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Economic Feasibility of a Small-Scale Wind Turbine in Coastal Area of South Sulawesi

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Abstract. To evaluate the exploitation potential of wind energy in the coastal area of South Sulawesi, Indonesia, an investigation on the economic feasibility of this project was performed. A 300-watt horizontal wind turbine was used as an example installed turbine. The wind speed range of 4-7 m/s which was the wind speed data in the coastal area of South Sulawesi was computed. The main economic analysis method employed was Capital Budgeting Analysis (CBA) method. In this method, 4 (four) indicators were used to evaluate the feasibility of the project which are payback period (PBP), net present value (NPV), internal rate of return (IRR), and benefit-cost ratio (BCR). A visual basic computer program based on the CBA method was also developed to make the computation more convenient. From the study, it was found that the wind speed range of 4-6 m/s resulted in a non-feasibility project while the highest wind speed (7 m/s) was found to be quite strong to make the project feasible.

1. Introduction

Indonesia, which has more than 17,000 islands and over 80,000 km of coastlines, is an archipelago country endowed with enormous potentials for renewable energy. It encourages implementing renewable energy projects in the country including renewable energy resources available in the coastal areas. One of the most abundant resources that has not yet been fully utilized in the ocean and coastal area is wind energy.

Based on this consideration, many studies on ocean wind energy have been performed. Purba et al. [1] determined suitable locations of Ocean Renewable Energy (ORE) including wind energy. In the previous study of Mahmuddin et al., in the ocean structure system laboratory, the wind energy potential has been assessed in Sulawesi and Maluku islands sea areas and the monthly wind power maps have been plotted [2] including designing the turbine controller using a microcontroller [3]. The monthly maps then are used to determine the suitable location of the proposed wind energy converter to harvest the energy called a Mobile Floating Structure (MFS) [4]. Finally, the concept of the structure was introduced and designed [5].

Ocean wind speeds in Indonesia can be categorized into moderate speed [2]. In coastal areas, the wind has varying speeds, but it is generally in the range of 4-7 m/s [6]. With this speed, if it is built at a certain height and using a proper turbine specification, the construction of small-scale wind power plants could be economically viable.

Evaluating the economic feasibility of the small-scale wind turbine has been performed both in the coastal and urban environment around the world. In Mexico, the techno-economic potential of this technology was analyzed [7], and in Egypt, the evaluation based on the new feed-in tariff was conducted with 8 different small wind turbines at 17 locations [8]. The economic viability of this technology was determined in the east coast of Peninsular Malaysia [9], and in a suburban area of Sicily, in the south of Italy, the economic analysis of this technology was performed [10].

Given the wind energy potential in a coastal area of South Sulawesi, the development of a small-scale wind turbine in this area is likely to be profitable. Therefore, the utilization of small wind turbines in coastal areas was studied further in the present study. In the present study, Capital Budgeting Analysis (CBA) method was used to evaluate the feasibility of the project. A visual basic computer program was also developed to make the computation more effective and convenient.

2. Capital Budgeting Analysis (CBA) Method

There are several Capital Budgeting Analysis (CBA) methods that are commonly method used to analyze the feasibility of a project which are:

2.1. Payback Period (PBP)

The Payback Period (PBP) method is an assessment technique to find out how long time is needed to get the investment back of a project or business. The formula used to calculate the PBP is [11]:

$$PBP = \frac{\text{initial investment}}{\text{average annual cash inflow}} \tag{1}$$

The investment cost is mainly originated from the turbine itself and its supporting equipment. The revenue is obtained by multiplying the turbine output power, operational hours, and the number of days in a month. The following interpretations are used to assess the feasibility of a project in terms of the Payback Period.

- PBP > project period, the investment is not feasible
- PBP ≤ project period, the investment is feasible

2.2. Net Present Value (NPV)

The Net Present Value (NPV) is the difference between net cash present value and investment present value over the life of the investment. The formula used to calculate the Net Present Value is [11]:

$$NPV = \sum_{t=1}^{n} \frac{B_t - C_t}{(1+i)^t} \tag{2}$$

where

B_t = benefit in year t (Rp.)
C_t = cost in year t (Rp.)
i = interest rate (%)
n = project period (year)

The results of the calculation of the Net Present Value (NPV) are used to make a decision on the investment based on the following interpretation:

- NPV > 0, the investment is feasible
- NPV < 0, the investment is not feasible
- NPV = 0, the investment has no effect

In addition, it must also be noted whether the NPV value generated is sufficient in accordance with the initial capital issued and the period of the investment. This is useful for knowing whether the investment being carried out provides a large enough benefit or not.

2.3. Internal Rate of Return (IRR)

The Internal Rate of Return (IRR) is an interest rate (not bank interest) that describes the rate of return on a project or investment as a percentage at which the NPV value is zero. Thus, the IRR is obtained by setting the value of NPV in Eq. 2 to zero and solving it for IRR as follows [11]:

$$NPV = \sum_{t=1}^{n} \frac{B_t - C_t}{(1+IRR)^t} = 0 \tag{3}$$

The IRR can not be solved analytically, so it will require several iterations to obtain a correct value. The feasibility of a project in terms of the Internal Rate of Return is interpreted using the following rules:

- IRR > bank interest rate, the investment is feasible
- IRR ≤ bank interest rate, the investment is not feasible

2.4. Benefit-Cost Ratio (BCR)

The Benefit-Cost Ratio (BCR) method which is also known as profitability index (PI), is also usually used at an early stage in evaluating investment planning. The BCR method emphasizes the comparison value between the aspects of the benefits that will be obtained with the aspects of costs and losses that will be borne (cost) with the investment. The general formula used in calculating the Benefit-Cost Ratio value is [11]:

$$BCR = \frac{\sum_{t=1}^{n} B_t (1+i)^{-t}}{\sum_{t=1}^{n} C_t (1+i)^{-t}} \tag{4}$$

To assess the feasibility of a project in terms of the Benefit-Cost Ratio, the following acceptance criteria are used:

- BCR ≥ 1, the investment is feasible
- BCR = 1, the investment is indifference
- BCR < 1, the investment is not feasible

3. Research Methodology

3.1. Research Location

Wind data used in the present study are taken from the wind speed in coastal areas of South Sulawesi, Indonesia which is in the range of 4-7 m/s as shown in Fig. 1.

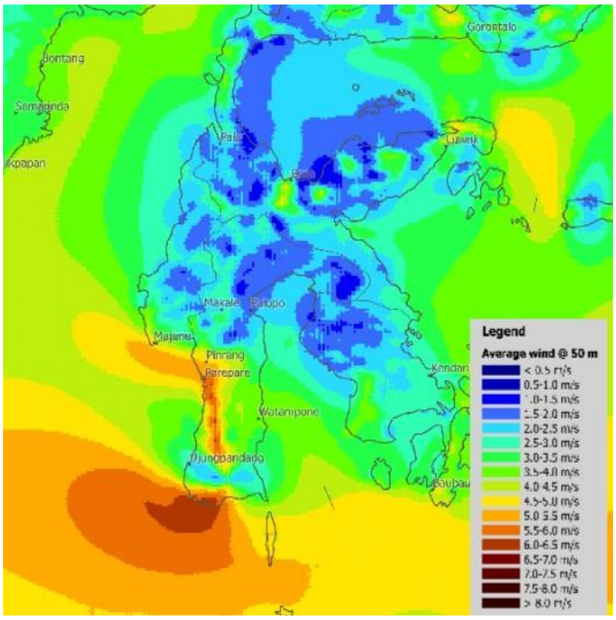

Figure 1. Wind energy potential in and around South Sulawesi Island, Indonesia [6]

3.2. Turbine Specification

The computation and simulation in the present research are assumed to install a small-scale wind turbine with specifications shown in Table 1. A photo of the turbine is shown in Fig. 2. The turbine is one of the research equipment owned by Ocean Structures System Laboratory, Marine Engineering Department, Hasanuddin University, Indonesia.

Figure 2. Wind turbine WKH-300 [12]

Table 1. Wind turbine specification

Description	Value
Brand	WindKean
Model	WKH-300
Max Power	300 watt
Output Voltage	24 volt
Number of blades	3
Blade diameter	2.5 m
Rated speed	8 m/s
Cut-in speed	3 m/s
Cut-out speed	25 m/s

In order to determine the output power of the turbine, the power curve of the turbine needs to be estimated. In the present study, a binomial model of the power curve was used. The equation for the model is as follows [2]

$$P = \begin{cases} 0, & 0 \le v < v_{ci} \\ P_R\left(A + Bv + Cv^2\right), & v_{ci} \le v < v_r \\ P_R, & v_r \le v < v_{co} \\ 0, & v \ge v_{co} \end{cases} \tag{5}$$

where

P_R = rated power output (watt)
v_r = rated wind speed (m/s)
v_{ci} = cut in wind speed (m/s)
v_{co} = cutout wind speed (m/s)

A, B, and C are equation coefficients that are obtained using the following formulas

$$\left.\begin{aligned} A &= \frac{1}{\left(v_{ci} - v_r\right)^2}\left[v_{ci}\left(v_{ci} + v_r\right) - 4v_{ci}v_r\left(\frac{v_{ci} + v_r}{2v_r}\right)^3\right] \\ B &= \frac{1}{\left(v_{ci} - v_r\right)^2}\left[4\left(v_{ci} + v_r\right)\left(\frac{v_{ci} + v_r}{2v_r}\right)^3 - \left(3v_{ci} + v_r\right)\right] \\ C &= \frac{1}{\left(v_{ci} - v_r\right)^2}\left[2 - 4\left(\frac{v_{ci} + v_r}{2v_r}\right)^3\right] \end{aligned}\right\} \tag{6}$$

Using the formulas above, the obtained power curve of the turbine is shown in Fig. 3.

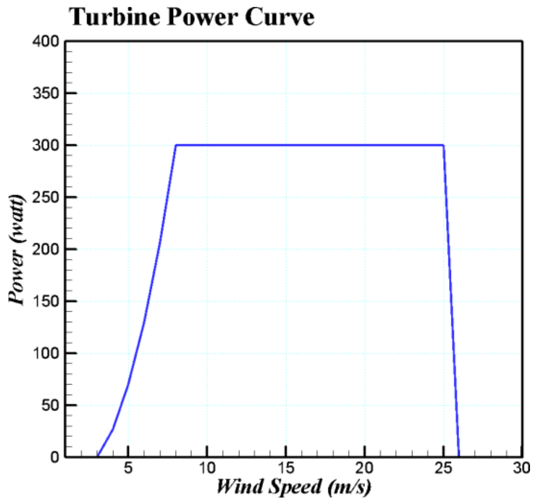

Figure 3. The power curve of the turbine WKH-300

The present study performs an investigation for the coastal area which has a wind speed range of around 4-7 m/s which is below the rated speed of the turbine. It can be shown that the speed region is in the unsteady region in Fig. 3.

3.3. Investment Cost

In order to install the turbine system, besides the turbine itself, it also needs several pieces of other supporting equipment. The costs of the turbine and its supporting equipment were assumed to be Rp. 7,734,000,-. The price was taken according to a study conducted by Suryasih [12].

3.4. Annual Cost

Several costs are incurred due to the operation and maintenance of the turbine. Those costs are classified as an annual costs. The annual cost in the present study is estimated from the investment cost which was approximated around 20% from the investment cost. The cost approximation was taken according to the same study conducted by Suryasih [12].

4. Results and Discussion

Based on the assumptions and variables stated in the previous section, computation to investigate the economic feasibility of installing a small-scale wind turbine in the coastal area of South Sulawesi was performed. The computation was performed using a computer program initially developed using Microsoft Visual Basic by Puspitasari [13]. The interface of the program is shown in Fig. 4.

Figure 4. Computer program interface

As shown in Fig. 4, there are 8 (eight) input data that need to be entered to perform a computation. Compulsory input data are turbine power or output, operational hours, investment cost, annual cost, interest rate, turbine life, electric price/kWh while the last input data which is turbine type is optional and it will not affect the computation results. Turbine power was obtained from the power curve in Fig. 3 which was dependent on the wind speed.

As the program output, as shown also in Fig. 4, there are 5 (five) variables that are resulted from the program which are project revenue, net present value (NPV), internal rate of return (IRR), benefit-cost ratio (BCR), and payback period (PBP). From these variables, 4 (four) variables are used to evaluate the economic feasibility of the project which are NPV, IRR, BCR, and PBP. The status of the project based on these variables is given in a text box on the right side of each variable. A general summary of the project's economic feasibility is also given in the last text box.

The computed wind speed range in the present research is given in subsection 3.1 which is 4-7 m/s. The results of the computation are shown in Table 2.

Table 2. Project economic feasibility

Wind Speed (m/s)	Indicators					Feasibility
	Revenue (Rp.)	NPV (Rp.)	IRR (%)	BCR	PBP (years)	
4	4,650,680.49	-8,420,160.00	-77.27	0.23	-6.60	Not Feasible
5	12,263,768.67	-4,364,169.84	-40.05	0.60	-12.74	Not Feasible
6	22,837,502.25	1,268,433.34	11.64	1.12	43.83	Not Feasible
7	36,371,881.24	8,478,549.40	77.80	1.78	6.56	Feasible

Table 2 shows 5 (five) indicators produced from the computation. The economic feasibility of a project can be directly judged from the value of 4 (four) indicators which are NPV, IRR, BCR, and PBP. When the value of either NPV or BCR is negative or the value of BCR is less than 1, the project is considered not feasible. When the value of both NPV and BCR is positive and the value of BCR is more than 1, the project is considered otherwise. Moreover, when the value of PBP is greater than the project lifetime, the project is considered to be not feasible and vice versa.

It can be seen also from Table 2, the computation was performed from wind speed range 4-7 m/s. The feasibility results for each wind speed are shown in the last column in Table 2. It can be seen that the project is not feasible when the wind speeds are 4 m/s and 5 m/s in terms of all indicators. The project starts to be feasible for all indicators except PBP when the wind speed increases to 6 m/s. At this point, the value of PBP is still very large which means the project is still not feasible because the PBP is longer than the turbine lifetime. However, as wind speed increases to 7 m/s the project has become not only feasible but also the PBP value is only 6.56 which less the project lifetime.

5. Conclusion

The economic feasibility of installing a small-scale wind energy project in the coastal area in South Sulawesi has been evaluated in the present study. A 300-watt wind turbine was used as a sample installation to determines the investment and operational costs of the project. The computation was performed using a developed computer program. It was found that the lower range of wind speed resulted in a non feasible project while the highest range of wind speed was considered feasible to be implemented.

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