Heat supply efficiency improvement in the Arctic regions with an increased wind potency

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Abstract. Arctic regions are known to be characterized by a situation when the cash costs associated with the heat power production for heat supply overshoot the heat power tariff. Therefore, part of the financial burden placed on the government by way of subsidizing the fossil fuel purchase and delivery to the settlements of the Arctic regions. Through the example the Tsypnavolok settlement, which is located in one of such regions, wind power plants using for heat supply are shown to be considered as a measure to reduce the government financial burdens. For Tsypnavolok the cost of power produced by the wind power plant revealed by calculations is amount to 67.02 USD/Gcal. This is not so many as the average heat tariff (67.9 USD/Gcal). At such heat supply indexes, wind power plants are not only to reduce the government financial burdens, but also to bring an extra income.

1. Introduction
Many countries view their future development in close liaison with the Arctic regions. One of the main concerns of the successful exploration and development of these areas is efficient and reliable operation of heat supply systems, which is being complicated by the severe climatic conditions and heating period duration. Large amounts of fossil fuel herewith are required for the uninterrupted operation of heat supply systems in the Arctic regions. This entails high cash costs for the fuel purchase and delivery to settlements. This problem is particular interest in hard-to-reach and remote settlements of the Arctic regions [1-2]. Therefore, solving the problems associated both with the fossil fuel delivery to the settlements of the Arctic regions and with the efficiency improvement of their heat supply is especially important for such regions.

The use of local renewable energy sources in heat supply systems may be one of the options aimed at solving the problems. The experience of Iceland gives a good example where geothermal energy is successfully used for heating needs [3].

2. Materials and methods
In the Arctic regions with an increased wind potency, there is a possibility of using wind power plants (WPPs) as an extra source of energy [4], including for heat supply [5-7]. In this case, it is important to assess the efficiency that can be, using WPPs in the heat supply systems of the Arctic regions, which is the main objective of this research.

In the regions mentioned, there are many settlements that have a similar organization of heat supply and the related problems described above. Therefore, the chosen object of the study was the heat supply system for the Tsypnavolok, which is one of such settlements.
The research presented in this paper was carried out in two main phases. The first phase included the collection and analysis of data on the heat supply state in Tsypnavolok. The data was obtained from reports on the heat supply companies operations and from regional government regulations. The review and analysis of the documents revealed a number of specific problems related to the heat supply management. The next phase of the research exemplified by Tsypnavolok showed that the use of WPPs for heat supply could be one of the problem-oriented options.

Various scientific approaches and methods applied in the research resulted in author’s achievement the research objective.

3. Results

Tsypnavolok is located in the Murmansk region in northwestern Russia. This inhabited locality is part of the Pechenga municipal settlement (Pechenga MS). As of 2020, Pechenga’s heat supply organizations, providing coverage of Tsypnavolok heating demand as well, imposed the tariff for heating to be at 49.4 USD/Gcal for the inhabitants and also approximately 71-102 USD/Gcal for other consumers (table 1). Given this, the average heating tariff for the Pechenga MS is possible to be approximately calculated. It is around 67.9 USD/Gcal. But this tariff is not enough to cover all the heat production costs. Therefore, the government has to subsidize this heat production, namely, purchasing and delivering of fossil fuel to the Pechenga MS inhabited localities.

Table 1. Heat tariffs for some heat supply organizations in the Pechenga MS.

| Organization name | Unit of Measurement | Customer Class | Period from 01.01.2020 to 30.06.2020 | Period from 01.07.2020 to 31.12.2020 |
|-------------------|---------------------|----------------|-------------------------------------|-------------------------------------|
| OOO “Teplostroy Plus” (Limited Liability Company) | USD/Gcal | Inhabitants | 49.4 | 49.4 |
| OOO “PromVoenStroy” (Limited Liability Company) | USD/Gcal | Inhabitants | 49.4 | 49.4 |
| OOO “Teplostroy Plus” (Limited Liability Company) | USD/Gcal | Other | 61.7 | 70.9 |
| OOO “PromVoenStroy” (Limited Liability Company) | USD/Gcal | Other | 81.1 | 102 |

Table 2 shows data on the amount of subsidies, provided to some heat supply organizations in the Pechenga MS in 2019. These organizations has been annually provided by the subsidies in order to compensate for shortfall in revenue associated with the fossil fuel price hike. The amount of subsidies is not constant from year to year and depends on the real cash costs for the fossil fuel purchase and delivery to the settlements of the Arctic regions.

Table 2. Subsidies to heat supply organizations in the Pechenga MS in 2019.

| Organization name | Amount, USD |
|-------------------|-------------|
| OOO “Teplostroy Plus” | 22180 |
| OOO “Teplostroy Plus” | 389430 |

As discussed above, to improve the heat supply efficiency as an extra source of energy, the use WPPs is available. Such WPPs can operate jointly with fossil fuel boiler rooms. This option of using WPPs reduces the boiler room involvement into heat supply and thereby save fossil fuel. The use of WPPs herewith is justified when the power cost produced by the WPP proved to be either less than or equal to the heating tariff. As exemplified by Tsypnavolok, the calculation results for such option of WPP using are further presented.
Tsypnavolok’s number of inhabitants is about 35 people. Given this, the 0.2 Gcal/h boiler room is required to meet industrial and municipal needs. The research [8] found that the WPPs optimal power operating jointly with a boiler room may amount to 0.6-0.8 of the boiler room power. 150 kW Bonus WPP can be recommended for Tsypnavolok (65% of the boiler room power) with the 23.8 m wind wheel diameter and the 30 m tower height.

To calculate the WPP annual power output, the probability function of the wind speed at the tower height and the WPP performance curve are both to be known. The Tsypnavolok average annual wind speed at the tower height is of 8.2 m/s. Hence, the probability function of the wind speed at the tower height looks as shown in figure 1. The WPP performance curve is shown in figure 2. Calculations showed that the WPP annual power output was of 570 thousand kWh per year.

![Figure 1. Probability function of the wind speed at an average annual wind speed of 8.2 m/s.](image1)

![Figure 2. 150 kW Bonus WPP performance curve.](image2)

The cost of energy produced by the WPP is possible to be determined, using the data presented. Relying on world prices for WPPs [9-10], unit costs on investments in WPPs amount to about 1,700 USD/kW. They include all costs associated with construction and commissioning of the WPP.

In some Arctic regions, there has already been an experience in the WPP construction. For example, one of the promising projects is the construction of the 201 MW “Kola Wind Farm” wind farm, whose unit costs on investments are estimated at 1.360 EUR/kW [11].

The power cost produced by a WPP depends on the annual depreciation charges, wage-and-salary disbursements and other expenses. If the WPP payback period is set equal to 15 years, then the power...
cost produced by the WPP is amount to 67.02 USD/Gcal. This is not so many as the average heat tariff (67.9 USD/Gcal).

This indicates that under such conditions, in the Arctic regions with an increased wind potency, the joint use of WPPs and boiler rooms for heat supply is more economically justified than using the boiler rooms only. By this token, this option for WPPs using provides an opportunity to reduce the boiler room involvement into heat supply and thereby save fossil fuel. Therefore this reduces government subsidies for such fuel to be purchased and delivered to the settlements of the Arctic regions.

Thus, the costing of power produced by the WPP and its comparison with the heat supply indexes (tariff and subsidies) of boiler rooms enabled the efficiency assessment of WPPs using in the heat supply systems of the Arctic regions.

4. Discussion

High cash costs for heat supply to settlements in the Arctic regions, funded in subsidies by the government for the fossil fuel purchase and delivery to these settlements, along with the environmental and public health degradation declined by fossil fuel boiler rooms, enhance the attractiveness of WPPs using for heat supply, providing the fossil fuel heat power replacement with power produced by WPPs.

The author points out that the possibility of WPPs operating for heat supply jointly with boiler rooms is of particular importance for the Arctic regions with an increased wind potency, since their use in heat supply systems is to minimize the problems of fossil fuel delivery to settlements in the Arctic regions and to improve the efficiency of their heat supply. At the same time, the need for subsidies in the share of power generated by WPP for heat supply completely disappears.

Thus, WPPs joint operation with boiler rooms for heat supply in the Arctic regions with an increased wind potency can be regarded as a measure to reduce the government financial burdens, which is of particular importance with the prevailing harsh economic environment in the country.

5. Conclusion

In order to solve the problems associated with high cash costs for settlements heat supply in the Arctic regions, funded in subsidies by the government for the fossil fuel purchase and delivery to these settlements, there is an available joint operation of WPPs with boiler rooms for heat supply. This option of using WPPs reduces the boiler room involvement into heat supply and thereby save fossil fuel. Therefore, this reduces government subsidies for such fuel to be purchased and delivered to the settlements of the Arctic regions.

Tsypnavolok, located in the Murmansk region in northwestern Russia, exemplifies that if the power cost produced by the WPP proved to be either less than or equal to the heating tariff, then joint operation of WPPs with boiler rooms for heat supply can be regarded as a measure to reduce the government financial burdens.

References

[1] Mortensen L, Hansen A M and Shestakov A 2017 How three key factors are driving and challenging implementation of renewable energy systems in remote Arctic communities. *Polar Geography* **40**(3) 163-85

[2] Hossain Y, Loring P A and Marsik T 2016 Defining energy security in the rural North—Historical and contemporary perspectives from Alaska. *Energy Research & Social Science* **16** 89-97

[3] Bustaffa E, Cori L, Manzella A, Nuvolone D, Minichilli F, Bianchi F and Gorini F 2020 The health of communities living in proximity of geothermal plants generating heat and electricity: A review. *Science of The Total Environment* **706** 135998

[4] Rafique S F, Shen P, Wang Z, Rafique R, Iqbal T, Ijaz S and Javaid U 2018 Global power grid interconnection for sustainable growth: concept, project and research direction. *IET*
Generation, Transmission & Distribution 12(13) 3114-23

[5] Li G, Zhang R, Jiang T, Chen H, Bai L, Cui H and Li X 2017 Optimal dispatch strategy for integrated energy systems with CCHP and wind power. Applied Energy 192 408-19

[6] Zheng J, Zhou Zh, Zhao J and Wang J 2018 Integrated heat and power dispatch truly utilizing thermal inertia of district heating network for wind power integration. Applied Energy 211 865-74

[7] Minin V A and Furtaev A I 2019 Prospects for the Development of Wind Energy Resources in the Western Sector of the Arctic Zone of Russia. International Scientific Multi-Conference on Industrial Engineering and Modern Technologies (FarEastCon) 8602694

[8] Zubarev V V, Minin V A and Stepanov I R 1989 Wind energy using in Northern regions (Leningrad: Science) 208

[9] Zore Z, Cucek L, Sirovnik D, Novak Pintaric Z and Kravanja Z 2018 Maximizing the sustainability net present value of renewable energy supply networks. Chemical Engineering Research and Design 131 245-65

[10] Duc Luong N 2015 A critical review on potential and current status of wind energy in Vietnam. Renewable and Sustainable Energy Reviews 43 440-8

[11] Bezhan A V 2020 Experience and prospects for the wind power plants constructing in the north western part of the Euro-Arctic region of Russia. IOP Conference Series: Earth and Environmental Science 539 012145