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Solution concerning climate change and utilization of Wind Turbine and Floating PV in Coastal Area

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Abstract

The global average sea level is rising at a rate of 3.2 mm per year according to recent observations of the IPCC. One of the main factors in sea level rise is thermal expansion, where greenhouse gases, especially CO2, accumulate and generate heat (climate change), thereby melting glaciers in the polar regions. Two villages in Kampung Bungin Bekasi, Indonesia, have already been experiencing flooding. Climate change can be addressed by environmental conservation and utilization of renewable energy to reduce CO2 production. Environmental conservation can be conducted by planting mangroves, while renewable energy is achieved by using natural renewable resources. Planting 10,000 mangrove seeds through citizen participation and by researchers from the University of Indonesia could create a new coastal ecosystem, which could prevent abrasion and become the habitat of sea biota. Renewable energy based on wind power and solar cell such as wind turbines and photovoltaics (PV) has been installed and used for streetlights, mosque lamps, and freezers. The wind turbine used in this study is made from wood, which is easy to obtain, and is designed to be compatible with the characteristics of Bungin Village, with a capacity of 500 Wp per unit. The total capacity of PV is 1800 Wp, which includes 720 Wp floating PV capacity and 1080 Wp PV monocrystalline capacity. Floating technology is chosen because the coastal areas have limited available land and the soil condition (sand) is inappropriate as a foundation for PV. The installed renewable energy is integrated and completed with a battery system and online monitoring to monitor the site in real time anytime and anywhere.

Keywords: climate change, renewable energy, Coastal Area, Wind Turbine, Floating PV

1. Introduction

Global warming is the rise in the Earth's surface temperature caused by an increase in carbon dioxide emissions and other gases known as greenhouse gases (GHG) that envelop the earth and heat. The function of GHGs is like that of the glass panels of greenhouses, capturing the sun's heat energy to avoid being completely released into the atmosphere again. Without these gases, heat will be lost to space, making the average temperature of the Earth 60 °F (33 °C) cooler. GHGs can be found in the atmosphere from the surface of the Earth to a height of 15 km. The GHG layer itself is formed at an altitude of 6.2–15 km. The following GHGs have the greatest impact:

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carbon dioxide (CO_2), nitrogen oxide, sulfur oxide, methane, chlorofluorocarbon, and hydrofluorocarbon (WWF Indonesia, 2017).

When sunlight enters the Earth's atmosphere, it passes through GHG. Soil, water, and other ecosystems absorb energy and light when sunlight reaches the entire surface of the earth. Once absorbed, this energy will be emitted back into the atmosphere. Some energy is returned to space, but most are captured by GHG in the atmosphere and returned to the Earth, causing the Earth to become warmer. The change process takes place quickly, thus resulting in abrupt climate change happens over a few years (Steffensen et al., 2008; Zikra, Suntoyo, & Lukijanto, 2015).

As the Earth becomes warmer, the icebergs melt, the volume of the oceans increases, and the sea level rises. According to National Aeronautics and Space Administration (NASA) data, the sea level has been rising by 3.2 mm per year (NASA, 2017). Rising sea levels are feared to threaten low coastal areas in the form of coastal abrasion and puddles. The possible impacts can cause great economic losses considering that the cities in Indonesia that serve as centers of residential, industrial, and agricultural activities are mostly located in coastal areas. Coastal areas are vulnerable to environmental factors such as climate variability, climate change, and rising sea level (Sullivan & Meigh, 2005; Measey, 2010; Balica, Wright, & van der Meulen, 2012).

The accumulation of CO_2 gas, such as those included as GHGs, is an indicator of climate change. The increase in the Earth's surface temperature causes ice to melt in the polar environment and increase the sea level. Countermeasures to CO_2 exposure are necessary to address possible threats.

The largest amount of CO_2 comes from the electricity, transport and industrial sectors (Shrestha, Anandarajah, & Liyanage, 2009; Nejat, et al., 2015). These sectors use fossil fuels, which produce high CO_2 emissions. Changes in the electricity production sector with renewable energy utilization and improved performance of transportation and industrial machinery can suppress CO_2 emissions in the sector. Increased reforestation efforts can also reduce the CO_2 emissions that have accumulated in the air.

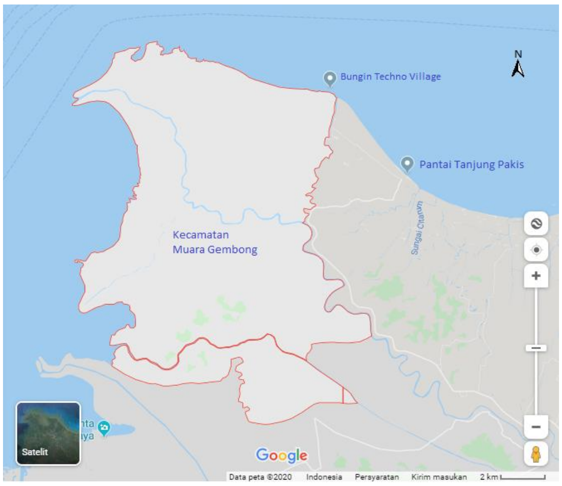
Development in coastal areas has been carried out throughout the country which is directly adjacent to the sea (Zubair, Tanvir, & Hasan, 2012; Ramli, Hiendro, & Al-Turki, 2016; Norton, David, Buckman, & Koman, 2018). This development focuses on preserving nature by preserving mangrove forest (Huxham et al., 2015; Roy, 2016;

Romañach et al., 2018). This is very helpful in sequestering carbon dioxide and resisting coastal abrasion. In some mangrove conservation areas it functions as a tourist site development (Cisneros-Martínez & Fernández-Morales, 2015; Carneiro, Breda, & Cordeiro, 2016; Cetin, 2016). The development of coastal areas with the intervention of new renewable technology by involving the participation of local communities is still rarely found.

Indonesia has a large coastal area, which is affected by the CO_2 that accumulates in the air. Increased concentrations of CO_2 cause the ocean to absorb more gas and become more acidic (Zikra, Suntoyo & Lukijanto, 2015). Increased acidity can have an impact on marine ecosystems, giving rise to problems such as coastal erosion, coastal flooding, and water pollution.

About the electricity production sector, Indonesia has the potential to overcome the accumulation of CO_2 gas emissions from the sun and wind. Indonesia is in the tropics, where the sun shines all year and the wind blows every day. The heat of the sun and the wind can be utilized as a new renewable energy source to generate electrical energy especially with a decentralization system (Marfai & King, 2008; Ismail, et al., 2015).

This research was conducted in Kampung Bungin, Desa Bakti, Muara Gembong District, Bekasi Regency. This location is directly adjacent to Karawang, which is separated by the Citarum River. Bekasi Regency is a district bordering DKI Jakarta, the capital city of Indonesia, which has a high population density. This area is located on the coast and has a strong potential to be affected by sea level rise (Takagi, Esteban, Mikami, & Fujii, 2016). Figure 1 shows where the research was conducted.



Fg. 1 Study Location Kampung Bungin in Java Island, Indonesia

Source: Author (2018 to 2019)

In Kampung Bungin, most of the population work as fishermen, and they use simple fishing technology, that is, using a net or a trap. They go to sea in the afternoon and return early in the morning. The fish they catch are then directly sold to the market on the same day.

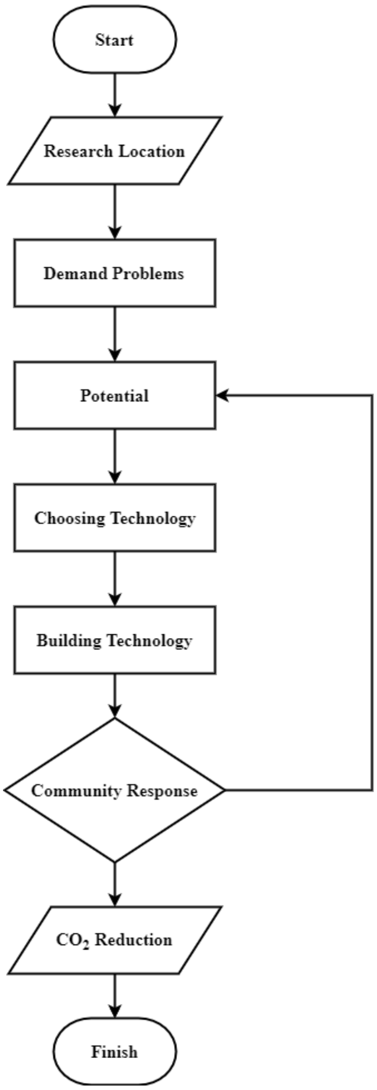
Globally in Indonesia Country, there is a tendency to increase electricity demand every year in various sectors as the population increases and the increase of development activities in the region. This condition is not in line with the increase in the provision of electrical energy where installed power capacity is still restricted, while the need for electrical energy continues to increase. Consequent is frequent blackouts of rotating electric currents, especially during peak hours as a result of usage over the available power. In Kampung Bungin the frequent blackouts happen for long hours.

This research aims to help the people of Kampung Bungin to improve their lives with technological intervention. Where the technology that will intervene is developed according to the demands of the local community.

2. Methods

The methodology is displayed in (Surjosatyo & Warits, 2016), which includes the research phases. Research locations are determined based on criteria for coastal areas, which have problems related to the main living demands and the potential for the development of new renewable energy. The potential is tested qualitatively and calculated quantitatively to produce solutions to existing problems in the area through technology application. The installed technology was started as a small-scale pilot project to determine the response of the surrounding population. The response from the population is the basis for developing the other potential at the site. Adapted technology is also increasingly developed in quality and quantity. Every technological approach has implications for reducing GHGs and CO_2. The level of reduction in CO_2 emissions is calculated by a conversion factor from the output of the produced technology.

In addition to the technological approach, an environmental conservation approach is also carried out to increase public awareness of mangrove planting activities. Mangrove planting also functions as an adhesive between the development of new renewable technologies that are installed in existing communities. Mangroves also have the potential to reduce CO_2 GHGs.



Fg. 2 Methodology of Research

Source: Author (2014)

In the process of developing technology, an approach is created with the local community through observation, interviews, and visits to residents' homes. This method is expected to establish good cooperation with the community, which is necessary because the operational process and maintenance of the technology installed will be carried out by local residents.

3. Result and Discussion

3.1.Building Technology

3.1.1. First Period Development (2014)

The potential of wind energy in Indonesia is relatively small because it is in the equator. However, some areas are geographically a wind region because they are areas that experience the nozzle effect or narrowing between two islands or mountain slopes between two adjacent mountains (Jacobson & Delucchi, 2011). According to a study by the National Aeronautics and Space Agency (LAPAN), of the 166 locations studied, 35 locations have good wind potential with wind speeds above 5 m/s at 50 meters altitude. LAPAN also found 34 locations with sufficient wind speed of 4–5 m/s. Thus, Indonesia has a great wind potential (Sari & Kusumaningrum, 2014). The General Plan of National Energy lists 60,647 MW for wind speeds of 4 m/s or more (Jacobson & Delucchi, 2011; GoI, 2017).

The construction process was first carried out in 2014 with a focus on electricity problems. With sufficient wind potential, the construction of one wind turbine unit was chosen as the pilot project. The wind turbine design still uses secondary data and observation data at the site.

The construction of a 500 Wp wind turbine is equipped with an electrical circuit and anemometer with a data logger for measuring wind speed. Halogen and siren lamps are mounted on high turbine poles, as shown in Surjosatyo & Warits (2016). Both lights were installed after discussions with the community, who stated that fishermen need the lights as a marker to enable them to return to land at dawn after catching fish.

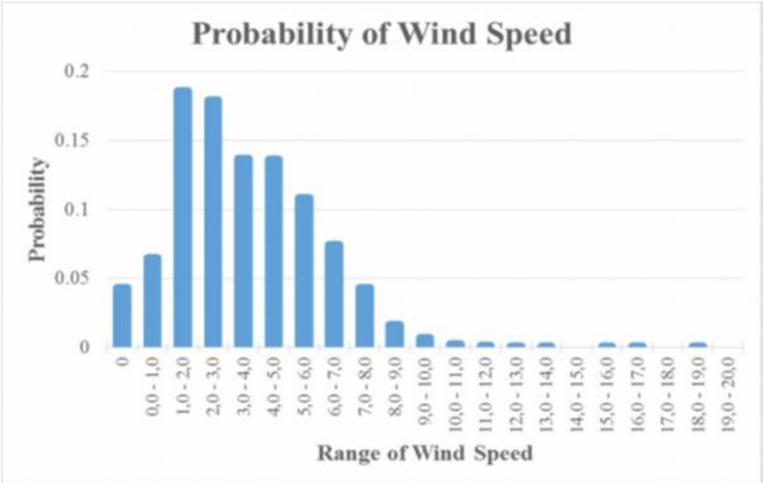
Fg. 3 Siren Lamp

Source: Author (2015)

3.1.2. Second Period Development (2016)

In the measurement phase of wind speed data, an anemometer is used and the measurement is carried out for one year to map wind speed to time frequency. Qblade and SolidWorks software were used for modeling in the wind turbine design stage.

a.



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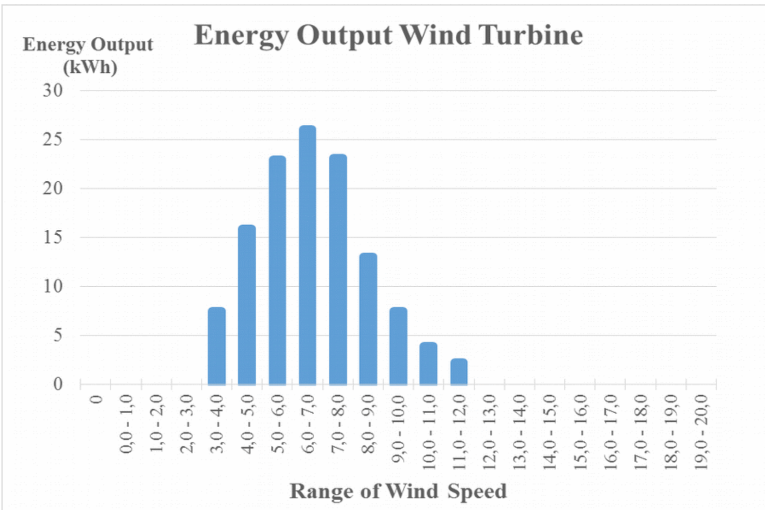


Fg. 4 (a) Wind Speed Frequency; (b) Output Energy from Anemometer

Source: Author (2014 to 2015)

In Kampung Bungin, wind speed is measured for one year using an anemometer before an appropriate wind turbine is designed. Figure 4 shows the result of mapping of wind speed to the frequency of wind and the resulting energy range.

The graph of the frequency of wind speeds shows that the wind with a low speed of 1–2 m/s has the highest frequency. The energy output graph shows that the new wind began to produce energy at a speed of 3–4 m/s. This finding suggests that while 1–2 m/s winds are most common, new winds can produce energy at 3–4 m/s. The wind turbines are designed accordingly based on the data. The wind turbine blade design was a NACA 4415 Taperless Twistless Wind Turbine Blade type made of Russian pine (*Pinus sibirica*) (Gibran, Safhire, & Warits, 2016). The wind turbines are designed from raw wood materials that are easy to obtain and are consistent with local characteristics. The capacity of the wind turbine is 500 Wp per unit; three units of wind turbine were installed, thus having a total capacity of 1500 Wp. (Gibran, Safhire, & Warits, 2016) shows the installed wind turbines in Kampung Bungin.

Fg. 5 Installed Wind Turbine and Seawater Desalination

Source: Author (2016)

During this second period of development, the phenomenon of abrasion was felt and a clean water crisis occurred in Kampung Bungin. This issue became another main focus aside from the continued development of the wind turbines. Ten thousand mangrove seeds were planted by citizens and researchers from the University of Indonesia, as shown in Figure 6. These mangroves could create a new coastal ecosystem that could prevent abrasion and become the habitat of sea biota. Mangrove forests are productive and have carbon production levels equivalent to those of moist tropical forests. Mangroves allocate more carbon proportionally below the surface of the land and have a ratio of carbon mass below the surface of the soil that is higher than trees on land. Most of the mangrove carbon is stored as a large pool in the soil and dead roots (Alongi, 2012). Aside from mangrove planting, a seawater desalination system was installed to meet the community's clean water demands.

Fg. 6 Mangrove Seedlings

Source: Author (2016)

In the process of planting mangrove seedlings, it is necessary to secure the animal seeds that are there. In the first mangrove planting experiment, mangrove seeds were eaten by goats, so the newly planted seedlings were equipped with nets to protect them from the animals around them.

3.1.3. Third Period Development (2017)

The focus of the development in the third stage is the development of technology into a hybrid system. Single-energy-source systems, such as standalone wind energy systems, cannot provide sustainable energy sources because of the limited availability of certain wind periods. Therefore, a hybrid system is used, which includes two or more renewable energy sources (Tina, Gagliano, & Raiti, 2006; Ramli et al., 2016). At present, the tendency is to update existing single-source systems (photovoltaics [PV], wind, hydro) to hybrid systems as well as for grid-linked applications where wind turbines are combined with solar panels to increase the capacity of the electric energy produced.

Indonesia is a tropical country that has enormous solar energy potential because its territory extends across the equator, with a large radiation level of 4.5–4.8 kWh/m^2/day (Asy'ari & Jarmiko, 2012; Shahsavari & Akbari, 2018). Solar energy is converted directly, and the application forms are divided into two types: solar thermal for heating applications and solar PV for power generation.

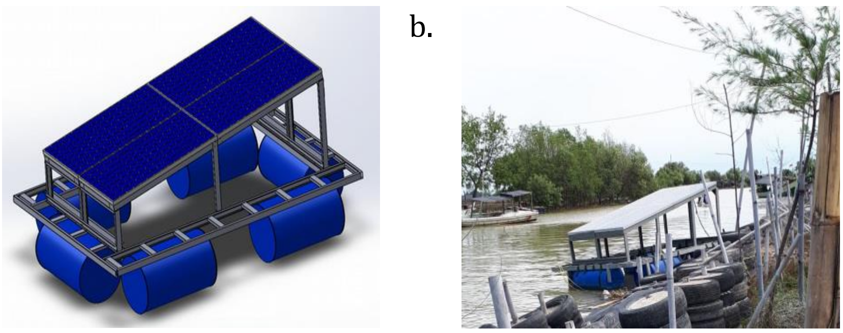
In the measurement phase, solar thermal data were measured by using a solarimeter and then compared with the solar thermal data of the rest of Indonesia to determine the mapping of the intensity of solar heat over time. At the PV type selection stage, adjustments were made to the local location. At the PV installation stage, land is the main topic of discussion because of the major land requirements for PV. Therefore, modifications were made to the PV mounting method, in which some of the PVs are placed on available land and others are placed on water (floating PV).

Floating-type PV solar panels have many advantages over solar panels installed on land, including fewer obstacles that block sunlight, comfort, energy efficiency, and higher power plant efficiency due to lower temperatures below the panel. The aluminum frame that supports the floating solar PV module is suitable because it can deliver cold temperatures from the water, thus reducing the overall temperature of the module. The average efficiency of floating-type solar panels is 11% higher than that of solar panels installed on land (Sahu, Yadav, & Sudhakar, 2016).

The work process to build the frame consists of cutting iron, welding, and drilling. After assembly, the frame is painted with iron-coated paint to reduce the risk of corrosion due to sea water, thereby extending the working life of the floating PV.

The floating PV frame is designed to be removable. During the installation in Kampung Bungin, the frame was transported in a disassembled state and then connected using nuts and bolts. A float made up of plastic drums is fastened to the frame and tightened with nuts and bolts. A monocrystalline solar panel is then placed on top of the frame. Figure 7 shows the complete floating PV set.

a. b.



Fg. 7 (a) Design Floating PV; (b) Installed Floating PV

Source: Author (2017)

The total PV capacity is 1800 Wp, which consists of the floating PV's capacity of 720 Wp and the land-based monocrystalline PV's capacity of 1080 Wp.

Fg. 8 PV on Land

Source: Author (2017)

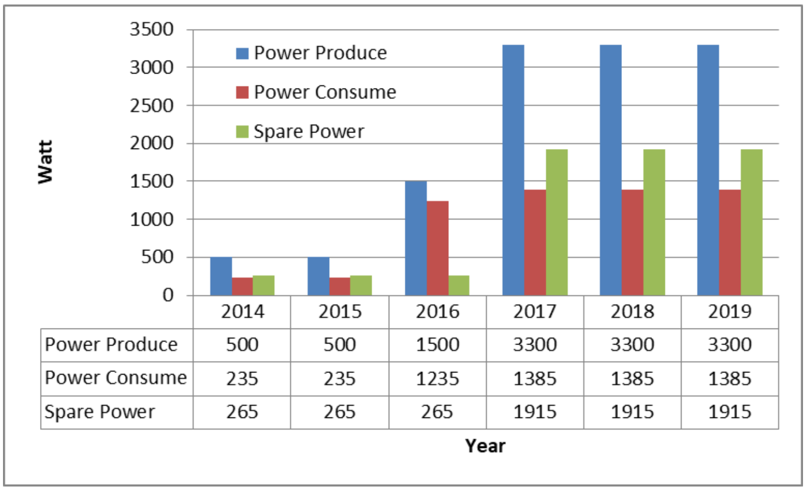
3.2.Operational Condition

New renewable energy technologies are integrated and equipped with a battery system and online monitoring system so they can be monitored in real time anywhere.

Fg. 9 Battery System for Wind Turbine and PV

Source: Author (2017)

The combined wind turbine and PV technologies generate a total power of 3300 Wp (1500 and 1800 Wp), which is used for street lighting, mosque lamps, and freezers.



	2014	2015	2016	2017	2018	2019
Power Produce	500	500	1500	3300	3300	3300
Power Consume	235	235	1235	1385	1385	1385
Spare Power	265	265	265	1915	1915	1915

Fg. 10 Power Condition Since First Period

Source: Author (2018 to 2019)

The power condition since the first development has developed. Development of power conditions can be found in the (Surjosatyo & Warits, 2016). During the first phase of development period in 2014, the power generated was 500 Wp which was used for lighting with a total power consumption of 235 W. In the second phase of development period in 2016, the power generated was 1500 Wp which was used for lighting and operational desalination equipment with a total power consumption of 1235 W. In the third phase of construction period in 2017, the generated power was 3300 Wp which was used for lighting, desalination equipment operations, and freezers with a total power consumption of 1385 W. There are spare power that can be used at any time such as charging electronic equipment or the use of emergencies for local residents.

The reduction of CO_2 emissions from electricity production can be calculated by the use of CO_2 conversion factor per electricity; this method was used by the Ministry of Energy and Mineral Resources. The conversion factor value of CO_2 amount per electricity production in 2016 is 0.877 ton CO_2/MWh (Ketenagalistrikan & S. D. M. D. J, 2016). Table 1 shows the calculation of the amount of CO_2 production from electrical equipment that has been replaced by renewable energy.

Table 1. List of Electrical Equipment with Renewable Energy Source

No	Electrical Equipment	Installation Location	Power per unit [watt]	Quantity [unit]	Total Power [watt]	Hours Utilization [hour/day]	Total [watt hour /day]
1	LED lamp	Streetlamp	10	10	100	12	1200
2	LED lamp	Power House, Mushola	6	12	72	12	864
3	Freezer	Power House	150	1	150	24	3600
4	Sea water pump	Desalination	500	1	500	2	1000
5	Clean water pump	Desalination	500	1	500	2	1000
6	Halogen lamp	Turbine Masts	55	1	55	24	1320
7	Siren lamp	Turbine Masts	8	1	8	24	192

Total Power	**1385**	**Watt**	**9176**	**Watt h**
	1,385	**kW**	**9,176**	**kWh**

Daily Carbon Emissions = Emissions Factor x Total electricity consumption

= 0,877 ton CO_2/MWh x 9,176x10^{-3} MWh

= 0,008047 ton CO_2

Carbon emissions per year:

Annually Carbon Emissions = Daily carbon emissions x number of days of the year

= 0,008047 ton CO_2 x 365 days

= 2,937 ton CO_2

Source: ICTF Bappenas Workhsop 12-13 March 2018 (Report

Wind turbines and PV have not been fully utilized for electricity production, thus resulting in an excess of unused power supplies. The potential excess electricity supply can reach 1,915 kW and is equivalent to 10,372 kg CO_2 reduction of carbon emissions per year. In the future, the excess power supply will be utilized to develop coastal potential such as marine product management through micro, small, and medium enterprises and to enhance tourism potential through pilot areas for new renewable energy development.

The social impact after the installation of and training on wind turbines and PV is that residents are more aware of the importance of technology to support personal and social life. Planting mangroves in the area of Kampung Bungin helps residents protect the coastline from abrasion and makes them aware of the risk of abrasion. The use of wind turbines and planting mangroves help minimize the production of CO_2 and reduce the consumption of fossil fuel-based generators in the Bungin area. The decrease of CO_2 in the atmosphere will reduce the greenhouse effect and help maintain the Earth's temperature, thus reducing the threat of climate change.

3.3. Community Empowerment

Community empowerment takes place at every stage of technological development. From the results of the evaluation using the interview method and focus group discussion, the most noticeable benefits were lighting, referring to both street lighting and lighthouse lamps (halogen and siren lamps), and constant availability of clean water. Every technology needs maintenance, even if it is simple. Maintenance is carried out by local management with funds obtained from the existing technology.

Coordination and evaluation of each phase of activities are carried out monthly, and focus groups are held under certain conditions. From this activity process, a product called "Ikan Bandeng Rorod" is produced by the women of Kampung Bungin. This product is sold in nearby locations and in the University of Indonesia canteens.

Fg. 11 Training Produce "Ikan Bandeng Rorod"

Source: Author (2017)

Fg. 12 Packanging “Ikan Bandeng Rorod”

Source: Author (2017)

Community empowerment during the process of technological development is not without obstacles. The obstacles faced such as passivity of citizens, coordination with the government, and lack of communication. Passive contribution of citizens are influenced by factors of urgent living demands. The residents prefer to fish to the sea than actively participate in the development of this technological innovation. However approach of each person can be solution for this problem. Basically the community strongly supports the existence of technology development activities in their area, but they are not interested in actively participating. Only a few residents said they were ready to participate actively.

Coordination with the government and lack of communication are another obstacle that are often faced by every technological building development. The condition of the government has a tier, where coordination is usually done at a level that is in direct contact with the location (Neighborhood Association Level (RT)). However, the level of government above it (village level) feels it needs to be coordinated more broadly and wants to be involved. Actually, the involvement of the above government level has been carried out with the issuance of permits from the activities carried out, as well as invitations given to certain activities. This is also caused by poor communication between all parties. In the future, this coordination will be improved to create a better working climate in an effort to support the sustainability of the technology that has been built.

4. Conclusion

Solar panels and wind turbines in coastal areas are used not only to reduce CO2 but also to solve installation problems to reduce the frequency of blackouts. The blade specification that we used for the turbine is NACA 4415 Taperless Twistless Wind Turbine Blade type made of Russian pine (Pinus sibirica). Each wind turbine has a capacity of 500 Wp. We installed three wind turbines, thus obtaining a total maximum power output of 1500 Wp. The wind turbines and PV produce as much as 1,385 kW or 9,176 kWh of electricity and can reduce gas emissions by up to 2,937 tons of CO2 per year. Floating PV is a good way to overcome the problem of placement locations in coastal areas. In Kampung Bungin, this method has been well implemented; with the installation of wind turbines and solar panels, CO2 was reduced by 2,937 tons per year. CO2 reduction can be increased by optimizing the use of energy generated by wind turbines and solar panels and by planting mangroves around the Kampung Bungin area.

Acknowledgment

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Author Contribution

Rifka Sofianita and Sri Rachmawati Siregar conceived of the presented idea. Sri Rachmawati Siregar developed the theory and performed the computations. Adi Surjosatyo and Rifka Sofianita verified the analytical methods. Rifka Sofianita encouraged Sri Rachmawati Siregar to investigate and supervised the findings of this work. All authors discussed the results and contributed to the final manuscript.

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