INDONESIA'S RENEWABLE ENERGY OUTLOOK: WHAT TO EXPECT FROM THE FUTURE RENEWABLE ENERGY OF INDONESIA. A BRIEF REVIEW

Ian Kurniawan[*], Reisya Ichwani[**], Richa Fionasari[***], Aryansyah[****], Adri Huda[*****]

[*]*Department of Chemical Engineering, Faculty of Engineering, Universitas PGRI Palembang, Palembang, Indonesia, iankurniawan@univpgri-palembang.ac.id*

[**]*Department of Material and Mechanical Engineering, Worcester Polytechnic Institute, Worcester, Massachusetts, United States of America, richwani@wpi.edu*

[***]*Language Center, Universitas Riau, Pekanbaru, Indonesia, richafiona@gmail.com*

[****]*Department of Energy, Ministry of Energy and Mineral Source of the Republic of Indonesia, Palembang, Indonesia, Arik120677@gmail.com*

[*****]*Department of Environmental Engineering, Faculty of Engineering, Universitas Sumatera Utara, Medan, Indonesia, adrihuda@usu.ac.id*

Email Correspondence : adrihuda@usu.ac.id

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Abstract: The government of the Republic of Indonesia has reported that Indonesia potentially have more than 400,000 Megawatts (MW) of renewable energy by 2021. However, there is no comprehensive study about the trend of development and priority movement in the renewable energy sector. The main reason for the absence of this study is the lack of significant information and reports on the prospects for renewable energy in Indonesia. The present study aims to provide a basic understanding of renewable energy sector growth in Indonesia. The study uses quantitative analysis with the secondary data obtained from the literature. The result showed that the hydropower plant contributed the highest energy production in Indonesia followed by bioenergy, solar energy, and wind energy. Furthermore, the production trends of hydropower plants and bioenergy were relatively stagnant over the last 11 years, and the highest significant improvement was found in the solar energy sector. However, the number of solar energy production was far away from the targeted goal in RUEN (National Energy Master Plan/*Rencana Utama Energi Nasional*) 2017. The high cost of the solar energy sector become the main reason for the unsuccessful development of solar energy in Indonesia. Furthermore, several administrations and regulations were found to the political reasons which delay the energy transition improvement. The Government of the Republic of Indonesia must be able to improve and form regulations in the form of tax reduction regulations and electricity export-import subsidies to spur the growth and development of renewable energy in Indonesia. Opening up space for renewable energy investment in the public sector is a real contribution to society and is a solution to accelerate the achievement of the energy transition in Indonesia.

Keywords: Renewable Energy; Energy Policy; Energy Transition; Green Technology Indonesia

Abstrak: Pemerintah Republik Indonesia telah melaporkan bahwa Indonesia memiliki potensi lebih dari 400.000 Megawatts (MW) Energi Baru dan Terbarukan (EBT) di tahun 2021. Namun, penelitian terhadap pola pengembangan dan pergerakan

pengembangan EBT masih belum banyak ditemukan. Alasan utama dari tidak ditemukan penelitian ataupun studi tentang potensi EBT di Indonesia adalah keterbatasan informasi dan laporan terhadap prospek EBT di Indonesia. Studi ini bertujuan untuk menyediakan pemahaman dasar dari perkembangan sektor EBT di Indonesia. Studi ini menggunakan analisis kuantitatif dengan menggunakan data sekunder yang diperoleh dari berbagai literatur. Hasil menunjukkan bahwa Pembangkit Listrik Tenaga (PLT) Air menjadi sektor yang paling banyak memproduksi EBT di Indonesia disusul oleh PLT Bioenergi, PLT Surya, dan PLT Bayu. Namun, pola produksi energi menunjukkan PLT Air dan PLT Bioenergi menunjukkan produktivitas yang relative tetap pada 11 tahun terakhir dimana peningkatan produktivitas terbesar berada pada PLT Surya. Namun, jumlah produktivitas PLT Surya masih tergolong kecil jika dibandingkan dengan jumlah produksi target yang dilaporkan pada Rancangan Utama Energi Nasional (RUEN) 2017. Biaya yang tinggi dari PLT Surya menjadi alasan utama dari ketidakberhasilan pengembangan PLT Surya di Indonesia. Selain itu, beberapa alasan administratif dan regulasi ditemukan menjadi alasan politis yang dapat memperlambat pengembangan transisi energi di Indonesia. Pemerintah Republik Indonesia harus mampu memperbaiki dan membentuk regulasi berupa adanya regulasi pengurangan pajak dan subsidi ekspor-impor listrik untuk memacu pertumbuhan dan perkembangan energi terbarukan di Indonesia. Membuka ruang untuk investasi energi terbarukan ke sektor public merupakan kontribusi nyata ke masyarakat merupakan solusi untuk mempercepat pencapaian transisi energi di Indonesia.

Kata kunci: Energi Baru dan Terbarukan; Kebijakan; Transisi Energi; Teknologi Hijau Indonesia

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Introduction

New and renewable energies become essential for meeting energy demand all over the world due to the limitation of fossil fuel and the fast growth of the population (OurWorldinData, 2022). The issue of climate change which made the earth's surface warmer gives additional stress to each country to provide a green and environmentally safe energy source. Paris Agreement has limited global warming to well below 2^{o}C (3.6^{o}F) and is pursuing efforts to limit it to 1.5^{o}C (2.5^{o}F) (European Commission 2023). Indonesia, the fourth most populated country in the world, has started to use renewable energies as the national energy source to meet national energy demands (Hakim, 2020). Indonesia has a potential renewable energy source to develop, such as hydropower, biofuel, biomass, solar energy, wind power, nuclear, and geothermal (Hartono et. al, 2020). The government of Indonesia believes that fossil fuels will be eventually substituted by new and renewable energy in the future either because of the scarcity of fossil fuels or other environmental issues. So far, renewable energy only provides 6% of national energy demand whereas Indonesia mostly depends on non-renewable

energy sources such as fossil fuel (41%), natural gas (24%), and coal (29%) and Indonesia is the top country which had the highest steam coal power plant among G20 countries (Ahdiat, A. 2022).

In Southeast Asia, Indonesia is reported as the third country which produces the most renewable energy as a national energy source where Indonesia contributes 8.81% of renewable energy. Vietnam is reported as the first rank where Vietnam uses approximately 21.98% of renewable energy as the primary energy source followed by Malaysia (15.52%) and Indonesia as the third place (OurWorldinData, 2022). Indonesia could increase the use of renewable energy as the primary energy source since there are many potential renewable energy sources in Indonesia (Halawa & Sugiyatno, 2001). The Ministry of Energy and Mineral Resources of the Republic of Indonesia reported that several sectors could boost the contribution of renewable energy mining in Indonesia such as hydropower, biomass/biofuel, solar power, wind power, and nuclear power. The government of the Republic of Indonesia has placed a national target in the renewable energy sector of 23% in 2025 and 31% in 2050 to support the primary energy source in Indonesia (IESR, 2017). Indonesia also showed its full support for the transformation to green energy and reduction of carbon emissions by joining the Paris Agreement or Paris Climate Agreement. The government of the Republic of Indonesia has targeted to reduce 29% below business as usual of greenhouse gas emission by 2030 (Tacconi 2018).

However, there is a lack of study shown by the small number of studies and publications about technology applied or developed in the renewable energy sector in Indonesia. There are no comprehensive studies or information about where and how to start the development of the renewable energy sector in Indonesia. In simple words, it is quite hard for someone or a company to participate in or support the program of energy transition. Thus, the government of Indonesia walks alone in the development of the energy transition, and it became less priority for the people in Indonesia. Furthermore, the regulation about the development of renewable energy seems incomplete to fully support the development of green energy in Indonesia. The monopoly system in energy management could incriminate the private sector to contribute to the development of green energy in Indonesia.

The present papers aim to provide existing facts about the development of new and renewable energy in Indonesia. The papers will talk about the statistical number of the renewable energy sector in Indonesia and some governmental regulations which have been made to achieve the national energy target. The discussion will finally drive us to see the Indonesian energy outlook and put hope in what green energy development will look like in the future.

Methods

The study uses secondary data obtained from works of literature and connects the data based on the authors' perspectives. The descriptive method was the study methodology where most of the discussion was made from the author's perspective with comprehensive support from the literature. The data was mainly extracted from the International Renewable Energy Agency (IRENA) which is the intergovernmental organization that supports countries to move to a sustainable energy future.

The study was divided into three sections which presented (i) the data on the status of renewable energy development in Indonesia; (ii) the potential source of renewable energy development in Indonesia; and finally (iii) the regulation and future direction of renewable energy development in Indonesia. All section aims to figure out the renewable energy outlook of Indonesia in the past, current, and future.

Results and Discussions

Current Indonesian Energy Sources

The data published by Our World in Data reported that the non-renewable energy source still become the main source of primary energy in Indonesia (Figure 1). Oil, Coal, and Gas based Generators supplied more than 85% of primary energy sources. Renewable energy sources only contribute approximately 10% of the primary energy source in Indonesia. However, energy production from non-renewable sources declines the energy production due to the increase of energy from renewable energy sources.

Furthermore, Figure 1 shows that hydropower became the first renewable energy source in Indonesia where energy production has been started before 1970. The second renewable energy source in Indonesia was geothermal and biomass which were reported by Our World in Data launched in 1990. The following renewable sources such as Biofuel, Windmill Energy and Solar Energy were started to produce renewable energy in 2002, 2007, and 2008, respectively.

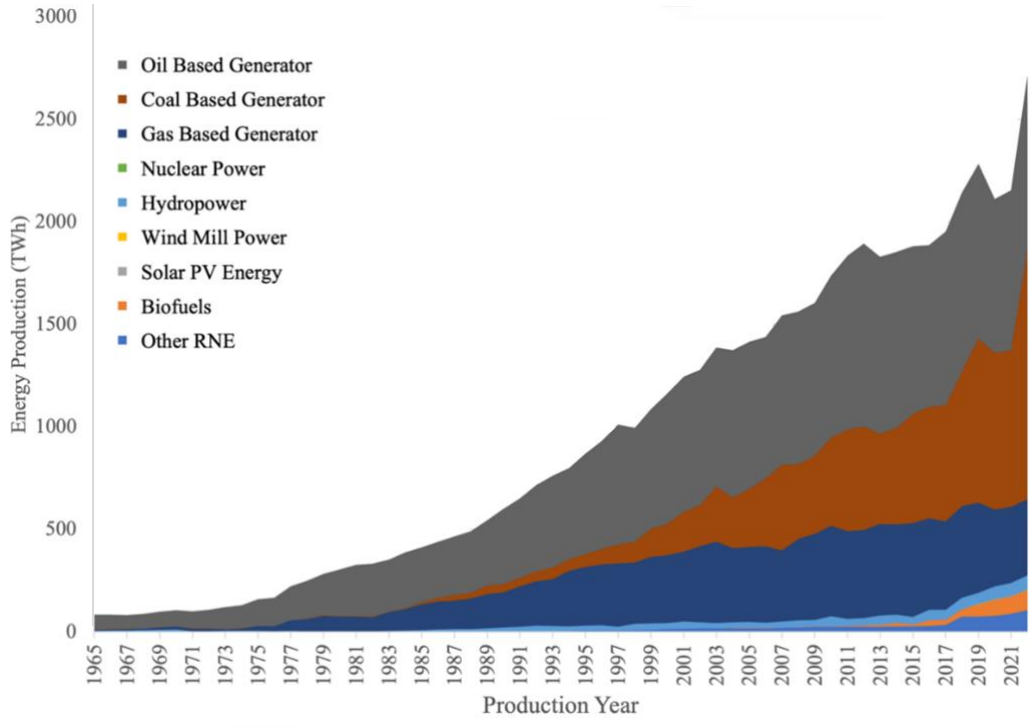

Figure 1. Primary Energy Source in Indonesia from 1965-2021

The total energy supply in Indonesia also showed a similar result to the primary energy source. The data published by the International Energy Agency (IEA.org), a non-profit organization of industrialized countries, reported that Indonesian energy was dominated by fossil-based energy where 31-35% of electrical production was coming from oil-based grid system followed by coal-based grid (20-30%), natural gas power plant (17-19%), biofuel and waste (13-19%), other renewable energy (7-10%) and hydropower (~1%)(IEA.org. 2020). Approximately 70% of total electricity was generated from the fossil-fuel-based power grid. Figure 2 shows the details of the total energy supply as a function of power sources in Indonesia from 2015 to 2019.

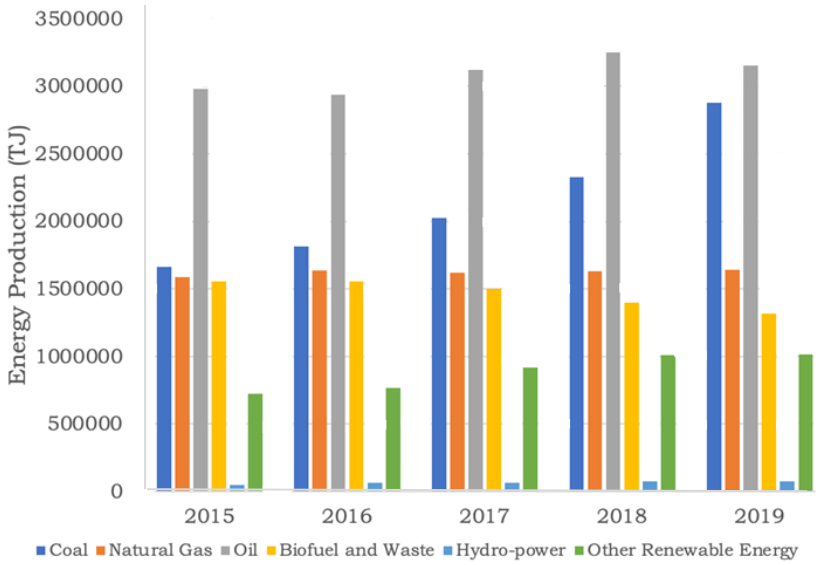

Figure 2. Total Energy Supply (TES) of Different Energy Sources from 2015-2018 in Indonesia (IEA, 2020)

In the case of Indonesia, most of the national power electricity was in Java and Bali where 68% of electricity was produced in the accumulation of powerlines in Java and Bali followed by the power grid in Sumatera (18%), Sulawesi (6%), Kalimantan (5.56%), Maluku and Papua (0.6%), and Lombok and Timor (1%) (Pusparisa, Y. 2020, PLN, 2018). The high amount of power grid in Java and Bali was because of the high energy consumption in Java and Bali islands where the capital city of Indonesia and other major cities of Indonesia which run the economic sectors such as Surabaya located in Java Island. On the other hand, Bali is the most visited city for tourism especially for foreign destinations making the energy supply and demand in Bali high compared to other cities in Indonesia. However, the fast economic development in Indonesia initiated high energy consumption outside the Java and Bali islands. Thus, the government of Indonesia has built a new power grid outside Java and Bali Island, especially renewable power grid plants such as Badak Solar Power Plant in Kalimantan Island, Wind Power Plant in Sidrap, South Sulawesi Island, Solar Power Plant in North Sulawesi Island, etc (SolarKita 2021).

Renewable Energy Outlook

The progress of renewable energy development in Indonesia showed progress where the trend of renewable energy development showed a positive value (IEA.org. 2020). Even though only a small percentage of renewable energy production has been realized, the development has been made especially in several sectors such as solar energy, wind energy, and nuclear energy where in 2015, the number installed capacity of renewable energy (excluding hydropower and biofuel and waste) was approximately 8.5%, where in 2020 reached approximately 10.1% (Our World in Data. 2022). However, the hydropower

biofuel, and waste power plants showed stagnant progress in the last couple of years due to several factors (IRENA 2019). In hydropower development, the main reason was the hydropower infrastructure was not massively improved in the last several years since the cost and investment values were high and the location of the water source was in a remote area with the limitation of transportation and public access which made the development need massive activities and costs (Patapati, 2021). The government of the Republic of Indonesia has found an alternative way to improve the hydro-based power system by improving the marine-based power plant and micro hydropower plant which is considered a good move since Indonesia is an archipelagos country (Bagherabadi, et al. 2022). Moreover, as an agricultural country, millions of basins and water irrigation systems could be exploited as the electrical power source to support the primary energy source of Indonesia, especially in the rural and remote areas (Didik, et al. 2018).

On the biofuel and waste development, the development was made only for biodiesel and bioethanol which is used as a substitution for fossil fuel and not to produce electrical energy. However, the progress is still in the good movement where in 2021, approximately 9.3 million liters of biodiesel have been used to substitute the use of fossil fuels (EBTKE, 2022). The other problem in the development of biofuel was the issue of food security where both biodiesel and bioethanol used food-based material. Biodiesel and bioethanol used palm oil and cassava or corn material, respectively, as the main materials to produce the biofuel. The use of food-based materials is feared to disrupt food supplies in Indonesia. The trend that occurs in the development of biofuels is relatively declining from year to year. The Indonesian government must formulate in detail the regulation about the distribution of the minimum and maximum amount of food-based fuel from the biodiesel and bioethanol industry or regulate the food-waste product as the raw material for biofuel.

Renewable Energy Potential in Indonesia

Nowadays, Indonesian energy demand (without traditional biomass uses) reached 114 million tons of oil equivalent (MTOE) which supplied 40% of transportation, 36% of industry, 16% of household needs, 6% of commercial activities, and 2% of other activities (Council, 2020). The Ministry of Energy and Mineral Natural Resource or *Kementerian Energi dan Sumberdaya Mineral* (KESDM) have investigated several sectors that could be potentially the renewable energy source shown in Table 1.

Table 1. Indonesia's Renewable Energy Potential

Renewable Energy Sources	Total Produced Energy
Hydropower Plan	94.3 Gigawatts
Geothermal Plan	28.5 Gigawatts
Bioenergy	
1. Biopower	23.6 Gigawatts
2. Biogas	200.000 Barrel per hour
Solar/PV Power Plan	207.8 Gigawatts
Windmill Plan	60.6 Gigawatts
Ocean Power Plan	17.9 Gigawatts

The total potential of renewable energy in Indonesia is 442 GW divided into several sectors (Table 1). The government of the Republic of Indonesia focused on the development of a solar power plant (SPP) where SPP contributes nearly 50% of the total renewable source coming from SPP (207.8 GW) and higher than hydropower as the most dominant renewable energy source so far in Indonesia. The development of SPP was considered a good move by the government of Indonesia since SPP become the most reliable renewable energy so far in the world. Solar photovoltaic was recorded as the fastest-growing renewable energy technology which played a major role in the future of global electricity generation (IRENA, 2019). The development of SPP in Indonesia was suitable to the characteristic of Indonesia where Indonesia is a tropical country that has long sun exposure and high sunlight intensity in all calendar years. In addition, SPP could reach remote areas which sometimes did not have electricity infrastructure.

Renewable Energy Development Progress in Indonesia

Talking about the potential of green energy in Indonesia, the government of Indonesia published the Primary National Energy Plant, or *Rancangan Utama Energi Nasional* (RUEN) in 2017. According to RUEN, the development of renewable energy in Indonesia only reached 2% of the total potential in Indonesia. To be more specific, only 8.215,5 MW of electrical production obtained from the renewable energy sector was achieved. According to the Indonesia Energy Transition Outlook (IETO) 2023, Indonesia has the potential for new energy in every region, including Sumatera, Jawa, Kalimantan, Sulawesi, and Papua. Due to its easy access to its location and available resources, Sumatra is the only region in the world with a significant potential for development (Suhono and Sarjiya, 2015). Sumatera has a significant amount of relatively similar biomass and biofuel potential. However, Sumatera Utara and Aceh have significant geothermal potential (Siregar et al., 2021; Isa et al., 2021). Table 2 shows the number of electrical productions coming from renewable energy.

Table 2. Renewable Energy Production Progress in Indonesia

Renewable Energy Sources	Total Installed Power (MW)	Target Installed Power (MW)	% Goal
Hydropower Plan	1,438.5	75,091	6,4
Geothermal Plan	1,438.5	29,544	4,9
Mini and Microhydropower	197,4	19,385	1,0
Bioenergy Plan	1,671	32,654	5,1
Solar/PV Power Plan	78,5	207,898	0,04
Windmill Plan	3,1	60,647	0,01
Ocean Power Plan	0,3	17,989	0,002

International Renewable Energy Agency (IRENA) in Renewable Energy Statistic 2019 reported that Indonesia has produced 8.8 GW of renewable energy which increase of approximately 508 MW of renewable electricity compared to the source in 2020. Figure 3 shows the renewable energy production reported by IRENA. The highest energy source came from hydropower which contributed 75% of renewable energy in 2021 followed by Bioenergy (21%), Solar Power (2.3%), and Wind Energy (1.7%). The result about electrical production from hydropower was strongly different from the one reported by RUEN 2017, whereas the result about other renewable energy was slightly different from the one reported by RUEN 2017.

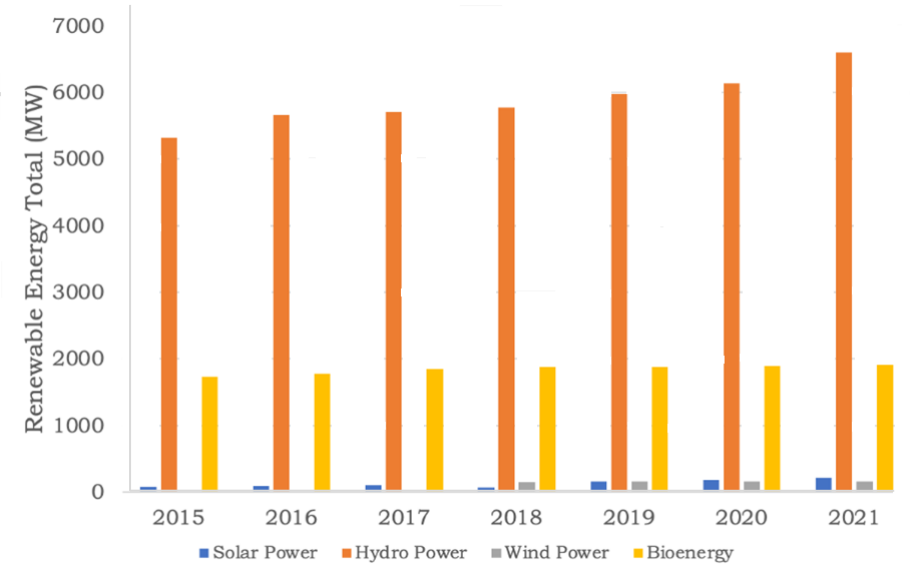

Figure 3. Renewable energy production in Indonesia reported by the International Renewable Energy Agency

PT. Perusahaan Listrik Negara (PLN) the company that supplies electricity in Indonesia also reported the installed power plant in Indonesia where hydropower is the highest plant-produced electricity (3516.51 MW) followed by Geothermal (579.26 MW), Microhydro Power (46.12 MW), Minihydro Power (34.35 MW), and Solar Power Plant (28.62 MW). The number of renewable

energies does not include the power plants that are not connected with the interconnection or line managed by PT. PLN. Furthermore, the Ministry of Energy and Mineral Resources of the Republic of Indonesia reported that the amount of electrical energy produced from the renewable energy sector only fulfils approximately 14% of the total capacity of renewable energy-based power plants which reaches 64.5% (ESDM, 2017). The main reason for unsuccessful development was the high investment values in the renewable energy sector and the high energy cost per kWh from renewable energy sectors. Table 3 shows the comparison of electrical prices produced by renewable energy power plants and fossil-based power plants.

Table 3. Levelized Cost of Energy (LCOE) of Energy

Energy Source	LCOE (Rp) per kWh	Type
Diesel-based Power Grid	3,992	Fossil-based Energy Source
Natural Gas and Steam-based Power Grid	1,843	
Natural Gas Power Grid	806	
Steam-based Power Grid	661	
Solar/PV Power Plan	8,786	Renewable Energy Source
Geothermal Plan	1,058	
Hydropower Plan	388	

Table 3 shows that the electrical price per kilo Watts hour (kWh) from renewable energy plants is slightly higher than the price from fossil-based power plants. The high price per kWh of electricity from renewable energy power plants was because of the high investment values. Forbes (2022) reported that the value of the investment in SPP with 4 kW – 7 kW reached $15,000-$ 25,000 of investment (Advisor, 2022). In comparison, the electrical rate of SPP is higher than the one produced by a diesel-based power grid which is known as the most expensive fossil-based power plant.

National Renewable Energy Lab (NREL) published the details of the investment cost of SPP which is shown in Figure 3. The highest investment values were coming from the high price of the module which was the main process in SPP. However, the price of modules kept decreasing since the discovery of cheap material and highly efficient materials (Benda & Černá, 2020). Moreover, it can be seen from Figure 3 that the soft cost which became the second most costly process in the development of SPP was relatively stable every year. This cost could be well maintained by making a good policy or regulation by the government to cut the soft cost which is mostly related to sales tax, compensation, or profit (NREL, 2020).

Energy Policy in Indonesia and Future Direction of Energy Development

The government of the Republic of Indonesia has started the transition of energy from fossil fuel to renewable fuel. The story began by releasing Law

Number 30 of 2007 about Energy. Another regulation is Presidential Regulation No. 79 of 2014 where the regulation put 23% of primary energy sources coming from renewable energy sources in 2025 and 31% in 2050. The presidential regulation became the base of the further movement where the government arranged the primary national energy planning or RUEN in 2017 which was supported by the presidential regulation no. 22 of 2017.

According to RUEN, the future direction of the energy transition will be focused on the development of SPP where approximately 207.8 GW become the target of development in 2050. The main reason for the development of SPP was the reliability of SPP which aligns with the characteristics of the Republic of Indonesia (Syahputra & Soesanti, 2021). The Implementation of Minister of Energy and Mineral Resources (MEMR) Regulation No. 26 of 2021 is anticipated to accelerate the growth of the rooftop solar PV market, particularly given the National Strategic Project (PSN)'s aim of 3.6 GW of rooftop solar electricity. However, the progress seems to have left behind the target where only 0.08% of the target was utilized so far in 2021 (Suparwoko & Qamar, 2022).

The low utilization rate was because of the consideration of SPP as an expensive technology. The energy cost produced by the SPP was higher compared to the energy cost produced by the coal-based power plant. However, the sustainability and environmental effects of coal-based power plants were never placed in the policy decision most of the parliament only taught about the financial advantages.

The target of 3.6 GW in 2025 and 207.8 GW in 2050 could not be achieved if the government does not open for private or community societies. The successful energy transition in Indonesia should begin with full support from the local people of Indonesia where the society has a high willingness to contribute to the energy transition for example by investing in the renewable energy sector. The successful energy transition by society could be achieved by releasing advantageous regulations, especially from the economic point of view. By involving society, the energy transition could be a massive movement and make the energy transition easier. The local people could contribute and invest their own money in the new and renewable energy sector for example SPP. Kalkbrenner and Roosen (2016) also reported that the social movement from citizen participation in energy transition played an important role in the local level energy transition (Kalkbrenner and Roosen 2016).

Furthermore, the government as the power-based regulation source should prepare for making better regulations to cultivate the willingness of people in Indonesia to reach the energy transition goal. Learning from another country such as the United States, the government could regulate several advantages which made private, or community sectors want to transform and invest in green energy infrastructure. One of the examples is giving a tax-free or tax deduction for people who contribute to the development of green energy systems. To be specific in the

private sector, the government could give a regulation for the green company to sell their green electricity to the community which provides an additional value in the investment of SPP. The successful of cultivation green energy could reduce the responsibility of the government of Indonesia to invest a high number of monies in green infrastructure and on the other hand also reach the target of energy transition in 2050.

The government of the Republic of Indonesia also revised regulations related to the export-import subsidies from SPP. The Ministerial Regulation of the Minister of Energy and Mineral Resource No. 49 of 2018 which only covers 65% of total exported electricity was revised with the Ministerial Regulation of the Minister of Energy and Mineral Resources No. 26 of 2021. In the first release, Regulation No. 26 of 2021 would cover 100% of total exported electricity which in the frame could stimulate the solar energy investment (EDSM, 2018). However, the new regulation of 26 of 2021 is still on hold and several regulations should be considered before fully implemented. One of the biggest concerns was the elimination planning of export of the electricity which could be the most stimulating movement of this new regulation (Dwi, 2023). The government planned that the owner of solar panels should use all the produced electricity on their own and not expect to sell the electricity to the government. This regulation was opposite to the main plan of the government to boost green energy investment and made the solar energy investment not economically feasible. The failure of regulation potentially failed to accelerate the willingness of people in Indonesia to contribute to installing the SPP. Thus, the target of 23% of green energy from renewable energy could be just a statement.

Setyawati (2020) have reported that approximately 71% of 987 PLN consumer have a high willingness to transform their electricity to SPP (Setyawati, 2020) but with better regulation, especially in the electrical export rate and an easy protocol installation. Based on the regulation of 26 of 2021, there are lots of steps and administrations that should be made before starting the installation of solar panels in the house. It could be said that the installation of solar energy was a complicated and highly costly investment. Therefore, the government needed to redesign the better regulation especially to support the green energy investment to stimulate the energy transition in the community. Good regulation should make the government reach the goal easier compared to achieving it by themselves.

Conclusion

Renewable energy has shown a promising development in Indonesia where the trend moved to a higher electrical production annually. Solar power plant (SPP) was aimed as the main core of electrical generation based on RUEN in 2025. The better electrical export rate could be a starting point to show that the green energy sector is profitable for everyone. However, better regulation and clear protocol should be made to stimulate the willingness of consumers to

participate in the renewable energy transformation in Indonesia. Regulations for tax reductions and electricity export-import subsidies to spur the growth and development of renewable energy in Indonesia must be established by the Indonesian Government to accelerate investment and the energy transition.

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Author Contributions

I.K.: Conceptualization, Supervision, Project Administration, R.I.; Writing – Editing, Data Analysis, Validation, R.F.; Editing, Language Improvement, A.H.; Conceptualization, Supervision, Writing original draft, Data Visualization. All authors have read and agreed to the published version of the manuscript.

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