TECHNICAL SCIENCES

RESEARCH OF THE ECOLOGICAL AND ECONOMIC EFFICIENCY OF THE "SMART HOME" TECHNOLOGY APPLICATION IN THE BUILDING HEATING SYSTEM

Polyvianchuk A.P.,
Doctor of Technical Sciences, Professor,
O.M. Beketov National University of Urban Economy in Kharkiv
17, Marshall Bazhanov, str., Kharkiv, 61002, Ukraine
Semenenko R.A.,
PhD Student at the Department of Engineering Ecology of Cities
O.M. Beketov National University of Urban Economy in Kharkiv
17, Marshall Bazhanov, str., Kharkiv, 61002, Ukraine
Skuridina O.O.,
Postgraduate Student at the Department of chemical engineering and ecology
Volodymyr Dahl East Ukrainian National University
59-a Tsentralnyi Prospect, Severodonetsk, 93400, Ukraine
Romanenko S.V.,
Postgraduate Student at the Department of Engineering Ecology of Cities
O.M. Beketov National University of Urban Economy in Kharkiv
17, Marshall Bazhanov, str., Kharkiv, 61002, Ukraine
Semenenko L.V.
PhD Student at the Department of heat engineering and energy efficiency technologies
National technical university "Kharkov Politechnical institute"
21, Kirpichev str., Kharkiv, 61002, Ukraine

Abstract

The work is devoted to the creation and practical use of a methodology for a comprehensive assessment of the environmental and economic efficiency of the use of "smart home" technology in the heating system of a building. Researched the effectiveness of the implementation in the 3-storey building of the educational building of the O.M. Beketov National University of Urban Economy in Kharkiv with a total heated area of 225.3 m^2 of the automated control system of thermal modes of rooms - HERZ Smart Comfort with "smart home" technology.

Keywords: building, heat consumption, heating system, energy efficiency, "smart home", environmental friendliness, economy.

Introduction

One of the priority directions for the development of modern municipal energy is to increase the energy efficiency of the sphere of heat consumption in buildings. This is due to the fact that, on the one hand, in the total energy balance of a building, the costs of its heat supply are the highest and amount to 89% [1], and on the other hand, there is a potential opportunity for a significant increase in the rationality of the use of thermal energy in buildings through the use of technology " smart home "in the operation of heating and hot water supply systems. These technologies can be effectively applied in buildings of various construction periods - both in modern buildings that have a sufficient level of energy efficiency in accordance with the requirements of the current building codes and do not require the implementation of other energy-efficient measures, as well as in buildings of earlier construction periods, which may require implementation additional measures to improve their energy efficiency, such as: thermal modernization of the enclosing structures and internal pipelines of the building, modernization of ventilation systems, hot water supply, etc.

At the O.M. Beketov National University of Urban Economy in Kharkiv (O.M. Beketov NUUEK) on the basis of one of the educational buildings introduced and experimentally investigated the system of automated control of thermal regimes of the premises of the building - HERZ Smart Comfort, which implements the technology "smart home" [2, 3]. Below are the results of a comprehensive assessment of the environmental and economic efficiency of using this system.

The purpose of the research was to create and practical application of a methodology for a comprehensive assessment of the environmental and economic efficiency of introducingin the heating system of a building the HERZ SmartComfort automated complex with "smart home" technology . For this, the following tasks were solved:

1. Development of a methodology for a complex appraisals of the the efficiency of using the "smart home" technology in the operation of the building heating system.

2. Research at a full-scale facility of the ecological and economic efficiency of using the HERZ SmartComfort system for automated control of thermal regimes in the premises of a building.

Presentation of the main material

As a full-scale facility for research used a fragment of the educational building of the O.M. Beketov NUUEK, which is a 3-storey building with 5 rooms with a total heated area of S_h = 225.3 m^2 (Pic. 1).

For this object, the actual need for premises in comfortable thermal conditions with a temperature $t_{in\text{-}comf}$ = 18 °C was analyzed and the coefficient of the relative need for comfortable heat supply γ_{comf} was determined:

$$\gamma_{comf} = \sum_{i=1}^{3} \frac{S_{hi}}{S_h} \cdot \gamma_{comfi} = \frac{79.2}{225.3} \cdot 0.18 + \frac{68.4}{225.3} \cdot 0.02 + \frac{77.7}{225.3} \cdot 0.27 = 0.162,$$

Pic. 1. General view of a full-scale object for research

where S_{hi} is the heated area of the i-th floor of the building, m^2;

γ_{comfi} – is the relative need for comfortable heat supply of the i-th floor:

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

where $\tau_{h(w)i}$ is the average weekly duration of the period of comfortable heat supply during the heating season for the i-th floor, hours;

$\tau_{h(w)}$ - the duration of the weekly period - 168 hours.

Implemented in the heating system of a full-scale object, the automated complex HERZ Smart Comfort with the "smart house" technology allows you to set the specified temperature regimes in the premises of the building: comfortable with a temperature t_{in}^{comf} – in rooms that need it, and economical with a temperature t_{in}^{ec} = 15 °C (3 °C lower from t_{in}^{comf}) – in other rooms.

Comprehensive assessment methodology efficiency application of "smart home" technology in the operation of the building heating system provides for the following calculations [4].

1. Determination of indicators characterizing the ecological effect of using the HERZ Smart Comfort system:

– absolute – ΔQ and relative – δQ saving thermal energy costs during the heating period (excluding thermal inertia of the building envelope):

$$\Delta Q = Q_1 - Q_2 = Q_{j(1)} \cdot \left(1 - \gamma_{comf}\right) \cdot \frac{t_{in}^{comf} - t_{in}^{ec}}{t_{in}^{comf} - t_{j(ex)}},$$

$$\delta Q = \frac{Q_1 - Q_2}{Q_1} \cdot 100\%,$$

where Q_1 and Q_2 are the total costs of heat energy for the entire heating period before and after the introduction of energy-saving measures, respectively, kW·h;

$Q_{j(1)}$ – heat energy consumption before the implementation of energy saving measures in the j-th month, kW·h;

$t_{j(ex)}$ – external temperature of atmospheric air in the j-th month;

– decrease in the mass (or volume) of the saved fuel – ΔM_{fuel} (kg) (or ΔV_{fuel} (m^3)):

$$\Delta M_{fuel} = 3.6 \cdot \frac{\Delta Q}{Q_l},$$

$$\Delta V_{fuel} = \frac{\Delta M_{fuel}}{\rho_{fuel}},$$

where Q_l is the lowest heat of combustion of fuel (natural gas), MJ/kg;

ρ_{fuel} – fuel density, kg/m^3 (we take: Q_l = 45.75 MJ/kg; ρ_{fuel} = 0.723 kg/m^3 [5]);

– reducing the mass of emissions into the atmosphere of pollutants and greenhouse gases – ΔM_{pol}:

$$\Delta M_{pol} = 3.6 \cdot K_{pol} \cdot \Delta Q,$$

where K_{pol} is the emission factor of the pollutant, g/GJ (we take: K_{CO2} = 58.7 kg/GJ; K_{NOx} = 0.064 kg/GJ [5]).

2. Determination of indicators characterizing the economic effect of using energy-saving measures: reduction of financial costs for heat energy consumed during the heating period – ΔC_h (UAH) and fuel – ΔC_{fuel} (UAH):

$$\Delta C_h = 8.598 \cdot 10^{-4} \cdot c_h \cdot \Delta Q,$$

$$\Delta C_{fuel} = c_{fuel} \cdot \Delta V_{fuel},$$

where c_h is the cost of a unit of thermal energy;

c_{fuel} – fuel cost (we take: c_h = 1365.28 UAH/Gcal [6]; c_{fuel} = 8.851891 UAH/m^3 [7]).

Research results

According to the presented methodology, according to the actual data of the values of $Q_{j(1)}$ and $t_{j(ex)}$, which were monthly monitored at a full-scale facility during the heating season 2020-2021, the energy efficiency indicators of the modernized building heating system - ΔQ and δQ were determined (Table 1) and other indicators of environmental and economic effects from the use of the HERZ SmartComfort system:

– reduction of natural gas consumption during the heating season, m^3:

$\Delta V_{fuel} = \frac{\Delta M_{fuel}}{\rho_{fuel}} = \frac{3.6 \cdot \frac{\Delta Q}{Q_l}}{\rho_{fuel}} = \frac{3.6 \cdot \frac{6280}{45.75}}{0.723} = 683$ m^3;

– reduction of CO_2 and NO_x emissions into the atmosphere:

$\Delta M_{CO2} = 3.6 \cdot 10^{-3} \cdot K_{CO2} \cdot \Delta Q = 3.6 \cdot 10^{-3} \cdot 58.7 \cdot 6280 = 1326$ kg;

$\Delta M_{NOx} = 3.6 \cdot 10^{-3} \cdot 0.064 \cdot 6280 = 1.42$ кг;

– reduction of payments for the use of thermal energy and fuel:

$\Delta C_h = 8.598 \cdot 10^{-4} \cdot c_h \cdot \Delta Q = 8.598 \cdot 10^{-4} \cdot 1365.28 \cdot 6280 = 7371$ UAH;

$\Delta C_{fuel} = c_{fuel} \cdot \Delta V_{fuel} = 8.851891 \cdot 683 = 6049$ UAH.

Table 1

Values of absolute and relative savings of thermal energy by a full-scale object during the heating period

Indicator	The month of the heating season						
	1	2	3	4	10	11	12
$Q_{j(1)}$, Gcal	8.90	7.77	6.70	1.19	2.14	6.13	8.08
Q_1, Gcal (kW·h)	40.91 (47578)						
ΔQ_j, Gcal	0.936	0.845	0.936	0.332	0.513	0.906	0.936
ΔQ, Gcal (kW·h)	5.40 (6280)						
δQ_j, %	10.5	10.9	14.0	27.9	23.9	14.8	11.6
δQ, %	13.2						

Thus, it has been established that the use of “smart house” technology in the heating system of a full-scale facility allows obtaining an annual environmental effect in the form of a reduction in heat energy consumption by 13.2%, which is 6280 kW·h, a decrease in natural gas consumption for heating by 683 m^3 and a reduction in emissions CO_2 and NO_x into the atmosphere by 1326 kg and 1.42 kg, respectively. The economic effect in the form of a decrease in financial costs for consumed heat energy and the cost of 7371 UAH and 6049 UAH respectively.

Conclusion

1. Created a methodology for a comprehensive assessment of the effectiveness application of «smart home» technology in the operation of the building heating system according to two criteria:

– ecological effect, which is characterized by indicators: absolute and relative reduction of heat energy consumption during the heating period, reduction of fuel consumption, reduction of emissions into the atmosphere of pollutants and greenhouse gases, in particular - NO_x and CO_2;

– economic effect, which is characterized by indicators: reduction of financial costs for consumed fuel and heat energy, profitability and payback period of energy-saving measures.

2. Investigated ecological and economic efficiency of using in the heating system of a 3-storey building of the educational building of O.M. Beketov NUUEK with a total heated area of 225.3 m^2 of an automated complex for controlling thermal modes of premises HERZ SmartComfort with “smart home” technology. It has been established that the use of this energy-saving measure allows to obtain an annual environmental effect in the form of a reduction in heat energy consumption by 13.2%, which is 6280 kW·h, a decrease in natural gas consumption for heating by 683 m^3 and a reduction in CO_2 and NO_x emissions into the atmosphere by 1326 kg, and 1.42 kg respectively. The economic effect in the form of a decrease in financial costs for consumed thermal energy and fuel is UAH 7371 and UAH 6049, respectively.

References

1. Buderus: Planning documents Logatherm WPL ... AR. Power range from 7 kW to 17 kW. Reversible air / water heat pump. Edition 2015/09, 2015,176.

2. HERZ Smart Comfort: remote control of home comfort [distancionnoe upravlenie komfortom doma]. [electronic resource]. https://is.gd/uNBsR0. [in Russian].

3. Polivyanchuk A.P. Mathematical modeling of diesel engine operation mode influence on mass emission of particulate matter with exhaust gases using microtunnel / A.P. Polivyanchuk, I.V. Gritsuk, E.A. Skuridina // Theoretical and practical aspects of the development of the European Research Area: monograph / edited by authors. – 4th ed. – Riga, Latvia : “Baltija Publishing”, 2020. – P. 269-301.

4. Polyvianchuk A. Evaluation of the energy saving measures effectiveness in the production, transportation and consumption of thermal energy in the communal sector / A. Polyvianchuk, R. Semenenko, S. Romanenko, L. Semenenko // Scientific and technical progress in European countries and the contribution of higher education institutions: collective monograph. Riga: Izdevnieciba «Baltija Publishing», 2020. – P. 166-191.

5. Kupalova, I. Determination of emissions by stationary sources. [Vyznachennia Obsiahiv Vykydiv Statsionarnymy Dzherelamy]. Visnyk. Officially about taxes, 32 (889), 2016, 32-37. [in Ukrainian].

6. Tariffs for heat energy for budget institutions, other consumers (except for population) and religious organizations. Communal Enterprise "Kharkiv heat networks" [electronic resource] (2021). [Taryfy na teplovu enerhiyu dlya byudzhetnyx ustanov, inshyx spozhyvachiv (krim naselennya) i relihijnyx orhanizacij. KP «Xarkivski teplovi merezhi»]. Retrieved from https://www.hts.kharkov.ua/index.php. [in Ukrainian].

7. Gas prices for industrial consumers, state employees, fuel and energy companies [electronic resource] (2021). [Ceny na gaz dlya promyshlennyh potrebitelej, byudzhetnikov, predpriyatij TEK]. Retrieved from https://kh.gaszbut.com.ua/ru/gas-supply/gas-cost/id/rozdribni-cini-dlja-potreb-promislovih-spozhivachi-41405. [in Russian].