IOP Conf. Series: Materials Science and Engineering **450** (2018) 072009 doi:10.1088/1757-899X/450/7/072009

Increase of energy efficiency of energy generation due to utilization of waste heat on district heating systems

D Karabarin and S Mihailenko

Department of Thermal power station of Polytechnic Institute of Siberian Federal University, 79 Svobodny avenue, Krasnoyarsk, 660041, Russia

E-mail: DKarabarin@sfu-kras.ru

Abstract. The relevance of the work is due to the implementation of the Federal law "on energy saving and energy efficiency and on amendments to certain legislative acts of the Russian Federation" and is aimed at reducing the cost of production of electric and heat energy in the Northern regions of decentralized energy of Russia. The aim of the work is iimproving the energy efficiency of thermal energy production through the modernization of coal-fired boilers, the rationale for the choice of an alternative technology to convert thermal energy into electricity in the areas of decentralized energy. Creation of the installations competing with diesel power plants on development of thermal and electric energy, increase of economic efficiency of production of energy in Northern regions of Russia. Research methods is analysis of existing technologies for the production of thermal energy in the areas of decentralized energy; Thermal, technical and economic analysis of technologies that allow to convert low potential thermal energy into electrical energy; Simulation of installation parameters based on the organic Rankine cycle using the software package Smoweb software package. Results are a comparative analysis of the existing technologies for the production of thermal energy in the areas of decentralized energy and selected the most effective option for improving energy efficiency; was made thermal and technical and economic analysis of the use of technologies that allow to convert low potential thermal energy into electrical energy for the district heating systems DHS-22 of villages Podtesovo

1. Introduction

It is no secret that at present the tariff for thermal and electric energy in the far North exceeds the average tariff for the Russian Federation by more than 5 times [1]. This is due to the existing method of generation and the lack of local mining of solid fuel which results in its delivery over long distances. One of the options for reducing tariffs is a switching to autonomous coal-fired boilers for large settlements and the development of renewable energy.

The population in many villages of the Far North is not growing, so housing construction is mainly of a replacement nature. Increased requirements for the construction of new buildings can only have a very limited effect, and emphasis must be placed on the overhaul of the existing stock of buildings.

There are very few or not at all installed heat meters for consumers. Therefore, both indicators of heat production and indicators of its consumption are mainly calculated values, and calculations for heat energy are still carried out according to the standards, and not for real consumption.

In programs for boosting energy efficiency there are projects for upgrading boilers, laying of heat networks with pre-isolated pipes, installation of individual heating units in apartment buildings and buildings of social sphere, on warming of houses, equipping house-to-apartment metering devices. An important measure is to optimize housing (decommissioning partially inhabited houses with relocation of people, preparing for and carrying out capital repair of housing for resettlement in existing houses)

Improving energy efficiency in the Northern environment is often not a task to reduce consumption, but to eliminate its deficit. At the expense of measures on increase of efficiency of use of energy and reduction of losses it is possible to completely cover the shortage of the supply of energy to end consumers.

High energy intensity hinders the development of the economy of the Far North and the possibility of forming their own tax revenues. Energy efficiency policies in the Northern regions have been sluggish and have given limited results, and the additional demand for energy in many regions has been driven not only by growth but also by increased energy intensity.

Currently, the widely distributed four technologies to obtain from low-grade heat energy electric: Stirling engine; Organic Rankine cycle; Rankine Microcycle; Thermoelectric converter; Kalina Cycle.

As noted in [2] Stirling Engine has a high efficiency and has found its application in industrial samples at temperatures 650-800 and above, but at this source of heat network water 95 is not applicable. The Rankine microcycle is effective only in the joint production of heat and electricity, which is not required for this task. Thermoelectric converters have low efficiency below 5%.

2. Organic Rankine cycle

The difference between the organic Rankine cycle from the usual Rankine cycle is that the working fluid is not water, but an organic compound (freon). The main reason for the replacement of the working fluid is the lower boiling point of the organic coolant compared to water. The scheme of utilization using organic Rankine cycle is shown in figure 1.

As noted in [3] that for the temperatures of the heat source 91-149 C as the working fluid is recommended to take freon R245fa due to its good thermodynamic properties. In [4] for utilization of heat of the steel industry with use of freon R245fa the electric efficiency of 10,2% was received. Since in Russia there is no freon R245fa on the market, it is advisable to replace it with freon with similar properties R142b.

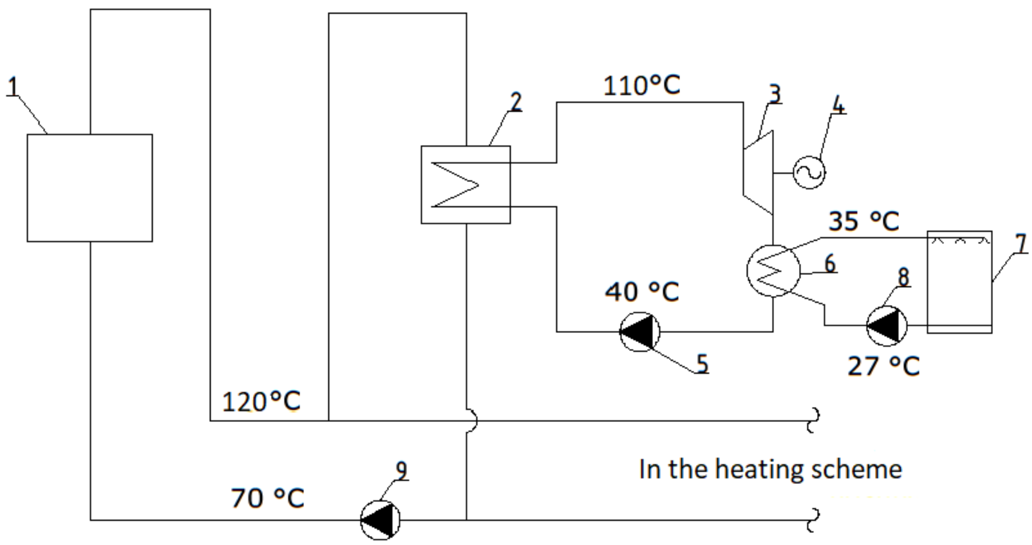

Figure 1. Diagram of the heat district systems using the organic Rankine cycle: 1 is the heat district systems; 2 is the Evaporator; 3 is the turbine; 4 is the generator; 5 is the feed pump; 6 is the condenser; 7 is the cooling tower; 8 is the circulation pump; 9 is the pump.

IOP Conf. Series: Materials Science and Engineering **450** (2018) 072009 doi:10.1088/1757-899X/450/7/072009

3. Kalina Cycle

Recycling scheme with the use of the Kalina cycle is presented in figure 2. As noted in [5] for the temperature of ammonia vapor before the turbine 90 C, a pressure of 25 bar, a degree of dryness of 0.8, an electric efficiency of 8.7% is obtained.

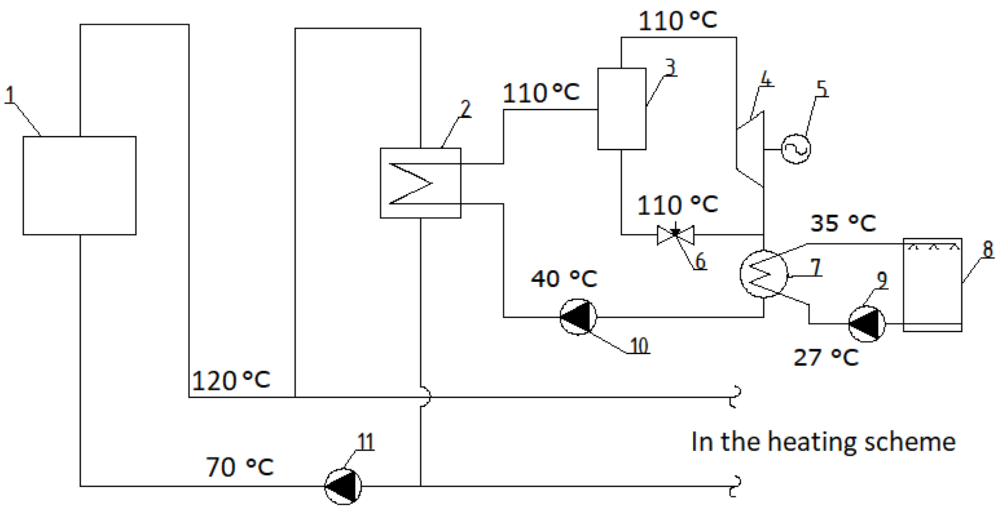

Figure 2. Diagram of the heat district systems using the Kalina cycle: 1 is the heat district systems; 2 is the Evaporator; 3 is the separator; 4 is the turbine; 5 is the generator; 6 is the throttle valve; 7 is the condenser; 8 is the cooling tower; 9 is the circulation pump; 10 is the feed pump; 11 is the pump.

4. Technology comparison

For comparison of technologies we will carry out the technical and economic analysis of possibility of realization of each of them. Specific capital costs have been taken pursuant to [6], [7] and the exchange rate on 1.09.2018., Tariff for electric energy is taken 36,47 according to [8].

The most important technical and economic parameters are presented in table 1.

Table 1. Comparison of technologies of use of heat.

Parameters	ORC	Kalina cycle
Water inlet temperature, °C	120	
Water temperature output, °C	70	
Working fluid	R142b	Water ammonia mixture
The parameters of the working fluid	P=1 MPa T=90 ˚C	P=2,5 MPa T=90 ˚C
Used heat, kW	24184	24184
Electric power, kW	2322,77	20104,01
Thermal capacity district heating systems, MW	19,917	19,917
Efficiency %	10,2	8,7
Operating Costs, mln. RUB. / year	11,376	11,075
Capital investments, mln.rub.	93,707	91,231
The cost of generated electricity, rub. /(kW*h)	20,46	24,02
The payback period, years	1	2

IOP Conf. Series: Materials Science and Engineering **450** (2018) 072009 doi:10.1088/1757-899X/450/7/072009

5. Result

Modernization of district heating systems using the technology of the organic cycle of the Rankine, on the example of HDS-22 village Podtesovo, will allow:

- To create an effective alternative to the existing method of energy production in the Northern regions from diesel power plants.
- Encourage the introduction of renewable energy in combination with Autonomous boilers for large settlements.
- Encourage the development of coal deposits in the North
- Increasing energy efficiency of energy production through the introduction of cogeneration in the production of thermal energy
- Stimulate the development of ORC technology in the Russian market
- Contribute to the development of low-power turbine construction in the Russian Federation.

References

[1] Bashmakov I 2017 Improving the efficiency of energy supply in the Northern regions of Russia *Energy Saving* **2**

[2] Bianchi M and De Pascale 2011 A Bottoming cycles for electric energy generation: Parametric investigation of available and innovative solutions for the exploitation of low and medium temperature heat sources *App. En.* ***88*** 15001509

[3] Velez F, Segovia J J, Martin M C, Antolin G, Chejne F and Quijano A 2012 A technical, economical and market review of organic Rankine cycles for the conversion of low-grade heat for power generation *Renewable and Sustainable Energy Reviews* ***16*** 41754189

[4] Kaska O 2014 Energy and exergy analysis of an organic Rankine for power generation from waste heat recovery in steel industry *Energy Convers and Manage 77* 108117

[5] Hettiarachchi H M, Golubovic M, Worek W M and Ikegami Y 2007 The performance of the Kalina cycle system 11 (KCS-11) with low-temperature heat sources *Journal of Energy Resources Technology, Transactions of the ASME* ***129*** 243-7

[6] Blinov A 2014 Efficiency of the use of ORC modules in a decentralized energy of the Russian Federation *LesPromInform* **8** 1014

[7] Pesquisa F 2012 Exergetic and economic analysis of Kalina cycle for low Temperature geothermal sources in Brazil *Proceedings of ECOS 2012 – The 25 international conference on efficiency, cost, optimization, simulation and enviromental impact of energy system* (Italy)

[8] The order of the Regional energy Commission of the Krasnoyarsk Krai dated 18.12.2017 N 622-p About establishment of tariffs for electric energy supplied by the limited liability company Energy (p. Khatanga)