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Model of energy safety evaluation

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Model vyhodnotenia energetickej bezpečnosti

The importance of energy safety stems out of the particular role of energy minerals in the present world. This role is conditioned by the civilization level and technological development on one hand, and the non-renewable character of resources and their geopolitical distribution.

The complexity of problems to be undertaken for providing energy safety is presented in the paper. The energy safety issue is analysed in view of the planned demand for energy minerals, and an exemplary outline of the proposed methodology of energy safety assessment is given.

Key words*: energy safety, energy minerals.*

Introduction

One of the basic aims of energy policy of Poland is providing the energy safety at a suitable level. However, the evaluation of safety level is dubious, what can be seen on the basis of unending polemics and debates on the energy safety and ways of providing it. Although discussed so frequently, this subject seems far from clear and well defined.

An attempt was made in the paper to assess the energy safety by presenting a methodology of its evaluation.

Notion of „energy safety"

The notion of energy safety has been defined in the Polish conditions several times but no satisfactory and accepted description has been made yet. Owing to this and the character of the notion itself, the objective assessment of the energy safety level is a difficult, frequently dubious question.

The document *„*Poland's energy policy by the year 2025*"* defines the energy safety as: *„a state of economy, thanks to which the current and perspective demand for fuels and energy can be covered in a technically and economically justified way, with the minimized negative environmental and social impact"* [9].

Similar to other definitions of energy safety, this one does not solve the problem of evaluation. The most important here is a conflict of economic interests, manifesting in, e.g. necessary costs on the diversification of deliveries or environmental protection, which in view of the minimization of costs must result in a question about the significance of specific criteria [2, 5].

This definition also needs to be more precise, in line with the following notations:

- *„ ...economically justified"* – which results in a question of subject of economy of deliveries. In practice, meeting the postulate of „providing economically justified prices" or „profitable for the supplier" stays in opposition to the competitive character of the market [1]. The energy safety for the end user mainly signifies the accessibility of energy in two aspects. First, it is the level of energy prices and delivery prices. Relatively high energy prices (as compared to the actual abilities of the clients) become an obstacle significantly limiting the energy use or even eliminating it in the case of high energy production. Secondly, the availability of technical infrastructure providing sure and continuous deliveries. In case of lack of a power it is of secondary importance to the consumer whether the cause is of international character or it stems out of local causes or power plant failure. The most important issue then is to restore the supplies and costs related with the lack of energy (damages) [7]. Therefore, in view of market mechanisms, the energy safety can be attributed to a service guaranteeing safe and continuous deliveries at an established level, and which can be realized on the basis of a contract [8].
- *„ ...meeting environmental protection requirements"* according to [1] this principle holds true in normal conditions. In the case of natural disasters and catastrophes, the energy safety means covering the energy demand. In such conditions the environmental issue is of secondary importance in view of possible losses of the consumers and the public life.

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- *„... state of economy”* – energy safety reduced to the „state of economy” is a far fetched generalization. The chain of factors determining the energy safety level goes far beyond economy, therefore the „energy safety” is not only a „state of economy”, but also a result of beyond-economy factors [7].

The energy safety is a complex category, where partial safeties can be distinguished. They are indicators of energy safety usually analysed only in one aspect, e.g. a technical (failure index) or economic aspect (costs of the energy recuperation). Although not perfect, this approach creates bases for a definition of types of hazards which can be expected in the present economic and political conditions. The correlation of indices is very important here. It can be exemplified by the Stirling diversification index, the growth of which in Polish conditions can be reached thanks to the import of fuels, which in turn, causes a decrease of the self-reliance index and an increase of the import dependence [8].

An outline of the energy safety evaluation model

By making an assumption that the evaluation of energy safety relies on a number of frequently contradictory aspects, the analyses have to be more of a multicriterial character. The evaluation of the energy safety conditioned by the assumed criteria should be made as a search for a compromise between some functions of purpose. Their total maximization is not possible owing to the correlations [8].

Determining the scope of the analysis should be a starting point for making an evaluation model of the energy safety (Fig. *1*). The scope is conditioned by the required space of analysis, i.e. state of energy safety in Poland, the safety of energy delivery to the consumer, or the safety of local power systems. It is also necessary to determine the variety of energy carriers to be analysed.

Another stage lies in defining frameworks of power development in an assumed time horizon by assuming respective energy prognoses, basic for a further analysis.

Owing to the numerous processes influencing the state of energy safety it is important to specify and classify the possible factors. The first steps can not be formalized *a priori*.

The assumed factors deciding about the energy safety level should be expressed as variables. This will enable a simplified determination of the energy safety components. Thus, the obtained values can be described in various physical units and may characterize the reality qualitatively [6].

Hence, the character of variables has to be defined. Naturally, the variables can be classified as [6, 8]:

- Quantitative indices:
  - stimulants ($s^{x_{ij}}$) – variables, the high values of which are desired from the point of view of general characteristic of the analysed phenomenon,
  - destimulants ($d^{x_{ij}}$) - variables, the high values of which are not desired from the point of view of the general characteristic of the analysed phenomenon.
- Qualitative indices ($J^{x_{ij}}$) – variables in the range [0, 1] defined with unmeasureable properties.

The qualitative indices (requiring the so-called expert decisions) determine the properties of unmeasurble character through their quantitative counterparts. This approach bases on the assumption that qualitative differences are a derivative of quantitative differences, therefore can be expressed in the form of quantitative properties. For doing so, the so-called an ordering scale has to be worked out, thanks to which the accessible information can be quantified [6].

After selecting the indices for analyses, the quantitative properties (and so the stimulants and destimulants) should be normalized to [0,1]. This should eliminate the influence of various units of measure with which these parameters were characterized. Owing to the different character of stimulants and destimulants, the indices are normalized according to various procedures. Thus the formed normalized matrix contains figure realizations from 0 to 1, the columns denote the successive scenarios of the energy situation development, the rows are the figure denotations of the specific indices. When the actual value of a given index is equal for all the scenarios, it is naturally eliminated. In such a case, the obtained partial evaluations do not have an influence on the global assessment.

The combined normalized matrix (quantitative index matrix) and the ordering matrix (qualitative data) define a new set, the so-called ordered matrix. To provide the distinction of evaluations of specific strategies, the obtained figure values undergo another transformation lying in the division of variables of specific indices into subintervals of equal range. Depending on the value of a coefficient in a given scenario, it is qualified to a specific subinterval. At a great number of subintervals (high distinction level) a significant distinction of results can be obtained. Thus, the obtained matrix is called the matrix of index evaluation [5, 8].

As the influence of the analysed indices on the energy safety varies, another step lies in determining weights and ascribing them to specific indices, assuming that the sums of weights are equal to unity.

On the basis of a sum of products of ascribed weights and indices for a given scenario the so-called global sum is calculated. At the last stage of the analysis, the index *f(B)* is determined. It is obtained as a quotient of the obtained global sum and the maximal global sum, which can be obtained by a given strategy. In this way, it is the figure value of the analysed level of energy safety [5].

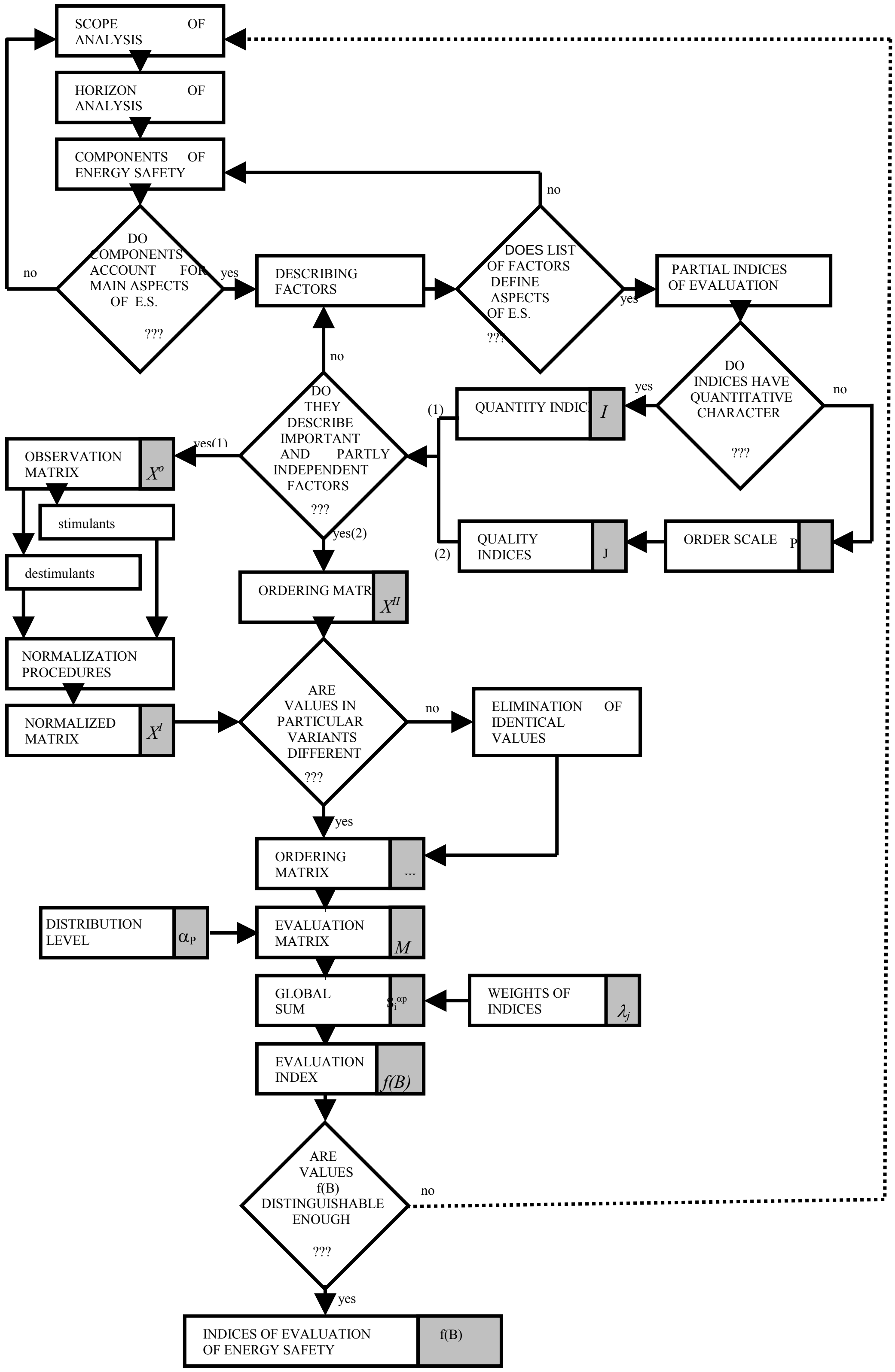


Fig. 1. Proposed algorithm of determining a summaric energy safety index f(B) [8].

Illustration of the energy safety analysis

The analysis of energy safety level encompasses:

- The scope of analysis: the primary energy carriers – hard coal (WB), lignite (WB), oil (RN), natural gas (GZ), renewables (EO);
- seven energy forecasts in *„Assumptions of Poland's energy by the year 2020"* (Survival, Reference, Progress Plus scenarios) and *„Poland's energy policy by the year 2025"*. (Treaty, Basic Coal, Basic Gas, Efficiency variants);
- the horizon of analysis: 2020;
- nine indices of the partial evaluation grouped in four components of energy safety: the security of deliveries, economic, environmental and the social-political aspects;
- five weight systems (W0 - W5) enabling a differentiation of the significance of specific indices of evaluation.

From the point of view of the presented analysis, the assumptions and preferences, the *Efficiency Variant* turned out to be the best of all methods (Fig. *2.*). It obtained the highest values of the *f(B)* index, regardless the assumed weight system.

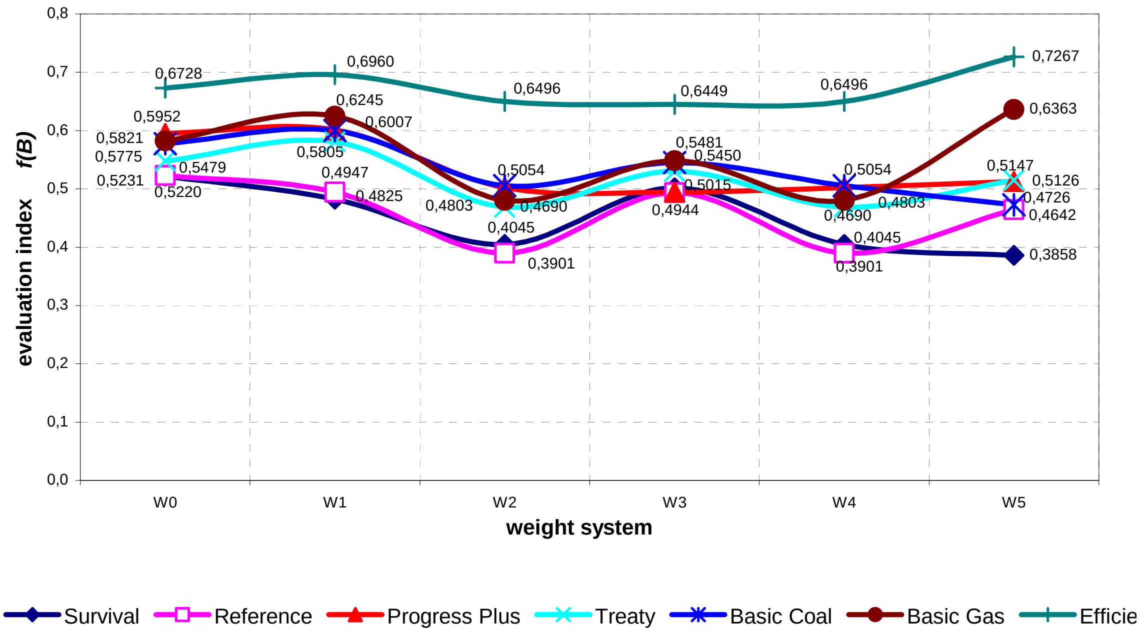
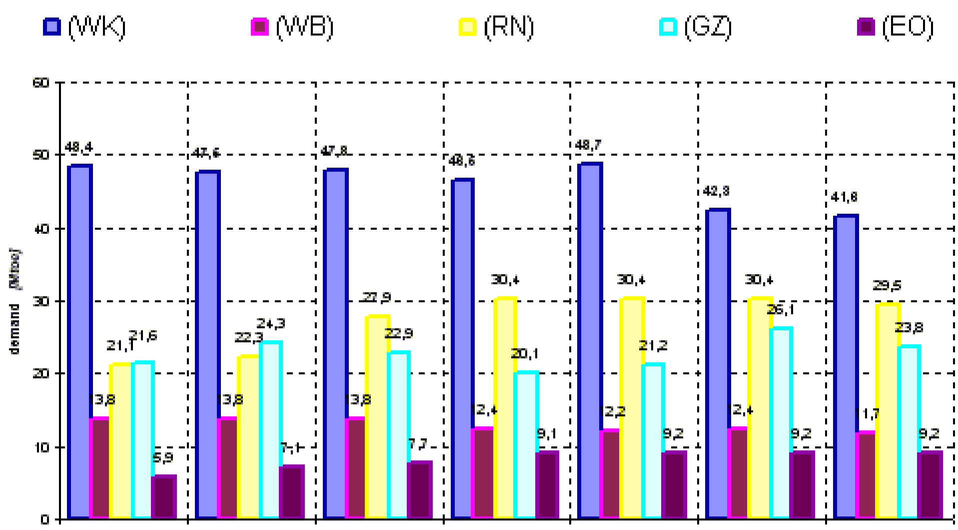


Fig. 2. Indices of the evaluation of energy safety f(B) for specific strategies and the assumed weight system – own study

The remaining scenarios occupied various positions in the ranking; among the relatively worst strategies were *Survival and Reference scenarios* (in *„Assumptions of Poland's energy by the year 2020"*), which obtained the lowest *f(B)* values three times.

The final result of the analysis expressed with the index of the energy safety evaluation *f(B),* corresponds to a specific structure of the energy carrier consumption (*Fig. 3*). Owing to the multiaspect character of the analysis, conclusions can be drawn only on the basis of the energy demand without accounting for the remaining factors, which seems to be a far fetched simplification. Therefore, the evaluation of the energy balance in view of energy safety analysis should be conditioned by the assumed criteria, and consequently, the construction and selection of assumed indices of the partial evaluation.



	Survival	Reference	Progress Plus	Treaty	Basic Coal	Basic Gas	Efficiency
Weight system	**Ranking of a strategy in reference to the other ones**						
W0	(7)	(6)	(2)	(5)	(4)	(3)	(1)
W1	(7)	(6)	(3)	(5)	(4)	(2)	(1)
W2	(6)	(7)	(3)	(5)	(2)	(4)	(1)
W3	(5)	(7)	(6)	(4)	(3)	(2)	(1)
W4	(6)	(7)	(3)	(5)	(2)	(4)	(1)
W5	(7)	(6)	(4)	(3)	(5)	(2)	(1)

Fig. 3. Balance of demand in view of the ranking of strategies and weight systems (the best (1) to the worst (7)) – own study

Conclusion

The origin of the problem of energy safety evaluation is of a multiaspect character of the notion, encompassing technical, economic, environmental, political and the social aspects, additionally expressed by qualitative and quantitative variables. Owing to the lack of accurate formulation of relations between specific aspects, the present definitions do not solve the problem. [8].

The obtained result of energy safety *f(B)* illustrates the degree of realization of purposes specified in the definition of energy safety, accounting for the state of knowledge and preferences of a person making the evaluation. The presented outline of the energy safety evaluation methods does not liberate decision makers from the responsibility for the analysis. However, it makes the evaluation process more comfortable, rational and transparent significantly improving the rate and quality of the undertaken decisions.

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