

Chapter 6

Assessment of Future Simulation Results

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Chapter 6

Assessment of Future Simulation Results

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

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

1. Business-as-Usual Scenario

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

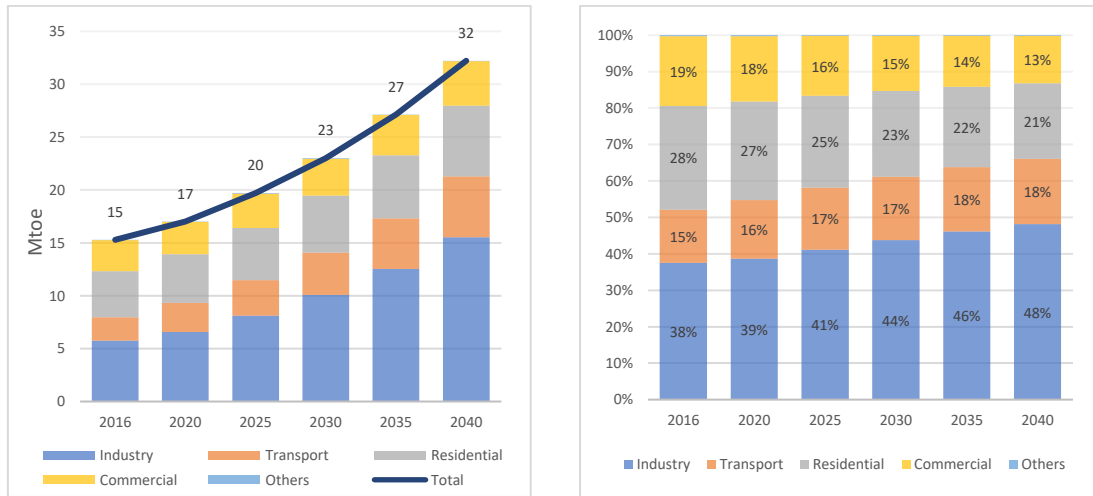
1.1. Final Energy Consumption

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

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

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

Figure 6.1. Total Final Energy Consumption by Sector, Myanmar



Mtoe = million tons of oil equivalent.

Source: Author.

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

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

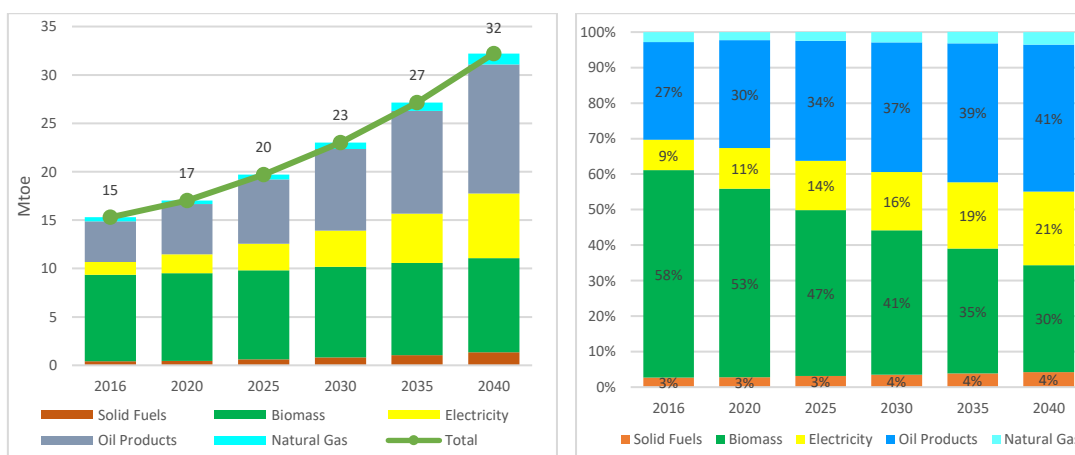
The residential sector's final energy consumption will grow slower, at an average annual rate of 1.8%, whilst the commercial sector's will grow at an average annual rate of 1.5%. Most growth in both sectors will be contributed by the rapid increase of electricity consumption: 6.4% per year for the residential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

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

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

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

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



Mtoe = million tons of oil equivalent.

Source: Author.

1.2. Power Generation

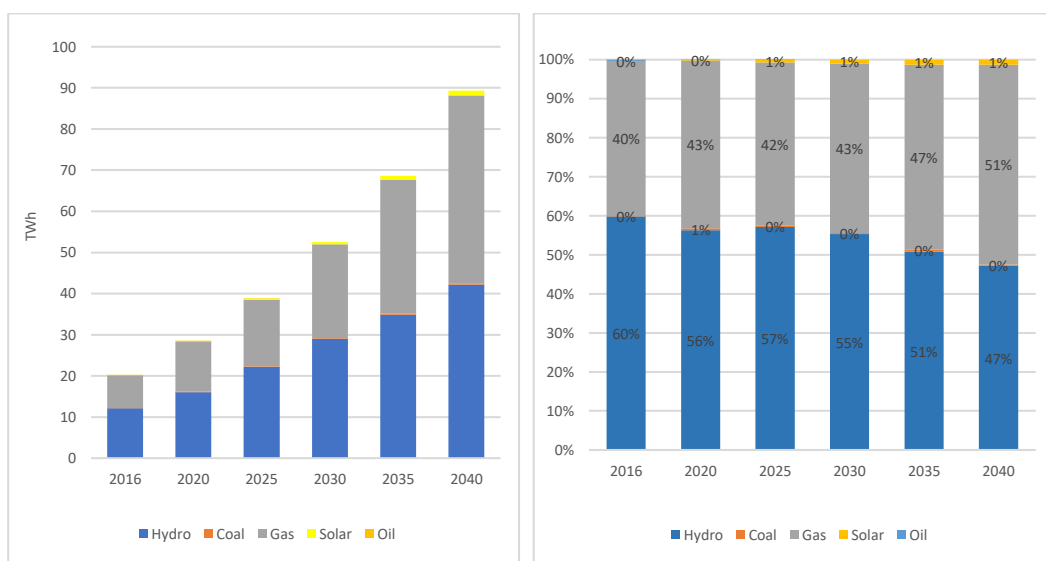
Power generation was mainly from natural gas before 2005. Total generation in 2000 was about 5 TWh and 62% of generation came from natural gas. Hydro's share in total production was only 37% and oil-based plants accounted for the rest. By 2016, power generation increased to 20.3 TWh, where hydropower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

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

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

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

Figure 6.3. Power Generation by Fuel Type, Myanmar



TWh = terawatt hour.

Source: Author.

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

1.3. Primary Energy Supply

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

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

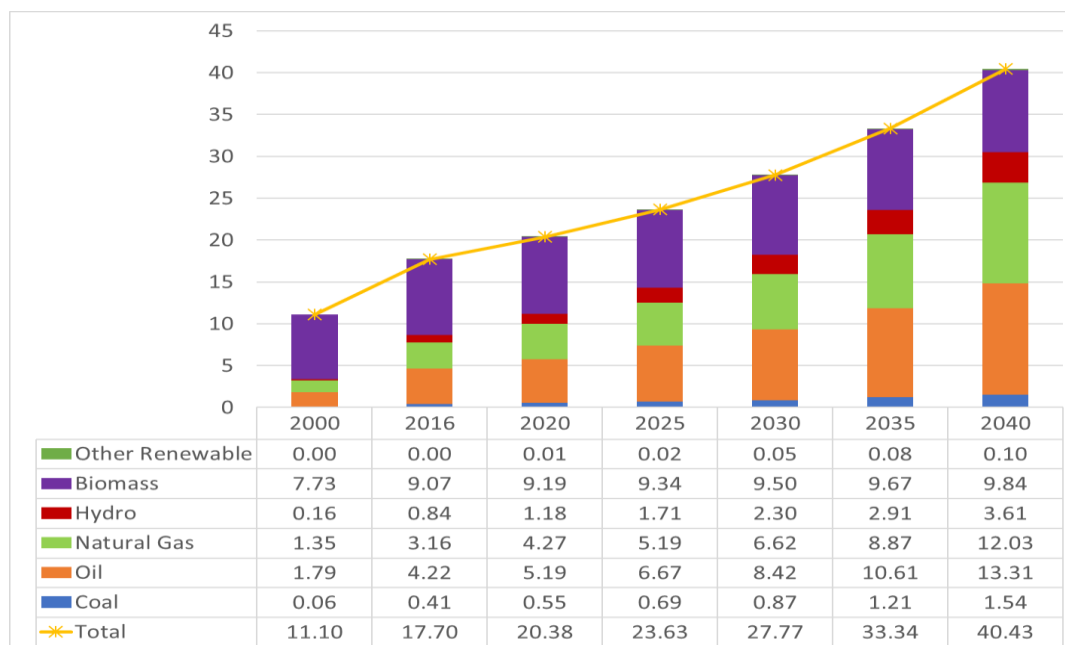
In BAU, the TPES is projected to increase faster than in the past, at an average annual rate of 3.5%, reaching about 40 Mtoe in 2040 (Figure 6.4). All fuel sources, except for RE (solar/PV and wind), will continue to increase but at a slower rate than in the past.

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

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

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

Figure 6.4. Total Primary Energy Supply, Myanmar



Mtoe = million tons of oil equivalent.

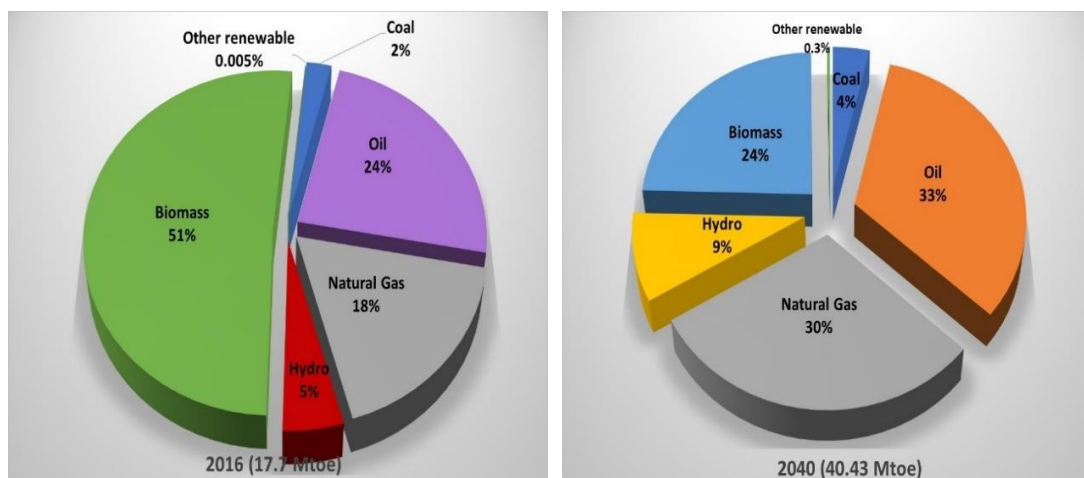
Source: Author.

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

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

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

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



Mtoe = million tons of oil equivalent.

Source: Author.

1.4. Carbon Dioxide Emissions

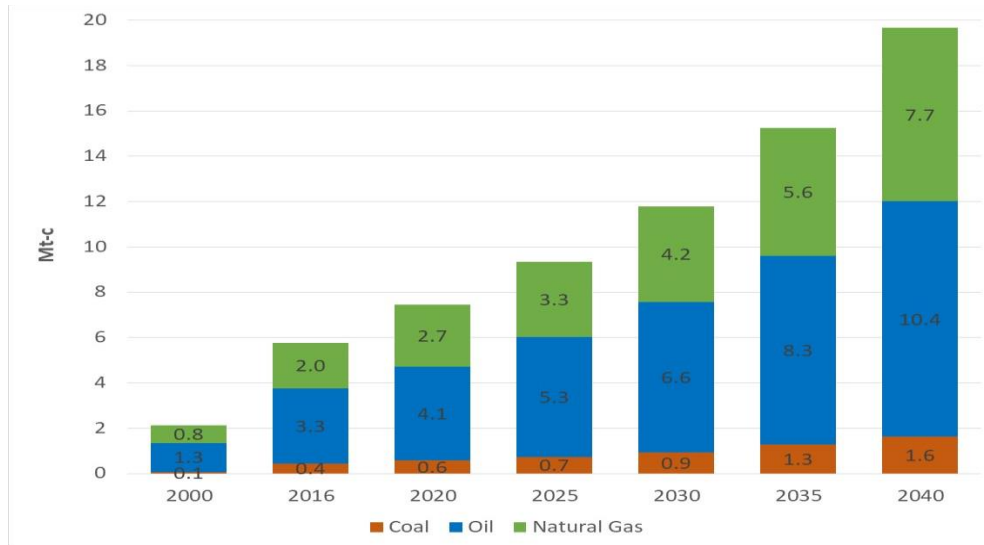
The major sources of carbon dioxide (CO₂) emissions are combustion of fossil fuels (coal, oil, and gas). In 2016, CO₂ emissions in Myanmar reached 5.8 million ton-c (in terms of carbon content) or about 21.1 million ton-CO₂. Most came from burning of oil, especially for transport. Total CO₂ emissions more than doubled in 2000–2016.

In BAU, total CO₂ emissions will reach almost 20 million ton-c by 2040, increasing at

an average rate of 5.2% per year (Figure 6.6).

Oil combustion will still be the major source of CO₂ emissions since its share in the TPES will still be higher (33% in 2040) than that of coal and natural gas, but its share of CO₂ emissions will decrease from 56% in 2016 to 53% in 2040 because of the increasing use of natural gas in power generation and industries. Natural gas will account for 35% of CO₂ emissions in 2016 but 39% in 2040.

Figure 6.6. Total Carbon Dioxide Emissions, Myanmar



Mt-c = million tons of carbon.

Source: Author.

1.5. Energy Indicators

Energy indicators are often used to analyse a country's import dependency on energy, energy consumption per capita, energy consumption per GDP, as well as CO₂ emissions.

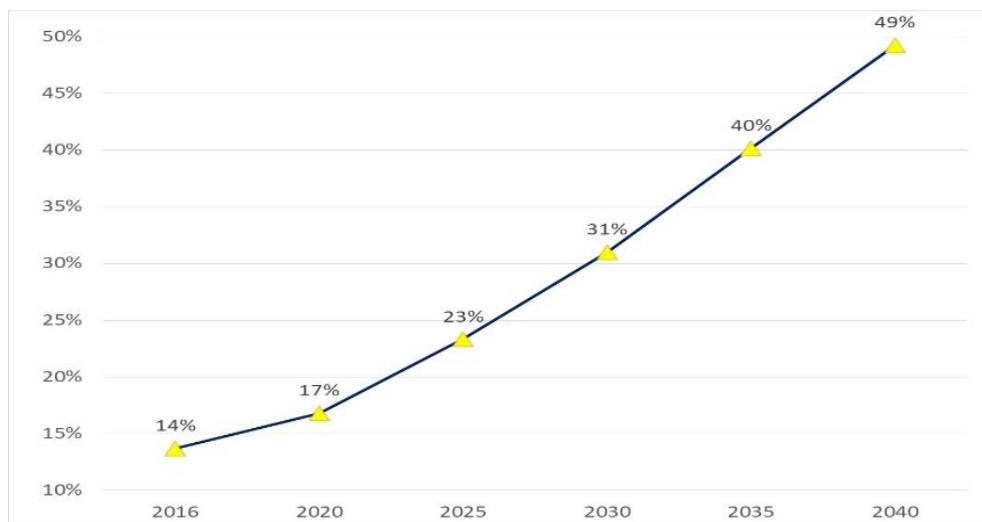
a) Import Dependency

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

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

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

Figure 6.7. Import Dependency, Myanmar



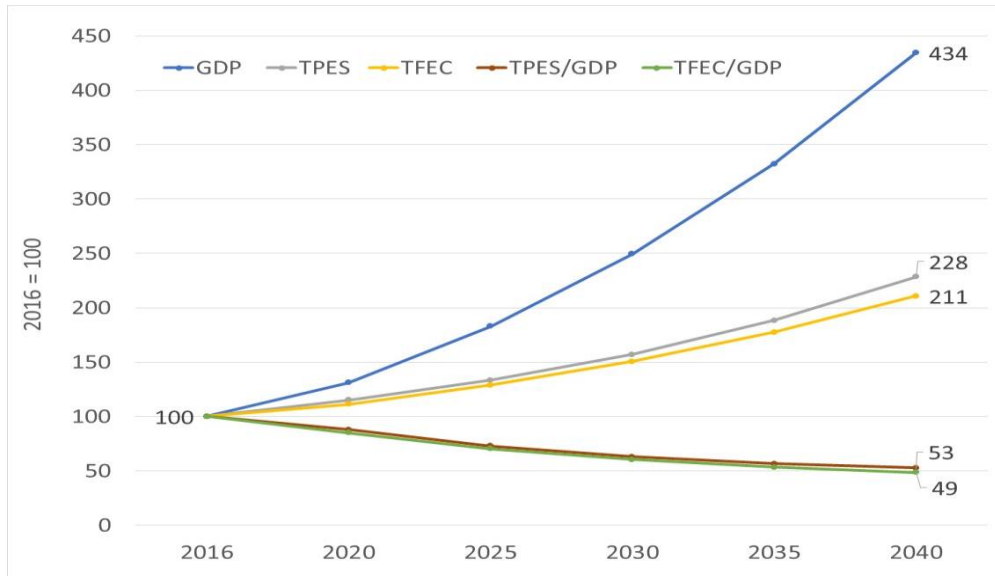
Source: Author.

b) Energy and Carbon Dioxide Emission Intensity

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

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

Figure 6.8. Energy Indicators, Myanmar

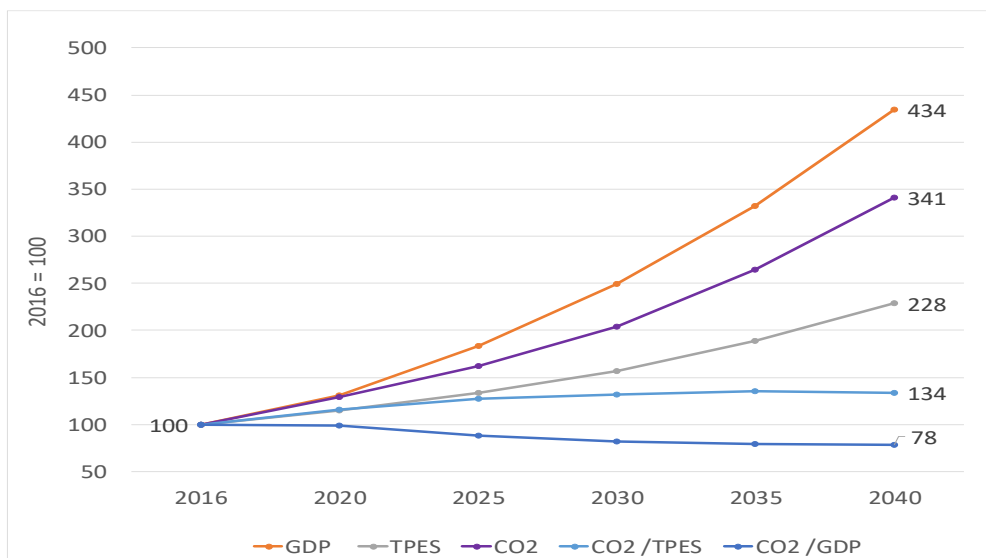


GDP = gross domestic product, TFEC = total final energy consumption, TPES = total primary energy supply.

Source: Author.

As with energy intensity, CO₂ intensity measures the ratio of GDP or the TPES to CO₂ emissions. In BAU, CO₂ emissions in 2040 will be 3.4 times the 2016 level, indicating slower growth than that of GDP. As a result, CO₂/GDP will decline by 0.8 times in 2040 (Figure 6.9). CO₂/GDP will decline at an average rate of 0.1% per year, from 77 ton-c/million US dollars in 2016 to 61 ton-c/million US dollars in 2040.

Figure 6.9. Carbon Dioxide Emissions Intensity, Myanmar



CO₂ = carbon dioxide, GDP = gross domestic product, TPES = total primary energy supply.

Source: Author.

CO₂/TPES will increase to 0.73 ton-c/toe by 2040 from 0.55 ton-c/toe in 2016 because the energy share will shift from low carbon energy (biomass and hydro) to fossil fuels (coal, oil, and gas).

2. Case Studies

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

- (1) **Changes in GDP.** GDP annual growth rate is assumed to increase by an additional 3% for the high case (GDPH) and decrease by 3% for the low case (GDPL) as compared with BAU.
- (2) **Changes in oil price.** Crude oil price is assumed to increase from US\$185 by 2040 in BAU to US\$250 by 2040 in the high oil price (OILH) case or strongly decrease to US\$20 by 2040 in the low oil price (OILL) case
- (3) **EEC promotion.** The TFEC is assumed to reduce by 10% (EE10) and 20% (EE20) in 2040 compared with BAU because of EEC activities.
- (4) **RE development.** Capacity from RE sources (solar/PV and wind) is assumed to be 10% (RE10) and 20% (RE20) higher in 2040 as compared with BAU. These additional increases are assumed for replacing gas-fired power plants.

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

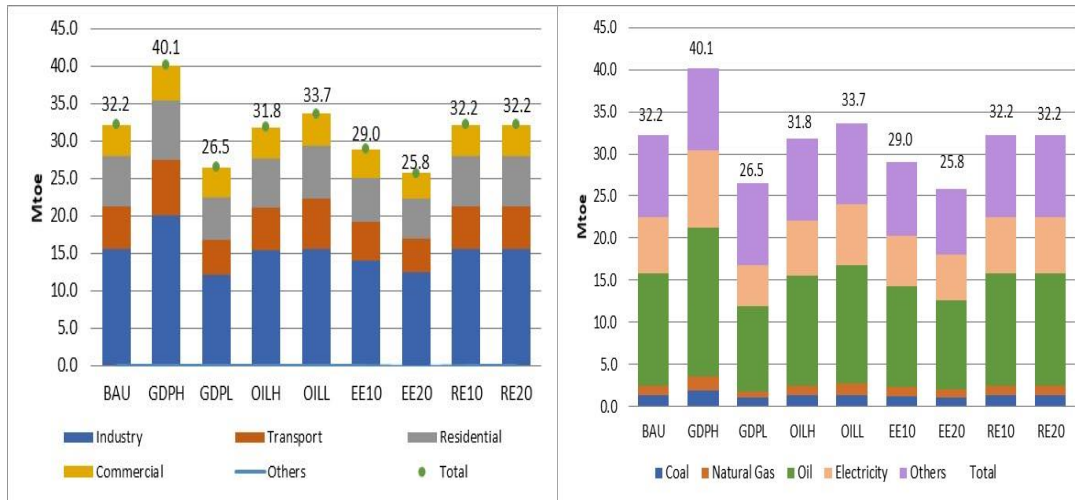
2.1. Final Energy Consumption

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

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

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

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



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

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

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

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

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

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

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

2.2. Power Generation

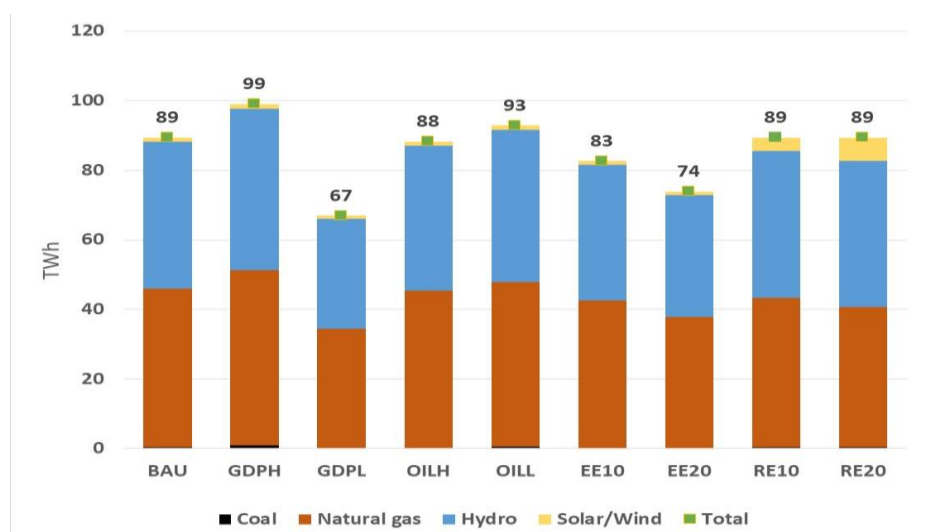
Electricity demand of the final energy consumption sector in case of GDPL will be 28% lower than in BAU. In EE10 and EE20, electricity consumption is only 10% and 20% lower than in BAU. Since own use and losses (distribution and transmission) are the same for all cases, then electricity generation will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

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

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

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

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



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

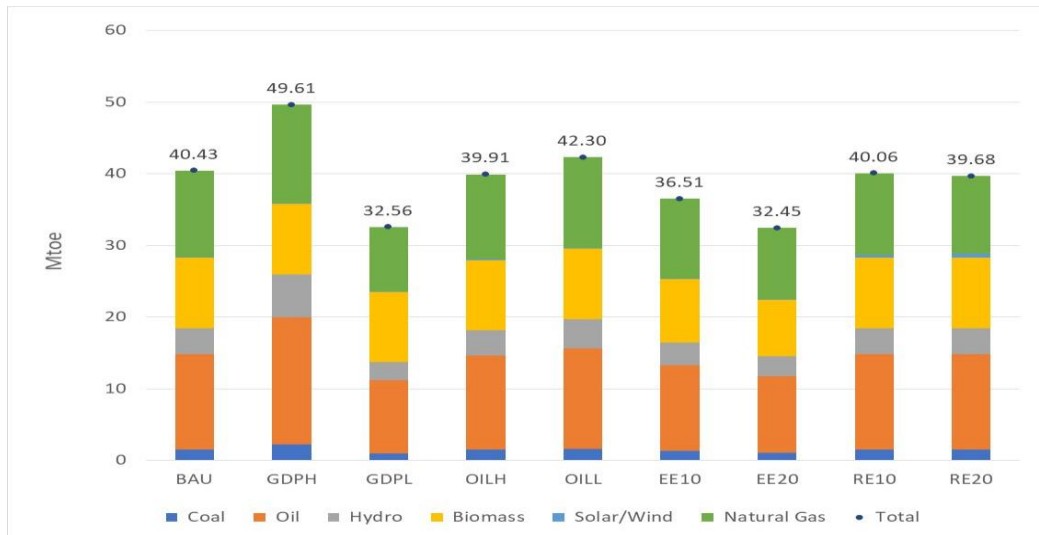
Source: Author.

2.3. Primary Energy Supply

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

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

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



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

Source: Author.

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

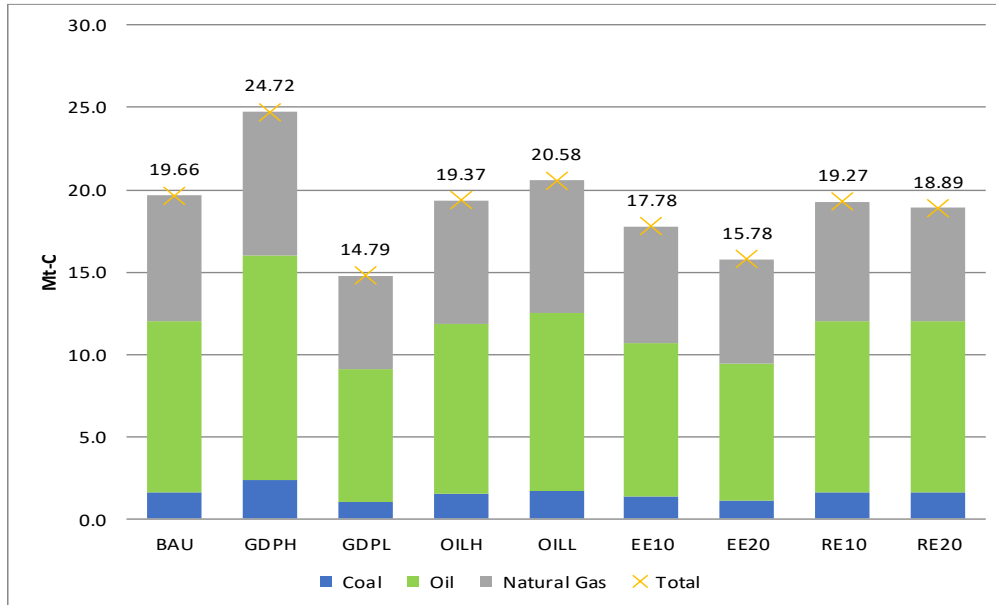
The TPES will be the smallest in EE20 as a result of implementing 20% EE policy in the final energy sectors. The TPES of RE10 and RE20 will impact only natural gas and RE supply (solar/PV and wind) as these cases only substitute natural gas with solar/PV and wind energy (increase 10% and 20%). Natural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

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

2.4. Carbon Dioxide Emission Reduction

The CO₂ emissions in BAU will reach 19.7 Mt-c by 2040, 3.4 times more than it was in 2016. GDPH will increase coal, oil, and natural gas supply as compared with BAU, resulting in higher CO₂ emissions. Total CO₂ emissions in GDPH will be 24.7 Mt-c by 2040, which is 26% higher than in BAU (Figure 6.13). CO₂ emissions will also be higher in OILL, but only by 5%.

Figure 6.13. Carbon Dioxide Emissions by Case, Myanmar



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

Source: Author.

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

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

BAU = business as usual.

Source: Author.

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

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

BAU = business as usual.

Source: Author.