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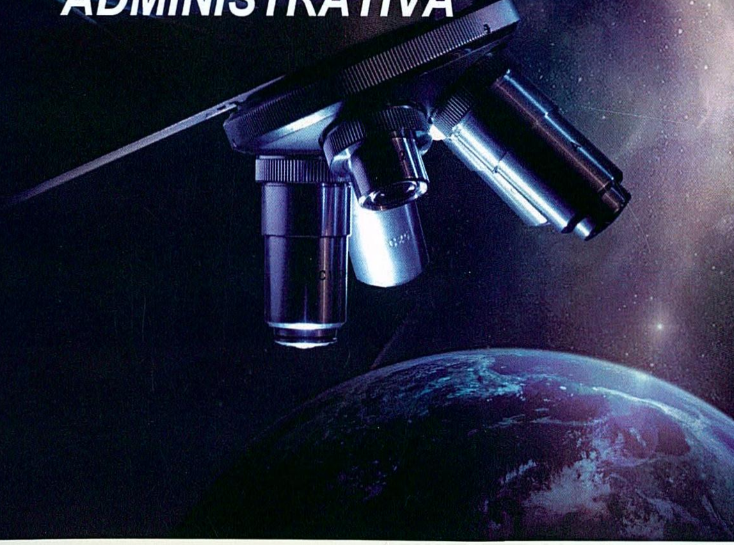

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LIFE – CYCLE OF ENERGY PRODUCT WITHIN THE CONTEXT OF ENERGY EQUIPMENT SERVICE PERIOD

In this paper the notion of "life-cycle of energy product" is researched and its stages are defined. The possible types of life-cycles for energy products are presented. Differences in terms of life-cycle of equipment, energy market life-cycle and the service period of equipment are determined. A formula for calculating the annual economic effect of energy equipment operation is suggested, taking into account the environmental factors.

Descriptive information: energy product, life-cycle, economic effect, service period, environmental correction.

INTRODUCTION

A lot of scholars worked on the conceptual definition of "life-cycle" and suggested their explanations, but the main point still remains the same – the existence of good or product is relative to time. The life-cycle of the product is a notion which displays the process of product development, its selling, acquisition of income, competitors' behavior, development of strategic marketing from the moment of initiation of the idea of product introduction till the time of its putting out from the market. The notion comes out of the fact that any product can be ousted from the market by more advanced or cheaper one. The differences between the life-cycles of different products are in their stages.

In economics there are two notions of life-cycle: product life cycle and lifespan of goods. The *product life cycle* is the period from the initiation of the new idea, its practical implementation into new products to the obsolescence of these products, their phasing out and significant decline of their practical use. *Lifespan of goods* is the period when the product is viable, it turns over at the market, is being used and brings the incomes to the producers and sellers. The differences between life-cycles are in the periods of the products existence and in life- cycle stages. The stages of product cycles are mentioned in the table.

Table 1 The stages of product life cycle and lifespan of goods, [1]

Stage of the Life Cycle	Product life cycle	Lifespan of goods
1	Initiation of the idea to introduce new product at the market	Product supply into the heavy selling
2	Researches and developments, experimental verification of the possibility of implementation the idea	Increase of selling the products as the result of demand growth
3	Appearance of the product at the market, shaping of demand (growth)	Period of maturity when the maximum selling volume is achieved
4	Large production of new products (maturity)	Saturation of the market with this product, reduction of demand and selling
5	Saturation of the market	Great drop of selling volume, incomes reduction
6	Selling decline and oust of the product from the market	

Based on the mentioned above material we can determine that product life-cycle and lifespan of goods have similar stages of existence despite of their names: introductory stage, growth stage, maturity and decline stages. At generally accepted bell-shaped graph of the product demand and time slot these stages of the life-cycle are clearly seen. But according to the experimental studies it was found that the life- cycle does not always correspond to this curve. In 1976 the scientists Rink and Swan proved that there are the products with life-cycle that has a deviation from the idealized curve. This occurs because some products pass the phase of entering into the market and immediately enter the phase of growth, the others don't reach the growth phase and goes into decline phase, the third ones slip out from the stage of decline and return to the dynamics.

THE OBJECT AND TASKS OF THE PAPER

The object of the paper is to investigate the notion of energy product life-cycle and to understand how it differs from life-cycle of energy market. To develop a formula for calculating the annual economic effect of energy equipment operation, taking into account the environmental factors.

To achieve this object it is necessary to solve the following tasks:

1) to explore the notion of life-cycle of energy product;

2) to determine the differences between energy product life-cycle and life-cycle of the market of energy product;

3) to propose a formula for calculating the annual economic effect of energy equipment operation taking into account environmental factors.

THE RESULTS OF RESEARCH

In modern marketing there are different types of life-cycles: "boom time", "delight", "nostalgia", "seasonal curve", and "scalloped curve" which depend on the specifics of certain products. Each of these can be presented for life-cycle of the energy product.

"Boom time" is a type of life-cycle which is characterized by rapid growth at the market and heavy selling over a long period of time. This type of life-cycle can be used for energy product as the electric energy can't be ousted from the market by competing products and thus it remains popular.

"Delight" is a type of life-cycle that is characterized by rapid demand for the product and the same quick decline. The energy product with the appearance on the market had extremely high demand. Due to the absence of product analogs its popularity is growing.

"Nostalgia" is a type of life-cycle which is characterized by rapid demand for the product, and the same quick decline, but then comes a slight revival on this product.

"The seasonal curve" is a type of life-cycle which describes the sale of products in accordance with the seasons or fashion. This type of life-cycle can be partially pertained to the energy product because electric energy has uneven daily electric network voltage. So, this graph can describe the life-cycle of the daily electric energy consumption. The rush hours are the following: from 8.00 to 11.00 in the morning and from 8.00 to 10.00 in the evening.

"Scalloped curve" is a type of life-cycle which characterizes the possibility of using marketing methods for continuation of life-cycle. This type is an analog of life-cycle of market Lamber product, so it can be used to describe the market of energy product.

Since electric energy is provided by energy resources, its life-cycle begins with the notion of electric energy and possible ways to get it, and thus it begins with a life-cycle of the product (energy resource). That's why the above-mentioned stages of the product life-cycle concern also the energy product when it enters the market and its demand increases with new technologies and equipment. Later when energy-saving technologies appear, the demand decreases, but still there are large volumes of electric energy consumption. As an energy product is non-competitive, its decline stage doesn't exist. That's why a permanent life-cycle without a decline stage is a life-cycle of the energy market. And the mentioned life-cycle is a life-cycle of the unit of an energy product, 1 kWh, 1 GWh, 1 TWh.

A life-cycle of the energy product unit should start with scientific and technical projection of energy equipment, which allows determination of the perspective directions, development of electroenergetics and estimation of scientific, technical and productive potentials. Here the degree, showing how economic environment is ready to implement various directions of scientific and technical progress, is determined. Also scientific and technical projection includes the cyclic development theory, which studies regularity of equipment generations changes and allows determination of innovation frequency or duration of economic adaptation [2].

As a rule, a life-cycle of the product begins with the idea of the final product as goods. Here an energy product is also unique because the idea of electric energy appeared in times of industrial revolution and transition from handwork to machining – the idea to automate work and to find power for operation of the machinery. At that time the first steam engines, where steam was an energy resource, were designed. Steam engines were changed by universal heat engines. The first heat engine was invented by Russian heat technician I.I. Polzunov in 1760s.

The main reason of transition from one stage of electroenergetics to the other was a lack of electric energy to meet consumption needs. That's why more powerful electric stations for improved permanent energy supply must be built. And only now humanity begins to think over harmful industry for the environment, to evaluate this harm in money. In 1950s technologies were changed because of increasing industrial capacity. Nowadays stations of the same capacities but with minimum environmental influence are built. Previously enterprises had capital and current expenses, now these expenses should also include ecological preventive and compensatory losses.

Heat machines were changed by heat electric station, heat and power plants, then nuclear power stations, hydroelectric stations, wind and solar electric stations. A life-cycle of the energy product can be called endless, the process of its production changes. Lumber called this life-cycle model as "an analysis of product market life-cycle", because not the product, but the technology of its production changes. This level of analysis is the most accurate to show consumers' behavior towards the product, and to demonstrate an evolution of the energy product, along with energy market, to which this product belongs. Every product market corresponds to its life-cycle: a life-cycle of the energy product is determined by the production technology, and a life-cycle of the energy market is determined by global demand, fig. [3].

A life-cycle of the energy product is the closest to Lumber theory when speaking about its infinity. It's wrong to say that a life-cycle of the energy product unit begins with researches of its production. Taking into account uniqueness of the product and its life-cycle, the stages should be determined.

According to the above-mentioned facts, a life-cycle of the energy product unit is the time from the moment when energy products are being produced and transformed into electric energy till their consumption and possible ways of utilization.

Then stages of the life-cycle of energy product unit partially coincide with stages of the product life-cycle and goods life-cycle. But still stages of a new life-cycle for the energy product should be determined:

1. scientific and technical projection of energy equipment;
2. generating of the idea how to search and produce an energy resource, implementation of the idea in research;
3. production of energy resource (coal, gas, turf, uranium…);
4. processing of energy resource to the condition when production of energy product becomes possible;
5. production of electric energy;

6. appearance of various wastes;
7. utilization of the product wastes at different stages of a life cycle;
8. distribution of electric energy;
9. consumption of electric energy;
10.utilization of electric energy.

It is known that the main assets remain one of the most important factors of economic growth, which is always the basic goal of any business activity due to the financial position of the company depends on the condition of the assets. As a result of this, the primary problem in economic policy of the most of countries is their reconstruction on a new technological level, and the task of modernization is considered not only as purely economic, but also as a social and economic that is why it becomes the object of national economic and sectoral management [2].

Almost all Ukrainian electric power stations were constructed at the begging of the XX century (Darnytsia TPS in 1936, Sumy TPS – 1957) and they still "successfully" operate. But should the equipment of electrical power station be in use, if it has already been operating for a half of a century?

The issue of "equipment service period" was considered by many authors. Equipment service period is a period of active work of main assets, which depends on many factors: scientific and technological progress, price, cost price of equipment, physical and psychological factors of service wear, the level of staff proficiency, availability of the same or similar types of equipment, demand on products, financial capacity of the enterprise and other. When the equipment service period increases, the performance becomes worse, the service expenses increase and thus the effect, obtained by this equipment, decreases. In addition, the duration of each subsequent repairing of equipment increases over the time, and the period between repairing reduces.

Enterprises activity with the expired service period, but which is somehow is extended, is dangerous from the economic, social and ecological perspective, as the risk of accidents increases and the efficiency decreases. Obsolete equipment reduces the possibility of reduction of CO_2 emissions in atmosphere.

For example, the main factors that effect on the service period of coal electrical power station include: disconnection frequency, quality of monitoring of station work, the possibility of its reconstruction, environmental standards. Thus the disconnection frequency for coal station is usually 5% for station with service period of 10-20 years. If a station is not modernized this rate increases to 20% when it reaches 40-year service period. It leads to a choice between low-efficiency and refusal from the station with high service period on the one hand, and between investments into new station on the other.

Upgrading of operating station is not always possible. Measures to reduce emissions of pollutants and co-firing of various fuels require a thorough economic evaluation, especially in the case of old stations, where changing the service conditions could adversely effect on the service period of boiler.

In Europe, new stations are usually equipped with facilities for wastewater treatment from sulfur compounds and emission control, and therefore at this stage their upgrading is irrelevant. Projects designed to extend the service period of stations are more relevant for countries with high number of stations that have long service period. For example, in Germany the age of a third of assets is less than 15 years. Taking into account their service period of 40-60 years, they can be recommended for upgrading. In contrary, in the UK most of the operating stations started up 30 years ago. In this case, it is appropriate to extend the service period of station. The processes of recovery, renovation and modernization of the existing equipment can be combined into one category "system of equipment reproduction".

The author [4] uses the term "system of reproduction cycles" as the totality of temporal characteristics that reflect the processes of creation, operation and reimbursement of a set of capital elements both in financial and in natural form that make a complete circular sequence and interconnected set of feedbacks.

In the system of reproduction cycles there are two blocks: the cycles of renovation of capital in the natural-material form and the cycles of financial ensuring of reproduction.

Efficiency of any equipment functioning is measured by coefficient of efficiency that decreases with the work time. So, the owners of power stations are always looking for ways to increase it. Today, the coefficient of efficiency of operating stations, with extended service period is on average significantly lower than those that could be achieved with the best of modern technology. The coefficient of efficiency of gas power stations reaches the level of 60% and of coal power stations varies in the range 46-49% that explains the high CO_2 emissions in atmosphere. Power producers seek primarily to minimize production costs. The deterioration of main assets increases the spending on environmental measures, which are now included in the calculation of expenses of enterprises [3].

At present, about 40% of the electricity is produced at coal power stations that are major polluters of the environment with direct and indirect emissions. One of the areas of reduction CO_2 emission in the atmosphere is increasing the capacity of nuclear power stations without direct emissions. In 2000, the USA nuclear power stations were the most cost-effective way to produce energy, and some of them got a license for the extension their service period up to 60 years. Throughout the life-cycle of nuclear power station's product (from resources extraction to waste disposal, including the construction of reactors and plants) CO_2 emissions in atmosphere are 2-6 grams of carbon equivalent per kW / h. The same value is inherent for wind and solar power stations. Emissions of these three types of energy stations are smaller than in coal, petroleum and natural gas stations (100-360 grams of carbon equivalent per kW / h). Upgrading of the equipment of obsolete coal stations can be achieved by adding biomass to energy resource. Such an integrated use of resources in a ratio of 95:5 will reduce CO_2 emissions on 300 megatons per year. Moreover, the integrated use is almost two times more effective than working solely on biomass.

Using systems of reproduction cycles for the analysis of the totality of reproduction processes allows taking into account the cumulative nature of the reproduction process in the formation of scientific progress management mechanism. This characteristic is reflected in the fact that each successive cycle of electrical energy comprises achieve of the former one, while there is a rise in the general level of equipment efficiency and social production as a whole, Figure 1.

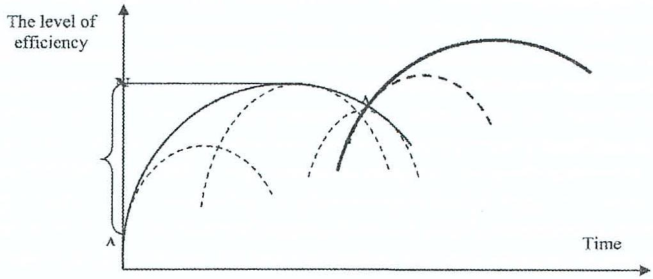

Fig. 1 – Dynamics of efficiency within the production cycles

______ Dynamics of production efficiency level within scientific center

---------Dynamics of production efficiency level within the cycle of recovery

Therefore, the notion "optimal service period of equipment" was introduced reasonably. It is defined as a time interval, during which the cost of using in the entire period of service assigned per unit of production will be minimal. If you eliminate the equipment before this period, the unit cost will exceed the minimum level due to increased depreciation, and if later, the unit cost will exceed the minimum level due to increasing costs of spare parts, supplies and repairs, because this equipment will not be able to function effectively in its present form. In this case, it is necessary to analyze the activity of operating assets and compare it according to the characteristics of new technologies.

For this purpose, on February 14, 1977 there was introduced a method of determining the economic efficiency of usage of new technology, inventions and innovations in economics by Resolution № 48/16/13/3. This method establishes uniform methodological principles for determining the economic efficiency of new technology, inventions and innovations for:

a) feasibility study of choosing the best options for creation and implementation of new equipment;

b) reflection of economic efficiency in the rules, regulations and performance of enterprises, associations, ministries, agencies and the national economy as a whole;

c) calculating the actual efficiency of new equipment, inventions and innovations;

d) calculation of premiums for creation and implementation of new equipment and rewards for inventions and innovations;

e) improving pricing [6].

Thus the calculation of the annual economic impact of the production and use of new long-term use means of labor (machines, equipment, tools, etc.) with improved quality characteristics (performance, durability, costs of operation, etc.) is performed by the formula 1:

$$PEE = \left[З_{ст} \cdot \frac{B_{н}}{B_{ст}} \cdot \frac{P_{ст} + E_{н}}{P_{н} + E_{н}} + \frac{(И^{1}_{ст} - И^{1}_{н}) - E_{н} \cdot (K^{1}_{н} - K^{1}_{ст})}{P_{н} + E_{н}} - З_{н}\right] \cdot A_{н} \qquad (1)$$

$З_{ст}$ ($З_{н}$) – given unit costs of basic (new) capital assets, UAH;

$B_{н}$ ($B_{ст}$) – annual production volumes obtained using the unit of new (basic) equipment;

$P_{ст}$ ($P_{н}$) – part of deduction from the carrying amount for the full restoration of basic (new) equipment.

These values are inversely proportional to the service period of appliances based on moral deterioration, formula 2:

$$P = \frac{1}{T_{сл}} \qquad (2)$$

$T_{сл}$ – service period of capital assets considering moral deterioration;

$E_{н}$ – normative efficiency ratio;

Assessment of economic efficiency of new equipment in the energy sector (excluding nuclear power) is performed using one for the entire economics normative coefficient of the economic effectiveness of capital investments, equal $E_{н} = 0.15$. Calculating the economic effectiveness of capital investments and the use of new equipment, inventions and innovations in nuclear energy sector is performed using one normative coefficient of effectiveness of capital investments in the amount of 0.1 and one normative coefficient for bringing different time costs in the amount of 0.1 [6];

$И_{ст}, И_{н}$ – annual operating costs of consumer using basic and new means of labor per output (work) generated by a new mean of labor. These costs take into account only a portion of amortization, aimed for overhaul of means of labor, i.e., excluding funds for their renovation, and depreciation costs in related capital investments;

$K^{1}_{н}, K^{1}_{ст}$ – related capital investments of consumer, excluding the cost of capital assets;

$A_{н}$ – annual production of new means of labor in current year, natural units.

In June 1986 there was developed the Guide for determining the economic efficiency of using new equipment, inventions and innovations in the energy sector. The Industry Guide is designed according to the all-Union "method of determining the economic efficiency of usage of new technology, inventions and innovations in economics, 1977" [6] and intended for mandatory use in the calculation of economic impact from the use of new equipment, inventions and innovations in the energy sector.

The calculation of economic impact from the creation and use of new equipment unit during lifespan, as applied to energy equipment or building structures with improved quality characteristics, is performed by formula 3:

$$PEE = \left[З_{ст} \cdot \frac{B_{н}}{B_{ст}} \cdot \frac{P_{ст} + E_{н}}{P_{н} + E_{н}} + \frac{(И_{ст}^{1} - И_{н}^{1}) - E_{н} \cdot \left(K_{н}^{1} - K_{ст}^{1} \cdot \frac{B_{н}}{B_{ст}}\right)}{P_{н} + E_{н}} - З_{н}\right] \cdot A_{н} \quad (3)$$

Unit costs of entrepreneurship activity consist of the sum of the cost of production and normative profit, formula 4:

$$З = C + E_{н} \cdot K \quad (4)$$

C – cost per unit of output, UAH;

K – specific capital investments in productive assets, UAH.

This formula shows us the full costs of production of energy products throughout the life cycle. Examining the direct and indirect CO_2 emissions let's introduce ecological correction σ^{x} to correct economic unit costs of power plants with socio-environmental component, formulas 5, 6.

$$\sigma^{пр} = \frac{CO_{2_{н}}^{пр}}{CO_{2_{ст}}^{пр}} \quad (5), \qquad \sigma^{непр} = \frac{CO_{2_{н}}^{непр}}{CO_{2_{ст}}^{непр}} \quad (6)$$

$CO_{2_{н(ст)}}^{пр}$ – direct CO_2 emissions using new (basic) process equipment;

$CO_{2_{н(ст)}}^{пр}$ – indirect CO_2 emissions using new (basic) process equipment.

Given the ecological correction the formula to calculate unit costs of power equipment becomes the following, formula 7:

$$З = C \cdot \frac{CO_{2_{н}}^{пр}}{CO_{2_{ст}}^{пр}} + E_{н} \cdot K \cdot \frac{CO_{2_{н}}^{непр}}{CO_{2_{ст}}^{непр}} \quad (7)$$

The formula shows that it is advisable to make a substitution of equipment in the case where the operating costs of the old (basic) capital assets of the life cycle of the product exceed the costs of new capital assets, i.e. when the number of repairs increases, and the operation time of stations between them is reduced.

CONCLUSIONS

This paper examines the concept of life-cycle of energy product, defines differences between it and life-cycle of energy product market. It was proposed to introduce changes to the method of determining the economic efficiency of usage of new technology, inventions and innovations in economics by entering an ecological correction to adjust economic unit costs of power plants with socio-environmental component.

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