



The energy mix dilemma in Indonesia in achieving net zero emissions by 2060

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ABSTRACT

Background: The global responsibility to reduce greenhouse gas emissions forces Indonesia to evaluate its energy policies and strategies. The energy mix dilemma in Indonesia arises as a consequence of rapid economic growth, rapid urbanization, and the continuously increasing energy demand. By 2060, Indonesia aims to have an energy mix dominated by renewable energy sources (RES) and to reduce its dependence on fossil fuels. The importance of reducing greenhouse gas emissions is becoming increasingly apparent, considering Indonesia is one of the countries highly vulnerable to climate change. **Method:** This study employs a combined approach of policy analysis and literature review. The method used in this research is an objective narrative literature review as a reference for conducting the literature study. **Findings:** In 2023, Indonesia is still heavily reliant on fossil fuels, primarily coal, oil, and natural gas. The Indonesian government has enacted several regulations related to energy use, including policies for the development of renewable energy. Despite efforts to reduce emissions through the application of clean technologies, the main challenge is significantly replacing fossil energy sources with renewable energy. Several inhibiting factors emerge as real challenges in the journey to achieve Net Zero Emissions. Technological and infrastructure constraints are the main obstacles. The strategic importance of sustainable economic growth is a central point in this dilemma. However, the transition to net zero emissions often requires structural adjustments that can impact the economy. **Conclusion:** The process of transitioning to renewable energy must be carefully implemented to avoid the risk of supply instability. The alignment between economic growth, energy security, and emission reduction is key to designing effective and sustainable policies. **Novelty/Originality of this Study:** This study provides a comprehensive examination of Indonesia's energy mix dilemma in the context of achieving net zero emissions by 2060, specifically highlighting the intricate balance between sustainable economic growth, energy security, and global climate commitments. By adopting a holistic approach that involves the government, private sector, and societal participation, the research offers innovative policy recommendations for transitioning from non-renewable to renewable energy sources while addressing socio-economic challenges.

KEYWORDS: energy mix dilemma; renewable energy sources (RES); net zero emissions.

1. Introduction

Indonesia faces a complex challenge in managing its energy mix to achieve the net zero emissions target by 2060. The energy mix dilemma in Indonesia arises as a consequence of rapid economic growth, rapid urbanization, and the continuously increasing energy demand. Rapid economic growth in Indonesia has been a driving force behind the increase in energy demand (National Energy Council, 2020). The growing energy demand, in line with rapid urbanization and industrialization, has led to increased energy usage across various sectors, including transportation, industry, and the domestic sector (Ministry of Energy and Mineral Resources, 2022). Therefore, managing the growing energy demand

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while remaining committed to the net zero emissions goal is a primary dilemma for Indonesia.

In 2022, Indonesia's energy consumption amounted to 1.18 billion barrels of oil equivalent (BOE), a 28.31% increase compared to the previous year's 924.19 million BOE (Ministry of Energy and Mineral Resources, 2022). By type, oil fuel consumption was the largest in Indonesia, at 477.82 million BOE, while electricity and coal consumption were 299.19 million BOE and 183.41 million BOE, respectively, as shown in Figure 1. Based on Indonesia's total population in 2022 of 275.77 million people, each person consumed energy equivalent to 4,300 barrels (BOE), all of which came from non-renewable energy sources. As a result, the trend of increasing population will undoubtedly require more energy, and if this trend continues with non-renewable energy consumption, it will negatively impact the environment. This issue not only affects the environment but also depletes Indonesia's natural resources, potentially leading to economic instability.

Meanwhile, the global responsibility to reduce greenhouse gas emissions forces Indonesia to evaluate its energy policies and strategies (Raharjo et al., 2022). Countries around the world are increasingly recognizing the need to actively contribute to global efforts to combat climate change. Therefore, Indonesia must design energy policies that not only meet domestic needs but also align with global commitments to achieve net zero emissions. Addressing this energy mix dilemma requires a holistic approach involving the government, private sector, and society (Rădulescu et al., 2022). The government needs to formulate policies that support the development of renewable energy sources, stimulate innovation in energy efficiency, and create incentives for transitioning to clean energy (Zahira & Fadillah, 2022). On the other hand, the private sector can play a key role in investing in and developing new environmentally friendly technologies.

Indonesia plays a crucial role in the global commitment to combat climate change, as manifested in its determination to achieve Net Zero Emission (NZE) by 2060 or even sooner. The main focus in achieving this commitment lies in the energy sector, as this sector is the main driver of carbon emissions in Indonesia (IESR, 2023). Currently, energy use in the country is still dominated by non-renewable resources, particularly oil and coal, which have negative environmental impacts (Setyono & Kiono, 2021). One of the most significant steps in reaching the NZE 2060 target is reducing dependence on non-renewable energy. This transformation can be achieved through an energy mix that includes diversifying energy resources (Muller and Teixido, 2021; Boedoyo, 2015). By integrating renewable resources, such as solar, wind, and biomass, Indonesia can gradually replace unsustainable energy consumption patterns with environmentally friendly resources (Vidal-Amaro, 2015). This process will result in a periodic transition from consumption patterns dependent on oil and coal to renewable energy, supporting the NZE 2060 agenda (Dallenes et al., 2023).

Net zero emissions refer to a state where the amount of greenhouse gases released into the atmosphere equals the amount that can be absorbed or removed from the atmosphere. The main goal of this concept is to achieve a balance between emissions produced by various human activities and the planet's ability to absorb or eliminate these emissions. The greatest effort to achieve the NZE goal comes from the energy sector, where the energy used and consumed transforms from non-renewable to new renewable energy. Achieving this target requires regular efforts to ensure the goal is realized. The NZE target set by the Indonesian government is by 2060, so efforts to transition energy sources through the energy mix are ongoing from now until 2060. Therefore, optimizing the potential of new renewable energy possessed by the country in this energy mix process is crucial to achieving NZE 2060.

Optimizing energy efficiency, introducing new technologies, and utilizing clean energy such as Renewable Energy Sources (RES) are key supporting steps (Sinaga et al., 2021). Enhancing infrastructure to support the use of electric vehicles, implementing strict emission standards, and providing tax incentives for sustainable industries are also necessary to achieve this transformation (Zahira & Fadillah, 2022; Cho et al., 2020). Indonesia's commitment to achieving NZE 2060 signifies a major transformation in the country's energy paradigm. This transformation is not only about technological changes but

also requires a shift in energy consumption culture and public awareness. Education and socialization regarding the importance of renewable energy and its positive impact on the environment need to be widely promoted to support sustainable behavior changes (Paundra & Nurdin, 2022; Dallenés et al., 2023). By leading these initiatives, Indonesia is not only fulfilling its obligations in addressing the global climate crisis but also creating a sustainable and environmentally friendly future for the next generation.

In 2021, the target for the energy mix was set at 14.5%, an increase of 1.1% from the previous year; however, the actual realization of the energy mix only reached 12.2%, an increase of 1% from the previous year (National Energy Council, 2022). According to data released by the government, the trend from year to year shows that the planned targets are never met. By 2060, the energy mix in Indonesia is targeted to be dominated by RES and reduce dependence on fossil energy. The importance of reducing greenhouse gas emissions is becoming increasingly apparent, considering Indonesia is one of the countries highly vulnerable to climate change. The increasing frequency and intensity of natural disasters, such as floods, droughts, and sea level rise, are clear indicators of the impact of climate change that has already occurred in various regions of Indonesia. Therefore, achieving net zero emissions by 2060 becomes a strategic and moral challenge for Indonesia, particularly in the energy sector.

This research is crucial in exploring the dilemma faced by Indonesia in managing its energy mix and achieving the net zero emissions target by 2060. This dilemma includes the complex conflict between the need for sustainable economic growth, energy security, and the global responsibility to reduce greenhouse gas emissions.

First, the need for sustainable economic growth is a crucial element in this dilemma (Liu et al., 2019). As a developing country with a large population, Indonesia faces pressure to increase economic productivity to improve the standard of living for its people. However, this challenge must be addressed without increasing greenhouse gas emissions, which requires fundamental changes in the economic structure and energy consumption. Second, energy security is an aspect that cannot be overlooked (Manganelli et al., 2021). Indonesia, as a country dependent on various energy resources, needs to ensure its energy supply is safe and sustainable. In pursuing the net zero emissions target, the transition from conventional energy sources to renewable and clean energy must be implemented without compromising energy supply security. Third, Indonesia also has a global responsibility to contribute to efforts to reduce greenhouse gas emissions (Raharjo et al., 2022). As a member of the international community, the country must play an active role in mitigating the impacts of climate change.

Therefore, this research will discuss the extent to which energy policies can be designed to fulfill Indonesia's global obligations without harming economic growth and energy security. An in-depth analysis of these three factors is expected to provide comprehensive insights into the necessary energy policies. The results of this research are expected to form the basis for decision-making in formulating balanced policies, ensuring sustainable economic growth while fulfilling global obligations to combat climate change.

2. Methods

The method used in this research is an objective narrative literature review, serving as a reference for conducting the literature study. The stages in this research include information and literature collection, information analysis, and review writing. The information and literature used are aligned with the discussed topic, which covers Indonesia's commitment to reducing emissions, the use of renewable energy sources (RES), the planned targets to achieve NZE 2060, and the targets and realization of the energy mix.

The initial stage of the research involves collecting information and literature from various sources related to the research topic. These sources include official state documents, government reports, scientific articles, and relevant publications, focusing on aspects such as energy policies, emission reduction commitments, the use of renewable energy sources (RES), and the targets and realization of the energy mix. After data

collection, information analysis is conducted by identifying and evaluating patterns, trends, and significant findings from various sources. This research emphasizes the selection of relevant and credible information and the comparison between sources to obtain a holistic understanding.

The next stage involves the objective writing of the literature review. In this process, a structured narrative is compiled, presenting the historical context, developments, and current issues surrounding the energy mix in Indonesia. This literature review not only presents the results of the analysis but also provides a comprehensive overview of the role of policies, the challenges faced, and potential solutions in achieving the NZE 2060 target. The discussion in this research includes an in-depth analysis of the current energy use conditions in Indonesia, the progress towards the set targets, and the critical challenges that might be encountered in achieving the NZE 2060 target. Through this scientific approach, it is hoped that this research can make a substantial contribution to the understanding and resolution of issues related to the energy mix in Indonesia.

3. Results and Discussion

3.1 Current energy usage conditions in Indonesia

In 2023, Indonesia still heavily relies on fossil fuels, especially coal, oil, and natural gas. Energy consumption tends to be concentrated in the industrial and transportation sectors. Although there has been an increase in the use of renewable energy sources such as hydro, solar, and wind, their contribution remains relatively small. The distribution of renewable energy is also uneven across different regions of Indonesia. Currently, the utilization of new renewable energy sources is still very minimal.

The development of the energy mix in 2022 was still dominated by coal at 42.38%, while renewable energy sources (RES) accounted for only 12.30%. This fell short of the desired target of 34.50% for coal and 15.69% for RES (National Energy Council, 2023). Additionally, the energy mix targets for the previous two years, 2021 and 2020, were also not met. According to data from the Ministry of Energy and Mineral Resources, 2022, the potential and utilization of new renewable energy sources are as follows.

Energy	Potential (GW)	Utilization (MW)
Solar	3,295	253
Hydro	95	6,679
Bioenergy	57	3,037
Wind	155	154
Geothermal	24	2,293
Ocean Current	60	0
Total	3,686	12,416

The Indonesian government's commitment to reducing emissions through the utilization of Renewable Energy Sources (RES) has been consistently reinforced as part of efforts to mitigate current climate change impacts. At COP21 in 2015, Indonesia pledged to reduce greenhouse gas (GHG) emissions by 29% (unilaterally) and 41% (with international assistance) by 2030 (GGGI Indonesia Team, 2021). During COP26 in 2021, Indonesia's President reaffirmed the commitment that Indonesia can contribute to accelerating global Net-Zero Emission goals. Furthermore, during the annual session of Indonesia's People's Consultative Assembly (MPR RI) in 2022, there was a discussion on the use of clean energy from solar heat, geothermal, wind, ocean waves, and bioenergy as part of Indonesia's energy mix. Lastly, at the G20 summit, Indonesia reiterated its commitment outlined in the Bali Compact, particularly emphasizing energy diversification and emission reduction.

The Indonesian government has introduced various regulations related to energy use, including policies promoting renewable energy development. Some regulations include

fiscal incentives for investments in the renewable energy sector and efforts to reduce fossil energy subsidies (Afin & Kiono, 2021; Adi et al., 2023). However, the implementation of these regulations faces challenges such as inadequate law enforcement and infrastructure limitations. Apart from infrastructure challenges in achieving the 2060 targets, the acceleration of RES development is facilitated through governmental regulations (Setyono et al., 2019). Presidential Regulation No. 112 of 2022 aims to accelerate the development of renewable energy for electricity provision by increasing investments in the RES sector, enhancing the national scale RES target, reducing trade in the energy sector, and lowering greenhouse gas emissions. Moreover, efforts to support RES utilization as a primary energy mix instrument and achieve global emission reductions require optimization, coordination, and synergy between central and local governments. Based on this, Presidential Regulation No. 11 of 2023 regarding Additional Concurrent Government Affairs in the Field of Energy and Mineral Resources (ESDM) concerning RES subfields was enacted to ensure alignment in RES understanding between the central and regional levels.

The energy sector in Indonesia contributes significantly to greenhouse gas emissions, primarily from coal and oil combustion. These emissions are a major cause of climate change and its environmental impacts (Jonek-Kowalska, 2022). Despite efforts to reduce emissions through clean technology adoption, the main challenge remains replacing fossil energy sources with RES significantly. In 2022, the actual reduction in GHG emissions exceeded the planned targets. The achievement of a 95,324,211 tons CO₂e reduction in GHG emissions from the energy sector in 2022 was largely due to energy efficiency, new and renewable energy sources, low-carbon fuels, and clean technology use (Ministry of Energy and Mineral Resources, 2022).

The Indonesian government has set ambitious targets to achieve Net Zero Emission by 2060. However, achieving these targets remains far from expectations. Accelerating renewable energy capacity and energy efficiency is essential to meet these projections. Additionally, financial and technological challenges need to be addressed to support this acceleration (Okere et al., 2021). Achieving the 2060 target requires more than USD 994 billion, highlighting the need for substantial investment (IESR, 2023; National Energy Council, 2022). Key obstacles include technological and infrastructure constraints for expanding renewable energy, resistance to change from industry and society, and financial challenges in facing large-scale energy transformation investments (Yudiartono et al., 2023; Ahluriza & Harmoko, 2021). Insufficient coordination among government sectors, private entities, and the public also poses a significant barrier.

3.2 Energy sector strategies to achieve net zero emission by 2060

Achieving the Net Zero Emission (NZE) 2060 target marks a monumental step in global efforts to mitigate the deadly impacts of climate change. This goal represents a crucial focus demanding a series of strategic steps involving the entire spectrum of economic and social activities. Efforts towards NZE 2060 signify a deep commitment to transforming the global energy foundation by replacing outdated paradigms overly reliant on fossil resources with more sustainable and environmentally friendly systems. In this context, the primary strategy revolves around developing renewable energy sources and implementing clean technologies (Ardiansyah & Ekadewi, 2022). Renewable energy sources such as solar power, wind energy, biomass, and hydroelectric power form the pillars of these strategic measures (Wierzbowski et al., 2017).

For example, the Indonesian government has designed eight strategies for developing renewable energy, including the construction of Renewable Energy Power Plants (EBT), rooftop solar PV installations, diesel-to-EBT power plant conversions, and geothermal potential exploration (Ministry of Energy and Mineral Resources, 2022). This diversification not only reduces dependence on fossil fuels but also creates a more robust and sustainable energy ecosystem (Irawan et al., 2023).

A key component in achieving NZE 2060 in the energy sector is the target to reduce emissions by 93% from Business as Usual (BaU) levels (Ahluriza & Harmoko, 2021). A

holistic approach is applied through supply optimization by leveraging RES as the primary electricity source and enhancing energy efficiency across the supply chain. RES is not only seen as the primary solution for energy transformation but also signifies a significant shift towards cleaner and sustainable resources. Diverse new energy sources, such as nuclear for electricity supply and hydrogen energy for the transportation sector, help design a diverse and reliable energy landscape (Triguero-Ruiz et al., 2023). The introduction of innovations and modern technologies, including carbon capture and smart grids, contributes significantly to improving operational efficiency and reducing environmental impacts.

The importance of achieving NZE 2060 lies not only in technological and infrastructural transformations but also involves fundamental changes in behavior and mindset among society, industry, and government. Awareness of sustainability, education, and cross-sector collaboration are key to ensuring that these changes not only become a goal but also create sustained positive change in facing the challenges of global climate change (Liu et al., 2019). This transformation requires engagement from all stakeholders and visionary leaders to ensure that the NZE 2060 goal becomes not just a vision but a tangible reality for future generations. The government has laid out a roadmap for transitioning to carbon neutrality by 2060, divided into milestones for 2025, 2035, and 2050 (National Energy Council, 2023).

Year	2025	2035	2050
Target	Reduction of emissions by 231.2 million tons CO2e	Reduction of emissions by 388 million tons CO2e	Reduction of emissions by 1,043.8 million tons CO2e
Supporters	<ol style="list-style-type: none"> 1. Rooftop Solar PV Utilization 2. Accelerated development of waste-to-energy 3. Small-scale biomass power plant development 4. Cofiring for existing coal-fired power plants 	<ol style="list-style-type: none"> 1. Green hydrogen development starting from 2031 2. Massive-scale Battery Energy Storage System (BESS) implementation by 2034 3. Geothermal power plant capacity reaching 11 GW by 2035 	<ol style="list-style-type: none"> 1. Green hydrogen development to replace natural gas for high-temperature heating processes starting from 2041 2. Dominance of primary Renewable Energy Sources (RES) over fossil fuels
Challenges	<ol style="list-style-type: none"> 1. Induction cooktops used by 8.1 million households 2. 300 thousand electric cars and 1.3 million electric motorcycles 3. Gas pipeline network for 5.2 million households 4. Dimethyl ether as LPG substitute 5. Mandatory 30% biodiesel by 2025 	<ol style="list-style-type: none"> 1. Induction cooktops used by 28.2 million households 2. 9.3 million electric cars and 51 million electric motorcycles 3. Gas network for 15.2 million households 4. 40% biofuel usage 5. Expansion of energy management implementation 	<ol style="list-style-type: none"> 1. Induction cooktops used by 46.6 million households 2. 50.2 million electric cars and 163 million electric motorcycles 3. Gas network for 22.7 million households 4. Maintained 40% biofuel usage

3.3 Challenges in the energy sector in achieving net zero emission by 2060

Indonesia boasts vast, dispersed, and diverse potential for new and renewable energy sources across nearly all regions, promising substantial contributions to achieving the utilization of new and renewable energy sources. Hydropower potential is widespread throughout Indonesia, notably in North Kalimantan, Aceh, West Sumatra, and Papua. Solar potential is spread across the nation, particularly in East Nusa Tenggara, West Kalimantan, and Riau, which exhibit higher solar radiation. Wind energy potential (>6 m/s) is predominantly found in regions like East Nusa Tenggara, South Kalimantan, West Java, South Sulawesi, Aceh, and Papua. Marine energy potential spans across Indonesia, especially in Maluku, East Nusa Tenggara, West Nusa Tenggara, and Bali. Geothermal energy

potential is distributed in areas along the Ring of Fire, encompassing Sumatra, Java, Nusa Tenggara, Sulawesi, and Maluku (National Energy Council, 2023).

Dependency on fossil fuels presents significant challenges in achieving the Net Zero Emission 2060 target. This dependency stems from well-established infrastructures integrated with fossil energy sources across various sectors, including industry, transportation, and other key sectors (Yudiarsono et al., 2023; Fadhillah & Nazarudin, 2023). Over time, this dependence has deepened in operational sustainability, posing a major hurdle to transitioning to clean energy. Industry is particularly exposed to fossil energy dependency, with fossil-based manufacturing and production processes forming the backbone. Shifting this foundation requires substantial investments in eco-friendly technologies and infrastructures (Rahardjo, 2014). Similarly, the transportation sector, heavily reliant on fossil fuels, faces similar challenges. Despite advancements in electric vehicles and other eco-friendly technologies, charging infrastructure and fleet adaptation require substantial time and investment. Transitioning to renewable energy, such as Renewable Energy Sources (RES), demands significant infrastructure investments and adaptations (Aditya et al., 2022). While RES technologies advance, their integration into existing infrastructures necessitates careful adjustments. Upgrading power grids, developing renewable power plants, and enhancing energy storage capacities are crucial changes needed for achieving maximum efficiency (Aditya et al., 2022).

The use of non-renewable energy for power generation in Indonesia remains high, with coal being the primary energy source. The nation's reliance on coal is evident from its accessibility for mining and as the largest contributor to state revenues, complicating energy mix adaptation efforts. According to the Ministry of Energy and Mineral Resources report, as of the end of 2022, the energy mix was at a 14.11% level while coal was at 67.21%. Looking at Figure 2, the growth trend of the EBT mix was also fluctuating and tended to stagnate, only increasing or decreasing by approximately 1-2 percentage points annually. If this trend continues, the EBT mix may only reach around 17% by 2025, far from the anticipated 23% target for the year 2025. On the other hand, despite the decline in fossil energy mixes like natural gas and oil fuel (BBM), coal's role in the national energy supply has grown rapidly. From 2017 to 2022, the coal mix increased by 8.8 percentage points, while the EBT mix only grew by 1.04 percentage points during the same period.

Achieving the Net Zero Emission target by 2060 poses a major challenge requiring significant investments in renewable energy projects. One of the significant obstacles faced is the lack of adequate financing sources to support the transition to clean energy (Setyono & Kiono, 2021; Marks-Bielska et al., 2020). Therefore, collaboration between the government and the private sector is crucial in identifying and implementing sustainable financing models and providing financial incentives to encourage the adoption of Renewable Energy Technologies (RET). In this context, it is important to understand that RET projects often require significant initial investments but offer long-term benefits in emission reduction and environmental sustainability. Hence, creating financing mechanisms that provide certainty and stability for investors is crucial, enabling them to commit to such projects.

Partnerships between the government and the private sector can create an environment supportive of investments in renewable energy sectors. The government can play a vital role in providing fiscal incentives, subsidies, or favorable financing schemes for RET-based projects. On the other hand, the private sector can bring innovation, technology, and managerial expertise needed to optimize the implementation of these projects. Sustainable financing models can also include financial instruments such as green bonds or sustainable investment funds. The government can facilitate the issuance of green bonds to support RET projects, while the private sector can engage in the capital market to obtain necessary funding (Zahira & Fadillah, 2022). Sustainability and project environmental performance can serve as the basis for investment returns.

Furthermore, financial incentives such as tax credits or reduced tax rates for companies investing in clean energy projects can stimulate private sector participation. The government can provide investment security guarantees and regulatory certainty to reduce

investment risks and enhance attractiveness to investors (IESR, 2023). With strong collaboration between the government and the private sector in addressing the lack of financing sources, Indonesia can create new opportunities to increase renewable energy penetration and achieve the Net Zero Emission 2060 target. These steps not only support the transition to clean energy but also have a positive impact on sustainable economic growth and the environment.

Indonesia's significant revenue from the energy sector, especially through tax revenues and royalties from the oil and gas industry, presents unique challenges alongside the transition to Net Zero Emission (NZE) 2060 (Dinata et al., 2023). This transition will directly impact the national revenue structure, with its connection to the energy sector being crucial in designing policies that manage this change (Setiawan, 2023). Thus far, the nation's substantial revenue from the oil and gas industry highlights economic dependence on non-renewable natural resources. Therefore, in the context of transitioning towards NZE 2060, the government needs to design policies that not only ensure sustained national income but also promote economic diversification.

The introduction of carbon taxes as part of NZE policies can be a smart and sustainable step to replace lost revenues from traditional energy sectors. Carbon taxes encourage companies to shift towards clean energy and create economic incentives that drive innovation in the Renewable Energy Technologies (RET) sector. Revenue from carbon taxes can be redirected to support investment and further development in the RET sector. Providing fiscal incentives for RET technologies is also a relevant strategy to achieve these goals. By offering tax relief or tax credits, the government can motivate companies to adopt clean technologies (Dinata et al., 2023; Setiawan, 2023). Concurrently, innovation in RET technologies can create new sectors capable of generating revenue for the country.

Diversifying national revenue sources through innovation in the energy sector has become essential to overcome potential economic challenges during the transition. Investment in research and development, renewable energy projects, and technological innovation can serve as alternative revenue sources. Through these steps, the government can establish a more robust and sustainable economic foundation, reducing dependency on income from conventional energy sectors. In this context, managing national revenue from the energy sector is not only a fiscal issue but also an integral part of a broader economic transformation. Well-planned and intelligent policies can help achieve a balance between economic sustainability, energy security, and global responsibility to reduce greenhouse gas emissions.

In implementing the energy transition, at least three aspects must be considered, commonly known as the energy trilemma: energy equity, energy security, and environmental sustainability (Sustainability). The energy equity provided must be easily accessible and affordable to the community (affordability). Energy security involves ensuring energy supply while considering supply chain sources domestically and internationally and the ability to meet increasing demand with reliable infrastructure (Ministry of Energy and Mineral Resources, 2022; Liu et al., 2019). Environmental sustainability entails developing infrastructure based on renewable energy and other low-carbon energy sources, as well as improving energy efficiency from both supply and demand perspectives.

Challenges in achieving Net Zero Emission 2060 also include technological limitations and shortages of trained human resources (SDM) in the renewable energy sector. The development of more efficient and affordable technology needs to be accelerated, while efforts in training and education must be enhanced to produce quality human resources in the field of EBT. Government and private sectors must collaborate to identify specific training and education needs, while promoting research and development to enhance the competitiveness of EBT technology. Based on these various aspects, the challenges faced by Indonesia in achieving the 2060 target include.

Technological innovation and good engineering practices in the EBT sector and energy conservation promote safety, reliability of the electric power system, and increasingly competitive prices. Current technology innovations that can be used as part of EBT

development may not necessarily be relevant in the future, but technology will continue to evolve and be renewed (Wei et al., 2021). Therefore, technology development must also be synchronized with the development of its human resources so that the operation of this technology can be carried out by local communities without relying on external support. The availability of supporting infrastructure for EBT development and energy conservation includes not only primary but also secondary or supporting infrastructure (Cho et al., 2020). Accessibility to reach EBT development sites or locations needs to be adjusted, and the development and construction of roads, settlements, and other infrastructure need to be accounted for in EBT development. Moreover, infrastructure from power plant construction to household connections must be included in energy blend planning to facilitate achieving these targets. Both primary and secondary infrastructure development must consider environmental aspects to avoid disrupting surrounding ecosystems. EBT and energy conservation development, both in electricity and non-electricity, must consider the balance of supply and demand growth. The NZE 2060 target with EBT utilization should be reviewed from the perspective of market supply and demand to ensure the success of EBT benefits not only environmentally but also economically. Thus, investments should be targeted appropriately. EBT development requires considerable financing alongside the use of the latest technology and human resource development (Okere et al., 2021). Additionally, financing is influenced by land availability and accessibility to the resources used. EBT development in achieving NZE 2060 depends on its social dynamics, where effective governance, regulations, and implementation are expected to make communities accept the presence of EBT, both directly impacting EBT infrastructure and indirectly.

3.4 Energy mix analysis in supporting nze-2060 achievement

In 2022, despite renewable energy contributions remaining relatively small, positive steps have been taken. The use of renewable energy, such as solar and wind power generation, has begun to expand. However, the greatest challenge lies in uneven distribution across Indonesia. Some regions still have limited access to these renewable energy sources. The energy mix achievement in 2022 shows that coal still dominates at 42.38%, while renewable energy (EBT) contributes 12.30% (National Energy Council, 2022). However, these achievements have not yet reached the desired targets, with coal exceeding and EBT falling below planned targets.

The Indonesian government has demonstrated its commitment to reducing greenhouse gas emissions (GHG) through commitments announced in various international forums and annual NDC reports (The Government of the Republic of Indonesia, 2022). In addressing climate change, the government focuses on clean energy utilization from renewable sources such as solar heat, geothermal, wind, ocean waves, and bioenergy. In concrete terms, Indonesia has formulated several energy-related regulations, including policies for renewable energy development. However, implementing these regulations still faces challenges, such as enforcement gaps and infrastructure limitations.

To support clean energy utilization, Presidential Regulation (Perpres) No. 112 of 2022 and Perpres No. 11 of 2023 serve as crucial instruments. These regulations aim to accelerate renewable energy development, increase investment, expedite the achievement of renewable energy targets, and reduce greenhouse gas emissions. Synergy between the central and regional governments through Presidential Regulation No. 11 of 2023, concerning Additional Concurrent Affairs in the Energy and Mineral Resources Sector in the Subsector of EBT, is expected to enhance alignment in understanding EBT between central and regional authorities for national energy mix success and greenhouse gas emissions reduction.

The year 2022 marked remarkable achievements in reducing energy sector emissions, with a decrease of 95.324.211 tons CO₂e. Although this achievement exceeds planned targets, the reality shows that these efforts are still insufficient to achieve the Net Zero Emission (NZE) ambition by 2060. Achieving this target requires substantial investment estimated at over USD 994 billion. Realizing NZE demands significant investments to

comprehensively transform energy infrastructure foundations. Several inhibiting factors emerge as real challenges in the journey towards NZE. Primarily, technological and infrastructural constraints are major obstacles. Despite rapid developments in renewable energy technologies, further efforts are needed to expand and update supportive infrastructure for renewable energy. This includes developing more advanced electricity networks, efficient energy storage, and other infrastructure adaptations.

Financial challenges are critical aspects in the NZE journey. Massive investments are needed to replace old infrastructure with more environmentally friendly technologies. Although these investments are considered long-term investment steps, careful financial strategies are still required to address risks and ensure project sustainability (Setiawan, 2023). Resistance to change, both from industry sectors and the general public, also poses significant obstacles. Established industries with existing infrastructure and business models may be reluctant to switch to renewable energy due to high initial investments and fundamental operational changes required. Moreover, public awareness and acceptance of renewable energy need to be increased to create further momentum in adopting clean solutions (Zahira & Fadillah, 2022). Furthermore, inadequate coordination between government sectors, private sectors, and communities remains a serious constraint. Energy transformation is not solely the responsibility of the government or private sectors but requires involvement and cooperation from all stakeholders. Better coordination in planning, implementation, and monitoring of renewable energy projects can optimize outcomes and expedite the journey towards NZE.

In executing the energy transition, the trilemma's three aspects—energy equity, energy security, and environmental sustainability—must be considered. Energy equity involves ensuring easy and affordable access for all communities. Energy security encompasses energy supply while considering supply chain sources domestically and internationally. Environmental sustainability involves developing infrastructure based on renewable energy and low-carbon energy sources to minimize environmental impacts. Through these comprehensive energy sector strategies, Indonesia strives not only to fulfill its global commitments in addressing climate change but also to lead the change towards a more sustainable and environmentally friendly future (Bappenas, 2021).

Although the Indonesian government has set ambitious Net Zero Emission (NZE) targets for 2060, the journey towards this goal is fraught with significant challenges. One major hurdle is the high dependency on fossil fuels, especially coal, which has been the backbone of the energy sector for decades (Paundra & Nurdin, 2022). Established infrastructure integrated with fossil energy sources also poses serious constraints. Several sectors, such as industry and transportation, have long relied on fossil fuels, and transitioning to renewable energy requires significant investments and infrastructure adaptations (Setyono & Kiono, 2021).

Achieving Net Zero Emission by 2060 also requires significant financial investments in renewable energy projects. This challenge is exacerbated by insufficient financing sources. Collaboration between the government and private sectors is key to identifying and implementing sustainable financing models and financial incentives that can promote clean energy technology adoption. State revenue, primarily derived from the energy sector through tax revenues and royalties from the oil and gas industry, also poses challenges. The transition to NZE 2060 will impact these revenue sources, and expanding state revenue through renewable energy sectors and tax innovations becomes crucial to address potential deficits.

Social dynamics also play a crucial role in facing these challenges. Good governance, effective regulations, and proper implementation are key to managing resistance to change, both from industrial sectors and the general public. Other challenges include technological limitations and shortages of trained human resources (SDM) in the renewable energy sector. Developing more efficient and affordable technology must be accelerated, while efforts in training and education must be intensified to produce quality human resources in the field of New and Renewable Energy (EBT) (National Energy Council, 2022).

The transition process towards Net Zero Emission (NZE) 2060 in Indonesia illustrates complex dynamics and requires collaborative efforts from various stakeholders. The steps taken by the Indonesian government reflect a serious commitment to addressing climate change and creating a sustainable energy sector. In executing the energy transition, balancing environmental sustainability, energy access equity, and energy security remains a primary focus. The government must ensure that access to clean energy is not only affordable but also equitable across all regions of Indonesia. Energy resilience, including source diversification, also serves as a strategy to reduce dependence on a single energy type (Aprilianto & Ariefianto, 2021). Close collaboration among the government, private sector, and all stakeholders is essential to closely identify specific training and education needs while promoting research and development to enhance the competitiveness of EBT technology. Based on these aspects, the challenges faced by Indonesia in achieving the NZE 2060 target involve profound changes in energy paradigms, financing, and human empowerment to create a sustainable energy future.

4. Conclusions

The government's target of achieving Net Zero Emission (NZE) by 2060 through the utilization of new and renewable energy faces dilemmas in its development. Energy sustainability is a key aspect in the goal of energy mix to ensure that current energy resources continue to sustainably benefit future generations. These dilemmas encompass significant tensions among three key dimensions: sustainable economic growth, energy security, and global responsibility related to reducing greenhouse gas emissions.

Firstly, strategic interests in sustainable economic growth serve as a central point in this dilemma. As a developing country, Indonesia is committed to enhancing the welfare of its people, with economic growth as a primary catalyst. However, the transition towards net zero emissions often requires structural adjustments that can impact the economy. Secondly, energy security emerges as a critical factor requiring special attention in policy formulation. With significant dependence on fossil fuels, Indonesia must maintain adequate energy availability to meet its domestic needs. The transition process towards renewable energy must be implemented carefully to avoid supply instability risks. Thirdly, in the context of global responsibility, Indonesia faces pressure to actively participate in efforts to reduce greenhouse gas emissions. Dilemmas arise when domestic efforts to meet economic and energy needs conflict with international obligations to reduce carbon footprints.

Overall, a deep analysis of these three aspects yields a comprehensive understanding of the complex dynamics involved in energy policy formulation. Forward steps should include developing holistic strategies that integrate energy efficiency, wise integration of renewable energy sources, and policies supporting sustainable economic growth. In conclusion, to successfully address these dilemmas, Indonesia needs to adopt an integrated approach that carefully considers its domestic needs, energy security challenges, and global commitments towards achieving net zero emissions targets. Aligning sustainable economic growth, energy security, and emission reduction is key to designing effective and sustainable policies.

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Author Contribution

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