WHOLE ISLAND TRANSITION ROADMAP

Final Report

November 2022

This report has been commissioned by South Asia Research Hub, Foreign, Commonwealth and Development Office (FCDO), Government of UK. However, the views expressed herein do not necessarily reflect the UK Government's official policies.

Table of Contents

Glossary

Terms	Definition
APBD	*Anggaran dan Pendapatan Belanja Daerah*/Regional Budget
APBN	*Anggaran dan Pendapatan Belanja Negara*/State Budget
BPP	*Biaya Pokok Pembangkitan*/Generation Cost
BPS	*Badan Pusat Statistik*/Central Statistics Agency
BUMD	*Badan Usaha Milik Daerah*/Regional-Owned Enterprises
BUMN	*Badan Usaha Milik Negara*/State-Owned Enterprises
BUMDes	*Badan Usaha Milik Desa*/Village-Owned Enterprise
Covid-19	Coronavirus pandemic
DGE	MEMR Directorate General of Electricity
DGNREEC	MEMR Directorate General of New and Renewable Energy and Energy Conservation
DPR	House of Representatives
DPRD	Local House of Representatives
FCDO	Foreign, Commonwealth, and Development Office
GDP	Gross Domestic Product
GHG	Greenhouse Gas
GR	Government Regulation
GW	Gigawatt
IIGF	*PT Penjaminan Infrastruktur Indonesia*/Indonesian Infrastructure Guarantee Fund
Inovasi	PT Inovasi Dinamika Pratama
IO	*Izin Operasi*/Operational Permit
IPP	Independent Power Producer
IUJPTL	*Izin Usaha Jasa Penunjang Tenaga Listrik*/Electricity Supporting Services Business License
IUPTL	*Izin Usaha Penyediaan Tenaga Listrik*/Electricity Supply Business License
MEMR	Ministry of Energy and Mineral Resources
MoF	Ministry of Finance
MoSoE	Ministry of State-Owned Enterprises
MW	Megawatts
NRE	New and Renewable Energy
PLN	*Perusahaan Listrik Negara*/The National Utility Company
PLTB	*Pembangkit Listrik Tenaga Bayu*/Wind energy power plant
PLTBm	*Pembangkit Listrik Tenaga Biomassa*/Biomass energy power plant

Terms	Definition
PLTD	*Pembangkit Listrik Tenaga Diesel*/Diesel power plant
PLTH	*Pembangkit Listrik Tenaga Hibrid*/Hybird energy power plant
PLTMh	Pembangkit Listrik Tenaga Mikro/Micro/Mini-hydro energy power plant
PLTMG	Pembangkit Listrik Tenaga Mesin Gas/Gas engine power plant
PLTS	Pembangkit Listrik Tenaga Surya/Solar energy power plant
PLTU	Pembangkit Listrik Tenaga Uap/Coal-fired power plant
PSO	Public Service Obligation
PSP	Private Sector Participation
PwC	PT PricewaterhouseCoopers Indonesia Advisory
RE	Renewable Energy
Roadmap	The Whole Island Energy Transition Roadmap
RUKN	*Rencana Umum Ketenagalistrikan Nasional*/National Electricity General Plan
RUPTL	*Rencana Usaha Penyediaan Tenaga Listrik*/Power Generation Business Plan
SHS	Solar Home System
SLD	Single Line Diagram
UIKL Sulawesi	*Unit Induk Pembangkitan dan Penyaluran Sulawesi*/PLN Generation and Distribution Main Unit of Sulawesi
UIW Sulserabar	*Unit Induk Wilayah Sulawesi Selatan, Tenggara, dan Barat*/PLN Main Unit of South, Southeast, and West Sulawesi
UK	Government of the United Kingdom
We	Foreign, Commonwealth, and Development Office

Executive Summary

The Foreign, Commonwealth and Development Office ("FCDO"), Government of United Kingdom ("UK") aimed to develop a whole island energy transition roadmap ("the Roadmap") focused on a specific remote island power system in Indonesia. This analysis is expected to help inform the planning process of the Government of Indonesia, local government, and *Perusahaan Listrik Negara*/The National Utility Company ("PLN") in designing and implementing a sustainable whole-island transition to low-carbon energy on the selected island, as well as encourage private sector investment.

Based on the results of the island suitability assessment according to the proposed selection criteria and weightages, Buton Island in Southeast Sulawesi Province, Indonesia was selected for development of the Roadmap.

The development of the Roadmap considered regulatory, technical, financial, and socioeconomic characteristics of the island. The Roadmap was then developed based on the prevailing regulations framework as explained in chapter two. It also considered the impact of different business models and energy mix scenarios for energy transition planning in Buton. The business models which were considered for the Roadmap included the PLN in-house and Independent Power Producer ("IPP") business models. The energy-mix scenario is based on data provided in the 2021-2030 Power Generation Business Plan (*Rencana Usaha Penyediaan Tenaga Listrik* – "RUPTL") for Buton Island.

In summary, the scenarios used for this Roadmap are as follows:

Table 1 - Scenarios Used in The Roadmap

Scenario Type		Description	Remark
Business Models Scenarios	PLN in-house	• Power plants are financed, built, and operated by PLN • Electricity is distributed to the community by PLN • Grants and PSO are considered as financial support	The type of business model which was applied for each power plant technology for RUPTL scenario was based on the RUPTL 2021-2030.
	IPP	• Power plants are financed, built, and operated by IPP • Electricity is distributed to the community by PLN • PSO is considered as financial support	
Energy Mix Scenarios	RUPTL Scenario (Base Case)	Refers to PLN's RUPTL 2021-2030 with the planned renewable energy power plants as follows: • 30 MW of Hybrid Energy Power Plant (PLT EBT Base); • 9.8 MW of Biomass Energy Power Plant (PLTBm); • 15 MW of Wind Energy Power Plant (PLTB). The installed capacity and planned COD of	The type of business model which was applied for each power plant technology in this RUPTL scenario was based on the RUPTL 2021-2030.

Scenario Type		Description	Remark
		each power plant is based on the RUPTL. Detailed information can be found in Table 14.	
	100% Renewables Scenario	The composition of power plant technology is based on the planned power plants on Buton Island as included in the RUPTL 2021-2030, as well as the suitable renewable energy technology to replace the existing conventional energy on Buton Island. It considers the potential and availability of renewable energy resources, Buton Island grid stability, future demand, and financial analysis. The types of power plant technology which were included in this scenario are as follows: • 45 MW of Solar PV with BESS (PLTS); • 9.8 MW of Biomass Energy Power Plant (PLTBm); • 15 MW of Wind Energy Power Plant (PLTB); • 9.432 MW of Mini-hydro Energy Power Plant (PLTMh), in addition to the existing 0.8 MW Rongi mini-hydro and 1.5 MW Wining mini-hydro power plants, hence the total capacity of PLTMh is approximately 11.732 MW.	N/A

As explained in the table above, RUPTL 2021-2020 specified the types of possible business model for each of the renewable energy power plants, whether they are to be delivered by PLN or IPP. For the 100% Renewables scenario, we assume that the additional RE power plants will be all delivered by the IPPs for a conservative approach. Therefore, there are two scenarios based on the business model and energy mix options as explained in Table 1.The scenarios are as detailed below:

Table 2 –Scenarios Evaluated for the Roadmap

Implementer	RUPTL Scenario	100% Renewables
PLN	**1** • PLN delivers PLT EBT Base ○ PLT EBT Base consists of the combination of solar PV and diesel generators • IPPs deliver PLTBm and PLTB	**2** IPPs deliver all additional RE power plants (i.e., PLTS, PLTBm, PLTB, and PLTMh) and replace existing generation fleet with RE
IPP		

As explained in the table above, the determination of the power plant types in the 100% Renewables scenario is based on the technical analysis results, therefore the 100% Renewables scenario is the ideal scenario.

Financial analysis was then performed for each of the above scenarios to obtain the lowest cost solution for the energy transition, using levelised cost of electricity ("LCOE") as the measure. LCOE is a measure of the average net present cost per unit of electricity generation over the lifetime of the technology option being assessed. As further explained in chapter six, it is a metric to compare different technology options for electricity generation as part of the process of system-level investment planning and setting remunerative feed-in tariffs (FiT). In addition to the LCOE, we also calculated the project Internal Rate of Return (IRR) Furthermore, technical analysis was performed to obtain the most optimal energy mix composition and ensure compliance to the grid code by using power-flow analysis through DIgSILENT PowerFactory software. GHG emissions were also calculated to understand the magnitude of GHG emissions from the existing power plants and its potential reduction from the planned transition to a 100% renewable energy system in Buton. The calculations were developed for the data sourced from RUPTL 2021-2030 and data as obtained from PLN office in Baubau and PLN South East West Sulawesi Region.

Results of the analysis are as explained below.

<table>
<tr><th>Analysis</th><th>Results</th></tr>
<tr><td>LCOE Estimation</td><td>
The results of the LCOE analysis are as follows:
<table>
<tr><th>Data source</th><th rowspan="2">Units</th><th colspan="2">TDIPS</th><th colspan="2">Actual project data</th></tr>
<tr><th>Project developer</th><th>PLN</th><th>IPP</th><th>IPP (low)</th><th>IPP (high)</th></tr>
<tr><td>Solar PV</td><td>USD cent / kWh</td><td>6.49</td><td>8.73</td><td>8.24</td><td>6.79</td></tr>
<tr><td>Solar PV + battery</td><td>USD cent / kWh</td><td>11.98</td><td>16.54</td><td>16.03</td><td>12.10</td></tr>
<tr><td>Wind</td><td>USD cent / kWh</td><td>7.51</td><td>9.76</td><td>8.56</td><td>12.01</td></tr>
<tr><td>Small hydro</td><td>USD cent / kWh</td><td>4.45</td><td>6.00</td><td>5.66</td><td>6.17</td></tr>
<tr><td>Biomass</td><td>USD cent / kWh</td><td>14.63</td><td>15.73</td><td>16.25</td><td>17.81</td></tr>
</table>
The difference between the PLN and IPP models is in terms of the capital structure and cost of capital. The comparison of LCOE values estimated using TDIPS data, which serves as a broad benchmark, reflects this difference, with values being higher under the IPP model of implementation. This is a consequence of the higher risk perception, and, consequently, returns expectation of the private sector compared to PLN, which is a state-owned enterprise more oriented towards achieving public sector policy outcomes than operating as a standalone, commercially viable entity.
Project IRR of each of the kinds of technology considered are as follows.
<table>
<tr><th>Data source</th><th rowspan="2">Units</th><th colspan="2">TDIPS</th><th colspan="2">Actual project data</th></tr>
<tr><th>Project developer</th><th>PLN</th><th>IPP</th><th>IPP (low)</th><th>IPP (high)</th></tr>
<tr><td>Solar PV</td><td>%</td><td>12.58%</td><td>9.48%</td><td>11.45%</td><td>17.86%</td></tr>
<tr><td>Solar PV + battery</td><td>%</td><td>0.28%</td><td>(2.71%)</td><td>(2.19%)</td><td>2.69%</td></tr>
<tr><td>Wind</td><td>%</td><td>10.31%</td><td>6.98%</td><td>11.82%</td><td>1.72%</td></tr>
<tr><td>Small hydro</td><td>%</td><td>36.26%</td><td>36.63%</td><td>47.33%</td><td>34.17%</td></tr>
<tr><td>Biomass</td><td>%</td><td>N/A</td><td>N/A</td><td>N/A</td><td>N/A</td></tr>
</table>
Based on the LCOE estimation analysis performed in Section 6, only solar PV and small hydro plants under the IPP model are able to satisfy the hurdle rate of 14%. The hurdle rate was determined based on our discussion with a power developer. In the case of
</td></tr>
</table>

<table>
<tr><th>Analysis</th><th>Results</th></tr>
<tr><td></td><td>small hydro projects, it should also be taken into account that project viability is highly site-specific.

The absence of sufficient biomass feedstock on Buton Island makes the option of a biomass plant unviable, even though it is the only technology that can provide reliable supply without providing grid level storage.

The option of solar PV + battery storage (hybrid system) addresses the issue of solar PV systems' generation inconsistency that commonly occurs due to their reliance on the sun's power availability over the course of the day. However, with the current high cost of battery storage and the policy environment around tariffs for renewable energy, hybrid deployments are not commercially viable.</td></tr>
<tr><td>Technical Analysis</td><td>To achieve renewable energy transition, it is important to ensure that the integration of new renewable energy-base power plants into the existing grid does not interrupt service or interfere with stable operation of the grid following the grid code requirements. During the grid simulation through the various scenarios, it was found that the grid conditions are sufficient to handle any potential short-circuit faults. As shown in the technical analysis, the scenario of 100% renewable energy shows that the protection schemes on the grid for short-circuit faults are also already sufficient.

There were some concerns over grid stability during the load flow analysis that was performed for the base case scenario (based on the RUPTL). It was found that the RUPTL energy mix could create stability issues on the grid and it would not be prudent to operate the grid in such a manner. For the scenario of 100% renewable, the energy mix has been adjusted to match the grid conditions and to ensure that the grid can be operated within the grid code. Based on the analysis results, one of the required upgrades is to add additional lines in parallel to the existing ones at Baruta and Tolandona, by adding approximately 20 km (10 km + 10 km) of double cable for a 20 kV line.

As such, the optimal energy mix based on the technical analysis is the one included in Scenario 2 (100% Renewables), as follows:
<table>
<tr><th>Power Plant Technology</th><th>Installed Capacity (MW)</th><th>Output*</th></tr>
<tr><td>Solar PV with BESS (PLTS)</td><td>45 MW</td><td>85%</td></tr>
<tr><td>Biomass Energy Power Plant (PLTBm)</td><td>9.8 MW</td><td>10%</td></tr>
<tr><td>Wind Energy Power Plant (PLTB)</td><td>15 MW</td><td>5%</td></tr>
<tr><td>Mini-hydro Energy Power Plant (PLTMh)</td><td>11.732 MW</td><td>Optimal use</td></tr>
</table>
From the simulations for both scenarios, the following conclusions can be yielded:
A centralised solar PV power plant with the said capacity in one location within the grid coverage will lead to a grid voltage drop. Therefore, to maintain the grid</td></tr>
</table>

Analysis	Results
	stability, added PV capacity will be scattered in a few locations, as near as possible to the existing diesel or other baseload power plants. • During load flow simulation during daytime and evening peak load, the voltage values in normal conditions fall within the set ranges (±10% for 150 kV system and +5% -10% for 20 kV system), meaning they comply with the grid code standard. • Some technical actions are proposed to address findings during evening load simulations, including upgrading some 20 kV distribution lines that are identified to be overloaded into two parallel lines to reduce the drop voltage. Also, the breaker connected to the Ereke sub-system should be opened (to be changed into an isolated system which operates independently) to minimise the drop voltage risk.
GHG Emissions Calculation	This analysis aims to calculate the potential avoided GHG emissions from replacing the fossil fuel-based power plants (Base Case) to renewable energy ones (100% Renewables Scenario). The estimated GHG emissions are then calculated based on the existing and planned power plants on Buton Island in accordance with the RUPTL 2021-2030 and data received from PLN offices in Baubau and PLN South East West Sulawesi Region for comparison, because there was a discrepancy found in relation to the existing power plants' installed capacity. Results from the GHG Emissions analysis are as indicated below. **Estimated GHG Emission based on RUPTL Data** Based on the calculation using data sourced from RUPTL 2021-2030, the following conclusions were obtained: • The estimated total emissions from existing power plants are 2.85 million tons of CO_2 for the remaining technical lifetime of each plant, which equals IDR 2,131.53 billion as total cost of emission; • From the planned power plants, the estimated total emissions are 2.97 million tons of CO_2 for the technical lifetime of each plant which equals IDR 2,223.8 billion as total cost of emissions; • Considering the existing and planned power plant data from RUPTL 2021-2030, the estimated total emission are 5.83 tons of CO_2 which equals IDR 4,355.33 billion. **Estimated GHG Emission based on PLN Offices' Data** The second calculation of estimated GHG emission is based on the data of existing power plants in Buton as received from PLN Baubau and PLN South East West Sulawesi Region while the planned power plant data refers to the information in RUPTL 2021-2030. The following conclusions were obtained: • The estimated total emissions from existing power plants are 2.81 million tons of CO_2 for the remaining technical lifetime of each plant which equals IDR 2,100.06 billion as total cost of emission; • From the planned power plants, the estimated total emissions are 2.97 million tons of CO_2 for the technical lifetime of each plant which equals IDR 2,223.8

Analysis	Results
	billion as total cost of emission; • Considering the existing and planned power plants data from the said PLN offices, the estimated total emissions are 5.79 tons of CO_2 which equals IDR 4,323.86 billion. As further explained in chapter 8, the calculation showed the potential impact of the generated emissions and their equivalent cost assuming that all of the existing non-renewable energy power plants will be replaced by 100% renewable energy power plants starting from 2026 until the end of the remaining operating period, while the planned power plants will be operated in accordance with the RUPTL 2021-2030 data and their expected technical lifetime. The emissions generated from the planned non-renewable energy power plants could be avoided and/or reduced if such plants were to be retired in order to expedite the transition towards 100% renewable energy on Buton Island.

Shifting from the conventional pathway of adding fossil fuel-based generation units, by implementing the RUPTL plan (Base Case) or transitioning Buton Island towards 100% renewable energy is possible but could be seen as ambitious within the ten-year timeframe. The barriers include the transparency of the procurement process and the relatively small project sizes resulting in difficulties financing the project commercially. Gradual and measurable actions toward transitioning to 100% renewable energy should be implemented to ensure there are no interruptions of service to the current and near-future electricity consumers. Below are some strategic actions that could be considered as part of a transition strategy to get Buton Island to 100% renewable energy:

- **1st phase:** Utilise the identified potential for hydro in Buton and Muna Islands;
- **2nd phase:** Add grid-connected solar PV and wind power plants in a hybrid configuration with existing and new fossil fuel generators to significantly decrease emissions by at least 25%. Relocation for existing diesel power plants may be required to move them closer to the solar power plants if the solar plants are unable to be located close enough. Wind contribution might be insignificant considering that there are very few wind resources on Buton Island;
- **3rd phase:** Substitute coal power plants with biomass;
- **4th phase:** Gradually substitute diesel on hybrid PV-diesel/ wind-diesel power plants with BESS;
- **5th phase:** Gradually phase out gas (considering gas infrastructure investment).

All things considered, the driving force of the renewable energy mix in Buton specifically is not the LCOE but the availability of resources. Buton is a good example of an island where very few other resources are available locally such as hydro, wind, and biomass. In other locations where biomass, wind, and hydro are more readily available, the LCOE will drive the energy mix as well as the technical requirements to create a 100% renewable energy grid that provides the lowest cost solution while allowing the grid operators to comply with the grid code and other requirements. Buton also showcases that when there are no other options, solar PV can be the energy transition technology of choice to transition to 100% renewable energy. When there is potential for hydro, it is apparent from the LCOE calculation that hydropower plants offer the most effective cost; however, the challenge is the dependency of this type of technology on the site-specific potential of the energy resource. Solar PV will become a better option as solar technology and BESS costs continue to decline due to growing demand and the advancement of technology and materials.

Based on the data collection and stakeholder engagement process throughout the development of the Roadmap, it could also be noted that the inventories of the existing and development plan of the energy sector specifically in relation to Buton Island's electricity system could be better aligned between the national RUPTL, data in PLN offices at Southeast Sulawesi region and Baubau city, and data from the MEMR regional department. Data such as the Commercial Operation Date ("COD") and operation status of existing plants, distribution lines map, and the electrification data, which include the number of electrified and unelectrified households, should be available and aligned between PLN and the government's database to avoid any discrepancies. In addition, the definition of non-PLN electrified households may be better clarified and reflect the actual condition on site so as to capture cases where unelectrified or non-PLN households have "illegal connections" to nearby PLN-connected houses in the neighbourhood. Further detailed study and site surveys may be required to identify the exact potential capacity and locations of renewable energy resources which could be utilised for power generation in Buton in order to verify the feasibility of the proposed renewable energy-based power plants. The level of details or data collection frequency for the data should also be enhanced to improve the accuracy of the analysis results.

1. Introduction

1.1. Project Background

Indonesia is an archipelagic nation spanning approximately 5,000 km from east to west and consisting of inhabited islands at a range of scales and population densities, from those like Sumatra, which has a landmass of over 450,000 square kilometres and a population of 50 million inhabitants, to small islands that are only a few kilometres from end to end. The country is estimated to have abundant renewable energy potential across sources like hydro, geothermal, biogas, biomass, solar and wind.

However, Indonesia faces challenges around supplying adequate and affordable electricity to its remote islands due to geographical barriers to grid extension, primary energy availability, and landed cost of fuel. High exposure to severe tropical weather and natural disasters such as earthquakes and volcanic eruptions[1] compounds the challenges. In the remote islands, which typically have small to medium size grids (<150 MW) which are not interlinked to larger grids, low electrification rates and high generation costs due to the generation fleet consisting of diesel generators and small coal plants are key challenges. Based on the local generation cost (*Biaya Pokok Pembangkitan* – "BPP") as determined by the Ministry of Energy and Mineral Resources ("MEMR") Regulation no. 10 Year 2017 and its amendments, the average BPP in these remote islands, especially in the central and eastern part of Indonesia, are the highest in Indonesia. Furthermore, the greenhouse gas ("GHG") emissions footprint of these electricity grids is high due to the reliance on diesel and coal for generation.

To support the National Utility Company (*Perusahaan Listrik Negara* – "PLN") 2021-2030 RUPTL's target total installed capacity of 29 GW of renewable energy in the 2030 energy mix and in order to develop a sustainable electrification plan and lessen PLN's financial burden in the Eastern Islands, it is critical to reduce the cost of generation of the most expensive grids, especially as the access gap is progressively reduced. Considering that globally renewable energy generation costs are decreasing, a sustainable deployment of renewable energy could be promoted to reduce the average generation cost as well as mitigate GHG emissions.

1.2. Objectives

Based on the above and complementary to existing work, the Foreign, Commonwealth and Development Office ("FCDO"/"we"), Government of United Kingdom ("UK") aimed to develop a whole island energy transition roadmap ("the Roadmap") focussed on a specific remote island power system in Indonesia. This Roadmap considers the following:

- options for appropriate, affordable and timely transition from the use of fossil fuels to renewable energy for electricity generation, and providing universal access to electricity in the chosen island;
- effective utilisation of natural resources available on the chosen island, while also ensuring affordability, reliability, sufficient consideration of local socioeconomic and environmental context, and local and national energy plans.

The Roadmap development includes consultation with local government and PLN offices, local communities, project developers and investors and any other stakeholders to provide inputs for this Roadmap, where relevant.

This analysis is expected to help inform the planning process of the Government of Indonesia, local government

[1] Hannah Ritchie and Max Roser, 2014 Our World in Data: Natural Disasters

and PLN in designing and implementing a sustainable whole island transition to low-carbon electricity in the selected island, as well as encourage private sector investment.

The results of this study may also be used to inform further UK government work via the Mentari programme to assist the chosen island in the transition to low carbon energy.

1.3. Assumptions and Limitation

The Roadmap has been developed based on the following assumptions and limitations:

1. **Selected Island**

   Buton Island was chosen as the focus for the roadmap development, based on the results of the Island Selection Criteria analysis and discussion with the FCDO, which is explained in more detail in Chapter 4.

2. **Site Visits**

   A site visit was conducted on 24 March 2022 to Kendari to meet the Southeast Sulawesi MEMR Agency.

3. **Data**

   The Roadmap has been developed based on the data obtained until 8 July 2022.

2. Legal and Regulatory Framework

2.1. Electricity Provision

a) Law No. 30 of 2007 on Energy (the Energy Law)

Article 33 of the Indonesian Constitution states that energy resources will be controlled by the state and used for the greatest benefit of the people. The Energy Law was enacted to set the foundation for implementation of the government's duty. It also states that one of the main objectives of energy resource management is to improve energy access for the poor and people living in the remote areas of Indonesia. Therefore, the government is required to work towards increasing the availability of energy and developing infrastructure to fulfil this obligation. Energy resources are required to be priced at fair economic value, with the government addressing affordability gaps for the poor through subsidies.

b) Law No. 30 of 2009 on Electricity (the Electricity Law)

The Electricity Law is the main law governing the electricity sector in Indonesia. It defines the principles that guide the development of the power sector and various activities that constitute electricity supply, vests authority and responsibility for licensing, tariff setting, and otherwise regulating each of these activities, and specifies the responsibilities for sector-planning. The Government of Indonesia and local governments are responsible for controlling electricity supply activities and appointing state-owned enterprises to implement electrification on their behalf. PLN, the main electricity sector state-owned enterprise, is given priority in distributing and supplying electricity to all areas of Indonesia. However, the government may extend the opportunity to other entities. The private sector and other forms of public entities (e.g., cooperatives) may also participate in the sector to help fulfil the power supply needs.

The implementation of the Electricity Law is mainly governed by the following regulations:

- Governmental Regulation No. 14 of 2012, as amended by Governmental Regulation No 23 of 2014 about Electricity Business Provision ("GR 14/2012").
- Governmental Regulation No. 42 of 2012 on Cross-Border Sales and Purchases of Electricity ("GR 42/2012").
- Governmental Regulation No. 62 of 2012 on Electricity Support Business ("GR 62/2012").

The implementation of the Electricity Law is also governed by additional regulations at the presidential, ministerial, provincial, and director-general level. Article 4 of the Law states that the central and regional governments will provide funds to supply electricity for indigent communities, construction of electricity supply infrastructure in less-developed regions, electric power development in remote or frontier areas, and rural electrification.

c) Indonesia Omnibus Law, Changes to the Electricity Law

The Omnibus Law was introduced in 2020 and amends parts of the Electricity Law, particularly relating to the licensing procedures for actors in the electricity sector and the licensing framework as a whole. Previously, the primary licences in electricity sector were the electricity supply business licence (*Izin Usaha Penyediaan Tenaga Listrik* – "IUPTL") for companies supplying electricity for public use, and operational licence (*Izin Operasi* – "IO") for companies supplying electricity for their own use (captive power plants).

Business entities that provided electricity supporting services, such as operation and maintenance and certification of electricity installations, obtained an electricity supporting services business licence (Izin

Usaha Jasa Penunjang Tenaga Listrik or "IUJPTL").[2] Prior to the Omnibus Law, the IUPTL, IO and IUJPTL could be issued by the Central or Regional Government based on their respective authorities, with the location of the project and existence of foreign investment being the determining factors for which government issued the licence.

Under the Omnibus Law, the specific nomenclaturse of IO, IUPTL and IUJPTL are revoked and replaced by a general Business Licence (*Perizinan Berusaha*), which can be issued by the Central or Regional Government based on their respective authorities. The details of the issuance process for this Business Licence were stipulated in implementing regulations(s) which were issued in early 2021:

- Governmental Regulation No. 5 of 2021 on Administration of Risk-Based Business Licensing ("GR 5/2021").
- Governmental Regulation No. 25 of 2021 on Administration of Power and Mineral Resources Sectors ("GR 25/2021").

All existing IUPTL, IO, IUJPTL licences that were issued in the previous licensing regime will remain valid until their expiration. Any new licence will be subject to the Omnibus Law and its implementing regulations (Article 184, Omnibus Law). As part of the general electricity plan, the Omnibus Law also revokes the obligation of the government to consult with the House of Representatives regarding the determination of the national general electricity plan. It also revokes the concept of regional general electricity plans.[3] Under the judicial decision based on procedural lapses in the law-making procedure, the implementation of this law has been partially put on hold. All implementing regulations already issued remain valid, but no new regulations can be issued until the law is published again following all procedural requirements. The Government has been given two years to complete the process. This situation increases uncertainty in the sector, especially in terms of incentivising private sector participation in the development and operation of renewable energy power plants.

2.2. Financial Support

a) Law No. 01 of 2004 on State Treasury

This Law defines the budget management, both for the State Budget (*Anggaran Pendapatan dan Belanja Negara* – "APBN") and the Regional Budget (*Anggaran Pendapatan dan Belanja Daerah* – "APBD"). Article 33 of the Law allows provisions of loans and grant to Local Government/State-Owned Enterprises (Badan Usaha Milik Negara or "BUMN") or Regional-Owned Enterprises (Badan Usaha Milik Daerah or "BUMD") as budgeted in the APBN.

b) Presidential Regulation No. 4 of 2016 on Development of Electrical Infrastructure (PR 4/2016)

As last amended by Presidential Regulation No 14 of 2017, this regulation provides that for development of generation facilities using new and renewable energy, the central or regional government may give government support in the form of fiscal incentives, feed-in tariffs and outright subsidies.

c) Governmental Regulation No. 25 of 2021 on Administration of Power and Mineral Resources Sectors (GR 25/2021)

[2] Thomson Reuters. Firmansyah, and Karim. R. Electricity Regulation in Indonesia: Overview (accessed on 11 February 2022)
[3] SSEK. Indonesia Omnibus Bill – Changes to the Electricity Law (accessed on 11 February 2022)

Article 22 of GR 25/2021 regulates how MEMR and governors will, to support the development of electricity supply, provide funds for indigent community groups, and the construction of power supply infrastructure in less-developed regions, remote and contiguous areas, and for rural electrification. In addition, funding can be allocated according to certain considerations for groups that drive the economy or society. Funds can be channeled through the community, consumers, and/or electricity business entities, and sourced from the state budget, regional revenue and expenditure budgets, and/or electricity business entities' grants, according to the prevailing laws and regulations.

2.3. Regulations on Tariff

a) MEMR Regulation No. 28 of 2016 on the Tariff of Electricity Supplied by PLN (as amended by MEMR Regulation No. 3 of 2020)

The regulation classifies electricity tariff based on its consumption need (social services, households, business, industrial, government offices and street lightings, and special purposes) and power capacity. The electricity price for consumers (the electricity tariff) is determined by MEMR, Governor or Regent, depending on the location (GR 14/2012). All determinations are subject to approval from the national or regional House of Representatives. In determining these tariffs, the government must consider (among other things) the consumer's capacity to pay for electricity, as well as the cost of supplying electricity. For sales of electricity from PLN, MEMR determines the electricity tariffs from time to time, most recently by MEMR Regulation No. 28 of 2016 on the Tariff of Electricity Supplied by PLN (as amended by MEMR Regulation No. 3 of 2020). Electricity sales by PLN at the wholesale level are also regulated under MEMR Regulation No. 28 of 2016 (as amended by MEMR Regulation No. 41 of 2017), particularly as set out in its Appendix XI. A threshold of 200 kVA is set for wholesale electricity.

b) MoF Regulation No. 44 of 2017 regarding Procedures for the Provision, Calculation, Payment of and Accounting for Electricity Subsidies (as amended by MoF Regulation No. 162 of 2017)

The electricity generation cost (BPP) reflects the costs incurred by PLN in generating power and in procuring electricity supply from third-party suppliers such as independent power producers ("IPPs"), but does not include the cost of transmitting the electricity. BPP is stipulated annually by MEMR, based on a recommendation from PLN, and includes both national and local BPPs, with reference to the BPP for the previous calendar year.

The current BPPs as of the time of this writing are stipulated in MEMR Decree No. 169.K/HK.02/MEM.M/2021 regarding the PLN Electricity Generation Basic Cost of 2020, which applies from a date yet to be specified.

The components used by the Government to calculate the BPP are stipulated in MoF Regulation No. 44 of 2017, and are as follows:

1. cost for the purchase of electricity including lease of power plant;
2. fuel cost, consisting of the following: oil fuel, natural gas, geothermal, coal, lubricant, and retribution cost for surface water;
3. maintenance cost, consisting of the following: materials and contractor service;
4. personnel cost;
5. administrative cost;
6. depreciation cost for operational fixed assets;
7. interest and financial expenses used for the provision of electricity, including income tax on the interest on international bonds and hedging transaction cost;

8. adjustment cost in connection with BPP components listed in numbers 1 through 7 above.

The electricity subsidy applies to customers whose electricity tariff is lower than the average cost of electricity supply. However, this scheme does not apply to customers that have adopted the automatic tariff adjustment mechanism or customers that are not charged by PLN (e.g. tenants in industrial estates). The amount of electricity subsidy is based on the MEMR calculation which is proposed to the MoF for incorporation into the APBN. When approved to be incorporated in the APBN, PLN is entitled to "reimburse" the subsidy on monthly basis for customers whose electricity tariff is lower than the average cost of electricity supply, within the agreed budget.

c) MEMR Regulation No. 50 of 2017 on the Utilisation of Renewable Energy for Electricity Supply

The regulation regulates a new appointment method and purchase price by PLN from renewable power plants. It provides that power purchases from power plants utilising renewable energy will be made through direct selection, whereas power purchases from renewable power plants that have high dependency on the weather (solar and wind) will be made through direct selection with a capacity quota. The regulation further provides that power purchase prices by PLN from renewable power plants will be determined based on a tariff that does not include the BPP.

The tariff for power purchase from renewable energy plants depends on the primary energy source and the level of regional BPP in the plant location compared to national BPP.

Table 3 - Renewable energy tariff matrix

	Regional BPP > National BPP	Regional BPP <= National BPP
Solar, wind, biomass, biogas, tidal, ocean thermal energy	Max tariff = 85% x Regional BPP	Max tariff = Based on bilateral negotiations
Hydro, municipal waste, geothermal	Max tariff = Regional BPP	Max tariff = Based on bilateral negotiations

2.4. Other Relevant Regulations

a) MEMR Regulation No. 11 of 2021 on Application Procedures for Electricity Provision Business Area

This regulation revokes MEMR Regulation No. 28/2012 on The Application Procedures for Electricity Provision Business Area as amended by MEMR Regulation No. 7/2016 which defined the procedure for the application and approval of an electricity business area. Under the new regulation, a concession area can be requested under the following conditions: i) if the current concession holder is unable to provide reliable electricity and distribution line; ii) if the current concession holder is unable to improve its reliability; iii) if the existing concession holder returns its concession area partially or entirely to the Government; iv) where the area has not been reached by the existing concession holder; and v) the proposed area is located in an integrated area that is designed to manage energy resources catering the electricity needs to power their business.

b) MEMR Decree No. 38 of 2016 on Acceleration of Electrification in Rural Areas by Setting Up Small-Scale Electric Power Supply Businesses

This regulation allows private business entities to provide electricity to currently unelectrified regions through a geographically limited concession area for up to 50 MW in generation capacity per site. The IPP can propose a tariff other than PLN's to be charged to the end-users, either with or without a subsidy. When a subsidy is proposed, PLN's tariff for 450 VA household applies. A tariff proposed with a subsidy should be approved by either the Minister or Governor within their authority; otherwise the private business entity has to apply PLN's tariff.

c) MEMR Regulation No. 47 of 2018 on Electricity Tariff Determination

This regulation details the mechanism of proposing a tariff from the concession area owner to the Minister or Governor as well as how the Minister or Governor determines the tariff. The Minister or Governor can set out certain tariff for the concession area owner after approval by the DPR/Local House of Representatives (*Dewan Perwakilan Rakyat Daerah* – "DPRD"). Under this regulation, concession area holders are allowed to set a temporary tariff that lasts for six months while waiting for approval from DPR or DPRD and are allowed to sell electricity to consumers sooner using these temporary tariffs. However, there is still uncertainty with respect to the timeframe for the approval from DPR, as this regulation does not set a clear timeframe.

d) Minister of Industry Regulation No. 54/M-IDN/PER/3/2012 regarding Local Content for Electricity Infrastructure as amended by Ministry of Industry Regulation No. 5/M-IDN/PER/2/2017

This regulation sets out the local content requirement for renewable energy technology. The amendment clarifies that the regulation applies to three types of solar power plants: (i) Solar Home Systems ("SHS"), (ii) off-grid centralised solar power plants, and (iii) on-grid centralised solar power plants. Furthermore, the local content requirements are categorised into three types: for goods, for services, and for a combination of goods and services. Activities that are considered as services are EPC services, testing and certification, training, and/or supporting services. The changes regarding local content requirements for solar power plants can be found below:

Table 4 - Local Content Requirement

Classification	Local Content Requirement		
	Goods	Services	Goods and Services
SHS	39.87%, containing: • Solar modules: 60% as of 1 January 2019 • Battery: 40% • Battery control unit: 10% • Module supporter: 42.4% • Cable: 90%	100%	45.9%
Off-grid centralised solar power plants	37.47%, containing: • Solar modules: 40% • DC combiner box: 20% • Distribution panel: 40% • Battery: 40% • Module supporter: 42.4%	100%	43.72%

Classification	Local Content Requirement		
	Goods	Services	Goods and Services
	• Cable: 90% • Protection system: 20% • Energy limiter: 40%		
On-grid centralised solar power plants	34.09%, containing: • Solar modules: 40% • DC combiner box: 20% • Distribution panel: 40% • Transformer: 40% • Cable: 90% • Module supporter: 42.4% • Cable: 90% • Protection system: 20%	100%	40.68%

2.5. Conclusion

Based on the legal and regulatory framework study conducted for this report, the government of Indonesia has shown a serious commitment to achieve its target to increase renewable energy utilisation, as apparent in the provision of a firm legal basis in the energy sector as well as efforts to ease investments in Indonesian renewable energy-based power generation. The new regulatory frameworks such as the regulation on rooftop solar power plants connected to the electricity grid of holders of an electricity supply business licence for public interest as issued in August 2021 by the MEMR, and the 23% target energy mix from renewable energy in 2025 as stipulated in PLN's electricity supply business plan for 2021-2030 are set to stimulate the increased use of clean energy, and eventually investment in the renewable energy sector.

Further adjustment is still needed to encourage private sector involvement in the sector. As of the date of writing this report, PLN is still the only one who can solely generate and distribute the electricity, with private involvement in electricity generation under the IPP scheme. However, the current risk allocation (i.e., on force majeure) in the Power Purchase Agreement (PPA) and the tariff requirement for New and Renewable Energy (NRE) is still disadvantageous to the private sector, thus limiting private investment.

To address the issue, the government of Indonesia has isssued a presidential regulation on 13 September 2022 to revise the price of electricity of New and Renewable Energy (NRE) through the Presidential Regulation no. 112/2022 regarding Acceleration of The Renewable Energy Development for Electricity Supply to attract more investment in the sector. It is a breakthrough in the government's policy which is intended to encourage investment through a competitive pricing scheme. The MEMR hopes that the planned presidential regulation revision, the implementation of the ESDM rooftop solar power plants regulation, provision of fiscal incentives and non-fiscal for NRE, and the ease of business licensing will help improve NRE development's progress towards the target of 23% in 2025.

3. Island Suitability Assessment

3.1. Island Selection Matrix

To assess the suitability of an island for the development of a renewable energy transition roadmap, the following indicative set of selection criteria were developed:

3.1.1. Gross Domestic Product ("GDP")

Energy is a crucial input to economic activity and given the limitation of time for the initial selection, the FCDO/we used GDP as a crude approximation for the energy consumption of the island. Given that the share of fossil fuels is high in the primary energy supply, transitioning an island with a relatively higher GDP value to renewable energy-based generation will have a higher impact on GHG emissions. In addition, assuming a relatively uniform energy intensity of GDP, transitioning a relatively higher GDP island will result in higher fiscal impact through reduction in subsidies and energy security impact through reduced reliance on import of fossil fuels.

We used aggregate GDP value on each island level as per the latest available data in the Central Bureau of Statistics (*Badan Pusat Statistik* or "BPS"). We also considered a qualitative assessment of the key economic activities on the selected island to inform how the transition would potentially impact the livelihood of its population.

For this criterion, we scored the two islands with the highest GDP with 1 point, the middle with 0 points, and the two islands with the lowest GDP with –1 point. Given the relative importance of this criterion, we gave it a weighting of 15% in the final score.

3.1.2. Population

The population of an island was included as a criterion, primarily since it provides an estimate of potential human impact from the transition to sustainable energy use, and where necessary, enhanced electrification. Furthermore, the size of the population is an indicator of energy demand and energy-demand growth as economic development progresses. If energy demand is already high, the planned transition will have a higher impact in terms of GHG-emission reduction, and if it is low, this will have higher impact in terms of the potential GHG emissions avoided.

For this criterion, we scored islands with population higher than 250,000 people with 1 point, between 250,000 and 200,000 with 0 points, and lower than 200,000 with –1 point. Given the relative importance of this criterion, we gave it a weighting of 15% in the final score.

3.1.3. Population Density

Population density was selected as a criterion for two reasons. The primary reason is to provide a moderating influence on the consideration given to the raw population figure, which can also be a function of the geographical area of an island or its proximity to economic centres. The secondary reason is that a more densely populated island would potentially be easier and less expensive to electrify due to lower distances to cover and lower possibilities of encountering difficult terrain in extending the grid or transporting plant and machinery to construction sites.

For this criterion, we scored islands with population density higher than 100 people/ km^2 with 1 point, between 50 and 100 people/ km^2 with 0 points, and lower than 50 people/ km^2 with -1 point. Given the relative importance of this criterion, we gave it a weighting of 10% in the final score.

3.1.4. Existing Diesel Replacement Programme

Inclusion of the island in the existing PLN Diesel Replacement Programme (Tranche 1) informs us whether the existing national programme is aligned with the objectives of this Roadmap . We referred to PLN Report, Konversi PLTD 225 MW di 200 Lokasi – Tahap 1 for the list of diesel power plants included on each island.

For this criterion, we scored islands which are included within the existing diesel replacement programme with 1 point, and islands which are not included with 0 points. Given the relative importance of this criterion, we gave it a weighting of 15% in the final score.

3.1.5. Renewable Energy Potential

The type and size of renewable energy potential of each island indicates the island's capacity for transition from fossil fuel to clean electricity generation. To assess this measurement, we refer to RUPTL from PLN for each island power plant development plan capacity, specific to renewable energy sources.

For this criterion, we scored islands with a renewable energy power plant capacity higher than 50 MW with 1 point, 0 points for islands with a capacity between 25 and 50 MW, and –1 point for islands with a capacity lower than 25 MW. Given the relative importance of this criterion, we gave it a weighting of 15% in the final score.

3.1.6. Implementation Feasibility

Implementation feasibility is a qualitative assessment of ease of implementing and sustaining the energy transition plan on the island. For the current assessment, we considered two aspects which feed into this criterion, namely 1) port infrastructure, and 2) local workforce availability.

Port infrastructure is considered as one of the sub-criteria as specialised plant and machinery will have to be transported to the island during the implementation stage, which will require adequate port infrastructure for berthing and unloading large ships. Realistically we foresee this becoming a limiting factor only in the case of wind power development owing to the large size of single components like turbine blades and towers, which will require port capacity to handle larger ships and more complex infrastructure for safe and efficient material handling.

For the purposes of this initial selection, we scored an island as 1 on this sub-criteria if it has a port capable of handling the movement of people and general cargo and 0 (zero) if none exists. Given the relative importance of this sub-criteria, as it is a potential binding constraint for implementation, we gave a sub-weighting of 80%.

Availability of local workforce is considered in terms of the working age population (15-64 years) on the island. The benefits that can accrue to the local population in terms of employment during project development, construction, and operations and maintance, will aid in securing social licence for infrastructure development on an ongoing basis, reduce cost and complexity of project development and offset potential negative impacts of a transient labour pool being introduced to small-island settings. This sub-criterion also aligns with FCDO's focus where local community engagement and the social context are important aspects of the development of the Roadmap and project.

For the purposes of this initial selection, we score the top two islands in terms of working age population as 1, the middle ranked one as 0, and the last two as -1. Given the relative importance of this sub-criteria, as it is not a potential binding constraint for implementation, we proposed a sub-weighting of 20%.

Finally, the weighted scores of both sub-criteria were combined to form the score for this criterion. Given the relative importance of this criterion, we gave it a weighting of 15% in the final score.

3.1.7. Transportation

To support implementation feasibility criteria, we would also consider ease of transportation to and from the island. The availability and frequency of any means of transportation may directly affect the implementation viability as it indicates the ease of logistics and/or access to sites for new development. We may need to consider in the assessment whether the site is too remote and difficult to access with the least reliable transportation options, hence increasing the cost of investment despite the available resources. The level of existing transportation access may also indicate the socio-economic growth potential of the island as better developed infrastructure could support mobility of people and logistics, and further provide better opportunities to attract people to come to the island.

For this criterion, we considered the availability and frequency of flights and ferries. We proposed a sub-weighting of 40% for flights, and 60% for ferries. A detailed explanation for each criterion is as follows:

- Flights: We gave a score of 1 if there are more than two scheduled flights per week, 0 if there is one scheduled flight per week, and -1 if there are none scheduled.
- Ferries: We gave a score of 1 if there are more than three scheduled ferries per week, 0 if there are one to two scheduled ferries per week, and -1 if there are none scheduled.

Finally, the weighted scores of both sub-criteria are combined to form the score for this criterion. Given the relative importance of this criterion, we proposed to give it a weighting of 15% in the final score.

3.2. Potential Islands Assessment

Based on the initial Terms of Reference for the roadmap as well as the subsequent discussions with the FCDO, a total of five islands were determined to be assessed against the above criteria, namely Buton, Alor, Kei, Rote, and Buru. An explanation for each island is provided below.

a) Buton

Buton has good economic resources as asphalt is one of its main commodities, while in terms of potential renewable energy resources, it has abundant geothermal (MEMR 2012 Study) and solar photovoltaic ("PV") potential.

b) Alor

Alor was considered due to its simplified electricity infrastructure, population, and physical size (both about half of Buton Island), and a significant number of existing solar PV mini grids which may indicates the potential solar energy resources as well as ease of project implementation. However, it has a relatively low electrification ratio and population centres that are far away from each other.

c) Kei Islands

During the discussion, Kei Islands were considered due to its potential renewable energy resources; however the Kei Islands are quite remote from other large cities and developed islands which possibly could be a limitation for the ease of implementation.

d) Rote

As stated in the kick-off meeting, the FCDO asked to add Rote to the list and deleted Flores, as Flores is considered too big for this project.

e) Buru

During the discussion, Buru was considered as another potential island for the roadmap due to its high population density which mostly consists of coastal villages.

3.3. Analysis Results

Based on our research, the results of the analysis on the five islands were as follows:

3.3.1. GDP Value

Based on the available data from BPS of each region as at 2020, both Buton[4] and Alor[5] have the highest GDP value, while Buru has the lowest.

Table 5 – GDP Value for each Island 2020

Selection criteria	Unit	Buton	Alor	Kei	Rote	Buru
GDP value	IDR Thousand	2,752	3,052	1,967	1,933	1,564
Score	Top 2 = 1 Middle = 0 Bottom 2 = -1	1	1	0	-1	-1

Source: BPS of each region

3.3.2. Population

The available data from BPS of each region as of 2020 show that Buton has a population higher than 250,000 while Alor and Rote each have a population lower than 200,000.

Table 6 – Population 2020

Selection criteria	Unit	Buton	Alor	Kei	Rote	Buru
Population	People	279,828	163,377	216,842	143,764	210,648
Score	>250k = 1 >200k and <250k = 0 <200k = -1	1	-1	0	-1	0

Source: BPS of each region

3.3.3. Population Density

Based on the available data from BPS of each region as at 2020, Kei and Rote have a population density higher than 100 people/ km^2 while Buru has a population density of <50 people / km^2.

Table 7 – Population Density 2020

Selection criteria	Unit	Buton	Alor	Kei	Rote	Buru
Area	km^2	4,408.0	2,124.5	1,286.2	1,280.1	12,655.6
Population Density	People / km^2	63.5	76.9	168.6	112.0	16.6
Score	>100 = 1 >50 and <100 = 0 <50 = -1	0	0	1	1	-1

Source: BPS of each region

3.3.4. Existing Diesel Replacement Programme – Tranche 1

Based on PLN's Existing Diesel Replacement Programme – Tranche 1, all islands, except Alor, had a diesel power plant included in the programme. Buton currently has three diesel power plants included, namely PLTD Talaga

[4] Badan Pusat Statistik Kab. Buton: https://butonkab.bps.go.id/indicator/52/62/1/pdrb-kabupaten-buton-atas-dasar-harga-konstan-2010-menurut-pengeluaran.html, accessed on 22 November 2021
[5] Badan Pusat Statistik Kab. Alor: https://alorkab.bps.go.id/indicator/52/182/1/pdrb-adhb-menurut-pengeluaran-2016-2020.html, accessed on 22 November 2021

in Centre Buton District, PLTD Kadatua and PLTD Molona in South Buton District. Kei, Rote, and Buru each have one diesel power plant included, PLTD Elat in Southeast Maluku District, PLTD Ndao in Rote Ndao District, and PLTD Air Buaya in Buru District, respectively.

Table 8 – Existing Diesel Replacement Program – Tranche 1

Selection criteria	Unit	Buton	Alor	Kei	Rote	Buru
Included / Not included	Yes / No	Yes (3 plants)	No	Yes (1 plant)	Yes (1 plant)	Yes (1 plant)
Score	Yes = 1 No = 0	1	0	1	1	1

Source: PLN Report, Konversi PLTD 225 MW di 200 Lokasi – Tahap 1

3.3.5. Renewable Energy Potential

Referring to PLN RUPTL 2021-2030, all islands have various capacities and renewable energy sources in their power plant development plan. Buton with wind, biomass, and hybrid energy; Alor with biomass energy; Kei with wind and hybrid energy; Rote with solar and biomass energy; and Buru with solar, bioenergy, hydro, and geothermal energy. For the selection criteria, Buton scores 1, Alor, Kei, and Rote score -1, and Alor scores 0.

Table 9 – Renewable Energy Potential 2021

Selection criteria	Unit	Buton	Alor	Kei	Rote	Buru
Renewable Energy Potential	MW	54.8	2.0	23.1	10.0	37.0
Score	>50MW = 1 >25MW and <50MW = 0 <25MW = -1	1	-1	0	-1	0

Source: RUPTL 2021 - 2030

3.3.6. Implementation Feasibility

Port Availability

All islands have primary ports that are utilised for general and cargo transportation of the island. For Buton, the ports are also utilised as the main access to transport asphalt as the main commodity of the island. Available ports in each of the islands are shown below.

More information is required to identify capacity of the ports to support construction logistics when implementing the energy transition, which will be carried out as work progresses on the selected island.

Table 10 – Port Availability 2021

Selection criteria		Buton	Alor	Kei	Rote	Buru
Port Name		Banabungi, Nambo	Kalabahi, Pertamina, Maritaing	Tual, Watdek Langgur	Baa Rote, Pantai Baru	Namrole, Ambalau, Fogi
Score (80% weightage)	Yes = 1 No = 0	1	1	1	1	1

Source: Various Research

Local Workforce (Working Age)

All statistics data are taken from the BPS. The results of each island are as follows:

- For Buton, we refer to the 2017 statistics as the latest data recorded. There were 40,860 people in the working age group (> 15 years age). Based on the level of education completed, most people in this group were high school graduates (10,286), followed by primary school graduates (8,126), junior high school graduates (7,184), and university graduates (5,891).
- For Alor, we refer to the 2019 statistics as the latest data recorded. There were 92,948 people in the working age group (> 15 years age).
- For Kei, we refer to the 2018 statistics as the latest data recorded for Southeast Maluku region. There were 48,718 people in the working age group (> 15 years age).
- For Rote, we refer to the 2018 statistics as the latest data recorded. There were 79,486 people in the working age group (> 15 years age). Based on the level of education completed, most people in this group were primary school graduates (27,356), followed by high school graduates (11,287), junior high school graduates (8,871), and university graduates (5,445).
- For Buru, we refer to the 2020 statistics as the latest data recorded. There were 100,857 people in the working age group (> 15 years age). Based on the level of education completed, most people in this group were high school graduates (31,110), followed by elementary school graduates (21,472), and junior high school graduates (20,472).

There is no official information on working age population distribution based on level of education for Alor and Kei, and to date there is no official information found on labour wage statistics on all islands.

Table 11 – Local Manpower 2021

Selection criteria	Unit	Buton	Alor	Kei	Rote	Buru
Working age group population	People (Year)	40,860 (2017)	92,948 (2019)	48,718 (2018)	79,486 (2019)	100,857 (2020)
Score (20% weightage)		-1	1	0	0	1

Source: BPS of each region

3.3.7. Transportation

All islands are accessible through the available transporation means, which include flights and ferries. Based on the availability of ports and flights, the table below summarises the scoring for each island.

Table 12 – Transportation Availability 2021

Selection criteria		Buton	Alor	Kei	Rote	Buru
Flights		At least 1x/week; inconsistent	1x/week	1x/week	1x/day	Everyday
Score (40% weightage)	>=2/week = 1 1/week = 0 0/week = -1	0	0	0	1	1
Ferries		1x/every 2 weeks	2x/week	1-2x/week	1x/day	Everyday
Score (60% weightage)	>=3/week = 1 1-2/week = 0 0/week = -1	-1	0	0	1	1

Source: Various Research

The table below summarises the results of the island selection criteria based on our analysis:

Table 13 – Results of the island selection criteria

Selection criteria	Weightage		Total Score*				
	Level 1	Level 2	Buton	Alor	Kei	Rote	Buru
GDP value	**15%**	N/A	**0.15**	**0.15**	**0.0**	**0.0**	**-0.15**
Population	**15%**	N/A	**0.15**	**-0.15**	**0.0**	**-0.15**	**0.0**
Population density	**10%**	N/A	**0.0**	**0.0**	**0.1**	**0.1**	**-0.1**
Existing diesel replacement program – Tranche 1	**15%**	N/A	**0.15**	**0.0**	**0.15**	**0.15**	**0.15**
Renewable energy potential	**15%**	N/A	**0.15**	**-0.15**	**-0.15**	**-0.15**	**0.0**
Implementation feasibility	**15%**		**0.09**	**0.09**	**0.12**	**0.12**	**0.15**
- port availability		80%	0.8	0.8	0.8	0.8	0.8
- local workforce (working age)		20%	-0.2	-0.2	0	0	0.2
Transportation	**15%**		**-0.09**	**0**	**0**	**0.15**	**0.15**
- Flights		40%	0	0	0	0.4	0.4
- Ferries		60%	-0.6	0	0	0.6	0.6
Total	**100%**	N/A	**0.60**	**0**	**0.22**	**0.22**	**0.2**
Rank			**I**	**V**	**II**	**III**	**IV**

*Note: Total score is based on the score assigned in the previous sections for each criterion, multiplied by their respective Level 1 and Level 2 weightage, as applicable

3.3.8. Conclusion

In summary, Buton obtained the highest score out of all islands based on the proposed selection criteria. Therefore, Buton is the highest-ranking island and based on the criteria agreed should be taken forward as the most suitable island for detailed assessment.

4. Buton Island Overview

4.1. Stakeholders Analysis

4.1.1. Central Government Stakeholders

a) Ministry of Energy and Mineral Resources

Under the Republic of Indonesia Presidential Regulation No. 68 of 2015 concerning MEMR and the Regulation of MEMR No. 15 of 2021, the duty of MEMR is to carry out governmental affairs in relation to energy and mineral resources as assistance to the President. One of the main functions of MEMR is to formulate and implement policies in fostering, controlling, and supervising oil and gas, electricity, minerals, coal, new energy, renewable energy, energy conservation, and geology.[6]

Furthermore, the Ministry is in charge of creating and implementing Indonesia's energy policy, including the National Electricity General Plan (*Rencana Umum Ketenagalistrikan Nasional* – "RUKN"), and regulating the power sector through the Directorate General of Electricity ("DGE") and the Directorate General of New and Renewable Energy and Energy Conservation ("DGNREEC"). MEMR is also responsible for preparing implementing regulations related to electricity, NRE and energy conservation, and approving PLN's RUPTL.

b) PT Perusahaan Listrik Negara

According to the company's objectives, PLN is to carry out the business of providing electricity for the public interest in an adequate quantity and quality and to foster profits and carry out the assignment of the Government in the electricity sector in order to support development by applying the principles of a Limited Liability Company.[7] PLN is responsible for the majority of Indonesia's power generation with exclusive powers over transmission, distribution and supply of electricity to the public. PLN is regulated and supervised by MEMR, Ministry of State-Owned Enterprises ("MoSOE") and MoF. In 2004, PLN was transformed from a public utility into a state-owned limited liability company (or Persero). The 2009 Electricity Law removed PLN's role as the Electricity Authority Business Licence (*Pemegang Usaha Kuasa Ketenagalistrikan* – "PKUK"). PLN is now simply the holder of an IUPTL, while the regulatory role is performed by the central and/or local government.

The 2009 Electricity Law also grants a right of first refusal to PLN for the supply of electricity in an area before the Central Government or Regional Governments can offer the opportunity to regional-owned entities, private entities, cooperatives, or self-reliant community institutions. PLN is also the provider of electricity of last resort. This means that, if PLN is not supplying a particular area and there are no regionally owned companies, private enterprises or cooperatives willing to supply then the Government can instruct PLN to ensure the supply of electricity.

c) Ministry of Finance

Based on Presidential Regulation Number 28 of 2015 concerning MoF and the Regulation of MoF No. 234/PMK.01/2015, the task of MoF is to run governance in terms of State finance in order to assist the President in running the State governance. Accordingly, one of the main functions of MoF is to formulate, stipulate, and implement policies in terms of budgeting, taxes, customs and excise, treasury, State assets management, fiscal balance, and budget financing and risk management.[8]

MoF approves tax incentives that may be offered by the Government for a power project as well as any

[6] Profile of MEMR. ESDM Website (accessed on 11 February 2022)
[7] Profile of PLN. PLN Website (accessed on 11 February 2022)
[8] Profile of MoF. MoF Website (accessed on 11 February 2022)

Government guarantees. The Directorate of Government Support Management and Infrastructure Financing (Direktorat Pengelolaan Dukungan Pemerintah dan Pembiayaan Infrastruktur) within the MoF is responsible for reviewing government support, providing technical guidance, evaluating the financing and maintaining investor relations. Any approved guarantees are administered by PT Penjaminan Infrastruktur Indonesia (the Indonesian Infrastructure Guarantee Fund – "IIGF"). MoF also recommends the maximum level of electricity subsidy to PLN in the national budget and reviews loan arrangements entered by PLN including the Government's guarantees of PLN's loans.

d) Ministry of State-Owned Enterprises

The principal task of MoSOE is to hold government affairs in the field of State-Owned Enterprises to assist the President in organising state governance. The development of State-Owned Enterprises includes the development of entities controlled by State-Owned Enterprises directly or indirectly in accordance with the provisions. In carrying out the tasks, the main functions of MoSOE are formulating and determining policies with regards to building strategic business initiatives, strengthening competitiveness and synergy, strengthening performance, creating sustainable growth, restructuring, business development, and enhancing the capacity of State-Owned Enterprises' business infrastructure.[9] Noting that PLN is a state-owned company, MoSOE supervises PLN's management, sets its corporate performance targets, approves its annual budget and assesses the achievement of those targets.

e) House of Representatives ("DPR")

Based on the Decree of the House of Representatives of the Republic of Indonesia Number: 44/DPR RI/I/2019-2020 concerning the Determination of Working Partners for the Commissions, Budget Agency, and State Financial Accountability Agency of the DPR RI for the 2019-2024 Membership Period, the Commission VII of the DPR is charged with developing regulations in the areas of energy, research and technology, and industry.[10] Along with MEMR, the Commission VII is responsible for the approval of energy-related legislation (including for electricity) and the supervision of energy-related Government policy.

[9] Profile of MoSOE. MoSOE Website (accessed on 11 February 2022)
[10] Profile of DPR RI Commission VII. DPR RI Website (accessed on 11 February 2022)

4.1.1. Regional and Local Stakeholders in Buton Island

a) PLN Regional/PLN Wilayah Sulawesi Selatan Barat in Makassar/PLN in Baubau City

PLN Regional/PLN Wilayah charged for Sulawesi Selatan Barat region in Makassar/PLN in Baubau City of Buton Island were engaged to obtain the following information used for the power analysis in this report:

- Electricity consumption, including for household, transportation, industry, and commercial customers.
- Electrification status, including the number of electrified households and/or settlements.
- Renewable energy resource assessment, including surveys and studies previously conducted to identify and measure the renewable energy resources and potential site location.
- Power plants and grid systems, including the information about existing power plants, energy production by type of power plant, consumption of fuel, unit price of fuel, transmission and distribution lines, substations, load profile and voltage profile of each substation, UFR, feeders, and grid studies.
- The Geographic Information System (GIS) of the existing substation, transmission lines, distribution lines, low voltage lines, generation power plants, and the single-line diagram.
- The power contract, including the commercial information such as consumer mix with contract demand, consumption mix, and revenue mix.
- Planned expansion by PLN on the low voltage, distribution, and transmission on Buton Island.

b) Energy Department for Southeast Sulawesi Province

The Energy Department in charge of the Southeast Sulawesi Province was engaged to provide data with regard to the following information:

- Electricity consumption, including for household, transportation, industry, and commercial customers.
- Electrification status, including the number of electrified households and/or settlements.
- Renewable energy resource assessment, including surveys and studies previously conducted to identify and measure the renewable energy resources and potential site location.
- Power plants and grid systems, including the information about existing power plants, energy production by type of power plants.
- Grid system, which includes the number of off-grid systems, generation capacity and generation mix, and consumer mix. Further coordination with the Fishery and Marine Department, and Cooperatives Department may be required to obtain the information.

c) Pertamina Regional in Baubau City

Pertamina Regional located in Baubau City of Buton Island was engaged to obtain the fuel and electricity consumption data, particularly for the conventional fuel usage on Buton Island such as kerosene, LPG, coal, diesel, and the fuel consumption information per each demand sector (household, transportation, industry, and commercial). However, as of the writing of this report, no data are available from Pertamina office in Baubau.

4.2. Social and Environmental Analysis

4.2.1. Alignment with Regional Plan

Southeast Sulawesi Province is well known for its abundant natural resources and its growing economy from industries such as mining, fisheries, agriculture, and tourism. According to the Ministry of Investment/Investment Coordination Agency (BKPM), South Sulawesi provincial government aims to develop a conducive climate for investments in the region to support economy and increase employment or collaboration with the local community.[11] Furthermore, the Coordinating Minister for Maritime Affairs and Investment has also initiated a strategy to accelerate the development of essential infrastructure, namely road infrastructure, dams, bridges, airports, food estate, asphalt, and the fishing industry, to support regional development.[12]

In the power sector, a vision to realise the energy sector as one of the main pillars to support regional development of Southeast Sulawesi through clean and affordable renewable energy utilisation was announced by the Governor of Southeast Sulawesi Province during the Governor's Forum on Energy Transition held by National Energy Council on March 9, 2022. As noted in his remarks, one of the key components of the provincial development plan is to drive regional development by reducing current dependence to only one energy resource, and to optimise the use of alternative energy resources with efficient and environmentally sound technology to address the need for enhanced electrification and affordable energy across the region[13].

This vision is in alignment with the prevailing regulatory framework, namely the Sulawesi Provincial Regulation No. 2/2021 on the Regional General Energy Plan for the Sulawesi Province.[14] The regulation sets the energy sector visions, frameworks, and the functions of Provincial government in providing guidance, supervision, socialisation, and evaluation. The objective of the regulation is to ensure the security and sustainability of energy supply until 2050, and to support the regional development plan in proposing the National/Regional Budget (APBN/APBD) in energy infrastructure development, particularly for the use of renewable energy resources. This regulation was also developed in accordance with other regional plans, namely the Regional Medium-Term Development Plan (RPJMD), the Regional Long-Term Development Plan (RPJPD), Regional Electricity General Plan (RUKD), Provincial Industrial Development Plan (RPIP), and the Regional Spatial Planning (RTRW). On that basis, the prevailing regulations may provide the required support and willingness to move forward with implementation from the provincial government as key to push forward the renewable energy transition target across the province, including Buton Island.

Buton Island is considered the country's largest asphalt producer, with a total estimated potential natural asphalt reserve of 694 million tonnes. Due to this abundant deposit, Indonesia is registered as the country with the biggest source of natural asphalt in Southeast Asia (Meyer and Duford, 1989). Increased utilisation of Buton asphalt in road construction has become a strategy supported by the Indonesian government to minimise asphalt imports and fulfil the estimated national demand of asphalt around 2 million tonnes per year. As a reference, the price of extracted Buton asphalt as per 2021 is estimated to be up to USD 350 per tonne. To this end, the Ministry for Maritime Affairs and Investment has also supported the development of asphalt industry in Buton with targeted capacity increase of 33% in 2025. This growth is expected to be able to fulfil the national demand for asphalt at 49.36%.[15]

Buton has long relied on fossil-fueled power plants including diesel and coal-fired technology to cater to its

[11] BKPM.go.id. *"Head of BKPM Ready to Facilitate Postponed Investment Execution in Southeast Sulawesi"* (accessed on 19 April 2022)
[12] Maritim.go.id. "To push Acceleration of Infrastructure Development and Regional Development, Coordinating Minister Luhut Holds Coordination Meeting with Southeast Sulawesi Provincial Government." (accessed on 19 April 2022)
[13] National Energy Board of Indonesia. "Implementation of RUED Southeast Sulawesi Province" (accessed on 19 April 2022)
[14] Peraturan.bpk.go.id. Peraturan Daerah Provinsi Sulawesi Barat Nomor 2 Tahun 2021 tentang Rencana Umum Energi Daerah.
[15] Dunia Tambang.co.id. "Knowing Buton Asphalt, the World's Treasure in Indonesia."

electricity demand. The addition of a 30 MW gas engine power plant to the Baubau Systemin 2019 is claimed to be improving the reliability of the system and contributing to level of reserve margin of the island's main grid which is currently estimated up to 40-50% according to the PLN Baubau. The existing energy mix in Southeast Sulawesi Province in 2021 based on the Governor's Forum on Energy Transition by the National Energy Council document is summarised in the table below:

Table 14 – Existing energy mix in Southeast Sulawesi Province in 2021

Energy Resource	Mix (%)
Crude oil	15.98
Coal	84.01
Renewable energy	0.016

Source: Southeast Sulawesi Governor's Forum Discussion Document as presented in the Energy Transition by the National Energy Council (2022)

With the existing level of reserve margin as mentioned above, the risk of power shortages was able to be minimised except for in the northern part of the island. The electricity service in northern areas of Buton remains a challenge, as the existing power plants are located at a distance, in the centre part of the island, resulting in limited and unstable supply to the north. This provides an opportunity for renewable energy-based electricity generation to be implemented throughout the island. Solar PV with a battery energy storage system, hydro power plants, biomass power plants, and other technologies, subject to the resources availability in the Region, can help to improve the electricity conditions and challenges as mentioned by the local authorities. The estimated potential of renewable energy resources in Southeast Sulawesi is presented in the table below:

Table 15 – Estimated Potential Renewable Energy Resources in Southeast Sulawesi

Renewable Energy Resource	**Estimated Potential Capacity**
Hydropower	6,340 MW
Micro/Mini hydropower	301 MW
Solar power	3.917 MWp
Geothermal	896 MW
Wind power	257 MW
Biomass	301 MW

Source: Southeast Sulawesi Governor's Forum Discussion Document as presented in the Energy Transition by the National Energy Council (2022)

From the previously held discussions with the local stakeholders in the energy sector in Buton, namely PLN Southwest Sulawesi, PLN Baubau, and the Department of Energy and Mineral Resources for Southeast Sulawesi Province, they have expressed their support and agreement towards the transition plan to more environmentally friendly technologies. However, it was noted that their priority for the Region is to expand the coverage of electricity supply to the unelectrified parts of the Island, and to maintain the current grid stability. Based on the Governor's Forum on Energy Transition by the National Energy Council document, the estimated total electrification ratio in Southeast Sulawesi is 99.56%. The estimated electrification ratio for each district/city in Buton Island region in 2021 is presented in the table below:

Table 16 – Estimated Electrification Ratio in Buton

No	District/City	Total Households	Electrified Households	Non-electrified Households	Electrification Ratio (%)
1	Baubau	36,710	36,710	0	100
2	Buton	23,410	22,970	440	98.12
3	South Buton	18,894	18,853	41	99.78
4	North Buton	15,844	15,735	109	99.31
5	Muna (Subdistricts of Pasir Putih and Maligano)*	2,912	2,876	36	98.76

Source: Southeast Sulawesi Governor's Forum Discussion Document as presented in the Energy Transition by the National Energy Council (2022)

**Note: only a partial of area in the Muna District, namely two subdistricts, are currently included in the calculation of electrification ratio performed by the Department of Energy and Mineral Resources*

4.2.2. Social and Environmental Aspect

Social Aspect

Buton Island is known to be highly heterogenous and multicultural as it consists of various tribes and sub-tribes, traditions, and languages. Two of the inhabitant tribes living in Buton are Kulisusu in the North Buton region and the Cia-Cia who inhabit the South Buton area. Others include the Wolio and Buton tribes. Latif, et al. (2019) describe the community in Buton as able to preserve the local identity and the particular beliefs of each sub-tribe, while at the same time enabling the integration process of Buton Island as a whole.[16] Based on BPS data for Buton in 2020, the estimated total population aged 15 years and over who were economically active was 45,712 people with an economic participation rate of over 65.34%. Based on educational attainment, the number of people who are economically active that have completed primary school was 17,675 people, followed by high school (15,005), junior high school (7,714), and university degree (5,318).[17] The biggest settlement and the most developed city in Buton Island is Baubau city which is the second largest city in South East Sulawesi Province.

Economic Aspect

According to the 2022 Statistics of Southeast Sulawesi, the economic structure in Southeast Sulawesi is still dominated by the primary sector and highly reliant on natural resources. This can be seen from the high percentage of GRDP in the agriculture, forestry and fisheries sectors. The second largest contribution derives from the mining and quarrying sector, then the construction sector, and followed by the wholesale and retail trade sector, car and motorcycle repair, and manufacturing industry sector.

The economic growth in the province from year to year shows a fluctuation. There was a slowdown from 6.76% in 2017 to 6.40 % in 2018. Then, it increased to 6.50% in 2019. However, it experienced a slowdown in growth to -0.65% in 2020 due to the Covid-19 pandemic. Then, the growth increased again to 4.10% in 2021, as can be seen in the following figure.

[16] Latif, Birkah, et al. 2019. "Society Differentiation, Can Human Rights be Protected?: Critical Study of the Tribes Castration on Community (Case Study of Laporo Buton)." *Jurnal Magister Hukum Udayana (Udayana Master Law Journal)* 8.2 (2019): 137-166.

[17] Buton Regency in Figures 2021. Central Bureau of Statistics.

Figure 1 – Growth Rate of Gross Regional Domestic Product at 2010 Constant Market Prices by Industry in Sulawesi Tenggara Province (percent), 2017-2021

Source: Central Statistics Agency of Southeast Sulawesi, 2022

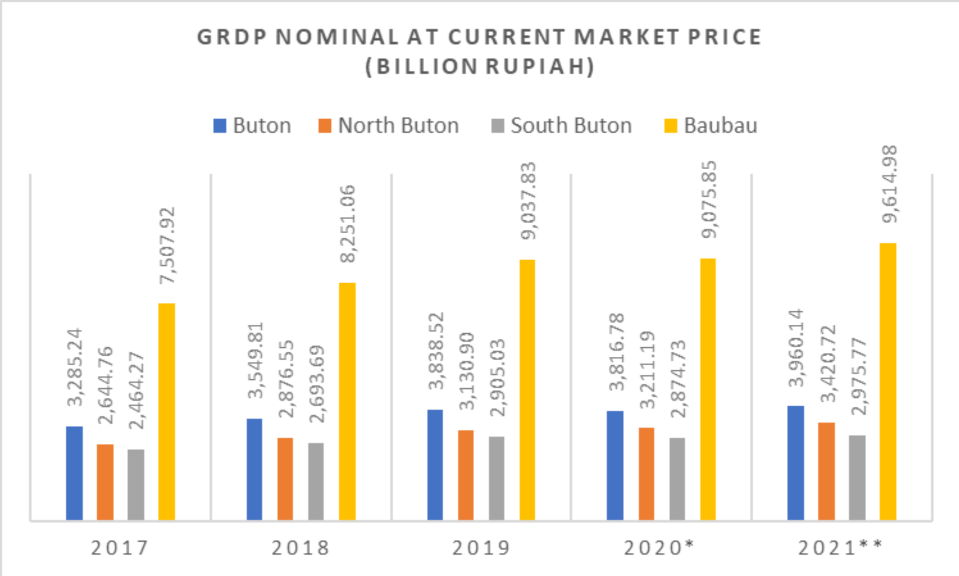
Southeast Sulawesi's economy, based on the amount of Gross Regional Domestic Product (GRDP) in 2021 at current prices, reached Rp 139.1 trillion and in 2010 constant prices reached Rp 97.27 trillion. Buton Island is part of Southeast Sulawesi province. Within Buton Island, there are three regencies and one city which are part of Buton Island, which are Buton regency, Buton Utara (North Buton) regency, Buton Selatan (South Buton) regency, and Baubau city. There is also part of Muna Island which is administratively included within Buton Island, however as at the writing of the report there is no publicly available data on the exact area, population and GRDP of this part of Island. The total GRDP at current price in 2021 for Buton Island is at IDR 19,971.61 billion, and the GRDP at 2010 constant price in 2021 for Buton Island is IDR 14,114.57 billion. The table below presents the known value of GRDP of each regency and city as part of Buton Island.

Table 17 – GRDP and Growth rate of GRDP

Regency/Municipality	GRDP at current price in 2021 (billion rupiah)	GRDP at 2010 constant price (billion rupiah) in 2021	Growth Rate of Gross Regional Domestic Product per Capita at 2010 Constant Price in 2021
Buton	3,960.14	2,847.09	2.62
Buton Utara	3,420.72	2,342.59	4.08
Buton Selatan	2,975.77	2,080.20	2.29
Kota Baubau	9,614.98	6,844.69	4.15
Total for Buton Island	**19,971.61**	**14,114.57**	**N/A**

Source: BPS of Southeast Sulawesi, 2022

The economic overview of Buton Island itself can be seen from the nominal value of the region's GRDP. The development of the GRDP value of Buton Island for four regencies and cities (Buton, North Buton, South Buton and Baubau City) over the last five years can be seen in the figure below.



*Note: *= Preliminary Figures, **= Very Preliminary Figures*

Source: Central Statistics Agency

Figure 2 – GRDP Nominal at Current Market Price

Based on the graph above, it can be seen that Baubau City has the highest GRDP value compared to other regencies and South Buton has the lowest GRDP. The value of the GRDP of the city of Baubau in 2021was 9.61 trillion rupiah. In summary, the development of macroeconomic indicators in Buton Island is presented as follows.

Table 18 – Macroeconomic Situation in Buton Island

No.	Macroeconomic Indicator	Buton	North Buton	South Buton	Baubau
1	GRDP (current price) in 2021	Rp 3.9 Trillion	Rp 3.4 Trillion	Rp 2.9 Trillion	Rp 9.6 Trillion
	GRDP (2010 constant price) in 2021	Rp 2.8 Trillion	Rp 2.3 Trillion	Rp 2.08 Trillion	Rp 6.8 Trillion
2	Economic Growth in 2021	2.62%	4.08%	2.29%	4.15%
3	Inflation in 2020	N/A	N/A	N/A	1.73%
4	Percentage Distribution of GRDP at current market price in 2020				
	• Agriculture, forestry and fishing	19.44%	39.35%	32.83%	15.20%
	• Mining and Quarrying	39.12%	7.07%	26.92%	3.93%
	• Manufacturing	2.50%	4.44%	3.51%	3.99%
	• Electricity and gas	0.04%	0.01%	0.03%	0.06%

No.	Macroeconomic Indicator	Buton	North Buton	South Buton	Baubau
	• Water supply; sewerage, waste management and remediation activities	0.43%	0.05%	0.27%	0.30%
	• Construction	6.46%	15.90%	14.79%	21.24%
	• Wholesale and retail trade; repair of motor vehicles and motorcycles	12.87%	13.46%	8.41%	19.94%
	• Transportation and storage	0.82%	1.47%	0.89%	4.71%
	• Accommodation and food service activities	0.13%	0.2%	0.13%	1.21%
	• Information and communication	0.29%	0.89%	1.01%	3.64%
	• Financial and insurance activities	0.67%	0.7%	0.86%	3.42%
	• Real estate activities	0.51%	1.67%	0.06%	2.58%
	• Business activities	0.02%	0.06%	0,02%	0.15%
	• Public administration and defence; compulsory social	9.77%	7.77%	2.52%	8.29%
	• Education	5.47%	4.20%	5.68%	7,22%
	• Human health and social work activities	0.89%	1.50%	1.47%	1,30%
	• Other services	0.57%	1.09%	0.61%	2,83%
5	Number of poor people in 2020	13,680	9,130	11,500	12,530
6	Percentage of poor people in 2020	13.21%	14.1%	14,11%	7.15%
7	Unemployment rate in 2020	4.78%	4.11%	3.90%	6.57%

Source: BPS

The economy of each region or municipality varies in terms of the industries it comprises. In 2020, the GRDP structure in Baubau City was dominated by construction (21,245), followed by wholesale and retail trade (19,945) and agriculture, forestry and fishing (15.20%). In Buton regency, the largest share of GRDP came from mining and quarrying (39.12%), followed by agriculture, forestry and fishing (19.44%) and wholesale and retail trade (12.87%). Meanwhile, the largest share of GRDP in North Buton was from agriculture, forestry and fishing (39.35%), Construction (15.90%) and wholesale and retail trade (13.46%). The largest share of GRDP in southern Buton was agriculture, forestry and fishing (32.83%), mining and quarrying (26.92%) and construction (14.79%).

The number of poor people[18] at Buton Island from the four regions was recorded at 46,840 in 2020, with the highest number of poor people in Baubau City (12,530 people). The highest unemployment rate was also in Baubau (6.57%). Nowadays, Baubau City, as the centre of the Island, continues to advance its development, while the economic conditions of the other regencies is also improving following the contribution of its industries such as fisheries, mining, agriculture, and forestry. Referring to the latest data available in the BPS, the most significant regional GDP contribution has come from these industries at 23.8%. The 2021 regional GDP of Southeast Sulawesi based on the current price is IDR 139.06 trillion, and IDR 97.28 trillion based on the constant price of 2010. The cumulative growth rate of the regional economy was 4.1% overall in 2021.

Regional economic growth has been stable since 2010. As published in the Regional Development Analysis issued by the National Development Agency in 2015, Southeast Sulawesi has managed to increase the regional income per capita from IDR 21,573.11 thousand in 2010 to IDR 32,115.11 thousand in 2014; although this is lower in comparison to the national rate for the same period. The unemployment rate and poverty percentage have been significantly reduced at 2.43% (from 2008 to 2015) and 7.28% (from 2007 to 2015) respectively. Baubau City, Buton District, and Wakatobi were some of the regencies with an economic growth rate above the average in the Province. However, this did not correspond to a significant reduction in the unemployment rate in the said regions (high-growth, less-pro poor). In order to have real poverty reduction in the region, creation of economic activities and sectoral development which able to absorb more resources, such as agriculture, micro, small, medium, and cooperatives will be prioritised. In addition, provincial government may optimise coordination on policies and poverty eradication programmes across the region.[19] Improvement in the electricity distribution and renewable energy transition plan may support the accessibility of power for the more remote settlements in the Island. With sufficient, safe, and reliable power, the residents and communities in Buton can potentially benefit from technology advancement to support their economic and social activities. This could ultimately lead to the improvement of the quality of living conditions, and further enable inclusive economic growth in all regions of Buton.

Environmental Aspect

In addition to its massive reserve of natural asphalt, Buton Island has also significant potential for nickel, crude oil, and gold as its mining commodities. In terms of biodiversity, Sulawesi Province itself has been deemed to possess a unique natural landscape with a combination of ocean, beach, forest, and mountain ecosystems. On the mainland of Sulawesi, there is a variety of habitats such as rivers, swamps, deep lakes and ancient lakes such as Lake Matano, Mahalona, Towuti, Poso, and savanna meadows. Various forest formations are found on this island ranging from mangrove forests, coast, swamp forest, and lowland forest to lower montane forest, upper mountain forest, and sub-alpine forest at an altitude of 3440masl in the centre of the island, namely Mount Rantemario in South Sulawesi.[20] Furthermore, the North Buton Wildlife Sanctuary (SMBU) in Buton Island is the largest of eight nature reserves in Southeast Sulawesi Province. The 28,000 hectares area reserves a diverse potential of flora including endemic plants.[21] A comprehensive study on the plant diversity in Buton Island is still lacking to date, however among the most notable plants are the beetroot or wola (*Vitex coffasus*) and suwele (*Palaquium obtusifolium*) as timber producing plants, and soni tree (*Dillenia serrata*) as one of endemic plants in Sulawesi which will require conservation efforts[22].

[18] Using basic needs approach as defined in the Handbook on Poverty and Inequality (World Bank), BPS defined 'poor' as having an average expenditure per capita per month below the poverty line (IDR 486,168 or equals to USD 32.5 per capita per month).
[19] Bappenas.go.id. Analysis Series Regional Development of Southeast Sulawesi 2015.
[20] Mustari, AH. 2020. *Identification and Bio-ecology Manual of Key Species in Sulawesi*. Bogor. IPB Press
[21] Uji, Tahan. 2005. *Diversity and Potential of Flora in the Wildlife Reserve of North Buton, Southeast Sulawesi.* Biodiversity Volume 6, Number 3 (205-211).
[22] Uji, Tahan. dan Windadri, FI. 2007. Diversity of Plants in Kakenauwe Natural Reserves and Lambusango Wildlife, Buton Island, Southeast Sulawesi.

Based on the findings of Operation Wallacea[23], the biodiversity of forests in Buton possess an extremely high conservation value with a total of 50 mammal species, 139 bird species, 60 herpetofauna species, 46 freshwater fish species, 184 butterfly species and 223 tree species have been detected in the area. The diversity of Buton is remarkably representative of species assemblages across Sulawesi as a whole, and faunal groups in the forests of Buton also display high incidence of endemism. Numerous organisms are locally endemic to the area and several of the species also act as important regional flagship for Wallacean biodiversity, such as the Lowland Anoa (*Bubalus depressicornis*), Booted Macaque (*Macaca ochreata burnnescens*) and the Knobbed Horbnill (*Aceros cassidix*). Some of these regionally endemic species can be found in the Lambusango forest. From the total of 65,000 hectares, more than half of the forest's area is dedicated as protected and production forest while the remaining area is utilised for conservation under the Kakenauwe Natural Reserves and Lambusango Wildlife.

However, according to Operation Wallacea, the biodiversity of the unique and highly-endemic ecological communities that exist in the forests of Buton is highly threatened by anthropogenic pressures, most significantly from habitat loss, degradation, and unregulated hunting. The most recent estimates for land change in southern Buton, for example, saw 13% of landcover change from forest to non-forest in an 11-year period. The energy transition plan which focuses on the application of environmentally sound technology, and the use of renewable energy resources should also take into account the significance of Buton's natural environment and its biodiversity. Aside from estimating the magnitude of greenhouse gas emission avoidance by phasing out of the fossil-fuelled power plants, new development projects in the energy sector should also consider the sustainability aspect and strive to minimise environmental impact from planning, construction, operation, and the possible disposal phase.

4.3 Renewable Energy Resource Assessment

The following section show the results of the resource assessment on renewable energy potentials in Buton. Resource assessment is essential to carry out to investigate the potential of each type of renewable energy source, also the indicative locations and, furthermore, the potential installed capacity if possible. It will further help to examine to what extent the renewable energy potential can support the island transition agenda while at the same time meeting current and future electricity demand coverage in the island.

Solar Resources

Solar resource assessment can be performed utilising the solar resource dataset that is publicly accessible. Global Solar Atlas is one of the platforms that provides the said information and has satellite data from SolarGIS, a well-known and reputable supplier of irradiation and meteorological data.

Referring to Irradiation taken from Global Solar Atlas, the highest irradiation on Buton Island is on the Southern part of the island, which it is estimated can produce 1,564 kWh/kWp (equals to 1.564 MWh of power produced by 1 MW peak of installed solar PV capacity). However, the total solar power capacity that can be harvested will depend on the land area availability on Buton island.

[23] Operation Wallacea Report. *The Biodiversity Value of the Buton Forests.*

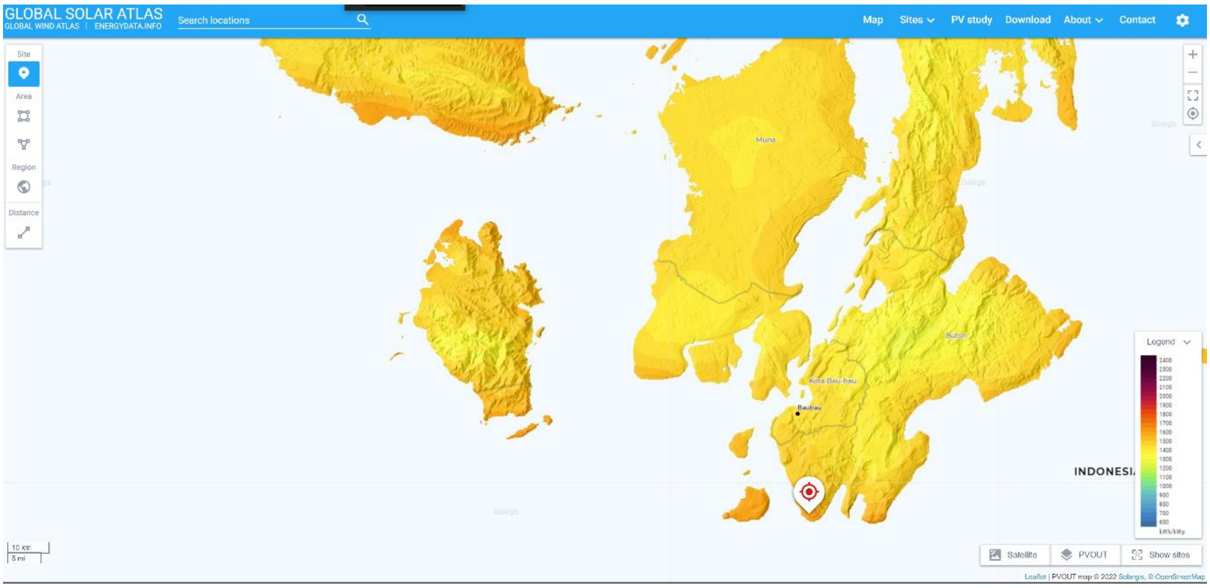


Figure 3 – Solar Resources Assessment for Buton Island

Irradiation information from Global Solar Atlas was used to determine the energy yield of the various locations where the solar PV systems have been simulated. Global Solar Atlas can produce a report on the irradiation and yield analysis based on the type of solar PV system installed as shown in the example below:

GLOBAL SOLAR ATLAS
BY WORLD BANK GROUP

Bola

-05.682586°,122.641281°
Bola, Southeast Sulawesi, Indonesia
Time zone: UTC+08, Asia/Makassar [WITA]

Report generated: 12 Jul 2022

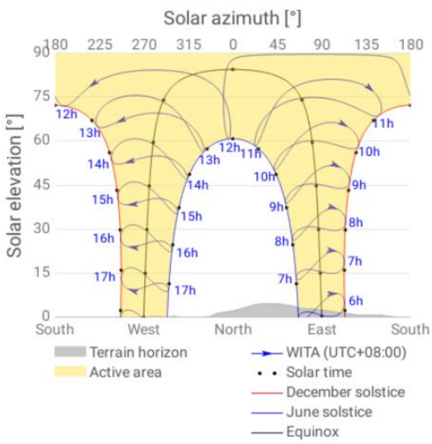
SITE INFO

Map data — Per year

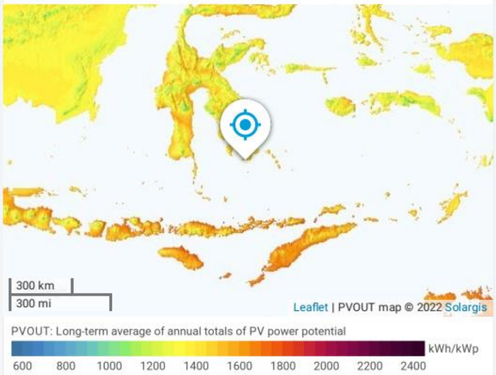
Direct normal irradiation	DNI	**1669.9**	kWh/m²
Global horizontal irradiation	GHI	**1961.4**	kWh/m²
Diffuse horizontal irradiation	DIF	**757.8**	kWh/m²
Global tilted irradiation at optimum angle	GTI opta	**1974.7**	kWh/m²
Optimum tilt of PV modules	OPTA	**8 / 0**	°
Air temperature	TEMP	**26.1**	°C
Terrain elevation	ELE	**158**	m

Map

Horizon and sunpath



PVOUT map



 Bola 1 / 4

Figure 4 – Irradiation and Yield Analysis Report

GLOBAL SOLAR ATLAS
BY WORLD BANK GROUP

PV ELECTRICITY AND SOLAR RADIATION

PV system configuration

Pv system: **Ground-mounted large scale**
Azimuth of PV panels: **Default** (0º)
Tilt of PV panels: **8º**
Installed capacity: **5000 kWp**

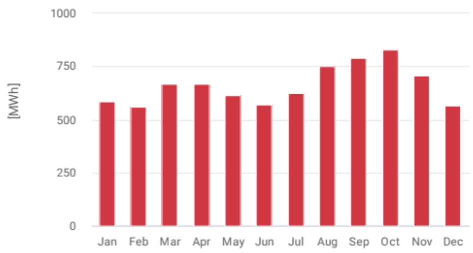
Annual averages

Total photovoltaic power output and Global tilted irradiation

7.937	1975.5
GWh per year	kWh/m² per year

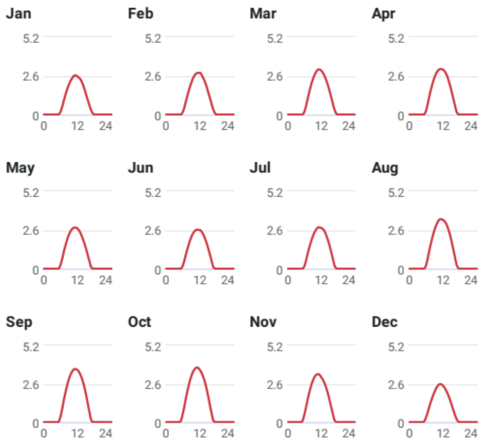
Monthly averages

Total photovoltaic power output



Average hourly profiles

Total photovoltaic power output [MWh]



UTC+08

Average hourly profiles

Total photovoltaic power output [MWh]

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0 - 1												
1 - 2												
2 - 3												
3 - 4												
4 - 5												
5 - 6									0	0	0	0
6 - 7	0	0	0	0	0	0	0	0	0	1	1	0
7 - 8	1	1	1	1	1	1	1	1	1	2	1	1
8 - 9	2	2	2	2	2	2	2	2	2	2	2	2
9 - 10	2	2	2	3	2	2	2	3	3	3	3	2
10 - 11	2	3	3	3	3	2	3	3	3	4	3	2
11 - 12	3	3	3	3	3	3	3	3	4	4	3	3
12 - 13	3	3	3	3	3	3	3	3	4	4	3	2
13 - 14	2	3	3	3	2	2	3	3	3	3	3	2
14 - 15	2	2	2	2	2	2	2	3	3	3	2	2
15 - 16	1	1	2	2	1	1	2	2	2	2	1	1
16 - 17	1	1	1	1	1	1	1	1	1	1	1	1
17 - 18	0	0	0	0	0	0	0	0	0	0	0	0
18 - 19												
19 - 20												
20 - 21												
21 - 22												
22 - 23												
23 - 24												
Sum	19	20	22	22	20	19	20	24	26	27	24	18

WORLD BANK GROUP ESMAP SOLARGIS Bola 2 / 4

Figure 5 – PV Electricity and Solar Radiation Analysis (1)

GLOBAL SOLAR ATLAS
BY WORLD BANK GROUP

PV ELECTRICITY AND SOLAR RADIATION

Annual averages

Direct normal irradiation

1679.1

kWh/m² per year

Monthly averages

Direct normal irradiation

Average hourly profiles

Direct normal irradiation [Wh/m²]

UTC+08

Average hourly profiles

Direct normal irradiation [Wh/m²]

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0 - 1												
1 - 2												
2 - 3												
3 - 4												
4 - 5												
5 - 6										37	45	14
6 - 7	115	109	149	196	185	133	124	179	254	343	337	173
7 - 8	241	253	314	384	352	291	305	387	448	483	455	256
8 - 9	300	327	389	461	399	346	358	468	538	586	532	305
9 - 10	342	365	449	511	448	405	410	538	623	674	587	338
10 - 11	381	408	485	536	474	442	446	586	674	723	626	387
11 - 12	407	424	509	545	482	446	467	611	694	742	618	395
12 - 13	382	429	484	539	470	446	461	606	686	710	546	367
13 - 14	370	382	428	519	434	434	468	598	655	669	518	320
14 - 15	325	346	380	456	382	394	422	553	610	610	474	288
15 - 16	235	265	317	367	314	323	351	477	514	500	398	215
16 - 17	174	189	233	265	242	237	265	359	369	355	299	164
17 - 18	87	97	104	55	38	37	54	114	59	52	47	64
18 - 19												
19 - 20												
20 - 21												
21 - 22												
22 - 23												
23 - 24												
Sum	3359	3595	4242	4833	4220	3935	4130	5476	6125	6485	5484	3286

WORLD BANK GROUP ESMAP SOLARGIS Bola 3 / 4

Figure 6 – PV Electricity and Solar Radiation Analysis (2)

GLOBAL SOLAR ATLAS
BY WORLD BANK GROUP

GLOSSARY

Acronym	Full name	Unit	Type of use
DIF	Diffuse horizontal irradiation	kWh/m², MJ/m²	Average yearly, monthly or daily sum of diffuse horizontal irradiation (© 2021 Solargis)
DNI	Direct normal irradiation	kWh/m², MJ/m²	Average yearly, monthly or daily sum of direct normal irradiation (© 2021 Solargis)
ELE	Terrain elevation	m, ft	Elevation of terrain surface above/below sea level, processed and integrated from SRTM-3 data and related data products (SRTM v4.1 © 2004 - 2021, CGIAR-CSI)
GHI	Global horizontal irradiation	kWh/m², MJ/m²	Average annual, monthly or daily sum of global horizontal irradiation (© 2021 Solargis)
GTI	Global tilted irradiation	kWh/m², MJ/m²	Average annual, monthly or daily sum of global tilted irradiation (© 2021 Solargis)
GTI_opta	Global tilted irradiation at optimum angle	kWh/m², MJ/m²	Average annual, monthly or daily sum of global tilted irradiation for PV modules fix-mounted at optimum angle (© 2021 Solargis)
OPTA	Optimum tilt of PV modules	°	Optimum tilt of fix-mounted PV modules facing towards Equator set for maximizing GTI input (© 2021 Solargis)
PVOUT_total	Total photovoltaic power output	kWh, MWh, GWh	Yearly and monthly average values of photovoltaic electricity (AC) delivered by the total installed capacity of a PV system (© 2021 Solargis)
PVOUT_specific	Specific photovoltaic power output	kWh/kWp	Yearly and monthly average values of photovoltaic electricity (AC) delivered by a PV system and normalized to 1 kWp of installed capacity (© 2021 Solargis)
TEMP	Air temperature	°C, °F	Average yearly, monthly and daily air temperature at 2 m above ground. Calculated from outputs of ERA5 model (© 2021 ECMWF, post-processed by Solargis)

ABOUT

This pdf report (the "Work") is automatically generated from the Global Solar Atlas online app (https://globalsolaratlas.info/), prepared by Solargis under contract to The World Bank, based on a solar resource database that Solargis owns and maintains. It provides the estimated solar resource, air temperature data and potential solar power output for the selected location and input parameters of a photovoltaic (PV) power system.

Sources: Solar database and PV software © 2021 Solargis

 Bola 4 / 4

Figure 7 – PV Electricity and Solar Radiation Analysis (3)

Based on assessment through Global Solar Atlas, all areas of of Buton have good to excellent irradiation for commercially viable solar PV installations. This is also reflected from the successful operations of solar PV mini-grids in some islands in South Buton Regency. Viability and feasibility considerations will depend on the availability of land and the land price. The southern part of the island has better irradiation; however, the land prices will be considerably higher considering its proximity to the city of Baubau as the capital city and the advanced infrastructure in general. In contrast, based on direct observations on the field, the north part of the Buton still has vacant land that is potentially viable for solar PV and costs far less, since this area is less developed compared to southern part of Buton. A technical study was done in North Buton, Kalisusu Barat Regency around 2015, but there have not been any updates since then. In addition, Lasalimu, which is planned to be developed as a Special Economic Zone area, can be also explored as the potential for future solar PV power plants.

Wind Resources

Buton has potential wind resources to be considered; however it is a site-specific technology for power plant development as the potential energy for power generation depends on the availability of locations with adequate resources. Wind resource assessment is fundamental to investigate whether a particular site or region has potential for installing an economically viable wind farm. To learn about the wind potential in Buton, several wind resource maps are accessible for public use, one of which is **Global Wind Atlas**, in addition to **windPROSPECTING**. windPROSPECTING is a mesoscale wind map developed through cooperation between DANIDA and the Government of Indonesia in 2014-2015 applying WRF (Weather and Research Forecast Model) driven by Era-Interim global data from the period 2004-2015. To match the location and validate the data from DANIDA's windPROSPECTING site, a second site analysis of wind potential in Buton is done using Global Wind Atlas. The data from both resources match for the site, and it can be concluded that the information is valid for use in the analysis of this project.

Buton has relatively low wind as a resource, as evidenced by the map for wind speeds provided by the Global Wind Atlas site. At the highest wind speed locations, it shows 6.5 m/s (equals to approximately 548.05 MW) and only in very specific locations. Most of the areas in Buton have an average wind speed lower than 5.3 m/s (equals approximately 297.1 MW).

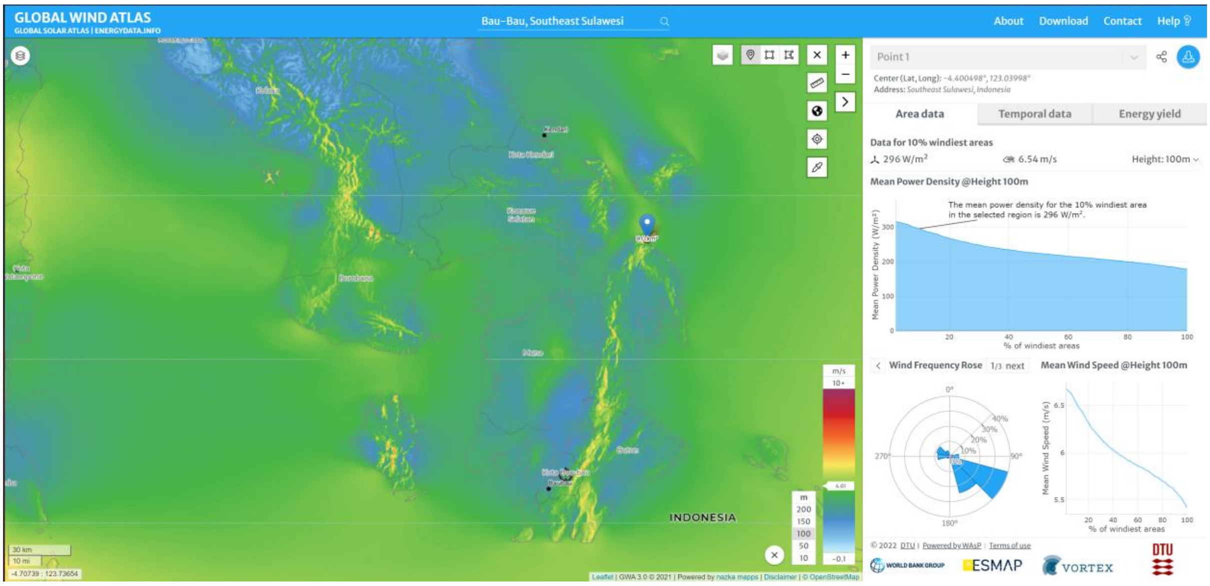


Figure 8 – Wind Resources Assessment for Buton Island (1)

A location on the north side of Buton has the best wind resources, with average annual wind speeds up to 6.54 m/s (equals to approximately 548.05 MW) but also the wind rose data show a consistent wind direction from the southeast. Additional wind data from the Global Wind Atlas also show that the wind speeds are very seasonal with high monthly averages in July and August having windspeeds reaching 150% of the annual average, whereas in the low seasons (November, December, February, March and April) the wind speeds reach as low as 40% of the annual average.

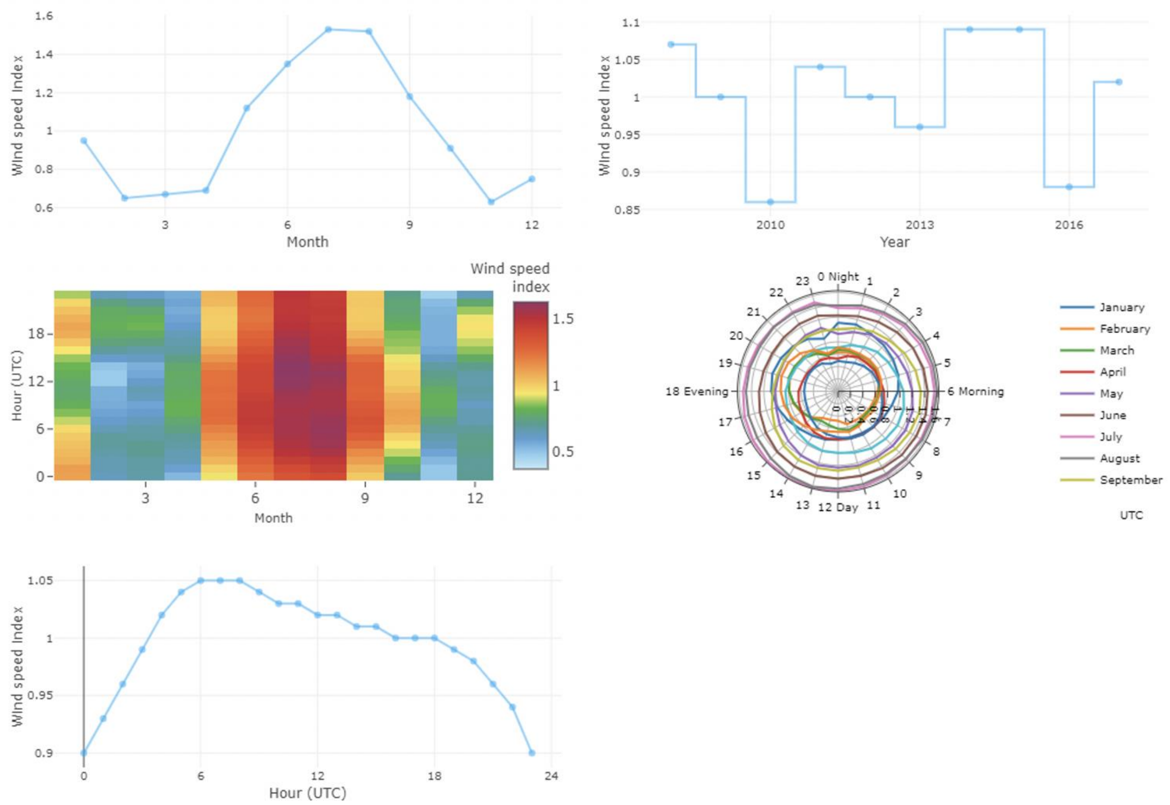


Figure 9 – Wind Resources Assessment for Buton Island (2)

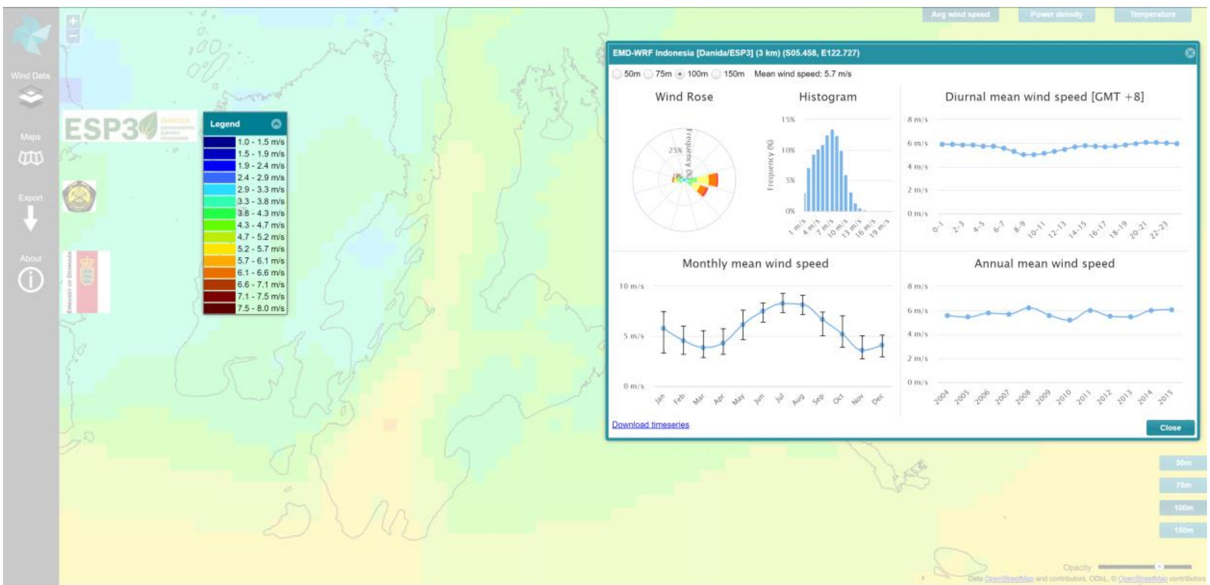


Figure 10 - Wind Resources Assessment for Buton Island (3)

Referring to DANIDA's windPROSPECTING, the data shown is for the highest wind speed location it has found on Buton Island at 5.7 m/s annual average (equals to approximately 369.58 MW[24&25]) and the data can also be compared with the second site selected from the Global Wind Atlas data. Both show similar characteristics and in general a conclusion can be made that there are only two good locations for wind in all of the island. The southern site has been validated for both data resources and therefore has been prioritised as the most likely location candidate. This is also supported by the previous initial studies for wind power plant conducted in Sampolowa District, South Buton Regency. One of these is denoted under The Promising Future Investment in South Buton Regency published by South Buton Regency Government.

Hydro Resources

Hydro power plant is also a site-specific renewable technology as the potential energy for power generation depends on the availability of locations with adequate resources. In general, based on data from the Department of Energy Southeast Sulawesi, Buton has very limited hydro potential. No large hydro plant currently operates in Buton. The largest plant is Wining Mini-hydro Power Plant with a capacity of 1.5 MW, followed by Rongi mini-hydro with a capacity of 0.8 MW. The hydro potentials identified by the Department of Energy Southeast Sulawesi only account for approximately 9.4 MW. This is the potential installed capacity from few mini-hydro and several micro-hydro power plants with a capacity of 0.4-0.5 MW. The table below lists potential hydro in Buton along with installed capacity. Potential hydro discovered in Muna Island is also included as most of the plants are geographically located in Buton, and the Raha System which supplies electricity to Muna Island has been interconnected with Baubau System in Buton. Given the current operating hydro power plants, the maximum installed capacity that can be supplied to the existing grid in Buton is approximately 11.732 MW.

Table 19 – Hydro Potential in Buton and Muna

Power Plant	Regency – District *(Kecamatan)*	Potential Installed Capacity (MW)
Kalima-lima Mini-hydro Power Plant	Muna – Maligano (part of Buton Island)	4.35
Wambeako Mini-hydro Power Plant	Buton – Pasar Wajo	1.5
Rongi Mini-hydro Power Plant	Buton – Rongi	1.3
Kabongka Micro-hydro Power Plant	Buton – Kabungka	0.306
Ronta Micro-hydro Power Plant	Buton Utara – Bonegunu	0.40
Kioko-1 Micro-hydro Power Plant	Buton Utara – Jungku	0.41
Kioko-2 Micro-hydro Power Plant	Buton Utara – Cumburu	0.43

[24]Power (W) = 1/2 x ρ (kg/m^3) x A (m^2) x v^3 (m/s) x 35% (turbine efficiency). Swept area (A) is based on the rotor with a diameter of 110 (suitable for wind speed lower than 7 m/s) sourced from manufacturer documentation; 35% of efficiency is applied. Source of the formula: https://www.e-education.psu.edu/emsc297/node/649

[25] Note: The wind in Buton is only available as a resource at specific locations and significantly depends on the turbine size which can be practically installed. For this assessment, we assume that a 110 m rotor diameter based on 2.0 MW platform is used as it is likely to be mobilised and built in Buton. A higher amount of power can be captured with larger turbines such as Vestas 172 m rotor diameter 6.0 MW turbines, however these may be not feasible to be delivered to Buton.

Power Plant	Regency – District *(Kecamatan)*	Potential Installed Capacity (MW)
Lanobake Micro-hydro Power Plant	Muna – Lanobake (part of Buton Island)	0.38
PLTMH Garu	Muna - Garu	0.356
Total potential installed capacity		9.432
Total potential installed capacity + existing capacity (0.8 MW Rongi + 1.5 MW Wining)		11.732

Source: Department of Energy and Mineral Resources Southeast Sulawesi

Bioenergy Resources

Bioenergy can be generated from the combustion of various biomass feedstocks and use of technology including liquid biofuels produced from bagasse and other plants, bio-refineries, biogas produced through anaerobic digestion of residues and wood pellet heating systems. For the context of power generation, biomass covers all renewable plant- and animal-based materials as the fuel for power and heat production. Langer, J. et al. (2021) summarise the types of biomass feedstocks typically found in Indonesia that can be used for power generation in the following diagram.[26] For this study, we narrow it down to biomass feedstock combustion and biogas produced from palm oil mill effluent (POME) as the mature technologies currently operating in other parts of Indonesia.

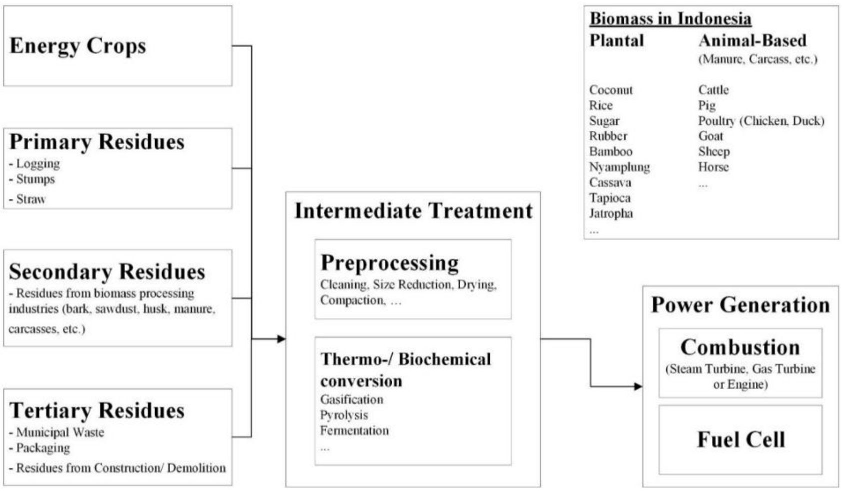


Figure 11 – Biomass Feedstocks and Option for Power Generation

One of the feedstocks which is commonly used for operating biomass power plants in Indonesia is palm oil by-products, mainly palm kernel shells. However, there are no palm oil plantations operating in Buton. According to Provincial Statistic Agency statistical data, none of the cities or regencies in Buton produce palm oil either. Considering that 32% of Buton's land areas are covered by intact natural forest according to the Global Forest Watch, a biomass combustion using wood chip cut from existing trees may not be an environmentally-sound option for power generation. In addition, there could be other risks on the inconsistency of feedstock quality

[26] Langer, J., Quist, J., & Blok, K. 2021. Review of renewable energy potentials in Indonesia and their contribution to a 100% renewable electricity system. *Energies*, *14*(21), 7033.

as well as social issues which may potentially arise. On that basis, future biomass power plant development in Buton would likely rely on feedstock such as wood pellet or palm kernel shell imported from outside of the island. Considering that density of the feedstock would impact the logistic and transportation costs, wood pellet is the preferred choice in comparison to palm kernel shell which has far greater volumetric size. Although wood pellets cost more than palm kernel shell, they contain higher calorific value and are denser in energy. Below is a comparison of wood pellets and palm kernel shell feedstocks as compiled by Institute for Energy Economics and Financial Analysis (IEEFA).[27]

Fuel type		Typical Calorific Value kcal/kg NCV	Typical Price Range *Not Normalized for CV*	Remarks
Wood Pellet		3,940 - 4,400	**IDR 1,040 to 2,000/kg at NCV > 3,940 kcal/kg** Vietnam FOB price index (Jul 2017-Sep 2019) **IDR 1,300+ /kg at NCV > 4,100 kcal/kg** Domestic market prices estimates	• Existing production is largely destined for export market with premium price • High production cost, majority of potential supplies are located outside of Java-Madura-Bali region (Jamali) • Properties could vary depending on the feedstock
Palm Kernel Shell		3,500 – 4,200	**IDR 825 to 960/kg at NCV > 3,500 kcal/kg** Indonesia FOB price index (Jul 2017-Sep 2019) excluding export tax package	• Existing production is largely destined for export market with premium price. PKS is a key biomass export with 1.72 miTonne exported in 2019 • Pulverized coal boiler which constitutes 85% of PLN CFPP capacity is largely unsuitable for PKS

Figure 12 – Biomass Feedstocks Comparison of Wood Pellet and Biomass

Further to the aforementioned overview of bioenergy resource availability in Buton, the potential local energy crops, for instance *kaliandra* wood on Sumba Island and bamboo on Mentawai Island, would need to be further investigated. Based on the desktop research for this roadmap development, there are no specific energy crops locally grown in Buton for biomass power generation. The closest potential probably comes from coconut commodities.

From the previously mentioned Provincial Statistic Agency dataset, an insight into coconut production in Buton is available. Baubau, Buton Regency, and North Buton Regency have coconut as one of the plantation commodities; although the quantity is far lower compared to other regencies in Southeast Sulawesi like Bombana and Konawe. Further identification finds that Lasalimu District in Buton Regency is the biggest coconut producer on the island, with a total production of 412.1 tons per year in 2015 according to the Provincial Statistic Agency. The coconut shells (endocarp) are considered a waste material, which comprises 15.18% of each fruit,[28] hence making a total potential of coconut shells for combustion up to 62.5 tons/year. This amount of fuel potentially could result in energy of approximately 833,290 MJ/year or equal to 234,525 kWh/year of electricity.[29]

Aside from coconut shell, there is also a previous study that discusses the potential of rice husk as an alternative power source in South Sulawesi that could potentially generate 1,700 GJ /year of energy. However, based on data from the Provincial Statistic Agency, Buton Regency, North Buton Regency, and Baubau City are the only

[27] Adhiguna, Putra. 2021. *Indonesia's Biomass Cofiring Bet: Beware of the Implementation Risks*. Institute for Energy Economics and Financial Analysis. Available at https://ieefa.org/wp-content/uploads/2021/02/Indonesias-Biomass-Cofiring-Bet_February-2021.pdf

[28] Cited from https://www.researchgate.net/figure/Average-composition-of-Coconut-Shells_tbl1_305692335

[29] Using assumptions: 75% plant efficiency and coconut shell calorific value of 18 MJ/kg (sourced from Abrahim, B., & Homenauth, O. (2019). Biomass energy potential of coconut varieties in Guyana. *Agronomy Science and Biotechnology*, *5*(2), 97-97.)

areas in Buton Island producing rice grain, with a quantity far lower than other areas in Southeast Sulawesi Province. Therefore, rice husk might not become the prioritised alternative for biomass generation in Buton.

For biogas power plants, there is no potential for development due to the absence of palm oil plantations, hence there would be no POME that is usually fed in as the fuel. POME aside, the livestock and cattle farming sector is not prominent in Buton Island. Although there are a few biogas initiatives within villages in Buton utilising livestock manure, the scale is relatively small and would not suffice for a utility-scale power plant.

Overall, we see wood pellets as the most viable option for biomass feedstock in Buton considering their efficiency, effectiveness, and uniformity. Wood pellets have a bulk density making them efficient to transport even from outside the islands. While coconut has a sound potential for biomass fuel in Buton, we would not recommend it as the first choice. Apart from the requirement of pretreatment and processing facilities, meaning that further investment is needed, historically there have been many issues for the operating biomass using feedstock supplied by typically community-owned plantation products. This can be seen from the cases of a biomass gasification plant in Sumba and also a bamboo-fired biomass power plant in Mentawai that once stopped operating. The management of the feedstock, delivery, and the transaction is done directly with the community, hence when social conflict appears, continuity and sustainability of the biomass fuel are at stake. This type of risk is likely to be avoided when using wood pellet or palm kernel shell, both of which are generated by industry.

Other Potential Resources

Other renewable potentials beyond this Roadmap that may be useful for future considerations to support Buton's energy transition agenda are geothermal and ocean energy. For geothermal, North Buton Regency may have a potential for geothermal exploration for future energy reserves.[30] However, further research must be conducted to know the exact potential of the geothermal reserves. This was indicated by sulphur and hot springs which are usually found in geothermal areas. In addition to North Butone, other areas including South Buton Regency, at Rongi, Sampolawa District, should also be explored for its potential geothermal resources. Also, ocean energy resource potential in Buton may be considered. As indicated on The Promising Future Investment in South Buton Regency, the government has also explored the potential of ocean energy considering their geographical locations. From their initial research, the ranges of ocean current speed near Siompu Island, South Buton Regency, was recorded around 5 – 11.7 m/s. Nonetheless, further studies, more comprehensive research, and demonstrations are required to estimate the potential generation from this energy prior to deployment.

[30] Sourced from https://www.thinkgeoenergy.com/north-buton-in-southeast-sulawesi-holds-large-geothermal-potential-for-development/

5. Scenarios

The business models considered for the Roadmap are the PLN in-house and IPP business models. The energy mix scenario is based on data provided in the 2021-2030 Power Generation Business Plan (*Rencana Usaha Penyediaan Tenaga Listrik* – "RUPTL") for Buton Island.

Table 20 - Summary of Scenarios Used in The Roadmap

Scenario Type		Description	Remark
Business Models Scenarios	PLN in-house	• Power plants are financed, built, and operated by PLN • Electricity is distributed to community by PLN • Grant and PSO are considered as financial support	The type of business model which was applied for each power plant technology for RUPTL scenario was based on the RUPTL 2021-2030.
	IPP	• Power plants are financed, built, and operated by IPP • Electricity is distributed to community by PLN • PSO is considered as financial support	
Energy Mix Scenarios	RUPTL Scenario (Base Case)	Refers to PLN's RUPTL 2021-2030 with the planned renewable energy power plants as follows: • 30 MW of Hybrid Energy Power Plant (PLTH) • 9.8 MW of Biomass Energy Power Plant (PLTBm) • 15 MW of Wind Energy Power Plant (PLTB) The installed capacity and planned COD of each power plant is based on the RUPTL. Detailed information is shown in Table 14.	The type of business model which was applied for each power plant technology in this RUPTL scenario was based on the RUPTL 2021-2030.
	100% Renewables Scenario	Composition of the power plant technology is based on planned power plants on Buton island in RUPTL, as well as suitable renewable energy technology to replace the existing conventional energy on Buton Island. The type of power plant technology included in this scenario considers potential renewable energy sources, Buton Island grid stability, demand, and the financial analysis, which are as follows:	N/A

Scenario Type		Description	Remark
		• 45 MW of Solar PV with BESS (PLTS) • 9.8 MW of Biomass Energy Power Plant (PLTBm) • 15 MW of Wind Energy Power Plant (PLTB) • 9.432 MW of Mini-hydro Energy Power Plant (PLTMh), in addition to the existing 0.8 MW Rongi mini-hydro and 1.5 MW Wining mini-hydro, hence the total capacity of PLTMh is approximately 11.732 MW.	

RUPTL 2021-2020 has specified the types of possible business model for each of the renewable energy power plants, whether they are to be delivered by PLN or IPP. As the combination of possible business models was specified within the RUPTL scenario, two scenarios were evaluated in this report as detailed below:

Table 21 – Scenarios Evaluated for the Roadmap

Implementer	RUPTL Scenario	100% Renewables
PLN	**1** • PLN delivers PLT EBT Base ○ PLT EBT Base consists of the combination of solar PV and diesel generators • IPPs deliver PLTBm and PLTB	**2** IPPs deliver all three plants and replace existing generation fleet with RE
IPP		

5.1. Business Model

5.1.1. Business Model Attributes

a) Generation

Renewable electricity generation in Indonesia is usually performed by PLN or an IPP selected through direct selection based on MEMR Regulation No. 50/2017. The winning bidder will enter a PPA with PLN to agree on the retail electricity price for a maximum of 30 years (according to MEMR Regulation no. 10/2017), benchmarked to the local generation cost determined under MEMR Regulation no. 50/2017. Financing for the electricity generated by PLN should come from PLN's own budget.

Other stakeholders who can also take part in power generation are MEMR, MoV, MoCSME, local government, and/or private sector entities. The aforementioned ministries can allocate their budget for rural electrification and will usually disburse the budget in the form of a CAPEX grant to the local government, who will subsequently transfer the generation assets to BUMDes.

As explained in the previous section, under MEMR Regulation no. 38/2016, private companies are also allowed to provide electricity to currently un-electrified regions through geographically based business area concessions for up to 50 MW in capacity per site. They are also allowed to propose a tariff other than PLN's tariff, as long as it is approved by the minister or governor. Otherwise, PLN's tariff will apply.

The generation cost of a power plant depends on the type of technology and capacity. As an illustration, for a

500 kWp solar PV + battery without genset backup, the average cost to serve (generation and distribution) is around IDR 908.03/kWh to Rp2805.5/kWh without CAPEX subsidy (based on the Consultant's preliminary calculation). The most financially viable power plants are the large ones that have an industrial or commercial anchor load and higher and stable demand, thus providing assured revenue and also enabling economies of scale with regards to generation and distribution.

For the purpose of this Roadmap, we consider electricity generation by PLN or in cooperation with an IPP, as the most practical methods for PLN.

b) Distribution

The generated electricity will then be distributed to the end-users (in this case, the community). The distribution network is usually constructed by PLN; although according to MEMR Regulation no. 50/2017, PLN can ask an IPP to also construct the distribution network using a business-to-business ("B2B") scheme. The distribution network will then be transferred to PLN after the COD.

The cost of metering installation is usually borne by a user who wants to connect to the system and can be performed with help from a third party (not through PLN). Based on MEMR Regulation no. 27/2017. the cost of connecting the system to a household ranges from IDR 0.4 million to IDR 3.9 million, depending on the power capacity and location, and can be upgraded for any additional power capacity requested by the customer.

However, most people in the last-mile area might not be able to cover such cost for system connection. Therefore, PLN might need to allocate more of its budget to connect these people to the system and this might result in higher unit cost than what PLN usually incurs for urban areas. As of 2019, a subsidy for the connection fee is allocated in the state budget.

c) Retailing

For PLN's concession area, the electricity retailing will be done by PLN. PLN will apply its tariff to the end-users, as regulated under MEMR Regulation no. 28/2016.

For concession areas that are non-PLN, the retailing is usually performed by either Village-Owned Enterprise (*Badan Usaha Milik Desa* – "BUMDes") or an IPP, as the concession area owner. As such, under MEMR Regulation no. 38/2016, BUMDes or the IPP is entitled to propose a certain tariff to MEMR. Either MEMR or Governor should then approve the proposed tariff. In a case where either MEMR or the Governor does not approve the proposed tariff, PLN's tariff should then be applied. The retailer will bear the demand risk due to projected connections or consumption not materialising and collection risk from non-payment of bills.

For the purpose of this Roadmap, we will assume that all of Buton Island is part of PLN's concession area, which will follow the tariff requirement based on the applicable regulation.

d) Financial Support

For the purpose of this report, apart from the PLN investment structure (equity and debt financing), the following financial support is also considered:

a) Public Sector Obligation ("PSO") as a form of electricity subsidy based on the MoF Regulation No. 44/2017 and its amendments as previously explained in Chapter 2.
b) Grant from potential donor(s) or Multi Development Banks ("MDBs"). A grant will be applicable to PLN in-house business model, where the grant will be provided to PLN in the form of capex grant to cover PLN's transmission and distribution cost.

e) End-user Payment

The consumer tariff will depend on the concession area owner. Within PLN's concession area, people will pay PLN's tariff based on MEMR Regulation no. 28/2016, while within a non-PLN concession area, the tariff is proposed by the concession area owner and agreed by the local government or MEMR for that area, otherwise the PLN tariff is used.

For the purpose of this Roadmap, we use PLN's tariff on the basis that the whole of Buton Island is part of PLN's concession area.

5.1.2. Business Model Scenario

The business models considered for this Roadmap are the PLN in-house and IPP. The description of each business model can be found below.

Table 22 - Business Model Scenario Used in The Roadmap

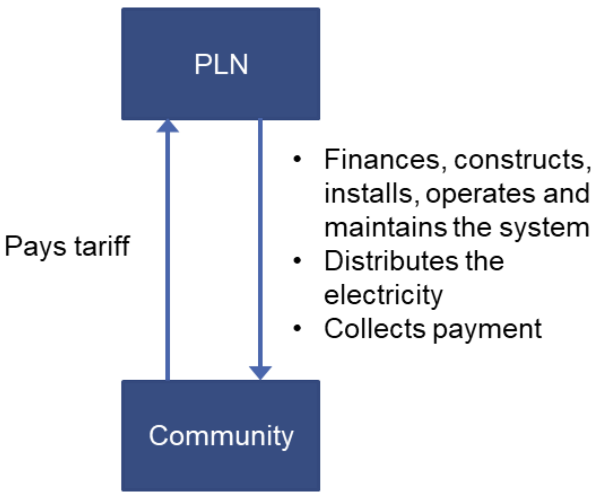
No.	Scenario Type		Description	Remark
1	Business Models Scenarios	PLN in-house	• Power plants are financed, built, and operated by PLN • Electricity is distributed to community by PLN • Grant and PSO are considered as financial support	The type of business model applied for each power plant technology for RUPTL scenario is based on RUPTL 2021-2030.
2		IPP	• Power plants are financed, built, and operated by IPP • Electricity is distributed to community by PLN • PSO is considered as financial support	

a) PLN in-house

- **Description**

  A conventional business model under which PLN is in charge of developing, financing, construction and operation of the power plant, up to the supply, billing and collection from users.

- **Project Structure and Payment Set Up**



PLN will finance the generation, distribution, and O&M of the power plant. For the payment set-up, PLN through PLN Wilayah will collect the payment directly from the users.

- **Roles and Responsibilities**

Table 23 – Roles and Responsibilities PLN in-house Scenario

Role	Institution	Responsibility
Investment in CAPEX	PLN	Provides CAPEX financing through its available budget
Financial Support	MoF	Provides annual PSO to PLN based on the PSO amount proposed by PLN
Owner of generation assets	PLN	Owns generation assets and is in charge of electricity generation
Owner of distribution assets	PLN	Owns distribution assets and is in charge of electricity distribution to end-users
Retailer	PLN	Responsible for billing and collection
O&M service provider	PLN	Operates and maintains generation plant and distribution network

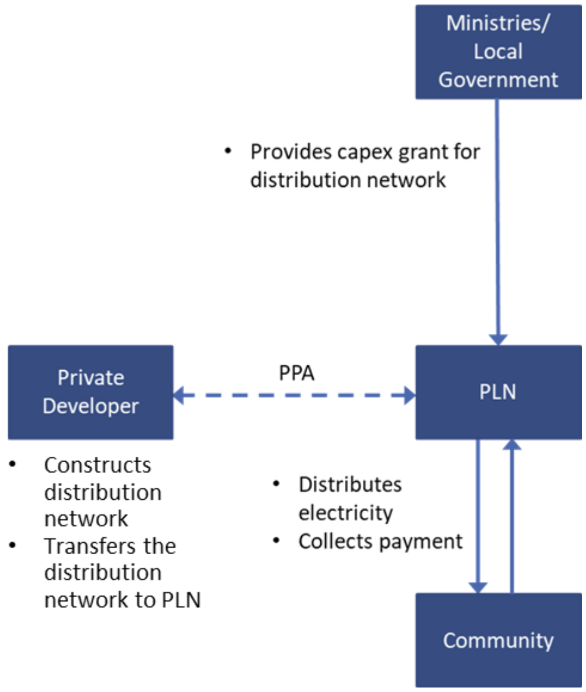
- **Legal Framework**
  - Law no. 30/2007 on Energy
  - Law no. 30/2009 on Electricity
  - MEMR Regulation no. 28/2016 on Electricity Tariff Provided by PLN
  - MoF Regulation no. 44/2017 as amended by MoF Regulation no. 162/2017 on Procedures for the Provision, Calculation, Payment and Accountability for Electricity Subsidy

b) IPP

- **Description**

There are several ways to involve the private sector in rural electrification, one of which is through an IPP scheme. In this model, the private sector finances, builds, and operates the generation assets, and in some cases, the distribution network. The private developer will enter a PPA with PLN and will transfer the assets to PLN at the end of the PPA. In case the developer also constructs the distribution network, the asset will be transferred to PLN after commissioning. PLN will then be the off-taker, retailing the electricity. However, considering that an individual project scale in a rural area might be too small for an investment, bundling a number of small projects into one big project with sizable economical value should be considered as a better approach for this scheme.

- **Project Structure and Payment Set Up**



The private sector finances the generation assets. PLN as the off-taker will need to pay the private developer for the electricity generation, while consumers will pay PLN using PLN's national tariff. MEMR, MoV, MoCSME or local government can provide a capex grant to cover the distribution network.

- **Roles and Responsibilities**

Table 24 – Roles and Responsibilities IPP Scenario

Role	Institution	Responsibility
Investment in CAPEX	Private developer	Provides CAPEX financing through debt and equity financing
Financial Support	MEMR/MoV/MoCSME	Can provide a grant for the distribution network
Owner of generation assets	Private developer under PPA with BOOT scheme with PLN	Owns generation assets and is in charge of electricity generation
Owner of distribution assets	PLN	Owns distribution assets and is in charge of electricity distribution to end-users
Retailer	PLN	Billing and collection from consumers
O&M service provider	Private developer	Operates and maintains the generation plant and distribution network

- **Legal Framework**
  - Law no. 1/2004 on State Treasury
  - Law no. 30/2007 on Energy
  - Law no. 30/2009 on Electricity
  - Government Regulation no. 10/2011 on Procedures for Foreign Loan and Grant Acceptance
  - MEMR Regulation no. 10/2012 on Implementation of Physical Activities for Utilisation of New and Renewable Energy
  - Government Regulation no. 14/2012 as amended by GR no. 23/2014 on Electricity Business Provision
  - MEMR Regulation no. 10/2017 on Key Points in Power Purchase Agreement as amended by MEMR Regulation no. 49/2017 and MEMR Regulation no. 10/2018
  - MEMR Regulation no. 50/2017 on Utilisation on Renewable Energy for Electricity Provision

5.2. Energy Mix Scenario

There are two scenarios considered for this Roadmap: i) RUPTL scenario and iii) 100% Renewables scenario. Detailed explanation of each of the scenarios is given below. A brief description of each scenario can be found in the following table.

Table 25 – Energy Mix Scenarios Used for The Roadmap

No	Scenario Type		Description	Remark
1	Energy Mix Scenarios	RUPTL Scenario (Base Case)	Refers to PLN's RUPTL 2021-2030 with the planned renewable energy power plants as follows: • 30 MW of Hybrid Energy Power Plant (PLTH) • 9.8 MW of Biomass Energy Power Plant (PLTBm) • 15 MW of Wind Energy Power Plant (PLTB) The installed capacity and planned COD of each power plant is based on the RUPTL. Please refer to the detailed information in Table 14.	The type of business model that will be applied for each power plant technology in this RUPTL scenario is as determined in the RUPTL
2		100% Renewables Scenario	Composition of the power plant technology will be based on planned power plants on Buton Island in the RUPTL, as well as suitable renewable energy technology to replace the existing conventional energy on Buton Island. The type of power plant technology included in this scenario considers potential renewable energy sources, Buton Island grid stability, demand, and the financial analysis, which are as follows: • 45 MW of Solar PV with BESS (PLTS) • 9.8 MW of Biomass Energy Power Plant (PLTBm) • 15 MW of Wind Energy Power Plant (PLTB) • 9.432 MW of Mini-hydro Energy Power Plant (PLTMh), in addition to the existing ones 0.8 MW Rongi mini-hydro and 1.5 MW Wining mini-hydro, hence the total capacity of PLTMh is approximately 11.732 MW.	N/A

5.2.1. RUPTL Scenario

In this report, the RUPTL scenario is used as the base scenario. The energy mix used in this scenario is based on the estimated electricity capacity generated from all the planned power plants on Buton Island. The composition of the energy mix is then as below.

Table 26 – Planned Power Plants in the RUPTL Scenario

Power Plant	Capacity (MW)	Expected COD
Hybrid Energy Power Plant (PLTH)	30	2027
Biomass Energy Power Plant (PLTBm)	9.8	2025
Wind Energy Power Plant (PLTB)	15	2025

Source: RUPTL 2021-2030

The definition of energy mix considered for the planned hybrid energy power plant is not detailed in the RUPTL 2021-2030, hence the analysis in this report assumes the mix will include solar PV-diesel hybrid power plants, with an average mix of 35% solar PV (installed DC capacity) and 65% diesel generator utilising well known PV-diesel hybrid inverters with nominal amounts of storage as required. The capacity of the PV-diesel hybrid power plants is calculated based on the capacity of the diesel power plants alone with the solar PV capacity not being used to indicate the installed capacity of the PV-diesel hybrid power plants.

In regard to demand, since there is no specific demand for Buton Island provided in the RUPTL, the total demand used for the analysis is based on the estimated generated electricity from the planned power plants as explained in the previous section. The proportion of the demand by group type (i.e. household or industrial) is based on the demand proportion in Southeast Sulawesi.

5.2.2. 100% Renewables Scenario

In this scenario, all energy will come from renewable energy, to cover the demand based on the available resources on Buton Island. In consideration of the renewable energy resource assessment in Buton, the scenario for 100% renewable energy-based generation will include the following RE power plants capacity**:**

1. Solar PV with BESS with a total capacity of 45 MW, spread across nine different locations within Buton networks, which gives each the capacity of 5 MW
2. Biomass power with a capacity of 9.8 MW connected to Pasar Wajo substation (20 kV)
3. Wind power with a capacity of 15 MW connected to Baubau Substation (150 kV)
4. Mini-hydro power with a new capacity of around 9.432 MW, in addition to the existing 0.8 MW Rongi mini-hydro and 1.5 MW Wining mini-hydro, giving a total capacity of approximately 11.732 MW

6. **Levelised Cost of Electricity** Estimation

6.1. Introduction

The levelised cost of electricity (LCOE) is a measure of the average net present cost per unit of electricity generation over the lifetime of the technology option being assessed. It is a useful metric for comparing different technology options for electricity generation as part of the process of system-level investment planning and setting remunerative feed-in tariffs (FiT). The LCOE of specific assets, and therefore the tariff required for commercial viability, will depend on site specific values for the multiple variables that go into estimating cost and generator output. When considering a specific asset, the LCOE serves as a useful guide for setting ceilings in a competitive procurement exercise or assessing the reasonableness of proposed tariffs in unsolicited bids.

In this study, the LCOE for five technology options – solar PV, solar PV + battery storage, wind, biomass and small hydro – has been estimated. The calculated values will be used in conjunction with the network analysis tool to obtain the optimal mix of generation from different technology options to serve system demand in a secure, affordable and sustainable manner under different levels of decarbonisation.

6.2. LCOE Basics

In calculating the LCOE, the annual generation and cost of generation are projected over the lifetime of the asset. These are then discounted back to zero date, using the weighted average cost of capital (WACC) as the discount factor according to the standard formula below:

$$\text{LCOE} = \frac{\sum \frac{\text{Cost}_t}{(1 + WACC)^t}}{\sum \frac{\text{Generation}_t}{(1 + WACC)^t}}$$

The key cost components considered in estimating the LCOE are (a) capital expenditure, (b) fuel cost, and (c) fixed and variable operation and maintenance (O&M) cost. The WACC is calculated based on the estimated capital structure as well as cost of equity and debt. In addition to the costs - capital, operational and financial – the capacity factor and plant operational period are also considered in the LCOE estimation.

6.3. LCOE Inputs

Inputs to the LCOE calculation have been grouped and LCOE values estimated based on two considerations. The first consideration is in terms of the source of values for capital and operating expenditure, and generation parameters. The sources mentioned are publicly available research and actual developer data from similar projects as explained in the following section. The second consideration is in terms of the project being developed by PLN or the private sector through an IPP model.

6.3.1. Currency

In calculating the LCOE, we used USD as the basis currency. Where data are available in IDR, we used Bank Indonesia exchange rate as of 18th May 2022 to convert it to USD for the year 2022. To project data in 2023 onwards, we used the exchange rate from Economist Intelligence Unit as of 9th May 2022.

6.3.2. Cost

The capital expenditure assumption used in the LCOE calculation is based on the data provided in the

'Technology data for the Indonesian Power Sector – Catalogue for generation and storage of electricity' ("TDIPS")[31] prepared and published by the DGE, MEMR, the Danish Energy Agency and the Embassy of Denmark. It provides a catalogue of technical and financial data across technologies and for 2020, 2030 and 2050 that is often referred to for renewable energy projects in Indonesia.

In addition to the publication, we also refer to actual data of project implementation in Indonesia from private sector developers in comparable geographies (namely Riau Islands, Central Sulawesi, North Sulawesi, etc.), which were collected through interactions with relevant developers and analysis of current market trends through our consortium's network. The values we obtained are in range, therefore we use the lower end of the range for the LCOE low estimate and the higher end of the range for the LCOE high estimate.

The difference between projects implemented by PLN and the private sector through an IPP model lies in the capital structure and the cost of capital. A summary of the cost assumption is presented below.

a) Capital Expenditure

The capex is the largest contributor to the LCOE for most of the technology options, except for biomass, where fuel cost is the most dominant component of the generation cost. For the LCOE calculation, we categorise the capex into the following components: (i) plant & machinery; (ii) land; and (iii) evacuation line. Details of capex for each technology option are as follows.

Table 27 – Capex for Plant, Machinery and Land

Data source	Capex Component	Amount Required	Units	TDIPS		Actual project data	
Technology Option				**PLN**	**IPP**	**IPP (low)**	**IPP (high)**
Solar PV	Plant		USD/MW	744,000	744,000	750,000	800,000
	Land	14 sqm/kW	USD/MW	80,500	80,500	21,000	140,000
Total plant, machinery and land capex for solar PV			USD/MW	824,500	824,500	771,000	940,000
Solar PV + battery	Plant		USD/MW	1,525,600	1,525,600	1,531,600	1,581,600
	Land	14[32] sqm/kW	USD/MW	80,500	80,500	21,000	140,000
Total plant, machinery and land capex for solar PV + battery			USD/MW	1,606,100	1,606,100	1,552,600	1,721,600
Wind	Plant		USD/MW	1,456,000	1,456,000	1,000,000	2,000,000
	Land	9 sqm/kW	USD/MW	76,500	76,500	45,000	108,000
Total plant, machinery and land capex for wind			USD/MW	1,532,500	1,532,500	1,045,000	2,108,000
Small hydro	Plant		USD/MW	2,272,000	2,272,000	1,200,000	2,500,000
	Land	2 sqm/kW	USD/MW	17,000	17,000	10,000	24,000
Total plant, machinery and land capex for small hydro			USD/MW	2,289,000	2,289,000	1,210,000	2,524,000
Biomass	Plant		USD/MW	1,964,000	1,964,000	2,000,000	3,000,000
	Land	1.2 sqm/kW	USD/MW	6,900	6,900	1,800	12,100
Total plant, machinery and land capex for biomass			USD/MW	1,970,900	1,970,900	2,001,800	3,012,100

In regard to land, each technology option has special considerations that might affect the land cost. Wind and small hydro require specific land requirements (i.e., far from residential area, specific wind speed/water availability) and have a transaction value of land in the range of USD 5 – 12 / sqm. On the other hand, solar PV and biomass generation plants can be sited with reasonable flexibility and have a purchase price of USD 1.5 –

[31] Technology Data for the Indonesian Power Sector, February 2021

[32] We assume to use a 10MW/20MWh battery, which requires land area of 5sqm/MWh. This number is negligible on a per kW basis.

10 / sqm. For the TDIPS scenario, we have assumed the land value to be the average of the range. For wind and small hydro, this translates to USD 8.5 / sqm and for solar PV, solar PV + battery, and biomass, USD 5.8 / sqm. In considering the transaction value of land for the project based on actual project values, we've taken the lower end of the range for the IPP (low) scenario and the higher end of the range for the IPP (high) scenario.

For each of the technology options, the land requirement is also considered for the calculation, which is taken as uniform across all scenarios. Land area requirement and price for each technology option is summarised in the table below.

The final component of capex is the evacuation line. We have uniformly assumed a 20 kV 3 circuit kilometre (ckt-km) line costing approximately IDR 400mn/ckt-km (or equivalent to USD 27.3 thousand ckt-km). This results in approximately USD 82,750 per project.

b) Operations & Maintenance Cost

O&M costs for renewable energy technology-based generation are largely fixed, except in the case of small hydro and biomass plants which have variable O&M costs.

Table 28 – O&M cost - Fixed & variable in the first year of operation

Data source	O&M cost component	Units	TDIPS		Actual project data	
Project developer			PLN	IPP	IPP (low)	IPP (high)
Solar PV	Fixed	USD/MW	16,173	16,173	16,173	16,173
Solar PV + battery	Fixed	USD/MW	19,284	19,284	19,284	19,284
Wind	Fixed	USD/MW	69,207	69,207	69,207	69,207
Small hydro*	Fixed	USD/MW	61,133	61,133	61,133	61,133
	Variable	USD/MW	4,041	4,041	4,041	4,041
Biomass*	Fixed	USD/MW	54,904	54,904	54,904	54,904
	Variable	USD/MW	23,408	23,408	23,408	23,408

*Small hydro & biomass have variable O&M Cost that depends on the amount of electricity produced on that particular year

c) Fuel Cost

Fuel cost is a cost item specific to the biomass technology option. Based on the resource assessment, Buton Island does not have a sufficient biomass supply for the planned biomass capacity of 9.8 MW. Therefore, the fuel in the form of wood pellets needs to be imported from suppliers located elsewhere. Based on actual project data, the cost of wood pellets is IDR 1300/kg or USD 0.09/kg generated 4520 kcal/kg of heat. This cost is inflated at the projected rate of inflation[33] over the operational lifetime of the project of 20 years.

Based on Indonesia specific research studies and actual project data, the station heat rate of biomass plant is assumed at 4034 kcal/kWh. This translates to a specific consumption of 0.89kg/kWh fuel and fuel cost of USD 0.08/kWh in the first year.

d) Financing Cost

The capital structure as well as the cost of equity and debt determine the financing cost. In our analysis, we have considered a different capital structure in terms of gearing and cost of capital for project implementation by PLN and the private sector under the IPP model.

Based on typical project financing structure for PLN group, we assume a debt-to-equity ratio of 70:30, a cost of debt of 4% based on a global bond issued in June 2020, and a cost of equity/hurdle rate of 7% which is the target profit margin for PLN. Based on conversations with domestic developers, the corresponding values for

[33] Inflation projection is based on Economist Intelligence Unit as of 9th May 2022

private sector implementation in IPP scheme are debt-to-equity ratio of 80:20, cost of debt of 8% and cost of equity/hurdle rate of 14%.

Based on these values, the WACC is calculated, which serves as the discount rate for calculation of the LCOE across all scenarios.

Table 29 – Financing cost

Data source	Units	TDIPS		Actual project data	
Project developer		PLN	IPP	IPP (low)	IPP (high)
Proportion of debt	%	70%	80%	80%	80%
Cost of debt	%	4%	8%	8%	8%
Proportion of equity	%	30%	20%	20%	20%
Cost of equity / hurdle rate	%	7%	14%	14%	14%
WACC (pre-tax)	%	4.9%	9.2%	9.2%	9.2%

6.3.3. Generation

The key parameters to estimate saleable output from each of the technology options are the capacity factor, auxiliary consumption, and the plant operational period. Values for capacity factor and auxiliary consumption have been obtained from the TDIPS and compared to the actual project data. The plant operational period has been taken as 20 years as this is the term of the standard PPA for renewable energy projects with PLN.

In the case of battery storage, the roundtrip efficiency value is another key parameter to consider.

Table 30 – Generation inputs – Solar PV

Data source	Units	TDIPS		Actual project data	
Project developer		PLN	IPP	IPP (low)	IPP (high)
Capacity	MW	10	10	10	10
Capacity factor	%	16%	16%	16%	23%
Auxiliary consumption	%	0.5%	0.5%	0.5%	0.5%
Capacity degradation	% per annum (pa)	0.25%	0.25%	0.25%	0.25%

Table 31 – Generation inputs – Solar PV & battery (additional inputs for battery)

Data source	Units	TDIPS		Actual project data	
Project developer		PLN	IPP	IPP (low)	IPP (high)
Power	MW	10	10	10	10
Capacity	MWh	20	20	20	20
Roundtrip efficiency	%	91%	91%	91%	91%
Capacity degradation	% pa	2%	2%	2%	2%

Table 32 – Generation inputs – Wind

Data source	Units	TDIPS		Actual project data	
Project developer		PLN	IPP	IPP (low)	IPP (high)
Capacity	MW	10	10	10	10
Capacity factor	%	34%	34%	30%	35%
Auxiliary consumption	%	0.5%	0.5%	0.5%	0.5%
Capacity degradation	% pa	0.38%	0.38%	0.38%	0.38%

Table 33 – Generation inputs – Small hydro

Data source	Units	TDIPS		Actual project data	
Project developer		PLN	IPP	IPP (low)	IPP (high)
Capacity	MW	10	10	10	10
Capacity factor	%	76%	76%	50%	80%
Auxiliary consumption	%	1%	1%	1%	1%

Data source / Project developer	Units	TDIPS		Actual project data	
		PLN	IPP	IPP (low)	IPP (high)
Capacity degradation	% pa	0.8%	0.8%	0.8%	0.8%

Table 34 – Generation inputs – Biomass

Data source / Project developer	Units	TDIPS		Actual project data	
		PLN	IPP	IPP (low)	IPP (high)
Capacity	MW	10	10	10	10
Capacity factor	%	76%	76%	70%	77.5%
Auxiliary consumption	%	6%	6%	6%	6%
Capacity degradation	% pa	0.36%	0.36%	0.36%	0.36%
Station heat rate	kcal/kWh	4034	4034	4034	4034
Fuel GCV	Kcal/kg	4520	4520	4520	4520
Fuel specific consumption	Kg/kWh	0.89	0.89	0.89	0.89

6.3.4. LCOE Values

Based on the input values for cost and generation across the four scenarios considered, the calculated LCOE values are as below.

Table 35 – LCOE values under scenarios considered

Data source / Project developer	Units	TDIPS		Actual project data	
		PLN	IPP	IPP (low)	IPP (high)
Solar PV	USD cent / kWh	6.49	8.73	8.24	6.79
Solar PV + battery	USD cent / kWh	11.98	16.54	16.03	12.10
Wind	USD cent / kWh	7.51	9.76	8.56	12.01
Small hydro	USD cent / kWh	4.45	6.00	5.66	6.17
Biomass	USD cent / kWh	14.63	15.73	16.25	17.81

The difference between the PLN and IPP models of implementation utilising63 TDIPS data is in terms of the capital structure and cost of capital. The comparison of LCOE values estimated using TDIPS data, which serves as a broad benchmark, reflects this difference with values being higher under the IPP model of implementation. This is a consequence of the higher risk perception, and consequently, returns expectation of the private sector compared to PLN, which is a state-owned enterprise more oriented towards achieving public sector policy outcomes than operating as a standalone, commercially viable entity. However, for PLN to expand the generation capacity, requires significant capital which PLN and/or the GoI might not be able to satisfy, therefore PLN and/or GoI needs to involve the private sector for the expansion. However, private sector involvement in the power sector in Indonesia, especially for NRE, is currently still limited by the regulations framework. Therefore, reforming the governance frameworks, as well as industry and market structure to be more attractive to the private market. A significant benefit of attracting Private Sector Participation ("PSP") into generation is the release of PLN organisational capacity and capital to address grid enhancements to integrate increasing proportions of variable renewable energy (VRE) and improving service quality to end consumers. Empirical evidence from power sector reforms in many jurisdictions over decades points to enhancing of service quality to consumers being a prerequisite for securing consumer willingness to pay economically viable end-user tariffs, which are otherwise often set below cost recovery levels.

Comparison of LCOE values obtained based on actual project data with implementation in IPP mode shows that values under the high scenario are higher as expected, except in the case of solar PV and solar PV + battery deployments. This reflects the fact that the underlying technology in wind, small hydro and biomass is mature, and the increase in production efficiency is not commensurate with the increase in capex, even though more of the available resource is utilised for providing higher quantum of energy to the grid from clean generation, thereby displacing a larger quantum of generation from fossil fuel sources. In the case of solar PV and batteries, where the technology is still evolving and improving, the increase in production efficiency from better technology requiring higher capital expenditure is justified commercially even without carbon pricing to internalise the cost of externalities from generating electricity from fossil fuels. We caution however that this comparison can only be used for a broad understanding, as specific projects will have to be assessed with a full feasibility study that produces site specific capex and generation profiles, to determine their commercial viability. This is especially true for wind and small hydro projects.

To ensure that a conservative estimation that is as reflective of the situation on the ground is done, we have used the IPP (high) scenario values for assessing the decarbonisation pathways to 2030.

6.4. Financial Viability

6.4.1. Tariff

As per the current regulatory framework, the tariff available for renewable energy plants is set at 85% of the BPP[34], if the regional BPP is higher than the national BPP.

The latest available BPP is based on the MEMR ruling No.169.K.HK.02.MEM.M.2021. According to this, national BPP is set at USD 7.05 cents/kWh, and that of Baubau's is at USD 10.78 cents/kWh.

Therefore, the tariff for renewable energy plants has been taken as USD 9.16 cents/kWh over the lifetime of the project.

6.4.2. Financial Analysis

Based on the tariff available and the technology option specific inputs under the four scenarios considered, the equity IRRs and debt service coverage ratios were estimated as below.

Table 36 – Financial analysis - EIRR

Data source	Units	TDIPS		Actual project data	
Project developer		PLN	IPP	IPP (low)	IPP (high)
Solar PV	%	12.58%	9.48%	11.45%	17.86%
Solar PV + battery	%	0.28%	(2.71%)	(2.19%)	2.69%
Wind	%	10.31%	6.98%	11.82%	1.72%
Small hydro	%	36.26%	36.63%	47.33%	34.17%
Biomass	%	N/A	N/A	N/A	N/A

Table 37 – Financial analysis – Minimum DSCR

Data source	Units	TDIPS		Actual project data	
Project developer		PLN	IPP	IPP (low)	IPP (high)
Solar PV	ratio	1.31x	1.06x	0.92x	1.12x
Solar PV + battery	ratio	0.66x	0.43x	0.44x	0.61x
Wind	ratio	1.26x	0.81x	1.00x	0.61x
Small hydro	ratio	2.71x	1.74x	2.05x	1.67x
Biomass	ratio	(1.14x)	(0.91x)	(0.85x)	(0.60x)

Considering the tariff applicable to renewable energy plants under current policy, and the estimated LCOE, only solar PV and small hydro plants clear the hurdle rate for implementation under IPP mode, with project financing. In the case of small hydro projects, this conclusion must be caveated with the fact that project viability is highly

[34] MEMR Regulation No. 50 of 2017, as revised by Regulation No. 4 of 2020

site specific.

The absence of sufficient biomass feedstock on Buton Island makes the option of a biomass plant unviable, even though it is the only technology that can provide reliable supply without providing grid level storage.

The option of solar PV + battery storage addresses the intermittency problem. However, with current cost of storage and the policy environment around tariffs for renewable energy, hybrid deployments are not commercially viable. The higher cost of solar PV + battery deployments should be considered in light of the ancillary services they provide to the grid like primary and secondary reserve for frequency regulation and supply security, in addition to energy production. Also, the deployment of sufficient grid scale storage delays or avoids the need for transmission enhancement to ensure safe integration of variable renewable energy into the grid. While generation from fossil fuels provides energy and ancillary services within the energy tariff, this cannot be the benchmark for comparison as the cost of carbon emissions is currently not considered in the pricing of fossil fuel generated electricity.

As mentioned earlier, meaningful power sector reforms to enhance governance frameworks, and industry and market structures are required to lower the risk perception and return expectation of private sector investors across the board. However, this is a process that will take time to plan and implement. In the meantime, international investors and developers who are showing increasing interest in the Indonesian renewable energy market are estimated to be implementing a portfolio building approach to capacity creation, with project level returns of secondary importance. Well-developed and structured renewable energy projects on Buton Island as part of a decarbonisation pathway of the island’s electricity supply may attract interest from these developers.

7. Technical Analysis

7.1. Buton Existing Electrical Grid Network

Buton Island has two main electricity grid systems, the Baubau System and the Ereke System. The two systems were recently interconnected and became the Baubau-Raha–Ereke System. The Baubau System is also interconnected to the Raha system supplying the island of Muna, next to Buton. The table below shows all the electricity generation units that are physically connected to the main electricity grid serving Buton Island.

Table 38 – Buton Island system generation units sourced from PLN Baubau

No.	Generation Units	Installed Capacity (kW)	Rated Capacity (kW)
1	Winning Mini-hydro Power Plant	1,600	1,400
2	Rongi Mini-hydro Power Plant	800	700
3	Baruta Coal-fired Power Plant	14,000	12,210
4	Baubau Gas Engine Power Plant	4,000	39,120
5	Baubau Diesel Power Plant	0	0
6	Pasar Wajo Diesel Power Plant	2,000	1,600
7	Raha System Diesel Power Plants	9,800	9,300
8	Ereke Diesel Power Plant	4,000	1,850

The physical locations of the power plants are illustrated in Figure 13. The green circle refers to the Baubau system (Buton Island) and dark blue one to Raha system (Muna Island). As the systems are interconnected and are referred to as the Baubau-Raha-Ereke grid system.

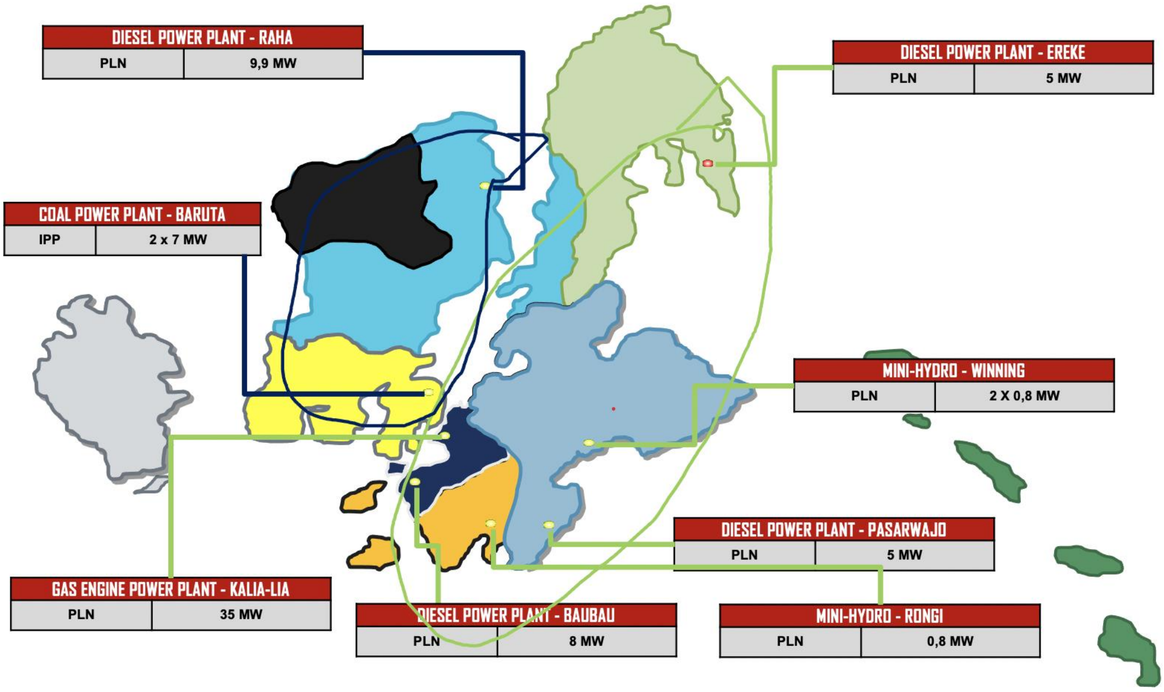


Figure 13 – Interconnected Electrical Grid System in and around Buton Island

According to PLN data as of February 2022, Buton Island's grid system consists of medium-voltage network lines of 20 kV (with a total length of 945.94 kilometre-circuit, kmc) and 0.4 kV low-voltage network lines (584 kmc). No high-voltage networks (150kV or above as typically utilized by PLN) currently operate in Buton. Substations and power plants in the electrical grid system are connected via a network of 20kV overhead distribution lines. At the time of writing this report, the 150 kV high-voltage network is still under construction, planned to connect Baubau Substation (capacity of 60 MVA) with the Baubau Gas Engine Power Plant Substation (capacity of 30 MVA). The construction of these two substations has been completed, but neither has been in operation as at the writing of this report. There has been no further information from PLN regarding the reason.

Concerning actual demand, we derived the raw data from feeder measurements at substations and a log-sheet from PLN Area Baubau, resulting in 41,955 MW of daytime peak load and 47,093 MW of evening load. Two daily load peaks occurred, at 11 am during the day and at 7 pm in the evening.

The simulation aimed to examine the energy transition scenarios with the prevailing grid code as regulated under the recently issued MEMR Regulation No. 20/2020. The grid code regulation was developed to assure the addition of renewable-based power plants in the power grid system starting from the connection stage to operation do not bring reliability issues to the systems in delivering the service to the community. The standards articulated in the MEMR regulation for the voltage value ranges considered acceptable under normal conditions are presented in the table below. The voltage values for 20 kV are not mentioned in the regulation, but it is common and accepted practice (including by PLN) to use the guideline for the 36 kV to be applied to the 20 kV lines.

Table 39 – Voltage ranges standards based on grid code regulation

Voltage values	Normal Conditions
500 kV	+10%, -10%
275 kV	+10%, -10%
150 kV	+10%, -10%
66 kV	+5%, -10%
36 kV	+5%, -10%

7.2. Methodology and Approaches

The roadmap includes the analysis of the island’s current system, the lowest-cost electrification analysis, and various scenarios based on the available renewable energy resources. From the technical side, the following approaches are used to support the development of various energy transition scenarios.

- Modelling business-as-usual conditions from PLN's RUPTL and other publicly available sources
- Creating demand-growth scenarios to include electrification of off-grid areas through grid extension using Geographic Information System (GIS) analysis to determine their least-cost electrification strategies
- Developing energy-transition scenarios such as zero net carbon and 100% renewable
- Conducting power flow analysis of the grid for the final scenarios to ensure compliance to grid code
- Developing separate analysis of the unelectrified areas in Buton and integrating the results to the roadmap scenarios

For the first scenario based on the RUPTL 2021-2030 scenario, the simulation will be conducted for the year 2030. It can be assumed that the energy mix under this scenario will meet the existing grid code in Buton as it exists today, since the additional planned capacity and type of technology comes from PLN. Further analysis using DIgSILENT PowerFactory will be beneficial to determine the optimum mix of diesel and solar PV, as RUPTL

2021-2030 indicates the plan to have a PV-diesel hybrid power plant in 2027; however, it did not detail the portion for each respective power plant. Although it is commonly assumed that the mix is 35% solar PV and 65% diesel for the hybrid power plants, the DIgSILENT PowerFactory will be able to define the specific mix for the context of Buton that meets the existing grid code.

In addition to the base scenario, scenario 2 (100% renewable scenario) is being developed to achieve 100% renewable energy. Significant deviation from the RUPTL scenario, especially with large additions of variable renewable energy included in the second scenario, will be based on previous experience to estimate its compliance with the grid code.

7.2.1. Future projection of energy demand

The future energy demand forecast is an equally important aspect aside from the supply dimension in designing the transition pathways towards low carbon. To estimate the future demand, we apply the forecasting method using PLN's growth in the number of electricity consumers denoted in the latest version of RUPTL. However, the first-hand data on PLN's customers in Buton are only available from local PLN units, since the publicly available information regarding PLN such as RUPTL or annual statistics provides data and information at the regional or provincial level.

7.2.2. Grid and Power Flow Analysis

In addition to the commercial analysis, the development of this roadmap also involves a technical analysis of the mix of grid performance due to the planned energy mix to ensure the compliance with the PLN's existing grid code, to pave the way towards zero-carbon electricity infrastructures. A power flow analysis and grid network simulation were then performed. In doing so, the following information from PLN was used:

1. Network topology;
2. Generator dispatch and system loading; and
3. Generator, distribution, and transmission line parameter data.

The initial options on the planned energy mix following the financial analysis were based on the two pre-determined scenarios, namely RUPTL and 100% RE, and followed by a power flow analysis. This was performed to validate the best-suited energy mix scenarios developed and iterated to identify the most cost-effective option from the financial analysis which also complied with PLN's existing grid code in Buton. Once the data were obtained, the grid network modelling performed the following analysis to determine the grid's performance in respect to the grid code requirements:

1. Grid connection performance
2. Steady-state power flow analysis
3. Short-circuit analysis
4. Impact on distribution system operations (AC optimal power flow to determine optimal dispatch of generation)
5. Stability analysis (PV output fluctuations, extreme ramp, and loss of generation events).

The grid modelling and power flow analysis was conducted using DIgSILENT (Digital Simulation and Electrical Network Calculation Program) PowerFactory, a power system analysis software application for analysing generation, transmission, and distribution networks, which has also been used by PLN. The utilisation of similar tool as PLN to apply the data from the existing electrical system and grid codes in Buton as also sourced from PLN, it may support the implementation of the proposed scenario, which has a stable grid management. Addressing the stability and intermittency concerns is important to increase the feasibility of the implementation of the roadmap by PLN in the future.

7.2.3. GIS and Least-cost Electrification Analysis

GIS analysis was used to determine clusters of population centres based on the combination of the collected field survey data, which results in energy demand analysis for the various population centres throughout the island, including the villages, households, and facilities far away from the population centres. Also, a separate analysis on the locations without electricity coverage at the current time was conducted in addition to grid analysis. For the unelectrified areas, GIS analysis methodology was utilised to select the most suitable topologies and technologies to best provide electricity to the areas.

In addition to the least-cost analysis, network topology and power flow analysis for the unelectrified area were also performed, by considering the following network topologies options:

- PLN grid extension;
- Renewable-based mini-grid; and
- Solar home system (individual rooftop solar PV).

This analysis utilized HOMER, a simulation software developed by the United States National Renewable Energy Laboratory (US NREL) that enables us to design a generation system and evaluate multiple options of lowest-cost system configuration. HOMER simulates a behavioural system of physics generator on each hour for one year and gives results through the total present value cost related to the plant installation and operation of the system during its lifetime. By simulating and comparing different types of system configurations determined by the user, HOMER can derive the lowest-cost or optimum-mix generating technology that can be used. The results of the least-cost electrification analysis using HOMER was also integrated into the various energy transition scenarios offered in this roadmap.

7.3. Source of Technical Data

Major technical data, especially for grid simulation and power flow analysis, are only available internally from PLN at regional or local offices. The RUPTL document also provides some prominent figures and data relevant to this roadmap; however, they usually come in aggregated numbers reflecting the regional or provincial data, while in this study the data needed are the ones at the level of Buton Island. However, granular data at that necessary level (consisting of multiple regencies) are not available publicly. Therefore, a proxy methodology, approximation, and extrapolation are used as inputs to the modelling exercises.

Publicly accessible data sources other than RUPTL were also used as a reference, such as PLN Statistics, which are issued on an annual basis and available on PLN's website. Although, similar to RUPTL, only regional or provincial-level data are available. Other publicly available government data or documents, along with previous studies and publications published by notable institutions providing data sets on renewable energy both in general and in the Indonesian context, are also used as the basis for making assumptions needed to design the scenario.

7.2.1 Demand Analysis

Energy demand is typically driven by economic activities and population growth, which is further affected by the development of infrastructure and other factors. The RUPTL document usually provides projection figures on demand growth within a period of ten years; however, they are usually presented as regional or provincial projection. While in this study, the inputs to the grid simulation need to specifically represent Buton Island.

We projected the demand growth by referring to the historical energy sales data for the past five years covering sales areas located on Buton Island. Raw data received from local PLN need further derivation and analysis as PLN sales areas do not follow the government administrative boundaries. The demand forecasts are then developed making optimal use of historical electricity sales in areas within Buton Island and applying a compound annual growth rate (CAGR) formula. The extraction of the projected energy demand based on the electricity sales data to customers in Buton is presented in the following table. The data were used as the basis for the computation of input parameters of the grid simulation in DIgSILENT software.

Table 40 – Total demand projection in 2021-2030 based on the electricity sales data

Electricity Sales (MWh)	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Residential	104,940	110,382	116,107	122,129	128,462	135,125	142,133	149,504	157,258	165,414
Social	6,418	7,012	7,661	8,370	9,145	9,991	10,916	11,926	13,030	14,236
Business	26,233	26,886	27,556	28,242	28,945	29,666	30,405	31,162	31,938	32,733
Industry	7,770	8,672	9,680	10,805	12,060	13,462	15,026	16,772	18,721	20,896
Public	9,273	9,843	10,448	11,090	11,771	12,494	13,262	14,077	14,942	15,860
Total	154,634	162,796	171,452	180,636	190,384	200,738	211,742	223,441	235,889	249,139
Growth (%)	**3.00**	**5.28**	**5.32**	**5.36**	**5.40**	**5.44**	**5.48**	**5.53**	**5.57**	**5.62**

On the other hand, the PLN unit in Bau-bau also projected the growth percentage of their electrical system based on the increased annual peak load. Given the historical peak load data from 2015-2020, a CAGR formula was applied to the historical data and found 11% and 4% growth rates for the Bau-bau-Raha system and Ereke system respectively. These growth rates were then used to determine the potential peak loads in the following years. Set out below is Buton Island's demand projection until 2030 based on the peak load data. However, since the hourly load profile data from PLN was not available, the peak load data was not sufficient as the simulation inputs in DIgSILENT. Hence, the peak load was calculated based on the projected electricity consumption growth by 2030 as presented in the table below. The data was used in addition to an estimate of the hourly load profile based on industry and typical best practices as applicable to this project.

Table 41 – Total demand projection in 2021-2030 based on the peak load data

	2021	*2022*	*2023*	*2024*	*2025*	*2026*	*2027*	*2028*	*2029*	*2030*
Total Rated Capacity (kW)	61,465	68,104	75,470	83,641	92,706	102,764	113,924	126,306	140,046	155,292
Total Peak Load (kW)	39,648	43,890	48,594	53,810	59,596	66,014	73,133	81,030	89,790	99,509
Growth (%)	**10.75**	**10.70**	**10.72**	**10.74**	**10.75**	**10.77**	**10.78**	**10.80**	**10.81**	**10.82**

7.2.2 Power Flow Analysis/ Grid Modelling

This technical analysis investigates the impact of connecting the proposed renewable-based power plants on the performance of the 150 kV and 20 kV network in Buton Island (currently operational and planned in the future). Network modelling and simulations are performed with DIgSILENT PowerFactory v15.1.6, a well-known simulation software that PLN is also familiar with. To comply with the requirements of PLN Guidance 357.K/DIR/2014 for renewable energy power plants lower than 10 MW of capacity connecting to the PLN distribution system, the following studies are considered:

1. **Load flow performance studies:** to assess how the connection of the renewable-based power plants will affect steady-state voltages, branch loading, and system losses.
2. **Short circuit studies:** to assess the short circuit capability of the existing network equipment to withstand the possible fault conditions including the presence of the renewable-based power plants.
3. **Stability studies:** to assess the effect of renewable-based power plants disturbances on the frequency and voltage stability of the existing electrical network in Buton Island.

7.4. Analysis Results

7.4.1 Grid Modelling and Analysis

7.4.1.1 Modelling Assumptions

a) RUPTL 2021-2030 Scenario (Base Case/Scenario 1)

The simulation of the first scenario using DIgSILENT is based on the added capacity of power plants as documented in PLN's RUPTL 2021-2030 for Buton Island as summarised in the table below:

Table 42 – Planned Power Plants in Buton

Power Plants Technology	Capacity (MW)	COD
Gas Engine Power Plant (PLTMG) Baubau 2	30	2023/2024
RE-based Power Plants (PLT EBT)	30	2027/2028
Biomass Power Plant (PLTBm)	9.8	2025
Wind Power Plant (PLTB)	15	2025

Source: PLN RUPTL 2021-2030

In the grid simulation, we put indicative locations of each planned power plant based on high-level resource assessment along with historical information available for public or previous studies done for Buton Island including the data shared by the MEMR representatives in Southeast Sulawesi Province. The select locations were identified as potential sites for each of the power plant's technology. As previously explained, many of the renewable energy-based power plants such as hydro power and wind power plants are site-specific and highly dependent on the availability of resources in the select area.

1. Gas Engine Power Plant Baubau-2 with a capacity of 30 MW

Based on information from the local PLN unit in Baubau, the planned Gas Engine PP Baubau-2 will be developed not far from the existing 30 MW Baubau-1 Gas Engine Powerplant. Hence, the added power plant is presumed to be located in Lealea District, Baubau City.

2. RE-based power plant with a capacity of 30 MW

Although the additional 30 MW renewable energy-based power plant is listed under PLN's future pipeline, it does not specify the types of renewable and the exact portion for the respective technology. Based on discussions with PLN, it is then assumed that the 30 MW additional renewable-based capacity is from solar PV combined with diesel power plants in a hybrid configuration.

When a large centralised solar PV power plant with 30MW in capacity was simulated at a single location, the simulation resulted in an undervoltage condition. Therefore, to maintain the grid stability, added PV capacity was successfully simulated to be distributed in several locations near the existing diesel or other base load power plants. The simulation of this configuration is based on the following locations:

a. 10 MW located in Baubau City or nearby, in which the operating system is planned to integrate with the existing Baubau Diesel PP as a hybrid power plant
b. 10 MW located in Raha Regency or nearby, to enable hybrid configuration between the added solar PV with the existing Raha Diesel PP
c. The remaining capacity is spread in some areas close to Winning Mini-Hydro PP (Buton Regency), Ereke Diesel PP (North Buton Regency), and Kapontori (Buton Regency). Kapontori is chosen considering voltage improvement and from the Single Line Diagram ("SLD"), there is a switching substation *(gardu hubung)* supplied by Baruta Coal-fired PP, which is also situated nearby.

3. **Biomass power plant with a capacity of 9.8 MW**

In principle, a biomass power plant can be constructed on any site with close proximity to the main road, preferably within a short distance from the closest port for ease of logistics. Based on our preliminary studies, there is currently a plan to establish a Special Economic Zone (SEZ) in Buton due to its asphalt resources. The specific location of SEZs is proposed to be located in Lasalimu District, Buton Regency.

For the simulation, the planned 9.8 MW Biomass PP is assumed to be in Lasalimu District. The location also offers the strategic advantage of being close to two existing ports: Lasalimu Port and Lawele Port. Based on the SLD Biomass PP is planned to connect to Pasarwajo Substation (20 kV). As previously explained in section 4 – Buton Island Overview above, Renewable Energy Resource Assessment for Bioenergy in Buton, the planned biomass power plant is assumed to use wood pellet feedstock imported from outside of Buton in sufficient quantity to the requirement of planned installed capacity (9.8 MW). This assumption is based on the consideration of the potential availability of supply identified as at the date of this report. Further analysis is required to verify the feedstock requirement and availability of supply for the biomass power plants.

4. **Wind power plant with a capacity of 15 MW**

Based on the resource assessment using the Global Wind Atlas, there are very few specific points in southern Buton that have the potential for wind power development. As previously explained in section 4.3 of this report, Renewable Energy Resource Assessment, the potential wind speed is estimated to be at 5.7 m/s annual average in Buton, which may result in around 0.11 kW/sqm wind power. This is aligned with previous studies that explored wind power potential in South Buton Regency. Both studies were conducted in Sampolawa District with different potential site coordinates. Therefore, for the simulation, the planned 15 MW wind PP is situated within Sampalowa District. Based on SLD, a biomass PP is planned to connect to Baubau Substation (150 kV).

b) 100% Renewable Energy (Scenario 2)

This scenario would cover the grid simulation of a 100% renewable energy-based generation for the electricity sector to cater to the island's growing electricity demand, with the following additional installed RE capacity**.**

1. Solar PV with BESS, with a total capacity of 45 MW, are spread across nine different locations within Buton networks, which gives each the capacity of 5 MW
2. Biomass power with a capacity of 9.8 MW connected to Pasar Wajo substation (20 kV)
3. Wind power with a capacity of 15 MW connected to Baubau Substation (150 kV)
4. Mini-hydro power with a new capacity of around 9.432 MW, in addition to the existing plants namely 0.8 MW Rongi mini-hydro and 1.5 MW Wining mini-hydro, given the total capacity is approximately 11.732 MW.

Learning from the simulation of Base Case (Scenario 1) in which a single large solar PV plant would negatively affect the grid's stability in spite of the presence of diesel and gas power plants, for Scenario 2 it was immediately decided to spread the 45MW of solar PV installations across nine separate locations. This is even more relevant in Scenario 2, as the lack of diesel and gas power plants need to be replaced with more expensive battery energy systems (BESS) or other means to balance the grid operations.

For the first load flow iteration, the dispatch management of the RE power plants' outputs is set in the following manner to generate RE-based electricity supplies that match the projected demand in 2030: solar PV and BESS 85%; biomass 10%; wind 5%; and make optimal use of from all hydropower generation (from 11.732 MW total installed capacity). This energy mix is purely driven by the availability of resources in Buton island.

There are very few hydropower and wind resources throughout the island and its surrounding areas. While tidal, ocean currents may be possible, their costs are still significantly higher than those solar PV with battery systems. In locations where renewable energy is abundant from a variety of sources; the energy mix will be determined through a balance of economic considerations and the ability to provide a reliable grid condition. A far higher ratio of run-of-river (RoR) power plants at a high-capacity factor should dominate the energy mix if the resources are available. RoR power plants are typically the least expensive to be operated compared to solar PV WITH BESS, wind, biomass, or others. It is prudent that in conducting the analysis, the financial modelling is paired with the grid study to ensure that a 100% renewable energy scenario will provide a reliable grid at the least cost possible.

7.4.1.2 Modelling Results

Scenario 1 - Aside from generation units and demand load, we also utilise first-hand grid data sourced from PLN, including the type and length of conductor, feeders, UFR, and a single-line diagram for the simulation. The grid simulation for this study is mainly performed for power flow analysis used to estimate the flow of several electrical parameters, such as voltage, current, and power, in electrical grids. Furthermore, the analysis of grid code compliance to the standard is also conducted to learn the impact of planned additional renewable uptakes to the grid stability and compliance to grid code requirements. The following table outlines load flow cases for daytime and evening time using Buton's projected demand for 2030. These considerations are taken to avoid the unbalanced generator loads (e.g. some generators overloaded while others only partly loaded) and an unbalanced voltage profile with both high and low voltage extremes.

Table 43 – Load flow considerations (daytime load and evening load) for Scenario 1

Scenario 1 - Peak Daytime Load (2030)	• Daytime maximum load, i.e. 11 am • System operating at load of around 64 MW • Diesel power plants (Baubau, Raha, Pasar Wajo, Ereke) are not dispatched • Distributed stack bus by synchronous generation
Scenario 1 - Peak Evening Load (2030)	• Evening daily peak, i.e. 7 pm • System operating at load of around 72 MW • All generators are dispatched except Baubau Diesel Power Plant and solar PV power plants • Distributed stack bus by synchronous generation

Figure 14 and 15 below show the power flow case simulation and analysis for Scenario 1 daytime and evening load respectively using the DIgSILENT software.

Red boxes in the figure above show newly added installed capacity. From the Scenario 1 daytime load simulation results, the following items are noteworthy to be highlighted.

- Renewable-based power plants with a capacity of 30 MW, which are presumed to be solar PV in this study should be scattered to minimise drop voltage in the network system.
- Tielines in Baruta and Watulea appear to be overloaded, hence it is assumed that in this simulation they are upgraded to two parallel lines
- No generators are overloaded, although there are several units set on a cold standby mode (ready-to-run back up system that is immediately called upon only on the failure of the primary system) to optimise dispatching
- During the simulation of Scenario 1 daytime case, there is no bus voltage below the +5% and -10% for 20 kV system and ±10% for 150 kV system voltage criteria.
- System active power losses are 6.92% of total generation (PLN typically accepts up to 10% losses on small systems such as Buton)
- Spinning reserve of 23.56% of total generation

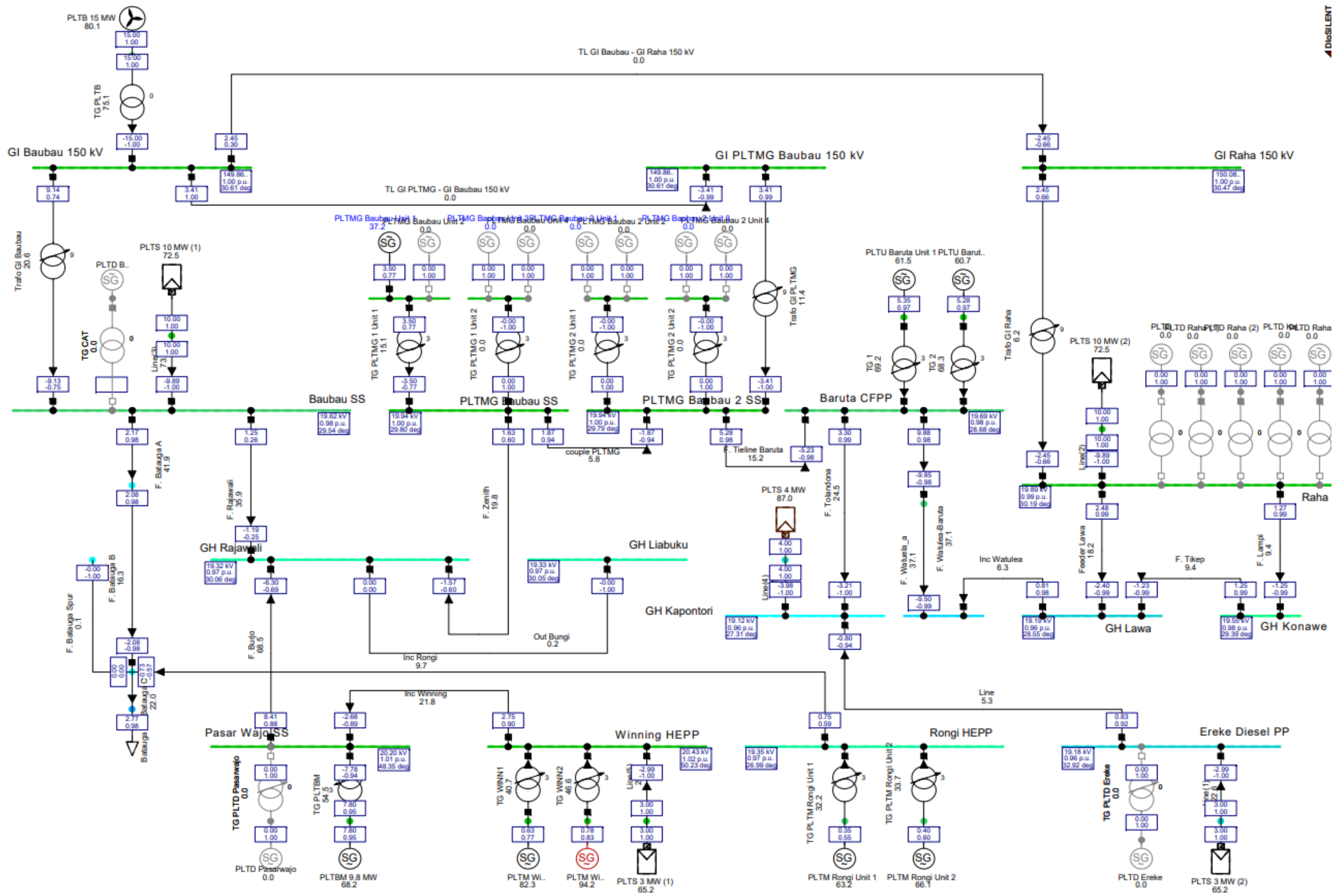


Figure 14 – Power Flow Simulation for Daytime Load (Scenario 1) using DIgSILENT

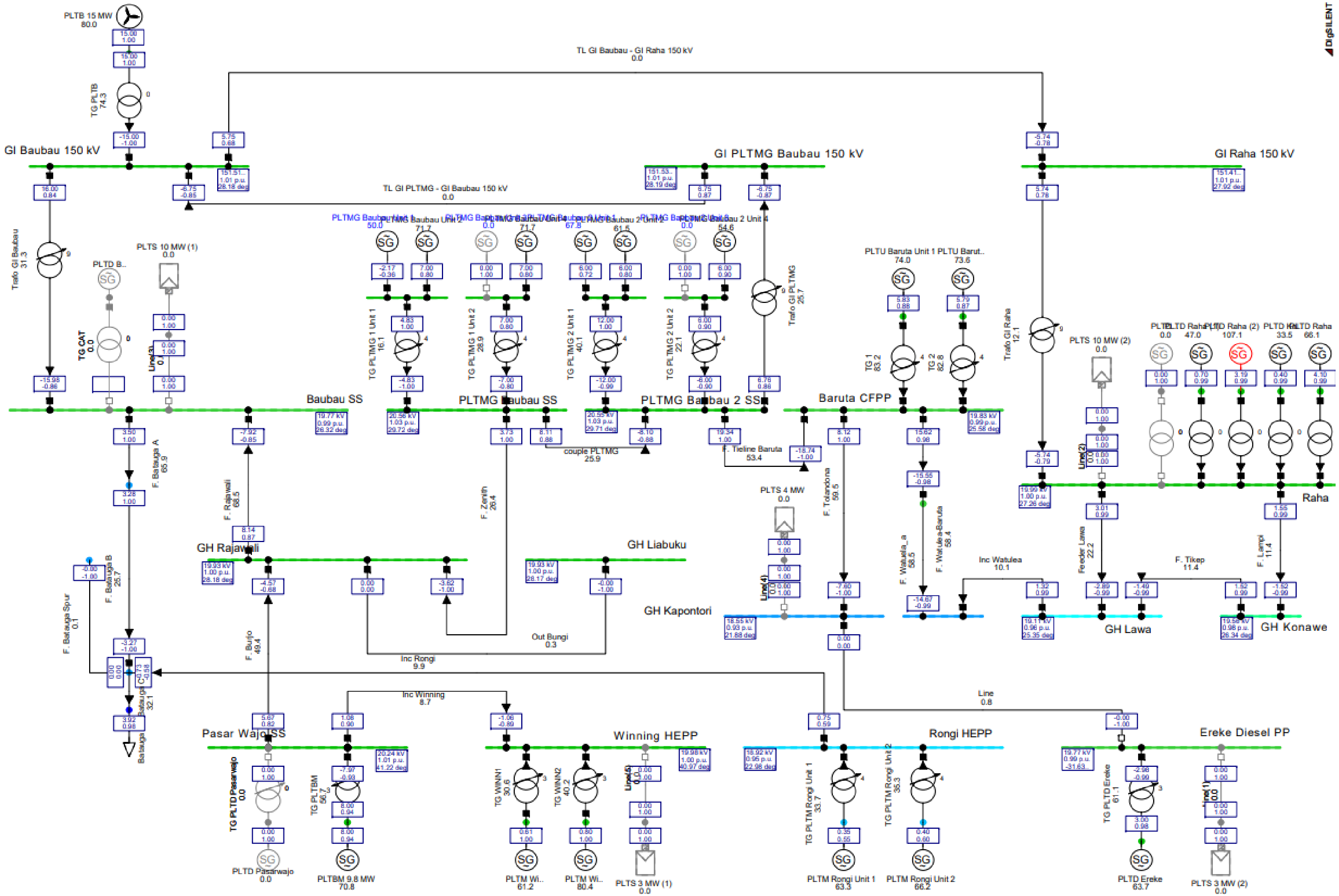


Figure 15 – Power Flow Simulation for Evening Load (Scenario 1) using DIgSILENT

The operating conditions for the evening load are similar to the daytime load simulation, and for both simulations it was assumed that an upgrade of the tielines in Baruta and Watulea was done to avoid overload. The difference is that during the evening, load demand is supported by Raha and Ereke Diesel Power Plants, which are set to come online, as a substitution for the solar PV power plants. The results also show that there are the grid bus voltages never reach higher than +5% and lower than -10% for as indicated in the grid code for the 20 kV system and ±10% for the 150 kV system voltage criteria. The simulation also results in 7.45% of systems losses and 55.10% of spinning reserve out of total generation

Scenario 2 – Using a similar dataset from the previous scenario simulation, scenario 2 with a 100% renewable energy mix purpose is modelled using DIgSILENT. The analysis also covers power flow and grid code compliance according to the power plants arrangement as follows:

Table 44 – Renewable Energy Mix for Scenario 2

Power Plant Technology	Installed Capacity (MW)	Output*
Solar PV with BESS (PLTS)	45 MW	85%
Biomass Energy Power Plant (PLTBm)	9.8 MW	10%
Wind Energy Power Plant (PLTB)	15 MW	5%
Mini-hydro Energy Power Plant (PLTMh)	11.732 MW	Optimal use

**Note: RE power plants' output as arranged in the DigSILENT power dispatch management to match the projected demand in 2030.*

Peak daytime load for the simulation of Scenario 2 with projected demand in 2030 following the considerations summarised in the table below:

Table 45 – Load flow considerations (daytime load) for Scenario 2

Scenario 2 - Peak Daytime Load (2030)	• Afternoon daytime maximum load, i.e. 11am • System operating at load of ~64 MW • All non-diesel power plants are dispatched including biomass and wind. Diesel power plants (Baubau, Raha, Pasar Wajo, Ereke) are not. • Distributed slack bus by synchronous generation
Scenario 2 - Peak Evening Load (2030)	• Evening peak load, i.e. 7 pm • System operating at load of around 72 MW • All non-renewable power plants are not dispatched • Distributed stack bus by synchronous generation

At the time of writing this report, the simulation for Scenario 2 showing a system normal configuration at the daytime peak load (11 am) has been completed. Figure 18 below illustrates the simulation conducted for Scenario 2 – daytime load case.

From the results, the following key information can be derived:

- There is no bus voltage below the +5% and -10% for 20 kV system and ±10% for 150 kV system voltage criteria, but tapping on the transformer substation primary side (2.5%) is necessary to maintain the voltage system criteria

- No generators are overloaded; although there are several units that should be set in cold standby mode
- The branch elements are overloaded, assumed to be upgraded into two parallel lines.
- System active power losses are approximately 4.34% of total generation.

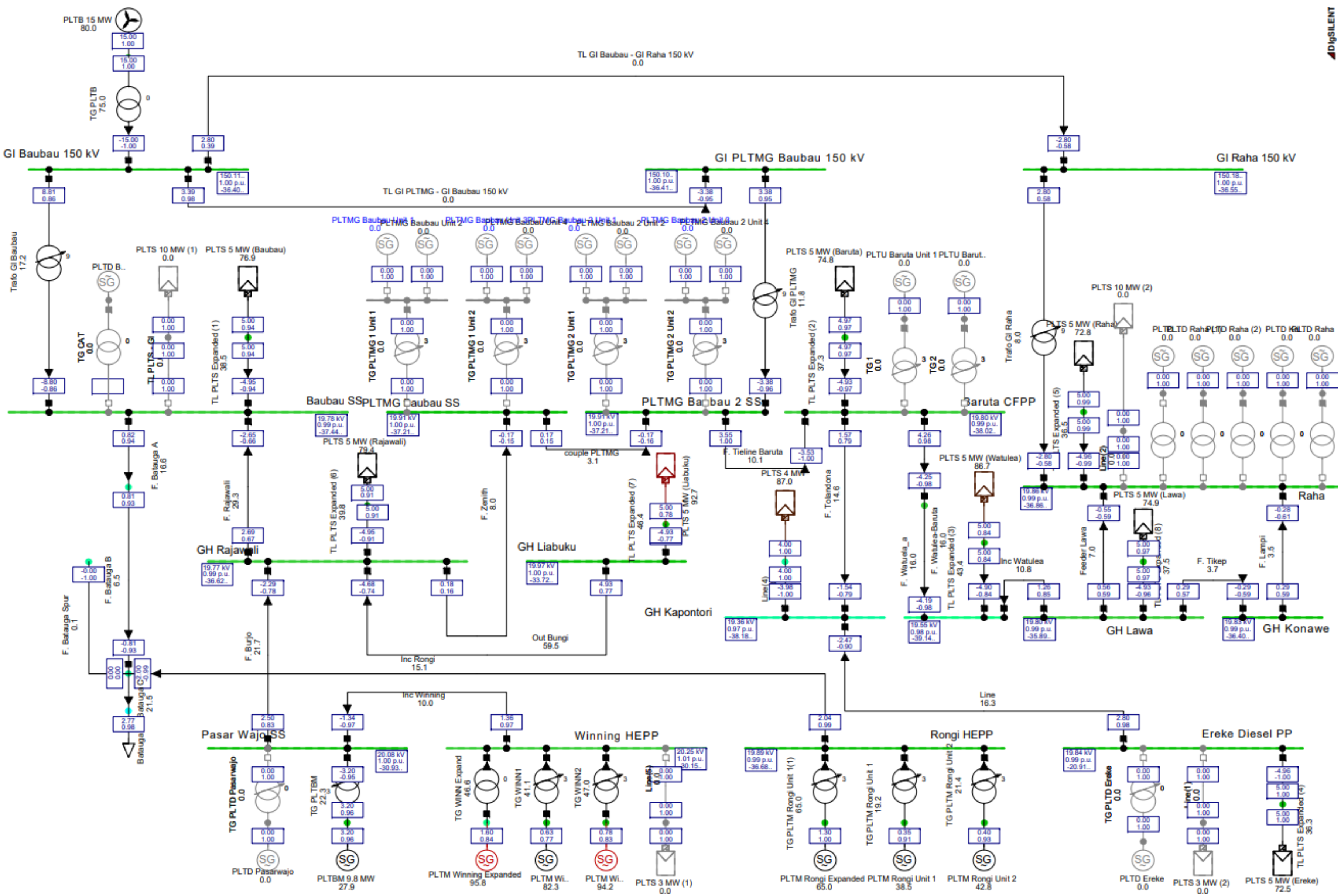


Figure 16 – Power Flow Simulation for Daytime Load (Scenario 2) using DIgSILENT

Furthermore, the simulation for Scenario 2 showed a system normal configuration at the evening peak load (7 pm) as illustrated in the following Figure.

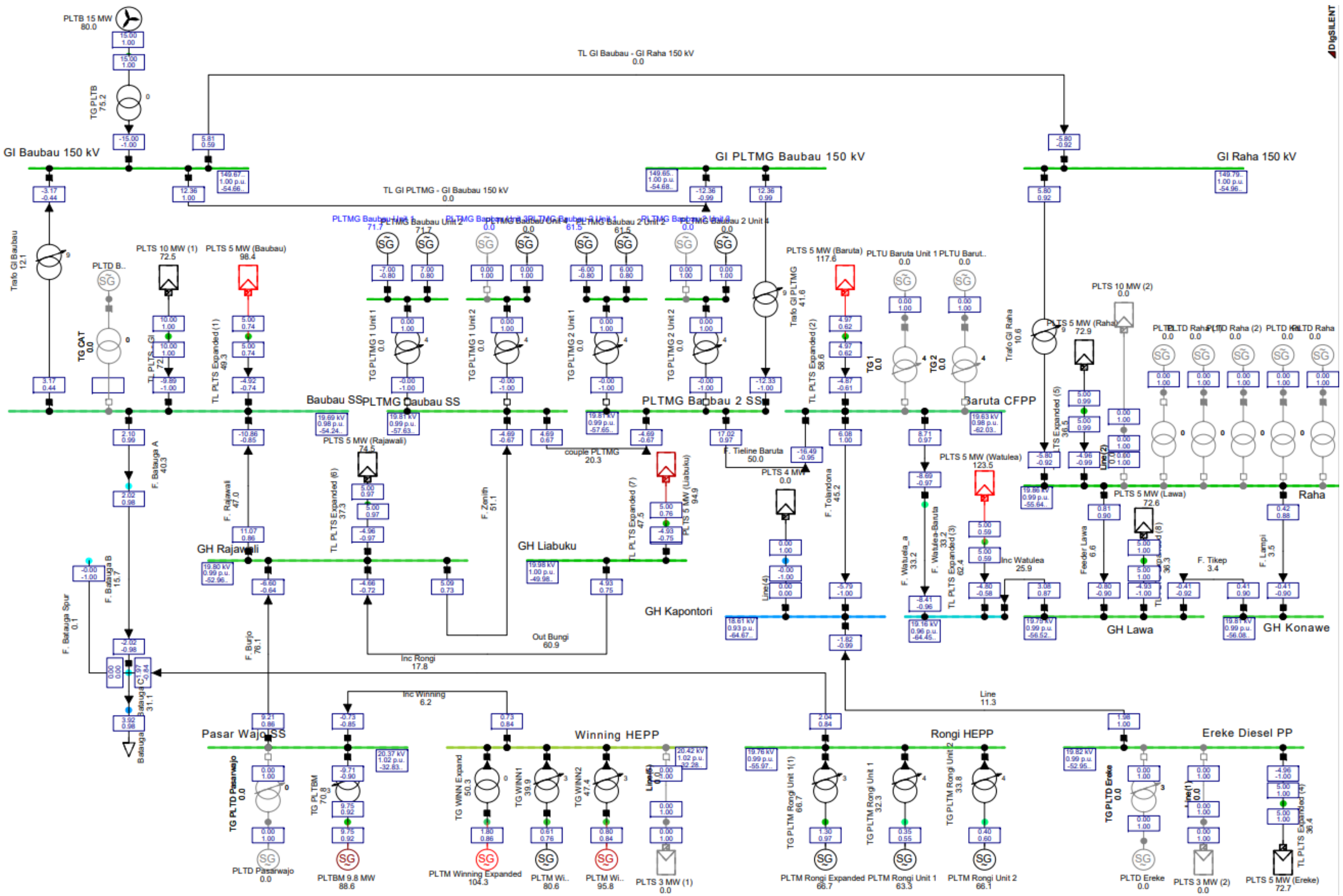


Figure 17 – Power Flow Simulation for Evening Load (Scenario 2) using DIgSILENT

Based on the power flow simulation for the evening peak load of the 100% RE (Scenario 2), the following observations were derived.

- There was no bus voltage below the +5% and -10% for 20 kV system and ±10% for 150 kV system voltage criteria, but tapping on transformer substation primary side (2.5%) was necessary to maintain the voltage system criteria
- During the evening load, solar PV would charge the batteries (during the day) and there is sufficient energy remaining to serve the evening loads as combined with other operating power plants on the grid. The battery backup capacity must be sufficient to serve the evening loads and the Solar PV capacity need to be sufficient to both serve the daytime loads as well as charge the batteries for the evening loads.
- The branch elements are overloaded and assumed to be upgraded into two parallel lines.
- System active power losses is approximately 9.74% of total generation.

Scenario 1 (Base Case) grid simulation needed to be performed twice because there was no hourly load data available from PLN. As the available data provided by PLN were peak load demands during the day and in the evening, assumptions of the load profile had to be made as a typical load profile based on previous experiences and projected total demands. The average loads peaked at 11:00 am (64MW) and 7:00 pm (72MW) when projected to 2030 (Table 41) usage. PLN's RUPTL projected the additional power plants to be built to provide a total of 121MW by adding 84.8MW of new generation to the36.2MW to the 2021 existing capacity as captured in section 7.1. This provides more than enough additional power to meet the peak loads predicted in 2030 based on demand growth on Table 41. Additionally, the highest peak load predicted in 2030 is through projecting PLN's peak load historical data to predict growth, which will reach 99.5 MW (Table 40). This can easily be handled by the total RUPTL plan to have 121 MW installed and operating.

On the other hand, for Scenario 2 (100% RE), a total of 79.2 MW of renewable-based power plants to be added will be sufficient to provide enough energy given the peak load conditions predicted for 2030 (64 MW daytime peak load and 72 MW night-time peak load) through simulation. While this is sufficient to generate the energy required for the 24-hour electricity use and peak power load through simulation, additional solar PV/BESS capacity will be needed to cover the peak power requirements predicted in 2030 based on PLN’s peak load historical data projection (99 MW). In-keeping with the 100% RE commitment, the additional power needs to be generated by adding the existing hydro power plants (2.4 MW) to the new power plants under Scenario 2 and by replacing diesel power plants with solar PV and BESS (roughly 17.4 MW) in addition to other renewable energy-based power plants (79.2 MW). If an hourly load profile was available from PLN, the amount of additional solar PV and BESS could be predicted much more accurately. If the peak power load needed to be covered for several hours, then a significant amount of BESS capacity needs to be installed along with the solar PV systems in sufficient quantities to recharge the BESS. It is also possible that the peak power load is only required for a few minutes, which will significantly reduce the requirements for the additional BESS and solar PV capacity.

As a note, if the hourly load profile data was available from PLN, and it was found that the peak power loads are only required very infrequently and for short periods, a peak power plant using diesel generators can be considered as a much less expensive option if a near-100% renewable energy scenario can be considered. A total of 99 MW of renewable energy-based power plant will be available and operational as projected in Scenario 2 by 2030.

7.4.2 Off-grid Analysis

Recent discussions with PLN Baubau Area revealed that up to the date of this report, neither PLN Baubau nor the Department of Energy at provincial level have a map of 20 kV distribution lines. Due to this limitation, the analysis is conducted through the preliminary identification of villages with less electricity coverage in Buton Island, and the existing diesel-based off-grid power plants operated across Buton.

7.4.2.1 Villages with Less Electricity Coverage in Buton Island

In this study, we define villages with less electricity coverage in Buton Island as villages with remaining unelectrified or non-PLN electrified households (HHs), which may be interpreted as households connected to off-grid power plants, including renewable-based generation. It is also possible that this type of household uses a diesel genset, be it privately owned or on a communal basis, as its source of power. Hence, it may also be considered to be included in the transition plan. The Department of Energy at provincial level shared the village electrification status in the entire South East Sulawesi Province. From the raw data received, the following details of villages with less electricity coverage in Buton Island were obtained, as the table below outlines.

Due to limitations in data, to ease the high-level analysis, we derive and classify the villages with less electricity coverage into the following groups, as the basic assumptions:

1. Villages with existing mini-grids (RE or diesel) refers to villages in which more than 70 HHs are connected to non-PLN source power generation;
2. Villages with the possibility of non-PLN HH (mostly individual genset, can be communal genset/ small-scale RE) are indicated by having fewer than 70 non-PLN electrified HHs;
3. Villages suitable for SHS: these are villages with small numbers of unelectrified HHs (estimated to be less than 40 HHs); and,
4. Villages suitable for RE-based mini-grid: these are village with high numbers of unelectrified villages potentially connected through a separate grid, which in this study we presume to be more than 70 HHs.

Table 46 – Number of Villages with Less Electricity Coverage in Buton Island

Regency	Number of villages with less electricity coverage	Type of Villages			
		With existing mini-grids	With possibility low non-PLN electrification HHs (genset, RE)	Suitable for SHS	Suitable for RE-based mini-grid
Baubau City	0	0	11	0	0
Buton Regency	26	3	24	26	0
North Buton Regency	16	4	56	16	0
South Buton Regency	2	8	9	2	0
Part of Muna Regency	5	3	0	4	0

The villages that are identified as having less electricity coverage are located in five areas in Buton including

Baubau City, Buton Regency, North Buton Regency, South Buton Regency, and areas of Muna Regency that are geographically part of Buton Island. However, the number of unelectrified or non-PLN electrified households in these villages is minor, on the whole, compared to the total households. From the screening of high-level villages, it can be noticed that none of the identified villages have an attractive size for RE-based mini-grid additions, considering the low number of potential connections. Although there are still villages with remaining unelectrified households, the number is small enough (fewer than 40 in a village) that it is suggested for these households to be connected through solar home systems (SHS) rather than the more costly mini-grid.

Furthermore, the current definition of “non-PLN electrified households” may be deemed as vague and not adequately reflecting the actual condition on the ground. Based on direct observation, interviews, and site visits to villages with non-PLN households in Baubau, unelectrified or non-PLN households can be “illegal connections” to nearby PLN-connected houses in the neighbourhood. Mostly this group belongs to people who cannot afford to buy a PLN meter, so they illegally connect to close neighbours who have installed PLN’s kWh meter and pay IDR 15,000-25,000 (1-1.8 USD) per month. They are recorded under “non-PLN electrified households” solely for administrative purposes, in this case to enable them to access Department of Public Housing assistance in installing kWh-meter assistance. From the table above it can be seen that Buton Regency and North Buton Regency are the areas with the highest number of villages with unelectrified households. However, reflecting what it is in such villages in Baubau City, there is also a possibility that similar cases happen in other areas in Baubau, with household being covered by PLN service, but not yet captured in the government database.

7.4.2.2 Diesel Mini-grid Identification

Diesel gensets are normally found in villages lacking access to the PLN grid. Some remote villages received a communal diesel genset from the National Program for Community Empowerment (*Program Nasional Pemberdayaan Masyarakat* - PNPM) back in the 2010s. Massive diesel genset replacement would support the whole island transition; thus it is important to investigate. However, through continuous engagement and correspondence with the Provincial Department of Energy at Kendari, it is confirmed that they do not keep inventories for diesel mini grids operating in non-PLN villages within Buton Island. They only do inventories for off-grid solar PV power plants that are identified to be operating in a few small areas in South Buton Regency, namely Batuatas West and East Villages, Wambongi Village, Taduasa Village, and Tolando Village. In addition to these villages, off-grid solar PV power plants also operate in three remote villages that are administratively under Muna Regency but situated in the northern part of Buton Island, namely Bhakealu Village, Kogholifano Village, and Labulawa Village.

Generally, based on the off-grid analysis of the villages with less electricity coverage across Buton that tend to have low numbers of unelectrified HHs, it can be concluded that PLN grid has reached almost all areas within Buton Island. Considering the scale of the project, the best option to address electrification access for the remaining unelectrified HHs for the identified villages is solar home systems (SHS). Grid extension would be too costly to deploy and the capacity of the mini grids would be too small, since there are fewer than 40 unelectrified HHs in most villages. On that basis, the off-grid electrification planning shall be excluded from this roadmap.

The data for electrified and non-electrified HHs are captured in the table below.

Table 47 – Electrified and Non-Electrified Households in Buton Island

No	District/City	Total Households	Electrified Households	Non-electrified Households
1	Baubau	36,710	36,710	0
2	Buton	23,410	22,970	440
3	South Buton	18,894	18,853	41
4	North Buton	15,844	15,735	109
5	Muna (Subdistricts of Pasir Putih and Maligano)*	2,912	2,876	36
	Total	**97,770**	**97,144**	**626**

Based on the data of non-electrified households and the identified distribution of capacity required, an estimate of cost for SHS provision could be obtained as follows. The estimated cost of required SHS in the unelectrified HHs was assumed to be USD 500 to USD 2,000 per SHS for the capacity range of 300 W to 1,000 W. Further study of the exact number of non-electrified HHs, required electricity capacity, and cost of SHS of each capacity specification is required to verify the estimated cost as presented in the table below.

Table 48 – Estimate of SHS Provision for Non-Electrified Households in Buton Island

Total Households	Percentage (%)	SHS Cost (USD)	Total SHS Cost (USD)
313	50	500	156,500
187.8	30	1,000	187,800
93.9	15	1,500	140,850
31.3	5	2,000	62,600
		Total	**547,750**

7.4.3 Cost Drivers

Buton Island, and many other remote islands in Indonesia face similar issues where resources may be limited, and the logistics of goods and materials trading are difficult. Another common issue throughout Indonesia’s remote islands is the infrastructure, especially manufacturing and transportation. This results in specific cost premiums on various factors that affect the cost of energy in Buton.

The first common cost driver is the availability of fuels and/or feedstock for bio energy projects. There are not enough agricultural activities (farming or ranching for cattle) where there are sufficient waste products to be used as feedstock for bio energy products. For biomass power plants, it is expected that wood pellets (or other feedstock as necessary) will need to be brought in from Java, Makassar, Kalimantan, or other locations throughout Indonesia. This adds significant enough costs to the feedstock price that there is an impact upon the financial performance of the projects.

Cost of logistics for goods and materials also add a premium to the project cost that can be as high as 10% or more. This impacts the financial performance of the project not just due to the additional capital expenditure but also to the financing costs of the additional capex which need to be added to the loan and/or equity of the project. The closest large international port to Buton Island is either Makassar or Manado, with the most commonly used port of entry for imported materials being Jakarta or Surabaya.

Availability of skilled workers to be hired during the construction and operation of the project will also affect the project's costs. Being able to hire from the local workforce can save the project a measurable amount of costs. While in some cases the premium of hiring skilled workers from outside of the region is not significant, there are occasions where the ability to hire a local workforce will make an impact on the IRR of the project. In this regard, based on BPS data for Buton in 2020, there was an estimated population of 45,712 people aged 15 years and who were economically active, with an economic participation rate of over 65.34%. Based on educational attainment, the majority of people who are economically active have completed primary school (17,675 people), high school (15,005), junior high school (7,714), and university degree (5,318).][35] According to these data, only a small proportion of the productive-age population have completed a university degree, indicating that it will be difficult to find a trained workforce; hence the workforce will need to be hired from outside of Buton island. Another alternative is to have training or capacity building for the local community, to enable them to develop the required skillsets to contribute to the development of the projects.

Lastly, the cost driver to be mentioned in this report is the availability of natural resources, goods, materials and services. Beyond the logistics issues of bringing these things to Buton Island, the lack of manufacturing capabilities locally to make the goods and materials needed for the power plants means potential increased cost. Two concrete examples for the business-as-usual scenario are importing gas and coal from outside of Buton Island. At present, Buton Island's electricity consumption only warrants the installation of relatively small gas and coal power plants. Reflecting from existing projects in Indonesia, it's rarely commercially viable to set up a fuel/feedstock infrastructure for projects on such a scale.

The combination of the above cost premiums, which stack up, may mean that projects in Buton Island generally require 15-30% additional funding (CAPEX and OPEX) compared to a similar project on Java Island.

7.4.4 Technical Analysis Conclusion

During the grid simulation through the various scenarios, it was found that the grid conditions are good enough to handle any potential short-circuit faults. This includes the scenario of 100% renewables, where it was also shown in the technical study document that the protection schemes on the grid for short-circuit faults are sufficient.

There were some concerns over the grid stability during the load flow analysis that was performed for the base case scenario based on the RUPTL). It was found that the RUPTL energy mix can create stability issues on the grid and it would not be prudent to operate the grid in such a manner. For the subsequent scenarios of 100% renewables, the energy mix has been adjusted to match the grid conditions and to ensure that the grid can be operated within the grid code. Based on the current analysis, one of the required upgrades is to add additional lines in parallel to the existing ones at Baruta and Tolandona, by adding approximately 20 km (10 km + 10 km)

[35] Buton Regency in Figures 2021. Central Bureau of Statistics.

double cable for 20 kV line.

From the simulations for both scenarios, the following conclusions can be yielded:

- A centralised solar PV power plant with the said capacity in one location within the grid coverage will lead to a grid voltage drop. Therefore, to maintain the grid stability, added PV capacity will be scattered in a few locations, as near as possible to the existing diesel or other baseload power plants.
- During load flow simulation during daytime and evening peak load, the voltage values in normal conditions fall within the set ranges (±10% for 150 kV system and +5% -10% for 20 kV system), meaning they comply with the grid code standard.
- Some technical actions are proposed to address findings during evening load simulations, including upgrading some 20 kV distribution lines that are identified to be overloaded into two parallel lines to reduce the drop voltage, also the breaker connected to the Ereke sub-system should be opened (to be changed into an isolated system which operates independently) to minimise the drop voltage risk.

Shifting from the conventional pathway of adding fossil fuel-based generation units, or even the business-as-usual case based on the existing plan, transitioning Buton Island towards 100% renewables is possible, but can be seen as ambitious within the ten-year timeframe. The barriers include the transparency of the procurement process and the relatively small project sizes, resulting in difficulties in financing the project commercially. Gradual and measurable actions toward transitioning to 100% renewable should be implemented to ensure there are no interruptions of service to the current and near-future electricity consumers. Set out below are some strategic actions that can be considered as a transition strategy to get Buton Island to 100% renewables:

- **1st phase:** Utilise the identified potential for hydro in Buton and Muna Islands;
- **2nd phase:** Add grid-connected solar PV and wind power plants in a hybrid configuration with existing and new fossil fuel generators to significantly decrease emissions, by at least 25%. Relocation for existing diesel power plants may be required to move them closer to the solar power plants if the solar plants are unable to be located close enough. Wind contribution might be insignificant considering that there are very few wind resources in Buton Island;
- **3rd phase:** Substitute coal power plants with biomass;
- **4th phase:** Gradually substitute diesel on hybrid PV-diesel/ wind-diesel power plants with BESS; and
- **5th phase:** Gradually phase out gas (considering gas infrastructure investment).

All things considered, the driving force of the RE mix in Buton specifically is not the LCOE but the availability of resources. Buton is a good example of an island where very few other resources are available locally, such as hydro, wind, and biomass. In other locations, where biomass, wind, and hydro are more readily available, the LCOE will drive the energy mix as well as the technical requirements to create a 100% renewable energy grid that provides the least cost solution, while allowing the grid operators to comply with the grid code and other requirements. Buton also showcases that when there are no other options, solar PV can be the energy transition technology of choice to become 100% renewable. When there is potential for hydro, it is apparent from the LCOE calculation that hydropower plants offer the most effective cost; however, the challenge is the dependency of this type of technology on the site-specific potential of the energy resource. Solar PV would become a better choice soon, when solar technology and BESS costs continue to decline due to growing demand and the advancement of technology and materials.

To achieve 100% renewable energy, it is not enough to simply install new power plants utilising renewable energy, but also to ensure that their integration into the existing grid does not interrupt service or interfere with a stable operation of the grid following the grid code requirements. In the technical study, it was found that:

- The installation of a 30 MW of hybrid PV-Diesel plants needs to be distributed in smaller power plants located throughout the island, rather than a centralised power plant. This will significantly reduce the risk of voltage drop on the grid system.
- The 20 kV line connection in 2030 on the Baruta line and Tolandona line needs to be upgraded in capacity due to overloading.
- During the 100% Renewable Energy scenario normal condition, the grid system still complies with the Grid Code Standard.
- The original impact study indicated that there is minimal impact on prospective fault levels with the solar farm connected.

8. GHG Emissions Calculation

This chapter discusses the estimated GHG emissions that can be avoided from replacing the fossil fuel-based power plants (Base case) to renewable energy ones (100% Renewables Scenario). The GHG emissions are then calculated for the Base Case, based on the emissions generated from the existing and planned power plants in Buton Island in accordance with RUPTL 2021-2030 and data received from PLN offices in Baubau and PLN South East West Sulawesi Region. Following the scenario as previously explained in previous chapters, the analysis assumes that all of the existing non-renewable energy power plants will be replaced to 100% renewable energy power plants starting from 2026 until the end of the remaining operating period, while the planned power plants will be operated according to the RUPTL 2021-2030 data and its expected technical lifetime accordingly. The following sections capture detailed information on the data and assumptions used for the purpose of the emission analysis.

8.1. Existing Power Plants

Referring to the latest RUPTL 2021-2030, electricity in isolated islands located in the Southeast Sulawesi, including Buton, is mainly supplied by fossil-fuel power plants, such as diesel, gas, and coal-fired power plants. The existing power plants on Buton Island, as listed in the RUPTL 2021-2030, are included in the table below:

Table 49 – Existing Power Plants as per RUPTL 2021-2030

Power Plant	Capacity (MW)	COD
Diesel Power Plant (PLTD)		
Isolated Baubau	30.15	COD information not available; in operation
Isolated Ereke	5.22	COD information not available; in operation
Micro/Mini-hydro Power Plant (PLTM)		
Isolated Baubau	1.6	COD 1993; in operation
Isolated Baubau	0.8	COD information not available; in operation
Gas Engine Power Plant (PLTMG)		
Isolated Baubau	30	COD 2019; in operation
Coal-fired Power Plant (PLTU)		
Isolated Baubau	14	COD 2015; in operation

Source: RUPTL 2021-2030, OJS.UHO: Evaluasi Sistem Tenaga Listrik Minihidro, Ekonomi Bisnis Article, Summary Report PLN, May 2021

Notes:

- *Commercial Operation Date ("COD") data of each existing power plants were not detailed in the RUPTL report 2015 to the latest publication in 2021. For the purpose of estimating the greenhouse gas emission in this report, the COD data are sourced from other publicly available data. Please refer to the references included in the following description.*
- *The calculation for estimated greenhouse gas emission in this report assumes that the COD of each power plant is at the beginning of each stated year, hence the direct emissions can be estimated from the first year of operation.*
- *Further confirmation with PLN and MEMR is required to confirm the current status, COD, and operating phase of each existing power plant in Buton.*

In reference to the information sourced from publicly available data, the existing mini-hydro power plant in Baubau area with a total capacity of 1.6 MW began operation in 1993[36], the COD of the existing gas power plant in Baubau with total capacity of 30 MW is 2019[37], and the COD of the existing coal-fired power plant in Baubau with total capacity of 14 MW is 2015[38]. Further confirmation with PLN and MEMR is required for this data.

Based on the planned Diesel Power Plants Replacement Program – Phase 1 as stipulated in the RUPTL 2021-2030, the existing diesel power plants in Buton Island, which are included in the program are PLTD Talaga and PLTD Kadatua, with total installed capacity of 700 kW and 840 kW respectively. The target commencement for the diesel replacement program was not detailed in the RUPTL 2021-2030. Aside from data on existing power plants in RUPTL, based on Buton Regency Regulation No 01/2014 on Regional Planning of Buton Regency for 2013 - 2033, there are few existing power plants in Buton Island, as summarised in the table below.

Table 50 – Existing Power Plants in Buton as per Buton Regency Regulation No 01/2014

Power Plant
Diesel Power Plant (PLTD)
1. PLTD Village at Talaga Raya District
2. PLTD Village at Mawambunga Village, Kadatua District
3. PLTD Village at Molona Village, Siompu Barat District
4. PLTD Village at Kancibungi and Gumanano Village, Mawasangka District
5. PLTD Village at Todangan Village, Kapontori District
6. PLTD Village Swadaya at Lapara Village, Siompu District
Micro/Mini-hydro Power Plant (PLTM)
1. PLTM Rongi at Sampolawa District
2. PLTM Wining at Pasarwajo District
Coal-fired Power Plant (PLTU)
1. PLTU Baruta Analalaki at Sangia Wambulu District

Source: Buton Regency Regulation No 01/2014

Notes:

- *The installed capacity of each power plant, its respective COD information, and the existing gas power plants are not detailed in the Buton Regency Regulation No 01/2014.*
- *From the Introduction Meeting with MEMR dated 24 March 2022, it was informed that the COD of PLTM Wining is 1997. Data to be further confirmed with PLN.*
- *Further confirmation with PLN and MEMR is required to for the current status, COD, and operating phase of each existing power plant in Buton.*

Considering the data availability on existing power plants based on Buton Regency Regulation No 01/2014, in the GHG emission calculation analysis, the first calculation of the GHG emission will consider data of the existing power plants in Buton Island as stated in the RUPTL 2021-2030.

Based on the data as received from PLN offices in Baubau and PLN South East West Sulawesi Region, the existing power plants in Buton along with each of the operational years are included in the table below:

[36] OJS.UHO: Evaluasi Sistem Tenaga Listrik Minihidro
[37] Ekonomi Bisnis Article
[38] Summary Report PLN, May 2021

Table 51 – Existing Power Plants as per PLN's Data

Power Plant	Capacity (MW)	COD
Diesel Power Plant (PLTD)		
PLTD BAUBAU	2.86	1973
PLTD BAUBAU	0.67	1977
PLTD EREKE	0.25	1978
PLTD EREKE	0.25	1980
PLTD BAUBAU	1.10	1984
PLTD BAUBAU	5.44	1985
PLTD BAUBAU	0.56	1986
PLTD EREKE	0.75	1997
PLTD BAUBAU	1.25	1998
PLTD BAUBAU	0.80	2001
PLTD EREKE	0.51	2010
PLTD EREKE	1.02	2012
PLTD EREKE	1.56	2015
PLTD BAUBAU	5.12	2016
PLTD EREKE	10.74	2017
Micro/Mini-hydro Power Plant (PLTM)		
PLTM WINNING	1.8	1997
PLTM RONGI	1.1	2019
Gas Engine Power Plant (PLTMG)		
PLTMG BAUBAU	39.12	2019
Coal-fired Power Plant (PLTU)		
PLTU BARUTA	14	2015

Source: Data received from PLN Baubau and PLN South East West Sulawesi Region

Notes:

- *The status of operation for each power plant was not included in the data shared by PLN. The calculation of estimated greenhouse gas emission in this report assumes that the technical lifetime of each technology follows the assumption included in report section 8.4. Hence, the existing diesel power plants that are still assumed to be operating are plants with COD from 2010 and after.*
- *The calculation for estimated greenhouse gas emission in this report assumes that the COD of each power plant is at the beginning of each stated year, hence the direct emissions can be estimated from the first year of operation.*
- *Further confirmation with PLN is required to confirm the current status of operation of each existing power plant in Buton.*

In comparing the data received from PLN offices in Baubau and PLN South East West Sulawesi Region and the data included in RUPTL 2021 - 2030, we noted a discrepancy in the total capacity of existing power plants in Buton, namely for the diesel, micro/mini-hydro, and gas engine power plants. The table below shows the summary of the existing power plants capacity in Buton from the two available sources.

Table 52 – Existing Power Plants Data Comparison

Power Plant	Capacity (MW)	
	RUPTL 2021-2030 data	PLN Local Offices data
Diesel Power Plant (PLTD)	35.37	32.88
Micro/Mini-hydro Power Plant (PLTM)	2.4	2.9
Gas Engine Power Plant (PLTMG)	30	39.12
Coal-fired Power Plant (PLTU)	14	14
Total	**81.77**	**88.90**

As of the writing of this report, we have not yet to received confirmation from PLN in regard to this discrepancy, hence we have included calculations of estimated greenhouse gas emission for both of the data received.

8.2. Planned Power Plants

Based on the RUPTL 2021-2030, planned power plants with renewable energy in Buton Island are as follows:

Table 53 – Planned Power Plants as per RUPTL 2021-2030

Power Plant	Capacity (MW)	Expected COD
Hybrid Energy Power Plant (PLTH)	30	2027/2028
Biomass Energy Power Plant (PLTBm)	9.8	2025
Wind Energy Power Plant (PLTB)	15	2025
Gas engine Power Plant (PLTMG)	30	2023/2024

Source: RUPTL 2021-2030

Notes:

- *The energy mix used for the planned hybrid energy power plant was not detailed in the RUPTL 2021-2030 nor in any other publicly available data.*
- *For the purpose of the estimated emission calculation, it is assumed that the planned hybrid energy power plant (PLTH) and gas engine power plant (PLTMG) will be commissioned for operations in 2027 and 2024 respectively. These assumptions are subject to further confirmation with PLN.*
- *Further confirmation with PLN and MEMR is required for the current status, COD of each existing power plant, and the detailed energy mix used for the planned hybrid energy power plant in Buton.*

In addition to the planned power plants with renewable energy, RUPTL 2021-2030 includes a plan for a new gas power plant (PLTMG) Baubau 2 with total installed capacity of 30 MW and target COD in 2023/2024. There were no data available related to the planned power plants in publicly available regional government regulations, including Buton Regency Regulation No 01/2014; hence, we are referring to RUPTL 2021-2030 for the planned power plants data. Further confirmation with PLN and MEMR is required for the status of each planned power plant.

8.3. Methodology

The GHG emission calculation in this report was developed in reference to the existing power plants data in Buton, as well as the RUPTL 2021-2030 data (Base Case) for the plan development of new generating units. It was assumed that Buton Island will implement 100% renewable energy as its electricity source by decommissioning all of the existing non-renewable energy power plants starting from 2026. This assumes that the associated planning, procurement, and construction phases will be conducted throughout 2022 to 2025. The planned power plants are assumed to be operated according to its planned COD according to the RUPTL 2021-2030 data and the expected technical lifetime accordingly. On this basis, the avoided greenhouse gas emissions are calculated by considering the emissions generated from existing and planned non-renewable power plants.

In reference to the 2006 Intergovernmental Panel on Climate Change (IPCC) Guidelines[39] and the 2019 Refinements[40], the estimated direct emission of the power plants shall be obtained by referring to the emission factor of selected electricity supply technology as provided in the guideline.

For existing power plants, the formula to calculate the estimated emissions are as follows:

$$Estimated\ GHG\ Emission\ = Total\ Installed\ Capacity \times\ Remaining\ operating\ period\ of\ each\ plant \times Emission\ Factor\ \times Capacity\ Factor$$

For planned power plants, the formula to calculate the estimated emissions are as follows:

$$Estimated\ GHG\ Emission\ = Total\ Installed\ Capacity \times Operating\ period\ of\ each\ plant\ \times Emission\ Factor\ \times Capacity\ Factor$$

As depicted in the equation above, referring to the type and capacity information of the existing and planned power plants in Buton as included in the RUPTL 2021-2030, the direct greenhouse emission is calculated by multiplying the installed capacity of each type of power plant with the respective technical or operating lifetime, capacity factor, and emission factor. Furthermore, the total estimated cost of the direct emission can be calculated to indicate the potential cost of emissions from the existing and planned power plants in Buton Island by applying the estimated total direct emission with the estimated cost of emissions. Details of the emission factor, capacity factor, and estimated cost of emissions assumptions are included in the following section of this report.

Furthermore, the total estimated cost of the direct emission can be calculated to indicate the potential cost of emissions from the existing and planned power plants in Buton Island by applying the estimated total direct emission with the estimated cost of emissions.

8.4. Assumptions

The assumptions used for the greenhouse gas emission analysis of the Roadmap for the RUPTL Scenario according to the information sourced from RUPTL 2021-2030 and other publicly available information, are detailed as follows:

8.4.1. Commercial Operation Date ("COD")

The first calculation in estimating the GHG emission considered for the GHG calculation in this report refers to the data of existing capacity power plants based on RUPTL 2021-2030. However, as noted in the previous section of the report, the COD for existing power plants was not detailed in the RUPTL. For the assumed COD of existing diesel power plants in 2015, we referred to RUPTL 2015-2024 which has included existing diesel power plants with total capacity of 24.4 MW and 2.3 MW for Baubau and Ereke respectively.

For the estimated COD of existing micro/mini-hydro power plants, gas engine power plants, and coal-fired power plants, we referred to the publicly available data as noted in previous section. As the months of COD are not detailed in the RUPTL nor the available public data received as at the

[39] 2006 IPCC Guidelines
[40] 2019 IPCC Refinements

development of this analysis, it is assumed that the COD of each power plant is at the beginning of each stated year, hence the direct emission shall be estimated from the first year of operation. This is subject to confirmation with PLN. Details of existing and planned power plants with the associated COD are included in the table below.

Table 54 – COD Assumptions of Existing and Planned Power Plants based on RUPTL data

Power Plants		Capacity (MW)	COD
Existing Power Plants			
PLTD Baubau	Diesel	30.15	2015
PLTD Ereke	Diesel	5.22	2015
PLTM Baubau	Micro/Mini-hydro	1.6	1993
PLTM Baubau	Micro/Mini-hydro	0.8	1993
PLTMG Baubau	Gas engine	30	2019
PLTU Baubau	Coal-fired	14	2015
Planned Power Plants			
PLTH	Hybrid Energy	30	2027
PLTBm	Biomass Energy	9.8	2025
PLTB	Wind Energy	15	2025
PLTMG Baubau 2	Gas engine	30	2024

Source: RUPTL and other publicly available data

Notes: Further confirmation with PLN and MEMR is required for the current status, COD, and operating phase of each existing power plant in Buton, and the detailed energy mix used for the planned hybrid energy power plant in Buton.

For the purpose of the emission calculation in this report, as previously explained the energy mix of the planned hybrid power plants is assumed to be using 65% diesel generator and 35% solar PV technology based on general energy mix for hybrid power plants. This information is subject to further confirmation with PLN and MEMR as per the existing condition and potential renewable energy in Buton Island.

The second calculation in the GHG emission calculation section referred to the capacity and COD data of existing power plants as received from PLN offices in Baubau and PLN South East West Sulawesi Region. Status of operation for each power plant was not indicated in the data shared by PLN. Hence, the existing diesel power plants, which are still assumed to be operating, are plants with the targeted COD of 2010 and beyond, based on the consideration of the typical technical lifetime of each technology as explained in section 8.4.2 of this report. Details of the existing and planned power plants based on the PLN offices to be considered in the estimated GHG emission calculations can be found in the table below.

Table 55 – Existing Power Plants as per PLN Offices' Data

Power Plant		Capacity (MW)	COD
Existing Power Plants			
PLTD Ereke	Diesel	0.51	2010
PLTD Ereke	Diesel	1.02	2012
PLTD Ereke	Diesel	1.56	2015
PLTD Baubau	Diesel	5.12	2016
PLTD Ereke	Diesel	10.74	2017
PLTM Winning	Micro/Mini-hydro	1.8	1997

Power Plant		Capacity (MW)	COD
PLTM Rongi	Micro/Mini-hydro	1.1	2019
PLTMG Baubau	Gas engine	39.12	2019
PLTU Baruta	Coal-fired	14	2015
Planned Power Plants			
PLTH	Hybrid Energy	30	2027
PLTBm	Biomass Energy	9.8	2025
PLTB	Wind Energy	15	2025
PLTMG Baubau 2	Gas engine	30	2024

Source: Existing power plants data as received from PLN Baubau and PLN South East West Sulawesi Region; planned power plants as referred from RUPTL 2021-2030

Notes:

- *The calculation of estimated greenhouse gas emissions in this report assumes that the COD of each power plant is at the beginning of each stated year, hence the direct emission can be estimated from the first year of operation.*
- *As there is no information received from PLN offices in Baubau nor South East West Sulawesi Region regarding planned power plants in Buton, the second calculation of estimated GHG emission would refer to the RUPTL data for planned power plants.*
- *Further confirmation from PLN is required to confirm the current status of operation of each existing and planned power plant in Buton.*

8.4.2. Technical Lifetime

The technical lifetime of each power plant refers to the information included in the Technology Data for the Indonesian Power Sector Catalogue for Generation and Storage of Electricity (February 2021) issued by the Directorate General of Electricity in close collaboration with the Danish Embassy and the Danish Energy Agency. Summary of the technical lifetime of each technology is as follows.

Table 56 – Technical Lifetime Assumptions

Power Plants	Technical Lifetime
Diesel	20 years
Gas Engine	25 years
Coal-fired	20 years

Source: Technology Data for the Indonesian Power Sector Catalogue for Generation and Storage of Electricity 2021

8.4.3. Emission Factor

The emission factor refers to the direct emission factor of each type of power plant as per the 2006 Intergovernmental Panel on Climate Change (IPCC) Guidelines and the 2019 Refinements, and the Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change[41] published in 2014. The assessment report is the latest assessment available until the development of this report. It has been made in reference to the 2006 IPCC Guidelines. There were no changes to the emission factors referred to in this report according to the 2019 IPCC Guidelines Refinements. Details of the data are presented

[41] 2014 Annex III: Contribution of Working Group III to the Fifth Assessment Report of the IPCC

in the table below.

Table 57 – Emission Factor (Direct Emissions) Assumptions

Power Plants	Emission factor	
	(g CO_2eq/kWh)	(t CO_2eq/MWh)
Coal	760	0.76
Gas Engine	370	0.37
Diesel	533	0.53

Source: 2019 IPCC Guideline and the Fifth Assessment Report (2014)

The calculation in this report refers to the direct emission factor in consideration that lifecycle emission as defined by IPCC Guideline will also include indirect emissions from infrastructure and supply chain activities, biogenic CO_2 and albedo effect, and methane, which are not included in this analysis.

The emission factor for diesel power plants refers to the Joint Crediting Mechanism (JCM) report[42] by applying the emission factor for diesel combustion of 72,600 kg CO_2/TJ as derived from "IPCC guideline 2006, Chapter 2, stationary combustion" divided by the plant heat efficiency (LHV) of 49% for diesel-fired power plants in Indonesia, the conservative emission factor is estimated to be at 0.53 t CO_2/MWh.

In relation to the direct emission calculation for planned biomass energy power plants, we refer to IPCC 2019 and the Fifth Assessment Report of IPCC Guidelines which noted it should be seen in connection with the CO_2 absorbed by growing plants and because biomass is accounted for in the land use sector it might be treated as zero (i.e., carbon neutral) in the energy sector, otherwise emissions would be accounted for twice. For the analysis in this report, it is assumed that the planned biomass energy power plants will be a dedicated technology using agriculture waste without co-firing of fossil fuel resources.

As of the development of this report, the estimation and reporting methodology of biomass energy emission has not yet achieved a scientific consensus, as the actual emission from bioenergy may be highly affected by the process and technology used for harvesting, processing, transportation, and other greenhouse gas emissions (CH_4 and N_2O) yield from the biomass combustion and biogenic part of waste burned.[43]

8.4.4. Cost of Emission

The estimated emission cost refers to the EU emission cost for the period 2021-2025 at € 47.25 per ton of CO_2 as per the IETA GHG Market Sentiment Survey 2021 Report[44]. The IETA greenhouse gas (GHG) Market Sentiment Survey was designed to assess key dimensions of EU's Emissions Trading System (ETS), such as future price and policy expectations. It reflects key issues and developments in GHG markets against a backdrop of significant changes, as well as political and economic development globally. The survey was conducted among IETA members, with more than one response per organisation possible, and was open from 19 April to 5 May 2021. Referring to the currency conversion rate of IDR 15,813 = 1 €[45], this equals to IDR 747,172 per ton of CO_2. For the period beyond 2025, this report assumed that there are no changes to the expected emission cost of € 47.25 per ton of CO_2 or IDR 747,172 per ton of CO_2. This report also assumed that there would be no change to the exchange

[42] Additional information on calculating the emission factors of Indonesia for the JCM
[43] IPCC FAQ on Biomass emission calculation
[44] IETA GHG Market Sentiment Survey Report 2021
[45] Bloomberg.com as per 23 March 2022

rate used as the assumption nor to the estimated emission cost used in the calculation of this report. If the emission cost were to be increased due to other factors such as inflation, the potential avoided emission cost may be higher than the estimated number as reflected in this report.

Considering that there has been no confirmed carbon price policy in Indonesia that could be referred to as at the writing of this report, it is also to be noted that the estimated avoided cost of GHG emission as calculated in this report should only inform the potential economic benefits which may be obtained from the 100% renewable energy-based transition and would not reflect the actual market price in Indonesia.

8.4.5. Capacity Factor

As at the date of writing of this report, the capacity factor data of each relevant power plants have not been received from PLN. On this basis, the calculation of estimated GHG emissions refers to the capacity factor of relevant technology power plants included in the Technology Data for the Indonesian Power Sector Catalogue for Generation and Storage of Electricity (February 2021) issued by the Directorate General of Electricity with the Danish Embassy and the Danish Energy Agency. Details of the capacity factors for each of the power plant technology are presented in the table below.

Table 58 – Capacity Factors Assumptions

Power Plants	Capacity Factor (%)
Diesel	70
Gas Engine	70
Coal-fired	70

Source: Technology Data for the Indonesian Power Sector Catalogue for Generation and Storage of Electricity 2021

Further confirmation with PLN is required to validate the assumptions of capacity factors.

8.5. Analysis Results

Based on assumptions as explained in the previous section, the greenhouse gas emission analysis results based on the RUPTL Scenario according to the RUPTL 2021-2030 and PLN offices data are as presented in Table 57 below. In conducting the analysis, we assume that the estimated emission of existing non-renewable power plants to be calculated from 2026 until the remaining operating period of the plants respectively. This assumes that it is deemed unlikely to stop the operations of all existing power plants in 2022, and that the estimated time for the necessary preparation phases shall also consider inclusion of the planning phase in 2022, procurement phase in 2023, and construction phase in 2024 to 2025, hence operations will commence in 2026. For the planned power plants, the analysis assumes that the operation period shall follow the COD as targeted in the RUPTL 2021-2030 data, and its estimated technical lifetime for each type of power plant. The following table summarises the estimated avoided GHG emission from existing and planned generation from diesel, coal, and gas power plants:

Table 59 – GHG Emission Analysis Results

Output		Estimated GHG Emission based on Data Source	
Existing Power Plants	**Unit**	**RUPTL**	**PLN offices**
PLTD Baubau	Million tCO_2	0.89	0.17
PLTD Ereke	Million tCO_2	0.15	0.45
PLTMG Baubau	Million tCO_2	1.22	1.59
PLTU Baubau	Million tCO_2	0.59	0.59
Estimated Total Emission	**Million tCO_2**	**2.85**	**2.81**
Total Cost of Emission	**Billion IDR**	**2,131.53**	**2,100.06**
Planned Power Plants	**Unit**	**RUPTL**	**PLN offices**
PLTMG Baubau 2	Million tCO_2	1.70	1.70
PLTH (Diesel 65%, PV 35%)	Million tCO_2	1.27	1.27
Estimated Total Emission	**Million tCO_2**	**2.97**	**2.97**
Total Cost of Emission	**Billion IDR**	**2,223.80**	**2,223.80**
Existing and Planned Power Plants	**Unit**	**RUPTL**	**PLN offices**
Estimated Total Emission	**Million tCO_2**	**5.83**	**5.79**
Total Cost of Emission	**Billion IDR**	**4,355.33**	**4,323.86**

Referring to the existing power plants in Buton Island, the estimated direct emissions as generated from diesel, gas, and coal-fired power plants throughout their respective expected technical lifetimes are detailed in the table above. The estimated direct emission factor of micro/mini-hydro as sourced from the 2019 IPCC Guidelines is zero; hence the emission calculation excludes the emission from the existing micro/mini-hydro power plant (PLTM Baubau).

Estimated GHG Emission based on RUPTL Data

Based on the calculation using data sourced from RUPTL 2021-2030, the following conclusions are obtained:

- The estimated total emission from existing power plants is 2.85 million tons of CO_2, which equals IDR 2,131.53 billion as the total cost of emissions;
- From the planned power plants, the estimated total emission is 2.97 million tons of CO_2, which equals IDR 2,223.8 billion as the total cost of emissions; and,
- Considering the existing and planned power plants data from RUPTL 2021-2030, the estimated total emission is 5.83 tons of CO_2, which equals IDR 4,355.33 billion.

Estimated GHG Emission based on PLN Offices' Data

The second calculation of estimated GHG emission is based on the data of existing power plants in Buton as received from PLN Baubau and PLN South East West Sulawesi Region while the planned power plants data refers to the information in RUPTL 2021-2030. The following conclusions are obtained:

- The estimated total emission from existing power plants are 2.81 million tons of CO_2, which equals IDR 2,100.06 billion as total cost of emission;
- From the planned power plants, the estimated total emission are 2.97 million tons of CO_2, which equals IDR 2,223.8 billion as total cost of emission; and,
- Considering the existing and planned power plants data from the said PLN offices, the estimated total emission are 5.79 tons of CO_2, which equals IDR 4,323.86 billion.

The calculations of estimated avoided cost due to the emission of power assumes cost of carbon of IDR 747,172 per ton of CO_2 (€ 47.25 per ton of CO_2 based on IETA GHG Market Sentiment Survey 2021 Report). It also assumes there would be no replacement and/or expedited retirement plan for the existing and planned power plants using fossil-fuel energy from 2026 aside from the data received from RUPTL 2021-2030 and PLN offices in Baubau or PLN South East Sulawesi Province Region. It is also to be noted that further confirmation with PLN and MEMR is required to enhance the analysis in consideration of other factors such as the technical feasibility and renewable energy potentials on Buton Island.

As previously mentioned, the existing diesel power plants that are included in the PLN Diesel Replacement Program Phase 1 based on RUPTL 2021-2030 namely PLTD Talaga and PLTD Kadatua have installed capacity of 700 kW and 840 kW respectively. In this analysis, these power plants have insignificant total capacity for the estimated emission impact to be considered; hence, we have excluded the estimation on the analysis of this report. Further confirmation is required with PLN and MEMR to confirm the detailed data for the retirement plan for the existing diesel power plants in Buton.

As detailed in the previous section regarding assumption of the emission factor of each power plant, we have also noted that the direct emission from planned biomass energy power plants should be treated as zero (i.e carbon neutral) in the energy sector according to the IPCC 2019 guidelines. Further confirmation is required as of the development of this report. The estimation and reporting methodology of biomass energy emission has not yet achieved a scientific consensus as the actual emission from bioenergy may be highly affected by the process and technology used for harvesting, processing, transportation, and other greenhouse gas emissions (CH_4 and N_2O) yielded from the biomass combustion and biogenic part of waste burned.

Further confirmation is required to confirm the data and assumptions used in order to enhance the analysis results, such as the COD data, capacity factor, current status, and operating phase of each power plant, and the real proportion of diesel and renewable energy used for the planned hybrid power plant. As at the date of writing of this report, such data are still in the process of being provided by the relevant stakeholders such as regional PLN and MEMR. This initial result will also need to be discussed with PLN as one of the stakeholders, to validate the data received as well as the adopted assumptions. The analysis will then be updated once the data are available and discussion with PLN is held. The report will then be updated accordingly to incorporate the updated information as mentioned above.

9. Follow Up Actions

Based on the analysis performed in previous sections, set out below are the follow up actions that should be taken into account for the energy transition plan in Buton island.

9.1. Financial Viability

Meaningful power sector reforms to enhance governance frameworks, and industry and market structures are required to lower the risk perception and return expectation of private sector investors across the board. However, this is a process that will take time to plan and implement. In the meantime, international investors and developers who are showing increasing interest in the Indonesian renewable energy market are believed to be implementing a portfolio building approach to capacity creation, with project level returns of secondary importance. Well-developed and structured renewable energy projects on Buton Island as part of a decarbonisation pathway of the island's electricity supply are likely to attract interest from these developers.

9.2. Technical Viability

Shifting from the conventional pathway of adding fossil fuel-based generation units, or even the business-as-usual case based on the existing plan, transitioning Buton Island towards 100% renewables is possible, but can be seen as ambitious to be done within the ten-year timeframe. The barriers include the transparency of the procurement process and the relatively small project sizes resulting in the difficulties of financing the project commercially. Gradual and measurable actions toward transitioning to 100% renewables should be implemented to ensure there are no interruptions of service to the current and near-future electricity consumers. Set out below are some strategic actions that can be considered as a transition strategy to get Buton Island to 100% renewables:

- **1st phase:** Utilise the identified potential for hydro in Buton and Muna Islands;
- **2nd phase:** Add grid-connected solar PV and wind power plants in a hybrid configuration with existing and new fossil fuel generators to decrease emissions by at least 25%. Relocation for existing diesel power plants may be required to move them closer to the solar power plants if the solar plants are unable to be located close enough. Wind contribution might be insignificant considering that there are very few wind resources in Buton Island;
- **3rd phase:** Substitute coal power plants with biomass;
- **4th phase:** Gradually substitute diesel in hybrid PV-diesel/ wind-diesel power plants with BESS; and
- **5th phase:** Gradually phase out gas (considering gas infrastructures investment).

9.3. GHG Emissions Calculation

Based on the data collection and stakeholder engagement process throughout the development of the roadmap, it could be noted that the inventories of the existing and development plan of the energy sector specifically in relation to the Buton island's electricity system could be better aligned between the national RUPTL, data in PLN offices at Southeast Sulawesi region and Baubau city, and data from the MEMR regional department. Data such as the Commercial Operation Date ("COD") and operation status of existing plants, distribution lines map, and the electrification data, which include the number of electrified and unelectrified households, should be available and aligned between PLN and the government's database to avoid any discrepancies. The level of details or data collection frequency for the data should also be enhanced to improve the accuracy of the analysis results.

Annex

Kick-off Minutes of the Meeting

Meeting	:	Whole Island Transition Roadmap (WITR) Kick-Off Meeting			
Date	:	15 November 2021	**Time**	:	16.30
Facilitator	:	FCDO	**Location**	:	Microsoft Teams

Participants

FCDO:

- David Lutman
- Alex Barton
- Anirban Ganguly
- Udit Mathur

PwC:

- Julian Smith
- Kiran Vergis
- Lavalette Erica
- Yolanda Mariska
- Laras Sekartaji

Inovasi:

- Andre
- Afifah
- Suhartono

No	Topic	Content	Action point
1.	**Introduction**	Introduction of team members from FCDO, and project organisation chart from PwC and Inovasi Dinamika Pratama.	
2.	**Project Information**	FCDO advised that the Whole Island Transition Roadmap (WITR) study may be further aligned to the Mentari program to further inform relevant findings and recommendations on technical analysis as well as on the social (community engagement) and policy development aspects.	Coordination with the Mentari program may be further required to understand the active and pipeline projects, and to understand expectations from the relevant stakeholders as the recipients of the report. PwC and Inovasi team to further schedule coordination meetings with FCDO to further align on the Mentari program, and to include identification of existing Mentari program in the Island Selection Criteria matrix.
3.	**Scope of Work and Indicative Timeline**	Scope of Work and the respective indicative timeline for the project as presented in the kick-off meeting: • Phase 0 – Mobilisation (1st week to 3rd week of Nov 2021) • Phase 1 – Scoping Analysis (2nd week Nov 2021 to 2nd week Dec 2021) • Phase 2 – Roadmap Development (3rd week Dec 2021 to 2nd week Feb	The closest deliverable is the Inception Report by PwC and Inovasi due on 23 November 2021.

No	Topic	Content	Action point
		2022) ● Phase 3 – Roadmap Finalisation (2nd week Feb 2022 to 4th week Mar 2022)	
4.	**Island Selection and Matrix**	Islands that have been considered in the proposal are as follows: ● Buton ● Alor ● Kei ● Buru ● Flores	
		Indicative selection criteria as included in the selection matrix are as follows: ● Economic value (GDP) ● Transportation ● Infrastructure ● Electrification ratio ● Population density ● PLN presence ● Existing RE plants ● Implementation feasibility ● Replicability to other islands ● Renewable energy potential	PwC and Inovasi to further include the description of each criterion and the impact to assessment, and to further consider adding the following: ● Island size suitability for the transformation ● Existing diesel plants on the Island and impact upon the replacement plan ● Impact on the local economy (activities, potential growth) ● Synergy to existing and planned Mentari programs
5.	**Any other business**	● Fortnightly project meeting to be further scheduled ● Communication to FCDO to further include Alex, Anirban, Udit, and Margaret for all matters. Sharing of large size files and graphics to be advised prior to sending to Anirban. Preference to conduct meetings in Microsoft Teams, otherwise PwC to organise invitations via Google Meet/Cisco Webex. ● Meeting to discuss island selection criteria to be scheduled and relevant report and references from World Bank to be further circulated.	

Introduction Meeting with PLN - Minutes of the Meeting

Meeting	:	Introduction Meeting with PLN			
Date	:	27 January 2022	**Time**	:	13.30
Facilitator	:	PwC	**Location**	:	Google Meet

Participants			
Rizka Sari	FCDO	Julian Smith	PwC
Atika Fanani	FCDO	Kiran Vergis	PwC
Anirban Ganguly	FCDO	Lavalette Erika	PwC
Eman	PLN	Yolanda Mariska	PwC
Faris Hibatulaziz	PLN	Laras Sekartaji	PwC
Hafizh	PLN	Afifah Eleksiani	Inovasi
		Natalia	Inovasi

No	Topic	Content	Action point
1.	**FCDO and Project Introduction**	• FCDO previously engaged in the Mentari program, which is aimed to support the Indonesian government in developing renewable energy • There are several strands in the Mentari program: policy (support Indonesian government in regulatory framework renewable energy), program brokerage (connect renewable program energy in Indonesia with investors), program demonstration (conducted in Sumba), and program networking (working together with universities and other institutions) • As for this Whole Island Transition Roadmap Program, FCDO would like to connect the renewable energy roadmap result in Buton to program brokerage from the Mentari program • This program is also expected to help PLN in the future so FCDO would like to ask PLN for support and work side by side with the team that will come for site visits • FCDO from Mentari program is currently working with JIZ to create the system in East Nusa Tenggara. FCDO plan to bring real potential project in Indonesia small islands to be developed in program brokerage • FCDO as donor ensure that all roadmaps will be in line with PLN and the local government plan • Support expected from PLN in the form of official letter so that PwC can conduct the project/site visit smoothly	• PwC will send a data request to PLN as well as consult and discuss further related to the project (assumptions, etc) • Pak Fariz (PLN) will communicate further with PwC, connect PwC to local PLN representative • Pak Eman (PLN) will update the progress meeting to the Directors

		• As the timeline is expected to be done in mid-2022, the result might be incorporated in RUPTL 2023	

Introduction Meeting with Sulawesi MEMR Agency - Minutes of the Meeting

Meeting	:	Introduction to Southeast Sulawesi MEMR Agency			
Date	:	24 March 2022	**Time**	:	09.00
Facilitator	:	PwC	**Location**	:	Google Meet

Participants			
Southeast Sulawesi MEMR Agency			
Atika Fanani	FCDO	Theodore Solaiman	PwC
Lavalette Erica	PwC	Blenda Wijoyo	PwC
Afifah	Inovasi	Laras Sekartaji	PwC
Natalia S.	Inovasi	Yolanda Mariska	PwC

No	Topic	Content	Action point
1.	**Project Introduction**	• FCDO shared a brief introduction of the FCDO, the Project's background and objective. • PwC shared a brief presentation on the WITR project, with its current progress and data request list as previously shared to MEMR by correspondence. The data is required to further develop the analysis and findings for the project. • SE Sulawesi MEMR Agency welcomed the intent of the project and noted that the requested data for existing electrification rate, existing power plants, and potential of RE sources in Buton Island can be further shared to the project team for reference. • Key information shared by the MEMR Agency is as follows: • The electrification ratio in Buton is currently estimated at 99%. • Electricity is important to support economic growth in Buton, for which the main commodity is asphalt. The planned expansion of the sector will require increased electricity supply. Detailed plan for Buton Island is available in the RUKD 2019-2028 for reference. • Data set as an overview of the existing electrified and non-electrified villages in Buton Island, and the renewable energy potential was shared by the Agency to the project team for reference. It was noted that the current data has not included all	• Data set for the existing electrification coverage in Buton, including the number of electrified and non-electrified villages, existing power plants (as registered by MEMR to date, but not yet overall), as well as the renewable energy potential to be shared to the project team for reference.

No	Topic	Content	Action point
		of the existing power plants in Buton. Data to be further verified with PLN. • Currently there is no demand data at Buton Island level only, it's still combined data for the Province level, Sulawesi Tenggara.	