Energy efficient technologies for residential buildings in Ural Region: case study of reconstructed cowshed

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Abstract. The development of the experimental implementation of energy-efficient technologies into the building design is interesting with regards to the Ural climate conditions. It is prime of importance to study the initial steps of rational and efficient introduction of green technologies and renewable energy sources into the building design. In this paper, we have turned our attention to the green technology implementation into the renovated building in the Urals. The renovated cowshed, located in the suburbs of Ekaterinburg, was used as an example to describe and evaluate the efficiency of successful implementation of renewable energy sources and different green solutions. The uniqueness of this building is in complete substitution of its previous functional usage with meeting such sanitary conditions, which are suitable for the living arrangements. The renovated house was equipped with power systems based on renewable energy sources, managed by a householder, and also the economical operation of solar panels along with energy system was organized. The all-year efficient work of the heat pump and the ground heat exchanger was provided, and also the efficient operation of heating and conditioning systems was maintained.

1. Introduction

Energy conservation is one of the key issues nowadays. The issue worth special attention is the energy-efficient technology implementation into the building design for harsh climatic conditions, in particular, the continental climate with extremes of temperatures. Such climatic conditions are typical for Canada, Finland, Sweden, Norway, Russia and many others. The analysis of successful green technology integration in this paper was made for Ural region, Russia.

Even though Russia is better than any other country provided with own conventional fuel and energy resources, the development of renewable energy resources (RER) is an extremely important strategy for the future of power engineering [1,2]. The need to foster the development of RER in Russia results from both energy security requirements in the regions outside of centralized energy supply systems with competitive RER technologies and requirements to create a reliable premise for the innovative energy development for future generations[3,4].

While independent power engineering employs competitive RER technologies, centralized power engineering requires the implementation of state economic support measures in a similar way to other countries [5]. To accelerate the adoption of Government regulations fostering RER development is essential in this field [6,7].
Accelerated RER development in Russia needs to be considered as a significant factor of economic modernization related to innovative production development, the design of innovative technologies, small and medium business development, creation of new jobs, improvement of social conditions and ecology, etc.[8].

The State should act as an interested party in RER development and actively contribute to the development of this new trend in power engineering mainly through the creation of incentives for business. Meanwhile, state involvement in RER development should become government business rather than charity work at the expense of taxpayers. Every rubble spent from the budget on RER support should be covered. According to the assessment and experience from other countries, the rubble can and should make a profit for the budget because of the business development [9,10].

2. Energy policy in Russia

The Far East appears to be attractive in terms of RER application in Russia [11]. The Republic of Sakha (Yakutia) is referred to as the principal direction of RER development in the region. Renewable energy is nearly a matter of survival for the region with a surface area of 3 084 000 km2, the population of only one million people and the average temperature amplitude under 900 C in January and July. Yakutia lacks Power Grid; the life in the Artic and the districts of the Far North is supported by the local energy system using mostly diesel fuel.

The first solar power station (SPS) in Yakutia was established in Batamay — the nearest settlement to the capital of the republic. The way from Yakutsk to the settlement on boat by the river Lena takes about four hours; for local community it is almost near. The station has 258 panels with total contracted capacity of 60 kW and allows saving 15 tons of diesel fuel annually. During the period of the active Sun, the station produces 70 per cent of the energy consumed by the settlement, and in the winter — about 40 per cent. The rest is produced by the diesel-generator. There are 13 SPSs in Yakutia (1335 kW), but it is not enough for the huge area with limited infrastructure. The unique normative basis was introduced to attract investments and to develop renewable energy in the republic. Nevertheless, the weakening of the rubble affected energy projects. According to expert estimates, the payback period of investments accounts for 7–10 years, yet the cost of equipment increased due to the current appreciation. This influenced economic parameters of projects bringing some of them to zero return; payback period was postponed [12].

However, the interest of foreign companies to the republic does not lessen and it is not only a matter of profit [13]. Climatic conditions in Yakutia are both advantage and disadvantage of the republic being unique testing area for designing innovative technologies in the field of RER or, as power engineers say, the place where nature tests people and equipment.

The development of RER is relevant only in several regions of Russia with either expensive traditional electricity for end users or without infrastructure. The Republic of Sakha (Yakutia), the Chukotka Autonomous Region, the Artic area of Russia and the Crimea, in particular, are such regions that have proper weather conditions to construct solar power stations thus solving the problem of the continent energy dependence. However, it is obvious that Government should subsidize RER in Russia [14].

3. The case study of the reconstructed cowshed

To exemplify that a dwelling house under reconstruction with little prior capital investment can be energy efficient, one may consider the townhouse in the Ural region (Figure 1). The reconstruction project of the cowshed and the decisions in engineering services and systems were carried out under the direction of the professor S. E. Shcheklein. The townhouse in the settlement Rastushchiy, Sverdlovsk region used to be the cowshed building owned by the state farm. Since the building was used to keep cows and then abandoned, it was decided to survey building structures and to decontaminate the whole building in order to make it suitable for permanent residence. First, specialists carried out the survey of the cowshed building and concluded that the building was in satisfactory condition. Then, some activities for building and ground sanitation were performed.
enabling living in the building safe. The excavation to a depth of 0.5 m, decontamination and protective treatment of walls, slabs, coatings and other building structures were done. The cowshed having been redesigned, the townhouse consisted of eight flats. The idea was that the building would possess higher heat insulation features, consume less heat energy, be comfortable, as well as have proper heat supply, sewerage and electricity systems. The tasks were gradually dealt with.

![Image](image.jpg)

**Figure 1.** The main façade of the reconstructed cowshed.

The owned drainage field is a natural swamp with the area of approximately one hectare. Waste water after treatment is discharged; thick, and biologically active fractions are removed before the waste discharge into the swamp. Analys is showed that the water is grey that is suitable for discharging into the river. The water is taken from the well about 100 m deep and then is collected in the membrane storage tank; the water is pumped from the well and stored in this tank. Water draw-off begins when the set point of the pump lowers. The pump is rarely switched on, it never operates during the daytime, and in the evening 150–200 liters of water can be drawn off without the pump.

### 3.1. Electricity

The main source of energy is local network with the capacity of 10 kW. One of the key issues is to reduce energy consumption so that a significant part of energy will be provided from renewable sources. The provision of all energy by means of renewable sources was not challenged. Solar batteries are used in the building for emergency stand-by power. Gas-fired heating is provided and there are also circulation pumps and automatic equipment. For the pump and controller to operate, the capacity of 150 W is required. The task of renewable energy resources is to provide reliable back up in the case of centralized power supply shutdown. Solar batteries with voltage of 12 V and total capacity of 800 W together with controller for charging are installed on the façade. There is additional electrical reticulation of 12 V round the house. There are two types of voltage: 12 V and 220 V (system).

The inverter is used when it is necessary to get 220 W from 12 V.

The next task appeared later is to organize the operation of solar batteries in parallel with that of energy power system, i.e. to obtain energy from energy power system and at the same time to generate 220 W from solar batteries to supply flats, and to give upover generation to the network. Themaintaskhere is to reduce own consumption, that is to take less from the energy power system. Such batteries with the capacity of 600 W are installed with special devices: controllers or inverters to maintain and equalize the amplitude by the network, phases and frequencies to protect the network.

In the summer months, energy consumption equals zero and sometimes goes negative which means energy is given up to the energy power system. Due to the lack of the legal instrument allowing to get money for giving up over generation to the network, 300 kW/h were given free of charge in 2016 in Russia. The economic efficiency consists in the absence of expensive accumulators and, consequently, of their maintenance required. Here, energy power system is used instead of accumulators and, if the system is reliable, it can be used as an unconfined accumulator.
In the summer with plenty of sun, the energy generated is given up to the system, and in the winter this energy can be taken relying on the system’s capability to get energy mostly indefinitely. This will require the bidirectional meter that calculates the amount of energy given up and consumed and, finally, provides the net difference. Yet there is no normative act for this process to enjoy legitimacy. Thus, one can give the energy up but cannot get the own energy; this is sure to be feasible in the nearest future. Nowadays, the microgeneration law is being developed on an urgent basis: the unit of any mode of operation with the capacity up to 15 kW based on RER application.

It would be possible to be connected to the network upon notification: as soon as the unit is bought and the certificate of registration and technical characteristics is presented, the unit needs to be registered. Then, the energy-supplying organization installs the bidirectional meter, signs the contract on settlement of accounts with the owner of the unit. There is also foreign experience available. In April, the Government of the Russian Federation issued such directive, which will have become the law by the autumn thanks to the active involvement of the Government. This will give a strong impetus to RER developing in Russia. Units are becoming cheaper as the most expensive elements of the structure – storage batteries are becoming irrelevant and there is the lack of further problems arising when working with accumulators, for instance, such as water/acid/charge or discharge resource.

Several wind power generators designed for slow wind velocity and with total capacity of 600 W were installed on the territory adjacent to the townhouse.

3.2. Hot water manufacture from the sun
A great number of Russian and foreign solar energy collectors were tested. For several years, neither gas nor electricity have been used to heat water in the townhouse in the summer. The current water heating system operates as follows: the temperature fixed at about 70°C is maintained in the storage tank with large volume of approximately 250 liters. The temperature in the tank must be at least 60°C, otherwise the water is a source for legionella – pathogenic bacteria. If the sun fails to heat the water to the required temperature, one should heat it by means of electricity, for example. Constant water draw-off is essential for legionella not to form. European regulation requires constant maintenance of water temperature at least 60°C. If a small-capacity unit is installed for a one-story cottage or a garden shed, it would be possible to do without a pump and to introduce the unit with natural coolant circulation.

3.3. Utilization of electric energy for heating with the use of the heat pump
Electric energy is taken from the network only for the compressor drive of the heat pump rather than for heating that demand slow potential heat source. For example, the average annual temperature of the soil accounts for 6–7 degrees. In this case, a well 100 meters deep is drilled and the heat exchanger goes in to the hole. The heat from the soil is taken away, the heat pump increases the temperature of the heat-transfer medium from 7 degrees to the required one. Moreover, depending on the value of the second temperature (i.e. required temperature) the coefficient of heat pump utilization is varied. When it is important to feed heat into radiators with the temperature of 70°C, for example, the coefficient of energy utilization would be just over 1 (about 1.5). When the temperature is increased to 400°C used for floor heating, the coefficient of utilization equals 2.5. For the temperature of 30–350°C, the coefficient of utilization accounts for 4. Such temperature can be applied for warm-air heating with the use of fan coils. During hot summer months, when the compressor is switched off and the slow circulation of heat-transfer medium between a fan coil and a small pump (20 W) begins between a fan coil, soil and a small. The temperature of heat-transfer medium in a fan coil is 7 degrees, the fan blows the air off, and so a fan coil can function as an air-conditioner. At the same time, the soil is heated; this means the energy accumulated by the soil in the summer can be used for 1–1.5 months to enhance the effectiveness. The principal scheme of engineering systems is presented on figure 2.
4. Conclusions
Many states are interested in renewable energy resources nowadays in connection with environmental problems and increasing energy costs [15,16]. In recent years, Russia has a growing interest in sustainable development and the use of renewable energy resources for decentralized energy consumers. Such interest is also due to the Far East Development Programme [17]. The importance of promoting RER application in Russia is justified on the ground that almost 70% of Russian territory is located in the area with decentralized energy supply [18]. Moreover, the implementation of RER will enable energy consumers to be independent on the price changes on energy sources because of the absence of fuel factor [19,20]. RER application is possible in Russia even in severe climatic conditions of the Urals region. Pilot and innovative project of reconstruction and reorganization of the cowshed into comfortable and energy-efficient dwelling house demonstrates practical RER application for heating, conditioning the house and for water heating. Local and seasonal application and implementation of RER gives a strong impetus to their development in Russia. New normative acts, laws as well as Government incentives would allow the application of RER to be more accessible for people [21,22].

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