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Studies energy efficiency of the renewable sources use considering climate in Latvia

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Abstract

The paper discusses problems of energy supply of buildings using renewable sources given the local climatic conditions. The meteorological conditions in Latvia and Riga for last year were analyzed. In paper shows examples of energy efficient buildings allowing that to provide comfort temperature and indoor air quality. The structure and composition of local building materials, providing good thermal insulation are described. The heating systems for test buildings using renewable energy sources were investigated. The assessment of the energy efficiency of the "air-air" and "air-water" heat pumps is studied.

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Keywords: energy efficiency, test buildings, renewable energy sources, energy consumtion, heating system, heat pump

1. Introduction

The continuous increase in prices for electricity, heating and operational expenses on the maintenance of premises arouses increased interest both in the use of renewable energy sources and in development of methods for efficient energy consumption. Actually, it is important not only to be able to produce cheap energy from renewable sources, but also to optimize its use, taking into account the climatic conditions of a particular locality. When constructing

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buildings and residential houses, it is important to use quality thermal insulating construction materials, and besides, to use energy sources effectively. In this regard, during the last decade it becomes urgent to develop "energy efficient" or so-called "passive" houses. The main feature of such a house is low power consumption, which is on average 10% of the specific energy consumption of most modern buildings [1-3]. In developed European countries there are different requirements for a passive house standard. As a rule, the rate of energy use for an object is determined by average heat energy losses per square meter, during a year or the heating season. A perfect passive house must have an independent power supply system, required to support and maintain a comfortable temperature inside the building. The heat generated by the residents and appliances in the house of this type should be enough to heat it, and, if necessary, alternative sources of energy may additionally be used. In order to solve the problems set forth the authors analyzed the features of the climate in Latvia, particularly in Riga, and reviewed the efficiency of renewable energy sources use for power supply to various buildings constructed from a variety of local building materials.

2. Statement of the problem

2.1. A brief description of the climate in Latvia

The geographical location of Latvia on the coast of the Baltic Sea and the Gulf of Riga largely determines its weather conditions. In general, the climate in Latvia can be characterized as intermediate between maritime and continental. According to long-term observations, the average annual temperature in Latvia is + 5.9°C. The warmest month is July. The average summer temperature is +17°C; the maximum temperature is +21.5°C. The coldest months are January and February; the average temperature is about -4.6°C, while the average minimum temperature is -7.7°C, Fig.1. Southern, southwestern and western winds dominate in Latvia. The strongest winds (the average monthly speed about 4 m/s) are observed in November, December and January. The weakest winds (the average monthly speed is about 2.8 m/s) blow in July and August [4, 5]. Figure 2 shows the diagrams of wind speed and solar radiationin Riga.

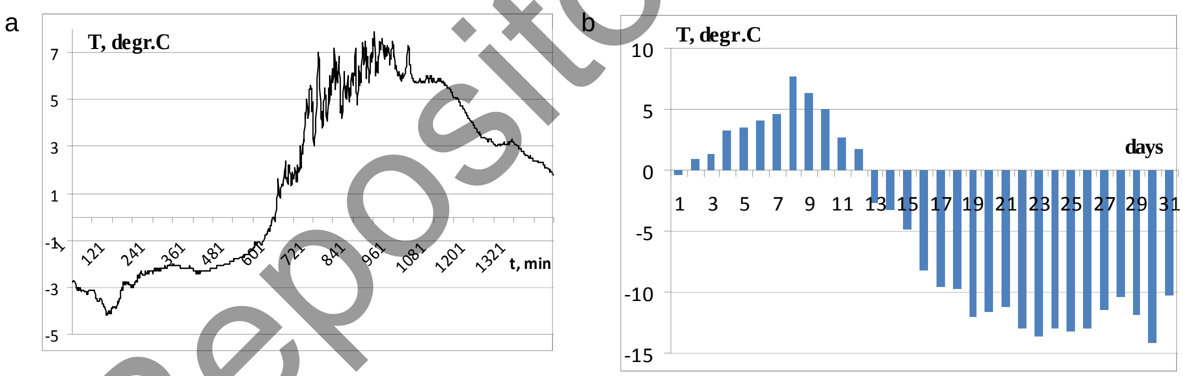

Fig. 1. Change of air temperature: a) at 17.03.2014; b) during January 2014, [5].

These data were measured on-line at the meteorological station in the Botanical Garden of the University of Latvia, there are every minute changes during the day and month. Analysis of the data shows that in the central part of Latvia, the average annual wind speed is (2÷3) m/s, and in Riga it is (1.37÷2.1) m/s. The most part of the territory is characterized by partly cloudy weather and light rain during the year. There are only 40-45 shiny days. Although the potential of the solar energy in Latvia is low, but still it is comparable with many European countries; however, it is not enough to heat the building during the day, and keep it warm at night. In the winter intensity of solar radiation accounts for (0.5÷0.8) kW/m^2, in the summer this parameter is 2.6 kW/ m^2. In Riga the climate is mild enough. In winter, it keeps very cold for a short time, there is often thaw weather. However, the heating season lasts about 6 months, so to heat and supply electricity to a house an additional source of energy is necessary.

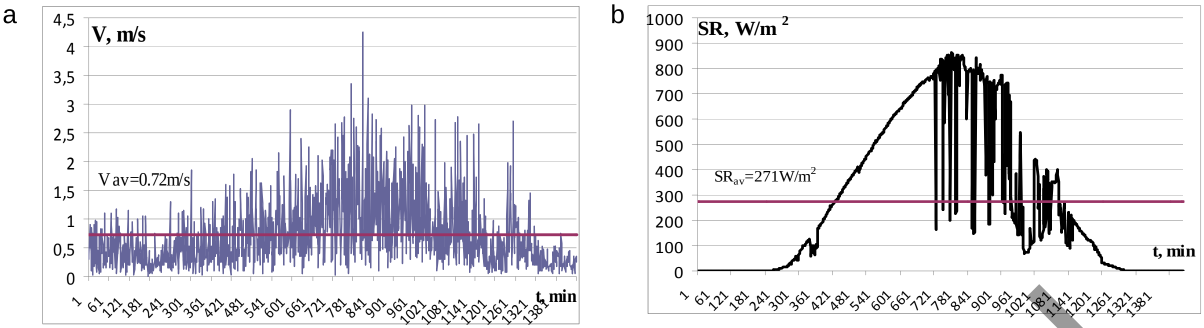

Fig. 2.Meteo data at 07.07.2014.Every minute change of: a) wind speed; b) level of solar radiation, [5].

2.2. Experiment conditions

To study the thermo-physical properties of the common construction materials made of local raw materials, in the laboratory of mathematical modeling of environment and technological processes of the University of Latvia (LU) five test buildings were built [5]. The test buildings with identical geometrical parameters are located in the same geographical conditions in the Botanical Garden of the University of Latvia.

The structure and composition of test buildings construction materials (Fig.3) are follows:

- AER – aerated concrete blocks (375 mm) with flexible stone wool layer on the external side;
- CER – perforated ceramic blocks (440 mm) with flexible stone wool insulation layeroutside
- PLY – modular plywood panels with flexible stone wool filling (200 mm) and fibrolite (70 mm) inside
- EXP – perforated ceramic blocks (500 mm)with cavities filled with insulating granules of polystyrene foam;
- LOG – laminated beams (200 mm) with flexible stone wool insulation layer and wood paneling inside

Fig.3. The construction materials structure of test buildings.

The materials of the exterior walls are different, but with approximately the same thermo-physical properties. The thermal transmission coefficient U of the walls varies in interval (0.15 ÷ 0.16) W/m^{2}K. The evaluation of thermal insulation properties of the construction materials was carried out in accordance with EN ISO 6946:2003 standard.

Heating /cooling systems using renewable energy sources were installed in the test buildings. They were a heat pump "air-air" and the system "water-air" with capillary type heat exchanger, read more in [5, 6]. Energy analysis of heating systems data as compared with a conventional electric oil heater through the seasons, taking into account the ambient temperature, was carried out.

On average, 38 sensors that measure the air temperature inside the building, pressure, humidity, power of energy consumption, the amount of electricity energy, heat consumption and others were set in each test building. Monitoring of the sensors readings is carried out automatically; data are recorded in the collection unit every minute. Besides, the special measuring equipment is connected to the site of the meteorological station.

It is not simple to analyze the energy consumption in different buildings with different heating systems. In our opinion, energy efficiency of buildings and heating systems can be most appropriately determined by SPF coefficient, which is determined by the ratio of consumed energy to the amount of produced one.

3. Discussion of results

Data on the consumption of electric energy in three test buildings for the period from 02.20.2014 to 29.04.2014 are shown in Table 1.Outside air temperature was an average 5.9ºC. During the heating period the temperature of (19÷20)°C was maintained inside the buildings.

Table 1. Energy consumtion of heating systems.

Type of heating system	Test building	W, (kWh)	SPF	T_{out}, ºC
electric heater	CER	287	**1.0**	5,9
«air-air» heat pump	LOG	190	**1.5**	
«air-water» heat pump	PLY	106	**2.7**	

The resulting heat can be estimated from the electric heater indications in the CER building; in this case as much energy is produced as it is consumed, that is SPF=1.0. The same thermal energy is produced in the other two buildings, because there is the same internal temperature. So, the most energy-efficient is the system «air-water» in the test building PLY, because with this system produced energy 2.7 times more energy than it is expended. It is also profitable to use the system «air-air» in a LOG building. Figure 4 shows the results of the assessment of energy efficiency of test buildings in March-April 2014, depending on the ambient temperature.

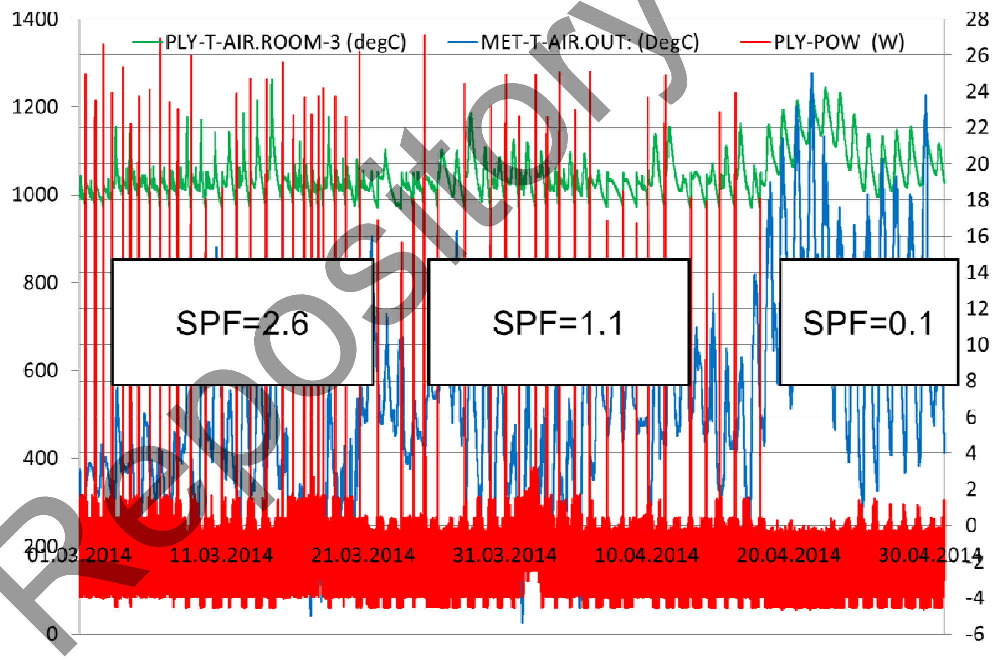

Fig.4. SPF assessment using PLY «air-water»heating system data.

The lines on the graph indicate the following:

– PLY-T-ROOM is indoor air temperature; numerical values are given in °C on the right;
– MET-T-AIR.OUT is outdoor temperature, °C;
– PLY-POW is power consumption, the numerical values are shown on the left, W.

The analysis of experimental data shows that the energy efficiency ratio depends not only on the ambient temperature, but also on the duration of the heating system operation. The more often it is turned on, as it was in the case of the lowest ambient temperatures in the period from 01.03.2014 to 03.21.2014, the greater the index SPF. During the period from 20.04.2014 to 30.04.2014, when the ambient temperature was quite high, the ratio of energy efficiency is the least, as this heating system did not operate and produced only 10% of the energy consumed.

Fig. 5 shows the dependence of the ratio of energy efficiency on the length of operation of the «air-water» heating system during a day.

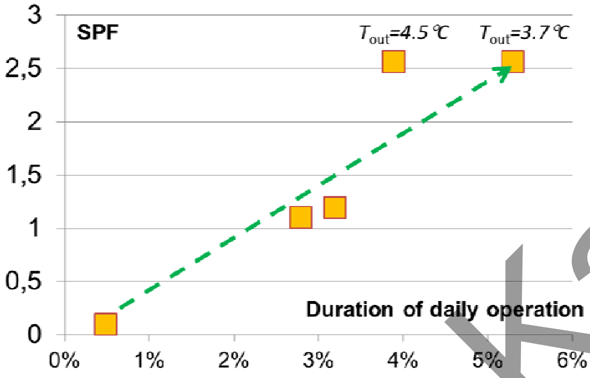

Fig.5. SPF assessment on the duration of using heating system «air-water».

The experiments show that the higher the outdoor temperature, the less the «air-water»heating system should operate in order to achieve the same level of energy efficiency.

4. Conclusion

Energy efficiency is dependent on the quality, thermal insulation properties and structure of a construction material. It was established experimentally that the most energy-efficient building is that of LOG type.

However, it should be noted that the results are valid only for the climatic conditions in Riga, for the mentioned test buildings and heating systems. However, the study results show that when analyzing the energy efficiency of buildings and heating systems under real operating conditions, it is necessary to consider not only the temperature difference between the outside and inside the building, but also the mode of their work.

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