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Bukit Selong Sembalun, WNT, Indonesia. Source: Canva

WEST NUSA TENGGARA

CLEAN ENERGY SOLUTIONS AND INITIATIVES IN ARCHIPELAGIC ELECTRIFICATION

Figure 1: Map of Province of West Nusa Tenggara, Indonesia
Source: Google Map Satellite, 2021

West Nusa Tenggara Province, Indonesia: Facts and figures

Population

5,473.700 (2020)

Total area

20,124.48 km²

Regional Budget

IDR 6,12 trillion (2023, ESDM)

The West Nusa Tenggara (NTB) province, with main islands Lombok and Sumbawa, pledged an ambitious target of 60% renewable energy in Lombok's electricity system by 2030, 100% renewable energy in the whole province's grid in 2040, and net zero emissions for all energy sectors by 2050. This commitment represents a pioneering initiative in Indonesia's energy landscape.

Introduction

Electricity plays a pivotal role in socio-economic development, serving as a fundamental pillar for industrial growth, urbanization, and improving living standards. As the largest economy in Southeast Asia and as a nation comprising over 17,000 islands (Portal Informasi Indonesia, 2023) [1], Indonesia faces unique challenges in ensuring reliable and sustainable electricity to its population of over 280.73 million people (Katadata, 2024)[2].

For regions consisting of numerous islands, providing clean and sustainable energy poses several challenges. These include limited infrastructure, transportation access, inter-island connectivity, and high investment costs for the technologies. Additionally, the limited local energy resources often lead to dependence on external energy sources, particularly imported fossil fuels such as coal, oil, and gas.

The Indonesian Ministry of Energy and Mineral Resources (MEMR) confirms these challenges, highlighting that island regions face difficulties in ensuring universal energy access due to their vulnerability to external factors such as natural disasters and climate change impacts, in addition to the aforementioned challenges. This makes their energy supply chains prone to disruptions. These challenges hinder Indonesia's progress towards achieving Sustainable Development Goal 7 (SDG 7), which focuses on universal energy access (KESDM, 2022)[3].

PT Perusahaan Listrik Negara (PLN), as a public service obligation (PSO), plays a crucial role in providing equitable electricity access across the nation. As of April 2024, the national electrification ratio is at 99.81%, representing the percentage of households with electricity compared to the total number of households. Meanwhile, the village electrification ratio is at 99.87%, reflecting the percentage of electrified villages relative to the total number of villages (Savitri, 2024)[4].

The MEMR employs two main strategies to expand electricity access across Indonesia, especially in remote, outermost, and underdeveloped areas (also known as 3T areas). The first strategy involves grid extensions to connect villages and households near existing PLN networks. The second strategy focuses on developing mini-grids powered by local renewable energy sources, which is particularly relevant for island regions (KESDM, 2023)[5].

West Nusa Tenggara (WNT), an island province, includes two major islands—Lombok and Sumbawa—as well as around 378 smaller islands, 38 of which are inhabited. Notable tourist destinations include Moyo Island, Gili Trawangan, Gili Meno, Gili Air, Gili Gede, Gili Lontar, and Bungi Island, among others (NTB, 2024)[6].

In the electricity sector, WNT's energy supply largely relies on fossil fuels, with gas turbine power plants contributing approximately 45%, diesel power plants 25%, and coal-fired power plants 24%. Renewable energy sources, such as solar and micro-hydro, contribute a smaller share. WNT also depends on diesel generators, with 94 units providing a total installed capacity of 168 MW. The reliance on fossil fuels presents a logistical challenge due to the scattered nature of the islands and the long, disconnected stretches of larger islands like Sumbawa. Additionally, fossil fuel-based electricity is costly and unreliable due to transportation and global pricing concerns (ICLEI, 2024)[7].

As of June 2024, PLN's data indicates an electrification ratio of 99.99% in WNT, with 99.76% of households receiving electricity from PLN. The

remaining 0.24% are either unelectrified or use electricity from independent power producers (IPPs) or private providers (PLN UIW NTB, 2024) [8]. The local government reports a 100% village electrification rate, with 1,143 villages in total. Of these, 1,138 villages are served by PLN, while five villages in the mountainous Sumbawa district receive electricity from non-PLN sources due to access constraints. These five villages—Tepal, Baodesa, Tangkam Pulit, Baturotok, and Mungkin—utilize micro-hydro power plants (MHPPs) as their electricity source (DESDM NTB, 2023)[9].

The context presented above sets the stage for a broader examination of the electricity planning in WNT Province as an archipelagic region striving to achieve a 100% renewable energy target. This case study aims to compare the current state of the electricity sector with future plans, highlighting ICLEI's support for WNT in reaching its 100% renewable energy target by 2050. This not only supports the regional target of achieving net zero emissions a decade ahead of the national target, but also contributes to the national target itself. The study includes modeling efforts to achieve 100% renewable energy based on regional potential, focusing specifically on the electricity sector due to its foundational role and direct impact on end users.

Figure 2. The Solar PV Power Plant on Medang Island, Sumbawa, WNT, has a capacity of 314 kWp and is equipped with a 550 kWh battery and an inverter, supplying 2,574 households on the 4.35 km² island with 24-hour electricity (Photo source: PLN)

PLN's Vision for Regional Electricity Development in WNT[1]

PLN, as a state-owned enterprise, is primarily tasked with providing electricity for public use and managing the distribution and transmission networks. According to the 2021-2030 Long-Term Electricity Supply Plan of PT PLN (RUPTL PLN), the electricity system in WNT is organized into several key segments: the Lombok 150 kV System, the Sumbawa-Bima 150 kV and 70 kV Systems, and various smaller networks.

From 2011 to 2020, WNT's electricity sales grew between 5% and 16%, with customer numbers increasing to 21%. PLN's forecasts suggest that electricity sales will grow by 7% to 9% in the coming years, while customer growth is expected to be around 3% to 4%. This growth is partly attributed to the increasing electricity demands of the Mandalika Special Economic Zone.

Currently, the majority of WNT's electricity is generated by diesel power plants), leading to high production costs. To mitigate this, PLN plans to integrate coal-fired power plants to lower generation costs and introduce gas-fired power plants using compressed natural gas (CNG) to reduce reliance on diesel during peak demand periods.

Reliability across the different systems varies. The Lombok system is stable, while the Sumbawa and Bima systems require optimization. To address this, PLN intends to deploy mobile power plants (MPP) or gas engine power plants with dual-fuel capabilities (high-speed diesel and gas), along with additional coal-fired power plants. This strategy aligns with the MEMR directive to replace some planned coal-fired plants with gas engine power plants.

Renewable energy sources are also being considered, based on the capacity quotas available for PLN and IPPs under power purchase agreements (PPA). These quotas can be filled by both listed and new potential energy sources.

Additionally, PLN is also exploring interconnections between the Lombok and Bali systems to integrate Lombok with the Java-Bali grid, with the aim of developing a Lombok-based renewable energy power plant after 2026. However, this plan requires detailed feasibility studies, particularly regarding operational and financial viability, and technical issues related to the depth of the sea trenches between Bali and Lombok.

To support energy access and improve electrification ratios, PLN has a rural electrification program extending to 2030. This program promotes the use of renewable energy in remote areas with distribution challenges, including replacing expired energy-efficient solar lamps and expanding grid or mini-grid networks.

Another key initiative is co-firing technology, which blends biomass with coal in power plants. This approach has been implemented at the Jeranjang Power Plant in Lombok and the Sumbawa Power Plant using biomass materials such as wood chips, corn cobs, and rice husks. Currently, biomass makes up 5% of the fuel mix, with efforts underway to increase this percentage to reduce coal emissions and accelerate progress towards net-zero emission targets.

Figure 3. Co-firing initiative at two coal power plants in WNT Province, with biomass comprising 10-50% of the daily fuel mix (Photo source: WNT Energy Agency)

1 Summarized from RUPTL PLN 2021-2030 (RUPTL PLN, 2021) [10]

Towards 100% Renewables in the Electricity Sector of West Nusa Tenggara Province

Renewable Energy Potential

WNT Province boasts substantial renewable energy potential across various sources, including solar, wind, hydro, geothermal, waste, and biomass. A detailed assessment of WNT's renewable energy potential has been developed as fundamental to a 100% renewable energy scenario modeled by Fraunhofer ISE (ICLEI, 2022)[11]. The key findings are as follows:

Table 1: Potential of various renewable energy sources in WNT

RE Potentials (MW)	Lombok	Sumbawa	RE Potentials	Lombok	Sumbawa
Installable Solar PV	18,274	16,258	Geothermal (MW)	70	75
Installable Wind	2,793	2,485	Municipal Waste (GWh)	3,126	1,355
Installable Rooftop Solar	4,224	1,591	Corn Waste Biogas (GWh)	501	2210
Run-of-River Hydropower	8,91	4,82	Rice Husk and Straw Biogas (GWh)	4,381	31,064
Reservoir Hydropower	79,25	119,5	Biogas from Coconut (GWh)	58	12

Source : ICLEI Local Governments for Sustainability (2022). 100% Renewables - Roadmap for Cities and Regions : Energy System Modelling Result for West Nusa Tenggara, Indonesia

Solar energy emerges as the most promising renewable resource in WNT. Both Lombok and Sumbawa islands exhibit significant solar potential, with capacities estimated at 18 GW for Lombok and 16 GW for Sumbawa. In addition, biogas potential, especially from rice husks and straw in Sumbawa, is substantial, amounting to approximately 31,064 GWh. Wind energy also holds considerable promise, with Lombok and Sumbawa having potential capacities of 2,485 MW and 2,793 MW, respectively. Furthermore, WNT has additional renewable energy potential from hydro, geothermal, municipal waste, and other biogas sources that can be harnessed.

Modeling 100% Renewable Energy Systems

Fraunhofer ISE conducted energy system modeling for WNT Province using the KomMod software, evaluating ten different scenarios. These scenarios varied based on three key factors: biomass and biogas fuel prices, energy demand, and whether the energy systems of the two islands were combined or modeled separately.

The primary scenario selected involves a combined energy system for Lombok and Sumbawa, with median energy demand and low fuel prices. This scenario estimated a total electricity demand of 18,507 GWh, which includes:

1. Cooling
2. Demand for electric vehicles, hydrogen, and synthetic fuels
3. Household cooking
4. Electrification of heating and fuel

In this specific scenario, several possibilities emerged, highlighting what one potential 100% RE scenario in West Nusa Tenggara could look like. The result shows that for the supply, the scenario relies heavily on solar photovoltaic (PV) systems, which contribute 69% of the electricity—comprising both solar farms and rooftop solar installations. This is followed by biogas power plants derived from biomass providing 18% of the electricity, and wind power plants, contributing 10%. Geothermal and hydropower contribute only a small portion of the electricity, despite their full utilization of available potential.

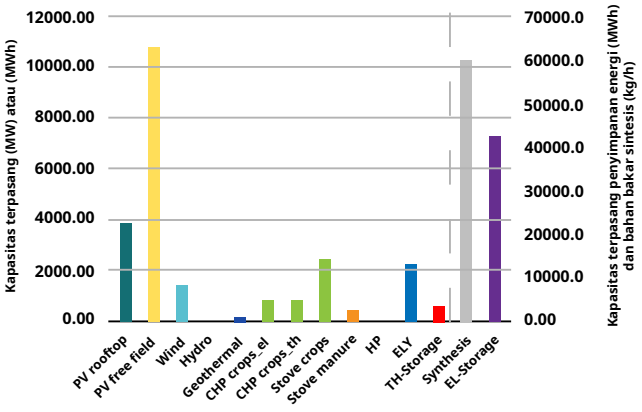

Figure 4: Kapasitas terpasang berbagai teknologi energi terbarukan dalam skenario utama

One insight that emerged was that the chosen scenario of combining the energy systems of Lombok and Sumbawa provides significant economic benefits. The modeling results indicate that a business-as-usual (BAU) scenario where the two systems are not interconnected would be 32% more expensive and would produce 4.5 times more carbon dioxide emissions from fuel combustion for the same energy demand. Additionally, the integrated energy system enhances energy supply resilience and promotes a more equitable distribution of wind and solar power generation across the two islands.

In summary, the transition to a 100% renewable energy system in WNT, supported by a combination of solar, wind, and biogas energy, offers both economic and environmental advantages. The integrated approach not only reduces costs and emissions but also strengthens the overall energy infrastructure, paving the way for a sustainable and resilient energy future for WNT.

WNT's 100% Renewables Strategy for the Electricity Sector

Electrification plays a key role in this transition by promoting cleaner energy solutions in households and transportation, such as electric stoves and vehicles, and enabling the integration of renewable energy. Decarbonizing the electricity sector by cutting fossil fuel use and increasing renewable energy is imperative for reaching the 100% renewable energy target. Key strategies to achieve these goals include:

Expanding Electrification and Household Connections

Increasing access to electricity is a critical driver for enhancing renewable energy utilization in WNT, particularly for households that depend on fossil fuels for cooking and transportation. Improving the electrification ratio, which measures household connections to PLN's electrical grid, will enhance access to electricity, particularly in remote areas that lack reliable power.

The aim is to achieve 100% electrification coverage from PLN and independent power producers (IPPs) by 2025 and 2030 for remote and outer islands, ensuring reliable, 24/7 electricity with minimal disruptions (measured by System Average Interruption Duration Index (SAIDI) and System Average Interruption Frequency Index (SAIFI). Yet, the electrification ratio is only one measure. It does not measure the share of household energy demand, which is another metric that must be accounted for to determine and fully realize the benefits of improved access to electricity. Increasing electrification must be accompanied by shifts in behavior when it comes to purchases, habits, etc.

Additionally, the energy mix target highlights the proportion of renewable energy in the total electricity capacity. As of late 2023, renewable energy accounted for just 13.1% of Indonesia's energy mix, while the National Energy General Plan (RUEN) target aims for 25% by 2025 (KESDM, 2024)[12]. Meeting these targets is essential for providing reliable and eco-friendly electricity to all communities, including remote areas. Achieving

regional energy milestones will significantly contribute to national electrification, energy mix, and emission reduction goals.

Implementing Biomass Co-firing and Phasing Out Coal-fired Power Plants

Biomass co-firing involves substituting a portion of coal with biomass in coal power plants (PLTU), reducing carbon emissions and utilizing more sustainable energy sources. In WNT, biomass for co-firing includes materials such as wood chips, corn cobs, rice husks, and wood shavings. For instance, the Jeranjang's coal power plant in Lombok, which supplies about 20% of Lombok's electricity, currently integrates a 7% biomass mix with plans to increase this to 14% by 2025 (Yunianto, 2024)[13].

The Roadmap targets 100% biomass usage by 2040, starting with the co-firing program in coal power plants that will incorporate 20% biomass by 2025, increasing to 60% by 2030, 80% by 2035, and reaching full 100% biomass utilization by 2040. Realizing this will require securing a sustainable biomass supply and ensuring system readiness. Existing waste streams can be considered to reduce the need for greenfield bioenergy sources. Phasing out coal-fired power plants is crucial for the energy transition, as it will significantly cut greenhouse gas emissions. Utilizing locally sourced biomass instead of imported coal will also enhance regional energy independence.

Retiring Diesel Power Plants by 2030

Currently, diesel power plants account for about a quarter of WNT's electricity supply, operating through 94 units. Phasing out these plants by 2030 is crucial to lowering generation costs and reducing reliance on diesel. The transition will begin in major cities and islands, progressively extending to remote areas where alternative solutions may be less available.

Replacing diesel power plants requires clean, sustainable energy sources. Local renewable options like solar, wind, hydro, and geothermal will be prioritized. This strategy aligns with PLN's de-dieselization program, which is part of the nation's energy transition and climate change mitigation efforts. It involves replacing diesel power plants used in isolated areas with solar power systems. PLN estimates that this initiative will contribute to reducing fuel consumption by 722.1 billion IDR and cut CO2 emissions by 132,000 tons annually (PLN, 2023)[14].

The implementation of this strategy in WNT begins with planning and site identification, which are expected to be completed by 2025. The implementation phase will then commence in 2025 and is projected to conclude by 2030.

Leveraging Solar Energy and Other Renewable Energy Sources

Maximizing the potential of renewable energy is key to replacing fossil fuel-based power plants such as oil and gas power plants (PLTMG), diesel power plants (PLTD), and coal power plants (PLTU), and meeting future electricity needs. Increasing the share of renewable energy in the grid also supports national objectives for efficiently adopting electric vehicles and stoves.

Solar PV power plants are becoming more cost-effective and have significant potential in Lombok and Sumbawa. This technology can be deployed on critical lands, rooftops, or floating systems on lakes or dams, targeting both commercial and residential sectors.

Other promising renewable energy sources include geothermal, wind, mini-hydro, and waste-to-energy (PLTSa). Geothermal energy offers a reliable base load and can be utilized directly in agriculture, industry, and tourism. Wind, hydro, and urban waste resources also present valuable opportunities to support WNT's energy transition. Waste-to-energy projects can address waste management challenges while generating energy, aligning with WNT's zero waste goal.

Key Learning from Experience

As an archipelagic province of Indonesia, where electrical authority is largely managed by PLN and the central government, an effective energy transition in WNT must be tailored to its specific conditions. The recommendations provided below should be adapted to align with each locale's unique context. To facilitate a successful energy transition, it is crucial to create an enabling environment through strengthened collaboration among local governments, energy distributors, and the private sectors. In WNT, this becomes especially critical with the proposed integration of the Lombok and Sumbawa energy systems, which will demand a well-developed infrastructure to ensure the effective deployment and utilization of renewable energy.

The lessons learned that can be applied by other regions/provinces with similar backgrounds to WNT in supporting the achievement of 100% RE include:

1. **Island integration to enhance energy supply and energy resilience**

Island integration between Lombok and Sumbawa is foreseen to offer significant advantages in enhancing energy supply and resilience. By connecting their energy systems, islands can share resources, leading to economic benefits through cost optimization and investment attraction. This integration improves energy security by ensuring a stable supply, allowing one island to compensate for any shortfalls in the other. Additionally, the merger allows for a more balanced distribution of renewable energy sources like biomass, wind, and solar, maximizing their efficiency and reducing reliance on fossil fuels.

2. **Renewables can help remote/disconnected islands be self-sufficient through mini-grids**

Renewable energy sources, especially solar PV, provide a practical solution for remote and disconnected islands to achieve energy self-sufficiency. In areas where access to the main national or regional grid is either challenging or unfeasible, mini-grids powered by renewable sources can offer a reliable and cost-effective alternative. These systems allow islands to generate their own electricity, reducing dependence on costly and polluting diesel generators. By harnessing locally available renewable resources, islands can achieve a more resilient and sustainable energy system while also contributing to the overall goals of reducing emissions and enhancing energy independence.

3. **Data-driven planning for effective strategies and implementation**

The WNT experience underscores the importance of robust data collection for energy modeling, which can provide a comprehensive projection of future energy demands across various sectors. Accurate and timely data enables stakeholders to make informed decision-making, enabling the optimal allocation of local resources. It also helps in identifying potential renewable energy sites, designing efficient mini-grid systems, and assessing the feasibility of inter-island connections. Without comprehensive modeling and data, it becomes difficult to develop realistic strategies and measure progress towards achieving 100% RE goal. Hence, data-driven planning should be a cornerstone of energy policy and infrastructure development of subnational governments.

In conclusion, achieving the 100% RE goal in WNT requires a tailored approach that recognizes the region's unique geographic and socio-economic context. Integrating energy systems between islands, promoting renewable energy for remote areas, and leveraging data-driven planning are key pillars to building a resilient and sustainable energy future not just for WNT, but for other archipelagic governments. Strengthening collaboration between local governments, energy distributors, and private sectors will also be essential in creating the infrastructure and policy frameworks needed for a successful transition.

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The 100% Renewables Cities and Regions Roadmap project facilitates the energy transition by raising local awareness on renewable energy sources, showcasing how local and national governments can create coordinated enabling frameworks and policies, exploring access to public and private sector finance, and building local renewable energy projects to address electricity, heating and cooling.

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