Ways to improve energy conservation in educational institutions

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Abstract: The article considers the method of identifying energy losses in the classrooms of building no. 4 Sumy NAU, which takes place in three stages. At the first, preparatory stage, with the help of a special device of the Fluke Ti25 thermal imager, the scanning method detects problem areas of the structural elements of the classroom – ceilings, walls and floors, which lose heat and require energy-saving measures. A large (more than 10%) difference in the surface temperature of a room element indicates a large loss of thermal energy. The thermographic method and the peer review method are used. At the second stage of information processing, measures to reduce heat loss are determined. At the third stage, the implementation of energy-saving measures. The practical relevance of this work is to find problematic building elements that require the use of measures to improve their energy efficiency.

Keywords: energy saving; energy losses in the classrooms; energy audit; thermal energy; energy-saving measures; thermographic method; energy efficiency.

Reference to this paper should be made as follows: Savchenko-Pererva, M. and Radchuk, O. (xxxx) 'Ways to improve energy conservation in educational institutions', *Int. J. Agriculture Innovation, Technology and Globalisation*, Vol. X, No. Y, pp.xxx–xxx.

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This paper is a revised and expanded version of a paper entitled 'Implementation of energy saving measures in the University building' presented at ISDC2020, Pingtung, 30 September 2020.

1 Introduction

Unstable pricing policy in the provision of energy resources leads to the actualisation of the issue of energy-efficient use of thermal energy. The introduction of energy saving measures is the main way to reduce the costs for premises and buildings maintaining. Currently, in order to improve energy efficiency, many enterprises are introducing energy management, which is used to determine the actual state of energy supply and energy consumption (Moynihan and Barringer, 2017). It is crucial to introduce the method of minimising the energy consumption by calculating reasonable amounts of energy consumption, as well as means to meet these amounts by optimising the heat transfer between processes, energy supply methods and improving the characteristics of technological processes. This method is called Pinch analysis or process integration (Cho et al., 2020).

Energy efficiency and energy preservation are key concepts for ensuring the efficiency of both business and the state as a whole. Energy preservation is a complex of organisational, legal, industrial, scientific, economic, technical and other measures aimed at rational and economical use of fuel and energy resources. Energy intensity of production is the amount of energy and fuel consumption for main and auxiliary technological manufacturing processes within the agro-industrial complex (Kostyuchenko, 2015; Nota et al., 2020), the performance of work, provision of services based on a given technological system (Kasianova, 2017). Energy efficiency is one of the main strategic directions for the development of the budget sector. It serves as a necessary tool for achieving comfortable conditions in the buildings of educational, health and public institutions, as well as a way to implement the living standards of the modern European community (Thomsen et al., 2016).

The main types of energy saving measures are as follows:

1 Organisational measures – quick-impact measures – internal energy audit, preparation of the enterprise energy passport, elaboration of measures for energy preservation and improving the efficiency of technological processes, monitoring the introduction of incentive measures and motivation of energy-saving behaviour, the introduction of the right to dispose of funds from energy saving, the establishment of rules for purchasing equipment for energy-efficient technologies. Quick-impact measures can be developed and implemented within a year and show a significant effect at low costs (Bevz, 2011).

2 Technological measures – basic measures – are more radical and contribute to the rapid implementation of cost-effective and financially attractive investments. Additionally, they require the introduction of energy efficiency standards in the

maintenance of industrial buildings, industrial equipment; introduction of recycling systems and windows cleaning; painting walls in light colours; use of waste heat from refrigerators and air conditioners for heating water; introduction of frequency regulation systems and other devices that increase the efficiency of electric motors in ventilation systems, pump stations and other facilities with variable load. However, energy-efficient projects may require financial support from banks and leasing companies (Dzhedzhula, 2014).

3 Investment measures – expensive and highly effective measures, which help to eliminate the main causes of low energy efficiency, in most cases guarantee more significant energy savings, but require higher initial funding. This is primarily the transition to alternative sources of energy supply and the use of modern energy-saving production technologies. In addition, organisational changes at the state and regional levels, such as pricing reform, improvement of electricity and gas markets, and the transition to integrated planning of various sources of energy supply, are of great importance for the implementation of this group of measures (Chystov, 2010).

Xu et al. (2019) and Potić et al. (2021) in their researches solve the problem of energy shortage on the basis of new approaches, using renewable and secondary energy sources. Moreover, jointly with other scientists, they formed approaches to implementing energy-saving measures both at enterprises and housing-and-municipal complexes (Tanić et al., 2015).

The main task of the energy saving project nowadays is to ensure efficient and rational use of fuel and energy resources (FER) in all industries of Ukraine. Ukraine experiences power shortages, that is why imports 75% of natural gas and 85% of oil and petroleum products. This structure of the fuel and energy balance is critical and unacceptable from the point of view of energy security. Based on this, one of the main tasks of the Ukrainian state is to significantly reduce inefficient consumption of energy resources. This issue can't be solved without a systematically energy policy, which consider the possibility of Ukraine to produce hydrocarbons domestically, develop renewed energy sources and energy efficiency, and move towards wide implementation of innovations. To do this, we need to focus on analysing the most crucial aspects of this problem and determine ways, means and methods of solving it. The continuous and rapid growth in the cost of fuel and energy resources motivates the search for ways to reduce their use, increase efficient and rational consumption by enterprises, production equipment (Sabadash, 2020; Sukmanov et al., 2020), conduct an energy survey and introduce a number of energy-saving measures (Danilkova, 2016) in public institutions: educational institutions, kindergartens, hospitals, etc. Ukrainian schools and universities, for the most part, remain among the least energy efficient institutions. And although the new tariffs make us think about saving even those for whom the preservation of the environment was not a matter of principle, the situation is still deplorable.

Most universities in Ukraine have fairly large territories. That is why the problem of energy conservation is one of the most important, since universities have to pay the cost for the used thermal energy, electricity, water, etc. millions UAH annually. The severity of the problem of energy supply for universities is associated with two circumstances:

1 insufficient budgetary financing of expenses (primarily utility costs, among which energy supply costs are the most significant)

2 low energy efficiency of universities.

Therefore, we propose one of the ways to reduce energy losses in higher education institutions that have buildings with a large number of rooms, by conducting an energy audit according to a special algorithm. The contribution of this study lies in the development of a methodology for the introduction of energy saving measures in primary institutions.

2 Literature review

There are significant changes in the world's energy development strategy (Ippolitova and Sorokotiazhenko, 2015). The leading countries of the world have defined a set of tasks for implementing energy strategies in the 21st century. The main development direction is to maintain continuity and consistency of actions while ensuring three components: energy supply (uninterrupted supply of electricity of appropriate quality), energy availability (energy preservation and affordable prices for electricity) and energy efficiency (minimal impact on the environment) (Tanić et al., 2012). These components are considered as the basis for achieving the global goal of ensuring stable development, which guarantees sustainable growth of the economy, the living standards, and protection of the natural environment.

Ukraine, like other countries, has taken certain steps towards energy conservation. In 1994, the Law of Ukraine 'On Energy Saving' (Law of Ukraine, 1994) was adopted, which provided for a system of organisational, regulatory and incentive measures to encourage the use of fuel and energy saving. Within the framework of organisational support, such state management bodies were created: the State Agency on Energy Efficiency and Energy Saving (1995) and the State Inspection for Energy Saving and its Territorial Bodies (1996). During 1997–2000, the concept and program of energy preservation, particularly in the public sector, was developed. In 2001 the State Budget provides funds for implementation of energy saving measures in the public sector in the volume of 25 million UAH. Taking into account the additional funds raised for these purposes from local budgets (24 million UAH), the expected reduction in budget expenditures on fuel and energy consumption in public sector institutions amounted to 66 million UAH. Thus, the payback period of these funds did not exceed one year. Statistics gave reason to believe that the chosen method is correct, especially since the efficiency of centralised energy saving programs is much higher for the economy. This is confirmed by the experience of the western countries. Unfortunately, the state policy in the field of energy conservation has not been sustainable. Frequent changes of the authority have undermined the manageability of the economy and the energy sector.

Thus, in terms of efficient use of energy – economic, scientific and socio-cultural development, Ukraine is among those countries where the stagnation of the current situation can provoke a serious economic crisis with subsequent large-scale social upheavals. The most difficult situation in terms of energy efficiency remains in housing and communal complexes, in public institutions, where worn-out thermal and water plants operate with low efficiency and use similar worn-out networks. As a result, energy losses reach 45–50% (Heiets, 2016).

To reduce heat loss, a systematic analysis of energy use and consumption can be used to identify, quantify and report on opportunities to improve energy efficiency.

The tasks of conducting an energy audit of buildings according to Dongellini et al. (2014) are:

- determination of the general state of the facility that consumes fuel and energy resources, its main divisions and technological processes as consumers of fuel and energy resources
- analysis of FER consumption balances separately for each type
- analysis of the balances of fuel and energy consumption in energy-intensive technological installations, technological processes and departments
- analysis of FER losses at facilities
- analysis of the cost of funds for fuel and energy resources in the cost of production
- assessment of the energy saving potential of facilities
- assessment of the level of efficiency in the use of fuel and energy resources
- analysis of the specific consumption of fuel and energy resources and comparison with the current norms and standards, preparation of proposals for its reduction
- assessment of the efficiency of the EMS
- development of recommendations for the implementation of energy-saving measures with their technical and economic assessment.

Comprehensive approaches to the inspection of structures during an energy audit include an assessment (Thomsen et al., 2016) of:

- indoor microclimate
- state of enclosing structures
- the state of engineering systems of heating, ventilation and air conditioning
- fire safety of the building
- thermal power state of the building.

Kontokosta et al. (2020) provide analytical recommendations that can be used as a template by practical engineers for assessing energy use at production facilities and implementing certain energy saving measures. In the studies of Kirimtat and Krejcar (2018) and Krarti (2020), an assessment and analysis of energy consumption was carried out and a number of energy saving measures were introduced for historical buildings. The proposed measures have significantly reduced energy losses, but options for reducing energy losses in public buildings have been little explored. In addition, their maximum effectiveness has not been proven. Therefore, conducting an energy audit on energy efficiency and energy saving in public premises and minimising energy and heat losses is an urgent need.

3 Research methodology

It is difficult to visually determine which elements of the building need measures to improve energy efficiency. If such measures are carried out on all elements of the building structure, this requires significant capital investments. It is also possible to develop an electronic thermal building simulator and compare it with actual characteristics. The buildings of educational institutions are distinguished by a large number of rooms and the size of the building itself. Thus, the area of the building where the studies were carried out is 12,000 sq.m and the number of rooms is 120 units (excluding corridors and halls). This approach requires large capital investments at the stage of developing a model and an electronic thermal building simulator. In conditions of limited funding, this is difficult to do. Therefore, a building inspection method is proposed that will identify the problematic elements of the building and only these elements should be applied energy efficiency measures. Inspection of the building for energy efficiency was carried out sequentially on its premises. Energy audit of each room was carried out by elements (windows, walls, ceiling, floor and doors) according to the developed algorithm.

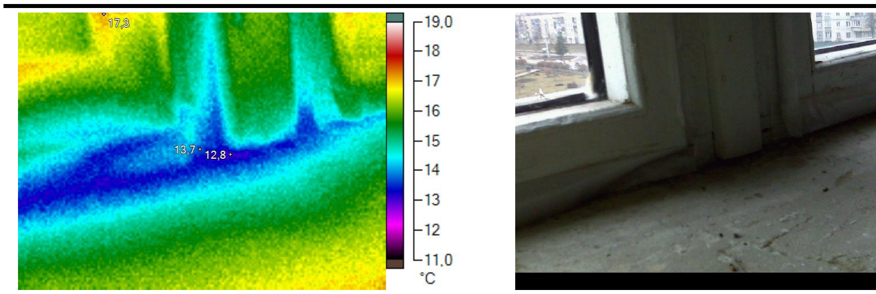
The algorithm for examining a room element is as follows: using a Fluke Ti25 thermal imager, an element was examined to obtain a thermographic image and its expert analysis to determine points with a minimum and maximum temperature. If the temperature difference, the minimum actual Tmin and the maximum actual Tmax, is greater than the allowable ΔT, then the element requires measures to improve energy efficiency. Temperatures minimum actual Tmin and maximum actual Tmax were determined from a thermogram, which was obtained using a device – a thermal imager, by visual expert assessment. The value of the allowable temperature ΔT was determined based on the financial condition of the enterprise. The smaller this value, the more funds should be used for measures to improve energy efficiency. Tangible financial results in saving energy resources, according to the experience of such studies, appear at $\Delta T \geq 10\%$.

4 Research and development of proposals

4.1 Research of heat loss of building windows

Based on the third main phase of energy audit - obtaining of information, which provides an in-depth familiarisation with the facility energy audits, documentation about the use of FER was measured at the target facility – building no. 4 of Sumy National Agrarian University. Measurements were made with a Fluke Ti25 thermal imager (serial number Ti 25-09070166) which has a measurement error of 2% and thermal sensitivity ≤0.1°C. During the survey, the air temperature outside was +9 °C. Building no. 4 is centrally heated by water heating system. According to the results of the survey, the device captures a light image of the object under observation and a thermographic image, which indicates the surface temperature in different colours. The highest temperature and the lowest temperature of the objects under observation was indicated as a marker with a digital value of the absolute temperature. Also attached is a graph of colors and corresponding temperatures. The survey of the building is presented by the elements of the premises (windows, walls, ceiling, floor and doors).

Figure 1 The result of examining the window of building no. 4 of the university with a thermal imager (see online version for colours)



IR004456.IS2
26.01.2020 11:29:09

Visible light image

Information on the image	
Average temperature	15.2°C
Image borders	12.8°C to 17.3°C
The model of the device	Ti25
The serial number of the device	Ti25-09070166
Manufacturer	Fluke
Calibration range	–22.0°C to 125.0°C

Markers of the main image	
Name	*Temperature*
Central point	13.7°C
Hot	17.3°C
Cold	12.8°C

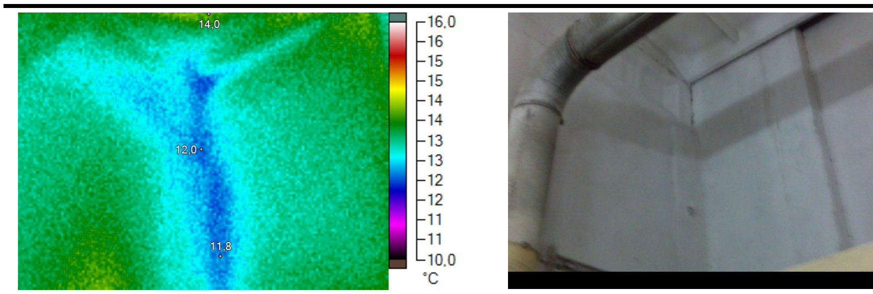
Figure 1 shows typical results for windows in building no. 4 (Savchenko-Pererva et al., 2021). The analysis of heat loss causes was conducted, and measures for its redacted were suggested. According to the expert assessment, specific places with temperature differences between different parts of the window indicate that there is a loss of heat energy. Figure 1 shows that the window temperature is Tmax = 17.3 °C. Analysing the thermogram of the survey, we determine that the minimum temperature at the junction of the window to the wall is Tmin = 12.8 °C.

The temperature difference is ΔT = 26%. This indicator indicates the need for measures to increase the energy efficiency of this element of the room. Such a difference indicates that the seal between the window and the wall does not keep heat. In this case, measures are needed to improve energy efficiency. Therefore, to reduce the energy consumption of heat, it is necessary to replace the seal. Using this method, it is necessary to scan all the windows of a given room and identify places that require the intervention of a construction company.

4.2 Research of heat loss of building walls and doors

Figure 2 shows the result of the survey of the building wall. Analysing the thermographic image of Fluke Ti25, we can identify a zone with a minimum temperature Tmin = 11.8°C. According to the thermogram, the maximum temperature is Tmax = 14°C. The difference between these temperatures is ΔT = 16%. This indicator indicates the need for measures to increase the energy efficiency of this element of the room. Additional studies of the building structure made it possible to establish that moisture was leaking through the roof of the building and, accordingly, the corner of the room began to freeze. Such studies were additionally carried out by specialists from a construction company, for whom the place of energy losses was identified by this method. The purpose of this study is to identify the elements of the premises that need measures to improve energy efficiency.

Figure 2 The result of examining the wall of the premises of building no. 4 of the university with a thermal imager (see online version for colours)



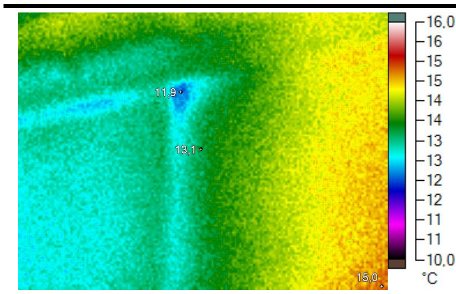
IR004481.IS2
26.01.2020 11:43:30

Visible light image

Information on the image	
Average temperature	13.0°C
Image borders	11.8°C to 14.0°C
The model of the device	Ti25
The serial number of the device	Ti25-09070166
Manufacturer	Fluke
Calibration range	–22.0°C to 125.0°C
Markers of the main image	
Name	*Temperature*
Central point	12.0°C
Hot	14.0°C
Cold	11.8°C

Figure 3 shows the result of the examination of the outer doors of the building no. 4 of the university, which are used as entrance doors. By analysing the thermal image of the Fluke Ti25, we can determine the area with the minimum temperature Tmin = 11.9°C. The maximum temperature on the door surface, according to the thermogram, is Tmax = 15 °C. The difference between these temperatures is ΔT = 21%. This indicator indicates the need for measures to increase the energy efficiency of this element of the room. An additional analysis of the design of doors and door frames in the temperature difference zone showed that the seal was out of order. Therefore, in order to reduce the energy consumption of heat, it is necessary to replace the seal in the lower part of the door. This additional analysis was carried out by a specialised construction firm based on the results of this study.

Figure 3 The results of the examination of the outer doors of the university with a thermal imager (see online version for colours)



IR004482.IS2
26.01.2020 11:43:39

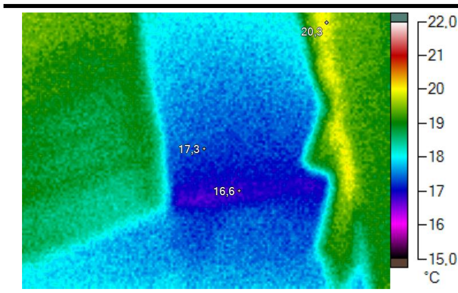
Visible light image

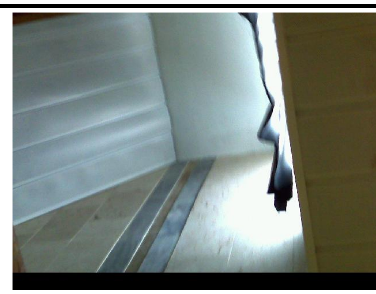
Information on the image	
Average temperature	13.5°C
Image borders	11.9°C to 15.0°C
The model of the device	Ti25
The serial number of the device	Ti25-09070166
Manufacturer	Fluke
Calibration range	–22.0°C to 125.0°C
Markers of the main image	
Name	*Temperature*
Central point	13.1°C
Hot	15.0°C
Cold	11.9°C

4.3 Research of heat loss of building ceiling and floor

Figure 4 shows the results of the examination of the ceiling of the room. According to the expert assessment of the thermogram, a point with a minimum temperature on the ceiling Tmin = 16.6°C and a maximum temperature Tmax = 20.3°C is visible. The temperature difference is ΔT = 18%. This indicator indicates the need for measures to increase the energy efficiency of this element of the room. Additional analysis of the roof structure showed that moisture seeps through the roofing. Therefore, to reduce the loss of thermal energy, it is necessary to repair the roofing. Additional studies were carried out by a specialised construction company based on the results of this study.

Figure 4 The results of the examination of the ceiling of the premises of building no. 4 of the university with a thermal imager (see online version for colours)





IR004384.IS2
26.01.2020 11:14:08

Visible light image

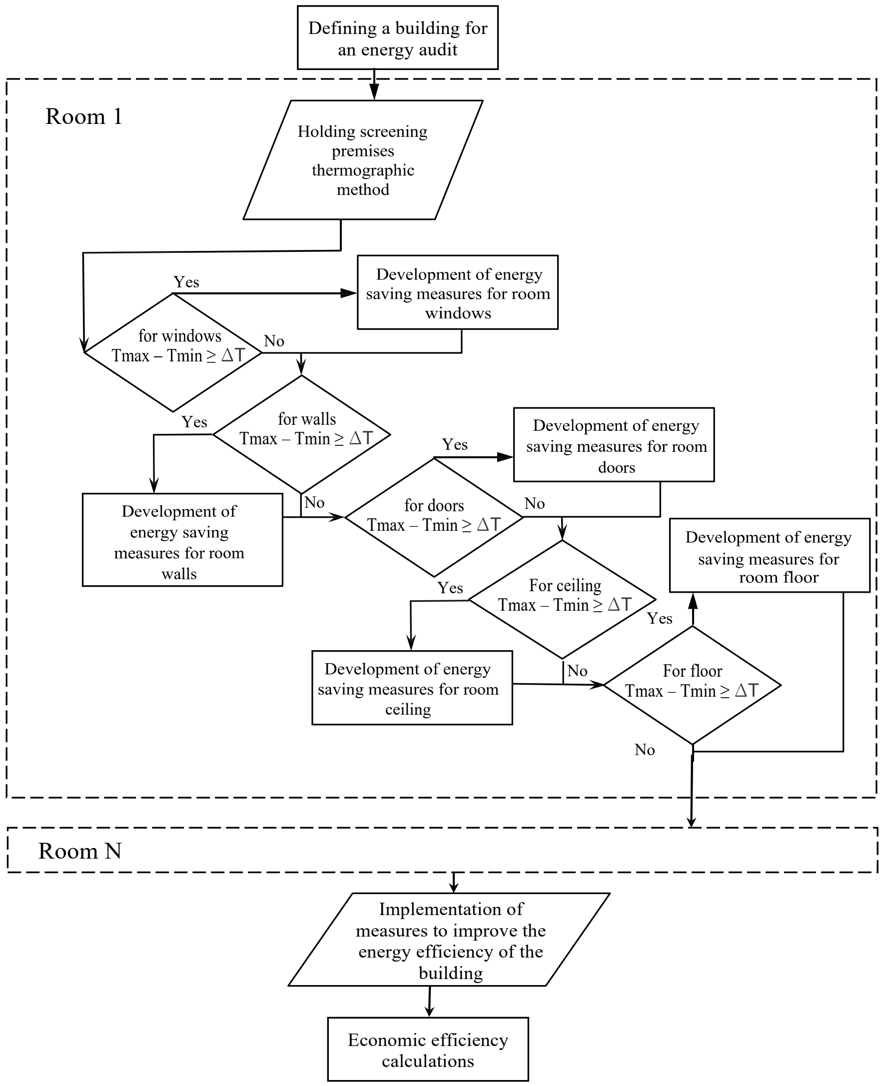
Information on the image	
Average temperature	18.3°C
Image borders	16.6°C to 20.3°C
The model of the device	Ti25
The serial number of the device	Ti25-09070166
Manufacturer	Fluke
Calibration range	–22.0°C to 125.0°C
Markers of the main image	
Name	*Temperature*
Central point	17.3°C
Hot	20.3°C
Cold	16.6°C

5 Analysis of research and economic calculations

The proposed algorithm for examining a room element using a Fluke Ti25 thermal imager allows you to step by step examine the entire building, identify the actual state of energy efficiency and develop improvement measures. The third stage of the energy audit of the building can be represented as an algorithm, which is shown in Figure 5.

The studies carried out made it possible to identify the elements (windows, walls, doors, floor, ceiling) of each room of the university building that need to be improved by developing measures to improve their energy efficiency. The main result of our research is to indicate exactly where it is necessary to carry out an energy efficiency measure. All activities are grouped by structural elements of the building, which allows for specialised repair work. Direct repair work is carried out by specialised construction companies.

Figure 5 Algorithm for the third stage of the energy audit of the building of the university



Achievement of a positive effect caused by energy-preservation measures can be estimated based on the assessment of energy savings in quantitative and monetary terms. To compare the current economic performance of the enterprise before and after the implementation of energy preservation measures, the total amount of profit remaining at the disposal of the enterprise, the part of it that variates directly due to the introduction of energy- preservation measures, is determined by the formula (Kasianova, 2017):

$$\Delta Pt = Cf_t \cdot \Delta Qf_t + Ch_t \cdot \Delta Qh_t + Ce_t \cdot \Delta Qe_t + \Delta E_t - \left(C_t + n \cdot I_t\right) + \Delta Z_t, \quad (1)$$

where

Cf_t is the price of saved standard fuel at current tariffs in year t, UAH/tons of standard fuel (t.s.f.)

ΔQf_t is the decrease in the supply of standard fuel to the enterprise per year t, t.s.f./year

Ch_t is the tariff for the purchase of heat per year t, UAH/GJ

ΔQh_t is the reduction of heat consumption per year t due to the introduction of energy saving preservation measures, GJ/year

Ce_t is the tariff for electricity received from the state electric power system per year t, UAH/kWh

ΔQe_t is the reduction of electricity consumption from the electric power system per year t due to the introduction of energy preservation measures, kWh/year

ΔE_t is the reduction of payments for environmental pollution per year t, caused by the introduction of energy preservation measures, UAH/year

C_t is the current expenses and capital investments per year t, which are related to the purchase, installation and operation of energy-preservation equipment, UAH

n is the internal rate of return

ΔZ_t is the reduction of maintenance expenditure at the enterprise per year t, which are due to the introduction of energy preservation measures, except for maintenance of energy-preservation equipment, UAH/year.

Thus, the energy efficiency of an energy-saving event *Ej* can be calculated using the formula:

$$Ej = E\left(\frac{1}{1-\frac{\Delta P}{P}}\right) \tag{2}$$

where E is the initial energy efficiency.

Energy efficiency after an energy-preservation measure is the sum of the initial energy efficiency by a coefficient that depends on the relative energy preservation. This coefficient shows how many times the energy efficiency of the considered useful effect increases with a relative energy preservation equal to $\Delta P/P$.

The calculation of the actual savings in heat energy costs after the implementation of measures has a predicted value. This is due to the fact that repair work is calculated for all university facilities. And this is the actual work on many buildings of the university. It is also incorrect to compare the costs incurred by the university during the heating season in different years, because the average ambient temperature is constantly changing and the university has fixed costs that do not depend on this average temperature and there are variable costs that depend on the ambient temperature. In general, in the 2020–2021 heating season, after energy-saving measures, heating costs decreased by 20% (UAH 1 million) and the microclimate in the entire building improved significantly (the indoor temperature levelled off). UAH 800,000 was spent on measures to improve energy efficiency.

6 Conclusions

Research conducted in the educational building no. 4 of Sumy National Agrarian University oriented at the energy audit of premises allows us to draw certain conclusions. Each element of the building room has a certain thermal conductivity, so the temperature on the surface of this element will differ depending on the type of element (windows, walls, ceiling, floor and doors). If we consider the element of the room separately, then the temperature on its surface, ideally, should be the same on similar surfaces of this element. The presence of temperature drops indicates hidden defects that are present in this element. Finding and eliminating such defects can improve the energy efficiency of the entire building as a whole.

Screening of premises elements: windows, walls, ceiling, floor, doors, heating systems with a special device thermal imager Fluke Ti25 allows us to identify places that have increased heat loss. Additional analysis of such places allows us to determine the causes of such energy losses and suggest measures to reduce them. In places with increased heat loss, the surface temperature is much lower than the temperature on a similar element of the surface of the room. This article considers places of heat loss that have more than 10% difference between the minimum surface temperature Tmin and the maximum temperature Tmax of the surface of the room element. This difference is used to achieve a significant economic effect. Each enterprise can set the indicator ΔT to determine the list of energy-preservation measures, depending on the financial soundness. The lower this indicator, the more money will need to be spent on energy- preservation measures. The suggested algorithm for conducting the third stage of energy audit of building premises allows us to systematise this process, divide it into components and, as a result, group energy saving measures by building elements (windows, walls, roof, floor, doors). Economic calculations allow us to compare enterprise performance before and after introduction of energy preservation measures.

References

Bevz, V.V. (2011) 'Development of energy saving mechanism at food industry enterprises', *Scientific Notes Collection of Scientific Papers*, Vol. 13, No. 1, pp.169–173.

Cho, H.M., Yun, B.Y., Yang, S., Wi, S., Chang, S.J. and Kim, S. (2020) 'Optimal energy retrofit plan for conservation and sustainable use of historic campus building: case of cultural property building', *Appl. Energy*, Vol. 275, pp.115–313, https://doi.org/10.1016/j.apenergy.2020.115313

Chystov, Y.I. (2010) 'The essence of the energy saving mechanism and its multifaceted nature', *Bulletin of Khmelnytsky National University. Economic Sciences*, Vol. 4, No. 5, pp.341–344.

Danilkova, A.J. (2016) 'Modalities for implementation of energy management in industrial plants', *Scientific Bulletin of Uzhhorod National University*, Vol. 8, No. 1, pp.58–61.

Dongellini, M., Marinosci, C. and Morini, G.L. (2014) 'Energy audit of an industrial site: a case study'. *Energy Procedia*, Vol. 45, pp.424–433, https://doi.org/10.1016/j.egypro.2014.01.046.

Dzhedzhula, V.V. (2014) *Energy Saving of Industrial Enterprises: Methodology of Formation, Management Mechanism*, Vinnytsia National Tavrichesky University, Vinnytsia, Ukraine.

Heiets, V.M. (2016) 'Development and interaction of economic and energy policy in Ukraine', *Bulletin of the National Academy of Sciences of Ukraine*, Vol. 2, No. 2, pp.46–53.

Ippolitova, I.Y. and Sorokotiazhenko, K.S. (2015) 'Formation of organizational and economic mechanism of energy saving at the enterprise', *Global and National Economic Problems*, Vol. 8, No. 8, pp.406–411.

Kasianova, N. (2017) 'Implementation of energy savings strategy for industrial enterprises', *Effective Economy* [online] http://www.economy.nayka.com.ua/?op=1&z=5916 (accessed 11 July 2019).

Kirimtat, A. and Krejcar, O. (2018) 'A review of infrared thermography for the investigation of building envelopes: advances and prospects', *Energy Build.*, Vol. 176, pp.390–406, https://doi.org/10.1016/j.enbuild.2018.07.052

Kontokosta, C.E., Spiegel-Feld, D. and Papadopoulos, S. (2020) 'The impact of mandatory energy audits on building energy use', *Nature Energy*, Vol. 5, No. 4, pp.309–316, https://doi.org/10.1038/s41560-020-0589-6.

Kostyuchenko, N. (2015) 'Community-based approach to local development as a basis for sustainable agriculture: experience from Ukraine', *International Journal of Agricultural Resources, Governance and Ecology*, Vol. 11, No. 2, pp.178–189.

Krarti, M. (2020) *Energy Audit of Building Systems: An Engineering Approach*, 2nd ed., CRC Press, 658pp.

Moynihan, G.P. and Barringer, F.L. (2017) 'Energy efficiency in manufacturing facilities: assessment, analysis and implementation', *Energy Efficient Buildings*, https://doi.org/10.5772/64902.

Nota, G., Nota, F.D., Peluso, D. and Lazo, A.T. (2020) 'Energy efficiency in industry 4.0: the case of batch production processes', *Sustainability*, Vol. 12, No. 16, p.6631, https://doi.org/10.3390/su12166631.

Potić, I., Joksimović, T., Milinčić, U., Kićović, D. and Milinčić, M. (2021) 'Wind energy potential for the electricity production – Knjaževac Municipality case study (Serbia)', *Energy Strategy Reviews*, Vol. 33, pp.100589, https://doi.org/10.1016/j.esr.2020.100589.

Sabadash, S. (2020) 'Improvement of equipment in order to intensify the process of drying dispersed food products', *Eastern-European Journal of Enterprise Technologies, Kharkiv*, Vol. 1, No. 11 (103), pp.15–21.

Savchenko-Pererva, M., Radchuk, O., Rozhkova, L., Barsukova, H. and Savoiskyi, O. (2021) 'Determination of heat losses in public premises with development of algorithm for implementation of the energy saving measures', *Eastern-European Journal of Enterprise Technologies*, Vol. 6, No. 11 (114), pp.48–59, https://doi.org/10.15587/1729-4061.2021.245794pp.105-106.

Sukmanov, V., Radchuk, O., Savchenko-Pererva, M. and Budnik, N. (2020) 'Optical piezometer and precision researches of food properties at pressures from 0 to 1000 MPa', *Journal of Chemistry and Technologies*, Vol. 28, No. 1, pp.68–87, DOI: 10.15421/082009.

Tanić, M., Kondić, S. and Zivkovic, M. (2012) 'Contribution To Infiltration Heat Losses Study in the Educational Facilities of the School Building', *12th International Multidisciplinary Scientific GeoConference, SGEM 2012, Conference Proceedings*, STEF92 Technology Ltd., Albena, Vol. 5, pp.199–206.

Tanić, M., Stanković, D., Nikolic, V., Nikolic, M., Kostić, D., Milojković, A., Spasić, S. and Vatin, N. (2015) 'Reducing energy consumption by optimizing thermal losses and measures of energy recovery in preschools', *International Scientific Conference Urban Civil Engineering and Municipal Facilities, SPbUCEMF-2015*, *Procedia Engineering*, Vol. 117, pp.919–932, https://doi: 10.1016/j.proeng.2015.08.179.

Thomsen, K.E., Rose, J., Mørck, O., Jensen, S.Ø., Østergaard, I., Knudsen, H.N. and Bergsøe, N.C. (2016) 'Energy consumption and indoor climate in a residential building before and after comprehensive energy retrofitting', *Energy Build*., Vol. 123, pp.8–16, https://doi.org/10.1016/j.enbuild.2016.04.049.

Xu, X., Wei, Z., Ji, Q., Wang, C. and Gao, G. (2019) 'Global renewable energy development: Influencing factors, trend predictions and countermeasures', *Resources Policy*, Vol. 63, p.101470, https://doi.org/10.1016/j.resourpol.2019.101470.