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Decision Support System for Sustainability Assessment of Power Generation Technologies

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1. Introduction

The necessity to achieve sustainable economic development, which would be environment-friendly, would conserve natural resources and would not contribute to social tensions, is increasingly the key attitude in development strategies and plans for a range of economic activities, and in search for the best solutions. Sustainable development is understood as a lasting ideology of social change—as a compromise, which reconciles environmental, economic and social goals of our society. In the context of sustainable development, the energy development—the ability to ensure sufficient energy sources to the public—is of particular importance. Sustainable energy development is a complete set of measures, including better performance of energy production and consumption, gradually decreasing consumption of fossil fuels, lower pollution, introduction of renewable energy sources and advanced energy technologies, ensuring socially just pricing and accessible energy. The future of energy must go hand in hand with the concept of sustainable development and must ensure economic development of the public. Lately, many European countries face the issues of growing energy demand, and the consequences of global warming, ever-higher import dependency, also high and fluctuating prices of resources and energy. These issues lead to revisions of development projects and social programmes in the energy sector, and encourage adoption of instruments able to reduce social tensions, to satisfy the demand and to improve social safety.

The EU energy policy is a means to ensure secure, competitive and sustainable energy. The document *Green Paper: A European Strategy for sustainable, competitive and secure energy* published by the European Commission on 8 March 2006 sets forth the key areas with specific energy development challenges. This document prescribes the axes for energy development, and contribution to economic growth and job creation in Europe. It also names the challenges to secure safe energy supply in the internal market, as well as the solidarity of member states, promotion of competitiveness, increasingly efficient and diverse energy, and innovation (Commission of the European...2006). Building of relevant strategies and development plans, selection of specific instruments in line with environmental conditions are among the priorities in each state.

Development based on the sustainability principles, as well as planning, building and validation of various strategic decisions, demands for analysis and assessment of versatile information, such as EU policies and guidelines; political, social, economic and environmental factors, and their changes; technical and technological data; and information from diverse stakeholder groups with different goals. When a decision-making process starts and we have to analyse diverse data, sometimes hardly fit for comparison, we want adequate tools, which help to consider our changing environment, to identify the weights of the defining criteria, and to reconcile economic, environmental, technological, social and other aspects. The information is abundant and often contradictory, thus only modern multiple criteria evaluation methods, based on the mathematical analysis of data, and integrated software applications make its assessment possible.

2. Multiple criteria analysis methods, their application

When it comes to handling of diverse practical tasks—notably to building of development scenarios, strategic scenarios and investment projects—one must consider economic, environmental, technological, social and other aspects, assess possible alternatives and rank them in the selected order of priority (Figueira *et al.* 2005). It may be selection of the best investment ortechnological project, analysis of alternative scenarios, environmental assessment of different regions in a quest for investment opportunities, etc. More and more books offer decision-making based on multiple criteria analysis methods. Effective decisions are of particular importance in investment projects aiming to ensure provision to the public, in projects financed by national authorities, and in cases that warrant objectivity, transparency and minimised influence of stakeholders.

A number of multiple criteria analysis and evaluation methods have been developed, and are used, worldwide. The newest multiple criteria evaluation methods, above all, facilitate assessment and comparison of objects described by both quantitative and qualitative criteria, by indicators expressed in different units of measurement (Scholz & Tietje, 2002). The scientists Gutsche, Zimmermann built and described typical systems of indicators, which can be used in multiple criteria analysis methods to measure the differences of quantity, quality and market conjuncture between a comparable object and a valuated object (Zimmermann & Gutsche, 1991). Ming-Te Lu developed an expert system, which uses a system of criteria and helps to select the most profitable or adequate real estate projects (Lu & So, 2005). Hwang and Quigley suggest a price assessment model based on the analysis of hedonic and sales comparison approaches; the model helps to estimate an efficient price indicator (Hwang & Quigley, 2004). Multiple criteria decision-making methods were used for evaluation of external services available to companies (Almeida, 2005), for evaluation of risk management and management of water supply systems (Morais & Almeida,. 2007), for project risk assessment (Zeng et al., 2007), for risk evaluation in natural gas supply systems (Brito & Almeida, 2008), and to reconcile infrastructure investments with environmental problems (Higgins et al., 2008). Multiple criteria methods are an attempt to choose an optimal decision when the alternative decisions must be concurrently assessed based on several contradictory criteria. Multiple criteria analysis methods view alternatives in an integrated manner: they deal with quantitative (operational territory, number of objects, cost, expenses, production capacity, etc.) and qualitative (legal acts, regulations, restrictions, stakeholder influence, technological novelty, compliance with environmental requirements, level of innovation, etc.) criteria of the current market conjuncture that describe the value of the item in question. Many current tasks related to energy strategy, development and technology selection are multiple criteria tasks.

Sources of literature, which discuss multiple criteria evaluation methods, also suggest conditional classifications: methods are classified according to the sets of alternatives, the units of measurement, the decision-making rules, and the standardisation of evaluation results. For instance, by the type of data, decision-making methods may be classified into three groups: 1) deterministic, 2) stochastic, and 3) fuzzy sets. There may be cases, however, when different types of data are combined. Many authors suggest classifications which generally differ only by the comprehensiveness and number of methods. The key difference between classifications suggested by various authors is that some classify methods only by the type of information about indicators, while others introduce categories of information about alternatives (Chen & Hwang, 1991; Hwang & Yoon, 1981; Triantaphyllou, 2000).

Multiple criteria decision-making methods are most often classified into two distinct groups with different methodology for identification of preferences and for aggregation of information about criteria (Hwang & Yoon, 1981; Zavadskas et al., 1994). The first group includes multiple criteria methods from the value (utility) theory based on the premise of compensation — comparison of criteria: a possibility to fully balance the negative aspects of one criterion with positive aspects of another . The other group includes the outranking methods based on the concept of value without compensation and denies that criteria may offset one another. This methods may be further classified into three subgroups: 1) selection of the most beneficial variant using the utility function, 2) compromise models for selection of the variant closest to ideal, 3) concordance models to determine the priority relations of the highest compatibility (Hwang & Yoon, 1981; Zavadskas et al., 1994; Guitouni & Martel, 1998; Jeroen, 1999).

Multiple criteria analysis methods are abundant; their choice is based on the available data, goals, desired result and participation of decision-makers in the evaluation process. We shall proceed with a brief review of several multiple criteria methods, which are most adequate worldwide and are best suited for environmental analysis, for evaluation of project alternatives and technologies in the energy sector, and for integrated handling of environmental issues.

1. Multiple criteria methods of the value (utility) theory. This group of methods uses qualitative input and produces quantitative output. The group has two main subgroups: analytic hierarchy process methods and fuzzy set methods. The *Analytic Hierarchy Process (AHP)* was developed by the American scientist Thomas A. Saaty; lately, it is gaining popularity worldwide and is the most frequently used method for paired comparison of indicators (criteria, objects, features). It helps to find the weights of indicators located on the same level of a hierarchy with respect to a higher level or weights of hierarchically unstructured indicators. This method is based on a paired comparison matrix. Experts compare pairs of all indicators (technologies) in question R_i and R_j $(i, j = 1, \ldots, m)$; here m is the number of compared indicators (features).

It is a convenient method, because paired comparison of indicators is simpler than comparison of all at once. The comparison of indicators is simple and rather reliable: it reveals the degree to which one indicator is more important than the other. This method enables transformation of a qualitative expert assessment of indicators into quantitative assessment. Such comparison produces a quantum matrix $P = \| p_{ij} \|$ $(i, j = 1, \ldots, m)$. Mr Saaty suggests evaluations using a 5-point scale (1-3-5-7-9), which is frequently used in real-life applications (Saaty, 2000; Tam et al., 2006).

Multipurpose problems need to be separated into several components, because it helps to simplify the problem and to structure it better. A hierarchy with different goals and/or layers of instruments must be compiled for each problem. This method is handy when one has to deal with problems hard to define and to assess expert opinions to be later used in problem solving. Moreover, the method is better at rendering the processes of human thinking than the method of logical strings. Besides being handy in finding the best solution, the Analytic Hierarchy Process also facilitates qualitative expression of priorities with the help of outranking tools.

The *Graphical Evaluation Method* is handy for visual representations of information related to facts identified after assessment of alternatives. Graphical visualisation of information also helps to determine the interrelations in and the structure of a phenomenon, and is useful in comparison of alternatives with several criteria, because it helps to visualise the interrelations between the respective criteria (Bertin, 1981; Khuri, 2002).

Sensitivity Analysis. Whereas the comparative scores and priorities of criteria are undefined in many comparisons of alternatives, evaluations and the selected valuation techniques are based on different premises. Since any evaluation aims to provide a decision-maker with the best alternative or a ranking of alternatives, such uncertainties are important only in assessment of their effect on the ranking. The decision-maker should find to what extent (percentage) the actual values could deviate from the values in the tables for effect evaluation or in the set of weights. The method offers the probability ranking of alternatives, which may be used in the analysis of ranking sensitivity of alternatives considering the overall uncertainty of the effects and priorities (Tam et al., 2006)

2. Outranking methods. Both input and output of these methods is quantitative. This group includes multiple criteria methods of the utility theory and a number of other types: TOPSIS (*Technique for Order Preference by Similarity to Ideal Solution*), SAW (*Simple additive Weighting*), LINMAP (*Linear Programming Techniques for Multidimensional Analysis of Preference*), ELECTRE (*Elimination Et Choix Traduisant la Realite*), PROMETHEE I, II, MELCHIOR, ORESTE, COPRAS, ARAS, etc. The methods in this group have a strict mathematical foundation on axioms. They are convenient because each alternative has its utility expressed in a quantitative form, and the comparison of values is simple. But these methods have a drawback: quantitative measurements are prone to inaccuracies due to slips by respondents or to other types of errors (Streimikiene & Mikalauskiene, 2009). When this group of methods is used, the results produced by various criteria are ranked and then the rankings are analysed. The outranking method is based on paired comparison of alternatives. All pairs for a criterion in question must be compared. The better alternative of each pair is determined by summing the results according to all criteria. This simple technique is used for quantitative data. Qualitative data, if any, are interpreted as unknown quantitative weights. The set *S* must be defined to include all strings of quantitative weights matching the qualitative priority information. Sometimes one alternative will be preferred from the entire set *S*, and in other cases one alternative may be preferred only from a certain part of the set *S*, with preference given to other alternatives in other parts of the said set. The distribution of weights in the set *S* is deemed unchangeable; the relative values of subsets in the set *S* may, therefore, be interpreted as a probability that one alternative in each pair is always preferable over the other. Probabilities are then summed to rank general alternatives (Von Winterfeldt & Edwards, 1986).

The *PROMETHEE* method differs from other multiple criteria methods with its deeper logics. The method is based on the so-called priority functions. Decision-makers may select these functions and set their parameters themselves. The PROMETHEE method offers a wide selection of functions to enable better reflection of the evaluator’s opinions. At the basis of the method, there is the matrix $R = ||r_{ij}||$ compiled from the defining indicators of compared objects and statistical data (or expert assessment), and weights of the indicators ω_i; ($i = 1, 2,..., m$; $j = 1, 2, ...,n$, here m is the number of indicators and n is the number of compared objects, i.e. alternatives).

Quantitative multiple criteria evaluation methods determine whether an indicator is maximising or minimising. The best values of maximising indicators are the highest, while the best values of minimising indicators are the lowest. The criteria in quantitative multiple criteria methods often combine normalised values and weights of indicators. The logics employed in the PROMETHEE method differs from other quantitative multiple criteria methods. The decision-maker is an active participant in the phase of problem shaping and problem solving. The decision-maker adds the priorities in the method's assessment procedure: determines the permissible extremes of differences q and s (highest and lowest) for each indicator (criterion) R_i. In the PROMETHEE method, alternatives A_j and A_k are considered indifferent with respect to the indicator R_i, if the difference $d_i(A_j,A_k) = r_{ij} - r_{ik}$ between the indicator's values r_{ij} and r_{ik} is below the lowest extreme value q. Also, the alternative A_j is preferred over the alternative A_k if the difference is above the highest extreme value s. Moreover, Decision maker sets a specific priority function $p(d)$ (with the parameters q and s) for each indicator. The function's values vary between 0 and 1, and show the extent to which the alternative A_j is more important than the alternative A_k (with respect to the indicator R_i). In practical applications, six variants of typical priority functions $p(d)$suffice (Podvezko & Podvezko, 2009). The PROMETHEE method bases its final evaluation on all positive priorities of each alternative. The PROMETHEE I method defines the relation of priority and indifference for all alternatives A_j and A_k with either plus or minus: P^+, P^-, I^+, I^-. The PROMETHEE II method ranks the alternatives by the differences $F_j = F^+_j - F^-_j$. The PROMETHEE I method determines the best of compared alternatives (Brans & Mareschal, 2005).

COmplex Proportional ASsessment method (*COPRAS*). This method was developed by K. Zavadskas, F. and A. Kaklauskas (1994), scientists from Vilnius Gediminas Technical University. In multiple criteria analysis, it is expedient to combine the quantitative and qualitative assessment. It is the COPRAS method that helps to analyse more aspects of one object by combining quantitative and qualitative criteria. This method has a huge advantage—it helps not only to compare any alternatives but also to measure their market value. In this method, the selected alternatives are subjected to integrated analysis, considering quantitative (e.g., operational territory, number of objects, cost of products or services, production capacity, the replacement cost) and qualitative (e.g., restrictions imposed by legislation and regulations, technological novelty, compliance with environmental requirements, level of innovation, stakeholder influence, etc.) criteria of the market conjuncture, which describe the object.

It is easy to express quantitative criteria by the quantitative measures of your choice (amount of money, technical parameters, etc.), but in case of qualitative criteria expressed by conditional measures (scores, percentages) it is a more complex procedure to measure their values and weights. Weights for qualitative criteria must be identified through analysis, scientific studies and databases, by comparing equivalents, and by analysing macro-, meso- and microenvironment in regions with similar development degrees or development trends.

Comparability demands for normalisation of the values of quantitative and qualitative criteria using relevant formulas. The expert assessment method is the most popular when it comes to identification of weights for criteria from a variety of fields. When expert methods do their job and we have the criteria weights, we may identify their priority in the order of importance. Although expert methods do not secure very accurate values of quantitative criteria, the integrated method for calculation of criteria weights considers their qualitative and quantitative characteristics. Weights may be assessed using the outranking method. The COPRAS method proceeds with calculations in the following sequence (Fig. 1):

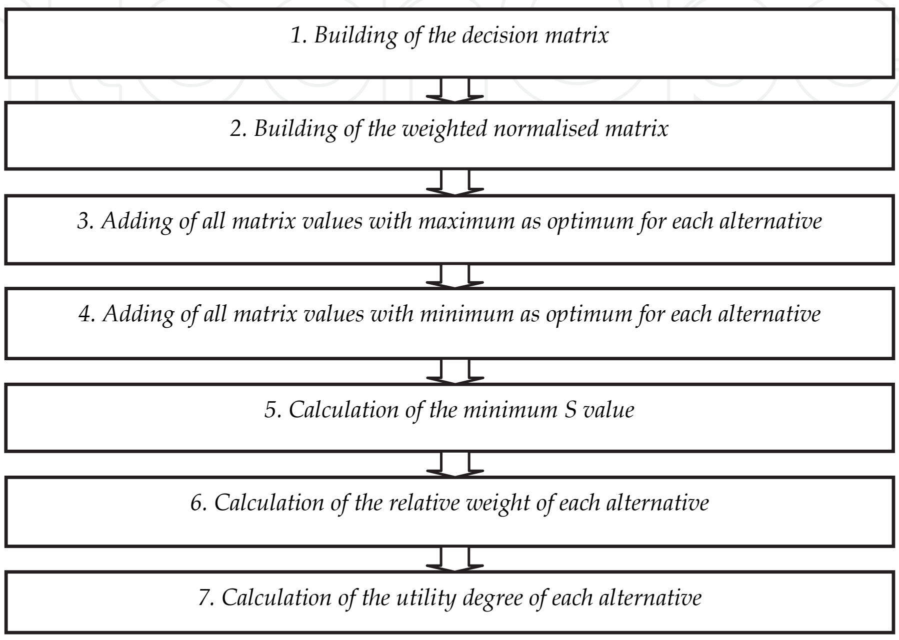


Fig. 1. The algorithm of calculations in the COPRAS method

Problem framing is the same as in other multiple criteria evaluation methods; it starts with building an initial decision-making matrix from n alternatives described by m indicators, thus { *fij* }, $i = 1, \ldots, m$, $j = 1, \ldots, n$. The weights of the indicators will be *qi*, i = 1, …, m.

Weighted normalized matrix. Comparison of indicators expressed in different measures demands for transformation of the indicators into dimensionless (normalised) values. Then a weighted normalised decision-making matrix is compiled. This stage aims to obtain dimensionless (normalised) weighted values from the comparative indicators. When the dimensionless weighted values are known, all indicators expressed in different measures may be compared.

The following formula is used for this purpose:

$$d_{ij} = \frac{x_{ij} \cdot q_i}{\sum_{j=1}^{n} x_{ij}}, \quad i = \overline{1,m}; \; j = \overline{1,n}, \tag{1}$$

here x_{ij} is the value of the criterion i in the alternative solution j; m is the number of criteria; n is the number of alternatives; q_i is the weight of the criterion i. The sum total of dimensionless weighted values d_{ij} for each criterion x_i is always equal to the weight q_i of this criterion:

$$q_i = \sum_{j=1}^{n} d_{ij}, \quad i = \overline{1,m}; \quad j = \overline{1,n}. \tag{2}$$

The value of the weight q_i of the criterion in question is proportionally distributed to all alternatives according to their values x_{ij}. Now the sums of weighted normalized minimising S_{-j} and maximising S_{+j} indicators describing the alternatives are calculated. The following formulas are used:

$$S_{+j} = \sum_{i=1}^{m} d_{+ij}; \tag{3}$$

$$S_{-j} = \sum_{i=1}^{m} d_{-ij}; \quad i = \overline{1,m}; \quad j = \overline{1,n}. \tag{4}$$

In this instance, the greater is the value S_{+j}, the more the environment of the object in question satisfies the positive criteria. The lower is the value S_{-j} (negative criteria of environmental factors), the more the environmental factors make negative impact on the object's utility degree. Anyway, the sum totals of the pluses S_{+j} and minuses S_{-j} of all alternatives are always, respectively, equal to all sum totals of weights of maximizing and minimizing criteria:

$$S_{+} = \sum_{j=1}^{n} S_{+j} = \sum_{i=1}^{m} \sum_{j=1}^{n} d_{+ij}; \tag{5}$$

$$S_{-} = \sum_{j=1}^{n} S_{-j} = \sum_{i=1}^{m} \sum_{j=1}^{n} d_{-ij}; \quad i = \overline{1,m}; \quad j = \overline{1,n}. \tag{6}$$

This way, the calculations may be verified again. The relative weight (efficiency) of compared alternatives is determined considering relevant positive $S+j$ and negative $S-j$ features. The relative weight Q_j of each object aj is determined using the formula (7). Here $S_{-\min} = \min S_j$.

$$Q_j = S_{+j} + \frac{S_{-\min} \cdot \sum_{j=1}^{n} S_{-j}}{S_{-j} \cdot \sum_{j=1}^{n} \frac{S_{-\min}}{S_{-j}}}; \quad j = \overline{1,n}. \tag{7}$$

The process continues by identifying the priority of the objects in question. The higher is Q_j, the more efficient is the object—it has a higher priority. If $Q_1 > Q_2 > Q_3$, then the first object is the best. The above method is a rather simple way to evaluate and then to sort out the most efficient variants. The resulting generalised criterion Q_j depends, directly and proportionally, on the relative impact on the final result by the values x_{ij} and weights q_i of the criteria in question. Thus the result is an unbiased line of priority of the objects in question (Zavadskas et al., 1994).

Identifying the line of priority of the alternatives. The line of priority of the alternatives is determined considering their relative weights. The higher is the relative weight Qj, the more efficient the alternative is and thus gets higher priority. Potentially the best relative weight Q_{max} of an alternative will always take the highest position with other alternatives listed below.

Calculating the utility degree. The utility degree N_j of the object a_j marks the extent to which the object meets the requirements of the environment and stakeholders. The utility degree, therefore, helps to measure and justify the market value of the object in question. The more criteria show that the object meets the environmental conditions, the higher, proportionally, is the object's utility degree, which, in turn, has a positive impact on the market value (Kaklauskas 1999; Zavadskas & Kaklauskas, 2008). Then we proceed with identification of the weights, utility degrees and priorities of the environmental criteria that describe the objects in question. The efficiency degree E_{ji} of the object a_j is calculated. It shows the percentage by which the object a_j is either better or worse than the object a_i. E_{ji} is calculated by comparing the utility degrees of the objects in question:

$$E_{ji} = N_j - N_i . \tag{8}$$

The average deviation k_j of the utility degree N_j of the object a_j is calculated by comparing it with other objects (n-1).

$$k_j = \sum_{i=0}^{n} E_{ji} : (n-1). \tag{9}$$

The initial value of the object in question is calculated using the following formula:

$$x_{11} = \sum_{j=1}^{n} x_{1j} : (n-1). \tag{10}$$

The market prices of other comparable objects must be known if we want to calculate the market value of the technology or object in question in the above way. Generally, the analysis may be based either on the prices, say, determined by independent appraisers or analysts (when assets or investment projects must be analysed), or on the value estimated using economic methods (e.g., when technologies must be evaluated). The best way to frame the problem would be as follows: to determine, through an integrated analysis of the positive and negative features, which market value of the object a_1 would make it competitive in the market on equal footing with other comparable objects. The revised value $x_{11\text{-p}}$ of the object a_1 is calculated using the formula (11) :

$$x_{11\text{-}p} = x_{11} \times (1 + k_1 : 100). \tag{11}$$

It is determined whether the revised value $x_{11\text{-p}}$ of the object a_1 was calculated accurately enough:

$$|k_1| < S \tag{12}$$

here S is the accuracy in percent for the calculations of the market value $x_{11\text{-}R}$ of the object a_1. The market value $x_{11\text{-}R}$ of the object a_1 shall be deemed calculated when the following equation is satisfied:

$$x_{11\text{-}R} = x_{11\text{-}P} \tag{13}$$

The utility degrees and the revised market values calculated for the objects in question using this method depend, directly and proportionally, on an adequate criteria system, weights of the criteria and values of the weights.

If energy objects must be analysed or technologies selected, economic information and economic valuation approaches are insufficient to ensure objectivity. Multiple criteria analysis facilitates processing of extensive quantitative and qualitative information, analysing of a range of external value-affecting factors and assessing of energy production technologies with different dimensions in view of the most significant factors. Comparisons of the utility degrees based on the defining quantitative criteria alone would hardly be comprehensive and reliable in case of energy production technologies.

The utility degree and the market value of the object, project or technology in question may be measured using the following sequence (Fig. 2):

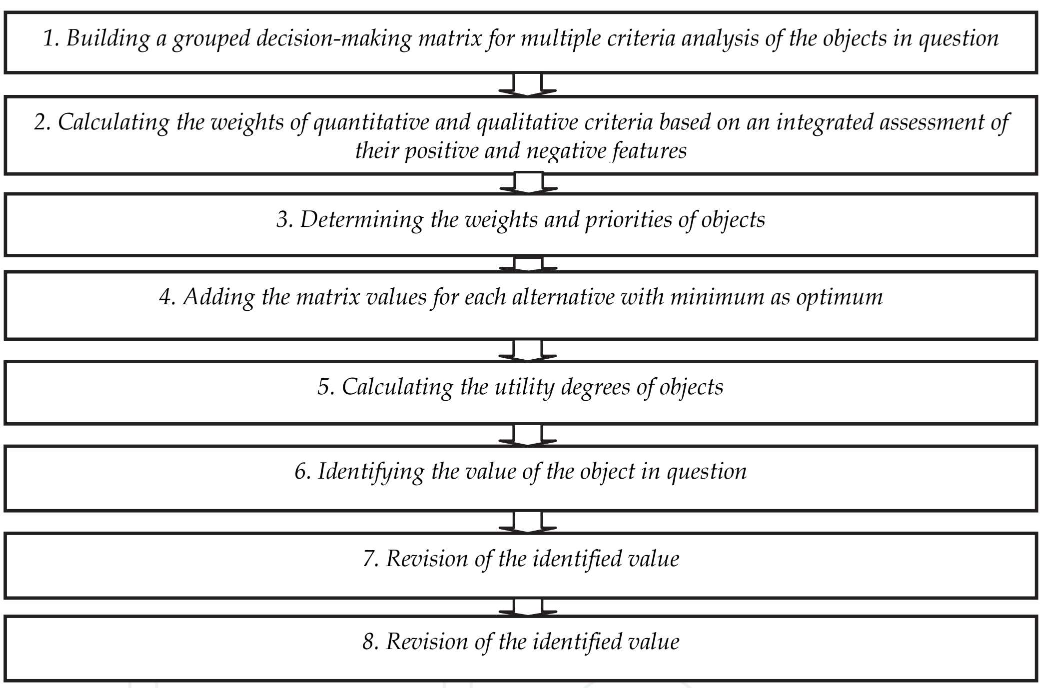


Fig. 2. The algorithm for calculation of the market value

2.1 Methods for identification of criteria values and weights

It is expedient to make an integrated analysis of objects by combining quantitative and qualitative assessment. Multiple criteria analysis methods are the right tool: they allow a more thorough look at an object through combined quantitative and qualitative criteria; they help to make an analysis by integrating both technical data and the results obtained using economic valuation approaches or analyses. The so-called *weighting methodologies* that help to determine criteria weights are one of the methods to determine preferences, and to make quantitative and qualitative assessment of the weights attributed by people to some criteria, which are then used to make decisions on implementation of a certain instrument. These methods encompass a wide range of surveys, which help to approximate the quantitative expression of social values, and a wide range of indirect valuation approaches, in which significant factors are identified through debates in task forces or between stakeholders by identifying their preferences. The Kendall's coefficient of correlation (Kendall, 1970) is the most popular tool in assessments of survey results.

The methods used to identify the values and weights of criteria that define environmental factors may be classified conditionally into two groups:

- methods for expression of criteria in quantitative terms (e.g. expression in money, technical parameters).
- methods for expression/description of criteria in conditional measures (scores, percentages). Such criteria are qualitative.

While quantitative criteria may be expressed in money or technical parameters for technologies, the measurement of the values and weights of qualitative criteria is a more complex task. Weights for qualitative criteria may be determined through analysis, scientific studies and databases, by comparing equivalents, and by analysing macro, meso and microenvironment in regions with similar development degrees or development trends. Values and weights of qualitative criteria are most often identified through expert or sociological surveys.

The expert assessment must necessarily include identification of criteria weights; otherwise it is difficult to assess the reliability of the research. Such calculations aim to determine whether different experts agree to a sufficient degree for expert assessment results to be a reliable basis. Kendall's coefficient of concordance W is the measure that describes the degree of agreement between expert opinions. This coefficient is calculated using a specific table of expert assessment indicators and the formulae available in literature sources. The calculated coefficient W shows the degree of agreement between individual opinions. This coefficient will be equal to 1 if all experts share one opinion. When all ranks differ and expert opinions do not match, the coefficient will be equal to 0 (Kendall, 1970; Zavadskas et al., 1994).

It is often difficult to reconcile opinions on most economic decisions, particularly in the energy sector. Reliable research demands for choosing experts from such social and interest groups, and with such knowledge and qualifications in the respective area, as to make it possible to reconcile the opinions on qualitative indicators. Decisions on the development of the energy sector, on choice of technologies, their performance and application, encompass a multidimensional and conflicting task: to minimise costs, to minimise the effect on environment, to ensure reliable energy supply, to supply more energy, to ensure socially-responsible pricing, to develop renewable resources, etc. Strategic decisions on the development of the energy sector, therefore, must be based on multiple criteria analysis or multiple criteria evaluation, because it helps to consider the relative importance of criteria to the decision-maker thus reconciling political, economic, environmental, social and other criteria, and to select the best solution in view of all criteria. *Multiple criteria* methods for evaluation or decision-making are, therefore, an attempt to simultaneously assess several alternative solutions on the basis of a set of contradictory criteria.

Multiple criteria analysis methods are, first and foremost, applied to determine the preferences of stakeholders involved in the decision-making process. These methods are of particular importance now, when public participation is part of all evaluation procedures dealing with strategic assessment of the impact on the environment. Community consulting is the best way to ensure that national policies serve the public. The energy sector is of particular relevance, because it is strategically important to each citizen both in terms of economic and social welfare. It explains increasing popularity of multiple criteria evaluation methods in decision-making on important issues of energy development.

3. Building the model for analysis of environmental factors in a multiple criteria decision support system

An important aspect in any analysis of alternative decisions is selection of suitable evaluation criteria, and indicators for quantitative and qualitative assessment. It is also important to build systems of criteria that define alternatives best. A multiple criteria task, therefore, involves research of environmental factors, as well as identification of the most important factors that affect activities or decisions. Lately, multiple criteria evaluation methods are also widely used in sustainability assessments. In the energy sector, decisions are made at three levels: decisions related to development scenarios in the energy sector or strategic priorities of national energy development (macro level); decisions that reconcile the sector's role in the national economy, the processes within the sector, the effect of the processes on the environment and the legal environment that regulates the sector (meso level); and decisions on the choice of specific technologies for energy production or implementation of specific energy projects (micro level). The analysis of alternative decisions made at these different levels demands for relevant criteria for the assessment of such alternatives, as well as for indicators to be used in quantitative and qualitative evaluation of the alternatives. Problems involving multiple criteria highly depend on the compiled decision-making model.

3.1 Analysis of environmental factors and stakeholders

Expert methods are used in environmental research to determine the factors of various levels, as well as systems and subsystems of their defining indicators, which provide a thorough description of the activities related to the sector in question. The following components of the developed model for analysis of environmental factors make the biggest impact on its effectiveness and performance:

- macro, meso and microenvironment with the defining factors;
- groups taking part in the decision-making process and their chances to influence the decision.

Macroenvironment Factors. This factors define the level of national or industrial performance. Besides, macrolevel factors affect the development degree of separate industries. The performance of energy companies vastly depends on the integrated effect of macrolevel variable factors, such as national economic, political and cultural development, international and political commitments, agreements, legal acts and strategies, the market, the tax system, conditions in the loan market, inflation, dependence on natural resources and raw materials, etc. The changes in the performance of the industry in question—decreasing or increasing demand for energy resources—depend on the integrated effect of macrolevel factors.

PESTEL (*Political Forces*, *Economical Forces*, *Socio-Cultural Forces*, *Technological Forces, Environmental Forces, Legal Forces*) is the most suitable tool for the research of macroenvironment in energy sector. This analysis covers the main aspects of macroenvironment, namely political, economic, socio-cultural, and technological aspects, and, most importantly, it also includes the environmental and legal aspects. This analytic technique is widely used in practical applications, for instance, analysing the necessity to change the efficiency of energy consumption in Chinese regions, at the same time considering the impact of environmental factors—the links between a variety of political, economic, social, technological, environmental factors aspects and legal acts, as well as the main factors (Shilei & Yong, 2009). The analysis of macroenvironment must include a thorough analysis of political and legal environment, because the energy sector is subject to strict legal regulation. The activities are regulated by EU and national legal acts. Recently, EU member states started harmonisation of these legal acts and their transfer into national legislative bases. This process simplifies the analysis of legal environment. The aspect of the environment protection is equally important. The PESTEL analysis of the environment includes quantitative (extrapolation, mathematical modelling, etc.) and qualitative (scenarios, Delphi, etc.) forecasting methods. The main factors for PESTEL analysis in the energy sector are shown in Table 1.

Factor	Components
Political	EU enlargement, tax (excise) policies, agreements on development strategies, etc.
Economic	national income, inflation, unemployment, industrial development, etc.
Social	demographic features, emigration, income distribution and levels of consumption, supply of skilled professionals, the culture of industrial relations, etc.
Technological	innovations, development of new products, speed of technology updates, dissemination of technical know-how, etc.
Environmental	global warming, pollution reduction and environment protection
Legal	laws that promote competitiveness in the sector, healthcare and labour laws, etc.

Table 1. The main factors for PESTEL analysis in the energy sector

Mesoenvironment Factors. The analysis of mesolevel environment is oriented towards the goals of a specific sector, its role in the national economy and the industry, the features which shape the type of activities, profit, processes within a specific industry, the impact of the processes on environment, fulfilment of the sector's social role, documents regulating specific activities and relations with national authorities. It is an intermediate level between microeconomics and macroeconomics (Pillet et al., 2005). The analysis of mesoenvironment aims to look into the relation between the environment of the object in question and the economics. This environment is analysed considering such factors as institutions involved in legislation of a variety of legal and normative acts at various levels, in supervision and in control. A direct relationship links the decisions made by such institutions and the legal acts which regulate corporate activities with corporate plans, and decisions. Indicators that look into the ability of a specific object to achieve its economic goals in a specific legal environment and to handle the environmental issues through resource-saving manufacturing tools and increasing use of renewable energy sources are significant in the analysis of mesolevel factors. It is at the mesolevel that the environmental dimension, and the external effect (effect of by-products and pollution on the environment) of activities, is analysed in the energy sector or in separate energy production technologies. An important aspect of this level is public participation in issues related to the quality of living and work environment. Another important aspect, though rarely considered, is social responsibility of energy companies. This aspect must be considered not only in the analysis of specific corporate activities, but also when drafting strategies, selecting development scenarios and technologies, because the activities in the energy sector are important not only from the economic perspective, but also when dealing with a range issues relevant to the public—

related to environment protection, resource saving, readiness to introduce innovations, etc. It expands the boundaries of macro and mesoenvironment, as well as the effect of these factors on the performance in the energy sector.

Environmental Factors. Making an analysis of activities in the energy sector, it is worthwhile to make a more thorough assessment of environmental factors. Companies operating in this sector make a considerable impact on the environment. Organic fuels of limited quantities are widely used in the process of energy production. Environment is polluted by SO_2, CO_2, NO_x and other types of particulate matter, which are a by-product of energy production and can affect the soil, the water, the air, the biological cycle, and can generate huge amounts of hard waste (Ashina & Nakata, 2008; Streimikiene & Pusinaite, 2008). Despite high economic performance parameters, nuclear energy includes a complex and expensive burying of radioactive waste accumulated during the energy production cycle. Even electricity transfer through open high voltage lines generates electromagnetic fields, the effect of which is considered in legal acts regulating operation of such objects. Cleaner production tools, therefore, is a very effective and economically beneficial course of action, when we must analyse the sector's development and select the energy production technologies. For many years, EU countries apply environmental protection measures based on market factors, for instance, environmental taxes to increase the market share of products, processes and services which are more acceptable in terms of environmental protection. Such taxes encourage companies to allocate more funds for R&D and to invest into technologies less damaging to the environment or consuming fewer resources (Staniskis & Stasiskiene, 2006).

Microlevel Factors. Microenvironment factors are related to a specific company that uses the relevant energy production technology, they affect its ability to achieve its goals. These factors embrace all things related to value delivery to the customer: activities of the company, of its suppliers (from primary energy sources to supply, distribution and service companies) of its competitors, consumers and the public. These factors depend on macro and mesolevel factors. The energy sector must continuously keep high levels of infrastructure maintenance, must modernise facilities, must expand, and must introduce innovative technologies and management processes. The efficiency of the sector's development and implementation of investment projects is affected by various microlevel factors: land prices; lengthy procedures of territorial planning; efficiency of the process related to reconstruction, modernisation, and supply of technologies, mechanisms and equipment; financing conditions of development projects; etc.

Analysis of Groups that Influence Decisions. The analysis of environmental factors cannot be thorough before the stakeholder groups, which affect activities and decisions, are considered in assessment of specific environment in the energy sector. Activities in this sector are controlled and coordinated by national institutions and a variety of EU institutions. Various institutional participants—starting with international alliances, committees of associations and ending with trade unions—have a direct influence on sector's activities. Assessment of stakeholder groups considers the type of their influence, their expectations, requirements, represented institutions, business sector, and possible effect on the decision. All macrolevel stakeholders are active in the energy sector: national governments, local governments, the public, suppliers of resources and technologies, manufacturers, nature activists, etc. In the energy sector, the same stakeholder group may have contradictory interests. For example, residents usually support companies which use renewable resources but are against construction of wind parks in their neighbourhood (Sims et al., 2008), suppliers of raw materials are interested in the development of the thermal energy sector and challenge the development of nuclear energy. The analysis of stakeholders and the obtained results help to assess the requirements and expectations of various groups, to evaluate them and to search for ways to influence hostile groups or to assist and strengthen the supporters. The interrelations of stakeholders are shown in Fig. 3.

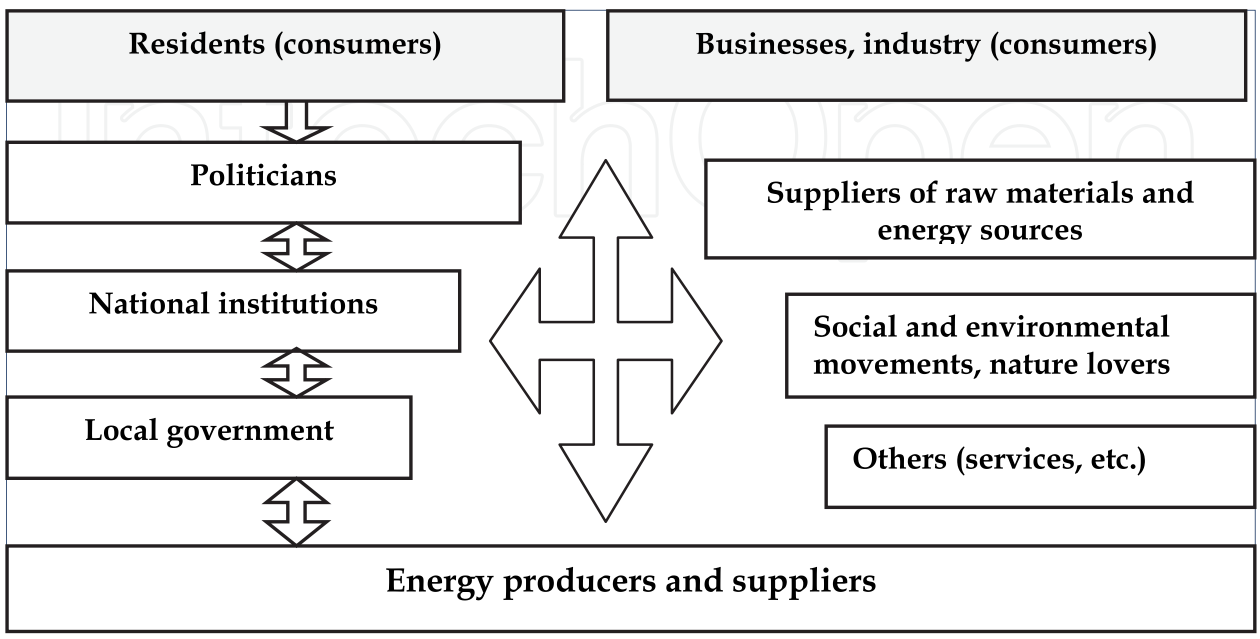


Fig. 3. Interrelations between stakeholders and the organisation in question

Consumers are also important members of the energy sector. Growing prices of raw materials, as well as electricity production, distribution and supply, make various groups observe the processes in the energy sector and participate in the development of strategies and in decision-making. Active involvement of stakeholder groups and political organisations may lead to economically unreasonable decisions harmful to the environment protection, but it also can and does make a positive impact: promotes transparency and responsibility, affects the process of market liberalisation.

3.2 Model for analysis of environmental factors in the energy sector

The above-discussed analysis of environmental factors helps to formulate the model for assessment of the energy sector (technologies), which is shown in Fig. 4. The model integrates the key factors affecting the performance and the requirements set forth in environmental policies. The model may be implemented through selection of decision support instruments, through comparison, ranking and assessment of energy production technologies.

Environmental analysis in the energy sector starts from identification of the environment factors with the biggest effect on performance; then a system of quantitative and qualitative value-affecting criteria must be built and their weights identified. The environment of separate energy objects or technologies must be described considering the environment of the entire sector and relevant information that affects activities must be selected. A most expedient variant is to make use of indicator systems built for the analysis of sustainable development and of criteria sets suggested by various authors, if the sets suit the specifics and environment of the sector in question. The most efficient environment of the objects in question is determined by comparing the values and weights of environmental criteria and by analysing conceptual information. The impact of the environment in question may be described only having a system of numerous criteria with different meanings and dimensions.

Having selected the methods of multiple criteria analysis and collected quantitative and qualitative information, it is now time to identify the values and weights of criteria. Multiple criteria analysis of alternatives helps to select the most efficient energy production technology in terms of environmental factors. The developed model for evaluation of environmental factors is handy in selection of decision support instruments with emphasis on the policy of sustainable energy development. If an energy development plan is required, the assessment, comparison and ranking of energy production technologies in the context of sustainable development helps to select the most promising projects, and the best future technologies of energy production, also to include them in energy models. Assessment of scenarios related to environmental policy instruments helps to select the environmental policy instruments that secure achievement of the priority goals related to the energy sector development at the lowest cost for the public.

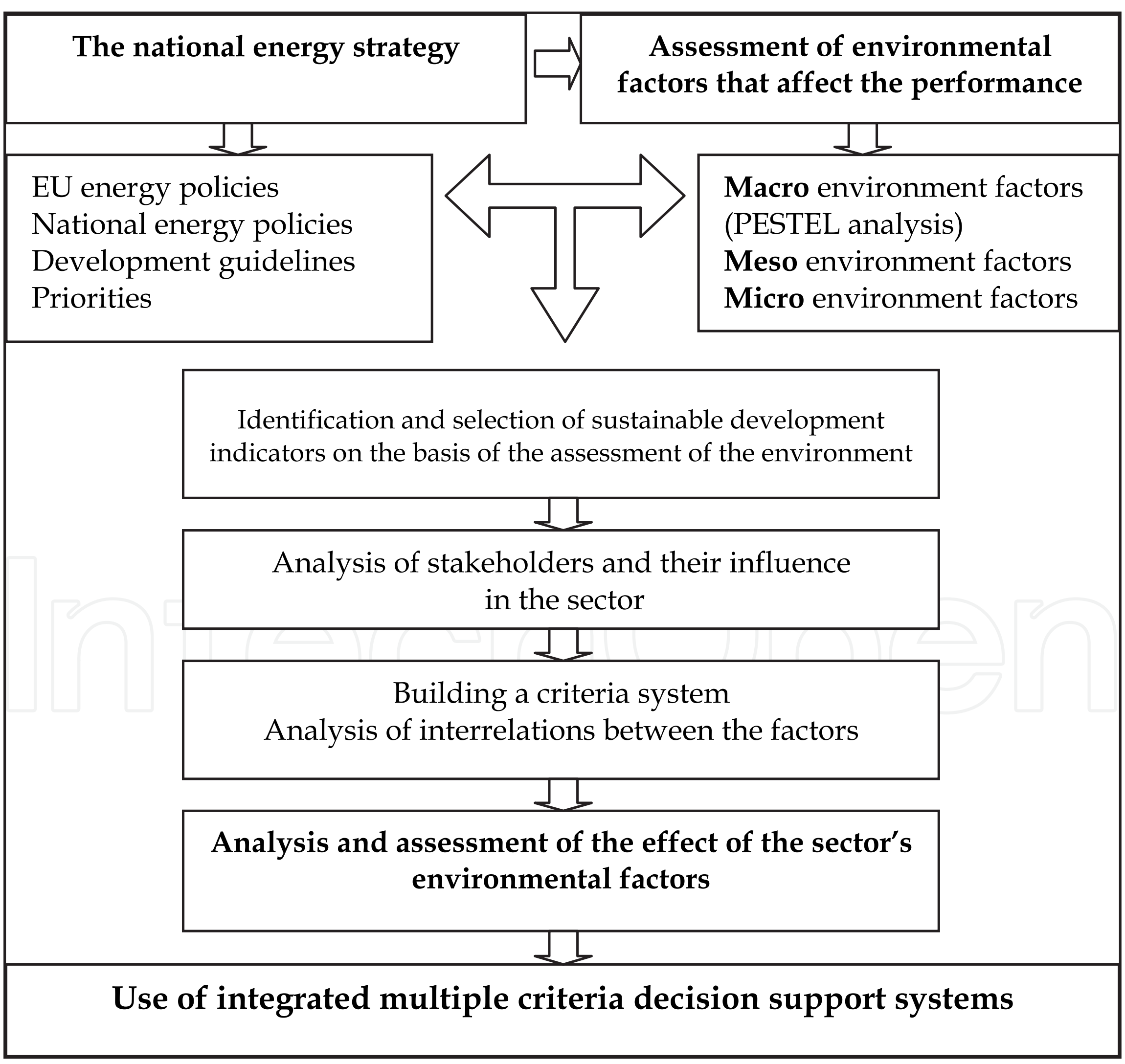


Fig. 4. Model for analysis of environmental factors in the energy sector

4. Decision making in the energy sector with the help of multiple criteria evaluation methods

A decision support system is treated as a chance, in view of the priorities, to select the best alternative from a set of alternatives framed or offered by the system. A typical decision-making procedure includes four main phases (Booty & Wong, 2010; Bergey et al., 2003):

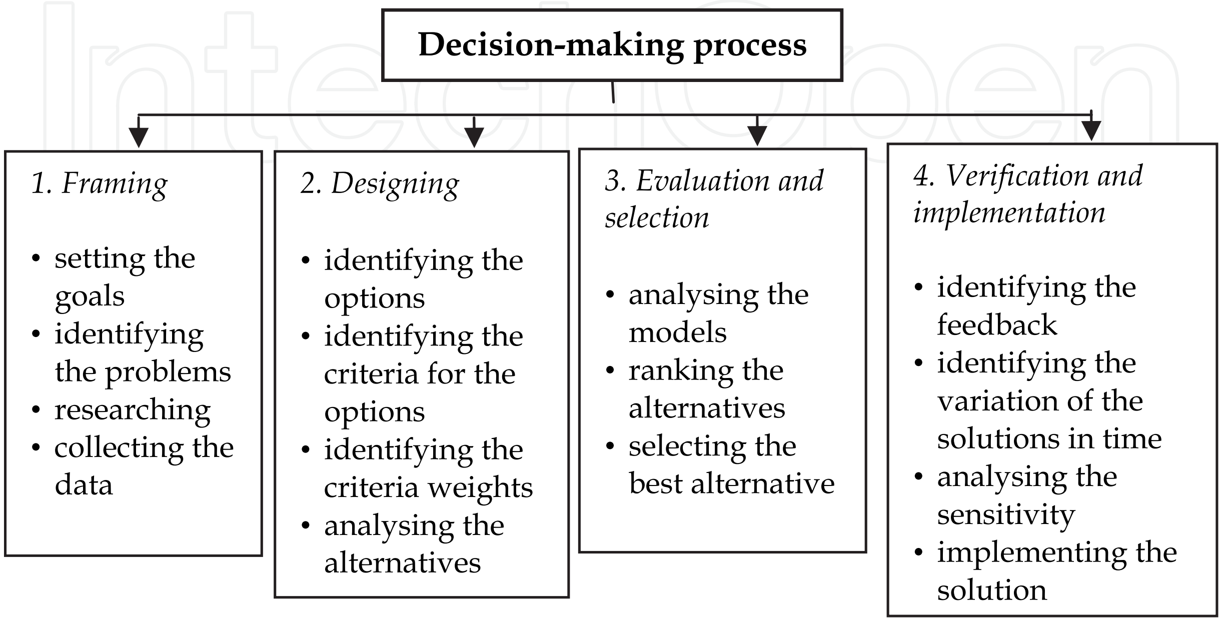


Fig. 5. Phases in decision-making

Each decision has a different context, thus we must consider:

- the goals;
- the object in question and its environment;
- the criteria defining the efficiency of our choice;
- the variables of the solution;
- the restrictions and risks.

The decision-making process starts from *goal setting* and problem identification. When our decision-making concerns the energy sector, the first and foremost step is defining the development priorities or the strategic goals of the development in the energy sector. The goal setting is of vital importance to make right decisions. The strategic goals must be clear and have explicit wording, they must be specific, measurable, matched, realistic, and time-dependent. Sometimes it is best to classify goals by their level. For instance, the Green Paper separates primary, interim and direct goals (Commission of the European..., 2006), but in real life primary and direct goals are more frequent. Primary goals are usually defined by variables at the strategic or higher level (degree of economic growth, social cohesion or sustainable development). These goals may be set forth in the White Paper, national strategies of economic development, and in other national strategic documents of importance. Direct goals are directly related to political instruments, programmes, or projects. Considering the suggested goals one must focus and select the criteria which contribute to direct—urgent—goals. These goals are seen in national energy strategies or development programmes for national energy sectors.

The next phase—*designing*—includes setting of the options, which may be handy while seeking the set goals. The options may include ranking of energy development scenarios or selection of the principal key political instruments, such as new environmental taxes for the energy sector, or individual projects to improve the reliability of energy supply. The most promising options are to be developed further. They may include the key political plans, such as changes in the tax policy, or more detailed options related to preparation of individual investment projects and development scenarios for electricity with the lowest costs. Here, feedback is important. The designing stage also must choose the way to compare the impact of different options or alternatives on implementation of the goals of the first priority. The selected criteria must reflect the performance related to the goals. Each criterion must be measurable for the sake of assessment—it must be possible to pick specific indicators that will help to assess the impact of choices on achievement of the set goals. This assessment may be also qualitative; it may express the relation between a certain criterion and the selected option. Identification of weights is an important aspect; a range of methods (described above) may be used for that purpose and the process also includes the assessment of the preferences of social groups.

The *evaluation and selection phase* includes the analysis of the alternatives. Practical solutions most often require financial analysis, price efficiency analysis, and, in some fields, the cost-benefit analysis. These types of analysis fully, or partially, depend on the expression in money. Conversely, multiple criteria analysis is directly related to some uncertainties and includes qualitative assessment; it allows to make the aspects considered sensitive by the public part of the decision-making process. The most solemn part of this phase is ranking of the alternatives to identify the best solutions. The reliability of the end result depends directly on the identified issues, analysed data, selected system of indicators, thoroughness in the assessment of environmental factors, etc.

The *implementation and verification phase* is for implementation of the selected solution and, if possible, verification of the result. It includes identification of the feedback and the variability of solutions in time, as well as the sensitivity analysis.

4.1 Information technology in decision-making: automated decision support systems

Multiple criteria analysis methods help to assess alternatives by processing huge amounts of information and data. Information technology may facilitate the process and make it suitable for problem solving at various levels. Mathematical data processing methods are used to build an information processing system for automated handling of any problems related to multiple criteria analysis of variants using a developed algorithm for the analysis of environmental factors. Automated decision support systems have a fundamental advantage: they may be modelled and adjusted on the basis of other systems, considering user needs and specific features of the alternatives in question. Automated decision support systems have the following advantages:

- possibility to base decision-making on data provided in a form adequate for the problem in question: numbers, text, graphical expressions, formulae, etc.;

decision support systems may be modelled and used both for individual and for group decision-making;

- customised software enables processing of huge amounts of information, and ensures access to data from diverse sources, as well as selection and addition of data that best reflect the needs and requirements;
- integrated software facilitates development of data models and complex studies, preparation of reports for users via a range of channels (internet, e-mail, printing and mobile devices).

Quite a few decision-making methods, expert decision support systems, neural networks, spreadsheets and analysers to facilitate decision-making are currently available worldwide. Decision support systems, by the type of support, are classified as follows: 1) individual decision support systems (IDSS); 2) group decision support systems (GDSS); 3) negotiation support systems (NSS), and 4) expert systems (ES). Expert systems are intended as a tool for skilled professionals of certain fields, for experts. Therefore, expert systems must incorporate a range of indicators that summarise the specific field-related knowledge and comprehensive information that describes the issue in question. The system "recognises" the situation, identifies the diagnosis, gives questions, and recommends decisions. These systems have many secondary functions: they make questions, model alternative decisions, and offer conclusions and recommendations.

Expert systems are gradually becoming an inseparable part of any decision-making process. Expert decision support systems are widely used in environmental studies, in political decision-making, in evaluations of strategies, development plans and projects, and in selection of alternatives, when such selection is not easy due to abundant factors that may affect the decision.

Expert systems may be classified into two groups:

1. Working expert systems: they are elaborated and approved expert systems continually used in decision-making and undergoing continual improvement (Svensson, 2002; Masood & Soo, 2002).
2. Conceptual expert systems: any systems in development and any expert systems for initial scientific assessment (Benavides & Prado, 2002).

Decision support systems successfully helped to handle a multiple criteria problem in the energy sector. One decision support system was developed specifically for Ghana and used in environmental research as a tool to justify the decisions related to restructuring of the electrical power industry (Bergey et al., 2003). One application was developed as a tool to analyse the dynamic price changes in the US wholesale market of electric power. This software is used for practical applications and is an effective instrument in modelling and simulation of situations in the market of electrical power trade (Sueyoshi & Tadiparthi, 2008). Literature sources cite a multiple criteria problem that was handled selecting competitive nuclear technologies, assessing environmental factors, and performing the analysis of alternatives. This decision-making process was based on the AHP methodology, which was also the basis for the relevant decision support system (Deok & Johoo, 2010; Shen et al., 2010). Decision support systems are used to select and maintain renewable energy technologies (Yue & Grant, 2007; Sliogeriene et al., 2009). They are also used to analyse the energy policies of EU member states, to set uniform evaluation criteria that help to consider countries with different levels of development and to assess their energy development in line with the principles of sustainable development, to assess the expansion of renewable energy sources, environment protection, and the performance of the energy sector (Patlitzianas & Psarras, 2007; Drozd, 2003). The ELECTRE methodology was used to develop a decision support system, which analyses the instruments that can help to improve the efficiency of energy consumption in view of environmental factors. Decision models also incorporate the cost-benefit analysis thus enabling the decision-maker to verify the final outcome of each decision (Neves et al., 2008). More decision support systems based on a number of multiple criteria analysis methodologies are available. But all these systems share one advantage: they can process huge amounts of information, and assess how the dynamically fluctuating impact of the environment affects the decisions.

Today the economic community of countries is becoming integrated fast, morphing into a single economic system. National economies become cells of a global economy, thus diverse decisions related to activities and development must be considered within a broader context. Integration into the community of global economic structures demands for internationally recognised and universally intelligible analysis and assessment methods, as well as for universally intelligible requirements and assessment criteria. Use of decision support systems can help to handle such tasks, because the systems facilitate use and assessment of a wide range of information and data, to come up with criteria systems for relevant factors, and to suggest solutions in line with the goals of the international community. Globalisation demands for knowledge how decision-makers come up and make decision in other parts of the world and how information systems (IS) may facilitate decision-making. Analyses consider the differences between national cultures, values, decision processes, and decision-making. “The existence of international differences in analyzing and conceptualizing strategic decisions raises doubts about the global applicability of IS such as decision support systems and executive information systems. The success of knowledge management and information systems in different countries and cultures will depend critically on how well IT applications are adapted to the decision styles of their users“ (Martinson & Davison, 2007).

Many tasks related to economic development are multiple criteria tasks. Within the context of sustainable development, energy is in the spotlight. The costs related to the building of energy infrastructure, exports and imports of energy sources and refined products, and end-user energy prices have enormous impact on the development of national economies; therefore, it is the trends of energy-related economic indicators that point out the potential of country’s economic development. Typical economic valuation methods and decision validation methods used in the market are the usual choice when one comes to practical issues of the development of the energy sector and selection of energy production technologies. These methods lack tools for integrated assessment of environmental factors, which could determine selection of more efficient and more economically promising technologies, as well as better environmental solutions.

The energy sector is marked by its versatile aspects, uncertainty, and the influence of interests; therefore, to validate various operational decisions, to model the development scenarios, and to make the decisions objective, we need methods, which would facilitate use of several interacting indications of values, validate the decisions in the decision-making process, and make the process more transparent. When it comes to modelling of variants related to the development and use of energy production technologies, as well as to management decisions, decision support system, which combines changing factors of macro-, meso- and microenvironment, environmental factors, as well as economic and technological indicators, would facilitate handling of practical tasks related to management of energy systems, to selection of effective technologies, to analysis of prices, and to search for the best development or management solutions.

4.2 Preparation of data for an automated decision support system

The selected objects operating in the energy sector were analysed using the method for multiple criteria complex proportional assessment and multiple criteria measuring of the utility degree and the market value, namely the COPRAS method. This method was selected because it allows:

- identifying the utility degree of alternatives, which shows the percentage at which one alternative is either better or worse than other alternatives in question;
- identifying the priority of alternatives;
- identifying the market value of alternatives in question;
- integrating classic valuation approaches based on economic indicators in the analysis.

The environmental studies performed by the authors were used as a basis to build the Decision Support System for Measurement of the Effect by the Environmental Factors on the Value of Energy Companies; the system, after more thorough studies and corrections, may be suggested for use in the energy sector as a tool helping to validate diverse decisions, to analyse and select energy production technologies.

In multiple criteria analysis methods, energy production technologies, or the companies which use such technologies, must be assessed considering quantitative (operational territory, number and length of engineering infrastructure objects, technical and technological parameters, economic indicators) and qualitative (condition, degree of modernisation and new technologies, environment protection, political, legal and legislative restrictions) criteria of the current market conjuncture, which describe the object, as well as other indicators that affect the value. When the key factors that may affect the result of the problem in question are selected, it is time to build the set of criteria and to determine weights of environmental indicators pertaining to the object in question.

When we have to assess alternatives in the energy sector, and to determine their efficiency, analysis focuses on a variety of energy production technologies, which differ both by their qualitative and quantitative parameters; the method of integrated analysis, however, allows to separate the factors that affect value, to determine the evaluation criteria, and thus to compare such technologies, to calculate their utility degrees, to make a priority line and to calculate the revised market value. The method of integrated analysis includes the following main steps:

1. Identification and description of qualitative and quantitative criteria that affect activities of a technological complex for energy production;
2. Building of an integrated database based on the description of the objects in question;
3. Use of multiple criteria analysis methods as a means to determine the utility degree and to revise the market value of the alternatives.

When the objects are already described in both quantitative and conceptual forms, an integrated database must be built to describe in detail internal and external factors that affect the value of the objects in question. The database is a basis for multi-variant designing and multiple criteria analysis of the objects. Even though the amounts of available data and information are huge, handling of a multiple criteria analysis problem is made considerably easier by using automated intelligent decision support systems designed in view of the selected goals.

4.2.1 Building of criteria systems

In order to assess the macro, meso and microenvironment factors that affect the utility degree, and the revised market value of the technological facilities for energy production, as well as in order to compare the objects, a system of defining criteria must be built. The system is built so that it helps to analyse the environment of the selected technological facilities together with economic and technical indicators pertaining to the objects. We divide the system of criteria into two main groups: qualitative criteria and quantitative criteria. The groups are then subdivided into subsystems, which may, in turn, be subdivided further:

Qualitative criteria:

- the subsystem describing the impact of macrolevel factors;
- the subsystem describing the impact of mesolevel factors;
- the subsystem describing the impact of microlevel factors.

Quantitative criteria:

- the subsystem describing the technical data;
- the subsystem describing the economic data;
- the subsystem describing the preliminary value.

The integrated method for the measurement of weights is used when the objects may be assessed using a sufficient pool of relevant quantitative criteria. A system of quantitative criteria includes economic, technical, or other criteria that describe the objects. Energy production technologies may be described by the rated capacity of the objects, the volume of energy production, the cost of energy production, profitability, number of users, book value or replacement value of the technological facilities and assets, etc.

Qualitative criteria that describe the impact of the environment are by no means less important than the quantitative criteria. The choice of qualitative criteria depends on the goals of the task; such criteria may describe the economic context and priorities, as well as attitudes and expectations of a range of social groups. Expert methods are used to identify the weights of qualitative criteria. When the integrated method is used to identify the weights of qualitative criteria, quantitative and qualitative features are considered.

4.2.2 Identifying values and weights of criteria

1. Expert assessment of energy production technologies (companies). The objects of the Lithuanian energy sector selected for the multiple criteria analysis problem to be handled with the COPRAS method produce energy using different technologies, and different primary energy sources. The objects are:

- *Kruonis Pumped-storage Hydroelectric Power Plant* - uses a combination of technologies based on renewable sources and traditional technologies;
- *Kaunas Hydroelectric Power Plant* - uses only technologies based on renewable sources;
- *The Lithuanian Power Plant* - uses traditional technologies (fuel oil and natural gas as the primary energy sources). Closing of Ignalina Nuclear Power Plant made this power plant the main electricity producer in Lithuania.
- *Experimental geothermal power plant* - uses a combination of technologies based on renewable sources and traditional technologies.

A questionnaire was compiled as a tool to analyse and determine the weights for qualitative criteria of the selected technological facilities of energy production. The questionnaire was compiled making it suitable for assessment of the main qualitative criteria defining the selected technological facilities of energy production. The questionnaires were filled in by groups of experts representing diverse social groups with different interests. The questionnaire was divided into three subsystems, each dealing with the effect either of macro, meso or micro qualitative factors. The subsystems include the criteria that describe the environment of the objects in question. Conditional measures—scores between 1 and 10—determine the criteria weights. Experts attributed bigger weights to the criteria they considered more important and such criteria had bigger impact on the final results of the assessment. The average estimates for each criterion determined on the basis of the results of expert assessment, and the resulting weights of the criteria, were identified for each group of experts.

Identifying Values and Weights of the Criteria. The results of the expert assessment were used to determine the weights of criteria defining the objects in question, and to arrange the weighted criteria in the order of their priority. Selected groups of experts took the job to determine the values and to list the criteria in line with the priorities selected by the experts. When the weights and the priorities of the criteria were clear, it was time to determine the key environmental factors that affect technological facilities of energy production. The research included a total of 29 criteria assessed by six groups of experts. The reliability was ensured by assessing the agreement between expert opinions with the help of the Kendall's coefficient of concordance. The value of the coefficient of concordance *W* is 0.29, which is above zero and thus ensures sufficient reliability of criteria weights obtained by the outranking method. The result, however, shows low degree of agreement between expert opinions. It is only natural when the experts selected for such expert assessment have different attitudes towards the environment that affects this industry. Moreover, 29 criteria selected for our research make it more complex and the deviation of expert opinions is more likely. To make the research more reliable, it is possible to determine criteria weights for each subsystem of the analysed environment—macro, meso and microenvironment—separately. This would make the research simpler for experts. Expert assessments are stochastic: changes in the composition of the groups would also change the assessments of the indicators, which determine the coefficient of concordance (Podvezko, 2005).The ranking of the key criteria obtained after the expert assessment is shown in Table 2.

x_i	**Criterion**	**Weight**
24	Experience of CEOs	0.061
14	Profitability	0.055
25	Supply of skilled professionals	0.053
27	Readiness to choose and introduce innovations	0.052
1	EU regulation of activities related to electric power supply	0.049
10	Environmental regulation	0.049
6	Investment conditions	0.047

Table 2. Criteria line-up by weight after the expert assessment

The results of expert examination suggest that experts consider the experience of CEOs, profitability, supply of skilled professionals, and readiness to introduce innovations as important factors for different technological facilities of energy production. The experts believe that environmental regulation, technological shift, and corporate social responsibility are also of importance. The latter criterion was ranked 12th of 29. It shows that both employees who were members of the groups of experts and other experts from energy companies expect responsibility when it comes to activities, to handling of environmental issues, and to the response to public needs. Such criteria as competitive environment and relations with authorities received low weights. This is because technological facilities of energy production are currently monopolies in the energy sector, the companies that could compete do not yet have favourable conditions to enter the market.

4.3 Decision support system for measurement of the effect by the environmental factors on the value of energy companies—ESIAPVN-DS

This section presents a case of the integrated multiple criteria analysis of alternatives using the Decision Support System for Measurement of the Effect by the Environmental Factors on the Value of Energy Companies. The system was developed using the algorithm developed by the authors and following the methodology suggested by the scientists E.K. Zavadskas and A. Kaklauskas (Zavadskas et al., 1994; Kaklauskas, 1999; Zavadskas & Kaklauskas, 2008). The system may be used to measure the utility degree, the priority and, if required, the market value of energy production technologies with different technological and economic parameters. The system has an innovative feature: recommendations and other information to facilitate decision-making are provided after the analysis of each criterion describing the environment. Environmental research in the energy sector and data assessment with multiple criteria analysis methods helped to build a universal set of criteria defining the environment in question.

The experimental Decision Support System for Measurement of the Effect by the Environmental Factors on the Value of Energy Companies (ESIAPVN-DS) in designed for measurement of the utility, priority and value in energy companies which use different energy production technologies. The system is suitable both for analysis of separate energy production technologies and of technological facilities (companies). The ESIAPVN-DS system speeds up handling of tasks, provides rather accurate and unbiased results, and enables the access to comprehensive data about the object in question. A huge advantage in the system is the interim result, which shows the impact of each criterion on the utility degree and value. In this research, this decision support system is used for the first time to perform multiple criteria analysis of energy objects with different operating parameters, features and levels of external effect. The decision support system consists of the following models:

- measuring model for the initial criteria weights;
- model for multiple criteria analysis and priority setting of objects;
- measuring model for the utility degree of objects;
- measuring model for the market value;
- recommender model.

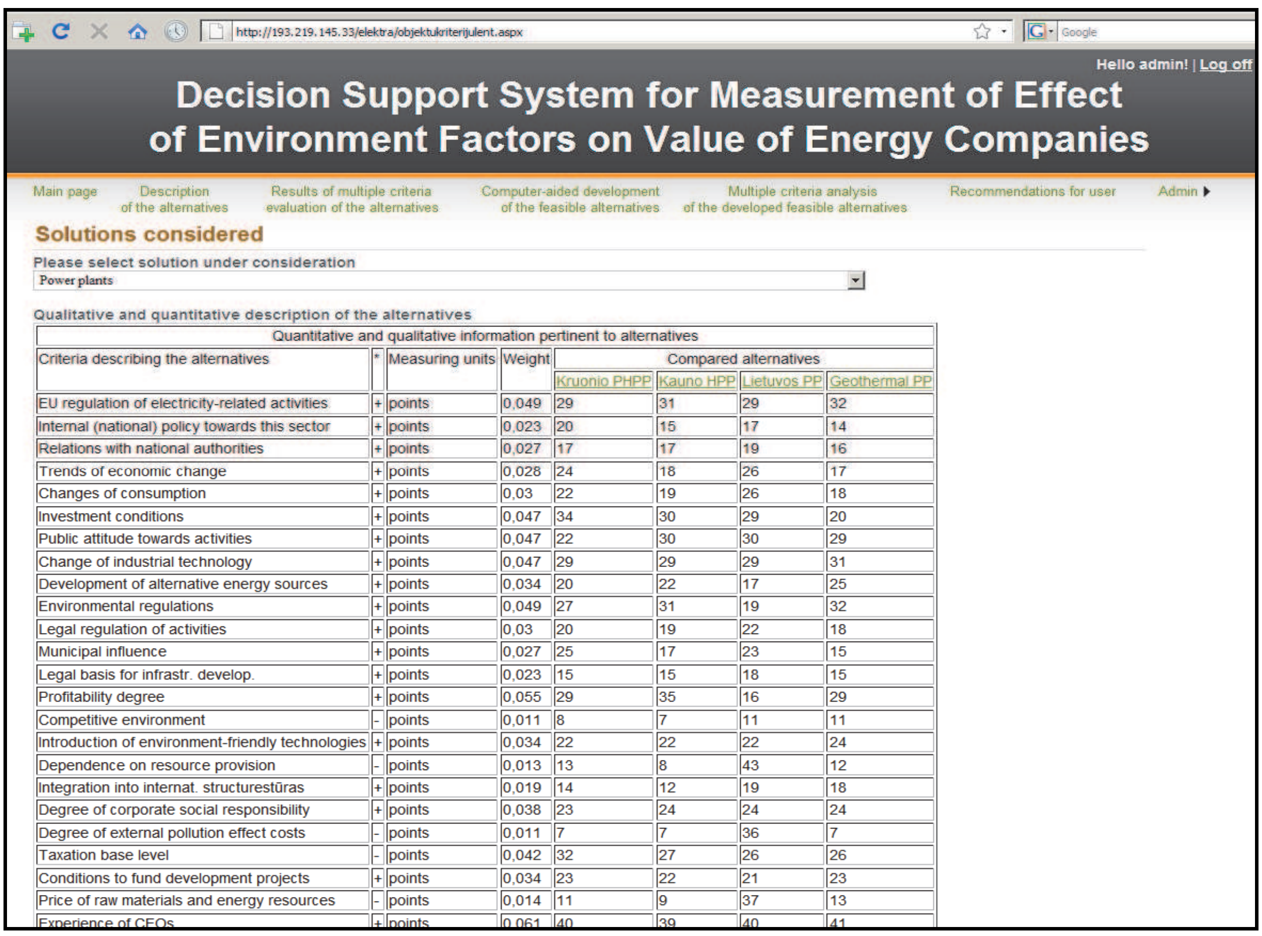
Users, with the help of the model base management system, may choose any model they need. The system is designed in a way that the output of certain models is used as the input in other models, while the output of these latter models is used as the input yet in other models. The ESIAPVN-DS system may process huge amounts of data to solve the main task. The system is, however, user-friendly.

When the ESIAPVN-DS system is used for measuring of the market value and the utility degree, the procedure includes the following stages:

Stage 1. Preparation of the data about the objects in question (projects, scenarios, technologies, technological facilities). It involves analysis of the materials describing the specific environment of the objects in question, the factors that affect the activities. The objects in question are described in quantitative and conceptual forms;

Stage 2. The system of quantitative and qualitative criteria built on the basis of the analysis of the factors that affect the environment of the object in question is used to determine the criteria values. A group of experts determines the initial values of the criteria, while the weights are already known from the expert assessment method. When the ESIAPVN-DS system and the built set of criteria are used, there is no need to determine the weights anew;

Stage 3. Input of the expert assessment data into the ESIAPVN-DS system for data processing;
Stage 4. The system's model bases are used to process the data: the programme compiles a matrix of normalised weighted criteria expressed in numbers, and determines the revised market value, priority and utility of the objects;
Stage 5. The ESIAPVN-DS system's recommender model analyses the results: the system gives the values of the criteria that affect the value, and automatically prepares and suggests recommendations on ways to reduce or increase the impact of certain criteria and thus to increase the market value of the object.
The ESIAPVN-DS system is available online at the address <*http://iti.vgtu.lt/elektra/*> . In the main page of the ESIAPVN-DS system, the system's administrator or a user may log in and fill in the main data tables (Fig. 6). The figure shows the expert assessment results of the energy objects selected for our analysis (Kruonis Pumped-storage Hydroelectric Power Plant, Kaunas Hydroelectric Power Plant, the Lithuanian Power Plant and the experimental geothermal power plant).

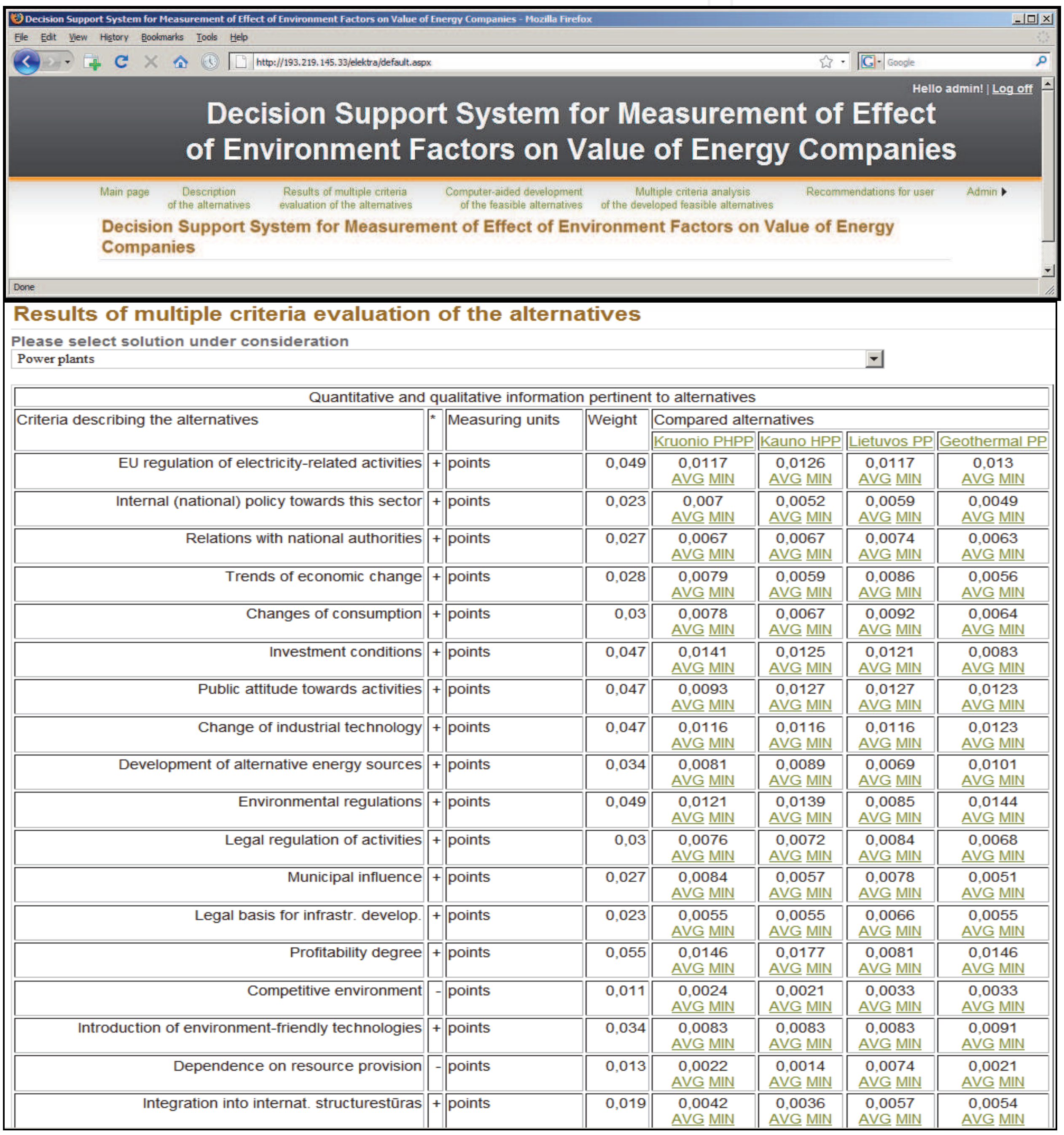


Quantitative and qualitative information pertinent to alternatives							
Criteria describing the alternatives	*	Measuring units	Weight	Compared alternatives			
				Kruonio PHPP	Kauno HPP	Lietuvos PP	Geothermal PP
EU regulation of electricity-related activities	+	points	0,049	29	31	29	32
Internal (national) policy towards this sector	+	points	0,023	20	15	17	14
Relations with national authorities	+	points	0,027	17	17	19	16
Trends of economic change	+	points	0,028	24	18	26	17
Changes of consumption	+	points	0,03	22	19	26	18
Investment conditions	+	points	0,047	34	30	29	20
Public attitude towards activities	+	points	0,047	22	30	30	29
Change of industrial technology	+	points	0,047	29	29	29	31
Development of alternative energy sources	+	points	0,034	20	22	17	25
Environmental regulations	+	points	0,049	27	31	19	32
Legal regulation of activities	+	points	0,03	20	19	22	18
Municipal influence	+	points	0,027	25	17	23	15
Legal basis for infrastr. develop.	+	points	0,023	15	15	18	15
Profitability degree	+	points	0,055	29	35	16	29
Competitive environment	-	points	0,011	8	7	11	11
Introduction of environment-friendly technologies	+	points	0,034	22	22	22	24
Dependence on resource provision	-	points	0,013	13	8	43	12
Integration into internat. structurestūras	+	points	0,019	14	12	19	18
Degree of corporate social responsibility	+	points	0,038	23	24	24	24
Degree of external pollution effect costs	-	points	0,011	7	7	36	7
Taxation base level	-	points	0,042	32	27	26	26
Conditions to fund development projects	+	points	0,034	23	22	21	23
Price of raw materials and energy resources	-	points	0,014	11	9	37	13
Experience of CEOs	+	points	0,061	40	39	40	41

Fig. 6. The main window of the ESIAPVN-DS system with values of the environmental criteria that affect energy companies

The system automatically processes the data and, upon clicking on relevant links, shows the results of multiple criteria evaluation of the objects. The system automatically solves the multiple criteria task: performs multiple criteria analysis of the selected objects, measures their utility degree and market value and thoroughly analyses the impact of the criteria on

the value. Simple active links in the main window lead to the model required for your decision. To access the measuring model for the initial criteria weights you must click "Description of the alternatives". This link leads to the expert assessment of the criteria and to their weights (qualitative and quantitative criteria, their values and weights are shown for each object). A click on the menu item "Multiple criteria analysis of the developed feasible alternatives" in the ESIAPVN-DS system leads to building of a normalised decision-making matrix, which helps to assess the criteria and to determine their values and weights.
The next link in the main window, "Results of multiple criteria evaluation of the alternatives", leads to the automatic assessments of the objects in question based on the criteria system (Fig. 7). The system shows the numerical values of normalised weighted



Results of multiple criteria evaluation of the alternatives

Please select solution under consideration

Power plants

Quantitative and qualitative information pertinent to alternatives							
Criteria describing the alternatives	*	Measuring units	Weight	Compared alternatives			
				Kruonio PHPP	Kauno HPP	Lietuvos PP	Geothermal PP
EU regulation of electricity-related activities	+	points	0,049	0,0117 AVG MIN	0,0126 AVG MIN	0,0117 AVG MIN	0,013 AVG MIN
Internal (national) policy towards this sector	+	points	0,023	0,007 AVG MIN	0,0052 AVG MIN	0,0059 AVG MIN	0,0049 AVG MIN
Relations with national authorities	+	points	0,027	0,0067 AVG MIN	0,0067 AVG MIN	0,0074 AVG MIN	0,0063 AVG MIN
Trends of economic change	+	points	0,028	0,0079 AVG MIN	0,0059 AVG MIN	0,0086 AVG MIN	0,0056 AVG MIN
Changes of consumption	+	points	0,03	0,0078 AVG MIN	0,0067 AVG MIN	0,0092 AVG MIN	0,0064 AVG MIN
Investment conditions	+	points	0,047	0,0141 AVG MIN	0,0125 AVG MIN	0,0121 AVG MIN	0,0083 AVG MIN
Public attitude towards activities	+	points	0,047	0,0093 AVG MIN	0,0127 AVG MIN	0,0127 AVG MIN	0,0123 AVG MIN
Change of industrial technology	+	points	0,047	0,0116 AVG MIN	0,0116 AVG MIN	0,0116 AVG MIN	0,0123 AVG MIN
Development of alternative energy sources	+	points	0,034	0,0081 AVG MIN	0,0089 AVG MIN	0,0069 AVG MIN	0,0101 AVG MIN
Environmental regulations	+	points	0,049	0,0121 AVG MIN	0,0139 AVG MIN	0,0085 AVG MIN	0,0144 AVG MIN
Legal regulation of activities	+	points	0,03	0,0076 AVG MIN	0,0072 AVG MIN	0,0084 AVG MIN	0,0068 AVG MIN
Municipal influence	+	points	0,027	0,0084 AVG MIN	0,0057 AVG MIN	0,0078 AVG MIN	0,0051 AVG MIN
Legal basis for infrastr. develop.	+	points	0,023	0,0055 AVG MIN	0,0055 AVG MIN	0,0066 AVG MIN	0,0055 AVG MIN
Profitability degree	+	points	0,055	0,0146 AVG MIN	0,0177 AVG MIN	0,0081 AVG MIN	0,0146 AVG MIN
Competitive environment	-	points	0,011	0,0024 AVG MIN	0,0021 AVG MIN	0,0033 AVG MIN	0,0033 AVG MIN
Introduction of environment-friendly technologies	+	points	0,034	0,0083 AVG MIN	0,0083 AVG MIN	0,0083 AVG MIN	0,0091 AVG MIN
Dependence on resource provision	-	points	0,013	0,0022 AVG MIN	0,0014 AVG MIN	0,0074 AVG MIN	0,0021 AVG MIN
Integration into internat. structurestūras	+	points	0,019	0,0042 AVG MIN	0,0036 AVG MIN	0,0057 AVG MIN	0,0054 AVG MIN

Dependence on resource provision	-	points	0,013	0,0022 AVG MIN	0,0014 AVG MIN	0,0074 AVG MIN	0,0021 AVG MIN
Integration into internat. structurestūras	+	points	0,019	0,0042 AVG MIN	0,0036 AVG MIN	0,0057 AVG MIN	0,0054 AVG MIN
Degree of corporate social responsibility	+	points	0,038	0,0092 AVG MIN	0,0096 AVG MIN	0,0096 AVG MIN	0,0096 AVG MIN
Degree of external pollution effect costs	-	points	0,011	0,0014 AVG MIN	0,0014 AVG MIN	0,0069 AVG MIN	0,0014 AVG MIN
Taxation base level	-	points	0,042	0,0121 AVG MIN	0,0102 AVG MIN	0,0098 AVG MIN	0,0098 AVG MIN
Conditions to fund development projects	+	points	0,034	0,0088 AVG MIN	0,0084 AVG MIN	0,008 AVG MIN	0,0088 AVG MIN
Price of raw materials and energy resources	-	points	0,014	0,0022 AVG MIN	0,0018 AVG MIN	0,0074 AVG MIN	0,0026 AVG MIN
Experience of CEOs	+	points	0,061	0,0152 AVG MIN	0,0149 AVG MIN	0,0152 AVG MIN	0,0156 AVG MIN
Supply of qualified specialists	+	points	0,053	0,0127 AVG MIN	0,0131 AVG MIN	0,0134 AVG MIN	0,0138 AVG MIN
Price of labour resources	-	points	0,05	0,0148 AVG MIN	0,0148 AVG MIN	0,0125 AVG MIN	0,0079 AVG MIN
Readiness to select and use innovations	+	points	0,052	0,0128 AVG MIN	0,0132 AVG MIN	0,0128 AVG MIN	0,0132 AVG MIN
Cooperation with science establishments	+	points	0,027	0,0058 AVG MIN	0,0049 AVG MIN	0,0073 AVG MIN	0,009 AVG MIN
Influence of stakeholder groups	-	points	0,028	0,007 AVG MIN	0,007 AVG MIN	0,007 AVG MIN	0,007 AVG MIN
Company's income capitalisation value	-	thousand LTL	0,2	0,1051 AVG MIN	0,0084 AVG MIN	0,0849 AVG MIN	0,0017 AVG MIN
Company's rated capacity	+	MW	0,3	0,0952 AVG MIN	0,0107 AVG MIN	0,1904 AVG MIN	0,0037 AVG MIN
Production cost (energy price)	-	cnt/kwh	0,5	0,1486 AVG MIN	0,0608 AVG MIN	0,2095 AVG MIN	0,0811 AVG MIN
The sums of weighted normalized maximizing (projects 'pluses') indices of the alternative				0,3046	0,2195	0,3962	0,2138
The sums of weighted normalized minimizing (projects 'minuses') indices of the alternative				0,2958	0,1079	0,3487	0,1169
Significance of the alternative				0,4708	0,5304	0,5157	0,5227
Priority of the alternative				4	1	3	2
Utility degree of the alternative (%)				88,77%	100,01%	97,23%	98,55%

Fig. 7. Compiling the normalised decision-making matrix, determining and comparing the utility degree of objects in the ESIAPVN-DS system

criteria and the sums of maximising and minimising normalised weighted indicators (S_{+j} and S_{-j}), and determines the weight Q_j, priority and utility N_j of the objects.

The system has an important advantage, because it shows the interim results—the analysis of weights of all criteria used in the research, and visual representation of the objects. Criteria weights are analysed by clicking any matrix cell with the value of the selected criterion (links AVG, MN) in the table of multiple criteria analysis of alternatives. The result is a percentage for each selected criterion, which is compared with an equivalent criterion of other objects and shows that an improved value of the criterion may increase the value of the object. The analysis of such results may be an effective and useful tool for comparisons of energy production technologies, for operational analysis, for management decisions and operational improvement plans, and for performance assessments. In the same model window, it is possible to choose an object, to click on the cell with the data of the replacement cost criterion, and the system will show the value of the object revised considering the effect of environmental factors.

The typical input data used in decision support systems for value measurements are the features of the objects and the values of the objects determined using the sales comparison approach. It is hard to come by comparable items when the valuation concerns energy objects and energy production technologies. Moreover, the value of past transactions sometimes does not reflect the real value. Thus the replacement cost of an object (technological facilities) is selected as the initial value in the ESIAPVN-DS system. The replacement cost of energy objects is generally well above the income generated by the objects. The replacement cost, however, is closer to the value suggested, in legal acts that regulate accounting and valuation, and in European valuation standards, for accounting of assets of economic infrastructure companies (European Valuation Standards, 2009).

To boost the reliability of the utility analysis and market value revisions for energy objects, the main quantitative criterion (replacement cost) is accompanied by additional quantitative criteria—the rated capacity of energy objects (MW), and production cost (cnt/kwh). The system measures the value of the energy objects in question by assessing the values of qualitative and quantitative criteria. This research also includes a quantitative criterion: the income value of the assets of the energy object determined by independent property valuators. Several integrated values (replacement cost and income) make the measured utility, priority and market value more reliable. The ESIAPVN-DS system lets to analyse the object's value using a rather large set of criteria for thorough description of the environment in question. The set may be supplemented or revised, if needed. The reliability of the determined value depends on the importance of selected quantitative and qualitative criteria.

The link "Computer aided development of the feasible alternatives" of the decision support system leads to automatically assessed weights for selected criteria of the objects, and the utility degree of the objects. The best result—the highest utility degree—belongs to Kaunas Hydroelectric Power Plant, followed by the experimental geothermal power plant. The geothermal power plant benefited from its use of renewable resources, and favourable assessment of the environment. Among the advantages of Kaunas Hydroelectric Power Plant are high profitability, positive environmental aspects, favourable public opinion about its activities, and low production costs. Stakeholders also see these objects in a favourable rather than hostile light.

The Lithuanian Power Plant came third by its utility. This power plant is marked by high production costs, negative effect on the environment, high environmental costs, it also depends on increasing prices of raw materials, and the access to resources. But its technical indicators (capacity), as well as the ratio between the produced amounts of energy and the cost of asset generation, make a positive impact. Kruonis Pumped-storage Hydroelectric Power Plant has the lowest utility among all objects. Economic criteria are responsible: rather high cost of produced energy, and high replacement cost. Low volumes of production (electric power) at that time also made impact in the research. Now the power plant is working at full capacity, thus the results would probably be better.

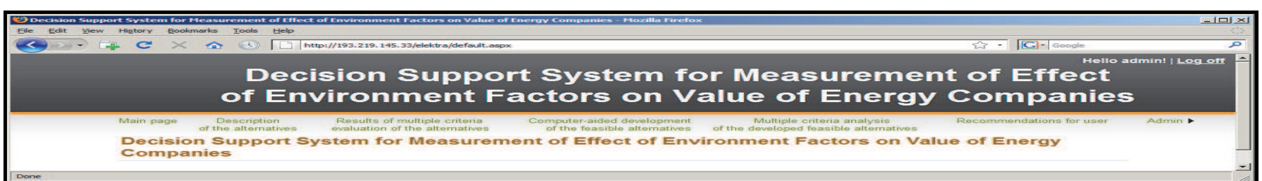
The utility degrees and values of the companies in question measured by the ESIAPVN-DS system are rather logical; also the results come fast, the results and conclusions give more information, the system provides recommendations and prevents errors. The values obtained using the traditional methods and included in the set of quantitative criteria ensure a more reliable result; they enable its comparison, and its use as a basis to validate the measured value. They also help to make a decision on the final value of the object.

4.3.1 Recommendations in the ESIAPVN-DS System

The problem is how to define an efficient energy production technologies life cycle when a lot of various interested parties are involved, the alternative project versions come to hundreds thousand and the efficiency changes with the alterations in the micro, meso and macro environment conditions and the constituent parts of the process in question. Moreover, the realization of some objectives seems more rational from the economic and ecological perspectives thought from the other perspectives they have various significance. Therefore, it is considered that the efficiency of energy production technologies life cycle depends on the rationality of its stages as well as on the ability to satisfy the needs of the interested parties and the rational character of the micro, meso and macro environment conditions.

Formalized presentation of the multiple criteria analysis (see Table 8) shows how changes in the micro, meso and macro environment and the extent to which the goals pursued by various interested parties are satisfied cause corresponding changes in the value and utility degree of diferent energy production technologies. With this in mind, it is possible to solve the problem of optimisation concerning satisfaction of the needs at reasonable expenditures. This requires the analysis of energy production technologies versions allowing to find an optimal combination of different interested parties goals pursued, micro, meso and macro environment conditions and finances available. (Sliogeriene et al., 2009).

The ESIAPVN-DS system gives comprehensive information about the quantitative effect on the value by the environmental factors of energy companies: the system analyses the effect of each criterion separately. For example, a click on any selected criteria value in its cell (links AVG, MN) within the matrix of alternatives (menu item "Descriptions of the alternatives") activates automatic assessment and the system offers a recommendation to increase the company's value by changing the criterion respectively (Fig. 8).

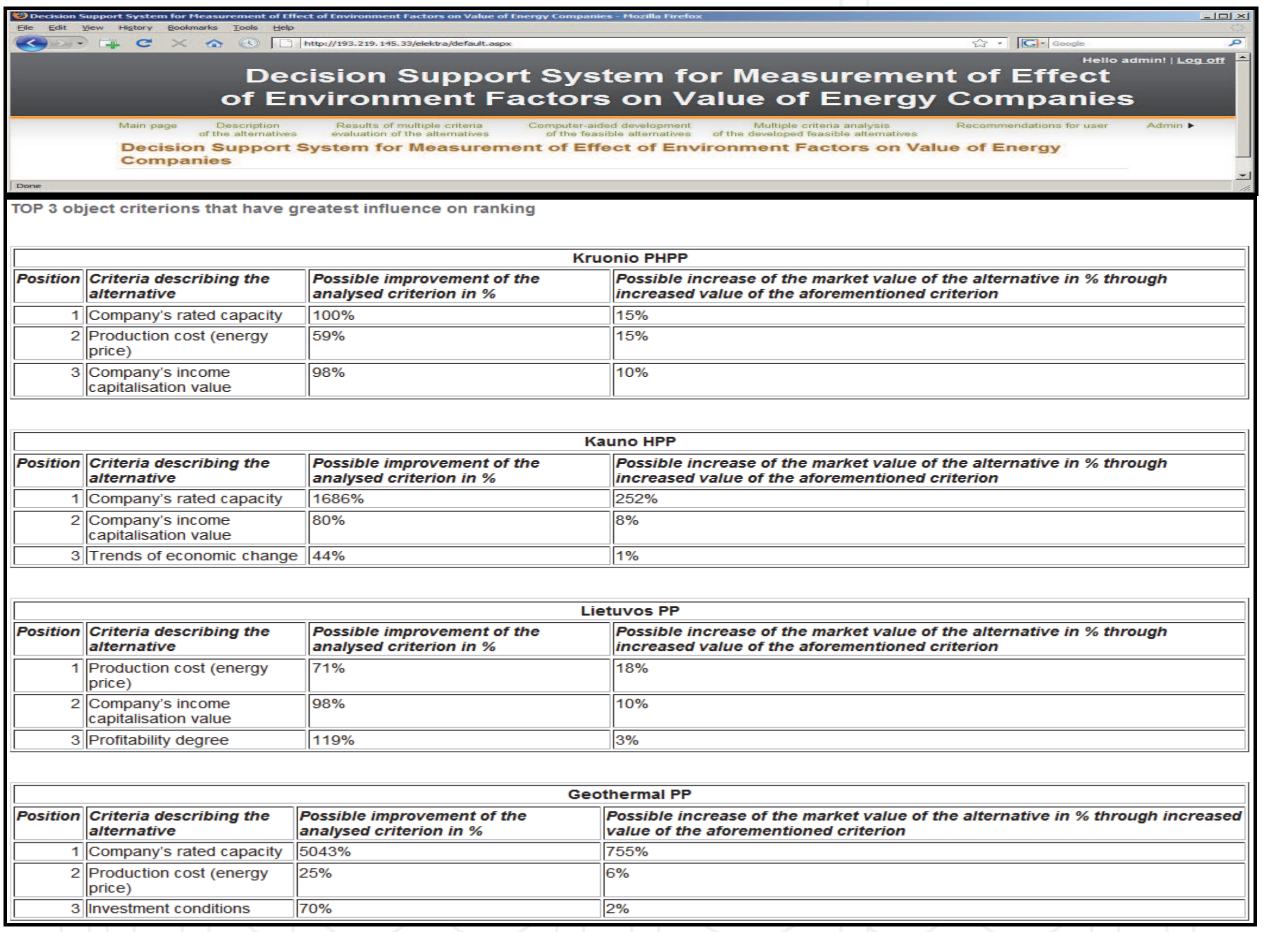


Quantitative and qualitative information pertinent to alternatives

Criteria describing the alternatives	*	Measuring units	Weight	- Compared alternatives - Possible improvement of the analysed criterion in % - Possible increase of the market value of the alternative in % through increased value of the aforementioned criterion			
				Kruonio PHPP	Kauno HPP	Lietuvos PP	Geothermal PP
EU regulation of electricity-related activities	+	points	0,049	29 (10,34%)(0,253%)	31 (3,23%)(0,079%)	29 (10,34%)(0,253%)	32 (0%)(0%)
Internal (national) policy towards this sector	+	points	0,023	20 (0%)(0%)	15 (33,33%)(0,383%)	17 (17,65%)(0,203%)	14 (42,86%)(0,492%)
Relations with national authorities	+	points	0,027	17 (11,76%)(0,159%)	17 (11,76%)(0,159%)	19 (0%)(0%)	16 (18,75%)(0,253%)
Trends of economic change	+	points	0,028	24 (8,33%)(0,116%)	18 (44,44%)(0,621%)	26 (0%)(0%)	17 (52,94%)(0,74%)
Changes of consumption	+	points	0,03	22 (18,18%)(0,272%)	19 (36,84%)(0,552%)	26 (0%)(0%)	18 (44,44%)(0,666%)
Investment conditions	+	points	0,047	34 (0%)(0%)	30 (13,33%)(0,313%)	29 (17,24%)(0,405%)	20 (70%)(1,643%)
Public attitude towards activities	+	points	0,047	22 (36,36%)(0,853%)	30 (0%)(0%)	30 (0%)(0%)	29 (3,45%)(0,081%)
Change of industrial technology	+	points	0,047	29 (6,9%)(0,162%)	29 (6,9%)(0,162%)	29 (6,9%)(0,162%)	31 (0%)(0%)
Development of alternative energy sources	+	points	0,034	20 (25%)(0,424%)	22 (13,64%)(0,231%)	17 (47,06%)(0,799%)	25 (0%)(0%)
Environmental regulations	+	points	0,049	27 (18,52%)(0,453%)	31 (3,23%)(0,079%)	19 (68,42%)(1,674%)	32 (0%)(0%)
Legal regulation of activities	+	points	0,03	20 (10%)(0,15%)	19 (15,79%)(0,236%)	22 (0%)(0%)	18 (22,22%)(0,333%)
Municipal influence	+	points	0,027	25 (0%)(0%)	17 (47,06%)(0,634%)	23 (8,7%)(0,117%)	15 (66,67%)(0,899%)
Legal basis for infrastr. develop.	+	points	0,023	15 (20%)(0,23%)	15 (20%)(0,23%)	18 (0%)(0%)	15 (20%)(0,23%)
Profitability degree	+	points	0,055	29 (20,69%)(0,568%)	35 (0%)(0%)	16 (118,75%)(3,261%)	29 (20,69%)(0,568%)
Competitive environment	-	points	0,011	8 (12,5%)(0,069%)	7 (0%)(0%)	11 (36,36%)(0,2%)	11 (36,36%)(0,2%)
Introduction of environment-friendly technologies	+	points	0,034	22 (9,09%)(0,154%)	22 (9,09%)(0,154%)	22 (9,09%)(0,154%)	24 (0%)(0%)
Dependence on resource provision	-	points	0,013	13 (38,46%)(0,25%)	8 (0%)(0%)	43 (81,4%)(0,528%)	12 (33,33%)(0,216%)
Integration into internat. structurestūras	+	points	0,019	14 (35,71%)(0,339%)	12 (58,33%)(0,553%)	19 (0%)(0%)	18 (5,56%)(0,053%)

Fig. 8. Calculations in the matrix of alternatives revealing how the criteria affect the value

The system's user may select any criterion relevant to the analysis in question. The ESIAPVN-DS system helps to get automated and unbiased recommendations about the effect of individual criteria. The recommendations are grounded on the values and weights of specific criteria, as well as on comparisons of the objects. The ESIAPVN-DS system lets to analyse individual criteria: not only to find the criteria with the biggest impact on the value, but also to compute the chance to improve the criteria. It is then possible to make reasonable decisions and choose for companies the development trends, innovations, optimisation of economic indicators, reduction of hostility among stakeholder groups, or initiation of amendments in the legislative basis. Figure 9 shows some recommendations suggested by the ESIAPVN-DS system.



Kruonio PHPP			
Position	Criteria describing the alternative	Possible improvement of the analysed criterion in %	Possible increase of the market value of the alternative in % through increased value of the aforementioned criterion
1	Company's rated capacity	100%	15%
2	Production cost (energy price)	59%	15%
3	Company's income capitalisation value	98%	10%

Kauno HPP			
Position	Criteria describing the alternative	Possible improvement of the analysed criterion in %	Possible increase of the market value of the alternative in % through increased value of the aforementioned criterion
1	Company's rated capacity	1686%	252%
2	Company's income capitalisation value	80%	8%
3	Trends of economic change	44%	1%

Lietuvos PP			
Position	Criteria describing the alternative	Possible improvement of the analysed criterion in %	Possible increase of the market value of the alternative in % through increased value of the aforementioned criterion
1	Production cost (energy price)	71%	18%
2	Company's income capitalisation value	98%	10%
3	Profitability degree	119%	3%

Geothermal PP			
Position	Criteria describing the alternative	Possible improvement of the analysed criterion in %	Possible increase of the market value of the alternative in % through increased value of the aforementioned criterion
1	Company's rated capacity	5043%	755%
2	Production cost (energy price)	25%	6%
3	Investment conditions	70%	2%

Fig. 9. Recommendations in the ESIAPVN-DS system

We shall use the criterion "legal regulation of activities" of the experimental geothermal power plant to illustrate the potential of the recommender module. Experts gave 18 points to this criterion of the experimental geothermal power plant (the worst legal regulation of activities among all energy objects in question). Calculations show that the legal regulation of activities may be improved by about 22 %. Such improvement of the legal regulation of activities by 22 % would raise the market value of the geothermal power plant by 2 %. The European Union strongly supports the expansion of alternative energy and encourages the governments of member states to reorganise their legislative basis respectively, thus creating favourable conditions for the expansion of alternative energy production sources.

This criterion may definitely be improved and the improvement may be achieved by efforts of CEOs and politicians.

The developed ESIAPVN-DS system ensures informative and unbiased results, which may be used in assessment of diverse energy objects aiming to determine their utility and the efficiency of their environment, but in other types of analysis as well. This system is experimental and not used for practical applications, because it needs further improvement and enhancement of individual functions, as well as continuity of studies. The current version of the system, however, may be used as an extra method or tool to control the reliability of results in a range of studies or analyses. The system, after further improvements, may be a useful tool in analyses dealing with the impact of environmental factors on the value, utility, and performance of objects, in identification of the vital values of environmental factors, and as an aid to plan the potential activities, to choose development scenarios, and to assess technologies. The ESIAPVN-DS system uses the set of criteria describing the environmental factors and the criteria weights and thus may analyse a variety of companies operating in the sector, may accumulate the data and use it later in analyses of other objects. In analysis of the development trends of the energy sector, in selection of alternatives, or in measuring of the utility degrees of individual energy production technologies, the main research interest is selection of the criteria and building of a system of universal criteria for the sector's analysis. Important aspects are choice of adequate criteria significant in the sector, finding the relation between criteria of various levels, and assessment of their weights. Then it would be possible to make the decision support systems for the analysis of the sector more universal, and to expand their application.

5. Conclusions

In the energy sector, decisions encompass interrelated solutions at various levels: selection of development scenarios in the energy sector; decisions on implementation of political instruments; or decisions on the choice of specific technologies for energy production in the future, and on promotion and implementation of specific energy projects. The analysis of alternative decisions made at different levels demands for relevant criteria for the assessment of such alternatives, as well as for indicators to be used in quantitative and qualitative evaluation of the alternatives. The methods based on multiple criteria analysis are promising when one has to analyse the energy sector and energy production technologies. Moreover, these methods have advantages over the traditional analysis methods based on economic data. The multiple criteria methods have tools that help to consider the full set of environmental factors of the object, and to integrate significant economic indicators. They also eliminate the bias of analysts and ground the assumptions on a comprehensive market analysis.

The experts assessed the impact on the value by environmental factors and their assessment suggests that the experience of CEOs, readiness to introduce innovations, environmental factors, and corporate social responsibility are important factors that affect the activities of the selected objects operating in the sector in question. The effect of these factors on operating decisions and the value of objects may only be assessed using innovative methods based on mathematical analysis, for example, multiple criteria complex proportional method for measurement of the utility degree and the market value.

The experimental Decision Support System for Measurement of the Effect by the Environmental Factors on the Value of Energy Companies (ESIAPVN-DS), based on the algorithm suggested by the authors and on multiple criteria analysis, enables a more comprehensive process for solution framing and has the following advantages:

- the system helps to quickly measure the utility, priority, and value of complex objects using contemporary methods, it helps to consider and analyse substantially more environmental factors, and to make integrated assessments of quantitative and qualitative indicators describing the objects in question;
- the DSS measures the value based on a comprehensive analysis of the environment, and grounds the assumptions with better accuracy; the measuring process not only shows the final value, but also offers comprehensive interim results helpful in decision-making at various levels (recommendations about the effect of separate environmental factors on the value, and about the possibilities to mitigate the negative effect of the factors thus improving the operating environment);
- the system can be easily supplemented, improved and then used to frame various solutions: to assess the impact of environmental factors, to identify the vital values of factors, to plan the courses of action, to submit reliable information to various institutions and, finally, to analyse the reasons behind changing value.

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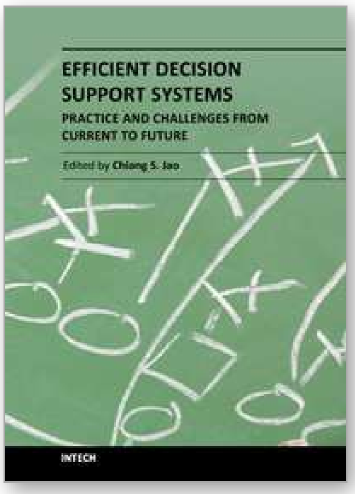

Efficient Decision Support Systems - Practice and Challenges From Current to Future
Edited by Prof. Chiang Jao

ISBN 978-953-307-326-2
Hard cover, 542 pages
Publisher InTech
Published online 09, September, 2011
Published in print edition September, 2011

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