ERIA Research Project Report 2020, No. 11

Energy Supply Security Study for Myanmar

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

Energy Supply Security Study for Myanmar

Economic Research Institute for ASEAN and East Asia (ERIA)
Sentral Senayan II 6th Floor
Jalan Asia Afrika no.8, Gelora Bung Karno
Senayan, Jakarta Pusat 10270
Indonesia

ERIA Research Project Report FY2020 No. 11
Published in October 2020

Preface

The Republic of the Union of Myanmar is a country rich in natural resources, especially natural gas and hydropower. Myanmar's import dependency ratio in 2017 was 19% according to Myanmar's national energy balance table 2017. On the other hand, Myanmar's energy demand, for example, total final energy consumption (TFEC) grew 3.8% per annum from 2000 to 2017 but oil and electricity marked much higher growth rates, 15.8% and 15.2%, respectively. On the other hand, biomass share to TFEC declined from 72.4% in 2010 to 50.5% in 2017 because biomass was replaced by oil and electricity. Thus, the growth rate of TFEC was much lower than oil and electricity. In addition, the gross domestic product (GDP) growth rate was 7.0% in the same period. In future, the energy demand of Myanmar will continue to increase in the same historical trend. On the other hand, natural gas production will decrease year by year according to the Natural Gas Master Plan for Myanmar developed by the Oil and Gas Planning Department (OGPD), Ministry of Electricity and Energy (MOEE), supported by the Economic Research Institute for ASEAN and East Asia (ERIA) in 2018-19. Therefore, the OGPD requested ERIA to seek the best ways for Myanmar to maintain its energy supply security in the future.

Myanmar's energy supply security was studied to seek the best energy mix in the future considering the following points of view: maintaining accessibility, affordability, and sustainability. Oil supply fully depends on imports into Myanmar, so that how to secure the oil imports is an issue. The security issue of natural gas is how to make its production period longer, therefore liquefied natural gas (LNG) imports and the diversity of the power generation mix are essential. Regarding the diversity of the power generation mix, hydropower generation will be a key role player, and how to maximise hydropower development is essential.

On behalf of the MOEE, I would like to express my special thanks to Professor Hidetoshi Nishimura, President of ERIA, for his continuous support to the MOEE regarding the preparation of Myanmar's energy supply security report. I am sure it will prove to be a useful report for the MOEE to establish appropriate energy policies to secure future energy supply for Myanmar.

U Win Khaing

Union Minister

Ministry of Electricity and Energy, Myanmar

October 2020

Acknowledgements

This report was developed by a working group consisting of the Myanmar team and the Economic Research Institute for ASEAN and East Asia (ERIA) team. The Myanmar team consisted of staff from the Oil and Gas Planning Department, Ministry of Electricity and Energy and line ministries. The ERIA team consisted of researchers of the Energy Unit of ERIA, an ASEAN energy expert on energy statistics and energy outlook, and researchers from the Institute of Energy Economics, Japan (IEEJ). We would like to acknowledge the members of the working group for their excellent work and contribution.

Special acknowledgements are also given to 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

Contents

List of Project Members

Oil and Gas Planning Department (OGPD) Team

U Tin Za w Myint, Director, OGPD, MOEE

Daw Win Win Kyu, Deputy Director, OGPD, MOEE

Daw Swe Swe Than, Assistant Director, OGPD, MOEE

U Han Tun Oo, Assistant Director, OGPD, MOEE

Economic Research Institute for ASEAN and East Asia (ERIA) Team

Mr Shigeru Kimura, Special Adviser to the President on Energy Affairs, ERIA

Dr Joko, Energy Economist, Energy Unit, ERIA

Ms Dian Lutfiana, Research Associate, Energy Unit, ERIA

Ms Cecilya Malik, ASEAN Energy Expert, Indonesia

Mr Ichiro Kutani, Institute of Energy Economics, Japan (IEEJ)

Ms Yumiko Iino, Institute of Energy Economics, Japan (IEEJ)

List of Figures

List of Tables

Abbreviations and Acronyms

AACR	annual average change rate
ACE	ASEAN Centre for Energy
ASEAN	Association of Southeast Asian Nations
BAU	business as usual
CAPEX	capital expenditure
CCGT	combined cycle gas turbine
EEC	energy efficiency and conservation
ERIA	Economic Research Institute for ASEAN and East Asia
GDP	gross domestic product
IEA	International Energy Agency
IEEJ	Institute of Energy Economics, Japan
IFC	International Finance Corporation
IMF	International Monetary Fund
JOGMEC	Japan Oil, Gas and Metals National Corporation
LCOE	levelised cost of electricity
LNG	liquefied natural gas
LPG	Liquefied petroleum gas
METI	Ministry of Economy, Trade, and Industry
MOEE	Ministry of Electricity and Energy
OGPD	Oil and Gas Planning Department
OPEX	operating expense
PV	photovoltaic
RE	renewable energy
SC	super critical
TFEC	total final energy consumption
TPES	total primary energy supply
UN	United Nations
USC	ultra-supercritical

Measurements

b/d	barrel per day
bbl	barrel
Bcm	billion cubic metre
GW	gigawatt
GWh	gigawatt hour
KW	kilowatt
kWh	kilowatt hour
Mcm	million cubic metre
MMBtu	million British thermal unit.
Mtoe	million tons of oil equivalent
MW	megawatt
MWh	megawatt hour
TWh	terawatt hour

Executive Summary

Natural gas is an important energy source for Myanmar and its share to total indigenous production was 61% in 2017, whilst 76% of the gas production was exported to Thailand and China in the same year. The major domestic use of natural gas in Myanmar is power generation (its share was 75% in 2017) and the remaining is used for heating demand in the industry sector and compressed natural gas vehicles in the road transport sector. However natural gas production is forecast to decline continuously up to 2040 according the Natural Gas Master Plan for Myanmar (2019) and on the other hand, electricity consumption will increase remarkably according to the Myanmar Energy Outlook (2020). Thus, the import of liquefied natural gas (LNG) and the diverse power generation mix will be options for Myanmar for securing domestic natural gas supply.

Myanmar is fully dependent on imports of oil and its import share was 92% in 2017. Therefore the issues of oil supply are: (i) having strategic oil stockpiles including national and private ones, (ii) the need to diversify oil import sources to seek a wider area such as Japan and the Republic of Korea, and (iii) shifting from internal combustion engine vehicles to electric vehicles, which will use electricity from hydropower generation.

Coal consumption in Myanmar is limited and its share to total primary energy supply (TPES) was 2.6% in 2017. But coal will be a strategic energy source in order to diversify power generation sources with the application of clean coal technology. But the coal mining sites are located in northern Myanmar, whilst the big electricity demand is from southern Myanmar. Consequently, logistics to bring coal from the north to the south is crucial.

Hydropower generation is a key energy source and its share to TPES was 5% in 2017. But looking at a generation basis, its share was around 60%, followed by gas power generation. Hydropower generation is classified as domestic energy and does not emit CO_2. Therefore, the deployment of hydropower generation will contribute to improving energy supply security and mitigate CO_2 emissions in Myanmar.

Biomass is being phased out from the energy market in Myanmar and this trend will continue in the future. But biomass's share to TPES was 43% in 2017 and if biomass is substituted by oil and electricity continuously in the future, energy supply security of Myanmar will be vulnerable. Thus, the continuous use of biomass is one option for Myanmar to maintain its energy supply security.

Renewable energy such as solar photovoltaic (PV) and wind power generation is an option for Myanmar, but due to its negative characteristics which are intermittency, seasonal fluctuation, low capacity factor, and relatively higher generation cost, the rapid increase of renewable energy is not an appropriate energy policy for Myanmar.

As a result of the study on energy supply security for Myanmar, this report suggests available energy supply security scenarios as follows:

1. The recommended power generation mix in 2040 would consist of coal 19%, natural gas 11%, hydropower 56%, and RE and biomass 12%. It will be a well-balanced composition of the power generation mix compared to the business as usual (BAU) scenario, which is coal 0.4%, natural gas 51.1%, hydropower 47.2%, and renewable energy and biomass 1.3%. This report suggests that Myanmar increase coal-fired power generation using both domestic and imported coal and enhance the development of hydropower generation as well as RE.

2. Natural gas consumption will be secured if Myanmar will apply the recommended power generation mix mentioned above. Natural gas production in the BAU scenario in 2040 will be 8 million tons of oil equivalent (Mtoe) and the energy supply security scenario will be 2.47 Mtoe, so that Myanmar will continue to export certain amounts of natural gas to neighbouring countries until 2040 compared to the BAU scenario.

3. The share of renewable energy and biomass power generation in 2040 will be 12% and it will be much higher than 1.3% of the BAU scenario. This report expects the generation cost of RE power will decline in future and it will be available to use an one of the power sources. Thus, the renewable energy power share of 8% of total power generation is not an ambitious target.

4. A key policy to maintain oil supply security for Myanmar is to prepare strategic oil stockpiles to consist of national and private ones and to set private stockpiling as a higher priority than national ones. Mandatory private stockpiling such as 30 days is suggested under workable sub-decrees or regulations.

5. The biomass share per TPES of the BAU scenario will be 24% in 2040, on the other hand, the same share in the energy supply security scenario will be 30%, slightly higher than in the BAU scenario. The facilitation of a biomass supply chain and application of efficient types of biomass cooking stoves are recommended.

6. The share of domestic energy of the security scenario in 2040 will be about 49.7% and it will be the same as in the BAU scenario (49.9%). Looking at details, the major energy imports of the security scenario in 2040 will be oil and coal, on the other hand, in the BAU scenario it will be oil and LNG. In addition, the share of coal, hydropower, and biomass (they are classified to lower the energy price) per TPES in the security scenario will be 55% in 2040, on the other hand in the BAU scenario it will be 37%. Therefore, CO_2 emissions of the energy supply security scenario will be 20.6 million carbon-ton, a bit higher than the BAU scenario (19.8 million carbon-ton). As a result, the security scenario will clear two criteria: accessibility and affordability. For sustainability, the utilisation of domestic coal for power generation with a robust coal supply chain in Myanmar (increase of share of domestic energy) and the deployment of hybrid power systems (combined hydropower and solar PV generation [reduction of CO_2]) will contribute to maintain the sustainability.

7. An energy efficiency and conservation policy is indispensable for Myanmar to curb energy consumption, especially fossil fuel consumption. The promotion of energy efficiency and conservation to be applied across the final consumption sectors should contribute to energy supply security in Myanmar through saving oil and electricity consumption.

This report presents an energy supply security scenario for Myanmar, but this scenario will be influenced by the social and economic situation of Myanmar and the world. Therefore, updating the scenario periodically like a rolling plan is recommended.

Chapter 1

Current Energy Security Situation

Myanmar is a country in Southeast Asia endowed with rich natural resources such as crude oil, natural gas, hydropower, biomass, and coal. Myanmar's proven energy reserves in 2017 comprised 105 million barrels of oil, 6.58 trillion cubic feet of gas, and 542.56 million metric tons of coal. The country also has a large potential in developing its renewable energy sources, which are wind, solar, geothermal, bioethanol, biodiesel, and biogas.

Myanmar exports substantial amounts of natural gas and coal to Thailand and other neighbouring countries. Although Myanmar is a net exporting country, it imports around 90% of its total oil requirements.

As a developing country in the Association of Southeast Asian Nations (ASEAN) Myanmar's gross domestic product (GDP) has grown by an average of 7.0% per year since 2010. The industry and service sector were the main contributor for this growth, whilst the agricultural sector has experienced a declining share during the same period.

Myanmar's population experienced average annual growth of 0.8% over the 2010–2017 period. Most of the population is in the rural areas (around 69%), with average growth of 0.5% per year, slower than growth in the urban areas (1.5% per year).

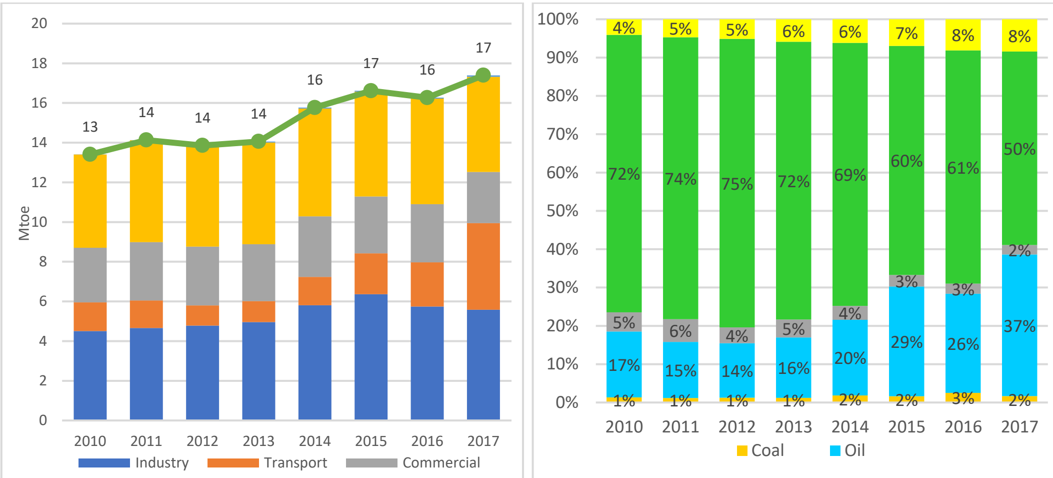
1.1. Final Energy Consumption

Based on the Myanmar Energy Balance Tables 2010–2017, total final energy consumption (TFEC) grew from around 13 million tons of oil equivalent (Mtoe) in 2010 to 17 Mtoe in 2017, at an average rate of 3.8% per year. Biomass is still the dominant fuel consumed in Myanmar, but with a declining share, from 72.4% in 2010 to 50.5% in 2017. Increasing household use of liquefied petroleum gas (LPG) or electricity for cooking, as well as increased use of more efficient biomass stoves, especially in the rural areas contributed to the reduction of biomass consumption in the country. Although other fuels have a smaller share in TFEC, both petroleum products and electricity experienced rapid growth over the 2010–2017 period. The average annual growth rate of petroleum product consumption was 15.8% per year, whilst for electricity, the growth was slightly slower at 15.2% per year. Coal consumption was also increasing at an average rate of 6.9% per year over the same period.

The main contributor of the rapid growth in petroleum product consumption is the increasing number of motor vehicles in road transport. As a result, the transport sector experienced the fastest growth compared to industry or the other sectors. The average annual growth of the transport sector of TFEC was 17.2% per year over the 2010–2017 period with gasoline and diesel consumption growing at 27% and 14% per year, respectively. Between 2016 and 2017, the total number of vehicles increased at an average of 8.2%[1] and total fuel consumption increased almost twofold. The rapid increase of the transport sector consumption contributed to the large increase of oil consumption from 2016 to 2017.

The industry sector, having the largest share in TFEC (32% in 2017), grew only by 3.1% per year over the same period. The residential sector consumption, accounting for 28% of TFEC in 2017, grew by 0.3% per year whilst the commercial sector consumption with 15% share in the 2017 TFEC, decreased at an average rate of 0.9% per year. Figure 1.1 shows the TFEC of Myanmar by sector and by fuel type.

Figure 1.1: Final Energy Consumption



Mtoe = million tons of oil equivalent.
Source: Myanmar Energy Balance Tables 2010–2017.

1.2. Power Generation

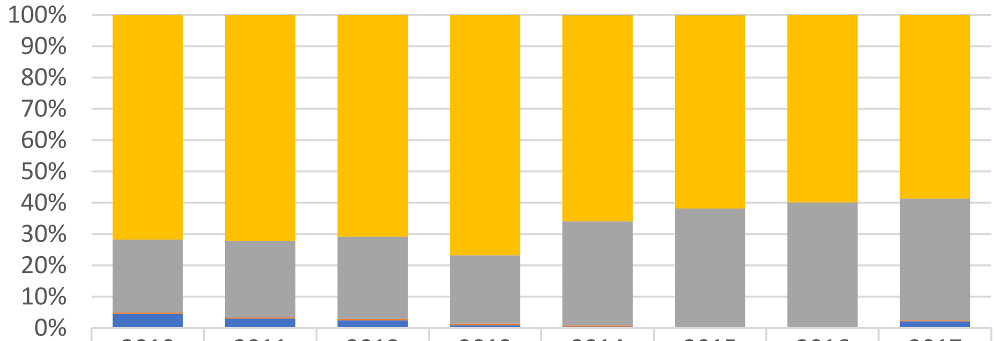
Myanmar's electricity demand was 17 terawatt hours (TWh) in 2017, almost threefold the demand in 2010. Around 50% of the total, was consumption in the residential sector, followed by the industry and commercial sectors, at 31% and 19%, respectively. Beside the domestic demand, Myanmar exports electricity to China in cross-border areas without national grid connection.

Total power generated in 2017 was 21 TWh with natural gas and hydro as the main power sources of the country. Hydropower had the biggest share in total generation (67%) followed by natural gas (31%). The remaining shares were that of coal, oil, and solar sources. Although natural gas has a lower share than hydropower in the country's power generation mix, generation from gas plants grew faster at 22.5% per year over the 2010–2017 period. Hydropower generation grew at 10.7% per year, lower than the total annual

[1] Myanmar Statistical Information Service. Registered Motor Vehicles by Type in Yangon and Other Areas 2010–2017.

growth rate of 13.9%, resulting in a declining share in total generation mix of the country. Figure 1.2 shows the power generation mix of Myanmar since 2010.

Figure 1.2: Fuel Share in Power Generation Mix



	2010	2011	2012	2013	2014	2015	2016	2017
Solar	0,00%	0,04%	0,04%	0,03%	0,1%	0,1%	0,05%	0,04%
Hydro	71,8%	72,2%	70,8%	76,7%	65,8%	61,8%	59,9%	58,6%
Natural gas	23,3%	24,5%	26,3%	21,9%	33,2%	37,8%	39,7%	38,9%
Oil	0,4%	0,4%	0,5%	0,4%	0,4%	0,3%	0,3%	0,3%
Coal	4,5%	3,0%	2,4%	0,9%	0,4%	0,00%	0,05%	2,1%

Source: Myanmar Energy Balance Tables 2010–2017.

Hydropower plants total installed capacity is around 3255 megawatts (MW), whilst the potential is more than 100 gigawatts (GW). Gas-based power generation installed capacity reached 2175 MW, whilst coal-based power generation remains at 120 MW and diesel plants 92 MW (Zaw, 2019).

The reliance on hydropower created a vulnerability of supply caused by seasonal changes, creating frequent power shortages during the dry season. The government plans to increase the role of natural gas in the future power generation mix. In the case of coal, public opposition has delayed the construction of additional coal-fired power plants. The increasing use of solar energy to complement hydropower generation will further secure the country’s supply mix as well as addressing short-term needs during the dry season.

In the past, the implementation of solar home system rooftop types as part of the rural electrification programme has made these technologies more common in Myanmar. Solar rooftop facilities in factories and large buildings also increase the use of solar energy in Myanmar, but most of these are off-grid area connections. One utility-scale solar PV project of 50 MW capacity was recently connected to the national grid.

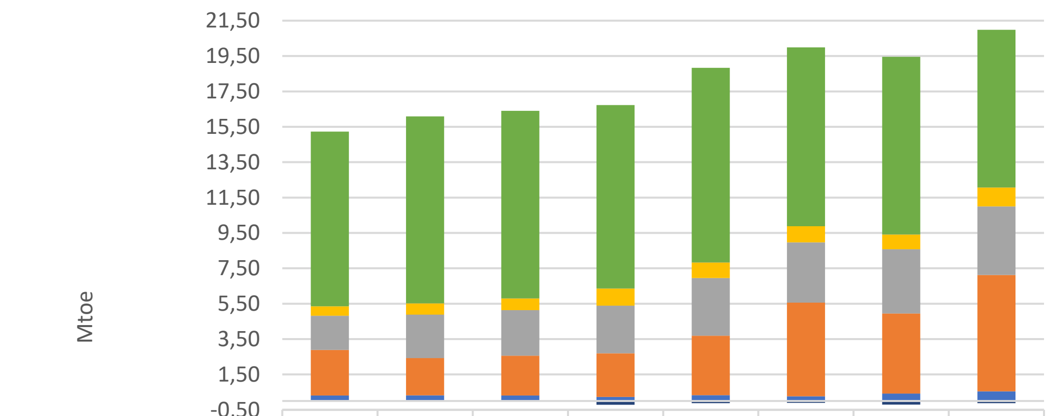
The estimated technical potential of solar energy in Myanmar can reach 118.2 TWh/year, one of the largest in the Southeast Asian region. About 60% of the country is suitable for solar PV generation particularly in the central dry zone where it is a flat plain area composed of infertile soil (Del Barrio-Alvarez and Sugiyama, 2020).

Wind energy can be another fuel mix option for power generation. The technical potential is much lower than solar energy, at around 365 TWh per year (Htet, 2019). Two feasibility studies have been completed for wind power projects in Myanmar – the 30 MW Chaung Tha project in the Ayeyarwady region and the 163 MW Phase-1 Magway region project.

1.3. Primary Energy Supply

The total primary energy supply (TPES) of Myanmar in 2017 reached almost 21 Mtoe, which was 1.4 times higher than 2010 (Figure 1.3). On average, the growth rate of TPES over the 2010–2017 period was around 4.6% per year.

Figure 1.3: Primary Energy Supply



	2010	2011	2012	2013	2014	2015	2016	2017
Electricity	0,00	0,00	0,00	-0,22	-0,13	-0,11	-0,20	-0,12
Biomass	9,87	10,56	10,60	10,37	11,00	10,12	10,04	8,91
Geothermal, Solar etc.	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Hydro	0,53	0,65	0,67	0,97	0,89	0,91	0,84	1,08
Gas	1,93	2,46	2,58	2,69	3,25	3,40	3,63	3,88
Oil	2,57	2,10	2,25	2,47	3,37	5,29	4,53	6,58
Coal	0,31	0,32	0,31	0,23	0,33	0,27	0,41	0,54

Source: Myanmar Energy Balance Tables 2010–2017.

The majority of the supply in Myanmar was still biomass but the share decreased from 65% in 2010 to 43% in 2017 as more households move to LPG, electricity, and efficient biomass stoves that are available in the market. Biomass supply slowed at an average rate 1.5% per year; from 10 Mtoe in 2010 to 9 Mtoe in 2017.

Oil supply grew faster than biomass and the other fuels, increasing its share from 17% in 2010 to 32% in 2017. The main contributors of the rapid growth of oil supply is the consumption of the transport sector, particularly road transport. In addition, increasing industrial heating demand and increasing LPG consumed by the residential and commercial sectors also contribute to the rapid growth in oil supply.

Natural gas supply also experienced rapid growth from around 2 Mtoe to almost 4 Mtoe in 2017. This was mainly due to the increased operation of gas turbine plants to meet the immediate shortfall in power generation. Increased demand from coal-fired power plants also contributed to the increase of coal supply but not as fast as natural gas. The average annual growth rate of coal supply between 2010 and 2017 was 8% per year, whilst natural gas was 10.5% per year.

Hydropower supply increased slightly faster than natural gas supply, at an average rate of 10.7% per year. Hydropower was still the major source of Myanmar's power generation mix. Beside hydro, the other renewable share, which is solar PV, is also growing fast, especially to support the rural electrification programme. The share in TPES of solar PV is negligible (0.004%).

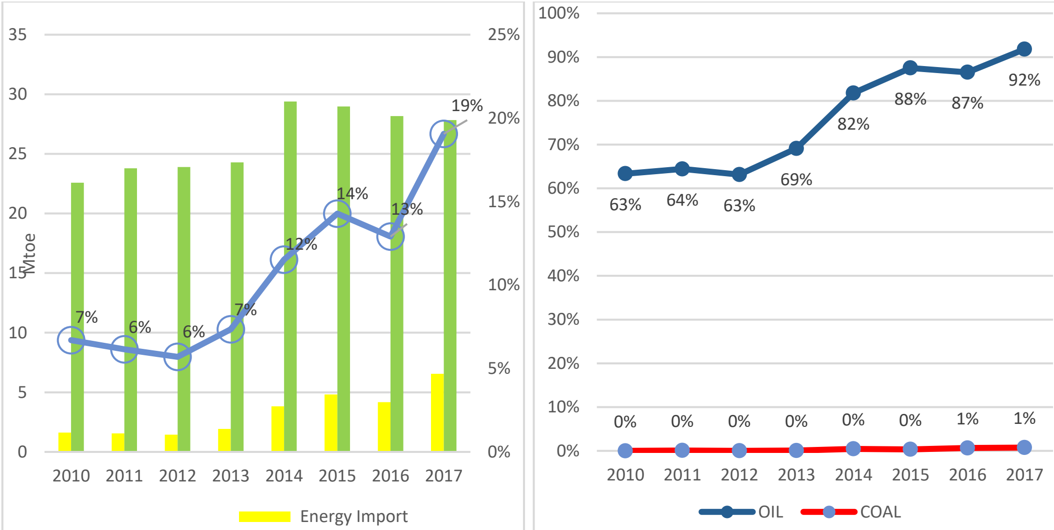
Since 2013, Myanmar has been exporting electricity to China. This occurred only as cross-border exports in areas without connection to the grid. The share in TPES is around 1% over the 2013–2017 period, and the electricity comes from hydropower plants.

1.4. Energy Security Indicator

Reliance on overseas energy sources is a major concern for energy security. Energy import dependency is the extent to which a country relies on imported fuels to meet the demand. The import dependency ratio (Figure 1.4) is measured as the ratio between the total energy import and the total energy supply defined as production plus import. Total import increased fourfold between 2010 and 2017 to meet the increasing oil demand. Coal has also been imported since 2011, but the share in total imports was only 4%, whilst the majority was oil imports. Total production also increased, but more slowly. By 2017, the total production was only 1.2 times higher than in 2010. The majority of the production is natural gas (61% of total production) and biomass. Oil and coal production combined was only around 3% in 2017. The resulting import dependency increased gradually from 7% in 2010 to 19% in 2017.

By fuel type, oil import dependency was already 98% in 2017, whilst in 2010 it was 63%. Coal import dependency, on the other hand was only 1% in 2017 indicating most of the increase in coal demand can still be met from domestic coal. Similarly, increased use of natural gas for power generation in 2017 has not triggered imports of natural gas since the domestic production is still sufficient to meet not only exports but also domestic demand. Figure 1.4 shows the import dependency of Myanmar in terms of total and by fuel type.

Figure 1.4: Import Dependency Ratio



Mtoe = million tons of oil equivalent.
Source: Myanmar Energy Balance Tables 2010–2017.

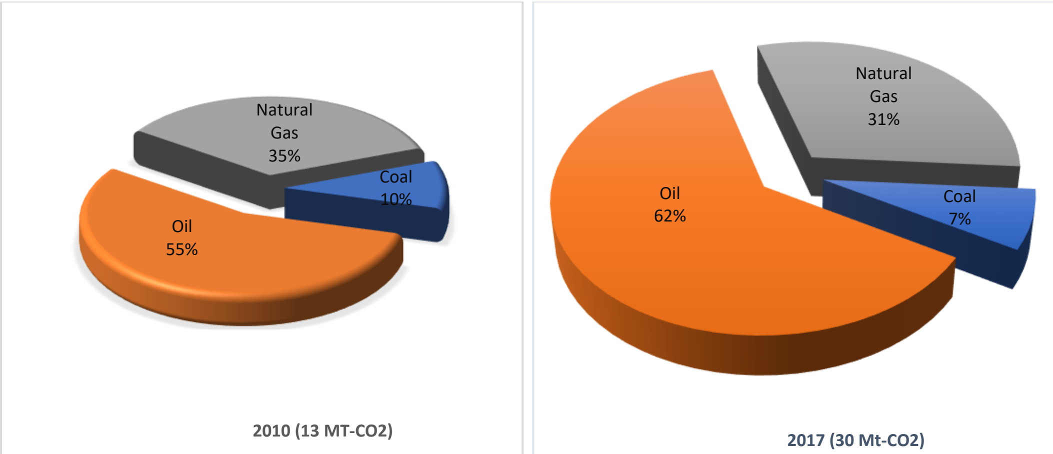
Due to continuously stable economic growth in Myanmar, which is realised by aggressive foreign investment in the country, oil and electricity demand will increase in the future. In addition, natural gas production shall decline year by year according to the report of the Natural Gas Master Plan for Myanmar (ERIA, 2018) if new gas fields are not discovered in Myanmar. So far the energy supply security level of Myanmar has not been serious, but in future due to the two reasons mentioned above, the energy supply security level of Myanmar will be vulnerable. Thus, energy policies to utilise domestic energy supplies, which are coal, hydropower, and biomass are crucial.

1.5. CO_2 Emissions

Myanmar's CO_2 emissions have been increasing at an average rate of 13% per year from 2010 to 2017. The total amount of CO_2 emissions in 2017 was 8 million ton-C (in terms of carbon content) or around 30 million ton-CO_2 (Figure 1.5). Combustion from oil fuels constitute the main source of the CO_2 emissions (32%), whilst natural gas and coal make up the remaining shares. Compared to 2010, the share from oil in 2017 is higher, whilst for coal and natural gas, the share in 2017 is lower than 2010. This was due to the faster growth of oil supply compared to coal and natural gas.

CO_2 emissions are a component being considered when discussing the future energy supply security of Myanmar. This study seeks the best energy mix to maintain not only the energy supply security level of Myanmar but also the CO_2 emissions level in the future.

Figure 1.1: CO_2 Emissions by Fuel Type



Source: Myanmar Energy Balance Tables 2010–2017.

Chapter 2
Supply Issues of Each Energy Source

Myanmar has a great potential to develop hydropower. In addition, it produces fossil fuels. The country is particularly rich in natural gas, exporting it to Thailand and China, whilst consuming it domestically. There is also a possibility to develop renewable energy resources, centred around solar PV.

On the other hand, both oil and natural gas production have been showing a downwards trend. The increasing import to offset the declining production may pose a risk to the energy security of the country. Further, existing plans to develop hydropower and coal-fired power plants may not be carried out as expected because of ongoing campaigns against their development. Cognisant of these, this section will present the situation of primary energy supply systems in the country and identify associated risks and challenges, for which potential economic impacts were estimated under two assumptions: international energy prices and the levelised cost of electricity (LCOE) in Myanmar (Table 2.1).

This revealed that the magnitude of the economic side effect of policy failure is large in an underdevelopment of hydropower and an overdevelopment of renewable energy, followed by an underdevelopment of natural gas. It suggests the government should place high priority on addressing issues related to these systems.

Table 2.1: Energy Supply Risks and its Economic Impact

	Risk	Magnitude of Economic Impact [US$ million/year]
Natural gas	Less than anticipated gas production	75–112
Oil	Less than anticipated crude oil production and/or refinery rehabilitation	4–12
Coal	Less than anticipated coal production	55
Hydropower	Less than anticipated hydropower development	91–321
Solar PV and wind power	More than anticipated development of expensive renewable energies	205–323

PV = photovoltaic.

Source: Authors.

2.1 Assumptions

To estimate the potential impacts of risks involved in primary energy supply systems, we consider costs incurred to generate electricity as well as market prices of energy source. First of all, before proceeding with estimation, we set international energy prices and the LCOE as follows.

2.1.1 International energy prices

Estimates appearing in the reference scenario of The Institute of Energy Economics, Japan Outlook 2020 (IEEJ, 2019) were adopted to set international energy prices (Table 2.2). The reference scenario assumes that oil prices will gradually rise in the medium and long run, whilst be increasingly more volatile in the short run. It projects an increase in demand for oil in response to the steady expansion of the global economy. On the supply side, it prospects continuous reliance on the Organization of Petroleum Exporting Countries (OPEC) and Russia, and an increase in marginal costs resulting from the shift of oil fields to ones with higher production costs. In regard to natural gas, such as liquefied natural gas (LNG), we adopted projected import prices of Japan, which has the biggest trading volume in the world. We assumed prices to increase to the same level as the current ones after temporarily decreasing from the 2018 level. Coal prices are assumed to rise in the long run, reflecting an upward trend in coal demand, primarily for power generation in Asia, as well as rallies from previous lows.

Table 2.2: Assumption of International Energy Prices

		2018	2030	2040
Crude oil	\$2018/bbl	71	95	115
Natural gas	\$2018/MMBtu	10.1	9.5	9.7
Thermal coal	\$2018/ton	118	110	120

Note: Applied linear interpolation for mid-years.
bbl = barrel (unit); MMBtu = million British thermal units.
Source: IEEJ Outlook (2020).

2.1.2 Levelised Cost of Electricity in Myanmar

The LCOE is the cost per unit of electricity generated and the following equation is applied for the calculation.

$$\frac{\sum_{t=1}^{n} \frac{I_t + M_t + F_t}{(1+r)^t}}{\sum_{t=1}^{n} \frac{E_t}{(1+r)^t}}$$

Where,

LCOE = the average lifetime LCOE generation

I_t = investment costs in the year t (including financing)

M_t = operations and maintenance costs in the year t

F_t = fuel expenditures in the year t

E_t = electricity generation in the year t

r = discount rate

n = economic life of the system.

However, given that the level of electricity transmission and distribution losses is still high in Myanmar, we considered 12% of the losses to calculate the amount of generated electricity in the denominator. Costs to reduce CO_2 emissions or any social costs are not taken into account in the LCOE calculation of this study.

a) Data sources

Three resources were primarily referred for relevant data. If data were not available because of limited use of particular energy sources in Myanmar, we used the data of other ASEAN members states instead.

Hydropower Gas power plant	Intelligent Energy System, Myanmar Energy Master Plan, December (Government of Myanmar, 2015)
Coal-fired power plant	Study on the Strategic Usage of Coal in the EAS Region: A Technical Potential Map and Update of the First Year Study*, September (ERIA, 2015)
Wind power plant Solar PV power plant	Levelised Costs of Electricity for Selected Renewable Energy Technologies in the ASEAN Member States II**, February (ACE, 2019)

* Data of Indonesia, ** Data of average of ASEAN Member States.

b) Preconditions of calculation

This report undertakes the LCOE calculation with the objective to assess risks involved in respective primary energy supply systems, which could compromise the energy security of the country by 2040. In light of this, the LCOE was calculated targeting highly-efficient thermal power plants (ultra-super critical [USC]and combined cycle gas turbine technology [CCGT]), which are expected to be introduced in the country in the future, and solar and wind power plants in ASEAN Member States where solar and wind power generation have been widely practiced.

- Capacity of model plants

  Values in the sources were adopted without any modification. When values in the sources vary, specific values were arbitrarily adopted within their range.

- Capacity factors

  The capacity factor of thermal power plants was set at 80% on the assumption that they would be a base load power source, whilst that of hydropower plants was set at 50%, in reference to the data provided by the Ministry of Energy and Mine (MOEE), and those of solar and wind power plants were 16% and 22% respectively, based on ASEAN Centre for Energy reports.

- Lifetime of plants

  The average lifetime of power plants using respective power generation technology was used.

- Investment costs and/or operations and maintenance costs

  In principle, values in the sources were adopted without any modification. However, concerning coal-fired power plants for which Indonesian data were used, the value was modified to 70% of those of Indonesia, considering the differences in purchasing power parity and labour costs between Indonesia and Myanmar. In addition, concerning solar PV and wind power plants for which ASEAN Member States' data were used, the lowest level investment costs in ASEAN Member States were adopted, considering the high potential for solar PV and wind power plants and low labour cost in Myanmar.

- Fuel costs

  Table 2.3 lists the assumptions of the fuel price.

Table 2.3: Assumption of Fuel Price

Fuel	Price	Note
Coal – domestic	$50/ton	Average price of Kalewa mine $58–73/ton (MEMP) Heat value = 5,200kcal/kg (MEMP)
Coal – import	$118/ton	International energy prices in 2018 (IEEJ Outlook, 2020) Heat value = 5,500kcal/kg (MEMP)
Natural gas – domestic	$10/MMBtu	Assume from the data provided by MOEE (Dec. 2019)
Natural gas – import	$11/MMBtu	Sum of $10/MMBtu cif price (IEEJ Outlook 2020) and $1/MMBtu of regasification cost (JOGMEC, Oct 2017)

cif = cost, insurance, and freight, kcal = kilocalorie, kg = kilogramme, MEMP = Myanmar Energy Master Plan , MMBtu = million British thermal unit.

Source: IEEJ.

- Discount rate

  10%, the Central Bank rate, was adopted in reference to the Myanmar Statistical Yearbook, 2018.

  The estimated LCOE for different power sources are listed in Table 2.4.

Table 2.4: Estimated LCOE for Different Power Sources

	Hydro	Coal domestic	Coal import	Gas domestic	Gas import	Solar PV	Wind
LCOE (kyat/kWh)	$0.047 (68)	$0.05 (72)	$0.076 (108)	$0.089 (127)	$0.096 (137)	$0.140 (201)	$0.158 (226)
Technology	—	USC	USC	CCGT	CCGT	—	—
Capacity (MW)	300	1,000	1,000	650	650	2	20
Capacity factor	50%	80%	80%	80%	80%	16%	22%
Thermal efficiency	—	45%	45%	55%	55%	—	—
Lifetime (year)	80	40	40	30	30	25	25
CAPEX (US$/kW)	1,700	1,323	1,323	918	918	1,500	2,321
OPEX (US$/MWh)	5.7	24.18	24.18	6.19	6.19	2.1	1.57

* US$1=MK1,429.81（period average of 2018).

CAPEX = capital expenditure, CCGT = combined cycle gas turbine, kW -= kilowatt, KWh = kilowatt hour, LCOE = levelised cost of electricity, MW = megawatt, MWh = megawatt hour, OPEX = operating expense, PV = photovoltaic, USC = ultra-super critical.

Source: World Bank, Official exchange rate – Myanmar.

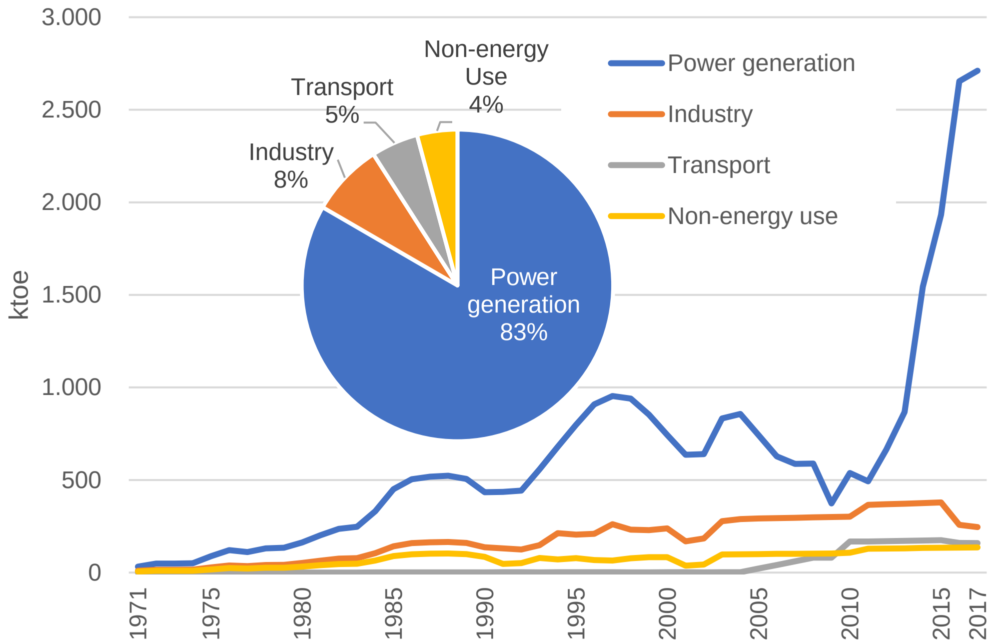
c) LCOE in risk scenario by 2040

The current LCOE was computed and applied for the period between 2018 and 2040. It is unlikely that the LCOE of hydropower generation will significantly decrease as the technology has already matured. Highly efficient thermal power plants (USC and CCGT), LCOE of which was calculated in this study, is yet to be widely adopted in Southeast Asia. However, the introduction of plants will likely be promoted by 2040. Therefore, it was considered appropriate to use the same LCOE throughout by 2040. A few large-scale power plants using renewable energy sources are currently in operation in the country. It is uncertain at this moment that technological progress will lead to cost reduction. Further, the amount of electricity generated from these sources will be likely limited in 2040. Thus, it was considered appropriate to apply the same LCOE throughout by 2040.

2.2 Natural Gas

In Myanmar, demand for natural gas for power generation has been rapidly rising as electricity demand increases. As a result, 83% of natural gas consumed in 2017 was used to generate electricity (Figure 2.1). The country produces natural gas, and gas thermal plants can be constructed within a relatively short time, leading to the increased demand for natural gas.

Figure 2.1: Natural Gas Demand by Sector

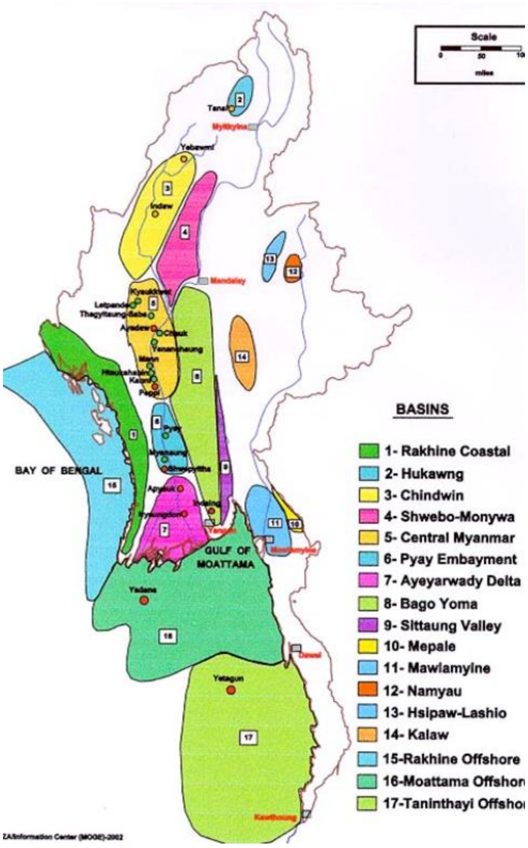


ktoe = kiloton of oil equivalent.
Source: IEA, World Energy Balance Table 2019.

2.2.1 Reserves

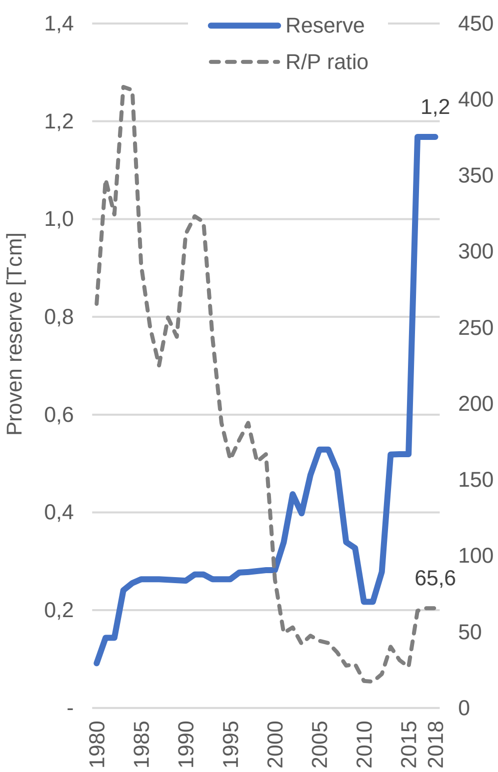
Proven reserves of natural gas in the country have almost doubled in the last several years because of the successful development of the Zawtika and Shwe gas fields since the 2010s (Figure 2.2). A reserves-to-production ratio (R/P ratio) demonstrated a downward trend as the result of increased consumption. However, it stopped falling with the increase in proven reserves. The recovery of the R/P ratio is modest because of the significant increase in consumption (Figure 2.3).

Figure 2.2: Oil and Natural Gas Basins



Source: Myanmar Oil and Gas Enterprise, Jul 2011.

Figure 2.3: Proven Reserves and R/P Ratio



R/P = reserves to production, Tcm = trillion cubic metre.

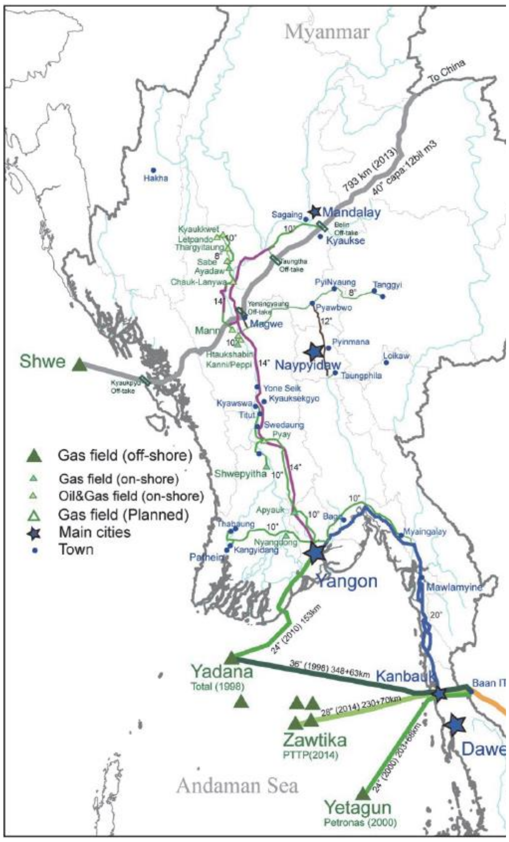
Source: BP (2019), Statistical Review of World Energy, June.

2.2.2 Production

Major gas fields are located offshore (Figure 2.4). The production of major gas fields, except the Shwe gas field, has been declining or is projected to start declining in the near future. It is also expected that the production of the Shwe gas field will start to decrease before 2030. The anticipated rapid decrease in natural gas production in the future has prompted the development of additional production wells.

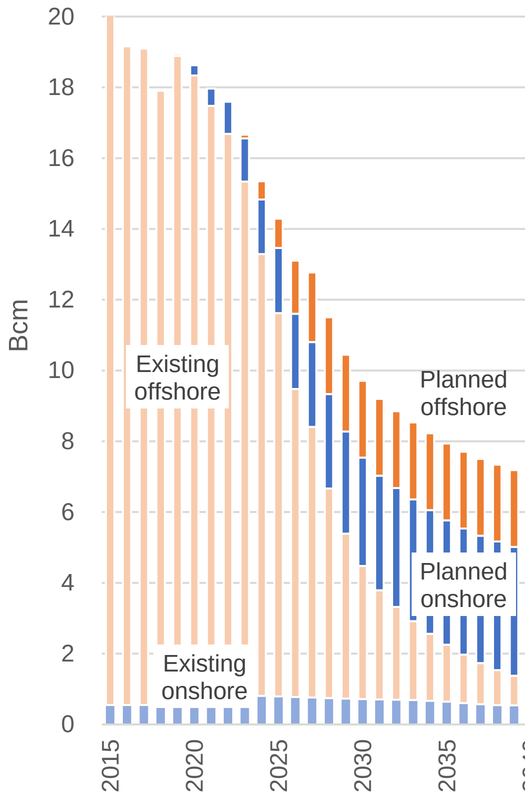
The offshore M3 and A6 blocks are under development, and their commercial production is expected to start in 2023 and 2025, respectively. The development of additional onshore blocks is also anticipated. However, the production of these additional blocks will be insufficient to offset the decrease in the existing fields. The declining trend in the overall production is, therefore, likely to continue (Figure 2.5).

Figure 2.4: Location of Gas Production Fields



Source: METI (2016), Survey of Natural Gas Use in Myanmar, February.

Figure 2.5: History and Prospect of Natural Gas Production



Bcm = billion cubic metre.

Source: Update from ERIA (2019), Natural Gas Master Plan for Myanmar, January.

2.2.3 Exports

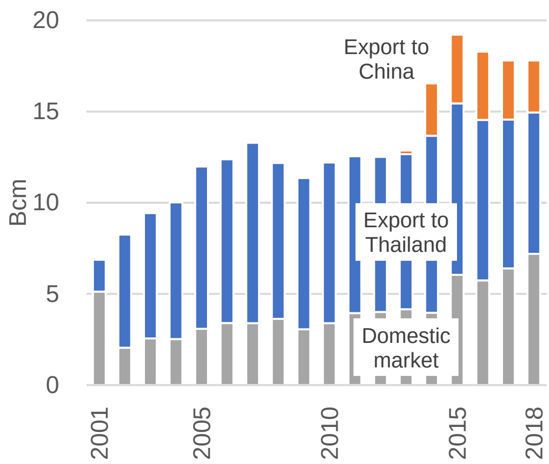
Myanmar signed a contract with Thailand for natural gas exports before consumption in the country started to increase. In the 2010s, it concluded export contracts with China and Thailand (Figures 2.6 and 2.7). Whilst they have benefitted the Myanmar economy in terms of foreign exchange earnings, they could pose a risk to the energy security of the country, given the rapidly increasing demand for natural gas and the expected decrease in domestic production.

Figure 2.6: Committed Gas Exports

	Yadana	Yatagun	Shwe	Zawtika
To	Thailand	Thailand	China	Thailand
Volume Mcm/yr	14.9-16.0	5.66-11.3	11.3	6.80
Start year	1998	2000	2013	2014

Mcm= million cubic metre.
Source: JOGMEC (2018), Natural Gas Upstream Investment in Myanmar, July.

Figure 2.7: Trajectory of Gas Supply Structure



Bcm = billion cubic metre.
Source: Update from ERIA (2019), Natural Gas Master Plan for Myanmar, January.

2.2.4 Prices

In Myanmar, most of the natural gas is produced at offshore gas fields. The gas is produced at offshore platforms and transported to demand centres or export destinations via pipelines. Therefore, the natural gas wholesale price can be estimated by well-head price and transportation price. Although the data are limited, we can assume that the wholesale natural gas price ranges from US$10/million British thermal units (MMBtu) to US$12.5/MMBtu (Table 2.5).

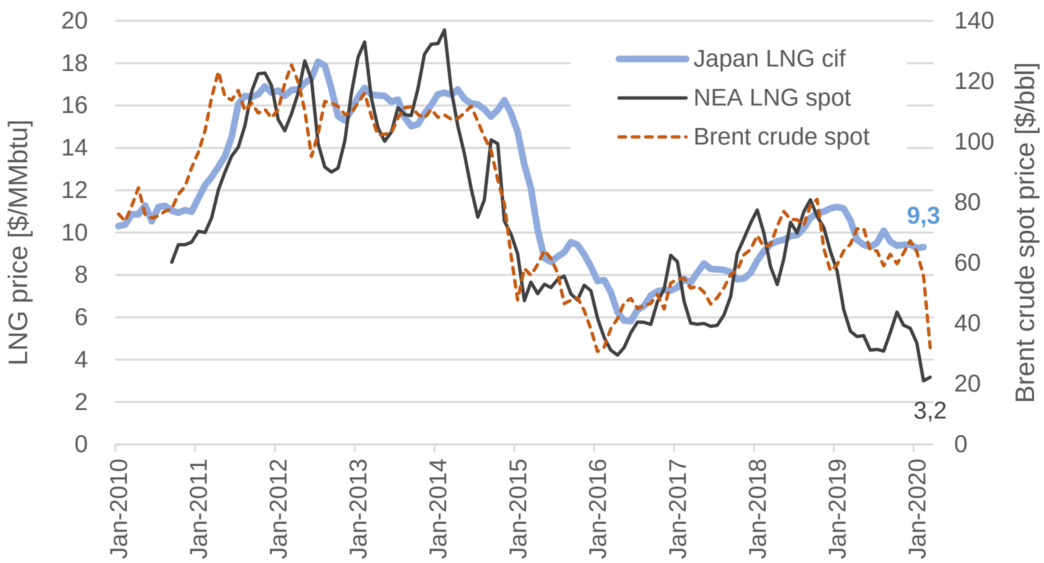
Table 2.5: Price of Domestic Natural Gas from Offshore Fields (US$/MMBtu)

Gas field	Wellhead price	Transportation price	Estimated minimum wholesale price
Yadana	8.9618	3.4773	12.4391
Yatagun	8.9618	No data available	(8.9618)
Shwe	7.4571	No data available	(7.4571)
Zawtika	8.9618	3.5847	12.5465

MMBtu = million British thermal unit.
Source: Ministry of Energy and Electricity, December 2019.

LNG prices in Asia remain low for both term and spot contracts as the result of the decreased oil prices for the former and the loosened supply–demand balance of LNG for the latter. Especially, spot prices significantly declined to below US$5/MMBtu in March 2020. Even a term-contract price, US$9.3/MMBtu, could be fairly competitive with the wholesale price of natural gas produced in Myanmar (Figure 2.8).

Figure 2.8: LNG Price in Asian Market



bbl = barrel, LNG = liquefied natural gas, MMbtu = million British thermal units, NEA = Northeast Asia.
Source: IEEJ; Data bank, World Gas Intelligence, Energy Information Administration.

2.2.5 Risk scenario

A risk involved in the natural gas supply system in Myanmar is that actual production in the country fails to meet the projections. In such case, to fill the gap would require gas imports. It could entail various risks on Myanmar's supply system, reflecting changing international situations, such as the suspension of exports in gas-producing countries resulting from accidents, and the increase in import prices as the result of the tightening supply–demand balance.

As discussed above, the country plans to increase its natural gas production by the development of onshore and offshore blocks. Here, the extent of economic impact is assessed on the assumption that the production of new gas fields is lower than projected.

Based on the following two scenarios, additional costs are calculated, given that the anticipated risk (lower gas production) occurs. Additional cost is considered equivalent to differences between LNG import prices and domestic gas wholesale prices. LNG price is assumed as US$10/MMBtu. It is assumed that a floating storage regasification unit, which requires a relatively small initial investment, is used as a regasification facility, and the cost is US$1/MMBtu.[2]

[2] JOGMEC, the expansion of LNG markets with the increase in the number of floating facilities (FSRU/FLNG). 19 October 2017. FSRU = floating storage and regasification unit. FLNG = floating liquified natural gas.

Assumed scenario

Reference	Achieve additional production as planned
Risk Scenario (Low gas production)	Achieve 50% or 70% less production than planned in new blocks

Formula

Additional cost

$= \sum_{year} Gas\ amount\ at\ rik\ \times\ (LNG\ price + Regas\ cost\ -\ wholesale\ price)$

Below are the outcomes. If the actual production from new blocks are half of what was projected, additional costs required to import LNG would be US$75 million per annum. If the actual production is 75% less than the projections, the country would be required to bear more additional cost, which is $112 million (Table 2.6).

These figures could be regarded as maximum amounts that can be rationally invested to attain the planned production. For instance, let us assume that the introduction of certain technology will help the country to produce natural gas as planned. If an annual cost incurred with the introduction of such technology is $75 million or less, it will be strongly recommended to make this investment. In contrast, if it exceeds $112 million per annum, the importation of LNG will be a more economically rational option.

Table 2.6: Annual Average Additional Cost of LNG Imports

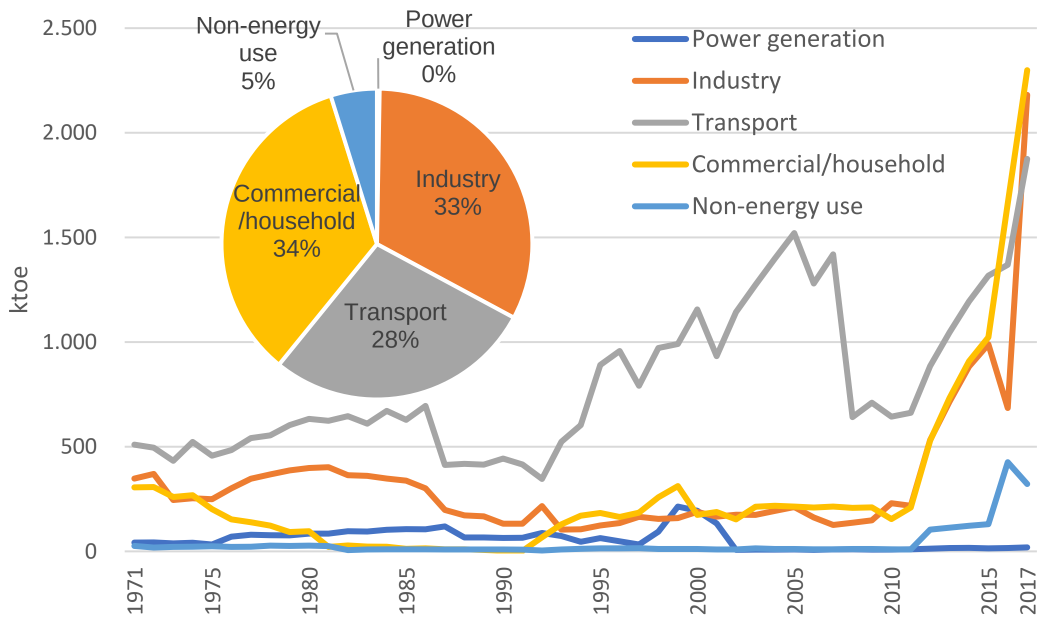
Scenario for domestic gas production from new blocks	Economic impact
50% less production than planned	$75 million/yr
75% less production than planned	$112 million/yr

Note: Calculation period from 2020 to 2040, Conversion factor 1 Bcm = 34.121 trillion Btu (BP, 2019).
Assume $10/MMBtu of domestic gas wholesale price and $10/MMBtu of LNG cif price.
Assume $1/MMBtu of regasification cost of floating storage regasification unit (JOGMEC, Oct. 2017).
Bcm = billion cubic metre, Btu = British thermal unit, cif = cost, freight, insurance, LNG = liquefied natural gas, MMBtu = million British thermal units.
Source: IEEJ.

2.3 Oil

As the country's economy grows, oil demand has been steadily increasing across all sectors except power generation and raw material use (Figure 2.9). Particularly, the significant increase has been observed since the 2010s, at an unprecedented rapid pace. Electricity and natural gas consumption likely grow further in the industrial and building sectors. On the other hand, it is probable that the transport sector will continuously rely on oil for the moment. Close attention should be given to the degree of demand increase.

Figure 2.9: Oil Demand by Sector



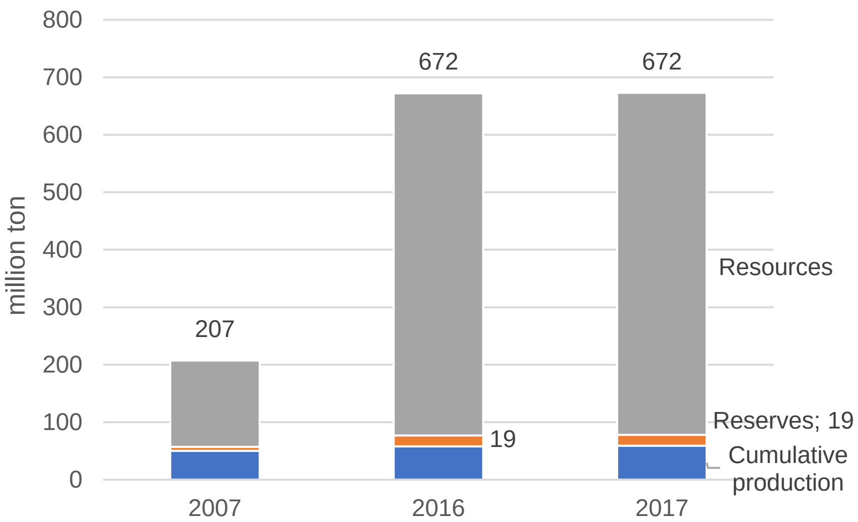
Ktoe = kiloton of oil equivalent.
Source: IEA (2019a), World Energy Balances 2019 extended edition database.

2.3.1 Reserves

As of 2017, the volume of oil resources in the country was estimated at 672 million tons (Figure 2.10). It is extremely large compared to the volume of oil supplied in the country (6.692 million tons), let alone the 2017 production (0.873 million tons). However, economically exploitable oil reserves are limited. The R/P ratio is for 21 years, equivalent to the volume of oil supplied in the country for only 2.8 years.

Although Myanmar could increase production in future, exploiting the abundant resources, it is still uncertain that the exploitation will be economically or technologically viable.

Figure 2.10: Crude Oil Resources and Reserves



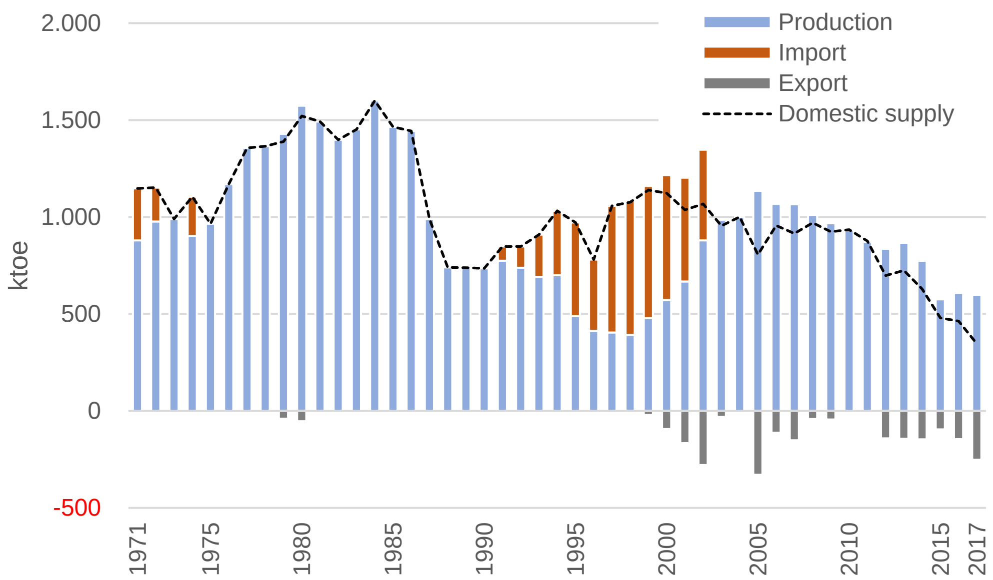
Notes: Resources = proven amounts of energy resources which cannot currently be exploited for technical and/or economic reasons, as well as unproven but geologically possible energy resources which may be exploitable in future.
Reserves = proven volumes of energy resources economically exploitable at today's prices and using today's technology.
Sources: BGR (2009, 2017, 2018).

2.3.2 Production

Oil production has been showing a downwards trend since 2005 (Figure 2.11). The rate of change from 2005 to 2017 was notable with the annual average of –5.2%. The government has made a series of efforts to increase the production, such as granting the concessions of blocks to foreign investors. As a result, there have been some signs of production recovery since 2015. However, it is hard to conclude at this moment that the production will make a full recovery.

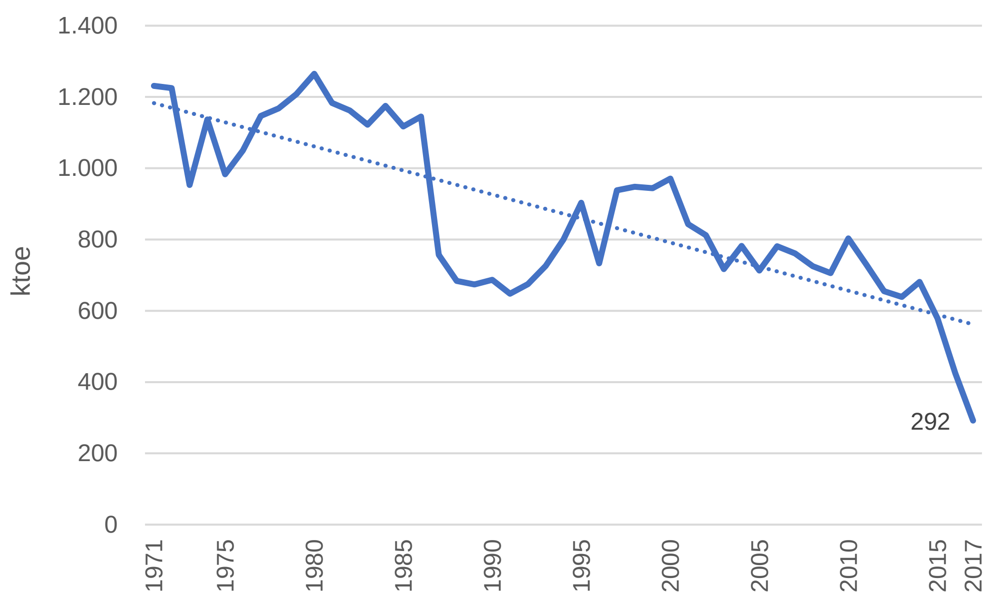
The volume of domestically produced oil products that is supplied in the country has been declining at a faster pace (Figure 2.12). As discussed below, the performance of refineries has been worsening. The breakdown of facilities, and lack of investment for an upgrade (domestic refineries cannot meet quality requirements for oil products) may compel domestic refineries to reduce the production. In turn, the country exports crude oil that they are not able to process domestically.

Figure 2.11: Crude Oil Supply Balance



ktoe = kiloton of oil equivalent.
Source: IEA (2019a), World Energy Balances 2019 extended edition database.

Figure 2.12: Oil Product Production from Refinery



Note: Sum of production from refinery, a transfer, and an industrial own use (negative value).
ktoe = kiloton of oil equivalent.
Source: IEA (2019a), World Energy Balances 2019 extended edition database.

2.3.3 Oil product supply

Myanmar has a total oil refining capacity of 51,000 barrels per day (b/d) across three refineries (Table 2.7) (MOEE, 2019a). However, aging facilities, the lack of proper maintenance, as well as the need for investment for an upgrade have adversely affected the performance of refineries, leading to decreased production. It has become more apparent since 2015. In contrast, oil demand increased significantly around the same time, resulting in the significant increase in the volume of imported petroleum products such as gasoline and diesel oil (Figures 2.13 and 2.14).

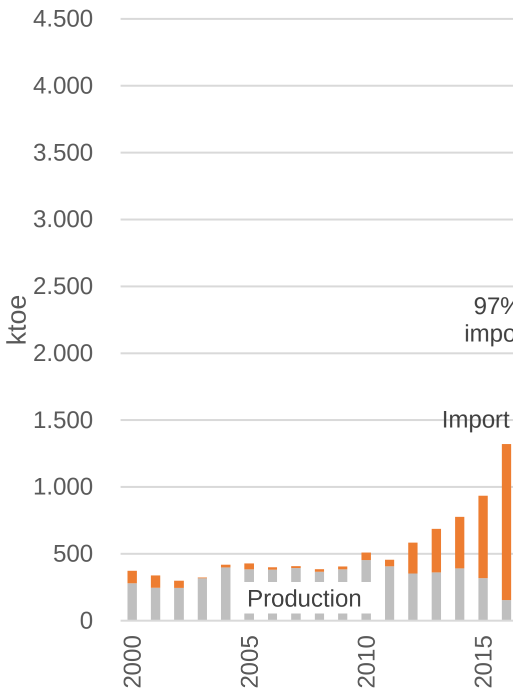
Currently, a plan to rehabilitate the existing Chauk refinery and to build new refineries with the total capacity of 470,000 b/d up to 2026 is under implementation. The existing old refineries, except Chauk, are scheduled to be closed with the completion of the new refinery. But we shall remind of the priority of planned projects that only a project at Thanlyin is placed as high priority. The new refinery will increase the volume of crude oil refined in the country, contributing to decreasing the volume of imported petroleum products. As a result, Myanmar will be able to reduce the reliance on imported oil.

Table 2.7 Existing and Planned Oil Refineries

	Name/location	Capacity	Note
Existing	Thanlyin	20,000 b/d	Commenced in 1963/1980
	Chauk	6,000 b/d	Commenced in 1954
	Thanbayakan	25,000 b/d	Commenced in 1982
Planned	KyaukPhyu, new	10 MMTPA (200,000 b/d)	To commence in 2020 Low priority
	Chauk, rehabilitation	6,000b/d	To commence in 2024 Low priority
	Thanlyin, new	10 MMTPA (200,000 b/d)	To commence in 2025 High priority
	Thanbayakan, new	3.5 MMTPA (70,000 b/d)	To commence in 2026 Low priority

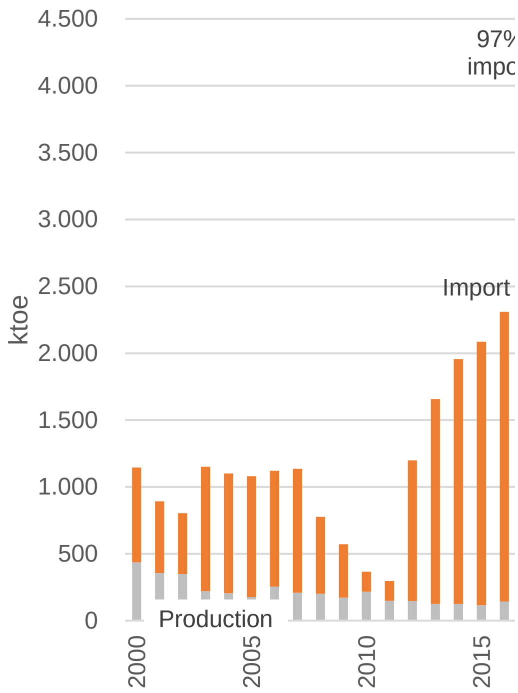
b/d = barrels per day, MMTPA = million metric ton per annum.
Sources: Existing: MOEE (2019a), Outlook for Myanmar Petrochemical Enterprise; Planned: Ministry of Energy and Electricity, April 2020.

Figure 2.13: Gasoline Supply



ktoe = kiloton of oil equivalent.
Source: IEA (2019c), World Energy Statistics.

Figure 2.14: Diesel Supply



ktoe = kiloton of oil equivalent.
Source: IEA (2019c), World Energy Statistics.

2.3.4. Risk scenario

In terms of Myanmar's oil supply system, the decreased volume of crude oil produced and refined in the country may pose a risk to the country's energy security. Having crude oil resources would be insufficient to ensure oil security unless it is accompanied with adequate capacity to produce a product. Myanmar currently imports 97% of oil products consumed in the country, indicating its vulnerability to outside factors.

As discussed above, the government has been making effort to increase crude oil production. Concurrently, the construction of a new refinery is underway to start operations in 2025. This section evaluates how the economy will be impacted by the success or failure of these endeavours.

There are two scenarios in relation to crude oil production to be considered: (i) oil production to decrease continuously at the current pace of –5% (annual average change rate [AACR]); and (ii) oil production to increase at AACR of 5% as the result of the successful development of new oil fields. The production in the new fields is assumed to start in 2025 or after.

With regard to refining capacity, there are also two scenarios to be considered: (i) production to decrease continuously at the current pace, AACR of –5%, and (ii) the new refinery at Thanlyin (200,000 b/d) to start operation in 2025 as scheduled.[3] In the latter, it is assumed that all existing refineries will be closed when the new refinery starts operation.

In accordance to the assumption above, a future supply–demand balance is estimated. Then, this estimate is multiplied by future crude oil and oil product prices, which are set separately below, in order to calculate costs to import crude oil and petroleum products. There are four scenarios in total. The scenario in which the increased crude oil production and the construction of the new refinery are both successfully achieved is considered as a base-case. Additional costs are calculated for the other scenarios, which will be incurred as the result of failed attempts to increase oil production or to complete the refinery.

Assumed scenario

	Crude oil production	Refinery capacity
1, Base case	Increase after 2025, AACR = 5%	New 200,000 b/d in 2025
2	Increase after 2025, AACR = 5%	Decline, AACR = –5%
3	Decrease, AACR = –5%	New 200,000 b/d in 2025
4	Decrease, AACR = –5%	Decline, AACR = –5%

Formula

Cumulative oil import cost = $\sum_{year}(Import\ amount\ \times Import\ price)$

Below are the outcomes. Given that crude oil production increases and the new refinery is completed, the cost to import oil will be $116 million annually (Table 2.8). If the country fails to increase oil production or to complete the new refinery, Myanmar would be required to pay from $4 million to $12 million in addition to the costs calculated above. However, the additional costs constitute only 4% to 10% of the cost of the base case, which is insignificant. The domestically produced crude oil accounted for 8% of the total oil demand in the country in 2018. Given their small proportion to the total demand, effects to reduce petroleum product import bills would be offset by increasing crude oil import bills. Nevertheless, higher self-sufficiency of petroleum products can bring a security benefit, as well as an economic ripple effect, to the country.

[3] According to demand outlook in the BAU scenario, 200,000 b/d (10 MMTPA) of refinery capacity can meet the oil demand up to around 2035.

Table 2.8: Oil Import Cost under the Different Scenarios

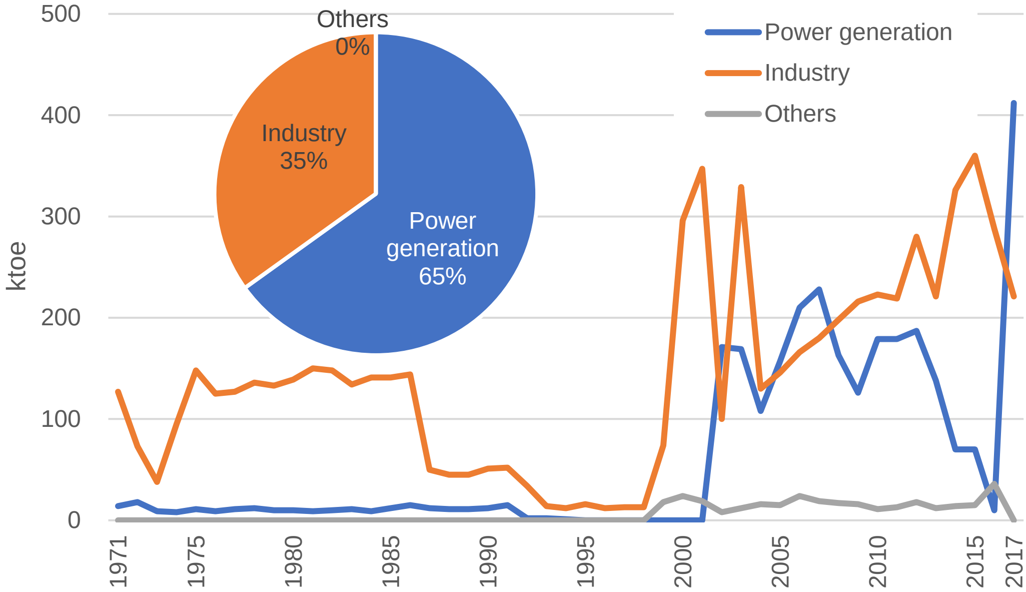
		Refinery capacity	
		Follow the degradation trend at AACR = –5%	Operate new refinery in 2025
Crude oil production	Follow the degradation trend at AACR = –5%	+ $11.9 million/yr from the base case	+ $4.3 million/yr from the base case
	Recover at AACR = 5% after 2025	+ $7.6 million/yr from the base case	Base case $116 million/yr

Notes: Calculation period from 2020 to 2040.
Refinery: A new refinery at Thanlyin (200,000 b/d or 10 MMTPA) will commence in 2025.
Assume no refinery gain. Apply conversion factor (from barrels to tonne) from BP 2019.
Assume 1.17 of price ratio of oil product basket against the Brent spot crude oil price.
AACR = annual average change rate, b/d = barrel per day, MMTPA = million metric ton per annum.
Source: IEEJ.

2.4 Coal

Coal demand in the country fluctuates widely every year (Figure 2.15). This may be attributable to the facts that there are only a small number of sectors having demand for coal and part of the consumption may not be well reflected in the statistical data. In recent years, coal consumption has been rapidly increasing in the power generation sector. It represented 65% of the total coal consumption in 2017. Coal demand of power plants is enormous compared to those of industrial sectors. Therefore, their future development must be given close attention for the projection of future coal demand.

Figure 2.15: Coal Demand by Sector



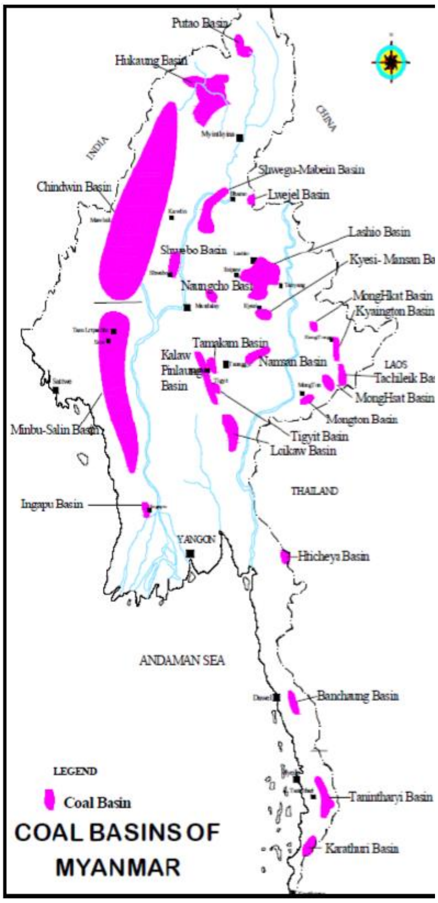
ktoe = kiloton of oil equivalent.
Source: IEA (2019a), World Energy Balances 2019.

2.4.1 *Reserves*

Coal reserves are estimated at 526 million tons.[4] However, in terms of probability, only 1% of the reserves are categorised into 1P (positive), the highest probability (Figures 2.16 and 2.17). Many reserves are categorised into 2P (provable), which constitutes approximately 50% of all reserves. In terms of grade, no bituminous coal, the highest-quality coal, is found in any reserves. Sub-bituminous coal accounts for 68% of the total deposits, constituting the largest proportion.

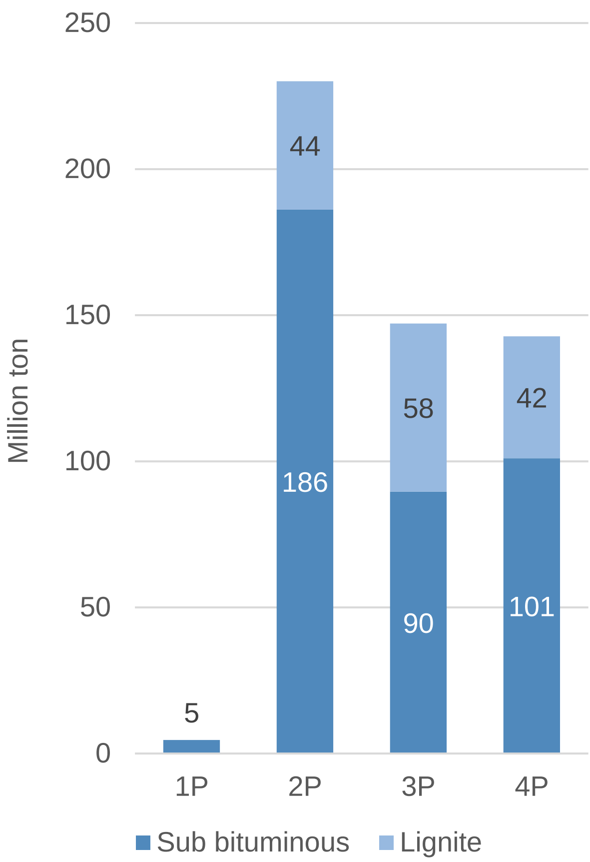
[4] Data provided by MOEE, December 2019.

Figure 2.16: Coal Basins



Source: Energy Master Plan, Dec. 2015 (Originally from the Department of Geological Survey and Mineral Exploration).

Figure 2.17: Coal Resources by Probability and Grade



1P = positive, 2P = provable, 3P = possible, 4P = potential.
Source: Data provided by MOEE, November 2019.

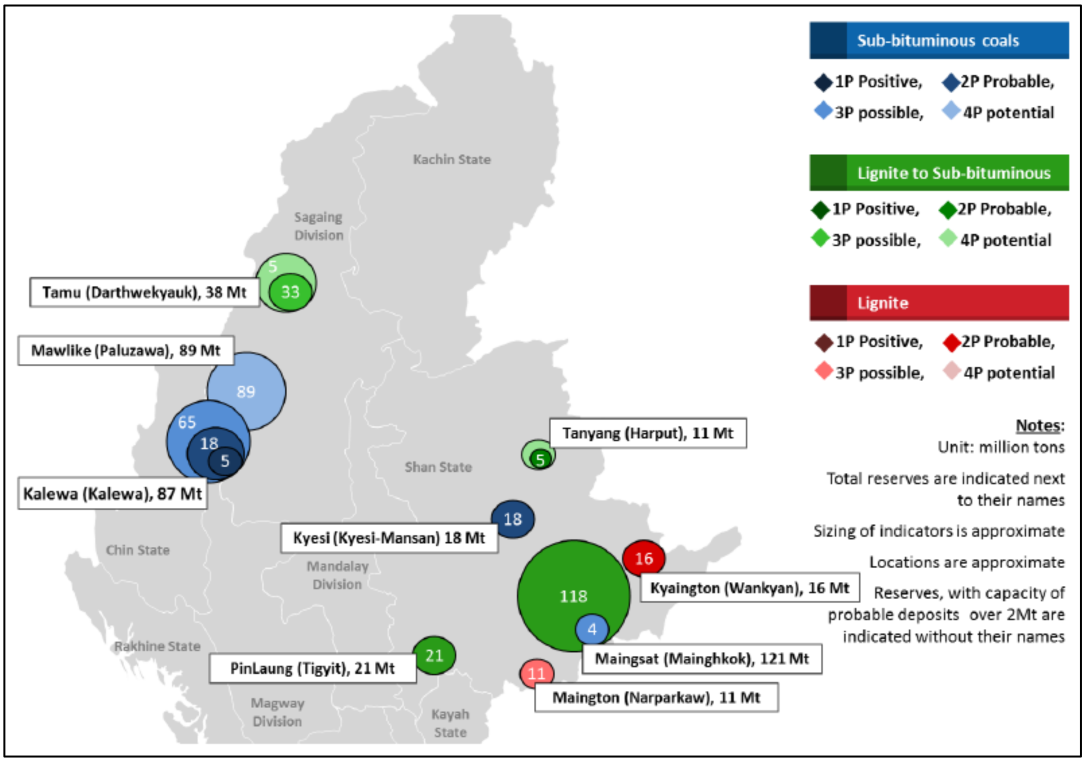
2.4.2 Production and supply

Major reserves are located in the central western and the central eastern parts of the country (Figure 2.18). In the central western part that is close to the borders with India and Bangladesh, the Mawliki and Kalewa coal basins are deposits of primarily sub-bituminous coal. On the other hand, in Shan state, located in the central eastern part of the country closest to Thailand, deposits such as those at Maigsat are mainly lignite.

Coal demand is mostly in Yangon, the southern part of the country. A challenge is how to transport from the coal producing states, which are 500–700 kilometres from Yangon in a straight line. It can be transported by train or on river ways. The train system, however, has limited capacity, which would require new investment. Rivers have a large volume of water during the wet season, whilst water levels are significantly low during the dry season, unsuitable for barge transportation.[5]

[5] Hearing from the Ministry of Electricity and Energy.

Figure 2.18: Major Coal Resources by Grade and Probability



Source: Myanmar Energy Master Plan, Dec. 2015 (Originally from the Ministry of Mines).

Another challenge is that there is a restriction on places where mine-mouth power plants are to be constructed because of the relatively small volume of deposits in each block. For instance, a super critical coal-fired power plant with power generation capacity of 600 MW would consume 71 million tons of coal in total if its lifetime is assumed to be 40 years (Table 2.9). Very few blocks could stably supply this amount of coal. In contrast, a coal-fired power plant with power generation capacity of 150 MW would consume 21 million tons in total over 40 years. More blocks can adequately meet this condition although the number is still small. Needless to say, a small-scale coal-fired power plant would be unable to enhance power generation efficiency, not commended from the environmental load point of view.

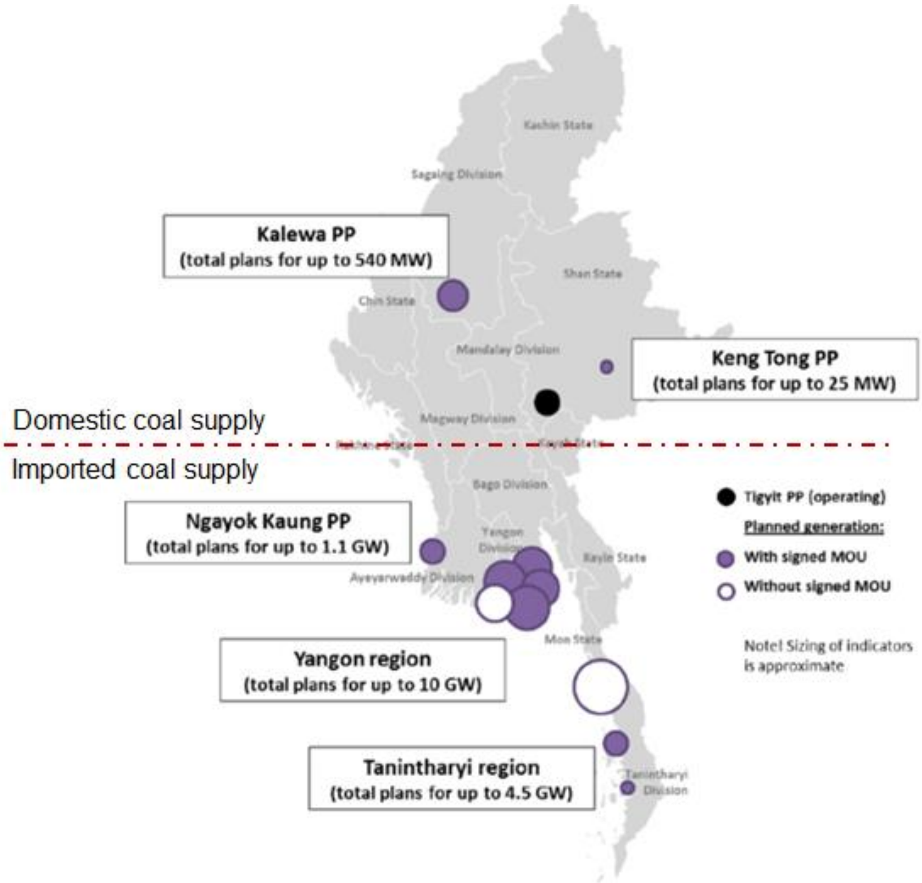
Table 2.9: Estimated Lifetime Coal Consumption

	150 MW	300 MW	600 MW	1,000M W
Boiler Technology (thermal efficiency)	Sub critical (35%)	Sub critical (38%)	Super critical (41%)	Ultra-super critical (45%)
Lifetime coal consumption	21 million tons	38 million tons	71 million tons	107 million tons

Note: Operating life: 40 years, capacity factor: 80%, heat value of coal: 5,200 kcal/kg.
kcal = kilocalorie, kg = kilogramme, MW = megawatt.
Source: IEEJ.

The country currently has several coal-fired power plant constructions plans. To address challenges associated with the transportation of domestically produced coal and the limited volume of deposits in each block, the government plans to introduce different coal supply systems, depending on the location of plants. A mine-mouth power plant will be constructed in an inland area where the domestically produced coal can be easily delivered. On the other hand, a coal-fired power plant using imported coal will be established along coastal areas where harbours have been developed (Figure 2.19). It is a rational decision, given the constraints of the coal supply systems in the country.

Figure 2.19: Distribution of Planned Coal-fired Power Plants



GW = gigawatt, MOU = memorandum of understanding, MW = megawatt, PP = powerplant.
Source: Modified from Myanmar Energy Master Plan, Dec. 2015 (Originally from the Ministry of Mine).

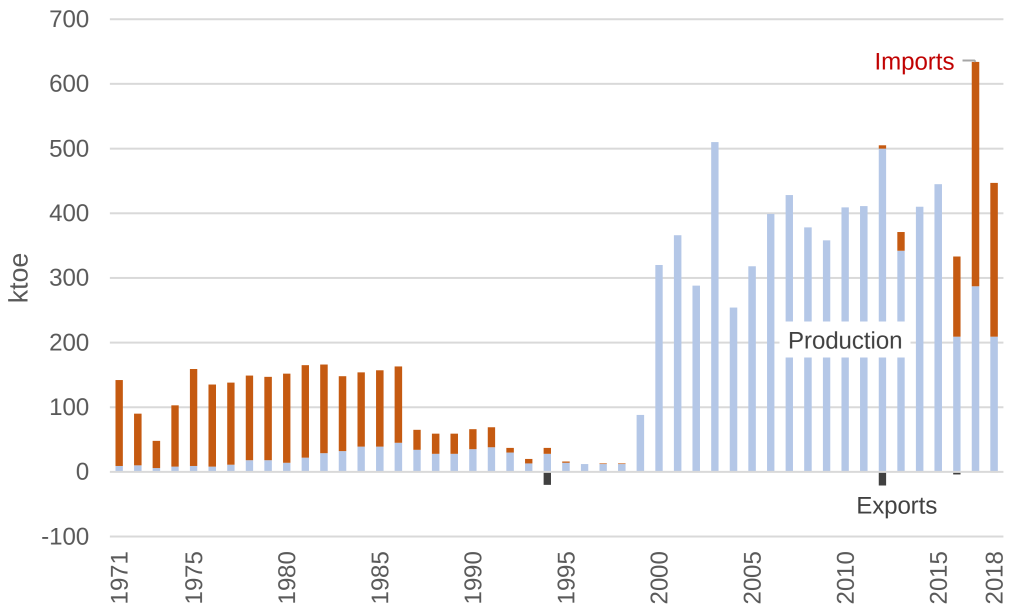
2.4.3 Import and export

Myanmar significantly increased its coal production in 2000 and has been self-sufficient for more than 10 years (Figure 2.20). However, the enactment of new environmental regulations in 2015 caused production reduction in some coalfields. Subsequently, the country was required to import coal to ease the resultant shortage. Action that has been taken to comply with the new regulations is expected to be completed in the next 1 or 2 years.[6] Subsequently, domestic production may bounce back in the future, leading to a decrease in coal imports.

However, the improvement of coal production has increasingly become more difficult not only because of environmental regulations in place, but also because of growing opposition from local residents. Cognisant of this, the government places a higher priority on the importation of coal than the increase in domestic production.[7]

On the other hand, the exportation of coal is hardly practiced. There is, however, a plan to export lignite coal to India.[8]

Figure 2.20: Trajectory of Coal Supply Balance



Kktoe = kilotons of oil equivalent.
Source: IEA (2019a), World Energy Balances 2019.

2.4.4 Prices

The prices of domestically produced coal are determined by the location of the coalfields. The 2019 price of bituminous coal on the demand side was approximately $80 per ton (Table 2.10).[9] This price was lower than international prices. Therefore, there is an economic significance of exploiting this situation.

[6] Hearing from the Ministry of Electricity and Energy.
[7] Hearing from the Ministry of Electricity and Energy.
[8] Hearing from the Ministry of Electricity and Energy.
[9] Hearing from the Ministry of Electricity and Energy.

Table 2.10: Price of Domestic Coal (2015 survey)

	Kalewa	Lasio 1	Lasio 2	Tiygit
Heat value [kcal/kg]	6,111	5,789	5,429	3,920
FOB price [$/ton]	41–57	37–47	36	31
Land freight cost [$/ton]	17–22	21	15	–
CIF price [$/ton]	58–73 *	58–68*	51*	31**

FOB = free on-board, CIF = cost, insurance, and freight, kcal = kilocalorie, kg = kilogramme.
* at Mandalay, ** at mine-mouth power plant.
Source: Myanmar Energy Master Plan, Dec 2015.

2.4.5 Risk scenario

A risk involved in the coal supply system in Myanmar is that actual production in the country fails to meet the projections. There is a plan to construct two coal-fired power plants that use domestically produced coal: the Kalewa plant (540 MW) and the Keng Tong plant (25 MW). Both plants are located inland. Therefore, imported coal would not be able to substitute domestically produced coal if the supply failed. Accordingly, the construction plan would be cancelled. In this case, the country needs to look for an alternative power source to generate a total of 565 MW in order to satisfy the increase in demand. LNG has been emerging as a likely substitute for coal.

In view of this, potential costs to generate power using domestically produced coal and LNG were calculated and compared to understand extra costs incurred to use LNG.

Assumed scenario

Reference	Construct 565 MW of mine-mouth coal power plant
Risk Scenario (Coal supply risk)	Construct 565 MW of LNG power plant

Formula

Additional cost = $\sum_{year} Generated\ electricity\ \times\ (LCOE_{LNG} - LCOE_{coal})$

Table 2.11 shows the outcomes. The LCOE of LNG power generation is higher than that of coal-fired power plants. Therefore, if domestically produced coal is totally replaced with LNG, additional costs of $55.4 million per annum would be incurred.

Table 2.11: Annual Additional Cost of LNG Imports

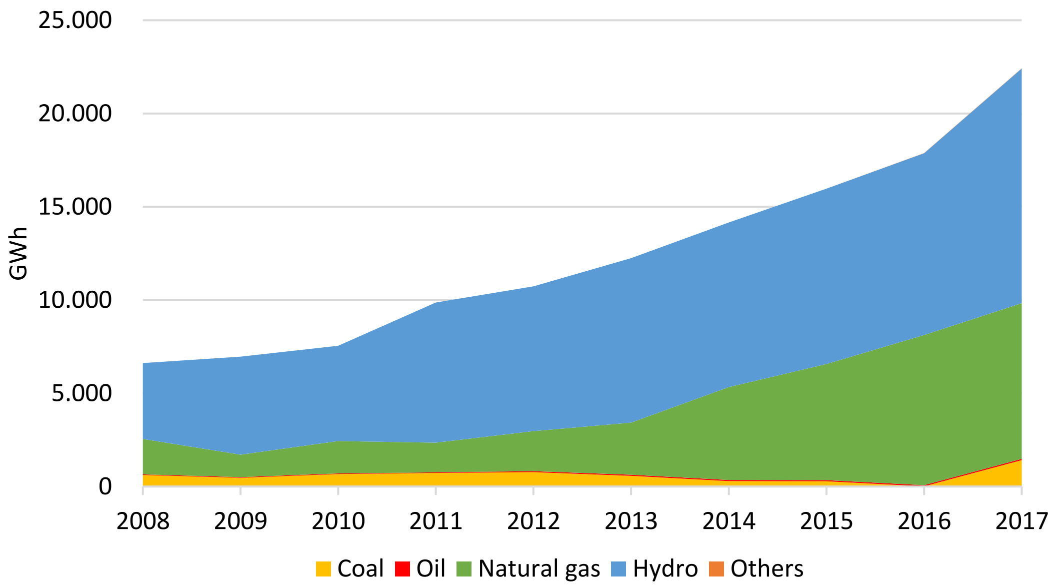
Alternative gas power plant: 565 MW (1)	$356.4 million/yr
Kalewa coal-fired power plant: 540 MW (2)	$287.6 million/yr
Keng Tong coal-fired power plant: 25 MW (3)	$13.3 million/yr
Additional cost (1)-(2)-(3)	$55.4 million/yr

Note: Calculation period from 2025 to 2040. Assume 80% of capacity factor.
LCOE of coal (domestic) power plant: $ 0.05/kWh
LCOE of gas (import) power plant: $ 0.096/kWh
kWh = kilowatt hour, LCOE = levelised cost of electricity, LNG = liquefied natural gas, MW = megawatt.
Source: IEEJ.

2.5 Hydropower

Myanmar has four major rivers flowing across the country, featuring abundant water resources. Ample water resources enrich biodiversity and nurture industries such as agriculture and fisheries, indispensable to the livelihoods of people. They also play a crucial role in hydropower generation, providing inexpensive energy to satisfy the increasing electricity demand in the country as the economy grows. Hydropower generation accounted for 56% of electricity generated in fiscal year 2017 (Figure 2.21).

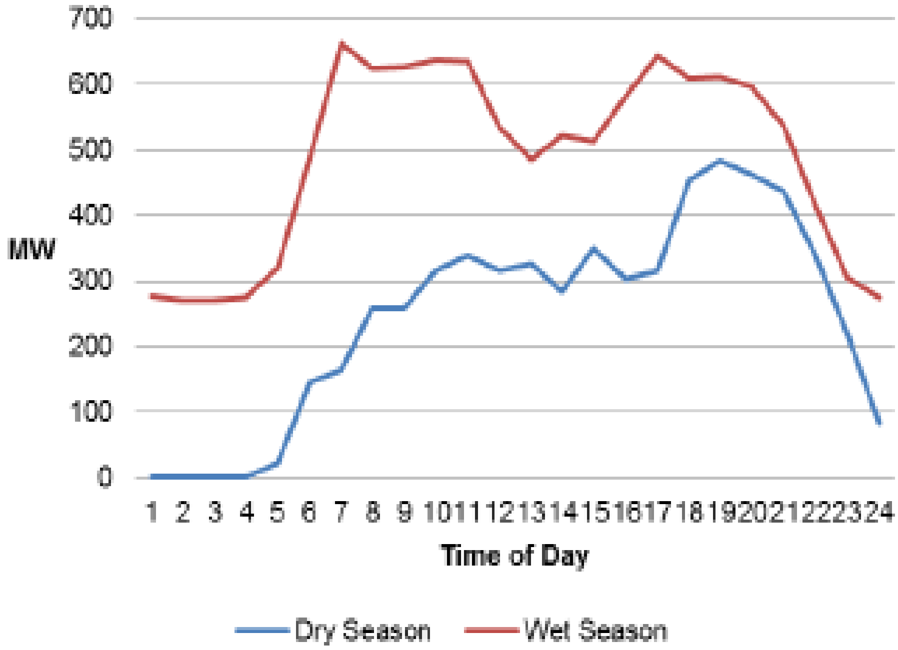
Figure 2.21: Trajectory of Electricity Output by Type



GWh = gigawatt hour.
Source: IEA (2019a), World Energy Balances 2019 extended edition database.

Myanmar has considerable seasonal fluctuations in rainfall. Significant differences in rainfall are observed between the wet and dry seasons. Rainfall directly affects the output of hydropower plants. Their capacity availability decreases during the dry season when rainfall is small, especially in April when the dry season is about to end. According to the MOEE, the ratio of typical capacity availability between rainfall and the dry season reaches as high as 1.35 (Figure 2.22). Approximately 60% of electricity is currently generated by hydropower plants. How to stabilise power supply in the dry season is one of the key challenges the country is currently facing.

Figure 2.22: Examples of Capacity Availability During Wet and Dry Seasons (Yeywa 790 MW)



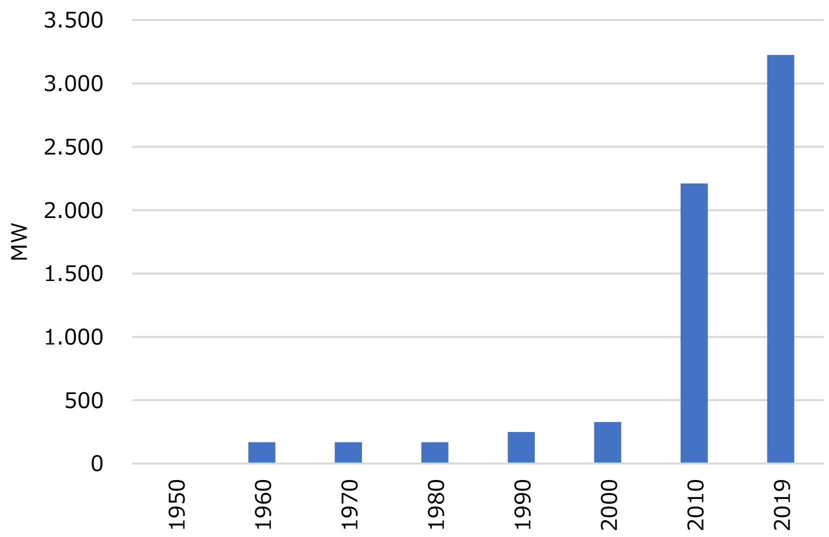
MW = megawatt.

Source: Myanmar Energy Master Plan, Dec. 2015.

2.5.1 Development and supply

The total power generation capacity of hydropower plants in Myanmar has been rapidly increasing after 2000 (Figure 2.23). Between 2006 and 2010, two large-scale hydropower plants were constructed. Since around 2010, the government started to enter into joint venture arrangements with foreign investors for selected projects to finance large-scale hydropower development. Also, the government supports the build–own–transfer structure in the hydropower sector. Some projects funded by either foreign or local private sectors are under such schemes.

Figure 2.23: Trajectory of Installed Capacity of Hydropower Plants



MW = megawatt.
Source: Data provided by MOEE, December 2019.

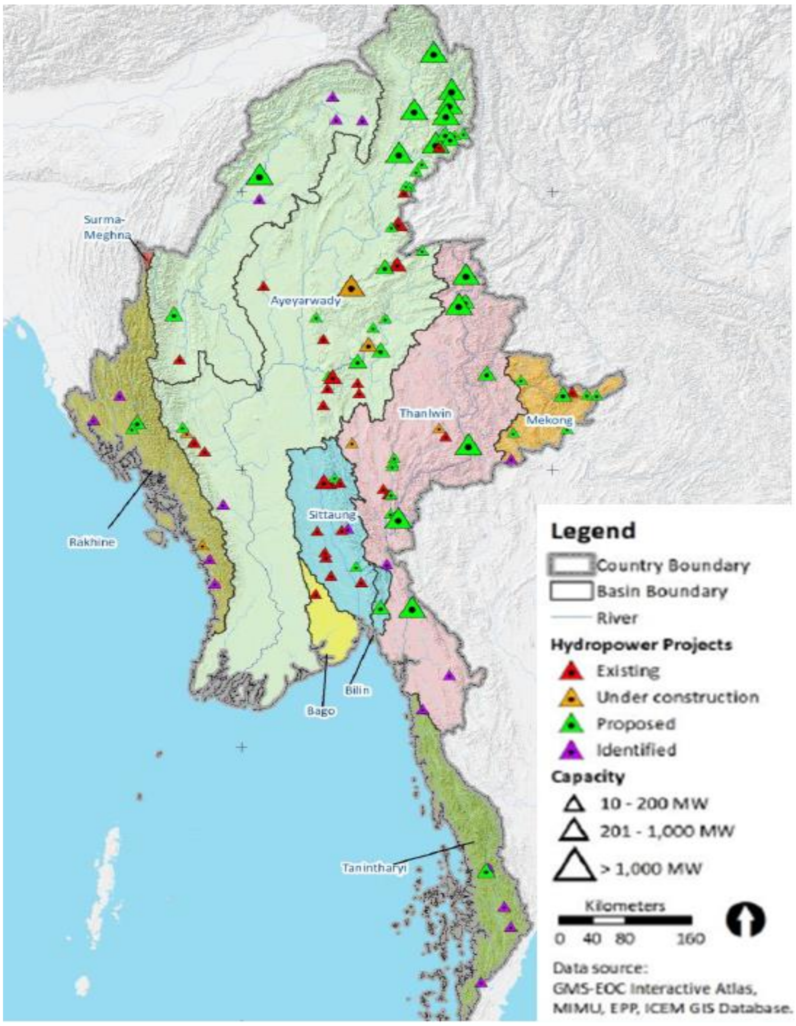
2.5.2 Planned hydropower plants

The Myanmar National Energy Policy (MNEP) describes the energy mix target of the country in 2030 as follows: 8,896 MW (37.7%) from hydropower, 4,758 MW (20.2%) from natural gas, 7,940 MW (33.6%) from coal, and 2,000 MW (8.5%) from other renewable energy sources. The government regards hydropower as the main source of electricity now as well as in the future. To achieve the target, the capacity of hydropower plants needs to be increased by approximately 5,600 MW by 2030.

As of 2019, 28 hydropower plants, 3,225 MW in total, were in operation.[10] In addition, as of 2018, six plants of 10MW capacity or greater (1,564 MW) were under construction and 69 plants of 10 MW capacity or greater (43,848 MW) were proposed and identified(IFC, 2018) (Figure 2.24, Table 2.12).[11] Most construction plans that have been approved are spearheaded by the private sector. Provided that the plans are implemented as expected, the country will generate the huge amount of electricity that will be sufficient not only to satisfy the domestic demand but also to export and earn hard currencies.

[10] Data provided by the Ministry of Energy and Electricity, December 2019.
[11] Excluding hydropower plants less than 10 MW.

Figure 2.24: Distribution of Hydropower Plant Projects



MW = megawatt.
Source: IFC (2018), Strategic Environmental Assessment of the Myanmar Hydropower Sector.

Table 2.12: Status of Hydropower Plant Projects

Project status	Number of projects	Capacity（MW）
Existing	28	3,225
Under Construction	6	1,564
Proposed/identified	69	43,848
Total	103	48,637

MW = megawatt.
Note: ‘Existing’ include the plants of all capacity. ‘Under construction’ and ‘Proposed/identified’ include the plants of 10 MW capacity or greater.
Source: Existing from the Ministry of Energy and Electricity November 2019, Others from IFC, Strategic Environmental Assessment of the Myanmar Hydropower Sector 2018.

2.5.3 Risks associated with hydropower plant development

Hydropower development is a crucial issue for the country to achieve the energy mix targets in the future. There are, however, potential risks that require attention.

a) Social and/or environmental risks (environmental destruction, displacement of local residents, etc.)

   The International Finance Corporation (IFC) published a report on the environmental assessment of the Myanmar hydropower sector in 2018, in cooperation with the ministries of Myanmar(IFC, 2018). The IFC recommended the government call off the planned medium and large-scale hydropower plant projects on account of the potential negative impact on the sustainability of major rivers. In response to campaigns against hydropower development organised by local residents, the government has suspended three major large-scale development projects (total capacity of 7,800 MW). Uncertainty has been growing when the projects will be completed. Because of mounting concern over the environmental and/or social impacts of hydropower development, these projects may face financing difficulties or be forced to postpone or cancel.

b) Risks associated with the hike of construction costs

   In Myanmar, it is projected for inflation and labour costs to rise in the future. The International Monetary Fund (IMF) predicted that, making 2011 as a base year, the inflation rate would become 7.5% in 2019 and hover around the 6% range thereafter (IMF, 2019). The MNEP forecasts an increase in labour costs that are currently at the lower end of spectrum in Southeast Asia. Consequently, according to it, the operating expense in hydropower development could rise from the 2015 level (1.2% of capital expenditure) to the international level (2.5% of capital expenditure) by 2035. The increase in construction costs resulting from inflation or the increased labour costs may reduce economies of new hydropower plants, hence would challenge the endeavours.

2.5.4 Risk scenario

A risk involved in hydropower development in Myanmar is the delay in development projects. The existing plan is aimed at increasing the capacity of hydropower plants by approximately 5,600 MW until 2030. If the country fails to proceed with the projects as planned, it will be required to identify alternative sources to fill the resultant shortage.

There are two scenarios in relation to hydropower development to be considered: (i) hydropower development to progress as expected in the business as usual (BAU) scenario, and (ii) hydropower development to achieve 25% or 50% less than in the BAU scenario. In the case of (ii), the country needs to look for an alternative power source to substitute the delay in hydropower development. Thermal power plants have been emerging as a likely substitute for hydropower.

In view of this, potential costs to generate power using hydropower plants were calculated and compared to understand extra costs incurred to use coal or gas thermal plants.

Assumed Scenario

Reference (BAU)	Power generation amount is 42,150 GWh in 2040
Risk Scenario (Less development risk)	Achieve 25% or 50% less development than BAU

Formula

Additional cost

$$= \sum_{year} Generated\ electricity \times \left(LCOE_{hydro} - LCOE_{coal\ or\ LNG}\right)$$

Table 2.13 shows the outcomes. The delay in hydropower development projects may incur the additional costs of between $91–$321 per annum. In addition, if imported fuels are used in thermal power plants that substitute hydropower plants, the energy self-sufficiency will inevitably decrease. The country will be more vulnerable to international situations, including the increase in international energy prices, which will negatively affect Myanmar's energy security.

The government should systematically develop hydropower that provides domestically produced, clean, and low-cost energy, taking social and environmental impacts into account.

Table 2.13: Annual Average Additional Cost of Generating Electricity

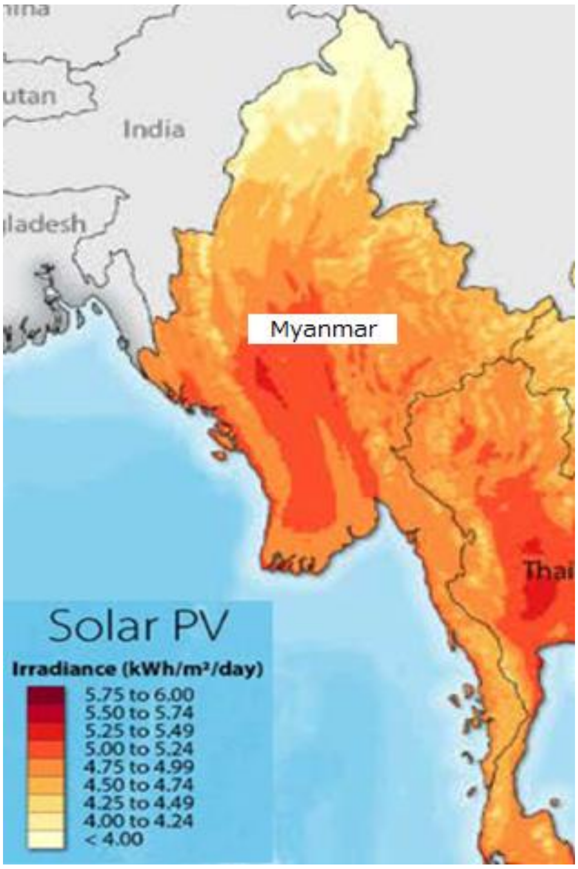
	Alternative power source	
	Coal ($118/ton)	Gas ($11/MMBtu)
25% less development	$91 million/yr	$154 million/yr
50% less development	$190 million/yr	$321 million/yr

Note: Assume 50% (hydropower) and 80% (coal and gas) of capacity factor.
LCOE of hydropower plant: $ 0.047/kWh
LCOE of coal (import) power plant: $ 0.076/kWh
LCOE of gas (import) power plant: $ 0.096/kWh
kWh = kilowatt hour, LCOE = levelised cost of electricity, MMBtu = million British thermal units.
Source: IEEJ.

2.6 Solar PV

Myanmar has a high potential for solar photovoltaic (PV) because of favourable insolation conditions (Figure 2.25). Small-scale solar PV has been increasingly common in rural areas. On the other hand, large-scale solar PV is yet to be fully developed.

Figure 2.25: Solar PV Potential in Myanmar



kWh = kilowatt hour, m^2 = square metre.
Source: Lee et al. (2019).

2.6.1 Development

Renewable energy sources including solar PV have been utilised for small-scale, off-the-grid power systems, contributing to the improvement of electrification rate in rural areas.

With regard to large-scale solar PV, Green Earth Power (Thailand) started operation of the Minbu Solar Power Plant in 2019, the first commercial solar PV plant in the country (Bangkok Post, 2019). It has currently an installed capacity of 40 MW, which will be increased to 170 MW, generating 350 GWh annually, and serving about 210,000 households. Further, Convalt Energy, a United States company, announced that it had invested $480 million in the development of solar PV with an installed capacity of 300 MW in the Mandalay region (Convalt Energy, 2017). Large-scale solar PV has been attracting more attention in Myanmar in recent years.

2.6.2 Potential of solar PV

The government announced in the MNEP its plan to increase the capacity of renewable energy to 2,000 MW by 2030. Solar power development potentially contributes to the quality improvement of Myanmar's electricity supply systems from several points of view.

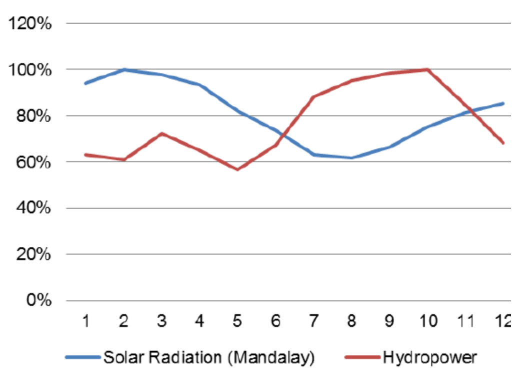
a) Improvement of access to electricity in rural areas

With assistance from international organisations, Myanmar has been promoting the introduction of small-scale, off-the-grid solar PV in rural areas where there is currently no access to electricity. Private companies have also been exploring business opportunities in this area. The government aims to increase the country's access to electricity from the current rate of about 40% to 100% by 2030. The development of solar PV will contribute to achieve this policy goal.

b) Stable electricity supply by promoting synergy between solar and hydropower

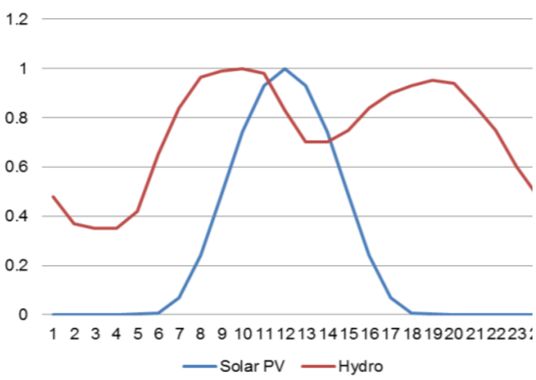
Hydropower, the key power source of the country, and solar power could complement each other to provide more stable electricity supply in the country. Taking seasonal variations into account, during the dry season, the amount of electricity generated by hydropower plants decreases, whilst abundant sunshine boosts the capacity factor of solar PV (Figure 2.26). Further, in terms of daily variation, in the daytime, the amount of electricity generated by hydropower plants can complement no output from solar PV in the night (Figure 2.27).

Figure 2.26: Seasonal Variation of Solar Energy vs Hydropower (monthly output as % of that of the highest month)



Source: Myanmar Energy Master Plan, Dec 2015.

Figure 2.27: Daily Variation of Solar Energy vs Hydropower (hourly output as % of that of the highest hour)



Source: Myanmar Energy Master Plan, Dec 2015.

Solar power is intermittent, so it needs to be backed up for a reliable supply of electricity. In this aspect, hydropower can play an important role because it has the ability to adjust its power output as electricity demand changes.

c) Electricity supply at low cost

The National Renewable Energy Laboratory discussed the potential of power generation from renewable energy sources in the ASEAN Member States in a report published in 2019 (Lee et al., 2019). The report describes the LCOE of solar PV and wind power plants in the ASEAN countries, taking several scenarios into consideration. It indicates that the LCOE of solar PV in Myanmar could be around $0.08/kWh, comparatively low amongst the ASEAN countries, along with Viet Nam, Thailand, and Cambodia. In other words, solar PV has the potential to generate electricity at low cost in the future.

2.6.3 Risks associated with solar PV development

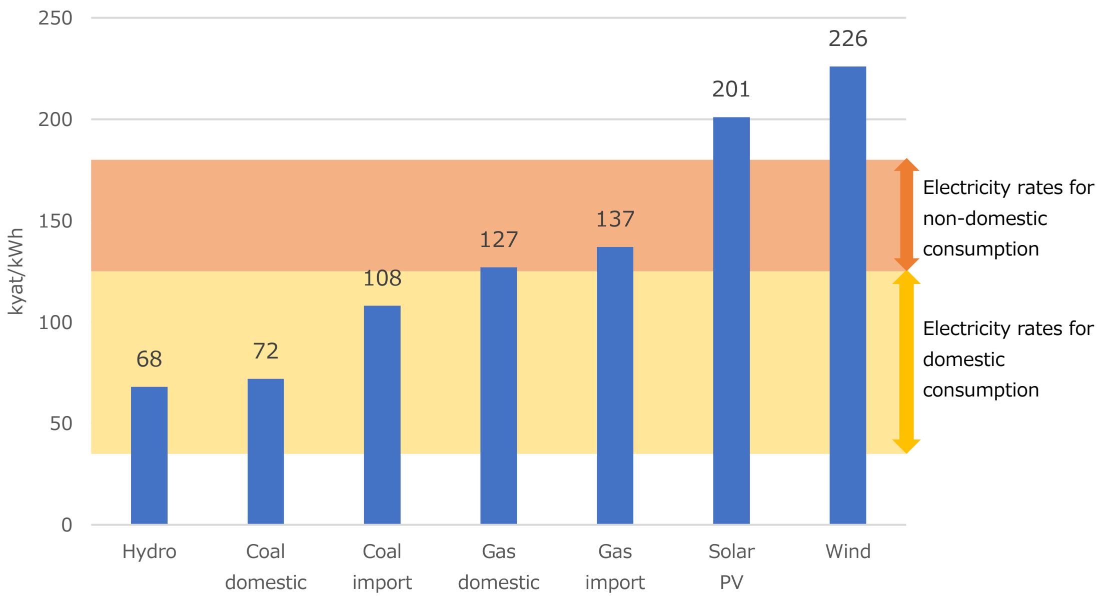
As discussed above, Myanmar has a high potential for solar PV, which could contribute to a stable electricity supply or lowering power generation costs in future. However, at this moment, the introduction of solar PV in the country deserves thoughtful consideration of the costs.

According to a report issued by the ASEAN Centre for Energy, based on the actual performance, the average LCOE of solar PV in the ASEAN countries is $0.181–0.187/kWh, depending on the size of the plants. As of 2016, the lowest LCOE of solar PV projects was $0.1/kWh. The LCOE of solar PV in ASEAN countries has been demonstrating a downward trend in recent years and will potentially decline further. However, they are currently higher than the international level.[12]

In reference to this report, we calculated the LCOE of solar PV in Myanmar at $0.140/kWh (201kyat/kWh). Although this value is lower than that of wind power plants, it is still higher than any other power sources (Figure 2.28). In Myanmar, the electricity rate is kept low by the government's subsidy programme (Myanmar Times, 2019). Thus, the introduction of solar PV, which currently incurs high cost to generate electricity, may negatively affect the sustainability of Myanmar's electricity supply systems.

[12] The International Renewable Energy Agency describes that the global weighted average of the levelised cost of electricity (LCOE) of newly ordered large-scale solar power projects was US$0.10/kWh in 2017.

Figure 2.28: Comparison of LCOE in Myanmar



kWh = kilowatt hour, LCOE = levelised cost of electricity, PV = photovoltaic.
Source: IEEJ.

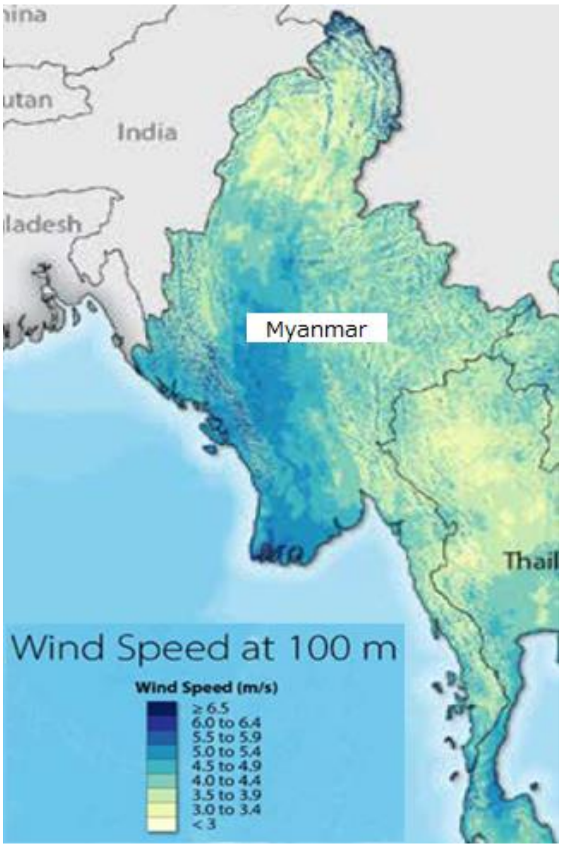
2.6.4 Risk scenario

The cost is high to generate electricity using solar PV, and the rapid promotion of solar PV could increase costs in the overall electricity supply system of the country. In the next section, we discuss the current situation of wind power and the associated risks in the country. Later, we will assess the impact to be potentially created, given that more solar PV and wind power plants are installed than planned.

2.7 Wind Power

In Myanmar, several small-scale wind power plants have been in operation although large-scale wind power plants are still at a verification stage. Areas suitable for wind power are limited either along the coast or offshore (Figure 2.29).

Figure 2.29: Wind Potential in Myanmar



Source: Lee et al. (2019).

2.7.1 Development

In 2014, the Ministry of Electric Power of Myanmar signed a memorandum of understanding (MOU) with Gunkul Engineering Public Company Limited of Thailand and China Three Gorges Corporation of China for a large-scale wind power plant development project. In 2015, Zeya & Associates Co., Ltd., Myanmar's power source development company and Vestas, a Danish manufacturer of wind turbines, agreed to construct a wind power plant with the installed capacity of 30 MW in Mon state (Ministry of Foreign Affairs of Denmark, 2015). Further, in 2017, the Magwe regional government signed an MOU with Infra Capital Myanmar ReEx, a local subsidiary of a Singaporean company, to assess the feasibility of wind power projects in the Magwe region of Myanmar (Infra Capital Myanmar ReEx, 2017). Wind power development is gathering momentum.

2.7.2 Potential of wind power

According to the National Renewable Energy Laboratory, the LCOE of wind power in Myanmar could be around $0.12/kWh, the second lowest in the ASEAN countries after Viet Nam (Lee et al., 2019). As well as solar PV, the development of wind power could contribute to the cost reduction in overall power supply systems in the country in the future.

2.7.3 Risks associated with wind power development

As discussed above, Myanmar has some promising potential for wind power, which could contribute to decreasing overall costs necessary to supply electricity in the country in future. However, at this moment, just like solar PV, the promotion of wind power deserves thoughtful consideration of the costs.

In reference to a report issued by the ASEAN Centre for Energy (ACE), we calculated the LCOE of wind power in Myanmar, which was $0.158/kWh (226kyat/kWh). This value is the highest amongst all power sources (Figure 2.29). Since Myanmar has limited experience in wind power, the LCOE of wind power installed in the future cannot be verified at this moment. The government should decide on the introduction of wind power, examining its effect on overall costs incurred in the country's power supply systems.

2.7.4 Risk scenario

In Myanmar, solar and wind power generate domestically produced, clean energy. They could be a source of low-cost electricity, contributing to a stable power supply in the country. On the other hand, at the moment, Myanmar has limited development of large-scale solar PV and wind power and their LCOE may be higher than any other power sources. In other words, their rapid expansion may lead to a cost increase in overall power supply systems in the country.

There are two scenarios in relation to renewable energy (RE) development. Here the RE includes solar PV, wind power, and biomass power plants, which are promoted by the government. The two scenarios are (i) RE development to progress as expected in the BAU scenario, and (ii) RE development to become larger than in the BAU scenario. In the case of (ii), the increase in electricity generated by RE will be offset by the decrease in electricity generated by gas power plants. In other words, additional costs will be the product of the amount of electricity increased by the larger than expected RE and the differences between the LCOE of RE and gas power plant.

Assumed Scenario

Reference（BAU）	Share of RE in generated electricity in 2040 is 1.3%
Risk Scenario (Accelerated development)	Share of RE in generated electricity in 2040 increase to 10% or 15%

Note: Assumed that the amount of power generated by solar PV, wind power or biomass power are the same.

Formula

Additional cost

$$= \sum_{year} Generated\ electricity \times (LCOE_{RE} - LCOE_{LNG})$$

Table 2.1415 shows the outcomes. If the proportion of electricity generated from RE reaches 10% of the total in 2040, the additional cost will be $205 million per annum. If it becomes 15%, the additional cost will be $323 million per annum.

In ASEAN countries including Myanmar, the LCOE of RE potentially becomes lower in the future. However, at the moment, the number of RE project cases are too little to assess future cost trends in Myanmar. The government is suggested to look into factors such as the decline in LCOE and the cost to integrate RE into grids when considering greater deployment of RE.

Table 2.14: Annual Average Additional Cost of Generating Electricity

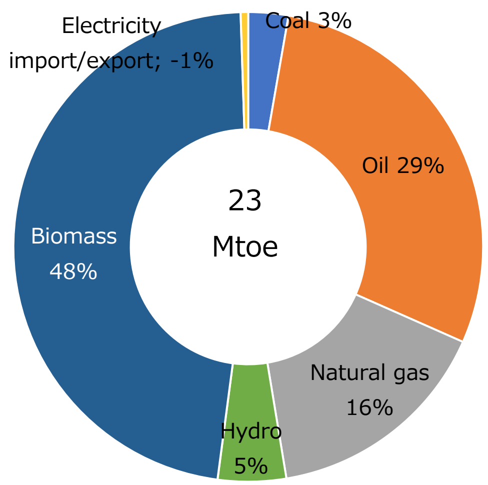
Share of Renewable Energy in 2040	Additional cost
10%	$205 million/yr
15%	$323 million/yr

Notes: Assume 80% for gas, 16% for solar PV, 22% for wind power, and 80% for biomass of capacity factor.
LCOE of gas (import) power plant: $ 0.096/kWh
LCOE of solar PV and biomass: $ 0.140/kWh
LCOE of wind power plant: $ 0.158/kWh
kWh = kilowatt hour, LCOE = levelised cost of electricity.
Source: IEEJ.

2.8 Biomass

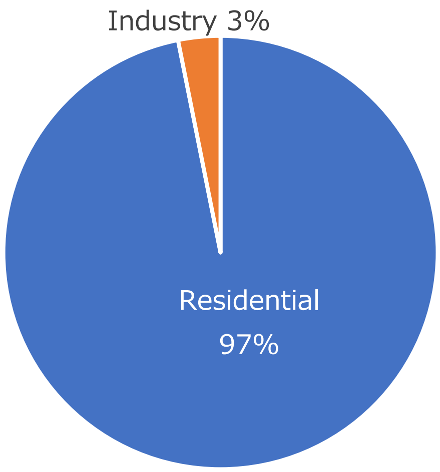
Biomass is an important energy source in Myanmar. In 2017, biomass constituted 48% of total primary energy supply, considerably higher than oil (29%), natural gas (16%), and hydropower (5%) (Figure 2.30). Most biomass is consumed at a household level, and ordinary households mostly use biomass as an energy source (Figure 2.31).

Figure 2.30: Structure of Total Primary Energy Supply (2017)



Mtoe = million tons of oil equivalent.
Source: IEA (2019a), World Energy Balances.

Figure 2.31: Biomass Demand by Sector (2017)

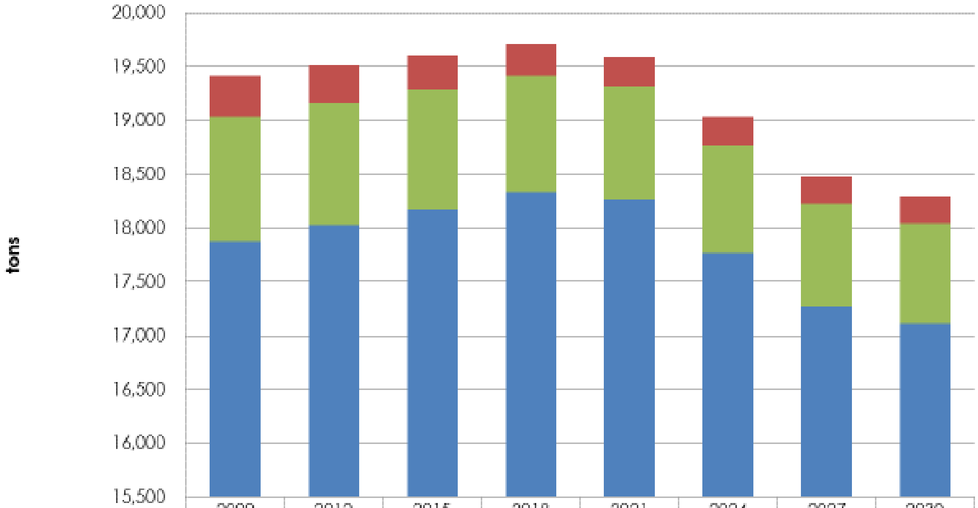


Source: IEA (2019a), World Energy Balances.

2.8.1 Issue of biomass

Biomass is an essential energy source for households. However, the use of firewood or charcoal is one of the factors leading to deforestation as well as causing serious health problems amongst people engaged in household chores, mainly women and children. The government has been exerting efforts to reduce the use of biomass that have used in ordinary households and develop alternative energy sources, such as promoting electrification and supplying oil products, e.g. LPG, to replace firewood (Figure 2.32).

Figure 2.32: Final Energy Consumption Projection by Energy Carrier: All Households, Biomass



	2009	2012	2015	2018	2021	2024	2027	2030
Charcoal	373	349	325	301	281	266	251	250
Agricultural Waste	1,161	1,135	1,109	1,083	1,049	999	949	935
Firewood	17,875	18,027	18,178	18,330	18,266	17,770	17,274	17,111

Source Myanmar Energy Master Plan, Dec 2015.

2.8.2 Clean utilisation of biomass

Whilst efforts are exerted to reduce the use of biomass to alleviate concerns over deforestation and people's health, cheap and domestically produced biomass is an essential energy source for ordinary households. In light of this, the government has been promoting the dissemination of energy-efficient biomass cookstoves with assistance from various international organizations such as the European Union (EU, 2018). Compared to traditional heaters or cooking stoves, they consume 40% less firewood or 35% less charcoal and are considered safer, contributing to the protection of forest resources, the alleviation of health hazards, and the reduction of household energy costs, amongst others. In addition, various activities are in progress to take advantage of ample agricultural waste: gasification of rice husks, biomass generated from animal waste, etc. to replace woody biomass.

The use of electricity, substituting biomass, may pose various risks to the country, such as increasing costs of fuel imports, compromising energy security by increased reliance on imports, uncertainty surrounding the development of power plants, etc. To improve the way to use cleaner biomass and to develop alternative energy sources to woody biomass should be promoted in a balanced manner so that Myanmar's energy security will be enhanced.

Chapter 3

Seeking the Best Energy Mix towards 2040

This chapter will examine scenarios that aim to enhance energy security of Myanmar by 2040.

First, we identify the basic issues to be considered to ensure energy security. Second, we will discuss several additional issues that are considered essential to define Myanmar's energy security. Lastly, based on the discussions above, we will present a suggested energy mix appropriate to Myanmar. To develop a viable energy mix target, we will focus on electricity, where demand has been rapidly increasing in recent years and where the implementation of relevant measures is relatively easy.

3.1 Angles of Energy Security

Energy security can be defined as ensuring the supply of a sufficient amount of energy at a reasonable price to sustain the lives of the people and economic activities in a country. The stabilisation of energy supply is a major challenge to energy-importing countries. They have limited influence on exporting countries or international markets, thereby unable to effectively control associated risks. For instance, oil importing countries in Asia heavily count on Middle Eastern countries for oil supply. As witnessed during the oil crisis in the 1970s, a sharp increase in oil prices has considerable negative impacts on a country's economy. In addition, during this crisis, some countries, including the United States, became unable to import crude oil from the Middle East. Impacts would be unmeasurable if this kind of situation should take place.

Drastic measures that should be in place to mitigate the effects of such energy crises are to improve energy self-sufficiency, more precisely, to reduce demand by the enhancement of energy efficiency and to increase energy supply by developing domestic energy resources. A country will be able to minimise energy imports by concurrently implementing measures targeting both demand and supply sides.

Myanmar has abundant water resources for hydropower generation, which can be further developed to increase energy self-sufficiency. The development of solar PV is also promising because of the availability of abundant solar radiation in most parts of the country. Although areas suitable to wind power generation are limited, the development of wind power plants should be promoted in potential areas.

Regarding fossil fuels, the country is particularly rich in natural gas, exporting it whilst consuming domestically. However, natural gas production has been showing a downward trend. The country must promote investment to increase production in order to ensure future supply. In addition, Myanmar has untapped coal resources, the development of which can be one of options to increase self-sufficiency. Unfortunately, crude oil production will unlikely increase to sufficiently fill the supply–demand gap. On the other hand, the improvement of the performance of oil refineries may lead to a reduction of petroleum products to be imported.

Even so, an increase in domestic energy supply will potentially fail to keep up with a demand increase, which will likely require the country to import energy. To mitigate risks involving energy imports, the country should diversify the countries from which they import energy, transportation routes of imports, and import infrastructure. A complete reliance on a particular country, transportation route, or import infrastructure may inflict enormous damage on the country when a problem emerges in a supply system. The country must prevent the complete halt of imports by having multiple options to spread risks. The diversification of energy sources is also an effective option. Especially, electricity can be generated from various primary energy sources. Thus, operating multiple energy supply systems will effectively contribute to stable energy supply.

Stockpiling oil is a last resort to the achievement of energy security. It incurs costs. However, given the magnitude of problems potentially caused by the complete halt of energy supply systems, it is considered rational to allocate some budget to this endeavour. Electricity cannot be stored for a long period of time at a reasonable cost with the use of current technology. Therefore, stockpiling of fossil fuels is a realistic option to sustain power supply.

Lastly, energy should be supplied at an acceptable price as the result of the implementation of the above-mentioned measures. Even if the constant supply of a sufficient amount of energy is ensured, nobody would be able to use it if it is extremely expensive. We will discuss in detail this issue in section 3.3.

We have discussed basic viewpoints and specific guidelines in relation to energy security. Although these guidelines are generally applicable to many countries, they are not an optimum solution for each country that reflect a country's specific conditions. When examining Myanmar's energy security or energy mix target, unique considerations need to be added from the viewpoints of access to energy, affordability, and environmental sustainability.

3.2 Energy Access

In 2018, 43% of the Myanmar people had access to electricity, whilst 21% had access to energy for clean cooking. The country has the lowest access to electricity amongst the ASEAN Member States and is in the subordinate group in terms of access to energy for clean cooking (Table 3.1).

Table 3.1: Access to Electricity and Clean Cooking, 2018

	Access to electricity	Access to clean cooking
Myanmar	43%	21%
Brunei Darussalam	>95%	>95%
Cambodia	72%	20%
Indonesia	98%	68%
Lao PDR	95%	6%
Malaysia	>95%	>95%
Philippines	>95%	44%
Singapore	>95%	>95%
Thailand	>95%	76%
Viet Nam	>95%	73%

Source: IEA (2019b), SDG7: Data and Projections, November. https://www.iea.org/reports/sdg7-data-and-projections/access-to-electricity#abstract

The extension of transmission and distribution lines is normally carried out to improve electricity access, such as transmitting high-voltage electricity over a long distance or extending low-voltage power distribution lines to neighbouring areas. What is important is to assess the economic rationality of investment in this endeavour. If a target area is densely populated with households without electricity, the extension of power lines will likely be considered economically rational. In contrast, investment in a sparsely populated area may not be adequately recouped, creating negative impacts: putting the concerned power company in financial distress or requiring current users to bear more costs. Although the national government has a responsibility to ensure power access for all Myanmar's people, the economic rationality of projects should not be overlooked.

To address this problem, the development of off-grid power generation systems involving solar PV and others has been attracting attention. Their output fluctuates depending on weather conditions. Therefore, grid-connected systems are better in terms of stable power supply. However, off-grid systems can be easily put into operation to supply power without installing long-distance transmission lines. Costs to operate solar PV have been showing a downwards trend globally, which also increases the appeal of off-grid systems. Further, their operation involves neither natural gas, whose production has been declining, nor petroleum, which needs to be imported. Hence, they are preferable from the energy security points of view.

Taking the many purposes and mobility of petroleum products including LPG into account, they are in a good position to promote energy for clean cooking. By replacing solid biomass fuels with LPG in cooking, people can greatly improve indoor environments. The problems here are that petroleum and LPG are expensive energy sources, and Myanmar needs to import them. Whilst petroleum and LPG would be the best energy to ensure clean cooking, their imports should be minimised as much as possible to enhance energy security. Natural gas is clean energy. However, huge initial investment is required to install pipelines to supply it to areas where no supply is currently available.

In light of this, the clean utilisation of solid biomass fuels such as firewood can be one way to address this problem. Combustion efficiency is low in the traditional ways of burning biomass fuels, which also produce a large amount of hazardous substances such as soot. The adoption of equipment that can efficiently combust solid biomass fuels could largely mitigate these problems. As equipment can be manufactured at a low cost, biomass fuels are more economically viable than commercial energy sources. Further, they are domestically produced, preferable from the energy security points of view as well.

We should bear in mind that the utilisation of solid biomass fuels is only a temporary measure to be taken because they have neither convenience nor comfort that commercial energy sources such as petroleum can offer. Once the country is sufficiently developed to the point where the government is able to supply an adequate amount of commercial energy sources across the nation and where all people are able to pay a bill according to their consumption, the replacement of biomass fuels with commercial energy sources should be promoted.

3.3 Affordability

Affordability is an important factor to be taken into account in the preparation of energy policy in developing countries. Myanmar is not an exception. GDP per capita of Myanmar was US$1,490 in 2017, the second lowest in the ASEAN countries after Cambodia (Table 3.2).

Table 3.2 GDP per Capita (2010 US$)

	2017	2040
Myanmar	1,490	5,050
Brunei Darussalam	31,349	74,919
Cambodia	1,137	2,694
Indonesia	4,131	12,779
Lao PDR	1,730	2,495
Malaysia	11,530	19,582
Philippines	2,891	7,771
Singapore	55,258	75,843
Thailand	6,128	15,076
Viet Nam	1,835	6,194

Sources: 2017 data from IEA (2019a), World Energy Balances 2019. 2040 data from ERIA Outlook (2018).

If incomes are low, people may have little money to spare for energy bills. Energy should be supplied at a price affordable to them. If energy supply costs exceed the amount that people can pay, energy companies or the government will be required to make up the difference. It is not sustainable and should be averted as much as possible.

Measures to be taken are simple and clear. They are to maximise the utilisation of low-cost energy sources. For instance, our study has found that, in Myanmar, hydropower can generate electricity at the lowest cost, followed by in order of coal, gas, wind, and solar PV. Based on this finding, we suggest that the country gives the highest priority to the development of hydropower plants and uses coal and natural gas to fill the resultant shortage, if any. High-cost solar PV will be exceptionally adopted for electrification in remote areas. This is the most economically rational option for the government to take.

There are, however, shortcomings in this option. For instance, the development of hydropower plants will likely involve different risks. It includes opposition from local communities, which may cause delays in work, an increase in costs to deal with such opposition, as well as overall project costs. Further, climate change could negatively impact plant outputs. Some projects may incur high costs. So, they require careful planning.

In terms of heat supply, coal can generate the same amount of heat at the lowest cost, followed by natural gas and petroleum. Therefore, except for vehicles which are operated mostly by petroleum, the use of coal is the most economically rational option to generate heat. Especially, domestically produced coal is inexpensive to use and preferable from energy security points of view. However, external costs to be incurred for consultation with local residents, the implementation of environmental measures and others should be taken into account in the preparation of coal-fired power plant construction projects.

From the affordability point of view, energy imports may be more preferable than solely relying on domestically produced energy sources. For example, if the cost to exploit the oil reserves in the country is as expensive as US$100/bbl, it will be better to import oil, substituting domestically produced oil. This is equally applicable to any other energy source. The national economy may be negatively affected by the high cost of domestically produced energy sources. Therefore, their development should be cautiously carried out, taking these risks into account.

In Myanmar, solid biomass fuels are widely used in households, which is the distinctive characteristic of Myanmar. Firewood is the most economical energy source for ordinary households because of its extremely low price. Nevertheless, it should be replaced by more expensive commercial energy sources to enhance people’s living standards and to nurture industries.

3.4 Environmental Sustainability

No further discussion is required to reiterate an importance to reduce environmental loads. The use of some energy sources could contribute to an increase in energy self-sufficiency. However, if their development causes serious environmental pollution, which is harmful to people’s health, or large-scale environmental destruction, the achievement of self-sufficiency will not be much. After all, fierce opposition amongst the people will force the energy system to be halted.

In terms of environmental loads, two aspects should be assessed: those associated with the installation and operation of facilities. During operation, hydropower, solar PV, and wind power plants produce the lowest environmental loads, whilst coal-fired power plants produce the highest. Hence, the former should be promoted as much as possible, whilst the operation of coal-fired power plants should be discouraged. The assessment of environmental loads to be produced during the construction and installation of facilities is not easy. For instance, the construction of hydropower stations with a dam may require deforestation and relocation of residents living in the areas. On top of that, aquatic life living downstream will be greatly affected. Solar power is seemingly the source of clean energy. The installation of solar panels may pose environmental risks, such as deforestation and spoiling landscapes. Although environmental loads produced by the operation of facilities may be easily measured and evaluated, the assessment of environmental impacts caused by the construction of facilities is not straightforward. It may pose unacceptable risks to the environment. An environment impact assessment should be thoroughly conducted prior to the issuance of a construction permit.

As discussed above, coal-fired power generation using domestically produced coal has advantages, potentially contributing to an increase in access to energy and affordability as well as energy self-sufficiency. Therefore, it can be promoted as one of the effective measures, given diverse challenges Myanmar currently faces. However, in this case, appropriate action should be taken to reduce environmental loads as much as possible. Specifically, high-efficient power generation technology should be adopted, and equipment to prevent air, water, and other pollution should be installed. The country could regret this in the future, unless these measures are properly implemented. For instance, China and India constructed a large number of coal-fired power plants in response to the rapidly growing electricity demand in the country. Now they suffer serious air pollution. Another example is Thailand. Coal-fired power plants were operated without air pollution mitigation measures. As a result, the public lost confidence in them, and the construction of new plants has become extremely difficult. Some are hesitant to introduce environmental measures into a project, which will incur higher initial investment costs. The implementation of proper pollution mitigation measures will, however, reduce external costs, whereby coal-fired power plants can be operated over a long period of time, continuously providing benefits to society.

3.5 Production Outlook

This section will present the outlook of fossil fuel production by taking into account the collected information together with some assumptions.

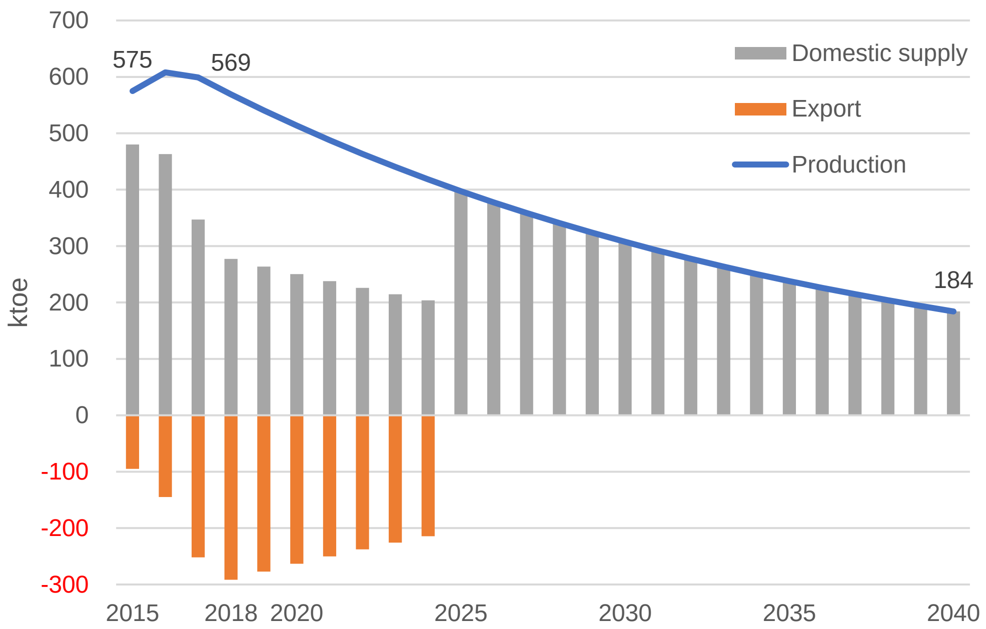
Crude oil

The study adopted the following assumptions.

- Crude oil production will decrease until 2040 at a rate of 5% per annum.
- The production of oil products from existing refineries will decrease until 2040 at a rate of 5% per annum.
- A new oil refinery with a capacity of 40,000b/d will start operation in 2025 and operation of all the existing refineries will be halted in the same year.
- After 2025, all domestic crude oil will be supplied to the new refinery and exports will be stopped.

Under these assumptions, crude oil production is prospected to decline until 2040. Domestic supply will drop up to 2024 but step up in 2025 when the new refinery starts operation (Figure 3.1).

Figure 3.1: Outlook of Crude Oil Production (ktoe)



Ktoe = kilotons of oil equivalent.
Source: IEEJ.

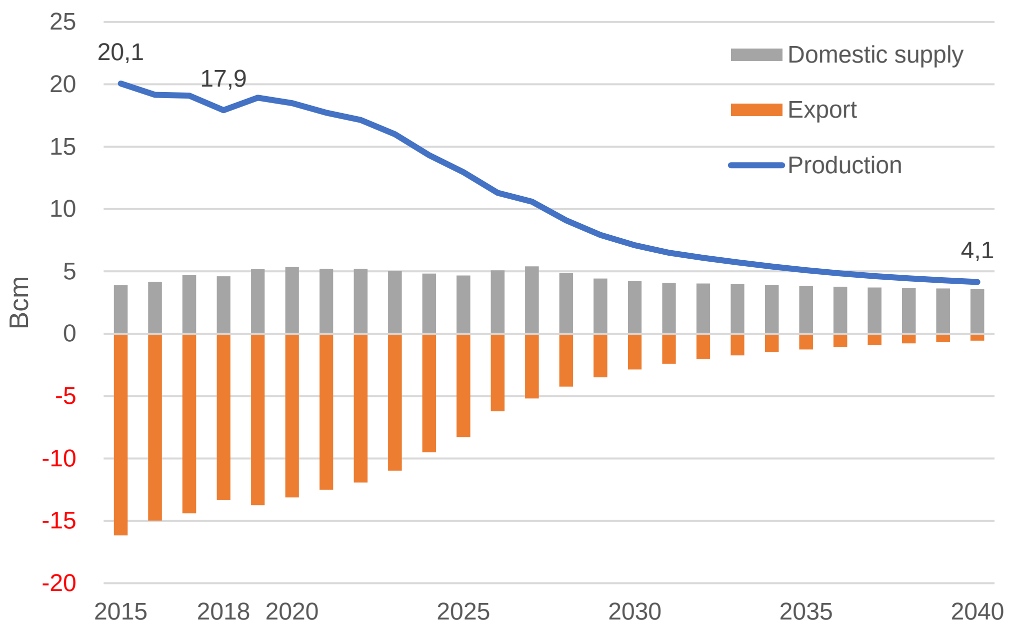
Natural gas

The study adopted the following assumptions.

- Production from existing gas blocks, both offshore and onshore, will slowly decrease.
- Offshore A-6 and M-3 blocks will start production in 2023 and 2025, respectively.
- 50% of the planned production will be achieved in new blocks.
- Export amounts will decrease along with a decline of production.
- No new export contracts will be concluded.

Under these assumptions, even expected new production, total natural gas production will gradually decrease until 2040. What Myanmar can do is to maintain the domestic supply amount by reducing the export amount (Figure 3.2).

Figure 3.2: Outlook of Crude Oil Production (Bcm)



Bcm = billion cubic metre.
Source: IEEJ.

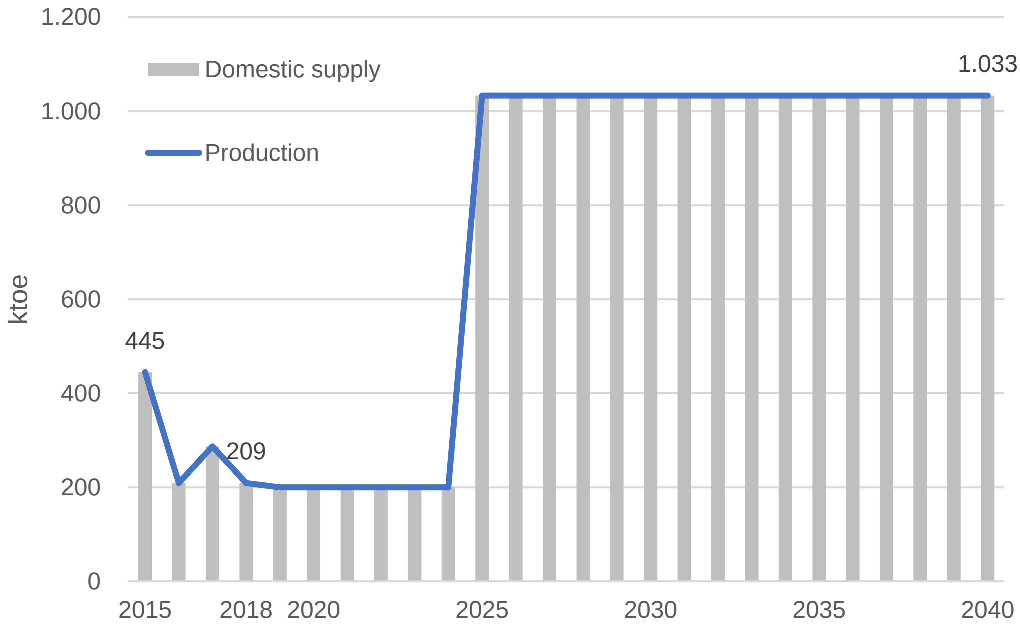
Coal

The study adopted the following assumptions.

- Coal production for existing demand, e.g. Tigyid power plant and industrial use, will keep the pace.
- Two new mine-mouth power plants, Kalewa (540MW) and Keng Tong (25MW), will start operation in 2025.
- No major exports will be made.

Under these assumptions, coal production will jump in 2025 in response to the start of operation of the new coal-fired power plants (Figure 3.3).

Figure 3.3: Outlook of Coal Production



ktoe = kilotons of oil equivalent.
Source: IEEJ.

3.6 Quantify the Best Energy (Power Generation) Mix

Given the discussions above, we will examine an energy mix target in 2040 ,which is considered desirable from the energy security point of view. In the process, access to energy, affordability, and environmental sustainability will be taken into account.

Electricity demand

The fundamental principle of energy security enhancement is to increase self-sufficiency. For this reason, efforts should be exerted to maximise energy efficiency. The ERIA Outlook 2018 presents the Advanced Policy Scenario, which assumes the implementation of more stringent energy-saving measures. A scenario that aims the enhancement of energy security should target the substantial improvement of energy efficiency. Thus, we adopt the total electricity demand outlined in the Advanced Policy Scenario.

Hydropower generation

Hydropower is a domestically produced energy source. It can generate power at a low cost, and associated environmental loads are low. It is one of the ideal energy sources. For this reason, the Myanmar National Energy Policy (MNEP) states that the power generation capacity of hydropower plants will be increased from the actual capacity of

2,361 MW in 2013 to 8,896 MW in 2030. In 2019, it reached 3,225 MW. To attain the 2020 goal, another 1,400 MW should be added, whilst to achieve the 2030 target, it should be increased by approximately 5,600 MW (Table 3.3).

Table 3.3: Power Development Plan up to 2030

	Actual in 2013	Actual In 2019	Plan in 2020	Plan In 2030
Hydropower	2,361 MW	3,255 MW	4,721 MW	8,896 MW
Other renewable	0 MW	40 MW	200 MW	2,000 MW
Gas	1,152 MW	2,217.39 MW	1,969 MW	4,758 MW
Coal	120 MW	120 MW	1,925 MW	7,940 MW
Total	3,633 MW	5,632.39 MW	8,815 MW	23,954 MW

MW = megawatt.
Note: Excludes diesel engine generator.
Source: Actual in 2019 from the Ministry of Energy and Electricity, December 2019.
Others from the National Energy Management Committee, Myanmar National Energy Policy, 2014.

The construction of, especially, a large-scale hydropower station confronts various challenges, such as opposition amongst local residents, lengthy environmental impact assessments, requiring huge investment, difficulty in funding as the result of these problems, and a long construction period. They will likely hamper the efforts of the country to increase the capacity by approximately 5,600 MW within the next 10 years. Cognisant of this, we come up with the 2030 target (8,896 MW) outlined in the MNEP as a realistic target for the increment of power generation capacity by 2040. The capacity factor of hydropower plants is assumed at 50%.

Renewable power generation

Renewable energy sources, which are biomass fuels and wind and solar power, are produced domestically like hydropower. Whilst they produce low environmental loads, power generation costs using these sources are high. These costs will likely decrease gradually as technology develops and the scale of facilities expands. At this moment, they are, however, very high, compared to conventional energy sources (Table 3.4).

Table 3.4: Levelised Cost of Electricity Generation (UScent/kWh)

Domestic gas	8.9	Hydropower	4.7
Imported gas (LNG)	9.6	Biomass	18.9
Domestic coal	5.0	Wind turbine	15.8
Imported coal	7.6	Solar PV	18.9

kWh = kilowatt hour, LNG = liquefied natural gas, PV = photovoltaic.
Source: IEEJ estimate.

Affordability is a key factor to be considered when Myanmar identifies energy sources for its use. As the use of high-cost energy sources will directly affect electricity rates, it is undesirable to promote them in a massive scale. Meanwhile, an off-grid power supply system involving renewable sources has good potential in remote areas where no grid system is available, which should be vigorously explored. Associated costs may significantly decrease in future. To prepare for such development in the future, the government should implement a phased-in increase in the use of renewable sources and closely monitor the price trajectory.

Cognisant of this, we come up with 75% of the 2030 target (2,000MW * 0.75 = 1,500MW) outlined in the MNEP as a realistic target for the increment of power generation capacity by 2040. The capacity factor of power generation plants using renewable sources is assumed 50% on average.[13]

Thermal power generation

The amount of electricity that should be generated by thermal power plants will be 43.84 TWh, which is calculated by subtracting the amount of power produced from hydropower (38.96 TWh) and renewable sources (6.56 TWh) from a total energy demand (89.37 TWh). Because of the reasons listed below, petroleum will not be considered as the energy source of thermal power plants.

- Myanmar is dependent on imported petroleum products. The expansion of oil-fired power stations will pose risks to the energy security of the country.
- As petroleum is the most expensive fossil fuel, its use cannot be recommended from the affordability point of view.
- Assume that in remote areas, diesel generators will be gradually replaced by grid-connected systems, and electrification will be promoted with the use of renewable sources.

Next, the balance between natural gas and coal power generation will be examined. One coal-fired power plant (Tigyit: 120 MW) is currently in operation, whilst two plants (Kalewa: 540 MW and Keng Tong: 25 MW) are in the pipeline. We assume that the two new plants will be constructed as planned because coal-fired power plants using domestically produced coal are superior to other plants in terms of the enhancement of energy security and cost effectiveness. Coalfields are dispersed across the country and relatively small volumes of deposits are found in each. Therefore, we conclude that the operation of mine-mouth power plants will be limited to these three plants. The total amount of electricity generated in these three plants using domestically produced coal will be 4.80 TWh per annum, provided that their capacity factor is 80%.

[13] Weighted average of three renewable energies. Biomass: capacity factor = 80%, kWh share = 50%; wind turbine: capacity factor = 22%, kWh share = 35%; solar PV: capacity factor = 16%, kWh share = 15%.

Natural gas supply to the domestic market in 2040 is assumed at 3.6 Bcm per year. If assume 3.6 Bcm be supplied for power generation, it can generate 20.72 TWh per year, provided that their thermal efficiency is 55% and heat value of natural gas is 9,000 kcal/m^3.

The sum of 4.80 TWh from domestic coal and 20.72 TWh from domestic gas clearly fall short of electricity that needs to be supplied by thermal power plants, 43.84 TWh. That is, the remaining electricity needs, 18.32 TWh, must be generated from imported fuel (Table 3.5).

The LCOE of an imported gas-fired power plant is 1.3 times more expensive than an imported coal-fired power plant. If the priority is to keep electricity rates low, the remaining electricity should come primarily come from imported coal.

Table 3.5: Baseline of an Electricity Supply Structure

Total generation	89.37 TWh
Hydropower	38.96 TWh
Renewable energy	6.56 TWh
Thermal power	43.84 TWh
Domestic coal	4.80 TWh
Domestic gas	20.72 TWh
Imported coal or natural gas	***18.32 TWh***

TWh = terawatt hour.
Source: IEEJ estimate.

3.7 Best Energy Mix

We present two scenarios (Table 3.6). One is a **clean scenario,** which suggests that coal use will be limited to domestic coal with high priority on the reduction of environmental loads. In other words, under this scenario, the imported amount of natural gas becomes larger. The other is a **least-cost scenario,** which pays attention to electricity rates, proposing that natural gas use is limited to a domestically available amount, 3.6 Bcm per annum. In this scenario, the rest of electricity will be generated from imported coal.

Table 3.6: Power Generation Mix Scenario, 2040

Scenario	2016	2040		
	Actual	BAU	Clean	Least cost
Electricity supply (TWh)	20.26 (100%)	89.37 (100%)	89.37 (100%)	89.37 (100%)
Coal	0.16 (0.8%)	0.36 (0.4%)	*4.80* (5.4%)	*23.12* (25.9%)
Oil	0.06	0	0	0

		(0.3%)			
	Natural gas	8.05 (39.7%)	45.68 (51.1%)	<u>*39.04*</u> (43.7%)	<u>*20.72*</u> (23.2%)
	Hydropower	12.13 (59.9%)	42.15 (47.2%)	38.96 (43.6%)	38.96 (43.8%)
	Solar PV, wind, etc.	0.01 (0.0%)	1.18 (1.3%)	6.56 (7.3%)	6.56 (7.3%)
Self-sufficiency of fuel for power generation (%)		100%	72%	80%	80%
Average LCOE (UScent/kWh)		6.40	7.17	7.42	7.01
CO_2 intensity ($g\text{-}CO_2/kWh$)		152	192	203	289

BAU = business as usual, LCOE = levelised cost of electricity, PV = photovoltaic, TWh = terawatt hour.
Notes: Carbon intensity (IEA): coal = 1.122 ton-C/toe, natural gas = 0.641 ton-C/toe.
Values in the clean scenario and the least cost scenario are indicative, thus not necessarily the same with those in Chapter 4.
Sources: Electricity supply in 'actual' and 'BAU' from chapter 4. Others from IEEJ estimate.

Energy security benefit

In both the clean and least-cost scenarios, the sum of electricity generation from indigenous resources, i.e. hydropower, other renewable energies, domestic coal, and domestic gas, would make up 80% of electricity demand in 2040. Despite the lesser use of hydropower than in the BAU scenario, due to the maximum use of domestically available fossil fuel resources and ambition to increase other renewable energies, the two scenarios have advantages in energy security.

Clean scenario

In the clean scenario, most of the electricity supply is split by hydropower and natural gas. It enables Myanmar to curb CO_2 emissions; 30% less than in the least-cost scenario. On the other hand, LCOE will become 16% higher than 2016 and 3% higher than the BAU scenario due to larger use of imported natural gas.

Least-cost scenario

This scenario proposes the greater use of inexpensive imported coal to substitute imported natural gas. It gives a more balanced power generation mix, thus a more resilient structure against possible risks, than the clean scenario. The increase in LCOE rates will be modest, 10% higher than 2016, compared to the clean scenario.

The LCOE becomes even lower than the BAU scenario. On the other hand, in terms of environmental loads, it has higher CO_2 emissions than the clean scenario.

Recommendation

Which scenario could be more preferable to Myanmar? The GDP per capita of Myanmar is projected to be US$5,140 in 2040 (Chapter 4), which is almost equivalent to Thailand (US$6,128) and Indonesia (US$4,131) in 2017. Low electricity rates have great significance in Thailand's and Indonesia's policies. Therefore, it is not difficult to imagine that affordability will be still a key factor in 2040 for Myanmar to take into account in deciding the best energy mix target. In view of this, the study recommends the **least-cost scenario**, which places high priority on low electricity rates, as the most viable option for Myanmar to take.

Chapter 4

Outlook for the Energy Supply Security Scenario

The outlook for the energy supply security (ESS) scenario was based on the business as usual (BAU) scenario of the Myanmar Energy Outlook 2020 (ERIA, 2020). The outlook analyses the future energy demand and supply of Myanmar until 2040 using the national historical data 2000–2016 from the Myanmar National Energy Statistics 2019 (ERIA, 2019).

The basic assumptions of the BAU scenario are the same as for the ESS, which are a population growth rate of 0.7% per year and a GDP growth rate of 6.3% over the 2016–2040 period. The difference with the BAU scenario is that the ESS scenario considers the following conditions discussed in chapter 3. These are:

- *Fossil fuel production level*

	2020	**2025**	**2030**	**2035**	**2040**
Crude Oil (ktoe)	514	397	307	238	184
Natural Gas (Bcm)	50.6	35.5	19.4	14.0	4.1
Coal (ktoe)	200	1033	1033	1033	1033

- *Biomass level in total primary energy supply (TPES)*

	2020	**2025**	**2030**	**2035**	**2040**
Biomass (Mtoe)	10.40	10.76	11.12	11.36	11.52

- *Power generation mix in 2040*

- Coal : 26%
- Natural gas : 23%
- Hydro : 44%
- Other Renewable : 7%

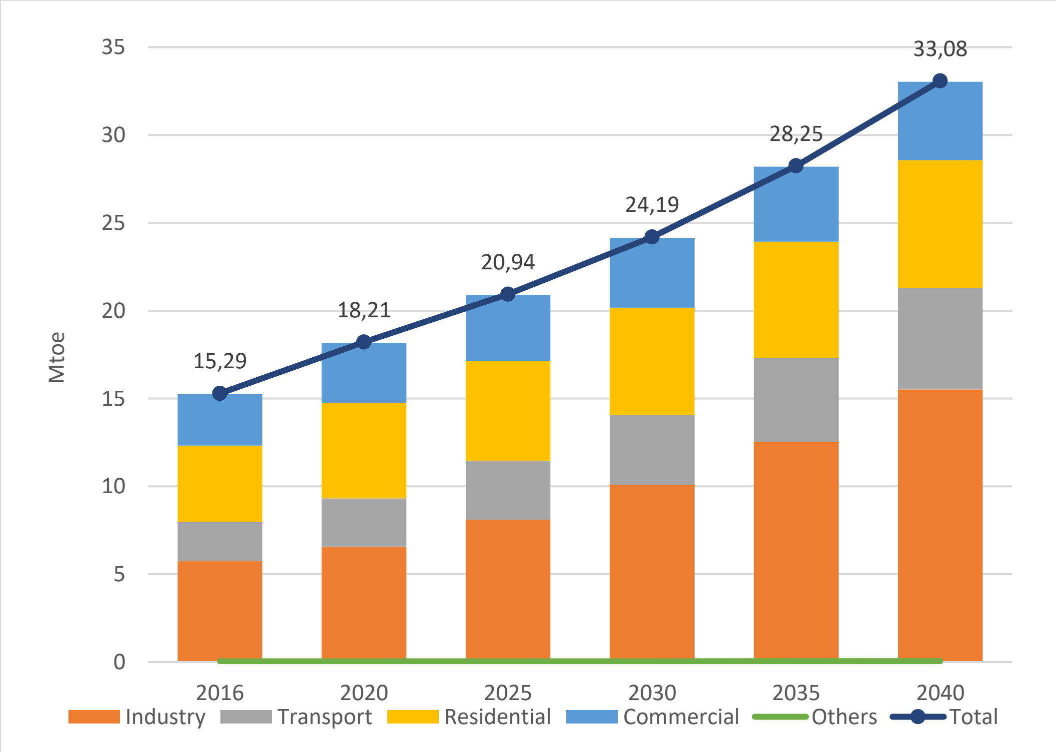
This chapter provides the results of the simulation runs for the ESS scenario, including the impact on CO_2 emissions and energy security indicators. The Energy Balance Table for the ESS scenario is shown in Table 4.1, whilst the BAU scenario is shown in Table 4.2.

4.1 Final Energy Consumption

Total final energy consumption (TFEC) of Myanmar is projected to increase at an average rate of 3.3% per year from 15 million tons of oil equivalent (Mtoe) in 2016 to 33 Mtoe in

2040 (Figure 4.1). Most of the demand will be from the industry sector and the growth in demand will be the fastest at 4.2% per year over the planning period. The transport sector demand will grow slightly slower at 4% per year, whilst the residential and commercial sector demand will grow at 2.2% and 1.8% per year, respectively.

Figure 4.1: Final Energy Demand by Sector



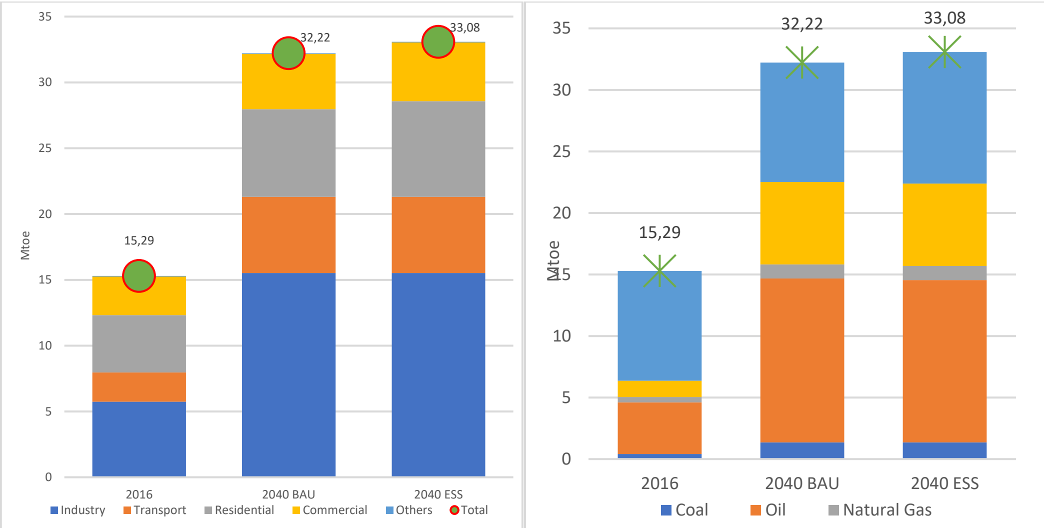
Mtoe= million tons oil equivalent.
Source: Authors' calculation.

By type of fuel, electricity consumption will grow the fastest, at 7% per year followed by coal at 5.1% per year, oil at 4.9% per year, and natural gas at 4.2% per year. Electricity, coal, and natural gas demand growth contributed to the rapid increase of the industry sector demand. In the case of oil, the majority of the demand is in the transport sector, especially road transport. Growth in the number of cars and motorbikes will contribute to the increase in oil demand in the future.

Biomass is mainly consumed by the residential sector for cooking purposes. As more households shift from biomass to LPG and electricity, and more efficient biomass stoves become more available, the increase in biomass demand will be small. In addition, industry will also use more efficient heating fuel, so that biomass will be replaced by diesel. In the BAU scenario, biomass will grow at an average of 0.3% per year over the 2016–2040 period.

In case of the ESS scenario, biomass supply is assumed to reach around 11.5 Mtoe by 2040. This amount is almost 70% of the 17 Mtoe total potential of biomass energy in 2017 (Tun and Juchelková, 2019). Consequently, the biomass demand under the ESS scenario has a higher rate of increase than the BAU scenario. In this case, biomass demand will increase at an average rate of 0.6% per year. Since more biomass is available for use, the ESS scenario will have smaller LPG demand than in the BAU scenario. Figure 4.2 shows the comparison of final energy demand in the BAU scenario and the ESS scenario by fuel and by sector.

Figure 4.2: Final Energy Demand Comparison



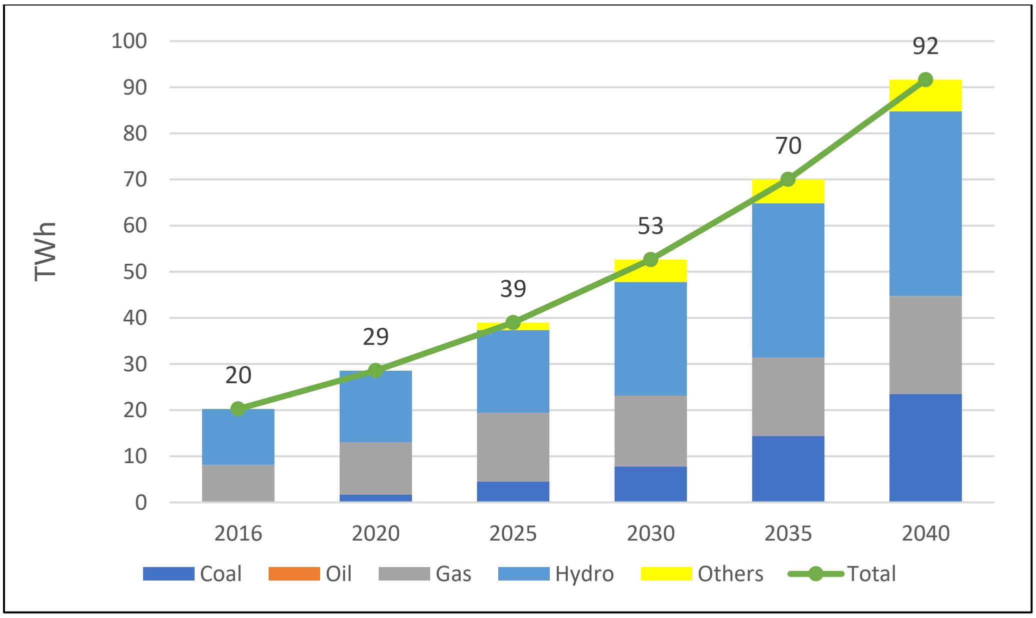
BAU = business as usual, ESS = energy supply security, Mtoe = million tonnes of oil equivalent.
Source: Authors' calculation.

a. Power Generation

Based on the energy statistics, Myanmar's export of electricity in 2016 was 205 ktoe (2.8TWh). In the BAU scenario as well as the ESS scenario, this amount is sustained until 2040. Thus, electricity generation will be able to meet both domestic and export demand. Transmission, distribution, and own use also need to be included in estimating electricity generation.

In the BAU scenario, total power generation will increase from 26 Mtoe in 2016 to 89 Mtoe in 2040 at an average growth of 6.4% per year (Figure 4.3). In the ESS scenario, growth is slightly higher at 6.5% per year. Electricity imports are still possible in the BAU scenario if domestic supply is not sufficient to meet demand. In the ESS scenario, the assumption was to exclude electricity imports in the model to enhance the security of energy supply.

Figure 4.3: Power Generation Mix ESS



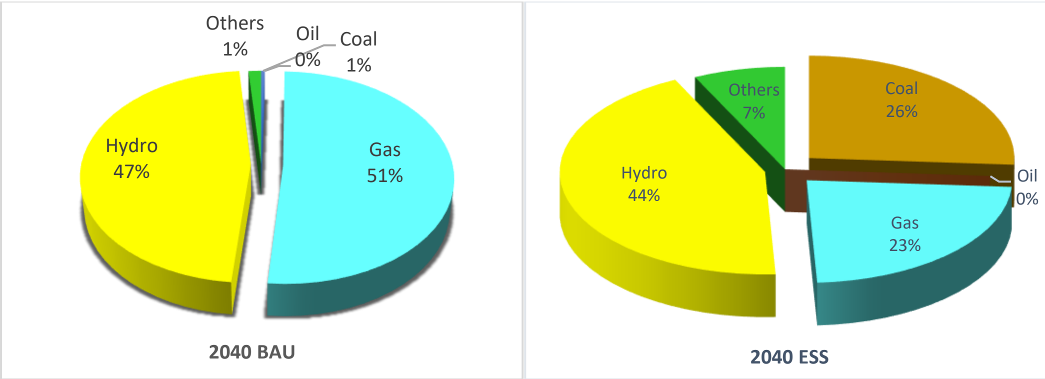
ESS = energy supply security, TWh = terawatt hours.
Source: Authors' calculation.

Based on the assumed generation mix for the ESS scenario, renewable energy (hydro plus other renewable) will be dominant in power generation at 51%, whilst the remaining will come from fossil fuel generation. There will be no oil-based generation assumed for the future.

The hydro share in total generation has been assumed to be 44% in 2040, whilst other renewables are around 7%. In the BAU scenario, generation from hydropower plants will be higher (47%). As a result, electricity generation from hydropower plants in 2040 will be lower in the ESS scenario as compared to the BAU scenario, 40 TWh versus 42 TWh, respectively. Other renewable share, on the other hand is lower in the BAU scenario (1.3%) with total generation of 1.2 TWh. Electricity generation from other renewables reaches 6.6 TWh in the ESS scenario, covering solar PV, wind, and biomass power plants. No generation from biomass plants was assumed in the BAU scenario since no plan existed for its development.

In the case of generation from fossil power plants, the share in total generation for coal-fired power plants in the ESS scenario was assumed to reach 26% by 2040, whilst natural gas was around 23%. In the BAU scenario, natural gas plants share in total generation will be 51% of the total generation, whilst coal was small. The development of new coal-fired power plants, particularly with large capacity, has raised opposition from environmental organisations as well as local and regional organisations. Based on this, no additional large coal-fired power plants have been assumed in the BAU scenario. Figure 4.4 shows the generation mix in ESS as compared to the BAU scenario for 2040.

Figure 4.4: Power Generation Mix Comparison with BAU in 2040



BAU = business as usual, ESS = energy supply security.
Source: Authors' calculation.

b. Primary Energy Supply

Myanmar's primary energy supply in the ESS scenario will be 40 Mtoe by 2040 with oil having the largest share of 33% followed by biomass at 29% (Figure 4.5). Although the share of these fuels in TPES are high, the growth over the 2016–2040 period is much slower than coal. Coal supply will grow at an average rate of 12.5% per year, whilst the rate of oil and biomass will be 4.9% and 1% per year, respectively.

As explain in the power generation section, the rapid growth of coal supply will be due to the increase in the use for power generation. Coal supply increase from 0.4 Mtoe in 2016 to 7 Mtoe in 2040. The ESS scenario coal supply in 2040 will be 4.5 times higher than in the BAU scenario.

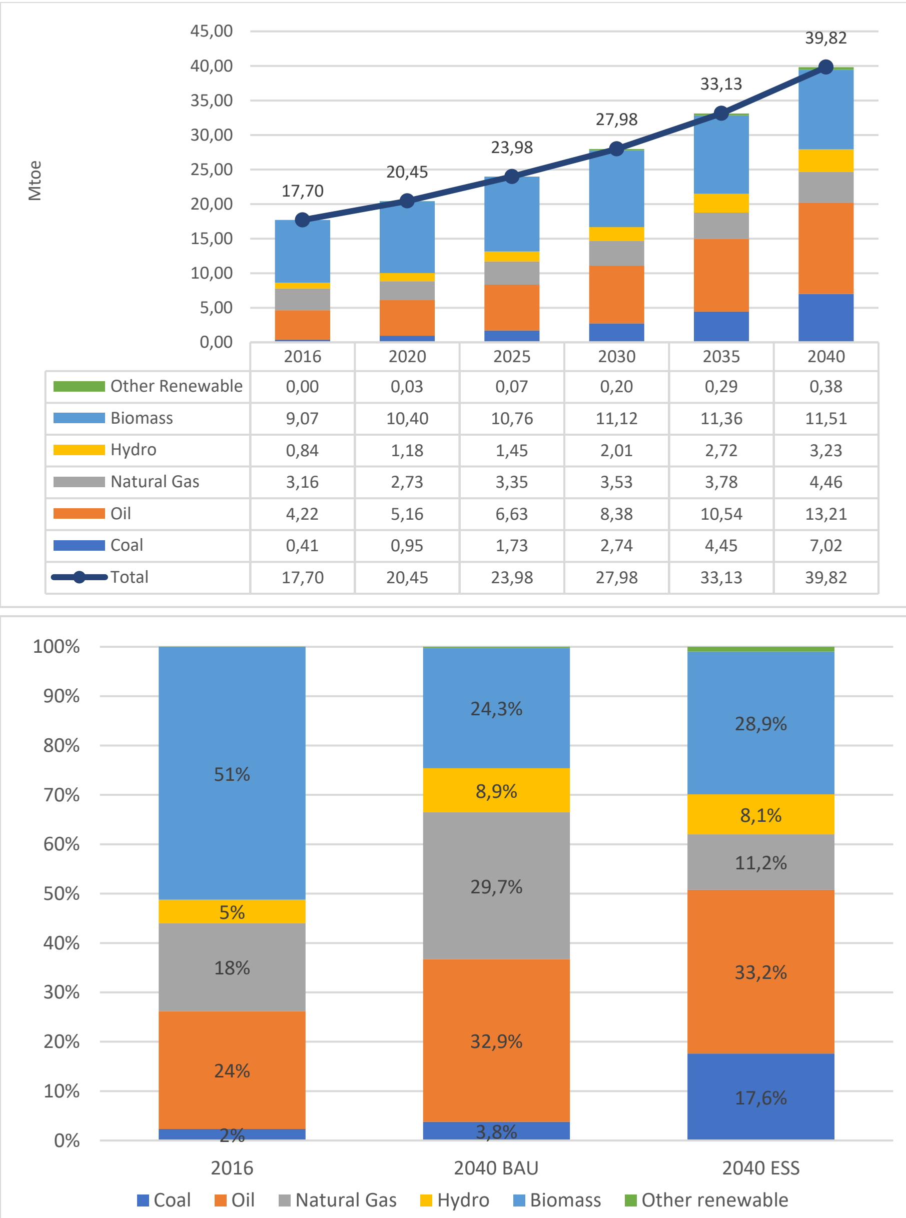
Oil supply in the ESS scenario will slightly be lower than the BAU scenario because the substitution from biomass to oil was assumed lower in the residential and commercial sector. Use in the transport sector remains the same between the ESS and BAU scenarios. Thus, the saving in oil supply between the ESS and BAU scenarios will only be around 0.1 Mtoe in 2040 (around 1% reduction of the BAU supply) 1% in 2040.

In case of biomass, the supply in the ESS scenario has been assumed to reach around 70% of the total potential by 2040. As a result, the biomass supply will increase by almost 17% in 2040 as compared to the BAU scenario. As discussed previously, the differences will mainly be in the residential sector and the power sector. In the BAU scenario, no assumption was made for biomass use in power generation, whilst in the ESS scenario, it was possible to ensure supply reached the target assumed for the scenario.

Natural gas supply, on the other hand, will be lower than in the BAU scenario because the ESS scenario assumes lower use for generating electricity. The average growth of natural gas supply in the ESS scenario will be 1.5% per year whilst in the BAU scenario, the growth was 5.7% per year. The reduction in natural gas supply of the ESS scenario in 2040 as compared to the BAU scenario will be around 63%.

Similarly, for hydropower, the supply in the ESS scenario will be growing more slowly than in the BAU scenario, 5.1% per year compared to 5.3% per year. For other renewables (solar and wind), the growth in the ESS scenario will be faster than the BAU scenario due to the increase installation of solar PV. The average growth of renewable supply will almost reach 29% per year whilst in the BAU scenario, it will be 22%. The renewable supply in 2040 for the ESS scenario will almost be four times higher than the BAU scenario. Figure 4.5 shows TPES of the ESS scenario and the comparison for the BAU scenario in 2040.

Figure 4.5: Primary Energy Supply of ESS and Comparison with BAU



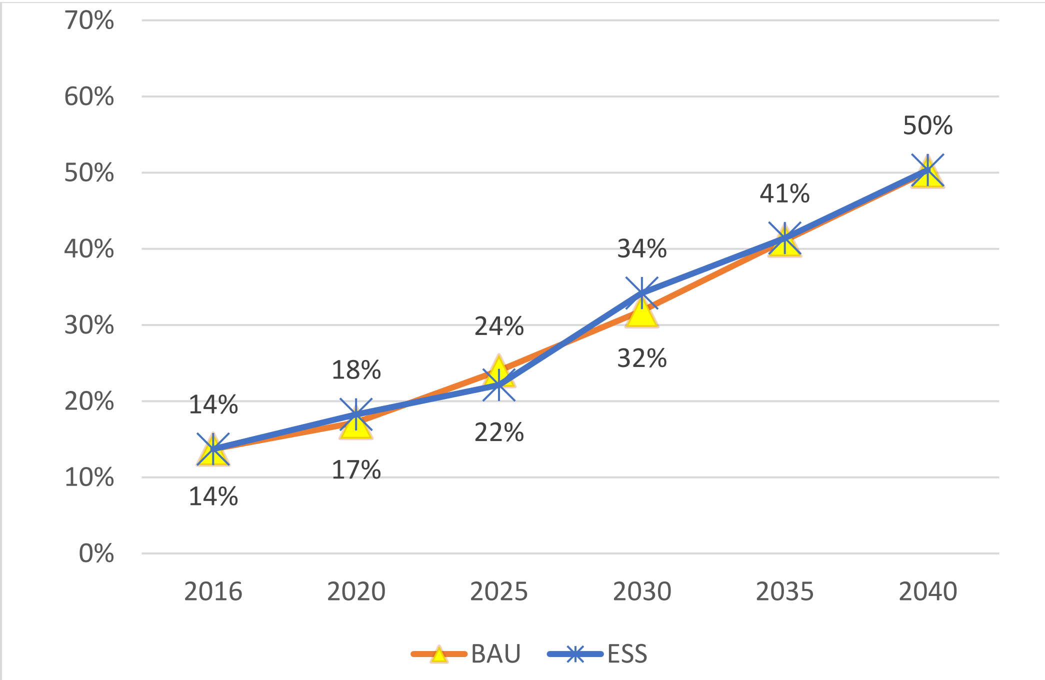
	2016	2020	2025	2030	2035	2040
Other Renewable	0,00	0,03	0,07	0,20	0,29	0,38
Biomass	9,07	10,40	10,76	11,12	11,36	11,51
Hydro	0,84	1,18	1,45	2,01	2,72	3,23
Natural Gas	3,16	2,73	3,35	3,53	3,78	4,46
Oil	4,22	5,16	6,63	8,38	10,54	13,21
Coal	0,41	0,95	1,73	2,74	4,45	7,02
Total	17,70	20,45	23,98	27,98	33,13	39,82

BAU = business as usual, ESS = energy supply security, Mtoe = million tons of oil equivalent.
Source: Authors' calculation.

c. Energy Security Indicator

As explained in section 2.4, import dependency ratio (IDR) is defined as the ratio between the total energy import and the total energy supply. In the ESS scenario, the import dependency ratio increases from 14% in 2016 to 50% in 2040 (Figure 4.6). Compared to the BAU scenario, this ratio is similar, indicating that the assumption for the ESS scenario is not sufficient to decrease the ratio. Oil is the main import fuel, and the transport sector has the largest share in TPES for both the BAU and ESS scenarios. Natural gas imports are more in the BAU scenario than the ESS scenario, but in the ESS scenario, coal imports increase significantly as natural gas imports decrease. The increase of biomass use and renewable must be higher than assumed in the ESS scenario.

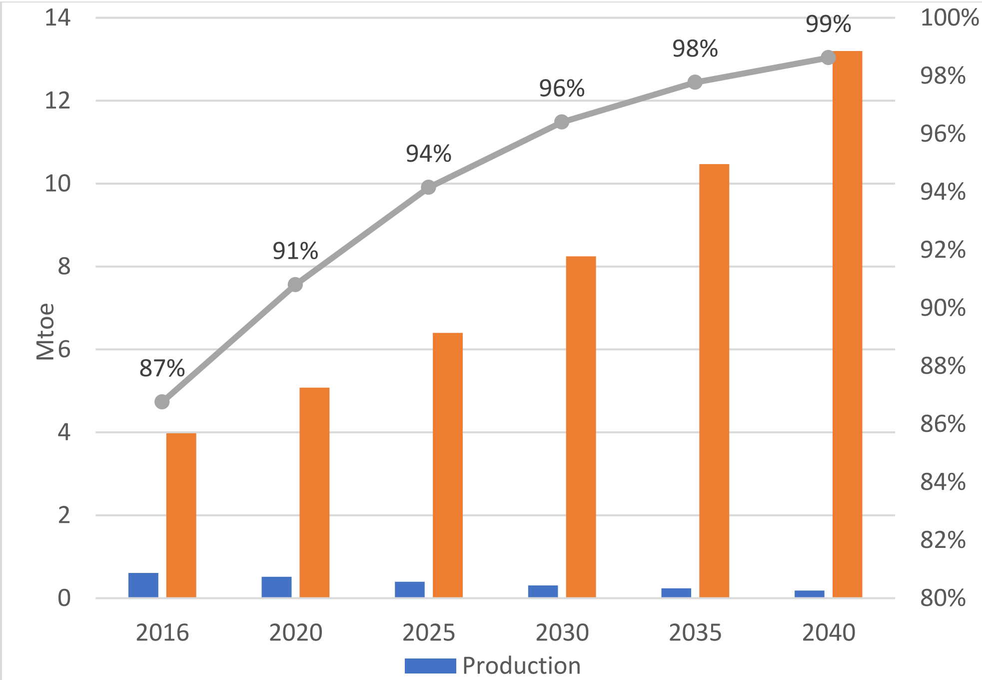
Figure 4.6: Import Dependency Ratio BAU and ESS



BAU = business as usual, ESS = energy supply security.
Source: Authors' calculation.

Oil dependency ratio was already 87% in 2016. Since oil demand increases at almost 5% per year over the 2016–2040 period, whilst production is declining, the imports will increase more than threefold by 2040 in the ESS and BAU scenarios. The IDR for oil in the ESS scenario will increase to 99% in 2040 (Figure 4.7).

Figure 4.7: Import Dependency Ratio for Oil

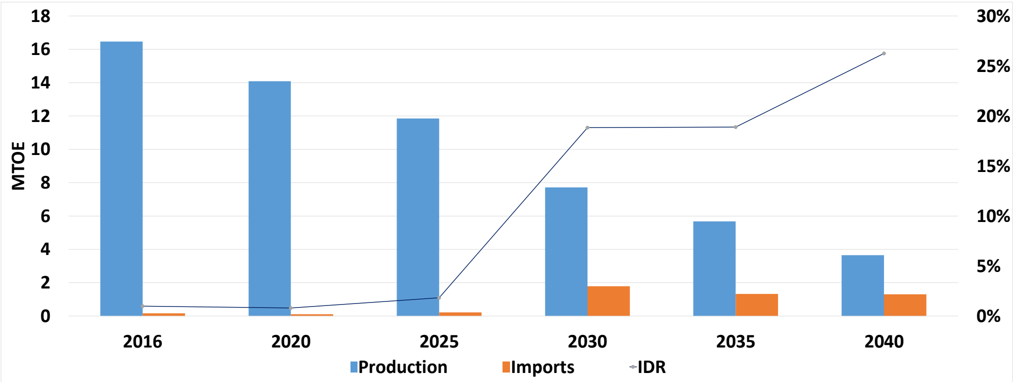


IDR = import dependency ratio, Mtoe = million tons of oil equivalent.
Source: Authors' calculation.

The import dependency ratio for oil can be smaller if Myanmar increases the use of alternative fuels such as electricity or biofuels in the road transport sector. In the case of electric vehicles, electricity demand will increase. In the ESS scenario, the option will be by using more hydro and other renewables to significantly decrease the import dependency ratio. If gas or coal generation, it will again impose imports since the domestic supply of these fuels will also be declining in the future. Both electric vehicles and biofuel options were excluded in the ESS scenario since more data and information will be required to estimate the substitution potential.

In the case of natural gas, Myanmar has exported natural gas to Thailand since 2000 and to China since 2014 with a total amount of around 75% of total production (ERIA, 2019). Since production is declining and domestic demand is increasing, Myanmar plans to import LNG to meet domestic demand, whilst maintaining current export contracts. Chapter 3 estimated natural gas production to decline at an average rate of 6% per year reaching 4.1 billion cubic meters (Bcm) in 2040. Assuming the same declining rate for production and export, the projected natural gas import in ESS will be 0.88 Mtoe in 2040. This will result in an import dependency ratio of 26% for natural gas in 2040 (Figure 4.8). Although not as high as oil, the ratio is increasing from the 2016 level (1%).

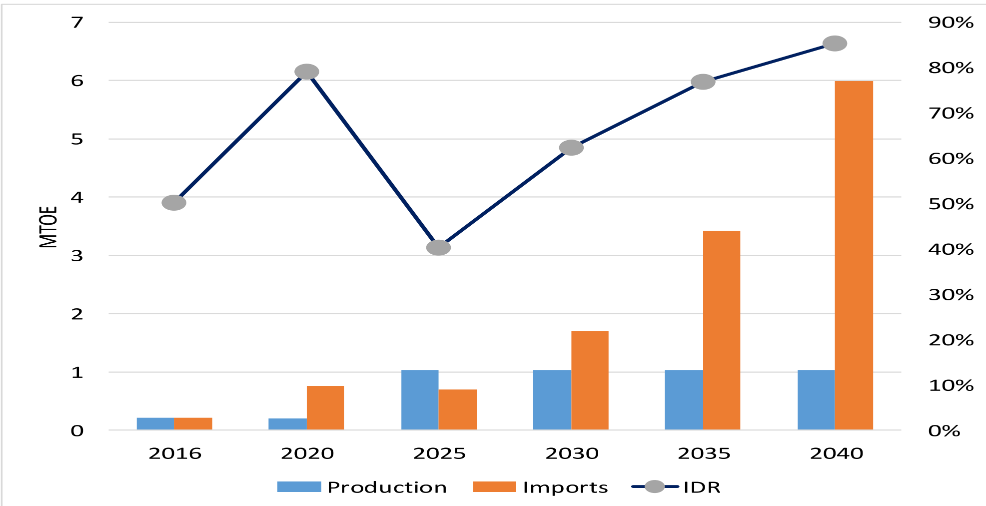
Figure 4.8: Import Dependency Ratio for Natural Gas



IDR = import dependency ratio, Mtoe = million tons of oil equivalent.
Source: Authors' calculation.

Coal imports will increase as demand for industry and power generation continue to grow. The ESS applies the same production level and power generation share as explained in chapter 3. As a result, imports of coal in ESS increase to around 6 Mtoe in 2040 from 0.2 Mtoe in 2016. The import dependency ratio for coal increases from 50% in 2016 to 85% in 2040 (Figure 4.9). In 2025. Myanmar increase the coal production in 2025, resulting in a decline in the ratio for 2025. Production levels maintain at the 2025 level until 2040 but demand continues to increase. Consequently, the ratio increases again since 2025.

Figure 4.9: Import Dependency Ratio for Coal



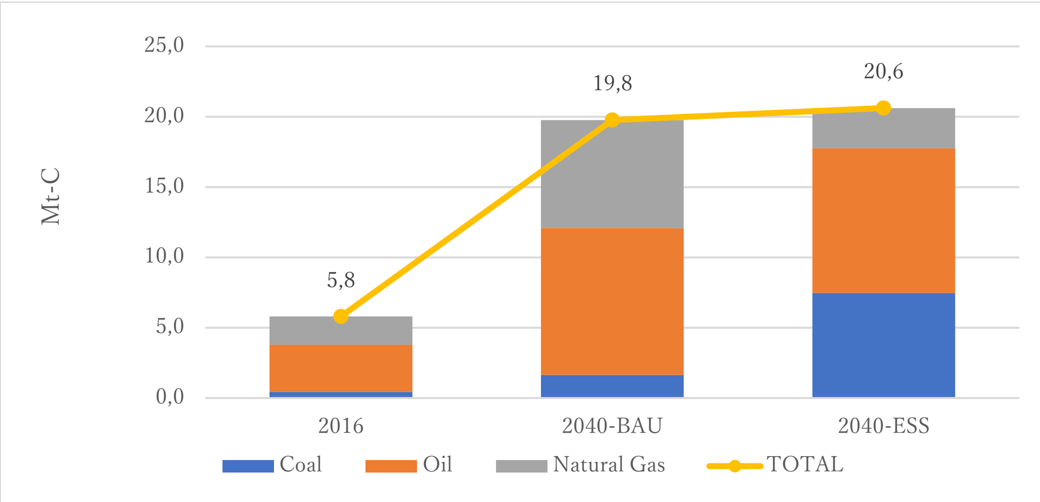
IDR = import dependency ratio, Mtoe = million tons of oil equivalent.
Source: Authors' calculation.

d. Impact on CO_2 Emissions

The ESS scenario will have more coal and less natural gas in the total TPES compared to the BAU scenario. The oil supply will be similar in the BAU and ESS scenarios. As a result, CO_2 emissions of the ESS scenario will be higher than the BAU scenario since the emissions factor of coal is higher than oil and gas. The CO_2 emissions of ESS 2040 will be 21 million ton-c (in terms of carbon content) or about 75 million ton-CO_2 (Figure 4.10). Compared to the BAU scenario, the CO_2 emissions of the ESS scenario will be 4% higher in 2040.

Oil combustion will still be the major source of CO_2 emissions since its share in TPES will still be higher (33% in 2040) than that of coal and natural gas. The share of CO_2 emissions from oil, however, will decrease from 56% in 2016 to 53% in 2040 because of the increasing use of coal in power generation and industries. The CO_2 emissions from combustion of coal increase from 0.4 to 7.5 million ton-c over the 2016 to 2040 period. CO_2 emissions from natural gas will increase from 2 to 3 million ton-c over the same period.

Figure 4.10: CO_2 Emissions Comparison in 2040 of BAU and ESS



BAU = business as usual, ESS = energy supply security, Mt-C = million tons of carbon equivalent.
Source: Authors' calculation.

e. Overall evaluation of ESS scenario

Table 4.1 shows a comparison between the BAU and ESS scenarios in terms of selected energy indicators. The ESS scenario will shift to more use of coal and renewables such as solar PV and biomass. As a result, there will be a large saving in domestic natural gas consumption. Natural gas demand in the ESS scenario will only be 4.46 Mtoe in 2040 compared to the 12.03 Mtoe in the BAU scenario, reducing significantly the production of natural gas from 8.01 Mtoe in the BAU scenario to 3.64 Mtoe in the ESS scenario.

The increased use of coal in the ESS scenario will be more than fourfold of the BAU scenario by 2040, from 1.54 Mtoe in BAU to 7.02 MTOE in ESS. Since the existing coal supply chain in Myanmar is not sufficient to bring coal from the mining sites (north) to the demand sites (south), the ESS scenario suggests imports of coal to meet the increasing demand. Considering that coal sources are more scattered in the world (not like oil that is concentrated in the Middle East), this import dependency of coal is less serious in terms of the country's supply security due to the diverse coal supply sources in the world.

The ESS scenario will also increase the use of solar PV systems because of the wider field potential for solar PV generation in the central area of Myanmar and the continuous declining trend in the price of solar PV systems. In the case of hydropower, the ESS scenario was supposed to increase hydropower generation because it is an affordable and clean energy source. Considering the strong public complaints in the construction of hydropower plants, the ESS scenario assumes the same hydropower generation level as in the BAU scenario.

As a conclusion, the ESS scenario is a better energy security policy than BAU according to the following reasons:

a. Import dependency is the same level of BAU
b. Share of domestic and affordable energy per TPES is much higher than BAU
c. Myanmar will continuously export natural gas to Thailand and China because proven reserves of natural gas will be maintained due to the saving in domestic use
d. Imports of oil will be slightly lower due to the continuous use of biomass for cooking in households
e. CO_2 emissions will be a little bit bigger than in the BAU scenario, although larger coal consumption has been assumed

Table 4.1 Summarised Comparison Between BAU and ESS

ITEM		BAU	ESS
1. Energy Share per TPES			
	Coal	3.8%	17.5%
	Gas	29.7%	11.1%
	Oil	32.9%	33.0%
	Hydropower	9.0%	8.6%
	Renewable	0.2%	0.9%
	Biomass	24.3%	28.8%
	Total	100.0%	100.0%
2. Import Dependency			
	Overall	50.1%	50.3%
	Coal	45.4%	85.3%
	Natural Gas	53.1%	26.3%
3. Share of Affordable Energy (Coal + Hydropower + Biomass)		37.1%	55.1%
4. Oil Import (Mtoe)		13.1	12.9
5. CO_2 Emissions (Mt-C)		19.8	20.6

BAU = business as usual, ESS = energy supply security, Mtoe = million tons of oil equivalent, Mt-c = million tons carbon equivalent, TPES = total primary energy supply.
Source: Authors' calculation.

Table 4.2 Energy Balance Table 2040, Energy Supply Security (ESS) Scenario (in Mtoe)

	Coal	Natural Gas	Crude Oil	Hydropower	Renewables	Biomass	Electricity	Oil Products	Total
Production	1,03	3,64	0,18	3,43	0,38	11,51	-	-	20,20
Imports	5,99	1,30	0,26	-	-	-	-	12,94	20,48
Exports	-	-0,48	-	-	-	-	-0,21	-0,17	-0,86
Total Primary Supply	7,02	4,46	0,44	3,43	0,38	11,51	-0,21	12,77	39,82
Coal production	-	-	-	-	-	-	-	-	-
Crude oil production	-	-	-	-	-	-	-	-	-
Natural gas production	-	-	-	-	-	-	-	-	-
Charcoal processing	-	-	-	-	-	-0,16	-	-	-0,16
Refinery	-	-	-0,44	-	-	-	-	0,42	-0,02
Electricity generation	-5,66	-3,31	-	-3,43	-0,38	-0,66	7,88	-	-5,58
Loss and own use	-	-	-	-	-	-	-0,98	-	-0,98
Total Transformation	-5,66	-3,31	-0,44	-3,43	-0,38	-0,82	6,90	0,42	-6,74
Industry	1,36	0,26	-	-	-	3,34	2,36	8,20	15,52
Transport	-	0,88	-	-	-	-	-	4,90	5,78
Residential	-	-	-	-	-	4,32	2,91	0,04	7,28
Commercial	-	-	-	-	-	3,03	1,41	0,02	4,46
Others	-	-	-	-	-	-	0,02	0,03	0,05
Total Demand	1,36	1,15	-	-	-	10,69	6,70	13,19	33,08

Source: Authors' calculation.

Table 4.3 Energy Balance Table 2040, Business as Usual (BAU) Scenario (in Mtoe)

	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	0	0	22,95
Imports	0,84	9,02	0	-	-	-	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

Source: Authors' calculation.

Chapter 5

Action Plans for Achieving the Energy Supply Security Scenario

Chapter 5 presents recommended measures for energy security enhancement. The measures can be grouped into two: one is accompanied by the structural changes in energy supply and demand, and the other group is the measures for emergency cases. We will discuss each group of measures in the following order.

Action plan for structural change	1.	Improve energy efficiency
	2.	Create well-balanced energy and/or import mix
	3.	Improve environmental sustainability of coal-fired power plants
	4.	Utilise LNG as a competitive fuel
	5.	Cleaner use of traditional biomass
Action plan for emergency case	1.	Contingency plan and demand restriction
	2.	Oil stockpile
	3.	Preserve gas and coal resources as a natural stockpile
	4.	Develop the last-resort power plant

Source: Authors.

5.1 Actions Plan for Structural Change

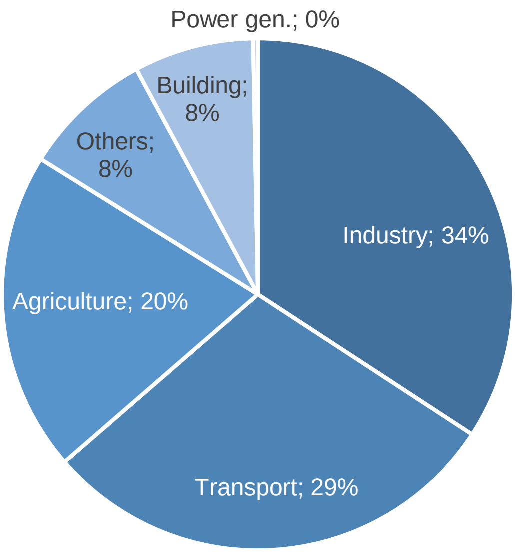
5.1.1 Improve energy efficiency

Every measure is required in all the sectors in order to reduce energy demand, hence the energy import requirement.

Oil

A reduction in oil imports is particularly important from the perspective of energy security because its self-sufficiency rate is the lowest. Industry and transport each account for about one-third of the total demand for oil (Figure 5.1). They are the two largest consumers of oil. Accordingly, measures for these two sectors will have the strongest impacts.

Figure 5.1: Structure of Oil Demand, 2017



Note: 'Others' consist of 'fishing' and 'final consumption not elsewhere specified'.
Source: IEA (2019a), World Energy Balances 2019.

Possible measures for the two sectors are listed in Table 5.1.

Table 5.1: Energy Efficiency Measures for Industry and Transport Sectors

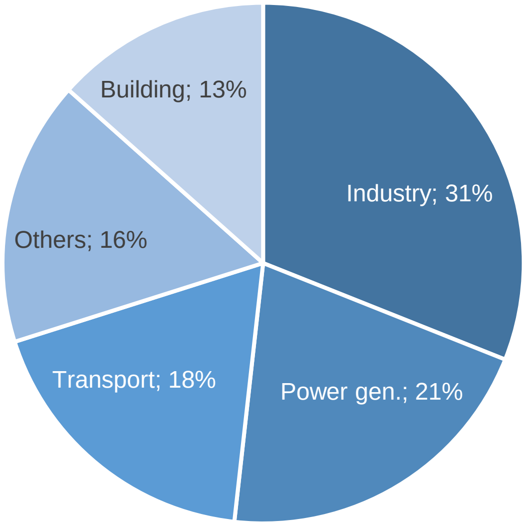
Industry	a.	Request energy consuming company to appoint a certified energy manager
	b.	Request energy consuming company to submit an annual energy report (energy efficiency target and achievement)
	c.	Provide energy efficiency learning programme
	d.	Provide energy audit service or invite an energy service company
	e.	Set a minimum energy performance standard (MEPS) for major industrial equipment
	f.	Change to cost reflective oil price
Transport	a.	Set MEPS for vehicle
	b.	Preferred tax rate for high efficiency vehicle
	c.	Periodical vehicle maintenance certificate
	d.	Request freight transport company to submit an annual energy report
	e.	Change to cost reflective oil price
	f.	Develop mass rapid transport mode, e.g. train or bus
	g.	Parking regulation that disincentivises passenger car

Source: Authors.

Other sectors

Industry occupies the largest share in the consumption of total energy, followed by power generation, transport, others, and the building sector (Figure 5.2).

Figure 5.2: Structure of Total Energy Consumption, 2017



Notes: Building: Sum of residential sector and commercial/public sector. It excludes consumption of biofuel and waste. 'Others' consist of 'agriculture/forest', 'fishing', and 'final consumption not elsewhere specified'.
Source: IEA (2019a), World Energy Balances 2019.

The industry and transport sectors consume mostly oil as sources of energy, the energy efficiency improvement measures for which are described above. Energy efficiency improvement measures for the power generation and building sectors are shown in Table 5.2.

Table 5.2: Energy Efficiency Measures for Power Generation and Building Sectors

Power generation	a.	Request power generator to adopt high efficiency technology
	b.	Set a maximum allowable degradation rate of thermal efficiency from design efficiency
	c.	Replace inefficient transformer
Building	a.	Set MEPS for heat insulation of building
	b.	Set MEPS for major appliances
	c.	Preferred tax rate for high efficiency building and appliances
	d.	Energy efficiency education in schools

Source: Authors.

5.1.2 Create well-balanced energy and/or import mix

The diversification of energy to use and the decentralisation of import countermeasures are important, as mentioned earlier. The government should nurture an environment for business and the people to take appropriate actions to achieve a well-balanced energy and/or import mix.

Establish, at least 10 years long, long-term plan

Changing the energy and/or import mix will require more than 1 decade. It is therefore necessary to establish long-term plans for a time span of 10 years or longer. The national and international energy situations and technologies will keep changing in the course of the long-term plan, but the commitment to achieving an optimum energy mix must not change. However, at the same time, it is not realistic to adhere to the share percentages of each energy component because of changes in surrounding conditions and technology. The energy mix targeted in the plan should be regarded as an overarching guide for decision making in specific policies and activities.

Share the principle of long-term plan amongst stakeholders

Energy supply and consumption involve many stakeholders. A good deal of consensus and concerted actions will help achieve the desired energy mix more efficiently. It is the responsibility of the government to not only formulate an energy mix plan, but also to broadly communicate its importance. Considering that the public sector is deeply involved in energy supply in Myanmar, consensus amongst government agencies and with energy suppliers is important. Already from the initial stage of plan formulation, public hearings and other measures should be carried out to enhance engagement of stakeholders.

Implement policies to guide the society

If the choice of energy type is left to the market, the use of inexpensive energy will increase and the desired mix will become unattainable. The same is true about the import mix. If left to market principles alone, dependence on cheap energy supply sources will be allowed to go up. Hence policy intervention is a must. Policy measures to guide the nation to the desired mix include the following:

- Set up targets and mandate compliance
- Set out a ceiling for each energy type and/or each supplier country
- Subsidise use of certain types of energy
- Make adjustments in taxes (lower rate for encouragement and higher rate for curbing)

5.1.3 Improve environmental sustainability of coal-fired power plants

To attain the recommended energy mix goals this study recommends the existing Tigyit coal-fired power plant needs to be continued and the two new projects (Kalewa and Keng Tong) must be steadily advanced. In addition, new projects based on imported coal must be realised.

One possible major impediment for the successful project implementation is opposition from the local communities. It must be reiterated that project acceptance by the local citizens is extremely important. Unless sufficient attention is paid in this regard, no successful project completion or stable plant operation will be possible. Environment protection measures must be implemented to the best possible extent to prevent local opposition. Specific actions will include:

- Review and upgrade the environmental standards for coal-fired power plants and apply such upgraded standards to all new plants.
- Review and upgrade the environmental assessment method for coal-fired power plants and apply such upgraded standards to all new plants.
- Study upgrade of environment protection measures at the Tigyit coal-fired power plant.
- Promote public relations (political importance of coal-fired power plants, environment protection measures).

In order to gain better acceptance, the involvement of local residents through the entire process of plant construction to operation will be needed to enhance their engagement and sense of participation.

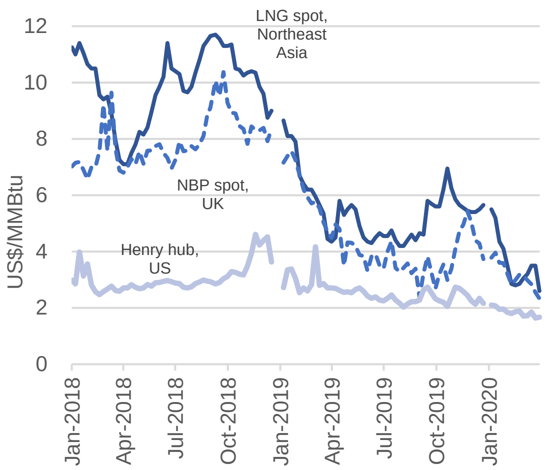
5.1.4 Utilise LNG as a competitive fuel

The recommended energy mix is based on the assumption that Myanmar will have kept supply of 10.8 Bcm of domestic natural gas in the year 2040. If this assumption is incorrect, the significance of using natural gas for energy self-sufficiency enhancement will be diminished and the energy and/or electricity mix picture will be altered substantially. It is necessary therefore to ensure the needed investment be made for the development of new natural gas resources. Needless to say, competitive terms and conditions should be offered to attract foreign investors in comparison to other gas producing countries.

If no new domestic resources are developed, is it better to exclude natural gas at all from consideration? The answer is no. As mentioned earlier, a well-balanced mix is key to attaining energy supply security. Even if domestic supply cannot be relied on, the use of natural gas as a component of the mix should be continued.

Imports of natural gas, particularly LNG, have perceived to be a costly option, especially in comparison to coal. It should be noted however that since 2019 the LNG spot price has been at unprecedentedly low levels because new liquefaction plants have come on stream and demand has slowed (Figure 5.3). The international market price is low enough to compete against the wholesale price of domestic natural gas to power plants in Myanmar (Table 5.3). Natural gas, although imported, would help lower the price risks considerably. Put differently, the development of domestic natural gas resources would pose big economic risks to Myanmar if the international price of LNG is to remain low. Even though the importance of domestic natural gas in energy supply security remains unquestionable, switching from domestic development to imports is worth considering if the domestic production is excessively higher than the import price.

Figure 5.3: World's Natural Gas/LNG Spot Price



LNG = liquefied natural gas; MMBtu = million British thermal units; NBP = national balancing point.
Source: Created from World Gas Intelligence.

Table 5.3: Comparison of Natural Gas Delivered Price at Power Plant (US$/MMBtu)

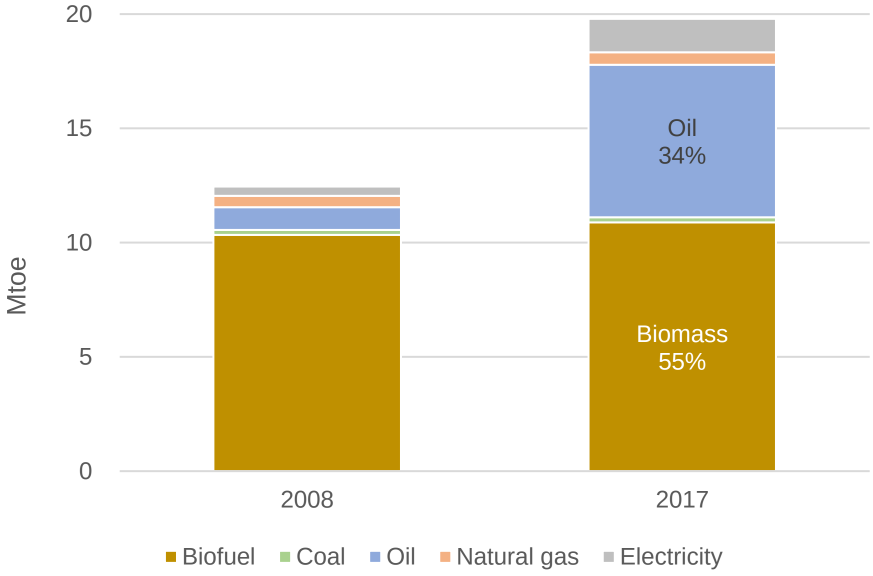
Import	Spot LNG price, cif	3–7
	Re-gas cost	1
	Delivered price at the power plant adjacent to re-gas terminal	4–8
Domestic	Delivered price at the power plant	10–12.5

cif = cost, insurance, and freight; LNG = liquefied natural gas.
Sources: IEEJ databank, World Gas intelligence.
Estimate from data provided by Ministry of Energy and Electricity, Dec. 2019.

5.1.5 Cleaner use of traditional biomass

Biomass is the predominant energy source in the household sector (Figure 5.4). Whilst biomass energy will be replaced by electricity, petroleum, or natural gas eventually, conversion by households will take a long time. Continued use of biomass is also a desirable option in terms of energy security as well as affordability and environmental sustainability. If Myanmar supplied LPG to all households instead of biomass, it will more than double the oil demand. Accordingly, proactive continuation of biomass use in households, accompanied by energy efficiency improvements and pollution prevention is a viable and realistic option.

Figure 5.4: Final Energy Consumption by Energy Type



Mtoe= million tons of oil equivalent.
Source: IEA (2019a), World Energy Balances, 2019.

Clean biomass cookers should be purchased by individual users, ideally speaking. However, a voluntary switch is unlikely to occur because the convenience and socioeconomic importance of such cookers is not well recognised by the general public. In addition, most households that depend on biomass energy are believed to have limited cash revenue. Thus, in order to effectively spread the use of clean cookers, subsidies or even free distribution must be considered.

5.2 Action Plan for Emergency Case

5.2.1 Contingency plan and demand restriction

The first thing to do in an emergency situation is to draw up a contingency plan. A contingency plan should consist of actions to cut demand and secure supply. Here, we discuss drawing up a contingency plan and cutting demand.

A contingency plan is drawn up in the following sequence.

a) Categorise the demand sector and count their demand

A decline in energy supply will force allocation to various users according to their relative importance. To do so, first determine the order of priority for energy supply and calculate their respective demand.

The highest priority will be given to keeping the government running and ensuring other functions indispensable for the lives of people (Table 5.4). The second group to be given priority are households because they are vulnerable compared to enterprises.

Table 0.4 Example of Priority to Protect Energy Supply

Primary	Government offices
	Military force, police, fire departments
	Water, energy supply
	Telecommunications
	Agriculture, food supply
	Hospitals
Secondary	Households
Tertiary	Other industries
	Other services

Source: Authors.

b) Study options of demand cut

For each sector, the possibilities of demand reduction should be explored, looking into every end use. For instance, the petroleum demand of a household can be cut by restricting the use of automobiles. Car use restriction can vary from selective restrictions (car number plate) to a complete ban. The demand cut can vary depending on the restriction intensity. It is recommended to have multiple demand cut options prepared in this way according to restriction intensity. This will make the subsequent work of supply and demand balancing easier.

c) Formulate scenarios of supply interruption

For every type of energy, the possibility of supply interruption should be assessed for the entire supply chain. The scenarios should be grouped according to their probability of occurrence and magnitude (severity). Large amounts of data would be required for a quantitative assessment of interruption probability. It may be substituted by a qualitative assessment such as high, medium, or low probability. For the assessment of interruption magnitude, the 'N-1' method used for adequacy assessment of power supply can be applied.

d) Calculation of supply availability

For each scenario, the supply availability should be calculated in the case that supply is interrupted. In the supply availability, any additional supply possibilities should also be considered. Examples of such additions could include increasing production, tapping oil stockpile, and suspending natural gas exports.

e) Allocation of supply

The supply availability assessed in C) is compared against the prioritised demands assessed in A) and the demand cut options determined in B) to determine the allocation of the supply. The process described in A) through E) is not linear or sequential. The assessments should be repeated and modified with feedback from each assessment step until the best possible solution is found.

The next subsection will discuss the major measures to secure energy supply.

5.2.2 Oil stockpile

Stockpiling is an effective measure against oil import interruption. Myanmar has already embarked on oil stockpiling (Table 5.5). The focus is on the stockpiling of petroleum products, a strategy consistent with the currently low capacity utilisation of the oil refineries. Oil demands in Myanmar are expected to grow steadily. Oil stockpiling capacity is required to progress at a rate faster than the demand increase.

Table 0.5 Oil Stockpile in Myanmar

		2016 actual	2020	2025
National	Crude	12 days	10 days	9 days
	Product	28 days	30 days	33 days
Private	Product	6 days	8 days	12 days

Number of days is consumption equivalent.
Source: MOME (2019b).

There are two ways to stockpile (Table 5.6). One is to build tanks within the national territory and the other is to purchase use rights of oil stockpiled in a foreign country ('ticketing'). Each method has its advantages and disadvantages. Myanmar should decide whichever best suits, or a mix of both, the country's circumstances. The partial use of the ticketing method is a good option, since the stockpile can be built up quickly and the risk can be spread out geographically by ticketing.

Table 0.6 Comparison of Oil Stockpiling Method

	Construct storage tank in national territory	Ticketing
Risk	Free from foreign risk	Free from homeland risk
Development	Need construction time	Immediate
Discharge	Immediate	Need shipping days

Note: Ticketing is a contract with another country to make use of oil in their tanks when necessary.
Source: Authors.

5.2.3 Preserve gas and coal resources as a natural stockpile

Myanmar possesses its own natural gas and coal resources. They can be considered as natural stockpiles. From the energy security perspective, these natural resources should be conserved as long as possible and should be maintained to be immediately ready for production and supply in emergency situations.

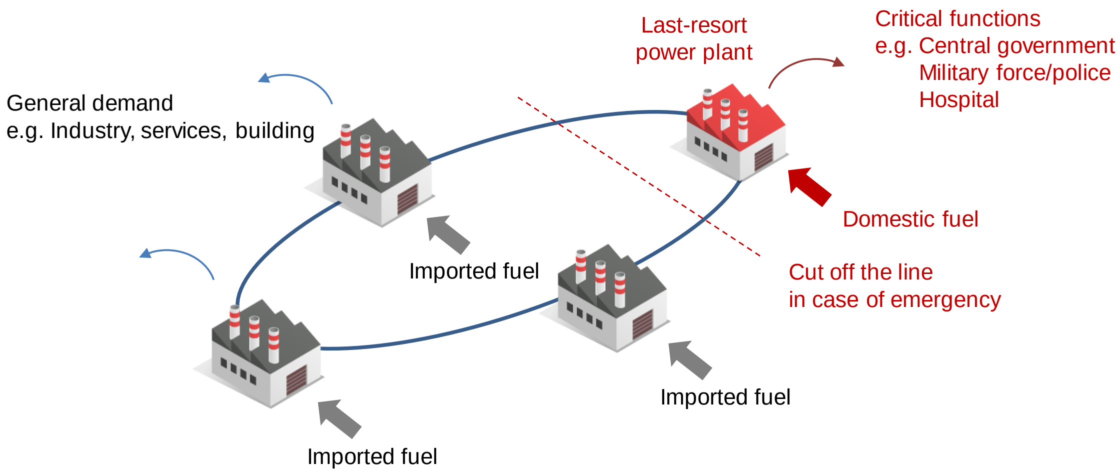
To secure domestic natural resources for long periods, investment for exploration and development should be made constantly and production levels should be controlled to prolong the production plateau for the longest time possible and moderate the pace of decline. Exports of natural gas, meanwhile, earn foreign currency, and in this sense exports should be maximised ideally. Natural gas conservation for energy security and export maximisation for acquisition of foreign currency are a trade-off. A fine balance must be maintained between them.

For maintaining a production and supply system, a certain level of production must be maintained at all times including in normal times. Once production is discontinued, it takes a long time to resume operations of the natural gas field or the coal mine. No prompt response is feasible. Therefore, the most realistic strategy will be to control the production with attention to the conservation requirement, accompanied by a contingency plan and procedures for production increase in emergency situations.

5.2.4 Develop a last-resort power plant

Electric power supply can be interrupted for many reasons. Coal-fired power stations could be halted by fuel shortages. Even with hydropower generation or renewable energy, it can easily happen that power generation is disrupted unexpectedly affected by river volume, sunshine, or other weather conditions. A way to reinforce readiness against such power disruptions is to select a last-resort power plant especially outfitted with features to counter potential risks and continue generating electricity (Figure 5.5).

Figure 5.5 Concept of the Last-resort Power Plant



Source: Authors.

In the selection of such a last-resort power plant, the risks and the availability of countermeasures should be weighed (Table 5.7). For instance, hydropower generation is domestically produced energy and generally free from risks originating in other countries. However, it is exposed to meteorological risks. Weather risks are beyond control and there can be no remedies once the risk becomes a reality. In contrast, thermal power generation based on imported energy has low weather risks but is vulnerable to overseas risks. Overseas risks however can be addressed by stockpiling and other preventive measures.

Table 0.7 Potential Risk and Availability of Counteraction

	Hydropower Plant	Gas / coal power plant	Oil power plant
Foreign risk	Zero – Low *1	Low – High *2	High
Meteorological risk	High	Low	Low
Availability of counter action			
Against foreign risk	-	Available	Available
Against meteorological risk	Not available	Available	Available

*1 Risk is low if a hydropower plant is located downstream of an international river.
*2 Risk is low if a power plant is fuelled by domestically produced energy. Risk is high if a power plant is fuelled by imported energy.
Source: Authors.

If power generation in any circumstances is to be pursued, the best option is to use a dual fuel (natural gas and oil) combined cycle gas turbine. The turbine is operated by natural gas alone in normal times. In the event of natural gas supply interruption, power generation is continued using oil from the stockpile tank. This kind of power plant will enable continued supply of electric power if meteorological or international incidents should occur. Note that oil stockpile costs are required in this option.

The second-best option is hydropower generation. In normal situations, power generation is stable and at low cost. However, it is subject to uncontrollable weather risks. This option alone does not guarantee 100% security.

Chapter 6

Conclusions and Recommendations

6.1 Conclusions

Firstly, this study analysed the historical energy demand supply situation of Myanmar using Myanmar's national energy statistics. Myanmar basically has been depending on three major domestic energy types of hydropower, natural gas, and biomass and their share was 5%, 19%, and 43%, respectively (total of 67%) in 2017. The oil share was 32% in 2017 but it fully depends on imports. So far the coal share was just 1% in 2017 and surplus coal was exported to neighbouring countries. As a result, the import dependency ratio has worsened from 7% in 2010 to 19% in 2017 due to significant increases in petroleum demand such as gasoline and diesel oil used as transport fuel.

Next this study assessed the supply issues of each energy source, which are natural gas, oil, coal, hydropower, and renewable energy. The country's energy system contains energy security risks. Both oil and natural gas production have been showing a downwards trend. Further, existing plans to develop hydropower and coal-fired power plants may not be carried out as expected because of ongoing campaigns against their development.

When estimated under certain conditions, the magnitude of the economic effect of policy failure is large in underdevelopment of hydropower (US$91–US$321million per year) and overdevelopment of renewable energy (US$205–US$323 million per year), followed by underdevelopment of natural gas (US$75–US$112million per year). It suggests the government should place high priority on addressing issues related to these systems.

Next this study examined an energy mix, more precisely a power generation mix, target in 2040, which is considered desirable from an energy security point of view. In the process, access to energy, affordability, and environmental sustainability viewpoints are taken into account.

Two scenarios have been developed. One is a **clean scenario,** which suggests that coal use will be limited to domestic coal with high priority on the reduction of environmental loads. In other words, under this scenario, import amounts of natural gas will become larger. The other is a **least-cost scenario,** which pays attention to electricity rates, proposing that natural gas use is limited to a domestically available amount, 3.6 billion cubic metres per year. In this scenario, the rest of electricity will be generated from imported coal.

Which scenario is preferable for Myanmar? The gross domestic product per capita of Myanmar is projected at US$5,140 in 2040, which is almost equivalent to Thailand (US$6,128) and Indonesia (US$4,131) in 2017. Low electricity rates have great significance in Thailand's and Indonesia's policies. Therefore, it is not difficult to imagine that affordability will be still a key factor in 2040 for Myanmar to take into account in deciding the best energy mix target. In view of this, the study recommends the **least-cost scenario**, which places high priority on low electricity rates, as the most viable option for Myanmar to take.

Base on the result of chapters 2 and 3, this study forecasts a new energy outlook scenario of Myanmar, namely the energy supply security (ESS) scenario base on the least-cost scenario mentioned in chapter 3. If Myanmar seeks affordability of energy supply, Myanmar will need to shift to more coal, hydropower, and biomass, with coal will be a key role player in future. Unfortunately, since the domestic coal supply chain is poor from the coal production sites in the north of the country to the coal demand sites in the south, transportation of coal will be limited. Therefore, the ESS scenario assumes a remarkable amount of imported coal. Import dependency and CO_2 emissions levels of the ESS scenario are almost same as in the business as usual (BAU) scenario, but energy supply affordability, oil demand, and preservation of natural gas resources are better than in the BAU scenario. As a result, this study recommends the ESS scenario as a feasible energy policy to maintain energy supply security for Myanmar.

Finally, this study presents recommended measures for enhancing energy security. The measures can be grouped into two: one is accompanied by structural changes in the energy supply and demand, including (i) improve energy efficiency, (ii) create well-balanced energy and/or import mix, (iii) improve environmental sustainability of coal-fired power plants, (iv) utilise LNG as a competitive fuel, and (v) cleaner use of traditional biomass and others. The measures for an emergency case includes (i) contingency plan and demand restriction, (ii) oil stockpiling, (iii) preserve gas and coal resources as a natural stockpile and (iv) develop a last-resort power plant.

6.2 Recommendations

This report describes the future energy demand supply situation if Myanmar can implement the energy supply security scenario, indicating: (i) power generation mix to shift to more coal and hydropower ,(ii) continued use of biomass, (iii) saving natural gas consumption, and (iv) appropriate increase of renewable energy such as solar PV and wind power generation. In addition, this report also emphasises the energy supply security scenario with three criteria: accessibility, affordability and sustainability. To realise the security scenario in the future, the Ministry of Electricity and Energy (MOEE) should establish comprehensive and appropriate energy policies with the support of laws, sub-decrees, and regulations. Otherwise, Myanmar will not be able to succeed in the implementation of the energy supply security scenario.

For the promotion of coal-fired power generation, the MOEE will be mindful of the need for the application of clean coal technologies. The MOEE will establish sub-decrees to regulate the owners of new coal-fired power plants to require them to apply super critical or ultra-super critical technologies to their power plants on a mandatory basis under stringent environmental regulation on air quality.

The MOEE will develop hydropower generation aggressively, but regulate environmental assessment sub-decrees and enforce hydropower entities to conduct environmental assessments before the construction of dams to mitigate damage to the ecosystem in the surrounding areas of the dams. As this is a matter for the Ministry of Environment, the MOEE should regulate the assessment sub-decrees with the collaboration of the Ministry of Environment.

The Oil and Gas Planning Department will request oil companies in Myanmar to stockpile 30 days of oil on a mandatory basis, and will establish a sub-decree on oil stockpiling. If some oil companies do not follow the sub-decree, the department will be able to demand them to stop business activities for around 1–2 months.

The continuous use of biomass will fully depend on the MOEE's support, which will provide efficient types of biomass cooking stoves to households especially in rural areas at reasonable prices. In addition, the MOEE will encourage private companies to develop a biomass supply chain in rural areas on a business basis. The MOEE will provide licences to private companies to engage in biomass logistics and monitor their business activities.

Regulations will not be needed for the promotion of various renewable energy types such as solar PV and wind power generation. On a business basis, the penetration of solar PV will depend on its affordability. In addition, the MOEE will seek international cooperation such as with ADB and the International Renewable Energy Agency to support the increase of variable renewable energy in Myanmar.

Last but not least, an Energy Efficiency and Conservation (EEC) Act will improve the energy supply security situation in Myanmar through savings of energy consumption. This is a matter for the Ministry of Industry, but as the EEC Act will be an important energy policy, the MOEE and the Ministry of Industry should cooperate to formulate this Act.

References

ASEAN Centre for Energy (ACE) (2019), 'Levelized Costs of Electricity (LCOE) for Selected Renewable Energy Technologies in the ASEAN Member States II'. Jakarta: ACE.

Bangkok Post (2019), '"Minbu 220MWDC Solar Power Plant" Phase 1 (50 MWDC) Grand Opening Honoured by Aung San Suu Kyi', 3 July, https://www.bangkokpost.com/thailand/pr/1706282/minbu-220mwdc-solar-power-plant-phase-1-50-mwdc-grand-opening-honoured-by-aung-san-suu-ky (accessed 24 April 2020).

BGR (2009), *Energy Resources 2009*. Berlin: BGR.

BGR (2017), *BGR Energy Sector Study 2017*. Berlin: BGR.

BGR (2018), *BGR Energy Sector Study 2018.* Berlin: BGR.

BP (2019), *Statistical Review of World Energy 2019.* London: BP.

Convalt Energy (2017), 'US Company to Invest US$480m in Myanmar Power Sector', http://www.convalt.com/solar.html (accessed 24 April 2020).

Del Barrio Alvarez, D. and M. Sugiyama (2020), 'A SWOT Analysis of Utility-Scale Solar in Myanmar'.

Economic Research Institute for ASEAN and East Asia (ERIA) (2015), 'Study on the Strategic Usage of Coal in the EAS Region: A Technical Potential Map and Update of the First Year Study', *ERIA Research Project FY 2014, No. 36*. Jakarta: ERIA.

ERIA (2017), 'Natural Gas Master Plan for Myanmar', *ERIA Research Project Report 2017, No. 17.* Jakarta: ERIA.

https://www.eria.org/uploads/media/RPR_FY2017_17_fullreport.pdf

ERIA (2019), *Myanmar Energy Statistics 2019*. Jakarta: ERIA.

ERIA (2020), 'Myanmar Energy Outlook 2020', *ERIA Research Project Report 2020, No 1.* Jakarta: ERIA.

Energy Information Administration, 'Petroleum and Other Liquids, Spot Prices'.

European Union (EU) (2018), '"San Pya" Cook Stoves to Improve Health and Help Preserve Myanmar's Forests', https://eeas.europa.eu/headquarters/headquarters-homepage/42382/san-pya-cook-stoves-improve-health-and-help-preserve-myanmars-forests_en (accessed 24 April 2020).

Htet, H. (2019), 'Challenges and Opportunities for Renewable Energy Development in Myanmar'.

Infra Capital Myanmar ReEx (2017), 'Infraco Asia Signs Memorandum of Understanding with Magwe Region Government for Wind Power Project', http://infracapmyanmar-reex.com/infraco-asia-signs-memorandum-of-understanding-with-magwe-region-government-for-wind-power-project/ (accessed 24 April 2020).

International Energy Agency (IEA) (2019a), *World Energy Balances 2019*, Extended Edition Database.

International Energy Agency (IEA) (2019b), *SDG7: Data and Projections*, November. https://www.iea.org/reports/sdg7-data-and-projections/access-to-electricity#abstract

International Energy Agency (IEA) (2019c), *World Energy Statistics 2019*, Extended Edition Database.

International Finance Corporation (IFC) (2018), 'Strategic Environmental Assessment of the Myanmar Hydropower Sector'.

International Monetary Fund (IMF) (2019), World Economic Outlook Database, April, Report for Selected Countries and Subjects. https://www.imf.org/external/pubs/ft/weo/2019/01/weodata/weorept.aspx?sy=2017&ey=2024&scsm=1&ssd=1&sort=country&ds=.&br=1&c=518&s=PCPIPCH&grp=0&a=&pr.x=23&pr.y=11 (accessed 24 April 2020).

Institute of Energy Economics, Japan (IEEJ) (2019), *IEEJ Outlook 2020*. Tokyo: IEEJ.

Institute of Energy Economics, Japan (IEEJ), Data Bank. Tokyo: IEEJ.

Japan Oil, Gas and Metals National Corporation (JOGMEC) (2018), 'Natural Gas Upstream Investment in Myanmar', July.

Lee, N., F. Flores-Espino, R. Oliveira, B. Roberts, T. Bowen, and J. Katz (2019), 'Exploring Renewable Energy Opportunities in Select Southeast Asian Countries: A Geospatial Analysis of the Levelized Cost of Energy of Utility-Scale Wind and Solar Photovoltaics,' USAID and National Renewable Energy Laboratory.

Ministry of Economy, Trade and Industry (METI) (2016), 'Survey of Natural Gas Use in Myanmar', February.

Ministry of Electricity and Energy (MOEE) (2019a), 'Future Outlook for Myanmar Petrochemical Enterprise', Presentation in Tokyo, 24 January.

Ministry of Electricity and Energy (MOEE) (2019b), 'The Oil Stockpiling Situation in Myanmar', 24 July.

Ministry of Foreign Affairs of Denmark (2015), 'Vestas Enters Myanmar Market for Wind Energy', https://myanmar.um.dk/news/newsdisplaypage/?newsid=30477ce0-5665-479a-bc37-be2e07da209d (accessed 24 April 2020).

Myanmar Times (2019), 'Myanmar Electricity Rates to Soar Next Month'. https://www.mmtimes.com/news/myanmar-electricity-rates-soar-next-month.html (accessed 24 April 2020).

Republic of the Union of Myanmar, National Energy Management Committee (2014), 'National Energy Policy'.

Republic of the Union of Myanmar, National Energy Management Committee (2015), 'Intelligent Energy System 2015: Myanmar Energy Master Plan'.

Republic of the Union of the Myanmar, Central Statistical Organization (2018), *Statistical Yearbook 2018*.

https://www.csostat.gov.mm/PublicationAndRelease/StatisticalYearbook (accessed 24 April 2020).

Tun, M.M. and D. Juchelková (2019), 'Biomass Sources and Energy Potential for Energy Sector in Myanmar: An Outlook', *Resources,* 8(102).

World Gas Intelligence, weekly publication from September 2010 to March 2020.

Zaw, H. (2019), 'Current Status of Myanmar's Electricity Sector', https://greatermekong.org/sites/default/files/Attachment%2011.3_Myanmar.pdf