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THE CONSUMERS' HEAT SUPPLY QUALITY AS A FACTOR OF THE SUSTAINABLE DEVELOPMENT OF THE COUNTRY URBAN AREAS' INFRASTRUCTURE

Abstract: *The article deals with the issues of the impact of the quality of consumers' heat supply on the sustainable development of the urban areas infrastructure focused on the implementation of the United Nations Program on Human Settlements (UN-Habitat). A group of five countries of Central Asia has been studied, the quality of heat supply to consumers of which has long been ensured through centralized systems. An analysis of the heat supply quality in these countries showed that the main advantage of district heating, cogeneration, is losing its usefulness for consumers due to the significant accumulated wear and tear of heat supply systems. Quantitative dynamic characteristics of the heat supply facilities functioning are considered. A set of indicators for evaluating investment projects aimed at improving the heat supply quality is presented, that made it possible to propose rating indicators of heat supply interconnected with the Sustainable Development Goals (SDGs).*

Keywords: *quality, sustainable development goals, urban areas, infrastructure, heat supply, ratings.*

1. Introduction

The United Nations Human Settlements Program (UN-Habitat), dedicated to the cities of the world – "World Cities Report 2020: The Value of Sustainable Urbanization" – notes that by 2030 it is planned to make the Global Sustainable Development Goals (SDG) the goals of all people, businesses and governments of all countries of the world (United Nations Human Settlements Programme, 2020). This is reflected in the multifaceted and action-oriented Decade of Action, which also focuses on sustainable urbanization based on the New Urban Agenda, which provides for "strengthening the role of affordable and sustainable housing and housing finance, including the creation of a social habitat" (New Urban Agenda, 2017), which in modern conditions acquires a crucial role in achieving SDGs. Obviously, the implementation of plans in the field of sustainable urbanization should be preceded by a comprehensive assessment of the current state of the infrastructure, its impact on the living conditions of people in modern cities around the world. Its integral component is the quality of providing consumers – objects for living and objects for all types of economic activity – with heat energy.

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It is quite natural that each country approached this issue differently, diametrically opposite approaches have developed in the world to ensure the quality of heat supply to residential, civil, industrial real estate in urban areas and the corresponding infrastructure. As the "one pole" of solutions for organizing heat supply, there are district heating systems for entire groups of consumers, the heat energy for which is generated by a powerful source, and at the "opposite pole" there are individual sources of heat supply for each property, the principle of operation and design of which are very diverse. Therefore, the topical issue is the question of where exactly it is advisable for modern society to invest in order to ensure the heat supply quality for the sustainable development of urbanized territories, focusing without fail on the balanced development of their infrastructure and, depending on this, the quality of life of the population in them.

2. Materials and methods

When compiling the research materials and choosing methods of analysis, it was taken into account that programs aimed at improving the quality of life of the population are being actively developed both at the level of individual countries and at the level of the international community, while the emphasis is shifting from the economic sphere towards solving social and environmental problems. These trends are most fully reflected in the UN program document "The 2030 Agenda for Sustainable Development", which contains 17 global goals (SDGs), as well as a number of tasks to achieve these goals (United Nations, n.d.).

The 17 sustainable development goals formed the basis of many national programs. The quality of life is the subject of study by many international institutions that develop country ratings. The examples are:

- Satisfaction with Life Index, based on the calculation of the combined indicator proposed by the British researcher Adrian G. White, which measures the level of subjective well-being of people in the countries of the world;
- Legatum Prosperity Index, based on the prosperity index proposed by the British think tank Legatum Institute, which measures the achievements of the countries of the world in terms of their well-being and prosperity and is compiled on the basis of many different indicators combined in nine categories, which reflect various aspects of the life of society and the parameters of public welfare;
- Quality of Life Index, calculated according to the methodology of the British research center Economist Intelligence Unit (an analytical division of the British publishing group Economist Group) and others.

In the Russian Federation, which shares the goals of sustainable development, since 2021, the Agency for Strategic Initiatives has been compiling the "Rating of the life quality in Russian regions" (Verstina et al., 2021), which is based on 141 indicators grouped by 10 environmental elements: Medical care, Education and development, Housing and infrastructure, Consumption and leisure, Cleanliness and ecology, Inclusion and equality, Safety, Social protection, Public services and services, Opportunities for work and own business.

Evaluation is carried out in three areas: subjective indicators of satisfaction, objective indicators of the environment and the dynamics of their changes. The main objective of the rating is to use it as a management tool for obtaining feedback from residents in order to prioritize investments in the sustainable development of territories, select the best projects in terms of improving the quality of life, their implementation and monitoring of results. The basic premise of the study is to consider the relationship between the proposed

decisions on the quality of heat supply to consumers in urban areas, which should improve the living conditions of people and the quality of life of the population, with the SDGs. This was determined based on a comprehensive analysis of the materials of the listed ratings, which showed that they largely correlate with the SDGs and indicators of their achievement, which are essential for determining the quality of life.

The main point of research in the formation of research materials and the choice of analysis methods in this work is SDG 7 "Ensure access to affordable, reliable, sustainable and modern energy for all". As a rule, when talking about this goal and indicators of its achievement, the electrical energy is considered. At the same time, the heat energy plays a significant role in ensuring quality in various areas of life, which was specified by the authors and defined as conditions for interpreting the results. For example, the ability to heat homes and social organizations (kindergartens, schools, hospitals) allows people to create comfortable living conditions and, therefore, is directly related to SDG 3 "Ensure healthy lives and promote well-being for all at all ages", as well as with SDG 11 "Make cities and human settlements inclusive, safe, resilient and sustainable". The quality of the processes of production and distribution of heat energy significantly influence the achievement of SDG 13 "Take urgent action to combat climate change and its impacts": today, a significant part of the heat energy is obtained by burning fossil fuels, which leads to an increase in CO_2 emissions, and accidents on heat networks in district heating systems cause damage to the environment. Many enterprises require high quality heat energy to maintain certain temperature conditions in order to ensure production processes, therefore, heat supply also has an impact on the achievement of SDG 9 "Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation". Thus, ensuring the heat supply quality in urban areas is invariant with respect to their country affiliation and is always an important component of ensuring the quality of life.

However, in the process of forming the research materials, the authors found that the heat supply quality and the achievement of the SDGs are hindered by many difficulties that "on the surface" look like a commitment to traditional forms of obtaining information about the quality of heat supply, as well as the use of standard solutions for organizing the supply of consumers with heat energy when implementing investment projects that improve the heat supply quality. At the same time, already at the stage of obtaining primary materials, it became clear that in the absence of a search for alternative investment solutions, a negative factor influencing the heat supply quality on the processes of sustainable development of territories is gradually formed, when problematic issues related to the cost of investing in inefficient heat supply projects are omitted, repeated and accumulated. In the study, we focused on the biggest problem area of heat supply quality – district heating supply to consumers, but at the same time considered all its aspects in quality assurance, both positive and negative.

For this purpose, we have chosen a region of the world where there are quite a lot of countries using district heating as the main form of providing consumers in urban areas, and at the same time they are located compactly, partially bordering each other. These are the countries of Central Asia – Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan, Uzbekistan, which are currently faced with a choice of directions for sustainable urban development and appropriate solutions to ensure the heat supply quality, but they do this in different ways. The main feature of all the studied countries is that their energy sector was formed in the middle of the last century according to the standard for all "post-Soviet countries" principles of building large generating capacities (the so-called

combined heat and power plants – CHPPs or large boiler houses), from which consumers of many urbanized territories were supplied through a system of heat networks laid mainly underground in channels or directly in the ground which became the main part of the infrastructure of urban areas at that time. For that period of intensive cities' construction in these countries, such a solution made it possible to build up new urbanized territories at a high rate and ensure a stable quality of heat supply to consumers, while creating more comfortable living conditions for people and ensuring their quality of life. Thus, for a rather long period, which has not ended even at the present time, the organization of heat supply to consumers in urban areas of these countries followed the path of traditional solutions, which grew in scale with an increase in the number of consumers and a change in the requirement for the quality of heat supply.

Let us present in a systematic way the source materials of the analysis in the context of studied countries, which generally characterize their infrastructure, taking into account the factor of heat supply. In Kazakhstan, the scale of district heating, as well as the size of the territory of the country itself, is enormous. The heat supply quality in the country is directly related to the age structure of engineering systems. The total length of heating networks is 12,300 km, of which 30% are main lines. Currently, there are 37 heat power plants (HPPs) of various forms of ownership in Kazakhstan. Of these, 28 HPPs have been in operation for more than 50 years – 76%, the remaining 9 HPPs have a service life of more than 30 years – 24% (Ministry of Energy of Kazakhstan, 2023). The average depreciation of heat networks is 59%, there is a low heat efficiency – 35-50%, compared with an average efficiency level of up to 70% in urban areas in the world.

The energy system of Kyrgyzstan includes 18 generating capacities, of which 2 are large heat power plants located in the cities of Bishkek (666 MW) and Osh (50 MW), from which heat energy is distributed to consumers through networks more than 500 km long. Annually only in Bishkek and Tokmok demand for heat in residential and public buildings remains unsatisfied by about 20-25% due to unreliable heat supply during the winter months. The problem is the import of energy resources in excess of 95%, as well as the actual wear and tear of heat networks, which is more than 70% (World Bank, 2015; Ministry of Energy of the Kyrgyz Republic, 2023; Orlova, 2022).

In Tajikistan, the share of HPPs in the country's energy system accounts for 718 MW, that presents only about 12.4% of the energy produced, which are represented by two HPPs – Dushanbe (198 MW), operating on gas and fuel oil, and Dushanbe-2 built during the Soviet period (400 MW), which runs on coal. Over the past few decades, the proportion of urban households provided with district heating has dropped from 35% to 4%. As a result, almost 50% of households in the urbanized area depend solely on electricity for heating. In 2021, the European Bank for Reconstruction and Development provided $10 million for a heat supply improvement project in Dushanbe, which is due to be completed in 2025 and will provide more than 500,000 residents with new district heating. (Ministry of Energy of Tajikistan, 2023).

The energy industry of Turkmenistan in recent years was presented in official sources with information on improving the supply of people in urban areas with heat energy. As part of the current state policy, geographic information systems (GIS) are being developed that make it possible to determine alternative options for heat supply to territories based on the design of renewable energy technologies (Ministry of Energy of Turkmenistan, 2023; Penjiev & Penzhieva,, 2015; Strebkov et al., (2012). At the same time, the country's position in traditional approaches to heat supply of objects based on gas remains strong – in terms of explored reserves and production of natural gas, Turkmenistan ranks fourth in the world in

terms of its reserves after Russia, Iran and Qatar. The website of the Ministry of Energy of the country notes that "In 2019, the heat power plants of JSC Heat Power Plants generated 56.4 billion kW of electricity, released 7.2 million Gcal of heat energy" (Ministry of Energy of Turkmenistan, 2023).

According to the Ministry of Housing and Public Utilities, there are currently 38,382 multi-storey buildings in Uzbekistan, of which 39.4% are connected to central heating, more than 14.6% are equipped with individual heating (double-circuit boilers, stoves, etc.), the remaining 46% of multi-storey buildings are heated with using heaters. There are 20 heat supply enterprises in Uzbekistan, which have 500 boiler houses on their balance. (Ministry of Energy of the Republic of Uzbekistan, 2023) Their equipment is obsolete, and about 60% of 4,500 kilometers of heating networks require repair (Sputnik Uzbekistan, 2021). The Ministry of Energy of Uzbekistan has developed a program for the development of heat generating capacities for the period up to 2030 and the decommissioning of obsolete power units at heat power plants with a total capacity of 6.4 GW.

For a more detailed analysis, statistical materials of the "EES EAEC. World Energy" informational and analytical portal, which contains energy profiles of the countries of the world (EES EAEC, 2023), as well as data on the reference group of European countries using district heating, were used.

3. Results

In the process of the analysis of the quality of heat supply to consumers the authors paid priority attention to the trends in the development of heat supply in the context of ensuring the quality of life of the population, which have been typical so far and are outlined in the estimated perspective. From the standpoint of influencing the sustainable development of urban areas, several significant results were obtained.

The study found that the analyzed countries differ significantly both in terms of the total capacity of the energy sector (from 3869 MW in Kyrgyzstan to 23965 MW in Kazakhstan), and in terms of the share of HPPs in the total installed capacity of power plants (Figure 1).

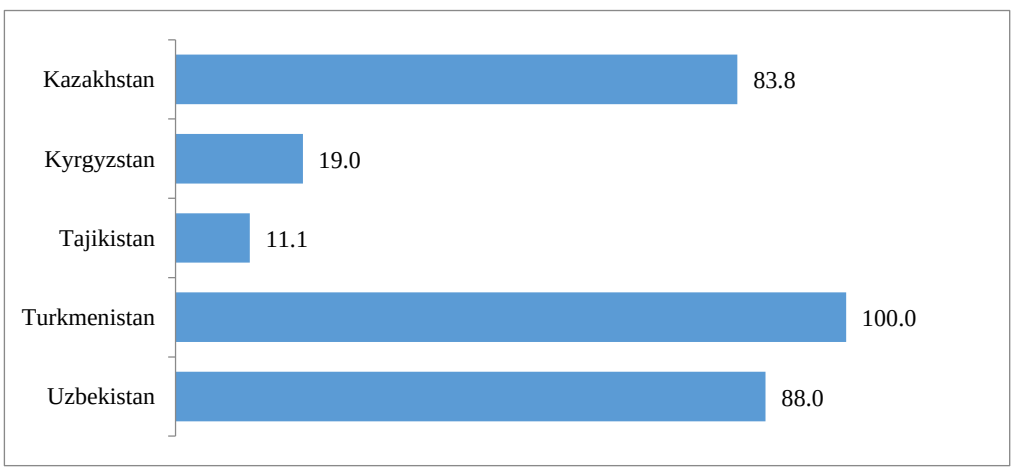

Figure 1. The share of HPPs in the energy balance of countries, %

Below the dynamics of power changes for the post-Soviet period is presented, starting from 1992, when these countries got the opportunity to independently choose the policy of investing in the development of urban areas (Figure 2).

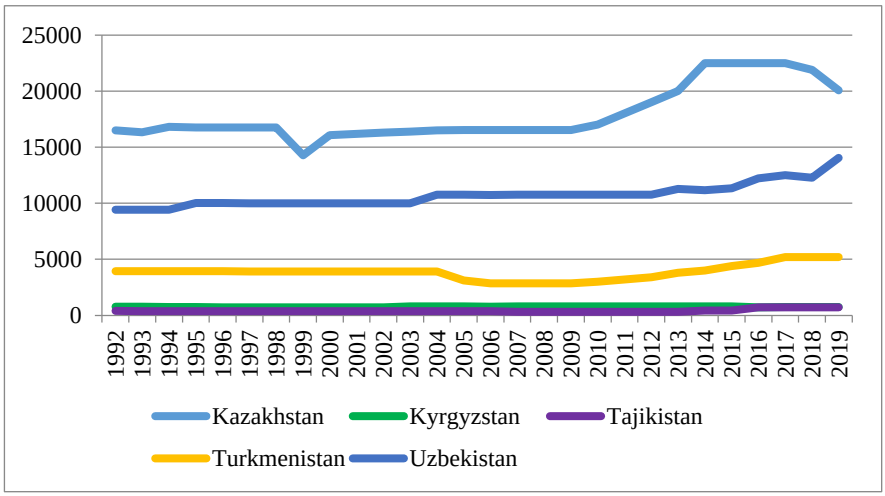

Figure 2. Installed capacity of HPPs, MW

It can be noted that the change in capacity in the set of measures to ensure the heat supply quality was characterized in different ways in the studied countries: in recent years, Kazakhstan, Uzbekistan and Turkmenistan have seen an increase in installed net capacity associated with investment projects in the construction of new energy facilities, while like Kyrgyzstan and Tajikistan, this indicator is at a constant level. The decrease in the net capacity of heat power plants in Kazakhstan, observed in 2019, is most likely due to the decommissioning of heat plants that have exhausted their resource.

At the same time, it should be noted that the overall dynamics of the development of these countries in the analyzed period is characterized by positive trends associated with the orientation towards the SDGs and the quality of life of the population. Figure 3 shows the dynamics of GDP per capita in purchasing power parity according to the IMF. (Statistics of the countries of the world, 2023)

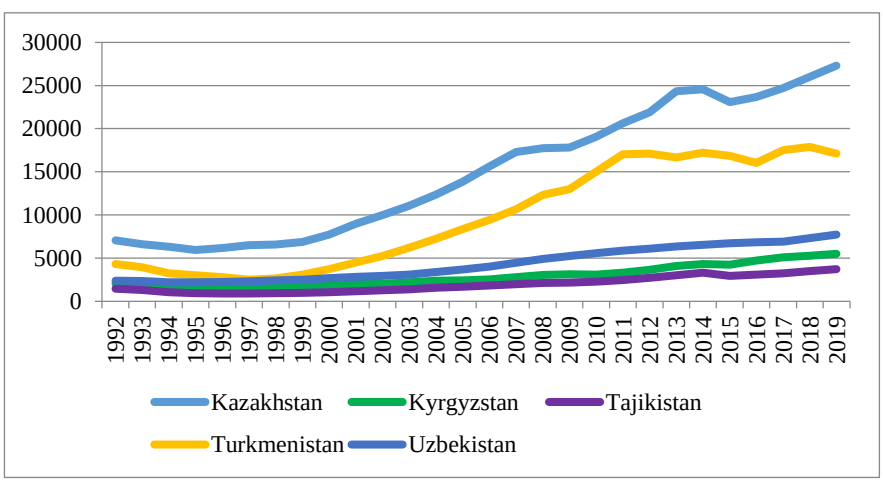

Figure 3. Dynamics of GDP per capita in purchasing power parity according to the IMF, USD

It should be noted that in the analyzed period there is a fairly stable growth of GDP per capita. The average annual growth rate was: in Kazakhstan - 105.14%, in Kyrgyzstan - 103.70%, in Tajikistan - 103.54%, in Turkmenistan - 105.22%, in Uzbekistan - 104.44%. Preliminary analysis shows so far a weak correlation between GDP growth and investments in the development of energy infrastructure, which will be shown in more detail later.

For this, let's move on to reviewing the results of the analysis of the production of heat energy generated at TPPs in the cogeneration mode, with which the concept of the heat supply quality in the countries under study has long been associated (Figure 4).

In Kyrgyzstan, Tajikistan and Turkmenistan the production of heat energy based on centralized sources is at the time of the study, as the analysis showed, at a low level. Moreover, for Tajikistan and Turkmenistan there is no detailed information on the consumption of heat energy as on the websites of the official structures of these countries, and on specialized resources dedicated to energy. So we will focus on the results of a comparative analysis of the development of heat power in Kazakhstan and Uzbekistan, where it significantly affects the infrastructure of urban areas. Figure 4 shows that over the post-Soviet period, the performance of the heat power industry in Uzbekistan has been at a stable level, while there is a slight jump in the production of heat energy in 2014. At the same time, the development of the industry in Kazakhstan has been characterized by a decline for 10 years, and only since 2001 an increase in heat energy generation is observed, which, nevertheless, did not allow reaching the level of 1992. Considering that detailed data on the production and consumption of heat energy have been available for Kazakhstan since 2008, and for Uzbekistan since 2014, let's analyze in more detail the information for the period 2014-2019 (Tables 1 and 2) in order to consider the aspect of the relationship between the structural characteristics of heat supply and its quality in these countries.

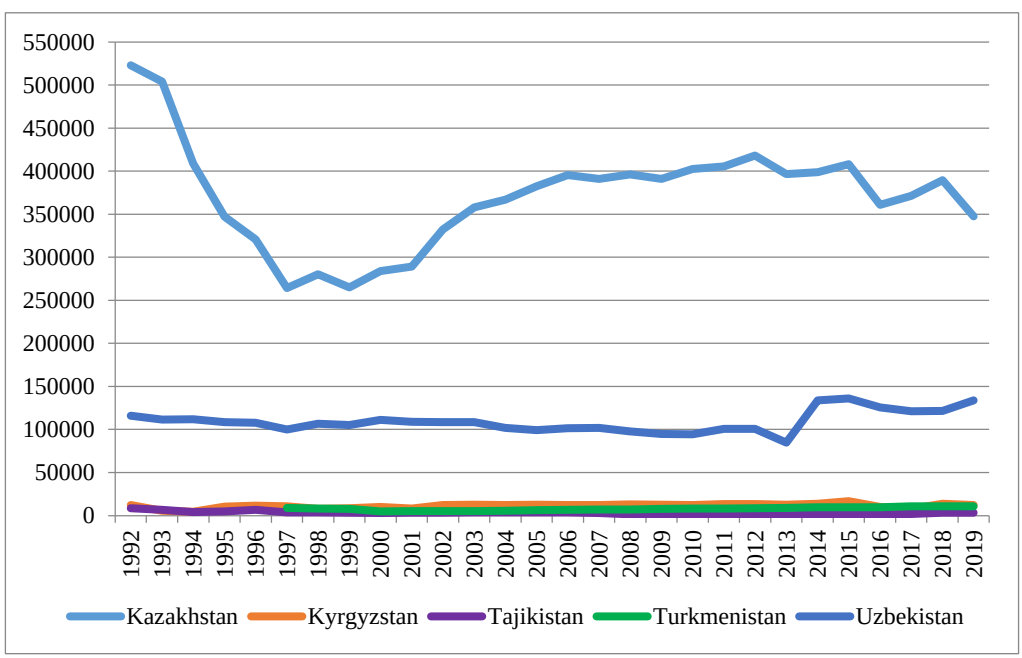

Figure 4. Production of heat energy based on centralized sources, TJ

Table 1. Kazakhstan: heat energy balance, 2014-2019, TJ (EES EAEC, 2023b)

Balance item	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**
Production-gross	398902	408147	361022	371187	389432	347364
Consumption for own needs of power plants and heating installations	50238	97660	45314	36345	37886	17434
Losses in networks	37904	29173	31795	34561	36400	32227
Consumption for own needs of the energy sector	25890	29428	34863	52538	54065	28246
Final (energy) consumption, including	284870	267730	249044	208342	260804	229052
Industry and construction	82517	79233	77686	79179	77440	86692
Household consumers	88468	86233	44602	32935	30500	46712
Commercial sector and public utilities	48620	58827	72859	88089	89864	89510
Agriculture, forestry and fisheries	4351	3442	3605	3762	–	6138
Others, unidentified	60914	39995	50292	4377	63000	–

Table 2. Uzbekistan: heat energy balance, 2014-2019, TJ (EES EAEC, 2023c)

Balance item	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**
Production-gross	133714	136022	125776	121032	121507	133833
Losses in networks	7953	8090	7481	7199	6780	7507
Final (energy) consumption, including	125761	127931	118295	113834	113999	126213
Industry and construction	21753	22128	20461	19690	18545	17968
Household consumers	52979	53893	49834	47954	45167	49354
Agriculture, forestry and fisheries	2652	2698	2494	2400	2261	2387
Others, unidentified	48378	49213	45506	43789	48025	56504

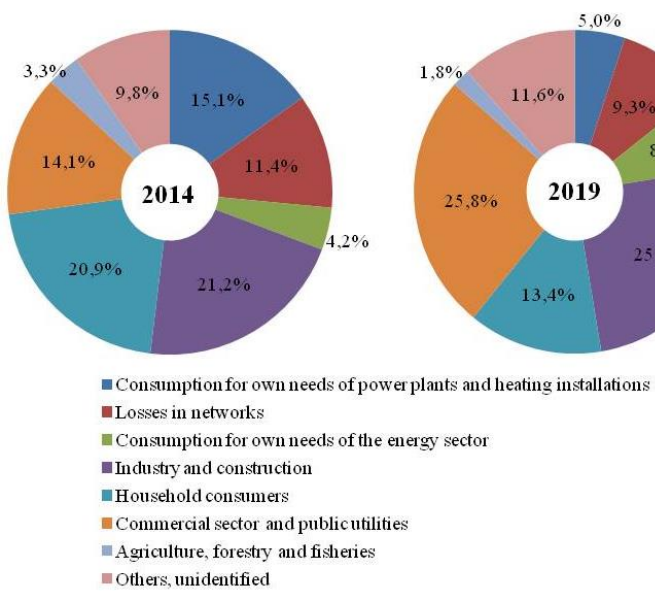

Figure 5. Structure of heat energy consumption in Kazakhstan in 2014 and 2019

The structure of the data presented in the tables 1 and 2 is slightly different: in Uzbekistan there is no allocation to separate categories of consumption of heat energy for own needs by heat stations and heating installations, as well as other enterprises of the energy and commercial sectors. It is assumed that these costs are attributed to unidentified consumers. Consider structural changes in the consumption of heat energy for the analyzed period (Figures 5 and 6).

The figure shows that over the period under review, the structure of heat consumption in Kazakhstan has changed significantly, which is also associated with corresponding changes in the infrastructure of urban areas as a whole. In 2014, unidentified consumers accounted for approximately one sixth of all heat energy produced (15.3%), by 2019 this figure had dropped to 11.6%. This sector can be classified in two ways: as an unauthorized extraction of heat energy, or as unregistered losses in networks, the official share of which in the analyzed period does not exceed 10%. The share of heat energy consumption for own needs by heat stations and heating installations decreased by 2 times, as well as the share of heat energy supplied to household consumers. At the same time, consumption by enterprises in the commercial sector and general use more than doubled. The share of heat supplied to household consumers decreased by 8.8 percentage points. Accordingly, both industry and the population of urban areas are interested in improving the heat supply quality in the country, investment projects in the development of which should be focused on eliminating the article "unidentified consumers" based on modern technical solutions.

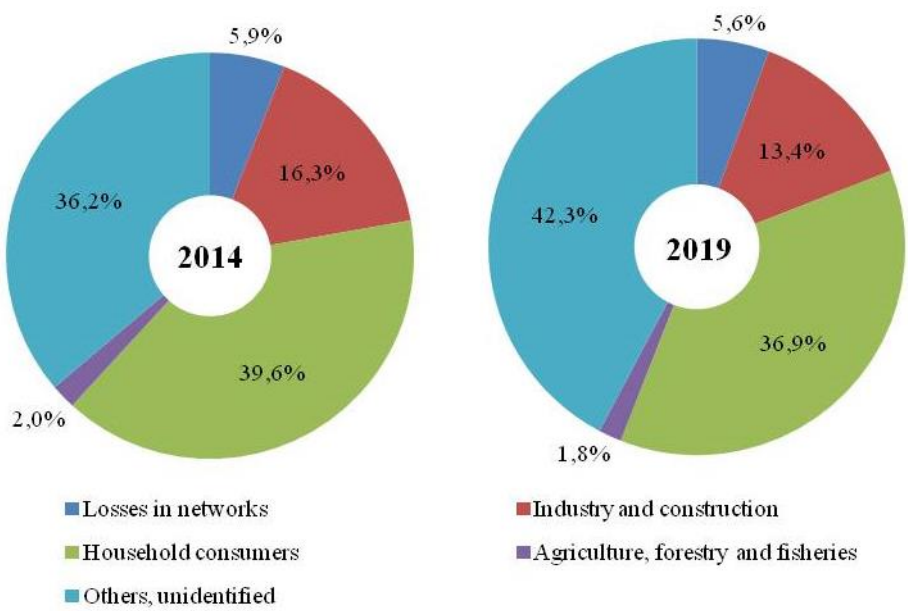

Figure 6. Structure of heat energy consumption in Uzbekistan in 2014 and 2019

An analysis of the heat energy consumption structure in Uzbekistan showed relative stability. However, it should be noted that more than a third of consumption in 2014 falls on unidentified consumers, which, first of all, indicates the imperfection of the heat energy accounting system in the country for a reliable assessment of sustainable infrastructure development in urban areas. In addition, from 2014 to 2019, this indicator

increased by 6 percentage points and accounted for almost half of all heat energy consumed. Official statistics shows rather low losses in networks (less than 6%), as well as a significant share of residential consumers (39.6 and 36.9% in 2014 and 2019, respectively). The share of the industrial sector is relatively small, and over the period under review decreased from 16.3% to 13.4%. Accordingly, the main interest in improving the heat supply quality in the country is the population, whose quality of life significantly depends on the receipt of heat energy with the required parameters and in the required volume. Therefore, investment projects in the development of heat supply should be focused, as in Kazakhstan, on the exclusion of the article "unidentified consumers", but at the same time take into account, as a matter of priority, the requirements for the quality of providing heat energy to consumers in the domestic sector.

From the analysis of the structure of consumption, let's move on to the consideration of the dynamics of absolute indicators (Table 3).

Table 3. Average indicators of the dynamics of heat consumption in Kazakhstan and Uzbekistan for 2014-2019

Balance item	Kazakhstan		Uzbekistan	
	Average absolute increase, TJ	Average growth rate	Average absolute increase, TJ	Average growth rate
Production-gross	-10307,6	97,3%	23,8	100,0%
Consumption for own needs of power plants and heating installations	-6560,8	80,9%	–	–
Losses in networks	-1135,4	96,8%	-89,2	98,9%
Consumption for own needs of the energy sector	471,2	101,8%	–	–
Industry and construction	835	101,0%	-757	96,2%
Household consumers	-8351,2	88,0%	-725	98,6%
Commercial sector and public utilities	8178	113,0%	–	–
Agriculture, forestry and fisheries	357,4	107,1%	-53	97,9%
Others, unidentified	521,5	100,8%	1625,2	103,2%

During the period under review, the production of heat energy in Kazakhstan annually decreased by an average of 10,307.6 TJ or 2.7%. In the structure of consumption, the most significant decrease was observed in the sectors of energy and household consumers (on average per year by 19.1% and 12%, respectively). Consumption increased in the commercial sector and at the enterprises of the agro-industrial sector (by 13.0% and 7.1% per year, respectively). Consumption in other sectors remained about the same. The noted structural shifts in the consumption of heat energy determine the need to provide a differentiated approach to the selection of projects aimed at improving the quality of heat supply, taking into account the needs of each of the categories of consumers. The production and consumption of heat energy in Uzbekistan for the period under review did not show significant changes, that indicates the stability of the structure of demand for heat energy products in this industry and the requirements for its quality. Comparison of the growth (decrease) rates of production and consumption of heat energy with the average annual GDP growth rates once again confirms the insufficient attention of the government to the development of energy infrastructure.

At the end of the presentation of the results, we characterize in specifics the heat supply quality negative impact on the sustainable

development of the infrastructure of urban areas. Based on the publications of a number of researchers, it has been established that the indicators of the "unidentified consumers" analysis in the above tables for the countries studied can be specified as follows. The existing defects in district heating systems manifest themselves as failures in their operation, leading to significant losses of heat energy and the heat carrier itself. And this reduces the quality of heating in the premises in the form of "underheating" or "overheating", and in some cases is a danger to people in the event of emergencies on the streets of cities, which occur when there are breaks in corrosive pipelines and coolant emissions. In exceptional cases, experts also described the destruction of road surfaces and sidewalks at the accident site, the appearance of funnels and "fountains" of hot water, which, mixed with the ground, spreads around at a sufficient speed and can harm people and neighboring buildings. Therefore, even now, organizations responsible for the heat supply quality should analyze such situations and prevent them to the maximum extent by implementing investment projects to improve heat supply in a timely manner. The results of a study previously published by the authors on Russian heat supply systems comparable to the countries of Central Asia showed that in the Russian Federation the share of heat networks with a service life of 30 years or more increased from 36.3 to 37.9% from 2015 to 2019, and the proportion of heating networks that need to be replaced has been about 30% over the past years, which leads to an increase in accidents. Thus, during the analyzed period, the number of accidents at heat supply sources, steam and heat networks annually ranged from 4000 to almost 6000 cases, and the loss of heat energy in some regions reached 20% (Verstina et al., 2021). The solution to the problems associated with reducing accidents and increasing the efficiency of heat supply can and should be the development of a methodology for monitoring the state and creating a system for preventive diagnostics of defects in heating networks using modern digital technologies.

In terms of identifying other possible countries for expanding the research base of the problems studied by the authors, the following should be noted: since 2005, for European countries, data on the share of cogeneration have been published, according to which, in many urban areas of Europe, about 20% of electricity was received from these sources. District heating is most developed in the Scandinavian countries – up to 55% of the total electricity production, in warmer European countries (for example, France, Greece) this figure is no more than 5%.

In the light of recent global changes in the world, Germany announced a doubling of electricity production at heat power plants and, at the same time, the "reactivation" of coal-fired heat power plants has begun. (Nikolaev, 2022)

Analyzing the data of statistical sources for a number of European countries (EES EAEC., 2023), first of all, it should be noted that they also lack a unified system for providing information on the quality of heat supply. The authors analyzed countries with different levels of heat production (Figure 7), focusing on two indicators that are significant from the SDG point of view: the share of losses in heat networks (energy efficiency, SDG 7) and the share of heat directed to residential heating (SDG 11) (Figure 8).

Focusing on the indicators of heat supply to residential consumers, the following differences can be noted: they account for 17.2% of the produced heat energy (Great Britain) to 51.8% (Sweden). This indicator can be considered as an indirect characteristic of the degree of heat supply centralization. It should also be noted that, despite the different scales of the heat and power industry, the level of losses in heat networks does not have sharp differences

and ranges from 7.8 to 12.7%, which is quite comparable with the indicators of the countries of Central Asia and the Russian Federation. In all likelihood, this is due to the general technical condition of heat networks and the need, as noted above, to implement investment projects for the modernization and introduction of innovations in heat supply.

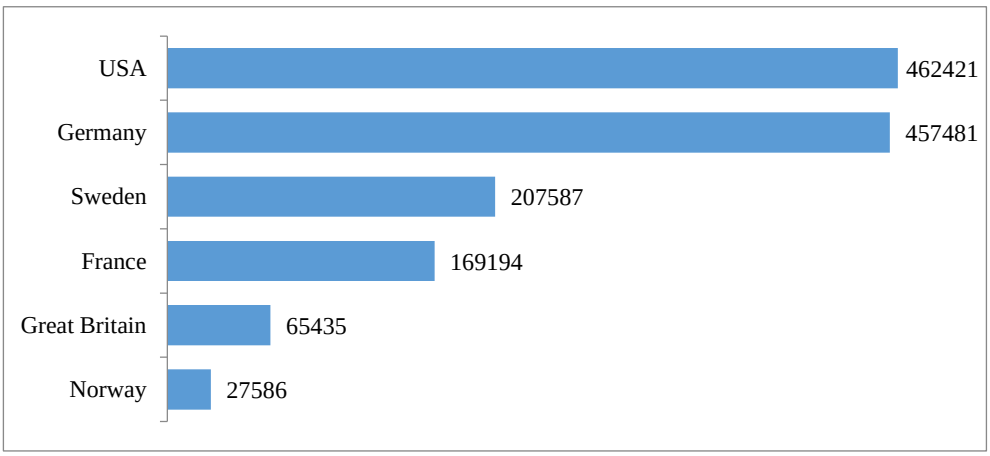

Figure 7. Heat production by selected countries in 2019

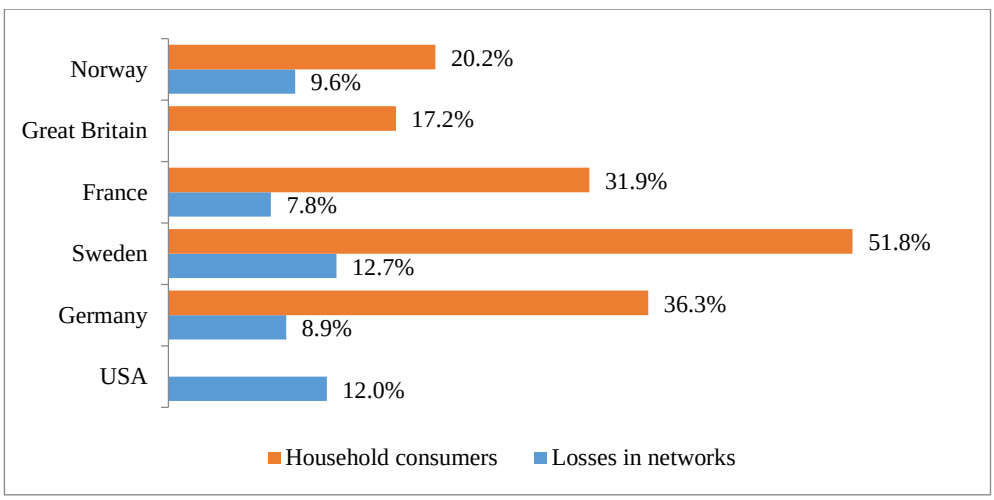

Figure 8. Structural indicators of heat consumption characterizing SDGs 7 and 11 (2019)
Note: No data available for US domestic heating and UK grid losses

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networks and the need, as noted above, to implement investment projects for the modernization and introduction of innovations in heat supply.

4. Discussion

The obtained results show a clear deficit in open sources of information, based on which it would be possible to make universal generalizations regarding the influence of the quality factor of heat supply to consumers on the sustainable development of the infrastructure of the urban areas of the studied countries, achieving complete certainty regarding the nature of investment projects that improve the quality of heat supply. In this regard, as discussed approaches to determining the prospects for improving quality in this industry, the authors considered issues that, if resolved in practice, will make it possible to draw the required generalizations and conclusions for decision-making at the state level, at the level of city leadership and services located on their territories.

Each of the studied countries so far has come with its own positive "accumulated potential" for district heating, but there are also common problems that the district heating of Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan, Uzbekistan creates to ensure the quality of life of people in the context of the SDGs.

Due to the constant shortage of financial resources for the maintenance and repair of district heating systems, which was most acutely felt during the transition of these countries to independent functioning in the status of independent states, a significant physical wear and tear of heat generating equipment and heating networks was accumulated, the service life of which was exceeded in many cases. As a result, cogeneration – the most efficient technology for the production of electricity and heat, which is used in district heating systems – is today becoming an unprofitable sector in the energy sector of Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan, and Uzbekistan. This negatively affects both the prospects envisaged in the New Urban Agenda comprehensive document and the implementation of individual SDGs, a significant part of which is related to the improvement of infrastructure in urban areas and the quality of life of the population of the countries of Central Asia considered, in particular SDG 7.

According to the authors, in this regard, it is important at the level of the city authorities and services located on their territories that operate heat supply systems to significantly expand the range of traditionally collected information on the heat supply quality to urban areas and in the context of SDG 11 "Make cities and human settlements inclusive, safe, resilient and sustainable", start collecting more data. This in a relatively short time will allows choosing the most effective directions for sustainable development of the urban areas of the studied countries of Central Asia and relevant decisions on investment projects in the field of heat supply, but at the same time not losing the accumulated potential of district heating.

Let us explain in more detail the content of information that can help improve the heat supply quality. In our opinion, at this stage of the Decade of Action, which is also focused on sustainable urbanization based on the New Urban Agenda, it is important to choose investments in the development of technical support and technologies for diagnosing the state of district heating systems as a priority position for "creating a social habitat" consumers in urban areas, especially in terms of their network structure, which is mainly represented by the underground laying of heat networks in channel and non-channel versions, the formation of systematized heat supply databases on this basis. Turning to aspects of the impact on the quality of life of people, it can be said that even determining the amount of investment in the development of heat

supply systems in urban areas is difficult, and in this context, investments in urbanization based on the New Urban Agenda acquire a certain degree of risk.

In this regard, it is important to have a certain system of indicators that can characterize the quality of heat supply to consumers and identify it as a factor in the sustainable development of the infrastructure of the country's urban areas. The authors, based on the principle of their minimum necessary and sufficient number, proposed two groups of indicators, using which makes it possible to plan investment projects that improve the heat supply quality: social and environmental, as well as technological efficiency.

To determine the social and environmental efficiency of the implementation of investment projects that improve the heat supply quality, the following list of indicators is proposed to characterize the relationship between the heat supply quality and the quality of life of the population in urban areas. (Table 4).

An indicator of the social efficiency of the implementation of investment programs that improve the heat supply quality, directly related to SDG 11, is the satisfaction of the population. However, to determine it, it is necessary to conduct specialized sociological researches. Such studies, as a rule, are carried out by research companies to determine the general state of the issue in the country (or a separate region) as part of the study of the processes of sustainable development of urban areas. Environmental performance indicators are focused on assessing the impact of heat supply organizations (HSO) on the environment, primarily through emissions (both heat energy and heat-carrying water), which are also closely related to the quality of life of the population of urban areas. The implementation of investment programs will be effective from a social and environmental point of view in case of positive dynamics of all these indicators.

To determine the technological efficiency of the implementation of investment projects that improve the heat supply quality, a list of indicators is proposed based on the results of summarizing the provisions of regulatory documents that are established in all countries operating district heating systems. (Table 5).

Table 4. Indicators of social and environmental efficiency of the implementation of investment projects that improve the heat supply quality

№	Indicator	Unit measurements
1	Reducing the number of interruptions in the supply of heat energy or coolant as a result of technological disturbances in heating networks per 1 thousand inhabitants	Unit/thous. lives
2	Reducing the number of complaints filed with local governments by consumers regarding heat supply per 1 thousand inhabitants	Unit/thous. lives
3.	Reducing the number of cases when people and (or) their property were damaged as a result of an accident on heating networks per 1 thousand inhabitants	Unit/thous. lives
4.	Reducing the number of detected cases of non-compliance of the parameters of the heat carrier supplied to the consumer, in relation to the normative ones, per 1 thousand inhabitants	Unit/thous. lives
5.	Reducing water consumption for heat supply needs per 1 km of the heat network	%
6.	Reducing heat losses, i.e. volumes of heat leakage into the environment	%

Table 5. Technological efficiency indicators for the implementation of investment projects that improve the heat supply quality

№	Indicator	Unit measurements
1	Reducing the number of interruptions in the supply of heat energy, coolant as a result of technological disturbances in heat networks per 1 km of heat networks	Unit/km
2	Reducing the value of technological losses during the transportation of heat energy, coolant through heating networks per 1 km of heating networks	Gcal/km
3	Reducing the amount of operating costs associated with the maintenance of a section of the heating network, calculated per 1 km of heating networks	monetary units/km
4	Reducing the specific cost of electricity for the transportation of heat energy	kW/Gcal
5	Reducing deviations from the norms of technological losses during heat transportation	^{o}C
6	Reducing the average level of wear and tear of heating networks	%

The technological efficiency of the implementation of investment projects that improve the heat supply quality is recognized in the case of a positive trend in all of these indicators.

To predict the situation of improving the quality factor of heat supply to consumers for the sustainable development of the infrastructure of the country's urban areas on the basis of the proposed indicators, it would be reasonable to use a general algorithm for calculating dynamic indicators, in which the value of the indicator of the current period is subtracted from the value of the indicator of the previous period. This will make it possible to monitor the processes associated with improving the quality of heat supply, thereby providing a connection with other indicators we have studied.

Another proposal related to monitoring that the authors would like to put forward in terms of the discussion on the most promising ways of implementation in the UN Human Settlements Program "World Cities Report 2020: The Value of Sustainable Urbanization" is the proposal to rank urban areas related to quality of heat supply to consumers. We are well aware that due to territorial, climatic and many other differences, it can be problematic to use this idea on a global scale, but it is quite possible to apply it to a certain group of countries with similar characteristics of heat supply to consumers that affect the quality of people's life in urban areas. Taking into account the studied characteristics of heat supply for the reference group of Central Asian countries – Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan, Uzbekistan – a number of proposals were formulated in Table 6.

Table 6. Proposed directions for the formation of indicators of urban areas ratings related to heat supply to consumers

№	SDGs	Indicator
1	7	Annual increase in heat supply
2	11	Number of failures in the operation of heat supply systems
3	11, 13	Losses of heat energy in heat supply systems
4	7	Specific consumption of energy resources and its change
5	9, 11	Amount of performed repairs of heat supply systems
6	7, 9	Number of heat supply facilities with heat consumption meters
7	7, 9	Number of heat supply facilities with heat consumption regulation
8	9	Amount of technical diagnostics of heat supply systems
9	11	Amount of heat supply development data submitted for public comment

It should be noted that the proposed indicators characterizing the development of heat supply in various countries and regions correlate with the above indicators of the effectiveness of investment projects that improve the heat supply quality, and contribute to the achievement of the SDGs listed above, as well as SDG 9 "Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation".

When formulating proposals, we proceeded from the fact that each of the directions for the formation of indicators should be directly or indirectly related to the SDGs (three main ones related to urbanization were chosen as the basic ones), be accessible for obtaining and interpreting in terms of the quality of people's life, and also to provide the possibility of carrying out a comparative analysis of urban areas on this basis. We also note that the rating should be aimed not only at measuring the dynamics of specific indicators, but also at identifying and disseminating the best practices for their provision.

5. Conclusion

The implementation of the planned measures for the sustainable development of the countries' urban areas infrastructure that support the United Nations Program on Human Settlements (UN-Habitat), implemented on the basis of a set of activities under the New Urban Agenda, is hampered by insufficient attention to the impact of the heat supply quality, which is closely interconnected with the people's life quality. The study conducted on a selected group of Central Asian countries made it possible to comprehensively characterize the problem of improving the quality of heat supply, which at the present stage of its development is still focused on traditional technical solutions that are gradually losing their effectiveness, which was confirmed by the data analyzed in the study. An obstacle in determining the directions of investment in projects that improve the heat supply quality is the lack of the required information for making such decisions, a clear lack of which was shown by the study. In this regard, based on the analysis of regulatory, technical and legislative information of the countries under study, the authors developed a system of indicators for assessing the social, environmental and technical effectiveness of projects that are interconnected with certain sustainable development goals (SDGs) and allow quantifying the prospect of quality improvement. Since the UN initiatives concern many countries of the world, it is important in solving problematic issues of infrastructure development to go beyond the boundaries of one country and develop solutions to improve the quality of heat supply, invariant with respect to its country of origin. In this regard, the authors proposed to organize ratings for the sustainable development of the urban areas infrastructure related to the heat supply quality, for which monitoring indicators were proposed and conditions for implementation were determined. At the same time, the position of the state, the leadership of municipalities in urban areas, which share the SDGs and are ready to ensure their implementation on the basis of timely qualitative information in the context of SDG 11 "Make cities and human settlements inclusive, safe, resilient and sustainable", is also important.

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