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COMPLEX ASSESSMENT OF THE ENERGY-SAVING MEASURES EFFECTIVENESS IN THE FIELD OF BUILDINGS HEAT SUPPLY

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In recent years, a significant number of cities in Ukraine, in particular, Kyiv, Kharkiv, Lviv, Ternopil, Chernivtsi and others. have joined the Covenant of Mayors on Climate and Energy [1], which provides for the holding municipal authorities measures to significantly reduce greenhouse gas emissions by 30% by 2030. Achieving this result requires a new strategy for the use and development of the municipal energy system, which envisages increasing the environmental safety of boiler plants and thermal power plants through the introduction of innovative high-efficiency energy-saving, environmental and economically sound technologies [2]. Actual scientific task that confronts the communal sector of the economy today is to increase the informative methods for assessing the effectiveness of measures energy saving in the areas of heat supply and heat consumption. To solve this problem, the effectiveness of the measures under study should be considered as a complex value, which takes into account the energy, environmental and economic consequences of their implementation. The authors suggested method of multi-criteria evaluation of the effectiveness of energy-saving measures. The essence of this method is that the overall effectiveness of energy-saving measures is considered as a 3-component vector E, components of which are energy – E_I, environmental – E_{II} and economic – E_{III} effects of their implementation (Fig. 1).

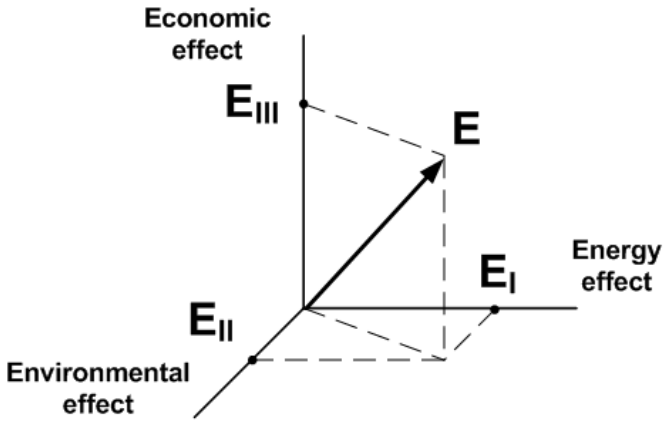

Fig. 1. Components of the overall effectiveness of energy conservation measures in the field of heat supply

At the same time, the following indicators are used to assess these components of overall efficiency:

– for *energy effect* E_I: absolute – ΔQ (kW·h) and relative – δQ (%) value of the saved amount of thermal energy for the heating period, which are determined by the formulas:

$$\Delta Q = Q_{tot1} - Q_{tot2}\,, \tag{1}$$

where Q_{tot1} and Q_{tot2} are the total heat losses due to the building enclosure during the heating period before and after the implementation of energy-saving measures, respectively, kWh;

$$\delta Q = \frac{Q_{tot1} - Q_{tot2}}{Q_{tot1}} \cdot 100\%\,; \tag{2}$$

– for *environmental effect* E_{II}: mass (volume) of fuel saved – ΔM_{fuel} (kg) (ΔV_{fuel} (m^3)), reduction of mass of greenhouse gas emissions, in particular – of CO_2 and pollutants – ΔM_p (kg):

$$\Delta M_{fuel} = 3,6 \cdot \frac{\Delta Q}{Q_l}\,, \tag{3}$$

where Q_l – the lower heat of combustion of the fuel, MJ/kg;

$$\Delta V_{fuel} = \frac{\Delta M_{fuel}}{\rho_{fuel}}, \quad (4)$$

where ρ_{fuel} – density of fuel, kg/m^3;

$$\Delta M_{3P} = 3,6 \cdot 10^{-3} \cdot K_P \cdot \Delta Q, \quad (5)$$

where K_P – coefficient pollutant emissions [3], g/GJ;

– for *economic effect* E_{III}: reduction of payment for the amount of heat consumed during the heating period – ΔC_{hc} (UAH) and for fuel – ΔC_{fuel} (UAH):

$$\Delta C_{hc} = 9,6 \cdot 10^{-4} \cdot c_{hc} \cdot \Delta Q, \quad (6)$$

where c_{hc} – the cost of a unit of thermal energy according to the set tariffs [4], UAH/Gcal;

$$\Delta C_{fuel} = 10^{-3} \cdot c_{fuel} \cdot \Delta V_{fuel}, \quad (7)$$

where c_{fuel} – the cost of fuel according to the set tariffs, UAH/ton or UAH/ths. m^3.

As a natural object for research on the effectiveness of energy-saving measures was chosen fragment of the administrative building O.M. Beketov National University of Urban Economy in Kharkiv (O.M. Beketov NUUE), in which are located: a lecture hall, a laboratory, a conference hall and offices of the university administration. This is a three-story building with two external walls and two internal walls adjacent to heated rooms with a total heated area of 225.3 m^2 (Fig. 2).

As an energy-saving measure for a full-scale object is recommended use smart home technology for control thermal modes building premises using the HERZ Smart Comfort automated system [5].

Fig. 2. Full-scale object for studying the efficiency of heat consumption

As a result of the analysis of the actual need of the building's premises for comfortable heat baking, at which the indoor air temperature – t_{in}^{comf} is maintained at 20 °C, the indicator of the building's relative need for comfortable heat supply – γ_{comf} was determined (Fig. 3):

$$\gamma_{comf} = \sum_{i=1}^{3} \frac{S_{hai}}{S_{ha}} \cdot \gamma_{comfi} = \frac{79,2}{225,3} \cdot 0,18 + \frac{68,4}{225,3} \cdot 0,02 + \frac{77,7}{225,3} \cdot 0,27 = 0,16, \quad (8)$$

where S_{hai} – the heating area of the i-th floor of the building, m^2; γ_{comfi} – relative need for comfortable heat supply of the i-th floor:

$$\gamma_{comfi} = \frac{\tau_{h(w)i}}{\tau_{h(w)}}, \quad (9)$$

where $\tau_{h(w)i}$ – the average weekly duration of the period of comfortable heat supply during the heating season for the i-th floor, h; $\tau_{h(w)}$ = 168 h – duration of one week period.

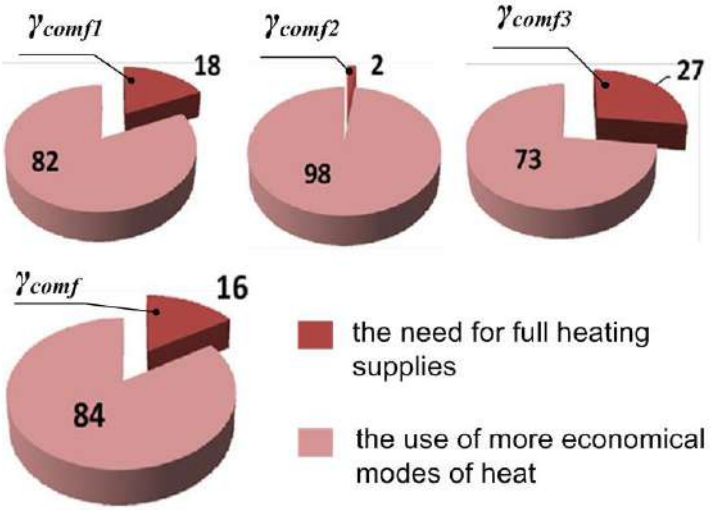

Fig. 3. The results of the analysis of the needs of the premises of the Full-scale object in a comfortable heat supply

Indicators of energy efficiency from the use of the system of regulation of thermal modes of premises of a full-scale object were determined by the formulas:

$$\delta Q = \left(1 - \gamma_{comf}\right) \cdot \frac{t_{in}^{comf} - t_{in}^{econ}}{t_{in}^{comf} - t_{out(a)}} \cdot 100\% = \left(1 - 0.16\right) \cdot \frac{20 - 16}{20 - \left(-0.8\right)} \cdot 100\% = 17\%, \quad (10)$$

where $t_{out(a)}$ = -0.8 ºC – average air temperature in Kharkiv for the heating period 2019;

$$\Delta Q = \left(q \cdot S_{ha}\right) \cdot \frac{\delta Q}{100} \cdot 10^3 = \left(97,5 \cdot 225,3\right) \cdot \frac{17}{100} = 3734 \text{ , kW·h} \quad (11)$$

where q = 97.5 (kW·h)/m^2 is the actual specific heat consumption of the administrative building of O.M. Beketov NUUE in 2019 year.

According to formulas (4) – (7), the indicators of environmental and economic effects from the implementation of the energy saving measure for the heating period were determined, which were:

– reduction of natural gas consumption for heating - ΔV_{fuel} = 406.4 m^3;

– reduction of CO_2 and NO_x emissions into the atmosphere – ΔM_{CO2}= 789.1 kg; ΔM_{NOx} = 0.86 kg;

– reduction of the payment for the use of thermal energy and fuel ΔC_{hc} = 4441 UAH and – ΔC_{fuel} = 4041 UAH.

The results of the realization of the method of multi-criteria evaluation of the effectiveness of energy-saving measures has proved its information content and the possibility of using it during in mathematical and physical modeling of the ecological and energy state of the studied objects.

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