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Renewable Energy

Policy and Strategy

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Publisher's Note

The impacts of climate change are becoming more and more apparent. The increasing air temperature and frequency of extreme weather have brought people's lives to an alarming condition. Floods, droughts, and damage to biodiversity and infrastructure in coastal areas have had an impact on people's economic systems and have become a financial burden in many countries. Indonesia's commitment to help reduce greenhouse gas emissions as one of the causes of climate change has been explained in very pragmatic terms, replacing the use of energy sources from fossil fuels with renewable energy, which is more environmentally friendly.

On the other hand, the contradiction between the decreasing availability of energy and the increasing demand for energy, requires efforts to find new energy sources. This step is not an easy move. It requires great impetus to be able to carry it out. The three main pillars of sustainable development (social, economic, and environmental aspects) are important considerations in every policy implemented.

The Directorate of Repositories, Multimedia, and Scientific Publishing (RMPI), as part of the National Research and Innovation Agency (BRIN), is encouraged by its role to contribute to enriching literacy regarding new and renewable energy issues. The scope includes technological aspects, supporting policies, financing, organizational systems, stakeholder participation, and how ideal communication must be built so that the plan towards net zero emissions can be implemented.

This book is a collection of thoughts from researchers and practitioners from different backgrounds who share similar concerns about energy and caring for a better environment. The author's ideas regarding ocean thermal energy conversion, technology for processing urban waste into energy, policy frameworks, financial systems, organizations, are important factors that can support the realization of net zero emissions. This is a unique feature presented in this book.

This book is intended for the general public. There is hope that with the presence of this book, national literacy will become richer and public awareness regarding the importance of new and renewable energy will become better. It is also hoped that this book will be the beginning of the emergence of new ideas to strengthen the national goal of achieving net zero emissions.

As a final note, we would like to thank the editors and authors who have contributed ideas and thoughts to this book. Hopefully, their works will be even more victorious.

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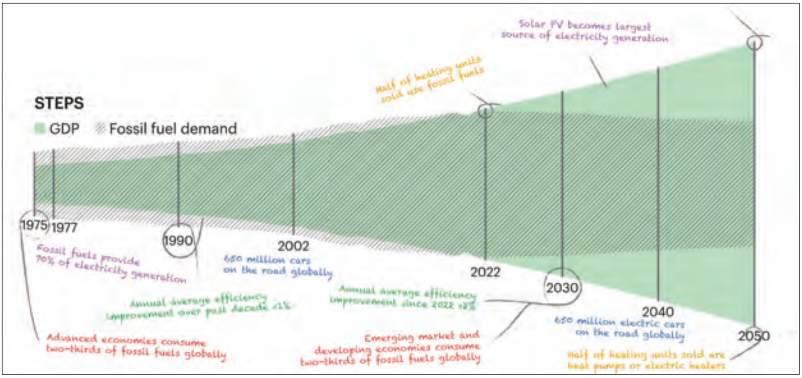
Foreword

Amid the threats of climate change, global warming, and the ever-dynamic global energy landscape, Indonesia has undertaken multifaceted initiatives to enhance the utilization of renewable energy. These endeavors aspire to be both sustainable and environmentally low impact, recognizing the urgency of aligning energy practices with ecological well-being. In the face of climate challenges and the evolving energy scenario worldwide, Indonesia's commitment to fostering renewable energy emerges as a crucial step towards a resilient and environmentally conscious future.

In terms of energy sources, almost all countries in the world have agreed to use clean energy sources and move towards carbon-free energy sources (net zero emission or carbon neutrality). This certainly needs to be done to anticipate climate change due to the growth of greenhouse gases originating from the energy sector, especially from fossil energy sources. Fossil energy sources are predicted to reach their peak of use in 2030 and are even expected to accelerate through a transition to the use of other energy sources. New and renewable energy sources will be the option, spearhead, and estuary of these global energy changes.



Source: IEA (2023)[1]

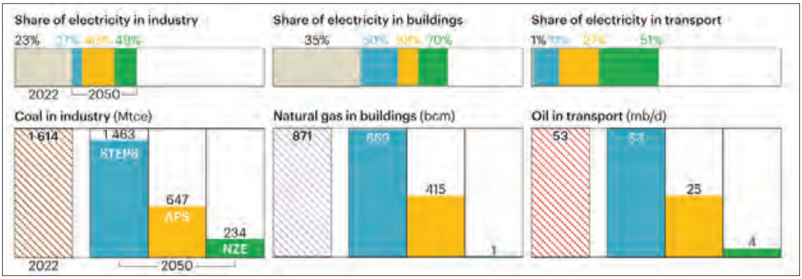
Figure 1 The Growth of Fossil Fuel and Solar Photovoltaics (PV) in the World

Clean energy developments are facing headwinds in some markets from cost inflation, supply chain bottlenecks, and higher borrowing costs. However, clean energy is the most dynamic aspect of global energy investment. For example, the progress of world's solar photovoltaics (PV) development has been growing for decades (see Figure 1). Its responses to the policy and the market stimuli are the key to explaining the differences in trajectories and outcomes across the world's renewable energy development. In all scenarios of the renewable energy roadmap, the momentum behind the clean energy economy issue is sufficient to reduce the demand for coal, oil, and natural gas within this decade, although the rates of post-peak decline varied widely.

Electrification is a key contributor to reducing fossil fuel demand, along with efficiency improvements and greater use of low-emissions fuels. Fossil fuels dominate the industry and transportation sector and are expected to decrease in 2050 through the development of alternative energy fuels. Hydrogen fuel and CCUS development are making

[1] Figure is quoted from International Energy Agency (IEA)'s report. IEA. (2023). Pathways for the energy mix. In *World energy outlook 2023* [Report]. https://www.iea.org/reports/world-energy-outlook-2023/pathways-for-the-energy-mix

much-needed progress. In world development, it is estimated that the pipeline of projects shows that more than 400 GW of electrolysis for hydrogen and over 400 million tonnes of CO_2 capture capacity are vying to be operational by 2030 (IEA, 2023)[2]. This could potentially meet the milestones of the achievement of Net Zero Emission by 2050 Scenario (see Figure 2).



Source: IEA (2023)[3]

Figure 2 Illustration of Fossil Fuel Share in Any Sectors up to 2050

Set against the backdrop of its abundant biodiversity and varied landscapes, Indonesia stands at the crossroads of opportunity and challenge in the realm of renewable energy. This book serves an exploration of the nation's stride in harnessing renewable energy, with a specific focus on ocean energy, biomass, and municipal solid waste. As we open the pages, we delve into discussions surrounding their potential, the policy and regulatory framework governing them, the challenges related to sustainability, and the intricate relationship between socio-economic development, environmental stewardship, and the pursuit of energy security, including the view through the lens of UN Sustainable Development Goals (SDGs). The book also explores financing strategies, including the utilization of Islamic waqf as a funding source, underscores the importance of effective

2 See IEA World Energy Outlook, 2023. IEA. (2023). *World energy outlook 2023* [Report]. https://www.iea.org/reports/world-energy-outlook-2023

3 Figure is quoted from International Energy Agency (IEA)'s report. IEA. (2023). Pathways for the energy mix. In *World energy outlook 2023* [Report]. https://www.iea.org/reports/world-energy-outlook-2023/pathways-for-the-energy-mix

communication and synergy among stakeholders, and highlights the crucial involvement of the youth. Finally, it synthesizes key strategies and recommendations, aiming to propel renewable energy towards a significant contribution to achieving Net Zero Emission by 2060 and realizing Golden Indonesia in 2045.

The journey towards a renewable energy future is challenging, and Indonesia's story reflects the global struggle for balance between economic growth and environmental preservation. However, it is a story of resilience, innovation, and determination, echoing the spirit of a nation committed to steering its energy trajectory towards a more sustainable and equitable course.

May this book inspire policymakers, researchers, entrepreneurs, and citizens alike to contribute to the ongoing narrative of Indonesia's renewable energy transformation and, in doing so, contribute to a more sustainable and resilient planet for generations to come.

November 2023

Haznan Abimanyu
Head of Research Organization for Energy and Manufacture
National Research and Innovation Agency (BRIN)

Preface

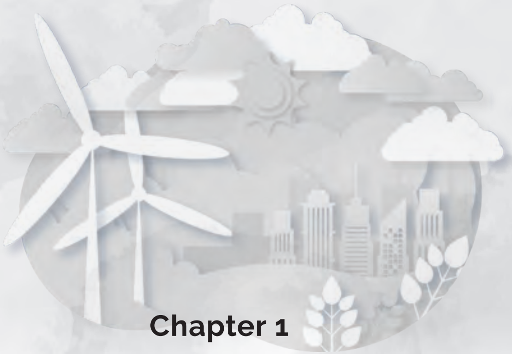
Renewable energy has received a lot of attention recently in relation to the global problem of climate change and global warming. The energy sector has a major contribution to this global problem. The use of renewable energy is a part of modalities to achieve the target of energy transition in 2045, and it is also very necessary to achieve net zero emission (NZE) for the world in 2050 and for Indonesia in 2060 or earlier. A proper strategy is needed to accelerate the energy transition, and this book covers new and renewable energy from the perspectives of technology, policy, regulation, strategy, cooperative and community economy, and everything that can support the current energy transition. Even though it is only a glimpse and not all aspects are discussed in this book, we hope that the existing chapters can represent and be of interest, especially adapted to the current conditions in Indonesia. For example, technological aspects are only discussed regarding marine energy and waste, where Indonesia has very abundant sources for these two energies but still faces several obstacles to application.

We hope this book will be a valuable source of knowledge for readers who want to understand more deeply about renewable energy and how the right policies and strategies can help achieve a more sustainable future. Apart from that, it is hoped that this book can become a reference for policymakers, especially in Indonesia, to achieve the target of net zero emissions in the energy sector.

We would like to express our deepest gratitude to all the authors who have participated in presenting the best articles and also to the BRIN Publishing team who have facilitated the process of this book from the beginning until it is published and read by readers. Hopefully this book will be a useful insight and inspire positive action in efforts to protect our planet.

South Tangerang, October 2023

Editors



Chapter 1

Prolog: Embracing the Future with Things May Renewed

Sudi Ariyanto, Septina Is Heriyanti

Amidst the emerald islands' strain of Indonesia, blue oceans gleam so wide
The sun, wind, and tide weave tales forevermore
Through woods and mountains that stand with pride
A prospering nation is in the making, under the equatorial sun's golden shine

Sudi Ariyanto

On the day before the 78th anniversary of Indonesian independence in 2023, the President of the Republic of Indonesia reiterated the dream of being one of the five biggest economies in the world in the golden age of Indonesia, i.e. in the year of 100th anniversary of the independence of the country in 2045. This dream was aspired by the founding fathers and is written in the country's constitution. Therefore, the statement of the President, said one day before the

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anniversary of Indonesian independence in 2023, strengthened the determination of the constitutional mandate for the welfare of the nation. Like other nations, and that has been shown by Indonesia, prosperity will not be achieved without struggle, and one of those struggles is to provide reliable and adequate energy.

Some literature shows that energy consumption has positive and significant impacts on economic growth (Dai et al., 2022). Some studies reveal that there is a two-way causality between energy consumption and economic growth (Zhixin & Xin, 2011). Using the data from the Shandong Province of China, Zang Zhixin and Ren Xin show that an increase in energy consumption drives economic growth which then stimulates more increase in the energy consumption. Studies conducted by Łukasz Topolewski on 34 countries in Europe (Topolewski, 2021) and Jaruwan Chontanawat on Indonesia, Thailand, and Malaysia (Chontanawat, 2020) show a one-way relationship, namely that the increase in economic outputs or activities, could lead to an increase in energy consumption. This means that when economic activity results in higher growth, the energy demand will also be higher. In their papers, Topolewski and Chontanawat promote the utilization of renewable energy based on environmental considerations.

Those are general statements of relations for all energies. What about energy that may be renewed, which is generally referred to as renewable energy? Of course, renewable energy can also play a role in the optimum energy mix. Since renewable energy comes from nature and uses natural resources, Indonesia has considerable resources that can potentially be used to produce renewable energy. Perhaps, therefore, it would not be too much to start this book with a poem about nature and the journey to prosperity of the nation. It is closely related to the dream of being a big economy in the world. This poem tells about the nature of Indonesia, which was blessed with seas, sunrays, wind, forests, and mountains, from where renewable energy can play a role in the welfare of the nation to be a prosperous country that is still in the making.

A. Renewable Energy and Natural Resources

The relationship between nature and the availability of renewable energy is important, as renewable energy sources depend on natural resources for production. Here is the relationship between nature and various renewable energy sources, including physical, chemical, or biological principles for its practical uses.

1. Solar energy

Solar energy comes from solar radiation. On solar panels, sunlight is converted into electricity through the photovoltaic effect, i.e., the conversion of photons to electrons, and electrons then flow in electrical circuits. Solar energy may be used for residential and commercial power generation, solar water heaters, and solar-powered appliances.

2. Wind energy

Wind energy is generated by the movement of air masses. Wind turbines capture the kinetic energy of the wind and convert it into electricity. The rotating blades of a turbine rotate a generator, generating electrical energy. Practical applications include wind farms for grid-connected power generation and small-scale wind turbines for local power supply.

3. Ocean energy

Ocean energy refers to all forms of energy derived from the sea. It comes from various sources, including waves, tides, currents, thermal energy, and salinity gradients. Wave energy is generated from the motion of ocean waves. Wave energy converters capture the kinetic energy of the waves and convert it into electricity. Current energy is generated from the kinetic energy of ocean currents. Underwater turbines capture the energy of ocean currents and convert it into electricity. Tidal energy is generated from the movement of tides. Tidal stream devices capture the kinetic energy of the currents flowing in and out of tidal areas, such as seashores. Ocean thermal energy is generated by converting the temperature difference between the ocean's surface water and deeper water into energy. Salinity gradient energy is generated from the energy associated with the salinity gradient at the mouth of rivers where freshwater mixes with saltwater. Pressure-retarded osmosis processes and associated conversion technologies are used to harness this energy.

4. Hydroelectricity

Hydroelectricity is generated from the energy of flowing or falling water through potential and kinetic energy conversion. Flowing or falling water rotates turbine blades, which are connected to generators to produce electricity. Practical applications include large-scale hydroelectric dams for power generation and small-scale hydro systems for off-grid power supply.

5. Biomass energy

Biomass energy is derived from organic materials such as wood, crops, as well as agricultural and animal wastes. It involves the combustion or conversion of biomass through chemical processes such as pyrolysis. The principles involved are the release of stored chemical energy through combustion or a chemical reaction. Others use biological processes in producing gas that can be utilized as an energy source, such as the fermentation process in biogas generation. Practical applications include biomass power plants for electricity generation, biomass stoves for cooking and heating, and biofuels for transportation.

6. Geothermal energy

Geothermal energy is obtained from the heat stored in the earth's crust. It uses the principles of heat transfer and thermodynamics. Geothermal power plants extract heat from underground reservoirs and convert it into electricity through steam turbines or binary cycle systems. Practical applications include geothermal power plants for electricity generation and geothermal heat pumps for heating and cooling buildings.

B. Renewable Energy and Economic Development

Here are some ways in which renewable energy can contribute to Indonesia's economic development.

1. Diversification of the economy: The transition to clean energy can help Indonesia diversify its economy and make its energy supplies more secure and affordable (IEA, 2022).
2. Improved socio-economic outcomes: A report by the International Renewable Energy Agency (IRENA) shows that a more comprehensive and ambitious energy transition will lead to improved socio-economic outcomes in Indonesia. Under the 1.5°C Scenario, Indonesia is projected to achieve 0.5% higher GDP, 2.6% more economy-wide jobs, and 8.1% higher social welfare than in the Planned Energy Scenario over the 2021–2050 period. In the renewable energy sector, the energy transition could increase employment substantially, from around 0.6 million currently to around 2 million by 2030 and 2.5 million (mainly bioenergy and solar technologies) by 2050 under the 1.5°C Scenario (IRENA, 2023).
3. Promotion of economic growth: Renewable energy, energy efficiency, and green finance promote economic growth and reduce carbon emissions in Indonesia. It is also suggested that investing in renewable energy can help Indonesia achieve sustainable economic development (Tiawon & Miar, 2022).

There are many benefits to using renewable energy in Indonesia. It is appropriate for renewable energy to be fought for its implementation.

C. How to Make the Best Use of Renewable Energy?

To optimally utilize renewable energy, enabling conditions are necessary. The Asian Development Bank (ADB) presents 6 factors for the successful exploitation of renewable energy: resource base, availability of proven technology, market for power output, implementation capability, availability of capital, as well as government policies and regulations (Asian Development Bank, 2020). Table 1.1 displays data sourced from Asian Development Bank, which has been reorganized to gain a better understanding of its positive enabling support.

Table 1.1 Enabling Factors for Renewable

No	Factor	Information/Data	Remark
1	Resource	• annual average insolation of 4.5 to 5.5 (kWh/m²/day) • 17,506 MW of reserves and 11,073 MW of resources for geothermal • 9.3 GW potential for wind energy • potential biomass production • potential ocean power	Favorable
2	Technology	Commercially proven generation technology is available from international markets for most of the renewable energy resources in Indonesia	Favorable
3	Market	• 2019–2028 forecasts power sales to grow at an annual average of 6.4% • 15% renewable share of total derated Perusahaan Listrik Negara (PLN) capacity in 2024, 21% share of planned total derated generation capacity in 2028	• Favorable • Realization of these planned additions will depend on a supportive enabling regulatory and policy environment
4	Human Resource	Many qualified engineering, procurement, and construction contractors	• Favorable • Some local developers for small projects lacks sufficient understanding of project risks and development requirements • Land access is still challenging
5	Finance	A wide range of commercial banks, multilateral and bilateral finance institutions, and private investors are available	• Favorable • Available funding schemes have not been fully utilized

No	Factor	Information/Data	Remark
6	Policy and Regulation	• policies and regulations issued by many agencies • interministerial coordination is weak • no apparent impacts analysis prior to the implementation of new policies and regulations	unfavorable

As is shown in the Table 1.1, ADB notes that most factors are sufficiently present in Indonesia to create a favorable environment for renewable energy development. However, government policies and regulations become the principal impediment to greater uptake of renewable energy (Asian Development Bank, 2020). It seems that the government creates challenges of spread authorities of policies and regulations provision, weak coordination among responsible ministries or agencies, and no apparent impact analysis for new policies and regulations.

The impediment may raise an impression of government ineffectiveness in securing its programs to introduce renewable energy to hold the biggest share in the energy production system, of an uncertain regulatory environment existence, or perhaps of a lack of government support. The obstacles coming from the government are indeed unnecessary since the government is supposed to issue policies and regulations that are conducive to renewable energy development and utilization. Erdiwansyah and his friends also expressed the same arguments in line with the Asian Development Bank. Erdiwansyah et al. (2022) concluded that the obstacles to renewable energy development in Indonesia were funding, policies, and laws; the funding was not adequate, while the policies and laws had not improved.

Based on information from ADB issued in 2020 and Erdiwansyah et al in 2022, one can say that there has been little improvement on the policy and regulatory side in a direction that is more conducive to the development and utilization of renewable energy in Indonesia until the 2020–2022 period.

The lack of conducive policies and regulations was one of the considerations and background for writing this book and for pinpointing the focus of this book. The focus of this book is on policies and strategies for the use of renewable energy in Indonesia. The authors' writings may contribute to improving policy and regulatory environment. Surely, this book will not provide a total solution to the problem, but at least it can provide a part of the overall solution.

D. A Glimpse at the Book's Chapters

This book is organized into several chapters on technology, policy, financing, and social aspects. The first chapter, which is meant to be a prologue, essentially conveys information about the background of the writing and organization of this book.

Chapter 2 is the first article addressing the aspect of technology. It is dealing with ocean-renewable energy in Indonesia. The content of the chapter is very relevant to the condition of Indonesia as an archipelagic country with the sea area of about two-thirds of the total area of the country. The authors provide a brief on the current state of ocean energy including technology to produce energy from waves, tides, currents, and thermal. One of the technologies discussed is offshore wind turbines. This is a type of renewable energy technology that generates electricity from wind blowing across the sea. Even though this technology is not energy that comes from the ocean, it is still related to the characteristics of the ocean, in particular the characteristics that affect the wind speed. The chapter is also discussing the development potential of ocean-renewable energy in the islands of Indonesia.

The second article addressing the aspect of technology is Chapter 3. It takes an issue relating to biomass energy. It may be well understood that human activities produce waste. Sometimes, the waste may affect the quality of the environment. In many cases, waste causes environmental problems which can also affect human health. One creative way to deal with waste is to turn it into something useful, for example, in the economic, artistic, or energy fields. The authors are forwarding an argument that the waste is convertible as biomass fuel for producing electricity. The case addressed is the success of DKI Jakarta, and it may be precedence for other cities in converting urban waste into sources of renewable energy. The practice may also provide double benefits in waste management and electricity production.

Chapter 4 deals with policy and regulation issues. The author describes the Government's commitment to renewable energy and the law on renewable energy. The policy and regulatory framework is described, including matters related to funding. This chapter also presents the successes and challenges of utilizing renewable energy. The author of this chapter also states that the development and utilization of renewable energy are still hampered by aspects of limited infrastructure and funding. It is hoped that the recommendations and steps to increase the use of renewable energy in this chapter can make a positive contribution to overcoming challenges in policy and regulatory aspects.

In Chapter 5, a different approach to dealing with the policy and regulation aspect is addressed using the United Nations Sustainable Development Goals as the basis for assessment. This chapter opens with a very factual statement, namely that extraordinary technological advances have enabled access to energy sources that have never been possible before, but it turns out that these are not able to overcome the challenges of environmental degradation and climate change. The authors opt to use the SGDs as the assessment tool because they may stand as comprehensive indicators measuring the progress toward well-being. Based on a theoretical approach, this chapter shows that it is difficult to achieve both economic and environmental goals simultaneously due to the complex relationships between various energy sources, including their different characteristics. The authors show that the adoption of low-carbon energy sources is inevitable to simultaneously achieve socioeconomic and environmental objectives in the context of sustainability. However, there is a reminder, that renewable energy cannot fully meet economic targets because other fossil energy sources are still needed. Therefore, every country should develop an optimum energy mix considering economic and environmental targets.

Next to this chapter on policy is those for financing. Developing a financing plan to implement new and renewable energy is necessary. The author of Chapter 6 notes that the aspects of renewable energy financing cover various matters related to funding, investment, and financial management for renewable energy projects. Financing for low-carbon energy in Indonesia is quite complex because it covers various aspects, including Indonesia's macroeconomic conditions. Sources of funding can come from the government, from other countries, as well as from the private sector. There is one good opportunity that can be exploited; funding from abroad is currently being directed more toward energy transition programs. Indonesia should prepare a financing plan for the success of the renewable energy program, and the government's role is needed, both as a provider of funds and as a bridge between renewable energy providers and funders. One of the interesting things about funding discussed in Chapter 7 is the potential for sharia funding, namely *sukuk* for renewable energy programs. As presented in Table 1.1, the funding potential in Indonesia has not been fully utilized. The arguments presented are very valid and interesting because the majority of Indonesia's population is Muslim. The author shows that *sukuk* can have extraordinary potential for funding renewable energy programs, although there are still several challenges that must be overcome. It is hoped that the recommendations and strategies presented can be part of the success of the renewable energy program in Indonesia.

The success of the renewable energy program, like any other program, depends on the communication with stakeholders as well as stakeholder engagement. Chapter 8 is an article that discusses social aspects, i.e., communication development and youth empowerment to support renewable energy programs. The authors show a new approach, namely utilizing youth to communicate government programs, and herein lies the importance of youth empowerment for the success of renewable energy programs. There is optimism on the authors' part that empowered youth will play a role in spreading information about renewable energy to wider circles, ultimately increasing public awareness.

The final chapter will be an epilogue of this book. The main contents are recommendations and strategies for accelerating the utilization of renewable energy in Indonesia's energy system to achieve the Net Zero Emission target in 2060.

The parties involved in making this book hope that they can contribute to Indonesia's renewable energy program with several arguments that may be new and several recommendations that can be implemented. Like the majority of the Indonesian people who wish for a prosperous Indonesia to be realized on the 100th anniversary of Indonesia's independence, the parties here have the same hopes as them. Hopefully, this book may be a contribution to a better Indonesia in the future. Again, it needs to be reiterated that this book is not aimed to offer all solutions to the problems in the use of renewable energy in Indonesia, but at least several things can be used as solutions for them.

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Chapter 2

Ocean Renewable Energy in Indonesia: A Brief on the Current State and Development Potential

Ristiyanto Adiputra, Muhammad Iqbal Habib, Erwandi, Aditya Rio Prabowo, Adnan Sandy Dwi Marta, Wahyu Widodo Pandoe, Navik Puryantini, Ruly Bayu Sitanggang, Achmad Nurfanani

A. Oceans as Potential Alternative Energy Sources

The geographical condition of Indonesia consists of thousands of islands, triggering difficulty in energy distribution and a large disparity in energy prices between the eastern and western parts. The disparity affects production and manufacturing costs and implies investment distribution. Additionally, the impact of climate change on the oceans, such as rising sea temperatures, rising sea levels, reducing oxygen levels, changing ocean currents, increasing ocean stratification, and increasing storm frequency, can cause problems for marine ecosystems (Brierley & Kingsford, 2009; Harley et al., 2006; Moreno et al., 2014).

However, most solutions to problems come from the root of the problem itself. As an archipelagic country, Indonesia faces numerous energy challenges, but definitely, Indonesia's ocean also provides

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the solution. Ocean renewable energy is developed as an alternative solution to mitigate climate change.

Movement and the physicochemical characteristics of saltwater are the primary sources of ocean energy. The tides, ocean currents, and wave phenomena are all examples of the movement of water masses. Technologies for energy conversion have been developed to use the mass motion of saltwater to power generators and turbines. The salt and heat content of the saltwater column are the physicochemical characteristics that can be an energy source. The osmosis principle can turn salt into a source of electrical energy. Based on the laws of thermodynamics, the heat of saltwater, defined as the difference between the temperature of the water at the surface and that at a particular depth, can be transformed into electricity.

Ocean energy in Indonesia, including tides, waves, wind, and ocean thermal, has the potential to be developed (Langer et al., 2021). Marine energy's theoretical and technical potential in Indonesia is estimated at 288 GW and 18-72 GW, respectively (Direktorat Jenderal Energi Baru Terbarukan dan Konservasi Energi, 2016). However, the potential has not been developed. The realization of the potential is zero percent, because, among other things, there are also no policies and regulations regarding ocean energy.

To draw attention, raise awareness, and encourage the development of ocean renewable energy, this paper presents a series of data to be reviewed, which focuses on ocean energy in Indonesia, including the potency, the research progress, the abandonment, and the planned project as a process of extracting marine energy in the fields of ocean thermal energy conversion, offshore wind turbines, ocean tidal, and ocean waves.

B. Ocean Thermal Energy Conversion (OTEC)

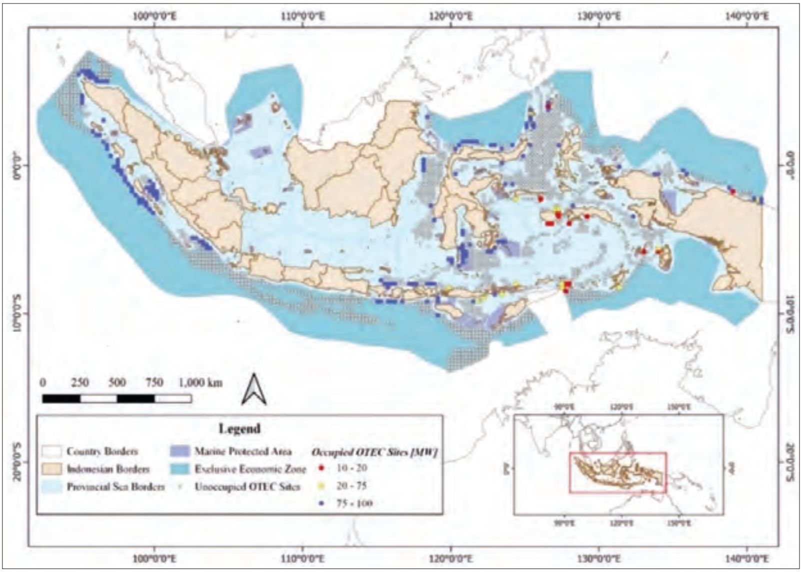
Ocean Thermal Energy Conversion, usually called OTEC, is a method of generating electricity using the temperature difference between the ocean's surface and deeper seawater (Nihous & Vega, 1993). Indonesia has an OTEC energy source that is abundant and regularly renewed when the sun is shining and the ocean currents are naturally present because Indonesia's climate tend to be pretty consistent throughout the year (Koto, 2016). Duxbury et al. (2002) states that in maritime tropical areas, thermal resources from ocean thermocline are one of the most potential sustainable energy sources. Indonesia's theoretical potential is 57 GW of energy sources and 43 GW in practice (INOCEAN, 2012). Langer et al (2021a) has conducted a map of OTEC potential site in Indonesia as shown in Figure 2.1. The aforementioned places include western coast of Sumatra, the southern part of Sulawesi, the northern and southern parts of Papua, and the southern part of Maluku. A study from Syamsuddin et al. (2015) states that potential sites for OTEC power plants are located in North Sulawesi and South Kalimantan at a depth of 500 m. These sites have temperature differences between the surface and deep sea of 21.78°C and 21.11°C, respectively. Using calculation in his paper, he can produce Carnot efficiency of 0.745152 and 0.732385, respectively, and are relatively stable each month.

The potential of the Makassar Strait as a suitable location for OTEC installations has been recognized due to its unique geographic characteristics and strategic positioning. Studies, such as the one conducted by Ilahude and Gordon (1996), have revealed that the area consistently exhibits high temperatures, particularly at the surface. This thermal profile makes the Makassar Strait an ideal candidate for harnessing ocean thermal energy. Furthermore, extensive research by Hammad et al. (2020) has identified a total of 17 promising sites within the Makassar Strait where floating OTEC stations could be deployed. These sites showcase an average temperature difference of 23.57°C, indicating the presence of substantial thermal gradients that can be utilized for power generation.

In terms of efficiency, the average Carnot efficiency at these identified locations is estimated to be 7.7%. While there is room for further optimization, this figure signifies the potential for converting a significant proportion of the available thermal energy into usable power through OTEC technology. Considering power generation capabilities, the envisioned OTEC stations in the Makassar Strait have the capacity to generate an average gross power output of approximately 177.66 MW, with a net power output of around 13.85 MW. This represents a substantial energy yield that can contribute to the regional power supply. Among the 17 potential locations in the waters of the Makassar Strait, the station situated at coordinates 01°01'51"N-120°13'21"E stands out as particularly promising. Its selection is based on a combination of factors, including favorable geographical conditions, ocean currents, proximity to the nearest coastline, and notable power generation capacity.

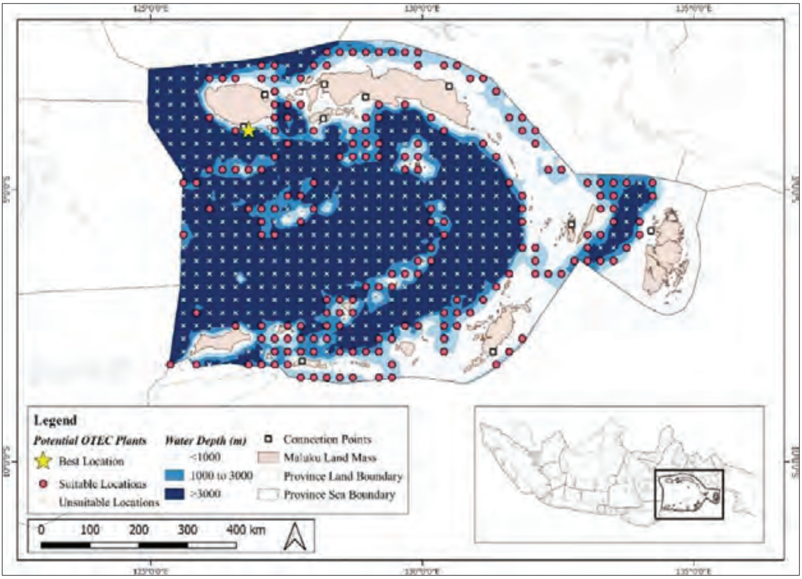
In east Indonesia, the northern region of Bali emerges as a promising location for the implementation of OTEC systems. Researchers, such as Ilahude et al. (2020), have conducted studies specifically focused on the potential for OTEC installations in North Bali. By utilizing annual temperature data obtained from HYCOM and employing (Uehara & Ikegami, 1990) equation to develop a temperature model, Ilahude's research reveals that the North Bali area exhibits a significant contrast in sea surface temperature compared to the deeper sea, ranging between 22°C and 25°C. Notably, through the analysis, it was determined that the location with the highest net power potential for OTEC deployment is situated in Tedjakula, Buleleng, boasting an impressive net power output estimated at 71,109 MW. This finding underscores the substantial energy potential that the northern part of Bali holds for OTEC applications in the country.

Using the method carried out by Langer et al. (2021b) in their research, it is estimated that there are 1,021 sites on the border of Indonesian provinces which are technically and economically suitable for OTEC. It implies that OTEC can be run almost throughout the Indonesian maritime region, where only the northern and southern regions of Sumatra, southern and western Kalimantan, northern Java, and the southern part of Papua do not have areas suitable for OTEC installation. Langer et al. (2021b) also stated that the best site for an OTEC plant is 13 km from Namrole and Maluku, as shown in Figure 2.2. This is in line with Indonesian Ocean Energy Association (INOCEAN)'s statement that mapping areas with temperature gradients above 20°C (Rahayu & Oktaviani, 2018). With a potential electric production of around 0–16 TWh, OTEC can cover about 6% of Indonesia's electricity needs in 2018 (Ministry of Energy and Mineral Resources, 2019). In another study, Langer et al. (2022) simulated an OTEC Enhancement Model considering the fulfillment of electricity needs and the global relevance of OTEC. The study states that an OTEC power plant with a capacity of 45 GW can be built and can cover 22% of the national energy needs in 2050. From Sutopo (2018), the economic potential of OTEC in Indonesia varies between 318 TWh and 3691 TWh with the economic potential of OTEC between provinces varying between 253 and 904 TWh. Differences in temperature and distance have the greatest influence on LCOE, followed by CAPEX values.



Source: Langer et al. (2021a)

Figure 2.1 Potential Site of the Ocean Thermal Energy Conversion in Indonesia



Source: Langer et al. (2021)

Figure 2.2 Site Map of Ocean Thermal Energy Conversion in Namrole, Maluku

The development of OTEC in Indonesia is currently not yet at the stage of installing power plants, either prototypes or commercially. In the world, OTEC power plants have been installed in several locations, e.g., Saga and Kumejima in Japan, with respective energy outputs of 30 kW and 100 kW. OTEC is still in the pilot project stage for several reasons, one of which is the problem with the cold water pipe (CWP) component (Adiputra & Utsunomiya, 2019). Indonesia had also made several plans for the development and research of OTEC. One was the plan to build a pilot plant in collaboration with Saga University in Japan. The pilot project of the OTEC power plant installation was planned to be built on Bali Island with an energy output of 5 MW (Martosaputro & Murti, 2014), yet no progress has been made up to now.

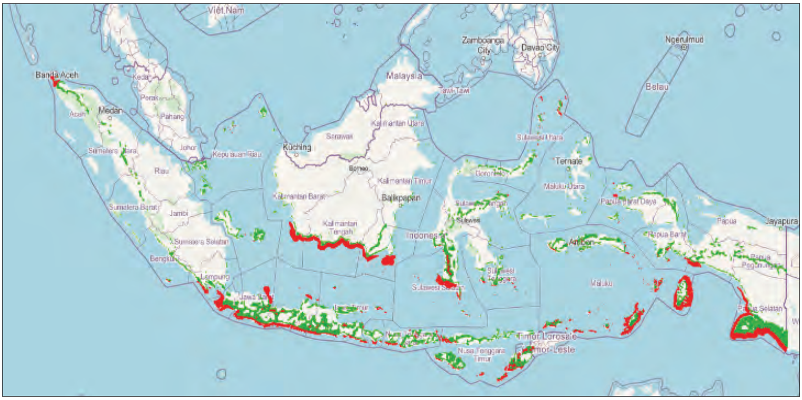
In the endeavor to develop OTEC in Indonesia, setting the site in Mentawai Island, Adiputra et al. (2020) proposed a preliminary design of OTEC to convert oil tanker ships into OTEC floating structures to reduce the capital cost of OTEC installation. Considering the problem in the CWP component, Adiputra and Utsunomiya (2019) also conducted research on the design of CWP components with a stability-based approach based on internal flow effect (IFE). Adiputra draws the conclusion that, in light of the findings, installing clump weights is important to limit motion displacement, FRP is the most suitable material, and the pinned joint at the top is preferred to lessen applied stress. Further, Adiputra and Utsunomiya (2021) then analyzed the CWP stability, imposing internal flow effect using the Galerkin and Frobenius methods on the frequency domain. In a recent study, the stability analysis was enhanced using the Finite Element Method in the time domain. The analysis shows that the instability occurs on 4.5–4.8 m/s fluid velocity (Adiputra & Utsunomiya, 2022).

C. Offshore Wind Turbine

Offshore wind turbines are basically energy from wind that flows over offshore areas. By definition, this technology can be included in wind energy, but here this technology is included in this section. Currently, Indonesia has a total installed capacity for onshore wind energy of 140 MW, separated into two locations, Jeneponto Wind Farm and Sidrap Wind Farm, with an output of 65 MW and 75 MW (National Energy Council, 2019). Developing wind energy power plants in Indonesia is still slow and focused on land-based power plants. According to the Ministry of Energy and Mineral Resources (MEMR)'s Handbook of Energy and Economic Statistics of Indonesia (HEESI) in 2021 (Ministry of Energy and Mineral Resources, 2021), wind energy can only supply 1,070,935 BOE. This is very far from hydro energy, which produces 45,947,523 BOE. The Electricity Supply Business Plan (Rencana Usaha Penyediaan Tenaga Listrik—RUPTL) of State Electricity Company of Indonesia (Perusahaan Listrik Negara—PLN) targets 255 MW of wind energy in 2025. Still, only 135 MW of new power plants were installed by the end of 2021. Specifically for offshore wind turbines, Indonesia does not yet have offshore power plants, although the potential is quite large. Offshore wind projects can provide a larger energy supply than onshore projects because they can exploit Indonesia's vast ocean territory. In addition, offshore wind projects can also accelerate the transition to green energy.

In comparison to other nations, such as Denmark and the United Kingdom where wind speeds are around 8.5 m/s, Indonesia has a less windy source with an average wind speed of about 4 m/s (Global Wind Atlas, n.d.). This is also supported by research from the Hydrodynamic and Ocean Energy Laboratory of Hasanuddin University, which states that wind speeds in Indonesia vary but are generally classified as moderate, so it is recommended to build mobile rather than fixed system power plants (Mahmuddin et al., 2015). With such wind conditions, Indonesia can still produce energy with a significant output. According to Janis Langer, low-speed offshore wind turbines still have a high potential for profitability, with a technological capacity of more than 6,816 TWh annually and a levelized cost of electricity (LCOE) value of 20 US¢ (2021)/kWh (Langer et al., 2022). The Indonesian Wind Energy Association states that the total potential for wind energy power plants in Indonesia is 154.88 GW, with about 58.25% coming from offshore power plants (EMD International A/S, 2017).

In Indonesia, there is a lot of room for wind energy. Wind energy resources are scattered throughout Indonesia and are available on the southern coast of Java, the eastern region, including Maluku and East Nusa Tenggara, and the southern section of Sulawesi Island. In addition, some areas in Kalimantan, Sumatra, and Papua, especially in the archipelago, also have wind energy sources that can be converted into electrical energy and distributed, especially in remote and difficult-to-access areas with access to main electricity facilities (Martosaputro & Murti, 2014). This is in line with the potential mapping for wind energy sources from the Ministry of Energy and Mineral Resources (MEMR), which can be seen in Figure 2.3.



Source: Ministry of Energy and Mineral Resources (2021)

Figure 2.3 Map of the Wind Energy Potential in Indonesia

The green part indicates wind speeds of 4–6 m/s, and the red part indicates wind speeds above 6 m/s. According to Figure 2.3 (ESDM One Map, n.d.), the regions with the greatest potential for wind energy resources are the southern portions of Java and Kalimantan, the southern portion of Sulawesi, the eastern portion of Indonesia, including Maluku and East Nusa Tenggara, and the southern portion of Papua Island.

Analysis of the potential of offshore wind turbines in Indonesia produces different results by some researchers. The most influencing factor is wind speed, where the measured wind speed can differ. According to Fauzy et al.'s study (2021), which evaluates the possibilities for offshore wind farms in tropical nations, particularly Indonesia, the mean annual wind speed offshore Jeneponto and Water Island in 2015 was 8.51 m/s and 8.04 m/s. Additionally, each location's wind energy capacity factor and field availability indicate strong potential for the generation of wind energy. A high-capacity factor is obtained when using turbines with low cut-in and rated wind speeds, demonstrating that these characteristics may increase the effectiveness of offshore wind turbine power production. In addition, increasing the wind farm size can increase energy production and reduce the LCOE.

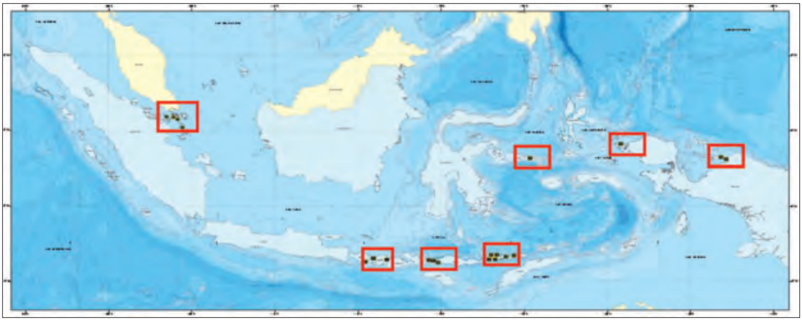
According to Nurlatifah et al. (2021), Indonesia is a promising location for the construction of offshore wind projects due to its average wind speed of 4–7 m/s. This value exceeds the cut-in value of the turbine, which is generally only 3–4 m/s. However, with such wind speed, the wind is unlikely to pass the rated speed. Thus, making the turbine unable to produce the maximum capacity. In terms of cut-off speed, no wind speed exceeds the cut-off speed. The recommended areas for offshore wind projects are Aceh, Southern Java, and South Papua because the seasonal monsoon circulation passes these areas. Indonesia's predominantly shallow waters show the economic viability of offshore wind turbine installations. According to Bosch et al. (2018), Indonesia has a potential of more than 2000 TWh/year in shallow water and 2000 TWh/year in transitional water. As for the total potential obtained (combining shallow, translational, and deep water), Indonesia has an offshore wind energy potential of 8318 TWh/year. This indicates that Indonesia has favorable conditions for developing affordable offshore wind turbines. Gernaat et al. (2014) estimated that the offshore technical potential of Indonesia is 53 EJ or equivalent to 4668 GW. However, it needs to be explained why the potential is so high, considering that the water depth is only limited to 80 m with a distance to shore of 139 km.

Other research by Pawara and Mahmuddin (2017) produced wind power density maps in the Maluku and Sulawesi areas each month in one year. The research found that in the Maluku and Sulawesi areas, the highest wind potential was in July, with a maximum energy density of between 416–463 watt/m^2 in the southern area of Maluku (Pawara & Mahmuddin, 2017). Another study by Purba et al. (2014) calculated the potential wind energy at several island points in Indonesia, namely Rondo, Berhala, Anambas, Biawak, and Miangas. These islands were chosen to represent the sea conditions where the islands are located. It was found that the maximum wind speed was on Rondo Island, with an average speed of 4.6 m/s and a maximum wind speed of 8.49 m/s. The power generated using a NEG Micon 2750 kW/92 m turbine is 1.5 MW (Purba et al., 2014). MEMR has identified several potential locations for building offshore wind turbines, including the Tanimbar Islands, Kupang, Sukabumi, and Jeneponto, with an estimated annual production of between 4–6 GWh (Balai Besar Survei dan Pengujian Ketenagalistrikan, Energi Baru, Terbarukan, dan Konservasi Energi, 2021).

D. Tidal Energy

The flow that happens in Indonesian region is caused by the "Great Ocean Conveyor Belt" or the thermohaline circulation since Indonesia is physically situated between the Pacific Ocean and the Indian Ocean. With a speed of 0.2–0.4 m/s, the global circulation travels over the Indonesian islands of Sulawesi, Kalimantan, Bali, and Nusa Tenggara (MEMR & INOCEAN, 2014). The thermohaline circulation causes a subcirculation on the Indonesian islands called the Indonesia Through Flow (ITF). This type of current, although small, can affect tidal energy sources considerably. Larantuka Strait and Boling Strait are examples of straits traversed by ITF currents (Firdaus et al., 2017).

The Ministry of Energy and Mineral Resource Republic of Indonesia (Direktorat Jenderal Energi Baru Terbarukan dan Konservasi Energi, 2011) stated that the current speed on the coast of Indonesian waters is usually less than 1.5 m/s. However, in some places, for example, in the straits of Bali, Lombok, and East Nusa Tenggara islands, current speeds can reach 2.5 to 3.4 m/s. MEMR also recorded the strongest tides in Indonesia in the strait between Taliabu Island and Mangole Island in the Sula Islands, Maluku Province. Based on the map of the distribution of tidal energy in Indonesia, which can be seen in Figure 2.4, tidal energy in Indonesia is found in several locations, e.g., the Sunda Strait in southern Sumatra, southern Maluku, northern Papua, Riau Islands areas, and eastern Indonesia, such as Bali, Lombok, and East Nusa Tenggara.



Source: INOCEAN (2012)

Figure 2.4 Potential Site of Tidal Energy in Indonesia

Several kinds of research have been conducted to determine the amount of energy that can potentially be extracted from tidal sources in the particular region of Indonesia. One such research is by Orhan et al. (2015), which stated that the potential energy from the tides in the Larantuka Strait in East Nusa Tenggara is around 20 GWh per year, with power densities at some locations reaching 6 kW/m^2 with current speeds of more than 4 m/s. Further research by Orhan and Mayerle (2017) showed an increase in the average power density value to 10 kW/m^2, with an estimated power that can be technically extracted at 200 MW. In western Indonesia, Ikhwan et al. (2022) researched extracting tidal energy in the waters off West Aceh and stated that the total energy that can be converted into electricity in the waters is around 507.36 kWh per day, and it is highly possible to build a tidal turbine power plant.

In 2009, research by Aziz (2009) stated that the Alas Strait has a total potential energy of 329.299 GWh per year that can be extracted from tides with a depth range of 24 to 40 meters and 641.622 GWh with a depth range of 24 to 80 meters. This is in line with other research by Orhan et al. (2017) who studied several straits in Indonesia and stated that the Alas Strait has the potential for energy production, at around 2,258 MW. In the same research, Orhan et al. also stated that the straits studied, e.g., the Bali Strait, Larantuka, Boling, Alas, and others, can produce around 4,800 MW.

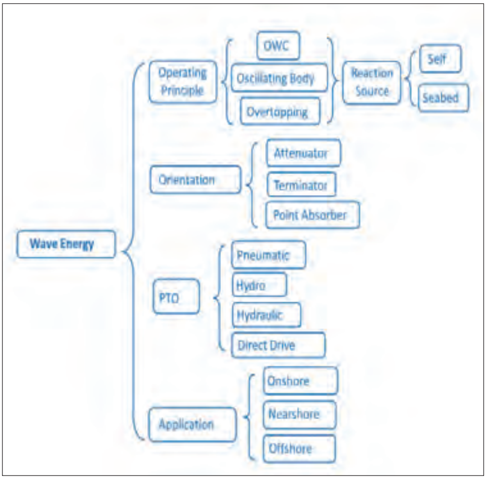
The development of tidal energy extraction in Indonesia is still in the research and prototype stage. Erwandi et al. (2011) conducted numerical ocean modeling to assess the potential of the marine current in several straits of Indonesian archipelago. The results were then used to design the rotor of the marine current turbine which was installed on the first-generation prototype with a capacity of 2 kW tested in Flores, East Nusa Tenggara, in 2010. The prototype was then continued to the second-generation turbine with a capacity of 10 kW and the third-generation with the same capacity (Kasharjanto et al., 2017). Another prototype has been tested by adopting the Gorlov turbine model with a capacity of 0.8 kW/unit (Direktorat Jenderal Energi Baru Terbarukan dan Konservasi Energi, 2011). In December 2018, Indonesia also adopted the Tidal Bridge project in PLN's RUPTL and is in the feasibility study phase for constructing a tidal energy power plant in Larantuka with around 30 MW installed capacity and could generate around 80 GWh/year. Recently, world tidal energy company Nova teamed up with Institut Teknologi Sepuluh November, planning to deliver a feasibility study for 100kW tidal turbine that could further generate 7 MW electricity in Larantuka strait.

Installation of the existing power plant had been attempted. The specific turbine design ("Kobold") was installed in Lombok with grant support from the Italian government through partnerships as part of the project "Promotion and Transfer of Marine Current Exploitation Technology in China and South East Asia (Pilot Plants)" that promotes a vertical axis marine current turbine technology. Unfortunately, the project failed and was abandoned because there was no clear planning or project document, which resulted in a lack of funds, misalignment, and misunderstandings amongst the parties. The United Nations Industrial Development Organization (UNIDO) independent assessment report (2015) is a detailed report on the project.

E. Wave Energy

Wave energy is an important source of renewable energy. If exploited extensively, it can make a significant contribution to the electrical energy supply of countries with sea-facing coasts (Falcão & Henriques, 2016). In addition to the abundant wave energy potential in Indonesia, wave energy devices are new renewable energy that has high consistency compared to several other renewable energies. Ocean Wave Power Generation is a technology to capture wave movement and use it to create energy which is then converted into electricity. The amount of energy generated depends on the speed, height, and frequency of the waves, as well as the density of the water (Ocean Energy Europe, 2022).

In general, a typical classification for Ocean Wave Power Plant is divided into 4 basic components. Classification is based on (1) operating principle, (2) orientation, (3) power take-off (PTO) type, and (4) application of this wave energy device (see Figure 2.5). Based on several studies related to capacity factor (CF) for wave energy, it has a CF of 25% to around 40%, with a design life of 20 years. This CF is influenced by the type of wave energy conversion used and the potential of its application. One of the parameters to be considered in selecting the type of wave energy device is the level of efficiency of this technology (Qiao et al., 2020).



Source: IRENA (2014)

Figure 2.5 Summary in Outline of Typical Classification for Wave Energy

Globally, Asia is the continent with the largest potential for ocean wave energy among other continents, with a potential for 6200 TWh/year of wave energy (Qiao et al., 2020). Indonesia is a country in Asia with a geographical location that is surrounded by two seas, the Indian Ocean and the Pacific Ocean, making it have promising potential for the development of wave energy power plants (see Figure 2.6). The Indonesian waters off the southern coasts of Java and Nusa Tenggara have a potential for wave energy of 10 to 20 kW per meter wave, according to the Medium-Term Development Plan (Direktorat Jenderal Energi Baru Terbarukan dan Konservasi Energi, 2015).

With this potential, Indonesia has begun to develop technology and commercialize wave energy extraction. In the early 2000s, the Agency for the Assessment and Application of Technology, Indonesia (BPPT) conducted research. It implemented a medium-scale prototype on Baron Beach in Yogyakarta as an educational vehicle (see Figure 2.7). This project or research project ended in 2006 due to changes in policy or research priorities. This activity was the first large-scale national research in Indonesia.

Source: INOCEAN (2012)

Figure 2.6 Potential Site of Tidal Energy in Indonesia

(a)

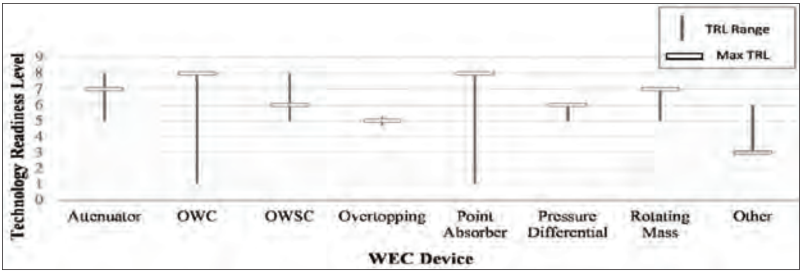
(b)

Note: (a) Full scale trial of PLTGL at Baron Technopark for 2004–2005
(b) Full scale trial of PLTGL at Baron Technopark at 2006
Source: Direktorat Jenderal Energi Baru Terbarukan dan Konservasi Energi (2016)

Figure 2.7 Testing of Wave Energy Harvesting Instruments by BPPT

Significant progress has been made in wave energy converters in recent years. There is increasing awareness in many countries, especially in Europe, that this technology will be ready for large-scale application in five to ten years (Cornett, 2008). Through PLN, the Indonesian government is considering and reviewing the implementation of sea current and wave energy power plants with potential in Bali, West Nusa Tenggara, and East Nusa Tenggara (PLN, 2021). At the end of 2022, the Swedish wave energy company, Waves4Power, and PLN Indonesia Power signed a memorandum of understanding (MoU) to develop the large-scale wave energy park or so-called WaveEL.

Based on several references, the Technology Readiness Level (TRL) for wave energy devices ranges from 1 to 8 (see Figure 2.8). The OWC and point absorber types of wave energy devices have the highest TRL compared to others. Wave energy devices, such as the OWC-type, which has been in operation for a long time, have demonstrated proven operational capabilities as a wave energy power plant. Therefore, this device can be said to be at TRL 9 (Mayon et al., 2022). The capital expenditure (CAPEX) of wave energy power plant technology is targeted to reach 3350 kEUR/MW in 2025 to enable the technology to meet the Strategic Energy Technology (SET) Plan target (with a capacity factor of 37%). Wave and tidal energy technology has lofty goals according to the SET Plan statement on marine energy. With a five-year delay, wave energy technology is anticipated to achieve the same goal, paying 15 EUR¢/kWh in 2030 and 10 EUR¢/kWh in 2035 (Magagna & Soede, 2019).



Source: Mayon et al. (2022)

Figure 2.8 Wave Energy Device Technology Readiness Level

The levelized cost of electricity (LCOE) for marine energy is lower than initially anticipated. The current wave LCOE is between 0.30 and 0.55 US$/kWh (IRENA, 2020). The results of a recent feasibility study on the development of wave energy technology and its implementation in eastern Indonesia conducted by PT Pembangkitan Jawa Bali (PJB), in conjunction with the Energy Study Center of UGM in 2022, shows that Southeast Maluku, Yamdena Island, has the potential for wave energy with slight to moderate characteristics. Wave energy in eastern Indonesia is typical of wave energy in Mutriku, Spain, or REWEC3, Italy. The study conducted in east Indonesia, focusing on the wave potential at Yamdena Island, Maluku, indicates an LCOE of $38.10 cents/kWh for an installed capacity of 1 MW. The LCOE is expected to decrease with an increase in the installed capacity, reaching cost parity with diesel power plants for installations exceeding 11 MW, at $16.25 cents/kWh. These results are consistent with the study by Australia's National Science Agency for the Wave Swell Energy project in 2021 that the projected LCOE of Wave Swell Energy (WSE) is around 0.5 US$/kWh for an installed capacity of 1 MW, although the potential waves with rough characteristics installed by WSE in King Island, Australia (Hayward, 2021).

E. Closing

This paper discusses Indonesia as an archipelagic country and its development potential to ocean renewable energy resources. As a commitment to help fight climate change, global warming, and carbon waste, Indonesia set a target to reach 23% of the renewable energy mix in 2025 and 31% in 2050. In order to achieve that target, Indonesia needs to maximize its renewable energy source potential. With a vast ocean area, Indonesia has a large amount of ocean renewable energy resources, including ocean thermal energy, offshore wind turbine, ocean wave energy, and tidal energy. Indonesia has several potential locations for OTEC energy, e.g., North Maluku, Mentawai, South Sulawesi, and Sunda Strait, with a total technical energy potential of 43 GW. In terms of offshore wind energy, several locations, e.g., South Sulawesi, West Papua, and East Nusa Tenggara, have promising wind energy potential with around 154.88 GW of energy that can be utilized. Larantuka Strait, Bali, Boling, and the Alor Island have a significant potential for tidal energy with an energy potential of around 4,800 MW. Ocean wave energy can be found along the southern coast of Java and East Nusa Tenggara, with a potential of around 10–20 kW per meter of the wave. Indonesia has also set government rules and plans, such as RUPTL and RUEN, in order to support ocean renewable energy development.

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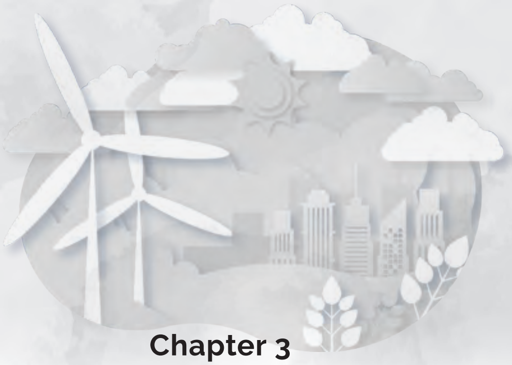

Chapter 3

The Conversion of Jakarta City Solid Waste into Electrical Energy

Parino Rahardjo

A. Introduction

The high population in urban areas has both positive and negative sides. The negative side is public health and environmental problems in urban areas, especially air quality. This air quality is influenced by the presence of industry, transportation, as well as households, offices. Urban waste is a problem that is no less complicated; the amount continues to increase following the population, causing various diseases and contributors to greenhouse gases. In Indonesia, it is known that the handling and management of solid waste has not been carried out properly but is disposed of in landfills and temporary disposal. Waste generation in cities in the province of Java Island shows that the City of Jakarta with the largest population can have the largest waste generation, as seen in Table 3.1.

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Table 3.1 Amount of Solid Waste Generation in Cities on Java Island

No	Cities	Generated Solid Waste	Total Population
1	Jakarta	3.112.381	10.748.230
2	Tangerang Selatan	355.009	1.354.350
3	Cilegon	833.169	434.896
4	Tangerang	504.258	1.930.556
5	Serang	213.464	352.331
4	Bekasi	668.179	2.543.676
5	Bandung	581.877	2.527.854
6	Yogyakarta	110.643	466.950
7	Semarang	431.085	835.083
8	Surabaya	651.043	835.083

Source: SIPSN (n.d.)

The City of Jakarta as the object of study was chosen because, as the nation's capital, it has various functions and activities. With a population of ±10 million people, the waste problem is a problem that must be solved because it has an impact on public health and the environment. The volume of waste increases linearly with the population growth and lifestyle. Due to limited land, the Regional Government of Jakarta has been using the Bantargebang Area in Bekasi City as landfill since 1989.

Regional Regulation of the Province of Jakarta Capital Special Region No. 1 of 2012, concerning the 2030 Regional Spatial Plan (RTRW), regulates the Waste Management Facility and Infrastructure System in articles 51 to 58. Article 54 paragraph 1 reads, "Construction of TPST (Tempat Pengolahan Sampah Terpadu/Integrated Waste Management Site) infrastructure and facilities as referred to in Article 51 paragraph 1 letter c, intended as a place to carry out collection, sorting, reuse, recycling, processing and final processing of waste" and paragraph 2 contains, "Construction of TPST infrastructure and facilities as referred to in paragraph 1 is regulated by the provisions as following: a. may be in the form of an Intermediate Processing Facility; b. equipped with high-tech, environment-friendly and land-saving; c. equipped with waste processing facilities; d. can cooperate with the surrounding administrative area; e. may involve the role of the private sector in the supply and/or operation and maintenance; f. pay attention to the provincial spatial layout plan, administrative city spatial layout plan, and regency administrative area spatial layout plan; g. pay attention to the geological aspects of the environmental layout of the site and its surroundings; h. paying attention to the socio-economic aspects of the surrounding community; and i. maximizing waste management and/or 3R (reuse, reduce, recycle) activities that generate income." Public health control in waste management is stated in Article 53 which states that health control starts from the Waste Storage Place as intended in Article 51 paragraph 1 letter b, intended as a holding place before the waste is transported to an integrated recycling place (TPST), and in paragraph 2, point f. prevent leachate from entering groundwater, springs and water bodies; paragraph 2, point g. anticipate health impacts on the surrounding environment; and h. control the impact of odors, flies, mice, and other insects.

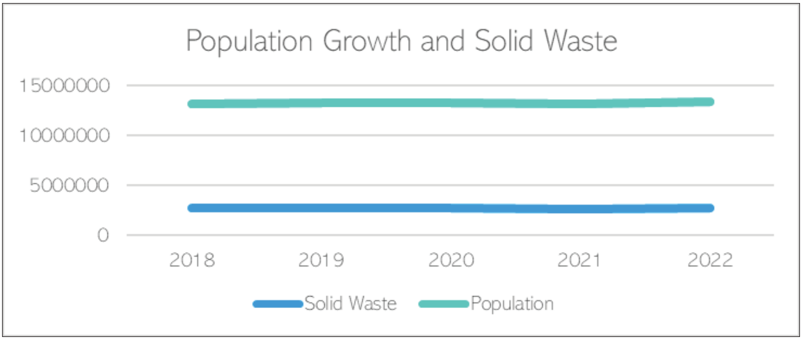


Figure 3.1 Solid Waste and Population Growth in Jakarta City

Based on the regional regulation regarding the 2030 Spatial Plan, waste management already has clear guidelines, especially those related to health and environmental issues. Without good waste handling and management, it will cause problems for public health and the environment. The volume of waste continues to increase along with the increase in population and only during the Covid-19 pandemic the amount of waste has decreased. This is due to people working from home. The relationship between waste volume and population in the City of Jakarta is shown in Figure 3.1.

B. The Problem of Urban Solid Waste in the Jakarta City

The final disposal site for solid waste in Jakarta City is located in Bantargebang District, Bekasi City. The Temporary Disposal Sites are spread across five areas of the City of Jakarta, with the closest distance to Bantargebang being 21 km and the farthest distance being 60 km. Temporary disposal sites in the City of Jakarta are located in five regions and spread over 15 places, as can be seen in Table 3.2. In 2021, the volume of waste transported will be around 86% of the total volume that must be transported. Compared to 2020, there was a decrease of around 5%, and trucks did not match the volume of waste that had to be transported.

Table 3.2 Location of Temporary Disposal Place and Distance to Bantargebang Bekasi Landfill

Location of Temporary Disposal Sites	**The Distance to Bantargebang Bekasi Landfill from the Temporary Disposal (Km)**
A. East Jakarta area	
1. RW 14, Jl. Telkom RW 14 Cibubur.	21
2. RW 13, Gg. Hanafi, Jl. Raya Centex Ciracas	28
3. PPSU RW 11 – Jl. Laut Banda Duren Sawit	25
B. South Jakarta area	
4.Kampung Kandang Jl. M Kahfi 1 Gg Tohir RW 04	32
5. Antam, Jl. Tanjung Barat Lama No. 139 Jagakarsa	30
6. RW 05 Komp. KODAM, Jl.. Pesang-grahan Raya J	38

Location of Temporary Disposal Sites	The distance to Bantargebang Bekasi Landfill from the temporary disposal (Km)
C. North Jakarta Area	
7. Terminal TG. Priok, Jl. R.E Martadinata	42
8. Honda RW. 09, Jl. Sunter Kemayoran RW. 09	36
9. RW 004, Jl. Inspeksi Kali Sunter Kelapa Gading	33
D. West Jakarta Area	
10. Jl. Kojan RW 06 Kalideres	58
11. RW 002 Tegal Alur, Jl. Bhakti Mulia Tegal Alur	60
12. RW 06 Pinggir Kali Pesanggrahan Kebon Jeruk	45
E. Central Jakarta Area	
13. Jl. Binatu RW 08 Petojo Utara Gambir	42
14. Menteng Tenggulun, Jl. Menteng Tenggulun	35
15. Rusun Benhil 2, Jl. Penjernihan 1 RW 08 Bendungan Hilir Tanah Abang.	37

Source: Defitri (2023)

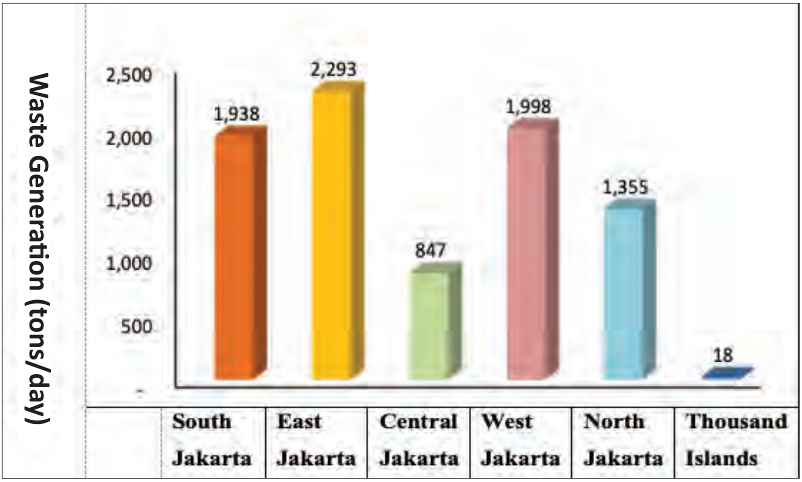
The large number of waste collection locations that are spread far from the solid waste final disposal site in Bantargebang Bekasi is a problem in urban solid waste management in the City of Jakarta. Table 3.3 shows the type and volume of urban solid waste from 2018 to 2022.

Table 3.3 Type and Volume of Urban Solid Waste from 2018 to 2022

Type of solid waste	Volume of solid waste (Ton)				
	2018	2019	2020	2021	2022
Organic	4009.43	3519.14	4078.28	3888.19	3761.9
Anorganic	3671.69	4139.86	3466.79	3305.2	3749.84
Toxic and Dangerous Materials	41.69	43.07	42.41	40.44	31.68
Amount	7722.81	7702.07	7587.49	7233.82	7543.42

Source: BPS Prov. DKI Jakarta (n.d.)

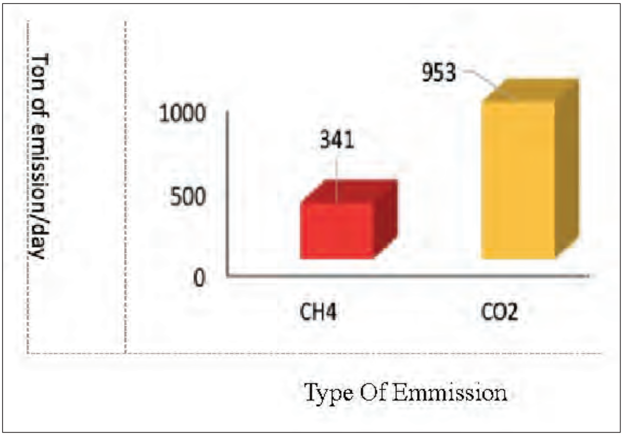
Figure 3.2 displays the volume of waste from five different parts of Jakarta City and one regency (Thousand Islands) that must be disposed of at the Bantargebang final disposal site. As we can see, between 2020 and 2022, less waste was transported to the final disposal site, which is thought to be a result of the Covid-19 pandemic, which has caused residents of Jakarta to stop going to work and school and instead stay at home.



Source: Dinas Lingkungan Hidup Provinsi DKI Jakarta (2022)

Figure 3.2 Estimated Daily Waste Production in Jakarta from Six Different Areas

The amount of waste produced, which is increasing in line with population growth, will undoubtedly endanger human health and the environment. Urban solid waste in the City of Jakarta produces emissions in the form of methane gas of 341 tons/day and CO_2 of 953 tons/day, as shown in Figure 3.3.



Source: Dinas Lingkungan Hidup Provinsi DKI Jakarta (2022)

Figure 3.3 Potential Greenhouse Gas Emissions from Solid (Organic) Waste in Jakarta

Bantargebang, as the final destination for waste, accommodates urban waste from Jakarta, where a waste processing system that stores without being closed has the potential to contribute to CH_4 and CO_2 greenhouse gas emissions. Bantargebang, as a final disposal site, has a land area and capacity, as shown in Table 3.4. The open landfill model is cheap and easy, but causes many losses, both for humans and the environment. The law regarding the environment Number 18 of 2018 prohibits waste management using the open dumping method at the final disposal site, as referred to in Article 29 paragraph 1F.

C. Environmental Impact of Urban Solid Waste Final Disposal

According to the United States Environmental Protection Agency (US EPA, 2023), methane emissions from urban landfills in 2021 will be roughly equivalent to greenhouse gas emissions from 23.1 million fossil fuel passenger vehicles, resulting in CO_2 emissions equivalent to 13.1 million household energy used for one year. At the same time, according to the World Bank (2022), the rate of waste generation is increasing worldwide. By 2020, the world is expected to generate

2.24 billion tons of solid waste, equivalent to an ecological footprint of 0.79 kilograms per person per day. With rapid population growth and urbanization, annual waste generation is expected to increase by 73% from 2020 to 3.88 billion tons in 2050.

The most pressing environmental problem regarding landfills is the release of methane gas. As the organic mass in landfills decomposes, methane gas is released. Methane is 84 times more effective at absorbing the sun's heat than carbon dioxide, making it one of the most potent greenhouse gases and a huge contributor to climate change, and the creation of landfills usually means destroying natural habitats for wildlife. The average landfill size is 600 hectares. For example, with more than 3,000 active landfills in the United States, 1,800,000 hectares of habitat have been lost (Vasarhelyi, 2021).

In Jakarta, the final disposal of urban waste located in Bantargebang, Bekasi has been carried out since 1989, initially using the open dumping method and then changing it to the landfill method. In 2019, following up Presidential Regulation No. 35 of 2018, the Bantargebang waste final disposal site has completed the construction of a waste management system that generates electricity in an effort to reduce the growing volume of urban waste generation.

Tabel 3.4 Types of Landfills in Bantargebang Bekasi City

Province	Location	Landfill type	Land Area (ha)	Capacity (m^3)	Existing Volume (m^3)
Jakarta	Jalan Raya Narogong Km 14 Pangkalan V Bekasi Jawa Barat	Open Dumping dan Controlled Landfill	111.97	21,879,000	22,387,370

Source: Dinas Lingkungan Hidup Provinsi DKI Jakarta (2022)

Generation of solid waste can produce leachate in landfills where the soil surface is not covered with waterproof materials such as geotextiles. Rainwater that falls on waste will seep into the soil and mix with surface water and groundwater, besides that it also causes air pollution (Alqassim, 2021).

Leachate can come from waste generation by mixing organic and inorganic waste. Chemical waste that is disposed of carelessly also has the potential to produce leachate-containing chemicals, such as from used batteries, electronic equipment, or household cleaners. The leachate content is influenced by several factors, such as the type of waste that is deposited to the conditions at the landfill site. The smell of leachate comes from the content of hydrogen sulfide. So, leachate is a pollutant, or causes severe contamination of groundwater and other water bodies (Rajoo et al., 2020). A study by Siddiqua et al. (2022) shows that landfills emit several gases, including sulfur dioxide (SO_2) and nitrogen dioxide (NO_2), that have a negative impact on the environment. Inhaling one of these gases can cause irritation of the throat and nose, which can potentially lead to asthma.

D. Urban Solid Waste Converted into Electricity: Experience in Other Countries

The availability of vacant land that has not been developed (not yet utilized), becomes an economical short-term waste disposal site. Landfilling is a technique used by most of the waste materials left over from incineration. The treatment of solid waste before disposing of it to landfill is mandatory in most developed countries, although such policies are often poorly implemented in developing countries.

In Indonesia, urban waste management is regulated in the Presidential Regulation of the Republic of Indonesia No. 35 of 2018, concerning the Acceleration of Development of Environmentally Friendly Technology-Based Waste Processing Installations into Electricity. Article 2 paragraph 1 states that waste management aims to improve public health and environmental quality, reduce the volume of generated waste, and the beauty of the city and water resources. In paragraph 2, it is stated that waste management is carried out in an integrated manner from upstream to downstream, and in paragraph 3, explains that the resources referred to in paragraph 1 are carried out to obtain added value as electrical energy. With Presidential Decree No. 35 of 2018, it is hoped that solid waste management in Jakarta will no longer be in the form of open dumping and make the City of Jakarta healthier with a controlled volume of waste generation.

Solid waste incineration is a simple incineration process. The incineration process, often described in the industry as heat treatment, uses a special incinerator that burns waste material to ash, heat, and flue gases (i.e., gases that escape from a chimney into the ambient air). In more modern facilities, the resulting by-products can be lumped and used for other purposes, by recycling them. For example, the heat generated from the combustion process can be used to generate electricity and solid waste, such as fly ash, which can be used as a material to make bricks, shingles, or tiles.

Burning trash is widely practiced, and really popular, in countries like Singapore, the Netherlands, and Japan, where land is scarce. Other European countries, such as France, Germany, and Luxembourg, also use incineration to dispose of Municipal Solid Waste (MSW). The inorganic material in the effluent that forms ash after combustion can be in the form of agglomerates or solid particles. There must be an adequate air supply for maximum combustion while eliminating the formation of carbon monoxide (CO) and dioxins. The heat generated from this process can be utilized as a source of electric power (Alqassim, 2021).

1. How a Waste Power Plant Works

The most common waste-to-energy conversion system in the United States is the mass combustion system. In this system, urban solid waste that is not recycled is burned in a large incinerator with a boiler and generator to generate electricity (U.S. Energy Information Administration, 2022). The amount of ash produced ranges from 15%–25% (by weight) and 5%–15% (by volume) of the processed urban solid waste. Generally, the remaining combustion consists of two types of materials, namely fly ash and bottom ash. Fly ash refers to fine particulate matter removed from flue gases and includes residue from other air pollution control devices, such as scrubbers. According to Meima and Comans (1997), combustion residues, such as bottom ash from urban solid waste incinerators, and alkaline coal fly ash produced worldwide in increasing quantities. Combustion residues, however, can pollute the environment due to the presence of potentially toxic elements relative to soils and sediments.

Fly ash usually amounts to 10–20 weight percent of the total ash. The remaining municipal solid waste (MSW) combustion ash is called bottom ash (80–90 percent by weight). The main chemical components of bottom ash are silica (sand and quartz), calcium, iron oxide, and aluminum oxide. Bottom ash usually has a moisture content of 22–62 percent dry weight. The chemical composition of the ash varies depending on the original MSW feedstock and the combustion process. The ash remaining from the MSW incineration process is sent to landfills (US EPA, 2023).

There is potential for air pollution due to the burning of urban solid waste, so each combustion furnace is equipped with a fly ash catcher as an effort to reduce air pollution in Indonesia. According to Syarifudin, at waste power plant/pembangkit listrik tenaga sampah (PLTSa) Bantargebang Bekasi, the ash left over from burning is used to make paving blocks. In 2020, 29.263 paving blocks have been produced (Wiryono & Maullana, 2021).

2. America's experience in managing urban solid waste into electrical energy

In the early 1990s, the United States burned more than 15% of all MSW. Most nonhazardous waste incinerators have pollution control equipment to remove mercury and dioxin emissions. The US Environmental Protection Agency (EPA) enacted the Maximum Achievable Control Technology (MACT) regulations in the 1990s. As a result, most of the existing facilities, which do not yet have pollution control equipment, have to be installed with closed or air pollution control systems. Currently, there are 75 facilities in the United States that recover energy from burning municipal waste. These facilities exist in 25 states, mainly in the Northeast. A new facility was constructed in Palm Beach County, Florida, in 2015 (US EPA, 2023). Other countries in the world that are densely populated and have limited land, for example, countries in Europe and Japan, have adopted burning waste that converts it into electrical energy as energy recovery due to limited land. The solid waste landfill option in America is a more viable option, especially in the short term, because of the lower economic costs of building a MSW landfill compared to building an incineration facility.

The reason for the slow pace of construction of municipal waste incinerator plants in the United States is due to public disapproval of factories that do not have emission control equipment, which causes air pollution. In addition, many residents do not want additional traffic jams due to the traffic of garbage trucks and the proximity of settlements to municipal waste incinerators. In addition, the investment required to build a MSW incineration facility can be significant, and the economic benefits may take several years to be fully realized. New factories usually need at least $100 million to finance their construction, and larger factories may need double to three times that amount.

MSW incineration facilities usually collect a tipping fee from an independent contractor who unloads the waste daily to recover costs. The factory also receives revenue after the electricity generated from the waste is sold to the power grid. The third possible revenue stream for the facility comes from the sale of ferrous and nonferrous scrap metals collected from the post-combustion ash stream (US EPA, 2023).

3. Sweden's experience in converting urban solid waste into electrical energy

In most countries, landfill is growing at an unsustainable rate. According to the International Solid Waste Association (ISWA), 40% of solid waste worldwide ends up in uncontrolled open landfills. As many as 38 out of 50 landfills are at risk of polluting the oceans and beaches, while 64 million people are directly affected, with serious health problems. Solid waste that decomposes in landfills produces methane gas, which is released into the atmosphere, causing climate change. At the current pace, at least 10% of global greenhouse gas emissions will come from the world's landfills by 2025.

As the world looks for ways to reduce the accumulation of solid waste in open dumps, the Swedish state sends less than one percent of its waste to solid waste landfills. Much of Sweden's success in reducing solid waste to open dumps is due to its high recycling rates. Between recycling solid waste and composting organic material, Sweden recycles about half of what it disposes of. Sweden is an early adopter of waste-to-energy. Its first factory went into operation amidst the post-war house building boom in the late 1940s. The new houses, which were built each had their heating connected to the district heating network, which was centrally located, and pumped it to each house so that each house did not have its own boiler.

For many years, most of the energy powering these district heating networks was supplied by waste-to-energy power plants, with major expansions beginning in the 1970s. Currently, Sweden has 34 waste-to-energy plants that supply heat to 1,445,000 households and 780,000 households with electricity, an impressive figure for a country with a population of only 10 million. In fact, Sweden has a shortage of waste to fuel in its waste-to-energy plants, so the rest of Europe now pays Sweden to take their 1.9 million tonnes of waste a year and burn it by converting it into energy that Sweden uses to heat its homes and earn as much as $100 million per year as a privilege (Sieg, 2022).

4. Urban Waste to Energy Project in China

The effective disposal of MSW is a serious environmental challenge in China. Due to rapid urbanization, China has become the second-largest producer of urban solid waste in the world. More than 35% of such waste is disposed of in inappropriate landfills, exposing residents to soil and groundwater contamination, as well as severe air pollution. According to the World Bank (EASUR, 2005), China has recently overtaken the US as the world's largest producer of MSW. In 2004, China's urban areas generated around 190,000,000 tons of MSW and by 2030 this amount is projected to be at least 480,000,000 tons. No country has ever experienced this large or rapid increase in waste generation. MSW generally refers to household and commercial waste as well as waste in urban areas. Estimates show that the People's Republic of China generates around 220 million tons of waste every year. The volume of urban waste increases every year in line with the increase in population and economic growth.

In 2009, not all urban waste was collected, sorted, recycled, and disposed of properly. Nearly 50% of the waste in the secondary urban areas of the People's Republic of China ends up in landfills and outengineered waterways. Failure to prevent such disposal practices and improperly managing MSW can lead to local, regional, and global environmental problems such as air pollution, soil and groundwater contamination, and greenhouse gas (GHG) emissions (ADB, 2015).

The newly amended Law of the People's Republic of China on the Prevention and Control of Environmental Pollution Caused by Solid Waste ("Solid Waste Law") came into force on September 1, 2020. This is the second major amendment after its enactment in 1995. The goals set by the Solid Waste Law are to protect and improve the ecological environment, to prevent and control environmental pollution caused by solid waste, to safeguard public health, to maintain ecological security, to promote ecological civilization development, and to promote sustainable economic and social development (Wang, 2020).

China is going a step further in urban waste management by introducing several waste collection solutions using advanced, intelligent, and unique technologies to help Beijing implement a waste classification system similar in Shanghai, Shenzhen, and 16 other cities across the country. Beijing has also introduced artificial intelligence (AI) in its waste management system. Facial recognition technology has been used in trash cans to encourage people to recycle more. The smart trash-can pilot program, which has been running since 2019, registered all participating citizens and took their photos. When residents take out their trash, the smart trash-can can automatically scans their faces to identify them. After the bin itself recognizes that the user is a resident, the lid is opened, and the recyclables are weighed. QR-coded trash bags ensure that the right waste has been dropped into the right bin. Residents are given prize credit for excelling at recycling. This step received appreciation from many parties (Lombard Odier, 2021).

With assistance from the Asian Development Bank (ADB), China is now developing waste-to-energy processing with appropriate and clean technology. Under a public-private partnership that offers concessions to urbanities, such factories have been built in four cities. This project uses advanced and reliable technology that does not require coal as an additional fuel. In addition, air emissions are treated to meet the world's most stringent environmental standards. Using the Asian Development Bank's innovative financing approach, a private company developed six waste to energy (WTE) plants that process 6,200 tons of urban solid waste, generating an additional 132 megawatts of power capacity and delivering 630 gigawatt-hours of electricity annually (ADB, 2015).

5. Japan's experience in converting urban solid waste into electrical energy: Improved collection efficiency and wide area transportation via transfer stations

Expansion of urban areas, encouraging the expansion of waste collection zones to increase the efficiency of collection and transportation operations in cities by building and adding waste transfer stations. Trash can be transferred from small or medium-sized dump trucks to larger trucks. Garbage collection operations and transportation costs constitute the largest weighting percentage of waste management. The expansion of the waste transfer station not only leads to cost reduction but also reduces CO_2 emissions, contributing to the prevention of global warming.

Determining whether or not to build a transportation station depends on its cost-effectiveness. In general, if the distance exceeds 18 km, the presence of transport stations must be considered. Improving the efficiency of collection and transportation leads to reduced costs while maintaining the principle of improving services to the population. Many roads are narrow in Japan, and garbage collection trucks weighing 1 to 2 tons were developed to be lighter to increase payload capacity. There are two types of garbage collection trucks, namely mechanical trucks (Mobile Packers) and compressor-type trucks.

Garbage with a high moisture content reduces the compression efficiency. However, with continuous modification, the truck can achieve a high degree of compression, with a load of 1.5 times more than a flat pile truck. The compressor-type truck presses the waste to the floor with a pressure plate, and after it has been broken down and the volume reduced, the waste is put into storage. The truck efficiently collects large solid waste that requires splitting, large PET bottles and plastic waste. Due to the problem of global warming all over the world, dump trucks of low pollution type, with electric motor drive and hybrid trucks, are being developed and put into practical use.

Since 1960, Japan has begun to manage urban solid waste by incineration. Currently, Japan has the world's leading incineration facilities. In the 2009 fiscal year, there were 1,243 incineration facilities. The process of burning solid waste uses several methods, such as stoker furnaces, fluidized bed furnaces, and fusion gasification furnaces. These methods aim to recycle ash. Stoker furnaces account for 70% of all furnaces, the improvement of this type of furnace is growing rapidly. At present, a high degree of environmental conservation technology is being introduced. Technologies related to high-efficiency power plants and technologies related to safe operation, such as automatic incineration devices and automatic cranes, are also being developed. Japan is accumulating know-how to handle various types of waste, from low-calorie waste generated when incineration facilities were first built to high-calorie waste. This technology can be utilized for the types of waste generated in the Asian region. The newest stoker furnace technology is low-air incineration aimed at high-efficiency power plants built in Japan. Other technologies were developed, including reducing dioxin emissions, removing acid gases and recycling combustion ash. The conventional stoker furnace has undergone significant improvements, with better heat recovery after combustion. This system allows for efficient, clean electricity generation compared to conventional methods. This new technology allows Japanese incineration plants to be safe and healthy while generating electricity efficiently (Japan Environmental Sanitation Center, 2012).

Japan already has high, reliable, safe and healthy technology for burning solid waste. When planning the construction of solid waste incineration facilities, the government engaged in communication with the local population, enabling rapid progress on plans for the construction of incineration facilities in urban and residential areas. There are many urban incineration plants, both large and small, which operate according to strict anti-pollution policies (Japan Environmental Sanitation Center, 2012).

The Japanese Ministry of Environment (2023) reports the condition of national waste in Japan as follows: (1) the total waste generated is 40.95 million tons, and 890 grams per day per person; (2) the total amount of waste and the amount of waste generated per person per day has decreased; (3) the number of waste incineration facilities has decreased (1,056 in 2020 to 1,028 factories in 2023); (4) the number of incineration facilities with power generation facilities reached 38.5% of the total, up from 36.6% in the previous fiscal year; and (5) the total amount of power generated at incineration plants increased (10,452 GWh, equivalent to the consumption of about 2.5 million households.

E. What Has Been and Must Be Done by the Government of DKI Jakarta in Terms of Urban Solid Waste Management

Presidential Regulation No. 35 of 2018 concerns the acceleration of development of environmentally friendly technology-based waste processing installations. The presidential regulation aims to reduce the volume of solid waste produced and generate electricity by utilizing solid waste as a raw material.

DKI Jakarta Government implements Presidential Regulation No. 35 of 2018 by building an installation named PLTSa Merah Putih, which was built in Bantargebang, in the final solid waste disposal area which was built in 2018, and in 2019 it was inaugurated by the Coordinating Minister for Maritime Affairs. Furthermore, in 2020 to 2022 PLTSa will be operated by the DKI Jakarta Provincial Government accompanied by BRIN. PLTSa is still in the small-scale pilot plant stage. Further steps are needed to optimize (Astungkoro & Ramadhan, 2023).

PLTSa Merah Putih uses thermal process technology combustion, which can destroy solid waste quickly, significantly and environmentally friendly. The PLTSa pilot project is designed to operate continuously 24 hours/day and 250–300 days/year, using solid waste fuel with a capacity of 100 tons/day and producing 700 kW of electricity, which will be used for the internal operations of the PLTSa unit (Wiryono & Maullana, 2021).

1. How efficient is the management of urban solid waste in DKI Jakarta?

In the following discussion, we will describe the management of waste into energy. The discussion is divided into three topics, namely operations, culture changes, and financing the construction of a solid waste processing plant into energy.

a. Operation

Bantargebang as a place for producing electrical energy called the Merah Putih Waste Power Plant (PLTSa) has the shortest distance of 21 km and the farthest distance of 60 km to the temporary solid waste disposal sites, which are spread over five areas in the City of Jakarta with 15 landfills. Long distances and heavy traffic conditions take a long time to travel, and the emissions emitted by trucks along the road are also increasing, as are the costs incurred. If the DKI Jakarta Provincial Government's plan to build four Intermediate Waste Management Facilities (FPSA) in the DKI Jakarta area can be realized, it will make efficient and effective waste management, especially if this temporary management facility is developed into a waste power plant (PLTSa).

Based on Japanese experience since 1960 in waste management, solid waste collection and transportation costs constitute a high percentage of all disposal operations to landfills. Improving the efficiency of waste collection and transportation leads to reduced operating costs while maintaining or improving services to the population.

Transferring to bigger trucks at transportation stations spread across five areas of Jakarta city, increasing transportation efficiency, and reducing truck fuel consumption. One large truck can replace 2–3 medium-sized trucks in transporting solid waste to the final storage location. This not only reduces operational costs, but also reduces CO_2 emissions, as one of the contributors to urban pollution.

Whether or not it is necessary to build transportation stations in five areas of the City of Jakarta following the experience of the Japanese State, if the transportation distance exceeds 18 km, a waste collection station should be considered, and using large trucks as transporters to be sent to the final collection point in Bantargebang, Bekasi. Collection of waste from residential areas requires small and medium trucks to transport waste to transit stations spread across 15 locations. From these 15 collection points, waste is transferred back to large trucks at transportation stations to be sent to final disposal sites to be converted into electrical energy.

The waste management process begins with sorting the type of waste that is carried out at temporary landfills, separating organic waste and non-organic waste, carried out with the aim of obtaining efficiency in the process of converting waste into electrical energy. Waste segregation can be carried out at solid waste final disposal sites at 15 locations in the city.

In the City of Jakarta, scavengers collect waste that has economic value. They operate in residential areas, bus terminals, and community gathering places. The waste they collect includes plastic drink bottles, cardboard, metal, glass, and electronic equipment. Apart from scavengers, in Jakarta there are many waste banks managed by the community. Phenomena like this can help reduce solid waste that has to be sent to landfills.

The quality of the outcomes of waste power plant combustion is highly dependent on the drying of waste as fuel. In general, organic waste that enters the combustion chamber has a high enough moisture content, so it does not achieve efficient results. The ideal is dry waste; the hotter it is burned, the higher the yield. To achieve self-burning, the waste that enters the bunker has a maximum moisture content of 55%. If the waste has a moisture content of more than 55%, additional fuel or pre-treatment is needed to reduce the moisture content before entering the bunker so that the combustion process can run optimally. The waste in the bunker is free from materials that are prohibited as fuel for burning, namely metal, glass, aluminum foil, PVC, and B3 waste. For large-sized waste, it will be set aside centrally before being brought to the factory (Manis et al., 2022). Since 2018, the DKI Jakarta Provincial Government has planned to build waste power plants (PLTSa), which convert waste into electrical energy. However, this plan has not yet been realized until 2023.

Sweden, which has almost the same population as the City of Jakarta, around 10 million people, has succeeded in managing its waste, thereby reducing waste. Nevertheless, there is another reason why Sweden is often described as the greenest country in the world. In the last few decades, the country has completely revolutionized waste management, drastically increasing its recycling rate and investing in technology to convert its waste into energy. Sweden is targeting households by implementing weight-based waste levies in an effort to encourage recycling. In addition, national laws prohibiting the accumulation of combustible and organic wastes, together with stricter standards for hazardous waste, landfill, and incineration imposed by the European Union on all its member states have allowed Sweden to reduce emissions and total waste landfill drastically. Since 1975, its recycling rate has jumped from a staggering 38% to 99%, and the country is now on the track to achieve its zero-waste goal, separating food waste, metal packaging, plastic, paper and glass, newspapers, electronics, tires, and batteries. To encourage everyone to do their part, Sweden built a waste collection station within 300 meters of all residential areas (Kim & Mauborgne, n.d.), and in the end, Sweden sold its waste management services to neighboring countries and made profits of up to 100 million dollars a year in foreign currency. Turning municipal waste into electrical energy in the United States can provide 2,700 MW of clean electricity for 24 hours per day, 365 days per year is enough to power about 2 million households (Pyper, 2011).

In Japan, in 2023, total power generated from waste incineration plants will reach 10,452 GWh, equivalent to the annual power consumption of around 2.5 million households (Ministry of the Environment and Forestry, 2023). Like Sweden, which earns foreign exchange by collecting state waste, Japan, which has experience in managing urban waste, has succeeded in selling waste management services and technology to other countries.

b. Culture Changes

In technology-based waste management, the human role remains the most important. Theory of environmentally responsible behavior (ERB) explains that having the intention to act is a key factor influencing responsible behavior to protect the environment. In addition to the intention to act, locus of control, attitude, sense of responsibility at a personal level, and knowledge are the main principles that influence the entire ERB (Siddiqua et al., 2022). In this theory, knowledge is the starting point for humans to understand, control themselves, and attitudes, which in the end humans will have the responsibility and positive behavior towards their environment. Waste management starts from oneself, home, school, workplace, then up to the city scale. Currently, waste management requires action and awareness from all elements of society, starting from disposing of waste according to its type, and in separate containers for its placement, for example, organic and non-organic waste disposal sites.

Changes in human and societal behavior regarding responsibility for the environment where the community is located require a long period of time. Changes in human behavior and society are in harmony with changes in the culture in which the community exists.

Culture is the way of life of a group of people—the behaviors, beliefs, values, and symbols that they accept, generally without thinking about it, and which are passed on through communication and imitation from one generation to the next. Culture is symbolic communication.

Thus, culture includes language, ideas, beliefs, customs, codes, institutions, tools, techniques, works of art, rituals, and ceremonies, among other elements. The term "cultural change" used by sociologists has changed. Communities take on new cultural characteristics, behavior patterns, and social norms. Community changes occur because of contact with other communities, because there is constant persuasion, related to waste handling, persuasions that are made, for example, how good it would be if our environment were free from garbage that makes life healthy and comfortable. This persuasion must be accompanied by examples, as well as providing motivation and ways to deal with waste in our environment. Community involvement in waste management independently is a form of community participation.

c. Financing the Construction of a Solid Waste Processing Plant into Energy

Urban waste management is the responsibility of the local government. However, as the nation's capital, the City of Jakarta should be able to work together with the central governments, as is the case in developing other infrastructure such as the mass rapid train (MRT) and light rapid train (LRT).

In most developing countries, governments face the challenge of meeting the growing demand for new and improved infrastructure services. Due to limited funds available from traditional sources, the government is motivated to look for alternative sources of funds to build infrastructure, such as waste-to-electricity processing plants.

Partnership with the private sector is an alternative to building a waste processing factory into electrical energy. In Indonesia, it is regulated in Presidential Regulation (Perpres) Number 67 of 2005 concerning Cooperation between the Government and Business Entities in the Provision of Infrastructure.

Because the infrastructure development budget owned by local governments is limited, the choice of financing instruments with the public-private partnership is an attractive option for the government as an off-budget mechanism created for infrastructure development for the following reasons: (1) the government does not require immediate cash outlay; (2) the private sector as a partner is not burdened with design and construction costs; (3) the private sector as a partner will bring advanced technology, so it is hoped that there will be transfer of technology and management of the conversion of waste into electrical energy.

In the financing scheme through the public-private partnership (PPP) mechanism, there are several models of financing instruments offered, including: supply and management contracts, turnkey, affermage/lease, concessions, private ownership of assets, and FPI Type. A description of all models of financing instruments can be seen in Table 3.5. In the case of solid waste management in the City of Jakarta, it is advisable to use a financing instrument with a concession scheme.

2. Concession

In this form of PPP, the government determines and grants special rights to private companies to build and operate facilities within a certain period of time. The government may retain final ownership of the facility and/or the right to provide the service. In concessions, payments can be made in two ways: the concessionaire pays the government for the concession right and the government can pay the concessionaire, subject to an agreement to fulfill certain conditions. Typically, such payments by the government may be required to make the project commercially viable and/or reduce the level of commercial risk taken by the private sector, with the concession period ranging from 5 to 50 years.

Tabel 3.5 Classification of PPP models

Brand Catagory	Main Variants	Ownership of Capital Asset	Respon-sibility of Investe-ment	Assumtion of Risk	Duration of Contract (years)
Suply and manage-ment contract	Outsourcing	Public	Public	Public	1–3
	Maintenance management	Public	Public/ Private	Public/Pri-vate	3–5
	Operational management	Public	Public	Public/Pri-vate	3–5
Turnkey		Public	Public	Public/Pri-vate	1–3
Affermage/ Lease	Affemage	Public	Public	Public/Pri-vate	5–20
	Lease	Public	Public	Public/Pri-vate	5–20
Conces-sions	Franchise	Public/Pri-vate	Public/ Private	Public/Pri-vate	3–10
	BOT	Public/Pri-vate	Public/ Private	Public/Pri-vate	15–30
Private ownership of assets and FPI Type	BOO/DBFO	Private	Private	Private	Indefinite
	PFI	Public/Pri-vate	Private	Public/Pri-vate	10–20
	Divestiture	Private	Private	Private	Indefinite

Source: Quium (2011)

In a build-operate-transfer or BOT type of concession (and its other variants, namely build-transfer-operate [BTO], build-rehabilitate-operate-transfer [BROT], build-lease-transfer [BLT] type of arrangement), the concessionaire makes investments and operates the facility for a fixed period of time after which the ownership reverts back to the public sector. In a BOT model, operational and investment risks can be substantially transferred to the concessionaire. The BOT scheme refers to the initial concession by a public entity, such as a local government, to a private firm, to both build and operate the project in question. After a set time frame, typically two or three decades, control of the project is returned to the public entity.

F. Closing

Garbage is an interesting phenomenon and is of global concern, from low-income countries to high-income countries. Many countries have realized that waste generation is one of the causes of the greenhouse gas effect because of the methane gas present in solid waste generation. Thus, integrated waste management in several countries by converting waste into electrical energy as a renewable energy substitute for fossil fuels can reduce emission levels and have a positive impact on emission control which leads to a reduction in the greenhouse gas effect. Many countries in the world have abandoned waste management using the open dumping method, which produces methane gas, which contributes to the greenhouse gas effect.

Management of urban solid waste using the waste-to-energy method by burning in an incinerator reduces waste by up to 80%–90%, and the ash from the combustion can be used as a raw material for making paving blocks which is a by-product other than electricity. With the combustion method that converts waste into electrical energy, the volume of solid waste generation and urban solid waste problems can be reduced. Learning from Sweden and Japan, waste brings blessings by bringing in foreign exchange for Sweden and Japan, which sells services and technology that converts waste into electricity.

The City of Jakarta has started to manage waste in an integrated manner using the burning method. PLTSa Bantargebang is already operating on a small scale and is planned to be built in four areas in DKI Jakarta. The electricity generated from the conversion can be used to drive public transport such as buses, MRT, and LRT, which can contribute to reducing emissions.

Even though waste management uses advanced technology, the role of humans remains the main factor, so education and outreach about waste is needed from an early age. Countries that have succeeded in managing waste by implementing integrated waste management require a long time to educate and socialize the society.

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Chapter 4

Renewable Energy and Sustainability: Assessment Based on the United Nations Sustainable Development Goals

Yogi Sugiawan, Falikul Fikri, Shunsuke Managi

A. Introduction

The world has witnessed remarkable technological advances that have enabled us to explore new frontiers and tap into previously inaccessible energy sources. However, these achievements have not solved the pressing challenges of environmental degradation and climate change. As a result, the global development agenda has shifted from a narrow focus on the limits of growth imposed by resource scarcity to a broader and more holistic vision of sustainability that balances economic, social, and environmental objectives (Ekins, 1993; Kaika & Zervas, 2013; Naveed et al., 2022). The notion of sustainability requires that the pursuit of well-being should be carried out within planetary boundaries so that intergenerational equity will be main-

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tained over time (Managi & Kumar, 2018). Nevertheless, the prevailing trend in worldwide economic advancement, which demonstrates a strong correlation with the swift exhaustion of natural resources and escalating carbon dioxide emissions caused by human activities, has resulted in the transgression of these boundaries (Sugiawan & Managi, 2019). Such an unsustainable development pattern stems from the high dependency on fossil fuels in most of the world's economy. In 2019, less than 16% of the world's primary energy consumption came from nonfossil or low-carbon energy sources, of which around 4% came from nuclear energy and more than 11% came from renewables (Ritchie et al., 2022).

Improving access to affordable, reliable, and modern energy services is essential for economic development. However, with the domination of fossil fuels in the global energy mix, increasing levels of energy consumption are positively correlated with increasing levels of carbon dioxide emissions and rapid depletion of natural capital, creating a strong interrelationship between economic development, energy consumption, and environmental degradation (Sugiawan et al., 2019). This has led to a so-called ethical dilemma between economic growth and environmental sustainability (Antonakakis et al., 2017). For instance, policies aiming to boost economic growth by promoting higher levels of energy consumption might be beneficial for improving the well-being of the current generation, yet they might pose a serious threat to the environment and the well-being of future generations. Similarly, policies aiming to restrain energy consumption might be beneficial for preserving the nature and well-being of future generations, but they might be harmful to the economy, which is unfavorable for the well-being of the current generation. As a result, efforts to decouple environmental degradation from economic growth and to find a balance between economic and environmental goals remain elusive.

Shifting to low-carbon energy sources is believed to be one of the most feasible options to detach environmental degradation from economic growth so that the well-being of the current and future generations can be achieved simultaneously (see, for instance, Pahle et al., 2016 and Bogdanov et al., 2021). However, the renewable energy sector still faces noteworthy challenges, making it grow slowly and unable to catch up with the rapid growth of global energy consumption. The intermittent nature and the economic competitiveness are the two main reasons why renewable energy sources are less favorable compared to fossil fuels, particularly in developing countries (Ang et al., 2022). Additionally, Diesendorf and Elliston (2018) argue that political, institutional, and cultural aspects are also responsible for the slow growth of renewable energy sources. As a result, the world still burns more and more fossil fuels each year, resulting in an increasing level of carbon dioxide emissions.

In light of the aforementioned context, the primary objective of this chapter is to evaluate the sustainability of energy consumption from the perspective of the United Nation's sustainable development goals (SDGs). The primary academic contribution of this chapter is to present empirical evidence with regards to the effects of low-carbon energy consumption, specifically renewable energy, on the sustainability of energy systems and sustainable well-being. Despite the extensive literature on this subject, there appears to be no prior empirical investigation from the UN SDGs perspective. For this purpose, the present chapter will utilize the nonparametric machine learning technique, renowned for its exceptional predictive performance. The subsequent section of this chapter is structured in the following manner. Section B assesses the environmental Kuznets curve (EKC) hypothesis as a means of determining whether it is possible to separate environmental degradation from economic growth. Section C aims to develop an empirical strategy to link the footprint of energy consumption with the SDGs framework. Section D delves into the significance of renewable energy sources in ensuring sustainable and affordable energy access. Section E sheds light on the crucial role that renewable energy sources play in advancing sustainability with respect to the SDGs. Section F concludes the discussion and provides policy recommendations.

B. Endless Quest for Decarbonizing the Economy

The environmental Kuznet curve (EKC) hypothesis proposes a positive outlook towards sustainability. The EKC hypothesis challenges the conventional wisdom that economic development leads to environmental degradation. Instead, it proposes that once a certain income threshold is reached, further economic growth can actually lead to environmental improvements. The hypothesis was inspired by the empirical findings of Grossman and Krueger (1991), who observed an inverted U-shaped relationship between income per capita and some pollutants. Later, Beckerman (1992) argued that poverty is the main cause of environmental problems and that becoming rich is the best solution. Panayotou (1993) coined the term EKC to distinguish this hypothesis from the Kuznets hypothesis, which describes a similar relationship between income inequality and economic development. The EKC hypothesis has attracted much attention and debate in the literature since its emergence in the early 1990s, as it implies that sustainability can be achieved by pursuing economic development.

The nexus between energy and growth is a subject of great interest in sustainability research, as it encompasses four primary hypotheses: the growth, conservation, feedback, and neutrality hypotheses (see, for instance, Hajko et al. (2018) for a detailed explanation regarding the four hypotheses of the energy-growth nexus). Out of the four primary hypotheses regarding the nexus between energy and growth, the EKC hypothesis stands out as a promising pathway towards sustainability, regardless of the type of causal relationship between energy consumption and economic growth. Within the literature on the energy-growth nexus, a more sustainable economy is depicted by either conservation or neutrality hypotheses since energy and environmental conservation policies, which may limit the consumption of fossil fuels, can be pursued without negatively impacting economic growth (Menegaki & Tugcu, 2017). However, the EKC hypothesis challenges this notion and suggests that energy-dependent economies, which are represented by growth or feedback hypotheses, can also trail the sustainable development path. While energy consumption is a significant driver of economic growth in such economies, the EKC hypothesis posits that as countries become wealthier, new and cleaner energy technologies, such as renewable energy sources and nuclear energy, become more affordable. Consequently, the detachment of environmental degradation from energy consumption can pave the way for economic growth that is sustainable and eco-friendly.

Understanding the EKC phenomenon requires an explanation of the three key impacts of economic progress, namely, the scale effect, the composition effect, and the technique effect (Stern, 2004). The scale effect pertains to the escalation in contamination emanations as a result of the amplification of economic activities and the persistent depletion of natural resources beyond their replenishment capacities (Panayotou, 1993). This effect is particularly striking in the early stages of development as the economy moves from an agrarian to an industrialized form. In relation to energy consumption, the scale effect is characterized by the extensive use of fossil fuels, notably coal, which is relatively low-cost but highly polluting. The composition effect relates to the alteration of a nation's economic structure, where the emphasis is shifted from industries that rely on resources to those that are based on knowledge and services. This transition positively affects the environment by decreasing the environmental impacts associated with the latter sectors (Dinda, 2004). This effect is more evident at the later stage of development when income per capita is high enough to afford cleaner and more efficient technologies. The technique effect refers to the improvement in environmental quality due to technological innovation and diffusion, which reduce the pollution intensity of production and consumption (Dinda, 2004). This effect depends on the level of investment in research and development, which is usually higher in developed countries. A good example of the composition and technique effect is the transition to relatively expensive low-carbon energy sources, which have replaced some of the more polluting and relatively cheaper coal. According to Our World in Data (Ritchie et al., 2022), in 2020, coal accounted for more than 27% of the global primary energy or decreased by around 3%

over the last decade. The EKC hypothesis suggests that environmental degradation will decrease as income exceeds a certain threshold, with composition and technique effects having a more positive impact than the scale effect. However, Al-Mulali et al. (2016) argued that the attainment of a particular income threshold necessitates a substantial portion of renewable energy sources integrated into the energy mix.

The EKC hypothesis presents a compelling framework for reducing carbon emissions in the economy; however, it is not devoid of shortcomings and critiques. One important consideration to bear in mind with the EKC hypothesis is that the point at which environmental degradation declines may only occur at extremely high levels of income per capita. These levels may be so high that they are unrealistic or even impossible to reach for many countries. For instance, Sugiawan and Managi (2016) estimated a turning point of the EKC at an income level of 7729 USD per capita for the case of Indonesia, or twice as much as the per capita income level of Indonesia in 2021, suggesting that this turning point is not likely to be achieved in the short-term. Moreover, Sugiawan et al. (2022) forecasted that despite the significant reduction in carbon dioxide emissions, the carbon peak in Indonesia's economy was not observed until 2050. Similarly, Bölük and Mert (2015) found that Turkey's economy will be decarbonized at an income level of 9920 USD per capita, which was considerably higher than the income level of Turkey in 2010. Nevertheless, all of the aforementioned studies have identified the significant role of renewable energy sources in reducing carbon dioxide emissions.

Regardless of the ongoing arguments regarding the validity of the EKC hypothesis and its appropriateness for sustainable development, it is imperative to evaluate the influence of renewable energy sources on a broader set of sustainability measures within the SDG framework. The SDG framework diverges from the EKC hypothesis in that it necessitates the attainment of socioeconomic and environmental objectives in every phase of development. Consequently, environmental deterioration that typically arises during the initial stages of economic growth is deemed unacceptable and constitutes a threat to sustainability. Nevertheless, economies have made greater strides in achieving socioeconomic-related SDGs compared to environmental-related SDGs (see, for instance, Halkos & Gkampoura, 2021), suggesting the existence of the EKC hypothesis. Bandari et al. (2022) argued that this prioritization is inevitable due to the unique resource constraints and varying stages of economic development of each nation. The impact of renewable energy consumption on sustainability will be rigorously discussed in the succeeding sections.

C. Empirical Strategy: Linking the Footprint of Energy Consumption with Sustainability in the SDG Framework

The SDGs provide a comprehensive framework for guiding humanity toward a more equitable and sustainable future. Among the 17 goals, SDG-7 aims to ensure access to affordable, reliable, sustainable, and modern energy for all. Furthermore, SDG-7 is specified further into five targets, i.e., (7.1) universal access to modern energy; (7.2) increase the global percentage of renewable energy; (7.3) double the improvement in energy efficiency; (7.4) promote access to research, technology, and investments in clean energy; and (7.5) expand and upgrade energy services for developing countries. To achieve this goal, a radical transformation of the current energy system, from fossil fuels to low-carbon energy sources, is required to create a balance between economic, social, and environmental goals. This, in turn, will accelerate the progress toward well-being in the SDG framework. However, the Sustainable Development Report 2022 (Sachs et al., 2022) reported that except for Latin America and the Caribbean, all regions in the world, on average, were not on track to achieving SDG-7. Additionally, He et al. (2022) estimated that despite the noticeable progress in SDG-7, the expected targets of SDG-7 are not likely to be achieved by 2030.

The SDGs were crafted as an integrated and indivisible set of 17 goals and targets with the intention of achieving them all simultaneously (Le Blanc, 2015). Notwithstanding this fact, the goals and targets were developed in a compartmentalized manner, resulting in inevitable trade-offs and synergies between the SDGs. The potential trade-offs across and within the SDGs are believed to be the main cause that hindered the simultaneous achievement of all 17 SDGs (see, for instance, Hametner, 2022). For instance, to expedite the advancement towards Target 7.1, underprivileged economies could potentially resort to more cost-effective energy sources, such as coal, to guarantee the accessibility and reasonable pricing of energy for all. Nevertheless, this strategy could prove detrimental to the realization of Target 7.2, which aims to enhance the worldwide proportion of renewable energy, as well as other environmental-related goals such as SDG-12 and SDG-13 (Sugiawan et al., 2023). It is, therefore, crucial to carefully evaluate the potential trade-offs between short-term gains and long-term sustainability while pursuing these targets.

In the light of sustainable development agenda, this chapter aims to explore the impacts of renewable energy sources on the SDGs by establishing the link between the footprint of energy consumption and the progress of SDGs. The first step of the analysis will be based on the following empirical relationship of the energy-SDG7 model:

$$SDG7_{it} = f\ (Fossil_{it}, Renewable_{it}, Nuclear_{it}) \qquad (4.1)$$

where *SDG7* is the progress of Goal 7 which is proxied by the SDG-7 Index score from the Sustainable Development Report 2022; *Fossil* is the aggregate of energy consumption from oil, coal, and gas; *Renewable* is the aggregate of energy consumption from hydropower, wind, and solar; and *Nuclear* is the total energy consumption from nuclear energy. To encompass a broader context of sustainability, the next step of the analysis will involve the following empirical relationship of the energy-SDGs model:

$$SDGS_{it} = f\ (Fossil_{it}, Renewable_{it}, Nuclear_{it}) \qquad (4.2)$$

where *SDGS* is the overall performance of SDGs which is proxied by the SDG Index score from the Sustainable Development Report 2022.

The data on energy consumption is measured in TWh and it was obtained from Our World in Data (Ritchie et al., 2022). The SDG Index score is a value from 0–100 which measures the country's progress in achieving the SDGs and it was obtained from https://dashboards.sdg-index.org/explorer. It is important to note that the calculation of the SDG-7 Index score only took into account Target 7.1 and 7.2. Hence, the SDG-7 Index score might not represent the actual performance of Goal 7. Similarly, the overall SDG Index score might deviate from the actual performance of all 17 SDGs, since the calculation of the SDG Index score did not take into account all the targets of the 17 SDGs. However, compared to other possible proxies, the SDG Index score is still a better proxy since it offers a more comprehensive and longer period of data. The present chapter undertakes an examination of a balanced panel comprising of 77 countries that spans the time period from 2000 to 2020. The selection of countries and the duration of the analysis were determined by the available data. To improve the model's predictive power and to make the model converge faster, the data on energy consumption is transformed into logarithmic forms.

Equations (4.1) and (4.2) are estimated by using the boosted regression trees (BRT) method, a widely recognized machine learning technique for its remarkable predictive performance (Elith et al., 2008). To prevent model overfitting, the sample is separated into two sets—the training set and the test set—based on the year. The training set comprises data from 2000 to 2015, whereas the test set comprises data from 2016 to 2020. This separation ensures that the model's accuracy is not compromised by its ability to fit itself to the sample data. To find the best model specification, this chapter relies on the automated machine learning (AutoML) tool which is available in the *forester* package in R. This tool will automatically find the best model specification by training the model with five different BRT methods, i.e., *decision tree*, *random forest*, *xgboost*, *catboost*, and *lightgbm*, and three different parameter optimizations, i.e., default, random search, and Bayesian optimization. The selection of the final model was determined by evaluating its predictive performance stability, which was determined by comparing the mean absolute error (MAE) with the lowest possible value and examining the smallest difference between the training and test set's MAE. Additionally, a reliable model should have an excellent predictive performance which is indicated by a mean absolute percentage error (MAPE) value of less than 0.1 (Sugiawan et al., 2019). Furthermore, to shed light on the "black box" characteristic of the BRT method, this chapter will rely on the *Shapley Additive exPlanations* (SHAP) method, developed by Lundberg and Lee (2017) to enhance the comprehensibility of the *xgboost* method. The SHAP method is available in *R* through the *SHAPforxgboost* package (Liu et al., 2021).

D. Promoting Access to Affordable and Clean Energy: Should We Invest More in Renewable Energy?

The impact of renewable energy consumption on the achievement of Goal 7 of the SDGs is assessed by using the energy-SDG7 model which is represented by Equation (4.1). Our analysis commences with evaluating the predictive performance of the model. The overall good fit of the model, for both the training and test set, is provided in Figure 4.1. The accuracy of the model is determined by the ratio between the predicted and the actual value. A value equal to 1 indicates a good fit, i.e., the forecasted value is equal to the actual value. The best model specification was found for the *lightgbm* method which was optimized by using the random search approach. Figure 4.1 shows that the progress in the SDG-7 Index score is well-predicted by our model with an in-sample MAE value of 1.378 and MAPE value of 0.020. For the test data set, as expected, the out-of-sample MAE and MAPE values dropped to 3.486 and 0.051, respectively. However, the MAPE values for both the training and test set are still below 0.1. Thus, it can be concluded that our model has excellent predictive performance and can be used for the subsequent analysis.

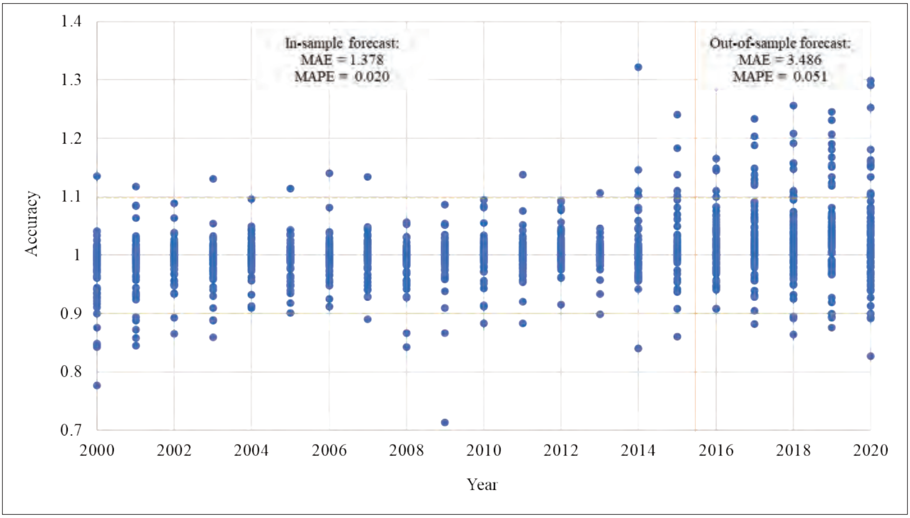

Figure 4.1 The Predictive Performance of the Energy-SDG7 Model

After confirming the reliability of the models, we carry on our analysis further by examining the SHAP importance plot as depicted in Figure 4.2. The vertical axis of the plot denotes the energy sources, whereas the horizontal axis denotes the SHAP value. The dots in the plot are indicative of SHAP values pertaining to particular energy sources, with orange dots denoting low feature value and purple dots denoting high feature value. The distribution of the dots in the plot portrays the correlation between energy sources and Goal 7 in the model. A positive correlation exists if the orange and purple dots are distributed in a pattern that resembles the color gradation of the feature value box (see the legend at the bottom part of the plot). On the contrary, a negative correlation exists if the orange and purple dots are distributed in an opposing pattern with the color gradation of the feature value box. If the orange and purple dots are distributed in a random pattern, then no inference regarding the direction of correlation can be made from the plot. The order of variables on the plot indicates the rank of importance, i.e., how significant the changes in variables will affect the progress of Goal 7.

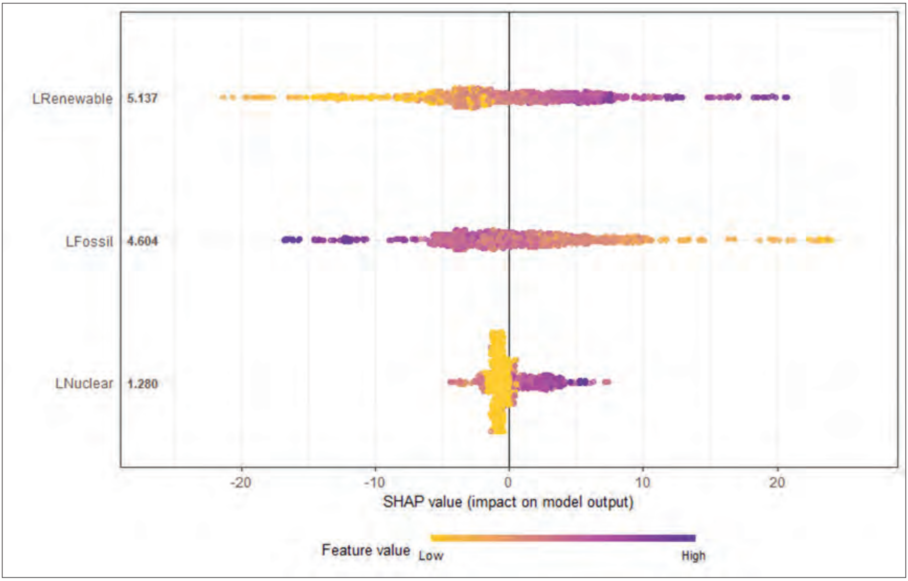

Figure 4.2 The SHAP Importance Plot of the Energy-SDG7 Model

From Figure 4.2, it can be seen that renewable energy sources are the most influential predictor of Goal 7, followed by fossil fuels and nuclear energy, with a SHAP value of 5.137, 4.604, and 1.280, respectively. Hence, compared to other energy sources, a small change in renewable energy consumption will have a more significant impact on the Goal 7 score. Figure 4.2 also captures the different impacts of each energy source in promoting the achievement of Goal 7. Unlike fossil fuels, high consumption of low-carbon energy sources is positively correlated with a high score of Goal 7. Additionally, Figure 4.2 also shows that among low-carbon energy sources, the impact of renewable energy sources on promoting Goal 7 is more prominent than that of nuclear energy. This is not a surprising result since the global consumption of renewable energy sources was almost three times higher than that of nuclear energy.

In order to fully grasp the relationship between energy sources and Goal 7 in terms of their functional structure, it is essential that the

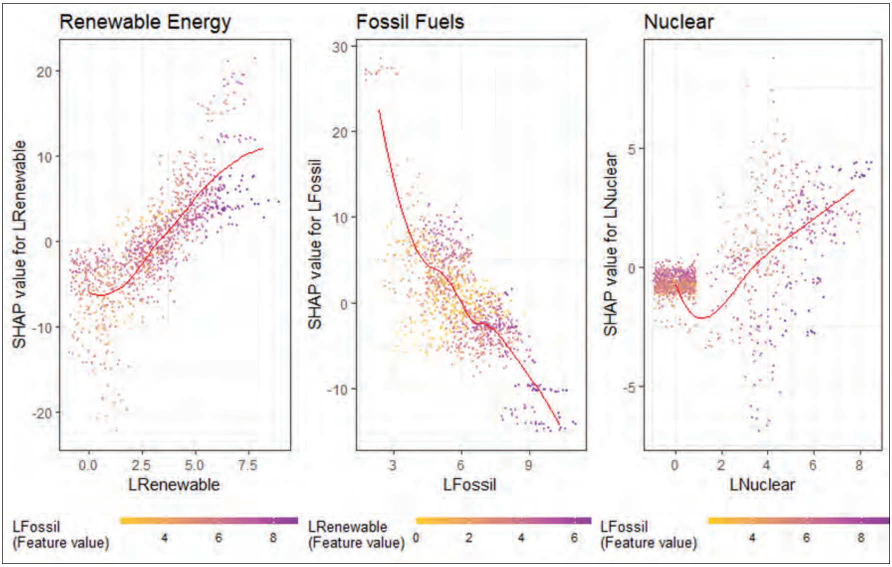

Figure 4.3 The Partial Dependence Plot of the Energy-SDG7 Model

importance plot is complemented with a partial dependence plot. This plot illustrates the model's fitted values in relation to individual predictors with great accuracy (Miller et al., 2016), as provided in Figure 4.3. Figure 4.3 shows that, to some extent, the relationship between energy consumption and the progress in Goal 7 can be approximated by a linear function. Additionally, consistent with the finding from the SHAP importance plot, we also found distinct effects of each energy source on the attainment of Goal 7, as evidenced by their respective slopes in the partial dependence plot. Positive slopes were found for low-carbon energy sources, while a negative slope was displayed for fossil fuels. The partial dependence plot is also able to portray the most significant interaction between energy sources that occurred in our model. From Figure 4.3, we found significant interactions between renewable energy and fossil fuels and between nuclear energy and fossil fuels. However, we found no evidence of significant interaction between low-carbon energy sources, i.e., between renewable and nuclear energy in promoting Goal 7.

The aforementioned findings suggest that the energy transition towards low-carbon energy sources is beneficial for accelerating the achievement of a sustainable energy system, as depicted by Goal 7 of the SDGs. Furthermore, in the framework of inclusive wealth (see, for instance, Managi & Kumar, 2018) for a detailed explanation of the notion of inclusive wealth), Sugiawan et al. (2023) showed that progress in Goal 7 will positively influence wealth accumulation, which is a necessary condition for achieving long-term sustainability. Thus, investing in low-carbon energy sources will be beneficial, not only for providing greater access to affordable and clean energy for all but also for achieving long-term sustainability in the framework of inclusive wealth.

Our findings also show that the interactions between each energy source were found to be complementary instead of substitutive. From Figure 4.3, we can see that high consumption of renewable energy is associated with a high score of Goal 7. However, this high score is still associated with the high consumption of fossil fuels, implying that renewable energy sources have not been able to substitute fossil fuel yet. For instance, a particular country may opt to boost new investments in renewable energy to achieve carbon neutrality. This obviously will result in an increase in the score of the SDG-7 Index, particularly for Target 7.2. However, such a policy might not be compatible with Target 7.1, which aims to provide greater access to electricity. Thus, at the same time, that particular country also invests in new fossil fuel power stations to provide affordable electricity. Such a policy will lead to a higher level of carbon dioxide emissions, resulting in a lower score of Goal 7. As a result, the final score of the SDG-7 Index will be determined by the net effect of the two policies. Hence, while investing in low-carbon energy sources can positively contribute to the achievement of Goal 7, the prevalent use of fossil fuels in the global energy supply has made the benefits less noticeable or even diminished.

E. Does Carbon Neutrality Matter to SDGs?

In the previous section, we established the link between energy consumption and Goal 7 of the SDGs and found that energy transition to low-carbon energy sources will be beneficial for promoting the achievement of Goal 7. While carbon neutrality is a crucial goal, it may not be adequate to guarantee sustainable development, and additional measures may be necessary to ensure intergenerational well-being (see, for instance, Sugiawan et al., 2019). The notion of sustainability requires intergenerational well-being to be maintained from being declined over time. Thus, evaluating the alignment of energy consumption with sustainable well-being, as proxied by the SDG Index score in this particular research, is of utmost importance. For this purpose, this chapter relies on the energy-SDGs model, which is provided in Equation (4.2). By doing so, this chapter will be able to discover whether energy consumption promotes or hinders the simultaneous achievement of the SDGs.

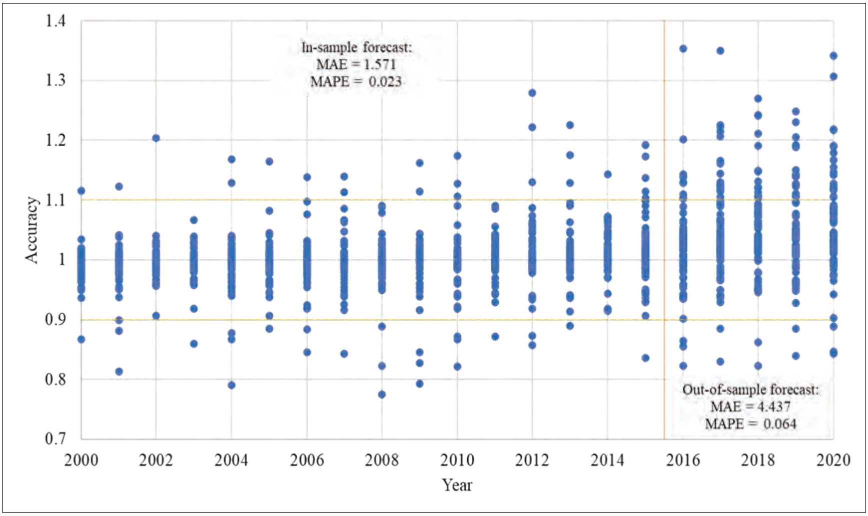

Figure 4.4 The Predictive Performance of the Energy-SDGs Model

Before commencing with the analysis, it is necessary to evaluate the reliability of the energy-SDGs model by looking at its overall performance. The graph shown in Figure 4.4 demonstrates that our model is a good fit, as it accurately predicts the progress of the SDG Index score with an in-sample MAE value of 1.571 and MAPE value of 0.023. Our model also shows a good predictive performance for the out-of-sample data with MAE and MAPE values of 4.437 and 0.064, respectively. This model specification was obtained from the *lightgbm* method which was optimized by using the Bayes optimization. Furthermore, in order to identify the significant predictors of SDGs, the next phase of the analysis will focus on the SHAP importance plot of the energy-SDGs model.

Figure 4.5 shows that fossil fuel is the most influential predictor of the SDG Index score, followed by nuclear and renewable energy, with a SHAP value of 2.694, 2.583, and 2.429, respectively. However, with such a slight difference in the SHAP values, it can be inferred

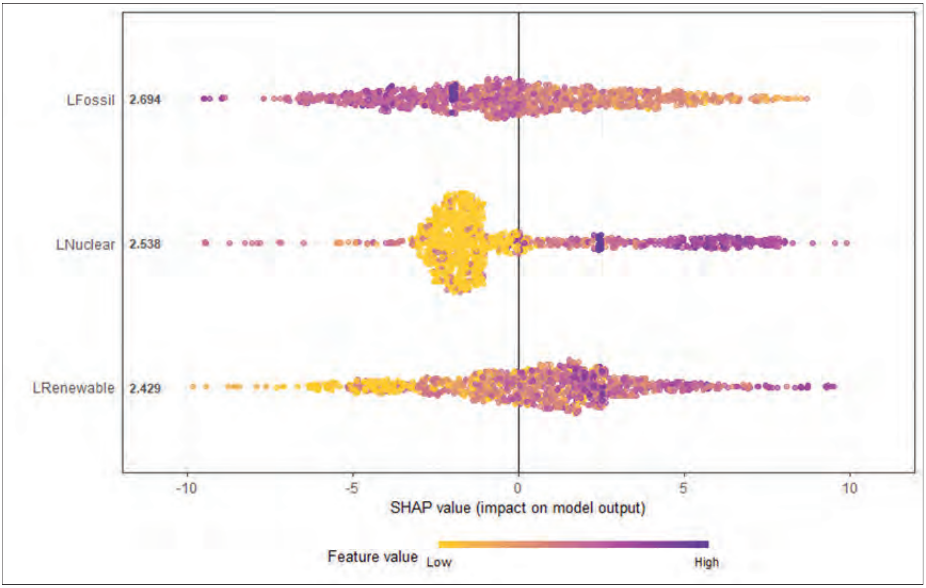

Figure 4.5 The SHAP Importance Plot of the Energy-SDGs Model

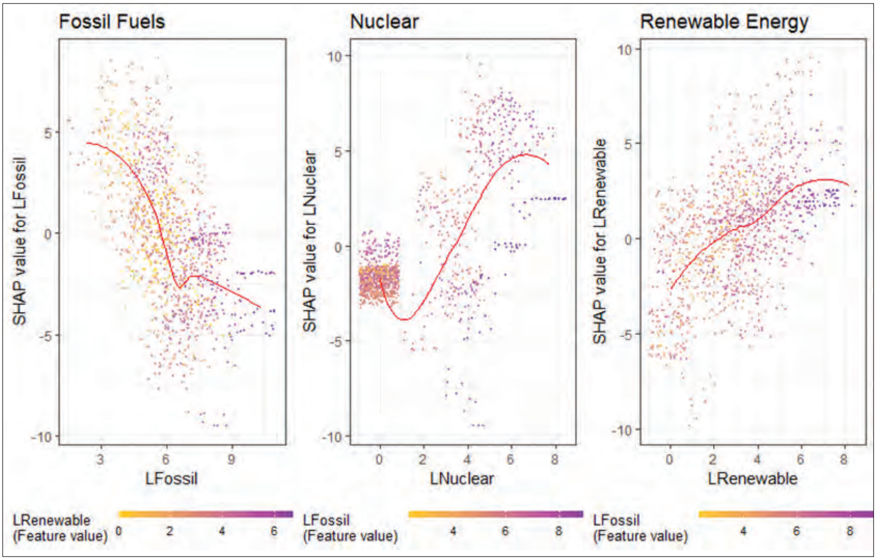

Figure 4.6 The Partial Dependence Plot of the Energy-SDGs Model

that no each energy source has a dominant impact on the SDG Index score. Figure 4.5 also shows that higher consumption of fossil fuels is associated with lower SDG Index scores, although the pattern is rather subtle. A contradictory yet more recognizable pattern is found for low-carbon energy sources, where higher consumption of nuclear and renewable energy is associated with higher SDG Index scores. To complement the results from the SHAP importance plot, we will evaluate the partial dependence plot which is provided in Figure 4.6.

The relationships between energy consumption and the progress in SDGs are rather complex and cannot be approximated by a simple linear function, except for the case of renewable energy. Consistent with the finding from the SHAP importance plot, we found positive correlations between nuclear energy and SDGs, and between renewable energy and SDGs. However, a positive correlation between nuclear energy consumption and SDGs occurred only temporarily around some threshold points. Confirming the preliminary findings from the SHAP importance plot, we also found a negative correlation between fossil fuels and the SDG Index score. Furthermore, similar to the case of the energy-SDG7 model, significant interactions between energy sources were found only between fossil fuels and either nuclear or renewable energy.

Complementing the previous section, the main findings in this section highlight the beneficial impacts of energy transition towards low-carbon energy sources in a more comprehensive context of sustainability. Our research findings suggest that the adoption of low-carbon energy sources is an advisable approach to simultaneously achieving socioeconomic and environmental objectives within the SDG framework. However, our findings are not without caution. According to York and Bell (2019), energy transition takes place if the deployment of renewable energy sources has managed to reduce or even replace the use of fossil fuels. Figure 4.6 suggests that higher SDG Index scores cannot be detached from the growth in fossil fuel consumption. In other words, the positive impacts of renewable and nuclear energy consumption on SDGs are achieved along with the increasing consumption of fossil fuels, implying that the role of fossil fuels in the global economy is still irreplaceable by low-carbon energy sources. Hence, Figure 4.6 provides no evidence of an energy transition towards carbon neutrality. Instead, it provides strong evidence of energy addition, which, according to York and Bell (2019), is not preferable for sustainability.

Energy addition portrays a phenomenon in which the deployment of low-carbon energy sources is intended to expand energy production from new sources while maintaining the use of fossil-powered energy sources (York & Bell, 2019). As a result, the prevalent use of fossil fuels in the global energy mix will create constant pressures on sustainability. Despite the persistence of fossil fuels, low-carbon energy sources are required to hold back the growth of fossil fuel consumption and ameliorate the externalities of the excessive use of fossil fuels. This is evident from Figure 4.6, where the negative slope of fossil fuels became less steep on a high amount of renewable energy consumption. Additionally, Figure 4.6 also shows that the mix between low-fossil and high-renewable will result in a higher SDG Index score compared to the mix between high-fossil and high-renewable. However, despite the multiple benefits that renewable energy can offer, energy transition from fossil fuels remains elusive. With the rapidly declining cost of renewable energy in recent years, one of the major challenges of transitioning to carbon neutrality is related to either social or regulatory barriers (Diesendorf & Elliston, 2018; Seetharaman et al., 2019).

F. Closing

This chapter aimed to assess the sustainability of energy consumption, particularly renewable energy, from the UN SDGs perspective. We opted to use the SGDs as our assessment tool since it provides comprehensive indicators that measure the progress toward well-being. By doing so, we can comprehensively assess the impacts of energy consumption on socioeconomic and environmental goals and ensure that those goals can be achieved simultaneously. For the proxy of SDGs, we employed the SDG Index score since it provides a more comprehensive and longer period of data. Our analysis was conducted in two steps. The first step of the analysis aimed to assess the impact of energy consumption on the sustainability of the energy system through the energy-SDG7 model. The second step of the analysis involved a more comprehensive assessment of sustainability through the energy-SDGs model. The nonparametric machine learning method, renowned for its exceptional predictive capabilities and ease of comprehension, was employed to scrutinize our models. Our analysis involved a balanced panel comprising 77 countries that span the period from 2000 to 2020.

We found beneficial impacts of low-carbon energy sources on the energy systems' sustainability and sustainable well-being. The beneficial impact of renewable energy was more pronounced in the case of the energy-SDG7 model, i.e., in promoting greater access to affordable and clean energy. The beneficial impact of nuclear energy was more pronounced in the case of the energy-SDGs model, i.e., in promoting the achievement of all 17 SDGs. We also found unfavorable impacts of fossil fuels on sustainability for both models. In the context of sustainable well-being, which is depicted by the energy-SDGs model, the detrimental effects of fossil fuels were even higher since fossil fuels were found to be the most significant predictor of SDGs. With the ongoing domination of fossil fuels in the global energy mix, the benefits from low-carbon energy sources became less noticeable or even diminished. Additionally, we found no evidence that the global energy transition towards low-carbon energy sources has been accomplished. Instead, we found evidence of energy addition, suggesting that the role of fossil fuels in the global energy mix remained irreplaceable.

While it is not within the purview of this chapter to propose novel policies, our results underscore some critical implications for policymaking. Firstly, in the pursuit of the 2030 Agenda for Sustainable Development, policymakers need to identify the barriers that hamper the deployment of renewable and/or nuclear energy since the energy transition towards low-carbon energy sources will provide multiple benefits, not only for the sustainability of energy system but also for the intergenerational equity of well-being. Secondly, in addition to boosting new investment in low-carbon energy sources, policymakers need to ensure the phase-out of fossil-powered energy sources so that the energy transition can be utterly achieved. Finally, to expedite the simultaneous achievement of sustainable development goals, this chapter suggests the necessity to formulate a balanced energy mix comprising both renewable and nuclear energy while taking into consideration the availability, affordability, accessibility, and acceptability of each energy source.

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Chapter 5

Regulatory Frameworks for Renewable Energy

Rachmat Trijono

A. Introduction

The use of green energy has become a demand on this planet Earth. Likewise, Indonesia has also stated its commitment to continue the use of new and renewable energy as part of the Paris Agreement (United Nations, n.d.). This is a manifestation of Indonesia's seriousness as part of achieving the Sustainable Development Goals (SDGs), particularly SDG No.7, namely ensuring access to affordable, reliable, sustainable, and modern energy for all (Department of Economic and Social Affairs, n.d.). This commitment is in line with Indonesia's commitment to reduce emissions.

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The Government of the Republic of Indonesia has issued several regulations to support the development and utilization of renewable energy. Indonesia set a goal to achieve net-zero emissions by 2060 and pledged alongside other countries to help limit global warming to less than 1.5 degrees Celsius above pre-industrial levels. Some of these regulations include: Vendu Reglement, Ordonantie 28 February 1908 Staatsblad 1908: 189 (Vendu Reglement Stb 1908/189), Presidential Regulation No. 5 of 2006 concerning National Energy Policy, Presidential Regulation No. 5 of 2006 concerning National Energy Policy, Presidential Regulation (*Perpres*) No. 5 of 2006 concerning National Energy Policy, Presidential Instruction No. 1 of 2006, Law No. 30 of 2007 concerning Energy which states that the government must promote the development of renewable energy and regulate its use effectively, Minister of Energy and Mineral Resources (ESDM) Regulation Number 17 of 2014 concerning the Purchase of Electric Power from PLTP and Geothermal Steam for PLTP by PT Companies State Electricity, Minister of Energy and Mineral Resources (ESDM) Regulation Number 50 of 2017 concerning Utilization of Renewable Energy Sources for The Provision of Electricity, Regulation of the Minister of Energy and Mineral Resources of the Republic of Indonesia Number 9 of 2020, Minister of Energy and Mineral Resources (ESDM) Regulation Number 15 of 2022 concerning Procedures for Determining Certain Natural Gas Users and Certain Natural Gas Prices in the Industrial Sector, Regulation 0733.K/DIR/2013, which requires PLN to credit energy produced by solar power to customers' accounts, and Presidential Regulation of the Republic of Indonesia Number 112 of 2022. If you pay close attention, these regulations were issued from various periods or years, some were even issued during the Dutch colonial period. This chapter provides an overview of renewable energy regulations in Indonesia.

The data used is secondary data (Vartanian, 2011), both in the form of laws and regulations, literature, and journals. All data describes the regulation of renewable energy, namely solar, wind, hydroelectric, geothermal, marine, hydrogen, biomass (Martens, 2010). This is important considering that the regulations applied by Indonesia must be able to achieve the criteria targeted, namely achieving net-zero emissions by 2060.

B. Indonesia's Regulatory Framework for Renewable Energy

Indonesia's abundant natural wealth for renewable energy must be supported by laws and regulations. This is important considering that Indonesia is a state of law (Constitution of the Republic of Indonesia, 1945).

Indonesia has a regulatory framework for renewable energy, which aims to achieve domestic energy supply security (*Perpres* No. 5, 2006). The following are some key regulations and policies related to renewable energy in Indonesia.

1. The Indonesian Government's Commitment

Formally, the development of renewable energy in Indonesia began in 2006. This was stated in Presidential Regulation (*Perpres*) No. 5 of 2006 concerning National Energy Policy. The targets of the National Energy Policy are as follows:

a. achievement of energy elasticity of less than one in 2025.
b. realization of an optimal (primary) energy mix in 2025, namely the role of each type of energy to national energy consumption:
    1) petroleum becomes less than 20%;
    2) natural gas becomes more than 30%;
    3) coal becomes more than 33%;
    4) biofuel becomes more than 5%;
    5) geothermal energy becomes more than 5%;
    6) other new and renewable energy, in particular, biomass, nuclear, small-scale hydropower, electricity solar, and wind up to more than 5%;
    7) other fuels originating from liquefaction coal to more than 2% (*Perpres* No. 5, 2006).

The steps taken to achieve this target are through the main policy and supporting policies. Main policy includes:

a. Provision of energy through:
    1) guarantee the availability of internal energy supply country;
    2) optimization of energy production;
    3) implementation of energy conservation.
b. Utilization of energy through:
    1) energy utilization efficiency;
    2) energy diversification.
c. Determination of energy price policy in the direction of price economy, taking into account assistance for poor households, in the long run, a certain time.
d. Preservation of the environment by applying the principles of sustainable development.

Supporting policies include:

a. energy infrastructure development in increasing consumer access to energy;
b. government and business partnerships;
c. community empowerment;
d. research and development as well as education and training (*Perpres* No. 5, 2006).

Indonesia is very serious about dealing with renewable energy, so the Government issued the Presidential Instruction (*Instruksi Presiden, Inpress*) No. 1 of 2006 to accelerate the supply and utilization of bio-fuels as other fuels (*Inpres* No. 1, 2006). This instruction is addressed to the Coordinating Minister for the Economy, Minister of Energy and Mineral Resources, Minister of Agriculture, Minister of Forestry, Minister of Industry, Minister of Trade, Minister of Transportation, Minister of State for Research and Technology, State Minister for Cooperatives and Small and Medium Enterprises, Minister of State for State Owned Enterprises, Minister of Internal Affairs, Minister of Finance, Minister of State for the Environment, Governors, and regents/mayors, to accelerate the supply and utilization of biofuels as other fuels.

As stated in the Presidential Instruction, each minister is instructed to take some measures according to their ministerial function. The Presidential Instruction No. 1 of 2006 instructions are as follows. The Coordinating Minister for Economic Affairs coordinates is instructed to prepare for the implementation of the supply and utilization of biofuels as other fuels. The Minister of Energy and Mineral Resources is instructed to:

a. establish and implement policies on the provision and utilization of biofuels as materials and other fuels, which among other things contain a guarantee of the availability of biofuels as well as guarantees of smooth operation and even distribution;
b. set incentive policy packages and tariffs for the development of supply and utilization of fuel vegetable (biofuel) as other fuel with coordination with related agencies;
c. establish standards and quality of biofuels as other fuel;
d. establish simple systems and procedures for testing the quality of biofuels as other fuel;
e. establish a simple trading system of biofuels as other fuel into the governance system trading in fuel oil;
f. socialize the use of biofuels as other fuel;
g. encourage companies engaged in energy and mineral resources to utilize fuel biofuels as other fuel.

The Minister of Agriculture is instructed to:

a. encourage the provision of fuel raw material plants vegetable (biofuel) including seeds and seedlings;
b. carry out counseling on the development of biofuel raw material plants;
c. facilitate the supply of seeds and plant seedling materials biofuel raw materials (biofuels);

d. integrate development activities and activities post-harvest plant raw materials for biofuels.

The Minister of Forestry was ordered to grant permits for the use of unproductive forest land for the development of biofuel raw materials by statutory provisions. The Minister of Industry was instructed to increase the production development of domestic biofuel raw material processing equipment and encourage business actors to develop the biofuel industry.

The Minister of Trade was instructed to:

a. encourage the smooth supply and distribution of raw materials biofuels;
b. ensure the smooth supply and distribution of components for the processing and utilization of bio-fuel equipment.

The Minister of Transportation was instructed to encourage increased use of biofuels as other fuels in the transportation sector. The State Minister for Research and Technology was instructed to develop technology and submit proposals for applications for the use of supply and processing technology, distribution of raw materials, and utilization of biofuels as other fuels. The State Minister for Cooperatives and Small and Medium Enterprises gave instructions to assist and encourage cooperatives and small and medium enterprises to participate in developing biofuel raw material factories as well as processing and trading of biofuel as other fuels. The Minister of State for State-Owned Enterprises (BUMN) was instructed to:

a. encourage state-owned enterprises in the fields of agriculture, plantations, and forestry to develop raw materials and biofuel crops;
b. encourage the state-owned industrial sector to develop the biofuel processing industry (biofuel);
c. encourage engineering BUMN to develop biofuel processing technology;
d. encourage BUMN in the energy sector to take advantage of it.

The Minister of Internal Affairs was instructed to coordinate and facilitate local governments and their staff as well as prepare the community for the provision of land in their respective areas, especially critical land for cultivating biofuel raw materials. The Minister of Finance was instructed to review laws and regulations in the financial sector in the framework of providing incentives and fiscal relief for the supply of raw materials and the use of biofuels as other fuels. The State Minister for the Environment was instructed to carry out outreach and communication to the public regarding the use of biofuels as other environmentally friendly fuels.

Governors and regents/mayors are instructed to:

a. implement policies to increase the utilization of biofuels as other fuel in their area according to their authority;
b. carry out socialization on the use of biofuels as other fuel in their area;
c. facilitate the provision of land in their respective areas by their authority, especially critical land for cultivation of biofuel raw materials;
d. report the implementation of this instruction to the Minister of the Interior Country (governor) and the Governor (regents/ mayor) (*Inpres* No. 6, 2006).

Presidential Regulation (*Perpres*) No. 5 of 2006 and Presidential Instruction (*Inpres*) No. 1 of 2006 confirm the Indonesian government's commitment to changing the use of fossil energy with renewable energy by supplying and using biofuels as other fuel.

2. Renewable Energy Law

Various laws and regulations relating to renewable energy have been issued by the Indonesian nation as a foundation for the government in realizing the provision of renewable energy. Law No. 30 of 2007 concerning Energy was passed because: first, energy resources are natural resources as mandated in Article 33 of the 1945 Constitution of the Republic of Indonesia which are controlled by the state and used for the greatest prosperity of the people. Second, the role of energy is very important for increasing economic activity and national resilience, so energy management which includes supply, utilization, and exploitation must be carried out in a fair, sustainable, rational, optimal, and integrated manner. Third, reserves of nonrenewable energy resources are limited so it is necessary to diversify energy resources so that energy availability is guaranteed by state (UU No. 30, 2007).

The main substances regulated in this law include (General Explanation of UU No. 30, 2007):

a. energy regulation which includes control and regulation of energy resources;
b. energy buffer reserves to guarantee national energy security;
c. energy crisis and emergencies and energy prices;
d. the authority of the government and regional governments in regulating the energy sector;
e. national energy policy, national energy general plan, and establishment of the national energy council;
f. community rights and roles in energy management;
g. fostering and supervising management activities in the energy sector;
h. research and development.

Minister of Energy and Mineral Resources Regulation No. 12 of 2017 (*Permen ESDM* No. 12, 2017) concerning the Development of New and Renewable Energy was passed to realize national energy security and reduce carbon dioxide (CO_2) emission levels, the use of renewable energy sources for the benefit of national electricity must be prioritized. Apart from that, the use of renewable energy sources for the benefit of national electricity is developed by considering the price of electricity based on sound business principles, so it is necessary to re-regulate the use of renewable energy sources for the supply of electricity, especially regarding the purchase of electricity from power plants that utilize renewable energy sources from State Electricity Company (PT PLN).

This Ministerial Regulation is a guideline for PT PLN in purchasing electricity from a power plant that utilizes renewable energy sources (*Permen ESDM* No. 12, 2017).

Renewable energy sources include:

a. sunlight that generates electricity from PLTS Photovoltaic;
b. the wind that generates electricity from PLTB;
c. water power that generates electricity from Water Power;
d. biomass that produces electricity from PLTBm;
e. biogas that generates electricity from PLTBg;
f. municipal waste which generates electricity from PLTSa; and
g. geothermal which produces electricity from PLTP.

3. Feed-in Tariff (FiT) Scheme

The feed-in tariff (FiT) scheme or benchmark price for electricity from renewable energy sources based on production cost components is the key to the success of renewable energy development. In addition, policy consistency is also needed to maintain business certainty for investors.

In Indonesia, the FiT scheme is a government policy program that aims to encourage the development of renewable energy by providing incentives in the form of guaranteed electricity rates for every kWh of electricity generated from renewable energy sources such as solar, wind, and biomass power (Dewan Energi Nasional, 2012).

Subsidies for Power Generation Business Units from renewable energy are distributed in two systems, namely the FiT system and the tradable green certificate (TGC) system. The FiT system is given to build new renewable energy (NRE) generating units to attract investors, while the TGC system is given more to existing renewable energy generating units to reduce operational costs. Aside from the unclear continuation of the Kyoto Protocol for the TGC system, so far, the more popular FiT system has been implemented. In developed countries (European Union), the classification of FiT is based on the following criteria (Dewan Energi Nasional, 2012):

a. the location of the power plant,
b. the type of fuel used in the power plant,
c. power generation capacity,
d. generator efficiency of the power plant.

In Indonesia, the implementation is in the form of tariff subsidies to consumers grouped into voltages of 450 kVa, 900 kVa, and so on. This subsidy was further elaborated by PT PLN based on the following criteria (Dewan Energi Nasional, 2012).

a. How many of these consumers whose electricity comes from the Power Generation Business Unit from renewable energy?
b. And how many of these consumers whose electricity comes from the Power Generation Business Unit from fossil energy?

The basic laws for FiT Schemes vary from country to country. However, generally, the basic law for the FiT Scheme is legislation in the field of energy or electricity that authorizes the regulator or electricity supply agency to set a guaranteed electricity rate for renewable energy (Dewan Energi Nasional, 2012).

Examples of the legal basis for the FiT Scheme in Indonesia include:

a. Minister of Energy and Mineral Resources (ESDM) Regulation No. 15 of 2022 concerning Procedures for Determining Certain Natural Gas Users and Certain Natural Gas Prices in the Industrial Sector (*Permen ESDM* No. 15, 2022). In the context of implementing the utilization of natural gas, the Minister of Energy and Mineral Resources determines the price of natural gas by considering: field economy, natural gas prices domestically and internationally, the purchasing power of natural gas consumers in the country, added value from the use of natural gas in the country *(Permen ESDM* No. 15, 2022). The Minister sets the Price of Certain Natural Gas at the point of delivery of natural gas users (plant gate) with a maximum price of US$6 per MMBTU. Certain Natural Gas Prices (HGBT) apply to natural gas users who purchase natural gas at the point of delivery of natural gas users (plant gate) at a price higher than US$6 per MMBTU.

Determination of HGBT is carried out based on adjustments to the calculation of Natural Gas Prices and/or natural gas distribution rates. Calculation adjustments are made to: price of natural gas purchased from contractors and/or tariff for natural gas distribution which includes the imposition of costs arising from liquefaction, compression, transportation through transmission and distribution pipelines, transportation of liquefied natural gas and transportation of compressed natural gas, storage, regasification, and/or trade, as well as reasonable margins (*Permen ESDM* No. 15, 2022). The determination of HGBT is intended for users of natural gas engaged in the industrial sector, consisting of the fertilizer industry, petrochemical industry, oleochemical industry, steel industry, ceramic industry, glass industry, and rubber glove industry (*Permen ESDM* No. 15, 2022).

b. Minister of Energy and Mineral Resources Regulation Number 10 of 2020 concerning Amendments to Minister of Energy and Mineral Resources Regulation Number 45 of 2017 concerning the Utilization of Natural Gas for Power Generation (*Permen* ESDM No. 10, 2020). This regulation was passed to increase the use of natural gas in the energy mix for electricity generation and to guarantee the availability of natural gas supply at a fair and competitive price, it is necessary to adjust the regulation of natural gas prices for power plants and adjust the arrangements for the mechanism for purchasing electricity.

c. Regulation of the Minister of Energy and Mineral Resources of the Republic of Indonesia Number 9 of 2020 concerning the Efficiency of Electricity PT PLN (Persero) (*Permen ESDM* No. 9, 2020). This regulation was made to improve efficiency in the electricity supply business of PT PLN (Persero). It is necessary to regulate a target-setting mechanism and realize electricity supply efficiency in the form of electricity generation efficiency and electricity network efficiency. The mechanism for determining the efficiency target for power generation is carried out by (1) paying attention to the pattern of loading operations, the reliability of the electric power system, the quality of electricity service, NPHR, and generation technology. (2) PT PLN (Persero) implements supply efficiency electric power at power plants based on the set SFC target amount for power plants. (3) The amount of SFC for a power plant is the weighted average of the volume of fuel used for electricity production for each type of power plant with the following classification: (a) steam power plant (PLTU) made from coal fuel, calculated based on the ratio between the total volume of coal (in kilograms) and total electricity production (in kilowatt-hour units); (b) gas-fired power plant (PLTG) or gas-fired steam power plant (PLTU), is calculated based on the ratio between gas volume (in metric units millions of British thermal units) and total electricity production (in kilowatt-hour units); (c) gas-fired steam power plant (PLTGU), is calculated based on the ratio between the total gas volume (in million metric British thermal units) and total electricity production (in kilowatt-hour units); (d) gas engine power plant (PLTMG) is fueled by gas, calculated based on the ratio between the total gas volume (in million metric British thermal units) and total electricity production (in kilowatt-hour units); (e) oil-fired diesel power plants (PLTD), are calculated based on the ratio between the total volume of fuel oil (in liters) and the amount of electricity production (in kilowatt-hour units); (f) Oil-fired steam power plant (PLTU), calculated based on the ratio between the total volume of fuel oil (in units of liters) and total electricity production (in kilowatt-hours units); and (g) oil-fired gas power plant (PLTG), steam gas power plant (PLTGU), or gas engine power plant (PLTMG), calculated based on the ratio between the total volume of fuel oil (in liters) and total electricity production (in kilowatt-hours units) (*Permen ESDM* No. 9, 2020).

d. Minister of Energy and Mineral Resources (ESDM) Regulation Number 17 of 2014 concerning Purchase of Electric Power from PLTP and Geothermal Steam for PLTP by PT Perusahaan Listrik Negara (Persero) (*Permen ESDM* No. 17, 2014). This regulation was passed with various considerations, namely (1) to accelerate the development of geothermal energy, it is necessary to rearrange the arrangements regarding the purchase of electricity from geothermal power plants; (2) that to provide certainty on the buying and selling price of geothermal steam for geothermal power plants, it is necessary to regulate the purchase of geothermal steam for geothermal power plants.
e. Minister of Energy and Mineral Resources (ESDM) Regulation Number 50 of 2017 concerning Utilization of Renewable Energy Sources for The Provision of Electricity (*Permen ESDM* No. 50, 2017). Considerations for ratification of Minister of Energy and Mineral Resources Regulation Number 50 of 2017 is to accelerate the development of renewable energy for the benefit of national electricity, it is necessary to rearrange the provisions regarding the mechanism and purchase price of electricity by PT PLN (Persero) which utilizes renewable energy sources as stipulated in the Minister of Energy Regulation and Mineral Resources Number 12 of 2017 concerning Utilization of Renewable Energy Sources for the Provision of Electricity as amended by Regulation of the Minister of Energy and Mineral Resources Number 43 of 2017 concerning Amendment to Regulation of the Minister of Energy and Mineral Resources Number 12 of 2017 concerning Utilization of Energy Sources Renewable for the Provision of Electric Power (*Permen ESDM* No. 50, 2017). To supply electricity sustainably, PT PLN (Persero) is required to purchase power from power plants that utilize renewable energy sources (*Permen ESDM* No. 50, 2017). In general, it is determined that the purchase of electricity from power plants that utilize renewable energy sources is carried out by PT PLN (Persero) through a direct selection mechanism (*Permen ESDM* No. 50, 2017). Purchase of electricity from a power

plant utilizing renewable energy sources based on high technology, varying efficiency, and highly dependent on local radiation or weather levels such as solar and wind energy, carried out by PT PLN (Persero) through a direct selection mechanism based on Quota Capacity (*Permen ESDM* No. 50, 2017). PLN (Persero) is required to operate a power plant that utilizes renewable energy sources with a capacity of up to 10 MW (ten megawatts) continuously (must-run) (*Permen ESDM* No. 50, 2017).

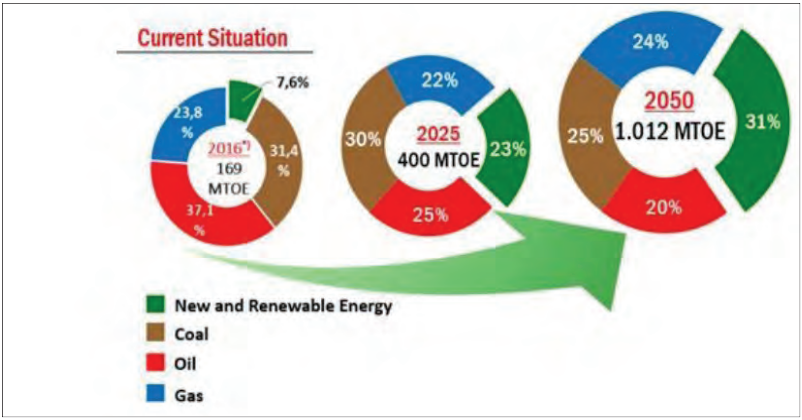
f. Regulation of the Minister of Energy and Mineral Resources of the Republic of Indonesia Number 13 of 2017 concerning Amendments to the Regulation of the Minister of Energy and Mineral Resources Number 15 of 2016 concerning Provision of 3 (Three) Hour Fast Licensing Services Regarding infrastructure in the Energy and Mineral Resources Sector (*Permen ESDM* No. 13, 2017). One of the considerations for the issuance of this regulation is that a Geothermal Permit is a permit to conduct geothermal exploitation granted based on the results of the offer of geothermal working areas through tender with administrative, technical, and requirements financial statements that have been fulfilled by applicants for Hot Permits Earth at the time of bidding for the geothermal working area. Fast Investment License Service 3 (three) hours, which one hereinafter referred to as Fast Service I23J is the service provided to the Permit Applicant concerned with infrastructure in the Energy and Mineral Resources Sector

4. Net Energy Metering (NEM)

Net Metering is a service system where the electricity generated by a solar power system that meets the requirements of a household can be connected (sent) to the PLN distribution network and can be reused for consumption by the household. In Indonesia, Net Metering has been mandated by PLN in Regulation No. 0733.K/DIR/2013, which requires PLN to credit energy produced by solar power to customer accounts. So that customers can send (export) their daily electricity production and at the same time consume (import) electricity from PLN for reuse. To implement the Net Metering, household customers will be equipped with a 2-way electric meter reader (kWh Meter EXIM—Export-Import) (MerketingSurendo777, 2020).

Solar panels on rooftop PLTS that use an on-grid system must be installed in areas that are included in the coverage of the PLN network. Electricity in the area also has to work 24 hours a day with infrequent power outages. This is because in installing a rooftop PLTS system, electricity is still needed as a trigger for the system to work. When the solar panels have been installed, the electricity generated will be used for household needs. But when the weather is hot, there is usually an excess of kWh from these solar panels. So, you can 'sell' or export this excess current to the PLN distribution network. Later, you can reuse the electricity for household needs through the Net Metering system using kWH EXIM. Net Metering-kWh EXIM is a service system where electricity generated by a solar power system that meets the requirements in households can be connected (sent) to the PLN distribution network. Furthermore, the electricity that has been sent can be reused for consumption by the household (DTEC Solutions, 2022).

The projected model for future energy growth is presented graphically in Figure 5.1. In 2016, the use of renewable energy, especially solar power plants (PLTS), was still relatively low. In 2016, the use of solar energy was 107.8 MW. Meanwhile, the potential for solar energy in Indonesia is very large, reaching 112 GWp. The government continues to refine regulations so that investors and developers in the new and renewable energy sector can still carry out requests and enthusiasm for the development of NRE generators. Licensing streamlining, tariff improvement, and incentives are still being studied to obtain an ideal pattern in supporting the NRE utilization program as a capital for national energy independence and security.



Source: WowShack Team (2018)

Figure 5.1 The Projection Model for Future Energy Growth

From Figure 5.1, in 2025 and 2050 there will be an increase in the utilization of NRE. Specifically for solar energy, in 2025 the Government is targeting solar energy utilization of 6500 MW and 45000 MW in 2050. The serious development of NRE is reflected in the targets set by the Government. This must be balanced with the current and future use of fossil energy. Government subsidies for fossil energy must be reduced or converted to NRE development.

5. Renewable Energy Development Acceleration Program (REDAP)

Formally, the acceleration of renewable energy development for the provision of electricity is regulated in the Presidential Regulation (*Perpres*) of the Republic of Indonesia Number 112 of 2022. This regulation was passed with the consideration of increasing investment and accelerating the achievement of renewable energy mix targets in the appropriate national energy mix with the national energy policy and reduction of greenhouse gas emissions; it is necessary to regulate the accelerated development of power plants from renewable energy sources (*Perpres* No. 112, 2022).

The Business Plan for the Provision of Electricity (*Rencana Usaha Penyediaan Tenaga Listrik)*, hereinafter abbreviated as RUPTL, is a plan for procurement of electricity, includes the generation, transmission, distribution, and/or sale of power electricity to consumers in a business area.

PT PLN (Persero) is preparing RUPTL by taking into account:

a. development of renewable energy by the renewable energy mix target based on the national electricity general plan;
b. balance between supply and demand; and
c. renewable energy generation economics.

The RUPTL is determined by the Minister after coordinating with the minister administering government affairs in the field of state-owned enterprises and the minister administering government affairs in the state finance sector by taking into account:

a. the aspect of the balance between supply and demand;
b. electricity system readiness; and
c. state financial capacity.

6. Renewable Energy Targets

The Indonesian government has set targets to develop NRE technologies in the next few years, referring to Presidential Regulation (*Perpres*) No. 5 of 2006 concerning National Energy Policy. In the Presidential Decree, it is stated that the contribution of NRE to the national primary energy mix in 2025 is 17% with a composition of 5% biofuels, 5% geothermal, 5% of other NRE (especially biomass, nuclear, water, solar, wind), and liquefied coal of 2%. This Presidential Regulation forms the basis for the development of renewable energy that has been carried out so far (*Perpres* No. 5, 2006).

The Indonesian government will continue to strive to achieve the new renewable energy mix target of 23% in 2025 even though until 2020 the achievement is only 11.5%. The government will pursue the NRE target of 23% by 2025 through three channels: electricity, the use of nonfossil fuels or biofuels, and the direct use of new, renewable energy. In terms of biofuels, the utilization of biofuels in Indonesia has become the highest in the world because the utilization of biodiesel in Indonesia has reached 30% or B30. Indonesia is the only country that utilizes biofuels in a large scale. In terms of electricity based on new and renewable energy, in the next five years the power generation capacity must increase by 2,000–3,000 megawatts (MW) per year to achieve the 23% EBT mix target in 2025 (Umah, 2021).

Another strategy to achieve the 2025 energy mix target is through investment. This investment value can help increase the energy market share in 2025. The investment consists of Geothermal PLT worth USD 17.45 billion, PLT Water or Microhydro worth USD 14.58 billion, PLT Solar and PLT Wind Turbine worth USD 1.69 billion, PLT Waste worth USD 1.6 billion, PLT Bioenergy worth USD 1.37 billion, and PLT Hybrid worth USD 0.26 billion. This investment figure indirectly has an impact on increasing the capacity of mixed NRE generators in Indonesia to 24,074 megawatt (MW) in 2025 from 10,335 MW in 2019. If translated into the next five years, the installed capacity of new and renewable energy generators will be 11,256 MW in 2020, 12,887 MW in 2021, 14,064 MW in 2022, 15,184 MW in 2023, and 17,421 MW in 2024 (Asian Development Bank, 2020).

7. Renewable Energy Auctions

The Indonesian government has also introduced renewable energy auctions to promote the development of renewable energy projects. The auctions provide a competitive and transparent process for awarding renewable energy projects to developers. The government sets a ceiling price for the auctions, and developers bid for the right regenerate response.

The current auction rules still refer to colonial heritage products, namely *Vendu Reglement, Ordonantie 28 February 1908 Staatsblad 1908: 189.* These rules are obsolete and lagging in keeping up with the needs and developments that exist in society. One by one, the regulations from the colonial era began to be revised and replaced.

Currently, the government is preparing to revise the rules regarding auctions.

In its implementation, the Ministry of Energy and Mineral Resources (ESDM) plans to reopen auctions for three to four geothermal working areas (WKP) in 2023. This commitment follows high investor interest in acquiring several potential fields within the country. Previously, the Ministry of ESDM had officially auctioned off two blocks, namely the Way Ratai WKP which is located in South Lampung Regency and the Nage WKP which is in Ngada Regency (Wahyudi, 2023).

C. Successes and Challenges Associated with Implementing Renewable Energy

The implementation of renewable energy regulations in Indonesia has significant potential for success but is also faced with various problems. Following are some examples of successes and problems associated with implementing renewable energy regulations in Indonesia.

1. Success

a. Potential natural resources: Indonesia has huge potential for renewable energy resources such as solar, wind, water, and biomass. This potential can be utilized efficiently to produce clean energy.

b. Energy diversification: Increased use of renewable energy can help reduce dependence on fossil fuels, such as oil and coal, which negatively impact the environment and supply availability.

c. Reduction of greenhouse gas emissions: Adoption of renewable energy can help Indonesia achieve its target of reducing greenhouse gas emissions according to commitments in international agreements, such as the Paris Agreement.

d. Job creation: The renewable energy industry can create new jobs in installation, maintenance, and research.

2. Problems

a. Limited infrastructure and technology: The infrastructure and technology needed to generate, distribute, and integrate renewable energy is still limited in Indonesia. This can slow down the growth of this sector.

b. Inconsistent regulation: Lack of consistency in renewable energy regulations and policies can hinder long-term investment due to uncertainty.

c. Dependence on fossil energy subsidies: Remaining fossil energy subsidies in Indonesia can reduce incentives for renewable energy development and discourage fair competition.

d. Financial capacity and investment: Developing a renewable energy project requires a large investment. The limited financial capacity of the government and the private sector to invest in these projects can be a constraint.

e. Land and local issues: Renewable energy projects often require quite large areas of land. Land issues, conflicts with local communities, and land rights can be serious problems.

f. Lack of awareness and education: Public awareness of the importance of renewable energy and its benefits is still lacking. Wider education and campaigning are needed to increase public understanding.

g. Uncertain economic advantages: Some renewable energies are still considered to have a higher initial cost compared to fossil energy. Even though these costs can pay off in the long run, many are still hesitant to invest.

h. Technical and technological challenges: Integration of renewable energy into conventional power grids can face technical challenges such as grid stability and energy storage.

The implementation of renewable energy regulations in Indonesia is a complex challenge involving various aspects, including political, economic, social, and technical. The government, private sector, and civil society need to work together to overcome this problem and maximize the potential of renewable energy to achieve sustainable development goals.

D. Closing

All the previously mentioned rules are still in place, meaning they still apply. Indonesia's regulatory framework for renewable energy is still developing and faces some challenges, such as limited infrastructure and financing. However, the government's commitment to promoting renewable energy and the implementation of various policies and programs are positive steps toward achieving a more sustainable energy system.

The Indonesian government has to work harder again in creating new regulations or revising regulations that are lagging behind the development of society and technology to encourage renewable energy. Furthermore, Indonesia has set a goal of achieving net-zero emissions by 2060 and promised with other countries to help limit warming globally to less than 1.5 degrees Celsius above pre-industrial levels.

Addressing the legal backlog of renewable energy technologies is an important step in facilitating the growth and development of the clean energy sector. Here are some steps we can take to solve this problem.

1. Regulatory update: Identify regulatory barriers that hinder the adoption of renewable energy technologies and seek to update existing regulations. Ensure that existing laws and regulations support the use of renewable energy by providing the necessary incentives, concessions and legal certainty.
2. New policy formation: Create new policies that encourage investment and development of renewable energy technologies. This can include fiscal incentives such as tax breaks, subsidies, and other financial support programs.

3. Awareness raising: Raise awareness among citizens, businesses, and governments about the benefits of renewable energy and the urgency to shift away from conventional energy sources which are more damaging to the environment.
4. Public and private collaboration: Facilitate collaboration between government, energy companies, research institutions, and civil society. This can assist in sharing knowledge, resources, and the latest technology to address legal and technical issues that may arise.
5. Research and development funding: Support research and development efforts in the field of renewable energy. Increased understanding of these technologies can help overcome legal barriers that may arise from a lack of knowledge.
6. Infrastructure development: Ensure that the necessary infrastructure for renewable energy, such as integrated power grids and energy storage systems, is also given adequate attention in laws and regulations.
7. Law enforcement: Ensure that existing laws are properly and fairly enforced. This includes protecting the rights of owners of renewable energy technology, enforcement of contracts, and respect for intellectual property rights.
8. Training and education: Support training and education for legal professionals and regulators involved in addressing legal issues related to renewable energy. Understanding technology and technical aspects will help them make better decisions.
9. Pilot projects and demonstrations: Support pilot projects and demonstrations of renewable energy technologies to prove the feasibility and reliability of these technologies. The results of these projects can be used to strengthen arguments for necessary legal and regulatory changes.

10. Development of standards and certifications: Assist in developing standards and certifications for renewable energy technologies. This can help in building trust in this technology in the eyes of governments, businesses, and society.

Addressing the legal backlog of renewable energy technologies is a complex task and requires collaboration across sectors. These steps can help create a legal environment that supports the sustainable growth and development of renewable energy.

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Chapter 6

Green and Renewable Energy Financing Policy in Indonesia

Eko Eddya Supriyanto

A. Introduction

As the national energy demand increases year on year, the search for new renewable energy alternatives is being reconsidered. In addition, international agreements to reduce the use of fossil energy to promote clean and carbon-free energy are also important to complete. Based on data from the Ministry of Energy and Mineral Resources, Indonesia's total energy consumption is about 909.24 million barrels of oil equivalent (BOE) in 2021. Meanwhile, Indonesia's energy consumption increased by 0.4% year-on-year from 905.6 million BOE (Dewan Energi Nasional, 2022).

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Supriyanto, E. E. (2023). Green and renewable energy financing policy in Indonesia. In S. Ariyanto & S. I. Heriyanti (Eds.), *Renewable energy: Policy and strategy* (115–144). BRIN Publishing. DOI: 10.55981/brin.900.c786 E-ISBN: 978-623-8372-25-6

Many countries in Asia are working to reduce greenhouse gas emissions to net zero. For this to become a reality, annual investment in renewable energy would need to increase from $62.3 billion in 2022 to $138.6 billion from 2026 to 2030 and $165.8 billion from 2031 to 2035 (Razzaq et al., 2023). According to Table 6.1, the People's Republic of China (PRC) currently accounts for almost 80% of all investments in Asia. China's share is expected to decline to 62% between 2026 and 2030 and 57% between 2031 and 2035 as other Asian countries need to step up investment in clean facilities. From 2031 to 2035, the rest of Asia will require an investment that is six to eight times the investment it is currently receiving. Even excluding the People's Republic of China, Asia will invest the most in emerging market and developing economies (EMDEs).

The use of renewable energy in Indonesia has increased significantly in recent years, thanks to the government's commitment to achieving net-zero emissions targets. Based on data from the Central Bureau of Statistics from 2015 to 2021, this figure continues to rise to 12.16% of the country's energy mix. The potential of new renewable energy (NRE) is being fully exploited and will likely accelerate the energy transition. In 2060, the NRE generation capacity is expected to be 700 GW from solar, hydro, wind, bioenergy, ocean, and geothermal energy (including hydrogen and nuclear).

Table 6.1 Annual Clean Investment Required under the Net-Zero Scenario ($ billion)

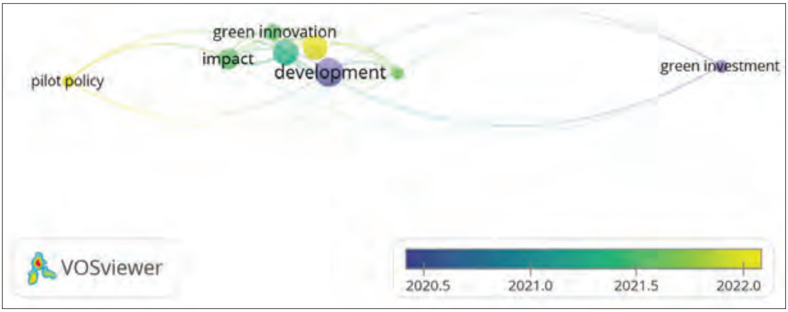
			Net Zero Scenario		
	2015	2022	(1) 2026–2030	(2) 2031–2035	(2) 2020 level
EMDEs	538	773	2.222	2.805	4
People's Republic of China (PRC)	287	511	853	947	2
EMDEs excluding the PRC	251	262	1.369	1.858	7

	Net Zero Scenario				
	2015	2022	(1) 2026–2030	(2) 2031–2035	(2) 2020 level
Southeast Asia	28	30	185	244	8
India and Other Asia	76	82	348	467	6
Africa	26	32	203	265	8
Latin America	63	66	243	332	5
Middle East and Eurasia	57	52	390	550	11
Asian EMDEs	391	623	1.386	1.658	3

Source: Razzaq et al. (2023)

This chapter discusses green finance and new renewable energy in the form of policy. Over the past decade, academic literature on green energy investments has proliferated and has attracted the attention of the academic community for several reasons. First, renewable energy stocks are becoming an important asset class due to a significant increase in investment (Dutta et al., 2023). Second, research on sustainable finance is also increasing as concerns about climate change and its potential impact on the economy and social welfare (Sharif et al., 2023). Third, socially and environmentally conscious investors plan to enter the green energy industry to build low-carbon portfolios (Belgacem et al., 2023). Fourth, investors and policymakers are interested in whether green energy stocks can hedge traditional and nontraditional asset classes (Barbier, 2022).

Research related to green energy, renewable energy, and green finance brings together several researchers from multiple disciplines and interdisciplinary backgrounds. After processing 100 manuscript articles on ScienceDirect containing keywords related to renewable energy, green energy, low carbon emissions, green policy, and green finance using the VOSviewer application, we found many topics were widely covered from 2020 to 2022. These include pilot policies, green innovation, impact, development, green investment, etc.



Note: Data processed with the VOSviewer application

Figure 6.1 Research Theme Data Processing based on ScienceDirect Manuscripts

Human activities, especially economic, domestic, industrial, business, and transportation activities, require energy. The majority of the world's energy supply comes from fossil fuels, which are nonrenewable resources. Energy demand is expected to continue increasing as oil and coal reserves decline. Additionally, the use of fossil fuels for energy results in excess carbon in the atmosphere, leading to global warming (Belgacem et al., 2023). Therefore, alternative energy supplies other than oil and coal are needed (Pan & Dong, 2023). New energy and renewable energy are alternative energies that not only have a low impact on the environment but also can contribute to the realization of a sustainable energy supply in the future.

Energy sustainability is a global issue, and its implementation requires the involvement of national and local governments, so access to clean and affordable energy is key to sustainable development by 2030 (UNDP Indonesia, 2015). In Indonesia, a new and renewable energy policy is included in Government Regulation No. 79 of 2014 on the National Energy Policy. The plan sets new renewable energy targets of 23% in 2025 and at least 31% by 2050. Meanwhile, dependence on oil and coal should be reduced by 20% and 25%, respectively. Achieving this goal requires a variety of initiatives and programs, the development and implementation of which are outlined in the

National Energy Master Plan (NEGP) and the state-level Regional Energy Master Plan (Kementerian ESDM, 2019).

The introduction of new and renewable energy requires a financial plan for a certain period of time. Indonesia's energy financing indicators should also be determined based on national energy needs and national energy security (Tanasya & Handayani, 2020). Aspects of renewable energy financing include a variety of issues related to the financing, investment, and financial management of renewable energy projects. Some aspects to consider regarding renewable energy financing are as follows.

1. Sources of financing for renewable energy projects include internal funds, debt, equity, and third-party funds such as banks and other financial institutions (Vargas-Hernándezet al., 2022).
2. Project scale. The size of a renewable energy project affects the type of financing available. Small projects may require funding from private investors or crowdfunding, whereas large projects may require funding from banks or institutional investors (Sun etal., 2022).
3. Costs and risks. The cost of renewable energy projects varies widely depending on the type of technology used, the location of the project, and other factors. Additionally, project financial planning should also consider risks such as political risk, operational risk, and financial risk (Lenaerts et al., 2022).
4. Incentives and regulations. Some countries have established incentives and restrictions to support renewable energy development. These include policy regulations such as tax incentives, subsidies, feed-in tariffs, and renewable portfolio standards (Jauhari et al., 2023).
5. Maintenance and operation. In addition to construction costs, financial planning must also consider the maintenance and operation of renewable energy projects. These costs may include routine maintenance, component replacement, and operating costs.

6. Financial management. Proper financial management is essential for the successful implementation of renewable energy projects. This includes cash management, risk management, and accurate and transparent financial reporting.
7. Assessment and risk mitigation. Renewable energy projects can be exposed to a variety of risks, including credit risk, operational risk, and market risk. It is important to conduct a risk assessment and take appropriate corrective actions to reduce the risk.

Potential areas for development in Indonesia include an estimated 23.7 gigawatts (GW) of geothermal energy, 154.9GW of wind energy, 75,000 MW of hydropower potential that will only be used by 7,572 MW (10%), and potential solar energy of 4.8 KWh/m^2 or equivalent with 112,000 GWp, of which approximately 10 MWp was used only in 2022. Renewable energy financing is based on policies and programs issued by the Indonesian government to build a green economy framework in the form of low-carbon green energy in the National Energy Plan, import tariff policy, green energy tax reduction policy, and equal distribution of electricity in rural areas, etc. (Kementerian ESDM, 2019).

B. National Energy General Plan 2019–2038

The 2019–2038 National Energy General Plan (NEGP) by the Indonesian government aims to increase renewable energy's role in the country's energy production to 23% by 2025 and 31% by 2030. The plan includes increasing the use of new and renewable energy, natural gas use as clean energy, energy efficiency, electricity access, developing energy infrastructure, and building nuclear reactors as well. The plan aims to achieve sustainable development goals, increase energy independence, and strengthen Indonesia's position as a country with abundant energy resources. The plan aims to achieve these goals over the next 20 years.

1. The Bright Electricity Program and the Village Electricity Program

The Indonesian government has launched the Bright Electricity Program and the Village Electricity Program to increase electricity access in rural areas, particularly those not covered by the national electricity network (Supriyanto, 2022). The Bright Indonesia Program targets 12,695 villages in six provinces in eastern Indonesia, focusing on renewable energy sources like micro-hydro, wind, and solar power. The country's electrification ratio has increased by 14.54% in the last five years, with 29 provinces reaching over 95% registered exporter (RE). Four areas, i.e., Central Kalimantan, Southeast Sulawesi, Maluku, and Papua, have reached 90%–95% RE, while East Nusa Tenggara still has an 85% RE. The government aimed to achieve 100% RE by 2020.

PLN (Perusahaan Listrik Negara/State Electricity Company), state-owned enterprises, and local governments are working together to provide access to electricity for rural communities and remote areas using renewable energy sources like solar panels and wind turbines. Investment cooperation is being conducted for turbine development in South Sulawesi and solar panels in Kalimantan and the islands. The Bright Electricity Program was launched in 1989 to provide electricity to people living in remote areas and outer islands using a micro-hydro power generation system and solar panels. The Village Electricity Program was launched in 2015 to provide electricity to all villages that the national electricity network has not touched, using various energy sources like solar panels, micro-hydro power plants, and generators. To encourage the development of these programs, the Indonesian government has established policies and regulations, including subsidies for renewable power plant development and increased investment in the renewable energy sector (Sari & Setiyono, 2022). Additionally, the government has facilitated the formation of village electricity cooperatives as PLN partners in operating power plants in isolated areas.

2. Feed-in Tariff and Purchase Price of Electricity

The Indonesian government has introduced higher tariffs for renewable energy purchases, aiming to encourage investment in the sector. The Ministry of Energy and Mineral Resources (ESDM) is implementing new rules regarding the purchase price of renewable energy-based power plants (NRE), using a feed-in tariff scheme. The Feed-in Tariff (FiT) and Purchase Price of Electricity are two key concepts in renewable energy development. FiT is a payment mechanism that encourages renewable energy providers to receive higher prices for each unit of energy produced, promoting the development of renewable energy sources like solar, wind, and hydropower (Triyanti et al., 2023).

Electricity Purchase Price is the price paid by electricity companies to renewable or conventional energy producers, which can vary depending on the type of energy and market conditions (Yangchongthuochuaya & Chaiyat, 2023). The Indonesian government has implemented a FiT mechanism through Regulation No. 49/2018 concerning the Construction of Small-Scale Solar Power Plants with Electricity Tariffs Provided by PT PLN.

The Purchase Price of Electricity is crucial for ensuring renewable energy's sustainable investment and development (Setyono et al., 2019). A high purchase price encourages renewable energy producers to increase production (Zhu et al., 2022), while a low purchase price can hinder investment and development. In Indonesia, the government has set a purchase price for electricity from renewable power plants, such as solar and wind power plants, which will be valid for a certain period, as stated in the Minister of Energy and Mineral Resources Regulation No. 50/2017 concerning the Purchase Price of Electricity from Solar and Wind Power Plants.

3. Tax Policy

The Indonesian government is committed to reducing greenhouse gas emissions and reducing fossil fuel consumption to combat climate change. There are various policies to implement this commitment, such as Government Regulation No. 79 of 2014 on National Energy Policy. The target mix of new and renewable energy is at least 23% in 2025 and 31% in 2050.

The Indonesian government imposes tax incentives on companies investing in the renewable energy sector. Indonesia, a country with rich natural resources and vast landscapes, has huge potential for NRE as a source of clean energy, also known as green energy. Based on data from the Ministry of Energy and Mineral Resources, a total of 442 GW of renewable energy potential can be used for electricity generation: hydropower, geothermal, bioenergy, solar, wind, and marine energy.

Tax incentives provided by the country to support the expansion of new renewable energy power plants include income tax relief, import relief in the form of exemptions from import duties and taxes related to imports, property taxes, and building tax compliance relief (Norouzi et al., 2022). President Jokowi also directed the Minister of Finance to support tax incentives in accordance with the presidential decree.

In order to assist in the implementation of this Presidential Regulation, the Minister or agency head and relevant local government shall immediately enact provisions for the granting of incentives within the scope of their specified powers within one year of the entry into force of this regulation. Governments can promote the development of green finance and renewable energy through appropriate tax policies. Below are some tax policies that can be introduced to support the development of renewable energy and green finance.

a. Tax incentives for investing in renewable energy

Governments may offer tax incentives, such as income tax exemptions and reduced tax rates, to companies or individuals investing in the renewable energy sector (Sharif et al.,2023). The Indonesian government offers several tax incentives to encourage investment in the renewable energy sector as follows.

1) Exemption from import taxes

The government exempts machinery, equipment, and raw materials used in renewable energy projects from import taxes.

2) Value Added Tax (VAT) Exemption

The government exempts the sale of renewable energy from her VAT.

3) Income tax deduction

The government will provide income tax relief to companies that invest in renewable energy projects.

4) Regional tax incentives

Some regions in Indonesia offer additional tax benefits, including property tax exemption for companies investing in renewable energy projects.

5) Electricity pricing

The state charges higher electricity rates for renewable energy than for conventional electricity.

6) Ease of financing

The government provides easy financing through programs such as the People's Enterprise Credit (*Kredit Usaha Rakyat*/KUR) and the Renewable Energy Revolving Fund (*Dana Energi Baru Terbarukan*/DEBT). Of course, this opportunity is provided in the form of cooperative economic units or village enterprises (BUMDes).

This tax incentive is expected to increase investment in Indonesia's renewable energy sector and contribute to achieving Indonesia's renewable energy share target of 23% by 2025. In summary, this system aims to build a sustainable economy by maintaining the balance of nature. The green economy is considered the best solution to exploitative economic systems that have traditionally tended to have a negative impact on the environment.

b. Carbon Tax

Carbon tax is levied on CO_2 emissions associated with industrial activities. The purpose of this tax is to reduce greenhouse gas emissions and encourage companies to use greener technologies such as renewable energy. The Indonesian government designed and implemented a carbon tax policy to reduce greenhouse gas emissions and promote the use of clean energy. Issues related to carbon tax in Indonesia include:

1) CO_2 tax policy

   The Indonesian government established a carbon tax policy in Law No. 11 of 2020 on Job Creation. The policy imposes a tax on greenhouse gas emissions equivalent to Rp75,000 per ton of carbon dioxide, or 5.35 US cents per kilogram.

2) Implementation plan

   Although the carbon tax policy has been approved, the implementation plan has not yet been implemented. The government is conducting further research and discussion on the implementation of this policy, including how to effectively calculate and apply tax rates.

3) Potential impact

   The carbon tax is expected to reduce greenhouse gas emissions and promote the use of clean energy in Indonesia. However, these taxes can affect the prices of fuels and carbon-based goods, so the economic and social impacts need to be carefully considered.

4) International support

   The Indonesian government has also received support from the international community in introducing a carbon tax. Several international organizations, such as the World Bank and the IMF, have advised and supported the implementation of a carbon tax in Indonesia.

Carbon taxes are an essential policy tool to achieve the goal of reducing greenhouse gas emissions. However, in order for the introduction of a carbon tax to positively contribute to Indonesia's sustainable development, the introduction of a carbon tax must be carried out carefully and the possible impacts must be taken into account.

c. Air Pollution Tax

Governments can impose air pollution taxes on companies and individuals that use fossil fuels such as coal and oil. The purpose of this tax is to reduce the use of fossil energy and encourage businesses to switch to renewable energy. An air pollution tax is a tax on activities that cause air pollution that can be harmful to human health or the environment. The Indonesian government has introduced the following policies related to air pollution tax.

1) Fuel Tax Policy

   The Indonesian government taxes motor fuels based on carbon monoxide (CO), hydrocarbon (HC), and nitrogen oxide (NOx) emission levels. This tax is known as an "emissions tax" or "green tax" and is intended to encourage the use of cleaner, more environmentally friendly fuels.

2) Motor Vehicle Tax Policy

   In addition to the fuel tax, the Indonesian government also imposes a vehicle tax based on emissions. This tax is known as the "vehicle emissions tax" and is intended to encourage the production and use of more environmentally friendly vehicles.

3) Government Regulation No. 41 of 1999

   This regulation regulates air quality management, including the regulation of exhaust gases from automobiles. The regulation also provides sanctions and fines for noncompliance with established emission standards.

4) Law No. 32 of 2009 on Environmental Protection and Environmental Protection

   This law empowers the government to enact regulations and policies related to environmental management, including air pollution control. Governments may impose taxes and fines on violators who do not comply with established regulations.

The air pollution tax is an important policy tool to control air pollution in Indonesia. Additionally, public education and awareness must be strengthened to ensure sustainable reductions in air pollution. The existence of tax incentives to encourage the development of renewable energy power plants is expected to have synergistic effects in other areas such as enabling better electricity supply to areas that are still under-served, fostering growth in the industrial sector, and creating employment opportunities.

d. Import Tax

Governments impose import duties on products that use fossil fuel sources or that are not environmentally friendly, potentially making those products more expensive and less attractive to consumers. Import duties are taxes levied on goods imported into a country. In Indonesia, the government has the following policies related to import taxes:

1) Import Tax

Import duty tariff (BM) is a tax levied on goods imported into Indonesia. BM rates vary depending on the type of goods being imported and are regulated by the Ministry of Finance. BM tariffs are aimed at protecting domestic industry and stimulating the production of domestic products.

2) Value-Added Tax

Value-added tax (VAT) is a tax levied on the added value of goods or services at each stage of production or sale. VAT is also levied on imported goods into Indonesia. VAT is a source of government revenue.

3) Import Income Tax

Import income tax (import PPh) is a tax levied on income from the importation of goods or services. Import PPh is calculated from the price of imported goods or services and is set by the importer.

4) Preferential Tariff Policy

Preferential regulations grant special duties or discounts on goods imported from aparticular country. The policy aims to increase trade between countries and strengthen economic ties between Indonesia and partner countries.

Import taxes play an important role in Indonesia's trade policy. The taxes not only provide state revenue but also protect domestic industry from unhealthy competition from imported goods. However, it should also be noted that import tax policies must be carefully and proportionately regulated so as not to disrupt trade relations between countries or worsen the global economic situation.

e. Import duty exemption

Governments can waive import duties on imports of renewable energy-related goods, such as solar panels and wind turbines, to make investment costs more affordable. Indonesia's Import Duty Waiver (BM) is a government policy that reduces import taxes on certain goods imported into Indonesia. BM exemptions are granted in various forms, including:

1) Exemption from import duties on imports of capital goods

   The government provides BM exemption for the import of capital goods to meet the needs of businesses, increase production, and expand their operations. The BM exemption for capital goods imports is aimed at promoting investment and industrial development in Indonesia.

2) Exemption from import duties on basic foodstuffs

   The government has provided BM exemption for the import of essential items such as rice, sugar, and edible oil. The BM exemption on imports of essential goods is aimed at maintaining the availability of essential goods in the domestic market and curbing inflation.

3) Exemption from import taxes on imports of raw materials

   The government exempts the import of raw materials for manufacturing products in the country from BM. The BM exemption for raw material imports is aimed at promoting domestic production and increasing the competitiveness of domestic industry.

4) Exemption from import duties on imports of special goods

The government provides BM exemptions for the import of special goods such as medicines and medical devices. The BM exemption for imports of special goods is intended to improve public health and welfare.

Import duty exemption in Indonesia is one of the government's measures to promote economic growth and improve the welfare of the people. However, exemptions from import duties must be carefully and proportionately regulated to avoid disrupting trade between countries or harming domestic industries.

4. Program for the Acceleration and Expansion of New and Renewable Energy Development

This program aims to increase the production of renewable energy and reduce dependence on fossil energy (Pan & Dong, 2023). The challenges associated with new and renewable energy are indeed quite draining of funding. A tough challenge for the current transition is creating opportunities for renewable resources to expand their contribution to the power generation mix. Figure 6.2 shows that, in 5 years from 2015 to 2020, renewable energy had increasing shares in the national energy mix.

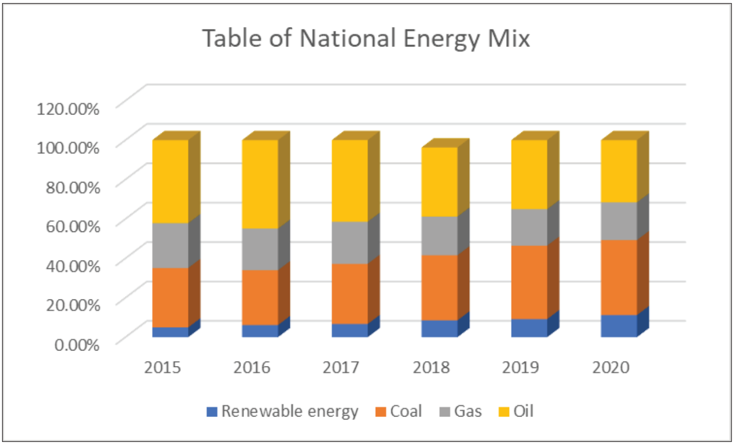


Figure 6.2 Development of NRE Share in the National Energy Mix

The Indonesian government has set a target to increase new and renewable energy use in the national energy mix to 23% by 2025 (Swainson & Mahanty, 2018), in line with global efforts to reduce greenhouse gas emissions and dependence on fossil fuels. To accelerate and expand NRE development in Indonesia, several steps can be taken, including increasing investment in new and renewable energy, encouraging technological innovation, improving regulation and supervision, increasing public awareness, and encouraging public-private partnerships. Emission reductions require the application of different clean energy technologies, such as hydrogen and hydrogen-based fuels, electrification of some industrial processes, and carbon capture, utilization, and storage (CCUS). By 2060, approximately 190 Mt CO_2 was extracted by CCUS, nearly one-third of current emissions. The total power generation devoted to hydrogen production is about 220 kW in 2060, almost as much as the total demand today across all sectors.

Energy is a fundamental resource that drives our modern society (Kasali, 2016). However, how we generate and consume energy has significant implications for the environment and our future (Logman, 2019). Reinventing energy means finding new and sustainable ways to power our homes, businesses, and transportation systems that reduce greenhouse gas emissions and preserve natural resources.

Renewable energy sources, such as solar, wind, geothermal, and hydropower, can reduce dependence on fossil fuels and lower carbon emissions. Governments and companies worldwide are investing in renewable energy technologies to meet their energy needs sustainably. Energy storage technologies, such as batteries and pumped hydro storage, can store excess energy generated by renewable sources for later use, ensuring a steady electricity supply. Energy efficiency measures can reduce energy consumption by increasing the efficiency of buildings, equipment, and transportation, reducing overall energy demand, and lowering carbon emissions.

A smart grid is a modern electricity grid that monitors and optimizes energy usage in real time, integrating energy storage, renewable energy sources, and electric vehicles. Carbon sequestration and storage (CCS) systems store underground carbon dioxide emissions from industrial operations, reducing greenhouse gas emissions. Reinventing energy requires collaboration from governments, companies, and individuals.

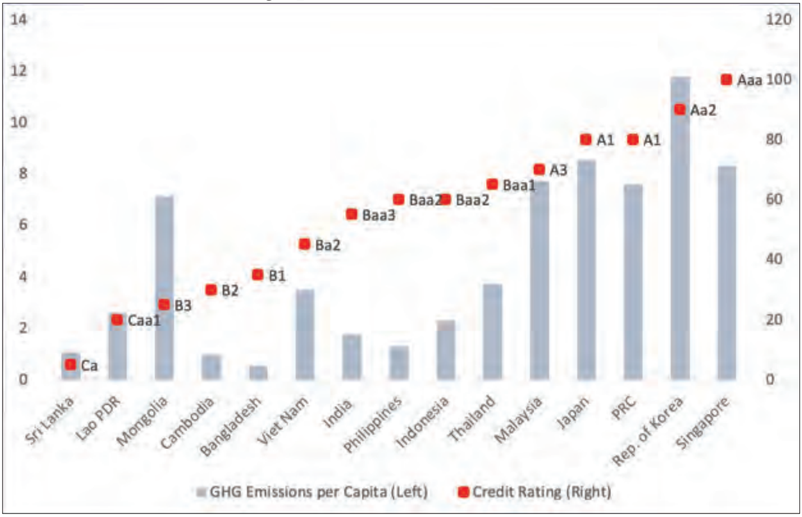
Governments can provide incentives and regulations to encourage renewable energy technologies, companies can invest in research and development, and individuals canreduce energy consumption by adopting energy-efficient behaviors and supporting sustainable energy policies. These steps aim to accelerate renewable energy development in Indonesia and help achieve the national energy mix target.

C. Proposal for a future Indonesian Renewable Energy financial policy scheme

The idea that financing renewable energy is more expensive than financing fossil energy is beside the point. This is because fossil energy cost calculations only account for fossil energy and do not account for future impacts. Impacts include the loss of green space due to land clearing for coal exploration, air pollution from the burning of coal in power plant turbines, and the process of transporting coal by ships that fall into the ocean after being hit by waves, leading to marine pollution and other negative effects (Ramirez et al., 2022).

Excluding the People's Republic of China, EMDEs account for approximately 70% of the world's population, yet only 20% of global clean energy investment comes from these countries. This indicates a lack of private capital due to economic, political, and exchange rate threats. Blended financing could benefit these countries by providing more public funding initially and gradually reducing funding as private capital increases based on track record and project expertise (Shirai, 2023). Through grants, technical assistance, loans, guarantees, and equity investments, public funds can reduce the risks borne by private investors.

Figure 6.3 shows Asia's per capita greenhouse gas emissions and sovereign debt valuations. Emissions-intensive countries with lower credit ratings may find it more difficult to attract private investment and require more public funding. Blended financing may not be suitable for low-income countries under severe debt pressure. These countries could consider climate change debt exchanges and subsidies based on climate change performance.



Note: The sovereign credit rating is adjusted to a numerical number ranging from 0 to 100.
Source: Shirai (2023)

Figure 6.3. Asia's Per Capita GHG Emissions (tons of CO_2 equivalent) and Sovereign Credit Ratings

A collective financing instrument called Just Energy Transition Partnership (JETP), announced at COP 26 in 2021, will help EMDE meet greenhouse gas reduction targets by replacing coal-fired power plants with clean energy sources. The Glasgow Financial Alliance for Net Zero Working Group is a coalition made up of Bank of America, Citi, Deutsche Bank, HSBC, MUFG, and Standard Chartered, as well as the UK, Germany, Japan, France, United States, and European Union, and others have pledged to fund on behalf of developed countries. They are also working together to mobilize funds from other public and private funds to meet their commitments. Agreements were reached with South Africa in 2021 worth $8.5 billion, in 2022 with Indonesia and Vietnam worth $20 billion, and in 2023 with Senegal worth €2.5 billion. Beneficiary countries need to develop plans to reduce their dependence on coal and ensure a smooth transition for affected companies and employees (Shirai, 2023).

Indonesia needs to build a financing system for renewable energy from upstream to downstream. Improving the efficiency of renewable energy financing in Indonesia also requires funding for renewable energy research. Policies to phase out coal-fired power plants should be replaced with renewable energy power plants. Currently, the construction of renewable energy power plants requires large amounts of capital and mutual cooperation from all involved parties to ensure the availability of energy from renewable sources.

Financing renewable energy is very complex, given that this policy requires political will and commitment from national leaders. So far, renewable energy is still financed from the national budget. If we look at a country like China, they have policies in the following areas: (1) energy saving and environmental protection industry; (2) clean manufacturing; (3) clean energy industry; (4) fields related to ecology and the environment; (5) sustainable infrastructure development; (6) environmentally friendly services (Ling et al., 2022). Meanwhile, the European Union commissioned her EU Technical Expert Group on Sustainable Finance to issue a final report on his EU classification (Lenaerts et al., 2022). They implement green finance for renewable energy through private and government investment programs in the form of green bonds determined by several project financing criteria (Wang et al., 2022).

We need to implement some of these plans and consider a few things. First, the concept and the NRE project being built must be carefully planned. Both from a development, risk mitigation, and operational perspective. Second, technology is essential because its use in NRE development also affects the level of funding. Third, project demand and location also influence financing levels. A weak market prevents one from making EBT loans in locations with low demand. On the other hand, regions with high demand can definitely expect stable EBT economic sales, so many investors will be interested in raising funds. Fourth, the price of electricity and the development of NRE must also take into account the cost of electricity. They assume that the NRE development capital is quite large.

Previously, foreign funds were more dominant in financing democracy, but now the direction of foreign funds has changed. However, today, these developed countries have an increasing tendency to finance the energy transition, especially in the application of development law, as this concept aims to advance the issue of energy transition, and today there is a lot of activity and funding from around the world. One example is the birth of Presidential Decree 112/2022, which was created to disburse $20 billion in international funds (Susanty et al., 2022). The terms of this loan can be fluid, with regulations and guarantees from governments committed to implementing the energy transition. Moreover, the government is also currently trying to increase the number of PLTUs retiring (Fitrady et al., 2021).

The proposals we would like to put forward concern renewable energy financing assessed on the basis of the resulting carbon footprint and measurement of private investment on an environmental, social, and governance (ESG) basis. As regulators, governments must be able to bridge the gap between renewable energy suppliers and financiers. Both funds are provided by the government and the private sector (Sun et al., 2023). Green energy and renewable energy support projects need to take into account the framework conditions of the energy and economic sectors, particularly reflecting the Indonesian government's commitment to efforts to reduce national emissions and adapt to the effects of climate change. The government aims to reduce greenhouse gas emissions by 41% with international support through climate finance, or 29% through business as usual, technology transfer, and capacity building from developed countries.

Table 6.2 Potential for Renewable Energy Funding in Indonesia

No	Types of Renewable Energy	Potency	Utilization	Location	Budget Require-ments	Financing Po-tential
1	Geothermal energy	23,7 GW	2.343 MW (9,8%)	Sumatra, Java, Bali	$14 M	Ministries/Agencies BUMN/D Overseas Private
2	Wind energy	154.9 GW	23%	Sulawesi, Lombok, Java, NTT , Sumatra	$12 M	Ministries/Agencies BUMN Foreign and national private
3	Waterpower Energy	75.000 MW	7,572 MW (10%)	Java, Bali , Sumatra	$17.6 M	Ministry BUMN Overseas Foreign and national private
4	Solar Energy	4,8 KWh/m2 atau 112.000 GWp	10 MWp	All islands in Indonesia	$40 M	Ministry BUMN Overseas Foreign and national private
5	Bioenergy	32,6 GW	10 GW	All islands in Indonesia	$10 M	CSR Overseas Foreign and national private WAQF Cash *Sukuk*

Source: Ditjen EBTKE (2022)

Table 6.2 shows the potential for renewable energy financing, which is available for both government-to-government (G to G), government-to-business (G to B), and business-to-business (B to B) investment programs, but still requires government oversight. Of course, the procurement of renewable energy meets the country's energy needs, but this energy can also be used for export to neighboring countries. Some new renewable energy financing models can be implemented through a number of mechanisms. Of course, there are advantages and disadvantages to this financing model, and we can learn from other countries' experiences in promoting renewable energy.

1. State Treasury Financing

Financing from national resources is what governments traditionally do. However, the number of problems facing the government means that the national budget is limited. However, funding from government budgets is an alternative, as is crowdfunding through both government-to-government and government-to-business projects. For example, the Ministry of Energy and Mineral Resources and the Provincial Government of Jambi have co-financed UNDP and BAZNAS with the equivalent of $350,000 and Jambi Bank's CSR funds worth $281,357 to generate a total of 180 kW of small hydropower for regeneration. This funding is a community idea made possible through a multi-party financial partnership. The concept of government funding does not have to be mandatory, and renewable energy can be financed in cooperation with other funding agencies. However, APBN's financing could act as an impetus for other lending institutions to co-finance the region's potential being developed for renewable energy at both micro and macro levels, as a government initiative towards the development of renewable energy.

2. International Funding

There are different types of international finance, including grants, and some borrow money. Foreign financing usually requires several clauses. For example, the government is committed to achieving the energy transition, which is why it issued Executive Order No. 112 of 2022 and signed the disbursement of $20 billion in global funds. The Indonesian government also signed an external financing agreement through thestate-owned electricity company to finance the development of pumped storage power plants in the Java-Bali system project worth USD 610 million and a capacity of 1,040 Megawatt (MW) units in 2022. This is in anticipation of the planned closure of several power plants in the Java-Bali region in 2025 and the net zero emissions target for 2060.

3. Sovereign Wealth Funds

A sovereign wealth fund (SWF) is an investment fund managed by a sovereign government that collects income from government-controlled assets (Kamiński, 2017). Most commonly, these funds are raised from the sale of natural resources for the purpose of investing in the interests of future generations, promoting government development goals, and/or serving as an economic stabilization tool. For example, what the United Arab Emirates did when it diverted revenues from its oil assets to finance the energy transition (Koch, 2022). This could serve as an example for Indonesia, where the government could encourage the Indonesian Investment Authority (INA) to facilitate a financing mix for new and renewable energy investments. Perhaps investing in renewable energy infrastructure could start with a blended financing model.

4. Banking Financing

Bank lending is traditional and has a long tradition of financing fossil fuels and renewable energy. Although the Indonesian financial industry remains subject to various obstacles, significant steps have been taken towards green lending from both banks and the government. Similarly, banks have begun to introduce various "green" requirements that take more account of the environmental aspects of lending. However, green finance efforts need to be accelerated.

Bank financing systems for new and renewable energy are very diverse. There is financing for infrastructure projects, green ecosystem capital financing in the energy sector, and *sukuk*. One of the banks that is currently stepping up green lending is UOB. With UOB's sustainable financing, companies that want to work on green energy can easily apply to UOB. The reason often lies in integrating sustainability concepts into business strategies. UOB's sustainable finance frameworks include the Green Trade Finance Framework, the Smart City Sustainable Finance Framework, the Real Estate Sustainable Finance Framework, and the Green Circular Economy Framework.

5. Green Bonds and Mutual Funds

Green finance schemes are currently being used as an alternative source of financing for low-carbon investments, including investments in the development and construction of renewable energy plants. The Indonesian government issued regulations on green bonds and green *sukuk* in 2017. Additionally, the Indonesian government launched a $3 billion green *sukuk* in 2018.

OJK said that as of the third quarter of 2021, the value of sustainable finance in Indonesia reached USD 55.9 billion or Rp809.75 trillion equivalents (exchange rate Rp14,440/USD). The issuance of green bonds in the domestic market was $35.12 million (Rp500 billion), representing 0.01% of the total outstanding bonds.

Meanwhile, the blended finance portfolio has received commitments worth $2.46 billion or Rp35.6 trillion. Regarding stock indexes related to governance and clean energy, the SRI-Kehati ESG Index showed its resilience during the pandemic and outperformed the Jakarta Composite Index (IHSG). In the banking sector, total loans related to sustainable finance amounted to $55.9 billion (Rs. 809.75 trillion).

6. Corporate social responsibility (CSR)

Corporate social responsibility can be a means of financing renewable energy. CSR of state-owned enterprises, domestic enterprises, and multinational private enterprises can be aimed at financing new renewable energy subsectors. Examples of CSR financing for renewable energy include financing biogas from household waste in Karang Asem, Bali, and energy-efficient and healthy stoves in Kulon Progo, Yogyakarta (Widjanarta, 2020).

7. Crowdfunding & Crowdsourcing

Crowdfunding, raised through public funds and charities, has the potential to be a highly effective resource for renewable energy financing (Ari & Koc, 2021). With an average share of 16% of total investments from 2018 to 2021, crowdfunding, especially through debt-based models, has become an important source of financing in the energy access sector. The research highlighted in this report shows that in 2021, energy access projects raised $61.5 million on crowdfunding platforms, making it a record year for energy access crowdfunding (Cogan et al., 2022).

According to the findings of the Purnomo Yusugiantro Center (PYC), a large number of respondents are in the next generation. This research could provide a perspective for communities that increasingly support green projects and renewable energy. Based on the funding from the study, approximately 5,949.1 MW off-grid solar power plants could be built. This amount could also finance 830 micro-hydropower plants with a capacity of 10 MW, which, if installed, could help provide energy to frontier, outermost, and less-developed areas.

8. Funding of Waqf *Sukuk*

Indonesia, with a Muslim and religious population of about 230 million and a middle class of about 74 million, can raise money in the form of waqfs to fund new renewable energy. As was done in Jambi province, BAZNAS, as the institution that administers zakat and cash waqf for Indonesian Muslims, is able to raise funds through renewable energy financing, which has a social and economic impact on surrounding communities.

The potential of waqf in the Islamic social sector includes the waqf system with a potential of around Rs 217 trillion. For the government, WAQF is a very cheap source of funds to finance SDG projects. Waqf can be used to support the achievement of the Sustainable Development Goals (SDGs). Examples include reducing poverty, providing health and education facilities, providing clean water and adequate sanitation, improving the quality of education and sanitation, improving economic well-being, and reducing economic inequality (Swastika & El Maza, 2019). Waqf may also be used to finance new renewable energy mixes.

D. Closing

Despite policies to promote renewable energy development in Indonesia, many challenges need to be overcome, such as rising production costs and infrastructure limitations. Therefore, ensuring the success of accelerating renewable energy developmentin Indonesia requires cooperation between the government, investors, and the public.

Compared to non-green investments, green investments in Indonesia are still developing slowly. Compared to the nonrenewable energy sector, investment in renewable energy is low. Indonesia has several measures to promote green investment through legislation and government initiatives, including energy programs, sustainable landscapes, special economic zones, and a green climate fund. This tax system can reduce greenhouse gas emissions and air pollution while promoting the growth of green finance and renewable energy. However, governments must consider the impact of this tax system on industry and the economy and ensure that the tax system is consistent with national energy policy. The most important thing in the development of renewable energy is the financing sector and the government's capacity and commitment to make this energy transition work according to the prescribed goals.

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Chapter 7

Cash Waqf Linked Sukuk and Renewable Energy: Potential, Model, Strategy

Siswantoro

A. Introduction

As a country with the fourth largest population in the world, Indonesia participates in contributing to global carbon emissions quite a large amount. Indonesia contributes carbon emissions number five in the world, with a contribution of carbon emissions reaching 102,562 $GtCO_2$ (Evans, 2021). According to the Ministry of National Development Planning (Bappenas), more than 90% of total carbon emissions in Indonesia come from the energy sector and land degradation (Setiawan, 2021). In addressing this issue, the government is targeting a reduction in carbon emissions by 31.89% in 2030 and net zero emission in 2060 (Putri, 2022).

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Siswantoro. (2023). Cash waqf linked sukuk and renewable energy: Potential, model, strategy. In S. Ariyanto & S. I. Heriyanti (Eds.), *Renewable energy: Policy and strategy* (145–169). BRIN Publishing.
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The Ministry of Environment and Forestry (KLHK) stated that the energy sector will be the focus of reducing emissions in the next few years compared to the forestry sector. So far, the energy sector has directly and indirectly contributed to other sectors, especially the transportation and industrial sectors, which have used non-environmentally friendly energy. In addition, the Ministry of Environment and Forestry claimed that the largest amount of carbon emissions in Indonesia was generated from fossil-based power plants. At the same time, from the forestry sector, it actually decreased during 2015–2018. On the other hand, domestic energy demand has actually increased. Indonesia also needs 2.9 billion barrels of oil equivalent (SBM) in 2050 or an increase of more than 236% in 2020 (Jayani, 2021). Therefore, the Indonesian government is committed to making an energy transition to renewable energy to overcome this problem. The energy transition program will encourage domestic energy needs to be met, while still paying attention to environmental aspects.

Although the environmental friendly energy transition scenario can have positive impacts on the economy, social and environment, its implementation faces funding constraints, especially in developing countries including Indonesia (Brunnschweiler, 2010; Geddes et al., 2018). Energy development with low carbon emissions requires large funds. Based on data from the Ministry of Finance, Indonesia requires an investment of around IDR 3,500 trillion to develop a renewable energy transition program (Fitriani, 2022).

The Ministry of Finance explained that the State Revenue and Expenditure Budget (APBN) scheme is unable to fund the low-emission energy transition program because the current annual APBN is only around IDR 3,000 trillion. Some policymakers in the energy transition program are pessimistic that investment in developing renewable energy technologies will run quickly, given that there is a significant financing gap (Geddes et al., 2018). Therefore, to fill this significant financing gap, financial cooperation from various sectors is needed, including conventional and nonconventional finance (Shahbaz et al., 2021).

According to Fateh and Elsayed (2019), the transition to environmentally friendly renewable energy requires a more advanced financial system that encourages and develops promising renewable energy technologies. In the absence of a well-developed financial sector, the state will find it difficult to finance projects. Given the result, financing is one of the most important obstacles in promoting renewable energy projects in developing countries (Becker & Fischer, 2013). Several conventional financial sources that have the potential to finance renewable energy include state treasury financing, international funding, sovereign wealth funds, banking financing, green bonds and mutual funds, corporate social responsibility (CSR), and crowdfunding.

In a country with a majority Muslim population, such as Indonesia, the developing financial sector is not only focused on the conventional financial sector, but nonconventional finance, such as Islamic finance, has also progressed rapidly. Indonesia is one of the countries with great potential for Islamic finance. One of the sharia financial schemes that can be developed to fund renewable energy projects is the Cash Waqf Linked Sukuk (CWLS) scheme. CWLS is a mechanism for depositing waqf funds (cash waqf) in State *Sukuk* (SBSN) to assist the Government's social facility development program (Hafandi & Handayati, 2021). The CWLS scheme is considered suitable for funding environmental and social-based projects, including renewable energy projects in Indonesia because of Indonesia's huge cash waqf potential. According to the Indonesian Waqf Agency (Badan Wakaf Indonesia), Indonesia's cash waqf potential can reach IDR 180 trillion per year, but the actual revenue is only IDR 860 billion or 0.478% (Badan Wakaf Indonesia, 2021).

The potential of CWLS as a financing alternative in funding social-environmental projects has been studied in previous studies. Faiza (2019) simulated the CWLS scheme for managing the impact of natural disasters such as the Yogyakarta and Central Java, earthquake. The simulation results found that investment funds sourced from CWLS could reach IDR 2.673 trillion so that they could cover the funding needs due to damage to public facilities caused by natural disasters. In other research, the CWLS scheme can also be used for social infrastructure development projects that benefit the community (Ubaidillah et al., 2021). In addition, Siregar et al. (2021) explained that the CWLS scheme with *salam* contracts is the best solution in funding food security projects during the COVID-19 pandemic. Saiti et al. (2019) stated that the CWLS scheme had a direct impact on reducing economic inequality, thereby increasing the welfare of people in Somalia because infrastructure development projects funded by CWLS can directly create jobs thereby reducing unemployment and poverty levels. According to Thaker et al. (2016) and Lahsasna (2010), CWLS is an alternative solution for funding Micro, Small and Medium Enterprises (MSMEs) in Malaysia.

Sukuk integration with waqf can also be used as financing for environmental and sustainable development goals. Musari (2022) proposes a climate change countermeasures model by utilizing CWLS through a sharia green financing scheme in Indonesia. The proposed model confirms that CWLS, as one of the Islamic social finance instruments in Indonesia, is an innovative instrument with the potential to finance social and environmental based projects. According to Fauziah et al. (2021), CWLS is not only a useful financial instrument for social development programs but can also facilitate sustainable development programs that have a positive impact on the environment. CWLS has greater benefits and opportunities than the risks and costs, so it has great potential in financing social-environmental projects in Indonesia.

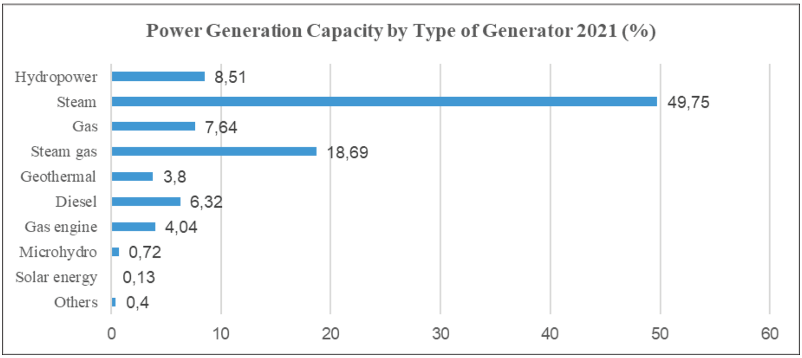
In another study, Mutmainah et al. (2022) developed a cash waqf integration model with blue *sukuk*, which is abbreviated as Cash Waqf Linked Blue *Sukuk* (CWLBS) for the purpose of sustainable maritime development. The proposed CWLBS model can be used to develop and increase access to fisheries business capital in order to encourage sustainable exclusive economic zone management. In addition, this model also serves to increase access for Muslims to become *waqifs* and participate in cash waqf programs through the use of digital platforms.

Although there have been many studies that have found that CWLS can be used for social investment projects, not many have highlighted CWLS financing schemes for green infrastructure projects such as renewable energy projects.

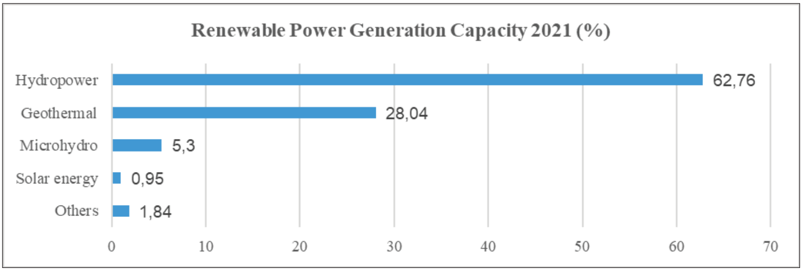
B. Development of Renewable Electrical Energy in Indonesia

Based on data from the Ministry of Energy and Mineral Resources (ESDM), the need for electricity consumption increases by 6.9% every year, but most of the power generation in Indonesia still comes from power plants with high carbon emissions such as steam power plant (PLTU) (Wiratmini, 2019). Energy sources produced from PLTU are obtained from coal or petroleum fuels, which can pollute the environment (see Figure 7.1).

Based on the Central Bureau of Statistics (Badan Pusat Statistik) (n.d.), the total installed electricity capacity in Indonesia reaches 66,514 MW, but almost half of it comes from steam power. Renewable energy power plants (e.g., solar, hydro, micro-hydro, geothermal, and other EBT power) contribute only 13.56% or 9,020 MW (see Figure 7.1). Most power plants powered by renewable energy are still dominated by hydropower, followed by geothermal power plants. Solar energy only contributed 0.95%, micro-hydro power contributed 5.3%, and other low-emission power plants contributed 1.84% (see Figure 7.2).

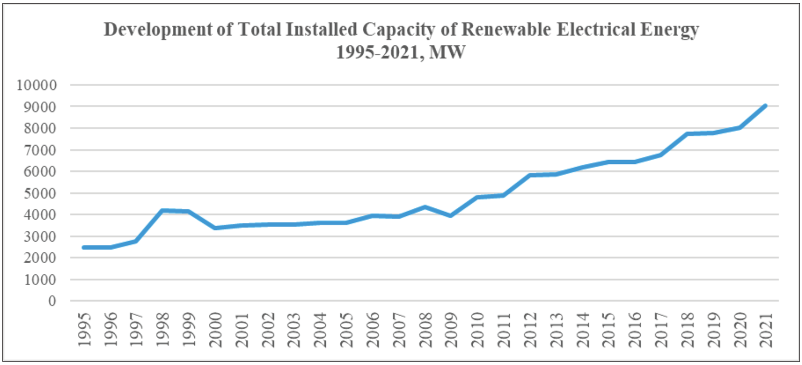


Source: Badan Pusat Statistik (2021)
Figure 7.1 Power Generation Capacity by Type of Generator 2021 (%)



Source: Badan Pusat Statistik (2021)

Figure 7.2 Renewable Power Generation Capacity 2021 (%)



Source: Badan Pusat Statistik (2021)

Figure 7.3 Development of Total Installed Capacity of Renewable Electrical Energy 1995–2021 (in MW)

Figure 7.3 reveals that the development of total renewable electric energy in Indonesia from 1995–2021 as a whole shows an increase for all low-emission power plants. The total electricity from low-emission power plants in 1995 was only 2,486 MW and increased to 9,020 MW in 2021. Solar, micro hydro and other low emission power plants were only developed in 2011. Hydro and geothermal power plants have been under development for a long time because these two plants are basically non-renewable but are considered to have low emissions when compared to coal or petroleum.

The installed capacity of electricity according to solar power in Indonesia is only 1 MW in 2019, then increases to 86 MW in 2021. Even so, according to the Ministry of Energy and Mineral Resources, the total installed capacity of electricity from solar power is still far from the potential of 207.8 GW. The installed capacity of electricity from micro-hydro power was only 15 MW in 2011, then increased to 478 MW in 2021, and the installed capacity of other renewable power plants increased from 38 MW in 2011 to 266 MW in 2021. The installed capacity of hydro and geothermal electricity also increased compared to 1995. The installed capacity of hydroelectric power was only 2,178 MW in 1995 but increased to 5,661 MW in 2021, while the installed capacity of geothermal electricity was only 308 MW in 1995, then increased to 2,529 MW in 2021.

C. Financial Sector and Renewable Energy

There are many potential financial sectors that can be utilized to finance renewable energy projects. In Indonesia, the development of the financial sector, particularly the banking, stock market and bond market, has been progressing quite rapidly. This is evidenced by the increasing value of conventional banking assets, stock market capitalization, and total outstanding bonds. Based on data from the Financial Services Authority (Otoritas Jasa Keuangan—OJK), the value of conventional banking assets as of December 2021 has reached IDR 10,112 quadrillion, or an increase of more than 8 times compared to 2001. Meanwhile, the capitalization value of the Indonesian stock market reached IDR 8,252 quadrillion (an increase of 33.4 times that of 2001) and total outstanding bonds of IDR 4,957 quadrillion in 2021 (58 times increase compared to 2001). The increase in Indonesia's financial sector provides potential funding for developing low-carbon energy.

According to Daszyńska-Żygadło et al. (2021), the financial instruments used by banks are the most effective in financing. This is based on ranking various instruments used by banks in the process of financing renewable energy that are environmentally friendly by assessing the structure and value of financing needs based on renewable energy in future scenarios. On the other hand, Kim and Park (2016) concluded that countries with well-developed financial markets (particularly bank credit and capital markets) tend to experience growth in the renewable energy sector, which is environmentally friendly due to easier and greater access to external funding. In addition, according to the findings Ji and Zhang (2019), the development of the financial sector (bank credit, capital markets, foreign investment) is very important and contributes an overall of 42.42% to variations in the growth of environmentally friendly renewable energy in China. In this study, in particular, the capital market is the dominant sector in influencing the development of low-emission renewable energy.

Apart from conventional finance, Indonesia also has quite large potential for nonconventional finance, such as Islamic finance. This is supported by the very large number of Muslim population in Indonesia. Based on OJK data, as of December 2022, Indonesia has total Islamic financial assets reaching IDR 2,375.84 trillion (not including Islamic stocks) or an increase of around 2 times compared to 5 years ago, which was only IDR 1,129.76 trillion. In addition, the Indonesian government has also issued State Sharia Securities (SBSN) financing instruments or state *sukuk*. The issuance of SBSN is not only intended as a source of financing for the State Budget but also represents the government's presence in supporting the development of the Islamic economy in Indonesia and the global market. As of April 1, 2021, the total issuance of SBSN has reached IDR 1,697.96 trillion, with the current outstanding reaching IDR 1,048.18 trillion, either through the issuance method by auction, book building, or private placement.

D. The Potential of Cash Waqf in Indonesia

Indonesia is a Muslim-majority country with enormous potential for cash waqf. Based on data from the Indonesian Waqf Agency (2021), Indonesia's cash waqf potential reaches IDR 180 trillion per year. The potential for cash waqf in Indonesia is also influenced by the number of benefactors in Indonesia, in addition to the large number of Muslim residents in Indonesia. According to data from the World Giving Index, 8 out of 10 Indonesians are classified as philanthropists because they are willing to donate money or wealth for social, environmental or religious activities (Charities Aid Foundation, 2021). The large number of philanthropic people in Indonesia should be able to encourage the exploration of the potential of cash waqf for social and environmental activities.

According to the World Bank (2020), there are five types of social classes which are classified based on their income (see Table 7.1), namely the upper class (expenditures above IDR 6 million per month), the middle class (expenditures IDR 1 million–IDR 6 million per month), the lower-middle class (expenditures IDR 0.5 million–IDR 1 million per month), vulnerable groups (spending IDR 354 thousand–IDR 532 thousand per month), and the poor (spending below IDR 354 thousand per month). The lower-middle class is the group that dominates the social class in Indonesia with a total of 44.5%, followed by the vulnerable group at 24%, the middle class at 20%, the poor at 11%, and the upper class at 0.5% (Lidwina, 2020).

Table 7.1 The potential of cash waqf in Indonesia

Expenditure per month	Classification	Number of Muslim	Cash Waqf Rate (2.5%) per month*	Potency per month (trillion)	Potency per year (trillion)
< IDR 354 thousand	Poor	16.81 million	IDR 8,850	IDR 0.148	IDR 1.785
IDR 354–532 thousand	Vulnerable	36.67 million	IDR 11,075	IDR 0.406	IDR 1.53
IDR 0.5–1 million	Lower-middle	67.99 million	IDR 18,750	IDR 1.27	IDR 15.3
IDR 1–6 million	Middle	30.56 million	IDR 87,500	IDR 2.67	IDR 32.1
> IDR 6 million	Upper	0.77 million	IDR 150,000	IDR 0.115	IDR 1.386
Total		152.8 million		IDR 4.38	+/- IDR 52

Note: The cash waqf rate per month is obtained from the middle value of the expenditure if it is a range of expenditure figures and the upper or lower limit if it is a single digit.

The total Muslim population in Indonesia is estimated at 237.55 million people or 86.7% of the total population and the number of productive age aged 15–64 years is 70.72% of the population or more than 191 million people (Badan Pusat Statistik, 2022) so that there are approximately 165 million Muslims are of productive-age. Data from the Charities Aid Foundation (2021) states that 8 out of 10 (80%) Indonesians are philanthropists, so it can be projected that there are around 152.8 million philanthropic Muslims of productive-age in Indonesia. If it is assumed that every productive age Muslim population in Indonesia has cash waqf of 2.5% of their monthly expenses, then the potential for cash waqf to be obtained is as follows.

If as many as 152.8 million philanthropic Muslims of productive age consistently donate money of 2.5% of their monthly expenses, then the potential for cash waqf that can be explored reaches IDR 4.38 trillion per month or around IDR 52 trillion per year. If the government targets only the lower-middle, middle, and upper groups, then the potential for cash waqf that can be obtained is up to IDR 48.78 trillion per year. The potential for cash waqf in Indonesia is relatively large, so if it is able to be explored and managed properly, it can be used for social-environmental-based projects that are beneficial to the community, including renewable energy development projects that require large investment costs.

The potential of cash waqf in Indonesia is relatively large, but in its realization, it encounters a number of obstacles. According to the Indonesian Waqf Agency (2021), Indonesia's cash waqf potential can even reach IDR 188 trillion per year, but the actual revenue is only IDR 400 billion or 0.213% of the potential. Several factors have contributed to the untapped potential of cash waqf in Indonesia, such as the strong understanding of the Muslim community that endowments must be in the form of land, lack of understanding of cash waqf, the low level of public trust in *nazhirs* as waqf managers (Faudji & Paul, 2020).

E. Cash Waqf Linked Sukuk Model for Renewable Energy Financing

Indonesia needs large funds to develop renewable energy, but the state budget is unable to finance the existing funding needs. Cash Waqf Linked Sukuk (CWLS) has great potential in financing renewable energy projects in Indonesia. *Sukuk* is a sharia investment instrument that is capable of channeling sharia financial funds to productive sectors and reaching all levels of society (Amanatillah, 2020). Furthermore, *sukuk* can finance social, environmental, or religious-based projects so that it has an impact on people's welfare (Oubdi & Raghibi, 2018). On the other hand, the utilization of cash waqf in Indonesia is not significant. This is evidenced by the low realization of cash waqf receipts in Indonesia, which is only 0.213% of the potential. Therefore, to make it easier for the community to channel cash waqf funds in a safe and productive way, as well as to develop social investment in Indonesia, the CWLS innovation was developed.

In order to explore the potential of cash waqf, the government has issued the Retail CWLS series SWR001 in October 2020 and the Retail CWLS series SWR002 in April 2021. The issuance of this CWLS is one of the government's efforts to support the national cash waqf movement, encourage the development of social investment, and the development of productive waqf in Indonesia. Sales proceeds of SWR002 amounted to IDR 24.141 billion, which came from individual endowments of IDR 15.661 billion and institutional endowments of IDR 848 billion. The sales value of SWR002 is higher when compared to the sales value of SWR001, which is only IDR 14.902 billion. Apart from that, the issuance of Retail CWLS series SWR002 also attracted 91.03% of new *waqifs*. This indicates that more and more *waqifs* are interested in social investment through the CWLS scheme. Even so, the government has not issued many *sukuk* for environmentally based projects such as renewable energy development. Therefore, this study proposes a CWLS model for financing renewable energy in Indonesia. The following Figure 7.4 is an explanation of the Cash Waqf Linked Sukuk Model for renewable energy financing in Indonesia.

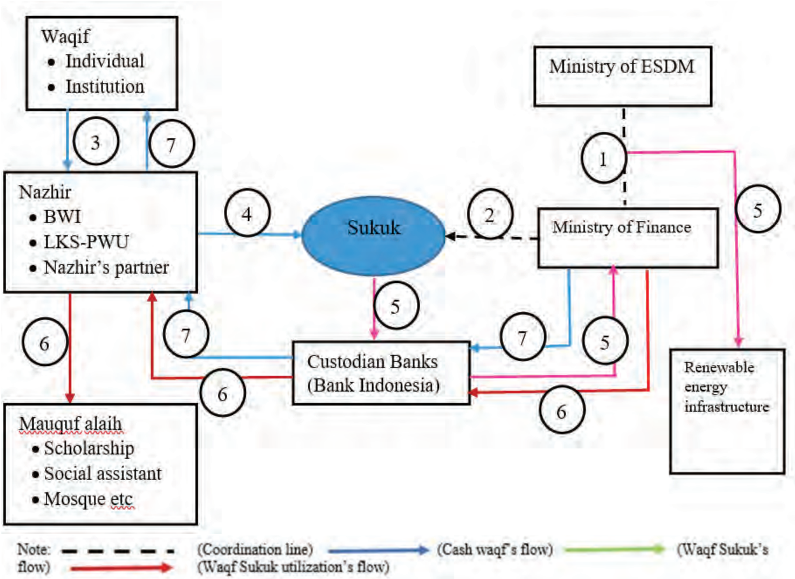


Figure 7.4 The CWLS Model for Renewable Energy Financing in Indonesia

The CWLS model scheme for renewable energy infrastructure development in Indonesia is explained as follows.

1. The Ministry of Energy and Mineral Resources (ESDM) proposed a renewable energy project to be funded by *sukuk* to the Ministry of Finance. The project proposal includes how much it costs to build a renewable energy project.
2. The Ministry of Finance issues *sukuk* waqf to finance renewable energy projects requested by the Ministry of Energy and Mineral Resources. Waqf *sukuk* schemes may not be traded on the secondary market. In addition, the issuance of *sukuk* also requires underlying assets, namely tangible assets such as land, buildings or other types of buildings, as well as assets that are intangible but have economic value, are not against sharia principles, and are not prohibited. In this case, the Ministry of Finance can include State Property (BMN) as the underlying asset for the issuance of waqf *sukuk*.

3. Individual or institutional *waqifs* hand over cash waqf of 2.5% of their income to the *nazhir* as the party that collects and manages the waqf funds. The *nazhir* appointed must be competent and trustworthy. The government can appoint *nazhir* partners such as Islamic banking or Islamic Financial Institutions Receiving Money Waqf (LKS-PWU) to collect, manage, and develop waqf funds. The cash waqf funds that have been collected are submitted to the Indonesian Waqf Agency (Badan Wakaf Indonesia—BWI) to be placed in state *sukuk*.
4. BWI purchases *sukuk* for renewable energy projects issued by the Ministry of Finance through Bank Indonesia as a custodian bank using cash waqf funds that have been collected by partner *nazhir* and LKS-PWU. Bank Indonesia then manages the sharia investment fund in the form of *sukuk* during the agreed tenor.
5. The *sukuk* waqf fund managed by Bank Indonesia is then distributed to the Ministry of Finance and the Ministry of Energy and Mineral Resources. The Ministry of Finance and the Ministry of Energy and Mineral Resources use the *sukuk* waqf funds to build and develop renewable energy projects in accordance with mutually agreed agreements.
6. The Ministry of Finance distributes returning *sukuk* in the form of coupons to *nazhir* through Bank Indonesia in accordance with the *ijarah* contract that has been mutually agreed upon. *Nazhir* as the party that manages the waqf funds uses the *sukuk* return funds for social purposes such as scholarships, social assistance and natural disasters, building mosques, and so on.
7. The Ministry of Finance fully returns the initial *sukuk* investment to BWI as *nazhir* after the tenor ends through Bank Indonesia. The Ministry of Finance fully returned the initial *sukuk* investment to BWI as the lowest point after the tenor ended through Bank Indonesia. The waqf *sukuk* are not returned to the *waqif* and can become BWI assets which can be reused to buy other waqf *sukuk* if the *waqif* deposits cash waqf permanently. On the other hand, BWI is obliged to return the cash waqf to the *waqif* if the

waqif deposits cash waqf temporarily. The return of waqf funds to the *waqif* is carried out after the maturity date in accordance with the nominal cash waqf deposited at the beginning of the agreement.

The contract proposed in the issuance of CWLS is an *Ijarah* contract. An *Ijarah* contract is an agreement in which one party leases the rights to its assets to another party based on the agreed fee and lease period (UU No. 19, 2008). In general, *sukuk* can be issued by three parties, namely the state, state companies and the private sector. In this scheme, *sukuk* is issued by the state through the Ministry of Finance. In this case, the *sukuk* issuer (Ministry of Finance) is obliged to pay income to the *sukuk* holder (*waqif*) in the form of profit sharing/margin/fee and repay the *sukuk* funds at maturity in accordance with the mutually agreed contract scheme (in this case, the *Ijarah* Agreement).

The Ministry of Finance provides coupons for *sukuk* with a fixed market value with the symbol "c" every year. The government sets a relative percentage of coupon rates, around 5 to 6 percent per year, with a relatively short tenor, generally under 2 to 3 years. In addition, in receiving waqf benefits from the management of *sukuk*, BWI as the recipient of the mandate (*nazhir*) can use a maximum of 10% of the returns for operational needs, while the remainder is channeled to *mauquf alaih*. *Ujrah* (u) *nazhir* for cash waqf management is a maximum of 10% of the coupon. After the end of the tenor period, the value of waqf utilization proceeds becomes "Mn" assuming n terms of the tenor of the *sukuk* so that the accumulation of waqf utilization income for *sukuk* is as follows:

$$M_n = (c - u)_1 + (c - u)_2 + \dots + (c - u)_n$$

or

$$M_n = \sum_{1}^{n} (c - u)_n .$$

Assuming fixed coupons and *ujrah*, the value of waqf utilization can be calculated as follows:

$$M_n = (c - u)_n.$$

Note:

Mn : The value of utilization of the *sukuk* waqf that can be received by *mauquf alaih* during the tenor period;

c : *Sukuk* coupon, calculated from the value of the *sukuk* multiplied by the specified coupon percentage;

u : *Ujrah* for *nazhir*, calculated at a maximum of 10% of the coupon value;

n : Year of tenor period.

The results of using CWLS funds can be used for many useful things such as building places of worship or tombs. In addition, the proceeds from using CWLS funds can also be distributed to *mauquf alaih* in the form of business capital financing for new business actors. For this scheme, *nazhir*, in this case BWI, can cooperate with the Financial Services Authority and Micro Waqf Banks (Bank Wakaf Mikro—BWM) as distributors of financing assistance funds. With the characteristics of waqf funds that are eternal and can only be used without transferring property rights, this scheme can minimize the margin or yield that must be paid by beneficiaries. Thus, the capital assistance from BWM is financed with a minimum margin.

Waqf funds can support productive activities and distribute welfare to the community. Even in the long term, waqf can play a role in reducing poverty, overcoming hunger, improving the quality of health and education, and reducing social inequality. With this development of CWLS, waqf is expected to become an economic instrument and a means of strengthening the social sphere.

F. Cash Waqf Linked Sukuk Financing Simulation for Solar Photovoltaics Infrastructure Development in Indonesia

There are many types of renewable energy power plants that have been developed in the world including bioenergy, geothermal, solar energy, hydropower, onshore wind, offshore wind, and others. However, solar photovoltaics (solar PV) is the cheapest type of renewable energy power plant at this time (see Table 7.2).

Table 7.2 Global weighted average total installed cost, capacity factor and levelized cost of electricity trends by technology, 2010 and 2021

	Total installed costs			Capacity factor			Levelized cost of electricity		
	(2021 IDR Million/kW)			(%)			(2021 IDR/kW)		
	2010	2021	Percent change	2010	2021	Percent change	2010	2021	Percent change
Bioenergy	24.52	33.74	38%	72	68	-6%	705	961	36%
Geother-mal	24.52	57.23	133%	87	77	-11%	452	975	116%
Hydro-power	11.88	30.61	158%	44	45	2%	352	688	95%
Solar PV	43.44	12.29	-72%	14	17	25%	3,768	688	-82%
CSP	85.14	130.36	53%	30	80	167%	3,235	1,635	-49%
Onshore wind	18.45	19.00	3%	27	39	44%	922	473	-49%
Offshore wind	44.06	40.98	-7%	38	39	3%	1,699	1,076	-37%

Note: 1 USD = IDR 9,036 (per 31 Dec 2010) and IDR 14,340 (per 31 Dec 2021)
Source: International Renewable Energy Agency (2021), processed

According to the International Renewable Energy Agency (2021), the total cost of installing solar PV is only IDR 12.29 million per kW in 2021, down by 72% compared to 11 years ago, which reached IDR 43.44 million per kW. Compared to other renewable energy power plants, the cost of installing solar PV is the cheapest at present, although the capacity factor is still the lowest, namely only 17% in 2021. In line with this, the Ministry of Energy and Mineral Resources stated that the cost of installing a power plant PV solar power is not as expensive as before. Currently, the average cost of installing a solar PV power plant is IDR 15 million per kW (Widyastuti, 2022).

The Indonesian government is targeting the installed capacity of Solar PV Power Plants in 2025 to reach 3,600 megawatt (MW) or around 3.6 gigawatt (GW). However, achieving this target is not easy because the installed capacity of solar PV until December 2021 was recorded at only 48.79 MW, with a total of 4,794 customers spread throughout Indonesia (Pradipta & Ardhi, 2022). If it is assumed that the installation cost of solar PV is IDR 15 million per kW, while the target installed capacity of solar PV power plants is 3600 MW in 2025, then an investment fund of IDR 54 trillion is required until 2025 to achieve this target. The cost is relatively large and quite burdensome for the government. Therefore, CWLS is a financing alternative that should be considered to cover solar PV investment costs.

The potential for cash waqf that can be explored in Indonesia reaches IDR 52 trillion per year. If the government targets only the middle and upper groups, then the potential for cash waqf that can be obtained reaches IDR 33.48 trillion per year or IDR 66.96 trillion by 2025. This amount has fulfilled 124% of the estimated solar PV financing target, amounting to IDR 54 trillion by 2025. In addition, if it is assumed that coupons resulting from the utilization of *sukuk* are 5.5% per year, with a tenor of 2 years (2024 and 2025), *ujrah* is 10%, and cash waqf obtained from the middle and upper groups is IDR 33.48 trillion per year, the value of using the *sukuk* funds is as follows:

$$c = IDR\ 33{,}480{,}000{,}000{,}000\ x\ 5.5\% = IDR\ 1{,}841{,}400{,}000{,}000;$$

$$u = IDR\ 1{,}841{,}400{,}000{,}000\ x\ 10\% = IDR\ 184{,}140{,}000{,}000;$$

$$M_n = \sum_{1}^{n} (c-u)_n$$

$$= (c-u)_n$$

$$= (IDR\ 1{,}841{,}400{,}000{,}000 - 184{,}140{,}000{,}000)_2$$

$$= IDR\ 3{,}314{,}520{,}000{,}000.$$

The calculation results above show that if the government is able to collect CWLS funds from the middle and upper groups of IDR

33.48 trillion per year, then this value is able to cover the financing needs of solar PV investment until 2025. Not only that, the results of the management of the waqf placed in a *sukuk* with a tenor of only 2 years is able to generate benefits of IDR 3.314 trillion. This value is large enough to be utilized by *mauquf alaih*. The results of using CWLS funds can be used to improve the welfare of the people such as building mosques, scholarships, social assistance, and others.

G. Challenges and Strategies for Development of Cash Waqf Linked Sukuk as Alternative Financing for Renewable Energy Projects in Indonesia

The potential for cash waqf in Indonesia is quite large, but its implementation is still not maximized. There are several challenges that cause the CWLS scheme to be underdeveloped in Indonesia. First of all, knowledge of sharia social investment in the form of CWLS and public awareness for cash waqf is still low. According to data from the Financial Services Authority (Otoritas Jasa Keuangan, 2022), public literacy about Islamic finance is only 9.14%, while Islamic financial inclusion is only 12.12%. In addition, public knowledge about waqf is still low, as evidenced by the waqf literacy index in 2020, which is low with a score of 50.48 (Badan Wakaf Indonesia, 2020). This could be due to the lack of socialization carried out by the government to the Muslim community, causing literacy in Islamic finance, especially CWLS, to be low and hindering the collection of cash waqf (Hakim, 2021).

The government needs to cooperate with community Islamic organizations such as Nahdatul Ulama or Muhammadiyah to participate in socializing CWLS to the wider community to overcome this problem. Socialization can be done directly to the public through seminars or with social media. The socialization theme must include the clarity of the CWLS scheme, the ease of investment and the low risk offered in CWLS (Yasin, 2021). The socialization should target the upper middle class with an expenditure of more than IDR 1 million per month. In addition, the government through the Indonesian Waqf

Agency can also initiate a money waqf movement program in which the community, especially the upper and middle class, can set aside 2.5% of their income every month to invest in the CWLS scheme.

Another problem is *nazhir*'s low ability to manage waqf funds. Financial management is one of the competencies that a *nazhir* must have so that the waqf funds that have been collected can be managed optimally. However, there are still many *nazhir*s who do not have good waqf fund management competencies (Farhand, 2020). This can have an impact on the lack of public trust in *nazhir*. Some people still trust community leaders as those who manage waqf assets compared to *nazhirs*. Therefore, the government needs to provide intensive assistance and coaching to *nazhirs* as waqf fund managers. The competence of waqf managers is an indicator that determines public trust in giving cash waqf to *nazhirs*. In addition, it is necessary to carry out strict, structured, and comprehensive supervision of the management of cash waqf in Indonesia. Supervision of waqf *sukuk* funds and their utilization in energy transition development programs is important to do so that waqf *sukuk* funds can be used in accordance with sharia principles and regulations that apply in Indonesia. BWI, the Sharia Supervisory Board, and the Financial Supervisory Board (Badan Pemeriksa Keuangan—BPK) are actors who play an important role in this oversight function (Disha et al., 2012).

On the other hand, the use of technology to access or invest in CWLS is still not optimal. Compared to the conventional financial technology, the use of Islamic financial technology, especially CWLS, is still not optimal. Therefore, a good cash waqf fund management database is needed to overcome this problem (Ginanjar, 2015). Transparency also needs to be improved. Waqf, as an Islamic financial instrument, has the principle that the object of waqf and *mauquf alaih* must be clear. Therefore, transparency in the management of CWLS is the main priority. In this case, if CWLS is used to build renewable energy infrastructure, the allocation of funds and beneficiaries must be clear (Putro et al., 2020).

H. Closing

According to the discussion that has been presented, it can be concluded that the CWLS scheme can be an alternative financing for low-cost renewable energy development programs (e.g., solar PV energy) in the future. Waqf funds collected through CWLS can be used in two ways. First, cash waqf is used to finance the development of renewable energy infrastructure through waqf *sukuk*. Funds from the utilization of waqf placed in *sukuk* can be distributed to *mauquf alaih* for programs for the benefit and welfare of the people such as providing scholarships, building mosques, social assistance, financing business capital and others.

The simulation results of implementing CWLS in the financing program for solar PV energy infrastructure development show that, if CWLS is collected in the amount of IDR 33.48 trillion per year, then this value is able to cover the entire financing for solar PV energy infrastructure development until 2025. Not only that, the management results waqf placed on *sukuk*, in a 2-year tenor can generate benefits of up to IDR 3.3 trillion. This value is large enough to be used by *mauquf alaih*. The results of using CWLS can be used for the construction of mosques, schools, as well as capital for the productive sector. Even though the CWLS scheme has great potential to finance the development of renewable energy in Indonesia, there are many obstacles that must be overcome immediately, such as low literacy of community waqf in Indonesia, lack of competence of *nazhir* as waqf managers, lack of maximum digitalization of CWLS, and obstacles related to transparency. The government is expected to be able to intensify socialization regarding CWLS to the public, develop *nazhir* competence, build databases and CWLS applications that make it easier for the public to donate cash, and must be more transparent about the collection, management, and distribution of cash waqf.

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Chapter 8

Communication Development and Youth Empowerment in Renewable Energy

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A. Introduction

Renewable energy has basically been echoed for a long time. How can people maximize and save energy use so that energy supplies are still fulfilled and look for other new energy alternatives? Based on a survey conducted by Coaction Indonesia of 96,651 netizens showing that there was a high level of public concern for renewable energy, it was noted that 23.8% of respondents chose the sun as a renewable energy source and 22.4% chose bioenergy (Koaksi Indonesia, 2019). Of the netizens who took part in the survey, a total of 67.6% of survey respondents were young respondents between 17 and 30 years old. This figure is consistent with the age category of social media users in Indonesia, which is dominated by young people. Furthermore,

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according to respondents, Indonesia has challenges in developing this renewable energy, namely that many people still do not understand the importance of renewable energy. In line with the results of research conducted by Saputra et al. (2021) which shows that, out of 346 youth respondents in West Sumatra, many young people do not fully understand renewable energy and the potential that exists in the West Sumatra area.

This is also not followed by empowering what youth should be able to do in supporting policies and development, as well as the development of renewable energy. Meanwhile, Indonesia has great potential to develop renewable energy. In 2025, Indonesia is expected to be able to develop alternative energy such as gas, coal, solar power, wind power, hydropower, geothermal, and nuclear (Rijanto & Armawi, 2011).

B. Communication Development and Youth Empowerment

Development should be carried out based on the needs of the community and what are shared aspirations with the goal of common welfare. According to Todaro (in Harjanto, 2011), development is defined as a multidimensional process which includes changes in social structure, changes in people's attitudes to life, and changes in national institutions. The development of a country is also directed at three main things: increasing the (1) availability and (2) distribution of basic needs for the community, and (3) increasing the ability of the community to access both economic and social activities in their lives.

According to Ginanjar Kartasasmita (1994, in Harjanto, 2011), development is a process of change towards a better direction through planned efforts. Meanwhile, Siagian (in Harjanto, 2011) defines development as "an effort or series of growth and change efforts that are planned and carried out consciously by a nation, state and government, towards modernity in the framework of nation building (nation building)".

With some of the definitions of development previously mentioned, it can be concluded that development is carried out consciously and planned with the aim of realizing people's welfare. The role of development communication has been widely discussed by experts. Rogers and Shoemaker (1981) states that, in simple terms, development is a useful change towards a social and economic system that is decided as the will of a nation. In another part, Rogers and Shoemaker stated that communication is the basis of social change. From the analysis of these experts, it can be concluded that development basically involves at least three components, namely (1) development communicators, who can be government officials or the community; (2) development messages that contain ideas or development programs; and (3) recipient of development, namely the wider community, both rural and urban residents who are the target of development, in this case, especially youth.

In development communication, what is prioritized is the activity of educating and motivating the community. The aim is to instill ideas, mental attitudes, and teach the skills needed by society (Nasution, 2009). To convey the message of development, development communication must consider important things that are useful for the community in accordance with development goals. The gap in the effects of communication can be minimized if the development communication strategy includes the following principles (Rogers & Adhikarya, in Nasution, 2009): (1) the use of messages specifically designed for specific audiences; (2) the "ceiling effect" approached by communicating messages to groups that are not targeted or of little benefit; (3) the use of a "narrow casting" approach or localizing the delivery of messages for the benefit of the public; (4) utilization of traditional channels; (5) introduction of opinion leaders in disadvantaged communities; (6) activation of the participation of change agents from the community itself; and (7) developing ways or mechanisms for audience participation.

In addition, in order for development communication to work in the community, it is appropriate that the strategies implemented are in accordance with the needs of the community. One strategy that can be used is the participation strategy, in which the community is invited to play an active role in the communication and information function. Community-based development is needed so that the participation strategy can work as expected. Community-based development allows communication to run well where this concept emphasizes the social learning process in which there is collaborative interaction between the bureaucracy and the community, starting from the planning process to evaluation based on mutual learning (Theresia et al., 2014).

This is what allows youth to play an active role in development and become part of the agent of change, especially in the case of renewable energy. According to the Law of the Republic of Indonesia Number 40 of 2009 concerning Youth (UU No. 40, 2009), what is meant by youth are Indonesian citizens who are entering an important period of growth and development aged 16 to 30 years. Collaboration between stakeholders and youth can facilitate development goals, especially regarding this renewable energy issue. The participation strategy and development principles form the basis of this research to formulate a development communication concept that aims at the role of youth in renewable energy.

Youth, in this case, needs to be empowered to have a significant role in understanding renewable energy. This is because youth empowerment is an activity to awaken the potential and active role of youth, so the role of youth is very important, considering that youth are always associated with change agents and become agents of change themselves. However, unfortunately, youth empowerment has not been widely discussed and researched in terms of development communication for renewable energy. What needs to be done to realize the role and empowerment of youth in renewable energy is to create an atmosphere or climate that allows the potential of the community (youth) to develop, strengthen the potential or power possessed by the community (youth), and empower the potential of the community (youth) (Theresia, et al., 2014). Empowerment must place the strength of the community, in this case, youth, as the main capital to increase community independence.

The participation of the community and youth is needed to realize participation in understanding renewable energy. Youth as agents of change should be the focus of development communication for the empowerment of renewable energy. In reality, there is not much research on youth empowerment in terms of renewable energy. For this reason, relevant research is needed on this issue so that youth begin to build awareness of the importance of renewable energy.

The lack of research on youth empowerment concerning development communication for renewable energy makes this research significant. So far, existing articles are only about renewable energy, without any further research on youth empowerment. So, this research needs to explore and discover further regarding development communication to empower youth in understanding renewable energy.

This research was carried out by means of a survey by distributing Google form to college students and students in Bogor especially in three villages in Pamijahan subdistrict, namely Pamijahan, Pasarean, and Cibitung Wetan. The selection of the three villages was due to their geographical location that is closer to the main road and the availability of internet access. The people there also use smartphones and are connected to the internet network. The number of respondents who returned Google form was 72 respondents, of which 35 were female respondents and the remaining 37 were male respondents. Meanwhile, the age of respondents ranged from 20–24 years with a bachelor's degree (S-1). All respondents have accounts on social media, including Facebook, Instagram, and Twitter and the respondents are active in using social media.

The data obtained from the respondents were analyzed quantitatively descriptive and qualitatively descriptive. For quantitative data, researchers only grouped data on age, gender, type of social media used and understanding of renewable energy. Meanwhile, for qualitative data, researchers asked further questions about renewable energy and not all respondents used the data. Researchers chose several representative people to answer research questions regarding the role of youth and renewable energy.

C. Youth Understanding of Renewable Energy

Renewable energy sources are a hot issue nowadays due to the depletion of existing resources. Researchers want to know the understanding of youth about renewable energy. Of the 72 respondents who answered the survey distributed by researchers, it appears that only 11 respondents understood renewable energy, 56 respondents had heard of renewable energy, and there were only 5 respondents who did not know about renewable energy.

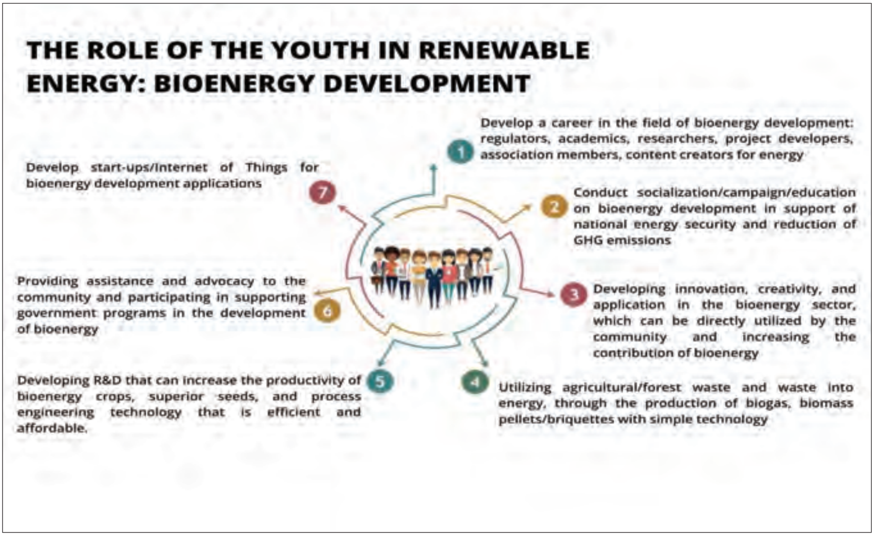
Some of the youth's understanding of renewable energy is that it is a source of energy available by nature and can be utilized continuously. They understand that renewable energy comes from "sustainable natural processes", such as solar power, wind power, water currents, biological processes, and geothermal. They also understand that renewable energy is energy used continuously, such as wind, water, and sun.

Information about renewable energy that the youth received mostly came from social media and some from teachers when they were in junior and senior high schools. Other sources that respondents get to find out about renewable energy are news, books, and articles they read or google themselves on the internet.

The respondents' ignorance about renewable energy was accompanied by the respondents' hopes as youths, namely, to be involved in issues or campaigns and to socialize renewable energy. As many as 68 respondents strongly agreed with youth involvement in campaigns and outreach, and only 4 respondents said it was just to get involved in the issue.

The data obtained show that youth basically understand and know about renewable energy. However, in reality, the role of youth has not been maximized in spreading campaigns or outreach to the community. Youth are also interested in getting involved in renewable energy issues. The government should be able to encourage and utilize the role of youth as agents of change to become aspirations and inspiration on renewable energy issues. As reported and conveyed by Andrah Feby Misna, Director of Bioenergy Direktorat Jenderal EBTKE, "one of the important actors in developing bioenergy is the younger generation, who can act as agents of change, who are active, adaptive, competitive, creative, and also master digital technology" (Direktorat Jenderal EBTKE, 2021).

Furthermore, the role and contribution of youth can be carried out in various lines. Youth do not only play a role in academic fields such as research development, but can also take advantage of digital communication platforms in disseminating information and knowledge related to renewable energy. As described in the Bioshare Series #5 activity, with the theme "Young Generation for Development of Bioenergy and Clean Energy" (Direktorat Jenderal EBTKE, 2021), the role of youth is described as in Figure 8.1.



Source: Direktorat Jenderal EBTKE (2021)

Figure 8.1 The Role of the Young Generation in the Development of Bioenergy

Figure 8.1 shows the roles in which the youth can participate. There are seven main roles of youth in the development of bioenergy or renewable energy. Role no. 2 is interesting and in line with what researchers are doing, namely, the active participation of youth in socializing or educating about renewable energy.

Youth are considered active, collaborative, and effective in helping disseminate information and knowledge as well as educate the public on renewable energy issues. Coupled with current technological advances, youth can also use social media and various other media in renewable energy campaigns. If youth can participate actively, development communication in terms of renewable energy can be maximized. Why does development communication become the target of youth empowerment? This is because youth can quickly absorb innovation and play a role in disseminating the expected information and education to the community.

In line with development communication, it is hoped that youth participation will enable youth empowerment so that youth will become more aware of their important role in the development of a nation. In addition, communication development can be built through existing social media that is actively used by youth. From these channels, the role and empowerment of youth can be increased. It is hoped that, as Figure 8.1 shows, the young generation can conduct socialization/campaign/education on renewable energy. Further to this, the results obtained from the survey show that there is a strong desire for youth to participate in campaigning for renewable energy issues.

D. Youth Empowerment and Media

A survey conducted by researchers shows that many young people want to be involved in campaigns or socialization of renewable energy. According to respondents, the role of youth is necessary because youth have a very important role to play in creating positive changes for the future. The younger generation is more acceptable to novel things. Youth are very happy to try something new and different.

They are inspired to create environmentally friendly technology so that renewable energy can be utilized even better and more and more people know about renewable energy. Also, because youth are the next baton for leadership, they must really understand the policies made, especially policies regarding renewable resources.

Some of the opinions of these respondents show that there is a high interest from youth to be empowered and involved in development, especially regarding renewable energy. This is what the government can do in terms of youth empowerment.

More about youth empowerment, the survey conducted also showed that youth are more likely to utilize existing media. The media in question is social media and other internet-based media. This is because by using the internet, apart from being more effective and efficient, young people can also connect quickly with anyone and then campaign for renewable energy issues. Data show that almost 90% of respondents stated that social media is the most effective and efficient channel in disseminating information about renewable energy.

The media chosen by respondents to assist the government in terms of development communication are media that are familiar with the community, including Facebook, Instagram, TikTok, YouTube and other media that can provide good support. Some examples that are already exist for the renewable energy campaign from youth are TikTok account @xeronav, @clarissachristiyan, @energibersih.ftw, and many more. The account @energibersih.ftw is consistent in voicing and giving information about renewable energy. Also, on other social media such as Instagram, there are some accounts who concern about the renewable energy, i.e., @official_energiterbarukan, @nasional_energi_terbarukan, @renewableenergy.itn, and others. It is an interesting fact that the young generation are aware about this issue and some of them have already used social media to give more information about the renewable energy. From their participation and awareness of these issues, it can be said that the development communication has been built and kept continuing among the youth.

Several examples of the media usage of renewable energy campaigns from the young generation prove that the youth concerned about the further condition of energy. By utilizing these media, they are accessed by the community on a daily basis, so the hope is that the community can quickly find out and understand about renewable energy.

E. Government and Renewable Energy Campaign

The researcher closed the survey by asking what kind of government's role was in campaigning for or socializing renewable energy. Respondents' answers varied, including holding energy-saving campaigns for schools, campuses, and remote towns or villages. The government always invites people to save energy and the government must facilitate and support renewable energy campaigns.

Youth also expect the government to encourage their people to make the use of renewable energy a culture and a lifestyle for each individual, for a better, cleaner, and more equitable Indonesia development. The government should also provide ways to create renewable energy and provide space for young people to create renewable energy and make more use of renewable energy, such as Portugal, which has succeeded in utilizing renewable energy.

Creating a new trend in society by campaigning for the use of renewable energy in everyday life and uploading videos on social media using hashtags #energyrenewableforourfuture can also be carried out by the government. Then, youth also expect education for all officials from the top to their subordinates, as well as working with well-known media so that information and knowledge about renewable energy can be conveyed more quickly. Furthermore, socialization adapts to the digitalization era to make it easier to access for anyone.

The youth's hopes should be used as a reference for the government to be able to collaborate with youth and the media on renewable energy issues. When the role and empowerment of youth can be properly responded to, youth as agents of change feel that they have played an active and participatory role in development and are able to communicate well with the target community in accordance with the government's expectations and goals.

F. Closing

It is interesting that, in fact, youths want to be involved in development in Indonesia. Youth empowerment needs to be carried out continuously by the government to assist the government in communicating what is the goal of development in Indonesia at this time, especially in the issue of renewable energy.

Youth involvement can be started by utilizing existing media to help campaign or socialize renewable energy to the community. It can be said that there should be good cooperation between the government and youth. Align with the youth's hopes for the government previously mentioned, the researchers feel optimistic that information and knowledge about renewable energy will be conveyed to the wider community so that people are starting to be aware of the existing energy and can switch to renewable energy.

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Chapter 9

Epilog: Sprint with Renewable Energy towards Net Zero Emissions 2060

Septina Is Heriyanti, Sudi Ariyanto

Today, the term "net zero emissions" is becoming increasingly popular, especially in the field of environmental sustainability. The core of the Paris Agreement is to achieve a balance between greenhouse gas emissions and the greenhouse gases (GHGs) that can be removed from the atmosphere in order to limit global temperature rise to below 2°C (Xu et al., 2023). The negative impacts of global climate change, such as rising global temperatures, extreme weather events, and rising sea levels, are key reasons why net zero emissions are essential. The development of green technologies and the implementation of green policies can be achieved through the cooperation and efforts of all countries to achieve net zero emissions targets. As an epilogue, this chapter focuses on the energy sector, and in particular renewable energy, as a potential pathway to achieving net zero emissions targets.

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Indonesia is a country committed to achieving net zero emissions by 2060 or earlier. With the fourth-largest population and the sixteenth-largest economy in the world, Indonesia is responsible for 3.5% of all greenhouse gas emissions (Climate Watch, n.d.). Indonesia's emissions reached 1.495 billion tons of CO_2 equivalent ($MtCO_2eq$) per year from 2018 to 2020. Recently, Indonesia's per capita emissions have become lower than those of developed countries but are still comparable to those of developing countries. Compared to China and India, whose greenhouse gas emissions significantly increased by more than 400% and 300%, respectively, between 1990 and 2018, Indonesia's 35% increase is considered modest. Deforestation (due to land use) and forest and peatland fires are some of the factors contributing to Indonesia's carbon emissions, accounting for 42% of the country's total greenhouse gas emissions. Fossil fuel use is the second largest source, accounting for 39% of Indonesia's emissions between 2000 and 2020, with the coal-based power sector accounting for the majority of energy sector emissions (World Bank, 2023).

A. The Perspective of Renewable Energy Development

The use of renewable energy is essential to achieving the Sustainable Development Goals (SDGs) by 2030. These SDGs are a roadmap established by the United Nations in 2015 to bring peace and prosperity to people and the planet now and in the future. The SDGs have 17 goals, most of which are related to the environment. The use of renewable energy is directly related to SDG goals 7 and 11 (affordable and clean energy), 12 (responsible consumption and production), and 13 (climate action) (Guchhait & Sarkar, 2023).

Intensive research on renewable energy is needed for a variety of reasons, including climate change, global warming, environmental degradation, and limited natural resources. The main purpose of renewable energy is to minimize carbon and greenhouse gas emissions. The government needs to play an active role and support the stabilization of the market and the spread of renewable energy.

According to Miskiewicz, the growth of renewable energy will be influenced by participation and improvement in e-government, the role of industry, and commercial activities (Miskiewicz, 2022). The use of renewable energy can solve two problems at the same time: the problem of limited energy resources and the problem of emissions. From an economic development perspective, the use of renewable energy has very high initial costs compared to fossil energy. However, as renewable energy technology advances and demand increases, costs will fall. For example, solar energy is predicted to become cost-effective across all industries by 2050 (IEA, 2023). On the other hand, the use of renewable energy can lead to increased employment opportunities and benefit the prosperity of societies (United Nations, 2022).

The availability of renewable energy resources has a significant impact on renewable energy production and consumption. Each energy source has a different efficiency, with wind energy having the highest energy efficiency, followed by geothermal, hydro, nuclear[1], and solar. From an application perspective, hydropower is the most common energy source, followed by solar, wind, bioenergy, and geothermal energy (Guchhait & Sarkar, 2023). As shown in Table 9.1, 11 countries in the world have successfully used renewable energy (RE) on a large scale.

Table 9.1 Top Countries in the Use of Renewable Energy

No	Country	% RE used	RE Sources
1	Sweden	100% by 2040	hydro, nuclear[1], wind
2	Costa Rica	98%	hydro, geothermal, wind, solar, biomass
3	United Kingdom	More than 7.5 millions home are powered by offshore wind	wind, tidal, hydro, solar energy
4	Iceland	Almost 100%	geothermal, hydro
5	Germany	46,9% in 2022, 80% by 2030 and almost 100% by 2035	solar, wind
6	Uruguay	98% of its electricity in 2021	hydro, solar, wind, bioenergy
7	Kenya	Over 310 MW from wind farm	wind, solar
8	China	1200 GW by 2030	wind, solar

[1] Indonesia classifies nuclear as new energy.

No	Country	% RE used	RE Sources
9	Morocco	580 MW from solar farm	solar
10	New Zealand	84% of its electricity	hydropower, geothermal dan wind
11	Norway	98% of its electricity in 2016	hydro, thermal, wind

Source: Climate Council (2022); How Electricity Works (n.d.)

In addition to the energy sources mentioned above, waste, which is currently a problem, can also be used as an energy source. Converting waste to energy can solve the waste problem while producing energy and is very important in a circular economy. Here is a comparison of converting waste into fossil fuels: the equivalent waste weights of 1 ton of oil and coal are 4 tons and 2 tons, respectively (Babcook & Wilcox, n.d.). Converting waste to energy as an alternative to landfilling and waste incineration is highly beneficial. Lack of infrastructure, technology, and appropriate rules for waste management leads to persistent problems (Caferra et al., 2023). The most important aspect influencing waste utilization in power plants is the waste location, which is highly influenced by social, legal, environmental, and transportation infrastructure (Silva et al., 2023). One of the drawbacks of the waste-to-energy process is the separation of the waste used as raw material.

Ocean-based renewable energy, such as ocean thermal energy, offshore wind turbines, ocean wave energy, and tidal energy, also offer enormous potential, particularly for countries with large ocean regions. Norway, for example, has the world's largest floating offshore wind park and plans to allocate 30 GW of offshore wind power generation by 2040. It is projected that using renewable ocean energy might reduce CO_2 emissions by up to 3.6 gigatonnes per year by 2050 (World Economic Forum, 2023).

B. The Challenging Path to Net Zero Emissions in Indonesia

The Indonesian government has committed to reducing carbon emissions by 29% by 2030 on a business-as-usual basis and 41% with international support. The biggest challenge for developing countries like Indonesia is finding a balance between economic growth and greenhouse gas emissions because as the economy expands, emissions will continue to rise. The following are the obstacles Indonesia faces in reaching its net zero emission target of the energy sector.

1. Dependence on fossil fuels

The dominance of fossil energy in the energy sector is a significant source of emissions, and Indonesia is obliged to reduce its reliance on fossil energy by transitioning to renewable energy.

2. Renewable energy technology readiness

This technological readiness is related to technological maturity, technological cost reduction and energy storage technology. In addition, the chosen technology must have a sustainable energy supply. The status of Indonesia as an archipelago with different potential resources from region to region greatly influences the choice of renewable energy technology suitable for use in a given region. This requires a thorough feasibility study of the matter to ensure the suitability of the chosen technology.

3. Financial constraints

Financial sources and systems are a challenge for the Indonesian government, as the transition to renewable energy requires significant investment. Indonesia has several funding sources to explore.

4. Renewable energy policies and regulations

The government has developed several renewable energy policies and laws. However, their implementation does not always meet expectations in terms of supporting the use of renewable energy, and some require additional regulations. Adopting renewable energy in Indonesia requires strong political will.

5. Economic growth

Ensuring sustainable economic growth without increasing emissions is a major challenge for developing countries such as Indonesia.

6. Public awareness and acceptance

Awareness of the importance of zero emissions and the adoption of cleaner technology is a challenge for Indonesia, with communities ranging from Sabang to Merauke and varied access to education and information.

C. Encouraging Green Energy through Regulations and Political Policies

Indonesia's energy transition phase is influenced by the global energy transition and depends on the development of important low-emission technologies. Appropriate policies that increase the use of low-emission technology and provide a clear direction for the necessary changes in each sector are also key factors in reducing carbon dioxide emissions in Indonesia. Improving energy intensity, carbon dioxide emissions from power plants, switching to low-emission fuels, and carbon capture utilization and storage (CCUS) are the four main pillars guiding the energy sector's transition to zero emissions (IEA, 2022). Energy efficiency can be improved through energy efficiency improvements, comprehensive policies, and better energy prices. Renewable energy technology, which is cleaner and more environmentally friendly, can produce low-emission fuel. With the introduction of CCUS, it is possible to continue using cheap fossil fuels and, at the same time, reduce emissions.

The use of renewable energy, together with energy efficiency policies, is crucial in reducing greenhouse gases. A number of industrial and financial policies must be implemented to achieve the goal of net zero emissions. Some of the things needed to support the energy transition include a fiscal framework to help set prices and protect investments, influence the financial system for green investments affected by climate and investment regulations, and trade policies to support companies in green exports and imports. In October 2021, the Indonesian government passed legislation to introduce carbon pricing tools, including the emissions trading system (ETS), which should start in 2024.

The Indonesian government has introduced various regulations on energy efficiency, especially in industry and construction. Energy efficiency is central to mitigating the effects of future electricity demand growth. Energy efficiency of electrical equipment can reduce the need to build new power plants. The implementation of energy efficiency can reduce electricity demand by approximately 30% by 2050 (IEA, 2022). Indonesia's policies related to standards, such as permissible standards of CO_2 emission, minimum standards of energy efficiency and others, are very necessary to achieve the goal of zero emission. Regarding industry, the Ministry of Industry has published energy consumption and emission intensity limitation standards for green industry certification requirements (*Permenperin* No. 48, 2020; *Permenperin* No. 49, 2020). The Ministry of Public Works and Housing has established regulations on building standards, one of which is the minimum energy efficiency standards for buildings, lighting, cooling equipment and other building systems (*Permen PUPR* No. 21, 2021). The Ministry of Energy and Mineral Resources approved regulations on Minimum Energy Efficiency Standards (MEPS) for equipment and accessories in 2021, which define product scope, test methods, evaluation criteria and labeling (*Permen ESDM* No. 14, 2021).

The Indonesian government has changed the composition of the energy mix to reduce energy sector emissions. In the years 2020–2030, the share of coal will be reduced from 43% to 30%, the share of oil from 31% to 25%, and the share of renewable energy will be increased from 6.1% to 25%. The use of renewable energy is growing, and the focus is on the use of biofuels (biodiesel mixture), the share of which should rise to 40% by 2025.

By 2050, the share of renewable energy replacing coal in electricity generation will produce approximately half of the reduction in energy sector emissions (IEA, 2022). To achieve the goal of zero emissions set by the Indonesian government, coal-fired power plants with extended lifetimes must be highly efficient and equipped with

Carbon Capture Storage (CCS) technology in the future. The use of electricity produced from renewable energy is still limited by the surplus of electricity produced by coal. The integration of renewable energy into the electricity sector requires the cooperation of the State Electricity Company (PLN) and the private sector to invest in network and transmission infrastructure, energy storage and digitization of network systems.

Indonesia is in the process of establishing an Energy Transition Mechanism Country Forum to organize and coordinate energy transition financing to prepare for the retirement of coal-fired power plants. Financial solutions to reduce energy transition costs can be used by combining international donors and philanthropic financing, carbon trading revenues with state budget, private sector and *sukuk* funds to optimize renewable energy resources.

Presidential Decree Number 112 of 2022 sets the prices of renewable energy at the same level or lower than the price of grid electricity produced by coal (*Perpres* No. 112, 2022). This low price of renewable energy can also be achieved by removing the Internal Market Obligation (DMO) for carbon and local content requirements of the renewable generation system, making it more competitive with fossil energy prices. The Indonesian government has also begun to limit or prohibit the construction of new coal-fired power plants, except for entities involved in the resource sectors or supporting important national strategic projects.

D. Accelerating renewable energy in Indonesia's energy system

These are several important strategies and aspects that the Indonesian government must address to boost the use of renewable energy in Indonesia.

1. Policy framework

These are many critical strategies and aspects that are important for the Indonesian government to adopt and strengthen policies that promote the use of renewable energy. This policy consists of setting clear targets, creating incentives, and creating a regulatory framework to attract investment in the renewable energy sector. For the effective development of renewable energy in Indonesia, the political will of the government is very important. In addition, the government also needs to carry out an impact analysis before implementing policies or regulations.

2. Regulatory stability

Regulatory stability is an important part of creating an investment climate for renewable energy. Stable and predictable laws make it easier to attract the investment needed to build a cleaner and more sustainable renewable energy infrastructure.

3. Investment and financing

It is important to develop an investment system that attracts both domestic and foreign investors, offering, for example, tax incentives, subsidies, and favorable loans for renewable energy projects. Various financing schemes can be developed for renewable energy initiatives, one of which is sharia financing, as Indonesia has a huge Muslim population (86.7%) (Badan Pusat Statistik, 2022). All the government needs to do is to inform people about this financial system, provide competent and reliable financial managers, and facilitate the operation of this finance with advanced technology.

4. Public-private partnership

It is believed that the partnership between the government and the private sector will accelerate the introduction of renewable energy. The partnership is also believed to ensure that the project primarily benefits the local community.

5. International Cooperation

International cooperation is necessary to promote information, technology development and implementation of renewable energy in Indonesia, especially with countries that are successful in the use of renewable energy.

6. Capacity building

Experts in renewable energy technology are very important. There are a number of things that can be done to achieve this expertise, including creating various educational and training programs in the field of renewable energy.

7. Technology diversification

Diversification of renewable energy sources is critical, especially in Indonesia, which has many potential natural resources such as solar, geothermal, hydro, wind, and biomass. Combining different renewable sources is very profitable in terms of consistent and sustainable energy supply. These renewable energy sources should be a part of the optimum energy mix of the country.

8. Resource assessment

There are many renewable energy sources in Indonesia that are scattered, so in-depth research is needed to choose the best place to develop renewable energy projects.

9. Power grid integration

Building a modern and integrated power grid in Indonesia is also critical, especially with distributed renewable energy sources in different regions. This includes transmission and distribution networks, applications of smart grid technology, and increase in energy storage capacity.

10. Public awareness and support

Increased public awareness of the importance of renewable energy can lead to faster adoption. Renewable energy is beneficial to society both economically and environmentally. Campaigns promoting the urgency of adopting renewable energy can be carried out in an engaging and organized manner using several media platforms that are now easily accessible to the public. The young generation may also be empowered to increase public support.

11. Environmental considerations

Before implementing a renewable energy project in the region, a comprehensive environmental assessment must be carried out so that environmental sustainability is considered in the project.

Indonesia has taken several initiatives to promote net zero emissions and the use of renewable energy. However, there is still a lot of work to be done, mainly in terms of investments, strict regulation, and public awareness. Multifaceted research and development of renewable energy technology must also be supported, as Indonesia has significant natural resource potential and human resources. Each region in Indonesia has a different renewable energy potential. Through careful planning, in-depth feasibility studies, strong government support, and community involvement, each region is expected to be able to take full advantage of renewable energy. Achieving net zero emissions and transitioning to renewable energy are essential parts of global efforts to address climate change.

Indonesia is moving towards a golden age and will become one of the countries with the largest economy in the world, becoming a new Indonesia with renewable energy.

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List of Abbreviations

ADB	:	Asian Development Bank
AI	:	Artificial intelligence
BAZNAS	:	Badan Amil Zakat Nasional (the Indonesian National Amil Zakat Agency)
BM	:	Bea masuk (Import duty)
BOE	:	Barrels of oil equivalent
BOT	:	Build-operate-transfer
BRT	:	Boosted regression trees
BUMN	:	Badan Usaha Milik Negara (State-Owned Enterprises)
CAPEX	:	Capital expenditures
CCS	:	Carbon capture and storage
CCUS	:	Carbon capture, utilization, and storage
CF	:	Capacity factor
CH_4	:	Methane

CO	:	Carbon monoxide
CO_2	:	Carbon dioxide
CSR	:	Corporate social responsibility
CWP	:	Cold water pipe
DIKPLHD	:	Dokumen Informasi Kinerja Pengelolaan Lingkungan Hidup Daerah (Regional Environmental Management Performance Information Document)
EKC	:	Environmental Kuznets curve
EMDE	:	Emerging market and developing economy
ERB	:	Environmentally responsible behavior
ESDM	:	Kementerian Energi dan Sumber Daya Mineral (Ministry of Energy and Mineral Resources)
ESG	:	Environment, social, and governance
FiT	:	Feed-in tariff
FPSA	:	Fasilitas Pengelolaan Sampah Antara (Intermediate Waste Management Facility)
FRP	:	Fibre-reinforced polymer
GHG	:	Greenhouse gases
GW	:	Gigawatt
GWh	:	Gigawatt hour
HC	:	Hydrocarbons
HGBT	:	Harga Gas Bumi Tertentu (Price of Certain Natural Gas)
HYCOM	:	Hybrid Coordinate Ocean Model
IDR	:	Indonesian rupiah
IHSG	:	Indeks Harga Saham Gabungan (Composite Stock Price Index)
IMF	:	International Monetary Funds
INA	:	Indonesia Investment Authority
ISWA	:	International Solid Waste Association

kVA : Kilovolt-ampere
kW : Kilowatt
kWh : Kilowatt-hour
LCOE : Levelized cost of energy
MACT : Maximum Achievable Control Technology
MAE : Mean absolute error
MAPE : Mean absolute percentage error
MEMR : Ministry of Energy and Mineral Resources
MMBtu : Million metric British thermal unit
MSW : Municipal solid waste
MW : Megawatt
NEGP : National Energy General Plan
NEM : Net Energy Metering
NO_2 : Nitrogen dioxide
NOx : Nitrogen oxides
NPHR : Nett Plant Heat Rate
NRE : New renewable energy
OJK : Otoritas Jasa Keuangan (Financial Services Authority)
OPEX : Operating expenditures
OTEC : Ocean Thermal Energy Conversion
PLN : Perusahaan Listrik Negara (State Electricity Company)
PLTMH : Pembangkit listrik tenaga mikrohidro (micro-hydro power plant)
PLTSa : Pembangkit listrik tenaga sampah (waste power plants)
PPP : Public-private partnership
PRC : People's Republic of China

PT PLN	:	State Electricity Company Limited Liability Company
PTO	:	Power take-off
QR	:	Quick response
RE	:	Registered exporter
REDAP	:	Renewable Energy Development Acceleration Program
RTRW	:	Rencana Tata Ruang dan Wilayah (Regional Spasial Plan)
SDGs	:	Sustainable development goals
SHAP	:	SHapley Additive exPlanations
SIPSN	:	Sistem Informasi Pengelolaan Sampah National (National Waste Management Information System)
SO_2	:	Sulfur dioxide
SWF	:	Sovereign wealth funds
TGC	:	Tradable green certificate
TWh	:	Terawatt hour
UAE	:	United Arabic Emirates
UN	:	United Nations
UNDP	:	United Nations Development Programme
UNESCAP	:	The United Nations Economic and Social Commission for Asia and the Pacific
US-EPA	:	United State-Environmental Protection Agency
VA-RTM	:	Volt Amper-Rumah Tangga Mampu (Affordable Households Volt Amper)
VAT	:	Value-Added Tax
WTE	:	Waste-to-Energy

Glossary

Agencies : an agency or organization that carries out the function of creating laws and implementing laws within the framework of a state or government structure and system

Agreement : an act regarding property between two parties in which one party promises or is deemed to carry out something, while the other party has the right to claim the agreement

Air pollution : one of the greatest environmental risk to health. By reducing air pollution levels, countries can reduce the burden of disease from stroke, heart disease, lung cancer, and both chronic and acute respiratory diseases, including asthma.

Artificial intelligence (AI) : the ability of machines and systems to acquire and apply knowledge, and to carry out intelligent behaviour

Authority	:	The institution appointed to be the personnel manager is automatically legitimized to have the authority to regulate various matters related to human resources or people within the organization.
Barrel	:	name for one of the units of volume; oil barrel: 42 US gallons, 158.9873 liters, or 34.97231575 Imperial (UK) gallons
Bioenergy	:	renewable energy obtained from biological sources
BOT	:	A build-operate-transfer (BOT) contract is a model used to finance large projects, typically infrastructure projects developed through public-private partnerships.
Bottom ash	:	Bottom ash is the main residue from municipal solid waste (MSW) incineration and refers to the incombustible materials that remain in the furnace after combustion. IBA (incinerator bottom ash) is a very heterogeneous material, comprising irregularly shaped particles and a wide particle size distribution. This material is a complex inorganic mixture generally composed of melt products, minerals, metallic compounds, ceramics, and glass.
Bright Electricity	:	The village lighting or village electricity program has been promoted by the Indonesian government since 1989.
Bureau	:	refers to the term bureaucracy, or an office that has affairs in a particular government which is tasked with making decisions in a particular field
Campaign	:	a series of planned communication actions with the aim of creating a certain effect on a large number of audiences carried out on an ongoing basis over a certain period of time

Capacity factor : the ratio of the output over a certain length of time to the nominal output that would be produced if the equipment were operating continuously at nameplate capacity over the same amount of time

CAPEX : money spent by a business to buy, improve, and maintain tangible assets like real estate, plants, buildings, technology, or equipment

Carbon dioxide : CO_2, a colourless gas having a faint sharp odour and a sour taste. It is one of the most important greenhouse gases linked to global warming, but it is a minor component of Earth's atmosphere (about 3 volumes in 10,000), formed in combustion of carbon-containing materials, in fermentation, and in respiration of animals and employed by plants in the photosynthesis of carbohydrates. The presence of the gas in the atmosphere keeps some of the radiant energy received by Earth from being returned to space, thus producing the so-called greenhouse effect.

Carbon tax : a tax imposed on the burning of carbon-based fuels, including oil, gas and coal

Carnot efficiency in thermodynamics : the maximum possible efficiency of a heat engine operating between two reservoirs at different temperatures

Cash waqf : waqf made by a person, group of people, institution or legal entity in the form of cash

Circular economy : an economic system or model that aims to generate economic growth by maintaining the value of products, materials, and resources in the economy for as long as possible, thereby minimizing the social and environmental damage caused by a linear economic approach

Climate change : long-term shifts in temperatures and weather patterns. Such shifts can be natural, due to changes in the sun's activity or large volcanic eruptions. But since the 1800s, human activities have been the main driver of climate change, primarily due to the burning of fossil fuels like coal, oil and gas.

Combustion residues : Combustion residues, such as municipal solid waste incinerator (MSWI) bottom ash and alkaline coal fly ash, are produced world-wide in ever-increasing quantities. Combustion residues, however, may pollute the environment because they are enriched in potentially toxic elements relative to soils and sediments.

Communication : the process of conveying messages or information from one party to another party so that the message in question can be understood. Communication can be done verbally or nonverbally.

Community : individuals or people who have similar characteristics such as geography, culture, race, religion, or equal socio-economic conditions

Crowdfunding : a method of obtaining capital by raising funds for a particular project or business

Culture changes : Culture change is based on person-directed values and practices where the voices of elders and those working most closely with them are solicited, respected, and honored. Core person-directed values are relationship, choice, dignity, respect, self-determination and purposeful living. Culture change supports the creation of both long and short-term living environments as well as home and community-based settings and are able to express choice and practice self-determination in meaningful ways at every level of daily life.

Cut-in speed : the minimum speed to generate electricity

Cut-off speed : the maximum speed to generate electricity. If the speed exceeds the cut-off, the power generated is zero.

CwC : a field of work quite distinct from conventional public information, messaging, or advocacy. CwC is based on the principle that information and communication are critical forms of aid, without which people affected by a crisis cannot access services or make well-informed decisions for themselves and their communities. However, access to information is only the first step; just as the absence of information can lead to inaction, inaccurate information can lead to counterproductive actions.

Decarbonization of economy: the process of reducing the amount of carbon, mainly carbon dioxide (CO_2), that is emitted into the atmosphere by human activities. The main goal of decarbonization is to mitigate the effects of climate change and achieve a low-carbon or net-zero economy, where the emissions produced are balanced by the emissions removed.

Deep seawater : seawater at a depth of more than 200 m where the temperature is suddenly cold

Development : an effort or activities to grow and change that is planned and implemented consciously by a nation, state and government in the context of nation building

Empowerment : the process of developing people's independence and welfare by increasing knowledge and skills in order to improve one's own situation and condition

Energy-growth nexus : a term that refers to study the causal relationship between energy consumption and economic growth. There are four main hypotheses that have been proposed to explain the energy-growth nexus, i.e., the growth hypothesis, the conservation hypothesis, the feedback hypothesis, and the neutrality hypothesis.

EKC hypothesis : a hypothesis that suggests that a relationship between environmental quality and economic development follows inverted U-shaped curve. According to the EKC, environmental degradation tends to increase in the early stages of development, as the economy grows and consumes more natural resources and produces more pollution. However, after reaching a certain level of income or development, the economy becomes more efficient and environmentally conscious, and environmental degradation starts to decrease. The EKC is named after Simon Kuznets, who proposed a similar curve for the relationship between income inequality and economic development.

Fly ash : Waste treatment using thermal technologies, such as incineration, leads to the production of pollutants and wastes, including fly ash (FA). Fly ash contains heavy metals (HMs) and other contaminants and can potentially pose high risks to the environment and negatively impact health and safety. Consequently, stabilizing fly ash prior to either use or landfilling is crucial.

Fossil energy : fuels that are made from fossils and cannot be renewed

Generated solid waste: The generation of solid waste is the inevitable consequence of all processes where materials are used. Extraction of raw materials, manufacture of products, consumption, and waste management all generate wastes. The rate of material use today is so large, both with regard to the total amounts and seen as a per capita average, that the waste generated will impact on the environmental quality and human health worldwide if it is not managed properly.

Geothermal : geothermal energy that comes from the earth's core

Global warming : the phenomenon of gradual increase in the average temperature of earth

Green bond : one of the financial instruments issued to finance or refinance part or all of environmentally friendly business activities

Green economy : economic development that focuses on sustainability and reducing environmental risks

Green energy : energy sources produced from natural resources that can be continuously renewed.

Green financing	:	comprehensive support of the financial services industry for sustainable growth resulting from harmony between economic, social and environmental interests
Green tax	:	a form of legalization of a high-cost economy, as well as being a disincentive for environmental protection efforts by entrepreneurs in Indonesia
Greenhouse	:	a building covered in clear or translucent material that can transmit light optimally for production and protect plants from climatic conditions that are detrimental to plant growth
Greenhouse Gases	:	gases that trap heat in the atmosphere
Incineration	:	Incineration is the process of burning hazardous materials at temperatures high enough to destroy contaminants. Incineration is conducted in an "incinerator," which is a type of furnace designed for burning hazardous materials in a combustion chamber.
Intergenerational well-being	:	the quality of life and well-being of people across different generations
Investment	:	the activity of saving or placing funds for a certain period with the hope that this saving will result in profits or an increase in investment value
Landfills	:	Landfills are locations where disposable materials are sent, which are then buried underground. During this process, precautions are taken to prevent the waste from reaching and potentially contaminating any groundwater. Modern landfills are well-

engineered and managed facilities for the disposal of solid waste. Landfills are located, designed, operated and monitored to ensure compliance with federal regulations. They are also designed to protect the environment from contaminants, which may be present in the waste stream. Landfills cannot be built in environmentally-sensitive areas, and they are placed using on-site environmental monitoring systems. These monitoring systems check for any sign of groundwater contamination and for landfill gas, as well as provide additional safeguards.

Leachate : Leachate is a by-product derived from municipal solid wastes due to their physical, chemical, and biological changes and will be formed in landfills, incineration plants, composting plants, and transfer stations, with high strength and toxicity.

Machine learning : a field of computer science that aims to teach machines how to learn from data and perform tasks that would normally require human intelligence

Management of solid waste : the collecting, treating, and disposing of solid material that is discarded because it has served its purpose or is no longer useful. Improper disposal of municipal solid waste can create unsanitary conditions, and these conditions in turn can lead to pollution of the environment and to outbreaks of vector-borne disease—that is, diseases spread by rodents and insects. The tasks of solid-waste management present complex technical challenges. They also pose a wide variety of administrative, economic, and social problems that must be managed and solved.

Mauquf alaih : parties who receive benefits from the management of waqf funds

Methane emissions : When Municipaly solid waste (MSW) is first deposited in a landfill, it undergoes an aerobic (with oxygen) decomposition stage when little methane is generated. Then, typically within less than one year, anaerobic conditions are established and methane-producing bacteria begin to decompose the waste and generate methane.

MMBtu : The unit of heat expressed in million BTU, (British thermal unit) is the heat required to raise the temperature of one pound of water one degree Fahrenheit.

Municipal solid waste (MSW) : more commonly known as trash or garbage—consists of everyday items we use and then throw away, such as product packaging, grass clippings, furniture, clothing, bottles, food scraps, newspapers, appliances, paint, and batteries. This comes from our homes, schools, hospitals, and businesses.

Mutual fund : a spot used to collect funds from the public to be invested in securities portfolios by investment managers

Nazhir : certain people or legal entities mandated to manage waqf assets in accordance with the purpose of the waqf

Nonparametric : a type of statistical method that does not make any assumptions about the characteristics of the sample or the population from which the data are drawn. It can be used for both descriptive statistics or statistical inference.

Open dumping : An open dumping is defined as a land disposal site at which solid wastes are disposed of in a manner that does not protect the environment, are susceptible to open burning, and are exposed to the elements, vectors, and scavengers.

OPEX : a cost incurred by a firm during regular operations.

Public-private partnership : A public-private partnership (PPP, 3P, or P3) is a long-term arrangement between a government and private sector institutions. Typically, it involves private capital financing government projects and services up-front, and then drawing revenues from taxpayers and/or users for profit over the course of the PPP contract.

Rated speed : the speed required for maximum output power

Regulation : an authoritative rule dealing with details or procedure

Renewable energy : an energy source that is available by nature and will not run out because it is formed from sustainable natural processes

Sorting the type of waste : Waste sorting is the process by which waste is separated into different elements. Waste sorting can occur manually at the household and collected through curbside collection schemes, or automatically separated in materials recovery facilities or mechanical biological treatment systems.

Sukuk : securities that represent asset ownership by investors through the issuance of sharia-based debt securities

Sulfur dioxide : a gaseous air pollutant composed of sulfur and oxygen. SO2 forms when sulfur-containing fuel such as coal, petroleum oil, or diesel is burned. Sulfur dioxide gas can also change chemically into sulfate particles in the atmosphere, a major part of fine particle pollution, which can blow hundreds of miles away.

Sustainable development : development that meets the needs of the present without compromising the ability of future generations to meet their own needs

Sustainable Development Goals : a set of 17 global goals that aim to achieve a better and more sustainable future for all people and the planet by 2030. They were adopted by the United Nations in 2015 as a universal call to action to end poverty, protect the environment, and promote peace and prosperity.

The BOT scheme : refers to the initial concession by a public entity such as a local government to a private firm to both build and operate the project in question. After a set time frame, typically two or three decades, control of the project is returned to the public entity.

Thermal gradients in OTEC : the differences in temperature between ocean surface waters and deep ocean waters

Ujrah : compensation or fees that must be paid for services that have been performed based on the agreed contract. According to the majority of scholars, the law of ujrah is permissible, provided that it is carried out in accordance with the provisions set by sharia.

Unique smart waste collection : a solution to help implementing a waste classification system, introducing artificial intelligence (AI) in its waste management system. Facial recognition technology in bins to encourage people to recycle more, register all participating residents and take their photos. When a resident throws away trash, the trash can automatically scans their face to identify them. Once the bin recognizes that the user is a resident, the lid is opened and the recyclables are weighed. QR coded trash bags ensure that the correct trash is thrown into the right bin. Residents are given point credit awards for excelling in recycling.

Urban areas : region surrounding a city. Most inhabitants of urban areas have non-agricultural jobs. Urban areas are very developed, meaning there is a density of human structures, such as houses, commercial buildings, roads, bridges, and railways.

Urbanization : refers to the concentration of human populations into discrete areas. This concentration leads to the transformation of land for residential, commercial, industrial and transportation purposes. It can include densely populated centers, as well as their adjacent periurban or suburban fringes.

Waqif : parties (individuals, organizations, legal entities) who endow their property for social purposes

Waste-to-energy conversion system : Waste to energy (WTE) conversion technologies can be employed to convert residual wastes into clean energy, rather than sending these wastes directly to landfill. Waste to energy conversion technology explores the systems, technology and impacts of waste to energy conversion.

Wave energy device : a machine to capture and converts wave potential into electricity

Wind farm : a location set aside for the production of wind energy

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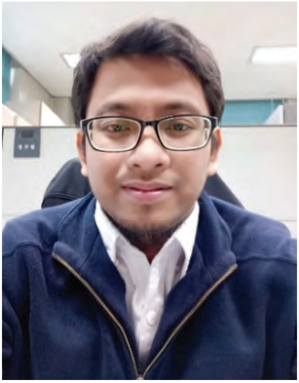

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Renewable energy is a term used to describe energy that comes from nature and is naturally replenished on a human timescale. The discussion on renewable energy has received increasing attention recently since it is viewed as the primary component of sustainable development and a promising solution to global energy and environmental challenges. In the context of Indonesia, this topic becomes important since Indonesia is bestowed with abundant renewable energy resources potential that is currently underutilized. Hence, it is enticing to delve deeper into different perspectives of renewable energy, which are discussed comprehensively in this book.

This book conveys the discussion of renewable energy from the perspective of Indonesia's condition. Chapters in the book address many aspects of new and renewable energy discourse, including technology, policy and regulation, financial strategy, and social aspects. Written by various qualified authors in each field, this book shows how collaboration is needed to implement the strategy and policy for using new and renewable energy in Indonesia.

Renewable Energy: Policy and Strategy is hoped to be a valuable source of knowledge concerning new and renewable energy solutions. Several recommendations can be implemented, and this book is here to become a reference for policymakers in achieving the net zero emissions target.

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