Chapter 5

Clean Power for Indonesia: Leading the Way in the Energy Transition

Indri Hapsari

A. Indonesia's Energy Transition Program

The Indonesian government has ambitious plans regarding the Indonesia Energy Transition in 2045. The program includes several important aspects, namely achieving carbon neutrality, meaning that greenhouse gas emissions produced by the energy sector and other sectors will be offset by efforts to reduce emissions and absorb carbon. The government focuses on developing clean energy sources, such as solar, wind, hydro, and biomass. This effort involves the construction of power plants based on renewable energy with significant capacity to reduce dependence on fossil energy. As for the fossil energy being used, the government is pushing for energy efficiency in all sectors, including industry, transportation, and buildings. These steps include

I. Hapsari
University of Surabaya, e-mail: indri@staff.ubaya.ac.id

Hapsari, I. (2023). Clean power for Indonesia: Leading the way in the energy transition. In A. Kiswantono & R. M. Shoedarto (Eds.), *Indonesia's energy transition preparedness framework towards 2045* (147–175). BRIN Publishing. DOI: 10.55981/brin.892.c815,
E-ISBN: 978-623-8372-41-6

using more efficient energy technologies, setting energy efficiency standards, and public awareness campaigns on wise energy use. In addition, the government plans to accelerate transportation electrification by promoting electric vehicles and developing the necessary charging infrastructure.

There are efforts to manage limited natural resources sustainably, including forest management, developing renewable energy in remote areas, and reducing environmental pollution. For this reason, it is necessary to open international cooperation to achieve the energy transition goal. For example, in China, they successfully use an evolutionary game model between electric power companies and solar investment companies under the background of energy reform in rural areas (Wenlong & Yunfeng, 2023). This involves cooperating with other countries, international organizations, and the private sector in technology development, knowledge exchange, and investment in the clean energy sector.

Amid Indonesia's vibrant energy scene, a multitude of energy suppliers, both public and private, intricately shape the nation's energy trajectory. Key among these players is PT PLN (Persero), the state electricity provider charged with distributing power nationwide. National energy giant PT Pertamina (Persero) contributes significantly, focusing on essential fossil fuels like oil, gas, and coal. Global players such as Chevron Indonesia actively enriches the oil and gas sector with international expertise. PT Adaro Energy Tbk stands out in coal mining, pivotal in coal production and marketing. This diverse energy landscape extends beyond these names, with various others actively engaging to drive Indonesia's energy advancement. At the forefront is Tangguh LNG (Liquid Natural Gas), managed by British Petroleum Berau Ltd. This LNG venture is converting natural gas into a liquid form for practicality and commercial viability. As Indonesia charts its energy course toward diversification and sustainability, these collaborations and innovations underscore the nation's commitment to a greener future.

As energy supply companies in Indonesia, they must declare themselves clean power companies. This will support the government's plan to implement the Indonesia Energy Transition program in 2045. Indonesia can significantly reduce greenhouse gas emissions, increase energy sustainability, create jobs, and improve people's quality of life when these companies turn into clean power companies.

The benefits of operating as clean power companies are they can adopt environmentally friendly technologies and practices to increase operational efficiency, reduce the consumption of resources such as energy and water, and optimize the use of raw materials. These benefits will reduce long-term energy costs, bearing in mind that energy from fossil sources can experience price fluctuations. Clean power companies will also attract consumers who are increasingly aware of environmental issues and get better support from the government and society. Another benefit is an increase in the reputation and image of the companies, and it is easier to influence employees to be more committed. These benefits can encourage innovation and creativity in finding sustainable solutions. Companies can have better relationships with related parties such as the government, the community, and non-governmental organizations. In the long run, they will positively affect the environment and society. Thus, clean power company is the main pillar to achieve a sustainable and environmentally friendly energy transition in Indonesia 2045.

This chapter delves into the concept of a clean power company, explaining its significance as an entity committed to environmentally sustainable energy practices. Indonesia's energy landscape is multifaceted, encompassing various sources, from conventional fossil fuels to burgeoning renewables. The imperative to transition from fossil fuels to renewable energy sources is imperative, given the pressing global concern of climate change. This transition, set to materialize by 2045, necessitates comprehensive preparations. Notably, the chapter outlines twelve strategic pathways to achieve the expected status of a clean power company, encompassing large-scale renewable energy projects, novel energy technologies like biomass, ammonia,

and hydrogen co-firing, and infrastructural advancements such as inter-island transmission and smart grids. As Indonesia embarks on this transformative journey, it must confront various challenges, including technical intricacies and policy complexities, while capitalizing on emerging opportunities in the sustainable energy sector. The chapter concludes by emphasizing the importance of an integrated and collaborative approach in realizing Indonesia's vision of becoming a clean power company and contributing to global environmental preservation.

B. Clean Power Company

Clean power companies focus on the production, procurement, and distribution of clean or renewable energy. The definition of a clean power company can vary, but fundamentally, these companies are committed to reducing environmental impact and assisting in the transition to cleaner and more sustainable energy.

Clean power companies use renewable energy sources, such as solar, wind, hydro, geothermal, or biomass energy. They also apply environmentally friendly technology and have a production process that is more efficient in producing energy. The main goal of clean power companies is to reduce greenhouse gas emissions and reduce dependence on limited fossil fuels that negatively impact the environment. Research by Jiaojiao and Feng (2022) on the carbon emission reduction efficiency and potential for clean energy power in 58 countries underscores the importance of clean energy companies. Clean energy companies can also be integrated energy solutions providers, including developing infrastructure and technology for energy storage, intelligent grid management, and digital technologies to monitor and optimize energy use.

Clean power companies have an essential role in reducing air pollution, maintaining environmental quality, and creating a more sustainable energy system. Through their efforts, clean power companies contribute to meeting society's energy needs in ways that

are environmentally friendly, sustainable and have the potential to generate long-term benefits for people and our planet.

Investing in clean energy sources must precede efforts that companies can make to become clean power companies. They can invest heavily in constructing and operating power plants using clean energy sources, such as solar, wind, hydro, or biomass. Companies might also build infrastructure that supports clean energy, including building environmentally friendly power grids and using efficient grid technology. For example, they optimized power supply system scheduling and clean energy application to make the process more efficient (Ling et al., 2022). The companies continue to conduct research and development to establish more efficient and economical clean energy technologies. They adopt digital and intelligent technologies for more effective energy management and monitoring. An example is the research of Kat (2023), who uses a techno-economic analysis with a high-resolution power expansion model to support the clean energy transition in the Turkish power sector. Another is from Tao et al. (2023), who uses the same method to examine and optimize a combined solar power and heating plant to achieve a clean energy conversion plant.

Companies need to focus on increasing energy efficiency in producing, distributing, and using electrical energy. They use more efficient technologies to optimize energy use and reduce waste. Companies also need to implement measures to reduce emissions of greenhouse gases such as carbon dioxide (CO_2). They can use carbon capture technologies and cleaner fuels and transparently monitor and report emissions.

Regarding human resources, the companies play a role in educating the public about the importance of clean energy and its positive environmental impact. They held an information campaign and invited the public to adopt environmentally friendly energy practices. Collaboration is needed with related parties such as the government, academic institutions, and environmental organizations to create policies and programs that support clean energy development. They

participate in global and regional initiatives to tackle climate change. Climate change has become the concern of Lund's (2015) research using clean energy systems as mainstream energy options.

Companies need to be involved in developing renewable energy projects such as large-scale solar or wind power plants. They invest in these projects to increase clean energy capacity in Indonesia. Compliance with regulations and environmental standards must become part of operational integrity by complying with applicable environmental provisions. There is a long-term commitment to become clean power companies. They continue to evaluate and improve to ensure their operations comply with clean and sustainable energy principles. Through these efforts, electricity supply companies can contribute significantly to accelerating the energy transition towards a cleaner and more sustainable one.

C. Energy in Indonesia

Energy in Indonesia comes from rich natural resources. Indonesia has abundant natural resources, including reserves of oil, gas, coal, and renewable energy potentials, such as solar energy, wind energy, hydro energy, and biomass. These rich natural resources are essential for meeting the country's energy needs. Despite having great renewable energy potential, Indonesia is still heavily dependent on fossil fuels, especially oil, natural gas, and coal. The country's energy sector is dominated by fossil-fuel power generation and transportation that uses fossil fuels. Dependence on fossil fuels creates challenges regarding greenhouse gas emissions and energy security. This energy security is needed to support rapid economic growth, which impacts increasing energy demand. The ever-increasing demand for energy creates pressure on the existing energy infrastructure and natural resources.

Despite significant efforts to increase access to energy in Indonesia, there are challenges in providing adequate access to power for the entire population, especially in remote and inland areas. Not to mention the global problems regarding climate change and environmental sustainability because of greenhouse gas emissions.

The impact of climate change on the energy sector is in the form of a decrease in the availability of energy resources. Climate change can result in changes in rainfall patterns and temperature, which in turn can affect the availability of energy resources such as water and hydroelectric energy. Decreased rainfall and drought can reduce hydroelectric power generation potential, while rising temperatures can reduce the efficiency of fossil fuel power plants. The result is the vulnerability of energy infrastructure. The increase in intensity of extreme weather, such as floods, storms, and heat waves, can cause disruptions to the energy supply, damage to transmission and distribution networks, and risks of fire or damage to energy facilities. Such circumstances can increase energy demand due to higher temperatures and more significant cooling requirements. This can lead to an increase in the use of electrical energy, especially for air conditioning systems, which can increase the pressure on power generation capacity.

Climate change can also increase the risk of natural disasters, such as floods, landslides, and strong winds. This can disrupt the energy supply, including power plants and supporting infrastructure, and disrupt energy distribution to the public. As a result, adaptation and mitigation are needed to reduce greenhouse gas emissions. This includes developing renewable energy, increasing energy efficiency, reducing power generation and transportation emissions, and managing energy resources more sustainably.

In dealing with the impact of climate change on the energy sector, the Indonesian government has taken steps to develop sustainable policies and strategies. This includes increasing the use of renewable energy, reducing emissions, increasing energy efficiency, and increasing adaptation to climate change in the planning and management of the energy sector.

D. Energy Transition

The energy transition in Indonesia refers to the change in the country's energy system from energy sources that are predominantly derived

from fossil fuels (such as oil, gas, and coal) to energy sources that are more sustainable and environmentally friendly, including renewable energy (such as solar, wind, water, biomass) and other clean energy technologies. This transition is essential because it can reduce negative environmental impacts. By switching to renewable energy sources and clean technologies, Indonesia can reduce greenhouse gas emissions, air pollution, and other environmental hazard.

Energy transition will create a diversification of energy sources, which might reduce the dependence on fossil fuels, thus decreasing the risk caused by fluctuations in price and supply. This can help achieve energy independence. By relying on abundant domestic energy sources, such as sunlight, wind, and biomass, the country can reduce its dependence on energy imports and improve energy security in the long term. Energy transition can also provide significant economic opportunities for Indonesia. Development of the renewable energy sector can create new jobs, drive sustainable industry growth, and increase investment in clean energy technologies. There has been an increase in people's access to affordable and sustainable energy. Renewable energy sources, such as solar and mini-hydropower plants, can be a solution for remote areas that are difficult to reach by conventional electricity grids.

To achieve a successful energy transition, collaboration between the government, the private sector, and society is required. Steps such as supporting energy policies, adequate infrastructure development, reducing barriers to investment, and public education on the importance of sustainable energy need to be taken to encourage an effective and sustainable energy transition in Indonesia.

E. Preparation for Energy Transition in 2045

Policies and regulations supporting Indonesia's energy transition are essential in directing and driving changes toward a more sustainable energy system. Several policies and rules that have been implemented in Indonesia are as follows.

1) **National Energy General Plan** (*Rencana Umum Energi Nasional* - RUEN). RUEN is a strategic planning document that regulates the direction of energy policy in Indonesia. RUEN aims to integrate sustainable energy policies, reduce dependence on fossil fuels, improve energy efficiency, and develop renewable energy resources.
2) **Law on New and Renewable Energy** (*Energi Baru dan Terbarukan* - EBT). The EBT Law is the legal basis for developing new and renewable energy in Indonesia. The law encourages investment in renewable power generation, including increased use of wind, solar, hydro, and biomass energy.
3) **National Energy Policy** (*Kebijakan Energi Nasional* - KEN). KEN is established to regulate sustainable energy policies and strategies in Indonesia. KEN emphasizes the development of renewable energy, energy efficiency, diversification, and reduction of greenhouse gas emissions.
4) **National Action Plan for Reducing Greenhouse Gas Emissions** (*Rencana Aksi Nasional Pengurangan Emisi Gas Rumah Kaca* - RAN-GRK). RAN-GRK is a policy framework for reducing greenhouse gas emissions in Indonesia. This plan covers the energy and other sectors and promotes clean energy, energy saving, and emission management.
5) **Local Government Policies**. Local governments also have an essential role in supporting the energy transition. Several regions have issued policies and regulations that support the development of renewable energy, such as setting targets for renewable energy, fiscal incentives, and permits that facilitate investment in the renewable energy sector.

In addition to these policies and regulations, there are also fiscal incentives, supporting permits, and cooperation with the private sector to encourage investment and development of clean energy technologies. This aims to create an enabling environment for a more sustainable energy transition in Indonesia.

How, then, clean power companies can be developed? These are the steps.

1) Development of renewable energy sources

The development of renewable energy sources in Indonesia has an essential role in reducing dependence on fossil fuels, reducing greenhouse gas emissions, and increasing the sustainability of the energy sector. In the development of renewable energy sources, things that need to be considered are the potential of natural resources. Indonesia has great potential to develop renewable energy, such as abundant sunshine, strong winds, and abundant geothermal resources. Optimum utilization of this potential can become the basis for developing renewable energy sources in Indonesia.

Some policies and regulations that support renewable energy development need to be implemented and strengthened. These include fiscal incentives, facilitating licensing, competitive electricity rates, and legal certainty for investment in the renewable energy sector. The development of renewable energy sources also requires adequate electricity infrastructure and networks. Building a solid and efficient grid and providing equitable access to electricity throughout the region is essential to support the use of renewable energy.

Capacity building in research, development, and application of renewable energy technologies needs attention. The result of efficient and affordable technology and increased skills and knowledge in the field of renewable energy will accelerate the growth of this sector in Indonesia. Cooperation between government, private industry, academia, and civil society is also needed. Good collaboration can result in innovation, adequate financing, and technology transfer to drive the growth of the renewable energy sector.

Developing renewable energy sources in Indonesia brings environmental benefits and can provide economic opportunities, create jobs, and increase access to sustainable energy for the whole society. Therefore, constant attention and commitment to developing renewable energy sources are essential for Indonesia's sustainable energy future.

2) Increasing the efficiency of energy use

Energy efficiency and energy conservation play an essential role in reducing energy consumption and increasing the sustainability of Indonesia's energy sector. Energy efficiency involves the more efficient and effective use of energy, in which greater energy output is produced using less energy. This helps reduce energy consumption, operating costs, and greenhouse gas emissions that contribute to climate change. The Indonesian Government has implemented policies and regulations to promote energy efficiency in various sectors. These include energy efficiency standards for household and industrial appliances, incentive programs for the efficient use of technology, and energy audits to identify opportunities for energy savings.

The energy conservation program involves ways to reduce energy consumption through wise use. This includes reducing energy waste, selecting efficient equipment, optimal temperature settings, using energy-efficient lighting, and education for better energy awareness. Implementing energy efficiency technologies and practices in the industrial sector can reduce energy consumption and operating costs and increase productivity and competitiveness. Another way is to pay attention to building designs that use efficient energy, good thermal insulation, efficient lighting, and cooling systems, and effective energy management can reduce energy consumption and optimize resource use. Energy efficiency and energy conservation provide multiple benefits, namely reducing energy consumption and operational costs, as well as having a positive impact on the environment. By adopting energy efficiency and conservation practices, Indonesia can achieve its goal of reducing greenhouse gas emissions and safeguarding the sustainability of the energy sector in the future.

As an example of increasing the efficiency of energy use, British Petroleum (BP) stands as one of the largest foreign investors in Indonesia, boasting a 70-year operational history and unwavering dedication to the country's energy needs (British Petroleum, 2018). Primarily engaged in oil and gas exploration and production, focusing on the Tangguh LNG refinery, BP's commitment extends to

downstream and petrochemical industries. With a strategic emphasis on growing gas and oil in the upstream sector, BP has prioritized increasing efficiency in production. One noteworthy initiative is the introduction of oil tankers equipped with more efficient engines and advanced energy management systems. This strategic direction aligns with the fact that gas combustion produces significantly lower CO_2 emissions than coal, contributing to emissions reduction as evidenced in the US. The highlight is the synergy between gas and renewables, where gas serves as a low-carbon backup for the intermittency of renewable energy sources. Beyond power generation, gas is crucial for heating homes, businesses, and high-temperature industrial processes. BP's role spans gas exploration, production, transportation, storage, and sale, positioning the company to thrive in a burgeoning and competitive global gas market. BP's involvement also extends to environmental sustainability, addressing methane emissions to ensure the longevity of gas as a lower-carbon resource.

Tangguh LNG represents the culmination of a collaborative effort across six integrated gas fields within the Wiriagar, Berau, and Muturi Cooperation Contract Areas in the Gulf of Bintuni, West Papua. Managed by BP Berau Ltd., Tangguh LNG commenced operations in 2009. BP's process involves converting natural gas into liquid form for more efficient domestic transportation and international export, enabling regional countries to transition away from coal. Some of the gas supply is directed to China, while another share is exported to South Korea.

3) Energy infrastructure development

Environmentally friendly energy infrastructure is crucial in realizing Indonesia's sustainable energy transition. Some of the environmentally friendly energy infrastructures in Indonesia include renewable power plants. Renewable energy infrastructure, such as solar, wind, and hydropower, is a crucial focus for reducing dependence on fossil energy sources contributing to greenhouse gas emissions. The construction of renewable power plants in various regions of Indonesia is an essential step towards achieving the renewable energy target.

Related to infrastructure, it is necessary to build an efficient transmission and distribution network. Efficient and sophisticated electricity transmission and distribution network infrastructure is needed to support the widespread deployment of renewable energy. Developing a strong and integrated network will ensure stable and affordable energy distribution to various regions in Indonesia. Energy storage infrastructure, such as batteries and thermal storage systems, allows energy storage from renewable sources to be used when needed. This helps maintain a stable and reliable supply of energy, especially from volatile energy sources such as solar and wind. Environmentally friendly energy infrastructure plays an essential role in achieving Indonesia's energy transition goals and environmental protection. With suitable investment and infrastructure development, Indonesia can accelerate its transformation towards a cleaner, more sustainable, and more competitive energy system.

Sustainable transport infrastructure, such as an electrified rail network, an efficient mass transit network, and electric vehicles, plays an essential role in reducing air pollution and greenhouse gas emissions from the transport sector. By building infrastructure that supports sustainable transport, Indonesia can reduce its dependence on fossil fuels and promote more environmentally friendly mobility. The development of research and development infrastructure, as well as production and distribution facilities for new and innovative energy technologies, will drive the growth of the sustainable energy sector in Indonesia. This infrastructure supports the development and adoption of new technologies that are more efficient and environmentally friendly.

4) Research and technological innovation

Indonesia's energy technology research and innovation are critical in driving a sustainable energy transition. Establishing an energy research center that focuses on developing renewable energy technologies and energy efficiency is necessary. These centers conduct research and development to improve Indonesia's energy sources' performance, efficiency, and sustainability.

The research center can become a forum for collaboration with international research institutions and other countries to share knowledge and technology in the energy sector. Energy technology research and innovation can be accelerated through this collaboration, and the results can be implemented more effectively. Of course, funding support is needed for energy technology research and innovation through various programs and institutions. Programs such as sustainable energy research, renewable energy technology development, and clean energy initiatives support research and development of technologies that have the potential to reduce emissions and improve energy efficiency. Research from Zhang et al. (2020) does innovation in the wind power sector, while research from Lamichaney et al. (2020) has innovation in combine hydrogen power and fuel cells to clean energy technologies, while Jahangiri et al. (2019) develop clean hybrid solar-wind power plants in Iran.

Increasing knowledge and skills in the energy sector through education and training is essential in encouraging research and innovation. Universities and educational institutions in Indonesia organize programs focusing on renewable energy and technology to produce a skilled and qualified workforce in this field. There are also incubation and acceleration initiatives supporting energy technology development in Indonesia. These programs help start-ups and emerging energy companies to develop and accelerate the potential implementation of energy technology innovations.

With sustainable energy technology research and innovation in Indonesia, solutions and technological developments that are efficient, environmentally friendly, and competitive can be created. This research and innovation will help Indonesia achieve its more sustainable energy transition target and reduce its dependence on fossil energy sources.

5) Diversification of energy sources

Diversification of energy sources in the context of the energy transition for Indonesia refers to efforts to reduce dependence on one particular

type of energy source and increase the use of various energy sources that are more sustainable and environmentally friendly. This is done by replacing or reducing the dominant use of fossil fuels (such as oil, gas, and coal) with cleaner, renewable alternative of energy sources (such as solar, wind, hydro, biomass and nuclear geothermal energy).

Diversification of energy sources has several significant benefits for Indonesia.

a) It reduces the risk of high dependence on imported fossil fuels, reducing vulnerability to global prices and supply fluctuations.
b) By leveraging abundant domestic energy sources, Indonesia can improve energy sustainability and reduce negative environmental impacts caused by the burning of fossil fuels.
c) Diversification of energy sources can create investment opportunities and new jobs in the renewable energy sector and other clean energy technologies, which have the potential to increase economic growth and strengthen the national energy sector.

In the energy transition context, diversification of energy sources plays an essential role in reducing greenhouse gas emissions, tackling climate change, increasing energy efficiency, and achieving sustainable development goals. Supporting policies and incentives are needed to encourage the diversification of energy sources, development of adequate infrastructure, investment in energy technology research and development, and cooperation between the government, the private sector, and the community. It triggered Buntaine and Pizer (2015) to find methods to encourage clean energy investment in developing countries.

The types of power renewables technologies to support Indonesia's economy are:

a) Solar Power:
    (1) Utilization of sunlight to produce electrical energy.
    (2) Installing solar panels on building roofs or open land.

(3) Great potential in Indonesia due to abundant sunshine throughout the year.

b) Wind Power:
   (1) Utilization of wind energy to generate electrical energy.
   (2) Construction of wind turbines in areas with strong winds.
   (3) Great potential in several regions of Indonesia such as Sulawesi, Nusa Tenggara, and Maluku.

c) Water Power (Hydropower):
   (1) Utilization of flowing water or waterfalls to generate electrical energy.
   (2) Construction of hydroelectric power plant (PLTA) in big rivers or mountainous areas.
   (3) Great potential in Indonesia, with many rivers and favorable topographical conditions.

d) Geothermal Energy (Geothermal):
   (1) Utilization of geothermal energy to generate electricity.
   (2) Construction of geothermal power plants in areas with high geothermal potential, such as around Sukabumi Temple and Ijen Crater.

e) Biomass:
   (1) Utilization of biomass such as agricultural waste, industrial waste, and forest biomass to produce energy.
   (2) Construction of a bioenergy factory to convert biomass into electricity or fuel.

f) Biogas:
   (1) Utilization of methane gas from organic waste such as animal manure or agricultural waste.
   (2) The use of biogas as an energy source for cooking or generating electricity.

g) Ocean Wave Energy:
   (1) Utilization of energy from ocean waves to produce electrical energy.
   (2) Construction of wave power plants on beaches with high wave potential.

h) Tidal Energy:
   (1) Utilization of tidal energy to produce electricity.
   (2) Construction of tidal power plants in areas with significant tidal differences.

6) Sustainability and energy security

Energy sustainability and security in the context of the energy transition for Indonesia refers to efforts to ensure a sustainable, reliable, and sustainable supply of energy in the long term while reducing negative impacts on the environment and achieving sustainable development goals.

Energy sustainability relates to using energy resources that can be maintained long-term without depleting or damaging the natural environment and considering social and economic aspects. This involves developing and utilizing renewable energy sources like solar, wind, hydro, biomass, nuclear, and geothermal energy. By using renewable energy sources, Indonesia can reduce its dependence on limited fossil fuels and contribute to reducing greenhouse gas emissions.

Energy security relates to a country's ability to deal with fluctuations in energy supply and ensure adequate energy availability under various conditions, including crises or supply disruptions. To achieve energy security, Indonesia needs to have sufficient diversification of energy sources, reliable energy infrastructure, responsive energy policies, and readiness to face changing global conditions.

In the energy transition context, sustainability and energy security are interrelated and mutually supportive. By developing sustainable energy sources, Indonesia can achieve long-term energy sustainability and reduce its vulnerability to fluctuations in energy

prices and supplies. In addition, strong energy security will ensure a reliable and sustainable supply of energy during the transition to a cleaner and more sustainable energy system.

7) The application of digital technology

The application of digital technology has become a key factor in efficient and sustainable energy management and monitoring. Research and technological innovation in terms of the application of digital technology in the energy industry aim to optimize energy use, increase operational efficiency, and reduce environmental impact. In this context, digital technology involves using sensors, monitoring systems, data analysis, artificial intelligence, and other digital platforms to collect, analyze and optimize energy data.

In the energy industry, applying digital technology can assist in more effective management and monitoring of energy resources, such as electricity, gas, and water. Digital technology can be used to monitor energy consumption in real-time, detect energy anomalies or leaks, and provide accurate information for better decision-making regarding energy use. In addition, research and technological innovation also focus on developing integrated energy management systems in which digital technologies are used to link various energy components, including energy production, storage, and consumption. This enables more efficient and sustainable management of the energy system.

The application of digital technology in energy management and monitoring provides significant benefits, including energy savings, reduced operational costs, reduced greenhouse gas emissions, and increased reliability of energy supply. In addition, digital technology can also drive the adoption of renewable energy and facilitate better integration between renewable energy sources and the electricity grid.

8) Use of nuclear power

There are several reasons why nuclear power is included in clean power energy. The first is that nuclear power plants have high efficiency in producing electrical energy. Nuclear reactors can convert most atomic energy into electrical energy with relatively low losses.

This makes it more efficient than conventional energy sources such as fossil fuel power plants. The process of generating nuclear power uses nuclear fuel, such as uranium. These nuclear fuels have a very high energy density, meaning that the fuel needed to produce the same energy is much less than fossil fuels such as coal or oil. This reduces fuel procurement costs and dependence on unstable fuel supplies.

Nuclear power plants have relatively low operating costs. After a nuclear power plant is built, its operating prices are more stable and predictable than a fossil fuel power plant. This is associated with lower fuel requirements and lower maintenance requirements. One of the main advantages of nuclear power plants is that no CO_2 emissions are produced in the electricity generation process. Nuclear power produces no greenhouse gas emissions, essential in fighting climate change and achieving zero-emission targets. Sadekin et al. (2019) reviewed nuclear power as the foundation of a clean energy future.

9) Battery storage usage

Battery storage allows power plants to store energy generated in times of overproduction, such as from renewable energy sources, and use it when energy demand is higher. Thus, battery storage helps improve energy use efficiency and optimizes the utilization of available energy sources. Battery storage systems can help overcome the challenge of unpredictable fluctuations in renewable energy sources, such as solar and wind. By storing energy from these sources during overproduction, battery storage allows for more stable and reliable use of renewable energy, independent of weather conditions.

Using battery storage can reduce the need for fossil fuel power plants as a backup source. This helps reduce greenhouse gas emissions and air pollution generated by fossil fuel power plants, achieving the zero emissions target. Battery storage can reduce the operating costs of a power generation system by optimizing energy use, avoiding purchasing energy from more expensive sources, and reducing maintenance costs. Thus, battery storage can help maintain lower running costs in the long term. Battery storage systems are also adaptable to

different power requirements and can be expanded as energy demand grows. This provides flexibility in meeting diverse energy needs and reduces the risks associated with unstable energy supplies.

10) Power with Carbon Capture and Storage (CCS) technology

CCS enables capturing and storing CO_2 from power generation and industrial processes. By keeping the CO_2 it produces, CCS helps reduce greenhouse gas emissions to the atmosphere, thereby supporting the goal of zero-emission. CCS allows using existing fossil fuels, such as coal or natural gas, without producing significant CO_2 emissions. In doing so, CCS maintains the potential use of existing energy resources while reducing environmental impact. As a result, CCS can help keep the stability of energy supplies from fossil fuel sources which are still the primary energy source in several countries. By maintaining the responsible use of fossil fuels through the capture and storage of CO_2, CCS helps prevent fluctuations in the energy supply that can affect economic and industrial stability.

CCS can provide new industry development opportunities, such as CO_2 capture and storage technology and related infrastructure development. This can create new jobs and stimulate economic growth. In the long term, CCS can help reduce operational costs by optimizing existing fossil fuels and reducing carbon emission offset costs. With technology development and more experience, the cost of implementing CCS will be lower.

11) Power with the use of hydrogen, ammonia, and biomass co-firing

Hydrogen, ammonia, and biomass are energy sources that can be produced cleanly and sustainably. When used as fuel in electricity generation, they make little or no greenhouse gas emissions. This supports efforts to achieve zero emissions. Combining all three in power generation can reduce dependence on limited fossil fuels and expand the diversification of energy sources. This can help maintain the stability of the energy supply and reduce the risk of fluctuations in fuel prices.

Along with technological advances and increased production scale, production costs and the use of hydrogen, ammonia, and biomass can become more efficient and affordable. In addition, the potential for utilizing waste biomass as fuel can reduce the cost of the required raw materials. SPX Flow Technology (2011) researched biomass energy production systems to do self-cleaning filters. In some cases, power with hydrogen, ammonia, and biomass co-firing can be used in existing infrastructure, such as coal-fired power plants that can be converted to take advantage of this clean fuel. This can reduce the cost of investing in new infrastructure, and using hydrogen, ammonia, and biomass as fuel can create opportunities for developing new industries and jobs in the renewable energy sector. This can drive economic growth and technological innovation.

12) Use of inter-island transmission

Inter-island transmission enables energy transfer from islands with abundant renewable energy potential to other islands in need. This allows the utilization of renewable energy sources, such as solar, wind, or hydro energy, which may be more abundant on some islands than others. Maximizing the utilization of renewable energy sources can achieve zero emissions. The inter-island transmission also enables energy system diversification by combining energy supplies from different sources and islands. Inter-island interconnection can reduce dependence on one energy source or island. This can help maintain the stability of the energy supply and reduce the risk of fluctuations in fuel prices.

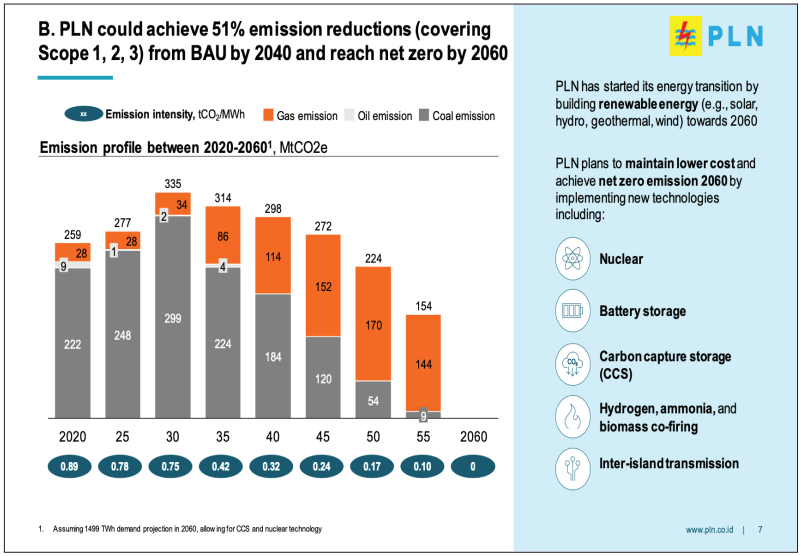
With inter-island interconnections, power plants can be built on a larger scale. These economies of scale can result in higher efficiencies in energy production, reducing overall production costs and ultimately keeping costs lower for consumers. In some cases, inter-island transmission can take advantage of existing electrical infrastructure on the islands. This can reduce the cost of investing in new infrastructure and optimally use existing assets. Inter-island transmission can create new economic and industrial development opportunities on different

islands. Developing interconnection infrastructure and using renewable energy sources can create jobs, increase investment, and promote economic growth in remote areas.

To provide a detailed example of the efforts carried out by a clean power company, PT PLN (Persero) could become an example based on the presentation made by this company at the State-Owned Enterprises (SOE) International Conference (Wahi, 2022). PLN is a state-owned electricity company in Indonesia and plays a vital role in developing renewable energy sources in the country. PLN has taken necessary steps towards achieving zero emissions by 2060 and has made significant progress through its five activities. *First*, PLN has built a large-scale renewable energy (RE) with an energy storage system on a battery. In 2021–2022, PLN will operate 900 MW of capacity from renewable energy. Furthermore, PLN has launched two new sub-holdings Generation Companies (Genco) to accelerate renewable energy development. *Second*, PLN has studied and implemented new energy (biomass, ammonia, hydrogen, co-firing, and nuclear) and new carbon capture, utilization, and storage (CCUS) technologies. Thirty-three locations have implemented co-firing of biomass, and trials of co-firing hydrogen and ammonia were carried out at PLTDG[1] Pesanggaran Bali (H_2) and PLTU[2] Gresik (ammonia). There are also five MoUs signed for developing green hydrogen and CCUS.

[1] Diesel and gas power plant (*pembangkit listrik tenaga diesel dan gas*)

[2] Electric steam power plant (*pembangkit listrik tenaga uap*)



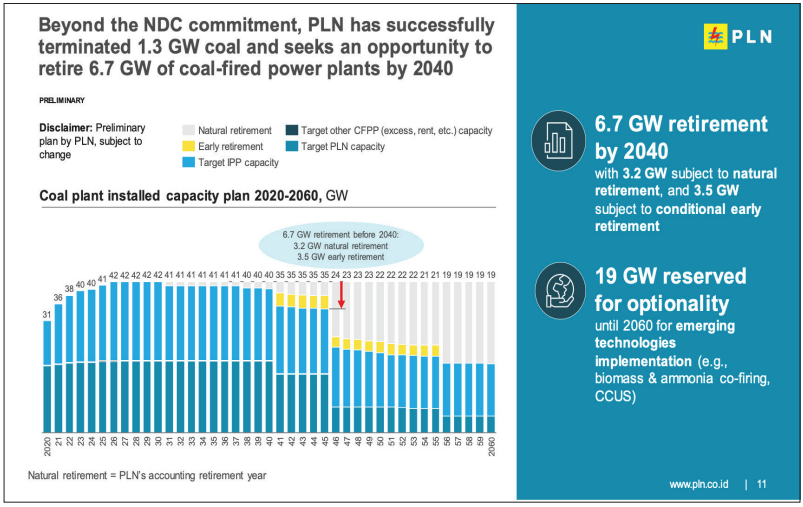
Source: PT PLN (2023)

Figure 5.1 PLN's Emission Profile 2020–2060

Figure 5.1 shows PLN's plan to achieve a 51% reduction in emissions by 2040 and aims to reach zero by 2060. The following is a graph of the emission profile between 2020 and 2060 in units of million metric tons of CO_2e. There was an increase in emissions from gas, while emissions from coal and oil decreased. Emissions from oil were initially low, followed by gas emissions, and coal emissions were highest. In units of tCO_2/MWh, the emission intensity is initially 0.89. By 2060, when the emission intensity reaches zero, there will be no more gas, oil, or coal emissions.

Third, PLN supports decarbonization in the upstream sector, such as launching a battery exchange business with BRIN, Grab, and VIAR, launched in 20 locations in 2022. PLN has also established 15 partnerships with EV4W (low speed), EV2W (high speed), and Grab to encourage the growth of the electric vehicle ecosystem. PLN successfully sold 1 TWh Renewable Energy Certificates (REC) in 2022

and established 8 MW of green energy as a service to Multi Bintang Indonesia. *Fourth*, PLN focuses on expanding interconnections and developing smart grids. Four islands have implemented smart micro grids with photovoltaic solar panels, batteries, hybrid diesel, and energy management systems in Nusa Penida, Semau, Selayar, and Bilicinge. *Fifth*, PLN has initiated efforts to reduce the use of fossil fuels through the early retirement of coal power plants and de-dieselization. The 1.3 MW coal power plant project (Jawa-3 CFPP coal-fired) has been successfully terminated. The early retirement roadmap has been arranged with the Ministry of Energy and Mineral Resources (ESDM) according to Indonesia's energy transition plan. Meanwhile, 46 MWp solar panels with the purchase of 100 MWh batteries are underway to replace diesel power plants in 36 locations.



Source: PT PLN (2023)

Figure 5.2 Coal Plant Installed Capacity Plan 2020–2060

PLN has succeeded in retiring a 1.3 GW coal power plant and is looking for opportunities to retire a 6.7 GW coal power plant by 2040. Figure 5.2 shows the planned capacity of coal power plants from

2020–2060. The number of "natural retirement" or power plants that retired in the economic year will increase from 2040–2060. PLN's capacity target will experience a significant decrease, and IPP's capacity target will slightly decrease. "Early retirement" will be implemented from 2040–2055. Coal-fired power plants will retire by 6.7 GW in 2040, with 3.2 GW for natural retirement and 3.5 GW for controlled early retirement. There is an allocation of 19 GW, which will be kept until 2060 for new technology implementation options (such as co-firing/biomass/ammonia) and CCUS. These steps demonstrate PLN's determination to become a clean company and contribute to the transition towards cleaner and more sustainable energy in Indonesia.

F. Challenges and Opportunities Ahead

Technology research and development are being carried out for power plants that use power from hydrogen, ammonia, and biomass co-firing. They are also being tested on a small scale. The Indonesian government has provided support and incentives for clean power companies investing in hydrogen, ammonia, and biomass co-firing technologies. The challenges faced include implementation costs such as infrastructure costs, initial investment, and maintenance. The infrastructure and fuel supply are only partially available in Indonesia. The availability of biomass as fuel in co-firing is also a challenge regarding a sustainable and sufficient biomass supply.

Some potential scientific gaps that may still need to be overcome on the way to a clean power company in Indonesia 2045 are the continuing research and development of clean energy technologies to increase efficiency, competitiveness, and technologies for renewable energy, such as solar, wind, hydrogen, and biomass. Then, it is necessary to develop infrastructure and an integrated grid system to overcome renewable energy production fluctuations. Policies and regulations are also needed to support and encourage clean energy development. Such policies must be consistent and sustainable to reduce barriers and encourage investment in the clean energy sector. Equally important is increasing public awareness about the importance of

clean energy and changing energy consumption behavior. This target for Indonesia in 2045 has been achieved in countries implementing clean energy. Indonesia still needs time to achieve this, mainly because of its high dependence on fossil energy, such as oil and coal.

The implementation of clean energy faces several challenges that must be overcome to achieve optimal success. Some of the main challenges in implementing clean energy include limited infrastructure. Development of infrastructure that supports clean energy, such as renewable power plants and distribution networks, often requires significant investments and takes a long time. These challenges include more financial resources, complicated licensing, and technical limitations in building efficient infrastructure.

Although clean energy technologies have decreased over time, there are still significant cost differences with conventional energy sources such as coal or oil. These challenges include a more extensive return on investment and dependence on financial support and incentives from the government or other institutions. Frequent energy policy changes can create uncertainty for investors and industry players. Changes in regulations, cuts in subsidies, or inconsistent decisions can hinder clean energy development and discourage investors from making long-term investments.

More decentralized clean energy systems, such as solar panels and wind turbines spread across multiple locations, require efficient integration into the existing electricity grid. These challenges include stable power distribution management, adequate energy storage, and coordination between clean energy producers and electricity service providers. Paradigm changes and public awareness of the importance of clean energy are still a challenge. Society needs to understand better the benefits of clean energy and the negative impacts of conventional power. In addition, the community's adoption of clean energy technology also depends on economic factors, availability, and habits that have been formed. Cooperation between the government, the private sector, and the community is essential to address this challenge. Clear policy support, appropriate incentives, increased investment

in technology research and development, and broader education will help accelerate clean energy implementation and achieve sustainable success.

G. Closing

In general, the progress made by clean power companies in Indonesia is developing, using clean energy technologies such as solar panels, wind turbines, and other renewable energy systems to meet the company's electricity needs. This progress has helped reduce dependence on fossil energy sources and greenhouse gas emissions. Clean power companies also encourage the use of electric vehicles or facilitate carpooling programs for employees to help reduce air pollution and the environmental impact of transportation. Some companies focus on more efficient and environmentally friendly waste management, including waste reduction, recycling, and using recycled materials. Socialization is increasingly being carried out to increase public awareness of environmental issues and the importance of adopting sustainable business practices.

The challenge that clean power companies face is limited access to clean technology, which is still expensive or challenging to implement in certain areas. Indonesia is also still dependent on fossil energy sources. Infrastructure and the costs of transitioning to renewable energy can be constraints. Another challenge is the ambiguity or changes in environmental policies and regulations in Indonesia, which can affect the company's business planning and strategy. Lastly is the lack of consumer awareness of environmentally friendly products and services.

Preparing and implementing the energy transition in Indonesia is essential for overcoming energy challenges, protecting the environment, increasing energy security, creating economic opportunities, and improving people's quality of life. This effort requires collaboration between the government, the private sector, and society to achieve a sustainable and future-oriented energy system. The energy transition in Indonesia brings long-term hopes and benefits, including energy

sustainability, environmental protection, improved public health, economic opportunities, and community empowerment. With a strong awareness and commitment to adopting clean and sustainable energy sources, Indonesia can take the lead in shifting towards a more sustainable and future-looking energy system.

References

British Petroleum (2018). *Advancing the energy transition*. https://www.bp.com/content/dam/bp/business-sites/en/global/corporate/pdfs/sustainability/group-reports/bp-advancing-the-energy-transition.pdf.

Buntaine, M. T. & Pizer, W. A. (2015). Encouraging clean energy investment in developing countries: What role for aid?. *Climate Policy*, *15*(5), 543–564. https://doi.org/10.1080/14693062.2014.953903

Jahangiri, M., Nematollahi, O., Haghani, A., Raiesi, H. A. & Shamsabadi, A. A. (2019). An optimization of energy cost of clean hybrid solar-wind power plants in Iran. *International Journal of Green Energy*, *16*(15), 1422–1435. https://doi.org/10.1080/15435075.2019.1671415

Kat, B. (2023). Clean energy transition in the Turkish power sector: A techno-economic analysis with a high-resolution power expansion model. *Utilities Policy*, *82*, 101538. https://doi.org/10.1016/j.jup.2023.101538

Lamichaney, S., Baranwal, R. K., Maitra, S. & Majumdar, G. (2020). Clean energy technologies: Hydrogen power and fuel cells. *Encyclopedia of Renewable and Sustainable Materials*, 366–371. https://doi.org/10.1016/B978-0-12-803581-8.11040-9

Ling, M., Yang, S., & Zhang, M. (2022). Power supply system scheduling and clean energy application based on adaptive chaotic particle swarm optimization. *Alexandria Engineering Journal*, *61*(3), 2074–2087. https://doi.org/10.1016/j.aej.2021.08.008

Liu, W., & Li, Y. (2023). Research on the evolution mechanism of promoting clean power supply under the background of rural energy reform in China. *Energy Reports*, *9*, 2592–2603. https://doi.org/10.1016/j.egyr.2023.01.097

Lund, P. D. (2015). Clean energy systems as mainstream energy options. *International Journal Energy Research*, *40*, 4–12. https://doi.org/10.1002/er.3283

PT PLN (2023, May 22), Transisi energi PLN menuju NZE 2060, *Press Release No.310. PR/ STH.00.01/V/2023* https://web.pln.co.id/cms/media/siaran-pers/2023/05/pln-telah-finalkan-sederet-proyek-transisi-energi-menuju-nze-2060/

Sadekin, S., Zaman, S., Mahfuz, M. & Sarkar, R. (2019). Nuclear power as foundation of a clean energy future: A review. *Energy Procedia*, *160*, 513–518. https://doi.org/10.1016/j.egypro.2019.02.200

SPX Flow Technology. (2011). Power generation: Self-cleaning filters in biomass energy production systems. *Filtration + Separation*, *48*, 33–34. https://doi.org/10.1016/S0015-1882(11)70261-0

Sun, J. & Dong, F. (2022). Decomposition of carbon emission reduction efficiency and potential for clean energy power: Evidence from 58 countries. *Journal of Cleaner Production*, *363*. https://doi.org/10.1016/j.jclepro.2022.132312

Tao, H., Zhou, J. & Musharavati, F. (2023). Techno-economic examination and optimization of a combined solar power and heating plant to achieve a clean energy conversion plant. *Process Safety and Environmental Protection*, *174*, 223–234, 132312. https://doi.org/10.1016/j.psep.2023.03.082

Wahi, I. (2022, October 17). 8 upaya PLN kurangi emisi karbon bakal dipamerkan dalam SOE international conference. *Harian Fajar*. https://harian.fajar.co.id/2022/10/17/8-upaya-pln-kurangi-emisi-karbon-bakal-dipamerkan-dalam-soe-international-conference/

Zhang, F., Tang, T., Su, J. & Huang, K. (2020). Inter-sector network and clean energy innovation: Evidence from the wind power sector. *Journal of Cleaner Production*, *263*, 121287. https://doi.org/10.1016/j.jclepro.2020.121287