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Assessment of the Wind Power Application in Indonesia

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A B S T R A C T

Energy and the environment are major topics of concern throughout the world nowadays. Consumption of fossil fuels is still the dominance to meet energy needs. The adverse effects of the consumption of fossil fuels on the environment and humans are priorities in determining policies. Many countries in the world have begun restructuring their energy mix and exploring the potential of new and renewable energy (NRE). Indonesia is currently in a stage of economic development where the demand for energy consumption is extremely high. The availability of fossil fuel energy is decreasing and is expected to run out in the next 42 years. In addition, environmental pollution due to the use of fossil fuels continues to increase. The application of NRE technologies and better efficiency in energy's use could help decrease dependence on fossil fuels. One of energy's commodities that warrants attention is wind energy. However, the development of wind power plants in Indonesia has many barriers. The low level of trust in wind availability and the high investment costs are the main barriers to its development. The current capacity of wind energy power plants in Indonesia installed is 1.96 MW, whereas the total amount wind energy available in Indonesia is 970MW. Wind power plants produce less carbon. This makes wind power one of the solutions to have environmentally friendly power plants. This assessment aims to increase awareness for planning for the future with the collaboration of conventional energy and NRE as clean technology to save the world from global warming.

1. INTRODUCTION

Indonesia is an archipelago located on the equator that has a tropical climate with 970 MW of wind energy potential. However, the capacity of wind power plants currently installed can only produce up to 1.96 MW (PPIPE BPPT, 2018). Based on these numbers, it is possible to develop wind power in Indonesia. Wind energy is a type of energy where the availability never runs out (Staffell & Green, 2014). The difference in air pressure on the earth due to its revolution is the reason for the abundance of wind power. Wind energy is one part of NRE that is environmentally friendly. Despite this, energy production in Indonesia is still dominated by fossil fuels. According to data (Kohler, Behrman, & Arianto, 2015), Indonesia's population reached 241 million people. In 2019, Indonesia's population is expected to reach 270 million with its population growth rate of 1.14% (Nations, 2019). Indonesia is the fourth most populous country in the world. Indonesia's population will reach 321 million by 2050. Energy consumption is increasing as the population in Indonesia increases. Energy consumption in 2018 increased 2.9% from the previous year. At the same time, carbon emissions from energy use grew by 2.0%, which equates to around 0.6 gigatonnes of total carbon emissions in the world (BP, 2019). Carbon emissions have more than tripled along with the increasing share of fossil fuels in the energy mix. Demand for fossil fuels continues to rise, while fossil fuel resources are running low. In this assessment we disaggregate fossil fuels into three types (petroleum, natural gas, and coal). According to estimates (PPIPE BPPT, 2018), Indonesia's fossil fuel supply will run out in the next 42 years. Therefore, it is necessary to restructure the energy mix and explore new and renewable energy to meet Indonesia's energy needs.

Globally, fossil fuels are the dominance of energy suppliers because the current technology is

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still oil fuels-based. In 2015, coal consumption had reached 1,044 MT, oil consumption reached 3,840 MT, and natural gasses reached 1,401 MT (Lakshmi et al., 2017). The uncontrolled use of fossil fuels has become a serious cause of environmental pollution (Cebrucean, Cebrucean, & Ionel, 2014). The combustion process in the mechanism produces greenhouse gasses which is the cause of the greenhouse effect (Sasana, Salman, Suharnomo, Nugroho, & Yusuf, 2018). Examples of greenhouse gases include carbon dioxide, methane, nitrous oxide and fluorinated gases. The ability of these gases to capture heat is what causes the greenhouse effect (Kweku et al., 2018). By 2015, around 32,294 Mt of greenhouse gases had been produced from fuel combustion processes (Lakshmi et al., 2017). Carbon emissions that are released by fossil fuels are the major cause of global warming (Alam, Murad, Noman, & Ozturk, 2016; Bimanatya & Widodo, 2018).

To pursue economic growth (Lacal-Arántegui, 2019), government policies must emphasize the maintenance of a sustainable environment (Chang, Fang, & Li, 2016; Maulidia, Dargusch, Ashworth, & Ardiansyah, 2019; Sasana et al., 2018). This assessment aims to promote the development and utilization of clean technology and NRE, one of which is clean and sustainable wind energy. Wind power is a popular renewable energy source because of the non-polluting nature of its operation so it can reduce carbon emission released by fossil fuel and offset the use of fossil fuels as energy generators.

2. THEORETICAL BACKGROUND

2.1 Utilizatian of wind energy worldwide

Wind power was first developed in Denmark with horizontal axis wind turbine technology and continues to grow until now. The total capacity of wind turbines in the world by the end of 2018 had reached 597 GW. The existence of wind turbines have supplied almost 6% of the total electricity demand in the world (Pitteloud, 2019). In 2018, the European wind market experienced a decline while the Chinese, Brazilian, Asian and African wind markets experienced growth (Pitteloud, 2019). By 2016 (Wind & Council, 2019), the European Union had 51 GW of installed capacity with investments reaching $ 112.5 billion.

Based on data (Wind & Council, 2019), China has the largest wind power generator market in the world with a total of 206 GW, equivalent to 36% of global onshore installations, followed by USA with a total capacity of 96 GW generated from wind power plants, equivalent to 17% of global onshore installations, thirdly Germany with a total of 2.4 GW, equivalent to 9% of global onshore installations, and fourthly India with a total of 2.2 GW, equivalent to 6% of global onshore installations.

As the largest producer of wind power in the world with rapid growth, China has abundant sources of wind power both onshore and offshore. North-east China, north-west China, and south-east China are the main regions where the development of wind power is growing rapidly. Currently, China is gradually developing offshore wind power to expand its wind power capacity. The rapid growth of wind power in China has had a positive impact on the development of wind power equipment manufacturing industries which have now succeeded in exporting wind turbines to various countries (Sun & Huang, 2014).

2.2 Wind power at Southeast Asia

Countries in Southeast Asia have begun to develop wind power. The Philippines currently has a wind power potential of 76.6 GW (Glassbrook et al., 2014; Silang et al., 2014), with most wind energy developer projects in the northern part of the country (Silang et al., 2014). Vietnam has a potential wind power of 513,360 MW and they are developing their potential of wind power to reach 1 GW(Martosaputro & Murti, 2014). While Laos has a wind power potential of 182,252 MW, and Cambodia has a potential of 26,000 MW (Nguyen, 2014).

2.3 Wind power in Indonesia

Existing condition

The current installed wind power capacity in Indonesia is 1.96 MW but it cannot be used commercially. Most of these installations are used for development and research projects. The largest wind turbine units installed in Indonesia today are able to produce 100 kW, located in Sukabumi (Nugraha et al., 2018), West Java and Selayar-South Sulawesi. These units are installed by the Ministry of Energy and Mineral Resources (Ministry of Energy and Mineral Resources, 2016). However, the largest wind power facility is installed in Nusa Penida, Bali with a total capacity of 735 kW which is the result of a collaboration between the Klungkung regional government, Bali, ESDM and PT. PLN (Persero). The second largest facility has a total capacity of 240 kW in Sangihe, North Sulawesi. This installation is also the result of collaboration between ESDM and PT. PLN (Martosaputro &

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Murti, 2014). Indonesia is currently developing its first commercial Wind Farm located in Sidrap, Sindereng Rappang Regency, South Sulawesi. According to a statement from PT. PLN, Sidrap wind farm will produce 75 MW and will be channeled to 70,000 households (The Jakarta Post, 2018). The location of the wind farm is shown in Fig. 1.

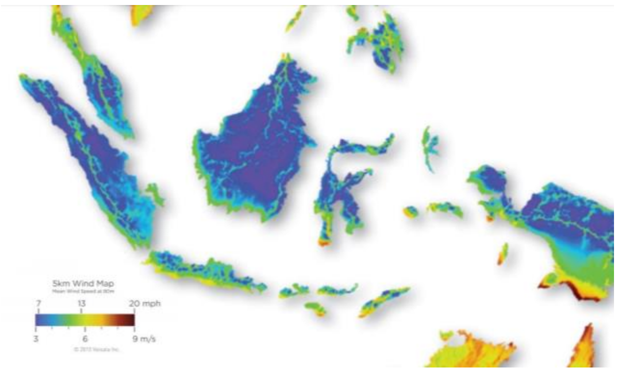
Source: Google maps, 2019

Fig. 1. Sidrap and Jeneponto wind farm locations

Another wind farm also being built is in the Jeneponto area, South Sulawesi, which has now reached 80% completion. Indonesia has set a target to achieve 1.8 GW of wind power energy by 2025 (International Renewable Energy Agency, 2018).

Potential wind areas

Based on the geographical locations compiled by IRENA, 85% of Indonesia's wind power potential is located on the islands of Java, Bali, Sulawesi and Nusa Tenggara. According to the visual map issued by Vaisala Energy (Vaisala, 2015), southern Papua namely Dolok, Merauke, Buraen in East Nusa Tenggara, the southern part of Sumba island, Trangan island and the Kumawa mountain region have the potential for high wind power (Muliadi, Ruwaidah, & Asyari, 2015). The wind speed map of Indonesia is shown in Fig. 2.



Source : Vaisala Energy

Fig. 2. Wind speed in Indonesia at 80 m height

Table 1. is a summary of data of wind power capacity in Indonesia in ascending order.

Table 1. A summary of the potential capacity of wind farms in Indonesia

Site	Wind Power Density (W/m^2)
Nusa Penida, Bali	30
Bantul, DIY	91
Selayar, South Sulawesi	143
Lebak, Banten	198
Purworejo, Central Java	231
Baron, DIY	245
Garut, West Java	268
Sukabumi,West Java	272
Oelbubuk, NTT	301
Sidrap, South Sulawesi	320
Jeneponto, South Sulawesi	491

Challenge

Today, the main challenge in developing wind power in Indonesia is high investment costs (Didane, Rosly, Zulkafli, & Shamsudin, 2017). Wind and solar energy production are the most expensive forms and produce less than 0.15 USD / kWh and more than 0.3 USD / kWh respectively (Shadman, Sadeghipour, Moghavvemi, & Saidur, 2016). In addition, climate change also contributes to the fluctuations in the output of wind power. Wind power output fluctuations lead to low levels of confidence in the availability of wind power for investors. Unlike heat (coal, oil, gas, or nuclear power) or hydro, electricity generated from wind power can vary greatly in several different time frames: every hour, every day or season (Petersen, 2017). On the other hand, fluctuations in wind power are also often the cause of reduced efficiency and damage to turbines.

Current fossil fuel subsidies have become a big problem and the crisis must be resolved immediately (Sasana et al., 2018). Therefore, wind power must be able to compensate. If wind power can provide, this will be a great opportunity for the development of wind power in Indonesia.

3. DISCUSSION

3.1 Carbon offsets from wind power turbine electricity

Marimuthu and Kirubakaran reported that a 1.65 MW turbine would generate 393.843 kg of CO_2

over its 20-year lifespan. When compared to coal power plants, wind turbines will run for 51 days to produce carbon that is equivalent to those produced by coal power plants in one day (Smoucha, Fitzpatrick, Buckingham, & Knox, 2016). Total emissions are obtained from the sum of emissions from turbine-forming materials. Emission factors for methane and nitrous oxide, when produced by turbines are converted to CO2. Previous studies on the material and weight for components showed that, on average, the generator was made of 79.67% steel and 20.33% copper. A list of estimates based on previous studies were established (Smoucha et al., 2016).

The Sidrap wind farm will produce 75 MW of wind power. Based on the results of each turbine lifecycle's analysis from Smoucha et al, 3.4 MW rated power has a total emission of 824 t CO2eq with a total carbon intensity of 5.4 kg / MWh, a 64 day payback period, and offset emissions of 92770 tCO_2eq. Then, the total offset emission can be determined from the 75 MW rate power as such:

$$Turbines\ needed = \frac{75\ MW}{3{,}4\ MW} = 22\ Turbin\ needed. \tag{1}$$

$$Total\ emission\ carbon = 22\ \times 824\ tCO2eq = 18.128\ tCO2eq \tag{2}$$

$$Total\ carbon\ intensity = 22\ \times\ 5{,}4\ kg/MWh = \ 118{,}8\ kg/MWh \tag{3}$$

$$Payback\ period = 22\ \times 64\ day = 1.408\ days\ equal\ 3{,}8\ years \tag{4}$$

$$Offset\ emission = 22 \times 92770\ tCO2eq = 2\ million\ tCO2eq \tag{5}$$

Large turbines produce less carbon emission than small turbines. However, small turbines restore financial capital more quickly even though there are fewer environmental benefits.

3.2 Carbon offsets from turbine electricity of fossil fuels

The amount of carbon emissions produced by fossil fuel power plant with bituminous coal is 426 tCO_2eq per hour, equivalent to 850 $kgCO_2$ / MWh (D. Cebrucean et al, 2014). On average, electricity sources from fossil fuels emit 0.4554 tCO_2eq / MWh (United States Environmental Protection Agency, 2017). To compare carbon emission generated, it is assumed that the rate of power produced at a fossil fuel power plant is equal to the rate of power produced at the Sidrap wind farm.

$$Total\ emission\ carbon = 75MW \times 0{,}4554\ tCO2 = 34{,}155\ tCO2\ or\ equal\ 31\ million\ kg\ /MWh \tag{6}$$

The total carbon emission generated from wind power is 118.8 kg / MWh while the total carbon emission generated from fossil fuels is 31 million kg / MWh (Smoucha et al., 2016). Although small-scale wind turbines produce more emissions than large turbines, the intensity of small-sized carbon wind turbines is far below non-renewable sources. This indicates that wind power is one of the best options currently available to produce low-carbon electricity to reduce the accumulation of greenhouse gasses (El-Aasar & Hanafy, 2018) in the atmosphere and prevent global warming.

3.3 The relationship between fossil fuels and human health

In 2014-2016, the Government of Indonesia's revenues from fossil fuel production averaged Rp 190 trillion (USD 16 billion) per year (Braithwaite, 2019). Indonesia is one of the five largest coal producers in the world and the second largest coal exporter (Lakshmi et al., 2017). Therefore, until now, coal is still the primary means to produce energy. Burning coal has harmful effects on human health. According to some recent studies, coal-based chemical processing releases CO2 two to four times more than oil-based chemical processing (Munawer, 2018). In addition, coal combustion produces emissions such as, COx, NOx, SOx, PM and some heavy metal pollutants that cause dangerous diseases such as lung cancer and chronic obstructive pulmonary disease (COPD) (Sanchez & Luan, 2018). SO_2 emissions cause heart destabilization, asthma, and cancer, while NOx causes persistent pulmonary hypertension (PPHN) and molecular abnormalities at the DNA level.

3.4 Mechanical problem

Wind turbines convert kinetic energy from wind power to electrical energy (Arshad, 2019; Ayodele, 2014). The operating range of wind turbines are determined by wind speed and wind direction (Kanya & Visser, 2018; Lee et al., 2016). Because the speed of the wind moves dynamically and fluctuates, damage to the turbine often occurs.

Changes in wind conditions can cause the production of wind power to deviate from the estimated generation level (Bruno, Horvat, & Raffaele, 2018). To avoid this problem, an in-depth review and study is needed before the construction of wind turbines.

4. CONCLUSION

Wind power is necessary to reduce the consumption of fossil fuels which has become the main cause of global warming as it produces carbon emissions in large quantities. Wind power is a clean option for mitigating carbon emissions and overcoming the increasing energy demand and environmental and health problems to achieve sustainable development. Wind energy is an energy source with promising prospects for large-scale commercial development. Trust, sustainability and economic factors are the main elements that need to be considered in its development. Determining the right locations for the development of wind power plants is one of the highest success factors. Therefore, before construction, an in-depth review of the location of turbine installation is needed to prevent the turbines from being damaged. To overcome the high cost of investment, private sector investments will have a major impact on its development.

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