ACTA UNIVERSITATIS AGRICULTURAE ET SILVICULTURAE MENDELIANAE BRUNENSIS

Volume LXI 318 Number 7, 2013

http://dx.doi.org/10.11118/actaun201361072843

MULTI-CRITERION ANALYSIS OF THE RISKS INVOLVED IN A BIOGAS PLANT IN RELATION TO THE STRUCTURE AND SOURCES OF BIOMASS AND ITS APPLICATION IN AGRICULTURAL COMPANIES

Jitka Šišková

Received: April 26, 2013

Abstract

ŠIŠKOVÁ JITKA: *Multi-criterion analysis of the risks involved in a biogas plant in relation to the structure and sources of biomass and its application in agricultural companies.* Acta Universitatis Agriculturae et Silviculturae Mendelianae Brunensis, 2013, LXI, No. 7, pp. 2843–2850

The dynamic development of the conditions in which society lives at present results in changes in the economic, legal, political as well as social environment. These changes are reflected not only in government policies, but also, consequently, in the individual building blocks of national economy, i.e. in businesses, where they lead to adjustments in technological processes in production, as well as in the approaches and tools used in decision-making and management. This factor has been largely neglected or underestimated in economic analyses at the present time. The structure of residues and of the source factors of a number of waste substances in crop farming and animal husbandry can have a significant effect on economic profitability of the functioning of a biogas plant and its output. The objective of this paper is to propose, in general terms, a new multi-criterion model of cost accounting applicable in successive systemic steps at the level of businesses. The model put forward herein will make it possible to assess the environmental practices of business entities, to make comparisons thereof at society-wide (regional or national) level and, as a result, to obtain tools for influencing and regulating deviations from an optimum interaction of interrelated systemic social factors.

multi-criterion analysis, records-keeping and accounting system in a business unit, environmental activities, management processes, biogas plants, sustainable development

The dynamic development of the conditions in which society lives at present results in changes in the economic, legal, political as well as social environment. These changes are reflected not only in government policies, but also, consequently, in the individual building blocks of national economy, i.e. in businesses, where they lead to adjustments in technological processes in production, as well as in the approaches and tools used in decision-making and management. Until now, it was accounting – financial and/or interdepartmental – that served as the basis of source information (Hájek, 2011). The new requirements call for a more comprehensive approach based on feedback links within companies that make it possible to carry out operative interventions and changes in the structure of production processes according to the current inputs and outputs in the company as they change in the course of time, depending on the development of the company.

Environmental protection is a very current issue that needs to be addressed. Environmental policies, as the instruments of its application, reflect the conflict of interest among the three areas involved here, i.e. among the economic, social and environmental factors (Hřebíček *et al.*, 2011).

Bringing these three pillars into a proper correlation is the only way of maintaining and preserving the environment in good shape for future generations without imposing restrictions on the needs of the present generation, which means adhering to the principles of sustainable development of society. Application and implementation of the required environmental activities in production processes will inevitably have an impact on management and organization structures in individual businesses (Hyršlová *et al.*, 2005). Interconnection between decision-making processes and the company's records and accounting data is a principal starting point for directing the tools of management at the present time not only within individual production businesses but also at the national or pan-European levels.

The interrelation between the three areas mentioned above – records-keeping and accounting systems, decision-making processes in business units and influences resulting from environmental activities – becomes a subject of interest in economic and organizational systems and their adjustment to the contemporary condition of society, because only production activities embracing the interaction among the three areas guarantee a trend of sustainable development of society (Remtová, 2006).

What has been missing is a decision-making model for records-keeping in relation to cost and material flow in business units that has a major impact on the social functions of the environment (Paras, 1999). A multi-criterion model closely linked to the records-keeping and accounting procedures in business units would significantly facilitate the management and decision-making processes in individual companies as well as in the society-wide context at the level of public administration; at the same time, such model would provide for balance among the influences of the economic, environmental and social pillars of the society's development.

MATERIALS AND METHODS

The objective of this paper is to propose, in general terms, a new multi-criterion model of cost accounting applicable in successive systemic steps at the level of business units designed to grasp, at the given time and in specific terms, environment-related developments in close interrelation to the material and energy flow in a business unit. The model put forward herein will make it possible to assess the environmental practices of business entities, to make comparisons thereof at society-wide (regional or national) level and, as a result, to obtain tools for influencing and regulating deviations from an optimum interaction of interrelated systemic social factors. The model will be constructed on the basis of a thorough analysis of systemic feedback influences in the chosen business unit; a selection of the necessary indicators with a definition of their relevant comparative weight will provide the basis for a multi-factor analysis of mutual systemic influences. Unification and standardization of the results thereof will make it possible to transform a model situation into a formula for universal use in business units.

The initial construction of a multi-factor model will be derived from an evaluation, based on objective methods of multi-criterion analysis, of the principal alternatives of the decision-making process for comprehensive use of available soil in relation to the utilization of primary and secondary resources from classical crop farming for a biogas plant as a modern source of renewable energy, while residual impacts on the stability of the agricultural system and on the principle of sustainable development of society would be kept to a minimum

The result will be a hybrid model information system created through interconnection of the information (records-keeping and accounting) system in a business unit and a variant decision support system (VDSS).

RESULTS

The systemic approach to the chosen analysis of a technological process of the selected environmental operation – a biogas plant – rests upon several areas linked to one another. The starting analysis should include a sufficiently detailed audit of the general economic, environmental and social influences that, in the area of their interaction, generate the actual performance effect; its function represents the interval level factor of the possible development of the chosen issue.

In the pursuit of a solution of the selected problem, it will be of interest to observe the interval level factor of possible development, because the actual performance effect is a function of

$$W(ef) = (s, Q, k)$$

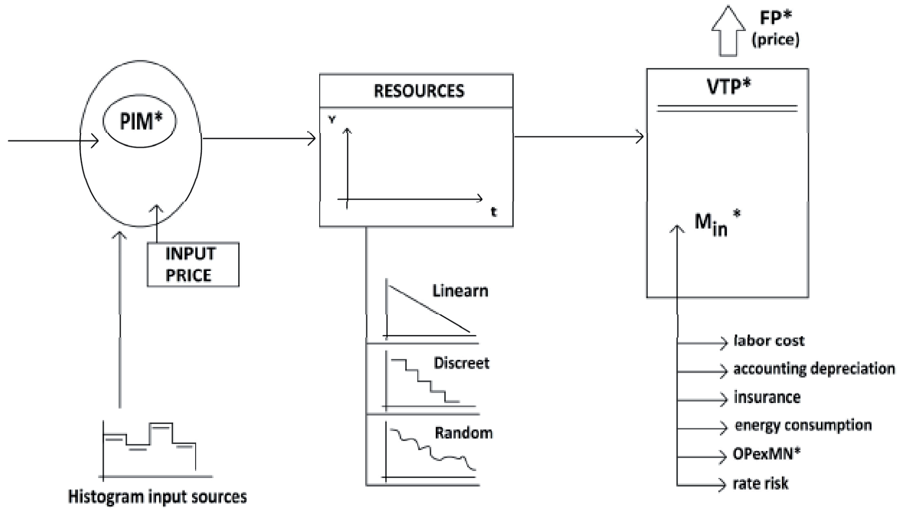
parameters that find themselves at the intersection of the following sets:

M_1 – vector of the structure of available biomass = s
M_2 – quantity of available biomass = Q
M_3 – coefficient of permeability, utilizability; qualitative coefficient (source production effect) = k.

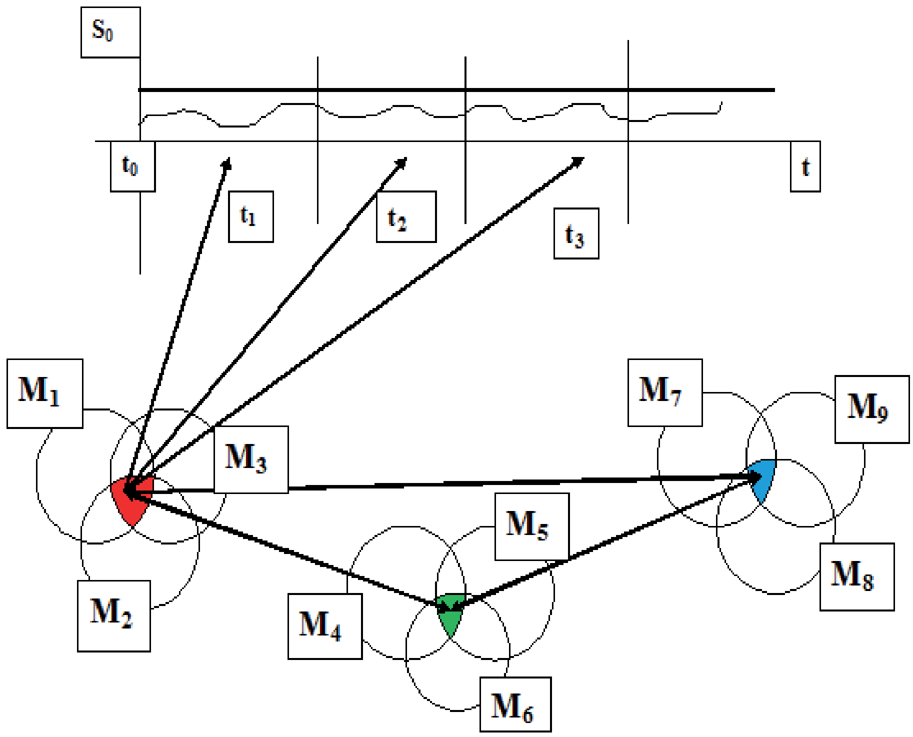
The function of intersection of the aforementioned systems fluctuates in the course of time (being dependent on intervals of varying duration in the course of a year).

The interval level factor of the performance effect is further affected by other instances of interaction among systemic influences of the selected technology (biogas plant).

M_4 – natural climatic conditions
M_5 – intensity of production
M_6 – structure of residual influences
M_7 – the technical and technological factors in the use of biomass (the loss and cost factors).



1: *A scheme of a systemic approach to a section, supported by objective quantification, of the examined system of the operation of a biogas plant*
Legend:
PIM – Insertion of input material; VTP – Production & technological process in a biogas plant; FP – Final product (heat, electrical energy); M_{in} – set of input costs; $OP_{ex}MN$ – other direct external material costs
(Source: author)



2: *Intersections of the interconnected influences bearing upon the performance effect of a biogas plant and its dependence on development in the course of time*
(Source: author)

M_8 – production costs (relations and links to the accounting system of a business unit)
M_9 – the stock-keeping theory – the Wilson model.

The initial scheme of the intersections of the performance effect of a biogas plant will be followed by an analysis of the structural material and economic flows in the system of the chosen business entity.

Alternatives of the behaviour of material flows:
a) continuous operation – linear decline;
b) non-linear – in the event of non-homogeneity of material;

c) progress in clearly delimited leaps - discreet behaviour under relatively constant conditions in the operation of a biogas plant;
d) progress in leaps, varying in both time and quality – varying intervals.

Alternative approaches to records-keeping and analytical accounting in a business unit:

a) exact – item quantification;
b) interval-based – in a certain period of time – in relation to the function of quality. In the given interval, there is a rectangular (equable) division, every value has a constant probability P(i). As the variability of biomass is high, these occurrences are rather rare;
c) introduction of the Gauss function, with a low value and a high value of the interval and a median (μ) – the determining deviation and spread will define the measure of dependence of the spread around the median (μ);
d) interval chart (finite number of intervals $I_1, I_2 \dots I_n$; finite number of parameters $P_1, P_2 \dots P_n$);
e) the Markov matrix – stochastic transfers between conditions.

This structure will be implemented into a starting multi-factor model of a structural section of the economic behaviour of a biogas plant consisting of an initial matrix quantifying the interrelations within the system that expresses the function

$$Y = f(S_{Si,j}).$$

Chart 3 demonstrates that it is necessary to distinguish between the following types of interrelations:

- relations quantified in retrospect
- quantified relations of mutual influences in the system
- forbidden relations.

To achieve the desired linkage to the records-keeping and accounting system of a business unit, it is necessary to supplement the aforementioned relations with a structure of primary factors – source accounts generated in the accounting systems of business units:

- labour costs (wages plus social security and health insurance of employees);
- depreciation (according to the business unit's depreciation standards);
- other input costs of the technology (electrical energy, chemical substances; methane bacteria, etc.);
- direct external material costs (fuel, material, services, repairs, etc.);

other financial expenses (fees, interest paid on loans, insurance premiums, etc.).

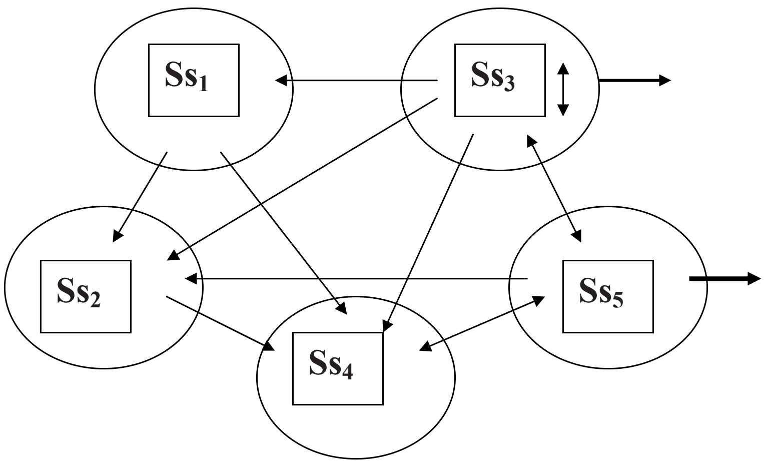
Last but not least, it is also necessary to consider the actual cross-section of the selected business unit in relation to the interrelations between input materials, the chosen processing technology (biogas plant) and the output product (electrical energy, heat).

Inside every plant, there is room for possible adaptability depending on the available technology; this room for adaptability is dependent on (is a function of) two principal technological sets, M_1 and M_2, where

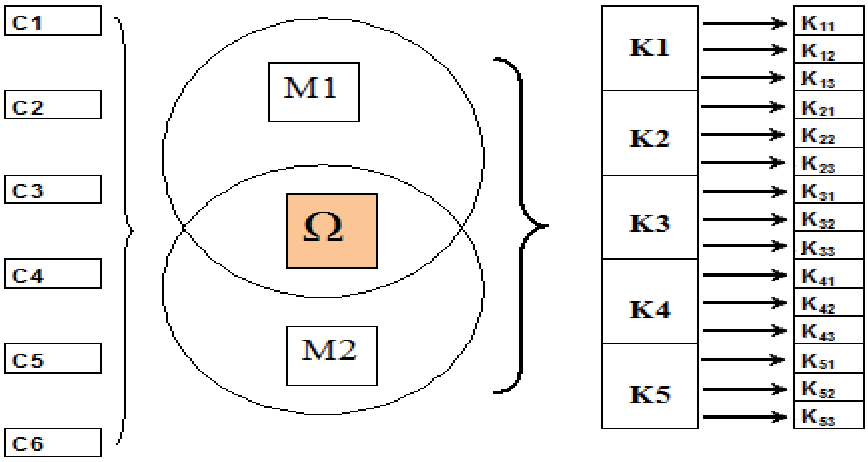
M_1 means the technology as such; and,

M_2 means availability of input materials.

The input factors are a function of the concrete assessment of the stability of the production system



3: *Structure of material and economic flows in the system of a biogas plant*
(Source: author)
Legend:
S_{S1} – structure of input materials
S_{S2} – stock (input material)
S_{S3} – auxiliary operations in a business unit
S_{S4} – technology of the operation of a biogas plant
S_{S5} – realized output (electrical energy, heat).



4: *Systemic scheme of the selection of multi-criterion standards in the operation of a biogas plant within an agricultural business unit*
(Source: author)

in the given period of time. Thus, we can proceed from the

$$C_{imp} = f(x) \times (P_{ij})$$

formula where e.g. corn straw is determined by the function of natural and climatic conditions and of the variety:

$$P_i = (P_{kp} \times P_{odr}).$$

For every material $m_1, \ldots, m_n$, we can determine the vector of input characteristics. It logically follows that the resultant transformation function

$$Y = f(XQ_z, XS_z)$$

is a function of the structure of the input biomass XQ_z in volume proportions, but also a function of the structural characteristics of the biomass XS_z in relation to key criteria, especially the content of carbon and the capability of acceptance and utilization of methanogeneous bacteria in the chosen technological process.

Chart 4 demonstrates that the actual production area, Ω, is the intersection of two sets, M_1 and M_2. Within this area, it is possible to use a number of input materials, with a high degree of variability:

1. grain straw
2. rape-seed straw
3. maize biomass
4. litter from animal farming
5. waste 1 – from animal farming
6. waste 2 – communal produce.

Not every input material is suitable for the given technology, nor does every material represent an optimum solution from the economic point of view. Every input has a price (C_1 – C_6); moreover, there are also the costs of logistics in the process (transportation, storage, etc.).

The Ω set is classified on the basis of 5 groups of grading comparative criteria:

K_1 – AT (adaptability of the technology, i.e., its ability to adjust to the variability of input material),

K_2 – N (the cost factor) – directly related to the accounting data (Profit and Loss Statement),

K_3 – COP (price of the output produce) – electricity, heat – appraised in relation to the output of the biogas plant with regard to the varying costs in different periods of time (this is a stochastic criterion because it is a function of the source structure of the costs and the economic appraisal of the output within the framework of the stability of the national economic system),

K_4 – PS (operating reliability) – the criterion of the efficiency effect that represents the correlation to the technological and technical installations and the possibility of elementary or derived (subsequent) failures of the technical facilities,

K_5 – E (the environment criterion) that includes:

a) environment-friendly technologies,
b) minimization of exhalations entering the air,
c) processing of waste biomass.

For the purposes of a multi-criterion analysis, it appears relevant to divide each of the groups of the aforementioned criteria into three sub-groups, i.e. to define individual sub-criteria within the context of the overall analysis.

The assessment of the principal relations and their mutual influences in the examined entity results in the application of a multi-criterion analysis (MCA) for which we have to choose an optimum number of the evaluated criteria. The number of criteria is a highly variable factor that can be easily adjusted to the current needs and conditions. Choice of a sufficient number of criteria is a basic pillar of statistical trustworthiness of the obtained results. Several basic situations can arise in the process of selection of the criteria to be analyzed:

a) the number of the chosen criteria is too small. This can result in a significant criterion being neglected, which distorts the output data;
b) the number of criteria is appropriate – this is the optimum situation;
c) the number of the chosen criteria is too high. In such case, the individual weight of the assessed criteria is reduced and their impact on the decision-making level is diminished. There can also be instances where the chosen criteria partly overlap, which significantly distorts their effect on the output data. Such redundant criteria must, therefore, be excluded from the decision-making process.

Systemic explanation of the selection of criteria:

In a comparative analysis, the choice of the number of criteria is of major significance. With a number below 10, there is the problem of insufficiency in the assessment of the examined area of decision-making and the possible alternatives for the purposes of a systemic analysis. On the other hand, using more than 25 criteria leads to a dilution of the crucial effect of these criteria and of the evaluation of their actual comprehensive systemic weight in the context of the stability of the analyzed systems.

Definition of the chosen criteria of a multi-criterion analysis:

K_1: NAIP – measure of adaptability to the input products
K_2: CPK – overall production capacity
K_3: InN – capital expenditure
K_4: NRP – annual operating costs
K_5: PkVV – ratio coefficient of the variability of the output (electrical energy, biogas)
K_6: kME – coefficient of the energy produced per unit of input (kWh, J)
K_7: N/J_{ME} – cost per unit of energy as defined above
K_8: MPE – maximum annual production effect
K_9: $P_{(i)}S$ – probability of the stability of the production
K_{10}: $P_{(i)}VZ$ – probability of generation of supplies of biomass (optimistic, standard, unfavourable year)
K_{11}: TAP – technology adaptability coefficient
K_{12}: RE – residual effects
K_{13}: ORZ – expected annual profit.

From the theoretical point of view, there are two types of problems:

a) by nature of the criteria: whether the given criterion is maximizing or minimizing;
b) whether there is full comparability among the individual criteria, i.e. whether they carry the same weight in the target effect.

In reality, the individual criteria do not carry the same weight because there are criteria ranking higher or lower both as regards decision-making processes in businesses and as regards strategic management within the European Union, especially in the field of the environmental protection aspects that cannot be explicitly valued within the framework of the records and accounting systems of business units.

When defining the weight of the criteria, it is important to identify whether we prefer a so-called primary or dual system of possible solutions, which occurs fairly often in the field of renewable energy resources.

The primary approach is based on the principle of a limited factor set of available resources, within which there is a limited number of factor-oriented alternatives based on technologies that – given the limited set of resources Ω (sources of biomass usable for energy production) – can be compared from the viewpoint of the targeted production effect represented beyond doubt by the measure of profitability of the operation of individual technologies.

The dual approach to the problem starts from the premise that we possess a relatively open set of available factor resources, i.e. those generated through processing of by-products of crop farming and animal husbandry, communal waste, overburden of soil and other components of biomass, to be able – with the chosen number of technological alternatives V_1-V_4 – to minimize the possibility that these resources might be left unutilized.

From the viewpoint of mathematical theory, it can be proved that the objective relationship between the primary and the dual principles can be clearly derived through a synthetic comprehensive model of the application of factor sources into synthetic output of simulated production.

For the aforementioned reasons, the method used here will be a focused expert quantification of the scale evaluation based on the Fuller Triangle within the meaning of objectively defined criteria.

The principle of the Fuller Triangle consists in binary relations between the K_i and K_j criteria (K_i/K_j), in defining the relationship between criterion *i* and criterion *j*.

The following multi-criterion analyses (MCAs) will be used for the resulting comparative analysis of selected biogas plants:

1. The AGREPREF method
2. Weighted aggregate
3. TOP SYS
4. ORESTE
5. MAC PAC
6. PROMETHEE.

CONCLUSIONS

With society progressing toward an environment-oriented approach and toward bringing production processes in individual businesses into line with society's interests, we witness a tendency to balance and adjust the basis of information in relation to decision-making and managerial activities. This subject has been dealt with by a number of authors in their papers on environment-oriented cost accounting, corporate reporting and environmental management (Hřebíček *et al*., 2011; Zimmermannová, 2011). By the same token, application of environmental policies into management processes needs to be supported by a unified information and records system based on environment-oriented accounting whose ongoing development has been described by authors for more than 10 years (Remtová, 2006; Grzebieluckas *et al*., 2013). As a result of ongoing developments and the need for changes in the factors of evaluation, accounting systems in businesses are beginning to be adjusted as well, embracing the concept of accounting oriented on sustainable development that must respond to the requirements stemming from the tools of environmental policies and their application into managerial systems in agricultural businesses (Šauer *et al*., 2012). The aforementioned topics are closely connected with the theme of voluntary environmental activities that are introduced more and more often into production processes with a view to keeping track of, and diminishing, externalities in the environment (Hájek, 2010; Andreoli *et al*., 2000; Haščič, 2012; Nasir *et al*., 2012).

Introduction of environmental activities and their linkage to environment-oriented accounting related to the implementation of environmental policies is, however, impeded by insufficient systemic analysis of the respective technologies not only within a business unit but also in relation to the environment. This is the area where there is a need for systematic model structures that will make it possible to apply a well-founded systemic approach in managerial decision-making.

Construction of biogas plants not only generates significant economic benefit to business entities but also, inherently, brings with it fundamental changes in the requirements concerning the structure of the production. The operation of biogas plants necessitates major structural adjustments in the production process, especially in crop farming (sowing patterns), but also in the structure of residual factors, i.e. in processing waste from existing animal farming, etc. Until now, this factor has been largely neglected or underestimated in economic analyses. The structure of the residues and of the source factors in a number of waste products in both animal and crop farming can represent a significant contribution to the overall economic profitability of the operation of a biogas plant and its output. The crucial points in this context are the structure of the concept and substitution of the structure of input factors in the operation of biogas plants and their proper assessment and incorporation into the records and accounting systems of the respective business unit.

The proposed model multi-criterion analysis addresses an entirely new, hitherto untackled problem of a systemic approach in corporate records-keeping and accounting systems; it is designed to assist, in the contemporary context, in the decision-making processes at the basic level of individual business entities but also in the evaluation at society-wide level of the introduction of new environmental activities, which is a process involving a great amount of time as well as substantial systemic requirements. Its proper application would prevent ill-conceived actions in the course of introduction of new, untested environmental activities, such as the improper evaluation of the expenditure factors of photovoltaic plant projects which, as a result of unsound legislation passed by the Parliament of the Czech Republic, will in the long term burden every citizen with expenses reaching hundreds of thousands of Czech crowns, and incur costs in billions of Czech crowns for the Czech Republic's budget. The proposed model approach is variable as regards both the timeframe and the criteria and its application would facilitate the decision-making processes in environmental policies leading to a sustainable development of society.

SUMMARY

The dynamic development of society at the present time is reflected in changes in management processes and, consequently, also in the instruments that can make it possible to carry out operative interventions in production structures in the context of the society's sustainable development. A model of decision-making relating to the cost and material flow would significantly facilitate management processes in individual business entities as well as at the society-wide level of public administration. The paper presents a proposal of a basic systemic analysis of the technological process of a selected environmental activity – a biogas plant – in an agricultural business. Employing a detailed audit of the related economic, environmental and social influences, it provides for the application of a multi-factor analysis of significant criteria/values. The starting point in the solution of the problem was the interval level factor of the possible development, determined by the function $W(ef) = (s, Q, k)$ where: s = the structure of the available biomass, Q = quality of the biomass, and k = the usability coefficient. The initial system is enhanced by an analysis of the structural and material flows in a business entity that will be implemented into the model of a structural section of the economic behaviour of a biogas plant, where the interrelations express the function $Y = f(S_{Sij})$. Last but not least, the analysis will embrace the relationship between the chosen technology and the input materials, which are determined by the function $C_{imp} = f(x) \times (P_{ij})$, where $P_i = (P_{kp} \times P_{odr})$. The resulting transformation of the function $Y = f\,(XQ_z, XS_z)$ is determined by the structure of the available biomass

and its volume. The aforementioned analysis demonstrates that the actual production area Ω is an intersection of the influences of the actual technology and availability of input materials. The analysis of the principal influences and their interrelation will be the basis for a multi-factor analysis, with an optimum number of the considered criteria being chosen for the purpose The proposed model represents an entirely new, hitherto untackled systemic approach that could facilitate decision-making processes in the course of the introduction of new environmental activities both in individual businesses and at society-wide level.

Acknowledgement

This paper has been written with the support of the internal grants agency of the Faculty of Economics and Management, Czech University of Life Sciences Prague, IGA PEF 20121071: Model of Cost Accounting and Its Application in Agricultural Businesses.

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Address

Ing. Jitka Šišková, Ph.D., Department of Trade and Accounting, Faculty of Economics and Management, Czech Univerzity of Life Sciences in Prague, 165 00 Praha 6 – Suchdol, Czech Republic, e-mail: siskova@pef.czu.cz