Business Models

to strengthen the role of **local government**
in implementing the **renewable energy potential**

in INDONESIA

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2021

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Layout and Cover Design
Rajib Khafif Arruzzi, Ilustrasi Freepik

Published by:
Center For Energy Studies, Universitas Gadjah Mada
Sekip Blok K1-A Yogyakarta 55281 Bulaksumur Indonesia
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First Edition Published October 2021

ISBN: 978-623-91932-3-2

FOREWORD

One of Indonesia's challenges as an archipelagic country is equal access to energy for its citizens. The unavailability of energy access has significant impacts on the welfare and productivity of the community in various sectors, ranging from households, transportation, and industry. Today, the supply of electrical energy at the national level is still dominated by fossil fuels that leads to increased carbon emissions and the vulnerability of future energy supply. The Indonesian government has committed to reducing emissions by 29 (or 41% with international cooperation) by 2030 by targeting 23% of renewable energy in the primary energy mix by 2025.

The problem of energy access is not only the responsibility of the Central Government —in this case, the Ministry of Energy and Mineral Resources--- but there is also a role for Local Governments to support the low-carbon energy transition. Energy transition planning can be an opportunity to empower local governments and local communities to participate in sustainable electricity business models. One of the local government supports sustainable energy is regional energy planning as contained in the Regional Energy General Plan (RUED), detailed urban spatial planning (RDTR/ Detailed Spatial Planning), and supports from other institutions in the region.

Local government participation needs to be fully encouraged. Local governments can contribute in various ways, starting from initiating renewable energy utilization programs, investing through regional-owned enterprises, ensuring community support, and other activities. The publication of the book **"Business Models to Strengthen the Role of Local Governments in Utilizing the Potential of Renewable Energy in Indonesia"** is one of the Center for Energy Studies, Gadjah Mada University, to address national problems. It is also to support the Local Government to develop renewable energy potential in the region.

This book provides several business models that can be developed—starting from on-grid, off-grid systems, renewable energy services to virtual power plants, which are potential developments in the future. The discussion also covers technical, economic, legal, and sustainability aspects that need attention. The case studies were conducted in three selected provinces: East Nusa Tenggara, West Nusa Tenggara, and East Kalimantan. Although it has case studies in its discussion, this book does not provide absolute suggestions for business models that can be developed in the three provinces. Furthermore, the proposed business model is not limited to the three selected provinces listed in this book.

Finally, this book still requires criticism, suggestions, and input from various parties for improvement in the future.

Yogyakarta, October 2021

Authors

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Glossarium

No	Names/Abbreviations	Descriptions
1	**APBD**	*Anggaran Pendapatan dan Belanja Daerah* Local government budget: drafted by local governments and adopted by a "perda" following debate and agreement within DPRDs
2	**APBN**	*Anggaran Pendapatan dan Belanja Negara Indonesia* State budget: national budget drafted by central government and, following discussion and negotiation, adopted as law by the DPR
3	**AC**	Alternate Current
4	**DC**	Direct Current
5	**BAPPENAS**	*Badan Perencanaan Pembangunan Nasional*
6	**BaU**	Business as Usual
7	**Energy Mix**	Percentage between total final consumption of renewable energy to total final energy consumption
8	**BIG**	*Badan Informasi Geospasial* / Geospatial Information Agency
9	**Bioenergy**	Biological source of renewable energy
10	**BMKG**	*Badan Meteorologi, Klimatologi, dan Geofisika* / Meteorology Climatology and Geophysics Council
11	**BPPT**	*Badan Pengkajian dan Penerapan Teknologi* / Agency for the Assessment and Application of Technology
12	**BUMD**	*Badan Usaha Milik Daerah* / Region-Owned Enterprises
13	**BUMDes**	*Badan Usaha Milik Desa* / Village-Owned Enterprises
14	**Cofiring**	Combustion of biomass mixed with coal
15	**CPO**	Crude Palm Oil
16	**CSR**	Corporate Social Responsibility
17	**Energy Density**	Value of energy stored in a system per volume
18	**Dirjen EBTKE**	*Direktorat Jenderal Energi Baru Terbarukan Dan Konservasi Energi* / Directorate General of New Renewable Energy and Energy Conservation
19	**DNC**	*Declared Net Capacity*
20	**Green Economy**	A powerful economic growth, but also eco-friendly
21	**Extensive**	Covering or affecting a large area
22	**Embargo**	Import or Export ban
23	**Emission**	Air Pollution Contributor
24	**Green House Effect**	Green house emission
25	**EMS**	*Energy management system*
26	**EPC**	*Engineering Procurement and Construction*
27	**ESDM**	Ministry of Energy and Mineral Resources
28	**ESP**	Energy Service Provider, Energy Service Provider

No	Names/Abbreviations	Descriptions
29	**ET**	Renewable energy
30	**Fluidized bed**	A type of boiler that uses bed material as a heat-conducting medium to stabilize heat in the furnace
31	**Flux**	Physical properties in space
32	**Fluctuation**	(Noun) Not fixed or changing
33	**Transient Disturbance**	Sudden changes due to the opening and closing of the switch
34	**Gasification**	Thermochemical conversion of solid fuel to gas
35	**Generator**	A device that converts mechanical energy into electrical energy
36	**GHI**	Global Horizontal Irradiation
37	**GIS**	Geographic Information System
38	**Hydrology**	The science of water movement
39	**HPSS**	Hydro Power Potential Study
40	**Incentive**	Compensation provided
41	**Instrument**	Tools
42	**Integration**	Blending to become a unified whole
43	**Intermittent**	Alternating working and not working
44	**Inverter**	Converting DC to AC
45	**IPP**	Independent Power Producer
46	**Energy Security**	Availability of uninterrupted energy sources at affordable prices
47	**Conversion**	Change from one system to another
48	**LAPAN**	National Institute of Aeronautics and Space
49	**LCA**	Life Cycle Analysis
50	**Logistics**	Movement of goods/services, energy, or other resources
51	**LOHC**	Liquid organic hydrogen carriers
52	**LSM**	Non-governmental organization
53	**NDC**	Nationally Determined Contribution
54	**O&M**	Operation and maintenance
55	**Off-grid**	Store power in battery or if not on the network
56	**On-grid**	Generates power when utility power grid (PLN) is available
57	**PBB**	United Nations
58	**PDB**	Gross domestic product
59	**Biomass Pelltes**	Biomass has a diameter of 6-10 mm and a length of 10-30 mm
60	**PEMDA**	Local government
61	**PLTA**	Hydroelectric power plant
62	**PLTB**	Wind Power Plant
63	**PLTBm**	Biomass Power Plant
64	**PLTD**	diesel power plant
65	**PLTGU**	Steam Power Plant

No	Names/Abbreviations	Descriptions
66	**PLTGU**	Gas and Steam Power Plant
67	**PLTMh**	Micro Hydro Power Plant
68	**PLTP**	Geothermal Power Plant
69	**PLTS**	Solar Power Plant
70	**PLTSa**	Garbage power plant
71	**PLTU**	Electric steam power plant
72	**POME**	Palm Oil Mill Effect
73	**PLN**	State Electricity Company
74	**PUPR**	Minister For Public Works and Human Settlements
75	**PV**	Photovoltaic, solar panel technology
76	**Ramp-down**	Decrease
77	**Ramp-up**	Enhancement
78	**Electrification Ratio**	Comparison of the number of households that have electricity to the total number of households
79	**RDTR**	Detailed Spatial Plan
80	**Reservoir**	Source place, storage place
81	**Rotor**	Rotating mechanical device
82	**RPJPN**	National Long-Term Development Plan
83	**RUED**	Regional Energy General Plan
84	**RUED-P**	Provincial General Energy Plan
85	**RUKD**	Regional Electricity General Plan
86	**RUPTL**	Electricity Supply Business Plan
87	**single-off taker**	Single Buyer
88	**Smelter**	Mining processing facilities
89	**Solar charge controller**	Electronic equipment used to regulate direct current, which is charged to the battery and taken from the battery to the load
90	**Supply-demand**	Offers
91	**Sustainable**	Continuity
92	***Talis***	Electric Tube
93	**Tax holiday**	Exemption of tax payments within a certain period
94	**Topography**	Earth's surface shape
95	**Torrefaction**	Thermochemical process for more effective use of biomass to produce solid fuel
96	**Transformer**	An electrical device that can be used to transfer power from one circuit to another
97	**Energy Transition**	Remodeling the procurement of fossil energy to renewable energy
98	**Turbine**	A rotating machine that takes energy
99	**UMKM**	Micro Small and Medium Enterprises
100	**UNFCCC**	United Nations Framework Convention on Climate Change Conference
101	**VPP**	Virtual Power Plant

No	Names/Abbreviations	Descriptions
102	**VRES**	Variable renewable energy sources

1. INTRODUCTION

1.1. Issues on Energy Access in Indonesia

Energy access -- in this context is limited to electrical energy -- should not be limited to electrification ratio, but also reliable and affordable energy sources. Energy access has become a severe factor in household welfare and productivity. Although energy is necessary, several regions in Indonesia face difficulties due to limited access to energy. In rural areas, limited infrastructure and high investment costs for sustainable energy are more complex. As a result, energy access issues are frequently resolved through the provision of temporary solutions, one of which is the use of diesel power plants (PLTD). Due to the use of PLTD, remote or rural areas become reliant on fossil fuels.

1.2. Renewable Energy Issues on the Primary Energy Mix

At the national level, the energy provision is still dominated by fossil fuel-generated electricity. The domination of fossil fuels has caused an increase in emission and vulnerability of future energy provision. The Government of Indonesia has pledged to reduce the emission by 29-41% in 2030 by targeting the shift into 23% of renewable energy in its energy mix by 2025. The Ministry of Energy and Mineral Resource (MEMR) released the plan to convert 13 GW of fossil fuel power plants into renewable energy to achieve the target. The conversion plan consists of 1.7 GW diesel-fired power plants (PLTD), 5.6 GW steam-fired power plants (PLTU), and 5.9 GW combined cycle power plants (PLTGU) spread throughout Indonesia [1].

1.3. Sustainability from the Perspective of the Community and Local Government

Energy issues should not be confined to the purview of state governments; instead, subnational governments must be empowered and involved in the low carbon energy transition. MEMR's conversion plan may present an opportunity to engage subnational governments and local communities in a more sustainable electricity business model. Sub-national governments can assist in promoting sustainable energy by participating in regional energy planning (RUED, Rencana Umum Energi Daerah), detailed urban spatial planning (RDTR, Rencana Detail Tata Ruang), and collaborating with regional institutions.

1.4. Regional Energy Security

The national electrification ratio reached 98.93% in 2020, but there is a significant disparity between energy access in Indonesia's western and eastern parts. The electrification ratio in Maluku, Papua and Nusa Tenggara is still less than 80% [2]. In addition to the problem of energy access, the sustainability of energy sources is also an issue that should be considered. Dependence on fossil fuel power plants has an impact on energy security risks. In Indonesia, large-scale power generation relies on coal which is mainly supplied from the island of Borneo. Meanwhile, in small islands, the supply of diesel fuel for PLTD is often problematic in terms of availability/logistics. For this reason, the use of renewable energy based on local potential is a promising solution, especially for people in the regions.

1.5. Sustainable Business Model for Renewable Development

New and renewable energy (NRE) development will be more appealing if it is economically viable. As a result, a sustainable business model is required that benefits all relevant stakeholders. Different business practices are necessary, which necessitate the involvement of private investors and other stakeholders. As a result, any renewable energy development initiative requires the collaboration of the federal government, local governments, private investors, and local communities.

1.6. The Importance of the Local Government Roles

Local government participation needs to be fully encouraged. The previous survey by PSE UGM showed that the involvement of various stakeholders was a significant factor in the operation of sustainable power plants [3]. Local governments can ensure that local communities and companies accept and support the construction of renewable energy power plants. Local governments can take part in the following activities:

- Initiation of RE utilization projects,
- Investment through regional-owned enterprises (BUMDs)
- Rally support from local communities
- Provision of O&M support from local communities
- Provision of regional-level incentives and investment facilities
- Collaboration with the Ministry of Finance in accessing national-level government incentives.

2. ENERGY DEMAND

2.1. Energy Demand

The need for electrical energy in Indonesia is increasing every year in various consumer sectors. Peak electrical load increases with an average increase of 5.81% every year [2] [4]. Table 2- 1 shows an increase in electricity consumption which has continued to rise since 2011 with an average of 5.7% per year [2][4]. Based on these data, it is predicted that Indonesia's electricity demand will grow at a 6.42% annual rate over the next ten years, assuming a 6.3% increase in economic growth. Electricity consumption is increasing in almost every sector, but particularly in the residential sector. It demonstrates that electrical energy's role in people's lives is becoming increasingly important.

Table 2- 1 Consumers Electricity Consumption in Indonesia (TWh) [2], [4]

Consumer Sectors	2011	2012	2013	2014	2015	2016	2017	2018	2019
Household	64.581	71.554	76.579	83.402	87.972	92.886	93.837	97.143	102.917
Industry	54.232	59.635	63.774	65.295	63.533	67.586	71.716	76.345	77.142
Commercial	27.718	30.084	32.886	35.507	36.108	38.963	40.873	43.244	46.118
Social	3.959	4.405	4.793	5.400	5.889	6.573	7.046	7.726	8.483
Government	2.750	3.018	3.220	3.440	3.669	3.969	4.083	4.363	4.720
Public	3.049	3.123	3.233	3.375	3.429	3.478	3.512	3.612	3.678
Total	156.288	171.819	184.484	196.419	200.600	213.455	221.066	232.433	243.058
Growth (%)		9,94%	7,37%	6,47%	2,13%	6,41%	3,57%	5,14%	4,57%

Electricity demand can be met by ensuring sufficient generating capacity throughout Indonesia to supply all consumer sectors. The supply of NRE power plants is also increasing in tandem with Indonesia's increased generating capacity. This growth is a contribution in reducing greenhouse gas (GHG) emissions in line with Presidential Regulation of the Republic of Indonesia Number 61 of 2011 concerning the National Action Plan for Reducing Greenhouse Gas Emissions and Law Number 16 of 2016 concerning the Paris Agreement, concerning the Commitment of the Government of the Republic of Indonesia to reduce greenhouse gas emissions by 29% by 2030 [5] [6].

2.2. Energy Transition

Indonesia's commitment to reduce greenhouse gas emissions caused by climate change is embodied in its energy transition plan. This effort is also a manifestation of the international commitments contained in the Nationally Determined Contribution (NDC) [7] in response to the 21st United Nations Framework Convention on Climate Change Conference (UNFCCC) in 2015. On the agenda, Indonesia stated that this would reduce greenhouse gas emissions by 29% under the Business as Usual (BaU) scenario in 2030 and 41% with international assistance. This commitment is strengthened through Law Number 16 of 2016 concerning the Ratification of the Paris Agreement on the United Nations Framework Convention on Climate Change [6].

In supporting this commitment, Indonesia has set a target of NRE in the national energy mix, at least 23% in 2025 and 31% in 2050. One of the challenges faced in developing renewable energy in Indonesia is the price of renewable energy, which is less competitive than fossil fuels. Other challenges faced related to the low utilization and development of renewable energy power plants include [8]:

a) No implementation of price policy,
b) Unclear subsidies on the buyer side,
c) Regulations that have not been able to attract investment,
d) No incentive for RE power plant,
e) Lack of availability in financing instruments following the investment needs,
f) Complicated and long permission process, and
g) Land and spatial problems.

The Ministry of Energy and Mineral Resources through the Directorate General of New, Renewable Energy and Energy Conservation (Dirjen EBTKE) also seeks to implement renewable energy development programs, some of which are as follows [1]: (1) Creation of new markets for RE; (2) Development of PLTS and PLTB on a large scale to attract investors as well as develop local industries; (3) Synergy of NRE development with the development of economic clusters, such as Special Economic Zones, Industrial Estates, and Featured Tourist Areas; and (4) Low-cost financing facilities for renewable energy investments

Based on [2], [9], 56% of Indonesia's electricity production is supplied by PLTU, followed by PLTGU at around 15% and PLTA at 8%. Recently, PLN also has approximately 5,200 PLTD in 2,130 locations. In November 2020, PLN launched a program called “225 MW Conversion in 200 EBT-based locations”. The program is divided into three conversion stages. In the first stage, the capacity of PLTD, which ET plants will replace, is 0.225 GW spread over 200 locations. In stages two and three, the PLTD capacity will be reduced to 0.5 GW and 1.3 GW.

As previously stated, the electrification rate varies considerably throughout Indonesia. This report will analyze samples from three locations: West Nusa Tenggara (NTB), East Nusa Tenggara (NTT), and East Kalimantan. According to data [3], NTT, NTB, and East Kalimantan have electrification rates of 59.09%, 99.70%, and 99%, respectively [10].

PLN tries to increase the electrification ratio in NTT, NTB, and eastern Indonesia by using electric tubes (*talis*). *Talis* works like a battery. *Talis* has various capacities, ranging from 300 Wh, 500 Wh, and 1,000 Wh, and is expected to be used for 3, 4, and 8 nights, respectively. This estimate assumes that the three lamps are five watts each and operate approximately eight hours per day.

Due to the presence of *Talis*, the development of RE potential in the area is expected to accelerate. *Talis* operations require a filling station that can be developed in accordance with the available energy resources in the surrounding area, such as hydropower, biomass energy, or solar energy. PLN intends to collaborate with the Talis municipality and local businesses to construct an electric charging station.

Local energy sources can be optimally utilized to meet the needs of nearby communities. The government's role can be sought to ensure that the portion is not excessive. It must be considered during the process to empower the community. Don't let the application of renewable energy technology be environmentally sustainable, for example, but not sustainable for its broad benefits. It is necessary to foster local participation by utilizing local resources, integrating them into national development, and ensuring that "self-development" is as efficient as possible. If citizens require electricity, they are also encouraged to contribute more.

The community must be involved from the beginning. Community involvement in the development of NRE potential needs to be supported by the local government. The local government can also play a role in increasing the capacity and ability of the community to manage NRE. It is crucial to conduct a feasibility study before starting any work involving social and economic aspects. A creative and productive plan is needed to involve the community. The market needs also need to be mapped to determine, among other things, the supply chain of the technology to be developed based on local potential. The involvement of the local community is crucial even for managing the NRE business in the region, for example, for business marketing bookkeeping management needs.

It is essential to consider the local access. There are at least two regional/local businesses that need to be considered, (1) Cooperatives and (2) Village Owned Enterprises (BUMDes). The explanation of this regional business is shown in Table 2- 2.

Table 2- 2 Potential Regional or Local Business To Be Considered

Cooperatives	Village-owned Enterprises
Business entities	One of the components in the village that can do business and have a business license can be used as a subsidy for electricity costs in the region
Do not have the technical capacity for NRE, limited experience and knowledge in business sustainability, market access.	

To achieve sustainable management of NRE technology in the regions, various stakeholders need to coordinate intensively from the planning stage. Community assistance needs to be done, among others, by understanding NRE to create a sense of ownership and maintain the technology that will be implemented. The identification of business models, small, medium, and large enterprises, and market access also needs to be considered in implementing NRE in the regions.

3. TECHNICAL ANALYSIS

3.1. Renewable Energy Potential

Potential mapping is the first step before making plans for the development of NRE technology in the regions. The renewable energy mapping is the initial stage to construct a RE power plant plan [11]. Therefore, the UGM Center for Energy Studies has mapped renewable energy sources using the GIS (Geographic Information System) method with ArcGIS 10.1 software. This GIS method can map areas that have the potential for development (1) solar power plant with GHI (Global Horizontal Irradiation) maps, (2) wind power plant with WV (Wind Velocity) maps, and (3) hydropower plant with hydro potential calculations, topographic analysis, and water discharge, (4) geothermal power plant by identifying its potential locations and (5) biomass power plant based on research on biomass sources that has been carried out by the Ministry of Energy and Mineral Resources [12]

3.1.1. Renewable Energy Potential in Indonesia

3.1.1.1. Solar Energy

Figure 3- 1 shows Indonesia's Global Horizontal Irradiation Map with a value range of less than 3.6 kWh/m2 and more than 6 kWh/m^2. Each point per area is digitized to extract its potential magnitude. The value of 4.5 kWh/m2 per day is used as the threshold value to determine the location of potential solar energy that can be utilized as a solar power plant for every province in Indonesia. The extraction result of the potential solar energy location is shown in Figure 3- 2.

Papua province is the largest province of solar energy potential with 14,815.10 MW, followed by Central Kalimantan province of 11,684.74 MW. It is caused by the flat topography area exposed by the solar energy is greater than other provinces. Meanwhile, the total solar energy potential in Indonesia is 122,426.73 MW or 122.43 GW.

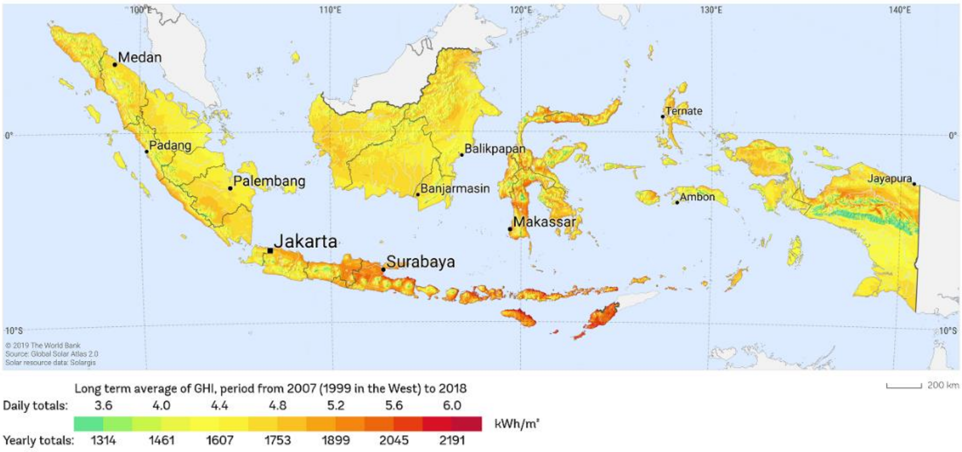


Figure 3- 1 Global Horizontal Irradiation Map of Indonesia (Source: World Bank Atlas, 2019)

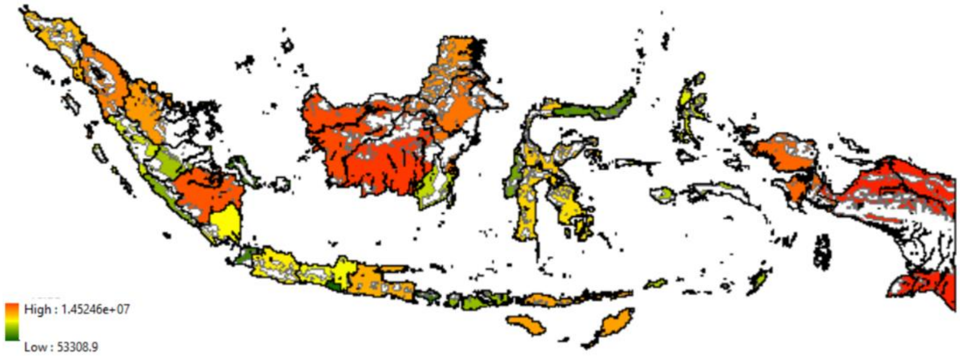


Figure 3- 2 Solar Power Map in Indonesia (MW)

3.1.1.2. <u>Wind Energy</u>

Figure 3- 3 shows the wind energy potential map for every province of Indonesia. Generally, the map showed the average annual wind velocity at an altitude of 75 m with a resolution of 5 km. In this study, each point per area is digitized to extract its potential magnitude. The value of 5 m/s per day is used as the threshold value to determine the location of potential wind energy that can be utilized as a wind power plant for every province in Indonesia. The extraction result of the potential solar energy location can be seen in Figure 3- 4.

Papua province is the largest province of wind energy potential with 46,371.84 MW, followed by Maluku province of 37,749.43 MW. This is because the flat topography area exposed to wind energy is more significant in this province than others. Meanwhile, Indonesia's total wind energy potential is 3,850,791.00 MW or 3,850.79 GW, for detail can be seen in Figure 3- 2 .

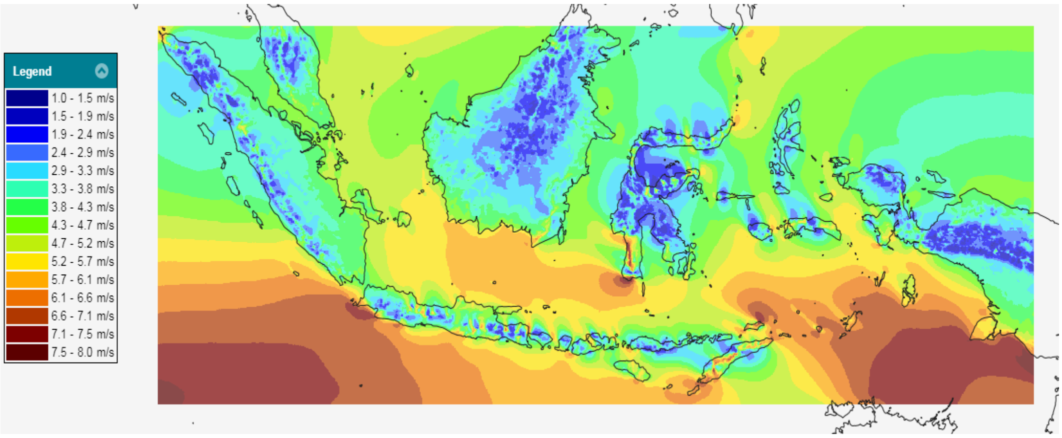


Figure 3- 3 The Wind Velocity Map of Indonesia (Source: World Bank Indonesia, 2019)

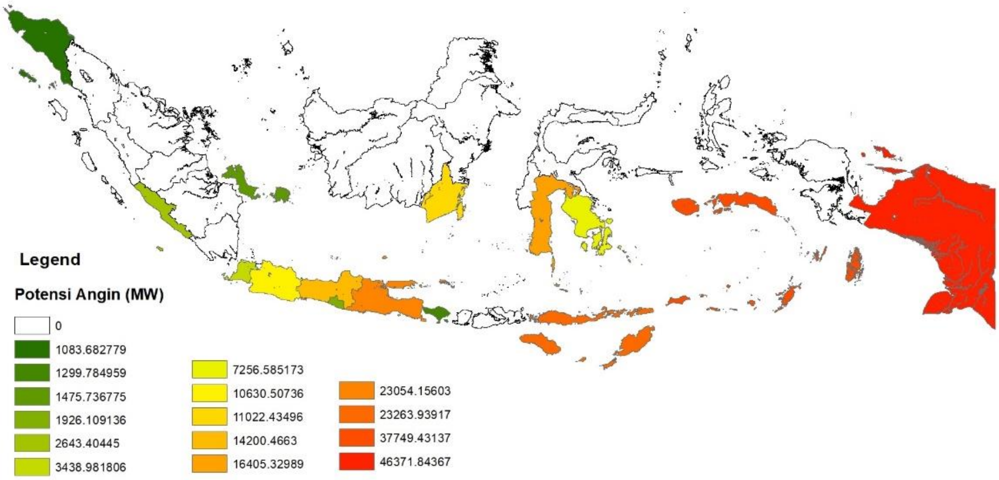


Figure 3- 4 Wind Power Map (MW) in Indonesia

3.1.1.3. Geothermal Energy

Several geothermal data from the Ministry of Energy and Mineral Resources of Indonesia (MEMR of Indonesia) was used to calculate geothermal energy potential, as shown in Figure 3- 5 . According to resources data, West Java province has the biggest potential of 1,859 Mwe that consists of a speculative potential of 1,125 Mwe and a hypothetic potential of 734 Mwe.

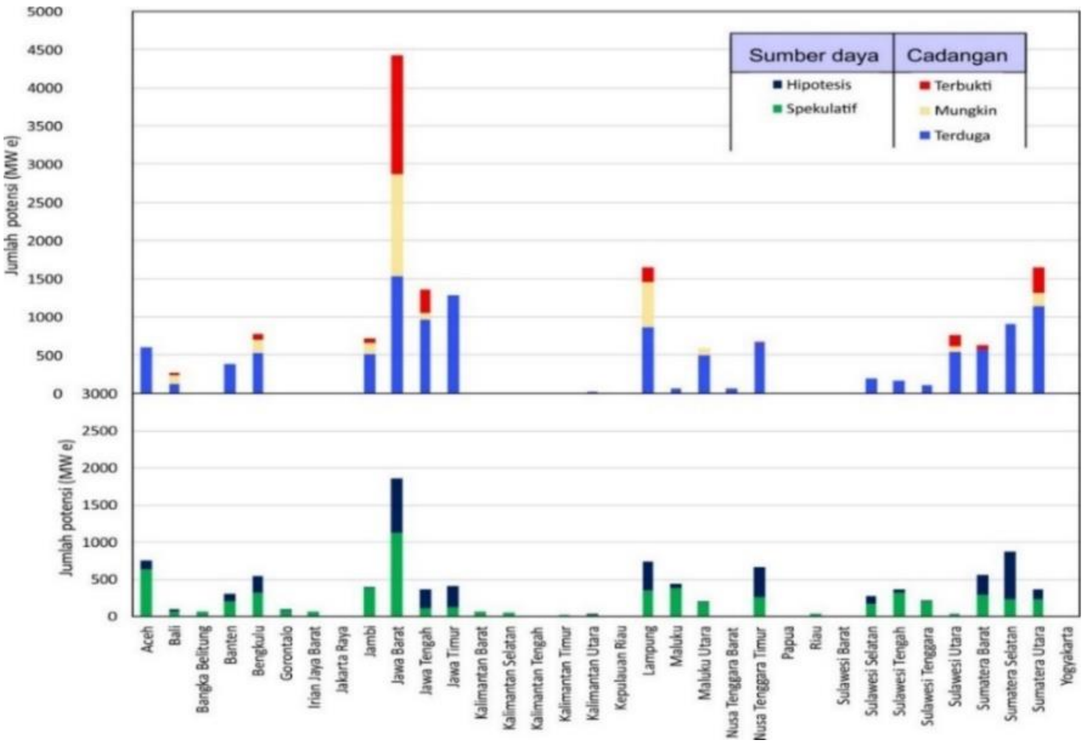


Figure 3- 5 Geothermal Energy Resources (Potential and Reserves) of Indonesia's Provinces (Direktorat Panas Bumi Ditjen EBTKE, 2017)

3.1.1.4. Hydro Energy

According to the Hydro Power Potential Study (HPPS) report in 1983, the potential for hydropower in Indonesia was 75,000 MW, and this data was repeated in the Hydropower inventory study in 1993. However, in the report of the Master Plan Study for Hydro Power Development in Indonesia by Nippon Koei in 2011, the potential for hydropower after further screening is 26,321 MW. Directorate General of New Renewable Energy and Energy Conservation (Ditjen EBTKE ESDM) also conducted a study in which they mapped the hydropower potential using the Geospatial Information Agency (BIG) data. This agency used river flow areas and elevation data from the Ministry of Public Works and Human Settlements (Kementerian PUPR) to calculate hydro energy in Indonesia.

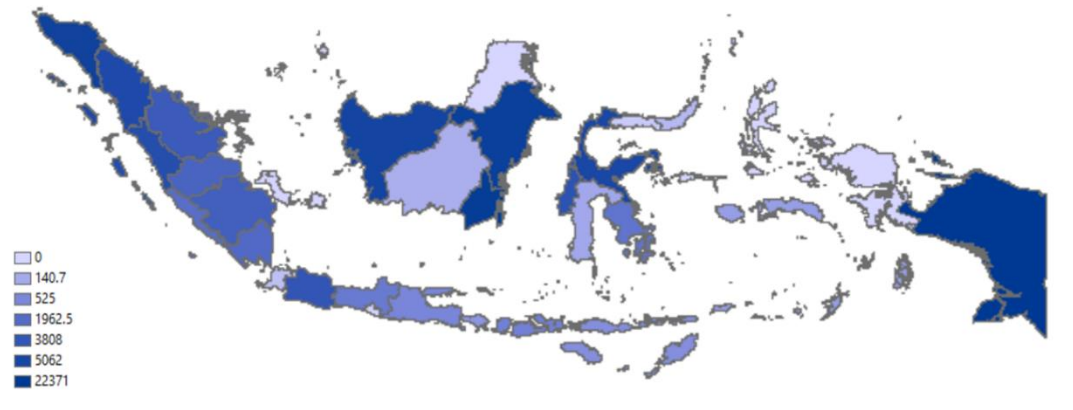


Figure 3- 6 Hydro Power Map (MW) in Indonesia

3.1.1.5. <u>Biomass Energy</u>

The mapping of biomass potential has been calculated using data from various biomasses found in 34 provinces of Indonesia. Figure 3- 7 shows that Riau province has the largest biomass energy potential of 3,500 MW, followed by East Java Province of 3,300 MW.

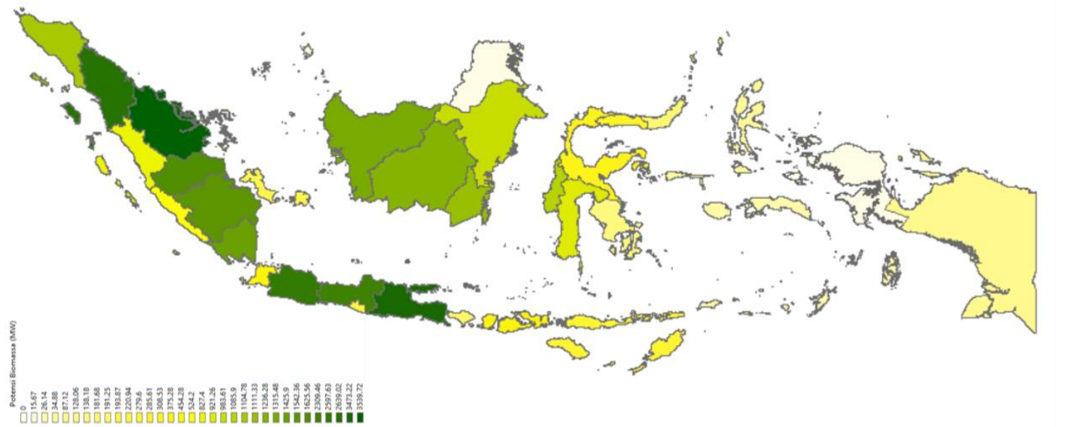


Figure 3- 7 Biomass Power Map (MW) in Indonesia

3.2. Supply Chain

3.2.1. NRE Power Plant Development

Based on Center for Energy Studies, National companies have sufficient capabilities in manufacturing technology for solar power plants components. Some components must be imported due to the unavailability of the primary material in the form of solar panels.

As illustrated in Figure 38, companies in western Indonesia dominate the distribution of suppliers of photovoltaic system components in Indonesia. Most PV system components suppliers are located in Jakarta and West Java, such as Banten, Bekasi, Bogor, Bandung, and Depok.

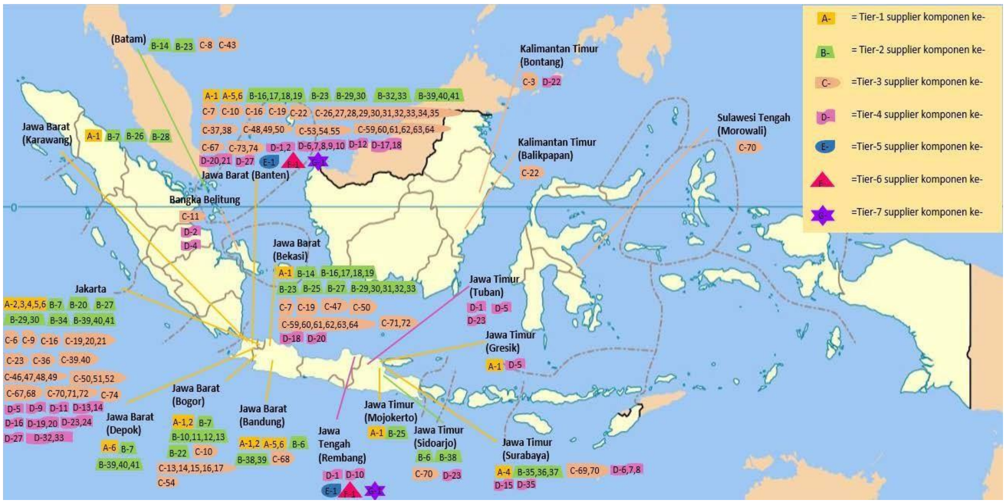


Figure 3- 8 The Readiness of the Electrical Component National Industry to Support Solar PV - PLTS (CES UGM, 2020)

3.2.2. Selection of Renewable Energy Generating Component Supplier

The process by which buyers identify, evaluate, and contract with suppliers is called supplier selection. When it comes to supplier selection, numerous criteria must typically be considered [13]. There are multiple decision-making tools available to assist in selecting suppliers, including Multi-criteria Decision Making (MCDM), Data Envelopment Analysis (DEA), Analytical Network Process (ANP), Analytic Hierarchical Process (AHP), and Technique for Others Reference by Similarity to Ideal Solution (TOR) (TOPSIS). It may require a different approach in certain circumstances. The selection is contingent upon the criteria and method desired. Several of the techniques are unique. The VIKOR set, which combines a two-tuple linguistic representation and a soft set, performs better than other methods in cases where information is incomplete. Sort II using AHP (Analytic Hierarchy Process) will perform better in ambiguous situations than other fuzzy methods [14]. AHP and ANP (Analytic Network Process) are more commonly used since they take a mathematical approach.

3.2.3. Analysis of National Readiness in the Production of NRE Power Plant Components

The government provides flexibility in NRE development by providing fiscal incentives, such as tax holidays and exemption from import duties for strategic SOEs and domestic industries developing RE power plants. However, this policy has not been able to spur an increase in ET's electricity capacity is necessary to assess the extent to which components manufactured by the domestic manufacturing industry are required. This analysis is critical for enhancing the technological capabilities of indigenous industries and developing appropriate policy formulations for stakeholders.

Table 3- 1 describes the fabrication conditions of each energy generated at the RE power plant.

Table 3- 1 Energy Classification Based on the Current Conditions (CES UGM, 2020)

Technology	Component Status
Wind	The component majority are imported
Solar	The component majority are imported
Biomass	Domestic production, except for turbines and generators
Geothermal	Domestic production, except for turbines and generators
Hydro	Domestic production, except for turbines and generators
Microhydro	Domestic production
Sea wave	Development stage and pilot project, there is no commercial stage in Indonesia
Battery	At this time, the construction phase of the battery factory is still hampered since currently lithium batteries are still imported from abroad.

Domestic component utilization, beginning with raw materials and technology, must be continuously improved to ensure energy independence. Several components are currently manufactured domestically, for example, in biomass, geothermal, hydro, and micro hydropower plants. The power plant industries must enhance their technical capabilities to independently calculate and design power plants to ensure the system's sustainability.

3.3. Selection Parameters and Considerations of Renewable Energy Technology

3.3.1. Hydropower Plant

A hydropower plant is quite similar to a coal power plant in which a power source is used to move a turbine that generates electricity. However, unlike a coal power plant that utilizes the energy contained in superheated steam, a hydropower plant utilizes the energy potential of the water within a dam. Based on the amount of capacity, hydropower plants usually be classified as follows [15]:

- Micro-hydro: less than 100 kW
- Mini-hydro: 100-500 kW
- Small hydro: 500 kW – 10 MW
- Large hydro: above 10 MW

The crucial factors that have to be considered in terms of designing a hydroelectric power plant are as follows:

1. Topographical Aspect
Dealing with the estimation of the topographical data within the area of a hydropower facility

2. Hydrological Aspect
Maintaining Water Debit to estimate the electricity generation

3. Civil aspect
Including the infrastructure design, such as the construction of the dam, hydraulic consideration of the structure, and designing the access support

4. Electromechanical aspect
Consisting of turbines, an electrical generator, and a control system

5. Economical Aspect
Economically evaluating the hydropower plants to estimate the feasibility of the proposed hydropower technology

3.3.2. Solar Photovoltaic

In both solar PV systems, the equipment usually consists of the vital part as follows [16]:

1. Solar Panel
This device is used to convert solar radiation into DC current. The current generated is proportional to the intensity. A higher number of cells or the panel size is required for a low solar irradiation area.

2. A Solar Charge Controller System
The output voltage from the solar panel needs to be adjusted before entering the battery. This device is used to control the voltage generated.

3. Battery
To prevent intermittency from the light intensity, electrical energy is stored inside the battery before it is utilized.

4. Power Inverter
The device will convert output current from the battery (DC) into AC for many purposes.

In principle, solar PV can consist of several important components, as presented in Table 3- 9 .

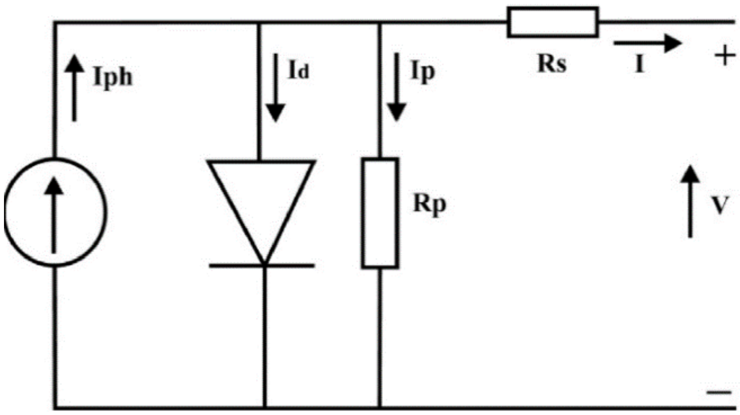


Figure 3- 9 Simplified Schematic of Solar PV Circuit

Several things must be considered to optimize the power generated by the solar PV, including:

1. Solar Irradiation Aspect
Electricity generated from the solar panel is directly proportional to the solar irradiation received. The ideal flux for solar PV is estimated to be around 5-6 $kWh/m^2/day$ [16].

2. Battery Aspect
Solar PVV can be implemented with or without battery storage. Battery storage provides the user with insufficient solar PV production, thereby increasing the system's reliability. However, adding energy storage will increase the cost of energy generation.

3. Economic Aspect

As the solar PV in this study will be focused on rural/remote areas, it is necessary to make sure that the facility is economically viable. The electricity generation using solar PV can be in the range of 0.06 to 0.22 US$ /kWh [17]. The cost of electricity generation can increase due to several factors, including power storage and tracing device addition. Table 3- 2 shows the component's cost for solar PV.

Table 3- 2 Cost Components Example of Solar PV

Parameters	Values
PV panel type	Polycrystals
Power capacity	30 kW
Cost of capital	US$ 50,000
Cost of replacement	US$ 50,000
Cost for operational and maintenance	US$ 0
Efficiency	17%
Derating factor	80%
Slope	7.12 deg
Azimuth	180 deg
Ground reflectance	20%
Lifetime	25 years

3.3.3. Wind Energy

Wind turbines harness wind energy by capturing and converting wind velocity into rotational energy via their blades. Wind turbines' sizes continue to grow to achieve greater generation capacity. Figure 3-10 summarizes how the wind turbine's size has increased over the course of the year:

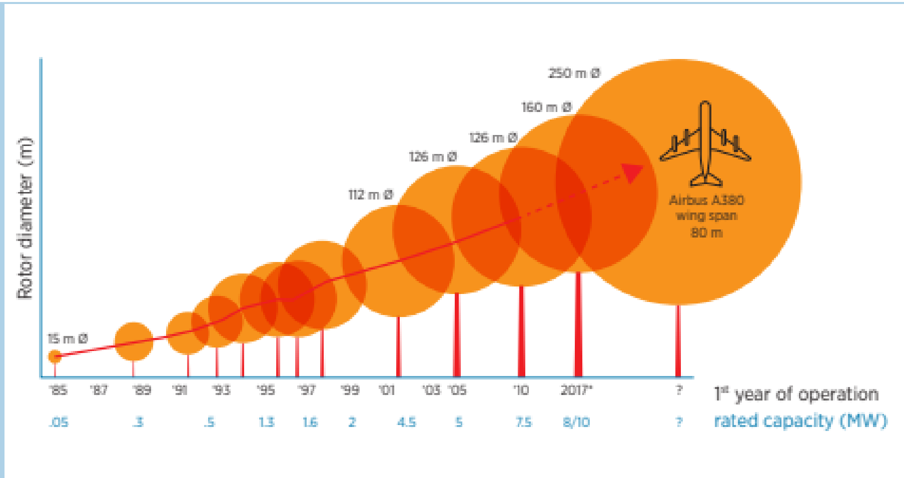


Figure 3- 10 Wind Turbine Development

Numerous factors should be considered in utilizing wind energy, including:

1. Wind potential aspect

Moreover, the wind potential has been considered, as well as the location and season. The win condition has a significant effect on the amount of electricity generated by the same turbine type. Selecting a site with a high wind density is critical for achieving efficient wind energy utilization.

2. Rotor diameter aspect

Increasing power generation also depends on the size of the rotor's diameter. The correlation between rotor size and power is shown in Table 3- 3 . The table shows that the larger the rotor, the higher the capacity generation.

Table 3- 3 Correlation Between Rotor Diameter and Power

Klasifikasi Ukuran	Radius Rotor	Daya yang Dihasilkan
Kecil	< 12 m	< 40 kW
Sedang	12- 45 m	40 kW - 1,0 MW
Besar	> 46 m	> 1.0 MW

3. Economical Aspect

The economic feasibility of a wind turbine should also be evaluated to provide a comprehensive assessment.

3.3.4. Biomass Energy

Several aspects should be considered to implement a biomass power plant, including:

1. Composition Aspect

A high-quality biomass feedstock contains little oxygen and ash. It can reduce the calorific value of the boiler and leave residue in the (unburnt ash) of each boiler. Along with the elemental composition, it is critical to determine the biomass's moisture content. Additionally, high moisture content can increase operating costs associated with drying, energy consumption, and transportation. Examples of moisture content for some biomasses are shown in Table 3- 4 .

Table 3- 4 Moisture Content of Several Biomass Resource

Biomass	Moisture Content
Corn stalks	40 – 60%
Wheat	8 – 20%
Rice straw	50 – 80%
Rice husk	7 – 10%
Cattle manure	88%
Tree bark	30 – 60%
Sawdust	25 – 55%
Food waste	70%
RDF pellets	25 – 35%
Water hyacinth	95,3%

2. Energy Density Aspect

One of the challenges that are often faced upon using biomass is the low energy density of the biomass. Low energy density will increase operating costs due to its high proportion of handling and transportation costs. Those drawbacks can be minimized by using the pellet-shaped biomass and torrefaction process. Pellets allow biomass to be transported more compactly. This method can be further improved through torrefaction, in which biomass is heated around 200^{O}C.

3. Combustion Aspect

Direct combustion of biomass for the power plant is still commonly used as co-firing with coal. Based on utility experience, the ratio of biomass and coal will also affect the process and equipment design. For instance, 5-8% biomass is allowable for a mixing process before pulverized, 25 – 50% biomass will need a fluidized bed system, and more than 50% is more suitable to use specific boiler design.

4. Economic Aspect

Biomass-based energy is somewhat unique in comparison to other renewable energy sources. This is because biomass must be handled or prepared before it can be used. It is likely to affect the overall cost of biomass energy generation.

3.3.5. Geothermal Energy

Several main components are always presenting geothermal power plants, including:

1. Production Well

The production well is located upstream of the geothermal power plant, which produces geothermal brine with a temperature of more than 240°C. The geothermal reservoir can be liquid, vapor-dominated, or hot water.

2. Steam and Electricity Generation Unit

For the most feasible process, several configurations of steam generation units and turbines can be chosen, such as single flash, double flash, binary system, etc., to produce superheated steam that later generates electricity.

3. Brine Cooling Unit

Superheated steam will condense after performing work in the turbine. Since the phase changing process occur at a relatively constant temperature, the condensate still has a high temperature. The hot condensate needs to be cooled using a heat exchanger/cooling tower before being re-injected.

Meanwhile, several aspects need to be considered in geothermal energy:

1. Complexity Aspect

The construction of a geothermal power plant requires upstream and downstream process design. This technology is very different from the aforementioned renewable energy resources that are relatively simpler and even possible to be deployed in a small-scale portable unit.

2. Environmental and Regulation Aspects

Given that it will also encompass upstream activities, it is understandable that those activities adhere to regulations. Typically, the regulation will be closely related to environmental considerations such as environmental impact assessment and site selection.

3. Enthalpy Aspect

The "energy content" of the geothermal reservoir is commonly represented based on the enthalpy value of the geothermal fluid. This estimated enthalpy is essential information as it will define the technology selection and operating condition.

4. Economic Aspect

Besides the technological aspect, it is also necessary to consider its economic value. Based on previous studies, it is estimated that generating cost of geothermal energy is around US$ 0.04-0.14/kWh. The cost breakdown is further examined in Table 3-5.

Table 3- 5 Cost Breakdown of Geothermal Power Plant

Parameters	Value (%)
Power plant	42
Production well	15
Steam field development	14
Contingency	9
Infrastructure	7
Exploration well	4
Injection well	4
Management and Supervision	3
Test well	1
Owner's cost	1

3.4. Technical Challenges of Renewable Power Generation

3.4.1. Limitations of VRES Integration

The current electricity system characteristics and sizes vary due to several factors, such as population growth, population density, and geographical factors [18]. Various system size differences become a challenge in system planning, both generation and transmission planning. This is related to the selection of candidate generators, transmission voltage levels, and possible interconnection systems. Therefore, it can be proposed to classify the system into several categories in planning the power system.

Table 3- 6 Electricity Systems Classifications [17]

System Classifications	Expansion Methods	System Sizes	Integration Systems
Large	GEP Grid	> 10 MW	Transmission System
Medium	Microgrid (interconnected-to-grid / isolated)	2-10 MW	Distribution System
Small	Microgrid (isolated)	< 2 MW	Isolated – Stand-alone

The classification of the electric power system size, as shown in Table 3-6, enables the size of the generator that can be integrated into the system to be determined. This generator's size is classified in several ways. The size of the generating unit is classified according to technical and design criteria to comply with network and connection regulations. For instance, based on the data in Table 3-6, a transmission system will integrate an electrical system with a capacity greater than 10 MW. The transmission system has classified the size of the connected generating unit, which refers to the grid-code document, such as the Jawa-Bali grid-code or the Sumatra grid-code. According to the Jawa-Bali grid-code, the classification of generating units is defined as small (<50 MW), medium (50 MW - <200 MW), and large (> = 200 MW) [19]. Meanwhile in Sumatera Grid-code, the classification of small units is generators <30 MW, medium (30-100 MW) and large generators (> = 100MW) [20]. In general, the classification of generator size with the level of system integration can be seen in Table 3- 7.

Table 3- 7 Generator Size Classification

System Classifications	Integrations	Sizes
Large	Transmission System	Large: ≥ 100 MW
		Medium: 30 MW - < 100 MW
		Small: < 30 MW
Medium	Distribution System	0.1 MW - <10 MW [18]
Small	Isolated – Stand-alone	<2.5 MW [18]

The electrical power system can be classified on a scale using the classifications in Table 3-6 and Table 3-7. This system scale can be considered the factors affecting the expansion method and its integration into the power system. System integration can occur at the transmission, distribution, or isolated level and the generator level. The existence of a classification that takes technical aspects and system design into account is another factor that contributes to the restriction of a generator's entry into the electrical system. The following will explain how the power plant integration limitation, particularly for renewable energy generation, is determined:

Transmission System

Renewable energy power plant integration has some challenges due to its characteristics, especially for intermittent or variable renewable energy sources (VRES). The impact of VRE in the system behavior also differs from a conventional power plant, especially for the power quality, response to a load change, and during network disturbances [21]. According to the system's flexibility to respond to a load change, the system must balance supply and demand. So, the system will have an uninterruptible supply. The operational range of power dispatch limits the integration of VRES [22]. The VRE integration needs some technical analysis, feasible studies of VRE maximum penetration and capability of the network, and the supporting technologies for maintaining the power system's reliability, sustainability, and quality. The power system utilities must provide some technical criteria for integrating VRE in their system, such as voltage regulation and reactive power capability, low and high voltage ride through, effective inertial response, control of power ramp rates and/or curtailing of power output, and frequency control [21].

Some characteristics of VRES power plants, such as wind and solar PV, are shown in Table 3- 8. Integrating VRES needs to consider many things. It must be viewed as the different characteristics of each type of VRES. Wind power is still a rotating machine, so it has very little inertia. In contrast, solar energy is only based on electronic power devices, so it does not have inertia. The wind power plant typically has a capacity factor of 20% until 50%, while solar PV has a capacity factor of 10% until 25%.

Table 3- 8 The Differences Between Wind and Solar Energy

Characteristics	Wind	Solar
Variability of power plant	Often random on sub-seasonal timescales, local conditions may yield a pattern.	Planetary motion (days, seasons) with statistical overlay (clouds, fog, snow, etc.).
Uncertainty when aggregated	The shape and timing of generation are unknown.	The unknown scaling factor of a known shape.
Ramping characteristic	Depends on resource; typically, few extreme events.	Frequent, largely deterministic and repetitive, and steep.
Scale	Community-scale and above.	Household and above.
Technology	Non-synchronous and mechanical.	Non-synchronous and electronic.
Capacity Factor	20% to 50% typically.	10% to 25% typically.

After recognizing the characteristics of each type of VRES, it is necessary to consider the grid's readiness to integrate VRES. The grid must meet specific requirements to integrate VRES. The first is static voltage control, which ensures that voltage regulation is maintained [8]. This is accomplished through dc-ac inverter control in solar photovoltaic systems, whereas in wind power plants, it is accomplished through built-in control for wind turbine types 3 and 4. Additionally, a capacitor bank or reactor can be added. When dynamic voltage regulation is required, FACTS devices such as the SVC and STATCOM can be used.

For supporting inertia response, synthetic inertia control in the inverter in solar PV can be achieved while the wind power plant is inherent in wind turbine Type 1 and Type 2. Other types of wind turbines, types 3 and 4, can be achieved by additional control in the inverter. For supporting frequency response, the dc-ac inverter control in solar PV can provide governor or AGC-like functions, while in the wind power plant, all turbines equipped with some form of pitch regulation can be supplied. It is necessary to estimate solar and wind energy to anticipate the intermittency of VRES based on regional conditions and parameters that affect their output energy. Therefore, the grid operators can schedule other conventional generators to follow the pattern of the VRES generator. It is also necessary to provide better monitoring systems like a wide-area monitoring system with PMU.

VRES can be integrated into a transmission network, a distribution network, or a stand-alone system. Several constraints must be considered when determining the maximum number of RE integrations such as wind and solar that can be carried out on the transmission system. This is because the VRES power plant generates fluctuating generators, which are dependent on the availability of primary energy at the time, specifically solar radiation and wind speed, which fluctuate over time. Non-VRE generators, on the other hand, must incorporate the active power fluctuations caused by VRE generators' intermittent operation. Due to the technical limitations of the generating system, it is essential to apply some limitations in the VRE integration. Similar studies were also carried out related to modeling and its effect on the transmission system [23] and determining the maximum penetration of the Java-Bali system [24]. There are several considerations in determining the limits of VRE integration in electric power systems to compensate for the intermittent from solar and wind energy, which are discussed as follows [24]:

A. Declared Net Capacity (DNC)
The non-VRE generation DNC restricts the potential of ramp-ups. The margin between the DNC and the unit dispatch value at the time slot t shall be the maximum ramp-up capacity available at that time. This unit capacity may vary with different values for each time slot. When the generator output reaches DNC, the ramp-up capability value is zero. An illustration of the DNC's limitations is presented in Figure 3- 11.

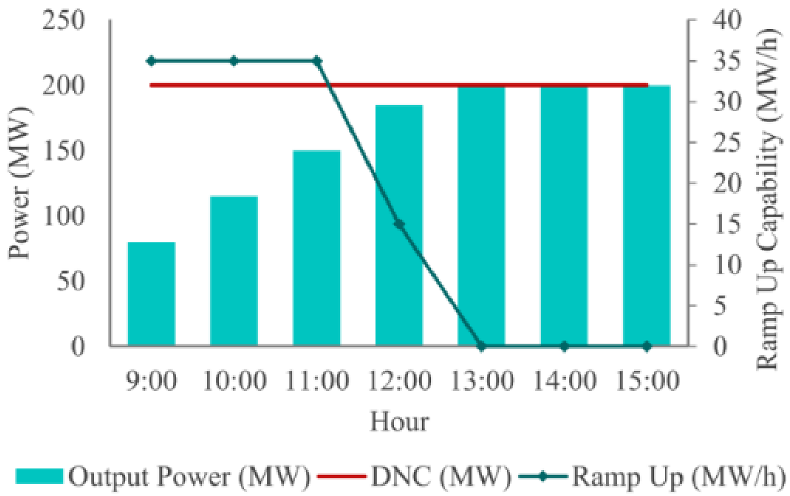


Figure 3- 11 Figurean NDC

B. Technical Minimum Load (TML)
TML is the smallest load that can be applied to a generator while considering its technical characteristics. The TML constrains the generator's ramp-down capability; the margin between the TML and the unit dispatch value at time slot t represents the generator's maximum ramp-down capability during that period. TML operation limitation is illustrated in Figure 3- 12.

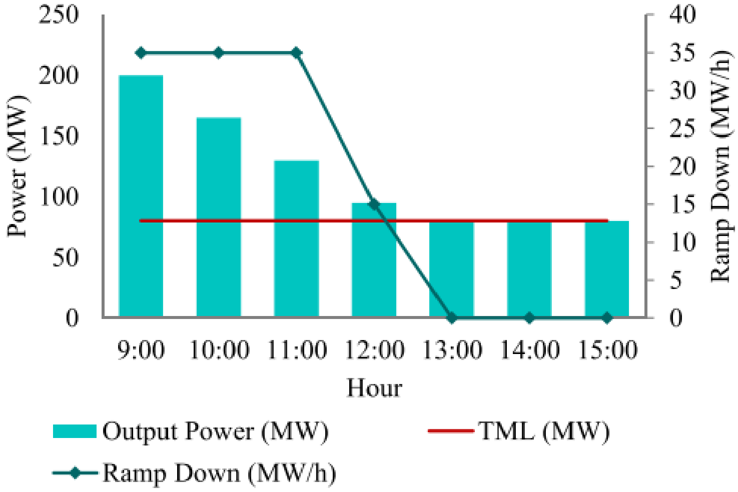


Figure 3- 12 An Illustration of TML Limitation

C. Coal Mill and Swing Gas Limitation

A coal mill is used to increase the coal feed quality and efficiency before entering the boiler. The power output of the plant depends on the number of active mills. The number of active mills determines the maximum power output. During mill operation, the generator cannot increase or decrease its power output, so the generator has no contribution in compensating the fluctuation. Additionally, most gas and combined-cycle power plants, particularly in the Java-Bali system, receive their gas from a pipeline and have a small amount of local gas storage, limiting the controllability of gas flow and preventing them from operating continuously for an entire year. These constraints are referred to as the "swing gas" factor, depicted in Figure 3- 13.

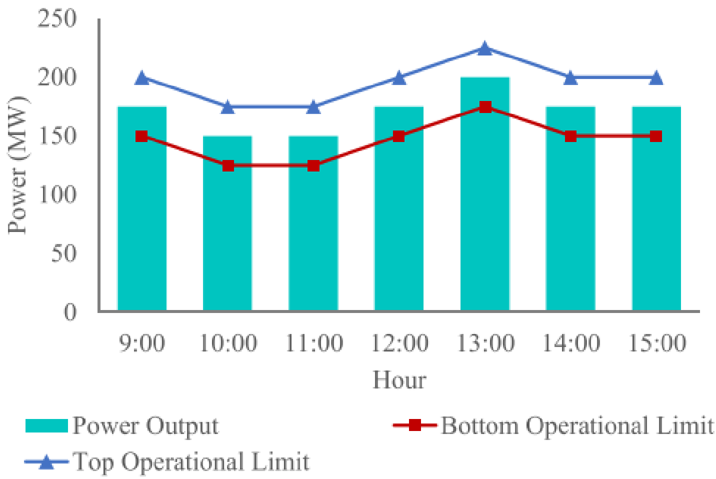


Figure 3- 13 An Illustration of Gas Generating Unit Limitation

D. Fixed power Generating Unit
Generation systems consist of many types of power plants. Some power plants are dispatchable, and some are non-dispatchable power plants, such as geothermal power plants. The output of the geothermal power plants tends to be constantly operated, considered for its economical fuel cost. Moreover, there is unavailability for the flexibility of the primary source. So, geothermal power does not contribute to system flexibility.

E. Power Systems Flexibility
The system's ability to compensate for load fluctuation is represented by flexibility. The flexibility in the generating system represents the capability of the generating unit to respond to variations in load or net load. The flexibility of the power system is a measure of its ramp rate capability.

F. Active Power Control
Active power control allows the systems to control the active power output of a generator unit in response to the frequency rate. With active power control, such as automatic generation control (AGC), generating units' output changes more frequently, which raises operating costs. However, system stability and reliability are also increased.

The interconnection of the RE power plant with the distribution network of PT.PLN is regulated explicitly in [25]. This regulation guides the connection of the RE power plant with a total installed capacity of up to 10 MW, connected at the connection point and operating in parallel with the PLN radial distribution system at a voltage of 20 kV or lower. Study [26] has interconnected PLTS with a distribution network in the Bantul area. In a study [25], the process of integrating PV with distribution networks considers several factors:

a) Network Voltage
The voltage on the network may fluctuate due to the PV system's entry into the distribution network. Due to the presence of this integration, a voltage spike may occur, resulting in interference in the form of overvoltage.

b) Line and Transformer Loading
Due to PV integration, the line loading and transformer loading is not allowed more than 80%.

c) Network Power Factor
The network power factor is not allowed to be less than 85%.

Hybrid System / Virtual Power Plant

Remote areas, such as small islands, border areas, and mountainous regions, are typically located outside large electricity networks. These areas generally operate on their independent power supply system, distinct from the major power grids. Utilizing local renewable energy sources is an efficient way to begin developing an electricity system in the area. However, utilizing local renewable energy sources such as wind and solar will present unique challenges, most notably those associated with their intermittent and uncertain nature [26].

The hybrid system model can be used to overcome the shortcomings of independent intermittent renewable energy generation. Hybrid systems are not a new concept in power generation development. However, hybrid systems have recently become a hot topic of discussion in the development of power generation. This is because of the growing use of renewable energy, which is intermittent and must therefore be combined with other forms of energy generation. Along with increasing system reliability, using a hybrid system aims to increase system efficiency [27]. The general classification of hybrid systems is depicted in Figure 3 14. Hybrid systems are classified into two categories based on the type of energy they use: fossil & non-renewable energy and non-renewable energy & non-renewable energy. Fossil & NRE power plants are tasked with assisting or acting as a backup for NRE power plants. In the NRE configuration, the two power plants complement each other and act as backups.

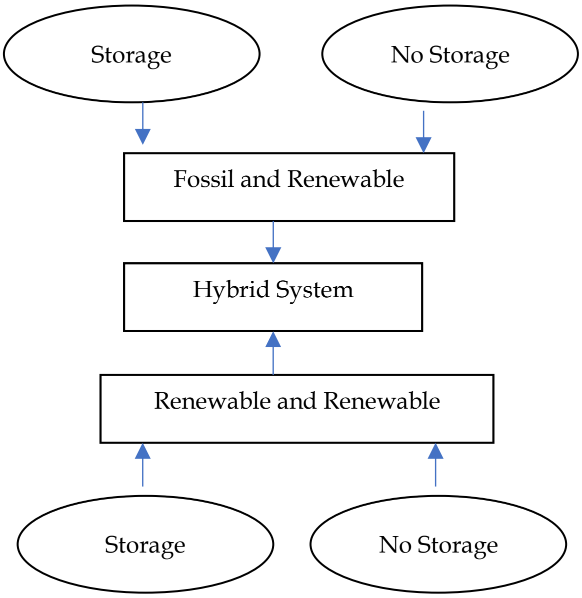


Figure 3- 14 Hybrid System Types

The two types of hybrid systems are regrouped into two types: using and not using storage. Systems that use storage have a more flexible generation operation area than those that do not use storage. This is because storage will provide energy that can be used at any time. To determine whether or not storage is used and determine the storage size, we can use an optimization process, either with the proper method or approach.

Table 3- 9 shows several previous studies that have been grouped based on the type of hybrid system.

Table 3- 9 The Division of Previous Research Based on the Type of Hybrid System Used

Types of Hybrid System	Types of power plant
Fossil and Renewable with storage	Wind + PV + Fuel cells + Microturbine [27]
Fossil and Renewable without storage	Wind + Gas turbine [28] PV + Gas turbine [29] Conventional + wind + PV [30]
Renewable and Renewable with storage	Wind + PV [31][32] Wind + Solar+ Pumped Hydro [33][34]
Renewable and renewable without storage	PV + Wind [35] Solar + wind + hydro [36] Wind + PV + biomass [37]

3.4.2. Power System Transition

For the existing system to properly receive intermittent NRE generators, integrating intermittent NRE in the grid requires several steps. The three significant steps are the interconnection study, the design study, and the control study [38]. These steps are shown in detail in Figure 3- 15

In the interconnection study, several analyzes were carried out to plan the generation and transmission expansion to accommodate the integration of VRES. The first one is the steady-state analysis that will conduct about the operational condition of the existing grid, so it can be seen how much VRES integration is allowed into the system. Primarily when the disturbance occurs like a short circuit or N-1 contingencies. The steady-state analysis uses a power flow study to determine transmission expansion planning, reactive power compensation requirement, power system operation planning, and power system performance under disturbance conditions [39]. The short circuit studies are then carried out to determine the power system equipment's specification and protection devices under short circuit conditions.

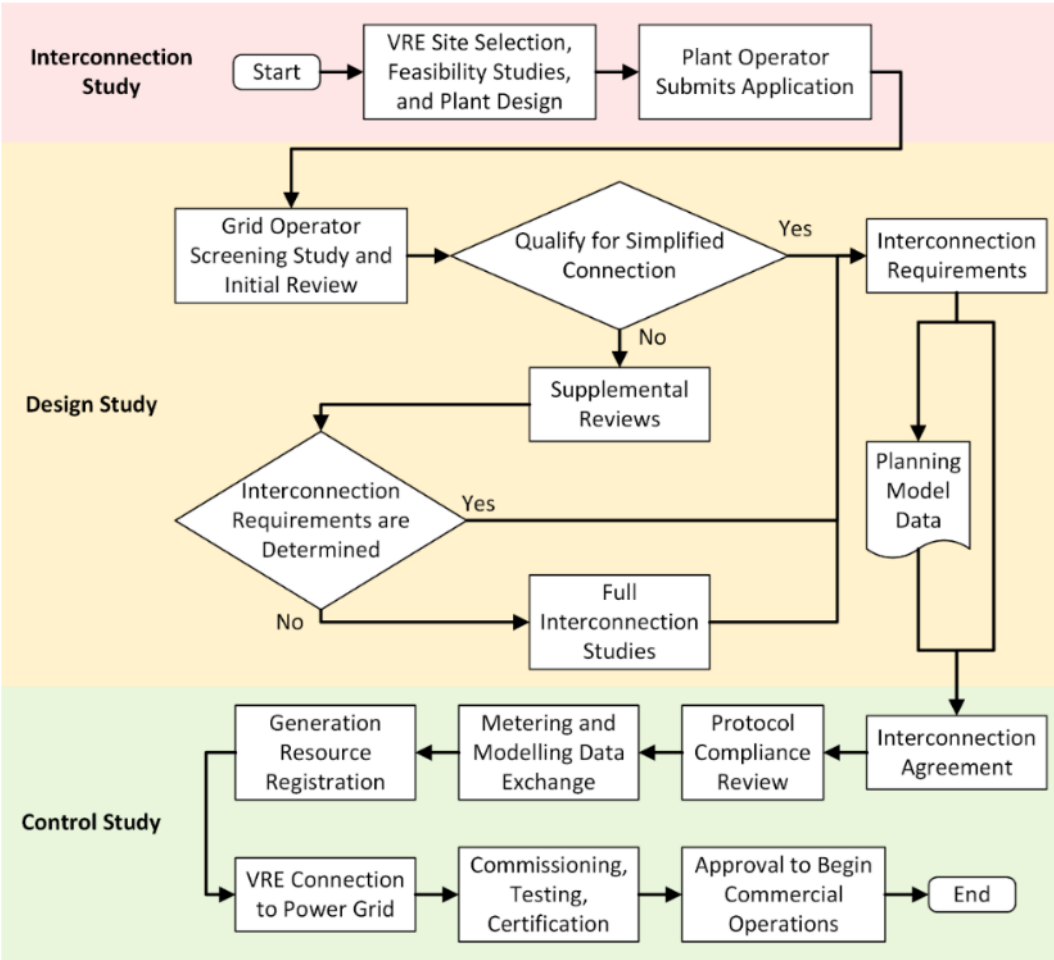


Figure 3- 15 The Steps of VRES Integration to Grid [38]

Another study is power dynamics and stability analysis. This study helps identify the proposed unit response to small and large tissue disturbances, including transient disturbances. This study ensures that intermittent NRE integration into the network will not reduce the system's ability to keep all machines in sync during and after an error occurs. The last is a facility study to calculate estimated investment costs, operating and maintenance costs, and energy costs that are averaged over the course of the project. Design studies are carried out by conducting reviews, detailed engineering designs, and complete interconnection studies. Thus, design studies are more detailed than interconnection studies. The final step of this study is control study, such as connecting intermittent NRE to the network, commissioning, real test, and power system certification. The primary technical data for intermittent NRE, wind, and solar power generation are shown in Table 3- 10 :

Table 3- 10 VRE Generation Technologies

Technology	Year	Capacity (MW)	Investment (M$/MWe)	Fixed O&M ($/MWe/year)	Capacity Factor (%)
Solar PV – large	2020	10	0.83	15,000	20
	2030	10	0.61	12,500	20
	2050	10	0.45	10,500	21
Wind – small onshore	2020	0.85	4.00	73,200	34
	2030	0.90	3.48	63,700	35
	2050	0.95	2.96	54,200	37
Wind - large onshore	2020	3.5	1.50	60,000	34
	2030	4.0	1.31	5,200	35
	2050	5.0	1.11	44,400	37
Wind - offshore	2020	8	3.50	72,600	48
	2030	10	3.05	64,700	49
	2050	12	3.59	55,000	50

The typical capacity factor of solar PV is between 20% - 21%. It means it can produce energy at full capacity in 4.8 until 5.04 hours. Wind energy has three different scales. There are small onshore, large onshore, and offshore wind power plants. The onshore wind power plant has a capacity factor of 34% - 37%.

In comparison, the offshore wind power plant has a capacity factor of 48% - 50%. The investment and fixed operations and maintenance (O&M) cost of solar and wind power plants decreases from 2020 to 2050. Solar PV has a lower investment and fixed O&M cost than wind power plants of the same size. The solar PV modules are typically 1-2 m^2 in size and have power densities in the range of 100 – 210 Wp/m^2. The expected lifetime of solar PV is 25 years. The size of the wind turbines has continued to increase over the years. Larger generators, taller hubs, and larger rotors all contribute to increasing wind turbines' power generation. Lower specific capacity (increasing the rotor area's size more than proportional to the increase in generator rating) increases the capacity factor (energy production per generator capacity). The power output at wind speeds below the rated power is directly proportional to the rotor swept area. Besides, the greater height of the turbine hub provides a generally higher wind resource.

4. ECONOMIC ANALYSIS

The transition to new and renewable energy cannot be delayed any longer to ensure that all countries in the world move together to slow down global warming. Although often regarded as an investment that is not cheap, the utilization of NRE will provide economic benefits, tangible and intangible, which are far greater than the potential costs that must be incurred if the transition is not carried out. Indonesia's commitment to contribute to tackling climate change—by signing the Paris Agreement in April 2016—ensures that Indonesia must immediately move to achieve emission reductions compared to business-as-usual conditions of 29 percent with its efforts or 41 percent with international cooperation.

Economic benefits from this energy transition will occur in the future and during the transition itself. Every economic actor is compelled to adapt as a result of the change. To make the transition, central and local governments, state-owned enterprises, the private sector, and the community must work cooperatively. New economic activities associated with the energy transition, both national and local, will emerge and add economic value, thereby directly contributing to the success of Indonesia's energy transition process. We will briefly describe the economic benefits of NRE development on the regional economy in the following sub-section, using examples from NTB, NTT, and East Kalimantan.

4.1. Local Economic Impacts

Renewable energy does not only reduces greenhouse gas and saves the earth but also could contribute to the national and local economy. In general, renewable energy consumption was found to have a positive impact on national economic growth. Some research found a positive correlation between GDP and renewable energy consumption, where every 1 percent increase in renewable energy consumption can increase total GDP by 0.105 percent [40]. Similarly, others also estimated that doubling the share of renewable energy would boost global GDP by 0.6 to 1.1 percent [4].

At the subnational level, economic benefits are inextricably linked to both public and private investment. Investment in renewable energy in rural areas can stimulate local economic growth, increase household income, and create new jobs. Along with investment benefits, decentralizing energy generation may have a positive effect. Electricity interconnection issues caused by the country's archipelagic nature can be alleviated by promoting decentralized energy generation. This will improve local communities' access to energy.

Aside from the above general impact, renewable energy can bring about benefits tailored to the local economic development agendas of West Nusa Tenggara (NTB), East Nusa Tenggara (NTT), and East Kalimantan. Although specific to each province, the benefits can apply to other provinces with similar economic development agendas.

Potential Benefits to NTB's Local Economy

The development of renewable energy will go hand-in-hand with industrialization in NTB. The renewable energy industry is listed among the leading priority sector in the province's Industrial Development Roadmap. The renewable energy industry requires the input of materials, services, and equipment from other manufacturing industries, thereby inducing demand for products from other manufacturing sectors. This will induce direct benefit—increase in job opportunities, additional regional income, and tax revenue—as well as indirect benefit from the growth of other manufacturing sectors.

Renewable energy could also potentially reduce the province's high unemployment rate. Most unemployed in the province are vocational high school graduates. The renewable energy industry will generate jobs suitable for these graduates, ranging from service technicians, electrical engineers, construction engineers, and maintenance engineers. The renewable energy industry has a long value chain, whereby investment in renewable energy will spawn new local business opportunities within each stage in the production chain.

Potential Benefits to NTT's Local Economy

Renewable energy development could alleviate the problem of energy access in the province. The province has long suffered from poverty, especially in remote areas where access to energy resources is limited. The electrification ratio in NTT was 85.84 percent in 2019, lower than the national average of 98.89 percent. Lack of electricity causes a "viscous circle" where income-generating activities are limited by lack of electricity, which will render electricity unaffordable to the poor. Decentralized renewable energy development has the potential to provide these remote communities with adequate energy access.

Second, utilizing the decentralized power plant scheme may also create employment and business opportunities for Nusa Tenggara's local communities. Additional business ventures could benefit communities. Village-owned

Enterprises (BUMDes) may be invited to join the renewable energy power plant's ownership and operation.

Potential Benefits to East Kalimantan

East Kalimantan's economy has been relying heavily on the unsustainable mining and extraction sector. The sector had contributed 48,6 percent to the province's GDP since 2010. Reliance on coal mining poses a significant risk to the province's economic resilience. International price fluctuation proved to be harmful to the sustainability of growth, particularly during 2020, when the province's sector contracted negative growth due to a decline in coal demand. If the regional economic activity does not move away from the dominance of coal mining, regional economic growth cannot be sustained.

Renewable energy development can also support the new capital city initiative. The plan calls for the development of a green city supported by a renewable energy system. At least 39 percent of new capital's energy is set to be supplied from renewable energy hydropower plants. It would be an excellent achievement for the provincial government if they could contribute to this target.

4.2. The Potential Environmental Benefit

Renewable energy has been known to produce lower greenhouse gas emissions compared to fossil fuel energy. Several studies have conducted a Life Cycle Analysis (LCA) to compare the relative benefit between renewable and fossil fuel. LCA is not limited to carbon emission but could also incorporate net energy ratio (NER), the ratio between helpful energy outputs dispatched to the grid compared to fossil energy used during the lifetime project [41]. The study found that renewable energy has a higher NER compared to fossil fuel. The NER number for renewable energy ranges from 9 up to 65 (wind is the highest with the NER up to 65), while the NER number for fossil fuel only ranges from 0.3 up to 0.4.

The greenhouse gas emission indicator in LCA also shows that renewable energy produces lower GHG emissions over lifetime projects. The lowest GHG emitter is geothermal (around 17 grams CO_2e/kWh), followed by tidal (around 22 grams CO_2e/kWh), hydro (around 25 grams CO_2e/kWh), biomass (around 55 grams CO_2e/kWh), and solar (around 70 grams CO_2e/kWh) [41]. Meanwhile, GHG emission resulting from coal is around 1000 grams CO_2e/kWh, and gas is around 500 grams CO_2e/kWh. The meta-study conducted by the World Nuclear Association also shows that renewable energy technology produces much lower GHG emission intensity per GWh electricity compared to fossil fuel over the project lifetime. The highest GHG emitter in renewable technology is Solar PV amounted to 85 tonnes CO2e/GWh, while the lowest GHG emitter in fossil fuel technology is natural gas amounted to 499 tonnes CO2e/GWh.

Open-pit mining continues to support the implementation of a coal-fired electricity generation system strongly. Additionally, the externalities associated with this coal mine have not been fully internalized. This has the potential to have a significant and long-term environmental impact, which runs the risk of triggering a broader impact, not just in terms of the environment.

By shifting into renewable energy, each region will be experiencing those environmental benefits. Moreover, to fully experience the benefit of renewable energy, each region should be focused on:

East Nusa Tenggara

The emission profile for East Nusa Tenggara from 2005 to 2013 is dominated by transportation (61 percent) and the energy sector (39 percent). Carbon emissions from the energy and transportation sector raised 122.92 percent and 167.64 percent in 2013, respectively. Thus, the use of renewable energy can be focused on this area to reduce GHG emissions. Besides, the emission reduction program is aligned with the Regional Development Plan of East Nusa Tenggara. The transportation sector could shift from conventional fossil fuel to biofuel. The energy sector could utilize renewable energy to produce more sustainable electricity.

West Nusa Tenggara

West Nusa Tenggara's emission profile is also dominated by transportation (78 percent) and the energy sector (22 percent). In 2013, emissions from the energy sector increased by 200.26 percent, while transportation emissions decreased by 1.43 percent. As a result, renewable energy can be concentrated in this region to reap the full benefits of emission reduction. Additionally, the government's Regional Development Plan states that renewable energy will assist the government in achieving sustainable management of natural resources by establishing an indicator of water and air quality by 2023 and a 5.83 percent renewable energy share in the energy mix.

East Kalimantan

East Kalimantan's emission profile is dominated by transportation (62%), followed by the energy sector (33%). (29 percent). The energy sector's emissions increased by 222.77 percent in 2013, and the transportation sector's emissions increased by 646.28 percent. East Kalimantan could develop renewable energy to mitigate the effects of economic and non-economic activities on carbon emissions.

Renewable energy sources could be used in place of fossil fuels to generate electricity.

Additionally, renewable energy development could be used as a strategy for land transformation in the former mining area. The government could use biofuel in place of refined fuel oil and renewable electricity to power electric vehicles. Finally, the Government's decision to deploy renewable energy is consistent with its regional development strategy; the Government intended to reform the ex-mining sector and transition to a green economy.

5. LEGAL ANALYSIS

5.1. Legal Mapping: Renewable Energy Development and the Role of Local Government in Central Level Regulation

The role of the Local Government in the development of Renewable Energy highly depends on the design of authority arrangements, which are constructed by the prevailing laws and regulations. Article 1 point 6 of Law 30/2014 on Government Administration defines authority as the power of Agencies and/or Government Officials or other state administrators to act in the realm of public law. Authority is the rights held by Government Agencies and/or Officials or other state administrators to make decisions and/or actions in government administration. The following factors influence how big the portion of the Local Government in playing its role:

1) To what extent do renewable energy regulations adhere to the Energy Decentralization concept, which entails the central government delegating government affairs in the energy sector to autonomous regions based on the Autonomy Principle. Regional Autonomy establishes the rights, powers, and obligations of autonomous regions to regulate and manage their government affairs in the energy sector, under the provisions of Article 1 point 6 of Law 23/2014. In general, there are two types of government affairs: mandatory government affairs, which all Regions must carry out, and optional government affairs, which regions must carry out following their potentials.

2) The Local Government can manage the scope of authority in developing Renewable Energy use in its territory. There are at least three ways to gain authority. **The first** is Attribution, which grants authority to Government Agencies and/or Officials by the 1945 Constitution of the Republic of Indonesia or the Law. **The second** is Delegation, which means transferring Authority from a higher Agency and/or Government Official to a lower Agency and/or Government Official. In this case, all responsibilities and liabilities are fully transferred to the recipient. **The third** is the Mandate: the transfer of Authority from a higher Agency and/or Government Official to a lower Agency and/or Government Official. Unlike the previous one, the responsibility and liability of the plaintiff remaining with the mandator.

3) The ability of heads of the local governments (both governors and regents/mayors) is needed to understand the scope of their authority and implement it in a concrete form, under the characteristics of their respective regions. It should be noted that the term "Local Government" refers to the Head of the Local Governments, by the provisions of Article 1 number 3 of Law 23/2014 on Regional Government. It is different from the "Local Government" that includes the Head of the Local Governments and the Regional House of Representatives (Regional People's Representative Council). Energy sector laws, such as Law 30/2007 on Energy, specifically designate Local Governments. Therefore, the Head of the Local Government has an important role. Also, the head of the local governments should be able to determine the RE development method that suits their regional characteristics. This is because RE is a local energy source.
4) The regulations should allow for flexibility in utilizing or implementing the authority for RE development. The degree to which a norm is flexible is determined by its design, whether imperative or facultative. Imperative standards are a priori obligatory and must be adhered to. On the contrary, due to their complementary, subsidiary, or dispositive nature, facultative norms are not a priori binding. This means that imperative standards can be enforced, whereas facultative standards allow for discretion in their application. However, once implemented, they will be enforceable.
5) To what extent the local government can take discretion to accelerate the development of RE. Article 1 point 9 of Law 30/2014 defines Discretion as Decisions and/or Actions that are determined and/or carried out by Government Officials to overcome real problems faced in the administration of government, especially in terms of laws and regulations that provide choices, do not regulate, are incomplete or unclear, and/or there is a stagnation of government.

5.2. Regulations on Local Governments

This subsection will further elaborate on the role of Local Governments in developing NRE, especially those related to the power generation sector.

5.2.1. The Energy Sector of The Job Creation Act

On November 2, 2020, the controversial Law 11/2020 on Job Creation was finally promulgated in the State Gazette of the Republic of Indonesia of 2020 No. 245. The law resulted in a significant change in the countries due to the Omnibus Law's new legislative technique. The law accomplishes its objectives by encompassing a variety of topics or subject matters. This method enables the law to depart from other standards deemed incompatible with the omnibus law's objectives. This method enables the revision of numerous substantially interrelated laws by enacting a single new law amending each of these laws, article by article. The aspect of simplicity is achieved because no rules need to be changed one by one. Other fundamental tenets, such as legal certainty and justice, can, however, deteriorate.

The Job Creation Act mandates local governments to provide funds for the following four targets:

1) poor people;
2) construction of electric power supply facilities in underdeveloped areas;
3) electric power development in remote and border areas; and
4) rural electricity development.

However, this funding norm is not constructed as an imperative norm that is *a priori* binding and mandatory. The existing norm design will make the implementation process difficult because the norm is not explicitly mentioned as a mandatory norm. Therefore, no one should obey it, and supervision on its implementation is not required either.

The Job Creation Act has also amended the Coal and Mineral Bill. This is very questionable as the bill had been amended by Law No. 3/2020 that was promulgated on June 10th, 2020, less than five months from the promulgation of the Job Creation Act, which is on November 2nd, 2020. The substance of the amendment to the Coal and Mineral Bill needs to be further elaborated because it has a significant impact on RE development.

5.2.2. Law on Regional Administration and its Amendment on the Job Creation Act

The Job Creation Act amends several articles in Law No. 23/2014 (Law on Regional Administration), which were previously amended by Law No. 9/2015 concerning the Second Amendment to Law No. 23/2014 on Regional Government through Article 176. The provisions in the Law on Regional Administration that is relevant to the development of RE in the electricity sector is Article 14 section (1): “The implementation of Government Affairs in the forestry, maritime affairs, as well as **energy** and mineral resources **is shared between the central government and provincial regions**”. Government affairs related to oil and gas management are excluded. They will be under the total control of the Central Government. The norm for government affairs division is still valid and has not been amended by the Job Creation Act.

Article 16, particularly for RE, can produce positive results if all central, regional, and IPP stakeholders are involved in the regulation-drafting process. Additionally, international benchmarking of RE governance is critical. Thus, a rational concept can be developed and integrated into Indonesia's primary energy management principles. A well-written regulation of Norms, Standards, Procedures, and Criteria can be used to "lock in" and optimize the Region's role, as Article 16 section (3) establishes the regulation as an implementation rule for Regional Government. On the other hand, if the resulting regulations on Norms, Standards, Procedures, and Criteria are unqualified, ambiguous/multi-interpretative, and excessively flexible, the Local Government's role will be compromised. It is likely to be determined by the Central Government.

5.2.3. Electricity Law

The Job Creation Act brought about significant changes in electricity governance because more than half of the articles in the Electricity Law were changed. 32 articles were changed, two were deleted, and one norm was added to the new article. All articles in the law that explicitly refer to regions have been amended by the Job Creation Act, as previously elaborated, so there is no need for further elaboration in this section. However, one provision in the Electricity Law supports RE, namely Article 6 section (2). This provision emphasizes the priority of using primary energy sources that come from new energy sources and renewable energy to ensure a sustainable electricity supply.

5.2.4. Energy Law

A quo law has stipulated the position of the Regional Government as part of implementing energy supply through the provisions of Article 20 section (2). Furthermore, it is said that energy supply is prioritized in underdeveloped areas, remote areas, and rural areas by using local energy sources, especially RE. Partisanship for the use of RE is affirmed in section (4), which states that local governments must increase the provision of RE in accordance with their respective authorities.

The two aforementioned standards contain both challenges and opportunities. The challenge is to manage section 2's provisions in such a way that RE is not viewed as a "marginal energy" that is developed only in undeveloped, remote, and rural areas. If this approach is taken, the target of 23 percent NRE in the national energy mix by 2025 will be challenging to achieve, as the small area scope will undoubtedly constrain RE capacity development. On the other hand, if properly managed, these two standards can become opportunities, as they can be used to manage (as well as compel) the participation and potential of Indonesia's 34 provinces, 415 districts, one administrative district, 93 cities, and five administrative cities. Many regions and their respective powers can contribute in achieving the desired energy mix if they are managed effectively through a tactical and concrete approach.

Article 20 is followed up by Article 26, which divides the authority in the energy sector between the central and regional governments. The provisions in section (2) determine that the authority of the provincial government includes:

1. making provincial regulations;
2. guidance and supervision of cross-regency / municipal exploitation; and
3. stipulating management policies across districts/cities.

The authority of the regency/city government is regulated in section (3), which includes:

1. making district/city regional regulations;
2. guidance and supervision of exploitation in districts/cities; and
3. stipulating management policies in regencies/cities.

Previously, the legal norms could be managed and directed to increase the role of the regions in accelerating the use of RE, but this condition changed with the enactment of the Job Creation Act. That section (4) regulates that the authorities of the provincial and district/city governments are exercised under the provisions of statutory regulations. Therefore, the implementation and actualization of these powers must be in line with the corridors of norms in the Job Creation Act, and the most relevant to RE are the provisions concerning amendments to the Electricity Law.

The Job Creation Act, which vests the Center with significant authority, particularly in licensing, has both negative and positive consequences. A quo law will be beneficial if used to reduce licensing and bureaucracy to attract investors. On the other hand, reducing the regions' licensing authority will undoubtedly impair their ability to implement their programs and policies. For instance, accelerated RE policies in regions have a better chance of success if they are designed to be mandatory and must be implemented by regional stakeholders. In that context, the use of RE can be integrated as a single unit by granting permits under the Region's authority. This method, however, was no longer feasible because the permits had been transferred entirely to the Central Government and incorporated into the vast scheme of Business Licensing.

Referring to the norms above, the role of the remaining regions and can be managed to accelerate RE development, especially for electricity generation, among others:

1. Creating Regional Regulations to establish a Municipally Owned Corporation or make equity participation in an existing Municipally Owned Corporation whose Articles of Association and Household Budget are open to undertaking the exploitation of RE or hybrid power generation.
2. Making Regional Regulations that open opportunities for cooperation, for example, using land owned by the Region, for RE or hybrid power plants.
3. Preparing Regional Regulations for providing incentives in the form of reduced local taxes and levies for IPP REs and hybrids.

The Energy Law also regulates the portion of the regional role in developing RE through R&D activities. Article 29 section (1) requires local governments to facilitate research and development of science and technology for energy supply and utilization. The provisions of section (2) even expressly state that R&D is directed primarily for the development of RE. The facilitation is regulated in Article 30 section (1) and (2), namely in funding allocated from the Local Government Budget. It means that there should be a mandatory allocation for R&D RE funding. The Local Government Budget requires the local government and the Regional People's Representative Council to budget each year. The standard should be one of the solutions for advancing RE. Regrettably, the imperative standard is not followed by imposing sanctions on regions that fail to meet their funding obligations. Additionally, Section 4 of Article a quo directed the formation of Governmental Regulations to serve as operational regulations that further regulate funding. However, this is not implemented until now.

5.2.5. The Management of Local Government's Role in Governmental Regulations on National Energy Policy

The position of the Governmental Regulations on National Energy Policy after enacting the Job Creation Act is quite interesting. The Governmental Regulations a quo is the implementing regulation of the Energy Law as stated in the preamble to point an of the Energy Law, which is not touched by the Job Creation Act. The Governmental Regulations that must be adjusted to the Job Creation Act within a maximum period of 3 months from the date of promulgation are all Government Regulations that are domiciled as implementing regulations of the Law which have been amended by a quo Law, as ordered by Article 185-point b. Even though it passed the Article a quo, the existence of the National Energy Policy cannot be separated from the Job Creation Act due to the provisions of Article 181 section (1), which orders that every statutory regulation under the applicable Law and contradicts the provisions of the Job Creation. The act must be harmonized and synchronized. This effort is within the Ministry of Law and Human Rights domain, which receives law attribution to act as coordinator. Meanwhile, no definite analysis can be given regarding the harmonization and synchronization because Article 181 section (3) states that the two efforts are further regulated in the Governmental Regulations, which have not existed until now.

An interesting provision in the National Energy Policy is stated in Article 21 section (1), which obliges Local Governments to participate in providing subsidies for RE in the event of one or two of the following conditions:

1. The price of RE is higher than the price of energy from fuel oil which is not subsidized; and/or
2. The application of a Just Economy cannot be implemented.

The Governmental Regulations on National Energy Policy provides a portion for the Regional Government to work on the RE economy to compete with established fossil energy. It is stated in Article 22 that regional governments provide fiscal and non-fiscal incentives to encourage the development, exploitation, and utilization of RE, especially for small scales located in remote areas. Incentives are not given for an indefinite period because section (2) strictly limits them until the RE economic value is competitive with conventional Energy.

5.3. Accelerating Achievement of the 23% Energy Mix Target Through Parallel Hybrid and RE Power Plants

The management of energy sources as a support for the national electricity capability cannot stand alone as a single policy because it involves the authority and targets achievements across sectors. The Ministry of Human Resources chairs the power generation policy, but in conversion to RE, it will require support from related sectors with relevant targets to justify and affirm the program. For example, sectoral policies at the Ministry of Environment and Forestry, which are in charge of externalities and environmental carrying capacity, can be integrated with the Ministry of Human Resources policies. In addition, sectoral policies at the Ministry of Home Affairs, Ministry of Villages, PDTT, and Regions are also relevant to be observed considering the characteristics of RE as a local energy source. Based on the above considerations, the analysis in this sub-chapter will be based on statutory regulations, which are themes of the game for energy management in general, as well as cross-ministerial sectoral regulations above and regional regulations which are used as examples

The hybrid power plant development program that utilizes fossil energy to RE was mandated 14 years ago through Law no. 17 of 2007 concerning the National Long-Term Development Plan 2005-2025 (UU RPJPN 2005-2025). This law is crucial since it contains the RPJPN, a national development planning document, and the crystallization of the formation objectives of the state for a period of 20 years, from 2005 to 2025. Strictly speaking, it is stated in Article 2 section (1) that it reads, "The National Development Program for the period 2005-2025 was implemented. in accordance with the National RPJP ", the RPJPN serves as a direction as well as a reference for all components of the nation, both the government and the business world, in realizing national ideals and goals. It is designed in such a way that the direction of development is mutually agreed upon, ensuring that all development efforts are synergistic, coordinated, and complementary.

However, a quo law focuses more on controlling (reducing) the consumption of fossil energy from petroleum for electricity generation by increasing the contribution of gas, coal, and RE such as biogas, biomass, geothermal (geothermal), and solar energy ocean currents, and wind power. The government's grand strategy has explicitly stated from the start that it will reduce consumption of oil and not of fossil energy in general, including coal and natural gas. At the time, the government prioritized diversifying or expanding the use of energy sources to contain the rate of petroleum consumption.

The hybrid generator development program can also be necessary to overcome climate change threats due to rising earth temperatures. The legal basis for reference is Law 16/2016 concerning the Ratification of the Paris Agreement to The United Nations Framework Convention on Climate Change. The Paris Agreement is legally binding to restrain global average temperature rises < 2^0 C above pre-industrialized levels and continue efforts to reduce temperature rises to 1.50C above pre-industrial levels through many programs. Major, including low emission development. One of the real forms is through the increase in RE, clearly stated in the General Elucidation of a quo Law. Indonesia implemented the Paris Agreement in two ways, namely adaptation and mitigation.

Long before that, there was a document on the National Action Plan for Climate Change Adaptation (RAN-API), which has elaborated on adaptation and interpreted it in 2 forms:

1) The adjustments to natural or artificial systems in response to climatic stimuli or effects, whether actual or predicted, intending to minimize hazards or maximize opportunities.
2) Natural or human efforts to adapt and reduce the impacts of climate change have or may occur.

Furthermore, it is stated in the National Action Plan upon Climate Change Adaptation (RAN-API) that climate change adaptation in Indonesia is meant as:

1) Adjustment efforts in the form of strategies, policies, management, technology, and attitudes so that climate change (negative) impacts can be reduced to a minimum, and if possible, can take advantage and maximize its positive effects.
2) Efforts to reduce the impacts (consequences) caused by climate change, either directly or indirectly, continuous or discontinuous and permanent, and the impacts according to their level.

In parallel with that, the National Action Plan also interprets mitigation efforts upon Climate Change Adaptation (RAN-API) as things that can reduce greenhouse gases in the atmosphere, for example, electricity generation with less greenhouse gas emissions or a reduction in electricity demand. This definition is clarified in Presidential Regulation No. 61/2011 Concerning the National Action Plan for Reducing Greenhouse Gas Emissions in Article 7. This regulation defines climate change mitigation as a control effort to mitigate the risks associated with climate change through activities that reduce greenhouse gas emissions or increase their absorption from various emission sources. As a result of this elaboration, it is possible to conclude that the hybrid generator development program is part of mitigating climate change.

The countries participating in the Paris Convention recognize that today's significant need is adaptation. However, simultaneous higher mitigation measures would reduce the need for additional adaptation efforts. Meanwhile, the need for a better adaptation will result in a greater need for costs. In other words, maximizing the mitigation approach will result in cost efficiency. In the context of this study, the construction of hybrid generators, which is in parallel with the construction of RE generators, is a mitigation effort to minimize the costs incurred to internalize externalities that arise due to the long-term existence of fossil plants.

6.STAKEHOLDER ANALYSIS

Stakeholders include all parties, individuals/groups, or organizations related to this program of increasing renewable energy role in Indonesia. It is essential to conduct stakeholders mapping to identify active and willing actors to encourage transition within their constituencies. In this identification process, stakeholders are evaluated for their interests and roles to increase the role of renewable energy. Based on their function, stakeholders can be categorized into main stakeholders (those who have a direct influence on the program), secondary stakeholders (those who have an indirect effect on the program), and tertiary stakeholders (those who are not related to the program but will be affected by the impact of the program). The stakeholders include:

Central Government

The effort to increase the role of renewable energy for energy transition demand a systematic, comprehensive approach. Therefore, it is run as a collaborative plan amongst ministries. The ministries involved focus on the Ministry of Energy and Mineral Resources and other ministries, such as the Ministry of Environment, the Ministry of Home Affairs, the Ministry of Industry, the Ministry of State-Owned Enterprises, and the Ministry of Finance. The Ministry of Home Affairs oversees the Regional Government's role in the energy sector within regional autonomy. The Ministry of State-Owned Enterprises plays a significant role, for instance, in determining the Pertamina and PLN to integrate renewable energy in their business strategy and process. The government also has the responsibility of creating dynamic harmony among all related stakeholders in the energy transition. It is worthy of being mentioned that these stakeholders have competing positions in several cases. A clear executive agenda within long-term national interests will be vital to mitigate this challenging issue.

Regional Government

At the provincial and regional levels, local governments play a vital role in the energy transition. In addition to issuing policies related to the energy transition, LGs can set an example to the community for cleaner and more sustainable energy. Regional budgets can be allocated to achieve this by installing PLTS in government buildings and public infrastructure. This budget is also used to maintain adequate operational and maintenance needs. Together with the regional legislature, the local government can formulate and implement regulations that aim to create an environment that supports the development of NRE. Various policy and regulatory options can be applied, such as the obligation to install solar power on the roof of a commercial building at a certain level before a construction permit or operational permit is issued. Furthermore, by increasing strategic affirmations through various policy and regulatory tools, local governments can grow different companies based on NRE.

Legislative Institutions

As the legislative institution at all levels possesses the authority and capacity to integrate renewable energy into the political agenda and various laws and regulations, it occupies a critical position in the energy transition. Among the anticipated expanded roles is its collaborative solid strategy with the government to support the domestic renewable energy industry. This can be fulfilled by giving stronger legal affirmative policy for national service and good to supply the demand. The legislative institution is also a vital player in harmonizing stakeholders in their transforming business strategy and culture due to energy transition. A legal and political approach will be essential to mitigate competing relationships among stakeholders to produce positive results.

Banking/Financial Institutions

Financial Services Authority can play a significant role in supporting the energy transition in Indonesia. Indonesia's renewable energy investment per unit capacity (USD/kW) is still relatively higher than fossil fuel. Furthermore, feed-in tariff, for instance, solar rooftop, is still not optimum in providing strong support for public participation. It makes financial institutions insecure about providing loans for renewable energy construction. Financial institutions should be convinced about the risks of implementing renewable energy so that the energy transition can go well.

Large Scale Business Sectors in Fossil and Renewable Energy

Large-scale businesses include those whose annual turnover is more than IDR 50 billion with a total workforce of more than or equal to 100 people. Large scale business in the fossil energy sector influences the implementation of the energy transition. These fossil-based enterprises can play a significant role by transforming the business strategy and culture into a sustainable energy system. The biggest challenge is internalizing various existing externalities in its business process, likewise, for companies in the renewable energy sector. Their vast capital and network strength could provide significant support in various renewable energy supply chain parts. The business sector could strengthen its capacity to create comprehensive and long-term benefits, such as decreasing technology imports and providing new jobs.

State-owned Enterprises (SOE)

Indonesia has more than 70 state-owned enterprises (BUMN) divided into 12 clusters. There are two important clusters regarding energy transition: (1) energy, oil and gas industries, and (2) mineral and coals industries. Like other enterprises, the SOE can play a significant role by transforming the business strategy and culture into a sustainable energy system. Having also the mission to fulfill a set of government targets in the energy system, the SOE could have even more substantial power to increase the speed and intensity of the energy transition. For example, PT.PLN (Persero) can significantly reduce the capacity of coal power plants and move to renewable energy.

Local Business Institutions

Cooperative and regionally owned enterprises (*Badan Usaha Milik Daerah-BUMD*) can play an active role in the energy transition. The government and many donor agencies currently promote public-private partnerships or other collaborative structures for implementing renewable energy in the regions [42]. A local business has a great opportunity in this increased initiative by developing and managing a new business process based on renewable energy. It can be managed by inclusively involving local resources. This local institution is one of the pillars to ensure significant local benefit from a decentralized renewable energy system. It will also realize the inherent characteristics of renewable energy in local community engagement.

Formal Education Institutions

Universities and vocational schools are essential stakeholders in the energy transition. Formal education institutions can facilitate systematic capacity building for energy transitions, regional energy planning and implementation, and renewable energy technology. The educational institution will enhance human resource capacity in both hard and soft skills. The energy transition entails a transformation of numerous established aspects of the energy system. The developed hard skills and soft skills are also critical for innovatively mitigating numerous bottlenecks during the transition.

Furthermore, by increasing the capacity of laboratories and workshops, the educational institution can produce various components of renewable energy technology. It will directly integrate the education institution into the supply chain of renewable energy. Moreover, a large number of renewable energy facilities are built and operated in off-grid schemes. This condition requires support from the educational institution to provide assistance and training to the community on managing these off-grid power plants.

NGOs

The energy transition entails a paradigm shift in several established facets of the energy system. Due to the NGO's extensive network, it is also capable of bridging gaps between stakeholders. By combining formal and informal touch, the NGO can foster mutual understanding between stakeholders with divergent interests. The NGO has the opportunity to assist and advocate on a grassroots level. Adopting a new era with a higher proportion of renewable energy can significantly positively impact numerous aspects of the community. By implementing a comprehensive scheme, the NGO can demonstrate how to maximize mutual benefit from the new energy system.

Religious Organizations

A message of sustainability and mutual benefit of the energy system is compatible with the religious mission of continuously building a better world for human beings. Therefore, there is a strong mutual interest between the institution's vision of the sustainable energy transition and religious organization.

Traditional Institutions

At the local level, decision-making will often be based on various local variables, such as cultural aspects. Often informal leaders have a strong influence on formal decision-making made by public and private institutions. Therefore, it will be strategic to convey

Local Communities

In the existing scheme of the energy system, the local communities play a role as energy consumers. Energy providers should fulfil their energy demand. In many cases, the local communities have a key role in achieving sustainability of energy infrastructure, which is operated not by big business players. In the future, a significant transition will push the local communities to also play a role as energy producers. In this new era, therefore, local communities will have the opportunity to be prosumers.

Table 6-1 Stakeholder Matrix

No.	Stakeholders	Expected Supports for Renewable Energy
1	Central Government	To develop and implement related policies, laws, and regulations at the national level, providing an enabling environment for renewable energy To provide a program for increasing use of renewable energy and increasing capacity of the national industry of renewable energy To manage relations among stakeholders at the national level
2	Local Government	To develop and implement related policies, laws, and regulations at the local level, providing an enabling environment for renewable energy To manage relations among stakeholders at the local level
3	Legislative Institutions	To develop a set of laws in providing an enabling environment for renewable energy To manage relations among stakeholders
4	Banking/Financial Institutions	To provide financial support for renewable energy project To increase its role in green financing
5	Large Scale Businesses on Energy	To increase integration of renewable energy in the business scheme To increase synergy among various players in renewable energy
6	State-Owned Enterprises	To increase integration of renewable energy in the business scheme To increase synergy among various players in renewable energy
7	Local business institution	To increase integration of renewable energy in the business scheme To increase synergy among various players in renewable energy
8	Formal Education Institutions	To develop mindset, knowledge, and skill related to renewable energy
9	NGOs	To provide advocation program related to renewable energy To provide a community empowerment program related to renewable energy
10	Religious Organizations	To encourage people to use renewable energy based on religious value To manage relations among stakeholders at the local level
11	Traditional Institutions	To encourage people to use renewable energy based on local wisdom To manage relations among stakeholders at the local level
12	Local Communities	To be active in increasing the use of renewable energy, especially in operation and maintenance aspects

7. BUSINESS MODEL

This section discusses the business model that was developed in response to the previous chapters' discussions. The proposed business model focuses on collaboration among stakeholders - particularly local governments and local entities - to develop a sustainable RE business ecosystem. This relates to the spirit of empowerment and strengthening the regions' capacity to play a more significant role in the energy transition era.

7.1. Parameter Identifications

7.1.1. Purposes and Categories

There are two main objectives of the business model identified in the report: (1) to act as a guide in reformulating the existing NRE business model so that it is more in line with national objectives, and (2) to promote the transition to a more sustainable renewable energy business model by emphasizing the participation of local human resources and natural resources.

Numerous challenges confront the current RE business model, imposing a significant burden on energy transition efforts. The primary challenge in the solar energy business is land acquisition and integration into the PLN grid. This is because the current regulation cannot balance the government's interests, PLN (as the sole taker), and private sector stakeholders (IPP). The wind energy industry faces similar difficulties, exacerbated by Indonesia's lack of adequate wind energy resources. To achieve the appropriate feasibility scale for this type of technology, a large area, and a large installed capacity are required. As a result, it will ultimately require a high cost of implementation.

There are various schemes to attract local stakeholders to participate in ET. However, this scheme often encounters problems in practice, especially when entered into operation and maintenance. This is due to the lack of competence of local human resources and the local government's inadequate budget. Frequently, inadequate local management capacity to carry out O&M and lack of coordination between local stakeholders cause O&M problems. This challenge needs to be addressed immediately, considering that public participation schemes have great potential to strengthen democratization in the energy sector.

The transition of the energy system to renewable energy will cause a significant change in the energy supply chain. The change will disrupt various aspects related to energy, such as

- Obsolescence of centralized electricity infrastructure, which has been the strength of the power industry
- Less dependence on centralized grid and trust in energy utility providers.
- New opportunities and roles for energy utility providers.
- Adoption of an online or digital platform for energy automation, own-generation system, and energy efficiency management system.
- Changes in the political landscape surrounding the electricity sector, fostered by the emergence of self-generation.

In the future, the energy business model will be dominated by the more vital role of the community and private sector. They will likely become government partners in the diversification and decentralization of the energy system. It is crucial to embrace the emergence of a "new era in energy sector business". A systemic transition should be conducted along with all aspects of the energy supply chain.

7.1.2. Key Stakeholders

Energy transition efforts must obtain optimal support from various stakeholders to provide broad-scale and long-term benefits. In general, the various stakeholders and the expected support are presented in Table 6-1.

7.1.3. Key Activities

Only activities that add value to consumers are considered key activities in the RE business model canvas. Power generation is the primary activity in on-grid and off-grid RE power plant businesses. Although both power plants engaged in complementary activities to their primary business, they remained minor contributors to its value delivery. Renewable service businesses engage in a broader range of critical activities, including energy consulting, installation, monitoring solution development, operation, and maintenance.

7.1.4. Value Proposition

Value propositions describe a bundle of benefits that a company offers to customers defined in the customer segment. These value propositions will determine whether or not a customer prefers one company over another. The value proposition for each business model offered in this study will be outlined below:

a. Off-grid business model: the value of micro-scale electricity, clean energy, flat monthly fee, local business establishment, and decentralized energy distribution.

b. On-grid business model: the value of higher reliability of electricity supply compared to off-grid connected electricity supply. It also offers regulated price and cost-efficiency

c. Service business model: one-stop solution for renewable energy service, thus providing attributes of accessibility and convenience, online consultation, certified engineers, and safety guaranteed installation

d. VPP business model: the value of reduced cumulative capital cost fulfilling the attribute of cost reduction. The aggregation of producers in combination with power dispatching features of VPP will also offer reduced output fluctuation due to intermittency, increased electrical stability, robust supply security, and increased leverage for RE suppliers

7.1.5. Cost Structure

Cost structure block in business model canvas (BMC) describes all costs associated with operating the business model, including creating and delivering value, maintaining customer relationships and other costs related to the business's income-generating activities. Thus, the key resources, key activities, key partnerships, customer relationships, and channel blocks activities will be reflected in the cost structure.

There are four types of the business model considered in this study, namely (1) off-grid, (2) on-grid, (3) service, and (4) VPP. The cost structure for these business models will typically include four types of cost: capital expense, operational expense, financing cost, and capital acquisition cost. The cost structure of the on-grid and off-grid business model is almost identical except for the grid interconnection cost. The service business model includes capital and operational expenses and excludes the financing and capital acquisition costs. The operational expense will typically be including marketing expenses to promote the business. Last, the VPP cost structure will be identical to the on-grid business model.

7.1.6. Revenue Streams

The revenue block in a Business Model Canvas represents the cash generated from each customer segments (Ostelwarder and Pigneur, 2010). Revenue is generated from the value that the business delivers to its consumers. In the case of the renewable energy business, the primary value is delivered through electricity generated by a power plant or through the services delivered by the business. In the case of renewable energy power plants, the sales price of electricity is usually the main driving factor for the revenue stream. The pricing of electricity in an on-grid power plant is different from those of off-grid.

The government regulates the electricity sales price for on-grid power plants. At the same time, there is some room for negotiation between independent power producers and PT. PLN (Persero), the price in practice closely follows the Ministry of Energy and Mineral Resources Regulation No. 50 Year 2017 (as amended by Regulation No. 4 Year 2020) on Renewable Energy for Electricity Generation.

In the case of off-grid power plants, the independent power producer sells the electricity in accordance with the terms of the agreement with the users. Users will generally seek the lowest possible price, taking their willingness to pay and budget constraints into account. The government is not involved in the price-setting process.

In addition to the revenue generated from electricity sales, a power plant might opt for additional side-income from activities other than but still related to electricity generation. Steam power plants—mainly those powered using biomass, biofuel, or geothermal—might want to recover and sell residual heat/steam for use in industrial heating. Additional revenue might also come from utilizing surplus electricity for use in other activities such as water heating. These additional side revenues add to the profit received by the company and increase the viability of the project.

Government subsidies and carbon credit could potentially be an additional—albeit minor—source of income. Currently, there are no available schemes for the disbursement of in-cash government subsidies or carbon credit. However, there is an ongoing discussion about whether renewable energy power plants should be 'compensated' for their contribution to reducing GHG emissions. When a carbon credit scheme is available, the polluting industry may want to trade its 'carbon cap' to non-polluting renewable energy power plants.

As for the renewable energy service business, the revenue stream could come from various sources. The primary revenue source will be from consulting services, energy solution installation services, operation and maintenance services, or any other within the main activity conducted by the firm.

7.2. Proposed Business Model

This section discusses several business models for developing RE in the region. The proposed business model's primary selling point is the availability of portions for local governments and other local actors to participate in its implementation actively. The business model is divided into two well-known approaches to renewable energy development: (1) on-grid systems and (2) off-grid systems. Additionally, three additional business models are quite novel and unfamiliar to the community: (1) an energy service business, (2) a virtual power plant system, and (3) an alternative hydrogen system. The five business models each explain a different aspect of the RE business activities.

Implementing the five business models requires a more in-depth understanding of the region's energy potential, the magnitude of energy demand, the conditions of development-supporting institutions, and technological mastery. Each business model requires a similar capital structure; the amount required is still determined by the scale of the business to be built. Meanwhile, the complexity of the implementation process for each type of business model is also dependent on the proposed project's technical situation.

The larger the scale of the business model, the higher the risk. This high risk demands a business model that can attract the support of many stakeholders. In general, large capital requirements can only be met through a combination of funds from several funding sources. In addition, the capital instruments used need to be more varied, demanding a diversification of the capital portfolio that is not limited to only loans and capital. In addition, large-scale RE projects demand political support from local government stakeholders. Although it tends to be more complicated, the RE business model applied on a large scale can significantly positively impact sustainable development.

7.2.1. On-Grid System

The On-grid business model focuses on the direct relationship between the developer (IPP) and the off-taker. IPP This model is an alternative that is commonly implemented when the national electricity grid covers an area. PLN as off-taker as well as network owner acts as a single bridge between IPP and end-users. In the on-grid business model, IPP sells RE electricity that has been generated directly to PLN. In general, the government (both central and local) acts as a regulator and licenser. However, this role can be improved. Through their BUMD or BUMDes, local governments can play an active role as the main actor in carrying out RE generation activities. This can be achieved by collaborating with IPPs or SOEs that have previously implemented RE nationally. A new business entity can be formed where there is a transfer of knowledge to local human resources.

IPP also has direct relationships with financial institutions such as banks or grant providers to obtain capital. Other supporting entities such as contractors, equipment suppliers, and consultants are also included in the main partners of the On-grid model. The On-grid Business Model Canvas in Figure 7- 1 should describe the relationships and overall activities in the proposed business model.

Business Model Canvas | Centre for Energy Studies, Universitas Gadjah Mada | ON – GRID Electricity Bussiness Models

<table>
<tr>
<td rowspan="2">Key Partners
(Mitra Utama)
• Renewable Energy Developer - IPP
• Offtaker and Network Owner - PLN
• National Government
• Local Government
• Contractors (O&M and EPC)
• Equipment suppliers
• Investors / Financing Bodies
• Technical, Legal & Financial Consultancies</td>
<td>Key Activities
(Aktivitas Utama)
• Identify and develop renewable energy projects
• Obtaining permissions, licenses and purchase agreement
• Renewable Energy Production and Selling</td>
<td rowspan="2">Value Propositions
(Proposisi Nilai)
• Higher reliability compared to off-grid
• Bigger market coverage
• Regulated price – fixed income</td>
<td>Customer Relationship
(Kemitraan Pelanggan)
• Electricity Production
• Electricity Selling
• Power Purchase Agreement
• Account Management</td>
<td rowspan="2">Customer Segment
(Segmen Pelanggan)
• Offtaker (Direct)
• Industrial Sector (Indirect)
• Households (Indirect)</td>
</tr>
<tr>
<td>Key Resources
(Sumber Daya Utama)
• Renewable Resources
• Transmission Infrastructure
• Skilled workforce
• Data (energy potentials, market, etc)
• Capital (Internal funding, grants, etc)
• Incentives</td>
<td>Channel
(Saluran)
• Direct sales to Offtaker</td>
</tr>
<tr>
<td colspan="3">Cost Structure (Struktur Biaya)
• Capital Expenses:
  • Buildings, Land Acquisition
  • EPC
  • Feasibility Study, Planning, and LIcensing
  • Grid interconnection
• Operational Expenses: Maintenance, Equipment replacement, general administrative, labor
• Financing cost
• Capital acquisition cost</td>
<td colspan="2">Revenue Streams (Arus Pendapatan)
• Main revenue stream:
  • Electricity sales from PT. PLN with price according to Ministerial Regulation
• Additional revenue stream:
  • Revenue from outside electricity generation, e.g. eco-tourism, electricity education services, etc.
• Capital injection and/or grants
• Subsidy
• Carbon credit</td>
</tr>
</table>

Figure 7- 1 On – Grid Business Model Canvas

As previously mentioned, the on-grid business model has two stakeholders as owners; government and IPP. The government or other banking institutions may act as owners or investors after directly funding the project. The owner of the power plant can be a combination of an independent IPP and the local government. This joint ownership is expected to increase the sense of belonging to an RE project.

The government participates as the owner, then implementing a new IPP within the regional scope will take the form of a new entity. The entity then carries out RE development and generation activities in regional coverage. Although this business model is relatively simple, where electricity sales are made only to PLN as a single-off taker, the role of local entities still needs to be prioritized. This role can be in the form of providing maintenance services to existing power plants in the region. Such as solar panel maintenance, maintenance of the area around the plant, pre-processing for bio-energy raw materials, and so on. With strong collaboration between stakeholders, it is hoped that the penetration of RE in the regions will be smoother and can maximize the utility of regional natural resources and human resources. The stakeholder structure of the on-grid business model can be seen in Figure 7- 1 .

7.2.2. Off-Grid System

In general, the off-grid RE business model is implemented in areas that are not feasible to be reached by the national electricity grid. The off-grid business model has a decentralized character and is isolated from the central national electricity system. This business model puts forward a value proposition in a micro-scale electricity ecosystem that can reach remote areas such as 3T. The technology used is often a standard technology that requires low maintenance. One of the main challenges in this business model is to train local human resources to generate, manage and maintain electrical installations independently. In addition, due to the absence of the PLN electricity network, the local electricity network also needs to be carried out independently. Therefore, the transfer of expertise is needed from RE developers to local communities if the RE generator is managed independently by the community. The choice of technology in this business model also needs to be done carefully according to the level of local human resources. Self-help management is essential because the geographical location of the target area of the off-grid business model is difficult to reach.

The influx of electricity to previously inaccessible remote areas can trigger the growth of new economic activities. The development of an off-grid system will maximize the utilization of local RE resources and increase the area's economic activity. Therefore, this business model needs to focus on and target the local industrial and household sectors.

In terms of funding, this business model can combine government, private and international grants. Due to the relatively small scale, the community can also participate in self-help funding schemes. In addition, income streams can also be generated from outside the main activity of electricity generation, such as eco-tourism, waste management for fuel, electricity cooperatives, etc.

The following Figure 7- 2 shows the main points of the off-grid business model. In Figure 7- 3 , the stakeholder structure of this business model is described. The government, IPPs, private banks, and International Funding Institutions are funding institutions for off-grid RE projects. In general, local governments and local institutions are more familiar with their regions than the central government, both in terms of governance, availability of natural resources, and human resource capabilities. Therefore, submitting a bottom-up RE development plan is expected to provide a more precise picture of technology and funding requirements.

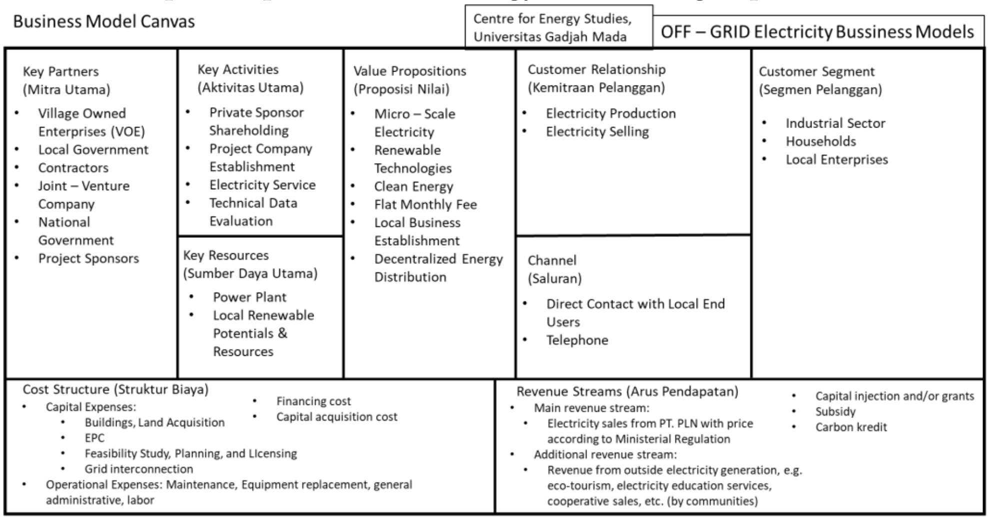


Figure 7- 2 Business Model Canvas for Off-Grid Electricity Business Models

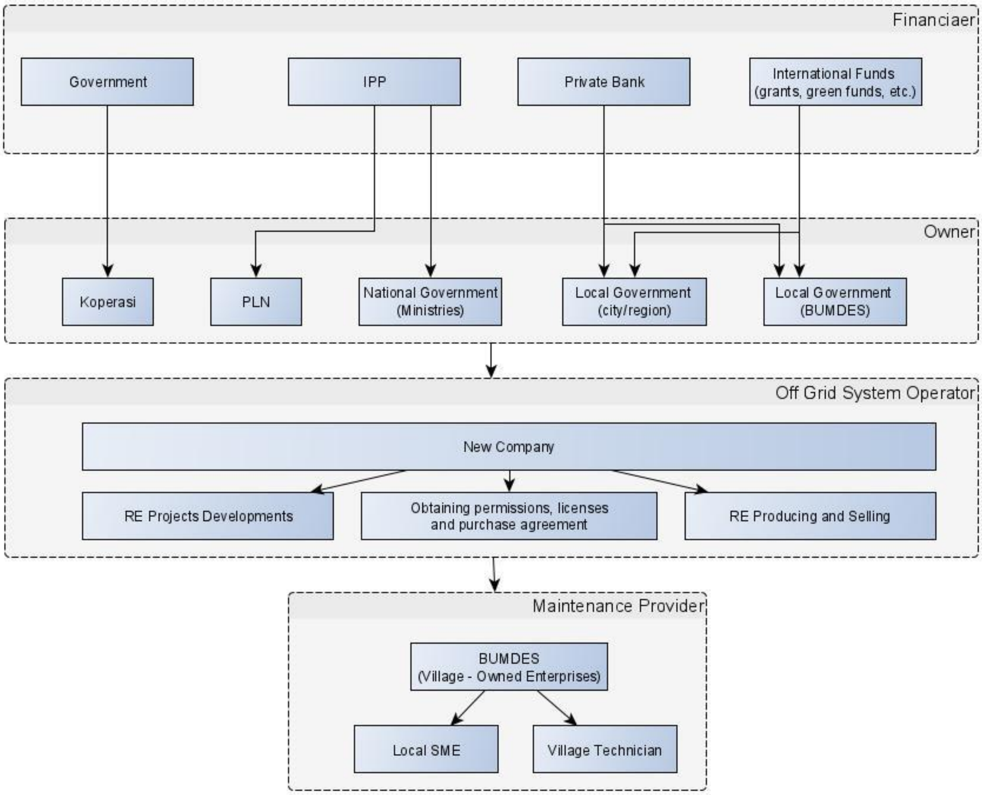


Figure 7- 3 Off-Grid Business Model Stakeholders Structure

Ownership of an off-grid RE business can be a combination of cooperatives, BUMDes, the central government, or local governments. Due to the relatively small scale, ownership of off-grid RE can also be done independently by the community through a cooperative system. A new entity can be created to carry out the RE development activities, from licensing, design and construction, to operation and maintenance. Due to its isolated nature, the role of local communities in the form of BUMDes and cooperatives will be very central. As with the on-grid business model, local business entities can also participate in managing off-grid RE infrastructure by providing supporting services.

7.2.3. Service System

The conversion of fossil energy sources to renewable energy sources in the electricity sector creates new challenges in meeting consumer energy needs. Challenges that arise along with the increasing role of intermittent RE generators such as wind and solar power, among others, are the emergence of the need for more extensive supply-demand predictions, demand flexibility, the certainty of supply of both spare parts and fuel, more reliable networks, and the ability to balance the better network.

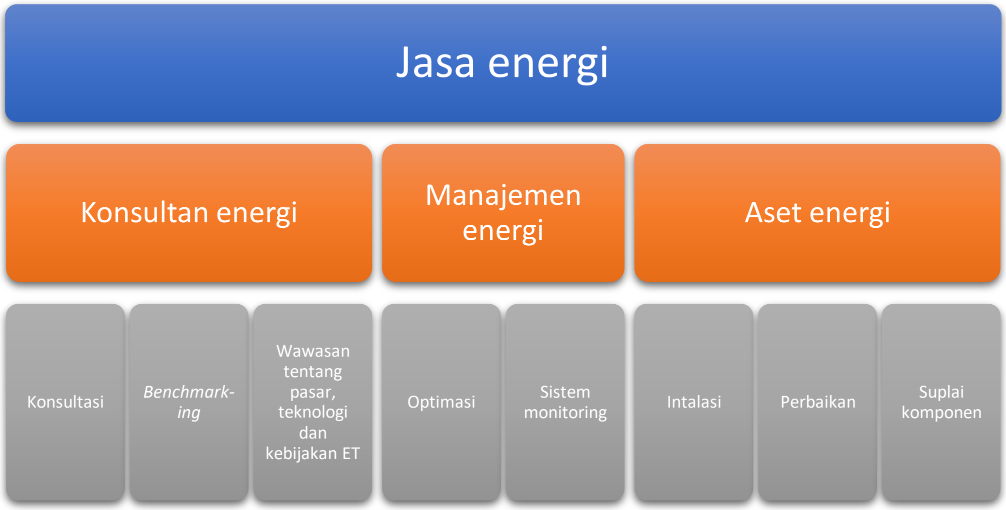


Figure 7- 4 Range of services offered by energy service providers

The energy services business model may be a way to address these issues. The energy service business model is a novel business model in which energy service providers (ESPs) - such as EPC and ICT firms - can offer various services to support the operation, maintenance, and sale of renewable energy power plant production activities. Thus, a business entity engaged in the RE sector should not limit its activities to energy production. ESP can deliver integrated services to end-users, including energy consulting, infrastructure installation and maintenance, energy management solutions, and other services. The various types of services that an ESP can provide are detailed in Figure 7- 4.

There are three main roles or activities in the energy services business model. First, as an energy consultant whose job is to help consumers formulate strategies according to their needs and energy use characteristics. Next is energy management solutions through monitoring and optimizing electrical loads. The third is services related to energy infrastructure assets, both installation and repair, and maintenance. Services that can be provided include installing RE generator equipment both on-grid and off-grid, installing storage systems, and other services related to maintenance, including the provision of spare parts. These three types of services can be offered to both IPP and retail consumers. The main advantage of this business model is the ability to provide a one-stop solution for RE businesses. The BMC energy service business model can be seen in Figure 7- 5 below:

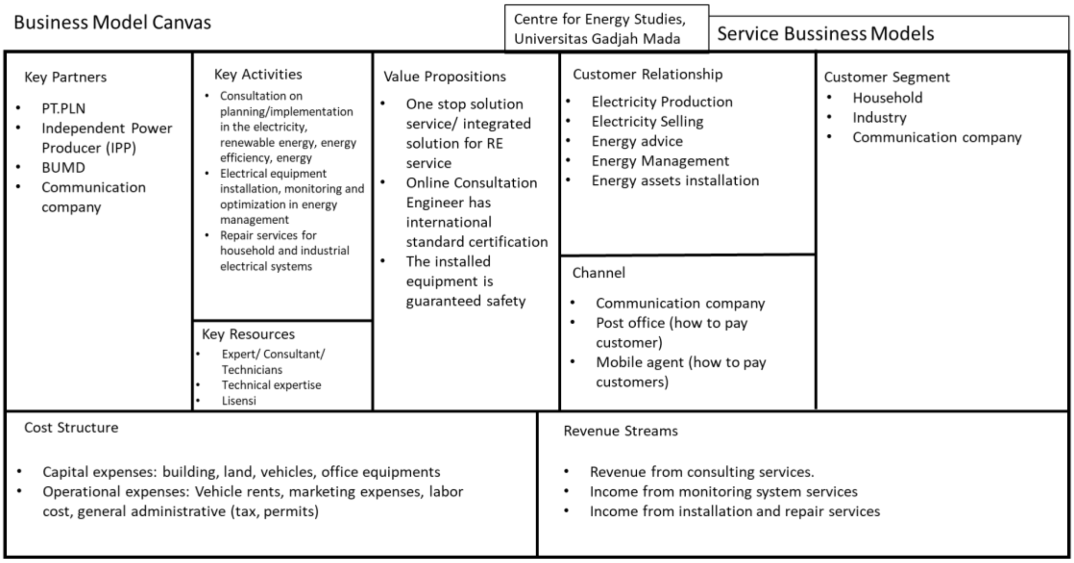


Figure 7- 5 Business Model Canvas for Service Business Models

As with other business models, funders for the energy services business model can come from the government (both central and local), IPPs, the private banking sector, and international grants. Ownership of this business model can be a combination of cooperatives as representatives of non-governmental organizations, private investors, and local government through BUMDes. Energy services business activities are carried out by a new entity formed based on the entity's ownership structure. With inter-institutional collaboration, it is expected that there will be a transfer of knowledge from RE business actors at the national level to HR at the regional level.

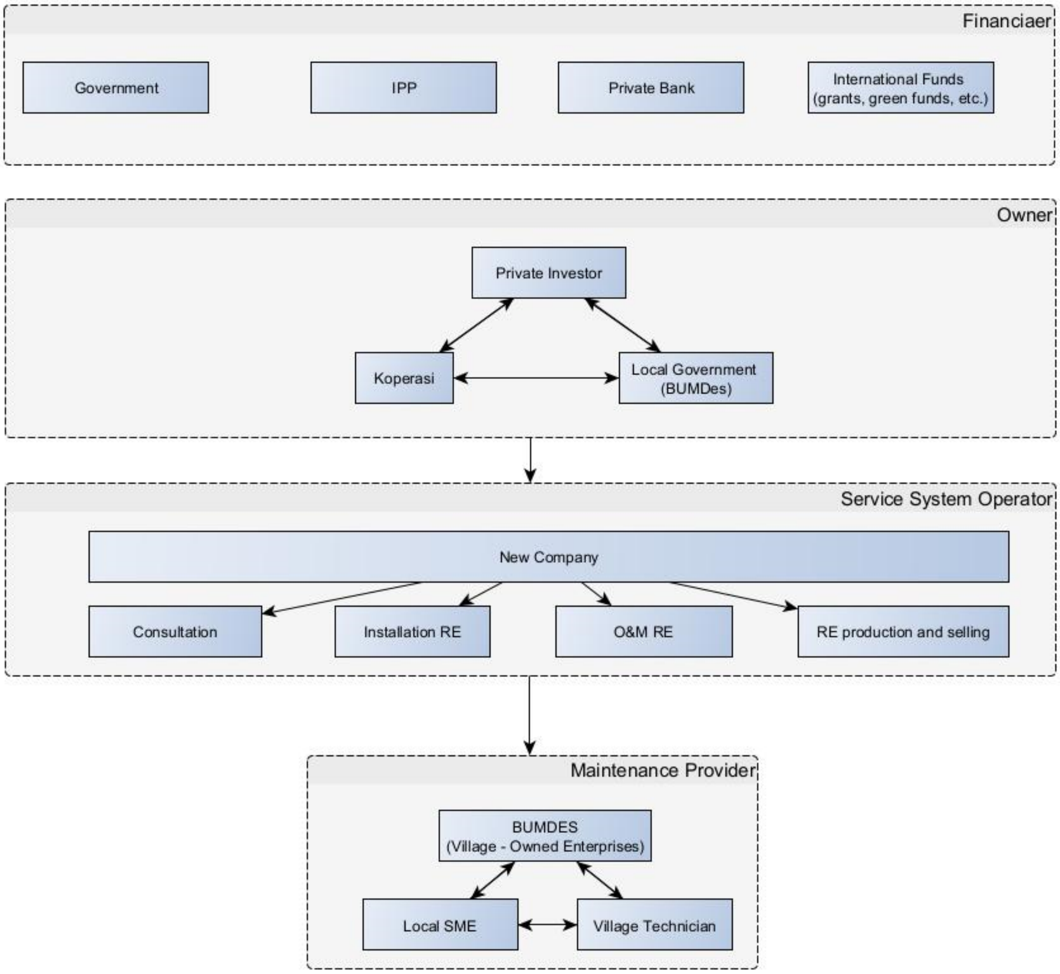


Figure 7- 6 Service Business Models Stakeholders Structure

7.2.4. VPP System

Based on the potential analysis, the most abundant renewable energy sources in East Kalimantan, West Nusa Tenggara, and East Nusa Tenggara are solar, water, and wind power. Solar and wind power have fluctuating and intermittent output characteristics due to their dependence on environmental conditions. Besides, these sources require a relatively wider installation area per unit of energy produced compared to other energy sources. These characteristics make the energy sources in the three provinces distributed.

Virtual Power Plant (VPP) technology is one of the techniques that can be used to improve the efficiency and stability of power plants. Therefore, in the end, it can increase the competitiveness of RE generators. VPP integrates a distributed energy system, an energy storage system, and consumers' flexibility of power usage. Energy producers can allocate their production capacity to VPP to be managed in real-time based on the supply-demand balance situation that occurred at that time. Thus, VPP will increase the reliability of energy supply, increase generator visibility, and provide greater benefits for distributed power plants (DER), which generally have a small scale.

Aggregating renewable energy sources into VPPs presents several challenges. One of them is the fluctuation in the output of electricity generated by intermittent generators. As the level of RE adoption increases through the DER system, the level of uncertainty in the electricity network increases. This results in inefficient and imprecise scheduling parameter estimates in the VPP system [8][9]. Additionally, information technology and energy management systems can introduce new security and privacy concerns to control and manage energy flows. Other issues that become a challenge for VPP are the uncertain and intermittent supply of electricity generated by renewable energy sources.

- Market price uncertainty
- Data ownership and privacy
- Cyber security

Figure 7- 7 shows the business model canvas of the VPP based on conditions obtained from focus group discussions with various stakeholders. In general, the critical partners of the VPP business model are similar to the existing business model with the addition of dispatching centers, transmission system operators, and telecommunications companies. There are different key activities of the VPP model compared to previous business models. In VPP, electricity from sustainable local sources is aggregated and managed in real-time based on current demand. Therefore, weather forecasting and scheduling of the electrical system are imperative to ensure no energy deficit during peak hours. Aggregation and energy management systems can reduce the effects of energy fluctuations from intermittent sources that cause energy losses. A balancing act is also required in a VPP network. The energy storage system is owned and utilized by the VPP system.

Shared infrastructure on a VPP, such as a storage system, can reduce the total capital required for the entire system. IPPs, SOEs, and the Government can invest in infrastructure construction and operations with VPP supporters. The VPP system will allow maximum utilization of local renewable resources, regardless of the availability characteristics of these resources. This is because the energy produced can be stored and managed more efficiently. A VPP system can improve regional energy security by ensuring that locally available resources can meet the region's energy needs at all times of the year.

Business Model Canvas

Centre for Energy Studies, Universitas Gadjah Mada

VPP Business Model

<table>
<tr>
<td rowspan="2">Key Partners
• Central Government
• Local Government
• Renewable Energy-Independent Power Producers
• Offtaker and Network Owner (PLN)
• Investors/Financing bodies
• Distribution System Operators
• Telecommunication company</td>
<td>Key Activities
• Identify and develop renewable energy projects
• Generate electricity
• Electricity pooling
• Supply-demand balancing
• Intra-network balancing
• Energy scheduling
• Monitoring
• Weather forecasting</td>
<td rowspan="2">Value Propositions
• Reduced cumulative capital cost due to shared infrastructure between VPP
• Reduced output fluctuation due to intermittency (less energy wasted)
• Increased electrical stability
• Energy diversification for more robust supply security
• Lower overall electricity production cost
• Increased leverage for RE suppliers</td>
<td>Customer Relationship
• Direct electricity selling (PLN)
• Business to Government relationship</td>
<td rowspan="2">Customer Segment
• PLN as single electricity offtaker
• Industrial and Residential sectors when PLN is not present (direct selling)</td>
</tr>
<tr>
<td>Key Resources
• Local renewable resources (Solar, Wind, Hydro, Biomass)
• Energy Storage System
• Energy Management System
• IT Platform
• Specialized human resources
• Funding</td>
<td>Customer channels
• Direct sales to offtaker</td>
</tr>
<tr>
<td colspan="3">Cost Structure
• Capital Expenses:
  • Buildings, Land Acquisition
  • EPC
  • Feasibility Study, Planning, and LIcensing
  • Grid interconnection
  • Financing cost
  • Capital acquisition cost
• Operational Expenses: Maintenance, Equipment replacement, general administrative, labor</td>
<td colspan="2">Revenue Stream
• Long term electricity selling contract to PLN via PPA
• Ancillary services for PLN
• Capital injections and grants</td>
</tr>
</table>

Figure 7- 7 The Virtual Power Plant Business Model Canvas

The sale of RE electrical energy needs to comply with the applicable regulations in Indonesia. The electricity generated by the RE generator can only be sold to PLN. In this case, the VPP business model is not much different from the on-grid and off-grid business models. In this system, the distribution system operator (DSO) is not able to buy or sell electric power. The primary function of a DSO is to manage and balance supply and demand in the area. Thus, private entities can act as DSOs for their VPP clusters. IPPs that are members of a VPP can manage the generation and store the generated electricity in such a way as to maximize profits. Independent VPP management by VPP will maximize system efficiency. Meanwhile, the management of electricity supply and demand by VPP will be implemented better if PLN as the main SOE that manages the national electricity system is directly involved as a DSO VPP. The collaboration between PLN and IPP RE can be one of the solutions to the DSO institutional problem in the VPP.

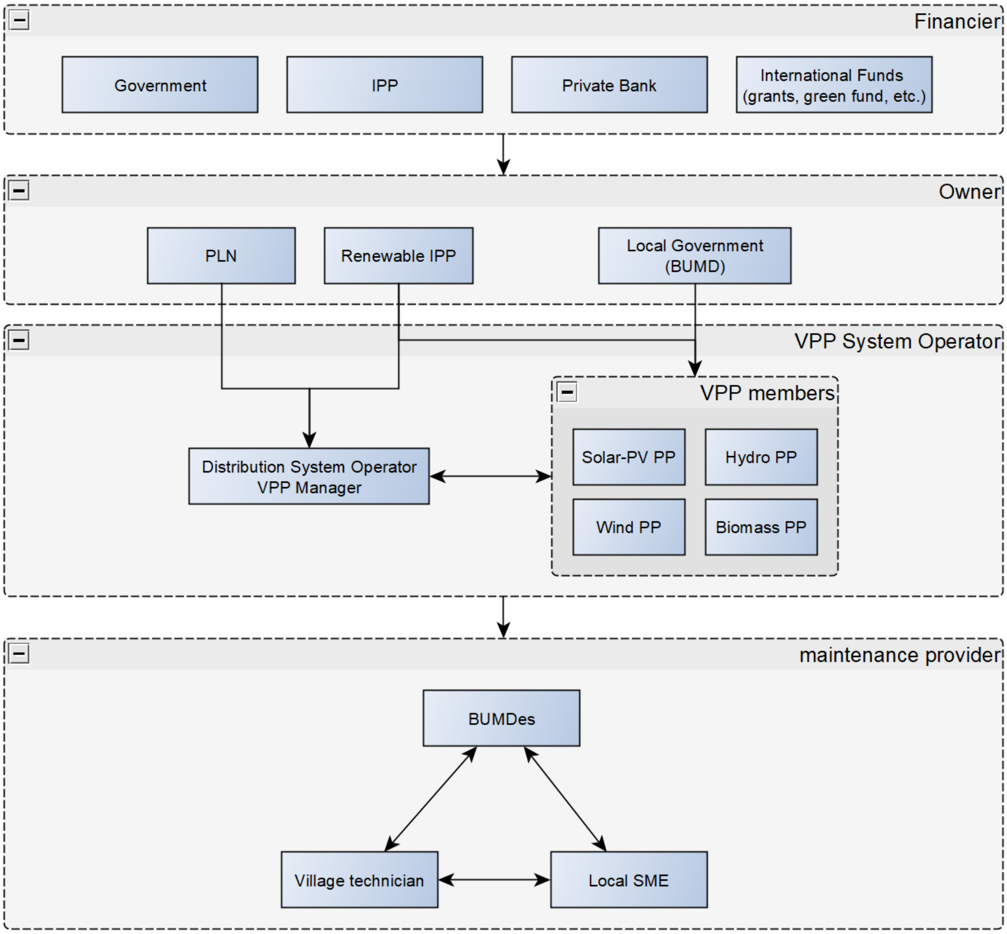


Figure 7- 8 Stakeholders positioning for Virtual Power Plant Business Model

The local government has a central role as the coordinating body for the VPP development plan and ensures that all decisions comply with local regulations. Co-ownership of VPPs and RE power plants by local governments and the private sector can also strengthen the RE ecosystem and collaboration between the government and the private sector. Local enterprises can support the construction, operation, and maintenance of VPP systems. Meanwhile, the main functions of generation and balancing are carried out by the VPP System operator and IPP members. Local companies on a smaller scale, such as BUMDes, local SMEs, and regional experts, can be given tasks to support generating activities to remain involved in the regional RE ecosystem. By providing a balanced role between national, local, and private entities, the formed RE ecosystem will strengthen with a greater sense of ownership among stakeholders.

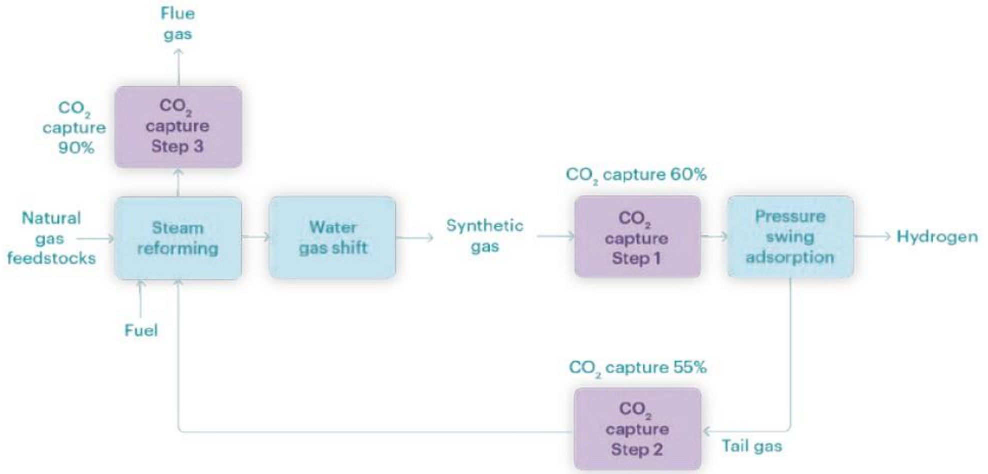
7.2.5. Alternative System: Hydrogen Energy System

7.2.5.1. Introduction to Technology

Hydrogen is one of the most abundant elements in nature, but it is rarely found in its pure state. Hydrogen must be synthesized from hydrogen-containing compounds found in fossil fuels such as natural gas. Electricity generated by geothermal, biomass, wind, or solar energy is also used to produce hydrogen. Nonetheless, the cost of hydrogen energy production is unsuitable for today. Hydrogen is not a renewable energy source derived from natural resources such as coal, petroleum, or natural gas, but rather a manufactured energy source. Hydrogen is typically produced using fossil fuels, nuclear energy, or renewable energy sources. The goal of production is to keep costs and emissions to a minimum. Hydrogen is frequently produced through water electrolysis and steam – methane reforming. Hydrogen is obtained from fossil fuels via the reform method, which utilizes thermal energy. Around 40% -45% of hydrogen is produced via gas-steam reforming, about a third via petroleum reforming, about a fifth via coal reforming, and about 4% via water electrolysis.

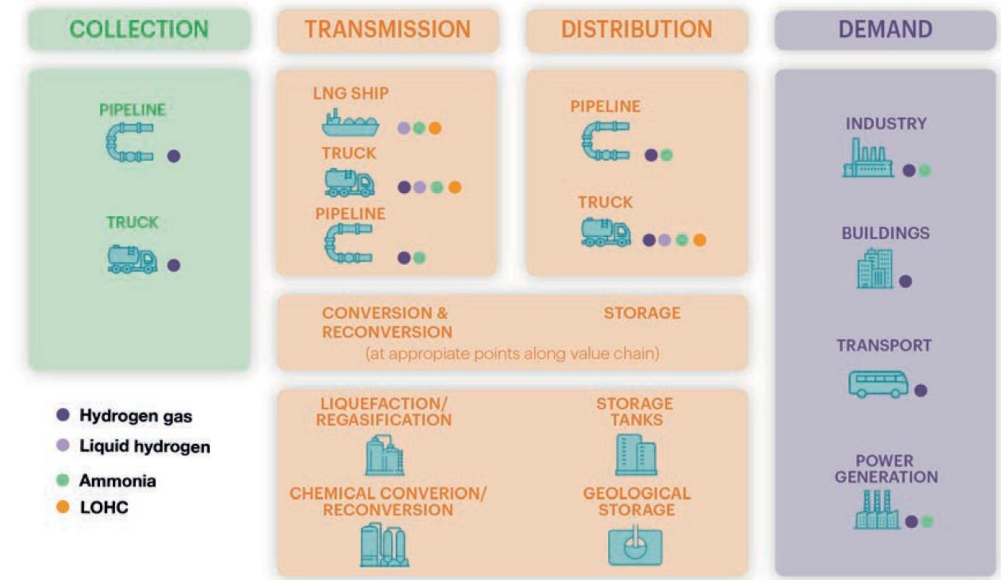
7.2.5.2. Storage Methods Overview

Hydrogen energy storage and transportation issues are the most recent and developing issues. Storage and transportation operations are at least as necessary as production processes. These processes play an essential role in the hydrogen economy. The purpose of storing hydrogen energy is to be safe and efficient and used anywhere and anytime. In its pure form, hydrogen has a low volumetric energy density and high gravimetric energy density. There are three methods used to store hydrogen. There are physical storage as compressed gas, physical storage as cryogenic liquid hydrogen, and solid-state storage methods. Commonly used methods are storage as compressed gas and liquid hydrogen. Hydrogen can be pressurized in suitable structures up to 700 bar and stored in gas in cylinders, containers, and underground cavities.



Source: IEAGHG (2017a), "Reference data and supporting literature reviews for SMR based hydrogen production with CCS".

Figure 7- 9 Production Process of Hydrogen from Gas



Note: LOHC = liquid organic hydrogen carrier.
Source: IEA 2019. All rights reserved.

Figure 7- 10 Transmission, Distribution, and Storage Elements of Hydrogen Value Chains

7.2.5.3. Present and Future Potential Uses of Hydrogen

Hydrogen is produced during chemical reactions. With the cost of renewable energy decreasing, particularly solar PV and wind, interest in electrolytic hydrogen is growing, and several demonstration projects have been completed in recent years. Electrolysis systems today have an efficiency of between 60% and 80%, depending on the technology and load factor. Producing all of today's dedicated hydrogen output (69 MtH2) with electricity would require 3600 terawatt hours (TWh), more than the European Union's annual electricity generation.

The changing annual hydrogen demand for each sector is divided into three phases in the implementation plan according to [43]. In phase 1, chemical synthesis application can be fulfilled entirely by green hydrogen. Phase 2 shows the role of hydrogen in the transition of heating, heavy-duty, and long-range transportation sectors to green alternatives. In phase 3, hydrogen will be used in tandem with electrification for a 100% renewable energy society enabled by hydrogen energy storage and hydrogen derive fuels

7.2.5.4. Hydrogen System Production Route

The technological aspect of hydrogen production holds an important key for creating sustainable hydrogen utilization in the future. As every technology will have its drawbacks, the most appropriate technology will become a challenge towards hydrogen utilization in Indonesia. Providing hydrogen for human purposes needs to be performed using processes or technologies. The industrial-scale of hydrogen production relies on natural gas or coal as the primary raw material. However, there is also another production route that is also possible to be applied. Several technologies of hydrogen production are as follows:

Table 7-1 Several Technological Descriptions in Producing Hydrogen

No.	Technologies	Raw Materials	Working Principles
1.	Steam Reforming	Natural gas, methanol	The catalytic chemical breakdown of natural gas (CH_4) into CO and H_2 (Synthetic gas/syn gas). It is usually performed at very high temperatures and pressure.
2.	Gasification	Coal, Biomass	Biomass is thermally degraded with a controlled amount of gasifying agent to prevent combustion. It can be performed catalyst or not
3.	Electrolysis	Water	Water is split into hydrogen and oxygen using an electrochemical reaction. Oxygen will be produced on the cathode side of the equipment.
4.	Dark/Light Fermentation	Simple organic acid	It is one of the biochemical methods to produce bio-hydrogen. This process needs microorganisms to carry out the fermentation process.
5.	Bio photolysis	Water	It is a sunlight-aided biochemical process of water to hydrogen production. Microorganisms will utilize light energy to split water molecules.

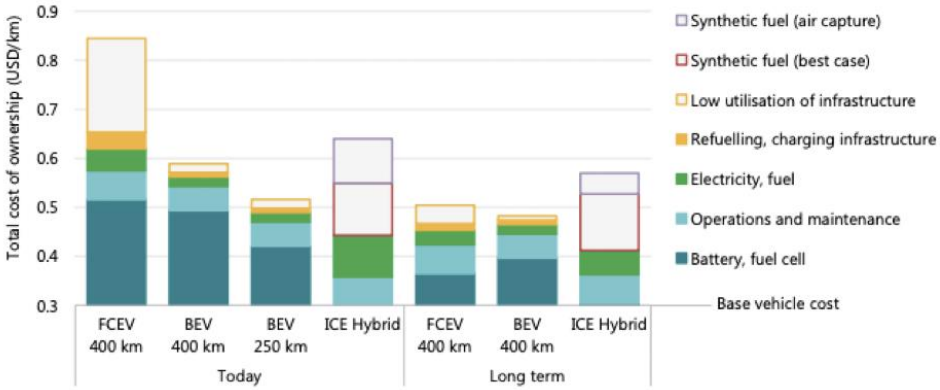
7.2.5.5. Economic and Environmental Aspects

Economical Comparisons to Other Fuels

Cost comparisons should consider the account alternative energy storage technologies such as electric batteries and gasoline. Costs associated with hydrogen production can be justified if it offers competitive energy storage options compared to other options. Due to the wide range of costs associated with various hydrogen feedstocks, it is exceedingly difficult to draw direct comparisons to gasoline or battery cells. However, several use cases and feedstocks are presented for illustration purposes.

Hydrogen has the potential to be used as a fuel cell in the transportation sector. In the United States of America, a 100-kilometer distribution distance is estimated to result in a delivered hydrogen price of US$7.5 – US$9/kgH2 (produced from natural gas with carbon capture and storage). In the United States, the price is roughly equivalent to US$1.1 to US$1.3 per liter of gasoline.

Hydrogen price competitiveness in use for the transportation sector can be evaluated in terms of vehicle total cost of ownership. A hydrogen fuel cell passenger car is currently more expensive than a battery-electric car. Fuel cells and fuel tanks are more expensive since hydrogen cars are designed to have long-range. Currently, the total cost of ownership for a hydrogen fuel cell vehicle (FCEV) is significantly more expensive than owning a battery electric vehicle (BEV) at 400km range. However, if fuel cells can be brought down to as little as US$50/kW along with the reduction in battery price, FCEV has the potential to be competitive with BEV at 400 km range



Notes: ICE = internal combustion engine. The y-axis intercept of the figure corresponds to base vehicle "glider" plus minor component costs, which are mostly invariant across powertrains. More information on the assumptions is available at www.iea.org/hydrogen2019.

Source: IEA 2019. All rights reserved.

Figure 7- 11 Comparison between Hydrogen and Other Fuels

Environmental Benefit and Considerations

As one of many available energy resources, hydrogen could produce both benefits and costs to the environment. Hydrogen has been seen as a clean source of energy since its combustion only produces harmless water. In achieving the full potential benefit of hydrogen, it must ensure a sustainable production process. As explained before, there are few ways of producing hydrogens, such as steam methane reforming using natural gas, gasification of coal and hydrocarbon, electrolysis, gasification of biomass, and nuclear power. Also, there has been rising attention to producing hydrogen from crude palm oil (CPO). To see the environmental impact of hydrogen production, it must incorporate the life cycle analysis, including the production input. This chapter will outline the environmental considerations for hydrogen according to its production method:

Table 7- 1 Hydrogen Production Method and Environmental Considerations

NO	Hydrogen Production Method	Environmental Considerations
1	Steam Methane Reforming using Natural Gas	CO_2 emissions due to burning natural gas activities Extracting and transporting natural gas could harm sensitive landscapes
2	Gasification of coal and other hydrocarbons	Coal mining could degrade land and water quality
3	Electrolysis using conventional grid or renewable power	Using electricity from renewable would produce low to zero emissions Using electricity from a conventional grid would generate more pollution compared to steam methane reforming with natural gas
4	Gasification of biomass	Feedstock should be sustainably cultivated, thus creating low to no net global warming emissions. Large-scale production of feedstocks could raise air, land, and ecosystem concerns.
5	Gasification of oil palm using supercritical water	Palm crops should be sustainably cultivated. The environmental problems of palm crop cultivation are deforestation, biodiversity loss, peatland conversion, land-use change, greenhouse gas emission, as well as air and water pollution.

7.2.5.6. Implementation Opportunity in Indonesia

The main objective of implementing a hydrogen energy system is to increase the efficiency and environmental performance of current or future power generation technologies. Indonesia's energy mix is currently dominated by coal, oil, and gas, accounting for 74% of its total energy supply [44]. Indonesia is also known as the world's leading Crude Palm Oil (CPO) producer, with 40.57 million tons of production in 2018 [45]. Despite the acknowledged environmental detriment of coal, the country possesses a large amount of coal and CPO potential that can sustain its short to medium-term economic growth. Therefore, these commodities are crucial and viewed as one of the leading national development capital to the Indonesian government. The hydrogen energy system can potentially eliminate the environmental disadvantage of energy production from such resources.

The hydrogen energy system can enhance the performance of the renewable system by acting as a medium to a large-scale storage system. A pilot project has been deployed to study the system, such as Baron Technopark, due to collaboration between BPPT and Toshiba [46]. The cost of renewable hydrogen is also expected to decline and become competitive with its fossil fuel counterpart [47]. By looking at the country's current state of reliance on fossil fuel and aggressive efforts to achieve a high share of renewable utilization, the hydrogen energy system can be a viable option to support a smooth transition.

Integrating hydrogen energy systems at the regional energy system level necessitates a thorough examination of various factors. The types of available resources and existing power generators in the region may dictate whether or not the hydrogen system is feasible to install. For instance, the hydrogen system will be effective when a large amount of highly fluctuating renewable energy is available. With the rapid decline in the cost of technology, an increasing proportion of the energy mix will be supplied by wind and solar energy, highlighting the system's intermittency problem. Proper large-scale storage will then be required to avoid wasting the energy generated by the costly investment. CPO Additionally, hydrogen-producing regions can benefit from the system by dark fermenting Palm Oil Mill Effluent (POME) to generate hydrogen. Consider the size of the energy demand-supply system, as a more extensive hydrogen system, will be more economical [48]. Due to the hydrogen system's ability to store energy over a longer period with minimal losses in the form of LOHC or ammonia, it can also assist in resolving seasonal energy balance issues [49]. Compared to battery storage, the system requires more installation components and is more complicated to install and operate. Laborers with a higher level of skill may be required to maintain the system.

Hydrogen has a flexible utilization method, either converting it to electricity using fuel cells or direct combustion to produce power. Due to its flexibility as an energy carrier, hydrogen has been adopted by EU countries in their energy mix. The hydrogen-natural gas blend can directly utilize the existing gas distribution network to transport hydrogen for residential and industrial uses. Implementation in Indonesia might be more challenging compared to EU countries. Indonesia has limited and Java-centric gas distribution network infrastructure-until recently, city gas infrastructure was developed in Prabumulih, Sumatera [50]. Hydrogen implementation outside Java Island will require a high amount of capital to construct new facilities and a gas distribution network. Alternatively, the renewable electricity can be converted to DME [51], [52] allowing it to be stored and blended with LPG gas and use existing infrastructure for distribution. By using DME as a medium to store energy potentially lowers the overall investment that is needed. Households will also easily adapt to the system without having to acquire new hardware.

The majority of a renewable energy project in Indonesia belongs to small to medium-sized planned generation capacity scale. Many of these projects are located outside Java Island by utilizing the available local energy resources to fulfil the local demand. Unlike battery energy systems with characteristics of very flexible sizing, instead of lowering the final energy cost, the hydrogen system could economically burden the system if the capacity is too small. Further looking at the limited infrastructure in Indonesia's case, developing hydrogen transmission and distribution or strengthening the regional grid is a dilemma. For small to medium scale, integrated onsite production and storage can be an obvious solution. When the energy system's scale is larger, stronger electricity grids will be essential to balance the supply and demand of energy between regions. Finally, the resources and capital to build economically and socially sustainable renewable energy systems are not limitless and need to be used efficiently, especially in current pandemic situations.

7.3. Case study

7.3.1. East Nusa Tenggara

7.3.1.1. <u>Solar Resources in East Nusa Tenggara</u>

Indonesia has several areas with potential solar energy sources (receiving very high radiation energy per m², such as East Nusa Tenggara, which has an average GHI intensity of 5.15 kWh/m2. The distribution map of solar potential is shown in Figure 7- 12 .

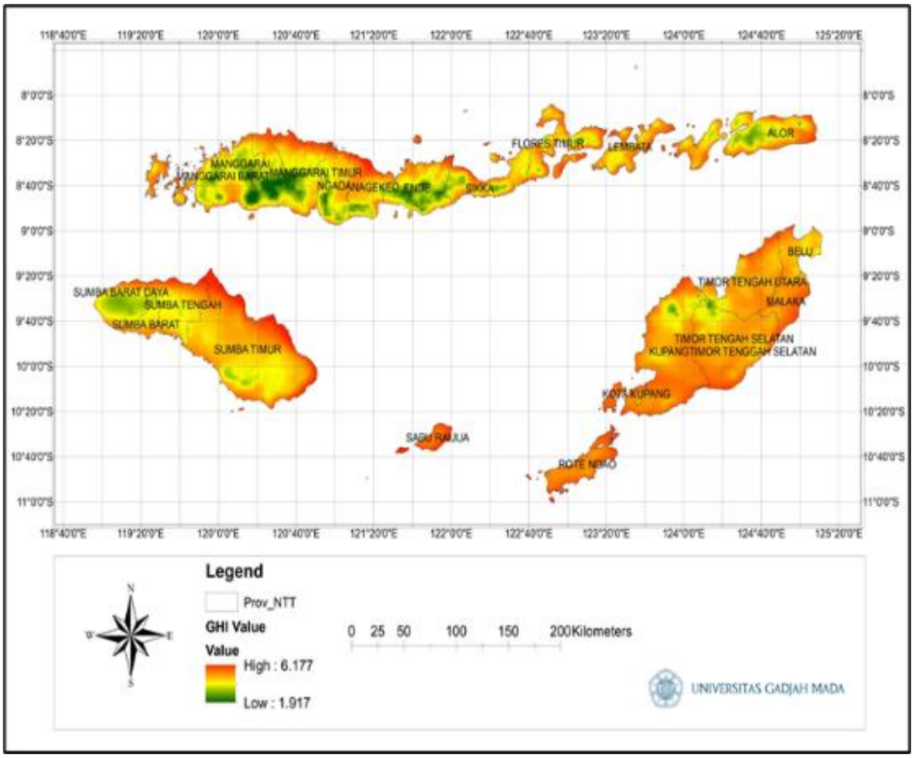


Figure 7- 12 Distribution Map of GHI Intensity (kWh/m2) in East Nusa Tenggara

7.3.1.2. Wind Resources in East Nusa Tenggara

Wind energy potential studies and measurements have been conducted by non-departmental government agencies (LAPAN, BMKG), local governments, and international institutions/companies. East Nusa Tenggara has an average wind speed of 4.62 m/s, as determined by measurements. The value of WV (Wind Velocity) is used to calculate the area's potential, which is defined as an area with a cutoff of greater than 5 m/s, as illustrated in Figure 7- 13 :

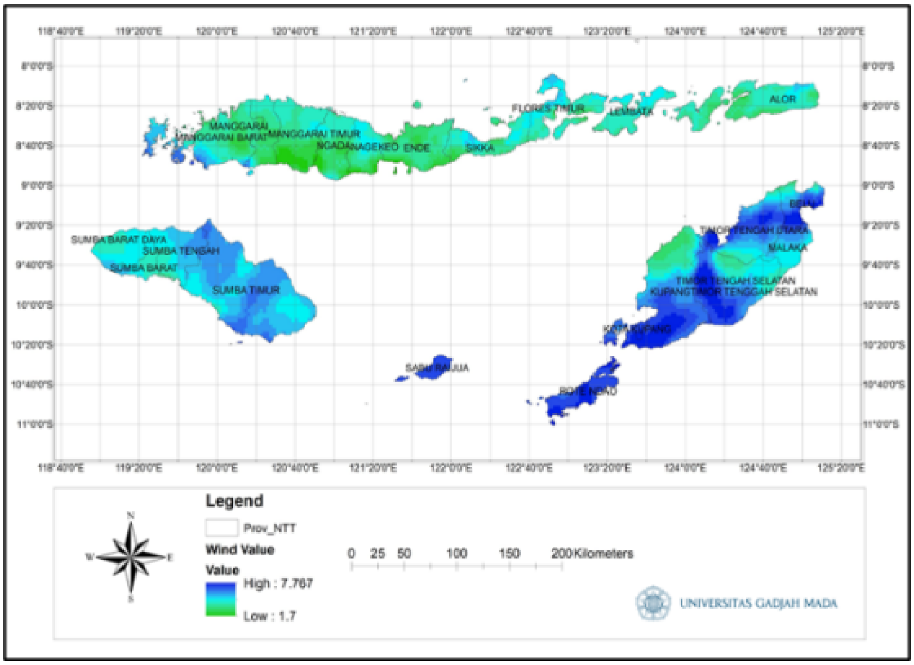


Figure 7- 13 Distribution of Wind Speed Intensity (m/s) in East Nusa Tenggara

7.3.1.3. Geothermal Resources in East Nusa Tenggara

Geothermal data refers to the 2017 Annual Report of the Ministry of Energy and Mineral Resources (Vol. 1 and 2), which states that East Nusa Tenggara Province has a geothermal potential of 1201 MWe in 28 locations, and Wae Sano Geothermal has the most extensive geothermal potential energy of 106 MWe.

7.3.1.4. Hydro Resources in East Nusa Tenggara

Meanwhile, East Nusa Tenggara Province has a water potential of 516 MW spread across 22 districts in East Nusa Tenggara. East Manggarai Regency with 102 MW of energy is the largest hydropower potential compared to 21 other districts.

7.3.1.5. Regulations Related to the General Plan of Energy for the Region of East Nusa Tenggara

East Nusa Tenggara (NTT) Province has a Regional Energy General Plan as outlined in the NTT Province Regional Regulations No. 10 of 2019 concerning the Regional Guidelines for the Regional Energy General Plan for the Province of NTT for the year 2019-2050, which was promulgated on October 15, 2019. The NTT Regional Energy General Plan-P contains policies, strategies, plans, programs, institutional and fiscal policies for the development of the energy sector in the 2015-2050 period.

In general, the modelling in the Regional Energy General Plan-P NTT shows the target of the primary energy mix in 2025 with a portion: 24% from New and Renewable Energy, 12% from coal, 10% from natural gas, and the remaining 54% from petroleum. As for the year 2O5O, it is targeted to achieve a mix with portions: 39% from New and Renewable Energy, 16% from coal, 14% from natural gas, and the remaining 31% still uses petroleum. Furthermore, in terms of quantity, the absolute value of the total primary energy supply in 2025 for NTT Province is estimated at 2.6 MTOE, producing 1 GW of electricity generation with the proportion of NRE around 0.54 GW. Meanwhile, for the year 2O5O, it is estimated that it will be 8.3 MTOE, which will produce a generator of 4.24 GW with a portion of NRE around 2.24 GW.

The above targets are distinct from the national energy mix target set forth in Article 9 letter f of the Governmental Regulations on National Energy Policy, which is as follows: new and renewable energy at a minimum of 23% in 2025 and 31% in 2050; petroleum at less than 25% in 2025 and less than 20% in 2050; coal at a minimum of 30% in 2025 and 25% in 2050; and natural gas at a minimum of 22% in 2025 and 25% in 2050. On the plus side, NTT province appears optimistic about the development of RE in its region, as evidenced by the province's targeting of a higher RE portion than the national target. Additionally, New Renewable Energy is being pushed to become the dominant source of electricity generation in NTT.

The NTT Regional Energy General Plan contains regional energy policies and strategies, which are defined as follows:

Table 7- 2 East Nusa Tenggara's Regional Energy General Plan

No	Policies	Strategies
Main Policies		
1	Energy availability	• Increasing the exploration, potential, and/or proven reserves of RE • Increasing the energy production and energy resources in the country and/or from external sources • Improving the reliability of energy production, storage, and distribution systems • Ensuring the carrying capacity of the environment and the capacity to accommodate the availability of energy sources • Prioritizing the land for energy if there are conflicts over land use • The exploration of New and Renewable Energy is still in good and correct ways • Developing and utilizing the technology in energy utilization, including preparation of energy reserves, both infrastructure and human resources • R&D
2	Regional energy development priorities	➢ Developing the Geothermal RE ➢ Developing RE micro / mini hydro ➢ Developing the solar RE ➢ Developing the Wind RE ➢ Developing the RE bioenergy ➢ Developing ocean currents RE

No	Policies	Strategies
3	Energy resources utilization	• Developing the Geothermal RE to support the construction of smelters and other infrastructure • Developing the New and Renewable Energy micro / mini for rural areas • Developing the solar RE for the provision of energy for rural communities, public facilities, as well as integrated marine and fisheries centers • Developing the wind RE for energy supply in coastal and rural areas • Developing RE bioenergy for household electricity • Developing the marine current RE for industry and rural electricity
Supporting Policies		
1	Conservation and diversification	• Conservation of energy resources is carried out with a cross-sectoral approach, at least through adjustments to provincial spatial planning and environmental carrying capacity • Energy conservation and efficient management of energy resources • Energy conservation in the industrial sector is carried out by considering the competitiveness • Local governments establish guidelines and implement energy conservation policies, especially in the field of energy-saving • Regional Governments following their respective authorities are obliged to carry out energy diversification to improve the conservation of energy resources and regional energy security

7.3.2. West Nusa Tenggara

7.3.2.1. Solar Resources in West Nusa Tenggara

Indonesia has several areas with potential sources of solar energy that receive very high radiation energy per m2, such as West Nusa Tenggara, which has an average GHI intensity of 4.92 kWh/m2. The distribution of solar energy potential is shown in Figure 7- 14 .

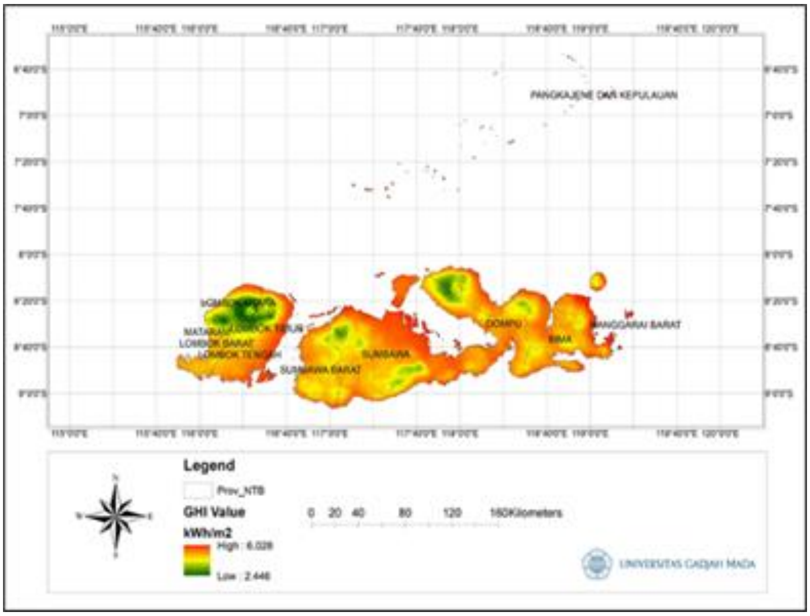


Figure 7- 14 GHI Intensity Distribution Map (kWh/m2) in West Nusa Tenggara

7.3.2.2. Wind Resources in West Nusa Tenggara

Studies and measurements of wind energy potential have been carried out, both by non-departmental government agencies (LAPAN, BMKG), local governments, and foreign institutions/companies. Based on the measurements, it is known that West Nusa Tenggara has an average wind speed of 4.74 m/s.

The WV (Wind Velocity) value is used to calculate the area's potential, defined as an area with a cutoff of greater than 5 m/s, as illustrated in Figure 7- 15 .

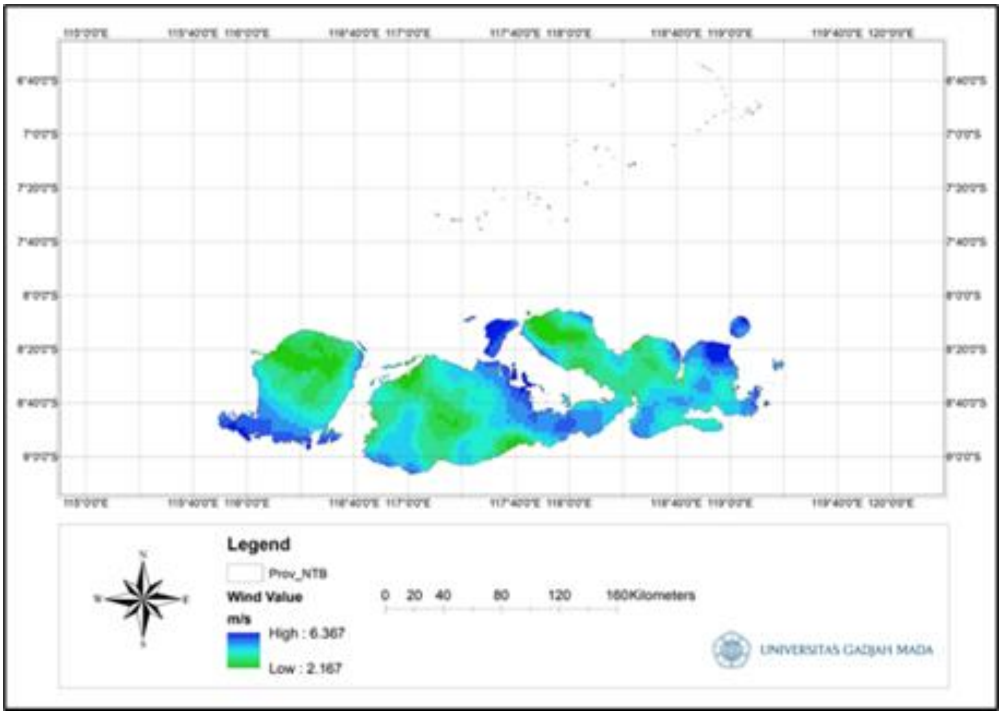


Figure 7- 15 Distribution of Wind Speed (m/s) in West Nusa Tenggara

7.3.2.3. Geothermal Resources in West Nusa Tenggara

Geothermal data refers to the 2017 Annual Report of the Ministry of Energy and Mineral Resources (Vol. 1 and 2), which states that West Nusa Tenggara's Province has a geothermal potential of 175 MWe consisting of 3 geothermal locations, namely the Sembalun Geothermal energy of 100 MWe.; Marongge geothermal energy of 6 MWe; and Huu Geothermal - Daha energy of 69 MWe.

7.3.2.4. Hydro Resources in West Nusa Tenggara

West Nusa Tenggara Province has a water potential of 240 MW spread over ten districts. Sumbawa Regency has the largest hydropower potential compared to other districts, which is 73 MW.

7.3.2.5. Regulations Related to the General Plan of Energy for the Region of West Nusa Tenggara

West Nusa Tenggara (NTB) Province has a Regional Energy General Plan detailed in the NTB Province Regional Regulations No. 3 of 2019 on the Provincial Regional Energy General Plan, promulgated on May 9, 2019. The Regional Energy General Plan's strategic value stems from its role as a guide in providing direction for energy management in the Region up to 2050 while remaining consistent. The General Plan serves the following purposes:

1. Reference in the preparation of regional development planning documents
2. Reference in the preparation of RUKD and RUPTL
3. Reference in preparing Local Government Budget
4. Guideline in the preparation of Provincial and Regency / City Strategic Planning
5. Guideline for LGs to coordinate energy planning across sectors
6. Guideline for the community to participate in the implementation of energy development in the regions

The NTB Regional Government determines that the use of RE is prioritized in underdeveloped areas, remote areas, and rural areas. This area has a mission to encourage RE and the Energy Independent Village (DME) formation. The Regional Energy General Plan-P NTB aims to develop rural electricity to increase the electrification rate of currently unconnected households to 27.33%. The development of off-grid electricity was chosen as a solution, focusing on developing MHP and small-scale Wind Power Plant and individual household electrical systems that use the Solar Home System (SHS). Furthermore, the NTB Regional Government generally targets the New and Renewable Energy contribution to reach 35% in 2025 and 50% in 2050 of the regional energy mix targets for utilization in the power generation sector. The activities set out to achieve the development goals of New and Renewable Energy above include:

1. Providing land for the development of the New and Renewable Energy installation in accordance with the RTRW
2. Developing guidelines for the provision of energy subsidies by the Regional Government whose budget is allocated in the Local Government Budget
3. Budgeting for New and Renewable Energy infrastructure development in a sustainable manner for villages that will not be electrified in the long term

4. Involving national infrastructure financing institutions to finance the New and Renewable Energy development project
5. Developing a New and Renewable Energy-based small power system for electricity supply in areas not covered by grid expansion.

The NTB Regional Government plays its role in supporting the development of RE by allocating a budget for programs and activities that are entirely derived from the following Local Government Budget:

Table 7- 3 West Nusa Tenggara's Regional Energy General Plan

Programs	No.	Activities	Locations
Formulation of policies for the use of solar energy	1	Formulation of policies regarding the obligation to use solar energy from rooftop on-grid solar power plants for central and local government office buildings	North Lombok Regency, West Lombok Regency, Mataram City, Central Lombok Regency, East Lombok Regency, West Sumbawa Regency, Sumbawa Regency, Dompu Regency, Bima City and Bima Regency
	2	Formulation of policies regarding the obligation to use solar energy from rooftop on-grid Solar Power Plants for luxury houses, hotels, apartments through the issuance of building permits (IMB)	
	3	Formulation of policies for the development of Green Energy Villages that Support the Development of Samota (Saleh Bay-Moyo Island-Mount Tambora)	Sumbawa Regency
	4	The formulation of policies by the regency/city government regarding the provision of land for the development of new and renewable energy sources (approximately 10,000 Ha in 2025 and 25,000 Ha in 2050)	North Lombok Regency, West Lombok Regency, Mataram City, Central Lombok Regency, East Lombok Regency, West Sumbawa Regency, Sumbawa Regency, Dompu Regency, Bima City and Bima Regency

7.3.3. East Kalimantan

7.3.3.1. Solar Resources in East Kalimantan

Indonesia has several areas with potential sources of solar energy that receive very high radiation energy per m2, such as East Kalimantan, which has an average GHI intensity of 4.5 kWh/m2, as shown in Figure 7-1.

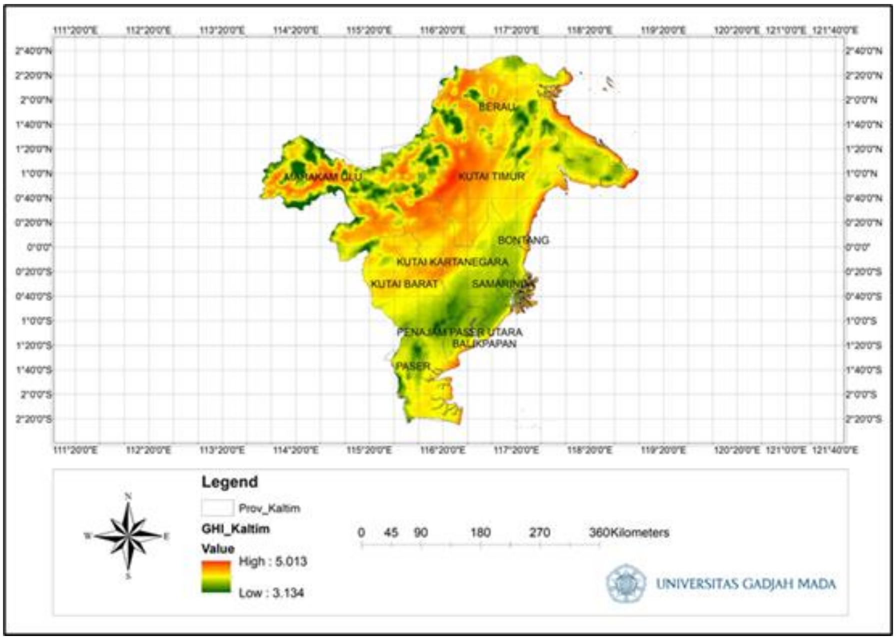


Figure 7-1 GHI Intensity Distribution Map (kWh/m2)

7.3.3.2. Wind Resources in East Kalimantan

Wind energy potential studies and measurements have been conducted by non-departmental government agencies (LAPAN, BMKG), local governments, and international institutions/companies. East Kalimantan has an average wind speed of 3.78 m/s, as determined by measurements. The value of WV (Wind Velocity) is used to calculate the area's potential, which is defined as an area with a cutoff of greater than 5 m/s, as illustrated in Figure 7-2.

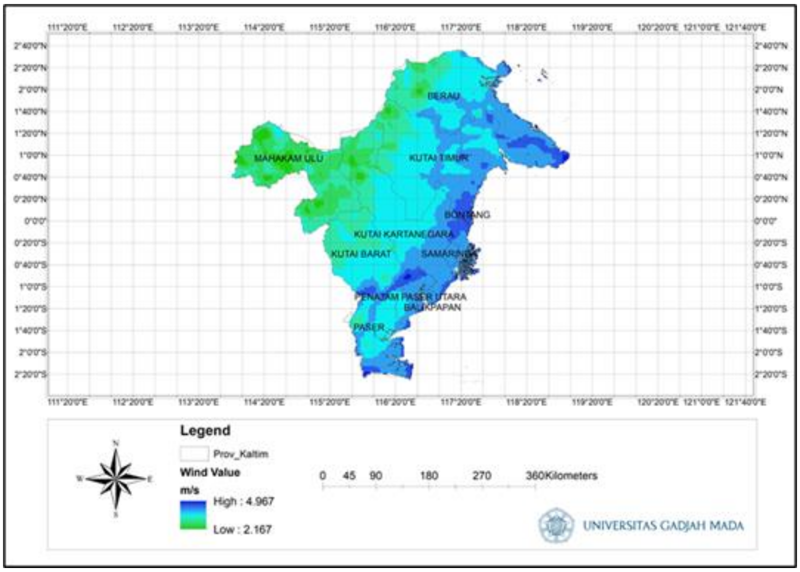


Figure 7-2 Distribution of Wind Speed (m/s) in East Kalimantan

7.3.3.3. Geothermal Resources in East Kalimantan

East Kalimantan Province has a geothermal potential of 17 MWe, consisting of 2 geothermal locations, namely Batuq River Geothermal energy of 7 MWe; and 10 MWe of Dondang geothermal energy, referring to the 2017 Annual Report of the Ministry of Energy and Mineral Resources (Vol. 1 and 2).

7.3.3.4. Hydro Resources in East Kalimantan

East Kalimantan Province has a water potential of 9529 MW accumulated from 10 districts in East Kalimantan. Mahakam Ulu Regency was selected as the largest hydropower potential compared to 9 other sub-districts, which amounted to 6187 MW.

7.3.3.5. Regulations Related to the Energy General Plan for East Kalimantan Region

The Province of East Kalimantan (Kaltim) has a Regional Energy General Plan outlined in the Regional Regulations of Kaltim Province No. 8 of 2019 concerning the Regional Energy General Plan, which was promulgated on November 6, 2019. This Regional Energy General Plan is binding for a period until 2050 and has strategic value as a document that:

1) becomes a reference in the preparation of regional development planning documents
2) becomes a reference in the preparation of RUKD and RUPTL

3) serves as a reference in preparing the Local Government Budget
4) serves as a guideline for Regional Apparatus to compile Strategic Planning and coordination of energy planning across sectors
5) serves as a guideline for the community to participate in the implementation of development in the energy sector

Partisanship for the development of RE has been explicitly stated in Article 5 section (4), which gives the Regional Government an obligation to increase the provision of RE. However, the priority is directed to underdeveloped, remote, and rural areas. This can still be managed and directed to increase the share of RE still because Article 8 section (2) has emphasized that the Regional Energy General Plan program is prioritized to increase the role of New and Renewable Energy in the energy mix targeted at 12.39% in 2025. and 28.72% in 2050.

The source of RE used in East Kalimantan Province to date comes from sunlight, water flow, palm oil mill effluent, and cattle livestock waste. However, its utilization is still limited to providing electricity at the household and village scale, especially in residential areas that the electricity distribution network of PLN has not reached. This area also manages palm oil (CPO) mixed with fuel oil. It needs integrated efforts and the political will of the local government to increase the share of RE and develop its utilization in the broader scope. Moreover, there are nine strategies selected and stipulated in the Regional Energy General Plan-P of East Kalimantan to increase the use of RE together with EB, namely as follows:

1) Increasing the potential exploration for New Energy and RE, with the program for improving data quality on potential New and Renewable Energy.
2) Enhancing the utilization of solar energy with the Solar Power Plants development program.
3) Increasing the utilization of municipal waste with the Garbage Power Plants development program.
4) Developing the utilization of Biogas with the Biogas Power Plant development program and the development of biogas as a substitute for mini/LPG for the household sector.
5) Raising the use of wind energy with a Wind Power Plant development program.
6) Intensifying the Biomass Utilization, with Biomass Power Plant development program.
7) Developing the small-scale water energy, with the development program of Micro-hydro/Mini-hydro Power Plant Development.
8) Increasing the use of biofuels with a biofuel utilization program.

9) Encouraging the use of coal methane gas fuel with a coal methane gas fuel utilization program.

Appendix II of the East Kalimantan Regional Energy General Plan elaborates the above strategies in the table below:

Table 7- 4 East Kalimantan's Regional Energy General Plan

No.	Strategies	No.	Actions	Fundings
1	Increasing the exploration of new and renewable energy potential	1	Inventory and mapping of potential water energy, biomass, bioenergy, solar energy, wind energy in East Kalimantan Province	APBN, APBD
		2	Study of options for using new energy in East Kalimantan Province	APBD, APBN
2	Increasing the utilization of solar energy	1	Socialization of on-grid rooftop solar energy utilization for government buildings, public facilities, luxury houses, hotels, and apartments.	APBD
		2	Socialization on the use of rooftop solar energy on-grid PLTS for luxury houses, hotels, apartments.	APBD
		3	Construction of rooftop PLTS on-grid for Government Buildings, public facilities, luxury homes, hotels, apartments	APBN, APBD, Private
		4	Construction of PLTS on the grid with a target total capacity of at least 19 MW in 2025 and 175 MW in 2050 in locations adjacent to the substation built by PT. PLN (Persero).	APLN, APBN, APBD, Loan
		5	Construction of Solar Home System (SHS) and off-grid Communal/Centralized PLTS with a total capacity of at least 1 MW in 2025 and 25 MW in 2050 for remote areas that PLN services and small islands have not reached.	APBN, APBD, CSR Fund
3	Increasing the utilization of municipal waste	1	Construction of PLTSa with a target total capacity of at least 1 MW in 2025 and 50 MW in 2050	APBN, APBD, Loan
4	Increasing wind energy utilization	1	PLTB development with a target in areas that have wind power potential	APBD, APBN, Loan
5	Increasing the biogas utilization	1	PLTBg development with a target in areas that have biogas potential in the plantation sector	APBD, APBN, Loan
		2	Biogas development for household-scale is at least 1200 units until 2025 and 2262 units until 2050.	APBD, APBN, Dana CSR
6	Increasing the utilization of biomass energy	1	PLTBm construction targets a total capacity of at least 216 MW by 2025 and 350 MW by 2050.	APBD, APBN, Loan
7	Increasing small-scale water energy utilization	1	Construction of on-grid PLTMH/PLTM with a target total capacity of at least 3.5 MW in 2025 and 70 MW in 2050	APBN, Private
		2	Construction of off-grid PLTMH/PLTM with a total capacity of at least 1.5 MW until 2025 and 55	APBD, APBN,

No.	Strategies	No.	Actions	Fundings
			MW until 2050 for remote areas that PLN services have not reached	Private, CSR Fund
8	Increasing the use of biofuels	1	Formulation of government policies related to the use of biofuels in the land transportation sector (cars, buses, and trucks) and sea transportation, including fishing boats	APBN
		2	Dissemination of Government policies related to the use of biofuels in the land transportation sector (cars, buses, and trucks) and sea transportation, including fishing boats	APBN, APBD
9	Utilizing the coal methane gas fuel	1	Diversification of the use of gas-fired power plants (PLTG) using coal methane gas.	Private

8. CONCLUSIONS AND RECOMMENDATIONS

The local government's role is critical to leverage local resources to meet the RE transition target. Numerous factors contribute to this sense of urgency, including the following: 1) energy inequality, which necessitates long-term infrastructure and institutional solutions; 2) regional renewable energy sources, which are distributed in nature and thus require different technologies and governance than fossil energy sources; and 3) trends in the economic value of renewable energy and energy storage technologies, which are improving over time, combined with a flexible implementation scale. Alternative business models that provide additional space for local governments are required to play their role in the RE ecosystem effectively. PSE-UGM has conducted a comprehensive interdisciplinary study in engineering, economics, and law to bridge the divide.

Technical analysis shows that Indonesia has sufficient RE resources with 26,321 MW of hydropower potential, 1,125 MWe of geothermal, 3,850 GW of wind, and 122 GW of solar. In addition, Indonesia also has biomass potential, especially in oil palm-producing areas. The choice of RE technology in an area needs to pay attention to the potential conditions, topography, infrastructure, economy, and the appropriate system complexity. Depending on the capacity, RE generators can be integrated either in the transmission, distribution network or through an off-grid (independent) scheme. The primary integration constraints will be encountered when intermittent RE sources are carried out on a massive scale. This is due to the limited ability of the national electricity network to absorb fluctuating RE electricity. Therefore, the introduction of regional character and the readiness of the national grid becomes the main priority in the success of the RE integration.

The transition to RE has the potential to generate economic benefits, both tangible and intangible, that far outweigh the investment required. These benefits are apparent after the RE targets are met and throughout the transition period. New economic activities can emerge and contribute to national and local value creation. The government has aided in the development of RE by providing various incentives and facilities. For instance, tax holidays and relief, as well as duty exemptions on components supporting the RE industry.

Local governments' capabilities and limitations in RE management are influenced by various factors, including the concept of decentralization in RE regulations, management authority, and flexibility in developing regional RE regulations. Based on the analysis from the regulatory perspective, the role of local governments in accelerating the energy transition is to make PERDA for the establishment of BUMD and investment in RE generators, make regional regulations that open up opportunities for cooperation, and formulate incentives for reducing regional taxes/retributions. Additionally, the KEN Regional Government must provide subsidies and receive a portion of the NRE economy to work on. The 2005-2025 RPJMN Law also requires hybrid power plants, which are included in the RE generation technology. The mandate to employ RE hybrid technology is bolstered further by Presidential Decree No. 61 of 2011 about RAN-GRK.

Collaboration between stakeholders is one of the keys to success in the RE transition at the local level. This collaboration can only be successful if all elements of both the main stakeholders (central government, local government, IPP, BUMD, financial institutions), secondary (legislative institutions, educational institutions, NGOs), and tertiary (religious organizations, traditional institutions, local communities). The synergy between the public and private sectors at the local level is also needed to form a resilient and self-reliant RE ecosystem. In addition to collaboration between institutions, strong coordination is also needed in the internal sphere of institutions. For example, the central government in its field needs to align the agenda between ministries. With the active role of all stakeholders, the burden of the energy transition will not be concentrated on one single entity, thus minimizing the potential for institutional bottlenecks to occur.

Various aspects are needed in selecting RE business models in an area so that the formed ecosystem can be self-sufficient, sustainable, and optimally in utilizing regional natural resources and human resources. There are four alternative business models developed in this study to increase the role of local governments.

1. An on-grid model in which the power plant is directly connected to the national electricity grid.
2. An off-grid model that is primarily used when the national electricity network is not economically viable.
3. A service business model that focuses on power plant support services, such as plant planning, management, and maintenance.

4. Aggregating a VPP business model based on the establishment of distributed generators to improve performance and efficiency.

Each business model necessitates collaboration between IPP and regional entities for knowledge to be transferred. Communities and local governments also contribute to RE activities, depending on the availability of natural resources. Hydrogen storage technology can also be used to help mitigate the resulting intermittent power supply. Thus, a robust regional RE ecosystem is expected to be established.

A review of three provinces (NTT, NTB, and East Kalimantan) demonstrates that the alternative models developed have the potential for successful implementation. The three provinces have an abundance of resources to meet local needs. NTB is concentrating its efforts on developing the manufacturing sector, which consumes a great deal of energy. NTT places a premium on the development of renewable energy in remote and rural areas. Meanwhile, East Kalimantan must transition away from the mining-based energy industry and toward a more sustainable renewable energy industry. Existing alternative models can be tailored to regional needs.

Strengthening the role of local governments in the RE ecosystem requires multidimensional efforts. From the studies that have been carried out, there are general points that can be recommended:

1. The selection of roles and business models or the RE ecosystem should be adjusted to the character of natural resources, human resources, and regional infrastructure.
2. The alignment of the national targets listed in the RUEN with each region's capabilities is needed to fulfill the RE target to be more harmonious and specific for each region.
3. It is recommended to develop the coordination between regions in RE development, mainly for RE sources that cover several areas in their development and operation.
4. Involvement of local stakeholders in the development and management of the RE ecosystem should be encouraged, be it BUMD, BUMDes, or other entities.
5. Affirmation of the role and authority of local governments in the development and management of local RE resources is needed.

6. RE development should be accompanied by the development of industrial ecosystems and supporting sectors to maximize the multiplier effect on the local economy.
7. Application of alternative energy storage technology is needed to anticipate massive intermittent RE adaptation, as well as to increase the absorption capacity of the National electricity grid.
8. Implementation in regional RE should not only focus on remote areas but also urban areas with consideration of infrastructure readiness and better economic capacity.

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ISBN 978-623-91932-2-5