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ASPECTS OF CHOOSING FUEL AND BOILER FOR A HEATING SYSTEM
in a one-family house

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DESCRIPTION

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Aspects of choosing fuel and boiler for a heating system

Abstract

Heating is one of the most important and expensive elements of engineering systems of a house. House heating cost calculation begins with the calculation of the most expensive component of the heating system –a heating boiler. The main aim of this work is to select the most suitable heat source and boiler for the heating system and to show its economic benefits. This work examines a problem of a heating boiler installation cost and heating system operation cost. The question of saving money when buying boiler is considered in this bachelor thesis.

A thermotechnical calculation of building envelope is done for the design and installation of the heating system and choosing the most appropriate boiler. Estimation of average amount of fuel per one heating season and average annual cost of fuel for boilers running on different fuel are represented in this work. Comparison of results shows the most cost-saving fuel. Estimation of a cumulative cost of the heating system is shown by using economical calculations in this bachelor thesis. Economical effectiveness calculations based on two fuel price forecast methods are represented in this part.

The main results show that choosing of a boiler with high efficiency and with low maintenance can provide significant savings of money every year for the customer. Results of this bachelor thesis prove the economic effect from using natural gas boiler by economic calculations. This bachelor thesis can be used as a supplementary literature for thermotechnical calculations procedure, a heat source and a boiler selection.

Subject headings, (keywords)

Heating system, boiler, thermotechnical calculations, energy source, economical effectiveness calculations, cumulative cost, operation cost, annual payment, forecast method, cost of gas connection

Pages	Language	URN
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Remarks, notes on appendices

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VOCABULARY

Cold (heating) season of a year- period of the year characterized by the average daily outdoor temperature equal to or lower than 10 or 8 ° C, depending on the type of building /1, p. 2 /.

Heat transfer coefficient (K) - a calculation value of the heat flow which is transferred from one coolant to the other through the wall with area of 1 sq.m. with temperature difference 1K.

Heating degree day - the conditional unit severity of climatic conditions in the form of higher average daily temperature above the specified minimum ("reference temperature"). Heating degree days correlated with controlled fuel (energy) to maintain the desired temperature in a residential installation.

Heating volume of a building - volume bounded by the inner surface of the building envelope - walls, roofs (attic floor), floor slab of the first floor or floor slab of a heated basement /2, Appendix B/.

Length of the heating season - estimated time (days) of the heating system of the building, which is a statistical average number of days in the year when the average daily temperature of the outside air is steady and lower than 8 or 10 ° C depending on the type of building /2, Appendix B/

Reduced total thermal resistance - thermal resistance of a single-layer structure enclosing the same area, through which passes the same with the real design heat flow at the same temperature difference between indoor and outdoor air.

Warm season of a year - period of the year characterized by average daily air temperature above 8 or 10 ° C depending on the type of building /1, p.2/.

NOMENCLATURE

t_{out} temperature of the five coldest days with occupancy equal to 0,92 (° C)

t_{int} estimated average temperature of the indoor air of the building (° C)

t_{hs} average temperature of outdoor air of the heating season (°C)

z_{hs} duration of the heating season (days)

$D_{d\ t}$ heating degree days (° C×days)

R_0 reduced total thermal resistance (m^2×°C/W)

R_{req} normalized values of thermal resistance of building envelope (m^2×°C/W)

a_{int} heat transfer coefficient of the inner surface of the enclosing structure

a_{out} heat transfer coefficient of the outer surface of the enclosing structure

δ thickness of the layer of the wall (m)

λ thermal conductivity of the layer (W/m×K)

A area of a room, m^2

n factor considering dependence of the enclosing structure in relation to the outside air for external walls and coatings (including ventilated with outside air), attic floors (with the roof of the piece goods)

i real interest rate (%)

Ni nominal interest rate (%)

Inf inflation rate (%)

a time discount factor

R^2 certainly factor of the approximation

1. INTRODUCTION

Nowadays intensive construction of cottages and townhouses, increasing demand of comfort and the use of new advanced materials require new technologies and modern engineering. Heating is one of the most important and expensive elements of engineering systems of a house.

Many factors affect the rational choice of heating system: the volume of the space to be heated, design and architectural solutions, economic aspects, access to a particular type of fuel, environmental aspects, human performance and others.

It`s very difficult to evaluate all the aspects and problems of selection, installation and operation of heating types. Moreover the market for equipment materials is wide and varied. In addition, global progress in the field of heating is available for consumers, and information about their properties and opportunities is available for specialists. Furthermore there is a steady trend away from central heating systems to stand-alone ones for an apartment, a group of apartments or a separate building.

In my work I consider a one-family house in Samara as an example of heating system design, choice of heat source and boiler. This city is one of the largest economic, transport, and educational - scientific centers in Russia. According to Federal State Statistics Service population of Samara is 1,172,348 people in 2014 year /3/.

Natural resources such as oil field, oil shale, natural gas, mineral construction raw materials are extracted in Samara region /4/. Such industries as petroleum processing, food processing and machinery-producing industry are concentrated in this region.

There are 63 petroleum refineries and natural gas liquids processing plants there (public limited company "Samaraneftegaz", Neftegorsk gas processing plant and others). Petrochemical complex of Samara Region is one of the basic in regional economics and includes extraction, oil refining, chemical and plastic industries, as well as main oil pipeline and oil-products pipeline transport. /5./ Production of petroleum products such as gasoline, fuel oil, diesel fuel is 10-12% on the national scale (Samara, Novokuibyshev and Syzransky refineries) /4/.

The one-family house “Teremok” considered in this thesis is located in Promyshlenny district of Samara (see figure below). It is a northeastern part of the city. The area of the district is 48.6 sq.km. Promyshlenny district is washed by the waters of two rivers – the river Volga and the river Samara on the both side of the district /6/. Buildings located on the bank of the river Volga are very popular because of the increasing popularity of this building area among developers. This area is also the most appropriate for the one-family houses construction according to the experts of suburban real estate /7/.

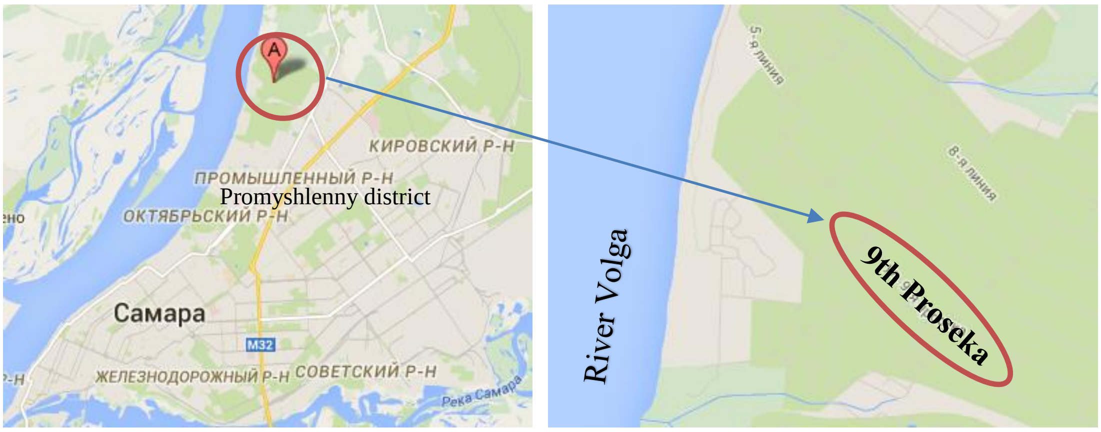


FIGURE 1. Promyshlenny district of Samara and 9th Proseka /8/

All houses are different and need to be evaluated based on their own unique characteristics. The volume of the one-family house “Teremok” is 2685 m^3, residential floor area is 612.7 m^2. The building has a basement, the first floor, the second floor and the attic floor. Floor plans, sections, facades are shown in appendixes 1-6.

2. AIMS AND METHODS

This bachelor thesis addresses the issue of energy source and boiler selection for a heating system in a one-family house and a question of saving money when buying boiler (only for heating exclude need for hot domestic water). This work also examines a problem of a heating boiler installation cost and heating system operation cost.

Economical comparison between different heat sources for a heating system in a one - family house “Teremok” located in Samara.

The main aim of this work is to select the most suitable heat source and boiler for the heating system and to show its economic benefits.

In order to reach specified aims the following methods are applied.

In this bachelor thesis heat loss of the building is calculated to define total energy consumption of the building for choosing a boiler with the correct capacity.

The heating system in a one-family house is designed to determine location of the heating equipment. Design heating system includes radiators and underfloor heating in the one-family house.

Parameters of different boilers (natural gas boilers, liquid boilers, solid boilers and electric boilers) are compared to be familiar with some properties of boilers such as range of boilers capacity, efficiency, the noise level produced during operation period, boiler installation permit and others.

Prices of different type of fuel are compared to find the cheapest cost of 1 kWh of energy without supplementary costs (such as storage for fuel and special conditions for fuel keeping).

Average costs of boilers with the cheapest cost of 1 kWh of energy with their installations are defined to evaluate and compare capital cost of these boilers. Average annual costs of boilers is calculated to estimate average annual operation cost of these boilers.

Forecast of fuel price using trendlines and forecast data of the Ministry of economic development of the Russian Federation is used to make analyzing between several boilers, running on the cheapest fuel (according to calculations). Cumulative costs of these boilers are calculated to show the most beneficial choice of a boiler.

3. DESIGN REQUIREMENTS

Heating system for a one-family house “Teremok” must be designed with due regard to safety requirements of normative documents of the state, as well as the instructions of companies - equipment manufacturers, hardware and materials. The instruction must not contradict the requirements of SNIP 41-01-2003 Heating, ventilation and conditioning rules and regulations /9/. Pipelines of heating systems must be designed from steel, copper, brass and plastic pipe approved for use in construction.

Heating of buildings can be provided from a central source of heat (thermal networks of the urban heating systems); or from an independent source of heat (including roof boiler); or else from individual heat generators for every apartments /9./

According to SNIP 41-01-2003 (Appendix B ”Heating system” table B1) the surface temperature of the accessible parts of radiators and piping for the water system with radiators, panels, convectors should not exceed 95° C for double-pipes or 105° C for single pipe. The surface temperature of the accessible parts of heating devices and pipelines of electric or gas heating system must not exceed 95° C ./9./

Design of heating and underfloor heating are made on the basis of architectural and engineering drawings and in accordance with the requirements of SNIP 41-01-2003 Heating, Ventilation and Air Conditioning /9/, SNIP 02.31.2001 Single-family houses /10/, SNIP 23-01-99 Building Climatology /11/, SP 31-106-2002 Design and construction of engineering systems of single-family homes /12/.

Graphical symbol correspond to GOST 21.206-93 “System of building design document. Pipelines. Symbols for presentation” /13/, GOST 21.205-93 “System of design documents for construction. Elements of sanitary engineering systems – symbols” /14/.

Technical solutions adopted in the working drawings, comply with environmental, health and sanitation, fire safety and other regulations valid in Russia, and provide safety for life and health of people.

Desired heating system must provide with the desired air temperature during the heating season /9, paragraph 6.3.1/. Heating devices should be usually placed under windows in places accessible for inspection, maintenance and cleaning /9, paragraph 6.5.5/.

Installed equipment must not obstruct the passage of people; it also has to be safe. It is necessary to eliminate the possibility of burns when touching the heating equipment (radiators) /9, paragraph 6.5.10/.

The heating system operates in a constant temperature of the heat transfer agent. The heat transfer agent for a heating system in a one-family house “Teremok” is water with parameters 80-60°C from its own boiler. Radiators "Elegance 500" are adopted as heaters. Heat output of “Elegance 500” is 190 W/column. Underfloor heating works with constant characteristics of the heat transfer agent: T_1=50°C; T_2=40°C.

4. THERMOTECHNICAL CALCULATION

There are two main reasons for thermotechnical calculation. Firstly, it is necessary for the design and installation of the one-family house heating system and choosing the most appropriate boiler. Secondly, a thermotechnical calculation of building envelope is done to get information about main leakage of the heat from the building.

Thermotechnical calculations are done in the following sequence:

1. The choice of parameters of outdoor air.

The designing (dimensioning) temperature of outdoor air is -30 °C for Samara /15, table 3.1/. An annual mean outdoor temperature is -5.2 °C for Samara /15, table 3.1/.

2. The choice of parameters of indoor air\

Indoor air temperature depends on the kind of the room shown in the table 1.
In this work temperature of indoor air in a cabinet, a fireplace room, dressing rooms, a kitchen, a hall, staircases, WC and other rooms is 20°C except corner rooms, where temperature of indoor air is 22°C. The indoor air temperature in a shower room is 25°C (see table 1).

TABLE 1. Optimal and permissible limits of temperature, relative humidity in the occupied zone premises of residential buildings /1, table 1 /

Season of a year	Name of premises	Temperature of indoor air, °C		Relative humidity, %	
		Optimal	Allowable	Optimal	Allowable
Cold	Living room	20-22	18-24	45-30	60
	Kitchen	19-21	18-26	NL˙	NL
	WC	19-21	18-26	NL	NL
	Bathroom, combined bathroom	24-26	18-26	NL	NL
	Lobby	16-18	12-22	NL	NL
	Pantry	16-18	12-22	NL	NL
Warm	Living room	22-25	20-28	60-30	65
The note: NL˙-no limitation					

It is necessary to know the operation conditions of enclosing structures needed for selecting thermotechnical parameters of materials for building envelope /2, table 2/. Zone of humidity in Samara is shown in the figure below. It is a dry zone.

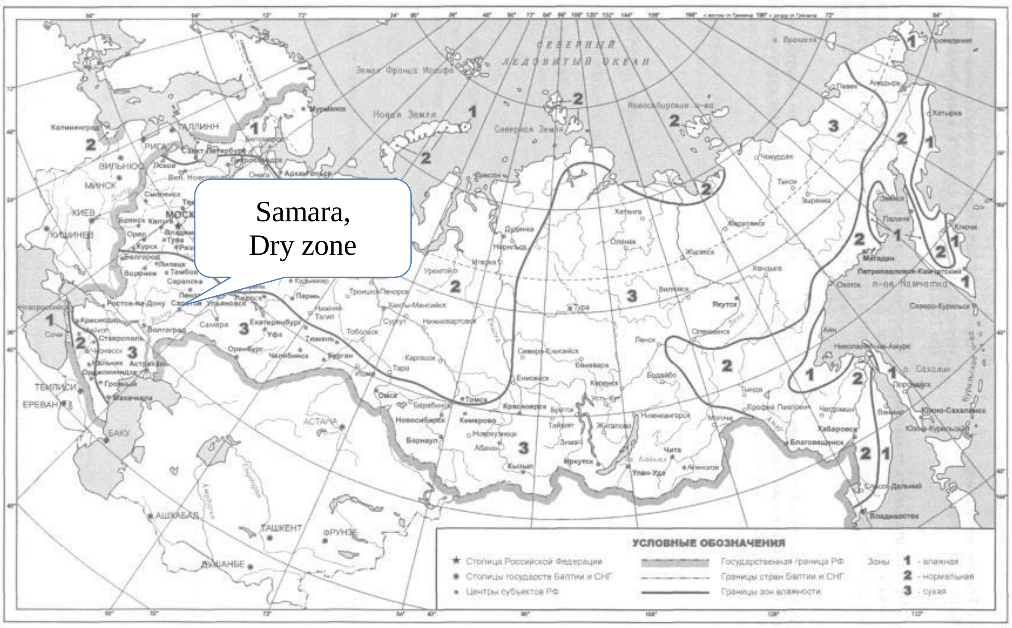


FIGURE 2. Map of zones of humidity /2, Appendix B /

Humidity conditions of the building premises during the cold season depend on the relative humidity and indoor air temperature according to the table 2. Temperature of indoor air varies from 12 to 26 in the cold season of the year in all rooms in examined house. If we want to achieve normal condition of premises of buildings, we must get relative humidity from 50 to 60%.

TABLE 2. Moisture condition of premises of buildings. /2, table 1/

Condition	Relative humidity of indoor air, % at the temperature, °C		
	<12	**From 12 to 24**	>24
Dry	<60	<50	<40
Normal	From 60 to 75	**From 50 to 60**	From 40 to 50
Moist	>75	From 60 to 75	From 50 to 60
Wet	-	>75	>60

3. The determination of the resistance of heat transfer of the building envelope for Samara.

Reduced total thermal resistance of building envelope, windows (with vertical glazing or at an angle more than 45°) should be not less than normalized values R_{req}, defined by table below, depending on the heating degree day.

TABLE 3. Normalized values of thermal resistance of building envelope /2, table 4/

Heating degree day Dd, ° C × d.	R_{req}, $m^2 \times {}^\circ C / W$		
	Walls	Camp ceiling	Windows, balcony doors
2000	2,1	2,8	0,3
4000	2,8	3,7	0,45
6000	3,5	4,6	0,6
8000	4,2	5,5	0,7
The note: R_{req} values for the quantities Dd, differing from the table, should be determined using the formula: $R_{req} = a \cdot Dd + b$, where:			
	a= 0,00035 b=1,4	a=0,00045 b=1,9	a=0,00075 b=0,15 (if Dd<6000)

The following information is needed to calculation of the heating degree days:

t_{out} = -30°C, Z_{hs} =203 days, t_{hs} = -5.2°C for Samara /15, table 3.1/.

Heating degree days is calculated from the equation (1) from /2, paragraph 5.3/.

$$Dd = (t_{int} - t_{hs}) \cdot z_{hs}, \quad (1)$$

where t_{int} is a temperature of indoor air, t_{hs} is an annual mean outdoor temperature, z_{hs} is a duration of the heating season.

Dd =(20-(-5,2))·203=5115,6 °C×d

$R_{req(walls)}$ = a ·Dd + b=0,00035·5515,6+1,4=3,19 m^2×°C/W

$R_{req(camp\ ceiling)}$=0,00045·5515,6+1,9=4,38 m^2×°C/W

$R_{req(Windows,\ balcony\ doors)}$=0,00075·5515,6+0,15=0,56 m^2×°C/W

The thermal resistance of the enclosing structure is defined by the formula (2) from /10, paragraph 2.6*/:

$$R_o = \frac{1}{\propto int} + R_k + \frac{1}{\propto_{out}} \qquad (2)$$

where α_{int} and α_{out} are heat transfer coefficients of the inner and outer surface of the enclosing structure, R_k is a thermal resistance of the enclosing structure.

Heat transfer coefficients for inner surface of walls, floors, smooth ceilings, ceilings a_{int} is equal to 8,7 /2, table 7/.

The thermal resistance R_k of the enclosing structure with successive homogeneous layers is defined as the sum of thermal resistances of the individual layers (see figure below).

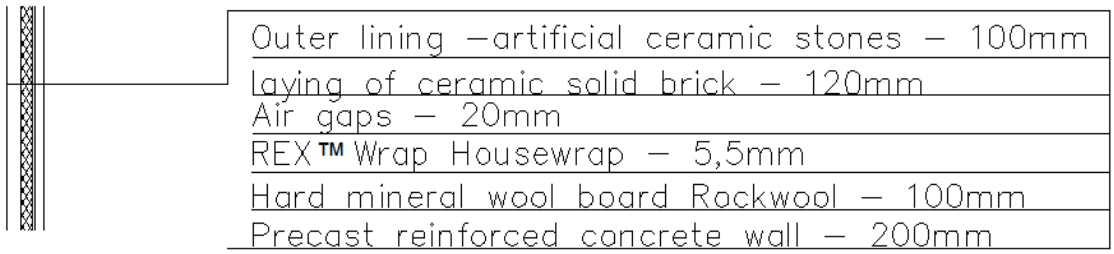


FIGURE 3. Section of an external wall of the house with an indication of layers

The thermal resistance of the enclosing structure with successive homogeneous layers is calculated from the equation (3).

$$R_к = R_1 + R_2 + R_3 + R_4 \qquad (3)$$

where R_1, R_2, R_3, R_4 are thermal resistances of layers of an external wall (see table 4).

Thermal resistance for each layers is calculated by the formula (4):

$$R_n = \frac{\delta n}{\lambda n} \qquad (4)$$

where n is a number of layer (1,2,3,4), δ is a thickness of the layer, λ is a thermal conductivity of the layer (see table 4).

TABLE 4. Thickness and thermal conductivity of layers of an external wall /16, 17/

Number of layer	Name of the layer	δ, m	λ, W/ m²×°C
1	Precast reinforced concrete	0,2	1,92
2	Hard mineral wool board	0,1	0,037
3	Air gaps	0,02	0,15
4	Laying of ceramic solid brick outer lin-ing – artificial ceramic stones layer	0,22	0,58

Heat transfer coefficients for outer surface of walls is 23 W/ m²×°C.

$$R_o = \frac{1}{8,7} + \frac{0,2}{1,92} + \frac{0,1}{0,037} + \frac{0,02}{0,15} + \frac{0,22}{0,58} + \frac{1}{23} = 3,48 \text{ m}^2\times°\text{C/W},$$

The heat transfer coefficient is calculated for each building envelope (walls, windows, doors) from the equation (5):

$$K_{walls} = \frac{1}{R_o} \qquad (5)$$

where K is a heat transfer coefficient of walls (W/ m²×°C)

$K_{walls} = \frac{1}{3.48} \approx 0.3$ W/ m²×°C

Calculated heat transfer coefficient for windows and doors is defined as the difference between the received heat transfer coefficient of the window (door) and the heat transfer coefficient the exterior wall by the following formula (6):

$$K_{(windows,\ doors)} = \frac{1}{Rreq(Windows, doors)} - \frac{1}{R_o} \quad (6)$$

$$K_{(windows)} = \frac{1}{0{,}56} - \frac{1}{3.48} = 1{,}5\ W/m^2 \times °C$$

$$K_{(Doors)} = \frac{1}{0.437} - \frac{1}{3.48} = 2\ W/m^2 \times °C$$

4. The calculation of heat loss through the building envelope

The calculation is made for all rooms of the building. Heat loss for each rooms which have building envelope (exterior walls, windows, entrance doors, ceiling below roof, uninsulated floor) is calculated by the formula (7) from /18, formula 7.1/:

$$Q_{basic} = K \cdot A \cdot (t_{int} - t_{out}) \cdot n \cdot (1 + \Sigma\beta) \quad (7)$$

where A-area of a room; n- factor which is equal to 1 according to /2, table 6/; β- multiplier that takes into account extra losses

The exterior walls area is measured with an accuracy of up to 0.1 meters. The area of the window is defined by minimum size of a construction opening.

Rules for the area of building envelope measurement shown in a figure 6.

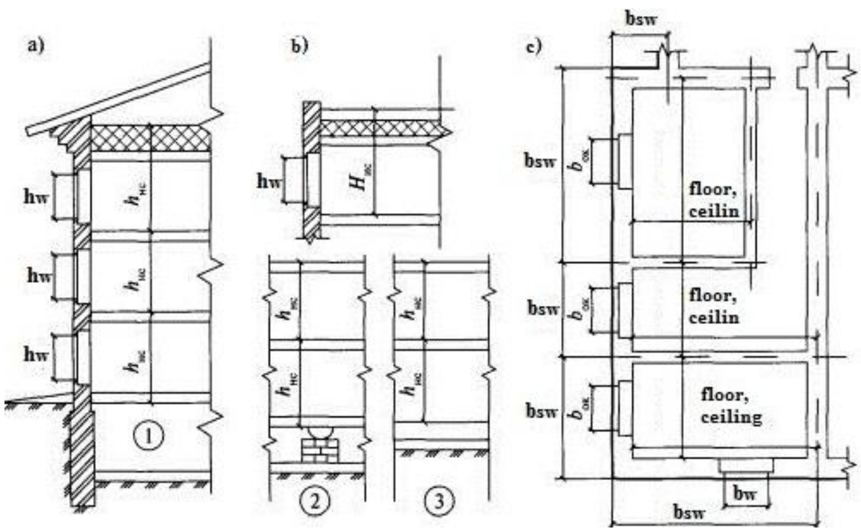


FIGURE 6. Rules for the area of building envelope measurement /18, paragraph 7.1, figure 34/

The length of the angular space walls is measured along the outer surface of the outer corners to the interior walls axes, the length of non-corner space is defined between the axes of the interior walls.

Additives to the main heat loss is shown in the figure below. Multiplier β is equal to 0,1 for the northern, northeastern, northwestern, eastern orientation; for the south-east and west β = 0,05; for the south and southwest β = 0.

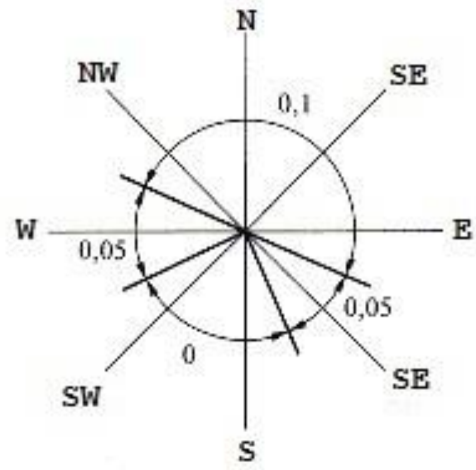


FIGURE 4. Additives to the main heat loss depending on the orientation of building envelope to the cardinal

There is an another method of determining heat losses for basement floor. Thermal resistance of uninsulated floor below ground level is determinated by 4 zones parallel to exterior walls (see figure below).

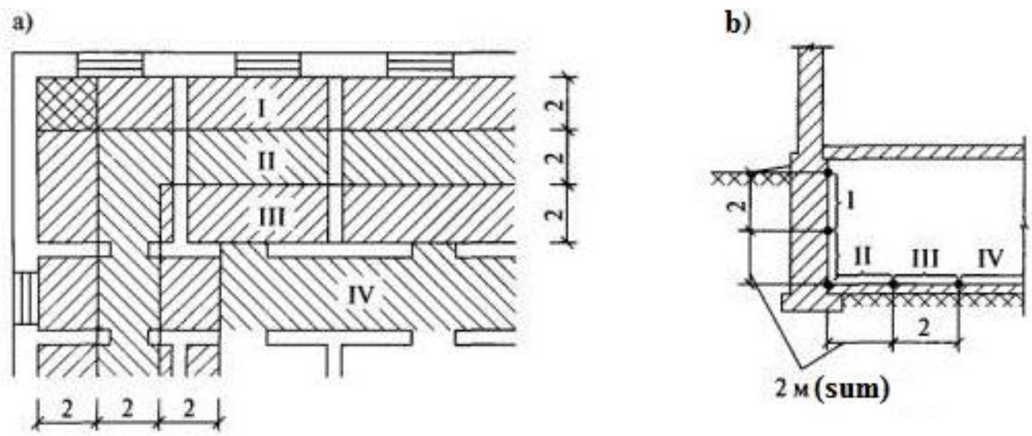


FIGURE 5. Parallel zones for heat loss calculations for the basement floor /18, paragraph 5.3, figure 29/

$R(1UI.F)=2,1\ m^2\cdot°C/W$ $R(2UI.F)=4,3\ m^2\cdot°C/W$

$R(3UI.F)=8,6\ m^2\cdot°C/W$ $R(4UI.F)=14,2\ m^2\cdot°C/W$

The basement height of walls is measured from the outer surface of the floor to the first floor level. The first floor height is measured from the first floor level to the level of the second floor surface. The height of the second floor is measured from the surface of the second floor to the floor level of the attic floor. Height of the attic floor is measured from the floor level of the attic floor to the top of the structure.

Infiltration heat loss is calculated for rooms where calculation of Q_{basic} was done. So this type of heat loss is defined from the equation (8).

$$Q_{inf}=0,3\cdot Q_{basic} \tag{8}$$

Total heat loss of the room is calculated by the formula (9).

$$Q_{room}= Q_{basic}+ Q_{inf} \tag{9}$$

Heat losses of the basement floor is 7,9 kW, of the first floor – 11,214 kW, of the second floor equal to 11,96 kW, of the attic floor is 6,97 kW. Total heat losses of the one-family house “Teremok” is 38,04 kW.

A computational procedure and the table with thermotechnical calculations are presented in appendixes 7-11. It should be noted that thermotechnical calculations compliance with SNiP 23-02-2003 /2/.

Design of radiator and underfloor heating system are shown in appendixes 12-19.

5. RESULTS FOR DIFFERENT FUELS

5.1. Properties of boilers running on different type of fuel

The rapid growth of individual housing construction in Russia contributes to the sales of boiler equipment. Today the market offers a whole range of domestic heating boilers: natural gas boilers, liquid fuel boilers (oil boilers), solid fuel boilers, multi-fuel boilers, electric boilers and others. The main parameters of different boilers are shown in the table 5.

Nowadays natural gas is the most available fuel in Russia and in Samara region /4, 5/. Less harmful substances polluting the atmosphere are contained in the combustion products. Heat only boilers are also known as “regular” or “conventional” boilers and are usually installed on an open vented system.

Condensing boilers produce condense from time to time. This type of boilers use heat from exhaust gases that would normally be released into the atmosphere through the flue. To use this latent heat the water vapour from the exhaust gas is turned into liquid condensate. In order to make the most of the latent heat within the condensate, condensing boilers use a larger heat exchanger, or sometimes a secondary heat exchanger. Due to this process, a condensing boiler is able to extract more heat from the fuel it uses than a standard efficiency boiler. It also means that less heat is lost through the flue gases Hence, condensing boilers are traditionally considered the most productive and economical /19./.

The gas main eliminates the need to have fuel in stock, and gas metering is easy with the help of the gas meter. In addition, hot water boilers running on natural gas undergo almost no corrosion and are more durable than solid or liquid fuel. It is significant that natural gas boilers should be provided with sensors for gas leakage and the level of carbon monoxide in the room. This type of boiler must be placed only in the boiler room, not adjacent to residential facilities. Gas cylinders must be stored in storage tank (outdoors in places protected from direct sunlight) /20./

Liquid fuel boilers (oil boilers) are usually used for heating of individual houses when there is no possibility to use gas or electric boilers, because the operation of the solid-fuel boiler is time consuming and requires constant human presence. Diesel heating boilers produce considerable noise and requires a separate room with a chimney and vent channel, not adjacent to residential facilities. If a container of fuel is on site, it is necessary to insulate the supply pipe. The overwhelming majority of oil boilers runs on diesel fuel. Kerosene, heating oil or fuel oil is used more rarely /20./

All household heating diesel boilers are floor-mounted and heat exchangers are made of cast iron or steel. Cast iron heat exchangers are more durable, but much heavier than steel. Fuel for a liquid-fuel boiler can be stored in the boiler room, using a special vessel and observing the rules of fire safety: plastic tanks are installed in a metal pan, steel (double-walled) containers are equipped with seal control (installed without pallet). Storage tank of fuel (2-5 tons) buried in the soil. There is a need for the storage of fuel /20./

Coal, wood, pellets, peat briquettes and other solid combustible materials are used as fuel in solid fuel boilers. Solid fuel boilers are used for heating of building in cases where the house is not supplied with gas and fuel oil or electricity is not available as a primary energy source.

Electrode boilers are the most common, because they have the best price-quality ratio, high efficiency (up to 98%). These boilers work using electricity, the principle of operation is based on the electrical conductivity of water. The enclosure must have impeccable ground, otherwise there is a danger of electric shock. Electrode boilers do not work in distilled water, since the efficiency decreases. The boiler should be cleaned from scale electrodes every year. Separate wiring for electric boilers is required /20./

TABLE 5. Properties of different boilers /20/

Parameters	Boiler			
	Natural gas boiler	**Liquid fuel boiler (oil boiler)**	**Solid fuel boiler**	**Electric boiler**
Fuel type	gas main, bottled gas	diesel oil (the majority), fuel oil, heating oil, waste oil	wood, coal, peat briquettes, coke, waste (sawdust)	electricity
Range of boilers capacity	From 4 kW to 15MW	From 10 kW to several thousand kW	From 1 kW to 1 MW	From 4 to 30 kW
Range of boilers efficiency	Convection boiler=92-94% Condensation boiler=96%	From 85 to 92 %	60-80%	87-98%
Fuel-consumption rate	0,102 m3 (to generate 1 kW of the boiler heat output) /22/	Fuel consumption (l/h) = burner capacity (kW) x 0.1	46,3 kg of fuel (firewood) for 1 m2 area of the house for 1 year	boiler capacity = consumption of electricity
Presence of soot	+	+	+	-
The noise level produced during operation of the boiler	Boilers with atmospheric burner =38dB. Boilers with ventilator burner =60dB	Modern diesel boilers with a well-tuned burner operate almost silently. Boiler fuel oil or waste oil =60dB.	Most imported modern solid fuel boilers operates with low noise up to 30 dB	Electric boilers are noiseless
The area of the house that the boiler is able to heat	Maximum area is about 800m^2	several hundred m^2	From 30 m^2 to 3700m^2	up to 300 m2. For homes with larger area significant power is required
Additional equipment of ventilation and chimney	+	+	+	-
Boiler installation permit	Permit of Gosgortechnadzor	Permission to install is not required	Permission to install is not required	Permit of Gosgortechnadzor (if the power boiler ≥10 kW

5.2. Comparison of fuels

Different amount of different fuels needed for heating the house. So it is necessary to estimate an average amount of fuel per one heating season and average annual cost of fuel to compare and find cost-saving fuel. Fuel requirements depend on the total energy consumption of the building defined by the thermotechnical calculations compliance with SNiP 23-02-2003 /2/ according to "Heat losses of buildings" /18/.

Total heat losses of the building is 38,04 kW according to thermotehnical calculation (see appendixes 7-11). All boilers have convection and radiation losses /21/.

"The losses represent heat radiating from the boiler (radiation losses) and heat lost due to air flowing across the boiler (convection losses)" /21/. Increase total heat losses in 20% is needed to take into account unaccounted losses compensation. It means that 45,7 kW is a total heat losses including unaccounted losses compensation.

Total energy consumption for space heating is a multiplication of total heat losses including unaccounted losses compensation and duration of the heating season (which is equal to 203 days for Samara or 4872 hours). So, total energy consumption for space heating is 222397,1 kWh.

There is a need to know average cost of fuel and cost of 1 kWh of energy to compare operation cost of different types of boilers. For this purpose I have followed steps, which are shown below:

1. Calculate real energy demand for a boiler depending its efficiency, kWh.
2. Calculate average annual amount of fuel (m^3, kg, dm^3) per one heating season using the calorific value of a fuel. The calorific value of a fuel is the quantity of heat produced by its combustion.
3. Calculate average cost of fuel, rub.
4. Calculate average cost of 1 kWh of energy, rub/kWh.

Natural gas boiler has an efficiency 96%

1. 222397,1 kWh/0,96=231663,6 kWh.

2. Net calorific value of natural gas by volume =9,8 kWh/m^3 /22/, it means that 0,102 m^3 of natural gas needed to produce 1 kWh of energy.

231663,6 kWh·0,102m^3/kWh=23630 m^3.

3. In accordance with the order №96 of 06.05.2014 Ministry of Energy and Housing and Communal Services of the Samara region the retail price of natural gas for residential heating at presence of gas metering devices from 01.07.2014 is 4,31Rub/m^3 /23/.

23630 m^3·4,31rub=**101845 rub**.

4. 0,102m^3·4,31rub=**0,44 rub/kWh**.

Liquid fuel boiler (oil boiler) has an efficiency 92%

Diesel:

1. 222397,1 kWh/0,92=241736 kWh.
2. Net calorific value of diesel by mass= 44,80 MJ/kg·0.2778=12.445 kWh/kg /24/.
3. $\frac{241736\ \mathrm{kWh}}{12.445\mathrm{kWh/kg}}$ =19424,34 kg.

Mass of dm^3 of diesel≈0,850kg/dm^3, $\frac{19424{,}34\mathrm{kg}}{0.85\ \mathrm{kg/dm^3}}$ = 22852,17 dm^3.

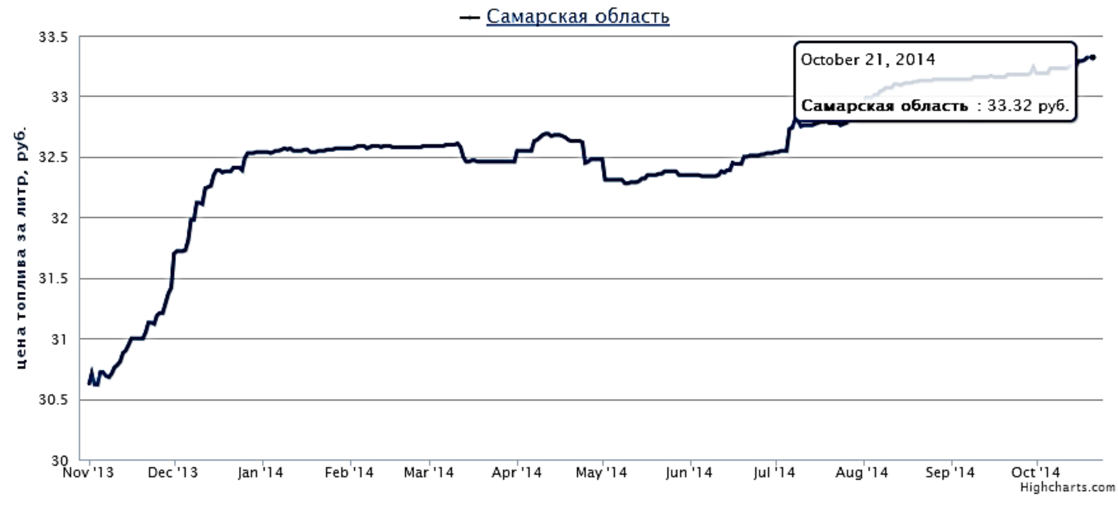


FIGURE 7. Index of fuel prices for Samara region /25/

22852,17 dm^3·33,32=**761434 rub**.

4. $\frac{0.08kg/kWh}{0.85kg/dm^3}\cdot 33{,}32\frac{rub}{dm^3} = \mathbf{3,13}$ **rub/kWh.**

There are at least five petrol-stations near the house (less than 5 kilometers distance between house and the fuel station) shown in the figure 8, it means that the delivery price can be neglected.

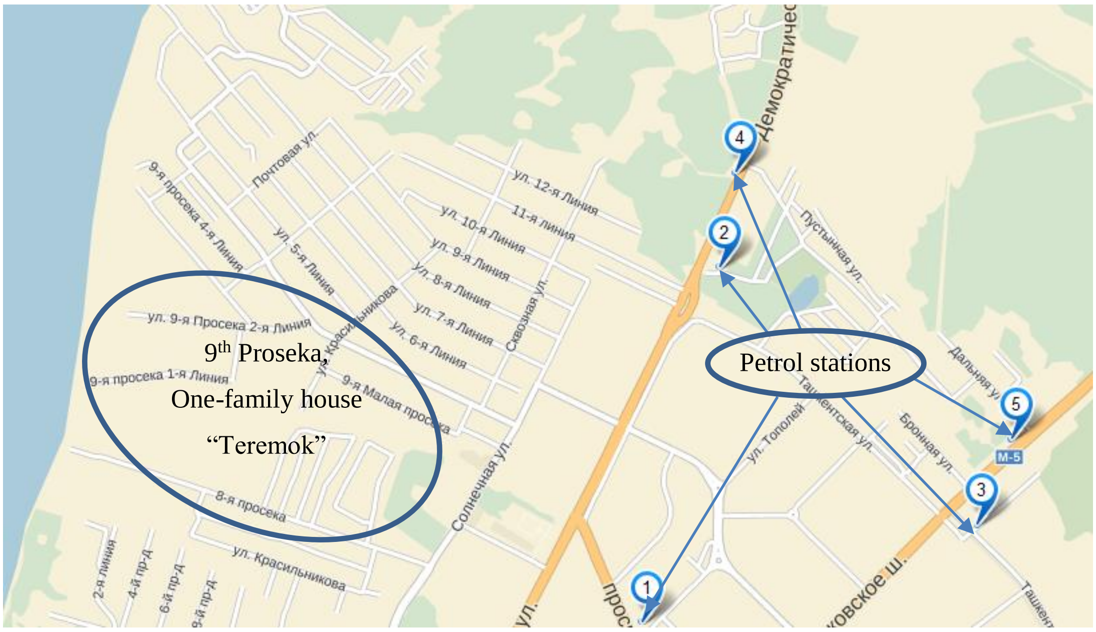


FIGURE 8. Petrol stations near the one-family house “Teremok” /26/

Mazut (Heavy fuel oil)

1. 222397,1 kWh/0,92=241736 kWh.
2. Net calorific value of mazut by mass is 39,20 MJ/kg·0,2778=10,890 kWh/kg.

It means that 0,09 kg of mazut needed to produce 1 kWh of energy.

241736 kWh/10,890 kWh/kg=22197,97 kg=22,198 ton.

3. Average price of mazut is 11500 rub/ton /27/.

22,198 ton·11500 rub/ton=**255277 rub**.

4. 0,09 kg/kWh·11,5 rub/kg=**1,04 rub/kWh**.

The shipment mazut is carried from the public limited company NK "Rosneft" enterprises of Novokuibyshev Refinery (see figure 9).

FIGURE 9. Delivery of mazut /26/

Waste oil

1. 222397,1 kWh/0,9=241736 kWh.
2. Net calorific value of waste oil by mass is 45 MJ/kg·0,2778=12,501kWh/kg /28/. It means that 0,08 kg or $\frac{0{,}08\ \text{kg}}{0.875\text{kg/dm3}}$ =0,09 dm^3 of waste oil needed to produce 1 kWh of energy.

241736 kWh/12,501 kWh/kg=19337,33 kg.

Mass of dm^3 of waste oil≈0,875kg/dm^3, 19337,33 kg /0,875 kg/dm^3=22100 dm^3.

3. Average price of waste oil include delivery is 14 rub/dm^3 /29/.

22100 dm^3·14 rub/dm^3=**309400 rub**.

4. 0,09 dm^3/kWh·14 rub/dm^3=**1,26 rub/kWh**.

Solid fuel boiler

Wood (this type of boiler has an efficiency about 80 %)

1. 222397,1kWh/0,8=277996 kWh.
2. The internal combustion energy of wood (birch) is 4,1 kWh/kg /22/. It means that 0,24 kg of birch needed to produce 1 kWh of energy.

277996 kWh/4,1 kWh/kg=66713,78 kg=104,31 m^3=105 m^3.

3. Mass of 1 m3 of wood (birch) at 20% moisture content = 650 kg. /30, 31/.

Average price of birch is 1700rub/m^3=2,6 rub/kg /32/.

1700rub/m^3·105 m^3=178500 rub.

4. 0,24 kg/kWh·2,6rub/kg=0,62 rub/kWh.

Cost of delivery from warehouse (in Samara) is about 26600 rub per one heating season /33/. It means that if 26600 rub equal to 66714 kg of peat then delivery of 1 kg of this type of fuel is 0,4 rub/kg. Therefore total average price of peat include delivery is 3 rub/kg (**200142 rub** per one heating season) and average cost of 1 kWh of energy is 0,24 kg/kWh·3 rub/kg=**0,72 rub/kWh**.

Coal (this type of boiler has an efficiency 75-90%)

1. 222397,1 kWh/0,8=277996 kWh.
2. Net calorific value of coal by mass is 27 MJ/kg·0,2778=7,5 kWh/kg. It means that 0,13kg of coal needed to produce 1 kWh of energy.

277996 kWh/7,5 kWh/kg=37066,18 kg=37067 kg.

3. Average price of coal 4300 rub/ton /34/.

4300 rub/ton·37,07 ton=159401 rub.

4. 0.13 kg/kWh·4,3rub/kg=0,52 rub/kWh.

Cost of delivery from warehouse (in Samara) is about 15200 rub per one heating season /33/. It means that if 15200 rub equal to 37067 kg of peat then delivery of 1 kg of this type of fuel is 0,41 rub/kg. Therefore total average price of peat include delivery is 4,71 rub/kg (174600 rub per one heating season) and average cost of 1 kWh of energy is 0,13 kg/kWh·4,71 rub/kg=0,61 rub/kWh.

Peat (this type of boiler has an efficiency about 80-85%)

1. 222397,1 kWh/0,83=267948 kWh.
2. Net calorific value of peat by mass is 17.15 MJ/kg·0,2778=4,76 kWh/kg /35/. It means that 0,21 kg of peat needed to produce 1 kWh of energy.

267948 kWh/4,76 kWh/kg=56292 kg=56,3 tons.

3. Average price of peat is 8000 rub/ton /36/.

8 rub/kg·56300 kg=450400 rub.

4. 0,21 kg/kWh·8 rub/kg=1,68 rub/kWh.

Cost of delivery from Kazan is about 90000 rub per one heating season /33/. It means that if 90000rub equal to 56300kg of peat then delivery of 1 kg of this type of fuel from Kazan to Samara is 1,6 rub/kg. Therefore total average price of peat include delivery is 9,6 rub/kg (**540480 rub** per one heating season) and average cost of 1 kWh of energy is 0,21 kg/kWh·9,6 rub/kg=**2 rub/kWh**.

Pellets (this type of boiler has an efficiency up to 93%) /37/

1. 222397,1 kWh/0,9=247108 kWh.
2. Net calorific value of pellets by mass is 4,8 kWh/kg /22/. It means, that 0,208kg of pellets needed to produce 1 kWh of energy.

   247108 kWh/4,8 kWh/kg=51480,8 kg=51,5 ton.
3. Average price of pellets 7000 rub/ton /38, 39, 40/.

   51,5 ton·7000 rub/ton=360500 Rub.
4. 0,208kg/kWh·7 rub/kg=1,46 rub/kWh.

Cost of delivery from warehouse (in Samara) to the one-family house is about 21000rub /33/. It means that if 21000 rub equal to 51500kg of pellet then delivery of 1 kg of this type of fuel is 0,4 rub/kg. Therefore total average price of peat include delivery is 7,4 rub/kg (**381100 rub** per one heating season) and average cost of 1 kWh of energy is 0,208 kg/kWh·7,4 rub/kg=**1,54 rub/kWh**.

Electricity (this type of boiler has an efficiency up to 98%)

1. 222397,1 kWh/0,98=226936 kWh.
2. 226936 kWh.

3-4.Price of electricity:

- single-rate tariff for houses, furnished in the prescribed manner by stationary electric and (or) electro heating installations is **2,22 rub/kWh** /41/.

  226936 kWh·2,22 rub/kWh=**503798 rub**.
- double-rate tariff : day tariff=**2,23 rub/kWh**, night tariff=**1,10 rub/kWh**

  $\frac{226936}{2}\cdot 2,23+\frac{226936}{2}\cdot 1,10=$**377848 rub**, if the boiler runs approximately equal time in days and nights.
- Triple-rate tariff: peak zone tariff=2,25 rub/kWh, semipeak tariff=**2,20 rub/kWh,** night tariff=**1,10 rub/kWh.**

  $\frac{226936}{3}\cdot 2,25+\frac{226936}{3}\cdot 2,0+\frac{226936}{3}\cdot 1,10=$ **404703 rub.**

Results of the calculations are in the table 6.

TABLE 6. Cost of 1 kWh of energy depending on type of fuel

Type of fuel	Average cost of fuel	Cost of 1 kWh of energy
Natural gas	101845 rub	0,44 rub/kWh
Diesel	761434 rub	3,13 rub/kWh
Mazut	255277 rub	1,04 rub/kWh
Waste oil	309400 rub	1,26 rub/kWh
Wood	200140 rub	0,72 rub/kWh
Coal	174600 rub	0,61 rub/kWh
Peat	540480 rub	2 rub/kWh
Pellet	381100 rub	1,54 rub/kWh
Electricity		
single-rate tariff	503798 rub	2,22 rub/kWh
double-rate tariff	377848 rub	2,23 rub/kWh, 1,10 rub/kWh
triple-rate tariff	404703 rub	2,25 rub/kWh, 2,20 rub/kWh, 1,10 rub/kWh

6. ANALYSIS OF FUEL PRICE CALCULATIONS

Natural gas is the cheapest way (0,44 rub) to get 1 kWh of energy (see figure below).

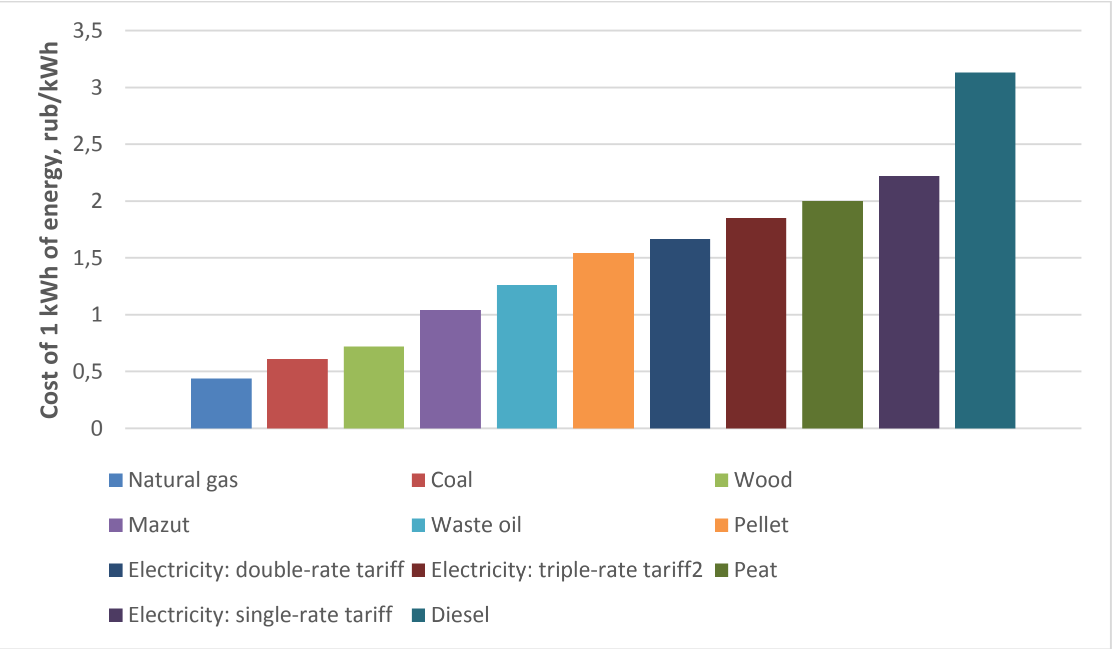


FIGURE 10. Comparison cost of 1 kWh of energy depend on type of fuel

According to cost calculations of 1 kWh of energy using diesel is seven times more expensive than using natural gas. Peat is four and half times more expensive than natural gas. Furthermore peat is difficult to deliver that is why it is not widespread in Samara region. Pellet is three and half times more expensive than natural gas. Thus diesel, pellet and peat are not beneficial for using.

Mazut and waste oil need special conditions and a warehouse for keeping, they also produce harmful substances. Moreover mazut must be warmed before boiler feed.
Although single-rate electricity tariff for houses is the cheapest electricity tariff, it is 3,7 times more expensive.

Using coal is almost 39 percent and wood is 63.6 percent more expensive than using natural gas. Furthermore there are some disadvantages of using wood and coal boilers: it takes a lot of efforts and time to put wood (every 2 hours) and coal (every 4 hours) into the stove. Besides there is no automatic mode of the operation.

7. RESULTS FOR BOILER SELECTION

Natural gas is the cheapest way (0,44 rub) to get 1 kWh of energy (see table 6). That is why let us consider to concentrate on natural gas boiler as a heat source of the heating system for a one family house.

All natural gas boilers are divided into single-circuit and double-circuit boilers depending on the application conditions. A single-circuit boiler is used only for space heating. Double-circuit boiler is used for heating and hot water supply.

A single-circuit boiler can be wall-mounted and floor-mounted. Sensors and thermostats in the single-circuit boiler fix the temperatures needed the system and turn on the gas valve. Water is heated to the appropriate temperature in the heat exchanger and fed to the heating circuit by a circulation pump /43/.

There are two types of natural gas boiler: wall-mounted and floor standing boilers. Floor-mounted boilers have maximum attainable power and can run on dual fuel.

Wall-mounted boilers are compact, lightweight and high-tech. This type of boilers also have closed expansion tank. It means that there is no contact with air and corrosion is reduced instead of systems with open expansion tank.

Wall-mounted boilers have variety of advantages: firstly, they are easy to install. Secondly, there is no need of big chimney, instead of that coaxial pipe for the burnt flue gases outlet and fresh air income is used. Whereas all the necessary components are integrated, installation does not require a lot of effort and money /43./.

Moreover there is a program for switching of a remote control or room thermostat due to built-in programmer. This type of boiler also has a scale-protection system. However, it should be noted that wall-mounted boilers need frequent cleanings. A copper heat exchanger requires regular maintenance as it is sensitive to boiler scale. Experts recommend to carry out preventive work every three years, but this date can vary depending on the water hardness and the frequency of the unit use /43/.

Condensing boilers have become a symbol of development of high technologies. ”Condensing boilers achieve high efficiency rating by passing the flue gas through a secondary heat exchanger, removing excess heat from the flue gases before passing this useful heat into the system water. The reduction in temperatures causes the water vapour within the flue gas to condense within the heat exchanger, with the water being removed through the drain or the flue /43./

Condensing boilers allow more heat to be extracted than a standard efficiency boiler, and limit the amount of heat lost through the flue gases; making them much more energy efficient and cost effective to run” /43/.

Buying such equipment has become the most popular due to the reduction of energy consumption (natural gas). Reduction of gas consumption up to 35% by using condensing boilers reduces the cost of the family budget. Wide temperature range allows to reach the most convenient and effective result. Hazardous waste of condensing boilers are minimum, so the use of this type of boilers is environmentally safe /43./

Ten different natural gas boilers with capacity about 45kW were compared /45/ (see table 7). Calculations of average cost of natural gas per one heating season are shown in table 8. There are boilers from well-known manufactures such as Ferroli (Italy), Beretta (Italy), Attack (Slovak Republic), Baxi (Italy), Mora (Czech Republic), Lamborghini (Italy), Protherm (Czech Republic), Alphatherm (Italy). Ten chosen boilers have approximately the same capacity and also all of these boilers are presented in Samara market. That is why these natural gas boilers are selected to compare.

There is only one condensing boiler - Baxi luna HT Residential 1.450, which has the highest (instead of others) efficiency (97,3%) and underfloor heating mode. This boiler has some important advantages: a coaxial pipe instead of chimney, good security, system (protection against gas unpacking, overheated water, power cutoff, circulation loss of water, lack of boiler draft and water freezing in heating circuit).

TABLE 7. Choosing natural gas boiler (38,04kw+20%=45,6kW) /45/

	Ferroli Pegasus D 45	Beretta Novella 45 RAI	Attack 45 KLV	Baxi luna HT Residential 1.450	Attack 45 EKO	Lamborghini ERA F45 M	Attack 45 P	Alphatherm Beta AG 45	Mora Classic SA50	Protherm Medved 50 PLO
Mounting	floor	floor	floor	wall	floor	floor	floor	floor	floor	floor
Condensing boiler	-	-	-	+	-	-	-	-	-	-
Capacity, kW	45	45	45	46,5	45	45	45	45	45	44,5
Combustion shaft	chimney	chimney	chimney	coaxial pipe	chimney	chimney	chimney	chimney	chimney	chimney
Summer mode	-	-	-	-	-	+	-	-	+	-
Underfloor heating mode	-	-	-	+	-	-	-	-	-	-
Efficiency, %	91,6	90	92	97,3	92	92	92	92	92	92
Gas flow rate m^3/h	5,24	5,1	4,7	4,91	4,7	5,24	4,7	4,7	4,7	5,2
Security system										
Gas unpacking	+	-	+	+	+	+	+	+	+	+
Overheated water + Flame-out										
Power cutoff	+	+	-	+	-	-	-	-	-	+
Lack of boiler draft	-	+	+	+	+	+	+	+	+	-
circulation loss of water	-	-	-	+	-	+	-	-	-	-
water freezing in heating circuit	-	-	-	+	-	+	-	-	-	-
Average price, rub	74000	65500	41000	82000	39000	62000	45000	54000	70000	50000

8. ECONOMICAL CALCULATIONS

8.1. Calculations of annual payments and average operation cost of different boilers

Economical calculations is a very important part of a process of finding the most suitable and economically effective boiler for the heating system. These calculations are needed to estimate a cumulative cost of the heating system. It is a sum of a capital cost (installation cost and a cost of a boiler) and an operation cost. Capital cost is a sum of a boiler cost and its installation cost, which is paid once before the boiler starts up.

Average installation cost of floor-mounted natural gas boiler is 15000rub /46/. Average installation cost of wall-mounted natural gas boiler is 8000rub /46/. Average costs of natural gas boilers are shown in the table 7.
The minimum lifetime for all of analyzed boilers is 15 years /47-55/.
In this bachelor thesis natural gas boiler are compared from the side of capital costs of boilers excluding capital costs of distribution systems (pipes, radiators and other heating equipments).

The real interest rate is calculated by the formula (10):

$$i = Ni - Inf \tag{10}$$

where i-real interest rate, Ni-nominal interest rate, Inf-inflation rate.

The real interest rate is the actual mathematical rate at which customers can increase their purchasing power with their loans. The nominal interest rate is the actual monetary price that borrowers (customers) pay to lenders to use their money /56/. Nominal interest rate is 17% /57/.

Inflation is an increase in the general price of goods and services resulting in a corresponding decline in the purchasing power of money. Customer must expect to be ready for this loss of purchasing power. In practice, interest rates observable in the market tend to take inflation into account /58, p.548/.

Nominal money growth is a sum of real money demand growth and inflation rate. Since real income and interest rates usually change only a few percentage points a year, real money demand usually changes slowly /59/. The rate of inflation in Russia is 7.15% (for October 2014 relative to October 2013) /60/.

i=17%-7,15%=9,85%

Annual payment is calculated using time discount factor determining by following formula (11):

$$a=\frac{i\cdot(1+i)^n}{(1+i)^n-1} \qquad (11)$$

where a is time discount factor, n is a lifetime of a boiler.

$$a=\frac{i\cdot(1+i)^n}{(1+i)^n-1}=\frac{0{,}0985\cdot(1+0{,}0985)^{15}}{(1+0{,}0985)^{15}-1}=0{,}13$$

An annual payment is a multiplication result of capital cost and time discount factor. The results of annual payments calculations of different boilers during the operation period are shown in the table below.

In this work operation costs of different boilers are calculated as average annual costs of natural gas. Natural gas price for Samara region is 4,31 rub/m3 in 2014 /23/. It means that cost of 1kWh of energy is 0,44 rub/kWh in 2014 year.

According to termotechnical calculations (see appendixes) total energy demand of the building is 38,04kW·120%·203days·24hours=222397,1 kWh. Total energy consumption for heating is calculated for every boiler depending on the efficiency of the boiler. Average operation costs of boilers are presented in the table below.

Capital cost divides to 15 years (all operation period) using time discount factor. Operation cost of a boiler depends on a fuel price. ”Gas pricing depends on three major factors: producer price; the price of transit and price of gas distribution” /61/. Forecast of natural gas price is needed to calculate average annual operation costs of boilers.

TABLE 8. Calculations of annual payments and average operation cost of different boilers for the first operation year

	Ferroli Pegasus D 45	Beretta Novella 45 RAI	Attack 45 KLV	Baxi luna HT Residential 1.450	Attack 45 EKO	Lamborghini ERA F45 M	Attack 45 P	Alphatherm Beta AG 45	Mora Classic SA50	Protherm Medved 50 PLO
Cost of boiler, Rub	74000	65500	41000	82000	39000	62000	45000	54000	70000	50000
Installation cost, Rub	15000	15000	15000	8000	15000	15000	15000	15000	15000	15000
Capital cost, Rub	89000	80500	56000	90000	54000	77000	60000	69000	85000	65000
Operation period, years	n=15 is the minimum lifetime for these system is 15 years /50-58/.									
The real interest of loan	i=Ni-Inf=17-7,5=9,85%=0,0985									
Time discount factor	a=$\frac{i\cdot(1+i)^n}{(1+i)^n-1}=\frac{0,0985\cdot(1+0,0985)^{15}}{(1+0,0985)^{15}-1}$=0,13									
Capital cost with using time discount factor	11601	10493	7300	11732	7039	10037	7821	8994	11080	8473
Total energy demand, kWh/year	222397.1									
Efficiency of boiler, %	91,6	90	92	97,3	92	92	92	92	92	92
Total energy consumption, kWh/year	242792	247108	241736	228568	241736	241736	241736	241736	241736	241736
Cost of 1 kWh of energy, Rub	0,44									
Average cost of fuel, Rub /2014/	106828	108727	106364	100570	106364	106364	106364	106364	106364	106364

8.2. Forecasting natural gas price

There are two natural gas price forecasts presented in this work. First method of forecasting was done by using trend line. Second method based on forecast data (from 26.09.2014.) of the Ministry of Economic Development of the Russian Federation code of rising prices.

Trend line is a graphic representation of trends in data series, in this case a line sloping upward to anticipate increasing gas prices over a period of 15 years. Several points are necessary to build up a trend line. In this case prices of natural gas in the period from 1998 till 2014 are used (see table below).

TABLE 9. Growth rates of natural gas prices /62-65/

Year	Price of natural gas, rub/m3
01.08.1998	0,18
01.06.1999	0,2
01.01.2000	0,25
01.05.2001	0,35
01.01.2002 / 16.03.2002 / 01.08.2002	0,41 / 0,5 / 0,59
01.02.2003	0,73
01.01.2004	0,87
01.05.2005	1,11
01.02.2006	1,16
01.02.2007	1,34
01.05.2008	1,64
01.01.2009 / 01.04.2009 / 01.07.2009 / 01.10.2009	1,828 / 1,92 / 2,028 / 2,113
01.01.2010 / 01.04.2010	2,324 / 2,386
01.01.2011	2,76
01.07.2012	3,2
01.07.2013	3,68
01.01.2014 / 01.07.2014	4,14 / 4,31

In this thesis the trendline is used like regression analysis for the purpose of the study of problems of prediction. There are six different trend: linear, logarithmic, polynomial, power, exponential, moving average. Certainty factor of the approximation R^2 indicates the conformity degree of trend model to source data. ”A trendline is most reliable when its R^2 value is at or near 1.” /62/. Blue curve in the figure 10 and figure 11 is the real natural gas price, red curves are different trendlines.

A linear trendline usually shows that something is increasing or decreasing at a steady rate. It should be noted that factor of the approximation R^2 equal to 0,9244, which is not so far from 1, but the direction of the trend line (red line on the figure) is not rise as a real price.

A logarithmic trendline shown in the figure 10 (2) uses either positive or negative values for situation when the value is initially increases or decreases quickly and then levels out /62/. The factor of the approximation is 0,6743, it means that this trendline describes the direction of the real curve of price only for 67% which is too low for forecasting. It is clear that this type of trendline is not applicable for the gas price forecast.

”A power trendline (see figure below) is a curved line that is best used with data sets that compare measurements that increase at a specific rate” /62/. This trendline goes above the real price curve in the beginning and it has a tendency to go under the real price curve after 2008 year. Therefore this type of trendline also is not applicable for the gas price forecast.

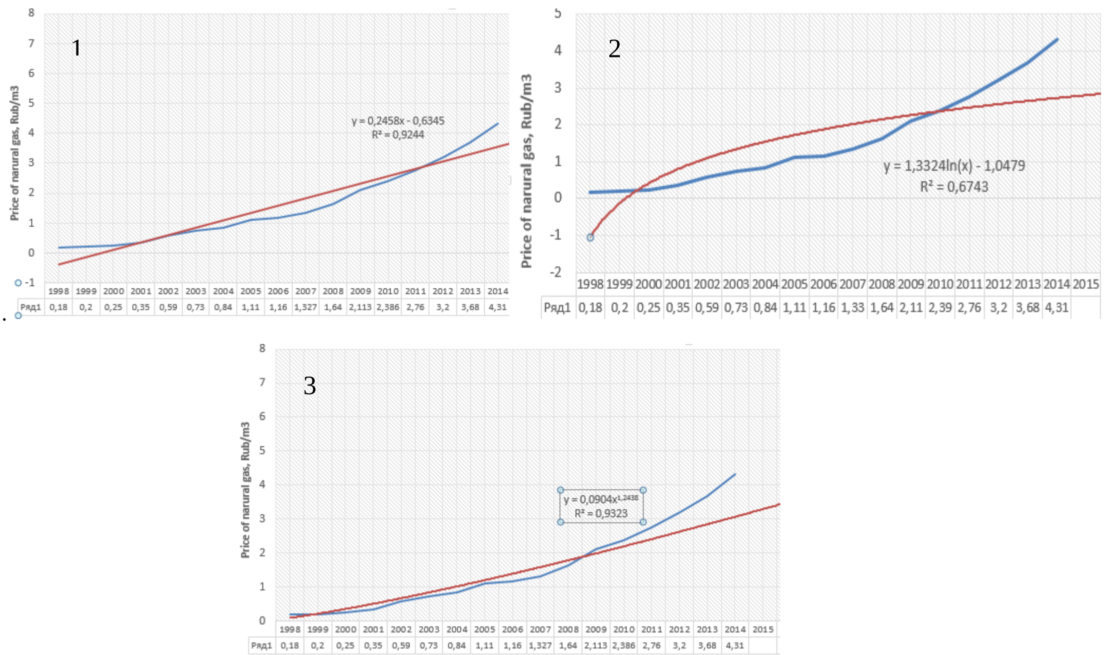


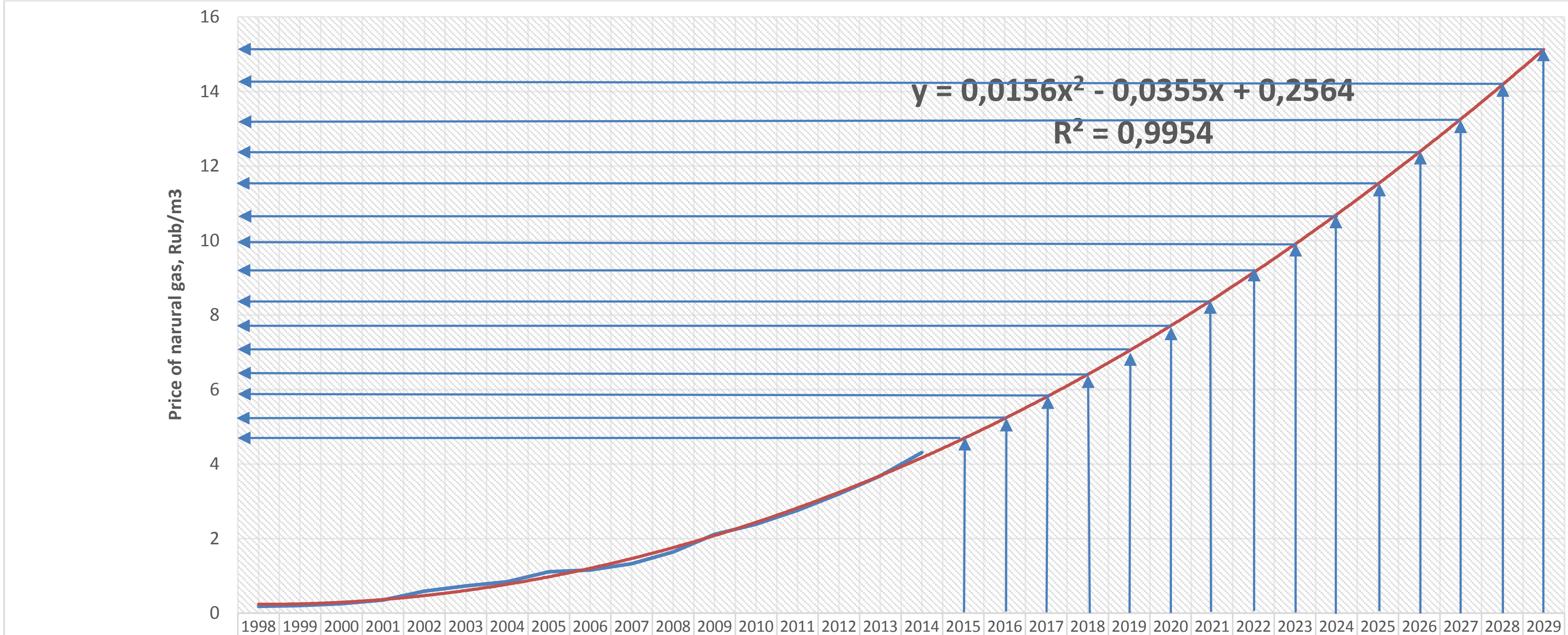
FIGURE 10. Linear (1), logarithmic (2) and power (3) trendlines

A polynomial trendline shown in the figure 11 is a type of trend that represents a large set of data with many fluctuations. As more data becomes available, trends often become less linear and a polynomial trend takes its place /67/. The factor of the approximation of the polynomial trendline is 0,9954, it means that this trendline describes the direction of the real curve of natural gas price for 99,54% which is close to 1. This type of trendline is the best suited trendline for the gas price forecast. Average annual growths of natural gas price are defined for 15 years using polynomial trendline. The results are presented in the table 10.

TABLE 10. Forecast of natural gas price growth (according to figure 11)

Year	Growth of price in % to previous year	Year	Growth of price in % to previous year	Year	Growth of price in % to previous year
2015	9	2020	7,3	2025	8,4
2016	10,6	2021	8,3	2026	6,9
2017	12,3	2022	10	2027	7,3
2018	11,3	2023	9,3	2028	7,9
2019	10,2	2024	7	2029	5,92

Results of economical effectiveness calculations using the first method of forecast are shown in the table 1* in Appendix 20. This table contains calculations of capital, operation and cumulative costs for each of ten natural gas boilers per every year. The graph “Savings from using Baxi 1.450” is the differences between the cumulative cost of using Baxi luna HT Residential (the cheapest value) and cumulative costs of other boilers operations.



	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029
Price of natural gas, rub/m3	0,18	0,2	0,25	0,35	0,59	0,73	0,84	1,11	1,16	1,327	1,64	2,113	2,386	2,76	3,2	3,68	4,31															

FIGURE 11. Polynomial trendline

Second method of forecast based on forecast data (from 26.09.2014.) of the ministry of economic development of the Russian Federation code of rising prices. "Guidelines for the regulation of retail gas prices, implemented to the population", establish a procedure for the formation of retail prices in all regions of Russia, determine the basic principles and procedure for the formation and regulation of retail prices /68/.

According to these guidelines, the retail price of natural gas, implemented to the population, consists of the wholesale gas prices, which is intended for further sale to population, the regional component of the retail prices, including the tariffs for gas transportation and payment for supply and sales services of gas supplier and the value added tax /68/.

In accordance with the basic parameters of the socio-economic Development of Russian Federation for 2015 and the planning period of 2016 and 2017, the annual change of prices (tariffs) for natural gas up to 2017 (in %, on average for the year to the previous year) shown in the table 11:

TABLE 11. Forecasts of growth of prices (tariffs) for products (services) of infrastructure companies and tariffs of housing and communal services in 2015 – 2017 /68/

	2013	2014	2015	2016	2017
	Report	Estimation	Forecast		
Natural gas (wholesale prices) on average, in % for all categories of consumers	115	107,9	103,8	106,6	104,6
Growth of prices for consumers, excluding the population, %	115	108	103,5	106,6	104,6
Size of tariff indexation	July 15%	July 0%	July 7,5%	July 5,5%	July 3,6%
Growth of rates for the population, %	115,0	110,2	105,8	106,6	105,0
Size of tariff indexation	July 15%	July 4,2%	July 7,5%	July 5,5%	July 4,5%

According to the forecast data (from 26.09.2014.) of the Ministry of economic development of the Russian Federation code of rising prices (regulated tariffs and market prices) for natural gas in 2015 – 105,8%, in 2016 – 106,6%, in 2017 – 105,0%. Put the case that average annual growth of natural gas price for the population is about 6%. This percentage is used for calculation of operation costs. Results of economical effectiveness calculations using the second method of forecast are shown in the table 2* in Appendix 22.

9. ANALYSIS OF RESULTS OF ECONOMICAL EFFECTIVENESS CALCULATIONS

According to the first forecast method average annual cost of fuel for the second year of operation period is 9% bigger (see table 10) than average annual cost of natural gas for the first year. In the same way average annual cost of fuel for the third year is 10,6% bigger than average annual cost of fuel for the second year of the operation period, for the fourth year is 12,3% bigger than for the third year.

Cumulative cost of a boiler (see table 1* in Appendix 20) is a sum of capital cost using time discount factor and operation cost (average annual cost of fuel).

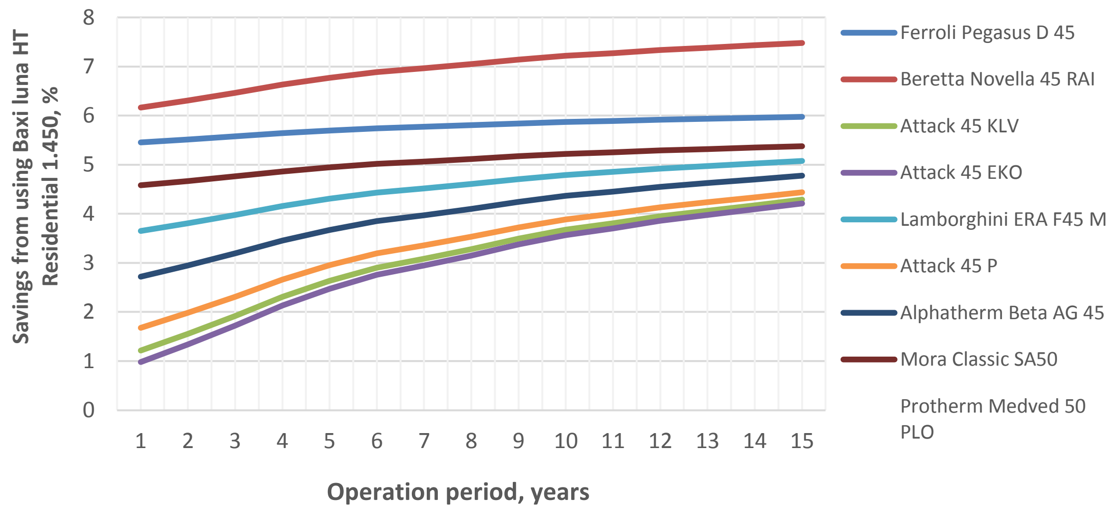


FIGURE 12. Savings from using Baxi luna HT Residential 1.450, % depending on an operation year /first forecast method/

According to the table 2* in Appendix 22 Baxi Luna HT Residential 1.450 is the most economic boiler. Savings from using Baxi luna HT Residential 1.450 (in %) depending on operation year are shown in the figure 12.

According to the second forecast method average annual cost of fuel for every next year of operation period is 6% bigger (see table 11) than average annual cost of natural gas for every previous year. Cumulative cost of a boiler (see table 2* in Appendix 22) is a sum of capital cost using time discount factor and operation cost (average annual cost of fuel). According to the table 2* in Appendix 22 Baxi Luna HT Residential

1.450 is the most economic boiler. Graphic presentation of savings from using Baxi (in %) depending on operation year are shown in the figure 13.

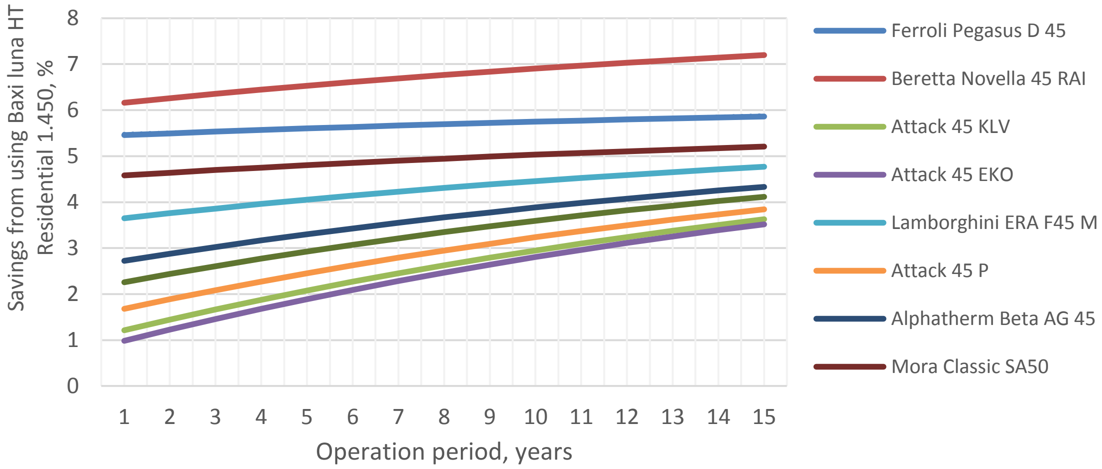


FIGURE 13. Savings from using Baxi luna HT Residential 1.450, % depending on an operation year /second forecast method/

10. RESULTS OF COMPARISON BETWEEN NATURAL GAS AND SOLID FUEL BOILERS

If a building has not connected to the main gas pipeline, gas connection is needed. From March 1, 2014 the payment for a technological connection of gas-powered equipment with gas flow rate 5 m^3/hour for individuals is from 20 000 rubles to 50 000 rubles. This price takes into account the previously connected gas flow at this point to connect gas-powered equipment of the applicant.

The distance from the building to the nearest gas distribution network of the gas distribution company, with a design working pressure not exceeding 0.3 MPa, is measured along a straight line to the connection point. This distance is less than 200 meters. /69/

Let us suppose that price of connection to the main gas pipeline is 50000 rubles. Gas connection to the building is made by following activities: development of technical specifications, design, project documentation development, construction and installation works, technical supervision, the conclusion of the contract, gas connection to the building. /70/.

Mounted gas pipeline with all necessary equipment accepts a special committee, consisting of the customer, the contractor and the representative of Gorgaz. The average payment is about 1500 rubles. Connection to the main gas pipeline by preliminary agreement costs about 3000 rubles. /71 /

The installation of gas metering with welding costs 5000 rubles /72/. So, total installation cost of gas connection is 50000+5000+1500+3000=59500 rubles. Technical annual maintenance of wall-mounted gas boiler costs about 2200 rubles /73/.

In this work comparison of natural gas and solid fuel boilers was done to evaluate influence of technological connection of gas-powered equipment to the cumulative cost of a heating system. A solid fuel boiler was selected because price of coal is not expensive. Cost of 1 kWh of energy, produced by coal fuel is only 0.17rub/kWh more expensive than cost of 1 kWh of energy produced by natural gas (see table 6 and figure 10).

There are boilers from well-known manufactures such as Dakon (Czech Republic), Bosch (Germany), Protherm (Slovak Republic, Czech Republic), Baxi (Italy), Buderus (Germany), Roda (Germany), Viadrus (Czech Republic), Hajdu (Hungary). Eight chosen boilers have the same capacity (45%) and approximately the same efficiency (about 82%) and also all of these boilers are presented in Samara market. That is why these solid fuel boilers are selected to compare.

Protherm Bober 60 DLO is selected (see table 13) because this type of boiler has the best operation period for solid fuel boilers (15 years) /74/, which is equal to operation period of the natural gas boilers.

Comparison between Baxi luna HT Residential 1.450 (the best natural gas boiler because of the highest efficiency and important agvantures) and Protherm Bober 60 DLO are done.

Installation cost of solid fuel boiler is 5700 rub. Technical annual maintenance of solid fuel boilers is about 8000 rubles /46/. Economic parameters of these boilers are shown in the table 14.

According to data of “Scenarios of development of power industry for the period up to 2030” published by Ministry of Energy of the Russian Federation forecast of average annual growth of coal and natural gas prices is shown in the table 12.

TABLE 12. The price indexes of coal and natural gas /75/

Year	Coal	Natural gas	Year	Coal	Natural gas
2015	1,06	1,08	**2023**	1,04	1,03
2016	1,06	1,08	**2024**	1,04	1,03
2017	1,06	1,08	**2025**	1,03	1,03
2018	1,06	1,08	**2026**	1,03	1,03
2019	1,05	1,08	**2027**	1,03	1,03
2020	1,05	1,08	**2028**	1,03	1,03
2021	1,04	1,08	**2029**	1,03	1,03
2022	1,04	1,08	**2030**	1,03	1,03

TABLE 13. Choosing solid fuel boiler according to heat losses (38,04kw+20%=45,6kW)

	Dakon DOR 45D	Bosch Solid 2000 K45-1 S62	Protherm Bober 60 DLO	Roda Brenner Sun BS-06	Buderus Logano S111-45D	BAXI BPI-Eco 1.450	Hajdu HVK 40	Viadrus Hercules U22 D9
Mounting	floor	floor	floor	floor	floor	floor	floor	floor
Type of fuel								
Wood	+	+	+	-	+	-	-	+
Coal	-	+	+	+	+	+	+	+
Other fuel	-	brown coal, coal briquet, coke	-	-	brown coal, coal briquet, coke	-	-	brown coal, coal briquet, coke
Capacity, kW	45	45	45	45	45	45	45	45
Combustion shaft	chimney	chimney	chimney	chimney	chimney	chimney	chimney	chimney
Efficiency, %	82	82	82	82	82	82	80	75 (wood) 78 (coal)
Size of chimney (diameter), mm	180	180	150	180	180	147	160	176
Fuel flow rate, kg/h	13,8 (wood)	10,6 (wood)	13,2 (wood), 7 (coal)		13,8 (wood)		8-9	12,8 (wood) 7,9 (coal)
Security system								
Overheated water	-	+	+	+	+	+	+	+
Average price, rub	60000	67000	74000	50000	76000	97500	62000	65000

TABLE 14. Boilers economic parameters

	Cost of boiler, Rub	Installation cost, Rub	Capital cost, Rub	Operation period, years	The real interest of loan	time discount factor	Capital cost with using time discount factor	Total energy consumption, kWh/year	Average cost of fuel, 2014
Baxi luna HT Residential 1.450	82000	67500	149500	15	0,0985	0,13	19487,335	228568	100570
Protherm Bober 60 DLO	74000	5700	79700				10388,9	271215,98	151880,95

TABLE 15. Comparison between solid fuel and natural gas boilers include gas connection cost

Boiler	Parameters	Operation period, years														
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Protherm Bober 60 DLO	Capital cost, Rub	10389	10389	10389	10389	10389	10389	10389	10389	10389	10389	10389	10389	10389	10389	10389
	Operation cost, Rub	151881	160994	170653	180893	191746	201334	211400	219856	228650	237796	247308	254728	262369	270240	278348
	Technical maintanance, Rub	8000	8640	9331	10078	10884	11755	12695	13711	14807	15992	17271	18653	20145	21757	23498
	Cumulative cost, Rub	170270	180023	190374	201359	213019	223477	234484	243956	253847	264177	274969	283770	292904	302386	312234
Baxi luna HT Residenti al 1.450	Capital cost, Rub	19487	19487	19487	19487	19487	19487	19487	19487	19487	19487	19487	19487	19487	19487	19487
	Operation cost, Rub	100570	108616	117305	126689	136825	147770	159592	172360	186148	191733	197485	203409	209512	215797	222271
	Technical maintanance, Rub	2200	2376	2566	2771	2993	3233	3491	3770	4072	4398	4750	5130	5540	5983	6462
	Cumulative cost, Rub	122257	130479	139358	148948	159305	170490	182571	195617	209708	215618	221722	228026	234539	241267	248220
Savings from using Baxi		48012	49544	51015	52411	53714	52987	51913	48338	44139	48560	53247	55743	58365	61119	64014

11. ANALYSIS OF COMPARISON BETWEEN NATURAL GAS AND SOLID FUEL BOILERS

For the case when a building has not connected to the main gas pipeline, comparison of cumulative cost of using natural gas boiler and solid fuel boiler was done (see figure 15).

FIGURE 15. Cumulative cost of natural gas boiler and solid fuel boiler

In spite of the fact that capital cost of a natural gas boiler is bigger than installation cost of a solid fuel boiler, cumulative cost of a natural gas boiler is cheaper than cumulative cost of a solid fuel boiler (see figure 15).

Moreover, a significant disadvantage of solid-fuel boilers is the necessity of cleaning the combustion chamber from carbon deposits and removal of burnt ash. If the boiler is located near the living accommodation, there is a lot of fine dust because of wood products transporting and keeping.

12. DISCUSSION

House heating cost calculation begins with the calculation of the most expensive component of the heating system –heating boiler. This study was designed to solve a problem of energy source and boiler selection for a heating system in a one-family house. The main results showed that choosing of a boiler with high efficiency and with low maintenance can provide significant savings of money every year for the customer.

The major implication of this bachelor thesis is a selection of a natural gas boiler because of some important advantages.

Firstly, natural gas boilers have the lowest average annual cost of fuel according to calculations, which was done in this work (comparison of boilers running on different type of fuel, see figure 10). An additional point is that one-family house “Teremok” is already has a gas point connection to municipal gas pipe-line.

Secondly, natural gas is not needed in special conditions and a warehouse for keeping. Furthermore, gas is supplied through the pipeline under the pressure automatically and constantly presents in the building. There is also no need to stock up on fuel for the future, which makes this type of fuel suitable for citizens who have not special place for keeping fuel.

Thirdly, natural gas boilers have long service period (about 15 years). Finally, ease of operation and maintenance should be noted as an important advantage. Hence, the results supported an earlier finding that natural gas is the most available fuel in Samara region /4,5/.

Baxi luna HT Residential 1.450 was selected because of the best efficiency (97,3%) and the cheapest cumulative cost (see tables 1* and 2* in Appendixes 20-23). There is also no need for individual boiler arrangement (it is a system with closed combustion chamber- condensing boilers).

These results of this work prove the economic effect from using natural gas boiler by economic calculations. In conclusion, even if the building does not have gas connection to the main pipeline, anyway it is the most suitable heat source for heating a one-family house located in Samara. The major point is that the distance from the building to the nearest gas distribution network of the gas distribution company must not be more than 200 meters.

This bachelor thesis can be used as a supplementary literature for thermotechnical calculations procedure, a heat source and a boiler selection.

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73. Прейскурант для физических лиц ООО "Газпром газораспределение Самара" на техническое обслуживание внутридомового газового оборудования. PDF-document. http://www.63gaz.ru/upload/price/individuals/Техническое%20обслуживание%20внутридомового%20газового%20оборудования-2.pdf. No update information. Referred 21.11.2014
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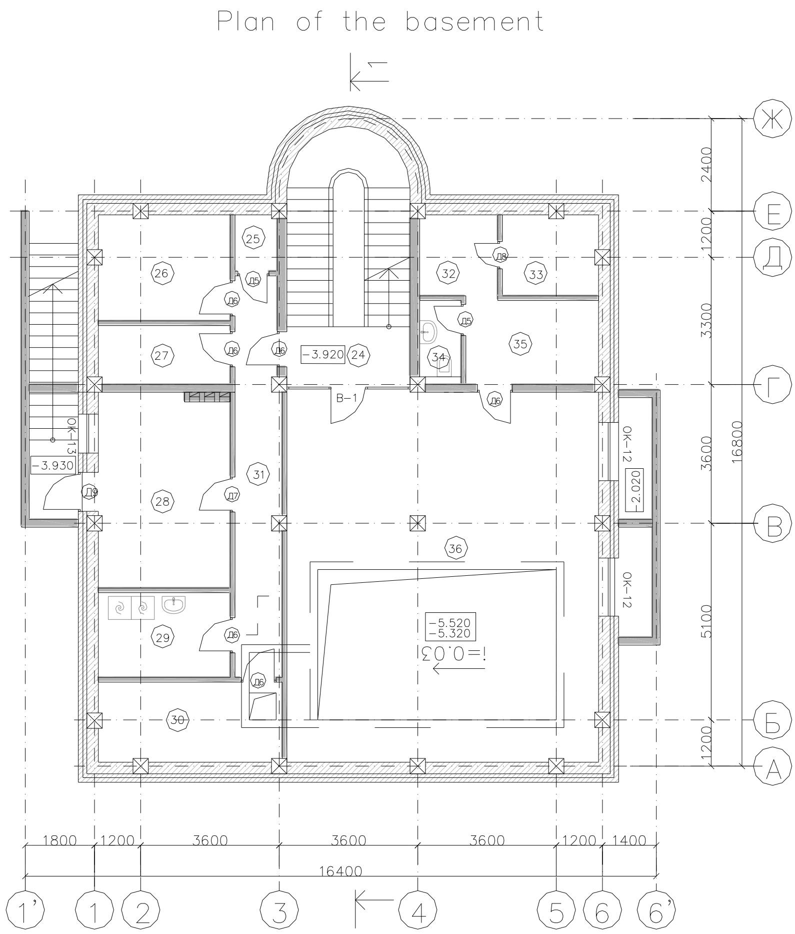
APPENDIX 1.

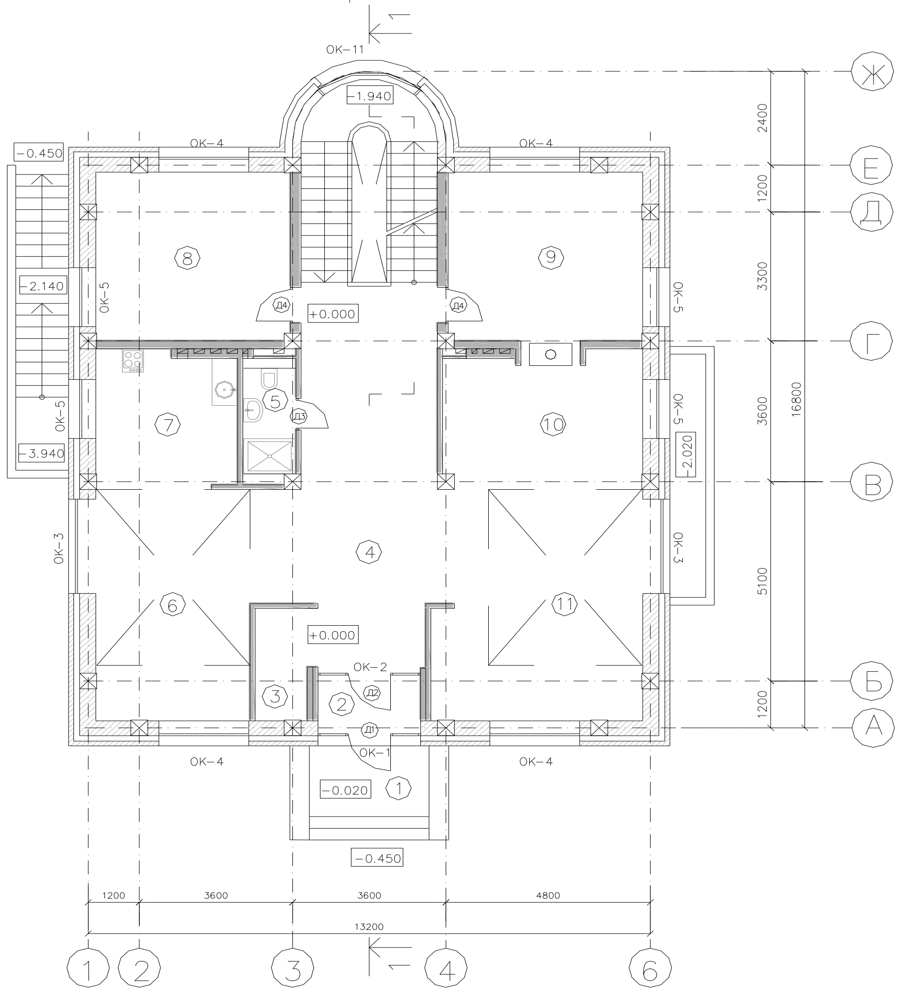


Schedule of premises of the basement

Room №	Room	Area, m²
24	Hall	21,3
25	Switchboard room	1,6
26	Ventilation chamber	9,4
27	Pantry	5,2
28	Boiler room	16,9
29	Laundry	7,5
30	Technical room	9,8
31	Corridor	12,2
32	Shower room	4,2
33	Sweating-room	5,2
34	WC	2,3
35	Changing room	7,5
36	Relaxation room	76,2
Total area of the basement		179,3

APPENDIX 2.

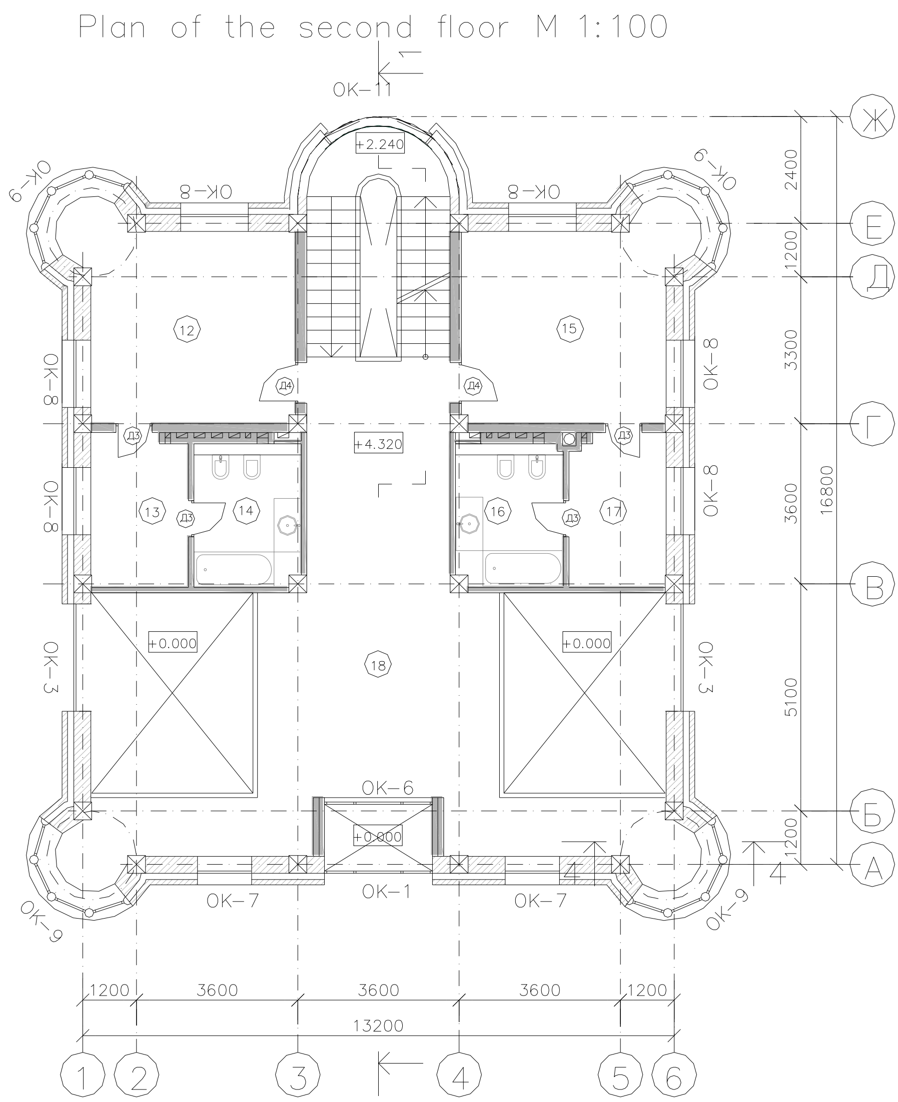
First floor plan M 1:100



Schedule of premises of the first floor

Room №	**Room**	**Area, m²**
1	Porch	5,1
2	Entrance hall	3,7
3	Cloakroom	3,4
4	Hall	30,7
5	WC	4,0
6	Dining-room	24,9
7	Kitchen	11,1
8	Bedroom	19,6
9	Cabinet	19,6
10	Fireplace room	15,3
11	Living room	28,9
Total area of the first floor		166,3

APPENDIX 3.

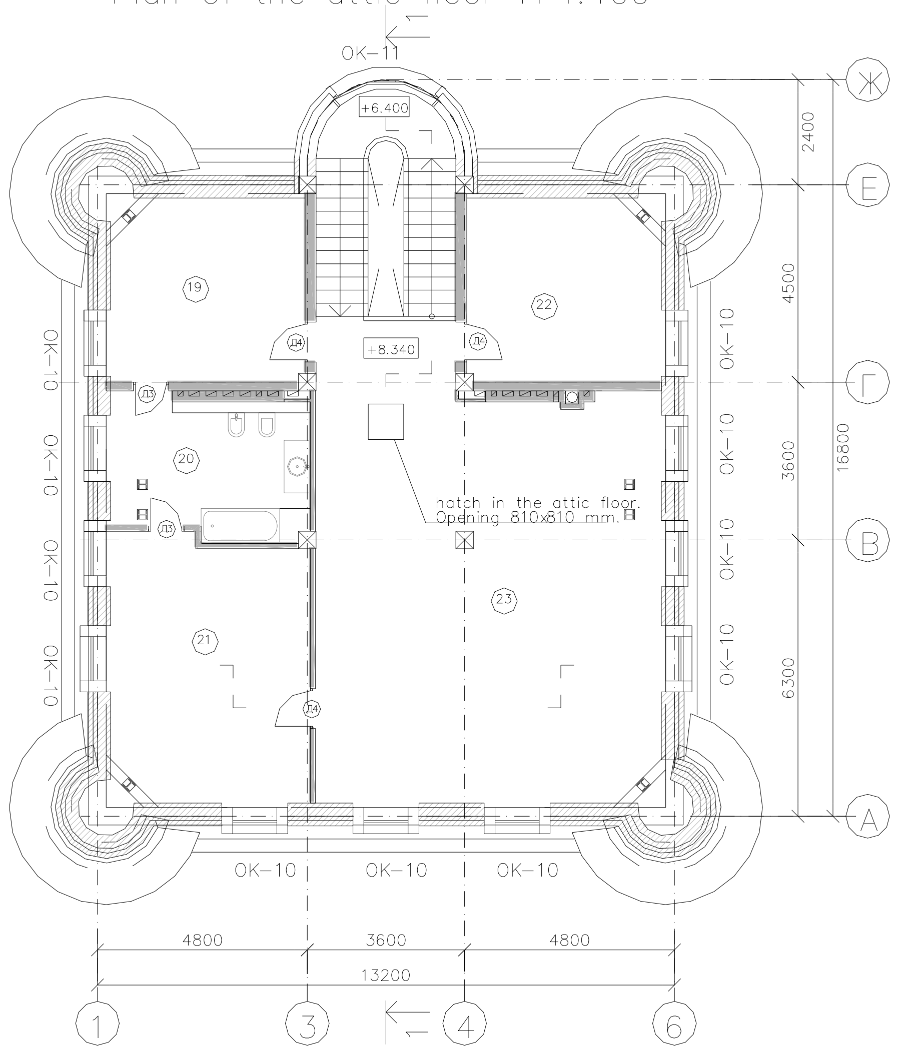


Schedule of premises of the Second floor

Room №	Room	Area, m²
12	Bedroom	21,2
13	Dressing room	7,0
14	WC	8,2
15	Bedroom	21,2
16	WC	8,0
17	Cloakroom	7,0
18	Hall	61,1
Total area of the second floor		133,7

APPENDIX 4.

Plan of the attic floor M 1:100

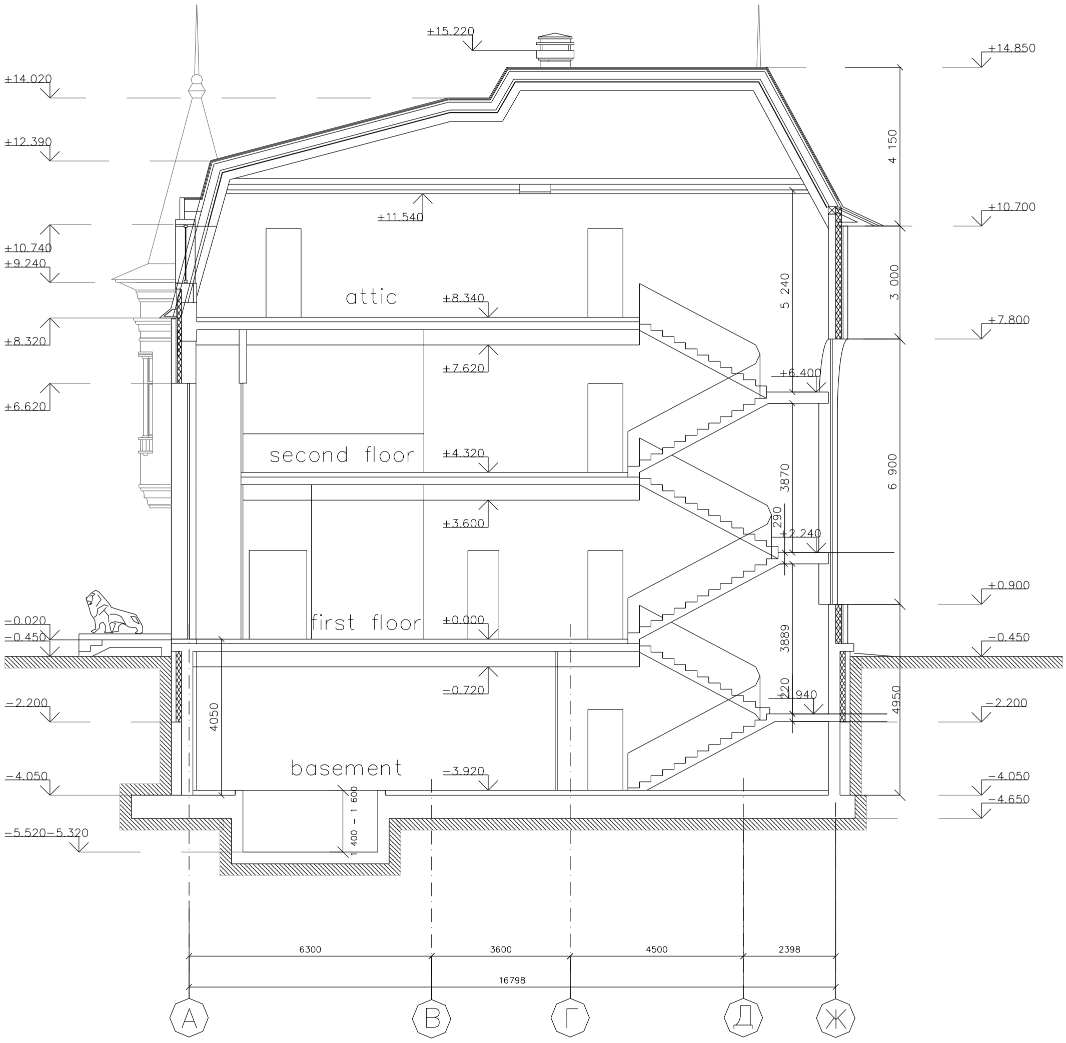


Schedule of premises of the attic floor

Room №	Room	Area, m²
19	Baby room	15,8
20	WC	13,2
21	Bedroom	23,3
22	Library	15,6
23	Children’s playroom	71,8
Total area of the attic floor		139,7

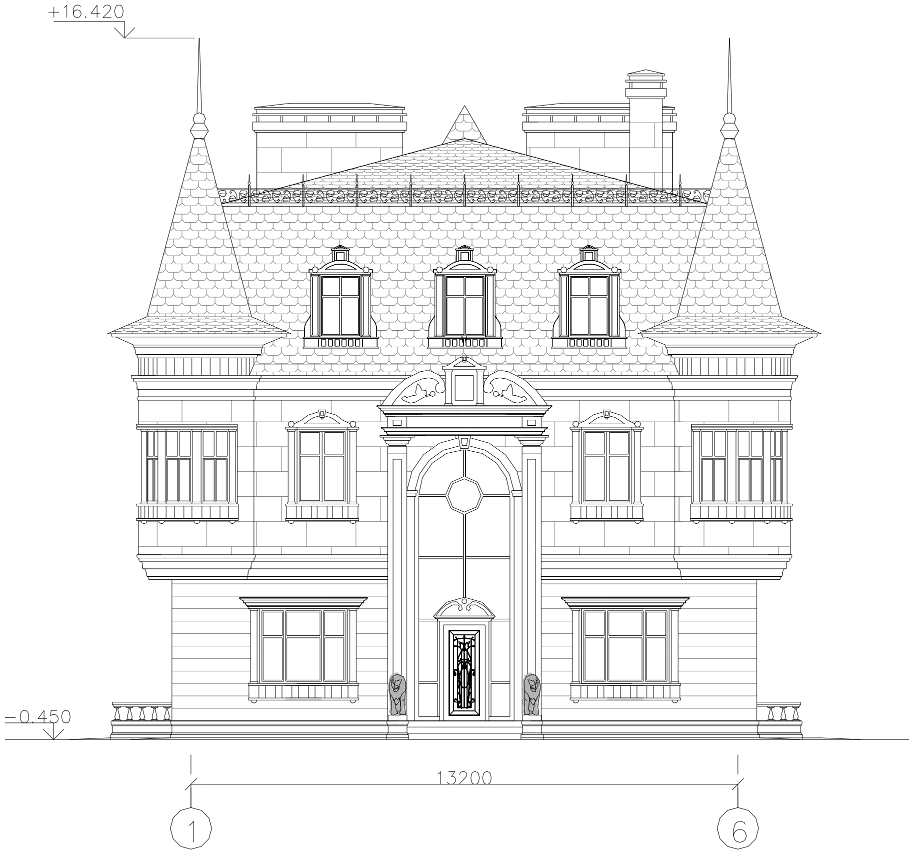
APPENDIX 5.

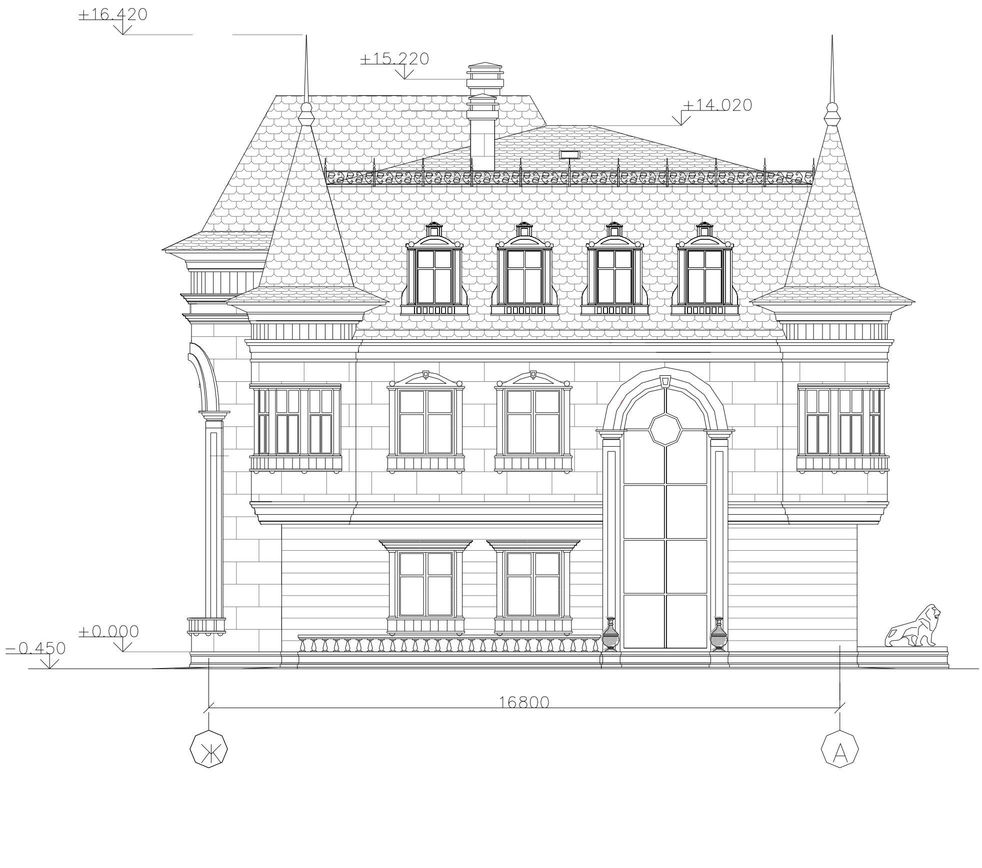
Section 1–1. M 1:100



APPENDIX 6.

Facades of ”Teremok”





Explanations to the table of thermotechnical calculation

The number and name of the premises are recorded in the first column. Design temperature of indoor air will be stored as the third grafe.

The list of all fences which the premises heat can be taken through is in the fourth column.

Type of construction:

SW-supporting wall; DG-double glazing; ED-entrance door; C-ceiling

SW (1UI.F) – supported wall below 0-level /first zone of uninsulated floor

SW (2UI.F) – supported wall below 0-level /second zone of uninsulated floor

SW (3UI.F) – supported wall below 0-level /third zone of uninsulated floor

F (3UI.F) – floor below 0-level / third zone of uninsulated floor

F (4UI.F) – floor below 0-level / fourth zone of uninsulated floor

The orientation of vertical protections to the cardinal is indicated in fifth the column.

Orientation:

N-nord	W-west	NW-northwest	NE-northeast
S-south	E-east	SW-southwest	SE-southeast

The enclosing structure dimensions (length and width, length and height) and the area of this design are specified in the sixth, seventh and eighth columns, respectively.

Heat transfer coefficients are recorded in the ninth column.

K_{walls}=0.3 W/ m^2×°C $K_{(Windows)}$= 1,5 W /m^2×°C $K_{(Doors)}$=2,0 W /m^2×°C

R(1UI.F)=2,1 m^{2}·°C/W → K(1UI.F)=$\frac{1}{R}$=$\frac{1}{2,1}$ = 0,476

R(2UI.F)=4,3 m^{2}·°C/W → K(2UI.F)=$\frac{1}{R}$=$\frac{1}{4,3}$ = 0,230

R(3UI.F)=8,6 m^{2}·°C/W → K(3UI.F)=$\frac{1}{R}$=$\frac{1}{8,6}$ = 0,116

R(4UI.F)=14,2 m^{2}·°C/W → K(4UI.F)=$\frac{1}{R}$=$\frac{1}{14,2}$ = 0,070

Temperature difference (t_{ind}-t_{out}) are specified in the tenth column.

n-factor considering dependence of the enclosing structure is indicated in the eleventh column.

Heat loss (Q_{basic}=K·A·(t_{int}-t_{out})·n·(1+Σβ)) are recorded in the twelfth column.

β- multiplier that takes into account extra losses are recorded in the thirteenth and the fourteenth columns.

For the northern, northeastern, northwestern, eastern orientation β = 0,1; for the south-east and west β = 0,05; for the south and southwest β = 0. There is no any others β-additives in this calculations.

Sum of twelfth, twelfth and fourteenth columns are calculated in the fifteenth column.

Multiplication of the eleventh and the fourteenth columns are calculated in the sixteenth column.

Sum of heat losses from all construction of the room ΣQ are calculated in the seventeenth column.

Infiltration heat losses calculated by the formula Qinf.=0,3·ΣQ are recorded in the eighteenth column.

Total heat losses Qroom=ΣQ 0,3·ΣQ are calculated in the nineteenth column.

APPENDIX 8.

Thermotechnical calculation

Item number	Room	tint	Building envelope						Temperature difference, °C	n	Qbasic	β additives		1+Σβ	Q, W	ΣQ, W	Qinf, W	Qroom, W
			Type of construction	Orientation	Length, m	Wide, m	Area, m²	K, W/(m²K)				orientation	others					
1	1	3	4	5	6	7	8	9	10	11	12,00	13	14	15	16,00	17,00	18,00	19,00
									First floor									
1	**Entrance hall**	20	DG	SW	1,2	4,32	7,63	1,500	50	1	572,12	0	0	1	572,12	850,42	255,12	1105,54
			ED	SW	1,21	2,3	2,78	2,000	50	1	278,30	0	0	1	278,30			
2	**Cloakroom**	20	SW	SW	1,62	4,32	7,00	0,300	50	1	104,98	0	0	1	104,98	104,98	31,49	136,47
3	**Dining-room**	22	SW	SW	2,12	4,32	14,48	0,300	52	1	225,89	0	0	1	225,89	1689,04	506,71	2195,75
			SW	W	3,9+0,54	4,32	19,18	0,300	52	1	299,21	0,05	0	1,05	314,17			
			DG	SW	2,11	1,8	3,80	1,500	52	1	296,40	0	0	1	296,40			
			DG	W	2,41	4,32	10,41	1,500	52	1	811,98	0,05	0	1,05	852,58			
4	**Kitchen**	20	SW	NW	3,6	4,32	12,83	0,300	50	1	192,45	0,1	0	1,1	211,70	434,45	130,33	564,78
			DG	NW	1,51	1,8	2,70	1,500	50	1	202,50	0,1	0	1,1	222,75			
5	**Bedroom**	22	SW	NW	4,96	4,32	17,63	0,300	52	1	275,02	0,1	0	1,1	302,52	1182,64	354,79	1537,43
			SW	NE	4,96	4,32	18,71	0,300	52	1	291,86	0,1	0	1,1	321,05			
			DG	NW	2,11	1,8	3,80	1,500	52	1	296,24	0,1	0	1,1	325,87			
			DG	NE	1,51	1,8	2,72	1,500	52	1	212,00	0,1	0	1,1	233,20			
6	**Cabinet**	20	SW	NE	4,96	4,32	17,63	0,300	50	1	264,44	0,1	0	1,1	290,88	1112,93	333,88	1446,81
			SW	SE	4,96	4,32	18,71	0,300	50	1	280,64	0,05	0	1,05	294,67			
			DG	NE	2,11	1,8	3,80	1,500	50	1	284,85	0,1	0	1,1	313,34			
			DG	SE	1,51	1,8	2,72	1,500	50	1	203,85	0,05	0	1,05	214,04			
7	**Fireplace room**	20	SW	SE	3,6	4,32	12,83	0,300	50	1	192,51	0,05	0	1,05	202,14	416,18	124,85	541,03
			DG	SE	1,51	1,8	2,72	1,500	50	1	203,85	0,05	0	1,05	214,04			
8	**Living room**	22	SW	SE	4,32	4,32	18,66	0,300	52	1	291,13	0,05	0	1,05	305,69	1789,61	536,88	2326,49
			SW	ЮЗ	5,85	4,32	21,47	0,300	52	1	334,99	0	0	1	334,99			
			DG	SE	2,41	4,32	10,41	1,500	52	1	812,07	0,05	0	1,05	852,68			
			DG	SW	2,11	1,8	3,80	1,500	52	1	296,24	0	0	1	296,24			
9	**Staircase**	20	SW	NE	5,02	4,65	13,33	0,300	50	1	199,96	0,1	0	1,1	219,95	1045,98	313,80	1359,78
			DG	NE	2,67	3,75	10,01	1,500	50	1	750,94	0,1	0	1,1	826,03			
																Total (first floor)		11214,07

APPENDIX 9.

Item number	Room	tint	Building envelope						Temperature difference, ^0C	n	Qbasic	β additives		1+Σβ	Q, W	ΣQ, W	Qinf, W	Qroom, W
			Type of construction	Orientation	Length, m	Wide, m	Area, m²	$K, W/(m^2K)$				orientation	others					
1	1	3	4	5	6	7	8	9	10	11	12,00	13	14	15	16,00	17,00	18,00	19,00
Second floor																		
1	**Bedroom**	22	SW	NE	2,12	4,02	11,9	0,300	52	1	185,43	0,1	0	1,1	203,98	1688,78	506,63	2195,42
			SW	NW	2,12	4,02	11,9	0,300	52	1	185,43	0,1	0	1,1	203,98			
			SW	N	4,23	4,02	9,4	0,300	52	1	146,49	0,1	0	1,1	161,14			
			DG	NE	1,51	1,8	2,7	1,500	52	1	212,00	0,1	0	1,1	233,20			
			DG	N	4,23	1,8	7,6	1,500	52	1	593,89	0,1	0	1,1	653,28			
			DG	NW	1,51	1,8	2,7	1,500	52	1	212,00	0,1	0	1,1	233,20			
2	**Dressing room**	20	SW	NW	3,75	4,02	12,4	0,300	50	1	185,36	0,1	0	1,1	203,89	428,13	128,44	556,56
			DG	NW	1,51	1,8	2,7	1,500	50	1	203,85	0,1	0	1,1	224,24			
4	**Bedroom**	22	SW	NE	2,12	4,02	11,9	0,300	52	1	185,43	0,1	0	1,1	203,98	1668,91	500,67	2169,58
			SW	SE	2,12	4,02	11,9	0,300	52	1	185,43	0,05	0	1,05	194,70			
			SW	E	4,23	4,02	9,4	0,300	52	1	146,49	0,1	0	1,1	161,14			
			DG	NE	1,51	1,8	2,7	1,500	52	1	212,00	0,1	0	1,1	233,20			
			DG	E	4,23	1,8	7,6	1,500	52	1	593,89	0,1	0	1,1	653,28			
			DG	SE	1,51	1,8	2,7	1,500	52	1	212,00	0,05	0	1,05	222,60			
5	**Dressing room**	20	SW	SE	3,75	4,02	12,4	0,300	50	1	185,36	0,05	0	1,05	194,62	408,67	122,60	531,26
			DG	SE	1,51	1,8	2,7	1,500	50	1	203,85	0,05	0	1,05	214,04			
7	**Hall**	20	SW	SE	5,28	4,02	15,1	0,300	50	1	227,21	0,05	0	1,05	238,58	4174,21	1252,26	5426,48
			SW	S	4,23	4,02	9,4	0,300	50	1	140,86	0	0	1	140,86			
			SW	SW			36,9	0,300	50	1	552,80	0	0	1	552,80			
			SW	W	4,23	4,02	9,4	0,300	50	1	140,86	0,05	0	1,05	147,90			
			SW	NW	5,28		15,1	0,300	50	1	227,21	0,1	0	1,1	249,94			
			DG	SE			6,1	1,500	50	1	456,75	0,05	0	1,05	479,59			
			DG	S	4,23	1,8	7,6	1,500	50	1	571,05	0	0	1	571,05			
			DG	SW	1,21	1,8	2,2	1,500	50	1	163,35	0	0	1	163,35			
			DG	SW			4,9	1,500	50	1	364,77	0	0	1	364,77			
			DG	SW	1,21	1,8	2,2	1,500	50	1	163,35	0	0	1	163,35			
			DG	W	4,23	1,8	7,6	1,500	50	1	571,05	0,05	0	1,05	599,60			
			DG	NW			6,1	1,500	50	1	456,75	0,1	0	1,1	502,43			
8	**Staircase**	20	SW	NE	5,02	4,02	12,6	0,300	50	1	189,31	0,1	0	1,1	208,24	831,94	249,58	1081,52
			DG	NE			7,6	1,500	50	1	567,00	0,1	0	1,1	623,70			
															Total (second floor)			11960,82

APPENDIX 10.

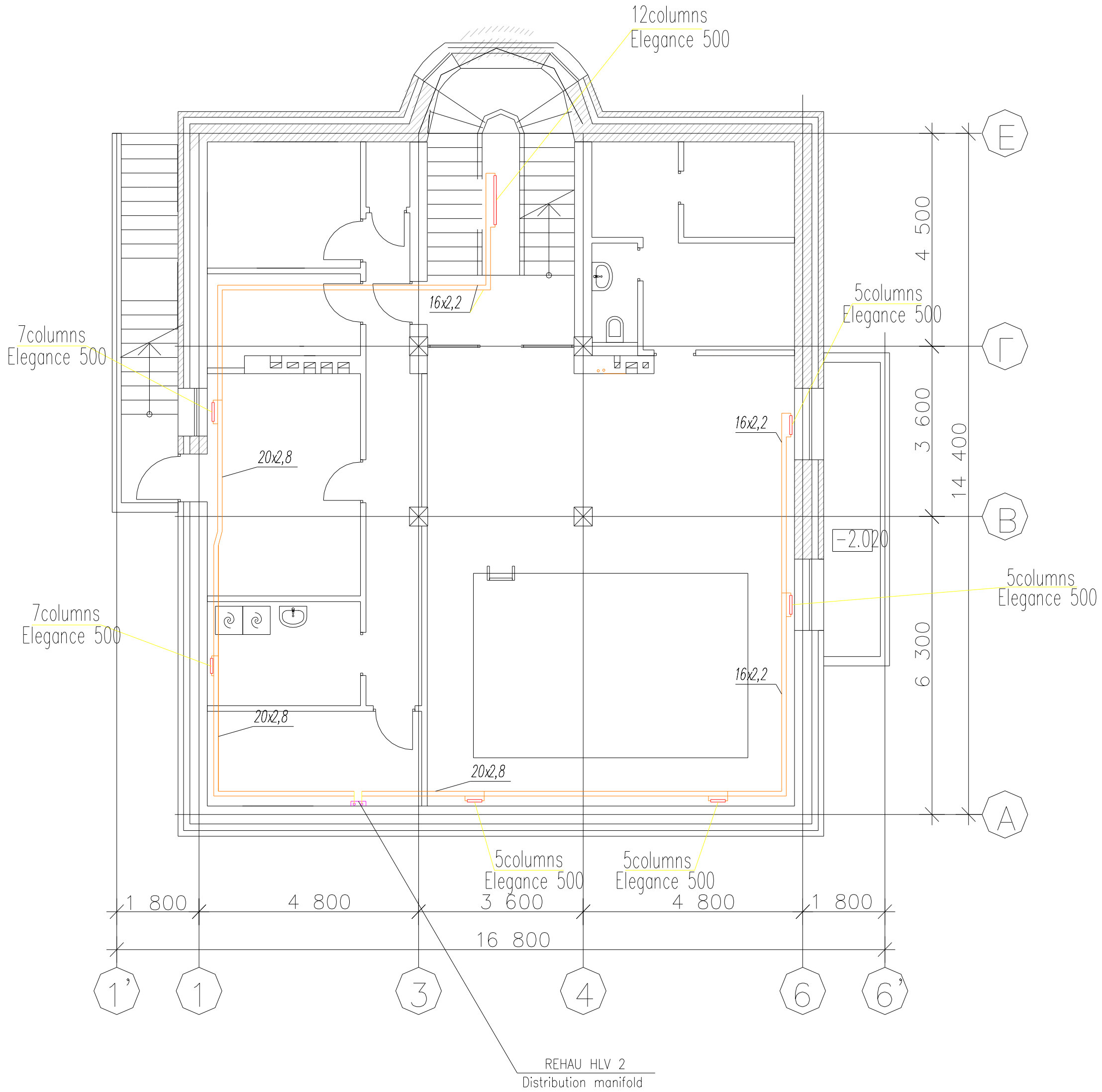
Item number	Room	tint	Building envelope						Temperature difference, ^0C	n	Qbasic	β additives		1+Σβ	Q, W	ΣQ, W	Qinf, W	Qroom, W
			Type of construction	Orientation	Length, m	Wide, m	Area, m²	$K, W/(m^2K)$				orientation	others					
1	1	3	4	5	6	7	8	9	10	11	12,00	13	14	15	16,00	17,00	18,00	19,00
Basement																		
1	**Ventilation chamber**	20	SW (1Ul.F)		7,33	2	14,7	0,476	50	1	348,91	0	0	1	348,91	610,31	183,09	793,41
			SW (2Ul.F)		7,33	2	14,7	0,230	50	1	168,59	0	0	1	168,59			
			SW (3Ul.F)		7,33	0,65	4,8	0,116	50	1	27,63	0	0	1	27,63			
			F(3Ul.F)				8,1	0,116	50	1	46,81	0	0	1	46,81			
			F(4Ul.F)				5,3	0,070	50	1	18,38	0	0	1	18,38			
2	**Switchboard room**	20	SW (1Ul.F)		0,9	2	1,8	0,476	50	1	42,84	0	0	1	42,84	74,33	22,30	96,62
			SW (2Ul.F)		0,9	2	1,8	0,230	50	1	20,70	0	0	1	20,70			
			SW (3Ul.F)		0,9	0,65	0,6	0,116	50	1	3,39	0	0	1	3,39			
			F(3Ul.F)		0,9	1,35	1,2	0,116	50	1	7,05	0	0	1	7,05			
			F(4Ul.F)		0,9	0,11	0,1	0,070	50	1	0,35	0	0	1	0,35			
3	**Pantry**	20	SW (1Ul.F)		1,8	2	3,6	0,476	50	1	85,68	0	0	1	85,68	164,66	49,40	214,05
			SW (2Ul.F)		1,8	2	3,6	0,230	50	1	41,40	0	0	1	41,40			
			SW (3Ul.F)		1,8	0,65	1,2	0,116	50	1	6,79	0	0	1	6,79			
			ПЛ(3 П.П.)		1,35	1,8	2,4	0,116	50	1	14,09	0	0	1	14,09			
			ПП(4 П.Л.)		2,65	1,8	4,8	0,070	50	1	16,70	0	0	1	16,70			
4	**Boiler room**	20	SW (1Ul.F)				9,5	0,476	50	1	225,86	0	0	1	225,86	901,71	270,51	1172,22
			SW (2Ul.F)				7,1	0,230	50	1	81,42	0	0	1	81,42			
			SW (3Ul.F)				2,7	0,116	50	1	15,43	0	0	1	15,43			
			DG		1,1	1,8	2,0	1,500	50	1	148,50	0	0	1	148,50			
			ED		1,1	2,7	3,0	2,300	50	1	341,55	0	0	1	341,55			
			F(3Ul.F)		1,35	5,2	7,0	0,116	50	1	40,72	0	0	1	40,72			
			F(4Ul.F)		2,65	5,2	13,8	0,070	50	1	48,23	0	0	1	48,23			
5	**Laundry**	20	SW (1Ul.F)		2	2,32	4,6	0,476	50	1	110,43	0	0	1	110,43	212,22	63,67	275,89
			SW (2Ul.F)		2	2,32	4,6	0,230	50	1	53,36	0	0	1	53,36			
			SW (3Ul.F)		0,65	2,32	1,5	0,116	50	1	8,75	0	0	1	8,75			
			F(3Ul.F)		1,35	2,32	3,1	0,116	50	1	18,17	0	0	1	18,17			
			F(4Ul.F)		2,65	2,32	6,1	0,070	50	1	21,52	0	0	1	21,52			
6	**Technical room**	20	SW (1Ul.F)		2	7,87	15,7	0,476	50	1	374,61	0	0	1	374,61	639,66	191,90	831,56
			SW (2Ul.F)		2	7,87	15,7	0,230	50	1	181,01	0	0	1	181,01			
			SW (3Ul.F)		0,65	7,87	5,1	0,116	50	1	29,67	0	0	1	29,67			
			F(3Ul.F)				7,7	0,116	50	1	44,55	0	0	1	44,55			
			F(4Ul.F)				2,8	0,070	50	1	9,82	0	0	1	9,82			
7	**Relaxation room**	20	SW (1Ul.F)		2	8,7	17,4	0,476	50	1	414,12	0	0	1	414,12	2023,29	606,99	2630,28
			SW (2Ul.F)		2	8,7	17,4	0,230	50	1	200,10	0	0	1	200,10			
			SW (3Ul.F)		0,65	8,7	5,7	0,116	50	1	32,80	0	0	1	32,80			
			SW (1Ul.F)				20,3	0,476	48	1	464,47	0	0	1	464,47			
			SW (2Ul.F)				17,7	0,230	50	1	203,91	0	0	1	203,91			
			SW (3Ul.F)		0,65	10,27	6,7	0,116	50	1	38,72	0	0	1	38,72			
			DG		1,51	1	1,5	1,500	50	1	113,25	0	0	1	113,25			
			DG		1,51	1	1,5	1,500	50	1	113,25	0	0	1	113,25			
			F(3Ul.F)				22,1	0,116	50	1	128,24	0	0	1	128,24			
			F(4Ul.F)				89,8	0,070	50	1	314,44	0	0	1	314,44			
8	**Changing room**	20	SW (1Ul.F)		2	2,34	4,7	0,476	50	1	111,38	0	0	1	111,38	209,55	62,86	272,41
			SW (2Ul.F)		2	2,34	4,7	0,230	50	1	53,82	0	0	1	53,82			
			SW (3Ul.F)		0,65	2,34	1,5	0,116	50	1	8,82	0	0	1	8,82			
			F(3Ul.F)		1,35	2,34	3,2	0,116	50	1	18,32	0	0	1	18,32			
			F(4Ul.F)		2,1	2,34	4,9	0,070	50	1	17,20	0	0	1	17,20			
9	**Sweating-room**	20	SW (1Ul.F)		2	5,75	11,5	0,476	50	1	273,70	0	0	1	273,70	457,45	137,23	594,68
			SW (2Ul.F)		2	5,75	11,5	0,230	50	1	132,25	0	0	1	132,25			
			SW (3Ul.F)		0,65	5,75	3,7	0,116	50	1	21,68	0	0	1	21,68			
			F(3Ul.F)				4,6	0,116	50	1	26,39	0	0	1	26,39			
			F(4Ul.F)		1,21	0,81	1,0	0,070	50	1	3,43	0	0	1	3,43			
10	**Shower room**	25	SW (1Ul.F)		2	1,82	3,6	0,476	55	1	95,30	0	0	1	95,30	173,99	52,20	226,19
			SW (2Ul.F)		2	1,82	3,6	0,230	55	1	46,05	0	0	1	46,05			
			SW (3Ul.F)		0,65	1,82	1,2	0,116	55	1	7,55	0	0	1	7,55			
			F(3Ul.F)		2,14	1,35	2,9	0,116	55	1	18,43	0	0	1	18,43			
			F(4Ul.F)		2,14	0,81	1,7	0,070	55	1	6,67	0	0	1	6,67			
11	**WC**	20	F(4Ul.F)		1,19	2,34	2,8	0,070	50	1	9,75	0	0	1	9,75	9,75	2,92	12,67
12	**Hall**	20	SW (1Ul.F)		2	6,85	13,7	0,476	50	1	326,06	0	0	1	326,06	598,04	179,41	777,45
			SW (2Ul.F)		2	6,85	13,7	0,230	50	1	157,55	0	0	1	157,55			
			SW (3Ul.F)		0,65	6,85	4,5	0,116	50	1	25,82	0	0	1	25,82			
			F(3Ul.F)				3,9	0,116	50	1	22,74	0	0	1	22,74			
			F(4Ul.F)				18,8	0,070	50	1	65,87	0	0	1	65,87			
13	**Corridor**	20	F(4Ul.F)		1,3	9,3	12,1	0,070	50	1	42,32	0	0	1	42,32	42,32	12,69	55,01
																Total (basement)		7899,52

APPENDIX 11.

Item number	Room	tint	Building envelope						Temperature difference, ^{0}C	n	Qbasic	β additives		1+Σβ	Q, W	ΣQ, W	Qinf, W	Qroom, W
			Type of construction	Orientation	Length, m	Wide, m	Area, m²	$K, W/(m^2K)$				orientation	others					
1	1	3	4	5	6	7	8	9	10	11	12,00	13	14	15	16,00	17,00	18,00	19,00
								Attic										
1	**Baby room**	20	SW	NE	5	3,45	17,3	0,300	50	1	258,75	0,1	0	1,1	284,63	885,80	265,74	1151,53
			SW	NW	4,8	3,45	16,6	0,300	50	1	248,40	0,1	0	1,05	260,82			
			DG	NE	1,01	1,52	1,5	1,500	50	1	115,50	0,1	0	1,1	127,05			
			C				15,8	0,300	50	0,9	213,30	0	0	1	213,30			
2	**WC**	20	SW	NW	3,2	3,45	9,5	0,300	50	1	142,57	0,05	0	1,05	149,70	443,40	133,02	576,42
			DG	NW	1,01	1,52	1,5	1,500	50	1	115,14	0,05	0	1,05	120,90			
			C				12,8	0,300	50	0,9	172,80	0	0	1	172,80			
3	**Bedroom**	22	SW	NW	6,76	3,45	20,3	0,300	52	1	315,92	0,1	0	1,05	331,72	936,41	280,92	1217,33
			SW	SW	5	3,45	15,7	0,300	52	1	245,08	0,05	0	1	245,08			
			DG	NW	1,01	1,52	1,5	1,500	52	1	119,75	0,1	0	1	119,75			
			DG	NW	1,01	1,52	1,5	1,500	52	1	119,75	0,1	0	1	119,75			
			DG	SW	1,01	1,52	1,5	1,500	52	1	120,12	0,05	0	1	120,12			
			C				23,2	0,300	52	0,9	325,73	0	0	1	325,73			
4	**Library**	22	SW	NE	5	3,45	17,3	0,300	52	1	269,10	0,1	0	1,1	296,01	667,85	200,35	868,20
			SW	SE	4,8	3,45	15,0	0,300	52	1	234,39	0,05	0	1,05	246,11			
			DG	SE	1,01	1,52	1,5	1,500	52	1	119,75	0,05	0	1,05	125,73			
			C				15,4	0,300		0,9	0,00	0	0	1	0,00			
5	**Children's playroom**	20	SW	SE	10	3,45	29,9	0,300	50	1	448,42	0,05	0	1,05	470,84	2428,05	728,42	3156,47
			SW	SW	8,6	3,45	26,6	0,300	50	1	398,99	0	0	1	398,99			
			DG	SE	1,01	1,52	1,5	1,500	50	1	115,14	0,05	0	1,05	120,90			
			DG	SE	1,01	1,52	1,5	1,500	50	1	115,14	0,05	0	1,05	120,90			
			DG	SE	1,01	1,52	1,5	1,500	50	1	115,14	0,05	0	1,05	120,90			
			DG	SW	1,01	1,52	1,5	1,500	50	1	115,14	0	0	1	115,14			
			DG	SW	1,01	1,52	1,5	1,500	50	1	115,14	0	0	1	115,14			
			C				71,5	0,300	50	0,9	965,25	0	0	1	965,25			
6	**Staircase**	20	SW	NE	5,02	2,46	12,3	0,300	50	1	185,24	0,1	0	1,1	203,76	203,76	61,13	264,89
																Total (attic)		6969,95

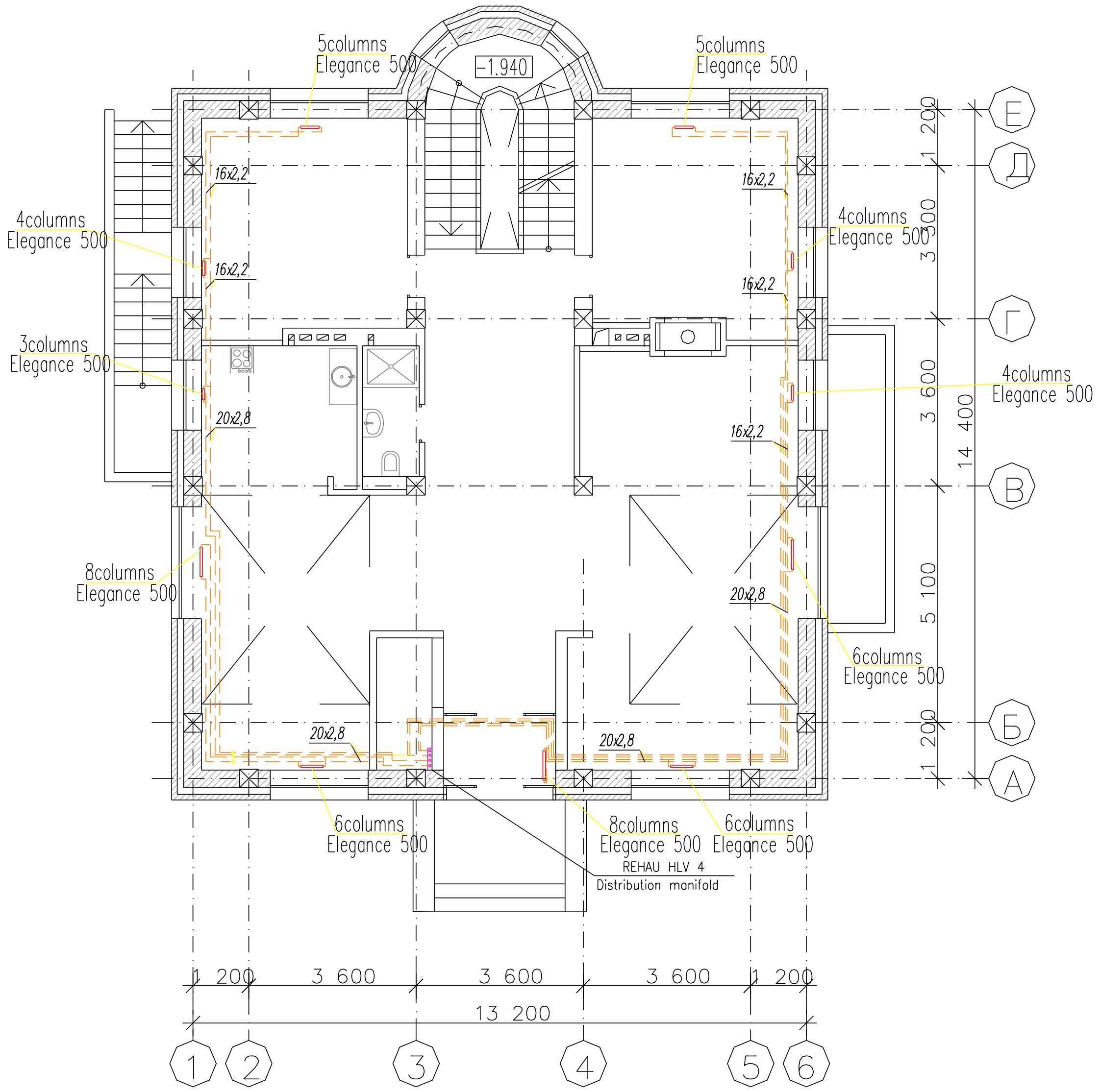
APPENDIX 12.

Design of radiator heating system of the basement



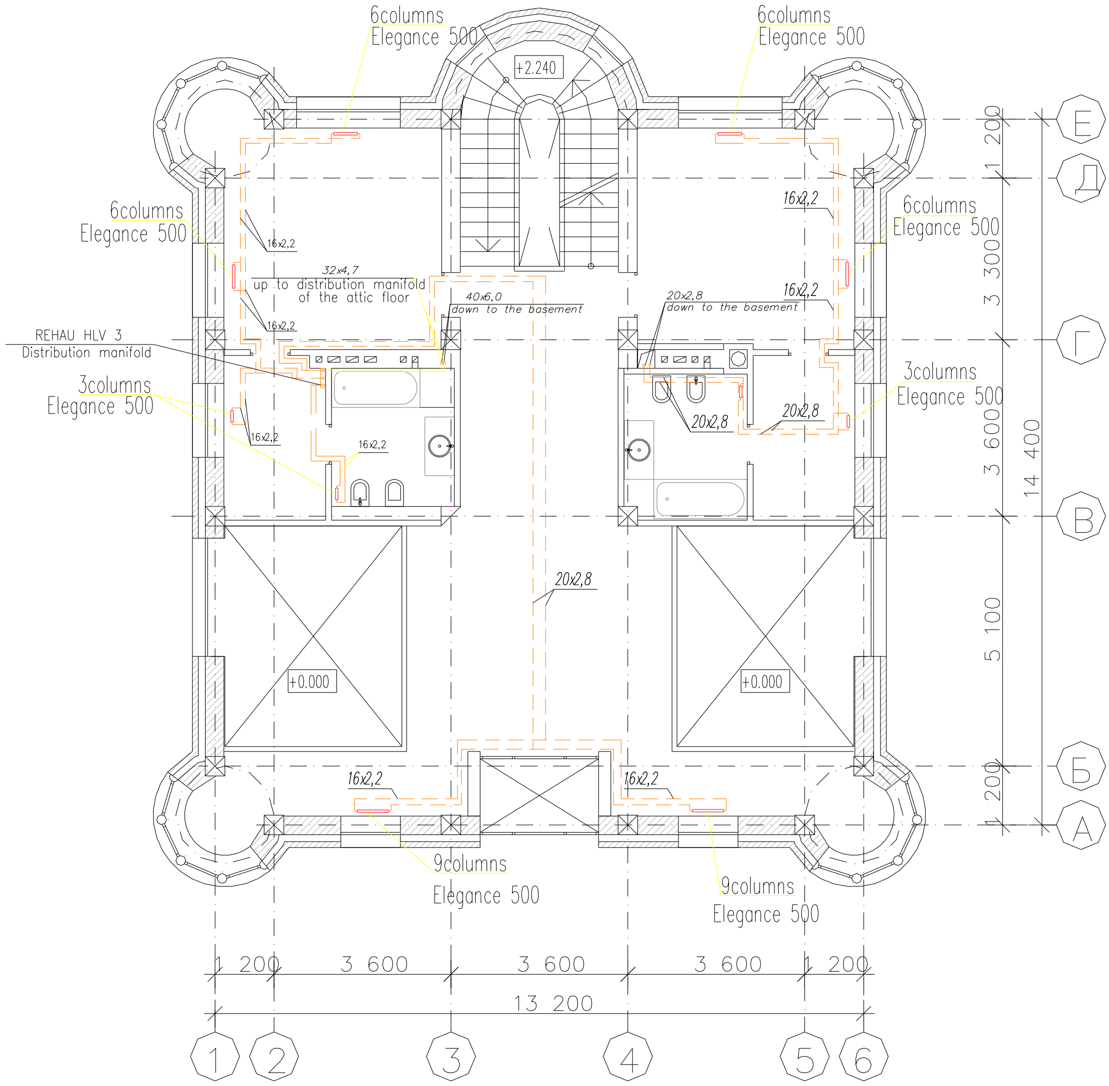
APPENDIX 13.

Design of radiator heating system of the first floor



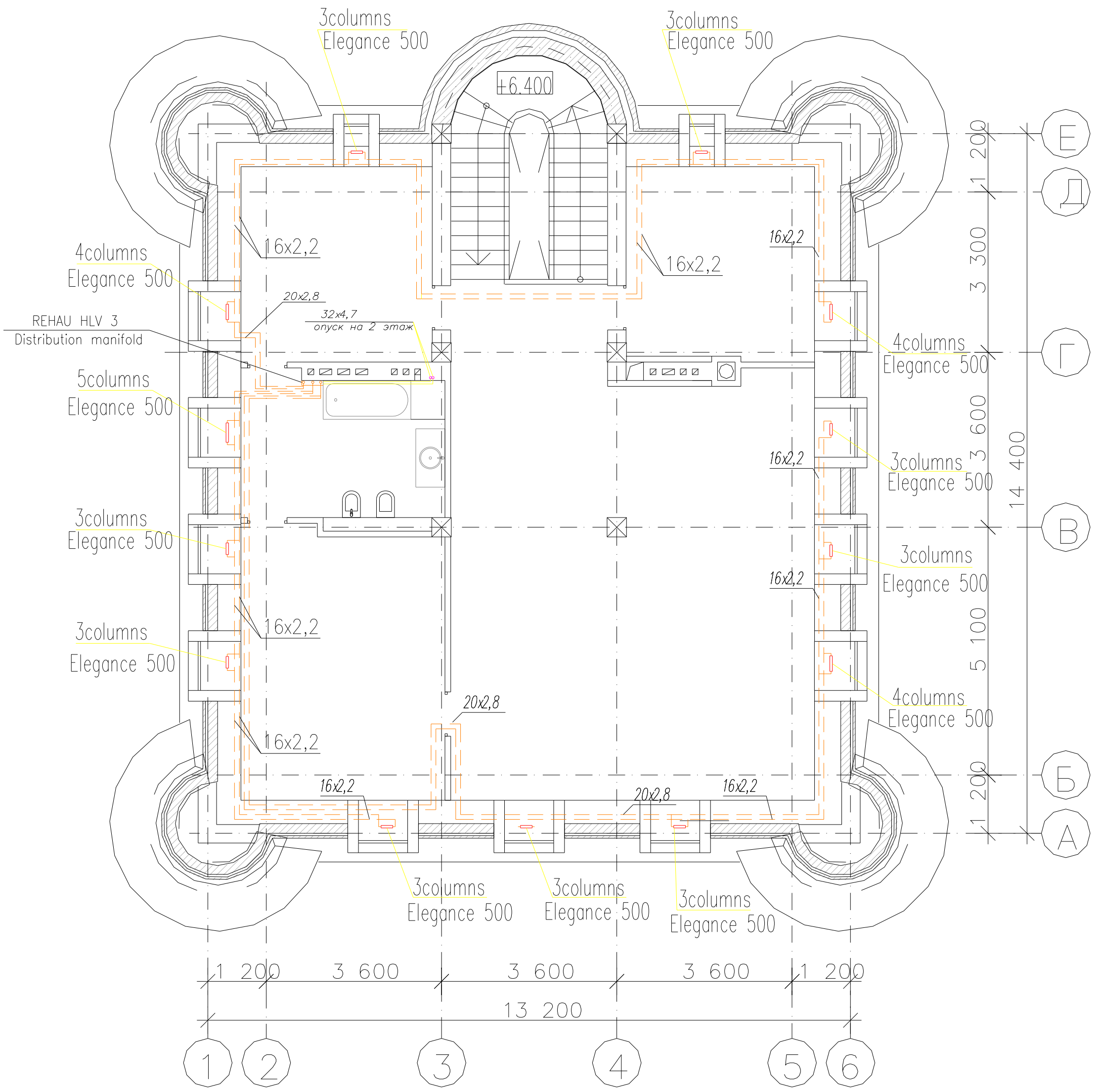
APPENDIX 14.

Design of radiator heating system of the second floor

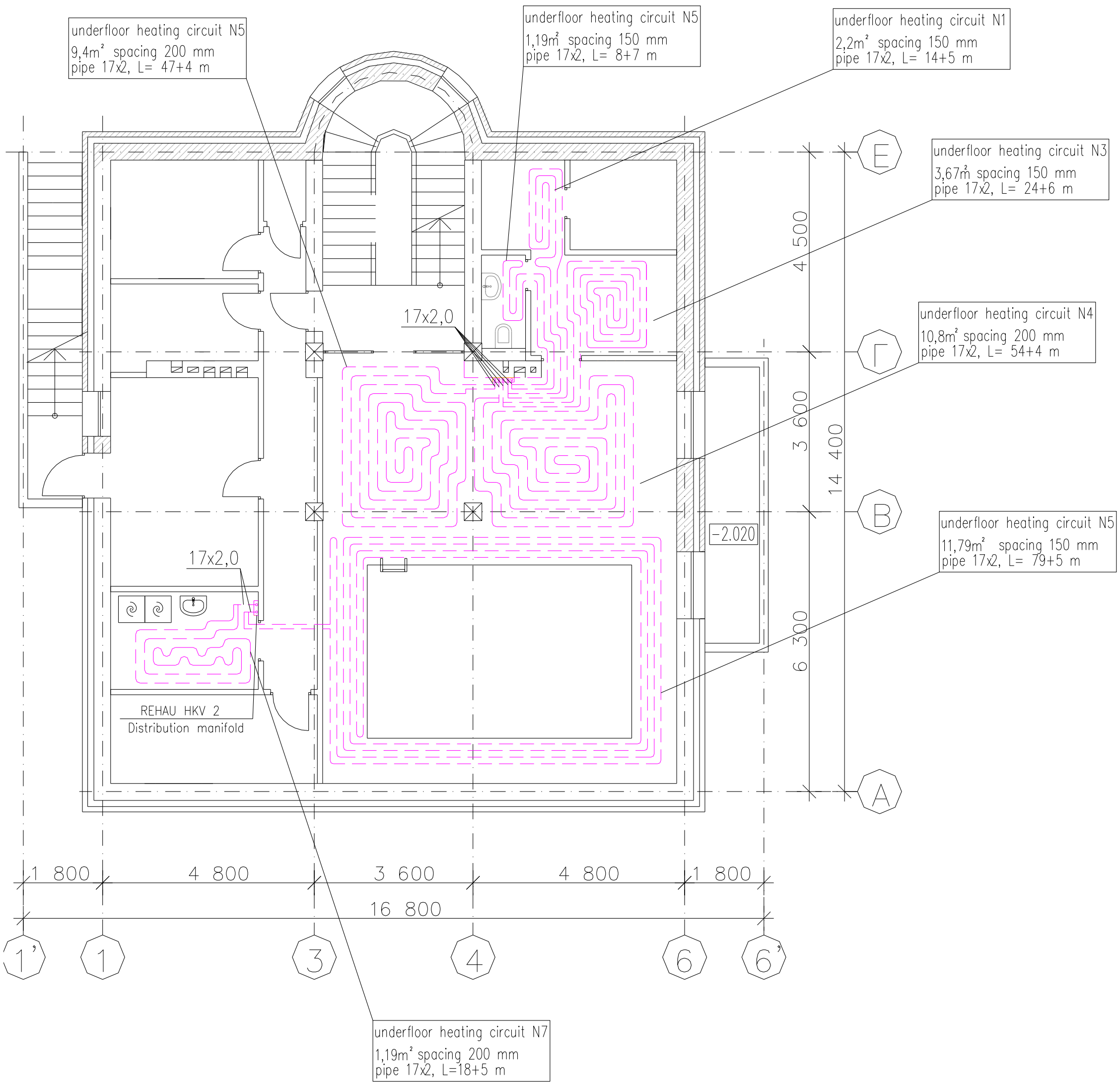


APPENDIX 15.

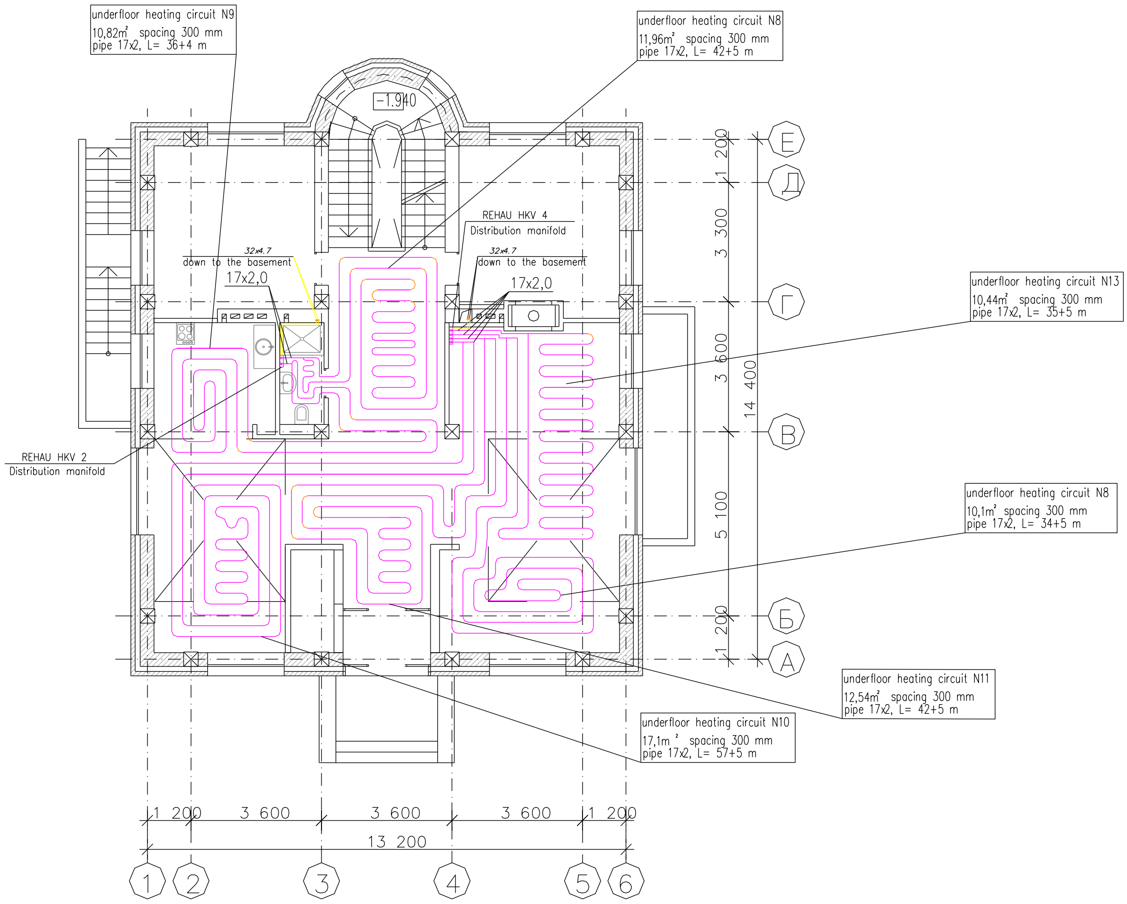
Design of radiator heating system of the attic floor



Design of underfloor heating system of the basement

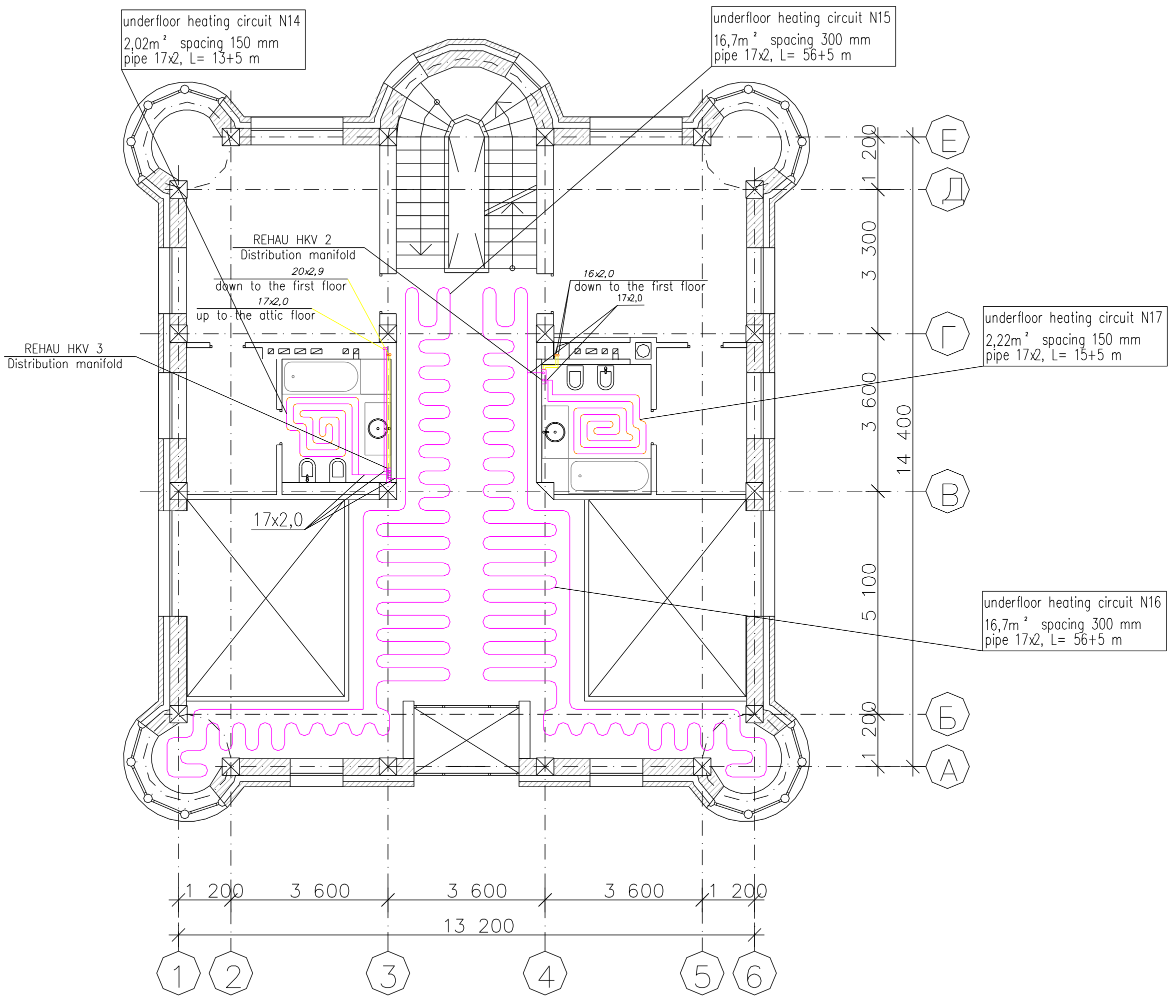


Design of underfloor heating system of the first floor



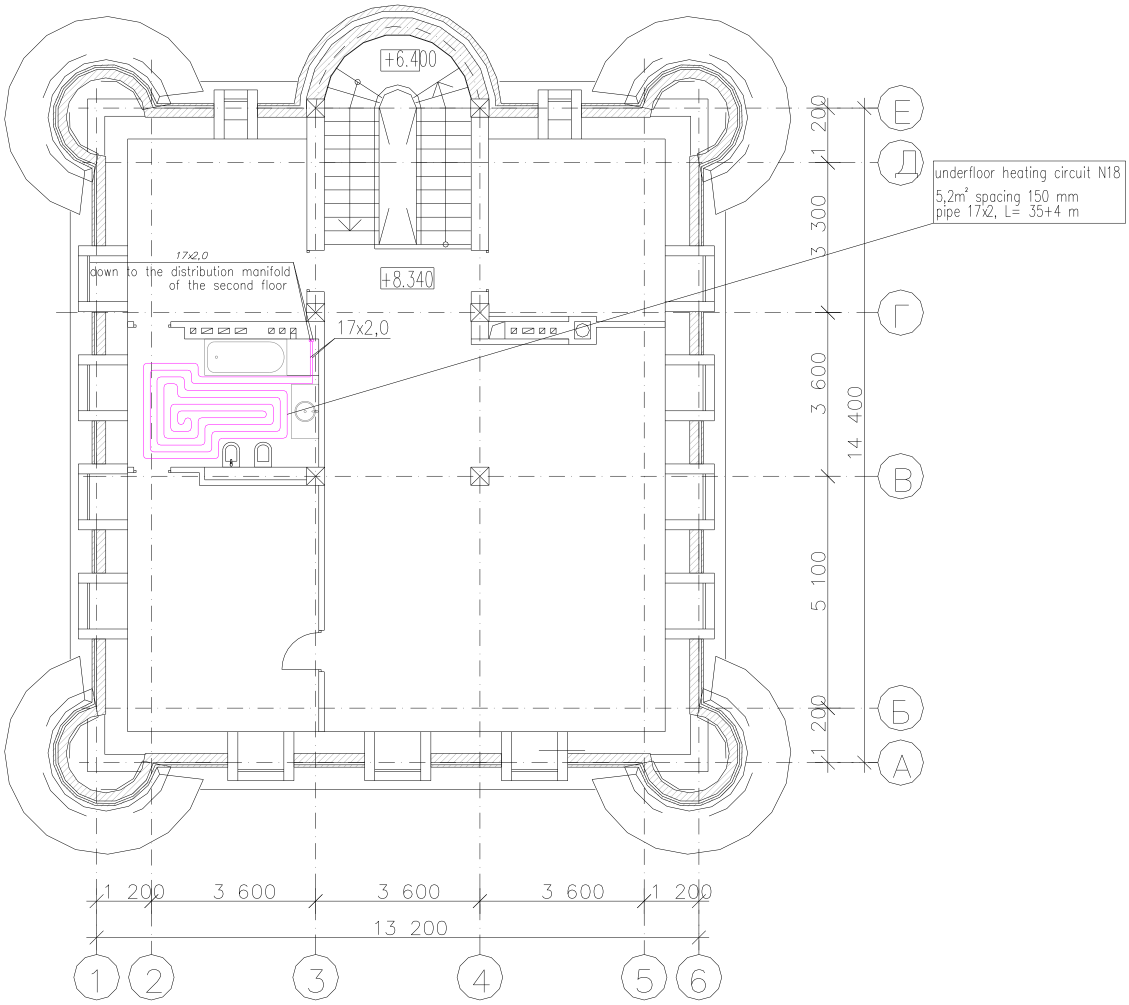
APPENDIX 18.

Design of underfloor heating system of the second floor



APPENDIX 19.

Design of underfloor heating system of the attic floor



APPENDIX 20.

TABLE 1*. Results of economical effectiveness calculations (first method of forecast)

Boiler	Parameters	Operation period, years														
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
Ferroli Pegasus D 45	Capital cost, Rub	11601	11601	11601	11601	11601	11601	11601	11601	11601	11601	11601	11601	11601	11601	11601
	Operation cost, Rub	106828	116443	128786	144626	160969	177308	190180	206022	226583	247633	264967	287251	307071	329364	355351
	Cumulative cost, Rub	118429	128044	140387	156228	172570	188909	201781	217623	238184	259234	276568	298852	318672	340966	366952
Savings from using Baxi *		6128	6691	7414	8342	9300	10257	11011	11939	13143	14376	15392	16697	17858	19164	20687
Beretta Novella 45 RAI	Capital cost, Rub	10493	10493	10493	10493	10493	10493	10493	10493	10493	10493	10493	10493	10493	10493	10493
	Operation cost, Rub	108727	118513	131075	147198	163831	180460	193561	209685	230611	252035	269678	292357	312530	335220	361669
	Cumulative cost, Rub	119221	129006	141568	157691	174324	190953	204054	220178	241104	262528	280171	302851	323023	345713	372162
Savings from using Baxi *		6919	7653	8596	9805	11053	12301	13284	14493	16063	17671	18994	20696	22209	23912	25896
Attack 45 KLV	Capital cost, Rub	7300	7300	7300	7300	7300	7300	7300	7300	7300	7300	7300	7300	7300	7300	7300
	Operation cost, Rub	106364	115937	128226	143998	160269	176537	189353	205126	225598	246556	263815	286002	305736	327932	353806
	Cumulative cost, Rub	113663	123236	135525	151297	167569	183836	196653	212426	232898	253856	271115	293301	313036	335232	361106
Savings from using Baxi *		1362	1883	2553	3412	4298	5184	5882	6741	7857	8998	9938	11147	12222	13431	14840
Baxi luna HT Residential 1.450	Capital cost, Rub	11732	11732	11732	11732	11732	11732	11732	11732	11732	11732	11732	11732	11732	11732	11732
	Operation cost, Rub	100570	109621	121241	136154	151539	166921	179039	193953	213310	233126	249445	270423	289082	310070	334534
	Cumulative cost, Rub	112302	121353	132973	147885	163271	178652	190771	205685	225041	244857	261176	282155	300814	321801	346266
Attack 45 EKO	Capital cost, Rub	7039	7039	7039	7039	7039	7039	7039	7039	7039	7039	7039	7039	7039	7039	7039
	Operation cost, Rub	106364	115937	128226	143998	160269	176537	189353	205126	225598	246556	263815	286002	305736	327932	353806
	Cumulative cost, Rub	113403	122975	135265	151037	167308	183576	196392	212165	232637	253595	270854	293041	312775	334971	360845
Savings from using Baxi *		1101	1623	2292	3151	4037	4923	5622	6481	7596	8737	9678	10886	11961	13170	14579

APPENDIX 21.

continuation of the table 1*																
Lamborghini ERA F45 M	Capital cost, Rub	10037	10037	10037	10037	10037	10037	10037	10037	10037	10037	10037	10037	10037	10037	10037
	Operation cost, Rub	106364	115937	128226	143998	160269	176537	189353	205126	225598	246556	263815	286002	305736	327932	353806
	Cumulative cost, Rub	116401	125974	138263	154035	170306	186574	199390	215163	235635	256593	273852	296039	315773	337969	363843
Savings from using Baxi *		4099	4621	5290	6149	7035	7922	8620	9479	10594	11736	12676	13884	14959	16168	17578
Attack 45 P	Capital cost, Rub	7821	7821	7821	7821	7821	7821	7821	7821	7821	7821	7821	7821	7821	7821	7821
	Operation cost, Rub	106364	115937	128226	143998	160269	176537	189353	205126	225598	246556	263815	286002	305736	327932	353806
	Cumulative cost, Rub	114185	123758	136047	151819	168090	184358	197174	212947	233419	254377	271636	293823	313557	335753	361627
Savings from using Baxi *		1883	2405	3074	3933	4819	5706	6404	7263	8378	9520	10460	11668	12743	13952	15362
Alphatherm Beta AG 45	Capital cost, Rub	8994	8994	8994	8994	8994	8994	8994	8994	8994	8994	8994	8994	8994	8994	8994
	Operation cost, Rub	106364	115937	128226	143998	160269	176537	189353	205126	225598	246556	263815	286002	305736	327932	353806
	Cumulative cost, Rub	115358	124931	137220	152992	169264	185531	198347	214121	234592	255550	272809	294996	314730	336927	362800
Savings from using Baxi *		3056	3578	4247	5106	5993	6879	7577	8436	9551	10693	11633	12841	13916	15125	16535
Mora Classic SA50	Capital cost, Rub	11080	11080	11080	11080	11080	11080	11080	11080	11080	11080	11080	11080	11080	11080	11080
	Operation cost, Rub	106364	115937	128226	143998	160269	176537	189353	205126	225598	246556	263815	286002	305736	327932	353806
	Cumulative cost, Rub	117444	127016	139306	155077	171349	187616	200433	216206	236678	257636	274895	297082	316816	339012	364886
Savings from using Baxi *		5142	5663	6333	7192	8078	8964	9662	10522	11637	12778	13718	14927	16002	17211	18620
Protherm Medved 50 PLO	Capital cost, Rub	8473	8473	8473	8473	8473	8473	8473	8473	8473	8473	8473	8473	8473	8473	8473
	Operation cost, Rub	106364	115937	128226	143998	160269	176537	189353	205126	225598	246556	263815	286002	305736	327932	353806
	Cumulative cost, Rub	114837	124409	136699	152470	168742	185009	197826	213599	234071	255029	272288	294475	314209	336405	362279
Savings from using Baxi *		2535	3056	3726	4585	5471	6357	7055	7915	9030	10171	11111	12320	13395	14604	16013

APPENDIX 22.

TABLE 2*. Results of economical effectiveness calculations (second method of forecast)

Boiler	Parameters	Operation period, years														
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
Ferroli Pegasus D 45	Capital cost, Rub	11601	11601	11601	11601	11601	11601	11601	11601	11601	11601	11601	11601	11601	11601	11601
	Operation cost, Rub	106828	113238	120032	127234	134868	142960	151538	160630	170268	180484	191313	202792	214960	227857	241529
	Cumulative cost, Rub	118429	124839	131633	138835	146469	154562	163139	172231	181869	192085	202914	214393	226561	239458	253130
Savings from using Baxi 1.450		6128	6503	6901	7323	7770	8245	8747	9280	9844	10443	11077	11750	12462	13218	14019
Beretta Novella 45 RAI	Capital cost, Rub	10493	10493	10493	10493	10493	10493	10493	10493	10493	10493	10493	10493	10493	10493	10493
	Operation cost, Rub	108727	115251	122166	129496	137266	145502	154232	163486	173295	183693	194714	206397	218781	231908	245822
	Cumulative cost, Rub	119221	125744	132659	139989	147759	155995	164725	173979	183788	194186	205208	216890	229274	242401	256316
Savings from using Baxi 1.450		6919	7408	7927	8477	9060	9678	10333	11027	11763	12543	13370	14247	15176	16161	17205
Attack 45 KLV	Capital cost, Rub	7300	7300	7300	7300	7300	7300	7300	7300	7300	7300	7300	7300	7300	7300	7300
	Operation cost, Rub	106364	112746	119510	126681	134282	142339	150879	159932	169528	179699	190481	201910	214025	226866	240478
	Cumulative cost, Rub	113663	120045	126810	133981	141581	149638	158179	167231	176827	186999	197781	209210	221325	234166	247778
Savings from using Baxi 1.450		1362	1709	2078	2469	2883	3321	3787	4280	4802	5356	5944	6566	7226	7926	8667
Baxi luna HT Residential 1.450	Capital cost, Rub	11732	11732	11732	11732	11732	11732	11732	11732	11732	11732	11732	11732	11732	11732	11732
	Operation cost, Rub	100570	106604	113001	119781	126967	134586	142661	151220	160293	169911	180106	190912	202367	214509	227379
	Cumulative cost, Rub	112302	118336	124732	131512	138699	146317	154392	162952	172025	181643	191837	202644	214098	226240	239111
Attack 45 EKO	Capital cost, Rub	7039	7039	7039	7039	7039	7039	7039	7039	7039	7039	7039	7039	7039	7039	7039
	Operation cost, Rub	106364	112746	119510	126681	134282	142339	150879	159932	169528	179699	190481	201910	214025	226866	240478
	Cumulative cost, Rub	113403	119785	126549	133720	141321	149378	157918	166971	176567	186738	197520	208949	221064	233905	247517
Savings from using Baxi 1.450		1101	1449	1817	2208	2622	3061	3526	4019	4542	5096	5683	6306	6965	7665	8406

APPENDIX 23.

continuation of the table 2*																
Lamborghini ERA F45 M	Capital cost, Rub	10037	10037	10037	10037	10037	10037	10037	10037	10037	10037	10037	10037	10037	10037	10037
	Operation cost, Rub	106364	112746	119510	126681	134282	142339	150879	159932	169528	179699	190481	201910	214025	226866	240478
	Cumulative cost, Rub	116401	122783	129547	136718	144319	152376	160916	169969	179565	189736	200518	211947	224062	236903	250515
Savings from using Baxi 1.450		4099	4447	4815	5206	5620	6059	6524	7017	7540	8094	8681	9304	9964	10663	11404
Attack 45 P	Capital cost, Rub	7821	7821	7821	7821	7821	7821	7821	7821	7821	7821	7821	7821	7821	7821	7821
	Operation cost, Rub	106364	112746	119510	126681	134282	142339	150879	159932	169528	179699	190481	201910	214025	226866	240478
	Cumulative cost, Rub	114185	120567	127331	134502	142103	150160	158700	167753	177349	187520	198302	209731	221846	234687	248299
Savings from using Baxi 1.450		1883	2231	2599	2990	3404	3843	4308	4801	5324	5878	6465	7088	7748	8447	9189
Alphatherm Beta AG 45	Capital cost, Rub	8994	8994	8994	8994	8994	8994	8994	8994	8994	8994	8994	8994	8994	8994	8994
	Operation cost, Rub	106364	112746	119510	126681	134282	142339	150879	159932	169528	179699	190481	201910	214025	226866	240478
	Cumulative cost, Rub	115358	121740	128505	135675	143276	151333	159873	168926	178522	188694	199476	210904	223019	235861	249473
Savings from using Baxi 1.450		3056	3404	3772	4163	4577	5016	5481	5974	6497	7051	7638	8261	8921	9620	10362
Mora Classic SA50	Capital cost, Rub	11080	11080	11080	11080	11080	11080	11080	11080	11080	11080	11080	11080	11080	11080	11080
	Operation cost, Rub	106364	112746	119510	126681	134282	142339	150879	159932	169528	179699	190481	201910	214025	226866	240478
	Cumulative cost, Rub	117444	123825	130590	137761	145362	153419	161959	171012	180608	190779	201561	212990	225105	237946	251558
Savings from using Baxi 1.450		5142	5490	5858	6249	6663	7102	7567	8060	8583	9137	9724	10346	11006	11706	12447
Protherm Medved 50 PLO	Capital cost, Rub	8473	8473	8473	8473	8473	8473	8473	8473	8473	8473	8473	8473	8473	8473	8473
	Operation cost, Rub	106364	112746	119510	126681	134282	142339	150879	159932	169528	179699	190481	201910	214025	226866	240478
	Cumulative cost, Rub	114837	121218	127983	135154	142755	150812	159352	168405	178001	188172	198954	210383	222498	235339	248951
Savings from using Baxi 1.450		2535	2883	3251	3642	4056	4495	4960	5453	5976	6530	7117	7739	8399	9099	9840