Chapter 15

Sustainable Energy Supply

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1. Introduction

The Socialist Republic of Viet Nam has sustained stable economic growth over the last 2 decades, with a Gross National Income of approximately $3,000 per capita in 2019. Viet Nam is actively striving to surpass the $10,000 per capita income threshold at the earliest opportunity to evade the middle-income trap. Viet Nam's objective to become a high-income country by 2045 was endorsed by the 13th National Congress of the Communist Party of Viet Nam. To achieve this, sustainable energy will be crucial in driving stable economic growth. In economic theory, continued sustainable growth can be explained by the trans-log production function, which includes energy as a production factor in addition to capital, labour, and land. Therefore, Viet Nam will need more energy, but it should be sustainable, such as with renewables, as well as new and innovative technologies such as hydrogen and carbon capture utilisation and storage (CCUS).

To attain high-income status by 2045, Viet Nam, as addressed during the 13th Congress of the Communist Party of Viet Nam, must place its emphasis on enhancing transportation and energy systems, developing information technology, and fortifying infrastructure to effectively address the challenges posed by climate change. Achieving near carbon neutrailty by 2045, and potentially full carbon neutraility by 2050 or 2060, should be part of this strategic endeavour. Although Viet Nam has been impacted by the negative consequences of the coronavirus disease (COVID-19) and Russia's invasion of Ukraine, particularly in terms of energy demand and supply, it is anticipated that energy demand in Viet Nam will recover after 2022.

Chapter 15 addresses how Viet Nam will shift towards renewables and cleaner energy. This means that Viet Nam will need to redesign its entire energy system. This chapter will review the historical energy demand supply and forecast future energy demand. Further, it will study the promotion of energy efficiency and conservation (EEC) in the final energy consumption sectors, i.e. industry, transport, commercial and residential sectors, as well as clean energy technologies. The chapter will also address decarbonisation in the electricity sector and solutions that can support sustainable growth through the introduction of ordinary renewables (biomass, hydropower) and variable renewables, such as wind and solar, and the possible option of nuclear. The chapter will also highlight the importance of hydrogen, ammonia, and battery storage as future available technologies at affordable costs. In addition, the introduction of efficient types of battery electric vehicles (BEVs) will be studied for Viet Nam's low-carbon energy transition in the road transport sector. Furthermore, the role of CCUS will be crucial to decarbonise the remaining emissions from power generation and industrial clusters such as the cement industry. Emissions in transportation sectors will need to be offset by negative emission technologies such as bioenergy and possibly direct air capture with CCUS.

Although COP 26 achieved consensus on limiting temperature rise to well below 2 degrees Celsius, or preferably to 1.5 degree Celsius compared to pre-industrial levels, the pathway to reach this goal will be different for each country based on their respective socioeconomic and political contexts. Viet Nam will need to consider other priorities such as energy access, energy affordability, and energy security while grafting any new energy policy design to meet the Paris Agreement and the recent commitment at COP 26.

2. Review of Energy Supply Demand in 1990–2019

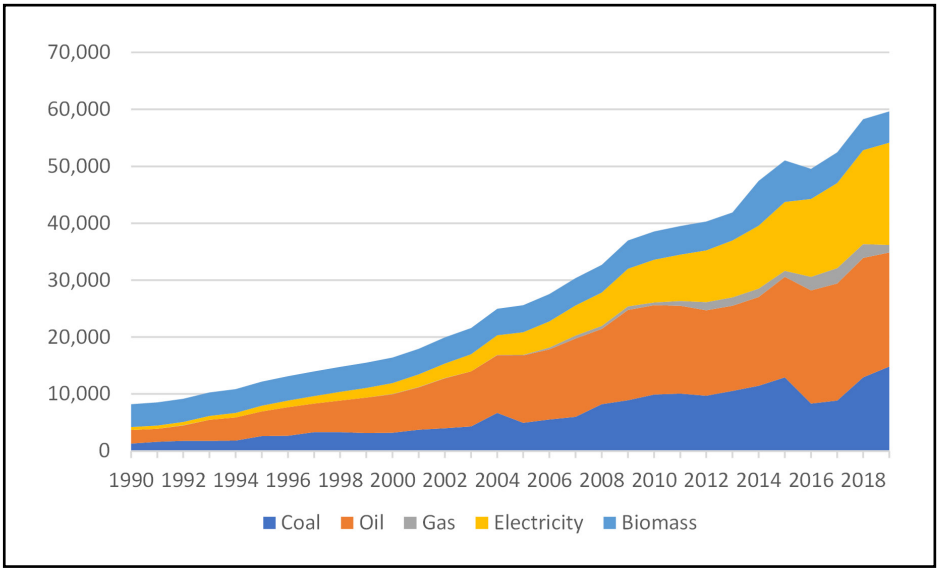
In this section, we review energy demand supply of Viet Nam historically using the Asia Pacific Economic Cooperation (APEC) Energy Database as managed by Asia Pacific Energy Research Center, which has been the coordinating agency of the Expert Group on Energy Data Analysis, one of the groups under the APEC Energy Working Group. Viet Nam joined APEC in 1998.

2.1. Total Final Energy Consumption

a. By fuels

Total final energy consumption (TFEC) of Viet Nam, which is induced by industry, transport, residential and commercial activities, increased from 8,277 ktoe in 1990 to 59,658 ktoe in 2019, with an annual growth rate of 7.1%. On the other hand, the growth rate of Viet Nam's constant gross domestic product (GDP) was 6.8% per annum in the same period, so that TFEC elasticity per GDP was more than 1. Looking at fuels, gas showed the highest growth at 20.4% per annum, followed by electricity at 12.9%, coal at 8.7%, oil at 7.7%, and biomass at 1.1% (Figure 15.1)

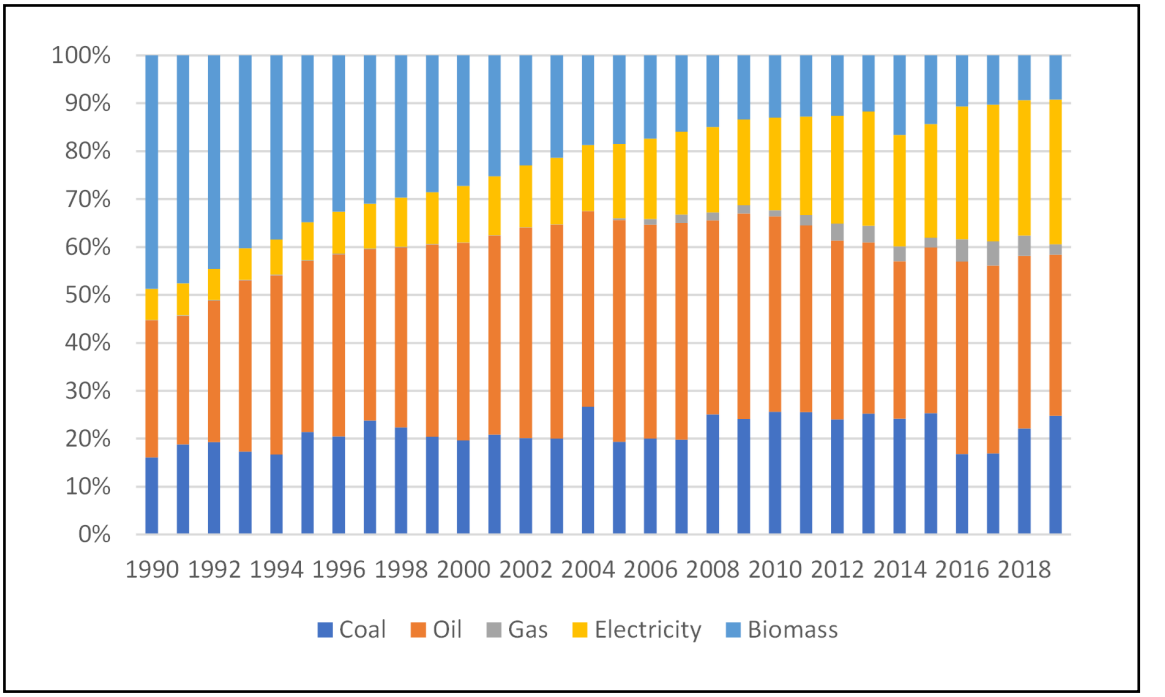
Figure 15.1. Historical Final Energy Consumption by Fuel (ktoe)



Source: APEC Energy database, 2022.

In 1990, Viet Nam's final energy consumption sector depended on traditional biomass at 49%, followed by oil at 29%, coal at 16%, and electricity at 6%. By 2019, this structure had largely changed, with 34% of consumption stemming from oil, followed by electricity at 30%, coal at 25%, biomass at 9%, and gas at 2% (Figure 15.2). In the last 30 years, biomass has been phased out from Viet Nam's energy market; on the other hand, electricity use has been increasing rapidly across the sectors. In addition to electricity, oil and coal are still important fuels for Viet Nam's economic activities. As mentioned, the long-term elasticity defined as TFEC/growth rate of GDP was 1.04 in 1990–2019. But if we use TFEC without biomass, the growth rate becomes 9.2% and the elasticity also changes from 1.04 to 1.35. Consequently, Viet Nam will need appropriate national energy efficiency and conservation policies and feasible action plans that will meet the specifications of each final sector in order to curb final energy consumption towards 2050.

Figure 15.2. Historical Final Energy Consumption by Fuel Share

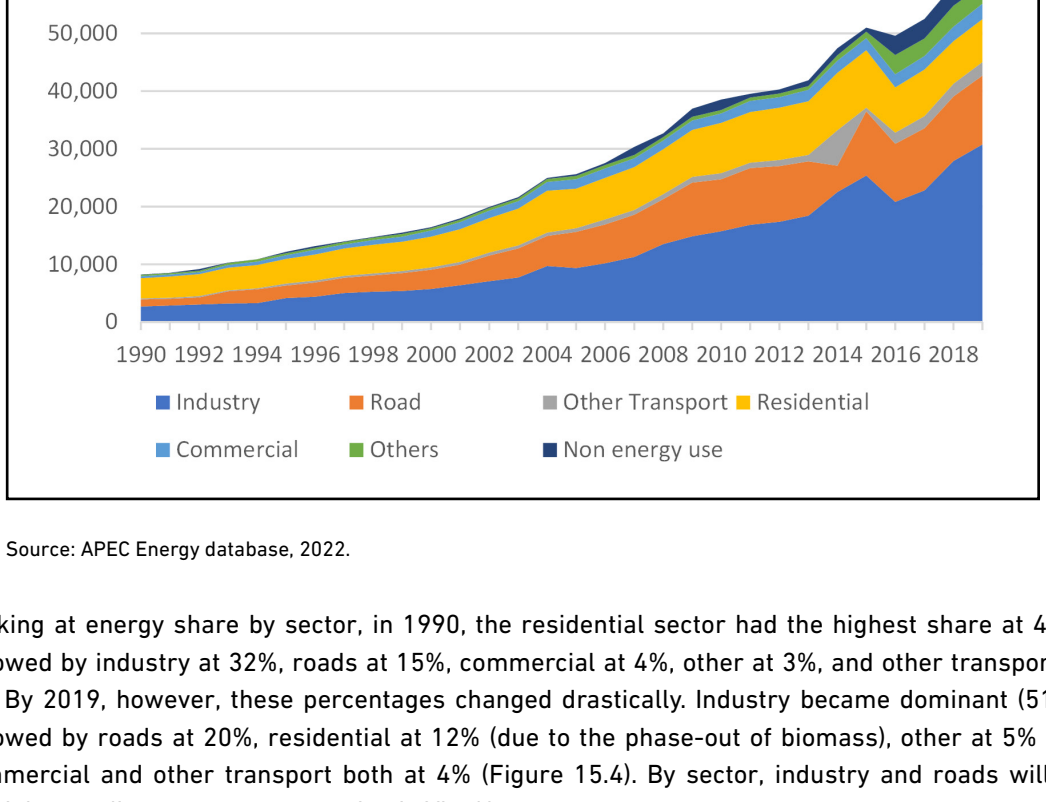


Source: APEC Energy database, 2022.

b. By sectors

As mentioned, final energy consumption consists of industry, transport, residential, commercial, and other sectors. Energy consumption of other transport excluding roads showed the highest growth at 9.8% per annum from 1990–2019, followed by other sectors at 9.3% per annum, industry at 8.8% per annum, road transport at 8.0% per annum, commercial at 7.4% per annum, and residential at 2.6% per annum (Figure 15.3).

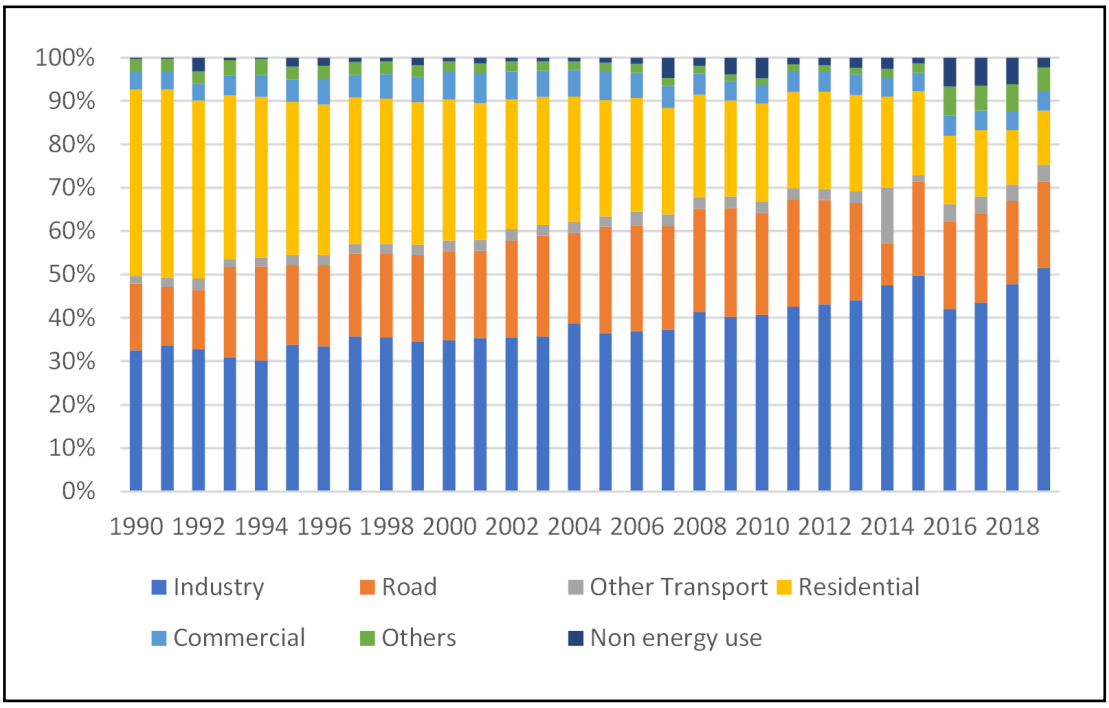
Figure 15.3. Historical Final Energy Consumption by Sector (ktoe)



Source: APEC Energy database, 2022.

Looking at energy share by sector, in 1990, the residential sector had the highest share at 43%, followed by industry at 32%, roads at 15%, commercial at 4%, other at 3%, and other transport at 2%. By 2019, however, these percentages changed drastically. Industry became dominant (51%), followed by roads at 20%, residential at 12% (due to the phase-out of biomass), other at 5% and commercial and other transport both at 4% (Figure 15.4). By sector, industry and roads will be crucial regarding energy consumption in Viet Nam.

Figure 15.4. Historical Final Energy Consumption by Sector Share (%)

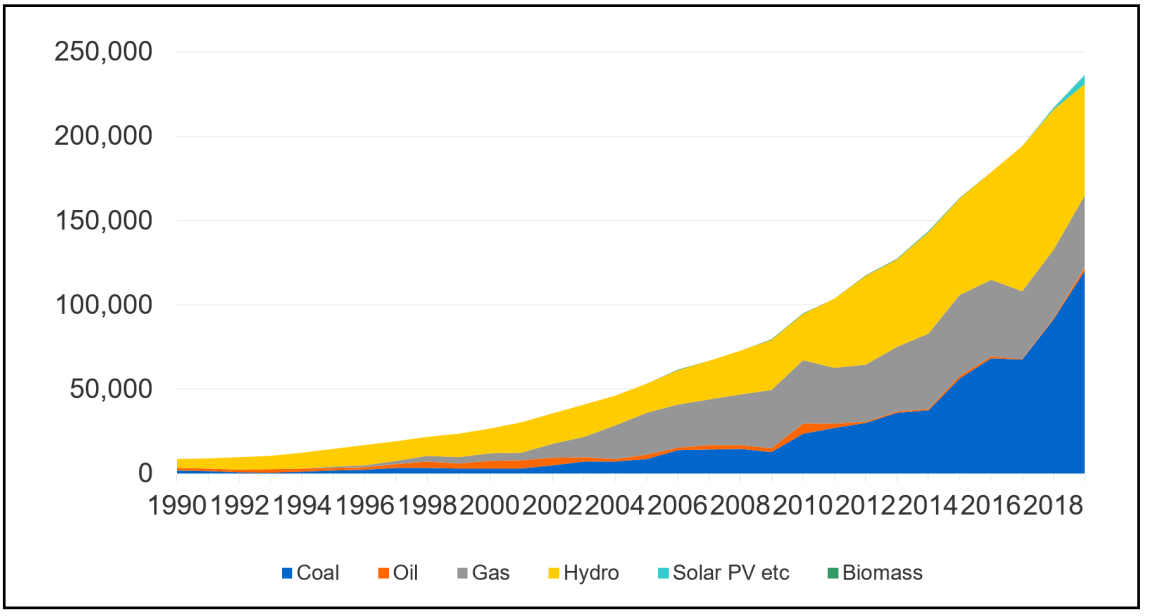


Source: APEC Energy database, 2022.

2.2. Power Generation

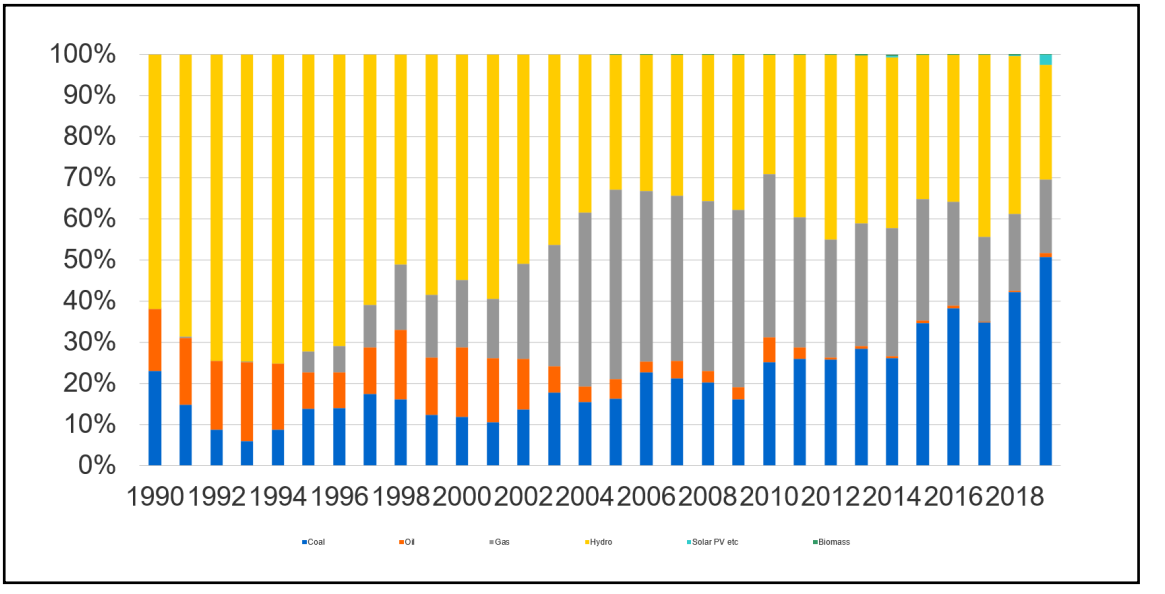
Hydropower, coal, and gas are major power generation sources in Viet Nam. Due to significant increase of electricity demand in 1990–2019, each power generation source has also increased. Gas power generation marked highest growth at 35.7% per annum in 1990–2019, followed by coal power generation at 15.2% per annum and hydropower at 9.0% per annum (Figure 15.5). Oil power generation has been phasing out, while renewables such as solar and wind have shown a remarkable increase recently. As a result, the share of hydropower generation was dominant at 61.8% in 1990 but it has decreased to 27.9% in 2019. On the other hand, the share of coal power generation, which marked the second largest share at 23.0% in 1990, has been dominant at 50.7% in 2019. Gas share in 1990 was just 0.1%, but it increased to 17.9% in 2019. Oil share in 1990 was 15.0%, dropping to 0.9% in 2019. Renewables have increased rapidly and their share in 2019 was 2.3% (Figure 15.6).

Figure 15.5. Historical Power Generation by Sources (GWh)



PV = photovoltaic.
Source: APEC Energy database, 2022.

Figure 15.6. Historical Power Generation by Fuel Share (%)

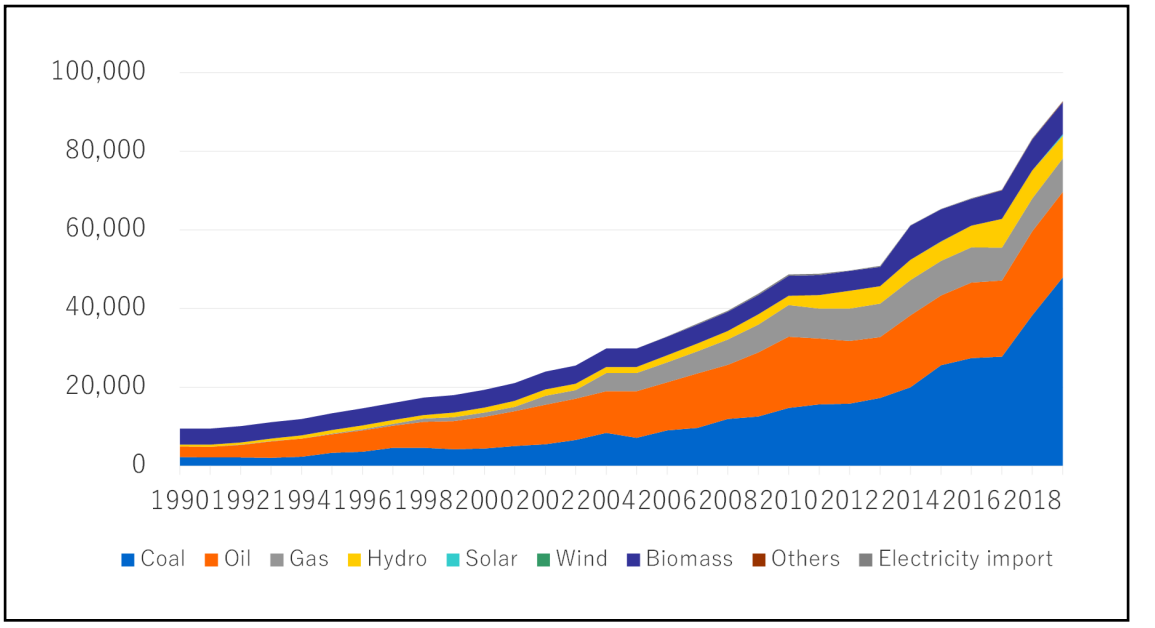


PV = photovoltaic.
Source: APEC Energy database, 2022.

2.3. Total Primary Energy Supply

Total primary energy supply (TPES) of Viet Nam increased from 9,440 ktoe in 1990 to 92,763 ktoe in 2019 and its growth rate was 8.2% per annum. On the other hand, the growth rate of Viet Nam's constant GDP was 6.4% per annum in 2000–19, so that TPES outpaced economic growth, similar to the circumstance with TFEC. Looking at fuels, gas showed the highest growth at 31.5% per annum, followed by coal at 11.2% per annum, hydropower at 9.0% per annum, oil at 7.4% per annum, and biomass 2.4% per annum (Figure 15.7). Solar and wind rapidly increased from 2014–19 and Viet Nam started importing electricity from neighbouring countries such as Lao People's Democratic Republic from 2006.

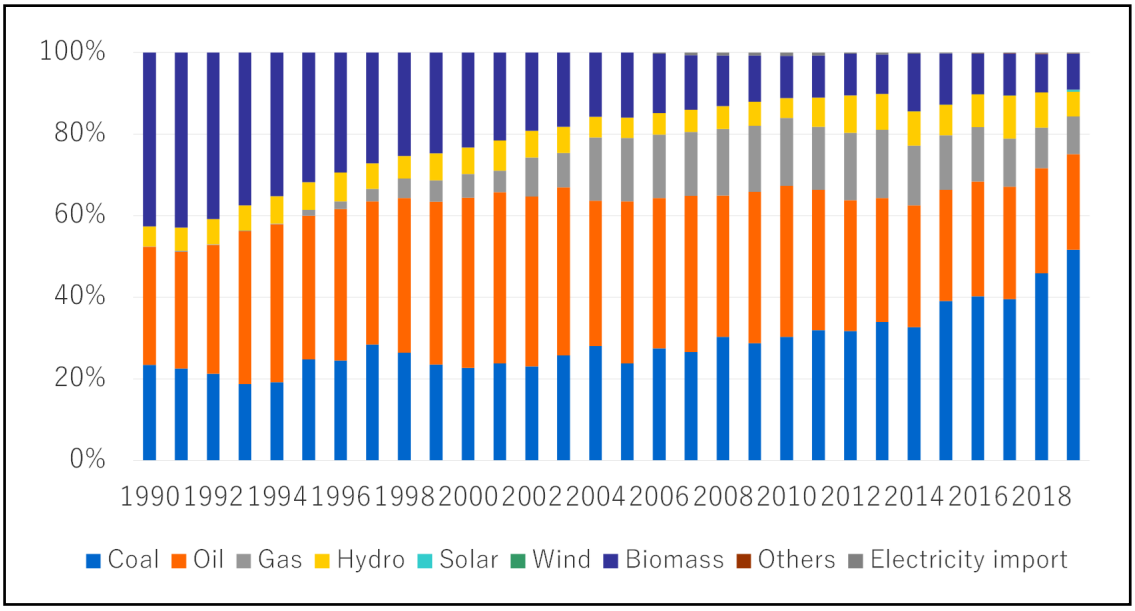
Figure 15.7. Historical Primary Energy Supply (ktoe)



Source: APEC Energy database, 2022.

Coal share increased from 23.4% in 1990 to 57.1% in 2019. On the other hand, oil share decreased from 29.0% in 1990 to 23.5%. Viet Nam started using gas in the early 1990s; currently its share is more than 10%. Hydropower maintained a constant share of 5%–6% from 1990–2019 (Figure 15.8).

Figure 15.8. Historical Primary Energy Supply by Fuel Share (%)



Source: APEC Energy database, 2022.

Biomass was phased out of the domestic energy market and its share decreased from 42.6% in 1990 to 8.8% in 2019. Viet Nam started electricity imports as mentioned, but its share has been less than 1%.

TPES is termed primary energy consumption or inland delivery of energy, so that its concept is the same as the total energy requirement of Viet Nam. Thus, we next assess Viet Nam's energy supply. There are two main sources: indigenous production and imports. Viet Nam's indigenous production increased 6.4% from 1990–2019, but its increase ratio was quite different before and after 2006. The growth rate from 1990–2006 was 11.0% per annum; by contrast, in 2006–19, it was 1.0% per annum due to curbs on fossil fuel production after 2007 (Figure 15.9). Looking at share by fuels, biomass was dominant in 1990 (40.9%), followed by oil (28.0%), and coal (26.4%) but this share changed by 2019. Remarkably, by 2019, coal became dominant (42.7%), followed by oil at 19.0%, gas at 14.2%, biomass 13.7%, hydropower at 9.5%, and solar/wind at 0.8%.

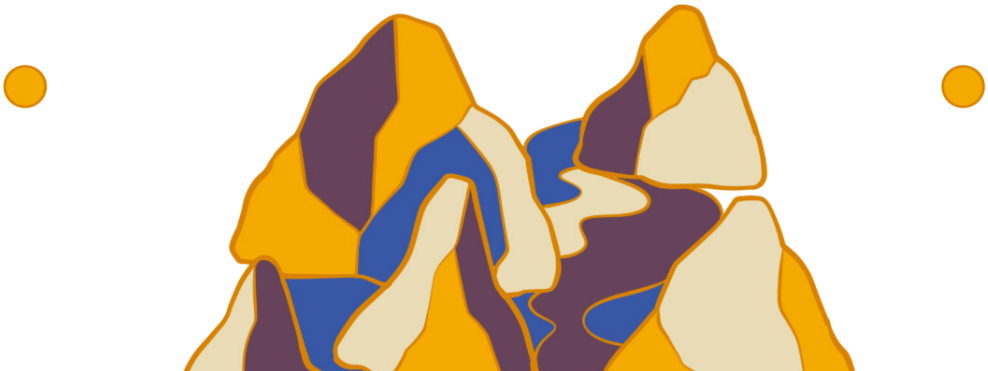
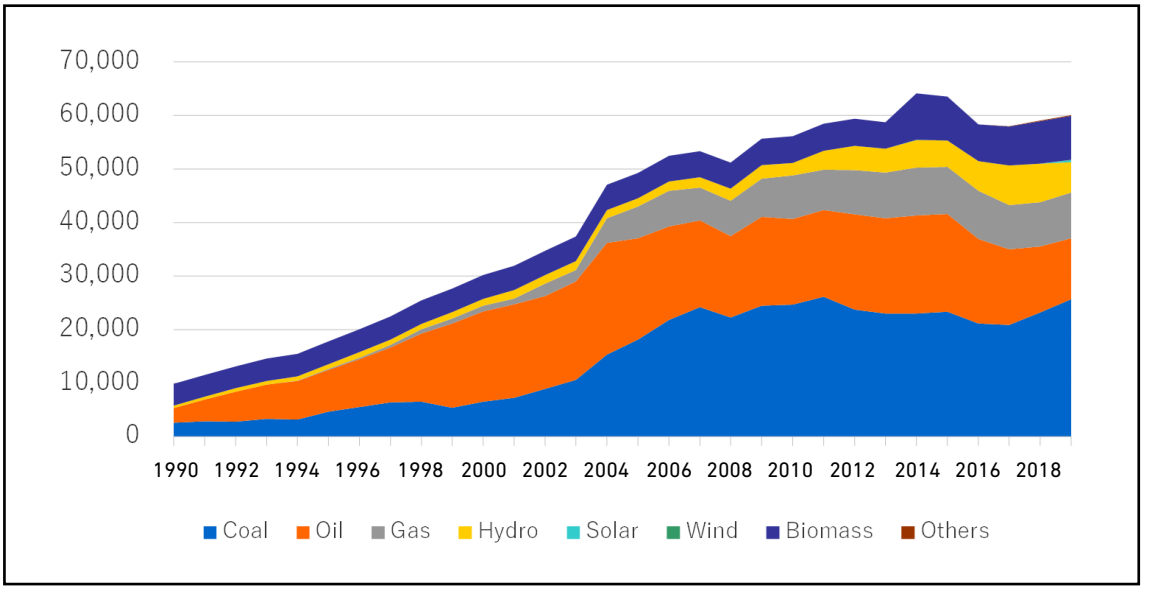


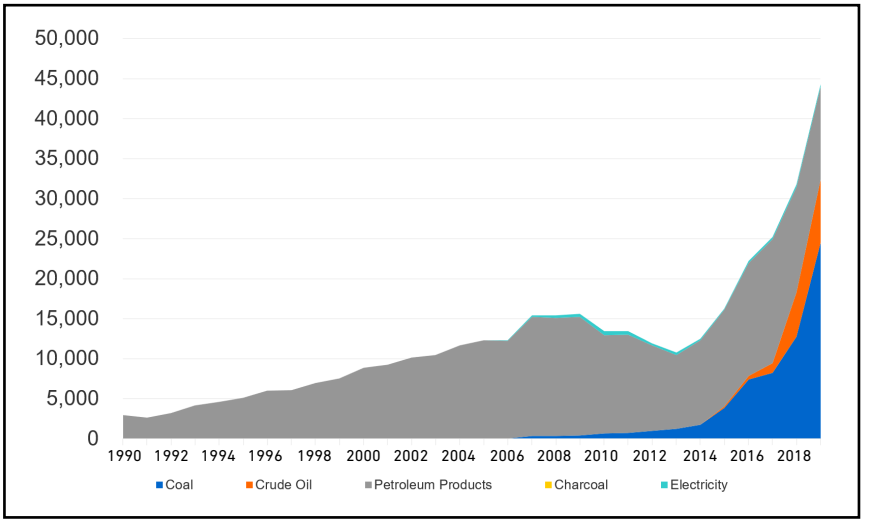
Figure 15.9. Historical Indigenous Product by Fuel (ktoe)



Source: APEC Energy database, 2022.

Contrasting with the production, import of fuels remarkably increased at 9.8% per annum in 1990 to 2019. The main import fuel has been petroleum products such as gasoline and diesel oil. Coal imports started in 2005 and was dominant at 55.3% in 2019. Crude oil was imported from 2015 due to start of a refinery operation and share of oil (crude oil and petroleum products) in 2019 was 44.0%. Coal and oil imports marked a significant increase from 2013–19 to 26.6% per annum, so that energy security, especially coal and oil, has been vulnerable (Figure 15.10).

Figure 15.10. Historical Energy Import by Fuel (ktoe)

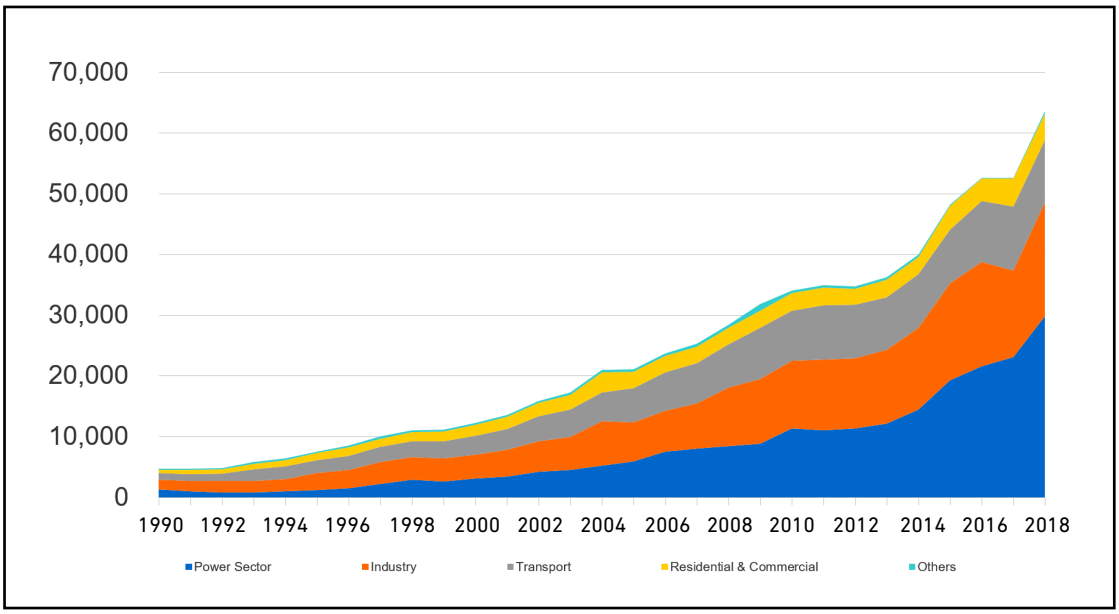


Source: APEC Energy database, 2022.

2.4. CO_2 Emissions

Due to the remarkable increase in energy consumption in Viet Nam, CO_2 emissions also increased from 4,752 kt-C in 1990 to 63,551 kt-C in 2018 and its growth rate was 9.7% per annum. By sector, power marked the highest growth at 11.7% per annum in 1990–2018, followed by industry at 9.4%, transport at 8.1%, and residential and commercial at 7.7% (Figure 15.11).

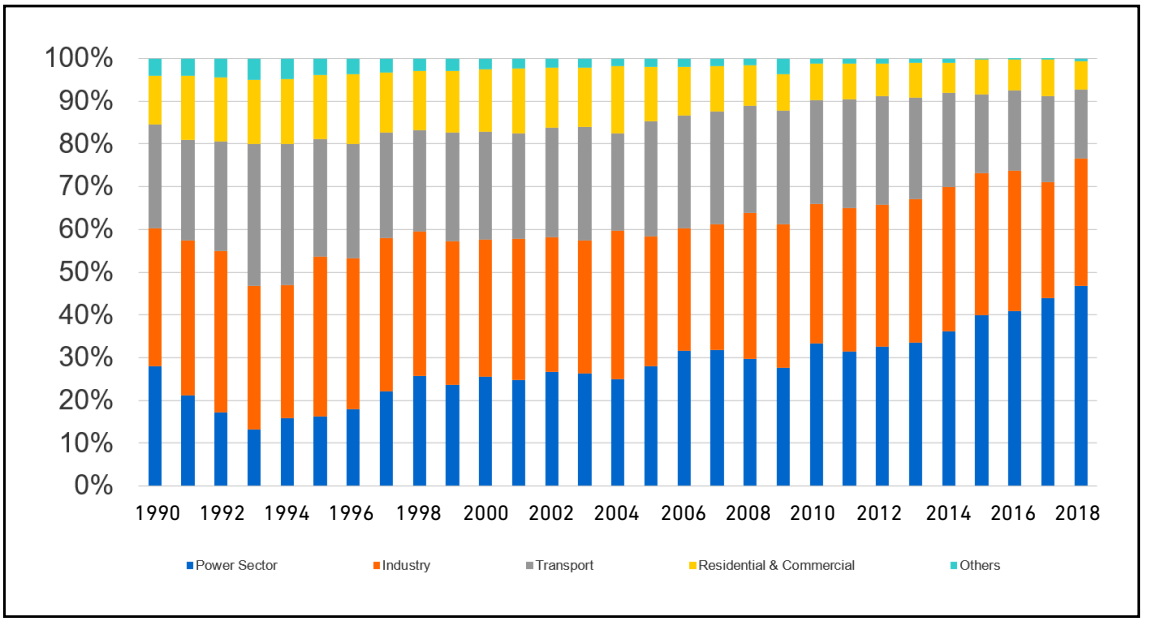
Figure 15.11. Historical CO_2 Emissions by Sector (kt-C)



Source: APEC Energy database, 2022.

The power sector share was dominant in 2018 at 46.9%, followed by industry at 29.7%, transport at 16.1%, and residential and commercial at 6.8% but the share in 1990 was quite different from 2019. Industry was dominant at 32.2%, followed by power at 28.0%, transport at 24.4%, and residential and commercial at 11.3% (Figure 15.12).

Figure 15.12. Historical CO_2 Emissions by Fuel Share (%)



Source: APEC Energy database, 2022.

2.5. Energy Indicators

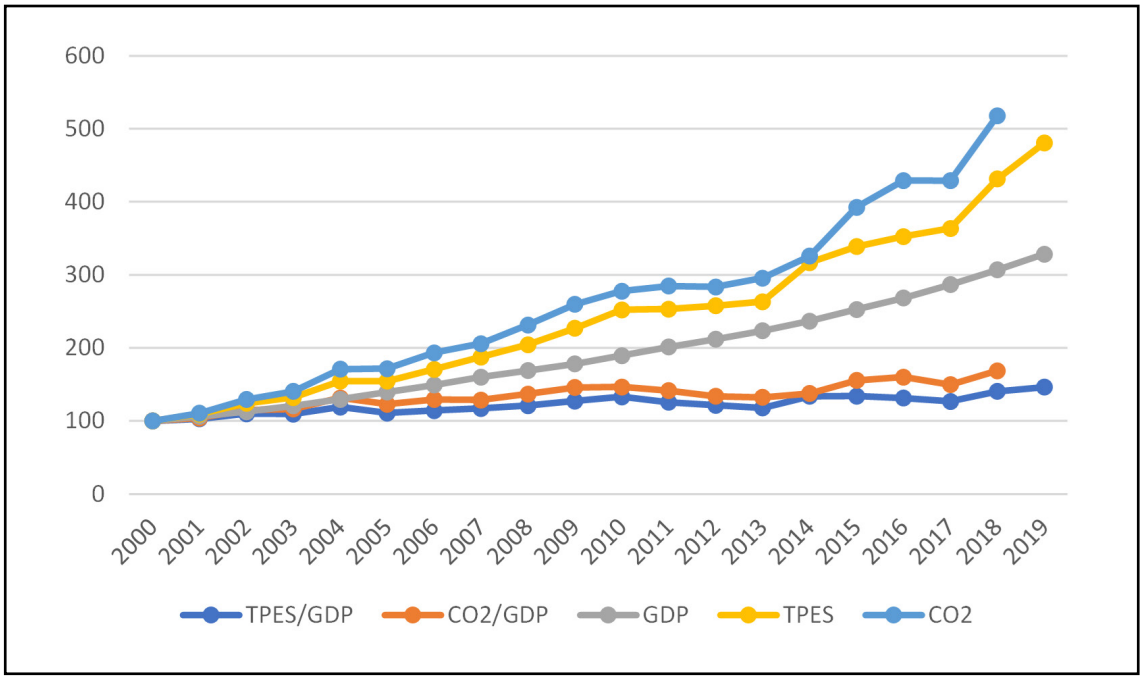
a. Relation between GDP and TPES & CO_2 emissions

In order to analyse the relation between economic growth and energy consumption, we define the following energy indicators:

- Energy intensity, defined as TPES/GDP
- CO_2 intensity, defined as CO_2/GDP

If these intensities are less than 1, it indicates a better situation between economic growth and energy consumption. Figure 15.13 shows the historical trend of the intensities. TPES and CO_2 emissions had higher growth compared to GDP; thus the intensities worsened from 1990–2019. The energy intensity in 2019 was 1.46 times that of 1990 and CO_2 intensity worsened 1.68 times from 1990–2018. It means that Viet Nam's economy has been requiring more energy consumption in order to increase GDP. As a result, CO_2 emissions increased over the same period due to shifting to fossil fuel consumption. This is a future energy issue for Viet Nam's Ministry of Industry and Trade (MOIT).

Figure 15.13. Historical Trend of Energy and CO_2 Intensities (2000=100)

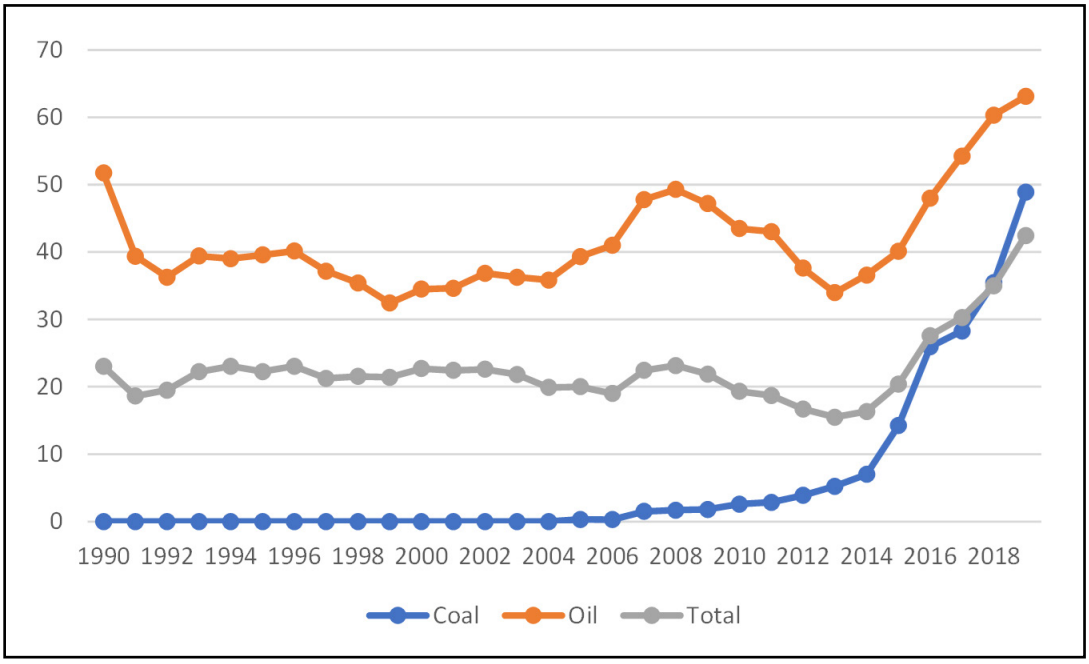


GDP = gross domestic product, TPES = total primary energy supply.
Source: Author's calculation.

b. Import dependency

In part (3) of section 2, we showed both indigenous and import fuel production. Then, we analysed import dependency of each fossil fuel. Total energy import dependency was around 20% in 1990–2013 but after 2013 the ratio went up over 40% until 2019. The reason was the increased imports of coal and oil after 2013; by 2019, the import ratio of oil was over 60% and coal was around 50%. Thus, EEC across the final sectors and development of domestic energy sources such as hydropower are essential policies for Viet Nam in term of improving supply security (Figure 15.14).

Figure 15.14. Historical Import Dependency by Fuel (%)



Source: Author's calculation.

3. Forecast of Energy Supply Demand Situation until 2050

In this section, we forecast Viet Nam's future energy supply, referring to the report 'Energy Outlook and Energy Saving Potential in East Asia 2020' published by the Economic Research Institute for ASEAN and East Asia (ERIA). ERIA has been updating the energy outlook and savings potential of the 17 East Asia Summit (EAS) countries every 2 years based on aggressive EEC and renewables targets reported under the EAS Energy Cooperation Task Force framework. The purpose of this energy outlook is to assess whether the reported EEC and renewables targets would be effective through analysing the energy-saving potential defined as business as usual (BAU) – alternative policy scenario (APS), including with aggressive EEC and renewables.

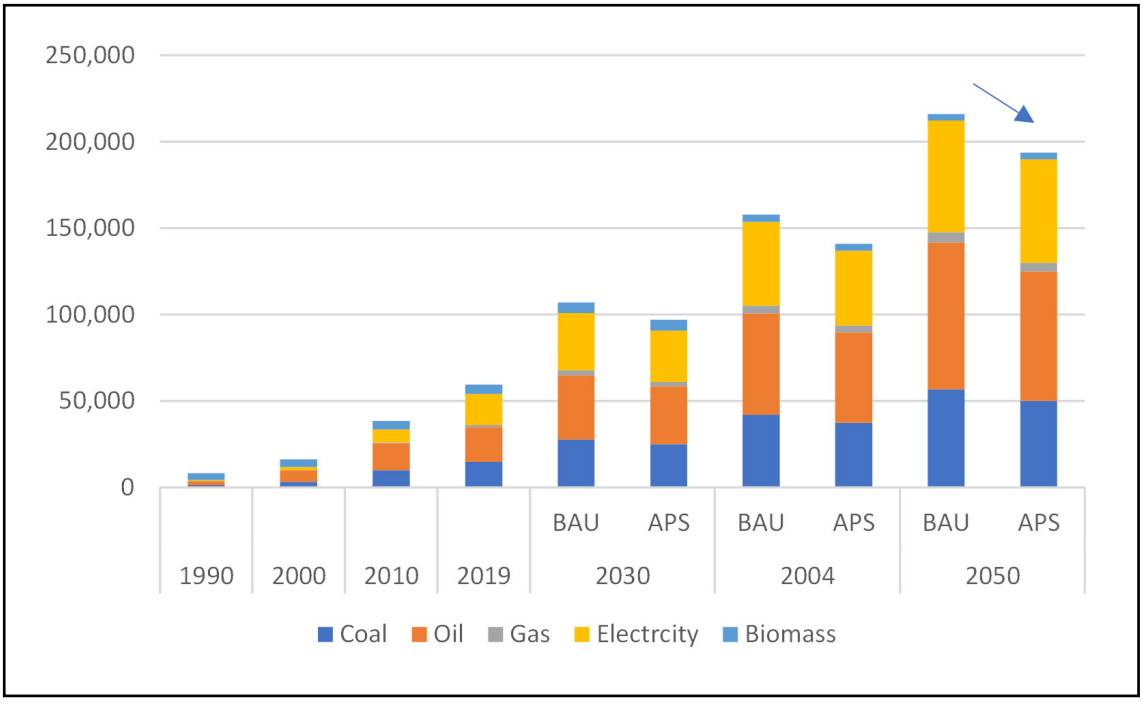
3.1. Total Final Energy Consumption

a. By fuels

Drawing on stable economic growth assumptions (5.2% per annum in 2019–50), TFEC will increase from 59.66 Mtoe in 2019 to 216.02 Mtoe in 2050 in BAU and 193.66 Mtoe in APS. The growth rate of TFEC in 2019–50 is 4.2% per annum in BAU and 3.9% per annum in APS. Thus, energy elasticity per GDP is less than 1 (0.81 and 0.75 respectively) from 2019 to 2050. Looking at fuels, gas has the

highest growth at 4.9% per annum, followed by oil at 4.7%, coal at 4.4%, and electricity at 4.2%. As a result, oil keeps the highest share at 39% in 2050, followed by electricity at 30%, and coal at 26%. Energy-saving potential defined as BAU – ASP is estimated as 22.36 Mtoe and the savings ratio is around 10% in 2050 (Figure 15.15).

Figure 15.15. Forecasted TFEC of BAU and APS by 2050 by Fuel (ktoe)

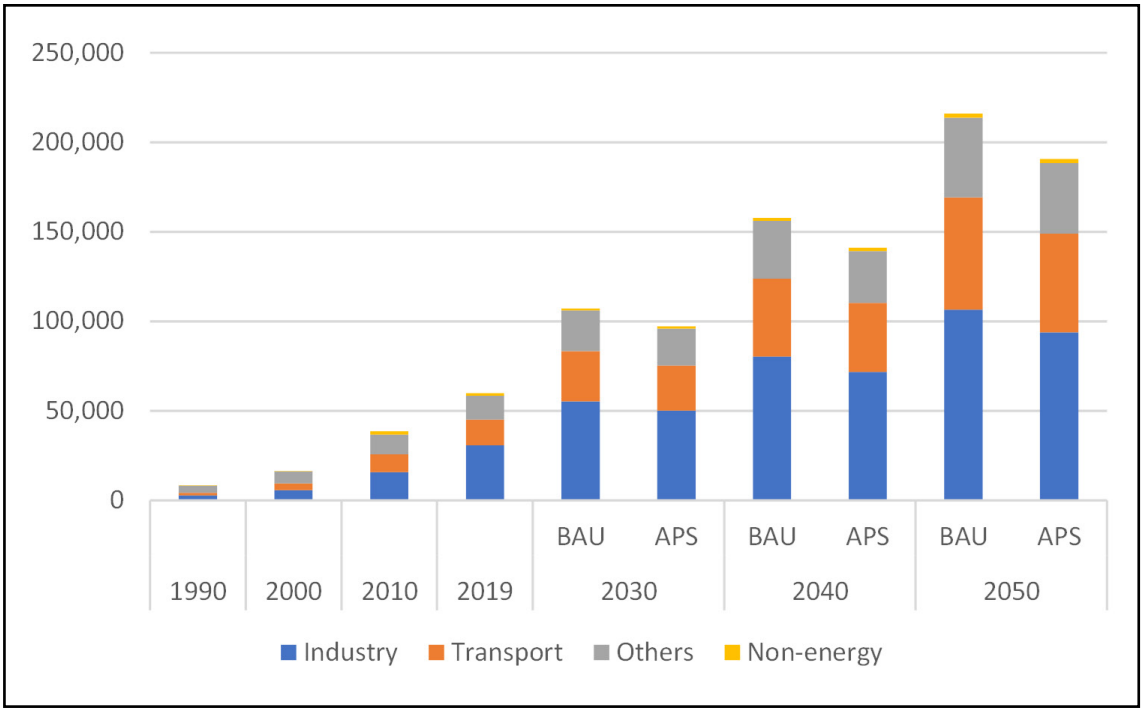


TFEC = total final energy consumption, BAU = business as usual, APS = alternative policy scenario.
Source: APEC Energy Database, 2022, and EAS Energy Outlook 2020.

b. By sectors

Towards 2050, the transport sector has shown the highest BAU growth rate at 5.0% per annum, followed by industry at 4.1% and others at 4.0%; APS shows similar results, but its growth rates are lower than BAU (Figure 15.16). As a result, shares by sectors are forecast to remain the same from 2019 to 2050 (industry is 50%, transport 30%, and others less than 20% up to 2050). Expected energy savings ratios are around 10% across the sectors in 2050, but this is not enough if Viet Nam is to achieve net-zero emissions by 2050. More ambitious EEC targets are recommended across the sectors; for example, industrial structure shifting from raw material production to knowledge-intensive industries, internal combustion engines giving way to BEVs/fuel-cell vehicles in the road transport sector, and promotion of net-zero energy houses and net-zero energy buildings in residential and commercial sector.

Figure 15.16. Forecasted TFEC of BAU and APS by 2050 by Sector (ktoe)

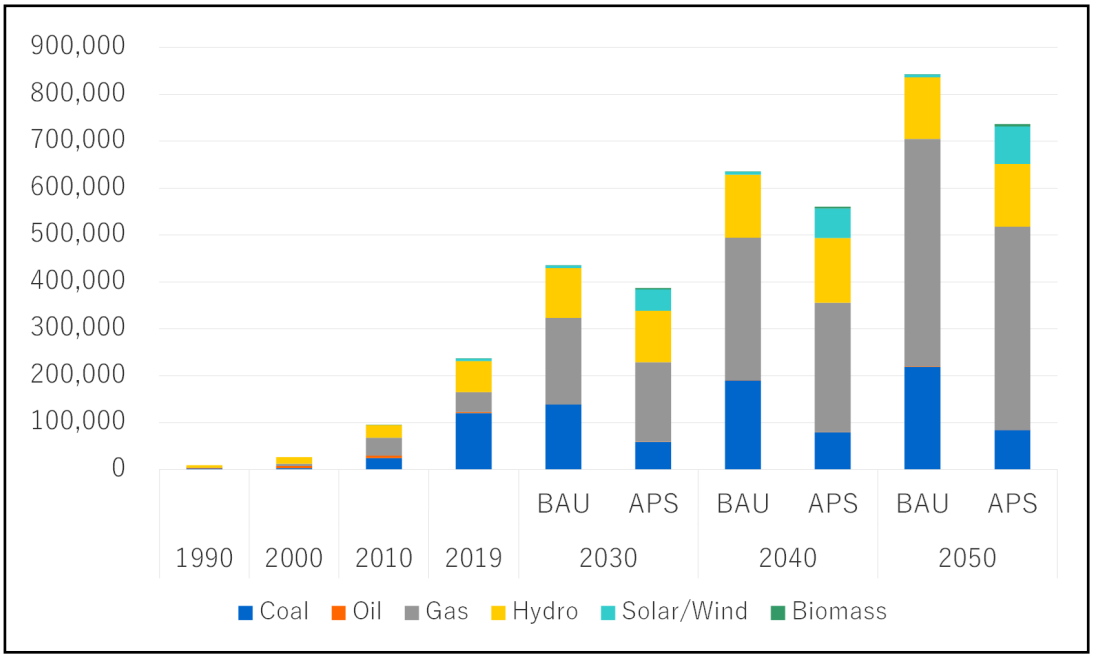


TFEC = total final energy consumption, BAU = business as usual, APS = alternative policy scenario.
Source: APEC Energy Database, 2022, and EAS Energy Outlook, 2020.

3.2. Power Generation

Viet Nam will shift to gas power as part of its clean energy transition. In BAU, gas power will grow the most from 2019–50 at 8.2% per annum, followed by hydropower at 2.2%, and coal at 2.0% (Figure 15.17). Oil will be phased out from the electricity market. In APS, gas, hydropower, and variable renewables such as solar/wind will increase significantly. On the other hand, coal power generation will be phased out, the same as oil power. While this is an appropriate energy transition pathway, more ambitious policies will be needed for achieving net-zero emissions in the power generation sector, such as nuclear power plants, shifting from gas and coal power generation to hydrogen/ammonia power generation and gas power generation with CCUS.

Figure 15.17. Forecasted Power Generation by 2050 by Fuel (GWh)

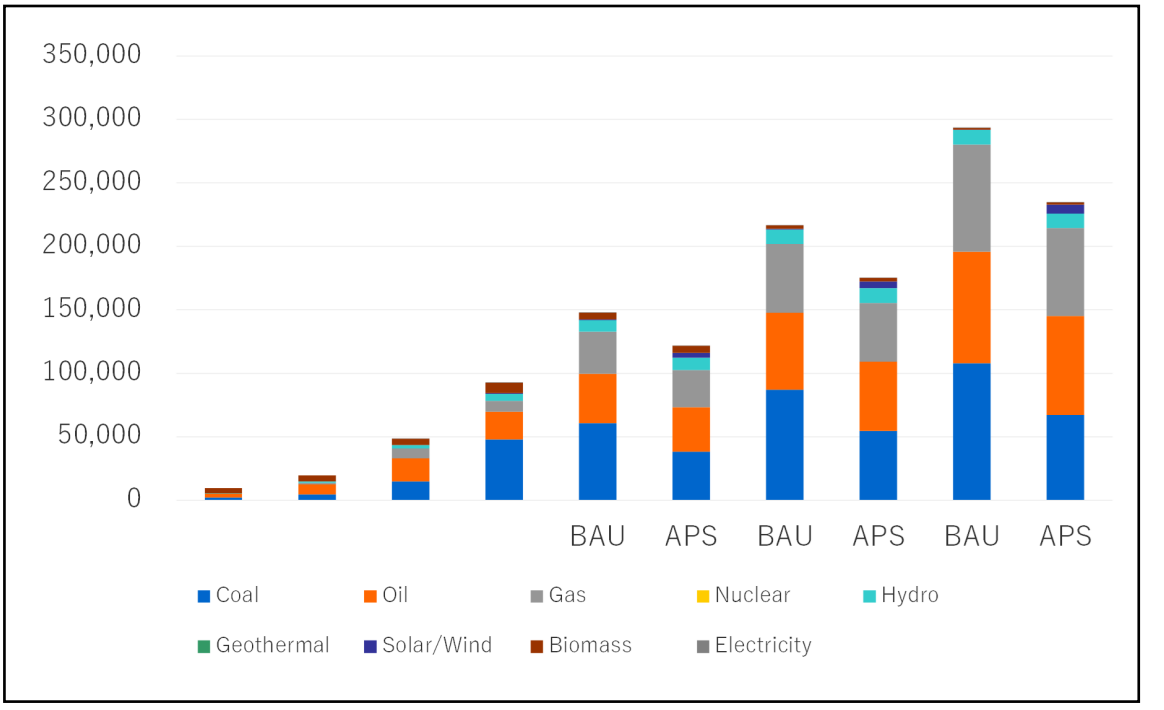


BAU = business as usual, APS = alternative policy scenario.
Source: APEC Energy Database, EAS Energy Outlook 2020.

3.3. Total Primary Energy Supply

TPES of BAU will increase from 92.76 Mtoe in 2019 to 293.59 Mtoe in 2050 and its growth rate is 3.8% per annum, while TPES of APS is 3.0% per annum in the same period. They are much lower than the historical growth rate of 8.2% per annum from 1990–2019 due to moderate GDP growth assumption until 2050, which is 5.2% per annum in 2019–50 compared to 6.8% per annum in 1990–2019. Other reasons include the promotion of energy saving across the final sectors, shifting from low-efficiency coal power plants to highly efficient gas power plants and increases in solar and wind. Thus, the energy elasticity per GDP of BAU and APS are 0.72 and 0.58, respectively. BAU and APS gas shows the highest growth rates at 7.7% per annum and 7.0% per annum in 2019–50, respectively, followed by oil at 4.6% and 4.2%, hydro at 2.2% and 2.3%, and coal at 2.6% and 1.1%. Renewables (except APS hydropower) will increase from 476 ktoe in 2019 to 6,905 ktoe in 2050 and the growth rate is 9.0% per annum. Thus, the concept of APS incorporates shifting coal to gas and a large increase of variable renewables such as solar/wind in power generation. The energy-saving potential of TPES is estimated as 58.81 Mtoe in 2050, 62% of which comes from coal, followed by gas (23%), and oil (15%). Nonetheless, the fossil fuel share of TPES in 2050 will be around 90%, which is very far from being carbon-neutral by 2050 (Figure 15.18).

Figure 15.18. Forecasted TPES of BAU and APS by 2050 by Fuel (ktoe)

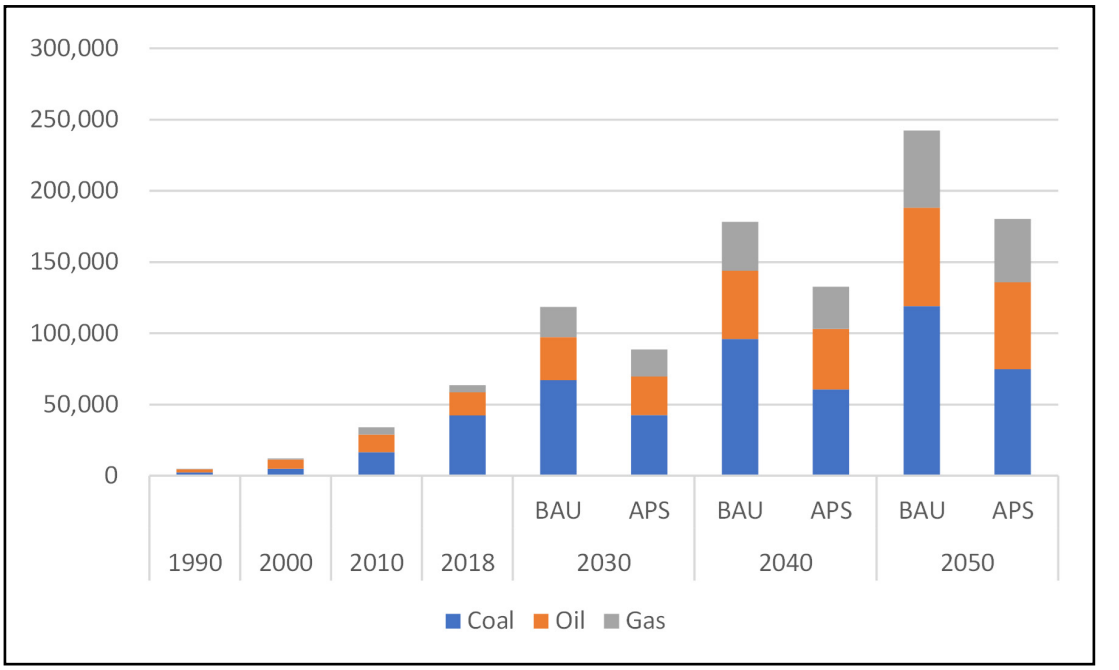


TPES = total primary energy supply, BAU = business as usual, APS = alternative policy scenario.
Source: APEC Energy Database, 2022, and EAS Energy Outlook, 2020.

3.4. CO_2 Emissions

CO_2 emissions will increase from 63.55 Mt-C (million tons of carbon) in 2018 to 242.4 Mt-C in 2050 and their growth rate is 4.3% per annum in case of BAU. 49% of CO_2 emissions come from coal, followed by oil (29%) and gas (22%). In APS, CO_2 emissions in 2050 will be 180.3 Mt-C and fuel shares are 41% of coal, 34% of oil, and 25% of gas, respectively. Therefore, expected CO_2 reduction in 2050 defined as BAU – APS is forecasted at 62.1Mt-C and the reduction ratio is 25.6% from BAU (Figure 15.19). Savings from reduced coal consumption contributes to 71% of CO_2 reduction, followed by gas (16%) and oil (13%). Aggressive energy policies including EEC and renewables, which are reflected in APS, contribute significantly to reduction of CO_2 through 2050, but the polices are not enough if Viet Nam is to achieve carbon neutrality by then, i.e. CO_2 emissions less than those of a forest carbon sink. Thus, the following energy policies and action plans towards clean energy are essential: shifting from oil to electricity or hydrogen in the transport sector; more electrification in the residential and commercial sector; applying CCUS to the raw materials industry; and shifting to clean thermal power generation such as hydrogen/fuel ammonia to replace coal and gas and applying CCUS for existing thermal power generation using coal and gas.

Figure 15.19. Forecasted CO_2 Emissions of BAU and APS by 2050
(kt-C)

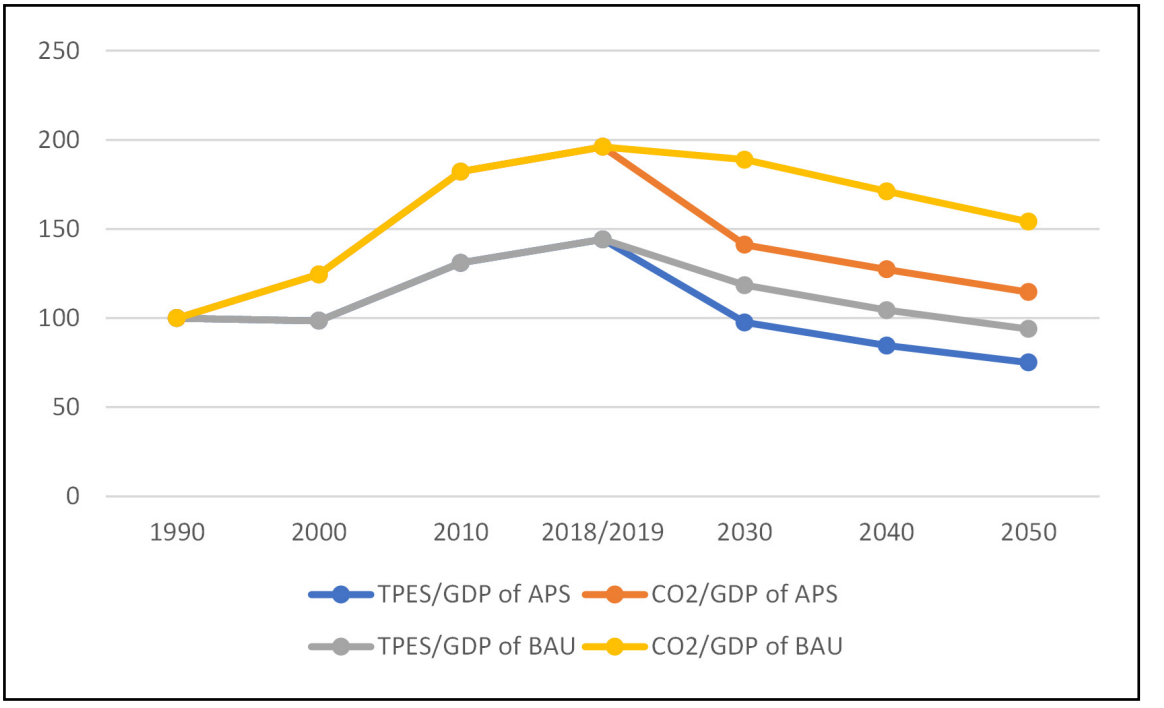


BAU = business as usual, APS = alternative policy scenario.
Source: APEC Energy Database, 2022, and EAS Energy Outlook, 2020.

3.5. Energy Indicators

Energy and CO_2 intensities defined as TPES/GDP and CO_2/GDP respectively will improve towards 2050 from 2018–19. The energy intensity in 2019 was 144 (1990=100); it will improve to 94 (BAU) and 75 (APS) by 2050. CO_2 intensity was 196 in 2018 and it will improve to 154 (BAU) and 114 (APS) by 2050 because carbon dependency, defined as CO_2/TPES (t-C/toe), is different between BAU and APS in 2050; 0.82 and 0.77, respectively. APS represents an energy composition that includes fewer carbon fuels (Figure 15.20).

Figure 15.20. Forecasted Energy Indicators by 2050 (1990=100)



TPES = total primary energy supply, BAU = business as usual, APS = alternative policy scenario, GDP = gross domestic product.
Source: Author's calculation.

4. Necessary Energy Technologies for Carbon Neutrality

According to 9.3, BAU is very far from being carbon-neutral until 2050; APS could reduce CO_2 emissions compared to BAU, but it is also still far from being carbon-neutral. Thus, in this section, necessary energy technologies to make Viet Nam carbon-neutral are reviewed and highlighted.

4.1. Energy Efficiency and Conservation

Viet Nam's fast-paced economic development and GDP growth have resulted in high energy demand. EEC will be significant to curb demand while maintaining growth because the same amount of energy use will lead to larger output. EEC can be an energy resource as it will become available for other economic activities. Saving electricity is even more significant as every kWh saved is fuel for power generation. EEC will also help by avoiding building more power plants.

To address the fast-growing energy demand, Viet Nam developed a comprehensive EEC law with 12 chapters, and 48 articles. The law was officially approved on 18 June 2010 and has been in effect since 1 January 2011. The Prime Minister's Decision No. 1427/QD-TTg indicates the National Targeted Programme on Energy Savings and Efficiency in 2012–15. On measures for EEC, Circular No. 64/2011/TT-BGTVT covers infrastructure planning and investment to operation and management. The Law on Energy Efficiency and Conservation also set national greenhouse gas (GHG) and carbon-intensity targets. The targets are (i) reduce GHG emissions in energy sector around 5% by 2020, 25% by 2030, and 45% by 2050 compared to BAU, and (ii) increase the share of renewables-based electricity to 4.5% in 2020, 15% in 2030, and 33.1% in 2050.

Viet Nam also issued the Decision No.280/QD-TTg on 13 March 2019, which aimed to implement National Energy Efficiency Program for 2019–30, with the main targets to ensure and stabilise national energy security and fulfil its commitment to reduce GHG emissions with concrete targets: (i) by 2025, to save 5%–7% of the national energy consumption and to reduce power loss to less than 6.5%; and (ii) by 2030, to save 8%–10% of the national energy consumption and to reduce power loss to less than 6.0%.

Viet Nam also issued the Decision No.24/2018/QD-TTg on 18 May 2018, which was a roadmap for elimination of energy-consuming equipment and prohibition of development of new power generating units with low efficiency. This roadmap aimed specifically at coal- and gas-fired power plants, and it took effect on 10 July 2018 with the following restrictions: (i) it is not permitted to build coal- or gas-fired power-generating units with outdated technologies, or with efficiency at the start of commercial operation lower than the regulated efficiency corresponding to each range of unit capacities as specified in the Appendix of this Decision/regulation; (ii) it is not permitted to import old power-generating units with capacity beyond the range of capacities specified in the Appendix of this Decision/regulation; and (iii) No approval for investment in coal- or gas-fired thermal power plants with lower efficiency than that corresponding to capacities of power-generating units specified in the Appendix of this Decision/regulation shall be given.

4.2. Nuclear and Biomass

Viet Nam has considered nuclear power generation since 1995. Several firm proposals surfaced in 2006, and Russia agreed to finance and build 2,400 MWe of nuclear capacity from 2020; Japan agreed to another 2,200 MWe. On 22 November 2016, The National Assembly's Resolution No. 31/2016/QH14 tasked the Government to halt the investment in nuclear power by: (i) applying solutions for issues related to stopping investment in nuclear power projects; and (ii) focusing on development of new and renewable energy resources, safe and efficient energy resources, and environmental protection to supply sufficient energy needed for socio-economic development.

Viet Nam has also issued several decisions/regulations to support the development and introduction of biomass power plants through various government mechanisms and supports. For instance, Decision No. 24/2014/QĐ-TTg, issued on 24 March 2014, aimed to support projects in Viet Nam in which the electricity price of biomass power connected to the grid is incentivised as follows: (i) for heat cogeneration projects, the price for power was set at VND1,220/kWh (excluding value added

tax, equivalent to $0.058/kWh); and (ii) for other biomass power projects (not heat cogeneration projects), the electricity price avoided the applicable cost tariff.

On 5 March 2014, Decision No. 31/2014/QĐ-TTg was issued to support the development of power generation projects using solid waste in Viet Nam. This decision aimed to provide incentives in the form of feed-in-tariffs for the electricity produced from solid waste power projects connected to the grid. The decision has set the electricity price of biomass power plant at $0.1005/kWh for incineration technology, $0.0728/kWh for burial of solid waste.

4.3. Carbon Capture Utilisation and Storage

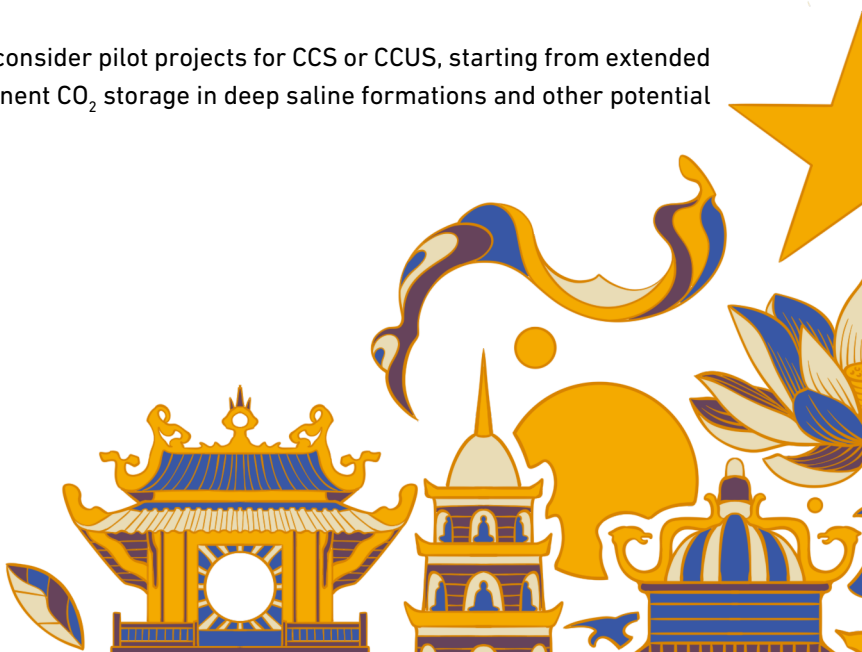
CCUS is vital if Viet Nam is to have any chance of reducing emissions to net zero and achieving global climate change targets. Currently, Viet Nam does not have any policy on CCUS, but it has the great potential to develop an associated value chain as it has industrial clusters that can be developed for the shared CO_2 emission pipeline. Further, it is important that Viet Nam consider extended oil recovery and other potential CO_2 storage.

Viet Nam's potential underground CO_2 storage, including depleted oil/gas reservoirs, deep saline aquifers, and coal formations, is huge (Harrison, 2022). As first steps in Viet Nam, there appear to be specific opportunities by applying carbon capture storage (CCS):

- t will enhance oil recovery while storing CO_2 in the river basin area of Cuu Long.
- It will enhance coal bed methane recovery while storing CO_2 in the Quang Ninh coal basin.
- More CO_2 storage is estimated at the depleted oil fields in Cuu Long, Song Hong, and North end.

These opportunities are not being exploited presently. CO_2 can be transported from the emitted sources to storage sites by onshore pipeline, offshore pipeline, or ship. CCS project developers, depending on distance between capture and storage sites, will select one or a combination of several methods for CO_2 transport. For example, pipelines and ships are likely to be used for long distances. If the transport distances are shorter, pipelines have more advantages. Regional planning for transport infrastructures may create CO_2 logistic hubs in ports and around heavy industry.

In this regard, Viet Nam may need to consider pilot projects for CCS or CCUS, starting from extended oil recovery to the potential of permanent CO_2 storage in deep saline formations and other potential of storage hubs.



4.4. Renewable Energy

According to MOIT (2016), Viet Nam has a solar power potential of 130 GW and a wind power potential of 27 GW.

On 25 November 2015, the Government of Viet Nam issued Decision 2068/QĐ-TTg on the National Strategy of Renewable Energy Development by 2030 and with a vision to 2050, with the goal of reducing the country's dependency on fossil fuels, maintaining national energy security, and contributing to global climate change mitigation. This Strategy included the objective to raise the share of electricity generation from renewables from 35% of total national production in 2015, to 38% by 2020, and to 43% by 2050. According to this Strategy, emphasis shall be given to hydropower, wind power, solar power, biomass energy and biogas, with a view to using various renewables for efficient power supply to the national electricity system and thermal energy for heating needs in production and residential activities.

Viet Nam's 'Revision of National Power Development Plan' (Decision No. 455/QD-TTg dated 18 March 2016) details its plans to increase wind power from 140 MW in 2015 to 800 MW in 2020, to 2,000 MW in 2025, and to 6,000 MW in 2030. The Decision also targeted to increase solar power capacity from the negligible rate in 2015–16 to around 850 MW in 2020, to around 4,000 MW in 2025, and to around 12,000 MW by 2030. The expected share of electricity generated from solar energy is around 0.5% in 2020, around 1.6% in 2025, and around 3.3% in 2030 (Vietnam Electricity, 2016).

Furthermore, Prime Minister Phuc said in June 2018 that Viet Nam will increase electricity output produced from renewable sources from approximately 58 TWh in 2015 to 101 TWh by 2020, and 186 TWh by 2030 (Pearson and Vu, 2018). According to Massmann (2020), the Government of Viet Nam also promulgated several policies to set fit-in tariffs for solar power (Decision 13/2020/QD-TTg), wind power (Circular 02/2019/TT-BCT), and bioenergy, i.e., solid waste (Decision 31/2014/QD-TTg).

According to Nguyen (2021), by 2020, Viet Nam's total installed capacity of renewable energy, excluding hydroelectricity, reached 17,430 MW, which was 25.3% of the total installed capacity of 69,000 MW. Also according to Nguyen (2021), by 2020, the total installed capacity of solar farms, solar rooftops, and wind in Viet Nam reached 8,550 MW, 7,711 MW, and 538 MW, respectively.

The total solar power installed capacity in 2020 was 16,261 MW, which was well beyond 2020's target of merely 850 kW. The installed capacity continued to increase, reaching 16,504 MW in 2021, according to the Viet Nam Electricity (2016), quoting VN Express (2022).

According to Massmann (2022), the latest draft of the National Power Development Plan VIII was approved on 26 April 2022 by the Appraisal Council; the MOIT was to submit the final draft for the Prime Minister's approval in May 2022.

The draft of the National Power Development Plan VIII includes the following:

- Solar power development: the total capacity of solar power sources will reach around 16,491 MW by 2025 and should remain unchanged until 2030, and reach between 74,741MW and 96,666 MW by 2045. In terms of proportion, the electricity produced from solar power is expected to reach a share of around 6.8%–7.0% by 2025, 4.5%–4.8% by 2030, and 11.1%–12.1% by 2045.

- Wind power development: Total onshore and nearshore wind power capacity should reach between 10,700 MW and 13,616 MW by 2025, between 11,700 MW and 16,121 MW by 2030, and between 36,170 MW and 55,950 MW by 2045. Total offshore wind power capacity should reach around 7,000 MW or possibly higher when economic and technical conditions allow in 2030 and should reach between 30,000 MW and 64,500 MW in 2045. Total electricity produced from wind power is expected to account for between14.4% and15.7% by 2025, between 10.3% and 15.6% by 2030 and between 31.2% and 43.2% by 2045.

4.5. Hydrogen and Ammonia

To develop renewable energy, Resolution No.55-NQ/TW of the Politburo on Orientations of Viet Nam's National Energy Development Strategy to 2030 and outlook to 2045, signed 11 February 2020, mentioned a mission to conduct technology research and develop plans for piloting electricity generation using hydrogen and encouraging its use consistent with global trends.

As the implementation of that resolution, Decision No. 1658/QD-TTg was issued on 1 October 2021 that stated the duty of MOIT to formulate the incentive mechanism for development of hydrogen in concert with offshore wind.

Nevertheless, while hydrogen use is encouraged and its development path is currently being designed, no energy policy on the use of ammonia has ever been promulgated in Viet Nam.

4.6. Electric Vehicles

In Viet Nam, the first policy related to electric vehicles can be traced back to 2006 with the Ministry of Industry's Decision No. 33/2006/QĐ-BCN on the necessity to produce high quality and clean-fuel motorcycles (powered 2-wheelers or P2Ws).

However, the intention to change fuel types vis-à-vis the reduction of fossil fuels and the increasing use of renewables and low GHG-emissions fuels was formalised only 6 years later, on 25 September 2012, with the issuance of the Prime Minister's Decision No. 1393/QD-TTg on the Approval of the National Strategy on Green Growth.

Prime Minister's Decision No. 1168/QD-TTg on the Approval for the Strategy to Develop the Automotive Industry in Viet Nam by 2025 with Orientation to 2035, issued on 16 July 2014, can be considered as the most important policy measure. The Decision encourages production of eco-friendly automobiles that include electric passenger cars (under nine seats) and electric buses.

Subsequently, Prime Minister's Decision 985a/QD-TTg, issued 1 June 2016, on the National Action Plan for Air Quality Management to 2020, with a Vision to 2025 included an instruction for the Ministry of Transport (MoT) to formulate and promulgate management and development policies for electric transport vehicles. This decision was followed by Prime Minister's Decision No. 2053/QD-TTg, issued on 28 October 2016, on the Implementation Plan of the Paris Agreement on Climate Change, where the MoT is instructed to carry out mitigation measures for greenhouse gas emissions in the transport sector from 2016–20 and 2021–30. As the implementation, the MoT issued its Decision No. 1456/QD-BGTVT on the Action Plan of Climate Change Adaptation and Green Growth Strategy in 2016–20 that included the objective to push the use of renewable and clean energy in the transport sector.

Cities' governments have also been involved in the promotion of electric vehicles in Viet Nam. For instance, Resolution No. 12/NQ-CP (2019) instructed people's committees of five central-level cities, i.e. Hanoi, Hai Phong, Da Nang, Ho Chi Minh City and Can Tho, to support the development of environmentally friendly buses. Hanoi People's Committee's Plan No. 201/KH-UBND, issued on 16 October 2020, on Public Passenger Transport Vehicle Development in the period 2021 to 2030, defined the number and share of vehicles by type and by key future timelines, i.e. 2020, 2025, and 2030.

The necessity of pushing electric transport vehicle development is also mentioned in Resolution No. 55-NQ/TW. In point 3 of item 3 (Key Measures and Tasks), an encouragement policy for consumers to use clean and renewable energy is needed, especially in industry and transport.

As one of the actions of the Resolution No. 55-nQ/TW implementation, on 2 October 2020, the government issued Resolution 140/NQ-CP. The Resolution 140/NQ-CP set the objective of reaching a reduction of greenhouse gas emissions from energy activities as big as 15% by 2030, and 20% by 2045 compared to BAU. The MOT is responsible for implementing research and development programmes for transport systems that save energy, use clean energy, and are environmentally friendly.

To accelerate the penetration of electric vehicles, the government has so far implemented only special consumption tax (SCT) incentives. Regulated in Law No. 106/2016 / QH13 dated 6 April 2016, the SCTs of electric vehicles are set lower than those of fossil fuel vehicles (Le, Nguyen, Do, 2021). Concretely, the SCT rates applied for under nine-

seat electric vehicles, 10–16 seat electric vehicles, and 16–14 seat electric vehicles are 15%, 10%, and 5%, respectively, compared to the SCT rates of 35%–150% applied to fossil fuel photovoltaics.

Apart from special consumption tax incentives, the government has also implemented import tax relaxations for electric vehicles. On 25 May 2020, the Government of Viet Nam issued the Decree 57/2020/ND-CP that stipulated that a preferential import tax rate of 0% will be levied on inputs, raw materials, and accessories that have not yet been domestically produced to serve the manufacture and process (assembly) of prioritised supporting products for the development of the automobile manufacture and assembly industry. This Decree applies to automobiles in general, including electric vehicles.

Incentives have also been given for the use of electric public transport, i.e. electric buses. The most important incentive is the reduction of SCT such as regulated by Decision 13/2015/QD-TTg, Law No. 106/2016/QH13, and Decree No. 10/2020/NQ-CP.

5. Preparation of a Pathway for Viet Nam to Apply Carbon-Neutral Technologies

The basic concept of a carbon-neutral scenario in Viet Nam by 2050 focused on the transition from a fossil fuels-based energy system towards cleaner and greener energy systems in which it highlights the importance of EEC, wind, solar, hydropower, biomass, and other clean fuels such as hydrogen and ammonia, the introduction of BEVs, fuel cell vehicles, large deployment of battery energy storage systems, nuclear, carbon sinks such as CCUS, and forestation, afforestation, and blue carbon; these energy technologies are summarised in Table 15.1

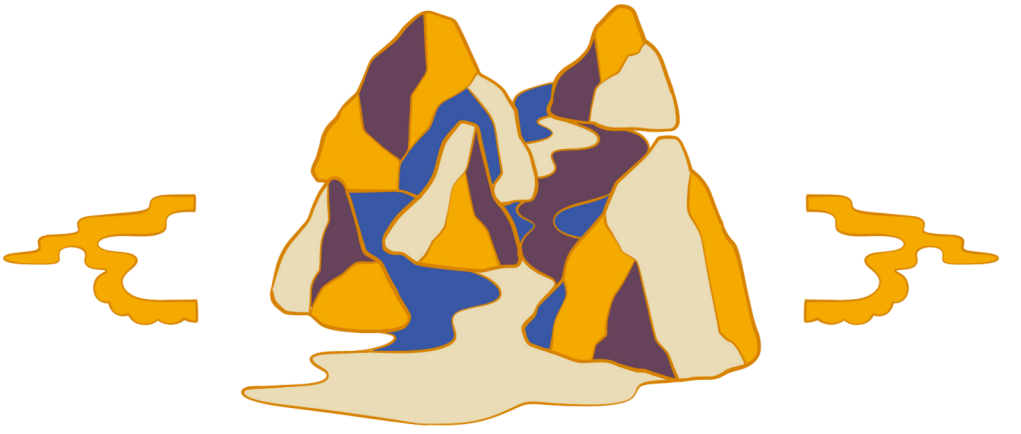


Table 15.1. Selected Low-Carbon Technologies in the Model

Renewables	Solar, Onshore wind, Offshore wind, Hydro, Geothermal, biomass
Nuclear	Light water reactor
CCUS	CO_2 capture: Chemical absorption, Physical absorption, Direct air capture CO_2 utilisation: Methane synthesis, FT liquid fuel synthesis CO_2 storage: Geological storage
Hydrogen	Supply: Electrolysis, Coal gasification, Methane reforming, H_2 separation from Ammonia, H_2 trade amongst ASEAN countries, H_2 imports from non-ASEAN countries Consumption: H_2 turbine, Natural gas-H_2 co-firing, fuel cell electric vehicle, H^2-based DRI+EAF, Fuel cell ship, H_2 aviation, H_2 heat for industries, Fuel synthesis (methane, FT liquid fuel, ammonia)
Ammonia	Supply: Ammonia synthesis, NH_3 trade amongst ASEAN countries, NH_3 imports from non-ASEAN countries Consumption: Ammonia turbine, Coal-ammonia co-firing, H_2 separation
Negative emissions technologies	Direct air capture with CCS, Biomass-fired power generation with CCS

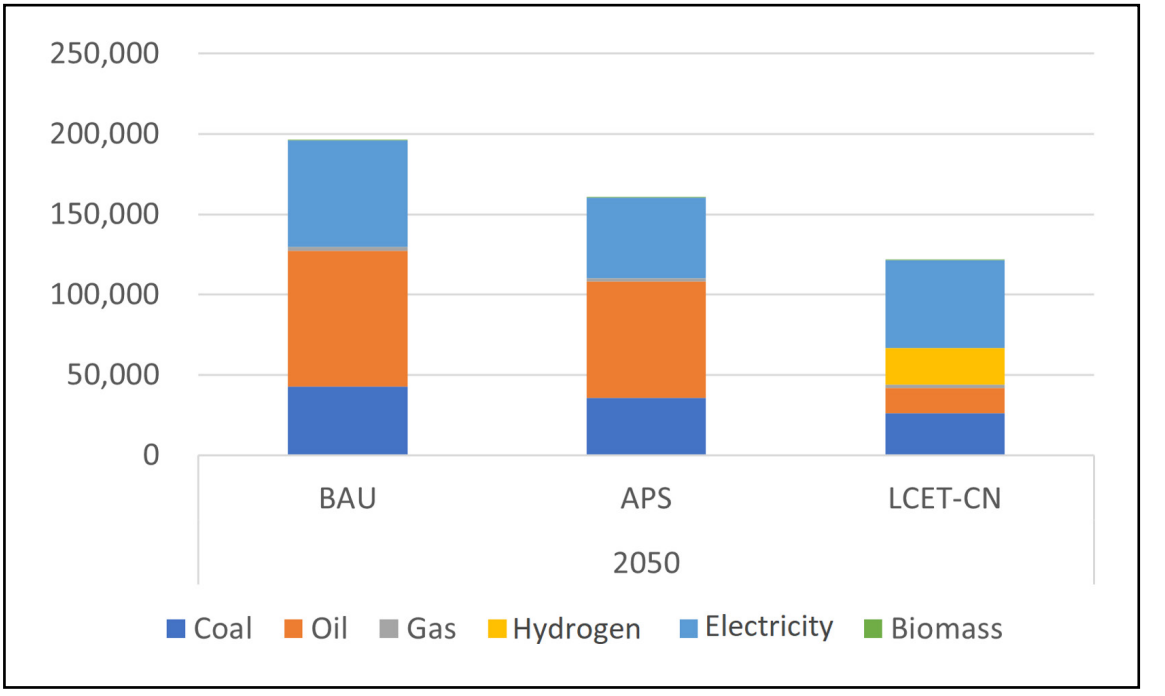
ASEAN = Association of Southeast Asian Nations, CCS = carbon capture storage, CCUS = carbon capture utilisation and storage, DRI = Direct Reduced Iron, EAF = Electric Arc Furnace, FT = Fischer-Tropsch.
Source: Author.

Paying attention to advantage of natural energy resources of Viet Nam, a carbon-neutral pathway namely Low-Carbon Energy Transition – Carbon Neutral (LCET-CN) is examined applying the following energy technologies:

a. Promoting EEC significantly compared to APS.
b. Promoting electrification across the final sectors.
c. Increasing renewables significantly compared to APS, especially solar and wind power.
d. Applying CCS for thermal power plants.
e. Producing hydrogen using electricity from wind power and using hydrogen for thermal demand in industry and fuel in the transport sector.

Final energy consumption in 2050 amongst the three scenarios is shown in Figure 15.21. Viet Nam needs more aggressive EEC than in APS, along with an increase of electrification across the sectors, especially the transport sector, and new uses of hydrogen for industry and transport activities.

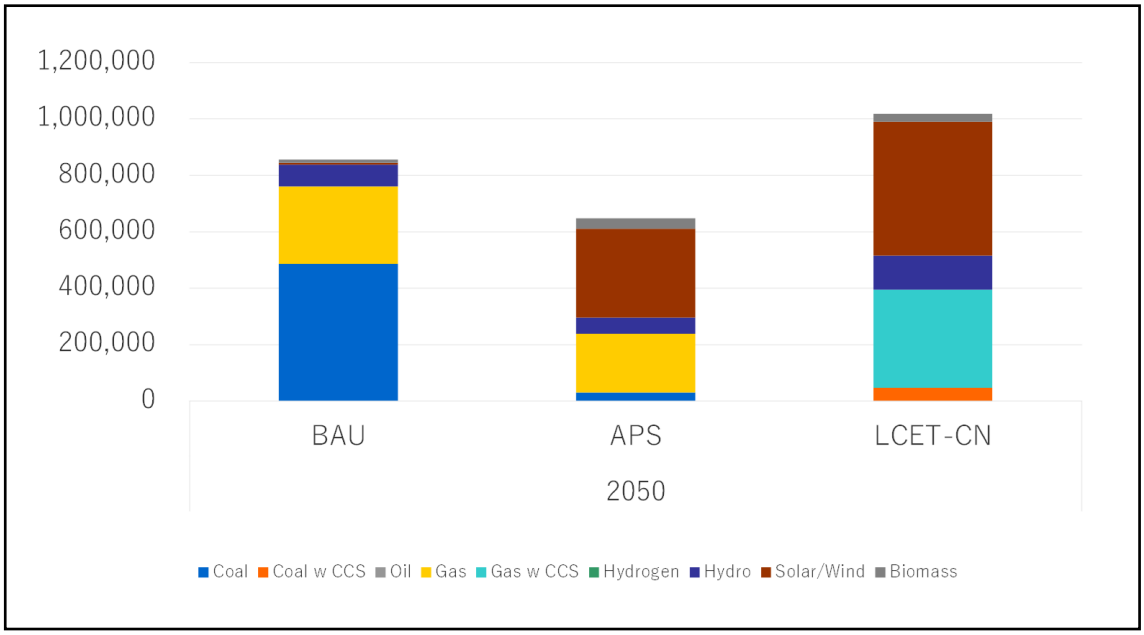
Figure 15.21. Final Energy Consumption in 2050 amongst BAU, APS, and LCET-CN
(ktoe)



LCET-CN = Low-Carbon Energy Transition – Carbon Neutral, APS = alternative policy scenario, BAU = business as usual.
Source: Author.

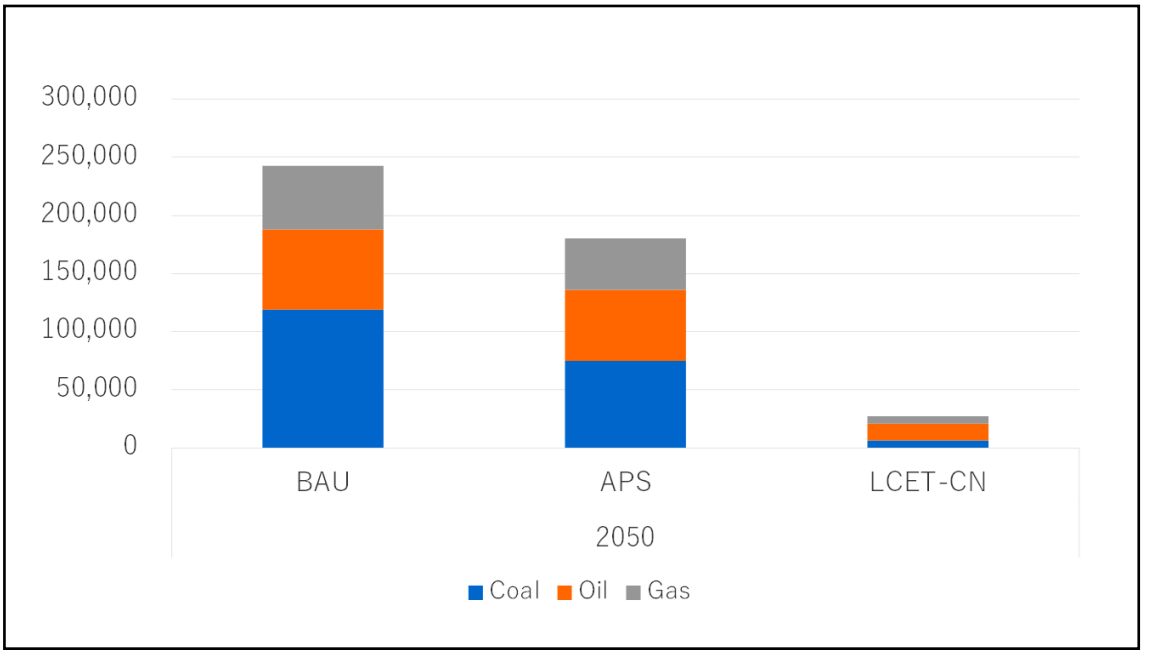
The power generation mix of LCET in 2050 is quite different from BAU and APS. BAU still depends on fossil power generation (coal and gas), but APS shifts more renewables such as solar and wind power. By 2050, the total share of solar and wind power in the LCET-CN scenario would reach around 50%; interestingly, this percentage falls within the 2045 targeted range of the total share of wind and solar power generation as determined in the draft of the National Power Development Plan VIII, i.e., between 42.3% and 55.3%. In addition, LCET-CN applies CCS to coal and power generation. Thus, the share of thermal power generation in 2050 declines from 90% of BAU to less than 40% of APS. The share of LCET-CN is same as APS but all the thermal power plants are equipped with CCS, so that CO_2 emissions reduce to 10% of APS (Figure 15.22).

Figure 15.22. Power Generation Mix in 2050 amongst BAU, APS, and LCET-CN
(GWh)



LCET-CN = Low-Carbon Energy Transition – Carbon Neutral, APS = alternative policy scenario, CCS = carbon capture storage, BAU = business as usual.
Source: Author.

Figure 15.23. CO_2 Emissions in 2050 amongst BAU, APS, and LCET-CN
(Mt-C)



LCET-CN = Low-Carbon Energy Transition – Carbon Neutral, APS = alternative policy scenario, BAU = business as usual.
Source: Author.

6. Conclusions and Policy Recommendations

Energy efficiency and electrification in the end-use sector can serve as a central strategy for decarbonising Viet Nam's energy systems, particularly when integrated with low-carbon power sources. Given renewables' potential in Viet Nam, the development of solar and wind power generation plays a major role in the decarbonisation of the region. At the same time, however, not only renewables but also other carbon-free technologies such as hydro, geothermal, and biomass contribute to carbon neutrality. Therefore, it is desirable to decarbonise power sources by effectively combining multiple technologies. While energy demand in Viet Nam is expected to continue to grow, progress in energy efficiency and electrification in the end-use sector are crucial for deeper decarbonisation. In addition, CO_2-free hydrogen and CCS are also essential to achieve carbon neutrality. Despite the high costs associated with these technologies at their current stage of development, they are expected to gain widespread adoption in the long run, thanks to cost reductions achieved through technological innovations. In essence, this underscores the pursuit of suitable pathways for transitioning to low-carbon energy solutions.

The expansion of storage battery capacity and the establishment of grid interconnections within the Ayeyawady-Chao Phraya-Mekong Economic Cooperation Strategy region are essential for scaling up renewable energy sources and reducing costs by mitigating the need for additional generation capacity. Research and development and international collaboration are key factors in accelerating the pace towards carbon neutrality in Viet Nam. Viet Nam's energy transition must take into account the role of various 'low-carbon' technologies, spanning from coal-fired to natural gas-fired power generation, more efficient turbines, and co-firing with hydrogen or ammonia. These technologies can collectively contribute to a gradual and systematic decarbonisation process in the power sector. Viet Nam has many existing coal-fired and gas-fired power plants, both old and relatively new, in operation. In the medium term, affordable low-carbon technologies will likely be introduced. Introducing low-carbon technologies effectively utilising existing facilities makes it possible to advance efforts towards decarbonisation while keeping expansion of the economic burden on the end-users to a moderate level. The final stage of achieving carbon neutrality requires introducing more expensive decarbonisation technologies such as hydrogen/ammonia, CCUS, and Direct Air Capture with Carbon Storage. However, it can be said that effective use of low-carbon technologies during the transition period leads to steady reduction of CO_2 emissions.

Therefore, this study recommends the following:

- Promoting EEC is essential for Viet Nam in the coming years for reducing energy consumption, especially petroleum and electricity consumption. The Government of Viet Nam should support the implementation of EEC action plans by establishing relevant policies, including mandatory and incentive-based measures. Further, Viet Nam should develop detailed EEC targets for the commercial, residential, industry, and transport sectors applying Energy Efficiency Indicators. The plans should include standard and labelling systems such as the green building index and Minimum Energy Performance Standards.
- Coal thermal power plants are one of the major power sources to meet the growing electricity demand in Viet Nam. Thus, shifting to natural gas from coal for power generation will reduce

emissions. In this instance, the establishment of transparent liquefied natural gas (LNG) markets in Asia will undoubtedly play a significant role in boosting LNG consumption within ASEAN as well as for Viet Nam's LNG supply security.

- Viet Nam is a net exporter of crude oil but is an importer of petroleum products for domestic demand because of limited oil refinery capacity. Viet Nam will expand its refinery capacity, but it will still have to import petroleum products until 2040. Petroleum products are mainly used for road transport; therefore, fuel switching from oil fuels to electricity and hydrogen is an important policy in Viet Nam in order to reduce the dependence on energy imports.
- A safe and stable electricity supply system is very important for Viet Nam, given how renewable energy sources have been developing and will develop in the coming years. Therefore, it is necessary to develop a power generation source with a reasonable structure, such as maximally mobilised hydropower sources, pump hydro and back-up systems such as battery storage, or hydrogen power generation. In this way, it is very important to give priority to wind power and solar power development in accordance with the ability to ensure system safety at reasonable prices and natural gas power as an important source of power supply.
- Viet Nam is a large coal exporter in the ASEAN and East Asia region, but, due to promotion of carbon neutrality globally, Viet Nam cannot export coal to other countries in the future. If so, Viet Nam will produce hydrogen applying gasification technology to coal with CCS and export it based on the hydrogen value chain network. Viet Nam expects continuous export of hydrogen instead of coal.
- For the CCUS, the establishment of policies and regulations for Enhanced Oil and Gas Recovery need to be accelerated. Viet Nam has the potential to store CO_2 in aquifers, and it needs to be linked to the wider ASEAN CO_2 storage hub. Thus, the promotion of CO_2 storage in Viet Nam is critical for the acceleration of the CCUS in the region.

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