ANALYSIS
of results of energy monitoring over the heating season of 2014-2015 after application of energy-efficient measures and renewable energy in a pilot four-room rural house

Promoting Energy Efficiency in Public Buildings in Uzbekistan

a joint project of the United Nations Development Programme (UNDP),
the Global Environment Facility (GEF),
and the State Committee for Architecture and Construction
of the Republic of Uzbekistan (Gosarchitectstroy)

Tashkent
2015

This analytic report was prepared by the project *Promoting Energy Efficiency in Public Buildings in Uzbekistan*, conducted jointly by the United Nations Development Programme (UNDP), the Global Environment Facility (GEF), and the State Committee for Architecture and Construction of the Republic of Uzbekistan.

Introduction

Since 2009, a special state program has been carried out in Uzbekistan on large-scale construction of individual housing and infrastructure in rural areas. The program aims for the fundamental renewal of villages and improvement of the quality of life of the rural population. In addition to the construction of houses based on standard designs, it also provides for the creation of utility service and social infrastructure at development sites.[1]

So, as a result of the implementation of the state program for construction of rural individual housing based on standard designs for 2009-2014, 1248 comprehensive new residential developments were created in 159 rural areas, with more than 33,500 modern comfortable individual houses comprising a total floor area of more than 4.6 million m^2. Under the program, 1677 km of water supply, 1,039 km of electric networks, 1,346 km of gas lines, 981 km of roads, and more than a thousand objects of social and market infrastructure entered into operation.[2]

The program will allow Uzbekistan to effectively develop rural areas and to implement investment plans for regional development, as well as to support the reforms for the development of the private sector and small businesses. Development of rural infrastructure and social services will help to improve the living standards of the rural population.[3]

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[1] Uza.uz, UzDaily.uz

[2] Decree of the President of Uzbekistan, PP-2282, 7 January 2015

[3] OLAM.uz

Design and construction of a pilot rural home and use of energy-efficient measures

1. **Design**

Under the direction of the UNDP/GEF project *Promoting Energy Efficiency in Public Buildings in Uzbekistan*, conducted jointly with Gosarchitectstroy, a pilot rural home with energy-efficient features and renewable energy was built in the Zangiata district of the Tashkent region. The pilot project sought to enhance practical experience; to yield analysis of application of new code requirements developed by the project; to implement new technical solutions; and to lay a foundation for future replication of positive results in state programs for rural housing in Uzbekistan.

In the selection of an optimal site for the construction of the pilot house, many developments in the nearby districts of Tashkent region were also examined. Experts of the design organization ToshuyzhoyLITI and representatives of the engineering and development company Qishloq Qurilish Invest took active part in this work, as well as experts of the UNDP/GEF project team. The objective of this working group was to survey individual subplots of all proposed developments in various districts of the Tashkent region, followed by selection of the site based on optimal orientation of the building for use of energy efficiency and renewable energy systems (Gosarchitectstroy protocol № EERV RU-001/2013 from 21 January 2014).

In developing the working design of the pilot house, decisions on building geometry were made in accordance with the standard design 184-33s TP-10/13, except for the extension of the boiler room by 400 mm. Level III of thermal performance, the maximum according to the building code KMK 2.01.04-97*, was applied, with the necessary parameters of building envelope insulation (basement, exterior walls, attic floors, as well as heat-supply and heat distribution systems) determined by calculation. A multi-layer building envelope (exterior walls, floors) was recommended and applied as yielding the most energy savings.

Another significant innovation, along with the implementation of the new provisions for thermal performance, was the first application of renewable energy systems in buildings of this type. Solar water heaters were used for household hot water supply, and a photovoltaic system was installed for electric supply for lighting and operation of circulating pumps for the heating system. Wall ventilators with heat recovery were applied to allow for ventilation without opening windows, filling the rooms of the house with fresh air without heat loss.

1.1. The Energy Passport of the pilot rural house

In accordance with the building code ШНК 1.03.01-08* *Contents, Development Procedures, Approval, and Confirmation of Design Documentation for Capital Construction of Enterprises, Buildings, and Structures*, a section entitled “Energy Efficiency” was included in design and cost estimation documentation for the pilot rural house, and an “Energy Passport” was completed, containing all general, energy-related, and operating design parameters of the building.

Table 1.1. **Technical and Economic Parameters of the Pilot Rural House**

№	Parameter	Units	Quantity
1.	Heated floor area	m^2	131.4
2.	Heat consumption for heating and ventilation	kWh/year	16,119
3.	Specific consumption of heat for heating and ventilation (per m^2)	kWh/(m^2.year)	110.3
4.	Area of building envelope elements	m^2	346
4.1	Walls	m^2	172.8
4.2	Windows	m^2	17.6

4.3	Entry doors	m^2	4.4
4.5	Attic floors	m^2	151.2
5.	Level of thermal performance	Level as defined by building code	III (highest)
6.	Building energy rating	Level as defined by building code	**A** (highest)

1.2. Cost parameters of the pilot rural house

Upon completion of design work, the plan review agency of Gosarchitectstroy presented its expert conclusions on all parts of the developed working design for the pilot rural house, with recommended cost of construction.

Overall cost of the pilot rural house after state plan review of the working design							
		State budget funds			**UNDP/GEF funds**		
Thousand Uzbek Soums	US dollars	Thousand Uzbek Soums	US dollars	%	Thousand Uzbek Soums	US dollars	%
220,796.10	**98,136.60**	**168,976.00**	**75,100.40**	**76.6**	**51,820.10**	**23,031.10**	**23.4**

2. Construction of the pilot rural house and technical measures

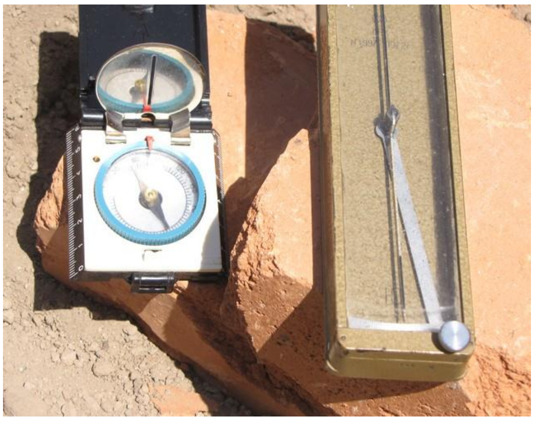
The following technical measures were applied in construction of the pilot rural house, as approved by the leadership of Gosarchitectstroy of the Republic of Uzbekistan:

Table. 1.2. **Technical measures**

№	**Energy-efficient technical measure or section**	**Construction process, material, or equipment used**	**Cost**	
			Uzbek Soums	**US dollars**
1	Exterior walls	Thermal insulation of exterior walls on the indoor side with Knauf Insulation mineral-wool panels of model brand Фасад TS 034 Aguastatik, 100 mm thick, in wooden framing elements, with Isocom vapor barrier and surfacing made of gypsum fiber plates 12 mm thick	10,336,136	4,337.40
2	Attic floors	Thermal insulation of attic floors and roofs with Knauf Insulation mats of model brand ТеплоКНАУФ Дом TS 040, 150 mm thick, with two layers of Isocom vapor barriers, and a layer of straw plates 50 mm thick, and a clay-based fixative surface layer 50 mm thick	7,199,023	3,020.90
3	Foundation and foundation elements	Thermal insulation of socles (foundation bases of walls) by polystyrene plates of model brand ПСБ-30 50 mm thick, on a hot bituminous adhesive with subsequent plaster surfacing along a mesh armature on a cement base.	2,072,701	869.70
4	Heat supply system	Instead of a typical inefficient standing boiler of brand КВ-30Т (30 kW), a wall-mounted autonomous Ariston	2,418,920	1,015

		boiler (produced by a joint enterprise of Uzbekistan and Italy) of 24 kW capacity and 95% efficiency was installed.		
5	Heating systems (heat delivery into rooms)	The system of heating pipes was modernized, with a 2-pipe heating system, instead of a single pipe as in the standard design. More heat-resistant PVC pipes were used. Manual heat regulators were installed on radiators with heat-reflective foil screens behind them on the walls. Devices for metering of hot water were also installed.	8,481,274	3,559
6	Ventilation and heat recovery	Wall ventilators with heat recovery of the Marley brand (Germany) were installed – a set of four per living area in the house, connected to power supply.	6,593,400	2,930.40
7	Photovoltaic system	A photovoltaic system with nominal capacity of 170-200W was installed on the roof, to serve as reserve electric supply for lighting and assurance of uninterrupted operation of boiler-room equipment (electricity supply for a circulating pump for heat delivery throughout the house.	4,742,170	1,990
8	Solar water heaters	Solar water heaters were installed on the roof as part of a system with 24-hour operation: 3 solar water-heating collectors, connected with a bivalent water heater of 500-liter capacity, for household hot water supply.	7,210,958	3,026
9	Windows and exterior doors	Installation of new technology of 3- and 4-chamber reinforced plastic frames with double glazing. Installation of window frames closer to the line of the outer walls, and not in the middle as in traditional solutions, at no incremental cost, with use of foam to fill all the voids between the window frame and the outer wall.	Completely covered by government budget financing	

Photo gallery of energy-efficient measures in the pilot rural house



Selection of a south-facing site

Construction of the house

Architects' oversight of construction

Visit by specialists from Knauf

Discussion of the design of the house

Thermal insulation and vapor barrier (from inside)

Insulation (from inside the house)


Attachment of the Isocom vapor barrier film

Plasterboard paneling

Manual heat controls

Wall-mounted autonomous boiler

Two-pipe heating system


Insulation of the foundation at the base of walls

Wall-mounted heat recovery ventilators

Insulation of the attic floor

Installation of material and equipment for solar-energy systems

Bathroom

Finished floor in living area

Indoor living areas

Overview of completed energy-efficient rural home[4]

[4] All photographs in this report are taken by the UNDP/GEF project *Promoting Energy Efficiency in Public Buildings in Uzbekistan*.

II. Energy audit of the pilot rural house

As already noted above, one of the main tasks of the project is the active implementation of updated building codes (bearing the Russian initials КМК, ШНК), which call for the mandatory use of energy-efficient technologies in construction and renovation of buildings.

To this end, the pilot rural house was built, with the UNDP/GEF co-financing to pay for energy-efficiency measures and renewable energy, together with contributions of the organizations authorized by the Government. In order to determine the economic and social benefits from the construction of the pilot house and justify the further spread of best practices, the project carried out energy audit, assessment of the level of energy consumption, and analysis of applied engineering solutions. The project also developed recommendations for the widespread adoption of energy-saving and renewable technologies in large-scale construction of rural housing in Uzbekistan.

The goals of the energy audit were as follows:

- Examination of electric equipment (lighting, air conditioners, etc.) and assessment of their condition;
- Examination of autonomous heat supply sources and assessment of their condition;
- Collection and processing of data on energy consumption of the pilot rural house;
- Uninterrupted monitoring of gas and electricity supply over the whole heating season, with measurement of actual energy consumption;
- Monitoring of outdoor and indoor air temperature over the whole heating season and uninterrupted (daily) measurement of indoor and outdoor air temperature over the coldest periods of five days or more;
- Assessment of humidity levels in living areas of the building;
- Measurement and assessment of lighting levels and lighting quality in living areas, as well as electricity consumption for lighting;
- Thermographic imaging of exterior and interior surfaces of the building, as well as of heating systems;
- Determination of actual specific consumption of energy and fuel;
- Calculation of annual specific energy-efficiency parameters of the building;
- Preparation and presentation of an Energy Passport for the pilot rural house;
- Collection of needed data and calculations for CO_2 emissions;
- Quantitative analysis and assessment of energy conservation and savings of financial resources;
- Compilation of an energy balance for the building;
- Presentation of recommendations on implementation of energy-efficient solutions and use of renewable energy in construction of rural housing on the basis of the energy audit.

2.1. General design aspects of the building

The pilot rural house is located in the Zangiata district of the Tashkent oblast, in a village named Ibrat. The house was built in accordance with the working design "Pilot 4-room rural house with increased energy efficiency and use of renewable energy" developed by ToshuyjoyLITI under its agreement with UNDP, PO/1308/13. The house was built and entered into operation in December 2014. A five-person family lives in the house.

Table 2.1. Geometric parameters of the house design

№	Parameter	Unit	Quantity
1	Area of rooms and kitchen	m^2	129.8
2	Total area	m^2	136.5
3	Heated floor area	m^2	146.1

4	Heated volume	m^3	387.2
5	Surface area of exterior envelope of the building	m^2	346

2.2. Electric supply and consumption systems

The house is supplied with electricity via aerial wires into the roof, from a low-voltage network of 380/220V, delivered from a transformer substation (TS) (Figure 2.1.1).

Transformer point　　　　Entry point for electricity

Figure 2.1.1. Electricity feed via transformer substation

An offshoot from the insulators of the entry point of the electrical network to the circuit panel of the home was implemented with a 10 mm^2 APV-0.38 wire section. In accordance with the design of the pilot rural home, the group networks were made via APPV-0.38 wire in the cavities of floor slabs and walls, hidden under a layer of plaster. Electric metering is provided by a microprocessor electricity meter DDS-28u, established in an electricity metering panel on the facade of the house.

2.3 Lighting system

Base and reserve lighting were provided for in the pilot rural house. There are 12 points in the base lighting system. For optimization of the design, energy-saving 15-20W compact fluorescent lamps are envisaged (one per light point). The total installed load is 210W (6×20W + 6×15W).

Photovoltaic (PV) panels were installed on the roof of the house, from which reserve electric lighting is fed into the network.

Figure 2.1.2. Photovoltaic panels

The reserve lighting network includes 8 points, where 9-15W LED lamps are used for a total of 6 hours per day. The overall installed load of the reserve lighting system is 120W (8×15W).

2.4. Heat supply and heat delivery systems

Heat supply of the pilot house is from a system with a gas-fired wall-mounted single-contour automated Ariston boiler with 24 kW capacity (figure 2.1.3). The key technical characteristics of the system are presented below in Table 2.2.

The boiler is linked to a piping system for heat delivery, which manages heat consumption and offers control of various parameters as well as distribution of heat to living areas of the house.

Table 2.2. Technical characteristics of the Ariston boiler

Parameter	Units	Quantity
Maximum/minimum rated thermal load	kW	25.8/11.0
Max/min heat production	kW	23,7/9.9
Max/min gas consumption for heating	m^3/hour	2.73/1.16
Combustion efficiency	%	91.9
Efficiency at 30% load	%	91.2
Mass of emitted combustion products	m^3/hour	63.6
Max/min temperature of working fluid	°C	82/35
Electric load	W	81-90
Voltage and frequency	V/GHz	230/50

Figure 2.1.3. Gas-fired wall-mounted single-contour automated Ariston boiler

The heating system uses two pipes, with mechanical circulation of the working fluid. (circulation pump built into the boiler). The working fluid is water, with outgoing and incoming temperature from and to the boiler of 95 and 70 °C, respectively. The heating elements are aluminum radiators (185 watts per section, total 74 sections installed, with a total capacity of 13.69 kW) (Figure 2.1.4.). It is possible to control temperature with a thermostatic dial on each radiator (Giacomini thermostats installed).

In order to reduce additional costs of heat, reflective panels made of foil-covered polyethylene foam are installed behind the radiators.

Figure 2.1.4. Aluminum sectioned radiators

The piping of the heating system is polypropylene with fiberglass – brand model PPR PN25.

2.5 Gas supply and consumption

Gas enters the house from a low-pressure municipal network, departing from a gas-distribution point (GDP), which belongs to the district gas supply organization (Figure 2.1.5.)

Gas distribution point   Municipal low-pressure gas network

Figure 2.1.5. Gas distribution point and municipal gas network

Gas is used for heating and for cooking in the house. A four-burner gas stove in the kitchen is used for cooking. The Ariston boiler discussed above is used for heating.

The maximal consumption of gas per hour by the house is 4.5 m^3/hour. Gas consumption is measured by a Novator gas meter on the façade of the house by the entryway to the courtyard (Figure 2.1.6.)

Figure 2.1.6. Gas meter

2.6. Cold and hot water supply

Cold water supply is provided for household use and drinking from the village network. A ВСКМ-20 water meter has been included for measurement of consumption.

Hot water supply is provided by a bivalent water heater, connected to a solar water-heating collectors, installed on the roof of the house (Figure 2.1.7). Other equipment of the solar water system (pump, control station, expansion vessel, and 500-liter tank) is located in the boiler room. To increase the reliability of the solar water system, there is the possibility of use of a gas boiler for further heating up to needed temperatures during the cold period of the year.

The system of cold and hot water supply uses polypropylene PPRS pipes, 25 and 20 mm in diameter.

Figure 2.1.7. Solar water-heating collectors for hot water supply

of the pilot rural house

2.7. Ventilation

The ventilation system of the pilot rural house consists of air handling units with both natural and mechanical movement of air. In the four living areas of the house (main room and three bedrooms), lamellar heat-recovery ventilators are installed, with a capacity of 30-60 m^3/hour (Figure 2.1.8).

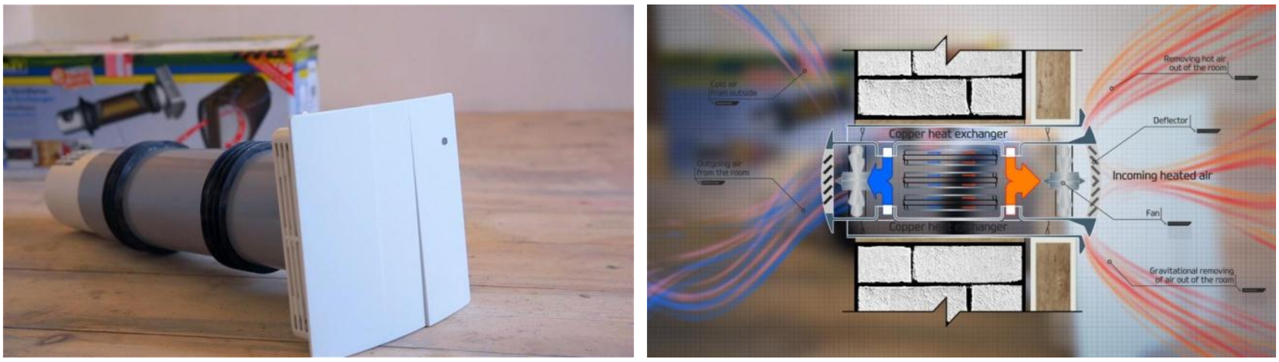


Figure 2.1.8. Heat recovery ventilators of the house

The pilot rural house is also equipped with constantly-running natural ventilation, implemented via 150 x 150 mm ducts in three rooms and a 200 x 200 mm duct in the kitchen, set in the interior brick walls.

2.7. Instrumental measurements in pilot and typical rural houses

One of the main objectives of the pilot rural home energy audit was to conduct instrumental measurements for monitoring and evaluation of temperature and humidity conditions, of artificial lighting of living areas, and thermal imaging of the building envelope.

In order to prepare a comparative analysis, instrumental measurements were performed both for the pilot rural house and for a typical rural house, identical to the pilot project in dimensions but lacking the energy-efficient features noted above.

The procedure and the measurement results for each of the indicators of both types of houses are presented below.

2.7.1. Instrumental measurements of temperature and humidity of the pilot house and other buildings

To analyze the dynamics of changes in temperature and humidity in the pilot rural house, running collection of data on indoor and outdoor parameters of the building was carried out with SciWilli data loggers (Figure 2.1.9).

Figure 2.1.9. Data collection using SciWilli loggers

Loggers collected data every 6 hours for 18 days (from 25 February to 14 March 2015). Dynamics of changes in temperature and humidity parameters are shown in Figure 2.2.1 - 2.2.3.

Measured data are presented in tabular form below in Annex 1 (Tables 2.3 – 2.5).

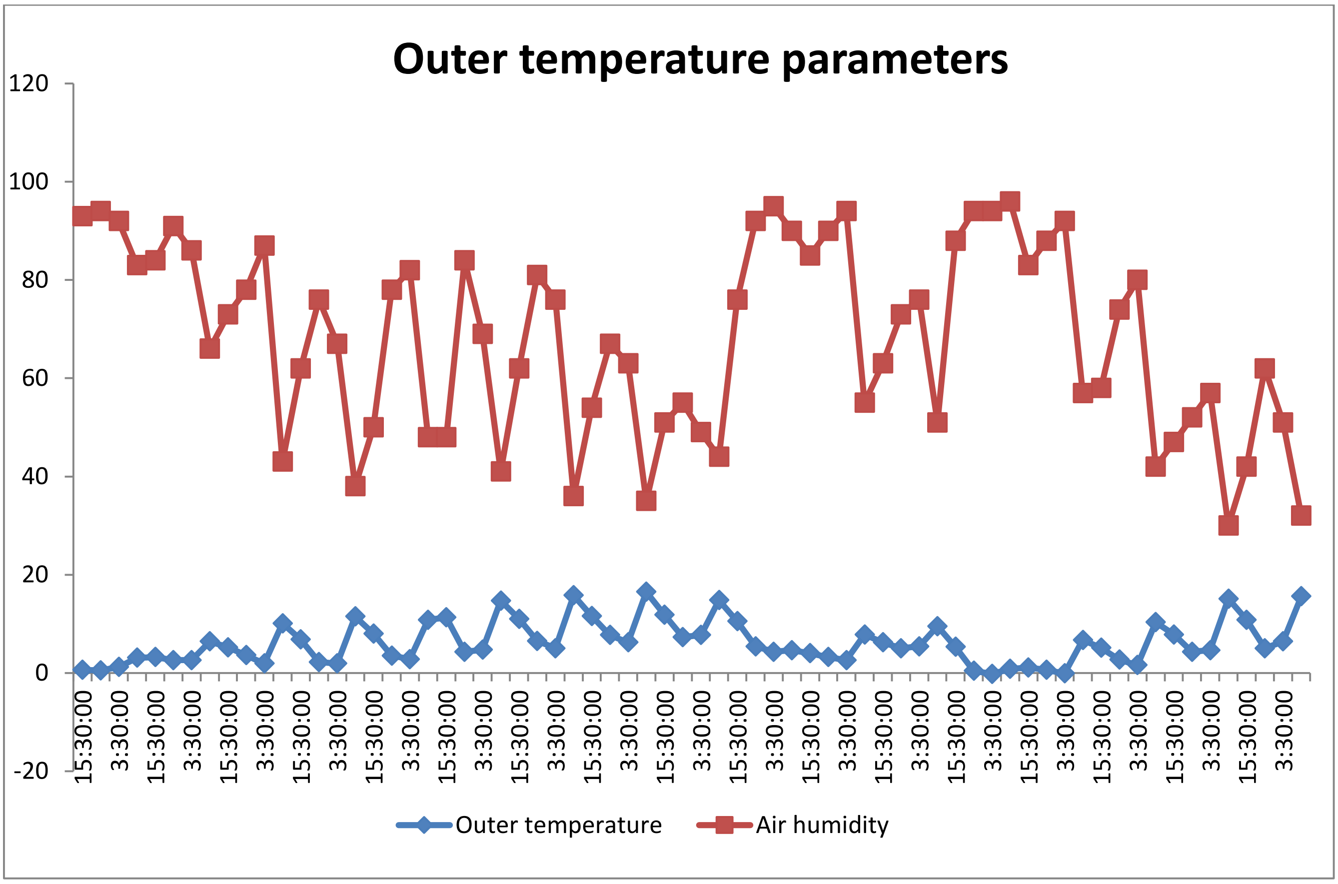


Figure 2.2.1. Parameters of outdoor air

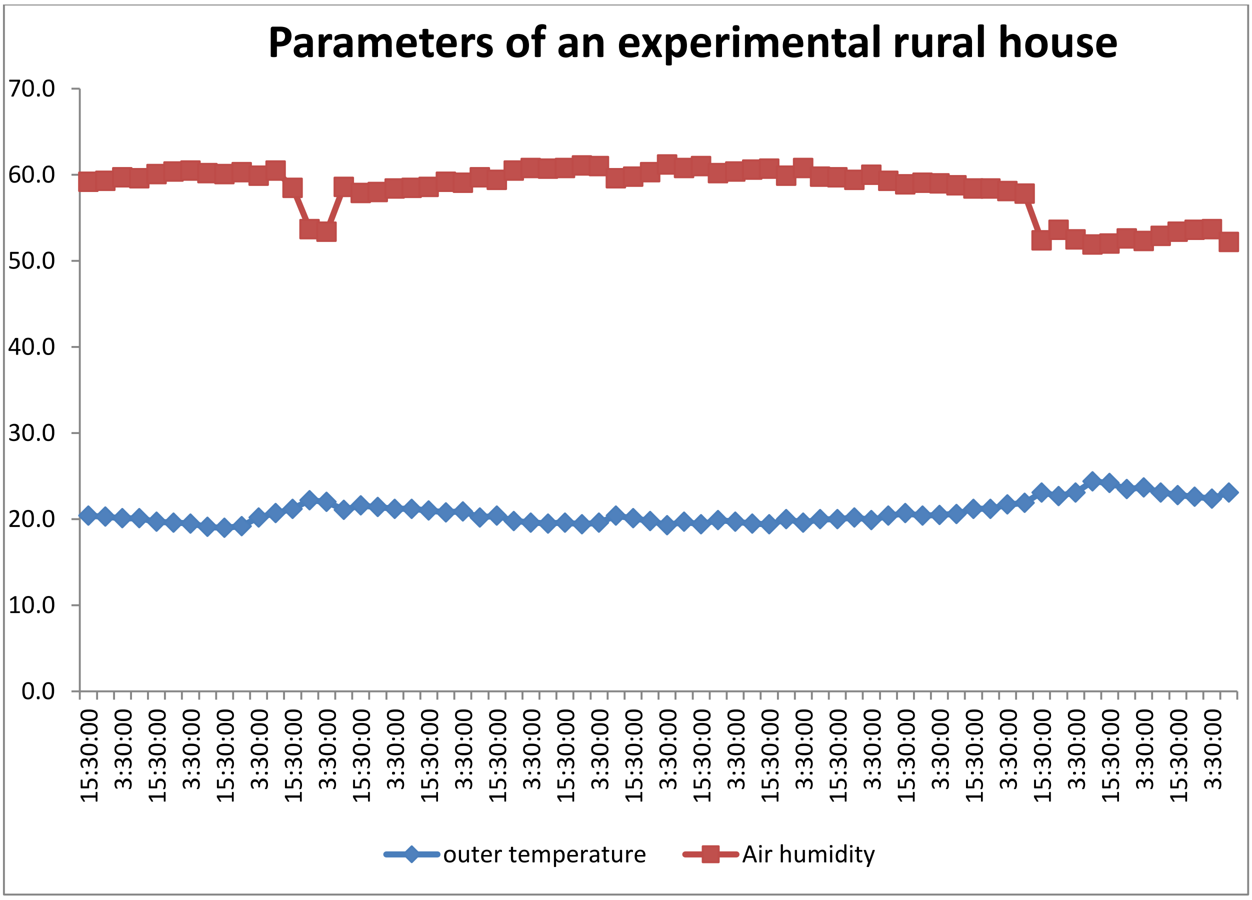


Figure 2.2.2. Indices of the pilot rural house

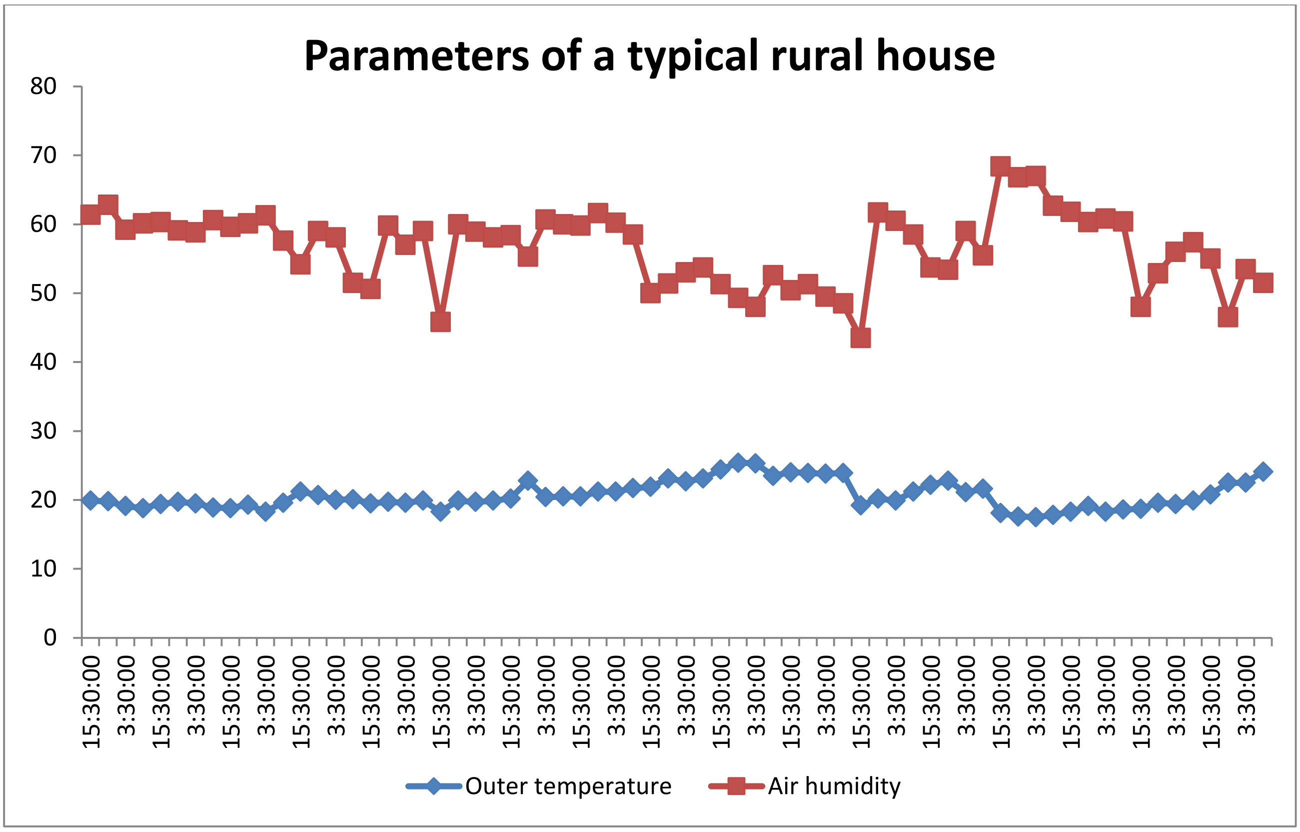


Figure 2.2.3. Indices of a typical rural house

Measurements of temperature and humidity conditions of the pilot house and typical rural houses

Comparative data are presented below for temperature and humidity inside the pilot and typical rural houses (averaged over the measurement period) relative to optimal and permitted levels as stipulated by state standards.

Table 2.6. **Measured temperature and relative humidity of indoor air of pilot and typical rural houses**

Indices	**Air temperature ^{0}C**	**Relative humidity, %**
Measured results for pilot rural house	20.8	58.3
Measured results for typical rural house	20.6	56.6
Levels stipulated by the state standard GOST 30494-96 (optimal)	19-20	30-45
Levels stipulated by GOST 30494-96 (allowed range)	17-23	Not more than 60

Conclusion: The results of measurements indicate that air temperature in both buildings slightly exceeds the optimal value, but lies within the permitted range according to the state standards GOST 30494-96. Relative humidity does not exceed the limits set forth in GOST 30494-96.

2.8. Measurement and assessment of lighting levels in living areeas

In order to assess lighting level in living areas of the pilot rural house (bedrooms, main room, kitchen, hallway, corridor), measurements were taken using a Yu-116 lux meter (Figure 2.2.4.). Energy-conserving 15-20W lamps were installed in living areas (one per area).

Figure 2.2.4. Measurement using Yu-116 lux meter in the pilot rural house

Conclusions on the results of light measurements in the pilot rural house

Artificial lighting in living areas in both cases did not meet regulatory requirements. The main reason for this noncompliance lies in the fact that the house was not occupied by tenants (they were moving in at the time) and, therefore, hanging light fixtures with several lamps were not yet installed (they are being selected and installed by home owners). At the time of entry into operation, 15-20W energy-saving lamps had been installed , one per occupied area, as provided for in the working building design, whereas in a typical home the lighting system would have 100-150W incandescent lamps in occupied areas.

In the corridor, bathroom, and toilet room of the pilot rural home, lighting levels did meet regulatory requirements. In the typical rural house, the requirements were met only in the toilet room and bathroom.

In this light, it was recommended to install light fixtures in the living areas and the kitchen with many lamps, and furthermore, to use energy-saving lamps (where possible, more modern light-emitting diodes) as well as to carry out timely replacement of spent lamps and cleaning of fixtures.

2.9. Thermographic imaging of the building envelope

The goal of the thermographic imaging survey was to define the condition of building envelope elements of the pilot and typical rural houses (Figure 2.2.5.).

Figure 2.2.5. Thermographic imaging survey of the pilot and typical rural houses

An infrared FLIR camera and a Testo-925 thermometer were used to carry out the thermographic survey. The processing of sections of the thermographic images was made possible with the help of software that came with the camera - ***FLIR QuickReporter***.

Thermographic imaging surveys of the exterior building envelope elements of the pilot and typical rural houses were carried out on 28 February 2015. Before the imaging surveys, to adjust the settings of the FLIR infrared camera, control measurements were carried out on the surface temperature of the walls using the Testo-925 thermometer. The heating systems of both buildings were operating during the thermal imaging surveys.

Time of surveys was as follows. Start at 20.30 and End at 22.00.

Table 2.7: **Atmospheric conditions during thermographic imaging**

Outdoor air temperature	+ 2 to +1 °C
Cloud cover	none
Direct solar irradiation	none
Precipitation	none
Wind speed	no wind
Indoor air temperature	from +20 °C to 22 °C

Thermographic images were taken of various sections of the buildings in order to facilitate comparison. The sites for the images were selected based on expected heat losses through the envelope.

Results of thermographic imaging

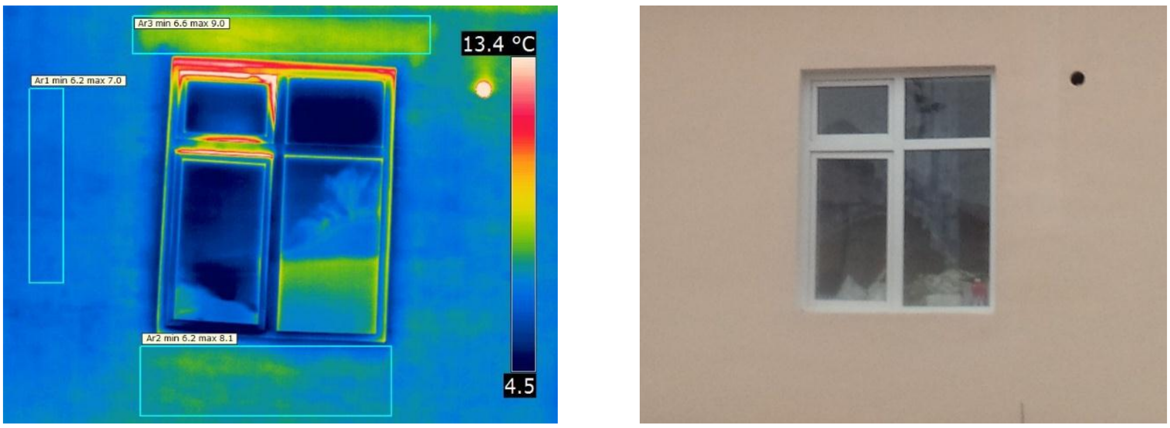


Figure 2.2.6.a) Thermographic image and photo of a section of the rear façade of the building (kitchen window) of the pilot rural house

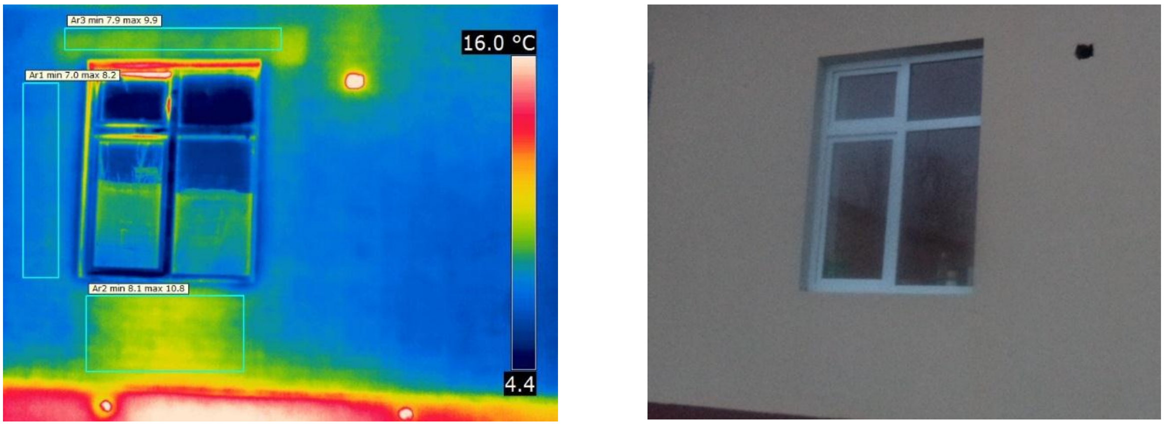


Figure 2.2.6.b) Thermographic image and photo of section of the rear façade of the typical rural house

An array of sections was selected for thermal imaging comparison (A1, A2, A3). The results are summarized in Table 2.8. As can be seen from the images, the average temperature of the outdoor surfaces of the experimental rural house is 0.5 to 2 °C less than the temperature of analogous sections of the typical rural house, indicating less heat loss through the building envelope of pilot house.

Table 2.8. **Results of thermographic imaging of sections of the rear façade of the buildings**

Section	**House**	**Surface temperature of the outdoor side of the building envelope section, ⁰C**		
		Minimum	**Maximum**	**Average**
A1	Pilot house	6.2	7.0	6.6
	Typical house	7.0	8.2	7.7
A2	Pilot house	6.2	8.1	7.5
	Typical house	8.1	10.8	9.6
A3	Pilot house	6.6	9.0	8.3
	Typical house	7.9	9.9	8.9

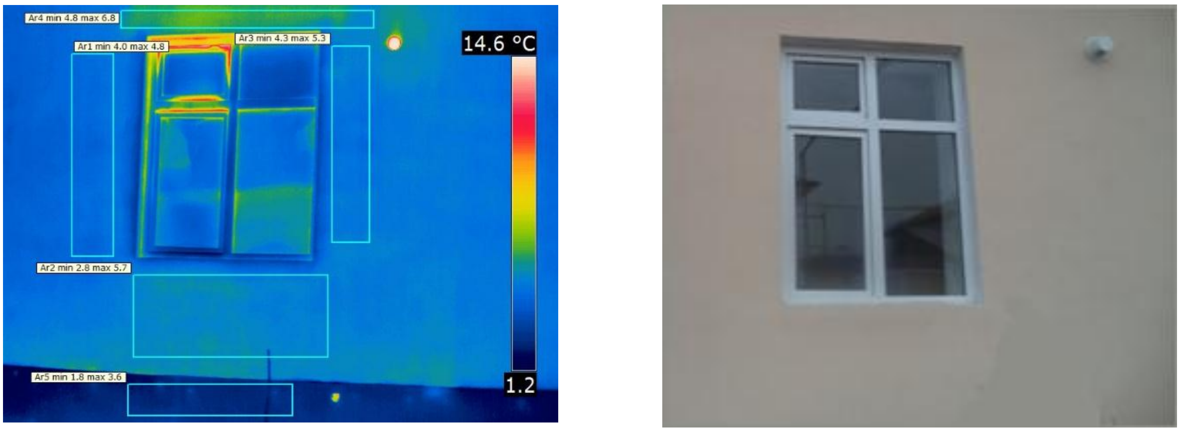


Figure 2.2.7.a) Thermographic image and photo of section of the front façade (streetside window) of the pilot rural house

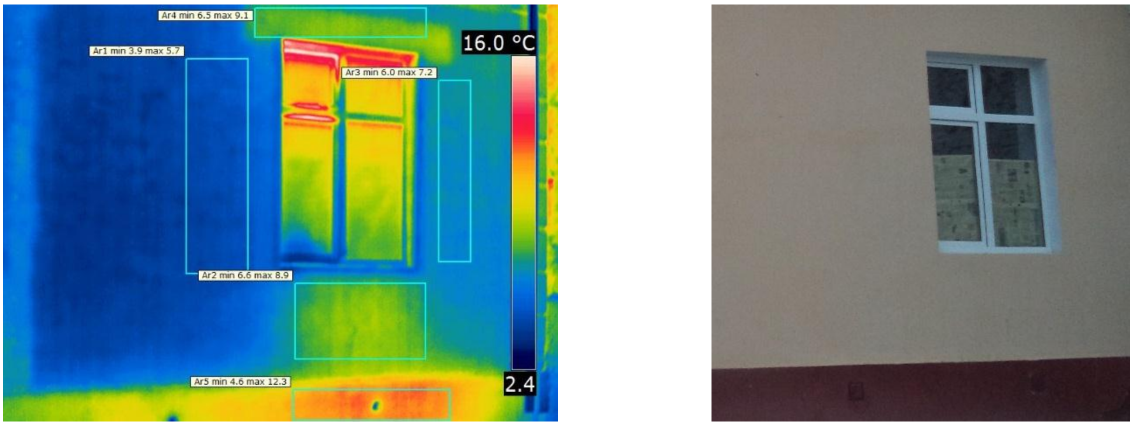


Figure 2.2.7.b) Thermographic image and photo of section of the front façade (street side window) of the typical rural house

An array of sections was selected for thermal imaging comparison (A1, A2, A3, A4, A5). The results are summarized in Table 2.9. As can be seen from the images, the average temperature of exterior surfaces of sections A1 through A4 of the experimental rural house is 1.2 to 4 °C less than the temperature of analogous sections of the typical rural house. At the foundation at the base of walls (socle) the average temperature of the pilot house is 9 °C lower than the analogous location on the typical house. These data make clear the lower heat losses through the building envelope of the pilot house.

Table 2.9. **Results of thermographic imaging of sections of the front façade of the buildings**

Section	**House**	**Surface temperature of the outdoor side of the building envelope section, ⁰C**		
		Minimum	**Maximum**	**Average**
A1	Pilot house	4.0	4.8	2.1
	Typical house	3.9	5.7	3.3
A2	Pilot house	2.8	5.7	1.9
	Typical house	6.6	8.9	5.8
A3	Pilot house	4.3	5.3	2.1
	Typical house	6.0	7.2	3.3
A4	Pilot house	4.8	6.8	1.9
	Typical house	6.5	9.1	5.8
A5	Pilot house	1.8	3.6	2.4
	Typical house	4.6	12.3	11.5

The situation is similar at the far third window of the front facade of the building. Results for comparison are summarized in Table 2.10. As can be seen on the images, the average temperature of sections A1, A2, A3, and A4 of the pilot rural house are 4.5 to 7 ° C lower than the temperature of analogous sections of the typical rural home, indicating lower heat loss through the building envelope of the pilot house.

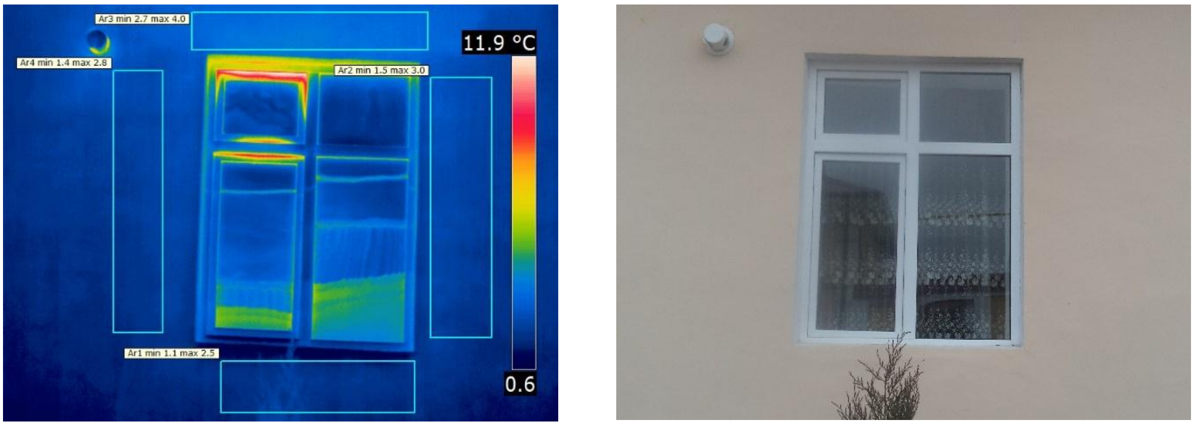


Figure 2.2.8.a) Thermographic image and photo of section of the front façade (far streetside window) of the pilot rural house

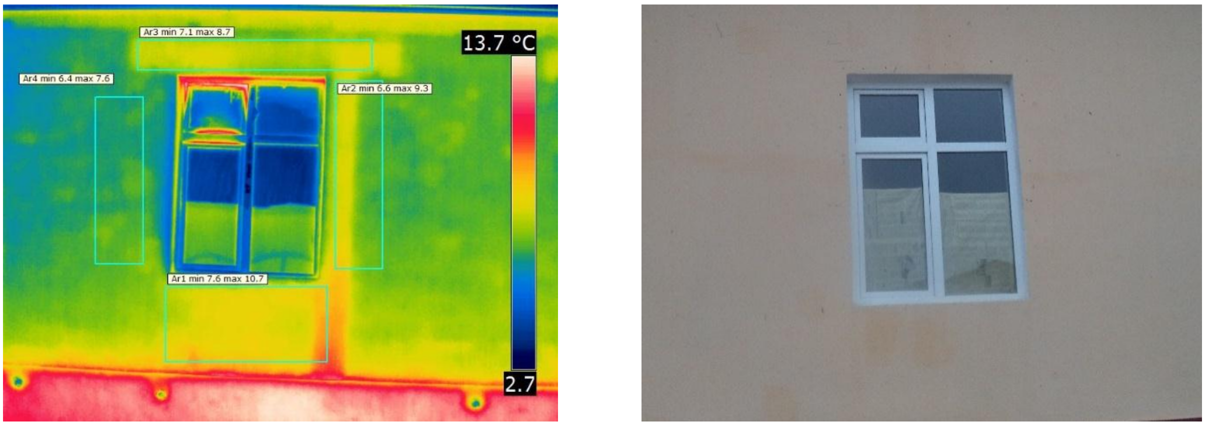


Figure 2.2.8.b) Thermographic image and photo of section of the front façade (far street side window) of the typical rural house

Table2.10. **Results of thermographic imaging of sections of the front façade of the buildings (far corner)**

Section	**House**	**Surface temperature of the outdoor side of the building envelope section, ⁰C**		
		Minimum	Maximum	Average
A1	Pilot house	1.1	2.5	1.8
	Typical house	7.6	10.7	8.7
A2	Pilot house	1.5	3.0	2.2
	Typical house	6.6	9.3	7.6
A3	Pilot house	2.7	4.0	3.4
	Typical house	7.1	8.7	8.0
A4	Pilot house	1.4	2.8	2.1
	Typical house	6.4	7.6	6.8

Conclusions on thermographic imaging surveys of building envelopes

As a result of the thermographic imaging surveys of the external surfaces of the building envelopes of the pilot and typical rural houses, the following conclusions were established.

1. The exterior façade of the typical rural house has zones of elevated heat losses relative to the pilot rural house. The temperature difference is on average 3 to 6 °C, and in various areas, the difference reaches 9 to 11 °C (wall foundation). The main cause of heat loss is the lack of insulation in the typical rural house. Gas consumption data for both rural houses confirm this difference.

2. The main areas of heat loss in both houses are window and door frames. The reasons for increased air infiltration through the given structures can be placed into the following main categories:

- window and door shutters are not adjusted (seals are not sufficiently pressed upon closing);
- the seal is damaged or of poor quality;
- during window installation, conditions for implementing joints were not fully observed

During energy monitoring, there were made recommendations to experts from construction organizations on the need for adjustment of all window and door frames, and, if necessary, replacement of various parts and rubber seals. All recommendations have been implemented by the builders, and the leadership of the branch of the rural housing investment agency "Qishloq Qurilish Invest" is recommended to pay special attention to these details during the monitoring of construction works.

To reduce losses in typical rural houses at low cost, it has also been recommended that heat reflecting panels be installed behind all heating devices to increase their efficiency and reduce heating of the walls behind the heaters.

3. Comparative analysis of energy consumption in the pilot and typical rural houses based on measurements and metering

To determine the specific consumption of energy for the pilot rural home and for comparison with the typical rural house within the framework of an energy audit conducted during 9-15 March 2015, gas consumption readings were taken for both houses.

3.1. Comparative analysis of natural gas consumption for heating

The average daily consumption of gas for the given period was 11.54 m^3, the minimum value was 10.4 m^3 (10-11 March 2015), and the maximum value was 13.2 m^3 (13-14 March 2015). During this period, gas consumption for food preparation did not take place because the house was not fully occupied – that is, all the natural gas was used for heating.

Table 3.1. **Gas meter readings from the energy-efficient house**

Date	Time	Meter reading and daily consumption of natural gas (m^3)
9 March 2015	8:00 AM	6.1
10 March 2015	8:00 AM	17.2
Consumption		11.1
10 March 2015	8:00 AM	17.1
11 March 2015	8:00 AM	27.5
Consumption		10.4
11 March 2015	8:00 AM	27.5
12 March 2015	8:00 AM	38.6
Consumption		11.1
12 March 2015	8:00 AM	38.6
13 March 2015	8:00 AM	50.5
Consumption		11.9
13 March 2015	8:00 AM	50.5
14 March 2015	8:00 AM	63.7
Consumption		13.2
Total consumption over 9-14 March 2015		**57.7**
Average daily consumption of gas		**11.54**

In order to assess the level of natural gas consumption of the typical rural house, natural gas consumption data were collected there too, during the period from 9 March 2015 through 14 March 2015, as shown below.

In the typical rural house during this period, food preparation accounted for about 10-15 percent of total gas consumption, while the rest was used for heating.

According to the data, the average daily consumption of gas for heating during the period is 22.9 m^3, the minimum was 20.48 m^3 (10-11 March 2015), and the maximum was 24.65 m3 (11-12 March 2015).

Table 3.2. **Gas meter readings from the typical rural house**

Date	Time	Meter reading and daily consumption of natural gas (m^3)	Not including food preparation (15%)
9 March 2015	8:00 AM	1319.2	
10 March 2015	8:00 AM	1347.4	
Consumption		28.2	23.97
10 March 2015	8:00 AM	1347.4	
11 March 2015	8:00 AM	1371.5	
Consumption		24.1	20.48
11 March 2015	8:00 AM	1371.5	

12 March 2015	8:00 AM	1400.5	
Consumption		29	24.65
12 March 2015	8:00 AM	1400.5	
13 March 2015	8:00 AM	1427.7	
Consumption		27.2	23.12
13 March 2015	8:00 AM	1427.7	
14 March 2015	8:00 AM	1453.9	
Consumption		26.2	22.27
Total consumption over 9-14 March 2015			**114.5**
Average daily consumption of gas			**22.9**

On the basis of data on actual consumption of natural gas, we can calculate the annual consumption of natural gas for heating for the pilot and typical houses:

Specific consumption of thermal energy for heating with respect to the heated area ($S_{heated}=146.1\ m^2$, see Table 1.1) of the pilot rural house was:

$$q_{heat.}^{year} = \frac{16119{,}4}{146{,}1} = 110{,}3\ \frac{kWh}{m^2}$$

Specific consumption of thermal energy for heating with respect to the heated area ($S_{heated}=146.1\ m^2$, see Table 1.1) of the typical rural house, not accounting for efficiency improvements, was:

$$q_{heat.}^{year} = \frac{31987{,}5}{146{,}1} = 218{,}9\ \frac{kWh}{m^2}$$

As is evident from the results, implementation of energy-efficient measures (insulation of the building envelope) has made it possible to reduce consumption of heat energy (natural gas used for heating) by almost 50 percent.

3.2. *Comparative analysis of electricity consumption*

For the analysis of energy consumption, the installed capacity of electrical household appliances were taken as the same for the pilot and typical rural houses, based on a standard list of household appliances (TV, washing machine, vacuum cleaner, air conditioner, refrigerator, iron). In addition to this list, the installed capacity of an electric hot-water heater was included for the typical rural house, and an electric water pump, the control system of the gas boiler, and heat-recovery vents were included for the pilot rural house.

It should also be noted that the lighting system in the pilot house was also replaced in order to reduce energy consumption, with use of energy-saving lamps and backup power supply from the PV system. The typical rural house, on the other hand, uses incandescent lamps.

The installed electric load of the lighting system of the pilot rural home was 210 W, with the possibility of partial compensation by the backup lighting system, which has a total load of 120 watts. The installed capacity of the lighting system of the typical rural house is 1300 watts. The installed capacity of electrical equipment including the lighting systems for both houses is presented in Table 3.3.

Table 3.3**. Installed electric load of appliances, equipment, and lighting in the pilot and typical rural houses**

№	**Type of equipment**	**Installed electric load (W)**	
		Typical rural house	**Pilot rural house**
1	Air conditioner*	1500	1500
2	Refrigerator*	250	250
3	Television*	150	150
4	Iron*	1000	1000
5	Vacuum cleaner*	1000	1000
6	Washing machine*	600	600

7	Lighting system	1300	90
8	Ariston water heater	1500	-
9	Control system for gas boiler	-	90
10	Electric pump	-	370
11	Ventilators	-	120
Total electric load		***7300***	***5170***
*The installed electric load of equipment is taken from the list shown in RD 34.20.185-94, Table 1.[5]			

From this, the calculated annual electricity consumption of the lighting system of the **pilot rural house** is:

$$W^{year}_{light.} = 90\,Watt \cdot 900\,h = 81\,kWh$$

The calculated annual electricity consumption by electric equipment of the **pilot rural house** is:

$$W^{year}_{heat.} = 5080\,Watt \cdot 900\,h = 4572\,kWh$$

The overall calculated electricity consumption by lighting and equipment of the **pilot rural house** is**:**

$$W^{year}_{heat.} = W^{year}_{light.} + W^{year}_{heat.} = 81 + 4572 = 4653\,kWh$$

The calculated annual electricity consumption of the lighting system of the **typical rural house** is:

$$W^{year}_{light.} = 1300\,Watt \cdot 900\,h = 1170\,kWh$$

The calculated annual electricity consumption by electric equipment of the **typical rural house** is:

$$W^{year}_{heat.} = 6000\,Watt \cdot 900\,h = 5400\,kWh$$

The overall calculated electricity consumption by lighting and equipment of the **typical rural house** is**:**

$$W^{year}_{heat.} = W^{year}_{light.} + W^{year}_{heat.} = 1170 + 5400 = 6570\,kWh$$

As is evident from the results of the calculations, implementation of energy-efficiency measures (use of energy-saving lamps and partial compensation of electricity consumption via a feed from the PV system, as well as replacement of the electric water heating system with the solar one) has made it possible to reduce electricity consumption by 29 percent.

3.3. Summary data on specific energy consumption

Summary data on specific energy consumption of both types of houses are presented below in tables and figures for various parameters.

Table 3.4 **Summary data on annual specific energy consumption**

House types and differences	**Specific consumption of heat energy, kWh/m²**	**Specific consumption of electric energy, kWh/,²**	**Overall specific energy consumption, kWh/m²**
Typical rural house	218.9	45	263.9
Pilot rural house	110.3	31.8	142.1
Difference	108.6	13.2	121.8
Difference in %	49.7%	29.3%	46.1%

[5] Norm and standards for determination of calculated electricity loads of buildings, micro districts and elements of the city network system can be found at: http://www.tipovoy-proekt.ru/normativ/rd/RD34.20.185-94.pdf

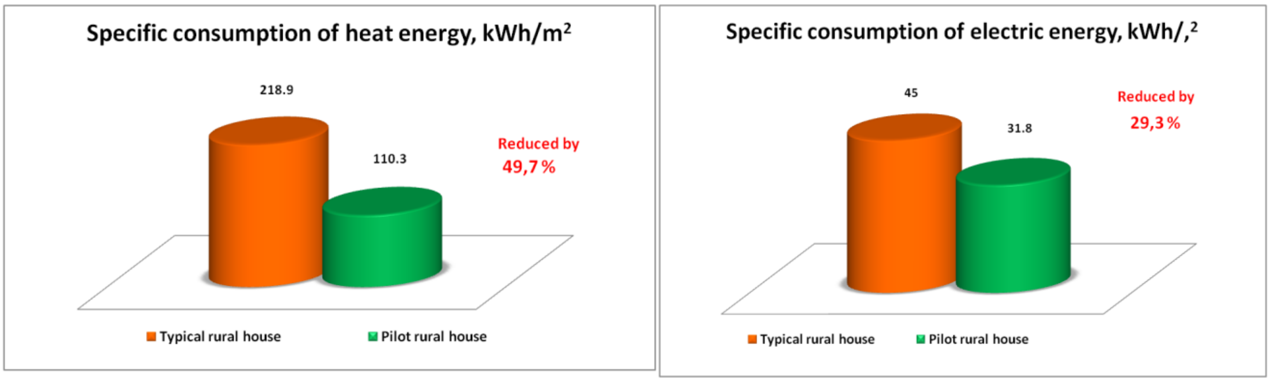


Figure 3.1.1. Bar charts for specific energy consumption parameters

3.4. Energy balances of the pilot and typical rural houses

Based on the results enumerated in the section above, energy balances for both rural houses can be formulated.

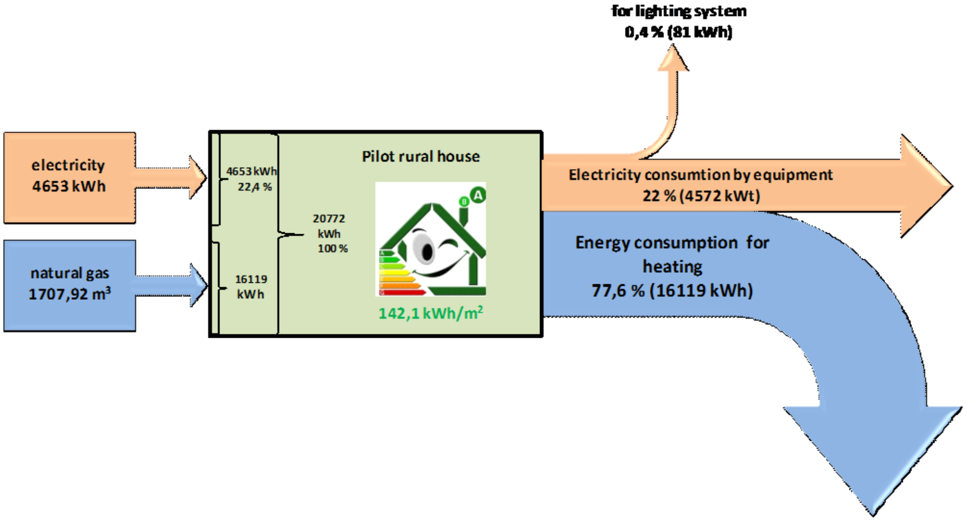


Figure 3.1.2. Energy balance of the pilot rural house

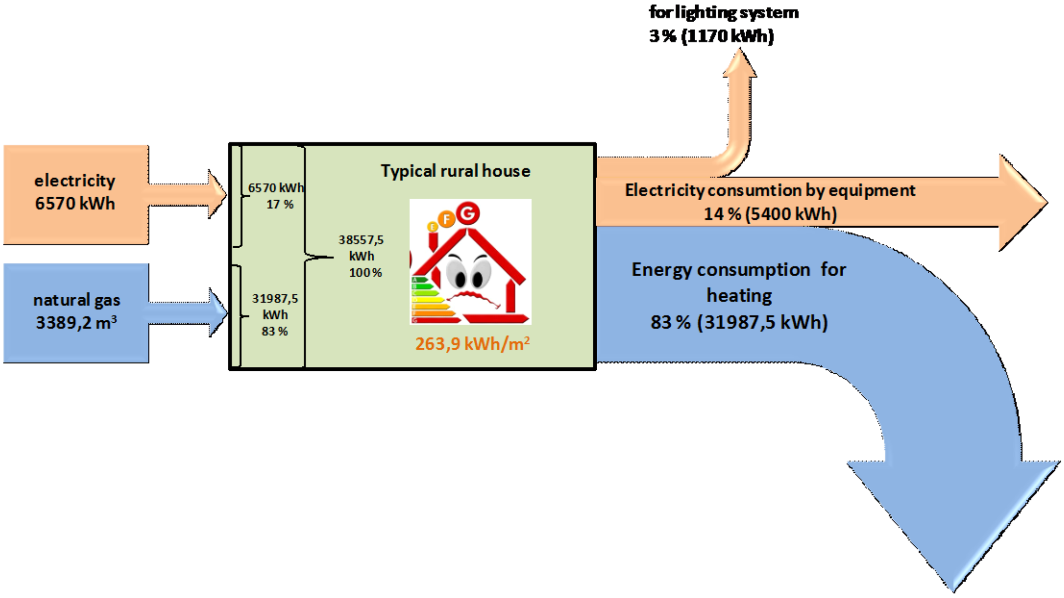


Figure 3.1.3. Energy balance of the typical rural house

3.5. Greenhouse gas emissions from both types of rural houses

One of the main tasks closely related with energy efficiency of buildings is reduction of greenhouse gas (GHG) emissions.

For this assessment, the baseline was set at the level of CO_2 emissions for the typical house without the implementation of energy-efficiency measures. As a result of implementation of an array of energy-efficiency measures, it is possible to determine a "measured" reduction of GHG emissions for the pilot house. This assessment of emission reductions is carried out with respect to the baseline of the typical house.

CO_2 emissions are known to result from two fundamental processes during building operation:

1) Fuel consumption for heating;
2) Electricity consumption for heating and for the operation of appliances and equipment.

3.5.1. Greenhouse gas emissions

Pilot rural house:

From fuel combustion by the heating system:

The consumption of heat energy for heating the pilot rural house was Q_h^y = 16,119.4 kWh, and the corresponding CO_2 emissions were:

$$M_{CO2} = 202 \cdot 16119{,}4 \cdot 10^{-6} = 3{,}26\ \text{tons}$$

From electricity consumption:

The calculated annual electricity consumption by the pilot rural house was W =4653 kWh, and the corresponding CO_2 emissions were:

$$M_{CO2} = 573 \cdot 4653 \cdot 10^{-6} = 2{,}67\ \text{tons}$$

The overall emissions of CO_2 from both heating and electricity were:

$$M_{CO2}^{sum} = 3{,}26 + 2{,}67 = 5{,}93\ \text{tons}$$

Typical rural house:

From fuel combustion by the heating system:

The calculated annual heat consumption for heating the house was Q_h^y = 31,987.5 kWh, and the corresponding CO_2 emissions were:

$$M_{CO2} = 202 \cdot 31987{,}5 \cdot 10^{-6} = 6{,}46\ \text{tons}$$

From electricity consumption:

The calculated annual electricity consumption by the typical rural house was W = 6570 kWh, and the corresponding CO_2 emissions were:

$$M_{CO2} = 573 \cdot 6570 \cdot 10^{-6} = 3{,}76\ \text{tons}$$

The overall CO_2 emissions from both heating and electricity were:

$$M_{CO2}^{sum} = 6{,}46 + 3{,}76 = 10{,}22\ \text{tons}$$

3.5.2. Summary of GHG emissions

Summary results of calculations of GHG emissions are presented below in the table as well as in bar charts.

Table 3.5. **Summary data on calculated GHG emissions**

House	CO_2 emissions from gas combustion for heating, tonnes	CO_2 emissions from electricity consumption, tonnes	Overall CO_2 emissions, tonnes
Typical rural house	6.46	3.76	10.22
Pilot rural house	3.26	2.67	5.93
Reduction in tonnes (and %):	**3.2 (49.5%)**	**1.09 (29%)**	**4.29 (42%)**

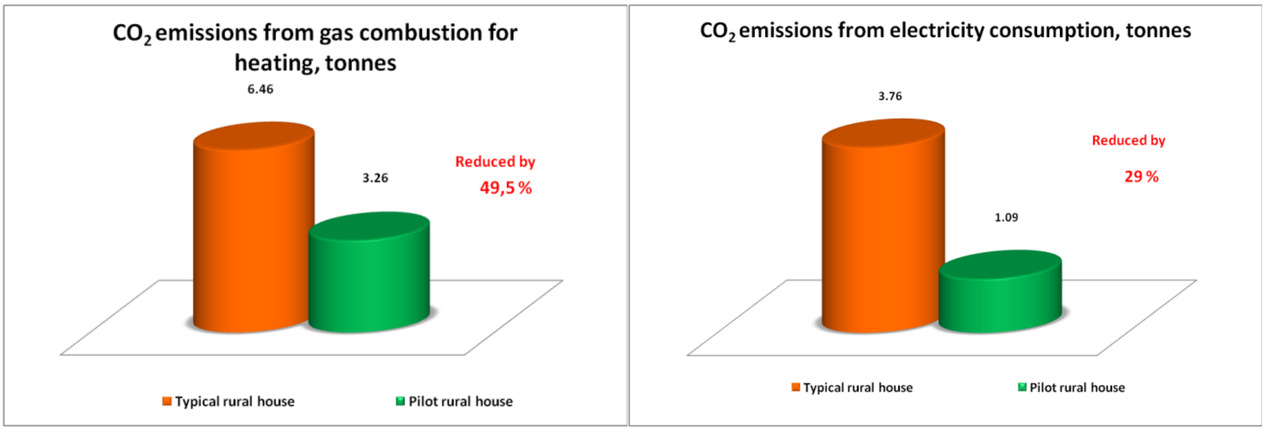


Figure 3.1.4. Bar charts for GHG emissions

The results of this assessment indicate that CO_2 emissions for the pilot house are 4.29 tonnes (42 percent) lower than GHG emissions for the typical house – that is, implementation of energy-efficiency measures have made it possible to reduce GHG emissions into the atmosphere by 42 percent.

4. Assessment of cost savings from implementation of energy-efficiency measures (at existing tariffs)

For quantitative assessment of cost savings, the following data were used:

- annual data on energy consumption for heating for the two buildings;
- calculated data for electricity consumption for the given period;
- data on tariffs for the given period, taken from 1 October 2014.

The tariff for electricity was 144.3 Uzbek Soums per kWh, and the tariff for natural gas for citizens was 181.62 Uzbek Soums per cubic meter [6].

<u>Pilot rural house:</u>

The annual calculated natural gas consumption for heating the house was:

$$Q_{heat.}^{year} = 11,54 \cdot 148 = 1707,92\ m^3$$

The cost for heating based on prevailing tariffs was:

$$S_{heat.}^{year} = 1707,92 \cdot 181,62 = 310,192 \text{ Th. Uzbek Soums } \textbf{or (US \$124.5)}$$

The calculated annual electricity consumption was W = 4653 kWt/hr. The cost of electricity according to prevailing tariffs was:

$$S_{electr.}^{year} = 4653 \cdot 144,3 = 671,428 \text{ Th. Uzbek Soums } \textbf{or (US \$269.6)}$$

The total cost for energy consumption of the house was:

[6] Source: [Web-portal for utility services and residential building stock](http://e-kommunal.uz/ru/) . http://e-kommunal.uz/ru/

$$S_{Soum}^{year} = S_{heat.}^{year} + S_{electr.}^{year} = 310,192 + 671,428 = 981,62$$ Th. Uzbek Soums **or (US $394.1)**

Typical rural house:

The calculated annual consumption of natural gas for heating the typical house was:

$$Q_{heat.}^{year} = 22,9 \cdot 148 = 3389,2\ m^3$$

The cost for heating according to prevailing tariffs was:

$$S_{heat.}^{year} = 3389,2 \cdot 181,62 = 615,546$$ Th. Uzbek Soums **or ($247.1)**

The calculated annual electricity consumption of the typical rural house was W = 6570 kWh. Based on this, the cost for electricity at prevailing tariffs were:

$$S_{electr.}^{year} = 6570 \cdot 144,3 = 948,051$$ Th. Uzbek Soums **or (US $380.7)**

The overall cost of energy consumption of the typical rural house was:

$$S_{Soums}^{year} = S_{heat.}^{year} + S_{electr.}^{year} = 615,546 + 948,051 = 1563,6$$ Th. Uz. Soums **or (US $627.8)**

Table 4.1. **Summary information on cost and cost savings**

	Heating cost		**Electricity cost**		**Total energy cost**	
	Thousand Uzb.soums	**US $**	**Thousand Uzb.soums**	**US $**	**Thousand Uzb.soums**	**US $**
Typical rural house	615.546	247.1	948.051	380.7	1 563.60	627.8
Pilot rural house	310.192	124.5	671.428	269.6	981.62	394.6
Cost reduction	**305.354**	**122.6**	**276.623**	**111.1**	**581.99**	**233.2**
Reduction in %	**49.6**		**29.2**		**37.2**	

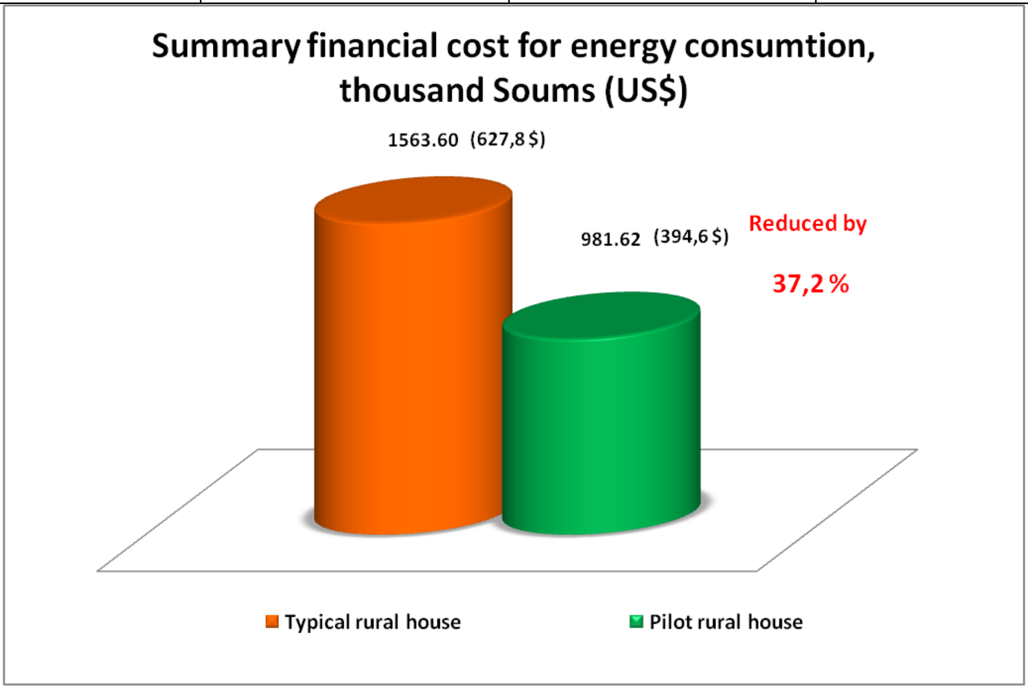


Figure 4.1.1. Total energy cost, thousand Uzbek Soums (US $)

As is evident from the results shown in Table 4.1, implementation of energy-efficiency measures (insulation of the building envelope, use of a more efficient boiler, PV-powered backup lighting, heat recovery in the ventilation system, and so on) has made it possible **to reduce energy costs by 582 thousand Uzbek Soums or more than US $233 per year**.

Conclusions on the energy audit

The energy audit indicates the following conclusions.

- The building envelope of the **typical rural house** fails to comply in terms of many parameters with Level II of thermal performance as stipulated by point 2.1 of the national building code КМК 2.01.04-97*, and in particular, with values for thermal resistance of walls (R_w = 0.8675 $m^{2}\cdot{}^{0}C/W$ < R^{II}_w = 1.8 $m^{2}\cdot{}^{0}C/W$) and attic floors (R_c = 0.7276 $m^{2}\cdot{}^{0}C/W$ < R^{II}_c = 2.08 $m^{2}\cdot{}^{0}C/W$). The overall thermal resistance of windows (R_F = 0.39 $m^{2}\cdot{}^{0}C/W$ = R^{II}_F = 0.39 $m^{2}\cdot{}^{0}C/W$) and ground-level floors (R_f = 3,88 $m^{2}\cdot{}^{0}C/W$) comply with code requirements.
- The building envelope of the **pilot rural house** outperforms regulatory requirements of point 2.1 of КМК 2.01.04–97*. The values of overall thermal resistance of the building envelope comply with, and in some cases go beyond **Level III of thermal performance**, specifically with regard to thermal resistance of walls (R_w = 3.87 $m^{2}\cdot{}^{0}C/W$ > R^{III}_w = 2.6 $m^{2}\cdot{}^{0}C/W$) and attic floors (R_c = 4.48 $m^{2}\cdot{}^{0}C/W$ < R^{II}_c = 2.96 $m^{2}\cdot{}^{0}C/W$).

  The overall thermal resistance of windows (R_F = 0.39 $m^{2}\cdot{}^{0}C/W$ = R^{II}_F = 0.39 $m^{2}\cdot{}^{0}C/W$) and ground-level floors (R_f = 3.88 $m^{2}\cdot{}^{0}C/W$) comply with normative requirements.
- The results of instrumental measurements show that under existing values of thermal resistance of the building envelope, the calculated value for consumption of heat energy for heating the **pilot rural house** is Q^h_y = 110.3 kWh/m^2. The calculated value for annual electricity consumption is W = 31.8 kWh/m^2. The total associated emissions of CO_2 equal 5.93 tonnes.
- The results of instrumental measurements show that under existing values of thermal resistance of the building envelope, the calculated value for consumption of heat energy for heating the **typical rural house** is Q^h_y = 218.9 kWh/m^2. The calculated value for annual electricity consumption is W = 45 kWh/m^2. The total associated emissions of CO_2 equal 10.22 tonnes.
- From the above quantitative figures, we conclude that the technical solutions applied in the pilot rural house have made it possible to reduce overall annual consumption of energy resources by **121.8 kWh/m^2 (by 46 percent)** and accordingly to reduce CO_2 emissions by 4.29 tonnes, and also to reduce energy costs by **582 thousand som (US $233**) **per year** under prevailing energy tariffs.
- The pilot rural house qualifies for a building energy rating of "A" under Uzbekistan's building energy rating system, which is part of recently revised building codes.

Detailed tabular data on energy-efficiency parameters for both types of rural houses are presented in Annex 2 (Tables 4.2 – 4.6).

5. Costs of construction, energy consumption, and other key parameters in construction of rural housing under various scenarios

One of the main goals of the joint project of UNDP, GEF, and Gosarchitectstroy of the Republic of Uzbekistan is demonstration of technical solutions that increase the energy efficiency of public buildings (including housing), based on the example of construction and renovation of pilot buildings, as well as the wide dissemination and large-scale use of these new solutions in future building design activity.

At the time of the UNDP/GEF project's midterm evaluation in April 2012, the international expert evaluator developed a number of recommendations, particularly on the development of new energy-efficient building designs that more fully embody integrated building design without decreasing in floor area, and also show the positive correlation between energy efficiency and returns on investment.

In order to fulfill these tasks and recommendations, in 2013 the project jointly with top national design organizations revised typical designs of 3-room, 4-room, and 5-room rural houses for increased energy efficiency, with use of both traditional construction methods (brick) and completely new approaches (use of aerated autoclaved concrete). It was in this context that this new demonstration project for the 4-room rural house was developed.

In order to assess cost indices, the level of energy consumption, and the influence of implemented technical solutions and in order to present recommendations on possible widespread application of energy-saving technologies in rural housing construction, a comparative analysis was conducted of various scenarios for construction of the 4-room rural house.

5.1. Definitions of the scenarios for rural house construction

- ***Baseline scenario*** – the typical rural house, as noted in the energy audit discussion above;
- ***Low-cost scenario*** – use of aerated autoclaved concrete (AAC) as the material for exterior walls, which complies with Level II of thermal performance according to point 2.1 of КМК 2.01.04-97*;
- ***Intermediate-cost scenario*** – use of oven-fired bricks and use of thermal insulation, to comply with Level II of thermal performance;
- ***High-cost scenario*** – use of thermal insulation, solar energy systems, heat recovery, etc., which complies with Level III of thermal performance;

The main parameters of all four scenarios for construction based on design documentation is presented below in Tables 5.1-5.6.

Table 5.1. **Cost parameters for construction scenarios**

Parameter	Unit	Low-cost scenario	Intermediate-cost scenario	High-cost scenario	Baseline scenario (typical rural house)
Cost	Thousand Uzb.soum	159,682.3*	176,421.9*	220,796.1	168,976.0
	Thousand US $.	67.5	74.6	93.4	71.5
Increase or decrease relative to baseline scenario	Thousand Uzb.soum	- 9,293.7	7,445.1	51,280.1	0.0
	Thousand US $	-3.74	3.0	20.6	0.0
	%	- 5.5	4.5	23.4	0.0

** cost of construction of buildings under these scenarios has been corrected in light of increases in construction costs of rural houses relative to designs from 2013.*

Table 5.2. **Geometric and climatic parameters**

Parameter	**Unit**	**Low-cost scenario**	**Intermediate -cost scenario**	**High-cost scenario**	**Baseline scenario (typical rural house)**
Number of stories		1			
Floor area	m^2	162.57			
Heated floor area	m^2	146.17			
Heated volume of the building	m^3	520.24			
Design indoor air temperature	^0C	20			
Design outdoor air temperature	^0C	-14			
Average outdoor air temperature during the heating season	^0C	3.5			
Duration of the heating season	days	148			
Degree-days in the heating season	^0C*days	2442			

Table 5.3. **Thermal resistance of building envelope elements**

Envelope element	Unit	Low-cost scenario	Intermediate-cost scenario	High-cost scenario	Baseline scenario (typical rural house)	Level II for thermal resistance	Level III for thermal resistance
Exterior walls	$m^2 \cdot {}^0C/W$	3.07	2.26	3.87	0.99	1.8	2.6
Attic floors	$m^2 \cdot {}^0C/W$	1.33	1.49	4.48	1.1	2.08	2.96
Ground-level floors and floors above unheated cellars and crawlspaces	$m^2 \cdot {}^0C/W$	3.88[1]	3.88[1]	3.88[1]	3.88[1]	1.84	2.56
Windows and balcony doors	$m^2 \cdot C/W$	0.39	0.39	0.39	0.39	0.39	0.42

Note:

- *The overall thermal performance of the building envelope complies with Level II code requirements in two scenarios: low-cost and high-cost;*
- *For the intermediate-cost scenario, the thermal performance of the attic floor needs to be improved (the insulation layer needs to be increased);*
- *The baseline scenario (typical rural house), for all parameters, complies only with Level I.*

Table 5.4. **Equipment affecting energy performance**

Type of system or equipment	Low-cost scenario	Intermediate-cost scenario	High-cost scenario	Baseline scenario (typical rural house)
Gas boiler	КОГн-15	КОГн-15	Gas-fired wall-mounted single-contour automated 24 kW Ariston boiler	КОГн-15
Lamps and lighting	ЛОН (incandescent)	ЛОН (incandescent)	Energy-saving lamps (CFL or LED)	ЛОН (incandescent)
Hot water supply	100-L electric water heater	100-L electric water heater	Solar water heaters, with total capacity of 500 L	100-L electric water heater
PV system for backup lighting	No	No	Yes	No
Room-by-room thermostatic controls for heating	No	No	Yes	No
Use of lamellar heat-recovery ventilators in the ventilation system	No	No	Yes	No

Notes: As is evident from the table, only the high-cost scenario employs equipment that affect energy consumption relative to the baseline scenario.

Table 5.5. **Calculated annual energy consumption**

Parameter	Unit	Low-cost scenario	Intermediate-cost scenario	High-cost scenario	Baseline scenario (typical rural house)	Level II for thermal resistance	Level III for thermal resistance
Heat consumption for heating during the heating season, $W_{от}$	kWh	23,270	23,402	16,119	31,987	22,189	18,037
Annual electricity consumption for lighting, $W_{ос}$	kWh	1,155[2]	1,155[2]	81[1]	1,170[1]	1,155[2]	1,155[2]
Annual electricity consumption for other electric equipment, $W_{об}$	kWh	5,408	5,408	4,572	5,400	5,408	5,408
Total annual energy consumption ($W_{от}$+$W_{ос}$+$W_{об}$)	**kWh**	29,833	29,965	20,772	38,557	28,752	24,600

1. For the high-cost and baseline scenarios, data from the energy audit were used (including partial compensation for lighting energy consumption by the PV system in the high-cost scenario).
2. For the other two scenarios, data on the installed lighting system were used, based on the use of 100-150W incandescent lamps (total load of 1300 W, as determined in the audit of the typical rural house).

<u>Total annual energy consumption and reduction relative to baseline</u>

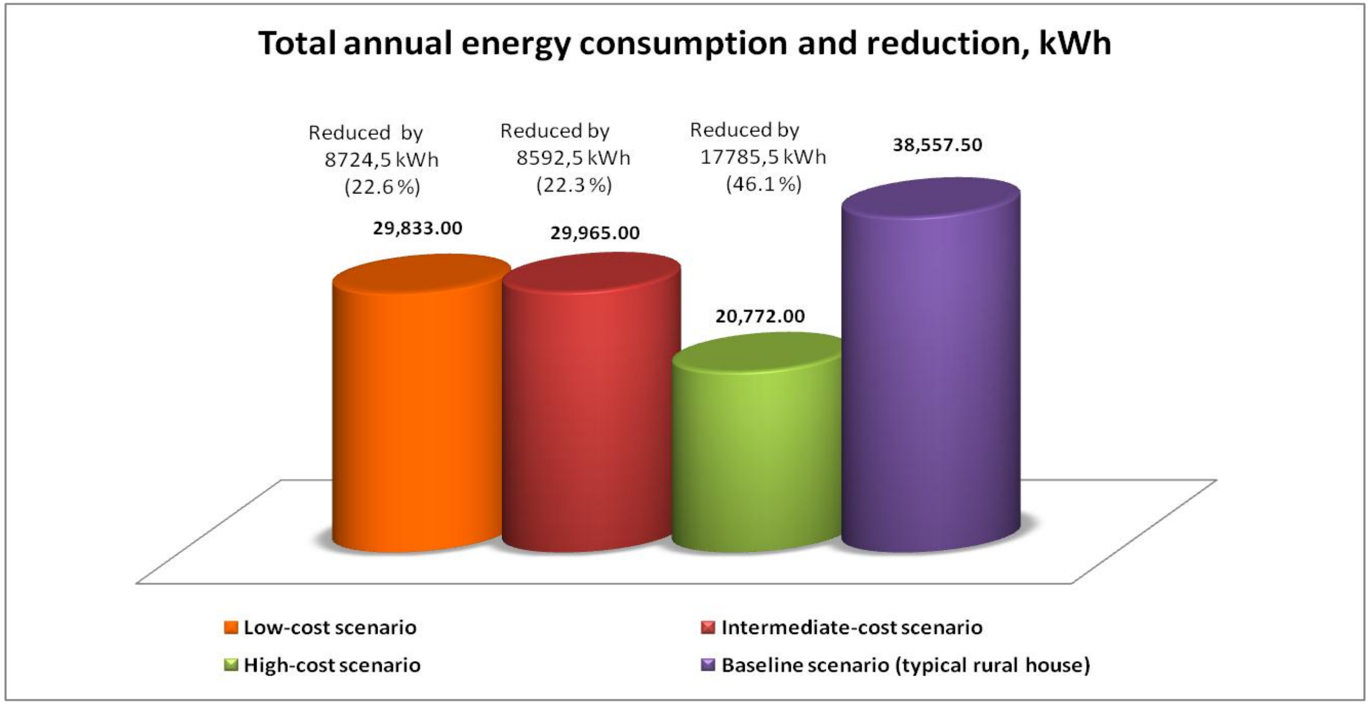
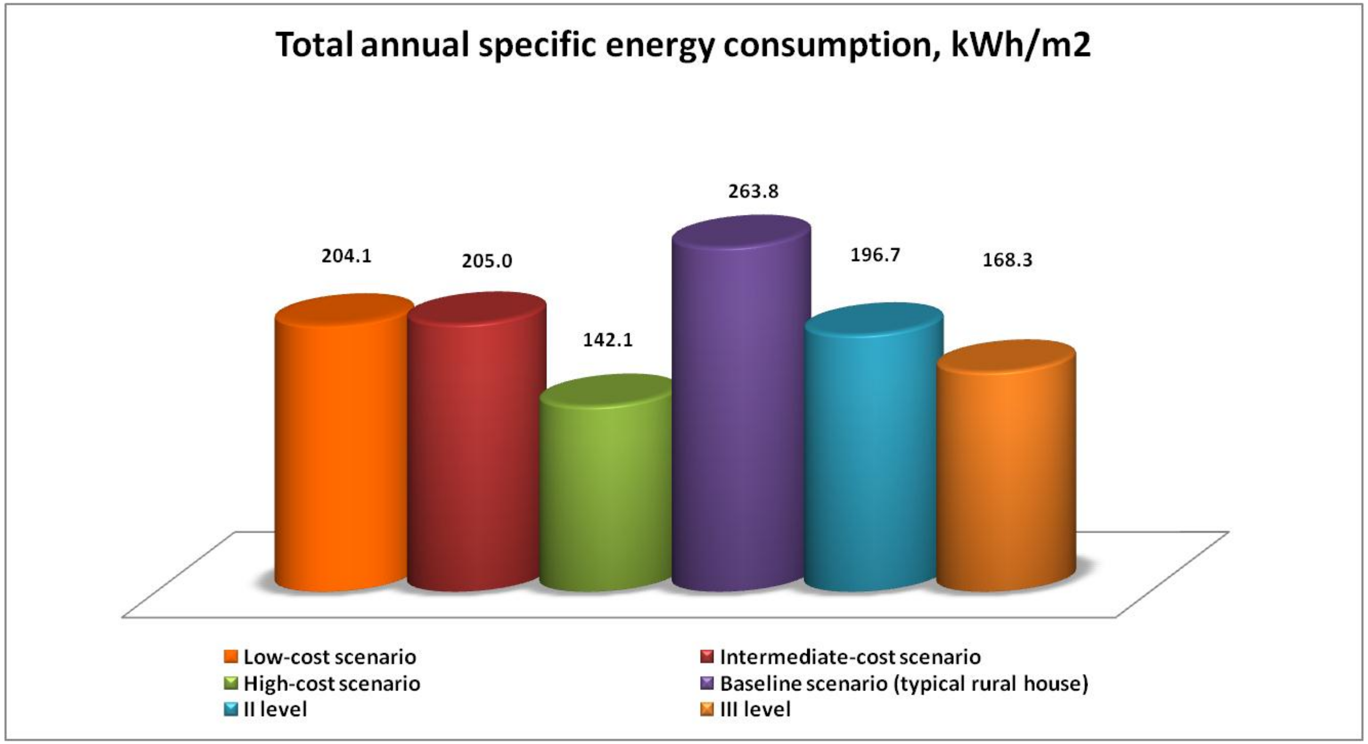


Table 5.6. **Specific (per square meter of floor area) energy consumption**

Parameter	**Unit**	**Low-cost scenario**	**Intermediate-cost scenario**	**High-cost scenario**	**Baseline scenario (typical rural house)**	**Level II for thermal resistance**	**Level III for thermal resistance**
Specific consumption of heat energy for heating during the heating season	kWh/m²	159.3	160.2	110.3	218.9	151.8	123.4
Specific electricity consumption for lighting and other equipment, per year	kWh/m²	44.9	44.9	31.8	44.9	44.9	44.9
Total annual specific energy consumption	**kWh/m²**	204.2	205.1	142.1	263.9	196.7	168.3

Total annual specific energy consumption



5.2. Energy balances of all scenarios

Based on the calculated results for annual energy consumption (Table 5.5), energy balances can be formulated for each rural-house construction scenario.

Table 5.7. **Energy balance of the rural house: baseline scenario (typical rural house)**

Parameter	Unit	Quantity
Heat consumption for heating during the heating season, $W_{от}$	kWh	31,987
Annual electricity consumption for lighting, $W_{ос}$	kWh	1,170
Annual electricity consumption for other equipment, $W_{об}$	kWh	5,400
Total annual energy consumption ($W_{от}$+$W_{ос}$+$W_{об}$)	kWh	38,557
Total specific annual energy consumption (per m² of heated floor area)	**kWh/m²**	**263.9**

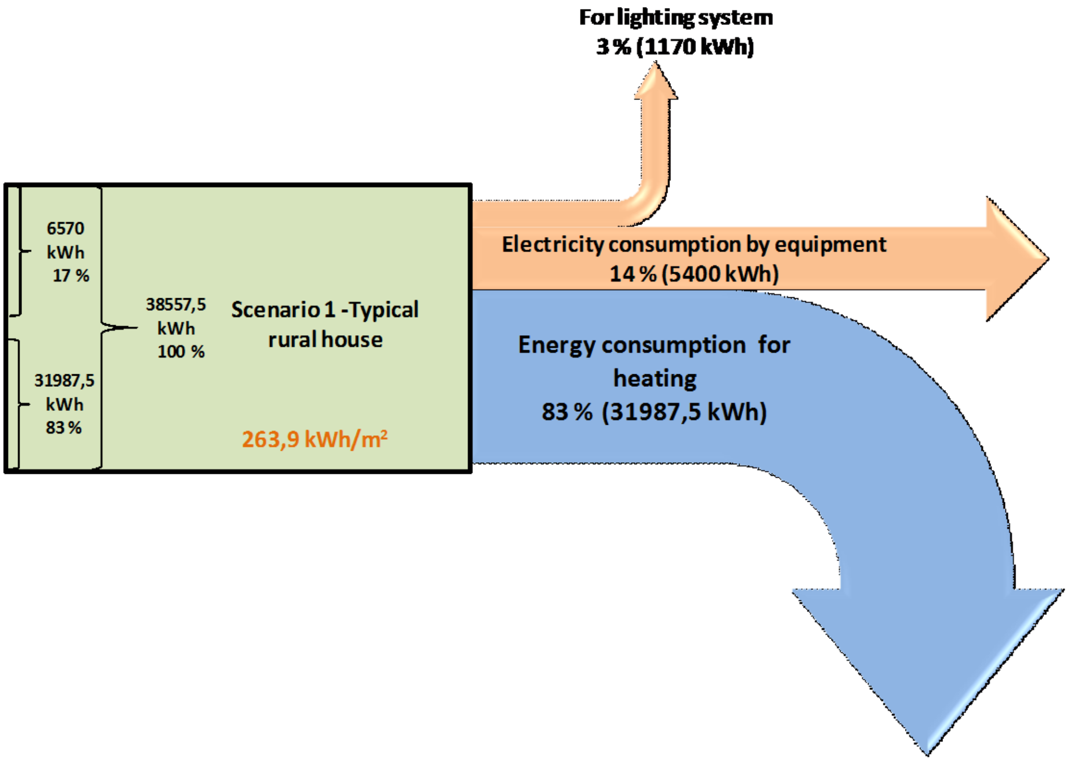


Figure 5.1.1 Energy balance: baseline scenario (typical rural house)

Table 5.8. **Energy balance of the rural house: low-cost scenario**

Parameter	Unit	Quantity
Heat consumption for heating during the heating season, $W_{от}$	kWh	23,270
Annual electricity consumption for lighting, $W_{ос}$	kWh	1,155
Annual electricity consumption for other equipment, $W_{об}$	kWh	5,408
Total annual energy consumption ($W_{от}$+$W_{ос}$+$W_{об}$)	kWh	29,833
Total specific annual energy consumption (per m^2 of heated floor area)	**kWh/m^2**	**204.2**

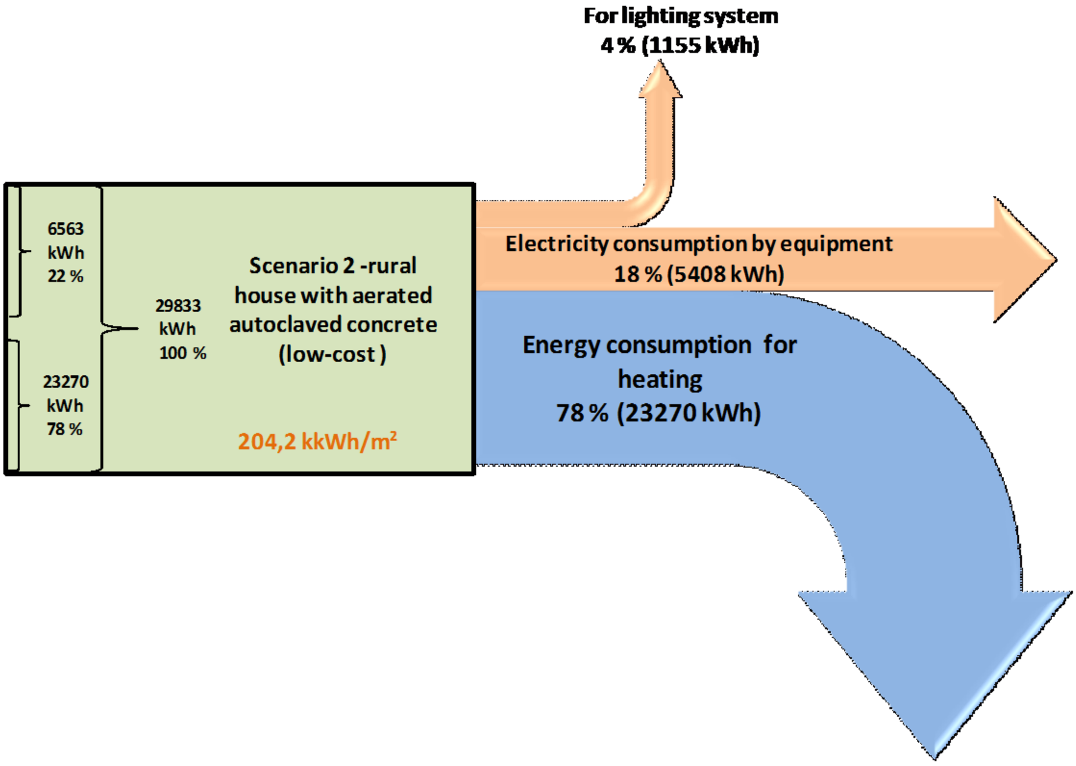


Figure 5.1.2 Energy balance: low-cost scenario

Table 5.9. **Energy balance of the rural house: intermediate-cost scenario**

Parameter	Unit	Quantity
Heat consumption for heating during the heating season, $W_{от}$	kWh	23,402
Annual electricity consumption for lighting, $W_{ос}$	kWh	1,155
Annual electricity consumption for other equipment, $W_{об}$	kWh	5,408
Total annual energy consumption ($W_{от}+W_{ос}+W_{об}$)	kWh	29,965
Total specific annual energy consumption (per m^2 of heated floor area)	**kWh/m^2**	**205.1**

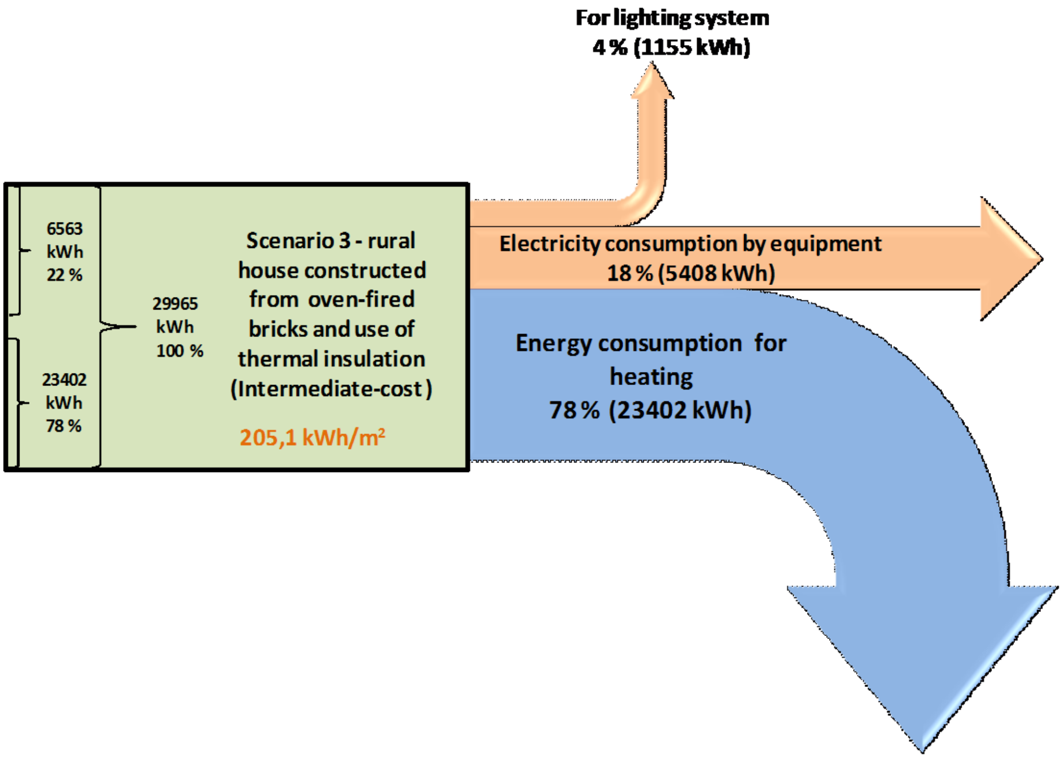


Figure 5.1.3 Energy balance: intermediate-cost scenario

Table 5.10. **Energy balance of the rural house: high-cost scenario**

Parameter	Unit	Quantity
Heat consumption for heating during the heating season, $W_{от}$	kWh	16,119
Annual electricity consumption for lighting, $W_{ос}$	kWh	81
Annual electricity consumption for other equipment, $W_{об}$	kWh	4,572
Total annual energy consumption ($W_{от}$+$W_{ос}$+$W_{об}$)	kWh	20,772
Total specific annual energy consumption (per m^2 of heated floor area)	**kWh/m^2**	**142.1**

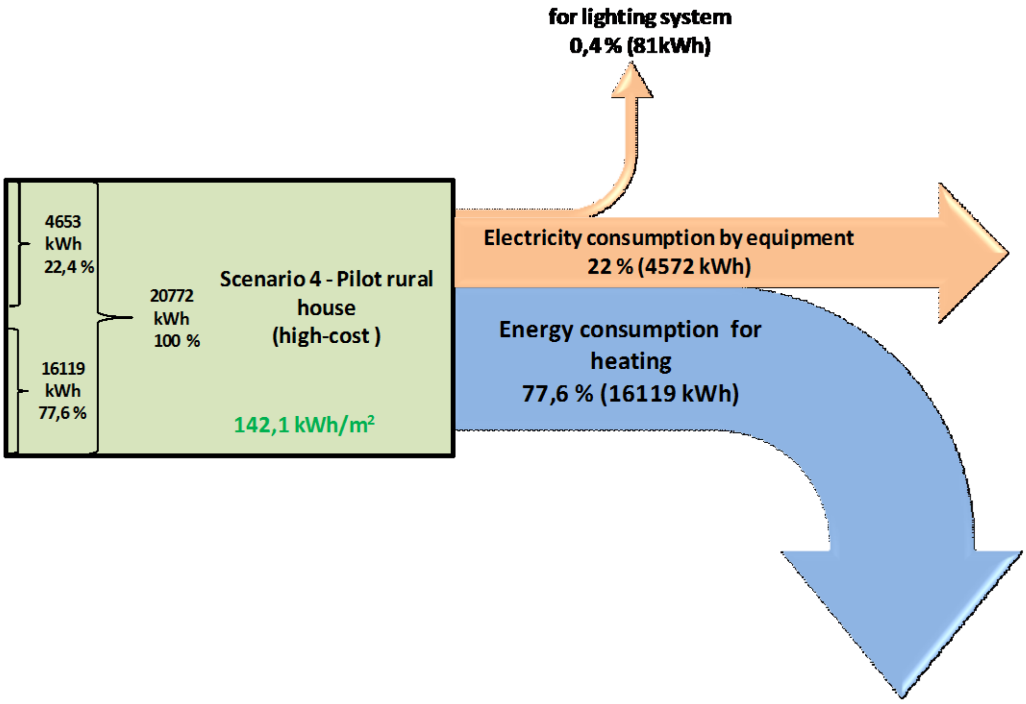


Figure 5.1.4 Energy balance: high-cost scenario

5.3. Comparison of GHG emissions from all scenarios relative to the baseline typical rural house

Based on energy consumption data, we can estimate emission reductions for each scenario relative to the baseline. The baseline, in turn, represents the GHG emissions scenario that would have occurred without the implementation of measures on energy efficiency and use of renewable energy systems.

CO_2 emissions are known to result from two fundamental processes during building operation:

1) Fuel consumption for heating;
2) Electricity consumption for heating and for the operation of appliances and equipment.

Based on various calculations in Table 5.11, figures are presented below for GHG emissions for all the scenarios of energy-efficient and "green" rural houses with respect to the baseline scenario (typical rural house).

Total CO_2 emissions and reduction relative to baseline

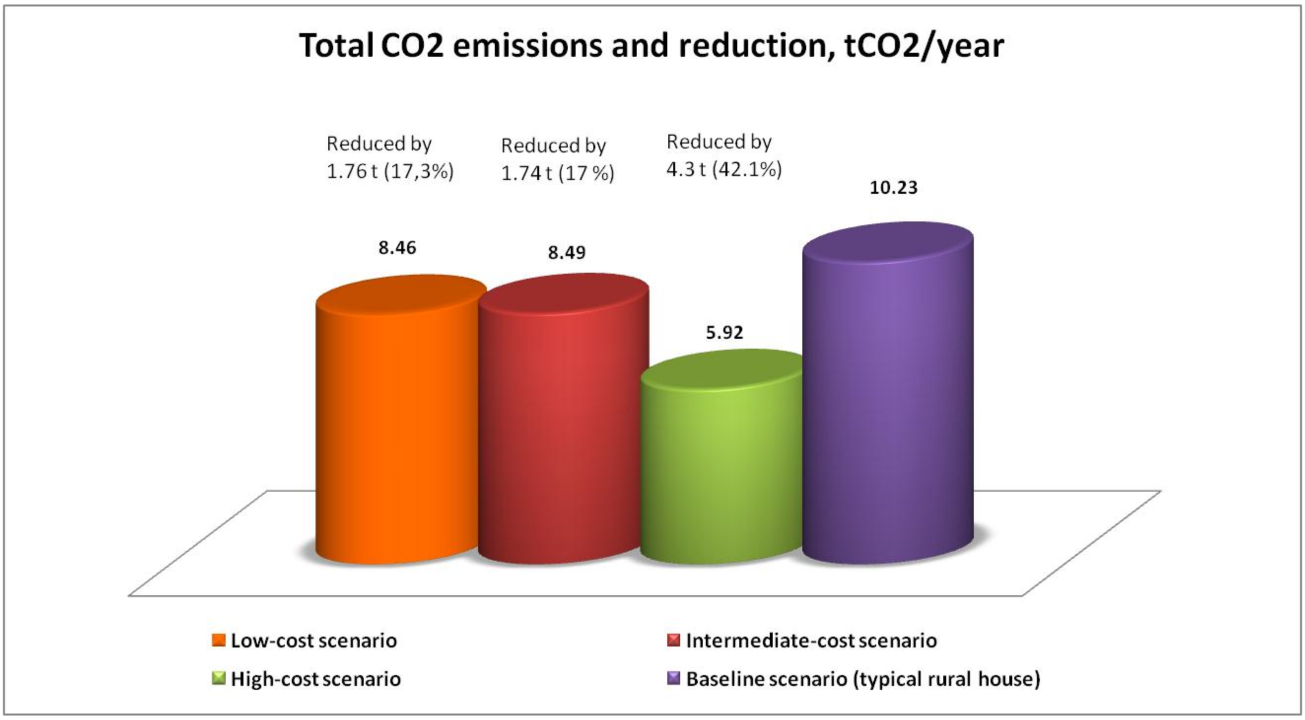


Table 5.11. **CO_2 emissions and reductions relative to the baseline (typical rural house)**

Parameter	Unit	Low-cost scenario	Intermediate-cost scenario	High-cost scenario	Baseline scenario (typical rural house)
Energy consumption for heating during the heating season	kWh	23,270	23,402	16,119	31,987
Annual electricity consumption	kWh	6,563	6,563	4,653	6,570
CO_2 emissions factor for fuel consumption for heating	kg CO_2/ kWh	0.202			
CO_2 emissions factor for electricity generation and transmission	kg CO_2/ kWh	0.573			
CO_2 emissions from heat consumption	tonnes CO_2/year	4.70	4.73	3.26	6.46
CO_2 emissions from electricity consumption	tonnes CO_2/year	3.76	3.76	2.67	3.76
Total CO_2 emissions	**tonnes CO_2/year**	**8.46**	**8.49**	**5.92**	**10.23**
Reduction in CO_2 emissions relative to baseline	**tonnes CO_2/year**	**1.76**	**1.74**	**4.30**	**-**
	%	**17.3**	**17.0**	**42.1**	

Note: The greatest reduction in GHG emissions relative to baseline comes from the high-cost scenario – 4.30 tonnes per year, or 42.1 percent.

5.4. Quantitative assessment of cost savings relative to baseline

For quantitative assessment of cost savings, the following data were used:

- annual data on energy consumption for heating for the two buildings;
- calculated data for electricity consumption for the given period;
- data on tariffs for the given period, taken from 1 October 2014.

Natural gas is the fuel used in all scenarios. Given its calorific value [7], as well as the necessary formulas, we calculated the quantity of natural gas needed to cover the heating needs of the rural house.

The electricity tariff in force during in the period under review (October 2014) amounted to 144.3 Uzbek Soums per kWh, and the tariff for natural gas amounted to 181.62 Uzbek Soums per m^3 [8].

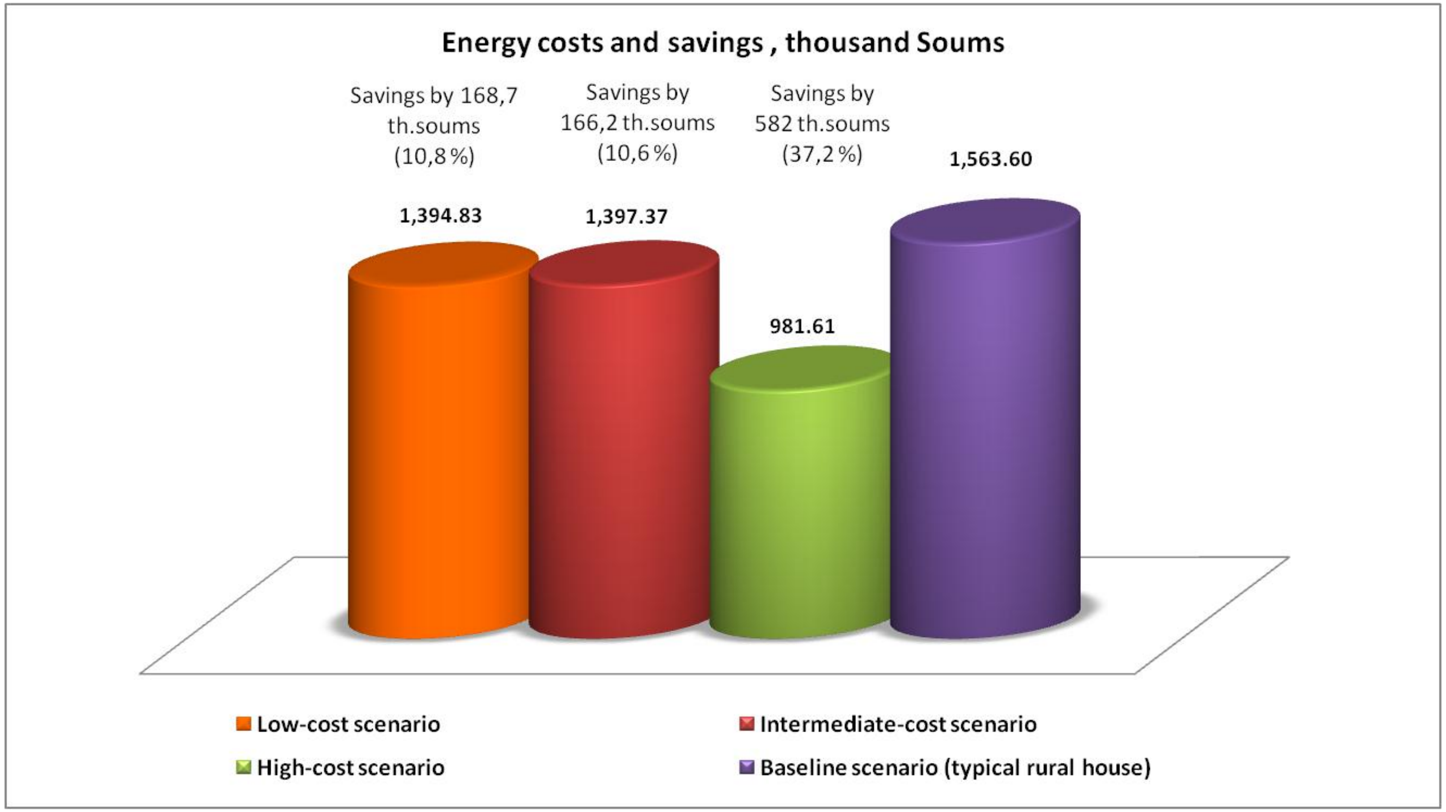
The calculation results are presented below in Table 5.12.

Table 5.12. **Quantitative assessment of energy consumption costs and savings relative to the baseline typical rural house**

Parameter	Unit	Low-cost scenario	Intermediate-cost scenario	High-cost scenario	Baseline scenario (typical rural house)
Heat consumption for heating during the heating season	kWh	23,270.0	23,402.0	16,119.0	31,987.5
Consumption of natural gas for heating	m^3	2,465.55	2,479.54	1,707.87	3,389.20
Annual electricity consumption	kWh	6,563.0	6,563.0	4,653.0	6,570.0
Prevailing tariff for natural gas (October 2014)	Uzb.soum per m^3	181.62			
Prevailing tariff for electricity (October 2014)	Uzb.soum per kWh	144.3			
Heating costs	Thousand Uzb.soum	447.79	450.33	310.18	615.55
Electricity costs	Thousand Uzb.soum	947.04	947.04	671.43	948.05
Total energy costs	**Thousand Uzb.soum**	**1,394.83**	**1,397.37**	**981.61**	**1,563.60**
Energy cost savings	**Thousand Uzb.soum**	**168.76**	**166.22**	**581.99**	**-**
	US $	**71.4**	**70.3**	**246.3**	
	%	**10.8**	**10.6**	**37.2**	

The reduction in heat and electricity consumption and the associated energy costs relative to baseline vary from 10.6 percent (low-cost and intermediate-cost scenarios) up to 37.2% (high-cost scenario).

Energy costs and savings relative to baseline



Conclusion

The overall summary results of the calculations for all scenarios are as follows:

Table 5.13. **Summary parameters for all scenarios**

Parameter	**Unit**	**Low-cost scenario**	**Intermediate-cost scenario**	**High-cost scenario**	**Baseline scenario (typical rural house)**
Construction cost	Thousand Uzb. Soums	159,682.3	176,421.9	220,796.1	168,976
	Thousand US $	67.5	74.6	93.4	71.5
Energy consumption per year	kWh	29,833	29,965	20,772	38,557
Specific energy consumption	kWh/m^2	204.1	205	142.1	263.8
Total CO_2 emissions	tonnes CO_2	8.46	8.49	5.92	10.23
Energy costs (based on tariffs in force in 1 March 2015)	Thousand Uzb. Soums	1,394.83	1,397.37	981.61	1,563.6
	US $	562.3	563.4	395.7	630.4

Financial parameters

As is evident from the data presented here, the low-cost scenario, which indeed is the lowest-cost scenario for the construction of the rural house, is **9,293.7 thousand Uzb. Soums (US $3747) or 5.5 percent less costly** than even the baseline scenario in terms of initial capital cost. This cost reduction arises from the use of aerated autoclaved concrete as the material for load-bearing building envelope elements of the building, and also serves as thermal insulation. However, it is necessary to plan for increased thermal insulation in the attic floor for this scenario.

Construction cost for the rural house under the intermediate-cost scenario exceeds baseline costs by **7,445.9 thousand Uzb. Soums (US $3002) or 4.5 percent**. The increased cost arises from use of thermal insulation for the building envelope. It is also necessary to increase the thermal performance of the attic floor (to increase the insulation layer) up to Level II of thermal performance.

The most expensive but also the most energy-efficient variant of the rural house is the high-cost scenario, whose costs exceeds the baseline by **51,280.1 thousand Uzb. Soums (US $20,675) or 23.4 percent.** Solar electric and water-heating systems were also applied, with further modernization of the systems of heat supply, heat delivery, and ventilation, all of which were absent in the other three scenarios.

Energy-efficiency parameters

The most energy-intensive scenario is the baseline typical rural house, while the least energy-intensive is the high-cost scenario – the pilot rural house (with increased energy efficiency and use of renewable energy), in which energy consumption was reduced for heating by almost 50 percent, and electricity consumption by 30 percent, with analogous proportional reductions in GHG emissions and energy costs. The overall reduction in energy costs for the high-cost scenario is **581.99 thousand Uzb. Soums (US $246.30) per year, or 37.2 percent**

The levels of energy consumption under the low-cost and intermediate-cost scenarios are practically identical, and do not differ significantly from the baseline scenario.

Recommendations on implementation of energy-saving technologies for large-scale application in rural housing in Uzbekistan

1. As typical construction of rural houses normally employs oven-fired brick, one must be sure to provide insulation of the thermal envelope, which ensures compliance with Level II of thermal performance as required by KMK 2.01.04-97 * "Building Thermal Engineering";
2. For the low-cost scenario (use of aerated concrete for the construction of the building envelope), additional insulation should be provided for attic floors, in order to meet the requirements for Level II of thermal performance;
3. In developments where there is reliable gas and electricity supply, heating systems and domestic hot water should be modernized. Automated dual-contour gas boilers for heating and hot water are recommended;
4. In developments where there are problems with electricity supply, photovoltaic panels should be applied to minimally cover lighting needs.
5. Given that electric water heaters are used in typical rural houses, in developments where there are problems with electricity, solar water heaters should be used for domestic hot water;
6. For the baseline scenario of the typical rural house, it is necessary to implement low-cost measures such as the installation of heat-reflective panels behind radiators and manual regulatory valves on the heating units.
7. The thermal insulation of exterior walls of rural houses should be carried out, using appropriate thermal insulation and auxiliary materials.
8. In the development of design documentation, as well as during the operation of rural houses, it is necessary to take into account the requirements specified for lighting and appliances in the Resolution of the Cabinet of Ministers № 8 of 22 January 2015, which, in particular, establishes the following, starting on 1 January 2016:
    - Requirements for mandatory contents of technical documentation, rating, and labeling of information on the energy efficiency category (rating level) for household electric appliances imported and sold in the territory of the Republic of Uzbekistan;
    - A rating system including categories of A, B, C, D, E, F, and G will be introduced;
    - Starting on 1 January 2016, import for sale in the territory of the Republic of Uzbekistan of household electric appliances whose labels do not include information on the energy efficiency rating will be prohibited;
    - There will be a staged ban on the import and sale of household electric appliances of energy-efficiency class G starting on 1 January 2017, class F starting on 1 January 2018, and class E starting on 1 January 2019.

Table 2.3. **Temperature and humidity data**

№	Date	Time	Temperature (T) (^{0}C)	Humidity (f) (%)	№	Date	Time	Temperature (T) (^{0}C)	Humidity (f) (%)
1	25.02.2015	15:35:12	0.6	93	35	06.03.2015	3:35:12	7.7	49
2	25.02.2015	21:35:12	0.5	94	36	06.03.2015	9:35:12	14.8	44
3	26.02.2015	3:35:12	1.2	92	37	06.03.2015	15:35:12	10.5	76
4	26.02.2015	9:35:12	3.1	83	38	06.03.2015	21:35:12	5.4	92
5	26.02.2015	15:35:12	3.2	84	39	07.03.2015	3:35:12	4.3	95
6	26.02.2015	21:35:12	2.6	91	40	07.03.2015	9:35:12	4.6	90
7	27.02.2015	3:35:12	2.6	86	41	07.03.2015	15:35:12	4	85
8	27.02.2015	9:35:12	6.4	66	42	07.03.2015	21:35:12	3.2	90
9	27.02.2015	15:35:12	5.2	73	43	08.03.2015	3:35:12	2.6	94
10	27.02.2015	21:35:12	3.6	78	44	08.03.2015	9:35:12	7.8	55
11	28.02.2015	3:35:12	1.9	87	45	08.03.2015	15:35:12	6.2	63
12	28.02.2015	9:35:12	10.1	43	46	08.03.2015	21:35:12	5	73
13	28.02.2015	15:35:12	6.8	62	47	09.03.2015	3:35:12	5.4	76
14	28.02.2015	21:35:12	2.2	76	48	09.03.2015	9:35:12	9.5	51
15	01.03.2015	3:35:12	1.9	67	49	09.03.2015	15:35:12	5.3	88
16	01.03.2015	9:35:12	11.5	38	50	09.03.2015	21:35:12	0.4	94
17	01.03.2015	15:35:12	8	50	51	10.03.2015	3:35:12	-0.2	94
18	01.03.2015	21:35:12	3.5	78	52	10.03.2015	9:35:12	0.8	96
19	02.03.2015	3:35:12	2.8	82	53	10.03.2015	15:35:12	1.1	83
20	02.03.2015	9:35:12	10.8	48	54	10.03.2015	21:35:12	0.6	88
21	02.03.2015	15:35:12	11.3	48	55	11.03.2015	3:35:12	-0.1	92
22	02.03.2015	21:35:12	4.3	84	56	11.03.2015	9:35:12	6.7	57
23	03.03.2015	3:35:12	4.7	69	57	11.03.2015	15:35:12	5.1	58
24	03.03.2015	9:35:12	14.7	41	58	11.03.2015	21:35:12	2.7	74
25	03.03.2015	15:35:12	11	62	59	12.03.2015	3:35:12	1.6	80
26	03.03.2015	21:35:12	6.5	81	60	12.03.2015	9:35:12	10.3	42

27	04.03.2015	3:35:12	5	76	61	12.03.2015	15:35:12	7.8	47
28	04.03.2015	9:35:12	15.8	36	62	12.03.2015	21:35:12	4.3	52
29	04.03.2015	15:35:12	11.6	54	63	13.03.2015	3:35:12	4.6	57
30	04.03.2015	21:35:12	7.7	67	64	13.03.2015	9:35:12	15.1	30
31	05.03.2015	3:35:12	6.2	63	65	13.03.2015	15:35:12	10.8	42
32	05.03.2015	9:35:12	16.5	35	66	13.03.2015	21:35:12	5	62
33	05.03.2015	15:35:12	11.8	51	67	14.03.2015	3:35:12	6.4	51
34	05.03.2015	21:35:12	7.3	55	68	14.03.2015	9:35:12	15.6	32

Table 2.4. **Data on temperature and humidity of indoor air (pilot rural house)**

№	**Date**	**Time**	**Temperature (T) (^{0}C)**	**Humidity (f) (%)**	**№**	**Date**	**Time**	**Temperature (T) (^{0}C)**	**Humidity (f) (%)**
1	25.02.2015	15:35:12	20.4	59.2	35	06.03.2015	3:35:12	19.3	61.2
2	25.02.2015	21:35:12	20.3	59.3	36	06.03.2015	9:35:12	19.7	60.8
3	26.02.2015	3:35:12	20.1	59.7	37	06.03.2015	15:35:12	19.4	61
4	26.02.2015	9:35:12	20.1	59.6	38	06.03.2015	21:35:12	19.9	60.2
5	26.02.2015	15:35:12	19.7	60.1	39	07.03.2015	3:35:12	19.7	60.4
6	26.02.2015	21:35:12	19.6	60.4	40	07.03.2015	9:35:12	19.5	60.6
7	27.02.2015	3:35:12	19.5	60.5	41	07.03.2015	15:35:12	19.4	60.7
8	27.02.2015	9:35:12	19.1	60.2	42	07.03.2015	21:35:12	20.0	59.9
9	27.02.2015	15:35:12	19.0	60.1	43	08.03.2015	3:35:12	19.6	60.8
10	27.02.2015	21:35:12	19.2	60.3	44	08.03.2015	9:35:12	20.0	59.8
11	28.02.2015	3:35:12	20.2	59.9	45	08.03.2015	15:35:12	20.0	59.7
12	28.02.2015	9:35:12	20.7	60.5	46	08.03.2015	21:35:12	20.2	59.4
13	28.02.2015	15:35:12	21.2	58.5	47	09.03.2015	3:35:12	19.9	60
14	28.02.2015	21:35:12	22.2	53.7	48	09.03.2015	9:35:12	20.4	59.3
15	01.03.2015	3:35:12	22.0	53.4	49	09.03.2015	15:35:12	20.7	58.9
16	01.03.2015	9:35:12	21.1	58.6	50	09.03.2015	21:35:12	20.4	59.1
17	01.03.2015	15:35:12	21.6	57.9	51	10.03.2015	3:35:12	20.5	59
18	01.03.2015	21:35:12	21.4	58	52	10.03.2015	9:35:12	20.6	58.8
19	02.03.2015	3:35:12	21.2	58.4	53	10.03.2015	15:35:12	21.2	58.4
20	02.03.2015	9:35:12	21.2	58.5	54	10.03.2015	21:35:12	21.2	58.4

21	02.03.2015	15:35:12	21.0	58.6	55	11.03.2015	3:35:12	21.7	58.1
22	02.03.2015	21:35:12	20.8	59.2	56	11.03.2015	9:35:12	21.9	57.8
23	03.03.2015	3:35:12	20.9	59.1	57	11.03.2015	15:35:12	23.1	52.4
24	03.03.2015	9:35:12	20.2	59.7	58	11.03.2015	21:35:12	22.7	53.6
25	03.03.2015	15:35:12	20.4	59.4	59	12.03.2015	3:35:12	23.1	52.5
26	03.03.2015	21:35:12	19.8	60.5	60	12.03.2015	9:35:12	24.4	51.9
27	04.03.2015	3:35:12	19.6	60.8	61	12.03.2015	15:35:12	24.2	52
28	04.03.2015	9:35:12	19.5	60.7	62	12.03.2015	21:35:12	23.5	52.6
29	04.03.2015	15:35:12	19.6	60.8	63	13.03.2015	3:35:12	23.7	52.3
30	04.03.2015	21:35:12	19.4	61.1	64	13.03.2015	9:35:12	23.1	52.9
31	05.03.2015	3:35:12	19.6	61	65	13.03.2015	15:35:12	22.8	53.4
32	05.03.2015	9:35:12	20.4	59.6	66	13.03.2015	21:35:12	22.6	53.6
33	05.03.2015	15:35:12	20.1	59.8	67	14.03.2015	3:35:12	22.4	53.7
34	05.03.2015	21:35:12	19.8	60.3	68	14.03.2015	9:35:12	23.1	52.2

Table 2.5. **Data on temperature and humidity of indoor air (typical rural house)**

№	**Date**	**Time**	**Temperature (T)**	**Humidity (f)**	**№**	**Date**	**Time**	**Temperature (T)**	**Humidity (f)**
			(^{0}C)	**(%)**				**(^{0}C)**	**(%)**
1	25.02.2015	15:35:12	19.9	61.4	35	06.03.2015	3:35:12	22.7	53
2	25.02.2015	21:35:12	19.8	62.8	36	06.03.2015	9:35:12	23.1	53.7
3	26.02.2015	3:35:12	19.1	59.2	37	06.03.2015	15:35:12	24.4	51.3
4	26.02.2015	9:35:12	18.8	60.1	38	06.03.2015	21:35:12	25.4	49.3
5	26.02.2015	15:35:12	19.4	60.3	39	07.03.2015	3:35:12	25.3	48
6	26.02.2015	21:35:12	19.7	59.1	40	07.03.2015	9:35:12	23.5	52.6
7	27.02.2015	3:35:12	19.5	58.8	41	07.03.2015	15:35:12	24	50.4
8	27.02.2015	9:35:12	18.9	60.6	42	07.03.2015	21:35:12	23.9	51.3
9	27.02.2015	15:35:12	18.8	59.6	43	08.03.2015	3:35:12	23.8	49.5
10	27.02.2015	21:35:12	19.3	60.1	44	08.03.2015	9:35:12	23.9	48.5
11	28.02.2015	3:35:12	18.3	61.3	45	08.03.2015	15:35:12	19.2	43.5
12	28.02.2015	9:35:12	19.6	57.6	46	08.03.2015	21:35:12	20.2	61.7
13	28.02.2015	15:35:12	21.2	54.2	47	09.03.2015	3:35:12	19.9	60.5
14	28.02.2015	21:35:12	20.7	59	48	09.03.2015	9:35:12	21.2	58.5

15	01.03.2015	3:35:12	20	58.1	49	09.03.2015	15:35:12	22.2	53.7
16	01.03.2015	9:35:12	20.1	51.5	50	09.03.2015	21:35:12	22.8	53.4
17	01.03.2015	15:35:12	19.5	50.6	51	10.03.2015	3:35:12	21.1	59
18	01.03.2015	21:35:12	19.7	59.8	52	10.03.2015	9:35:12	21.6	55.5
19	02.03.2015	3:35:12	19.6	57	53	10.03.2015	15:35:12	18.1	68.4
20	02.03.2015	9:35:12	19.9	59	54	10.03.2015	21:35:12	17.6	66.8
21	02.03.2015	15:35:12	18.3	45.8	55	11.03.2015	3:35:12	17.5	67
22	02.03.2015	21:35:12	19.9	60	56	11.03.2015	9:35:12	17.8	62.7
23	03.03.2015	3:35:12	19.7	58.9	57	11.03.2015	15:35:12	18.3	61.8
24	03.03.2015	9:35:12	19.9	58.1	58	11.03.2015	21:35:12	19.1	60.3
25	03.03.2015	15:35:12	20.2	58.4	59	12.03.2015	3:35:12	18.3	60.8
26	03.03.2015	21:35:12	22.8	55.3	60	12.03.2015	9:35:12	18.6	60.4
27	04.03.2015	3:35:12	20.4	60.7	61	12.03.2015	15:35:12	18.7	48
28	04.03.2015	9:35:12	20.5	60	62	12.03.2015	21:35:12	19.6	52.9
29	04.03.2015	15:35:12	20.5	59.8	63	13.03.2015	3:35:12	19.4	56
30	04.03.2015	21:35:12	21.2	61.6	64	13.03.2015	9:35:12	19.9	57.4
31	05.03.2015	3:35:12	21.2	60.2	65	13.03.2015	15:35:12	20.8	55
32	05.03.2015	9:35:12	21.7	58.5	66	13.03.2015	21:35:12	22.5	46.5
33	05.03.2015	15:35:12	21.9	50	67	14.03.2015	3:35:12	22.5	53.5
34	05.03.2015	21:35:12	23.1	51.4	68	14.03.2015	9:35:12	24.1	51.5

Table 4.2. **Thermal resistance of envelope elements**

Building envelope section	**Unit of measure**	**Pilot rural house**	**Typical rural house**	**Level II for thermal resistance, according to building code**	**Level III of thermal resistance, according to building code**
Exterior walls	$m^{2} \cdot {}^{0}C/W$	3.87	0.99	1.8	2.6
Level of compliance	*Level*	III	I		
Attic floors	$m^{2} \cdot {}^{0}C/W$	4.48	1.1	2.08	2.96
Level of compliance	*Level*	III	I		
Floor at ground level, floor above unheated cellar or crawlspace *	$m^{2} \cdot {}^{0}C/W$	3.88	3.88	1.84	2.56
Windows, balcony doors	$m^{2} \cdot {}^{0}C/W$	0.39	0.39	0.39	0.42
Level of compliance	*Level*	II	II		

*There is no code-stipulated value for floors at ground level.

Table 4.3. Calculations of annual energy consumption

Parameter	**Units**	**Pilot rural house**	**Typical rural house**	**Level II according to building code**	**Level III according to building code**
Heat consumption for heating the building during the heating season, $W_{от}$	kWh	16,119	31,987	22,189	18,037
Annual consumption of electric energy for lighting, $W_{ос}$	kWh	81	1,170	1,155	1,155
Annual consumption of electric energy for other equipment, $W_{об}$	kWh	4,572	5,400	5,408	5,408
Total energy consumption by the building ($W_{от}+W_{ос}+W_{об}$)	**kWh**	20,772	38,557	28,752	24,600

For all the parameters of annual energy consumption shown in the table, the pilot rural house outperforms the requirements of Level III for thermal performance, while the typical rural house complies only with Level I.

Table 4.4. **Specific (per m^2 of floor area) indices of energy consumption**

Parameter	Unit	Pilot rural house	Typical rural house	Level II for thermal resistance	Level III for thermal resistance
Specific consumption of heat energy for heating (over the heating season)	kWh/m^2	110.3	218.9	151.8	123.4
Specific consumption of electric energy by equipment, appliances, and lighting (per year)	kWh/m^2	31.8	44.9	44.9	44.9
Overall specific energy consumption by the building per year	**kWh/m^2**	142.1	263.9	196.7	168.3

Specific indices of energy consumption per meter of floor area of the pilot rural house for all parameters outperform the requirements of Level III of relevant building codes for thermal performance of buildings, while the indices for the typical house comply only with Level I.

Table 4.5. **Calculations of CO_2 emissions and reductions relative to the baseline level of the typical rural house**

Parameters	Units	Pilot rural house	Typical rural house
Energy consumption for heating during the heating season	kWh	16,119.0	31,987.5
Annual consumption of electricity	kWh	4,653.0	6,570.0
CO_2 emissions factor for gas combustion	kg CO_2/ kWh	0.202	
CO_2 emissions factor for electricity generation and transmission	kg CO_2/ kWh	0.573	
CO_2 emissions from heat consumption	tonnes CO_2/year	3.26	6.46
CO_2 emissions from electricity consumption	tonnes CO_2/year	2.67	3.76
Total tonnes of CO_2 emissions	tonnes CO_2/year	**5.92**	**10.23**
Reduction of CO_2 emissions relative to baseline	tonnes CO_2/year	**4.30**	**-**
	%	**42.1**	

Table 4.6. **Quantitative assessment of financial outlays for energy consumption and savings relative to the baseline typical house**

Parameters	Units of measure	Pilot rural house	Typical rural house
Heat consumption for heating over the heating season	kWh	16119.0	31987.5
Natural gas consumption for heat generation	m^3	1707.87	3389.20
Annual electricity consumption	kWh	4653.0	6570.0
Natural gas tariff	Uzb. Soums per m^3	181.62	
Electricity tariff	Uzb. Soums per kWh	144.3	
Cost of heating	Thousand Uzb. Soums	310.18	615.55
Cost of electricity	Thousand Uzb. Soums	671.43	948.05
Total cost	Thousand Uzb. Soums	**981.61**	**1 563.60**
Savings from reduced energy consumption	**Thousand Uzb. Soums**	**581.99**	**-**
	%	**37.2**	

The annual reduction of natural gas consumption by the pilot rural house relative to the typical rural house is 1.7 thousand m^3 per year, which corresponds to US $425 based on export prices of natural gas[7].

[7] http://neftegaz.ru/news/view/107164