDP = industrial gross domestic product.
Source: Author.

Figure -1. Plot of Actual and Fitted Values for Sub-bituminous Coal Demand in Industry, Myanmar



INHC = sub-bituminous coal demand in industry, ktoe = thousand tons of oil equivalent.
Source: Author.

1.2. Electricity Demand

*INEL = 13.8777*CONSTANT + 0.2329E-4*MMINGDP - 0.040165*RPOIL + 75.1668*DUM0912*

Table -2. Ordinary Least Squares Estimation for Electricity Demand in Industry, Myanmar

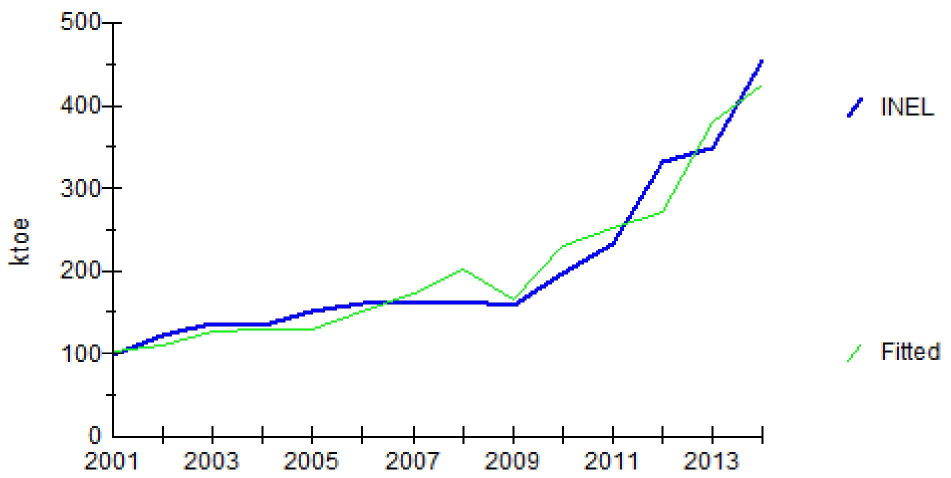
Dependent variable is INEL
14 observations used for estimation from 2001 to 2014

Regressor	Coefficient	Standard Error	T-Ratio[Prob]
CONSTANT	13.8777	37.3863	.37120[.718]
MMINGDP	.2329E-4	.2023E-5	11.5118[.000]
RPOIL	-.040165	.041065	-.97808[.351]
DUM0912	75.1668	21.0243	3.5752[.005]

R-Squared	.93252	R-Bar-Squared	.91227
S.E. of Regression	30.5465	F-stat.F(3, 10)	46.0615[.000]
Mean of Dependent Variable	203.3878	S.D. of Dependent Variable	103.1313
Residual Sum of Squares	9330.9	Equation Log-likelihood	-65.3793
Akaike Info. Criterion	-69.3793	Schwarz Bayesian Criterion	-70.6574
DW-statistic	2.3245		

DUM0912 = dummy variable for 2009–2012, INEL = electricity demand in the industry sector, MMINGDP = industrial gross domestic product, RPOIL = relative price of crude oil.
Source: Author.

Figure -2. Plot of Actual and Fitted Values for Electricity Demand in Industry, Myanmar



INEL = electricity demand in the industry sector, ktoe= thousand tons of oil equivalent.
Source: Author.

1.3. Demand for Petroleum Products

$$INPP = 689.4636*CONSTANT + 0.6668E\text{-}4*MMINGDP - 0.095630*RPOIL + 0.16475*INPP(-1) + 286.3320*DUM0810 + 432.2258*DUM11 - 1020.0*DUM15$$

Table -3. Ordinary Least Squares Estimation of Demand for Petroleum Products in Industry, Myanmar

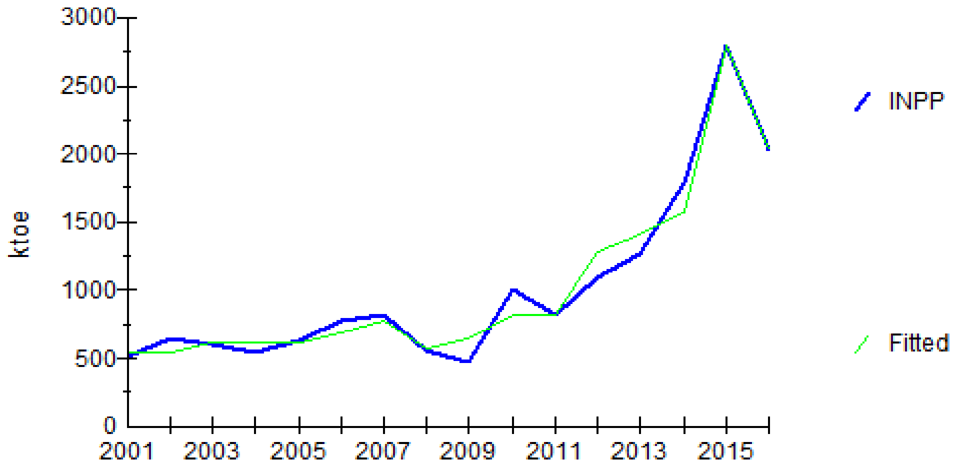
Dependent variable is INPP
16 observations used for estimation from 2001 to 2016

Regressor	Coefficient	Standard Error	T-Ratio[Prob]
CONSTANT	689.4636	299.9711	2.2984[.047]
MMINGDP	.6668E-4	.1164E-4	5.7296[.000]
RPOIL	-.095630	.18501	-.51688[.618]
INPP(-1)	.16475	.11750	1.4021[.194]
DUM0810	286.3320	103.9895	2.7535[.022]
DUM11	432.2258	155.2978	2.7832[.021]
DUM15	-1020.0	170.8498	-5.9701[.000]

R-Squared	.97115	R-Bar-Squared	.95192
S.E. of Regression	143.4966	F-stat. F(6, 9)	50.4999[.000]
Mean of Dependent Variable	1021.4	S.D. of Dependent Variable	654.4448
Residual Sum of Squares	185321.5	Equation Log-likelihood	-97.5611
Akaike Info. Criterion	-104.5611	Schwarz Bayesian Criterion	-107.2651
DW-statistic	2.3240	Durbin's h-statistic	-.73424[.463]

DUM0810 = dummy variable for 2008–2010, DUM11 = dummy variable for 2011, DUM15 = dummy variable for 2015, INPP = petroleum product demand in industry, INPP(-1) = petroleum product demand in industry in the previous year, MMINGDP = industrial gross domestic product, RPOIL = relative price of crude oil.
Source: Author.

Figure A-3. Plot of Actual and Fitted Values for Demand for Petroleum Products in Industry, Myanmar



INPP = petroleum product demand in industry, ktoe = thousand tons of oil equivalent.
Source: Author.

2. Transport Sector

2.1. Motor Gasoline Demand in the Road Transport

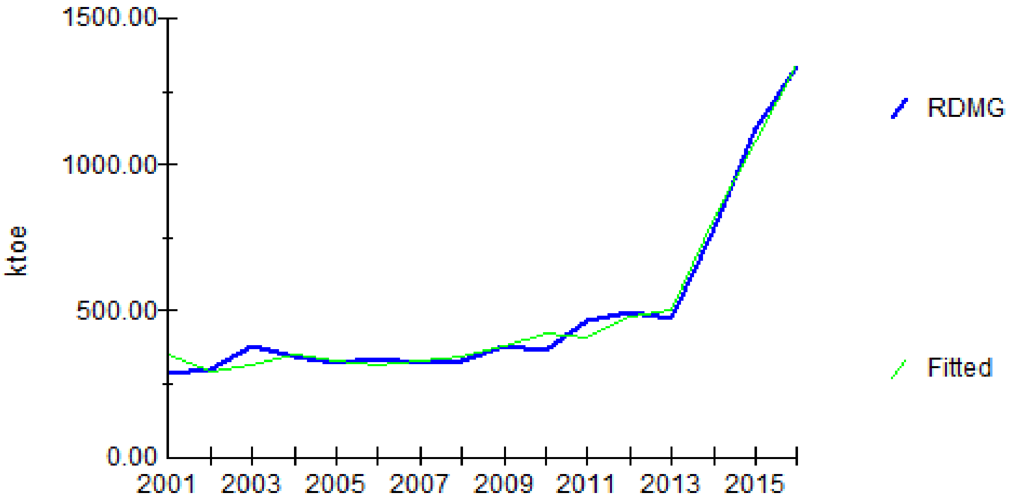
$$RDMG = 139.4596*CONSTANT - 0.097656*RPOIL + 0.1612E\text{-}5*MMGDP + 0.75141*RDMG(-1) + 305.1426*DUM0013$$

Table -4. Ordinary Least Squares Estimation of Demand for Motor Gasoline for Road Transport, Myanmar

```
*******************************************************************************
 Dependent variable is RDMG
 16 observations used for estimation from 2001 to 2016
*******************************************************************************
 Regressor              Coefficient       Standard Error         T-Ratio[Prob]
 CONSTANT                 139.4596            64.2725              2.1698[.053]
 RPOIL                    -.097656            .063906             -1.5281[.155]
 MMGDP                    .1612E-5           .8129E-6              1.9833[.073]
RDMG(-1)                   .75141            .096855              7.7581[.000]
 DUM0013                  305.1426            50.2524              6.0722[.000]
*******************************************************************************
 R-Squared                     .98551   R-Bar-Squared                    .98024
S.E. of Regression            43.4495  F-stat.F(  4,  11)  187.0657[.000]
 Mean of Dependent Variable  503.9480   S.D. of Dependent Variable     309.1259
 Residual Sum of Squares      20766.5   Equation Log-likelihood        -80.0511
 Akaike Info. Criterion      -85.0511   Schwarz Bayesian Criterion     -86.9825
 DW-statistic                  2.1955   Durbin's h-statistic      -.42418[.671]
*******************************************************************************
```

DUM0013 = dummy variable for 2000–2013, MMGDP = gross domestic product, RDMG = motor gasoline demand for road transport, RDMG(–1) = motor gasoline demand for road transport in the previous year, RPOIL = relative price of crude oil.
Source: Author.

Figure A-4. Plot of Actual and Fitted Values of Demand for Motor Gasoline for Road Transport, Myanmar



ktoe = thousand tons of oil equivalent, RDMG = motor gasoline demand for road transport.
Source: Author.

2.2. Lubricant Demand in Road Transport

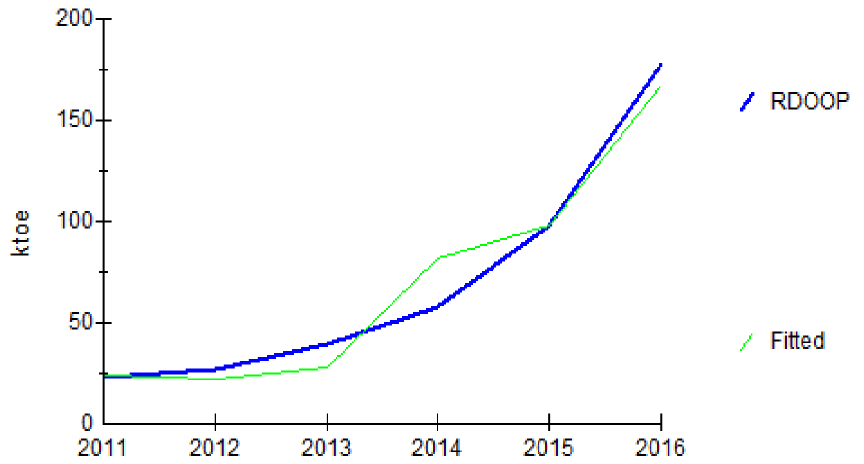
*RDOOP = -6.9320*CONSTANT - 0.22618*RPOIL + 0.3703E-5*MMGDP + 55.8092*DUM15*

Table -5. Ordinary Least Squares Estimation of Demand for Lubricant in Road Transport, Myanmar

```
*******************************************************************************
 Dependent variable is RDOOP
 6 observations used for estimation from 2011 to 2016
*******************************************************************************
 Regressor              Coefficient       Standard Error         T-Ratio[Prob]
 CONSTANT                  -6.9320            198.9186           -.034848[.975]
 RPOIL                     -.22618              .10806            -2.0931[.171]
 MMGDP                    .3703E-5            .2726E-5             1.3585[.307]
 DUM15                     55.8092             28.9376             1.9286[.194]
*******************************************************************************
 R-Squared                     .95090   R-Bar-Squared                   .87725
 S.E. of Regression           20.7166   F-stat.F(  3,    2)    12.9107[.073]
 Mean of Dependent Variable   70.1929   S.D. of Dependent Variable     59.1291
 Residual Sum of Squares     858.3542   Equation Log-likelihood       -23.4034
 Akaike Info. Criterion      -27.4034   Schwarz Bayesian Criterion    -26.9869
 DW-statistic                  2.4159
*******************************************************************************
```

DUM15 = dummy variable in 2015, MMGDP = gross domestic product, RDOOP = lubricant demand for road transport, RPOIL = relative price of crude oil.
Source: Author.

Figure A-5. Plot of Actual and Fitted Values of Demand for Lubricant in Road Transport, Myanmar



ktoe= thousand tons of oil equivalent, RDOOP = lubricant demand for road transport.
Source: Author.

2.3. Demand for Oil Products in Road Transport

$$RDOIL = 781.3236*CONSTANT - 0.69850*RPOIL + 0.1038E\text{-}4*MMGDP + 0.22108*RDOIL(-1) + 260.3233*DUM0813$$

Table -6. Ordinary Least Squares Estimation of Demand for Oil Products for Road Transport, Myanmar

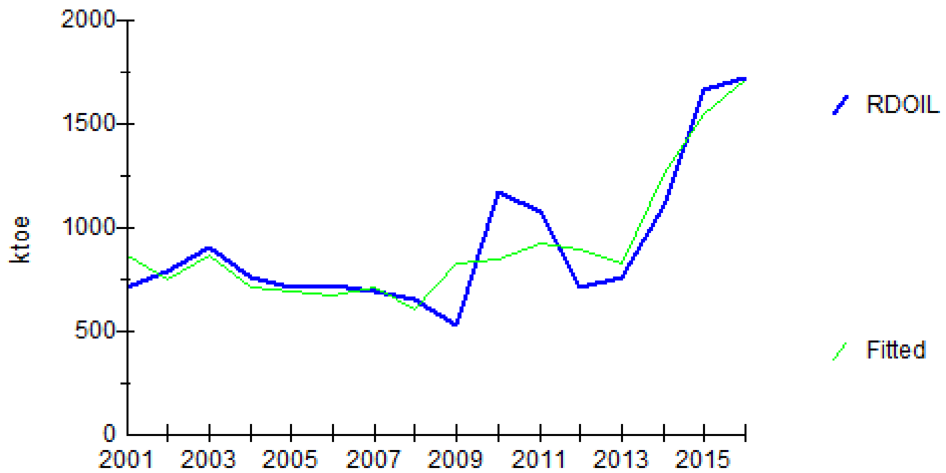
Dependent variable is RDOIL
16 observations used for estimation from 2001 to 2016

Regressor	Coefficient	Standard Error	T-Ratio[Prob]
CONSTANT	781.3236	275.6219	2.8348[.016]
RPOIL	-.69850	.21557	-3.2402[.008]
MMGDP	.1038E-4	.2694E-5	3.8515[.003]
RDOIL(-1)	.22108	.21052	1.0502[.316]
DUM0813	260.3233	104.4798	2.4916[.030]

R-Squared	.81833	R-Bar-Squared	.75226
S.E. of Regression	174.0536	F-stat.F(4, 11)	12.3871[.000]
Mean of Dependent Variable	917.0609	S.D. of Dependent Variable	349.6944
Residual Sum of Squares	333241.2	Equation Log-likelihood	-102.2553
Akaike Info. Criterion	-107.2553	Schwarz Bayesian Criterion	-109.1868
DW-statistic	2.4308	Durbin's h-statistic	-1.5973[.110]

DUM0813 = dummy variable for the years 2008-2013, MMGDP = gross domestic product, RDOIL = demand for oil products for road transport, RPOIL = relative price of crude oil, RDOIL(-1) = demand for oil products for road transport in the previous year.
Source: Author.

Figure A-6. Plot of Actual and Fitted Values of Demand for Oil Products for Road Transport, Myanmar



ktoe= thousand tons of oil equivalent, RDOIL = demand for oil products for road transport.
Source: Author.

2.4. Total Energy Demand in Road Transport

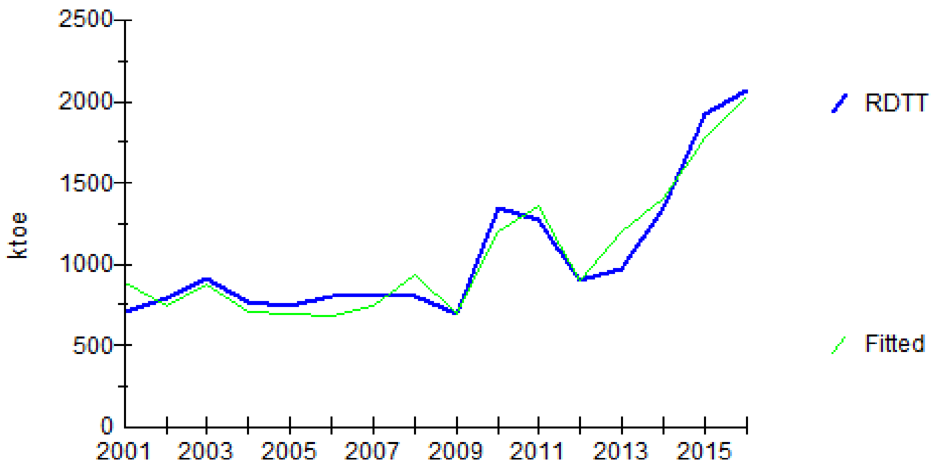
$$RDTT = 84.5159*CONSTANT + 625.7970*GDPC - 0.80750*RPOIL + 0.35481*RDTT(-1) + 504.9038*DUM09 + 416.8222*DUM12$$

Table -7. Ordinary Least Squares Estimation of Total Energy Demand for Road Transport, Myanmar

```
*******************************************************************************
 Dependent variable is RDTT
 16 observations used for estimation from 2001 to 2016
*******************************************************************************
Regressor              Coefficient       Standard Error         T-Ratio[Prob]
 CONSTANT                  84.5159             307.0845            .27522[.789]
 GDPC                     625.7970             117.1100            5.3437[.000]
 RPOIL                     -.80750               .18808           -4.2934[.002]
 RDTT(-1)                   .35481               .16543            2.1448[.058]
 DUM09                    504.9038             149.3584            3.3805[.007]
 DUM12                    416.8222             147.0256            2.8350[.018]
*******************************************************************************
 R-Squared                      .93366   R-Bar-Squared                   .90049
 S.E. of Regression           134.6383   F-stat.F(  5,  10)    28.1482[.000]
 Mean of Dependent Variable     1053.8   S.D. of Dependent Variable    426.8137
 Residual Sum of Squares      181274.7   Equation Log-likelihood       -97.3845
 Akaike Info. Criterion      -103.3845   Schwarz Bayesian Criterion   -105.7022
 DW-statistic                   1.7809   Durbin's h-statistic       .58454[.559]
*******************************************************************************
```

DUM09 = dummy variable in 2009, DUM12 = dummy variable in 2012, GDPC = gross domestic product per capita, RDTT = total energy demand for road transport, RDTT (-1) = total energy demand for road transport in the previous year, RPOIL = relative price of crude oil.
Source: Author.

Figure A-7. Plot of Actual and Fitted Values of Total Energy Demand for Road Transport, Myanmar



ktoe = thousand tons of oil equivalent, RDTT = total energy demand for road transport.
Source: Author.

2.5. Aviation

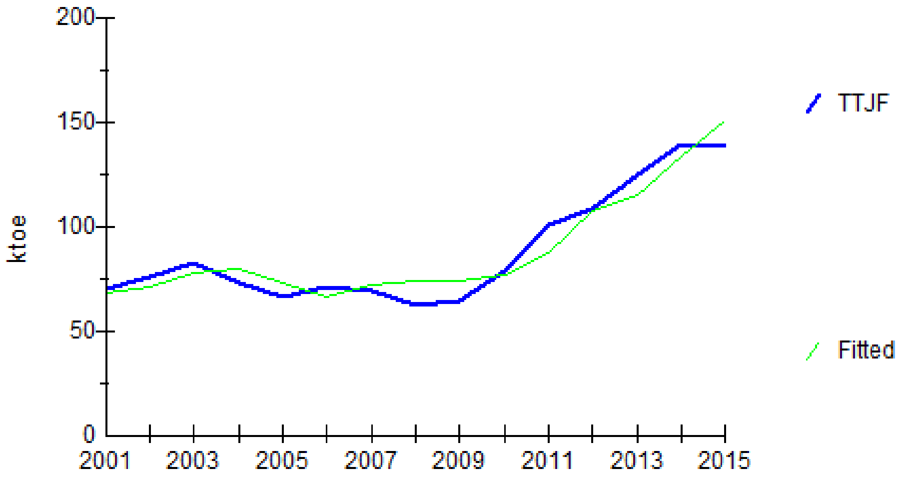
*TTJF = 18.9831*CONSTANT + 0.2842E-6*MMGDP - 0.016262*RPOIL + 0.88702*TTJF(-1)*

Table -8. Ordinary Least Squares Estimation of Total Jet Fuel Demand for Aviation Transport, Myanmar

```
*******************************************************************************
 Dependent variable is TTJF
 15 observations used for estimation from 2001 to 2015
*******************************************************************************
 Regressor              Coefficient       Standard Error         T-Ratio[Prob]
 CONSTANT                  18.9831             15.5685            1.2193[.248]
 MMGDP                   .2842E-6            .1600E-6            1.7761[.103]
 RPOIL                   -.016262             .011862           -1.3709[.198]
 TTJF(-1)                  .88702              .13967            6.3510[.000]
*******************************************************************************
 R-Squared                     .91760   R-Bar-Squared                   .89513
 S.E. of Regression            8.7738   F-stat.    F(  3,  11)    40.8338[.000]
 Mean of Dependent Variable   88.4193   S.D. of Dependent Variable     27.0936
 Residual Sum of Squares     846.7773   Equation Log-likelihood       -51.5345
 Akaike Info. Criterion      -55.5345   Schwarz Bayesian Criterion    -56.9506
 DW-statistic                  1.4285   Durbin's h-statistic      1.3159[.188]
*******************************************************************************
```

MMGDP = gross domestic product, RPOIL = relative price of crude oil, TTJF = total jet fuel demand for aviation transport, TTJF(-1) = total jet fuel demand for aviation transport in the previous year.
Source: Author.

Figure A-8. Plot of Actual and Fitted Values for of Total Jet Fuel Demand for Aviation Transport, Myanmar



ktoe = thousand tons of oil equivalent, TTJF = total jet fuel demand for aviation transport.
Source: Author.

*DAJF = 39.8634*CONSTANT - 0.041349*RPOIL + 0.2816E-6*MMGDP + 0.80633*DAJF(-1)*

Table -9. Ordinary Least Squares Estimation of Jet Fuel Demand for Domestic Aviation Transport, Myanmar

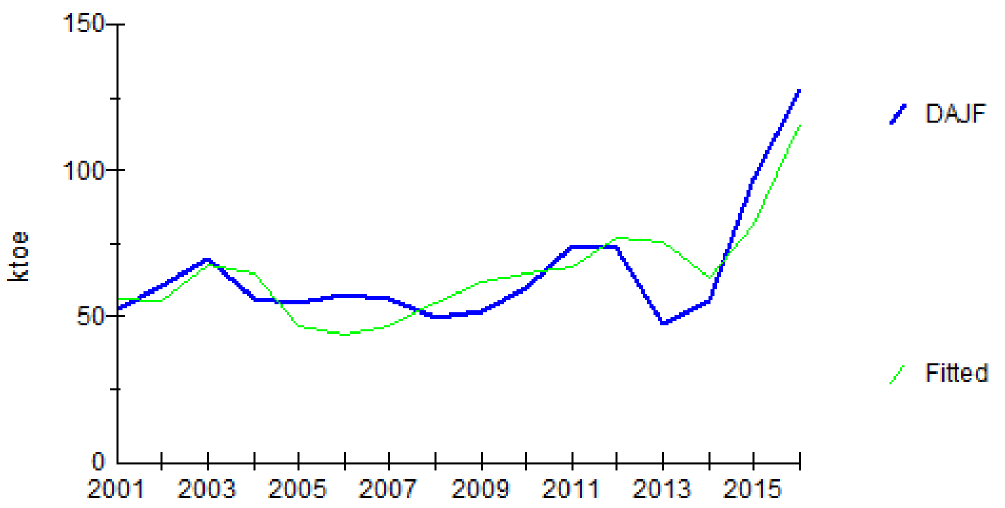
Dependent variable is DAJF
16 observations used for estimation from 2001 to 2016

Regressor	Coefficient	Standard Error	T-Ratio[Prob]
CONSTANT	39.8634	20.2871	1.9650[.073]
RPOIL	-.041349	.014095	-2.9335[.013]
MMGDP	.2816E-6	.1642E-6	1.7151[.112]
DAJF(-1)	.80633	.27042	2.9817[.011]

R-Squared	.70581	R-Bar-Squared	.63226
S.E. of Regression	12.6068	F-stat. F(3, 12)	9.5965[.002]
Mean of Dependent Variable	65.2468	S.D. of Dependent Variable	20.7889
Residual Sum of Squares	1907.2	Equation Log-likelihood	-60.9493
Akaike Info. Criterion	-64.9493	Schwarz Bayesian Criterion	-66.4945
DW-statistic	1.3822	Durbin's h-statistic	*NONE*

DAJF = jet fuel demand for domestic aviation transport, DAJF(-1) = jet fuel demand for domestic aviation transport in the previous year, MMGDP = gross domestic product, RPOIL = relative price of crude oil.
Source: Author.

Figure A-9. Plot of Actual and Fitted Values of Jet Fuel Demand for Domestic Aviation Transport, Myanmar



DAJF = jet fuel demand for domestic aviation transport, ktoe = thousand tons of oil equivalent.
Source: Author.

3. Residential Sector

3.1. Electricity Demand in the Residential Sector

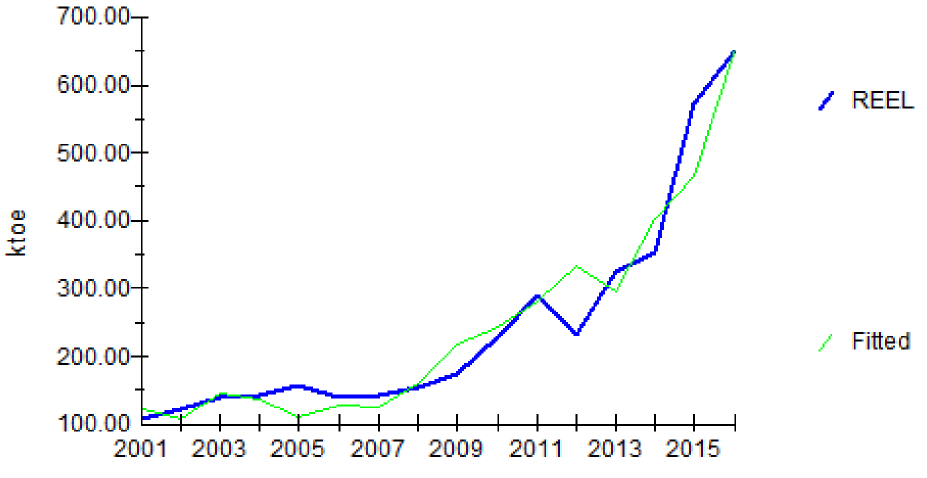
$$REEL = 33.7965*CONSTANT + 0.1892E\text{-}3*GDPC - 0.11731*RPOIL + 0.80166*REEL(-1)$$

Table -10. Ordinary Least Squares Estimation for Electricity Demand in the Residential Sector, Myanmar

```
*******************************************************************************
 Dependent variable is REEL
 16 observations used for estimation from 2001 to 2016
*******************************************************************************
 Regressor              Coefficient       Standard Error         T-Ratio[Prob]
 CONSTANT                  33.7965            62.8351             .53786[.601]
 GDPC                      .1892E-3           .9235E-4            2.0485[.063]
 RPOIL                     -.11731            .063269            -1.8542[.088]
 REEL(-1)                   .80166            .21667              3.6998[.003]
*******************************************************************************
 R-Squared                     .92286   R-Bar-Squared                   .90357
 S.E. of Regression           50.2206   F-stat.F(  3,  12)   47.8510[.000]
 Mean of Dependent Variable  245.5625   S.D. of Dependent Variable    161.7244
 Residual Sum of Squares      30265.3   Equation Log-likelihood       -83.0644
 Akaike Info. Criterion      -87.0644   Schwarz Bayesian Criterion    -88.6095
 DW-statistic                  2.6289   Durbin's h-statistic      -2.5215[.012]
*******************************************************************************
```

GDPC = GDP per capita, REEL = electricity demand in the residential sector, REEL(-1) = electricity demand in the residential sector in the previous year, RPOIL = relative price of crude oil.
Source: Author.

Figure A-10. Plot of Actual and Fitted Values for Electricity Demand in the Residential Sector, Myanmar



ktoe = thousand tons of oil equivalent, REEL = electricity demand in the residential sector.
Source: Author.

3.2. LPG Demand in the Residential Sector

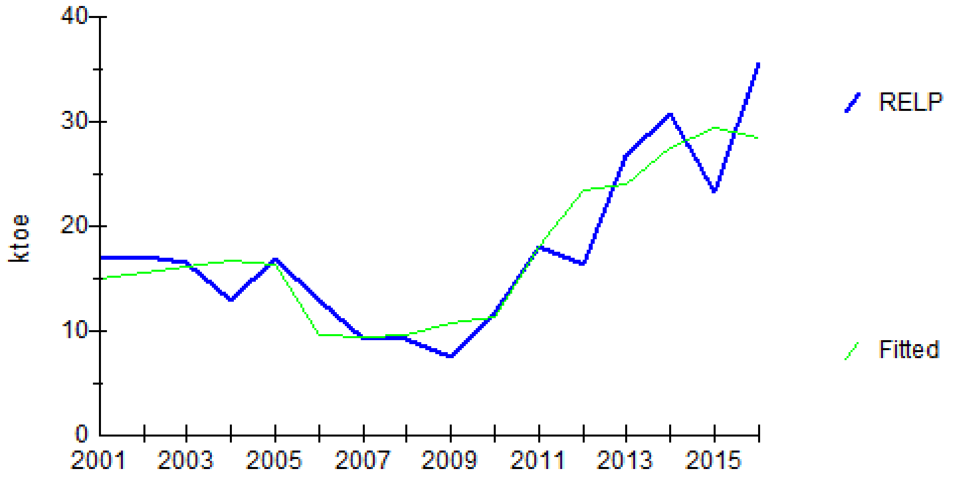
$$RELP = -4.7855*CONSTANT + 0.1449E\text{-}4*GDPC - 0.5858E\text{-}3*RPOIL + 0.23149*RELP(-1) + 8.6175*DUM0610 + 3.1833*DUM11$$

Table -11. Ordinary Least Squares Estimation of LPG Demand in the Residential Sector, Myanmar

```
*******************************************************************************
 Dependent variable is RELP
 16 observations used for estimation from 2001 to 2016
*******************************************************************************
 Regressor              Coefficient       Standard Error         T-Ratio[Prob]
 CONSTANT                   -4.7855               8.9889         -.53238[.606]
 GDPC                      .1449E-4             .5330E-5          2.7187[.022]
 RPOIL                    -.5858E-3             .0057419         -.10202[.921]
 RELP(-1)                    .23149               .30078          .76964[.459]
 DUM0610                     8.6175               3.5765          2.4095[.037]
 DUM11                       3.1833               5.4711          .58184[.574]
*******************************************************************************
 R-Squared                     .78596   R-Bar-Squared                   .67894
 S.E. of Regression            4.4781   F-stat.F(  5,  10)    7.3441[.004]
 Mean of Dependent Variable   17.5800   S.D. of Dependent Variable      7.9031
 Residual Sum of Squares     200.5299   Equation Log-likelihood       -42.9300
 Akaike Info. Criterion      -48.9300   Schwarz Bayesian Criterion    -51.2478
 DW-statistic                  2.4836   Durbin's h-statistic            *NONE*
*******************************************************************************
```

DUM0610 = dummy variable for 2006–2010, DUM11 = dummy variable in 2011, GDPC = gross domestic product per capita, RELP = LPG demand in the residential sector, RPOIL = relative price of crude oil, RELP(-1) = LPG demand in the residential sector in the previous year.
Source: Author.

Figure A-11. Plot of Actual and Fitted Values of LPG Demand in the Residential Sector, Myanmar



ktoe = thousand tons of oil equivalent, RELP = LPG demand in the residential sector.
Source: Author.

4. Commercial Sector

4.1. Electricity Demand in the Commercial Sector

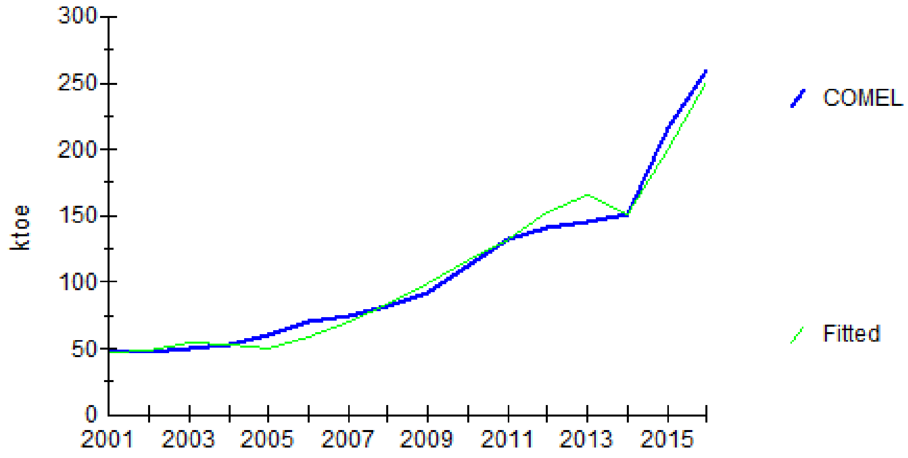
$$COMEL = -26.0884*CONSTANT + 0.4849E\text{-}5*MCSGDP - 0.025305*RPOIL + 0.62662*COMEL(-1) + 31.6028*DUM14$$

Table -12. Ordinary Least Squares Estimation of Electricity Demand in the Commercial Sector, Myanmar

```
*******************************************************************************
 Dependent variable is COMEL
 16 observations used for estimation from 2001 to 2016
*******************************************************************************
 Regressor              Coefficient       Standard Error         T-Ratio[Prob]
 CONSTANT                 -26.0884            18.1135            -1.4403[.178]
 MCSGDP                   .4849E-5           .1975E-5             2.4548[.032]
 RPOIL                   -.025305            .012552             -2.0159[.069]
 COMEL(-1)                 .62662             .25465              2.4607[.032]
 DUM14                    31.6028            11.7940              2.6796[.021]
*******************************************************************************
 R-Squared                     .97967   R-Bar-Squared                   .97227
 S.E. of Regression           10.4591   F-stat.F(  4,  11)  132.5020[.000]
 Mean of Dependent Variable  108.4375   S.D. of Dependent Variable     62.8133
 Residual Sum of Squares       1203.3   Equation Log-likelihood       -57.2651
 Akaike Info. Criterion      -62.2651   Schwarz Bayesian Criterion    -64.1965
 DW-statistic                  .99644   Durbin's h-statistic            *NONE*
*******************************************************************************
```

COMEL = electricity demand in the commercial sector, COMEL(-1) = electricity demand in the commercial sector in the previous year, DUM14 = dummy variable in 2014, MCSGDP = commercial gross domestic product, RPOIL = relative price of crude oil.
Source: Author.

Figure A-12. Plot of Actual and Fitted Values of Electricity Demand in the Commercial Sector, Myanmar



COMEL = electricity demand in the commercial sector, ktoe = thousand tons of oil equivalent.
Source: Author.

5. Other Key Variables

5.1. Gross Domestic Product Deflator

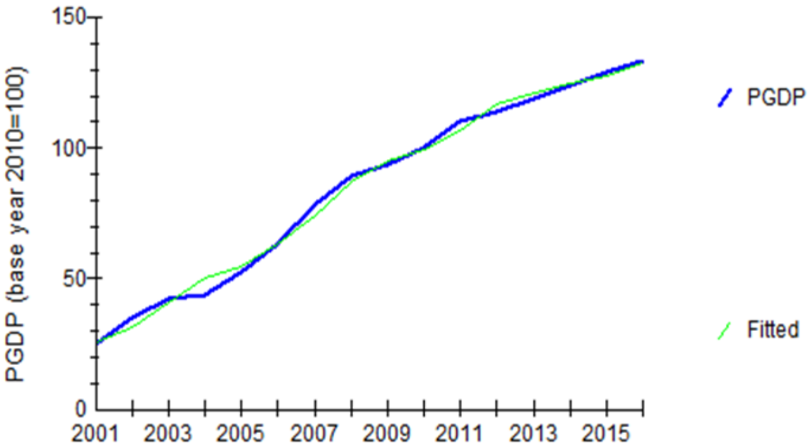
$$PGDP = 2.1175*CONSTANT + 0.0084665*RPOIL + 0.97967*PGDP(-1)$$

Table -13. Ordinary Least Squares Estimation of Gross Domestic Product Deflator, Myanmar

```
*******************************************************************************
 Dependent variable is PGDP
 16 observations used for estimation from 2001 to 2016
*******************************************************************************
 Regressor              Coefficient       Standard Error         T-Ratio[Prob]
 CONSTANT                    2.1175               3.3034            .64101[.533]
 RPOIL                     .0084665             .0033092            2.5584[.024]
 PGDP(-1)                    .97967              .020659           47.4206[.000]
*******************************************************************************
 R-Squared                      .99432   R-Bar-Squared                    .99344
 S.E. of Regression             2.9491   F-stat.    F(  2,  13)    1137.4[.000]
 Mean of Dependent Variable    84.4813   S.D. of Dependent Variable      36.4207
 Residual Sum of Squares      113.0626   Equation Log-likelihood        -38.3458
 Akaike Info. Criterion       -41.3458   Schwarz Bayesian Criterion     -42.5047
 DW-statistic                   1.7885   Durbin's h-statistic       .42447[.671]
*******************************************************************************
```

PGDP = gross domestic product deflator, POILJ = price of crude oil, PGDP(-1) = gross domestic product deflator in the previous year.
Source: Author.

Figure A-13. Plot of Actual and Fitted Values of Gross Domestic Product Deflator, Myanmar



PGDP = gross domestic product deflator.
Source: Author.

5.2. Industrial Gross Domestic Product

$$MMINGDP = -1566795*CONSTANT + 0.14423*MMGDP + 0.67479*MMINGDP(-1)$$

Table -14. Ordinary Least Squares Estimation of Industrial Gross Domestic Product, Myanmar

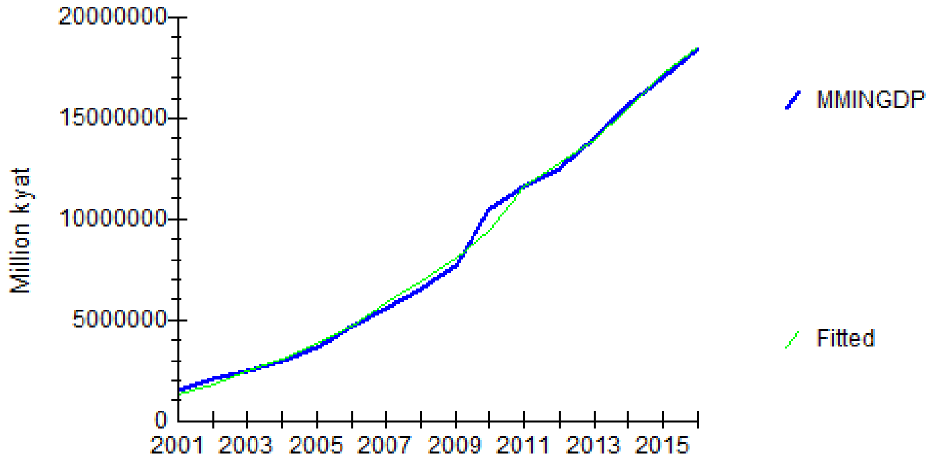
Dependent variable is MMINGDP
16 observations used for estimation from 2001 to 2016

Regressor	Coefficient	Standard Error	T-Ratio[Prob]
CONSTANT	-1566795	657587.0	-2.3826[.033]
MMGDP	.14423	.042822	3.3681[.005]
MMINGDP(-1)	.67479	.11829	5.7046[.000]

R-Squared	.99592	R-Bar-Squared	.99530
S.E. of Regression	393276.4	F-stat. F(2, 13)	1587.6[.000]
Mean of Dependent Variable	8551875	S.D. of Dependent Variable	5733494
Residual Sum of Squares	2.01E+12	Equation Log-likelihood	-227.1582
Akaike Info. Criterion	-230.1582	Schwarz Bayesian Criterion	-231.3171
DW-statistic	2.0270	Durbin's h-statistic	-.061284[.951]

MMGDP = gross domestic product, MMINGDP = industrial gross domestic product, MMINGDP(-1) = industrial gross domestic product in the previous year.
Source: Author.

Figure A-14. Plot of Actual and Fitted Values of Industrial Gross Domestic Product, Myanmar



kyat = currency of Myanmar, MMINGDP = industrial gross domestic product.
Source: Author

5.3. Commercial Gross Domestic Product

*MCSGDP = -138528.5*CONSTANT + 0.085424*MMGDP + 0.86841*MCSGDP(-1)*

Table -15. Ordinary Least Squares Estimation of Commercial Gross Domestic Product, Myanmar

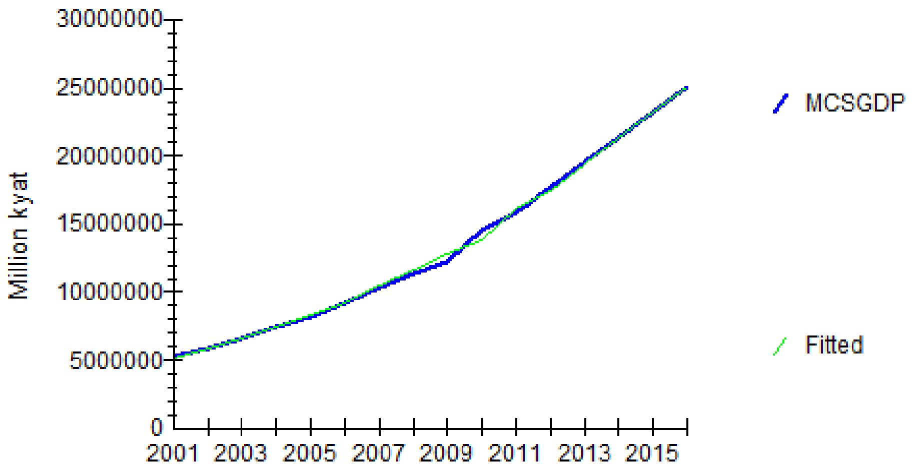
Dependent variable is MCSGDP
16 observations used for estimation from 2001 to 2016

Regressor	Coefficient	Standard Error	T-Ratio[Prob]
CONSTANT	-138528.5	286541.8	-.48345[.637]
MMGDP	.085424	.039294	2.1740[.049]
MCSGDP(-1)	.86841	.097244	8.9302[.000]

R-Squared	.99786	R-Bar-Squared	.99753
S.E. of Regression	320140.2	F-stat.F(2, 13)	3030.5[.000]
Mean of Dependent Variable	1.34E+07	S.D. of Dependent Variable	6442146
Residual Sum of Squares	1.33E+12	Equation Log-likelihood	-223.8661
Akaike Info. Criterion	-226.8661	Schwarz Bayesian Criterion	-228.0250
DW-statistic	2.7250	Durbin's h-statistic	-1.5740[.115]

MCSGDP = commercial gross domestic product, MCSGDP(-1) = commercial gross domestic product in the previous year, MMGDP = gross domestic product.
Source: Author.

Figure A-15. Plot of Actual and Fitted Values of Commercial Gross Domestic Product, Myanmar



kyat = currency of Myanmar, MCSGDP = commercial gross domestic product.
Source: Author.