Chapter 2

Case Studies: Keeping CO_2 emission at 2013 level by 2040

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Chapter 2

Case Studies: Keeping CO_2 Emissions at 2013 Level by 2040

This chapter presents case studies where a scenario of keeping carbon dioxide (CO_2) emissions at 2013 level up to 2040 is set by the working group. For some countries belonging to the East Asian Summit, finding the best energy mix while keeping CO_2 from 2013 till 2040 at the same level is a very challenging task. Upscaling renewable energy with energy efficiency programmes remains the key energy policy towards low-carbon economy in East Asian Summit countries. The Paris Agreement bridges today's policies and climate neutrality before the end of the century. However, the Energy Outlook and Saving Potential in East Asia 2016 by the Economic Research Institute for ASEAN and East Asia shows that although emissions reductions under the Alternative Policy Scenario are significant, CO_2 emissions from energy demand in the Alternative Policy Scenario case in 2040 will still be above the 2013 levels and more than three times higher than the 1990 levels. This chapter explores the possibility of each country in ASEAN plus Australia and China keeping CO_2 emissions to the 2013 level up until 2040. Since some countries such as Japan, the Republic of Korea, China, and New Zealand will likely reduce energy consumption, they are not included in this case study.

For this case study, the scenarios are:

- Apply renewable energy and nuclear power generation aggressively;
- Apply energy efficiency and conservation to achieve the maximum energy savings;
- Keep CO_2 emissions to the 2013 level till 2040 to see how it affects the compositions of energy mix in each country.

To achieve this scenario, each country will need to make drastic change to their energy mix, with highly ambitious energy savings through energy efficiency and conservation and huge contribution from renewable energy where nuclear options become dispensable. This study makes clear that reduction of CO_2 emissions is very difficult for some East Asian Summit countries expecting economic growth.

2A.Australia's Case Study: Keeping CO_2 Emission at 2013 Level by 2040

1. Introduction

In 2013, Australia's total primary energy consumption was 129 million tonnes of oil equivalent (Mtoe). Black and brown coal together accounted for 35% of this consumption, its lowest share since the early 1970s. Oil accounted for around 35% of the total primary energy consumption. The share of natural gas increased in recent years to 23%, supported by greater uptake in the electricity-generation sector and growth in industrial use. Total share of fossil fuels was 94%. The remainders were bioenergy, hydropower, wind energy, and solar energy. Carbon dioxide (CO_2) emission in 2013 was 103 million tonnes of carbon (Mt-C).

Australia is endowed with abundant, high-quality, and diverse energy resources. It has around 34% of the world's uranium resources, although not consumed domestically. The country has 14% of the world's black coal resources and almost 2% of the world's gas resources. Australia also has large, widely distributed wind, solar, geothermal, hydroelectric, ocean energy, and bioenergy resources. Wind and solar energy resources are being increasingly exploited, whereas geothermal and ocean energy resources remain largely undeveloped.

Australia's energy resources are a key contributor to its economic prosperity. It exports black coal, uranium oxide, and liquefied natural gas and imports liquid hydrocarbons, including crude oil and most petroleum products.

In 2013, Australia's population was 23.1 million and the nominal gross domestic product (GDP) was US$1,472 billion. Nominal GDP per capita was about US$63,700, around 70% higher than the average of Organisation of Economic Co-operation and Development (OECD) countries. Primary energy consumption per capita was 5.6 tonnes of oil equivalent (toe)/person, 30% higher than the average of OECD countries (4.2 toe/person). Australia heavily relies on fossil fuels. Due to the high carbon intensity of its energy use, CO_2 emission per capita was about 4.5 tonnes of carbon (t-C)/person in 2013, 70% higher than the average of OECD countries (2.6 t-C/person).

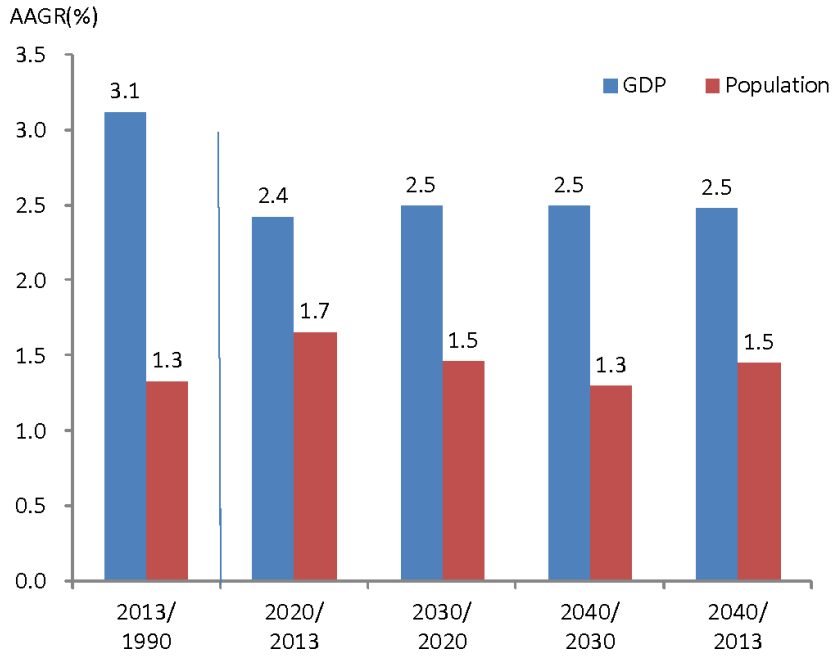
As Australia's population and GDP are predicted to increase steadily in the next decades, a significant increase in energy consumption is expected. To suppress Australia's CO_2 emissions

related to energy by 2040 to below 2013 level, several scenarios are discussed in this report.

2. Modelling Assumptions and Scenario Setting

Growth of population and economy affect the size and pattern of energy demand. During 2013–2040, Australia's population is projected to increase by 1.5% per year, reaching 34 million by 2040. The average annual growth rate of real GDP is 2.5% during the same period (Figure 2A-1).

Figure 2A-1. Assumption for Growth Rate of GDP and Population



GDP = gross domestic product.
Source: Author's calculations.

In 2009, Australian governments entered into a partnership agreement and developed a National Strategy on Energy Efficiency to accelerate energy efficiency efforts. These activities – in particular, improved efficiency of refrigeration, air conditioning, and electronics; minimum performance standards for a range of common household appliances; and energy efficiency requirements in the Building Code – are beginning to show up in Australia's energy use trends.

For renewable energy, the Australian government set, in June 2015, a new target for Large-scale Renewable Energy Target of 33 terawatt-hours (TWh) by 2020, declining from the previous target of 41 TWh by 2020.

In this report, four scenarios are discussed to restrain Australia's CO_2 emissions related to energy by 2040 (see Table 2A.1).

Table 2A-1. Scenario Setting

	Final Energy Demand	Power Generation
Business as Usual Scenario (BAU)	Extension of historical trend based on current policy	
Energy Conservation Scenario (ECS)	Enhanced energy conservation	Same as BAU
Low-Carbon Power Generation Scenario (LCP)	Same as BAU	Further development of renewable energy
Alternative Policy Scenario (APS)	Between BAU and ECS	Between BAU and LCP

Source: Author's assumption.

3. Results of Energy Consumption and CO_2 Emissions

Final energy demand

In the Business as Usual (BAU) scenario, final energy demand will increase at 2.2% during the outlook period, and reach 145 metric tonnes of oil equivalent (Mtoe) by 2040 from 81 Mtoe in 2013 (see Figure 2A.2).

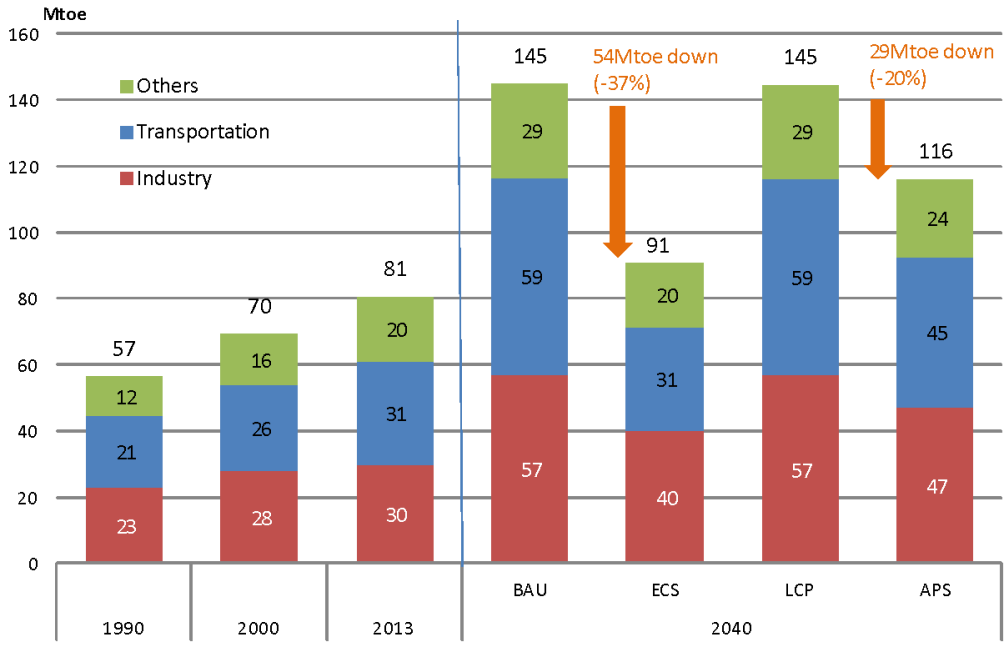
The transport sector accounted for 38.5% of final energy demand in 2013. The transport sector's consumption, most of which are oil and petroleum products, is expected to grow steadily over the projection period at an average rate of 2.4% per year, driven largely by economic growth. Its share in final energy demand is projected to increase to 40.9% in 2040. The industry sector (here, including the non-energy use) is the second largest user of final energy in Australia, accounting for a share of 37.1% in 2013. This sector covers several relatively energy-intensive subsectors such as petroleum refining, iron and steel, aluminium smelting, and minerals processing. Whereas energy consumption in the industry sector is projected to increase at an average annual rate of 3.1% over the outlook period, the share of the sector is expected to increase to 39.4%. The mining sector is projected to have the highest energy consumption growth rate over the outlook period. This reflects the continuation of global demand for energy and mineral commodities and the large number of mineral and energy projects (including liquefied natural gas and coal seam gas) assumed to come on stream over the outlook period.

The ‘others’ including agriculture, commercial, and residential sectors is projected to increase at 1.4% per year.

In the Energy Conservation Scenario (ECS), significant energy savings need to be achieved in all sectors. Final energy demand in 2040 will be 91 Mtoe, 13% higher than the 2013 level, but 54 Mtoe (37%) lower than that in BAU. The transport sector accounts for around half of the total energy saving. With improvement of fuel economy and the further development of electric vehicles, energy consumption per car is assumed to decrease by 35% from the 2013 level. About 30% of energy saving will come from the industry sector. Average annual growth rate of the industry sector’s energy demand needs to be suppressed to 1.7%. Energy demand of others sector in 2040 is assumed to be suppressed into the 2013 level, 31% lower than that in BAU.

In the Alternative Policy Scenario (APS), the final energy demand will reach 116 Mtoe by 2040, an increase of 36 Mtoe from 2013, between the level of ECS and BAU. The industry sector will account for nearly half of the increment of final energy demand during the outlook period. The transport sector’s demand will increase moderately at 1.4% per year according to the expanding volume of cars. The energy consumption per car is assumed to be improved by 7% from the 2013 level, much modest compared with ECS. The average annual growth rate of the others sector’s energy demand will be 0.7%, half of that in BAU.

Figure 2A-2. Final Energy Demand by Sector



Note: 'Others' sector includes agricultural, residential, and commercial sectors. Non-energy use is included in energy consumption of the 'Industry' sector.

Mtoe = metric tonne of oil equivalent.
Source: Author's calculations.

Power generation

For electricity generation, coal has been the major fuel source for electricity generation in Australia, although its share in total production fell from 83% in 2000 to around 65% in 2013. In contrast, natural gas-fired generation continued to rise from 2006, and reached 21% in 2013. The share of renewables in Australian electricity generation rose from approximately 8% in 2000 to around 13% in 2013. Although hydropower is still the largest resource for power generation, rapidly increased use of wind energy and solar photovoltaic system in recent year accounts for most of the increment of renewables (see Figure 2A.3).

In the BAU scenario, electricity generation is projected to grow by 34% (or 1.1% per year) from 249 TWh in 2013 to 334 TWh in 2040. Coal is expected to remain the dominant source of electricity generation. The share of coal in electricity generation is projected to remain broadly constant at around 64%, growing at 1% per year. Due to the declining cost of renewable generation (mostly wind and solar energy) over the projection period, electricity production

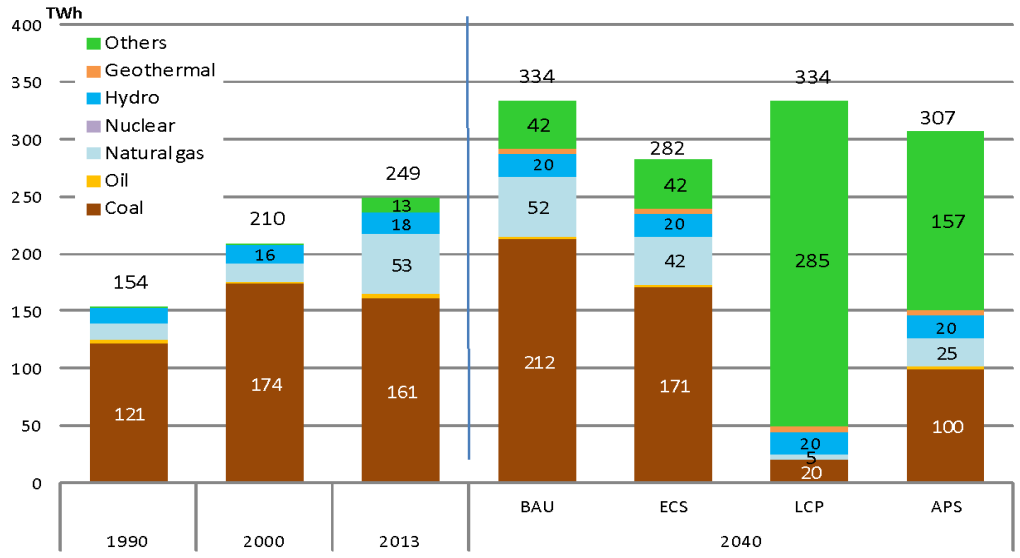
from renewables is expected to grow by 2.9% per year over the projection period. The share of renewables is expected to increase to 20% by 2040. Meanwhile electricity production from natural gas is expected to keep the current level and drop its share to 16% by 2040.

In ECS, due to moderate increase of electricity demand, total electricity production in 2040 is only 13% up from the 2013 level, 16% lower than that in BAU. In ESC, due to less demand, coal and natural gas electricity production in 2040 will be lower than that in BAU. The total amount of electricity production by fossil fuels will be almost the same as that in 2013.

In Low-Carbon Power Generation Scenario (LCP), given the same electricity consumption as BAU, to reduce CO_2 emissions from the fossil fuel-fired power generation, wind and solar power generation should increase dramatically from BAU. The share of renewables in electricity production is assumed to exceed 90%.

In APS, due to less demand and further development of renewable energy, coal and natural gas power generation in 2040 will decrease to half of that in BAU. Renewables need to triple that in BAU, with the share of 59% in 2040.

Figure 2A-3. Electricity Production by Fuel Type



APS = Alternative Policy Scenario, BAU = Business as Usual, ECS = Energy Conservation Scenario, LCP = Low Carbon Power Generation, TWh = terawatt hour.
Source: Author's calculations.

Primary energy consumption

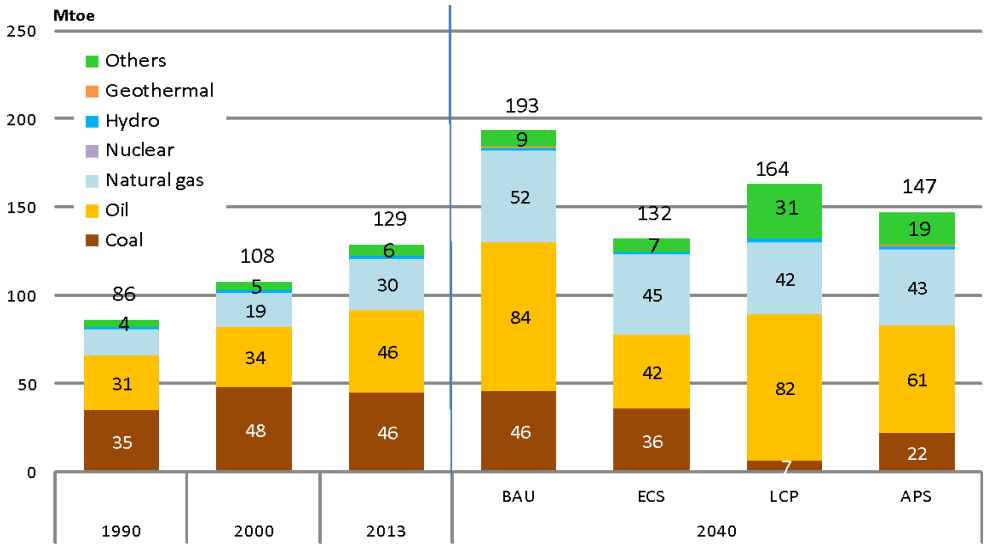
In BAU, total primary energy consumption is projected to reach 193 Mtoe in 2040, a growth of nearly 50% (or 1.5% per year) over the projection period. This compares with average annual growth in primary energy consumption in Australia of 1.8% per year from 1990 to 2013. Oil will increase its presence in Australia's energy consumption, and the share will increase from 36% in 2013 to 44% in 2040 due to increasing demand of the transport sector (see Figure 2A.4). The use of gas (conventional and unconventional natural gas) is expected to grow over the outlook period and increase its share from 23% in 2013 to 27% in 2040 with the growth in consumption of gas in liquefied natural gas production. The consumption of coal will keep the current level, dropping its share from 35% to 24%. Renewable energy consumption is projected to increase at the rate of 1.3% per year over the projection period. The growth in renewable energy is mainly driven by strong growth in wind and solar energy. Meanwhile, the increase of hydropower and biomass energy will be limited.

In ECS, due to the saving of final energy demand and the less power generation, primary energy consumption in 2040 will be 32% lower than that in BAU, slightly up from the 2013 level. The sum of fossil fuel consumption in 2040 will be 1.8 Mtoe, higher than that in 2013. Increased demand of natural gas in industry and liquefied natural gas production will surpass the decreased demand in power generation.

In LCP, primary energy consumption in 2040 will be larger than that in 2013. To offset the increase of oil in final demand, coal in power generation needs to be reduced dramatically, replaced by renewable energy.

In APS, primary energy consumption is projected to grow at a lower rate of 0.5% per year to 147 Mtoe in 2040. Coal is expected to decline at 2.7% per year. Increase of oil and natural gas demand will be moderate compared with BAU, being 1.1% and 1.4% per year, respectively. Renewables energy in 2040 will triple the level in 2013 and double that in BAU.

Figure 2A-4. Primary Energy Consumption and Its Composition



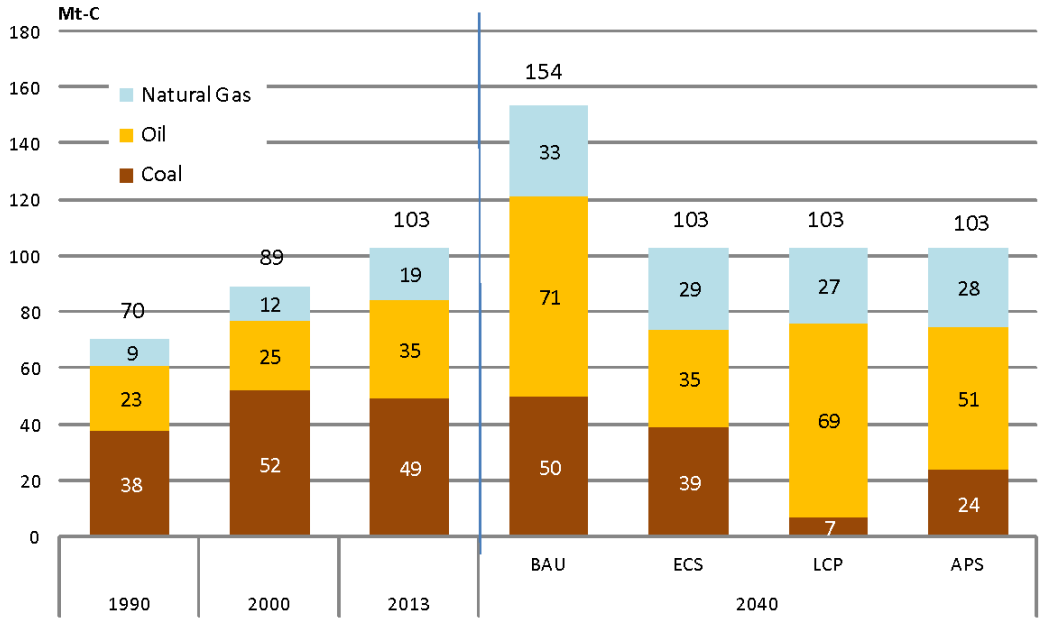
APS = Alternative Policy Scenario, BAU = Business as Usual, ECS = Energy Conservation Scenario, LCP = Low Carbon Power Generation, Mtoe = metric tonne of oil equivalent.
Source: Author's calculations.

CO_2 emissions

CO_2 emissions in BAU will increase by 50% from 103 metric tonnes of carbon (Mt-C) in 2013 to154 Mt-C in 2040 (see Figure 2A.5).

In ECS, CO_2 emissions in 2040 are suppressed to the 2013 level by the stabilisation of oil demand and the shift from coal to natural gas. In LCP, CO_2 emissions from oil consumption will double the 2013 level. However, with the dramatic shift from coal and gas to renewable energy in power generation, total CO_2 emissions in 2040 will eventually be almost the same as that in 2013. In APS, with the conservative assumptions on energy saving in final demand than ECS and the moderate development of renewables compared to LCP, CO_2 emissions in 2040 is also suppressed to the 2013 level.

Figure 2A-5. CO_2 Emissions from Energy Consumption



APS = Alternative Policy Scenario, BAU = Business as Usual, CO_2 = carbon dioxide, ECS = Energy Conservation Scenario, LCP = Low Carbon Power Generation, Mt-C = million tonne of carbon.
Source: Author's calculation.

Conclusions and Implications

The current projections show that Australia's energy consumption will continue to grow over the next 40 years at a lower rate than in the past 20 years. This is because of the substitution of renewables for fossil fuels in electricity generation – which require much less energy use to generate electricity – and because of expected energy efficiency improvements.

Renewables will show significant increase in the next decades, mainly driven by strong growth in wind and solar energy. However, oil and coal will continue to supply the bulk of Australia's energy needs, although the share of coal in the energy mix is expected to decline. The use of gas is expected to grow steadily over the outlook period.

Transition to a low-carbon economy will require long-term structural adjustment in the Australian energy sector. Although Australia has an abundance of energy resources, this transformation will need to be underpinned by significant investment in energy supply chains to

allow for better integration of renewable energy sources and emerging technologies into its energy systems. It will be critical to ensure that the broader energy policy framework continues to support cost-effective investment in Australia's energy future, and timely adjustments to market settings in response to emerging pressures and market developments.

References

Syed, A. (2016), *Australian Energy Government Projections to 2050*. Jakarta: Economic Research Institute for ASEAN and East Asia.

Council of Australian Government (2009), *National Strategy on Energy Efficiency*. https://www.gbca.org.au/uploads/56/2360/Energy_efficiency_measures_table.pdf (accessed 24 April 2017)

CHAPTER 2B.Cambodia's Case Study
Keeping CO_2 Emissions at 2013 Level by 2040

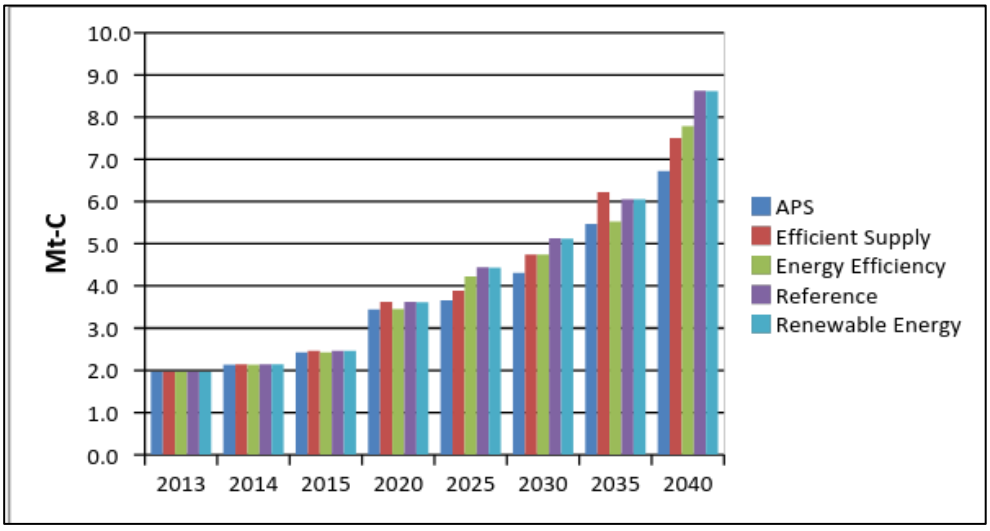
1. Background

The Energy Outlook and Energy Saving Potential in East Asia 2016 by the Economic Research Institute for ASEAN and East Asia (ERIA) projects an increasing energy demand in the Alternative Policy Scenario (APS) and the Business as Usual (BAU) scenario. As a result, total carbon dioxide (CO_2) emissions will also increase in the future.

APS is a combination of different scenarios. In the case of Cambodia, the scenarios include reference (BAU), energy efficiency (APS1), renewable energy (APS2), efficient supply (APS3), and alternative policy (APS).

For the BAU scenario (Figure 2B.1), Cambodia's total CO_2 emissions were around 2 metric tonnes of carbon (Mt-C) in 2013 (base year) and projected to reach almost 9 Mt-C by 2040.

Figure 2B.1. CO_2 Emissions of Cambodia in ERIA's Outlook 2016



APS = Alternative Policy Scenario, CO_2 = carbon dioxide, ERIA = Economic Research Institute for ASEAN and East Asia, Mt-C = metric tonne of carbon.
Source: Author's calculations.

Assuming implementation of more efficient technology in the final and supply sector

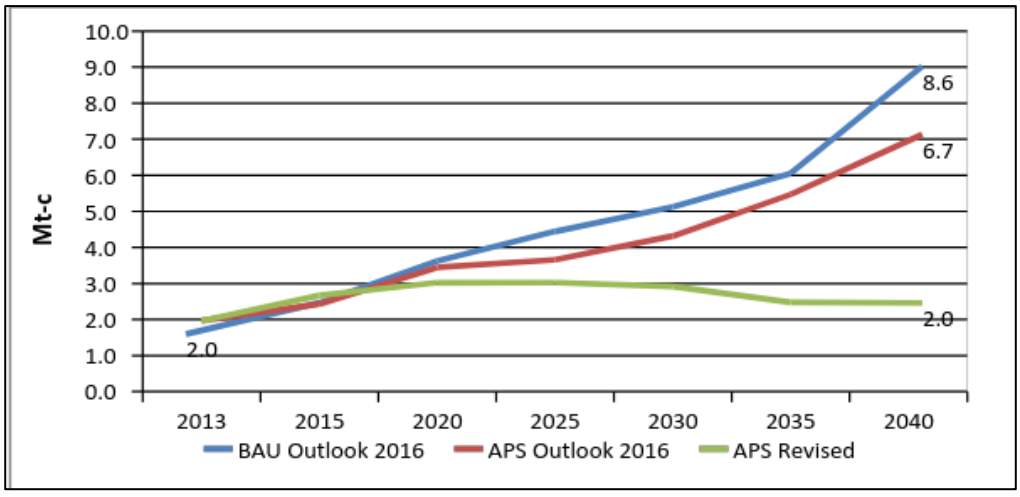
and higher penetration of renewable energy, total CO_2 emissions will only increase to around 7 Mt-C by 2040. Thus, implementing APS will result in a 22-% reduction of CO_2 emissions in 2040 as compared to the BAU scenario.

This case study is to identify possible solutions to mitigate CO_2 emissions in 2040 to the 2013 level. Since APS has the lowest CO_2 emissions, this scenario will be the basis for the case study.

2. Methodology

The APS consists of APS1, APS2, and APS3. Implementing APS still results in an increase of CO_2 emissions in 2040 compared to the base year 2013. To ensure that the total CO_2 emissions remain at the 2013 level (Figure 2B.2), more efforts will be needed to achieve national development target without increasing CO_2 emissions from its base year level.

Figure 2B.2. CO_2 Emissions Comparison



APS = Alternative Policy Scenario, BAU = Business as Usual, CO_2 = carbon dioxide, Mt-C = metric tonne of carbon.
Source: Author's calculations.

The parameters to consider would be energy saving in the final consumption sector, high-efficient thermal power plants, hydropower and geothermal resources, solar/photovoltaic (PV) and wind resources, and other renewable energy.

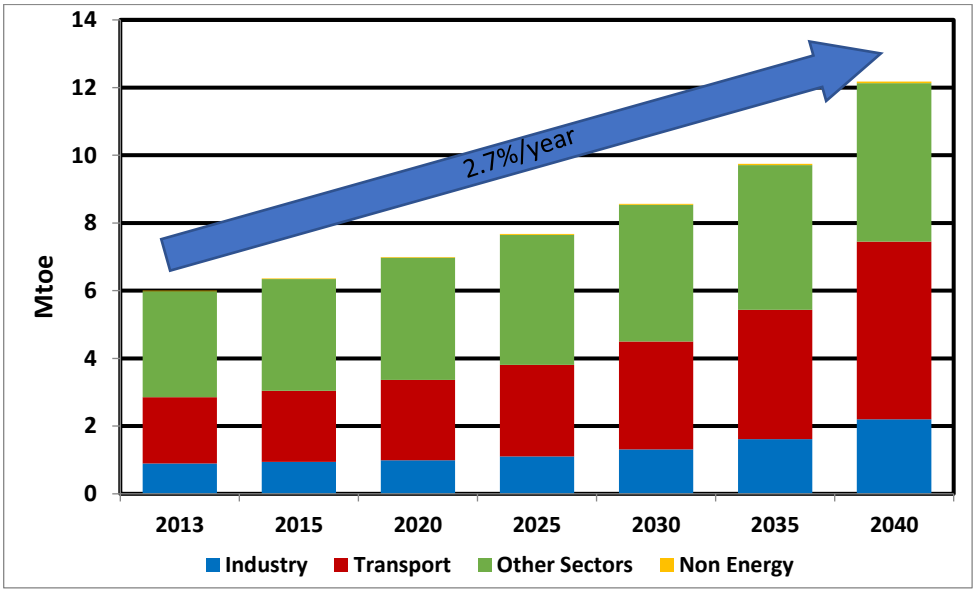
The approach for the exercise will be to make energy efficiency targets more stringent; use less fossil fuels and more renewable energy; increase use of biofuels such as

biogasoline (bioethanol), biodiesel, and biogas; limit use of fossil fuels in the power sector; and increase use of renewables for power generation.

3. Final Energy Demand

In the ERIA's Energy Outlook and Energy Saving Potential in East Asia 2016, (Energy Outlook 2016), the final energy demand of Cambodia under APS will be growing at an average rate of 2.7% over the 2013–2040 period (Figure 2B.3).

Figure 2B.3. Final Energy Demand in ERIA's Outlook 2016 APS

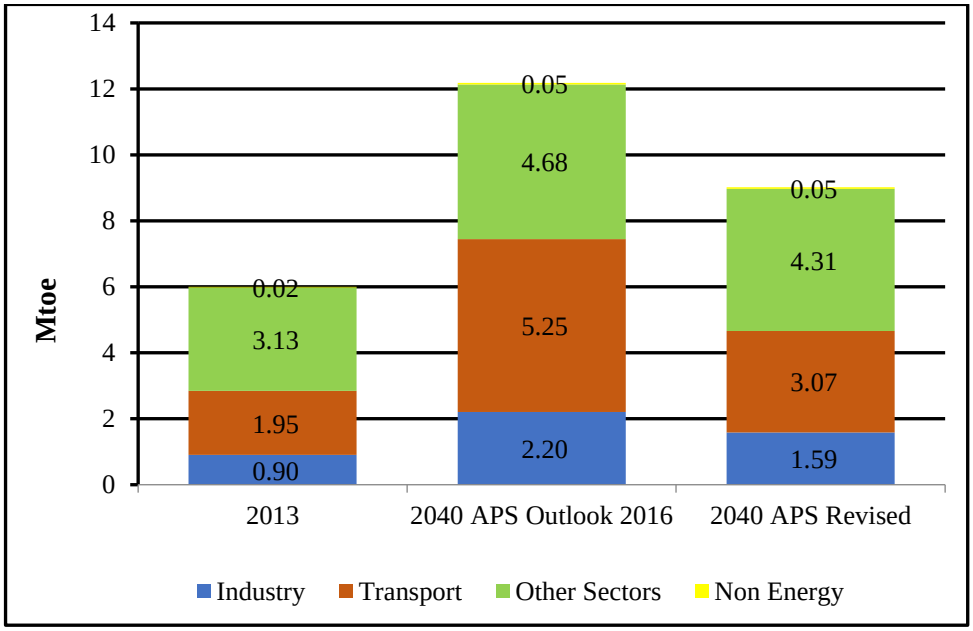


APS = Alternative Policy Scenario, ERIA = Economic Research Institute for ASEAN and East Asia, Mtoe = metric tonne of oil equivalent.
Source: Author's calculations.

Revising the assumption for energy efficiency (EE) and increased use of biofuels will slow down the increase of the final energy demand. The final energy demand of the revised APS will grow at an average annual rate of 1.5% per year over the 2013–2040 period. Revising the EE target will reduce the total final energy demand of 2040 by almost 26% the level of the APS in the ERIA's Energy Outlook 2016 (Figure 2B.4).

The use of biofuels will be increasing since the assumption was revised especially in the transport sector. Biogas for households is also assumed to increase more in the revised APS.

Figure 2B.4. Final Energy Demand Comparison

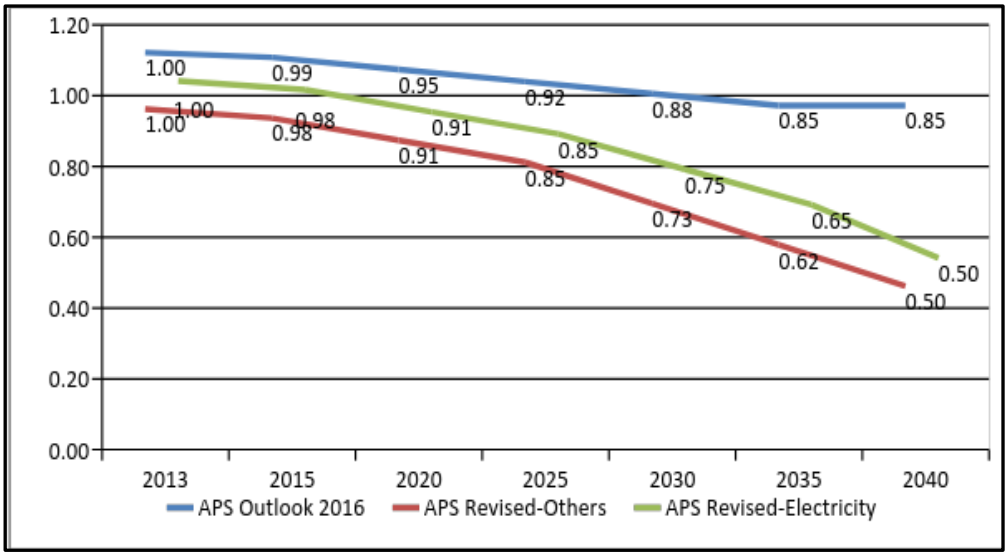


APS = Alternative Policy Scenario, Mtoe = metric tonne of oil equivalent.
Source: Author's calculations.

4. EE Targets

The EE target for electricity and others in the ERIA's Energy Outlook 2016 APS is assumed to be 15% by 2040. In the revised APS, the target is more stringent. Around 50% saving target is assumed for both electricity and other fuels (Figure 2B.5).

Figure 2B.5. EE Targets



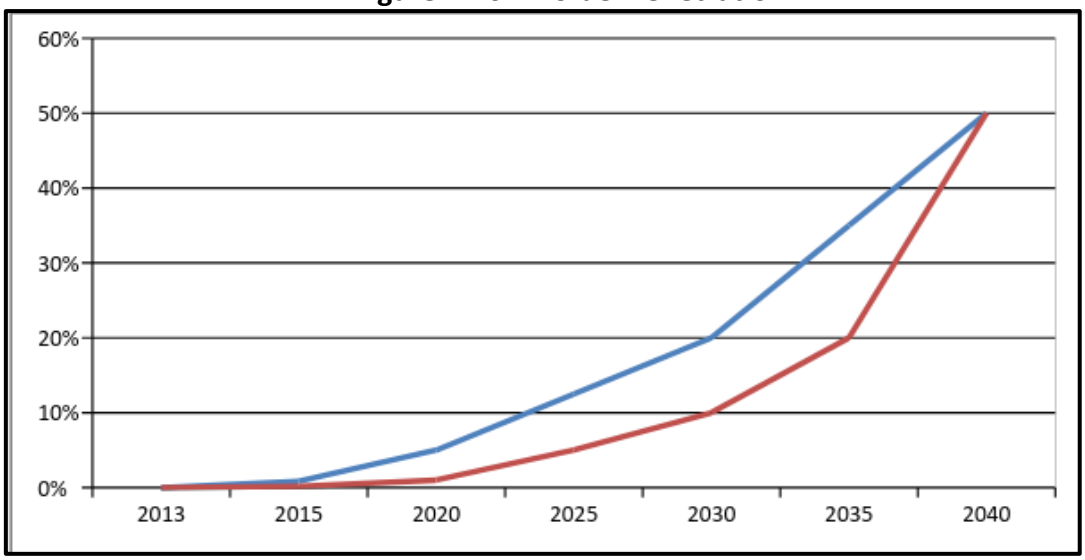
APS = Alternative Policy Scenario, EE = Energy Efficiency

Source: Author's calculations.

Biofuel Penetration

Beside the EE target, biofuel penetration is included in the revised APS. In the APS of the ERIA's Outlook 2016, no penetration of biofuel is assumed. It is assumed that the penetration of biofuel in the revised APS will reach 50% by 2040 for both biodiesel and biogasoline (Figure 2B.6).

Figure 2B.6. Biofuel Penetration



Source: Author's calculations.

Power Generation

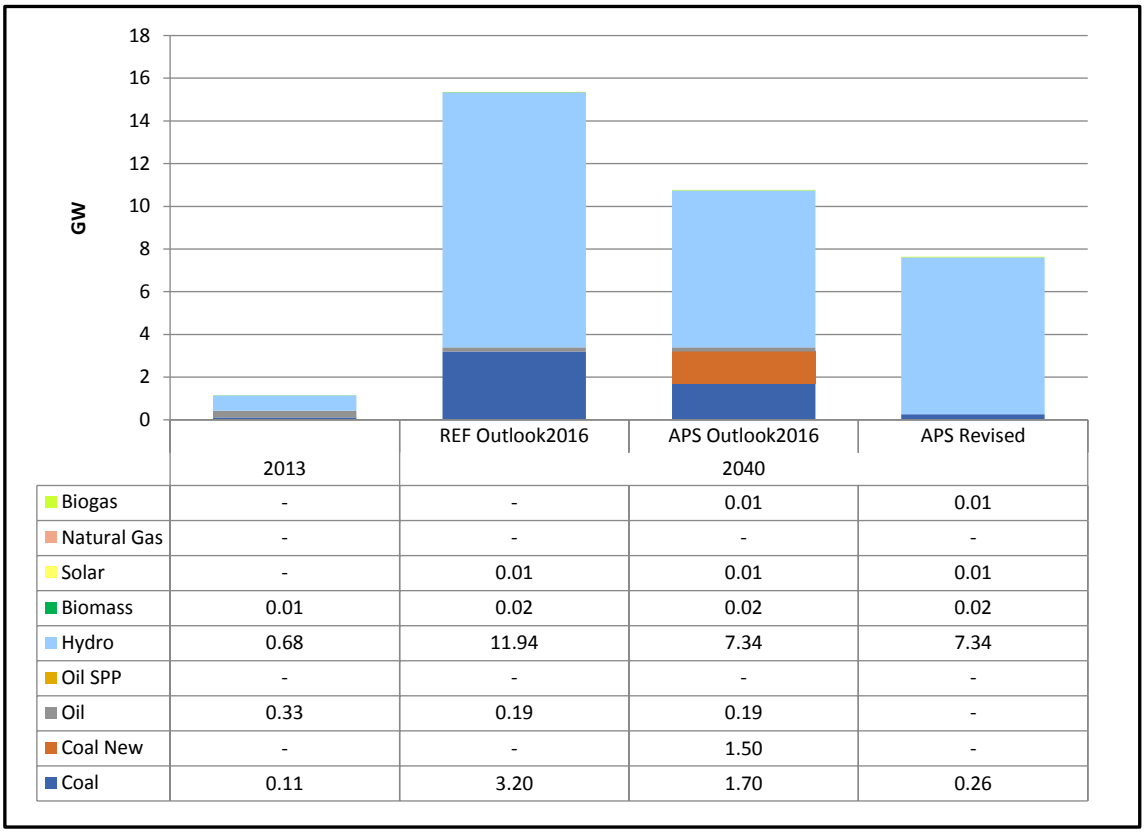
The parameters in the power generation sector of the LEAP (Long-range Energy Alternatives Planning) model include dispatch rule, merit order, efficiency, maximum availability, exogenous capacity, etc., most of which are similar to that of APS in the ERIA's Energy Outlook 2016. The difference is in the capacity expansion of the various power plants. In the revised APS, more renewable energy capacities are being assumed for the future.

Capacity

As shown in Figure 2B.7, the total capacity in APS of the ERIA's Energy Outlook 2016 is around 11 gigawatts (GW) in 2040 while it is lower (almost 8 GW) in the revised APS. An assumption is made on the expansion of fossil fuels in the revised APS so as to achieve

CO_2 emissions by 2040 similar to the 2013 level.

Figure 2B.7. Total Capacity (GW)



	2013	2040		
		REF Outlook2016	APS Outlook2016	APS Revised
Biogas	-	-	0.01	0.01
Natural Gas	-	-	-	-
Solar	-	0.01	0.01	0.01
Biomass	0.01	0.02	0.02	0.02
Hydro	0.68	11.94	7.34	7.34
Oil SPP	-	-	-	-
Oil	0.33	0.19	0.19	-
Coal New	-	-	1.50	-
Coal	0.11	3.20	1.70	0.26

GW = gigawatt.
Source: Author's calculations.

In the case of coal power plants, no additional expansion is assumed except the one planned in 2015 (258 MW). In addition, the existing 110-MW coal power plants are assumed to be retired in 2040.

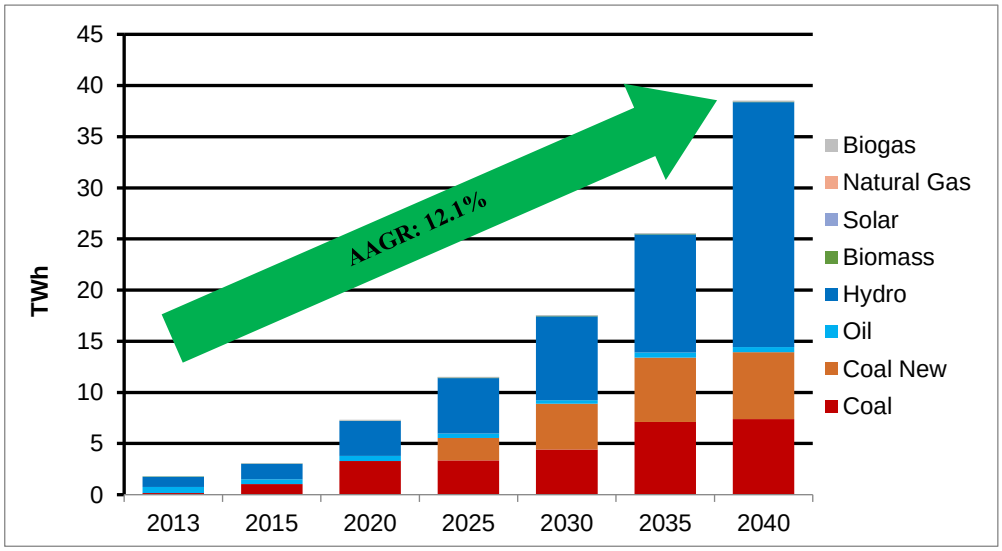
There is also no expansion assumed for oil power plants and that the existing plants will gradually be retired by 2030.

In the case of renewable power plants, the expansion assumed in APS of the ERIA's Energy Outlook 2016 will still be the same in the revised APS. Thus, hydropower plants will dominate the total capacity in 2040. Biomass and solar and wind energy plants capacities will be small (20 MW for wind power and 10 MW for solar energy and biomass, respectively).

Power generation

The revised APS generation of electricity will be around 23 TWh in 2040, lower than the 38 TWh generated in APS of the ERIA's Energy Outlook 2016 (Figures 2B.8 and 2B.9). The average annual growth rate of electricity production in ERIA's Energy Outlook 2016 APS is 12.1% while in the revised APS, the rate is slower, at 9.9% per year.

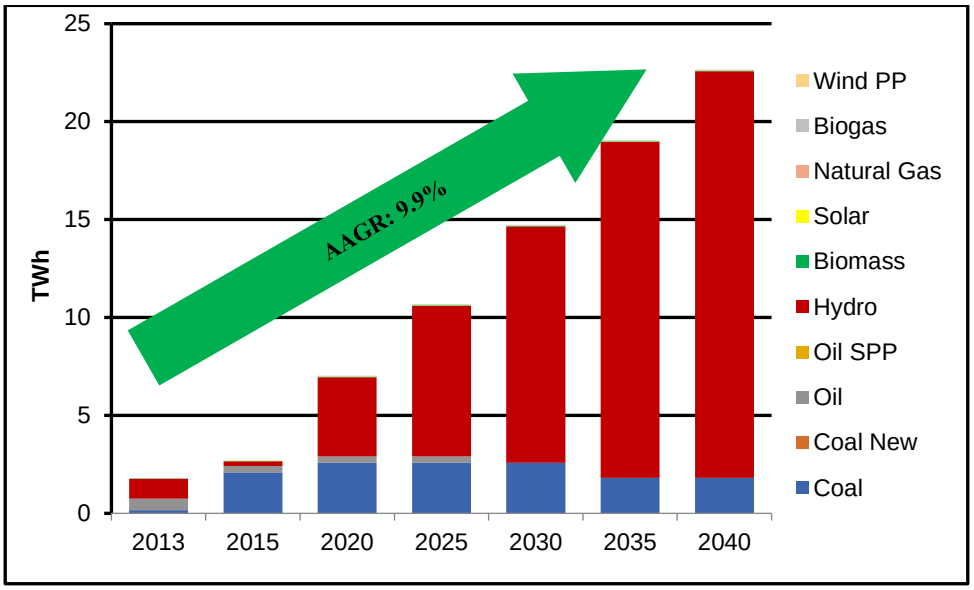
Figure 2B.8. Power Generation by Type in APS Outlook 2016



AAGR = Average Annual Growth Rate , APS = Alternative Policy Scenario, TWh = terawatt hour.
Source: Author's calculations.

Since the target is to achieve CO_2 emissions in 2040 to the same level as that of in 2013, the renewable generation in the revised APS will account for almost 92% of the total generation. In ERIA's Energy Outlook 2016 APS, the renewable share in total generation is around 62%. Generation from hydropower plants dominates the total generation of renewable energy for both APSs.

Figure 2B.9. Power Generation by Type in APS Revised

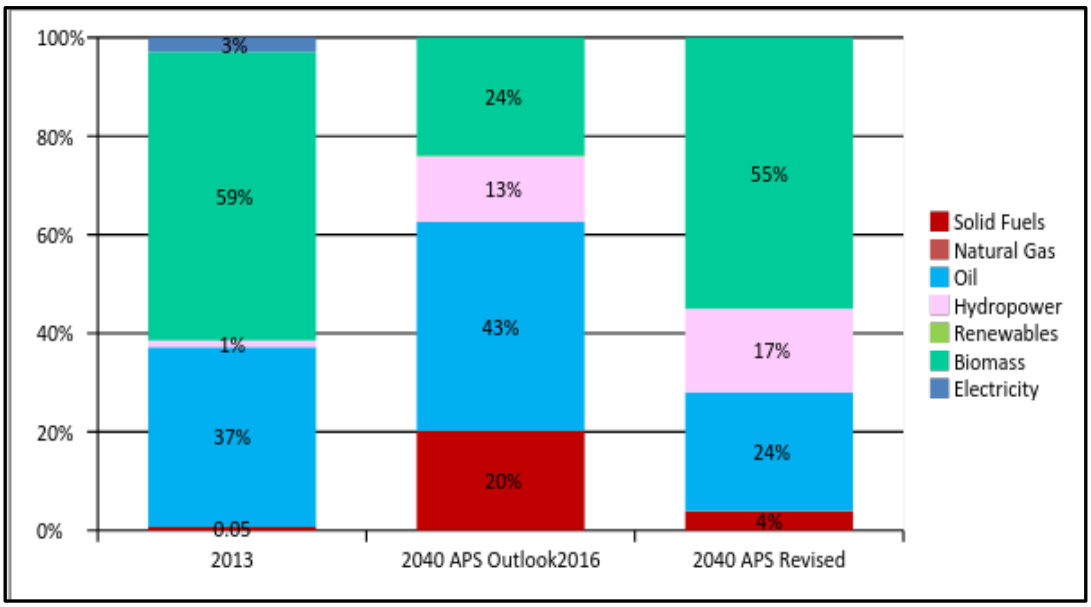


AAGR =Average Annual Growth Rate, PP = power plants, SPP =, TWh = terawatt-hour.
Source: Author's calculations.

Primary Energy Supply

With revised EE target, biofuel penetration, and increased share of renewable energy in the power sector, the total primary energy supply of the revised APS will be around 10 Mtoe in 2040. The total primary energy supply of the revised APS in 2040 is 32% lower than the total primary energy supply in APS of the ERIA's Energy Outlook 2016 (Figure 2B.10). In terms of the share in the total energy mix of 2040, 72% comes from renewable energy including biomass and hydropower.

Figure 2B.10. Primary Energy Supply

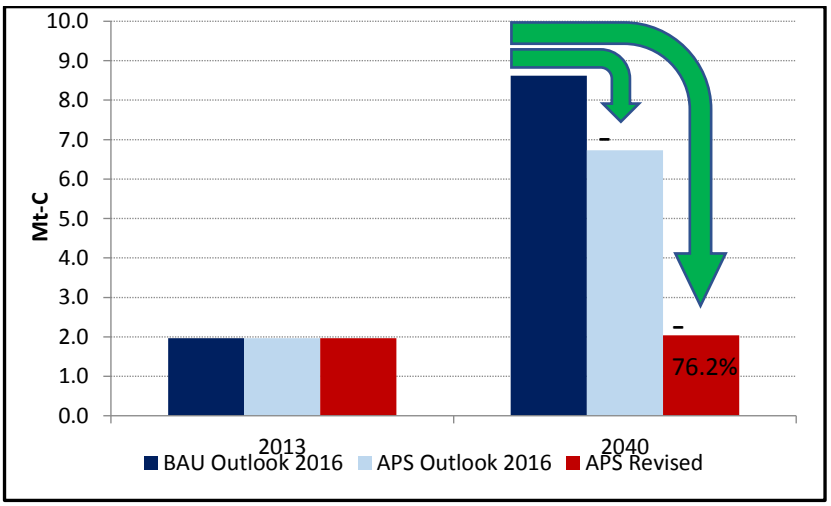


APS = Alternative Policy Scenario.
Source: Revised LEAP model outcome.

CO_2 Emissions

The resulting CO_2 emissions of the revised APS in 2040 (3.7 Mt-C) is 76% lower than the level in APS of the ERIA's Energy Outlook 2016, which is 10.7 Mt-C (Figure 2B.11).

Figure 2B.11. CO_2 Emissions Reduction by 2040



APS = Alternative Policy Scenario, BAU = Business as Usual, CO_2 = carbon dioxide, Mt-C = metric tonne of carbon.
Source: Author's calculations.

Conclusion

ERIA's Energy Outlook 2016 results in total CO_2 emissions of almost 8.6 Mt-C by 2040 for the BAU scenario and 6.7 Mt-C for APS. For the total CO_2 emissions in 2040 to have the same level as the base year (3.7 Mt-C), efforts imposed in APS of the ERIA's Energy Outlook 2016 have to be more stringent in the revised APS.

Revising the EE target, the biofuel penetration, and increasing the share of renewables in power generation have made it possible for the total CO_2 emissions of the revised APS to be similar to the base year level. The CO_2 emissions reduction in the APS of the ERIA's Energy Outlook 2016 is around 22% by 2040, while the revised APS will result in a 76% reduction compared to the BAU scenario.

CHAPTER 2C. India's Country Report[1]

Keeping CO_2 Emissions at 2013 Level by 2040

1. Energy situation

India is currently the fourth largest consumer of primary energy in the world after China, USA, and Russia. Its primary energy consumption per capita (toe/person) has grown at an annual rate of 2.5% from 0.35% in 1990 to 0.62% in 2013 (IEA, 2015; TERI, 2016).

India's total primary energy consumption grew at an annual rate of 4.1% from 306.62 million tonnes of oil equivalent (Mtoe) in 1990 to 775.45 Mtoe in 2013. Between 1990 and 2013, the annual growth rates of primary energy consumption from the various sources of energy were: coal, 5.8%; oil, 4.7%; natural gas, 6.4%; nuclear power, 7.8%; hydropower, 3.0%; and solar and wind power, 29%. In 2013, coal was the dominant source of primary energy and about 341.38 Mtoe of coal were consumed. This represents 44% of the total primary energy consumed in that year. This was followed by biomass and oil with shares of 24.3% and 22.7%, respectively. Natural gas had a share of 5.7% while other sources of energy had shares of approximately 28% (IEA, 2015).

India's final energy demand has been increasing over the years. Its total energy demand grew at an annual rate of 3.4% from 243.49 Mtoe in 1990 to 528.34 Mtoe in 2013. Within the same period, the industry sector grew at an annual rate of 4.4%, transportation at 5.7% while other sectors grew at 2.3%. The final energy demand from the non-energy sector grew at an average annual rate of 4.5%. In 2013, the share of the industrial sector in the total energy demand was 33.9%, the transportation sector had share of 14% while other sectors had shares of 45.1%. The non-energy sector's share in the final energy demand was only 6.9% (IEA, 2015).

With respect to power generation, India has made a giant stride in increasing its power generation output. As of March 2015, India had a total installed power capacity of 271 gigawatts (GW) which represents an increase of around 11% during 2014–2015. Power generation is mainly from thermal plants and coal-fired plants that make up about 87% of the entire thermal plants in the country. For electricity consumption, the industry sector accounts for the highest share with 35%, followed by the household sector with 26% and agriculture with 21%.

India's total carbon dioxide (CO_2) emissions from fossil fuel combustion have also been on the rise in the last 2 decades. This can be akin to the use of coal, oil, and natural gas for electricity

[1] Based on model run and broad assumptions by the Institute of Energy Economics, Japan (IEEJ).

generation, transportation, and other economic activities. CO_2 emissions from fossil fuel combustion have increased from 794.0 million tonnes of carbon dioxide (Mt-CO_2) in 1998 to 2019.7 Mt-CO_2 in 2014 or about 154% increase. CO_2 emission from coal was the highest due to the high reliance on coal for power generation. In 2014, CO_2 emission from coal was 1492.9 Mt-CO_2; oil, 468.2 Mt-CO_2; and gas, 57.3 Mt-CO_2. In terms of sectoral CO_2 emissions, emission from electricity generation was the highest in 2014 with 1046.6 Mt-CO_2, followed by manufacturing and construction industries with emissions of 533.4 Mt-CO_2. Emissions from the transport sector, other sectors, and other energy industry use were 231.8 Mt-CO_2, 171.8 Mt-CO_2, and 36.2 Mt-CO_2, respectively (IEA, 2016).

2. Modelling Assumptions

Macro-economic assumptions

It is assumed that India's gross domestic product (GDP) will continue to grow robustly at a rate of 6.5% from 2013 to 2040 due to increase in workforce population, improved quality of labour force, opening up of the market, and growing foreign direct investment. By 2040, India is poised to become the third largest economy in the world.

With its population assumed to grow at an annual rate of 0.9%, India's total population will reach 1.6 billion in 2040 to become the world's most populous country.

In 2040, India's GDP per capita will reach US$5,200 (2005 constant price) or 4.3 times higher than that in 2013.

Business as Usual (BAU) scenario

It is assumed that in the future electricity supply, the share of coal in electricity generation will continue to be the largest. The shares of nuclear power and others, especially wind and solar power, are projected to increase by 2040, whereas the shares of oil and hydropower are expected to fall.

Case setting for mitigating CO_2 emissions by 2040

Building on the Alternative Policy Scenario (APS) developed a year ago, three cases have been established for CO_2 emissions mitigation.

Assumptions across APS are:

APS 1: The assumptions made in this scenario are energy-saving measures in the final demand. This is achieved by introducing the best available technologies in the industry sector, improved vehicle fuel economy and introduction of hybrid electric vehicles, plugin hybrid electric vehicles, electric vehicles, and fuel cell vehicles in the transport sector, and the use of efficient appliances in the household sector.

APS 3: This scenario assumes further development of renewable energy resources like wind energy, solar photovoltaic (PV) system, hydropower, and biofuels.

APS 4: This scenario assumes a further development of nuclear energy in the power sector.

APS 5: This scenario assumes a combination of APS 1, APS 3, and APS 4.

The main assumptions for three cases are as follows:

Case 1: This case considers dramatic energy conservation by increasing efficiency in the final energy demand. The case assumes that APS1 will quadruple.

Case 2: This case looks at zero emission in the power sector by increasing the share of non-fossil fuels in the power generation. The case assumes that the sum of APS3 and APS4 will be tripled.

Case 3: Full mitigation is considered in this case through enhancing APS5. Thus, this case assumes a compromised combination of case 1 and case 2 scenarios. It is worth mentioning that the aim of case 3 is to suppress the CO_2 emissions in 2040 under the 2013 level by back casting, so there are no detailed realistic technologies and policies which are assumed.

The case settings are further summarised in Table 1C.1.

Table 1C.1. Case Settings for CO_2 Mitigation by 2040

	Case①	**Case②**	**Case③**
Final energy demand	<< APS1 <BAU	= BAU	<APS1< BAU >Case①
Low carbon power generation	= BAU	Zero emission power	>APS3 + APS4 < Case②

APS = Alternative Policy Scenario, BAU = Business as Usual, CO_2 = carbon dioxide.
Source: Author's assumptions.

3. Outlook Results

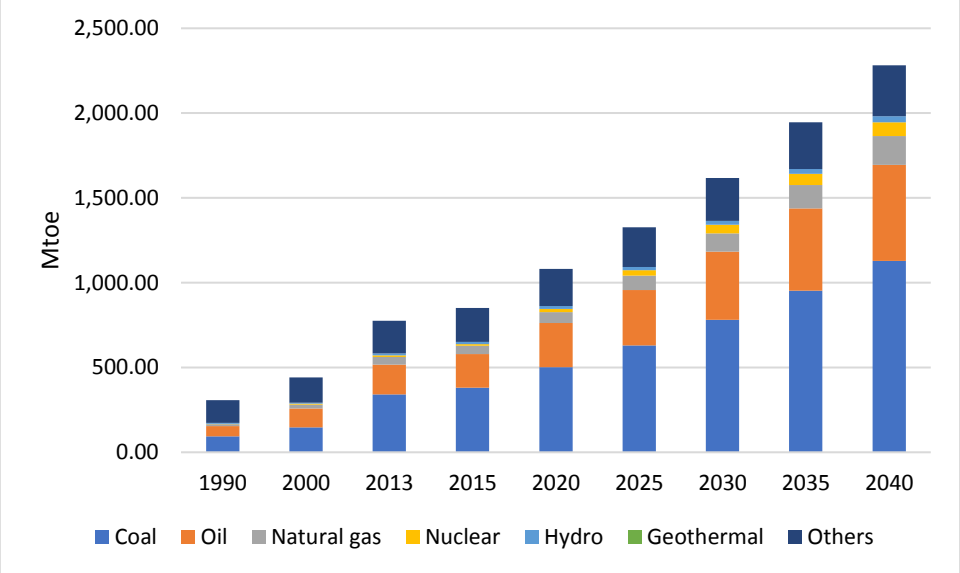
Results of BAU

Primary energy supply

Under the BAU scenario, primary energy consumption is expected to increase and grow at an annual rate of 4.1% from 775.45 Mtoe in 2013 to 2,281.14 Mtoe by 2040 (Figure 1C.1). During this period, the average annual rate of coal consumption grew by 4.5% and oil by 4.4%. Natural gas and nuclear energy grew by 5.1% and 8.5%, respectively. Hydropower consumption also experienced a growth increase of 4.0% while solar, wind, and ocean energy consumption grew at 9.6%.

Also, in 2040, coal will have the dominant share of total primary energy consumption with 49.5%, followed by oil with 24.8%. Biomass energy (others) consumption will have a share of 11.2% while natural gas will have 7.5%.

Figure 1C.1. Total Primary Energy Supply in BAU



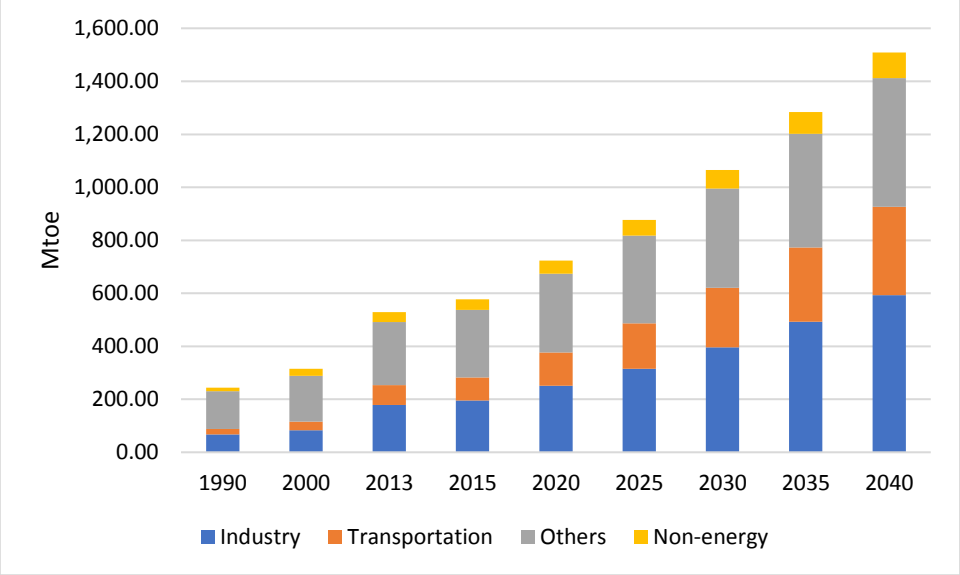
BAU = Business as Usual, Mtoe = million tonne of oil equivalent.
Source: Author's calculations.

4. Final Energy Demand

In the BAU scenario, total sectoral final energy demand is expected to increase by an annual rate of 4% from 528 Mtoe in 2013 to 1508 Mtoe in 2040 (Figure 2C.2). Energy demand in the industry sector increased from 179 Mtoe in 2013 to 593 Mtoe in 2040. The industry sector contributes the largest to total final energy demand in 2040 with a share of 39.3%. The transport sector final energy demand increased from 75 Mtoe in the base year to 334 Mtoe in 2040. This represents a share of 22% in the total final energy demand in 2040. The final energy demand of the other sectors and non-energy use also witnessed increase of 238 Mtoe and 36 Mtoe in 2013 to 486 Mtoe and 96 Mtoe, respectively, by 2040.

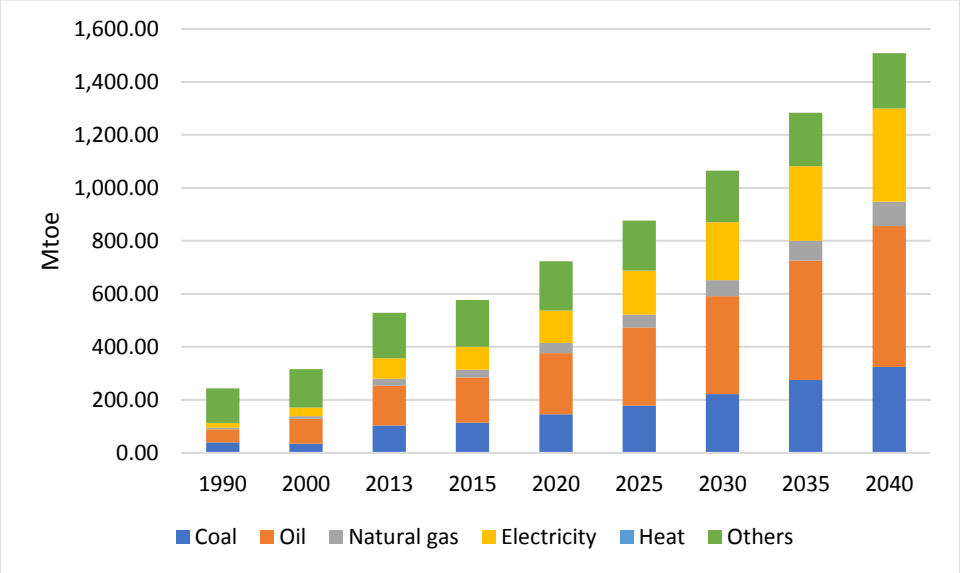
In view of the final energy demand of different sources of energy, it is observed that during 2013 to 2040, electricity demand will grow at a rate of 5.8%, coal will grow at 4.3%, and oil by 4.8%. The demand for natural gas and others will also grow at rates of 4.7% and 0.7%, respectively. The results further show that by 2040, the demand for oil will be the largest with a share of 35.2%, followed by electricity with a share of 23.3%. The final energy demand for coal by 2040 will be 324.71 Mtoe, which represents a share of 21.5% in the total final energy demand (Figure 2C.3).

Figure 2C.2. Sectoral Final Energy Demand in BAU



BAU = Business as Usual, Mtoe = metric tonne in oil equivalent.
Source: Author's calculations.

Figure 2C.3. Final Demand of Energy Sources in BAU



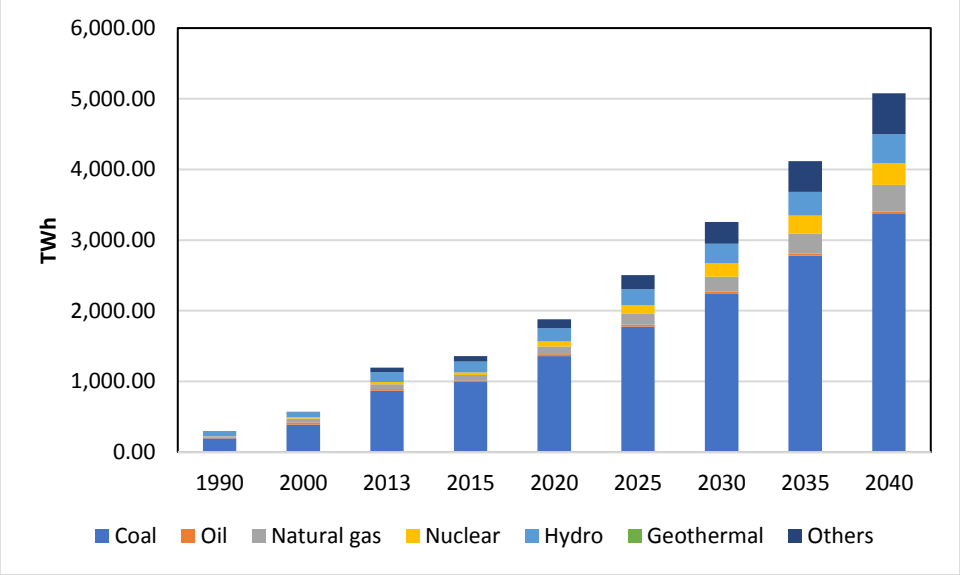
BAU = Business as Usual, Mtoe = million tonne in oil equivalent.
Source: Author's calculations.

5. Power Generation

Total power generation is expected to increase at an annual rate of 5.5% from 1,193 terawatt hours (TWh) in 2013 to 5,077 TWh by 2040 (Figure 2C.4). Coal continues to dominate the Indian electricity generation mix as the power generated from coal increased at a rate of 5.2% from 869 TWh in 2013 to 3,377 TWh in 2040. Generation from hydropower also increased at an annual rate of 4% during the same period from 141.64 TWh to 408 TWh. Also, power generation from oil, natural gas, nuclear power, and others grew at annual rates of 0.2%, 6.8%, 8.5%, and 8.7% respectively.

Owing to the high reliance on coal for power generation, the share of coal in the power generation mix in 2040 is the highest with 66.5%, followed by 'others' with 11.4%, then hydro with 8.0%. Oil, natural gas, and nuclear power will have shares of 0.5%, 7.5%, and 6.1%, respectively, in 2040.

Figure 2C.4: Power Generation Output in BAU



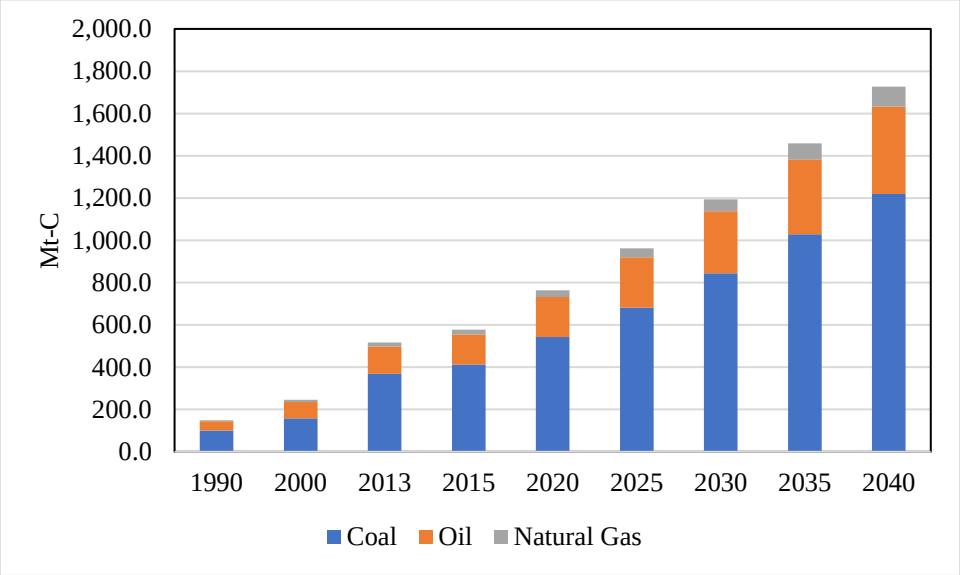
BAU = Business as Usual, TWh = terawatt hour.
Source: Author's calculations.

CO_2 Emissions

In BAU, total CO_2 emissions grew from 516.7 million tonnes of carbon (Mt-C) in 2013 to 1,726.6 Mt-C in 2040 which is around 4.6% annual growth during this period (Figure 2C.5). Much of the emissions is observed to be from coal which grew at an annual rate of 4.5% from 368.7 Mt-C in 2013 to 1,219.3 Mt-C in 2040. Also, emissions from oil and natural gas grew at rates of 4.4% and 6.0% from 128.3 Mt-C and 19.6 Mt-C in 2013 to 413 Mt-C and 94 Mt-C in 2040, respectively. The

shares of emissions from coal, oil, and natural gas in 2040 are 70.6%, 23.9%, and 5.4%, respectively.

Figure 2C.5. CO_2 Emissions in BAU



BAU = Business as Usual, CO_2 = carbon dioxide, Mt-C = metric tonne of carbon.
Source: Author's calculations.

Energy reduction and CO_2 mitigation in the case scenarios

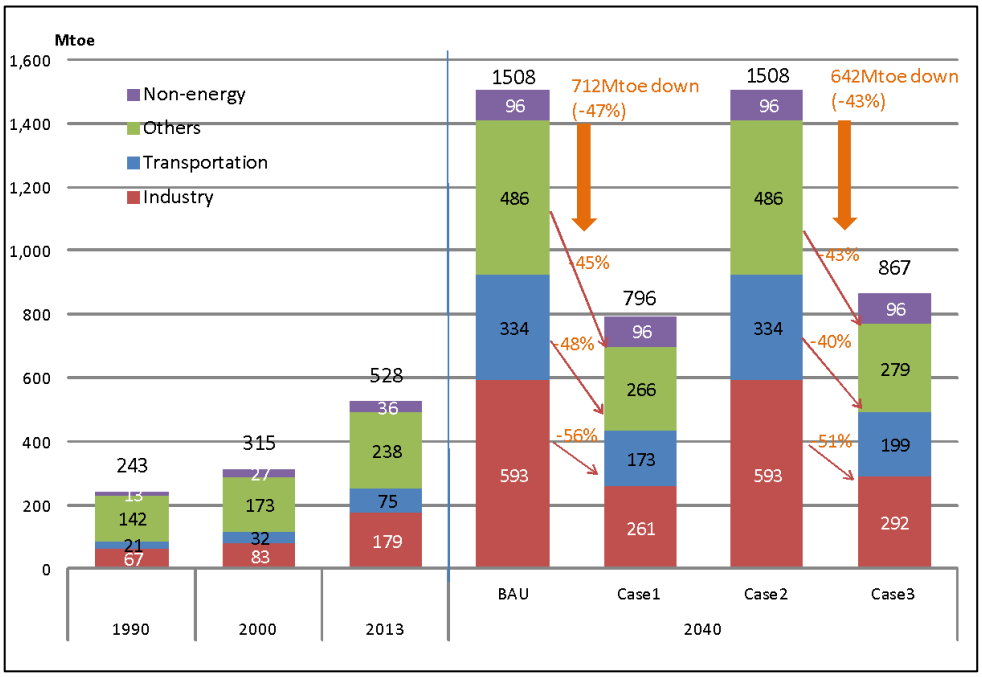
Final energy demand

With the implementation of case 1 which represents a strong practice of energy efficiency and conservation, energy demand by 2040 will be 796 Mtoe (Figure 2C.6). This is a drop by 47% which corresponds to a reduction of 712 Mtoe by 2040 relative to BAU. The percentage of energy demand reduction is observed to be largest in the industry sector with a drop of 56% which is equivalent to 332 Mtoe reduction relative to BAU. This great reduction of energy demand is due to the use of energy-efficient machineries and the gross practice of energy conservation in the industry sector. With the introduction of fuel-efficient and economic vehicles in the transportation sector, strong reduction was also recorded and energy demand reduced to 173 Mtoe which is equivalent to 48% reduction compared to BAU. Strong reduction was also observed in the other sectors. Final energy demand reduced by 45% which amounts to 266 Mtoe by 2040. The final energy demand of the non-energy use sector remains constant at 96 Mtoe.

Under case 2, final energy demand remains constant as in BAU scenario which has already been highlighted.

In case 3 scenario, final energy demand is expected to be 867 Mtoe by 2040. This implies a 43% reduction in energy demand which is equivalent to 642 Mtoe compared to BAU. Sustaining the efforts on energy efficiency practices, the industry sector continues to remain with the greater share of percentage reduction. Final energy demand in the industry sector is expected to be 292 Mtoe by 2040 which is a drop of 51% relative to case 2 and BAU scenarios. The final energy demand in other sectors is also expected to fall by 43% to 279 Mtoe. The transport sector also has a reduction of 40% which is equivalent to 199 Mtoe in the final energy demand.

Figure 2C.6. Final Energy Demand in Cases 1-3



BAU = Business as Usual, Mtoe = million tonne of oil equivalent.
Source: Author's calculations.

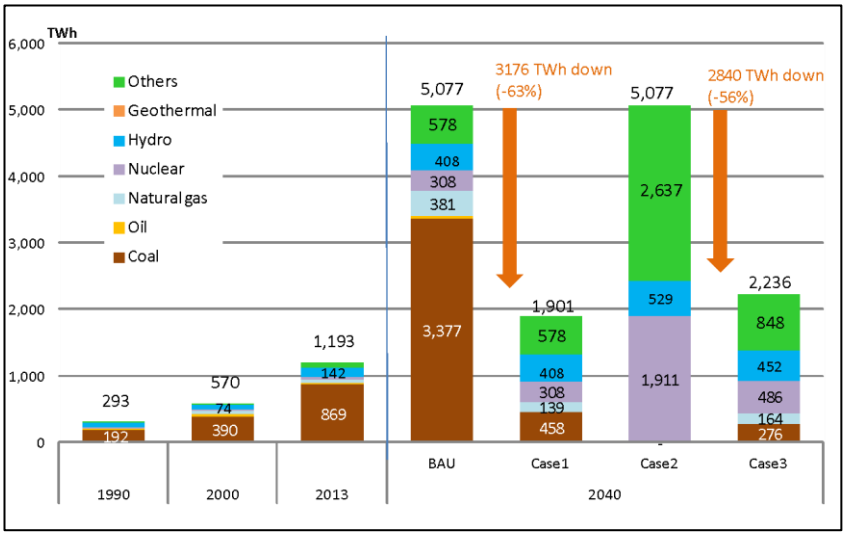
Power Generation

Under case 1, total power generation will increase at an annual rate of 1.7% from 1,193 terawatt hour (TWh) in 2013 to 1901 TWh in 2040 (Figure 2C.7). This represents a 63% decrease in total power generation or 3176 TWh relative to BAU. In an attempt to decarbonie the power sector, power generation output from coal will be 458 TWh in 2040, which is equivalent to 2919 TWh or 86% reduction compared to BAU. Also, power generation from natural gas is expected to drop in 2040 by 242 TWh which is approximately a 64% decrease compared to BAU. Power output from oil is also expected to fall by 16 TWh. Power generation from nuclear power, hydropower, and 'others' energy stand at 308 TWh, 408 TWh, and 578 TWh, respectively, in 2040 which is the same as in the BAU scenario.

In case 2, power generation will increase from 1,193 TWh in 2013 to 5,077 TWh in 2040, which is approximately a 5.5% annual increase just as in the case of BAU. In this scenario, it is assumed that by 2040, the power sector is fully decarbonied, thus the share of coal, oil, and natural gas in the electricity mix will be negligible or equivalent to zero. Power generation from 'others' is expected to be the highest at 2,637 TWh, which is about 2059 TWh increase compared to BAU. Nuclear power and hydropower generation is also expected to increase in 2040 to 1,911 TWh and 529 TWh, respectively. This represents an increase of 1603 TWh and 121 TWh in nuclear power and hydropower generation, respectively, when compared to BAU.

In case 3, power generation is expected to increase at a rate of 2.4% annually from 1,193 TWh in 2013 to 2,236 TWh in 2040. This represents a decline in power generation in 2040 by 56% or 2840 TWh compared to BAU. In 2040, combining case 1 and case 2 as depicted in case 3 scenario shows that power generation from 'others' will be the maximum which is 848 TWh, an increase of 270 TWh relative to BAU. This scenario also suggests that hydropower and nuclear power generation will increase to 452 TWh and 486 TWh which corresponds to an increase of 44 TWh and 178 TWh, respectively, when compared to BAU. It was further observed that power output from coal will drastically decline to 276 TWh, which is about 3101 TWh reduction relative to BAU. The output from natural gas and oil also declined by 217 TWh and 14 TWh, respectively, when compared to BAU.

Figure 2C.7. Power Generation in Cases 1-3



BAU = Business as Usual, TWh = terawatt hour.
Source: Author's calculations

Primary Energy Supply

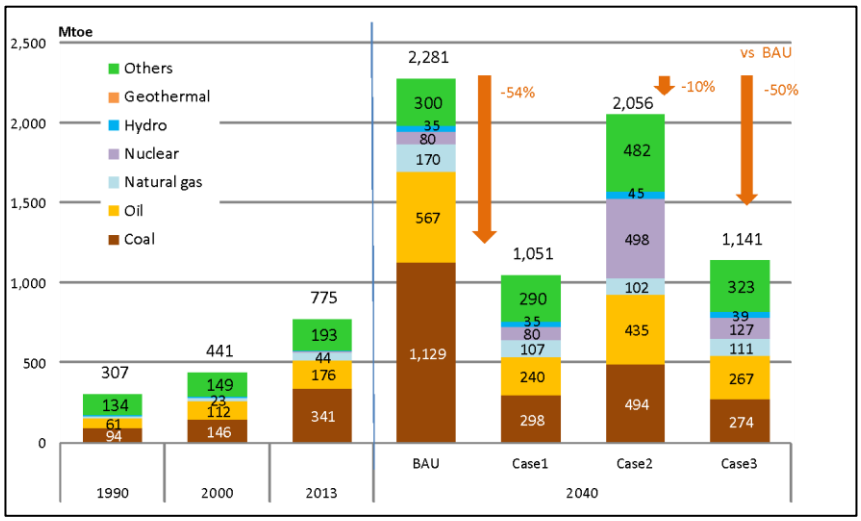
In case 1, total primary energy supply increased from 775 Mtoe in 2013 to 1,051 Mtoe in 2040 (Figure 2C.8). This represents a decrease of 54% compared to BAU. In 2040, much of the decrease was observed to come from coal. The consumption of coal, oil, and natural gas is 298 Mtoe, 240 Mtoe, and 107 Mtoe, respectively, which is equivalent to reductions of 831 Mtoe,

327 Mtoe, and 63 Mtoe, respectively, when compared to BAU. Also, the 'others' consumption reduced to 290 Mtoe or 10 Mtoe reduction relative to BAU. However, the consumption of nuclear power and hydropower remains constant at 80 Mtoe and 35 Mtoe, respectively, just as in BAU.

Under case 2, total energy consumption will increase from 775 Mtoe in 2013 to 2,056 Mtoe in 2040. When compared to BAU in 2040, this is just a 10% decrease in energy consumption. Owing to the efforts to keep a low-carbon economy, the consumption of coal, oil, and natural gas will decline to 494 Mtoe, 435 Mtoe, and 102 Mtoe, respectively, which represents a reduction of final energy consumption by 635 Mtoe, 132 Mtoe, and 5 Mtoe, respectively, relative to BAU. On the other side, energy consumption from nuclear power, hydropower, and others resources will increase. By 2040, the consumption of nuclear power and hydropower will be 498 Mtoe and 45 Mtoe, respectively, which corresponds to an increase of 418 Mtoe and 10 Mtoe, respectively, compared to BAU. Also, the consumption of 'others' will increase by 182 Mtoe in 2040 relative to BAU.

Under case 3, total energy consumption in 2040 will decline by 50% relative to BAU. Coal will continue to have the largest share in energy reduction. The consumption of coal will be 274 Mtoe, which is about 855-Mtoe reduction compared to BAU. Furthermore, the consumption of oil and natural gas will fall to 267 Mtoe and 111 Mtoe, respectively. This corresponds to reductions of 300 Mtoe and 59 Mtoe in oil and natural gas, respectively, compared to BAU. This scenario also suggests that the consumption of nuclear power, hydropower, and 'others' energy will increase in 2040 by 47 Mtoe, 4 Mtoe, and 23 Mtoe, respectively, compared to BAU.

Figure 2C.8. Primary Energy Supply in Cases 1-3



BAU =Business as Usual, Mtoe = metric tonne of oil equivalent.
Source: Author's calculations.

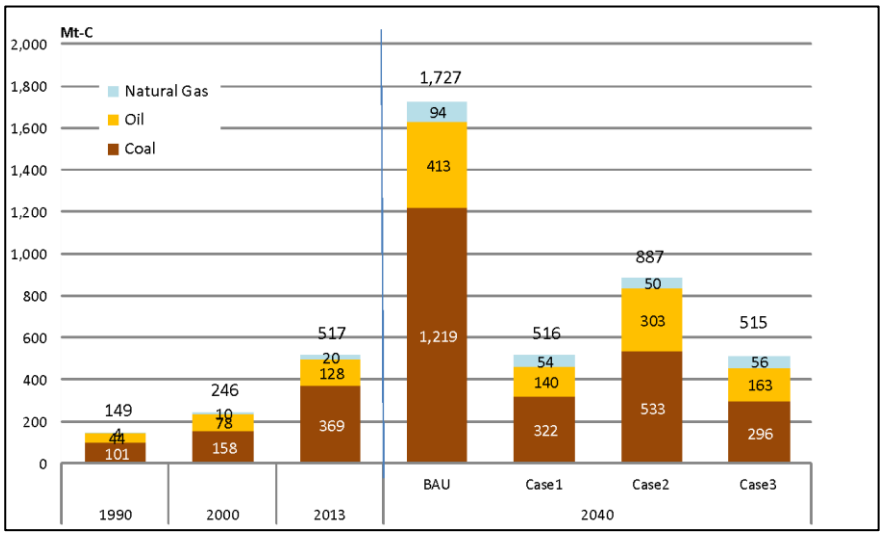
CO_2 Emissions

In case 1, total CO_2 emissions in 2040 will drop to 516 Mt-C or by 70% compared to BAU (Figure 2C.9). As expected, most of the emission reduction will be coming from coal. Coal emission will decline to 322 Mt-C in 2040, which represents a reduction of 897 Mt-C relative to BAU. Also, emissions from oil and natural gas will fall to 140 Mt-C and 54 Mt-C, respectively, by 2040. Comparing with BAU, this implies a reduction of 273 Mt-C and 40 Mt-C from oil and natural gas, respectively.

In case 2, total emissions will be 887 Mt-C by 2040, which represents a decline of 840 Mt-C or 49% relative to BAU. With great efforts to shift from fossil-based fuels to sustainable energy sources, emission from coal in 2040 will be 533 Mt-C, which is a reduction of 686 Mt-C compared to BAU. The emissions from oil and natural gas are 303 Mt-C and 50 Mt-C, respectively, which represent reductions of 110 Mt-C and 44 Mt-C, respectively, compared to BAU.

Under case 3, total emissions will be 515 Mt-C in 2040, which is 1212 Mt-C or approximately 70% reduction compared to BAU. Emissions reductions in 2040 from coal, oil, and natural gas will decline by 923 Mt-C, 250 Mt-C, and 38 Mt-C, respectively, relative to BAU.

Figure 2C.9. CO_2 Emission in Cases 1-3



BAU = Business as Usual, CO_2 = carbon dioxide, Mt-C = million tonne of carbon.
Source: Author's calculations.

Energy and CO_2 Emissions Intensity

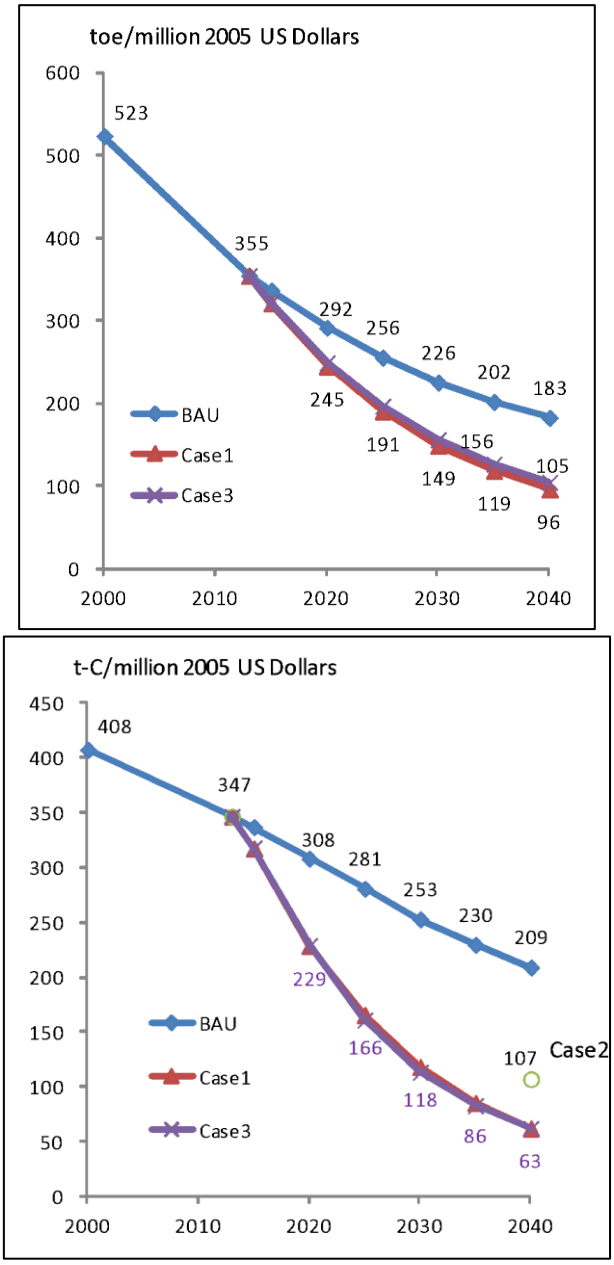
Final energy consumption per GDP

Final energy consumption per GDP will gradually decline in the BAU scenario at an annual rate of 2.4% from 2013 and will be 183 toe/US$2005 million in 2040. In case 1, final energy consumption per GDP will also decline at a rate of 4.7% to 96 toe/US$2005 million in 2040 which represents a reduction of 87 toe/US$2005 million relative to BAU. Also, reduction will occur in case 3 and will decline at a rate of 4.4% to 105 toe/US$2005 million which is about 78 toe/US$2005 million reduction compared to BAU (see Figure 2C.10).

CO_2 emissions per GDP

CO_2 emissions per GDP will gradually decline in the BAU scenario at an annual rate of 1.9% from 2013 and will be 209 t-C/US$2005 million in 2040. In case 1 and case 3, CO_2 emissions per GDP will also decline at an average rate of 6.15% to 63 t-C/US$2005 million in 2040 which represents a reduction of 146 t-C/US$2005 million relative to BAU. Also, reduction will occur in case 2 and will decline at a rate of 4.2% to 107 t-C/US$2005 million which is about 102 t-C/US$2005 million reduction compared to BAU (see Figure 2C.10).

Figure 2C.10. Final Energy Consumption and CO_2 Emissions per GDP



BAU = Business as Usual, CO_2 = carbon dioxide, GDP = gross domestic product, toe = tonne of oil equivalent, t-c = tonne of carbon.
Source: Author's calculations.

Implication

Increasing energy efficiency, demand side management, and use of new and sustainable energy technologies will go a long way towards achieving low-carbon economy by 2040.

Modelling results show that with the available technologies in India, it will be impossible to suppress CO_2 emissions in 2040 to 2013 level. For example, in case 2, the result shows that even if the Indian power generation is fully replaced with non-fossil fuel, emissions will still be higher compared to 2013. Hence, there is a need to accelerate efforts towards investment in research and development in the energy sector. This will involve the deployment of new technologies and improved energy efficiency practice in all sectors of the economy. This will have a strong effect on fuel use in the various sectors of the economy and demand-side practices. Mitigating CO_2 in the Indian economy will definitely come with several policy and financial challenges. Thus, there is the need to put forward sound policies that can encourage energy consumers to change their behaviour towards adopting energy efficiency practices and policies that can clear all the obstacles that might be limiting energy efficiency improvements.

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2D. Indonesia's Case Study
Keeping CO_2 Emissions at 2013 Level by 2040

Background

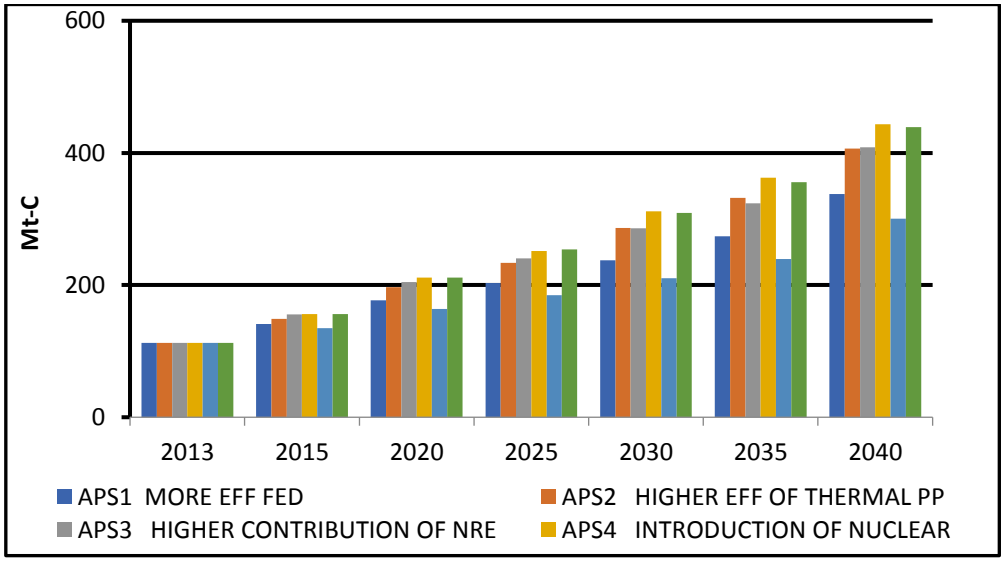
The Energy Outlook and Energy Saving Potential in East Asia 2016 by the Economic Research Institute for ASEAN and East Asia (ERIA) projects an increasing demand for the Alternative Policy Scenario (APS) and the Business as Usual (BAU) scenario. As a result, total carbon dioxide (CO_2) emissions will increase in the future.

APS is a combination of different scenarios. In the case of Indonesia, the scenarios are reference (BAU), more efficient FED (APS1), higher efficiency of thermal power plants (APS2), higher contribution of non-renewable energy (APS3), introduction of nuclear power (APS4), and combined APS1 to APS4 (APS5/APS)

For the BAU scenario (Figure 2D.1), Indonesia's total CO_2 emissions were 113 metric tonnes of carbon (Mt-C) in 2013 (base year) and projected to reach 439 Mt-C by 2040. Assuming that the government of Indonesia will apply more efficient technology in the final sector and higher efficiency of thermal power plants in addition to promoting higher penetration of new and renewable energy and constructing nuclear power plants (APS), then total CO_2 emissions will only increase to 301 Mt-C by 2040. Thus, implementing APS will result in a 31% reduction of CO_2 emissions in 2040 compared to BAU.

This case study on CO_2 emissions aims to identify possible solutions to mitigate CO_2 emissions in 2040 to the 2013 level. Since the APS scenario has the lowest CO_2 emissions, then this scenario will be the basis for the case study.

Figure 2D.1. CO_2 Emissions of Indonesia in ERIA's Outlook 2016



CO_2 = carbon dioxide, ERIA = Economic Research Institute for ASEAN and East Asia, Mt-C = metric tonne of carbon, BAU= Business as Usual, APS = Alternative Policy Scenario, PP= power plant, EFF=efficiency, FED = final energy demand, NRE = new and renewable energy.
Source: Author's calculations.

Methodology

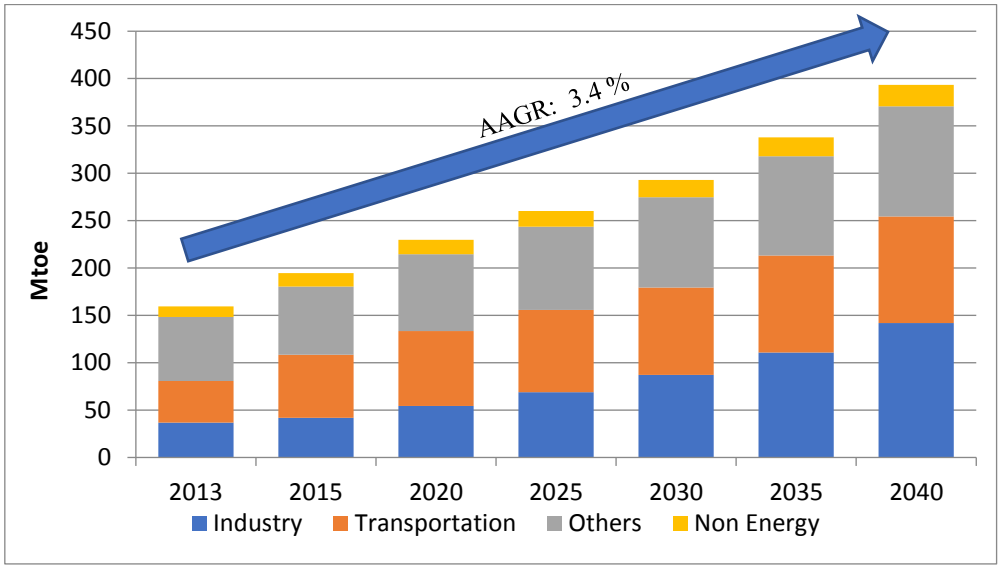
APS consists of APS1, APS2, APS3, and APS4. Implementing APS still results in an increase of CO_2 emissions in 2040 compared to the base year. To ensure that total CO_2 emissions remain at the 2013 level, more efforts will be needed to achieve national development target without increasing CO_2 emissions from their base year level. The parameters to consider would be: energy saving in final consumption sector, high-efficient thermal power plants, hydropower and geothermal energy, solar/photovoltaic (PV) system and wind energy, other renewables, and nuclear energy.

The approach for the exercise will be: less usage of fossil fuels and more of renewables; increase use of biofuels such as biogasoline (bioethanol), biodiesel, and biojetkerosene; limiting use of coal and natural gas in power sector; and increase use of renewables in power generation.

Final Energy Demand

In ERIA's Energy Outlook and Energy Saving Potential in East Asia 2016 (Energy Outlook 2016), the final energy demand of Indonesia under APS will be growing at an average rate of 3.4% over the 2013–2040 period (Figure 2D.2).

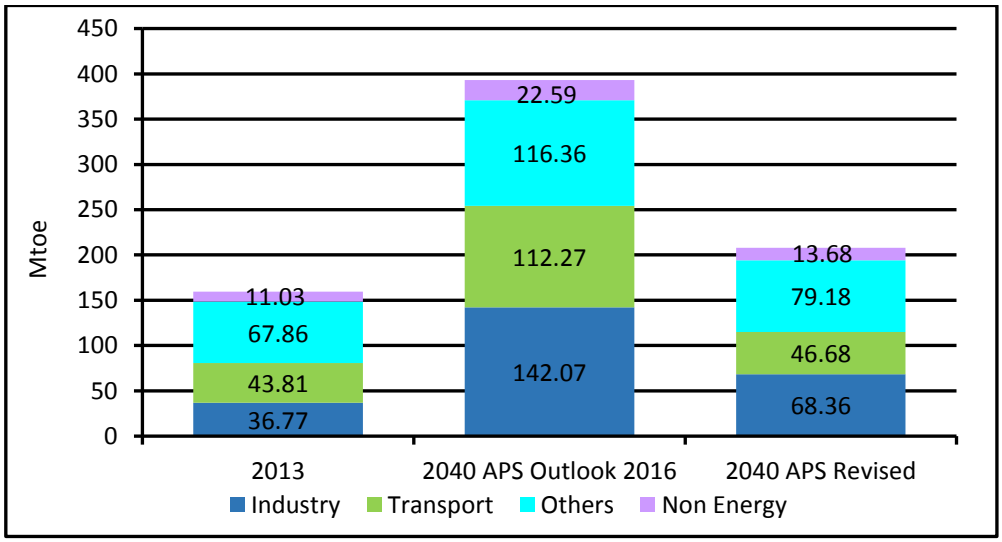
Figure 2D.2. Final Energy Demand in ERIA's APS Outlook 2016



AAGR = average annual growth rate, APS = Alternative Policy Scenario, ERIA = Economic Research Institute for ASEAN and East Asia, Mtoe = metric tonne of oil equivalent.
Source: Author's calculations.

Revising the assumption used for energy efficiency and conservation (EEC) and increased use of biofuels will slow down the increase of the final energy demand. The final energy demand of the revised APS will grow at an average annual rate of 1% per year over the 2013–2040 period. Revising the EEC target reduced the total final energy demand of 2040 by almost 50% the level of ERIA's Energy Outlook 2016 APS (Figure 2D.3).

Figure 2D.3. Final Energy Demand Comparisons



APS = Alternative Policy Scenario, Mtoe = metric tonne of oil equivalent.
Source: Author's calculations.

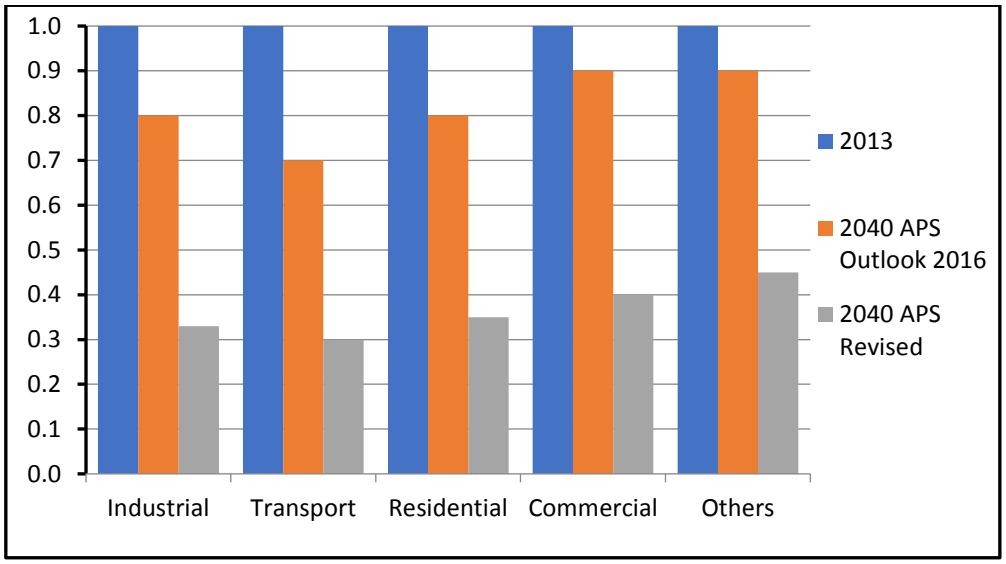
The use of biofuels will be increasing since the assumption was revised especially in the transport sector. Introduction of jet kerosene was assumed in the revised APS, which was excluded in ERIA's Energy Outlook 2016 APS.

EEC targets

The EEC target in ERIA's Energy Outlook 2016 APS is different depending on the sectors. It is assumed that by 2040, there will be a 30-% energy-saving target for the transport sector, a 20-% energy saving for the industrial and residential sectors, and a 10-% saving for the commercial and others sectors.

In the revised APS, the target was more stringent: around 50% saving target for the others sector, a 60-% target for the residential and commercial sectors, and a 70-% saving target for the industry and transport sectors (Figure 2D.4).

Figure 2D.4. EEC Targets

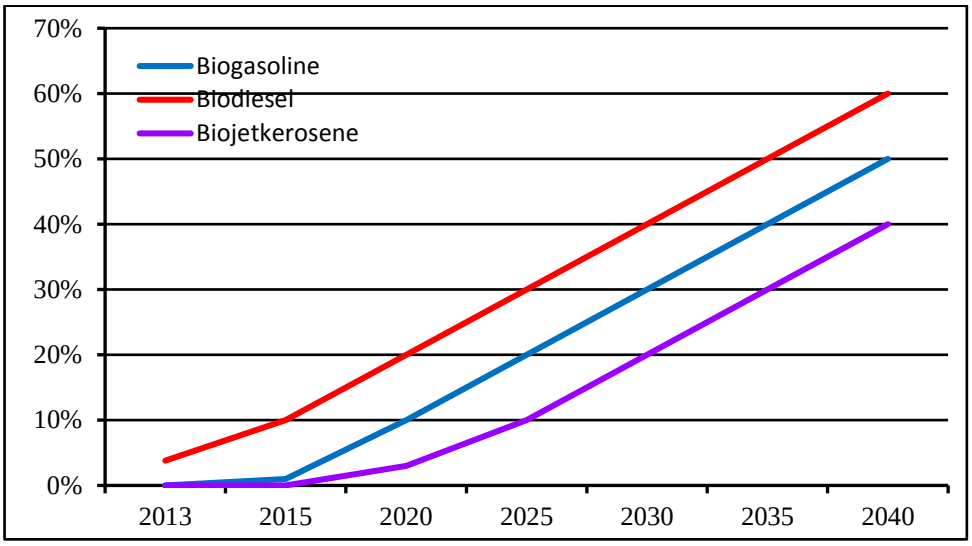


EEC = Energy Efficiency and Conservation, APS = Alternative Policy Scenario
Source: Author's calculations.

Biofuel penetration

Beside the EEC target, the biofuel penetration is also revised. In ERIA's Energy Outlook 2016 APS, penetration of biofuel is around 30% by 2040 for biodiesel and 20% for biogasoline. No penetration of biojetkerosene is assumed in ERIA's Energy Outlook 2016 APS. In the revised APS, the penetration of biodiesel increased to 60% by 2040, while biogasoline has a 50-% penetration rate and biojetkerosene around 40% (Figure 2D.5).

Figure 2D.5. Biofuel Penetration



Source: Author's calculations.

Power Generation

The parameters in the power generation sector of the long-range energy alternatives planning model include dispatch rule, merit order, efficiency, maximum availability, exogenous capacity, etc. Most of these technical parameters are similar to that of ERIA's Energy Outlook 2016 APS.

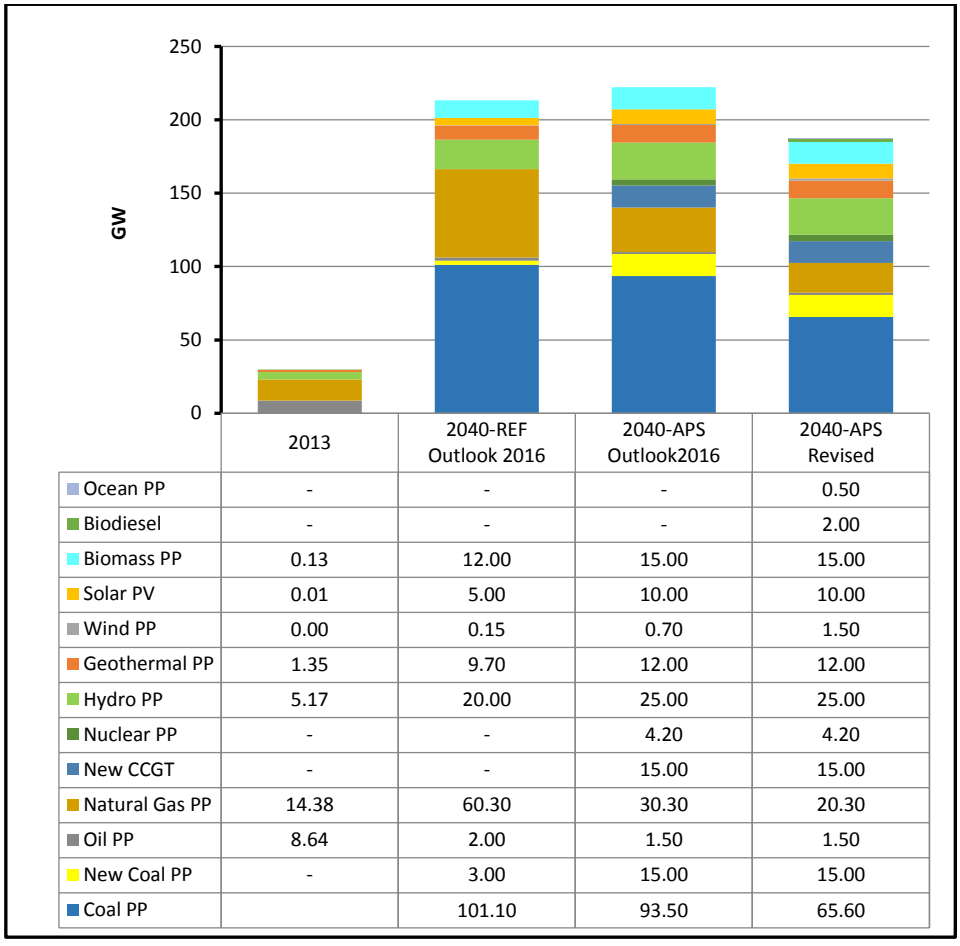
The difference is in the capacity expansion of the various power plants. In the revised APS, there are more renewable energy capacity being assumed for the future.

Capacity

As shown in Figure 2D.6, total capacity in ERIA's Energy Outlook 2016 APS is around 222 gigawatts (GW) in 2040 while it is only 188 GW in the revised APS. The coal- and gas-fuelled power plants are assumed to be lower in the revised APS to allow more renewable-based power generation to be in the generation mix. The ocean thermal energy conversion and biodiesel power plants that were not assumed in the previous ERIA's Energy Outlook have been added in the revised APS.

The nuclear power plant is also assumed in the revised APS, but similar to the assumptions in the APS of the ERIA's Energy Outlook 2016. It is assumed that four nuclear power plants will be in operation in 2040 with a total capacity of 4.2 GW.

Figure 2D.6. Total Capacity (GW)



	2013	2040-REF Outlook 2016	2040-APS Outlook2016	2040-APS Revised
Ocean PP	-	-	-	0.50
Biodiesel	-	-	-	2.00
Biomass PP	0.13	12.00	15.00	15.00
Solar PV	0.01	5.00	10.00	10.00
Wind PP	0.00	0.15	0.70	1.50
Geothermal PP	1.35	9.70	12.00	12.00
Hydro PP	5.17	20.00	25.00	25.00
Nuclear PP	-	-	4.20	4.20
New CCGT	-	-	15.00	15.00
Natural Gas PP	14.38	60.30	30.30	20.30
Oil PP	8.64	2.00	1.50	1.50
New Coal PP	-	3.00	15.00	15.00
Coal PP		101.10	93.50	65.60

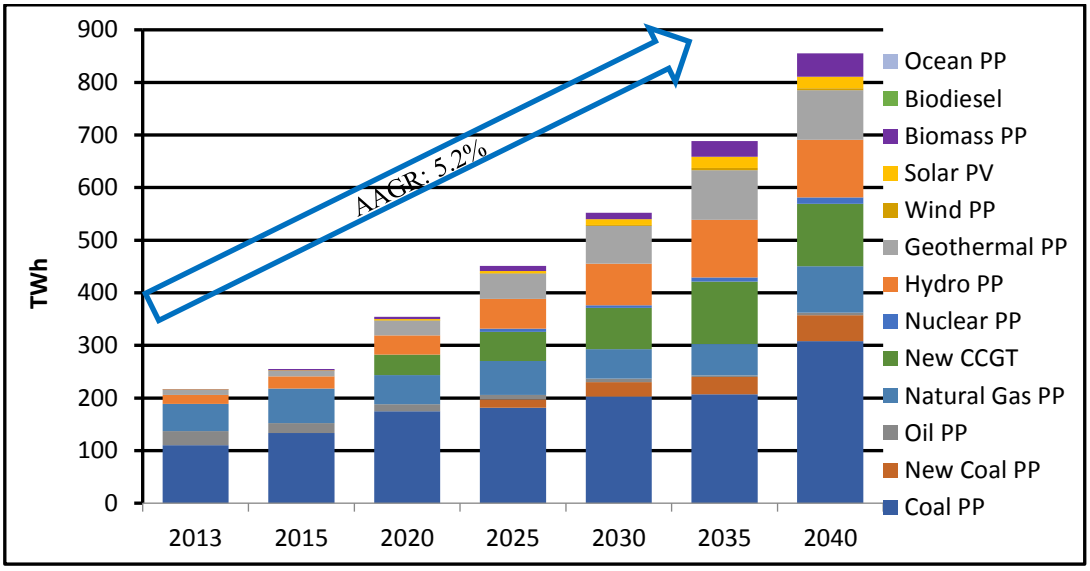
APS = Alternative Policy Scenario, REF = Reference, CCGT = Combined Cycle Gas Turbine, PP = Power Plant, PV =Photovoltaic, GW = gigawatt,
Source: Author's calculations.

Power Generation

The capacity expansion assumed in the revised APS generates around 410 terawatt hours (TWh) of electricity, lower than the 550 TWh power generated in APS of ERIA's Energy Outlook 2016 (Figures 2D.7 and 2D.8). The average annual growth rate of electricity production in APS of ERIA's Energy Outlook 2016 is 5.2% while in the revised APS, the rate is slower, at 2.4% per year.

Around 60% of the total generation comes from renewable energy in the revised APS with the rest coming from fossil fuel power plants. The nuclear power plant generation is included on the renewable generation but with smaller amount of electricity generated as compared to APS of ERIA's Energy Outlook 2016.

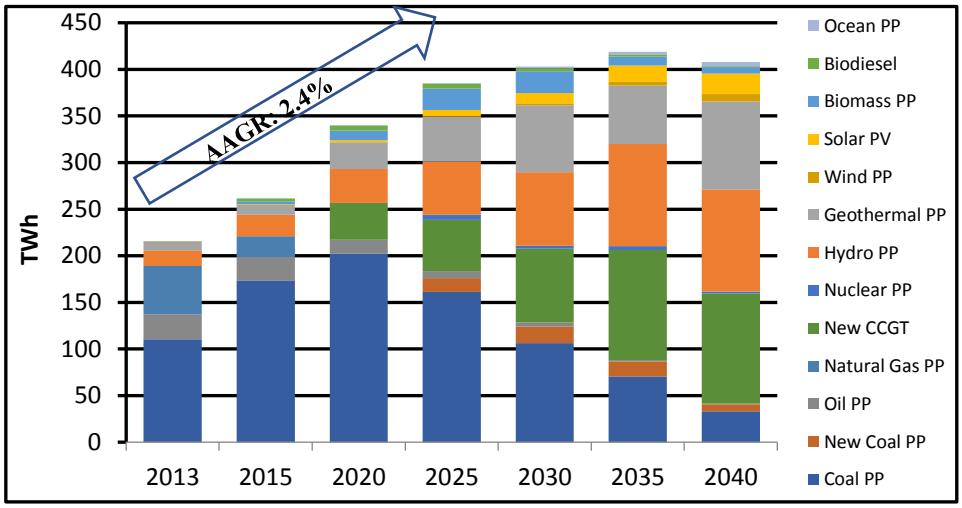
Figure 2D.7. Power Generation by Type in ERIA's Energy Outlook 2016 APS



AAGR = average annual growth rate, APS = Alternative Policy Scenario, CCGT =combined cycle gas turbine, PP = power plant, PV = photovoltaic, TWh = terawatt hour.
Source: Author's calculations.

In terms of renewable energy, more hydropower and geothermal plants are being generated in the revised APS as compared to APS of ERIA's Energy Outlook 2016. Similarly, solar/PV generation also increased in the revised APS. Generation from coal and natural gas-fuelled power plants has been reduced in the APS scenario, more significantly for coal power plants.

Figure 2D.8. Power Generation by Type in the Revised APS

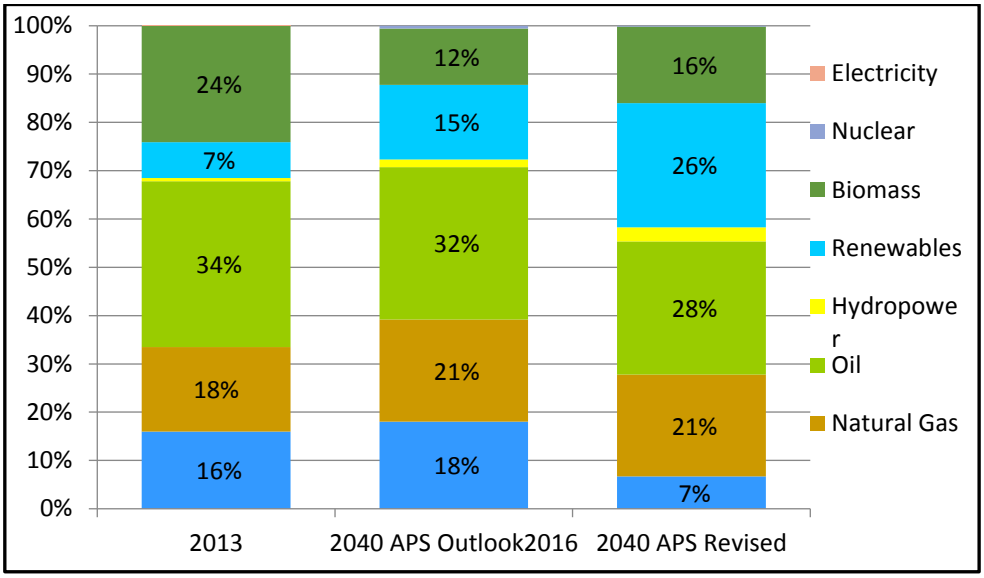


AAGR = average annual growth rate, APS = Alternative Policy Scenario, CCGT = combined cycle gas turbine ,
PP = power plant, PV = photovoltaic, TWh = terawatt hour.
Source: Author's calculations.

Primary Energy Supply

With revised EEC target, biofuel penetration, and increased share of renewable energy in the power sector, the total primary energy supply of the revised APS will almost be 340 Mtoe in 2040, around 42% lower than in APS of ERIA's Energy Outlook 2016 (Figure 2D.9). In terms of share in the total energy mix, 44% comes from renewable energy including biomass while the remaining is that of fossil fuel. Coal share decreased significantly in the revised APS from 18% in APS of ERIA's Energy Outlook 2016 to 7% in the revised APS.

Figure 2D.9. Primary Energy Supply

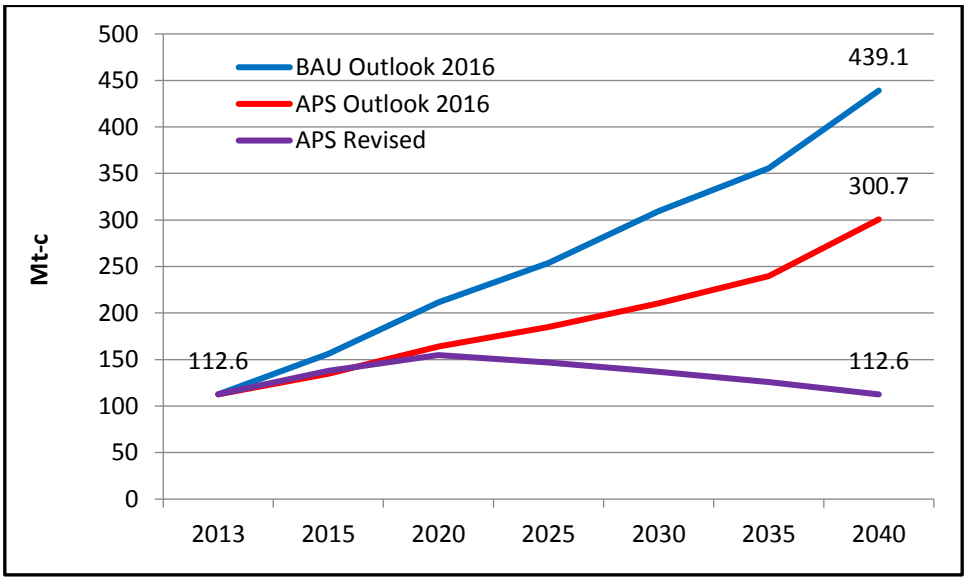


APS = Alternative Policy Scenario.
Source: Author's calculations.

CO_2 Emissions

The resulting carbon dioxide (CO_2) emissions of the revised APS will be 112.6 metric tonnes of carbon (Mt-C), similar to the base year value of 2013 and lower than in APS of ERIA's Energy Outlook 2016, which is 300.7 Mt-C (Figure 2D.10).

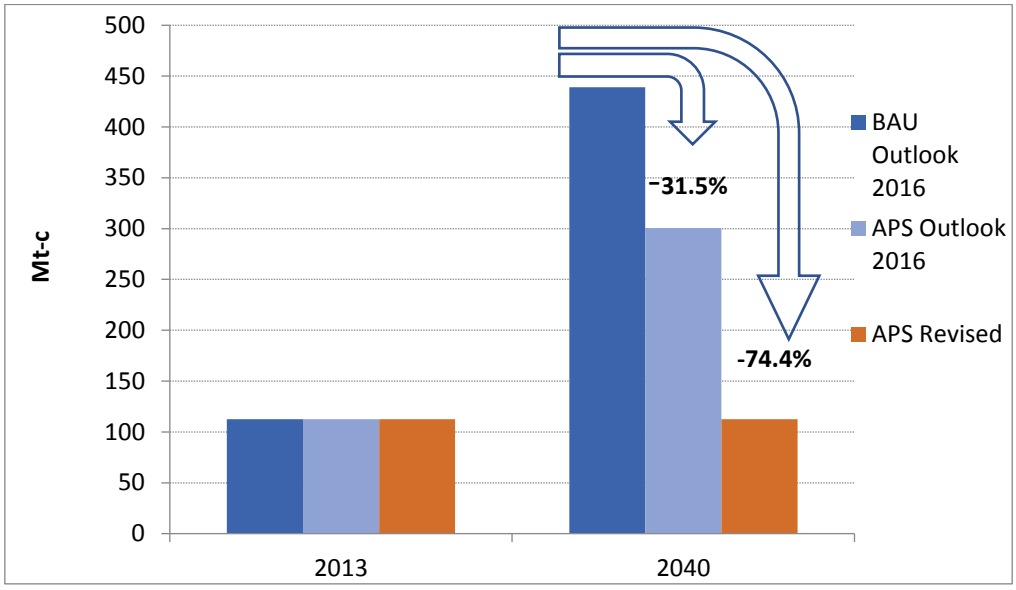
Figure 2D.10. CO_2 Emissions Comparisons



APS = Alternative Policy Scenario, BAU = Business as Usual, CO_2 = carbon dioxide, Mt-C = metric tonne of carbon.
Source: Author's calculations.

Compared to the BAU scenario of ERIA's Energy Outlook 2016, the total CO_2 emissions of APS will be 31.5% lower. In the case of the revised APS, the total CO_2 emissions will be 74.4% lower to beat the same level as the base year (Figure 2D.11).

Figure 2D.11. CO_2 Emissions Reduction by 2040



APS = Alternative Policy Scenario, BAU = Business as Usual, CO_2 = carbon dioxide, Mt-C = metric tonne of carbon.
Source: Author's calculations.

Conclusion

ERIA's Energy Outlook 2016 resulted in total CO_2 emissions of 439 Mt-C by 2040 for the BAU scenario and 301 Mt-C for APS. For the total CO_2 emissions in 2040 to be at the same level as the base year (113 Mt-C), efforts imposed in APS of ERIA's Energy Outlook 2016 have to be more stringent in the revised APS.

Revising the EEC target, the biofuel penetration, and increasing share of renewable in power generation have made it possible for the total CO_2 emissions of the revised APS to be similar to the base year level. Since the CO_2 emissions reduction in APS of ERIA's Energy outlook 2016 is around 31.4% by 2040, the revised APS will result in a 74.4-% reduction compared to the BAU scenario.

2E.The Lao People's Democratic Republic's Case Study

Keeping CO_2 Emissions at 2013 Level by 2040

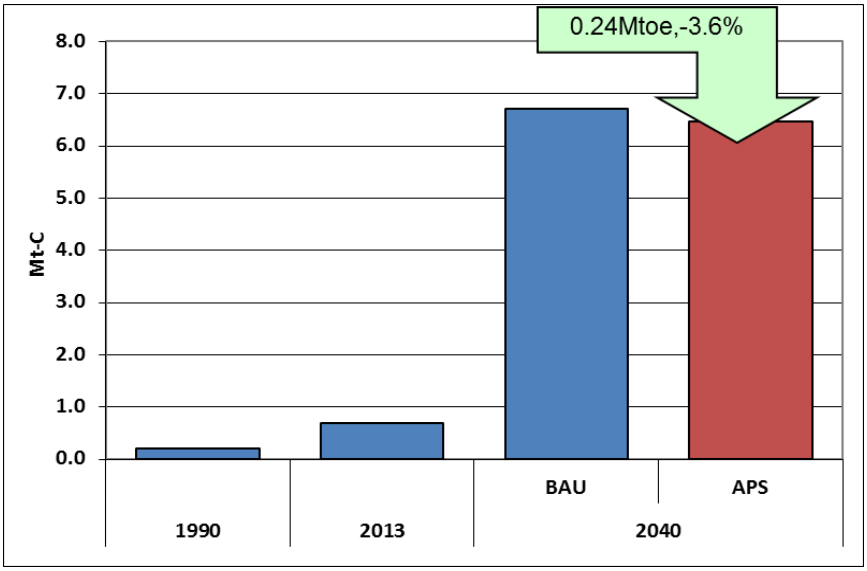
Introduction

This study identifies some necessary scenarios in mitigating the carbon dioxide (CO_2) emissions of the Lao People's Democratic Republic (Lao PDR) in 2040 to the same level of 2013 in the energy sector. In this case, the Lao PDR will attempt a trade-off between greenhouse gases (GHG) and future energy consumption through national energy policies and plans. Energy efficiency and non-carbon energy on national plans might or might not be achieved with this goal. If the national plans alone are not adequate, an analysis will be made to make this target a success.

CO_2 Projections of BAU and APS in 2040

Based on the Business as Usual (BAU) scenario, the Lao PDR's CO_2 emissions are expected to increase sharply from 0.7 million tonne of carbon (Mt-C) in 2013 to 6.7 Mt-C in 2040 because of the annual increase of final energy demand which is expected at 4% coupled with the increase of coal consumption in power plants for power export during this period. However, in APS-5, which combines all four Alternative Policy Scenarios (APS), CO_2 emissions are expected to go down by 3.6% to 0.24 Mt-C (see Figure 2E.1). This reduction of CO_2 reduction was made by implementing the Lao PDR government's measures in energy efficiency and renewable energy development.

Figure 2E.1. CO_2 Projections of BAU and APS in 2040



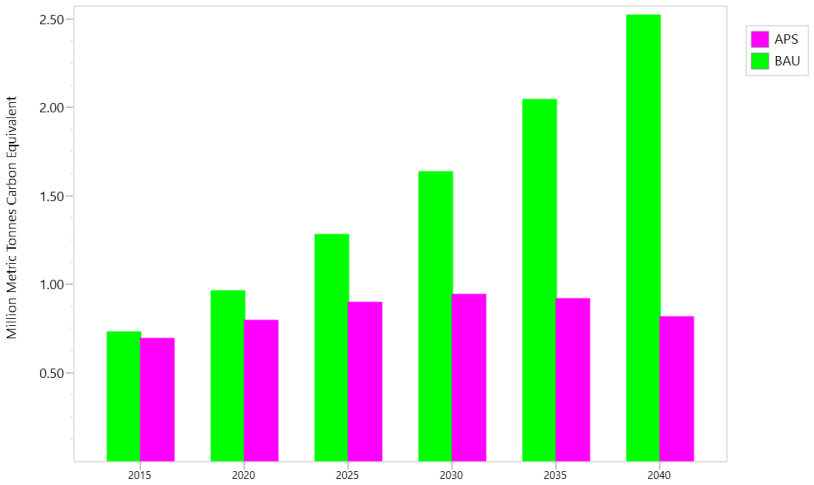
APS = Alternative Policy Scenario, BAU = Business as Usual, Mt-C = metric tonne of carbon, Mtoe = metric tonne of oil equivalent.
Source: Author's calculations.

Scenarios of Keeping CO_2 Total Emissions at 2013 Level by 2040

In order to reduce the 2040 CO_2 total emissions to the 2013 level, the Lao PDR should try many measures or scenarios of energy saving and renewable energy development (see Figure 2E.2). With those measures, the following can be assumed:

1. The Lao PDR will reduce final energy demand to 70% by 2040. This would be the actual saving or reduction.
2. The Lao PDR will increase the share of biodiesel in the total diesel supply by 20% by 2040.

Figure 2E.2. CO_2 Emissions Mitigation in 2040 at 2013 Level



APS = Alternative Policy Scenario, BAU = Business as Usual.
Source: Author's calculations.

Final Energy Demand with CO_2 Emissions Mitigation

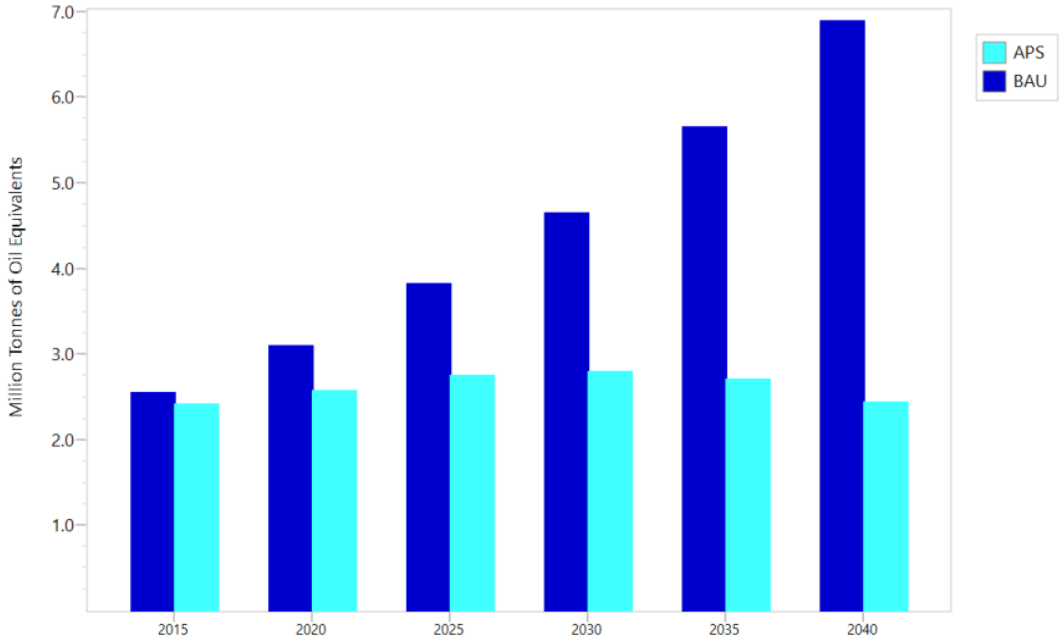
After the Lao PDR's implementation of the above measures, final energy demand is expected to be reduced from 6.9 metric tonnes of oil equivalent (Mtoe) in BAU to 2.4 Mtoe in APS as shown in Table 2E.1 and Figure 2E.3.

Table 2E.1. Final Energy Demand Keeping CO_2 Emissions at 2013 Level by 2040 (BAU vs APS)

Scenarios	2015	2020	2025	2030	2035	2040
APS	**2.4**	**2.6**	**2.8**	**2.8**	**2.7**	**2.4**
BAU	**2.6**	**3.1**	**3.8**	**4.7**	**5.7**	**6.9**

APS = Alternative Policy Scenario, BAU = Business as Usual.
Source: Author's assumption.

Figure 2E.3 Final Energy Demand Keeping CO_2 Emissions at 2013 Level by 2040 (BAU vs APS)



APS = Alternative Policy Scenario, BAU = Business as Usual.
Source: Author's calculations.

2F.Malaysia's Case Study

Keeping CO_2 Emissions at 2013 Level by 2040

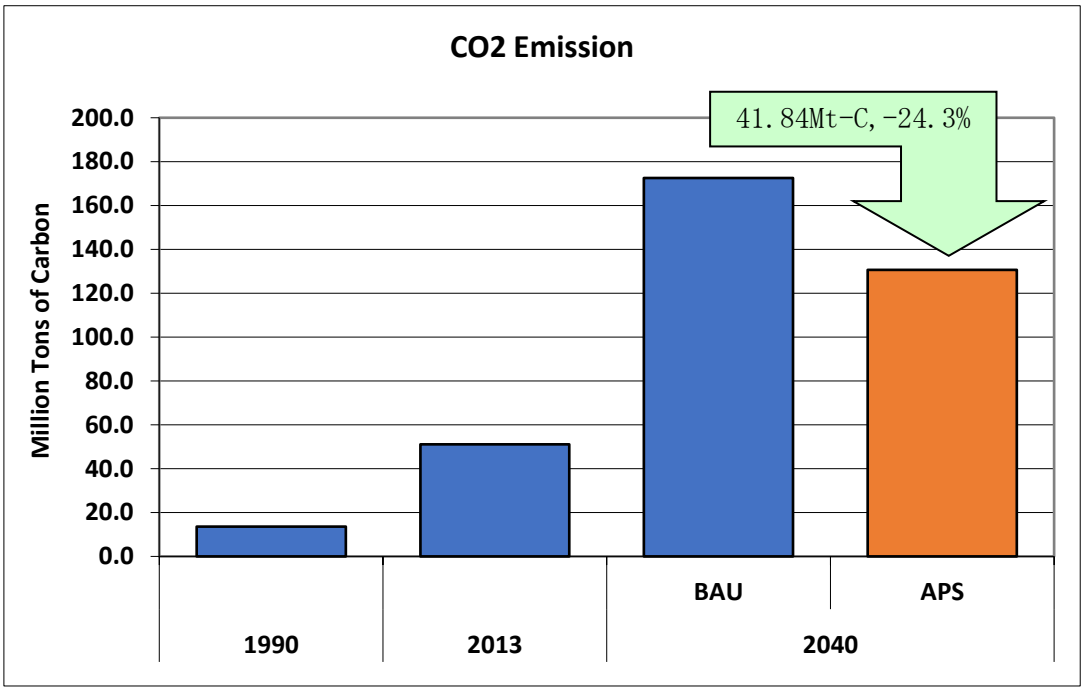
Introduction

This chapter discusses efforts to reduce Malaysia's carbon dioxide (CO_2) emissions level in 2040 to the same level as in 2013. With this target, existing targets or mitigation options will be enhanced by more extreme target or reduction. The mitigation options will be based on current scenarios already identified during last year's project where the level of reduction of emissions in 2040 will be same as in 2013. Although this exercise may not reflect the current and future policies in Malaysia, its analysis may provide an insight for policymakers on the possible mitigation actions that can be implemented.

Methodology

The energy data are from the International Energy Agency (IEA) and the base year for this exercise is 2013. By using the previous year's result as derived from LEAP software, the modification in meeting the objective was made for the LEAP model. Based on last year's result, the total CO_2 emissions in 2013 were 51.1 metric tonnes of carbon (Mt-C). Figure 2F.1 shows the current Business as Usual (BAU) and Alternative Policy Scenario (APS) results for CO_2 emissions in 2013 and 2040.

Figure 2F.1. Current Level of CO_2 Emissions in 2013 and 2040 for BAU and APS



APS = Alternative Policy Scenario, BAU = Business as Usual, CO_2 = carbon dioxide.

Source: Author's calculations.

The figure above shows that in 2040, there is a potential reduction of 24.3% between APS and BAU scenario or a 38.74-Mt-C reduction that can potentially be avoided if mitigation options are implemented. The current mitigation scenarios are shown in Tables 2F.1 to 2F.5:

Table 2F.1. Energy Efficiency Assumptions

Scenario	Assumption
APS1	1. Electricity demand in industrial sector (INEL)
	Potential reduction of electricity demand in industrial sector from 2015 until 2040 by 1.35% per year.
	2. Total energy demand in industrial sector (INTT)
	Potential reduction of total energy demand (electricity + petroleum products + coal + natural gas) in industrial sector by 1% per year from 2015 until 2040.
	3. Total energy demand in commercial sector
	Potential reduction of total energy demand in commercial sector by 1% per year from 2015 until 2040.

APS = Alternative Policy Scenario.
Source: Author's assumption.

Table 2F.2. Higher Efficiency of Thermal Electricity Generation

Scenario	Assumption
APS2	1.Higher efficiency of coal power plant by 40% in 2040
	2. Higher efficiency of natural gas power plant by 46.3% in 2040.

APS = Alternative Policy Scenario.
Source: Author's assumption.

Table 2F.3. Renewables Energy Assumptions

<table>
<tr><th>Scenario</th><th colspan="7">Assumption</th></tr>
<tr><td rowspan="8">APS2</td><td colspan="7">1. By 2030, Malaysia is expected to have these renewable energy (RE) capacities in power generation. The breakdown of the capacity based on type of fuels type is shown below:</td></tr>
<tr><td colspan="7">Cumulative Capacity (MW)</td></tr>
<tr><td>Year</td><td>Biomass</td><td>Biogas</td><td>Mini-Hydro</td><td>Solar PV</td><td>Solid Waste</td><td>Total</td></tr>
<tr><td>2015</td><td>330</td><td>100</td><td>290</td><td>55</td><td>200</td><td>975</td></tr>
<tr><td>2020</td><td>800</td><td>240</td><td>490</td><td>175</td><td>360</td><td>2,065</td></tr>
<tr><td>2025</td><td>1,190</td><td>350</td><td>490</td><td>399</td><td>380</td><td>2,809</td></tr>
<tr><td>2030</td><td>1,340</td><td>410</td><td>490</td><td>854</td><td>390</td><td>3,484</td></tr>
<tr><td colspan="7">2. By 2020, 7% of Malaysia’s share of diesel consumption in transport sector will come from biodiesel.</td></tr>
</table>

APS = Alternative Policy Scenario, MW = megawatt, PV = photovoltaic.
Source: Author’s assumption.

Table 2F.4. Nuclear Energy Assumptions

Scenario	Assumption
APS4	1. By 2027, a 2000-MW nuclear plant is expected to be commissioned.

APS = Alternative Policy Scenario, MW = megawatt.
Source: Author’s assumption.

Table 2F.5. APS Assumptions

Scenario	Assumption
APS5	APS1 + APS2 + APS3 + APS4

APS = Alternative Policy Scenario.
Source: Author's assumption.

Based on all scenarios above, the modification procedures to meet the objective of this exercise will be applied to the LEAP model as shown in Table 2F.6.

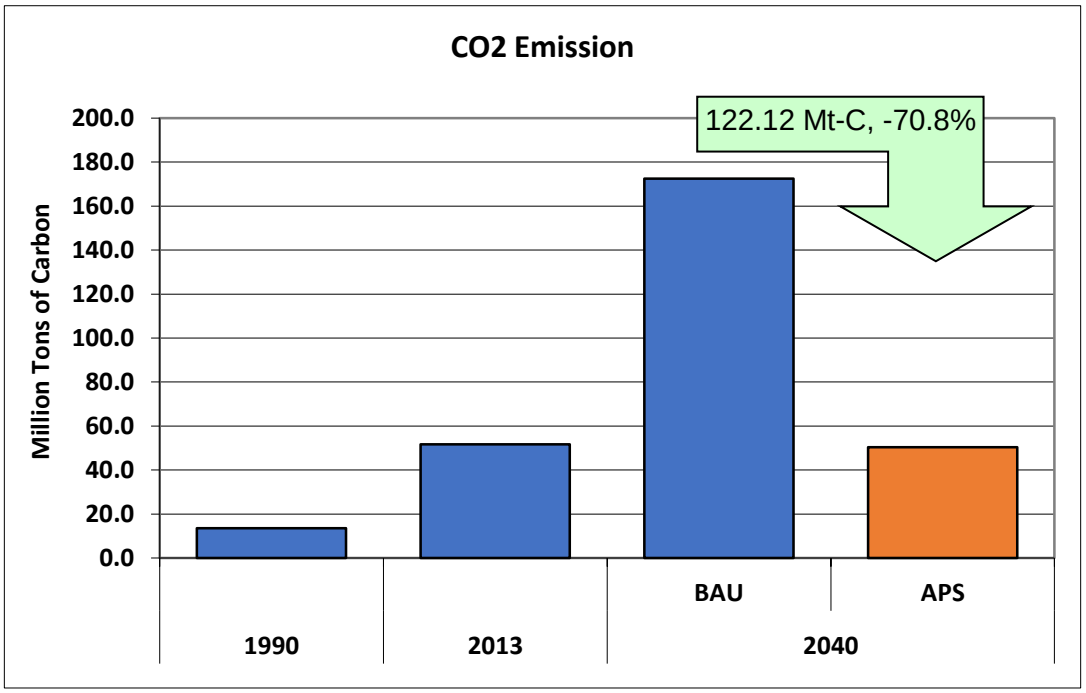
Table 2F.6. Modification Effects on Selected Scenarios

Scenario	Modification
APS1	Industry sector: Reduction of energy for all types of fuel from 2016 until 2040 at 52% compared to the BAU scenario
	Others sector: Reduction of energy for all types of fuel from 2016 until 2040 at 52% compared to the BAU scenario
	Transport sector: Reduction of jet kerosene, gasoline, and diesel from 2016 until 2040 at 52% compared to the BAU scenario
APS2	Power plants: By 2040, the new gas plant will have 55% efficiency while the new coal plant will have 40% efficiency
	Fuel switching from coal to gas by 1000 MW each year from 2020 until 2040
APS3	For power sector: Double the target capacity of RE as in APS scenario
	For transport sector: Increase the share of biodiesel from 10% to 20%
APS4	Introduction of nuclear power plant in 2027 at 2000 MW until 2040

APS = Alternative Policy Scenario, BAU = Business as Usual, MW = megawatt, RE = renewable energy.
Source: Author's assumption.

These modifications only cover the mitigation scenarios based on their potential of reducing CO_2 emissions. Figure 2F.2 illustrates the objective or target of emissions level in 2040.

Figure 2F.2. Target of CO_2 Emissions in 2040

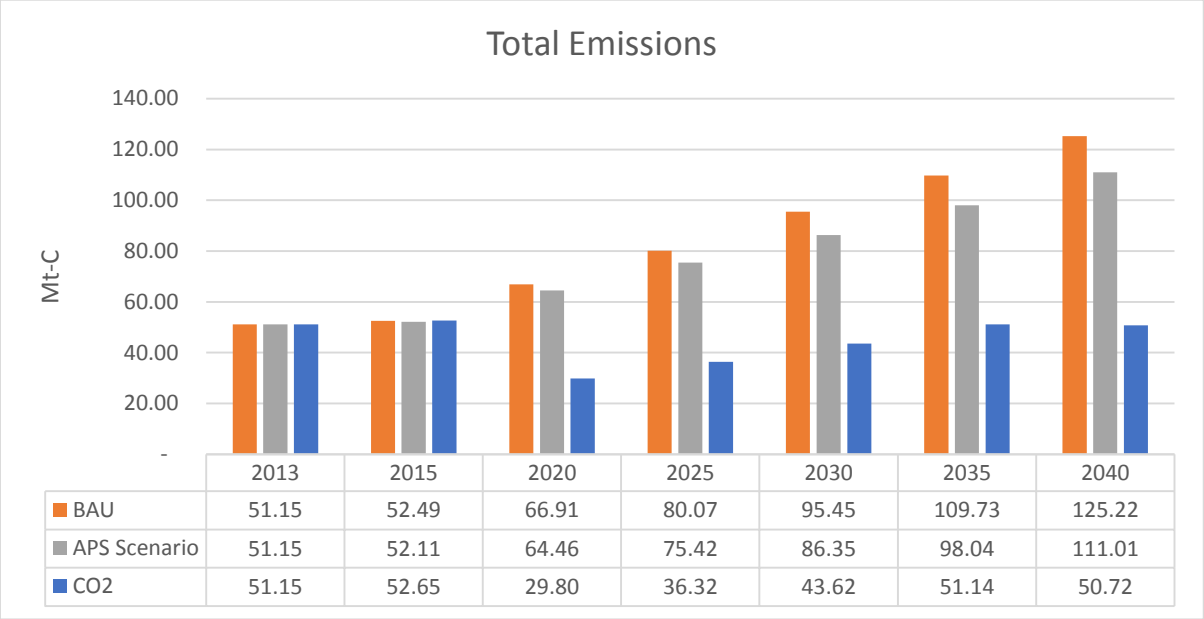


CO_2 = carbon dioxide.
Source: Author's calculations.

Results

Based on the modification effects applied to the LEAP model, results for total emissions for each scenario are shown in Figure 2F.3:

Figure 2F.3. Results of Total Emissions by Scenario



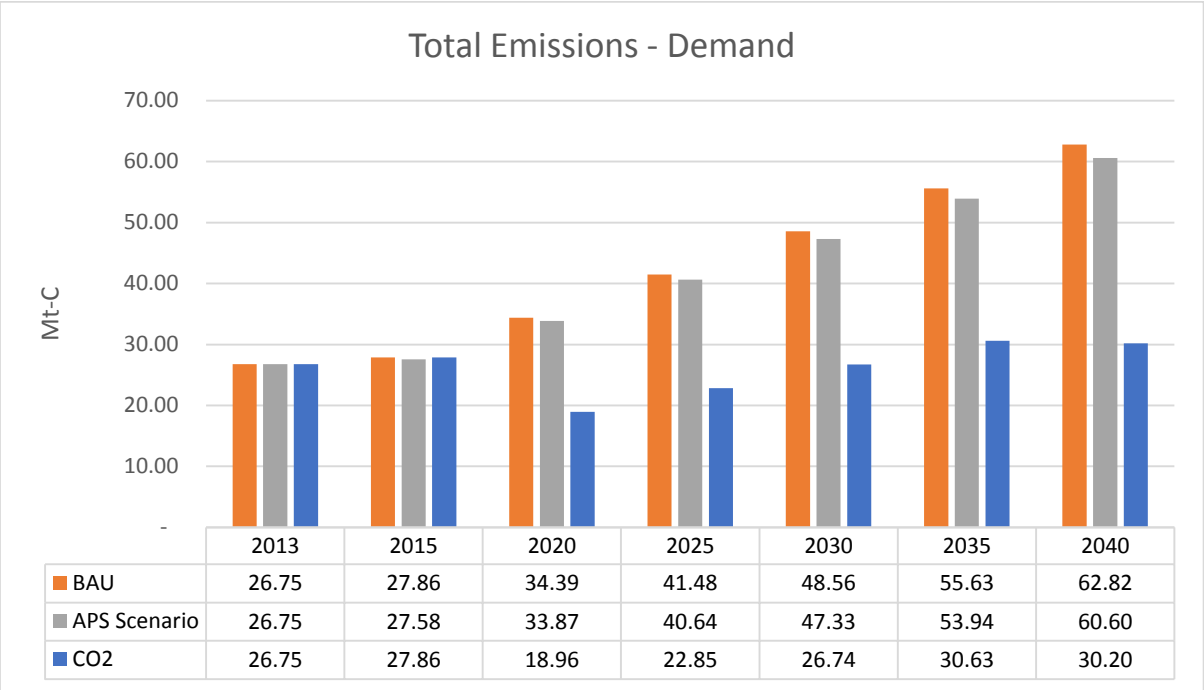
	2013	2015	2020	2025	2030	2035	2040
BAU	51.15	52.49	66.91	80.07	95.45	109.73	125.22
APS Scenario	51.15	52.11	64.46	75.42	86.35	98.04	111.01
CO2	51.15	52.65	29.80	36.32	43.62	51.14	50.72

Mt-C = metric tonne of carbon.

Source: Author's calculations.

By 2040, the level of total CO_2 emissions is projected at 50.721 metric tonnes of carbon (Mt-C), lower than the 51.1-Mt-C target. This indicates that the modification effects applied are overestimated. The result, however, is not so far from the actual target. From the total CO_2 emissions, contribution from the demand sector is shown in Figure 2F.4:

Figure 2F.4. Total CO_2 Emissions from the Demand Sector

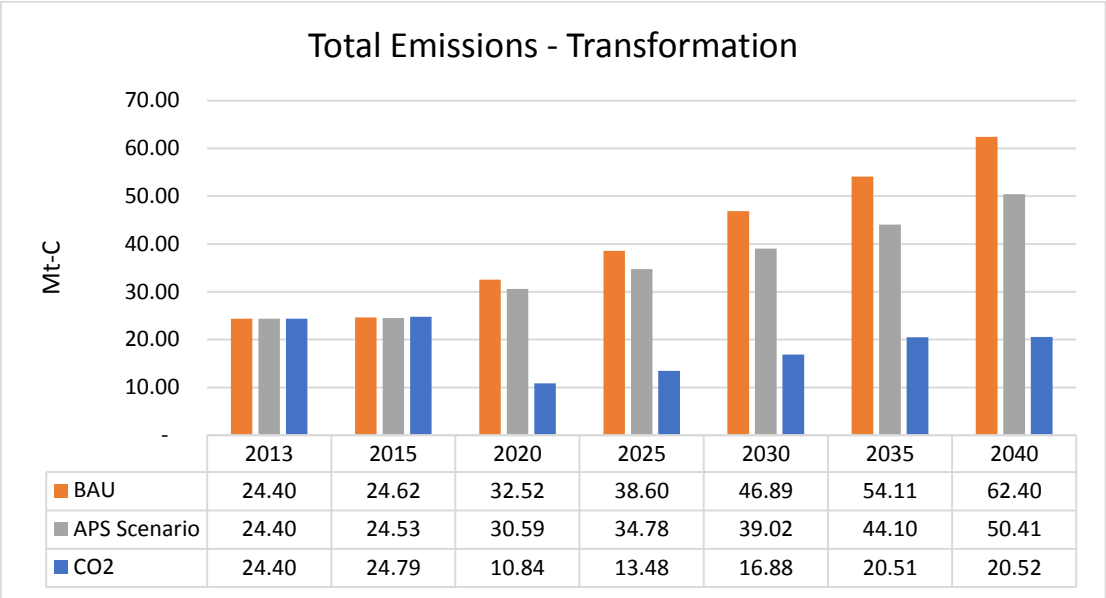


	2013	2015	2020	2025	2030	2035	2040
BAU	26.75	27.86	34.39	41.48	48.56	55.63	62.82
APS Scenario	26.75	27.58	33.87	40.64	47.33	53.94	60.60
CO2	26.75	27.86	18.96	22.85	26.74	30.63	30.20

CO_2 = carbon dioxide.
Source: Author's calculations.

In 2040, the total CO_2 emissions from the demand sector is 30.197 Mt-C, and 62.82 Mt-C, and 60.60 Mt-C for the BAU and APS scenarios, respectively. Result from LEAP shows that under transformation sector, total CO_2 emissions are projected at 20.52 Mt-C as shown in Table 2F.5.

Figure 2F.5. Total CO_2 Emission from Transformation Sector



	2013	2015	2020	2025	2030	2035	2040
BAU	24.40	24.62	32.52	38.60	46.89	54.11	62.40
APS Scenario	24.40	24.53	30.59	34.78	39.02	44.10	50.41
CO2	24.40	24.79	10.84	13.48	16.88	20.51	20.52

Mt-C = metric tonne of carbon.
Source: Author's calculations.

Conclusions

The results show that extreme measures in mitigating CO_2 emissions in the energy sector will affect the total level of emissions in the future. However, a lot of factors need to be considered in the mitigating scenarios, such as investment cost for a high-efficient power plant, tariff setting when fuel switching is applied at the power plant, public acceptance for a nuclear power plant, issues on security of supply when converting fossil fuel power plants into renewable power plants and others.

In tackling the climate change issues especially in the energy sector, policymakers should consider and identify the near-, medium- and long-term plans in mitigating CO_2 emissions. Cost-effective measures should be priorities to minimise losses and maximise savings. Workshops and roundtable discussions should be regularly conducted for inputs and better planning.

2G.Myanmar's Case Study

Keeping CO_2 Emissions at 2013 Level by 2040

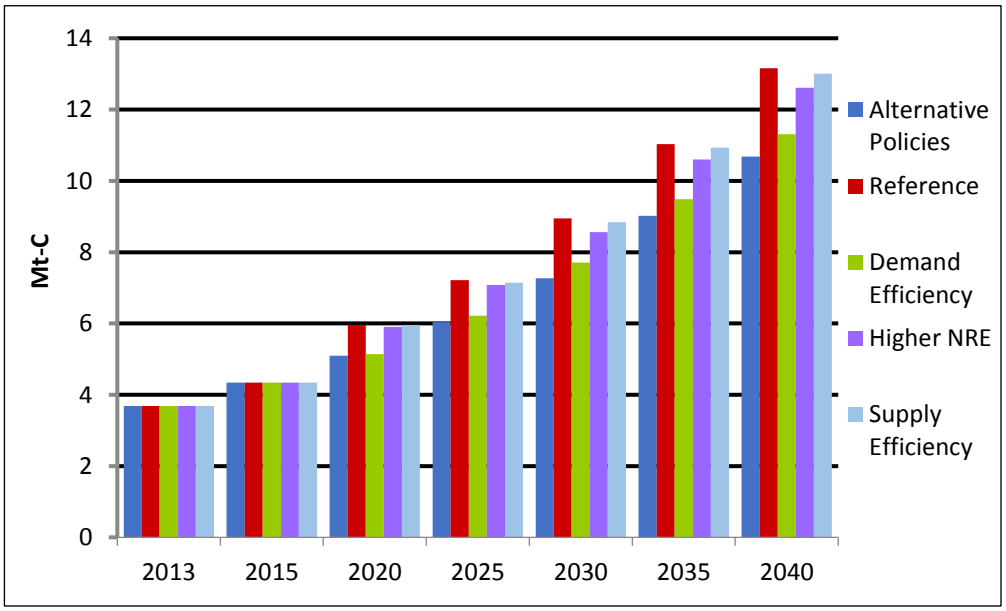
Background

The Energy Outlook and Energy Saving Potential in East Asia 2016 by the Economic Research Institute for ASEAN and East Asia (ERIA) projects an increasing demand for both the Alternative Policy Scenario (APS) and the Business as Usual (BAU) scenario. As a result, the total carbon dioxide (CO_2) emissions will also be increasing in the future.

APS is a combination of different APS scenarios. In the case of Myanmar, the scenarios are: reference (BAU), energy efficiency (APS1), efficient supply (APS2), higher renewable energy (APS3), and alternative policies (APS).

The total CO_2 emissions in 2013 (base year) was around 3.7 metric tonnes of carbon (Mt-C) and are projected to reach 13 Mt-C by 2040 for the BAU scenario (Figure 2G.1).

Figure 2G.1. CO_2 Emissions of Myanmar in ERIA's Energy Outlook 2016



CO_2 = carbon dioxide, ERIA = Economic Research Institute for ASEAN and East Asia, Mt-C = metric tonne of carbon.
Source: Author's calculations.

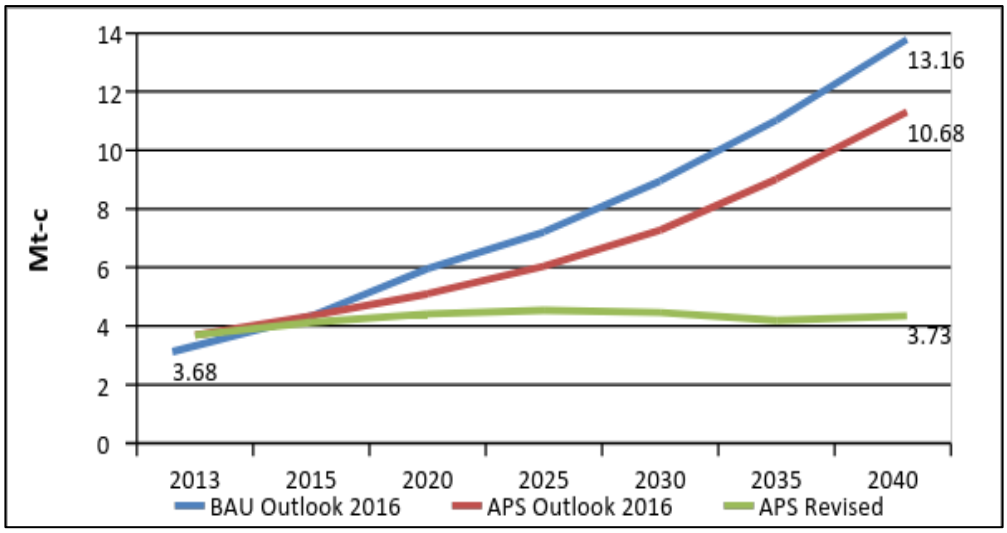
With the implementation of more efficient technology in the final and supply sector and with higher penetration of renewable energy (APS), the total CO_2 emissions will only increase to around 10.7 Mt-C by 2040. Thus, implementing APS will result in an 18.8-% reduction of CO_2 emissions in 2040 compared to BAU.

This case study on CO_2 emissions is to identify possible solutions to mitigate CO_2 emissions in 2040 to the 2013 level. Since the APS scenario has the lowest CO_2 emissions, this will be the basis for the case study.

Methodology

APS consists of APS1, APS2, and APS3. Implementing APS results in an increase of CO_2 emissions in 2040 compared to 2013. To ensure that the total CO_2 emissions remain at the 2013 level (Figure 2G.2), more efforts are needed to achieve national development target without increasing CO_2 emissions from its base year level.

Figure 2G.2. CO_2 Emissions Comparisons



APS = Alternative Policy Scenario, CO_2 = carbon dioxide, Mt-C = metric tonne of carbon.
Source: Author's calculations.

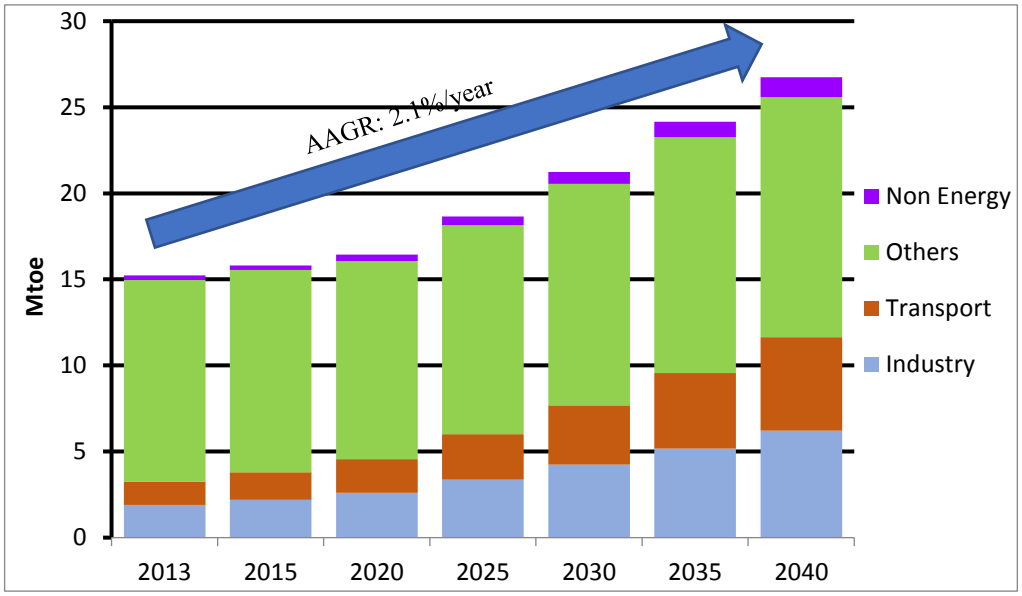
The parameters considered were: energy saving in the final consumption sector, high-efficient thermal power plant, hydropower and geothermal energy, solar/photovoltaic and wind energy, and other renewables.

The approach for the exercise will be: make energy efficiency targets more stringent; use less fossil fuels and more renewables; increase use of biofuels such as biogasoline (bioethanol), biodiesel, and biogas; limit use of fossil fuels in the power sector; and increase use of renewables in power generation.

Final Energy Demand

In ERIA's Energy Outlook and Energy Saving Potential in East Asia 2016, (Energy Outlook 2016), the final energy demand of Myanmar under APS will be growing at an average rate of 2.1% over the 2013–2040 period (Figure 2G.3).

Figure 2G.3. Final Energy Demand in ERIA's Energy Outlook 2016 APS

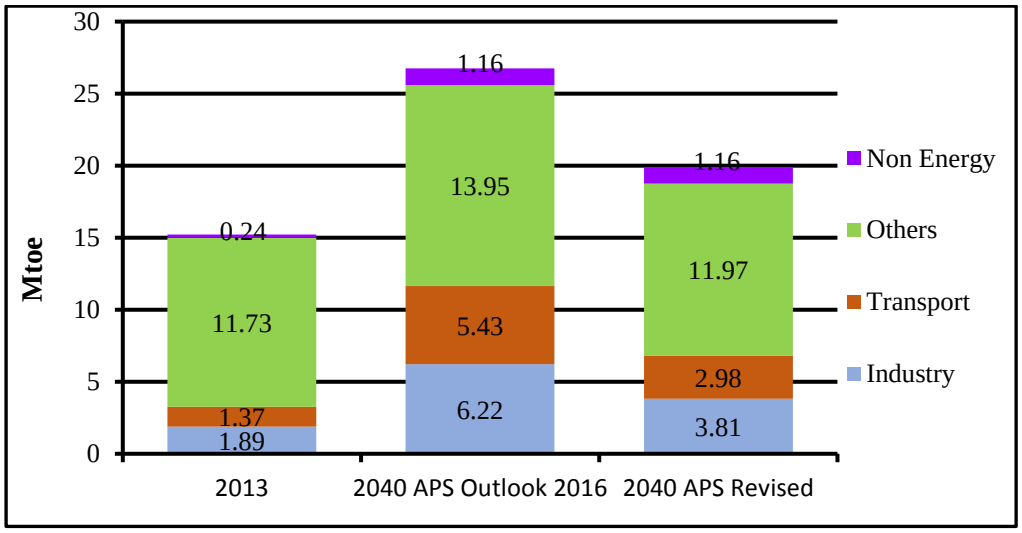


APS = Alternative Policy Scenario, ERIA = Economic Research Institute of ASEAN and East Asia, AAGR = Average Annual Growth Rate, Mtoe = metric tonne of oil equivalent.
Source: Author's calculations.

Revising the assumption for energy efficiency (EE) and increasing the use of biofuels will slow down the increase of the final energy demand. The final energy demand of the revised APS will grow at an average annual rate of 1% per year over the 2013–2040 period. Revising the EE target will reduce the total final energy demand of 2040 by almost 25% the level of APS in ERIA's Energy Outlook 2016 (Figure 2G.4).

The use of biofuels will be increasing since the assumption was revised especially in the transport sector. Biogas for households was assumed in the revised APS, which was excluded in APS of ERIA's Energy Outlook 2016.

Figure 2G.4. Final Energy Demand Comparisons

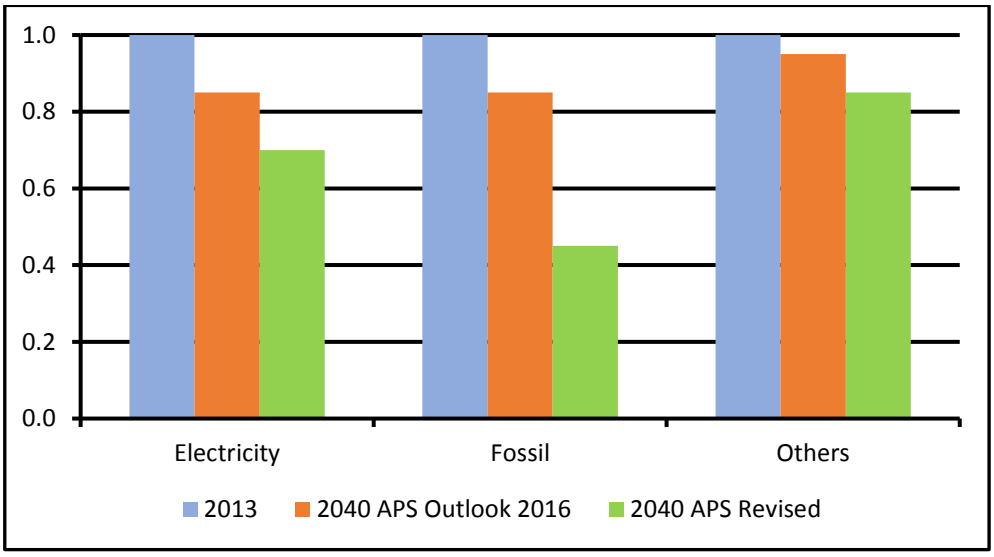


APS = Alternative Policy Scenario, Mtoe = metric tonne of oil equivalent.
Source: Author's calculations.

EE Targets

The EE target in APS of ERIA's Energy Outlook 2016 is assumed to be 10% by 2040 for electricity and fossil fuel. There is no EE target for other fuels. In the revised APS, the target is more stringent. Around 50% saving target is assumed for fossil fuel, a-30% saving target for electricity, and a-10-% saving target for other fuels (Figure 2G.5).

Figure 2G.5. EE Targets

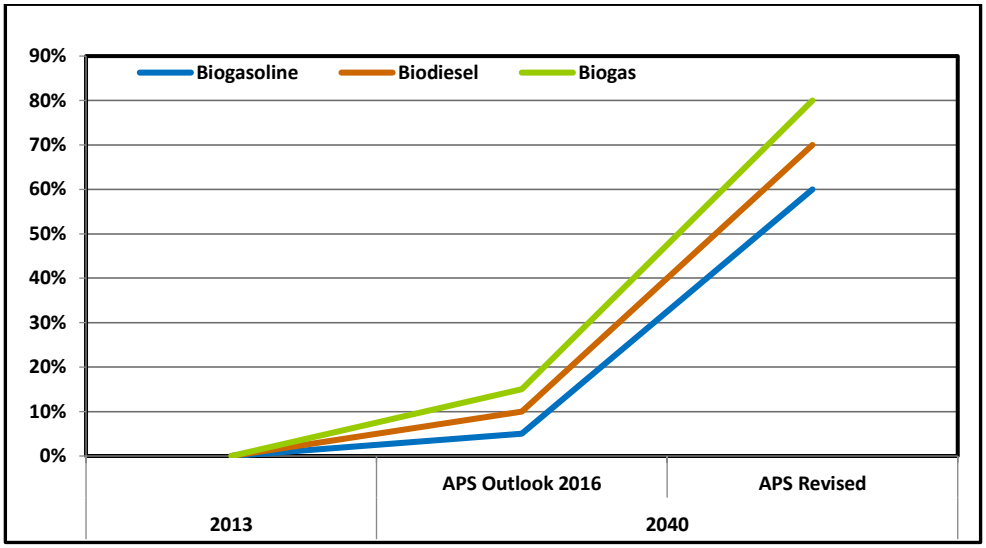


EE = Energy Efficiency.
Source: Author's calculations.

Biofuel Penetration

Beside the EE target, the biofuel penetration rate was also revised. In APS of ERIA's Energy Outlook 2016, penetration of biodiesel is assumed to reach 10% by 2040 and 5% for biogasoline. No penetration of biogas is assumed in APS of ERIA's Energy Outlook 2016. In the revised APS, the penetration of biodiesel increased to 70% by 2040, while biogasoline has a 60-% penetration rate and biogas around 80% (Figure 2G.6).

Figure 2G.6. Biofuel Penetration



APS=Alternative Policy Scenario.
Source: Author's calculations.

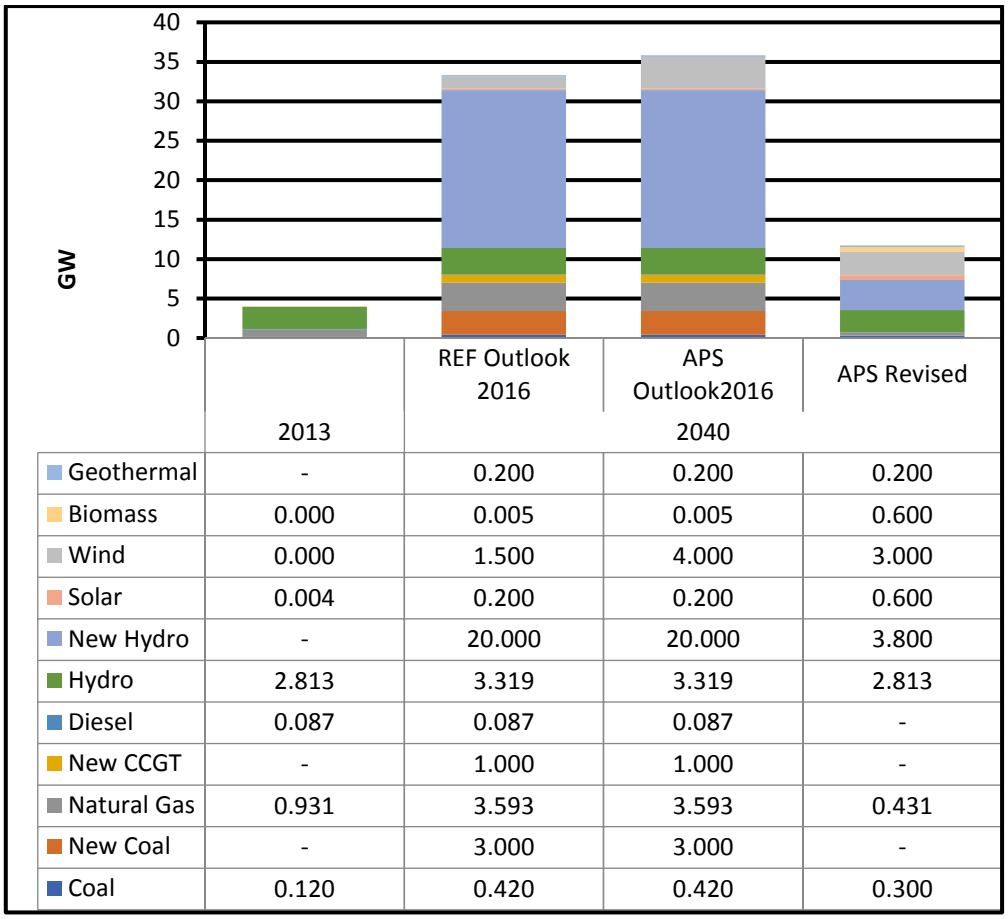
Power Generation

The parameters in the power generation sector of the long-range energy alternatives [lanning model include dispatch rule, merit order, efficiency, maximum availability, exogenous capacity, etc. Most of these technical parameters are like those in APS of ERIA's Energy Outlook 2016. The difference is in the capacity expansion of the various power plants. In the revised APS, there is more renewable energy capacity being assumed for the future.

Capacity

As shown in Figure 2G.7, total capacity in APS of ERIA's Energy Outlook 2016 is around 36 gigawatts (GW) in 2040 while in the revised APS it is 16 GW. An assumption is made on the expansion of fossil fuels in the revised APS to achieve CO_2 emissions of 2040 at the same level of 2013.

Figure 2G.7. Total Capacity (GW)



	2013	REF Outlook 2016	APS Outlook2016	APS Revised
		2040		
Geothermal	-	0.200	0.200	0.200
Biomass	0.000	0.005	0.005	0.600
Wind	0.000	1.500	4.000	3.000
Solar	0.004	0.200	0.200	0.600
New Hydro	-	20.000	20.000	3.800
Hydro	2.813	3.319	3.319	2.813
Diesel	0.087	0.087	0.087	-
New CCGT	-	1.000	1.000	-
Natural Gas	0.931	3.593	3.593	0.431
New Coal	-	3.000	3.000	-
Coal	0.120	0.420	0.420	0.300

GW = gigawatt, APS = Alternative Policy Scenario, REF = Reference, CCGT = Combined Cycle Gas Turbibe.
Source: Author's calculations.

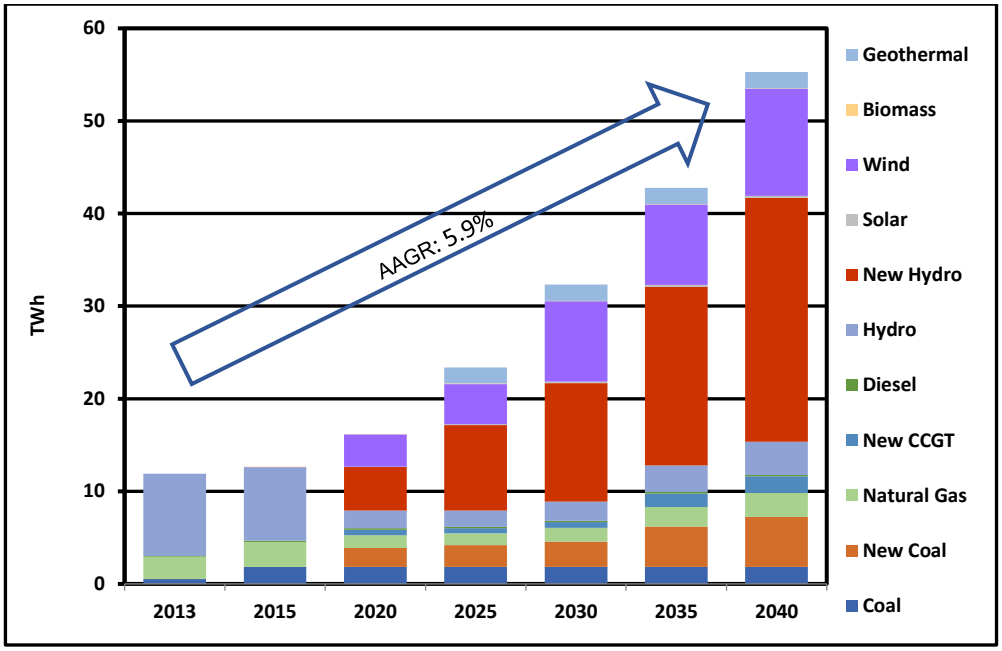
In the case of coal power plants, the assumption for capacity expansion is the one already planned in 2015 (300 MW). The existing 120-MW coal power plant is also assumed to be retired in 2040. No expansion is assumed for natural gas-fuelled plants and that some of the existing plants will be retired gradually by 2040 (300 MW). The existing diesel plants are also assumed to be retired by 2030.

Based on the assumptions for the fossil-fuelled power plants, electricity production will be based mostly from renewable plants. Since there is also reduction in electricity demand as a result of the revised EE targets, the new hydropower capacity is also assumed to be reduced. The existing hydropower capacity remains the same as that of APS in ERIA's Energy Outlook 2016. Similarly, there is also reduction in the new capacity assumption for wind energy plants. The biomass, geothermal, and solar plants have been assumed to expand the same as it is in APS of ERIA's Energy Outlook 2016.

Power Generation

The revised APS generation of electricity will be around 42 terawatt hours (TWh) in 2040, lower than the 55 TWh generated in APS of ERIA's Energy Outlook 2016 (Figure 2G.8 and Figure 2G.9). The average annual growth rate of electricity production in te APS of ERIA's Energy Outlook 2016 is 5.9% while in the revised APS, the rate is slower, at 4.8% per year.

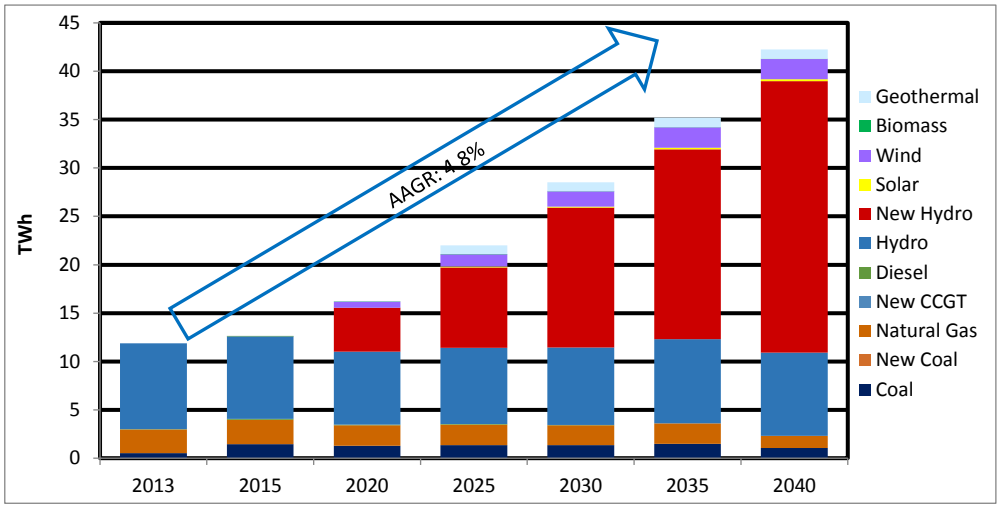
Figure 2G.8. Power Generation in ERIA's Energy Outlook 2016 APS



AAGR = Average Annual Growth Rate, APS = Alternative Policy Scenario, CCGT = Combined Cycle Gas Turbine, ERIA = Economic Research Institute for ASEAN and East Asia, TWh = terawatt hour.Source: Author's calculations.

Around 95% of the total generation comes from renewable energy in the revised APS while the rest will come from the fossil-fuelled power plants. In APS of ERIA's Energy Outlook 2016, the renewable share in total generation is 79%.

Figure 2G.9. Power Generation by Type in the Revised APS

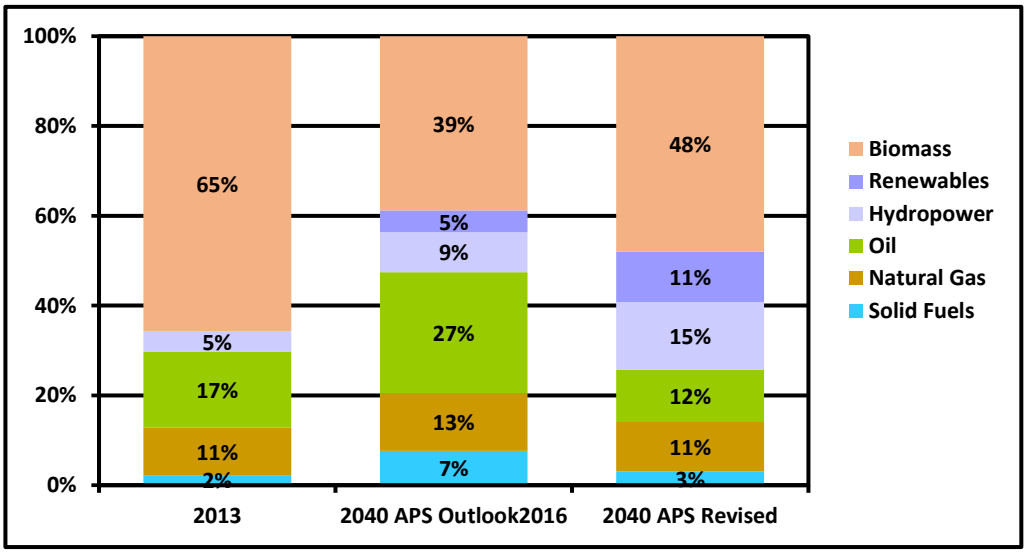


AAGR = Average Annual Growth Rate, APS = Alternative Policy Scenario, CCGT = Combined Cycle Gas Turbine.
Source: Author's calculations.

Primary Energy Supply

With revised EE target, biofuel penetration, and increased share of renewable energy in the power sector, the total primary energy supply of the revised APS will almost be 21 Mtoe in 2040, around 28% lower than in APS of ERIA's Energy Outlook 2016 (Figure 2G.10). In terms of share in the total energy mix, 74% comes from renewable energy including biomass.

Figure 2G.10. Primary Energy Supply

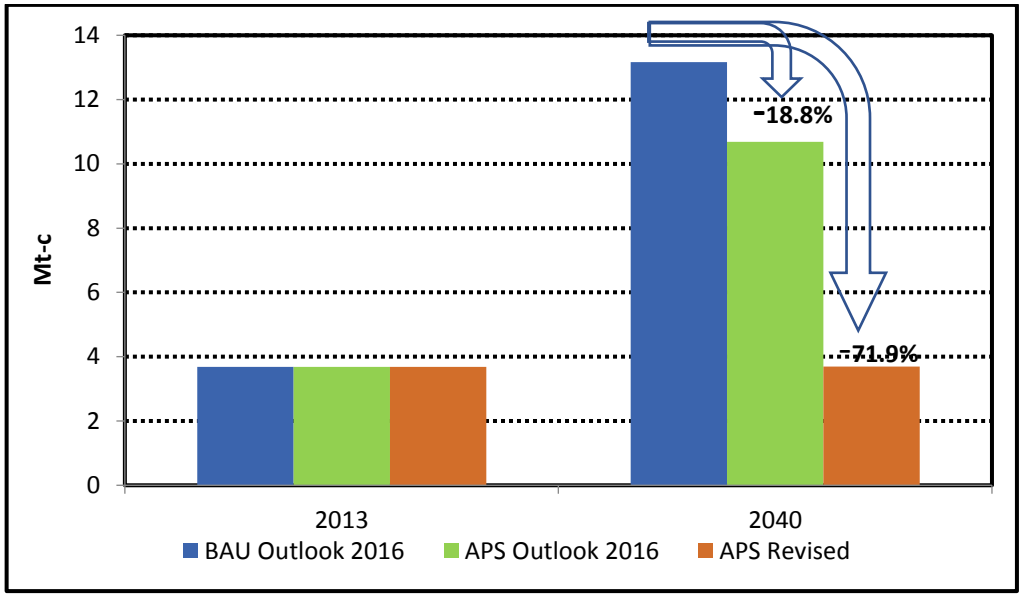


APS = Alternative Policy Scenario.
Source: Author's calculations.

CO_2 Emissions

The resulting carbon dioxide (CO_2) emissions of the revised APS, which are assumed to be the same as the base year value (3.7 Mt-C), are almost 72% lower than the level in APS of ERIA's Energy Outlook 2016, which are 10.7 Mt-C (Figure 2G.11).

Figure 2G.11. CO_2 Emissions Reduction by 2040



APS = Alternative Policy Scenario, BAU = Business as Usual, CO_2 = carbon dioxide, Mt-C = metric tonne of carbon.
Source: Author's calculations.

Conclusion

ERIA's Energy Outlook 2016 results in total CO_2 emissions of almost 13.2 Mt-C by 2040 for the BAU scenario and 10.7 Mt-C for APS. For the total CO_2 emissions in 2040 to be the same as that of 2013 (3.7 Mt-C), efforts in the revised APS have to be more stringent that those in APS of ERIA's Energy Outlook 2016.

Revising the EE target, the biofuel penetration, and increasing the share of renewables in power generation have made it possible for the total CO_2 emissions of the revised APS to be similar to the base year level. The CO_2 emissions reduction in APS of ERIA's Energy outlook 2016 is around 19% by 2040, while the revised APS will result in a 72% reduction compared to the BAU scenario.

2H.The Philippines' Case Study

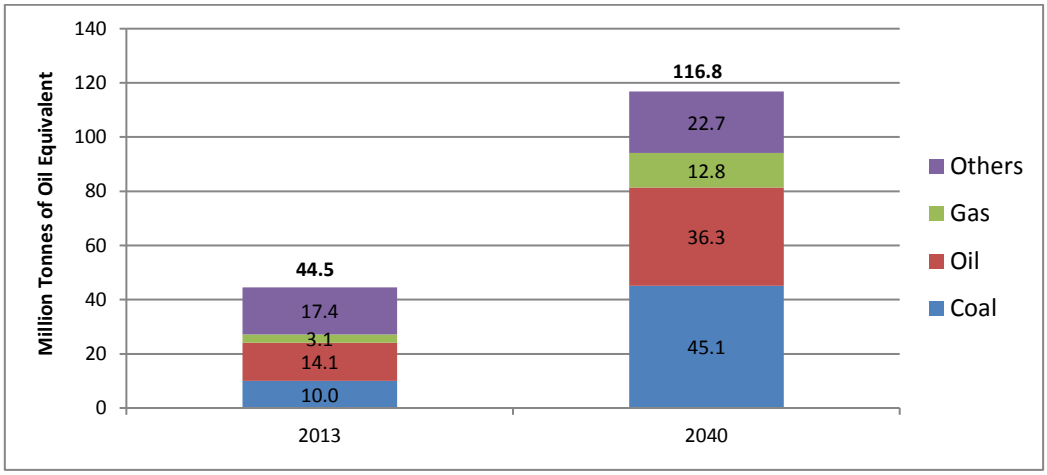
Keeping CO_2 Emissions at 2013 Level by 2040

Introduction

Based on report of the Economic Research Institute for ASEAN and East Asia (ERIA) on the energy supply and demand outlook for the Business as Usual (BAU) scenario for the period 2013–2040, the Philippines' primary energy consumption is expected to increase by 3.6% per year from its 2013 level of 44.5 metric tonnes of oil equivalent (Mtoe) to 116.8 Mtoe in 2040. Consumption for all major energy sources is projected to increase during the period, with coal growing the fastest at 5.7% per year. During the same period, natural gas is also expected to expand with a growth rate of 5.4% per year, while oil growth rate is estimated at 3.6% per year. On the other hand, major renewable energy consumption from geothermal and hydropower will come at an average growth rate of 1.7% and 1.5%, respectively, while the aggregated consumption of other fuels can be expected at a meagre level of 0.1% growth rate.[1]

Coal will account for the largest share in the total energy supply of the country by 2030 up to the end of the period, reaching 38.6% share by 2040. Oil and natural gas, being part of the country's major energy sources, are projected to register the shares of 31.1% and 11.0%, respectively, at the end of the period. Geothermal and hydropower, mainly used for power generation, will register shares of 11.1% and 1.1%, respectively. Meanwhile, the requirements for other fuels in 2040 will comprise the 7.2% share in the supply mix (Figure 2H.1).

Figure 2H.1. Primary Energy Consumption by Source, BAU Scenario, 2013 and 2040



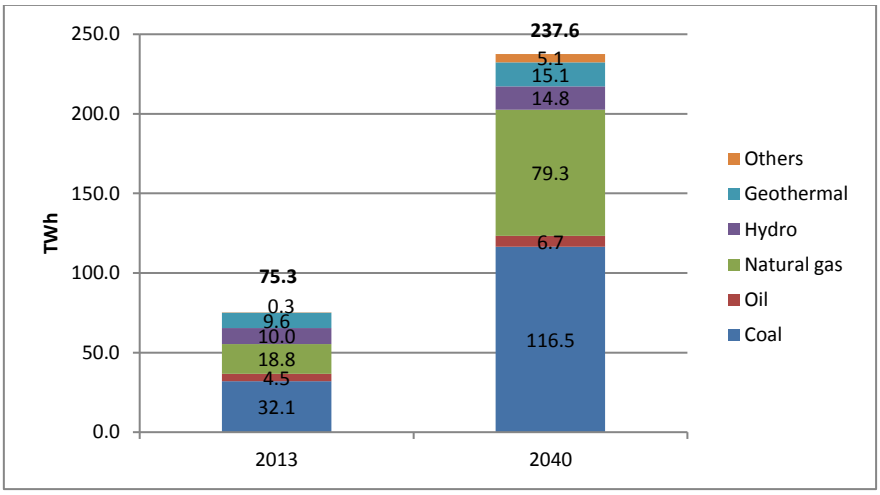
BAU = Business as Usual.
Source: Author's calculations.

The country's total power generation in 2013 reached 75.3 terawatt hours (TWh) and is

[1] ERIA 2015 Energy Supply and Demand Outlook Report - Philippines

expected to increase by 4.3% yearly across the planning period. Coal remained the major source in power generation in 2013, accounting for an average share of 42.6%. At the end of the planning period, the share of coal is expected to be at 49.1%, as its level will increase at an annual average rate of 4.9%, from 32.1 TWh in 2013 to 116.5 TWh in 2040. Natural gas, as the second biggest source of power generation, will increase its output from 18.8 TWh in 2013 to 79.3 TWh in 2040, at an average rate of 5.5% a year. On the other hand, oil's share to generation mix will continue to decline, reaching a measly 2.8% share by 2040. Hydropower and geothermal power generation are expected to grow at a steady rate of 1.4 and 1.7% a year, respectively. Other sources of power generation, an aggregate output from solar, wind, and biomass resources, are expected to increase at an annual average rate of 11.4% (Figure 2H.2).

Figure 2H.2. Power Generation by Source, BAU, 2013 and 2040



BAU = Business as Usual.
Source: Author's calculations.

Sensitivity Analysis on the Level of GDP Growth Rate to the Primary Energy Consumption

The purpose of simulating high and low gross domestic product (GDP) scenarios is to analyse the effect of one unit increase or decrease of GDP growth rate at the level of primary energy consumption. It is somehow related to measuring the energy intensity per unit of economic output. As shown in Table 2H.1, high GDP scenario will increase by 1 percentage point from 2016 to 2040 from the BAU scenario level. By contrast, low GDP scenario will decrease by 1 percentage point from the BAU scenario level during the period.

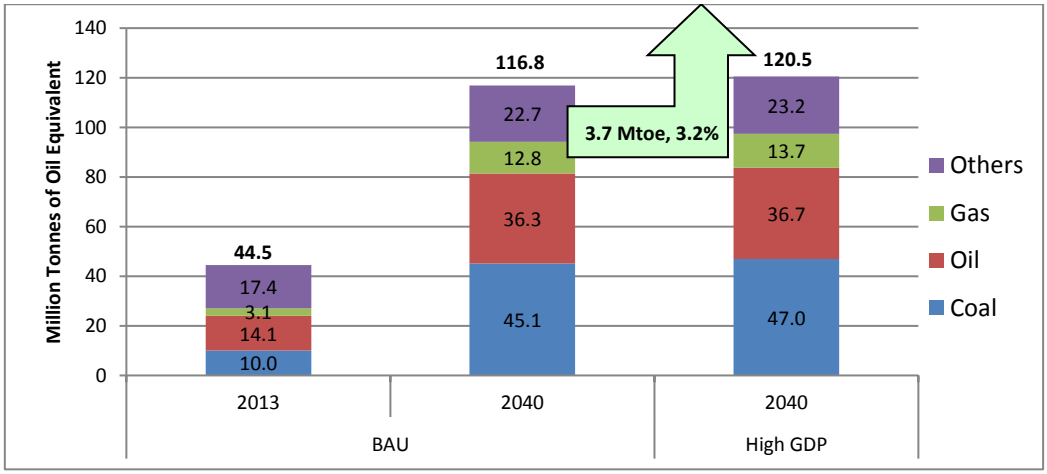
Table 2H.1. GDP Growth Rate (BAU, High GDP and Low GDP), 2013–2040

BAU scenario	Base year: 2013 Growth (2013, 7.1%; 2014, 6.1%; 2015, 5.8%; 2016–2020, 6.2%; 2021–2026, 6%; 2027–2029, 5.8%; 2030–2040, 5.5%)
High GDP scenario	Base year: 2013 Growth (2013, 7.1%; 2014, 6.1%; 2015, 5.8%; 2016–2020, 7.2%; 2021–2026, 7%; 2027–2029, 6.8%; 2030–2040, 6.5%)
Low GDP scenario	Base year: 2013 Growth (2013, 7.1%; 2014, 6.1%; 2015, 5.8%; 2016–2020, 5.2%; 2021–2026, 5%; 2027–2029, 4.8%; 2030, 4.5%)

BAU = Business as Usual, GDP = gross domestic product.
Source: Author's assumptions.

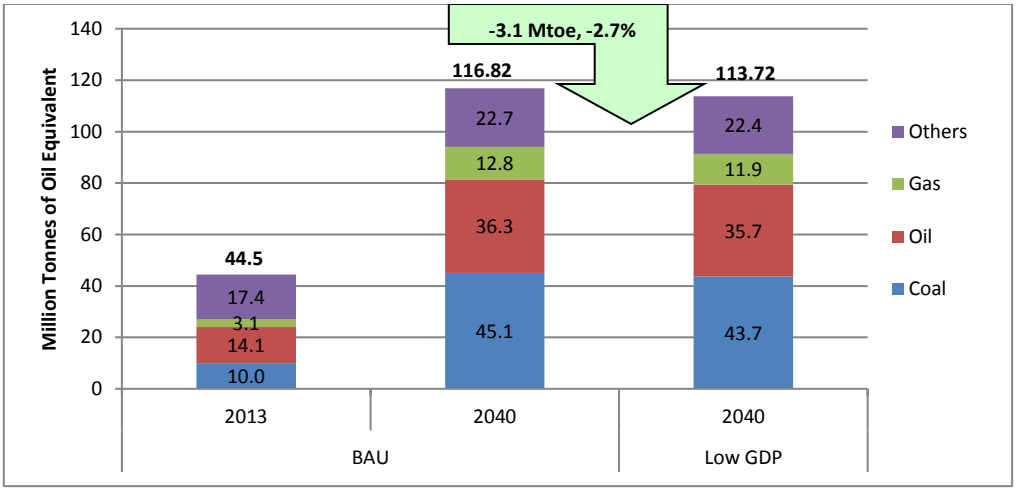
As a result of the simulation made, a percentage point increase of economic output may require additional 3.2% of energy supply in 2040, while a decrease of a percentage point in economic output may defer 2.7% of energy requirement during the period. The effect of 1 percentage point increase or decrease of GDP growth to the primary energy consumption is approximately 3% plus or minus. In high GDP scenario, natural gas will increase the highest at 7.0% in 2040 in comparison with the BAU level of the same period while coal will also increase significantly by 4.2% (Figure 2H.3). Low GDP scenario, on the other hand, has almost the same trend with high GDP scenario but in the opposite direction in such a way that natural gas and coal will decrease by 7.3% and 3.0%, respectively, in 2040 compared with the BAU scenario (Figure 2H.4).

Figure 2H.3. Primary Energy Consumption, BAU and High GDP, 2013 and 2040



BAU = Business as Usual, GDP = gross domestic product.
Source: Author's calculations.

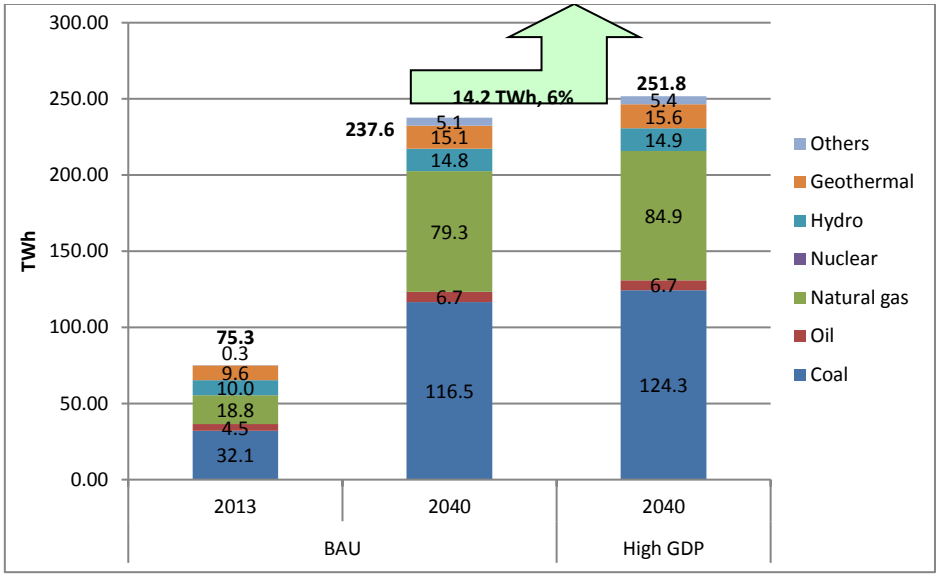
Figure 2H.4. Primary Energy Consumption, BAU and Low GDP, 2013 and 2040



BAU = Business as Usual, GDP = gross domestic product.
Source: Author's calculations

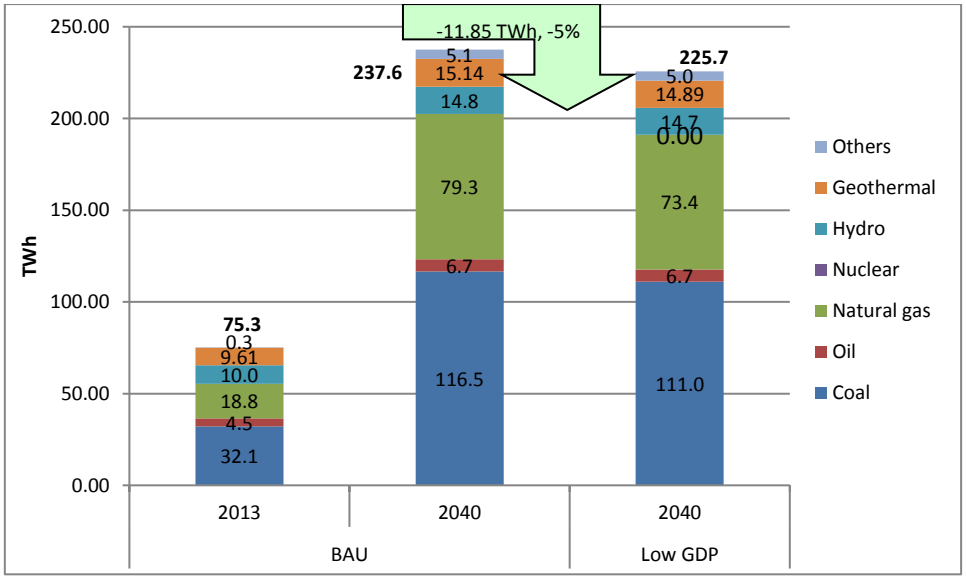
In power generation, the high GDP scenario will register a total generation output of 251.8 terawatt hours (TWh), a 6-% increase from the BAU scenario in 2040 (Figure 2H.5). Majority of increase will come from fossil fuel sources such as coal and natural gas at 6.6% and 7.0%, respectively. A combine generation output from other renewables such as wind, solar, and biomass resources will also increase significantly by 4.8% during the period. On the other hand, the low GDP scenario will account for a total of 225.7 TWh generation output in 2040, a 5-% level of reduction from the BAU scenario during the period (Figure 2H.6). On this account, coal and natural gas will be reduced by 4.7% and 7.4%, respectively, while an aggregate generation output from other renewables will reduce by 2.0%.

Figure 2H.5. Power Generation by Source of Energy, BAU and High GDP, 2013 and 2040



BAU = Business as Usual, GDP = gross domestic product, TWh = terawatt-hour.
Source: Author's calculations.

Figure 2H.6. Power Generation by Source, BAU and Low GDP, 2013 and 2040



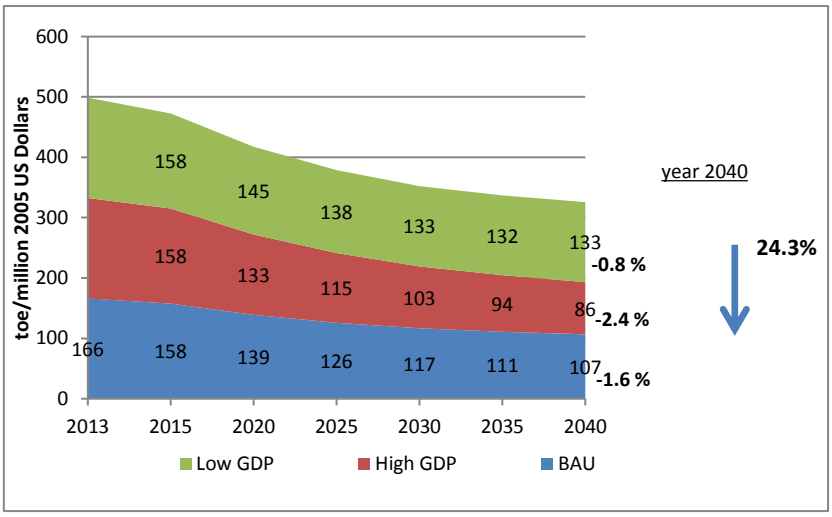
BAU = Business as Usual, GDP = gross domestic product, TWh = terawatt hour.

Source: Author's calculations.

In terms of energy and economic account, the impact of a percentage point increase in GDP growth rate in 2040 is indicated by the 19.3% reduction on energy intensity (ratio of final energy consumption and GDP in toe/million US$ 2005) in comparison with the BAU scenario level. On the other hand, a reduction of a percentage point in GDP growth rate will register a 24.3%

increase in energy intensity from the BAU scenario in 2040. However, considering the annual average growth rate of energy intensity from 2013 to 2040 by scenario, the effect of an increase and decrease by a percentage point in GDP growth rate in energy intensity is plus and minus -0.8% (Figure 2H.7).

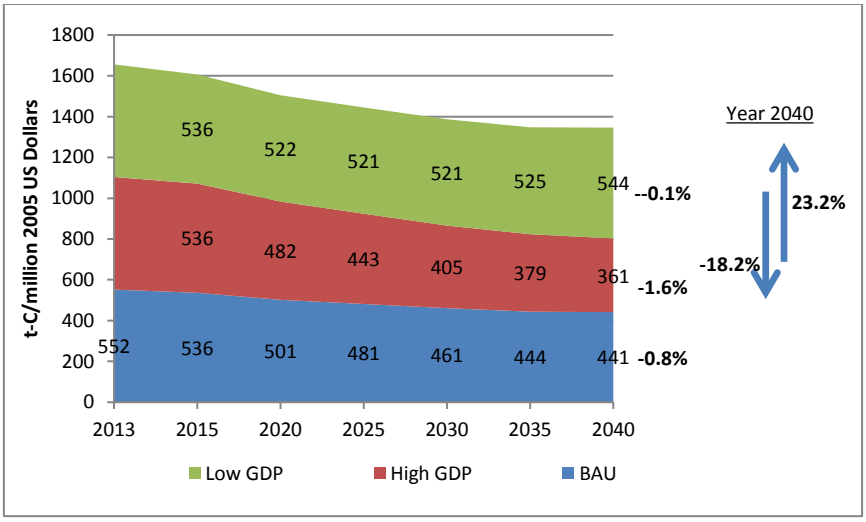
Figure 2H.7. Final Energy Consumption per Unit of GDP, BAU, High and Low GDP, 2013– 2040



BAU = Business as Usual, GDP = gross domestic product, toe = tonne of oil equivalent.
Source: Author's calculations.

For carbon dioxide (CO_2) emission per unit of GDP (t-C/million 2005 US$), the high GDP scenario will register a 19.3-% reduction in 2004 from the BAU scenario level. By contrast, CO_2 emission per unit of GDP in the low GDP scenario will increase significantly by 24.3% during the period (Figure 2H.8). In terms of annual average growth rate for 2013–2040, the impact of a percentage point increase and decrease on GDP growth rate for the CO_2 emission per unit of GDP will be -0.8% and 0.7%, respectively.

Figure 2H.8. CO_2 Emission per Unit of GDP, BAU, and High and Low GDP, 2013 and 2040

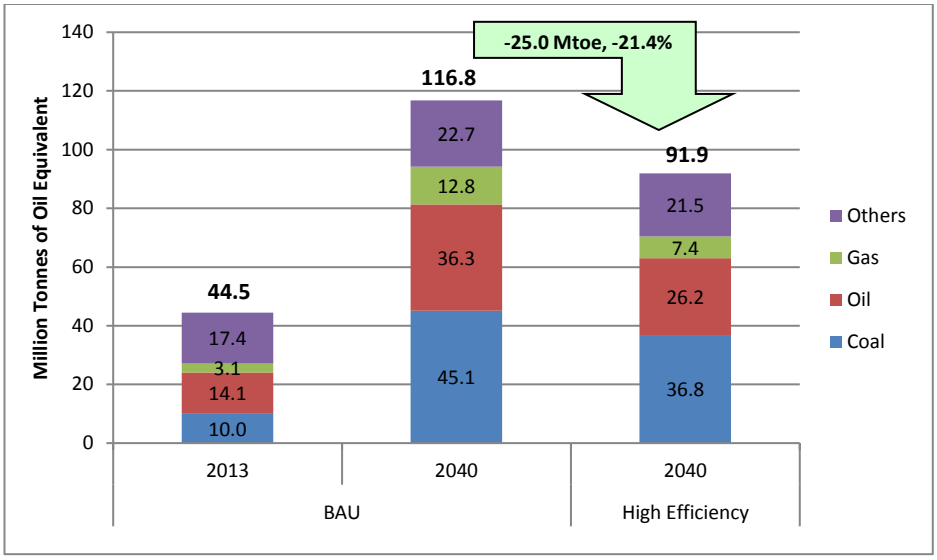


BAU = Business as Usual, CO_2 = carbon dioxide, GDP = gross domestic product, t-C = tonne of coal.
Source: Author's calculations.

Sensitivity Analysis on Setting Higher Energy Efficiency Target in the Demand Sector to the Primary Energy Consumption Level

In the high energy efficiency scenario, the 30-% energy saving target for each of the industry, transport, residential, and commercial sectors is assumed to be realised by the end of the period. This target will reflect a 21.4-% reduction on primary energy consumption in 2040 based on the BAU level for the same period (Figure 2H.9). The reduction on primary energy consumption will be derived mainly from fossil fuel sources such as coal (18.4%), oil (27.7%), and natural gas (42%). At least a 5.4-% reduction on energy requirement from renewables is expected by 2040 under this scenario.

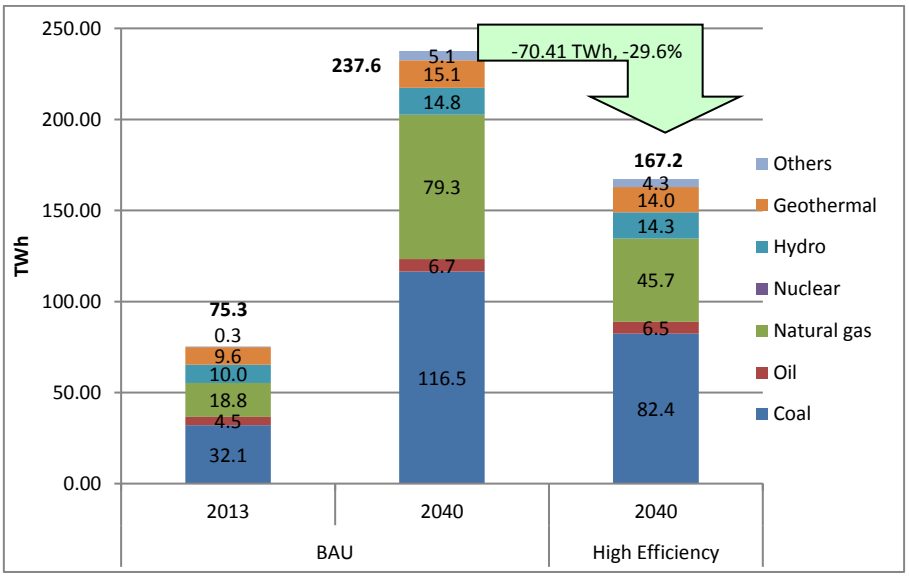
Figure 2H.9. Primary Energy Consumption, BAU and High Energy Efficiency, 2013 and 2040



BAU = Business as Usual, Mtoe = metric tonne of oil equivalent.
Source: Author's calculations.

For the high energy efficiency scenario, there will be a 29.6-% reduction on generation output in 2040 from the BAU level (Figure 2H.10), mostly from coal and natural gas at 29.3% and 42.4%, respectively.

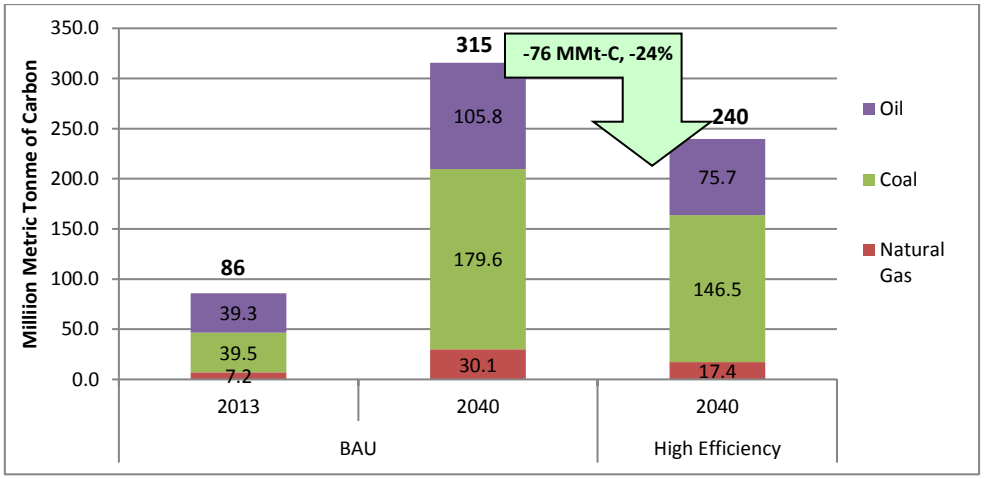
Figure 2G.10. Power Generation by Source, BAU, and High Energy Efficiency, 2013 and 2040



BAU = Business as Usual, TWh = terawatt hour.
Source: Author's calculations.

Achieving a 30-% energy saving target will reflect CO_2 emissions reduction of 24% in 2040 from the BAU scenario level. As the sources of CO_2 (coal, oil, and gas) emissions will be reduced by about 25%, a 24-% reduction on CO_2 emissions is expected in 2040 as compared with the BAU level (Figure 2H.11).

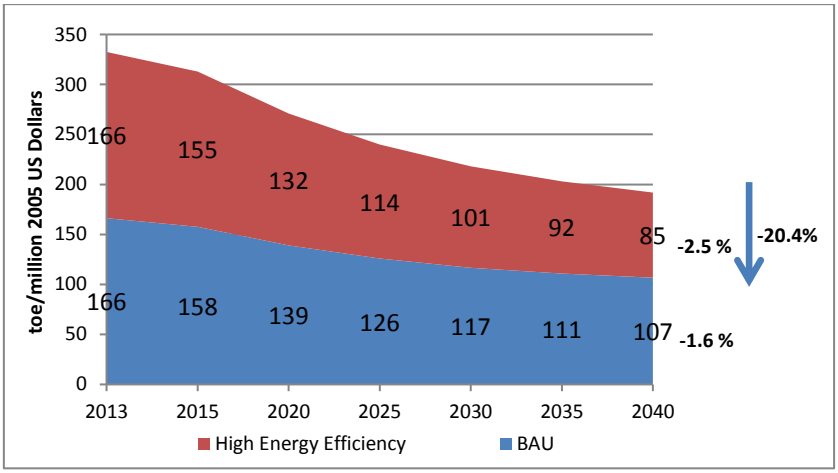
Figure 2H.11. CO_2 Emissions by Source of Energy, BAU, and High Energy Efficiency, 2013 and 2040



BAU = Business as Usual, CO_2 = carbon dioxide, MMt-C = million metric tonne of carbon.
Source: Author's calculations.

Energy intensity for the high energy efficiency scenario will be declined by 20.4% in 2040 in comparison with the BAU scenario level. Considering the annual average growth rate of energy intensity for the entire period, the effect of the 30% energy saving from each major economic sector is the reduction of energy intensity by 0.8% from the BAU scenario level (Figure 2H.12).

Figure 2H.12. Final Energy Consumption per Unit of GDP, BAU and High Energy Efficiency, 2013– 2040

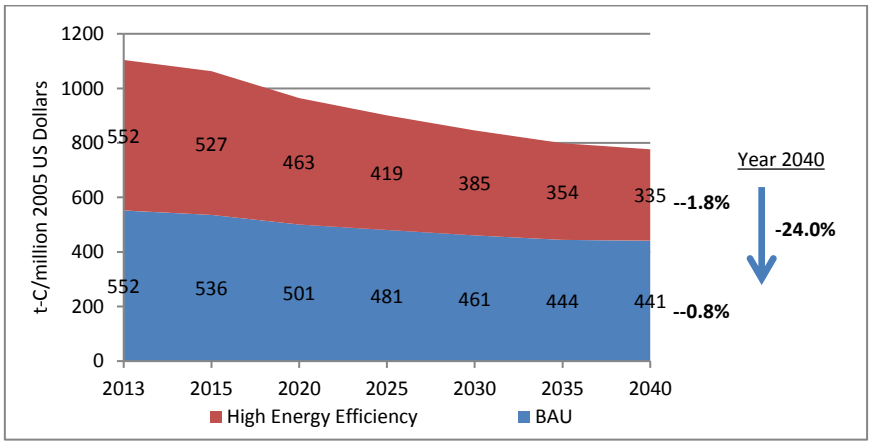


BAU = Business as Usual, GDP =gross domestic product, toe = tonne of oil equivalent.

Source: Author's calculations.

On the other hand, the CO_2 emission per unit of GDP will be declined by 24% in 2040 from the BAU scenario level. In terms of annual average growth rate from 2013 to 2040, the CO_2 emission per unit of GDP is expected a reduction of 1% in comparison with the BAU scenario level (Figure 2H.13).

Figure 2H.13. CO_2 Emission Per Unit of GDP, BAU and High Energy Efficiency, – 2013 and 2040



BAU = Business as Usual, CO_2 = carbon dioxide, GDP = gross domestic product, t-C = tonne of carbon.

Source: Author's calculations.

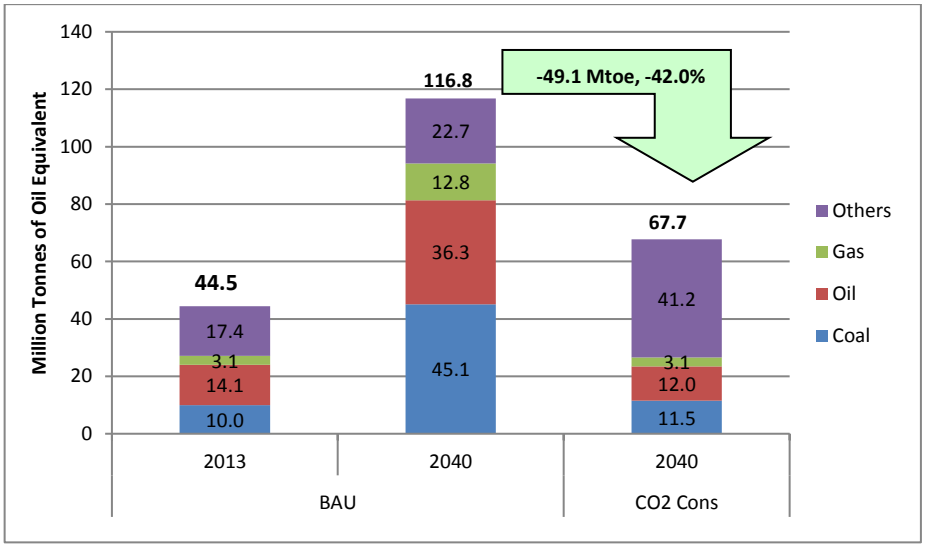
Feasible Solutions on Mitigating CO_2 Emissions in 2040

In the CO_2 constraint scenario, the condition is to limit the CO_2 emissions level in 2040 to be equal to the emissions level of 2013. Trial and error simulations have been made to find out the best solution to satisfy the requirement of this scenario. In the case of the Philippines, it may not be possible to achieve this kind of target since based on the BAU scenario, the share of fossil fuel in the total primary energy consumption in 2040 will be more than 80%. However, to address this condition as part of mitigation measures to constraint the level of emissions in 2040, the following assumptions have been instituted as a result of feasible solution of model simulation:

- Seventy percent energy savings from oil and coal demand for the non-power application and 46% savings from electricity demand.
- Improve thermal efficiency of coal power plant by 2020 from 36% to 44% by prioritising the project for high-efficient coal plant such as supercritical and ultra-supercritical technology (2,200 MW additional capacities).
- Improve thermal efficiency of gas power plant (CCGT) by 2021 up to 60% (2,100 MW additional capacities).
- 1.200 MW additional power capacities from nuclear power plant from 2023 to 2040.
- Additional capacities from wind, solar, and biomass sources from the BAU scenario at 1,927 MW, 2,299 MW, and 198 MW, respectively, from 2015 to 2040.
- Achieving the target of increasing the total installed capacity of hydropower and geothermal power in 2040 at 10,606 MW and 5,856 MW, respectively, from total installed capacity of hydropower at 4,644 MW and geothermal power at 2,109 in the BAU scenario by 2040.

As a result of model simulation for CO_2 constraint scenario in consideration with the specified assumptions, the primary energy consumption in comparison with the BAU scenario will be reduced by 42% in 2040 (Figure 2H.14). The reduction in energy requirements in 2040 will come from fossil fuel sources such as coal (74.6%), oil (67.1%), and gas (75.5%). By contrast, an aggregate supply from other energy sources such as renewables and other new technologies will significantly increase by 81.6% at the end of the planning period.

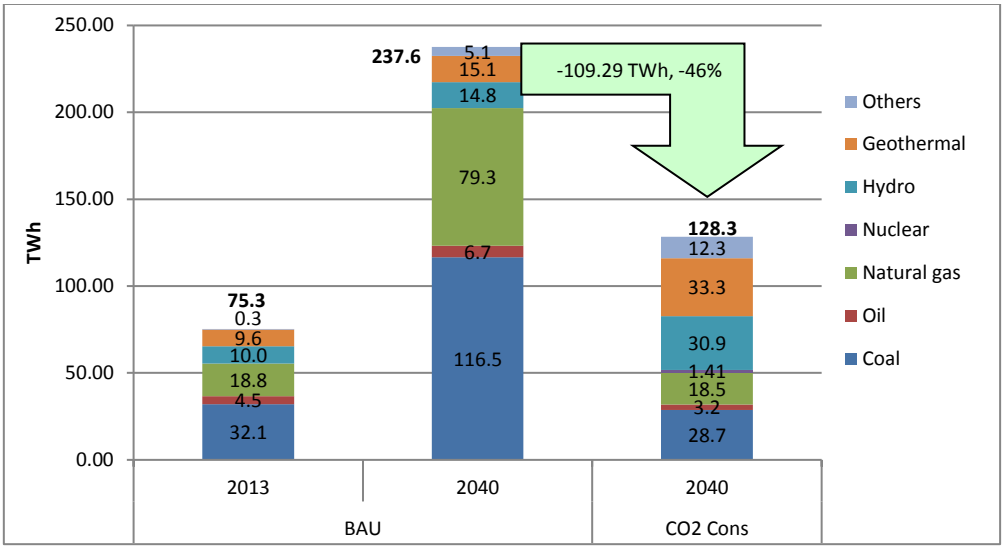
Figure 2H.14. Primary Energy Consumption, BAU, and CO_2 Cons, 2013 and 2040



BAU = Business as Usual, CO_2 = carbon dioxide, Mtoe = metric tonne of oil equivalent.
Source: Author's calculations.

In power generation, the reduction in generation output is expected to be at 46% level in 2040 from the BAU scenario (Figure 2H.15). An aggregate fossil fuel reduction as a source of power generation is anticipated at about 75% while other sources of energy will significantly increase their generation output by around 122% during the period.

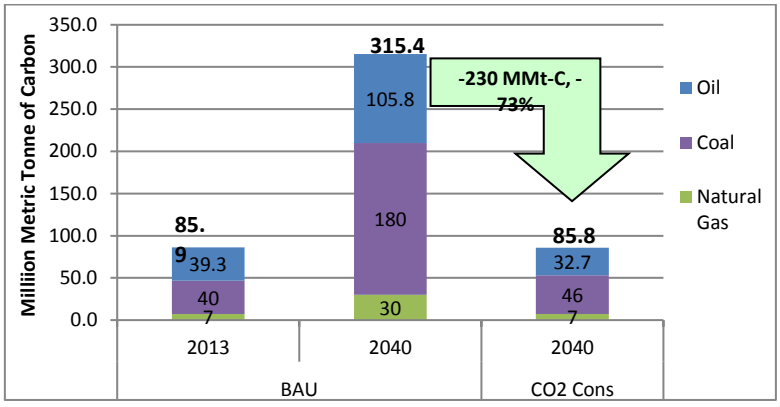
Figure 2H.15. Power Generation by Source, BAU and CO_2 Cons, 2013 and 2040



BAU = Business as Usual, CO_2 = carbon dioxide, TWh = terawatt hour.
Source: Author's calculations.

It can be observed that the CO_2 emissions level in 2040 will be at the same level with 2013 emissions (Figure 2H.16). This can only happen if the CO_2 emissions from the BAU scenario in 2040 at 315.4 metric tonnes of carbon (Mt-C) can be reduced by 230 Mt-C. In the CO_2 constraint scenario, fossil fuel application from transformation to final end-use sector was abruptly reduced to satisfy the given condition of CO_2 mitigation measure at the end of the planning period.

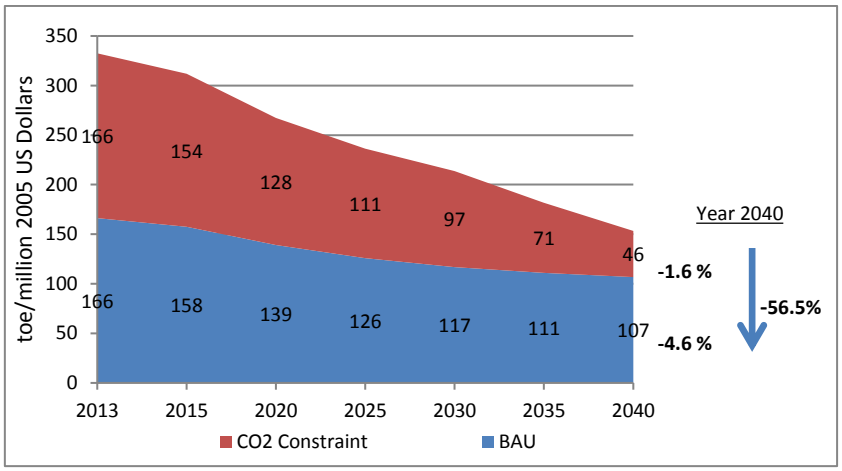
Figure 2H.16. CO_2 Emission by Source of Energy, BAU and CO_2 Cons, 2013 and 2040



BAU = Business as Usual, MMt-C = million metric tonne of carbon.
Source: Author's calculations.

Energy intensity in the CO_2 constraint scenario will be reduced by 56.5% in 2040 compared with the BAU scenario level (Figure 2H.17). Likewise, a decline by 3 percentage point in the annual average growth rate of energy intensity from 2013 to 2040 is expected.

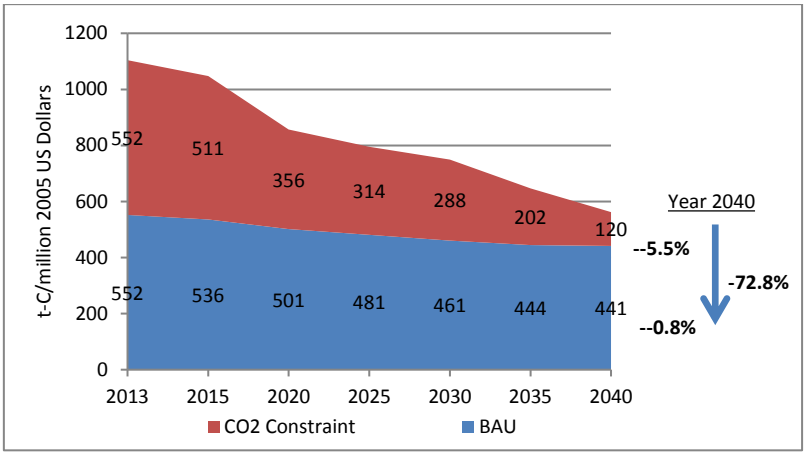
Figure 2H.17. Final Energy Consumption per Unit of GDP, BAU and CO_2 Constraint, 2013–2040



BAU = Business as Usual, CO_2 = carbon dioxide, GDP = gross domestic product, toe = tonne of oil equivalent.
Source: Author's calculations.

As a result of limiting the 2040 emissions level, a 72.8% reduction in CO_2 emission per unit of GDP is anticipated (Figure 2H.18). The level of CO_2 emission per unit of GDP in terms of annual average growth from 2013 to 2040 will register a negative 5.5%, a 4.7 percentage point reduction from the BAU scenario level of negative 0.8%.

Figure 2H.18. CO_2 Emission Per Unit of GDP, BAU and CO_2 Constraint, 2013 and 2040



BAU = Business as Usual, GDP = gross domestic product, t-C = tonne of carbon.
Source: Author's calculations.

Conclusion and Recommendation

In the case of the Philippines, without further policy intervention in mitigating CO_2 emissions, an average growth rate of CO_2 emissions from 2013 to 2040 can be estimated at about 5% yearly. This is because the country is highly dependent on the use of fossil fuel, which is projected to be more than 70% by 2040 in terms of its share in the total primary consumption based on the BAU scenario. Likewise, fossil fuel contribution in power generation will reach more than 80% of the total generation output in 2040. The fact that fossil fuel for power and non-power application are reliable energy sources such as coal in power sector and oil in transport sector, it may not be very possible to change the demand mix sharply to be more leaning to a utilisation of cleaner energy even in the long-term. Achieving high renewable energy utilisation target in power generation may not be enough to reduce the fossil fuel contribution abruptly in the power sector in view of the country's first and foremost challenge which is the stability of power supply. In this regard, the country should also need to be focused on the strict implementation of energy conservation and efficiency programmes and promotion of alternative fuels and technologies. For instance, coal is becoming a very important fuel in the industry sector for non-power demand due to its high utilisation in cement production. In the CO_2 constraint scenario, utilisation of coal in non-power application has been reduced by 70% as part of the solution to satisfy the condition in limiting CO_2 emissions in 2040. In reality, however, there is no strict policy and programme to reduce utilisation of coal for non-power application in the country. If intensive coal utilisation is inevitable, there must be a policy to impose the use of clean coal and efficient technology for its power and non-power application. Likely, it is not possible to reduce oil demand sharply in the transport sector, although its demand level in the CO_2 constraint scenario has been reduced by 70%. However, if there is a policy intervention for massive replacement of oil-fuelled vehicles in the transport sector to be substituted by alternative fuels

and technologies like electric and biofuel vehicles, it may be possible to reduce oil demand significantly in the sector.

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Economic Research Institute for ASEAN and East Asia, 'Energy Supply and Demand Outlook Report FY 2015-206 – Philippines'.

Philippine Statistical Authority, 'Chapter 3. Economic Account', *2015 Philippine Statistical Yearbook.*

2I.Singapore's Case Study

Keeping CO_2 Emissions at 2013 Level by 2040

Study Objectives and Assumptions

This study is a follow-up exercise based on the Business as Usual (BAU) results of primary energy consumption and carbon emissions for Singapore from the 2016 report of the Economic Research Institute for ASEAN and East Asia (ERIA). The main objective is to find out the extent in which Singapore will have to increase its mitigation efforts to reduce carbon emissions to 2013 levels by 2020. An alternative aggressive Alternative Policy Scenario (APS) is set in a hypothetical sense, which does not assume any cost and other resource constraints[1]. The assumptions made for the APS are as follows:

1) All fuel use for final energy demand in the industry sector is reduced by 45% (10% for APS5) in 2040.
2) All fuel use for final energy demand in the residential sector is reduced by 23% (7.5% for APS5) in 2040.
3) For commercial buildings, fuel use for final energy demand is assumed to reduce by 40% (20% for APS5) in 2040.
4) Transport fuel consumption for final energy demand is assumed to decrease by an AAGR of 0.5% from 2018 onwards.
5) Naphtha demand is assumed to experience 0% growth to 2040.
6) For power generation, policy measures are assumed to have the following impact:

i) Solar power gradually increases to 22% of the total electricity generation in 2040 (8% for APS5).

ii) The efficiency of both CCGT and OCGT power plants improve by 15% and 8% from 2013 levels.

Outlook Results

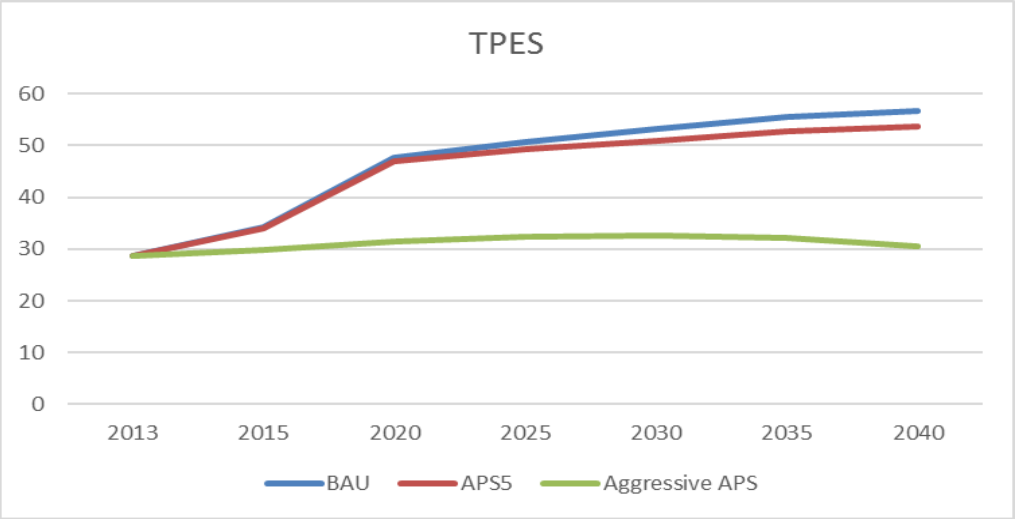
Total primary energy supply

Based on the above assumptions, APS will lead to a 46% reduction relative to BAU, with base year set at 2013, in total primary energy supply (TPES) in 2040. This is much greater than the 5.2% reduction achieved in APS5 (Figure 2I.1). Aggregate TPES in 2040 is 30.6 metric tonnes of oil equivalent (Mtoe), as compared to 56.6 Mtoe for BAU. Oil consumption remains relatively

[1] The APS does not reflect the national position for climate policies, and hence should only be taken as an academic exercise.

stable, increasing at only 5.7% from 19.22 Mtoe in 2013 to 20.32 Mtoe in 2040. Natural gas consumption will peak sometime in 2025–2030, before decreasing to 8.49 Mtoe in 2040. This represents an AAGR of -1.8% from 2030 to 2040. Biomass consumption increases at an AAGR of 0.6% from 2013 to 2040. The largest increase comes from solar power, which will rise by 28% from 0.0014 Mtoe to 1.07 Mtoe in 2040. In terms of proportion, oil will make up two-thirds of the total TPES, with natural gas next at 27.7%. Renewables including solar power will make up 5% of the TPES.

Figure 2I.1. Total Primary Energy Supply (TPES)



BAU = Business as Usual, APS = Alternative Policy Scenario.
Source: Author's calculations.

Final energy demand

The total final energy demand will increase by an AAGR of 0.6% from 2013 to 2040 if aggressive policies are set to reduce carbon dioxide (CO_2) emissions in the economy. This increase would be largely driven by industry, which increased at an AAGR of 1.5% from 6.92 Mtoe to 8.87 Mtoe. Other sectoral energy use remains largely constant over time, all of which increase only marginally at rates of up to an AAGR of 0.4. In terms of fuel use, natural gas demand will rise the fastest to 2.23 Mtoe in 2040, which is a 71% increase from 2013 levels.

Power generation

Taken separately from final energy demand, electricity demand will be predominantly supplied by natural gas at 43.7 Mtoe, although renewables (solar + biomass energy) will rise at an AAGR of 9% to 14.09 Mtoe in 2040.

CO_2 reduction potential

If emissions are constrained to reach 2013 levels in 2040, the share of natural gas in contributing to this amount would be 60% by 2040, with a slight decline from 2013 levels at 5.4 Mtoe. CO_2 emissions from oil remain largely stable but peak at around 2030. This represents savings of 57% from BAU levels.

Policy Implications

The results highlighted here are driven mainly by aggressively constraining TFEC across all the sectors from 23% to 45%. Such assumptions are very ambitious since such reduction will impact on the economy and are not considered for this scenario. In addition, the assumptions for solar penetration in electricity generation would also be over-achieving at 22% in 2040 since the Solar Research Institute of Singapore predicts only a 10–20% penetration from solar power by 2050 (Tan, 2016).

The results from APS5 are hence still more realistic when it comes to determining further energy savings potential and will require a 'whole-of-government' approach and collaboration by private industries to achieve the emissions reduction associated with it.

References

Tan, A. (2016), 'Cutting emissions by tapping the sun', *The Straits Times.* 18 March

2J.Thailand's Case Study

Keeping CO_2 Emissions at 2013 Level by 2040

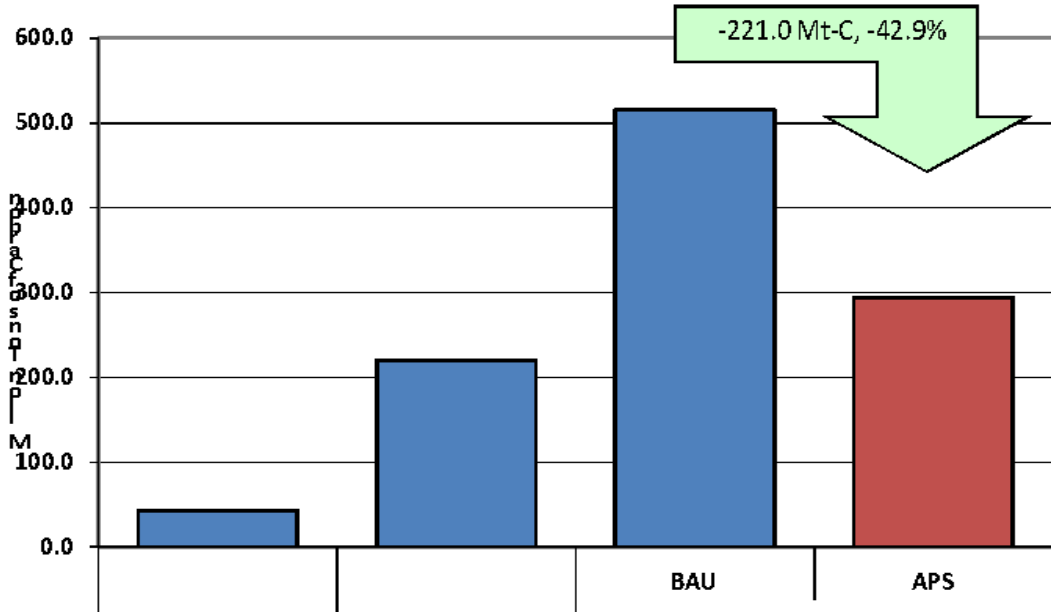
Introduction

This chapter discusses a scenario of Thailand contributing in mitigating carbon dioxide (CO_2) emissions in 2040 to the emissions level of 2013. Through national energy policies and plans, Thailand faces the challenge of a trade-off between greenhouse gases (GHG) and future energy consumption. Achieving energy efficiency and use of non-carbon energy might not be an easy goal for the country. If the national energy plan alone is not adequate, the analysis here might provide additional input to make the target a success.

Energy Consumption and CO_2 Emissions in 2040 BAU and APS

Based on the 2016 energy model, the results in 2040 of Alternative Policy Scenario (APS)-5 (all four APSs combined) could cut down Thailand's primary energy consumption by 91.7 metric tonnes of oil equivalent (Mtoe) from BAU's 2040 level of 301.5 Mtoe to 209.7 Mtoe of APS-5. In the BAU case, CO_2 emissions will increase to around 3.2% per year from 220.5 metric tonnes of carbon dioxide equivalent ($MtCO_2e$) in 2013 to 515.2 $MtCO_2e$ in 2040. When BAU combines national policy and main energy efficiency plan, renewable development plan, and power development plan, it will reduce CO_2 from energy consumption by around 221.0 $MtCO_2e$ or 42.9% reduction compared to BAU (see Figure 2J.1).

Figure 2J.1. Primary Energy and CO_2 Mitigation, APS-5 (combined)



APS = Alternative Policy Scenario, BAU = Business as Usual, Mt-C = metric tonne of carbon, Mtoe = metric tonne of oil equivalent.
Source: Author's calculations.

Even though APS-5 would be able to reduce CO_2 emissions, , efforts to mitigate CO2 emission to the 2013 level will not be achieved because emissionS in APS-5 will be at 290 Mton-CO2eq higher than emissionS at 2013 level (220 Mton-CO_2eq). If CO_2 mitigation to the 2013 level will be applied to such a scenario, Thailand will need to put more efforts to its present policy and plan.

Mitigating CO_2 Emissions in 2040 to the 2013 Level

To mitigate CO_2 emissions to the 2013 level, Thailand would have to go beyond its national energy plans. To achieve the target, several ways have been planned:

- Use LEAP model to simulate more energy efficiency in the industry sector, from 22 up to 44%.

-Increase renewable energy to double the present plan.

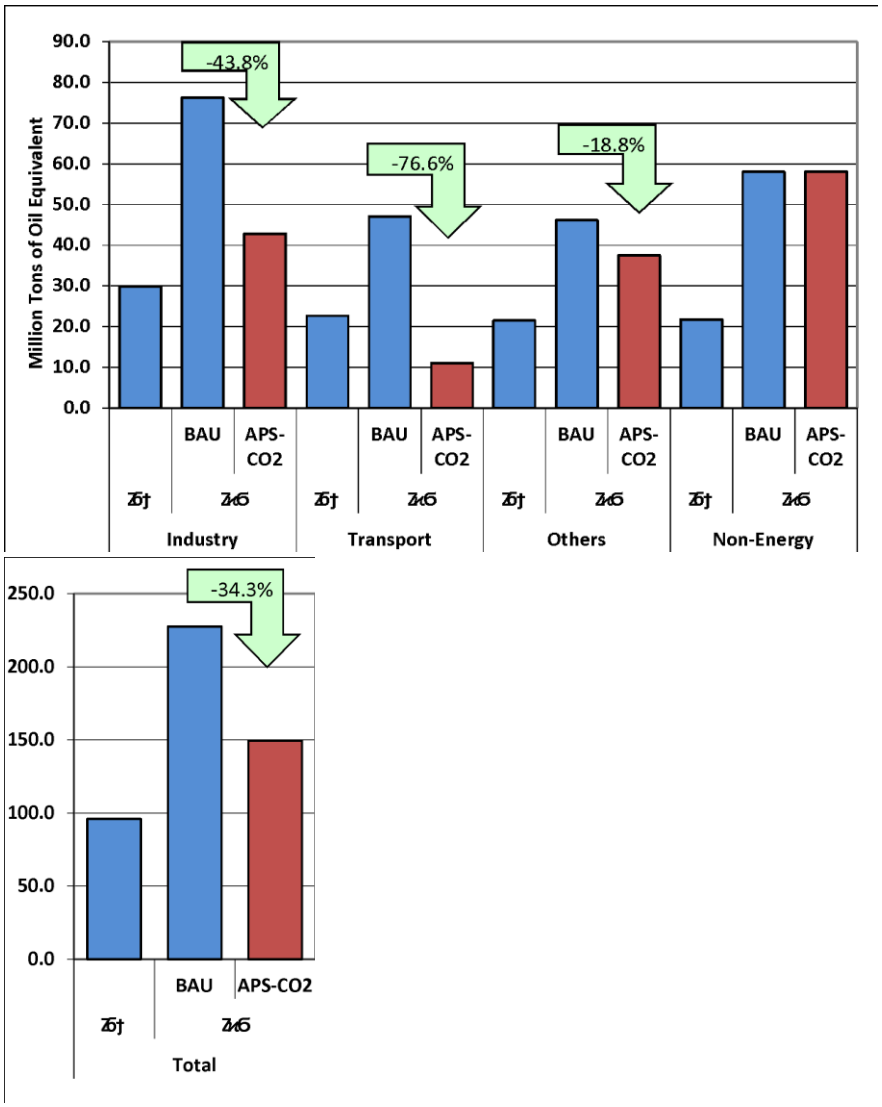
-Add more non-carbon energy in the power fuel mix. Thailand needs to increase nuclear power from 2,000 megawatts (MW) to 4,000 MW by 2036. It should also use to the maximum potential renewable energy as recommended in the PDP.

With Thailand implementing all plans to achieve CO_2 mitigation, a new case called APS-CO_2 will be created, which is APS-5 (combined).

Final Energy Demand with CO_2 Mitigation

Once Thailand implements its plans to CO_2 mitigation, its final energy demand will be impacted by more demand to reduce CO_2 from energy consumption. Final energy demand will probably be reduced by 34.3% from 230 metric tonnes of oil equivalent (Mtoe) to 150 Mtoe in BAU. In this case, consumption in the industry sector will be decreased by 76.3 Mtoe, 59.6 Mtoe, and 42.9 Mtoe in BAU, APS-5, and APS-CO_2, respectively (see Figure 2J.2). However, the rest of the sectors will almost remain the same as APS-5.

Figure 2J.2 Final Energy Consumption by Sector, APS-CO_2



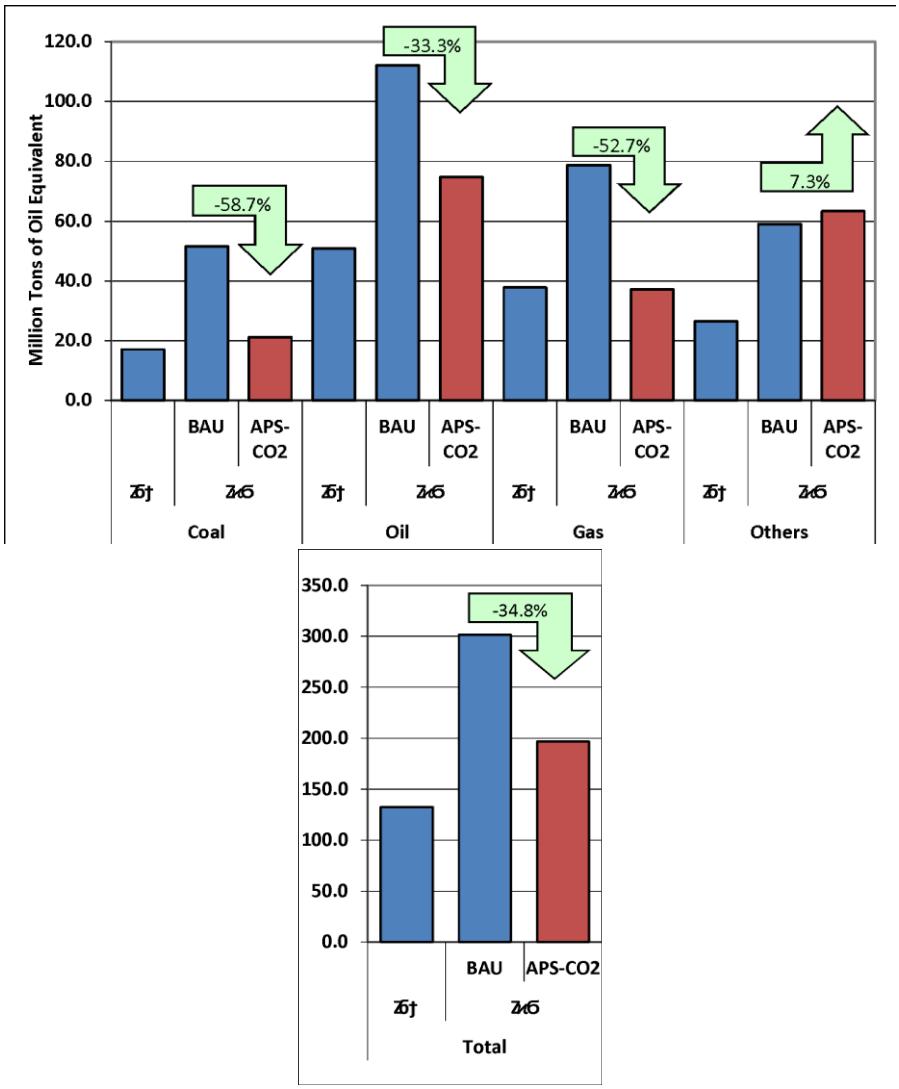
APS = Alternative Policy Scenario, BAU = Business as Usual, CO_2 = carbon dioxide.

Source: Author's calculations.

Primary Energy Under CO_2 Mitigation

Primary energy is also affected by CO_2 mitigation. Primary energy in 2040 will decrease by 34.8% from 301.5 Mtoe in BAU to 196.7 Mtoe in this case. The amount of primary energy under APS-5 does not differ much from that of APS-CO_2: 209.7 Mtoe and 196.7 Mtoe, respectively (see Figure 2J.3). Although natural gas will decrease the most, it will be compensated with an increase in biomass.

Figure 2J.3. Primary Energy Results

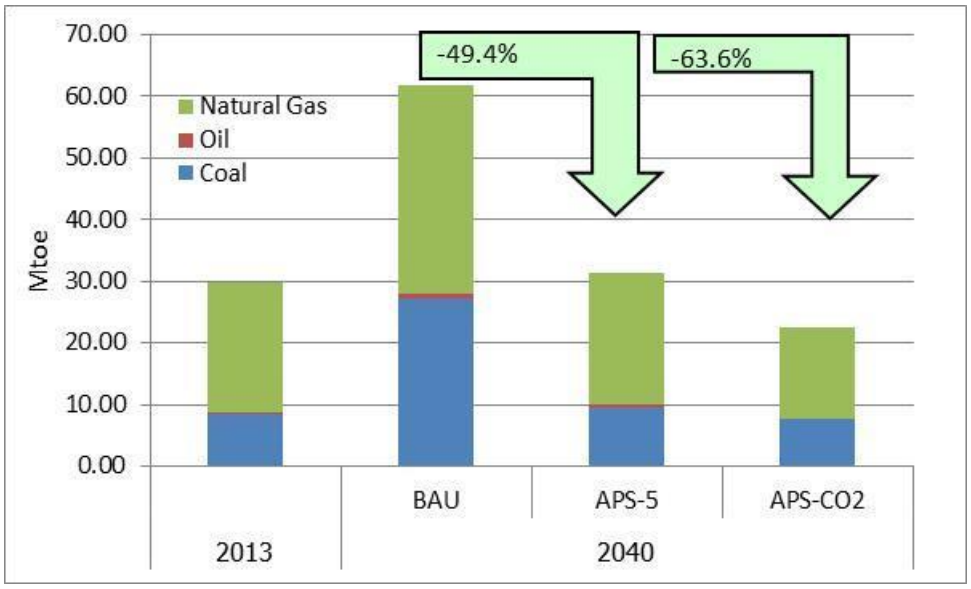


APS = Alternative Policy Scenario, BAU = Business as Usual, CO_2 = carbon dioxide,
Source: Author's calculations.

Fuel Mix

In power generation in 2040, fossil fuels in APS-CO_2 will decline by 63.6% from 61.9 Mtoe in BAU to 22.5 Mtoe, a decline driven by both coal and natural gas, which will grow from 27.3 Mtoe and 33.9 Mtoe in BAU to 7.6 Mtoe and 14.9 Mtoe in APS-CO_2, respectively. (see Figure 2J.4).

Figure 2J.4. Fuel Mix in Power Generation, APS-CO_2

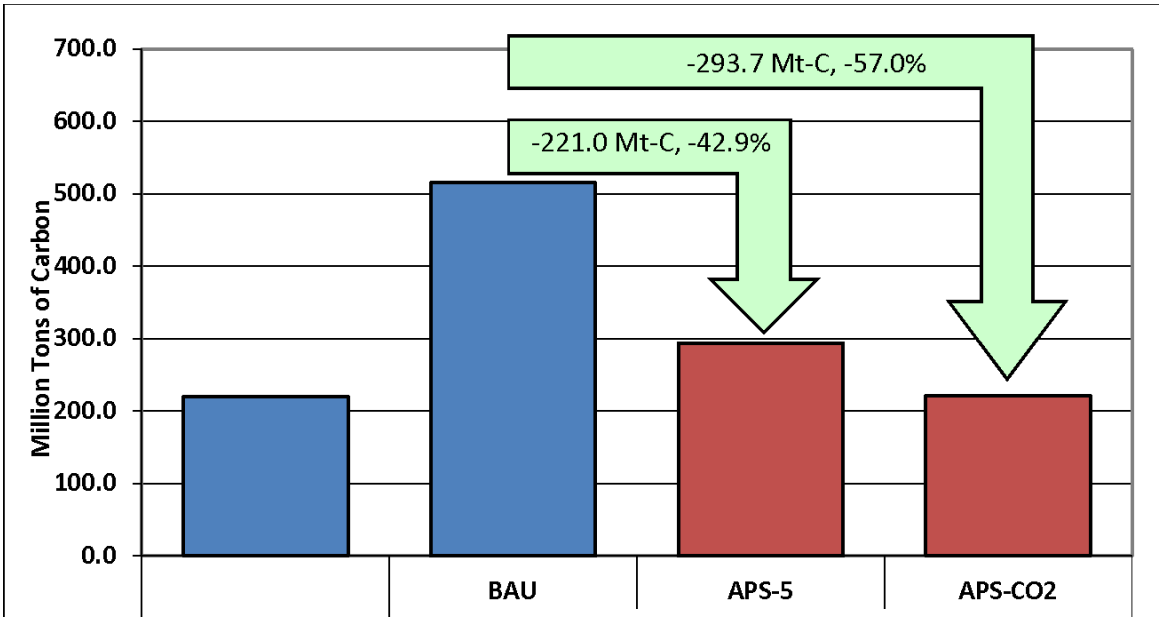


APS = Alternative Power Scenario, BAU = Business as Usual, Mtoe = metric tonne of oil equivalent.
Source: Author's calculations.

CO_2 Mitigation Outcome

In APS-5, CO_2 mitigation cannot be achieved alone with Thailand's national plans but will need APS-CO_2 to meet the target. CO_2 will be reduced from 515.2 MtCO_2e in BAU to 294.2 MtCO_2e in APS-5 and finally to 221.5 MtCO_2e in APS-CO_2, which is close to the 220.5- MtCO_2e 2013 level target. To mitigate CO_2 to the 2013 level, CO_2 must be reduced by around 293.7 MtCO_2e or at least 57% (see Figure 2J.5). In addition, Thailand needs to put more effort in energy efficiency through non-carbon energy sources such as renewables and nuclear power while cutting use of other commercial energy and fossil fuels such as coal and natural gas in power generation.

Figure 2J.5. CO_2 Mitigation at 2013 Level



APS = Alternative Policy Scenario, BAU = Business as Usual, CO_2 = carbon dioxide.

Source: Author's calculations.

2K.Viet Nam's Case Study:

Keeping CO_2 Emissions at 2013 Level by 2040

Introduction

Climate change is one of the most serious challenges to mankind. Each country needs to make a specific contribution to climate change response to protect the Earth's climate system for the current and next generations. As one of the countries severely affected by climate change, Viet Nam is willing to respond to climate change and supports a new post-2020 international agreement to keep the global average temperature increase below 2°C by the end of the century compared to the pre-industrialization period.

Results of the 2015 energy outlook model implemented by a working group under the Economic Research Institute for ASEAN and East Asia (ERIA) show that greenhouse gas (GHG) reduction in the Alternative Policy Scenario(APS) of Viet Nam is around 49.7 metric tonnes of carbon (Mt-C), equal to the 29.6% reduction in 2040, but the annual increase in carbon dioxide (CO_2) emissions between 2013 and 2040 was projected to be 4.5% per year, which is still conservative compared with its potentials. To reduce CO_2more with Viet Nam's maximum efforts to contribute to the international efforts to keep the global average temperature increase below 2°C, this study intends to propose possible solutions for Viet Nam to achieve no-increase of CO_2 emissions by 2040 from the 2013 base year.

Modelling Assumptions

In this outlook, Viet Nam's gross domestic product (GDP) is assumed to grow at an average annual rate of 6% from 2013 to 2040. Growth is projected to be faster in the first outlook period, increasing at 6.8% per year between 2013 and 2020. For the remaining periods of 2020–2030 and 2030–2040, the country's economic growth will be slightly reduced at an annual rate of 6.2% per year and 5.2% per year, respectively. Population growth is projected to increase at a much slower rate, increasing by 0.7% per year between 2013 and 2040.

The share of electricity generated from coal-fired power plants is projected to increase considerably at the expense of other energy types (thermal power and hydropower). Viet Nam is expected to increase its imports of electricity, particularly from the Lao PDR and China.

Nuclear power plants were abandoned through the decision of Viet Nam's National Assembly in November 2016,the main reason for which is economic issue due to increasing investment cost of nuclear power while that of oil is decreasing. The suggestedsolution is to develop renewable

energy, gas, and coal power plants. In this study, it is assumed that imported coal power plants would be substituted for nuclear power plants in the Business as Usual (BAU) scenario, and then in APS, renewable energy technologies would be strongly developed to replace the imported and domestic coals for power generation.

Viet Nam's energy saving goal is assumed to be between 60% and 65% of total energy consumption by each sector, based on the potential by each sector. The energy-saving goals are expected to be attained through the implementation of energy efficiency programmes in industry, transport, residential, and commercial sectors on the demand side.

On the supply side, energy efficiency improvement in power generation, development of renewable energy technologies, particularly solar photovoltaic system, hydropower, wind power, and biomass are expected to come online intensively from 2017 in line with the renewable energy development strategy.

From the above analysis, proposed APSs consist of scenarios such as EEC scenarios (APS1), improvement of energy efficiencies in power generation (APS2), and development of renewable energy (APS3).

- APS1: EEC measures on the demand side

Based on energy-saving potential by each sector, it is assumed that EEC measures would be implemented in the industry, transport, agriculture and commercial sectors, and residential sector to achieve 60%–65%energy reduction by 2040.

- APS2: Improvement of energy efficiency in thermal power plants

It assumes that efficiencies of coal, natural gas, and residue fuel oil thermal power plants will increase to 45%, 45%, and 40%, respectively, by 2040 compared with 37%, 40%, and 32%, respectively, in BAU, while natural gas with CCGT technologies will increase to 60% by 2040 compared with 52% in BAU.

- APS3: Development of renewable energy technologies

Installed electricity-generating capacity from renewable energy sources is assumed to reach 58,100 megawatts (MW) in 2040 with solar photovoltaic system contributing 30,000 MW; wind, 14,500 MW; biomass, 7,500 MW; small hydropower, 5,900 MW; and biogas, 200 MW.

- APS4: Combining all APSs from APS1 to APS3.

Outlook Results

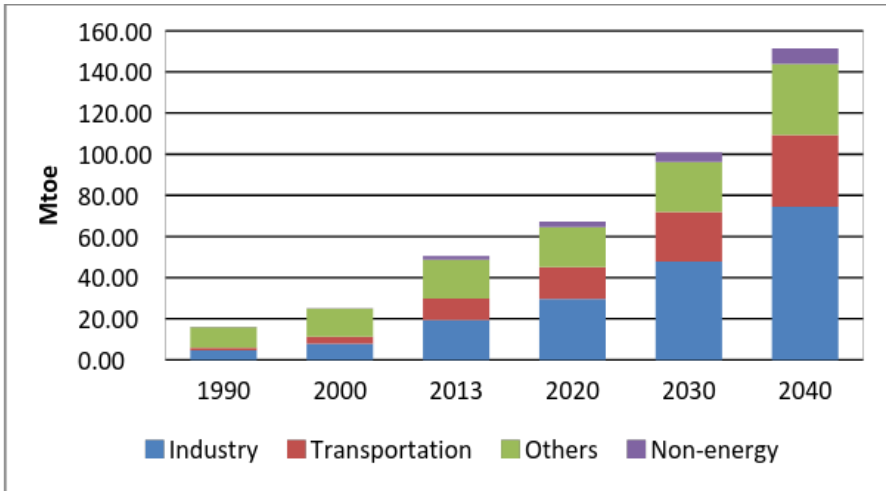
BusinessasUsual (BAU) scenario

Total final energy consumption

Viet Nam's total final energy consumption (TFEC) in 2013 was 50.5 metric tonnes of oil equivalent (Mtoe), increased 5.1% per year, which was 3.1 times more than its 1990 level of 16.1 Mtoe (see Figure 2K.1).

For 2013–2040, TFEC is projected to increase at an average rate of 4.2% per year under BAU. The growth is driven by strong economic growth which is assumed to be at an average annual growth of 6% and the rising population an average annual growth of 0.7%. On a per sector basis, the strongest growth in consumption is projected to occur in the industry sector, increasing by 5.1% per year. This is followed by the transportation sector (4.6% per year) and the residential/commercial (others) sector (2.3% per year). The non-energy use is expected to increase at growth rate of 5.7% per year.

Figure 2K.1. Final Energy Demand by Sectors, BAU



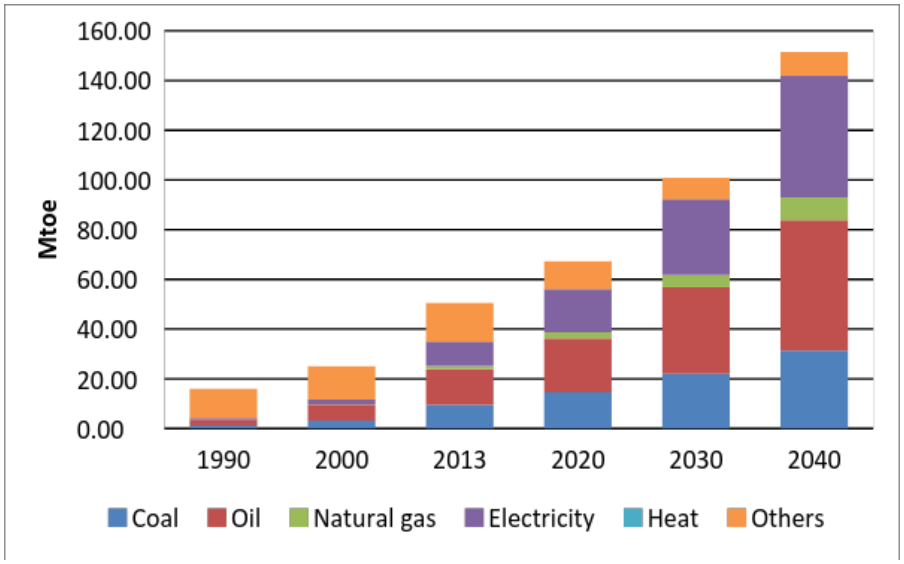
Mtoe = metric tonne of oil equivalent.
Source: Author's calculations.

The bulk of the country's energy consumption or more than 63% in 1990 came from the residential/commercial (others) sector, where biomass fuel used for residential cooking took the dominant share. This share will have a trend of decreasing strongly to 37.5% by 2013 and 22.8% by 2040 due to the substitution of biomass fuels by commercial fuels with higher efficient use. The decreasing share of the sector is due to the impact of the growing economy. The impact of economic growth will translate to improvement of standard of living, thus increasing the transition from biomass fuels to the model fuels.

On a per fuel basis, other fuels (mostly biomass) were the most consumed product, accounting for 73.9% of total final energy consumption in 1990 but this declined to 30.8% in 2013. Oil was the second most consumed product, accounting for 14.5% of total final energy consumption in 1990 and increasing to 28.2% in 2013. The share of coal consumed from 1990 to 2013 had an increasing trend from 8.3% to 18.9%. Electricity took a small share of 3.3% in 1990 but increased significantly to 19.4% in 2013 (see Figure 2K.2).

Under BAU, natural gas is projected to exhibit the fastest growth in final energy consumption, increasing at 7.4% per year between 2013 and 2040. Electricity is projected to have the second highest growth rate of 6.1% per year, followed by oil at 4.9% and coal at 4.5%. Other fuels (mostly biomass) are projected to reduce at an annual rate of 1.7% due to transition from biomass fuels to modern fuels.

Figure 2K.2. Final Energy Demand by Fuel, BAU



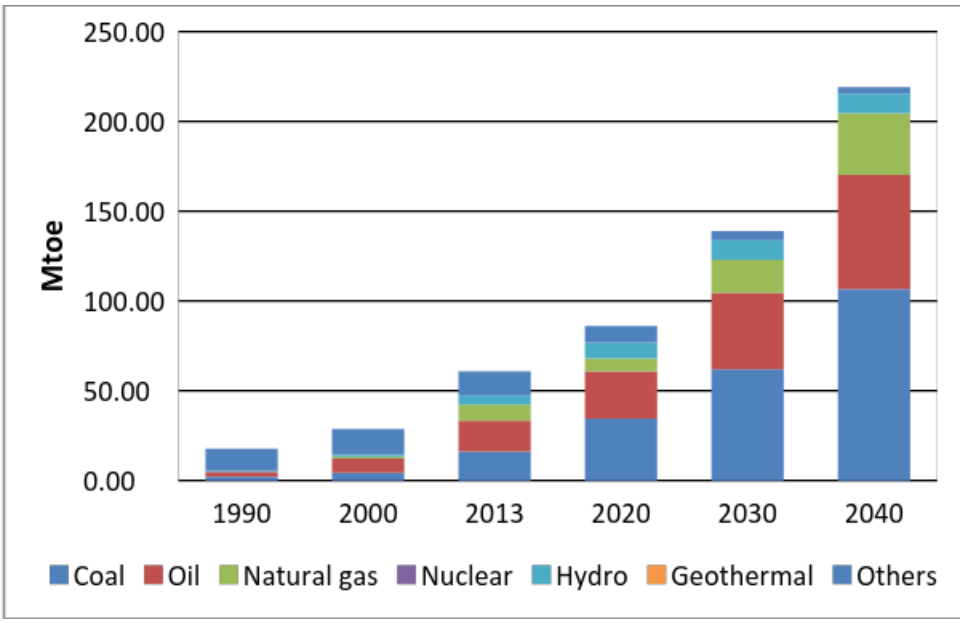
Source: Author's calculations.

Total primary energy consumption

The total primary energy consumption (TPEC) in Viet Nam grew at a higher rate than the final energy consumption, increasing at 5.5% per year or 3.4 times from 17.9 Mtoe in 1990 to 60.1 Mtoe in 2013. Among the major energy sources, the fastest growing were natural gas, hydropower, coal, and oil. Natural gas consumption grew at an average annual rate of 41.6% between 1990 and 2013 while hydropower, coal, and oil consumptions grew at 10.8%, 9.0%, and 8.4% per year, respectively (see Figure 2K.3).

In BAU, Viet Nam's TPEC is projected to increase at an annual rate of 4.9% per year or 3.6 times from 60.1 Mtoe in 2013 to 219.2 Mtoe in 2040. The fastest growth is expected in coal, increasing at an annual average rate of 7.2% between 2013 and 2040, followed by natural gas, oil, and hydropower at 5.1%, 5.0%, and 3.0%, respectively, while other fuels (mostly biomass) will decrease strongly at 4.7% per year.

Figure 2K.3. Primary Energy Demand, BAU



Mtoe = metric tonne of oil equivalent.
Source: Author's calculations.

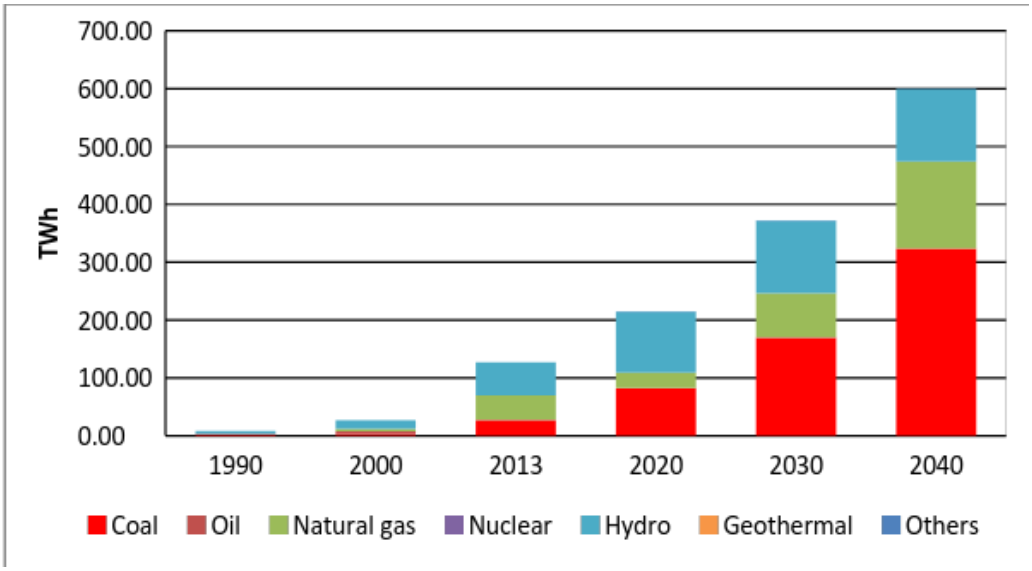
Oil accounted for the largest share of 28.2% of TPEC in 2013 and will increase slightly to 29% in 2040. The share of coal was 26.5% in 2013 and will increase strongly to 48.6% in 2040. Natural gas accounted for a share of 14.7% in 2013 and is projected to increase to 15.7% in 2040. These growths are due to the projected decline from hydropower and others whose shares are projected to decline from 8% to 4.9% and from 22.4% to 1.7%, respectively.

Power generation

Power generation output increased at 12.4% per year or 14.7 times from 8.7 terawatt hours (TWh) in 1990 to 127.3 TWh in 2013. The fastest growth occurred in the natural gas power generation (47.1% per year) followed by coal (12.0%), and hydropower (10.8% per year). These fast growths were due to the decrease of oil at 3.8% (see Figure 2K.4).

To meet the demand of electricity under BAU, power generation is projected to increase at an average rate of 5.9% per year or 4.7 times between 2013 and 2040. The fastest growth will be in coal power generation (9.7% per year) followed by the other (wind and biomass power) generation (7.0% per year), natural gas (4.8% per year), and hydropower generation (3.0% per year).

Figure 2K.4: Power Generation by Type of Fuel, BAU



Source: Author's calculations.

By end of 2013, majority of the country's power requirement came from hydropower, which comprised about 44.7% of the total power generation mix. The share of natural gas power generation was around 33.7% while the rest were from coal and oil power generation.

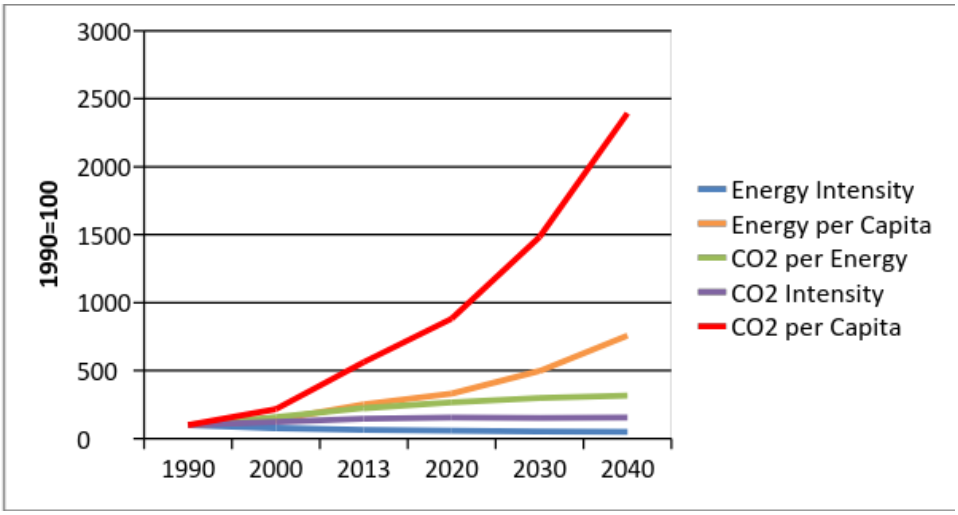
In BAU, coal will be the major fuel for power generation for 2030–2040, with its share increasing from 45.3% in 2030 to 53.9% in 2040. On the other hand, the share of hydropower in the total power generation will decline from 33.7% in 2030 to 20.9% in 2040.

Energy indicators

For 1990–2013, Viet Nam's energy intensity showed a decreasing trend. Both primary and final energy intensities of the country decreased from 1,006 tonnes of oil equivalent (toe)/million 2005 US$ and 905 toe/million 2005 US$, respectively, in 1990 to 660 toe/million 2005 US$ and 547 toe/million 2005 US$, respectively, in 2013. The major reason was the high economic growth rate which resulted in significant reduction in biomass fuels used for cooking in the residential sector, although the energy requirement in the industry sector and transport sector was increasing fast in recent years. The final energy intensity under BAU is estimated to continue the decreasing trend from 547 toe/million 2005 US$ to 338 toe/million 2005 US$ by 2040. This decreasing trend is a good indication that energy will be used efficiently in the future for economic development.

Meanwhile, primary energy per capita had an increasing trend that was 0.27 toe/person in 1990 to 0.68 toe/person in 2013 and will also have trend of increasing to 2.05 toe/person in 2040.This indicates that in the future, the living standards and people's income will increase resulting in increase in total primary energy consumption per capita (Figure 2K.5).

Figure 2K.5. Energy Indicators



CO_2 = carbon dioxide.
Source: Author's calculations.

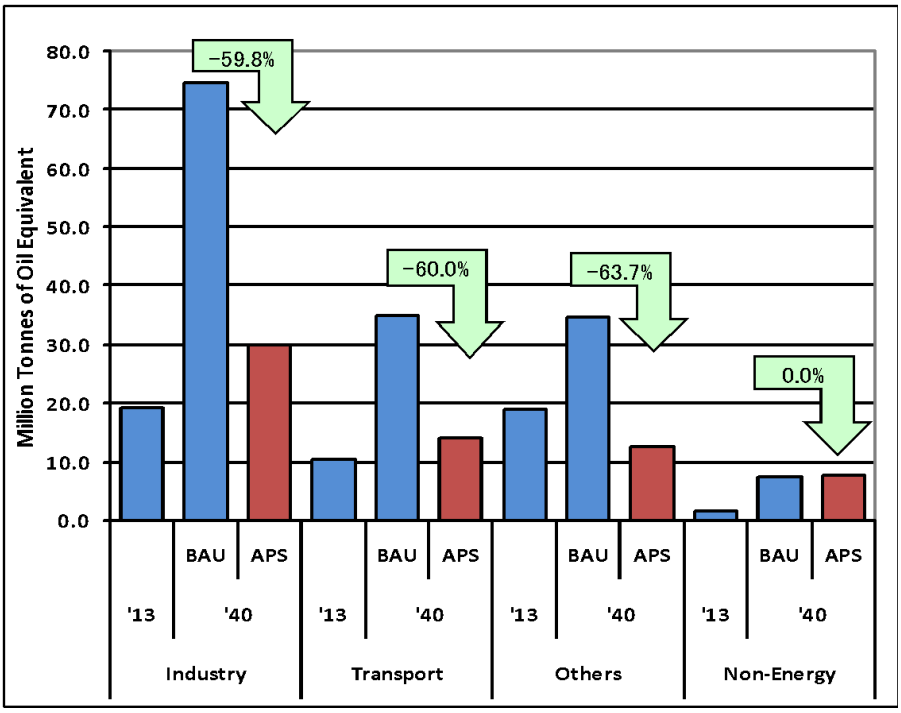
As regards GHG emissions, CO_2 intensity and CO_2 per energy had an increasing trend in 1990–2013, from 265 tonnes of carbon (t-C)/million 2005 US$and 0.26 t-C/toe in 1990 to 389 t-C/million 2005 US$and 0.59 t-C/toe in 2013, respectively. In BAU, CO_2 intensity and CO_2 per energy will also have trend of slightly increasing up to 2020 with 413 t-C/million 2005 US$and 0.70 t-C/toe, respectively. Beyond 2020, CO_2 intensity will slightly decline up to 2040 with 407 t-C/million 2005 US$ while CO_2 per energy will maintain a slight increase at around 0.83 t-C/toe. However, CO_2 per capita has an increasing trend continuously due to energy demand increasing faster than population growth rate.

Energy saving and CO_2emissions reduction potential

Total final energy consumption

In APS4, TFEC is projected to increase at a slower rate of 0.9% per year (compared with 4.2% in BAU) from 50.5 Mtoe in 2013 to 64.0 Mtoe in 2040 because of strong measures on EEC (APS1) in industry, transport, and other sectors such as agriculture, residential, and commercial sectors (see Figure 2K.6).

Figure 2K.6. Total Final Energy Consumption, BAU vs. APS



APS = Alternative Policy Scenario, BAU = Business as Usual,
Source: Author's calculations.

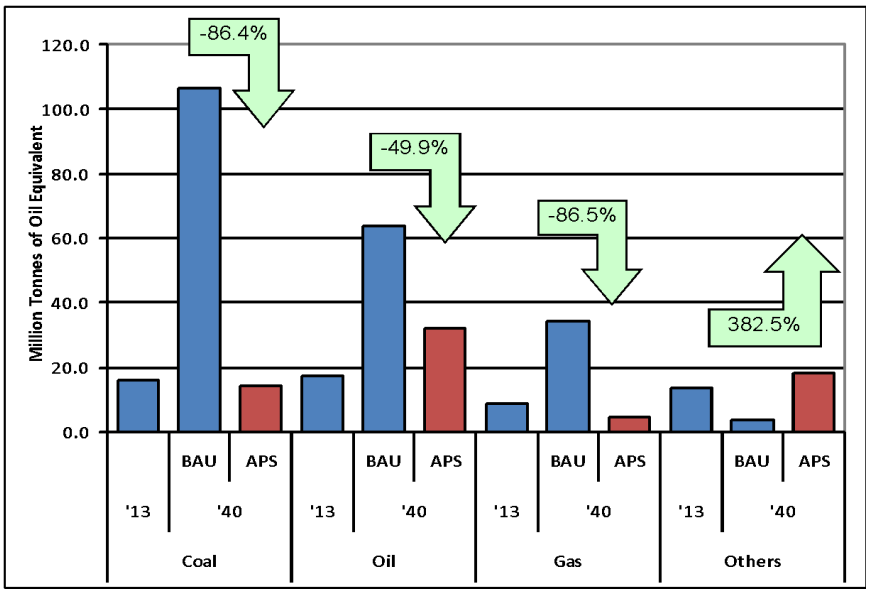
The bulk of the savings are expected to occur in the others sector with 22.0 Mtoe, equivalent to 63.7% reduction, followed by the transportation sector with 20.9 Mtoe, equivalent to 60% reduction, and the industry sector with 44.5 Mtoe, equivalent to 59.8% reduction.

Total primary energy consumption

In APS4, TPEC is projected to increase at a slower rate of 1% per year from 60.9 Mtoe in 2013 to 78.8 Mtoe in 2040. Hydropower is projected to grow at highest average annual rate of 2.6% compared with 3% in BAU, followed by oil with 2% (compared with 5% in BAU) over the same period. Meanwhile, coal and natural gas are projected to decrease at average annual rate of 0.4% and 2.4%, respectively (see Figure 2K.7).

The reduction in the primary energy consumption, relative to the BAU scenario, stems mainly from strong EEC measures on the demand side (APS1), the more aggressive uptake of energy efficiency in thermal power plants (APS2), and strongly developed renewables (APS3) on the supply side.

Figure 2K.7. Primary Energy Saving Potential by Fuel, BAU vs. APS

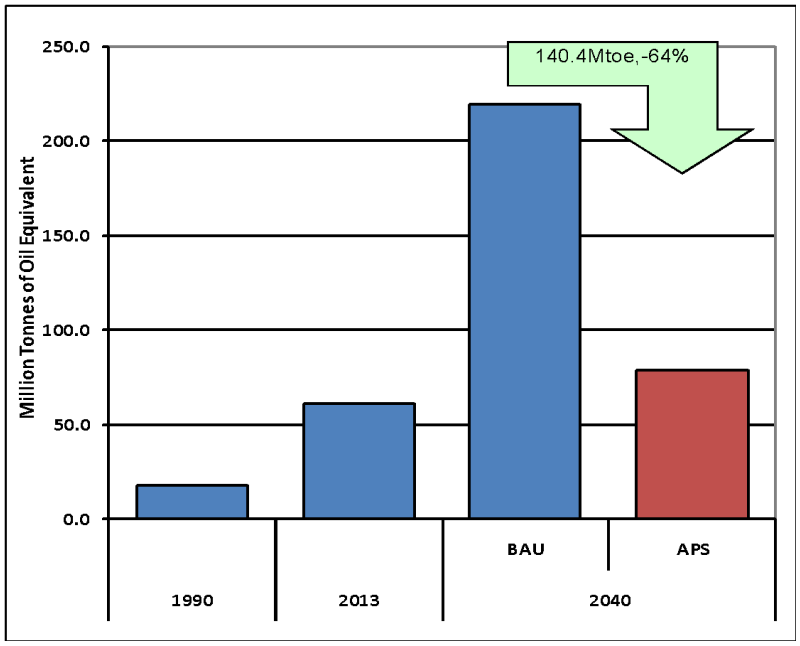


Source: Author's calculations.

In aspect of energy saving, coal is expected to achieve the highest amount of energy saving with 92.1 Mtoe, equivalent to 86.4% reduction, followed by oil and natural gas with 31.7 Mtoe and 29.8 Mtoe, equivalent to 49.9% and 86.5% reduction, respectively. These great reductions are due to the rapidly increased exploitation of others (renewable energy sources) at 382.5% to substitute for fossil fuels in power generation (on the supply side) and especially the strong energy saving measures on the demand side.

The total savings are equal to 140.4 Mtoe or equivalent to 64% of Viet Nam's total primary energy consumption in 2040 (Figure 2K.8).

Figure 2K.8: Evolution of Primary Energy Demand, BAU and APS



Source: Author's calculations

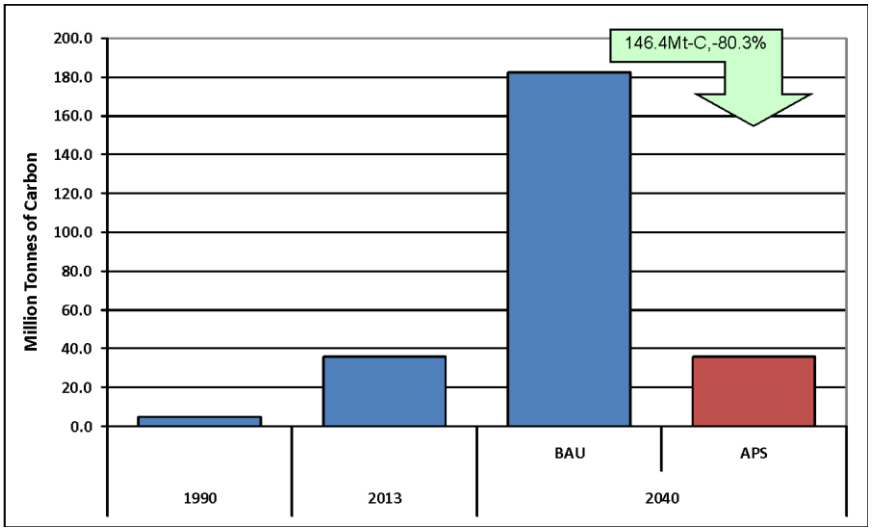
CO_2 reduction potential

CO_2 emissions from energy consumption under the BAU scenario are projected to increase by 6.2% per year from 35.9 metric tonnes of carbon (Mt-C) in 2013 to 182.3 Mt-C in 2040. Meanwhile, under APS4, the annual increase in CO_2 emissions between 2013 and 2040 is projected to be 0% yearly, which means that Viet Nam could achieve no-increase of CO_2 emissions by 2040 from the base year.

No-increase of CO_2 emissions from the base year is mostly due to EEC measures on the demand side (APS1), improvement of energy efficiency in thermal power plants (APS2), and development of renewable energy technologies (APS3).

Improvement on CO_2 emissions under APSs will be around 146.4 Mt-C lower, equal to 80.3% reduction in 2040, indicating the extreme efforts of Viet Nam in reducing CO_2 emissions (see Figure 2K.9).

Figure 2K.9: Evolution of CO_2 Emissions, BAU and APS



Source: Author's calculations

Key Findings and Solutions for GHG Mitigation

Key findings

From the results of study, some keys findings can be recognised as follows:

- Energy demand by 2040 is projected to highly increase at three times over the next 25 years as population and economic activity increase.
- Coal thermal power plants will be the major power generation in Viet Nam in coming years. Its share in the total of power generation output is increasing continuously from 21.1% in 2013 to 53.9% in 2040 in BAU. This is the area with the largest energy-saving as well as GHG mitigation potential in Viet Nam.
- EEC scenarios on the demand side are most effective compared with other proposed scenarios on energy saving as well as GHG emissions reduction.

The above findings showed that the effort of Viet Nam to achieve no-increase of CO_2 emissions by 2040 from base year is extremely difficult.

Solutions for GHG mitigation

From the above findings, the following solutions are recommended to implement the efforts for GHG mitigation at 2013 level in Viet Nam:

1) Improve effectiveness and efficiency of energy use to reduce energy consumption.

- Innovate technologies and apply advanced management and operation procedures for efficient and effective use of energy in production, transmission, and consumption, especially in large production facilities where energy consumption is high;
- Apply energy efficiency and renewable energy technologies in energy consumption sectors and power generation sector;
- Develop public passenger transport to replace private transport means in large cities. Restructure freight transport towards a reduction in the share of road transport in exchange for an increase in the share of transportation via rail and inland waterways;
- Establish standards on fuel consumption and develop a roadmap to remove obsolete and energy-consuming technologies in energy production and consumption systems.

2) Change the fuel structure in industry and transportation

- Change the energy structure towards a reduced share of fossil fuel, encouraging the exploitation and use of renewable and low-GHG emission energy sources;
- Encourage buses and taxis to use compressed natural gas and liquefied petroleum gas; implement management solutions for fuel quality, emissions standards, and vehicle maintenance;
- Apply market instruments to promote structural change and improve energy efficiency; encourage the use of clean fuels; support the development of renewable energy; implement the roadmap to phase out subsidies for fossil fuels;
- Label energy-saving equipment and issue national standards for the quality of equipment.

3) Promote effective exploitation and increase the proportion of renewable energy sources in energy production and consumption.

- Develop and implement financial and technical mechanisms and policies to support research and the application of appropriate advanced technologies; exploit and optimise the use of both on-grid and off-grid renewable energy sources;
- Develop a renewable energy technology market, domestic industries, and local service providers.

4) Enhance international cooperation.

- Enhance cooperation in scientific research, in information exchange on the formulation and implementation of policies, and in the basic content of climate change strategies and policies;
- Enlist the support of other countries and international organisations in finance, capacity building, and technology in the implementation of climate change strategies and policies;
- Facilitate international cooperation to implement foreign direct investment on climate change-

related projects.

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