International Conference on Smart Energy Systems and 4th Generation District Heating
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HEAT SUPPLY PLANNING IN THE CONDITIONS OF DEVELOPMENT OF ENERGY-EFFICIENT TECHNOLOGIES IN CONSTRUCTION

ENERGY SYSTEMS INSTITUTE SB RAS

Ekaterina E. Iakimetc, *junior researcher*
prof. Valery A. Stennikov, *deputy director*
MELENTIEV ENERGY SYSTEMS INSTITUTE

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HEAT SUPPLY SYSTEMS IN RUSSIA

Russia has extensive co-generated heat and electricity system.
More than one-half of electricity is co-generated with heat.

NUMBER OF CHP AND HEAT-ONLY BOILER PLANTS IN RUSSIA:

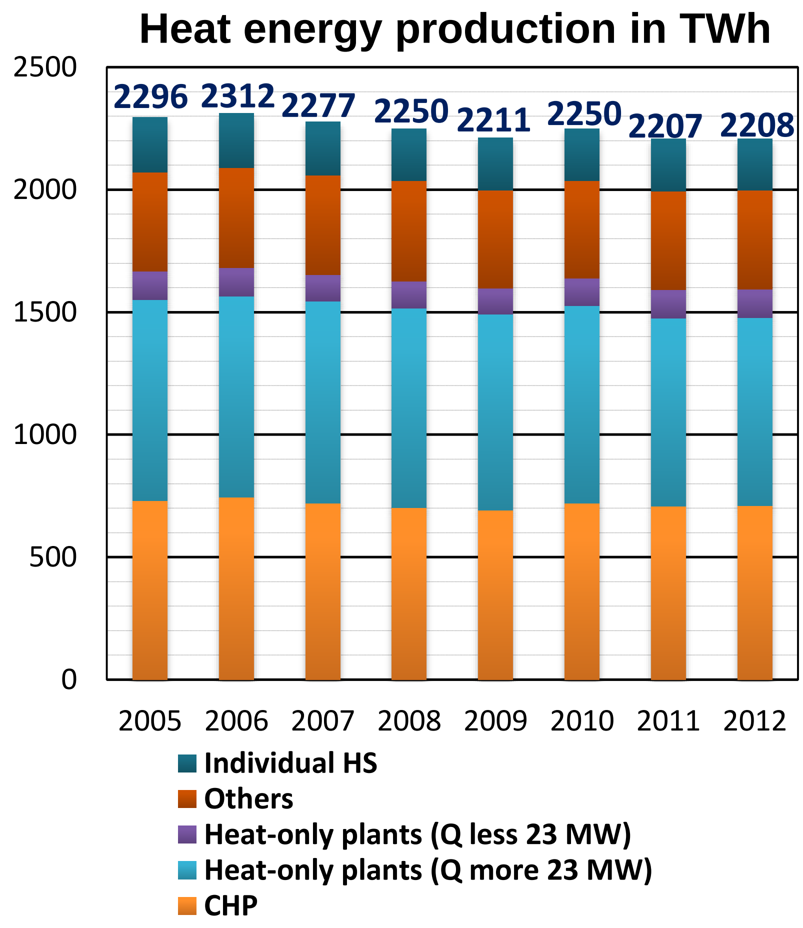
- 567 CHP
- 73511 heat-only plants (only 3392 of them with heat capacity more than 23 MW)

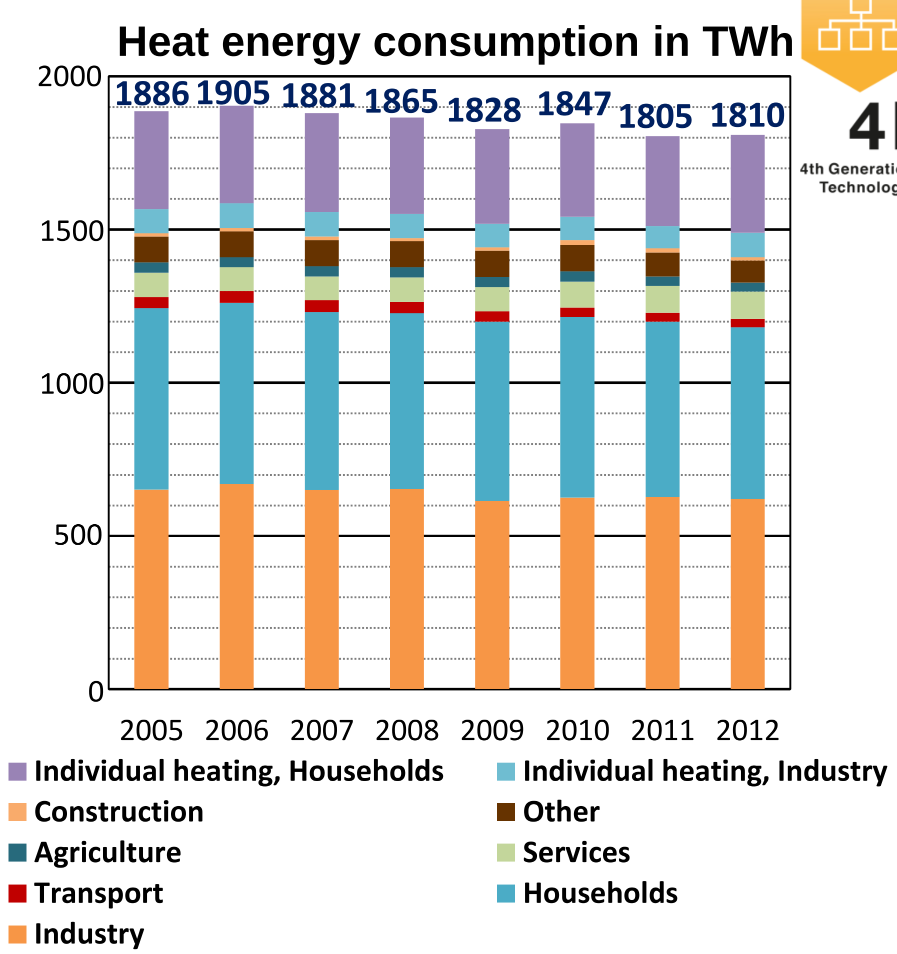
HEAT ENERGY PRODUCTION IN RUSSIA (2012 year):

- 709 million MWh by CHP
- 769 million MWh by heat-only plants with heat capacity more than 23 MW
- 209 million MWh by heat-only plants with heat capacity less than 23 MW
- 405 million MWh by individual sources
- 116 million MWh by other

The length of DH pipes - 169525 km.

HEAT ENERGY PRODUCTION AND CONSUMPTION IN RUSSIA





Source: the Energy strategy of Russia until 2035

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REQUIREMENTS
TO THE HEAT RESISTANCE FOR A BUILDING

- *According to the Construction Norms and Regulations 23-02-2003 "THERMAL PERFORMANCE OF THE BUILDINGS" were approved different requirements for heat resistance for buildings constructed before the year 2000 and after.*

The Value of standardized specific heat energy consumption for heating an apartment in five large cities of Russia, Wh/(m^2 ·degree-day)

city	buildings constructed before the year 2000				buildings constructed after the year 2000			
	1-2 fl.	3-4 fl.	5-9 fl.	>9 fl.	1-2 fl.	3-4 fl.	5-9 fl.	>9 fl.
Moscow (-28 ˚C)	58.9	36.1	30.1	28.8	20.6	17.1	15.4	14.1
Novosibirsk (-39 ˚C)	50.7	31.8	27.5	26.2	19.9	16.9	15.5	14.1
Irkutsk (-36 ˚C)	52.3	32.7	28.5	27.3	19.9	16.9	15.4	14.2
Yakutsk (-54 ˚C)	46.6	28.8	25.6	24.5	20.1	17.1	15.7	14.3
Vladivostok (-24 ˚C)	63.3	38.5	31.9	30.7	19.7	16.9	15.0	14.2

CLASSES OF ENERGY EFFICIENCY FOR BUILDINGS

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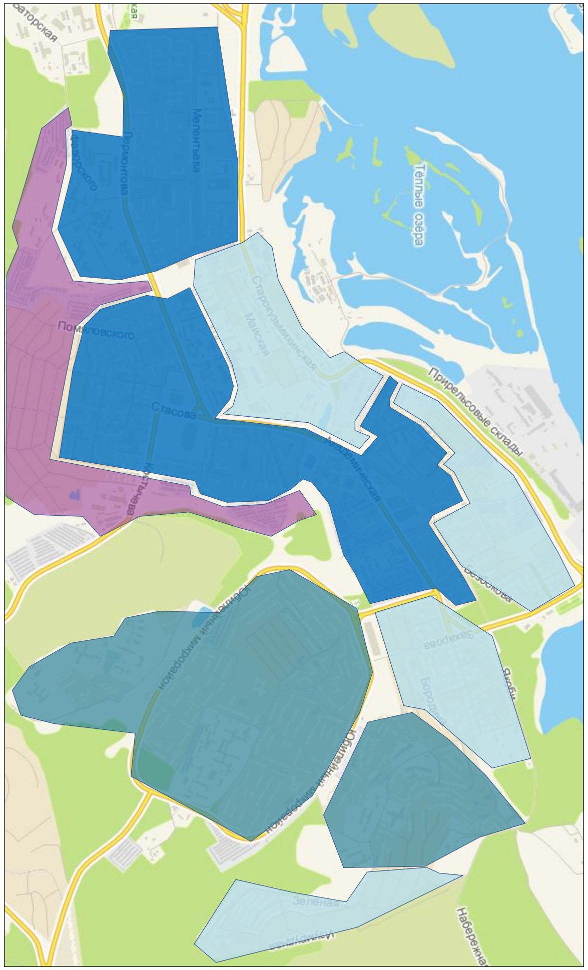
Class designation	The name of energy efficiency class	Deviation of the values of specific heat consumption from the standardized level, %
For new or renovated buildings		
A	The highest	less than -45
B++	The increased levels	from -36 to -45
B+		from -26 to -35
B	High	from -11 to -25
C	Normal	from +5 to -10
For existing buildings		
D	Lower level	from +6 to +50
E	The lowest	more than +51

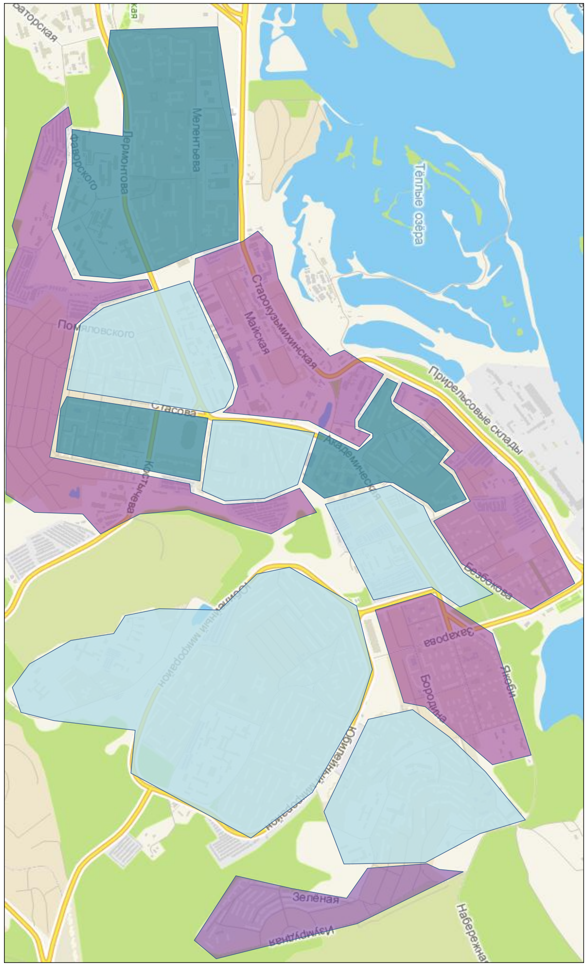
HEAT DENSITY MAPS

>60 MW/km^2
40-60 MW/km^2
20-40 MW/km^2
<20 MW/km^2

Existing heat density map



Heat density map after adaptation of buildings to requirements



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ENERGY PLANNING PROBLEMS

1. Territory zoning. It is territory division into zones of the district heating (DH) and individual heating.

2. Justification of optimum levels of district heating and concentration of heat sources capacities.

Regulatory legal acts:

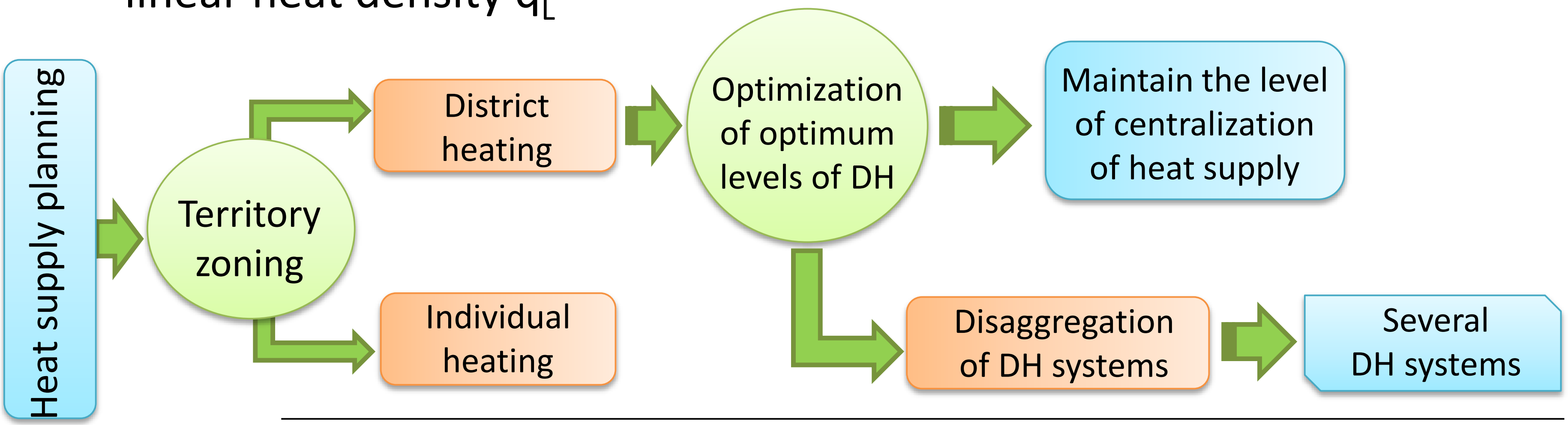
1. The Federal law № 190-FZ *On heat supply* (27.07.2010, ed. by 02.03.2014).
2. The Governmental order № 154 «*On requirements to heat supply schemes, the order of their development and approval*» (22.02.2012)
3. The Construction Norms and Regulations 11-04-2003 «*Guidelines on procedure of development, agreement upon, assessment and approval of town-planning documentation. Basic principles for urban planning and design (instruction)*» (The project of detailed planning)

HEAT SUPPLY PLANNING

The technique* allows to plan heat sources locations and a zone of their coverage when developing heat supply schemes.

Criteria for limitation of systems scale are:

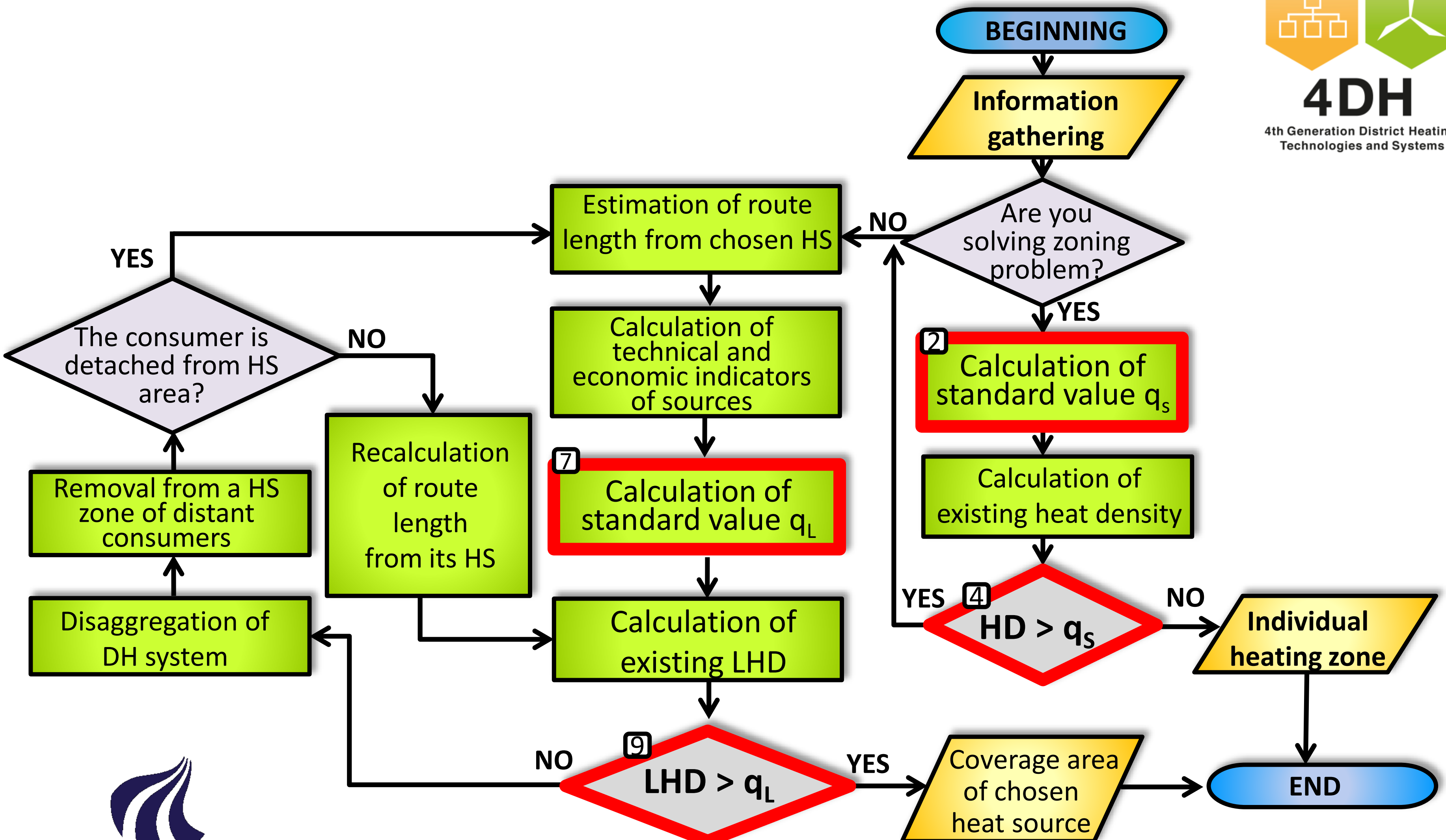
- heat density q_S
- linear heat density q_L



1. V.A. Stennikov, E.E. Iakimetc, S.V. Zharkov. Optimal planning of the urban heat supply // Industrial power engineering – 2013, №4. P. 9-15.

2. E. Iakimetc, V. Stennikov. Optimization methods of heat supply systems' scales// Proceedings from the 14th International Symposium on District Heating and Cooling, 6-10 September, Stockholm, SWEDEN. P. 526-529, 2014.

THE GENERAL ALGORITHM FOR THE TERRITORY ZONING AND DETERMINATION OF RATIONAL SCALES OF DH SYSTEMS



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FEATURES OF REGULATION CRITERIA DEFINITION

We take into account:

1. Different climatic conditions in the country.
2. The scale of built-up areas of settlements.
3. Economic conditions and characteristics of the territory.
4. Features of energy systems.

STANDARD VALUE OF HEAT DENSITY CRITERION DEFINITION

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Standard value $\mathbf{q_S}$ is defined by comparison costs for DH system and for individual heating

$$Z_S^{DH} + Z_{HN} \leq Z^{IND}$$

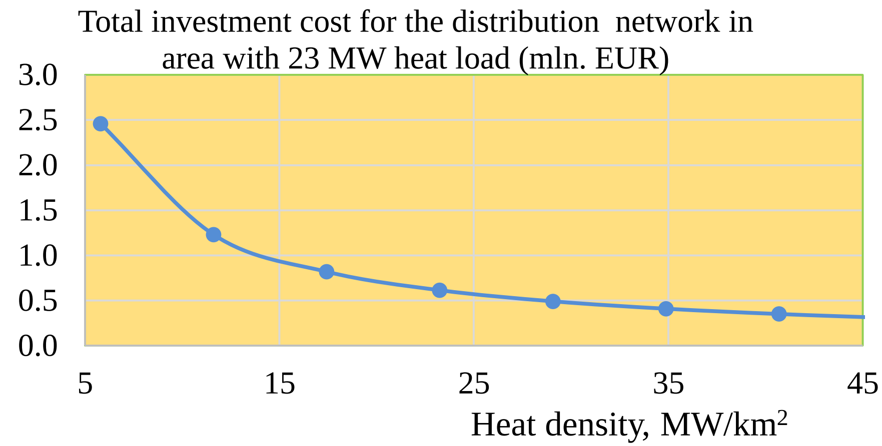
Specific heat supply cost for DH

$$z_{HN} = (p+\alpha) \cdot k_{HN} = (p+\alpha) \cdot \frac{m}{q_S}$$

Equation for specific investment cost for pipeline construction subject to heat density.

$$k_{HN} = \frac{m}{q_S}$$

p – pipeline operation costs and depreciation charges in shares from investment cost for pipeline construction;
α – annuity;
m – approximation coefficient of numerical values of the specific cost of pipe laying with various values of heat density;
q_S – standard value of heat density (*MW/km²*).



STANDARD VALUE OF HEAT DENSITY CRITERION DEFINITION

Annual heat supply cost for DH

for heat sources →

$$Z_{S_n}^{DH} = C_n + D_n \cdot Q_n, n \in N$$

for heating networks →

$$Z_{HN} = (\alpha + f) \cdot \sum_i k_i(d_i) \cdot l_i + \frac{c_e \cdot \tau \sum_i x_i \psi_i \cdot l_i}{362{,}7 \cdot \eta}, \quad i \in I$$

specific investment cost for pipeline construction →

$$k_i(d_i) = a_i + b_i d_i^{u_i}, i \in I$$

share of pipeline operation costs and depreciation charges from investment cost for pipeline construction →

$$p = f + \frac{c_e \cdot \tau \cdot \sum_i x_i \psi_i}{362{,}7 \cdot \eta \cdot \sum_i k_i(d_i)}, \quad i \in I$$

f – depreciation charges, charges for maintenance and repairs of networks in shares from capital investments; Q_n – optimal heat output of the n-th heat source; a, *b, u* – coefficients in the equation of cost of a pipeline; *l* – route length; *τ*– number of hours of unit operation; c_e– electricity cost; *η* – efficiency coefficient of pump; x_i – flow rate in the network sections ; ψ_i– the specific pressure drop in a network; D_n, C_n –coefficients of variable and constant costs for heat energy generation in a heat source.

STANDARD VALUE OF HEAT DENSITY CRITERION DEFINITION

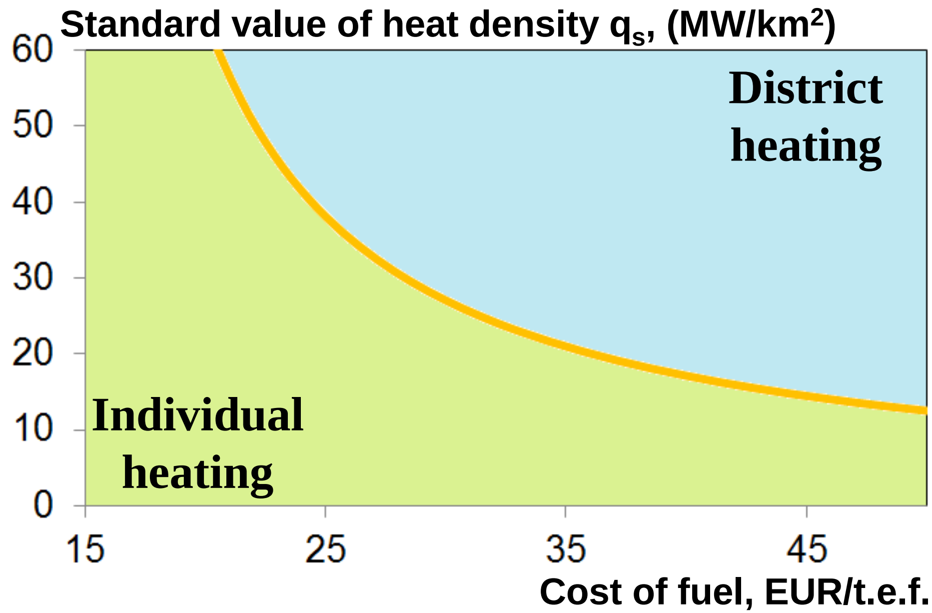
Equation for standard value of heat density →

$$q_s = \frac{1{,}16 \cdot m \cdot (p + \alpha)}{0{,}001 \cdot \tau \cdot c_f \cdot b_f - \frac{C_n}{Q_n^{DH}} - D_n + \alpha \cdot (k_S^{IND} - k_{Sn}^{DH})}$$

Equation for existing value of heat density →

$$HD = \frac{\sum_1^J Q_j}{S}, j \in J$$

c_f – cost of fuel;
b_f – specific consumption of fuel for heat energy production in decentralized sector;
k_S^{IND}, k_S^{DH} – additional specific investment cost for individual heating or for increasing of heat source capacity in district heating system.
HD – heat density for area,
S – the total land area of district.



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STANDARD VALUE OF LINEAR HEAT DENSITY CRITERION DEFINITION

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Annual heat supply cost for DH

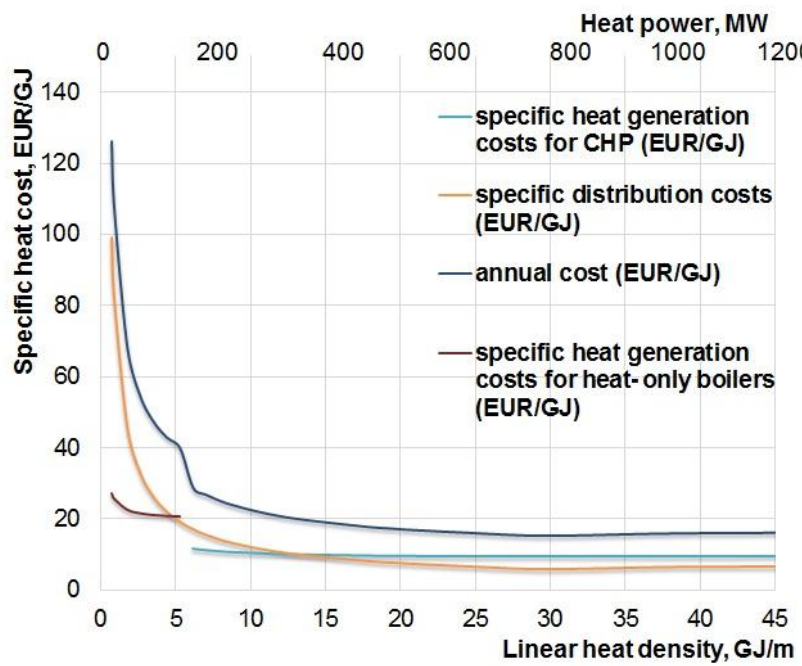
short equation

$$Z = Z_{HN} + Z_S$$

full equation

$$Z_n = (f + \alpha)\sum_i (a + bd_i^{\,u}) \cdot l_i + \frac{c_e \cdot \tau \cdot \sum_i (x_i \cdot \psi_i \cdot l_i)}{362{,}7 \cdot \eta} + D_n \cdot Q_n + C_n, i \in I, n \in N$$

Specific heat distribution cost for different linear heat density values



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STANDARD VALUE OF LINEAR HEAT DENSITY CRITERION DEFINITION

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Equation for standard value of linear heat density for main pipeline

$$q_L = \left(\frac{11{,}55 \cdot c_e \cdot \tau \cdot \psi}{\Delta t \eta} + \frac{0{,}176\, fb}{\psi^{0.27} \Delta t^{0.551} Q_n^{0.449}} \right) \cdot \frac{\tau \cdot Q_n^{2}}{C_n}$$

Standard value of linear heat density for all pipelines

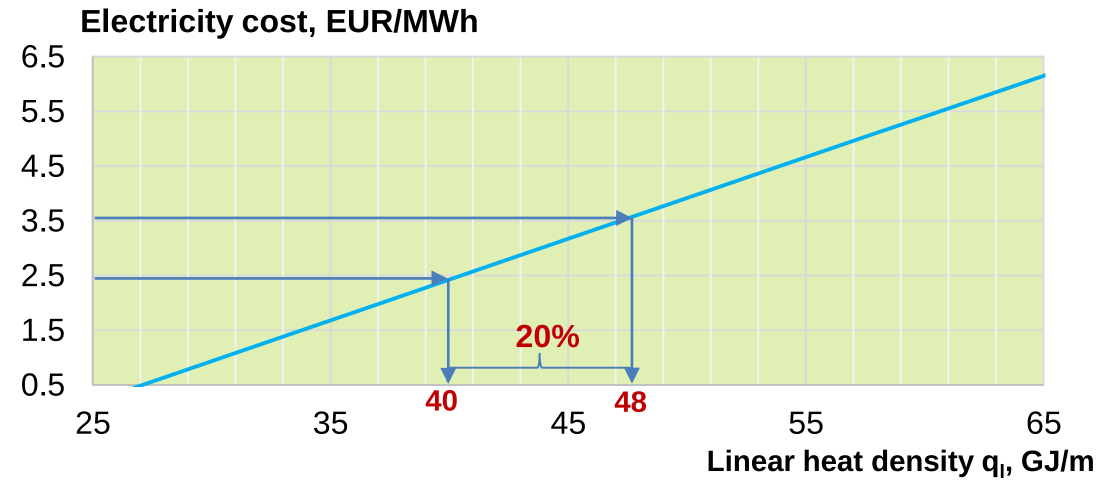
$$q_l = \frac{q_L}{1+P}$$

P – coefficient of branching of a heating network

Equation for existing value of linear heat density

$$LHD = \frac{Q_n \cdot \tau}{\sum_i l_i}, i \in I$$

The corresponding standard value of linear heat density with respect to electricity cost for other equal parameters



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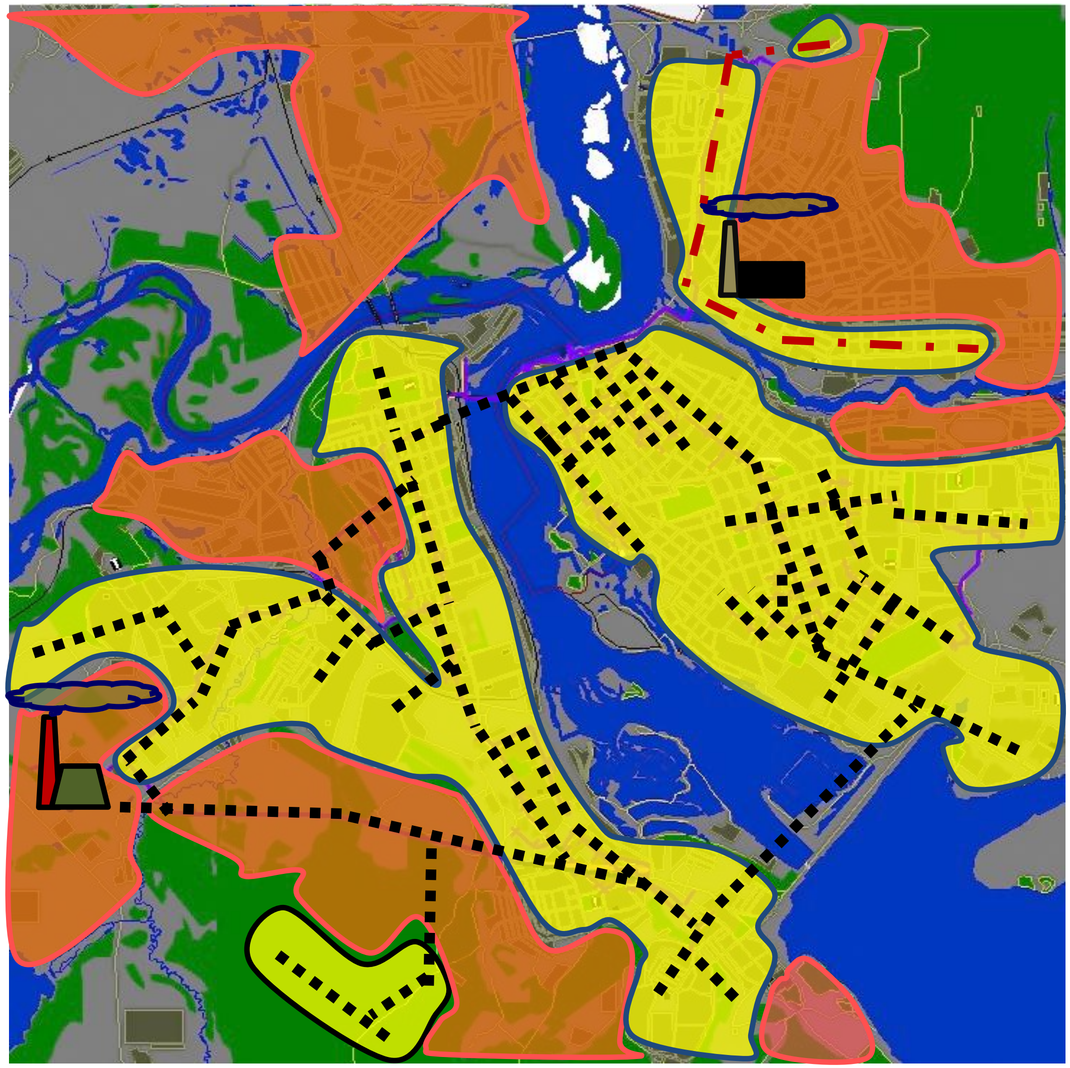
EXAMPLE

Individual heating

District heating

Pipelines from heat source-1

Pipelines from heat source-2



Variant 1

$$q_{S1} = 23{,}5 MW / km^2$$

$$q_{L1} = 35 GJ / m$$

Variant 2

$$q_{S1} = 35 MW / km^2$$

$$q_{L1} = 56 GJ / m$$

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EXAMPLE

Individual heating

District heating

Pipelines from heat source-1

Pipelines from heat source-2

Pipelines from heat source-3

Variant 1

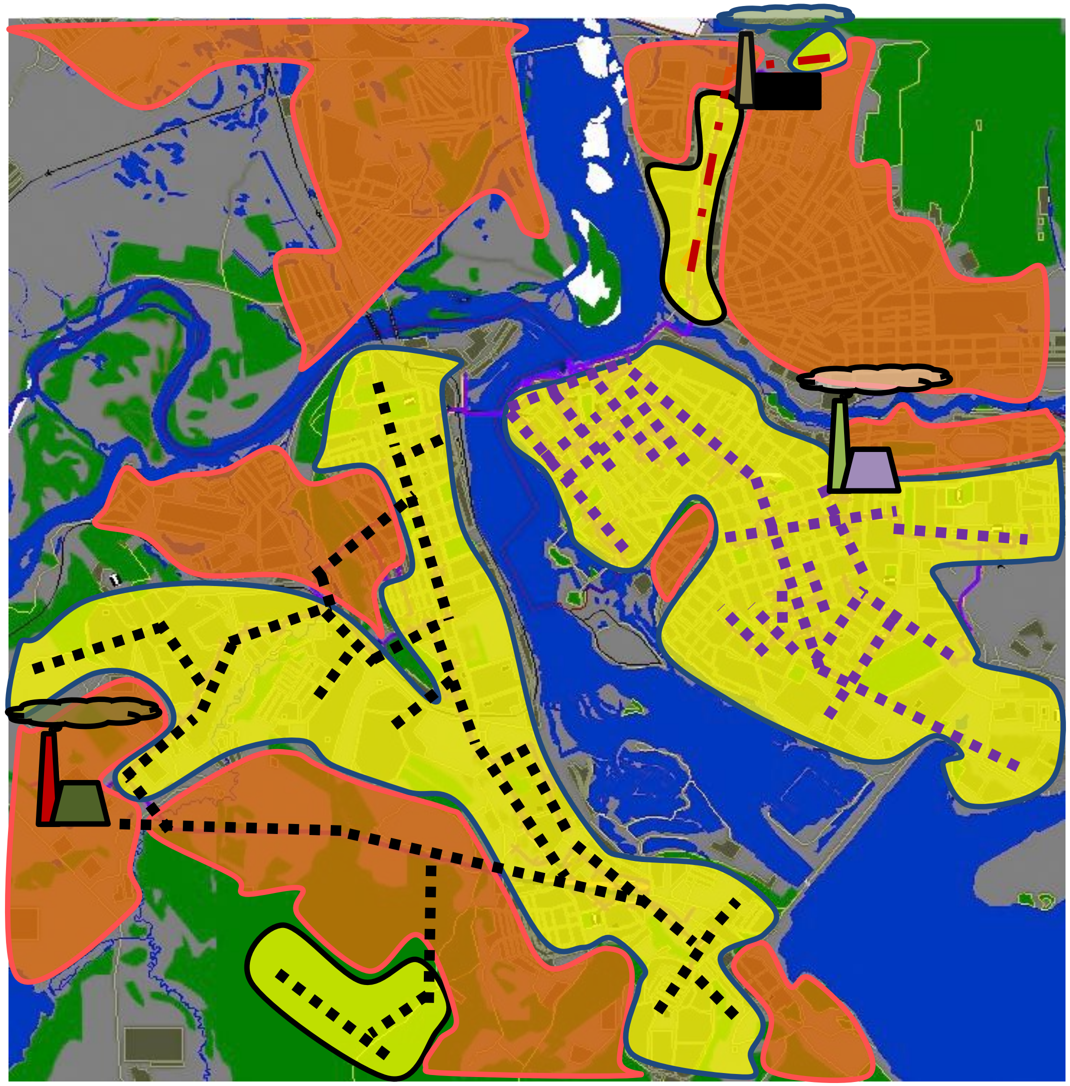
$$q_{S1} = 23{,}5 MW / km^2$$

$$q_{L1} = 35 GJ / m$$

Variant 2

$$q_{S1} = 35 MW / km^2$$

$$q_{L1} = 56 GJ / m$$



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CONCLUSIONS

- Construction of building according to new standards of energy efficiency will reduce heat load density. It will influence on the efficiency of heating systems that is why there is a necessity of implementation of the energy planning considering new circumstances.
- Several equations for determination of the standard values of heat density criteria for planning of heat supply are offered.
- Standard value of heat density criterion q_S for territory zoning mostly depends on: type and cost of used fuel, technical and economic characteristics of heat supply system, heat losses and climatic regional characteristics.
- Standard value of linear heat density criterion q_l depends on: cost characteristics for heat sources, technical and economic characteristics of heat pipelines.
- The Investigations of the influence of standards of heat load density (q_S, q_l) for urban planning proved that they define the rational determination of areas of district heating and individual heating, structure and scales of the heat supply systems.

LITERATURE

[1] V.A. Stennikov, E.E. Iakimetc, S.V. Zharkov. Optimal planning of urban heating // Industrial Energy. 2013, Vol. 4, pp. 9-15.

[2] V. Stennikov, E. Iakimetc. Search for optimal value of criterion for rational area zoning by type of heat supply // PRESCO 2012 PROCEEDINGS "The Energy Debate: Challenges & Alternatives", Hiroshima, Japan, pp. 90 - 95.

[3] V.Ya. Khasilev. Configuration analysis of nonsymmetric heating networks and its application to the choice of district heating power // Proceedings of the USSR Academy of Technical Sciences. 1945, Issue 10-11, pp. 1105-1114.

[4] L.A. Melent'ev. Cogeneration. 1944, Part 1, M: USSR Academy of Sciences, P. 248.

[5] L.A. Melent'ev. Cogeneration. 1948, Part II. M: USSR Academy of Sciences, P. 280.

[6] S.F. Kop'ev. Heat supply. 1952, M: Gosstroiizdat, P. 280.

[7] L.S. Khrilev, I.A. Smirnov. Optimization of cogeneration and district heating. 1978, M: Energiya, P. 264.

[8] E.Ya. Sokolov. Cogeneration and heating networks. 1999, M: MEI, P. 472.

[9]. IEA. District heating distribution in areas with low heat demand density. - 2008. SenterNovem. - 119 p.

[10]. U. Persson, Werner S. Heat distribution and the future competitiveness of district heating. Appl. Energy 2011;88: 568–576.

[11]. IEA. District heating distribution in areas with low heat demand density. - 2008. SenterNovem. - 119 p.

[12]. E. Iakimetc, V. Stennikov. Optimization methods of heat supply systems' scales// Proceedings from the 14th International Symposium on District Heating and Cooling, 6-10 September, Stockholm, SWEDEN. P. 526-529, 2014.

[13]. S. Frederiksen, S. Werner, 2013. District Heating and Cooling. Studentlitteratur AB, Lund.

Thank you for attention!

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