

# Wind Power in Heat Energy Systems

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**Abstract.** The article discusses opportunities for the use of wind power plants in order to supply heat to coastal settlements. The possibilities of meeting the needs of heat consumption in the city of Paldiski in Estonia using general data from wind power output serves as an example in the present paper. Monthly electricity and heat consumption graphs and schedules of the Republic of Estonia together with production charts of wind power plants were used as initial data for the research. The investigation of wind energy production charts shows that, due to stochastic peculiarities of the wind, it is especially complicated to match the latter and the electricity consumption charts. There have even been cases, where the dispatcher has been forced to limit wind energy production maxima so that it would not interfere with the work of generators at large power plants. However, satisfactory correlation was revealed between the monthly graphs of both electricity and heat energy overall annual consumption, and wind power production charts. Nevertheless, there are still high deviations, and therefore, in order to use wind energy for heating purposes, powerful storage devices or additional feeding units are necessary to level the fluctuations of electric power produced by wind plants.

The problems related to the production usage of wind power plants in heat and power engineering are to a certain extent less complicated due to the fact that heating systems can be supplemented with additional heat energy storages. Considering the above mentioned issues, the authors suggest a more extensive usage of wind power plants for heating towns and settlements, particularly in cases when production peaks interfere with the work of power systems.

Due to new capacity installations, the overall production of the wind power plants is constantly increasing. Thus, the authors recommend that the maximum power usage coefficient of an operating wind power plant, not their overall production data should be used for analyzing the efficiency of the present power plants and for designing new ones. This will be more correlated with power and heat consumer load curves.

**Key words:** Energy, heat energy system, boiler, wind power, production and consumption charts

## INTRODUCTION

Energy system is a system meant for the production, transmission and distribution of power and heat energy to consumers, which consists of energy producers (power plants and CHP-s, district heating boiler houses), electrical- and heating networks, and consumers. This kind of system is responsible for a smooth supply of high quality electrical and heat energy to consumers.

Since a vast majority of wind power plants produces electrical energy, one of the main wind power engineering problems is matching the wind parks production schedules and energy production and consumption charts. Due to wind stochastic characteristics, the abovementioned charts do not particularly match and, thus, the actual fuel economy and air pollution reduction percentages are considerably smaller compared to those expected (Liik et al., 2005). This problem has been thoroughly discussed by Ivo Palu in his research (Palu et al., 2008; Palu et al., 2009; Palu, 2009).

Wind energy share in the world's power engineering is constantly increasing. The development of wind power engineering in the European Union has been much more rapid than in the rest of the world which is mainly a tribute of praise to Germany and Spain.

In recent years, wind power engineering has developed considerably in the United States of America; in addition, focus on the problems in the field has grown both in China and India. By the end of 2008, 28.8% of all wind parks of 120,798 megawatts installed worldwide is located in the United States, 19.8% - in Germany, 13.9% - in Spain, 10.1% - in China, and 8% - in India. During 2009, 30.9% of additional capacity of 27,061 megawatts were in the USA, 23.3% - in China, 6.7% - in India, 6.2% - in Germany and 27% - in the rest of the world (US and..., 2009).

Estonia's opportunities of wind energy usage are relatively limited, primarily due to the modest size of its territory and population; thus, wind power engineering development data are not in absolute terms comparable to those of the countries considerably larger than Estonia. Nevertheless, significant progress has been made in the field of wind power engineering, which is mainly due to local enthusiasts. Estonian data related to the capacity of wind power plants (at the end of 2008) and their output for the years 2006...2008 is given in Table 1.

**Table 1.** Wind power plants in Estonia and their power output in 2006-2008

Year	Installed capacity of power plants, MW	Electricity production, GW·h <sup>-1</sup>
2006	31	76
2007	58	91
2008	77	133

The table shows that throughout the observed period, the capacity of wind power plants in the Republic of Estonia has increased by approximately 2.5 and wind energy output by 1.75 times. Furthermore, in 2008, capacity installation increase constituted 32.8% and wind power output growth over 46%.

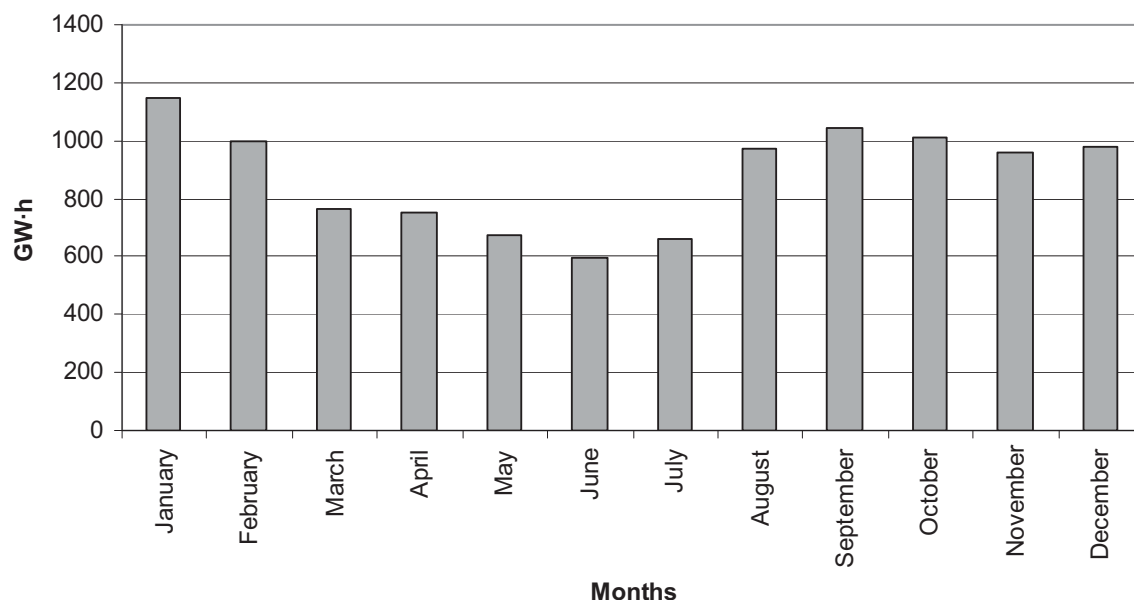
It is interesting to note that the total capacity of wind parks in Estonia at the end of 2008 accounted for a little over 0.06% of the world's total wind power capacity.

#### **Estonia's power and wind power engineering data in 2008**

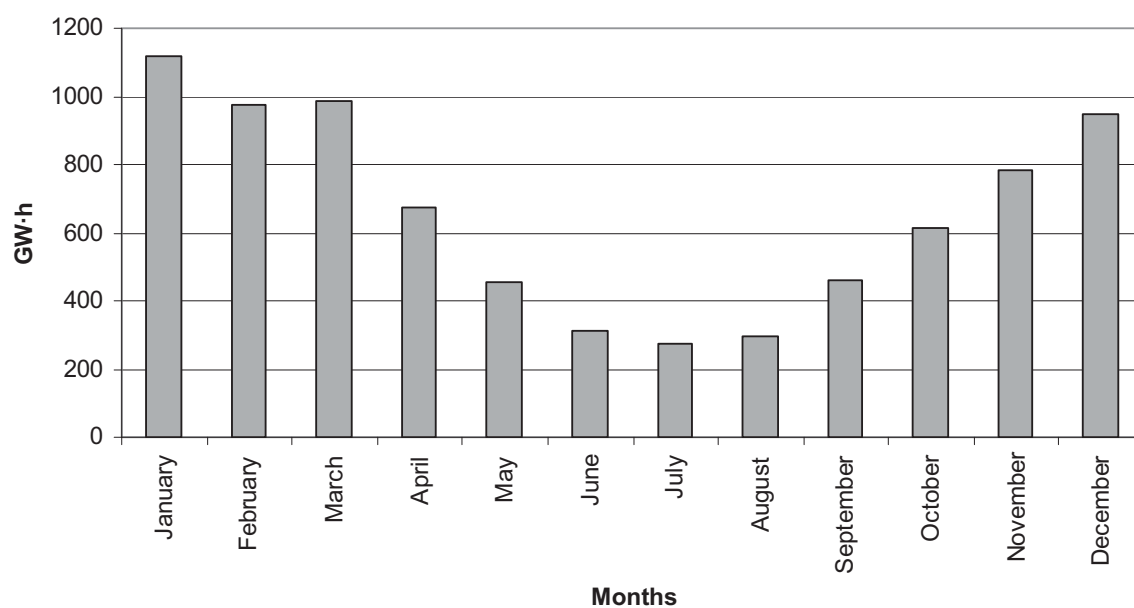
Figs 1 and 2 represent Estonia's overall power and heat production (consumption) charts in 2008 (Power and..., 2009). Fig. 3 shows data from the same period on the output of wind power plants in Estonia. Figs. 1 and 2 show that the

monthly need for both electrical and heat energy to a certain extent correlates to wind power output.

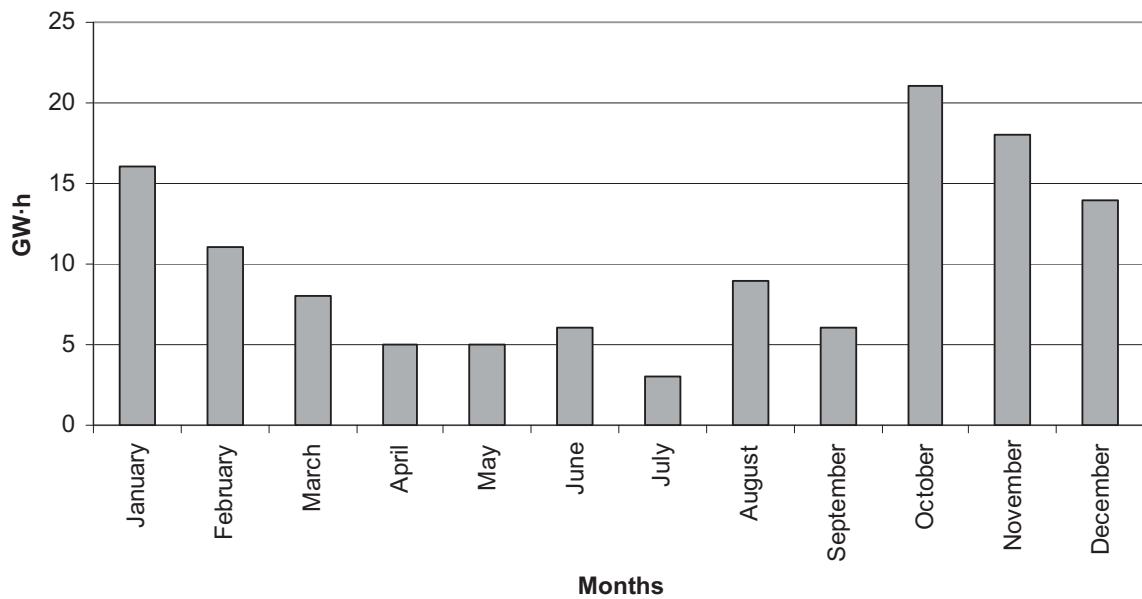
Subsequently, we are to check the compatibility of both electricity and heat consumption charts with the wind power output in Estonia in 2008. Therefore, we analyse the above mentioned charts in proportional units. Fig. 4 shows charts about electricity and heat consumption as well as wind power output.



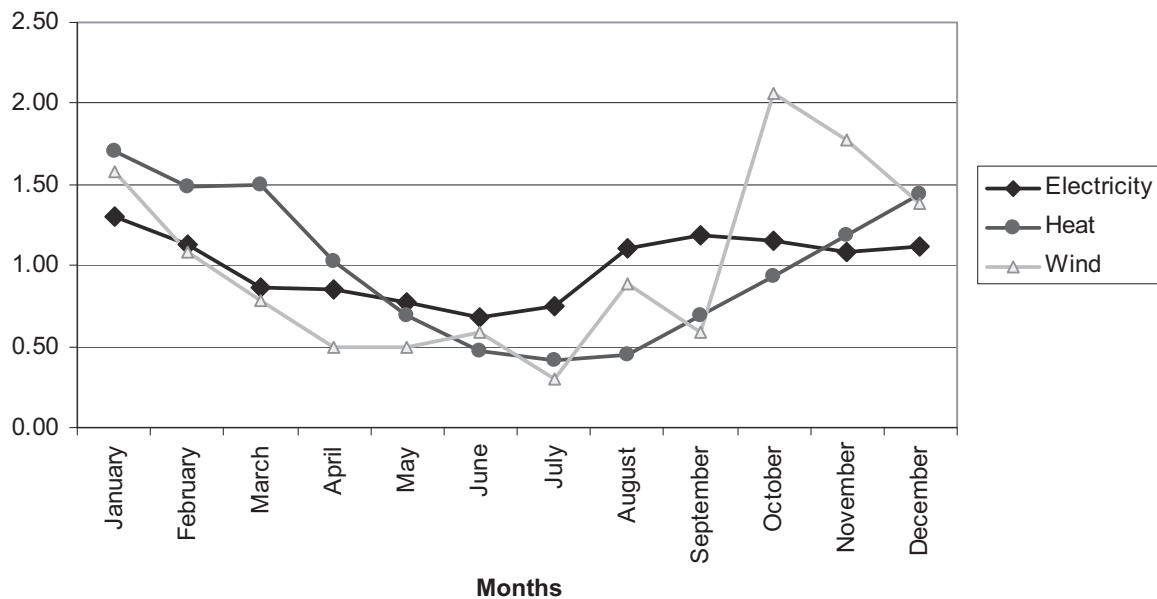
**Fig. 1.** Electricity production in Estonia in 2008.



**Fig. 2.** Heat production in Estonia in 2008.



**Fig. 3.** Wind power production in Estonia in 2008.

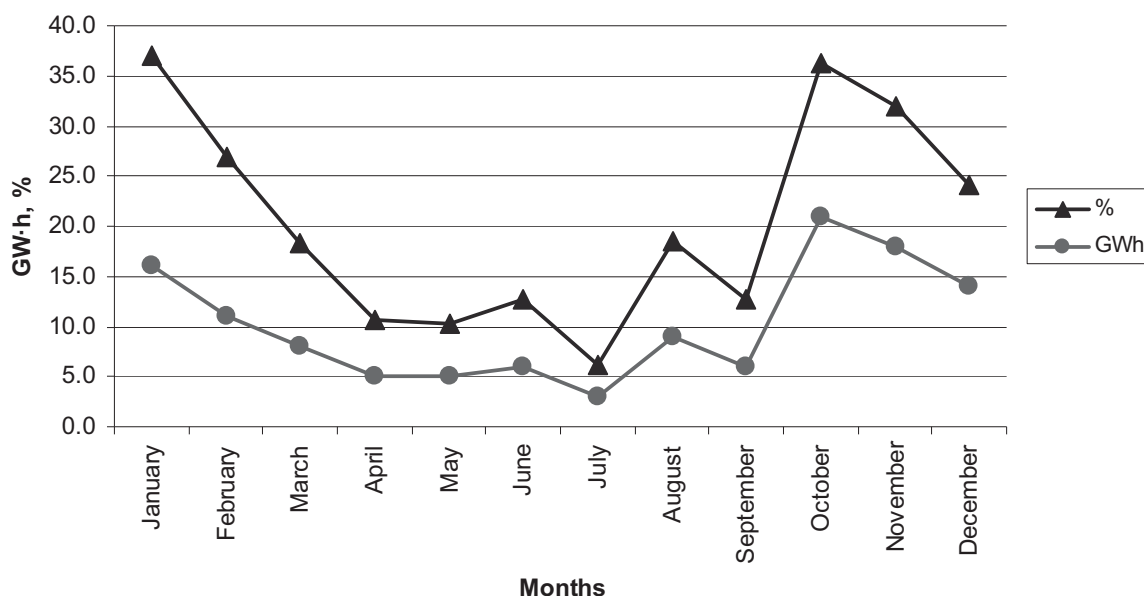


**Fig. 4.** Estonia's electricity and heat consumption and the wind (electrical) power output in proportional units in 2008.

On the basis of the above mentioned charts, correlation coefficients of wind power output and electricity and heat consumption were marked in Fig. 4. Correlation coefficient values between the wind and electrical power was 0.699, and the wind and heat power was 0.532.

It should be noted that the wind power output characterizes the actual situation, but its potential is of greater interest and is better characterized by the maximum power usage coefficient. For example, the installed capacity of wind power plants in Estonia increased three times in 2008; in February – 0.8 MW (Virtsu additional windmill), in April – 6.9 MW (2-nd Virtsu wind park), and in October – 12 MW (Esivere Wind Farm Stage 1).

In Fig. 5, the overall monthly wind power output in Estonia and the maximum capacity usage coefficient of wind power plants in 2008 are compared.



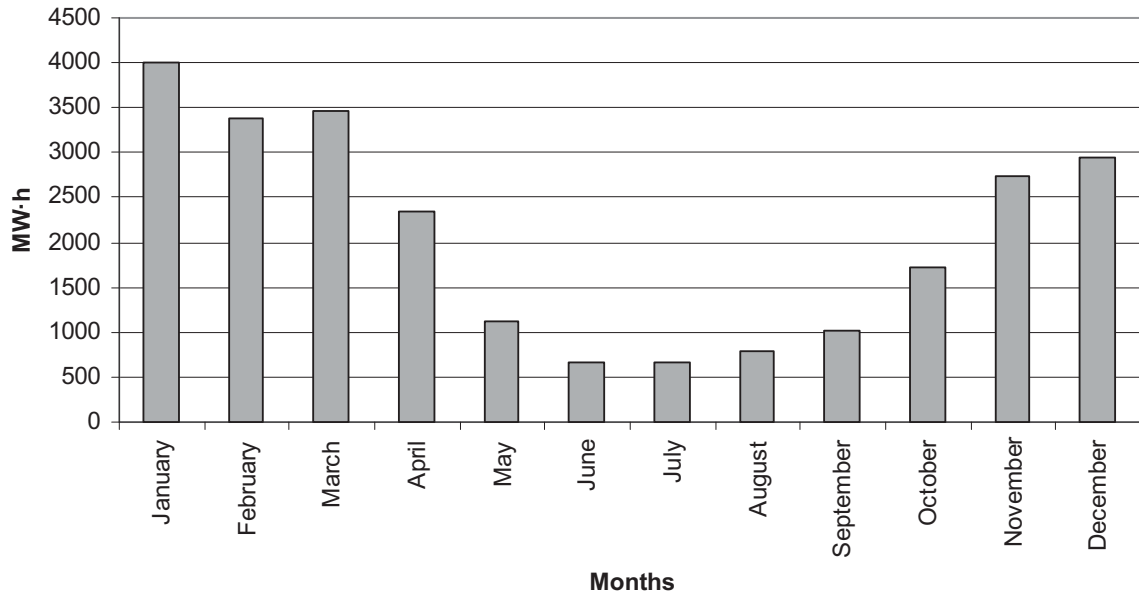
**Fig. 5.** The output of Estonian wind power plants and their maximal power usage coefficient in 2008.

Correlations between maximum wind power usage coefficient with monthly electrical power consumption and monthly heat power consumption are 0.765 and 0.657, respectively; these are significantly better than correlations with total wind power output data.

### **Opportunities for wind power usage for heating a small town**

Considering the substantial wind resources of Estonian coastal areas, the authors explored the idea of the prospects of wind power usage for heating coastal towns. As the result of the cooperativeness of the employees of Paldiski Heat AS, the authors managed to acquire information on heat production and consumption in the town of Paldiski in 2007 and 2008. Thus, the abovementioned town with a population of approximately 4,350 inhabitants was chosen for analysis.

Fig. 6 shows the monthly heat production in the town of Paldiski in 2008.



**Fig. 6.** Heat production in Paldiski in 2008.

Heat power output for the town of Paldiski in 2008 was 24,811 MW h<sup>-1</sup> (compared to 2007 data: 25,601 MW h<sup>-1</sup>). The above data show that no significant changes occurred in the town's heat system throughout the year.

Supposing that in order to meet the town's heat consumption needs we intend to build a wind park, the annual power output of which corresponds to the demand (i.e. ~ 25,000 MW h<sup>-1</sup>). Assuming that the maximum power usage coefficient of a wind park generator corresponds to Estonia's average annual data of a currently operating wind farm (20.4% in 2008), we get the necessary wind park power formula:

$$P = W/(k_{mv} \cdot T), \quad (1)$$

where  $P$  is the rated (maximum) power of the wind generator, MW,  $W$  - energy produced by the device during the observed time interval, MW h<sup>-1</sup>,  $T$  - observed time period in hours,  $k_{mv}$  - maximum power usage coefficient.

In this case, the predetermined amount of energy is 25,000 MW h<sup>-1</sup> and the period is 1 year (given – 8,760 hours, although in 2008 there were 8,784 hours). Operating with this year's data, we conclude that the capacity of approximately 14 MW is needed to produce the necessary amount of energy.

Since the maximum power usage coefficient of a wind mill differs from month to month, we get the formula (2) to calculate the possible monthly power output in  $W_k$ .

$$W_k = P \cdot k_{mv} \cdot T_k, \quad (2)$$

where  $P$  is power of a wind generator (in this case, 14 MW) and  $T_k$  - the calculated number of hours per month.

The results of the calculation are shown in Table 2.

**Table 2.** Potential monthly power output

Month	Number of hours	$K_{mv}$	$W_{exp}$ , MW·h <sup>-1</sup>	$W_{Ps}$ , MW·h <sup>-1</sup>	Wind parks possible overproduction (+) and underproduction (-), MW·h <sup>-1</sup>
January	744	37.1	3,864	3,995	-131
February	672	26.9	2,531	3,388	-857
March	744	18.3	1,906	3,459	-1,553
April	720	10.6	1,068	2,333	-1,265
May	744	10.2	1,062	1,113	-51
June	720	12.7	1,280	668	612
July	744	6.1	635	670	-35
August	744	18.4	1,917	788	1,129
September	720	12.7	1,280	1,008	272
October	744	36.2	3,771	1,723	2,048
November	720	32.1	3,236	2,730	506
December	744	24.1	2,510	2,936	-426
Total			25,061	24,811	

This table shows that the expected wind farm power output of 14 MW exceeds  $W_{exp}$  heat consumption of the town of Paldiski  $W_{Ps}$  during five months of the year, whereas, during the remaining seven months, the indicator is lower. The deficit occurs predominantly during the first months of the year as those are the months of a considerably lower temperature and predominantly lower probability of the occurrence of strong winds. This situation is made more complicated by the fact that underproduction occurs in succession for several months. This requires a unit of a significantly higher power capacity. Similar wind power storage problems are dealt with in the following articles (Pöder et al., 2009). In case of minor consumers, chemical storages (batteries) may be used, whereas, in case of major consumers, mainly water based heat capacity storages are necessary.

## CONCLUSIONS

All the facts considered, it appears that although the use of wind power systems compared to heat systems is to a certain extent less complicated, in case of year-round usage, several essential problems may occur related mainly to the difference between wind power output charts and consumer needs. As Estonia has no conditions for establishing energy-efficient power storage devices of acceptable energy capacity (hydro-pumped storage, compressed air storages), fuel and gas boiler houses are irreplaceable in local heating systems. In the near future, wind power usage may become economically rational in these heating systems, mainly due to increase in fuel and, particularly, gas price in the international market. The possibilities of wind power usage in gardening enterprises require more detailed investigation. In winter, power is necessary there for heating and lighting

greenhouses, and in summer for irrigation (inside and outside the greenhouse), production storage, etc.

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