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Cost Benefit Analysis of Hybrid PV On Grid-Cold Storage Containers in Remote Areas of Indonesia

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***Abstract*— *Indonesia has a huge potential for fish resources, reaching 6.4 million tons annually. Cooling fish is one of the processes commonly used to treat fish spoilage. One of the popular types of fish cooling media is cold storage container (CSC). The reliability of the electricity supply for CSC is one of the obstacles in remote areas in Indonesia. Solar energy can be combined into Hybrid PV on the grid, potentially reducing CSC operational costs. Cost Benefit Analysis (CBA) is needed to assess the economic feasibility of the technology. This research was conducted by calculating athe investment and operational costs as well as studying the value of the benefits of implementing an On-Grid hybrid system with PV. The energy required for CSC operations is 30 kWh per day, and when the electricity supply is unreliable, it is 5 kWh per day. The energy produced in solar power plant is 25 kWh per day. The investment cost of the subsidy in this project is Rp. 539,556,000 and annual operating costs of Rp. 270,811,946. The NPV value reached Rp2,415,808,506.13; IRR of 16.15%; payback period of 8.56. The benefits obtained from implementing the PV On Grid hybrid system for the CSC project include CSC industrial production income, electricity cost savings from using PV On Grid, increasing business income in the fisheries sector, and energy reliability in supplying cold storage in remote areas.*

I. INTRODUCTION

The ocean is one of the most abundant sources of natural wealth. The vast marine area of Indonesia holds the potential wealth of marine resources that have not been explored and exploited optimally, some of which are not even known to their true potential. Although the data shows that the Indonesian ocean area has promising fishery potential, its utilization is still not optimal. This can be seen from the high poverty rate, especially in coastal areas [1]. Indonesian fish products are obtained from seawater and freshwater fishing. Indonesia's ocean area indicates very high diversity of fish species. This is tremendous potential if it can be utilized and managed correctly. The prospect of Indonesia's marine fishery resources reaches 6.4 million tons per year [2] and has the potential to support food security. Indonesia's marine wealth makes various parties tempted to take advantage of it. Not only local people but also foreign parties are also tempted to reap as much profit as possible from the potential of Indonesia's marine wealth. This is evidenced by the presence of foreign parties who are desperate to break through the national border area without official permission, only to secretly extract the natural wealth of Indonesia's oceans [3].

Fish is one of the sources of animal food, which has advantages such as having complete essential amino acid content, much-needed saturated fatty acid content, sufficient vitamin and mineral content and high digestibility. Besides that, fish is a highly perishable food product. Shortly after the fish are caught or die, the fish begin to experience a process of quality decline or deterioration, which is caused by three kinds of processes, namely pre-rigor mortis, rigor mortis and post-rigor mortis [4]. Judging from the external appearance, the flexibility of the fish flesh, the condition of the eyes, and the state of the gills and scales, the condition of the body or legs become parameters in assessing the level of physical freshness of fish. To maintain the freshness of the fish, a cooling process can be carried out to extend the shelf life of the fish. In tropical conditions, fish decompose within 12-20 hours [5], depending on the species, equipment or method of catching. The most important factor affecting the shelf life of this fish is storage temperature. Keeping fish at 0 to 2°C can extend storage before spoilage by up to 10 days compared to storage at 5°C [6]. At a temperature of 8°C, fish can be stored up to about two days, at a temperature of 5°C, it can last five days, while at a temperature of 1°C, it can reach 17 days [7]. Cooling fish is one of the processes commonly used to treat fish spoilage during catching, transportation, and temporary storage before being processed into other products. Thus, cooling media is needed to maintain the freshness of the fish for a certain time.

Fish cooling media was developed as a temporary storage place for fish with a certain temperature, one of the popular types is cold storage container (CSC) [8]. The reliability of the electricity supply for CSC is one of the obstacles in remote areas in Indonesia. On the other hand, solar energy is a renewable energy that is portable, clean, and environmentally friendly. Indonesia, located on the equator, has abundant solar energy potential throughout the year [9]. Solar energy can be combined with the grid into Hybrid PV (Photovoltaic) on the grid, reducing CSC operational costs. In addition, a Cost Benefit Analysis (CBA) [10] is needed to assess the economic feasibility of the technology.

Thus, CBA in a cold storage container system with an air blast freezer system powered by Hybrid PV on the grid is proposed in this study. The combination of solar energy with an electrical grid (Hybrid PV-on Grid) is expected to make electricity costs from CSC more economical, with adequate energy supply reliability for remote areas in Indonesia. The CBA technique is proposed to analyze the economic benefits of the proposed technology.

II. METHODS

This research has three framework stages, as shown in Fig. 1. This research uses analysis and explanation methods from primary/secondary data, questionnaires and observations as well as interviews with CSC producers, business actors and policymakers. This method is expected to produce beneficial findings and requires serious attention to various things deemed necessary to make changes in realizing energy and food security to support the stability of national security. The hybrid PV-on-grid system is expected to provide CSC energy efficiently. The on-grid system is used when the CSC is cooling (25 kW), and the PV system (5 kW) is used when the CSC stand-by maintains the temperature reached. Therefore, researchers can find out the usefulness of the PV - On Grid system in operating CSC to maintain fish quality to achieve food security. A research location is a place related to discussing research objectives or problems. It is also one type of data source, one of Indonesia's remote areas.

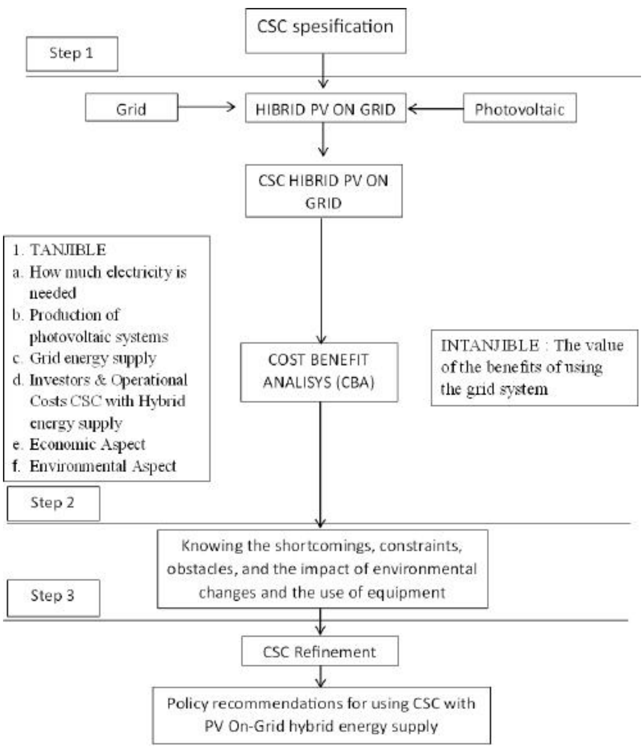


Fig. 1: Framework of hybrid PV on-grid cold storage containers

III. RESULT AND DISCUSSION

3.1 Cold storage container & PV-on grid hybrid system

The first stage of the research was conducted to determine the technical specifications of the CSC with a capacity of 20 feet with Hybrid resources (On-grid and PV) used as a storage area for specific products with a certain temperature and varying sizes/capacities, ranging from medium to large capacity. In this cold storage, a vapor compression refrigeration system is used. The components of the refrigeration system in cold storage are divided into two parts: the main components and the supporting components. The main components consist of a compressor, condenser, expansion device, and evaporator. The supporting elements are the liquid receiver, solenoid valve, sight glass, filter dryer, thermostat, oil separator, evaporator pressure regulator (EPR), accumulator and high-low pressure.

The refrigeration system has a cooling medium referred to as refrigerant. Refrigerant is a fluid that acts as a cooling medium that absorbs heat from the material to be cooled and dissipates heat to the outside air. Refrigerant is known as cold fluid, freon, CFC, HCFC, HC, and HFC. The refrigerant requirements are non-toxic, odorless in all circumstances, non-flammable, non-destructive to the environment, non-corrosive, easy to detect in case of leakage, and can mix with other materials but no reaction occurs, and have good chemical stability [11]. This study uses CSC due to the container's flexibility which can be built in one place and can be moved easily. According to its benefits, especially in supporting the economy, fisheries, defense and during natural disasters as a storage aid for supplies during the emergency response period for food that fresh in maintaining nutritional needs as well as an emergency power source, the design of CSC as the object of research is shown in Fig. 2. Specifications of 20 ft refrigerated containers are shown in Table 1.

Fig. 2: Cold storage container

While the source of CSC electricity is obtained from hybrid PV and Grid power, Photovoltaic (PV) systems are used to utilize solar energy in remote areas of Indonesia. The on-grid method provides electrical energy when the PV system does not produce optimal energy, such as during the rainy season [12]. Hybrid PV (Photovoltaic) on the grid is expected to provide technical and economic benefits for coastal communities in remote areas of Indonesia.

Table.1: CSC specification

Internal dimension	**Door Opening**	**Weight**	**Load Capacity**
Length: 5,455 mm 17 ft 10.76in Width: 2,290 mm 7 ft 6.16in Height: 2,262 mm 7 ft 5.06in	Width: 2,290 mm 7 ft 6.16in Height: 2,227 mm 7 ft 3.68in	Weight Max Gross: 24,000 kg 52,910 lb Tare: 2,960 kg 6,530 lb Max Payload: 21,040 kg 46,380 lb	28.3 m^2 998 ft^2

During the operational period, the electricity supply needs are 30 kW. During standby, it is 5 kW, so the Automatic Transfer Switch (ATS) subsystem is used. In addition, research was conducted to determine the factors that influence the effectiveness and efficiency of the developed system. The effectiveness review consists of the amount of electricity required from the on-grid and PV systems. While the efficiency is seen from the investment and operational costs of the hybrid CSC and the value of benefits from utilising the solar power plant system using the Cost Benefit Analysis Method (Liu, 2020). It can be seen that the electricity demand from the grid is 25 kW and from PV is 5 kW with the calculation of electricity consumption after it is calculated, namely:

Energy = Power x time .... (1)

Cold storage energy = 25 kW x 24 hours/day
= 600 kWh/day
= 219.000 kWh/year

Air blast freezer energy cycle = (32 kW x 6 hours/cycle) x 2
= 384 kWh/day
= 140.160 kWh/year

Real energy total = 219.000 kWh + 140.160 kWh

CSC per year = 446.760 kWh/year

As for the amount of electricity from PV of 5 kW at standby time of about 5 hours/day, it is obtained from the integration of a solar power plant using 10 100 Wp solar panels and added other equipment such as inverters, controls and batteries by 20% with the effectiveness of sunlight for 5 hours in the calculation:

Power from solar power plant = Amount of usage x Long standby x effectiveness of sunlight x 20% additional equipment…………………………………................(2)

Power from solar power plant = 5 kW x 5 hours/day x 5 hours x 20%

= 25 kW/day

This research considers various aspects, namely economic aspects, quality and quantity aspects, the energy produced and aspects of technology's friendliness to the environment. So that by using a solar power plant to support CSC electricity supply other than on the grid, it can be seen the impact of saving on electricity sources from fossil resources. In addition to using CBA analysis, this study uses Internal Rate of Return (IRR) analysis [13] and Payback Period (PP) [14]. This calculation determines the feasibility of the project carried out by considering the value of the investment, which is assessed in future value and paying attention to the net benefits, which are evaluated in the present value. From the research, the calculation of the project's investment and operational costs is as in Table 2.

Table.1: The project's investment and operational costs

Investment Cost		
20ft CSC construction fee, Tunnel (including tax)	Rp	200.000.000
The investment cost for solar power plant land (100 m^2)	Rp	50.000.000
The cost of procuring five kWP solar panels	Rp	180.000.000
The cost of procuring a five kWP solar panel battery	Rp	15.000.000
Cost of procurement of five kWP Controller and Monitoring System	Rp	194.556.000
Total	Rp	539.556.000
Operating costs		
Labor costs	Rp	54.859.061
Facility fee	Rp	166.945.197
Profit sharing fee	Rp	980.392
Marketing Fee	Rp	784.313
Insurance fee	Rp	1.753.114
Overhead Cost (5% operational)	Rp	45.489.869
Total	Rp	270.811.946

This research has tangible benefits and intangible benefits [15]. Tangible benefits are real benefits that directly affect the company's profitability and result in direct costs. Intangible benefits are benefits that do not involve directly and are difficult to measure in monetary terms. The tangible benefits of this study are the selling value of CSC processing and the savings of funds from a solar power plant. The intangible benefit of this research is an increase in food and energy security for remote communities. On the other hand, the proposed technology can be used for disaster emergencies as storage of food aid as well as an emergency power source. For defense purposes, it can be obtained as a prototype for food storage for the assignment of soldiers to the outer islands where transportation is difficult to access in stockpiling supplies.

3.2 IRR & Payback Period Analysis

The feasibility of using solar energy as a support for CSC energy supply is arranged in the form of cash flow consisting of income and expenses. Cash flow records the transaction costs and benefits in the construction of CSC with On-Grid energy supply arranged in a five kWP hybrid PV in the first year until the technical life of the project ends. The economic feasibility of the CSC project in this study is based on the results of calculations with the Internal Rate of Return (IRR) criteria, Payback Period and sensitivity analysis. The calculation of project feasibility is carried out by taking into account the value of the investment, which is assessed in future value, and the net benefits evaluated in the present value. Future value is obtained by multiplying the investment by the discount factor, and current value is obtained by multiplying the net benefits by the discount factor value at the assumed interest rate.

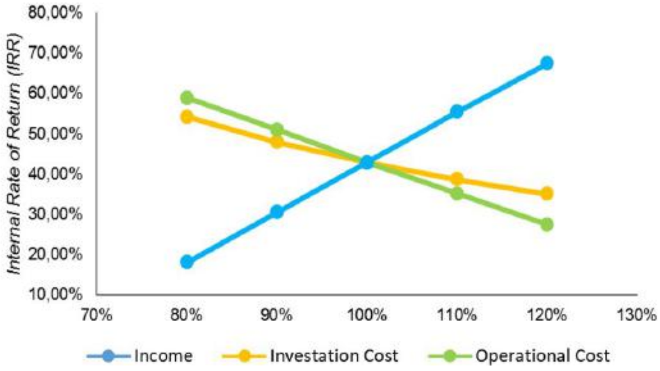
The basic assumptions used in this calculation are the project age of 20 years [16-19], an interest rate of 8% [20-23], inflation is stagnant, and fish prices are fixed. Fish production follows the Indonesian government's projections, and the electricity supply support time is 5 hours. The Indonesian government does not subsidize the project. The net cash flow (NCF) in the first to the second year is negative because, in that year, no operations or production were carried out but only invested or developed CSC projects, so there was no incoming revenue. Investment in this project reached Rp. 539,556,000 consisting of construction costs for CSC, land costs for solar power plants and costs for procurement of components for solar power plants. In the third year, the project has carried out operations or production. The first production requires an operational cost of Rp. 955,287,258 and earned an income of Rp. 1,389,682,491.

Operational costs consist of labor, facility, cooperation, marketing, insurance, and overhead costs. Meanwhile, the income is derived from the income from the production of CSC processing and the income from the benefits of the solar power plant. It is known that the project has a payback period of 8.56, or will cover capital in the 5th year of the 6th month. And this project has an IRR value of 16.15%. It is known that the private sector will manage this project, so when it is associated with the value of the payback period and IRR, this project is quite attractive to the manager. It has a sufficient payback period value and an IRR of 3% of the value of the credit interest rate used, namely 11%. The payback period value of 8.56 indicates that this project will cover the capital in the 5th year. The change in the village administration period is carried out every 7 years, so that this project is possible to run.

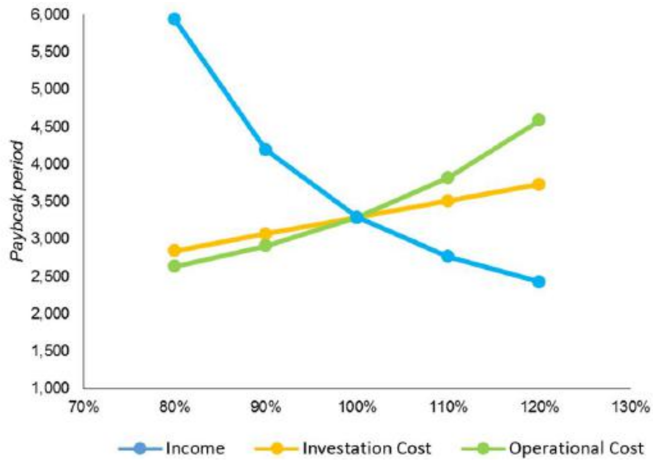
The second stage of research is carried out to discover the shortcomings, constraints, and obstacles in the field so that recommended solutions can be found to solve existing problems. In this second stage, research is also carried out to measure changes that occur in natural, environmental, and equipment factors. The shortcomings of this project include the quality of human resources, which are less skilled in the operation and maintenance of CSC. A lack of knowledge about the function of CSC in fish storage causes fishermen to use traditional fish storage methods. There are certain times when fishing capacity is reduced due to weather factors causing CSC to only be in a standby position. CSC Hybrid PV On Grid needs maintenance on the Solar Panel System. In the third stage, the final refinement of the existing prototype from all aspects is carried out for final testing. So that the perfect prototype can be obtained so that it can be operated and commercialized.

Sensitivity analysis simulates the decrease and increases in the investment, operations, and income value in 80%, 90%, 100%, 110%, and 120%. The simulation results of sensitivity analysis in Fig. 3 show that the CSC project with the addition of a 30 kWp hybrid solar power plant system shows that revenue is very sensitive to changes in the simulation to IRR, followed by investment and operations. In addition, these results indicate that income is susceptible to changes in the simulation to the payback period, followed by operations and investment.

In Fig. 3(a), it can be seen that the line that shows the most sensitive number is on the income line. This indicates that a decrease or increase in income can affect the IRR of this project. These results can be seen by decreasing income by 10%, which will reduce the IRR by 12%, and with an increase in income by 10%, it will increase the IRR by 13%. For this reason, the manager must carry out the best management approach with consumers so that consumers remain or increase the number of product purchases in this project.



(a)



(b)

Fig. 3: Sensitivity analysis of investment, operations, and income to (a) internal rate of return (b) payback period

In Fig. 3(b), it can be seen that the line that shows the most sensitive number is on the income line. This indicates that a decrease or increase in income can affect the payback period of this project. These results can be seen by decreasing income by 10%, which will increase the payback period by 0.907, and with an increase in income by 10%, it will reduce the payback period by 0.524. For this reason, the manager is obliged to carry out the best management approach with consumers so that consumers remain or increase the number of product purchases in this project. The increase in income will reduce the value of the payback period of the project. In another sense, it will speed up the process of returning capital.

With companies engaged in the CSC fish storage business in remote areas of Indonesia, it is hoped that there will be an increase in fish catches because fishermen will no longer worry about marketing and fish quality. There will be pretty high economic growth in the local area, namely: from an increase in business activity fisheries produced by fishing vessels which include fishing activities (supply of supplies in the form of food, fuel, ice cube, freshwater, spare parts) and marketing (local and export), employment of both fishermen and local communities in several businesses, other businesses support the business of catching and storing fish, increasing the income of fishermen and local communities and increasing regional income through levies on catches, and increasing foreign exchange through exports.

CSC is expected to utilize local fishermen in remote areas to reduce fishing density and potential conflicts and prevent damage to the coastal environment due to the disposal of damaged fish (fish spoils quickly or does not market standards). CSC is expected to encourage local fishermen to catch more fish, and they can even operate fishing vessels in the Exclusive Economic Zone [24]. On the other hand, local fishermen should be given education about caring for the marine environment, such as avoiding fishing gear that damages the environment, explosives, and hazardous chemicals (potassium). Besides that, the fishing method using Long-Line fishing gear is one of the environmentally friendly fishing methods because it is operated passively [25,26]. Functions and benefits of the existence of CSC: Fish can last a long time and do not rot quickly; Fish quality is maintained; Fish prices can be maintained or stable; Can accommodate and store fish when the stock is large; Can accommodate fish deposited from the sea.

If this effort produces positive results, traditional fishermen who usually only catch in the coastal ocean will likely switch to offshore fishing patterns in the Exclusive Economic Zone (EEZ). If conditions are like this, many companies will facilitate both providing facilities, technology (capture/handling technology), and marketing. To further expedite export trade, it is necessary to join the Regional Fisheries Management Organization (RFMO) [27-29].

IV. CONCLUSION

CSC 20 ft with a capacity of 30 kW using an energy supply from On Grid of 25 kW and PV of 5 kW is a breakthrough in developing the economy of coastal communities. CSC can also be developed for private business units. The policy of using CSC can support Indonesian Food Security, considering that the function of CSC in the fisheries sector is to maintain the quality of fishery products so that they remain good and safe for consumption. In the operation of CSC in the fisheries sector, Hybrid PV – On Grid technology is an attempt to make its use more efficient.

The calculation is obtained from the study's results where the 20 ft CSC with PV On Grid hybrid energy source obtained an IRR value of 16.15%, Payback period value of 8.56, credit interest rate (interest rate) of 8% with investment in this project reaching Rp. 539,556,000, operational Rp. 955,287,258 and income earned Rp. 1,389,682,491 so that the business using CSC as a fish storage tool is feasible to be developed. Besides that, CSC provides various other advantages from existing calculations, both tangible and intangible, so further development is needed to achieve the perfection of the tool as expected.

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