International Journal of Research in Engineering and Science (IJRES)
ISSN (Online): 2320-9364, ISSN (Print): 2320-9356
www.ijres.org Volume 2 Issue 1 ǁ Jan 2014 ǁ PP.30-35

Relation between Energy Saving and Economic Indices of Company

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ABSTRACT : Owing to the application of energy, tangible products made of raw materials take on those properties that determine their market demand. Raw materials acquire these properties and qualities during a process that is referred to as the energotechnological process. In general there are two definitions of a technological process. According to the first definition, the technological process is a sequence and combination of operations, and according to the second definition, which is more concise and derived from the content of the term itself, technology is a science about material treatment methods that allow this effect to be optimised. The first definition relates mainly to the organisation and structure of production. The priority of the second definition is obvious when creating new production, making advanced improvements to the existing production and ensuring the pre-eminence of the products in market competition. Obviously the second definition is more universal and preferable, and it is clear that practical utility of this definition is based on science about the energy impact on various material media. Thus energy shall be considered as one of two major factors of production efficiency (along with the material component).
The considered methods of calculation of separate aspects of the problem of energy saving represent a complete logically bracketed approach and allow for proceeding to form a common methodology of energy saving in the company as well as in territorial and production groups.
Keywords: *energy efficiency, economic effectiveness*

I. INTRODUCTION

Economics has various views on energy in production. A traditional and widely spread point of view is that energy is considered to be an item of production costs that needs to be taken into account when estimating product costs and shall be simply compensated by obtained revenue after selling the products. The other point of view has just emerged and is based on admission of the fact that it is impossible to produce material goods without consumption of energy. According to this point of view, there are considerations that the user value of products shall be proportional to the amount of the used energy and the scope of a company's current assets shall be proportional to the generating capacity of the company. Ignoring this factor inevitably leads to unbalancing of the whole production-consumption system, initiates inflation and various forms of artificial enhancement of purchasing power without consideration of production capability, which finally leads to the growth of inflation. It is evident that the point of view based on the recognition of the core role of energy in the economy of a developing production shall be preferred over the unfavourable cost-based concept, especially for the branch in crisis. However, this point of view only assumes a functional relation between energy and the production potentials of a company but it does not reveal this relation.

In order to get a general idea of the existing estimates of energy consumption in production let's consider the basic provisions relating to energy in microeconomics. Economics considers energy sources as a subject of labour with raw materials, materials. Costs of fuel and energy are included among product costs. Systematic reduction of product costs is considered to be one of the major conditions of production efficiency enhancement. Therefore, energy saving shall be considered not only as a method of reducing production costs, but as a way to improve total production efficiency. From the point of view of production patterns there are shop costs, overall production costs (manufacturing costs) and total production costs. Target product costs reflect maximum allowable costs.

Element-by-element classification of production energy supply costs stipulates the following energy elements [1]:

-fuel including the costs of all types of fuel used for production and general plant needs;

-energy including the costs of all types of purchased energy (electricity, steam, hot water, compressed air, etc.) used for production and general plant needs;

Depending on the share of costs in product costs for certain elements, there are labour-intensive, material-intensive, asset-intensive and power-intensive production operations.

II. MATERIALS AND METHODS

There is a special manufacturing and distribution costs list used to group costs. For example, there can be such cost items as fuel and energy for process tasks, shop costs, general plant costs. The last two items can include costs of energy to maintain working conditions – heating, lighting, ventilation, etc. Usually planned costs of energy for all cost items are calculated on the basis of rates per production unit, cubic meter of building, square meter of premises, etc. If energy consumption rates for maintaining working conditions are justified and quite accurate, then rates of technological processes are not always theoretically justified. Analysis of product costs per certain period of time is carried out using factorial analysis on cost elements per euro of marketable products. The formula for calculation of savings per unit of products due to energy saving measures at the normative approach is the following:

$$E = \left(\frac{H_0 \cdot C_{TO}}{K_o} - \frac{H_1 \cdot C_{T1}}{K_1} \right) P \quad (1)$$

where E – energy costs saving; H_0, H_1 – energy consumption rates before and after energy saving measures;

K_0, K_1 – utilisation rate of normative resource before and after the energy saving measures; C_T – energy price;

P – annual production.

This formula is used for all factors that are conditionally combined in a group of factors affecting the technical level of production and determining current production costs (raw materials, materials, fuel). One of the advantages of the formula is a generalised accounting of main internal production parameters (consumption rate, resource utilisation rate). However, of two main external parameters – energy price and product price – only one is considered. Besides, the formula does not consider the possible growth of efficiency of the energy influence on the production process that leads not only to reduction of energy consumption, but also to an increase of the production rate per unit of energy. This is what makes energy different from materials and raw materials, and implementation of the stated energy capabilities is a task for power and process engineers that is not a part of the used economic assessments. The formula used to account for saving resulting from decrease of the labour-output ratio production or increase of labour productivity is closer to energy properties:

$$E = \left(\frac{t_0 \cdot h_0}{K_0} - \frac{t_1 \cdot h_1}{K_1} \right) K_c \cdot K_i \cdot P_1 \quad (2)$$

where t_0, t_1 – labour-output ratio for products before and after taking efficiency improvement measures, labour hours; h_0, h_1 – average base hour rate before and after the measures; K_c, K_i – rates considering additional costs and insurance; P_1 – new production output.

This formula considers increase of production output, but the mechanism of the estimation of the labour-output ratio and average base hour rate cannot be similar for energy; therefore, the given formula can be regarded only as an approximation.

A method of index numbers allowing the calculation per 1 euro of marketable products to be made is used when planning reduction of product costs. The share of product costs reduction due to energy saving can be calculated by the following formula:

$$\alpha_E = \left(\frac{1 - Y_s}{Y_p} \right) K_E \quad (3)$$

where α_E – share of energy costs per 1 euro of marketable products; Y_s, Y_p – the energy utilisation efficiency index for the subsequent and previous years (ratio of energy costs to value of the manufactured products); K_E – share of energy costs in product costs.

The specificity of this formula is that positive improvement of the index ($Y_s – Y_p$) refers to its value for the previous year (Y_p). This principle can be entirely used in estimates of energy utilisation improvement but it shall be applied rather to the stage of absolute cash settlements in order to evaluate the possibility of self-sufficiency of energy saving measures. Besides, use of share of energy costs in product costs for the subsequent year (K_E) in the formula deteriorates the total calculated result (α_E).

Because of the emergence of a new point of view on the role of energy in production, it is necessary to develop new methods of calculating the energy utilisation efficiency based on market conditions of existing and developing energy consumers.

First of all it is necessary to combine the existing methods of energy utilisation parameters' calculation for the microeconomic level with economic methods that could allow energy to be introduced into a self-accounting system, create a basis for self-sufficiency of energy saving measures and introducing energy services into a self-accounting system that encourages improvements in the economic efficiency of energy utilisation [2].

To estimate ratios of energy and economic production indices let us introduce the following concepts and generalisations:

- C_E – energy costs estimated as: $C_E = Q * C_T$, (C_T – base hour rate);
- $\sum C_i$ – total production costs;
- $K_E = \frac{C_E}{\sum C_i}$ - share of energy costs in total costs;
- $P_p \cdot P$ – earned revenue (P_p – product price);
- $\alpha = \frac{P_p \cdot P}{\sum C_i}$ – production gross income margin (α > 1.0).

If value K_E is applied to revenue, we obtain balance-sheet cost equation for energy item of costs as:

$$K_E \cdot P_p \cdot P = \alpha \cdot Q \cdot C_T \qquad (4)$$

By going to energy intensity and cost factor , $\alpha_E = \frac{\alpha}{K_E}$ we obtain:

$$P_p = \alpha_E \cdot Q_P \cdot C_T \qquad (5)$$

The contents of the factor α_E is a multiplicity of exceedance of price, market, conditional (on condition of constant prices P_p and C_T) energy intensity (P_p/C_T) over technical energy intensity estimated by the composition, structure and properties of energy saving elements. Evidently in stable market conditions (P_p, C_T) a decrease of products' energy intensity will be followed by hyperbolic growth of α_E and simultaneous growth of the company's total revenue position. It is expedient to call α_E a special gross income margin of energy at energy saving and consider it to be the main index that binds the efficiency of energy utilisation with production economic indices. The given conclusion shall not raise any doubts because a similar transaction table can be prepared for each item of the costs and values of the left and the right parts will lead to obvious congruence:

$$P_p \cdot P = \alpha \sum_{i=1}^{n} C_i \qquad (6)$$

If any item of costs is similar to energy in terms of the ability to increase utilisation efficiency, a special gross income margin can also be introduced for it. Fig.1 represents a symmetric hyperbolic curve with $Q_P; \frac{\alpha}{K_E} \cdot C_T$ axes [3].

Energy intensity Q_p corresponds to point 3 of the hyperbolic curve, which is crossed by its bisectrix. It means that the product indirect market value of energy is equal to the product price. The amount of this price on the consumer market equals $\frac{C_T \alpha^{(3)}}{K_E^{(3)}}$.The indirect price of other components, equal to the product price, is estimated in the same way. Equalisation of indirect prices of components occurs because the total revenue position for all invested money is determined by dividing the total amount from sales by total costs. When considering production as an energy and monetary system we can leave this equation and evaluate the possibility of more rapid growth of efficiency of investments in energy comparing with investments in other components.

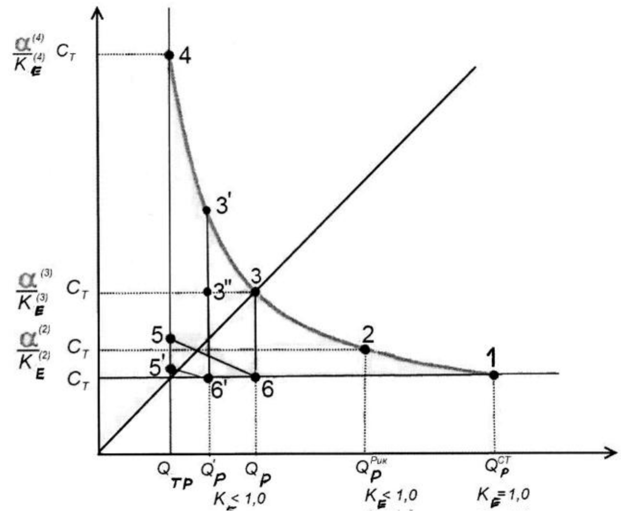

Fig. 1.

In Fig. 1 the value of energy C_T at purchase corrsponds to point 6. At transfer of energy inside the company to the technological process Q_{TP} (line 6-5) there are losses as a multiple of the transfer energy intensity Q_E, therefore the value grows to an amount of $C_T Q_{TP}$ (point 5). As a result of a technological process with the use of energy and sale of product, the indirect value of energy increases from point 5 to point 4. However, this indirect value shall not be related to the energy used in the technological process but to purchased energy. Therefore, the indirect price shall be reduced following the hyperbolic curve (line 4-3) and shall correspond to the real position (point 3; Q_P). The process of purchased energy cost recovery is completed by the energy and monetary process with line 3-6. Note that the described process takes place in the form of cycle 6-5-4-3-6 with the internal total area within the accepted coordinates equal to monetary losses due to imperfection of both the monetary and energy mechanisms of the system.

Let us consider the situation that occurs after taking energy saving measures that decreased the energy intensity of products to value Q'_P. In this case the cycle starts in point 6'; following a less steep (than 6-5) line it moves to point 5', then to point 4, but as a result of recalculating the indirect value per smaller scope of energy (than in point 6), the process will move to point 3'. The location of point 3' above point 3 indicates that using less energy gives higher revenue. It is also supported by the fact that area 6'-5'-4 -3'-6' is smaller than the previous one since monetary losses are decreased. Payback of payment for energy is 3'-6' out of total revenue 3''-6', which is conversed to the energy part of the system. There is no developed and accepted mechanism for use of the remaining part for the needs of further increasing the energy efficiency of production. The necessity of development of such a mechanism is confirmed by the fact that during transition to mode 6' a specific revenue position of energy $\left(\frac{\alpha}{K_E}\right)$ has increased since value K_E has decreased. The existing mechanism of diffusion of profits based only on value α, which is common for all components, automatically balances their efficiency at income determination.

Let's consider further possibilities of efficiency enhancement. The length of line $Q'_P - Q'_{TP}$ is determined by losses during transfer of energy from the meter installation place to the technological process. The efficiency of an even greater decrease of losses is evident. There is one more possibility that can be referred to more science-intensive possibilities. The location of point Q_{TP} (technological process) is conditionally determined in Fig. 1 basing on the symmetry of a half-hyperbola. Thorough analysis of energy losses upon delivery of the raw material component and thermodynamic analysis of the process of work execution with raw materials allows for stating with a high degree of possibility the requirements for energy type, its minimal amount and the way of delivery to the technological process; fulfilment of these requirements will move line 6'-5' to the left and this will lead to favourable movement of points 4' and 3' up along the hyperbolic curve and will automatically define growth of efficiency.

Energy efficiency as an object of scientific and production activity is a very complicated scientific and technological path that is based both on fundamental science and on a number of specific applied scientific directions. Practical implementation of energy saving measures is carried out by way of development of new efficient techniques. That is why efficient and full-scale energy saving cannot be created within the framework of microeconomics only because it can have only indirect demand (through product price) in this production field. The existing methods of considering energy saving as one of the resources in production stimulates the search for cheaper energy rather than science-intensive ways of reduction of its consumption at the expense of improvement of energy generation and production as a whole. Macroeconomics with its generalised interactions of markets and factors that ensure this interaction also allows greater priority to be given to energy as a basis for production development and as an equivalent of prices.

In macroeconomic theory, the concept of the scientific-and-technological progress of production includes factors that can lead to growth of production output at constant labour costs and capital investments or can reduce labour costs and capital investments at constant production output [4]. According to this concept, energy saving can be referred to a factor of scientific-and-technological progress. Labour accounting used to estimate a relative increase of its amount should be considered as the most reasonable for energy efficiency out of two accepted ways of expression of scientific-and-technological progress in production function. In production function *y*, total time dependence is as follows:

$$Y_t = \int \left(N_t; K_t\right) \tag{7}$$

where N_t and K_t – used amount of labour and capital. Growth *N* on the account of energy saving with temporary rate λ is shown as follows:

$$Y_t = \int \left[(1+\lambda)^t\right] \cdot N_t; K_t \tag{8}$$

At $0 < \lambda < 0.3$, when , $(1+\lambda)^t \approx e$ another formula of production function recording can be used:

$$y = \int \left(e^{\lambda t}\right) \cdot N_t; K_t \tag{9}$$

Increased value N_t due to multiplication by $e^{\lambda t}$ shows which equivalent quantity of labour units needs to be spent in order to obtain y_t of products without taking technological progress measures.

While estimating the specific models of production development due to technological progress in macroeconomic conditions, it is necessary to consider the requirement of neutrality in relation to growth balance. It shall result in the provision of consistency of the maximum yielding capacity of capital. Harrod neutrality corresponds to such method to the maximum extent. The balance is maintained by $y = f(K_1)$ transfer to a new production function $i = \frac{\delta y}{\delta k}$, at which the capital rate and its average yielding capacity are preserved.

Analysis shows that in this case the average yielding capacity of capital is determined by the interest rate and does not depend on time (i.e. balance between labour and capital is preserved) and total expression of production function, when using energy saving as technological progress, is as follows:

$$y = f\left(e^{\lambda P}\right) \cdot N_p; K_p \tag{10}$$

Let us consider the relation between production growth on a company scale and energy saving measures. Let us use the obtained relation between production capacity M_P , energy intensity of products Q_P and generating capacity of production *P*:

$$M_P = \frac{1}{Q_P} P . \tag{11}$$

If the planned rate of production growth is *r,* then after time *I* discounted production scope *P* shall be:

$$M_P \cdot t(I+r)^{'} = P(I+r)^{'} = P_t \tag{12}$$

If energy intensity during this time stays constant, then the increase of production is possible only due to the increase of energy consumption, i.e.:

$$P(I+r)^t = \frac{Q_t}{Q_P} \tag{13}$$

This gives:

$$Q_t = P \cdot Q_P (I + r)^t = Q(i + r)^t \tag{14}$$

Thus, generating capacity of a company shall increase at the same rates (rate) as the planned production.
If the company develops due to energy saving, then in this case:

$$P(I + r)^t = \frac{1}{Q_{nt}} \cdot Q \tag{15}$$

or

$$Q_{nt} = \frac{Q}{P(I + r)^t} = Q_P \frac{1}{(I + t)^t} \tag{16}$$

If a concept of energy intensity decrease rate can be introduced r_{QP}, then it is possible to use standard formula of discounted value calculation P_{Pt}:

$$Q_{nt} = Q_P \frac{1}{(I + r)^t} = Q_P (I + r_{QP})^t \tag{17}$$

This gives:

$$r_{QP} = -\frac{r}{1 + r} \tag{18}$$

Thus, energy intensity decrease rate is smaller than the production growth rate.

III. Conclusion

Obtained formulas allow for relating cost over time for energy saving with the gained production effect of the company. If production development is planned to be carried out due to investments with the determined interest rate, then gained formulas allow the rate of energy supply to be calculated for production development less effectively (due to increase of consumed power) and more effectively (due to decrease of energy intensity of products).

The considered methods of calculation of separate aspects of the problem of energy saving represent a complete logically bracketed approach and allow for proceeding to form a common methodology of energy saving in the company as well as in territorial and production groups.

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