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Enterprise energy supply system design management based on renewable energy sources

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ABSTRACT

BACKGROUND AND OBJECTIVES: The problem of energy saving and the transition to technologies that allow to partially or completely move away from the use of gas and other fossil fuels are a priority in Ukraine today. By consuming traditional energy sources using outdated technologies for energy supply of industrial facilities, Ukraine consumes 3-4 times more fuel per unit of Gross Domestic Product compared to developed countries. For industrial enterprises, the energy intensity of costs is 35-40% of the total cost. At the same time, obsolete fixed assets, especially its active part (the degree of physical wear and tear of industrial equipment is 60-65%), are characterized by a large share of energy and heat loss.

METHODS: Modeling, structural analysis, and theoretical research based on current advances in the theory and practice of creating energy-efficient buildings using energy from alternative sources.

FINDINGS: Calculations and structural analysis of costs by stages of the life cycle of the design solution of the hot water supply and heating system with energy-efficient fencing and heat pump have been made. Peculiarities of calculation of assessment and design solutions in accordance with the Ukrainian legislation have been determined. The study has been conducted in seven Ukrainian industrial enterprises in the energy sector.

CONCLUSION: It is determined that the structural analysis of costs by stages of the project life cycle on the basis of standard costing should be used at the stage of designing a new power system or upgrading an existing one through marketing research. All this will contribute to the formation of a fundamentally new approach to solving technical and economic problems of the introduction of modernized energy supply systems for industrial purpose.

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INTRODUCTION

The introduction of new engineering and design solutions in energy supply systems, which provide for the integrated use of energy from renewable sources (solar and geothermal energy, environmental heat, etc) will solve an important economic and scientific problem of reducing the consumption of traditional fuel and energy resources for Ukraine. The most important direction of these measures is the construction of buildings with minimal energy consumption, which will allow to achieve a high level of energy efficiency. An integrated approach to the design of energy supply systems that use renewable energy sources (RES) includes a number of factors. Among them are; 1) cost and time distribution of renewable energy sources; 2) realized technical potential of renewable energy sources corresponds to certain climatic zones; 3) technical and institutional problems and the cost of implementing various renewable energy technologies in energy systems and markets; 4) comprehensive assessment of socio-economic and environmental aspects of the introduction of renewable energy sources and other energy efficient technologies; 5) political, institutional, and financial mechanisms to ensure the cost-effective use of renewable energy sources in a variety of conditions. The presence of a set of these indicators is essential and allows to objectively choose the composition of the energy supply system that uses renewable energy sources (Dwijaksara *et al.,* 2019).

Existing solar heating and cooling technologies, which are used in residential and commercial buildings, are an established market. It is distributed differently in most countries of the world and continues to grow at a rate of about 16% per year (Choi *et al.,* 2018). In Europe, the corresponding market volume has more than tripled recently. Despite these achievements, the use of solar energy is relatively small in Europe in hot water and heat supply systems (Cai *et al.,* 2019). For example, in Germany, the share of solar energy use in small buildings in the above systems does not exceed 15% (Wang *et al.,* 2018). This market is dominated by vacuum collectors, which today are structurally and technologically advanced and suitable for mass production; important production sites of vacuum collectors are located in Europe, Turkey, Brazil, China, and India (Guo, Qiao and Liu 2019). A significant share of the export market is made up of integrated solar water heating systems, not solar collectors. The largest exporters of these systems are Australia, Greece, USA, and France (Rafiei and Ricardez-Sandoval 2020). Competition in this area is the increase in the energy efficiency of energy supply systems through the use of a passive component. Close co-operation between the two industries is not enough but the spread of systematic design methodologies used by different countries has improved design opportunities. For example, windows are an important part of passive heating of buildings, and the presence of new generation windows with high efficiency (low emissivity, argon filling) affects the growth of solar energy in meeting the heat supply needs in the construction sector (Tezel *et al.,* 2018). Another characteristic of passive design is the addition of internal mass to the structure of the building. New materials, which are often used for more efficient heat retention, are readily available, designed to accumulate heat materials that use the heat of phase transformations (eg, paraffin), and are considered materials of the future (Zhang *et al.,* 2018). Economic indicators of renewable energy use depend on the appropriate design of the innovative energy supply system in accordance with the needs for energy services. In some regions, such as southern China, solar water heating systems are competitive in cost with traditional systems (Sun *et al.,* 2018). Solar water heating systems are usually more competitive in regions with high levels of solar radiation but this situation is changing with regard to space heating, which is usually associated with a higher total heat load (Gao *et al.,* 2019). In colder regions, capital expenditures may be spread over a longer heating season, and solar thermal energy may become more competitive in this case (Marinakis and Doukas 2018). Investment costs for solar heating systems vary greatly depending on the complexity of the technology used, as well as market conditions in the country of operation. Costs for innovative water supply systems range from a low of 83 c.u./m^2 to 1.200 c.u./m^2 (for some space heating systems) (Panetto *et al.,* 2019). The normalized cost of heat reflects a wide range of investment costs and depends on a number of variables, including the specific type of system, investment costs for the system, solar radiation available in a specific place, efficiency of conversion of this system, operating costs, system strategies, and discount rate (Li *et al.,* 2020). The normalized cost of heat for solar thermal systems, taking into account a wide range of initial parameters, was calculated in a wide range of 9 to 200 c.u./GJ (Kot 2018). The normalized cost of heat is in the range from 30 c.u./GJ to 50 c.u./GJ in the regions of some areas of Central and Southern Europe and reaches almost 90 c.u./GJ in regions with less solar radiation (Pan *et al.,* 2020). Over the last decade, for every 50% of increase in the installed capacity of solar water heaters in Europe, investment costs have fallen by 20% (Drobyazko 2020). The tendency to reduce the cost of power supply systems is achieved through the use of cheaper materials, more efficient production processes, mass production and direct inclusion in the design of buildings collectors as multifunctional building components and modular systems that are easy to install (Al-Tarazi and Chang 2019). Reducing costs is a key issue in making direct solar energy more commercially viable and able to claim a larger share of the global energy market (Mafini and Loury-Okoumba 2018). Potential use depends on actual resources and the availability of appropriate technology. At the same time, the current regulatory framework can significantly promote or deter the spread of direct solar energy (Máša *et al.,* 2018). Minimum building standards for the orientation and insulation of buildings can significantly reduce the energy needs of buildings and increase the share of renewable energy supply without increasing overall demand (Sahu 2018). Transparent and streamlined administrative procedures related to the installation and connection of a solar energy source to existing grid infrastructures can also reduce the cost of direct solar energy. In many countries, the development of energy supply systems over the decades has made it possible to ensure efficient and cost-effective distribution of electricity, gas and heat, as well as the transportation of energy to provide useful energy services to end users (Drobyazko *et al.,* 2020). Enhanced integration can lead to a full range of energy services for large and small settlements in both developed and developing countries based on renewable energy sources (Wei *et al.,* 2019). Power supply systems are constantly evolving to increase the efficiency of renewable energy conversion technologies (Xiao *et al.,* 2018). For different countries, the increase in the use of RES technologies can help reorient foreign exchange flows from energy imports to imports of goods that cannot be produced locally such as high-tech industrial goods (Ma *et al.,* 2019). The use of integrated energy supply systems in buildings, which include heat pumps, heat accumulators, energy barriers, is the result of finding ways to the most economical means of energy conservation and recovery of energy flows of objects (Li *et al.,* 2019). The introduction of such systems contributes to the spread of technical support for energy production directly at the facility. These systems are able to partially or completely replace the energy generated by traditional energy sources. The lack of modern analytical support for cost management, adapted to the economic activity of the enterprise in operational and strategic aspects, which leads to unreasonable management decisions due to misunderstanding of the target cost mechanism, and as a result the revenue of the individual enterprise, is one of the main reasons for irrational management of operating costs of Ukrainian manufacturers (Lopes *et al.,* 2019). This actualizes the study of improving the cost analysis of operating activities of industrial enterprises in terms of formulating its objectives, identifying new objects of cost analysis of operating activities, modeling the system of factors and reserves to minimize costs in a competitive environment, expanding the information base analysis, analysis of operating costs. This is especially relevant during implementation control systems for the design of the enterprise's energy supply system on the basis of renewable energy sources – the theory of life cycle is one of the fundamental factors. There are phases of the life cycle (pre-production costs, production costs, after production costs), at each stage there is a change in costs (deviation from the actual value). It is necessary to choose an adapted method of determining costs at each stage by designing the energy supply system of the enterprise. The purpose of this study is to scientifically substantiate theoretical approaches and improve methodical support for economic cost analysis in the design of energy supply systems taking into account different concepts of product costing and strategic cost control. This study was conducted for the period 2017-2019 in Central Ukraine (in three regions - Kirovograd, Dnepropetrovsk, Zaporozhye) at seven industrial enterprises.

MATERIALS AND METHODS

Description of the empirical basis of the study

When calculating the proposed design solution of the energy supply system of enterprises, the data of Ukrainian enterprises were used: Dniprenergotechnologiya LLC; PCF Velta LLC; RPE Ecoenergo-ORGCHIM LLC; Ukrtorgtara LLC; Promelectropostach LLC; Plant-firm OS LLC; RPA RAKURS LLC. It should be noted that all 7 industrial enterprises belong to the sector of equipment production in the energy industry, therefore, the energy intensity of costs is 35-40% of the total cost. At the same time, old fixed assets, especially its active part (the degree of physical wear and tear of industrial equipment is 60-65%), are characterized by a large share of energy and heat loss.

These enterprises are located in Central Ukraine in three regions: Dnepropetrovsk, Kirovograd, Zaporozhiye. They have the same climatic conditions, so natural factors favor the use of solar energy as an alternative source of energy. This study presents the selected design solution of the power supply system at these enterprises, the calculations performed and the implementation of the project. During 2017-2019, this design solution was implemented at these enterprises, and during the production stage of the life cycle, it was necessary to adjust the costs in accordance with the real conditions of the activity of the enterprises.

Formation of research hypotheses

The research proceed from certain concepts, which are based on modeling, structural analysis, and theoretical research, which rely on modern achievements in the field of theory and practice of creating energy-efficient buildings that use energy alternative sources. The underlying hypothesis (H0) is the hypothesis that the management of alternative energy sources in the activity of enterprises leads to a synergistic effect, consisting of three effects - economic (H1), environmental (H2), and social (H3). When evaluating the efficiency while selecting among alternative projects, it is necessary to take into account not only the economic effect (as the achievement of the highest results by the production enterprise at the lowest cost of living and ngible labor or the reduction of total costs per unit) but the social and environmental one. At the same time, it is necessary to assess this efficiency from the position of the appearance: internal and external. In this study, the authors focused on the economic effect at the lowest cost based on following statements:

H1.1 - depends on the life cycle of the project. When implementing energy saving projects, the business entity is faced with the need to choose from the available limited alternative resources: cash, labor, material, etc. Decisions on the implementation of energy saving projects are made by the company's management, which increases the subjectivity of this decision for many reasons, such as: mentality, professional experience, judgment, etc. To reduce the subjectivity of the calculation of profit growth through the implementation of the project, it is necessary to turn to the methods of evaluating projects in the field of social diagnostics.

H1.2 - depends on the chosen method of assessment and calculation, taking into account the calculation of the budget for the implementation of projects, the cost of deferred decisions. The cost of deferred decisions allows to identify alternative scenarios 'with a project - without a project.' The implementation of energy saving projects (programs) affects the market value of the enterprise, is a key factor, the dominant factor of competitiveness, economic and energy security, etc. It is necessary to dwell on this in more detail.

Description of the main calculation method

A set of scientific methods was used to accomplish the tasks and achieve the purpose of the work: methods of scientific generalization, comparison, grouping and system analysis (to determine the nature of costs, mechanisms of their creation and behavior, to develop a classification of operating costs, to study conceptual approaches to the management of operating costs); methods of analysis and synthesis (to develop a technology for enterprise operating costs analysis); economic-mathematical methods, tabular techniques (when conducting experimental procedures for analysis of production costs using different systems of product costing, analysis of operating costs using strategic cost control systems, and when determining their impact on making decisions regarding the efficiency of an enterprise. When using the 'standard costing' calculation, the cost of a particular product is influenced by the following factors: production volume, direct material costs, direct labor costs; other direct costs, variable production overheads and fixed allocated production overheads. In our view, a factor model for the analysis of the cost of a separate type of product (*P*) based on the use of information found out using the 'standard costing' system, using Eq. 1.

$$P = Q \times (C_1 + C_2 + C_3 + C_4 + C_5) \quad (1)$$

Where, *Q* – the number of products manufactured, C_1 – the direct material costs per product, C_2 – the direct labor costs per product, C_3 – the other direct costs per product, C_4 – the variable production overheads per product; C_5 – the fixed allocated production overheads per product.

Based on the research results of foreign scientists and the experience of developing the concept of intelligent energy systems, it can be noted that the process of creating an intelligent energy system in developing countries should be considered as a complex of interrelated tasks of political, economic, environmental and social nature (Wu *et al.,* 2019). As of today, society and economic sectors are interested in implementing research results related to the development of innovative design solutions for an integrated energy supply system including a heat pump, energy-active enclosures, a seasonal soil heat accumulator and using alternative energy sources such as energy of solar radiation, heat of soil and air, incl. ventilation air (Huang *et al.,* 2019). The proposed organizational-methodical stages (technology and tools) of the complex analysis of the enterprise operating costs provide the achievement of the management and strategic goals of a modern strategically oriented industrial enterprise (Table 1).

There were also singled out factors of influence on the cost of a separate type of production when using direct costing calculation, such as: direct costs and variable (general) production overheads. This

Table 1: Organizational-methodical stages (technological map and methodical tools) of the complex analysis of the enterprise operating costs

Technology of analytical research	Methodical tools for analysis of operating costs	Level of making management decisions
	Traditional approach to the analysis of operating costs	
Stage 1	Analysis of the total cost of products sold: - estimation of validity of the planned level of cost of finished goods (by norms, prices for materials); - analysis of production budget execution; - analysis of costs by economic elements - analysis of costs by items of calculation and changes in left-over stock of finished products in storage; - analysis of costs for 1 dollars USA of products sold; - cost analysis of separate types of products	Accountants, economists, cost engineers, technologists
	Operational analysis of production costs	
Stage 2	Cost analysis of a separate type of production by composition of groups: - in the standard-costing or the standard method; - in direct costing; - in absorption costing	Mid-level management – heads of subdivisions, leading specialists
Stage 3	Cost analysis of a unit of production by product functions and processes: - cost analysis using the Kaisen costing process; - analysis of costs using the target costing process; - process analysis of general expenses of production (AB costing)	Mid-level management – heads of subdivisions, leading specialists
	Strategic analysis of operating costs	
Stage 4	Analysis of costs by value chain; - analysis of costs by life cycle of operations; - competitive and comparative analysis by the method of benchmarking; - analysis of costs for quality assurance	Top level management (top management)

allows to define a new object of analysis – the cost of production at variable costs, which enables the analysis of marginal profitability for a separate type of production, and making management decisions on the issues of assortment and the development of an assortment policy (Rafiei and Ricardez-Sandoval 2020). In the process of study, it has been found out that the methods of accounting production costs and calculating the historical cost of production sold did not take into account the limitation of the price offer of competitors, which reduces the amount of planned profit, and the marginal utility (consumer value) of the product for buyers (Marinakis and Doukas 2018). The search for reserves to reduce operating costs can be carried out based on identifying sources of competitive advantages in the value chain. To identify the sources of competitive advantage, it is necessary to analyze the nine interrelated business activities that form a value chain in strategic management (Yuyin and Jinxi 2018): five main (inbound logistics, manufacturing, outbound logistics, marketing and sales, after sales) and four auxiliary (enterprise infrastructure, personnel management, technological development, logistics). Strategic analysis of operating costs by the value chain is carried out using a comparative analysis of the value chain of the enterprise with direct competitors and in the branch of operation (Variny *et al.,* 2019). Taking into account the division of operating costs for quality assurance into two large groups; 1) costs related to achieving product quality compliance, or preventative costs that characterize attempts to ensure and guarantee an adequate level of product quality (Choi *et al.,* 2018); 2) costs of product quality compliance, or costs for elimination of defects related to product quality restoration, it is proposed to carry out a structural analysis of costs for quality assurance of operating activity, which allows to allocate them across responsibility centers and provides greater control over costs for quality assurance and search for reserves for their minimization at all stages of the operating activity of the enterprise (*Wang et al.,* 2018). When using the method of absolute differences, the pattern of calculating the effect of the deviations of the listed factors on the change in production cost of products is illustrated as follows (Table 2).

The proposed factor model of cost analysis of a particular type of product on the basis of 'standard-costing' calculation provides the identification of the centers that allowed the greatest deviation of direct production costs from the set standards and gives essential information for making management decisions in the area of direct cost standards planning in preparation of production cost budgets for separate types of products. Using the 'absorption costing' system can confirm the influence of the following factors on the cost of a particular type of production: direct costs, fixed allocated (general) production overheads, and fixed unallocated (general) production overheads. Since unallocated fixed (general) production overheads are not attributed to period costs but are included in

Table 2: Pattern of calculating the effect of the deviations of the listed factors on the change in production cost of products when using the 'standard costing' system

Item No.	Effect of the deviations of the listed factors on the change in production cost of products	Equation
1	Effect of deviation (change) in scope of activity	$dP_Q = dQ \times (C_1^{s\tan} + C_2^{s\tan} + C_3^{s\tan} + C_4^{s\tan} + C_5^{s\tan})$
2	Effect of deviation in standards of direct material costs per product	$dP_{C_1} = Q^{fact} \times dC_1$
3	Effect of deviation in standards of direct labor costs per product	$dP_{C_2} = Q^{fact} \times dC_2$
4	Effect of deviation in standards of other direct costs per product	$dP_{C_3} = Q^{fact} \times dC_3$
5	Effect of deviation in standards of variable production overheads per product	$dP_{C_4} = Q^{fact} \times dC_4$
6	Effect of deviation in standards of fixed allocated production overheads per product	$dP_{C_5} = Q^{fact} \times dC_5$
Total amount of change in the cost of production must be equal to the amount of all types of deviations		$dP = dP_Q + dP_{C_1} + dP_{C_2} + dP_{C_3} + dP_{C_4} + dP_{C_5}$

the cost of production by types of production when using the concept of 'absorption costing' calculation, full cost of production is becoming the object of analysis, the relevant information on which enables the analysis of price elasticity of customer demand and the analysis of price offers of competitors in conditions of fluctuations in demand for a particular type of production and ensures making management decisions in the area of pricing and development of a pricing policy regarding the assortment positions. Using 'direct costing' calculation allows to distinguish the factors influencing the cost of production of a particular type of production, such as: direct costs and variable (general) production overheads. This allows to define a new object of analysis – the cost of production at variable costs, which enables the analysis of marginal profitability for separate products, and making management decisions on the issues of assortment and the development of an assortment policy. The peculiarity of using traditional methods of calculation in the management accounting of Ukrainian enterprises is the peculiarities of the national legislative framework. Firstly, the instructions for industrial enterprises in determining the cost of work, services, and products are very outdated, originating with the Soviet method. Outdated standards, lack of the concept of 'life cycle' of both the enterprise itself and works, services and products, taking into account market factors, inflationary processes. Secondly, accounting legislation in Ukraine, including parts of management accounting, calculation, has only declaratively harmonized standards in this area for 21 years. At the same time, the system of integration of accounting information in the management system of the enterprise has not yet been determined. Therefore, in this study, the methods for determining the value are brought to the harmonization of Ukrainian legislation (first of all, the concepts of 'liquidation value', 'residual value') in the conditions of real industrial enterprises, where the methods of valuation and calculation are in accordance with Soviet standards of the 1970s. This dissonance in the methods leads to many problems, according to the top management of the surveyed enterprises, the main one is the impossibility of entering foreign markets. At the same time, it is the asymmetry of information in the entire management system that acts as an internal factor, first of all, the discrepancy between the methods of assessment and calculation as the primary link of the entire system.

RESULTS AND DISCUSSION

Currently, the problems of energy conservation, efficient use of energy resources are very relevant for many reasons. First, it is the constant rise in prices for traditional energy and the reduction of their reserves on Earth. Secondly, it is a significant environmental burden on the environment when using traditional energy sources. In addition, when using traditional energy sources in various areas of the economy, where thermal energy is consumed, there are significant costs for the maintenance of pipeline heat distribution systems. District heating systems are branched, reversible type, with unstable modes of operation, ie those where the heat load changes significantly during the heating period and during the day. With a long service life, they are crucial in terms of assessing the effectiveness of the heating system itself. Therefore, in Ukraine and around the world, to provide consumers with electricity and heat, their combined generation when using energy from alternative sources becomes popular. The introduction of these energy generation technologies will solve the problem of inefficient use of energy by consumers because it leads to an extremely high level of specific energy consumption in the country.

The efficiency of the energy supply system in terms of economical energy use requires simultaneous resolution of issues: 1) selection of appropriate design solutions for a complex system of energy supply and air conditioning (heating, air conditioning, ventilation, and hot water supply) depending on the purpose of the building; 2) determining the impact of the components of the energy supply system on the level of energy efficiency of buildings; 3) selection of a simple and effective method of technical and economic assessment of the efficiency of operation of a complex system of energy supply and air conditioning.

When designing energy supply systems, the main goal is to minimize the total investment in their construction under conditions of high efficiency. That is, it is necessary to consider the following: 1) compliance with system efficiency and rational use of energy resources; 2) increase of energy efficiency. Such a comprehensive approach is possible provided that a systematic analysis and development of a methodology for building energy-efficient energy supply systems and air conditioning of buildings with energy-efficient fencing and the use of energy from alternative sources. To do this, it is necessary to assess the effectiveness of the selected options for the implementation of energy supply systems from the standpoint of the consumer, developer, and the state. Therefore, it is advisable to consider the design solutions and methods of calculating a comprehensive system of energy supply and air conditioning, taking into account construction and installation costs.

There are many options for power supply schemes. Examples are as:

a) traditional implementation of energy supply systems: Heating and hot water supply, centralized from the district heating network (Wu *et al.,* 2019); Heating and hot water supply from the roof boiler room, etc (Ünal *et al.*, 2019);

b) use of alternative energy sources: Scheme with heat pump with one heating circuit with mixer, "natural cooling" function, energy-active fencing for hot water preparation and buffer capacity of the heating circuit (Ashraf *et al.*, 2020); design solution with two heating circuits with mixer, "natural cooling" function, hot water supply function by means of energy-active barriers and buffer capacity of the heating circuit (Epoh and Mafini 2018); Design solution, which provides for the presence of two heating circuits with a mixer and a buffer tank of the heating circuit, energy-efficient fencing, which is used for hot water supply and "natural cooling" air conditioning system (Giama and Papadopoulos 2018); Design solution, which includes one heating circuit without mixer, air conditioning, and hot water preparation function (Hong *et al.,* 2018).

The choice of the optimal variant of the design solution of the power supply system is possible due to the system analysis. The basis of this method is to compare the efficiency of options for power supply systems from three positions: 1) consumer: When considering the options of energy supply systems from the consumer's point of view, the selected options for the implementation of energy supply systems should provide minimal operating costs, provided that sufficient comfortable conditions are created; 2) state: From the standpoint of the state, engineering systems must ensure minimum integrated consumption of all types of energy resources; 3) service organization. From this point of view, engineering systems must provide the greatest profit, which inversely depends on the capital costs of construction of these engineering systems with the necessary energy supply. In te current study, the choice was made by users - Dniprenergotechnologiya LLC; PCF Velta LLC; RPE Ecoenergo-ORGCHIM LLC; Ukrtorgtara LLC; Promelectropostach LLC; Plant-firm OS LLC; RPA RAKURS LLC. Top management chose 'minimum operating costs' as the main priority criterion. The amount of operating costs, in accordance with Ukrainian legislation and internal regulations and standards, consists of: salaries of service personnel, depreciation, maintenance costs, costs of auxiliary materials, other operating costs. The lowest operating costs are the Design solution of the hot water supply and heating system with energy-efficient fencing and heat pump. The use of one heating circuit and hot water supply when using an energy-efficient fencing is one of the options. This variant of the design solution is presented in Fig. 1.

For efficient operation of the given scheme of hot water supply, it is necessary to use the heat pump with the built-in water heater (BWH), the distributing comb with a heating circuit without the mixer. BWH is structurally a large-capacity tank, which houses the heat exchangers of the heat pump and the electric heater. The minimum flow rate of the heat pump 4 through the bypass valve is provided by the built-in secondary pump. In these heating systems, the bypass valve is connected to the distribution floor of the underfloor heating system. This allows to ensure the required minimum water flow in the heating circuit. To heat premises by means of a heat pump, the primary circuit is activated when the actual temperature (measured by the temperature sensor of the return line of the secondary circuit) is below the set value (adjustable controller), the heat pump 4 and the built-in primary pump 3 are switched on. The secondary circuit is involved when the heat pump 4 supplies heat to the heating circuit. The controller of the heat pump 4 regulates the supply temperature of the coolant, which, in turn, helps to regulate the parameters of the heating circuit. The built-in secondary pump supplies the heat carrier through the three-way switching valve to a heating circuit or to the built-in BWH. The flow in the heating circuit is regulated by opening and closing the valves on the distribution comb of the 'warm floor' system. If the actual temperature on the return line temperature sensor exceeds the set value set on the controller, the

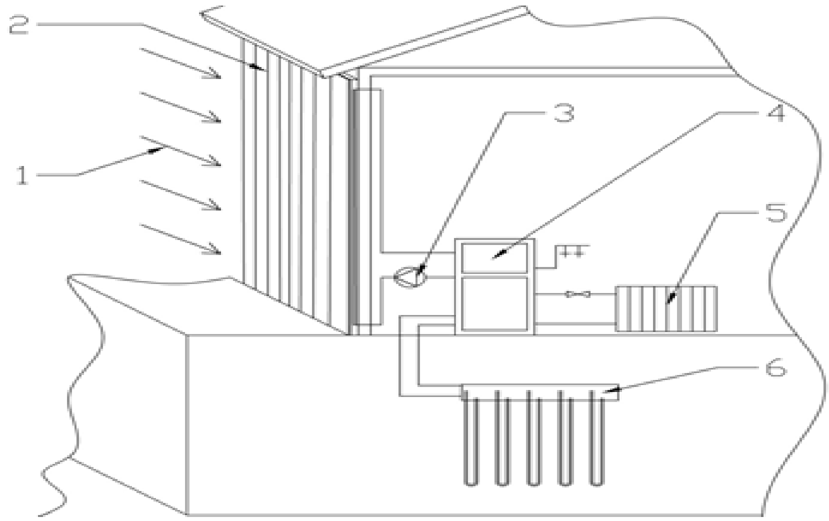

Fig. 1: Design solution of a hot water supply and heating system with an energy-efficient fencing and a heat pump (1: Solar radiation; 2: Energy-efficient fencing; 3: pump; 4: Heat pump; 5: Heating battery; 6: Ground heat exchanger)

heat pump 4 and the secondary pump are switched off. The request for hot water preparation comes from the built-in BWH temperature sensor and the controller that controls the built-in secondary pump in conjunction with the built-in three-way switching valve or the water heater filling pump. The water temperature rises due to the presence of the controller to a value that is necessary for the consumer. If the actual value on the temperature sensor of the capacitive water heater exceeds the set one on the controller, the controller will switch the supply of coolant to the heating circuit via the 'heating/ hot water' three-way valve. The water temperature can exceed 60 ^{O}C due to the use of a built-in instantaneous heater for the coolant. The use of such a design solution is good to provide the consumer with hot water. In this mode of operation, the main elements are energy-efficient fencing, which can be located on the walls and roof of the house. BWH heating by means of energy-protective fencing is performed when the temperature difference between the temperature sensor of the energy-active fencing circuit and the built-in BWH temperature sensor exceeds the temperature difference that is set on the controller. To do this, the heat pump controller controls the pump of the energy barrier circuit. If the temperature drops below the temperature difference, the controller will switch off the energy barrier circuit again. Taking management decisions on the implementation of the project of the energy supply system of enterprises requires a structural analysis of costs by stages of the product life cycle. Based on the results of this analysis, information is formed on the comparability of costs recognized at the production stage of the product life cycle of the assortment item and other operating costs recognized at the pre-production, non-production, and post-production stages of the energy saving project life cycle. The structural analysis of expenses on stages of a life cycle of the circuit solution of hot water supply and heating system with an energy-active protection and the heat pump is carried out (Table 3).

It is necessary to determine that the planned period of implementation of the design solution of the hot water supply and heating system with energy-efficient fencing and heat pump in Table 3 is defined as 5 years. This is due to the peculiarity of Ukrainian tax legislation - a group of 5 fixed assets has a minimum service life of 5 years. In reality, with the corresponding operating costs, the term is much longer. It is 10-15 years (according to the technical documentation). In order to be able to identify changes in cost, the following valuation tools must be used. Adaptability of the proposed method of factor analysis of deviations from the standards of production costs of operating activity of the enterprise

Table 3: Structural cost analysis by stages of the life cycle of the design solution of the hot water supply and heating system with energy-efficient fencing and heat pump

No	Name of the indicator	Amount, USD	Total amount of costs, %
1	Production planned per month, sq. m	9600	X
2	Production planned per year, sq. m	75 600	X
3	PRE-PRODUCTION COSTS TOTAL pre-production costs, USD	310635	15
4	PRODUCTION COSTS Direct costs of materials and components for 1 product, USD	8.32	
5	Direct costs of piecework wages for 1 product, USD	3.57	
6	Direct production costs of the annual program, USD	898770.6	X
7	Indirect production costs of 1 item, USD	5.10	
8	Indirect production costs of the annual program, USD	385187.4	
9	Planned production period, years	5	
10	TOTAL production costs, USD [(line 6+line 8) x3 years]	1283958	62
11	NON-PRODUCTION COSTS Administrative costs in the reporting period, USD	41418	X
12	Planned period of business continuity, years	5	
13	TOTAL administrative costs, USD (line 12x3 years)	207090	10
14	Sales costs (commercial) for the annual production program, USD	33134.4	X
15	Planned implementation period, years	5	
16	TOTAL sales costs (commercial), USD (line 16x3 years)	165672	8
17	POST-PRODUCTION COSTS Utilization of technological equipment for scrap metal	103545	X
18	TOTAL post-production costs	103545	5
19	Total life cycle costs (USD)	2070900.00	100

Table 4: Input data for calculation of deviations from standards using standard costing calculation system

Designation	Indicator	Standard	Fact	Absolute deviation
P	Manufacturing cost of production, USD	2070900.00	2219950.00	149050.0
C_1	Quantity of products manufactured	30000.00	29.000.00	-1000
C_2	Direct material costs per product, USD	50.02	55.60	+5.58
C_3	Direct labor costs per product, USD	7.86	9.25	+1.39
C_4	Other direct costs per product, USD	3.00	3.16	+0.16
C_5	Variable general production costs per product, USD	4.15	4.54	+0.39
C_6	Fixed allocated general production costs per product, USD	4.0	4.0	0

on the basis of information found out using standard costing calculation system will be demonstrated with the help of Table 4, which contains the input data for calculation of deviations, as well as Table 5, which illustrates the results of factor analysis.

Absorption costing calculation confirms the influence of several other factors on the manufacturing cost of a separate type of production, namely: direct costs, fixed allocated general production costs, and fixed unallocated general production costs. Since unallocated fixed general production costs are not attributed to period costs but are included in the manufacturing cost by types of production when using the concept of 'absorption costing' calculation, the full manufacturing cost is becoming the object of analysis, the relevant information on which enables the analysis of price elasticity of customer demand and the analysis of price offers of competitors in conditions of fluctuations in demand for a particular type of production and ensures

Table 5: The results of factor analysis of changes in manufacturing cost and the effect of deviations from standards based on the use of information found out using standard costing calculation system

Designation	Indicator	Amount (USD)
dP_{C1}	effect of volume changes	-69030.00
dP_{C2}	effect of changes in the standards of direct material costs	161820.00
dP_{C3}	effect of changes in the standards of direct labor costs	40310.00
dP_{C4}	effect of changes in the standards of other direct costs	4640.00
dP_{C5}	effect of changes in the standards of variable general production costs	11310.00
dP_{C6}	effect of changes in the standards of fixed allocated general production costs	0
dP	the total amount of change in manufacturing cost	149050.00

making management decisions in the area of pricing and development of a pricing policy regarding the assortment positions. Also, there were singled out factors of influence on the manufacturing cost of a separate type of production when using direct costing calculation, such as: direct costs and variable general production costs. This allowed to define a new object of analysis - the cost of production at variable costs, which enables the analysis of marginal profitability for separate products, and making management decisions on the issues of assortment and the development of an assortment policy. In the process of research it has been found out that the methods of accounting production costs and calculating the historical cost of production sold did not take into account the limitation of the price offer of competitors, which reduces the amount of planned profit, and the marginal utility (consumer value) of the product for buyers.

CONCLUSION

The selection of projects of energy supply system of enterprises is made on the basis of renewable energy sources with the task of maximizing the economic effect, which takes into account both economic components (project life costs, project budget, cost of deferred decisions) and social and environmental effects. The method for structural cost analysis by stages of the project life cycle on the basis of standard costing, which should be used at the stage of designing a new power system or upgrading an existing one through marketing research, is stated. Product life cycle cost extends the boundaries of traditional cost management approaches by accounting for the cost of a product's lifetime to determine the target profit. At the same time, using the concept of LCC (life cycle cost) in management accounting allows to improve the methodology of internal audit of operating costs. All this allows to create a mechanism for consistent and purposeful management of the process of creating the target value of the product. According to the authors, the limitation of the proposed study is based on the principle of Ceteris paribus. This means that the economic interests of alpha stakeholders in the implementation of alternative projects for indoor climate systems are necessary. Alpha stakeholders form their requirements in accordance with the goals and motivations and influence the project based on their interests, professional competencies, and the degree of involvement in its implementation. In order to eliminate possible shortcomings and violations of the balance of interests, competencies and the degree of involvement of project agents, it is important to note some recommendations for its implementation: 1) The built alternative allows to make decisions on reducing the use of natural gas. This is possible due to: the introduction of the latest energy-saving technologies used to reduce energy intensity of production and increase the competitiveness of products; carrying out engineering and technical, scientifically implemented measures; 2) Under modern conditions of world economic development, industrial enterprises implement the optimal strategy based on energy saving and consider energy efficiency as an important component of innovative industrial development. 3) The volume and scope of renewable energy sources, which will partially replace natural gas, are increasing. Further research can be focused on: the possibility of combining these accounting cost models, as each of them focuses on solving the problem of optimal cost and performance management, development of post-production cost accounting model (waste management and process equipment).

AUTHOR CONTRIBUTIONS

S. Drobyazko developed the whole concept and led the study. M. Skrypnyk made a detailed content analysis of scientific research. N. Radionova has collected and analyzed empirical data. O. Hryhorevska formed the results of the study in graphical form. M. Matiukha focused on structuring the manuscript.

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CONFLICT OF INTEREST

The authors declare no potential conflict of interest regarding the publication of this work. In addition, ethical issues including plagiarism, informed consent, misconduct, data fabrication and, or falsification, double publication and, or submission, and redundancy have been completely witnessed by the authors.

ABBREVIATIONS

dP_Q	Effect of deviation (change) in the scope of activity
dP_{C_1}	Effect of deviation in standards of direct material costs per product
dP_{C_2}	Effect of deviation in standards of direct labor costs per product
dP_{C_3}	Effect of deviation in standards of other direct costs per product
dP_{C_4}	Effect of deviation in standards of variable production overheads per product
dP_{C_5}	Effect of deviation in standards of fixed allocated production overheads per product
dP	Total amount of change in the cost of production must be equal to the amount of all types of deviations
%	percent
BWH	built-in water heater
c.u./GJ	conventional units of fuel per kilojoule
c.u./m²	conventional units of fuel per square meter
C1	The direct material costs per product
C2	The direct labor costs per product
C3	The other direct costs per product
C4	The variable production overheads per product
C5	The fixed allocated production overheads per product
Eq	equation
et.al	others
etc.	Et cetera
Fact	Actual value of the indicator
Fig.	Figure
GDP	gross domestic product
H	hypothesis
i.e.,	in other words
LCC	Life-cycle costing
LCC	Limited Liability Company
P	Cost of a separate type of product
PCF	Production and commercial firm
PRA	Production and research association
PRE	Production and research enterprise
Q	The number of products manufactured
RES	Renewable energy sources
sq. m	square meters
Stand	The standard value of the indicator
USA	United States of America
USD	US dollar
°C	degrees Celsius

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