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Economic Feasibility Evaluation of the Use of Wind Microgenerator in Multifamily Building in Southern Brazil

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Abstract: There is a growing worldwide interest in the potential of using existing buildings to generate their own energy as a way to alleviate problems related to the exhaustion of energy resources, environmental degradation and the constant increase in energy-related prices. Among the distributed electricity generation solutions on the market today, wind energy can be a solution for many existing city buildings worldwide. Thus, the objective of this article is to investigate the economic viability of generating wind energy in a multifamily building located in Southern Brazil, (city of Passo Fundo), seeking to supply the condominium electric energy for the period of one year of consumption with a renewable source. To this end, the energy demand of the condominium and the energy generation of the wind turbine were taken into account to calculate the economic viability of the system. The results showed a positive NPV (net present value) demonstrating the economic feasibility of carrying out such an investment. The IRR (internal rate of return) was 15.22% and the return on investment (payback) occurs in 7.88 years.

Key words: Wind energy, microgeneration, renewable energy, economic analysis.

1. Introduction

The energy crisis scenario that occurred in Brazil in 2001, together with the increase in energy consumption, led to the creation of Law No. 10,295 on the National Policy for the Conservation and Rational Use of Energy [1], determining energy consumption levels of equipment and buildings.

In the national energy scenario, the consolidated report of the National Energy Balance annually publishes data on energy production and consumption in Brazil. According to the report, residential buildings were responsible for 26.1% of final electricity consumption in 2019 [2], with an increase in consumption of 4% in 2020, due to factors linked to Covid-19 pandemic such as home office and purchase of appliances to increase comfort in homes, causing an increase in electrical consumption in the residential sector [2]. Within residential energy consumption, the most used primary energy was electricity, representing 46% of total energy consumption [2].

One of the ways to reduce the pressure on the electrical system is the insertion of on-site renewable energy generation. According to Li et al. [3], there is a growing worldwide interest in the potential of buildings that aim to generate their own energy as a way to alleviate problems related to the exhaustion of energy resources and the degradation of the environment. In Brazil, normative resolutions No. 482/2012 and

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687/2015 of the National Electric Energy Agency [4, 5] allow the insertion of locally produced renewable energy to the distribution network, generating consumption credits in case of surplus production, to be discounted in a bill from a property of the same owner.

In this context, one of the renewable energy sources that can be installed, both on a small scale (distributed generation) and on a large scale (wind farms) is the use of wind to generate energy. It is an essential energy source for achieving the CO_2 emission reduction targets outlined in international agreements [6].

Studies on the technical feasibility of installing small wind turbines in single and multi-family homes attest that it is technically possible to generate enough energy through the wind to supply the residential demand depending on the amount and constancy of the winds in the region studied [7-9]. However, few national articles calculate the economic feasibility of installing such wind turbines with a detailed presentation of the calculations performed to assess the economic feasibility of installing them.

In this sense, this article aims to investigate the economic viability of generating wind energy in a multifamily building located in Southern Brazil, more precisely in the city of Passo Fundo, seeking to supply the condominium electric energy for the period of one year of consumption with a renewable source. It is important to emphasize that this is a hypothetical study of economic feasibility, since the wind turbine has not yet been installed in the building in question.

2. Method and Materials

To quantify the energy demand of the studied building, electric energy bills of the studied building were used. In this way, it was possible to establish monthly consumption in kWh of the condominium as well as the amounts in local currency (BRL: R$) paid to the distributor. These values were used to calculate the economic viability that will be described later.

The next step was to verify the potential for generating energy from the wind with the wind turbine positioned above the roof of a 12-story multifamily residential building with an approximate height of 40 m. In order to verify the wind regime of the studied city and, consequently, the energy generation potential, the object of study is presented as follows.

2.1 Object of Study

The present study was carried out in Passo Fundo/RS (28°15′ S, 52°24″ W and 687 m of altitude), which, according to the Köppen classification, is located in the temperate fundamental climate zone (C), with a humid fundamental climate (f) and specific subtropical variety (Cfa) [10]. Table 1 shows the average monthly speeds of the Passo Fundo wind regime determined from measurements from Embrapa Trigo meteorological station in the period 1977 to 1994, with a height of 10 m as a reference [10]. It is important to highlight that monthly average values of the winds do not have a significant variation in the different months of the year in this city, being the maximum variation when comparing the months with the highest average speed (4.7 m/s) and with the lowest (3.8 m/s) of only 0.9 m/s (Table 1). This fact gives Passo Fundo regular volumes of wind throughout the year, which is beneficial for the installation of wind turbines.

However, taking into account that the wind turbine to be studied is located on top of a multifamily residential building of approximately 40 m in height, and the wind turbine tower is 6 m long (totaling at least 46 m), and that the wind speed is greater as the altitude increases, higher speeds are expected in relation to those shown in Table 1. Thus, according to the Wind

Table 1 Average speed (m/s) of Passo Fundo at a height of 10 m in the period 1977-1994.

	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Speed (m/s)	4.1	3.9	3.8	4.0	3.9	4.2	4.7	4.4	4.7	4.5	4.3	4.2

Source: Empraba Trigo [10].

Table 2 Specifications of the wind turbine model selected in this study provided by the manufacturer.

Specification	Value	Specification	Value
Rotor diameter	3.72 m	Kilowatt hour per month	400 kWh/month*
Weight	77 kg	Limit wind	63 m/s
Wind for start of generation	3.5 m/s	Nominal speed	50-325 rpm
Nominal power	2.4 kW	Charging	Inverter 120-240 V, 50-60 Hz
Propellers	Triple injected mold	Braking system	Electronic with regulator control
Nominal wind	9.4 m/s	Lifespan	20 years, without maintenance

* Generation taking into account an average monthly wind speed of 5.4 m/s.
Source: Energia pura [11].

Atlas of Rio Grande do Sul [12], the average annual wind at a height of 50 m in Passo Fundo is around 6 to 7.5 m/s, generating a flow of wind power from 250 to 500 W/m^2.

Therefore, for the calculations of the study, a conservative annual average of 5.4 m/s will be used, since this is the value informed by the manufacturer that generates 400 kWh/month. As the focus of this study is to assess the economic viability of the system, aspects that do not influence this aspect, such as legislation and technical aspects related to noise generated by the wind turbine, were not taken into account.

2.2 Wind Turbine

The specifications of the equipment selected in this study are described in Table 2.

In contact with the company that installs wind turbines with these specifications, the budgeted amount for the installation of the system was R$ 47,000.00 (amount budgeted in October 2021). This value includes the wind turbine itself with the specifications in Table 2 with a price of R$ 35,000.00 and the 6 m tower for installation on the roof of the building with a price of R$ 12,000.00. The equipment has an internal universal inverter, which does not require a separate purchase. For the financial calculations, the payment in cash without interest or installments was taken into account. According to the company, it is not necessary to carry out any maintenance until 20 years of use, however, to maintain the conservative character of the study, a percentage of the initial investment of 1% p.a. was used [13].

2.3 Economic Feasibility Study

From the condominium monthly electricity consumption, the investment made in the purchase and installation of the wind turbine and its energy generation, it is possible to develop the economic feasibility study. The study calculations were carried out based on the indicators for the month of October 2021 with the following considerations:

- Wind turbine with a lifespan of 20 years without maintenance;
- Average consumption of electric energy of 567.92 kWh/month (the bills of the last 12 months were added and the value was divided by 12);
- Residential consumer belonging to the three-phase 220/127 V subgroup B1, with a conventional tariff of 0.99 R$/kWh [14]. Red flags and taxes were not taken into account.
- Default value of 8.63% p.a. for the correction of the electricity tariff, based on the annual readjustment of 2019 [14];
- Initial investment of R$ 47,000.00 according to market research;
- Operation and maintenance costs of 1% p.a. on the total initial investment [13];
- Selic interest rate (the basic interest rate of the Brazilian economy) of 6.25% for October 2021 [15].

For the economic feasibility analysis, three methods were used: Payback period of the investment, NPV (net present value) and IRR (internal rate of return). To calculate the NPV, a 20-year cash flow was used. The results found in this study are presented as follows.

3. Results and Discussion

From the calculations of generation and actual energy consumption, it was possible to calculate the decrease in the amount to be paid to the energy distributor and consequently how much the system would save annually. As informed by the manufacturer in the methodology and taking into account Passo Fundo wind regime, the energy generation per month for calculation purposes was fixed at 400 kWh per month, totaling 4,800 kWh per year.

To calculate the condominium consumption, an energy bill with the consumption history was consulted and an average of the last 12 months was calculated (September 2020 to August 2021). Thus, the monthly average consumption of the condominium was 567.92 kWh per month. Taking into account generation and consumption, each month there would be 167.92 kWh left over for payment to the distributor, a decrease of 70.4% with the installation of one wind turbine.

From the investment of R$ 47,000.00 informed by the supplier and with the aforementioned generation and consumption data, investment analysis indexes were calculated. The first calculation performed was the NPV; in order to be carried out, it was necessary to calculate the annual revenue flows of the 20 years delimited in this study. Revenue values were calculated by multiplying the energy value annually corrected by the energy generated annually (4,800 kWh) and subtracting the percentage of operation and maintenance. Thus, in the first year, the amount of revenue would be R$ 4,692.10 and it increases from year 2 onwards as the price of energy also increases (correction of 8.63% per year). Thus, the NPV calculated at a rate of 6.25% (Brazilian base tax rate in October 2021) resulted in a positive value of R$ 59,021.42, demonstrating the economic feasibility of carrying out such investment. As the rate used increases, the NPV decreases until it reaches zero at 15.22%, which is the IRR of the investment. The return on investment (payback) occurs in 7.88 years (95 months).

Thus, taking into account the energy generation from the Passo Fundo wind regime and installation at height so that the average wind generation is what is defined by the company that supplies the wind turbine, the investment made becomes economically viable, reducing considerably the payment of the energy bill on a monthly basis (-70.4%). It is important to note that tariff flags were not taken into account.

Despite the economic study being viable at a rate of 6.25% (positive NPV), if other forms of distributed generation are considered and if the interested party has an available roof/coverage area, the wind option may not be the most attractive. According to studies of Lima et al. [16], who carried out economic feasibility studies on photovoltaic generation in the same city of this research, around 9 m^2 of solar panels would be needed for the average monthly generation of 165 kWh. In other words, it is possible to estimate that with about 22 m^2 of area it would be possible to generate the equivalent of 400 kWh of the wind turbine, requiring 22 panels and an investment of approximately R$ 25,000,000 based on the same study. As these values were estimated, comparative studies of the same building between the two sources are recommended to draw a more accurate comparison.

Another aspect to be highlighted is that a very conservative average annual wind speed was used for a height of 50 m in Passo Fundo of 5.4 m/s. If the minimum value informed in the Wind Atlas [12] is taken into account, which is 6.0 m/s, the annual energy generation would be 6,585 kWh, supplying almost all consumption (96.6%) of the referred building, increasing economic feasibility. In this new scenario, the NPV would increase to R$ 100,412.80, the IRR would be 20.07% and the payback would decrease to 6.12 years. In other words, the annual wind average to be considered in the study directly impacts the economic results, and other studies can be carried out exploring this variable.

Finally, in this study, only one specification of wind turbine available in the Brazilian market was studied, making it possible to verify if other models have a more interesting feasibility. Hybrid generation can also be interesting for some businesses or industries, as solar and wind power generation are complementary due to seasonality [17]; while solar generates more electricity in the summer due to increased solar radiation, wind generates more energy at night and in winter.

4. Conclusions

The growth of distributed energy generation motivated the realization of the economic feasibility study of the installation of a wind turbine on the roof of a multifamily building in Passo Fundo/RS. From the calculation and analysis of NPV, IRR and payback, it is concluded that the investment of the case studied in this research is financially viable. However, it is important to emphasize that the profitability of the system may be affected due to uncertainty due to the long period of 20 years without maintenance of the system, the growth of interest and possible changes in the current legislation.

Anyway, in view of the current scenario of tariff growth, interest rates on the rise, the population's growing interest in generating their own energy, it is believed that investments in distributed energy generation equipment tend to increase. In this context, wind energy should be one of the options to be studied to verify its feasibility, both technical and economic. This study's premise was to examine only the economic aspect of distributed wind generation, not taking into account technical and legal aspects.

Analyzing the results, it is possible to verify that as an investment, the installation of a wind turbine on the roof of a building in Passo Fundo is feasible due to the NPV being positive. However, the payback period was relatively high (7.88 years) and other forms of distributed generation, such as solar photovoltaic, for example, may have an advantage in this regard. The IRR was also not very high in the present study, and if the financial aspect of the investment is strictly evaluated, it is possible that there will be competition with other forms of investment. It is worth mentioning that the energy generation projections were conservative, and it is possible for the system to generate more energy due to the Passo Fundo wind regime and the height of the system. If the average monthly generation was higher, the economic viability would be even better, as the NPV and IRR would increase and the payback would decrease.

As limitations of the study and suggestions for future work, it is recommended a real case be studied, that is, in which a wind turbine was installed so that energy generation is more accurate; other wind turbine specifications be evaluated; technical aspects of installing a wind turbine be analyzed on the roof of a multifamily residential building (e.g. noise); the possibility of hybrid generation be evaluated (solar and wind); a comparison of the same location be performed with other forms of distributed generation (e.g. solar photovoltaic); the influence of other buildings be studied in the surroundings on the wind regime.

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