MATEC Web of Conferences 92, 01072 (2017) DOI: 10.1051/matecconf/20179201072
Thermophysical Basis of Energy Technologies - 2016

Estimation of energy efficiency of residential buildings

Sergey Glushkov[1,*], *Nikolay* Kachalov[1], *Elena* Senkiv[1], *Victoriya* Glushkova[2]

[1]National Research Tomsk Polytechnic University, 634050 Tomsk, Russia
[2]Tomsk State Pedagogical University, 634061 Tomsk, Russia

Abstract. Increasing energy performance of the residential buildings by means of reducing heat consumption on the heating and ventilation is the last segment in the system of energy resources saving. The first segments in the energy saving process are heat producing and transportation over the main lines and outside distribution networks. In the period from 2006 to 2013. by means of the heat-supply schemes optimization and modernization of the heating systems. using expensive (200–300 $US per 1 m) though hugely effective preliminary coated pipes. the economy reached 2.7 mln tons of fuel equivalent. Considering the multi-stage and multifactorial nature (electricity. heat and water supply) of the residential sector energy saving. the reasonable estimate of the efficiency of the saving of residential buildings energy should be performed in tons of fuel equivalent per unit of time.

1 Introduction

Optimization of the use of energy-efficient solutions for construction and operation of residential buildings is not just technically. but also economically a difficult problem. The concept of heating optimization includes various options for energy saving. including reduction of heat losses in the main and distribution heat networks. increase of the use of CHP heat productivity. thus increasing their overall efficiency and reduce specific fuel consumption [1].

2 Analysis of the energy consumption of new residential areas

The data representing a change of requirements to reduction of energy consumption in the USA over the period of 2010-2030 [2]. which are shown in table 1. are of a great interest for the development of the process of increasing energy efficiency of the residential buildings in Siberian region. As table 1 shows. energy consumption (excluding electricity) in the US residential buildings constructed in 2007. is about 20-30% less compared with those in the Siberian region (90 + 70 = 160 kW*h / m^2*year) (in the USA - 104.5-128.3 kW*h / m^2*year). It should be noted that as early as in 1999-2001 US standard allowed

* Corresponding author: glushkov@tpu.ru

energy consumption (excluding electricity) in the amount of 147.3-163 kW*h / m^2*year. By 2015 this difference increased to about 35-50% (56.9-72.7 kW*h / m^2*year in the USA and 110 kW*h / m^2*year in Siberia) for practically the same climatic conditions.

Table 1. Requirements to Lowering power consumption (kW*h / m^2*year) in the USA.

Year	Standard				Indicator on energy-efficiency design ASHRAE5
	ASHRAE 90.1[1]	ASHRAE 90.1[2]	ASHRAE 189.1		
			1[3]	2[4]	
2007	128.3	–	104.5	154.8	117.9
2010	96.7	154.8	89	129.4	84.4
2013	85.3	132.7	78	114	75.8
2015	72.7	113.8	56.9	100.6	56.9
2020	56.9	75.9	40	57.5	0
2025	44.2	56.9	19.9	27.8	0
2030	31.6	50.6	0	0	0

[1]Without taking into account the consumption of electricity by the equipment users (eg. office equipment. food processors. etc.).
[2]Taking into account the consumption of electricity by the equipment users.
[3] Aimed to reduce energy consumption by 30% compared with standard 90.1-2004 (without taking into account electrical energy consumption by users of equipment).
[4] Aims to reduce energy consumption by 30% compared with standard 90.1-2004 (taking into account users of the electrical energy consumption of the equipment).
[5] Aimed to reduce energy consumption by 30% compared to standard 90.1 for 2007-2009; by 50% - for the period of 2009-2011; transition to buildings with zero energy consumption - 2013-2015

Transition of new residential buildings to heat consumption in the amount 19.9-44.2 kW*h / m^2*year) (the USA) by 2025 requires development and production in the sphere of obtaining and use of the maximum sizes of the RES (renewable energy sources) from the exhaust warm air and water. This is particularly important for the Siberian region.

Improving energy efficiency of residential buildings by reducing heat costs for heating and ventilation is the last element in the system of energy saving. The first elements in this process are energy efficiency of producing heat and its transportation by main lines and outside distribution networks. Optimizing heating schemes and modernization of heating networks using expensive (200-300 US dollars per 1 m) but very effective pre-insulated pipes since 2006 till 2013 resulted in savings. The total loss of heating energy in the utilities sector in Siberia remains high.

In terms of energy consumption of housing and communal sector (~ 40%) the energy balance of the residential district of Tomsk approximately corresponds to the USA. where residential and commercial buildings consume more than 40% of fossil energy resources. more than 70% of electricity and 50% of natural gas [2]. Approximately 1/3 of the total CO2 emissions in the atmosphere of the United States is generated by power supply of residential and commercial buildings.

It should be noted that in the USA energy performance of new buildings deteriorates by 30% during the first three-four years of use [2]. This problem is typical for Siberia. Therefore. it is necessary to pay more attention to the process of commissioning and changeover of heating systems during operation

3 The energy efficiency rating of the essential services system inside the building

Energy efficiency of separate buildings does not guarantee high energy efficiency of entire residential areas. as modern essential services of residential building requires the use of various energy carriers (hot and cold water. electricity. gas). The delivery of energy with the necessary parameters to the consumers requires significant additional energy expenses. demanding additional charges in foreign currency. In such formulation the problem of energy efficiency of residential areas. even in the areas of European countries has not been previously considered.

The objectives of the proposed program are:

• Evaluation of energy consumption. spent on the production of various types of energy used to provide essential services system of both separate buildings and a group of buildings;

• accounting losses in producing and transportation of various types of energy to consumers.

The problems are technically solved by means of assessing the energy efficiency of the essential services system inside the building. including the characteristics of different types of energy sources. systems of its delivery to customers and in-house consumption of various types of energy. They consist in the fact that consumption of all types of energy (electricity. heating. gas. water). used for the building. obtained from external distribution networks. leads to the initial fuel consumption or equivalent energy spent on the production of the used energy. which is compared with the current standards.

Energy efficiency of buildings should be considered as the final element of the overall energy-saving system. which includes main lines and distribution networks for the delivery of various types of energy to the consumer. as well as generators of all kinds of energy. All energy generators (boilers. CHP plants. power plants. etc.). as well as a network for the delivery of all types of energy to consumers with certain operating efficiency. on which significantly and sometimes decisively the overall energy efficiency of the entire essential services system for residential buildings is dependent. Here we should also add the flow of electricity for pumping in heating systems and air in the quartz-family-recuperators heat exchangers “air – air”. It is necessary to point out that the electric power is generated with conversion factor of about 0.3 from fuel compared to 0.8-0.9 for the thermal energy. In addition. it is necessary to take into account energy consumption for cleaning. pressure build-up and delivery of tap water [3].

Currently. the main indicator of the efficiency of the heat consumption for heating the building is the annual consumption (kW*h / m^2). referred to 1 m^2 of the total area of the apartment. This indicator is useful for all types of energy when transferring their characteristics to the appropriate dimension. Taking into account the dependence of the total energy of the system of essential services of the building on the sources of energy supply. then kilogram of fuel equivalent corresponding to the old technical units of 7.000 kcal. which is equivalent to 8.14 kW*h. can be used as the index. Therefore. consumption of energy source. called the fuel (in kW*h / m^2*year or in kg of oil equivalent/ m^2*year) can serve as general indicator of energy efficiency of life support systems in buildings.

Primary energy evaluation is performed separately for each of the types of energy (electricity. heat. water. gas). In case of domestic use of natural gas. which is ready fuel. its preparation and delivery can be disregarded. as they are carried out outside the general system of essential services of the considered objects.

Methods of evaluating of the overall energy efficiency of the building is based on the full consideration of all types of energy (electricity. heat. fuel gas. water) consumed from the outside distributive networks for the normative life support conditions. Then it is also necessary to take into account the loss of energy and transportation costs of each energy source from the source of its receipt to the consumer. The final step is the account of the energy conversion factor of fuel energy into the energy of some necessary for the sustenance of the building energy carrier. Often this is called efficiency factor.

In general. the total amount of energy consumed by the building during the year (referred to 1 m^2 of total area) from external energy distribution networks is determined by the expression

$$Q = Q_1 + Q_2 + Q_3 + Q_4,$$

where Q_1 is the annual electricity consumption of household appliances (refrigerator. TV. lighting. electronics. etc...). apartment and house flow boosters (apartment and house fans are heat exchangers. recuperators “air – air”. pumps for provision of coolant circulating in an independent system. etc.); Q_2 - the annual consumption of electrical energy referred to 1 m^2 of total area. for heating and hot water. kW*h/m^2; Q_3 - the annual consumption of electrical energy referred to 1 m^2 of floor area. for the cold water. kW*h / m^2; Q_4 - annual consumption of gas energy. referred to 1 m^2 of total area. kW*h/m^2.

It should be noted that the return of any kind of energy at the expense of resources of the building (residential heat. heat recovery of exhaust air. solar cells to generate electricity. preliminary heating of the hot water by the warm waste. use of rainwater. etc.) reduces energy consumption from the external distribution networks. However. the given expression does not take into account the difference in the flow of natural energy resources. spent for the receipt and transmission of electric power and heat to the consumer. and this difference is quite significant.

Transportation loss of electricity for tap water during the operation of the electric pumps are about 1-2 kW*h / m3 depending on the distance of transportation [4]. As an example of calculation of the power consumption let us take a two-room apartment with total area S = 60 m^2. in which three people live. which roughly corresponds to the current average area of 20 m^2 per person.

To calculate the power consumption of running water let us take daily consumption of 140 liters of cold water and hot water to 70 liters. which generally corresponds to 210 liters per day per person and approximately equal to the average consumption. Power consumption of 1 m3 of water delivered to the consumer. as a rule. is 1-2 kW*h / m3. Heating 210 liters of water per day for the three people to about 60 ° C requires 14.62 kW*h for an apartment. or 0.2442 kW*h / m^2. which is 89 kW*h / m^2 for a year. Annual specific energy consumption for the supply of tap water with minimal energy consumption of 1 kW*h / m3 is at least 4 kW*h / m^2.

It is obvious that energy consumption for essential services in an old apartment is only a part of the cost of natural resources. the share of which for the new. so-called energy-efficient apartments. the sources of energy and transportation systems increases.

4 Conclusion

The real energy savings in the current transition to the energy efficiency of buildings is of 15-20%. which is clearly insufficient and points to the need of natural energy savings in all directions. Further reduction of heat consumption in residential buildings is possible through the use of effluent waste water heat with the temperature of 30-35 ° C.

The use of the roofs of residential buildings to produce electricity from the sun and wind is not yet economically viable.

The use of heat pumps can be economically justified in some cases. with the absence of the main lines and the necessary distribution networks in the vicinity.

References

1. S.A. Chistovich, *Avtomaticheskoye regulirovaniye raskhoda tepla v sistemakh teplosnabzheniya i otopleniya* (Stroyizdat Publ., Moscow, 1975) [in Russian]
2. L.D. Boguslavskiy, *Snizheniye raskhoda energii pri rabote sistem otopleniya. ventilyatsii i konditsionirovaniya vozdukha* (Stroyizdat Publ., Moscow, 1982) [in Russian]
3. J. Laustsen, *Energy Efficiency Requirements in Building Codes. Energy Efficiency Policies for New Buildings* (JEA Information Paper, Paris 2008)
4. S.N. Osipov, Effektivnyye metody proektirovaniya. stroitel'stva I ekspluatatsii sistem teplosnabzheniya: Sbornik, 33 (1990) [in Russian]