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# Rethinking Energy Security in Indonesia from a Net Zero Perspective

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**Abstract**
This study investigates Indonesia's ability to safeguard its energy security within a net-zero framework. To achieve this goal, we calculated current and projected figures for three critical variables—total emissions of Kyoto gases, $CO_2$ emissions per sector, and the primary energy mix—until the end of the century, utilizing the Integrated Assessment Model (IAM) IMAGE 3.2. This research enriches the study of energy security in Indonesia, focusing on the impacts of Net Zero Emissions (NZE) commitments. Three scenarios (CurPol, NDC, and Glasgow) were assessed. The findings reveal a potential challenge as the country's reliance on finite fossil fuels appears unavoidable, posing a risk of missing its net-zero target and vulnerability to energy crises. Moreover, neither the current policies nor the Nationally Determined Contributions (NDC) align with Indonesia's net-zero goal. Compounding this issue is the absence of a legal framework for the net-zero target, reducing the commitment to a mere narrative. To reconcile energy security with the net-zero target, Indonesia must prioritize energy efficiency, integrate carbon capture and storage (CCS) technology to control fossil fuel emissions, and significantly elevate the share of renewables—particularly solar and biomass—to at least 50% in the country's primary energy mix.

**Keywords:**
energy security, net zero emissions, renewable energy, carbon capture and storage, Integrated Assessment Model

## 1. Introduction

The Paris Agreement aims to limit global warming to well below 2 ºC, preferably 1.5 ºC, in comparison to pre-industrial levels (Li et al., 2024). According to the IPCC (2022), achieving a target of 1.5 ºC would enable reaching net zero emissions (NZE) by approximately 2050. If global warming is maintained below 2 ºC, the projection for achieving NZE is estimated to be later, around 2070 (IPCC, 2022). NZE denotes a commitment to maintaining the ecological balance between anthropogenic greenhouse gas (GHG) emissions and the atmosphere's capacity to remove them (Virmani et al., 2022). Processes such as reforestation and direct air capture (DAC) can be employed for the removal of GHGs (Lomax et al., 2015).

Indonesia, along with the other top ten emitters globally, is responsible for more than two-thirds of worldwide emissions (Nurrahmawati & Kusumawardani, 2021). At the Conference of the Parties (COP26) in 2021, Indonesia unveiled its ambitious goal of achieving NZE by 2060 (IEA, 2022). Unfortunately, as of May 2023, the status of Indonesia's NZE target remains "proposed/in discussion," indicating that the commitment and strategies to attain this ambitious goal are still unclear (Net Zero Tracker, n.d.). Nevertheless, the IEA (2022) asserted in its joint statement with the Ministry of Energy and Mineral Resources (MEMR) that Indonesia's NZE is achievable. This confidence stems from promising improvements in the country's energy landscape through policies and regulations, including enhanced Nationally Determined Contributions (NDC), Long-term Strategy for Low-carbon and Climate Resilience (LTS-LCCR), and Regulation No. 26/2021, aiming to accelerate the installation of rooftop solar PV in Indonesia (IESR, 2021). Unfortunately, over half of Indonesia's energy mix still relies on fossil fuels (IEA, 2022). Indonesia has been a net importer of oil since 2004 (Erianto, 2022). As an emerging economy, it becomes imperative for Indonesia to increase its energy supply, which is currently dominated by fossil fuels, potentially hindering the country's progress towards decarbonization and its net-zero goal. Additionally, excessive reliance on energy imports may jeopardize Indonesia's energy security, especially considering potential crises such as pandemics, financial downturns, and geopolitical conflicts that could further destabilize the country's energy system (Secretariat General of the National Energy Council, 2021). Consequently, it is crucial to assess how Indonesia can safeguard its energy security while ensuring the country can achieve its net-zero target.

Thus far, the schools of thought on energy security and net zero have not been inextricably correlated. Many studies treat energy security and NZE as distinct concepts rather than utilizing NZE as a lens to evaluate a country's energy security. Employing NZE as a framework to address energy security issues is crucial for aiding countries not only in decarbonizing their energy systems but also in mitigating geopolitical hegemony over energy resources. In Indonesia, most energy security studies concentrate on unlocking the country's substantial renewable potential, as evidenced by Kumar (2016) and Rahman et al. (2021). Furthermore, examinations of NZE in Indonesia are often limited to providing an overview of NZE transitions within the power sectors of Southeast Asia as a collective entity, exploring multiple scenarios as presented by Handayani et al. (2022), or outlining the roadmap to achieve NZE in the energy sector (IEA, 2022). Hence, the objective of this study is to fill this gap by assessing how and to what extent Indonesia can safeguard its energy security from an NZE perspective.

To accomplish the objective of this study, two research questions were formulated as follows. Firstly, how is the current energy system in Indonesia? An energy system refers to an end-to-end system that encompasses the technical and socioeconomic aspects of both energy supply and demand sides in a specific area, such as a country (Groscurth et al., 1995). Consequently, this question aims to examine Indonesia's existing energy systems, emphasizing the essential strategies and challenges in the country's endeavors to attain NZE. Secondly, in what way and to what extent can Indonesia's energy systems progress from current strategies to NZE? This question seeks to examine the disparities between Indonesia's current strategies and its NZE target, as well as explore potential pathways to address such disparities. To answer this question, three critical variables characterizing the country's energy system will be assessed: total emissions of Kyoto gases, $CO_2$ emissions per sector, and the primary energy mix. Further details about these variables are provided in the following chapter.

## 2. Methodology

This chapter outlines the data collection and analysis process employed to generate knowledge relevant to addressing the research questions of this study. Quantitative research was chosen as the primary approach in this study, given the widespread use of quantitative research in climate change studies (Massazza et al., 2022). Furthermore, the quantitative approach was selected to identify numerical trends in the key variables of Indonesia's energy system.

In its analysis, this study utilized 15 documents to identify the key strategies and challenges for achieving NZE in Indonesia. These documents are categorized into reports, government documents, journal articles, and media releases. Among the 15 documents are reports from the International Energy Agency (IEA), the Net Zero Tracker database, and a document from the National Energy Council's Secretariat General of Indonesia.

Integrated Assessment Models (IAMs) have been extensively employed to address central questions about climate change, contingent on the assumptions used as inputs to the models and the background information utilized to construct different scenarios. One such question pertains to how the world can achieve NZE and the extent to which this goal can be realized at the lowest possible cost (Dowlatabadi, 1995). Given the limited availability of studies on how Indonesia can safeguard its energy security from a NZE perspective, this study employed IMAGE 3.2 as the model and compared the current and projected trends of the key variables in Indonesia's energy system across three different scenarios, one of which incorporated the country's NZE target. The subsequent section will furnish greater details about IMAGE 3.2, the scenarios, and the variables assessed in this study.

### *2.1 IMAGE 3.2*

The Integrated Model to Assess the Global Environment (IMAGE) is a global-scale integrated assessment model (IAM) designed to simulate the environmental consequences of human activities (PBL Netherlands Environmental Assessment Agency, 2021). Developed by the IMAGE team in the 1980s, this framework has evolved to ensure scientific excellence, extending its application beyond the Netherlands. The IMAGE team at PBL collaborates closely with institutes and universities worldwide. IMAGE is commonly used to address two main types of issues: first, projecting how the future may unfold if current conditions (business as usual) persist, and second, assessing how measures such as net-zero targets could prevent undesirable effects on the global environment and human development (Stehfest et al., 2014). The IMAGE 3.2 version was released in 2020 (PBL Netherlands Environmental Assessment Agency, 2021).

### *2.2 Scenarios*

The methods employed in Exploring National and Global Actions to reduce Greenhouse gas Emissions (ENGAGE)'s Task 4.5 served as the reference for this study. T45 corresponds to Task 4.5 of ENGAGE, which aims to examine whether global and national mid-century strategies and policies align with the overarching objectives of the Paris Agreement (personal communication, October 26, 2022). Additional details about the scenarios are provided in Table 1 (personal communication, October 26, 2022).

**Table 1.** Analyzed scenarios.

| **Scenario name** | **Descriptions** |
|---|---|
| Current policies *(GP_CurPol_T45)* | It pertains to presently implemented policies adopted by the government, encompassing both binding and non-binding targets supported by effective policy instruments. Additionally, it includes planned policies slated for adoption until 2030. Notably, this scenario deliberately excludes any aspirations or commitments, such as a NZE target. |
| NDC (*GP_NDC2030_T45*) | It seeks to depict Indonesia's objectives as outlined in the country's NDC. For this study, the Indonesian NDC from 2021 was utilized, featuring an unconditional GHG emissions reduction target of 29% and a conditional reduction target of up to 41% by 2030, compared to the BAU scenario (Climate Policy Database, n.d.). |
| Glasgow *(GP_Glasgow_T45)* | It will consider both the NDC pledge and the NZE declared at COP26 in Glasgow. Specifically, Indonesia aims to achieve NZE by 2060 (Net Zero Tracker, n.d.). |

"GP" refers to global policies, representing scenarios designed for global models. These scenarios within the global model encompass the intricate interactions of energy, economy, and climate on an international scale. Notably, these interactions incorporate elements often treated as "exogenous assumptions" or "boundary conditions" in national models, such as world fossil fuel prices (Fragkos et al., 2018, p. 463). The utilization of a global model in this study is justified by the understanding that technological advancements and socioeconomic changes in Indonesia are not isolated phenomena but are influenced by transnational entities (Krey et al., 2019).

## 2.3 Variables

Three variables were selected to portray the trends in GHG emissions and the energy mix in Indonesia over time. These variables include the total Kyoto gas emissions, $CO_2$ emissions per sector, and the primary energy mix. The analysis encompassed both current and projected trends of these variables, extending up to the year 2100. The assessment was conducted across three different scenarios: GP_CurPol_T45, GP_NDC2030_T45, and GP_Glasgow_T45. This approach aimed to capture and characterize crucial elements within Indonesia's energy system.

### 2.3.1 Total Emissions of Kyoto Gases

Under the Kyoto Protocol, the seven GHGs, collectively known as the Kyoto gases, contribute directly to climate change due to their positive radiative forcing effect—meaning the Earth receives more energy from the sun than it emits to space (MIT, n.d.). These seven Kyoto gases, measured as Carbon dioxide equivalents ($CO_2e$), include Carbon dioxide ($CO_2$), Methane ($CH_4$), Nitrous oxide ($N_2O$), Hydrofluorocarbons (HFCs), Perfluorocarbons (PFCs), Sulphur hexafluoride ($SF_6$), and Nitrogen trifluoride ($NF_3$).

### 2.3.2 $CO_2$ Emissions per Sector

Due to its abundance and prolonged presence in the atmosphere relative to other GHGs, $CO_2$ emissions were chosen as a key metric for measuring sectoral contributions (Mohajan, 2017). This study focuses on the three primary sectors responsible for generating $CO_2$ emissions in Indonesia: energy, AFOLU (Agriculture, Forestry, and Other Land Use), and industrial processes (Dunne, 2019).

### 2.3.3 Primary Energy Mix

Diversifying the sources of primary energy, including the integration of renewable energy, emerges as a pivotal strategy to significantly mitigate GHG emissions (Kumi & Mahama, 2023). Initiatives focused on such diversification are expected to play a crucial role in aiding countries to progress towards achieving their NZE commitments (IEA, 2021). The term "primary energy," referred to as total energy supply (TES) by the International Energy Agency (IEA), denotes the energy supplied by each fuel to an energy system before undergoing any conversions. For example, it encompasses the energy provided by combusting coal (considered primary energy) before its conversion into electricity (considered secondary energy) (IEA, 2021).

## 2.4 Data Visualization

To visualize the characterizations of the variables per scenario, this study employed the pyam package, an open-source Python toolset that includes a range of tools and functions for analyzing and visualizing input data, including results from IAMs (International Institute for Applied Systems Analysis [IIASA] & the pyam developer team, n.d.). Within the pyam package, two types of charts were generated: Timeseries data charts illustrating the total emissions of Kyoto gases and Stacked bar charts depicting the primary energy mix. In the case of $CO_2$ emissions per sector, the Seaborn package was utilized to craft stacked bar charts with facet grids. The study's data visualization outcomes, presenting key findings, will undergo further analysis by delving into existing literature on energy security and NZE, particularly with Indonesia serving as a case study. This analysis seeks to illuminate how Indonesia can safeguard its energy security within a NZE framework and to what extent.

## 3. Results and Discussions

### *3.1 The Current Energy System in Indonesia*

Indonesia is actively implementing three key strategies within its energy system to progress towards the NZE future. The first strategy is to set comprehensive regulations and product standards in place, aiming to reduce energy intensity by 1% annually from 2015 to 2025. This initiative is spurred by the growing demand for energy-efficient structures, appliances, and construction equipment. The second strategy is to increase the utilization of renewable energy sources, including hydro, geothermal, and solar PV, with a target for these renewables to constitute over 50% of the country's national electricity supply plan by 2030. The third strategy is the electrification of transportation, though its visible impact is expected post-2030. This strategy is anticipated to contribute to a substantial 20% reduction in emissions by 2050.

Indonesia's energy system grapples with three significant challenges, shaping the complexity of its sustainability efforts. Firstly, the compounding factors of population growth, urbanization, and industrialization exert continuous pressure, driving up the nation's energy demand. Secondly, the inadequacy of robust enforcement of existing regulations and limited access to financial instruments present hurdles in incentivizing energy efficiency improvements. Thirdly, stringent Local Content Requirements (LCR) in renewable energy development, exemplified by the 40% LCR mandate for solar projects, pose challenges for local industries unprepared to meet such standards, thereby hindering the flourishing of the renewable supply chain in the country. Local content requirement aims at pushing domestic industrial development and apply to a wide range of sectors, including energy (Derbyshire et al., 2021). Moreover, subsidies for fossil fuels to maintain a low coal price (USD 70 per ton) and unattractive pricing schemes for electricity generated by renewables further compound the challenges. This includes agreed prices for hydro, biofuel, and tidal projects, as well as a ceiling price set at 85%–100% of the average cost of production (7.05 US cent per kWh). These factors collectively contribute to rendering renewables an unattractive investment niche for many business players in the country.

### *3.2 Total Emissions of Kyoto Gases*

Figure 1 illustrates the trends in the total emissions of Kyoto gases in Indonesia from 2005 to 2100 for three distinct scenarios: CurPol, NDC, and Glasgow. The total emissions in the NDC and Glasgow scenarios exhibit relatively similar patterns, fluctuating until approaching 2030 before drastically declining. The total emissions in Indonesia will come close to zero around 2060, aligning with Indonesia's targeted year to achieve NZE.

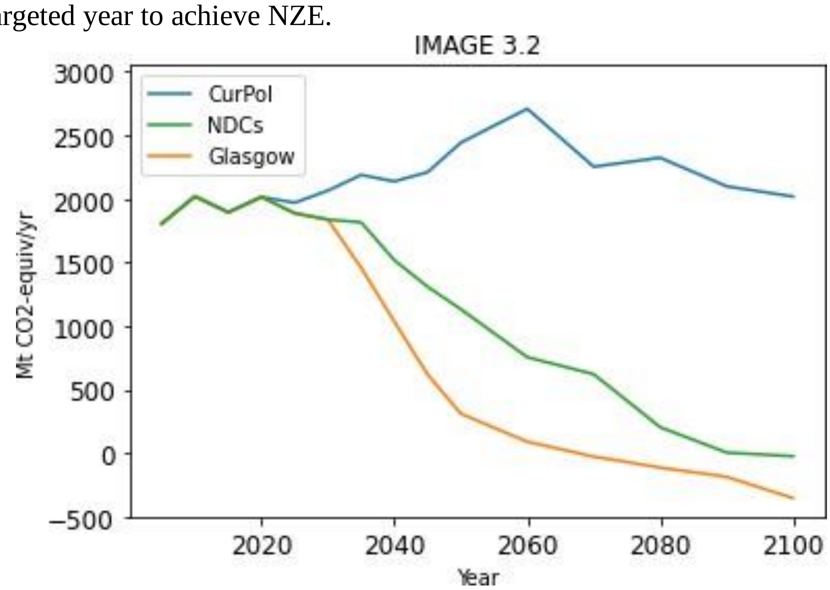


**Figure 1.** Total emissions of Kyoto gases in Indonesia, focusing on scenarios: CurPol, NDC, and Glasgow.

This finding indicates that Indonesia's NDC scenario presents a comparatively smaller gap to achieve NZE when contrasted with the CurPol scenario. The updated version of Indonesia's NDC, submitted to the UNFCCC on September 23, 2022, reveals enhancements in the country's emission reduction targets. Specifically, Indonesia increased its unconditional emission reduction target from 29% to 31.89%, while the conditional emission reduction target was elevated from 41% to 43.20% (I Republic of Indonesia, 2022). These ambitious initiatives are likely pivotal factors contributing to Indonesia's potential significant strides in reducing total Kyoto gas emissions, aiming to approach zero by 2060—the targeted year for achieving NZE.

### *3.3 $CO_2$ per sector in 2060*

Figure 2 illustrates $CO_2$ emissions per sector in Indonesia for 2060. The selected sectors in this study encompass AFOLU, energy, and industrial processes. Energy exhibits the largest share of $CO_2$ emissions in Indonesia for 2060. According to IMAGE 3.2, $CO_2$ emissions from the energy sector in Indonesia for 2060, resulting from the NDC scenario, decrease significantly compared to the CurPol scenario. However, $CO_2$ emissions from AFOLU are notably present in the NDC scenario. Lastly, among all scenarios, the Glasgow scenario has the lowest $CO_2$ emissions per sector for 2060, equivalent to the removal of all $CO_2$ emissions per sector projected by the CurPol scenario.

In Figure 2, the AFOLU sector exhibits a small share in the country's $CO_2$ emissions in 2060, despite the sector accounting for more than 60% of the country's emissions (Climate Links, 2017; Dunne, 2019). This seemingly low figure suggests that Indonesia's rigorous policies on $CO_2$ emissions from AFOLU, set at 59% in 2030, may facilitate the transformation of the AFOLU sector into a net sink. This transformation is estimated to be equivalent to the removal of 1 Gt $CO_2e$ from the atmosphere (Boer & Dewi, n.d.; IEA, 2022). Furthermore, the energy sector emerges as the largest contributor to the $CO_2$ emissions in 2060 due to the ongoing dominance of fossil fuels, such as coal, to meet the increasing energy demand of the country, as illustrated in Figure 3.

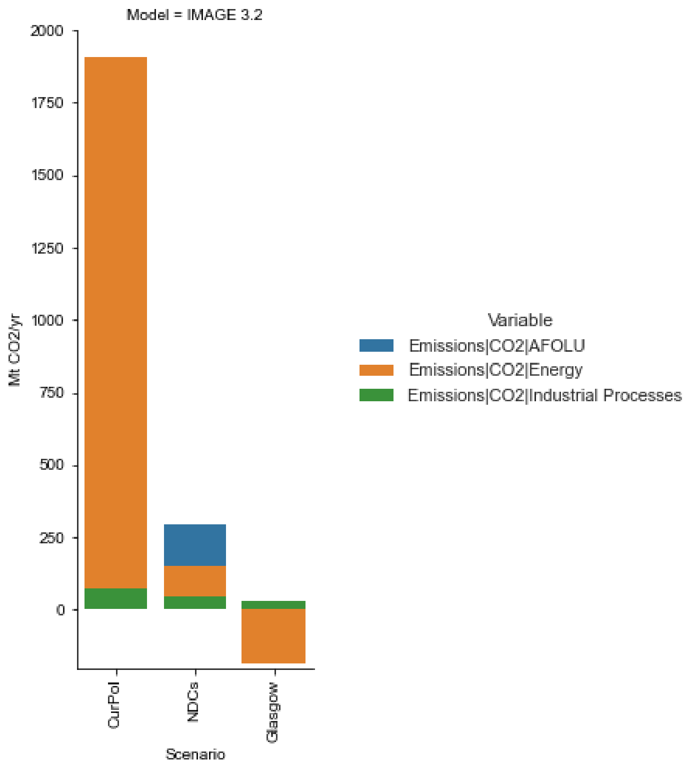


**Figure 2.** The emissions of $CO_2$ per sector by 2060 in Indonesia, focusing on scenarios: CurPol, NDC, and Glasgow.

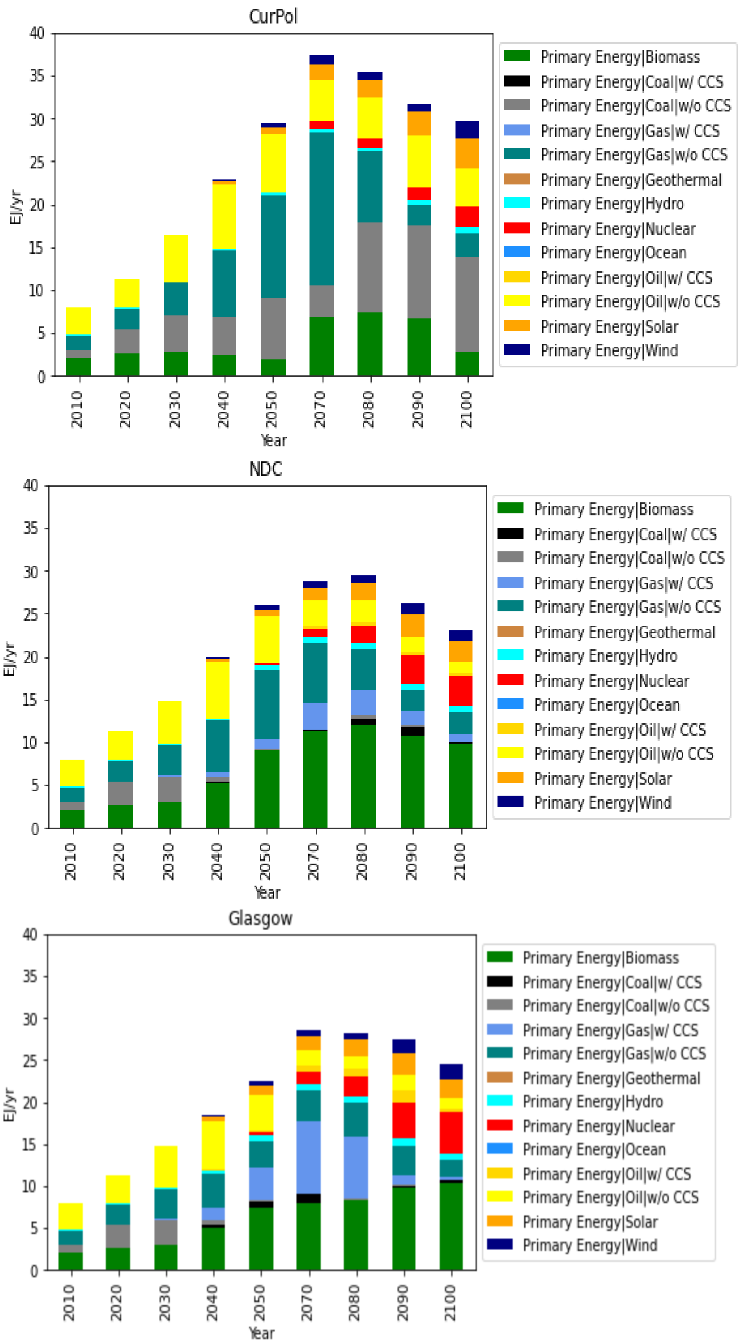


**Figure 3.** Primary energy mix in Indonesia (2010–2100), focusing on scenarios: CurPol, NDC, and Glasgow.

### *3.4 Primary Energy Mix*

In the CurPol and NDC scenarios, fossil fuels without carbon capture and storage (CCS) technology are projected to remain dominant in Indonesia's primary energy mix until 2100. Regarding the renewable energy share in the primary energy mix, IMAGE 3.2 indicates that biomass exhibits substantial shares in each scenario, followed by solar and wind. Additionally, nuclear and gas with CCS technology will begin to significantly feature in the country's primary energy mix after 2050.

The significant contribution of the energy sector to $CO_2$ emissions in Indonesia by 2060 can be attributed to two main factors: (i) the prevalence of fossil fuels in the country's primary energy mix, as depicted in Figure 3, and (ii) a substantial increase in energy-consuming appliances in households and machines in industries between 2022 and 2060 (IEA, 2022). Consequently, it is crucial for Indonesia to expedite advancements in technology efficiency within the country's primary energy mix. Simultaneously, there is a pressing need to promote cleaner energy sources such as biomass, solar, and fossil fuels with CCS technologies to enhance their shares in the primary energy mix (IEA, 2022; MEMR, 2021).

According to Figures 1, 2, and 3, fossil fuels are expected to continue playing a role in Indonesia's primary energy mix throughout the entire century. Consequently, ensuring energy security in Indonesia from the NZE perspective will focus on decarbonizing fossil fuels rather than eliminating them. Furthermore, a full-scale adoption of green energy (i.e., green energy represents the most environmentally beneficial renewable energy resources and technologies due to its NZE character (EPA, n.d.)) from now until 2100 may pose a risk to the country's energy security due to (i) the concentration of raw materials and technological advantages in renewables being dominated by a few countries, such as China (IRENA, 2023), and (ii) various challenges like financial barriers, technological limitations, and political gaps affecting local industries, including stringent LCR in renewable energy development, hindering the flourishing of the domestic renewable energy value chain. This study also underscores the necessity of a significant reduction in Indonesia's overall primary energy mix for the country to move towards net zero. We show that energy efficiency is crucial in facilitating Indonesia's NZE transformation. This is because merely implementing adequate energy solutions will not be sufficient to support the NZE transition unless there is a shift towards a more efficient energy consumption process.

## 4. Conclusions

This study reveals that reducing GHG emissions from the energy sector is crucial for Indonesia's progress toward net zero. However, challenges such as poor investment and a lack of technological capacity have solidified the enduring role of fossil fuels in ensuring energy security. This has resulted in a disconnect between the narratives of net zero and energy security in Indonesia, potentially derailing both goals. Therefore, the contribution of our study is to assess how Indonesia can safeguard its energy security while moving towards net zero. This study formulated two research questions with answers as follows.

The first research question, "How is the current energy system in Indonesia?" indicates that Indonesia has adopted promising strategies in its energy systems, including improving energy efficiencies, increasing renewable energy shares, electrifying industries, and implementing Carbon Capture, Utilization, and Storage (CCUS) for fossil fuel emissions. Despite these efforts, challenges such as population growth, urbanization, and industrialization have led to continued reliance on fossil fuels until the end of the century. Furthermore, the absence of a legal commitment to net zero exacerbates this reliance.

The second question is described as follows: "In what way and to what extent can Indonesia's energy systems move forward from current strategies to net zero?" The following scenarios, from least stringent to most stringent, represent Indonesia's reductions in total Kyoto gas emissions: CurPol, NDC, and Glasgow. Concerning achieving net zero, IMAGE 3.2 demonstrated that the Glasgow scenario is the most feasible pathway for Indonesia to pursue. This indicates that, to achieve its net-zero target, Indonesia must explicitly implement the net-zero pledge declared at COP26 in the country's overarching energy rules and regulations. Regarding $CO_2$ emissions per sector, energy exhibits the largest share of $CO_2$ emissions in 2060. When comparing the results of each scenario, the Glasgow scenario shows the least amount of $CO_2$ emissions per sector in Indonesia in 2060, equaling up to 100% of the total removal of $CO_2$ emissions per sector calculated by the CurPol scenario. Drawing from this, it becomes imperative for Indonesia to adopt stringent measures to mitigate $CO_2$ emissions per sector, especially from the energy sector. Unfortunately, fossil fuels without CCS technology are still present in each scenario. However, in the Glasgow scenario, fossil fuels with CCS technology become significantly prominent, accounting for more than 75% of the primary energy mix. Furthermore, in the Glasgow scenarios, the declining trends in the shares of renewables and higher energy efficiencies in overall primary energy mixes are most evident compared to other scenarios.

In summary, this study underscores the pivotal role of energy in Indonesia's journey toward meeting its net-zero target. This entails advancing energy efficiency measures, increasing the proportion of renewables in the primary energy mix, and integrating CCS technology to manage fossil fuel emissions. Regrettably, as revealed in this study, existing policies and NDCs are not aligning with Indonesia's net-zero objective. While NDCs outline the intended strategies for achieving net zero, a substantial gap persists between the country's NDC and Glasgow scenarios. This gap is widening between current policies (CurPol) and the more ambitious Glasgow scenarios. This challenge is further compounded by Indonesia's failure to legally entrench its net-zero commitment. Consequently, despite making ambitious net-zero pledges and expressing a commitment to take action, Indonesia lacks the necessary speed and rigor to realize its net-zero target. By outlining strategies to secure the country's energy future through a net-zero lens, Indonesia could enhance its capacity to not only address the impacts of present and future energy crises but also mitigate the consequences of climate risks that the nation faces.

For future studies, it is highly recommended to conduct a more in-depth analysis of the results presented in this study by establishing connections with the aspects of IMAGE 3.2 documentation, such as model scope and methodology. This approach would facilitate a deeper investigation into the underlying reasons behind the outcomes observed in each scenario. Additionally, future studies should evaluate GHG emissions reductions from non-energy sectors using the CurPol, NDC, and Glasgow scenarios from multiple Integrated Assessment Models (IAMs). Such studies could offer comprehensive recommendations to guide Indonesia on how to achieve net zero. Moreover, it would be worthwhile for future research to leverage the key findings of this study to assess the net-zero transition in Indonesia in a just manner. This could involve considering socioeconomic factors that influence the energy regime in the country.

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