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Risk and uncertainty in the production of energy plants

Marcin Rabe

University of Szczecin, Center for Energy Management, POLAND
e-mail: marcin.rabe@wzieu.pl

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Abstract

The study is devoted to the presentation of the concept of risk and uncertainty accompanying the production of energy crops. The problem with risk assessment and uncertainty is often the difficulty of expressing them in numerical terms. In order to avoid risk and uncertainty, it is necessary to set the criteria and objectives of the activity before proceeding with energy crop production planning. The aim of the study is to try to provide this gap, using energy plants for planning in any area. Multicriteria methods minimize the risk of plant production for energy purposes. If we can not determine the probability of occurrence of certain phenomena and their inclusion in the model, we are not able to determine how well the solutions resulting from the models are accurate and what is the probability of their implementation in the specific conditions of the farm. The research material in the article is taken from many sources, both domestic and foreign, including Empirical data from Eurostat, OECD and GUS, scientific institutes of energy and fuels, regional energy institutions.

Introduction and literature review

Currently, the risk and uncertainty is connected with the most fundamental aspects of psychology, mathematics, statistics and history. The term of risk and uncertainty goes hand in hand with economic problems for a very long time, although the theory of economics did not address this issue. It was not until Knight (1921, pp. 3–4) applied the concept of risk and uncertainty to economics. Risk means a situation in which we know the probability of occurrence of various economic results that can be obtained. If such a result is not known, then we are dealing with a state of uncertainty. This situation means that the expected result can be obtained, but you can not say anything about the probability concept of this event.

The risk of colloquial use is quite ambiguous, often defined by the authors. Every now and then it is identified directly with the probability and magnitude of the loss. The natural course of these two concepts is the creation of the product of probability and the size of the potential loss (Tyszka, 1986, pp. 106–114). It means so-called Expected loss, a term known to economic statistics.

The current approach to cultivating energy crops involves considering risks and uncertainties from the point of view of an agricultural holding operating in a competitive environment. Competition in this context consists in cultivating energy plants by an agricultural holding and gaining an advantage over commercial agricultural production, which will allow to achieve a competitive market advantage over other alternative energy sources, such as solar energy, wind energy, hydropower, geothermal energy. (Bieńkowska-Gołasa, 2016, pp. 72–80)

The analysis of competition in relation to alternative energy sources, including agriculture, is the basis for strategic planning and operation of farms that want to develop a strategy of operation that enables building and maintaining competitive advantage on the market of alternative energy sources. One of the instruments supporting the implementation of the farm operation strategy is risk management and uncertainty occurring in business operations. These proceedings are aimed at securing a certain level of farm income, inter alia by planning the production of energy crops, and above all reducing risks and uncertainties in the future period (Kowalski, 2018, pp. 117–128).

In the methods of supporting decision-making in the production of energy crops, attention must be paid to the problem of decision selection and energy production planning as well as the associated risk and uncertainty. Each decision sometimes has very far-reaching consequences, and its consequences are often very complex. In the case of choosing the optimal variant in planning production of energy crops, the choice must be multi-faceted, taking into account various problems. When assessing production options for energy crops, you can not rely only on the financial analysis of the investment, and also consider important issues such as environmental aspects (ecological costs, loss of soil fertility), agroenergetic aspects, technological aspects, organizational aspects or social aspects, which are associated with risk (Rosa, 2017, pp. 93–102).

The decision about choosing the variant of the project implementation in planning the production of energy crops also requires examining the options in terms of their positive and negative impact. Positive aspects include benefits and opportunities, while the negative are elements related to costs, risks and uncertainty. The problem with the assessment of these aspects is often the difficulty of expressing them in numerical terms. For example, some of the benefits are qualitative, at least environmental or risk elements (Sobczyk, Wota, Krężołek, 2011, pp. 34–39).

The decision is often an accidental or purely intuitive choice, not supported by any analysis or strategy planning. To avoid errors and random selection, it is necessary to set the criteria and objectives of the action before planning a decision support model to reduce the risk and uncertainty. Therefore, goals can have many different characters:

- competitive goal – when increasing the value of one of the objectives reduces the implementation of the other, e.g. maximizing profit and increasing its risk,
- conjugated goals between which there is a relationship where progress in achieving one goal is accompanied by the increase of the other,

– complementary goals that support each other,
– supplementary aims – independent of each other, reducing or increasing the implementation of one does not affect the size of the second goal (Malicki, 1999, pp. 44–45).

The described relationships between particular goals are not permanent. Some of them may go into the second, depending on the size of energy plant production. Objectives can also be complementary, i.e. complement each other in the use of one factor of production, while at the same time competing with each other for a different factor (Perloff, Rausser, 2016, p. 266).

The character of relationships between particular criteria is difficult to determine and are risky. Their shaping can be observed only in the process of optimizing the mathematical model of planning decision support in the production of energy crops.

The task in planning the model is to construct such a production plan that would maximally achieve individual goals in accordance with its preferences and be competitive with other alternative energy sources.

Creating a model that takes into account the rare risk and uncertainty is accompanied by reflection on their theoretical foundations. The problem with risk assessment and uncertainty is often the difficulty of expressing them in numerical terms. In order to avoid risk and uncertainty, it is necessary to set the criteria and objectives of the activity before proceeding with energy crop production planning. The aim of the study is to try to provide this gap, using energy plants for planning in any area. Multicriteria methods minimize the risk of producing plants for energy purposes.

Methods

The research material is taken from many sources, both domestic and foreign, among others Empirical data from Eurostat, OECD and GUS, scientific institutes of energy and fuels, regional energy institutions. The research methodology has been adapted to the purpose of the article. To realize the formulated goal in the article, the following research methods were applied:

1. Analysis of the literature on the subject, allowing to achieve cognitive and research goals.
2. Multicriteria methods of the energy optimization model minimizing the risk of plant production for energy purposes, with the use of several objective functions.
   – minimization of energy production costs,
   – maximizing the level of energy plant production,
   – minimization of adverse impact of production on the natural environment (soil fertility).

When developing models supporting decision making in the production of energy crops, it is also important to examine various types of technologies that may appear in the system. They should be assessed in relation to specific conditions, such as investment accessibility. Thus, determining the optimal set of techniques that will be included in the model requires some calculations that will be used to build a model of alternative energy sources, where the production of energy plants will be competitive to other energy carriers.

In this method, functional $fj(x)$ are ordered according to the hierarchy defined by the decision maker, and then optimized in sequence. If mi = max$D$ $fi(x)$, then function fi + 1 is maximized on the set Di with an additional constraint added in the form $fj(x) > mi - di$. The lexicographic method has a simple interpretation and requires arbitrary selection of acceptable deviations from the value. These deviations are determined by the decision-maker during the optimization process. The optimization process itself is carried out sequentially according to a set order, starting with a function with the highest hierarchy of validity. When maximizing further functionalities, additional limitations are imposed on functional ones already optimized. The extreme of the last functional, with all additional restrictions, is a sought-after compromise solution (Malicki, 1999, pp. 44–45).

A mathematical description of the procedure can be presented as follows. Let *fi*, ..., *fr* be the considered functions set by the decision-maker according to decreasing importance gradation, and let *X* be the starting decision space $Ax < b$, $x > 0$, with $D0 = X$. We calculate:

$$L_1 = \max f_1(x) = f_1(x_1).$$

The production plan matrix and the calculation program can be constructed in such a way that the values of all *fi* – functional devices (xi) for $i = 1, ..., r$ in the first solution *x*1 are obtained simultaneously. If the solution *x*1 and the value *fi*(*x*1) satisfy decisively, then the procedure can be completed in the first step. It is impossible to obtain a higher value of the function, under the assumed production conditions.

If this value is too small, you have to go back to the earlier stages of the procedure, making adjustments to the assumptions.

If *f*1(*x*1) is satisfactory, but the values of other functionalities are unacceptable, the decision-maker returns to the previous stage or determines the amount *d*1, which is willing to reduce *l*1 to get a better solution due to other criteria. When *d*1 is specified, we designate:

$$D1 = \{x\ e\ D_0 : f1 > f1 - d1\}.$$

Creating this set consists in adding an additional constraint *f*1 > *f*1 – *d*1 to the existing model constraints. Then we calculate $L2 = \max f2(x) = f2(x2)$, obtaining at the same time the values of *f*1(*x*2) for $i = 1, ..., r$. The following restriction is fulfilled:

$$fi(x_2) > 1 - d1.$$

If the solution is satisfactory, the procedure ends, if not, the procedure is the same as for function *f*1. We revise the assumptions or determine the deviation *d*2, which we are willing to reduce *l*2. In the latter case, we create a set:

$$D_2 = \{x\ e\ D1 : f_2 > f_2 - d2\}.$$

We continue this procedure until a satisfactory solution is reached or all functionalities are exhausted. If the final solution does not meet the decisions of the decision maker, it is necessary to repeat the procedure with other initial assumptions or another selection of dit deviations, deciding to reduce the assumed threshold values of certain functionalities (Heady, 2015, pp. 274–281).

The basic features of this method are:

- a clear interpretation of the solutions obtained,
- the possibility of including more functionalities than in other multicriteria methods, no need to consider substitutability of particular criteria,
- the possibility of using it for large optimization tasks, the possibility of considering various types of criteria in the task: linear, quotient, non-linear,
- dialogic nature allowing to continue the procedures until a satisfactory user's compromise solution is obtained (Lewandowski, 2010, pp. 16–18).

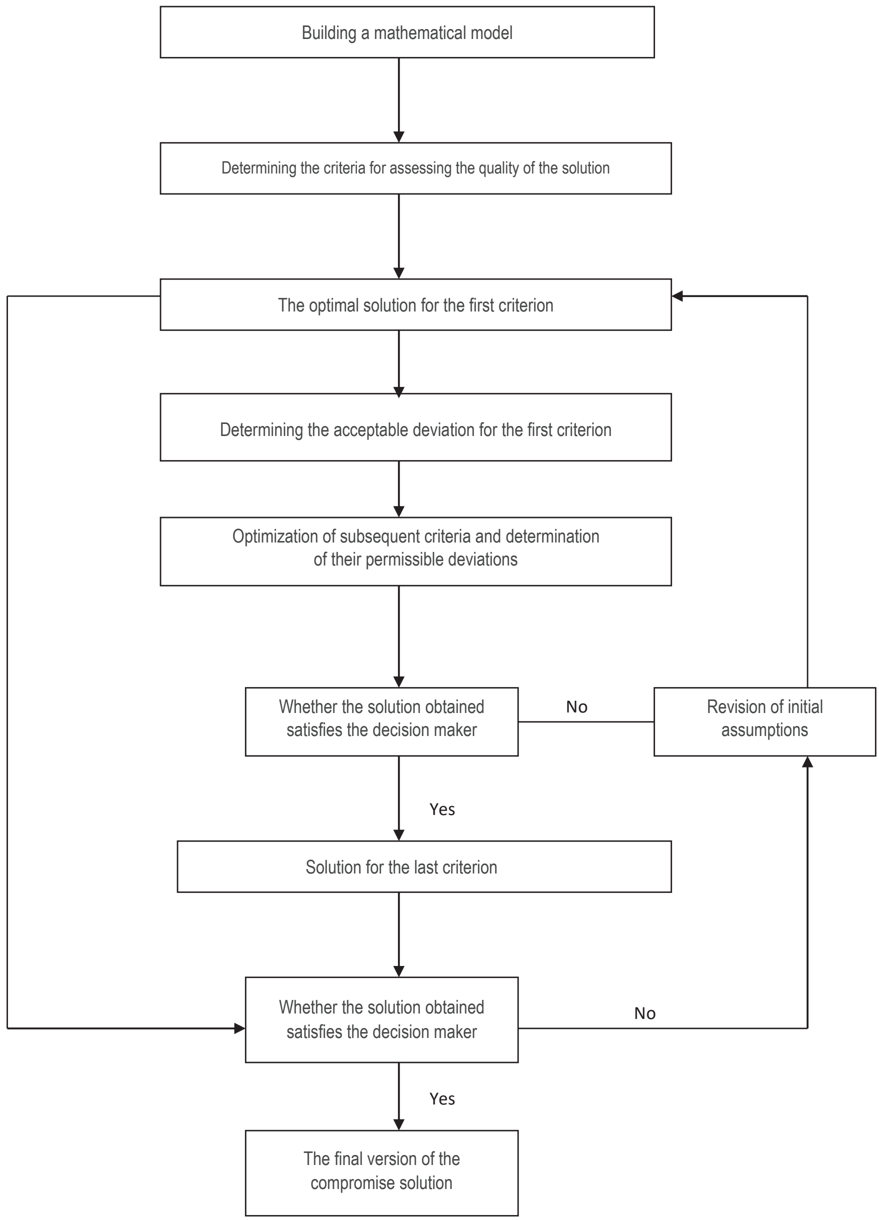

Figure 1. Procedure for preparing a plan using the lexicographic method

Source: own study.

Disadvantages of this method:
- no guarantee that the solution received is pareto-optimal,
- labor consumption of the method - to obtain a satisfactory solution for a compromised user, it is achieved through multi-criteria recurrence of calculations, in each case verifying the initial, fixed threshold values or permissible deviations from the maximum values.

These disadvantages compensate to a certain extent the simplicity of calculations, a clear interpretation of the procedure and the introduction of structural variables into the program that allow obtaining for each solution the value of all its important parameters.

The application of the multicriteria method will allow to build a mathematical model supporting decision making in the power industry minimizing the risk of plant production for energy purposes, the solution of which will be characterized by the following features:
- minimal cost of electricity production,
- maximum level of renewable energy use,
- maximum production level of energy plants,
- minimal impact on the natural environment.

Results

The article proposes an original model of a regional system of alternative energy sources that minimizes the risk of producing plants for energy purposes, exploring various types of technologies that may appear in the system. With the help of the optimizing multi-criteria model, a scenario optimizing the regional energy potential was developed. For the construction of optimization models, the values of technical and economic parameters were first calculated and the minimum or maximum levels of balance conditions (rather than by-side conditions) were established. The model adopted 24 decision variables. The lexicographic method was used to search for compromise solutions.

The objective function (minimized) consisted of four components:
- costs related to production,
- costs related to certificates,
- ecological costs and
- loss of soil fertility.

In the optimization model, only one function (L(x)), which was a component of the above components, was minimized.

The model assumes that a large share in the production of electricity may be the agriculture of the region, which, apart from the basic function of food production for the population, will play the agroenergetic role.

It was also assumed that the basic energy plants for biomass will be used for energy willow, miscanthus, poplars, Jerusalem artichokes, Palestinian mallow, for the production of biogas maize, sugar beets, and for biodiesel – cereals and oilseed rape.

It is assumed that energy crops should be competitive with commercial agricultural production and be an element of the market game.

The model assumes that arable land classes I–III b are used for food production. Other arable lands – class IVa–IVb plots – will be used in 25% for the production of biomass, and class V–VI land for 55% for planting permanent energy crops.

The costs of cultivation of perennial energy crops include expenditures incurred on land reclamation after their period of use.

The basic agrotechnical restrictions for particular groups of plants have also been adopted (max. Of the given crop in the structure of sowing and soil fertility) = in accordance with the principle of sustainable development.

It is also assumed that energy investments will be characterized by a high capital intensity and a long investment cycle, 5–10 years, as well as a long period of return of incurred investment outlays.

The assumptions of the model also assumed that there are wind farms, hydropower plants, biogas power plants at landfills, biomass production plants, including sawmills and electricity producing plants.

The main objective of the model is to achieve results that can be used in the formulation of regional policy, in relation to the future production of renewable energy, structure and specialization. It may depend on issues such as land use, current production structure, soil, types of farms, choice of technology, skills of work and their use, availability of resources. The model, meeting the above requirements, will be an effective solution for models of the energy system.

The construction of the model should therefore ensure that it can be used in changing conditions, i.e. that various aspects of the system are considered, although they do not have to be present in all cases.

This model is to be a tool in planning development, with significant changes in the structure of operations, etc., are not implied. It was assumed that additional inputs and supplies of raw materials may appear and that a conscious policy on the development of renewable energy would be exerted.

Table 1. Scenario solution (optimization of the use of plant production for energy purposes)

Types of energy	x_1	x_2	x_3	x_4	x_5	x_6	x_7	x_8	x_9	x_{10}	x_{11}	x_{12}	x_{13}	x_{14}	x_{15}
Energy production	0	3,016.53	59.86	8.23	383.53	0	1,452.85	1,502.29	21.521	23.39	533.92	0	416.51	1,914.57	9,333.45
Energy raw materials	x_{16}	x_{17}	x_{18}	x_{19}	x_{20}	x_{21}	x_{22}	x_{23}	x_{24}						
Crop size	0	0	0	0	0	0	0	0.059	0						

Source: own study based on the model.

In this scenario, we note that the total energy production in the West Pomeranian Region will be 9,333 GWh (i.e. we assume coverage of demand in the region), of which 3,016 GWh is energy production from cofiring, and 8 GWh is hydropower created in new hydropower plants. In solar installations, 383 GWh of energy can be generated. In the case of new wind power plants, as much as existing, there will be 2,955 GWh of energy generated. In both new and existing installations in the region, 638 GWh of energy will be produced in general for biogas. The remaining 2,331 GWh of energy will be generated in new and existing installations producing energy from biomass combustion. The average construction cost of one MW in this energy scenario will amount to PLN 9,333,509 and the loss of soil fertility in this scenario will amount to 0.059 t/ha.

Analyzing the structure of new generation capacities, presented for example in three scenarios in the power industry developed in the West Pomeranian Region, we can present the number of new jobs created in the region.

Table 2. Number of new jobs created in the West Pomeranian Region

Type of renewable energy	Number of jobs
Hydropower	3
Solar energy	2,558
Wind energy	9,137
Energy produced from biogas	1,880
Energy produced from biomass	2,447

Source: own study.

Own research on a sample region (West Pomeranian region), as well as calculations of the original model, indicate the possibility of building a regional system of obtaining energy from alternative sources that minimizes the risk of producing plants for energy purposes. The constructed mathematical model and its validation confirm that it can be a tool to simulate the energy policy of each region in terms of risk and uncertainty.

Limitations

The conducted study is one of the first studies examining the risk and uncertainty of energy plant production. The limitation of this study, however, is that the study concerns only the example of the region which is the West Pomeranian Region.

Conclusions

Risk and uncertainty are objective states related to management, especially when we try to specify the behavior of an economic entity in the annual plan for the production of energy crops. In agricultural production, with the extended production cycle, the importance of decisions made under uncertainty and risk increases. The longer the time horizon, the more likely it is to create different situations that can significantly affect the economic result.

Risk and uncertainty are very important for econometric models used for planning production of energy crops. The condition for success is the accurate determination of the forecasted parameters of the plan model and adequate knowledge of cause-and-effect relations of the phenomena included in the model.

If we can not determine the probability of occurrence of certain phenomena and their inclusion in the model, we are not able to determine how much the solution is the resulting models are accurate and the probability of their implementation in specific farm conditions.

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