The development of the district heat supply system of the city of Karaganda

Mereke Agilbayeva^{1,*}, and *Alexey Kalinin*²

¹Omsk State Transport University, Omsk, Russia

²Karaganda State Technical University, Karaganda, Kazakhstan

Abstract. The district heating system of Karaganda (Kazakhstan) is considered in the article. The characteristics of the existing cogenerators and the state of the pipeline networks are given. Given the analysis of the existing state of the entire district heating of Karaganda. Proposed the program for the integrated development of the heat supply system bringing world experience in implementing the main development and modernization of heating networks. Shown the experience of reconstruction of heat supply facilities in the city of Karaganda within the framework of the state loan program “Nurly Zhol”. Based on the statistical data on the development of the city of Karaganda and its heat supply system the predicted heat loads are given until 2030. Due to the shortage of available heat capacity, options for the development of a centralized heat supply system in Karaganda are given and analyzed.

1 Introduction

Based on the past, the USSR held leading positions in the world in the implementation of a district heating system based on cogeneration district heating. Thermal power plants were built in all major cities, from which district heat supply was provided to residential microdistricts and industrial facilities. In Kazakhstan, heat supply in 30 large cities including the city of Karaganda is also built on Soviet principles. The city of Karaganda, founded in 1934 and actively growing and developing in the 60-90s, was the center of the coal industry of Kazakhstan and all the Central Asia. The main source of district heating in the city of Karaganda are two power plants of combined electric and thermal energy production (TPS-1 and TPS-3), as well as about 440 individual heat sources (industrial and municipal boilers and autonomous heating systems) with a capacity of 0,1 to 54 Gcal/h. There is also a large number of heating stoves for individual low-rise buildings that produce up to 390 Gcal/h.

2 Historical overview and current condition

Due to the growing demand for electricity in Karaganda and the Karaganda coal basin, the construction of the Karaganda TPS-1 (thermal power station) was started in the late 50s of

* Corresponding author: mereke_2006@mail.ru

the last century. Originally designed as a boiler room for a number of mines, the power plant was intended for district heating of mine shafts and supplying them with electricity. In 1960, the first phase of TPS-1 was launched, and in 1964 the power of the station was increased by four BKZ-50 boilers and four turbine units.

District heating in Karaganda has been organized since 1962. The thermal capacity of the power plant at that time was 117 Gcal/h. Currently, the installed heat capacity of TPS-1 is 460 Gcal/h, and the available – 234,5 Gcal/h.

The construction of the Karaganda TPS-3 was launched in January 1970. In 1977, the first boiler units No. 1 and 2 were put into operation. In 2015-2016, the company expanded capacity and a new power unit was launched (boiler unit No. 8 and turbine No. 6), which made TPS-3 The largest TPS in Kazakhstan. The installed thermal capacity of TPS-3 is currently 1,429 Gcal/h, and the available - 1,052 Gcal/hour.

The district heating network in Karaganda is a two-pipe open system, which simultaneously provides heating in the winter and hot water throughout the year, i.e. hot water supply (HWS) is carried out by direct selection from the district heating (DH) system.

The total length of the pipeline network in Karaganda is about 435 km (aboveground sections - 70% and canals with pipes - 30%). 58 pumping stations for 3800 buildings located on a vast territory of 500 km². If we proceed to the assessment in specific units, then the connection of the building accounts for 114m of pipes and trenches, reflecting a rather low building density and a large length of pipelines. This inevitably leads to high heat losses.

Above ground pipes are often poorly laid and poorly maintained. The casing, as a rule, passes water and insulation is completely absent in most areas. These reasons together with the wind factor affect the heat loss in above-ground pipes.

The insulation on the pipes in the channels is often damaged and cannot be replaced due to flooding due to heavy rains or leaks (breakouts) of the pipes. Therefore, the outer surface of pipes is subject to severe corrosion. Lack or insufficient insulation, damage to the casing and insulation lead to significant heat loss in existing climatic conditions.

Poor condition of pipelines leads to heat losses in the amount of 1375000 Gcal per year (on average for 2009-2012). This corresponds to 40% of the heat supplied from two heat sources (TPS). Approximately 550,000 Gcal of these losses (40% of losses or 16% of heat generation) may be the result of leaks; the remainder is convection heat loss.

There is almost no active control of heat consumption or flow control on the consumer side. Heat accounting is almost completely absent for apartment buildings that consume up to 70% of the generated heat; however, at most enterprises and in public buildings there are heat meters, and new consumers are connected only with heat meters. All this makes it necessary to carry out heat supply from the source according to the method of central quality control - by changing the temperature of the coolant depending on the outside temperature according to a single schedule for all consumers with constant circulation in the networks. This leads to a significant waste of heat by consumers.

By 2020 turbines No. 1-4 (TPS-1) will run for more than 30 years, and TPS-1 will be 59 years old by 2020. There are environmental and technical problems already in the operation and reconstruction of equipment related to the station being located within the city and in the mining zone and the lack of new areas for ash storage.

Pipelines are generally characterized by a high degree of deterioration and intense corrosion processes. The total length of heating networks according to the commissioning year of sections of heating networks is:

- 101,3 km - over 50 years;
- 534,2 km - over 40 years;
- 256,7 km - more than 30 years.

The service life of heating networks in accordance with the “Regulation on the system of scheduled preventive repairs of the main equipment of utilities” exceeds the standard period (16 years) by 4,5-2 times. Physical deterioration of heating networks is up to 70%.

The existing heat supply system in Karaganda has exhausted its technical service life and, in its current state, does not meet modern requirements in terms of efficient and rational operation and reliability of heat supply.

The heating networks of the city of Karaganda must be modernized, and at the same time, it's not just to restore the resource but to create heating systems of a qualitatively different level.

3 Development and modernization of heating networks

The heat supply system of the city, along with the power supply system provides life support for all social entities, as well as the effective development and operation of facilities of all sectors of the economy on its territory.

The program for the comprehensive development of the heat supply system should be formed on the basis of a systematic approach, determine a single policy for organizing activities, long-term development, harmonizing interests and developing production and investment programs for heat supply entities [2].

The program for the integrated development of the heat supply system should contain the results of a systematic study in the following areas [2]:

1. A detailed technical, economic and organizational analysis of the current state of the heat supply system in the region with the formulation of the existing problems of reliability, quality, economy, environmental friendliness and accessibility for consumers. A set of basic parameters of the heat supply system is being formed that determine the level of efficiency of its operation (cost of 1 Gcal of heat released, specific consumption of network water, specific energy consumption and costs of heat transport, specific fuel consumption for heat load, specific fuel consumption per inhabitant of the region, unit cost repair and emergency recovery work, specific number of employees, etc.).

2. Short and medium-term forecast of the conditions for the development of the existing heat supply system with the development of a standard set of technical solutions: replacing sources and networks that have exhausted their resources, building new sources and networks to connect new consumers, increasing the energy efficiency of existing energy technologies through the development and implementation of energy-saving projects.

3. Development of a necessary set of technical, economic, organizational and administrative decisions within the framework of a systematic approach that takes into account the interests of all the main heat supply entities of the megalopolis, as well as functionally related to the heat supply of urban infrastructure organizations. The decisions of this stage should be aimed at reducing costs in the system, as well as improving energy efficiency and energy saving.

4. Development of the Program for the comprehensive development of the region's heat supply system for the next regulatory period with an assessment of the feasibility and economic efficiency of a set of technical, economic, organizational and administrative decisions, including optimization of the load of heat supply sources and reduction of the unit cost of heat energy. The main criterion for optimizing the loading of sources in the system should be the generation of electric and thermal energy share from heat consumption at the TPS.

5. Development of an optimal set of financing methods including: own resources released due to changes in technological processes, energy saving measures, due to connection tariffs, private investments, loans, concession schemes, targeted repayable budget loans, etc. The choice of a specific financing scheme program is determined by the

state of the local budget and the solvency of consumers, but in any case, consumer tariffs should not dominate the optimal financing scheme; housing and utility sector.

6. Development and maintenance for organization of the Program for the integrated development of the heat supply system in the region and its approval by the representative body of the municipality (Departments of energy and utilities of the region's Akimat). All heat-supplying organizations of the region, consumer representatives, supervisory and regulatory bodies should be involved in the preparation of the initial data for the program under development. Certified developers should be involved in the development of the program on a competitive basis. The processes of development and discussion of the program should be public in the region. The examination of the program should be carried out by the scientific and design organizations of the energy profile. After approval by the representative body of local self-government, the Program must have the force of local law. The powers of local governments involved in the development and implementation of the Program should be supported by the norms of existing and new laws requiring development, for example, the law "On Heat Supply".

As the world experience shows, the main activities of existing programs for the development and modernization of heating networks can be divided into five types:

1. A survey of heat supply facilities.
2. Construction of new sources of thermal energy.
3. Modernization and reconstruction of thermal power plants, boiler rooms, heating networks and central heating plants.
4. Construction of heating networks.
5. The introduction of resource-saving technologies.

To maximize the effect of programs, they should be implemented in conjunction with the modernization of the thermal protection system of residential and public buildings, the improvement of their engineering systems, measures for warming apartments, equipping them with metering devices and effective water-folding fittings.

In Kazakhstan, in accordance with the Program for the modernization of housing and utility services until 2020, developed in order to implement the Decrees of the President of the Republic of Kazakhstan dated February 18, 2011, heat energy is saved in multi-apartment residential buildings and social facilities by a set of works on their thermal modernization [1].

Energy conservation measures in apartment buildings include:

- conducting the energy audit of multi-apartment residential buildings in various climatic zones of the republic and in various designs by the Agency;
- as a pilot project, the Agency will install automatic heating units in multi-apartment residential buildings - 3 houses in each region;
- preparation of methodological materials on the organization of thermal modernization for the heads of CAO (cooperative of apartment owners) and condominiums, their consultation on these issues;
- explanatory and propaganda work will be carried out in the media.

4 Experience in implementing a program for the development of a heat supply system in Karaganda and a forecast for the development of the city until 2030

Sustainable economic growth in Kazakhstan is ensured by accelerating diversification through industrialization and infrastructure development, increasing the competitiveness of human capital. For the period from 2015 to 2017, the industrial production in Karaganda increased by 39,1%, and for the 9 months of 2018 the physical volume index (IFO)

amounted to 100,6% compared to the same period of the previous year. Growth is also observed in the electricity supply sectors by 12,5% and water supply by 25,3%. The population of the city of Karaganda on June 1, 2018 was 500,7 thousand people.

Since 2015, the state loan program “Nurly Zhol” has been implemented within the framework of which heat supply, water supply and sanitation facilities have been announced for 2016-2018. The goal of the program is to provide the population with high-quality thermal energy and uninterrupted hot water supply, connect additional consumers to the city’s heat supply systems, reduce heat losses and make-up water losses using modern transmission technology. An indicator of the final result is the expected decrease in heat losses by 19,7 thousand Gcal/year, an improvement in the quality of heat supply to residents and social facilities.

So, in 2015 within the framework of the “Nurly Zhol” program, 4 projects for the reconstruction of main heating networks for a total amount of 2007 million tenge were implemented; in 2016-1 project for the reconstruction of a main heating network for 433,3 million tenge was implemented; in 2017-1 project for the reconstruction of the main heating network for 1060,1 million tenge was implemented, in 2018-4 projects for the reconstruction of the main heating networks with a total length of 4,591 km were implemented.

Analysis of the heating networks complex operation in the heat supply zone of TPS-1 (reconstruction was performed in this area) shows that since the beginning of the heating season 2017-2018, the average hourly circulation decreased from 6260 to 6010, the number of defects decreased from 28 to 0, the quality of heat supply to consumers of 385 residential buildings and social facilities improved. The decrease in heat loss over the entire heating season (214 days) is 25 680 Gcal. The economic effect of reducing excess losses is 96,98 million tenge per year.

In 2017 repairs of heating networks were performed for a total of 587347,54 thousand tenge, as a result of:

26738 m of heating networks were replaced, including 26,6 km in 2016 with thermal insulation);

2,748 m of heating mains (2,2 km in 2016);

23 990 m of distribution heat networks (24,4 km in 2016).

Karaganda continues being developed and built. So, according to the data of the state institution (SI) “Department of Architecture and Urban Planning of the City of Karaganda”, the dynamics of changes in the population and area of residential development of the city of Karaganda with a forecast until 2030 are shown in table 1. Figures 1 and 2 show graphs of changes in these two indicators taking into account statistical data from 2005, as well as data for calculating the district heating scheme of the city of Karaganda.

Table 1. Dynamics of changes in the population and residential area of Karaganda with a forecast until 2030.

Indicators	2014	2020	2025	2030
Population, thousand people	488	513	535	557
Residential buildings, mln.m ²	10,68	11,91	13,19	14,44
including - multi-storey	8,76	9,53	10,39	11,18
- one storey	1,92	2,38	2,80	3,26
Provision of living space, m ² / person.	21,9	23,2	24,7	25,9
Housing input, mln.m ²		1,23	1,28	1,25
including - multi-storey		0,77	0,86	0,79
- low storey		0,46	0,42	0,46

Table 2. The predicted increase in heat loads is given in the city of Karaganda (Gcal/h).

Name	Growth in 2015-2020	Growth in 2021-2025	Growth in 2026-2030	Total 2015-2030
Total in the city	128	158	138	424
including:				
Low storey building	37	33	38	108
multi-storey building	46	57	47	150
public building	32	45	32	109
industrial enterprises	13	23	21	57

The total heat demand in Karaganda during the period under review (until 2030) will increase by 424 Gcal/h (by 28%), including:

residential buildings - at 258 Gcal/h;
 public buildings - at 109 Gcal/h;
 industrial enterprises, as well as small and medium-sized businesses - at 57 Gcal/h.

The predicted heat loads in the district heating system of Karaganda until 2030 are shown in table 3.

Table 3. Predicted heat loads in the district heating system of Karaganda (Gcal/h).

	2014	2020	2025	2030
Heat load of housing and utility services, total	1 297	1 412	1 547	1 664
including:				
low storey building	248	285	318	356
multi-storey building	764	810	867	914
Public building	285	317	362	394
Thermal load of industrial enterprises	183	196	219	240
Heat load throughout the city (Housing and utilities + industry)	1 480	1 608	1 766	1 904
The increase in thermal loads throughout the city:				
in the period 2015 - 2020		+128		
in the period 2021 – 2025			+158	
in the period 2026 – 2030				+138

5 Options for the development of a district heating system in Karaganda

Using the obtained statistics and based on the experience of implementing the heat supply system development program in Karaganda, we will consider some promising options for the future district heating system in the region.

Option 1. Construction of new TPS using modern high-tech equipment with high rates of combined generation of electricity for heat consumption. The construction of a new TPS also involves the replacement of the thermal power of the morally and physically worn-out equipment of decommissioned TPS-1.

The city of Karaganda is in need of additional heat and electricity. According to the program “Development of the Karaganda energy complex in 2012-2023”, the preliminary cost of the project for the construction of TPS-4 is 380 billion tenge (2,5 billion dollars). Kazakhstan Utility Networks LLP intends to invest 20 percent of its own funds in this project, and 80 percent of the funds will be borrowed.

The available capacity of Karaganda TPS-4, proposed for construction, should be at least 530 Gcal/h and 700 MW, taking into account the retirement of capacities of Karaganda TPS-3 and TPS-1.

The project should be carried out in three stages. The first, in 2012-2017, involves the receipt of 300 MW of electric and 288 Gcal of thermal energy. The second stage is 2017-2020, the third is 2020-2023. As a result, TPS-4 will generate 900 MW of electric and 863 Gcal of thermal energy.

Based on the above mentioned, by 2020 Karaganda TPS-4 could replace the output to replace turbine No. 1 (175 Gcal/h and 110 MW) of Karaganda TPS-3, as well as covering the thermal and electric power of the shutting down TPS-1 (235Gcal/h and 32 MW).

Also, in this version of the development of the central heating system, it is assumed that after the turbine No. 1 is brought to the TPS-3, it will be expanded by turbine units and boiler units to the available heat capacity by 2030 to 1200 Gcal/h.

Table 4. Provision of thermal loads of the central heating zone of the city of Karaganda for 2030 according to option 1.

Indicator	2015	2020	2025	2030
Estimated heat load of the DH zone	1480	1608	1766	1904
Available heat capacity of the city of Karaganda:	1287	1400	1863	2063
TPS-1	235	235	0	0
TPS-3	1052	877	1000	1200
TPS-4	0	288	863	863
Deficit (-) / Excess (+)	-193	-208	97	159

Option 2. Assumes overhaul and modernization at TPS-1 and TPS-3 of Karaganda without the construction of a new TPS-4. Up to 2020, overhaul and reconstruction of existing equipment is carried out at TPS-1 to extend the operating life with bringing the available heat capacity to 320 Gcal/h. In the period 2025-2030 - the withdrawal from the central heating system of the city of Karaganda due to material and physical wear and tear of the equipment. Overhaul and reconstruction of existing equipment are also carried out at TPS-3, and starting from 2025 new turbos and boilers are introduced to replace the thermal capacity of the closed TPS-1, bringing the available heat capacity to 1600 Gcal/h by 2030 (table 5).

Table 5. Provision of thermal loads of the central heating zone of Karaganda for 2030 according to option 2.

Indicator	2015	2020	2025	2030
Estimated heat load of the DH zone	1480	1608	1766	1904
Available heat capacity of the city of Karaganda:	1287	1372	1200	1600
TPS-1	235	320	0	0
TPS-3	1052	1052	1200	1600
Deficit (-) / Excess (+)	-193	-236	-566	-304

Option 3. Also without the construction of a new TPS-4 in the city of Karaganda. It assumes that TPS-1 is maintained in operation with overhaul and modernization, bringing the available heat capacity to 320 Gcal/h. At TPS-3, overhaul and reconstruction of existing equipment is also carried out to bring the available heat capacity to 2030 Gcal/h by 2030 (table 6).

Table 6. Provision of thermal loads of the central heating zone of Karaganda for 2030 according to option 3.

Indicator	2015	2020	2025	2030
Estimated heat load of the DH zone	1480	1608	1766	1904
Available heat capacity of the city of Karaganda:	1287	1372	1372	1520
TPS-1	235	320	320	320
TPS-3	1052	1052	1052	1200
Deficit (-) / Excess (+)	-193	-236	-394	-384

Analyzing the data of tables 4-6, it follows that the development of a district heating system in the city of Karaganda is possible only with the construction of a new TPS-4. This will help to avoid heat shortages in the future. No major repairs and reconstructions of existing equipment at TPS-1, which has exhausted its resources, and parts of turbine and boiler units of TPS-3 will bring the desired result.

The implementation of the project for the construction of TPS-4 would allow:

- to increase the reliability of providing consumers of Karaganda with electric and thermal energy;
- improve the environmental situation in the region through the use of modern technology for burning solid fuel;
- to develop the coal mining industry of the Karaganda region by burning brown coal grade B-3;
- create jobs for qualified personnel during the construction and operation of new power units;
- increase tax revenues to local budgets.

At the same time, in order to increase the energy efficiency of heat supply in the city of Karaganda, as well as in many CIS cities, it is necessary to reduce losses in distribution heat networks and hot water supply systems by up to 3% (now it reaches 25%), reduce the heat carrier consumption for recharge to 0,5 volumes of the heat supply system per year, ensure the reduction of heat losses from the imbalance of supply and demand to a minimum due to the introduction of automation, dispatching systems (SCADA and AEMS systems) and regulation (installation of heat meters for each consumer), to increase and control the regulatory requirements for the efficiency of heat energy use among consumers.

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