ECONOMIC ASSESSMENT OF ONSHORE MICRO WIND TURBINES FOR POWER GENERATION IN LATVIA

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Abstract. The paper illustrates economical assessment of the grid-connected onshore micro wind turbines. The calculation is based on onshore wind speed hourly minimum value of 4 m height in Latvia approximated according to each wind turbine tower height. The result shows that increase in annual expenditure on electricity produced by onshore micro wind turbines is more than 264 %.

Keywords: power generation economics, wind turbines.

Introduction

In order to preserve the climate balance in the world, carbon dioxide (CO_2) emissions per capita should not exceed 3.8 tons per year. Carbon dioxide emissions in Latvia currently exceed this specified threshold, reaching 4.1 tons of CO_2 per capita per year. [1] One of the ways to reduce CO_2 emissions is increasing the use of energy resources that creates the least amount of CO_2 emissions, such as wind or sun.

The total wind energy potential in Latvia is estimated up to 1.5 TWh (at present installed power capacity is 0.112 TWh). [2-4] Therefore, making economical assessment of the onshore micro wind turbine for power generation in Latvia is worthwhile.

Average hourly wind speed in Liepaja (Latvia) at 10 meter height is shown in Fig. 1.

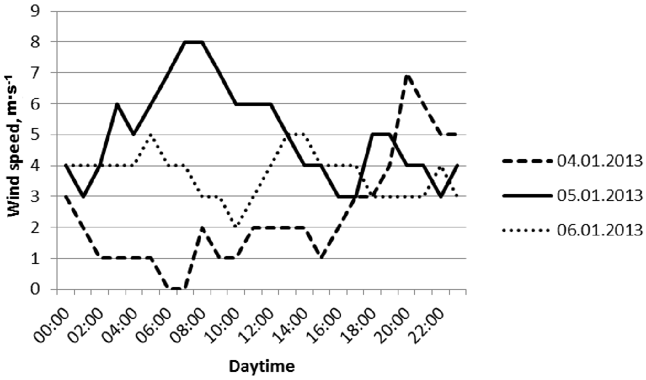

Fig. 1. **Average hourly wind speed in Liepaja (Latvia) 10 meter height [5]**

The stochastic fluctuations in the wind turbine output power may have large amplitude at the very short-term scale (at the minute or intra-minute scale) due to electricity generation of wind turbines changes markedly between 6 and 10 $m \cdot s^{-1}$ wind speeds. Average hourly wind speed seasonal change in Liepaja (Latvia) at 10 meter height shown in Fig. 2.

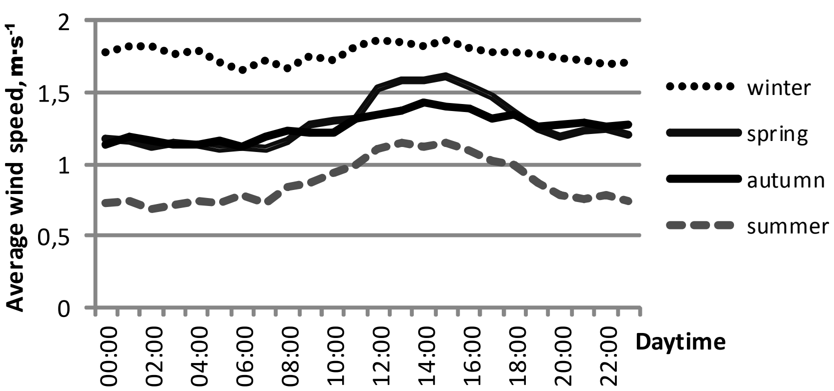

Fig. 2. **Average hourly wind speed in Liepaja (Latvia) 10 meter height [5]**

Therefore, the calculated output power accuracy is highly dependent on what wind speed data are used – hour, minute or intra-minute scale.

Materials and methods

A case study was carried out for 3 type horizontal axis wind turbines with rated power 1 kW, 3 kW and 5 kW. The study is conducted for commercially available wind turbines. More detailed technical specification of these wind turbines is shown in Table 1 and online in [6].

Table 1

Technical specification of wind turbines

Parameter	1 kW	3 kW	5 kW
Tower height, m	8	9	12
Cut-in wind speed, $m \cdot s^{-1}$	2.5	3	3
Working wind speed, $m \cdot s^{-1}$	2.5…40	3.5…40	3.5…40
Lifetime, years	10	10	10
Installed capital cost, EUR	3927.06	7071.26	11891.8
Annual operating expenses, EUR per year	500	500	500

Power curves for these wind generators are shown in Fig. 3.

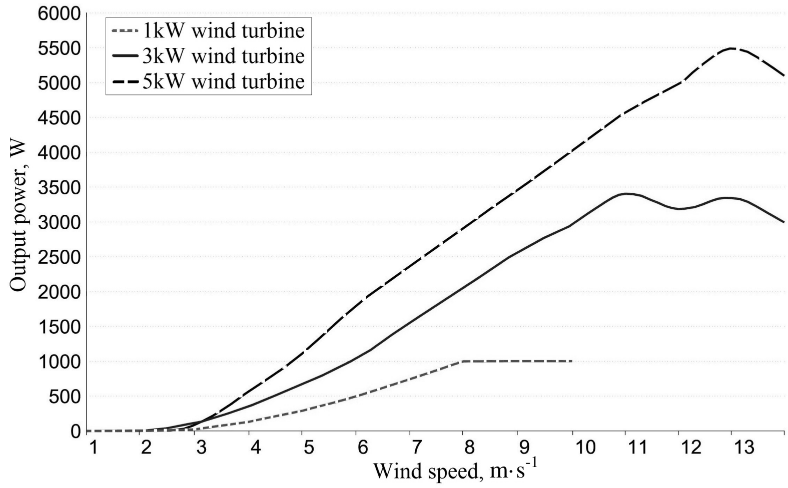

Fig. 3. **Power curves for 3 type wind turbines with rated power 1 kW, 3 kW, 5 kW [6]**

The wind speed map of Latvia is shown in Fig. 4. A case study was carried out for five cities-Liepaja, Pavilosta, Mersrags, Ainazi and Rezekne using hourly wind speed data [5].

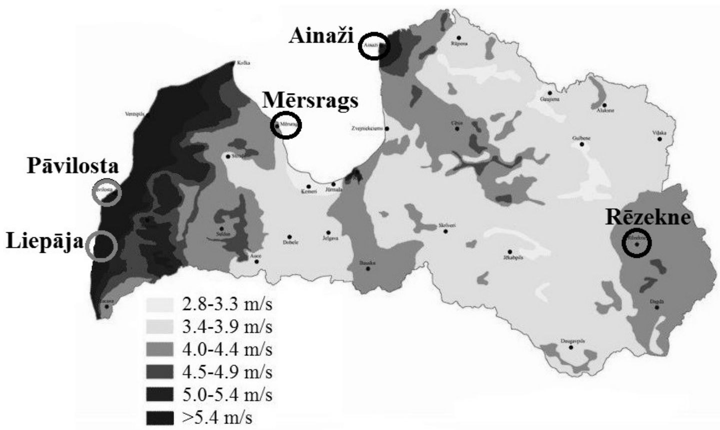

Fig. 4. **Average yearly wind speed in Latvia 10 meter height [7]**

In order to estimate the wind speed at certain height *h*, the relationship would be rearranged to:

$$V_h = V_0 \cdot \left(\frac{h}{h_0} \right)^{\alpha}, \tag{1}$$

where V_h – wind speed at certain height h, m·s^{-1};
V_0 – wind speed at a reference height h_0, m·s^{-1};
h_0 – reference height, m;
α = 0.16-0.24 empirically derived coefficient that varies dependent upon the stability of the atmosphere [8].

Since 2011 there are two tariffs for households in Latvia. "Start" tariff, i.e., 0.1164 EUR·kWh^{-1} is applicable to a user's consumption from 0 to 1200 kWh over a period of 12 months from the 1st April until the 31st March next year. "Base" tariff, i.e., 0.1515 EUR·kWh^{-1} is applicable to a user's consumption starting from 1201st kWh over a period of 12 months from the 1st April until the 31st March next year [9].

The NET billing system for electricity micro generation in Latvia is implemented in accordance with the Electricity Market Law and it is in force from January 1, 2014. The NET billing system means subtracting the electric energy supplied out of a customer's site during the billing period from the electric energy supplied into the customer's site during the billing period, and calculating a net charge or credit to the customer based on the resulting net usage of electric energy during the billing period.

If, in accordance with the calculated amount of electricity consumption and the electricity generated by a micro generator, household has transferred to the distribution system operator's network more electricity than consumed, the corresponding amount of electricity is counted within the next settlement period within the framework of one calendar year. The NET billing system settlement period is one calendar month. If a household whole year produces more electricity than it consumes, the difference between the consumption and the generated electricity is transferred to the distribution system operator's network without receiving compensation [10].

Annual expenditure on electricity produced by onshore micro wind turbines in Latvia can be calculated using the algorithm (see Fig. 5).

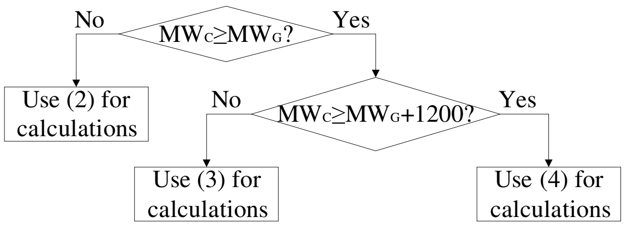

Fig. 5. **Algorithm for annual expenditure on electricity produced by onshore micro wind turbines or solar cells**

Brackets used in the algorithm`s diagram correspond to equation numeration.

In case when the annual energy consumption is lower than the annual energy generation by the wind turbine (or by another renewable energy source, i.e., solar cells), annual expenditure on electricity can be calculated using (2).

$$AE_e = MW_G \cdot PC, \tag{2}$$

where MW_G – annual energy generation by wind turbine, kWh;
PC – prime cost (the same value for the whole lifetime period), EUR.

In case when the annual energy consumption is higher than the annual energy generation by the wind turbine but at the same time lower than the sum of annual energy generation by the wind turbine and 1200kWh, annual expenditure on electricity can be calculated using (3).

$$AE_e = MW_G \cdot PC + \left(MW_C - MW_G \right) \cdot T_S, \tag{3}$$

where MW_C – annual energy consumption, kWh;

T_S – "Start" tariff, EUR.

In case when the annual energy consumption is higher than the annual energy generation by the wind turbine (or by another renewable energy source, i.e., solar cells) and at the same time higher than the sum of annual energy generation by the wind turbine (or by another renewable energy source, i.e., solar cells) and 1200 kWh, annual expenditure on electricity can be calculated using (4).

$$AE_e = MW_G \cdot PC + \left(MW_C - MW_G - 1200\right) \cdot T_B + 1200 \cdot T_S, \qquad (4)$$

where T_B – "Base" tariff, EUR.

Results and discussion

Breakdown of households by annual average consumption of electricity in Latvia is shown in Fig.6. It shows increase in the energy consumption from 1996 to 2010. In 1996 more than 50 % of household electricity consumption does not exceed 1000 kWh per year, but in 2010 more than 50 % of household electricity consumption exceeds 1600 kWh per year.

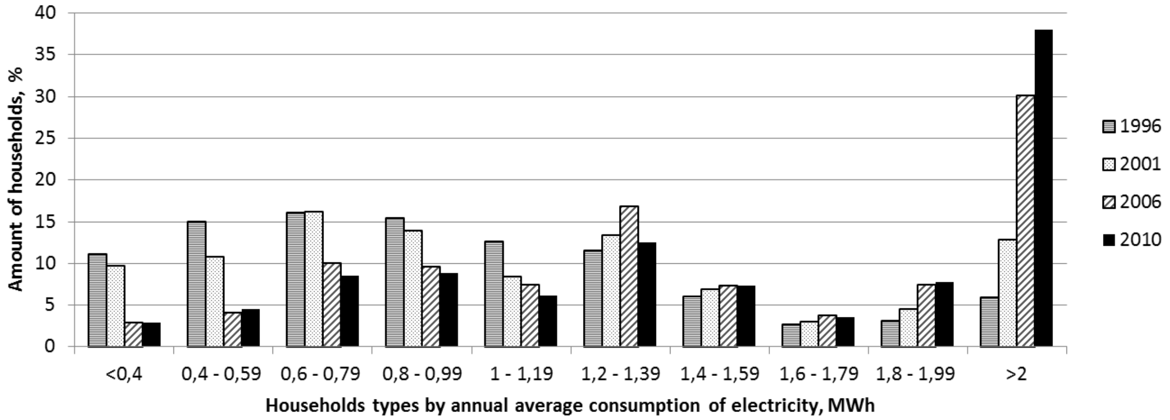

Fig. 6. **Breakdown of households by annual average consumption of electricity in Latvia [11]**

Annual expenditure on electricity depending on the household type by annual average consumption of electricity is shown in Fig. 7. In 2010 more than 50 % of household expenditure on electricity exceeds 200.28EUR per year.

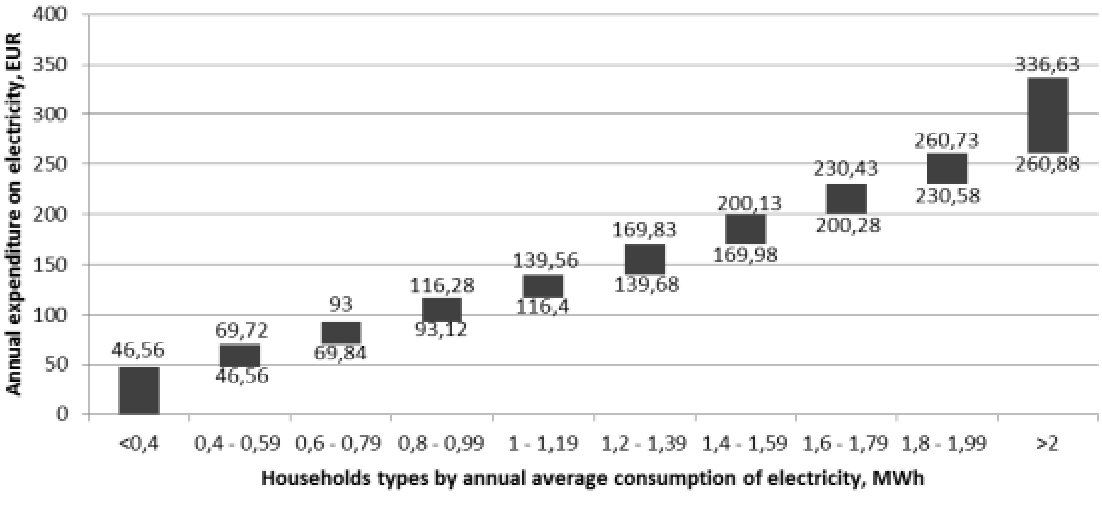

Fig. 7. **Annual expenditure on electricity depending on the household type by annual average consumption of electricity in 2010**

Increase in annual expenditure on electricity due to using wind turbines for all five cities – Liepaja, Pavilosta, Mersrags, Ainazi and Rezekne are so similar that the results can be reflected by one figure.

Increase in annual expenditure on electricity depending on the household type by annual average consumption of electricity (due to using 1 kW wind turbine) is shown in Fig. 8. Increase in annual expenditure on electricity more affect households with lower electricity consumption due to the fact that a household with lower electricity consumption has a proportionately higher part of electricity produced by onshore micro wind turbine. The prime cost of electricity produced by onshore micro wind turbines is more than 100 times higher than the electricity tariff.

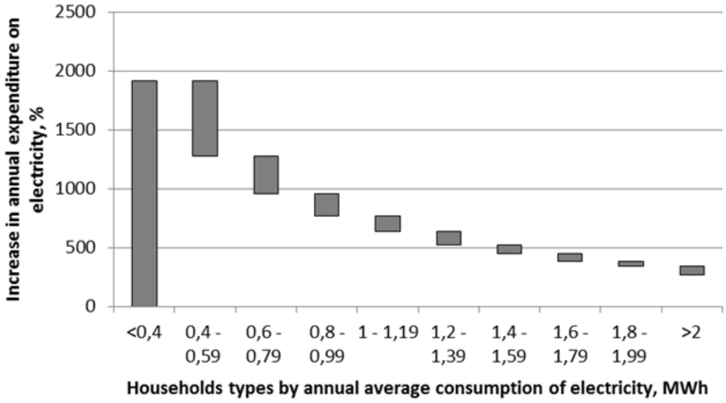

Fig. 8. **Increase in annual expenditure on electricity depending on the household type by annual average consumption of electricity (due to using 1 kW wind turbine)**

Increase in annual expenditure on electricity depending on the household type by annual average consumption of electricity (due to using 3 kW wind turbine) is shown in Fig. 9. Increase in annual expenditure on electricity due to using a 3 kW wind turbine is higher than in the case, when using the 1 kW wind turbine, due to the fact that onshore 3 kW wind turbine has higher investment cost but at the same time productivity is not proportional to the amount of the investment cost.

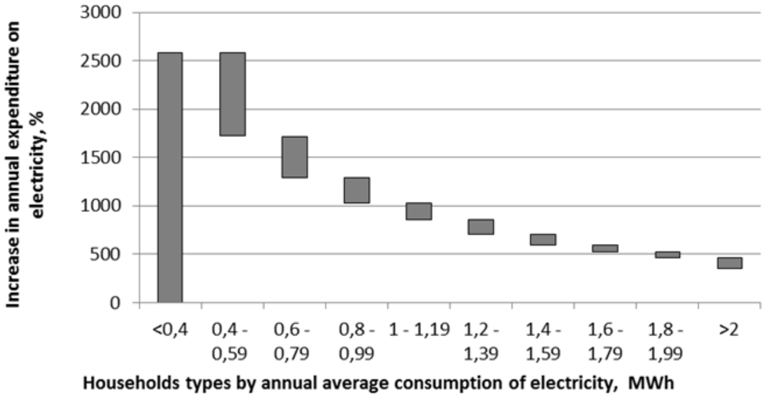

Fig. 9. **Increase in annual expenditure on electricity depending on the household type by annual average consumption of electricity (due to using 3 kW wind turbine)**

Increase in annual expenditure on electricity depending on the household type by annual average consumption of electricity (due to using 5 kW wind turbine) is shown in Fig. 10.

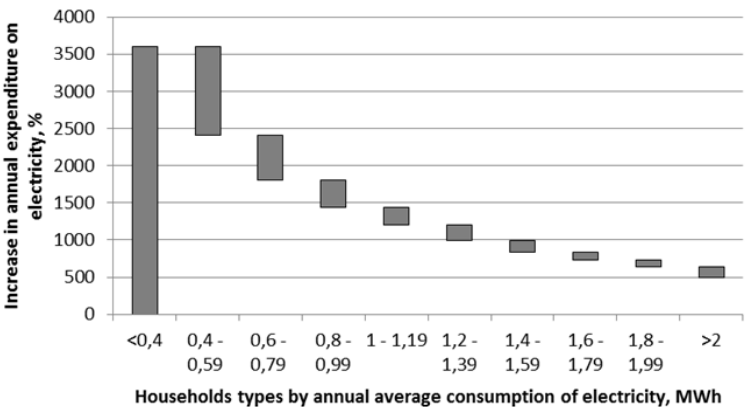

Fig. 10. **Increase in annual expenditure on electricity depending on the household type by annual average consumption of electricity (due to using 5 kW wind turbine)**

All three figures, i.e., Fig. 8, Fig. 9, and Fig. 10 show that electricity produced by onshore micro wind turbines in Latvia is not beneficial. Increase in annual expenditure on electricity produced by onshore micro wind turbines is more than 264 %.

Conclusions

The results of the performed study show that from the economic point of view onshore micro wind turbines (1 kW, 3 kW and 5 kW) for power generation in Latvia are unprofitable due to low productivity and high initial cost of construction and operations. Increase in annual expenditure on electricity produced by onshore micro wind turbines is more than 264 %.

It means that considering using of large wind farms or another renewable energy source instead of onshore micro wind turbines for reduction of CO_2 emissions is worth.

Acknowledgment

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