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SUBSTANTIATING THE CRITERIA OF CHOOSING PROJECT SOLUTIONS FOR CLIMATE CONTROL SYSTEMS BASED ON RENEWABLE ENERGY SOURCES

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Обґрунтовано вибір проектних рішень систем забезпечення кліматичних умов у приміщеннях на основі використання різних видів відновлюваних джерел енергії. Засоби, якими пропонується вирішення завдань проекту, є використання взаємодії між різними стейкхолдерами, необхідної для ефективного функціонування кількість підсистем у відкритій системі, тобто врахування ефекту синергетики. Доведено, що запровадження комплексної системи кліматизації та енергозабезпечення дозволить об'єднати функції, притаманні розрізненим інженерним системам, забезпечить перетворення та перерозподіл енергетичних потоків різних видів, що дозволить мінімізувати експлуатаційні витрати. Побудована Ієрархічна структура задачі ухвалення вибору альтернативних проектних рішень систем кліматизації на основі методу Analytic Hierarchy Process, що дозволяє отримати множину оптимальних варіантів застосування відповідного інструментального апарату Data Envelopment Analysis дозволяє побудувати систему оцінювання енергоефективності проектів складних систем кліматизації та енергозабезпечення при використанні різних видів відновлюваних джерел енергії. Побудовано функціонал, призначений для вибору оптимального варіанту проектного рішення системи кліматизації та енергозабезпечення. Запропоновані проектні рішення розглянуто з позиції визначення мінімізації сумарних витрат енергоресурсів та експлуатаційних витрат трьох альфа-стейкхолдерів. Запропонований показник відносної інтегральної енергоефективності дозволяє здійснити оптимальний вибір складних систем із різнорідними вхідними та вихідними характеристиками

Ключові слова: системи кліматизації, відновлювані джерела енергії, проектні рішення, енергоефективність, ранжування

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1. Introduction

In the field of project management, a portfolio is formed by consistent objective selection from the assigned totality of projects as homogeneous objects. Each of them is characterized by sets of identical inputs and outputs in certain dimensions, division of totality into two classes – leaders and outsiders. The multistage process of evaluating indicators that determine the effectiveness of the relevant managerial decision that was made, consequential dividing homogeneous objects with renewed inputs/outputs into two independent classes, is completed, if necessary, by determining a single winner.

Consumers face the problem of energy saving. The main consumers of energy resources in Ukraine are industry (30.2 % of total energy consumption), household (32.8 %), and transport sectors (19.5 %) [1]. At the same time, over the past 5 years, the total level of the energy capacity of the Ukrainian industry decreased only by 4 %, at a decrease in total added value by 37 %, and the decrease in energy consumption volumes by 39 % [2]. Poor dynamics of decrease in power consumption volumes indicates a low level of production modernization in general.

The insufficient level of formation of scientific principles for construction and selection of energy-efficient climate control systems based on using solar energy and energy of environment remains an unresolved problem of the formation of power supply systems in many countries of the world [1, 2]. Fragmentation in the choice of project solutions of complex climate control systems in premises and power supply of buildings for residential, industrial, or recreational purposes leads to an insufficient effect of energy saving of fossil resources.

Thus, the further development of foundations for the formation of energy efficient systems for providing climatic conditions in premises based on the use of solar energy and energy of the environment is of important scientific and practical significance. It is a relevant scientific and practical issue for the development of the power industry in the world, requiring further elaboration and solution.

Thus, the complex of issues related to outlining the specifics of the implementation of project solutions of systems for ensuring climatic conditions in premises, based on renewable energy sources, requires in-depth analysis and methodological refinement. It is becoming increasingly harder for power supply companies to determine a set of indicators of the effectiveness of the tools of project solutions needed to create long-term relationships in the market and to meet the needs of a customer.

2. Literature review and problem statement

When determining the criteria for choosing a project solution of the systems for ensuring climatic conditions in premises, it is necessary to take into account the restrictions caused by economic feasibility issues. The content-analysis of scientific sources as for the outlined problem was conducted and the directions of realization of implementation of calculation of the efficiency of project solutions of energy projects were established.

In paper [3], the necessity of comparison of technical and economic efficiency of the systems of providing climatic conditions in premises was substantiated. However, the criterial apparatus of the research was considered insufficiently – the well-grounded selection of indicators influencing the evaluation of the efficiency of energy projects was not performed.

The appropriateness of the application of the criteria of the effectiveness-consumption type is emphasized in paper [4]. The use of this approach leads to the minimization of costs to ensure the effectiveness of the system for providing the climatic conditions in premises. For this purpose, it was proposed to use the so-called optimization criterion or the criterion of resource distribution optimization. Obviously, the use of only the minimization criterion significantly narrows the alternative choice of a project.

The opposing viewpoint was considered in paper [5] – maximization of the target effectiveness of the systems for providing climatic conditions in premises within fixed costs of operations performance. The disadvantage of determining this optimization criterion is the limitation of solving the project problem at the early stages. In this case, the need to form a flexible estimate for the entire period of implementation of project solutions of the climatic systems based on renewable energy sources is not taken into account.

In order to overcome the outlined shortcomings, there arises a need to determine the criteria during technical-economic substantiation.

Thus, the authors of research [6] emphasize the importance of determining technical capabilities and the economic feasibility of taking necessary measures. Paper [7] contains thorough consideration of the need to justify the project capacity at the initial stage of the implementation of a project of providing climate conditions in premises.

The possibility of analyzing the initial data on providing the basic energy resources, substantiation of prospects of their use, or obtaining was determined in article [8]. In research [9], the estimation of the impact on the environment during the implementation of energy saving projects was analyzed.

The main technological, construction, and architectural-planning solutions as the basis for projecting these projects were determined in paper [10]. The authors of paper [11] constructed the system of basic solutions and indicators to assess energy efficiency and compare project options. Article [12] emphasized the necessity of constant accounting and using secondary and renewable resources.

However, the explored studies of determining the criteria for the selection of the systems for providing climatic conditions in premises are fragmentary. Currently, there is no unified integrated approach to solving the problem of determining the criteria for choosing a project solution of the systems of providing climatic conditions in premises, based on renewable energy sources.

All this gives grounds to argue that it is advisable to conduct research to substantiate the criteria for choosing project solutions of the systems of climate conditions in premises with the use of modern scientific tools.

3. The aim and objectives of the study

The aim of this study is the scientific substantiation of the choice of project solutions of the systems of providing climatic conditions in premises based on the use of different types of renewable energy sources.

To achieve the aim, the following tasks were set:

– to determine the criteria for the estimation of power supply and climate control systems;

– to develop functionality to optimize the choice of a project solution of a power supply and climate control system, taking into account the interests of alpha stakeholders;

– to offer the indicator of relative integrated energy efficiency of complex climate control and energy supply system using different types of renewable energy sources.

4. Materials and methods to study the substantiation of choosing project solutions for climate control systems in premises

These aggregated indicators were selected based on the Analytic Hierarchy Process (AHP), which is primarily focused on the construction of models of the choice of a priori known alternatives in the final set.

During the research, the following general scientific methods were used: system analysis, grouping (in developing the scheme of hierarchical levels and components); analysis, logical generalization. The following specific methods were applied: Analytic Hierarchy Process (when selecting the aggregated project evaluation indicators); the Data Envelopment Analysis method; the graphical method for visibility of the research results.

The means for solving the tasks of a project are the use of the effect of the interaction of a large number of subsystems in an open system, that is, the synergy effect. This will enable creating a comprehensive scientific and methodological approach to the construction of energy-efficient systems for providing climate conditions in premises, based on solar energy and the environment energy. A complex climate control and energy supply system is able to unite the functions inherent in separate engineering systems and ensure the transformation and redistribution of energy flows of different RES types.

Let us explore the features of the Data Envelopment Analysis methodology in the framework of our research. The evaluation technique is based on the use of the toolset of mathematical optimization, implemented as a software module in the Excel environment, which is automatically valid in a working spreadsheet-template.

In analyzing the data shell, the main concept is effectiveness, which is determined by the ratio of the sum of all input parameters to the weighted sum of all input factors [13].

The criterion for determining the effectiveness of the DEA methodology is reaching the Pareto optimum. According to the research needs, the absolute criterion for determining the effectiveness of climate control systems should satisfy three conditions:

a) none of the output parameters can be increased without increasing one or more input factors or decreasing other output parameters;

b) none of the input factors can be decreased without decreasing one or more input parameters or increasing other input factors.

In practice, the effectiveness assessment by qualitative indicators is quite subjective, it is very difficult to identify the standard. That is why it is necessary to solve the problem of forming an effectiveness boundary for qualitative indicators.

5. Results of studying the substantiation of choosing project solutions for climate control systems in premises

5. 1. Selecting the criteria for assessing power supply and climate control systems

Under today's market conditions, there are many variants of project solutions of the climate control systems in premises.

Most energy-efficient technologies help to increase production efficiency. The issue of the implementation of these technologies is a prerequisite for the development of business plans for the innovative development of enterprises, especially industrial ones. Fixed assets and technologies of many Ukrainian industrial enterprises were created in Soviet times and need significant power modernization. At the same time, operating costs in the process of technological processes are gaining special significance.

The selection of an optimal variant of a project solution of a climate control and power supply system is possible due to the performance of system analysis. This method is based on a comparison of the effectiveness of variants of climate control and power supply systems with the basic criteria:

– of a consumer. They are used during considering the variants of climate control and power supply systems from a consumer's position. They should ensure minimum operating costs when creating sufficiently comfortable conditions;

– of an investor. From the standpoint of an investor, engineering systems must ensure minimal integral consumption of all types of energy resources;

– of an organization that maintains the engineering climate control system. From the position of a servicing organization, engineering systems must provide the highest profit.

When analyzing and choosing the implementation of the climate control and power supply systems, it is advisable to take into account such aggregated indicators:

– specific consumption of energy carrier per one square meter of the heated area (X_1, m^3/year×m^2);

– specific estimated water consumption (on average per year) for household and sanitary needs per one square meter of the heated area (X_2, m^3/year×m^2);

– specific capital expenses for creation engineering networks per one square meter of the heated area (X_3, USD thousand/m^2);

– specific operation costs per one square meter of the heated area (X_4, USD thousand/m^2).

These indicators are calculated as follows. Specific energy carrier consumption per square meter determined from dependence (1):

$$X_1 = \frac{V_h}{A_h}, \tag{1}$$

where A_h is the heated area, m^2; V_h is the energy carrier (gas) consumption. V_h can be taken per year, or one heated season.

Specific water consumption for household and sanitary needs are calculated from dependence (2):

$$X_2 = \frac{I_h}{A_h}, \tag{2}$$

where A_h is the heated area, m^2; I_h is the water consumption (per year).

Specific capital costs consist of the costs of equipment, materials, transportation, and mounting works of the climate control system, labor costs, and other costs necessary for a particular project solution. This indicator is calculated from dependence (3):

$$X_3 = \frac{Y_1 + Y_2 + Y_3 + Y_4 + \ldots + Y_n}{A_h}, \tag{3}$$

where A_h is the heated area, Y_1 is the salary of employees, Y_2 is the cost of technological equipment, Y_3 is the cost of the tool, Y_4 is the cost of materials, Y_n is other costs to create an engineering solution.

Specific operating costs per square meter are determined from dependence (4):

$$X_4 = \frac{Y_1 + Y_2 + Y_3 + Y_4 + \ldots + Y_n}{A_h}, \qquad (4)$$

where A_h is the heated area, Y_1 is the salary of service staff, Y_2 is the depreciation costs, Y_3 is the costs of current repairs, Y_4 is the costs of auxiliary materials, Y_n are other maintenance costs.

Solving the problem is the process of gradual formation of priorities. At the first stage, the most important elements of the problem are identified, at the second stage, the best way to verify assertions and to evaluate elements is determined. The whole process should be subject to verification and rethinking until it is determined that it embraced all important characteristics of problem-solving.

Thus, the first step in the hierarchy analysis method is decomposition and representation of a problem in a hierarchical form. Consider the dominant hierarchies, which are built from the top (aim in terms of management) through intermediate levels (criteria on which the following levels depend) to the lowest level, which is usually a list of alternatives. A hierarchy is considered complete if each element of an assigned level functions as a criterion for all elements of the level below. That is, a hierarchy can be divided into sub-hierarchies that have a common highest element. The law of hierarchical continuity requires that the elements of the lower level should be leveled pairwise in relation to the elements of the following level, etc., to the top of a hierarchy.

Fig. 1 shows the hierarchical structure of the problem.

Analysis of specific indicators does not provide an answer about the variant of implementation of engineering power supply systems, which is the best from the consumer's position. To solve the problem of optimal choice, it is advisable to use the method of multi-criteria estimation of generalized comparative.

The data obtained during the experimental works, carried out by the authors, were chosen as an information basis for the calculation of indicators of the effectiveness of choice of the variants of climatic control systems.

According to the research results, the following project solutions were chosen:

1. Heating and hot water supply from the roof boiler, etc.
2. Energy-efficient enclosure and a heat pump in the power supply system with one heating circuit and system of hot water preparation.
3. A scheme with a heat pump with one heating circuit with a mixer, air conditioning function, energy-active enclosure for preparation of hot water, and buffer capacity of the heating circuit.

4 Schematic solution with two heating circuits with a mixer, air conditioning function, hot water supply function with the help of energy-active enclosures, and a buffer capacity of the heating circuit.

5. The schematic solution implies the existence of two heating circuits with the mixer and buffer capacity of the heating circuit, an energy-active enclosure used for hot water supply and an air conditioning system.

6. The schematic solution, which includes one heating circuit without a mixer, air conditioning function and hot water preparation.

For these project decisions, specific indicators were calculated according to (1)–(4). The results are shown in Table 1. During the estimation of climate control and power supply, the subjectivity factor is minimized. That is why, it is advisable to use it in the analysis of complex systems with disparate input and output characteristics (Table 1), which are the above project solutions.

With this approach, it is possible to obtain the values of generalized efficiency coefficients that determine the efficiency or a degree of inefficiency of each object. The objects with maximum efficiency coefficient (in the DEA methodology it is equal to unity) form the efficiency limit of or so-called effective front. The objects located on this boundary are most effective.

Table 1

Variants of the systems of climate control and energy provision of climatic conditions in premises

No. of entry	Variant of project solution	Indicators			
		Specific consumption of energy carrier (gas) per square meter of heated area	Specific estimated water consumption (average per year) for domestic and sanitary needs	Specific capital costs	Specific maintenance costs
1	Heating and hot water supply from the roof boiler, etc.	72.1	5.07	2.57	0.33
2	Energy-intensive enclosures and heat pump in the power supply system with one heating circuit and hot water preparation system	4.58	0.6	12	0.07
3	Scheme with a heat pump with one heating circuit with a mixer, air-conditioning function, energy-active fencing for hot water and buffer capacity of the heating circuit	4.58	0.7	15	0.116
4	Schematic solution with two heating circuits with a mixer, conditioning function, heat water supply function with the help of energy active enclosures and buffer capacity of the heating circuit	4.58	0.8	15.1	0.133
5	A schematic solution which implies the existence of two heating circuits with a mixer and buffer capacity of the heating circuit, the energy-active enclosure is used for hot water supply and air conditioning systems	4.58	0.8	15.3	0.15
6	Schematic solution, which includes one heating circuit without a mixer, function of conditioning and hot water separation	4.58	0.8	14	0.125

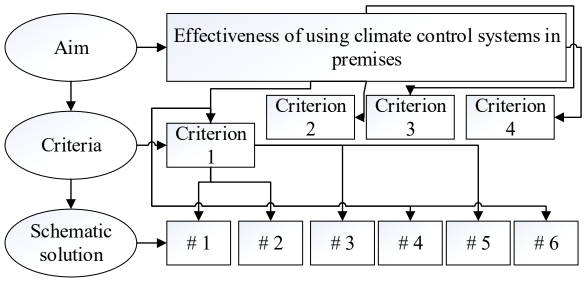

Fig. 1. Hierarchical structure of the problem of approval of the decision of selecting alternative project solutions of the climate control systems in premises based on renewable energy sources (projected by authors):
Criteria: 1 is the specific consumption of energy carrier per square meter of heated area (X_1, m^3/year×m^2); 2 is the specific estimated water consumption (on average per year) for household and sanitary needs per square meter of the heated area (X_2, m^3/year×m^2); 3 is the specific capital costs to create engineering networks per square meter of heated area (X_3, USD thousand/m^2); 4 is the specific maintenance costs per square meter of the heated area (X_4, USD thousand/m^2)

5. 2. Constructing the functional to optimize the selection of a project solution of a power supply and climate control system taking into account the interests of alpha-stakeholders

When using the DEA method, any complex power supply system is characterized both by input parameters and output parameters. In power supply systems under consideration (more information on their construction is presented in [1, 2]), the output magnitudes are formed in such a way that each of them characterizes the factor, which has a positive role in the total indicator of efficiency. They include, for example, energy carrier consumption, water consumption for and household and sanitation needs, specific capital expenditures, and others. In the general case, such output indicators in power supply systems under consideration are the magnitudes characterizing production-technological (volume and quality of products, reliability, durability), managerial (sustainability, the possibility of observation, etc.), economic (income, profitability, etc.), environmental (clean production), etc.

The operation costs, a decrease in which results into an increase in indicator of total efficiency, for example, the use in power supply systems of energy- active enclosures as converters of the energy of renewable sources, are accepted as input magnitudes (X_1, X_2, X_3, X_4).

Based on the choice of inputs and outputs, the totality of which gives a sufficiently complete and adequate characteristic of systems from the position of a researcher, the structure of integrated indicator of the efficiency of the system under consideration, has positive weight factors. They characterize the relative contribution of each of the output factors Yi in total efficiency coefficient F_n. Respectively, s_{1n}, s_{2n}, s_{2n}, s_{3n}, s_{4n} are the weights of output magnitudes X_1, X_2, X_3, X_4. In the formation of appropriate functionality in the general case, their values are unknown, for them, a prerequisite is that they are more than 0.

The magnitudes of all efficiency indicators have a corresponding boundary. In addition, these values are ranked in the numerical interval from 0 to 1, based on conditions of maximization of efficiency indicators for each system.

Taking into consideration the above factors for analysis of comparative efficiency of power supply from a consumer's position is formed based on the DEA methodology of generalized estimation of the n-th variant of implementation of power supply systems in the form of the following functional (F_n). This functionality corresponds to the minimization of the total consumption of energy resources and operating costs:

$$F_n = \max_{s_1, s_2, s_4 \in H} \frac{1}{s_{1n}X_{1n} + s_{2n}X_{2n} + s_{4n}X_{4n}}, \tag{5}$$

where s_{1n}, s_{2n}, s_{4n} are the positive weight factors characterizing a relative contribution of each individual indicator – X_1, X_2, X_4 in total efficiency coefficient F_n for the n-th variant of power supply.

The calculation of numerical indicators of integrated energy efficiency F_n (n=1, 2...6) for each variant of implementation of power supply systems according to the DEA method is based on the position that the values of all indicators of integrated energy efficiency F_n are normalized in the interval [0; 1].

The system of constraints, which determines the region of values $H\epsilon(s_{1n}, s_{2n}, s_{4n})$ in functional (5), takes the following form:

$$\left\{\frac{1}{s_{1_1}X_{1_1} + s_{2_1}X_{2_1} + s_{4_1}X_{4_1}} 1\right\}\{...\}\times$$
$$\times\left\{\frac{1}{s_{1_2}X_{1_2} + s_{2_2}X_{2_2} + s_{4_2}X_{4_2}} 1\right\}\times$$
$$\times\{...\}\left\{\frac{1}{s_{1_6}X_{1_6} + s_{2_6}X_{2_6} + s_{4_6}X_{4_6}} 1\right\}. \tag{6}$$

The solution to (5) and (6) provides the values of energy efficiency indicators of the variant of the climate control and power supply system from the consumer's position (taking into account the data shown in Table 1). The visual image is shown in Fig. 2.

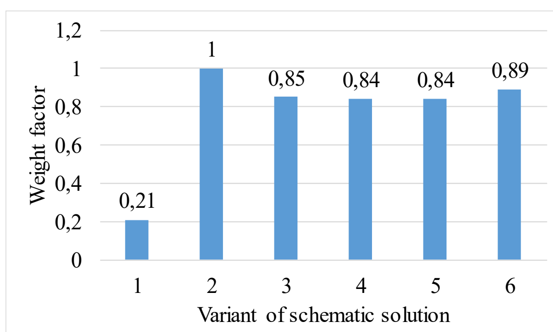

Fig. 2. Indicators of energy efficiency of the variant of a climate control and power supply system from the consumer's position

The maximum value of energy efficiency indicators in the variant of a climate control and energy supply system – the RES converter and a heat pump in the power supply system with one heating circuit and the system of hot water preparation (F_n=1). It is characterized by the minimum value of specific operating costs and specific consumption of gas and low cold water consumption. The minimum values in the variant of the climate control and energy supply system – heating and hot water supply from the boiler located on the roof (F_n=0.21). In the variant of the schematic solution of the climate control and power supply system, which includes one heating circuit without a mixer, the function of air conditioning and hot water preparation (F_n=0.89). In variants 3, 4, 5, the values of indicators of energy efficiency are approximately the same (F_n=0.85; 0.84).

Thus, solving equations (5), (6) allowed assessing and revealing the best variant of the examined climate control and power supply systems from the consumer's position.

Analysis of the values of weight factors, which were obtained in solving (5), (6), revealed that the indicators of specific operating costs have the highest values. The remaining weight factors have less influence on the magnitude of the functional (5).

The next stakeholder, whose position should be considered when choosing a schematic solution, is the investor. That is why it is necessary to assess the optimal variant of the proposed schematic solutions of power supply systems from this position.

The optimal variant was chosen according to two indicators:

– gas consumption (X_1);

– specific water consumption (X_2).

In this case, the minimum integral consumption of these two resources is determined.

The numerical values of energy consumption indicators are shown in Table 1. It is clear from Table 1 that specific gas consumption is minimal for variants 2, 5. Specific cold water consumption is minimal for variants 2, 3. But these indicators do not provide complete information on the effectiveness of the climate control and energy supply system from the investor's position.

In accordance with the DEA methodology, we form the functional of generalized estimation of energy efficiency of the n-th variant of the implementation of climate control and power supply systems (F_n) using different types of energy of alternative sources from the investor's position in the form of functional:

$$F_n = \max_{s_1, s_2 \in H} \frac{1}{s_{1n} X_{1n} + s_{2n} X_{2n}}. \tag{7}$$

For each of the variants of a climate control and energy supply system, we maximize functional (7) in the presence of the following system of restrictions, which determines the region of values $H \in (s_{1n}, s_{2n})$:

$$\left\{\frac{1}{s_{1_1} X_{1_1} + s_{2_1} X_{1_1}} 1\right\}\{\ldots\}\times$$
$$\times\left\{\frac{1}{s_{1_2} X_{1_2} + s_{2_2} X_{2_2}} 1\right\}\{\ldots\}\left\{\frac{1}{s_{1_6} X_{1_6} + s_{2_6} X_{2_6}} 1\right\}. \tag{8}$$

The ranked indicators of the comparative efficiency of each variant were determined. Variant 1 has the highest rate of comparative energy efficiency (F_n=1). In the variant of the climate control and power supply system, the RES converter and heat pump in the power supply system with one heating circuit and the system of hot water preparation F_n=0.38. In variants 3, 4, 5, and 6, the value of the indicator of comparable energy efficiency F_n=0.35. Analysis of weight factors revealed that consumption of energy carrier and water has the greatest influence on the value of functional (7). The solution to (7) and (8) allowed ranking the proposed variants of the climate control and power supply system from the investor's position (Fig. 3).

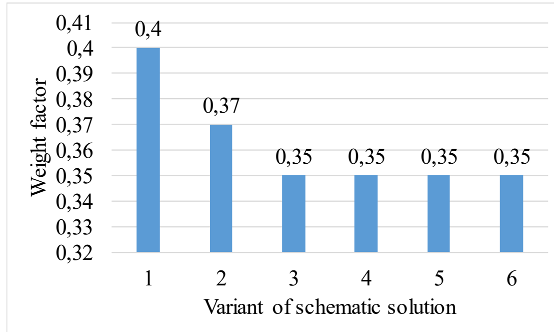

Fig. 3. Indicators of energy efficiency of the variant of a climate control and power supply system from the investor's position

To assess the variants of the climate control and power supply systems from the position of a servicing organization, it is advisable to use three indicators:

– specific capital costs – X_1;

– specific gas consumption – X_2;

– specific cold water consumption – X_3.

Table 1 shows that specific gas consumption is minimal in all variants except for the first one. Variants 2 and 3 have the minimum cold water consumption. Variant 1 has specific capital expenditures.

Analysis of the indicators shown in Table 1 does not provide complete information about the variants of implementation of power supply systems from the position of a servicing organization.

To analyze effectiveness, we proposed the model based on the DEA methodology for generalized estimation of the variant of implementation of climate control and power supply systems, which contain RES converters, a heat pump, and use alternative power sources.

To minimize costs, in this case, it is advisable to consider the consumption of energy resources and capital costs:

$$F_n = \max_{s_1, s_2, s_3 \in H} \frac{1}{s_{1n} X_{1n} + s_{2n} X_{2n} + s_{3n} X_{3n}} \tag{9}$$

and the system of constraints:

$$\left\{\frac{1}{s_{1_1} X_{1_1} + s_{2_1} X_{2_1} + s_{3_1} X_{3_1}} 1\right\}\{\ldots\}\times$$
$$\times\left\{\frac{1}{s_{1_2} X_{1_2} + s_{2_2} X_{2_2} + s_{3_2} X_{3_2}} 1\right\}\{\ldots\}\times$$
$$\times\left\{\frac{1}{s_{1_6} X_{1_6} + s_{2_6} X_{2_6} + s_{3_6} X_{3_6}} 1\right\}. \tag{10}$$

The solution to (5) and (6) allowed ranking the proposed variants of the climate control and power supply system from the position of a servicing organization (Fig. 4).

Variant 5 has the maximum value of comparative efficiency of power supply, taking into account capital costs (F_n=1). The high efficiency rate is caused by the minimum value capital costs of equipment and low energy consumption. Variant 1 has the lowest indicator of comparative efficiency (F_n=0.69) when heating and hot water supply are provided through the use of a boiler located on the roof of a building. Low values of indicators of comparative efficiency are explained by the high consumption of the energy carrier. Variant 2 has F_n=0.83, variant 3 has F_n=0.90, variant 4 – F_n=0.94, variant 6 has F_n=0.86, the values of comparative efficiency are close to the maximum and are caused by the high value of capital costs (Fig. 4).

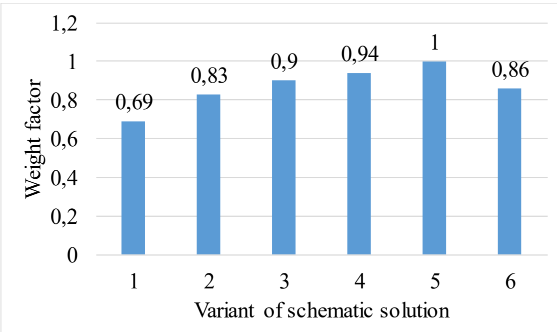

Fig. 4. Indicators of energy efficiency of the variant of a climate control and power supply system from the position of a servicing organization

It is advisable to determine from analysis of weight factors that the indicator of specific capital costs has the greatest influence of functional efficiency. Thus, in equations (9) and (10), the obtained results were ranked, and the variants of the climate control and energy supply systems, which use RES converters, heat pumps, and alternative energy sources were proposed from the position of a servicing organization.

5. 3. Determining the indicator of relative integrated energy efficiency of complex climate control and energy supply systems at using different types of renewable energy sources

The above indicators do not enable obtaining a definite answer about the choice of a rational system of climate control and energy supply system, which satisfies all three directions (consumer, servicing organization, investor).

That is why at the last stage it is necessary to assess the variants of energy supply systems, taking into account all four indicators presented in Table 1. To do this, according to the DEA method, we form the functional of the generalized integrated evaluation of energy efficiency of the option for the implementation of the climate control and power supply system, which corresponds to the minimization of the weighted amount of costs:

$$F_n = \max_{s_1,s_2,s_3,s_4 \in H} \frac{1}{s_{1n}X_{1n}+s_{2n}X_{2n}+s_{3n}X_{3n}+s_{4n}X_{4n}} \quad (11)$$

and the system of restrictions

$$\left\{\frac{1}{s_{1_1}X_{1_1}+s_{2_1}X_{2_1}+s_{3_1}X_{3_1}+s_{4_1}X_{4_1}}1\right\}\{...\}\times$$
$$\times\left\{\frac{1}{s_{1_2}X_{1_2}+s_{2_2}X_{2_2}+s_{3_2}X_{3_2}+s_{4_2}X_{4_2}}1\right\}\{...\}\times$$
$$\times\left\{\frac{1}{s_{1_6}X_{1_6}+s_{2_6}X_{2_6}+s_{3_6}X_{3_6}+s_{4_6}X_{4_6}}1\right\}. \quad (12)$$

Thus, based on systemic and multi-criteria assessment, we proposed an approach that allows studying the problem of power supply efficiency from the position of a consumer and a servicing organization.

Solutions of (11) and (12) allowed ranking the proposed variants of the climate control and power supply system of all three stakeholders: a consumer, a servicing organization, and an investor (Fig. 5).

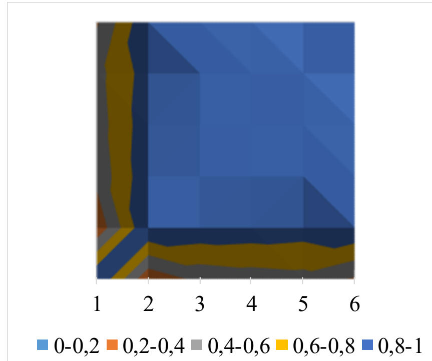

Fig. 5. Relative integrated energy efficiency of projects of climate control and power supply system from positions of a consumer, an investor, and a servicing organization

Variant 2 has the maximum value of the integrated indicator of energy efficiency indicator (F_n=1), which is correlated with the assessment of a climate control and power supply system from the consumer's position. The variant with a boiler on the roof has F_n=0.86. In other variants, the values of integrated effectiveness are in the range (F_n=0.95÷0.99).

This approach allows choosing the option of the schematic solution of a climate control and energy supply system, which will meet not only engineering needs but will be advisable from the economic point of view.

6. Discussion of the results of substantiation of the selection of project solutions of the climate control systems based on renewable energy sources

According to the stakeholders' concept, the necessity to take into account the interests of all three alpha stakeholders of alternative projects of climate control systems in premises, based on renewable energy sources: a consumer, an investor and a servicing organization, was determined.

In contrast to the existing scientific and methodological approaches [3–12], the authors used the methods of Analytic Hierarchy Process and Data Envelopment Analysis. Their application allows determining the plane of alternative projects and constructing the general vector of the optimal variant of choosing a schematic solution of a climate control and energy supply system. The latter is the functional of minimization of the total consumption of energy resources and operating costs of three groups of agents: a consumer, investors, and a servicing organization.

According to the authors, the limitations of the proposed research are based on the Ceteris paribus principle. This means that the coincidence of the economic interests of Alfa-stakeholders is necessary when it comes to the implementation of alternative projects of climate control systems in premises. Alfa-stakeholders form their requirements according to the goals and motivation and influence a project, based on their interests, professional competencies, and a degree of involvement in its implementation.

In order to neutralize possible deficiencies and violations of the balance of interests, competencies, and a degree of involvement of project agents, it is important to outline certain recommendations for its implementation:

1) The constructed alternative variant makes it possible to decide on a decrease in the use of natural gas. This is possible due to the introduction of the newest energy-saving technologies, which are used to reduce production energy intensity and enhance the competitiveness of products; implementing engineering-technical and scientific measures.

2) Under current conditions of the world economy, industrial enterprises implement the optimal strategy based on energy saving and consider energy efficiency as an important component of the innovative development of the industry.

3) The volumes and the scope of application of renewable energy sources that will partially replace natural gas are increasing.

The conducted study does not solve all topical issues of management of the projects of climate control systems in premises, based on renewable energy sources. The following scientific developments are promising:

– formation of a procedure of communication interaction between the groups in energy markets;

– development of a toolset for analysis of the development of the processes of self-organization and adaptation of agents in the implementation of energy-saving technologies;

– construction of the model for determining the structure and attributes of the cognitive space of behavior of power consumers in the market environment.

7. Conclusions

1. The criteria for the estimation of climate control and power supply systems were determined: specific power consumption, specific water consumption, specific capital costs; specific operating costs. It was proposed to choose alternative climate control systems based on the Analytic Hierarchy Process method. Due to its use, it is possible to obtain a set of optimal variants for business plans for the purpose of innovative development of the energy sector.

2. The functional, designed to optimize the choice of a project solution of a climate control and power supply system, taking into account the interests of Alfa-stakeholders: a consumer, an investor, a service organization, was constructed This approach is based on minimizing the subjectivity factor in evaluation. This makes it possible to perform an in-depth assessment of the priority level of alternative projects with their further grading based on the results obtained.

3. The indicator of relative integrated energy efficiency of projects of a climate control and energy supply system, which allows outlining the ways of implementation of complex systems with disparate input and output characteristics, was proposed.

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CONSTRUCTING AND INVESTIGATING A MODEL OF THE ENERGY ENTROPY DYNAMICS OF ORGANIZATIONS

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Енергоентропія є «вищим» показником стану організації, розвиваючи ідеї ефективності та цінності. Інтегральність полягає в урахуванні рівня порядку в організації (інформаційної ентропії) разом із здатністю ефективно «вивільняти» енергію для корисної роботи. Універсальність забезпечується незалежністю від роду діяльності організації. Запропоновано формалізацію енергоентропії організацій. Відповідно до пропонованого підходу, енергоентропія визначається: приростом сумарної енергії і його співставленням з «ідеальним» варіантом; рівнем вільної енергії та інформаційної ентропією, яка відображає здатність структури організації забезпечувати певні результати. Основні параметри стану організації – вхідна та вихідна (вільна) енергія. Їх комбінація визначає приріст енергії, безліч можливих комбінацій – інформаційну ентропію. Ідентифікована схема зміни в часі основних «енергопараметрів» організації.

Представлені два основні варіанти динаміки приросту енергії, як підсумку комбінації вихідної і вхідної енергії, – рівномірне зростання і зростання з прискоренням (уповільненням). Проведені експериментальні дослідження, які полягали в розгляді формалізацій найбільш можливих варіантів динаміки впливаючих параметрів. Проаналізовано вплив різних комбінацій їх динамік (одночасне зростання/зниження, зростання/зниження з різною швидкістю) на динаміку енергоентропії. Встановлено, що збільшення частки вільної енергії не забезпечує відтік енергоентропії без зменшення ступеня невизначеності результатів, що виражається в зниженні інформаційної ентропії. Зроблено висновки щодо необхідної динаміки параметрів для забезпечення життєдіяльності організації згідно енергоентропійної концепції

Ключові слова: інформаційна ентропія, вільна енергія, ефективність енергообігу, структура організації, формування негентропии

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1. Introduction

From the point of view of system methodology, an organization is a system that exchanges energy, information, and substance with the environment, where the universal equivalent of any kind of resource – money – acts as energy. The existence of energy exchange determines the existence of the corresponding entropy, which in [1] was determined as the organization's energy entropy. The introduction of such a term was based on the need to clearly identify entropy, related to the energy exchange, as the organization is also characterized by the existence of information entropy. It should be noted that the term "organization" in this case implies generalization of orga-