# Chapter 2

# Supply Issues of Each Energy

October 2020

**This chapter should be cited as**

Energy Study team (2020), 'Supply Issues of Each Energy', in ERIA and Myanmar's Ministry of Electricity and Energy (eds.) *Energy Supply Security Study for Myanmar.* ERIA Research Project Report FY2020 no.11, Jakarta: ERIA, pp.8-46.

# 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<br>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<br>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)<br>Heat value = 5,200kcal/kg (MEMP) |
| Coal – import | $118/ton | International energy prices in 2018 (IEEJ Outlook, 2020)<br>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.

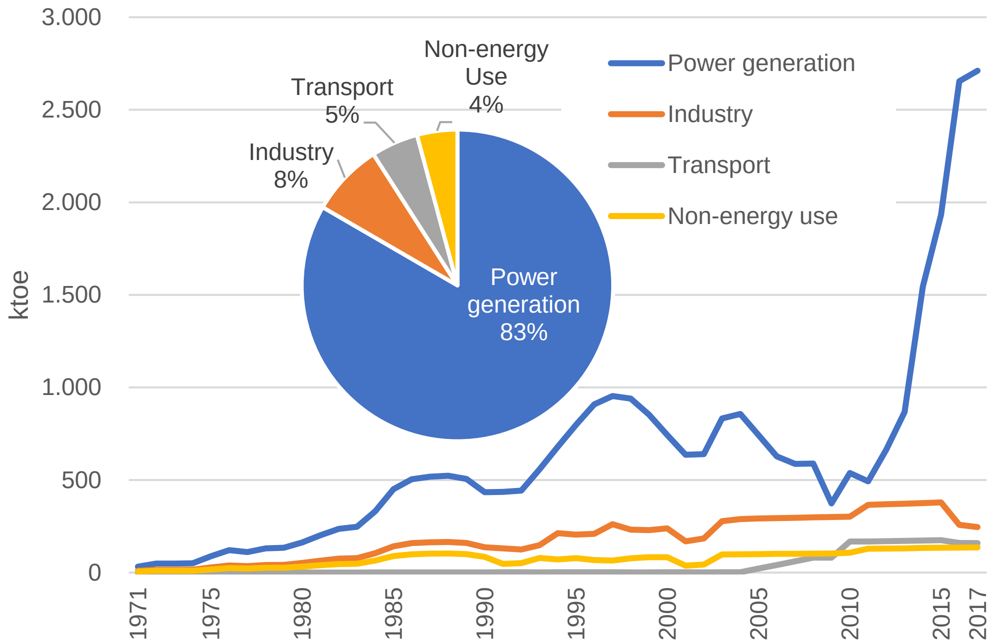
c) LCOE in risk scenario by 2040

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**

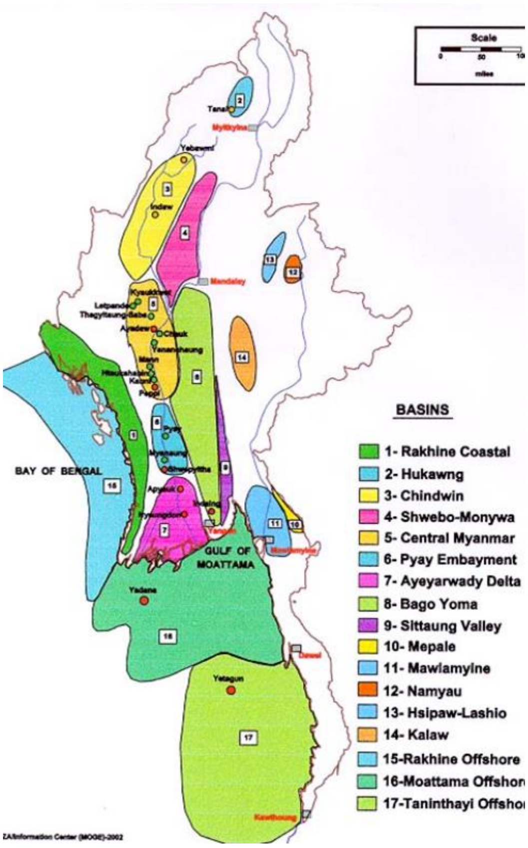



ktoe = kiloton of oil equivalent.
Source: IEA, World Energy Balance Table 2019.

### 2.2.1 *Reserves*

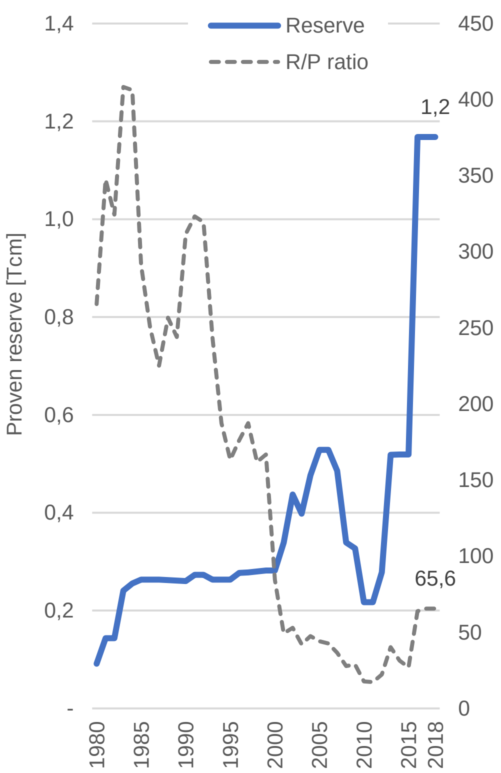
Proven reserves of natural gas in the country have almost doubled in the last several years because of the successful development of the Zawtika and Shwe gas fields since the 2010s (Figure 2.2). A reserves-to-production ratio (R/P ratio) demonstrated a downward trend as the result of increased consumption. 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.

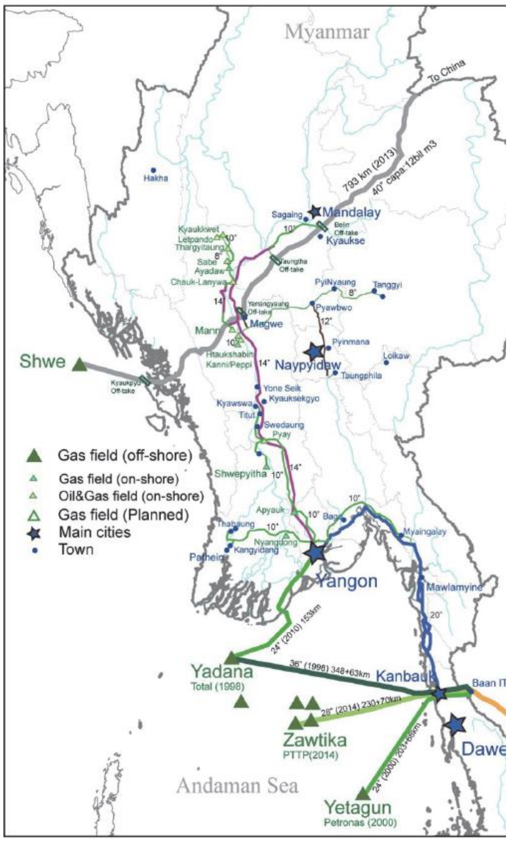
Source: BP (2019), Statistical Review of World Energy, June.

### 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.

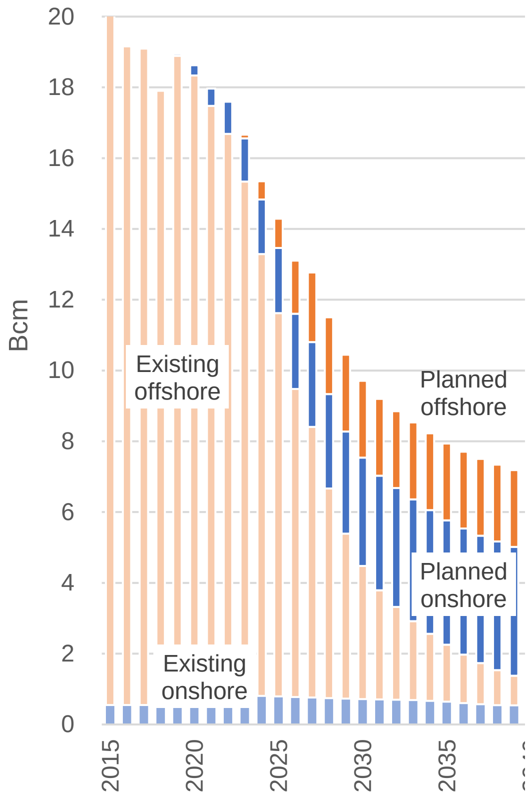
The offshore M3 and A6 blocks are under development, and their commercial production is expected to start in 2023 and 2025, respectively. The development of additional onshore blocks is also anticipated. However, the production of these additional blocks will be insufficient to offset the decrease in 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*

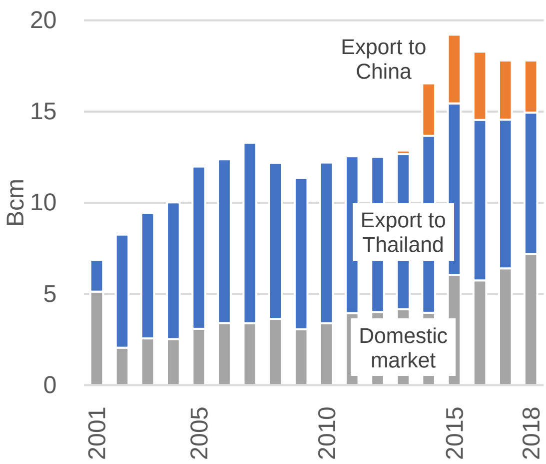
Myanmar signed a contract with Thailand for natural gas exports before consumption in the country started to increase. In the 2010s, it concluded export contracts with China and Thailand (Figures 2.6 and 2.7). Whilst they have benefitted the Myanmar economy in terms of foreign exchange earnings, they 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).

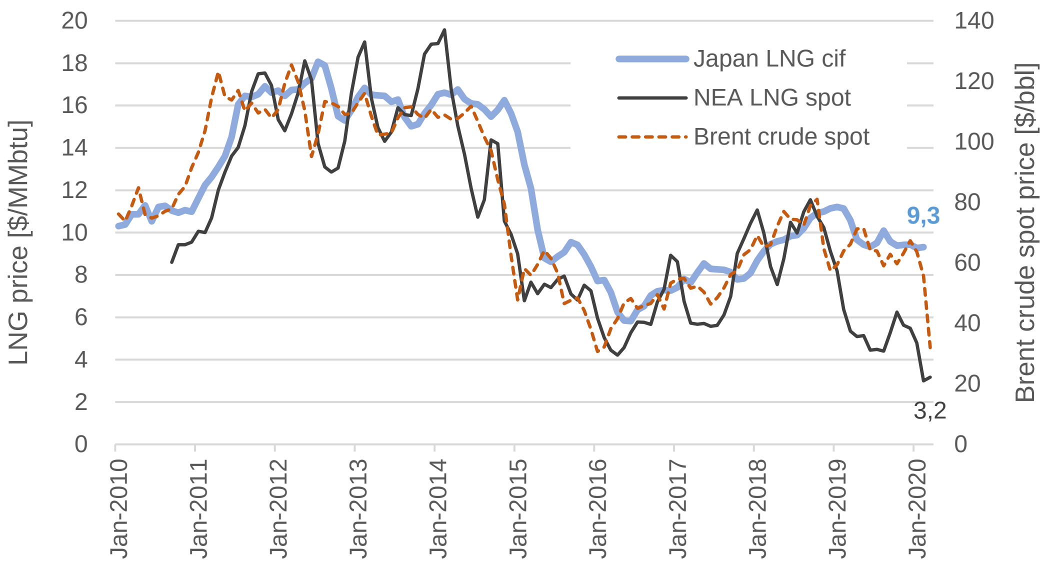
**Table 2.5: Price of Domestic Natural Gas from Offshore Fields (US$/MMBtu)**

| 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<br>(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**

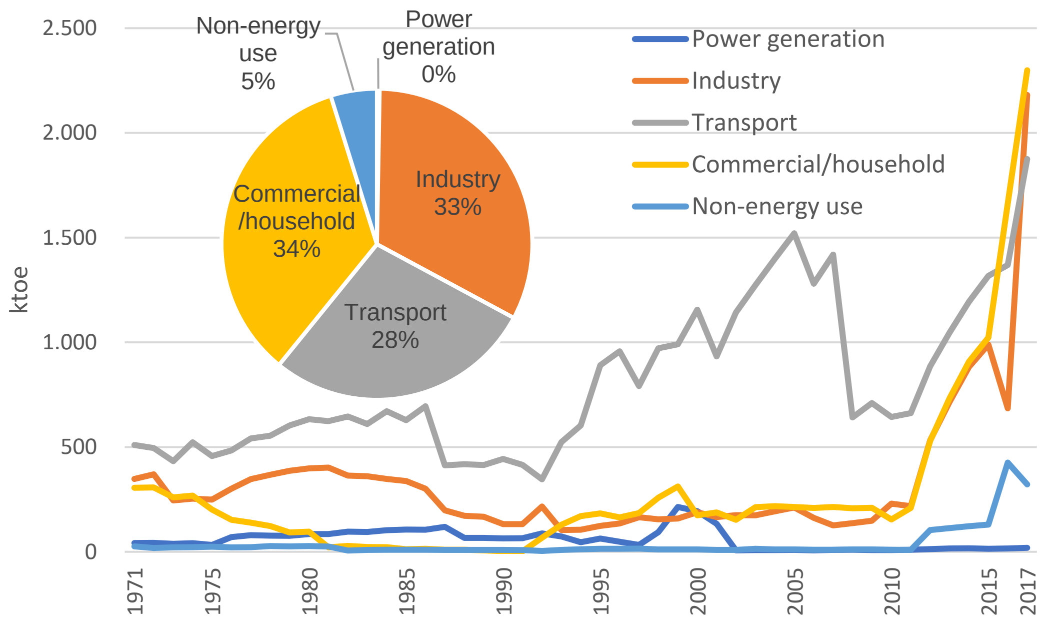
| Scenario for domestic gas production from new blocks | Economic impact |
|---|---|
| 50% less production than planned | $75 million/yr |
| 75% less production than planned | $112 million/yr |

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**



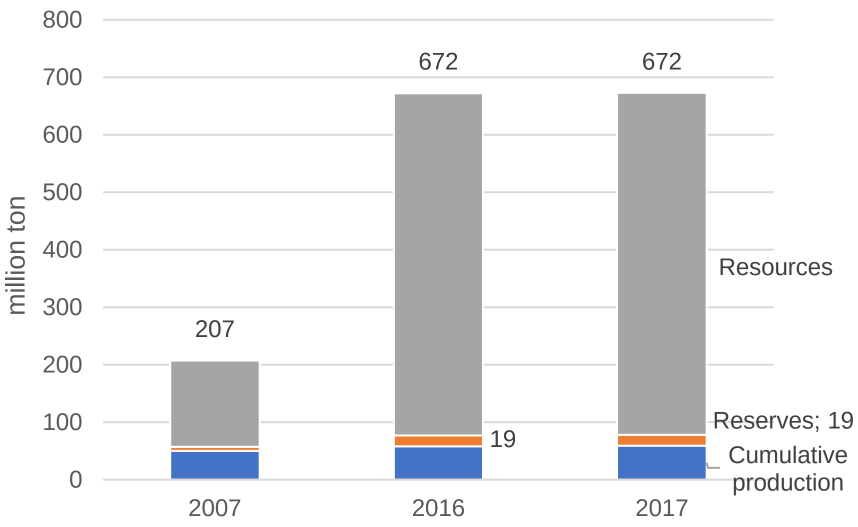

Ktoe = kiloton of oil equivalent.
Source: IEA (2019a), World Energy Balances 2019 extended edition database.

### *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**



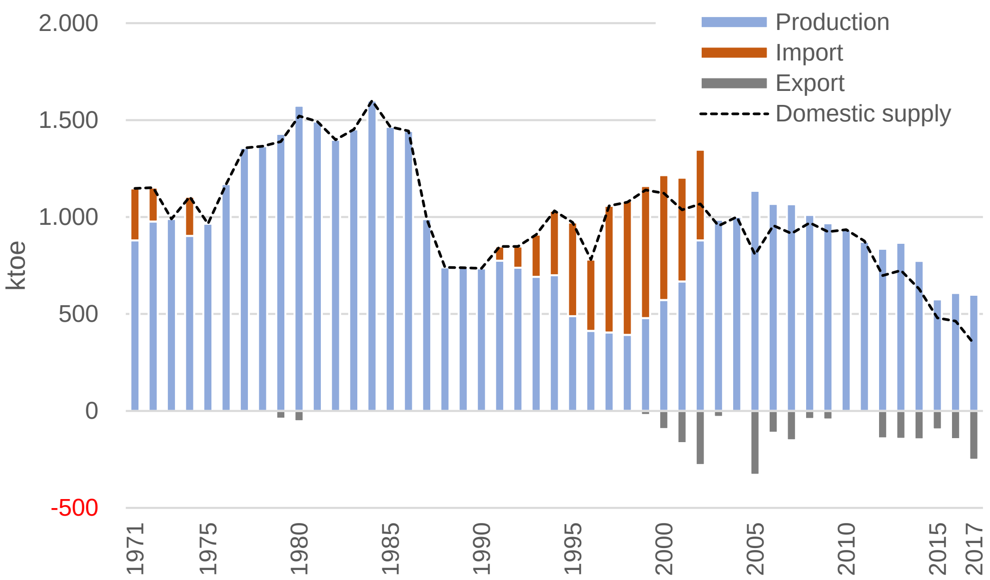

Notes: Resources = proven amounts of energy resources which cannot currently be exploited for technical and/or economic reasons, as well as unproven but geologically possible energy resources which may be exploitable in future.
Reserves = proven volumes of energy resources economically exploitable at 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.

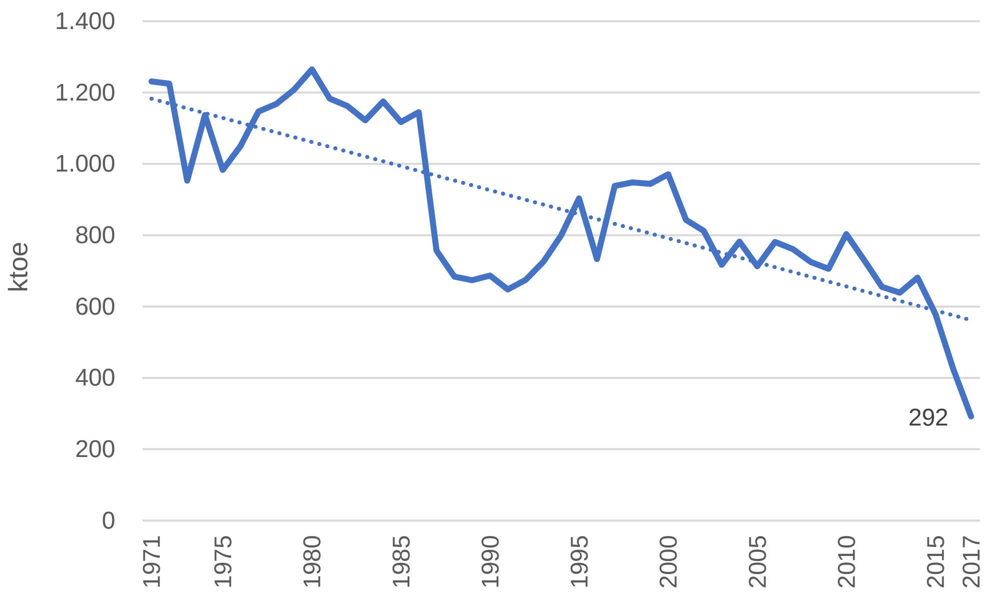
**Figure 2.11: Crude Oil Supply Balance**




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).

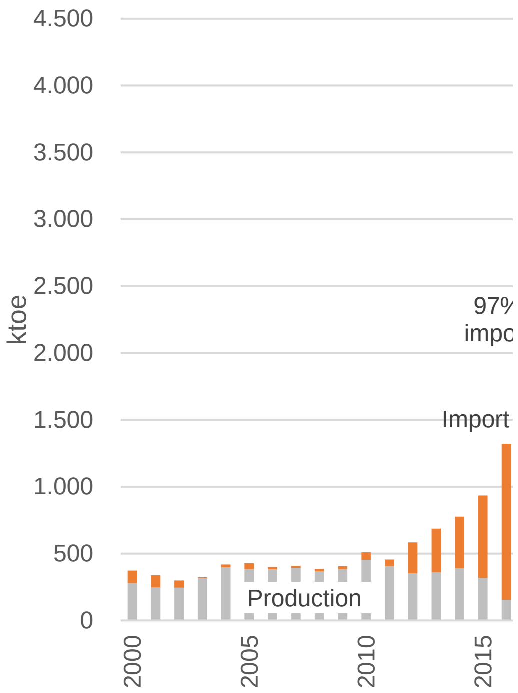
Currently, a plan to rehabilitate the existing Chauk refinery and to build new refineries with the total capacity of 470,000 b/d up to 2026 is under implementation. The existing old refineries, except Chauk, are scheduled to be closed with the completion of the new refinery. But we shall remind of the 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<br>(200,000 b/d) | To commence in 2020<br>Low priority |
| | Chauk, rehabilitation | 6,000b/d | To commence in 2024<br>Low priority |
| | Thanlyin, new | 10 MMTPA<br>(200,000 b/d) | To commence in 2025<br>High priority |
| | Thanbayakan, new | 3.5 MMTPA<br>(70,000 b/d) | To commence in 2026<br>Low priority |

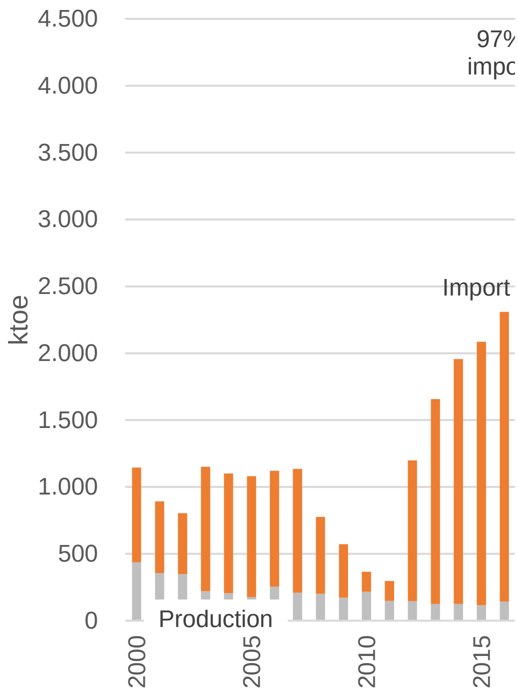
b/d = barrels per day, MMTPA = million metric ton per annum.
Sources: Existing: MOEE (2019a), Outlook for Myanmar Petrochemical Enterprise; Planned: Ministry of Energy and Electricity, April 2020.

**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**

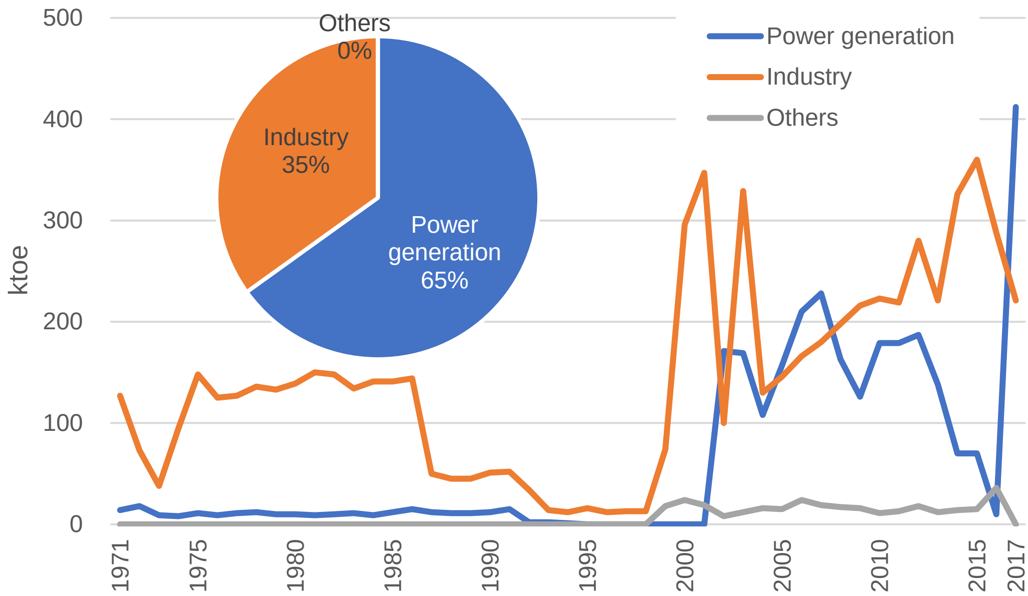
| | | Refinery capacity | |
|---|---|---|---|
| | | Follow the degradation trend at AACR = –5% | Operate new refinery in 2025 |
| Crude oil production | Follow the degradation trend at AACR = –5% | + $11.9 million/yr from the base case | + $4.3 million/yr from the base case |
| | Recover at AACR = 5%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

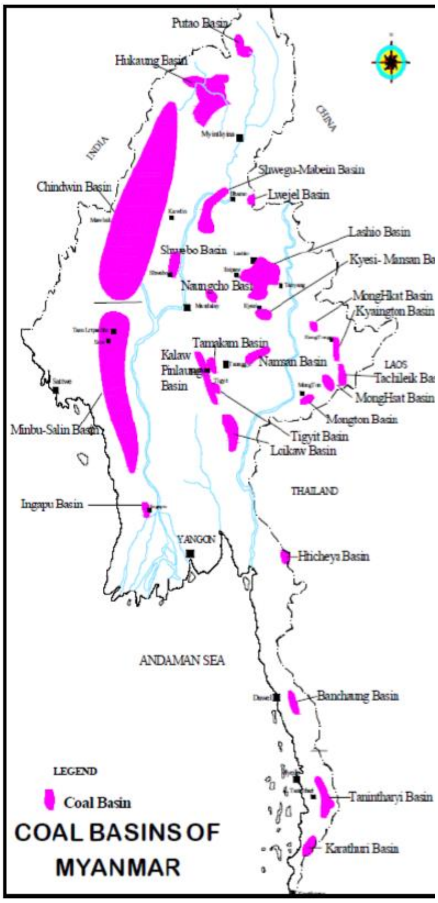
Source: IEA (2019a), World Energy Balances 2019.

### *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.

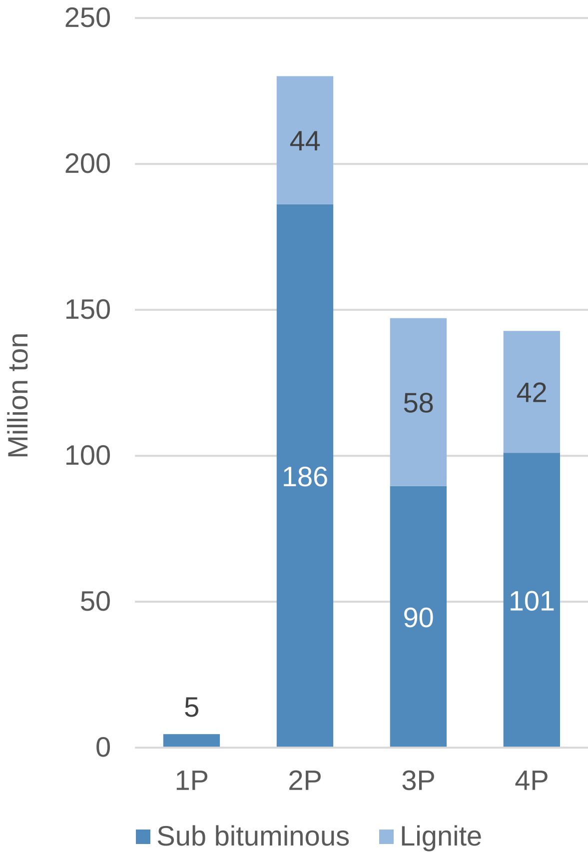
[4] Data provided by MOEE, December 2019.

**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.

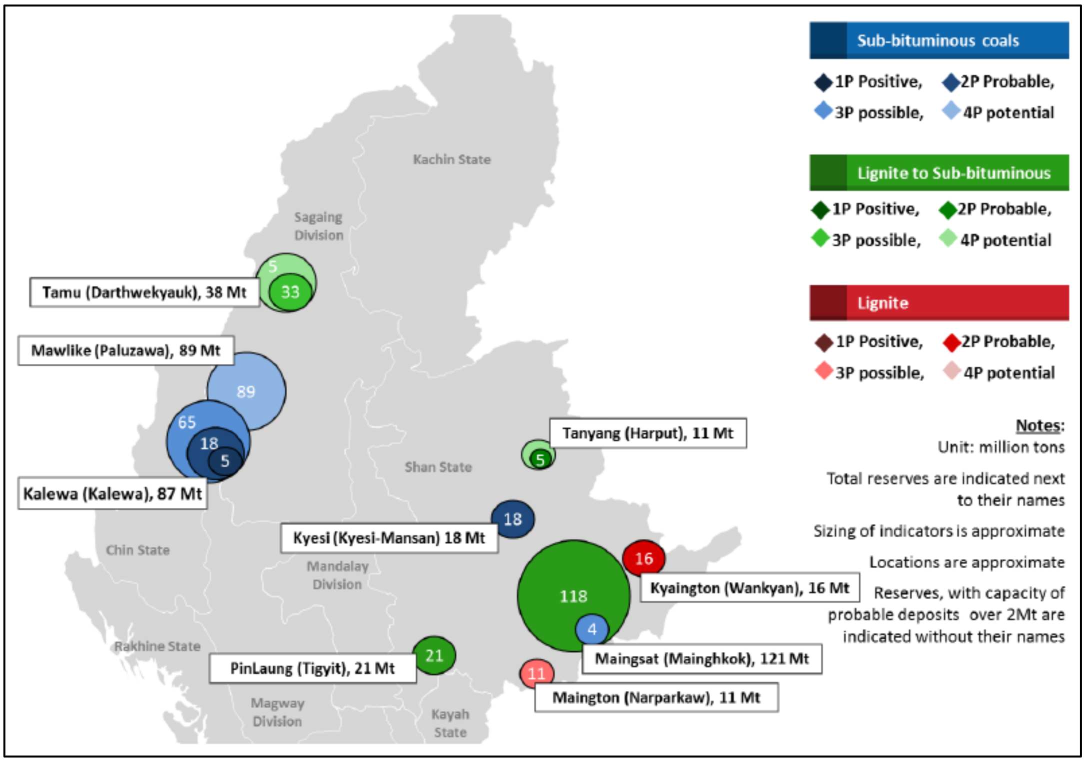
### *2.4.2 Production and supply*

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.

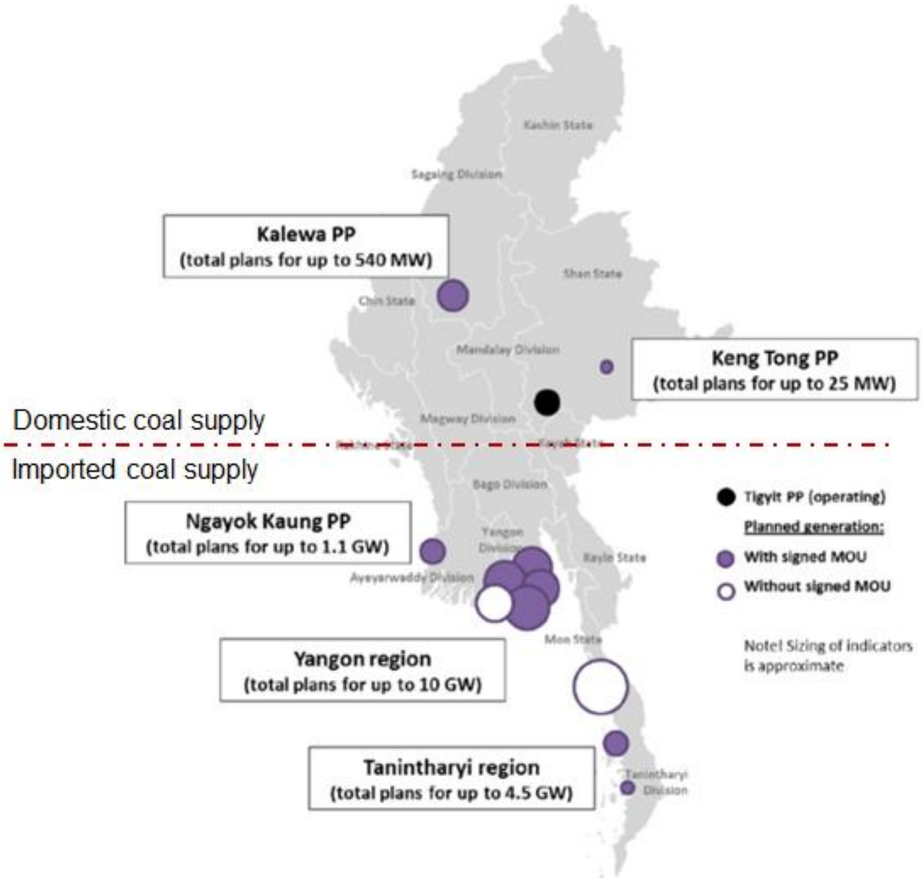
**Table 2.9: Estimated Lifetime Coal Consumption**

| | 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).

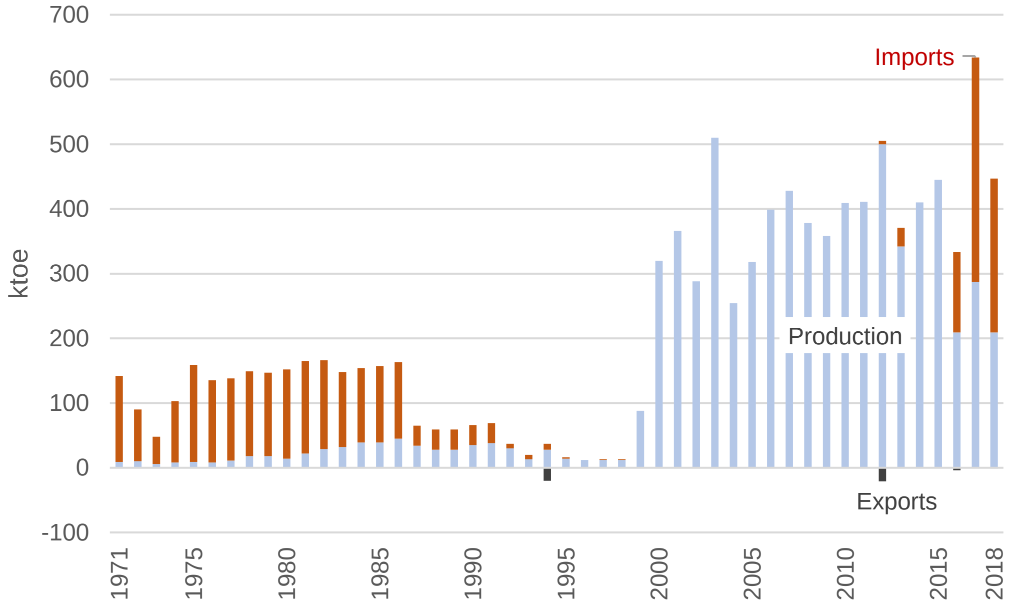
### *2.4.3 Import and export*

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**

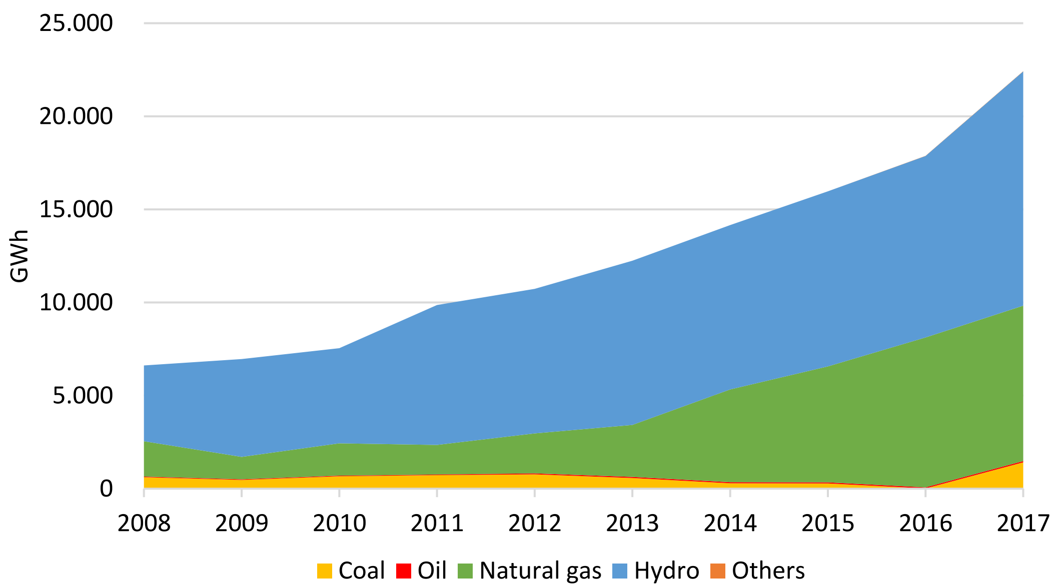
| | |
|---|---|
| Alternative gas power plant: 565 MW (1) | $356.4 million/yr |
| Kalewa coal-fired power plant: 540 MW (2) | $287.6 million/yr |
| Keng Tong coal-fired power plant: 25 MW (3) | $13.3 million/yr |
| Additional cost (1)-(2)-(3) | $55.4 million/yr |

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).

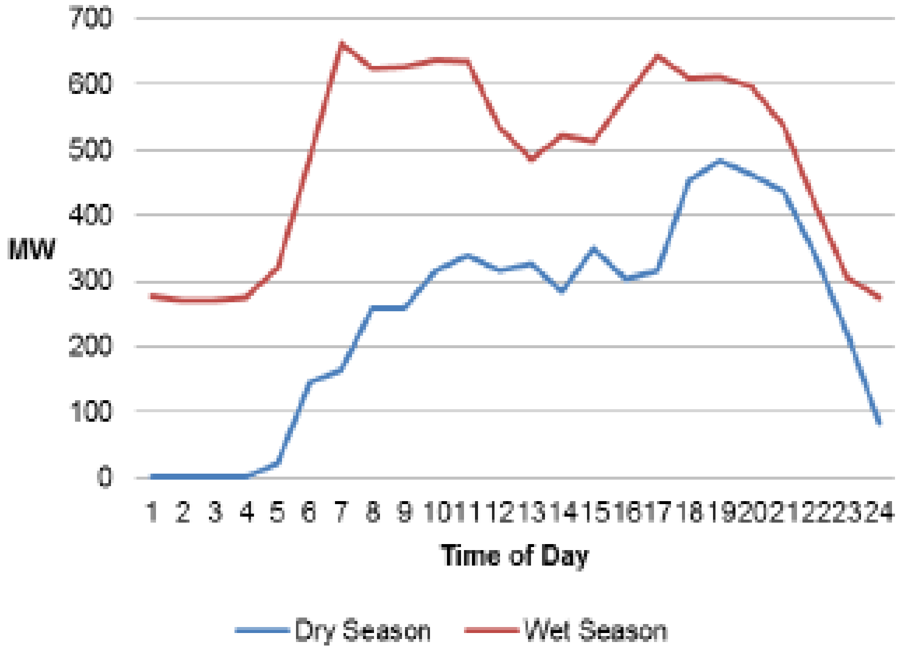
**Figure 2.21: Trajectory of Electricity Output by Type**




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)**

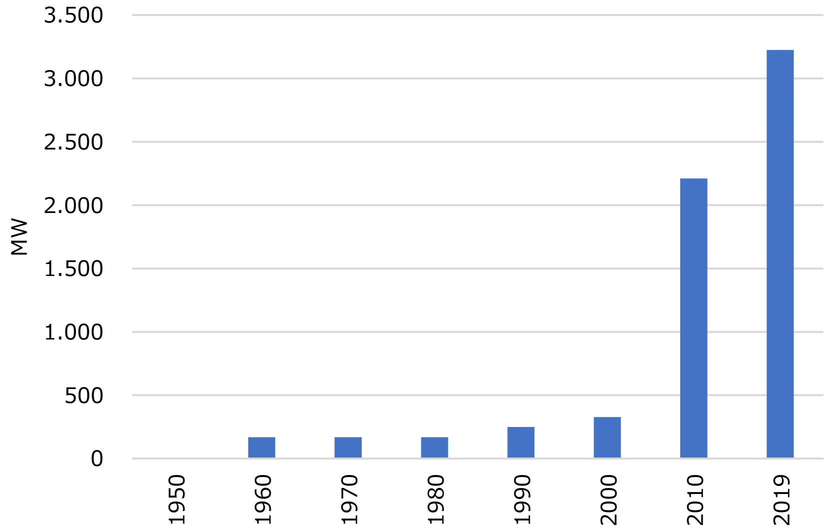



MW = megawatt.
Source: Myanmar Energy Master Plan, Dec. 2015.

*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.

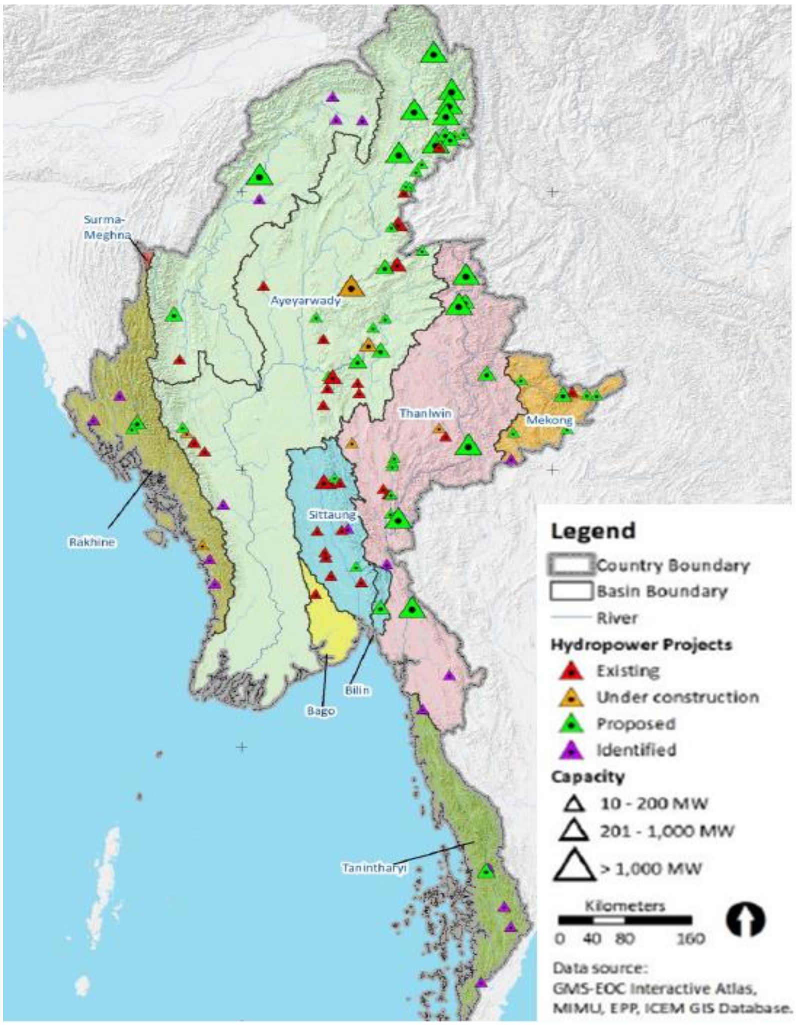
### *2.5.2 Planned hydropower plants*

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**

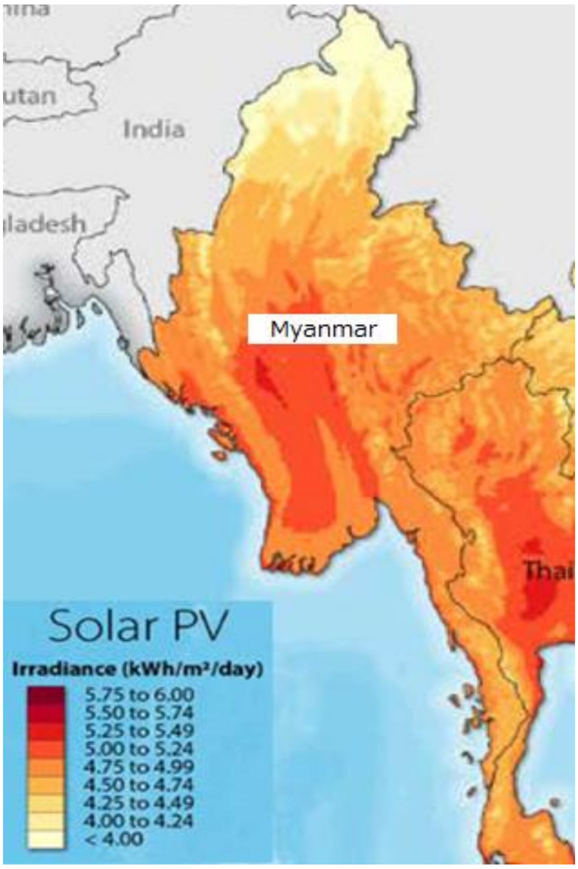
| | Alternative power source | |
|---|---|---|
| | Coal (\$118/ton) | Gas (\$11/MMBtu) |
| 25% less development | \$91 million/yr | \$154 million/yr |
| 50% less development | \$190 million/yr | \$321 million/yr |

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.

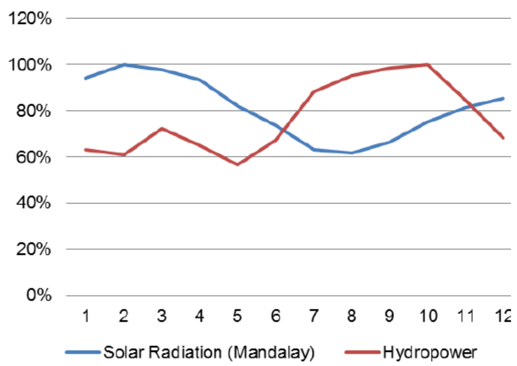
a) Improvement of access to electricity in rural areas

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

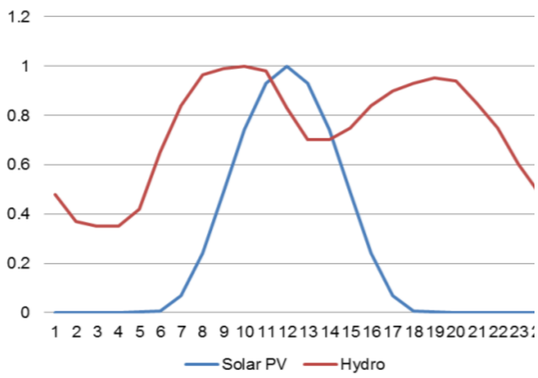
Hydropower, the key power source of the country, and solar power could complement each other to provide more stable electricity supply in the country. Taking seasonal variations into account, during the dry season, the amount of electricity generated by hydropower plants decreases, whilst abundant sunshine 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*

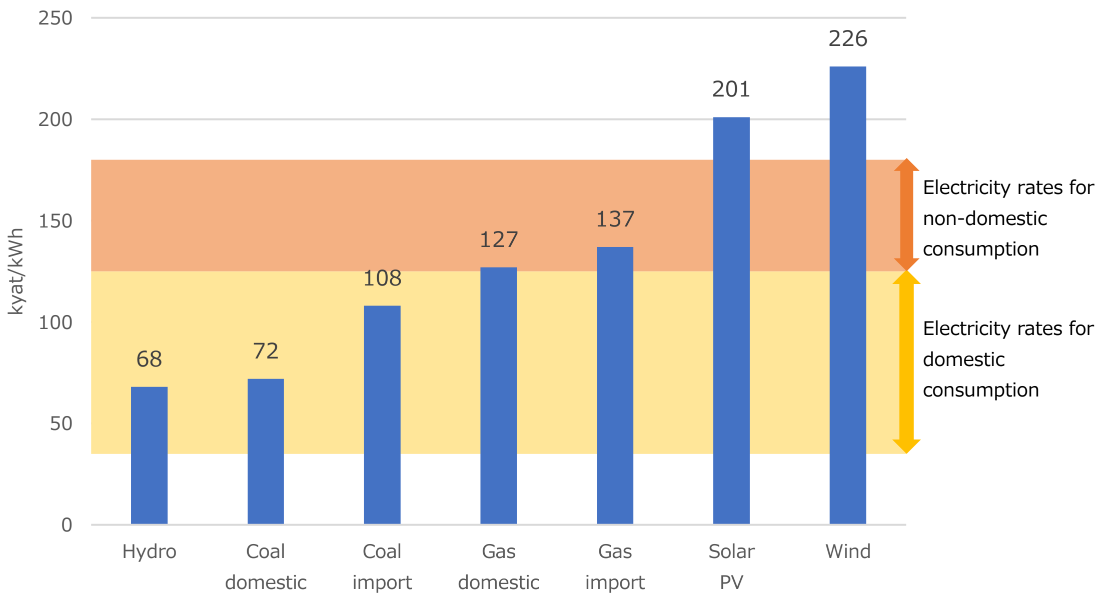
As discussed above, Myanmar has a high potential for solar PV, which could contribute to a stable electricity supply or lowering power generation costs in future. However, at this moment, the introduction of solar PV in the country deserves thoughtful consideration of the costs.

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.

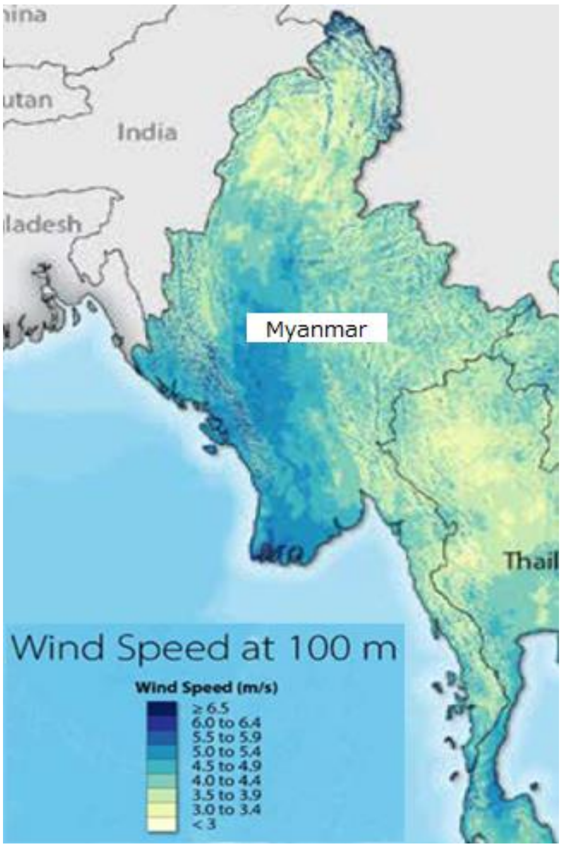
### *2.6.4 Risk scenario*

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<br>(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**

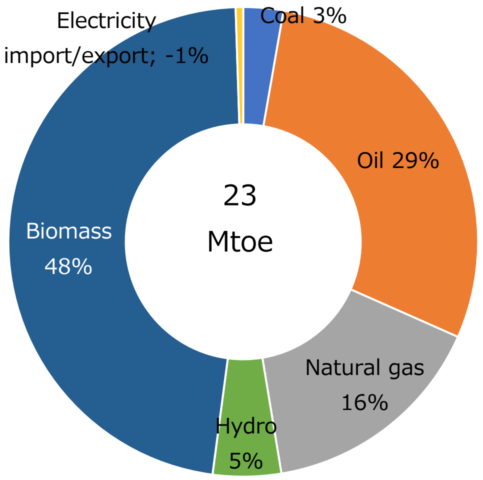
| Share of Renewable Energy in 2040 | Additional cost |
|---|---|
| 10% | $205 million/yr |
| 15% | $323 million/yr |

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

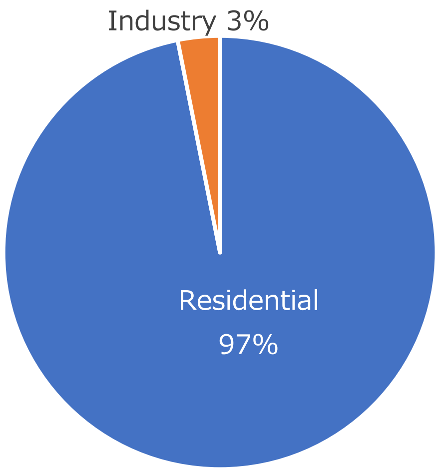
Biomass is an important energy source in Myanmar. In 2017, biomass constituted 48% of total primary energy supply, considerably higher than oil (29%), natural gas (16%), and hydropower (5%) (Figure 2.30). Most biomass is consumed at a household level, and ordinary households mostly use biomass as an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

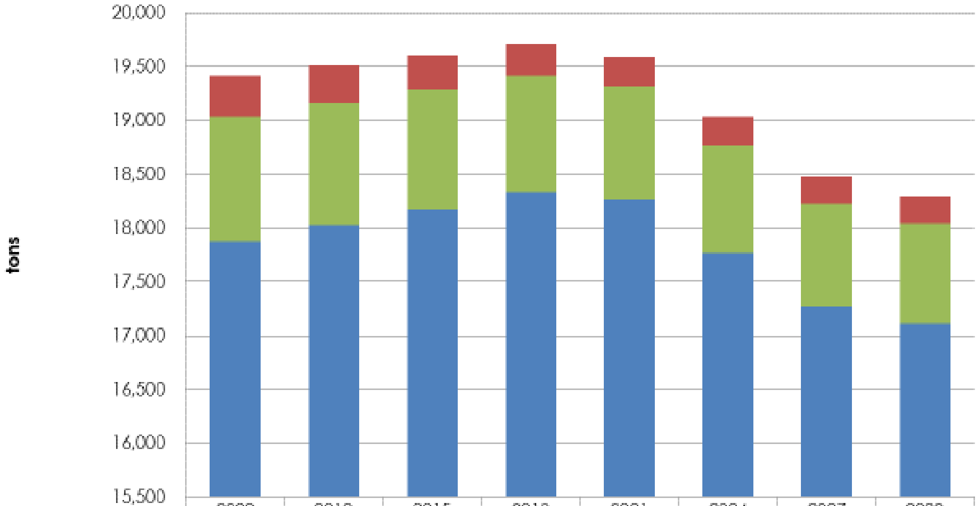



Source: IEA (2019a), World Energy Balances.

### *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.