Chapter 6
Indonesia Country Report

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National Energy Council, Indonesia

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

Net-zero emissions refers to achieving an overall balance between greenhouse gas (GHG) emissions produced and taken out of the atmosphere (Climate Council, 2023).

To achieve net-zero emissions, the use of fossil energy should be reduced and new and renewable energy should be increased. Fossil energy can still be used but is supported by clean technology such as clean coal technology, carbon capture and storage (CCS) and carbon capture, utilisation, and storage (CCUS). Meanwhile, accelerating the use of new and renewable energy is carried out by increasing the use of electricity through the substitution of conventional vehicles for electric vehicles, and the use of biofuels, hydrogen, and batteries. Besides that, new and renewable energy needs to be supported by the application of smart grids and energy conservation to achieve energy security and sustainable development.

Through the Long-term Strategy for Low Carbon and Climate Resilience 2050 (Government of Indonesia, 2021) published by the Ministry of Environment and Forestry, Indonesia wants to reduce GHG emissions to 540 million tonnes of carbon dioxide equivalent (Mt-CO_2e) by 2050 (about 150 million tonnes of carbon [Mt-C]), peaking in 2030. Target emissions in 2050 can be achieved through a net-carbon sink of the forestry and land-use sector. Carbon neutrality can be achieved by reducing emissions in energy, waste, and the industrial processes and product use sector. To reach this goal, the forestry sector must continue efforts to increase the amount of carbon absorbed to achieve and maintain the net-carbon sink, even after 2030. On the other side, significant changes are needed in the energy sector, including increasing the use of renewable energy sources, improving energy efficiency, reducing coal consumption, and implementing CCS and CCUS.

Efforts to reduce emissions in the power sector include a sharp increase in renewable energy (RE) generation such as hydro, geothermal, biomass, wind, and solar. This scenario will also develop nuclear and hydrogen power plants to start production in 2040. Coal-fired power plants will be phased out by 2050, with coal-fired power plants with CCS being developed by 2040. The same scenarios will also be implemented for gas-fired power plants.

2. Indonesian Regulations to Support Net-zero Emissions Target

At the United Nations Climate Change Conference in Glasgow in 2021 (COP26), the President of the Republic of Indonesia conveyed a commitment that Indonesia will be able to reach net-zero emissions by 2060 or sooner if it obtains climate financing support from developed countries. To achieve the net-zero emissions target, it is necessary to develop clean energy so that the primary energy supply of RE must be more dominant than energy from fossil fuels. Whilst in the National Energy Policy, the RE target in primary energy supply is 23% in 2025 and 31% in 2050 (Ministry Energy and Mineral Resources, 2014).

In line with Indonesia's commitment to the Paris Agreement, Indonesia's energy system needs a larger portion of renewable energy. So, in 2022, the National Energy Council revised the National Energy Policy with the ambitious RE target to achieve net-zero emissions by 2060.

To support increasing the RE target, some regulations have been developed to increase the biofuel target, the development of electric vehicles (EV) and rooftop solar photovoltaic (PV) systems, cofiring coal power plants with biomass, electric batteries, low price RE generation, and de-dieselisation. The explanation for each topic follows.

2.1. Biofuel

In 2015, the Ministry of Energy and Mineral Resources published Regulation Number 12 on the Provision, Utilisation and Trading of Biofuels as Other Fuels. Since 2016, biofuel in biodiesel (mix of fatty acid methyl ester and diesel) or B20 has been about 20%. The target implementation of biofuel is shown in Table 6.1.

Table 6.1. Minimum Target of Biodiesel

Sector	2015	2016	2020	2025
Micro Enterprises, Fisheries Enterprises, Agricultural Enterprises, Transport, and Public Services (PSO)	15%	20%	30%	30%
Transport, Non PSO	15%	20%	30%	30%
Industrial and Commercial	15%	20%	30%	30%
Power Generation	25%	30%	30%	30%

Source: Ministry of Energy and Mineral Resources.

Last year the B40 road test was launched successfully and since February 2023, the mandatory programme of B35 started. However, the implementation of bioethanol (mix of gasoline and alcohol) has not been implemented to date, even though there are mandatory requirements (Table 6.2).

Table 6.2. Minimum Target of Bioethanol

Sector	2015	2016	2020	2025
Micro Enterprises, Fisheries Enterprises, Agricultural Enterprises, Transport, and Public Services (PSO)	1%	2%	5%	20%
Transport, Non PSO	2%	5%	10%	20%
Industrial and Commercial	2%	5%	10%	20%

Source: Ministry of Energy and Mineral Resources.

2.2. Electric Vehicles

Since 2019, the government is committed to accelerating the development of the EV industry through Presidential Regulation Number 55 of 2019 (Ministry of State Secretariat, 2019) as steps to stimulate the EV market. To formulate further the above strategies, the government also established Presidential Instructions Number 7 of 2022, which directs the use of battery EVs as operational vehicles and/or individual vehicles in central government agencies and regional governments. The directions include:

- accelerating the production of various types of battery-based electric vehicles (battery electric vehicles), both motorcycles and four-wheeled or more motorised vehicles, to meet the needs of the transformation of fuel-powered vehicles into battery-based electric motorised vehicles (battery electric vehicles);
- providing technical support for deepening the structure of the domestic battery-based electric vehicle industry so that it is able to meet the achievement targets at the domestic component level (TKDN);
- accelerating the development of main components and supporting components for the battery electric vehicle industry; and
- accelerating the production of charging stations and supporting components for the battery-based electric motorised vehicle industry.

To increase the penetration of EVs, the government will offer a subsidy on the sale of all electric motorbikes – incentives will be offered to buyers of electric motorbikes that are manufactured in Indonesia. The subsidy is around Rp7 million. With this incentive, it is hoped that the sales target for electric motorbikes can reach 200,000 units but with the condition that the domestic component level reaches 40%.

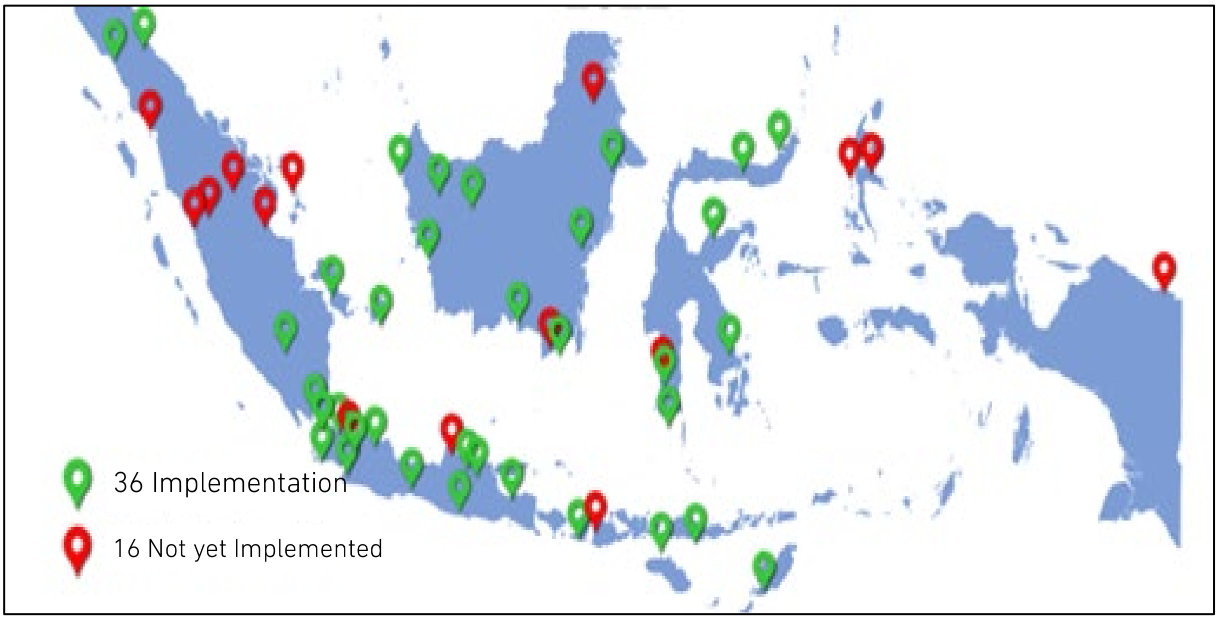
According to data from the Police Department, as of May 2023 there were around 37,000 registered EVs – 30,000 two-wheeled EVs and 7,000 four-wheeled EVs. Meanwhile, according to Statistics Indonesia, the total population of two-wheeled vehicles was around

125 million, and four-wheeled vehicles around 17 million. It means that in 2022, the number of electric motorbikes was only 0.02% and electric cars about 0.04% of the total.

2.3. Cofiring

One programme to support the reduction of emissions is cofiring of coal power by replacing some coal with biomass. The implementation of cofiring is in addition to supporting the recycle, reduce, reuse, and recover (4Rs) energy from waste. Cofiring technology development is low cost because there is no investment needed for the construction of new power plants. Currently, 36 power plants have implemented cofiring commercially (Figure 6.1) in 2023, producing 24 terawatt-hours (TWh) of green energy. The biomass cofiring programme is targeted to use 10.2 million tonnes of biomass in 2025.

Figure 6.1. Cofiring Implementation in Indonesia in 2022



Source: Ministry of Energy and Mineral Resources.

2.4. De-dieselisation

Base on Indonesia's Business Plan for Providing Electricity, there are 5,200 diesel-fired power plants in 2,130 locations (Figure 6.2), which can potentially be included in the de-dieselisation programme. The programme is divided into three schemes: (i) conversion of diesel-fired power plants to RE, (ii) conversion of diesel-fired power plants to gas, and (iii) network expansion to an isolated system to eliminate diesel-fired power plants.

To support the conversion of diesel-fired power plants to gas, the government has set a strategy through the Ministry of Energy and Mineral Resources (MEMR) Decree 249.K/MG.01/MEM/2022 issued in October 2022, which mandated the state oil and gas company Pertamina to supply gas for Perusahaan Listrik Negara (PLN) power generation in 47 power generation dual fuel and mobile power plants.

Figure 6.2. Location of Diesel-fired Power Plants

Source: Business Plan for Providing Electricity PLN 2021–2030 (RUPTL PLN).

2.5. Nuclear Energy Programme Implementing Organisation

One of the programmes to support achieving the net-zero emissions target in 2060 is the construction of a nuclear power plant. Therefore the Minister of Energy and Mineral Resources Decree Number 250.K/HK.02/MEM/2021 has been issued to establish the Nuclear Energy Program Implementation Organization.

2.6. Solar Rooftop

Indonesia has a big potential for solar power. Based on data from the Directorate General of Renewable Energy and Conservation, the potential for solar in Indonesia is about 3,294 GWp (gigawatt peak). The Minister of Energy and Mineral Resources Regulation Number 49/2018 on the Use of Rooftop Solar Power is to encourage domestic use of solar energy. The regulation was amended in 2019 with Regulation Number 13/2019 and Number 16/2019, which address concerns related to licensing and electricity sales to PLN. In 2021, 3,900 customers installed rooftop solar power and in 2023 the number increased to around 8,500 customers This is due to support from the financial sector that provides low-interest loans.

But with an increasing supply of electricity from coal-fired power generation in 2020 and 2021 and electricity consumption growth decreasing due to the COVID-19 pandemic, PLN has limited buying electricity from solar to only 20% of total power generated. It is hoped that the abolition of the export–import provisions for electricity will reduce PLN's financial burden. Currently the capacity of rooftop solar power is 114 megawatts.

2.7. Carbon Capture and Storage, and Carbon Capture, Utilisation, and Storage

Carbon capture, utilisation, and storage (CCUS) refers to a suite of technologies that enable the mitigation of carbon dioxide (CO_2) emissions from large point sources such as power plants, refineries, and other industrial facilities, or the removal of existing CO_2 from the atmosphere.

Indonesia has a CCS plan to be implemented in the oil and gas sector. The government is targeting oil production of 1 million barrels of oil per day and gas production of 12 billion standard cubic feet per day by 2030. On the other hand, Indonesia is committed to supporting the reduction of GHG emissions towards net-zero emissions in 2060 or sooner. CCS and CCUS technology is one of the solutions to achieve these two targets. In the energy transition, natural gas will still play an important role as a bridge to the use of RE.

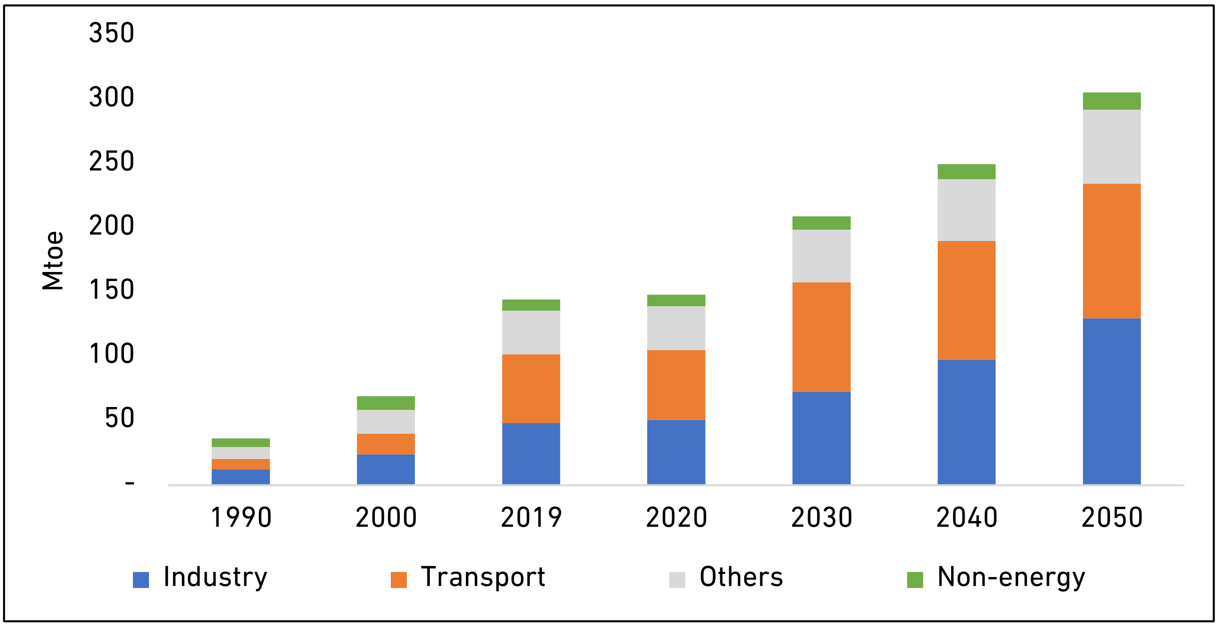
To support emissions reduction, Indonesia published Regulation of the Minister of Energy and Mineral Resources of the Republic of Indonesia Number 2 of 2023 concerning the Implementation of Carbon Capture and Storage, as well as Carbon Capture, Utilization and Storage in Upstream Oil and Gas Business Activities (MEMR, 2023).

Currently there are 16 CCS and/or CCUS projects in Indonesia that are still in the study and preparation stages, and most of them are targeted to operate before 2030. The CCS/CCUS project that has received a Plan of Development approval is Tangguh BP Berau in Papua. In addition, there is also a huff and puff CO_2 injection pilot test by Pertamina in Jatibarang Field (West Java).

3. Final Energy Consumption

Final energy consumption is projected to increase by an average annual growth rate of 2.4% per year (2019–2050). The final energy consumption in the LCET–CN scenario in 2050 is about 306 million tonnes of oil equivalent (Mtoe), mainly influenced by improving energy efficiency in all sectors.

Figure 6.3. Final Energy Consumption by Sector, 1990–2050



Mtoe = million tonnes of oil equivalent.
Source: Author.

Figure 6.3 shows the final energy consumption by sector. Until 2050, the biggest growth rate of energy consumption comes from the industry sector (3.2%), followed by the transport sector (2.2%), whilst the growth rate of the 'others' sector is 1.7% and the non-energy sector is 1.4%. In 2050 the share of final energy consumption will be dominated by the industry sector (42%), which is supported by the economic growth rate increase of about 5% per year.

To achieve emissions reduction according to the LCET–CN scenario, the change that will be made is to replace a portion (10%) of gas and coal consumption in several industrial subsectors with hydrogen. Therefore, in 2050 the share of fossil fuel decreases to 78% from 83% in 2019 and the share of electricity increases from 17% in 2019 to 20% in 2050, and the share of hydrogen will be 3% in 2050 from zero in 2019. Hydrogen as part of clean energy, will start to be used in 2035 for some industries like chemical, non-metallic, and pulp and paper.

In the transport sector, gasoline and diesel consumption that dominated in 2019 will decrease to 37% in 2050 because of the change in the share of electricity (14%), hydrogen (7%), and biofuel (41%).

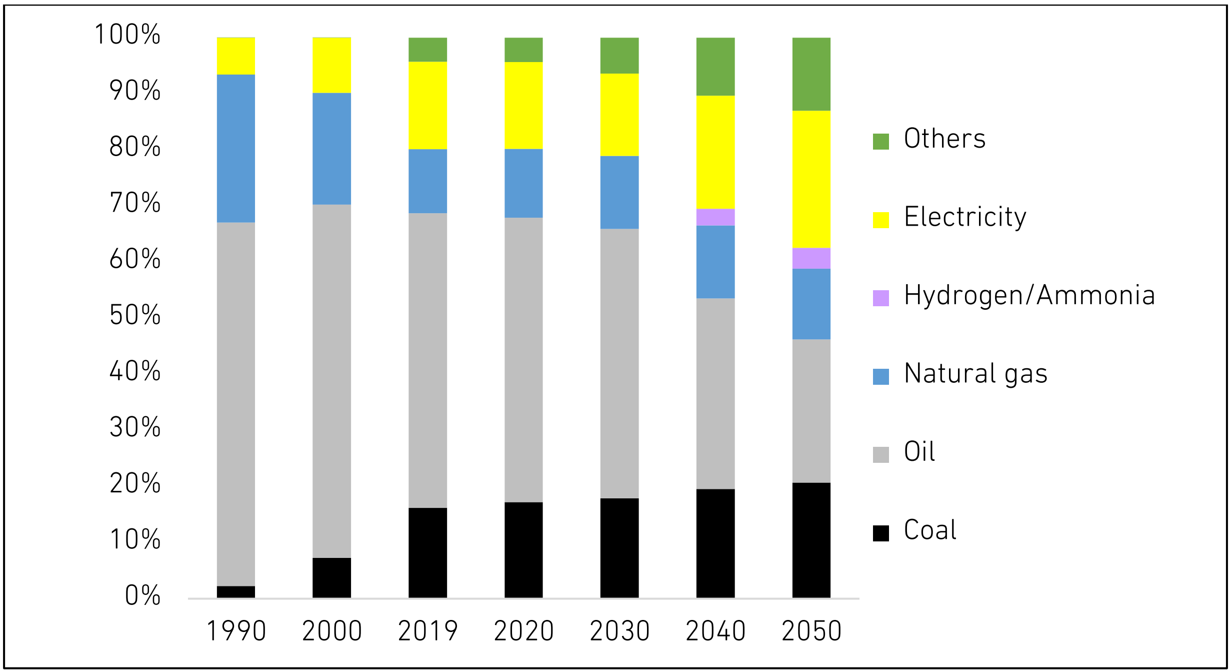
The annual growth rate of biofuel will increase to an average of 6%, in line with biodiesel and bioethanol used, especially in the transport sector. The mix of biofuel in biodiesel and bioethanol projection can reach 40%. In 2023 the content of biofuel in biodiesel was about 35%, but there is no implementation timeline for bioethanol.

Total final energy consumption of electricity 2019–2050 increases with annual growth rate of average 4%. Electricity consumption in 2050 will increase to 75 Mtoe or 884 terawatt-hours (TWh). The biggest growth of electricity consumption comes from the transport sector through the substitution of gasoline and diesel with electricity for cars and motorcycles.

Whilst in the 'others' sector, the reduction in emissions to achieve net-zero emissions concerns the substitution of liquid petroleum gas (LPG) with electricity for cooking, especially in the household sector. The aim this programme, besides the reduction of carbon, is also to reduce dependency on LPG imports. Currently LPG imports have been around 70% of total LPG consumption in Indonesia.

The projection of final energy consumption by type of energy (Figure 6.4) shows that in 2050 the share of fossil fuel will still be 59% because coal and gas will still be used in the industry sector, and oil will be used in the transport sector (with a mix of mix of fatty acid methyl ester to become biofuel). As a result, the share of others (biofuel) will increase from 4% in 2019 to 13% in 2050, whilst the share of electricity will also increase from 7% in 2019 to 24% in 2050 in line with the increasing numbers of EVs and electric stoves.

Figure 6.4. Share of Final Energy Consumption by Energy Type, 1990–2050



Source: Author.

The EV and electric stove programmes will increase electricity consumption, absorbing the current oversupply of electricity in Java Island from the 2015 35 GW coal-fired power plant development programme.

4. Power Generation

Based on projections, the production of electricity in 2050 for the LCET–CN scenario will achieve 1090 TWh, with the growth rate of about 4.3% for 2019–2050. After 2030, a new large-scale RE generation development programme begins with the construction of solar (about 27 MW), geothermal (7 GW), wind (4 GW), and biomass (including municipal solid waste) (about 8 GW). On the other hand, fossil fuel generation will decrease after 2035, with the capacity of coal-fired power plants decreasing from 40 GW in 2030 to zero in 2050, oil-fired power plants decreasing from 4 GW in 2035 to 1 GW in 2050, and gas-fired power plants decreasing from 21 GW in 2035 to 7 GW in 2050.

New technology for power generation projection will develop in 2040 such as coal-fired power plants with CCS, and gas-fired power plants with CCS and hydrogen. Nuclear power is also projected to enter the electricity system starting in 2040 with a capacity of 4 GW.

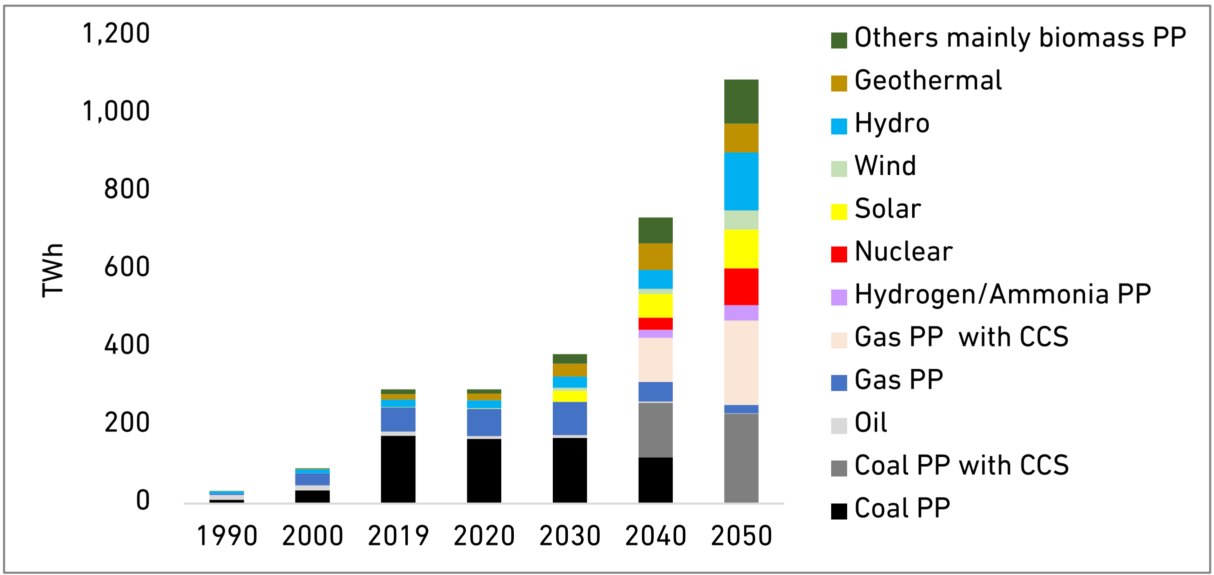
Figure 6.5 shows the production of electricity from 2019–2050. The figure shows that the biggest share of production of electricity comes from coal-fired power plants with CCS (around 21% or 231 TWh) and gas-fired power plants with CCS at about 20% (217 TWh). Coal-fired power plants and gas-fired power plants with CCS are included in the electricity system in Indonesia because coal and gas reserves in Indonesia are large. It is hoped that by 2040, CCS power plants will be economical or can compete with other RE power plants.

Production of electricity from hydro in 2050 is about 14% or 149 TWh. The total hydro potential in Indonesia is around 95 GW and almost half of it is in Kalimantan, about 38% is in Papua, and the rest is spread across Java and Sumatra. Therefore, hydro is expected to be up to 60 GW by 2050.

The production of electricity from solar achieves 99 TWh or 9% from the total production. Even though Indonesia has very large solar potential, due to limited land, solar only around 120 GW can be developed up to 2050.

To build a nuclear power plant requires 10–15 years of preparation so it is estimated that a new nuclear power plant will be able to produce electricity around 2040. The production of electricity from nuclear power plants is projected to be about 32 TWh in 2040, and will increase to 95 TWh in 2050.

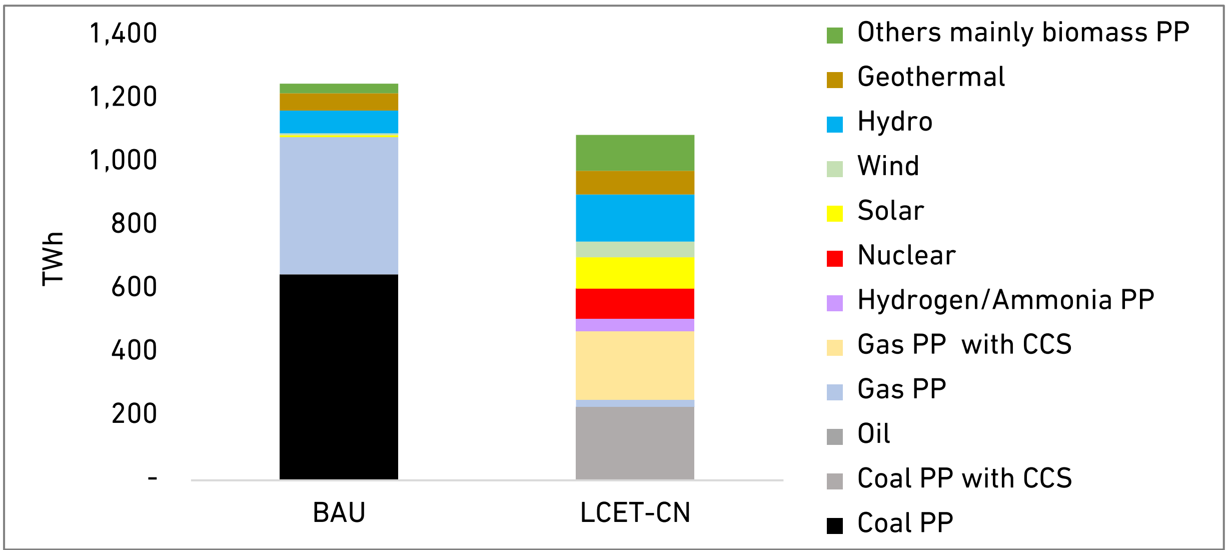
Figure 6.5. Production of Electricity LCET–CN Scenario,1990–2050



CCS = carbon capture storage, PP = power plant, TWh = terawatt-hour.
Source: Author.

When compared with the business as usual (BAU) scenario, the production of electricity from fossil power generation in the LCET–CN scenario is much lower. Electricity production from fossil fuel generation in the BAU scenario is1,038 TWh or 86% from total production electricity in 2050, whilst in the LCET–CN scenario it is only 470 TWh (43%) but using clean technology. The comparison of electricity production in 2050 between the BAU and LCET–CN scenarios is shown in Figure 6.6.

Figure 6.6. Comparison of Electricity Production in BAU and LCET–CN Scenarios, 2050



BAU = business and usual, CCS = carbon capture storage, LCET–CN = low-carbon energy transition–carbon neutral, PP = power plant, TWh = terawatt-hour.
Source: Author.

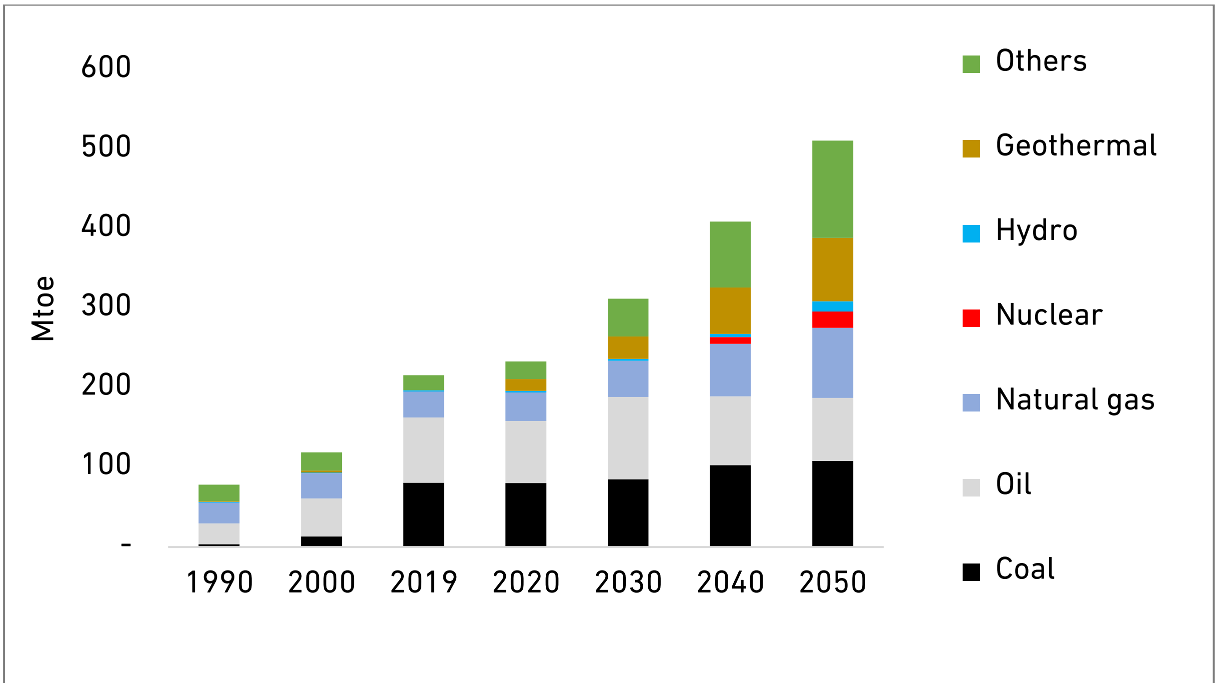
5. Primary Energy Supply

Total primary energy supply (TPES) in the LCET–CN scenario increases by about 3% per year in 2019–2050, so TPES in 2050 will achieve 512 Mtoe. The share of fossil energy in TPES decreases, from 90% in 2019 to 54% in 2050 in line with efforts to reduce emissions to commitment net-zero emissions by 2060. The average coal and gas growth in 2019–2050 is 1% per year and 3% per year, respectively but oil supply shows negative growth, due to the substitution of gasoline and diesel with electricity and biofuel in the transport sector.

In the 2019–2050 period, the growth rate in the primary energy supply of solar is 24% and wind is 16%. Currently, the cost of constructing solar power plants is expensive. However, the cost of installing solar has decreased compared to the previous 5 years so that it is estimated that by 2050, solar can compete with fossil fuel power plants.

Although the growth rate of hydro, geothermal, biofuel, and biomass in 2019–2050 is about 6%, in 2050 the biggest share of TPES from RE is geothermal, because all potential of geothermal will develop in 2050 as the base load of supply electricity. Figure 6.7 shows the primary energy supply in the LCET-CN scenario in 1990–2050.

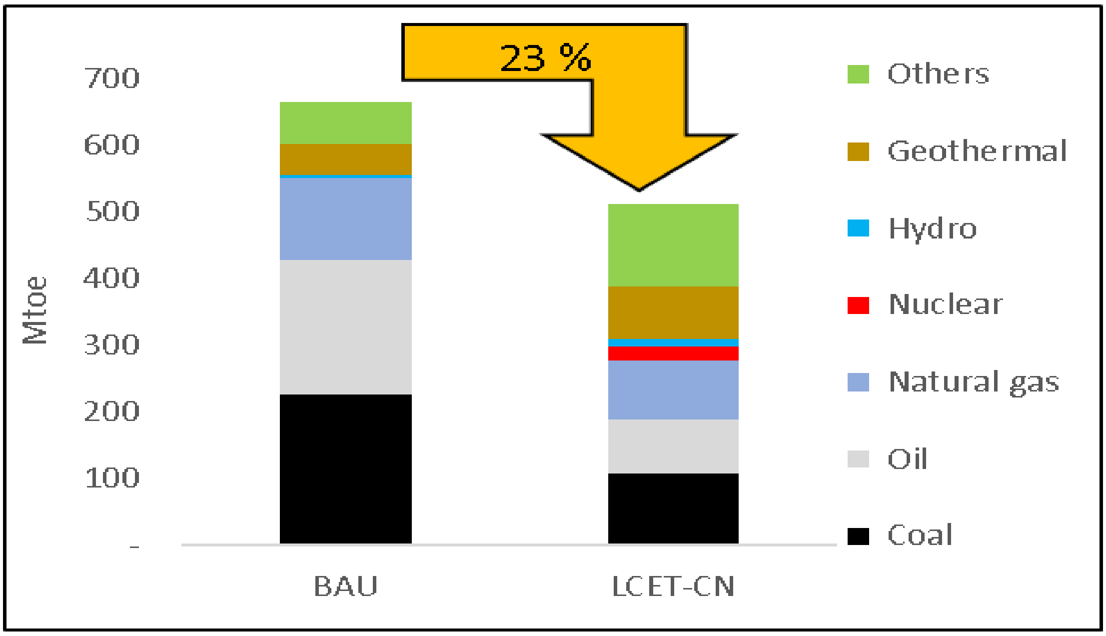
Figure 6.7. Total Primary Energy Supply, LCET–CN Scenario,1990–2050



LCET–CN = low-carbon energy transition–carbon neutral, Mtoe = million tonnes of oil equivalent.
Source: Author.

TPES in 2050 in the LCET–CN scenario is 23% lower than the BAU scenario, because of the reduction in primary energy supply of fossil fuels. Primary energy supply of coal in the BAU scenario is 225 Mtoe, but in the LCET–CN scenario it is only 108 Mtoe, because coal in industry is subtitute with hydrogen and coal for generation is limited for coal-fired power plants with CCS. For gas, which is 122 Mtoe in BAU and 88 Mtoe in LCET–CN as a result subtitution gas in the industry sector and limited gas used for electricity generation except for gas-fired power plants with CCS in 2050. Primary energy supply of oil in the LCET–CN scenario is about 79 Mtoe, much lower than the BAU scenario (203 Mtoe) because there is subtitution of oil with hydrogen in industry–and commercial–and subtitution oil with electricity in the transport sector. On the other side, primary energy supply of RE is higer than BAU, due to increasing RE in the power sector, including nuclear. The comparison TPES in 2050 in the two scenarios is shown in Figure 6.8.

Figure 6.8. Comparison Total Primary Energy Supply BAU and LCET–CN Scenarios, 2050



BAU = LCET–CN = low-carbon energy transition–carbon neutral, Mtoe = million tonnes of oil equivalent.
Source: Author.

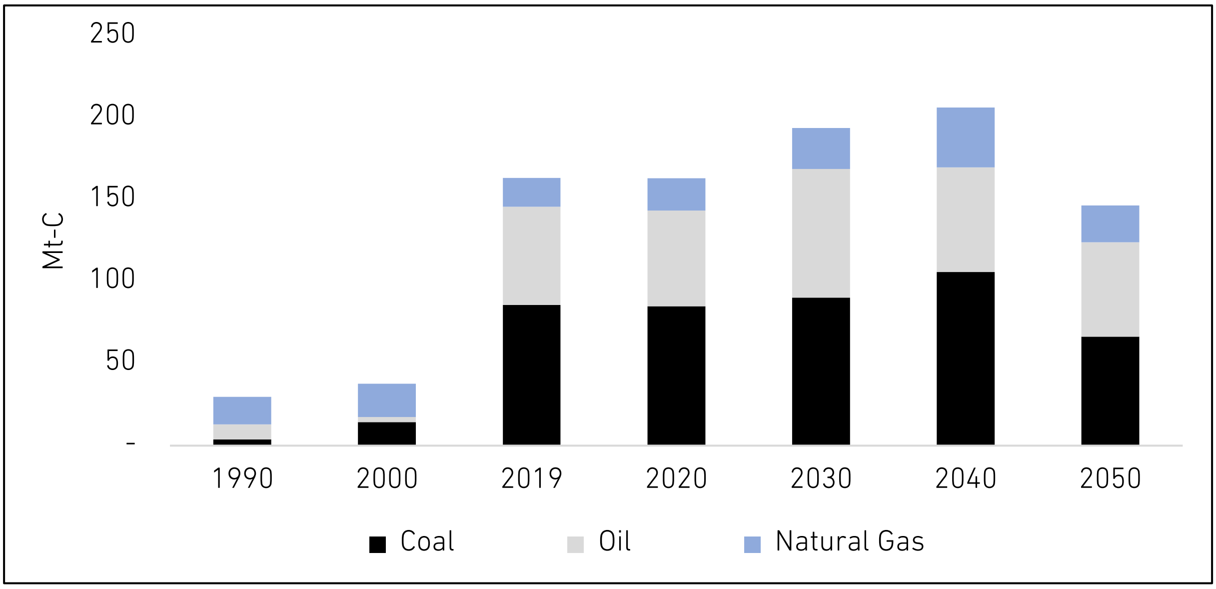
6. Carbon Dioxide Emissions

The CO_2 emissions in the LCET–CN scenario projection increases from 164 Mt-C in 2019 to 207 Mt-C in 2040 (peak emissions) and decreases to 147 Mt-C in 2050. The reduction of carbon is mainly from decreasing the number of coal-fired power plants from 2035 until 2048 and changing them to plants with CCS from 2040, and also decreasing the number of gas-fired power plants from 2036.

In the industry sector, especially iron and steel, coal is still needed for the processing plants and gas is needed for producing feedstock fertiliser. Oil is also used in the transport sector as a mixed biofuel and LPG is still used in the 'others' sector for cooking, so emissions are difficult to reduce.

The biggest emissions in 2050 will come from coal, followed by oil and gas so total emissions will be about 147 Mt-C or 529 Mt-CO_2. These target emissions as mentioned in the Long-term Strategy for Low Carbon and Climate Resilience document, which is set to target a reduction in emissions in 2050 of about 540 Mt-CO_2. The trend of emissions in the LCET–CN scenario 2019–2050 is shown in Figure 6.9.

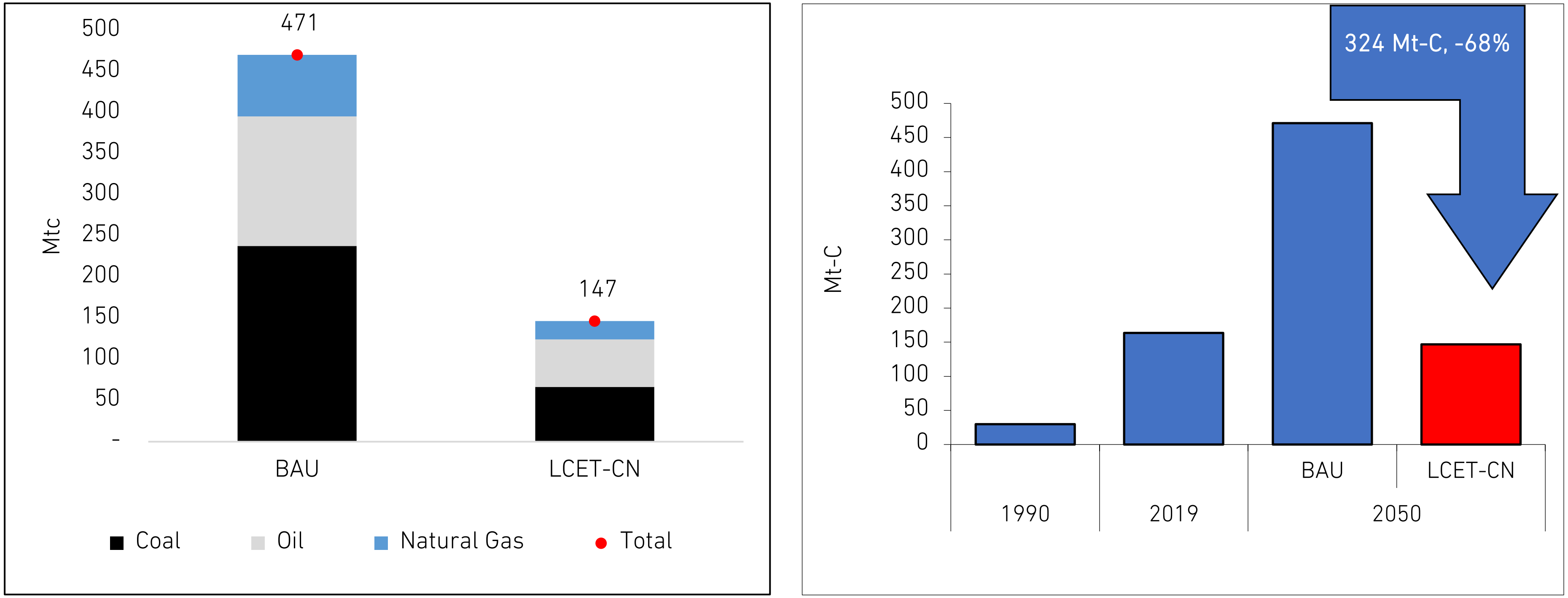
Figure 6.9. CO_2 Emissions in LCET–CN Scenario,1990–2050



CO_2 = carbon dioxide, LCET–CN = low-carbon energy transition–carbon neutral, Mt-C = million tonnes of carbon.
Source: Author.

Carbon emissions in the 2050 LCET–CN scenario are much lower than in the BAU scenario as shown in Figure 6.10.

Figure 6.10. Comparison of CO_2 Emissions between BAU and LCET–CN Scenarios, 1990–2050



BAU = business as usual, CO_2 = carbon dioxide, LCET–CN = low-carbon energy transition–carbon neutral, Mt-C = million tonnes of carbon.
Source: Author.

7. Cost Benefit Analysis

In this chapter, a cost and benefit analysis will be carried out looking at fuel costs, power plant energy requirements, CCS, energy savings, and total cost benefit analysis for the BAU and the LCET–CN scenarios.

7.1. Fuel Cost Analysis

The fuel cost analysis in both scenarios is calculated based on the primary energy supply for fossil fuel throughout 2019–2050, as well as hydrogen contained in the LCET–CN scenario. The supply of fossil energy is then multiplied by the energy price in 2019/2020 as current condition and for conditions in 2050, the primary energy supply, multiple with the assumed price of each fossil energy in 2050 (Table 6.3).

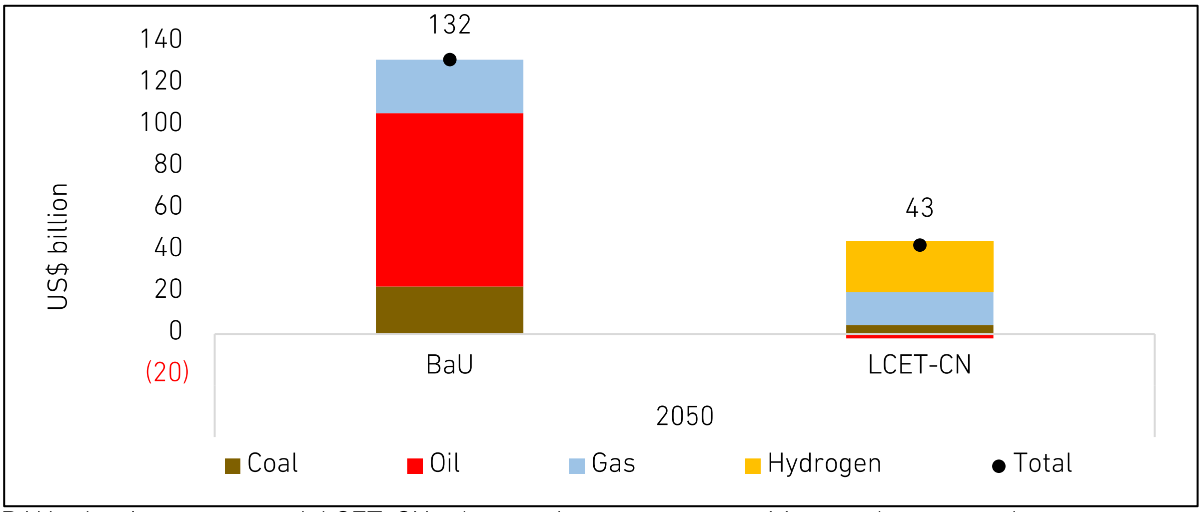
Table 6.3. Assumptions for Fossil Energy Prices in 2019 and 2050

	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$

bbl = barrel, MMBtu = metric million British thermal unit, Nm^3 = normal metric metre.
Source: ERIA.

From the calculation results, fuel costs until 2050 in the LCET–CN scenario will reach US$34 billion, but fuel costs in the BAU scenario are three times higher than the previous scenario. This condition is mainly influenced by the decrease in oil use in the LCET–CN scenario so that oil fuel costs become negative, or a cost savings of around US$2 billion. However, there are additional fuel costs for hydrogen of around US$25 billion. A comparison of the fuel cost in the BAU and LCET–CN scenarios is shown in Figure 6.11.

Figure 6.11. Comparison of Fuel Cost in BAU and LCET–CN Scenarios

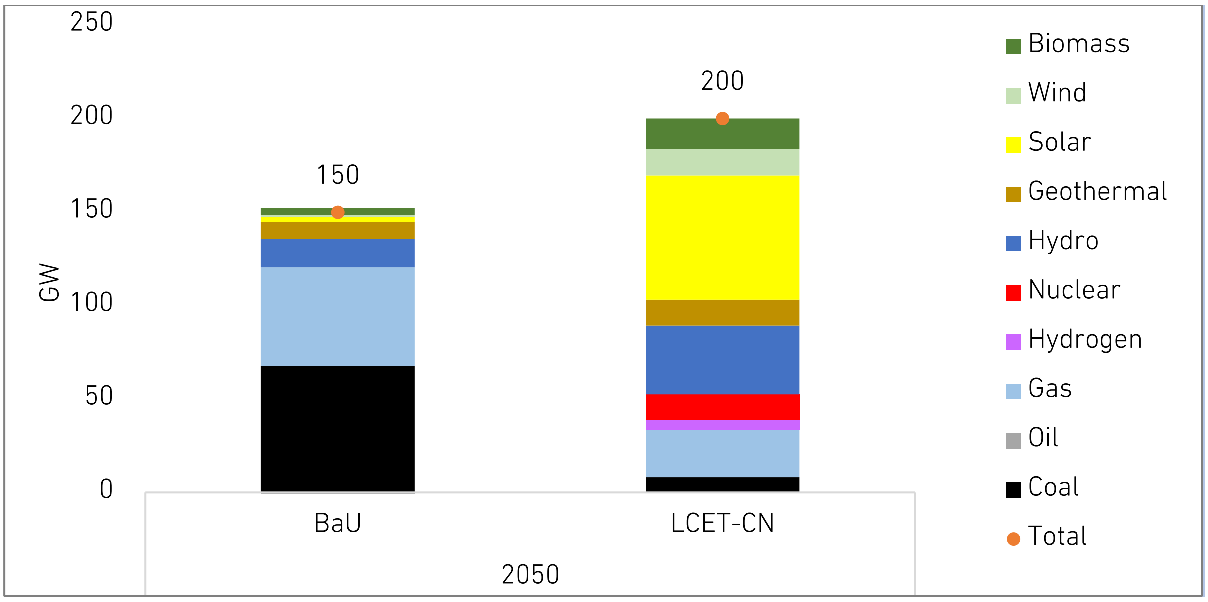


BAU = business as usual, LCET–CN = low-carbon energy transition–carbon neutral.
Source: Author.

7.2. Power Investment

Based on the projection results for the BAU and LCET–CN scenarios until 2050, 1,253 TWh of electricity are needed for the BAU scenario and 1,090 TWh for the LCET–CN scenario. To meet this electricity production, the generating capacity required for the BAU scenario is around 150 GW and for the LCET–CN scenario is 200 GW in 2050. Projections for additional capacity of generation in each scenario can be seen in Figure 6.12.

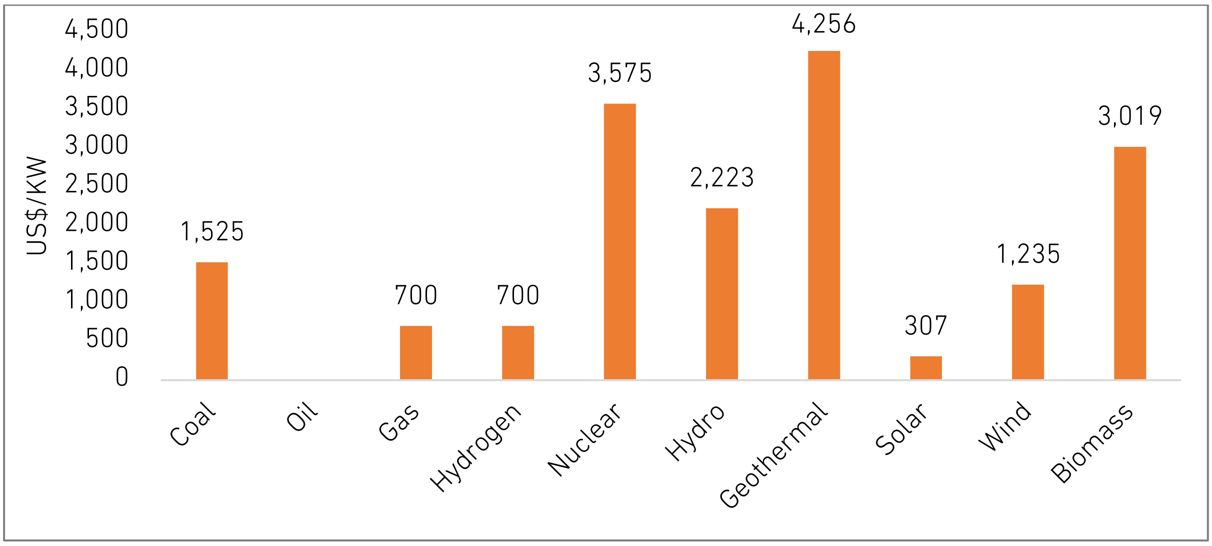
Figure 6.12. Comparison of Additional Capacity of Power Plants in BAU and LCET–CN Scenarios



BAU = business as usual, GW= gigawatt, LCET–CN = low-carbon energy transition–carbon neutral.
Source: Author.

To find out the investment costs of each power plant, the additional power plant capacity during 2019–2050 is multiplied by the assumed construction costs as shown in Figure 6.13.

Figure 6.13. Construction Costs of Power Plants

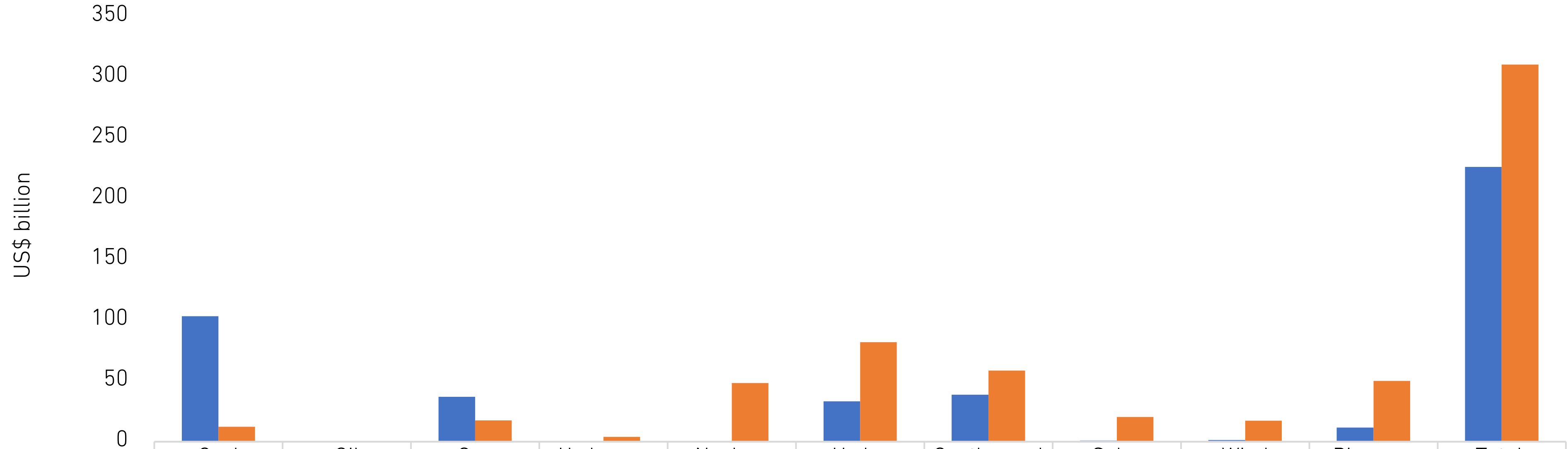


KW = kilowatt.
Source: Author.

Based on Figure 6.13, the most expensive construction cost of power generation in 2050 is geothermal, followed by nuclear, biomass, and hydro.

Investment costs in the LCET–CN scenario are more expensive than the BAU scenario as a result of 83% of electricity generation coming from new and renewable energy which is more expensive than fossil generation, especially geothermal, nuclear, biomass, and hydro. Comparison construction cost between the two scenarios can be seen in Figure 6.14.

Figure 6.14. Construction Cost by Type of Generation



	Coal	Oil	Gas	Hydrogen	Nuclear	Hydro	Geothermal	Solar	Wind	Biomass	Total
2050 BaU	103,257	0	36,926	0	0	33,321	38,770	866	1,339	11,521	225,999
2050 LCET-CN	12,360	0	17,600	3,961	48,263	81,974	58,538	20,414	17,292	50,006	310,408

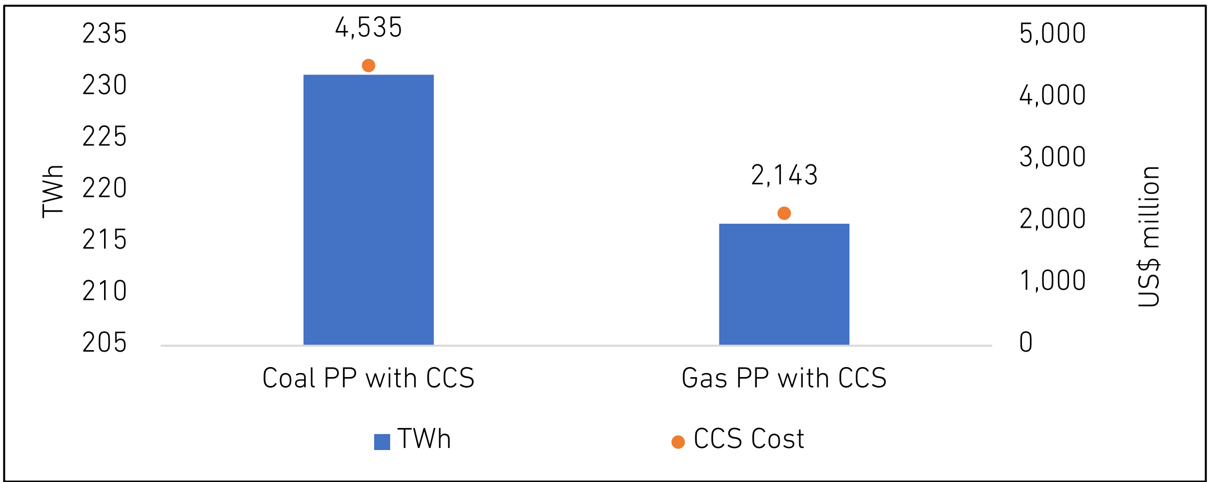
2050 BaU   2050 LCET-CN

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

7.3. CCS Cost

CCS is technology for reducing emissions when fossil fuel is used, especially in the power sector. With CCS technology in the LCET–CN scenario, emissions will be reduced to achieve the target. Based on the calculations, in 2050 coal-fired power plants with CCS will produce 231 TWH electricity with coal consumption of about 45 Mtoe and will produce emissions of about 46 Mt-C. If the assumption cost of CCS development is about US$30/$CO_2$ ton, the cost to develop CCS technology is about US$4.5 billion. On the other side, consumption of gas-fired power plants with CCS is about 37 Mtoe and will produce 22 Mt-C or 79 Mt-CO_2. With CCS technology, emissions will decrease to 71 Mt-CO_2 so the cost to develop CCS technology is about US$2.143 million. Total cost CCS development will be about US$6.678 million in 2050 (Figure 6.15).

Figure 6.15. Cost of CCS in LCET–CN Scenario in 2050



CCS = carbon capture and storage, LCET–CN = low-carbon energy transition–carbon neutral, TWh = terawatt-hour.
Source: Author.

7.4. Energy Savings

Energy savings are calculated based on energy consumption in 2050 for the BAU scenario compared to the alternative policy (AP) scenario which uses energy savings as one of the assumptions. In the BAU scenario total energy consumption in 2050 is about 448 Mtoe, higher compared to the AP scenario of about 377 Mtoe. Energy saving calculated especially for energy consumption in the industry and 'others' sectors, so total energy saving is about 38 Mtoe (Table 6.4).

Table 6.4. Energy Saving in BAU and AP Scenarios
(Mtoe)

Sector	BAU	AP	Energy Saving
Industry	146	121	25
Others	97	84	13
Total	243	205	38

AP = alternative policy, BAU = business as usual, Mtoe = million tonnes of oil equivalent.
Source: Author.

If the energy savings are equated to crude oil with the assumption that 1 Mtoe is equivalent to 1.09 billion kilolitres (kl), then savings in 2050 will reach 42 million kl. If the energy saving effect is assumed to be US$385/million kl, then the total energy savings cost obtained will be almost US$16 billion.

7.5. Overall Cost

Based on analysis on the overall calculation from Section 7.1 and 7.2, the breakdown of the total investment cost is showed in Table 6.5.

Table 6.5. Overall Cost
(US$ million)

	BAU	LCET–CN
Fuel cost	131,679	42,554
Power capital cost	7,290	10,013
CCS in 2050	0	6,678
Total	**138,969**	**59,245**

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

8. Conclusion and Recommendations

To achieve the reduction of 540 million Mt-CO2e in emissions by 2050, Indonesia must demonstrate significant commitment and effort. Currently, the renewable energy (RE) share in the primary energy supply is only 12.3%, with 87.7% still reliant on fossil fuels.

Efforts that need to be made by Indonesia include the preparation of a roadmap towards net-zero emissions, such as switching fuel to electricity and hydrogen, increasing the share of biofuel in the transport sector, substituting oil, gas, and coal with hydrogen in the industrial sector, and increasing the use of RE for electricity generation, including nuclear and the use of coal and gas-fired power plants with carbon capture and storage (CCS).

From the overall calculation of the total energy cost, the LCET–CN (Low Carbon Energy Transition–Carbon Neutral) scenario anticipates lower fuel costs compared to the BAU (Business As Usual) scenario. However, the LCET–CN scenario requires larger power investment and CCS costs compared to BAU. This indicates that for Indonesia, the LCET–CN scenario could be one of the pathways to achieving net-zero emissions by 2060.

Other parameters, such as a robust legal framework, knowledge of clean energy technologies, and public awareness, need to be prioritised to implement net-zero emissions. Additionally, cooperation with developed countries is essential to support emissions reduction in areas like investment, technology transfer, and other activities.

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