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Economic profitability of the secondary materials utilization as a substitute of raw materials

Introduction

Any product has a possibility of turning into waste when it loses its economic value with the passing of time. Once raw materials are used and waste is created, the properties of the materials are not necessarily lost but can be restored using regenerative processes. Despite the fact that properties of the primary materials have been lost, the waste still carries both the subjective human work and energy used in its production. Differences between the properties of secondary materials (waste) and those of primary raw materials are not substantial; many times these changes are only superficial. The reason is that primary raw materials often have not undergone fundamental changes during the production process.

Waste accumulates over time unless decomposed in the ecosystem or recycled. Today, the accumulation of waste has reached such a magnitude that it can become a real threat to the existence of the whole ecosystem (Li-Teh et al.). The promotion of environmental management and the mission of sustainable development worldwide have exerted the pressure for the adoption of proper methods to protect the environment. The hierarchy of disposal options, categorizes environmental impacts into six levels, from low to high: to reduce, reuse, recycling, compost, incinerate and landfill. Recycling, being one of the strategies in minimizing waste, offers three benefits: reduce the demand for new resources, cut down on transport and production energy costs, utilize waste which would otherwise be lost to landfill sites (Xavier et al. 2006).

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All over the world, various research on economic and ecological profitability of secondary materials recycling in the substitution of raw materials was presented by many authors. Highfill and McAsey developed a theoretical model for a municipality that has a landfill site with finite capacity and two alternatives for waste disposal: landfilling and recycling. They showed that if the capacity of the landfill is taken into account, it might be efficient for a municipality to recycle some of its waste, even though recycling is more expensive in terms of total costs. In fact, the model showed that the cost calculation should also include dynamic considerations over time, not only the costs of present treatment, so that anticipated future costs are also taken into account (Highfill, McAsey 1997).

Xavier Duran et al., developed a model for assessing the economic viability of construction and demolition waste recycling-the case of Ireland. The model developed in this was based on the potential decisions facing the waste producer and the aggregate user. 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 economics of Construction and demolition waste (C&DW) recycling. Conclusions were presented which suggested that economic viability is likely to occur when the cost of landfilling exceeds the cost of bringing the waste to the recycling centre and the cost of using primary aggregates exceeds the cost of using recycled aggregates (Xavier et al. 2006).

Few studies deal with cost-benefit analysis of waste recycling presented pioneer research in analyzing cost-benefit of recycling. Doron Lavee presented a study conducted in Israel in the years 2000–2004. The economic analysis's shows that if municipality efficiently adopts recycling, it can take advantage of anticipated reduction in the quantity of waste directed to landfills and thus reduce overall waste management costs by average 11%. The results shows that for most municipalities in Israel (51% of the municipalities), it would be efficient to adopt recycling and that the optimal amount of waste recycling in Israel it 27.7% (excluding organic waste) of all municipal solid waste. The analisysis reveals that recycling is very advantageous for the large municipalities (recycling is efficient for 87% of all such municipalities) and much less advantageous for the regional municipalities (recycling efficient for 25%) (Doron 2007).

Vivan W.Y. Tam in his pioneering work, studied the cost and benefit on the current practice in dumping the construction waste to landfills and producing new natural materials for new concrete production, and the proposed concrete recycling method to recycle the construction waste as aggregate for new concrete production. With the advent of the cost on the current practice, it is found that the concrete recycling method can result in a huge sum of saving. The benefits gained from the concrete recycling method can balance the cost expended for the current practice. Therefore, recycling concrete waste for new production is a cost-effective method that also helps protecting the environment and achieves construction sustainability (Vivian 2008).

1. The model

The model outlined in this section builds on a models described for (Kalinowski 2000; Panek 2000; Sołtysiak 2002).

In this model the emphasis is put on the economic conditions of the recycling plant dealing with secondary materials. Those conditions will be discussed depending on:

— x_1 – capital costs,
— x_2 – ecological unit cost of secondary materials utilization [zł/Mg],
— x_3 – unit costs of processing 1 Mg of secondary materials as raw material,
— x_4 – marketing costs of the obtained product, mass fraction of this substitute obtained from the secondary materials mass,
— x_5 – social unit costs [zł/Mg] taking into account, for example, certain aspects of creation of the new workplaces, etc.,
— x_7 – the amount of work allocated for the production in fixed units,
— x_8 – fixed costs,
— x_9 – the amount of the raw material/secondary materials modified.

These quantities are related to one another, e.g.:

— the application of machines may lead to reduction in employment,
— the volume of production has an impact on ecological costs connected with it.

Unit costs of the particular elements of the production would be as follows: $\nu_1, \nu_2, \nu_3, ..., \nu_k$. It means that the work unit costs v_1 zł , technical maintenance unit of the work equipment costs v_2 zł. ,etc. On the other hand, the unit of the manufactured product has a price y zł.

Having K capital destined for plant exploitation, the question arises- what is the best way of dividing the capital between particular expenditure in order to have the highest profit?

The production function has a form:

$$y = f(x_1, x_2, x_3, x_4, ..., x_k), \qquad x = (x_1, x_2, ..., x_k) \in R_+^k$$

We may conclude that the production function has the following features: If the production from the following means $(x_1, x_2, ..., x_k)$ amounts to $(x_1, x_2, x_3, x_4, ..., x_k)$ the production from $(sx_1, sx_2, sx_3, sx_4, ..., sx_k)$ means for $s > 1$ reaches, in general, less than $sf(x_1, x_2, ..., x_k)$.

It leads to the conclusion that the production function is the homogenous function of θ degree for $0 < \theta < 1$ i.e. $f(sx_1, sx_2,..., sx_k) = s^\theta f(x_1, x_2,..., x_k)$ for $(x_1, x_2,..., x_k) \in R_+^k$, $s > 1$ or

$$f(sx) = s^\theta f(x) \quad \text{for} \quad x \in R_+^k , s > 1 \tag{1}$$

The most conspicuous feature of the plant is, for a very long period of time, a random vector that may be chosen, i.e. the condition represented as equation 1 means that every amount of products needed in the production process is available (both factors and means of production). As a result, the access to materials is unlimited.

The recycling plant model produces one commodity and uses *K* for its production. Other factors and means of production can be discussed according to this assumption:

Assuming that the scalar function is represented as

$$f: R_+^k \to R_+^1$$

where

$R_+^k = \langle x \in R^k | x \geq 0 \rangle$

is the volume of production dependent on *x* vector, means consumption and other factors of the production

The following assumptions linked with the f function are made

F1: $f(0) = 0$.

F2: $f(x)$ is continuous for $x \in Int(R_+^k)$

F3: $f(x)$ is increasing with regard to all of the variables

F4: $f(x)$ is the positive homogenous function of θ. degree; Hence,

$f(sx) = s^\theta f(x)$ for $x \in R_+^k$, $\theta \in (0,1)$

One must assume that the unit price of the manufactured product is *p*, whereas *v* is the *k* dimensional vector of the prices of means of production

$$v = (v_1, v_2, ..., v_k)$$

where

$p > 0$, $v_i > 0$ for $i = 1, 2, \ldots, k$

The issue of income maximization in which conditions have a form of a long-lasting development strategy are represented as follows:

$$\max\{p \cdot f(x) - (v,x)\}, \quad x \in R_+^k \tag{2}$$

The issue of income maximization is solved in two-stages on the basis of two equivalent methods:

1. Maximization of the production in which the costs of production are fixed

$$d(u) = \max_{\langle v,x \rangle = u} f(x) \tag{3}$$

having F1-F4 assumptions we conclude that:

$$d(u) = \max_{\langle v,x \rangle = u} f(x) = \max_{\left\langle v,\frac{x}{k} \right\rangle = u} f\left(\frac{x}{k}\right) = \max_{\frac{1}{k}\langle v,x \rangle = u} \left(\frac{1}{k}\right)^\theta f(x) = \left(\frac{1}{k}\right)^\theta \max_{\langle v,x \rangle = ku} f(x) = \left(\frac{1}{k}\right)^\theta d(ku)$$

so $d(ku) = k^{\theta} d(u)$.
$d(u)$ is the homogenous function of u scalar variable and θ degree; Hence, it has a form

$$d(u) = Bu^{\theta}, \text{ where } B = d(1) = \max_{\langle v,x \rangle = 1} f(x) \tag{4}$$

The production costs level to be determined; by means of the aforementioned costs of production the maximal income appears.

The function:

$$z_2(u) = pBu^{\theta} - u \tag{5}$$

in which the u level of costs is given stands for the income.

The graph of the function $z = z_2(u)$ to be examined. For this purpose, $z_2(\bar{u}_1) = 0$, $z'(\bar{u}) = 0$, $z_2(\bar{u})$ is determined.
We have

$$pB\bar{u}_1^{\theta} - \bar{u}_1 = 0$$

$$pB\bar{u}_1^{\theta-1} = 1$$

$$pB = \bar{u}_1^{\theta-1}$$

$$\bar{u}_1 = (pB)^{\frac{1}{1-\theta}} \tag{6}$$

Having derivative given $\bar{u}$ is determined

$$z'_2(\bar{u}) = pB\theta u^{\theta-1} - 1 = 0$$

$$pB\theta = \bar{u}^{1-\theta}$$

$$\bar{u} = (pB\theta)^{\frac{1}{1-\theta}} \tag{7}$$

The quantity

$$z_2(\bar{u}) = pB\bar{u}^{\theta} - \bar{u} = \bar{u}\,\frac{1-\theta}{\theta} \tag{8}$$

Fig. 1 presents the profit depending on the level of costs $|0 < \theta < 1|$.

In this case the production brings in the profit for $0 < u < \bar{u}_1$. Nevertheless, the profit is maximal for $u = \bar{u}$. Fig. 2 showing the profit increase as a result of the cost increase for $|\theta > 1|$.

The production makes a loss for $0 < u < \bar{u}_1$. However, the losses are the highest for $u = \bar{u}$.

Still, for $u > \bar{u}_1$ production costs increase causes unlimited profit increase which is contradictory to the economy.

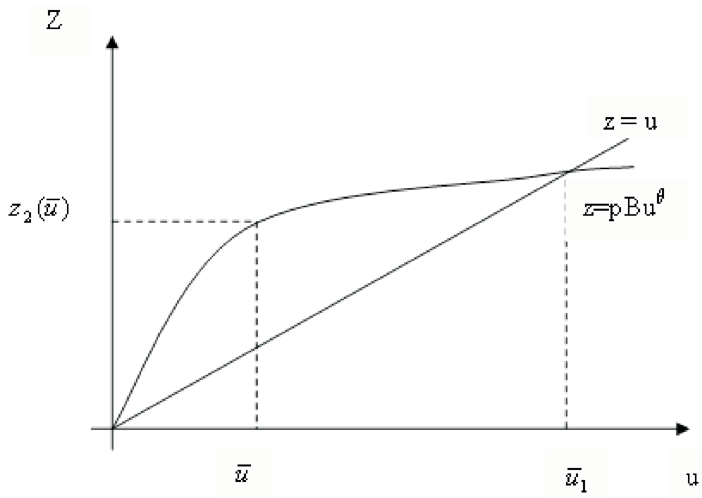

Fig. 1. Diagram representing the profit depending on the level of costs $|0 < \theta < 1|$

Rys. 1. Wykres obrazujący zysk w zależności od poziomu kosztów $|0 < \theta < 1|$

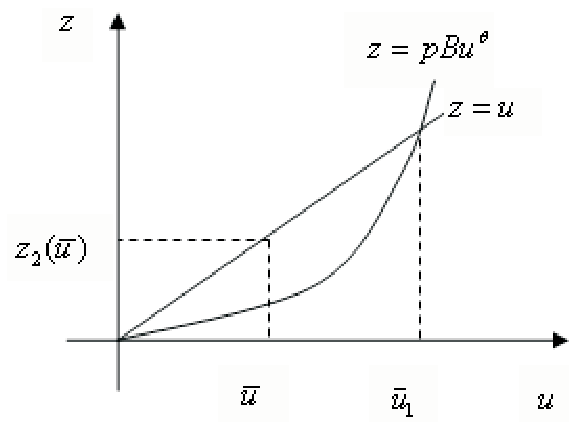

Fig. 2. Diagram representing the profit increase as a result of the cost increase for $|\theta > 1|$

Rys. 2. Wykres obrazujący wzrost zysku spowodowanego wzrostem kosztów dla $|\theta > 1|$

If $\theta = 1$ the function 5 is linear

$$z_2(u) = (pB - 1)u$$

Moreover, it does not reach its extreme.

In this case, the income or losses are proportional to factor $pB - 1$. This situation is contradictory to economic experience.

2. Production costs minimization when the volume of production is fixed

$$C(y) = \min_{f(x)=y} \langle v, x \rangle \tag{9}$$

The above function is called the plant cost function. It determines the dependence of minimal production costs on the volume of production.

From dependence F1–F4 we get

$$C(y) = \min_{f(x)=y} \langle v, x \rangle =$$

$$= \min_{f\left(\left(\frac{1}{k}\right)^{\frac{1}{\theta}} x\right) = y} \left\langle v, \left(\frac{1}{k}\right)^{\frac{1}{\theta}} x \right\rangle = \left(\frac{1}{k}\right)^{\frac{1}{\theta}} \min_{\frac{1}{k} f(x)=y} \langle v, x \rangle = \left(\frac{1}{k}\right)^{\frac{1}{\theta}} \min_{f(x)=ky} \langle v, x \rangle = \left(\frac{1}{k}\right)^{\frac{1}{\theta}} C(ky) \tag{10}$$

Then $C(ky) = k^{\frac{1}{\theta}} C(y)$

As a result, the function $C(y)$ is homogenous of $\frac{1}{\theta}$ degree and y variable. It means that it has a form

$$C(y) = Ay^{\frac{1}{\theta}} \tag{11}$$

where $A = \min_{f(x)=1} \langle v, x \rangle$

Now we determine the production level giving the maximal profit.

The function

$$z_1(y) = py - Ay^{\frac{1}{\theta}} \tag{12}$$

defines the income when the production level is y.

First we study he graph of the function $z = z_1(u)$. For this purpose $z_1(\bar{y}_1) = 0$, $z'(\bar{y}) = 0$, $z_2(\bar{y})$ is determined.
We have

$$z_1(\bar{y}_1) = p\bar{y}_1 - A\bar{y}_1^{\frac{1}{\theta}} = 0$$

$$A\bar{y}_1^{\frac{1}{\theta}-1} = p$$

$$\bar{y}_1 = \left(\frac{p}{A}\right)^{\frac{\theta}{1-\theta}} \tag{13}$$

having a derivative given we define $\bar{y}$

$$z'_1(\bar{y}) = p - \frac{A}{\theta}(\bar{y})^{\frac{1}{\theta}-1} = 0$$

$$\bar{y}^{\frac{1-\theta}{\theta}} = \frac{p\theta}{A}$$

$$\bar{y} = \left(\frac{p\theta}{A}\right)^{\frac{\theta}{1-\theta}} \tag{14}$$

The quantity

$$z'_1(\bar{y}) = p\bar{y} - A\bar{y}^{\frac{1}{\theta}} = p\bar{y}(1-\theta) \tag{15}$$

Course of the profit of the plant $z_1(y)$ depending on the production level y for $|0 < \theta < 1|$ is shown in fig. 3.

In this case, the production brings the profit for $0 < y < \bar{y}_1$, however, the highest profit is when $y = \bar{y}$.

Fig. 4 presents the profit dependence on the rate of production $|\theta > 1|$. If $\theta > 1$

The production makes a loss for $0 < y < \bar{y}_1$; While the loss is for $y < \bar{y}$.

Still, for $y > \bar{y}_1$ production costs increase causes unlimited profit increase which is contradictory to economy.

If $\theta = 1$ the function

$$z_1(y) = (p - A)y \tag{16}$$

Is linear and does not have the extreme.

In this case, the income or losses are proportional to $p - A$ factor; nevertheless, this situation is contradictory to the economic experience.

Therefore, the production function (1) makes economic sense when $0 < \theta < 1$.

Using directly the necessary condition of the extreme of numerous variables of the function the issue of profit maximization can be solved.

From the previous deliberations it results that the maximum exists. Thus, if for the function:

$$z(x) = pf(x) - (v_1x_1 + v_2x_2 + \dots + v_kx_k)$$

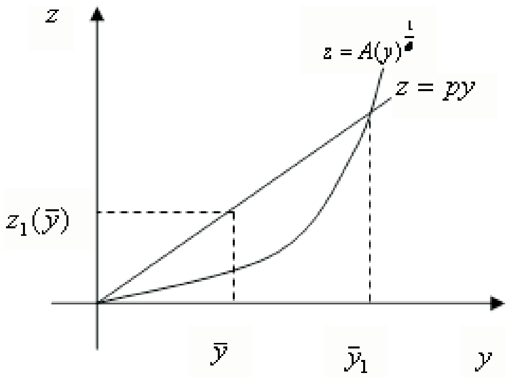

Fig. 3. Diagram representing the profit of the plant $z_1(y)$ depending on the production level y for $|0 < \theta < 1|$

Rys. 3. Wykres przedstawiający zysk zakładu $z_1(y)$ w zależności od poziomu produkcji y $|0 < \theta < 1|$

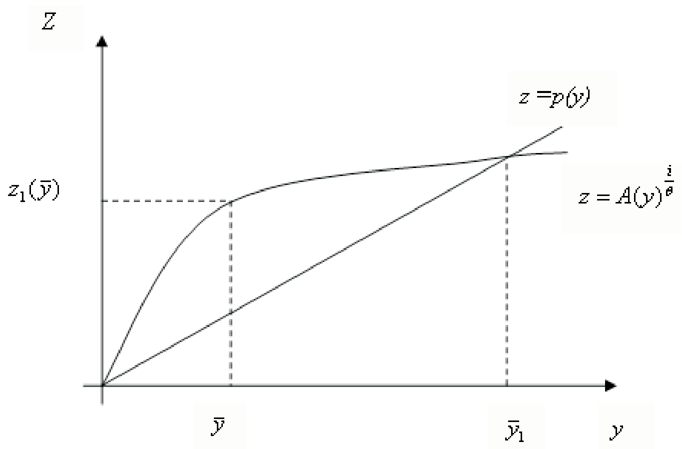

Fig. 4. Diagram illustrating profit dependence on the rate of production $|\theta > 1|$

Rys. 4. Wykres przedstawiający zależność zysków od wielkości produkcji $|\theta > 1|$

the necessary condition appears

$$\frac{\partial z(x)}{\partial x_i} = p\frac{\partial f}{\partial x} - v_i = 0,\ i = 1, \ldots, k \tag{17}$$

From this condition there is the conclusion, that the maximum exists only in one point.

Assuming that the $\bar{x}$ is the solution of the system (17), i.e.

$$p\frac{\partial f(\bar{x})}{\partial x_i} = v_i,\ i = 1, 2, \ldots, n \tag{18}$$

By multiplication each equation by $\bar{x}_i$ and therefore adding all of the equations of the system (18) up we get:

$$p \cdot \sum_{i=1}^{n} \bar{x}_i \frac{\partial f(\bar{x})}{\partial x_i} = \sum_{i=1}^{n} \bar{x}_i \bar{v}_i \tag{19}$$

The function $f(x)$ is homogenous of θ degree

$$f(kx_1, kx_2, ..., kx_n) = k^{\theta} f(x_1, x_2, ..., x_n) \text{ for } k > 0 \text{ and } x_k \in R_k^+$$

We differentiate with regard to k variable; consequently, we get:

$$\sum_{i=1}^{n} x_i \frac{\partial f(kx)}{\partial x_i} = \theta k^{\theta-1} f(x_1, x_2, ..., x_n)$$

we substitute $k = 1$; hence, we get the identity:

$$\sum_{i=1}^{n} x_i \frac{\partial f(x)}{\partial x_i} = \theta f(x) \tag{20}$$

Substituting (20) to (19) we get:

$$\theta p f(\bar{x}) = \langle \bar{v}, \bar{x} \rangle \tag{21}$$

As a result

$$\max\{pf(x) - \langle v, x \rangle\} = pf(\bar{x}) - \langle v, \bar{x} \rangle = pf(\bar{x}) - \theta p f(\bar{x}) = (1-\theta) p f(\bar{x})$$

In which $\bar{x}$ is the solution of the system (18).

Conclusion

Once raw materials are used and waste is created, the properties of the materials are not necessarily lost but can be restored using regenerative processes. Despite the fact that properties of the primary materials have been lost, the waste still carries both the subjective human work and energy used in its production. Differences between the properties of waste and those of primary raw materials are not substantial; many times these changes are only superficial. The reason is that primary raw materials often have not undergone fundamental changes during the production process. Secondary materials from consumption and production is not included in economic circulation until energy and materials have been extracted from it.

The basic criterion of every enterprise connected with using secondary materials (waste) as a substitute for primary materials is the economic profitability which determines whether to implement the enterprise or not. The utilization is not profitable if we only take into account the costs of collection, transportation, processing and the value of the secondary material obtained. We must consider the costs of output (production), processing of the raw materials and the energetic materials, environmental costs connected with this, installation building and exploitation of waste processing or building new landfills, storage and many indirect costs which are difficult to estimate (environmental costs).

According to what has been said, on the basis of the equations (3)–(8) the recycling plant dealing with secondary materials is able to make maximal profit by introducing the maximization of the production with the fixed costs of production. The profit $z_2(u)$, having the costs of the production given, is the increasing function for $0 \langle u \langle \bar{u} = (pB^{\theta})^{\frac{1}{1-\theta}}$ and reaches the maximal value on the right end of the interval. Then, the profit comes to $z_2(\bar{u}) = \bar{u}\,\frac{1-\theta}{\theta}$. $z_1(\bar{y}) = p\bar{y}(1-\theta)$. The second possibility of maximizing the profit of the plant can be achieved by minimizing the costs of the production while the volume of the production is fixed.

On the contrary, the profit $z_1(y)$ with y being the volume of the production is the increasing function for $0 \langle y \langle \bar{y} = \left(\frac{p\theta}{A}\right)^{\frac{\theta}{1-\theta}}$ and reaches the maximal value on the right end of the interval when the profit amounts to $z_1(\bar{y}) = p\bar{y}(1-\theta)$.

In conclusion, the issue of profit maximization of the recycling plant dealing with secondary materials has an unambiguous solution if the production function $f(x_1, x_2, ..., x_k)$ is homogeneous of θ degree $|0 < \theta < 1|$.

Achieving the maximal income by means of maximization of the production, having the costs fixed as well as minimization of the costs of production makes economic sense for $0 < \theta < 1$.

Considering the given analysis, we can state that if $f(x)$ function is the homogeneous one of θ. degree for |0 < θ < 1. and $B = \max_{\langle v_1, x\rangle = 1} f(x)$, $A = \min_{f(x)=1} \langle v, x\rangle$, appears there the condition: $A^{\theta} B = 1$.

It results from the optimal comparison of the profit in two ways: $z_1(\bar{y}) = z_2(\bar{u})$.

Poland does not have sufficiently good solutions on this field. The proposed mathematical model showing the profitability of the use of waste as a substitute for primary materials can help to analyse these processes.

Numerical example

$f(x_1, x_2) = x_1^{\frac{1}{4}} x_2^{\frac{1}{4}}$ the production function in which unit prices of the materials amount to q_1, q_2, whereas unit price of the production amounts to p will be discussed here

B parameter is determined:

$$B = \max_{q_1 x_1 + q_2 x_2 = 1} x_1^{\frac{1}{4}} x_2^{\frac{1}{4}}$$

Applying the so called Kuhn-Tucker method

We have: $L(x_1 x_2, \lambda) = (x_1 x_2)^{\frac{1}{4}} - \lambda(q_1 x_1 + q_2 x_2 - 1)$

Hence we get

$$\left.\begin{aligned} \frac{\partial L}{\partial x_1} &= \frac{1}{4} x_1^{\frac{-3}{4}} x_2^{\frac{1}{4}} - \lambda q_1 = 0 \\ \frac{\partial L}{\partial x_2} &= \frac{1}{4} x_1^{\frac{1}{4}} x_2^{\frac{-3}{4}} - \lambda q_2 = 0 \\ \frac{\partial L}{\partial \lambda} &= q_1 x_1 + q_2 x_2 - 1 = 0 \end{aligned}\right\} \quad (1)$$

After rearranging the system of equations (1) we get

$$\left.\begin{aligned} &\sqrt[4]{\frac{x_2}{x_1^3}} = 4\lambda q_1 \\ &\sqrt[4]{\frac{x_1}{x_2^3}} = 4\lambda q_2 \\ &q_1 x_1 + q_2 x_2 = 1 \end{aligned}\right\} \quad (2)$$

$\frac{x_2}{x_1} = \frac{q_1}{q_2}$, so $q_1 x_1 = q_2 x_2$

Dividing the first two equations of the system (2) by their members we have: $\frac{x_2}{x_1} = \frac{q_1}{q_2}$, consequently $q_1 x_1 = q_2 x_2$

$$2q_1 x_1 = 1,\ 2q_2 x_2 = 1$$

Substituting it for the third equation we get:

$$2q_1 x_1 = 1,\ 2q_2 x_2 = 1$$

Hence

$$x_1 = \frac{1}{2q_1},\ x_2 = \frac{1}{2q_2}$$

Therefore

$$B = \left(\frac{1}{2q_1} \cdot \frac{1}{2q_2}\right)^{\frac{1}{4}} \tag{3}$$

Substituting the expression (3) for $\theta = \frac{1}{2}$ to (7) and (8) we get:

a) $\bar{u} = \left[p\left(\frac{1}{4q_1 q_2}\right)^{\frac{1}{4}} \cdot \frac{1}{2} \right]^2 = \frac{p^2}{8\sqrt{q_1 q_2}}$ – these are the optimal costs of production,

b) $z_2(\bar{u}) = \bar{u}\,\frac{1-\frac{1}{2}}{\frac{1}{2}} = \bar{u} = \frac{p^2}{8\sqrt{q_1 q_2}}$ – it represents the profit when the optimal production is given.

The $\bar{u}$ sum needs to be invested in order to get $z_2(u)$ profit.

A parameter is determined:

$$A = \min_{(x_1 x_2)^{\frac{1}{4}} = 1} (v_1 x_1 + v_2 x_2)$$

Using the so called Kuhn-Tucker method

We have: $l(x_1 x_2, \lambda) = v_1 x_1 + v_2 x_2 - \lambda(x_1 x_2 - 1)$

Consequently, we get

$$\left.\begin{aligned} \frac{\partial l}{\partial x_1} &= v_1 - \lambda x_2 = 0 \\ \frac{\partial l}{\partial x_2} &= v_2 - \lambda x_1 = 0 \\ \frac{\partial l}{\partial \lambda} &= x_1 x_2 - 1 = 0 \end{aligned}\right\} \qquad (4)$$

We solve the system(4); after rearranging we have

$$\left.\begin{aligned} x_2 &= \frac{v_1}{\lambda} \\ x_1 &= \frac{v_2}{\lambda} \\ x_1 \cdot x_2 &= 1 \end{aligned}\right\} \qquad (5)$$

Substituting it for the third equation $\frac{v_1 v_2}{\lambda^2} = 1, \ \lambda = \sqrt{v_1 v_2}$

We get $x_1 = \frac{v_2}{\sqrt{v_1 v_2}}, \ x_2 = \frac{v_1}{\sqrt{v_1 v_2}}$

Hence

$$A = v_1 \frac{v_2}{\sqrt{v_1 v_2}} + v_2 \frac{v_1}{\sqrt{v_1 v_2}} = 2\sqrt{v_1 v_2}$$

As a result

a) $\bar{y} = \frac{\frac{1}{2} p}{2\sqrt{v_1 v_2}} = \frac{p}{4\sqrt{v_1 v_2}}$ – it is the optimal production

b) $z_1(y) = p \frac{p}{4\sqrt{v_1 v_2}} \left(1 - \frac{1}{2}\right) = \frac{p^2}{8\sqrt{v_1 v_2}}$ – it accounts for the profit.

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EFEKTYWNOŚĆ EKONOMICZNA WYKORZYSTANIA SUROWCÓW WTÓRNYCH JAKO SUBSTYTUTU SUROWCÓW MINERALNYCH

Słowa kluczowe

odpady, recykling, koszty, warunki ekonomiczne, funkcja produkcji

Streszczenie

Koszty związane z wykorzystaniem odpadów jako substytutu surowców pierwotnych zależne są od wielu czynników. W pracy rozpatrzymy funkcjonowanie zakładu w zależności od: kosztów inwestycyjnych, jednostkowego kosztu ekologicznego recyklingu odpadu [zł/Mg], jednostkowego kosztu przetworzenia 1 Mg odpadu jako surowca wtórnego [zł/Mg], kosztu sprzedaży uzyskanego produktu, udziału masowego uzyskanego substytutu z masy odpadów, jednostkowego kosztu społecznego [zł/Mg] uwzględniającego między innymi aspekty powstawania nowych miejsc pracy, itp., ilości pracy przeznaczonej na produkcję w ustalonych jednostkach, koszty stałe oraz ilości przerobionego surowca (odpadów). Czynniki te będą rozważane dwoma sposobami: a) Maksymalizacją produkcji przy ustalonych kosztach produkcji, b) Minimalizacją kosztów produkcji przy ustalonej wielkości produkcji.

Na świecie stworzono wiele prac zmierzających do określenia opłacalności ekonomicznej jak i ekologicznej wykorzystania odpadów jako substytutów surowców pierwotnych. Niestety w Polsce, do tej pory nie opracowano dostatecznie dobrych rozwiązań w tym zakresie. Brak takich opracowań utrudnia pracę zespołów specjalistów z różnych dziedzin w racjonalnym planowaniu przebiegu procesów recyklingu. Proponowany model może pomóc w analizie opłacalności wykorzystania odpadów jako substytutów surowców pierwotnych.

ECONOMIC PROFITABILITY OF THE SECONDARY MATERIALS UTILIZATION AS A SUBSTITUTE OF RAW MATERIALS

Key words

Waste, recycling, costs, condition, production function

Abstract

The costs connected with utilizing secondary materials (waste) as substitute of the raw materials depend on many factors. In this paper, the emphasis is put on the functioning of the plant depending on: capital costs,

ecological unit cost of waste recycling [zł/Mg], unit costs of processing 1 Mg of waste into secondary materials, marketing costs of the obtained product, mass fraction of the substitute obtained from the waste mass, social unit costs [zł/Mg] taking into account such aspects as creating new workplaces, etc., amount of work allocated for the production in fixed units, fixed costs and the amount of the processed raw material (waste). The factors will be considered in two ways: a)maximization of the production with the costs of production fixed, b)minimization of the costs of production with the volume of production fixed.

Much research has been done throughout the world to determine the economic and ecological profitability of secondary materials (waste) utilization in the substitution of raw materials. Unfortunately, Poland does not have sufficiently good solutions on this field. The deficiency in such solutions impedes the work of groups of specialists in various fields involved with the rational planning of recycling. These are the result of our mathematical model of economic profitability of the secondary materials (waste) utilization as the substitute of primary materials, at the moment no empirical analyses have been carried out on this issue. We think that it might be a good topic for further applied studies.