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ECONOMIC CALCULUS OF THE EFFECTIVENESS OF WASTE UTILIZATION PROCESSED AS SUBSTITUTES OF PRIMARY MATERIALS

Along with technical and legal means, economic instruments are crucial components in the field of utilizing waste as substitutes of primary materials. Economic calculus of the effectiveness of replacing primary materials with secondary materials consists of determining the difference between the total costs of the production in which waste are used as secondary materials and the production in which primary materials are implemented. Choosing an appropriate method of calculation is significant when it comes to defining the effectiveness of substituting primary for secondary materials. The method should allow measuring and comparing the final results of investments. Also, it ought to be adjusted to the character of a given project. The aim of this paper is twofold. One is to review the area and to introduce the reader with methods of calculation of the effectiveness of waste utilization as secondary materials (literature review). Then the calculation of the effectiveness of the production in which certain wastes are utilized was proposed the effectiveness of waste utilization processed as substitutes of primary materials is analyzed. Looking at the calculation of economic effectiveness, one may assume that the production is profitable when the effectiveness index is higher for the production in which waste material is used.

1. INTRODUCTION

Waste management should always deal with the use of waste as substitutes for primary materials. Waste should also be utilized as a source of energy. Re-use of waste should be treated as a way of reducing environmental pollution.

The rules of market economy require meeting the regulations of economic calculus when it comes to undertake a business enterprise. Economic calculus allows evaluation of final results before initiating such an enterprise. It protects contractors against undertaking risky ventures and enables them to choose optimum solutions [1].

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While calculating the effectiveness of such enterprises, one needs to compare the input and output. Economic calculus of various projects can be presented either in a relative form or in an absolute one. The absolute form signifies the profitability of given ventures, and provides the possibility of comparing their effectiveness. The relative form defines the relationship between the amount of functional values that are utilized and work input destined for this purpose.

When examining the effectiveness of particular enterprises, one needs to take into account measuring instruments and consider the categories of input and output. In order to evaluate the investment in which secondary materials are implemented, a thorough analysis is needed. So far, there have been several varied methods of calculating economic effectiveness among which the drawn – calculi method is the most highly recommended. The method takes diverse solutions into consideration, and also presents the whole range of incurred costs. "Ecobalances" in which all costs (including disposal costs and the ones devoted to preserving good environmental conditions) are considered, present a specific case of economic calculi. Moreover, energy consumption is the most significant component in determining the profitability of a given enterprise [2].

Calculation of the actual level of the co-effectiveness is one of the most serious and, at the same time, one of the most difficult issues when investing in waste recycling [3]. Many researches on effectiveness of recycling were done by many authors. A notable exception is Duran's *A model for assessing the economic viability of construction and demolition waste recycling* which in his case study develops a model to assess the economic viability of certain markets for recycled construction and demolition waste. Once the model is developed and the underlying assumptions outlined and analysed, the paper then proceeds to assess the impact of the imposition of environmental taxes and the use of subsidies on the economic construction and demolition waste recycling. The underlying methodology of the model developed is clear and has a wider international applicability and relevance to the study of construction and demolition waste recycling [4].

Battol presented economic potential of recycling business in Lahore, Pakistan. The paper presents the state of solid waste reuse and recycling in Lahore, Pakistan, discusses the problems, and proposes a recycling program and highlight the usefulness of such a program in solving the problems associated with municipal solid waste. Data on solid waste recycling were gathered from residents of low-, middle- and high-income groups, as well as from scavengers and junkshops. A cost analysis is presented to show the income that can be generated through a well planned recycling program. It is shown that 21.2% of all recyclable waste in Lahore is recycled, and it generates an amount of Rs. 271 million (US $ 4.5 million) per year through the informal sector. However, if the recycling practice is owned by the formal sector, it can save an amount of Rs. 65 million by reducing the collection cost. If recycling is adopted as an industry, it can generate revenues of Rs. 530 million (US $ 8.8 million) per year and can also save enormous amount of energy, as well as the natural resources [5].

Hage analyzes the determinants of recycling efforts in Swedish households, and focuses on the case of packaging waste (i.e., paper, glass, plastic, and metal). The analysis builds on a theoretical framework that integrates norm-motivated behavior into a simple economic model of household choice by assuming that the individuals have preferences for maintaining a self-image as morally responsible, and thus norm compliant, persons. The study showed the importance of both economic and moral motivations and the interdependence between these, it is important that future policy efforts recognize this dual motivation rationale. One important implication of this finding is that policy should preferably be presented in "packages" emphasizing both the moral obligations of individual recycling efforts as well as the measures introduced to facilitate households' efforts. For instance, if weight-based collection fees are implemented, supplementary information should stress the environmental importance of increased material recycling and thus not only direct attention towards the incentive effects of the policy instrument [6].

2. METHODS OF MEASURING THE CALCULUS OF THE EFFECTIVENESS LITERATURE REVIEW

Various methods of calculating of the effectiveness of waste utilized as secondary materials have been proposed. Among them there is one that aims at complex evaluation by analyzing the shaping of capital expenditure and the costs of production. It all comes down to calculating "absolute pay-back period" and "relative pay-back period". Thanks to the input, especially input on technical advances, the annual economy of operating costs is observable. Consequently, the expenditure is reimbursed after some time [7]. The formulas are as follows:

- for absolute pay-back period

$$\frac{\delta_2}{\chi_1 - \chi_2} = T_a \tag{1}$$

- for "elative pay-back period"

$$\frac{\delta_2 - \delta_1}{\chi_1 - \chi_2} = \frac{\Delta_\delta}{o_\chi} \tag{2}$$

in which δ_1, δ_2 – expenditure of technological progress, χ_1, χ_2 – annual exploitation costs and O_χ – the exploitation costs savings.

Since the macro scale calculus signifies social effectiveness, the choice of the most rational solutions is probable. On the other hand, microscale calculus, based on incurred expenses and predicted effects, presents the situation after undertaking an investment project. Since the calculus cannot include the expenses that are not incurred by the project, one is not allowed to include the expenses connected with external infrastructure if a given enterprise does not have a share in financing the investment. However, fines for environmental pollution and all additional charges, including the ones destined for the whole infrastructure, need to be covered by the enterprise.

Simplified formula of the calculus of the complex effectiveness of investment has a form [8]:

$$E = \frac{(\Omega - \Psi) + \theta\varepsilon}{\Phi(\alpha + \vartheta) + \Gamma\alpha + \Phi\varepsilon(\alpha + \vartheta) + \Gamma\varepsilon\alpha}. \tag{3}$$

where Ω is the predicted annual production value, Ψ is the predicted annual current production cost (as proper cost decreased of amortization, credit's interest and increased of tax wages fund), $\theta\varepsilon$ is the additional effect nascent beyond the enterprise, Φ is the value of technological progress expenditure in the enterprise with cost of environment protection, α is the rate of discount level of projects financed by bank credit, defined in valid acts, ϑ is the averaged depreciation rate calculated according to valid trade regulations, $\Gamma\alpha$ are the expenditures for creating the stock of circulating assets, assumed as height of predicted assets after achievement of target productive ability, $\Phi\varepsilon$ is the value of investment expenditures beyond the enterprise, stimulated by given investment, $\Gamma\varepsilon\alpha$ are the additional expenditures beyond the enterprise for creating the stock of circulating assets connected with the plans stimulated by given investment. The condition of effectiveness is fulfilled when $E > 1$.

Extended formula of the calculus of the complex effectiveness of investment has a form

$$E = \frac{\sum_{t=0}^{n} \varphi_t (\Omega_t - \Psi_t) + \sum_{t=0}^{n} \varphi_t \theta\varepsilon_t}{\sum_{t=0}^{n} \varphi_t \theta_t + \sum_{t=0}^{n} \varphi_t \theta\varepsilon_t} \tag{4}$$

where t ($t = 0, 1, 2, 3, \ldots, n$) are the sequence years of the computational period, φ_t is the discount coefficient, decreasing in following years (calculated for each year), θ_t is the capital expenditure for investment projects, $\theta\varepsilon$ is the additional capital expenditure beyond the enterprise (fundamental investment).

Secondary materials are said to be used as substitutes for primary materials. When it comes to market economy, the basic form of evaluation of secondary and raw materials should be calculated economically. The calculus of economic effectiveness consists in comparing total costs of the production in which secondary materials are used with the costs of production in which primary materials are utilized. Prices of secondary materials are usually lower; nevertheless, processing costs and their consumption are higher because of additional technological treatments.

The effects of implementing waste utilized as secondary materials can be defined in terms of profit increase. It brought about reduction of production costs and the possible difference between the prices of products made from raw materials. The increase (or decrease) in the amount of total profit is calculated in the following way:

$$Y = \sum_{i=1}^{n} [(\xi\omega_i - \zeta\omega_i) - (\xi\varsigma_i - \zeta\varsigma_i)]\wp\,\omega_i, \tag{5}$$

where i is the consecutive number of a product, $\xi\omega_i$ is the real or planned average price of sold product, manufactured with waste as secondary materials, $\xi\varsigma_i$ is the average price of sold product manufactured of raw materials, $\zeta\varsigma_i$ is the elementary average production cost of product manufactured of raw materials, $\zeta\omega_i$ is the elementary average production cost of product manufactured with waste as raw materials, $\wp\omega_i$ – the quantity of production units of manufactured products with waste contribution as secondary materials.

The following condition needs to be fulfilled so that the production is profitable:

$$\xi\omega_i - \zeta\omega_i > \xi\varsigma_i - \zeta\varsigma_i$$

If a given enterprise bears the costs of waste storage while processing raw materials, these costs should be treated as the additional ones. Moreover, they have the influence on the final result of secondary waste utilization. If the application of secondary materials instead of primary ones does not change the value and price of the products, the increase (or decrease) in the amount of total profit Zn_1 is calculated in the following way:

$$\Delta Y_1 = \sum_{i=1}^{n} (\zeta\varsigma_i - \zeta\omega_i)\wp\,\omega_i \tag{6}$$

3. EVALUATION OF THE EFFECTIVENESS OF WASTE UTILIZED AS SUBSTITUTES FOR PRIMARY MATERIALS

Economic effectiveness is a result of economic activity. It is defined as a ratio of final effects in the period of economic operation to incurred costs. The basic problem of every enterprise is estimation of its effectiveness. The instrument on the basis of which the management process is evaluated is the economic calculus. Economic calculus is a foundation for the decision of whether to undertake the enterprise or not. It consists of comparing the input and output while taking into account various divisions of the factors of production [9].

The choice of waste calculation is of great importance when it comes to determining the effectiveness of waste utilized as substitutes for primary materials. The applied method should allow measuring and comparing the effects of various enterprises and activities; nevertheless, it ought to be adjusted to the character of such an enterprise.

Production of waste used as substitutes for primary materials involves undertaking various activities. As a result, determining the economic effectiveness of the production does not always allow defining the production entirely. It often happens that particular stages of the production, such as recovery of secondary materials, their treatment, and processing should also be determined. The calculus of the effectiveness of the production in which certain wastes are utilized can be calculated as follows:

$$\nu = \rho - \upsilon \tag{7}$$

where

$$\rho = \sum_{i}^{n} \xi\omega_i \wp\, \omega_i, \qquad \upsilon = \sum_{i}^{n} \zeta\omega_i \wp\, \omega_i, \qquad \rho > \upsilon$$

in which ν is the difference between value of sale and total cost of operation, ρ is the value of sale of batch with waste as secondary materials, υ is the total cost of batch after analyzed operations.

The costs of waste processing used as substitutes for secondary materials are different from the once processed as substitutes for primary materials. It often happens that the costs of secondary materials are lower, but the costs of waste processing are higher because of additional and purifying treatments or else due to lower capacity. Consequently, the calculus of economic effectiveness comes down to determining the difference between the total costs of the production in which wastes are used as primary materials and the costs of methods in which primary materials are used [10].

In order to calculate economic effectiveness *E* of productions that do not include capital expenditure, we need to make calculations and compare the effectiveness of relative production in which wastes are used. The wastes are utilized as substitutes for secondary materials and primary materials, respectively. To make calculations of profitability index, we implement the following dependence:

$$E = \frac{\sum_{i}^{n} (\xi\omega_i - \zeta\omega_i) \wp\, \omega_i}{\sum_{i}^{n} \zeta\omega_i \wp\, \omega_i} \tag{8}$$

To examine the profitability of the production with waste used as substitutes for primary materials, we need to calculate separately the effectiveness index obtained from the production of primary materials ($E\varsigma$) and the profitability index gained from the production of secondary materials ($E\omega$).

Based on Equation (8), the effectiveness index of the production of primary materials is as follows:

$$E_{\varsigma} = \frac{\sum_{i}^{n} (\xi\varsigma_i - \zeta\varsigma_i)\, \wp\, \omega_i}{\sum_{i}^{n} \zeta\varsigma_i\, \wp\, \omega_i} \tag{8a}$$

while the effectiveness index of the production of secondary materials is:

$$E_{\omega} = \frac{\sum_{i}^{n} (\xi\omega_i - \zeta\omega_i)\, p_{w_i}}{\sum_{i}^{n} \zeta\omega_i\, \wp\, \omega_i} \tag{8b}$$

Consequently, the production is profitable if:

$$E\omega \geq E\varsigma$$

4. DISCUSSION

Traditional analysis of costs and merits should be enriched by including various costs to the economic calculus. These costs are connected with the resources taken directly or indirectly from the natural environment. Through implementing appropriate methods, qualitative features of environment that are difficult to measure can be considered in terms of money [11].

Along with technical, legal, and organizational treatments, economic instruments play a significant role in the field of environmental protection since dealing with environmental risk is examined on the economic level. As a result, environmental protection is said to be an important economic activity.

The choice of appropriate measuring instruments is important when it comes to examining the effectiveness of economic enterprises. To examine the profitability of the production with waste used as substitutes for primary materials, we needed to separately calculate the effectiveness index obtained from the production of primary materials and the profitability index gained from the production of secondary materials. Looking at the calculation of economic effectiveness, one may assume that the production is profitable when the effectiveness index is higher for the production in which waste material is used.

Altogether more than 1.7 billion tons of wastes are landfilled in Poland (state on end of 2007 year) and every year this amount increases approximately by 133 million tons. Unfortunately, according to the statistics for the whole Poland, landfill is the main disposal method. The data show that waste deposited varies between 96% and 98%. Other methods are used on a negligible scale. Due to requirements of recycling and in order to achieve the levels of recycling and decrease amount of waste directed to landfills defined in EU directives and Polish acts, presented method included in Sect. 3, where the effectiveness of waste utilization processed as substitutes of primary materials were analyzed, might be a good way for optimization the cost-effectiveness of existent plant and planning new plants of waste utilization as substitute raw materials.

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