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Recent Geothermal Power Projects in Russia

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ABSTRACT

Russia possesses up-to-date technologies of geothermal electrical and heat power plant construction and maintenance, as well as power equipment engineering and manufacturing. The consistent increasing fossil fuel prices and the availability of a considerable number of drilled wells are stimulating advances in geothermal technologies for heat and electric supply.

There are prospective plans to construct the 2nd stage of the Mutnovsky GeoPP 50 $MW_{(electric)}$; pilot Binary GeoPP (BGeoPP) using northern (near Pauzhetsky geothermal power plant) and southern (in Krasnodar region) plant design, with 2.5 $MW_{(electric)}$ for each unit, district heating of Vilyuchinsk (Kamcharka), Rozoviy (Krasnodar region). The approved geothermal roadmap for up to 2020 governs constructing geothermal electric and heat plants with 336 $MW_{(electric)}$ and 552 $MW_{(heat)}$ of installed capacity respectively in different Russian regions.

1. INTRODUCTION

Up to the present 500-25000 KW geothermal power units have been developed and created in Russia using low- and high-temperature geothermal resources for electricity production (fig. 1) including BGeoPPs:

I. Binary geothermal power plants (thermal water with temperature of 90-120^{o}C):

- In 1967 the first in the world pilot 800 KW Paratunsky BGeoPP was constructed;
- SC “GEOENCOM” developed the engineering design for construction of 2500 KW Pauzhetsky GeoPP;

II. Combined cycle geothermal power plants (geothermal steam and separate with temperature of 100-160^{o}C):

- Engineering design of combined cycle Unit IV of Verkhne-Mutnovsky GeoPP developed with capacity of 6500 KW.

III. Geothermal power plants on geothermal steam (geothermal fluid – steam-water mixture with temperature of 120-160^{o}C):

- Since 1966 14.5 (6+6+2.5) MW Pauzhetsky GeoPP is operating;
- In 1992 500 KW GeoPP “Omega” was commissioned (Kunashir island);
- In 1994 the engineering design was developed and equipment was manufactured for two 2.5 MW turbo-generators and two 23 MW turbo-generators for GeoPP “San Jasinto” (Nicaragua);
- Since 1999 12 (3x4) MW Verkhne-Mutnovsky GeoPP is operated;
- In 2001 3.4 (2x1,7) MW Mendeleyevsky GeoPP was commissioned (Kunashir island);
- Since 2002 50 (2x25) MW Mutnovsky GeoPP are opperating;
- Commissioned in 2006 3.4 (2x1.7) MW Okeansky GeoPP (Iturup island).

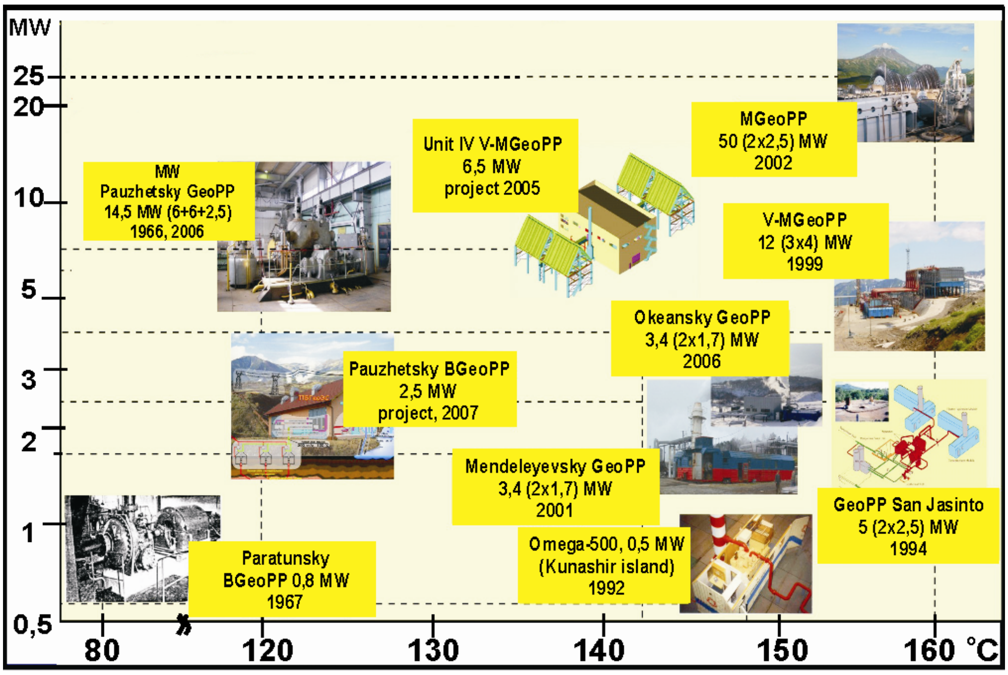

Figure 1: Capacity and temperature of the used fluid of Russian geothermal electricity generating units.

Geothermal fluid is the working fluid of the first circuit of geothermal power plants (GeoPPs) and of heat power plants (GeoHPPs); it is notable for specific chemical composition, diversity of operational and environmental features (Povarov et al. 2005, Povarov and Tomarov 2006). More than 3000 geothermal wells were drilled in Russia with total cost of about 250 billion rubles, and this has laid a massive groundwork for further development of geothermal technologies. Location of geothermal resources determines the geography and regional character of the geothermal power industry. Kamchatka region, Chukotka, Kuril islands, Northern Caucasus, Kaliningrad region and Transbaikalia are attractive today for prospective electricity generating capacities as high-temperature geothermal resources ($t>100^oC$) are available there.

High prices of imported fossil fuel and the availability of confirmed high-temperature reserves in addition to drilled wells stimulated the creation of a series of geothermal power units recently at Kamchatka and Kuril islands (Povarov and Tomarov 2006).

The new stage of development for the Russian geothermal power industry presumes that not only the construction of traditional cycle power units on geothermal steam but also the adoption of technologies for use of low-potential geothermal resources for electricity and heat production.

Russia possesses up-to-date technologies for geothermal electricity and heating power plant construction and maintenance, as well as power equipment engineering and manufacturing. The constant increase of fossil fuel prices and the availability of a considerable number of drilled wells have stimulated advances in geothermal technologies for heat and electricity supply.

There are prospective plans to construct the 2[nd] stage of Mutnovsky GeoPP 50 $MW_{(electric)}$; pilot Binary GeoPP (BGeoPP) using northern (near Pauzhetsky geothermal power plant) and southern (in Krasnodar region) plant design, with 2.5 $MW_{(electric)}$ each unit, district heating of Vilyuchinsk (Kamcharka), Rozoviy (Krasnodar region). The approved geothermal roadmap up to 2020 governs constructing geothermal electric and heat plants with 336 $MW_{(electric)}$ and 552 $MW_{(heat)}$ of installed capacity respectively in different Russian regions.

2. RUSSIAN GEOTHERMAL BINARY POWER TECHNOLOGIES

Russia was the first country in the world that created the Paratunsky binary power plant in 1967 using the heat of hot (80^oC) water for electricity generation. The unit's rated electric power was 750 KW. The scientists from the Institute of thermal physics of Siberian branch of Academy of sciences of the USSR used Freon R12 as the working fluid (WF).

The successful experience of Russian scientists was used abroad, and up to the present more than a thousand binary units of various capacity have already been produced and are now operated in the world.

At Kamchatka and Kuril islands as well as in many regions of Russia such as Northern Caucasus, Kaliningrad region, Transbaikalia etc, low-temperature geothermal reservoirs are available, and their potential is sufficient for the provision of heat and electricity for these regions.

SC "GEOENCOM" developed an engineering design of standard binary GeoPP where Freon R-134a is used as the working fluid (M. Boyarskiy et al. 2005).

Revival of Russian binary power technologies and arrangement of serial production of BPPs should become a basis for large-scale use of geothermal resources and other heat sources in various regions of the country. According to the strategy of SC "Rushydro", creation and elaboration of binary geothermal power technologies in the Northern and Southern variants are planned.

Binary technologies are supposed to be implemented to increase the efficiency of using the potential of geothermal resources at both currently operating and newly constructed GeoPPs of Kamchatka (fig. 2).

Construction of binary power units in Northern variant is planned at Mutnovsky (Kamchatka), Mendeleyevsky and Okeansky (Kurils) geothermal reservoirs.

At present SC "New binary power unit", with scientific-technical support of SC "GEOENCOM", is completing the work for creation and construction of a pilot binary 2.5 MW power unit on the Pauzhetsky GeoPP site.

The thermal circuit diagram of the Pauzhetsky binary geothermal power plant including evaporator, steam superheater, condenser, turbine and feed pump is presented in Fig 3a. The power facility conventionally consists of three circuits, some of which are open. Geothermal fluid (water separated from steam-water mixture with temperature about 120 ^oC) is the heat source in the first circuit. At figure 3b t-Q diagram of heat exchanger equipment of PBGeoPP is shown with noted minimum temperature heads in heat exchangers.

SC "GEOENCOM" completed the development of technical solutions and feasibility study for the project of construction of geothermal units using waste fluid of Mutnovsky GeoPP.

In Figure 4 the circuit diagram of 10 MW combined GeoPP for expansion of Mutnovsky GeoPP is presented consisting of low-pressure turbo-generator on geothermal steam and binary plants on organic working fluid.

3. NEW PROJECTS OF GEOTHERMAL HEAT SUPPLY

Almost all parts of Russian territory have heat energy and water reserves available that may be used for heat supply of settlements as well as industrial and agricultural enterprises. The region of the Northern Caucasus should be specially marked out (Stavropol and Krasnodar regions, Daghestan, Chechnya, Adygei, Kabardino-Balkaria and Karachai-Circassia) being extremely rich in thermal water of temperatures of 125-130 ^oC here.

Implementation of modern technical solutions presumes creation of efficient geothermal heat supply system providing minimal geothermal fluid flow rate with more efficient response of its heating potential. Some examples of such an approach are presented below.

In order to make efficient use of geothermal resources, the decision was made to develop and implement the project of geothermal heat supply of Rozovy settlement basing upon modern advanced technologies of renewable energy sources. Directorate on the problems of the fuel-energy complex of Krasnodar regional Administration and SEKR "Center of energy saving and new technologies" as well as Labinsk district Administration are the initiators and principal project investors.

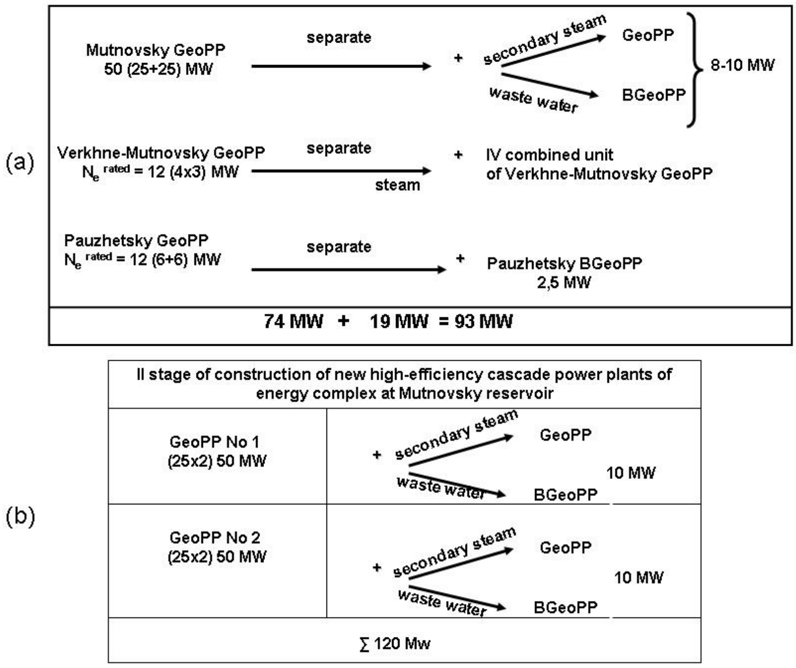

Figure 2: Increase of efficiency of using the potential of geothermal resources at operating (a) and new (b) GeoPPs of Kamchatka (available GeoPP capacities are noted).

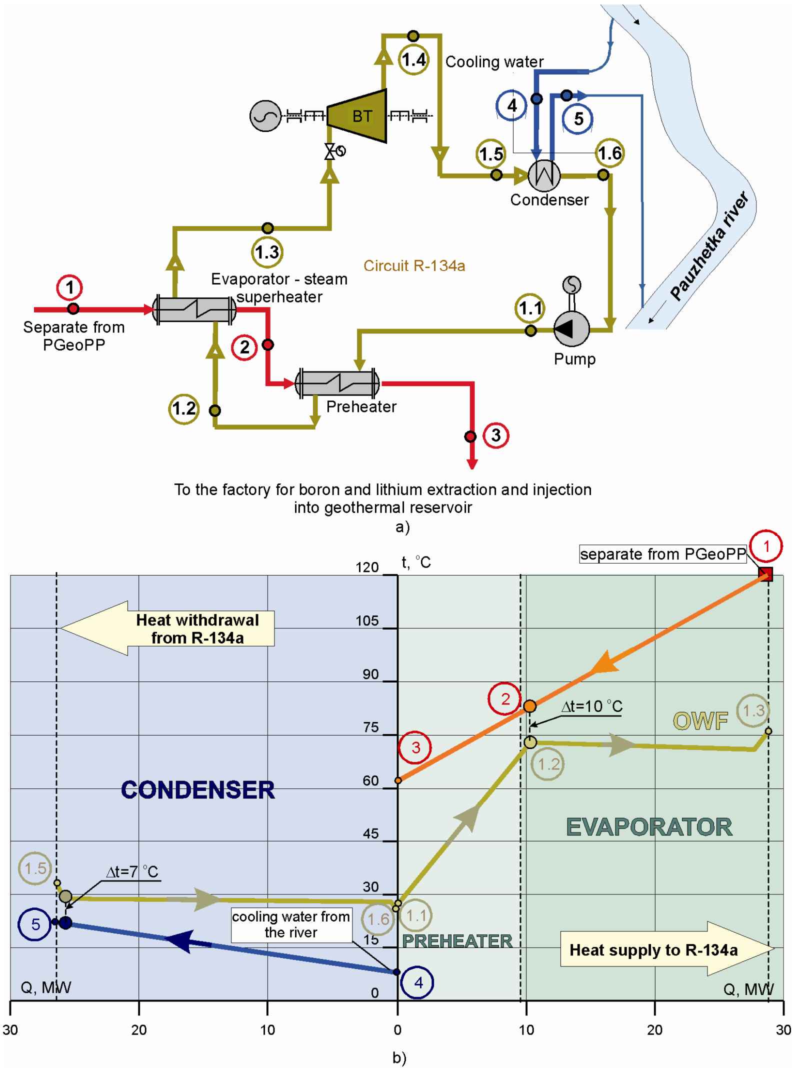

Figure 3: Thermal circuit diagram, principal calculation points of PBGeoPP (a) and t-Q diagram (b) of heat exchanger equipment.

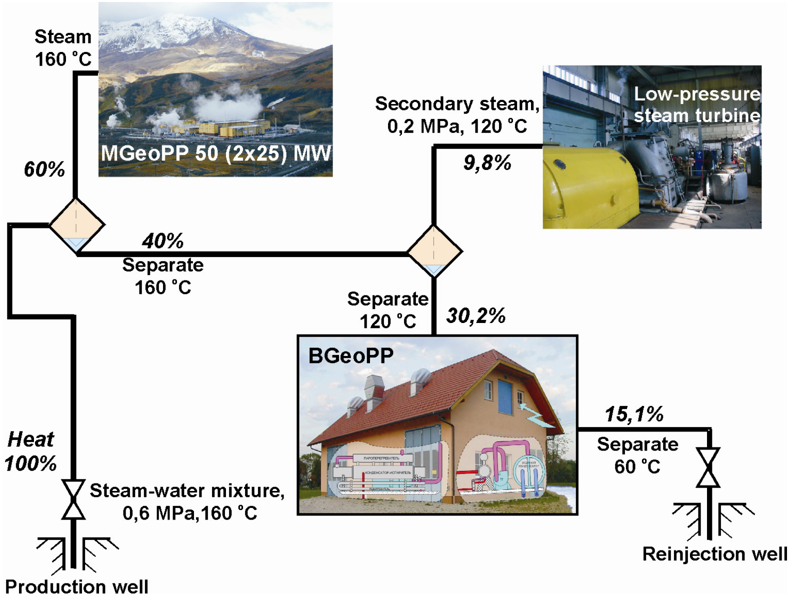

Figure 4: Circuit diagram of using BPP and low-pressure steam turbine for increase of efficiency of geothermal resources use at Mutnovsky GeoPP.

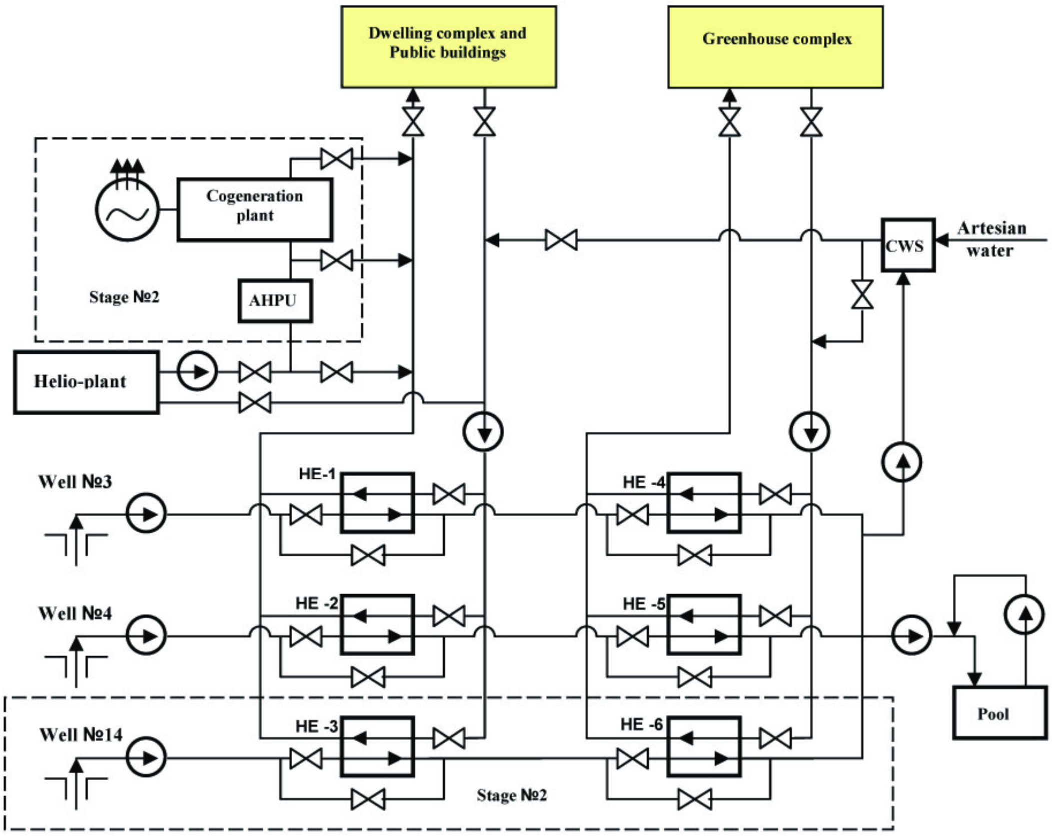

Figure 5: Circuit diagram of geothermal heat supply system of Rozovy settlement.

SC "GEOENCOM", together with SC "Geotherm-EM", completed the development of construction documents, and SC "Yuzhteplo" started the construction of geothermal heat supply system of Rozovy settlement.

The circuit diagram of geothermal heat supply of Rozovy settlement is presented at fig. 5. Rated heat load is 9,16 MW (2,8 MW – settlement heating, 0,55 MW – hot water supply, 5,8 MW – heating of greenhouses).

For provision of hot water supply of the central part of Rozovy settlement in summer time (when the wells are disconnected for restoration of geothermal reservoir potential), helio-plant is included into the scheme operating together with air heat pump unit and cogeneration diesel power unit.

Power supply of circulation pump of the helio-plant and other auxiliaries of the hot water supply system in summer time is provided by photoelectric plant. The auxiliary power supply to geothermal heat supply system as well as coverage of thermal loads during peak heating periods and partial coverage of hot water supply in summer are supplied from a cogeneration unit operating on rapeseed bio-fuel. The project envisages a system of automatic regulation and process control.

With the purpose of transferring the heat supply of Vilyuchinsk city (Kamchatka region) to local geothermal resources, it is proposed to create an environmentally friendly geothermal heat supply system using the thermal water of Verkhne-Paratunsky reservoir.

The concept for geothermal heat supply of Vilyuchinsk city developed by SC “GEOENCOM” envisages stage-by-stage transfer to the use of geothermal resources for heating and hot water supply of the consumers.

The circuit diagram of geothermal heat supply system and parameters of fluids for the outdoor air temperature of minus 20 ^{o}C are presented in Fig. 6. One heat pump is conditionally shown in the scheme.

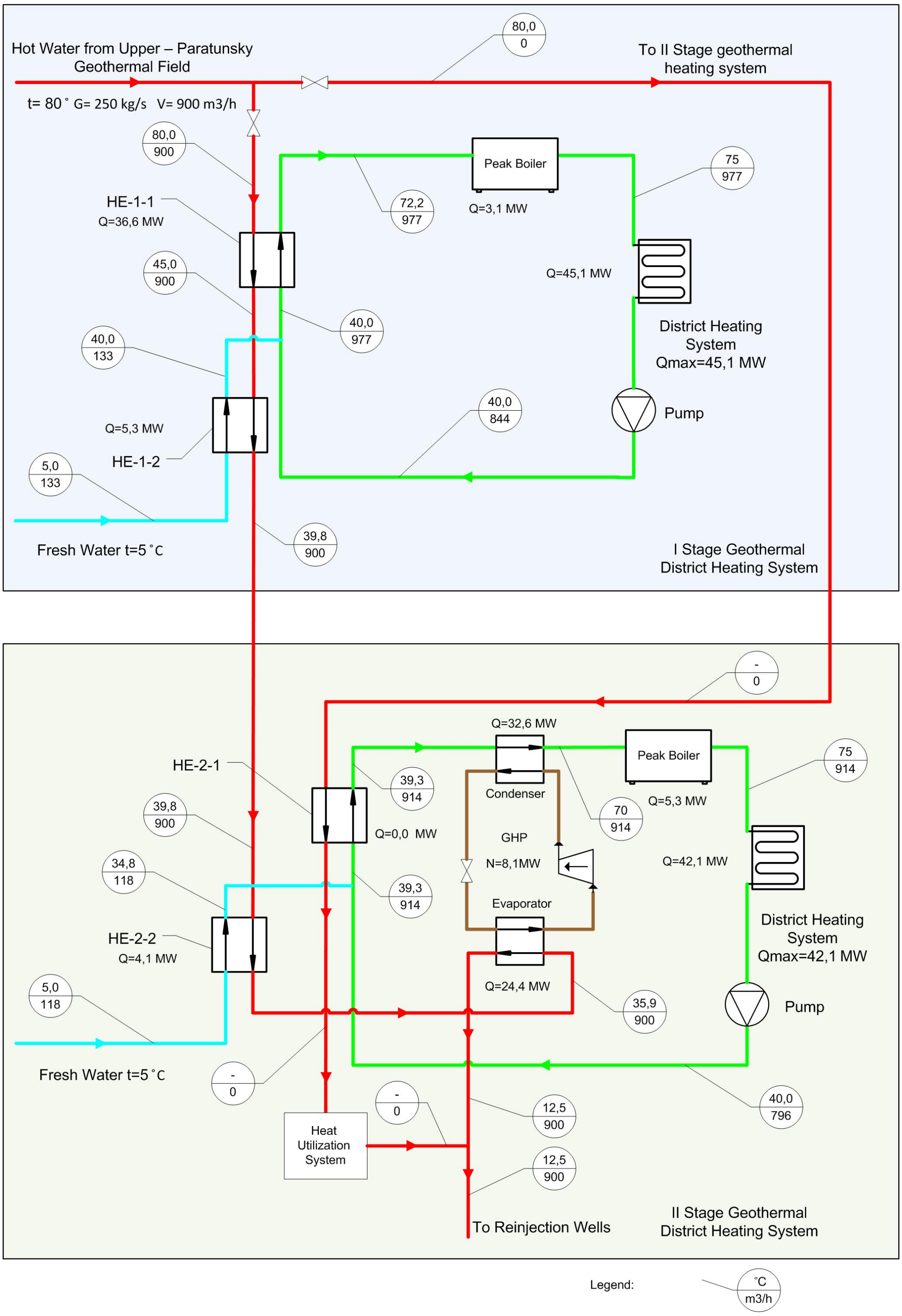

Figure 6: Circuit diagram of geothermal heat supply system and parameters of fluids for outdoor air temperature minus 20^{o}C.

Direct use of geothermal heat is the most efficient and simple solution for heat supply. But the fluid temperature (80^{o}C) is insufficient for heating of the heating-system water up to 95 ^{o}C required during maximum load, and thus proper peak heating in the boiler-house is necessary.

It is expedient for geothermal heat supply system to decrease the temperature schedule from 95/70 ^{o}C to 75/40 ^{o}C for more complete use of heat potential of the thermal water. At the same time the increase of surface of heating devices will be necessary as their average temperature would decrease.

Transfer to the reduced temperature schedule permits excluding the additional peak heating of heating-system water in boiler-houses partially or completely and thereby reduces the consumption of fossil fuel.

The adopted concept of the project implementation would provide 99.9% of the contemporary district heating and hot water supply needs, about 45 MW, from the direct use of thermal water heat. The project envisages an increase of geothermal heat supply system capacity up to 87.2 MW (75.0 Gcal/h) for provision of heat supply of new consumers. Waste thermal water after stage I heat exchangers heats the make-up water in the stage II heat exchanger and then comes to evaporators of heat pumps, and this way the residual heat is transferred to heating-system water heating it up to 70 ^{o}C. For temperatures of outdoor air below 16.2 ^{o}C, the heating-system water is supplementally heated up to the necessary temperature in peak electric boilers.

In Fig. 7 the annual load schedule of geothermal heat supply system of Vilyuchinsk city is presented. Direct use of geothermal heat covers 86.5% of annual needs, 13.33% are provided by heat pumps and 0.17% - by peak boiler-houses.

The project of geothermal heat supply of Vilyuchinsk city permits excluding the combustion of fossil fuel (mazut) for heat production in boiler-houses completely, and some increase of electricity consumption is covered by its direct supply from Mutnovsky GeoPP.

Preconditions for large-scale introduction of geothermal energy technologies in various regions of Russia are available today.

4. PRIORITY GEOTHERMAL PROJECTS OF RUSSIA FOR THE PERIOD OF 2008-2015

Kamchatka region:

- Creation of 2,5 MW Pauzhetsky geothermal power plant – 2008-2010. The project implementation is done by SC “New binary power unit”.
- Increase of rated capacity of Mutnovsky GeoPP by 10 MW due to disposal of heat power of reinjection separate – 2008-2011.
- Creation of geothermal heat supply of Vilyuchinsk city (Elizovo district) with capacity of 87.2 MW (75 Gcal/h) – 2009-2012.
- Construction of II stage Mutnovsky GeoPP with capacity of 100 (50+50) MW – 2010-2015.

Kuril islands:

- Expansion of Okeansky GeoPP (3.6 MW) by power units with total capacity up to 9.0 MW (Iturup island);
- Construction of North-Kuril GeoHPP (Paramushir island) with capacity of 4.5 MW_e and 8.0 MW_t;
- Reconstruction of Mendeleyevsky GeoPP (Kunashir island) (3.6 MW) with increase of rated capacity by 6.0 MW_e;
- Construction of geothermal heat supply system of Kurilsk city (with capacity more than 11.6 MW (10 Gcal/h), Iturup island).

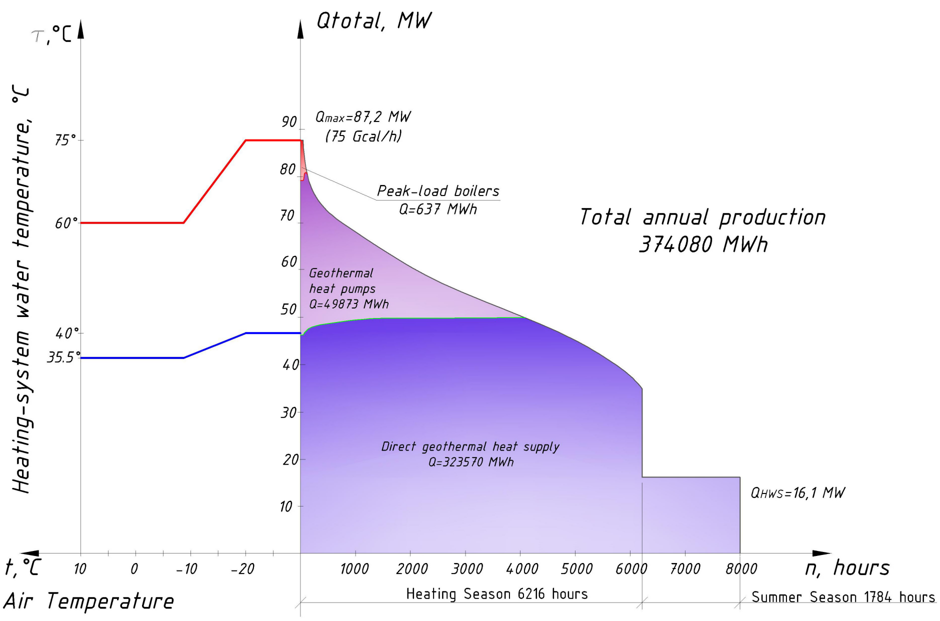

Figure 7: Annual schedule of geothermal heat supply system load of Vilyuchinsk city with total rated capacity of 87,2 MW (75,0 Gcal/h).

Krasnodar region:

- Construction of geothermal electricity (basing upon 4,0 MW binary power plant) and heat supply (40.0 MW_t) of Labinsk city – 2008-2011;
- Creation of the system of complex use of geothermal resources for power supply in Mostovskoy settlement, 20,0 MW_t – 2008-2010;
- Demonstrational project of complex use of geothermal resources and other renewable energy sources for power supply of housing and communal services and industrial enterprises of Rozovy settlement – 2008-2009.

Stavropol region:

- Creation of local geothermal heat and electricity supply system basing upon geothermal resources of Kazminsky reservoir with construction of BPP with capacity of 2.5 MW and heat supply plant up to 60.0 MW_t.

Kaliningrad region:

- Creation of a geothermal heat and electricity supply system in Svetly settlement (4.0 MW_e and 50.0 MW_t).

Implementation of top-priority geothermal projects would permit constructing more than 10 power units through 2015 with total rated capacity of more than 125 MW_e.

According to various estimates, final target indices of forecasted commissioning of new geothermal electricity and heat generating capacities in Russia for the period until 2020 are up to 866.2 MW_e at GeoPPs for an optimistic scenario, and up to 849.0 MW_t – direct geothermal heat supply (table 1, *-Capacities commissioning, MW according expected/optimistic schedule; HP - heat pumps, DHS - direct heat supply).

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Table 1: Forecast of new geothermal electricity and heat generating capacities commissioning for the period till 2020

Regions	*Regions Forecast reserves of geothermal resources, MW_e/MW_h*	*t, °C*	*2010*			*2015*			*2020*		
			GeoPP	*HP*	*DHS*	*GeoPP*	*HP*	*DHS*	*GeoPP*	*HP*	*DHS*
Kamchatka	5600/1600	60-320	79	5	80/120*	100/170*	10	70/100*	100/350*	20	80/100*
Sakhalin region (Kurils)	1600/400	85-320	7,2(4x1,8)	1	2/4	10/30	15	5/10	10/50	15	10/15
Krasnodar region	1000/100	70,5-116	-	1,5	10/20	5/15	50	30/40	5/30	100	50/70
Stavropol region	600/60	55-120	-	1,5	5/10	5/10	50	30/50	5/20	100	50/70
Republic of Daghestan	900/130	40-82	-	2	5/10	2,5/10	25	20/40	2,5/50	50	40/70
Chechen republic	1000/100	60-100	-	2	5/10	2,5/15	25	20/40	2,5/30	50	40/70
Total:			**86,2**	**13**	**107/174**	**125/250**	**175**	**175/280**	**125/530**	**335**	**270/395**