ENJUST
Energy Justice
ENJUST 2(1): 46–63
ISSN 3047-9851

Institute for Advanced Science, Social and Sustainable Future
MORALITY BEFORE KNOWLEDGE

Energy landscape: Petroleum utilization prospects amid global energy transition dynamics

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Received Date: January 21, 2025 Revised Date: February 27, 2025 Accepted Date: February 28, 2025

ABSTRACT

Background: Petroleum has played a critical role in supporting industrialization and global economic growth since the Industrial Revolution. It has not only been the foundation of many economies, particularly transportation and industry, but it remains so today. However, the environmental impacts of petroleum use have become a global concern, prompting a shift to renewable energy. **Methods:** This study uses a qualitative approach with literature review and descriptive analysis to examine the prospects for petroleum use in Indonesia in the energy transition. Data were obtained from academic journals, government reports, and environmental studies to illuminate patterns of petroleum use, renewable energy developments, and their impacts on energy security and future policies. **Findings:** Indonesia has large potential for renewable energy sources such as hydropower, geothermal energy, and bioenergy, but their utilization is still minimal. Around 90% of this renewable energy potential has not been utilized. For example, hydropower, geothermal energy, and bioenergy which are environmentally friendly and capable of producing significant energy have not been fully developed. The biggest challenge in the transition to renewable energy lies in changing public perception, as many people still rely on fossil fuels. In addition, the Indonesian government faces the task of building infrastructure that is evenly distributed throughout the country. **Conclusion:** A proactive and gradual approach is needed to engage the public in renewable energy development and to raise awareness of its long-term benefits. Reducing dependence on petroleum requires strong policies, investment in renewable infrastructure, and public participation in the energy transition process. **Novelty/Originality of this article:** Unlike previous studies that have focused primarily on energy security and policy frameworks, this study emphasizes the importance of public perception and infrastructure readiness in supporting a successful transition from fossil fuels to renewable energy.

KEYWORDS: challenges; energy transition; environmental; petroleum.

1. Introduction

Anthropogenic petroleum uses started during the second phase of the Industrial Revolution and traffic fleets. The International Energy Agency (IEA) states that petroleum consumption reached around 100 million barrels per day in 2023 and projects a flat increase until 2050, as shown in Figure 1 (IEA, 2023). This implies that the dependency on petroleum to satisfy the world demand for energy still is magnifying. According to Matsuo et al. (2013), oil consumption in Asia is projected to increase sharply, it was from 24.1 million barrels per day (Mb/d) in 2010 to be estimated at about 40.7 Mb/d in 2035, as shown in Figure 2. This growth accounts for about 60% of the increase in global oil demand, making Asia a key player in determining the future direction of global energy. China is expected to lead this surge, accounting for almost half of the regional growth, while India

Cite This Article:
Saputra, R. (2025). Energy landscape: Petroleum utilization prospects amid global energy transition dynamics. *Energy Justice, 2*(1), 46-63. https://doi.org/10.61511/enjust.v2i1.2025.1748

will contribute about 30%. By 2035, Asia's share of global oil consumption will increase from 31% to 40%, asserting its dominance in the world's energy landscape. The main driver of this increase is the transportation sector, driven by rapid motorization.

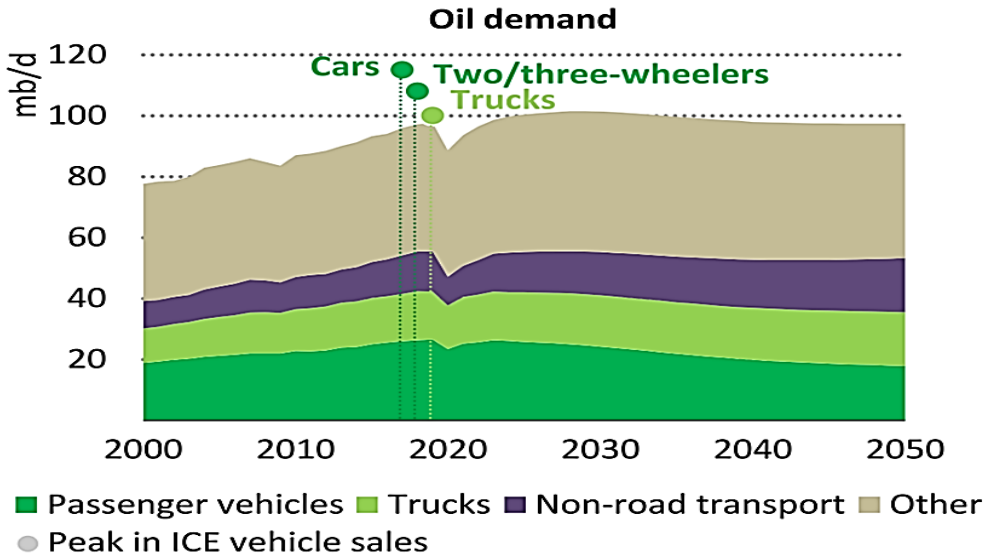


Fig. 1. Global oil demand by sector from 2020 to 2050
(IEA, 2023)

With the increase in petroleum demand in the last few decades around the globe, there has been a variety of adverse environmental ramifications causing it; this being an extended challenge still dealt with today. One of the main effects is a rise in air pollution through carbon dioxide levels due to burning fossil fuels. In addition to the effect on the global climate change rate (IPCC, 2022), this process has a severe impact on air quality leading to an effect on human health and disruption of the overall balance of the ecosystem with significant public concern (U.S. Environmental Protection Agency, 2021).

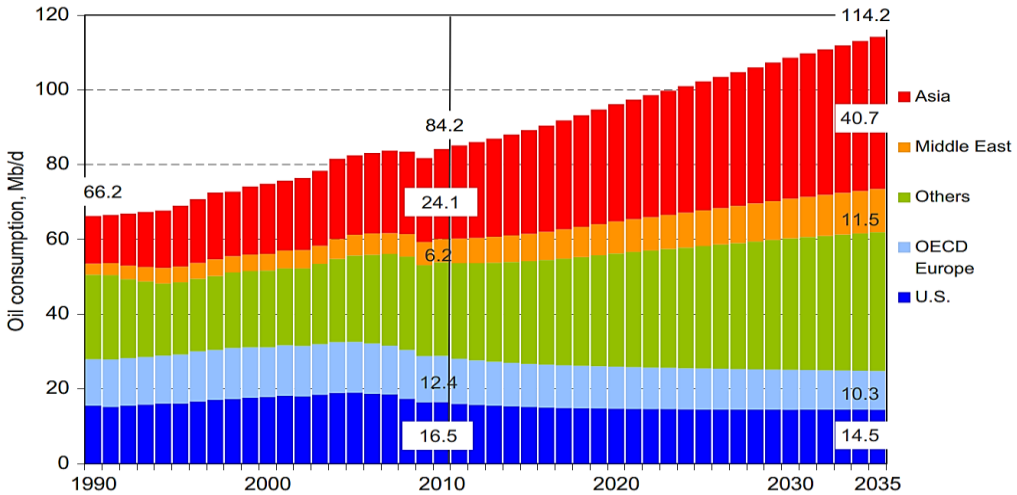


Fig. 2. Global petroleum consumption
(Matsuo et al., 2013)

Today the structure and interdependence of the world economy have changed significantly as countries shift from using petroleum to using alternative energy sources. The purpose of this shift is more so to attain sustainability and eliminate negative effects on the environment. In this regard, energy resources in the world need to be renewable if the climate change goals set by the Paris Agreement which seeks to limit the increase in global average temperature to rise by no more than 1.5 degrees Celsius above pre-industrial levels are to be achieved (IEA, 2021).

In Indonesia, petroleum is still the highest demand for national energy support to maintain economic growth stability. In the past, Indonesia was a part of big player in petroleum production in Southeast Asia dan was a member of the Organization of Petroleum Exporting Countries (OPEC) up to 2008. However, in the last few decades, oil production in Indonesia has continued to decline. Indonesia's oil production will only be in the range of 616 thousand barrels per day, far below the production in 1995 which reached more than one million barrels per day (MEMR, 2023). The decline in oil production is due to the depletion of reserves and the lack of investment in the exploration of new oil production fields. However, to meet national energy needs and maintain economic stability, Indonesia still relies on oil imports from other countries.

In addition to the problem of diminishing reserves, petroleum as a non-renewable energy source also faced various major challenges of significant negative environmental impacts, especially contributing to increased greenhouse gas emissions, accelerating climate change, as well as air, soil, and groundwater pollution that endangers ecosystems and human health (IPCC, 2022). The realization of the negative implications of petroleum use on environmental damage has prompted global policies to transition towards cleaner or renewable energy. Clean or renewable energy sources such as solar, water, wind, geothermal, and biomass offer a more sustainable and environmentally friendly solution (IRENA, 2018).

The Indonesian government has responded to this by formulating various new policies in the process of transitioning to renewable energy. This can be seen from the Indonesian government's target to create national energy needs in 2025 by implementing renewable energy at 23%, although in 2023 the realization of the renewable energy transition is still around 13.1% of the target of 17.9% (IESR, 2024). However, moving from the use of non-renewable energy to renewable energy still has many challenges, including low public participation and awareness of the benefits of using renewable energy for environmental health, lack of funding or investors, geopolitics influence, unstrict policy, and inadequate infrastructure to support the application of renewable energy, especially in remote areas far from urban areas. This is the major reason for Indonesia still relies on petroleum uses as a national energy source to maintain the country's economic cycle and stability.

This article aims to evaluate the prospects of petroleum use in Indonesia. In this context, it is necessary to explore and assess the long-term viability of petroleum energy utilization in Indonesia during the global transition to environmentally friendly energy as well as to examine community views and challenges, especially from social, economic, and environmental aspects. This study aims to answer these questions, evaluate the future position of petroleum uses, and investigate the possibility of transitioning to cleaner and more sustainable energy sources and their environmental impacts.

2. Methods

This research was conducted using a qualitative approach with a literature review method to examine the prospects for the use of petroleum in Indonesia in the future. This approach was chosen because it supports an in-depth study of the various perspectives from previous research and challenges faced by the community regarding the use of petroleum in the context of the transition to environmentally friendly energy. This research design also supports the exploration of social, economic, and environmental views that are relevant to the topic being studied.

Data collection in this study was carried out through secondary data sources. Several types of data sources used include academic journals, and agency reports that discuss the use of petroleum, and renewable energy, and the impacts of the use of these resources. In addition, government reports containing policies, statistics, and analyses related to the oil and gas industry in Indonesia and energy transition plans are also important sources. This study also uses environmental assessments, namely studies that identify the environmental impacts of petroleum use, including greenhouse gas emissions and other pollution. The use

of secondary data sources aims to obtain comprehensive and relevant information for more in-depth analysis.

Data analysis in this research was carried out using a descriptive analysis method. This method allows researchers to describe the current conditions and trends in petroleum use in Indonesia, as well as identify community views and challenges related to petroleum use and the potential for a transition to cleaner and more sustainable energy sources. Through this descriptive analysis, researchers are expected to be able to transmit the future position of petroleum utilization in the context of energy and insecticide policies and suggest mitigation measures to reduce the negative impacts of fossil fuel use, including mitigation of greenhouse effects resulting from vehicle exhaust emissions.

The following are research questions taken from the problems raised: how is the pattern and current condition of petroleum use in Indonesia to meet national energy needs? how is the development progress of renewable energy transition in Indonesia, including the challenges faced and public perceptions of the change to sustainable energy? what are the prospects for petroleum use in Indonesia in the context of the global transition to renewable energy, including its impact on national energy security and future energy policies?

Based on these research questions, it is expected to answer the problems raised, including evaluating the pattern and current condition of petroleum use in Indonesia to meet national energy needs, evaluating the development progress of renewable energy transition in Indonesia, including the challenges faced and public perceptions of the change to sustainable energy, and determining the prospects for petroleum utilization in Indonesia in the context of the global transition to renewable energy, including its impact on national energy security and future energy policies. To understand how the research works, Figure 3 shows the research conceptual framework to gain the above objectives.

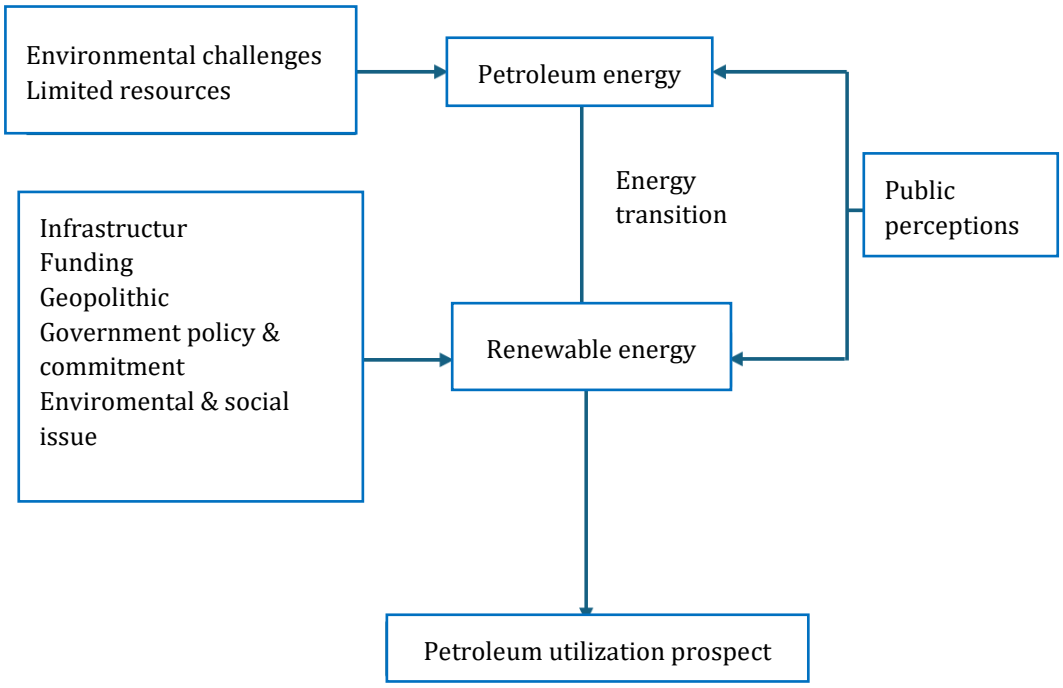


Fig. 3. Research conceptual framework

3. Results and Discussion

This section will discuss the conditions and patterns of petroleum use in Indonesia, and how petroleum still plays a role in meeting national energy needs. In addition, this section will explore Indonesia's journey in shifting to renewable energy, highlighting the progress that has been made and the challenges faced.

3.1 Pattern and current condition of petroleum uses in Indonesia

Indonesia's energy uses are still significantly dependent on non-renewable sources, known as fossil fuels such as petrol fuels and coal, which are still higher than renewable energy (Yana et al., 2022). Based on the energy consumption type, it was reported that petrol fuel was still highly used in 2014 (32%) and then followed by coal consumption with a share of about 23%. In addition, final energy consumption in Indonesia increased sharply due to rapid urbanization and industrialization activities (Deendarlianto et al., 2020). Indonesian energy balance for 2021 according to MEMR (2021) is shown in Table 1.

Table 1. Indonesian energy balance for 2021

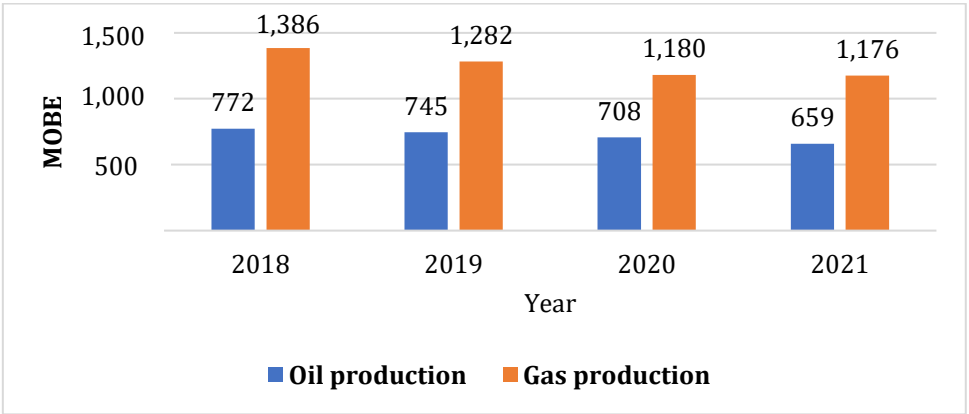
Fuel Type	Primary energy supply	Power plant	Final energy consumption (million BOE)			
			Industry	Transportation	Household	Others
Coal	558.782	470.962	87.820	0	0	0
Petroleum	133.009	17.512	25.776	388.157	2.675	10.788
Natural gas	324.608	83.804	88.841	0.066	0.308	0.701
Hydro	45.948	45.948	0	0	0	0
Geothermal	29.533	29.533	0	0	0	0
Solar energy	0.789	0.789	0	0	0	0
Wind energy	1.071	1.071	0	0	0	0
Biofuel	65.567	0	0	0	0	0
Biogases	0.180	0	0	0	0.180	0

(MEMR, 2021)

The transportation sector was the first rank in Indonesian petroleum consumption in 2021, its about 388.157 million BOE. After that, it's followed by industrial needs (25.776 million BOE) and others (10.788 million BOE). Households were not taking part much in petroleum uses (2.675 million BOE). The contribution of petroleum to the power plant sector or electricity generation sector was not much coal, which was still the largest contributor to electricity generation with a total of 470.962 million BOE. Once compared to renewable energy in terms of electricity generation, it was reported 114.762 million BOE, far less than fossil energy. The main contributor of renewable energy is hydro (45.948 million BOE) followed by Geothermal (29.533 million BOE). According to that, this indicates that the use of fossil energy in Indonesia is still very strong, especially coal and petrol fuels.

Looking at the high level of petroleum energy demand in Indonesia, especially in the transportation sector and petroleum is non-renewable energy and its reserves in nature are also limited, it gives a new challenge for Indonesia to provide the availability of energy for economic stability. Figure 4a shows how the decline in oil and gas production in Indonesia from 2018 to 2021 including the estimated oil and gas reserves from 2020 to 2022 as displayed in figure 4b. Another reason why the global transition to renewable energy is being campaigned for is considering its limited availability and its disproportionate relationship with global energy demand.

a)



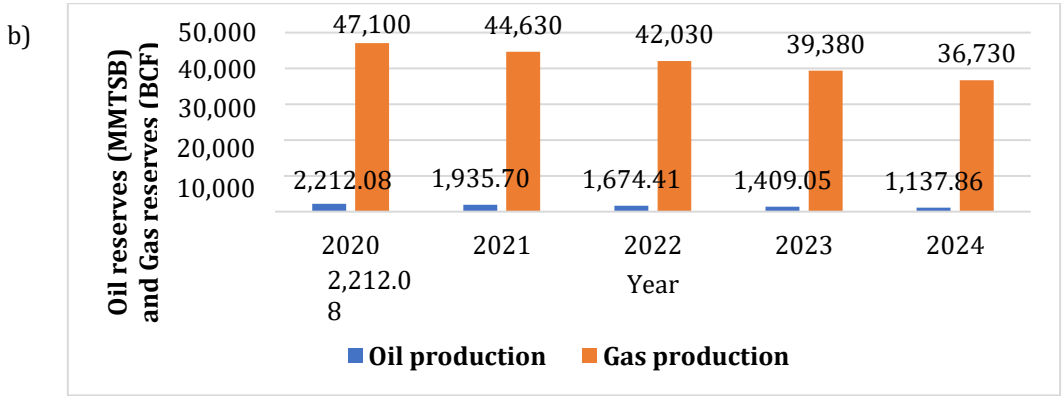


Fig. 4. a) oil and gas production from 2018 to 2021; b) Estimate of oil and gas reserves in Indonesia from 2020 to 2024
(MEMR, 2021)

Considering its limited reserves in the subsurface, oil production in Indonesia showed a decline from year to year. In 2018, it was reported that oil production was about 772 million BOE, then decreased to 659 million BOE in 2021, which is a decrease of around 14.6% from 2018. The availability of oil reserves in Indonesia is also predicted to continue to decline until 2024, with total reserves of around 1137.86 MMSTB, or a decrease of around 48.56% from 2020. Oil and gas reserves are estimated to be available for up to 9.5 years from 2024 with the assumption that there are no discoveries, and the level of oil production was approximately 700,000 barrels of oil per day (BOPD) (Pambudi et al., 2023). The main challenge facing the energy sector in Indonesia is the issue of sustainability.

As Indonesia's oil consumption has now exceeded domestic oil production and oil reserves continue to decline, the increase in oil demand will become a greater burden on the economy due to increased oil imports (Deendarlianto et al., 2020). This is due to the continued increase in rapid motorization in the transportation sector, which was most affected by transportation fuel rather than economic growth (Atty et al., 2013). Figure 5 depicts Indonesia's oil balance from 1971 to 2013 and how Indonesia struggled against declining oil reserves over the years to meet domestic supply. Oil imports in Indonesia began to show a significant increase in 1986 and continued to experience an upward trend until 2013. This oil import activity is predicted to continue to increase up to 2024 considering that petroleum usage is still massive in Indonesia and oil production levels are decreasing (Pambudi et al., 2023). This indicates that Indonesia is still heavily dependent on the use of petroleum fuels. Campaigns on the health and environmental impacts of petrol use in Indonesia are also not massive, so this is also a factor in the lack of public awareness. Ho et al. (2022) said that public discussions rarely address the significant dangers of burning fossil fuels to human health, despite the evidence of global mortality. This is in contrast to the prominence given to the impact of nuclear energy risks, which is often shaped by famous historical events.

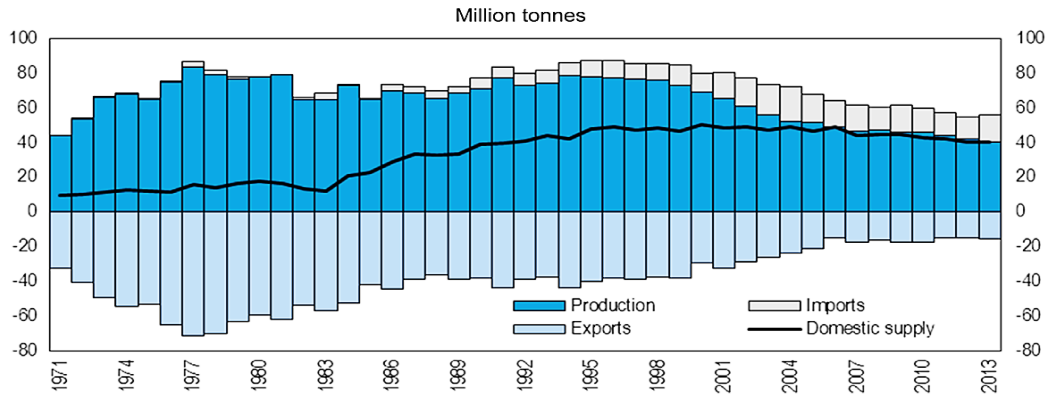


Fig. 5. Indonesia's oil balance from 1971 to 2013

Research has shown that petroleum usage has a significant negative environmental impact, especially in the transportation and energy sectors, which worsens air quality and public health. Emissions from motor vehicles in large cities, which mostly use petroleum fuels, contribute significantly to the deterioration of air quality, impacting both human health and the broader ecosystem (Akomolafe et al., 2024). These emissions include particulates (PM2.5 and PM10), carbon monoxide (CO), nitrogen oxides (NO_x), and volatile organic compounds (VOC), which are directly related to the increasing number of respiratory diseases, such as asthma, bronchitis, and chronic obstructive pulmonary disease (COPD) with long term health consequences (Akomolafe et al., 2024). Based on Sugiyono (2002), also explained the impacts of emissions on human health and the environment as presented in Table 2.

Table 2. The effect of particle emissions on health and the environment

Air emission	Health impacts	Environment impacts
SO_2	Respiratory issue; Chronic pneumonia	Acid rain can damage the environment of lakes, rivers, and forests; Disturbs visibility
NO_x	Pain in the respiratory tract	Acid rain; Ozone depletion causing forest destruction
Particle/Dust	Irritation of the eyes and throat; Bronchitis and respiratory tract damage	Disturbs visibility
CO_2	No direct effect	Global warming; Ecosystem degradation

(Sugiyono, 2002)

In addition to health, emissions in the air also have an impact on climate change, as mentioned in Table 2 where it has an impact on ozone depletion and global warming caused by CO_2. The energy sector contributed 74% to greenhouse gas (GHG) emissions, as petroleum is the one of main contributors generating 35% of CO2 emissions, despite providing only 32% of the global energy supply (Wardhana & Marifatullah, 2020). In Indonesia, it was dominated by transportation uses, as the top three contributors to energy sector emissions, about 27% of Indonesia's total GHG emissions (IESR, 2022). Therefore, decarbonization of the transportation use sector is a crucial aspect for Indonesia to meet the net zero emissions goal in 2050. IESR (2022) developed a strategy called IESR's pathway, which outlines that GHG emissions in Indonesia should be reduced by 3 million tonnes of CO_2-eq each year until 2030 and by 7 million tonnes of CO_2-eq from 2030 to 2050. In contrast, the Long-Term Scenario for the Low Carbon Scenario Compatible with the Paris Agreement (LTC LCCP) projects that GHG emissions from the transport sector will be reduced by 20 million tonnes of CO_2 equivalent (CO_2-eq) by 2050. The comparison of IESR's pathway and LTC LCCP is presented in Figure 6. Achieving these targets presents significant challenges for Indonesia, especially given the current low rate of energy transition to renewables, which needs to be accelerated under the IESR pathway.

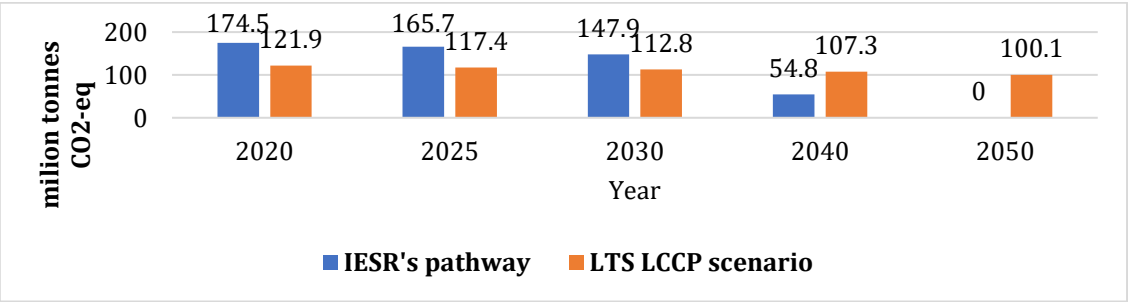


Fig. 6. Decarbonization ambitious projections for indonesia transport sector ghg emission (IESR, 2022)

3.2 Development progress of renewable energy transition

The global energy transition towards renewable energy is encouraging Indonesia to start abandoning non-renewable energy, especially petroleum energy by formulating various new policies in the process of transitioning to renewable energy. Geologically and geographically, Indonesia has great potential in developing renewable energy including solar (207 GW), wind (60.6 GW), hydro-energy (75 GW), micro-hydro (19.3 GW), bioenergy (32.6 GW), and geothermal energy (32.6 GW) (DEN, 2021). However, the utilization of this capacity is still far from optimal due to various challenges, such as limited funding, policies that do not fully support it, inadequate infrastructure, and the influence of geopolitical factors (Resosudarmo et al., 2023). According to Pambudi et al. (2023), the following are the selected few renewable energy potentials in Indonesia such as hydro, geothermal, and bioenergy.

3.2.1 Solar energy

Solar energy has emerged as one of the most promising renewable energy sources in Indonesia. According to Pambudi et al. (2023), the potential capacity of solar energy in Indonesia is 207,898 MW with an average solar irradiation of 4.80 kWh/m^2/day as presented in Table 3. The use of solar energy in Indonesia continues to progress, both on and off the electricity grid, contributing to the country's energy supply. As of the fourth quarter of 2021, the total installed solar energy capacity reached 201.1 MW (Figure 7), which is a significant achievement.

Table 3. The potential of solar energy in 34 provinces in Indonesia

No.	Province	Area (km^2)	Technical potential (MW)
1	Aceh	57,956.00	7881
2	Bali	5780.06	1254
3	Bangka-Belitung	16,424.06	2810
4	Banten	9662.92	2461
5	Bengkulu	19,919.33	3475
6	D.I. Yogyakarta	3133.15	996
7	DKI Jakarta	664.01	225
8	Gorontalo	11,257.07	1218
9	Jambi	50,058.16	8847
10	West Java	35,377.76	9099
11	Central Java	32,800.76	8753
12	East Java	47,803.49	10,335
13	West Kalimantan	147,307.00	20,113
14	South Kalimantan	38,744.23	6031
15	Central Kalimantan	153,564.50	8459
16	East Kalimantan	129,066.64	13,479
17	North Kalimantan	75,467.70	4643
18	Riau Islands	8201.72	753
19	Lampung	34,623.80	7763
20	Maluku	46,914.03	2238
21	North Maluku	31,982.50	2020
22	West Nusa Tenggara	18,572.32	3036
23	East Nusa Tenggara	48,718.10	9931
24	Papua	319,036.05	7272
25	West Papua	102,955.15	2035
26	Riau	87,023.66	6307
27	West Sulawesi	16,787.18	1677
28	South Sulawesi	46,717.48	7588
29	Central Sulawesi	61,841.29	6186
30	Southeast Sulawesi	38,067.70	3917
31	North Sulawesi	13,892.47	2113
32	West Sumatera	42,012.89	5898

33	South Sumatera	91,592.43	17,233
34	North Sumatera	72,981.23	11,851
	Total		207,898 MW

(Directorate General of EBTKE, 2020)

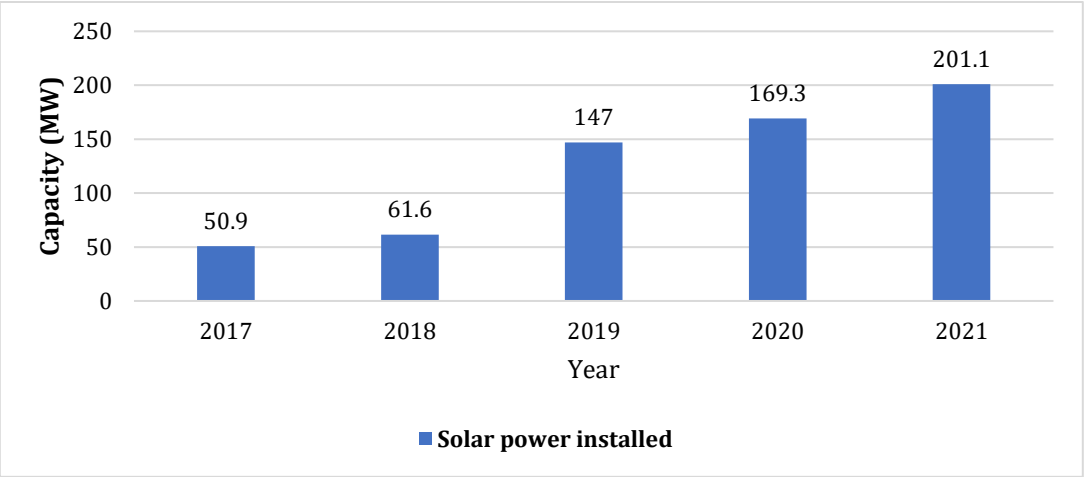


Fig. 7. Solar power plant installed until the fourth quarter of 2021
(MEMR, 2021)

3.2.2 Wind energy

Wind energy in Indonesia also shows great potential with a total capacity is about 60,6 GW (Table 4), especially in eastern regions, which have average wind speeds above 6 m/s, sufficient to support high-efficiency wind power plants (Ismail et al., 2020). According to Pambudi et al. (2023), Indonesia is targeted to achieve 7 GW of wind energy by 2030, up from 4.8 GW in 2023. As of the fourth quarter of 2021, Indonesia had an installed wind capacity of 154.3 MW, and the target for 2025 is to reach 255 MW. The main wind power plants in the country include the Sidrap and Tolo power plants. The Sidrap Wind Power Plant, located in Sidenreng Rappang, South Sulawesi, operates with 30 wind turbines, generating 75 MW. The Tolo Wind Power Plant, also in South Sulawesi, has 20 wind turbines with a total capacity of 72 MW, each turbine generating 3.6 MW. These developments reflect the country's ongoing efforts to diversify its renewable energy sources and make progress towards achieving its long-term energy goals.

Table 4. The potential of wind energy in 34 provinces in Indonesia

No.	Province	Area (km^2)	Technical potential (MW)
1	East Nusa Tenggara	48,718.10	10,188
2	East Java	47,803.49	7907
3	West Java	35,377.76	7036
4	Central Java	32,800.76	5213
5	South Sulawesi	46,717.48	4193
6	Maluku	46,914.03	3188
7	West Nusa Tenggara	18,572.32	2605
8	Bangka Belitung	16,424.06	1787
9	Banten	9662.92	1753
10	Bengkulu	19,919.33	1513
11	Southeast Sulawesi	38,067.70	1414
12	Papua	319,036.05	1411
13	North Sulawesi	13,892.47	1214
14	Lampung	34,623.80	1137
15	D.I. Yogyakarta	3133.15	1079
16	Bali	5780.06	1019
17	South Kalimantan	38,744.23	1006
18	Riau Islands	8201.72	922

19	Central Sulawesi	61,841.29	908
20	Aceh	57,956.00	894
21	Central Kalimantan	153,564.50	681
22	West Kalimantan	147,307.00	554
23	West Sulawesi	16,787.18	514
24	North Maluku	31,982.50	504
25	West Papua	102,955.15	437
26	West Sumatera	42,012.89	428
27	North Sumatera	72,981.23	356
28	South Sumatera	91,592.43	301
29	East Kalimantan	129,066.64	212
30	Gorontalo	11,257.07	137
31	North Kalimantan	75,467.70	73
32	Jambi	50,058.16	37
33	Riau	87,023.66	22
34	DKI Jakarta	664.01	4
	Total		60,647 MW

(IEA, 2017)

3.2.3 Hydro energy

Almost all provinces in Indonesia have hydro-energy potential supported by complex hydrological and geological systems. Table 5 shows the distribution of potential for hydro energy in Indonesia in provincial regions. This potential consists of hydro of 75,000 Mega Watt (MW) and a micro-hydro of 19,370 MW.

Table 5. The potential of hydro energy in Indonesia by 2021

No.	Island	Hydro (GW)	Micro-hydro (GW)
1	Sumatra	15.6	5.73
2	Java	4.2	2.91
3	Kalimantan	21.6	8.1
4	Sulawesi	10.2	1.67
5	Bali and Nusa Tenggara	0.62	0.14
6	Maluku	0.43	0.21
7	Papua	22.35	0.62
	Total	75.00	19.37

(DEN, 2021)

However, based on figure 8, indicates that newly utilized hydro-energy was 6601.80 MW by the fourth quarter of 2021, which was summed from 5,638.7 MW, micro-hydro of 126.4 MW, and mini-hydro of 375.5 MW or approximately 6.5% of the potential of the hydropower plant in Indonesia (MEMR, 2021). This shows that the energy potential from hydropower still has great potential for Indonesia.

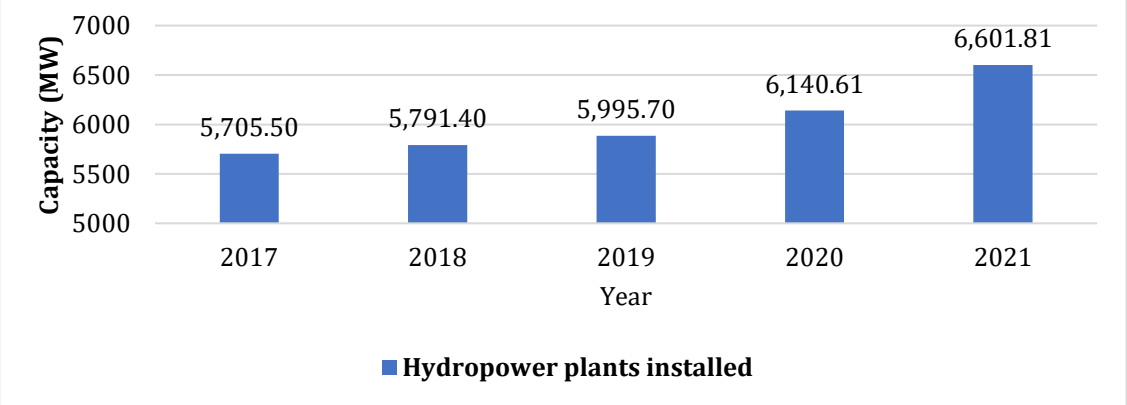


Fig. 8. The installed capacity of hydropower plants as of the fourth quarter of 2021 (MEMR, 2021)

3.2.4 Bioenergy

In addition to electricity generation, bioenergy can be used for transportation, industry, and household sectors (Al Hakim, 2020). Materials such as manure, agricultural waste, plantation waste, and municipal waste are easily found and can be converted into energy (Pambudi et al., 2023). For example, biomass can be used to generate electricity and heat. Agricultural and plantation waste can be converted into biofuel or biogas.

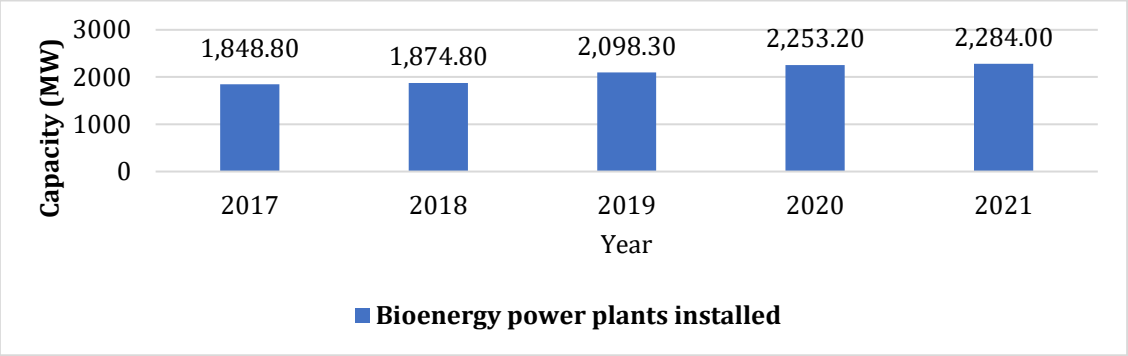


Fig. 9. The installed capacity of bioenergy power plants as of the fourth quarter of 2021 (MEMR, 2021)

Household and municipal waste can be processed in biogas plants to produce methane, which can be used for cooking, heating, or generating electricity. Bioenergy stoves can burn these materials to generate heat. By using these materials, we reduce waste and help create cleaner, more sustainable energy. Table 6 shows the potential of bioenergy in Indonesia. It showed that the total potential capacity of bioenergy in Indonesia is 32,653.8 MW for 2021, while the installed capacity was still at 2284 MW as displayed in Figure 9, or it can be concluded that about 93% of the bioenergy potential is undeveloped in Indonesia.

Table 6. The potential of bioenergy in Indonesia by 2021

No.	Province	Area (km^2)	Technical potential (MW)
1	Riau	87,023.66	4195.1
2	East Java	47,803.49	3420.9
3	North Sumatra	72,981.23	2911.6
4	West Java	35,377.76	2554.1
5	Central Java	32,800.76	2232.5
6	South Sumatra	91,592.43	2132.6
7	Jambi	50,058.16	1839.9
8	Central Kalimantan	153,564.50	1498.9
9	Lampung	34,623.80	1492.1
10	West Kalimantan	147,307.00	1308.2
11	South Kalimantan	38,744.23	1289.9
12	Aceh	57,956.00	1174.3
13	East/North Kalimantan	129,066.64	964.3
14	South Sulawesi	46,717.48	959.4
15	West Sumatra	42,012.89	957.8
16	Bengkulu	19,919.33	644.8
17	Banten	9662.92	465.1
18	West Nusa Tenggara	18,572.32	394.1
19	Lampung	34,623.80	7763
20	Central Sulawesi	61,841.29	326.9
21	East Nusa Tenggara	48,718.10	240.5
22	D.I. Yogyakarta	3133.15	224.2
23	Bangka Belitung	16,424.06	223.1
24	West Sulawesi	16,787.18	205.9
25	Bali	5780.06	191.6
26	North Sulawesi	13,892.47	164.0

27	Southeast Sulawesi	38,067.70	1677
28	Gorontalo	11,257.07	130.6
29	Jakarta	664.01	126.6
30	Papua	319,036.05	96.5
31	West Papua	102,955.15	54.9
32	North Maluku	31,982.50	34.5
33	Maluku	46,914.03	32.6
34	Riau Islands	8201.72	15.9
	Total		32,653.8 MW

(MEMR, 2021)

3.2.5 Geothermal

Geothermal energy began to be developed around a century ago, starting with the drilling of the first geothermal well in Kamojang by the Dutch colonial government in 1926. Furthermore, the use of this energy developed until it operated commercially in 1983 (Sumardi et al., 2022). The distribution of potential geothermal energy in n is presented in Table 7. It showed that the total potential capacity of geothermal energy in Indonesia is 23,766 MW for 2021, while the installed capacity was still at 2286.1 MW as displayed in Figure 10, or it can be concluded that about 90,38% of geothermal potential areas in Indonesia are not utilized and developed.

Table 7. The potential of geothermal energy in Indonesia by 2021

No.	Location	Potency (MW)
1	Sumatra	9517
2	Java	8050
3	Bali	335
4	Nusa Tenggara	1399
5	Kalimantan	175
6	Sulawesi	3071
7	Maluku	1144
8	Papua	75
	Total	23,766

(MEMR, 2021)

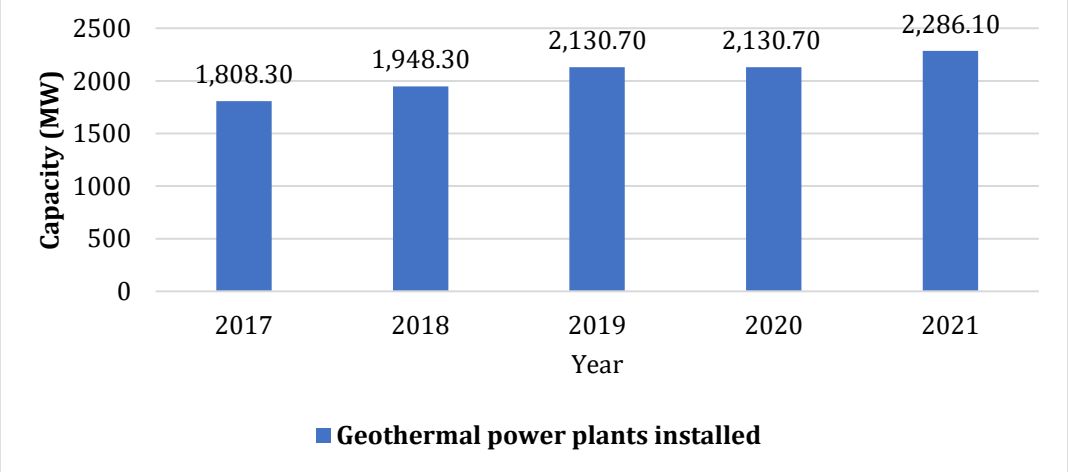


Fig 10. The installed capacity of geothermal power plants as of the fourth quarter of 2021 (MEMR, 2021)

3.3 Energy transition status in Indonesia

Indonesia has a lot of potential for renewable energy such as hydropower, geothermal, and bioenergy, but its utilization is still very minimal. Around 90% of this renewable energy potential has not been utilized optimally. For example, hydropower which can produce a lot

of energy, as well as geothermal, hydro-energy, and bioenergy which are environmentally friendly, have not been fully developed.

Based on the comparison of four selected countries in Asia as shown in Figure 11, it is clear that Indonesia faces a major challenge in carrying out the clean energy transition. Although there are efforts to switch to renewable energy sources, this process tends to be very slow compared to other countries such as China, Vietnam, and India (Resosudarmo et al., 2023)

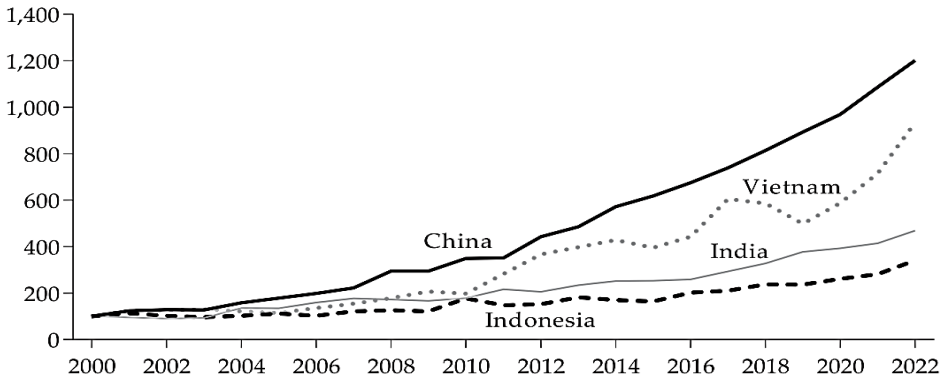


Fig. 11. Rate of energy transition (indexed) in Selected Asian Countries (EMBER cited by Resosudarmo et al.,2023)

Burke et al. (2019) explained three main reasons the renewable energy transition in Indonesia was making slow progress: (1) First, the fossil fuel-based energy sector plays a very large role in the Indonesian economy recently, especially from energy coal-based and petroleum. Fossil mining activities have become one of the main sources of income for the country, so dependence on fossil fuels remains high. This condition ultimately becomes an obstacle to the wider application of renewable energy in Indonesia. (2) Second, persistent resistance from the utility sector has made it difficult for private companies to implement renewable power generation. In Indonesia, the electricity sector is largely controlled by the State Electricity Company, PLN. Over the past decade, PLN has focused on expanding the country's electricity supply, driven by optimistic economic growth projections. This has led to the construction of coal-fired power plants and the signing of power purchase contracts with private companies operating coal-fired power plants. The high electricity demand projection, coupled with the government's policy in Presidential Decree 5/2006 to increase the proportion of coal in the national energy mix from 26% in 2008 to 33% in 2025 has spurred the development of coal-fired power plants over the past decade (Resosudarmo et al., 2012). (3) Third, energy subsidies, both for liquid fuels and electricity, have been a long-standing policy in Indonesia. The government has regulated liquid fuels and electricity prices, which makes energy subsidies volatile. In 2022, total energy subsidies reached around IDR 134 trillion ($9 billion), or around 7% of the government budget, or equivalent to 0.7% of the national Gross Domestic Product (GDP). Subsidies also have unintended consequences, including higher demand, traffic congestion, and environmental damage, with deadweight losses estimated at USD 4–8 billion per year (Davis, 2014). To provide a clearer picture of the magnitude of energy subsidies, in May 2023, the price of 92 octane gasoline (Pertamax type) in Indonesia was recorded at IDR 13,300 per liter. For comparison, the price of 91 octane gasoline in Melbourne, Australia, and 92 octane gasoline in Singapore reached A$1.7 (IDR 17,000) and S$2.67 (IDR 26,700) per liter, respectively. With relatively cheap fuel prices domestically, Indonesians tend to be less motivated to use fossil fuels more efficiently or switch to renewable energy sources. This is why it comes as no surprise that Indonesians have predominantly relied on fossil fuels as their primary energy source in recent years.

On the other hand, to comply with the global energy transition decision, the Indonesian government has set an ambitious target through the National Energy Policy, namely to achieve the use of renewable energy of 23% in the energy mix by 2025. However, this does

not appear massive, major challenges remain, such as an investment structure that is not yet attractive to investors, the dominance of fossil fuel use, and the slow adoption of new technologies (Dutu, 2016). One of Indonesia's biggest challenges is the distribution of adequate infrastructure to support this energy transition, as is known Indonesia's geographical conditions consisting of thousands of islands also complicate the development of energy infrastructure, especially in remote areas (Sumarsono et al., 2018).

Geopolitical factors also become significant obstacles. The world's dependence on the supply chain of renewable energy technology, such as solar panels and wind turbines, is a challenge for Indonesia, especially because of the dominance of production by certain countries such as China. Diplomatic tensions or fluctuations in international relations can have an impact on the cost and availability of these components (Maulidia et al., 2019). In addition, global competition in accessing financing for renewable energy projects is also getting tighter, especially amidst the debate between developed and developing countries regarding funding for the energy transition (Resosudarmo et al., 2023).

However, Indonesia has a strategic advantage as the world's largest producer of nickel, which is the main ingredient in battery production for renewable energy technology. This potential can be utilized to improve Indonesia's bargaining position in geopolitical negotiations regarding clean energy investment. However, a careful diplomatic strategy is needed so that the benefits of this sector have a positive impact on national development (Raihan, 2023). To encourage private sector investment, stable and simple regulations are key. A clear policy environment will help reduce risks for investors while accelerating renewable energy development (Maulidia et al., 2019). In addition, special attention needs to be paid to the social and economic impacts of this energy transition, such as ensuring affordable energy access for the wider community and creating new jobs in the green energy sector (Udin, 2020).

4. Conclusions

The pattern of petroleum use in Indonesia shows a worrying trend, with increasing dependence on oil imports every year. However, Indonesia still relies on petroleum as its main energy source, even though the country has enormous renewable energy potential, such as water, geothermal, solar, wind, and biomass. This potential has not been optimally utilized, although proper management can reduce dependence on fossil fuels, reduce environmental impacts, and strengthen national energy security.

However, the biggest challenge in this energy transition is changing the perspective of people who still depend on fossil fuels and how the Indonesian government can build infrastructure that is evenly distributed throughout Indonesia. Therefore, a proactive and gradual approach is needed to involve the community in the development of renewable energy, as well as to socialize its long-term benefits. In addition, to achieve the net zero emissions target, the gradual cessation of coal use is also an important step. If these steps are taken with supportive policies, Indonesia can make maximum use of renewable energy, reduce dependence on energy imports, and ensure the sustainability of more environmentally friendly energy in the future.

Acknowledgement

I would also like to express my gratitude to Safira Putri Nabilla as the reviewer, who has provided constructive input to improve the quality of this work. In addition, I would also like to thank my friends from the School of Environmental Sciences, Universitas Indonesia, for their encouragement and assistance. Any shortcomings in this paper are entirely my responsibility.

Author Contribution

Robby Saputra contributed to conceptualization, methodology, formal analysis, investigation, resources, data curation, original draft preparation, visualization, and project administration.

Funding
This research received no external funding.

Ethical Review Board Statement
Not available.

Informed Consent Statement
Not available.

Data Availability Statement
Not available.

Conflicts of Interest
The author declares no conflict of interest.

Open Access

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