

Yuliana Oleksandrivna KOPETSKA

Postgraduate Student,
Department of Environmental Management and Business,
Taras Shevchenko National University of Kyiv,
E-mail: yuliana.dm@mail.ru

THEORETICAL FOUNDATIONS FOR THE RESEARCH OF ENERGY CONSERVATION AND ENERGY EFFICIENCY

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Abstract

The paper presents an overview of energy conservation and energy efficiency issues at industrial enterprises of Ukraine. The purpose of the study is to explore the essence of these categories and to analyze different approaches to the interpretation of these terms by domestic and foreign scientists. The paper also aims to determine the main factors affecting the energy efficiency, as well as the negative consequences of inefficient use of energy resources. Upon examination of existing approaches, the author clarifies the definition of such notions as "energy conservation" and "energy efficiency" and proposes to understand "energy efficiency" as a wider notion than "energy conservation". If the first one means "useful, effective", the second one means only "reduction in use" of energy resources. On the basis of this analysis, the main features of energy efficiency are determined. Unlike energy conservation, energy efficiency always results in economic benefit, as well as ecological and social advantages. The paper also draws attention to such a notion as "rebound effect" of energy efficiency, which is in the spotlight of studies of foreign scientists, but is not studied appropriately in domestic scientific literature. The research also provides the analysis of energy consumption in Ukrainian industrial sector during 2007-2014, which showed downward trend in consumption of energy resources during these years.

Keywords: energy conservation; energy efficiency; energy resources; "rebound effect" of energy efficiency; energy balance.

Юліана Олександрівна КОПЕЦЬКА

аспірантка,
кафедра екологічного менеджменту та підприємництва,
Київський національний університет імені Тараса Шевченка
E-mail: yuliana.dm@mail.ru

ТЕОРЕТИЧНІ ЗАСАДИ ДОСЛІДЖЕННЯ ЕНЕРГОЗБЕРЕЖЕННЯ ТА ЕНЕРГОЕФЕКТИВНОСТІ

Анотація

У статті розглядаються питання енергозбереження та енергоефективності на промислових підприємствах України. Мета дослідження полягає у з'ясуванні сутності цих категорій та аналізі різних підходів до інтерпретації цих термінів вітчизняними та зарубіжними вченими. Також ставиться завдання визначити основні чинники, що впливають на ефективність використання енергоресурсів, а також негативні наслідки, до яких призводить їх нераціональне використання. Уточнено визначення понять «енергозбереження» та «енергоефективність», згідно з якими пропонується розуміти «енергоефективність» як більш широке поняття, ніж "енергозбереження". Якщо перше поняття означає «корисне, ефективне використання», то друге – лише "зменшення споживання" енергоресурсів. На основі цього аналізу визначаються основні характеристики енергоефективності. На відміну від енергозбереження, енергоефективність завжди призводить до економічної вигоди, а також екологічних та соціальних переваг. Звертається увага на таке поняття, як "зворотний ефект" енергоефективності, яке знаходиться в центрі уваги досліджень зарубіжних вчених, але не вивчене належним чином у вітчизняній науковій літературі. Також проведено аналіз споживання енергоресурсів в українському

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промислового секторі протягом 2007-2014 років, який виявив тенденцію до зниження споживання енергоресурсів в ці роки.

Ключові слова: енергозбереження; енергоефективність; енергетичні ресурси; «зворотний ефект» енергоефективності; енергетичний баланс.

JEL classification: D 200, L 600, Q 300, Q 400

Introduction. The level of energy efficiency is one of the most important indicators of the state economy. In the context of energy prices rising and growing demand for energy resources, issues of energy conservation and energy efficiency both for the economy as a whole and for individual businesses are very important. Efficient use of energy resources at the enterprise contributes to reducing of costs, improving product competitiveness, decreasing negative influence on the environment, that leads in particular to improving the image and providing social and economic benefits for the enterprise.

The issue of energy conservation and efficiency has been attracting the attention of scientists since the mid-twentieth century. However, the profound studies of domestic scientists started in the 1990s. The issue of state management of energy conservation was comprehensively studied by Kytskai L. [1], Kulyk M. [2] and others. Issues of energy conservation in industrial production were in the spotlight of studies of Yarullina G. [3], Sergeev N. N. [4], Mataras E. V. and Olehnovich L. V. [4] etc.

However, despite numerous studies on conservation and efficient use of energy resources, there is still uncertainty about the interpretation, relationship and interdependence of the concepts of "energy conservation" and "energy efficiency" in domestic literature. Implementation of an energy efficiency policy, formulation the right strategy and goals, as well as their successful realization require a clear understanding of the essence of energy conservation and energy efficiency, impact factors and consequences that can be caused by inefficient use of energy resources. That is why studies of these two notions are of great relevance and importance.

The purpose of this paper is the further development of theoretical basis for the research of energy conservation and efficiency.

Results. Given the relevance, energy conservation and efficiency issues were considered by many domestic and foreign scholars. The results of the analysis of their works showed that there are differences in the interpretation of the terms "energy conservation" and "energy efficiency". For example Yarullina G. believes that energy conservation is an activity aimed at more effective meeting the needs of society in energy services. At the same time, she offers an indicator of minimum social costs as a criteria of efficiency. It is associated with covering the energy needs in the long term, which takes into account environmental and social aspects of energy conservation [3, p. 22].

The analysis of categories "energy conservation" and "energy efficiency" was also performed by Sergeev N. N. [2], who provided the definition of energy conservation by various scientists. Thus, according to Mataras E.V. and Olehnovich L. V. "energy conservation means the transition to energy efficient technologies in all economic sectors, including the energy sector, and especially in energy-intensive industries, as well as domestic household sector" [5]. Kopeykin B. A. and Smirnov E. A. believe that energy conservation should target fuel economy due to saving of certain types of energy on its processing stages [6, p. 27]. In our opinion, the last two approaches to interpretation of energy conservation have technical nature and do not reveal the whole essence of the given notion.

To our mind, the most successful interpretation is given by Andrizhyevskiy A. A. who defines the energy conservation as "organizational, scientific, practical and information activities aimed at the efficient use of energy resources, which is implemented with the use of technical, economic and legal methods" [7, p.10]. A meaningful definition of energy conservation is also given by Danilov O. L. and Kostyuchenko P. A., who interpreted it as "a system of legal, organizational, scientific, industrial, technical and economic measures aimed not only at efficient use of primary energy resources, but also at involving into economic circulation the alternative and renewable energy sources to reduce the consumption of fossil fuel" [8, p. 39].

The Law of Ukraine "On energy conservation" defines the energy conservation as "activities (organizational, scientific, practical, informational), which is aimed at the rational use and economical consumption of primary and processed energy and natural energy resources in the national economy and is implemented using the technical, economic and legal methods" [9].

Most researchers define the reduction of energy consumption as a main feature of energy conservation. However, this feature is only partially reflects the essence of the notion. Reduction of energy resources consumption cannot only be the result of their conservation, but also a consequence of reduced quality of products and production volumes.

The notion of energy efficiency in contrast to energy conservation does not have a definition which is fixed in the legislation. The interpretation of the term is foreseen in the draft Law of Ukraine "On energy efficiency":

those are "organizational, scientific, practical, informational activities which are aimed at the efficient use of energy resources" [10, cl. 1].

Results of the analysis of foreign scientists' studies showed that such a term as "energy efficiency" is used more often than "energy conservation". Thus, Kenneth Gillingham, Richard G. Newell and Karen Palmer in their monograph «Energy efficiency economics and policy» suggest definition of these notions [11, p. 1]. They understand energy efficiency as the energy services which are provided by per unit of energy input. For example, the energy efficiency of an air conditioner is the amount of heat removed from air per kilowatt-hour (kWh) of electricity input. At the individual product level, energy efficiency can be considered as one of product characteristics such as product cost and other attributes. Energy conservation is defined by these authors as a reduction in the total amount of energy consumed. Thus, energy consumption may be reduced with or without an increase in energy efficiency, and energy consumption may increase alongside an increase in energy efficiency [11, p. 2].

The above mentioned researchers emphasize the importance of understanding the difference between these two notions especially when considering issues such as the "rebound effect". The "rebound effect" is widely explored by foreign scientists, in particular such as Horace Herring [12], Greening L., Greene D. L., Difiglio C. [13]. The main idea is that the increase in energy efficiency could lead to lower prices per unit of energy consumed. As a result, consumption of energy resources may increase, partly offsetting the impact of growth in efficiency of energy resources consumption. Thus, increase in energy efficiency does not always lead to a reduction in energy consumption and reducing of CO₂ emissions in air. Improvement of energy efficiency reduces the hidden cost of energy making it more accessible and leading to a larger consumption. As a result, we have the "rebound effect" of energy efficiency.

Belarusian researcher Petrusha Yu. also says about the need to distinguish between categories of "energy conservation" and "energy efficiency". According to him, energy efficiency remains important at the level of domestic consumption, but in the professional field it is substituted by the task of managing energy efficiency. The author believes that "the category of "energy efficiency" should qualify the level of quality of energy consumption at different stages of transformation of energy resources both in energy consumption (in economic sectors) and in energy production (extraction of fuel, heat and power engineering)" [14].

There is also a point of view on energy efficiency among the foreign and domestic scientists, according to which in addition to economic parameters that are determined by the system of economic efficiency indicators, environmental and social aspects are also considered. So, "when calculating the economic efficiency of energy use as an effect in general it is proposed to consider the covering of those energy needs which in the absence of energy conservation would lead to excessive demand for energy resources" [4, p. 33].

The difficulty in interpretation and distinguishing between "energy conservation" and "energy efficiency" is explained in particular by the fact that they are interrelated. However, energy conservation on its own can not be the main objective, because, as mentioned above, it can have or do not have economic benefits. If energy conservation aims, above all, to reduction of energy consumption, the energy efficiency – to useful (effective) consumption of energy resources. That is why Sergeev N. N. defines the energy efficiency as characteristics that reflect the correlation of the beneficial effect from use of energy resources and expenses of energy resources made in order to obtain such an effect, in relation to technological process, product, legal entity, private entrepreneur [4, p. 33].

Golovchanska O. A. and Riabych O. N. consider energy efficiency as one of indicators of rational use of energy resources. In their view, energy efficiency is the correlation of the actual value of the indicator of energy resources use and theoretically attainable value [15]. According to L. I. Kytskay, "energy efficiency characterizes the degree of energy use per unit of the end product" [1].

Lir V. E. considers economic efficiency of energy use, understanding it as the ability of an energy supply system during its functioning to create economic effect (potential efficiency) and the real creation of such an effect (actual efficiency) [16].

Thus, the analysis of existing definitions of "energy conservation" and "energy efficiency" found that the majority of them are too narrow, either focused only on the technical aspects, or not quite complete, given the current conditions and trends in this area. So, summing up these definitions and supplementing them with our own vision, we offer the following interpretation of these terms. Energy conservation – is a set of organizational, economic, technical, scientific and informational measures aimed at the reduction of energy resources consumption and reduction of losses in their production, distribution and consumption, while maintaining the quality and volume of output.

Energy efficiency is the beneficial use of energy resources, which is realized through the effective use of non-renewable, renewable and secondary (technological) energy resources, introduction of new energy efficient technologies, as well as implementation of other energy saving measures the economic effect of which exceeds the cost of their implementation, which results in getting economic, environmental and social effects.

On the basis of the above mentioned facts, we can determine the following basic features of energy efficiency:

- reduction of the final energy resources consumption;

- reduction of energy intensity of production;
- efficient use of non-renewable energy resources;
- involving in use renewable energy resources as well as energy resources which are the side products of technological processes (secondary or technological energy resources);
- reduction of environmental pollution.

Consequently, energy conservation can be understood as a part of energy efficiency. One way to achieve energy efficiency is rational, economical use of heat and electric power. Therefore the notion of energy efficiency is wider and covers not only energy conservation, but also other ways to reduce consumption of energy resources. However, we should remember that a decrease in energy consumption can have both a positive (energy efficiency improvement, economic benefits) and negative effect (decrease in quality and volume of output). Figure 1 shows the factors that have a direct and indirect impact on the achievement of energy efficiency.

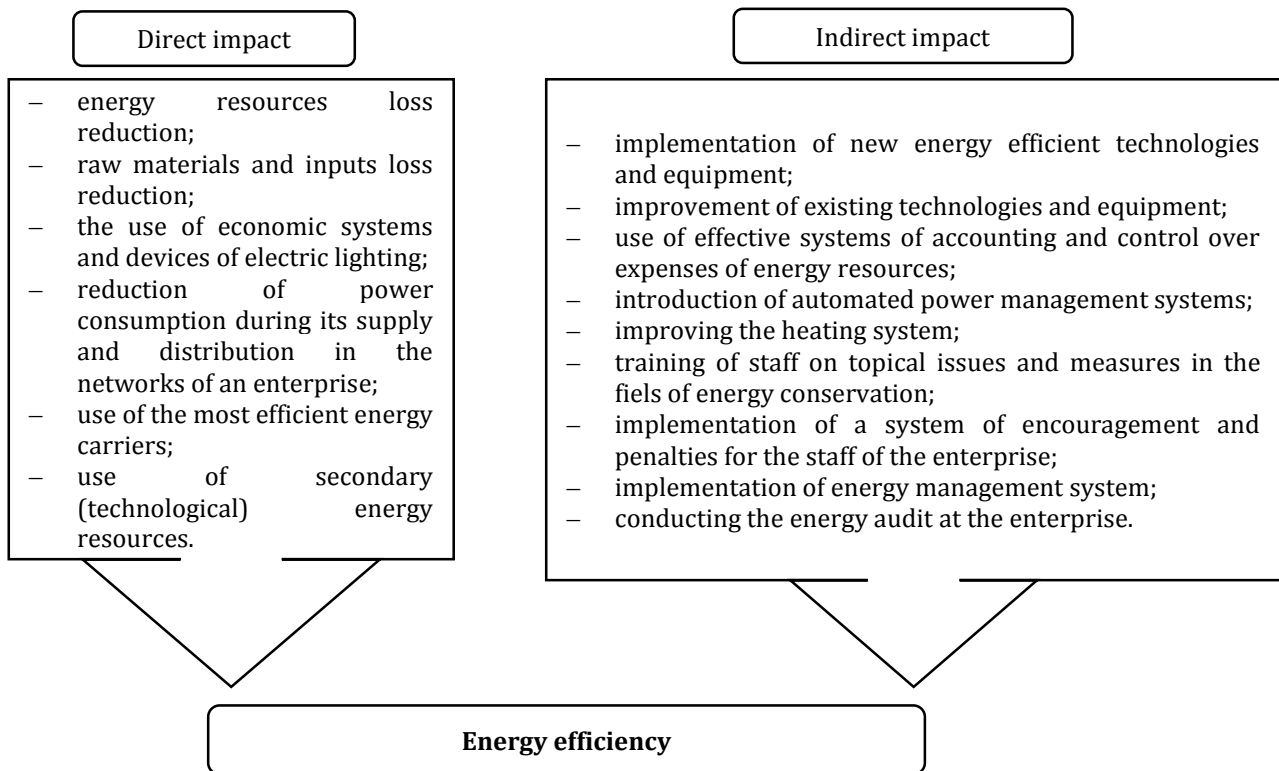


Fig. 1. Factors that impact on the achievement of energy efficiency of an enterprise

Source: compiled by the author.

The results of the analysis of Ukrainian enterprises' activities indicate that most of them use their resources inefficiently and build the work of their units incorrectly. This leads to increase of costs for energy resources, as well as cost of production.

The largest share in the structure of energy resources consumption in Ukraine is occupied by industrial enterprises. Thus, according to Ukraine's energy balance compiled by the State Statistics Service of Ukraine [17], in 2014 the industrial domain consumed 20570 thousand tons of oil equivalent (hereinafter - toe), representing about 33.5% of total amount of energy resources consumption this year. Analysis of energy balances of Ukraine for the period of 2007-2014 showed the general trend towards reduction of consumption of energy resources in Ukrainian industry (Fig. 2). However, we should pay attention to the fact that such data is not only the result of energy efficiency, but also the overall decline in the output at industrial enterprises of Ukraine in recent years.

So the problem of energy conservation and energy efficiency is extremely topical for the majority of enterprises, especially industrial ones. To solve the problem, it is important to understand the causes of inefficient use of energy resources, among which are the following:

- outdated technological equipment;
- nonproductive use of heated spaces;
- inefficient internal logistics;
- poor use of refrigeration chambers;
- imperfect distribution of production functions and load of production;
- the lack of coordinated system of informing about production volumes;
- the lack of knowledge and motivation regarding energy efficiency and resource savings between enterprise

staff;

- lack of system for management and monitoring of energy resources consumption etc.

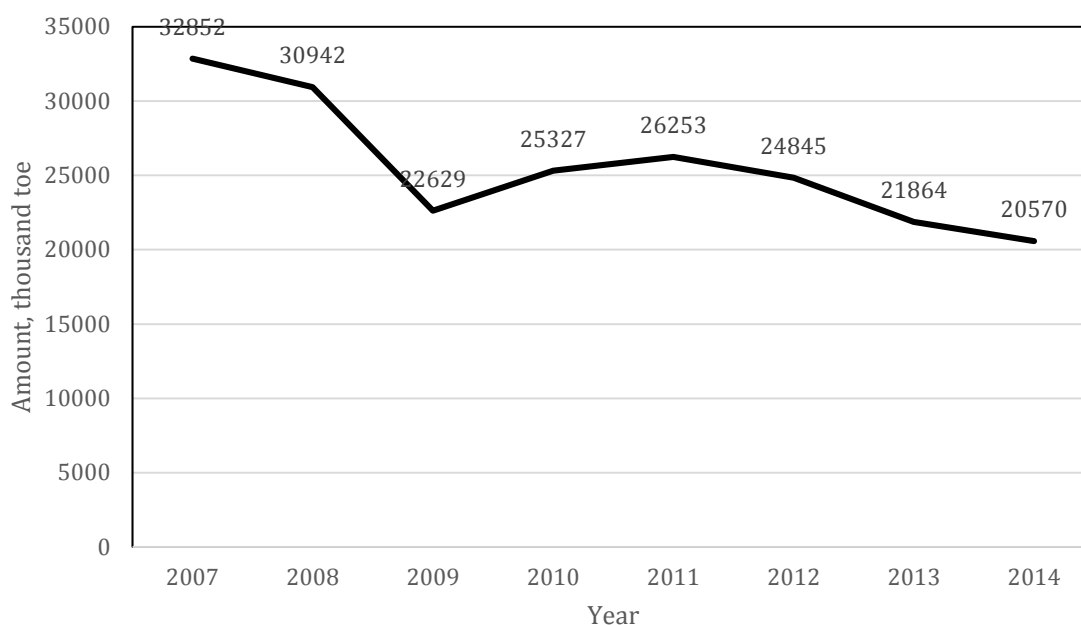


Fig. 2. Dynamics of consumption of energy resources in the industrial sector of Ukraine in 2007-2014

Source: compiled by the author on the basis of data [17].

The above mentioned reasons lead to a number of negative consequences that affect the efficiency of energy resources use and increasing costs. Among such negative effects we can identify the following ones:

- the use of excessive amounts of heat and power;
- accelerating the depreciation of equipment;
- an increase in downtime and overloading of the equipment;
- involvement of excessive staff and lower productivity of work;
- deterioration of product quality;
- an increase in production defects and accident rate.

Therefore, the reduction of the efficiency of energy resources consumption is caused by many factors that are closely interrelated. To achieve tangible results it is necessary to introduce an effective energy resources management system at an enterprise, which consists primarily of monitoring the consumption of energy resources and costs for their payment and factors affecting their growth, as well as to develop measures for their reduction.

Conclusions. The results of analysis of domestic and foreign scientific papers on energy conservation and efficiency issues found out the lack of a single generally accepted view on the understanding of these two categories. The notions of "energy conservation" and "energy efficiency" were clarified. It was investigated that the latter one is wider. If energy conservation is aimed directly at the reduction of consumption of energy resources, i.e. their rational use, energy efficiency covers a wider range of issues and always brings not only economic, but also environmental and social benefits. In order to track the results of energy efficiency some measures were implemented at the enterprise. The necessity to know the main indicators of energy efficiency requires further comprehensive studies.

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