Chapter 3

Seeking the Best Energy Mix towards 2040

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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.

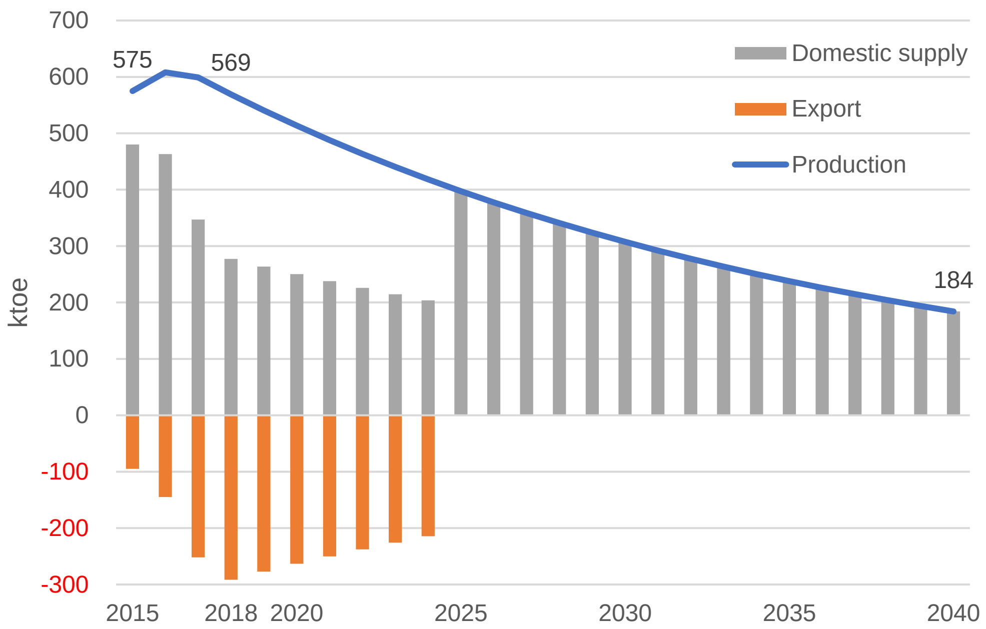
Crude oil

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.

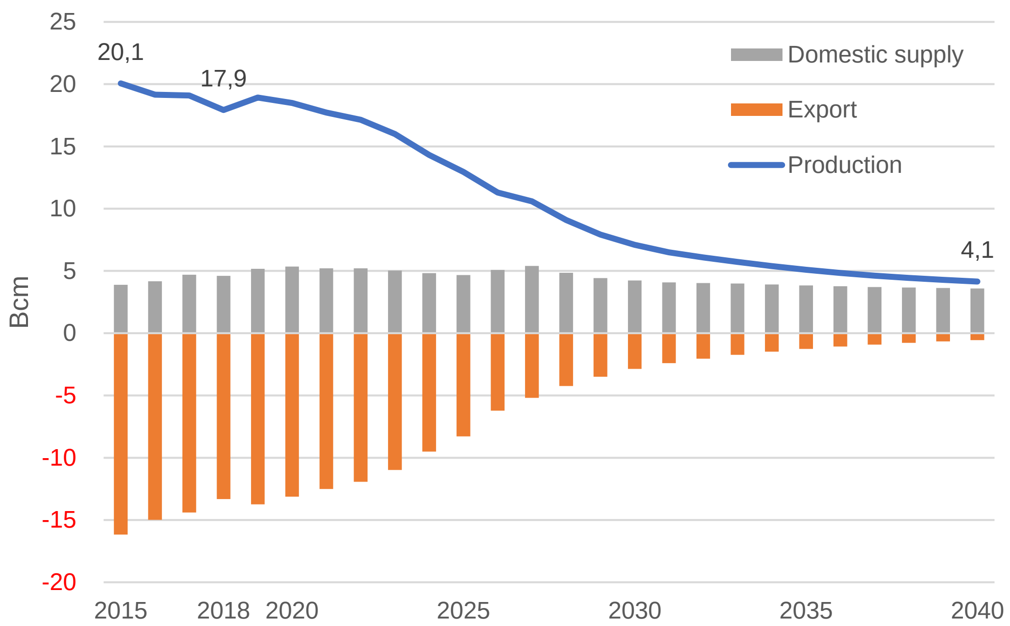
Natural gas

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.

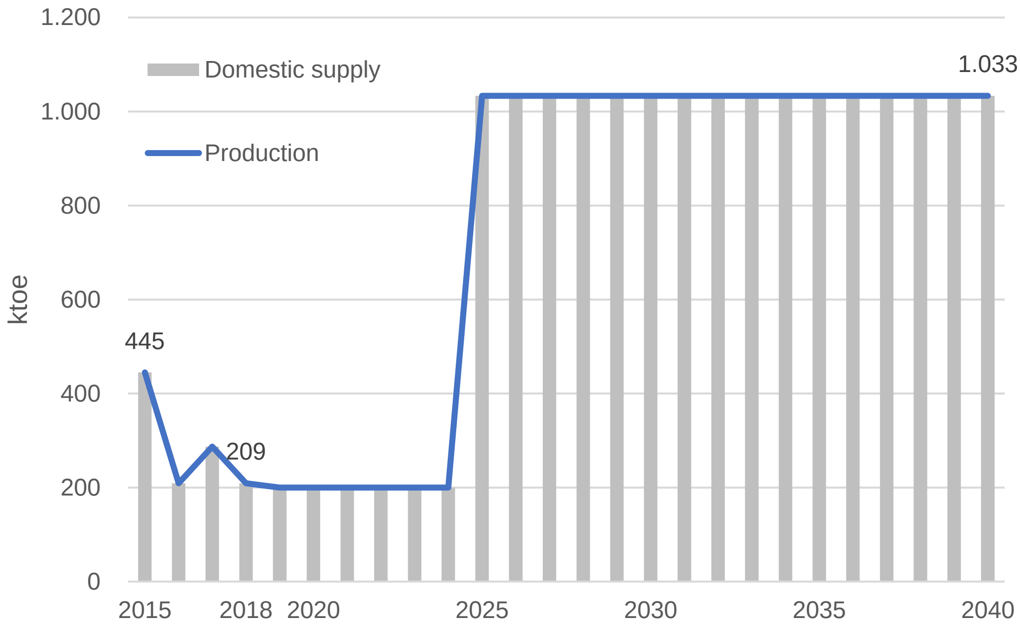
Coal

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 (0.3%)	0	0	0
Natural gas	8.05 (39.7%)	45.68 (51.1%)	*39.04* (43.7%)	*20.72* (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-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.