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Analysis of an energy- and eco-efficient design concept of two-storey residential house in Shiryaevo village.

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DESCRIPTION

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Analysis of an energy- and eco-efficient design concept of two-storey residential house in Shiryaevo village

Abstract

The aim of the thesis is to find an affordable option of energy consumption for the environmentally friendly two-storey residential house in climate conditions of Samara region (in Shiryaevo village).

The Shiryaevo village is located in the eco-friendly region. This position requires a «green» and passive construction. But not all the technological solutions may be suitable because the Samara Region has extremes weather conditions that the winter is very cold and very hot in summer. In addition to this, not all solutions are available for sale in the region.

With the help of literature materials, searching for similar climatic conditions and calculations, technological solutions that are suited to achieve this goal were selected. After comparing the materials were chosen the most environmentally friendly, thus meeting the requirements of high-quality thermal insulation. By the combination of a geothermal heat pump, solar panels, underfloor heating and ventilation with the heat recovery energy balance of the building is achieved. Small carbon dioxide emittions and eco-friendly materials allow the house placement in the selected ecological region.

For maintaining the ecology of the region in the perspective, precisely this type of houses should be built in the entire village.

Subject headings, (keywords)

Passive house, eco house, heat pump, sollar collectors, underfloor heating

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NOMENCLATURE

U-value – heat transfer coefficient, W/m^2K;

R – coefficient of heat transfer resistance, m^2K/W;

λ – thermal conductivity, W/mK;

d – thickness, m;

$\Sigma Q_{o.i.}$- sum of main heat losses, W;

β - counted additives;

$K_{o.i.}$- coefficient of heat transfer oh heating envelope, $W/(m^2K)$;

r- heat transfer performance uniformity factor;

α_o- the heat transfer coefficient of the outer surface of the building envelope;

α_{in}- the heat transfer coefficient of the inner surface of the building envelope;

$A_{o.i.}$- the surface area, m^2;

t_{in}- temperature of indoor air;

t_{out}- temperature of outdoor air;

q_{calc} – density of the heat flow, W/m^2

P – heat losses, W;

$t_{average}$ – average temperature of the floor surface, °C;

t_{room} – the room air temperature, °C;

α_{floor} – convective heat transfer coefficient of the floor, 10 – 12 W/m2K;

t_{supply} – supply water temperature, °C;

t_{return} – return water temperature, °C;

ΔT_{diff}- temperature difference between return and supply water, °C;

q_v – volume flow rate, dm^3/h;

C_p – specific heat capacity, kJ/kgK;

P_e – heatig power of the ground loop of the heat pump, kW;

P_h – nominal heating power of the heat pump, kW;

COP – coefficient of performance;

L – length of the collector, m;

$Q_{DHW\text{-}day}$- average daily consumption of the thermal energy for DHW, kWh/day;

$Q_{heat\text{-}day}$- average daily consumption of the thermal energy for heating, kWh/day;

$Q_{total\text{-}day}$- total daily consumption of the thermal energy, kWh/day;

$Q_{h.season}$- thermal energy consumption in the heating season(180 days), kWh;

Q_{year}- thermal energy consumption for heating in year, kWh;

$W_{heating}$- consumption of electric energy to produce heat energy, kWh;

$kg\,\frac{CO_2}{MWh}$ - typical emission factor;

V- volume of consumption hot water, l;

Load- absorbed energy transfer of vacuum tubes to collector area, kWh;

ΣHRV- heat recovery;

$q_{m,v}$- ventilation mass flow rate, kh/h;

Φ_{vent}- ventilation heat losses, W.

1 INTRODUCTION

1.1 General overview

Energy efficiency is a global issue that is widely discussed nowadays. People understand that it is time to develop new technologies, to seek new ways of energy consumption. Passive house technology is one of the solutions. Through design features, these houses consume a minimal amount of energy. The architectural concept of the passive house is based on the following principles: compactness, efficient insulation, lack of thermal bridges of materials and components joints, the correct geometry of the building, zoning, orientation. But not every energy efficient solution is environmentally friendly.

Russia is a big country with different climatic zones. In Samara temperature reaches -30^{0}C in winter and +40^{0}C in summer and the proximity of the Volga River affects the humidity (average value is 72 %). People in this Russian industrial city (1.5 million people) do not pay enough attention to ecology and energy efficiency in construction. But in some areas of the Samara region, where there are no operating factories, nature is protected by various organisations. One of these places is the village Shiryaevo. Residents need a passive house project, but it must be suitable for the climatic conditions of the region and eco-friendly.

Different heating systems and energy production solutions are reviewed in this bachelor thesis according to principles of green and passive constructing. After analyzing the existed solutions, we can find a technological options for the design of an energy- and eco-efficient house in Shiryaevo. The main task of the thesis is not to find the most inexpensive solution. It is more important to choose an option, where technology lives in harmony with nature and environmental requirements for that ecology region.

1.2 Background

A village Shiryaevo was selected for the research work. It is an eco-friendly district in Samara region. This village is located on the right bank of the Volga within Zhigulevsk reserve in a wide valley near of the Zhiguli Mountains and the national park "Samarskaya Luka" (Figure 1) . It is a part of the Middle Volga complex biosphere reserve, created under the auspices of UNESCO. /1./

FIGURE 1. Location of the Shiryaevo village /2/

The climate is continental. Cloudy days dominate in the cold time of the year, and clear and cloudy days dominate in the summer. The region has the warm and snowless winter with individual cold periods, short spring, hot dry summer, and brief autumn. In the cold part of the year the south-western and southern winds are prevailing, in warm part- the northern, western and north-western winds. The region is located on the border of forest-steppe and steppe climatic zones. The average January temperature - minus 13.9 degrees, the average temperature in July - plus 20.1 degrees. The average annual rainfall for the region is about 494 mm. /3./

Now the "old fashion" houses are located in the village Shiryaevo - some still have a furnace, most made of wood, in some homes are not held sewage system (Figure 2). In the near future, the village will be the restructured. Appropriately government will need passive house project which is not affected to the region's ecology. One house will not be able to harm the ecology of the region, but the whole village can affect to the ecological level. In this bachelor thesis, the heating system and the building envelope will be selected, which will be optimal in the climatic conditions of the region. In the future, it could be used in the development of a new project of a passive house in the Shiryaevo eco-village.

FIGURE 2. Typical houses for Shiryaevo village.

1.3 Aim

Aim of the thesis is to find an affordable option of energy consumption for environmentally friendly two-storey residential house in a climate conditions of Samara region.

1.4 Methods

The thesis examined the construction site - a two-storey residential building with total area of 257.4 m^2. By comparing the advantages and disadvantages of different technological solutions, it will be possible to choose the most suitable house’s options for the climatic conditions of Samara.

Method applied in thesis:

1. Calculation of heat losses of the building
2. Selection of technological solutions to cover heat losses
3. Calculation of electricicty consumption and installation properties.

2 PASSIVE HOUSE CHARACTERISTICS

Low energy consumption and small heat losses caused by five principles of the passive house: absence of thermal bridges, superior windows, ventilation with heat recovery, carefully designed insulation and airtightness (Figure 3).

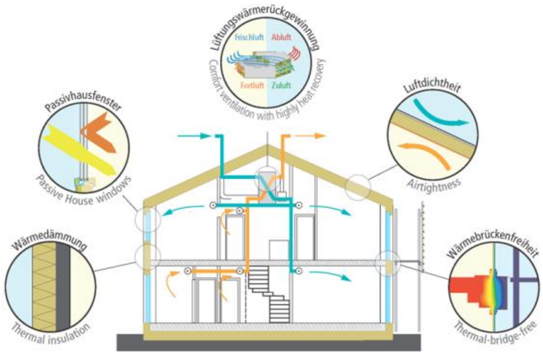


FIGURE 3. Requirements for passive house construction /4/

On the Figure 4 shown infrared pictures of a passive house (at the bottom) and an old building for comparison. The picture clearly shows the difference in construction and obvious difference in heat losses (the old building is not able to retain heat in contrast to the passive house).

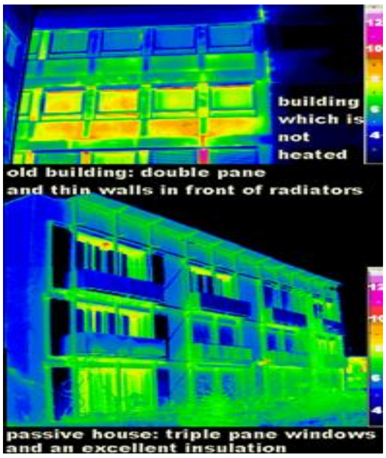


FIGURE 4. Infrared test shows the passive house main principle. /5/

2.1 Thermal insulation

The elements of the building envelope (external walls, roof) must have heat transfer coefficient U-value less than 0.15 W/(m²K). It means 0.15 watts per degree of temperature difference and per square meter maximum losses. The thickness of the insulating material used depends on its quality and varies from 25 to 40 cm. Highly insulating building envelope can be designed according to all construction methods (solid, steel, wood, etc.). /4./

Thermal insulation provides higher temperature on the inner surface in winter and lower temperature in summer. These temperatures are quite near to room air temperature. Improved thermal insulation is not good only in the cold, but in the warm climate too. All traditional insulation materials can be used for a passive house. There are, however, some innovative materials such as foam glass gravel and vacuum insulated panels. /5./

Vacuum insulated panels (Figure 5): Due to the vacuum insulation, insulation performance can be achieved in 8-10 times higher as compared with the conventional material. These panels are essential in those circumstances where a thin insulating layer is needed, the thickness ranges from 10 to 40mm. The core (with vacuum) is protected by an adhered rub granules material, that allows installation of the vacuum insulation panels on the balconies, on the floor and under the screed. /6./

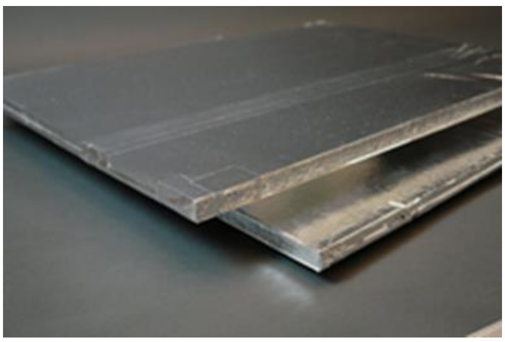


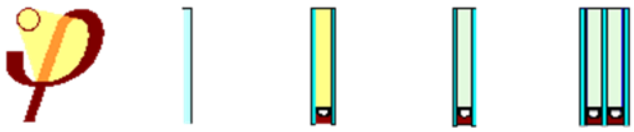
FIGURE 5. Vacuum insulated panels.

Foam glass gravel(Figure 6): It is environmentally friendly, frost resistant, non-flammable insulation material that can carry heavy loads. High insulation characteristics provided due to a large number of enclosed cells in each pellet (λ= 0.08 w/mK). Category of building material A1(non-combustible material). It does not absorb water, it is durable. /6./

FIGURE 6. Foam glass gravel.

2.2 Windows

In a typical house through the windows goes 10-20% of heat loss. Installation of windows with triple glazing in passive homes helps to reduce heat loss to a minimum. It is especially important in cold countries. The average U-value for windows with double glazing is 2.9 W/m^{2}K. With three glasses and additional thermal protection glazing, this U-value can be about 0.7 W/ m^{2}K(Figure 7). To prevent heat loss, a special frame for the glazing should be designed. Window frame must be filled with krypton or argon to prevent the heat transfer, as well as it should be equipped with low-e glazings. Thin, transparent metal layers are deposited on the glass surface. The gap between the two panes of glass in the pane is filled with argon or krypton with low conductivity. This reduces radiant heat transfer. The coated side of the glass faces in the gap. This design allows the use of windows in any climate. Windows passive houses eliminate the convective flow of cold air, even in extreme weather conditions. For cold- temperature climates, U-value is 0.80 W/(m^{2}K) or less, with g-values about 50% (g-value is the total solar transmittance, the proportion of the solar energy available for the room). /7./



Type	single	double	double low-e, Ar	triple low-e, Ar
U_g- value (W/(m²K))	5.60	2.80	1.20	0.65
Surface temperature (-10 °C out / 20 °C in)	-1.8 °C	9.1 °C	15.3 °C	17.5 °C
solar transmittance	0.92	0.80	0.62	0.48

FIGURE 7. Comparison of different windows construction /8/

Using the heat from solar radiation through the window for passive houses is more effectively due to the high transmittance of solar energy. It reduces the energy demand and increases the energy balance of the building. This type of windows is perfect for reducing energy consumption and heating costs.

2.3 Ventilation heat recovery

Effective to use ventilation with heat recovery in order to save energy and ensure high indoor air quality requires(Figure 8). Passive house constantly draws fresh outside air and gradually releases the stale air out through mechanical ventilation. Convenient to use heat recovery ventilation (HRV) in dry or cold climate.

Odours and moisture are exhausted at a controlled rate, while simultaneously setting submits fresh outdoor air. The exhaust air is not mixed with the incoming flow and two flows pass energy to each other(Figure 9). 75% of the heat from the exhaust air passes the fresh air into the room through the heat exchanger. /9./

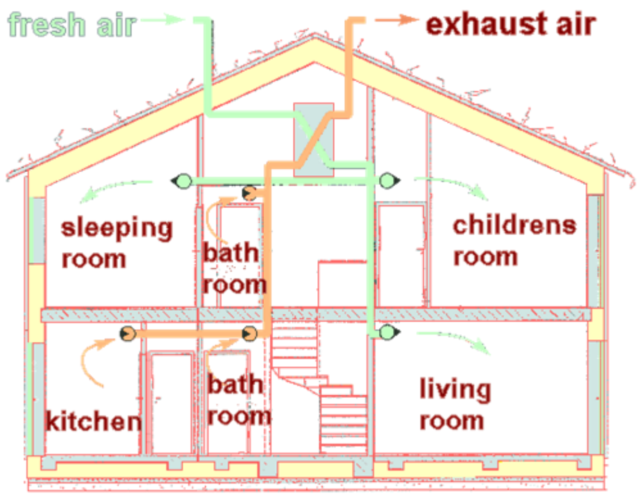


FIGURE 8. The scheme of a comfortable ventilation system. /9/

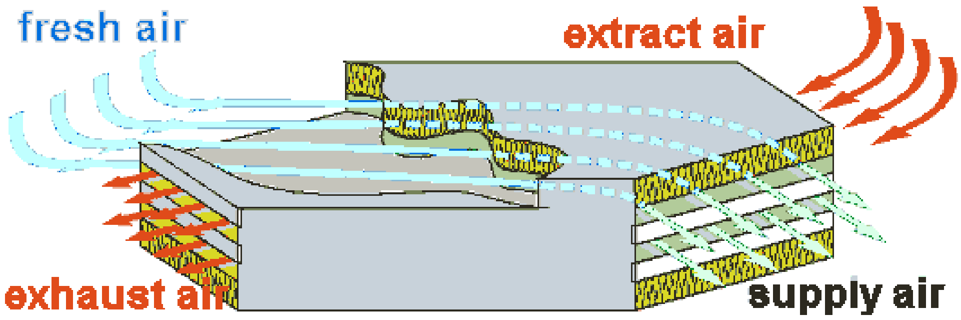


FIGURE 9. Principle of heat exchanger working. /9/

This technology creates a healthy indoor air quality in the building. It works around the clock but energy efficient, moving the small air flows. The temperature does not exceed 55 °C and the mass flow is limited to avoid dry air. This type of fresh air heating (not used recirculating air) is only suitable for passive houses. /10./

2.4 Airtightness

Airtightness controls the air flow from outside to inside the building to prevent cold air infiltration. Also, unexpected air leakage from inside to outside (warm air flow) does not occur. Having a good airtightness allows to reduce heat losses, provide a stable temperature throughout the building, reduce energy costs, improve the thermal performance of the structure (prevents wicking of insulation).

Builders need to seal the point, where pipes and cables created holes in the outer walls of the building. They have to eliminate the slightest leakage of air. The passive house must be completely sealed. After the completion of the construction work, it is necessary to check the airtightness by using a special test - blower-door test. The fan is used to "push" the air out of the building. This creates a small pressure difference between inside and outside space. This difference in pressure is a cause of air penetration through the holes in the external constructions. In a passive house, ventilation can not exceed a certain level. Uncontrolled leakage through gaps must be smaller than 0.6 of the total house volume per hour during a pressure test at 50 Pascal (both pressurised and depressurised). /11./

2.5 Thermal bridges

A thermal bridge is a place or element with poor insulation compared to adjacent areas of heat. It provides the heat loss in cold countries and additional unwanted heat in hot countries. All corners, edges, connections and penetrations must be carefully designed to minimise thermal bridges. Thermal bridges can lead to mould growth due to condensation on the inner surfaces. Significant heat losses may occur, which will increase heating costs and reduce efficiency.

It is possible to reduce or eliminate thermal bridges via heat transfer-resistant material or limiting penetrations. During the design phase is usually made thermal bridge analysis using analytical tools (eg THERM) and a resource library. Thermographic images can show the effectiveness of efforts to eliminate thermal bridges. /12./

3 GREENHOUSES CHARACTERISTICS

Green (or "sustainable", as it called in some literature) building must ensure and improve the environment in the area of construction, the quality of life within the local climate. Green building uses recycled materials and saves resources. It reduces emissions of harmful substances. That contribute the comfort of human life and decreases the risk of bacteria. Green building reduces energy consumption and, respectively, building costs.

The greenhouse is to make maximum use of the factors of its location, to reap the benefits of energy efficiency (orientation, soil, wind direction, etc.). This building should not throw out carbon dioxide. It is unacceptable, so particular attention paid to the selection of construction materials. It is important for the environment and the health of the inhabitants. Materials and components of green house must be ecological (the production must be eco too) and they should not cause an allergic reaction. Green building devotes special attention to energy efficiency, using the principles of the passive house, but paying attention to the environmental engineering solutions. In addition to the efficient use of energy, the greenhouse focuses on the efficient use of water. The concept of green house encourages the use of natural energy sources (sun, water, wind). /13,14./

This section will describe “green” materials for thermal insulation of the house.

3.1 Materials

3.1.1 Eco wool

Eco wool is widespread nowadays. This material is used to insulate various facilities, such as warehouses, shopping areas, public non-residential buildings, residential premises. Eco wool indispensable in rooms with high humidity where condensation may occur.

The compound of the building material is not less attractive. Most of it is secondary processing cellulose (about 80%), which makes eco wool environmentally friendly. Also, boric acid (about 12%) is present in the compound and has an antiseptic property. It prevents the development of bacteria and protects the material from the effects of fungal microorganisms. 8% sodium tetraborate in compound reduces flammability and combustibility because it is a durable flame retardant having insecticidal properties. /15./

Eco wool has significant disadvantages. This building material has excellent insulation properties, but after a while, they reduced considerably, and the thermal conductivity increases accordingly. During operation, eco wool reduces in volume about 20% of the total weight. Eco wool absorbs moisture, so the layer of insulation should be aired and to be able to give moisture to the atmosphere. Modern professional inflatable pneumatic devices help to install eco wool with high quality, preventing shrinkage of the insulation in the future. However, it is important to notice that the installation must do a professional, eco wool quite choosy for vocational skills. The rigidity of eco wool as compared with polystyrene boards are much lower. This factor does not apply to material frameless self-insulation during installation of floor screeds. Experts do not recommend the use of eco wool near an open fire, chimneys, flues. It begins to decay gradually due to exposure to high temperatures. For added protection eco wool must be protected from direct sources of flammable constructions with the help of unique non-flammable and non-combustible materials. /15./

However, eco wool acquired popularity because of its impressive merits. This building material has a high level of sound insulation around 9 dB at 15 mm thickness layer. For warming the room, you need only 28 to 65 kilogrammes per meter cubed eco wool. Eco wool easily "blown" in remote places (for comfortable installing) and it is seamless material (this allows you to save on heating in the winter). For a human, this material is attractive because it does not cause allergic reactions and diseases of the skin, so it does not have in its compound poisonous and toxic substances. Eco wool is done from paper industry waste, which adds to the score for environmental friendliness. /15./

3.1.2 Linen slabs

Linen slabs are very easy to install and use. There is no need to apply a vapour barrier when installing linen panels. Wooden house construction remains dry, mould and fungus do not form. Flax absorbs excess moisture and distributes throughout the volume. Heat transfer in the room is regulated naturally.

Flax - it is related material for wood, it is homogeneous. Due to its high elasticity, thinner design can be made. Linen insulation neutralises the electrostatic field, it does not conduct electricity and eliminates static charges. The heat capacity of that material is higher than for example in mineral wool, it can significantly save on heating in winter and keeps cool in the summer. Clay not contained in the compound of flax slabs. Fibres are connected thermally. Linen fibres absorb moisture, fully preserving insulating properties and its size. A lifetime of linen panels is not less than 75 winters. From the point of safety and environmental protection of view, linen plates suitable for thermal insulation as well as possible. Flax – it is natural antiseptic. Its antibacterial properties retained in the insulation. Parasites do not appear in the constructions. Linen works as a filter to absorb odours, clean the air, inhibits pathogenic microflora, organisms (such as ciliates, textile insects, clothes moth clowns bugs and others). Linen plates are non-toxic, does not raise dust and do not cause allergic reactions. Stone wool produced from non-renewable sources of raw materials in the enormous cost of thermal energy (1000 degrees), which has a limited supply on the planet(Table1). Using natural plant insulation and sound insulation slab materials, we think not only about today but also future generations. /16,17./

TABLE 1. Comparative characteristics of flax insulation and mineral analogues. /17/

	flax insulation	mineral analogues
Density	25-30	30
Coefficient of thermal conductivity,	0,0366	0,04
Compressive strength	0,04	0,05
Heat capacity	1500	800
Life time	Not less than 75 years	15-40 years
Compound	85% flax, 15% thermally bonded fiber	mineral fibers
Restrictions on use	-	Installation in wet weather is prohibited; condensation; allergies and irritation; includes volatile organic compounds; expensive disposal.

4 AVAILABLE HEATING SOLUTIONS

TABLE 2. Comparison of different heating system. /18/

Heating system	Annual energy need, kWh	CO_2 emissions $kgCO_2$/year	Cost/year, €/a
GSHP	6752	2673	810
Light oil boiler	21325	5693	1653
Natural gas boiler	21325	4307	938
Wood boiler	23664	9347	1071

According to the Table 2, the most environmentally friendly solution from presented solutions of passive construction options is ground-source heat pump, because it need less energy than others and it’s CO2 emissions twice or more eco-friendlier than other options. In this chapter will be considered environmentally friendly heating alternatives.

4.1 Brine-to-water heat pump

In this kind of heat pumps, only renewable energy sources are used. Brine-to-water heat pump combines geothermal and air heat in one device. The pump has brine evaporator and outside air evaporator, which are connected to the heat pump cycle. The device selects the most preferable and efficient operating mode (geothermal heat, air heat or both of them). The control unit processes data from the complex heating system and monitors the process. Brine- to- water heat pump can be used for heating, DHW and cooling. Maximum (minimum) flow temperature in heating (cooling) operation is 55 °C (7 °C). DHW temperatures up to 60 °C with synchronous cooling or heating request. Cooling and heating with two compressors allow flexible adaptation of the performance. /19./

4.2 Ground source heat pump

The surface temperature of the ground is in normal conditions constant at more than 10 meters depth and it is independent of the changing seasons. The heat of the ground is a source of energy in the ground source heat pump. It can be used for domestic hot water and space heating. This pump is suitable for different types of climate and it can be used in different kinds of buildings. The principle of operation of GSHP that delivers heat to the ventilation system and domestic hot water is shown in the Figure 10. /18,19./

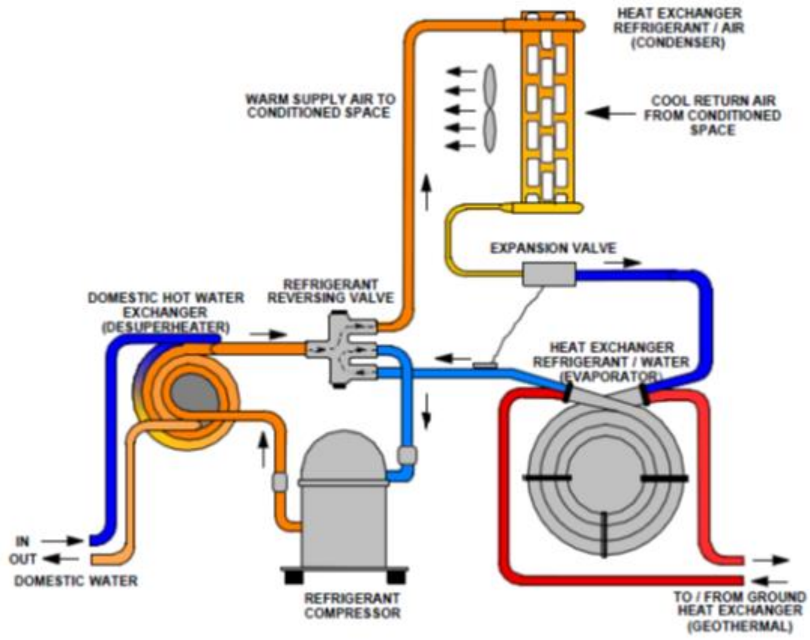


FIGURE 10. The principle of operation of GSHP that delivers heat to the ventilation system and domestic hot water. /18/

In the summer period, the ground source heat pump injects the excess heat in the ground, and in winter it collects heat from the ground's surface, thus becoming a source of heat and cooling machine at the same time. GSHP can serve either as a heating source in winter (collects heat from the ground) or as a cooling machine in summer (injects excessive heat to the ground). /19./

The position of the pipes in GSHP can be horizontal and vertical (borehole). Horizontal pipe must be installed below the freezing level of soil. Vertical borehole drilled in depth about a hundred meters. There are some pros and cons in different pipe system.

Horizontal pipe system, need a huge area for the pipes. The area must not be any constructions which lead to soil sediment. For horizontal pipe system doesn't need a drill machine. It is simple for installing.

On small plots of land, on which can not be install horizontal pipe system, drilling borehole and installation of the vertical heat exchanger is an indispensable solution. But it is necessary to remember about the documents. Drilling wells to a depth of over 100 meters requires a license for the use of natural resources (license for subsoil use and permission to drill wells), on the basis of what is given permission to drill wells. /18./

Vertical and horizontal pipe loops shown on the Figure 12.

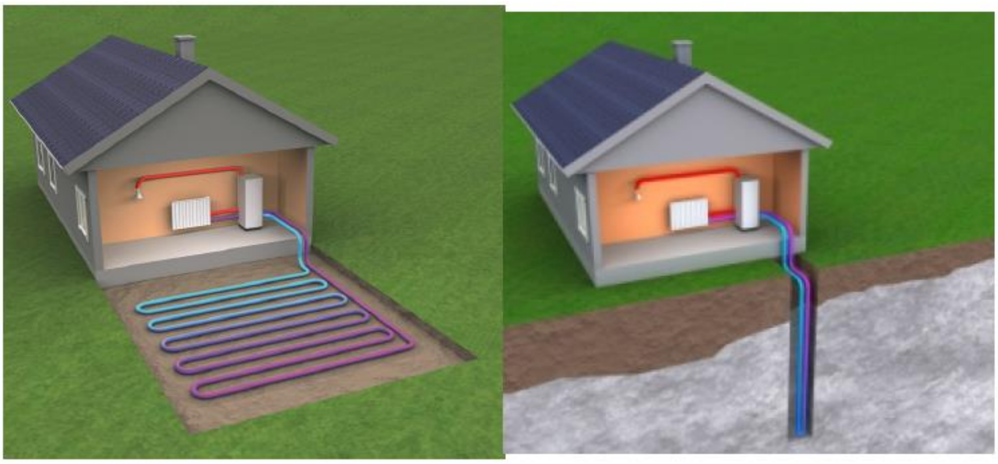


FIGURE 11. Vertical and horizontal pipe loops. /18/

4.3 Solar collectors

Sollar collector is a box covered with glass. Inside the coil is placed (curved copper tube, which is welded to the plate - absorbers). A more complex structure - parallel arranged tubes. This is done to reduce the resistance, which occurs during the passage of coolant. The sun heats the plate. They transfer heat to the tube. The tube transfers heat to the circulating liquid in it. The design is simple, but some of the energy will inevitably dissipate into the surrounding air by convection. To collect the maximum amount of energy required to provide the largest possible heat absorption on the plates of the absorber and reduce the heat losses in the panel itself. It is well known that the best black body absorb heat, but the use of ordinary paint does not give good results. Most used selective coating absorber that prevents convection energy loss. The lower part of the box is filled with insulation layer of mineral wool. Their demands are made to the glass. It must be strong enough thick to withstand hail. At the same time it must be as transparent as possible, and then vice versa - the thinner, the better. Importantly surface quality. Commonly used optical tempered glass, which reduced the maximum metal content. Every extra percentage is important, because all the energy, glass delayed until absorber just will not come, and lost no avail. /20,21./

The vacuum collectors are used in parallel arranged glass tubular elements assembled into a module. The tubes are made on the principle of the thermos and made of high quality optical glass. The inside of the tube is sometimes granite or do a U-shaped. Of course, compared to flat panels, such modules are obtained by more complex and more expensive, but the vacuum collectors collect heat approximately 1.2-1.4 times higher in the winter work well, also capable of receiving energy from the scattered and reflected light (in the cloud weather and snow from the crust). /21./

From one square meter flat solar collector under conditions of Samara for household needs can be produced about 500 kW • h of heat per year. The annual demand of one man in hot water requires 1500 kW • h of heat and for heating one square meter modern home - about 100 kW • h per year. Solar collector is an additional source that can supply the heating system from 30 to 70% of the required heat. If in the winter and summer boiler and solar collector in turn take on major seasonal features in the off-season periods of the smooth interaction established between them. Such a rational combination not only allows to unload the boiler, but also provides a more gentle mode of its operation. The presence of the solar collector creates the conditions for long service life and increases the reliability of the equipment. /21./

4.4 Direct heat storage solar system

This system is versatile enough for the ever-changing climate. The main part of the structure – a solar collector, by which the heat is going directly to the building wall. Phase change material (PCM) has a melting temperature is about 30 degrees, and when it undergoes a phase change, it can release or absorb a significant amount of energy (~190 kJ/kg) as latent heat(Figure 12). The wall of the building at night keeps the received heat from the sun during the day. But PCM cools at night and ,after curing, produces heat, used for space heating. It is necessary to maintain the wall temperature at least 20 degrees. /19./

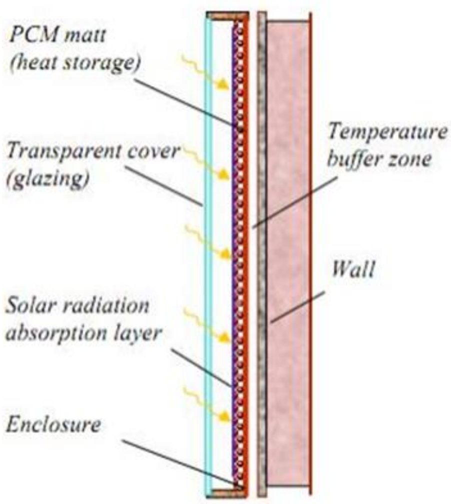


FIGURE 12. Construction of direct heat storage solar system

This system is easy to install, no additional equipment. During the summer, the system prevents the building from overheating and accordingly reduces the energy consumption for cooling. It also helps to save the minimum heat loss, adding insulation.

4.5 Underfloor heating

Invisible type of installation allows to forget about cleaning the dust and dirt of the radiators and pipes protruding. When the system does not raise dust into the air, creating ideal conditions for people suffering from allergies. Gentle radiant heat acts directly on the objects in the room, bypassing the intermediate stage of the initial warm air. The result - the same level of comfort, but at room temperature 2 ° C below. This has beneficial effects on human health, because to keep feet warm and head out in the cold - it's exactly what a person needs.

Every square meter of housing can be used underfloor heating system to heat the room that allows you to create a healthy indoor climate. It is possible to use different energy sources, but the most effective operation of the system is in its use with renewable energy sources. Compared with the traditional operation of heating systems, the use of underfloor heating systems can save up to 12 percent of the electricity and maintenance costs. /22./

5 CALCULATIONS

5.1 The plan of the facility

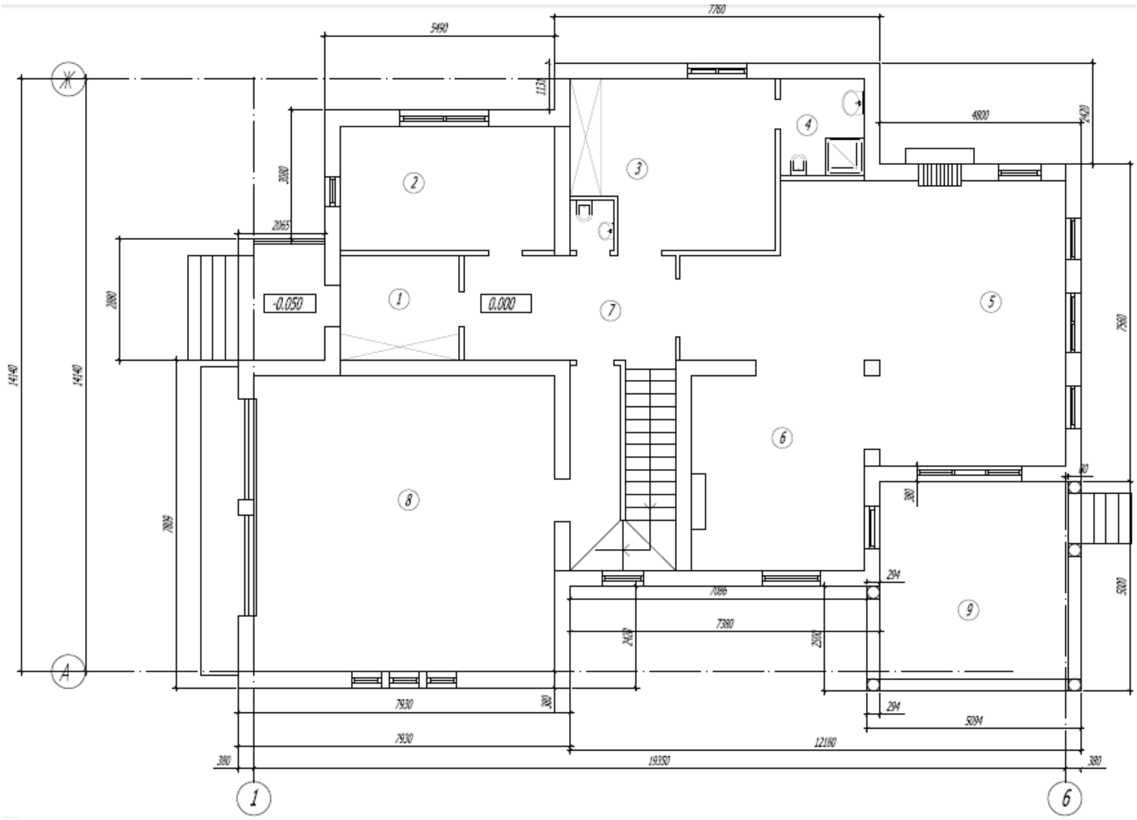


FIGURE 13. First floor plan.

TABLE 3. Schedule of premises (1st floor):

Room number	Designation	Area, m^2
1	Tambour	7,1
2	Cabinet	15,1
3	Guest bedroom	20
4	Guest WC	4,6
5	Living room	34,6
6	Kitchen-dining room	29,9
7	Hall with stairs1	25,1
8	Garage	49.6
9	Terrace	24,7

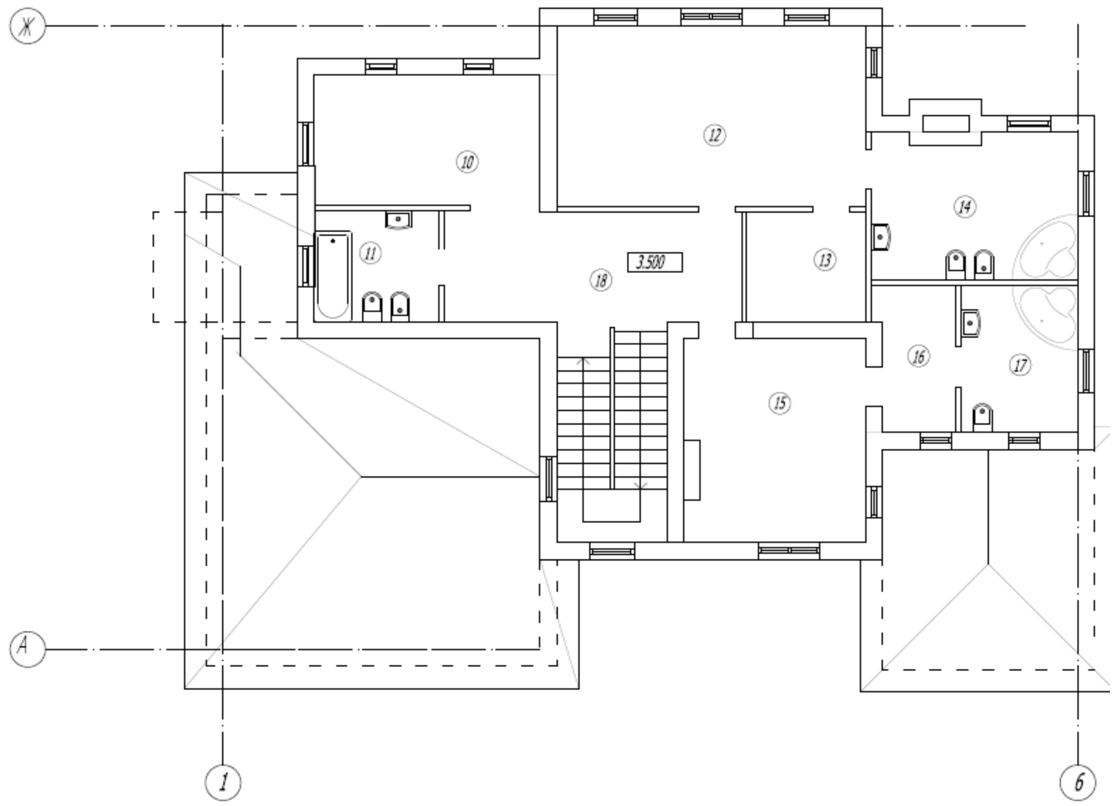


FIGURE 14. Second floor plan

TABLE 4. Schedule of premises (2st floor):

Room number	**Designation**	**Area, m²**
10	Bedroom1	14.94
11	WC1	7.114
12	Bedroom2	28,64
13	Dressing room1	6,7
14	WC2	15,62
15	Bedroom3	19,13
16	Dressing room2	5,98
17	WC3	9,2
18	Hall with stairs2	25.1

5.2 The climatic conditions of the construction area

The data shown in this section are taken from СНиП 23-01-99 «BUILDING CLIMATOLOGY». The desired settings selected and translated into English. /23./

5.2.1 Climatic parameters of cold season

TABLE 5. Climatic parameters of cold season.

Region	Air temperature of the coldest day ^{0}C	Air temperature of the coldest five-day period ^{0}C	Absolute minimum temperature of ambient air ^{0}C	The average monthly relative humidity of the coldest month	Rainfall in November-March	Prevailing wind direction for the December-February
Samara	-37.5	-33	-43	84%	176	SE

5.2.2 Climatic parameters of warm season

TABLE 6. Climatic parameters of warm season.

Region	Avarage air temperature ^{0}C	Avarage maximum air temperature of the warmest day ^{0}C	Absolute maximum temperature of ambient air ^{0}C	The average monthly relative humidity of the coldest month	Rainfall in April-October	Prevailing wind direction for the December-February
Samara	+26	+28	+39	64%	307	W

5.2.3 Average monthly and annual air temperature

TABLE 7. Average monthly and annual air temperature (^{0}C)

	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Год
Samara	-13.5	-12.6	-5.8	5.8	14.3	18.6	20.4	19	12.8	4.2	-3.4	-9.6	4.2

5.3 Selected specifications

Orientation

Most of the glazed part of the facade is located on the south. So at the top of the drawing – south, in the bottom – north.

External wall

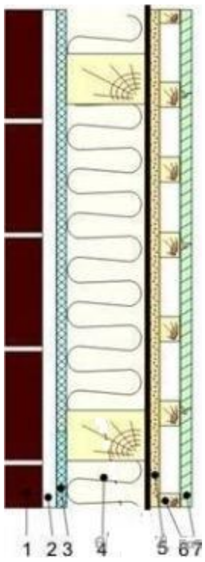


FIGURE 15. The construction of the exterior wall

TABLE 8. The construction of the exterior wall

№ Layer	Material	Thickness	Heat conduction coefficient
1	Brick	0.25	0.8
2	Air	0.04	2.56
3	Windproof slab ISOPLAAT	0.12	0.055
4	Flax insulation VAL-FLAX	0.2	0.0389
5	QUICK DECK	0.016	0.2
6	GREEN BOARD	0.014	0.95
7	ISOTEX	0.012	0.045

Windows

In the calculations was used six-chamber glazing REHAU INTELIO , 86 mm thick with thermal resistance R = 0.95 m^2°C/W(Figure 16,17).

FIGURE 16. The constriction of choosen window.

Selected sizes : 0,8m x 1,5m ; 1,5m x 1,5m ; 2,1m x 1,5m

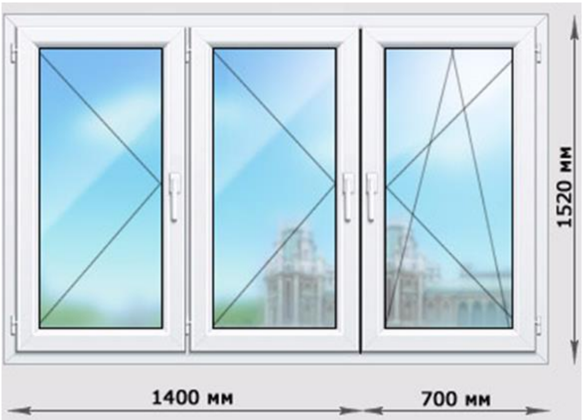


FIGURE 17. Sizes of choosen windows.

One leaf is "blind", and the other is swivel-hinged. The using of special glass provides exceptional sound insulation, so that reduces the noise level in the room in half. Convection limiter divides the airspace of the insulating glass unit by two antechambers. They are working independently, thereby reducing heat loss by reducing air convection in the space of the glazing rebate. In winter glass saves up to 90% of the thermal wave and thus increases the temperature in the room at 4 degrees. Moreover, in the summer it reflects infrared radiation and brings the cool in the house.

Biochemical experiments show that sunlight helps the formation of serotonin in the human body. This hormone is responsible for energy, mood and health. Features of engineering solutions contribute to reducing the height of the construction profile and let the room for 10% more light comparing to conventional plastic windows. The smooth surface of the profiles does not absorb dust and dirt. That profile is environmentally friendly. It reduces the risk of allergies and skin rashes.

Roof

Dry loose expanded clay layer creates a well-ventilated space, and at the same time retains heat. The loose expanded clay layer well lets air and moisture, and therefore outside the required wind and water resistant resin layer. Leave a small gap between a ventilated roof and expanded clay layer to release moisture vapor out.

Inside a layer of expanded clay needs a vapor barrier protection. Expanded clay back-fill is done in a special frame. On the floor, make a special box, it is poured concrete block and placed on top of the wooden or tiled flooring.

Amount of residents

Choosen house project is designed for one family - two adults and three children.

Choosing heating solutions

Underfloor heating is best suited to the GSHP. Compared with the traditional operation of heating systems, the use of underfloor heating systems can save up to 12 percent of the electricity and maintenance costs.

Sunny weather is usual for Samara, so it is suitable to use solar collectors for water heating. Solar collector is an additional source that can supply the heating system from 30 to 70% of the required heat. The presence of the solar collector creates the conditions for long service life and increases the reliability of the equipment. Vacuum solar collector was used for calculations.

5.4 Calculations of heat losses through the building envelope.

Calculations are making according to СНиП 23-02-2003 «THERMAL PERFORMANCE OF THE BUILDINGS» /24./

Total heat losses through the building envelop ΣQ_{tp} can be calculated according to formula:

$$\Sigma Q_{tp} = \Sigma Q_{o.i}(1 + \Sigma \beta_i) \quad (1)$$

Where ΣQo.i –sum of main heat losses, counted additives β - additional heat losses(Table 9)

TABLE 9. Additional heat losses accorging to the orientation

North	0.1
South	0
East	0.1
West	0.1

For calculating every $Q_{o,}$ some values must known. $K_{o.i}$ – coefficient of heat transfer of heating envelop, W/(m^{2}K). For exterior walls it calculated according to table with the helps of following formulas:

Reduced total thermal resistance:

$$R_0 = \left(\Sigma Rsl + \frac{1}{\alpha_o} + \frac{1}{\alpha_{in}}\right) r, \frac{m^2K}{W} \quad (2)$$

r - heat transfer performance uniformity factor= 0.8

α_o - the heat transfer coefficient of the outer surface of the building envelope

α_{in} - the heat transfer coefficient of the inner surface of the building envelope

$$R_0 = \frac{1}{8.7} + \frac{0.25}{0.8} + \frac{0.04}{2.56} + \frac{0.12}{0.055} + \frac{0.2}{0.0389} + \frac{0.016}{0.2} + \frac{0.014}{0.95} + \frac{0.012}{0.045} + \frac{1}{23} = 8.17\ \frac{m^2K}{W} \quad (3)$$

Coefficient of exterior wall heat transfer K(Table 10):

$$K = \frac{1}{R_0} = \frac{1}{8.17} = 0.122\ \frac{W}{m^2K} \quad (4)$$

TABLE 10. Coefficients of heat transfer for used constructions

Floor 1	0.476
Floor 2	0.233
Floor 3	0.116
Floor 4	0.072
Ex wall	0.122
Door	1.339
Roof	0.130
Window	1.053

Calculation of main heat losses

$$Q_o = K_{o.i}A_{o.i}(t_{in} - t_{out})n_i \quad (5)$$

Where $A_{o.i}$ – the surface area, m^2, t_{in} *and* t_{out} – temperature difference between outdoor and indoor air, °C

t_{out}=-30 for Samara region

Calculated results are shown in the Appendix 1. The main resilts shown in the Table 11

TABLE 11. Heat losses for each floor

	Floor	Area, m^2	Losses,W
Total area	1st	150.08	8698
257.39	2nd	107.31	6830

5.5 The calculations of the underfloor heating

The underfloor heating parameters will be calculated by method described in the book "Designing of the underfloor heating Uponor". /25./

1. Calculation of density of the heat flow:

$$q_{calc\_1st} = \frac{P_1}{A_1} = \frac{8698}{150,08} = 57.95 \frac{W}{m^2} \quad (6)$$

$$q_{calc\_2nd} = \frac{P_2}{A_2} = \frac{6830}{107.31} = 63.65 \frac{W}{m^2} \quad (7)$$

Where A_1-1st floor area, A_2-2nd floor area, P_1-1st floor heat losses, P_1-2nd floor heat losses

2. Calculation of average floor surface temperature:

$$t_{average1} = \frac{q_{calc\_1st}}{\alpha_{floor}} + t_{room} = \frac{57.9}{11} + 21 = 26.26^o C \quad (8)$$

$$t_{average2} = \frac{q_{calc\_2nd}}{\alpha_{floor}} + t_{room} = \frac{63.65}{11} + 21 = 26.78^o C \quad (9)$$

Where $t_{average1}$ - average temperature of the 1st floor surface, °C; $t_{average2}$ - average temperature of the 2nd floor surface, °C; t_{room} - temperature of the room, °C; q_{calc_1st}= density of the heat flow on 1st floor, W/m^2 ; q_{calc_2nd}= density of the heat flow on 2nd floor, W/m^2 α_{floor}= heat transfer coefficient of the floor, 10 – 12 W/m^{2}K

$$\Delta T_1 = t_{average1} - t_{room} = 26.26 - 21 = 5,26^0 C \quad (10)$$

$$\Delta T_2 = t_{average2} - t_{room} = 26.78 - 21 = 5,78^0 C \quad (11)$$

3. Construction of the floor have an effect on the temperature drop. This temperature has a big meaning in underfloor heating design. Transfer coefficient of the materials which located above the pipes must be calculated to finding floor surface temperature drop.

1st layer is fibreboard: d1 = 0.01m, λ1 = 0.14 W/m*K, 2nd layer is laminate: d1 = 0.01m, λ1 = 0.15 W/m*K

$$R = \frac{d_1}{\lambda_1} = \frac{0.01}{0.14} + \frac{0.01}{0.15} = 0.13\frac{m^2K}{W} \quad (12)$$

$$U = 1/R = 1/0.13 = 7.69\frac{W}{m^2K} \quad (13)$$

Temperature drop through the floor materials determine by the values of the density of heat flow and thermal resistance coefficient. It is 7^0C (Figure 18).

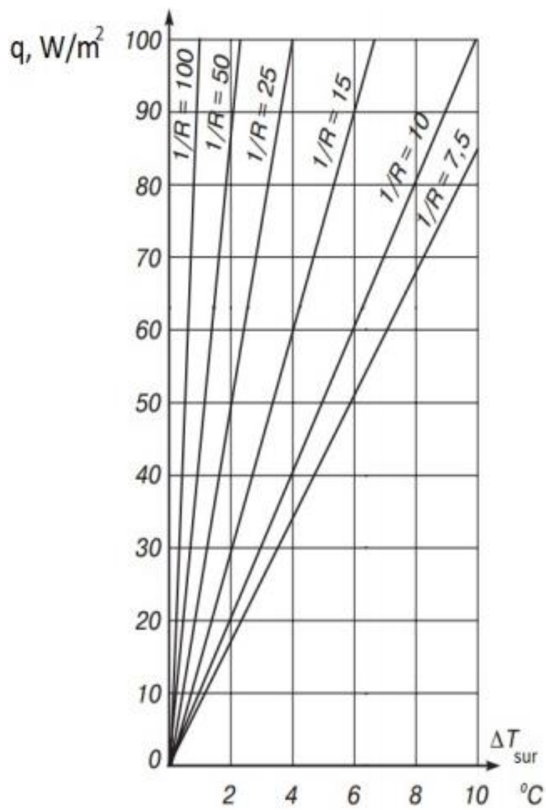


FIGURE 18. Decreasing floor surface temperature through the floor cover materials

In underfloor heating may be used concrete or wood above pipes. Lowering the temperature through the floor construction is shown in figure below, where line A refers to a self-leveling concrete floors, line B refers to a roofed floors with fibreboard 16 mm thick, line C refers to the floors wooden structure with fibreboard 22 mm thick. In this calculations was used 16mm thick fibreboard. Line B were choosen and it shows 17.5°C temperature (Figure 19).

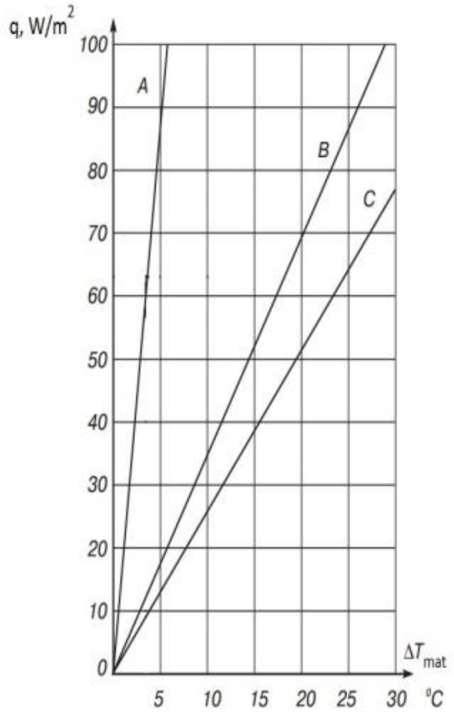


FIGURE 19. Temperature drop through the floor with different structure

4. As usual, the temperatire difference between return and supply is designed as $\Delta T_{diff} = 5^{o}C$. The temperature in the underfloor heating pipes is achieved at a certain heat flux density and developed in accordance with the temperature of the room.

   Calculation of the average return and supply water temperature of the underfloor heating:

$$t_{averagewater} = t_{room} + \Delta T_{\alpha} + T_{sur} + T_{mat} = 21 + 5.5 + 7 + 17.5 = 51^{0}C \quad (14)$$

   for ΔT_{α} were used average temperature between ΔT_1 and ΔT_2

5. Calculation of volume flow of the water inside the pipes

$$q_v 1 = \frac{P}{c_p \cdot \rho \cdot \Delta t} = \frac{8.698}{4.2*1*5} = 0,414\frac{l}{s} = 1491\frac{l}{h} \quad (15)$$

$$q_v 2 = \frac{P}{c_p \cdot \rho \cdot \Delta t} = \frac{6.830}{4.2*1*5} = 0,325\frac{l}{s} = 1171\frac{l}{h} \quad (16)$$

Where: q_{v1} - volume flow for 1st floor, l/s; q_{v2} - volume flow for 2nd floor, l/s; C_p - specific heat capacity, kJ/kg*K;

5.6 The calculations of the ground-source heat pump

For calculations DHP-L Opti 16 from Danfoss company was choosen.

1. Calculation of power circuit GSHP. The values P_h= 16.4 kW and COP=4.8 are taken from the passport of heat pump

$$P_e = P_h(1-\frac{1}{COP}) = 16.4*(1-\frac{1}{4.8}) = 12.98kW \tag{17}$$

Where COP- coefficient of performance of the heat pump, P_h - nominal power of the heat pump

2. In the thesis, q_{ground} = 60 W/m was chosen for the vertical borehole and q_{ground} = 10 W/m for the horizontal loop. The length of the collector can be calculated:

$$L = \frac{P_e}{q_{ground}} = \frac{12980}{70} = 185m \tag{18}$$

$$L = \frac{P_e}{q_{ground}} = \frac{12980}{20} = 649m \tag{19}$$

For the horizontal loop the total length of the ground heat exchanger is 649 m. Here pipes located with the 0.7 m distance from each other. One borehole need to 649*0.7=454.3 m^2 place the pipes horizontally.

For the vertical borehole the total length of the ground heat exchanger is 185 m

Heating:

It is necessary to determine the average daily consumption of thermal energy given the fact that the hot water in the peak mode operates about 8 hours, and maintains the temperature of remaining time (roughly the daily peak value of the coefficient k = 0.5)

QDHW-day= 4,1*0,5*24hour= 49,2 kWh/day (20)

In rational choice of heating temperature during the day is allowed to peak value ratio = 0.7

Qheat-day= 15,5*0,7*24hour= 260,4 kWh/day (21)

Total daily consumption of thermal energy

Qtotal-day= 49,2+260,2=309,6 kWh/day (22)

Thermal energy consumption in the heating season (at full power - 180 days)

Qh.season=309,6*180= 55728 kWh (23)

Consumption of electric energy to produce heat energy by the heat pump over the year taking into account the COP = 4,8

Wheating =55728/ 4,8 = 11.610 kWh/a (25)

For calculation of CO_2 emissions was used Table 12 and following formula.

TABLE 12. Typical emissions factor

Fuel type	CO_2 emission kg CO_2/MWh
Heavy oil	278
Light oil	267
Natural gas	202
Wood	395
Electricity	369
District heating	161

$$CO_2 = W_{Heating} * kg\frac{CO_2}{MWh}, \frac{kgCO_2}{year} \quad (26)$$

$W_{heating}$- shows how much electricity do heat pump use annually to heat the building, $kg\frac{CO_2}{MWh}$ - typical emission factor, shows how much CO2 emit per MWh energy.

$$CO_2 = 14.010 * 369 = 5169.7 \frac{kgCO_2}{year} \quad (27)$$

5.7 Determining the size of the solar collector

For the project vacuum solar collector ATMOSFERA was choosen.

The size of the reservoir is determined by considerations of expediency. The average family uses 98 liters of hot water per adult and 49 liters per child. From this is determined the size of the solar collector tank.

1. Determination of whether the water temperature should be increased and its volume.

   V=100*2+ 50*3= 350 liters (28)

   The temperature of the incoming water in the summer = 20 ° C. It must be heated to 56 ° C. 56-20 = 36 ° C.

2. Calculation amount of energy required to heat the determined amount of water.

   350 x 36°C =12600 kcal. (29)

   (1L required 1kkal to raise the temperature by 1 ° C.)

   12600 / 859.8 = 14.65 kWh (1kWh = 859.8 kcal). (30)

3. Determine the solar collector output value based on the value of illumination.

   In July in Samara estimated illumination value = 5,9.

   5.9 * 0.7= 4.13 kWh absorbed energy transfer value of vacuum tubes to collector area of absorption (31)

   4.13 * 0.08 m2 absorption area = 0.3304 kWh / tube /. (32)

4. Determine the number of tubes of the solar collector to provide load.

Using the value calculated above, define the number of tubes, which must be set at a given load.Load = 14.65 kWh. (34)

absorption area = 0.3304 kWh / tube /.

14.65/ 0.3304 = 45 tubes. (35)

Manufacturer has 20 and 30 tubes collectors. Two solar collectrors with 30 and 20 tubes construction was choosen (50 tubes).

5.8 The calculations of ventilation heat losses.

$$\Phi_{VENT} = q_{m,v} \cdot c_p \cdot (1 - \Sigma_{HRV})(T_{in} - T_{out}) \quad (36)$$

where Σ_{HRV}= heat recovery=0.85; $q_{m,v}$=ventilation mass flow rate.

$$q_v = n \cdot V_{in} = 0,5 \cdot V_{in} (\frac{m^3}{h})$$
$$\Rightarrow q_{m,v} = \rho \cdot q_v = \rho \cdot 0,5 \cdot V_{in} = 1,2 \cdot 0,5 \cdot 771 = 462,6 kg/h \quad (37)$$

$$\Phi_{VENT} = q_{m,v} \cdot c_p \cdot (1 - \Sigma_{HRV})(T_{in} - T_{out}) =$$
$$= 462,6 \cdot 1 \cdot (1 - 0,85)(21 - (-30)) = 3539 \frac{kJ}{h} = 983W \quad (38)$$

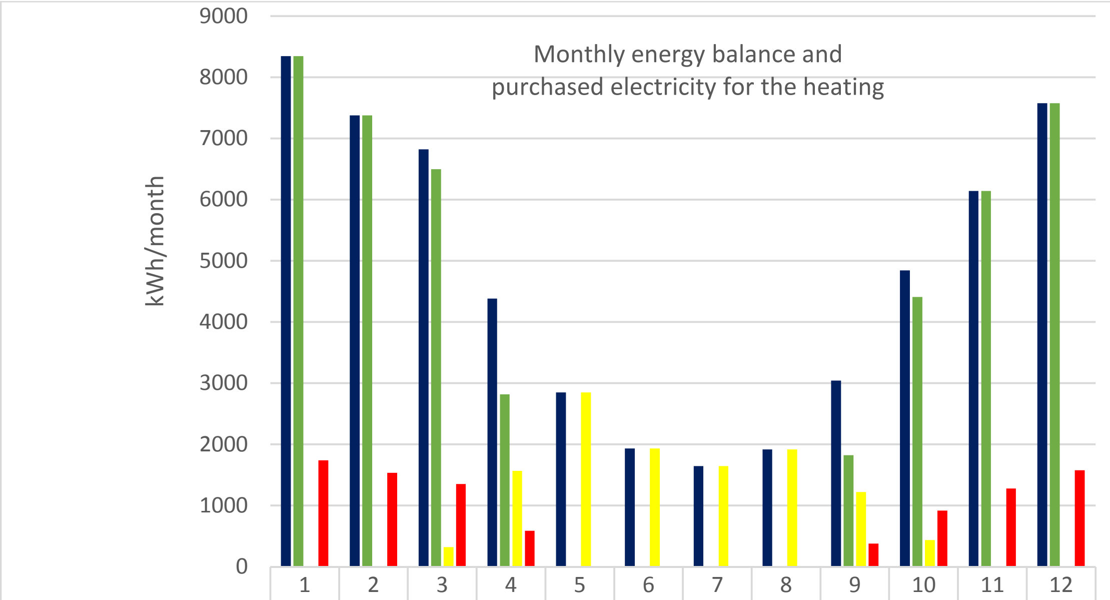
5.9 Monthly energy demand.

According to point 5.2.3, monthly energy demand and average energy demand was found (Table 13).

TABLE 13. Monthly energy demand.

N month	vent	heat losses	DHW	Sum,W	Monthly demand, kWh/month
Jan	664.9875	8499.059475	2050	11214.05	8343.25
Feb	647.64	8277.34488	2050	10974.98	7375.19
Mar	516.57	6602.16794	2050	9168.738	6821.54
Apr	292.98	3744.51316	2050	6087.493	4383.00
May	129.1425	1650.541985	2050	3829.684	2849.29
Jun	46.26	591.23892	2050	2687.499	1935.00
Jul	11.565	147.80973	2050	2209.375	1643.77
Aug	38.55	492.6991	2050	2581.249	1858.50
Sep	158.055	2020.06631	2050	4228.121	3145.72
Oct	323.82	4138.67244	2050	6512.492	4688.99
Nov	470.31	6010.92902	2050	8531.239	6347.24
Dec	589.815	7538.29623	2050	10178.11	7572.51
					56876.00

According to calculations in points 5.6 and 5.7, it is visible, that producing energy by equipment "covered" energy demand of the house. (Figure 20).



	1	2	3	4	5	6	7	8	9	10	11	12
Heat demand	8343	7375	6822	4383	2849	1935	1644	1920	3044	4845	6143	7573
Heat by GSHP	8343	7375	6499.9	2816.9	0	0	0	0	1821.5	4408.9	6143	7573
Heat by sun	0	0	322.14	1566.1	2849	1935	1644	1920	1222.5	436.13	0	0
Purchased electricity	1738	1536	1354	587	0	0	0	0	379	919	1280	1578

FIGURE 20. The scale of monthly energy balance.

6 ANALYSIS OF RESULTS

The analysis results of an energy- and eco-efficient design concept of two-storey residential house in Shiryaevo village are shown below. Chosen technological solutions suitable for demanding climate of the Samara. Requirements of passive and environmentally friendly construction are met to the maximum, all the necessary equipment is available in the public domain, or have the opportunity to order from nearby towns. There is also a chance to expand and improve the project further, taking into account other engineering systems and technological solutions.

Heat losses:

	Floor	Area, m^2	Losses,W
Total area	1st	150.08	8698
257.39	2nd	107.31	6830

U-values:

Floor 1	0.476
Floor 2	0.233
Floor 3	0.116
Floor 4	0.072
Ex wall	0.122
Door	1.339
Roof	0.130
Window	1.053

Airtighness: n_{50} = 0.4 / h

Ventilation system: with heat recovery: 85%

Heating system:
floor heating + heat to HRV, GSHP, solar collectors , heat storage

<u>GSHP:</u>

DHP-L Opti 16 from DANFOSS

vertical loop depth 185m

CO_2 emssions 5169 kgCO_2/year

<u>Underfloor heating:</u>

UPONOR for timber floor

volume flow of water inside the pipes 1st fl.-1491 l/h, on 2nd fl.-1171 l/h

average floor surface temperature 26,5 ^{0}C

average supply and return temperature 51 ^{0}C

<u>Vacuum solar collectors:</u>

ATMOSFERA СВК-А

absorbed energy: 0,3304 kW/tube/day

amount of tubes: 50

<u>Heat storage</u>

350 liters

The energy balance of the building has been achive(Figure 21). This indicates that the house is comfortable to live in all year round.

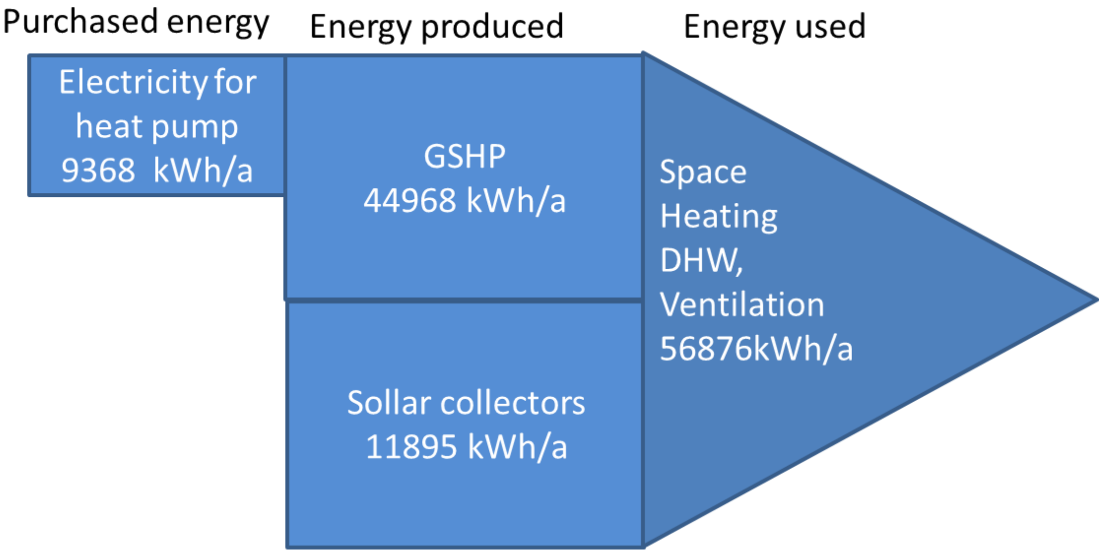


FIGURE 21. Energy balance chart.

7 CONCLUSION

This study was designed to create an energy- and eco-efficient design concept of two-storey residential house in Shiryaevo village. The project must comply with the requirements of passive construction and environmentally friendly (green) construction.

Despite the extreme climatic conditions and the lack of a wide range of technological solutions, the following parameters were chosen: ground source heat pump,that emits the least amount of carbon dioxide, used for heating and easy to install; underfloor heating (suitable for GSHP); solar collectors, that can help with heating of water and ventilation with heat recovery, which is characterized by its energy efficiency and positive influence on the indoor climate. The colaboration of these technology solutions help to achieve the aim.

Construction of a whole village of these energy efficient and green buildings will help to preserve nature Zhiguli Mountains in its original form and not to aggravate the ecology of the region. Unfortunately, the construction of this house will be able to afford not to everyone. Also in Russia, which has a lot of gas and oil, pay back period of that type of houses may takes a years. But if it possible to use at least some of the options, human can takes part in the global fight for the environment, starting with the design and construction of his own house.

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APPENDIX 1

Surface number	Surface name	Inside temperature tв.от, ºС	Characteristic of envelope						Temperature difference, tв-tн	Main heat losses Qо, Вт	Add β		Coefficient (1+Σβ)	Heat losses throught the envelope Qтп, Вт	Heat losses	
			Name	orientation	Sizes , м		Area, м2	Heat transfer coefficient K, Вт/м2*К			On orientation	Others			With infiltration Qи, Вт	All losses Qот, Вт
					a	b										
1 этаж																
1	Tambour	20	Пл 1	-	x	x	5.00	0.476	50	119			1	119		119
		20	Пл 2	-	x	x	2.10	0.233	50	24			1	24		24
		20	НС	В	2.7	3.5	7.35	0.122	50	45	0.1	0.05	1.15	52		52
		20	Д	В	1	2.1	2.10	1.339	50	141	0.1	0.05	1.15	162	112	273
															SUM	469
2	Cabinet	22	Пл 1	-	x	x	11.92	0.476	52	295			1	295		295
		22	Пл 2	-	x	x	3.18	0.233	52	38			1	38		38
		22	НС	В	3	3.5	7.35	0.122	52	47	0.1	0.05	1.15	54		54
		22	НС	Ю	5.5	3.5	18.05	0.122	52	115	0	0.05	1.05	120		120
		22	ОК	Ю	0.8	1.5	1.20	1.053	50	63	0	0.05	1.05	66	64	130
		22	ОК	В	2.1	1.5	3.15	1.053	50	166	0.1	0.05	1.15	191	193	384
															SUM	1022
3	Guest bedroom	22	Пл 1	-	x	x	5.51	0.476	50	131			1	131		131
		22	Пл 2	-	x	x	5.51	0.233	50	64			1	64		64
		22	Пл 3	-	x	x	8.97	0.116	50	52			1	52		52
		22	НС	Ю	5.6	3.5	17.35	0.122	50	106	0	0.05	1.05	111		111
		22	ОК	Ю	1.5	1.5	2.25	1.053	50	118	0	0.05	1.05	124	120	244
		22	НС	В	1.1	3.5	3.85	0.122	50	23	0.1	0.05	1.15	27		27
															SUM	630
4	Guest WC	25	Пл 1	-	x	x	3.48	0.476	53	88			1	88		88
		25	Пл 2	-	x	x	1.12	0.233	53	14			1	14		14
		25	НС	В	2.4	3.5	8.40	0.122	55	56	0.1	0.05	1.15	65		65
		25	НС	Ю	2.1	3.5	7.35	0.122	55	49	0	0.05	1.05	52		52
															SUM	218
5	Living room	22	Пл 1	-	x	x	14.80	0.476	50	352			1	352		352
		22	Пл 2	-	x	x	9.86	0.233	50	115			1	115		115
		22	Пл 3	-	x	x	10.20	0.116	50	59			1	59		59
		22	НС	Ю	4.8	3.5	15.60	0.122	50	95	0	0.05	1.05	100		100
		22	НС	З	7.5	3.5	21.60	0.122	50	132	0.1	0.05	1.15	152		152
		22	НС	С	5	3.5	14.35	0.122	50	88	0.1	0.05	1.15	101		101
		22	ОК	Ю	0.8	1.5	1.20	1.053	50	63	0	0.05	1.05	66	64	130
		22	ОК	З	0.8	1.5	1.20	1.053	50	63	0.1	0.05	1.15	73	74	146
		22	ОК	З	1.5	1.5	2.25	1.053	50	118	0.1	0.05	1.15	136	138	274
		22	ОК	З	0.8	1.5	1.20	1.053	50	63	0.1	0.05	1.15	73	74	146
		22	ОК	С	2.1	1.5	3.15	1.053	50	166	0.1	0.05	1.15	191	162	353
															SUM	1928
6	Kitchen-dining room	22	Пл 1	-	x	x	4.45	0.476	50	106			1	106		106
		22	Пл 2	-	x	x	4.45	0.233	50	52			1	52		52
		22	Пл 3	-	x	x	4.45	0.116	50	26			1	26		26
		22	Пл 4	-	x	x	5.48	0.072	50	20			1	20		20
		22	ОК	С	1.5	1.5	2.25	1.053	50	118	0.1	0.05	1.15	136	116	252
		22	ОК	З	1.5	1.5	2.25	1.053	50	118	0.1	0.05	1.15	136	116	252
		22	НС	З	2.5	3.5	6.50	0.122	50	40	0.1	0.05	1.15	46		46
		22	НС	С	4	3.5	11.75	0.122	50	72	0.1	0.05	1.15	82		82
															SUM	836
8	Garage	22	Пл 1	-	x	x	15.63	0.476	50	372			1	372		372
		22	Пл 2	-	x	x	10.73	0.233	50	125			1	125		125
		22	Пл 3	-	x	x	9.46	0.116	50	55			1	55		55
		22	Пл 4	-	x	x	13.78	0.072	50	49			1	49		49
		22	НС	С	7.9	3.5	24.05	0.122	50	147	0.1	0.05	1.15	169		169
		22	НС	В	7.8	3.5	27.30	0.122	50	167	0.1	0.05	1.15	192		192
		22	ОК	С	0.8	1.5	1.20	1.053	50	63	0.1	0.05	1.15	73	62	134
		22	ОК	С	0.8	1.5	1.20	1.053	50	63	0.1	0.05	1.15	73	62	134
		22	ОК	С	0.8	1.5	1.20	1.053	50	63	0.1	0.05	1.15	73	64	137
		22	К	-	x	x	49.60	0.130	40	258			1	258		258
															SUM	1625
													SUM 1st floor			6727

APPENDIX 1

								2nd floor									
10		22	НС	В	3	3.5	8.25	0.122	50	50	0.1	0.05	1.15	58		58	67
		22	НС	Ю	5.5	3.5	17.97	0.122	50	110	0	0.05	1.05	115		115	132
		22	ОК	Ю	0.8	0.8	0.64	1.053	50	34	0	0.05	1.05	35	26	62	71
	Bedroom1	22	ОК	Ю	0.8	0.8	0.64	1.053	50	34	0	0.05	1.05	35	34	69	80
		22	ОК	В	1.5	1.5	2.25	1.053	50	118	0.1	0.05	1.15	136	138	274	315
		22	Пл 1	-	x	x	11.99	0.476	50	285			1	285		285	328
		22	Пл 2	-	x	x	2.94	0.233	50	34			1	34		34	39
		22	К	-	x	x	14.93	0.130	40	78			1	78		78	89
															SUM	976	1122
11		25	Пл 1	-	x	x	6.69	0.476	53	169	0		1	169		169	194
		25	Пл 2	-	x	x	0.42	0.233	53	5	0		1	5		5	6
	WC1	25	НС	В	2.8	3.5	8.60	0.122	53	56	0.1	0.05	1.15	64		64	74
		25	НС	С	2.5	3.5	8.75	0.122	53	57	0.1	0.05	1.15	65		65	75
		25	ОК	В	0.8	1.5	1.20	1.053	53	67	0.1	0.05	1.15	77	74	151	173
		25	К	-	x	x	7.11	0.130	43	40			1	40		40	46
															SUM	494	568
12		22	НС	Ю	7.8	3.5	22.65	0.122	50	138	0	0.05	1.05	145		145	167
		22	НС	В	1.1	3.5	3.85	0.122	50	23	0.1	0.05	1.15	27		27	31
		22	ОК	Ю	0.8	1.5	1.20	1.053	50	63	0	0.05	1.05	66	64	130	150
		22	ОК	Ю	1.5	1.5	2.25	1.053	50	118	0	0.05	1.05	124	120	244	281
	Bedroom2	22	ОК	Ю	0.8	1.5	1.20	1.053	50	63	0	0.05	1.05	66	64	130	150
		22	ОК	З	0.8	1.5	1.20	1.053	50	63	0.1	0.05	1.15	73	74	146	168
		22	НС	З	2.4	3.5	7.20	0.122	50	44	0.1	0.05	1.15	51		51	58
		22	Пл 1	-	x	x	18.19	0.476	50	433			1	433		433	498
		22	Пл 2	-	x	x	10.45	0.233	50	122			1	122		122	140
		22	К	-	x	x	28.64	0.130	40	149			1	149		149	171
															SUM	1577	1814
13	Dressing room1	20	Пл 1	-	x	x	6.70	0.476	50	160			1	160		160	183
		20	К	-	x	x	6.70	0.130	38	33			1	33		33	38
															SUM	193	222
14		25	Пл 1	-	x	x	12.03	0.476	53	304			1	304		304	349
		25	Пл 2	-	x	x	3.59	0.233	53	44			1	44		44	51
		25	К	-	x	x	15.62	0.130	43	87			1	87		87	100
	WC2	25	ОК	Ю	0.8	1.5	1.20	1.053	53	67	0	0.05	1.05	70	64	134	154
		25	ОК	З	0.8	1.5	1.20	1.053	53	67	0.1	0.05	1.15	77	74	151	173
		25	НС	Ю	4.8	3.5	15.60	0.122	53	101	0	0.05	1.05	106		106	122
		25	НС	З	3.8	3.5	12.10	0.122	53	78	0.1	0.05	1.15	90		90	103
															SUM	916	1053
15		22	НС	З	2.5	3.5	7.55	0.122	50	46	0.1	0.05	1.15	53		53	61
		22	НС	С	4.3	3.5	12.80	0.122	50	78	0.1	0.05	1.15	90		90	103
		22	ОК	З	0.8	1.5	1.20	1.053	50	63	0.1	0.05	1.15	73	74	146	168
	Bedroom3	22	ОК	С	1.5	1.5	2.25	1.053	50	118	0.1	0.05	1.15	136	88	224	258
		22	Пл 1	-	x	x	8.24	0.476	50	196			1	196		196	226
		22	Пл 2	-	x	x	8.24	0.233	50	96			1	96		96	110
		22	Пл 3	-	x	x	2.65	0.116	50	15			1	15		15	18
		22	К	-	x	x	19.13	0.130	40	99			1	99		99	114
															SUM	920	1058
16		20	Пл 1	-	x	x	3.33	0.476	50	79			1	79		79	91
		20	Пл 2	-	x	x	2.65	0.233	50	31			1	31		31	35
	Dressing room2	20	ОК	З	0.8	0.8	0.64	1.053	48	32	0.1	0.05	1.15	37	39	76	88
		20	НС	С	2	1.3	1.96	0.122	50	12	0.1	0.05	1.15	14		14	16
		20	К	-	x	x	5.98	0.130	38	30			1	30		30	34
															SUM	230	264
17		25	Пл 1	-	x	x	8.56	0.476	53	216			1	216		216	248
		25	Пл 2	-	x	x	0.86	0.233	53	11			1	11		11	12
		25	НС	З	3.8	3.5	12.66	0.122	53	82	0.1	0.05	1.15	94		94	108
	WC3	25	НС	С	3.1	3.5	10.21	0.122	53	66	0.1	0.05	1.15	76		76	87
		25	ОК	З	0.8	0.8	0.64	1.053	53	36	0.1	0.05	1.15	41	39	80	92
		25	ОК	С	0.8	0.8	0.64	1.053	53	36	0.1	0.05	1.15	41	33	74	85
		25	К	-	x	x	9.20	0.130	43	51			1	51		51	59
															SUM	603	693
														SUM 2nd floor		4757	5471
7,18		21	Пл 1	-	x	x	20.15	0.476	51	489			1	489		489	563
		21	Пл 2	-	x	x	2.76	0.233	51	33			1	33		33	38
		21	К	-	x	x	22.90	0.130	51	152			1	152		152	175
	Hall with stairs	21	НС	С	3	3.5	8.25	0.122	51	51	0.1	0.05	1.15	59		59	68
		21	НС	В	4.8	3.5	16.16	0.122	51	101	0.1	0.05	1.15	116		116	133
		21	ОК	С	1.5	1.5	2.25	1.053	51	121	0.1	0.05	1.15	139	116	255	293
		21	ОК	В	0.8	0.8	0.64	1.053	51	34	0.1	0.05	1.15	40	39	79	91
															SUM	2018	2321
														SUM building		13502	15528