MINISTRY OF ENERGY AND MINERAL RESOURCES

Roadmap to Net Zero Emissions in Indonesia's Energy Sector by 2060

2023

ROADMAP TO NET ZERO EMISSIONS IN INDONESIA'S ENERGY SECTOR BY 2060

Citation: DGNREEC-MEMR. 2023. Roadmap to Net Zero Emissions in Indonesia's Energy Sector by 2060. Directorate General of New, Renewable Energy and Energy Conservation (DGNREEC), Ministry of Energy and Mineral Resources, Jakarta.

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Published by

Ministry of Energy and Mineral Resources (MEMR)

Jalan Medan Merdeka Selatan No. 18 Central Jakarta

Special thanks to the Energy Transition Partnership (ETP) and the United Nations Office for Project Services (UNOPS) for their support.

Acknowledged by:

International Energy Agency (IEA), Danish Energy Agency (DEA), International Renewable Energy Agency (IRENA), CLASP, Ministry of Transportation, Ministry of Industry, Ministry of Environment and Forestry.

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1 INTRODUCTION

The energy sector plays a strategic role in Indonesia's economy. It not only serves as a source of state revenue but also functions as an economic growth catalyst. Without sufficient energy supply, various industries and production operations would not be able to run optimally, which can eventually influence domestic economic activities. Currently, there is a shifting paradigm in Indonesia's energy policy that considers energy resources not only as mere commodities but also as national development capital.

With Indonesia's changing socio-economic landscape and its commitments to reducing greenhouse gases (GHG) as part of the Paris Agreement to limit the global temperature increase to well below 1.5 degrees by 2030, there is an urgent need for an energy transition that can sustain its growing population, support its expanding economy, and fulfill its climate commitments.

This *Roadmap to Net-Zero Emissions in Indonesia's Energy Sector by 2060* (RNZE 2060) encompasses strategies that Indonesia needs to take on to reduce its emissions in the energy sector while still meeting its energy needs that are aligned with the expected growth in the country's population and GDP in the next coming decades. This energy transition could be achieved by the development of new and renewable energy (NRE), energy efficiency implementation, and low-carbon development. The RNZE 2060 is a guidance for energy stakeholders—such as ministries, financial institutions, the private sector, and communities—towards implementing GHG emission-reducing mitigation actions in the energy sector by 2060.

The RNZE 2060 is organized as follows:

The chapter "Indonesian Context" will first provide an overview of Indonesia in relation to its energy sector, including the current status and outlook of its economy, energy, and emissions. It will also explore policies relevant to the energy sector, categorized among five different themes: (1) planning; (2) finance; (3) electricity and new and renewable energy; (4) energy efficiency; and (5) climate.

The following chapter, "A pathway to net zero emissions by 2060", presents a high-level overview of the *Roadmap to Net-Zero Emissions in Indonesia's Energy Sector by 2060* and discusses the approach and methodology for designing the strategies covered in the roadmap.

Chapter 4, "Sectoral pathways (energy supply/upstream)", explores in more detail the sectoral pathways for energy supply/upstream subsectors. The subsectors are categorized into three groupings: (1) *extraction*, which includes coal, oil and gas, and NRE; (2) *transformation*, which includes power generation and oil and gas refinery; and (3) *transmission and distribution*. For each of these subsectors, the following are explored: demand and production, emissions, and strategy.

Chapter 5, “Sectoral pathways (energy demand/downstream)”, also explores in more detail the sectoral pathways, but for energy demand/downstream subsectors. It focuses on the following subsectors: (1) transport, (2) industry, (3) residential, and (4) commercial. Each main subsector is further divided into sub-subsectors, where applicable. For each sub-sector, the following are explored: activity drivers and demand, emissions, and strategy.

The last chapter, “Implementation roadmap”, summarizes the pathways outlined and explores the conditions needed to realize *Roadmap to Net-Zero Emissions in Indonesia’s Energy Sector*. It discusses enabling factors, challenges, and investments that need to be considered to facilitate the implementation of the RNZE 2060.

2 INDONESIAN CONTEXT

This chapter provides an overview of Indonesia in relation to its energy sector, including the current status and outlook of its economy, energy, and emissions. It will also explore policies relevant to the energy sector, categorized among five different themes: (1) planning; (2) finance; (3) electricity and new and renewable energy; (4) energy efficiency; and (5) climate.

2.1 Overview

As the largest economy in Southeast Asia and the 10th largest economy in the world based on purchasing power parity, Indonesia has accomplished a significant amount of economic growth and development over the last few decades.[1] Now, Indonesia has plans to accelerate its economic growth and reach "developed country" status by 2043, a feat to be fueled by a sizeable increase in energy demand and consumption.

However, Indonesia's road to its current economic growth has been heavily paved by a dependence on fossil fuels—particularly coal—for power generation, which has led to a significant amount of GHG emissions in the country. Currently, Indonesia is among the highest GHG-emitting countries in the world,[2] albeit its low emission per capita. To address this, the President has confirmed Indonesia's commitment to achieve net-zero emissions (NZE) by 2060 or sooner.

Indonesia therefore needs to consider an energy transition that can fulfill the needs of its growing population and economy, as well as its responsibilities to mitigating climate change through the reduction of GHG emissions. Several Indonesia-specific considerations need to be made in formulating strategies for the RNZE 2060 that address these two goals. These include the current unevenness in regional development, Indonesia's archipelagic geography, geographical distribution of NRE potential, current policy gaps, and technology needs. Some of these will be described in this chapter, while others will be addressed more closely with the elaboration of the sector-specific strategies in the following chapters.

[1] The World Bank. 2022. *The World Bank In Indonesia: Overview*.

[2] Climate Watch. *Global Historical Emissions*.

2.2 Economy

Indonesia is one of the fastest growing economies in the world. By 2022, based on data from the International Monetary Fund (IMF), Indonesia will be among the 10 countries with the largest economies or gross domestic product (GDP) in the world. Indonesia is ranked seventh, ahead of Brazil, the United Kingdom and France.[3] Indonesia's economic growth in the last two decades has shown an increasing trend, with only a dip in 2020 due to the COVID-19 pandemic. However, with the recovery of the global economy, Indonesia's economic growth is expected to continue to expand, which will have an impact on export performance and increase domestic demand due to higher consumption and investment. Indonesia's current economic conditions and future projections will be described in general in the following sections.

2.2.1 Current Status

Based on the trade balance in 2022, Indonesia experienced a surplus of USD 54.53 billion—growing by 53.96% from 2021. This is due to the high prices of leading export commodities in the global market. Indonesia's leading export commodities in 2022 are coal, palm oil, and iron & steel.

Based on gross domestic product (GDP), Indonesia's economic growth has fluctuated since 2016, with a sharp decline to -2.07% in 2020 due to restrictions on economic activity caused by the COVID-19 pandemic. However, as the economy recovers, Indonesia's economic growth has increased until 2022. As shown in **Figure 2.1**, according to data from the Statistics Indonesia (*Badan Pusat Statistik*, BPS), Indonesia's economy grew by 5.31% in 2022, higher than the performance in 2021, which experienced a growth of 3.70%.[4] Moreover, Indonesia is categorized as an upper-middle income country with a GDP per capita of USD 4,784 in 2022.

The strong economic growth was supported by all major sectors, namely industry, trade, agriculture, mining, and construction, which continued their positive growth trend. The highest source of Indonesia's economic growth by business field in 2022 (c-to-c) is Manufacturing Industry (1.01%), followed by Transportation (0.73%) and Trade (0.72%).

By expenditure, almost all expenditure components experienced growth in 2022. The highest source of Indonesia's economic growth by expenditure in 2022 (c-to-c) is Household Consumption (2.61%), followed by Gross Fixed Capital Formation (1.24%) and Net Exports (0.81%).

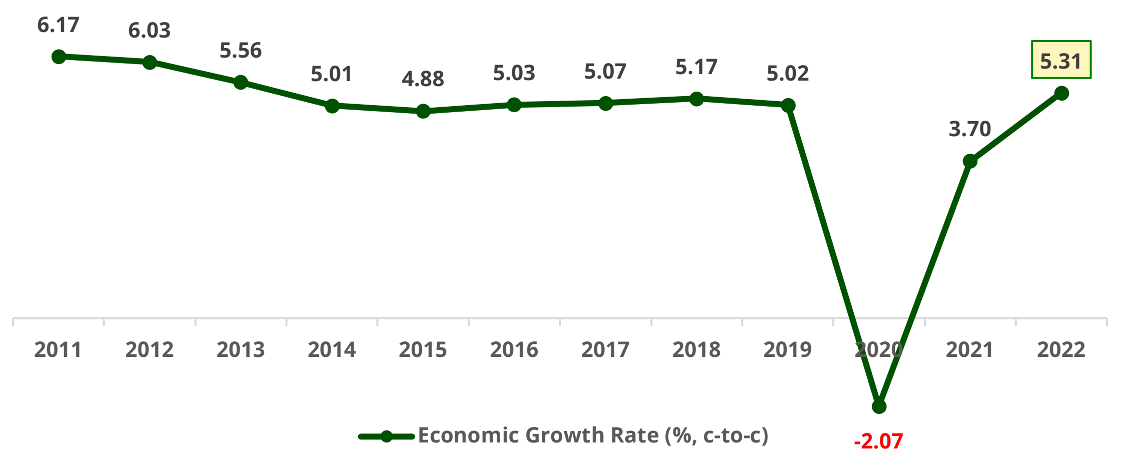
Spatial economic growth (**Figure 2.2**) also continued to strengthen, particularly in Java, Sulawesi and Maluku & Papua. The mining and quarrying sector is the main contributor to economic growth in Kalimantan, Sulawesi, Maluku & Papua. However, based on the

[3] IMF. 2022. World Economic Outlook IMF October 2022.

[4] BPS. 2023. Official Statistics News (February 6, 2023) - Indonesia's Economic Growth in Q4-2022.

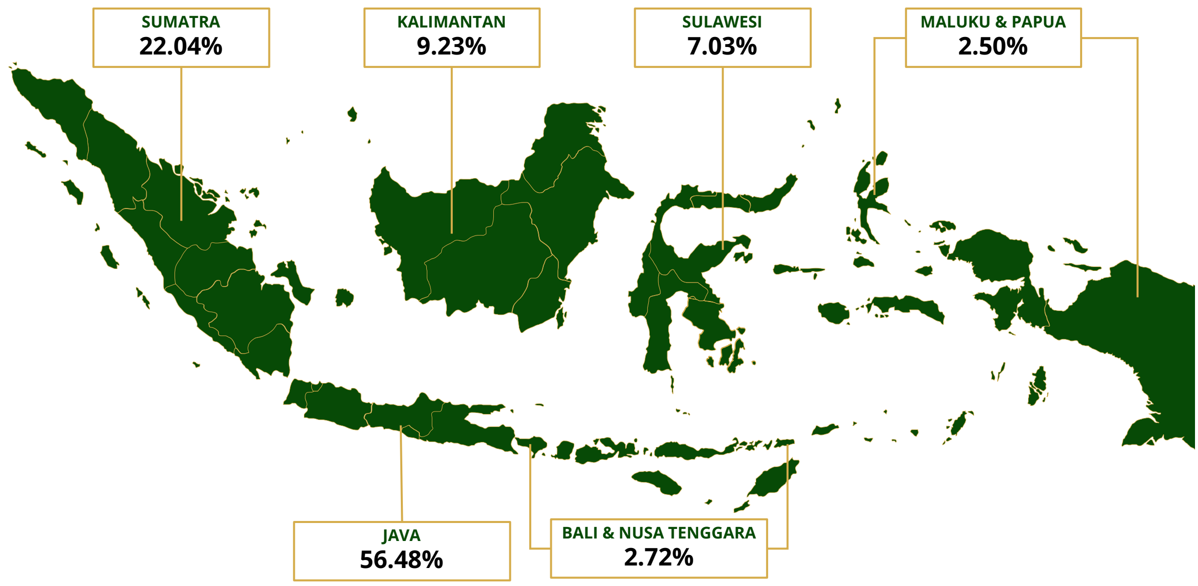
distribution of GDP (at current prices) in 2022, Indonesia's economic structure is still spatially concentrated in Java (56.48%) and Sumatra (22.04%).

Figure 2.1 Economic growth rate 2011-2022 (in %, c-to-c)



Source: BPS. 2023. Official Statistical News – Economic Growth (Gross Domestic Product)

Figure 2.2 Spatial economic growth



Source: BPS. 2023. Official Statistical News - Economic Growth (Gross Domestic Product)

2.2.2 Outlook

Amidst the global economic turmoil, Indonesia's economic growth is expected to continue to increase, supported by the increasing public consumption and investment as well as the continued positive export performance amidst the slowdown in global economic growth. In line with the vision of Indonesia Emas 2045 "The Sovereign, Advanced and Sustainable Archipelago", Indonesia aims to become a developed country or categorized as a high-income country in 2045. Based on data from the Ministry of National Development Planning/Bappenas, to realize this vision, Indonesia's GDP per capita income is targeted to reach USD 15,287 in 2045, with an average growth of 6% from 2022-2045. With this economic growth target, Indonesia can exit the middle-income trap by 2043.

In addition, the role of the Eastern Indonesia region in 2045 is targeted at 25%. The development direction of the Indonesia region is as follows:

- Sumatra: a new industrial center and gateway to the Asian region
- Java: trade and services center
- Kalimantan: processing industrial and national energy center
- Sulawesi: food industrial center and gateway to Eastern Indonesia
- Bali, Nusa Tenggara, and Maluku: international tourism and fisheries center
- Papua: food base and natural resource-based economic sectors

2.3 Energy and Emissions

Strong economic growth leads to an increase in energy demand, which is currently supplied primarily by coal. In 2022, the energy sector's CO_2 emissions per unit of energy consumption were one-third higher than in 2000. Total emissions from the energy sector have grown faster than energy demand, more than doubling over the past two decades.

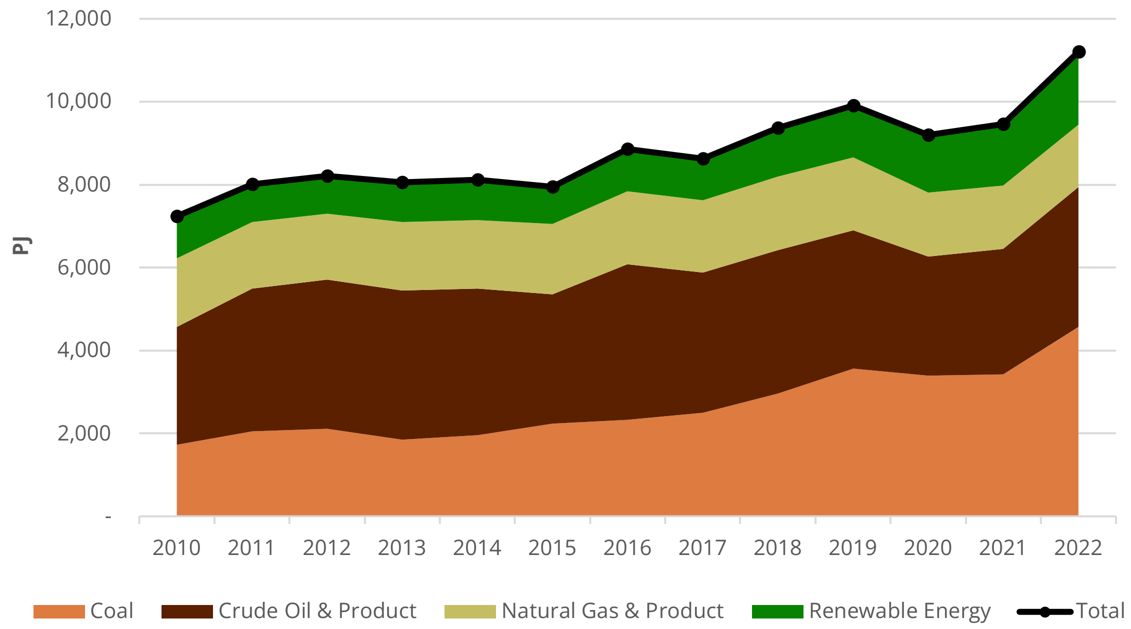
2.3.1 Energy

The total energy supply in 2022 reached 11,205 PJ, with the primary energy mix increasing by 18.5% compared to the previous year. The increase in energy supply from 2010 to 2022 was 54.8%, with the largest share coming from coal (40.7%), followed by oil (30.2%), natural gas (13.4%), and the rest from renewable energy. In 2020 and 2021, energy supply decreased due to the COVID-19 pandemic and began to increase in 2022 as the national economy recovered. The trend of energy supply from 2010-2022 is illustrated in **Figure 2.3**.

Energy demand by final energy end-use subsector increased by 21.6% in 2022 compared to the previous year. The largest contributor to energy consumption is the industry subsector (43.9%), followed by the transportation (35.2%), residential (13.3%), commercial (4.1%), and other subsectors. Based on the trend of total energy consumption in

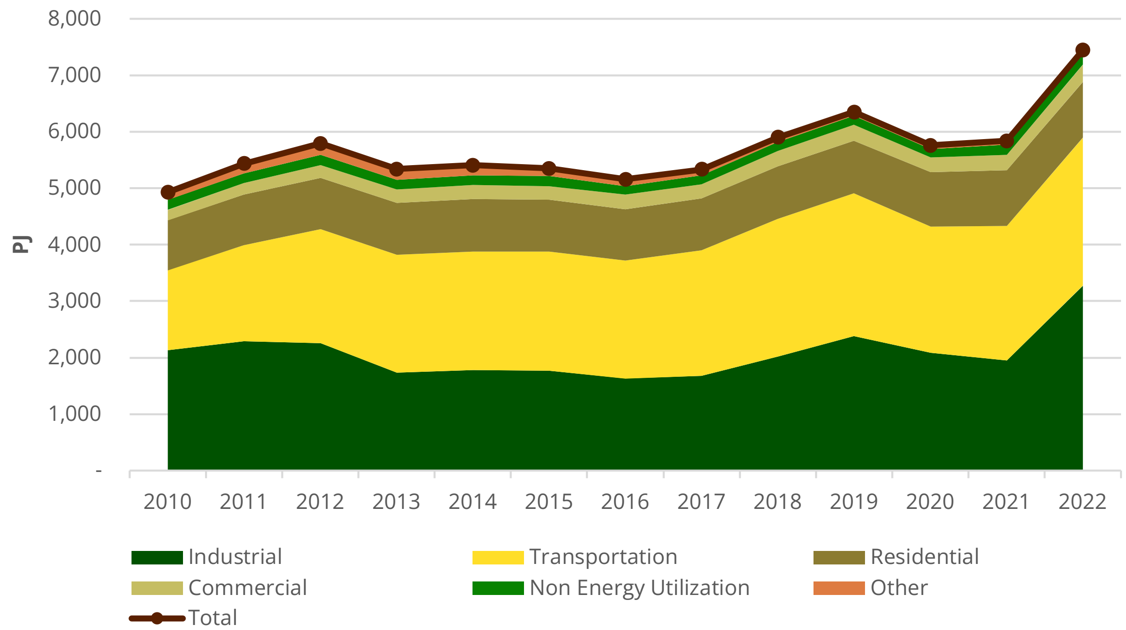
Figure 2.4, the industry subsector experienced an increase in energy consumption of 67.4% compared to the previous year, while the residential subsector experienced a decrease of 0.1%.

Figure 2.3 Primary energy supply by source



Source: MEMR. 2022. Handbook of Energy and Economic Statistic of Indonesia (HEESI)

Figure 2.4 Total energy consumption by subsectors



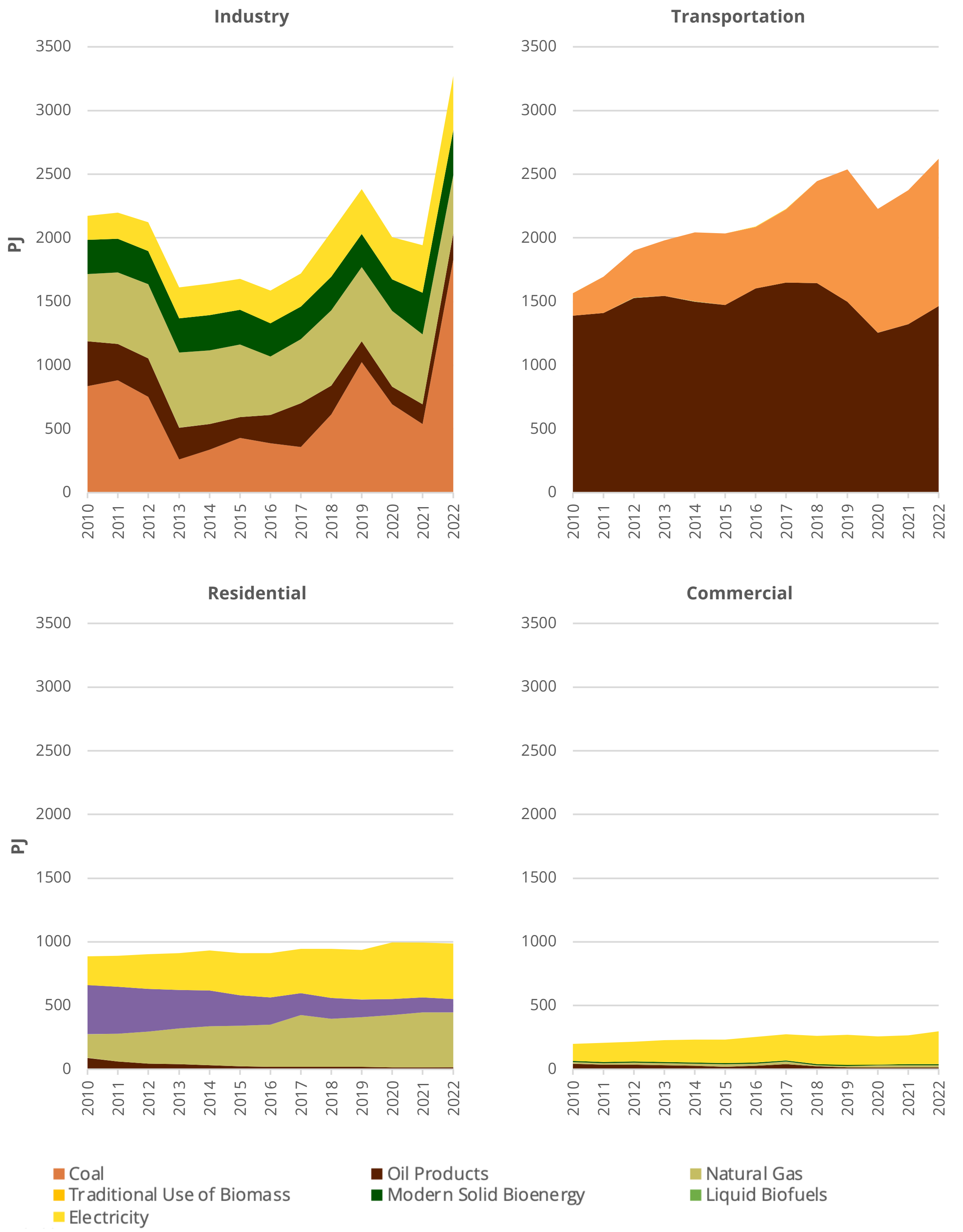
Source: MEMR. 2022. Handbook of Energy and Economic Statistic of Indonesia (HEESI)

Final energy consumption by fuel for each subsector—industry, transportation, residential, and commercial—is shown in **Figure 2.5**. In the industry subsector, fuel consumption in 2022 increased significantly compared to 2010. Coal is the dominant fuel consumed by the industry subsector in 2022, accounting for 56% of total fuel consumption, followed by natural gas (14%), electricity (13%), solid bioenergy (11%), and other fuels. Electricity consumption in 2022 was doubled compared to 2010, while fuel oil consumption decreased significantly over the period 2010-2022.

In the transportation subsector, fuel consumption is dominated by fuel oil. However, policies related to the use of biofuels (which account for 44% of final energy consumption in the transportation subsector), can reduce fossil fuel consumptions. In the residential and commercial subsector, electricity consumption nearly doubled in 2022 compared to 2010, mainly due to increased demand for air conditioning. In contrast, traditional biomass use in the residential subsector declined as access to gas cooking increased.

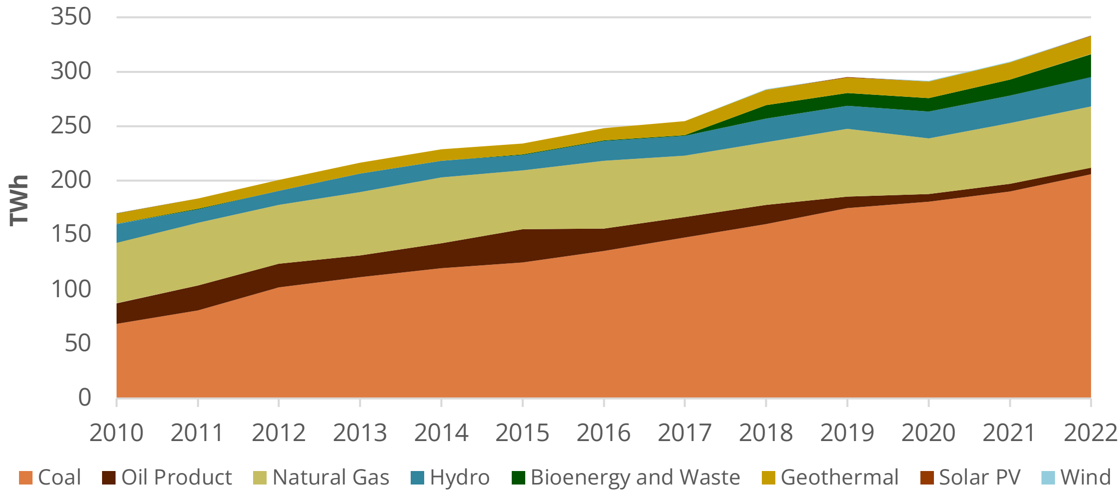
In the electricity generation subsector, coal is the dominant fuel—61.74% of the total fuel consumed (**Figure 2.6**). Electricity production from coal-fired power plants has more than doubled, from 68.48 TWh in 2010 to 205.91 TWh in 2022—accounting for two-thirds of Indonesia's total electricity production. Over the same period, the use of fuel oil for electricity generation has decreased to 1.83% in 2022. Meanwhile, the use of natural gas for electricity generation has stagnated in recent years. Electricity generation from renewable energy sources—hydro, bioenergy, and geothermal—has increased significantly over the past 10 years. In 2022, 65.38 TWh of electricity were generated from renewables—one-fifth of total electricity generation.

Figure 2.5 Final energy consumption by fuel for each subsector



Source: MEMR. 2022. Handbook of Energy and Economic Statistic of Indonesia (HEESI)

Figure 2.6 Electricity generation mix by source

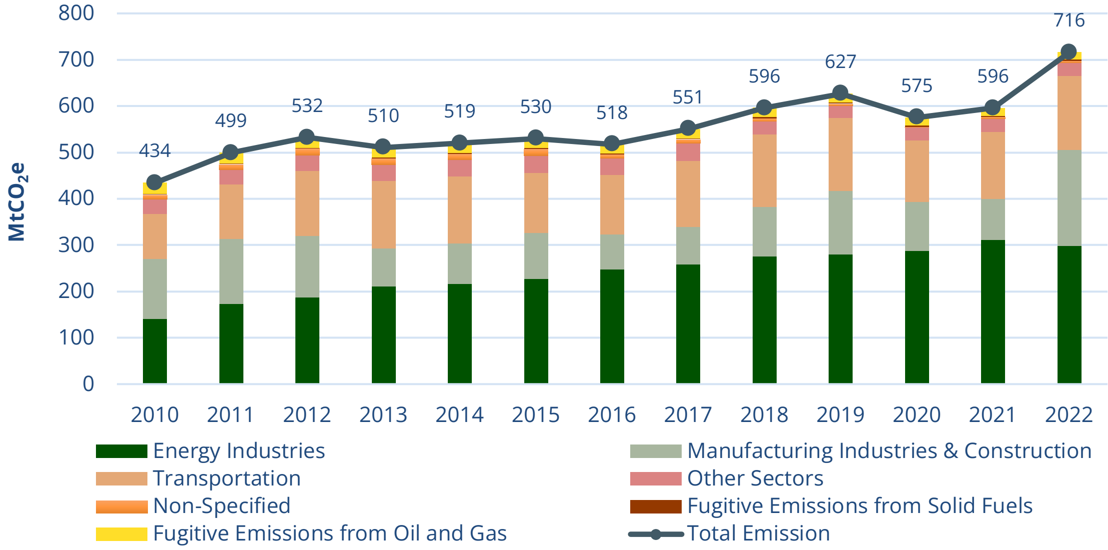


Source: MEMR. 2022. Handbook of Energy and Economic Statistic of Indonesia (HEESI)

2.3.2 Emission

The energy sector's greenhouse gas (GHG) emissions reached 716 $MtCO_2e$ in 2022, increased by 16.77% compared to the previous year. The largest emitter is the Energy Industries subsector (41.68%), followed by the Manufacturing Industries and Construction (29%) and Transportation (22.19%). The energy sector's GHG emissions for 2010-2022 is shown in **Figure 2.7**.

Figure 2.7 GHG emissions by category in 2010-2022

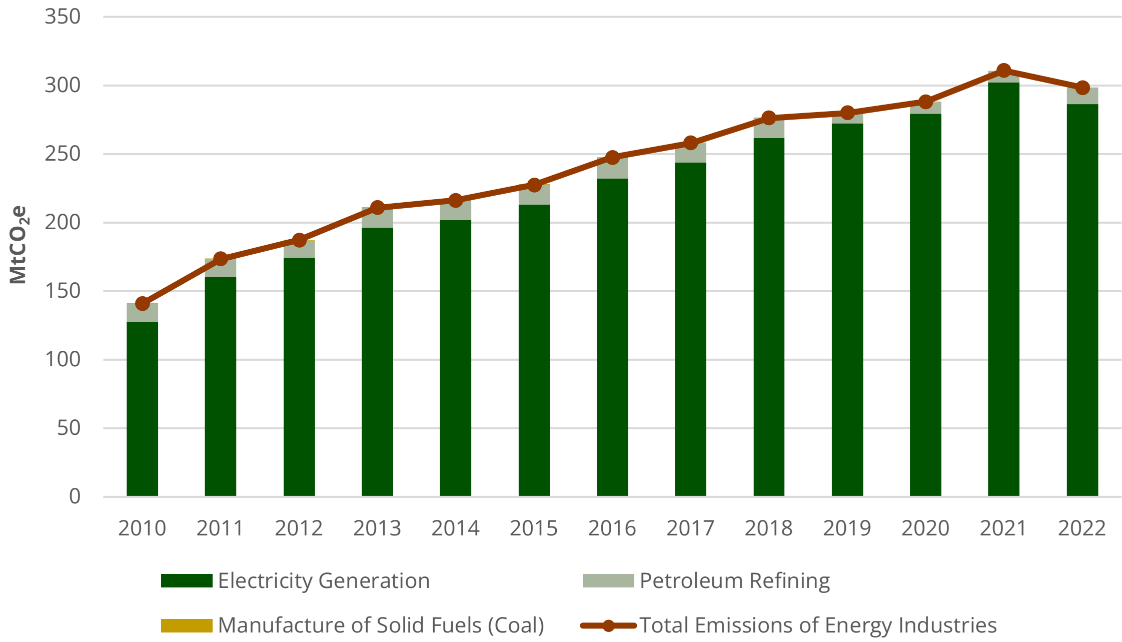


Source: Energy and Mineral Resources Data and Information Technology Center. 2022

Energy industries include power plants, oil refineries and coal processing. This category accounts for 298 $MtCO_2e$ of emissions, with power plants being the largest emitter (96.03%). The manufacturing industries and construction is the second largest emitter, contributing 208 $MtCO_2e$ in 2022. This is followed by the transportation subsector, which contributed 159 $MtCO_2e$ in 2022—increased by 9.41% from the previous year.

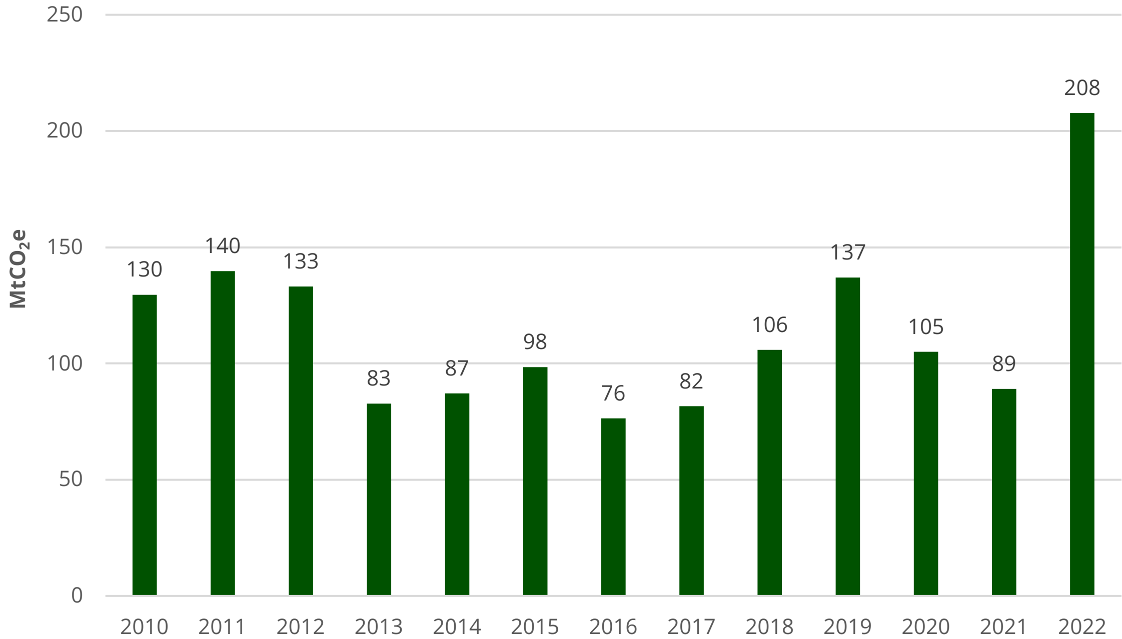
The residential and commercial subsectors contributed emissions of 29 $MtCO_2e$ in 2022, with residential being the largest emitter (93.87%). While the other subsectors, contributed 4 $MtCO_2e$ in 2022. The GHG emissions of each sub-sector in 2010-2022 are shown in **Figure 2.8** to **Figure 2.12**.

Figure 2.8 GHG emissions of energy industries 2010-2022



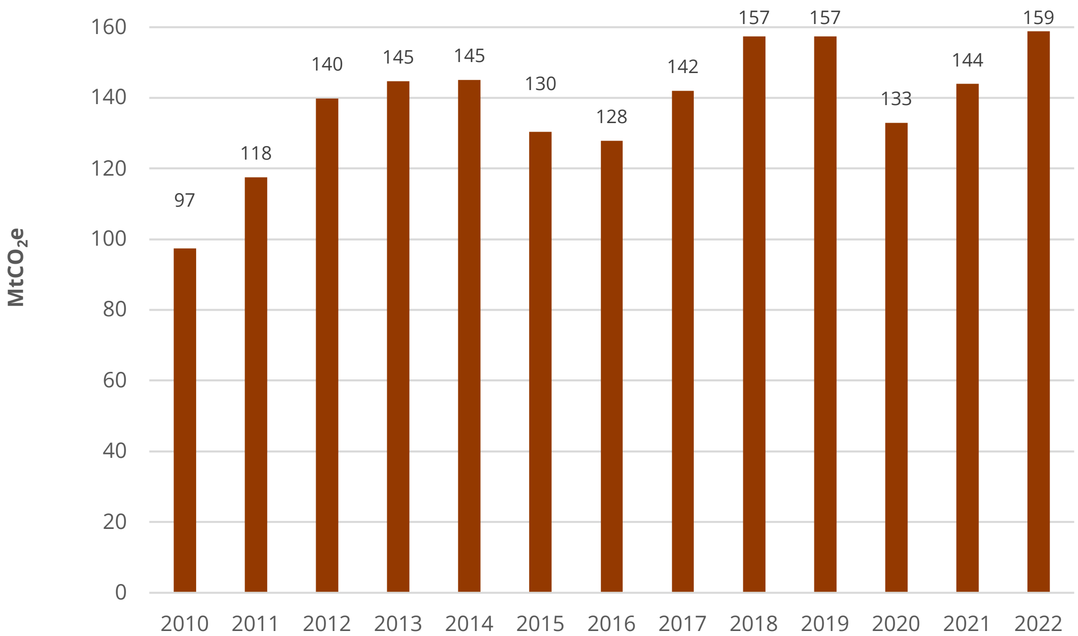
Source: Energy and Mineral Resources Data and Information Technology Center. 2022

Figure 2.9 GHG emissions of manufacturing industries and construction 2010-2022



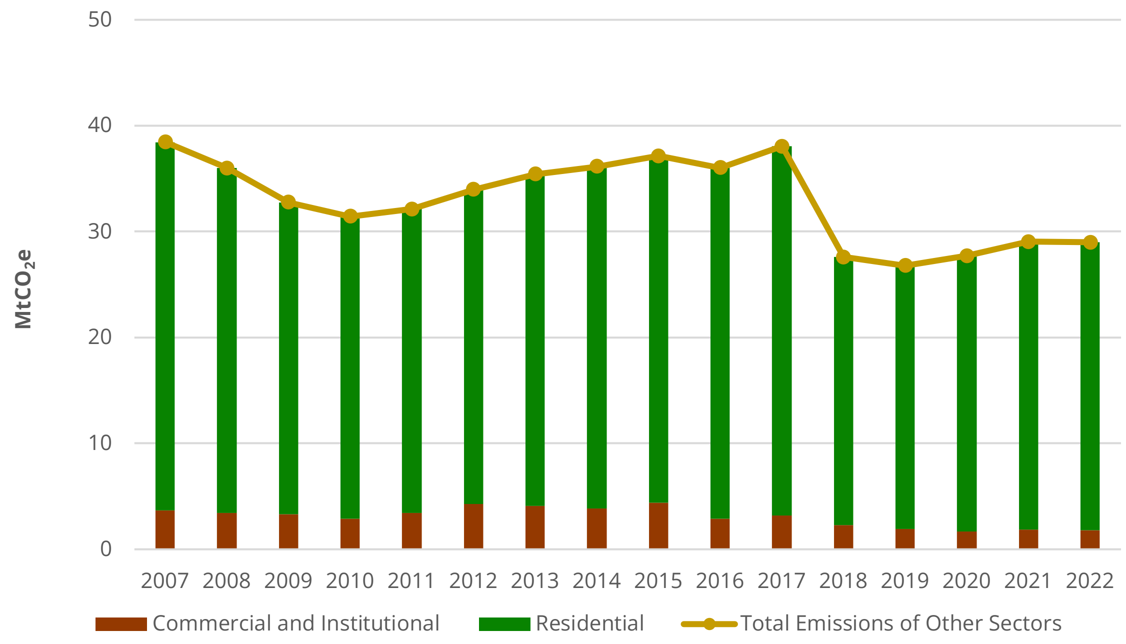
Source: Energy and Mineral Resources Data and Information Technology Center. 2022

Figure 2.10 GHG emissions of transportation 2010-2022



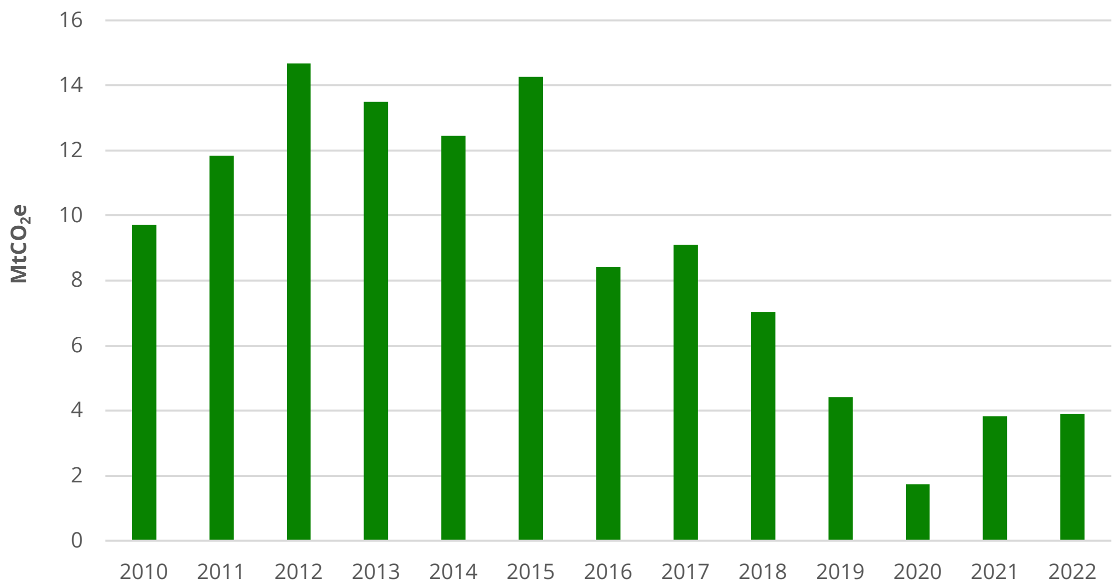
Source: Energy and Mineral Resources Data and Information Technology Center. 2022

Figure 2.11 GHG emissions of residentials and commercials 2010-2022



Source: Energy and Mineral Resources Data and Information Technology Center. 2022

Figure 2.12 GHG emissions of other subsectors 2010-2022



Source: Energy and Mineral Resources Data and Information Technology Center. 2022

2.4 Climate and Energy Policy and Planning

To reach the target of Net Zero Emission (NZE) by 2060 or sooner, Indonesia must significantly reduce emissions. To achieve emission reductions, the government has enacted and planned policies that provide a legal framework. Climate and energy policies in Indonesia cover from planning to financial policies that support the achievement of national climate and energy targets in the implementation of sustainable development.

2.4.1 Planning

As a form of responsibility at the global level towards achieving the Paris Agreement targets (Law 16/2016), Indonesia sets national climate targets as an effort to hold the rate of global temperature increase below 2°C from pre-industrialization levels and limit it to below 1.5°C. The Ministry of Environment and Forestry (MoEF) as the National Focal Point of the United Nations Framework Convention on Climate Change (UNFCCC), has submitted an increased ambition to reduce GHG emissions through the Enhanced Nationally Determined Contribution (E-NDC) document. The GHG emission reduction targets in the E-NDC are tabulated in **Table 2.1**.

Based on the E-NDC document, Indonesia's GHG emission reduction target with its own ability (unconditional, CM1) and with international assistance (conditional, CM2) is 31.89% and 43.2%. For the energy sector, the GHG emission level in 2010 was 453.2 MtCO_2e and is projected under the BaU scenario to be 1,669 MtCO_2e in 2030. The energy sector is targeted to reduce GHG emissions in 2030 by 358 MtCO_2e under the CM1 scenario and 446 MtCO_2e under the CM2 scenario.

Table 2.1 GHG emission reduction target based on E-NDC

Sector	GHG Emission Level 2010* (MtCO_2e)	GHG Emission Level 2030			GHG Emission Reduction				Annual Average Growth BAU (2010-2030) (%)	Average Growth 2000-2012 (%)
		MtCO_2e			MtCO_2e		% of Total BAU			
		BaU	CM1	CM2	CM1	CM2	CM1	CM2		
Energy*	453.2	1,669	1,311	1,233	358	446	12.5	15.5	6.7	4.5
Waste	88	296	256	253	40	43.5	1.4	1.5	6.3	4.0
IPPU	36	69.6	63	61	7	9	0.2	0.3	3.4	0.1
Agriculture	110.5	119.66	110	108	10	12	0.3	0.4	0.4	1.3
Forestry and Other Land Uses (FOLU)**	647	714	214	-15	500	729	17.4	25.4	0.5	2.7
Total	1,334	2,869	1,953	1,632	915	1,240	31.89	43.20	3.9	3.2

Notes:
CM1 = Counter Measure 1 (unconditional mitigation scenario)
CM2 = Counter Measure 2 (conditional mitigation scenario)
*) including fugitive
**) including emission from estate and timber plantations

In addition, Indonesia has also mapped out a long-term emissions pathway towards the NZE target in 2060 or sooner through the Long-Term Strategy for Low Carbon and Climate

Resilience (LTS-LCCR). The LTS-LCCR 2050 document is a long-term direction that guides the implementation of climate change mitigation and adaptation, submitted to the UNFCCC together with the Updated NDC. The LTS-LCCR projects a Low Carbon Compatible with the Paris Agreement Target (LCCP) pathway scenario, where total emission reductions rely on energy sector mitigation measures and significant forestry & land use (FOLU) sector emission reductions towards zero emissions before 2030 and removal after 2030.

A low-carbon and resilient transition is also reflected in Indonesia's development plans. Indonesia's current development goals are outlined in the National Long-Term Development Plan (*Rencana Pembangunan Jangka Panjang Nasional*, RPJPN) 2005-2025, which will then be followed by the RPJPN 2025-2045 with the vision of a Golden Indonesia 2045 in realizing Indonesia as a sovereign, developed and sustainable archipelago. One of the targets in the RPJPN is to reduce the intensity of GHG emissions towards NZE. To achieve NZE by 2060 or sooner, the Government of Indonesia has developed medium and long-term plans, with mainstreaming climate action as a top priority-through energy planning and management strategies.

2.4.2 Financial

The government continues to encourage policies related to sustainable finance in line with its commitment and efforts towards green economy and sustainable development programs. There is an integrated funding cooperation platform to support infrastructure development in line with the achievement of sustainable development goals (SDGs), namely SDG Indonesia One. SDG Indonesia One was established in 2018, with a mandate from the Ministry of Finance to PT SMI (Persero). Through an innovative financing mechanism that combines public and private funding (blended finance), the platform leverages funds from various sources, including private, philanthropic, donor agencies, bilateral and multilateral financial institutions, banking, insurance, and other investors over time.

At the G20 Summit (November 2022), the Government of Indonesia officially launched the Energy Transition Mechanism (ETM), for which PT SMI (Persero) was appointed as the country platform manager for the energy transition in Indonesia. The country platform for the ETM is a framework that provides financing needs in accelerating the national energy transition by mobilizing funds from public and private sources in a sustainable manner. In addition, the government is currently in the stage of drafting fiscal support policies through funding and financing frameworks in order to accelerate the energy transition, especially in the electricity subsector.

2.4.3 Electricity and New & Renewable Energy (NRE)

The provision and utilization of energy in a sustainable manner has been regulated in Law 30/2007 concerning Energy. The Energy Law mandates energy management based on the principles of benefit, efficiency, justice, sustainability, community welfare, environmental preservation, national resilience, and others. Energy management is carried out with the aim of achieving energy management independence, ensuring domestic energy availability, achieving increased community access, ensuring optimal, integrated and sustainable resource management, and ensuring energy affordability.

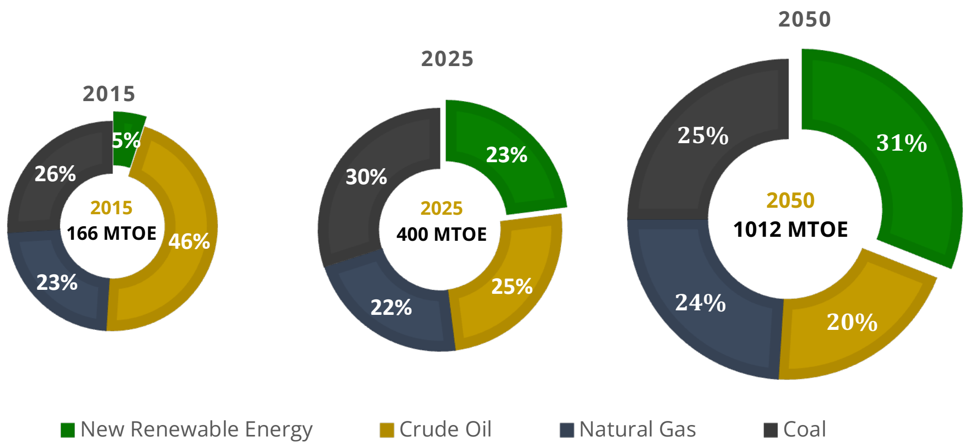
The Energy Law also mandates the government to establish a National Energy Policy (*Kebijakan Energi Nasional*, KEN), which is stipulated in Government Regulation 79/2014. KEN serves as a guideline to provide direction for the management of energy independence and security to support sustainable national development. The target of KEN is that energy sources are intended as development capital for the prosperity of society by optimizing their utilization for national economic development, domestic value-added creation, and employment. Furthermore, the target of primary energy supply and utilization in KEN is as tabulated and illustrated in **Table 2.2** and **Figure 2.13**, respectively.

To achieve KEN targets and as a guideline for energy planning, the National Energy General Plan (*Rencana Umum Energi Nasional*, RUEN) was issued through Presidential Regulation 22/2017. RUEN is the basis for the development of sectoral and regional energy planning documents such as the General Plan for Electricity (*Rencana Umum Ketenagalistrikan Nasional*, RUKN), the General Plan for Electricity Supply (*Rencana Umum Penyediaan Tenaga Listrik*, RUPTL), and the Regional Energy General Plan (*Rencana Umum Energi Daerah*, RUED).

Table 2.2 KEN targets for 2025-2050 period

KEN Targets	2025	2050
Energy role	As development capital	
NRE mix	23%	31%
Energy supply	> 400 MTOE	> 1.000 MTOE
Power generation	> 115 GW	> 430 GW
Energy elasticity	< 1	< 1
Electricity/capita/year	2,500 kWh	7,000 kWh
Electrification ratio	~ 100%	~ 100%

Figure 2.13 KEN targets for 2025-2050 period



Source: Government Regulation 79/2014

Electricity

Indonesia's electricity subsector is regulated by Law 30/2009. The law mandates related to the supply and utilization of electricity as well as electricity supporting business in realizing the achievement of national development goals. In addition, the Law also mandates the utilization of primary energy for power generation implemented in accordance with KEN. Through the derivative regulation of Electricity Law, Government Regulation 23/2014 on Electricity Supply Business Activities, it is mandated that the preparation of electricity supply plan for public interest is implemented in accordance with the General Plan of Electricity (RUKN and RUKD) and RUPTL.

To achieve the renewable energy mix target in the primary energy mix, especially for power generation, the government through the MEMR issued MEMR Regulation 4/2020[5] which has an impact on renewable energy sources. This regulation provides opportunities for projects that are still under development to move from the Build Own Operate Transfer (BOOT) scheme to Build Own Operate (BOO). Then, in the current electricity supply plan (RUPTL 2021-2030), renewable energy is planned to fulfill more than half of the additional power generation capacity. The portion of additional NRE plants amounted to 51.6% or 20.9 GW. Based on the type of power plant, the largest renewable power plants are hydro/micro-/mini-hydro PP (10.391 GW), solar PV PP (4.68 GW), geothermal PP (3.355 GW), base NRE PP (1.01 GW), wind PP (0.597 GW), bio PP (0.590 GW) and battery energy storage systems (0.3 GW). Meanwhile, for power plants with fossil energy sources, the portion of additional generation amounted to 48.4% (19.562 GW)-where CFPP occupied the largest portion with 13.819 GW, followed by Gas-Steam/Gas Engine PP with 5.828 GW, and Diesel PP 5 GW.

[5] This regulation is the second amendment to MEMR Regulation 50/2017 on Utilization of Renewable Energy Sources for Electricity Supply.

Furthermore, with the issuance of Presidential Regulation 112/2022 on the Acceleration of Renewable Energy Development for Electricity Supply, the provisions for purchasing renewable energy electricity have been determined. In this regulation, in the future national power plant development plan, the CFPP that is built is only the CFPP that has been determined in the 2021-2030 RUPTL. The development of a new CFPP is allowed if it is integrated with an industry that is built oriented towards increasing the added value of natural resources, such as a smelter or CFPP included in the National Strategic Project (*Proyek Strategis Nasional*, PSN)—which contributes greatly to job creation and/or national economic growth. In addition, the Government of Indonesia has prepared renewable energy programs that aim to maximize the use of RE in Indonesia, one of which is the policy of using bioenergy in Waste to Energy PP (Presidential Regulation 35/2018), with the proposed plant construction in 12 cities as well as a co-firing program at the existing CFPP.

Non-Electricity

In terms of demand, the energy transition policy is in line with the Grand Strategy of National Energy (GSEN) which aims to reduce fuel imports. Based on the renewable energy mix target in Indonesia's primary energy mix stated in KEN and RUEN, the Government of Indonesia also targets the use of biofuels as an energy diversification measure. Policies have been issued that mandate the blending of biofuel in fuels used in the transportation subsector, as well as subsidy mechanisms. Mandated biofuel blending levels include a 35% biodiesel blend target (B35) and a 5% bioethanol blend (E5) in fuel oil. The biodiesel blending mandate is supported by a subsidy to cover the price difference between fossil fuels and biofuels. The subsidy is financed by a levy on palm oil exports. Additionally, the government also supports the construction of refineries to convert bioenergy waste into biofuels and other renewable fuels, such as bio-based LPG and naphtha and the use of biomass in the industry subsector.

In the transportation subsector, the government has targeted the acceleration of electric vehicle (EV) deployment, which has been applied to public vehicles in DKI Jakarta Province. The government has initiated the development of a battery-based electric car industry through Presidential Regulation 55/2019 on the Acceleration of the Battery-Based Electric Motor Vehicle Program for Road Transportation and the Roadmap for the Development of Battery-Based Electric Vehicles (*Kendaraan Berbasis Listrik Berbasis Baterai*, KBLBB) which contains guidelines for mastering the main components of motor vehicles containing batteries, electric motors, and converters. The government has mandated PT PLN (Persero) to cooperate with state-owned and private enterprises in developing electric vehicle charging infrastructure. For the residential subsector, the government targets to reduce the use of LPG for cooking by switching to electric induction stoves and utilizing Dimethyl Ether (DME).

Just Energy Transition Partnership (JETP)

The Government of Indonesia and the International Partners Group (IPG) launched a US$20 billion Just Energy Transition Partnership during the G20 Summit in Bali, Indonesia in November 2022.[6] JETP Indonesia and its commitment of US$20 billion towards Indonesia's energy transition can help the country realize its 2060 NZE goals.

The Government of Indonesia and the IPG have agreed for JETP Indonesia to focus on addressing targets within Indonesia's on-grid system and have set the following targets:

- Total on-grid power sector emissions peaking by 2030 with an emission target of no more than 250 MT CO_2 in 2030
- A renewable energy generation share of 44% by 2030
- Achievement of net zero emissions in the power sector by 2050.

Total investment costs have been estimated to be at least US$97.1 billion between 2023-2030 and US$580.3 billion between 2023-2050, targeting five investment focus areas (IFAs):

1. **IFA 1: Transmission Lines and Grid Deployment.** Around 14.000 km circuit of transmissions costing up to US$19.7 billion by 2030.
2. **IFA 2: Early Coal-fired Power Plant (CFPP) Retirement and Managed Phase-out.** Coal flexibility retrofits and early retirements requiring up to US$2.4 billion by 2030.
3. **IFA 3: Dispatchable Renewable Energy Acceleration.** 16.1 GW built out by 2030, costing up to US$49.2 billion by 2030.
4. **IFA 4: Variable Renewable Energy (VRE) Acceleration.** 40.4 GW built out by 2030, costing up to US$25.7 billion by 2030.
5. **IFA 5: Renewable Energy Supply Chain Enhancement.**

JETP Indonesia aims to deploy the US$20 billion commitment to act as a catalyst for reaching the total investment needed to reach JETP's 2030 targets.

Priority projects have already been identified for each IFA in the Comprehensive Investment and Policy Plan (CIPP).

[6] JETP Indonesia. 2023. *Comprehensive Investment and Policy Plan 2023*.

2.4.4 Energy Efficiency

In an effort to improve the economy and competitiveness, achieve energy security and address global climate change, the Government of Indonesia is committed to implementing energy conservation. The implementation of energy conservation is carried out at all stages of energy management, including energy supply, energy exploitation, energy utilization and conservation of energy resources. The energy conservation target until 2025 refers to KEN, which is to reduce energy intensity by 1% per year until 2025 and achieve final energy savings of 17% by 2025.

To achieve these targets, the government has issued Government Regulation 33/2023 on Energy Conservation which regulates the implementation of energy conservation at all stages of energy management both on the upstream and downstream sides, through the following programs.

a. Energy Management

The implementation of energy management includes the appointment of an energy manager; preparation of energy efficiency programs; implementation of periodic energy audits; and implementation of recommendations on energy audit results. The implementation of energy management is reported to the Minister of Energy and Mineral Resources yearly.

The implementation of energy management is required for energy providers carried out in energy resource exploitation and/or energy production activities that utilize energy more than 6,000 TOE per year. In the transportation and industry subsectors, energy users more than 4,000 TOE per year are required to implement energy conservation through energy management. For the commercial building subsector, energy management must be implemented if energy users use energy more than 500 TOE. For the record, the implementation of energy management in industries that consume more than 6,000 TOE in 2020 can reduce emissions by 6.7 $MtCO_2e$.

b. Energy Performance Standards and Energy Efficient Labels

The government has set Minimum Energy Performance Standards (MEPS) for energy-using equipment. MEPS is a specification that contains a number of minimum energy performance requirements under certain conditions, which are effectively intended to limit the maximum amount of energy consumption of permitted energy-using equipment. The implementation of MEPS is done by the inclusion of energy-saving mark labels, which are intended to protect and provide information to consumers in the selection of energy-saving and efficient household appliances and prevent inefficient household appliance products from entering the Indonesian market.

Energy efficient labels (*Label Tanda Hemat Energi,* LTHE) is the highest validation at the national level that is affixed to energy-using equipment as information that the equipment has met the requirements as stated on the label. For manufacturers, LTHE plays an important role in ensuring the feasibility of the product's energy efficiency level and becoming the first choice for consumers and ruling out competing products that do not yet have LTHE. With the existence of LTHE, the Government hopes to encourage producers to always improve product quality in terms of energy efficiency in the context of saving national energy.

In 2021, MEMR Regulation No. 14 of 2021 on the Application of Minimum Energy Performance Standards for Energy Utilization Equipment has been established, which states that manufacturers and importers are required to apply MEPS to energy utilization equipment that will be traded in Indonesian territory. In addition, several Ministerial Decrees have also been issued regarding the establishment of certain equipment performance standards, including:

- MEMR Decree No. 103K/EK.07/DJE/2021 for air conditioning equipment
- MEMR Decree No. 113K/EK.07/DJE/2021 for refrigerators
- MEMR Decree No. 114K/EK.07/DJE/2021 for fans
- MEMR Decree No. 115K/EK.07/DJE/2021 for rice cookers
- MEMR Decree No. 135K/EK.07/DJE/2022 for light-emitting diode (LED) lighting equipment

c. Fuel Switching

One of the energy conservation activities in order to reduce GHG emissions is through the application of low-carbon fuels and fuel switching. Some of the activities that have been implemented to date include:

- Utilization of fuel oil with higher octane value than RON88. The implementation of this activity is aimed at reducing GHG emissions by 234 thousand tCO_2e in 2020.
- Conversion of kerosene to LPG for household cooking needs. The implementation of this activity reduces GHG emissions by 11.75 million tCO_2e in 2020.
- Construction of gas networks for households. The implementation of this activity reduces GHG emissions by 234 thousand tCO_2e in 2020.
- Substitution of fuel oil with natural gas for transportation. The implementation of this activity reduced GHG emissions by 3.3 thousand tCO_2e in 2020.

Additionally, to energy conservation programs, sectoral ministries have also developed energy efficiency standards. The Ministry of Industry (MoI) has developed green industry standards (MoI Regulation 51/2015) in several industry subsectors that set energy and emission intensity limits based on the type of product or process. In the commercial building subsector, the Ministry of Public Works and Public Housing (MoPWPH) has set standards for building management, energy efficiency, water use efficiency, indoor air quality, and waste management through MoPWPH Regulation 21/2021. This regulation must be applied to most residential buildings of at least four floors, mixed-use buildings, office buildings with an area of more than 50,000 m^2, hospitals with an area of more than 20,000 m^2, and other buildings with an area of more than 10,000 m^2.

2.4.5 Climate

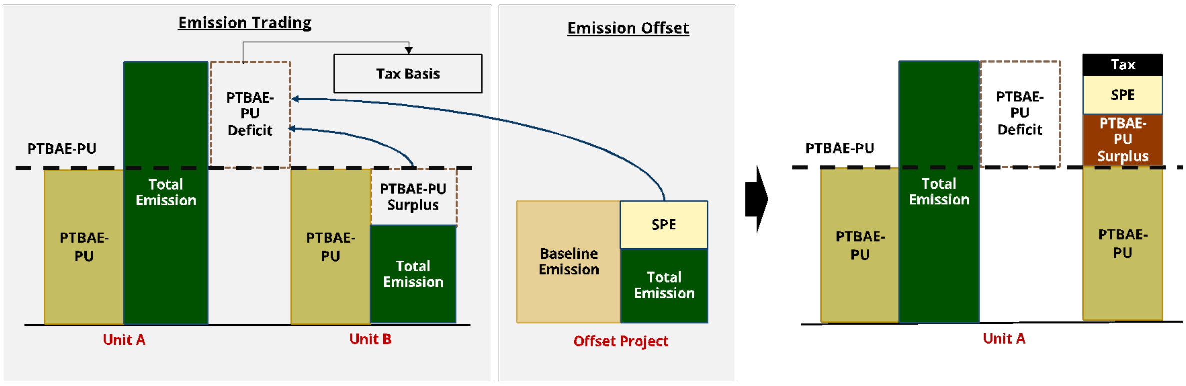
Carbon Pricing

In order to achieve the national climate targets contained in the NDC and accelerate GHG emission control in national development, Indonesia has compiled and issued several regulations related to the carbon pricing (*Nilai Ekonomi Karbon*, NEK). Presidential Regulation 98/2021 was issued as the basis for the implementation of NEK and guidelines for emission reduction through policies, steps, and activities in achieving NDC targets and controlling GHG emissions. As an implementation of the regulation, the Ministry of Environment and Forestry (MoEF) has issued MoEF Regulation 21/2022 concerning NEK Implementation Procedures aimed at providing detailed provisions regarding the implementation of NEK implemented in various sectors and subsectors. Meanwhile, for the power generation subsector, MEMR has issued specific regulations through MEMR Regulation 16/2022. In addition, the Government of Indonesia has also issued and prepared several other derivative regulations such as Coordinating Ministry for Maritime and Investment Affairs (CMMIA) Regulation 5/2021 on the Structure and Work Procedures of the NEK Implementation Steering Committee and MoEF on NEK implementation in the Forestry and Other Land Use (FOLU) and waste sectors.

Referring to the MoEF Regulation 21/2022, the mechanism for implementing NEK can be carried out through carbon trading mechanisms, performance-based payments, levies on carbon, and/or other mechanisms in accordance with the development of science and technology as determined by the Minister. Related to the implementation of carbon trading, trading is carried out through emission trading and emission offsets. Emission trading is applied to businesses and/or activities that have GHG emission cap (*Batas Atas Emisi*, BAE) that have been determined through the *Persetujuan Teknis Batas Atas Emisi* (PTBAE). PTBAE is a technical agreement on the highest emission level set in a period. The PTBAE is the basis for the stipulation of the *Persetujuan Teknis Batas Atas Emisi – Pelaku Usaha* (PTBAE-PU). In addition to emission trading, emission offsets also have provisions and procedures for use—therefore they can be used as GHG emission offsets. Emission offsets are carried out for businesses and/or activities that do not have BAE. Emission trading and emission offsets are conducted through carbon exchanges or direct trading. Through the Financial Services Authority Regulation 14/2023 on Carbon Trading through Carbon Exchange, the implementation of carbon exchange is regulated and supervised by the Financial Services Authority (*Otoritas Jasa Keuangan*, OJK).

As for the power plant, the implementation of carbon trading is carried out using a cap, trade, and tax scheme, as illustrated in **Figure 2.14**. Generating units that produce emissions in excess of the given PTBAE-PU (deficit) are required to purchase emissions from other generating units that produce emissions below the PTBAE-PU (surplus) and/or purchase GHG Emission Reduction Certificates (*Sertifikat Pengurangan Emisi*, SPE). Meanwhile, if the purchase of surplus or SPE has not fulfilled the compliance obligations of business actors, the remaining deficit will become the basis for tax imposition. Then, as an offset to GHG emissions, emission offsets are carried out in businesses and/or activities that have obtained SPE originating from energy sector emission reduction activities, such as renewable energy generation, transportation subsector activities, buildings, industry—including the implementation of energy efficiency and other activities. For the record, PTBAE-PU surplus cannot be submitted as SPE.

Figure 2.14 CFPP cap, trade, and tax illustration



Source: Center for Climate Change Financing and Multilateral Policy, Fiscal Policy Agency, Ministry of Finance. 2023. Optimizing Carbon Pricing Towards Green Economy.

Renewable Energy Certificate (REC)

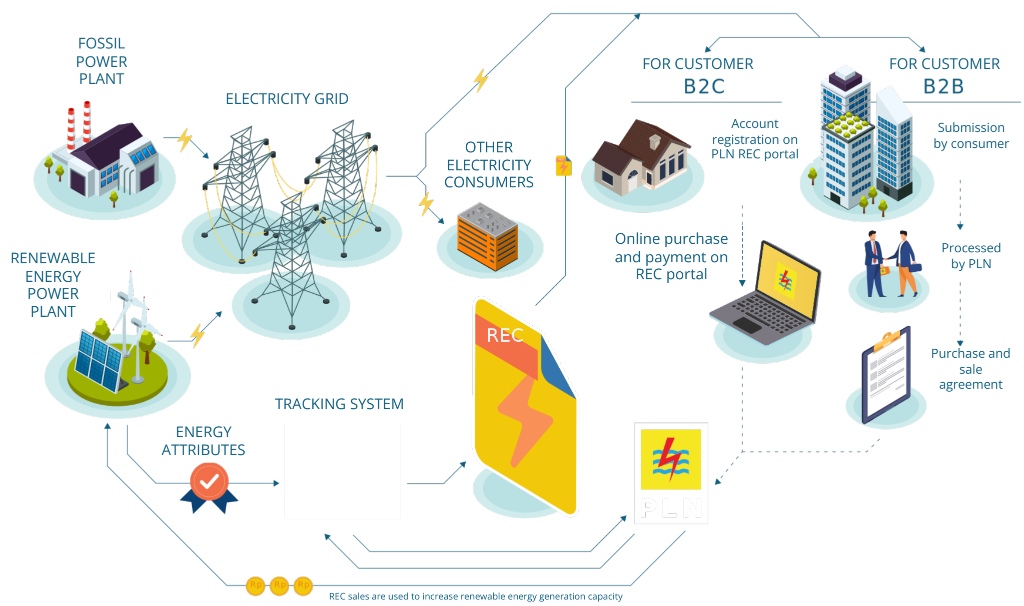
Renewable Energy Certificate or REC is an instrument that represents one MWh of electricity produced by renewable energy generation (one REC unit). PT PLN (Persero) launched REC with the aim of supporting the achievement of a renewable energy mix of 23% by 2025, the electrification target in Indonesia, the NDC target and the transition to renewable energy. RECs have a role as an instrument for recognition of renewable energy use, a procurement option for transparent fulfillment of renewable energy use targets and encouraging the growth of the national renewable energy market.

RECs are issued to meet the needs of consumers where more than 240 multinational companies have committed to use 100% renewable energy as a source of energy for facilities and supply chains, including in Indonesia. Therefore, REC is one of PT PLN (Persero)'s green product innovations to make it easier for customers to get recognition for the use of renewable energy. RECs can also encourage the development of renewable energy power plants. The sale of RECs will encourage the construction of renewable energy power plants so that Indonesia can achieve its renewable energy target. In addition, RECs can also attract sustainable energy investment, especially investment in renewable energy power plants.

Figure 2.15 shows the scheme of PLN's REC product service. PT PLN (Persero) established an electronic tracking system that ensures that RECs have been used, so that they cannot be traded again. The entire process has been verified and meets international standards. Environmental attributes attached to RECs such as carbon attributes cannot be sold and used in other market instruments. PT PLN (Persero) works with tracking system company APX Inc. to enable verification of each claim for renewable energy use through a tracking system with international standards, facilitate, transfer, issue and retire RECs, and create a credible renewable energy use claim structure.

REC services can be purchased by customers either bundled or separately. RECs purchased on a bundled basis have characteristics, namely the REC service fee component becomes an integral part of the electricity usage fee bill and the number of units purchased can be adjusted according to consumer needs. Meanwhile, for RECs purchased separately, the REC service fee component is separate from the electricity usage fee, so that a non-electricity billing register number is given, the number of REC units purchased can be adjusted according to consumer needs, and this service can be used by consumers who have a Customer-ID or who do not have a Customer-ID. For the record, the REC service fee of IDR 35,000 per REC unit (or per MWh) includes the administration fee for the transfer of REC ownership, but does not include VAT.

Figure 2.15 Renewable Energy Certificate illustration



Source: PT PLN (Persero)

3 A PATHWAY TO NET ZERO EMISSIONS BY 2060

The energy transition roadmap towards carbon neutral consists of supply and demand side roadmap. In general, the roadmap on the supply side outlines a plan to provide energy by maximizing the NRE potential and gradually reducing fossil energy utilization. The NRE mix is targeted to reach 100% by 2060 with an estimated capacity of 708 GW dominated by Solar Power Plant (PP), followed by Wind PP, Hydro PP, Biodiesel PP, Nuclear PP, Geothermal PP, and Tidal PP. The additional CFPP/Steam Gas PP is only for those have been contracted/constructed and the additional PP after 2030 are only from NRE. PLN's CFPP will retire earlier than its operating life based on asset revaluation, while IPP's CFPP will retire after the PPA expires. The Steam Gas PP will retire after 30 years. The provision of electricity needs should be supported by reliable connectivity and requires a super grid after 2025. The super grid serves to overcome the mismatch between local renewable energy sources and locations of high energy demand. In addition, the super grid will reduce the intermittency impact of increasingly massive capacity of Variable Renewable Energy (VRE).

The roadmap on the demand side describes a long-term strategy on the energy user side, namely transportation, industry, residential, and commercial subsectors. Policies in industry subsector include reducing the share of coal and increasing the share of gas and electricity in the total energy consumption in industry. Natural gas and coal as non-energy demand used for the fertilizer industry and reductant of steel and mineral industry are also considered in the modeling of final energy demand. Another policy in industry subsector is increasing the efficiency of the production system. Policies in transportation subsector are focused on the use of electric vehicles including electric motorcycles, cars and buses aiming to increase electric vehicles efficiency. These policies will also reduce imported oil fuels and increase the use of 40% biodiesel. Policies in residential subsector include reducing LPG imports through domestic LPG production, electric stoves, city gas, and energy efficiency enhancement for residential electrical appliances. In commercial subsector, the policy comprises energy efficiency programs including energy management optimization and efficient equipment utilization.

3.1 Design of Modeled Pathways

3.1.1 New and Renewable Energy Potential

The potential and utilization of new and renewable energy, as shown in **Table 3.1**, is used as an assumption in calculating the capacity of power plants in NZE modelling. The largest renewable energy potential is solar energy, with a potential of 3,295 GW, followed by wind energy of 155 GW, hydro energy of 95 GW, ocean energy of 60 GW, bioenergy of 57 GW, and geothermal energy of 24 GW.

Table 3.1 NRE potential

Type of Energy	Potential (GW)	Utilization* (GW)
Solar	3,295	0.25
Hydro	95	6.67
Bioenergy	57	3.03
Wind	155	0.15
Geothermal	24	2.29
Ocean	60	0
Total	3,686	12.41

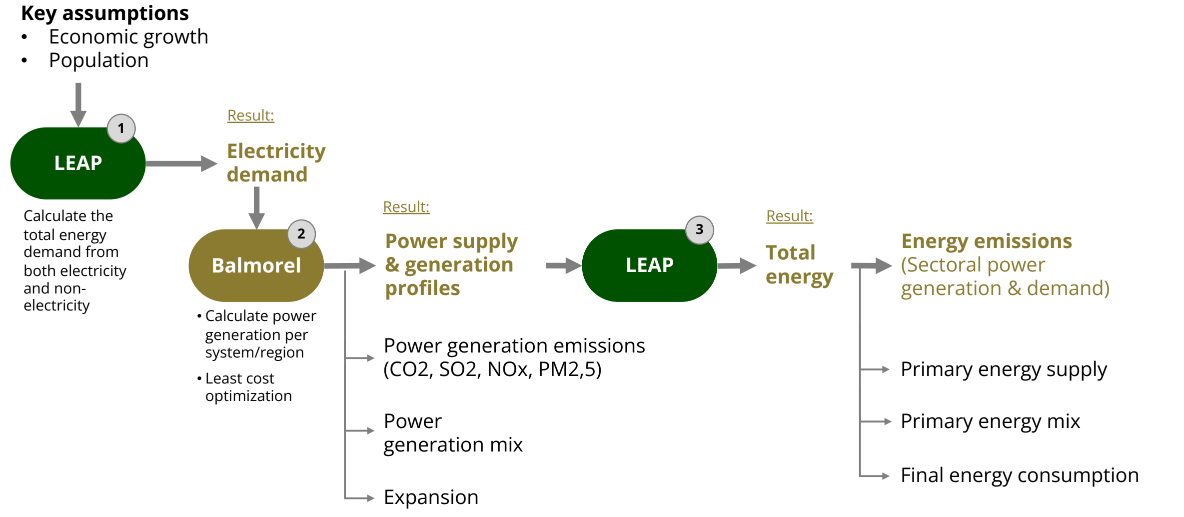
*) Realization up to 2022

Source: Center for Survey and Testing, Electricity, New Energy and Energy Conservation of MEMR (*Balai Besar Survei dan Pengujian, Ketenagalistrikan, Energi Baru, dan Konservasi Energi*, BBSP KEBTKE – KESDM)

3.1.2 Scenario design and modelling approach

Modeling is carried out through three stages, namely modelling to produce electricity demand output, supply and power generation profiles, and total energy. The modelling was conducted through the Low Emissions Analysis Platform (LEAP) and Balmorel software. In the first stage, the modelling was conducted by inputting economic and population growth assumptions in LEAP. Based on these inputs, LEAP calculated the total energy demand from both electricity and non-electricity, with the output of electricity demand. The output of the first stage became an input in the Balmorel software, which was then used to calculate per system or region and least cost optimization. The output of the second stage of modelling in Balmorel is the profile of electricity supply and generation. In addition, it also produced electricity generation emissions (CO_2, SO_2, NO_x, $PM_{2.5}$), electricity generation mix, and expansion. Furthermore, the output in the form of supply and power plant profiles then became the third stage input for LEAP to determine the total energy, which consists of energy emissions (electricity generation and sectoral demand), primary energy supply, primary energy mix, and final energy consumption. The energy modelling workflow for the NZE Energy Sector 2060 roadmap is illustrated in **Figure 3.1**.

Figure 3.1 Energy modelling flow

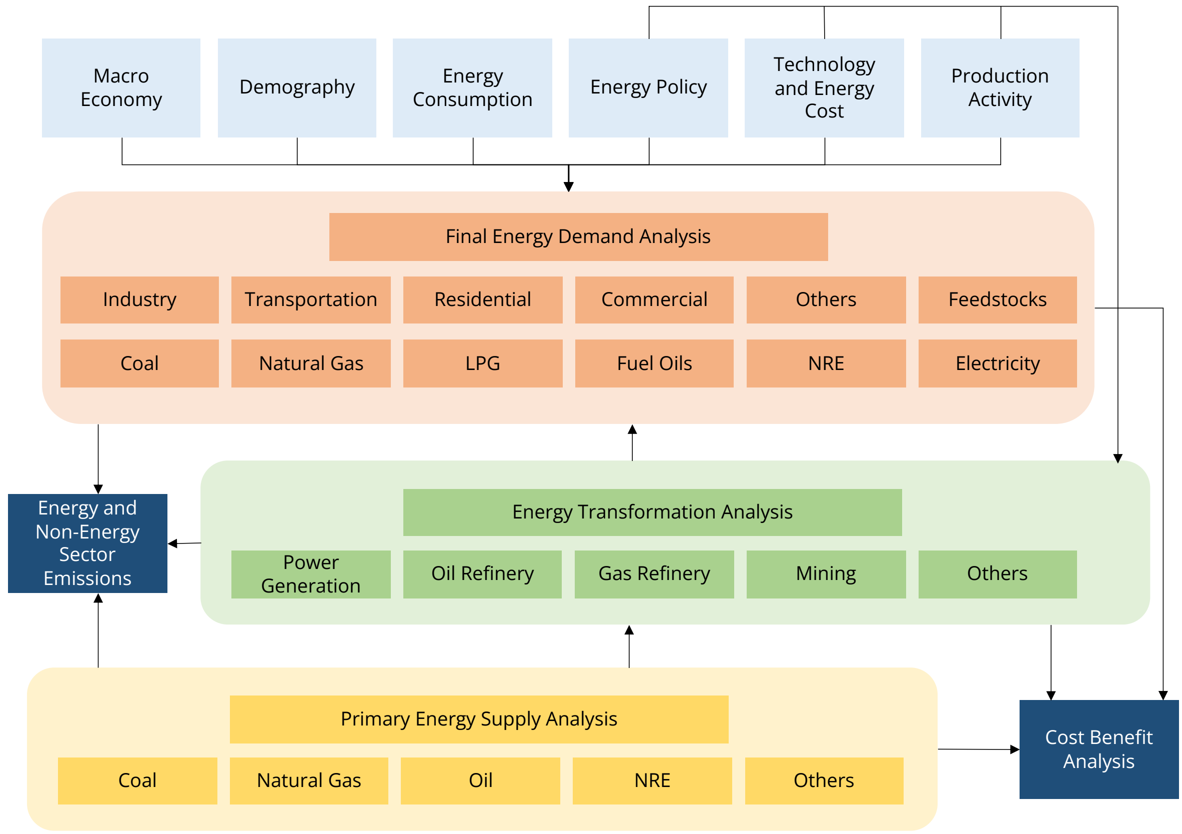


The analysis of energy supply and demand modeling in the LEAP Integrated Energy Model is divided into three stages, namely the analysis of final energy demand, energy transformation, and primary energy supply. The final energy demand analysis is conducted using macroeconomic assumptions, demographics, energy consumption, energy policy, technology and energy costs, and production activities. Similarly, the analysis of primary energy supply is carried out by considering the utilization of various types of energy sources and potential energy resources. While the energy transformation analysis is carried out by considering the energy development plan. The modelling analysis framework in LEAP is illustrated in **Figure 3.2**.

In the LEAP model, energy demand forecasts were calculated based on the multiplication of activity and energy use intensity. Energy activities are driven by economic growth, population, or production. While energy intensity is the level of energy consumption per GDP value or per population and household or per production in a given time. Energy intensity can be assumed to remain fixed over the simulation period or to decrease to indicate an increase in energy efficiency.

In accordance with the modeling analysis framework, the parameters considered in making projections of final energy demand are socio-economic data, namely population and economic growth, historical energy use data to determine energy intensity, and energy use patterns due to improvements in people's lifestyles which can be influenced by projected increases in GDP or increasingly efficient technology.

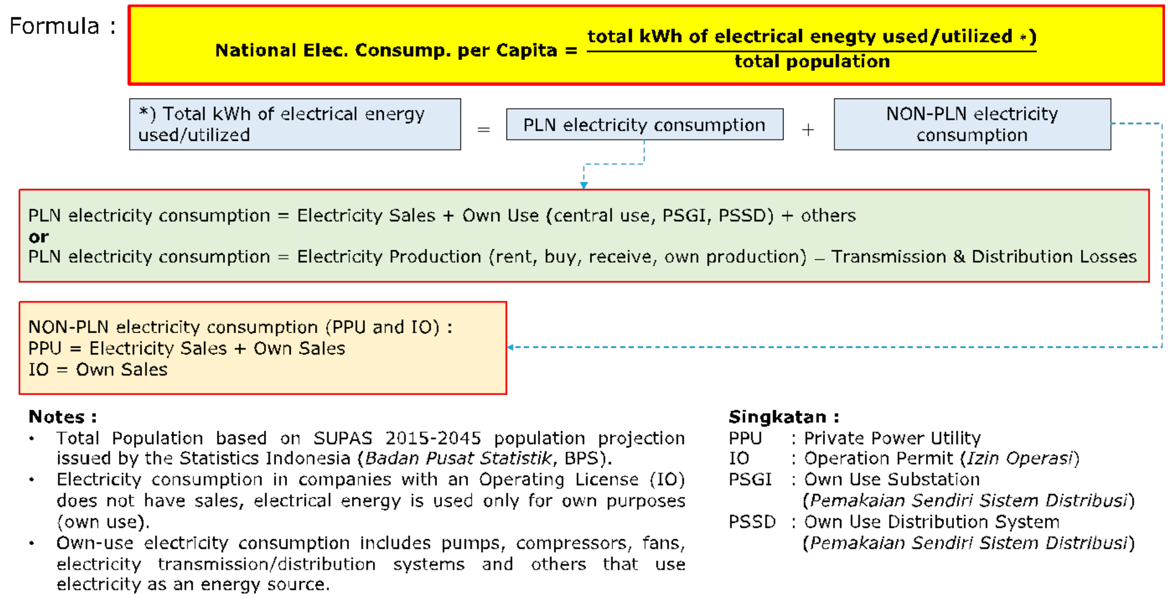
Figure 3.2 Analysis framework: energy supply and demand with LEAP integrated energy model



Electricity consumption per capita

The estimation of electricity consumption per capita was carried out through analysis of the data on electricity sales in companies holding Electricity Supply Business License (*Izin Usaha Penyediaan Tenaga Listrik untuk Kepentingan Umum*, IUPTL), namely PT PLN (Persero) Independent Power Producer (IPP) and Private Power Utility (PPU), and electrical energy used by Electricity Supply Business License for Own Interest (*Izin Usaha Penyediaan Tenaga Listrik untuk Kepentingan Sendiri*, IUPTLS) holders in Indonesia. The national per capita electricity consumption was estimated based on the amount of electrical energy used (kWh) divided by the total population, as shown in **Figure 3.3**.

Figure 3.3 Calculation of electricity consumption per capita



3.1.3 Key Assumptions for Energy Modeling

In the energy demand modeling, the main assumptions used are population growth and GDP growth, as tabulated in **Table 3.2**. Population growth data up to 2045 refers to data from the Central Statistics Agency (BPS), while population growth data from 2045 to 2060 were sourced from the Institute for Economic and Social Research of the University of Indonesia (*Lembaga Penyelidikan Ekonomi dan Masyarakat Universitas Indonesia*, LPEM-UI). GDP growth assumptions were based on Bappenas projections. Based on these data and assumptions, the population in Indonesia is projected to reach 331 million people in 2060. The average GDP growth for 2023-2060 is 5.82%.

Table 3.2 Macro assumptions and parameters

Parameter	Unit	Average (2023-2060)	2019	2020	2021	2022	2025	2030	2035	2040	2045	2050	2055	2060
Demography														
Population	million	310.82	267.1	270.2	272.7	275.7	282.5	294.1	304.3	312.5	319.0	324.0	327.9	331.3
Number of Household (HH)	million HH	80.75	68.9	69.7	70.4	71.2	73.0	76.1	78.9	81.1	82.9	84.4	85.5	86.5
Macro Economy														
GDP	thousand trillion rupiahs	41.48	10.9	10.7	11.1	11.7	13.7	18.1	24.5	34.3	45.2	57.0	71.2	88.0
GDP Growth	%	5.46	5.0	-2.1	3.7	5.3	5.4	6.0	6.7	7.0	5.0	4.7	4.5	4.3
GDP per Capita	million rupiahs	130.25	41.0	39.7	40.8	42.5	48.4	61.6	80.5	110.2	141.8	175.9	217.1	265.7

3.2 Pathways Overview

3.2.1 Key pillars of the transition pathway

To achieve a transition towards net-zero emissions by 2060, Indonesia must employ strategies to tackle different aspects of the energy sector, deploying a wide range of technologies and practices to do so. These strategies can be categorized into five pillars: (1) NRE utilization; (2) low-carbon practices; (3) electrification; (4) energy efficiency; and (5) carbon capture, utilization, and storage (CCS/CCUS). These pillars are upheld in both energy supply/upstream subsectors and energy demand/downstream subsectors.

NRE utilization will primarily involve the higher penetration of new and renewable energy in Indonesia’s energy sector. There are many options for renewable energy sources in Indonesia, including biomass, solar, wind, hydropower, geothermal, and nuclear. Many of these NRE sources will be utilized for power generation through the construction of NRE power plants that can support variable renewable energy in the country. Energy demand/downstream subsectors can also directly utilize NRE through plans for increase in the utilization of biofuels in various sectors, including transport and industry. Strategies for improving transmission and distribution with the higher penetration of VRE will also be key in this pillar.

To expedite Indonesia’s journey towards achieving the NZE target, it is imperative that Indonesia embrace deep decarbonization strategies, particularly by harnessing the potential of green hydrogen and bioenergy utilization in the industry and transportation subsectors (also known as the hard-to-abate subsectors). Green hydrogen, produced through renewable energy-powered electrolysis, offers a clean alternative to conventional fossil fuels, significantly reducing carbon emissions in industry and transportation subsectors. In the NZE scenario for Indonesia's energy sector, green hydrogen will be utilized to replace natural gas in the high-temperature heating process in the industry subsector starting in 2041. In the transportation subsector, green hydrogen is used as truck fuel starting in 2037.

Simultaneously, bioenergy, derived from sustainable sources such as agricultural waste or dedicated energy crops, presents an environmentally friendly option to replace carbon-intensive fuels. By integrating these innovative technologies into Indonesia’s energy mix, Indonesia can substantially curb greenhouse gas emissions, foster sustainability, and propel the establishment of a cleaner and greener future, where NZE become a tangible reality. In the NZE scenario of Indonesia's energy sector, bioenergy, especially biomass, is used to replace fossil fuels in the high-temperature heating process in the industry subsector, especially in the cement industry. In the transportation subsector, bioenergy in the form of biofuels is used as a substitute for fossil fuels.

Low-carbon practices focus primarily on shifts in current practices towards less carbon-intensive (non-NRE) options. In power generation, this encompasses biomass co-firing in coal-fired power plants and conversion of CFPPs and diesel PPs to gas PPs. This also involves the shifts in current carbon-intensive operations and practices, including the elimination of CFPPs in the RUPTL, the phasedown of coal-fired power plants, and zero-routine flaring in oil and gas extraction operations. In downstream subsectors, transport fuels with higher octane numbers are to be utilized, as well as a higher penetration of natural gas in urban public transportation. In residential subsector, this covers the utilization of dimethyl ether (DME) as an alternative fuel, especially when mixed with LPG, and the increase in the number of city gas connections.

To accelerate the achievement of NZE targets in Indonesia, a comprehensive approach is needed across multiple subsectors, including industry, transportation, residential and commercial. A particularly important strategy is the widespread adoption of **electrification** powered by renewable energy sources. By shifting industrial processes to utilize electricity generated from NRE, the industry subsector can significantly reduce the carbon footprint associated with manufacturing and production. In the transportation subsector, the shift towards electric vehicles driven by the demand for clean energy is further contributing to the reduction of greenhouse gas emissions. Improving electrification in residential and commercial spaces through renewable energy sources not only improves energy efficiency but also ensures a cleaner energy mix. This comprehensive approach to electrification from renewable energy forms the cornerstone of a transformative strategy that propels Indonesia towards a more sustainable and environmentally responsible future, aligned with the global goal of achieving NZE.

Energy efficiency efforts should also be prioritized in achieving NZE targets in the energy demand/downstream subsectors for all four subsectors: transportation, industry, residential and commercial. In the industry subsector, the application of advanced technologies and process optimization can significantly reduce energy intensity and lower carbon emissions. In the transportation subsector, the use of fuel-efficient vehicles and the transition to electricity alternatives play an important role in reducing energy intensity and reducing emissions. In the residential subsector, promoting energy-efficient appliances, by implementing energy efficiency standards such as MEPS, contributes to a substantial reduction in energy consumption. Similarly, in commercial buildings, investing in energy-efficient lighting, heating, ventilation and air conditioning (HVAC) systems can help lower overall energy demand. By focusing on energy efficiency measures across these various subsectors, energy intensity can be effectively reduced, paving the way to a more sustainable future and achieving NZE targets critical to global climate goals.

Moreover, in order to achieve the NZE target, it is paramount that Indonesia harness the potential of **carbon capture, utilization, and storage (CCS/CCUS)**, particularly within the challenging hard-to-abate industry sector. CCS/CCUS technologies offer a vital pathway to significantly curbing emissions from industries that rely heavily on fossil fuels, such as cement and steel production. By capturing carbon dioxide emissions at their source and securely storing them underground or repurposing them for valuable applications like enhanced oil recovery or the production of synthetic fuels, CCS/CCUS not only mitigates environmental impact but also facilitates economic growth. In the NZE scenario for Indonesia's energy sector, CCS/CCUS will be implemented in the extraction of coal, oil, and gas, as well as in remaining coal-fired power plants. In addition, the industry subsector, especially the cement industry, will also implement CCS technology starting in 2036.

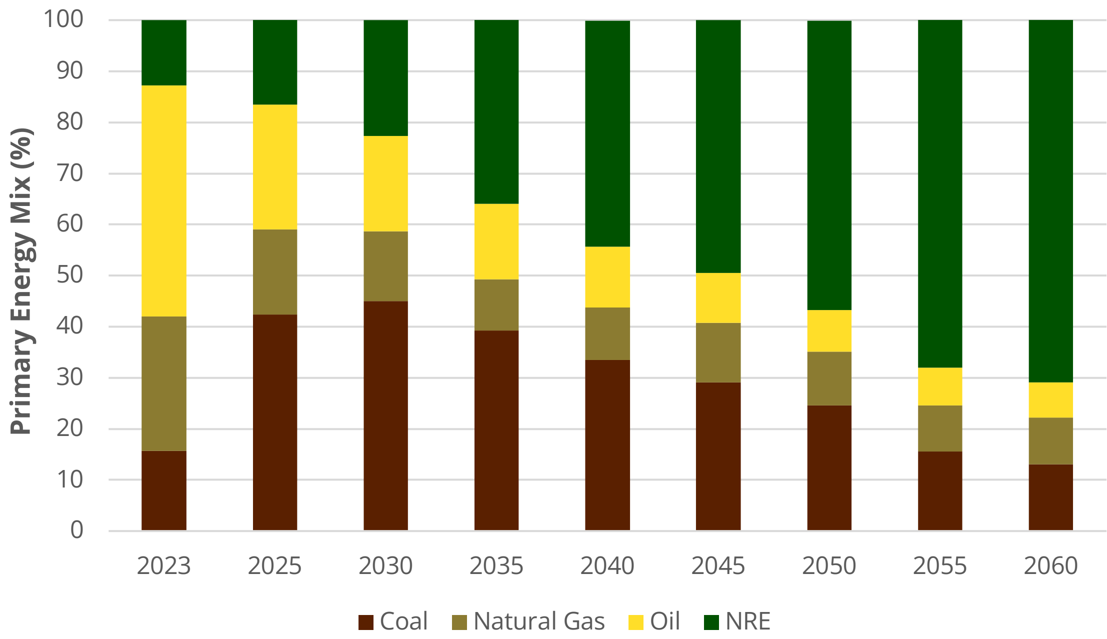
3.2.2 Total energy supply

The total primary energy supply of the NZE scenario in 2060 is projected to reach 659 MTOE—increased by 77% from 2023. Coal is still used as a primary energy source with a peak in 2035, reaching 178 MTOE (39% of total primary energy supply). Coal is still used in the industry subsector in order to increase coal downstreaming in accordance with the Government's plan outlined in the Roadmap for Coal Development and Utilization 2021-2045. Furthermore, coal utilization will decrease until it reaches 86 MTOE in 2060.

The decline in coal supply is in line with the energy transition to renewable energy sources. The share of renewable energy continues to increase with an average growth of 4% per year and begins to dominate in 2037, with a mix of 39% of total primary energy supply (188 MTOE) and continues to increase to 71% (468 MTOE) in 2060. These renewable energy sources are mainly used in the power generation subsector.

Other primary energy sources, namely natural gas and oil, will continue to decline until 2060, reaching 60 MTOE (9%) and 46 MTOE (7%), respectively. Natural gas will still be used for the needs of the industry subsector, while oil is used for the transportation subsector. The projection of the primary energy mix up to 2060 is shown in **Figure 3.4**.

Figure 3.4 Projected primary energy mix 2023-2060



Type of Energy	Energy Supply (MTOE)								
	2023	2025	2030	2035	2040	2045	2050	2055	2060
Coal	23.6	118.2	164.4	177.6	175.7	165.7	150.2	99.6	86.1
Natural Gas	39.6	46.4	50.0	45.7	54.0	66.4	64.4	57.3	59.9
Oil	68.0	68.4	68.1	66.5	61.9	55.2	50.0	47.2	45.5
NRE	19.2	46.8	82.8	163.9	232.3	281.7	345.4	435.6	467.6
Total	**150.4**	**279.8**	**365.3**	**453.6**	**523.9**	**569.0**	**610.0**	**639.7**	**659.1**

3.2.3 Final Energy Demand

As previously explained, the demand-side (downstream) subsector will transition to electricity starting in 2035. Electric energy is projected to become the main energy in 2060, with a total demand of 123 MTOE, 42% of the total final energy demand. Utilization of renewable energy and natural gas will also increase, reaching 77 MTOE (26%) and 41 MTOE (14%) respectively in 2060. The utilization of RE is mostly in the industry and transportation subsectors. Gas utilization will be optimized to meet the needs of industry, residential, and transportation.

Meanwhile, the use of coal and crude oil will decline to around 10 MTOE (3%) and 45 MTOE (15%) in 2060. Coal utilization is still needed for energy-intensive industries including cement, iron, and other steel. Meanwhile, fuel oil is still needed to meet industry and transportation needs. Projections of final energy demand by energy type are shown in **Figure 3.5**.

Final energy demand by subsector is shown in **Figure 3.6**. The industry subsector is the main driver in increasing energy consumption, followed by the transportation and residential subsectors. The final energy needs of the industry subsector in 2060 reached 146 MTOE (49%), followed by the transportation (15%), residential (11%), commercial (10%). For non-fuel oil needs, natural gas, methanol, and syngas as feedstock contribute 15%. Based on the projection results, the industry subsector needs more attention in order to conserve and improve energy efficiency towards NZE.

Figure 3.5 Projected final energy demand by energy type

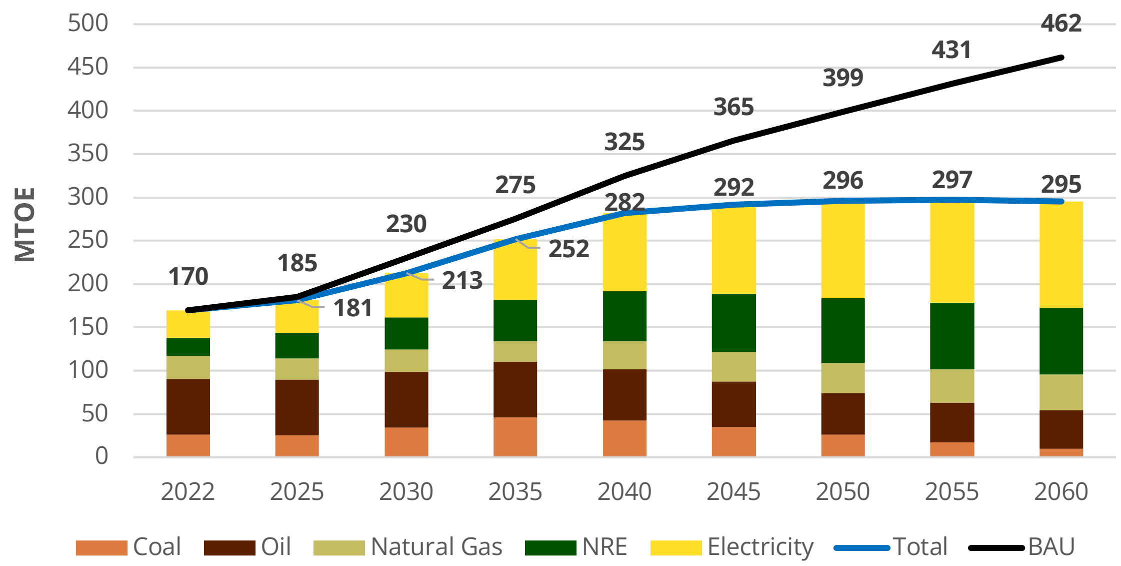
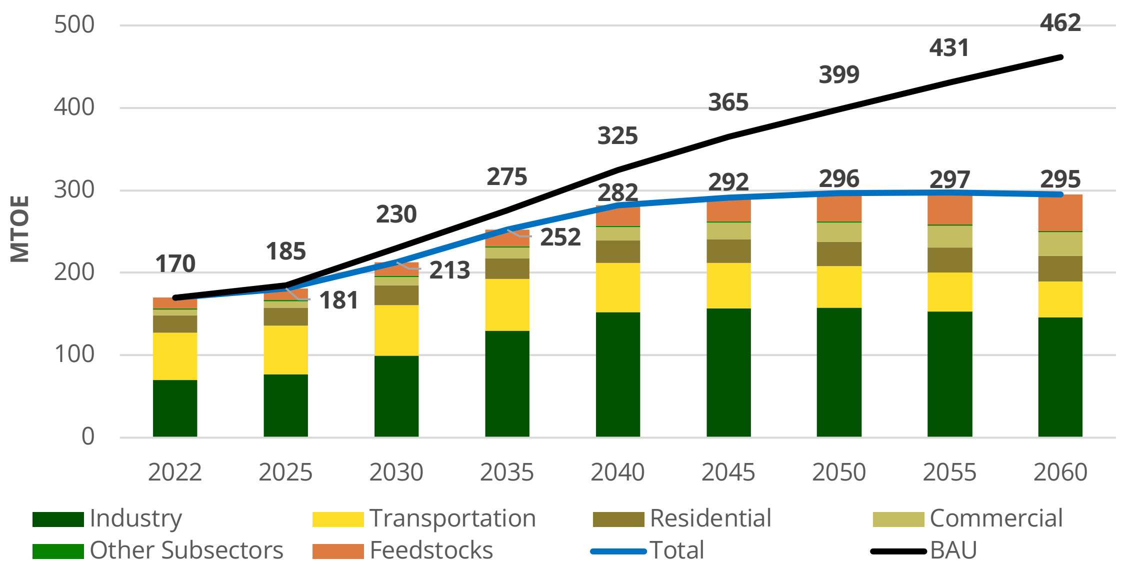


Figure 3.6 Projected final energy demand by subsectors



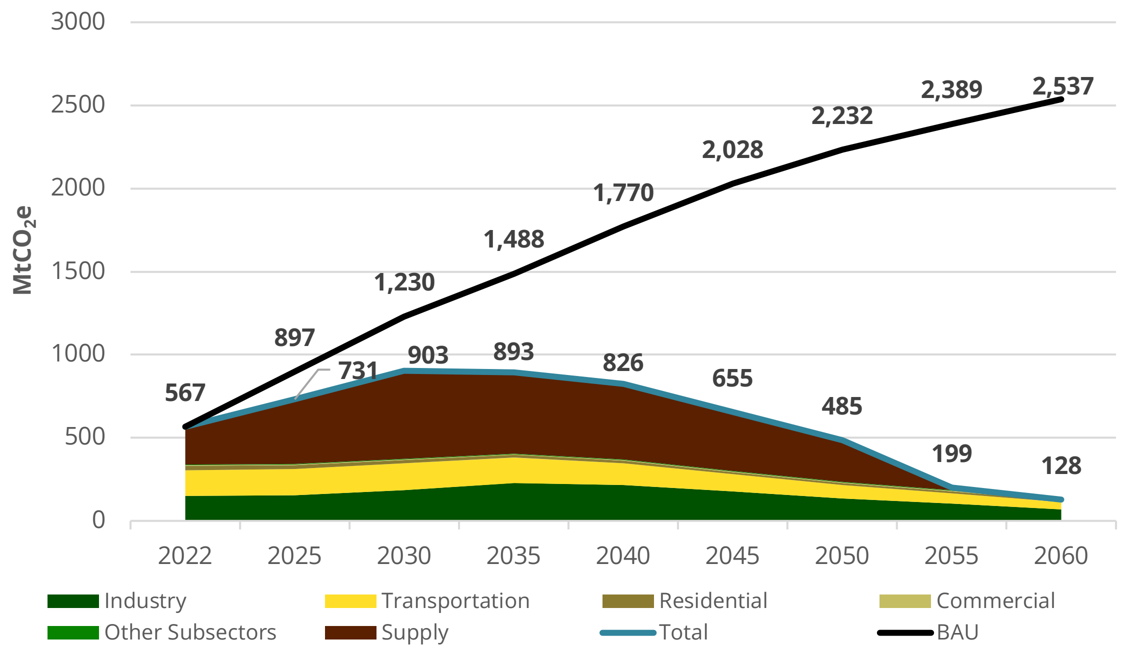
3.3 Emission Trends

In the NZE scenario, emissions in the energy sector in 2060 are reduced to 128 million tons CO_2e from 793 million tons CO_2e in the BAU scenario. To achieve the NZE target, each subsector must implement mitigation actions, which will be fully explained in Chapter 4 (supply side) and Chapter 5 (demand side).

Based on the emission projections shown in **Figure 3.7**, the power generation subsector will reach a peak emission in 2030 of 530 million tons of CO_2e. Subsequently, emissions will decrease significantly as fossil-based power plants retire. By 2056, the power generation subsector's emissions are expected to be close to zero and reach zero by 2059. The transportation subsector will experience peak emissions in 2030, at around 160 million tons CO_2e, and will drop to around 44 million tons CO_2e in 2060.

Meanwhile, the industry subsector is projected to reach peak emissions in 2036 with emissions of around 230 million tons of CO_2e and will become the largest emitter in 2060 with emissions of 69 million tons of CO_2e. The emissions of other subsectors, namely residential, commercial, and other subsectors, in 2060 will reach 9.6-, 3.5-, and 1.8 million tons of CO_2e, respectively.

Figure 3.7 Projected emissions by subsectors



4 PATHWAYS FOR ENERGY SUPPLY SIDE (UPSTREAM)

This chapter describes the energy supply side/upstream pathways, which is divided into three parts, namely (i) extraction (coal and oil and gas); (ii) transformation (power plants and oil and gas refineries); and (iii) transmission and distribution.

4.1 Extraction

4.1.1 Coal

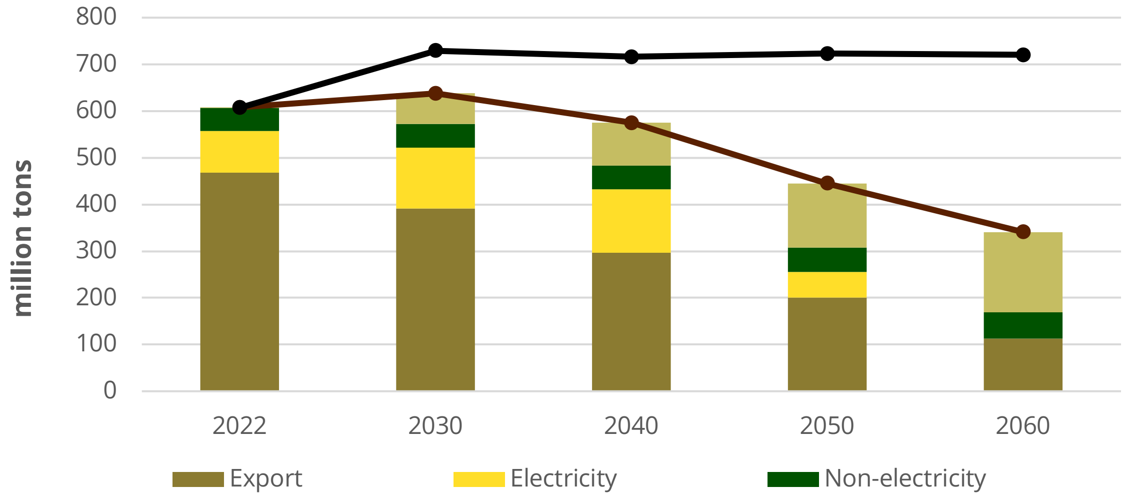
Based on data from the Geological Agency of the Ministry of Energy and Mineral Resources (MEMR) in 2022, Indonesia has coal resources of 99 billion tons with coal reserves reaching 35 billion tons. With such abundant resources, coal is the most dominant national primary energy source, especially in power generation. However, the coal industry is currently facing challenges related to the issue of negative impacts on the environment. This could have an impact on the decline of Indonesia's coal market, which is currently dominated by exports.

To face these challenges, the Government has formulated a policy to encourage the development and utilization of coal to increase the added value of domestic coal—called coal Value Added Improvement (*Peningkatan Nilai Tambah*, PNT)—as outlined in Law 4/2009 on Mineral and Coal Mining. The policy of increasing added value is regulated again in Law 3/2020 on the Amendments to Law 4/2009. In addition, the Government through the Ministry of Energy and Mineral Resources (MEMR) has also developed the Coal Development and Utilization Roadmap 2021-2045 which designs ten coal development and utilization programs for energy needs, and industrial needs (non-energy) by considering industry readiness and supporting Indonesia's commitment to reduce CO_2 emissions to achieve Net Zero Emission (NZE).

In the NZE scenario, the use of coal as the national primary energy source will gradually decrease, as shown in **Figure 4.1**. National coal production is projected to reach its peak in 2030 at 729 million tons and then drop significantly until 2060. By 2050, coal production will drop by 47%. National coal production is estimated to be only around 341 million tons in 2060 if the development of renewable energy is in line with the target.

The amount of coal demand for the power sector will peak in 2035 at 147 million tons, an increase of around 63% from the coal demand in 2022. Furthermore, coal demand begins to decline to 136 million tons in 2040. The largest decline in coal demand will occur in 2050 to 55 million tons. As for 2060, coal is expected to no longer be used as an energy source for the electricity subsector. The decline in coal consumption will also occur in the non-electricity subsector (textile, cement, paper, smelter, fertilizer, and chemical industries). As an energy source, coal will slowly be replaced by more environmentally friendly energy. However, coal as a raw material is still needed in the processing process. Therefore, the industry still needs 55.7 million tons of coal in 2060.

Figure 4.1 Projections of coal production, demand, and exports



Strategies to move towards NZE in the coal subsector include the use of biofuel in mining equipment and optimization of domestic coal utilization.

Use of Biofuel

Coal mining activities generate emissions from mining equipment, such as excavators and haulers, and from processing and/or refining plants. These emissions are the result of the combustion process of fuel oil. Therefore, efforts to mitigate greenhouse gas (GHG) emissions in upstream coal mining activities are to encourage business entities holding mining licenses to use biofuels such as B20 and B30 biodiesel.

Optimizing Domestic Coal Utilization

As previously explained, the Government has developed the Coal Development and Utilization Roadmap 2021-2045. In the document, ten coal development and utilization programs were designed as summarized in **Table 4.1**. Coal utilization is no longer focused as an energy source, but also as a raw material for other industrial activities. In addition, coal-derived products are economically expected to be able to compete with products derived from oil and gas so that they can become import substitutes.

The implementation of the program requires various stages of study with a timeline as shown in **Table 4.2**. In general, the stages of the coal development and utilization program consist of the process of preparing the development program/feasibility study, construction, development, and optimization of coal development and utilization. The 2021–2025 period is a period of preparation and ensuring the feasibility of all coal downstream programs. Optimization of the development of the coal downstream industry is carried out in an integrated manner with clean coal technology to meet the needs of energy and industrial raw materials that are oriented towards minimum – zero carbon emission.

Table 4.1 Coal development and utilization program

<table>
<tr><th colspan="3" rowspan="2">Coal Development and Utilization Program</th><th colspan="3">Program Sector</th></tr>
<tr><th>Energy
Coal Utilization for National Energy Needs</th><th>Non-Energy
Coal Utilization for Industrial Needs</th><th>Environment
Supporting CO_2 Emission Reduction</th></tr>
<tr><td rowspan="8">DEVELOPMENT</td><td>1.</td><td rowspan="2">Coal Gasification</td><td colspan="2">Methanol and DME</td><td></td></tr>
<tr><td>2.</td><td colspan="2">SNG, Ammonia, Hydrogen (H_2)</td><td></td></tr>
<tr><td>3.</td><td>Coal Liquefaction</td><td>Gasoline and Solar</td><td></td><td></td></tr>
<tr><td>4.</td><td>Coal Briquette</td><td>Coal-Biomass Briquettes and Carbonized Briquettes</td><td></td><td></td></tr>
<tr><td>5.</td><td>Cokes Making</td><td></td><td>Metallurgical Coal</td><td></td></tr>
<tr><td>6.</td><td>Coal Upgrading</td><td colspan="2">Coal for Power and Industry</td><td></td></tr>
<tr><td>7.</td><td rowspan="2">Coal Extraction</td><td></td><td>Advanced Materials and Rare Earth Metals</td><td></td></tr>
<tr><td>8.</td><td></td><td>Humic Acid and Fulvic Acid</td><td></td></tr>
<tr><td rowspan="2">UTILIZATION</td><td>9.</td><td>Blending Facility:
Biomass Cofiring; dan IGCC Implementation.</td><td>Electricity and CCT Application in Power Plants</td><td></td><td></td></tr>
<tr><td>10.</td><td>CCS/CCUS Implementation of Coal Development and Utilization Facilities</td><td></td><td></td><td>CO_2 Emission Reduction</td></tr>
</table>

Table 4.2 Timeline of coal development and utilization program

Coal Development and Utilization Program				TIMELINE									Feasibility Study – Development Preparation Development – Technology Implementation					
	No.	Downstream Technology	Downstream Products	2021-2030					2031-2040					2041-2045				
				2022	2024	2026	2028	2030	2032	2034	2036	2038	2040	2041	2042	2043	2044	2045
DEVELOPMENT	1	Coal Gasification	Methanol & DME															
	2		SNG, Ammonia, Hydrogen, Olefin															
	3	Coal Liquefaction	Gasoline & Solar															
	4	Coal Briquette	Coal-Biomass Briquettes and Carbonized Briquettes															
	5	Cokes Making	Metallurgical Coal															
	6	Coal Upgrading	Coal for Power and Industry															
	7	Coal Extraction	Advanced Materials and Rare Earth Metals															
	8		Humic Acid and Fulvic Acid															
UTILIZATION	9	Blending Facility; Biomass Cofiring; and IGCC Implementation	Electricity and CCT Application in Power Plants															
	10	CCS/CCUS Implementation of Coal Development and Utilization Facilities	CO_2 Emission Reduction			**Feasibility Study Period**												

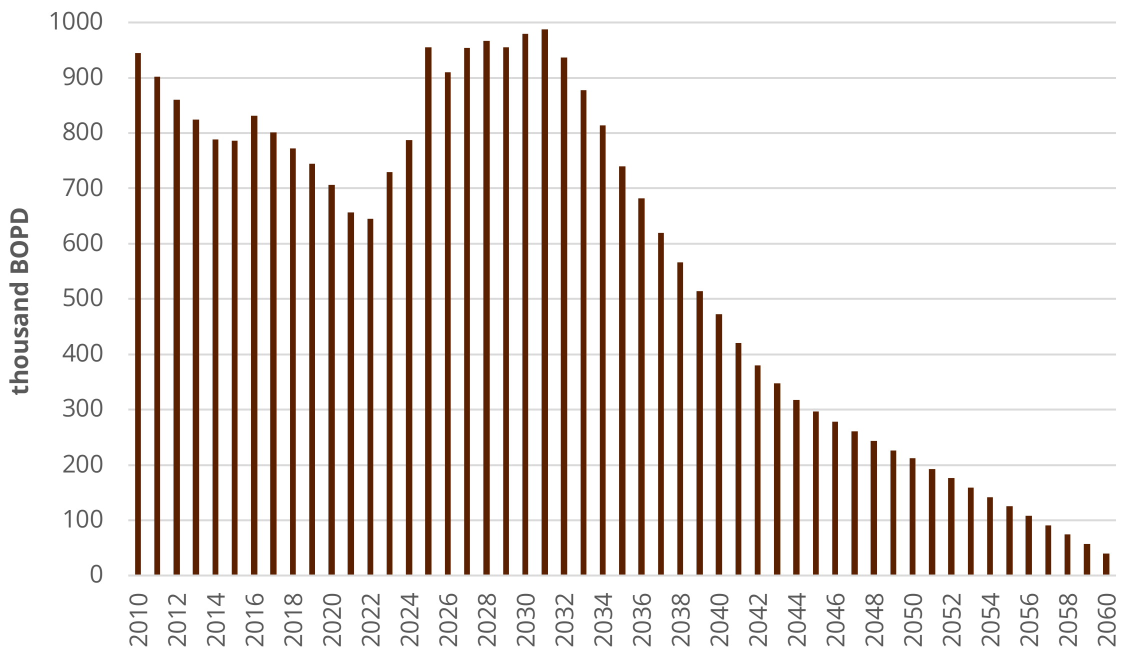
4.1.2 Oil and Gas

National crude oil production has decreased since 2010 from 945 thousand Barrel Oil Per Day (BOPD) to 706 thousand BOPD in 2020. The ability of domestic crude oil production has decreased due to the depreciation of the productivity of national oil fields due to age.

In 2030 the government has set crude oil production target of 1 million BOPD. As shown in **Figure 4.2**, the peak of crude oil production is estimated to occur in 2030 at 979 thousand BOPD which comes from production activities in existing fields, conventional and unconventional field development, and increased production through workover and Enhanced Oil Recovery (EOR).

For the period of 2030 to 2060, crude oil production is estimated to decline to only around 40 thousand BPOD in 2060 or only 5% of peak production in 2030. The decline in production is calculated through the BaU scenario without considering any new field discoveries or other programs to increase oil production. The ability of domestic oil production continues to decline because most oil fields are old fields that naturally experience a decline in production. In addition, upstream oil and gas investment dynamics also have the potential to decline due to energy transition plans in many countries that reduce oil demand and prices.

Figure 4.2 Production and projection of crude oil production 2010-2060



The projection of national natural gas production until 2060 is shown in **Figure 4.3** Peak natural gas production is estimated in 2029 at around 11,158 MMSCFD from production activities in existing fields, conventional and unconventional field development, and increased production through workover and enhanced gas recovery (EGR). New gas fields developed and assumed to be in production before 2029 are Masela, Sakakemang, Baronang and the IDD project. Gas production in 2029-2060 is expected to decline by 93% or to around 690 MMSCFD in 2060 if there are no new field discoveries or other programs to increase natural gas production (BaU scenario).

The emission of upstream oil and gas business activities and its projection until 2060 are shown in **Figure 4.4**. Upstream oil and gas emissions data comes from the activities of Production Sharing Contractors (PSCs), with the scope of GHG emissions considered, including CO_2, CH_4 dan N_2O. In 2020, the GHG emissions of upstream oil and gas business activities was 20.54 million tons of CO_2e. Meanwhile, in 2030, it is projected that the emissions of oil and gas business activities will peak at 31.42 million tons of CO_2e. Then, after 2030, emissions are projected to drop significantly to reach a level of 2.84 million tons of CO_2e in 2060.

Figure 4.3 Production and projection of natural gas production 2010-2060

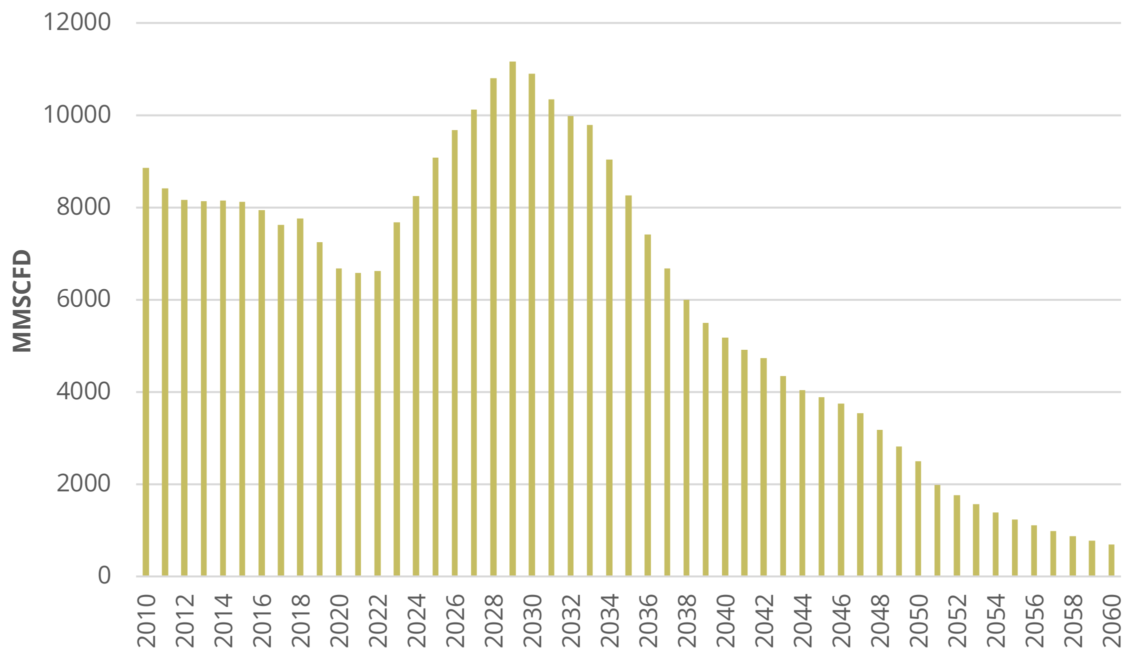
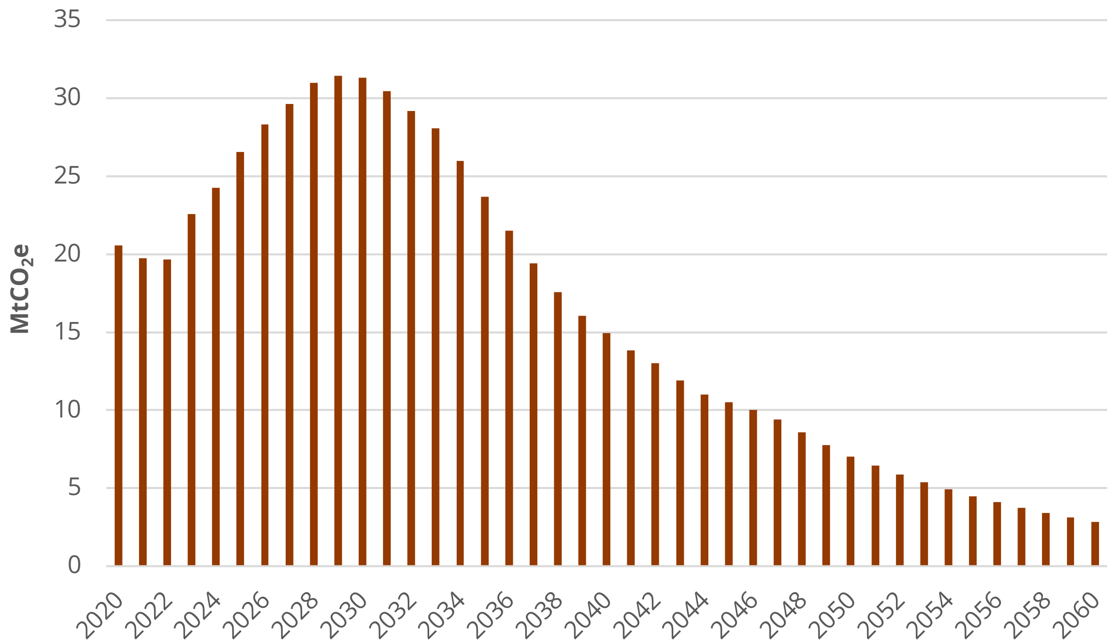


Figure 4.4 Emission of upstream oil and gas business activities



Mitigation measures taken on the oil and gas supply side are Zero Routine Flaring (ZRF) activities in 2030 and CCS/CCUS for EOR and EGR. In general, both activities can reduce emissions as tabulated in **Table 4.3**. The GHG emission reduction target through ZRF uses the basic assumption that the natural gas burned is pure natural gas. The fraction oxidized to CO_2 is assumed to be 100%. The resulting emission reduction is a reduction from flaring activities. The emission reduction results do not calculate emissions from flared gas utilization or commercialization activities.

Table 4.3 Emission reductions from ZRF and CCS/CCUS (in million tons CO_2e)

Initiative	2020-2030	2031-2040	2041-2050	2051-2060
Zero Routine Flaring	7.76	0	0	0
CCS/CCUS Implementation	11.5	22.5	6	3
Total	19.26	22.5	6	3

The description of mitigation measures consisting of ZRF and CCS/CCUS programs in oil and gas business activities is as follows.

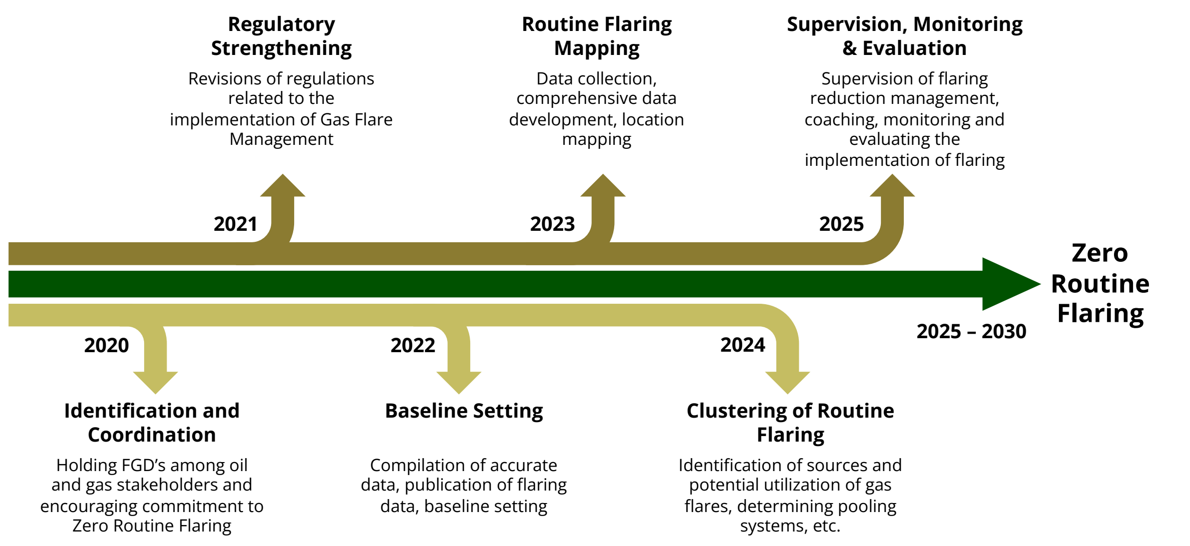
Zero Routine Flaring (ZRF) in 2030

Indonesia is one of the countries that has a Zero Routine Flaring (ZRF) 2030 policy as declared by the Minister of Energy and Mineral Resources to the World Bank. Based on the roadmap to achieve ZRF in 2030, as illustrated in **Figure 4.5**, the first strategy is to strengthen regulations through MEMR Regulation 17/2021 on Flare Gas Management in Oil and Gas Business Activities, as a legal basis for obtaining comprehensive flaring data.

The second strategy is the development of baseline flaring data based on reports from all oil and gas Contractor Cooperation Contract (*Kontraktor Kontrak Kerja Sama*, KKKS) and oil and gas processing business entities. The baseline data is the basis for quantifying the annual flaring reduction target.

The next strategy is to map locations that conduct routine and non-routine flaring with large volumes (high flaring intensity). Routine flaring locations are then grouped (clustered) then the feasibility of the development of a collection facility as a joint flaring utilization facility (pooling system) that can be used for its own or other parties' interests (commercialization) will be analyzed. Supervision, monitoring, evaluation, and cooperation between parties are carried out on an ongoing basis on reporting, mapping, and clustering data to achieve the ZRF target in 2030.

Figure 4.5 Roadmap of ZRF Indonesia



CCS/CCUS Program

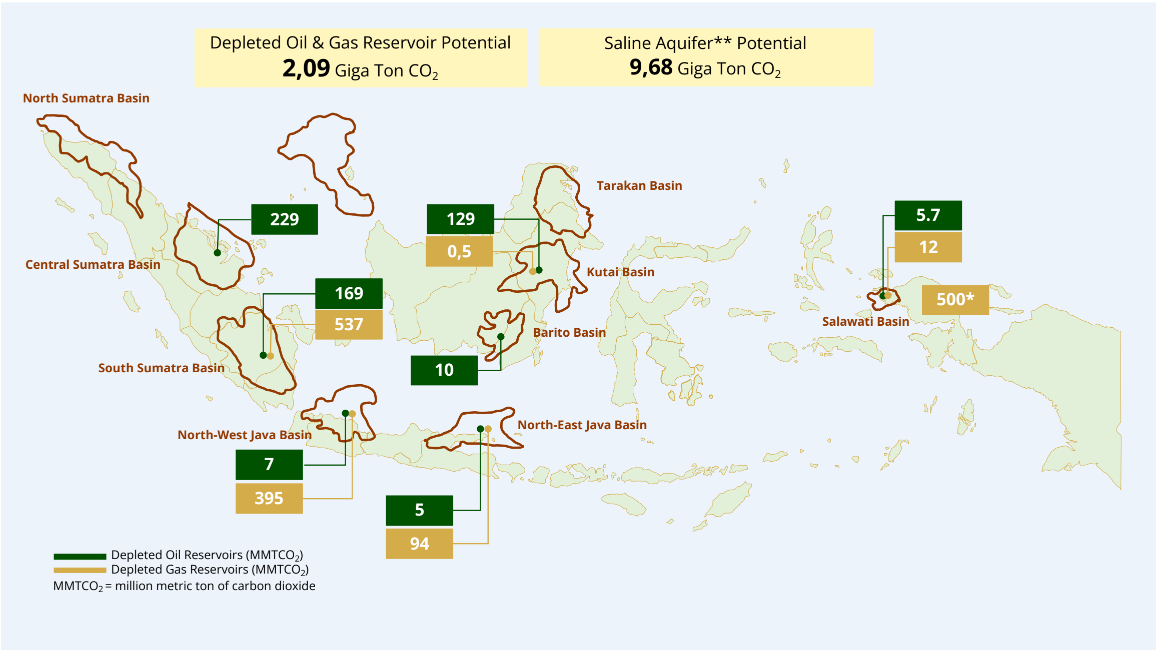
Carbon Capture & Storage (CCS) and Carbon Capture, Utilization, & Storage (CCUS) are one of the technologies that can significantly reduce GHG emissions while increasing oil and gas production through EOR/EGR. The results of studies by Center for Oil and Gas Testing (LEMIGAS) and various other agencies on depleted oil and gas reservoirs estimate that the storage potential in Indonesia is around 2.09 giga tons of CO_2.

Some of the CCS/CCUS projects being developed in Indonesia include (i) Gundih CCUS/CO_2-EGR is targeted to start operating in 2027 and has the potential to absorb 2 to 3 million tons CO_2 over 10 years; (ii) Sukowati CCUS/CO_2-EOR is targeted to start the Pilot stage in 2026-2027, and the full-scale stage in 2031. The emission sequestration potential is ± 10 million tons CO_2 over 15 years; and (iii) Tangguh CCUS/CO_2-EGR is targeted to start operations in 2026 and has the potential to sequester ± 25 million tons CO_2 over 10 years.

Studies of CCUS potential have also begun in other locations, such as Sakakemang CCS, Abadi CCS/CCUS, CCS for producing Clean Fuel Ammonia in Central Sulawesi, East Kalimantan CCS/CCUS Study, Study of CCUS for Coal to DME, and Arun CCS/CCUS.

The potential storage capacity in depleted oil and gas reservoirs is shown in **Figure 4.6**. The potential is spread over several regions, especially in Sumatra, Java, Kalimantan, and Papua. Indonesia also has saline aquifer potential of 9.68 giga tons of CO_2 from the South Sumatra and West Java basins.

Figure 4.6 Potential storage capacity in depleted oil and gas reservoir



4.2 Transformation

4.2.1 Power Plant

The power generation subsector is one of the key subsectors in realizing the energy transition to NZE in the energy sector by 2060 or sooner. Currently, electricity supply is still dominated by fossil fuel power plants that produce emissions. Therefore, a transition needs to be done by replacing fossil fuel power plants with cleaner, low-emission, and environmentally friendly new and renewable energy (NRE) power plants.

As of December 2022, the total installed capacity of power plants in Indonesia is 82.5 GW (**Figure 4.7**). Around 54% (44.5 GW) of Indonesia's power plants are coal-fired. Meanwhile, NRE-based power plants only account for 14% of the total generating capacity (11.3 GW). Based on the owner of the power plant (**Figure 4.8**), around 49% of power plants are owned by PT PLN (Persero), 31% by IPP, 11% by PPU, 8% by IUPTLS holders, and the rest by the government.

Figure 4.7 Installed capacity per type of power plant in 2022

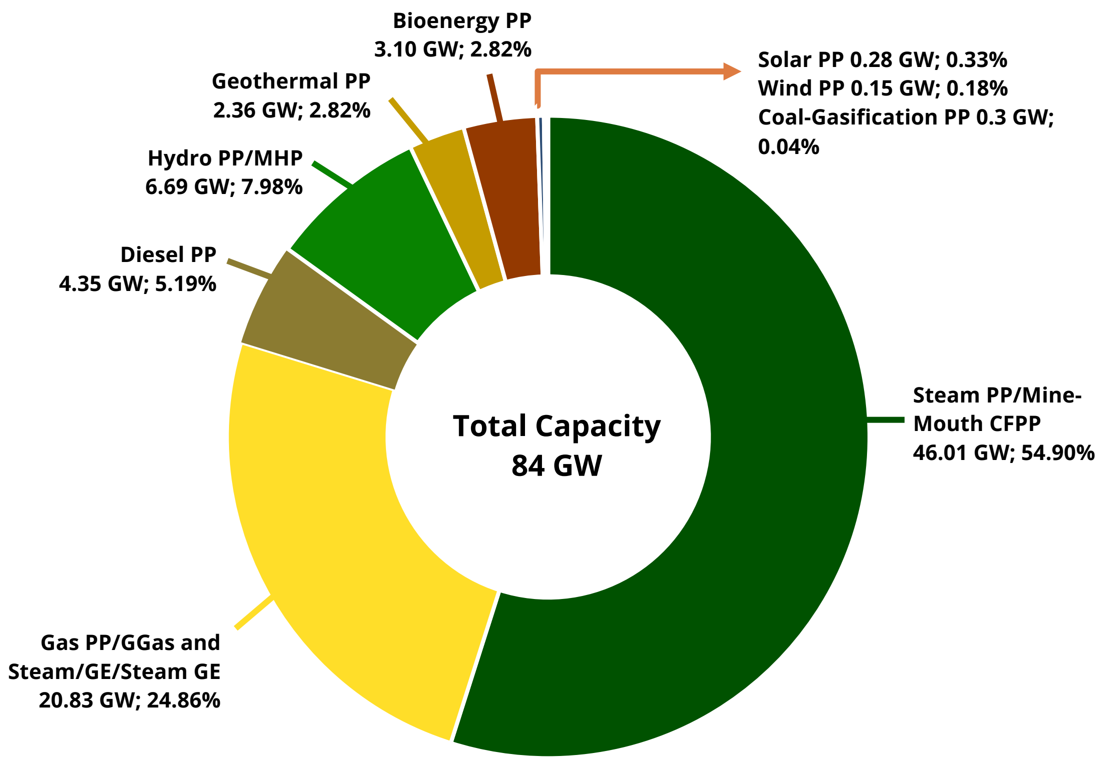
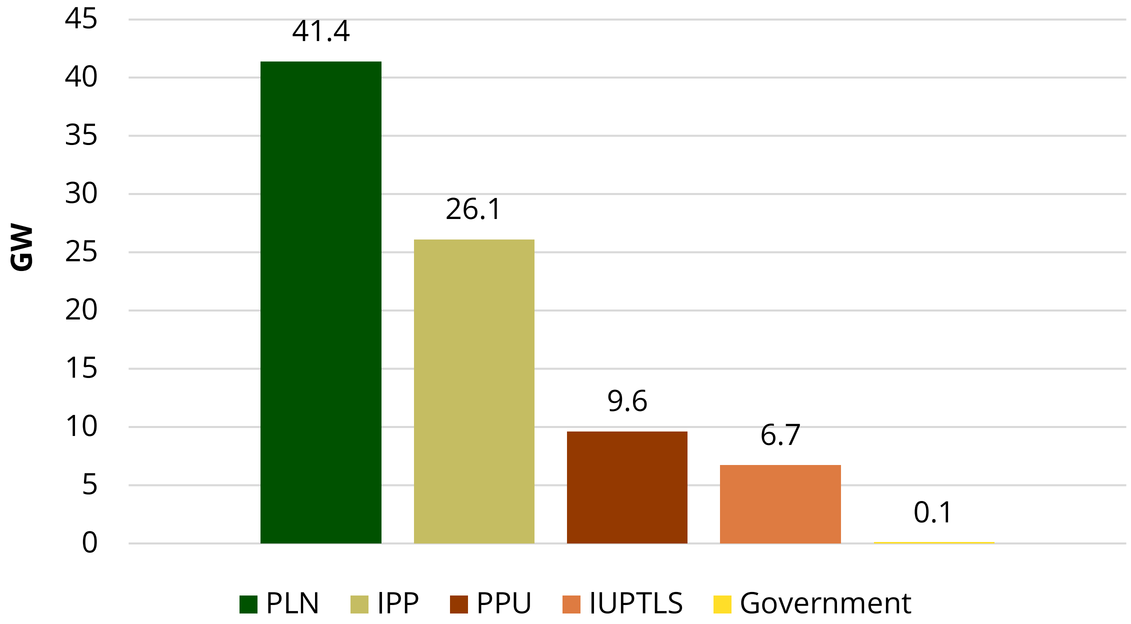
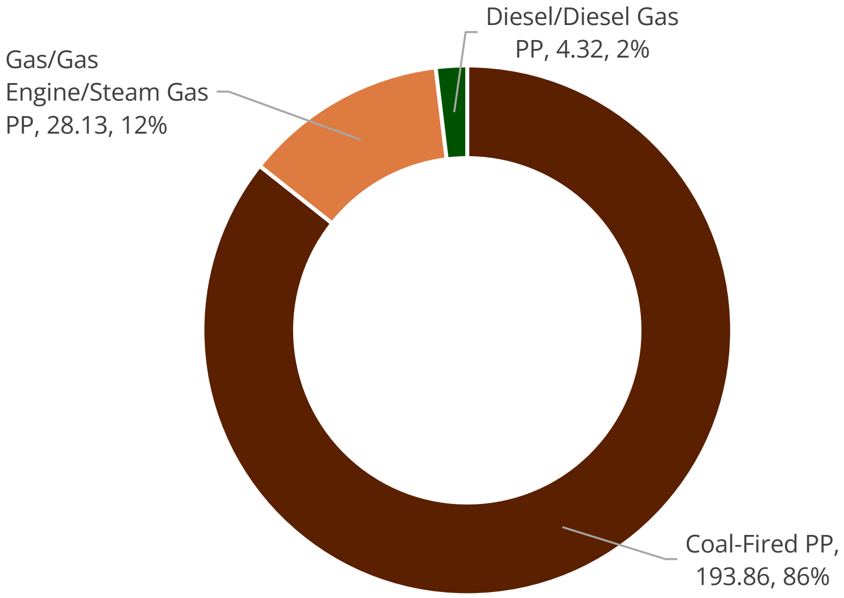


Figure 4.8 Installed capacity per power plant owner in 2022



The GHG emission level of the electricity generation subsector in 2021 was 226.33 million tons CO_2. The largest emissions come from coal-fired power plants (CFPP) 193.86 million tons CO_2, followed by gas-fired/gas engine/steam gas power plants at 28.13 million tons CO_2; diesel/diesel-gas power plants at 4.32 million tons CO_2; and cumulative of biogas, biofuels, and municipal solid waste (MSW) power plants at 13.77 million tons CO_2.

Figure 4.9 Power plant emissions in 2021



The realization of electricity consumption per capita from 2015 to the 3rd quarter of 2021 is illustrated in **Figure 4.10**. The COVID-19 pandemic in 2020 reduced electricity sales so that the realization of national per capita electricity consumption was only 1,089 kWh/capita or grew 0.5% from the previous year. This growth is below the target set by the government in the Ministry of Energy and Mineral Resources' Strategic Plan (*Rencana Strategis,* Renstra) 2020-2024. To encourage an increase in national per capita electricity consumption, efforts such as increasing installed capacity, expanding access to transmission and distribution networks, increasing electricity sales, providing electricity subsidies for the low-income category, encouraging policies for electric vehicles and electric stoves, and supporting policies for developing industrial estates, super-priority tourism destinations, special economic zones and smelter construction or others can be carried out.

Based on the National Electricity General Plan (*Rencana Umum Ketenagalistrikan Nasional*, RUKN), electricity demand is projected to increase with an average growth of 3.9% per year from 413 TWh (1,477 kWh/capita) in 2024 to 1,491 TWh (4,504 kWh/capita) in 2060. The projected electricity demand has considered the planned development of Industrial Estates (*Kawasan Industri*, KI), Special Economic Zones (SEZ), smelters, Integrated Marine and Fisheries Centers (*Sentra Kelautan dan Perikanan Terpadu*, SKPT), and Tourism Priority Areas. In addition, the increase in PPU and captive (IUPTLS) demand for the mineral refining industry that supports the energy transition (BESS raw material production) has also been considered. Projections of electricity demand and electricity consumption per capita in 2024-2060 are shown in **Figure 4.11**.

Figure 4.10 Actual and projected electricity consumption

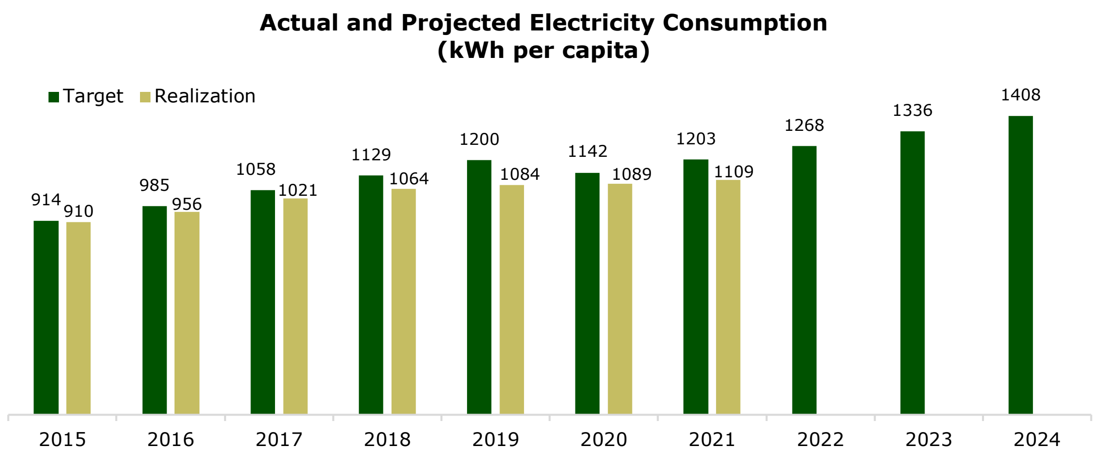
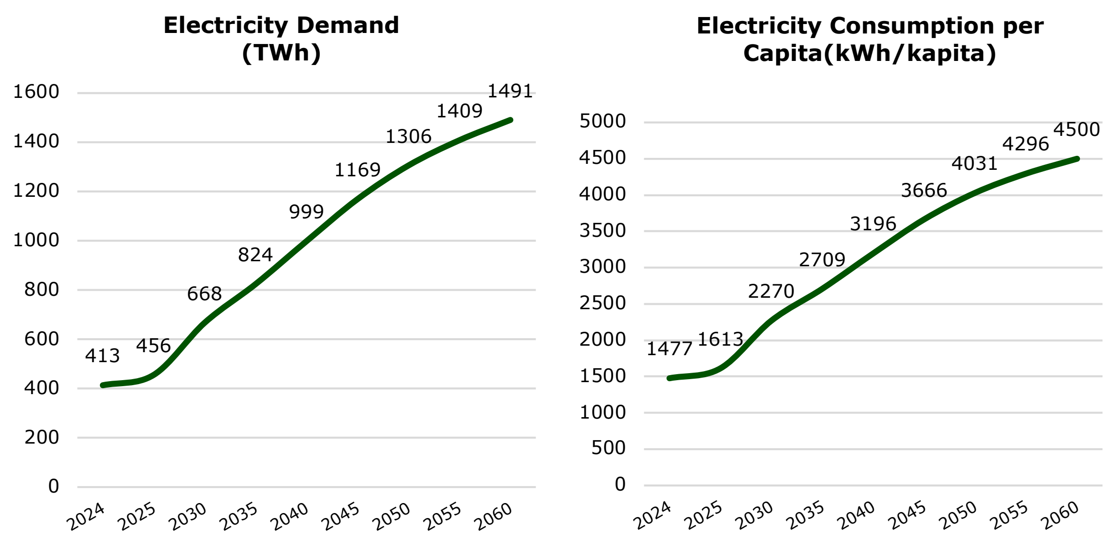


Figure 4.11 Projected electricity demand and consumption per capita 2024-2060



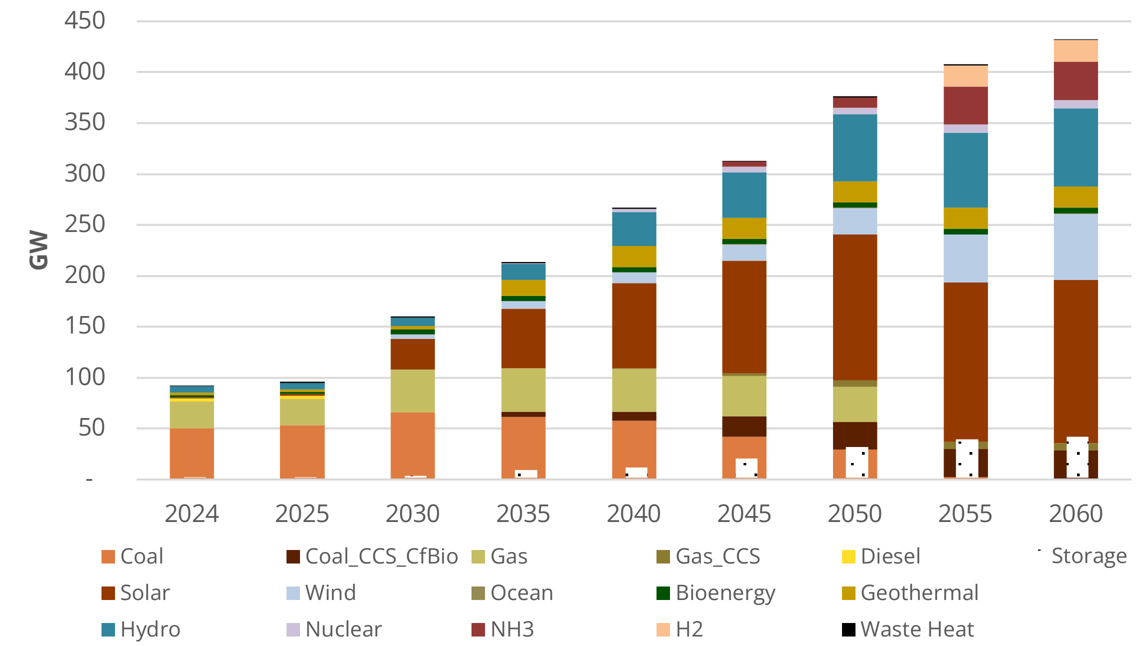
Source: Directorate General of Electricity – MEMR. 2023

To meet the electricity demand until 2060, it is necessary to plan for optimal generating capacity that utilizes local renewable energy potential, as well as addressing transmission needs between systems within one island or between islands for sharing the renewable energy potential.

The RUKN supply optimization modeling projects a generating capacity of 432 GW in 2060, comprising 52% renewable energy plants equipped with 40 GW of storage capacity and 48% non-various renewable energy (VRE) plants—18% hydropower, 9% NH_3 Steam PP, 7% Biomass Cofiring + CCS, 5% Geothermal PP, 5% H_2 Gas Steam PP, 2% Gas PP + CCS, 2% nuclear PP, 1% bioenergy PP, and 0.1% Waste Heat. The projected power generation capacity and production until 2060 are illustrated in **Figure 4.12** and **Figure 4.13**.

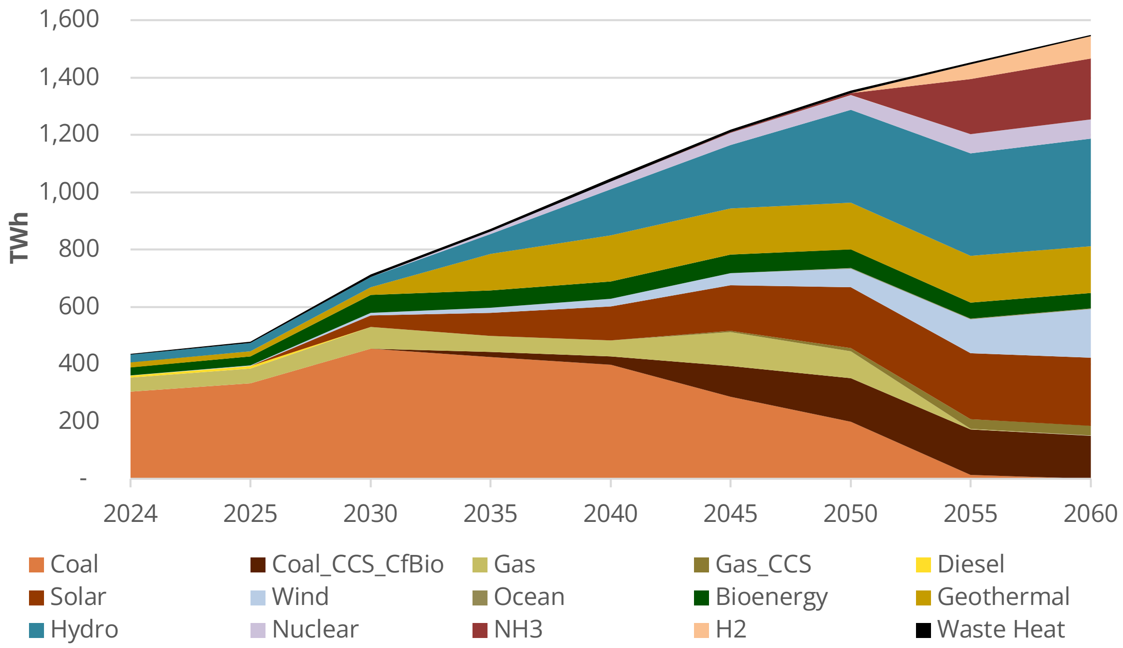
The projection of the energy generation mix in 2025 consists of 69% coal, 17% NRE, 11% natural gas, and 2% crude oil. After 2030, the share of NRE sources continues to increase each year due to the expansion of NRE power plants and no further development of fossil fuel power plants, as well as the retirement of coal-fired power plants. In 2060, the projection of the renewable energy sources mix has reached 88%, comprising 38% NRE PP, 26% VRE PP, and 23% new energy (NE) PP. The projection of the energy generation mix for electricity generation is illustrated in **Figure 4.14**.

Figure 4.12 Projected power generation capacity



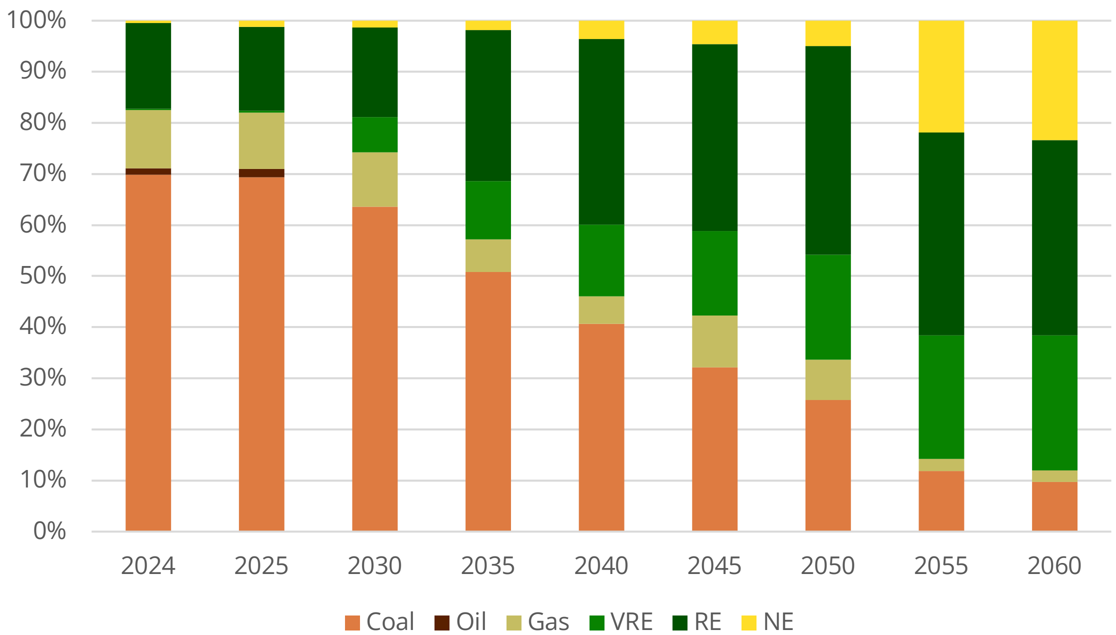
Source: Directorate General of Electricity – MEMR. 2023

Figure 4.13 Projected power generation production



Source: Directorate General of Electricity – KESDM. 2023

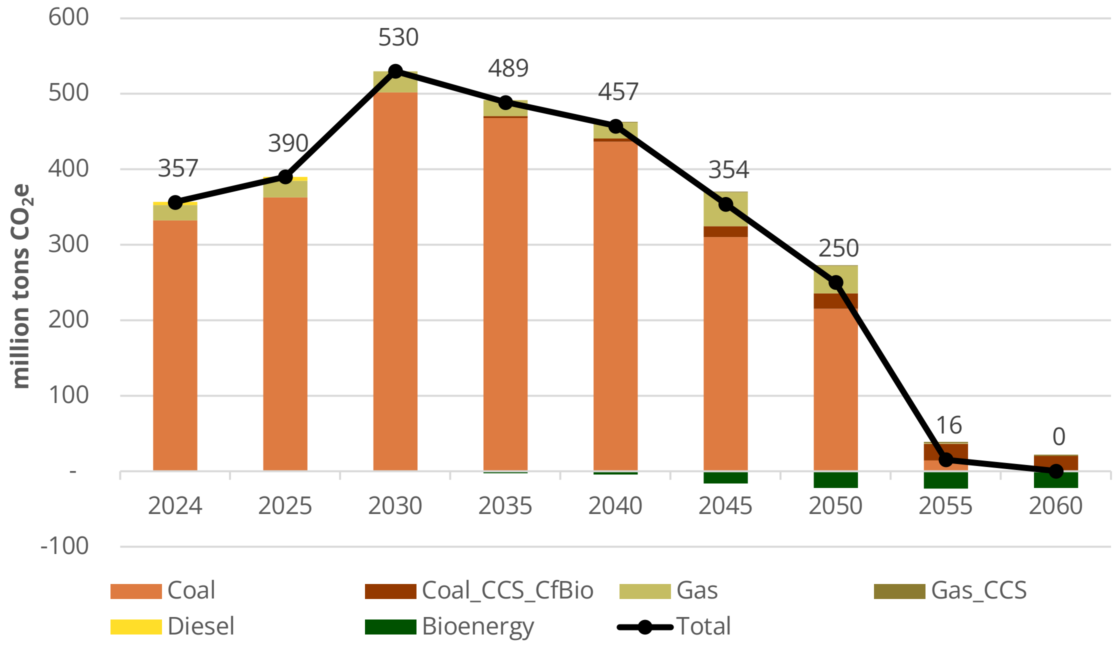
Figure 4.14 Projected energy mix of power generation



Source: Directorate General of Electricity – KESDM. 2023

Based on RUKN modeling, projected power generation emissions will reach zero by 2060. The peak of electricity generation emissions is expected to occur in 2030, around 530 million tons of CO_2. Then, emissions will gradually decrease to 457 million tons of CO_2 in 2040, and 250 million tons of CO_2 in 2050. Projected power generation emissions are illustrated in **Figure 4.15**.

Figure 4.15 Projected power generation emissions



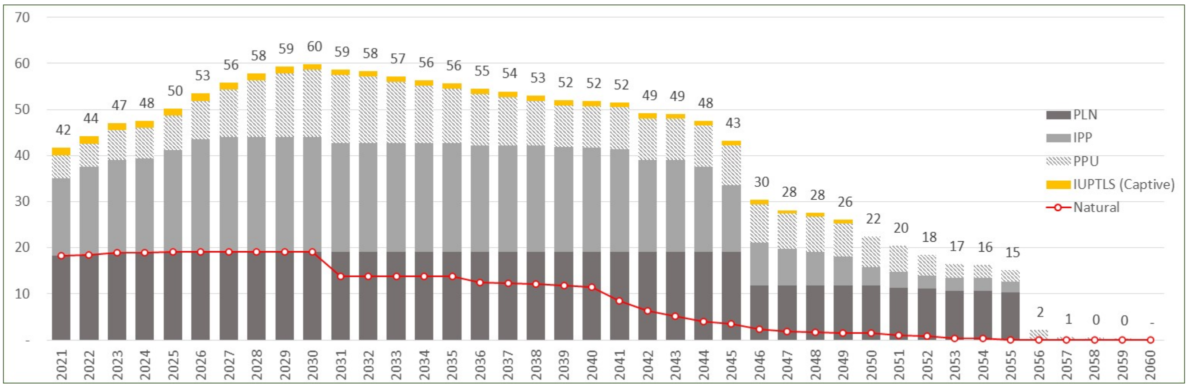
Source: Directorate General of Electricity – KESDM. 2023

Emission reduction strategies to achieve the 2060 NZE target in the power generation subsector include phasing down/retirement of power plants, biomass co-firing, dedieselization, and development of renewable power plants.

Phasing down/retirement PLTU

One of the efforts to achieve the NZE 2060 target is to carry out the retirement of existing CFPP in stages through the CFPP monetization scheme, techno-economic lifetime, and the end of the power purchase agreement (PPA) contract. Based on the coal power plant retirement plan, as illustrated in **Figure 4.16**, no additional CFPPs are present unless contracts and construction have been completed. PLN CFPPs will be retired sooner than the lifetime after asset revaluation, and all IPP CFPPs will be retired after the end of PPA. The CFPP capacity is projected to be less than 1 GW in 2057.

Figure 4.16 Coal-fired power plant retirement plan



Biomass Co-firing

The government encourages all electricity business area holders, especially PT PLN (Persero), to utilize more biomass-based fuels for co-firing with coal in several existing and planned CFPPs. Co-firing in CFPPs is one way to increase the renewable energy mix, and it can be implemented without incurring significant investment costs. Additionally, it serves as a solution for waste management.

Co-firing trials, conducted without additional investment, involved a 5% biomass blend. The tests took place in CFPPs employing various technologies such as CFB, stoker, and PC, utilizing biomass feedstocks including wood chips, wood pellets, sawdust, palm kernel shells, and solid waste/SRF/shredded fuel pellets at percentages ranging from 1% to 30%. These trials were carried out at 47 CFPP sites throughout the year 2021.

The biomass co-firing program in CFPP can help meet the NZE target and enhance the renewable energy mix by leveraging the current overcapacity of the plant, eliminating the need for substantial new capacity. The implementation of biomass co-firing in CFPP, owned by PT PLN (Persero), involves an average mixture of 10% for CFPP in Java-Bali and 20% for CFPP outside Java-Bali. The total capacity of the power plant is 2,700 MW with a 70% capacity factor (CF). New CFPPs commissioned after 2025 must be capable of operating with a minimum co-firing share of 30%. This strategy aims to decrease the coal mix in CFPP to 59.4% by 2030.

A total of 114 CFPP units owned by PT PLN (Persero) and its subsidiaries in 52 locations are ready to implement co-firing, with a combined capacity of 18,664 MW. The planned distribution of the co-firing program at PLN's CFPP is illustrated in **Figure 4.17**.

Figure 4.17 Map of the plan of the co-firing program at PT PLN (Persero)'s CFPP

Source: PT PLN (Persero)

Dedieselization

The dedieselization program is one of the leading initiatives to reduce the use of imported fuel oil and increase the efficiency of power plants, especially in remote and isolated areas, as well as increase power hours. To date, there are around 5,200 units of diesel power plants distributed across 2,130 locations and are still in operation. The implementation of the dedieselization program is divided into three schemes as follows:

- Conversion of diesel PP to RE PP and the use of hybrid schemes with batteries in isolated systems where transmission construction for interconnection to the grid is not possible. The total capacity of diesel PP that will be converted to RE is 499 MW.
- Conversion of diesel PP to gas PP with a total capacity of 304 MW.
- Interconnection of isolated systems to the grid so that the diesel PP in these systems is no longer operated. The capacity of the diesel PP that will be carried out this network expansion is 1,070 MW.

<u>Conversion of Diesel Power Plant (*Pembangkit Listrik Tenaga Diesel*, PLTD) to New and Renewable Energy (NRE)</u>

The PLTD conversion program (499 MW) to NRE power plants will be implemented in stages as part of the energy transition towards NZE. In the initial phase, the conversion of PLTD to NRE power plants will take place in 183 distributed locations, with an installed capacity of 212 MW of PLTD. This will involve a hybrid scheme incorporating Solar Power Plant (*Pembangkit Listrik Tenaga Surya*, PLTS), PLTD, and battery systems. According to the RUPTL2021-2030, 1,219 MW of PLTS allocated for dedieselization, targeting 499 MW of PLTD with COD targets set between 2023 and 2025.

The priority scale is applied to PLTD units that are over 15 years old, located in isolated electricity systems, have fuel consumption above 0.27 liters/kWh, and have not operated continuously for 24 hours. The selection of PLTD locations for inclusion in the conversion program to NRE is conducted based on a consideration of both technical and non-technical criteria. These criteria encompass factors such as the age of the PLTD, the electricity system (on-grid or isolated), fuel consumption, ownership (PLN or non-PLN), interconnection plans, and potential NRE sources. The PLTD to NRE conversion program will be implemented by PT PLN (Persero) by considering the workability and funding capability of PT PLN (Persero). The evaluation results related to the funding capability of PT PLN (Persero) still provide opportunities for the private sector to conduct part of the program.

<u>Conversion of Diesel Power Plant (PLTD) to Gas Power Plant (*Pembangkit Listrik Tenaga Gas*, PLTG)</u>

The initial effort to reduce fuel oil usage began in 2008 with the adoption of biofuel. Power plants that use fuel oil are required to use biofuel (B30) as a substitute for High-Speed Diesel (HSD).

The types of power plants that cannot use B30 are gas-fired power plants with gas engine. The Ministry of Energy and Mineral Resources cq. Directorate General of Oil and Gas provides relaxation for these types of power plants to use HSD, but the plant operators are required to develop a fuel oil-to-gas energy conversion plan. The plan has been regulated through the MEMR Decree 13K/13/MEM/2020 on the Assignment of the Implementation of LNG Supply and Infrastructure Development, as well as the Conversion of Fuel Oil Use with LNG in Electricity Supply. The total number of power plants to be converted is 52 power plant locations with a capacity of 1,697 MW and gas requirements reaching 166.98 BBTUD.

Regarding the use of LNG for the power generation subsector, the government has issued regulations and policies in order to provide guaranteed and competitive gas allocations and prices at the plant gate, including (i) MEMR Regulation 10/2020 on the Amendments to MEMR Regulation 45/2017 on Natural Gas Utilization for Power Plants, which regulates the price of natural gas; and (ii) MEMR Decree 135.K/HK.02/MEM.M/2021 on the

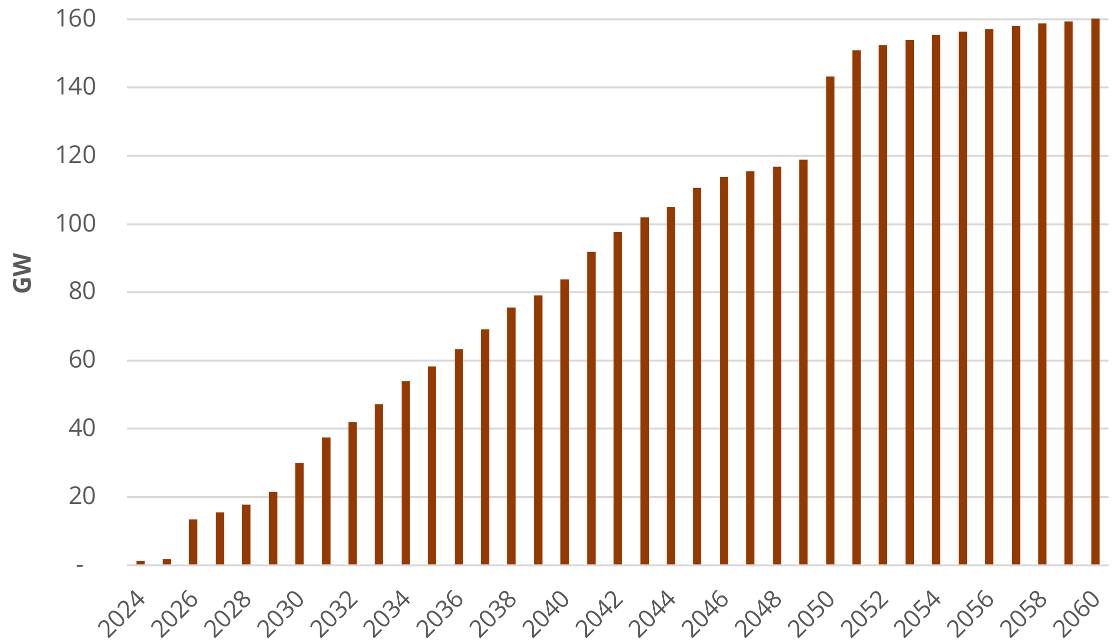
Amendment to the MEMR Decree 118.K/MG.04/MEM.M/2021 on the Price of Certain Natural Gas in Power Plants (Plant Gate), which stipulates the allocation and price of certain natural gas for PT PLN (Persero) for the period 2021-2024.

Development of New & Renewable Energy Power Plants

Solar PV Power Plant (*Pembangkit Listrik Tenaga Surya*, PLTS) Utilities

The development of PLTS Utilities, including ground mounted and floating PV, is one of the key elements in achieving the NZE target for the power generation subsector since it represents one the least cost and fastest development technologies. The cumulative development of PLTS will reach 32 GW by 2030 and increase to 421 GW by 2060. The PLTS development plan in the NZE scenario is illustrated in **Figure 4.18**.

Figure 4.18 PLTS development plan in NZE scenario



Rooftop Solar PV

The development of Internet of Things (IoT) technology has encouraged the use of distributed energy resources (DER) systems, also known as distributed generation (DG). Rooftop Solar PV and energy storage are one form of DER, potentially creating new sales business patterns in the electricity subsector. **Table 4.4** shows that the potential of rooftop solar PV in Indonesia reaches 32.5 GW.

Table 4.4 Rooftop Solar Potential

No.	Customer Category	Potential Capacity (GW)
1	Residential	19.8
2	Government	0.3
3	Business	5.9
4	Industry	1.9
5	Social	4.6
	TOTAL	**32.5**

In the National Energy General Plan, the government aims to develop 6.5 GW of solar power by 2025. One of the strategies to achieve this target involves mandating that all government buildings use Rooftop PV on at least 30% of the roof area. Additionally, the government has introduced a requirement for the use of Rooftop PV on at least 25% of the roof area for buildings seeking Building Approval (*Persetujuan Bangunan Gedung*, PGB), particularly luxury houses, housing clusters, and apartments. In the 2020-2024 National Medium-Term Development Plan (*Rencana Pembangunan Jangka Menengah Nasional*, RPJMN), Rooftop PV is also highlighted as a strategy to diversify energy and electricity, ensuring access, energy supply, and electricity are distributed evenly, reliably, efficiently, and sustainably.

The MEMR has also issued MEMR Regulation 26/2021 on Rooftop Solar PV connected to the Electricity Network of Holders of Electricity Supply Business License for Public Interest (*Izin Usaha Penyediaan Tenaga Listrik untuk Kepentingan Umum*, IUPTLU) to encourage the installation of Rooftop Solar PV by customers of PT PLN (Persero). Other support provided includes the provision of parallel operation facilities for Rooftop PV users, the establishment of a billing system to accommodate export-import offset and credit deposits from Rooftop PV users, the provision of sufficient and appropriate reserve margin to offset the intermittency of Rooftop PV, and the maintenance of the reliability and quality of Rooftop PV users and the environment by balancing local supply and demand. Additionally, there is the implementation of a fair business scheme for customers and PLN.

The government also encourages the installation of Rooftop Solar PV in government, commercial, and industrial buildings with the following provisions:

- The rooftop solar PV system that is constructed and installed is not subject to the capacity charge and emergency energy charge that are part of the parallel operation cost.
- Rooftop Solar PV systems built and installed for industrial use are subject to a capacity charge, which forms a part of the parallel operation fee. The capacity charge is paid monthly and is calculated based on the total inverter capacity in kilowatts (kW), multiplied by five hours, and then multiplied by the electricity tariff.

The government has a rooftop solar development target for each customer type with a total capacity of 3.6 GW by 2025, as tabulated in **Table 4.5**. The rooftop solar target has the potential to reduce emissions by 4.5 $MtCO_2e$.

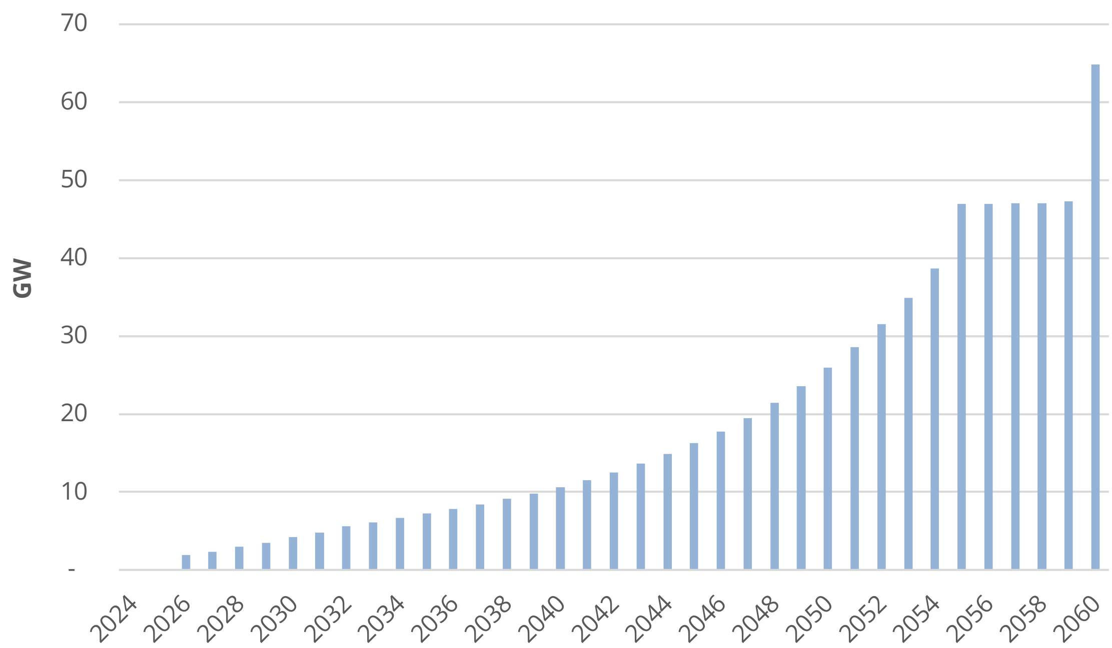
Table 4.5 Target capacity of rooftop solar power plant until 2024

Customer Category	Assumed Number of PLN Customers	Assumed Potential Capacity of Rooftop Solar PV	Target Capacity (MW)
Government	• 1% of Customers < 6600 VA • 10% of Customers > 6600 VA	• 100% installed power • Up to 80% installed power	37.35
Social	• 1% of Customers 1300VA-200kVA • 5% of Customers > 200kVA	• 100% installed power • 10% of installed power	16.65
Residential	• 2% of Customers 1300VA • 10% of Customers > 2200VA	• 100% installed power • Up to 90% installed power	1,525
Business	• 7,5% of Customers 1300-5500 VA • 10% of Customers > 6600	• 100% installed power • Up to 80%	728.68
Industry	• 10% of Customers 1300VA – 14kVA • 20% of Customers > 14 kVA	• 100% installed power • 100% installed power	1,525
Total			**3,610**

Wind Power Plant (*Pembangkit Listrik Tenaga Bayu*, PLTB)

Wind power development is one of the renewable energy options that can be developed in the NZE scenario in the power generation subsector because wind power is one of the least cost and fast development technologies. The cumulative development of PLTB will reach 1 GW in 2030 and increase to 94 GW in 2060. The PLTB development plan in the NZE scenario is illustrated in **Figure 4.19**.

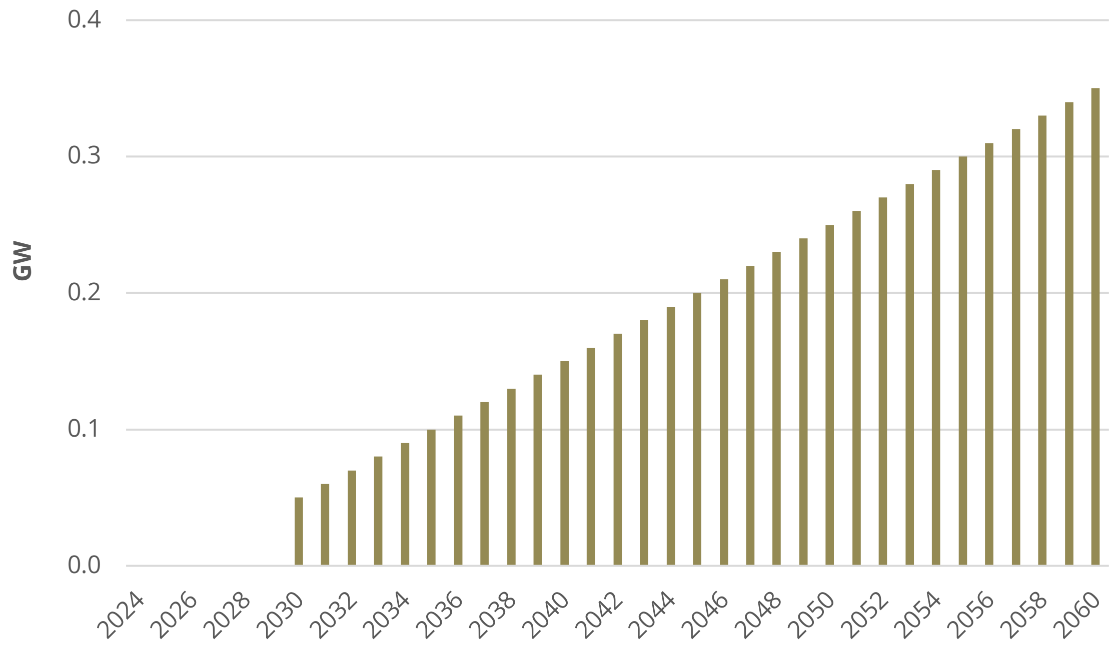
Figure 4.19 PLTB development plan in NZE scenario



Ocean Current Power Plants (*Pembangkit Listrik Tenaga Arus Laut,* PLTAL)

PLTAL is one of the last options of renewable energy that can be developed in the NZE scenario of the generation sector. The development of PLTAL will begin in 2054 with a capacity of 0.2 GW and will cumulatively reach 1 GW in 2055. The PLTAL development plan in the NZE scenario is illustrated in **Figure 4.20**.

Figure 4.20 PLTAL development plan in NZE scenario



Geothermal Power Plant (*Pembangkit Listrik Tenaga Panas Bumi*, PLTP)

Geology Agency estimates geothermal energy resources in Indonesia to reach 23,765.5 MW in 2022 distributed over 357 locations as tabulated in **Table 4.6**. About 9.2% of the total existing resources or about 2,185.7 MW have been utilized into power plants. The development of PLTP takes about 7-9 years from exploration activities to commercial operation date (COD).

The geothermal development plan in the electricity subsector to achieve the NZE target by 2060 is shown in **Figure 4.21**. In addition, the Government has also developed a geothermal development strategy until 2060 which is summarized in **Table 4.7**.

Table 4.6 Geothermal resources and utilization in Indonesia in 2022

No.	Island	Total Loca-tion	Resources (MWe)					Installed Capacity (MWe)
			Speculative	Hypothetical	Alternative			
					Possible	Suspected	Proven	
1	Sumatra	104	2,187.5	1,567	3.514	867	1169.4	962.55
2	Java	77	1,164	1,270	3.121	363	1,855	1,253.8
3	Bali	6	70	21	104	110	30	-
4	Nusa Tenggara	34	215	146	731	138	33,5	19.08
5	Kalimantan	14	151	18	6	-	-	-
6	Sulawesi	90	1,352	342	996	180	120	120
7	Maluku	33	560	80	496	6	2	-
8	Papua	3	75	-	-	-	-	-
Total		361	5,774.5	3,444	8,968	1,664	3,209.9	2,355.43
					13,841.9			
			23,060.4					

Source: Geology Agency MEMR. 2023. Indonesia's Mineral, Coal and Geothermal Resources and Reserves Balance in 2022

Figure 4.21 Projected geothermal development by 2060

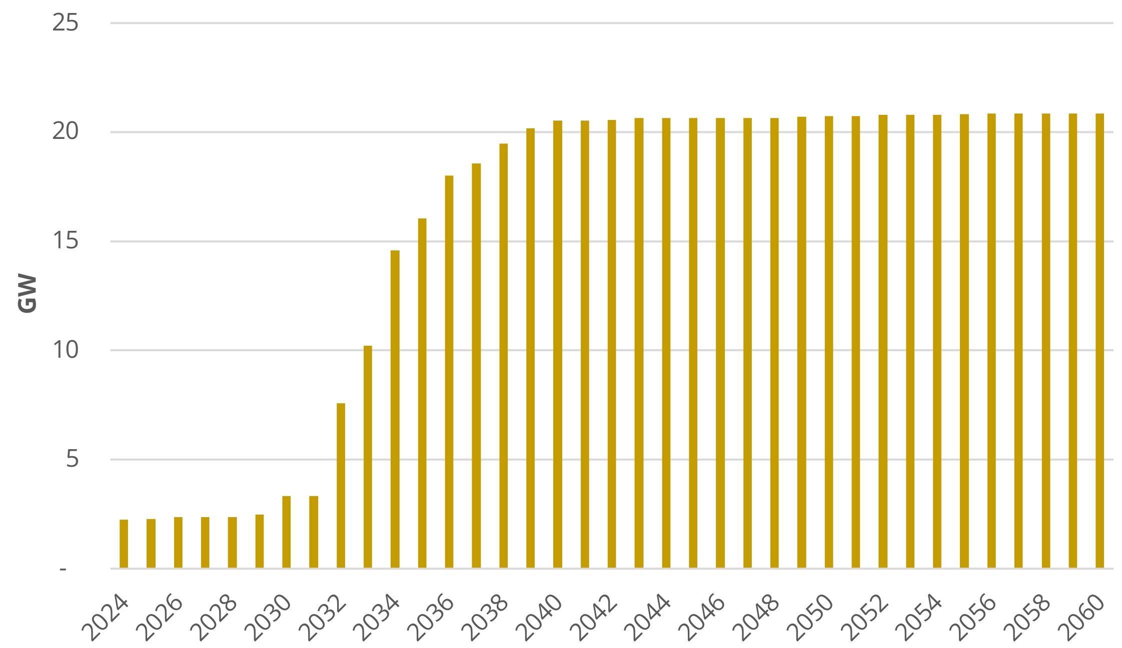


Table 4.7 Strategy matrix for geothermal development until 2060

	2021-2025	2026-2030	2031-2035	2036-2040	2041-2045	2046-2050	2051-2055	2056-2060
Target installed capacity (GW)	4	5	11	12	14	18	20	22
Additional capacity (GW)	1.9	1	6	1	2	4	2	2
Policy & regulation	• Benchmark geothermal electricity prices that achieve project feasibility • Sustainability of funding for massive exploration programs in the next 5 years by KESDM • Development of geothermal project infrastructure access by KPUPR • Adjustment of conservation area zones/blocks that have geothermal prospects • Carbon market mechanism • Power wheeling		• Adjustment of the IPB/Concessionaire time period for expansion development to make the PPA 30 years • Adaptation of policies and regulations to support the development of PLTP with deep drilling and EGS technology		• Adaptation of policies and regulations to support offshore geothermal development			
Development	• Optimization of existing fields with small-scale geothermal power plant development • PPA in 2023-2025 for 443 MW for COD until 2030 and 6,210 MW for COD 2031-2035. PPA in 2028-2030 for 1,000 MW for COD 2046-2040. • Public hearings, advocacy, and education of the public and other stakeholders in a massive and structured manner to mitigate resistance to the PLTP project.		• Inter-island interconnection built • PPA of 3,000 MW for COD 2041-2050 • Hybrid geothermal power plant with solar power plant (PLTS)		• PPA of 2,950 MW for COD 2051-2060 • Power plant project with deep drilling		• Enhanced Geothermal Systems (EGS) Power Plant Project	
Technology & R&D	• Pilot project of deep drilling program to support the development of PLTP after 2035 • Study on the application of Enhanced Geothermal System (EGS) technology		• Feasibility study of geothermal projects with deep drilling program • Pilot project of EGS technology		• Feasibility study of geothermal power plant project with EGS technology • Offshore geothermal development study		• Feasibility study of offshore geothermal project	

Bioenergy Power Plant

The Directorate General of New, Renewable Energy and Energy Conservation of the Ministry of Energy and Mineral Resources in collaboration with GIZ and UNDP-MTRE3 conducted a study of bioenergy potential—theoretical and technical potential. Based on the study, the technical potential of bioenergy reaches around 16 GW, which includes wood from Energy Plantation Forest (*Hutan Tanaman Energi*, HTE); waste in industries including palm oil (palm kernel shell, fiber, TBK, and POME), sugarcane (bagasse), rice (husk), cassava (liquid waste), and wood. The largest bioenergy potential is in Riau, Central Kalimantan, North Sumatra, West Kalimantan, East Kalimantan, and South Sumatra.

The government in collaboration with PT PLN (Persero) has planned the development of 590.3 MW of bioenergy power plants consisting of 71.7 MW of biomass power plants, 16.5 MW of biogas power plants, 227.5 MW of waste-to-energy power plants, 224.6 MW of bioenergy power plants (open to all types of bioenergy power plants) as outlined in the RUPTL PLN 2021-2030, as tabulated in **Table 4.8**. The potential GHG emission reduction from the Bioenergy Power Plant development plan is 3.43 million tons CO_2e.

Table 4.8 Bioenergy Power Plant development plan by 2030

Type of Power Plant	Capacity (MW)										
	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	Total
Biomass	1	20.8	19.9	20	-	-	-	10	-	-	71.7
Biogas	-	4	12.5	-	-	-	-	-	-	-	16.5
MSW	9	5.5	-	80	183	-	-	-	-	-	277.5
Bioenergy	2	13	55.2	91.4	38	20	-	5	-	-	224.6
Total	**12**	**43.4**	**87.6**	**191.4**	**221**	**20**	**-**	**15**	**-**	**-**	**590.3**

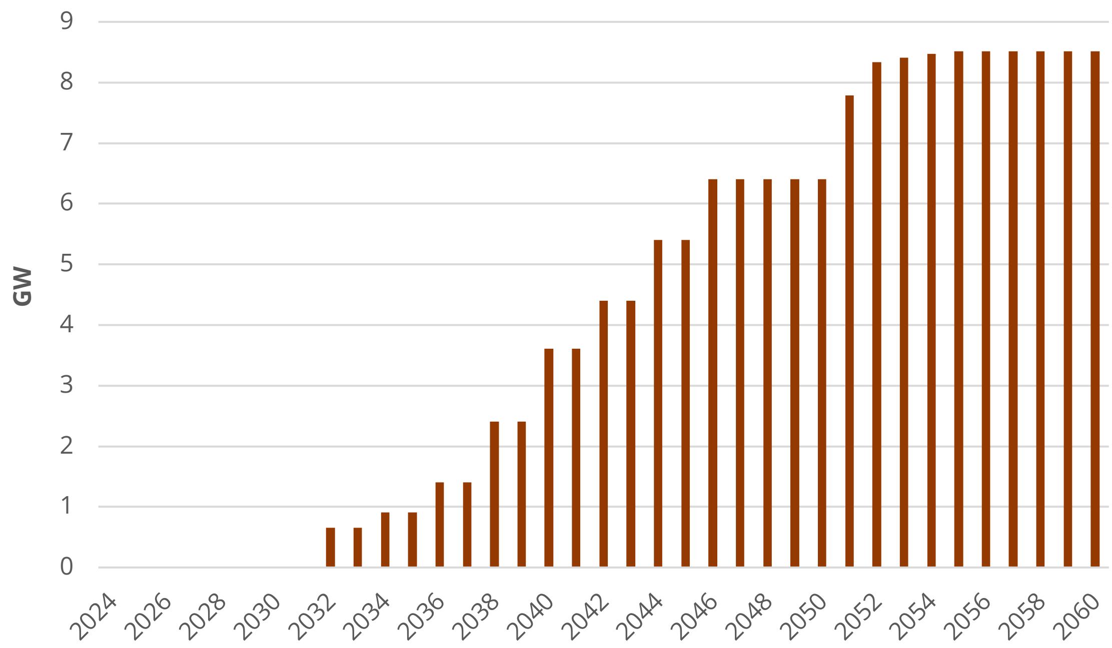
There is potential for the development of Bioenergy Power Plants other than the RUPTL development plan, namely the plan to develop off-grid/captive power Bioenergy Power Plants. Strategies to achieve the target include the utilization of HTE and RDF as potential feedstock for biomass power plants, utilization of critical/marginal land for HTE, and utilization of BioCNG as feedstock for Bioenergy Power Plants.

<u>Nuclear Power Plant (*Pembangkit Listrik Tenaga Nuklir*, PLTN)</u>

Indonesia has uranium and thorium potential that can be developed into nuclear power plants. Based on data from the National Nuclear Energy Agency (*Badan Tenaga Nuklir Nasional*, BATAN), the total uranium and thorium resources in Indonesia are 89,483 tons and 143,234 tons, respectively. While the total measured potential for uranium is 39,441 tons and 20,960 tons for thorium.

In the NZE scenario, nuclear power plant technology is needed to support the reliability of the power system as a baseload. PLTN will be developed in 2039 by 1 GW (see **Figure 4.22**), and then increased to 5 GW in 2046 as one of the alternatives to replace the retirement of CFPPs. The capacity of PLTN significantly increases in 2056 to 22 GW and continues to increase to 31 GW in 2060.

Figure 4.22 PLTN development plan in NZE scenario



CCS/CCUS Implementation at Coal Development and Utilization Facilities

The main challenge in the utilization of coal in CFPPs is the reduction of CO_2, SO_2, NO_X, and PM emission. To improve air quality, the development of technologies to reduce the release of pollutants is ongoing. The application and operation of modern technologies are more effective at reducing emissions than current practices. Clean Coal Technology (CCT) can be used to reduce carbon emissions from processed coal, making it more environmentally friendly. The majority of these technologies are mature with competitive markets. However, the realization of pollutant emission reduction is more influenced by compliance with laws and regulations, rather than the ability of modern pollution control technology.

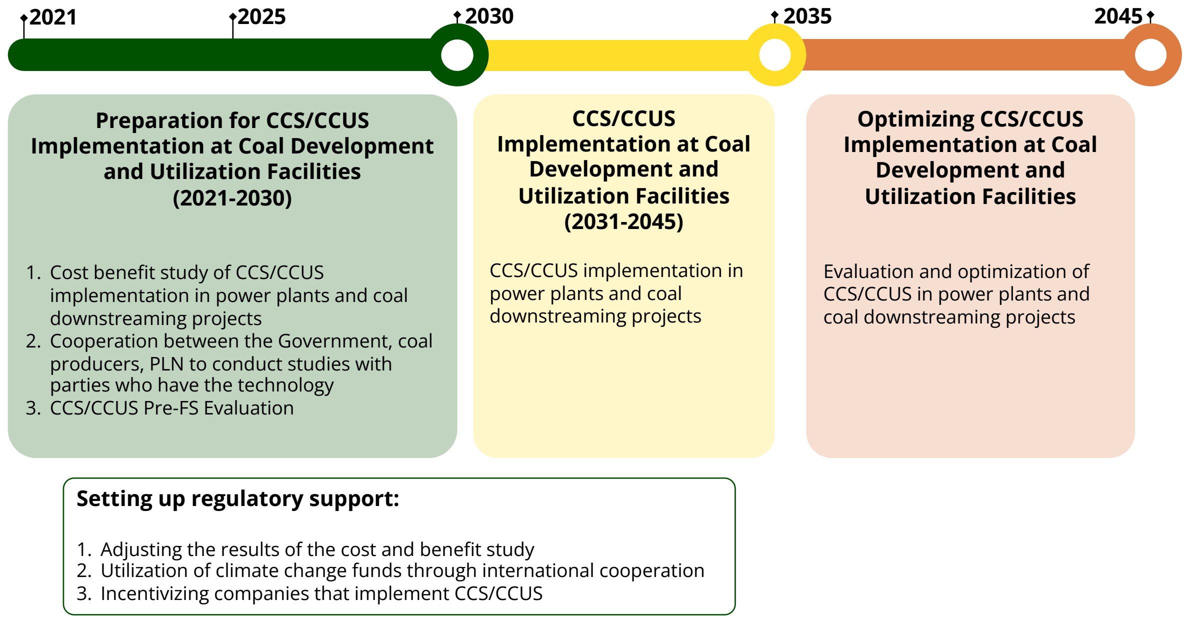
The large utilization of coal, especially in CFPP, must be balanced with the application of environmentally friendly generation technology to reduce CO_2 emissions. Clean coal technology that has great potential to be implemented is Carbon Capture and Storage (CCS)/Carbon Capture, Utilization, and Storage (CCUS) technology. The use of CCS/CCUS in CFPP can reduce emissions while increasing energy efficiency.

In 2015, Indonesia conducted a study analyzing the readiness of CCS technology implementation in CFPP in West Java and South Sumatra areas. The most suitable method to capture these emissions is post-combustion CO_2e capture. The CO_2e capture process is carried out by retrofitting existing power plants by adding CO_2e absorption units. CCS studies that have been conducted estimate that the application of CSS has an impact on increasing the Capital Expenditure (CAPEX) of power plants by up to 60%. However, the increase in investment has a positive impact on electricity supply because the power plant can be operated in the long term.

Figure 4.23 shows the roadmap for CCS/CCUS implementation at coal development and utilization facilities. The main focus in the initial phase of the program during 2021-2030 is to prepare the implementation of CCS/CCUS in coal development and utilization facilities. The implementation starts by conducting a cost-benefit study of CCS/CCUS implementation in downstream projects. The results of the study will serve as the basis for the pre-FS evaluation of CCS/CCUS.

Furthermore, the focus of the second phase (2031-2045) is the implementation of CCS/CCUS in CFPP and coal downstreaming projects. The implementation requires supervision to ensure target achievement. Regulatory support needed includes utilizing climate change funds through international cooperation and providing incentives for companies that implement CCS/CCUS. The next stage in 2035-2045 is the optimization of CCS/CCUS implementation in coal development and utilization facilities in CFPP and coal downstreaming projects.

Figure 4.23 Roadmap for CCS/CCUS implementation at coal development and utilization facilities



4.2.2 Oil and Gas Refineries

The national fuel oil and biofuel demand profile based on the NZE scenario modeling is illustrated in **Figure 4.24**. National fuel oil and biofuel demand increases along with the increase in GDP. National fuel oil and biofuel consumption in 2030 is projected to reach its peak, 49 MTOE. Then, national fuel oil and biofuel demand is projected to decline significantly in 2060, to reach 24 MTOE.

The projection of gasoline production including gasoline with various RON and gasoil is shown in **Figure 4.25**. In 2030, gasoline and gasoil production are projected to reach 263.53 million barrels and 228.85 million barrels, respectively. These projections have considered Pertamina's refinery development programs in the Refinery Development Master Plan (RDMP) and Grass Root Refinery (GRR).

Projections of production of all types of fuel oil (gasoline and gasoil) from 2030 to 2060 consider the possibility of a decrease in fuel oil demand due to the planned transition to clean energy in all sectors. The transition in the transportation sector is the substitution of fuel oil to biofuel and electric vehicles. The transition in the manufacturing and power generation sectors is the gasoil to gas substitution and renewable energy program. The increased use of biofuel, both biodiesel and green diesel (D100), will disrupt the demand for fuel oil, especially gasoil. Therefore, fuel production during 2030–2060 is assumed to be constant due to the clean energy transition, the new condition of refineries, and the absence of plans to increase refinery capacity.

Figure 4.24 Profile of national fuel oil and biofuel demand under the NZE scenario

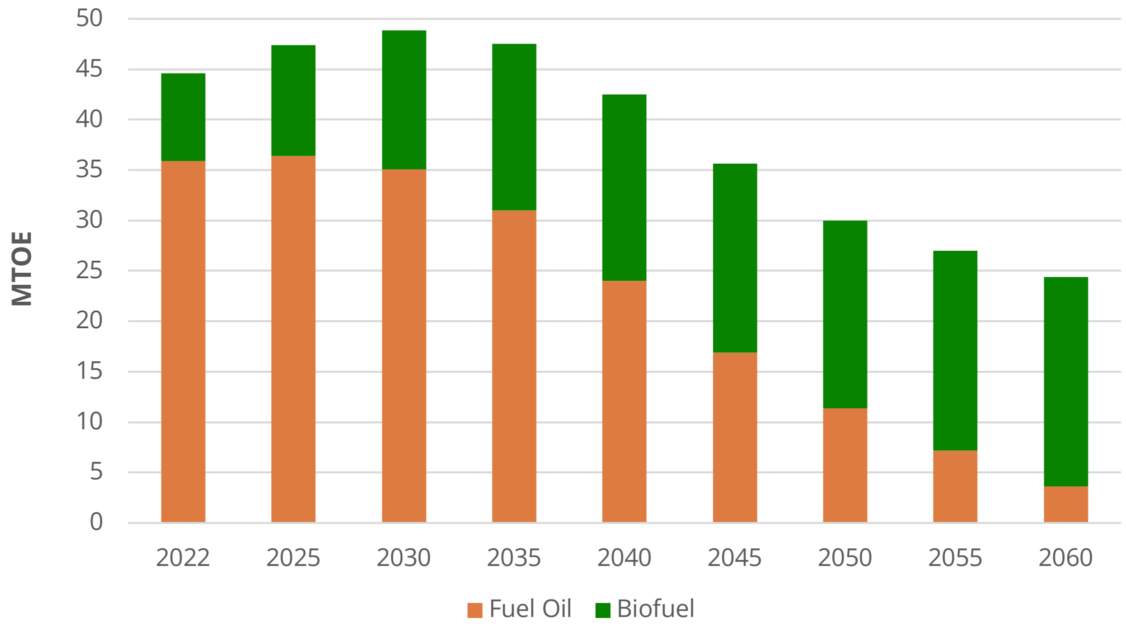
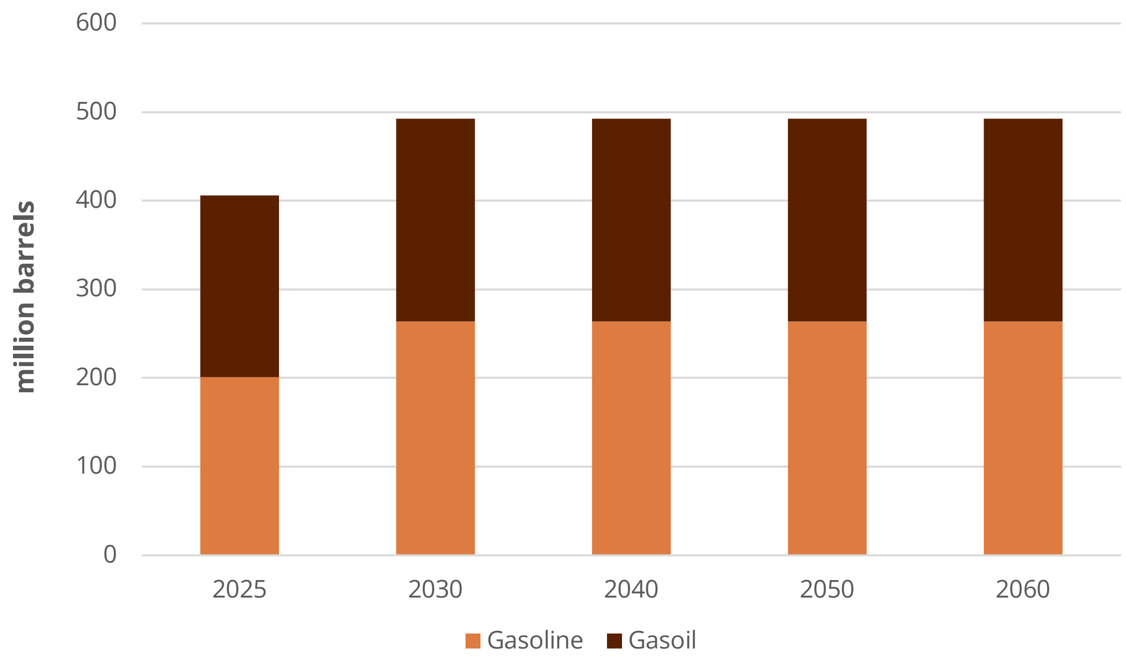
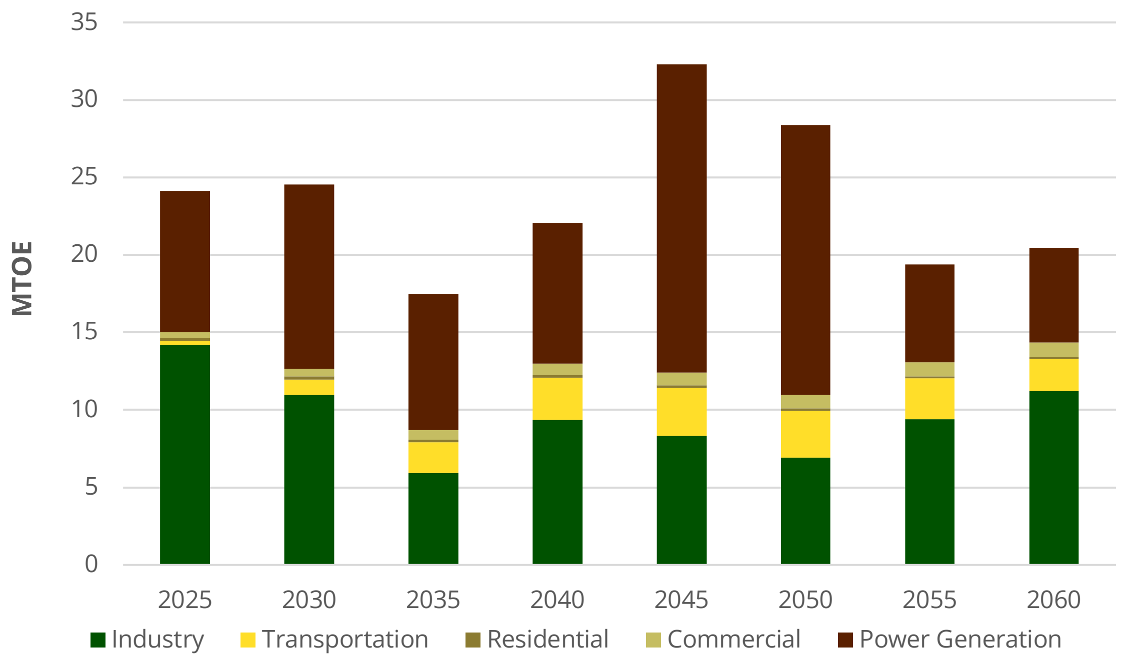


Figure 4.25 Projection of national fuel oil production in 2025-2060



Projections of national gas demand in NZE scenario is shown in **Figure 4.26**. The projected national gas demand is mapped based on the industry, transportation, residential, commercial, and power generation subsectors. National gas demand in 2025 will reach 24 MTOE, with the highest consumption coming from the industrial subsector. National gas demand will reach its peak in 2045, at 32 MTOE with the highest demand from the power generation subsector. Subsequently, national gas demand will decrease until it reaches 21 MTOE in 2060.

Figure 4.26 National gas demand profile in NZE scenario



Projections of national Liquefied Petroleum Gas (LPG) and Liquefied Natural Gas (LNG) production until 2060 are shown in **Figure 4.27** and **Figure 4.28**. LNG projections have considered production through upstream and downstream schemes with the assumption of the same feed gas volume (no additional feed gas and refinery capacity). In the long term, LPG demand has the potential to decline due to energy diversification through various government programs, such as city gas networks, induction stoves, and DME. For example, the city gas network program has started since 2009 and will be expanded to various regions to reduce subsidized LPG consumption. The target of city gas network development in National Energy General Plan (*Rencana Umum Energi Nasional*, RUEN) is 7.7 million house connection (*sambungan rumah*, SR) in 2030. Therefore, LPG and LNG production from 2030 to 2060 is assumed to be constant due to the decline in LPG demand and there are no plans to increase the capacity of LPG and LNG refineries in both upstream and downstream schemes.

Figure 4.27 LPG production projections 2025-2060

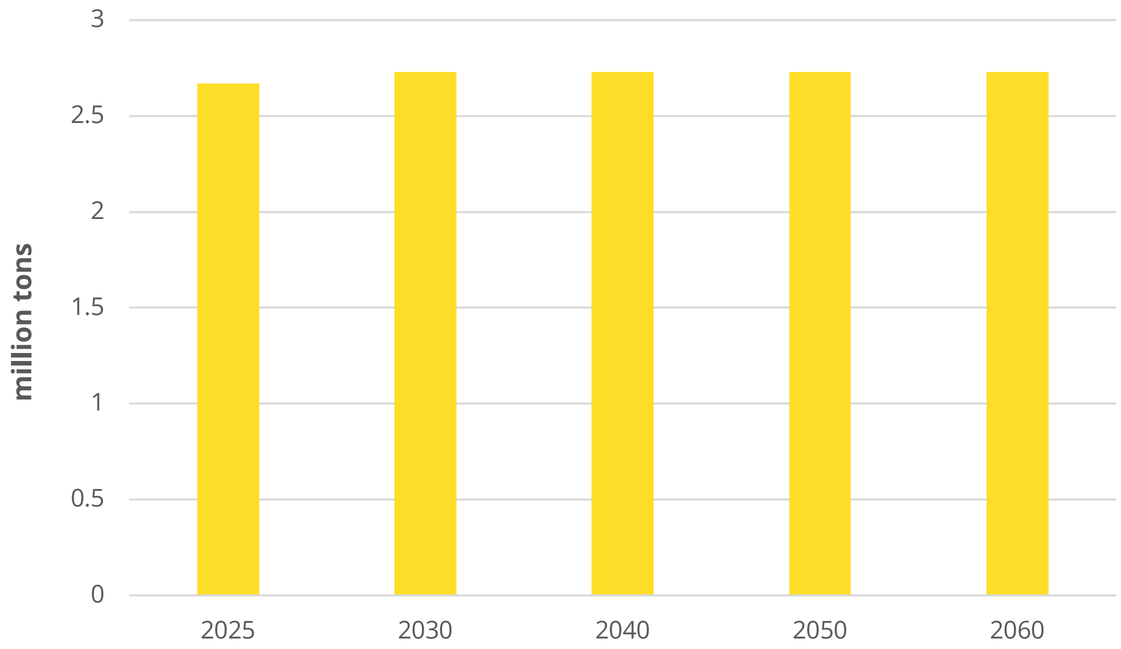
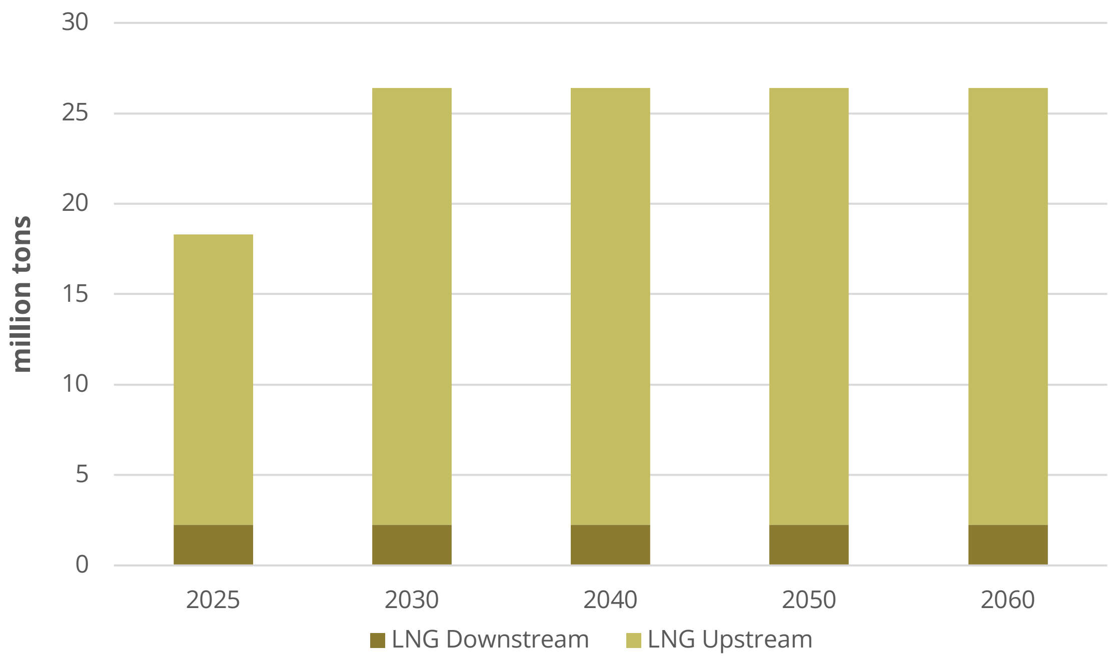
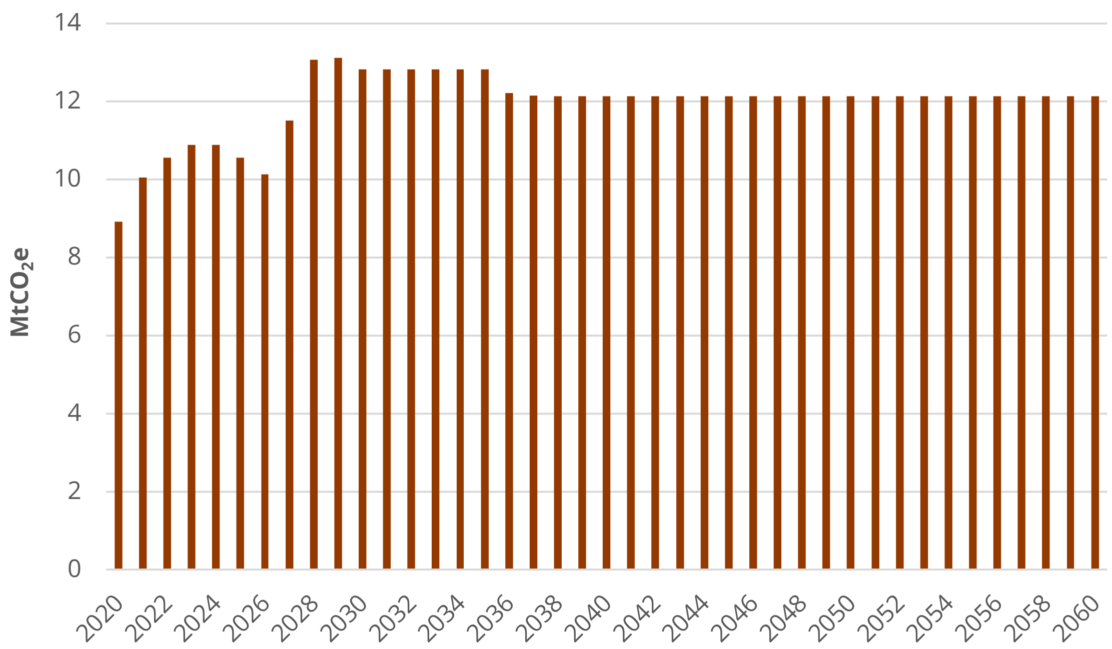


Figure 4.28 LNG production projections 2025-2060



The emission of downstream oil and gas business activities and its projection until 2060 are shown in **Figure 4.29**. Downstream oil and gas emission data includes data on oil and gas processing activities, gas distribution and trading by State Gas Company (*Perusahaan Gas Negara*, PGN), and fuel distribution and trading by PT Pertamina Patra Niaga. The peak emission of downstream oil and gas business activities is projected to occur in 2030 at 44.12 million tons CO_2e. The increase in emissions from 2020 occurred due to an increase in production in the upstream oil and gas sector by 1 million BOPD of oil and 12 BSCFD of natural gas. The decrease in emissions after 2030 will be due to a decrease in upstream oil and gas production activities and the downstream side did not experience an increase in processing activities (refineries) and fuel distribution. Emissions in 2060 are estimated at 14.98 million tons CO_2e, which needs to be compensated by reducing emissions in other sectors to achieve the NZE target in 2060.

Figure 4.29 Emission of downstream oil and gas activities



In the downstream side of oil and gas business activities, emission reduction strategies are carried out by the Business Entity (*Badan Usaha*, BU)/Permanent Establishment (*Bentuk Usaha Tetap*, BUT) subsectors. Several decarbonization initiatives have been implemented in oil and gas refinery operations, as well as oil and gas marketing and distribution activities, including energy conservation activities, fuel substitution to biodiesel and nature-based solution initiatives through reforestation or tree and mangrove planting activities. Emission reduction initiatives will continue to be enhanced to achieve Net Zero Emission in the oil and gas subsector.

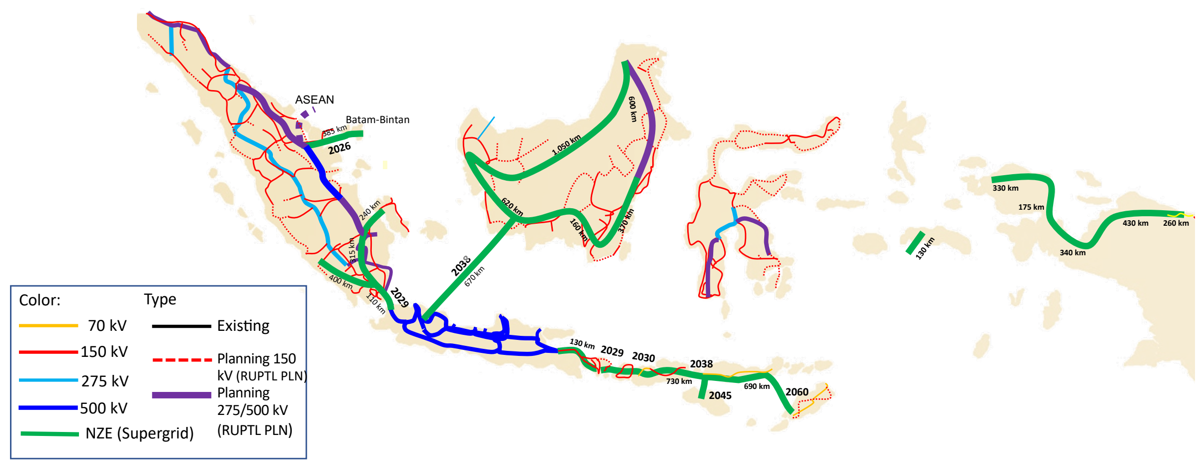
4.3 Transmission and Distribution

The potential for NRE resources is distributed throughout Indonesia, with the greatest potential for hydro, solar and wind energy in Kalimantan; Maluku, Papua, and Nusa Tenggara (MPNT); and Sulawesi, respectively. Meanwhile, electricity demand is concentrated in Java. Therefore, inter-system transmission within one island and between islands to share NRE potential is needed. The super grid interconnection plan is tabulated in **Table 4.9** and the transmission needs for inter-island NRE potential sharing are illustrated in **Figure 4.30**.

Table 4.9 Super grid interconnection plan

No.	System Interconnection	Year of Operation Plan
1.	Sumatra-Batam-Bintan	2026
2.	Manokwari-Sorong	2029
3.	Bali-Lombok	2036
4.	Sumatra-Java-Kalimantan	2044
5.	Bali-Sumba	2046
6.	Lombok-Sumbawa	2049
7.	Sumbawa-Flores	2052
8.	Major Inter-Systems in NTT	2056
9.	Jayapura-Sorong	2052
10.	Kalimantan-Sulawesi	2056

Figure 4.30 Transmission needs by 2060



To meet the transmission needs target by 2060, the government plans and implements several strategies including power wheeling, utilization of Battery Energy Storage System (BESS), and pumped storage (PS) with the following description.

Power Wheeling

Collaboration among Electricity Business License holders in the form of power wheeling, either network or distribution of electricity, has benefits to fulfill the quality standard and reliability of power system and development of NRE power plant. MEMR Regulation 11/2021 on Implementation of Electricity Business has regulated the provision of power wheeling. However, the procedure and tariff imposition of power wheeling, specifically for NRE power plant, needs to be regulated in more detail to:

- Increase the supply of electricity, improve network utilities, and meet electricity demand including through the use of NRE for electricity supply.
- Accommodate efforts to fulfill the NRE needs of RE100 group companies through the provision of NRE power plants owned by the company.

Power wheeling can be applied to:

- Electric power transmission network, which is carried out through network leases utilizing transmission networks between high voltage or extra high voltage substations;
- Electric power distribution network, which is carried out through network leases to distribute power from wheeling plants with a power capacity of ≤10 MW, utilizing distribution networks in one substation; or
- Cross-country power wheeling to support power export activities.

The setting of network rental prices can use the postage stamp calculation method, which is a network rental fee based on the amount of energy transacted (without considering wheeling distance). Another method is the MW-km calculation, which considers the amount of energy delivered, the distance of delivery, and the additional costs that must be borne by the network owner to maintain system reliability.

Battery Energy Storage System (BESS)

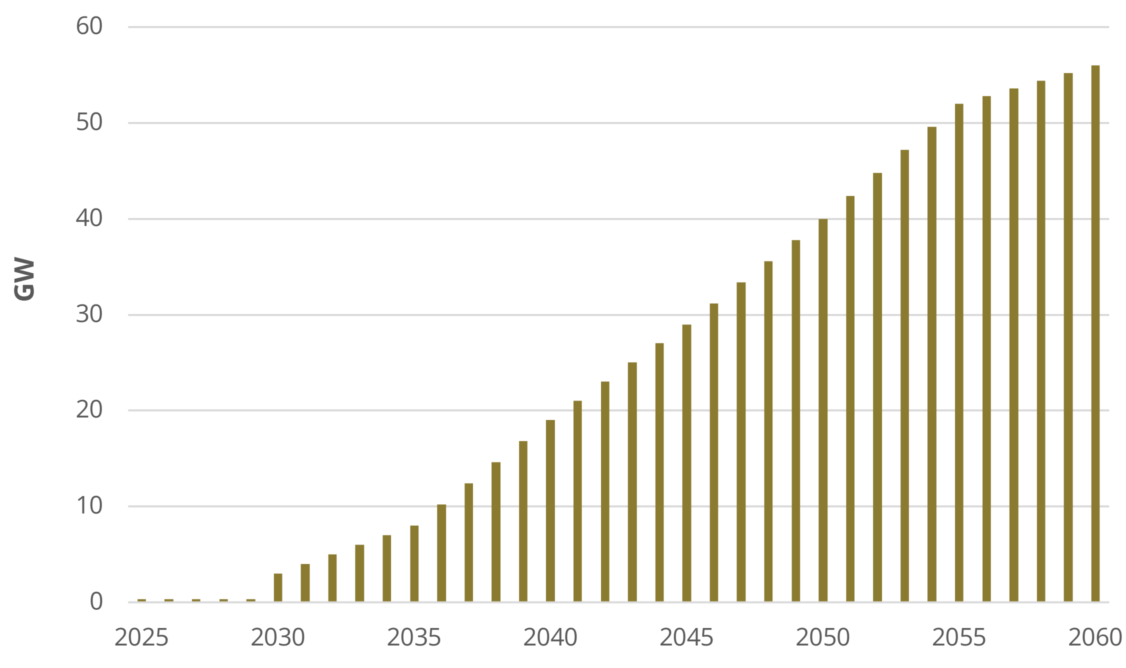
Various renewable energy (VRE) power plants have fluctuations in power output due to changes in weather conditions, cloud movements, and wind speed fluctuations. To overcome these challenges, BESS and pumped storage technologies are used which can store energy when there is a spike in power output and release energy when there is a decrease in power output.

BESS combined in a hybrid method with VRE power plants has several functions including blackstart, peak shaving, frequency regulated (frequency smoothing) and firming capacity. The use of BESS as frequency regulation will reduce the nature of variability and fluctuations in power output from VRE power plants. The power output becomes smoother and does not cause voltage and frequency fluctuations in the electricity system (smoothing function). The use of BESS as a firming capacity provides a more certain power output with power adequacy in accordance with the electricity load. As a result, VRE power plants can compete with conventional baseload plants. However, in terms of economics, the concept of BESS as a firming capacity requires high costs because of the large capacity required.

The use of BESS for smoothing needs is usually used to keep the system voltage and frequency within safe limits. Firming also has the same function but is usually required for systems with various renewable generation capacities above the quota. Therefore, the need for BESS for firming is usually greater. With the cost of BESS, which is still quite high, VRE power plants with BESS requirements for firming will become uncompetitive. Technically, VRE power plants must compete with reliable baseload plants (such as coal-fired power plants (CFPPs) and hydroelectric power plants. Financially, VRE power plants with BESS firming must at least be equivalent to the operating cost at base load or not higher than the marginal cost of the system.

The BESS development plan under the NZE scenario is illustrated in **Figure 4.31**. The additional BESS capacity during 2025–2029 is 0.3 GW. BESS development will increase in the period 2030–2060 to 56 GW or an average of 1.8 GW/year.

Figure 4.31 BESS development plan in NZE scenario

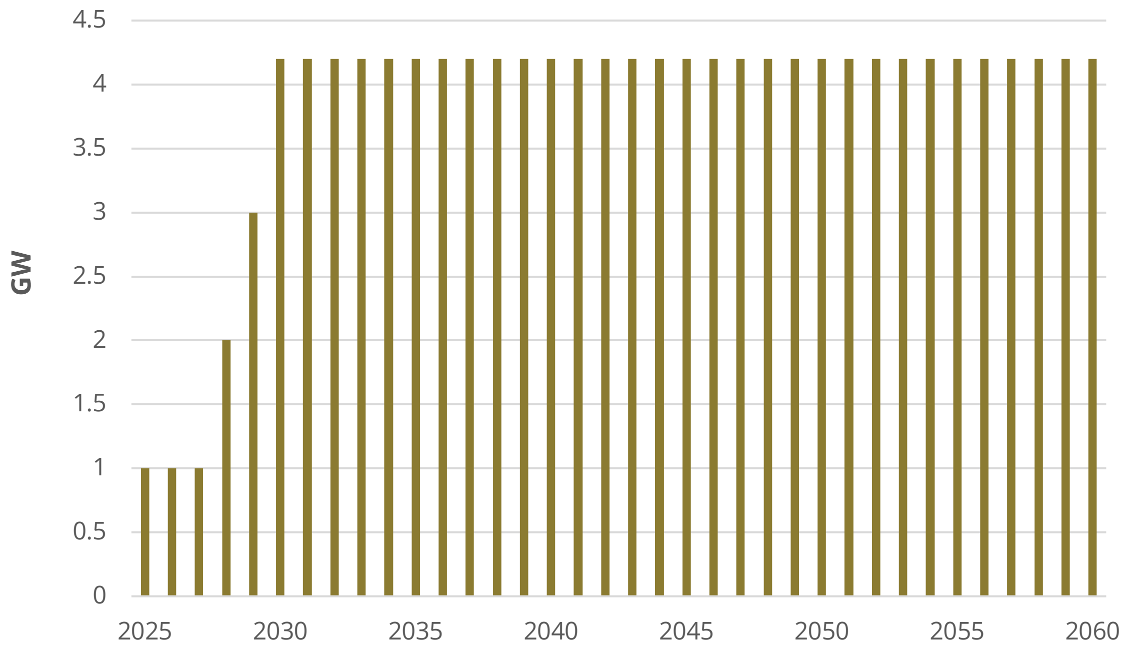


Pumped Hydro Storage (PHS)

Another technology that can be used is Pumped Hydro Storage (PHS) which can store excess electrical energy from VRE power plants and maintain the balance of demand and supply of electricity in the system. PHS can reduce the cost of supply especially during peak load (which usually uses expensive fuel oil and gas), increase the load factor and capacity factor of CFPP, and act as flexible generation to compensate for the intermittent nature of VRE power plants.

Figure 4.32 shows the PS development plan to support the energy sector NZE. PHS capacity will increase by 4.2 GW over 2021–2030. Currently, pumped storage hydropower plants under development include Cisokan Hydropower Plant (1,040 MW), Matenggeng Hydropower Plant (943 MW), Grindulu Hydropower Plant (1,000 MW) and West Java Distributed Hydropower Plant (760 MW). For the Sumatra system, the analysis of load conditions in the Sumatra System power balance shows an oversupply of base energy until 2030. The oversupply is due to the fact that many baseload plants are already committed, resulting in excess generation during off-peak times. A 4x250 MW pumped storage hydropower plant and a 300 MW Sumatra BESS will be developed in the Sumatra system to store excess power during off-peak conditions and then used during peak load.

Figure 4.32 PHS development plan in NZE scenario



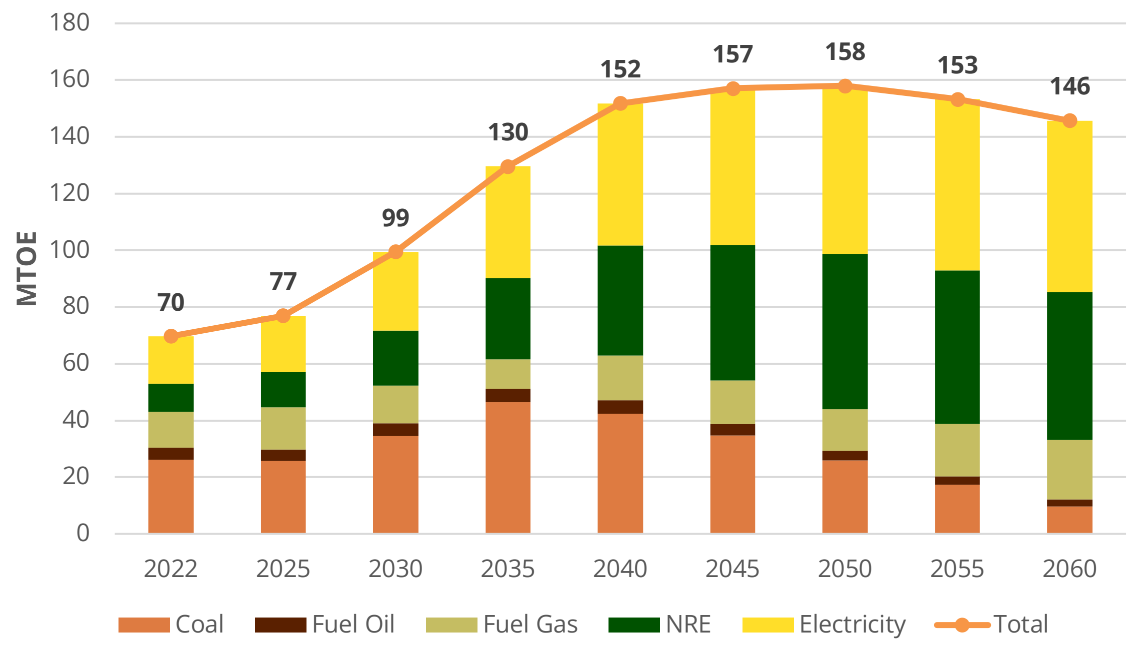
5 PATHWAYS FOR ENERGY DEMAND SIDE (DOWNSTREAM)

5.1 Industry

The industry subsector in Indonesia, both oil and gas and non-oil and gas, is the subsector with the largest final energy consumption. In 2022, the final energy consumption of the industry subsector reached around 70 MTOE—41% of the total final energy consumption. The type of energy consumed in the industry subsector consists of coal (38%), electricity (24%), fuel gas (18%), NRE (14%), and fuel oil (6%). Around 90% of final energy consumption in the industry subsector comes from six energy-intensive industries, namely the cement and non-metal industry, iron and steel industry, chemical fertilizer and rubber industry, pulp and paper industry, textile and leather goods industry, and food and beverage industry.

The industry subsector is projected to remain the largest final energy user subsector in 2060 with an energy consumption of 146 MTOE, with the largest consumption will be electricity (41%), followed by NRE (36%), fuel gas (14%), coal (7%), and the remaining portion sourced from fuel oil. The high electricity consumption is driven by electrification of industrial equipment, especially for low-temperature heating. Projections of final energy consumption in the industry subsector are shown in **Figure 5.1**.

Figure 5.1 Projected final energy demand in the industry subsector



The industry subsector will experience peak emissions in 2036 at 229.5 million tons CO_2e and is projected to decline to 68.7 million tons CO_2e in 2060. Projected industry subsector emission by industry type is shown in **Figure 5.2**. The largest emitter is the cement and nonmetal industry with an average share of 23%, followed by the iron and steel industry (21%), food and beverages (15%), chemical fertilizers and rubber (14%), pulp and paper (13%) and textiles and leather goods (10%).

Efforts made to achieve the NZE target in the industry subsector will reduce the energy intensity of this subsector by an average reduction of 2% annually. Energy intensity in the industry subsector will be reduced from 137 BOE/billion IDR in 2022 to 73 BOE/billion IDR in 2060. Compared to the BAU scenario, energy intensity in the industry subsector under the NZE scenario will be reduced by 33% in 2060. The energy intensity of the industry subsector is shown in **Figure 5.3**.

Figure 5.2 Projected industry subsector emissions by industry type

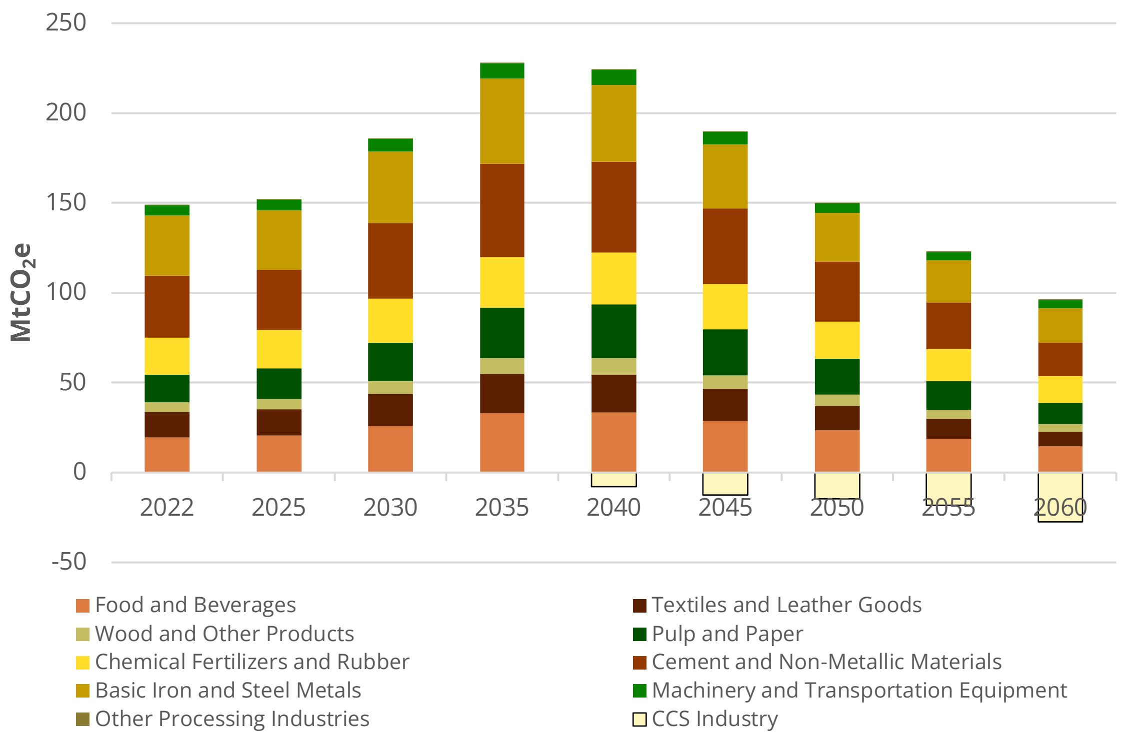
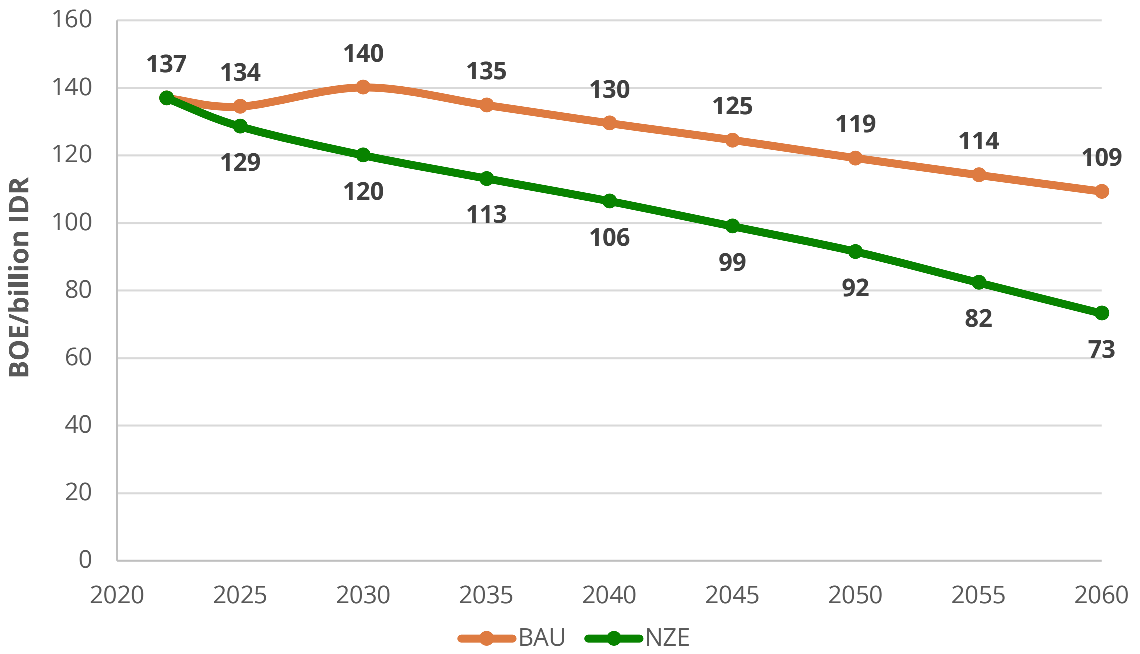


Figure 5.3 Energy intensity of industry subsector



To facilitate the achievement of Net Zero Emissions (NZE) targets in the industry subsector through initiatives focused on energy efficiency and emission reduction, the Government has issued related policies and regulations. These encompass Energy Management, the Green Industry Policy, and the National Industry Development Master Plan (RIPIN).

Energy Management in the Industry Subsector

Energy management in general has been regulated in Government Regulation 33/2023, as explained in Chapter 2. In addition, MEMR Regulation 14/2012 on Energy Management also regulates the implementation of energy savings by energy users that can be carried out through air conditioning systems, lighting systems, supporting equipment, production processes, and/or significant energy user equipment. Energy savings on the significant energy user equipment can be done through:

- load optimization, including the installation of inverters, especially for engine using electric motors operating under dynamic loads and substantial capacities.
- optimizing the air-to-fuel ratio for efficient combustion;
- utilizing exhaust gases, such as through co-generation or combined heat and power (CHP) systems;
- reducing heat losses, including adequate and optimal insulation on equipment;
- fuel switching, such as using natural gas as a fuel to replace High-Speed Diesel (HSD);
- performing maintenance on equipment on a regular basis.

Green Industry Policy

In accordance with Law 3/2014 on Industry, Green Industry refers to an industry that places a paramount focus on efficiency and effectiveness in resource utilization throughout its production processes. This commitment aims to harmonize industrial development with the sustainable preservation of environmental functions and deliver societal benefits. To actualize green industry practices, various programs have been implemented, including the establishment of Green Industry Standards, recognition through Green Industry Awards, and the attainment of Green Industry Certification.

The Green Industry Standards (*Standar Industri Hijau*, SIH) serve as a reference for industry stakeholders to collaboratively establish consensus on raw materials, auxiliaries, energy, production processes, products, management practices, waste management, and other relevant aspects to realize green industry principles. As of now, the Ministry of Industry has issued 37 Green Industry Standards, covering a range of industries including coated sheet steel, Portland cement, pulp and paper, ammonia and urea fertilizers, SP-36 fertilizer, ammonium sulfate fertilizer, solid nitrogen, phosphorus, and potassium fertilizers. Additionally, standards extend to textiles for dyeing, printing, and finishing, textiles for finishing fabric and fabric printing, basic oleochemicals derived from vegetable oils, palm oil-derived cooking oil, refined white sugar, biscuits and other dry bread products, bottled mineral water, powdered milk processing, instant coffee processing, wheat flour, snack products, and more.

The Ministry of Industry has undertaken the development of a roadmap for the establishment of Green Industry Standards over the period of 2022-2030. This initiative is particularly directed at priority industries, encompassing steel, metal, and petrochemical sectors. Furthermore, in the long-term perspective, both energy consumption and emission limits will continue to be tightened, considering the technological developments. The national objective is to achieve a reduction in energy intensity of 0.4 to 0.8 by 2060. Industries are strongly encouraged to adopt cleaner energy sources, such as electricity, gas, as well as new and renewable energy.

The National Industry Development Master Plan ***(Rencana Induk Perindustrian Nasional*, RIPIN)**

To enhance and elucidate the government's role in national industrial development, a systematic, comprehensive, and futuristic plan has been formulated in the form of the National Industry Development Master Plan 2015-2035—hereafter referred to as RIPIN 2015-2035. RIPIN 2015-2035 has been developed with meticulous attention to various aspects that exhibit strong characteristics and relevance to national industrial development, including technological developments, energy scarcity, and the depletion of non-renewable raw materials.

The current energy scarcity is becoming more pronounced. Therefore, to ensure the sustainability of industrial development, it is imperative to implement policies emphasizing energy conservation and diversification. Additionally, there is a need for heightened attention to the development of renewable energy sources and cost-effective nuclear energy. Regarding the scarcity of non-renewable raw materials, such as crude oil used in petrochemical industry feedstocks, which can lead to elevated operational costs, anticipatory measures involve reinforcing Research and Development (R&D) initiatives to explore alternative raw materials, including the utilization of recovery processes.

Moreover, to protect the environment and ensure the future sustainability of the industry subsector, RIPIN 2015-2035 also prioritizes the development of green industries. This encompasses the implementation of eco-product regulations, the utilization of renewable and environmentally friendly energy, and the management of hazardous materials. Strategies for emission reduction in the industry sector can be implemented through various measures such as fuel switching, energy efficiency, the adoption of clean energy, Carbon Capture, Utilization, and Storage (CCUS) implementation, material efficiency, and electrification strategies.

The projections for energy consumption and emissions, along with the strategies to achieve Net Zero Emissions (NZE) for each energy-intensive industry, will be outlined in the following sections, including (i) cement and non-metal; (ii) iron and steel; (iii) food and beverages; (iv) chemical fertilizers and rubber; (v) pulp and paper; and (vi) textiles and leather goods.

Cement and Non-Metal Industry

As the Indonesian economy continues to grow, activities in the cement and non-metal industry are also on the rise. The energy consumption of the cement and non-metal industry in 2022 was 12 MTOE, with coal dominated the energy consumption. In 2060, the energy demand for this industry is projected to increase with an average annual growth of 2%, reaching 23 MTOE by 2060.

To facilitate the achievement of Net Zero Emissions (NZE) targets in the industry subsector, an energy transition will be implemented in cement and non-metal industry. Coal consumption is anticipated to reach its peak in 2035 and gradually decline until 2060. This reduction in coal consumption will be substituted with the utilization of NRE and electricity. The projection for final energy demand in the cement and non-metal industry, categorized by energy type, is depicted in **Figure 5.4**.

Through the energy transition in the cement and non-metal industry, emissions from this industry are expected to reach its peak in 2037 at 52.4 million tons of CO_2e, gradually decreasing to 18.6 million tons of CO_2e by 2060. The emission projection for the cement and non-metal industry is presented in **Figure 5.5**.

Figure 5.4 Projected final energy demand in the cement and non-metal industry

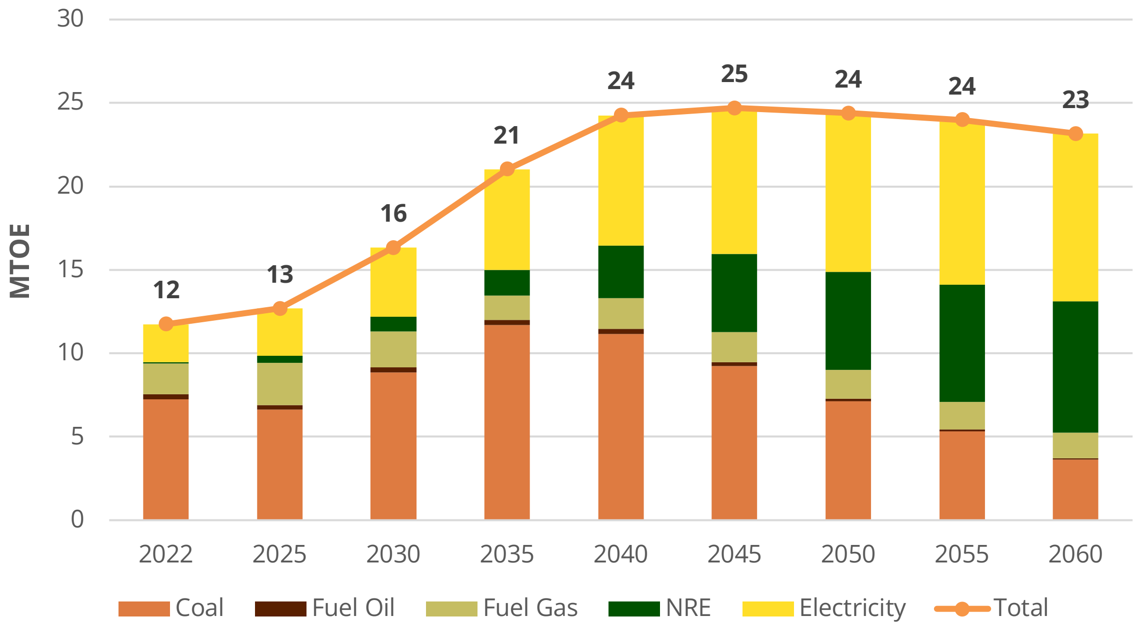
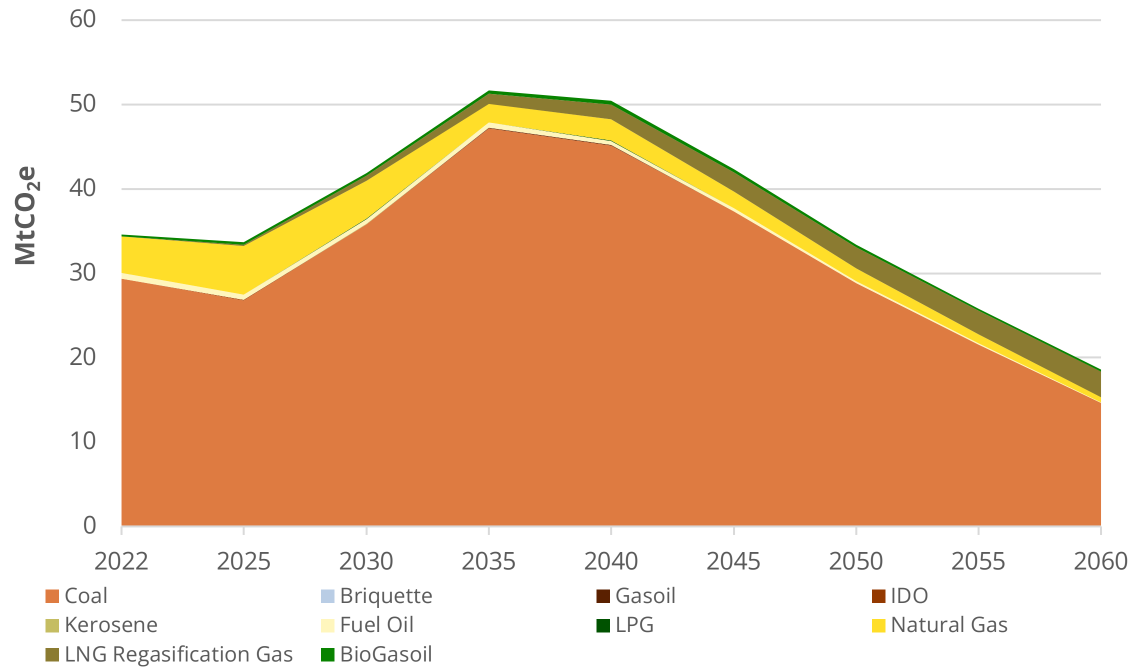


Figure 5.5 Projected emissions of the cement and non-metal industry



To facilitate the energy transition in the cement and non-metal industry, the Ministry of Industry has enacted Ministerial 26/2018 on Green Industry Standards for the Portland cement industry. This regulation sets forth standards for both energy consumption and emissions in the production of Portland cement, as tabulated in **Table 5.1**.

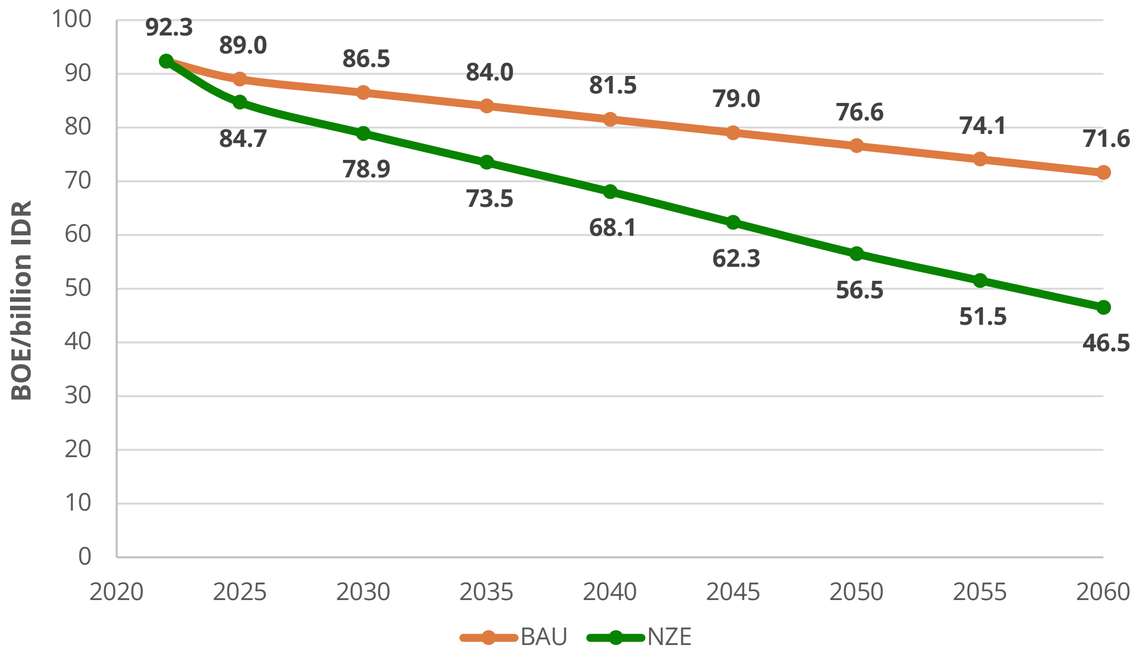
Table 5.1 Green Industry Standards for the Portland cement industry

Industry	Heat Consumption Limit	Electricity Consumption Limit	Emission Limit
Portland Cement (Kiln production before 1995, capacity ≥ 400,000 ton/year)	1,000 kcal/kg clinker	110 kWh/ton cement	750 kg CO_2/ton cement
Portland Cement (Kiln production before 1995, capacity < 400,000 ton/year)	1,050 kcal/kg clinker	120 kWh/ton cement	750 kg CO_2/ton cement
Portland Cement (Kiln production since 1995)	860 kcal/kg clinker	100 kWh/ton cement	750 kg CO_2/ton cement

The cement industry can explore alternative fuel sources, such as utilizing waste from landfills. Additionally, it is crucial to coordinate the supply of sustainable biomass across the sector to enable cost-competitive access for use in cement production. Accelerating innovation and implementing low-carbon technologies, particularly Carbon Capture, Utilization, and Storage (CCUS), as well as alternative binding materials, will play a crucial role in reducing emissions from the cement industry post-2030.

Efforts to achieve Net Zero Emissions (NZE) in the cement and non-metal industry will result in a reduction in the energy intensity of this subsector to 46.5 BOE/billion IDR by 2060—a decrease of 35% from the Business as Usual (BAU) scenario. In the NZE scenario, the energy intensity in this industry is expected to decrease by an average of 2% annually. The energy intensity in the cement and non-metal industry will decrease from 92.3 BOE/billion IDR in 2022 to 46.5 BOE/billion IDR in 2060. The energy intensity of the cement and non-metal industry is illustrated in **Figure 5.6**.

Figure 5.6 Energy intensity of the cement and non-metal industry



Iron and Steel Industry

Anticipated growth is foreseen in the activities of the iron and steel industry. The energy consumption of this industry was 11 MTOE in 2022, with coal being the predominant energy source. By 2060, a steady average annual growth rate of 2% is projected, resulting in an energy demand of 19 MTOE.

To align with the NZE objectives in the industry subsector, an energy transition will be implemented in the iron and steel industry. Coal consumption is projected to reach its peak in 2035, followed by a gradual decline until 2060. This reduction in coal consumption will be supplanted by the utilization of NRE and electricity. Projections for the final energy demand in the iron and steel industry by energy type, are illustrated in **Figure 5.7**.

Through the energy transition in the iron and steel industry, emissions from this sector are forecasted to peak in 2036 at 47.5 million tons of CO_2e, gradually diminishing to 19.4 million tons of CO_2e by the year 2060. The emission projections for the iron and steel industry are presented in **Figure 5.8**.

Figure 5.7 Projected final energy demand in the iron and steel industry

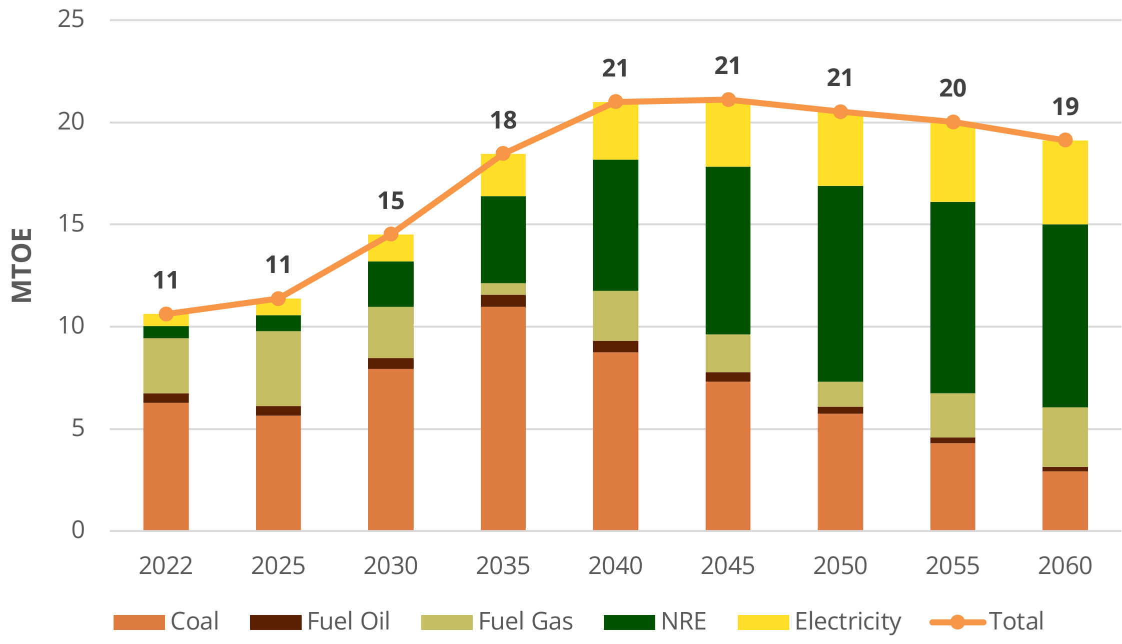
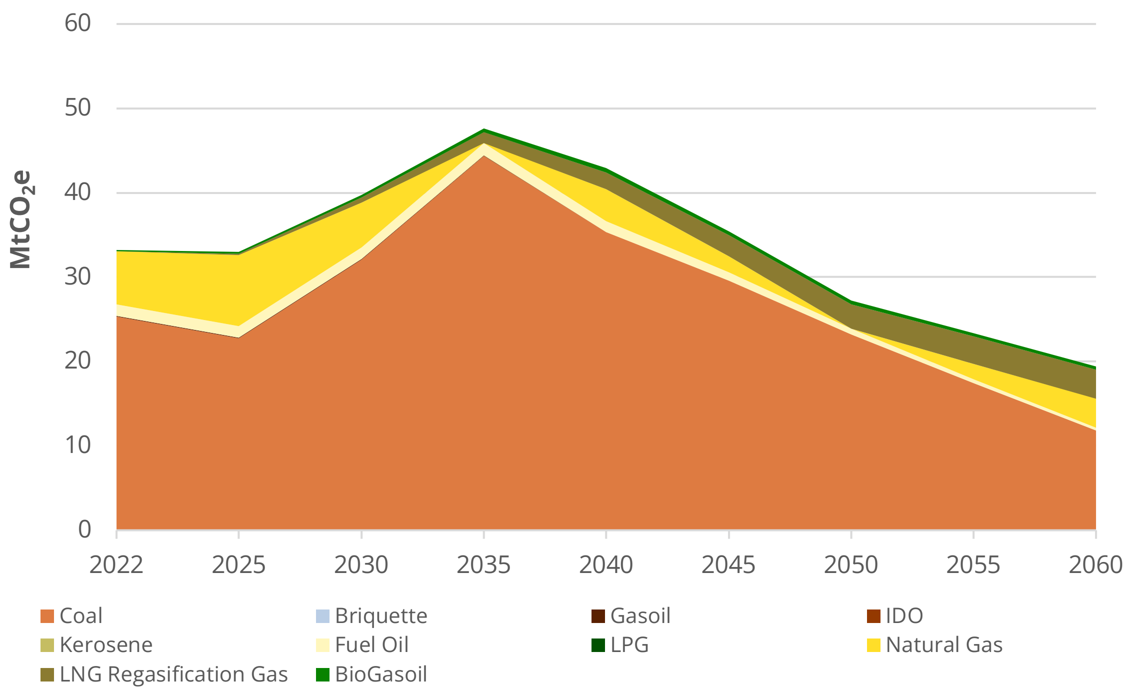


Figure 5.8 Projected emissions in the basic iron and steel metals industry



To support the energy transition in the iron and steel industry, the Government has developed a roadmap for the development of steel industry technology, including improving energy efficiency in the production process, in the National Industrial Development Master Plan 2015-2035, as tabulated in **Table 5.2**.

Table 5.2 Roadmap for the development of steel industry technology

2015 – 2019	2020 - 2024	2025 - 2035
• Ironmaking Coal Based: Blast Furnace for pig iron and nickel pig iron • Rotary Hearth Furnace (RHF) • Gas-based direct reduction, coal-based direct reduction • Grate Kiln for pellet production • Shaft Furnace for pellet production • Traveling Grate for pellet production • Rotary Kiln for sponge iron • Commencing the development of local technology (lab-pilot scale)	• Ironmaking Coal-Based: Coal Gasification Process • Direct Smelting: Gas-based direct reduction for sponge iron and RHF for iron nugget • SL-RN Extra (Rotary Kiln with Waste Heat Recovery) for sponge iron • Initiating the development of local technology (pilot-demo scale)	• Coal-based: Coal Gasification • Direct Smelting: Gas-based direct reduction for sponge iron and RHF for iron nugget • Commencing the development of local technology (demo-commercial scale)
• Steelmaking • Electric Arc Furnace (EAF) • and Basic Oxygen Furnace • (BOF)	• Steelmaking • Efficiency of EAF and BOF	• Steelmaking • Energy efficiency and pollution reduction for EAF and BOF

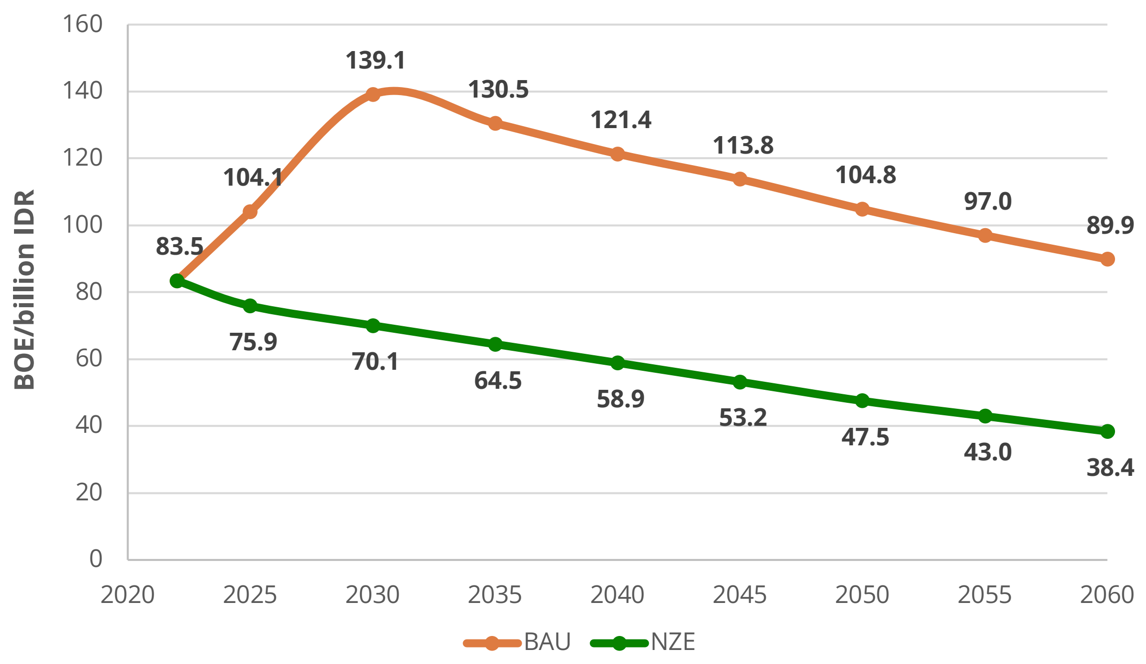
In the short and medium term (five to ten years ahead), emission reduction in the steel industry can be achieved by implementing energy efficiency measures. The implementation of cost-effective Best Available Technology (BAT) should be promoted while transitioning to near-zero-emission technologies. Significant energy efficiency improvements can be obtained by enhancing operational and process efficiency. This can be accomplished by adopting energy management systems.

Secondary production also needs improvement through more effective collection and sorting of scrap iron. Collaboration among the steel industry, manufacturers of steel products, and waste collectors is essential to ensure that scrap iron returns to steel producers for use as raw materials.

In the long term, achieving significant emission reduction requires the adoption of new production processes for primary steel, including other innovative technologies such as the application of new smelting technology, direct reduction, and CCUS technology.

Efforts to reach NZE targets in the basic iron and steel metals industry will reduce the energy intensity of this subsector to 38.4 BOE/billion IDR in 2060—a decrease of 57% from the Business as Usual (BAU) scenario. In the NZE scenario, the energy intensity in this industry is expected to decrease by an average of 2% annually. The energy intensity in the iron and steel industry will decrease from 83.5 BOE/billion IDR in 2022 to 38.4 BOE/billion IDR in 2060. The energy intensity of the iron and steel industry is illustrated in **Figure 5.9**.

Figure 5.9 The energy intensity of the iron and steel industry



Food and Beverage Industry

The activities in the food and beverage industry are projected to increase as the economic growth. The energy consumption of this industry was 12 MTOE in 2022. Currently, the food and beverage industry has been utilizing NRE and electricity, with almost equivalent portion as coal. By 2060, the energy demand for this industry is projected to increase at an average annual growth rate of 2%, reaching 25 MTOE in 2060.

In order to support the achievement of NZE targets in the industry subsector, an energy transition will be undertaken in the food and beverage industry. The dominance of NRE and electricity consumption is expected to continue until 2060. Projections for the final energy demand in the food and beverage industry by energy type are illustrated in **Figure 5.10**.

Through the energy transition in the food and beverage industry, emissions from this sector are forecasted to peak in 2037 at 34.1 million tons of CO_2e, gradually decreasing to 14.6 million tons of CO_2e by the year 2060. The emission projections for the food and beverage industry are presented in **Figure 5.11**.

Figure 5.10 Projected final energy demand in the food and beverage industry

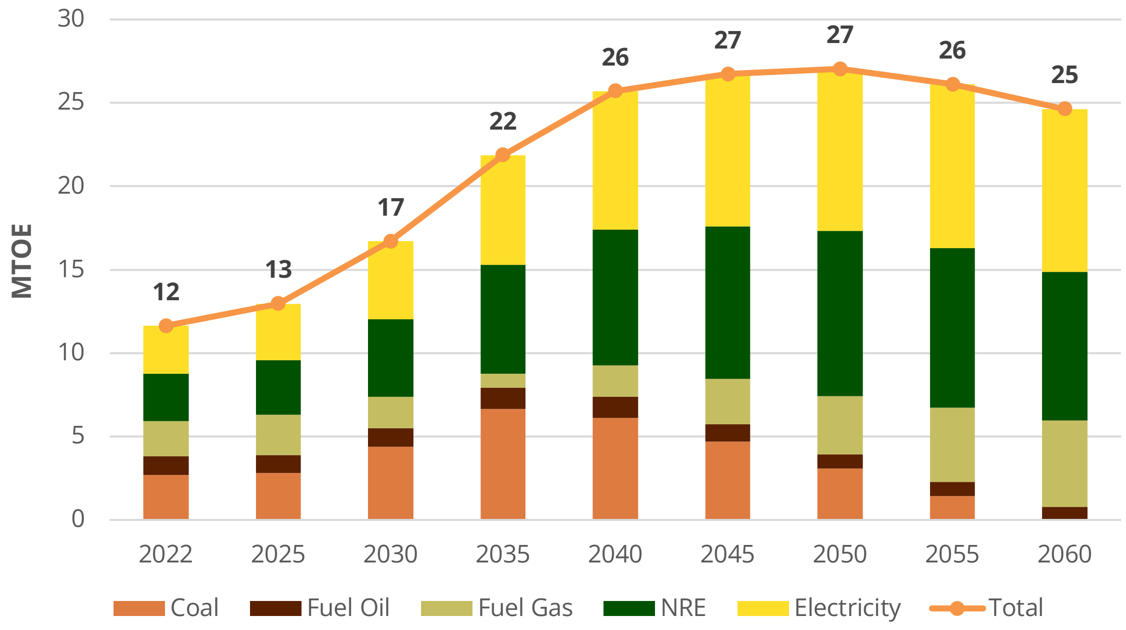
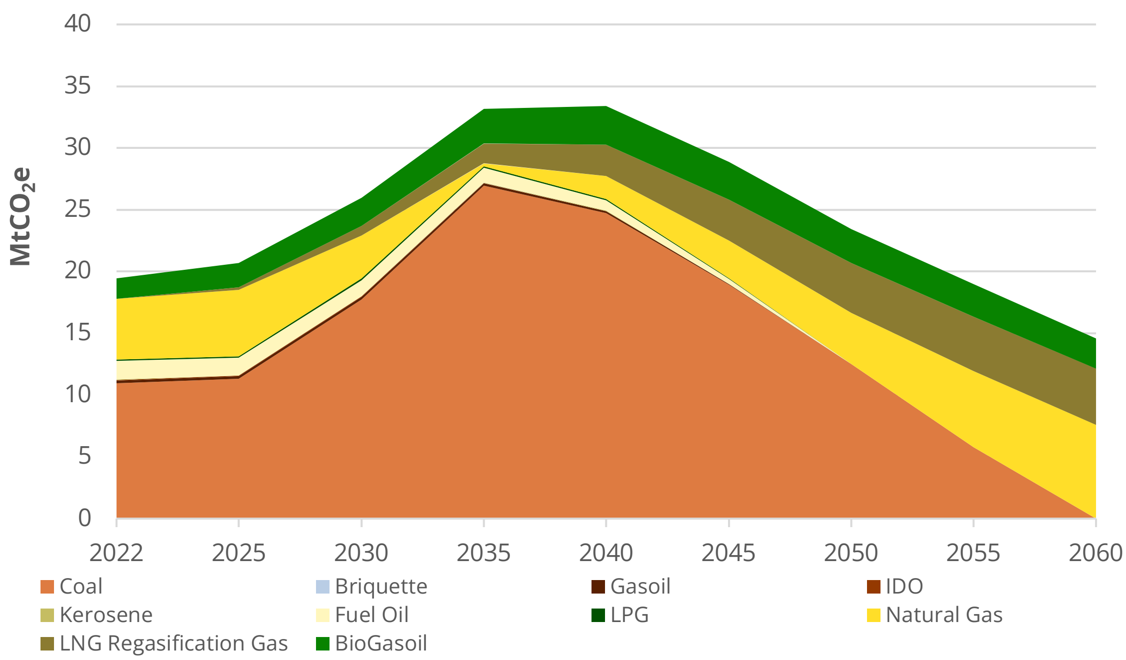


Figure 5.11 Projected emissions in the food and beverage industry



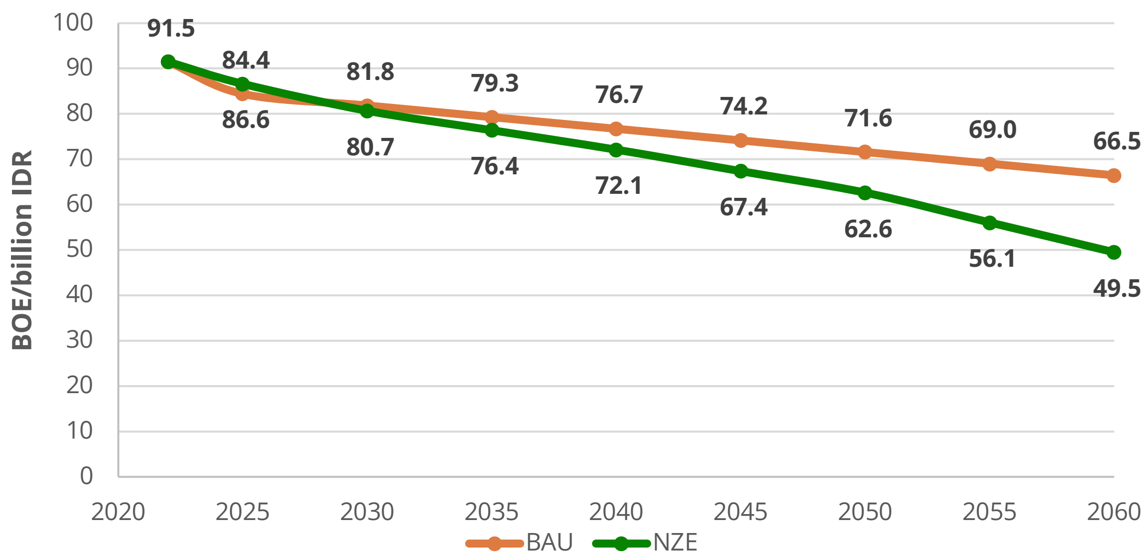
In the context of achieving NZE in the food and beverage industry, several strategic actions can be implemented. These include optimizing energy efficiency in the production processes of food and beverages, transitioning to a decarbonized electricity source, increasing the utilization of biofuels from 30% to 40%, and enhancing the consumption of biomass. Given the significant reliance of the food and beverage industry on cooling systems and chillers, improvements in energy efficiency can be attained with minimal or no capital investment.

To achieve these goals, a three-fold strategy for energy-saving in cooling systems and chillers is proposed: (i) component engineering, focusing on the proper operation and maintenance of cooling components, including optimal settings for water temperature and flow rate; (ii) system engineering for multiple cooling units, involving the operation of the most efficient equipment mix under various load conditions; and (iii) retrofitting, incorporating the latest energy-efficient technologies and equipment into existing systems.

Notably, the establishment of green industry standards plays a pivotal role, imposing limits on energy consumption and emissions intensity for six specific types of food and beverage products. These standards are anticipated to contribute to a reduction in energy intensity and, consequently, a decrease in emissions within the industry.

The comprehensive efforts directed toward achieving the NZE target in the food and beverage industry are projected to result in a reduction of this industry's energy intensity to 49.5 BOE/billion IDR by 2060, marking a 26% decrease from the Business as Usual (BAU) scenario. Under the NZE scenario, a yearly average reduction of 2% in energy intensity is expected. This will translate to a decrease from 66.5 BOE/billion IDR in 2022 to 49.5 BOE/billion IDR in 2060, as illustrated in **Figure 5.12**.

Figure 5.12 The energy intensity of the food and beverage industry



Fertilizer and Chemical Industry

Activities in the fertilizer and chemical industry are projected to increase. The energy consumption of the fertilizer and chemical industry in 2022 was 12 MTOE. Currently, the fertilizer and chemical industry already utilizes electricity as the primary energy source, with consumption almost equal to natural gas and coal. In 2060, the energy demand for this industry is projected to increase with an average annual growth of 2%, reaching 24 MTOE in 2060.

In order to support the achievement of the NZE target in the industry subsector, energy transition will continue in the fertilizer and chemical industry. The consumption of coal and natural gas will decrease, replaced by NRE and electricity until 2060. The projection of final energy demand in the fertilizer and chemical industry based on energy types is shown in **Figure 5.13**.

Through the energy transition in the fertilizer and chemical industry, emissions in this industry will peak in 2038 at 29.3 million tons of CO_2e, and then decline to 14.9 million tons of CO2e in 2060. The projection of emissions in the fertilizer and chemical industry is illustrated in **Figure 5.14**.

Figure 5.13 Projected final energy demand in the fertilizer and chemical industry

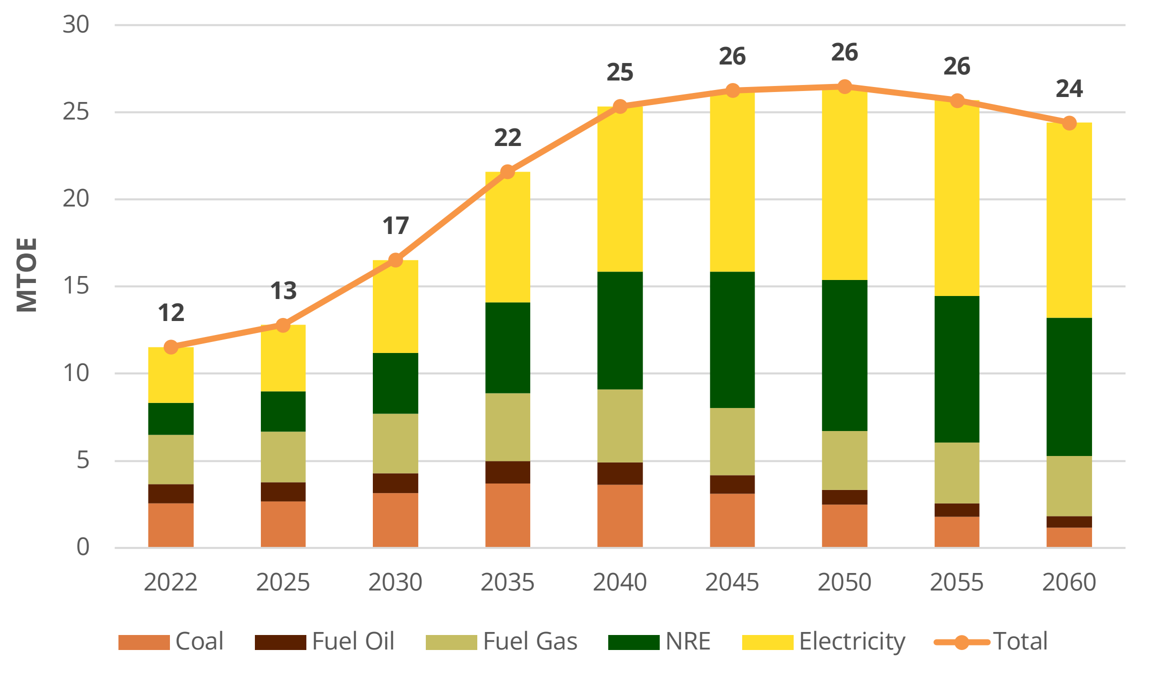
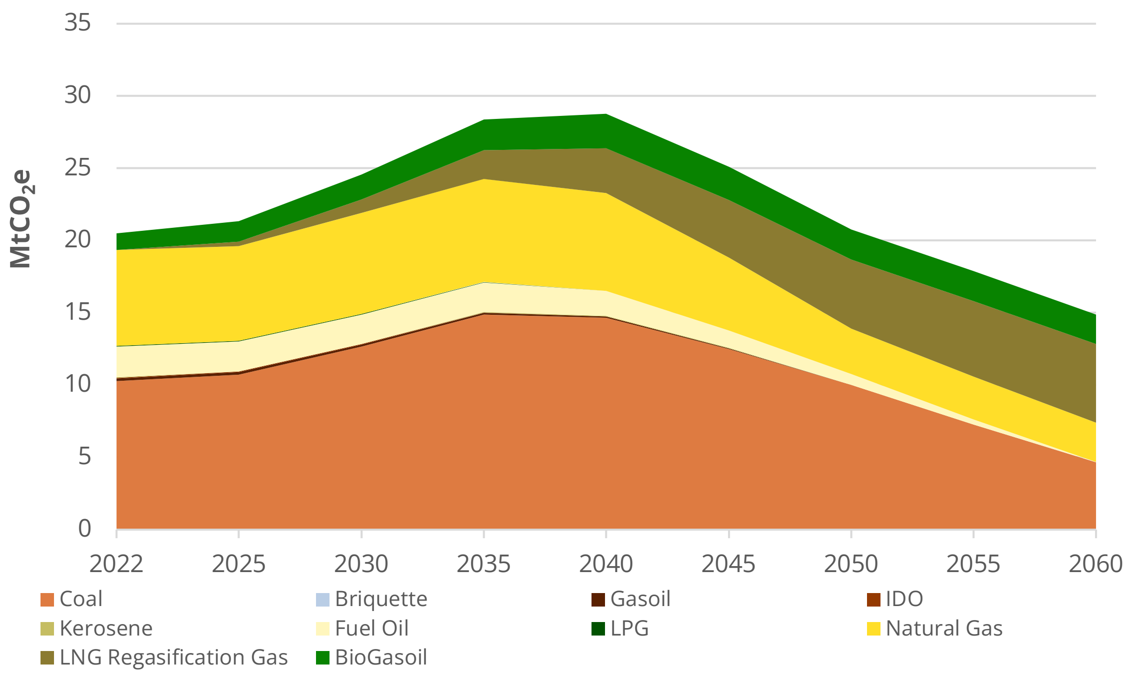


Figure 5.14 Projected emissions in the fertilizer and chemical industry



To achieve the emission target in 2060, the fertilizer and chemical industry needs to undertake mitigation actions, including maximizing energy efficiency in the production process, reducing coal consumption, fuel switching from coal to natural gas and hydrogen, and increasing the use of NRE such as biofuels and biomass.

To promote environmentally friendly and sustainable fertilizer production, the Ministry of Industry has established green industry standards limiting energy consumption and emissions resulting from fertilizer production. Additionally, the Ministry of Industry has set green industry standards regulating limits on energy, thermal, and electrical consumption, as well as emissions produced by the chemical industry.

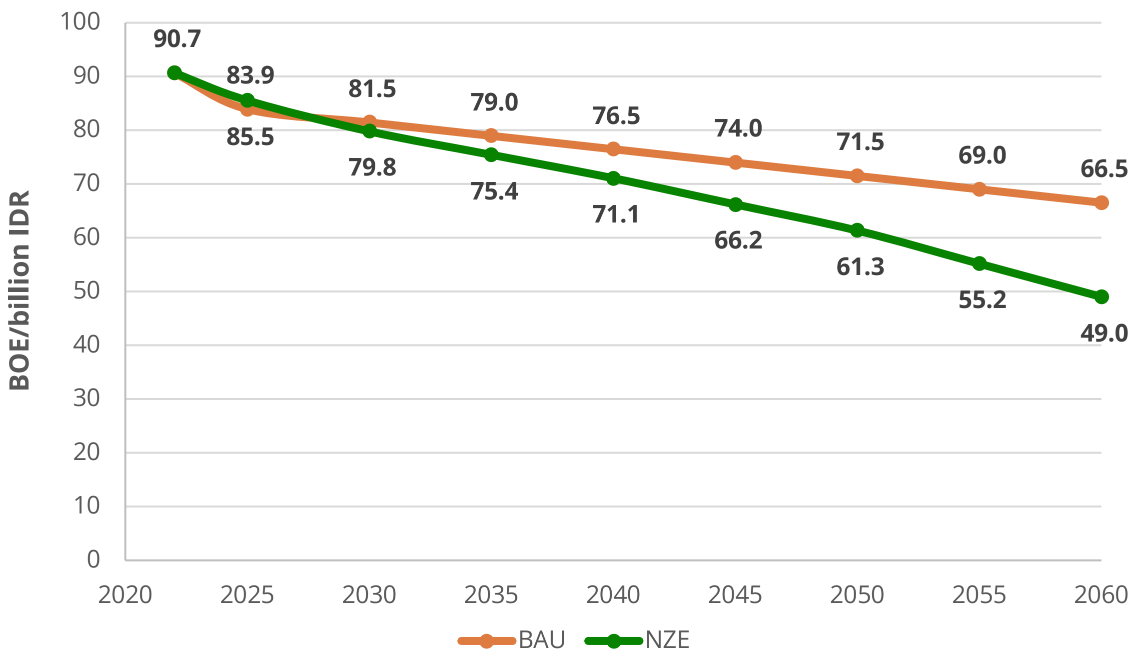
As one of the priority and flagship industries nationally, the fertilizer industry plays a crucial role, particularly in meeting the fertilizer needs in the agriculture and plantation sectors. The National Industrial Development Master Plan (RIPIN) 2015-2035 encourages the implementation of energy-efficient technologies, specifically to reduce energy consumption and emissions. **Table 5.3** provides the technology roadmap in the fertilizer industry outlined in RIPIN 2015-2035.

Table 5.3 Technology roadmap for the fertilizer industry

2015 - 2019	2020 - 2024	2025 - 2035
• Compound Fertilizer Production Technology (Licensing and Reverse Engineering) • Technology for Enhancing the Efficiency of Existing Fertilizer Plants • Slow-Release Fertilizer Technology	• National Pilot Plant for Compound Fertilizer Technology • Technology for Improving the Efficiency of Existing Fertilizer Plants	• Large-Scale National Technology for the Compound Fertilizer Industry

Efforts to achieve the NZE target in the fertilizer and chemical industry aim to reduce the energy intensity of this subsector to 49 BOE/million IDR by 2060—a 26% reduction from the Business-As-Usual (BAU) scenario. In the NZE scenario, the energy intensity in this industry is projected to decrease by an average of 2% annually. The energy intensity in the fertilizer and chemical industry is expected to decrease from 90.7 BOE/million IDR in 2022 to 49 BOE/billion IDR in 2060. The energy intensity of the fertilizer and chemical industry is illustrated in **Figure 5.15**.

Figure 5.15 Energy intensity of the fertilizer and chemical industry



Pulp and Paper Industry

Activity in the pulp and paper industry is projected to increase. The energy consumption of the pulp and paper industry in 2022 was 10 MTOE. Currently, energy consumption in the pulp and paper industry is dominated by NRE. By 2060, the energy demand of this industry is projected to increase with an average growth of 2% each year, reaching 22 MTOE in 2060.

To support the achievement of the NZE target in the industry subsector, energy transition will continue to be carried out in the pulp and paper industry. Coal consumption will continue to decrease until 2060, replaced by NRE and electricity. The projected final energy demand of the pulp and paper industry by energy type is shown in **Figure 5.16**.

Through the pulp and paper industry's energy transition, the industry's emissions will peak in 2039 at 30.2 million tons of CO_2e and decline to 11.9 million tons of CO_2e in 2060. Projected emissions from the pulp and paper industry are shown in **Figure 5.17**.

Figure 5.16 Projected final energy demand of the pulp and paper industry

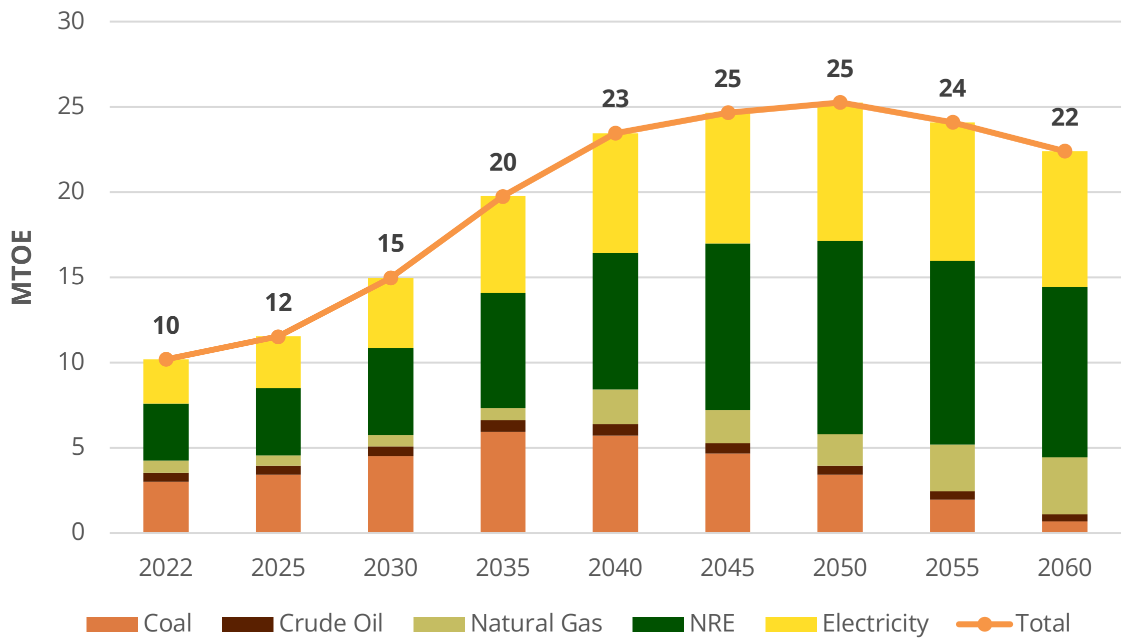
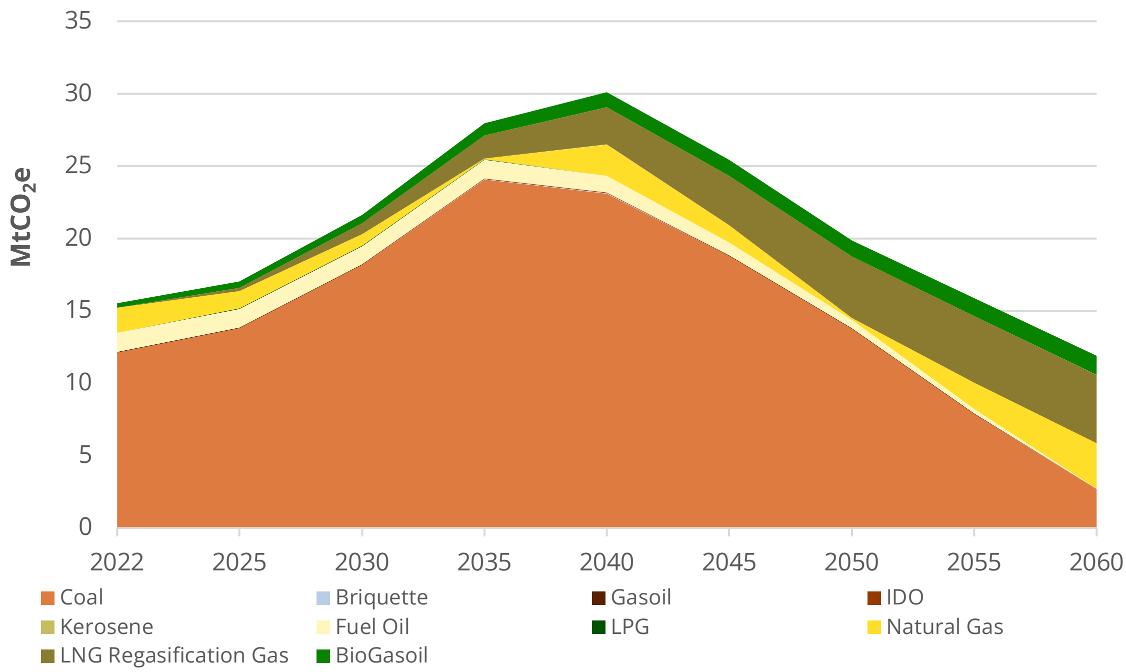


Figure 5.17 Projected emission of the pulp and paper industry



The pulp and paper industry stands out as one characterized by a high intensity of energy consumption. The technological attributes employed in this subsector hinge on factors such as the type of raw materials, the pulp manufacturing process, and the nature of the end products. Energy for each stage of pulp and paper production is derived from various fuel sources, including coal, gas, oil, electricity, black liquor, and biomass.

This industry notably relies heavily on biomass waste, particularly black liquor generated during the production process, as a substantial energy source. Moreover, alternative biomass sources like palm shells and sawdust are also utilized for energy generation.

To enhance energy efficiency and mitigate emissions in the pulp and paper industry, the Ministry of Industry has enacted two Ministerial Regulations that establish Green Industry Standards for both Integrated Pulp and Paper Industry and Cultural Paper Industry. The details are outlined in **Table 5.4.**

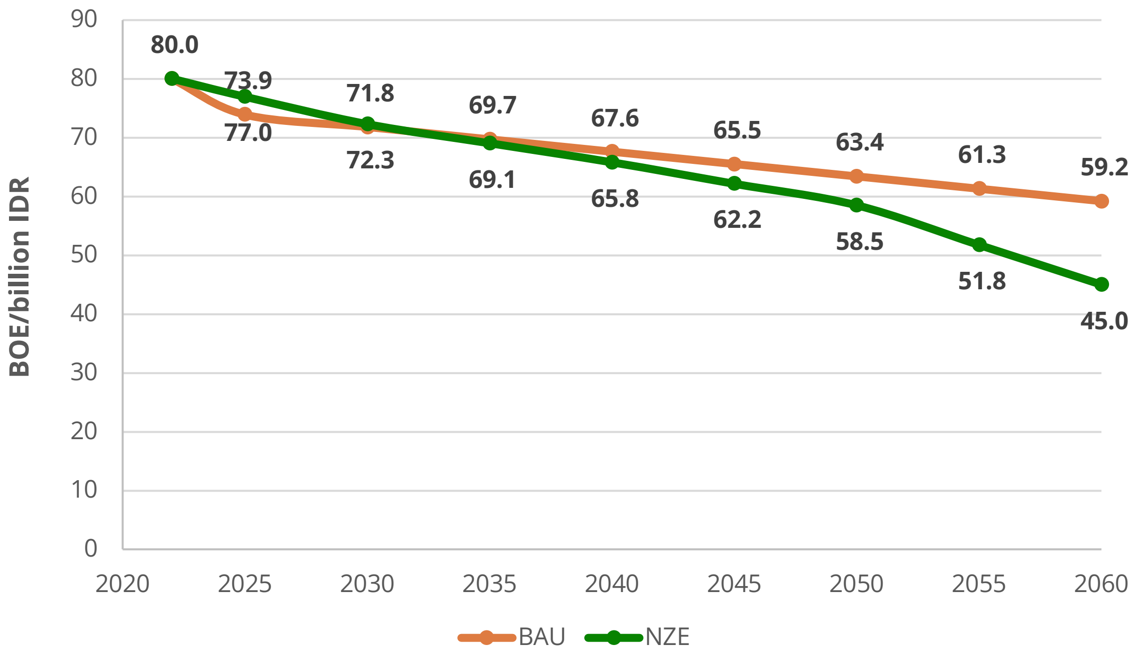
Table 5.4 Green Industry Standards for the Pulp and Paper Industry.

Regulation on Green Industry in the Pulp and Paper Industry	Energy Consumption Aspect	GHG Emission Aspect
MoI Regulation 11/2019 (Green Industry Standards for Pulp and Integrated Pulp and Paper Industry)	• **Pulp**: Maximum 1.05 MWh/ton Pulp • **Integrated Pulp & Paper**: Maximum 1.5 MWh/ton Paper	• Maximum 0.35 ton CO_2/ton Pulp • Maximum 1.5 ton CO_2/ton Paper
MoI Regulation 40/2019 (Green Industry Standards for Cultural Paper Industry)	• Print-coated paper products: Maximum 1100 kWh/ton Print-uncoated and multipurpose • Paper products: Maximum 1000 kWh/ton Product	• Maximum 14 ton CO_2/ton Product

Enhancing energy efficiency in the pulp and paper industry is a pivotal strategy for decarbonizing this subsector. Efficiency improvements can be realized through waste heat recovery and co-generation. Additionally, ensuring the optimal operation of equipment through routine maintenance, coupled with the implementation of an energy management system, is crucial for achieving peak energy performance. Noteworthy energy efficiency initiatives in the pulp and paper industry encompass reductions in excess air in power boiler systems (utilizing biomass or coal), enhancements to insulation and piping systems, and minimization of boiler blowdown. Further strategies include improvements to dryer performance, such as the installation of spoiler bars and the removal of condensate poor good. Optimizing biomass utilization involves techniques like biomass gasification, maximizing the use of non-condensable gases (NCG), and utilizing bio sludge as fuel in recovery boilers. The utilization of biogas as an environmentally friendly and renewable fuel is also a part of the multifaceted approach. Additional measures involve energy savings through heat recovery, the adoption of high-efficiency electric motors, and the implementation of Variable Speed Drives (VSD).

The efforts directed at achieving the NZE target in the pulp and paper industry aim to reduce this industry's energy intensity to 45 BOE/billion IDR by 2060—an impressive 24% reduction from the Business as Usual (BAU) scenario. In the NZE scenario, the industry anticipates an annual average reduction of 1% in energy intensity. Consequently, the energy intensity in the pulp and paper industry is projected to decrease from 80 BOE/billion IDR in 2022 to 45 BOE/billion IDR in 2060. The depicted trajectory of energy intensity in the pulp and paper industry is illustrated in **Figure 5.18**.

Figure 5.18 The energy intensity of the pulp and paper industry



Textile and Leather Goods Industry

Activity in the textile and leather goods industry is projected to increase. The energy consumption in the textile and leather goods industry in 2022 was 7 MTOE, with coal and electricity consumption dominated. By 2060, the energy demand in this industry is projected to increase at an average annual growth rate of 2%, reaching 17 MTOE in 2060.

To support the achievement of the NZE target in the industry subsector, energy transition will be implemented in the textile and leather goods industry. Coal consumption is expected to peak in 2036, gradually decreasing until 2060. This reduction in coal consumption will be replaced by an increased utilization of NRE and electricity. The projection of final energy demand in the textile and leather goods industry based on energy types is illustrated in **Figure 5.19**.

Through the energy transition in the textile and leather goods industry, emissions from this sector will peak in 2037 at 21.9 million tons of CO_2e and decrease to 8.3 million tons of CO_2e by 2060. The emission projections for the textile and leather goods industry are presented in **Figure 5.20**.

Figure 5.19 Projected final energy demand in the textile and leather goods industry

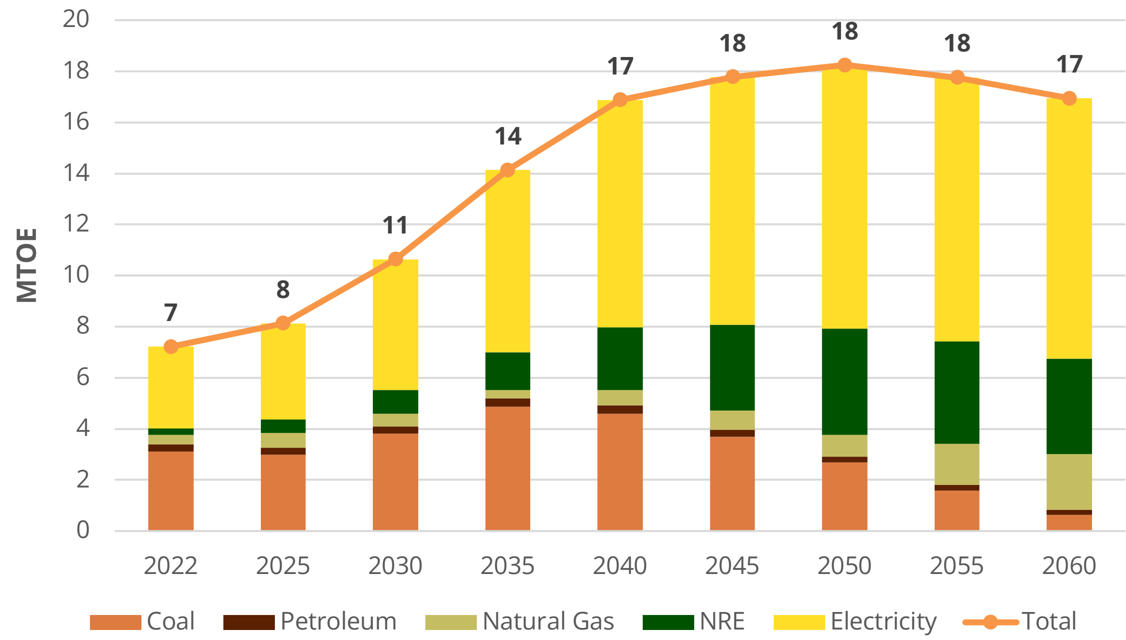
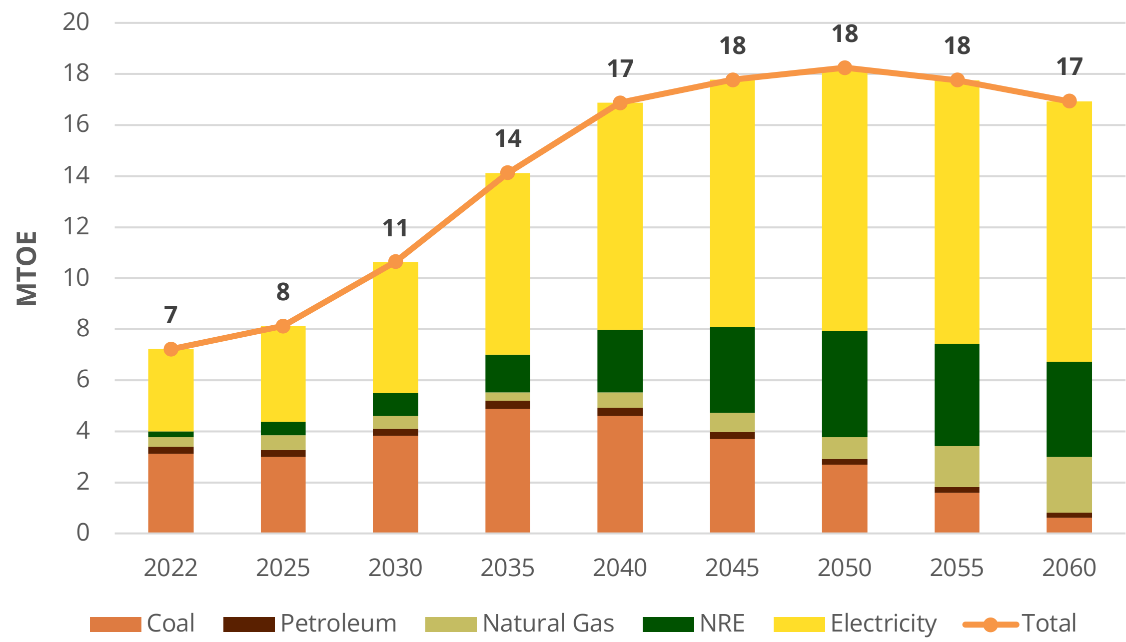


Figure 5.20 Projected emission in the textile and leather goods industry



As one of the national priority industries, the government pays special attention to improving the productivity of the textile industry. In addition, most of the textile equipment is very old with equipment age above 20 years. **Table 5.5** summarizes the technology roadmap in the textile industry as stated in RIPIN 2015-2035.

Table 5.5 The roadmap of technology in the textile industry

2015 - 2019	2020 - 2024	2025 – 2035
• Raw material and dye materials • Efficient cutting and sewing • Environmentally friendly leather processing • Eco-friendly dye materials • Energy-efficient fabric treatment • Customized product design and CAD/CAM • High-speed, efficient cutting, trimming, and sewing • Healthy and environmentally friendly leather processing	• Lightweight, strong, and biodegradable synthetic microfiber materials • Eco-friendly dye materials • Energy-efficient fabric treatment • Customized product design and CAD/CAM • High-speed, efficient cutting, trimming, and sewing • Healthy and environmentally friendly leather processing • Advanced spinning and knitting (microfiber) • Recycle technology for fiber	• Lightweight, strong, and biodegradable synthetic nanofiber materials • Eco-friendly dye materials • Product design and CAD/CAM customization • High-speed, efficient cutting, trimming, and sewing • Healthy and environmentally friendly leather processing • Advanced spinning and knitting (nanofiber)

The textile industry remains heavily dependent on fossil fuels, particularly for heat and steam generation. To mitigate greenhouse gas (GHG) emissions in this subsector, several strategies are viable. These encompass optimizing energy efficiency in the production process, curbing coal consumption, increasing the utilization of NRE sources like biofuels and biomass, decarbonizing the electricity supply, and undertaking the restructuring of machinery and equipment in the textile industry.

Currently, Green Industry Standards for the textile sector are voluntary and have been established only for specific processes such as dyeing, printing, and finishing. The machinery restructuring program has yielded positive outcomes, benefiting both the expansion of the national textile industry and the enhancement of energy intensity, as tabulated in **Table 5.6**.

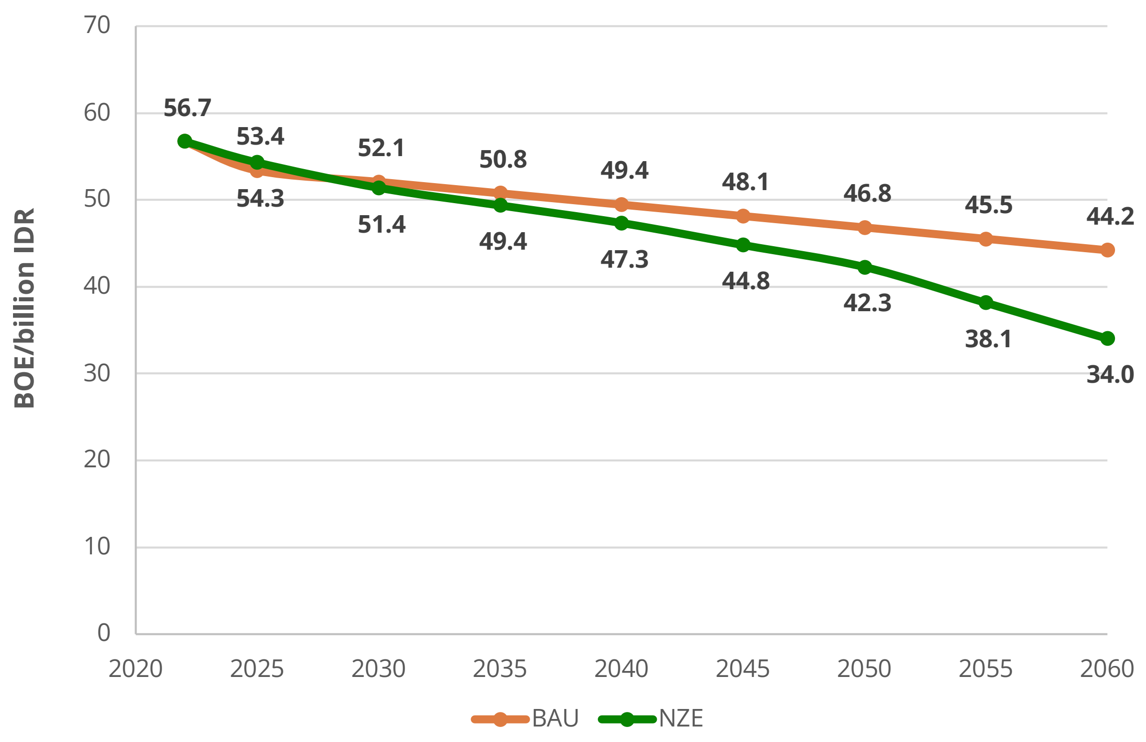
Table 5.6 Impact of textile industry machinery restructuring

Evaluation Parameter	Before	After	Change (%)
Installed Capacity (ton/year)	381,160,131	464,062,963	21.75%
Production Realization	315,781,541	382,803,728	21.22%
Energy			
Consumption (kWh)	12,303,956,825	13,146,661,289	6.85%
Efficiency (kWh/ton)	38.96	34.34	-11.86%
Labor (persons)	714,311	742,606	3.96%

Source: Ministry of Industry, 2021

In pursuit of achieving the NZE target in the textile and leather goods industry, initiatives have been undertaken to reduce the energy intensity of this subsector to 34 BOE/billion IDR by the year 2060—a reduction of 23% from the Business as Usual (BAU) scenario. Under the NZE scenario, the industry experiences an annual average decrease of 1% in energy intensity. The energy intensity in the textile and leather goods industry is anticipated to decrease from 56.7 BOE/billion IDR in 2022 to 34 BOE/billion IDR in 2060, as illustrated in **Figure 5.21**.

Figure 5.21 Energy intensity of the textile and leather goods industry



5.2 Transportation

In 2022, the final energy consumption of the transportation subsector was 58 MTOE—the second largest final energy consumer after the industry subsector. The most common type of energy used in this subsector is fuel oil (87%), and the rest is biofuel. In the NZE scenario, the transportation subsector is projected to consume 44 MTOE of energy in 2060, a 24% decrease from 2022 energy consumption. The transportation subsector's energy demand is dominated by fuel oil, which peaks in 2023 and then declines until 2060. The decline in fuel oil demand is replaced by an increase in electricity demand by 2060 due to policies to accelerate the use of electric vehicles, vehicle efficiency, and other policies that support the migration of private to public transport. The projected energy demand of the transportation subsector until 2060 is illustrated in **Figure 5.22**.

The transportation subsector is divided into road transportation, civil aviation, water-borne navigation, and railways. Projected energy demands up to 2060 by transport mode is dominated by road transportation (**Figure 5.23**), followed by civil aviation, water-borne navigation, and railways.

Figure 5.22 Projected energy demand of transportation subsector by energy source

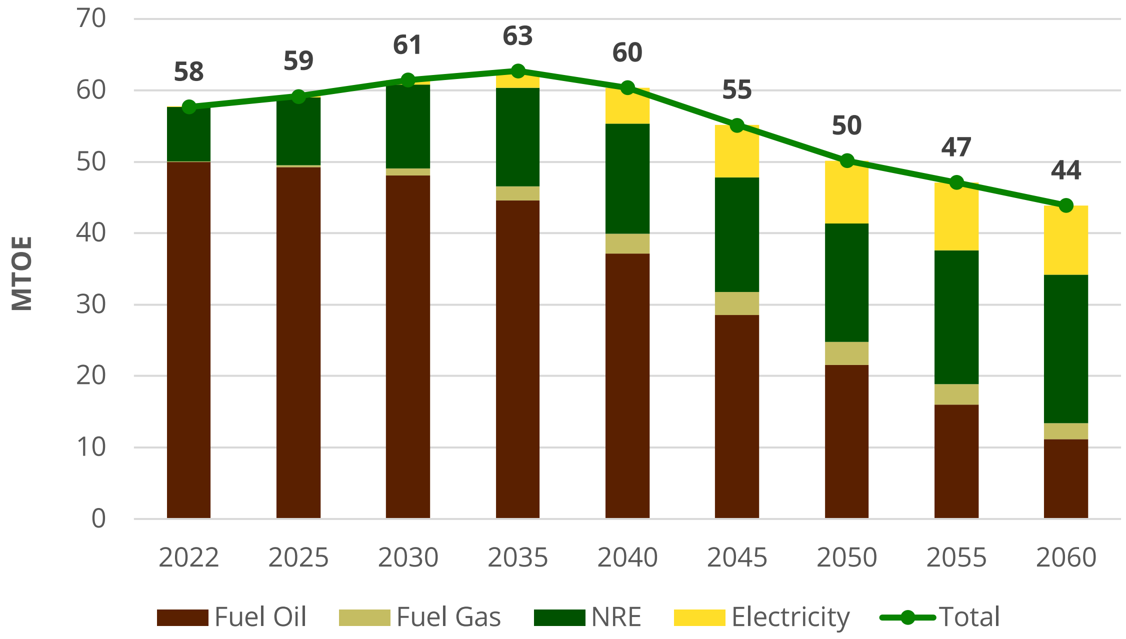
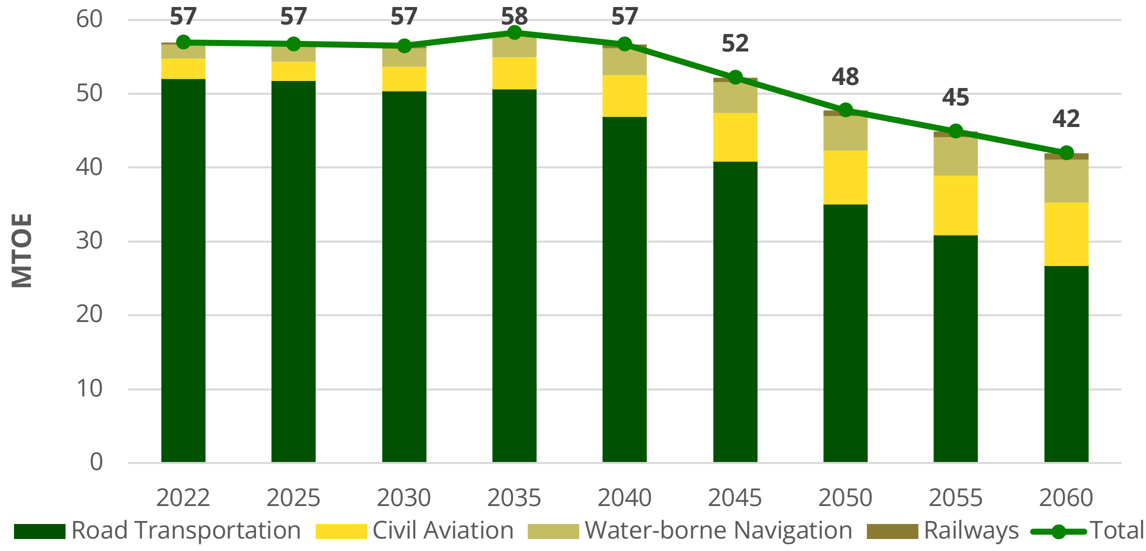


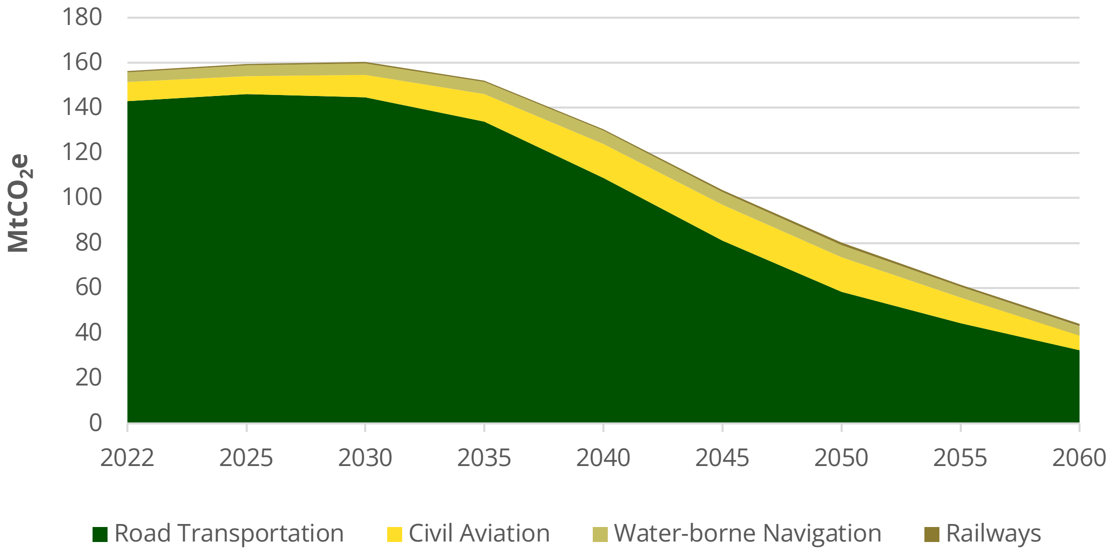
Figure 5.23 Projected energy demand of transportation subsector by transport mode



GHG emissions from the transportation subsector in 2022 will reach 156 million tons CO_2e. GHG emissions from jet fuel consumption of international aviation and diesel oil consumption for international water-borne navigation are still included in the total GHG emissions.

In the NZE scenario, transportation subsector GHG emissions are projected to reach 44.1 million tons CO_2e in 2060. The contribution share of each transport mode will be 32.4 million tons CO_2e for road transportation, 6.5 million tons CO_2e for civil aviation, 4.2 million tons CO_2e for water-borne navigation, and 1 million tons CO_2e for railways. The projected emissions of the transportation subsector are illustrated in **Figure 5.24**.

Figure 5.24 Projected GHG emissions of the transportation subsector



GHG emission reductions in the transportation subsector can be achieved through the implementation of strategies, including strategies that focus on the dominant mode of transport, i.e., road transportation; energy switching from the dominance of fuel oil; migration of more efficient private vehicle technology; and strategies that synergize with the roadmap of other sectors.

Coordination across ministries and agencies is required to achieve the transport subsector GHG emission target. This is because reducing transport subsector emissions is the authority of the Ministry of Transportation and, the Ministry of Energy and Mineral Resources, the Ministry of Industry, and local governments. Policies on the use of NRE and the economic value of fuel or power are the authority of the Ministry of Energy and Mineral Resources, while the use of road transport modes such as electric-based cars, motorbikes, and buses, increasing the efficiency of transport modes and the economics of the automotive industry. The Ministry of Industry regulates national logistics policies. The Ministry of Transportation is responsible for public passenger and goods transport facilities and infrastructure.

To achieve the NZE target in transportation subsector, the Ministry of Transportation needs to build and develop the necessary facilities and infrastructure, implement the transition of Internal Combustion Engine (ICE) vehicles to Battery Electric Vehicles (BEV), develop and update master plans for each transportation mode, and implement policies related to scrapping transportation modes, and prepare the use of carbon pricing as incentives and disincentives for energy transition and vehicle engine transition. In addition, it is necessary to prepare a carbon emission limitation policy to achieve the targets of each transportation mode. Several mitigation action activities that support the achievement of the NZE target in transportation subsector are tabulated in **Table 5.7**.

Table 5.7 Mitigation actions for the transport subsector

Mitigation Action Activity	Modes of Transport			
	Road	Civil Aviation	Water-borne Navigation	Railways
Electric transportation	√	X	X	√
Mass transportation	√	X	X	√
Operation management	√	√	√	√
Transport rejuvenation	√	√	√	√
Long distance ferry	X	X	√	X
Freight trucks to trains	√	X	X	X
Smart Driving	√	X	X	X
Eco Facilities	√	√	√	√
Efficient mode of transport	√	√	√	√
Biofuel	√	√	√	√
New energy	X	X	√	X
Double track	X	X	X	√

Emission reduction efforts to achieve the NZE target in transportation subsector are divided into two categories: reducing emissions through energy transition and increasing energy efficiency. Several policies developed to achieve the 2060 transportation subsector GHG emission target are tabulated in **Table 5.8**. The programs required to achieve the GHG emission target for the transportation subsector include utilizing renewable energy, using low-carbon fuels, and using efficient transportation modes. These programs involve discontinuing the sale of Internal Combustion Engine (ICE)-based cars from 2035 and ICE motorcycles from 2030, increasing the biofuel blend target to 40% (B-40), using 30% bio-avtur, 5% bioethanol (E-5) and 15% gasoline methanol, utilizing green hydrogen and green ammonia as ship fuels, using LNG as marine fuel, the development of rail (MRT/LRT) and road (BRT) based mass transit in several major cities in Indonesia, shore connection and short sea shipping of ship transportation, improvement and construction of new national railway lines, and others.

Table 5.8 NZE emission reduction scenarios in the transportation subsector

NZE Emission Reduction	
Energy Transition	Improved Energy Efficiency
1. Stop importing fuel other than jet fuel by 2030. 2. Utilization of 40% biodiesel (B40). 3. Use of hydrogen for trucks with 5% hydrogen truck sales penetration by 2040 and 20% by 2060. 4. Eco-fuel aviation. 5. Low-carbon fuel for shipping from 2035 with a mix of e-ammonia, hydrogen, and biofuels. 6. Low-carbon fuel for aviation from 2040 and will reach 45% by 2060.	1. Stopping the sale of oil-fueled motorcycles by 2035. 2. Discontinuation of oil-fueled car sales by 2040. 3. Electrification at Ports or electric vessels for shorter distances and/or hybrid vessels. 4. Technology efficiency in the transportation subsector is projected to be 20-25% by 2060.

7. Use of e-fuel derived from biosyngas and green hydrogen for vehicles.	

To achieve the 2060 NZE target, several policies and strategies have been established and developed by the Ministry of Transportation and Ministry of Energy and Mineral Resources. The policies are related to the development of electric vehicles and the preparation of infrastructure that supports the level of energy efficiency in vehicles in the transportation subsector. The policies and strategies are developed and classified by transportation mode including road transportation, civil aviation, water-borne navigation, and rail transportation.

Road Transportation

With population growth and economic activity, the energy demand for road transportation will increase. In 2022, the energy demand for road transportation reached 53 MTOE. This energy demand is projected to decrease with an average decrease of 2% per year to 29 MTOE in 2060. The decrease in energy consumption results from the transition in road transportation using electric vehicles, especially electric motorcycles and cars, which have started since 2020. The projected energy demand for road transportation until 2060 is illustrated in **Figure 5.25**.

With this energy demand, the projected GHG emissions of road transportation is expected to decline gradually by 2024, along with the penetration of electric vehicles. In 2060, GHG emissions of road transportation are projected to be 32.4 million tons of CO_2e. The projection of GHG emissions from road transportation until 2060 is illustrated in **Figure 5.26**.

Figure 5.25 Projected final energy demand of road transportation

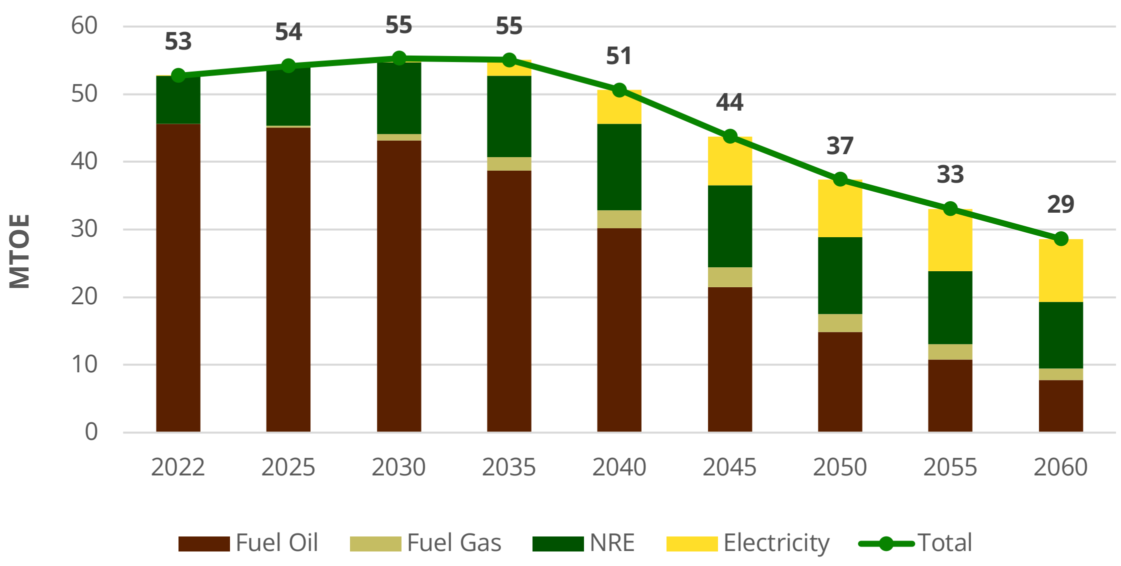
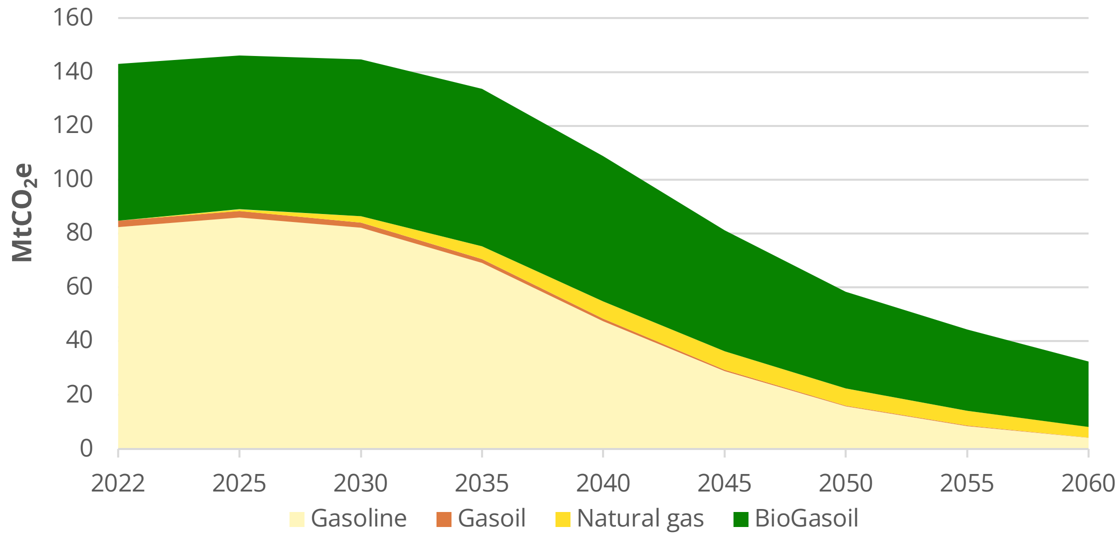


Figure 5.26 Projected emissions of road transportation



Efforts to support decarbonization strategies in road transportation are diversification towards electric vehicles, mass transportation, improving the efficiency of transportation equipment and management efficiency, as well as using clean energy, as tabulated in **Table 5.9**.

Table 5.9 Roadmap for road transportation

Action Plan	2022 – 2025	2026 – 2030	2031 – 2060
Electric motorcycle program	• 11,240 units of Public Electric Vehicle Battery Swap Station • 757,140 units of electric motorcycles	2030: 13 million units	2040: 100% of 2-wheeled vehicle sales are electric motorcycles
Electric car program	• 88,045 units of Public Electric Vehicle Charging Stations • 19,220 units of electric car	2030: 2 million units	2050: 100% of 4-wheeled vehicle sales are electric cars
Electric bus program	10,227 units of electric bus	2030: 16 thousand units	2060: 80% of bus sales are electric buses
Improved mass transportation: Buses	Addition of Bus Rapid Transit (BRT)		
Improved efficiency of transportation equipment	Energy efficient vehicle/ Low-Cost Green Car (LCGC)	Public transport rejuvenation	

Action Plan	2022 – 2025	2026 – 2030	2031 – 2060
Improved efficiency of road transportation management	• Odd-even regulation • Area Traffic Control System (ATCS) • Traffic Impact Analysis (*Analisis Dampak Lalu Lintas*, ANDADALIN) • Non-Motorized Transportation (NMT) Campaign	• Expansion of public parking at stations/terminals (park & ride) • Smart drive culture campaign	
Increased use of clean energy	• Increased use of gasoline vehicles (replacing fuel) • Increased use of biodiesel to replace fuel • Solar Public Street Lighting	Increased octane number (RON>88)	

Diversification of electric vehicles is carried out for motorcycles, cars, and buses. The number of electric motorcycles is targeted to be 757 thousand units in 2025 and continue to increase to 13 million units in 2030. Sales of two-wheeled vehicles in 2040 will be entirely electric motorcycles. The target for electric car users is 19,220 units in 2025, 2 million units in 2030, and 100% of new car sales are electric cars in 2050. To encourage the achievement of these targets, the Ministry of Energy and Mineral Resources has planned the development of 11,250 units of Public Electric Vehicle Battery Exchange Stations (*Stasiun Penukaran Baterai Kendaraan Listrik Umum*, SPBKLU) and 88 thousand units of Public Electric Vehicle Charging Stations (*Stasiun Pengisian Kendaraan Listrik Umum*, SPKLU) until 2025, and the number will continue to increase in the medium and long term. The decarbonization strategy of the transportation subsector through this energy transition needs to be supported by several policies, including the policy on the supply of certain types of fuel and the allocation of its use, the subsidy policy and the selling price of fuel and electricity, the policy on the development of infrastructure networks for electric vehicles, and the design of the fuel oil to electricity conversion program supported by the Ministry of Energy and Mineral Resources (energy and infrastructure providers), the Ministry of Transportation (procurement of public transport vehicles) and the Ministry of Finance (incentives and disincentives fiscal policies).

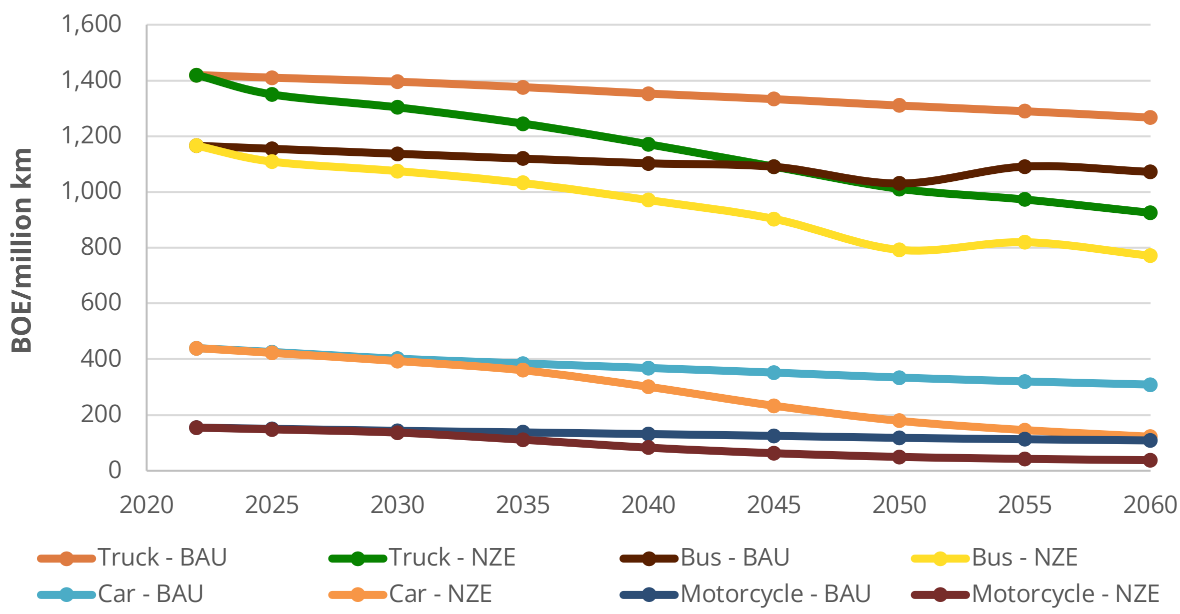
Decarbonization through increased energy efficiency must be balanced with the development of vehicle technology that increases the efficiency of vehicle engines. Electric vehicle technology is one of the developments in automotive technology that is currently expected to improve energy efficiency. The Ministry of Energy and Mineral Resources study assumes that the energy efficiency of electric vehicles is 80-85%. This study needs to be supported by a policy on fuel efficiency, which is generally the domain of authority of the Ministry of Energy and Mineral Resources and the Ministry of Environment and Forestry to become input for the Ministry of Transportation to exercise its authority. Decarbonization of the transportation subsector through increased efficiency needs to be supported by several policies, including the standard fuel efficiency policy for vehicle engines as a reference for the automotive industry, a roadmap for the development of the automotive industry that is aligned with the technology migration target from ICE vehicles to Non-ICE (Battery Electric Vehicle, BEV), a carbon tax policy to incentivize the purchase of electric vehicles and disincentives for ICE vehicles and the design of the ICE to BEV vehicle conversion program supported by the Ministry of Energy and Mineral Resources (energy and infrastructure providers), the Ministry of Industry (facility providers), the Ministry of Transportation (focusing on vehicles and goods) and the Ministry of Finance (fiscal policy). BEVs are a reliable mode of electricity-based road transportation because, in addition to reducing air and noise pollution in big cities, these vehicles will gradually reduce GHG emissions by 100% by 2060—when all power plants no longer emit GHG emissions while producing electricity. Therefore, the government enacted Presidential Regulation 55/2019 to accelerate the utilization of BEVs, especially for motorcycles, cars, and buses.

The Ministry of Transportation's short-term policy (2020-2024) on the utilization of BEV includes the utilization of BEV as official vehicles in government agencies and government business entities, the development of BEV-based tourism transportation, and the development of BEV-based public transit in the New National Capital City Government Center Central Zone (*Kawasan Inti Pusat Pemerintahan Ibu Kota Nusantara*, KIPP IKN). In addition, the Ministry of Energy and Mineral Resources will stop importing fuel (except for avtur) starting in 2030. The cessation of imports is carried out to encourage the growth of domestic BEV utilization, which will reduce the consumption of gasoline and biodiesel.

By 2030, the sales target of electric vehicles includes 12.2 million electric motorcycles, 1.7 million electric cars, 400 thousand electric trucks, and 25.9 thousand electric buses. Furthermore, there will be no more sales of ICE motorcycles starting in 2030, ICE cars beginning in 2036, ICE trucks, and ICE buses starting in 2040, which will be replaced by electric-based vehicles. In addition to BEV trucks, ICE trucks will also be replaced by fuel cell trucks starting in 2035. ICE vehicles are still operating according to their lifetimes. The projected sales of electric-based road transportation in 2060 are 15.8 million BEV motorcycles, 5.46 million BEV cars, 2.7 HEV cars, 0.5 million PHEV cars, 1.1 million BEV trucks, 367 thousand fuel cell trucks (FCV) and 38 thousand BEV buses, respectively. All targets for electric vehicles and fuel cells must be synchronized with the Ministry of Industry as the authority in developing the national BEV industry action plan.

Compared to the BAU scenario, the effort to achieve the NZE target in road transportation will reduce the energy intensity by about 60-65% for cars and motorcycles and about 27-28% for trucks and buses. The energy intensity of road transportation for each vehicle type is shown in **Figure 5.27**.

Figure 5.27 Energy intensity of road transportation



Civil Aviation

In line with the growth of economic activity, the energy demand for civil aviation will increase. In 2022, the energy demand for civil aviation was 2.8 MTOE. This energy demand is projected to increase by 3% annually to reach 8.6 MTOE in 2060. About 81% of civil aviation energy demand in 2022 was supplied to meet the energy needs of passenger aviation, while the rest is for freight aviation. By 2054, jet fuel will be the primary fuel type used in civil aviation. Starting in 2031, civil aviation energy consumption begins to shift to bioavtur, and by 2041 to e-jet fuel. The projected energy demand for civil aviation by 2060 is illustrated in **Figure 5.28**.

With this energy demand, the projected GHG emissions of civil aviation will peak in 2045 at 15.8 million tons CO_2e. After that, the GHG emissions will decline along with bioavtur and e-jet fuel penetration. In 2060, GHG emissions from the civil aviation will be 6.5 million tons CO_2e. The projected GHG emissions of the civil aviation by 2060 are illustrated in **Figure 5.29**.

Figure 5.28 Projected energy demand for civil aviation

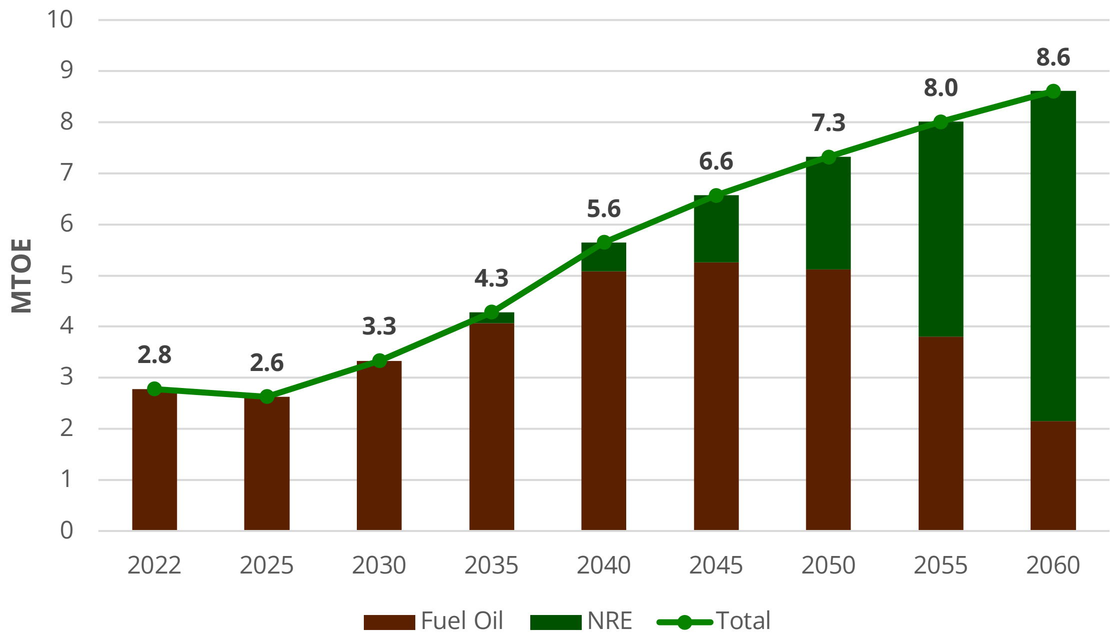
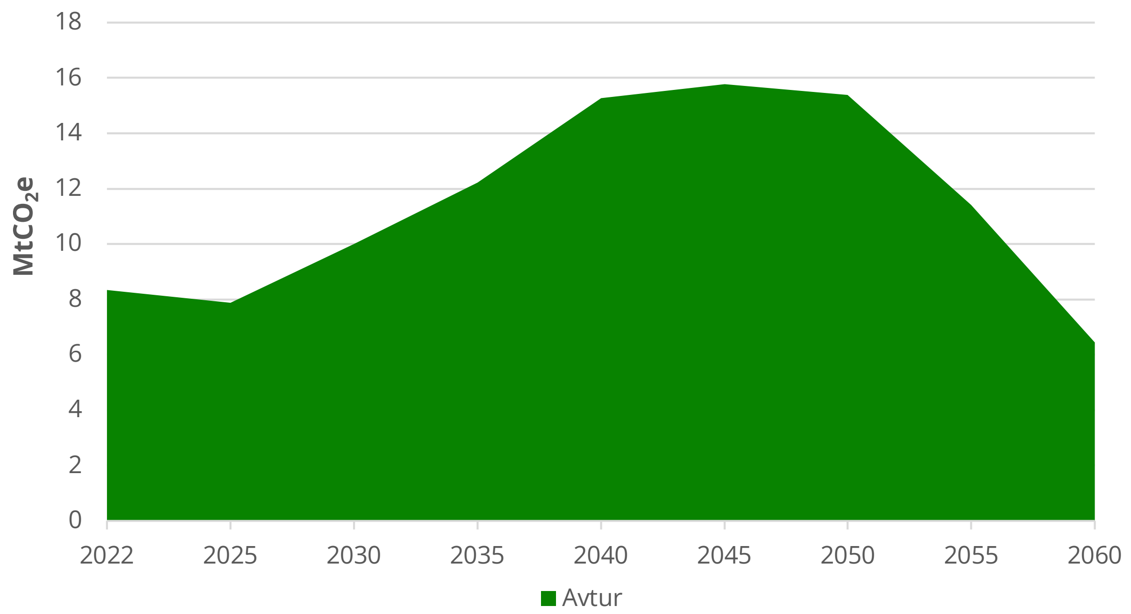


Figure 5.29 Projected GHG emissions of civil aviation



In order to achieve the NZE target for the transportation subsector, the civil aviation will make a transition by utilizing green aviation fuel (bioavtur) as aircraft fuel. In November 2023, Pertamina and Garuda Indonesia successfully carried out the first commercial flight using environmentally friendly fuel, Pertamina Sustainable Aviation Fuel (SAF) or Bioavtur. In addition to bioavtur, the use of e-jet fuel will also be encouraged. The government has also developed a roadmap for civil aviation until 2060 which is tabulated in **Table 5.10**. The action plan consists of improving the efficiency of civil aviation management, eco airports, and increasing the use of biofuel.

Table 5.10 Roadmap for civil aviation

Action Plan	2022 – 2025	2026 – 2030	2031 – 2060
Improved efficiency of air transportation management	• Performance Based Navigation (PBN) • Improvement of aircraft operation and maintenance systems and procedures	Aircraft rejuvenation	
Increased use of biofuel	Use of biofuel in Ground Support Equipment (GSE) vehicles at least 50% of international airports by 2022; 75% of international airports by 2023; and 100% of international airports by 2024.		

The Ministry of Transportation has also made efforts to reduce aviation fuel consumption, including through the Performance Based Navigation (PBN) System, improvement of aircraft operation and maintenance systems and procedures, and aircraft rejuvenation. PBN is an onboard navigation system that helps determine flight routes efficiently without entirely depending on navigation stations on the ground. There are two procedures of PBN, namely, Area Navigation (RNAV) and Required Navigation Performance (RNP). With RNAV, the aircraft can choose a more efficient route as long as the route is within the working scope of the ground navigation station. RNP is the positioning of the aircraft on its trajectory and reports out-of-tolerance deviations.

Efforts made to achieve the NZE target in the civil aviation will reduce the energy intensity of this subsector. Compared to the BAU scenario, the energy intensity of civil aviation under the NZE scenario will be reduced by 18% in 2060 for both passenger and freight aviation. The energy intensity of passenger and freight aviation 2060 will be 236 BOE/million passenger-km and 170 BOE/million tons-km, respectively. The energy intensity of passenger and freight aviation are shown in **Figure 5.30** and **Figure 5.31**, respectively.

Figure 5.30 Energy intensity of passenger aviation

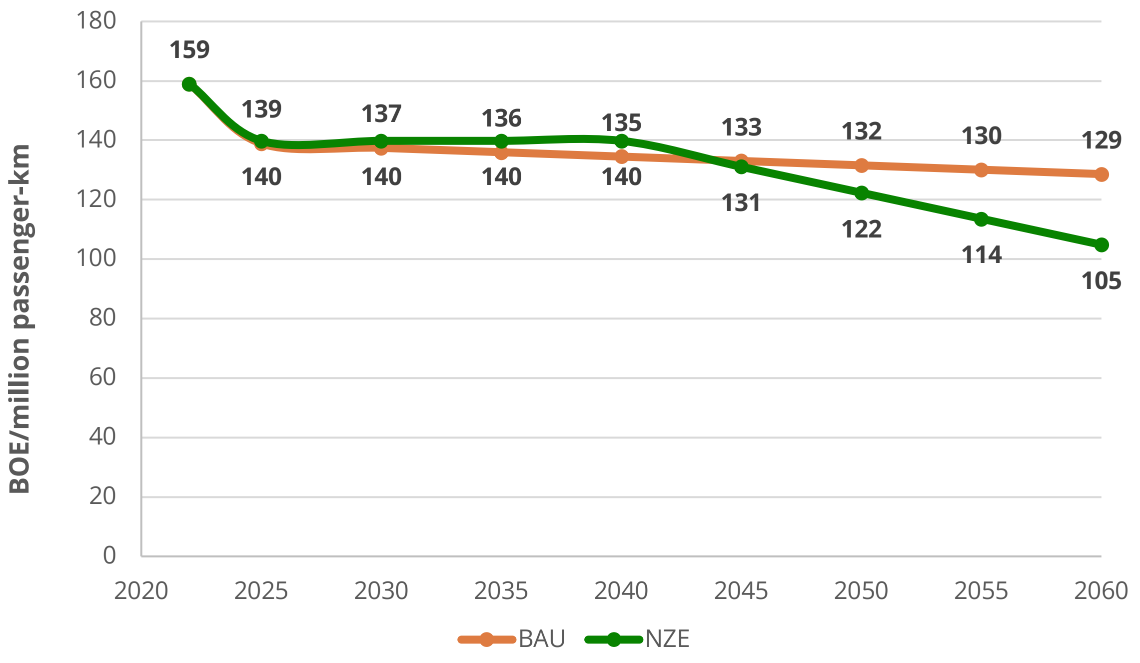
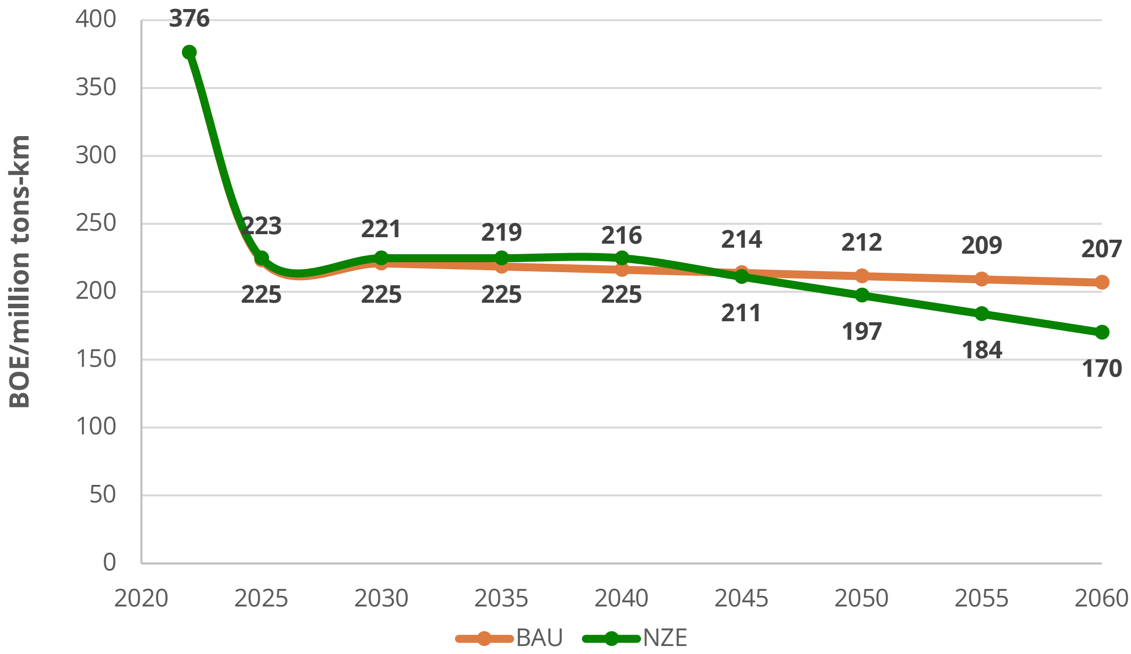


Figure 5.31 Energy intensity of freight aviation



Water-borne Navigation

Water-borne navigation activities and energy demand will increase as Indonesia's GDP grows. In 2022, water-borne navigation energy consumption reached 1.9 MTOE. In the NZE scenario, water-borne navigation energy consumption will increase with an average growth of 3% annually to reach 5.8 MTOE in 2060. Utilization of fuel oil in water-borne navigation will decrease and be replaced by natural gas, NRE, and electricity. The projected energy demand of water-borne navigation by 2060 is illustrated in **Figure 5.32**.

With the composition of energy demand projections described above, the GHG emissions will reach its peak in 2042 at 5.76 million tons CO_2e. After that, the emissions will drop to 4.22 million tons of CO_2e in 2060. The projection of GHG emissions of water-borne navigation is shown in **Figure 5.33**.

Figure 5.32 Projected energy demand of water-borne navigation

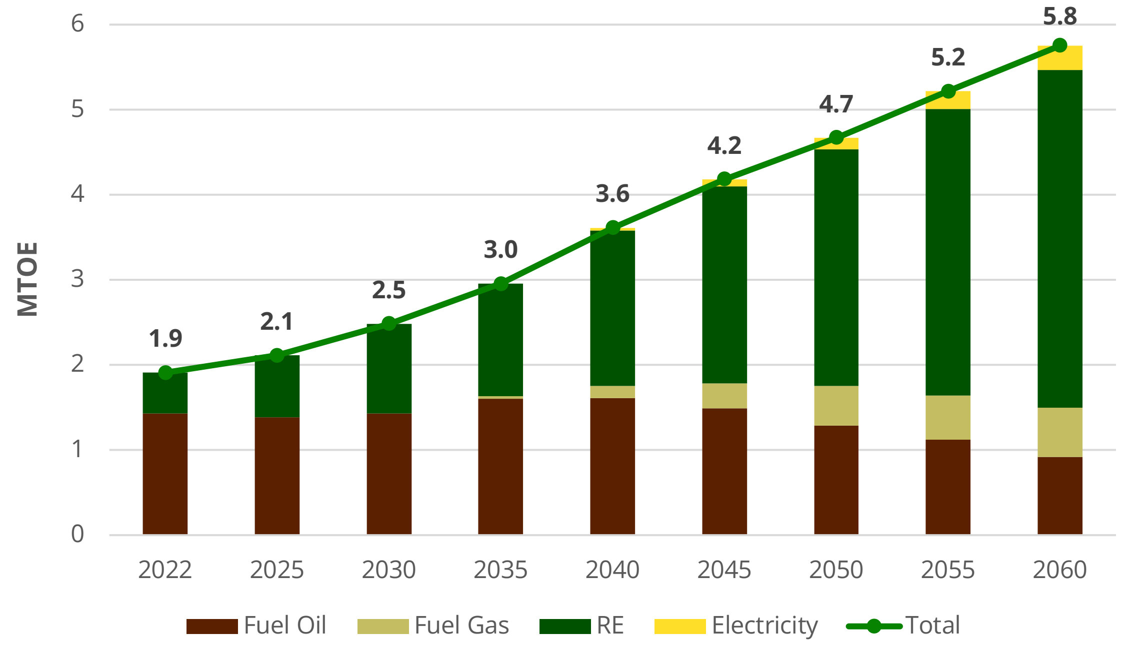
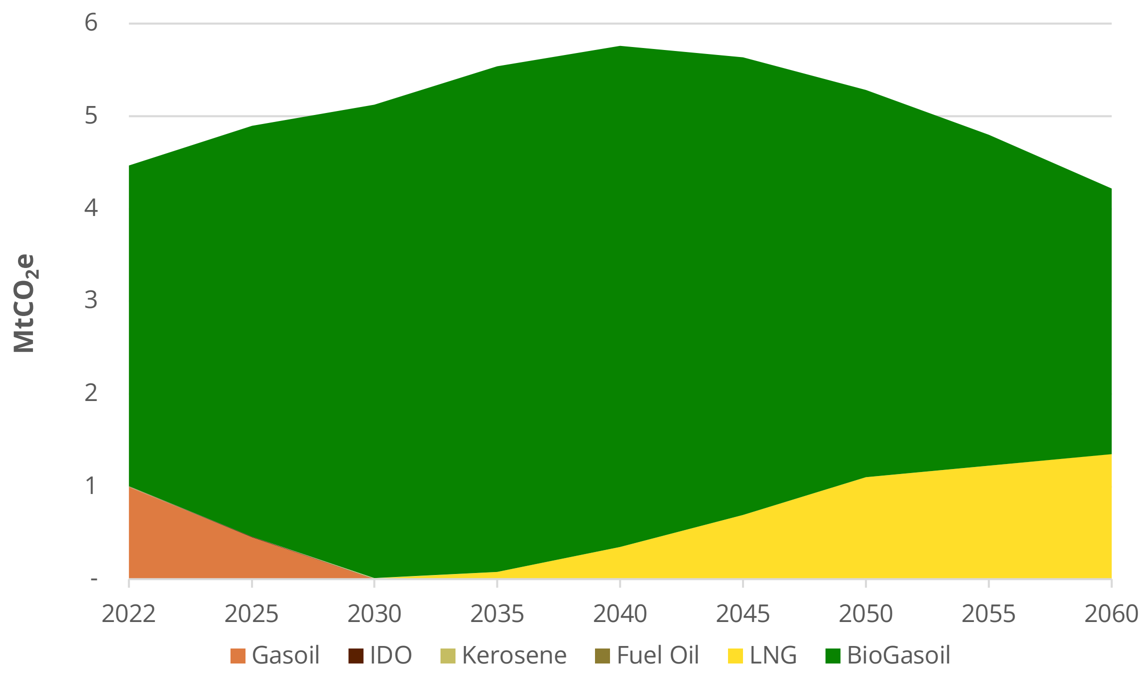


Figure 5.33 Projected GHG emissions of water-borne navigation



To reduce emissions in the water-borne navigation, the Government of Indonesia, through the Ministry of Transportation, divides the effort strategy into two categories: efforts in the fleet and at the port or terminal. The system is prepared to follow the International Maritime Organization (IMO) scheme, with the Energy Efficiency Design Index (EEDI)[7], Ship Energy Efficiency Management Plan (SEEMP)[8], construction of Navigational Aids (*Sarana Bantu Navigasi Pelayaran*, SBNP), and ship modernization. EEDI is applied to new ships to ensure that their design meets energy efficiency principles and environmental protection. SEEMP has been mandatory since January 1, 2013, for vessels of 400 GT and above. SEEMP is similar to energy management in principle, requiring regular measurement and reporting of energy use. SEEMP requires fleet operators to conduct fuel-saving plans and evaluate their success.

In the context of fuel efficiency, the Ministry of Transportation has carried out ship modernization through the procurement of six new ships and rejuvenation of six ships. In addition, the Short and Safe Passage Route (Short Sea Shipping) has taken place through the operation of cargo ships from Lembar Port in Surabaya to Padang Bai Port in Lombok as a substitute for truck transportation on the highway and sea via ships through several ports (Ketapang, Gilimanuk, Jimbaran, Padang Bai). As for the shore connection, onshore power supply facilities are currently available at 21 ports. Some of the shore connection[9] facilities utilized 2019 are at Diamond Port, Nilam Port, Semarang Port, and Lembar Port. Based on the description above, the action plan for reducing emissions from water-borne navigation is classified into three categories: increasing the efficiency of ships, using renewable energy, and eco seaports (**Table 5.11)**.

Table 5.11 Action plan for emission reduction in water-borne navigation

Category	Action Plan
Improved efficiency of ships	• Energy Efficiency Design Index (EEDI) • Ship modernization • Ship Energy Efficiency Management Plan (SEEMP) • Construction of Navigational Aids (SBNP) • Short and safe routes (short sea shipping)
Use of renewable energy	Increased use of biodiesel to replace fuel
Eco Seaport	• Greening the environment • Use of renewable energy • Use of Public Street Lighting-Solar Power for lighting • Energy conservation • Port operational management efficiency

[7] EEDI is an index of emissions released for each unit of shipping distance or grams of CO_2 per ton-mile.

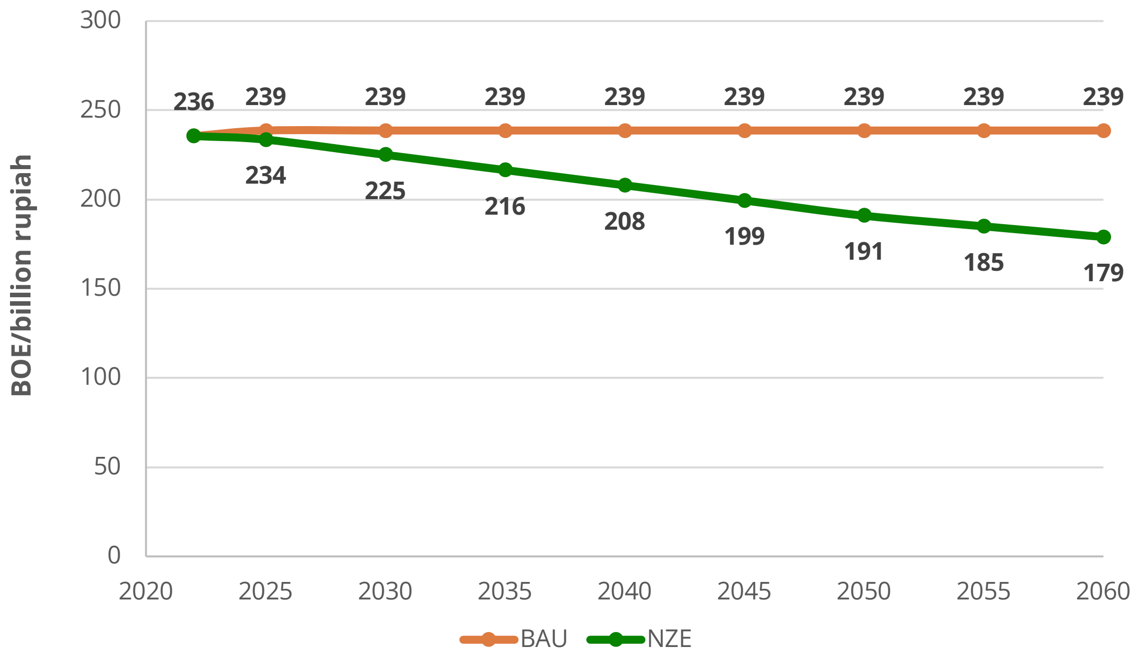
[8] SEEMP aims to establish a mechanism for companies and/or ships to improve the EE of ship operations.

[9] Shore connection is an electrical system to connect ships that are docked at the dock with the electricity network on land which allows ships to continue to get electricity supply to turn on cooling equipment, heating, lighting, and other equipment and turn off the ship's auxiliary engine during the ship's loading and unloading process at the port.

In the water transportation emission reduction action plan category, the Ministry of Transportation regulates the Ship Energy Efficiency Management Plan (SEEMP). To support the implementation of SEEMP, marine fleet operators conduct periodic certification of marine vessels. Another strategy to increase the efficiency of ships is the provision of Navigational Aids (SBNP). Forms of SBNP include flare towers, flare signs, buoys, daymarks, radio beacons, and radar beacons. SBNP is very useful in assisting the navigation process to obtain a safe and short shipping route (short sea shipping). The use of renewable energy in water transportation modes includes the policy of using biodiesel to replace fuel oil. The use of renewable energy in water transportation modes includes the policy of using biodiesel to replace fuel oil. Ship fuel consumption since January 1, 2019, must be reported through the Data Collection System (DCS) Fuel Consumption of Indonesian-flagged Ships as an implementation of SEEMP.

Efforts made to achieve the NZE target in the water-borne navigation will reduce the energy intensity of this subsector with an average reduction of 1% annually. The energy intensity will be reduced from 236 BOE/billion rupiah in 2022 to 179 BOE/billion rupiah in 2060. Compared to the BAU scenario, the energy intensity of water-borne navigation under the NZE scenario will be reduced by 25% in 2060 (**Figure 5.34**).

Figure 5.34 Energy intensity of water-borne navigation



Railways

GDP and population growth boost activity in the transportation subsector, especially railways. With the increase in activities, the energy demand for railways also increases, from 0.25 MTOE in 2022 to 0.91 MOTE in 2060. Based on energy type, railways predominantly use biofuel (biogasoil). Therefore, emissions from railways are projected to increase along with the increase in energy consumption of 1 million tons of CO_2e in 2060. The projected energy demand and GHG emissions from railways by 2060 are illustrated in **Figure 5.35** and **Figure 5.36**, respectively.

Figure 5.35 Projected energy demand of railways

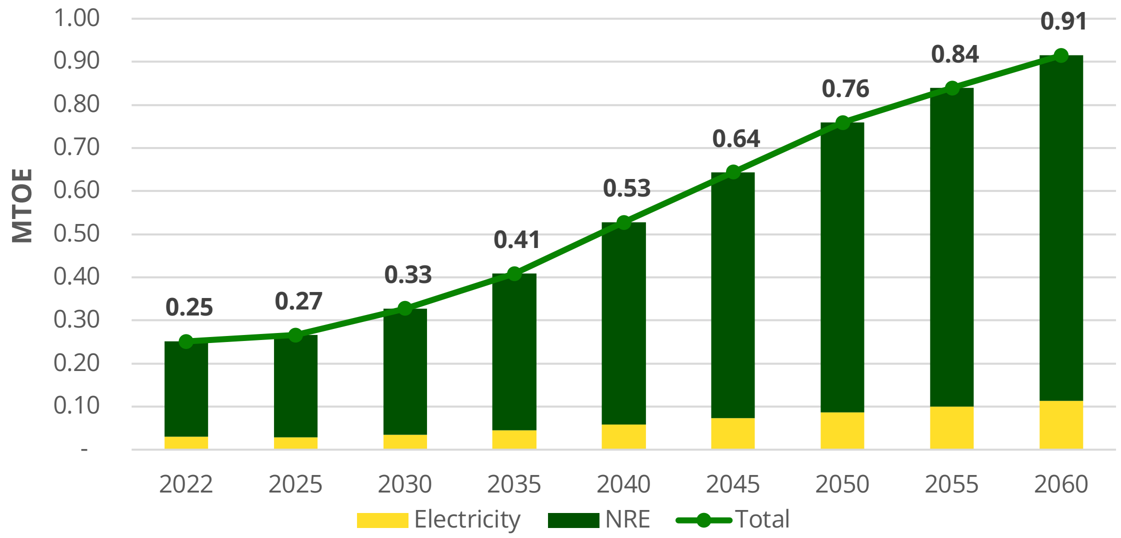
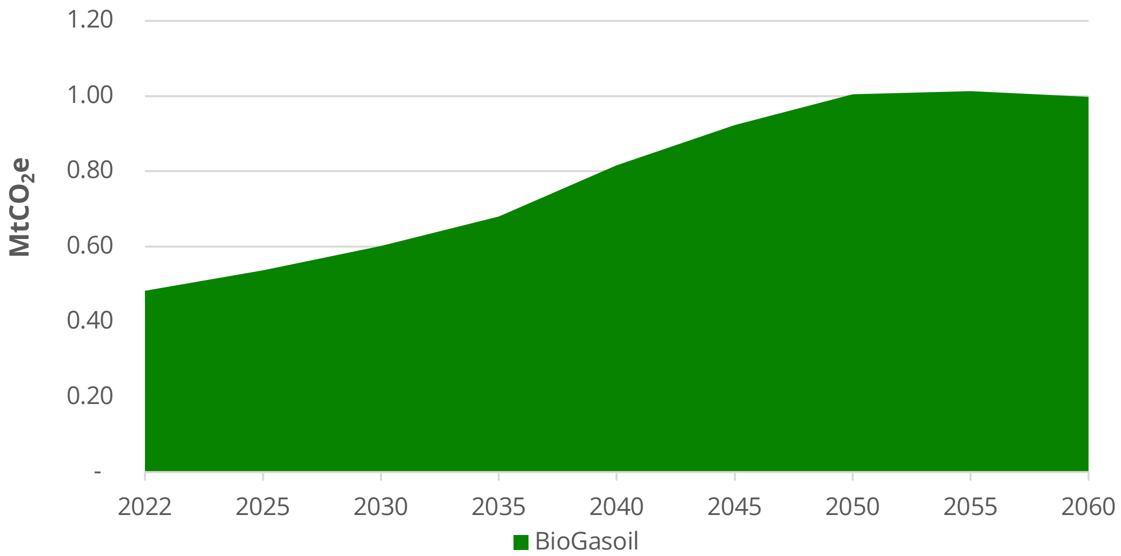


Figure 5.36 Projected GHG emissions of railways



To support the achievement of NZE targets in the energy sector, the government plans to improve mass transportation, especially railways, including the development of urban railways, the development of double-track railways, and the addition of Mass Rapid Transit (MRT) and Light Rail Transit (LRT). The roadmap of railways by 2060 is tabulated in **Table 5.12**.

Table 5.12 Roadmap for railways

Action Plan	2022 – 2025	2026 – 2030	2031 – 2060
Improved mass transportation: Train	• Development of Jabodetabek, Surabaya, & Bandung Urban Railways • High-speed train development • Double track railway on the north coast of Java	• Increased use of railways for freight transportation (shift from trucks to trains) • 2027: Jakarta Mass Rapid Transit (MRT) Phase 2 (Thamrin - Kota)	Addition of Light Rail Transit (LRT)

Efforts made to achieve the NZE target for railways will reduce the energy intensity of this mode of transportation. **Figure 5.37** and **Figure 5.38** show the energy intensity of each type of railway transportation mode, namely passenger trains, electric trains (*Kereta Rel Listrik*, KRL), and freight trains, respectively. The energy intensity of passenger trains and KRL in the NZE scenario will be reduced by about 27-28% compared to the BAU scenario, to 63.3 and 11.5 BOE/million passenger-km in 2060, respectively. Meanwhile, the energy intensity of freight trains in the NZE scenario will be reduced by 20% compared to the BAU scenario, to 36.8 BOE/million ton-km.

Figure 5.37 Energy intensity of passenger rail and KRL

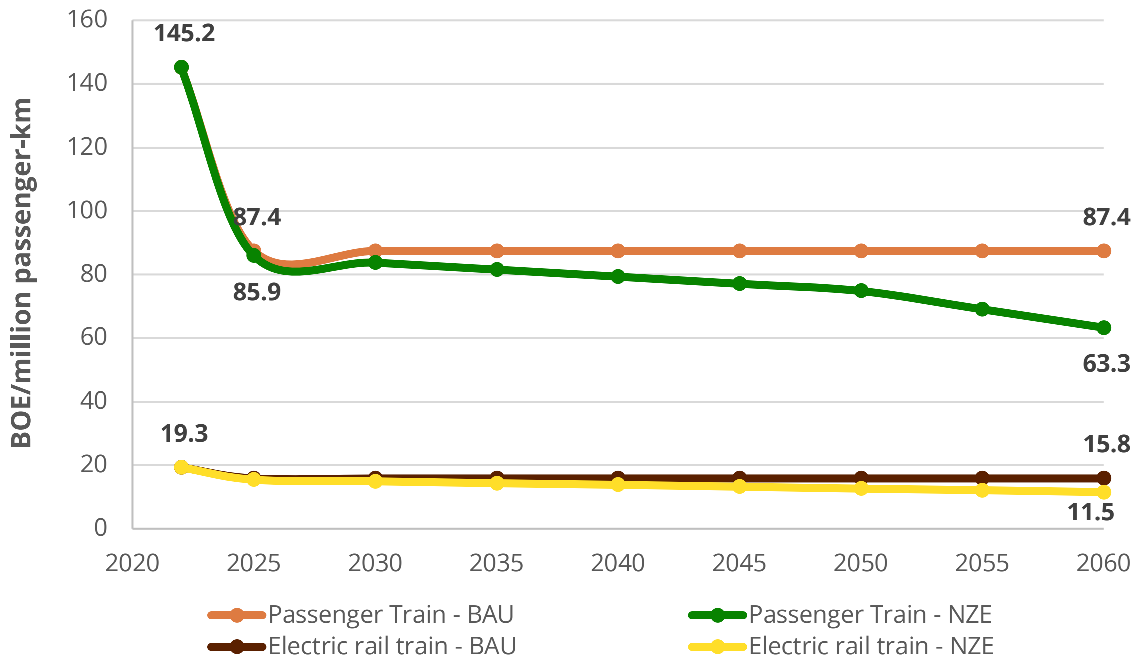
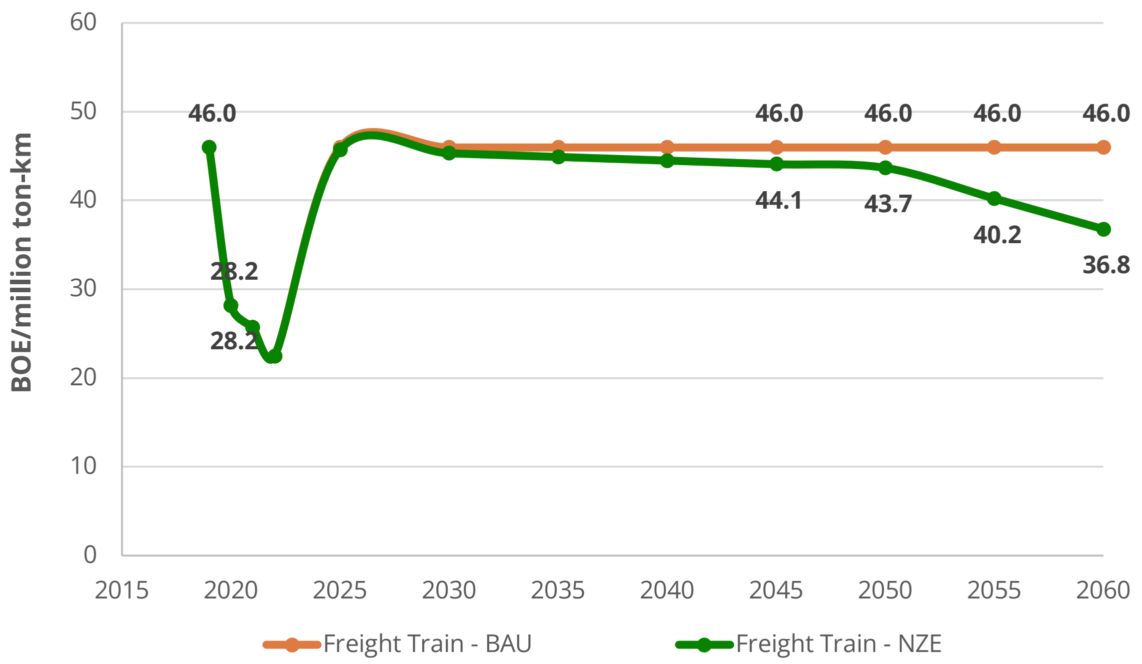


Figure 5.38 Energy intensity of freight train



5.3 Residential

As Indonesia's population grows, the number of households is also projected to increase. Hence, a surge in energy demand in the residential subsector is foreseen along with this demographic expansion. By 2022, the energy demand of the residential subsector is estimated to be 21.2 MTOE, with a predicted escalation of 32% to 31.1 MTOE by 2060.

Based on energy type, energy consumption in the residential subsector in 2022 is dominated by the use of gas (44%) for cooking and electricity (42%) for household appliances. In the NZE 2060 scenario, efforts are made to electrify the residential subsector and reduce emissions. The use of induction or electric stoves will continue to be encouraged as a strategy for energy transition in the residential subsector. Therefore, electricity consumption will steadily rise, ultimately reaching 27 MTOE by 2060—87% of the total energy consumption of the residential subsector.

Meanwhile, the consumption of fuel oil and gas is expected to decline, and by 2060 it is projected to reach 0 MTOE and 4 MTOE respectively. The decline in gas consumption is driven by the LPG stove reduction policy which is offset by the utilization of dimethyl ether (DME). The projected energy demand of the residential subsector is shown in **Figure 5.39**. By implementing energy transition measures, the emission level of the residential subsector is projected to decrease from 26.3 million tons CO_2e in 2022 to 9.6 million tons of CO_2e in 2060, as indicated in **Figure 5.40**.

Figure 5.39 Projected energy demand of residential subsector

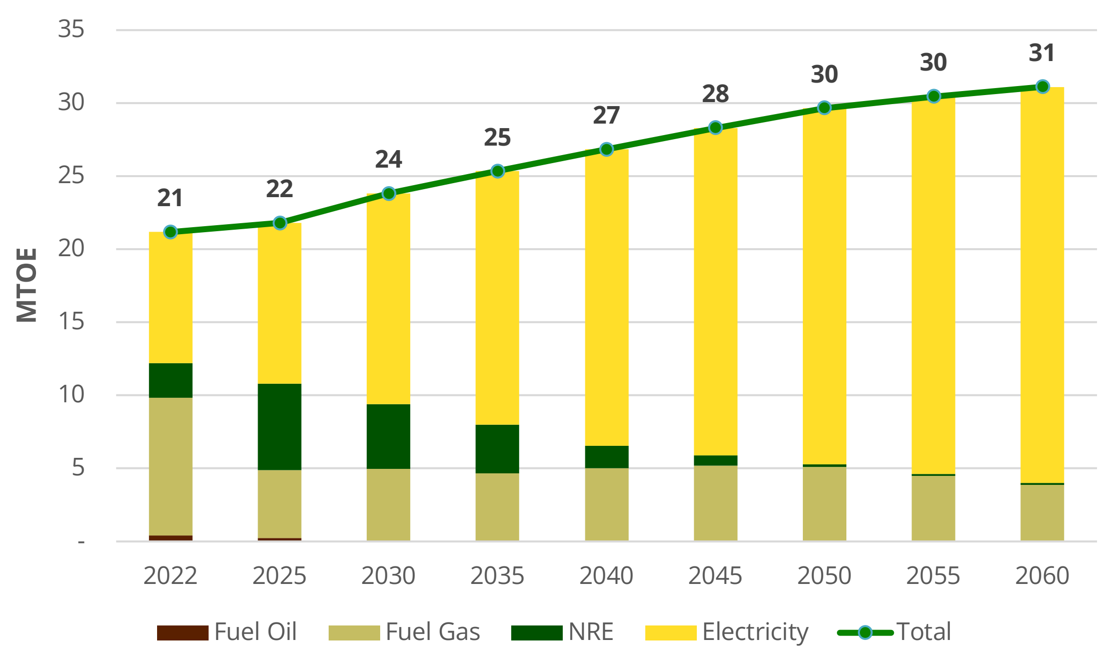
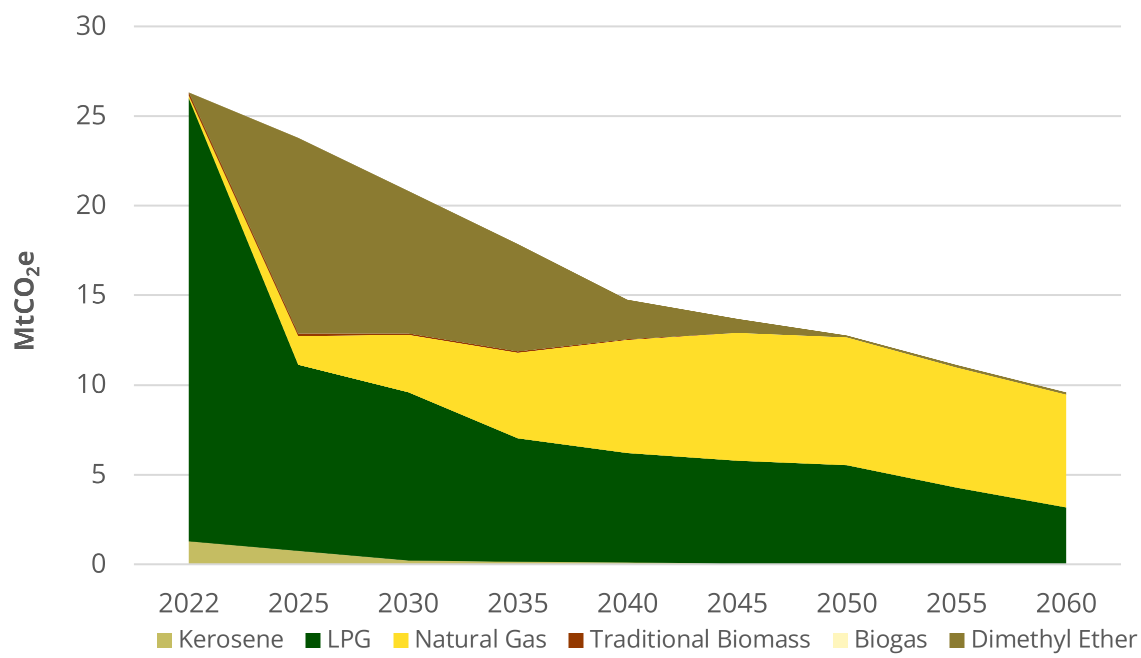


Figure 5.40 Projected emissions of residential subsector



As previously described, strategies to achieve the NZE goal in the residential subsector are pursued through energy efficiency initiatives such as optimizing energy management and using high-efficiency household appliances, encouraging the adoption of electric or induction stoves, incorporating DME, and developing gas networks for households. The description of the efforts and plans to attain the NZE objective in the residential subsector is presented below.

Energy Efficiency through Minimum Energy Performance Standard (MEPS) Implementation and Energy Efficient Labelling

PT PLN (Persero) reported residential electricity consumption of 102,917 GWh in 2019. According to the 2019 survey on residential energy use, the 42 appliances that were surveyed accounted for an estimated electricity use of 65,583 GWh, which suggests that 36% of the residential energy consumption is attributed beyond the surveyed household appliances. Of the 18 products earmarked for MEPS implementation and energy labelling, 13 devices are identified as major contributors of energy use in the residential subsector. These include (1) rice cookers, (2) refrigerators, (3) lighting, (4) televisions, (5) portable fans, (6) single-split air conditioning units, (7) water dispensers, (8) washing machines, (9) irons, (10) water pumps, (11) blenders, (12) induction stoves, and (13) showcase refrigerators.

As Indonesia transitions to NZE by 2060, the projected energy demand from priority products can be reduced through efficiency improvements in effective appliances. Household appliances account for a significant share of the projected trend to 2060. Each appliance contributes to the overall savings potential.

In 2020, CLASP and Ispos estimated the number of electrical appliances and electricity consumption for each household as shown in **Table 5.13**, based on survey data from 5,443 households. Households with access to electricity certainly own lighting (100% penetration) with an average ownership of 5.4 units per household. Hence, the total number of lamps in use in Indonesia is approximately 351.8 million units in 2020. TVs (93%), fans (64%), irons (70%), refrigerators (69%), and rice cookers (69%) were among the appliances with high ownership level.

Table 5.13 Penetration rate and number of appliances owned per household

Household Appliances	Penetration Rate	Number of appliances owned per household (unit)
Water Dispenser	20%	
Fan	64%	1.3
Refrigerator	69%	1
Washing Machine	29%	1
Rice Cooker	69%	1
Air Conditioner (AC)	5%	1.2
Lighting (Lamp)	100%	5.4
Water Pump	35%	1
Iron	70%	1
TV	93%	1.1

Source: CLASP and IPSOS

To enhance the efficiency of household appliances, the Ministry of Energy and Mineral Resources has implemented the Minimum Energy Performance Standard (MEPS) policy along with energy-saving labels. These regulations apply to five specific electricity-using appliances: rice cookers, fans, air conditioners, refrigerators, and lamps. Moving forward, it is imperative that the MEPS policy and energy-saving labels are applied to a wider range of appliances, including televisions, electric stoves, blenders, water pumps, washing machines, irons, chillers, electric motors, boilers, and transformers. The roadmap for MEPS and energy-saving labels implementation is outlined in **Table 5.14**, while **Table 5.15** to **Table 5.19** show the proposed MEPS and energy-saving labels for rice cookers, fans, air conditioners, refrigerators, and lamps, respectively.

Table 5.14 Roadmap for MEPS and energy saving labels implementation

Year	Appliances	Description
2021	Rice Cooker	The MEPS for this appliance is shown in **Table 5.15** and will be increased periodically
	Fan	The MEPS for this appliance is shown in **Table 5.16** and will be increased periodically
	Air Conditioner	The MEPS for this appliance is shown in **Table 5.17** and will be increased periodically
	Refrigerator	The MEPS for this appliance is shown in **Table 5.18** and will be increased periodically
2022	Lighting (Lamp)	The MEPS for this appliance is shown in **Table 5.19** and will be increased periodically
	TV	-
	Electric Stove	-
	Blender	-
	Pompa Air	-
	Washing Machine	-
	Iron	-
	Chiller	-
	Electric Motor	-
	Boiler	-
	Trafo	-

Table 5.15 Proposed MEPS and energy saving label for rice cooker

Products and categories	1 Star	2 Star	3 Star	4 Star	5 Star
Energy saving rate (Wh/liter)	$250 * V^{-1/3}$	$230 * V^{-1/3}$	$210 * V^{-1/3}$	$190 * V^{-1/3}$	$170 * V^{-1/3}$

Table 5.16 Proposed MEPS and energy-saving labels for fans

Diameter	1 Star	2 Star	3 Star	4 Star	5 Star
Service Value – Diameter < 12 inch (m^3/minute/W)	0,6–0,72	0,72–0,84	0,84–0,96	0,96–1,08	≥ 1,08
Service Value – Diameter ≥ 12 inch (m^3/minute/W)	1,0–1,2	1,2–1,4	1,4–1,6	1,6–1,8	≥ 1,8

Table 5.17 Proposed MEPS and energy-saving labels for air conditioners

Indicators	1 Star	2 Star	3 Star	4 Star	5 Star
Cooling Seasonal Performance Factor (CSPF) (W/W)	3,1 – 3,4	3,4 – 3,8	3,8 – 4,2	4,2 – 5,0	≥ 5,0

Table 5.18 Proposed MEPS and energy-saving labels for refrigerator

Indicators	1 Star	2 Star	3 Star	4 Star	5 Star
Energy consumption (kWh/year)	(0,85 * Vadj) + 270	0,75 * 1 star	0,75 * 2 star	0,75 * 3 star	0,75 * 4 star

Table 5.19 Proposed MEPS and energy saving labels for lamps

Category	1 Star	2 Star	3 Star	4 Star	5 Star
Household light	80	90	100	110	120
Professional light	90				
Public street lighting	120				

Migration of LPG Stoves to High Efficiency Electric Stoves and the Role of DME

One of the efforts to diversify LPG is the migration to electric stoves, in particular induction stoves. The main market for electric stoves is 1.5 million household electricity customers (R1 2,200 to R3 > 5500 VA) who can use induction stoves with a power capacity of 2,000 W. The implementation of induction stoves migration for all household customers (69.3 million households) requires a policy of power limit exemption with the application of tariff blocks. The initial priority for induction cooker migration targets is MEMR staffs (approximately 50,000 employees), PLN employees (around 50,000 employees), State-owned Enterprises employees (approximately 2 million employees), and employees of companies in other energy and mineral resources sector in Indonesia.

Based on the proposed roadmap for migration to electric stoves, as shown in **Table 5.20**, there are four stages in the implementation of this migration. The initial phase aims to sustain the current endeavors of PT PLN (Persero) that promote the use of electric stoves within the community. These efforts encompass reduced costs for electricity installation, large-scale campaigns for electric stove migration, as well as promotional discounts for electric stoves and cooking utensils. The target users of this first phase are affluent electricity consumers.

The next step is to carry out a field experiment within the community regarding the use of induction stoves to obtain supporting data for policymaking. The field experiment is designed to identify any challenges that come up when using electric stoves and to gauge the community's acceptance of them. Both induction stoves and electric pressure cooker (EPC) can be tested during the trial, which can be carried out among PLN customers who already use electric stoves or randomly selected respondents.

The third stage is the specification of residential buildings developed by the Ministry of Public Works and Housing, which are designed to use electric stoves. This policy can also be applied to the issuance of Building Approval (*Persetujuan Bangunan Gedung*, PBG) for new apartments and housing. The efficiency of induction stoves is higher (70-80%) than LPG stoves (≥ 40%), according to research conducted by the Research and Development Agency of MEMR. Therefore, the mandatory use of electric stoves will not pose any harm to building occupants.

The fourth stage involves the national migration program within the Java-Madura-Bali (Jamali) Electricity System. The national entails a trade-in of LPG stoves for electric stoves and cooking utensils for 450 VA and 900 VA households. The Jamali system has an electricity generation cost (*Biaya Pokok Penyediaan*, BPP) below the national BPP so the electric stove migration will minimize additional electricity subsidies for each 450 VA and 900 VA household that still receive electricity subsidies. The low BPP will boost PT PLN (Persero)'s revenue from non-subsidized customers who utilize induction stoves. The Jamali system also has technical readiness with a load factor of 59%, a capacity factor of 59%, and a reserve margin of approximately 33.5%.

The national migration program will then proceed to other regions, specifically those with a BPP below the national average BPP by 2031, and all regions of Indonesia by 2035. These policies aim to increase the number of households using induction cookers to 2 million in 2022, 5 million in 2023, 9.3 million in 2025, 20 million in 2030, and 58 million in 2060.

Table 5.20 Roadmap for migration to electric stoves

Action Plan	Period	MEMR	Ministry of Industry	Ministry of Finance	Ministry of Public Works and Housing	PLN
Discount on the cost of increasing electricity power	2022-2060					√
Massive electric stove migration campaign	2022-2060	√				√
Price discounts and other promotions for electric stoves and cookware	2022- 2060		√			√
Field experiments on energy efficiency and public acceptance of the use of induction stoves and electric pressure cookers	2022	√				√
Government project residential buildings equipped with electric stoves	2024-2036				√	
National migration program in Java Island	2026– 2030	√		√		√
National migration program in regions with regional BPP below electricity base tariff	2031– 2040	√		√		√
National migration program in other regions	2035– 2040	√		√		√

To support this strategy, it is necessary to standardize induction stoves to ensure user safety and prevent the entry of low-quality imported products, as well as to ensure that circulating induction stove technology is truly efficient. The current standard, Ministry of Industry Regulation 58/2020 on Indonesian National Standard (*Standar Nasional Indonesia*, SNI) for Kitchen Appliances and Liquid Heating Equipment for Household Electricity Uses, does not currently encompass induction stoves. Consequently, the SNI, MEPS, and Energy Saving Labels for induction stoves must be standardized immediately. Other necessary support is required to create a domestic induction stove industry that fulfils the requirements of this technological shift by offering more reasonably priced options to increase the use of induction stoves within residential sector.

During the transition period, Dimethyl Ether (DME) can be utilized as an LPG mixture to balance the shift of LPG to induction stoves. DME can be produced from diverse feedstock sources like coal, natural gas and biomass via gasification technology. In the strategy to achieve the NZE target, DME performs a crucial part in curtailing fuel imports, particularly in the residential sector.

City Gas Network

The development of city gas networks for households is one of the efforts to diversify LPG to improve energy security in the future. The RUEN has set a target for the development of the national gas network until 2030. The cumulative target of household gas network development in 2020 is 1,834,000 house connections (*Sambungan Rumah*, SR) with realization reaching 696,011 SR (see **Figure 5.41**). Financing for developing the current city gas network is provided by the government budget (76.9%), Pertamina (0.7%), and PGN (22.4%). **Figure 5.42** illustrates the allocation of city gas networks funded by the state budget. Cities with gas networks above 50,000 SR are South Sumatra (122,358 SR), East Java (86,116 SR), East Kalimantan (61,264 SR), and West Java (59,207 SR). The development of city gas networks for house connections is a strategic priority project of the National Medium-Term Development Plan (*Rencana Pembangunan Jangka Menengah Nasional*, RPJMN) 2020-2024 towards 4 million SR. The cumulative objective of the city gas network for 2024 comprises 366,070 SR from the state budget, 2,489,555 SR from Public-Private Partnership (PPP), and 633,930 SR from State-owned Enterprises. The number of SR will continue to rise to 4,734 thousand SR by 2025 and 7,734 thousand SR by 2030.

Figure 5.41 Target of household gas network development

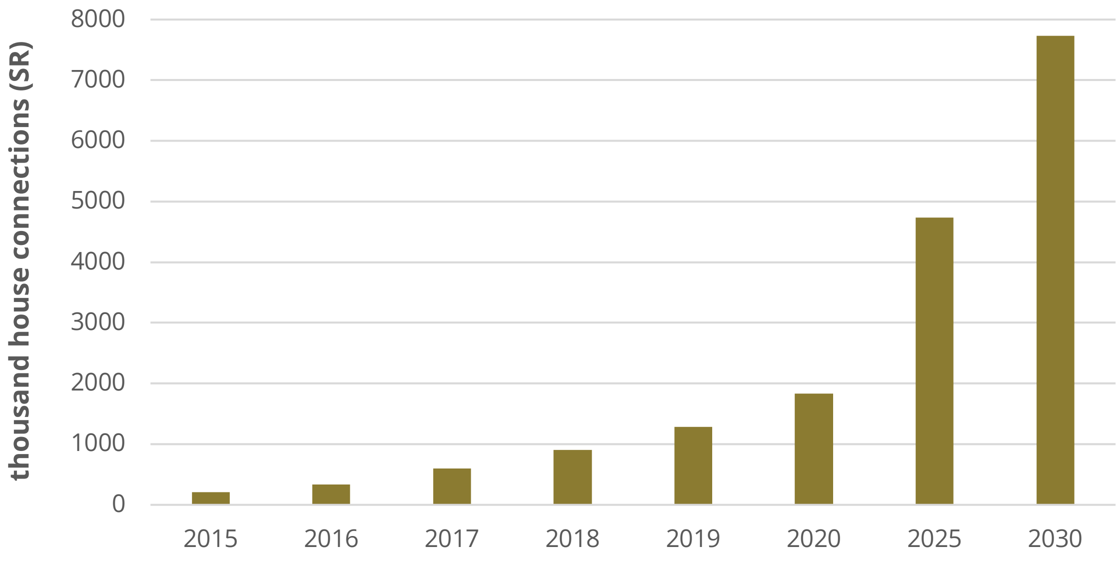
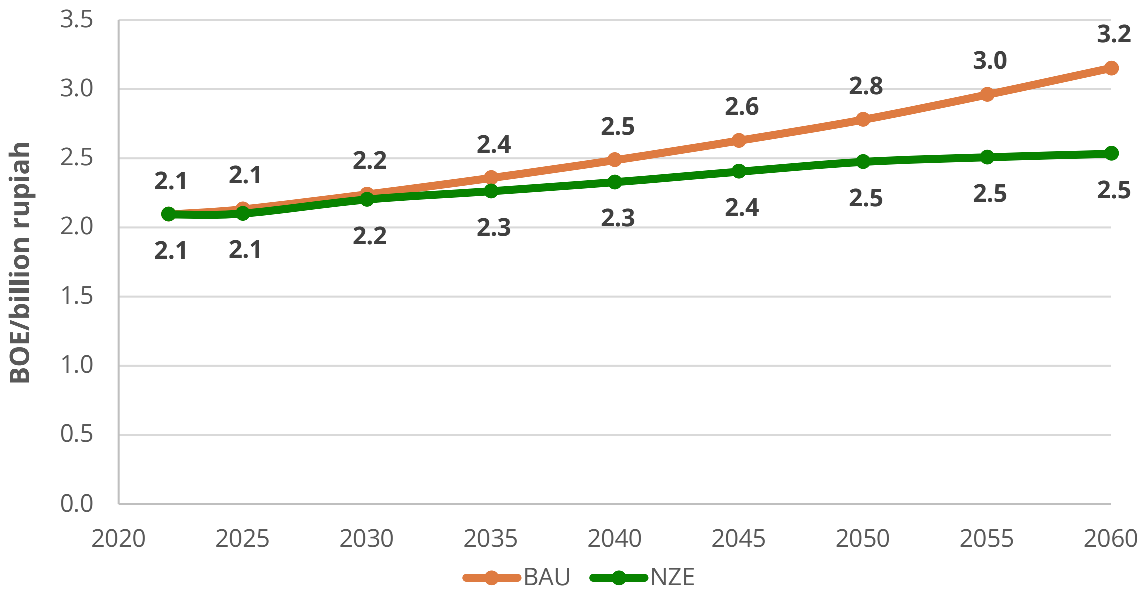


Figure 5.42 Distribution of gas networks with state budget financing

Efforts made to achieve the NZE target in the residential subsector will lower the energy intensity of this subsector by an average of 0.5% annually. Energy intensity in this subsector will decrease from 2.1 BOE/household in 2022 to 2.5 BOE/household in 2060. In comparison to the BaU scenario, the NZE scenario will decrease the energy intensity in the residential subsector by 20% by 2060. **Figure 5.43** illustrates the energy intensity of the residential subsector.

Figure 5.43 Energy intensity of residential subsector



5.4 Commercial

In line with the national GDP growth, the activities in commercial subsector, both private and government activities, will increase. This increase will result in an upswing in energy demand. There will be a 75% increase in the energy demand of this subsector, escalating from 7 MTOE in 2022 to 28 MTOE in 2060.

By energy type, electricity use dominates energy consumption in the commercial subsector. Air conditioning accounts for the majority of electrical energy usage in this subsector, followed by elevators, lighting, and others. In the NZE scenario, it is projected that electricity consumption in the commercial subsector will increase from 5.9 MTOE in 2022 to 25.7 MTOE in 2060. Furthermore, there is a projected increase in the utilization of renewable energy and natural gas until 2060, reaching 1.30 MTOE and 0.94 MTOE respectively. With the transition to using NRE sources and electrification, fuel oil consumption will be reduced to 0.35 MTOE by 2060. Fuel oil such as gasoil, IDO, and kerosene will still be used as a biogasoil blend up to 2060. **Figure 5.44** depicts the projection of commercial subsector energy demand by energy type.

The emission levels in the commercial subsector are also forecasted to rise, from 1.8 $MtCO_2e$ in 2022 to 3.5 $MtCO_2e$ in 2060. The use of LPG and natural gas are the primary sources of emissions in the commercial subsector. **Figure 5.45** shows the projection for GHG emission levels in the commercial subsector.

Figure 5.44 Projected energy demand of the commercial subsector by energy type

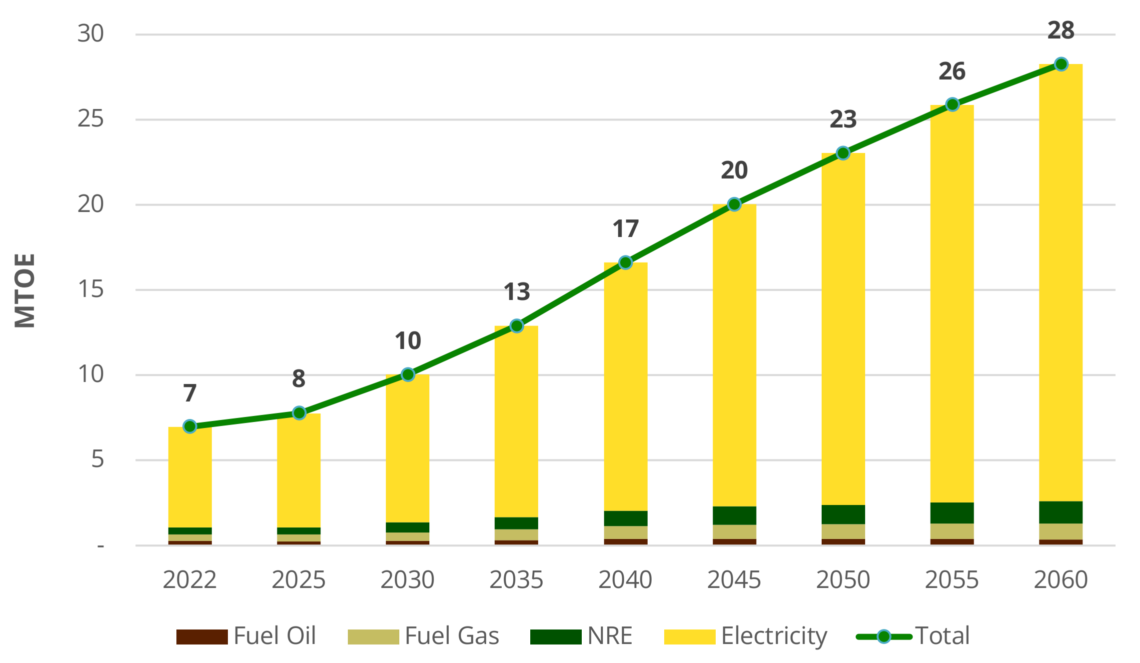
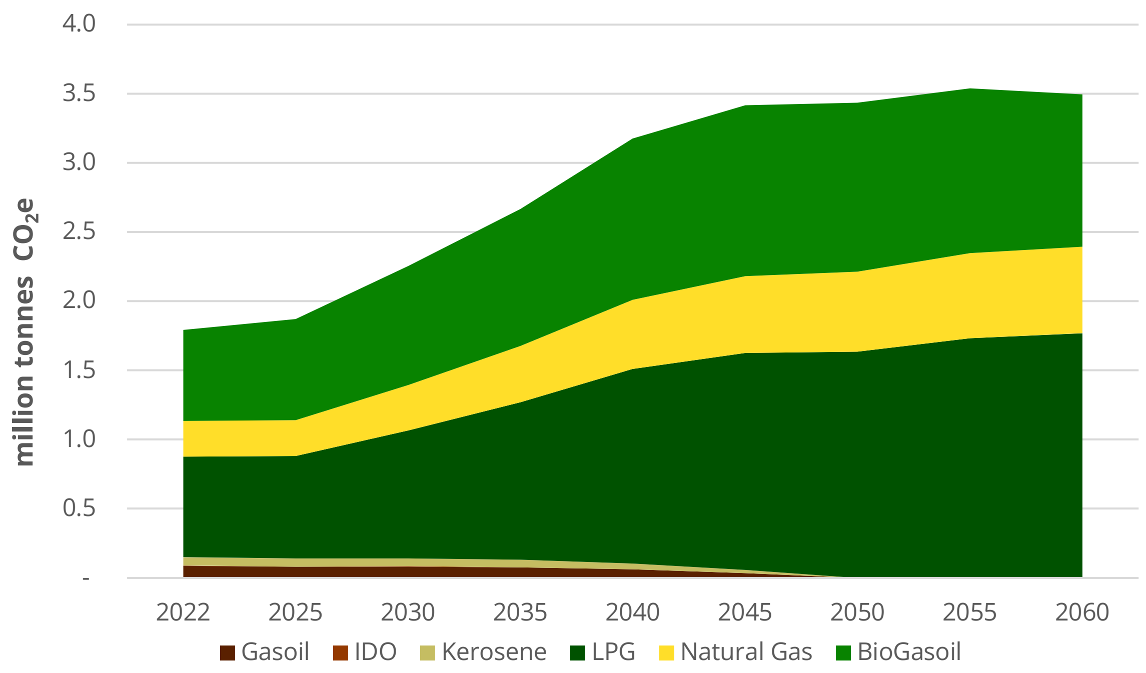


Figure 5.45 Projected GHG emission of commercial subsector



In the context of energy transition in the commercial subsector, it is necessary to improve energy efficiency, one of which is through the use of high-efficiency local lamps. The commercial subsector (commercial buildings, government, industry) will switch from using fluorescent lamps—compacted fluorescent lamps (CFL) and linear fluorescent lamps (LFL)—to light-emitting diode (LED) lamps.

The government has also developed a roadmap to improve energy savings for lighting. The first roadmap is to implement MEPS and gradually improve the MEPS score as tabulated in **Table 5.20**. The second roadmap is to accelerate the transition to 100% LED or other high-efficiency lighting, as described in **Table 5.21**.

The roadmap outlines a plan of action to replace energy-intensive and/or mercury-containing lamps in government and SOE buildings with high-efficiency local lamps that have local content (*Tingkat Komponen Dalam Negeri*, TKDN) certificates, meet safety SNI requirements, and fulfil MEPS. In the short term, it is necessary to phase out mercury-containing lamps in government agencies and SOEs buildings. Additionally, government agencies and SOEs are obligated to use local lamps that comply with safety SNI and MEPS.

In the medium term, the MEMR will increase the MEPS of lamps to 130 lm/W for non-street lighting devices (*Alat Penerangan Jalan*, APJ) type and 180 lm/W for APJ type. This increase takes into account the upward trend of LED lamp technology efficacy from 95 lm/W in 2016 to 169 lm/W in 2020 and an estimated 203 lm/W in 2025. Furthermore, there will be an expansion of the policy to phase out mercury-containing lamps in all non-government/SOE professional buildings and premises. CLASP and PwC have forecasted that this situation will arise naturally in 2029. Alongside this, the Ministry of Public Works and Public Housing should urge planning consultants and construction service contractors to commit to utilizing lamps that meet the safety standards of SNI and MEPS, with a minimum of 40% TKDN.

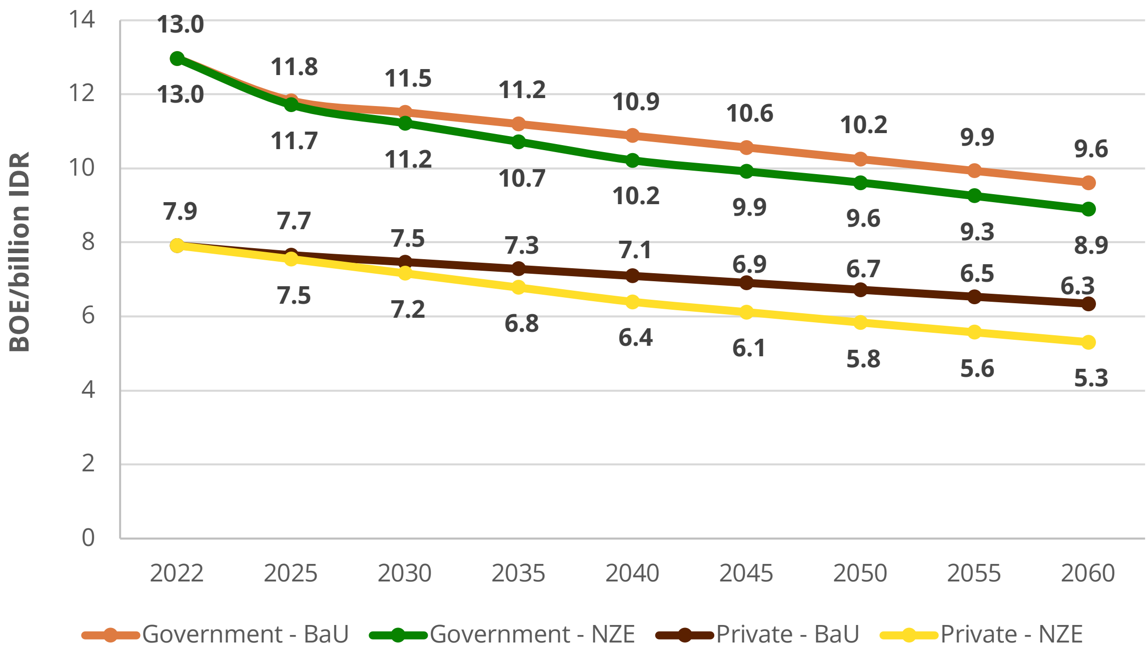
In the long term, the development of high-efficiency lighting is focused on MEPS increase and high-efficiency lamps market share boost. The Ministry of Energy and Mineral Resources need to formulate a work program to achieve MEPS enhancement up to 150 lm/W for non-APJ LED lamps and 210 lm/W SKEM for APJ LED lamps by 2032. Efforts to increase demand for local and high-efficiency lamps are centered on the obligatory application of such lamps in all new professional commercial buildings. The Ministry of Industry, in conjunction with the Ministry of Home Affairs and the Ministry of Public Works and Public Housing, need to create a regulation mandating the adoption of lamps containing 40% TKDN and Corporate Contribution Value (*Bobot Manfaat Perusahaan*, BMP) in the issuance of a Function Worthiness Certificate (*Sertifikat Laik Fungsi*, SLF). This policy should be endorsed by the building assessment team in the Ministry of Public Works dan Public Housing to promote the use of lighting products that comply with the safety SNI standards and MEPS along with 40% TKDN and BMP to all local authorities.

Table 5.21 Action plan to accelerate the use of high efficiency lamps

Action Plan	MEMR	MOEF	MoI	LKPP	MOPW	Local Government
SHORT TERM						
MEPS 80 lm/W for bulb type lamps, 90 lm/W for tube type lamps, and 120 lm/W for APJ type lamps	2022					
Phasing out mercury-containing lamps in government and SOEs buildings		2022				
Regulation of waste lamp disposal		2023				
Obligation of government agencies and SOEs to use local lamps (TKDN and BMP at least 40%) that fulfil safety SNI and MEPS			2023			
LKPP Electronic Catalogue which contains local non-APJ lamps that comply with safety SNI and MEPS				2023		
Socialization of local lamp brands (TKDN and BMP at least 40%) that meet safety SNI standards and MEPS	2023		2023			
MEDIUM TERM						
SKEM 130 lm/W for non-APJ type lamps and 180 lm/W for APJ type lamps	2026					
Safety SNI obligation for lamps in public procurement			2026			
Phasing out mercury-containing lamps in all other professional buildings		2027				
Commitment of planners and construction contractors to use local lamps (TKDN and BMP 40%) that fulfil safety SNI standards and MEPS					2026	
LONG TERM						
MEPS 150 lm/W for non-APJ LED lamps and SKEM 210 lm/W for APJ LED lamps	2032					
Provision of a SLF with the requirement to use lamps that fulfil MEPS and SNI safety with a minimum TKDN and BMP of 40%			2033		2033	2033

The implementation of energy efficiency measures will lower the energy intensity of the commercial subsector. In the NZE scenario, the energy intensity of the private sector will be reduced by 16%, while the government sector will be reduced by 8% in comparison to the BAU scenario. Both government and private sectors will experience a yearly average reduction of 1% in energy intensity. The energy intensity of the government sector will decline from 13 BOE/billion rupiah in 2022 to 8.9 BOE/billion rupiah in 2060. On the private sector, the intensity of energy will decrease from 7.9 BOE/billion rupiah to 5.3 BOE/billion rupiah by 2060. **Figure 5.46** illustrate the energy intensity for the government and private sectors.

Figure 5.46 Energy intensity of commercial subsector



Additionally, the Government promotes energy efficiency in commercial buildings with the Green Building and Net Zero Emission Building (NZEB) programs. Currently, the Government is developing a Net Zero Emission Building (NZEB) roadmap. The proposed NZEB plan is outlined in **Table 5.22**.

Table 5.22 Net Zero Emission Buildings (NZEB) roadmap

Roadmap	2022 – 2030	2031 – 2040
Preparation (regulation, capacity building, assessment institution)	2023	
NZEB obligation on buildings of central government agencies & SOEs or Regionally Owned Enterprises (ROEs) in Java Island	2024	
NZEB obligation on all professional buildings in Java Island	2028	
NZEB obligation on all government agency buildings (central and local) and SOEs/ROEs		2031
NZEB obligations on all professional buildings		2033
NZEB's obligation to grant PBG and SLF for new buildings		2033

The Indonesian government has also created Indonesian National Standards regarding energy efficiency in commercial buildings, encompassing various aspects such as:

- SNI 6389:2020; Building Envelope Energy Conservation in Buildings.
- SNI 6197:2020; Energy Conservation in Lighting System.
- SNI 6390:2020; Energy Conservation of Air Conditioning Systems in Buildings.
- SNI 6196:2011; Energy Audit Procedure for Buildings.
- SNI 6572:2001; Procedures for Designing Ventilation and Air Conditioning Systems in Buildings

6 IMPLEMENTATION ROADMAP

In this section, pathways defined to achieve Indonesia's NZE 2060 energy sector targets are first summarized.

Then, in the subsequent sub-sections, the enabling factors to facilitate these strategies will be explored. These will consider activities in policy support, infrastructure, research and development, technology, financing, and human resources that can promote Indonesia's NZE activities. Within policy support, reforms in policies related to decarbonization and NRE deployment, energy efficiency, the finance sector, and a just transition will be explored.

Existing challenges to creating this enabling environment will also be discussed. Issues include access to technology, challenges to infrastructure development, financial challenges, Indonesia's well-established fossil fuel-based energy system, governance, barriers to nuclear energy penetration, and just transition.

Lastly, estimates for investment needs will be discussed.

6.1 Summary of pathways

This section summarizes the strategies to achieve the NZE 2060 energy sector targets, both in the supply (upstream) and demand (downstream) sectors, divided into six periods.

As discussed, the pathways identified in this document and summarized in this section were derived from the modeling results conducted by Indonesia's Ministry of Energy and Mineral Resources and encompass the government's priority programs with regards to transforming the energy sector towards net-zero emissions by 2060.

The timing for different measures was considered in the strategy, with more available technologies and more attainable initiatives, e.g., co-firing, electrification, and energy efficiency, being prioritized in the earlier periods. Meanwhile, emerging technologies, such as CCS, are being saved for later periods.

In the demand side, it relies on incremental increases in the magnitude of different measures from one period to the next, e.g., the number of induction stove users, the number of EV users, and the number of households served by the gas network.

The strategies are outlined in **Figure 6.1**.

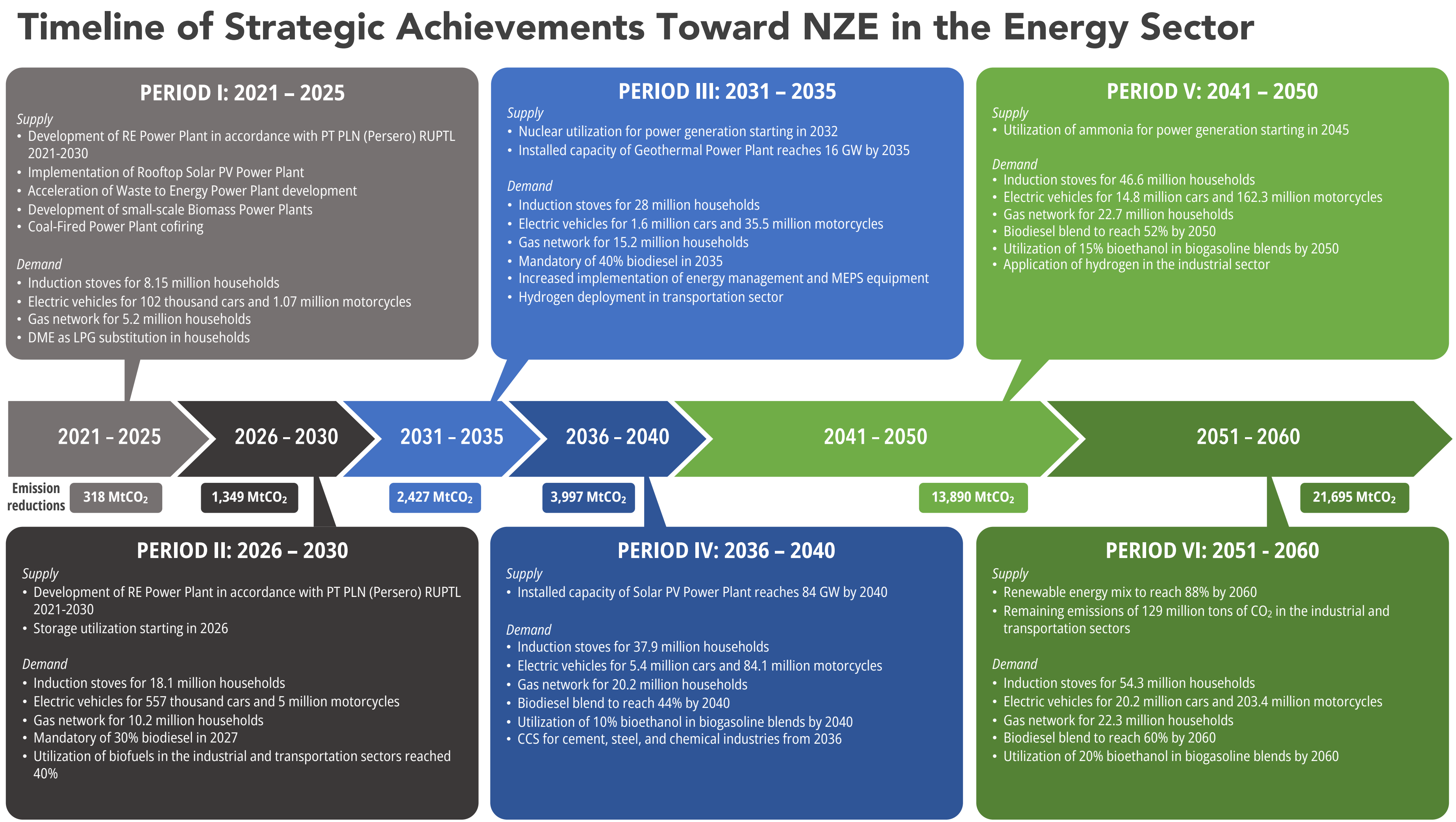


Figure 6.1 Timeline of strategic achievements toward NZE in the energy sector

6.2 Enabling factors

In order for the NZE strategies outlined in Chapters 4 and 5 to meet the NZE targets, an enabling environment must be fostered to facilitate activities from the supply and demand side. If met, it can give way to a sustainable energy sector that is marked by the following:

- A significant portion of energy production will be powered by renewable energy.
- The Indonesian population will have universal access to electricity based on a combination of a well-integrated energy system and distributed energy systems despite the archipelagic nature of the country.
- Remaining fossil fuel generation will be priced according to actual generation costs.
- NRE competitive procurement processes will be implemented.
- The public transport sector will be dominated by EVs and hydrogen, with a high degree of penetration in private transport.
- A majority of domestic users will have access to gas and high energy efficiency (EE) appliances.
- The government will have supported during the first years the implementation of energy efficiency programs to increase the adoption of highly efficient appliances.
- Indonesia will have created a secure investment environment for national and international investors.
- It will have promoted a local industry for green technologies that is competitive in the international sphere.
- Subsidies for energy production will have been eliminated. Demand side subsidies are only in place to support the most vulnerable users.

To achieve this, enabling factors must be met, including supporting policies that include fiscal reforms, infrastructure development, funding support, and research and development of technology that promote the energy transition.

6.2.1 Policy support

The decarbonization of the production matrix and the acceleration of NRE deployment require a concerted policy and fiscal reform effort in multiple fronts. Policies that give advantage to coal production will be gradually discontinued, including domestic coal price control (DMO), to allow NRE to compete with market-based costs of coal-fired power generation.

The accelerated and competitive deployment of NRE requires the reform of the local content requirement (LCR) policy to prioritize NRE generation cost reduction. The government will promote local industry competitiveness through robust NRE generation deployment planning that provides certainty to investors both in NRE and local component industries.

6.2.1.1 Decarbonization and NRE deployment

The decrease on DMO will be coupled with regulatory reforms that allow PLN to procure based on different factors aside from the lowest production costs, which has been distorted by the DMO. This will increase the fairness of comparison with NRE. Procurement policies for PLN will be complemented with supporting policies for dispatching, preferential pricing, and use of auctioning to arrive at a situation in which Indonesia has established a stable, substantial, and multi-year pipeline of auctions for NRE with competitive and transparent tariff setting. In parallel, investor security and support will be enhanced through revised power purchase agreement (PPA) regulations.

A strategic plan will be developed to increase the availability of biomass and regular supply, while at the same time, avoiding any negative socio-economic impacts to farmer or food consumers.

At the medium-term, the repurposing or retirement of CFPPs will be supported facilitating the renegotiation of PPAs, market-level asset valuation, and transfer of obligations.

Indonesia's carbon pricing instrument implementation will advance over the years to support the implementation of the NZE. Additional industries will be included over time under the cap-and-trade program and other domestic instruments considered, supported by increased regional and global cooperation to attract finance and support this ambitious NZE implementation.

Overall, policy support should be coordinated among the different sectors and ministries to reach a unified roadmap towards NZE. More streamlined coordination can help mitigate the risk of delays in the formulation of the appropriate regulations and policies to guide the transition.

Table 6.1 Summary of issues, current status, desired outcomes, key actions, and key actors/stakeholders for policy support for decarbonization and NRE deployment.

Issues	Current status	Desired outcomes	Key Actions	Key actors and stakeholders
NRE is still at a financial disadvantage	Procurement by PLN is distorted by DMO	PLN to procure based on different factors aside from the lowest production costs	Reforms in PLN's procurement policies, coupled with supporting policies for dispatching, preferential pricing, and use of auctioning	MEMR
	NRE PPA regulation lowers the appetite for further NRE investment.	Investor security and support will be enhanced	Revised power purchase agreement regulation	MEMR

Issues	Current status	Desired outcomes	Key Actions	Key actors and stakeholders
NRE high deployment rates required in coming years.	Local content production capacity is limited. Local content requirements (LCR) impact NRE competitiveness and limit development agencies/banks support.	Indonesia industrial capabilities for NRE components evolve to make it a competitive global player. Minimum local content requirements regulations are not needed	Comprehensive firm NRE deployment plan backed by GoI and support package for industrial development. Revision of LCR regulation for NRE projects.	Ministry of Industry, MEMR
Socio-economic impacts of an increase in demand for biomass in power generation	There are no stipulations to address the socio-economic impacts of the shift in farming activities	Negative socio-economic impacts on farmers and food security are avoided	Development of a strategic plan	MEMR, Ministry of Agriculture, MoEF, Ministry of Agrarian Affairs and Spatial Planning, local governments
Repurposing or retirement of CFPPs face challenges related to conditions in PPAs and asset valuation	Existing regulation prevent transactions that may be perceived to be financially non-viable for SOE and the GoI.	Regulation incorporates provisions for coal retirement cases in which asset valuation, PPAs and other aspects may need to be revised	Renegotiation of PPAs, market-level asset valuation, and transfer of obligations	MEMR, MoF, Ministry of State-Owned Enterprises
Carbon pricing instruments	Only the energy supply sector is partially included in Indonesia's cap-and-trade program.	More industries and companies are financially incentivized to seek emission-reducing technology and operations	Industries will be included over time under the cap-and-trade program and other domestic CPIs	MoEF, MEMR, Ministry of Industry, Ministry of Agriculture, Ministry of Transportation, Ministry of Public Works and Housing
Coordination among different sectors and ministries	Poor coordination among different sectors and ministries	Effective coordination among different sectors and ministries towards NZE implementation	Enhance the role of the National Energy Council in coordinating different ministries	National Energy Council

6.2.1.2 Energy efficiency

Enabling energy efficiency can accelerate many demand-side measures towards NZE. Promoting energy efficiency in industries, commercial users, and domestic users requires the deployment of policies and financial support for the implementation of EE programs, the development of attractive EE business models, and advancements in energy efficiency standards and labels based on existing Minimum Energy Performance Standard (SKEM) and marks/labels budling on the Regulation of the Minister of Energy and Mineral Resources Number 14 of 2021.

In the building sector, Indonesia will progress on the implementation of EE standards aimed at the residential sector and increase the coverage of those for industries. Implementation will be supported by the design of EE programs for appliances and industrial components. EE programs will also ensure that more vulnerable users are supported in the shift to more efficient appliances.

In the transport sector, the planned penetration of EVs, will be coupled with stringent fuel efficiency standards for passenger vehicles.

Table 6.2 Summary of issues, current status, desired outcomes, key actions, and key actors/stakeholders for policy support for energy efficiency.

Issues	Current status	Desired outcomes	Key Actions	Key actors and stakeholders
Need for further policy support for energy efficiency	There are decrees for performance standards for certain equipment, including air conditioning equipment, refrigerators, fans, rice cookers, and light-emitting diode (LED) lighting equipment	EE standards are created for all sectors, especially the residential and commercial sectors	Deployment of policies and financial support for the implementation of EE programs	MEMR
	Minimum Energy Performance Standards (MEPS) for energy-using equipment specify the minimum energy performance requirements to limit the maximum amount of energy consumption of	Standards are raised over time to permit only the most EE equipment in all sectors.	Advancements in energy efficiency standards and labels based on existing MEPS	MEMR

Issues	Current status	Desired outcomes	Key Actions	Key actors and stakeholders
	permitted energy-using equipment.			
	Business-as-usual business models are typically not based on EE standards	Sectors to be affected by EE standards are able to adapt to new standards through new business models	Development of attractive EE business models	MEMR, Ministry of Industry, Ministry of Transportation, Ministry of Public Works and Housing
High costs of more efficient appliances	Households typically purchase cheaper appliances that are not EE; high EE appliances are typically unaffordable	More vulnerable users are supported in the shift to more efficient appliances.	Subsidy programs and other incentives	MEMR, Ministry of Finance
Lack of incentives for larger penetration of higher EE vehicles	Low penetration of high EE vehicles	Higher penetration of energy efficient vehicles	Stringent fuel efficiency standards for passenger vehicles Stringent fuel efficiency standards for cargo vehicles	MEMR, Ministry of Transportation

6.2.1.3 Finance sector

Local financial institutions will have a large role to play in support energy transition activities, but they will also need support to provide an enabling financial environment for them.

First, the capacities of local financing institutions must be strengthened for them to support energy transition activities. Risk perception remains high but can be curbed through adequate capacity building to equip decisionmakers in the financial world with the appropriate knowledge to support investments in NRE and other NZE activities. Frameworks, taxonomies, and reporting requirements should all be updated to facilitate the development of sustainable NZE-aligned projects.

Table 6.3 Summary of issues, current status, desired outcomes, key actions, and key actors/stakeholders for policy support for the finance sector.

Issues	Current status	Desired outcomes	Key Actions	Key actors and stakeholders
Lack of regulation to facilitate the development of sustainable NZE-aligned projects.	Indonesia's Green Taxonomy	Frameworks, taxonomies, and reporting requirements are aligned with Indonesia's NZE objectives	Frameworks, taxonomies, and reporting requirements should all be updated	Ministry of Finance, Financial Services Authority
High risk perception from local financing institutions	Financial institutions do not fully understand Indonesia's NZE goals and are wary of investing in these activities	Decisionmakers are equipped in the financial world with the appropriate knowledge to support investments in NRE and other NZE activities.	Adequate capacity building	Ministry of Finance, Financial Services Authority

6.2.1.4 Just transition

The most imminent enabling factor for just transition is its integration in Indonesia's regulatory and institutional framework, where cohesion and alignment will be key.

Just transition will be captured in planning for all relevant sectors, considering their interplay with other sectors. Such policies will identify relevant stakeholders and impacted communities and lay out the groundwork for the sector's development that addresses their needs.

Similarly, as just transition is a cross-sectoral endeavor, coordination among corresponding ministries, private entities, and the workforce will be key. A just transition working group or a committee that engages stakeholders from relevant sectors can drive cohesive planning. These should involve players not only from economic sectors but also from sectors such as education, manpower, and social protection.

Financial support should also be defined for just transition activities. A just transition investment vehicle that can channel financing from project financing for relevant energy transition activities, as well as from donor countries and philanthropies, can be pivotal in accelerating just transition implementation. Central banks should also explore ways to incentivize private investments into projects that can advance a just transition in Indonesia.

Table 6.4 Summary of issues, current status, desired outcomes, key actions, and key actors/stakeholders for policy support for just transition.

Issues	Current status	Desired outcomes	Key Actions	Key actors and stakeholders
Lack of integration in the regulatory and institutional framework	There are few stipulations for a just transition in sectoral planning	Just transition is captured in planning for all relevant sectors	Policies and planning are updated	Ministry of Finance, BAPPENAS, MEMR, Ministry of State-Owned Enterprises, Ministry of Manpower, Ministry of Social Affairs, local governments
	There is no institution that convenes different ministries to plan for a cross-sectoral just transition	There is coordination among corresponding ministries, private entities, and the workforce to drive planning	A just transition working group or a committee is created	Ministry of Finance, BAPPENAS, MEMR, Ministry of State-Owned Enterprises, Ministry of Manpower, Ministry of Social Affairs, local governments
Lack of just transition financing	There is no dedicated financing channel for just transition activities	A clear channel for financing towards just transition activities is functional	Creation of a just transition investment vehicle	Ministry of Finance
	There are few incentives for private banks to invest in just transition-aligned projects	Private banks are incentivized to invest in just transition-aligned projects	Central banks creates the appropriate policies	Ministry of Finance

6.2.2 Infrastructure

Infrastructure to meet Indonesia's growing energy demand, which needs to be met through clean energy, must be developed to support decarbonization and ensure energy security.

While the RNZE recognizes the need of a super grid to optimize the distribution of NRE in various parts of Indonesia, further action must be taken to ensure that such infrastructure is properly equipped to handle an increase in NRE capacity. This expansion will also require the incorporation of more control centers to handle distribution, especially with the planned deployment of technologies such as BESS, pumped storage, and hydrogen. Such work has already been commenced in the Java-Bali power system, where a project through the Energy Transition Partnership supported the upgrade of the system's Main Control Center (MCC), the Disaster Recovery Center (DRC), and the Advanced Control Center system SCADA/EMS and its supporting systems.

Supply chains to support new or evolving industries towards NZE should also be supported by adequate infrastructure. Pushes for biomass utilization in power generation will require ample infrastructure for farmers to increase their production and transport feedstocks to power plants. For energy efficiency, the manufacturing industry must be properly equipped with the knowledge and the supply chain to highly produce EE appliances and products and to distribute them.

Infrastructure to support shifts in consumer practices, such as in household and transport, needs to be created. A stronger push for conversion to natural gas in households should be supported by the expansion of the gas network in cities to increase access. To meet clean cooking targets, access to appliances such as induction cookers should also be made easier, with financial support or subsidies being potential methods of facilitating household access. Supporting electrical infrastructure to properly operate them should also be constructed in households. In the transport sector, adequate infrastructure planning, such as Public Electric Vehicle Charging Stations (Stasiun Pengisian Kendaraan Listrik Umum, SPKLU), needs to be done to promote the uptake of EVs.

Table 6.5 Summary of issues, current status, desired outcomes, key actions, and key actors/stakeholders for infrastructure.

Issue	Current status	Desired outcome	Actions	Key actors and stakeholders
Need for better transmission and distribution	Grids in Indonesia are largely isolated within islands, and the centers for power generation are loads are inconveniently co-located	A supergrid allows for power transmission and distribution between the major islands	Improvement of energy infrastructure development outside of Java	MEMR, Ministry of Finance, PLN, local governments
	The grid is equipped to handle a low share of NRE	The grid is technically equipped to handle the higher penetration of NRE	Upgrade of grid power system Incorporation of more control centers	MEMR, PLN
Need for infrastructure for biomass utilization in power generation	There is no clear infrastructure to facilitate an increase in biomass production for utilization in power generation	Farmers are incentivized to increase their production and transport feedstocks to power plants	Construct adequate infrastructure to support farmers Establish a sustainable biomass supply chain	MEMR, MoEF, Ministry of Finance, Ministry of Agriculture
Need for industrial capacity for	There are no established supply chains for the	Manufacturing industry can efficiently produce	Technical capacity building and	MEMR, Ministry of Industry

Issue	Current status	Desired outcome	Actions	Key actors and stakeholders
manufacturing of EE equipment	manufacturing of EE products.	and highly distribute EE products.	development of a supply chain Incentives and policy support through MEPS	
Improvement of natural gas distribution infrastructure	Limited network of natural gas pipelines	Higher access to natural gas	Expansion of the gas network	MEMR, Ministry of Public Works and Housing
Accessibility of EE appliances	Low access to EE appliances	Higher access to EE appliances	Financial support or subsidies and other incentives	MEMR, Ministry of Finance
			Supporting electrical infrastructure for EE appliances	MEMR, Ministry of Public Works and Housing
Promotion of the uptake of EVs	Few charging stations for EVs	EV users can rely on a secure network of charging stations	Adequate infrastructure planning and installation of Public Electric Vehicle Charging Stations	MEMR, PLN, and private companies

6.2.3 Research and development

Another enabling factor of the energy transition is research and development of technologies to utilize in the NZE transition. To bolster research and development in the country, more cooperation should be fostered with research institutions under the leadership of the Ministry of Education, Culture, Research, and Technology (MOECRT).

Higher education institutions and the private sector should form more partnerships to drive the pursuit of research and development relevant to Indonesia's growing economic sectors. Private sector investment into academic research should thus be incentivized to engage research institutions in finding solutions for issues within Indonesia's energy transition. In addition, while some partnerships have already been formed between domestic and foreign universities, further collaboration should be pursued to strengthen the national research ecosystem. Such partnerships can help develop innovative approaches as well as accelerate the pipeline from research to industry application.

Table 6.6 Summary of issues, current status, desired outcomes, key actions, and key actors/stakeholders for research and development.

Issue	Current status	Desired outcome	Actions	Key actors and stakeholders
Need to accelerate research and development to support NZE strategies	Few pipelines for the application of academic research to industrial application	Academic research can contribute to finding solutions for issues within Indonesia's energy transition	Incentivize private sector investment into academic research	Ministry of Education, Culture, Research, and Technology (MOECRT), National Research and Innovation Agency (BRIN)
	Limited number of innovative approaches to NZE strategies	Innovative approaches to NZE strategies are developed	Pursue further collaboration between domestic and foreign universities	Ministry of Education, Culture, Research, and Technology (MOECRT), National Research and Innovation Agency (BRIN)

6.2.4 Technology

Many NZE 2060 strategies rely on unlocking the potential of existing technology and leading the implementation of new technologies in Southeast Asia. Three enabling factors can be identified to maximize the role of technology in advancing Indonesia's efforts to NZE by 2060: (1) accelerate existing clean technology penetration; (2) transition acceleration; and (3) pilot new technologies and accelerate commercial stage.

Indonesia still has the opportunity to considerable increase the implementation of well-known existing clean technologies both in the supply and demand sides. Solar, geothermal, nuclear, co-firing, biomass generation, personal EVs, efficient industry equipment and high EE appliances are some of the examples. Policy reforms as those listed above, enhancing investors' confidence and targeted financial support are the main drivers for accelerating their implementation. Infrastructure also plays a role in this acceleration with, for example, integrated urban planning and the super grid facilitating the interconnectivity among islands.

While it is urgent that the energy mix shifts away from fossil fuels towards NRE, ensuring energy security and reliability will still be a priority. Fossil fuels will still have a role to play during this transition through the utilization of natural gas, the continued the use of coal but decreasing with increasing the efficiency of existing CFPPs, co-firing, new CFPPs that are more efficient, and gradual retirement.

The NZE implementation relies on new technologies or technologies not used in Indonesia before to play an important role. The first periods of implementation of the NZE will help us to pilot these technologies and confirm their viability in Indonesia.

International partnerships, finance and domestic leadership will allow us to further scale Carbon Capture, Utilization, and Storage (CCUS) technology and a clean hydrocarbon system, among others.

Table 6.7 Summary of issues, current status, desired outcomes, key actions, and key actors/stakeholders for technology.

Issue	Current status	Desired outcome	Actions	Key actors and stakeholders
Accelerate existing clean technology penetration	Barriers to clean technology penetration hinder implementation	Greater implementation of existing clean technologies Nuclear energy	Policy reform, e.g., regarding DMO, LCR, PPAs	MEMR, Ministry of Industry
			Design and installation of a super grid	MEMR, Ministry of Finance, PLN, local governments
			Integrated urban planning for adequate infrastructure for gas networks	MEMR, Ministry of Public Works and Housing
			Improve research into nuclear technology and build international cooperation	MEMR, Ministry of Education, Culture, Research, and Technology, National Research and Innovation Agency
Transition acceleration	While less carbon-intensive than coal, oil and gas are still fossil fuels that have the potential to contribute significantly to the country's total GHG emissions	Oil and gas can become low-carbon fuels during the transition to NZE	Optimize the production of oil and gas	MEMR
	Dependence on oil and gas as transition fuels	Accelerated shift away from all fossil fuels	Transition from petroleum-based oil & gas products to bio- or green- (drop-in) or alternative fuels (including biodiesel, bioethanol, drop-in fuels, DME, methanol, etc.)	MEMR
New technology acceleration	Uncertainty regarding which new technologies are viable in Indonesia	New technologies that are viable in Indonesia are identified and successfully demonstrated	Pilot new technologies	MEMR, PLN, National Research and Innovation Agency

6.2.5 Financial support

Financial support is another enabling factor because of the large amount of investment needed for NZE. On both the supply and demand sides, fiscal and non-fiscal incentives, grant support, and financing schemes from the government, the private sector or development partners are needed to encourage the formation of enabling environment through financial support. This should be supported by financial policy reform as previously discussed.

Financing platforms such as JETP and the Asian Development Bank's Energy Transition Mechanism should be explored as ways to channel financing to Indonesia's NZE activities.

Table 6.8 Summary of issues, current status, desired outcomes, key actions, and key actors/stakeholders for financial support.

Issue	Current status	Desired outcome	Actions	Key actors and stakeholders
Need for more financial support	Gaps in financing for NZE strategies remain	An enabling environment for financial support	Fiscal and non-fiscal incentives, grant support, and financing schemes	Ministry of Finance, BAPPENAS, private sector, and development partners

6.2.6 Human Resources

In the development of decarbonization, the opportunity aspects on both the supply and demand sides require the participation of all stakeholders, including the development of human resources to achieve a just energy transition and meet climate change mitigation goals. It has been estimated that the number of jobs to be created with the deployment of NRE technologies can range from 2.1 million – 3.7 million.[10] Indonesia's workforce must be equipped with the appropriate skills to be able to properly support the country's energy transition.

Table 6.9 Summary of issues, current status, desired outcomes, key actions, and key actors/stakeholders for human resources.

Issue	Current status	Desired outcome	Actions	Key actors and stakeholders
Need for a skilled workforce to support NZE activities	There are gaps in understanding of skills needed for new economic activities in NZE scenario	There is adequate understanding of the skills needed to properly redesign academic and vocational training programs	Conduct analyses of the skills needed for the workforce	Ministry of Manpower, Ministry of Education, Culture, Research, and Technology, MEMR, BAPPENAS

[10] GGGI. 2020. _Employment assessment of renewable energy: Power sector pathways compatible with NDCs and national energy plans_.

Issue	Current status	Desired outcome	Actions	Key actors and stakeholders
	The workforce is not properly equipped with the relevant skills to support economic activities in NZE scenario	The future workforce is equipped with the appropriate skills to support NZE activities	Redesign curricula in academic and vocational institutions, as well as for training (upskilling and re-skilling)	Ministry of Education, Culture, Research, and Technology, MEMR, BAPPENAS

6.3 Challenges

Challenges related to the development of decarbonization in the context of achieving the NZE target include aspects of economics & technology, infrastructure, supply & demand, funding, and aspects related to ensuring a just transition.

6.3.1 Technology access

The availability of technology, which plays an important role in realizing many NZE 2060 strategies, remains low in Indonesia. Currently, technology is still largely imported, and there is still a need to promote good engineering practices. Different factors—technical, social, political, and financial—hinder the development and deployment of technology needed in Indonesia's transition to NZE. This NZE plan envisions the deployment of technologies not used in Indonesia to date, a priority then is focus on piloting projects using these new technologies to confirm the deployment windows proposed for these technologies to contribute to the NZE and adapt the plan as necessary.

Some of the technical challenges include complementary technology components not being available yet, the relatively weak performance of certain elements, limited raw materials, and interdependence between components. In addition, differences in technology standards, compatibility and structural issues can also lead to technological bottlenecks supporting the energy transition. These bottlenecks can arise at various phases of technology development, some occurring in the early phases of technology development or during times of high demand growth. In addition, prices are increasingly competitive, where the price of decarbonization development remains relatively expensive compared to fossil fuel.

One regulatory challenge to accelerating the deployment of technology is local content requirement policies. Stringent requirements demanded by this policy can hinder the utilization of much more accessible technologies from abroad. While LCR may prove to be effective in promoting domestic industries, care should be taken in implementing too high requirements at this early stage of Indonesia's pathway to NZE. A robust multiyear plan for the installation of NRE projects and the strong support of the GoI for its timely implementation will attract investment in local production both from domestic and international investors and support Indonesia to become a leading player in NRE components production.

6.3.2 Infrastructure challenges

Accelerating decarbonization and renewable energy penetration will require reliable infrastructure that can facilitate the integration of new NRE facilities and expand power distribution towards 100% energy access in Indonesia. However, the archipelagic nature of Indonesia's geography, as well as its sheer size, presents challenges to building this infrastructure. For example, NRE supply centers tend to be far from load centers, requiring significant amounts of transmission lines to connect them. Connecting inter-island grids towards creating a supergrid, e.g., between Java and Kalimantan, will also require substantial effort, due to the distances that need to be covered, as well as the challenges that come with installing and maintaining subsea cables.

Many of these challenges are linked to technological and financial challenges and can be addressed through related strategies, such as fostering research and development and providing financial incentives for private investments.

6.3.3 Financial

Regarding funding, the energy transition towards the NZE target requires a large amount of investment at US$28.5 billion per year. In addition, there are funding limitations, considering the scarcity of concessional loans and high investment risk perception.

At the moment, there is limited capacity among national financial institutions to tackle the financing needed to drive the transition. An enabling environment to incentivize investments is also still lacking.

Strategies to address bottlenecks need to involve many parties. From the industrial sector, these problems will be identified and solved by parties that are economically related. For example, in PV development, for example, when the high cost of one element hinders production, the industry should increase production capacity to minimize costs. Another issue is standards on certain components, for which parties need to coordinate to reach a mutual agreement. Policymakers also play a crucial role in clearing bottlenecks to support one particular component that is not yet developed, conflicts of interest between parties, initial investments that are not economically feasible, etc.

6.3.4 Well-established fossil fuel-based energy system

Upending the existing energy system towards NZE is fundamentally challenging due to the need to restructure many aspects of relevant stakeholders' operations, particularly those of PLN.

For example, because PLN's business model has relied on coal-fired power generation, any move towards making renewable energy more competitive jeopardizes PLN's businesses. PLN would require a redesign of its business model to be able to accommodate a shift in the country's power generation.

Early CFPP retirement also presents challenges to an energy system that has until recently envisioned power generation to capitalize on the country's abundant resources of coal. Currently, many CFPPs are young, with corresponding long-term contracts having been signed relatively recently. Pursuing their early retirement comes with its challenges, not least of which is negotiations with asset owners who are expecting to profit from the long-term operation of their CFPPs.

Due to the substantial shift in PLN's operations expected during Indonesia's NZE efforts, incentives should be provided to accelerate its transformation. At the same time, PLN must be ready to commit within its governance to embark on such a transformation to give way to its sustainable growth through the integration of renewable energy.

6.3.5 Governance complexities

Energy transitions involve many stakeholders in different sectors and ministries that need to coordinate and align among themselves to reach a suitable roadmap towards NZE. As different sectors and ministries come with their own objectives, there is the challenge of conflicting interests that may lead to delays in formulating the appropriate regulations and policies to guide the transition. Planning for the just element of the energy transition also presents challenges, as considering the social aspect of economic development requires policymakers to find a balance between economic development and people's welfare in planning.

Dialogue between relevant sectors and ministries should be conducted in a regular manner to facilitate their alignment. Formal channels for cooperation can accelerate dialogue and reaching agreements towards NZE strategies.

6.3.6 Negative perceptions towards nuclear power

While nuclear has been considered a viable technical alternative to fossil fuels as a complement to other NRE, its utilization remains controversial. Social acceptance remains low due to perceived risks, leading to limited international financing available for it.

Indonesia should be wary of relying too much on nuclear power to drive its decarbonization efforts, as the potential failure of its deployment due to lack of social, political, or financial support may jeopardize Indonesia's NZE objective. At the same time, social acceptance can be garnered through effective communication of the potential impact of nuclear power on energy security and of responsible management of waste, backed by evidence from project developers.

6.3.7 Just transition socio-economic and distributional risks

A just energy transition ensures that no one is left behind during Indonesia's transition to NZE. The level of transformation of the energy sector required to achieve this NZE will create multiple opportunities for job creation in new industries and emerging business models. At the same time, an increased focus on the deployment of NRE as a shift from investing in fossil fuel generation will potentially lead to negative socio-economic impacts, which need to be properly assessed and managed. The Government of Indonesia is fully committed to ensure people impacted by the transition are properly supported. This implies establishing the proper institutionalization of just transition, assignment of responsibilities, developing internal technical capabilities, and financing.

Strategies taken should consider their distributional and socio-economic impacts. Any potential energy price increase is to be analyzed with a focus on understanding how it can impact industry competitiveness and domestic users. A special attention will be paid to the impacts on low-income families, other vulnerable groups of the society, and how it can be detrimental from a gender perspective.

Strategies related to workers in the fossil fuel industry and related businesses will ensure their future employability and proper compensation when appropriated. Retraining and reskilling programs will support their employability. While NRE deployment will create new opportunities, there may be specific fossil fuel-dependent provinces and regencies that may experience negative impacts on jobs and on the community. New safety nets and support social structures will be timely developed.

Many demand-side measures that call for a consumer shift towards energy efficient products can introduce distributional impacts to the population. While energy efficient products—such as appliances and electric vehicles—present opportunities for long-term energy savings, they tend to have high upfront costs, presenting a significant barrier to lower-income households. With these households unable to afford energy efficient appliances, they may end up spending a greater percentage of their incomes towards electricity. In addition, if policy is passed towards the sale of more efficient appliances, some households may not be able to obtain them at all if costs remain high, thereby impacting their quality of life. A similar case can be observed with electric vehicles, whose high upfront costs may impede mobility, as well as affect livelihoods in the case of transport operators who have relied on internal combustion engine vehicles.

Meanwhile, biomass utilization can introduce negative socio-economic impacts to the agricultural sector, as well as to local communities. An increase in biomass utilization in power generation through direct combustion or co-firing will require an increase in biomass production in Indonesia. This may have negative impacts on different stakeholders throughout Indonesia, especially in regions such as Sumatra and Kalimantan, where biomass potential is high.

As increased biomass production will require more land, Indonesia should take measures to ensure that land is acquired justly, consulting with local communities and indigenous groups that may occupy the desired lands. Their rights to the land and to the livelihoods it may provide them should be respected and considered in land acquisition processes.

In addition, while increased biomass production is expected to create jobs for farmers and others in related sectors such as transport, Indonesia should ensure that these opportunities are made available to many. Although it is expected for biomass plants to want to source their feedstocks from as few suppliers as possible, potentially those with large capacities, this may neglect small-scale farmers, thereby depriving them of the opportunity to reap the benefits of this new industry.

To effectively address such just transition challenges, policymakers need to be equipped with ample data and modeling to identify who will be impacted and how. Adequate stakeholder engagement will also be key in understanding these impacts better and molding the appropriate strategies and policies to address their needs.

6.4 Investment

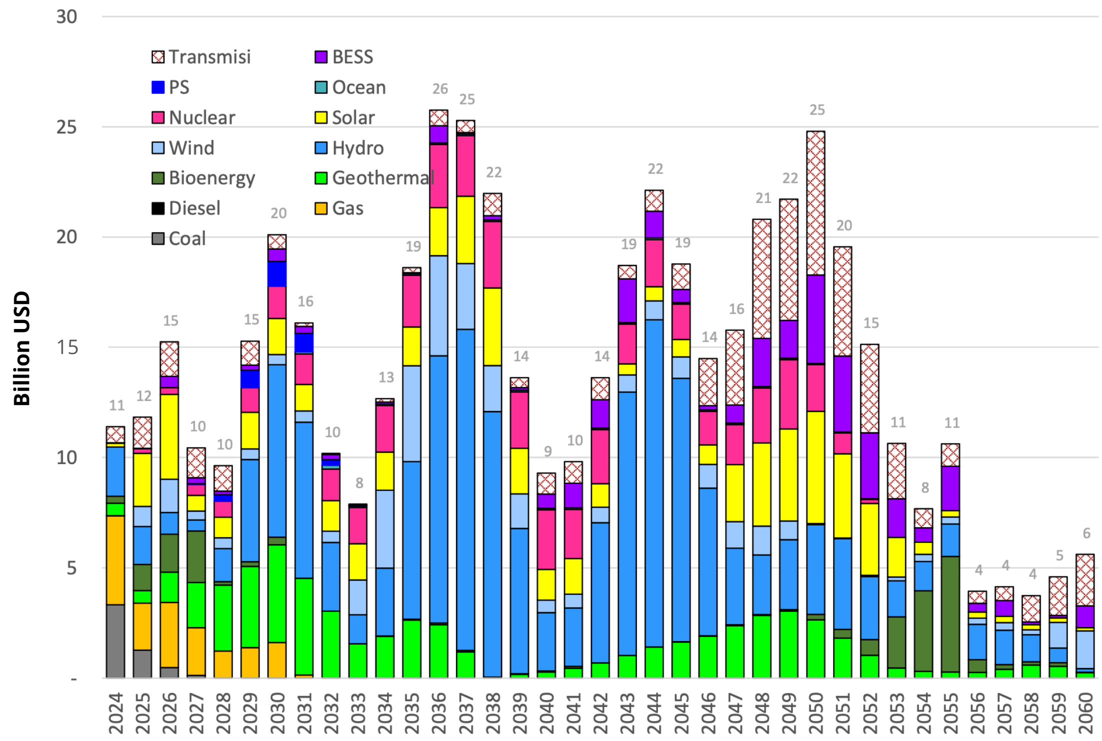
Investment is vital for the energy transition. On the supply side, the investment required for electricity generation and transmission until 2060 is estimated at USD 532 billion, consisting of USD 472 billion for generation and USD 60 billion for transmission (**Figure 6.2**).[11] Based on the modeling results of the power sector, power plants that require large amount of investment include hydro, solar, geothermal, and nuclear PP. The reason is because these power plant types will be developed in a significant number to meet the targets set in the NZE scenario.

On the demand side, the amount of investment is also massive. Energy Transition Partnership (ETP) study together with the Ministry of Energy and Mineral Resources[12] has estimated the energy efficiency investment needed to achieve the Enhanced NDC target. Based on the study, investment needs for energy management in the industrial subsector reached IDR 2.2 trillion. Meanwhile, investment needs to improve energy efficiency in household appliances reached IDR 101 trillion. In addition, to develop a smart grid that supports system reliability, PLN has made an estimated investment of around IDR 25 trillion. Meanwhile, the housing sector also requires considerable investment because each household connection to the city gas network costs around IDR 8 million.

[11] As estimated by MEMR.

[12] ETP. (2023). *Investment Framework for Indonesia's Energy Efficiency Landscape*.

Figure 6.2 Power plant and transmission investment needs



Effective policies are needed to increase participation by the private sector in NZE projects while simultaneously optimizing returns and reducing infrastructure risks. Fiscal and financial policies, market-based instruments, and regulations should be elaborated to boost investment in NZE projects.

Table 6.10 Policy instruments to support investment

Fiscal and Financial	Feed-in tariff
	Feed-in premium
	PPA Tender
	Tax deduction policy
	Grant
	Investment subsidy
	Guarantee
	Carbon tax
Public direct investment	
Market-based	Carbon certificate
	Green certificate
Regulation	Quota/Portfolio standard
	Net metering
	Technology standardization
	Grid preference

6.5 Overall Recommendations

Based on the discussions in this section, the following key considerations and recommendations towards Indonesia's NZE goals are as follow:

- **Carry out policy reform to eliminate barriers to higher NRE penetration.** Existing regulations favor the use of coal and hinder the further development and integration of NRE into Indonesia's energy system. These regulations, which include domestic market obligations and local content requirements, should be reviewed and redesigned to tilt the scales towards the promotion of NRE. This should be accompanied by a reform of PLN procurement processes and a revision of the regulation of PPAs.
- **Strengthen infrastructure for transmission and distribution and for low-carbon alternatives.** Construction of the supergrid to connect Indonesia's major islands can help increase energy security throughout the country. However, it must be further equipped to handle the higher incorporation of NRE into the power system through the upgrade of control centers. Similarly, needed infrastructure should also be constructed to facilitate the shift in consumer behavior, including the development of EV charging stations and the expansion of gas networks. Making access easier can accelerate the uptake of these low-carbon alternatives.
- **Support the development of supply chains for NRE and high EE products.** The capacities of supply chains supporting NRE should be increased. For example, an increase in the utilization of biomass in power generation should be coupled with the provision of ample support to farmers that will grow the feedstock for power plants that will shift towards co-firing. Similarly, the manufacturing industry should be adequately supported to yield high EE products.
- **Push for energy efficiency upstream and downstream.** Energy efficiency can have a significant impact on energy demand and emissions and should be promoted upstream and downstream. Policy should be strengthened to gradually increase the standards for high EE products and operations, including household appliances, passenger vehicles, and cargo vehicles. Labelling should be enforced to help shift manufacturing and consumer practices towards increasingly higher EE products.
- **Plan for implementing pilot projects as soon as feasible.** The NZE success depends on the use of technologies which are new to Indonesia, some of them also incipient regionally and globally. Pilot projects will allow for local technical capacity development, further understanding the viability of use in the local context and confirming their deployment pace planned.
- **Embed just transition in the institutional and regulatory framework and identify socio-economic and distributional impacts of NZE activities.** Just transition should be incorporated into planning in all relevant sectors. Cohesion will be key, so coordination among the relevant sectors and ministries will be

required. An entity that engages different ministries, the private sector, and the workforce can help advance a just transition that is aligned with the country's needs. Alongside this, the socio-economic and distributional impacts of NZE activities should be assessed and mitigated.

- **Promote technological adoption through research and development.** Research and development should be promoted, pushing for collaboration between the industry and research institutions, as well as between domestic and foreign institutions. These can help accelerate the incorporation of the needed technology to facilitate the higher penetration of NRE.
- **Bolster financing through an enabling environment.** An enabling financial environment through policy is needed to unlock private investments in NRE. Capacities of financing institutions should be increased to improve their understanding of Indonesia's NZE goals and activities and thus decrease the risk perception.
- **Promote timely skills transfer programs to equip the workforce with the adequate skills for economic activities towards NZE.** The Indonesian workforce needs to be properly equipped with the adequate skills to work in NZE activities. The proper identification of the skills needed and the subsequent redesign of existing curricula in academic and vocational institutions, as well as training centers for upskilling and reskilling, should be done in a timely manner to prepare the workforce.