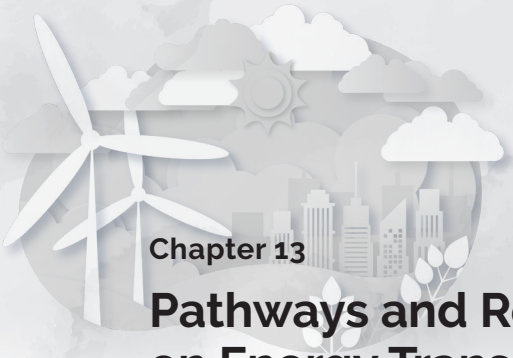

Chapter 13

Pathways and Recommendations on Energy Transition Strategy to Achieve Net-Zero Emissions by 2060

Harun Ardiansyah & Putty Ekadewi

A. Indonesia's Path towards a Net-Zero Future: Identification of Necessary Actions

Indonesia is the biggest economy in Southeast Asia. The power behind Indonesia's massive economy is the size of the country and its population, which is advantageous in the country's case with a population of more than 270 million. Economic growth always goes together with energy consumption. As an effect, Indonesia's final energy demand is expected to shoot up in the near future to 388 MTOE (million tons of oil equivalent) with 1.2 TOE (tons of oil equivalent) per capita in 2050 (APEC, 2019). The growth in demand is double the country's energy demand in 2020, which means in a span of 30 years Indonesia must be ready to double its energy supply. Talking about energy sup-

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ply, the country is currently relying on fossil fuels, especially coal to generate electricity from coal power plants. Coal power plants are widespread in the country, one of the reasons being the abundance of coal, making Indonesia one of the world's most important coal exporters. In fact, coal export in 2018 was more than three-fourths of the total production (IESR, 2019a).

Contrary to the current situation, in the future fossil fuels are expected to be abandoned in favor of cleaner energy sources. The drive behind this transition is mainly environmental. The Earth is facing its biggest climate crisis if it stays on its current track of dependence on fossil resources. The environmental effect is so detrimental that it may topple down our current living systems: introducing famine, infectious diseases, biodiversity collapse, and deaths from major natural disasters.

Aside from the environmental factors, overall drastic growth in population is also threatening the Earth's ability to supply energy equal to the human population if world governments continue to rely on fossils. Fossil fuels are considered non-renewable since they took a long time to renew themselves, so these resources are finite in nature. If we continue to rely on fossils, it is just a matter of time before we deplete the earth's natural deposit of fossils. The consequences will be grave in the society as governments fight over fossil fuels, leading to wars.

Collectively, we are aware of these threats. World governments have crafted plans, goals, associations, and planned actions together to start the transition to non-fossil-based renewable energies. In Indonesia, the guideline to base energy transition was set on the National Energy Plan (RUEN-Rencana Umum Energi Nasional) in 2017. The aim is to gradually increase renewables proportion in the national energy mix to 31.2% by 2050 while reducing fossil proportions (Rencana Umum Energi Nasional, 2017). The target is set quite loose for renewables, as all forms of renewables are grouped into the same category. Globally, renewables already make up 29% of the global share of electricity generation in 2021 (IEA, 2021). However,

the latest data in Indonesia show that renewables make up only 11.2% of the national energy mix in 2020 (Ditjen EBTKE, 2021). In the Southeast Asian region, Indonesia is trailing behind Vietnam, which generates more than twice the amount of Indonesia's renewable energy production (IRENA, 2020).

Indonesia's path towards a net-zero future can only be achieved if we successfully transition to renewables, focusing on carbon-free renewables. Aside from pushing for energetic transition, the country also needs to take care of other aspects as outlined in this chapter.

1. Investing in Carbon Capture and Offset Technologies

The Indonesian government holds power to develop carbon capture and carbon offset technologies through state-owned companies like PT Pertamina or PT PLN. Using state-owned enterprises to achieve national directives makes coordination easier to jumpstart the process, which will help the country speed up its efforts to reduce carbon release into the atmosphere. Technologies to take up carbon exist and are ready to be deployed. Carbon capture and storage (CCS) work by taking up CO_2 released from a power plant before it is emitted. The amount of removed CO_2 can reach 85–95% for a thermoelectric plant (Eldardiry & Habib, 2018). However, the use of CCS technology to complement existing power plants must not serve as a justification to continue burning coals to generate electricity.

Since state-owned companies already hold the biggest share of electricity generation in the country, nationwide government-backed installations of CCS units will substantially impact the country's emissions rate, pushing ahead the country in reducing CO_2 emissions.

Another important technology, especially for the Indonesian energy sector, is bioenergy with carbon capture and storage (BECSS). The advantage of BECSS over CSS is the ability to reach negative net carbon emissions. In BECSS, bioenergy crops are grown to naturally take up environmental CO_2, CSS technology is applied at the end to take up released CO_2 from the use of the bioenergy crops, i.e., in combustion processes. By itself, bioenergy is already considered car-

bon neutral. As the country is already putting its vision on bioenergy, adding CSS technology would complete the cycle, in line with the country's net-zero emissions target.

2. Reforestation and Restoration of Green Areas in Urban Settings

Forests are known to be the natural carbon sink. Indonesia has lost 18% of its natural forest areas (a reduction from 74% to 56% forest coverage) in the 3–4 decades leading up to 1990 due to urban developments (Indrajaya et al., 2022). The loss of natural carbon sink has affected the natural balance of carbon (CO_2). Reforestation and green area restoration will help offset the carbon released from human activities thanks to their ability to carry out photosynthesis. Moreover, the presence of green areas in urban settings increases the livelihood of the surroundings by providing benefits like shading, aesthetic improvements, restoring mini-ecosystem, and function as recreation sites among others.

3. Strengthening and Equalizing Access to Public Transport Friendly Infrastructure

Indonesia's public transport sector is developing little by little. Reforms have been carried out in several parts of the country, notably the Jakarta Metropolitan Area (Jabodetabek), in various modes of transport. Jakarta has been equipped with a bus rapid transit system (BRT) called TransJakarta since 2004. The system can now reach satellite areas to help daily urban mobility, reducing both congestion and individual carbon footprints of its users. The regional train system has also been updated to increase user comfort, enticing middle-upper class citizens to use the system. In 2019, the city installed a line of mass rapid transit (MRT) and light rail transit (LRT) lines, further increasing urban mobility. This level of accessibility is still limited to the capital city and its suburbs. In most parts of the country, public transport is still weak. To reduce carbon emissions from the transportation sector, accessibility of public transport needs to be improved to equal that of Jakarta.

4. Biodiversity and Environmental Protection

Indonesia is a known biodiversity hotspot, which existence is threatened by the rapid rise of global surface temperature and the looming climate crisis. Biodiversity collapse can have widespread effects affecting agricultural supply chains. For example, the dwindling bee population is already identified as a potential threat to food industries (UNEP, 2010). Therefore, Indonesia's efforts to achieve a net-zero future must not disregard biodiversity and the ecological cost of the energy transition as discussed in a previous chapter.

5. Developing Policies to Incentivize Low-Carbon Industries and Enforcing Carbon Tax in Manufacturing Sectors

Incentives help attract new actors into the scene; developing a low-carbon industry from scratch requires large capital and technologies, often resulting from the result of intense research and development (R&D) activities. The presence of incentives helps build up investors' confidence in the project by lowering risks and opening economic opportunities. On the other hand, the enforcement of carbon tax work to disincentivize large carbon emitters due to a real economic consequence of CO_2. Carbon taxes have been successfully implemented in Sweden, Canada, and France since this policy decouples the economic growth (GDP) trend from carbon emissions (Criqui et al., 2019).

6. Simplifying Investments and Bureaucracy on Renewable Energy Projects

Similar to putting incentives on low-carbon industries, the simplification of bureaucracy and investments in renewable energy projects aims to bring private actors to the scene, which will drive innovations and increase market competitiveness. Complicated bureaucracy has been identified as one of the causes behind the stalling of Indonesia's growth in the renewable energy sector, making this problem urgent to solve (IESR, 2019b).

7. Regulating Costs Between Conventional and Renewable Energy in the Market to Maintain Competitiveness

Still related to the economics of transition, the price is one common factor preventing the Indonesian public from preferring low-carbon energy. Indonesia's demographic is highly price-sensitive, especially on fuel costs. Government-subsidized petrol, albeit at lower octane numbers (88 and 90) than the others offered (92 and 95), is highly popular in the field. To ease the transition, not only does the government need to monitor pricing, but programs intending to reduce capital costs need to be considered, for example, solar PV subsidy or a reduction in tax on electric vehicles.

8. Public Education on the Importance of Energy Transition and Carbon Offset Activities

Finally, the most important point is to build awareness of the public on the importance of renewable energy with an emphasis on transitioning to a net-zero future. Public awareness helps bridge the inevitable economic gap to push forward renewable, carbon-free energy while pulling back economic support for fossil energy. Failure to communicate the country's vision and policies are detrimental to the success of reaching Indonesia's net-zero target by 2060. After all, it is part of the government's job to communicate well with the public it represents.

We must realize that energy transition alone cannot entirely reduce human activities' carbon emissions. However, energy drives human activities; as such, we need to start a carbon-free future by transitioning to renewable and carbon-free energy. The transition itself is affected by social, economic, and political factors. It also needs to take care of the environmental and sustainability aspects. All actions identified previously are all interlinked to achieve a net-zero future. The following section in this chapter summarizes and presents recommendations for Indonesia to implement each energy source and technology.

B. Recommendation for Carbon-Free and Renewable Energy Implementation

From the previous sections, options for carbon-free and renewable technologies have been explored. Each technology has its uniqueness and challenges. However, they have one similarity, the potential for deployment in Indonesia is extremely likely. To deploy these technologies, some recommendations can be implemented.

1. Investment and Market Climate

In an industry, investment and market climate is important to ensure that the industry can grow and survive, including in the energy sector. The government should invest more to ensure that the energy market creates a conducive sector and can grow. This can be done by policies that will benefit the energy market. However, the government should also concern about the citizen. It is not ideal if the government is only concerned with the market and investment, and not with the well-being of the citizen. In this case, NIMBY (not-in-my-backyard)-ism could grow rapidly, and hold up Indonesia's growth.

2. Solar Energy

Indonesia has a large potential for solar energy deployment. Even among ASEAN members, Indonesia has the largest solar energy potential. Located in the equatorial region, solar irradiation in Indonesia is relatively evenly distributed along the countries. Indonesia's global horizontal irradiation is also better than some countries that invest heavily in renewable energy. The question is then shifted to the sites and locations to put these solar panels to achieve their maximum potential. Currently deployed technology is mainly the land-based solar panels, which took much of Indonesia's land area. According to data from the Geospatial Information Agency (BIG), Indonesia has a land area of 1.9 million km^2 and a maritime area of 6.4 million km^2. On top of the land area, 5800 lakes and reservoirs can be found with a total area of 5,868 km^2. Indonesia needs to explore other solar

panel technology that can be optimized in Indonesia. One of the technologies is floating solar PV.

As the name suggests, floating solar PV or floating solar panel requires no land space to generate electricity. This works best with some water bodies such as lakes and reservoirs. Current technology of floating solar PV technology has also been optimized to reach higher performance than rooftop solar PV. The performance ratio is 10% to 15% higher than typical rooftop PV systems. Floating solar panels are also able to reduce water evaporation. This is useful for areas that are susceptible to drought.

Like other technology, some aspects of solar energy need to be optimized to generate electricity effectively. Some challenges remain become questions that researchers need to solve. Some of them include the capital cost of solar panels which is still higher than conventional energy producers. Intermittency of solar energy has also been a limiting factor in optimizing solar panels. Other challenges also involve the land use of solar panels and the waste generated by the retired solar panels.

3. Hydropower

Indonesia has a great potential in hydropower. However, those potentials are limited to Indonesia's geography and socio-economic issues. Indonesia's rivers are typically not ideal site for constructing a large-scale hydropower plant. Also, the ecological issues due to the possible destruction of the river ecosystem and NIMBY syndrome can affect large-scale hydropower plant projects. Although hydropower plants are necessary to be the renewable energy baseload, the use of hydropower can be expanded in different ways. One way is to reduce the capacity of the hydropower plant and create micro-hydropower plants. Micro-hydropower plants will be an essential addition to residential and farming areas. The other way is to use pumped storage hydroelectric plants. PSH offers flexibility and reliability to fulfill the supply and demand of electricity. PSH can also be built far from rivers

and residential areas. In these ways, hydropower can be a renewable energy backbone for Indonesia.

4. Wind Energy

As mentioned in strategic planning in Directorate General of New, Renewable and Conservation Energy, MEMR, 2020–2024, the technical potential of wind power notes in the MEMR is about 60.6 GW, with the utilization being about 0.15 GW until 2020. This utility is still far from the target in RUEN that in 2020, at least 0.6 GW of wind power is already installed in Indonesia.

Several locations have been developed into PLTB, such as in Jeneponto and Bantul. The Jeneponto PLTB, located in Jombe Village, Turatea District, Jeneponto, will contribute around 70 MW to the Sulselrabar PLN System. Meanwhile, the PLTB Bantul is the largest PLTB in Indonesia and is part of the Electricity Infrastructure Program (PIK), better known as the 35,000 MW Electricity Program. With 30 wind turbines installed, 50 MW of electricity can be harvested later. Other PLTB locations are in Bangka Belitung, Bali, and Nusa Penida, each with one unit, Selayar Island with three units, and North Sulawesi with two units (2007 status). In addition, the government also plans to build PLTB in various areas, such as Sukabumi, West Java.

Some solutions can be implemented to advance the development of wind energy sources in Indonesia. First, it can be built in the middle of the sea so there is no need for land acquisition. It is well known that land acquisition has become a complicated issue in several areas. Second, it can be built in remote areas to meet the needs of people in remote areas of the country, including in the outermost, underdeveloped, and remote areas. This can increase the national electrification ratio and provide equal distribution of electricity.

5. Biomass

As an archipelago located on the equator, Indonesia is uniquely blessed with bountiful sunlight all year. This leads to a plentiful growth of vegetation and crops, translating to a high biomass yield over all corners of the country. This presents a prospect and a challenge in itself. With such high biomass yield, Indonesia has enormous potential for its biomass to be used as an energy source. On the other hand, being an archipelagic nation means many scattered islands must be connected to the grid to allow electrical access to all parts of the society.

Currently, two types of major waste biomass are found to have the highest potential for conversion to bioenergy: rice husks and palm oil wastes. They are produced as by-products of rice cultivation and palm oil production. Both are high in volume and represent a significant untapped portion of biomass energy that can be utilized for energy production and converted to the proper form of biofuel based on needs. Rice husks can be fermented into bioethanol and solid biofuels for combustion. Palm oil mill effluents (POME) can be utilized to produce biogas as an alternative to natural gas resources.

However, there are two issues hampering progress in biomass utilization. The first issue is the relatively high price of electricity from New Renewable Energy (NRE) sources. Currently, energy subsidy is concentrated in minimizing fuel oil, LPG, and electricity price. Electricity price reduction comprises 42% of total subsidy, and as of 2021, 47% of total electricity production comes from coal-based steam power plants. Therefore, it is interesting that this subsidy portion can be potentially redirected towards reducing the price of electricity from NRE sources, making them more competitive in general and incentivizing investments in NRE-based power plants. The second issue is the relatively high-interest rate for NRE projects from the financial sectors, which is unfortunately true. To realize the transition to NRE from fossil-based energy quicker, cooperation from all sectors is required to convince the financial sector that investments in NRE projects are the way forward.

6. Geothermal

The development of the geothermal industry is still facing many challenges, especially related to the participation of international or domestic companies in investing their money and taking a risk in Indonesia's geothermal industry. The characteristic of the geothermal industry is high risk, high capital, and high technology, which means there are no possibilities to reach the target that Indonesia's government has made without support from international companies. There are many recommendations for encouraging the development of the geothermal industry in Indonesia:

1. Applying and implementing a new fiscal term to support the project's economic viability. It is called cost recovery; these fiscal terms also have been used in Indonesia's oil and gas industry and have proven their success in accelerating the development of the industry. There are many reasons for these issues because there are many similarities between those two industries geothermal and oil and gas.
2. Indonesia needs to adopt or use Australia's standard reporting code to accommodate investor's interests because many international companies have used those codes and gained international recognition.
3. Doing more investigations and studies to get proven and mature data, especially through exploration drilling. Indonesia needs to conduct a Government Drilling Program, based on advice given by investors, the lack of quality and quantity data is one of the concerns and needs to improve. So, the climate of investment in Indonesia's geothermal industry will be more attractive because the government has successfully decreased the uncertainties by providing proven and mature drilling data, which is one of the most important things.

4. Decreasing the total project investment or capital expenditure, by selecting and applying new technologies suitable to geothermal layers or lithology formations and characteristics of the geothermal reservoir.
5. It is necessary to improve the laws and regulations related to geothermal utilization and management so that it is more comprehensive and does not overlap with other regulations. The government must also play a more active role from just policy discourse into a more concrete and implementable policy that can attract investors and clarify authority in applying rules and governance to geothermal.

7. Nuclear

Nuclear energy has been developed for more than 70 years. However, there are still a lot of controversies surrounding the technology. This is because the first introduction of nuclear energy to the world was through atomic bombs in Hiroshima and Nagasaki in 1945. Since then, nuclear energy has experienced its ups and downs. Just like any other technology, nuclear energy is not perfect. Few things need to be resolved by the nuclear energy industry and the government, mainly nuclear waste and financial problems with investing in nuclear energy. Some steps have been taken to solve this problem, from an engineering and public policy standpoint.

Right now, nuclear energy is gaining back its momentum. There has been a massive support for nuclear energy, especially from the young generations. Nuclear energy has everything necessary to tackle climate change: low carbon emissions, safest energy source, and creates high-paying jobs. For Indonesia, nuclear energy is the key to tackling climate change and economic recovery post-COVID-19. Nuclear energy can be the baseload of energy in Indonesia to provide carbon-free and reliable energy all the time. Nuclear energy can also accelerate the economy by creating new and sustaining jobs for families within the localities of the nuclear reactor.

To achieve this, Indonesia first needs a national strategy for deploying nuclear energy. If the strategy is settled and all the infrastructures are prepared, Indonesia's first nuclear power plant can be operational earlier than 2045. This strategy will reflect Indonesia's national position on nuclear energy. Indonesia has all the infrastructure needed for nuclear energy but the national position. Nuclear energy program implementing organization (NEPIO) is one step necessary to ensure the national position. NEPIO will ensure that all the infrastructures and organizations necessary to build Indonesia's first nuclear power plant are fulfilled and run well.

8. Hydrogen

Hydrogen plays a crucial role as a versatile clean energy carrier and industrial feedstock in decarbonizing hard-to-abate sectors. As one of the world's largest greenhouse gas emitters, Indonesia could harness the benefits of hydrogen to meet its climate targets. The main driver for developing an economically sustainable hydrogen industry in Indonesia is its abundant renewables across the country, including solar, hydropower, wind, biomass, geothermal, and tidal. As the global hydrogen market is estimated to reach US$201 billion by 2025, Indonesia has a huge opportunity to export renewable resources in the form of hydrogen and its derivatives, such as ammonia and methanol, thus ramping up national revenues.

Despite the enormous potential to be a global clean hydrogen powerhouse, Indonesia is facing a number of challenges associated with the adoption of hydrogen across its value chain. At the moment, green hydrogen produced using renewable electricity is costlier than gray and blue hydrogen. In addition, utilizing hydrogen for new downstream applications can be more expensive than its fossil counterparts. Another critical challenge is the lack of dedicated hydrogen infrastructure for large-scale storage and long-distance transport. The absence of a national hydrogen strategy exacerbates the hydrogen uptake as it reflects the low commitment made by the government on hydrogen and ultimately discourages potential investors. The govern-

ment gives insufficient recognition of hydrogen value to reduce carbon footprints in hard-to-abate sectors.

To stimulate the development of the hydrogen industry in Indonesia, a national hydrogen strategy, which comprises a national hydrogen roadmap and enabling policies, is proposed based on Indonesia's current position and existing barriers in hydrogen uptake across the country. Indonesia's national hydrogen roadmap should aim for an integrated system across the hydrogen value chain. The roadmap must focus on green hydrogen as the ultimate target due to its suitability to meet net-zero targets. A step-by-step approach for the transition from gray to green hydrogen is adopted. In the early stage, gray hydrogen has to be phased out and replaced with blue hydrogen which is equipped with carbon capture and storage technology while facilitating green hydrogen uptake at the same time. In the middle stage, the crucial decision has to be made where Indonesia needs to start the development of green hydrogen hubs across the country and build the required infrastructure. As a result, Indonesia could become a global hydrogen powerhouse beyond 2050 with deployment across various sectors and export capability to resource-constrained countries such as Singapore, Japan, and South Korea.

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