Island Charging Concept in Archipelago of Indonesia

L H Sijabat¹ and E A Setiawan¹,²

¹Departement of Energy System Engineering, University of Indonesia, Kampus UI Depok 16424, Indonesia

Abstract. Indonesia's archipelago country has enormous diversity, and potential for renewable energy (solar and wind energy), one of which is located on Timor Island, East Nusa Tenggara Province, but the need to use energy is still minimal. This is due to the lack of welfare of the population, which results in low energy production. Here is a great opportunity for Timor Island to become a new force in developing renewable energy in an archipelago as island charging, which is even the largest in the world. Island charging is expected to increase economic growth for the region by creating new benefits for the islands around Timor Island, which have a wealth of natural resources by supplying the energy needs of the mining industry such as those on Wetar Island, Maluku Province. End of this concept is the Levelized Cost of Storage (LCOS) on the Mobile Energy Storage System (MESS), which is influenced by both land and sea modes of transportation.

1. Introduction

1.1. Problem in Archipelago of Indonesia

Archipelago country consists of large and small islands connected by waters and forming a geographical unit [1]. There are five large islands in Indonesia, including Java, Sumatra, Sulawesi, Kalimantan, and Papua, and thousands of other small islands with a total of 17,504 islands. Currently, electrification is still concentrated on large islands, and remote islands are still difficult to reach from the electricity provider managed by the State Electricity Company (PLN). It becomes a challenge in fulfilling 100% electrification, especially since the population density is uneven [2,3,4]. Besides, there are many mountains and highlands in Indonesia where the area is quite at risk being hit to disasters such as floods, landslides, volcanoes, and earthquakes. This geographical characteristic differs greatly from that of a continental country whose entire area island and is not connected by oceans so that it is very profitable in the use of fossil and nuclear energy, the existence of interconnection of electricity between countries or the network does not depend on one country alone and also the availability of long-distance transmission networks (super grid) which allows trading of high volumes of electricity across very long distances [5,6]. This causes the use of glasses with the electricity system belonging to this continental country to be unsuitable for an archipelago country like Indonesia because it causes inefficiency and ineffectiveness.

Although currently energy sources for generation are still dominated by fossil energy, Indonesia, as a country participating in the Conference of the Parties (COP-15), is committed to setting a new renewable energy development target of 23% by 2025 and 31% by 2050, according to with the
potential energy capacity that is scattered in various regions or other islands in Indonesia [7]. This potential needs to be utilized as much as possible to distribute electricity to islands that have abundant natural resources such as fisheries, mining, tourism, etc. Renewable energy technology is also growing, causing the cost of renewable energy from year to year to get closer to the ideal value that is ready to compete with the cost of electricity from fossil fuels. This can be seen from the decreasing movement of the learning curve, which is even predicted until 2030. It will continue to decline both the utility-scale photovoltaic and wind power based on the paper from Yi Zhou and Alun Gu [8] in figures 1 and 2. A continuously decreasing battery learning curve based on the Blomberg data in figure 3, a learning rate of around 18% and this means that for every doubling of cumulative volume, they observe an 18% reduction price [9]. This is why the Island Charging concept was initiated as a solution to the electricity problem in the Indonesian archipelago, which can also improve the surrounding population's economic welfare, which will be further explained in the case study of Timor Island, East Nusa Tenggara.

**Figure 1.** Learning Curve model fitting and scenario analysis of Wind Power investment cost reduction.

**Figure 2.** Learning Curve model fitting and scenario analysis of Utility-Scale Photovoltaics investment cost reduction.

**Figure 3.** Learning Curve model of Lithium-ion battery pack.
1.2. Scheme of Island Charging Concept

Figure 4 describes the supply chain on the movement of goods grouped into 5 groups based on the same activity and location. Group number 1 describes the utilization of renewable energy potential on an island in the form of wind turbines and photovoltaics built close to energy sources’ location. The two power plants will later distribute energy to various sectors in need, such as households, businesses, social and industrial groups. Two problems result from the construction of wind turbines and photovoltaics, namely intermittency and energy oversupply, which is wasted. So the Energy Storage System (ESS) is a solution to the above problems, especially since technology and reliability have increased [10]. So it is necessary to build an ESS Station by calculating the ESS configuration based on the planned capacity. This ESS will distribute electricity when wind turbine and photovoltaic experience intermittent and save electricity when there is an oversupply of energy in a wind turbine or photovoltaic. The ESS Station placement should be in a strategic location, taking into account the land's flat contours, free from flooding and free from landslides. Then, another problem arises if it turns out that the load on the island is small, but the potential for renewable energy is abundant. ESS can be relied on to supply electricity to outside the island or nearby islands with a wealth of natural resources or have economic content in them.

If you want to supply electricity outside the island, you need to determine the right method. There are two alternative methods of supplying electricity, first with a cable system and secondly with a system of transportation modes. In this paper's concept of Island Charging, the authors are more interested in distributions that utilize transportation modes (land and sea) than cable installations (air and underwater).

### Table 1. Capital Cost of

| Submarine Cable in Java-Bali (4.5 KM) |
|-------------------------------------|
| **Detail Work** | **Total Cost** |
| (USD) |
| Material Cost | 12,288,727 |
| Civil Work | 46,811,587 |
| Electrical Construction Cost | 4,852,698 |
| Survey & Commisioning | 646,987 |

The main reason for not using cable systems both air and underwater is the high capital costs, especially the cost of submarine cables (initial investment) [11] as shown in table 1 in the example of the case of 150 kV submarine cable installation that has been done in Java -Bali in Indonesia, not to mention the lengthy installation time for submarine cables (taking into account waves, currents, movement of sea sand), high Operation & Maintenance (O&M) costs especially for submarine cables and in air, cable distribution considering the topography of the local area ( slope), cumulatively uses much land on all tower tracks for air cables, plus the completion of land acquisition in Indonesia does not require a small amount of time. Finally, the absorption of labor (operation & maintenance) is small. In the transportation mode, all cable distribution problems are not found by distributions that use the transportation mode. It is just that the distribution method with this mode of transportation has a high
dependence on the means of transportation and is also influenced by weather factors. However, these are only external obstacles, which are statistically very rare. The electricity distribution that uses this mode of transportation is also called the Mobile Energy Storage System (MESS). The advantage lies in its flexibility and is very suitable to be applied in an archipelago country.

Group number 2 in Figure 4 describes electricity distribution activities using land transportation modes using heavy equipment such as cranes with loading/unloading functions and truck trailers carrying the ESS from the ESS Station to the port, which is then ready to be unloaded onto the ship.

Then group number 3 in figure 4 shows the ship and the amount of cargo that can be transported to the destination port where ship capacity, number, size of ESS and type of ships such as Landing Craft Tank (LCT) and Cargo will affect the productivity of transportation modes such as loading/unloading cycles both from in terms of time and cost. Furthermore, for group number 4 in Figure 4 is the main objective of the presence of the Island Charging concept, namely the creation of prosperity for energy-producing islands and energy-receiving islands will get benefits in the form of electricity which then in a domino effect will add new economic value to islands that receive electricity.

![Figure 4. Scheme of Island Charging](image)

Prosperity for the energy-producing islands comes from the addition of new business fields in trade and services to absorb local and national workers. For energy-receiving islands, of course, they will also get electricity supply to meet the main needs both in the fisheries, mining, plantation, and tourism sectors, which previously could not be developed due to energy constraints. It is hoped that an
increase in the economic cycle will occur, which will require electricity to support this sectoral business sector.

Finally, group number 5 in Figure 4 shows that if the MESS life cycles have run out, the recycling manager will then go to disposal (battery bank) to be prepared for the recycling process [12]. However, if the MESS is not recycled, it will be sent or collected by the producer depending on the initial sale and purchase agreement. The main products from battery recycling is lithium. In 2011, 73% of all recycled waste was obtained as secondary raw materials to be processed in the battery manufacturing process, and the rest that cannot be recycled will be discarded [13]. However, according to a 2020 report, the hydrometallurgical process can provide about 95% [14]. The recycled raw materials will be sent to the battery manufacturer for further processing by the manufacturer to produce cell batteries packed into modules and arranged in the form of shelves that are then wrapped into a container system called MESS.

This paper consists of 4 important parts, namely the first part contains an introduction which discusses the birth of the island charging concept, the second part is about the methodology on how to obtain and process the data, the third part is about to discuss and results regarding the potential of renewable energy on Timor Island which is intended as Island Charging and then the fourth part is a conclusion where the LCOS for MESS in the Indonesian archipelago needs to be studied further, especially on the components of sea transportation costs which can affect the overall MESS cost.

![Figure 5. Map of Timor Island, Nusa Tenggara Timur and Wetar Island, Maluku in Indonesia.](image)

2. Methodology

This paper's methodology is divided into 3 parts, namely the time and place of research, data collection methods, and input data. Research on Timor Island and Wetar Island's case study, shown in
Figure 5, was started by the author from September 2020 to the end of November 2020. The data collection method uses various literature studies such as maps, journals, and articles that can be accounted for, interviews with producers MESS to obtain more accurate data and energy potential data retrieval using Homer software [15].

The Input data in this case study is the division of the administrative area of Timor Island, which consists of 5 districts (Timor Tengah Utara, Timor Tengah Selatan, Belu, Malacca, Kupang) and 1 city (Kupang) [16]. Timor Island's area is around 30.74% of East Nusa Tenggara's area or 14,732.35 km2 with a population of 35.52% of the total population of East Nusa Tenggara, which is 1,907,963.55 people and the electricity production generated by Timor Island in 2018 is 572,511 MWh [17]. This is due to low energy production, which is directly proportional to the population's low welfare [18]. Wetar Island itself needs 90,000 KWh/day of electricity for the mining industry. Furthermore, it is necessary to consider the Levelized Cost of Storage (LCOS) as a consideration of the economic value of MESS [19]. However, the authors only relate the transport mode linkage as the greatest influence on the LCOS component of MESS.

3. Discuss & Results
The author from Homer's software obtained the energy potential with Global Horizontal Irradiation (GHI) and wind speed from January to December on Timor's island. Then the data were further processed with the results as in Figures 6 and 7. Here shows that the potential for renewable energy (photovoltaic and wind power) on Timor Island is superior to others, with an average value of 6.36 KWh/m2/day and 5.43 m/s, respectively. It can be seen in Figure 8a-8b regarding the schedule and configuration of MESS for the needs of the mining industry from 2021 to 2034 and enlarged in the figure for transportation of MESS in 2021 and 2022 each by 46 times with an average of 32,850,000 kWh per year electricity needs. 360 MESS units are stationed on Wetar Island to supply electricity to the mining industry with a planned capacity of 2 MWh.

![Solar Energy Potential](image)

**Figure 6. Solar Energy Potential.**
Furthermore, Island Charging using MESS needs to consider the correct formula for Levelized Cost of Storage (LCOS) like equation (1) as the key to success in island charging economics. The purpose of this LCOS is to determine all overall costs with details of capital costs, installation costs, operation & maintenance (O&M) costs, charging costs, transportation costs, replacement costs, and end of life costs, which are then compared to the cumulative energy generated by MESS under its lifetime with the modified formula like equation (2) [20-22].
Figure 8a. Schedule and Configuration of MESS from 2021-2034.

Figure 8b. Schedule and Configuration MESS from 2021-2021.
Where:

- **Capital Cost**: Design work, procurement, delivery & insurance of MESS (USD)
- **Installation Cost**: Installation or construction, start up and commissioning activities (USD)
- **O&M Cost**: The operating and maintenance cost can be divided into variable and fixed categories (USD)
- **Charging Cost**: Cost for energy to technology with energy (USD)
- **Transportation Cost**: Total of Land and Sea Transportation cost (USD)
- **Replacement Cost**: Aging MESS components (USD)
End of Life Cost: Disposal or Recycle Cost
Battery Capacity: the amount of electricity delivered by the ESS (KWh)
Number of Cycles: Number of full charge-discharge cycles before end of usable life (times)
Efficiency: Proportion of energy discharged over energy required to charge store (%)
DOD: Depth of Discharge (%)
DEG: Annual Degradation or Loss in usable energy capacity (%)
r: Rate at which future cost / revenues of technology are discounted (%)
n: Period (year)
N: Life Time (year)

4. Conclusion
Electrification planning must be based on the geostrategy for renewable energy development, namely utilizing every energy potential on an island (isolated) or at least close to an island with great renewable energy potential. There are 3 important factors in the concept of Island Charging, namely renewable energy, MESS, and transportation. Where these three factors are integrated and affect, especially for the MESS economy, which is calculated by LOCS, in the LCOS itself, the marine transportation mode component has a huge role with the priority scale compared to the MESS capital cost component when faced with the characteristics of an archipelago country like Indonesia.

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