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Analytical Study on Integrating Diesel and Solar Power Systems for Sustainable Energy Supply on Tello Island

Ni Putu Diva Iswarani[1], Aqiqah Amalia Nasir[2], Rijal Hakiki[3], Joni Welman Simatupang[4*]

[1,2,3]Environmental Engineering Study Program, President University, Cikarang, Indonesia
[4]Electrical Engineering Study Program, President University, Cikarang, Indonesia
***Koresponden email**: joniwsmtp@president.ac.id

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Abstract
Electricity problems encountered on a daily basis cannot be separated from the problem of high electricity prices and electricity shortages that still exist in several areas of Indonesia. This paper will analyse the renewable energy potential of Tello Island and the feasibility study of building a power plant, as well as the carbon offset that can be reduced by switching from fossil energy to renewable energy. The use of solar panels as a hybridisation of a diesel power plant will reduce the use of fossil fuels. Based on the economic analysis of the PLTS on Tello Island, it can be concluded that the initial investment cost for the design of the PLTS system on Tello Island was IDR 2,467,599,996. With an NPV of IDR 416,062,532 (>0), a B-CR of 1.17 (>1), a PBP of 1.45 (< investment period), which is 1 year and 5 months, and an IRR of 26%, it shows that the investment in solar power plants to be designed in the Tello Island building is feasible. Based on the automatic screening carried out on amdal.net, the electricity generated in one area only requires effort documents Environmental Management and Environmental Monitoring Effort (UKL & UPL), do not require AMDAL because the solar power plants built include low voltage. If it is assumed that the diesel power plants on Tello Island consume 60% of the electricity, the CO2 eq produced is reduced to 600 CO2 eq for the production of 750 kWh.
Keywords: *renewable energy, solar, power plant, tello island*

Abstrak
Permasalahan penggunaan energi listrik yang ditemui sehari-hari tidak lepas dari permasalahan tingginya tarif listrik dan kelangkaan pasokan listrik yang masih terdapat di beberapa wilayah di Indonesia. Tujuan dari penelitian ini adalah untuk menganalisis potensi energi terbarukan di Pulau Tello dan menganalisis studi kelayakan pembangunan pembangkit listrik, serta menganalisis *carbon offset* yang dapat dikurangi dari perubahan energi fosil ke energi terbarukan. Dengan menggunakan panel surya sebagai hibridisasi pembangkit listrik tenaga diesel maka penggunaan bahan bakar fosil akan semakin berkurang. Berdasarkan analisis keekonomian PLTS yang dilakukan di Pulau Tello dapat disimpulkan bahwa biaya investasi awal yang dikeluarkan untuk perencanaan sistem PLTS di Pulau Tello adalah sebesar Rp. 2.467.599.996. Dengan NPV sebesar Rp 416.062.532 (>0), B-CR sebesar 1,17 (>1), PBP sebesar 1,45 (< umur investasi) yaitu 1 tahun 5 bulan, dan IRR sebesar 26% menunjukkan bahwa Investasi pembangkit listrik tenaga surya yang akan dirancang di Gedung Tello Island layak dilakukan. Berdasarkan penapisan otomatis yang dilakukan, listrik yang dihasilkan di satu kawasan hanya memerlukan dokumen Upaya Pengelolaan Lingkungan Hidup dan Upaya Pemantauan Lingkungan Hidup (UKL & UPL), tidak memerlukan AMDAL karena PLTS yang dibangun termasuk tegangan rendah. Jika pembangkit listrik tenaga diesel diasumsikan mengambil 60% daya di Pulau Tello, maka CO2 eq yang dihasilkan akan berkurang menjadi 600 CO2 eq dalam menghasilkan 750 kWh.
Kata Kunci*: energi terbarukan, solar, pembangkit listrik, pulau tello*

1. Introduction

Electricity problems we encounter daily cannot be separated from the problem of high electricity prices and electricity scarcity that still occurs in several areas in Indonesia. Many areas in Indonesia are not yet covered by electricity and still rely on oil lamps or candles as a source of lighting. This of course will be a gap in the community, especially for those who live in remote areas and cannot be reached by electricity facilities. As an answer to this problem, PLN, as the largest electricity provider company, has built Diesel Power Plants in various remote areas in Indonesia. However, diesel as a power plant still requires fossil fuel as a raw material for making electricity. The principle of the diesel power plant is to produce electricity by converting primary energy into mechanical energy driving the generator, which is then converted by the

generator into electrical power. However, this process also raises other problems: waste, noise, cold water supply, and etc [1]. Fossil fuels presently meet all global energy needs to some extent. These Fossil Fuels should be slowly replaced by renewable energy sources because of their depletion rates and emission legislation [2].

In the face of escalating environmental concerns, the imperative to phase out power plants with deleterious effects on our ecosystem has never been more pressing. Embracing a sustainable paradigm, adopting renewable energy emerges as a beacon of hope. Moreover, this conscientious transition leads to a noteworthy reduction in carbon dioxide equivalent (CO2 eq) emissions, marking a pivotal step towards a greener, more sustainable future. Concerning Agenda 2030, renewable energy is aligned with SDGs number 7 about Affordable and Clean Energy and SDGs number 13 about Climate Action [3]. As one of the areas categorized as 3T, Tello Island relies on PLTD to provide electricity. Tello Island is an island located in the Nias Islands, South Nias Regency, North Sumatra Province. Tello Island has a circumference of only 14 KM and has 23 villages with one sub-district [4]. Over time, Tello Island has become one of the tourist destinations in the South Nias area. This development will of course be in line with other increasing needs, one of which is electricity.

The merger of traditional and renewable energy sources has emerged as a light of hope in the search for sustainable and efficient energy solutions. Energy from the sun can be considered the main source of all types of energy. It can be used by various techniques such as using sunlight to generate electricity directly or using heat from the sun as thermal energy using Photovoltaic (PV) cells [5]. Solar energy is environmentally friendly technology, a great energy supply and one of the most significant renewable and green energy sources [6]. Hybrid power systems, particularly those that combine diesel generators with photovoltaic (PV) technology, are a game changer on the way to cleaner, more dependable energy generation. Despite the high solar energy potential in Indonesia, the number of installed photovoltaic (PV) rooftops is relatively small [7]. This dynamic pair, which combines the destructive power of the sun with the dependability of fossil fuel, provides a compelling answer to the problems of energy access, cost-effectiveness, and environmental sustainability [8].

The ageless reliability of diesel generators is combined with the boundless potential of solar energy generated by PV panels in hybrid power systems. They solve the inherent intermittent nature of solar electricity while lowering the carbon footprint associated with diesel-only systems. This combination not only improves energy resilience but also lays the road for a more sustainable future in power generation.

2. Material and Methods

This research performed a simple literature study using several research papers about the potency and application of Renewable Energy in rural areas which have been conducted with several case studies. A literature study is a type of research in which the researcher gathers several books and periodicals pertinent to the issue and study goals [9]. Literature searches, both international and national, were carried out using the Google Scholar database using the Publish or Perish software. This research was conducted in three analyses: the first analysis was to find the solar energy potency in Tello Island; the second analysis was feasibility analysis to know the cost project from this project; and the third analysis was to find the amount of CO2eq that generated before and after the renewable energy implemented. Furthermore, from those analyses, this research will try to see the feasibility of building a solar power plant on Tello Island.

3. Results and Discussion

3.1. Solar Energy Potential

Solar energy is a type of renewable energy resource that has been extensively–scale developed and has full applications due to energy transmission limitations. Solar energy often provides the least-cost options for economic and community development in rural regions around the globe, while supplying electricity, and creating local jobs. PV projects in developing nations have provided a positive change in the lives of rural people [2]. Based on the data given by PLN the cost of the solar power plant is less than other power plants such as steam power plants, gas engine power plants, and diesel power plants. Solar power can save fossil energy and improve green energy and lifestyle [10]. By using solar panels as a hybridization of a diesel power plant, it will reduce the use of fossil fuels. Based on a few of the renewable energy options available, solar energy was selected as a new renewable energy source with an average irradiation of 4,709 kWh/m2 per day in Tello Island.

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Figure 1.
a. Residential Land use in Tello Island, b. Contour Profile in Tello Island, c. Area Plan Installation in Tello Island (insert)

The data above is residential land use area data which has an area of 879 m^2 out of a total island area of 14 km^2 or only around 0.004% of the total island area. Astronomically, Tello Island City is located at -00.050232° and 098.283123°. Tello Island is a lowland with an average altitude ranging from 2.48 - 54.56 meters above sea level. Contour appearance using Q-Gis software with Contour plugins. Meanwhile, for land use data, use Q-Gis with the open street maps plugin. Installation of Solar Panels on Tello Island will be focused on areas with flat contours to reduce installation costs and simplify maintenance. Based on the calculation the total area needed for the solar installation is 2666.67 m^2. The solar panel installation will be placed near the diesel power plant. The proposed areas are as follows in **Figure 1c.**

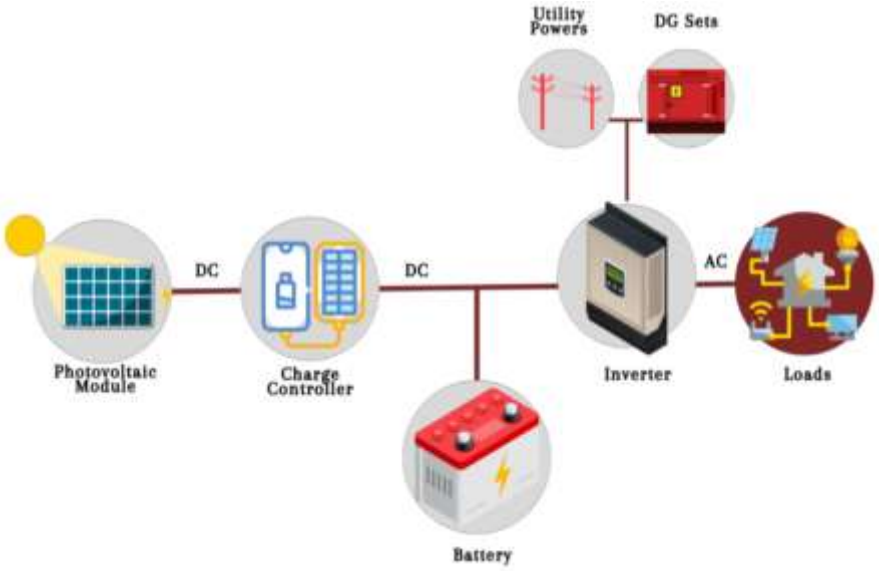

Figure 2. PLTS System [11]

Aside from that, seven elements of hybrid power systems need to be considered. The calculation for other solar panel support needs is done using the calculation from Guide Feasibility Study of Power Plant Centralized Solar Power (PLTS) by US AID [12]. The following is a more extensive description of these seven parts in the Tello Island hybridization power system construction plan:

1. **Fraction of Electricity Produced by PV System**
   The Polycrystalline Solar Panel was used for the solar panel with a maximum output power of 400 watts, the total panel is 479 units, and the efficiency of the solar panel is 15%.
2. **Total Amount of Battery Storage**
   The Battery with a specification of 24 Voltage was used, with a 4-battery series and the parallel is 40. Therefore, it is calculated that the amount of battery used is 157 units.

3. **Total Amount of Inverters**
   The inverters used with a specification of inverter type 5000 Watt and a voltage of 48 Vdc. and the total amount of inverters is 17 units.
4. **Area of Solar PV Plant**
   The total area or the field for the solar PV power plant is 2,666.67 m2.
5. **Hybrid Power System Configuration and Site Location**
   Considering the existing electricity system in Tello island as well as the most feasible site for the installation of a PV array, the HPS configuration or we could say the single line diagram (SLD) of HPS is designed to connect the existing Diesel Generators. The main reason for choosing the site location of the installed PV system is due to the nearest distance from the existing diesel power system. So, it makes it easy and low-cost to install.
6. **Load factor**
   To prove the solar PV that could generate all the customers in the island at least 90% the author will use the 1300 Volt-Ampere (VA) customers. The load factor is 58.04%.
7. **The Optimization of Hybrid Power System Operation**
   One of the primary goals of this HPS is to offer 24-hour power service for Tello Island with renewable energy. The increased use of renewable energy in the system is projected to reduce diesel fuel consumption, making the generation system more sustainable by lowering fuel reliance. As a result, the system's functioning finally maximizes the energy generation from the PV system. The battery banks are meant to sustain the operational generators when transient loads occur, such as significant abrupt demand from the consumer or a change in generating output, in normal operation.

3.2. Project Cost

The complete cost of building and establishing a solar energy-producing facility is referred to as the project cost of a solar power plant. It includes solar panels, inverters, mounting structures, labor, maintenance, and other components. The ultimate cost is determined by variables such as project size, location, technology, and regulatory concerns. Accurate cost assessment is critical for successfully planning and implementing a solar power plant project. The calculation for the cost is based on the calculation of daily energy use by the people is around 750 kWh. The solar panel is calculated and designed with 100% capacity to replace diesel power plants, however according to several studies solar power plants only have an efficiency of 40% - 60%. Therefore, so that electricity can be supplied in 24 hours, the use of solar power plants will be encouraged by the presence of diesel power plants. The following is an estimated project cost calculation that could potentially be employed to build a solar power plant on Tello Island. The following are the tools and materials used in building a solar power plant (asset calculation) along with the estimated budget used:

Table 1. Project Cost

Item(s)	Number of Units	Price per Unit	Total Price of Asset(s)
Solar Panels 400 wp	479	Rp2,400,000	Rp1,149,600,000
Battery 24 Volt 100 Ah	200	Rp3,000,000	Rp600,000,000
Inverter 5.000 watt	17	Rp5,600,000	Rp95,200,000
Mppt 80 A	50	Rp5,000,000	Rp250,000,000
Cables Nya 1.5 ml	10	Rp300,000	Rp3,000,000
Cables Nya 2.5 ml	100	Rp197,000	Rp19,700,000
Cables NyAf 4 mm	30	Rp300,000	Rp9,000,000
MCB DC 40A	8	Rp160,000	Rp1,280,000
MCB AC Inverter 40 A	5	Rp70,000	Rp350,000
Tape	15	Rp10,000	Rp150,000
Bolt	200	Rp500	Rp100,000
Boxpanel	5	Rp300,000	Rp1,500,000
Total Asset			Rp2,129,880,000
Net Working Capital (Operational and Management)			Rp337,719,996
Project Cost			**Rp2,467,599,996**

Table 2. Feasibility Test Result

NPV	IDR 416,062,532
IRR	26%
Payback Period	1.45
Benefit-Cost (B/C) Ratio	1.17

With an NPV of *Rp* IDR 416,062,532 (>0), a B-CR of 1.17 (>1), a PBP of 1.45 (< investment life) which is 1 year and 5 months, and an IRR of 26%, it shows that the PLTS investment that will be designed in the Tello Island Building is feasible. A thorough analysis and elaboration of key financial metrics such as Net Present Value (NPV), Internal Rate of Return (IRR), and other significant data may be found in elsewhere**.**

3.3. Price Comparison

One of the aims of this hybridization of power plants is to reduce the cost of electricity from the sole use of diesel as electricity. The following is a comparison scheme for the hybridization of diesel power plants and solar power plants. This price comparison is based only from the operational cost and not considering the development cost. The assumption of the electricity usage of each house is 25 kWh, and the price for each kWh for PLTS is IDR 2,028.36 and PLTD IDR 4,500/kWh.

Table 3. Price Comparison

PLTD	PLTS	Hybrid (60:40)
IDR 112,500	IDR 50,709	IDR 75,425

Based on the calculation of the electricity price scheme the electricity from PLTD is the highest with IDR 112,500. Meanwhile, the electricity from PLTS is the cheapest with IDR 50,709, but the Solar panels installed cannot meet the daily electricity needs of the people of Tello Island. So, a hybrid method is used with the electricity price that must be paid for each house being IDR 75,425. Where this price is still lower than using full PLTD.

Based on the price comparison the hybrid system of PLTS and PLTD will decrease the cost of electricity. So, it is more economically efficient rather than relying only on diesel power plants.

3.4. Electricity Payment Scheme

The electricity payment scheme calculation is carried out by assuming that each house uses 25 kWh with 1300 Volt-Amperes (VA) for each house. There are 2 schemes for the electricity payment scheme one is with the assumption of 60% subsidies from the government and the other one is without subsidies. For the one with subsidies, the electricity price is IDR 1.206,8/kWh and IDR 3.017/kWh for non-subsidies. The payment scheme can be seen in **Table 4.**

Table 4. Payment Scheme

Subsidies of 60%			
Subsidies	60%	IDR 75.425,4	IDR 45.255,24
Customer Tariff	40%	IDR 75.425,4	IDR 30.170,16
Price/kWh			IDR 1.206,8
Non-Subsidies			
Price/kWh			IDR 3.017

3.5. Environmental Analysis

In the construction of solar power plants, it is also necessary to pay attention to carbon which can be reduced by building solar power plants to replace diesel power plants. To produce 1.2 kWh diesel power plants, produce around 2.4 kg CO2 eq.

Table 5. CO2 Eq. Production

Items	CO2 Production		Unit
	PLTD	Hybrid PLTD 40% and PLTS 60%	
Total Power Energy	750	300	kWh
kWh/1 Liter fuel	1,2	1,2	kWh/L
Total Fuel Used	625	250	Liter
CO2 eq/1 Liter fuel	2,4	2,4	kg CO2/L
Total CO2 eq	1,500	600	kg CO2

Based on the case study the cost of fuel for PLTD is IDR 8,500/liter, to create 750 kWh/h it will need 625 Liters of fuel. The total cost of the fuel can reach IDR 5,312,500. This number is higher than the operation and cost that is needed with solar panels. This can reduce the fuel consumption by up to 375 liters of fuel. Using solar panels will reduce the cost of fuels, it can also reduce the CO2 eq from the fuels. Based on the calculation, the generation of 750 kWh of electricity can generate up to 1,500 kg CO2 eq in a day. By using a hybrid system, the CO2 emission can decrease to 600 kg CO2 eq in a day.

In building a power plant, several documents are needed to support the development. In the Standard Classification of Indonesian Business Fields, the construction of solar plants on Tello Island is included in the Generation, Transmission, Distribution, and Sales of Electric Power in One Business Unit number 35115. Based on the automatic screening carried out on amdal.net, power generated in one area only requires Effort documents Environmental Management and Environmental Monitoring Efforts (UKL & UPL), do not require AMDAL because the solar power plants built include low voltage.

4. Conclusion

We got five conclusions from this review and literature study paper as follows: First, based on the economic analysis of PLTS carried out on Tello Island, we can conclude that the initial investment costs incurred for planning the PLTS system on Tello Island were IDR. 2,467,599,996. With an NPV of *Rp* IDR 416,062,532 (>0), a B-CR of 1.17 (>1), a PBP of 1.45 (< investment life) which is 1 year and 5 months, and an IRR of 26%, it shows that the PLTS investment that will be designed in the Tello Island Building is feasible. Second, the Hybrid system to provide 24-hour electricity in Tello Island is more cost-friendly with IDR 75,425.4/house and if compared with full PLTD the price contribution is IDR 112,500/house. Third, one electricity payment scheme is with the assumption of 60% subsidies from the government and the other one is without subsidies.

For the one with subsidies, the electricity price is IDR 1.206,8/kWh and IDR 3.017/kWh for non-subsidies. Fourth, if the diesel power plants are balanced with new renewable energy which is assumed to take up 60% of the power on Tello Island, the CO2 eq produced will be reduced to 600 CO2 eq in a day. And the fifth, based on the automatic screening carried out on amdal.net, power generated in one area only requires Effort documents Environmental Management and Environmental Monitoring Efforts (UKL & UPL), do not require ANDAL because the solar power plants built include low voltage.

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