The Role of Onshore Wind Power to Advancing Environment Sustainability in Tropical Country: Study of Indonesia

Master Thesis

Reco Rambang Putra Negsagis

Supervisor: Dr. Jamil Khan

Examiner: Dr. Karin Ericsson

ISRN: LUTMDN/TMHP-26/5707-SE

ISSN: 0282-1990

Department of Energy Science

Faculty of Engineering, LTH

Lund University

Lund, Sweden

June 2026

ABSTRACT

This thesis analyses the role of onshore wind energy in supporting environmental sustainability in Indonesia by evaluating its electricity generation potential, CO_2 emission reductions, development barriers, and policy implications. Thailand is used as a comparative case to identify policy lessons relevant to wind energy development in tropical countries. The study adopts a mixed method approach consisting of a literature review, quantitative analysis, comparative policy assessment, and an analysis of wind energy development under two scenarios: a high-wind scenario and a low-wind scenario. The results indicate that Indonesia possesses considerable onshore wind energy potential that could contribute to electricity generation and CO_2 emission reduction. The analysis of high-wind and low-wind scenarios shows that wind power can support Indonesia's energy transition, although its contribution to the national electricity mix is expected to remain relatively modest. The study identifies grid infrastructure limitations, limited domestic industrial capacity, investment and financing challenges, regulatory and permitting barriers, and social acceptance issues as the main factors hindering wind energy development in Indonesia. The comparison with Thailand demonstrates that policy consistency, investment and financial incentives, effective licensing procedures, and transparent and competitive procurement mechanisms play an important role in accelerating wind energy development. This study concludes that onshore wind energy has the potential to support environmental sustainability and emission reduction in Indonesia. However, its contribution to the national electricity system is relatively small.

Keywords: onshore wind energy, environmental sustainability, renewable energy, CO_2 emission reduction, Indonesia, Thailand, energy transition.

TABLE OF CONTENT

LIST OF TABLES

LIST OF FIGURES

LIST OF ACRONYMS

IEA	International Energy Agency
IRENA	International Renewable Energy Agency
GWEC	Global Wind Energy Council
MEMR	Ministry of Energy and Mineral Resources
IIEE	Indonesian Institute for Energy Economics
NZE	Net Zero Emissions
BESS	Battery Energy Storage System
JETP	Just Energy Transition Partnership
PPA	Power Purchase Agrrement
OSS	Online Single Submission
NRE	New and Renewable Energy
RfP	Request for Proposal
FiT	Feed-in Tariff
AEDP	Alternative Energy Development Plan
ERC	Energy Regulation Comission
PDP	Power Development Plan
OECD	Organisation for Economic Cooperation and Development
IESR	Institute for Essential Services Reform

INDONESIAN ACRONYMS

RUPTL	Rencana Umum Penyedia Tenaga Listrik (Electricity Business Plan)
PLN	Perusahaan Listrik Negara (State Electrical Company)
RUEN	Rencana Umum Energi Nasional (National Energy Plan)
TKDN	Tingkat Komponen Dalam Negeri (Domestic Content Level)
KKPR	Kesesuaian Kegiatan Pemanfaatan Ruang (Suitability of Space Utilization Activities)
BPN	Badan Pertahanan Nasional (National Land Agency)
KEN	Kebijakan Energi Nasional (National Energy Policy)
BPP	Biaya Pokok Penyediaan (Cost of Supply)
DPT	Daftar Penyedia Terseleksi (Selected Provider List)

1. INTRODUCTION

1.1 Background

The global transition toward sustainable energy systems has become an urgent priority in response to climate change, environmental degradation, and increasing energy demand. Energy sector is one of the largest contributors to global greenhouse gas emissions, mainly due to its reliance on fossil fuels for electricity generation (IEA, 2023). In this context, renewable energy technologies play an important role in helping to reduce CO_2 GHG emission, improve air quality, and support long-term environmental sustainability.

Among various renewable energy sources, wind power has emerged as one of the most mature and cost competitive technologies on global scale. Over the past two decades, wind energy has experienced rapid technological advancement and significant cost reductions, making it one of the fastest growing renewable sources for electricity generation worldwide (IRENA, 2022).

However, developments of wind power in large scale are currently only concentrated in regions with strong and relatively stable wind resources, such as, Europe, North American and parts of East Asia (GWEC, 2023). In contrast, the deployment of wind power in tropical countries faces distinct technical and environmental conditions. Tropical regions are characterized by more variable wind regimes influenced by monsoon patterns and seasonal climatic variability (IRENA, 2022). Despite these challenges, many tropical countries possess considerable untapped wind energy potential, particularly in coastal zones, islands, and elevated terrains.

Indonesia as one of the largest archipelagic nation in the world faces dual challenges; meeting rapidly growing electricity demand while restrain the increase in emission rates. Heavily depending on fossil fuel in electrical sector still become a major problem to cut down greenhouse gas emission and air pollution (MEMR, 2024). Although deployment of wind power is still limited compared to others renewable energy technologies. Recent project located in South Sulawesi have demonstrated that wind farm can operate under tropical wind conditions.

Nowadays, coal fired power plants still strongly dominate Indonesia’s electricity system (IRENA, 2022). Although coal-based power generation has supported economic growth and improved access to electricity, it has also had negative impacts on the environment, including greenhouse gas emissions and air pollution. In response to these challenges, Indonesia has committed to increasing the share of renewable energy and reducing emissions in line with the Indonesian government's commitment to achieve net zero emissions (NZE) by 2060 (IIEE, 2023).

Within this context, onshore wind power represents a renewable energy source with increasing strategic relevance for Indonesia. National assessments have identified several regions such as Sulawesi, Nusa Tenggara, and parts of Java as having promising wind resources suitable for electricity generation (MEMR, 2024). The development of projects such as the Sidrap and Jeneponto wind farms indicates that wind energy can be technically viable in Indonesia's tropical climate.

This situation raises an important academic and practical question: to what extent can onshore wind power contribute to a sustainable environment in a tropical country like Indonesia? While there have been many studies on the environmental benefits of wind power in countries with strong winds, fewer studies have examined the environmental impact of wind power in tropical countries, where wind regimes, capacity factors and also system characteristics differ significantly (Swarno et al., 2020). This difference shows that environmental performance and the contribution of wind power must be assessed systematically..

To provide a more comprehensive understanding of wind power development, this study also includes a comparative perspective by using Thailand as a reference case. Thailand is chosen because it shares similar geographical and climatic conditions with Indonesia, particularly as both countries are in tropical regions with comparable wind characteristics. However, despite these similarities, Thailand has made much greater progress in developing onshore wind energy, with around 1.5 GW of installed capacity (ThaiWEA, 2023), while Indonesia's development remains relatively limited. This difference makes Thailand a useful example to understand what factors can support successful wind power deployment, especially in terms of policies.

1.2 Objectives

The study evaluates Indonesia's current onshore wind power contribution and future development scenarios based on the RUPTL 2025–2034 planning period. The overall aim of this study is to examine the role of onshore wind power in advancing environmental sustainability in Indonesia. To achieve this aim, the study pursues the following research questions:

- How much electricity could onshore wind power generate in Indonesia under high-wind and low-wind scenarios, and what would be the corresponding reductions in CO_2 emissions?
- What are the main obstacles and conflicting interests affecting wind power development in Indonesia, and how significant are they under high wind and low wind scenarios?

- What policy lessons could Indonesia draw from Thailand to better promote onshore wind power?

The study aims to empirically assess the environmental contribution of onshore wind power in the Indonesian electricity system, especially in terms of emission reduction and sustainability outcomes. Second, this study seeks to contribute to the academic literature on the deployment of renewable energy in tropical countries. Third, the findings are expected to offer insights for energy planners, policymakers, and stakeholders who are involved in supporting Indonesia's transition toward a more sustainable and low carbon energy system.

To ensure a clear structure of the analysis, each research question is addressed in a specific chapter of this thesis. Research question one, which focuses on the estimation of electricity generation and avoided CO_2 emissions under different scenarios, is discussed in chapter four. Research question two, which examines the main obstacles and conflicting interests affecting wind power development in Indonesia, is analyzed in chapter five. Finally, research question three, which compares Indonesia with Thailand in terms of policies supporting wind power development, is addressed in chapter six. This structure allows for a systematic and coherent analysis of the research objectives.

1.3 Scope of the study

The scope of this study is as follows:

- Only onshore wind energy discussed; offshore wind energy isoutside the scope of the study.
- For the high wind and low wind scenario the year will be referred to in accordance with Electricity Business Plan (RUPTL) released by Indonesia's State Electrical Company (PLN), which is 2025-2034.
- In comparison with Thailand, only the policy aspect is discussed.

1.4 Report structure

The structure of the thesis is arranged as follows:

- Chapter 1 provides the background, objectives, scope, and structure of the report.
- Chapter 2 describes the methodology used in this study.
- Chapter 3 provides the current conditions on wind energy development including the potential of onshore wind energy.

Chapter 4 presents the calculation of today's avoided CO_2 emissions and potential future avoided CO_2 emissions produced by wind turbines in Indonesia. It also includes high wind scenario and low wind scenario.

- Chapter 5 explains the main obstacles in wind energy development in Indonesia and provides recommendations for these obstacles.
- Chapter 6 compares the political aspects with another tropical country: Thailand and provides important insights into what Indonesia can learn from these aspects.
- Chapter 7 concludes the results of this study with the conclusion.

2. METHODOLOGY

2.1 Literature review

This study adopts a qualitative literature review approach to establish a theoretical and empirical foundation for the analysis of wind power and its environmental contribution. The literature review focuses on identifying key concepts, methodologies, and findings related to wind energy, avoided CO_2 emissions, and renewable energy development in tropical countries.

The results of the literature review are used throughout the thesis to support all research questions. The reviewed studies help explain wind power development, identify key challenges, and provide a basis for comparison with Thailand. These findings are discussed in the analysis and discussion chapters.

Relevant literature was collected from multiple sources, including peer reviewed journal articles, international reports, and institutional publications, such as those from the International Energy Agency (IEA), International Renewable Energy Agency (IRENA), World Bank, and the Ministry of Energy and Mineral Resources (MEMR) of Indonesia. Academic literature was searched using ScienceDirect and Lund University's LUBsearch. The search was conducted using keywords such as "onshore wind power", "renewable energy policy", "wind energy development", "CO_2 emission reduction", "Indonesia", and "Thailand". To ensure the relevance of the literature, data collected published in the last ten years.

More than 80 publications were identified in the literature search process, following a screening and relevance assessment, 48 studies were selected and used in this research. For example, Bridle et al (2018) analyzed the policy and investment challenges in Indonesia's renewable energy sector, highlighting barriers related to regulation and financing. In addition, IRENA (2022) provided insights into global wind energy development trends, while the Indonesian Institute for Energy Economics (IIEE, 2023) presented a comprehensive roadmap for wind power development in Indonesia, including current conditions, regulatory frameworks, key challenges, and strategic recommendations for accelerating deployment.

2.2 Quantitative methodology

This study employs a quantitative analytical approach to assess the environmental contribution of wind power in Indonesia, particularly in terms of avoided CO_2 emissions. The quantitative method is used to estimate the current and future potential wind power production and the corresponding emissions reduction based on installed capacity, capacity factors, and grid emission factors. This approach allows for a systematic comparison between current conditions and future development scenarios, including both high wind and low wind scenarios.

2.2.1 Data collection

The analysis in this study is based on secondary data obtained from various reliable sources. These data are used to provide consistency and accuracy in the calculation. The data sources include:

- Wind energy potential data (RUEN)
- National wind energy roadmap
- Grid emission factors from MEMR and international datasets
- Supporting data from academic literature

These datasets are combined to build a comprehensive analytical framework that supports the estimation of current and future environmental impacts of wind power development in Indonesia.

2.2.2 Estimation of Electricity Generation

The official annual electricity generation data for the existing wind farms in Indonesia, particularly the Sidrap and Tolo wind farms, were not publicly available in sufficient detail. Therefore, the electricity generation was estimated using installed capacity data combined with assumed capacity factors and annual operating hours based on commonly used wind power generation calculations. To estimate the annual electricity generation from wind power, a calculation approach is applied based on installed capacity and operational performance. The following equation is used:

$$\boxed{\mathbf{E = Capacity \times CF \times 8760} \qquad \mathbf{Eq\ (1)}}$$

Where:

E: annual electricity generation (MWh/year)

Capacity: installed wind power capacity (MW)

CF: capacity factor

8760: number of hours in a year

The capacity factor is assumed based on typical values for wind energy systems in tropical regions, where wind speeds are generally moderate compared to temperate regions. The capacity factor of onshore wind turbines is 23 - 44 percent (Opoura, 2025). The value of the capacity factor used in the calculation is 35%. This assumption allows for a consistent estimation of electricity output across different locations in Indonesia. Although actual capacity factors may vary depending on site specific conditions such as wind speed distribution and turbine technology, the use of a uniform value ensures comparability in the analysis.

2.2.3 Calculation of Avoided CO_2 Emissions

The environmental contribution of wind power is assessed using the avoided CO_2 emission approach. This method estimates the amount of carbon emissions that can be reduced by replacing conventional fossil fuel-based electricity generation with wind power. The calculation is expressed as follows:

$$\boxed{\textbf{Avoided } \mathbf{CO_2} = \mathbf{E \times EF} \qquad \textbf{Eq (2)}}$$

Where:

E: Annual electricity generation (MWh/year)

EF: Grid emission factor (tCO_2 /MWh)

The grid emission factor reflects the carbon intensity of the electricity system in Indonesia, indicating how much CO_2 is emitted per unit of electricity generated. In the context of Indonesia, this value is relatively high due to the dominance of fossil fuel-based power plants, particularly coal. Therefore, replacing conventional electricity generation with wind power can result in significant reductions in CO_2 emissions. The value of the grid emission factor in Indonesia is 0.78 tCO_2/MWh (Climatiq, 2022).

2.2.4 Scenario Analysis

To evaluate the potential environmental impacts of onshore wind power development by 2034, two development scenarios are defined in this study.

- High wind scenario: This scenario assumes that wind power capacity develops in line with national targets. It represents an optimistic pathway in which technical, financial, and regulatory barriers are effectively addressed, allowing for the full utilization of wind energy potential. The high-wind scenario was developed based on the planned onshore wind power capacity stated in Electricity Business Plan (RUPTL) released by Indonesia's State Electrical Company (PLN) 2025-2034 period, which includes approximately 515.3 MW of future wind power development projects.

- Low wind scenario: This scenario reflects a more conservative development pathway, where wind power expansion occurs at a slower pace and remains below national targets. This condition may result from persistent challenges such as limited investment, infrastructure constraints, and regulatory inefficiencies. the low-wind scenario was constructed using a conservative assumption of 50% of the planned capacity, resulting in an estimated capacity of 257.7 MW. These two scenarios were used to evaluate the potential contribution of wind power under different development conditions.

2.3 Analysis of Obstacles and Conflicting Interests

Analysis of obstacles and conflicts of interest in the development of onshore wind energy in Indonesia was carried out using a qualitative approach based on the literature reviewed in Section 2.1. The analysis focuses on the issues and barriers that most frequently arise in the literature, including power grid limitations, investment and financing challenges, regulation and licensing, limited local industrial capacity, and community social acceptance. These barriers are then analyzed in the context of high-wind and low-wind scenarios to assess their significance to wind energy development in Indonesia.

In addition, this study also analyzes conflicts of interest among key stakeholders, such as the government, State Electrical Company (PLN), private investors, local industries, and local communities, especially related to the determination of energy tariffs, infrastructure development, land use, and Domestic Component Level (DCL) policies. Domestic Component Level (DCL), known in Indonesia as Tingkat Komponen Dalam Negeri (TKDN), is a government policy requiring a minimum share of locally produced goods and services in infrastructure and industrial projects to support domestic industries and reduce reliance on imports.

2.4 Comparative analysis methodology

A comparative analysis methodology is applied in this study to evaluate differences and similarities between Indonesia and Thailand specifically in terms of policy frameworks for onshore wind power development. The comparison is conducted using a qualitative approach based on secondary data, including government regulations, policy documents, and institutional reports. Thailand is selected as a reference case due to its similar tropical climate and wind resource characteristics, while having achieved a more advanced level of wind power deployment.

Currently, Thailand has approximately 1.5 GW of onshore wind power capacity in operation (ThaiWEA, 2023), demonstrating a more mature level of deployment compared to Indonesia. By analysing Thailand’s experience, this study aims to identify key factors that can support or accelerate wind power development in Indonesia.

The analysis focuses on key policy aspects, including policy target, government incentives, licensing processes, and institutional roles that influence the development of wind power. By examining these elements, the study aims to identify policy factors that have supported the successful implementation of wind energy in Thailand. The findings are then used to assess policy gaps in Indonesia and to provide recommendations for improving the regulatory environment to accelerate wind power development.

3. WIND POWER DEVELOPMENT IN INDONESIA

3.1 Current situation

Indonesia generated approximately 306 TWh of electricity in 2023 (RUPTL PLN, 2025). In comparison, the share of installed renewable electricity generation capacity in Indonesia was 14.11% (12.5 GW, including both on-grid and off-grid systems), while solar and wind power accounted for only 185 MW and 154 MW of installed capacity, respectively (Halimatussadiah et al., 2024). Indonesia targets a 29% reduction in greenhouse gas emissions by 2030, equivalent to an emissions reduction of approximately 358 $MtCO_2e$, but emissions reached 723 $MtCO_2$ e by 2022, making it difficult to achieve this goal (IETO, 2025).

Wind power development in Indonesia is still at an early stage compared to other energy sources. Currently, there are two utility scale wind farms in operation, namely Sidrap Wind Farm (75 MW) and Tolo/Jeneponto Wind Farm (72 MW), both located in South Sulawesi. Project level studies have begun to examine operational wind farms in Indonesia. For example, (Khamim Asy'ari et al., 2020a) evaluated of wind turbine installation and development at Sidrap wind farm, South Sulawesi. However, most existing studies focus primarily on technical feasibility or resource assessment, rather than explicitly quantifying the environmental contribution of operational wind power projects within the national electricity system.

Table 1. Electricity generation values two wind farms in Indonesia (Langer et al., 2023)

		Sidrap	Jeneponto
Coordinates		119.71° E 3.99 °S	119.76° E 5.65 °S
Size [MW]		75 MW	72 MW
Number of turbines		30	20
Hub height [m]		80	133
Rotor diameter		114	130
Average 100m wind speed [m/s]	GWA	7.18	6.16
	ERA5	3.21	4.91
Correction factor		2.24	1.26
Start of commercial operation		5th April 2018	14th May 2019
CAPEX [US$ (2017) million]		150	160
Inflation-corrected CAPEX [US$ (2021) million]		162	173
Calculated CAPEX [US$ (2021) million] and deviation [%]		97 (−40%)	106 (−39%)
Recorded electricity generation 2020 [GWh]		473	
Calculated electricity generation 2020 [GWh] and deviation [%]	Uncorrected	181 (−62%)	
	Bias-corrected	494 (+4%)	

As shown in Table 1, the comparison between calculated and recorded electricity generation from the Sidrap and Jeneponto wind farms demonstrates that estimation methods based on installed capacity and wind data can provide reasonable results when appropriate correction factors are applied.

3.2 Wind energy potential in Indonesia

Indonesia has significant wind energy potential due to its geographical location as an archipelagic country with diverse wind pattern. According to Indonesian Institute for Energy Economics (IIEE) and the National Energy Plan (RUEN), the total onshore wind energy potential in Indonesia is estimated to exceed 60 GW (IIEE, 2023).

Several studies focusing on Indonesia emphasize that while the country has considerable wind potential, real deployment remains limited. Hardianto et al (2017) Reported significant wind energy potential at Puger Beach and recommended an optimal turbine layout design based on local wind resource assessment. This study shows that wind power is technically feasible in selected regions. Similarly, Kumar (2016) examined renewable energy development in Indonesia and concluded that wind power could play a growing role in emission reduction.

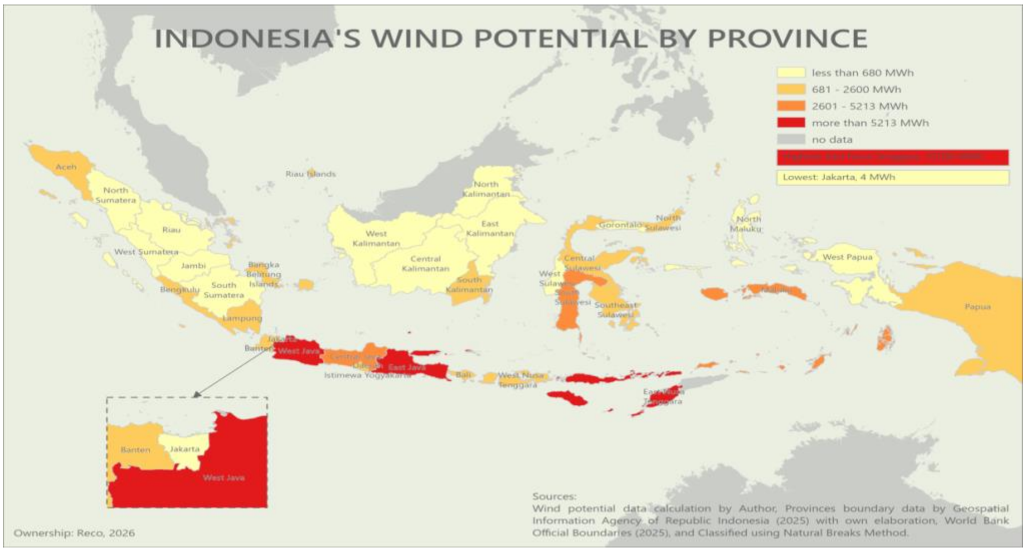

Figure 1. Indonesia's wind potential map by province. Source: Created by the author

The map presented in figure 1 is derived from a combination of multiple sources. The wind energy potential data were collected by the author based on available datasets from IIEE (2023), while the provincial boundary data were obtained from the Geospatial Information Agency of the Republic of Indonesia. Additional geographic references were supported by the World Bank official boundaries dataset (2025). The classification of wind potential levels was conducted using the Natural Breaks method, which groups data into classes based on inherent distribution patterns. This approach allowed for a more accurate representation of spatial variations in wind energy potential across Indonesia.

4. ELECTRICITY GENERATED AND AVOIDED CO_2 EMISSIONS

4.1 Today's Electricity Generated and Avoided CO_2 Emissions

Wind power development in Indonesia is currently represented by two operational wind farms, namely Sidrap wind farm and Tolo wind farm, both located in South Sulawesi. Since detailed official annual electricity generation data for the existing wind farms in Indonesia were not publicly available, this study estimated electricity production using installed capacity data, assumed capacity factors, and annual operating hours following commonly used wind power generation calculation methods (see Eq 1). The avoided CO_2 emissions from these wind farms are estimated based on their annual electricity production, combined with the grid emission factor of the Indonesia electricity system (see Eq 2)

4.1.1 Sidrap Wind Farm

Sidrap wind power farm is the first commercial scale wind power farm built in Indonesia that is in Mattirotasi and Lainungan Villages, Watangpulu district, Sidenreng Rappang Regency, South Sulawesi Province. This wind power farm has a generation capacity of 75 MW, each turbine with a produce capacity of 2.5 MW. The Sidrap wind power farm has 30 turbines and can supply electricity to more than 70,000 customers in South Sulawesi, with an electric power of 900 Volt Ampere (Khamim Asy'ari et al., 2020b).

Table 2. Sidrap wind farm

Site	**Generation Capacity (MW)**	**Capacity Factor**	**MWh/year**	**EF(tCO_2 /MWh)**	**Avoided CO_2 (tCO_2 /year)**
Sidrap Wind Farm	75	0.35	229950	0.78	**179361**

Table 2 shows the potential for electrical energy production and carbon emission reduction from the Sidrap wind farm with an installed capacity of 75 MW. With a capacity factor of 0.35 and a total operating time of 8,760 hours per year, this farm can produce electrical energy of around 229,950 MWh per year. Based on Indonesia's grid emission factor of 0.78 tCO_2/MWh, electricity generated by the Sidrap Wind Farm could avoid approximately 179,361 tCO_2 emissions annually. This shows that the development of wind power plants has a significant contribution in supporting the clean energy transition as well as climate change mitigation efforts.

4.1.2 Tolo Wind Farm

Tolo wind power farm is the second largest wind farm in Indonesia located in South Sulawesi, Indonesia. Located about 6 km inland from the coastline in Jeneponto regency, it has a capacity of 72 MW with 20 wind turbines and has been operating commercially since 2019.

Table 3. Tolo wind farm

Site	Generation Capacity (MW)	Capacity Factor	MWh/year	EF(tCO_2 /MWh)	Avoided CO_2 (tCO_2 /year)
Tolo Wind Farm	72	0.35	220752	0.78	**172186**

Table 3 shows the potential for electrical energy production and carbon emission reduction from the Tolo Wind Farm with an installed capacity of 72 MW. Assuming a capacity factor of 0.35 and a total operating time of 8,760 hours per year, this plant can produce electrical energy of around 220,752 MWh per year. Based on the network emission factor of 0.78 tCO_2/MWh, the use of wind energy at the Tolo wind farm can avoid carbon emissions of 172,186 tons of CO_2 per year. This shows that the Tolo wind farm makes a significant contribution to the provision of clean energy while supporting efforts to reduce greenhouse gas emissions in the electricity sector.

4.2 Potential Electricity Generation and Avoided CO_2 Emissions

To estimates the potential future electricity generation and avoided CO_2 emissions from wind power development in Indonesia, the data based on wind energy potential in 34 provinces in Indonesia with an annual average speed greater than 4 m/s at an altitude of 50 m based on the Roadmap for Onshore Wind Energy Development in Indonesia were used (IIEE, 2023). It should be emphasized that the results presented in this section is a theoretical potential and not a realistic or achievable development scenario in practice. Therefore, the realizable wind energy capacity in Indonesia is likely to be much lower than the theoretical potential shown in this analysis. The analysis uses the estimated wind power capacity in each province to calculate potential electricity generation, applying an assumed capacity factor. The resulting electricity generation is the multiplied by the grid emission factor to determine the avoided CO_2 emissions. This approach allows for a comprehensive assessment of the environmental contribution of wind power at the national level and highlights the regional distribution of emission reduction potential across the country.

Table 4. Potential wind power generation (IIEE, 2023) and avoided CO2 emissions

No	Regional	Annual Production (GWh)	Avoided CO_2 ($MtCO_2$ /year)
1	Java	70,493	54.98
2	Sumatera	22,679	17.68
3	Kalimantan	7,744	6.04
4	Sulawesi	25,273	19.71
5	Nusa Tenggara, Maluku, Bali, Papua	59,753	46.60
	Total	**174,942**	**145.01**

Table 4 shows the estimated total annual electricity production potential and avoided CO_2 emissions from onshore wind power development in Indonesia, As for the details of the calculation for each region, can be found in the Appendix 2. Based on the analysis, the combined onshore wind power potential across the analysed regions could generate approximately 175 TWh of electricity annually. This indicates that wind energy could provide a significant contribution to Indonesia's future electricity supply and support the national renewable energy transition.

In addition, the estimated environmental impact of this potential is substantial, with total avoided CO_2 emissions reaching approximately 145 $MtCO_2$ per year. This result highlights the important role that large-scale onshore wind power development could play in reducing dependence on fossil fuel-based electricity generation and supporting Indonesia's climate mitigation efforts. It is important to note that the wind energy potential estimated in this section represents a theoretical potential or estimated technical potential, not a fully realizable development scenario.

Although the theoretical potential presented in this section provides an overview of the magnitude of onshore wind energy resources available in Indonesia, the realization of this potential in practice will be greatly influenced by various technical, economic, regulatory, and infrastructural factors. Therefore, the next section focuses on more realistic development scenarios to assess the possible contribution of wind energy under different scenarios.

4.3 High wind scenario

The high wind scenario represents an optimistic pathway in which Indonesia utilizes its wind energy potential in line with national energy targets. This scenario was developed based on the planned wind power capacity outlined in PLN's RUPTL 2025–2034, which includes various proposed onshore wind power projects across several regions in Indonesia.

This scenario illustrates a development where wind energy has expanded considerably, and related challenges have been handled successfully. Measurement and modeling of wind resources is carried out accurately and based on reliable long-term data, thereby reducing uncertainty in energy production estimates. In addition, policy and regulatory frameworks have evolved to become more stable, transparent, and consistent, providing certainty for investors and project developers. Infrastructure support has also been adequate, characterized by the readiness of the power grid that is able to integrate wind power plants efficiently and the existence of supporting systems such as energy storage and good logistics access. The combination of these factors creates an ecosystem conducive to wind energy development, where project risks can be minimized, and technical and economic performance can be optimized.

Table 5. PLN's planning (RUPTL PLN, 2025)

No	Project Category	Location	Capacity	Target
1	Wind Power (main)	Sumatera	55 MW	2026
2	Wind Power (main)	Sumatera	55 MW	2028
3	Wind Power (national quota)	Spread	110 MW	2030
4	Wind Power (national quota)	Spread	100 MW	2034
5	Wind Power + BESS	East Nusa Tenggara	30 MW	2027
6	Wind Power + BESS	East Nusa Tenggara	30 MW	2028
7	Wind Power + BESS	East Nusa Tenggara	22 MW	2033
8	Wind Power + BESS	East Nusa Tenggara	3,3 MW	2029
9	Wind Power (additional)	Spread	110 MW	2030-2034
		Total	515.3 MW	

*BESS: Battery Energy Storage System

Based on the General Plan for Electricity Supply (RUPTL) released in 2025 by the State Electricity Company (PLN), the development of wind power plants is planned to be realized in stages until it reaches a total capacity of 515.3 MW. This development includes several project categories, namely Wind Power (main) refers to projects with clearly identified locations and development schedules. Wind Power (national quota), where capacity has been allocated but the project locations have not yet been determined, and Wind Power (additional) which represent future capacity additions beyond the identified main projects.

In the East Nusa Tenggara region, the development of wind power is also combined with an energy storage system (Battery Energy Storage System / BESS), with a total planned capacity of 85.3 MW spread over several stages until 2033. The integration with BESS demonstrates efforts to improve system reliability and address wind energy intermittency. Overall, the plan reflects a phased strategy in wind energy development in Indonesia.

Table 6. High wind scenario electricity generated and avoided CO2 emissions

Scenario	**Capacity (MW)**	**Capacity Factor**	**MWh/year**	**EF(tCO_2 /MWh)**	**Avoided CO_2 (tCO_2 /year)**
High wind	515.3	0.35	1579909.8	0.78	**1232329**

Table 6 shows the results of calculations in the high wind scenario, with a total installed capacity of 515.3 MW, an estimated annual electricity production of around 1.58 TWh is obtained assuming a capacity factor of 0.35 and the number of annual operating hours of 8760 hours. Using a grid emission factor of 0.78 tCO_2/MWh, the potential carbon emission reduction that can be achieved is estimated to reach around 1.23 million tons of CO_2 per year ($MtCO_2$/year**).** These results show that wind energy development in accordance with PLN's could play a meaningful role in supporting Indonesia’s decarbonization efforts, particularly in reducing emissions from coal dominated electricity generation.

The estimated emission reduction of approximately 1.23 $MtCO_2$ per year shows the valuable environmental contribution of wind energy development in a high wind scenario. On average, passenger cars produce 4.6 tCO2/year (EPA, 2025), so this amount of 1.23 MtCO2 is equivalent to removing around 267,000 passenger cars from the road every year. From an environmental perspective, one mature tree can absorb 21 kg of CO2/year (Viessmann, 2022), so the reduction in emissions is also comparable to the ability of about 58 million mature trees to absorb carbon for one year. This comparison shows the potential real impact of large-scale wind energy development in supporting the energy transition and climate change mitigation efforts in Indonesia.

However, this value still depends on the assumption that all installed capacity can operate optimally according to the set capacity factor. In addition, this contribution also reflects the maximum potential in development conditions that run as planned (high wind scenario). Therefore, these results can be used as a reference to compare environmental impacts with more conservative scenarios, as well as to assess the extent to which wind energy can play a role in supporting national decarbonization targets.

Indonesia targets renewable energy mix of 34.3% in electricity generation by 2034 (RUPTL PLN, 2025). This transition is mainly driven by the development of hydro power plants and solar power, which together dominate the planned addition of renewable energy capacity. In contrast, the role of wind power plants in the basic planning scenario is still relatively limited. Based on the projection of total new renewable energy capacity of around 42.6 GW, the contribution of wind energy is estimated to be only around 0.5 GW, or equivalent to around 0.5% of the total energy mix.

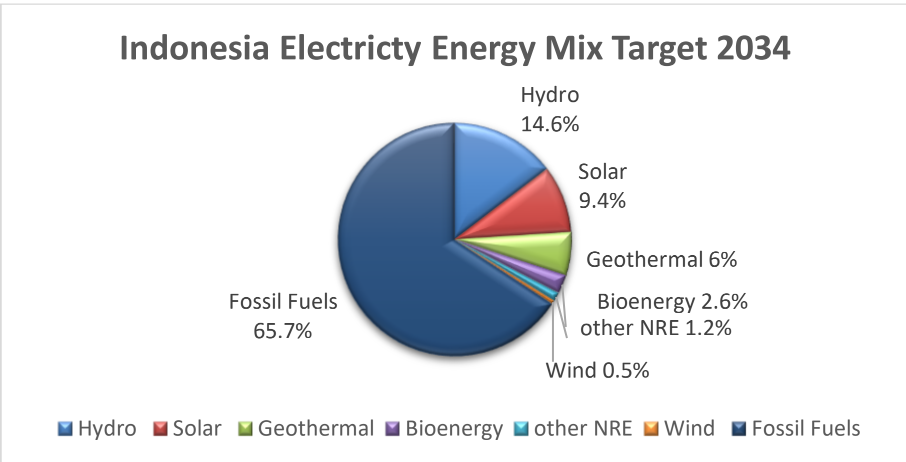

Figure 2. Electricity energy mix target 2034 (RUPTL PLN, 2025)

In the high wind scenario, the role of wind power conceptually achieves the allocation target in the general plan, which reflects the acceleration of the utilization of wind energy potential to diversify the renewable energy portfolio. Although the potential of wind in Indonesia is relatively limited compared to other renewable energy sources, increasing the portion of wind power can provide benefits at the system level, such as geographical diversification of generation, complementary production profiles, and increased flexibility of the electricity system when combined with energy storage technology. Therefore, although the contribution of wind energy in the official planning framework is still small, wind power still has a strategic role in alternative scenarios to realize a more balanced and resilient low-carbon electricity system.

4.4 Low wind scenario

The low wind scenario represents a more modest development pathway for wind power in Indonesia, where the expansion of installed capacity occurs at a slower rate and remains below national targets. This scenario reflects conditions in which existing barriers such as limited investment, regulatory uncertainties, grid constraints, and institutional challenges are not fully resolved. As a result, the deployment of wind power is assumed to reach only a portion of the planned capacity.

In this study, the low wind scenario assumes that wind power development achieves approximately 50% of the national target capacity. Based on this assumption, the installed capacity is used to estimate annual electricity generation using a standard capacity factor, followed by the calculation of avoided CO_2 emissions. The results from this scenario provide a lower bound estimate of the environmental contribution of wind power and serve as a comparison to the high wind scenario.

Table 7. Low Wind Scenario Target

Scenario	**Installed Capacity**	**Description**
Low-wind scenario	257.7 MW	Assumes that only 50% of the planned wind capacity in the RUPTL PLN 2025–2034 is realised by 2034

In the low wind scenario, the development of wind power plants is assumed to run slower than the optimistic plan in the high wind scenario. In this scenario, only part of the capacity planned in PLN's RUPTL can be realized due to various obstacles, such as limited investment, regulatory uncertainty, network infrastructure readiness, and licensing and land acquisition challenges. Based on this assumption, the total capacity of wind power development in the low wind scenario is estimated to reach around 257.7 MW.

This capacity development will continue to be carried out in stages until 2034 and includes several project categories, such as major projects in Sumatra, national quota based projects, and wind power projects integrated with the Battery Energy Storage System (BESS) in the East Nusa Tenggara region. Integration with BESS is maintained in this scenario to support the stability of the power system and improve the reliability of wind energy generation despite its more limited development capacity.

This low wind scenario reflects a more conservative or business-as-usual condition, where wind energy development in Indonesia still faces various structural obstacles that slow down project implementation. Therefore, this scenario is used to provide an overview of the minimum contribution that wind energy can still achieve to electricity production and CO_2 emission reduction in Indonesia if development targets are not fully realized.

Table 8. Low wind scenario electricity generated and avoided CO2 emissions

Scenario	**Capacity (MW)**	**Capacity Factor**	**MWh/year**	**EF(tCO_2 /MWh)**	**Avoided CO_2 (tCO_2 /year)**
Low wind	257.7	0.35	790108	0.78	**616284**

Based on the calculations in the low wind scenario, with a total installed capacity of 257.7 MW, an estimated annual electricity production of around 0.79 TWh is obtained assuming a capacity factor of 0.35 and the number of annual operating hours of 8760 hours. Using a grid emission factor of 0.78 tCO_2/MWh, the potential carbon emission reduction that can be achieved is estimated to reach around 616,284 tons of CO_2 per year or around 0.62 $MtCO_2$/year. These results show that although wind energy development is progressing more slowly than in the high-wind scenario, the contribution to carbon emission reduction is approximately halved.

The estimated avoided emissions of approximately 0.62 $MtCO_2$/year under the low wind scenario still represent a meaningful environmental contribution. This amount is equivalent to removing around 134,000 passenger vehicles from the road annually. From an environmental perspective, the avoided emissions are also comparable to the annual carbon absorption capacity of approximately 29 million mature trees. This shows that even under a conservative wind power development pathway, wind energy can still contribute to emission reduction in Indonesia.

Compared to the high wind scenario, the low wind scenario still shows an increase in wind energy capacity in Indonesia, although on a more limited scale. However, the amount of emission reductions generated in this scenario is only about half of the potential in a high wind scenario. This shows that the level of realization of wind power projects will greatly affect the large contribution of wind energy to decarbonization efforts in the national electricity sector. Thus, the low wind scenario provides an overview of the minimum environmental impact that can still be achieved if wind energy development faces various implementation obstacles in the future.

5. MAIN OBSTACLES AND CONFLICTING INTEREST

Although Indonesia has great wind energy potential and environmental benefits described in the previous chapter, the development of wind energy in Indonesia is still relatively limited. Until now, only a few utility-scale wind power projects have been successfully developed and operated commercially. This shows that the development of wind energy in Indonesia is not only influenced by technical potential, but also by various economic, regulatory, institutional, and infrastructure challenges. In addition, the involvement of many stakeholders with different goals and interests adds complexity to the project development process.

This chapter discusses the main obstacles and conflicts of interest affecting the development of wind energy in Indonesia. The analysis of these barriers was carried out through a qualitative review of academic literature, policy documents, institutional reports, and previous research related to the development of renewable energy and wind energy in Indonesia. The analysis focuses on the issues and barriers that most often arise in the literature, particularly those related to transmission network limitations, investment and financing challenges, regulation and licensing, and inter institutional coordination. In addition, this chapter also discusses how various stakeholders, such as the government, PLN, private investors, and local governments have different priorities that can influence the decision-making process and project implementation.

The significance of these various obstacles is then analyzed in the context of the high wind and low wind scenarios described in the previous chapter. In the high wind scenario, the resolution of these obstacles is an important factor to achieve large-scale wind energy development and maximize the resulting environmental benefits. In contrast, the low wind scenario reflects conditions in which these challenges are still not fully addressed, resulting in slower wind energy development and lower CO_2 emission reductions. Through this discussion, this chapter aims to provide a clearer understanding of the non-technical factors that can determine the role of wind energy in supporting the energy transition in Indonesia.

5.1 Grid and Transmission Constraints

One of the main obstacles in wind energy development in Indonesia is the limited infrastructure of the power grid and transmission system. Most of the regions with the best wind energy potential are in areas relatively far from the main electricity demand centers, such as East Nusa Tenggara and South Sulawesi. The research by Yuwono et al (2025) explained that the development of renewable energy in Indonesia requires expanding the scope of the electricity grid to connect renewable energy sources located in remote areas with the center of electricity demand. The study also emphasized that the construction and improvement of transmission networks requires enormous investment and faces complex economic and geographical challenges.

In addition to transmission limitations, the intermittent characteristics of wind energy are also a challenge for the stability of the electrical system. Electricity production from wind power is highly dependent on wind conditions that can change depending on the weather and season. Research by Alam et al (2020) explained that the large-scale penetration of renewable energy can lead to various technical challenges to grid systems, such as frequency instability, low system flexibility, and increased complexity of power grid control. In the Indonesian context, this challenge becomes more significant because the national electricity system is still dominated by coal-based plants that are relatively less flexible in responding to fluctuations in renewable energy production.

Some studies also emphasize the importance of modernizing the power grid and integrating energy storage technology to support the development of wind energy. Studies by Amiruddin et al (2024) show that the development of a super grid and the integration of a Battery Energy Storage System (BESS) can improve system flexibility and help reduce the cost of the long-term electricity system in Indonesia. In addition, the implementation of smart grids is also considered important to improve the efficiency and ability of the system to integrate variable renewable energy such as wind and solar energy. Research on smart grids in Indonesia shows that infrastructure readiness and regulatory support are still the main challenges in its implementation.

Grid and transmission limitations become increasingly significant in high wind scenarios, where wind energy capacity develops more aggressively according to national development targets. In these conditions, the construction of new transmissions, increased grid flexibility, and investment in energy storage technology are very important to maintain the reliability of the electricity system. On the other hand, in the low wind scenario, infrastructure limitations are one of the main factors that slow down the development of wind energy, making the contribution to reducing carbon emissions lower. Thus, the readiness of the power grid can be considered as one of the main determining factors in the success of wind energy development in Indonesia

5.2 Local Industry and Workforce Challenges

One of the important challenges in wind energy development in Indonesia is the limited capacity of the domestic industry in producing the main components of wind power plants. Until now, only wind turbine tower is produced in Indonesia by Kenertec Power System located in Cilegon, Banten (IIEE, 2023) . Most of the key technologies and equipment for wind energy projects, such as turbines, generators, blades, and control systems, still rely on imports from abroad. This condition shows that the supply chain of the wind energy industry in Indonesia is still not developed optimally. According to Aditya et al (2025), the limitation of domestic manufacturing capacity is one of the obstacles in accelerating the development of renewable energy in Indonesia, especially for relatively new technologies such as wind energy.

Figure 3. Main components of wind turbine (Bilderzwerg – stock.adobe-com, 2022)

Based on the regulation of the Minister of Industry of the Republic of Indonesia number 35 of 2025, Indonesia has enacted the Domestic Content Level (TKDN) policy as an effort to encourage the growth of local industries and create jobs. In their development, wind energy projects could potentially be required to meet this requirement. However, premature implementation can have a negative impact, especially on the availability and supply chain of equipment and materials for the construction of wind power plants, considering that domestic manufacturing capacity is still not fully ready to support these needs. The TKDN in Indonesia's electricity sector generally ranges between 40% and 60% (MoI, 2025) depending on the type of power plant and project components. For wind power projects, achieving this target remains challenging due to the limited domestic manufacturing capacity for key components such as turbines and blades. Bridle et al

(2018) also explained that the implementation of TKDN that is too fast in the renewable energy sector can slow down the development of projects if the capacity of the domestic industry is not ready to support the needs of the necessary technology and equipment.

In addition to manufacturing limitations, the lack of local workers who have special expertise in the field of wind energy is also a challenge in the development of wind power in Indonesia. The development and operation of wind energy projects requires experts in various fields, such as turbine design, installation, operation and maintenance, grid integration, and energy storage systems. However, the availability of human resources with these competencies is still relatively limited in Indonesia. This condition causes project developers to still rely on foreign experts, especially in the construction and commissioning stages of the project. According to IRENA (2023), renewable energy development in developing countries often faces skills gaps, especially for technologies that require specific technical capabilities such as wind energy.

Problems related to the limitations of local industries and competent labor become more significant in the high wind scenario, where wind energy development is carried out on a larger scale and requires stronger industrial capacity. In these conditions, increasing domestic manufacturing capabilities, technology transfer, and developing skilled workforce are important factors to support the acceleration of the development of wind power projects. Conversely, in the low wind scenario, limited industrial capacity and human resources can further slowdown project implementation and lead to a high dependence on technology imports. Therefore, the development of domestic industry and the improvement of the competence of local labor are important aspects in supporting the sustainability of wind energy development in Indonesia.

Table 9. Proposed measures for the development of local knowledge and expertise in wind energy development (IIEE, 2023).

Action	Activity
Identify industry needs and standards	This entails identifying specific skills and certifications required in the wind industry. Positions that may include wind turbine technicians, electrical technicians, safety specialists, and project managers. It is also important to understand industry safety standards and regulatory requirements.
Funding and resources	Getting funding is an important step to start a training program. Funding can come from a variety of sources, including government grants, industry sponsorships, development banks, and international

	funding (e.g. JETP). A variety of resources should be used to design and realize training facilities, equipment, curriculum development, and training materials.
Certification process	A clear set of criteria for certification, including the number of hours of training required, specific skills to master, and written or practical exams to be established. In addition, this may require the establishment of a certification body (or working with an existing Institution) to issue internationally recognized industry certificates.
Internships and practical experience	This includes offering opportunities for on-the-job training or internships on existing (or under construction) wind projects to provide practical experience.
Continuous improvement	This is aimed at ensuring the program is updated in line with the latest industry developments, technological advancements, and changing standards.

As shown in Table 9, developing local knowledge and expertise is essential to support the long-term growth of Indonesia's wind energy sector. This can be achieved by identifying industry skill requirements, providing adequate funding and training resources, establishing certification systems, expanding internship and practical training opportunities, and continuously updating training programs to meet evolving industry standards (IIEE, 2023).

5.3 Investment and Financing Challenges

Investment and financing challenges are one of the main obstacles in the development of wind energy in Indonesia. Compared to conventional power plants, wind power projects require relatively high initial investment costs, especially for turbine procurement, transmission infrastructure development, and integration of supporting systems such as the Battery Energy Storage System (BESS). According to research by Bridle et al (2018) , high start-up costs and policy uncertainty in Indonesia's energy sector are factors that reduce investor interest in renewable energy projects, including wind energy. In addition, investment risks in Indonesia's electricity sector are also affected by regulatory changes, lengthy licensing processes, and uncertainty in electricity tariff schemes.

In Indonesia, electricity tariffs for renewable energy projects are primarily determined through negotiations with PLN under the Power Purchase Agreement (PPA) framework and are subject to government regulations. Unlike countries that apply stable feed-in tariffs or competitive auction mechanisms, tariff determination in Indonesia has changed several times over the years, creating uncertainty for investors. This lack of long-term pricing certainty reduces investment attractiveness and increases the perceived financial risk of renewable energy projects. The study by Aditya et al (2025) explain that regulatory uncertainty, financing limitations, and inconsistent policy implementation remain major barriers to renewable energy investment in Indonesia. This condition makes it difficult for project developers to obtain financing from financial institutions and international investors.

In addition to regulatory and tariff factors, limited access to green financing is also an important challenge. Although international funding for clean energy projects continues to increase, access to such financing in Indonesia is still relatively limited due to the perception of high investment risks. Developing countries often face higher renewable energy financing costs than developed countries due to political, regulatory, and market stability risk factors (IRENA, 2022). In the Indonesian context, this condition causes the capital cost of wind power projects to be more expensive and has an impact on the low competitiveness of wind energy compared to coal-based plants.

Investment and financing challenges are becoming increasingly important in high-wind scenarios, where wind energy development requires much greater capacity expansion in a relatively short period of time. To achieve this target, large-scale investment support, long-term regulatory certainty, and incentive schemes that can increase investor confidence are needed. On the other hand, in the low wind scenario, limited investment and financing cause project development to take place more slowly and the realized capacity becomes smaller. Therefore, the success of wind energy development in Indonesia is highly dependent on the government's ability to create a stable and attractive investment climate for the private sector.

5.4 Regulatory and Permitting Issues

Regulatory and licensing challenges are one of the main factors affecting the slow development of wind energy in Indonesia. Although the government has introduced various policies to support the development of renewable energy, the implementation of regulations on the ground still faces various obstacles. One of the main challenges is the complexity of the licensing process which involves many government agencies and takes a relatively long time. According to Aditya et al

(2025), complex regulatory and bureaucratic uncertainty is one of the main obstacles in attracting renewable energy investment in Indonesia. This condition increases project risk and can reduce investor interest in developing wind power projects.

The government has implemented the Online Single Submission (OSS) system to simplify the business licensing process, including renewable energy projects. However, in practice, some types of strategic permits still require a lengthy administrative process and complex interagency coordination. One of the main examples is the issuance of Suitability of Space Utilization Activities (KKPR), which is an important requirement in the procurement of land for wind energy projects. The KKPR approval process often takes longer than set due to the high number of applications and the evaluation process is centered on the National Land Agency (BPN). Research by Bridle et al (2018) also shows that the licensing and land acquisition process is one of the biggest challenges in the development of renewable energy in Indonesia.

Beside licensing issues, the number of regulations that must be met to build wind power in Indonesia (see Appendix 3) is an obstacle in its development. Frequent regulatory changes also create uncertainty for project developers and investors. Several policies related to renewable energy tariffs, Power Purchase Agreement (PPA) schemes, and Domestic Content Level (TKDN) rules are still inconsistent and can affect the economic viability of wind energy projects. In the context of wind power, the implementation of TKDN too early has the potential to limit the availability of components and equipment because domestic manufacturing capacity for wind energy technology is still relatively limited. According to Aditya et al (2025), energy policy instability and lack of long-term regulatory certainty are one of the main factors slowing down the energy transition in Indonesia.

Quoting from IIEE (2023) one example of a regulation that has changed is on renewable energy tariffs, where the chronological order of change over the last eight years is described below:

- Based on the Regulation of the Minister of Energy and Mineral Resources 50/2017, the new renewable energy (NRE) tariff offered is determined based on the cost of supply (BPP) of generation for each region.
- In several Request for Proposal (RfP) documents for wind projects issued in 2017, PLN indicated that the owner's estimated tariff is lower than the rate regulated by the Minister of Energy and Mineral Resources Regulation No.50/2017.

- In 2022, Presidential Regulation Number 112 of 2022 concerning the Acceleration of the Development of New and Renewable Energy for Power Plants has been issued. According to this regulation, the purchase price of electricity is based on the highest supply tariff, which will be evaluated annually by the Energy and Mineral Resources.

Regulation and licensing issues are becoming increasingly important in the high wind scenario, where accelerating the development of wind energy capacity requires a faster and more efficient project implementation process. In these conditions, regulatory reform, simplification of licensing, and increased coordination between agencies are very important to support the realization of wind energy development targets. On the other hand, in the low wind scenario, various unresolved regulatory obstacles can cause project delays, low investment realization, and limited growth of wind energy capacity in Indonesia. Thus, the effectiveness of policies and licensing systems is one of the key factors in determining the success of wind energy development in the future.

5.5 Social and Community Challenges

Aside from technical, economic, and regulatory challenges, wind energy development in Indonesia also faces various social barriers and challenges related to local communities. The construction of wind power projects generally requires large-scale land and is often located in rural or coastal areas close to community activities. This condition can raise concerns from the community regarding land use, landscape changes, environmental impacts, and economic benefits obtained from the project. Research on wind energy development in Indonesia by Pambudi et al (2025) also shows that local community acceptance is one of the important factors that need to be considered in the development of wind energy projects. The study emphasizes that the optimization of the location of the wind power does not only depend on the potential of wind and access to the power grid but also needs to consider the environmental impact and the acceptance of the local community.

In some cases, local communities can support wind energy projects because they are able to increase regional investment, create jobs, and improve access to infrastructure. However, there is also a potential for conflict if the community feels that they are not involved in the decision-making process or do not get direct benefits from the project being developed. Lindvall (2024) also explained that low community participation and lack of transparency in the development process of renewable energy projects can increase social resistance to the project. Therefore, good communication between project developers, local governments, and local communities is very important to build trust and increase social acceptance of wind power.

In addition, other social issues are related to public perceptions of the environmental and health impacts of wind turbines, such as noise, visual changes in the landscape, and disruption to local activities. Although some studies have shown impacts such as noise, visual changes to the landscape, and disturbances to the surrounding community, most studies have concluded that these impacts are relatively small compared to the environmental benefits resulting from reduced greenhouse gas emissions and reduced use of fossil fuels (US Department Energy, 2024). However, negative public perceptions can still affect the project implementation process if not handled properly. In the Indonesian context, these social challenges become more complex due to the different social and cultural characteristics of the community in each wind energy development area.

Social and community barriers become increasingly important in high wind scenarios, where wind energy development is carried out on a larger scale and involves more regions and local communities. In these conditions, the public consultation process, community involvement, and distribution of economic benefits are important factors to support the success of the project. In contrast, in low wind scenarios, low public acceptance and unresolved social conflicts can slow down project implementation and reduce the realization of wind energy capacity. Thus, the success of wind energy development in Indonesia depends not only on technical and economic aspects, but also on the level of social acceptance and support of local communities.

5.6 Comparative Assessment of Challenges

Although the categories of obstacles faced in high-wind and low-wind scenarios are essentially similar, scale and degree of significance of the obstacles differ quite significantly between the two development paths. Therefore, this section presents a comparative analysis of the barriers that have been identified to assess how their impact differs in different wind energy development conditions as well as to evaluate which barriers are relatively more difficult to overcome in the context of the energy transition in Indonesia.

Table 10 is derived from the analysis presented in Sections 5.1–5.5. The literature reviewed in these sections identifies various challenges related to grid infrastructure, investment and financing, regulatory and permitting issues, local industry capacity, and social acceptance. Based on these findings, the comparison between the high-wind and low-wind scenarios represents the author's qualitative assessment of how the significance of these barriers may differ under different levels of wind power deployment. In general, the low-wind scenario is expected to face similar challenges, but at a smaller scale and with lower complexity than the high-wind scenario.

Table 10. Comparative assessment of challenges under high-wind and low-wind scenarios. Source: Author's analysis based on the literature reviewed in sections 5.1-5.5

Challenge Aspect	High-Wind Scenario	Low-Wind Scenario
Grid Infrastructure	Requires large-scale transmission expansion, grid modernization, and integration of energy storage at the national level.	Most only require local network integration and infrastructure upgrades on a smaller scale.
Investment and Financing	Requires large amounts of long-term domestic and international investment with strong policy certainty	Relying more on small-scale investments with slower project development
Regulatory and Permitting	Requires major regulatory reforms, stronger institutional coordination, and a faster licensing process	Existing regulatory barriers mainly cause implementation delays without requiring a massive transformation of the system
Local Industry	Domestic manufacturing capacity and local supply chains are becoming increasingly important to support large-scale development	Dependence on imports is still relatively manageable because the scale of the project is smaller
Social and Community	Potential for land use conflicts and greater stakeholder resistance due to wider project expansion	Social impact tends to be more local and limited to specific project areas

Table 10 shows the difference between the two scenarios. In a high-wind scenario, the challenges that arise become more complex as the development of wind energy is carried out on a larger scale. For example, large-scale transmission expansion, power grid modernization, and energy storage integration are needed to support higher wind energy penetration in the national electricity system. In addition, this scenario also requires large amounts of long-term investment, stronger regulatory reforms, and more intensive institutional coordination to ensure that the implementation of the project runs smoothly. The development of domestic manufacturing capacity and local supply chains is also becoming increasingly important to support large-scale development while meeting the requirements of the Domestic Component Level (TKDN). On the other hand, the wider expansion of the project also has the potential to increase land-use conflicts and resistance from various stakeholders in some regions.

In contrast, the low-wind scenario reflects more limited development conditions. Most of the challenges in this scenario have to do with the slow implementation of the project compared to the planned needs or targets. Grid integration is still relatively manageable and uses existing grids, while the investment and infrastructure requirements are also smaller than in high-wind scenarios. Dependence on the import of wind energy components is also relatively manageable due to the more limited scale of development. Additionally, social and community impacts in low-wind scenarios tend to be more local and limited to specific project areas. Overall, this comparison shows that the high-wind scenario requires much greater structural, institutional, and infrastructure changes than the low-wind scenario.

In addition to the qualitative differences between high-wind and low-wind scenarios, it is also important to assess the relative difficulty of the obstacles that have been identified. Although all the barriers discussed in this chapter can affect the development of wind energy in Indonesia, some challenges are expected to have a higher level of complexity and are more difficult to overcome than others. Therefore, the following diagram presents a comparative assessment of the level of difficulty of the main obstacles affecting the development of onshore wind energy in Indonesia. The difficulty level assessment in Figure 5 is compiled based on the author's qualitative evaluation using three main criteria, namely: (1) the number of stakeholders involved in the resolution of the obstacle, (2) the amount of investment or financial resources required, and (3) the estimated time required to overcome the obstacle. Obstacles that involve multiple actors, require a large investment, and require a long turnaround time are categorized as having a higher level of difficulty. In contrast, obstacles that involve fewer actors, require lower costs, and can be solved in a relatively short time are categorized as having a medium level of difficulty.

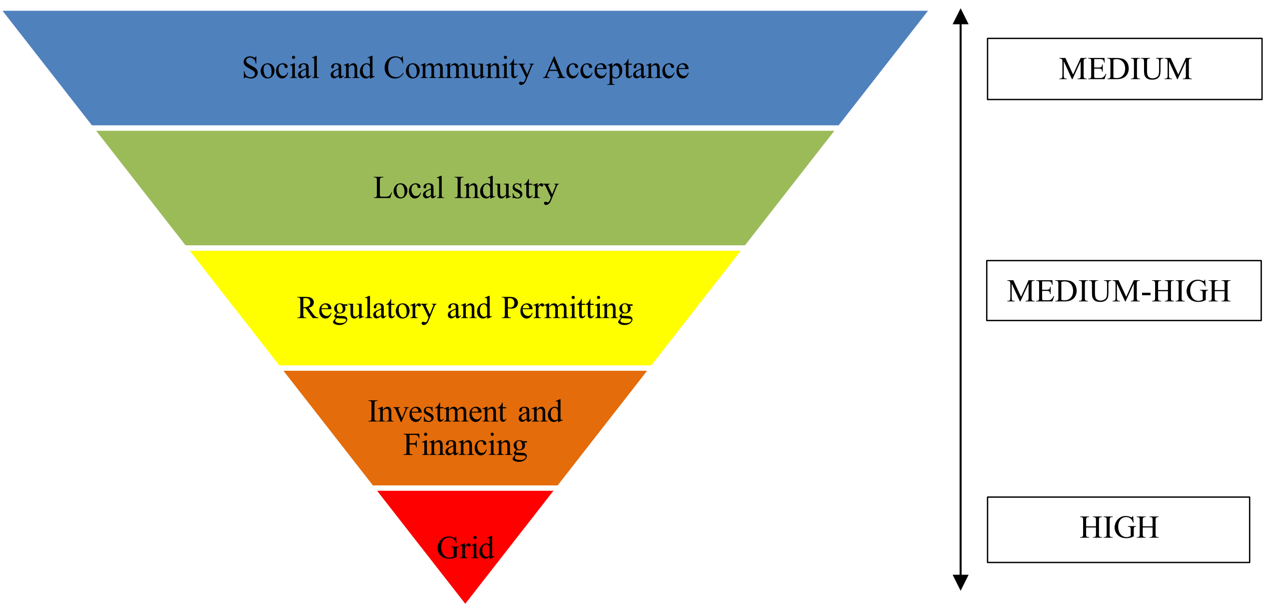

Figure 4. Qualitative assessment of the relative difficulty of onshore wind power development challenges in Indonesia. Source: developed by the author.

Figure 4 shows the relative difficulty of the various major barriers affecting the development of onshore wind energy in Indonesia using the inverted pyramid approach. The diagram shows that downward barriers are considered more difficult to overcome because they have higher structural, financial, and institutional complexity. Grid infrastructure challenges were identified as the most difficult obstacles because large-scale wind energy development requires significant transmission expansion, power grid modernization, energy storage system integration, and long-term infrastructure investment in Indonesia's geographically dispersed electricity system. In addition, the development of the electricity grid also requires strong coordination between the government, PLN, and private investors, thereby increasing the complexity of these challenges.

Investment and financing challenges are also considered very significant because large-scale wind energy development requires large amounts of long-term capital investment, a stable policy framework, and increased investor confidence. Meanwhile, regulatory and licensing issues are also considered to be the main obstacles due to regulatory inconsistencies, long licensing processes, and overlapping authorities between institutions that can slow down project implementation. On the other hand, challenges related to local industrial development are considered to have a medium level of difficulty because Indonesia still has limited domestic manufacturing capacity and experts for wind energy technology, while the Domestic Component Level (TKDN) policy can also increase the complexity and cost of projects.

In addition, social and societal acceptance is considered relatively more manageable than other barriers. While land use conflicts, environmental impact concerns, and community perceptions may still arise in some areas, these challenges have the potential to be addressed gradually through stakeholder engagement, transparent communication, local community participation, and economic benefit-sharing mechanisms. Overall, this analysis shows that the most difficult obstacles to overcome are those that require long-term structural transformation, institutional reforms, and large-scale infrastructure investment, particularly those related to the development of power grids and regulatory systems.

5.7 Conflicting Interests Among Stakeholders

Wind energy development in Indonesia involves a variety of stakeholders with different goals, interests, and priorities. These differences in interests often cause conflicts that can affect the decision-making process, project implementation, and the achievement of renewable energy development targets. According to Bridle et al (2018), the complexity of energy sector governance in Indonesia has led to differences in priorities between the government, PLN, private investors, local governments, and local communities in the development of renewable energy. This condition is one of the factors that slows down the development of wind energy in Indonesia.

It is important to know that there are several stakeholders involved in the development of onshore wind power in Indonesia. These actors have roles and responsibilities in the development of renewable energy and are interrelated in complex ways. Figure 5.1 illustrates the relationship between stakeholders.

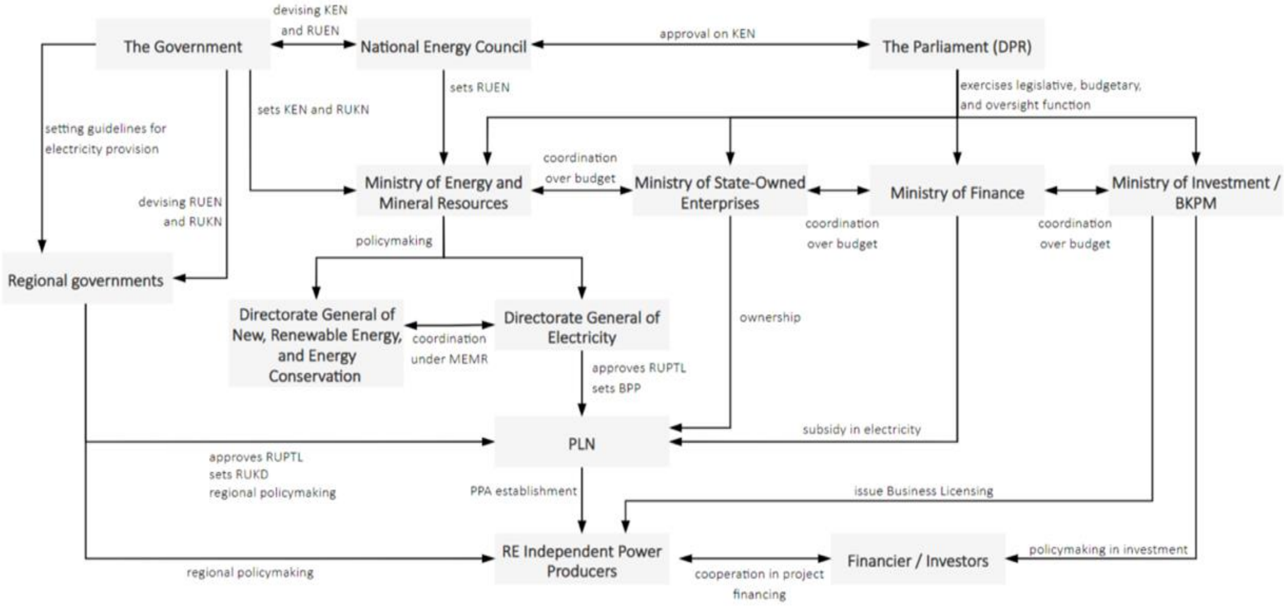

Figure 5. Complex relationships of stakeholders (Simanjuntak, 2021)

Figure 5 shows the complexity of the relationship between stakeholders involved in the governance of renewable energy and the electricity sector in Indonesia. The picture shows that wind energy development is influenced by many institutions with different responsibilities, interests, and levels of authority, creating a highly interconnected and sometimes complex decision-making process. This complexity has the potential to create conflicts of interest, bureaucratic delays, and regulatory uncertainty which can ultimately be the main obstacles in the development of large-scale wind energy in Indonesia.

One of the main conflicts of interest affecting the development of wind energy in Indonesia lies in the difference in goals between the government and PLN in keeping electricity prices affordable and investors need for financially attractive renewable energy tariffs (Bridle et al., 2018). On the one hand, the Indonesian government and PLN are trying to maintain relatively low electricity prices to maintain energy affordability for the community and reduce the financial burden on the state and consumers. On the other hand, private investors need stable and attractive electricity tariffs to ensure project viability, return long-term investment costs, and reduce financial risks in renewable energy development. These differences in priorities create challenges in the Power Purchase Agreement (PPA) negotiation process and can reduce investor confidence and project bankability, especially for large-scale wind energy projects that require high initial investment and long payback periods.

Another conflict of interest in wind energy development in Indonesia is related to the relationship between the Domestic Component Level (TKDN) policy implemented by the government and the interests of wind energy project developers (Bridle et al., 2018). On the one hand, the Indonesian government encourages TKDN policies to strengthen domestic industries, create local jobs, and reduce dependence on imports of renewable energy technology. Through this policy, the government hopes that renewable energy projects will not only support the energy transition, but also contribute to the development of the national industry. On the other hand, wind energy project developers often face difficulties in meeting TKDN requirements because domestic manufacturing capacity and experts in Indonesia are still limited (Bridle et al., 2018). Many of the key components of wind turbines and other supporting technologies still have to be imported because local industries are not yet able to produce them at an adequate scale, quality, and level of cost efficiency. As a result, stringent TKDN requirements can increase project costs, complicate the procurement process, and potentially slow down the implementation of wind energy projects. This creates a trade-off between efforts to support the development of the national industry and the acceleration of renewable energy development, especially for large-scale wind energy projects that require advanced technology and significant investment.

6. COMPARATIVE ANALYSIS WITH THAILAND

Thailand is currently considered one of the most advanced renewable energy development countries in Southeast Asia, particularly in the development of solar energy and wind energy. In recent years, Thailand has developed more than 1.5 GW of installed wind energy capacity which is mostly in the northeastern region of the country (ThaiWEA, 2023) . Wind energy development in Thailand is supported by various policy mechanisms such as Feed-in Tariffs (FiTs), long-term renewable energy planning through the Alternative Energy Development Plan (AEDP), as well as renewable energy procurement programs coordinated by the Energy Regulatory Commission (ERC). These policies help create a relatively stable and attractive investment environment for renewable energy developers and investors. Therefore, Thailand is an important comparative study to understand how policy frameworks and institutional arrangements can support onshore wind energy development in tropical countries.

Thailand's experience in developing wind energy shows that government policies have a very important role in driving the growth of renewable energy. Although Indonesia and Thailand both have relatively similar wind energy potential and geographical characteristics, the development of wind energy in Thailand is much faster than Indonesia's. This difference shows that the success of wind energy development depends not only on the potential of natural resources, but also on the effectiveness of policies and regulations implemented by the government.

Therefore, this chapter discusses some policy lessons that Indonesia can learn from Thailand's experience in promoting onshore wind energy. The focus of the discussion included policy consistency and long-term targets, support for renewable energy investments, the effectiveness of regulations and licensing, and competitive procurement system in renewable energy development . Through this analysis, it is hoped that several policy approaches can be identified that have the potential to help Indonesia accelerate wind energy development and support the transition to a more sustainable energy system.

6.1 Policy Consistency and Long-Term Targets

One of the key factors that differentiates wind energy development in Thailand and Indonesia is the level of policy consistency and clarity of long-term targets set by the government. Thailand is considered more consistent in integrating renewable energy into the national energy strategy through relatively stable long-term policies.

Table 11. Installed renewable capacity and targeted capacity in Thailand's AEDP for 2037.

Fuel	2021 capacity	2037 target capacity
Solar PV	2.9 GW	15.6 GW
Wind	1.4 GW	3 GW
Hydro	2.7 GW	3 GW
Biofuels and waste	2.6 GW	5.8 GW

Thailand has set a specific target for wind energy development through the Alternative Energy Development Plan (AEDP) 2018–2037, with a target of wind energy installed capacity of around 2,989 MW by 2037 (IEA, 2021). The target is also integrated into Thailand's Power Development Plan (PDP), which demonstrates a stronger policy and long-term planning commitment to renewable energy development which provides a clear direction of energy development for investors and project developers. This consistent policy helps create market certainty and increases investor confidence in the development of renewable energy, including wind energy.

On the other hand, Indonesia has also set renewable energy development targets through the National Energy Policy (KEN), the National Energy General Plan (RUEN), and the 2025–2034 PLN RUPTL. In the latest RUPTL, PLN began to increase the portion of renewable energy development, including wind energy, as part of efforts to support the national energy transition and reduce carbon emissions. The 2025–2034 RUPTL includes a plan to develop wind power in stages until it reaches more than 500 MW of installed capacity. However, compared to Thailand, the implementation of renewable energy policies in Indonesia still faces various challenges, such as regulatory changes, uncertainty in tariff mechanisms, and complex licensing processes. According to Aditya et al (2025), lack of policy consistency and frequent regulatory changes are one of the main factors that slow down the development of renewable energy in Indonesia. This condition shows that although the renewable energy development targets have been set, the success of its implementation still depends heavily on policy stability and the effectiveness of regulatory implementation in the field.

Policy inconsistencies can also be seen from changes in wind energy development targets in PLN's RUPTL document. In the 2021-2030 RUPTL, the target capacity of wind power is planned to reach around 597 MW (RUPTL PLN, 2021). However, in the 2025-2034 PLN RUPTL, the planned wind energy development capacity decreased to around 515.3 MW (RUPTL PLN, 2025). This change in target shows that the direction of wind energy development in Indonesia is still undergoing adjustment and is not fully stable in long-term planning. For investors and project developers, significant target changes can create market uncertainty and reduce confidence in the prospects for wind energy development in Indonesia. In contrast, Thailand tends to maintain a more consistent renewable energy policy direction through long-term targets integrated in the AEDP and PDP. Therefore, target consistency and policy stability are important factors that Indonesia needs to strengthen to increase investment attractiveness and accelerate the development of wind energy in the future.

The difference in the level of consistency of this policy can be seen from the development of wind energy capacity in the two countries. Thailand has managed to develop more than 1.4 GW of onshore wind energy, while Indonesia still has relatively small capacity and is limited to several major projects such as Sidrap and Tolo Wind Farm. This shows that the existence of long-term targets alone is not enough, but also the implementation of stable and consistent policies is needed to support the realization of renewable energy projects.

6.2 Investment and Financial Incentives

One of the main factors that differentiates the development of wind energy in Thailand and Indonesia is the investment policies and incentive mechanisms implemented to support renewable energy. Thailand is considered more successful in creating an attractive investment climate through relatively stable tariff policies and consistent government support for renewable energy projects. One of the important policies implemented by Thailand is the use of the Feed-in Tariff (FiT) mechanism, which provides fixed electricity prices and long-term contracts for renewable energy developers, including wind energy. This policy provides income certainty for investors and helps reduce the investment risk of renewable energy projects.

Research on the implementation of Feed-in Tariff (FiT) in Thailand shows that tariff policies that provide long-term electricity price certainty play an important role in increasing investor confidence and accelerating the development of renewable energy (Mohjoh, 2024). However, the effectiveness of the policy also depends on the consistency of regulations and government support in its implementation. Thailand implements a special FiT mechanism for renewable energy, including wind energy, at a rate of around 0.201 USD/kWh (Niyomtham et al., 2022) through long-term electricity purchase and sale contracts. This tariff mechanism provides better income certainty for developers of renewable energy projects and helps increase investor confidence in the clean energy sector.

In contrast to Thailand, the renewable energy tariff mechanism in Indonesia has historically been associated with PLN's Cost of Supply (BPP). Although recent regulations such as Presidential Regulation No. 112 of 2022 have begun to introduce more flexible pricing schemes for renewable energy, BPP is still one of the important references in determining renewable energy electricity tariffs in Indonesia.

In essence, one of the main policy differences between Thailand and Indonesia lies in the mechanism of setting renewable energy tariffs. Thailand implements a more stable Feed-in Tariff (FiT) system with predetermined electricity prices for renewable energy projects, providing greater income certainty for investors. On the other hand, renewable energy tariffs in Indonesia are still largely determined through the negotiation process and mechanisms associated with PLN's electricity generation costs, so that it can increase investment uncertainty and affect the bankability of renewable energy projects.

In addition to tariff mechanisms, Thailand also provides investment support through clearer and more integrated long-term energy planning. Clarity on renewable energy development targets in AEDP and PDP helps create market certainty for investors and financing institutions. According to OECD (2024), Thailand is considered to have more supportive clean energy investment and financing conditions due to the presence of clear long-term energy targets, relatively consistent policy support, and a more structured financing mechanism for renewable energy projects. This condition helps increase the bankability of renewable energy projects in Thailand compared to several other developing countries in the Southeast Asian region.

Thailand and Indonesia implement different renewable energy pricing mechanisms, which ultimately affect project risk, and investor confidence in renewable energy development. A comparison of the renewable energy pricing mechanism between Thailand and Indonesia is summarized by the author in Table 12.

Table 12. Comparison of renewable energy pricing mechanism between Thailand and Indonesia (Compiled by the author based on (Mohjoh, 2024),(Niyomtham et al., 2022), and (OECD, 2024)).

Aspect	Thailand	Indonesia
Pricing Mechanism	Applies a stable FIT system	Tariffs determined negotiations

Tariff Structure	Predetermined	Flexible and case-specific
Investment Risk	Lower investment risk	Higher project risk
Investor Confidence	Stronger investor confidence	Relatively lower

As shown in Table 12, the renewable energy pricing mechanism in Thailand provides a higher level of certainty for investors through a predetermined tariff structure and a more stable FiT system. This approach helps reduce investment risk and increase investor confidence in renewable energy projects, including onshore wind energy development. In contrast, the pricing mechanism for renewable energy in Indonesia is still relatively more flexible and depends on the conditions of each project because tariffs are generally determined through a negotiation process. While such an approach allows adjustments based on project characteristics, it can also increase uncertainty for investors regarding the long-term profitability and financial viability of the project. As a result, the difference in pricing mechanisms can affect the investment climate and the speed of renewable energy development in both countries.

6.3 Regulation and License Effectiveness

One of the important differences between Thailand and Indonesia in renewable energy governance can be seen in the structure of their regulatory and licensing systems. In Thailand, most of the energy sector's regulatory and licensing responsibilities are centralized under the Energy Regulatory Commission (ERC), which serves as an independent energy regulator. The establishment of the ERC through the Energy Industry Act B.E. 2550 helped create a clearer institutional structure by separating policymaking, regulation, and operational functions (Puree Sirasoontorn, 2021). The ERC functions as an independent energy regulator responsible for overseeing licensing, tariff regulation, and oversight of the energy sector. Meanwhile, policy-making functions remain under government institutions such as Ministry of Energy (MOE) and National Energy Policy Council (NEPC), while operational activities are mostly carried out by electricity operators such as Electricity Generating Authority of Thailand (EGAT) (Puree Sirasoontorn, 2021). As a result, renewable energy developers in Thailand generally face a more centralized and coordinated licensing process under a single regulatory authority. This institutional arrangement helps to improve administrative efficiency, reduce overlap of authority, and create greater clarity for investors and project developers alike (Aggarwal & Usapein, 2024)

The licensing and approval process of renewable energy projects in Indonesia involves many institutions with interconnected responsibilities. Renewable energy developers often need to coordinate with the Ministry of Energy and Mineral Resources for electricity business licenses and technical approvals for the energy sector, local governments for location permits and spatial suitability, and PLN for grid connection arrangements and Power Purchase Agreements (PPAs). The involvement of many such institutions can increase administrative complexity, create overlap of authority, and potentially prolong the project development process. As a result, renewable energy developers in Indonesia may face a more fragmented licensing process (Simanjuntak, 2021). In contrast, in Thailand, various regulatory and licensing processes for the energy sector are more centralized through the Energy Regulatory Commission (ERC), which acts as the main regulator of the energy sector. The ERC is responsible for issuing various permits related to energy business activities, including electricity generation licenses, regulation of electricity grid connections, supervision of electricity tariffs, and operational regulation of the electricity sector. This condition helps to simplify licensing coordination, reduce institutional fragmentation, and create a more structured administrative process than in Indonesia (Aggarwal & Usapein, 2024; OECD, 2024).

Thailand's experience shows that increasing the effectiveness of regulation and licensing depends not only on ambitious renewable energy targets, but also on the ability to create clearer institutional coordination and a more efficient administrative system. For Indonesia, improved coordination between institutions, simplification of the licensing process, and increased transparency in the project approval process can help accelerate the development of wind energy and create a more supportive investment environment for renewable energy projects.

6.4 Competitive Renewable Energy Procurement

Another policy lesson that Indonesia can learn from Thailand is the importance of a more competitive, transparent, and clearly scheduled renewable energy procurement system. In the development of renewable energy, procurement mechanisms such as competitive bidding or renewable energy auctions can help create market certainty for investors, increase the transparency of the project selection process, and encourage more competitive electricity prices. In general, (IRENA, 2019) explained that the renewable energy auction mechanism is widely used globally because it can increase competition in project procurement and reduce the cost of technology such as solar PV and onshore wind.

In the case of Thailand, a real example can be seen from the renewable energy procurement program through the 2022–2030 Feed-in Tariff (FiT) scheme. In 2022, Thailand's Energy Regulatory Commission (ERC) issued regulations for the procurement of electricity from renewable energy in the period 2024–2030. The scheme includes the procurement of around 5

GW of renewable energy capacity, including solar, wind, biogas and waste-to-energy, through a more structured selection process (Watson Farley & Williams, 2022). The program provides investors with clear market signals regarding the capacity to be purchased, the development period, and the tariff framework used. With a more open and planned procurement process, investors can better assess project opportunities and prepare financing more definitively.

Another real case is the second round of renewable energy procurement in Thailand through the Renewable Energy Waitlist Scheme in 2024. The scheme provides an additional opportunity for developers who have not been successful in previous procurement rounds to re-enter the renewable energy project selection process (Chavapol Akkaravoranun, 2024). This shows that Thailand is not only setting renewable energy targets but also providing the market with a repeatable and more predictable procurement mechanism. This approach is important because investors need certainty about when the project will be tendered, how much capacity is available, and how the selection process will be conducted.

In contrast, in Indonesia, renewable energy procurement still faces challenges related to transparency, timeline certainty, and complexity of the project selection process. Report by (OECD, 2021) explained that the renewable energy procurement process in Indonesia still needs to be strengthened to be fairer, more efficient, and more transparent for Independent Power Producers (IPPs). The OECD report also highlights that procurement processes under certain mechanisms can be complex, lengthy, and less transparent, which can affect investor interest in renewable energy projects. In addition, the study on renewable energy barriers in Indonesia also shows that procurement issues are one of the main barriers, mainly due to limited procurement volumes, unattractive pricing policies, and processes that are not fully transparent (Halimatussadiah et al., 2024). One of the real cases in renewable energy procurement in Indonesia is the Selected Provider List (DPT) mechanism, which is a prerequisite for developers to participate in renewable energy project tenders. The study highlights that the DPT renewal and selection process is still not fully transparent and does not have a routine and clear schedule for developers (IESR, 2025).

Therefore, Thailand's experience shows that policies in a more structured renewable energy procurement system can be an important instrument to expand the clean energy market and increase investor confidence. For Indonesia, the development of a more scheduled, transparent, and competitive procurement mechanism can help accelerate the development of onshore wind energy. It can also provide greater certainty for project developers regarding investment opportunities, selection processes, and electricity purchase schemes. Thus, reforms in the renewable energy procurement system can be one of the important steps to increase investment attractiveness and accelerate the implementation of wind energy projects in Indonesia.

6.5 Policy Recommendations for Indonesia

Based on the comparison between Thailand and Indonesia, the author summarizes several policy recommendations can be proposed to support the future development of onshore wind power in Indonesia which is illustrated in the table 13 below.

Table 13. Recommendations and actions for wind power development policies in Indonesia

No	Policy Aspect	Recommendations	Action
1	Policy consistency and long-term targets	Strengthen and consistent long-term renewable energy policy and targets.	Develop more consistent and long-term RUPTL planning for renewable energy development
2	Investment and Financial Incentives	Improve renewable energy investment attractiveness and financial support	Provide stable and attractive renewable energy tariffs
3	License effectiveness	Simplify licensing procedures and improve institutional coordination	Simplify renewable energy licensing processes by creating an institution that specializes in licensing
4	Competitive procurement	Developed more transparent and competitive procurement mechanism.	Implemented structured and transparent procurement programs

Table 13 summarizes some policy recommendations and actions that can support the development of onshore wind energy in Indonesia based on lessons learned from Thailand's experience. The first recommendation emphasizes the importance of policy consistency and long-term renewable energy targets. A more consistent and long-term oriented RUPTL can help create greater certainty for investors and improve renewable energy development planning in Indonesia.

The second recommendation focuses on increasing investment attractiveness and financial support for renewable energy projects. The provision of stable and attractive renewable energy tariffs can help improve project bankability, reduce investment risks, and encourage greater private sector participation in wind energy development. In addition, stronger financial support could also help accelerate the development of renewable energy in regions with high wind potential.

The third recommendation relates to improving the effectiveness of the renewable energy licensing system. Simplifying the licensing process through the establishment of a dedicated agency focused on renewable energy licensing can help reduce bureaucratic complexity and improve coordination between institutions involved in the project approval process. This approach also has the potential to speed up the project development process and improve administrative efficiency.

The final recommendation emphasizes the importance of developing a more transparent and competitive renewable energy procurement mechanism. The implementation of a more structured and transparent procurement program can help create clearer market signals, increase investor confidence, and strengthen competition in renewable energy development. Overall, the recommendations show that the acceleration of wind energy development in Indonesia does not only depend on technical potential, but also requires a supportive policy framework, efficient institutions, attractive investment conditions, and transparent market mechanisms.

7. DISCUSSION AND CONCLUSIONS

This study analyzes the role of onshore wind power in supporting environmental sustainability in Indonesia, especially through its contribution to electricity generation and CO_2 emission reduction. The results of the study show that Indonesia has significant onshore wind energy potential, especially in the Sulawesi, Nusa Tenggara, Java, and Sumatra regions. Based on the analysis conducted, the theoretical potential of onshore wind energy in Indonesia is estimated to be able to produce 175 GWh of electricity per year and reduce 145 $MtCO_2$ emissions annually. These results show that wind energy has the potential to make an important contribution to the energy transition and climate change mitigation efforts in Indonesia. While the theoretical potential indicates the maximum available wind resource, the high-wind and low-wind scenarios were developed based on the planned wind capacity in PLN's RUPTL 2025–2034 to represent more realistic implementation pathways.

The analysis of high wind and low wind scenarios also shows how different development pathways can affect the environmental contribution of wind energy in Indonesia. In the high wind scenario that refers to PLN's 2025–2034 RUPTL planning, the installed capacity of wind energy is estimated to reach 515.3 MW, generate 1,6 GWh of electricity per year, and reduce 1.23 $MtCO_2$ emissions per year. In contrast, in the low wind scenario, which assumes slower implementation and unresolved structural barriers, the capacity achieved is only about half of the planned target, so the resulting environmental benefits are also lower. This comparison shows that the level of policy implementation, infrastructure readiness, and investment realization greatly affect the contribution of wind energy to Indonesia's decarbonization goals in the future.

This study also identifies several major obstacles in the development of onshore wind energy in Indonesia. The results of the study show that the limitations of the electricity network and transmission are still one of the most difficult obstacles due to Indonesia's geographically dispersed electricity system and the need for transmission network development and large-scale modernization of the electricity system. Investment and funding challenges are also significant obstacles as renewable energy projects still face regulatory uncertainty, relatively unattractive tariff structures, and limited access to long-term financing. In addition, the complexity of regulations and licensing also slows down the implementation of projects due to the large number of institutions involved and the length of the administrative process. Meanwhile, local industry limitations, labor capacity gaps, and community acceptance issues also affect project development, although these challenges are relatively easier to overcome than infrastructure and investment barriers. Overall, this study shows that the development of wind energy in Indonesia is not only influenced by technical factors, but also by institutional, economic, and social factors.

A comparative analysis with Thailand provides important insights into how policy frameworks and institutional arrangements can affect the development of renewable energy in tropical countries. Although Indonesia has large theoretical wind energy potential, Thailand has achieved more advanced wind energy development because it has stronger policy consistency, more stable investment mechanisms, and clearer institutional coordination. The implementation of long-term renewable energy planning through the Alternative Energy Development Plan (AEDP), a stable Feed-in Tariff (FiT) system, more centralized licensing coordination through the Energy Regulatory Commission (ERC), and a more structured procurement mechanism have helped create a more stable and attractive investment environment for renewable energy developers in Thailand. In contrast, renewable energy development in Indonesia still faces challenges related to policy inconsistencies, licensing complexity, and investment uncertainty. These findings show that strengthening institutional effectiveness and increasing long-term policy certainty are important factors to accelerate the development of renewable energy in Indonesia.

Based on the results of this study, several policy implications can be proposed for Indonesia. First, strengthening the consistency of long-term renewable energy policies through the preparation of a more stable and consistent RUPTL can increase investment certainty and support the development of long-term projects. Second, the provision of more stable and attractive renewable energy tariffs can help improve project bankability as well as encourage greater private sector participation in wind energy investments. Third, simplifying the renewable energy licensing process through strengthening institutional coordination or the establishment of special licensing institutions can help reduce administrative complexity and project delays. Finally, the implementation of a more transparent and competitive renewable energy procurement mechanism can increase investor confidence and strengthen the development of the renewable energy market in Indonesia. These steps can help create a more supportive ecosystem for the development of onshore wind energy in the future.

This research has several limitations. The analysis in this study mainly focuses on policy, and the obstacles development of onshore wind energy, and does not include detailed techno-economic modeling, electricity system simulations, and in-depth financial feasibility analysis. In addition, some of the calculations in this study are still based on assumptions related to capacity factors and development targets due to limited detailed operational data from wind energy projects in Indonesia. Therefore, further research can further explore the techno-economic feasibility of onshore wind energy, potential and feasibility of offshore wind power, power grid integration strategies, energy storage optimization, public acceptance, and comparison of renewable energy development between Southeast Asian countries.

Overall, this study shows that onshore wind energy has significant potential to support environmental sustainability and emission reduction in Indonesia. Nevertheless, wind energy is likely to account for only a relatively small portion of the national electricity mix. The success of wind energy development depends not only on the availability of wind resources, but also requires a supportive policy framework, effective institutions, infrastructure readiness, attractive investment conditions, and transparent market mechanisms. Comparisons with Thailand show that policy consistency, institutional coordination, and investment certainty can play an important role in accelerating the development of renewable energy in tropical countries. Therefore, strengthening these various aspects will be an important step if Indonesia wants to expand the development of onshore wind energy and support the transition to a more sustainable and low-carbon energy system in the future.

REFERENCES

Aditya, I. A., Wijayanto, T., & Hakam, D. F. (2025). Advancing Renewable Energy in Indonesia: A Comprehensive Analysis of Challenges, Opportunities, and Strategic Solutions. *Sustainability (Switzerland)*, *17*(5). https://doi.org/10.3390/su17052216

Aggarwal, S., & Usapein, P. (2024). Regulatory challenge of the license and permission for energy industry operation on renewable energy growth in Thailand. *Journal of Infrastructure, Policy and Development*, *8*(1). https://doi.org/10.24294/jipd.v8i1.2620

Alam, M. S., Al-Ismail, F. S., Abido, M. A., & Salem, A. (2020). *High-Level Penetration of Renewable Energy with Grid: Challenges and Opportunities*. https://doi.org/10.1109/ACCESS.2020.3031481

Amiruddin, A., Dargaville, R., & Gawler, R. (2024). Optimal Integration of Renewable Energy, Energy Storage, and Indonesia's Super Grid. *Energies*, *17*(20). https://doi.org/10.3390/en17205061

Andika Yusni Mubaroh, & Safaat Yulianto. (2025). Pendekatan Data Panel Dalam Menganalisis Pertumbuhan Ekonomi di Pulau Jawa (Panel Data Approach in Analyzing Economic Growth on Java Island). *Jurnal Riset Statistika*, 65–74. https://doi.org/10.29313/jrs.v5i1.7126

Boling, R. A., Tanesib, J. L., Sutaji, H. I., Lapono, L. A. S., & Lewerissa, R. (2024). Re-evaluation of a geothermal system model based on high-resolution gravity field inversion: A case study of the Maritaing geothermal field, Alor Regency, East Nusa Tenggara Province, Indonesia. *Kuwait Journal of Science*, *51*(2). https://doi.org/10.1016/j.kjs.2024.100187

Bridle, R., Gass, P., Halimajaya, A., Lontoh, L., Mcculloch, N., Petrofsky, E., & Sanchez, L. (2018). *Missing the 23 Per Cent Target: Roadblocks to the development of renewable energy in Indonesia GSI REPORT*. www.iisd.org/gsi

Chavapol Akkaravoranun (2024). *Second round of renewable energy auctions set to launch in Thailand*.

Climatiq. (2022). *Indonesia Grid emission factor*. Accessed February 6, 2026, from https://www.climatiq.io/data/emission-factor/b6e5806a-cbb5-4daa-b2d8-d4ed004f4e95

EPA. (2025). *United States Environmental Protection Agency. (2025). Greenhouse gas emissions from a typical passenger vehicle.*

GWEC. (2023). *Global Wind Energy Council Report 2023*. https://www.connaissancedesenergies.org/sites/connaissancedesenergies.org/files/pdf-actualites/GWR-2023_interactive_v2_compressed.pdf

Halimatussadiah, A., Kruger, W., Wagner, F., Afifi, F. A. R., Lufti, R. E. G., & Kitzing, L. (2024). The country of perpetual potential: Why is it so difficult to procure renewable energy in Indonesia? *Renewable and Sustainable Energy Reviews*, *201*. https://doi.org/10.1016/j.rser.2024.114627

Hardianto, T., Supeno, B., Saleh, A., Setiawan, D. K., Gunawan, & Indra, S. (2017). Potential of Wind Energy and Design Configuration of Wind Farm on Puger Beach at Jember Indonesia. *Energy Procedia*, *143*, 579–584. https://doi.org/10.1016/j.egypro.2017.12.730

IEA. (2021). *Thailand's Clean Electricity Transition How accelerated deployment of renewables can help achieve Thailand's climate targets*. www.iea.org

IEA. (2023). *International Energy Agency Report 2023*. https://doi.org/https://iea.blob.core.windows.net/assets/86ede39e-4436-42d7-ba2a-edf61467e070/WorldEnergyOutlook2023.pdf

IEO. (2019). *ISSN 2527 3000*.

IESR. (2025). *Overcoming Energy Transition Barriers with Renewable Energy Procurement Process Reform*.

IETO. (2025). *Imprint Indonesia Energy Transition Outlook 2025 Navigating Indonesia's Energy Transition at the Crossroads: A Pivotal Moment for Redefining the Future*. *5*, 2025. www.iesr.or.id|iesr@iesr.or.id

IIEE. (2023). *20240919-Roadmap-Onshore-Wind-Energy-v5.0_ID*.

IRENA. (2019). *Renewable energy auctions: Status and trends beyond price (preliminary findings)*.

IRENA. (2022). *International Renewable Energy Agency Report 2022*. www.irena.org

IRENA. (2023). *Renewable energy and jobs: Annual review 2023*. www.irena.org

Khamim Asy'ari, M., Indriawati, K., Noriyati, R. D., & Musyafa, A. (2020a). Evaluation of Wind Turbine Installation and Development at Sidrap Wind Farm, South Sulawesi, Indonesia. In *International Journal of Mechanical & Mechatronics Engineering IJMME-IJENS* (Vol. 20).

Khamim Asy'ari, M., Indriawati, K., Noriyati, R. D., & Musyafa, A. (2020b). Evaluation of Wind Turbine Installation and Development at Sidrap Wind Farm, South Sulawesi, Indonesia. In *International Journal of Mechanical & Mechatronics Engineering IJMME-IJENS* (Vol. 20).

Kumar, S. (2016). Assessment of renewables for energy security and carbon mitigation in Southeast Asia: The case of Indonesia and Thailand. *Applied Energy*, *163*, 63–70. https://doi.org/10.1016/j.apenergy.2015.11.019

Langer, J., Zaaijer, M., Quist, J., & Blok, K. (2023). Introducing site selection flexibility to technical and economic onshore wind potential assessments: New method with application to Indonesia. *Renewable Energy*, *202*, 320–335. https://doi.org/10.1016/j.renene.2022.11.084

Lindvall, D. (2024). *How to Build Public Acceptance for Wind Power Across Europe How to Build Acceptance for Wind Power Across Europe*.

MEMR. (2024). *HANDBOOK OF ENERGY & ECONOMIC STATISTICS OF INDONESIA 2023*. https://esdm.go.id/assets/media/content/content-handbook-of-energy-and-economic-statistics-of-indonesia-2023.pdf?

MEMR. (2025). *content-handbook-of-energy-and-economic-statistics-of-indonesia-2024*.

Mohjoh, P. (2024). *The challenge of feed-in-tariff (FIT) policies applied to the The challenge of feed-in-tariff (FIT) policies applied to the development of electricity from sustainable resources-lessons development of electricity from sustainable resources-lessons for Thailand for Thailand*. https://digital.car.chula.ac.th/chulaetdhttps://digital.car.chula.ac.th/chulaetd/73581

MoI. (2025). *permenperin-no-35-tahun-2025*. https://peraturan.bpk.go.id/Details/333003/permenperin-no-35-tahun-2025

Niyomtham, L., Waewsak, J., Kongruang, C., Chiwamongkhonkarn, S., Chancham, C., & Gagnon, Y. (2022). Wind power generation and appropriate feed-in-tariff under limited wind resource in central Thailand. *Energy Reports*, *8*, 6220–6233. https://doi.org/10.1016/j.egyr.2022.04.068

OECD. (2021). *Clean Energy Finance and Investment Policy Review of Indonesia*. OECD Publishing. https://doi.org/10.1787/0007dd9d-en

OECD. (2024). *Clean Energy Finance and Investment Roadmap of Thailand*. OECD Publishing. https://doi.org/10.1787/d0cd6ffc-en

Opoura. (2025). *Wind Power Capacity Factor*.

Pambudi, N. A., Ulfa, D. K., Nanda, I. R., Gandidi, I. M., Wiyono, A., Biddinika, M. K., Rudiyanto, B., & Saw, L. H. (2025). The Future of Wind Power Plants in Indonesia: Potential, Challenges, and Policies. In *Sustainability (Switzerland)* (Vol. 17, Number 3). Multidisciplinary Digital Publishing Institute (MDPI). https://doi.org/10.3390/su17031312

Puree Sirasoontorn. (2021). *Institutional Dynamics of Thai Energy Regulation*.

RUPTL PLN. (2021). *MENTERI ENERGI DAN SUMBER DAYA MINERAL REPUBLIK INDONESIA KEPUTUSAN MENTERI ENERGI DAN SUMBER DAYA MINERAL REPUBLIK INDONESIA*.

RUPTL PLN. (2025). *RENCANA USAHA PENYEDIAAN TENAGA LISTRIK (RUPTL)*.

Sani, L., Khatiwada, D., Harahap, F., & Silveira, S. (2021). Decarbonization pathways for the power sector in Sumatra, Indonesia. In *Renewable and Sustainable Energy Reviews* (Vol. 150). Elsevier Ltd. https://doi.org/10.1016/j.rser.2021.111507

Sarjiya, Putranto, L. M., Tumiran, Budi, R. F. S., Novitasari, D., & Deendarlianto. (2023). Generation expansion planning with a renewable energy target and interconnection option:

A case study of the Sulawesi region, Indonesia. *Renewable and Sustainable Energy Reviews*, *183*. https://doi.org/10.1016/j.rser.2023.113489

Simanjuntak, J. S. (2021). *TECHNO-ECONOMIC AND INSTITUTIONAL ASSESSMENT OF WIND ENERGY IN INDONESIA A spatial evaluation of wind energy potential and its pertinent institutions*.

Swarno, H. A., Zaki, S. A., Hagishima, A., & Yusup, Y. (2020). Characteristics of wind speed during rainfall event in the tropical urban city. *Urban Climate*, *32*. https://doi.org/10.1016/j.uclim.2020.100620

ThaiWEA. (2023). *Thailand onshore wind power installed capacity*.

US Department Energy. (2024). *How wind power helps us breathe easier*.

Viessmann. (2022). *How much CO_2 does a tree absorb?*

Watson Farley & Williams. (2022). *Thailand's 5 GW renewable PPA FiT scheme: 2022–2030.*

Yuwono, B., Kranzl, L., Haas, R., Dewi, R. G., Siagian, U. W. R., Kraxner, F., & Yowargana, P. (2025). Incorporating grid development in capacity expansion optimisation - a case study for Indonesia. *Applied Energy*, *378*. https://doi.org/10.1016/j.apenergy.2024.124837

APPENDIX 1 – AI Contribution Statement

Artificial Intelligence (AI) tools, specifically ChatGPT were used in a limited and supportive capacity during the preparation of this thesis. The AI tool was primarily utilized for language improvement, grammar checking, sentence restructuring, and enhancing the clarity and coherence of academic writing. In addition, AI assistance was occasionally used to support brainstorming and improving the organization of several sections of the thesis.

All research design, data collection, analysis, interpretation of results, figures, tables, arguments, and final conclusions were independently conducted and critically reviewed by the author. The author takes full responsibility for the accuracy, originality, and academic integrity of the content presented in this thesis.

APPENDIX 2 – Detail Calculations of Electricty Generation and Avoided CO_2

Java Island

Java islands is the most progressive area in Indonesia, the largest economic contribution in Indonesia is supported by this area with a value of 61.67% of the total gross regional domestic product (Andika Yusni Mubaroh & Safaat Yulianto, 2025). However, currently power plants on the island of Java are dominated by coal, while the potential for wind energy in this region is quite high.

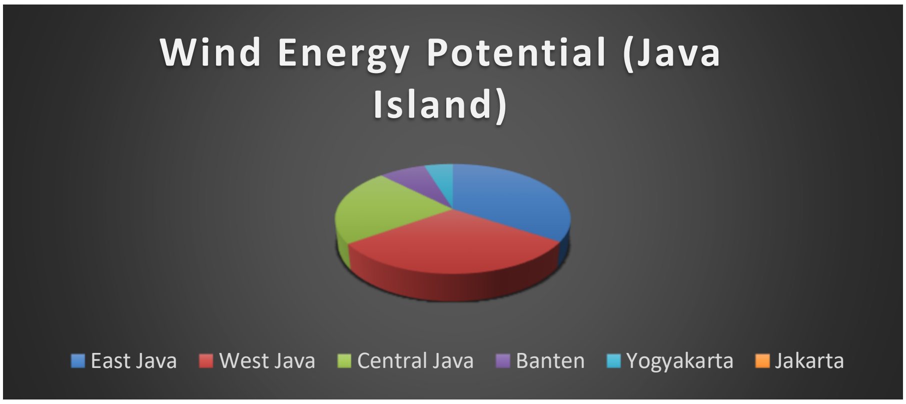

Figure 6. Wind energy potential in Java Island (IIEE, 2023)

Figure 6 further illustrates the dominance of East Java and West Java in the overall wind energy potential, indicating that these provinces play a significant role in the development of wind power on the island. Overall, the distribution highlights the uneven spatial potential of wind energy across Java.

Table 1. Wind energy potentials in Java Island (IIEE, 2023), and based on a capacity factor of 0.35 and grid emission factor of 0.78.

Province	Wind Energy Potential (MW)	TWh/year	Avoided CO_2 (tCO_2 /year)
East Java	7907	24.24	**18909432**
West Java	7036	21.57	**16826453**
Central Java	5213	15.98	**12466785**
Banten	1753	5.7	**4192264**
Yogyakarta	1079	3.3	**2580406**
Jakarta	4	0.01	**9565**
			54984908

Table 14 presents the estimated avoided CO_2 emissions from wind energy potential across provinces in Java Island, the total potential avoided emissions reach approximately 54.98 million tCO_2 /year. Indicating a significant environmental benefit from wind energy deployment in the region. East Java contributes the largest share with 18.91 million tCO_2 /year. Overall, the results highlight that the majority of emission reduction potential in Java is concentrated in provinces with higher energy capacity, particularly East Java.

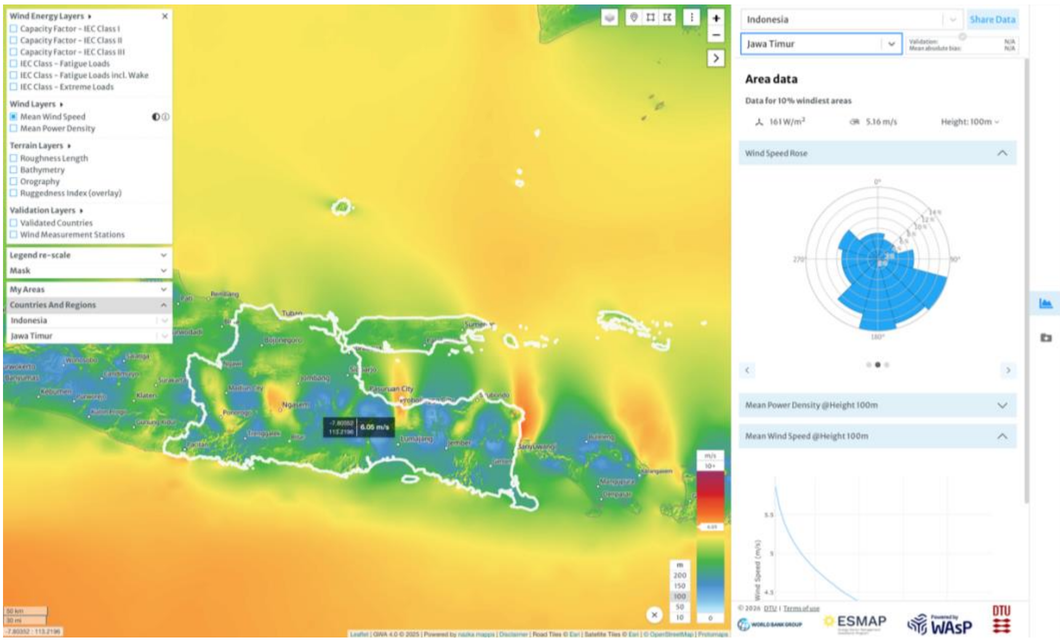

Figure 7. East Java wind condition (Global Wind Atlas)

Referring to the wind condition map taken from the Global Wind Atlas as illustrated in figure 8, the highest wind potential is observed in the coastal area around Probolinggo City, where the average wind speed reaches approximately 6 m/s at height of 100 meters. Indicating that Probolinggo has more favorable wind conditions for wind energy development. The relatively strong and consistent wind speed in this region suggests a higher potential for electricity generation from wind power, making it a promising location for future wind energy projects in East Java.

Sumatera island

Sumatera island is the second most populated island in Indonesia (Sani et al., 2021). The grid in Sumatra supports large electricity demand (15% of the national demand) and is located close to abundant renewable resources that could be exploited for electricity generation (IEO, 2019).

Table 2. Wind energy potential in Sumatera Island (IIEE, 2023)

No	Province	Wind Energy Potential (MW)
1	Bangka Belitung	**1787**
2	Bengkulu	**1513**
3	Lampung	**1137**
4	Riau Islands	**922**

5	Aceh	**894**
6	West Sumatera	**428**
7	North Sumatera	**356**
8	South Sumatera	**301**
9	Jambi	**37**
10	Riau	**22**
	Total	**7397**

Table 15 presents the distribution of wind energy potential across provinces in Sumatra Island based on data from IIEE (2023). The total wind energy potential in the region is estimated at 7,397 MW, indicating a moderate contribution compared to other regions in Indonesia. Bangka Belitung has the highest potential at 1,787 MW, followed by Bengkulu at 1,513 MW. In contrast, Provinces like Jambi and Riau have very limited wind energy resources with only 37 MW and 22 MW respectively.

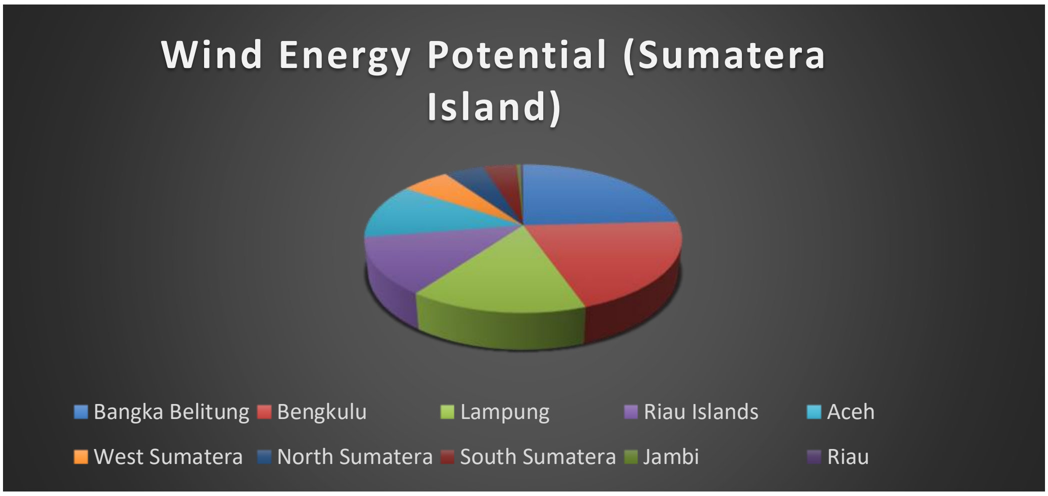

Figure 8. Wind energy potential in Sumatera Island (IIEE, 2023)

Figure 8 illustrates the distribution of wind energy potential across provinces in Sumatera Island based on IIEE (2023). The pie chart clearly shows that Bangka Belitung and Bengkulu dominate the overall wind energy potential. Meanwhile, Jambi and Riau account for only a small proportion of the total potential. The visual distribution highlights the uneven spatial pattern of wind resources in Sumatera, with a concentration of higher potential in coastal and island regions.

Table 3. Avoided CO_2 emissions in Sumatera Island

Province	Wind Energy Potential (MW)	Capacity Factor	Hours in year	MWh/Year	Grid Emission Factor (tCO_2 /MWh)	Avoided CO_2 (tCO_2 /year)
Bangka Belitung	1787	0.35	8760	5478942	0.78	**4273574**
Bengkulu	1513	0.35	8760	4638858	0.78	**3618309**
Lampung	1137	0.35	8760	3486042	0.78	**2719112**
Riau Islands	922	0.35	8760	2826852	0.78	**2204944**
Aceh	894	0.35	8760	2741004	0.78	**2137983**
West Sumatera	428	0.35	8760	1312248	0.78	**1023553**
North Sumatera	356	0.35	8760	1091496	0.78	**851366**
South Sumatera	301	0.35	8760	922866	0.78	**719835**
Jambi	37	0.35	8760	113442	0.78	**88484**
Riau	22	0.35	8760	67452	0.78	**52612**
					Total	**17689777**

Table 16 presents the estimated avoided CO_2 emissions from wind energy potential across provinces in Sumatera Island, calculated using a capacity factor 0.35 and a grid emission factor of 0.78 tCO_2 /MWh. The total potential avoided emissions are estimated at approximately 17.69 $MtCO_2$ /year, indicating a notable environmental contribution from wind energy in the region.

Kalimantan Island

Kalimantan island, precisely in the province of East Kalimantan, has the largest coal reserves in Indonesia, approximately 36.2 million tons, or 41.3% of the national coal reserves (MEMR, 2025). With the abundance the coal reserves make the wind potential on this island neglected.

Table 4. Wind energy potential in Kalimantan Island (IIEE, 2023)

No	Province	Wind Energy Potential (MW)
1	South Kalimantan	**1006**
2	Central Kalimantan	**681**
3	West Kalimantan	**554**
4	East Kalimantan	**212**
5	North Kalimantan	**73**
	Total	**2526**

Table 17 presents the distribution of wind energy potential across provinces in Kalimantan Island based on data from IIEE (2023). The total wind energy potential in the region is estimated at 2526 MW, which is relatively lower compared to other major islands in Indonesia. Among provinces, South Kalimantan shows the highest potential at 1006 MW, opposite with North Kalimantan has lower wind energy potential at 73 MW.

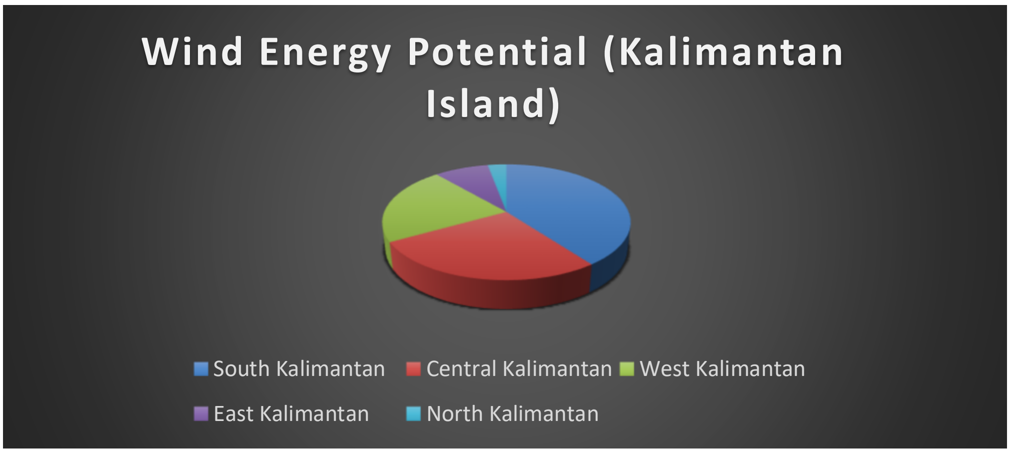

Figure 9. Wind energy potential in Kalimantan Island (IIEE, 2023)

Figure 9 illustrates the distribution of wind energy potential across provinces in Kalimantan Island. The chart shows that South Kalimantan accounts for the largest share of wind energy potential, followed by Central Kalimantan and West Kalimantan, which also has significant portions. In contrast, East Kalimantan and North Kalimantan represent relatively small shares of the total potential. The visual representation confirms the uneven distribution of wind resources across the island, with a clear concentration in the southern and central regions. The dominance of South Kalimantan highlights its strategic importance for future wind energy development in Kalimantan, while other provinces may have more limited opportunities due to lower wind resource availability.

Table 5. Avoided CO_2 emissions in Kalimantan Island

Province	**Wind Energy Potential (MW)**	**Capacity Factor**	**Hours in year**	**MWh/year**	**Grid Emission Factor (tCO_2 /MWh)**	**Avoided CO_2 (tCO_2 /year)**
South Kalimantan	1006	0.35	8760	3084396	0.78	**2405828.88**
Central Kalimantan	681	0.35	8760	2087946	0.78	**1628597.88**
West Kalimantan	554	0.35	8760	1698564	0.78	**1324879.92**
East Kalimantan	212	0.35	8760	649992	0.78	**506993.76**
North Kalimantan	73	0.35	8760	223818	0.78	**174578.04**
					Total	**6040878.48**

Table 18 presents the estimated avoided CO_2 emissions from wind energy potential across provinces in Kalimantan Island, calculated using a capacity factor of 0.35 and a grid emission factor of 0.78 tCO_2 /MWh. The total potential avoided emissions are estimated at approximately 6.04 million tCO_2 /year, indicating a relatively modest contribution compared to other major islands in Indonesia. Among the provinces, South Kalimantan contributes the largest share with approximately 2.41 million tCO_2 /year. Overall, the result highlight that the emission reduction potential in Kalimantan is relatively limited and unevenly distributed.

Sulawesi Island

Sulawesi is a strategic economic region in eastern Indonesia that is facing high growth in electricity demand (Sarjiya et al., 2023). Based on the existing power generation conditions in Sulawesi, the energy mix still dominated by coal at 44% (RUPTL PLN, 2021). Two wind power plants that are already operating in South Sulawesi prove that the potential of wind in this region can be very utilized.

Table 6. Wind energy potential in Sulawesi Island (IIEE, 2023).

No	Province	Wind Energy Potential (MW)
1	South Sulawesi	**4193**
2	Southeast Sulawesi	**1414**
3	North Sulawesi	**1214**
4	Central Sulawesi	**908**
5	West Sulawesi	**514**
	Total	**8243**

Table 19 presents the distribution of wind energy potential across provinces in Sulawesi Island based on data from IIEE (2023). The total wind energy potential in the region is estimated at 8243 MW, indicating a relatively significant contribution compared to other regions in Indonesia. Among the provinces, South Sulawesi shows the highest potential at 4193 MW, accounting for more than half of the total wind energy capacity on the island. On the other hand, West Sulawesi has lower potential at 514 MW.

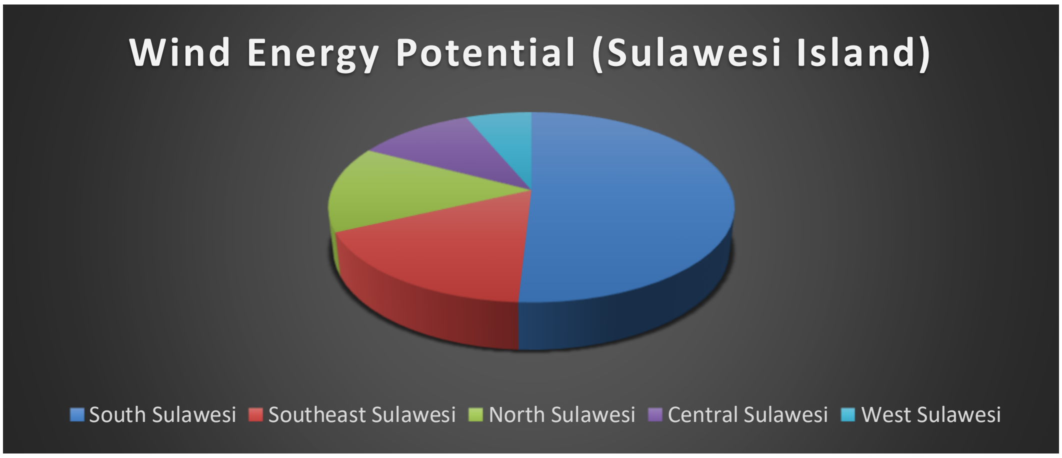

Figure 10. Wind energy potential in Sulawesi Island (IIEE, 2023).

Figure 10 illustrates the distribution of wind energy potential across provinces in Sulawesi Island. The chart clearly shows that South Sulawesi dominates the overall wind energy potential, contributing the largest share among all provinces. Meanwhile, West Sulawesi contribute relatively smaller shares. The visual distribution highlights the uneven spatial pattern of wind resources in Sulawesi, with a strong concentration in South Sulawesi. That suggests that future wind power development in the island is likely to be focused in this region, where wind conditions are more favorable.

Table 7. Avoided CO_2 emissions in Sulawesi Island

Province	**Wind Energy Potential (MW)**	**Capacity factor**	**Hours in year**	**MWh/year**	**Grid Emission Factor (tCO_2 /MWh)**	**Avoided CO_2 (tCO_2 /year)**
South Sulawesi	4193	0.35	8760	12855738	0.78	**10027475.64**
Southeast Sulawesi	1414	0.35	8760	4335324	0.78	**3381552.72**
North Sulawesi	1214	0.35	8760	3722124	0.78	**2903256.72**
Central Sulawesi	908	0.35	8760	2783928	0.78	**2171463.84**
West Sulawesi	514	0.35	8760	1575924	0.78	**1229220.72**
					Total	**19712969,64**

Table 20 shows the estimated avoided CO_2 emissions from wind energy potential across provinces in Sulawesi Island, calculated using a capacity factor of 0.35 and a grid emission factor of 0.78 tCO_2 /MWh. The total avoided emissions are estimated at approximately 19.71 million tCO_2 /year, indicating a substantial environmental contribution compared to other regions in Indonesia. Among the provinces, South Sulawesi contributes the largest share with 10.03 million tCO_2 /year. Overall, the result highlight that the emissions reduction potential in Sulawesi is strongly concentrated in South Sulawesi, reinforcing its importance as a key region for wind power development in Indonesia.

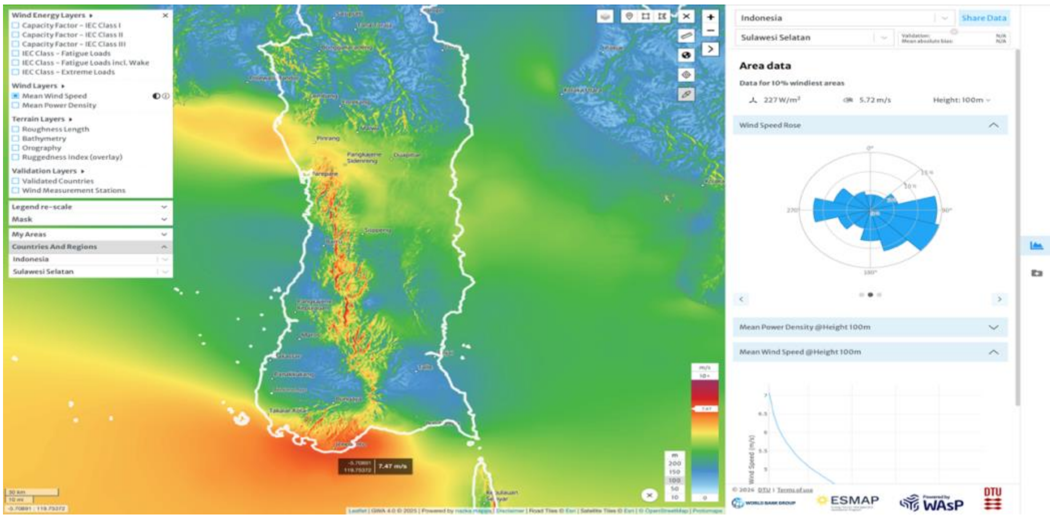

Figure 11. South Sulawesi wind condition (Global Wind Atlas)

Figure 12 outlines the wind conditions in South Sulawesi based on data from the Global Wind Atlas. The map shows a clear spatial variation in wind speed, with the highest wind potential in the southern coastal region, particularly in Jeneponto, where the average wind speed reaches 7.47 m/s at a height of 100 meters. This indicates highly favorable conditions for wind energy development compared to other areas in the region. The strong wind resource in Jeneponto has already been utilized, as evidenced by the operation of the Tolo Wind Farm with an installed capacity of 72 MW. This confirms that regions that regions with higher wind speeds are more likely to attract wind power development and highlights the importance of resource availability in determining the location of wind energy projects in Indonesia.

Nusa Tenggara, Maluku, Bali dan Papua

A study from (Boling et al., 2024) states that the east Nusa Tenggara has the potential for geothermal energy reaching 700 MW. However, there has been no study that shows that the highest wind energy potential in Indonesia comes from this region.

Table 8. Wind energy potential in Nusa Tenggara, Maluku, Bali, and Papua (IIEE, 2023).

No	Province	Wind Energy Potential (MW)
1	East Nusa Tenggara	**10188**
2	Maluku	**3188**

3	West Nusa Tenggara	**2605**
4	Papua	**1411**
5	Bali	**1019**
6	North Maluku	**504**
7	West Papua	**437**
8	Gorontalo	**137**
	Total	**19489**

Table 21 presents the wind energy potential across regions in Eastern Indonesia, including Nusa Tenggara, Maluku, Bali, and Papua, based on data from IIEE (2023). The total wind energy potential in these regions is estimated at 19489 MW, representing a substantial contributing to Indonesia's overall wind resource. Among the provinces, East Nusa Tenggara exhibits the highest potential at 10188 MW. On the contrary the province with smaller shares wind energy potential is Gorontalo with 137 MW.

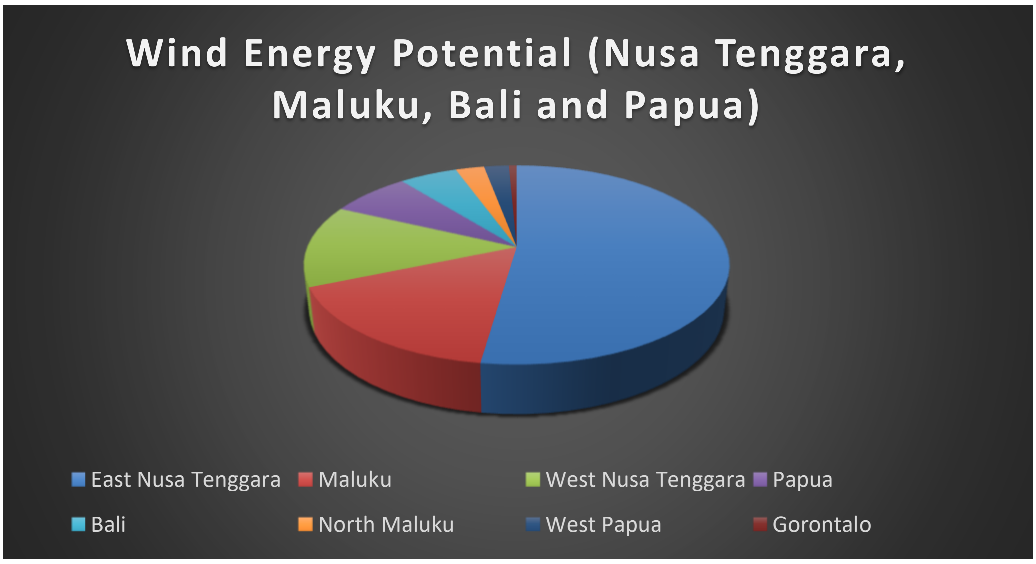

Figure 12. Wind energy potential in Nusa Tenggara, Maluku, Bali, and Papua (IIEE, 2023)

Figure 12 demonstrates the distribution of wind energy potential across regions in Musa Tenggara, Maluku, Bali, and Papua. The chart clearly shows that East Nusa Tenggara dominates the overall wind energy potential, contributing the largest share among all regions. The visual distribution highlights the uneven spatial pattern of wind resources in Eastern Indonesia, with a strong concentration in East Nusa Tenggara, making it a key region for future wind power development.

Table 9. Avoided CO_2 emissions in Nusa Tenggara, Maluku, Bali, and Papua

Province	**Wind Energy Potential (MW)**	**Capacity factor**	**Hours in year**	**MWh/year**	**Grid Emission Factor (tCO_2 /MWh)**	**Avoided CO_2 (tCO_2 /year)**
East Nusa Tenggara	10188	0.35	8760	31236408	0.78	**24363398.24**
Maluku	3188	0.35	8760	9774408	0.78	**7624038.24**
West Nusa Tenggara	2605	0.35	8760	7986930	0.78	**6229805.4**
Papua	1411	0.35	8760	4326126	0.78	**3374378.28**
Bali	1019	0.35	8760	3124254	0.78	**2436918.12**
North Maluku	504	0.35	8760	1545264	0.78	**1205305.92**
West Papua	437	0.35	8760	1339842	0.78	**1045076.76**
Gorontalo	137	0.35	8760	420042	0.78	**327632.76**
					Total	**46607553.72**

Table 22 shows the estimated avoided CO_2 emissions from wind energy potential across regions in Nusa Tenggara, Maluku, Bali, and Papua, calculated using a capacity factor of 0.35 and a grid emissions factor of 0.78 tCO_2 /MWh. The total potential avoided emissions are estimated at approximately 46.61 million tCO_2 /year, indicating a substantial environmental contribution from wind energy in Eastern Indonesia. Among the regions, East Nusa Tenggara contributes the largest share with around 24.36 million tCO_2 /year and Gorontalo show smaller contributions with only 0.33 million tCO_2 /year due to their lower wind energy potential. In general, the result highlight that the emission reduction potential in these regions is in East Nusa Tenggara, emphasizing its importance as a key area for future wind power development in Indonesia.

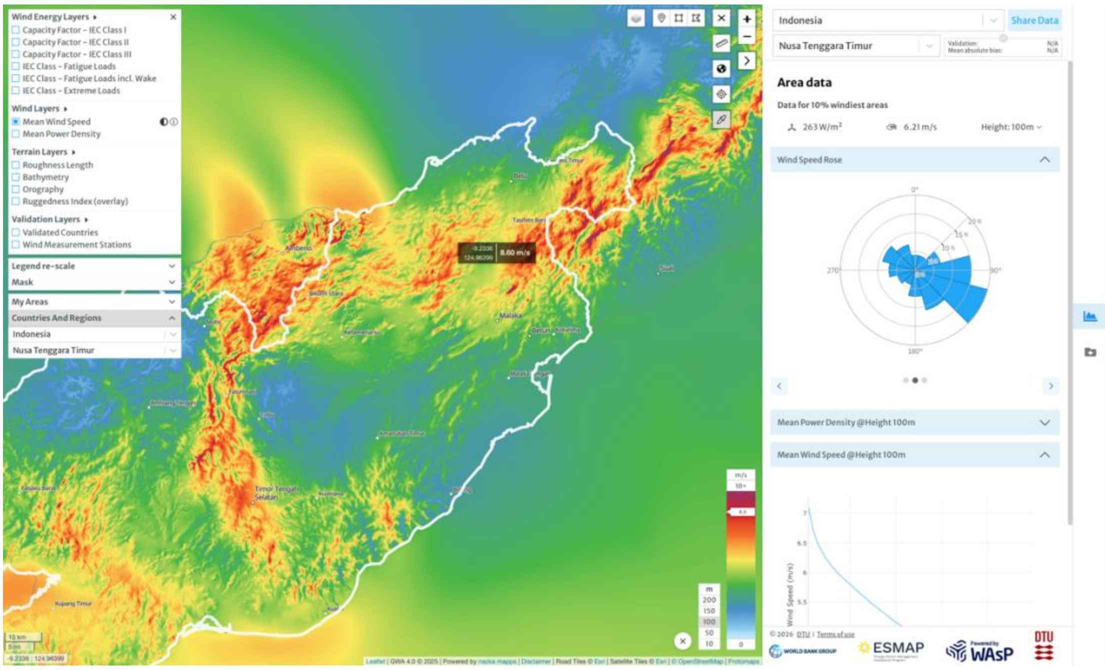

Figure 13. East Nusa Tenggara wind condition (Global Wind Atlas)

Figure 13 illustrates the wind conditions in East Nusa Tenggara based on map from Global Wind Atlas. The map shows a strong spatial variation in wind speed, with the highest wind potential concentrated along coastal and elevated areas. In particular, West Tasifeto, located in Belu regency, exhibits the highest wind speed in the region, reaching 8.60 m/s at a height of 100 meters. This value indicates exceptionally favourable wind conditions compared to other areas in Indonesia. Such strong and consistent wind resources make West Tasifeto a highly promising location for the development of wind power plants. The presence of high wind speeds in this area highlights its strategic importance for future renewable energy projects and supports its potential role in contributing significantly to Indonesia’s wind energy expansion

APPENDIX 3 – Regulations Wind Energy Development in Indonesia

The table below highlights some of the relevant regulations regarding wind energy development. These regulations are in the form of laws, government regulations, presidential regulations, and ministerial regulations.

Table 10. Regulations related to wind energy development (IIEE, 2023)

NO	REGULATION	SUBJECT	DESCRIPTION
General			
1	Law No.30 of 2007	Energy	It regulates the management of energy resources, energy reserves for energy security, the authority of the central and regional governments in regulating energy.
2	Government Regulation No.79/2014	National Energy Policy	The target is to increase the portion of new and renewable energy in the primary energy mix to 23% by 2025 and 31% by 2050.
3	Presidential Regulation No.22/2017	National Energy General Plan	Description and plan to implement national and cross-sectoral energy policies in order to achieve national energy policy targets.
Electricity			
4	Law No.30/2009	Electricity	Regulating the division of the electricity supply business area in an integrated manner, the application of regional tariffs that are limited to certain areas.
5	Government Regulation No.23/2014	Electricity Supply Business Activities	Regulating conditions in the electricity supply business.

6	Regulation of the Minister of Energy and Mineral Resources No.7/2016	Procedures for the implementation of business areas for the provision of electricity for the public interest	Regulating business licensing regarding the provision of electricity for public purposes.
7	Regulation of the Minister of Energy and Mineral Resources No.12/2016	Electrical Licensing Procedure	Regulating licensing procedures for electricity companies, including business licensing for the provision of electricity for public purposes.
8	Regulation of the Minister of Energy and Mineral Resources No.24/2017	PLN power plant cost determination mechanism	Regulating the mechanism for determining the cost of electricity generation by PLN, excluding electricity transmission costs.
9	Regulation of the Minister of Energy and Mineral Resources No.39/2017	Implementation of physical activity on new and renewable energy and energy conservation	Implementation of physical activity on new and renewable energy and energy conservation.
10.	Regulation of the Minister of Energy and Mineral Resources No.10/2018	About the principle of the power purchase and sale agreement	Regulating the principles in the purchase of electricity between PLN as a buyer and a business entity as an electricity seller.
11.	Regulation of the Minister of Energy and Mineral Resources No.30/2018	Delegation of the granting of electricity business licenses in the context of the implementation of one-stop integrated services to the head of the investment coordinating board.	Regulates the delegation of authority from the minister of energy and mineral resources to the head of the investment coordinating body that includes several permits.

12	Regulation of the Minister of Energy and Mineral Resources No.4/2020	Utilization of renewable energy sources for the provision of electricity	Regulating the purchase process through the terms of direct appointment, cooperation scheme, and assignment of electricity purchase to PLN for renewable energy power plants with funding derived from grants.
13	Regulation of the Minister of Energy and Mineral Resources No.20/2020	Grid rules of electric power systems	Manage grid management, connections, planning and execution of operations, energy transactions, measurements, and summary of operational schedules.
14	Presidential Regulation No.112/2022	Accelerating the development of renewable energy for the supply of electricity	Regulating the acceleration of electricity development from new and renewable energy sources, including the purchase price of electricity for each new renewable energy source.
Job creation			
15	Law No.11/2020	Job creation	This regulation is related to the government's job creation efforts with the aim of absorbing as much Indonesian workforce as possible amid an increasingly tight competitive landscape and increasing global economic demands.
16	Government Regulation No.5/2021	Risk-based business licensing	Regulating risk-based business licensing, including electronically integrated business

			licensing system services/Online Single Submission (OSS).
17	Government Regulation No.21/2021	Implementation of spatial planning	Regulating conditions related to spatial planning, space utilization, space utilization control and spatial planning supervision.
Local Content (TKDN)			
18	Law No.3/2014	Industry	The scope of this regulation includes national industrial master plans, national industrial policies, industrial estates, industrial infrastructure development, industrial empowerment, licensing, and capital investment.
Fiscal Facilities			
19	Regulation of the Minister of Finance No.21/2010	Provision of tax and customs facilities for activities that utilize renewable energy sources	Tax and customs facilities that can be provided by the government for the use of renewable energy sources are Income tax facility, Value-added tax facility, Import duty facility.
20	Minister of Finance Regulation No.188/2015	Exemption of import duties for the import of machinery and goods and materials for construction or industrial development in the context of capital investment	This regulates the exemption of rice from goods and services in accordance with applicable regulations.

21	Minister of Finance Regulation No.66/2015	Import duty regulations on the import of capital goods in order to build or expand the power generation industry for the public interest.	Import duty exemption is granted for capital goods used in the power generation industry under certain conditions.
22	Government Regulation No.78/2019	Income tax facility for investment in certain business fields or certain regions	This is related to the provision of income tax facilities for certain business sectors. Investments in renewable energy are given an additional year of option to extend carryforward tax losses.
23	Regulation of the Minister of Finance No.117PMK.010/2020	Implementation of government regulation No.78/2019	This regulation acts as a technical guide on tax facilities provided through government regulation No.78/2019.
24	Presidential Regulation No.49/2021	Investment business field	This regulation provides a list of investment businesses and stipulates that under certain conditions, power plants (>1 MW) can be opened for 100% foreign investment and enjoy tax facilities.
25	Investment Coordinating Board Regulation No.4/2021	Guidelines and procedures for risk-based business licensing services and investment facilities	This regulation regulates the procedures and guidelines for risk-based business licensing services and investment facilities that apply to the power generation sector.

26	Investment Coordinating Board Regulation No.7/2020	Details of the business field and type of production of the pioneer industry as well as the procedure for providing corporate tax deductions	This regulation establishes a new list of standard classifications of Indonesian business fields that can be subject to tax holidays, among others, registered business fields including industries that produce the main components for power generation engines and renewable energy power plants.
27	Minister of Finance Regulation No.130/2020	Provision of corporate income tax reduction facility	Under certain conditions, the corporate tax reduction can be applied to pioneer industries, industries that produce power generation machinery and renewable power plants (depending on the economic infrastructure)
Environmental Management			
28	Law No.32/2009	Environmental protection and management	This regulation regulates the planning, utilization, control, and management of hazardous and toxic materials as well as hazardous and toxic waste.
29	Government Regulation No.22/2021	Implementation of environmental protection and management	Regulating environmental approval, water quality protection and management, air quality, marine quality, environmental damage control, and waste management control.

30	Regulation of the Minister of Environment and Forestry No.6/2021	A list of businesses or activities that must have environmental impact analysis, environmental management efforts, and environmental monitoring efforts	This regulation regulates the list of businesses or activities that are required to have various types of environmental permits.
31	Regulation of the Minister of Environment and Forestry No.6/2021	Procedures and requirements for the management of hazardous and toxic waste materials	This regulation regulates procedures for managing hazardous and toxic waste materials.
32	Regulation of the Minister of Environment and Forestry No.7/2021	Forestry planning, changes in forest area designation and forest area function changes	This regulation regulates forestry planning, changes in the designation and function of forest areas.
33	Regulation of the Minister of Environment and Forestry No.8/2021	Forest management and forest management and forest utilization plans	The scope of this regulation includes forest governance and the preparation of forest management plans, licensing of forest use businesses, forest utilization businesses, and processing of forest products.
Transportation			
34.	Regulation of the Minister of Transportation No.84/2014	Procedures for loading, arranging, transporting and unloading goods by rail	This regulates the procedures for loading and unloading goods and loading and unloading goods using rail transportation.
35	Regulation of the Minister of	The implementation of Indonesian national standards (SNI) on	This regulation is related to the mandatory application of SNI in

	Transportation No.44/2005	flight operation safety areas as mandatory standards	the safety area of flight operations.