Chapter 16
Viet Nam Country Report

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1. Introduction

1.1. Basic Concept of Low-carbon Energy Transition–Carbon Neutrality

The energy sector is the primary source of greenhouse gas (GHG) emissions in Viet Nam, accounting for approximately 65% of the country's total emissions by 2016 (MONRE, 2020). Thus, a transition to a low-carbon energy system is necessary to reduce the energy-related carbon dioxide (CO_2) emissions from fossil fuels and can make a significant contribution to achieve a carbon neutral target in Viet Nam by 2050.

Low carbon energy transition-carbon neutrality (LCET–CN) is a significant structural change in an energy system regarding energy supply and consumption to achieve carbon neutrality or to a balanced state between emitting carbon and absorbing carbon from the atmosphere.

LCET–CN can be done through investment in low-carbon technologies such as renewable energy, energy efficiency and conservation (EE&C), and other new technologies such as hydrogen and carbon capture and storage (CCS).

Investment in renewable energy and energy efficiency will be strongly implemented from 2020 to 2050, whilst hydrogen and CCS technologies will consider implementation when these technologies are mature enough and widely commercialised. It is expected to apply hydrogen by 2035 and CCS by 2040.

Investments in low-carbon technologies will increase costs due to the high cost of new technologies, but benefit from energy savings and reduced CO_2 emissions.

This study will develop a LCET–CN scenario and calculate the investment costs and emissions reduction benefits of the LCET–CN scenario compared with the BAU scenario.

1.2. Energy Policies to Achieve LCET–CN Scenario

Viet Nam has committed to develop and implement strong emissions reduction measures to achieve net-zero emissions by 2050 using its own resources, along with cooperation and support from the international community.

The Government of Viet Nam recently implemented a series of strategies and policies in the energy sector to fulfil its commitment of increasing the share of renewable energy sources in power generation, enhancing energy efficiency, and promoting fuel switching to reduce GHG emissions. The targets for reducing GHG emissions, conserving energy, promoting fuel switching, and advancing renewable energy development, as outlined in legal documents, are summarised in Table 16.1.

Table 16.1. Mitigation Targets and Related Legal Documents

Legal Document	Mitigation Targets and Actions
National Climate Change Strategy, Vision to 2050	**Targets:** Viet Nam will strive to achieve net-zero emissions by 2050. • By 2030: GHG emissions in the energy sector decreases by 43.5% from BAU and emissions do not exceed 457 $MTCO_2e$. • By 2050: Total national GHG emissions reach net zero, GHG emissions in the energy sector reduces by 91.6% from BAU, and emissions do not exceed 101 million tonnes of CO_2 equivalent.
National Power Development Plan period 2021–2030, with Outlook to 2050 (PDP VIII)	**Targets:** • Increase the share of renewable energy in power generation to 49.6% in 2030 and from 82.0% to 91.8% in 2050 in term of installed capacity. • Increase the share of electricity generated from renewable resources from 30.9% to 39.2% in 2030 and from 67.5% to 71.5% in 2050.
MOIT's Action Plan for Implementing the Viet Nam's Commitments at COP26	• Strengthen implementation of energy efficiency measures by improving Minimum Energy Performance Standards (MEPS). • Phase out the use of fossil fuels in the energy sector. • Apply CCS in industry fields such as cement, steel, and chemical industries. • Develop renewable energy projects such as solar PV, wind power, hydropower, hydrogen, CCS, and energy storage technologies. • Promote electrification and energy efficiencies in residential, transport sectors.
Action Plan on Green Energy Transition GHG Emissions Reduction in Transport Sector	**Target:** Develop a green transport system towards net-zero emissions by 2050. • By 2030: Promote energy efficiency and encourage the switch to electricity and green energy in fields where technologies, institutions, and resources are available to fulfil the country's commitments in its NDC. • By 2050: Prioritise the development of sustainable modes of transport and achieve net-zero emissions by transitioning all transportation means, equipment, and infrastructure to use electricity and green energy.

BAU= business as usual, CCS = carbon capture and storage, COP26 =26th Session of the Conference of Parties, GHG = greenhouse gas, MOIT = Ministry of Industry and Trade, NDC = nationally determined contribution, PV = photovoltaic.
Source: Compiled by author.

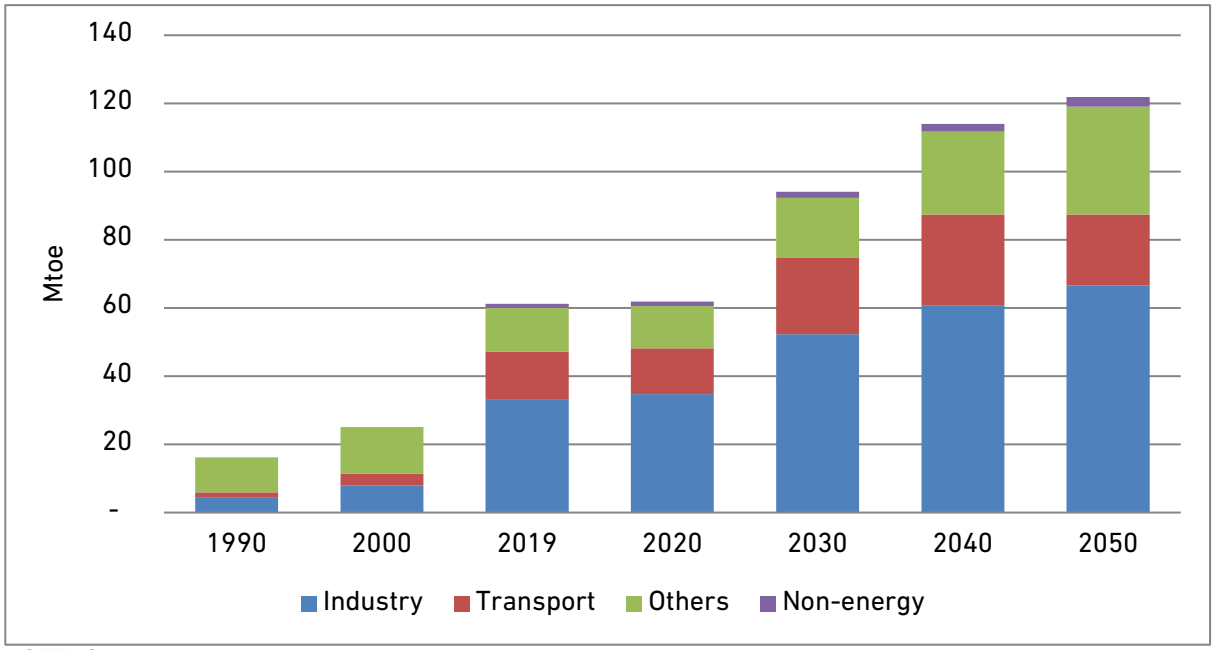
2. Analysis of LCET–CN Results

2.1. Total Final Energy Consumption

Viet Nam's total final energy consumption (TFEC) in 2019 was 61.3 million tonnes of oil equivalent (Mtoe), which has increased by 4.7% per year, 3.8 times more than its 1990 level of 16.1 Mtoe. On a per sector basis, the fastest growth occurred in the transport sector (8.3% per year), followed by the industry sector (7.1%), and the residential/commercial ('others') sector (0.9% per year). Non-energy use is expected to grow at 13.9% per year.

For 2019–2050, the TFEC is projected to increase at an average rate of 2.2% per year under the LCET–CN scenario. The increase is driven by strong economic growth, which is assumed to be at an average annual growth rate of 5.2% and the rising population with an average annual growth rate of 0.4%. On a per sector basis, the 'others' sector is expected to exhibit the strongest growth in energy consumption, with an annual increase of 2.9%. This is followed by the industry sector with an annual growth of 2.3% and the transport sector with 1.3%. Non-energy use is expected to grow at 2.8% per year. Figure 16.1 shows the final energy consumption by sectors from 1990 to 2050.

Figure 161. Final Energy Consumption by Sector, LCET–CN Scenario, 1990–2050



LCET–CN = low carbon energy transition–carbon neutral, Mtoe = million tonnes of oil equivalent.
Note: 'Others' includes residential and commercial sectors.
Source: Author's calculations.

The 'others' sector was the primary source of the country's energy consumption in 1990, accounting for around 63%. This was mainly due to the use of biomass fuel used for residential cooking. This share decreased to 21.1% by 2019 due to the growing economy,

which led to the substitution of biomass fuels with more efficient commercial fuels. Economic growth is expected to continue improving the standard of living, thus increasing the transition from biomass to modern fuels such as liquefied petroleum gas.

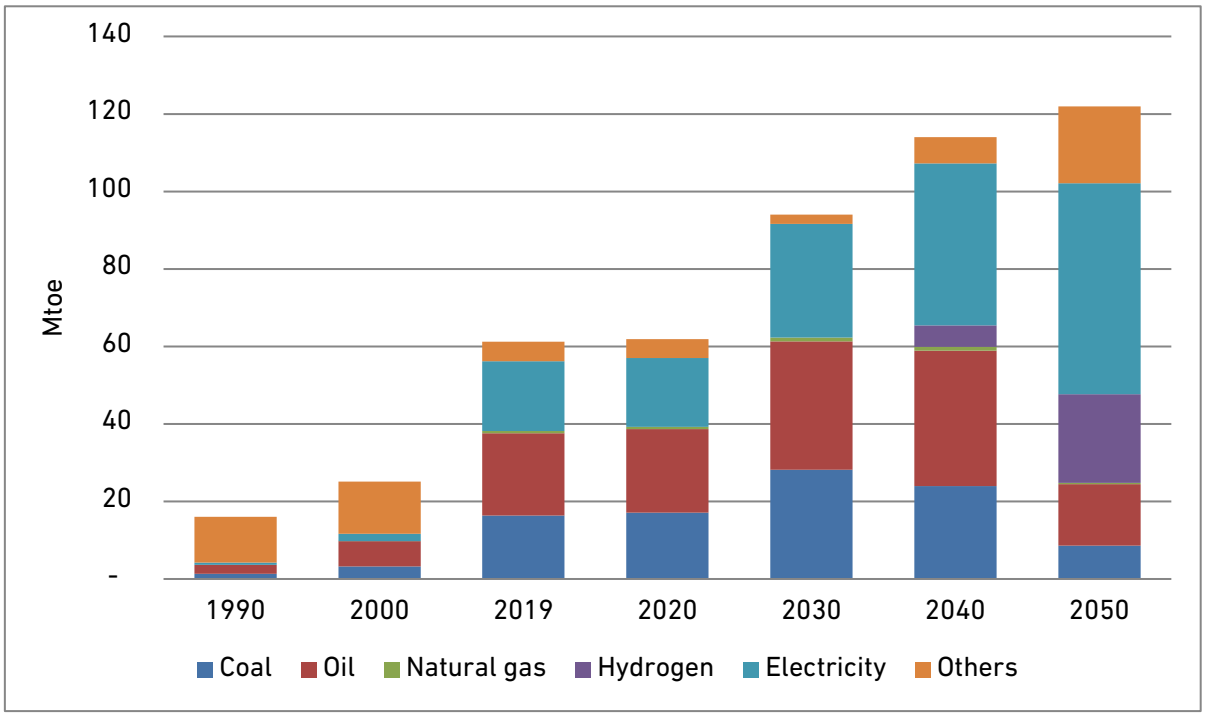
During 2019–2050, the industry sector is expected to remain the largest consumer of energy in Viet Nam. However, its share of energy consumption will increase from 54.0% in 2019 to 56.2% in 2020, before slightly declining to 54.6% in 2050. Meanwhile, the 'others' sector will become the second largest consumer, with its share increasing slowly from 21.1% in 2019 to 26.0% in 2050.

In 1990, other fuels – mainly biomass – had the highest consumption rate, accounting for 73.9% of the TFEC. However, this share decreased dramatically to 8.3% in 2019. Oil was the second most consumed product, making up 14.5% of the TFEC in 1990 and increasing to 34.7% in 2019. Coal consumption increased from 8.3% in 1990 to 26.7% in 2019. Electricity had a small share of 3.3% in 1990 but increased to 29.4% in 2019.

On a per fuel basis under the LCET–CN scenario, other fuels (mainly biomass) are projected to exhibit the fastest growth in final energy consumption, increasing at 4.5% per year between 2019 and 2050. Electricity was the second-highest growth rate of 3.6% per year, due to the increasing use of electricity in transport. The remaining fuels are projected to be decreased, due to fuel switching from fossil fuel to clean energy such as hydrogen, electricity and biomass. Coal is projected to decrease at the highest annual rate of 2.0% per year, followed by natural gas with 1.3% and oil with 1.0%.

In 2019, oil products held the largest share of energy at 34.7%. This share is projected to decrease to 13.0% in 2050. The second-largest share of demand is electricity, which is projected to increase from 29.4% in 2019 to 44.6% in 2050. By 2050, coal will decrease from 26.7% in 2019 to 7.1% in 2050, whilst other fuels (mainly biomass) will increase from 8.3% in 2019 to 16.2% in 2050. However, natural gas is expected to decrease from 0.9% in 2019 to 0.3% in 2050. (Figure 16.2).

Figure 16.2. Final Energy Consumption by Fuel Type, LCET–CN Scenario, 1990–2050



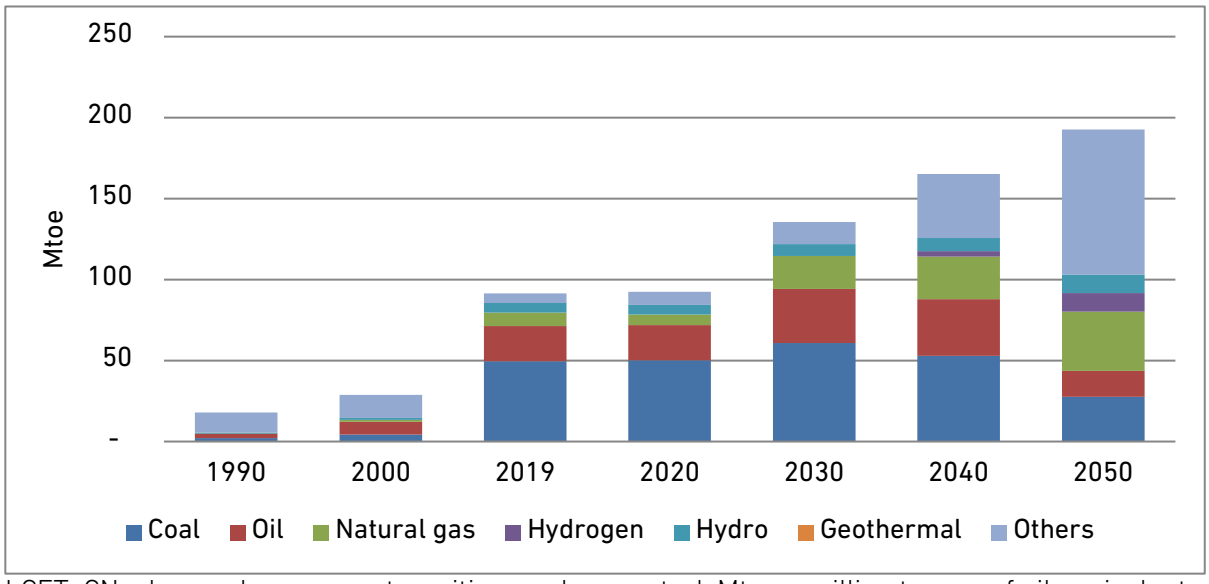
LCET–CN = low carbon energy transition–carbon neutral, Mtoe = million tonnes of oil equivalent.
Note: 'Others' is mainly biomass.
Source: Author's calculations.

2.2. Total Primary Energy Supply

The total primary energy supply (TPES) of Viet Nam grew at a higher rate than the TFEC. It increased by 5.8% per year, from 17.9 Mtoe in 1990 to 91.4 Mtoe in 2019. Also, between 1990 to 2019, natural gas consumption grew at an average annual rate of 31.3%, coal at 11.3%, hydropower at 9.2%, and oil at 7.5%.

In the LCET–CN scenario, Viet Nam's TPES is projected to increase at an annual rate of 2.4%, from 91.4 Mtoe in 2019 to 192.6 Mtoe in 2050. The fastest growth is expected in other fuels (mainly biomass), increasing at an annual average rate of 9.1% between 2019 and 2050, followed by natural gas at 5.0% and hydro at 2.1%. Meanwhile, coal and oil will decrease at 1.9% and 1.0% per year, respectively. Figure 16.3 shows the primary energy supply by source in for 1990–2050.

Figure 16.3. Primary Energy Supply, LCET–CN Scenario, 1990–2050



LCET–CN = low carbon energy transition–carbon neutral, Mtoe = million tonnes of oil equivalent.
Note: 'Others' is mainly biomass.
Source: Author's calculations.

In 2019, other sources accounted for the smallest share of TPES at 6.5% and is expected to increase strongly to be the largest share at 46.5% in 2050, whilst natural gas would increase from 8.9% to 19.0%. This growth is due to the projected decline of coal from 54.2% in 2019 to 14.4% in 2050, oil from 23.9% to 8.2%, and hydro from 6.5% to 5.9%.

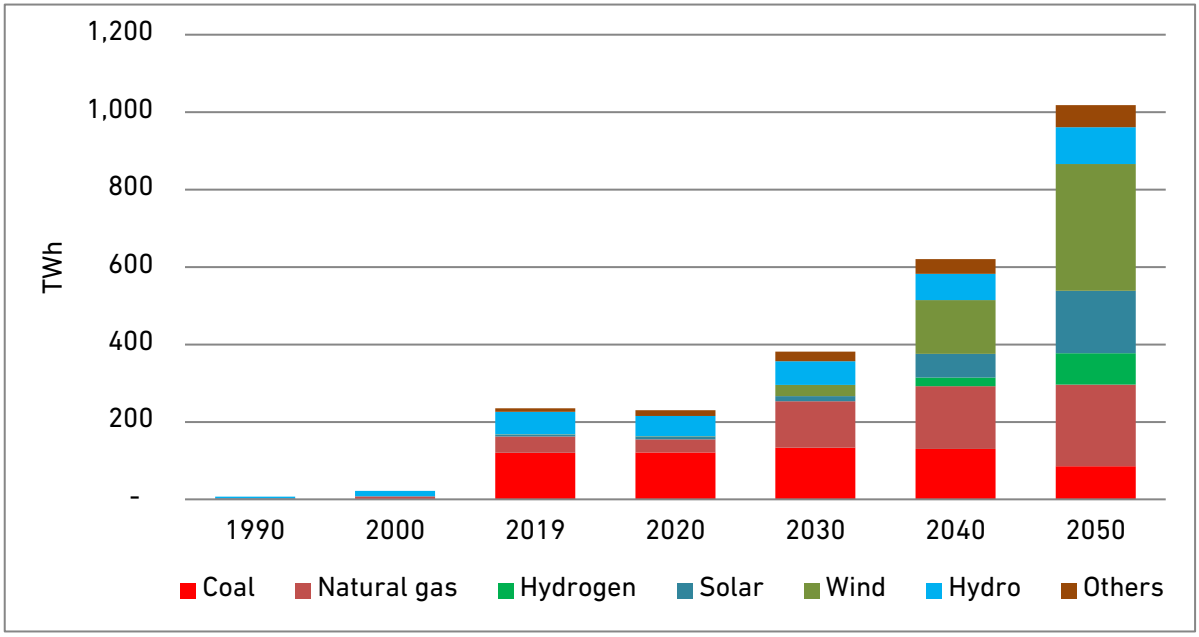
2.3. Power Generation

Power generation output increased at 12.1% per year, or 27.3 times, from 8.7 terawatt-hours (TWh) in 1990 to 236.9 TWh in 2019. The fastest growth occurred in natural gas power generation (35.8% per year), followed by coal (15.2%), hydro power (8.5%), and oil power (1.7%).

Under the LCET–CN scenario, power generation is projected to increase by an average of 4.8% per year, or 4.3 times between 2019 and 2050, to meet electricity demand. Wind power generation is projected to experience the highest growth rate of 21.8% per year, followed by solar (12.0%), others, including biomass, small hydro and imported electricity (6.2%), natural gas (5.3%) and hydro (1.6%). The high growth rates of wind and solar are due to their substitution for coal, which are projected to decrease at an annual rate of 1.1%.

Figure 16.4 shows the power generation output by type of fuel under the LCET–CN scenario from 1990 to 2050.

Figure 16.4. Power Generation by Fuel Type, LCET–CN Scenario, 1990–2050



LCET–CN = low carbon energy transition–carbon neutral, TWh = terawatt hour.
Note: 'Others' includes biomass, wind, solar and imported electricity.
Source: Author's calculations.

By the end of 2019, most of Viet Nam's power came from coal, which comprised about 50.7% of the total power generation mix. The share of hydro power generation was around 24.3%, whilst the rest was from natural gas (18.0%), solar (2.0%), oil (0.9%), wind (0.3%), and 'others' (around 3.8%).

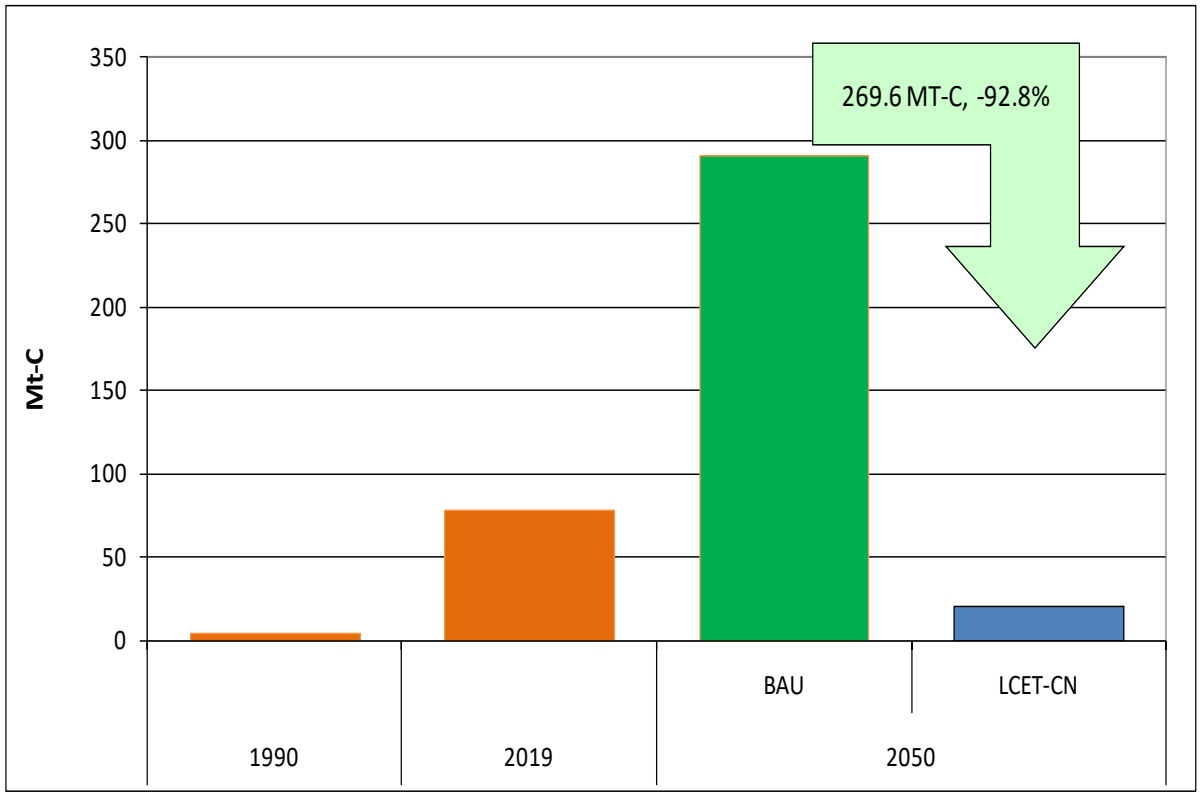
From 2020 to 2050, wind is projected to be the highest energy transition to replace coal for power generation under the LCET–CN scenario with its share growing from the smallest share of 0.5% in 2020 to the largest share of 32.2% in 2050. Natural gas is anticipated to be the second highest energy transition from natural gas without CCS (with its share increasing from 14.5% in 2020 to 31.2% in 2030) to natural gas with CCS with the second largest share of 20.8% in 2050. The third highest energy transition is solar, with its share increasing from 3.4% in 2020 to 15.8% in 2050. These high growth rates are due to the projected decline of coal with the highest energy transition from 52.6% (without CCS) in 2020 to 8.3% (with CCS) in 2050 and the share of hydro in the total power generation will decline from 22.4% in 2020 to 9.3% in 2050.

2.4. Carbon Dioxide Emissions

The total CO_2 emissions under the LCET–CN scenario is projected to decrease by 4.2% per year from 78.5 million tonnes of carbon (Mt-C) in 2019 to 20.9 Mt-C in 2050, which is lower than CO_2 emissions in 2019 at 57.7 Mt-C. In 2050, CO_2 emissions in the BAU scenario is projected at 290.5 Mt-C, thus the reduction in LCET–CN scenario, compared to BAU is about 269.6 Mt-C, or 92.8% (Figure 16.5).

The above calculation results show that Viet Nam could achieve carbon neutrality by 2050 because LCET scenario can achieve 20.9 Mt-C that is lower than the potential of carbon sink by forest with 27.5 Mt-C until 2050. The LCET scenario includes EE&C measures and significant use of variable renewable energy, such as solar PV and wind. It also integrates new energy technologies, such as hydrogen from national grid and CCS applied to coal and gas power plants. Implementing ambitious EE&C measures, renewable energy development, and new technologies will be crucial for reducing CO_2 emissions across various sectors. There are lots of challenges ahead of Viet Nam, but if the country could tackle these challenges, the LCET–CN scenario suggests it can achieve carbon neutrality by 2050.

Figure 16.5. Evolution of Carbon Dioxide Emissions, BAU and LCET–CN Scenarios, 1990, 2019, and 2050



BAU = business as usual, LCET–CN = low-carbon energy transition–carbon neutral, Mt-C = million tonnes of carbon.
Source: Author's calculations.

2.5. Hydrogen Demand Across the Sectors

Hydrogen is a clean alternative fuel, which has the potential to provide for energy in transportation, distributed heat, power generation, and energy storage systems. Hydrogen fuel can be produced through several methods. The most common methods today are natural gas reforming (a thermal process) and electrolysis.

In Viet Nam, hydrogen can be produced from a domestic resource with electrolysis technology using the national grid and partly imported. Because Viet Nam's power source to 2050 is mostly produced from renewable energy (RE) sources and gas with the use of CCS, therefore, there are a little carbon emissions and could be critical for achieving LCET–CN.

Hydrogen is expected to start using from 2035 for industrial production, transportation and power generation. By 2050, the total demand for hydrogen is about 34.5 Mtoe, in which around 11.6 Mtoe, accounting for 33.5% of total demand, will be used for power generation.

On the demand side, by 2050, the total hydrogen is expected to reach about 22.9 Mtoe, accounting for 66.5% of total demand. Hydrogen consumption demand in industry sector will be the higher with 12.0 Mtoe (or 52.4%), which are mainly used for the production of iron and steel and other industries. The remained amount of hydrogen with 10.9 Mtoe (or 47.6%) will be used to replace diesel oil and fuel oil in transport.

3. Cost Comparison between BAU and LCET–CN Scenarios

3.1. Introduction

To achieve the target of carbon neutral by 2050, investing in energy-saving technologies, RE, hydrogen, and CCS in the LCET–CN scenario will reduce energy consumption and reduce emissions but will increase investment costs compared to BAU. This section will focus on cost calculation and comparison between the two scenarios – BAU and LCET–CN.

Because the cost calculation for the cost of scenarios is complicated, whilst the input data are limited or not available, then in this study, the calculations are based on the available calculation results on the consumption of the types of fuel in different sectors, input fuel for power generation and electricity produced from different power generation technologies in the base year of 2019 and 2050. It is assumed that the difference in energy use between 2050 and 2019 will be an effort on energy efficiency and energy transition for the whole period of 2019–2050.

3.2. Cost Comparison

Fuel Cost

Applying energy efficiency measures on the demand side and a strong shift from fossil fuels to clean fuels, especially using RE and hydrogen in power generation, will significantly reduce primary energy demand in the LCET–CN scenario. Based on the assumption of fuel prices of each type, it is possible to calculate and compare fuel costs in the two scenarios – BAU and LCET–CN.

Assumptions on Fuel Costs

The assumptions on fuel costs in physical units at the 2019 constant prices are presented in Table 16.2.

Table 16.2. Assumptions on Fuel Costs

Fuel	2019/2020		2050 (2019 constant price)	
Coal	80.03	US$/ton	98	US$/ton
Oil	41	US$/bbl	100	US$/bbl
Gas	7.77	US$/MMBTU	7.5	US$/MMBtu
Hydrogen	0.8	US$/$Nm^3$	0.3	US$/$Nm^3$
CCS		US$/$CO_2$ ton	30	US$/$CO_2$ ton

bbl = barrel, CCS = carbon-capture and storage, CO_2 = carbon dioxide, MMBtu = metric million British thermal unit, Nm^3 = normal cubic metre.
Source: ERIA.

The calculation results show that coal demand in the BAU scenario during the period of 2019-2050 increases to 124.9 Mtoe at a cost of US$19,739.0 million, followed by the oil increased to 63.4 Mtoe at a cost of US$43,601.5 million and natural gas, increased to 29.4 Mtoe at a cost of US$8,497.4 million. The total incremental cost in the BAU scenario is US$7,1837.9 million (Table 16.3).

Table 16.3. Fuel Costs in BAU Scenario

Fuel	Primary Energy Consumption			Fuel Cost (US$ million)
	2019	2050	2050–2019	2050–2019
Coal	49.5	174.4	124.9	19,739.0
Oil	21.8	85.2	63.4	43,601.5
Gas	8.1	37.5	29.4	8,497.4
Hydrogen	0.0		0.0	0.0
Total	79.5	297.2	217.7	71,837.9

BAU = business as usual, LCET–CN = low-carbon energy transition–carbon neutral.
Source: Author's calculations.

In the LCET–CN scenario, the highest decrease in coal demand by 2050 is 21.8 Mtoe compared to 2019, equivalent to a reduced cost of US$3,451.7 million, followed by oil with a decrease of 6.0 Mtoe with a decrease in cost compared to 2019 of US$4,102.3 million due to the strong use of renewable energy replacing coal for power generation,

and the use of clean fuels (electricity and hydrogen) to replace oil in transportation. Meanwhile, natural gas increased by 28.5 Mtoe with an additional cost of US$8,224.4 million and hydrogen increased by 11.6 Mtoe, with an additional cost of US$13,480.3 million. The total additional cost compared to 2019 in the LCET–CN scenario is US$14,150.8 million (Table 16.4).

Table 16.4. Fuel Costs in LCET–CN Scenario

Fuel Type	Primary Energy Consumption			Fuel Cost (US$ million)
	2019	2050	2050–2019	2050–2019
Coal	49.5	27.7	–21.8	–3,451.7
Oil	21.8	15.9	–6.0	–4,102.3
Gas	8.1	36.6	28.5	8,224.4
Hydrogen	0.0	11.6	11.6	13,480.3
Total	79.5	91.7	12.2	14,150.8

LCET–CN = low-carbon energy transition–carbon neutral.
Source: Author's calculations.

Power Generation Investment

Investment costs for power generation technologies are calculated based on input data such as investment cost per unit of capacity, capacity factors, and corresponding power output of each power plant.

Table 16.5 shows investment costs and capacity factors of power generation technologies in 2019 and 2050.

Table 16.5. Investment Cost and Capacity Factors

	Investment Cost (US$/KW)		Capacity Factors (%)	
	2019	2050	2019	2050
Coal	1,500	1,525	75	80
Oil			75	80
Gas	700	700	75	80
Hydrogen		700		80
Hydro	2,000	2,223	50	40
Solar	1,600	307	17	17
Wind	1,600	1,235	40	40
Biomass	2,000	3,019	50	70

KW = kilowatt.
Source: Author's calculations.

Based on data on investment cost per unit of capacity, capacity factor, output difference between the years 2050 and 2019, we can calculate the additional capacity in the period of 2019–2050 and then calculate the investment cost for power generation for the period 2019-2050 of the BAU and LCET–CN scenarios, as shown in Table 16.6.

Table 16.6. Power Generation Investment Costs – BAU Scenario

	Generation Outputs (TWh)			Additional Capacity (MW)	Costs (US$ million)
	2019	2050	2050–2019	2019–2050	2019–2050
Coal	120.2	536.8	416.6	59,452	90,665
Oil	2.1	0.0	–2.1	0	0
Gas	42.6	220.9	178.3	25,445	17,812
Hydrogen	0.0	0.0	0.0	0	0
Hydro	66.1	91.1	24.9	7,116	15,819
Solar	4.8	6.1	1.3	894	275
Wind	0.7	0.7	0.0	7	9
Biomass	0.4	1.0	0.7	114	344
Total	236.9	856.73	619.8	92,428	124,922

BAU = business as usual. MW = megawatt, TWh terawatt-hour.
Source: Author's calculations.

In the BAU scenario, the power output from coal-fired power plants in 2050 increases significantly with 416.6 TWh compared to 2019, equivalent to an additional capacity of 59,452 MW and an additional investment cost of US$90,665 million. This is followed by gas with an increase in power output of 178.3 TWh, equivalent to a capacity of 25,445 MW and an additional investment cost of US$ 17,812 million and hydro with an increase of 24.9 TWh, equivalent to a capacity of 7,116 MW and an additional investment cost of US$15,819 million. Whilst renewable power sources (solar, wind, biomass) increased insignificantly to about 2 TWh, equivalent to a capacity of 1,015 MW and an additional investment cost of US$627 million.

In the LCET–CN scenario, due to a strong shift from coal power to clean energy sources such as RE and hydrogen, the electricity output from coal-fired power in 2050 will decrease significantly by 35.0 TWh compared to 2019, equivalent to a reduced capacity of 4,996 MW and a reduced investment cost of US$7.619 million. Meanwhile, renewable power sources (solar, wind, biomass) increased significantly. The highest is wind power, increased by 326.8 TWh, equivalent to a capacity of 93,264 MW and additional investment cost of US$115,181 million, followed by solar power, increased by 156.3 TWh, equivalent to a capacity of 104,968 MW and additional investment cost is US$32,252 million, and

biomass power, increased by 27.3 TWh, equivalent to a capacity of 4,452 MW and an additional investment cost of US$13,439 million.

In addition, the electricity output from natural gas increased by 168.8 TWh, equivalent to a capacity of 24,081 MW and additional investment costs of US$16,857 million, followed by hydrogen, increased to 80.7 TWh, equivalent to a capacity of 11,521 MW and an additional investment cost of US$ 8,065 million, and hydropower increased by 58.2 TWh, equivalent to a capacity of 16,609 MW and additional investment costs of US$36,922 million (Table 16.7).

Table 16.7. Power Generation Investment Costs – LCET–CN Scenario

	Generation Outputs (TWh)			Additional Capacity	Costs
	2019	2050	2050–2019	2019–2050	2019–2050
Coal	120.2	85.1	–35.0	–4,996	–7,619
Oil	2.1	0.0	–2.1	0	0
Gas	42.6	211.4	168.8	24,081	16,857
Hydrogen	0.0	80.7	80.7	11,521	8,065
Hydro	66.1	124.3	58.2	16,609	36,922
Solar	4.8	161.1	156.3	104,968	32,225
Wind	0.7	327.5	326.8	93,264	115,181
Biomass	0.4	27.6	27.3	4,452	13,439
Total	236.9	1,017.9	781.0	249,899	215,071

LCET–CN = low-carbon energy transition–carbon neutral, TWh = terawatt-hour.
Source: Author's calculations.

Carbon Capture and Storage Cost

CCS will be calculated mainly for power generation using fossil fuels including coal and natural gas.

The cost of CCS is mainly calculated for coal and gas power plants with CCS equipment installed. With assuming that CCS devices can capture up to 90% of CO_2 emissions and the average cost of capture is about US$30/$CO_2$ ton, the total cost for CCS can be calculated by US$3,962 million, of which US$2.049 million for gas power and the remaining US$1,913 million is for coal power.

Overall Cost

Based on the above calculation results, it is possible to compare costs between the LCET–CN and BAU scenarios as presented in Table 16.8.

Table 16.8. Cost Comparison between LCET–CN and BAU Scenarios in 2050

(US$ million)

	BAU	LCET–CN	LCET–CN vs. BAU
Fuel Cost	71,838	14,151	–57,687
Power Capital Cost	124,922	215,071	90,148
CCS	0	3,962	3,962
Total	196,760	233,183	36,423

BAU = business as usual, CCS = carbon capture and storage, LCET–CN = low-carbon energy transition–carbon neutral.
Source: Author's calculations.

From Table 16.8, it is shown that investing in clean energy sources such as RE and hydrogen to replace coal for power generation and oil products for transportation in the LCET–CN scenario leads to higher costs than BAU by US$90,148 million, but reduces the fuel costs by US$57,687 million. However, even though the investment costs in RE and hydrogen are high, there still be a great benefit to reducing CO_2 emissions and therefore, if carbon prices are taken into account, the costs in the LCET–CN scenario can be significantly reduced.

In addition, the cost for CCS in the LCET–CN scenario is about US$3,962 million. The total cost in the LCET–CN scenario is US$36,423 million higher than the BAU.

4. Conclusions and Recommendations

4.1. Conclusions

- Energy transition in energy use and power generation are important activities to achieve the carbon neutral in Viet Nam by 2050. The increasing investment costs for energy transition, especially investment in RE and hydrogen will reduce the cost of using fossil fuels such as coal and oil products as well as reduce CO_2 emissions.
- The total cost in the LCET–CN scenario is US$36,423 million higher than the BAU scenario, mainly due to the higher investment costs in RE sources. However, if carbon prices are included in the calculation, the costs in the LCET–CN scenario can be significantly reduced.
- The additional cost due to investment in CCS is US$3,962 million. Due to the assumption that CCS starts to invest in 2040 and will be widely used by 2050, if the cost of CCS technology is reduced by 2050, the investment cost for CCS may decrease accordingly.

4.2. Recommendations

To achieve the goal of net-zero emissions by 2050, Viet Nam must reduce its reliance on fossil fuel quickly – especially coal-fired power – and switch to renewable energy sources and low greenhouse gas emissions technologies such as CCS and hydrogen. However, whilst the cost of solar and wind energy has been decreasing rapidly, their reliability depends on the weather and time of day. Further, CCS and hydrogen technologies are still in their early stages and require substantial financial investments. Therefore, promoting EE&C measures is essential for Viet Nam in the coming years to reduce overall energy consumption, especially in using fossil fuel. Therefore, the Government of Viet Nam should:

- further improve standards and technical regulations on energy consumption norms in different sectors, strengthening the implementation of energy efficiency measures.
- issue policies on the development and application of energy service companies, enabling assessment of energy efficiency potential and external investment in EE&C measures, and
- enhance the implementation of solutions for the efficient use of energy and promote the transition to clean energy and electrification in industry, transport, services, trade, etc.

Coal thermal power plants play a significant role in meeting Viet Nam's growing electricity demand. However, because of the goal of achieving net-zero emissions, the country is transitioning from coal to natural gas for power generation and exploring options for natural gas or LNG imports. The development of transparent markets in Asia will enhance Viet Nam's LNG supply security.

The demand for petroleum products in Viet Nam will increase in the coming years. Whilst Viet Nam is a net exporter of crude oil, it relies on petroleum product imports due to limited oil refinery capacity for domestic needs. Efforts will be made to expand its refinery capacity, but petroleum product imports will still be needed until 2040. To reduce dependence on energy imports, Viet Nam is implementing policies focused on fuel switching from oil to electricity and hydrogen, especially for road transport.

As renewable energy sources will expand rapidly in the coming years, ensuring a safe and stable electricity supply system is crucial for Viet Nam. Therefore, it is necessary to develop a well-balanced power generation portfolio that maximises the use of hydropower resources, prioritise the development of wind and solar power, whilst ensuring safety at reasonable prices, and develop natural gas power as an important source of power supply.

Shifting energy towards net zero emissions by 2050 is a big challenge for Viet Nam, especially the challenges on finance, technology, policy institutions, and regulatory

framework for the energy transition. In order to overcome these policy challenges, some recommendations are proposed as follows:

- Formulation of the Law on Renewable Energy, in support of RE manufacturing industry development, RE deployment, electricity transmission and storage improvement, green hydrogen production and use, etc.
- Develop policy on cooperation in research and development (R&D) between public and private sector entities, focusing on R&D of technological innovations in solar and wind power, energy storage, energy efficiency, green hydrogen and derivatives, and CCS, as well as information technology applications in the power sector, as appropriate.
- Develop a long-term legal framework to achieve net-zero emissions and ensure the transition from fossil energy to low-emissions energy.
- Complete the legal framework on green credit, mechanisms and policies and sanctions to create favourable conditions for credit growth for projects on the list of green classification, response to climate change and energy transition.

References

General Statistics Office, Government of Viet Nam (2020), *Statistical Yearbook of Viet Nam*. Ha Noi: General Statistics Office.

Government of Viet Nam (2017), Decision No. 60/QD-TTg dated 16 January 2017 of the Prime Minister for Approving the Development Plan of the Gas Industry of Vietnam by 2025, with Vision to 2035. Ha Noi: Government of Viet Nam.

Government of Viet Nam (2019), Decision 280/QD-TTg dated 13 March 2019 of the Prime Minister on Approval for National Program for Thrifty and Efficient Use of Energy for the Period of 2019 -2030. Ha Noi: Government of Viet Nam.

Government of Viet Nam (2022a), Decision No. 876/QD-TTg dated 22 July 2022 of the Prime Minister on Approving the Action Plan on Green Energy Transition and Mitigation of Carbon Dioxide and Methane Emissions from Transportation. Ha Noi: Government of Viet Nam.

Government of Viet Nam (2022b), Decision No. 896/QD-TTg dated 26 July 2022 of the Prime Minister on Approving the National Strategy for Climate Change until 2050. Ha Noi: Government of Viet Nam.

Government of Viet Nam (2023), Decision No. 500/QD-TTg dated 15 May 2023 of the Prime Minister on Approving the National Power Development Plan for the Period 2021–2030, with Vision to 2050. Ha Noi: Government of Viet Nam

Ministry of Industry and Trade (2022), Decision No. 626/QD-TTg dated 05 April 2022 on Approving the Action Plan of Ministry of Industry and Trade for Implementing Viet Nam's Commitments at COP26. Ha Noi: Ministry of Industry and Trade.

Ministry of Natural Resources and Environment (MONRE) (2020), *Viet Nam – Report on National GHG Inventory for 2016*. Ha Noi: Ministry of Natural Resources and Environment.

Viet Nam Electricity (2018), *Annual Report*, *2018*. Ha Noi: Viet Nam Electricity.

Viet Nam Electricity (2021), *Annual Report*, *2021*. Ha Noi: Viet Nam Electricity.