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ENVIRONMENT FACTORS OF ENERGY COMPANIES AND THEIR EFFECT ON VALUE: ANALYSIS MODEL AND APPLIED METHOD

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Abstract. Practical tasks related to property management and disposal in energy companies can be solved only if the actual property value of these companies is known. Traditional practical property valuation methods are based on the analysis of incurred property development costs or financial indicators of activities and are inadequate to account for the influence of environment factors on corporate activities and, in turn, on the value of companies. An analysis model for environment factors affecting energy companies was developed to improve objectiveness of valuation; through analysis of the model's components it is possible to analyse external macro, meso and microenvironment of a particular company and to assess efficiency of such environment, as well as the impact of separate factors on value. A criteria system developed using the Analysis Model for Environment Factors and the Decision Support System for Measurement of Effect of Environment Factors on Value of Energy Companies, which was developed by the authors, were used to solve a practical task, which helped to evaluate the effectiveness of the Model of Environment Factors. The practical task included measurement of the utility degree and market value of the selected electricity companies and assessment of the impact of the criteria, which affect the environment, on the value of the selected energy companies.

Keywords: environment factors, ecology, energy sector, infrastructure, model, multiple criteria method, valuation.

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1. Introduction

Economic infrastructure companies, electricity companies among them, share a feature: they perform an assigned specific function in a specific territory using sophisticated, unique and expensive infrastructure. Real property of such companies makes the biggest share in the corporate capital structure and is created through a long-term operating process. It is difficult, and often inexpedient, to compete with economic infrastructure companies because normally one infrastructure company of a respective branch operates in a certain territory, which may be a city, a district, a region or another administrative division, and satisfies the needs of the economy and residents of such territory. Management of infrastructure companies and of their operating costs must include management of the structure and value of fixed assets. Although economic infrastructure companies are usually a part of the state-controlled public sector, improved practice of their management may make them effective competitors of private companies.

It is difficult to monitor the property value in infrastructure companies. Special-purpose property (e.g. pipelines, electric transmission and distribution lines, transmission substations, pumping stations, etc.) is rarely sold as individual property items and generally is not displayed in market; thus a database of such property sales is not available, though such database would facilitate measurement of preliminary property value. Therefore, a separate property valuation procedure is required in order to learn the value of special-purpose property controlled by a company. Practical valuation of special-purpose property usually depends on: the professional qualities of a specific company or appraiser involved in property valuation; the selected assumptions; and possibilities to learn about and compare practices of such property valuation in various countries. Regular property valuation methods do not account for the trends of changing value, and economic methods based on subjective assumptions of appraisers fail to ensure objective valuation. However, property valuation in infrastructure companies, both based on traditional property valuation methods and on contemporary methods involving mathematical statistics or multiple criteria analysis, must include analysis of the specific features and environment of infrastructure companies, as these factors have significant impact on the activities of such companies.

Such scientists as Bradley, Fulmer, Rosen, Lane, Navickas, who are considered to be the originators of studies in this area, analyse specific features of activities of infrastructure companies. The scientists have defined infrastructure as a set of general conditions, which may facilitate development of private companies within the main economic branches and are designed to satisfy the needs of the entire society. Infrastructure is specified as a set of economic resources, the functioning of which determines the level of active economic practices (Bradley *et al.* 2004). There are two main branches of infrastructure: economic and social. Economic infrastructure covers all branches which provide for activities within the economic process (Navickas, Čibinskienė 2004). Activities of infrastructure companies are related to "providing" economic branches, product transfer and storage processes, as well as collection, processing and information transfer processes. Activities of infrastructure companies are inseparable from safeguarding of public interests. Jan Eric Lane analyses the principles of operation and management of infrastructure companies, as well as the influence of state control and regulation on infrastructure companies in order to safeguard public interest. The author specified that two parameters determine the efficiency of companies which safeguard public interest: the amount of resources consumed in production of one product item and the degree at which an organisation achieves its goals (Lane 1995). Resource amount management means management of their value as well.

Recently, the impact of infrastructure companies, electricity companies among them, on environment came into spotligh, when the significance of environmental factors shaping the quality of life was assessed. However, usually only the amount of pollution emissions and implementation efficiency of environmental programmes are considered in analysis of the effect on environment of energy sector objects. Various countries take up studies in order to learn about the influence of the location of energy sector objects on the value of neighbouring property. For example, analysis of the impact of the wind park in Great Britain on the price of nearby residential houses has shown that the traditional value criteria, such as the type of ownership and sales timing, are the main factors influencing the price level (Sims *et al.* 2008). In contrast, such objects as high voltage electricity transfer lines, thermal power plants, sewage management companies or highways make negative impact on the life quality of people in the neighbourhood and the level of property prices (Des Rosiers 2002). When solving a property valuation task, it is equally important to measure both economic parameters and perspectives of company's activities and the environmental aspects, to determine the factors which affect the value, as well as the impact of infrastructure objects themselves on environment (Rosen 2002). In future, solutions of property valuation problems will focus on the importance of assessment of environment factors and the environmental aspect.

The pollution emissions of economic infrastructure objects attributed to electricity, heating, gas supply, utility, communication and transport infrastructure, the influence of electromagnetic field generated by electricity transmission lines, waves of communication objects, transmission of flammable and potentially dangerous substances through main pipelines and other activities affect environment at various degrees. Besides, the location of unattractive and environmentally-aggressive special-purpose objects makes negative impact on activities of nearby residents (e.g. quality of agricultural products), on their accumulated property, on its attractiveness and on price levels (Gwartney *et al.* 1997). Property which is close to sewage treatment plants, high voltage substations, thermal power plants or waste combustion companies will have lower value compared to the same type of property neighbouring with objects which do not pollute environment and located in a place with well-developed infrastructure of social services. Therefore, proper environment indicators, which have the biggest impact on activities of the analysed object, must be selected and their weights assessed for property valuation in infrastructure companies, energy companies among them. Then valuation methods, which allow to integrate values of the effect of environment factors into the value of the analysed property, can be selected and applied.

Chapter 2 of this paper presents the Analysis Model for Environment Factors, which affect electricity companies, developed by the authors; its main elements are based on the analysis and simulation of macro, meso and microlevel variable factors affecting the efficiency. Also, chapter describes the model's elements characterising the environment of the analysed sector. Chapter 3 dwells on the suggested multiple criteria designing methods: the expert method, the multiple criteria complex proportional evaluation method and the multiple criteria methods for the measurement of the utility degree and market value of real estate. Chapter 4 handles a practical task: the utility degree and market value of the selected electricity companies was measured using the Analysis Model for Environment Factors and multiple criteria analysis methods.

2. Integrated analysis model for environment factors which affect energy companies

Business value is typically multidimensional and indefinite; thus, it is expedient to use several methods in the valuation and to make several interrelated estimates of value aspects. Although scientific and methodological literature suggests various valuation methods, there is a lack of valuation methodology which would regulate valuation of special-purpose property in large economic infrastructure companies and could be used as a basis for integrated assessment of environment factors affecting companies or their property value. Numerous valuation methods currently suggested for practical application can be divided into three main groups: property, market and income valuation methods. However, these methods do not facilitate integrated assessment of macro, meso and microfactors affecting property values, as well as of goals and influence of stakeholder groups. The method for the valuation of corporate property or business must be selected considering:

- the purpose of valuation;
- the business field and property group to which belongs the valuated object;
- which property value is relevant;
- which value is the best to express property value in open market;
- which environment factors have the biggest impact on changing value.

In order to find the instruments suitable to measure the factors which affect property value of energy companies and which can best reflect the impact on value and to foresee trends of value changes, we suggest an Analysis Model for Environment Factors in this sector; components of the model integrate the analysis of a company's condition and the value-affecting variable factors of macro, meso and microenvironment. The theoretical Analysis Model for Environment Factors affecting company's value is provided below in Fig. 1.

The analysis of factors affecting a company's value can be divided into four main areas:

1. Analysis of a company's condition within the analysed period including internal processes of the company's financial state, property structure, technical condition, etc.;
2. Comparative analysis of the same type of corporate operating indicators and environment factors;
3. Analysis of macro, meso and microlevel environment factors affecting operating efficiency;
4. Analysis of the impact of groups which affect decisions.

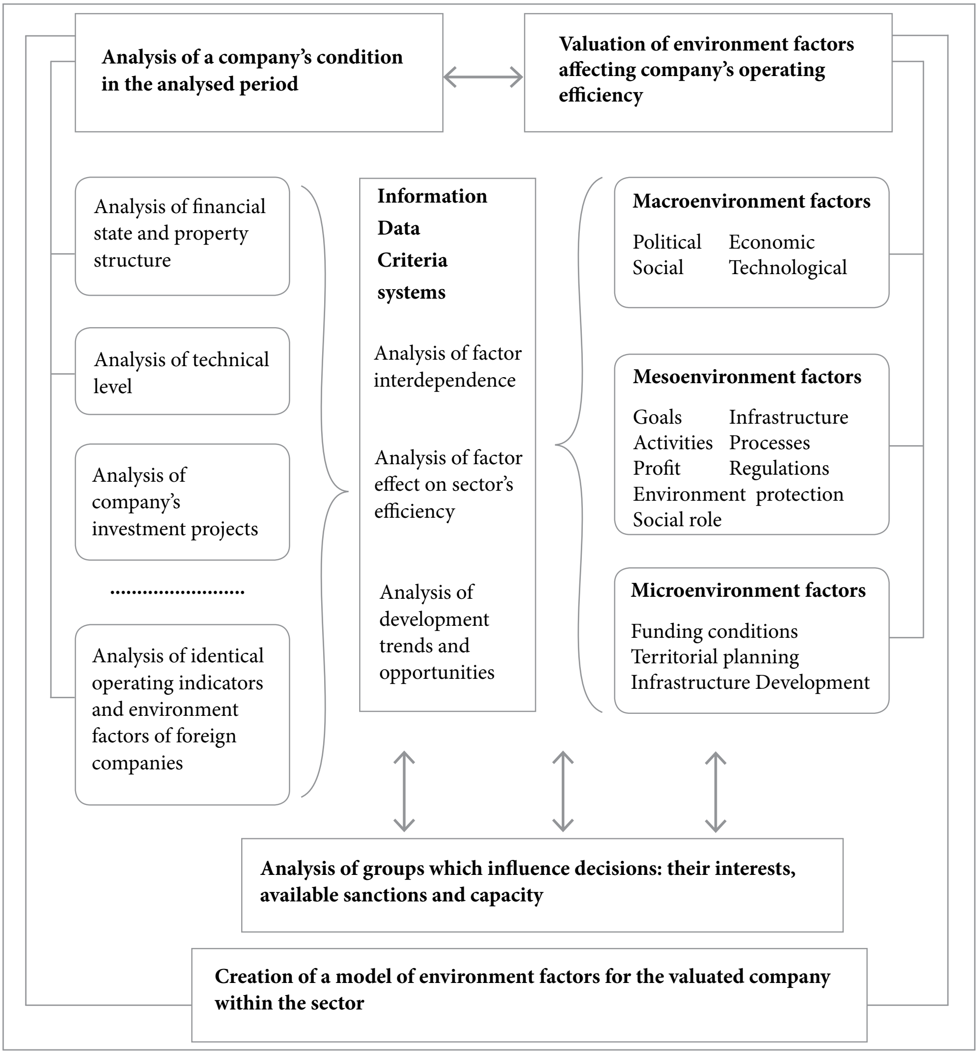


Fig. 1. The theoretical analysis model for environment factors affecting company's value

The above model has already been applied in the development of Lithuanian construction industry (Zavadskas, Kaklauskas 2008), in sustainable development of Vilnius (Zavadskas *et al.* 2007), in housing credit access (Zavadskas *et al.* 2004) and in facilities management (Lepkova *et al.* 2008).

2.1. Analysis of a company's condition within the analysed period

First, considering the valuation task, an analysis of a company's financial state, indicators of financial activities and property structure is performed. Corporate operating efficiency is defined by the management of cash flows, the balance of income-to-cost ratio, management of material resources, ability to achieve goals, efficient project management and other types of internal information which may affect corporate value. An important part of this analysis is the analysis of property structure, because property, which consists of special-purpose infrastructure, is the decisive element which is the basis for activities in energy sector. The main features of such property are its complexity and specific nature. Poorly developed infrastructure seriously limits possibilities to offer services and causes system malfunctions, growing demand for production and consumption cause backlogs and a company fails to use the potential granted by the market. In electricity sector, infrastructure and buildings with equipment, which belong to power plants, comprise up to 90% of a company's property; electricity transfer lines and the infrastructure of distributions lines comprise up to 80% of corporate fixed assets. Besides, repair and maintenance of property account for a large lump of operating costs in this sector. Issues related to facility and infrastructure management, investments into infrastructure development, modernisation and upgrade of the available infrastructure using state-of-the-art technology make up the main part of processes of corporate management in energy sector. When electricity companies are being divided and restructured, when separate types of activities undergo the process of privatisation or investments are planned, separate infrastructure items or property items are the objects of valuation, and their value depends on the environment factors which affect the value of the entire property. The analysis of a company's condition within the analysed period, as well as the analysis of its cash flows, property and internal processes, is a basis to come up with preliminary conclusions on the company's value.

2.2. Comparative analysis of the same type of corporate operating indicators and environment factors

To validate preliminary conclusions and to make them more reliable, an analysis of comparative examples is made. The analysis of countries with similar economic levels and companies operating within the same economic sector guarantees more objective results. Historical aspects of the sector's development are also considered. Lithuanian electricity companies or a group of companies can be compared to electricity companies of Eastern Europe (Czech Republic, Poland, Slovakia, Hungary), the Baltic States (Latvia, Estonia) or the Scandinavian Countries (Finland, Sweden). The results of the comparative analysis and the accumulated materials help to determine the development trends of the analysed sector: general economic trends at national or regional level and trends within the same type of sectors in the selected countries are compared, differences with Lithuania are specified.

2.3. Analysis of environment factors affecting corporate operating efficiency

Using expert methods, the next phase determines macro, meso and microlevel factors, as well as the systems and subsystems of defining indicators, which provide a thorough description of activities of the sector in which the company operates. The following structural elements of the developed model make the biggest impact on its effectiveness and efficiency:

– macro, meso and microenvironment;
– groups taking part in the decision-making process.

Macroenvironment Factors

Macrolevel factors define the level of national or industrial efficiency. Besides, macrolevel factors affect the development level of separate industrial branches. The efficiency of electricity companies significantly depends on the integrated effect of macrolevel variable factors, such as national economic, political and cultural development level, legal acts regulating activities, market, tax system, possibilities and conditions within the loan market, inflation, possibilities to acquire resources, etc. The efficiency level of a branch changes depending on the integrated effect of macrolevel factors: the need for energy resources decreases or increases.

PEST analysis (Political-Legal, Economic, Socio-Cultural and Technological Forces) is the most popular analytic technique in studies of macroenvironment of electricity companies, as well as companies of other industrial branches. This analysis covers four aspects of macroenvironment: political and legal, economic, socio-cultural and technological. PEST analysis applies quantitative (extrapolation, mathematical modelling, etc.) and qualitative (scenarios, Delphi, etc.) forecasting methods to analyse the environment. The analysis of macroenvironment must include a thorough analysis of political-legal environment, because activities of energy companies usually obey strict legal regulation. Their activities are regulated by EU and national legal acts. Recently, EU members started harmonisation of these legal acts and their transfer into national legal bases. This process simplifies the analysis of legal environment.

Expert assessment of macroenvironment criteria revealed that EU regulation of activities, which attempts to create a competitive market of electricity supply and distribution, as well as technological changes and standardisation of environmental requirements are the most significant criteria affecting activities of energy sector. Whereas activities within the energy sector are relevant to all aspects of public life, the impact of public opinion on activities was specified as a significant criterion (see the research results in Chapter 5).

Mesoenvironment Factors

The analysis of mesolevel environment is oriented towards the goals of a specific economic sector, its role in national economy and the branch, features which shape the type of activities, profit, processes within a specific branch, impact of the processes on environment, fulfilment of the sector's social role, documents regulating activities and relations with state institutions. It is an intermediate level between microeconomics and macroeconomics.

In order to make a consistent analysis of mesoenvironment, the relation between the environment of the analysed economic object and economy must be examined. Besides, the specific environment, in which the analysed company operates, must be assessed. The analysis of this environment is based on the analysis of such factors as institutions involved in legislation (legal and normative acts), supervision and control at various levels. There is a direct relation between the decisions of institutions together with their legislative processes (legal acts which regulate corporate activities) and corporate plans and decisions. Vasiliauskas applied Porter's National Diamond to present the specific features of the interaction between companies and the national economy management, thus pointing out the relation between macroenvironment factors and specific environment of institutions (Vasiliauskas 2005).

Indicators which assess the ability of a specific analysed object to achieve economic goals when it solves environmental issues and implements resource-saving manufacturing measures and technologies, as well as renewable energy sources, are significant in the analysis of mesolevel factors. Educational background of society, as well as active contribution to the solution of quality issues related to residential and work environment, also makes impact. This expands the limits of macro- and mesoenvironment and the influence of these factors on operating efficiency of energy companies. It is at the mesolevel that the environmental dimension and the external effect (the effect of by-products and pollution on the environment) of activities are analysed in infrastructure companies within the energy sector. The expert study of the influence of mesoenvironment factors of energy companies has shown that respondents from various social groups consider profitability and introduction of environment-friendly technologies as the most significant mesoenvironment criteria in activities. It is important to note that the criterion of corporate social responsibility is also considered rather significant (see Chapter 5).

Environmental Factors

Making the analysis of activities within the electricity sector, it is worthwhile to make a more thorough assessment of environmental factors. Companies within this sector make a considerable impact on the environment. Organic fuel, which is of limited quantities, is 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 the process of energy production and can affect soil, water, air and biological cycle and generate huge amounts of hard waste (Norvaiša, Galinis 2004). Despite high economic efficiency 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 assessed, and legal acts regulate the conditions for operation of such objects. Therefore, cleaner production in the electricity sector is a very effective and economically efficient course of activities.

The Sixth Environment Action Programme of the European Community sets the environmental goals and priorities, which are a part of the EU Sustainable Development Strategy. The programme also foresees measures to achieve these goals. For many years already, EU states apply environmental measures based on market factors, such as environmental taxes, in order to increase the market share of products, processes and services, which are more acceptable in terms of environment protection. Such taxes encourage companies to allocate more funds to research and to invest into technologies less damaging to environment or requiring fewer resources (Staniškis, Stasiškienė 2006).

In Lithuania, the analysis of environment factors yet rarely includes assessment of external environment pollution costs. Although Lithuanian power plants pay taxes for pollution emissions into atmosphere, these taxes are, however, rather small compared to the external costs per one ton of pollution emitted into the atmosphere. Increased pollution taxes would affect the cost structure of energy companies, especially in 2010 and later, when Lithuanians will no longer have the source of cheap and rather clean energy, i.e. Ignalina Nuclear Power Plant. Therefore, the analysis of corporate activities must also consider increasingly strict environmental requirements and the foreseen increase of pollution taxes.

M*icrolevel Facto*rs

Microenvironment factors are related to a specific firm or company and affect its ability to achieve its goals. These factors embrace all things related to customer value delivery: activities of the company itself, suppliers (from energy sources to various support services), companies within the supply and distribution chain, competitors, consumers and society. These factors depend on macro and mesolevel factors.

Energy sector must continuously keep high levels of infrastructure maintenance, must modernise and develop objects, must implement innovative technologies and management processes. The efficiency of the sector's development and implementation of investment projects is affected by various microlevel factors, such as: land prices; extended procedures of territorial planning and preparation of special and detailed plans; efficiency level of the process related to the supply of technologies, mechanisms and equipment for reconstruction and modernisation; funding conditions of development projects; etc. During the survey, respondents also stressed the importance of the experience of top managers and readiness of personnel to apply innovations.

2.4. Analysis of groups affecting decisions

The analysis of environment factors cannot be thorough until stakeholder groups, which affect activities and decisions, are considered in assessment of the specific environment of energy sector. Such scientists compiled a list of questions which help to identify the main stakeholder groups, the type of their influence, their level, their expectations and requirements, as well as possible outcomes (Arimavičiūtė 2005). The author suggest distinguishing the following types of stakeholder groups based on the results of the analysis and assessment:

- potentially problematic;
- hostile;
- rather insignificant;
- supporting.

The analysis and the obtained results help to assess the requirements and expectations of various groups, to evaluate them and to search for the ways to affect hostile groups or to help and strengthen the supporters (Arimavičiūtė 2005). In the energy sector, the same stakeholder group may represent various interests depending on the type of company's activities. For example, residents usually support companies which use renewable resources but are against construction of wind parks in the neighbourhood of their property. The suppliers of raw materials are interested in the development of the thermal energy sector and challenge the development of nuclear energy.

Interrelations of stakeholder groups are shown in Fig. 2.

The activities within the energy sector are controlled and coordinated by the State and various EU institutions. Various institutional participants – starting with international alliances, association committees and ending with trade unions – have a direct influence on the operation of the sector's companies. The following parties have vested interests in activities of the energy sector: suppliers of resources and raw materials which affect energy prices; manufacturers of devices and equipment; organisations offering designing, construction and other services.

Consumers are also important members of the energy sector. They may be industrial companies and household consumers. Although lately energy consumption was increasing in our country, growing prices of raw materials, as well as electricity production, distribution and supply, make various groups observe the processes within the energy sector and participate in management bodies of energy companies. Natural monopolies, which dominate Lithuanian electricity sector, basically eliminate competitive environment and the consumer's right to choose. Active involvement of stakeholder groups and political organisations affects the process of market liberalisation.

3. Measurement of the utility degree and market value using multiple criteria analysis methods

Multiple criteria decision making methods have been applied to a variety of problems, such as maintenance outsourcing (Almeida 2005), construction and real estate (Kaklauskas *et al.* 2005, 2007a, b; Zavadskas *et al.* 2008a), maintenance strategy (Almeida, Bohoris 1996), water supply management (Morais, Almeida 2007), project risk assessment (Zeng *et al.* 2007), multi-criteria risk analysis (Brito, Almeida 2008), service outsourcing contracts (Almeida 2007) and construction bidding (Seydel, Olson 2001).

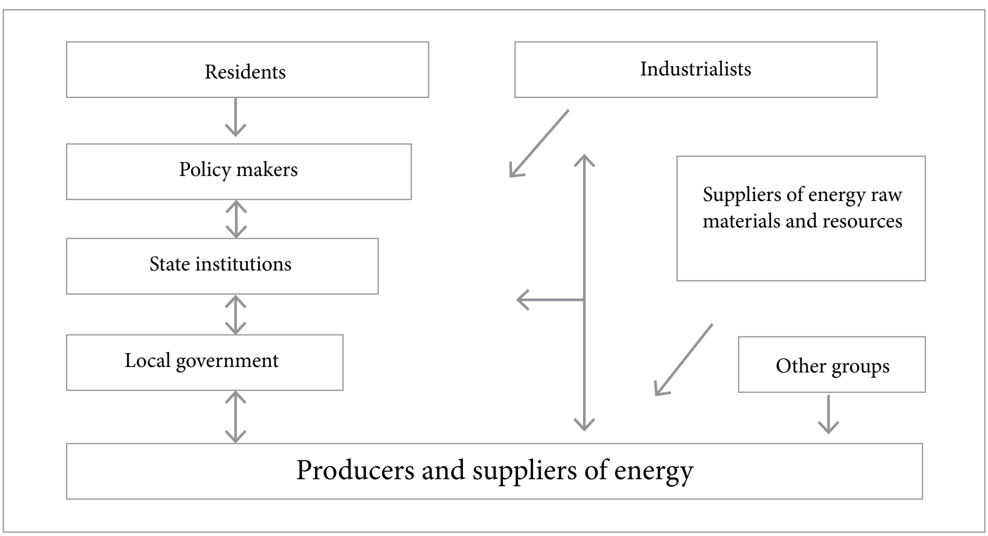


Fig. 2. Interrelations between stakeholder groups and the analysed organisation

The efficiency must be analysed within the limits determined by micro, meso and macrolevel factors in order to describe the operating efficiency of an energy sector company. These factors constantly change. Changes of these factors also mean changes in the efficiency degree of the analysed branch. Having assessed the impact of macro, meso and microlevel factors and stakeholder groups, it is possible to determine the influence of the factors on corporate operating processes and on the value. The analysis must include formulation of possible variants of organisational or corporate strategy in the analysed sector; these variants must be evaluated on the basis of multiple criteria analysis methods and the most efficient variants must be selected. Organisations or companies cannot adjust or change macro-, meso- or microlevel variables, but can understand their effect, assess them, forecast possible changes and mitigate risks in the implementation of various projects (Kozlinski, Guseva 2006).

In order to process the information about the effect of environment factors and to determine their impact on value, it is expedient to use contemporary multiple criteria analysis methods, that allow to analyse sufficient amount of quantitative and qualitative indicators which define objects, as well as to determine the utility degree and market value of objects. Based on multiple criteria analysis methods, a company or separate property items are appraised considering indicators which describe the analysed object and affect its value; they are market conjuncture, quantitative (number of property items, territorial coverage, length and amount of engineering infrastructure objects), qualitative (condition, modernisation, degree of technological novelty, environment protection, reliability, etc.), political-legal (laws, norms, regulations, limitations, restrictions) and other indicators.

Lithuanian scientists Zavadskas and Kaklauskas suggested the following multiple criteria methods for the comparison of alternative real estate items, for the measurement of the utility degree and for the measurement of the market value (Zavadskas *et al.* 2008a, b, 2001; Kaklauskas *et al.* 2006, 2007a, b; Banaitienė *et al.* 2008):

- setting of weights of complex indicators considering their qualitative and quantitative characteristics;
- multiple criteria complex proportional evaluation method;
- multiple criteria method for the utility degree and market value measurement of real estate items.

The developed Analysis Model for Environment Factors helps to determine the weights of operating indicators and environment effect indicators of the analysed objects. The environment of the analysed electricity sector, as well as energy sector objects, has its peculiar features, is affected by various market conjuncture conditions and is influenced by stakeholder groups with confronting interests. These features impede comparison of objects within the electricity sector. However, using the complex analysis method, it is possible to measure the utility degree of objects and to determine objective market value for separate objects of electricity sector.

The complex analysis method is realised in the following main stages:

1. Measurement and description of qualitative and quantitative criteria which determine activities of a property object/set;

2. Development of an integrated database based on the obtained description of analysed objects;
3. Use of multiple criteria analysis methods in order to measure the utility degree and market value of the obtained alternatives.

Based on the obtained quantitative and conceptual description of objects, an integrated database is developed, which provides comprehensive descriptions of internal and external factors affecting the value of the analysed objects and facilitates their multi-variant designing and multiple criteria analysis.

3.1. Multiple criteria complex proportional evaluation method and method for measurement of the utility degree and market value of objects

This method assumes direct and proportional dependence of the significance and priority of the investigated versions on a system of criteria adequately describing the alternatives and on values and significances of the criteria. The system of criteria is determined and the values and initial significances of criteria are calculated by experts. All this information can be corrected by interested parties (customers, users, etc.) taking into consideration their pursued goals and existing capabilities. Hence, the assessment results of alternatives fully reflect the initial data jointly submitted by experts and interested parties.

The determination of the significance and priority of alternatives is carried out in four stages.

Stage 1. The weighted normalized decision-making matrix D is formed. The purpose of this stage is to receive dimensionless weighted values from the comparative indexes. When the dimensionless values of the indexes are known, all criteria, originally having different dimensions, can be compared. The following formula is used for this purpose:

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

where x_{ij} is the value of the i-th criterion in the j-th alternative of a solution; m – the number of criteria; n – the number of the alternatives compared; q_i – significance of i-th criterion.

The sum of dimensionless weighted index values d_{ij} of each criterion x_i is always equal to the significance q_i of this criterion:

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

In other words, the value of significance q_i of the investigated criterion is proportionally distributed among all alternative versions a_j according to their values x_{ij}.

Stage 2. The sums of weighted normalized indexes describing the j-th version are calculated. The versions are described by minimizing indexes S_{-j} and maximizing indexes S_{+j}.

The lower value of minimizing indexes is better. The greater value of maximizing indexes is better. The sums are calculated according to the formula:

$$S_{+j} = \sum_{i=1}^{m} d_{+ij}; \quad S_{-j} = \sum_{i=1}^{m} d_{-ij}, \qquad i = \overline{1,m}; \; j = \overline{1,n}. \tag{3}$$

In this case, the values S_{+j} (the greater is this value (project 'pluses'), the more satisfied the interested parties are) and S_{-j} (the lower is this value (project 'minuses'), the better is the goal attainment by the interested parties) express the degree of goals attained by the interested parties in each alternative project. In any case the sums of 'pluses' S_{+j} and 'minuses' S_{-j} of all alternative projects are always respectively equal to all sums of the significances of maximizing and minimizing criteria:

$$\begin{aligned} S_{+} &= \sum_{j=1}^{n} S_{+j} = \sum_{i=1}^{m}\sum_{j=1}^{n} d_{+ij}, \\ S_{-} &= \sum_{j=1}^{n} S_{-j} = \sum_{i=1}^{m}\sum_{j=1}^{n} d_{-ij}, \qquad i = \overline{1,m}; \; j = \overline{1,n}. \end{aligned} \tag{4}$$

In this way, the calculations made may be additionally checked.

Stage 3. The significance (efficiency) of comparative versions is determined on the basis of describing positive projects ('pluses') and negative projects ('minuses') characteristics. Relative significance Q_j of each project a_j is found according to the formula:

$$Q_j = S_{+j} + \frac{S_{-\min} \cdot \sum_{j=1}^{n} S_{-j}}{S_{-j} \cdot \sum_{j=1}^{n} \frac{S_{-\min}}{S_{-j}}}, \quad j = \overline{1,n}. \tag{5}$$

Stage 4. Priority determination of projects. The greater is the Q_j, the higher is the efficiency (priority) of the project.

The analysis of the method presented makes it possible to state that it may be easily applied to evaluating the projects and selecting most efficient of them, being fully aware of a physical meaning of the process. Moreover, it allowed to formulate a reduced criterion Q_j which is directly proportional to the relative effect of the compared criteria values x_{ij} and significances q_i on the end result. Calculation of the weighted normalized decision matrix are presented in Table 1.

3.2. A method of defining the utility and market value of property

Significance Q_j of property a_j indicates satisfaction degree of demands and goals pursued by the interested parties – the greater is the Q_j , the higher is the efficiency of the property. In this case, the significance Q_{max} of the most rational property will always be the highest. The significances of the remaining property are lower as compared to the most rational one. This

Table 1. Environment factors multiple criteria analysis results

Quantitative information pertinent to projects									
Criteria describing macro, meso and microenvironment factors	*	**Significance**	**Measuring units**	**Compared property**					
				a_1	a_2	…	a_j	…	a_n
X_1	z_1	q_1	m_1	d_{11}	d_{12}	…	d_{1j}	…	d_{1n}
X_2	z_2	q_2	m_2	d_{21}	d_{22}	…	d_{2j}	…	d_{2n}
X_3	z_3	q_3	m_3	d_{31}	d_{32}	…	d_{3j}	…	d_{3n}
…	...	...	...	...	...	…	...	…	...
X_i	z_i	q_i	m_i	d_{i1}	d_{i2}	…	d_{ij}	…	d_{in}
…	...	...	...	...	...	…	...	…	...
X_m	z_m	q_m	m_m	d_{m1}	d_{m2}	…	d_{mj}	…	d_{mn}
The sums of weighted normalized maximizing (projects 'pluses') indices of the project				S_{+1}	S_{+2}	…	S_{+j}	…	S_{+n}
The sums of weighted normalized minimizing (projects 'minuses') indices of the project				S_{-1}	S_{-2}	…	S_{-j}	…	S_{-n}
Significance of the project				Q_1	Q_2	…	Q_j	…	Q_n
Priority of the project				P_1	P_2	…	P_j	…	P_n
Utility degree of the project (%)				N_1	N_2	…	N_j	…	N_n

* – The sign z_i (+ (−)) indicates that a greater (less) criterion value corresponds to a greater significance for a client

means that total demands and goals of interested parties will be satisfied to a smaller extent than it would be in the case of the best property.

The degree of property utility is directly associated with quantitative and conceptual information related to it. If one property is characterized by the best comfortability, aesthetics, price indices, while the other shows better maintenance and facilities management characteristics, both having obtained the same significance values as a result of multiple criteria evaluation, this means that their utility degree is also the same. With the increase (decrease) of the significance of the property analyzed, its degree of utility also increases (decreases). The degree of property utility is determined by comparing the property analysed with the most efficient property. In this case, all the utility degree values related to the property analyzed will be ranged from 0% to 100%. This will facilitate visual assessment of property efficiency.

The degrees of utility of the property considered as well as the market value of a property being valuated are determined in seven stages.

Stage 1. The formula used for the calculation of property a_j utility degree N_j is given below:

$$N_j = (Q_j : Q_{max}) \cdot 100\% , \quad (6)$$

here Q_j and Q_{max} are the significances of the property obtained from the equation (5).

The degree of utility N_j of property a_j indicates the level of satisfying the needs of the parties interested in the property. The more goals are achieved and the more important they are, the higher is the degree of the property utility. Since clients are mostly interested in how much more efficient particular property is than the others (which ones can better satisfy their needs), then it is more advisable to use the concept of property utility rather than significance when choosing the most efficient solution.

The degree of property utility reflects the extent to which the goals pursued by the interested parties are attained. Therefore, it may be used as a basis for determining property market value. The more objectives are attained and the more significant they are, the higher will be the property degree of utility and its market value.

Thus, having determined in such a way the ratio of degree of utility and market value of property, one can see what complex effect can be obtained by investing money into the property. There is a complete clarity where it pays better to invest money and what is the efficiency degree of the investment.

Stage 2. The efficiency degree E_{ji} of money invested into property a_j is calculated. It shows by how many percent it is better (worse) to invest money into property a_j compared with property a_i. E_{ji} is obtained by comparing the degrees of utility of the property considered:

$$E_{ji} = N_j - N_i . \tag{7}$$

The received results are presented as a matrix clearly showing utility differences of the property (see Table 2).

Stage 3. The average deviation k_j of the utility degree N_j of the property a_j from the same index of other property $(n - 1)$ is being calculated.

$$k_j = \sum_{i=1}^{n} E_{ji} : (n-1). \tag{8}$$

Table 2. Calculation of average deviations of the property utility degrees

Property considered	Utility degree deviation of a property analyzed compared to other property, %					Average deviation k_j of utility degree N_j of property a_j compared to other $(n-1)$ property, %
	a_1	a_2	a_3	a_i	a_n	
a_1	0	E_{12}	E_{13}	…	E_{1n}	k_1
a_2	E_{21}	0	E_{23}	…	E_{2n}	k_2
a_3	E_{31}	E_{32}	0	…	E_{3n}	k_3
…	…	…	…	…	…	…
a_j	E_{j1}	E_{j2}	E_{j3}	…	E_{jn}	k_j
…	…	…	…	…	…	…
a_n	E_{n1}	E_{n2}	E_{n3}	…	0	k_n

Stage 4. The development of a grouped decision making matrix for property multiple criteria analysis. The market value of a property being valuated is calculated according to a block-diagram presented in Fig. 3.

At the beginning, a grouped decision making matrix for property multiple criteria analysis is developed (see Table 3), the first criterion of which is based on the actual purchasing/selling prices of the property compared and the value of a property being valuated. The initial value of property being valuated is obtained from the following equation:

$$x_{11} = \sum_{j=2}^{n} x_{1j} : (n-1). \tag{9}$$

In this matrix, property a1 to be valuated should be assigned the market value (x_{11-R}). Other comparison standard property (a_2 – a_n) were sold, their purchasing/selling prices ($x_{12} - x_{1n}$) known. All the values and significances of the criteria related to other property are also known (see Table 3).

The problem may be stated as follows: what market value x_{11-R} of valuated property a_1 will make it equally competitive on the market with comparison standard property (a_2 – a_n)? This may be determined if a complex analysis of the benefits and drawbacks of the property is made.

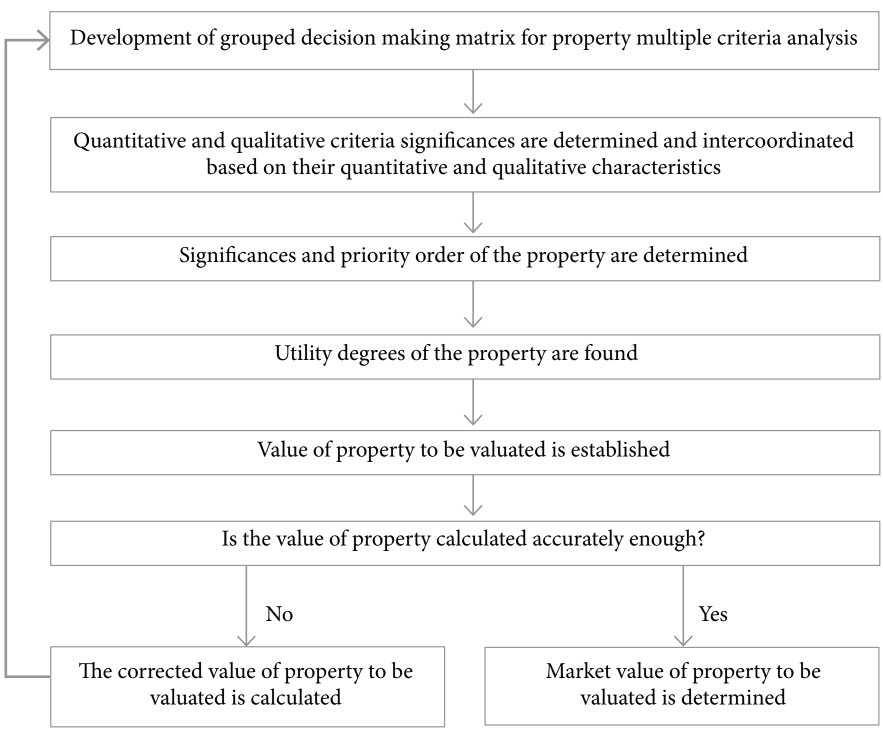


Fig. 3. Block-diagram of property market value estimation

Table 3. A grouped decision making matrix for property multiple criteria analysis

Criteria describing the compared property	*	Significance	Measuring units	Property to be valuated and comparison standard property					
				a_1	a_2	…	a_j	…	a_n
1. Price of a property a_1 being valuated and actual purchasing/selling prices of comparison standard property (a_2–a_n)	z_1	q_1	m_1	x_{11}	x_{12}	…	x_{1j}	…	x_{1n}
	z_2	q_2	m_2	x_{21}	x_{22}	…	x_{2j}	…	x_{2n}
	...	...	...	...	...	…	...	…	...
Quantitative criteria	z_i	q_i	m_i	x_{i1}	x_{i2}	…	x_{ij}	…	x_{in}
	...	...	...	...	...	…	...	…	...
	z_t	q_t	m_t	x_{t1}	x_{t2}	…	x_{tj}	…	x_{tn}
	z_{t+1}	q_{t+1}	m_{t+1}	x_{t+11}	x_{t+12}	…	x_{t+1j}	…	x_{t+1n}
Qualitative criteria	z_{t+2}	q_{t+2}	m_{t+2}	x_{t+21}	x_{t+22}	…	x_{t+2j}	…	x_{t+2n}
	...	...	...	...	...	…	...	…	...
	z_i	q_i	m_i	x_{i1}	x_{i2}	…	x_{ij}	…	x_{in}
	...	...	...	...	...	…	...	…	...
	z_m	q_m	m_m	x_{m1}	x_{m2}	…	x_{mj}	…	x_{mn}

* – The sign z_i (+ (–)) indicates that a greater (less) criterion value corresponds to a greater significance for a client

Using a grouped decision making matrix (see Table 3) and the equations 1–9 the calculations are made.

Stage 5. The corrected value x_{11-p} of property to be valuated a_1 is calculated:

$$x_{11-p} = x_{11} * (1 + k_1 : 100) . \tag{10}$$

Stage 6. It is determined whether the corrected value x_{11-R} of property being valuated a_1 had been calculated accurately enough:

$$| k_1 | < s , \tag{11}$$

where s is the accuracy, %, to be achieved in calculating the market value x_{11-p} of a property a_1. For example, given s = 0,5%, the number of approximations in calculation will be lower than at s = 0,1%.

Stage 7. The market value x_{11-R} of property a_1 to be valuated is determined. If inequality 2.20 is satisfied the market value of property a_1 may be found as follows:

$$x_{11-R} = x_{11-p} . \tag{12}$$

If inequality 11 is not satisfied, this means that the value of property being valuated had not been calculated accurately enough and the approximation cycle should be repeated. In this case, the corrected value $x_{11} = x_{11-p}$ of property being valuated is substituted into a grouped decision making matrix of property multiple criteria analysis and the calculations according to the formulae 1–9 should be repeated until the inequation 11 is satisfied.

Solving the problem of determining the market value x_{11-R} of a property a_1 being valuated, which would make it equally competitive on the market compared with the property (a_2–a_n) already sold, a particular method of defining the utility degree and market value of property was suggested. This was based on a complex analysis of all the benefits and drawbacks of the property considered.

According to this method the property utility degree and the market value of property being estimated are directly proportional to the system of the criteria adequately describing them and the values as well as significances of these criteria.

The complex proportional valuation method is used in the valuation of economic infrastructure energy companies to determine the priority of objects selected for analysis, as well as their utility degree, which directly depends on the system of criteria defining the selected objects and on the value and weight of these criteria. The system of criteria, which define objects, is based on expert evaluation.

4. Measurement of the utility degree and market value of energy objects using multiple criteria analysis methods

Four objects of energy sector were selected for the practical task of multiple criteria analysis; they represent traditional and alternative types of energy production: Kruonis Pumped-storage Hydroelectric Power Plant, Kaunas Hydroelectric Power Plant, Lithuanian Power Plant and the Experimental Geothermal Power Plant.

Kruonis Pumped-storage Hydroelectric Power Plant (Fig. 4) is an engineering hydrotechnical complex consisting of two water storages (the upper and the lower reservoir), four connecting pipelines, ditches, hydro-aggregates, as well as hydroelectric technical facilities (embankments, dikes, platforms) and equipments. The power plant was launched in full power in 1998. Whereas Kruonis HAE ensures energy balance in the common energy system and only a small part of the produced electricity is sold at the electricity auction, its rated potential is underused.

Fig. 4. Kruonis Pumped-storage Hydroelectric Power Plant

Kaunas Hydroelectric Power Plant, which was constructed and launched in 1960, is the biggest power plant that uses renewable resources in Lithuania (Fig. 5). The facilities of the hydroelectric power plant include auxiliary structures of the power plant and hydrotechnical buildings: dam, embankments and dikes. The machinery plant located in the dam contains hydrotechnical equipment, turbines and generators. This object is especially attractive in economic and environmental terms. The power plant produces over 80% of our national energy based on renewable resources. However, the amount of produced electricity depends on the seasonal amounts of water resources.

Fig. 5. Kaunas Hydroelectric Power Plant

Fig. 6. Lithuanian Power Plant

Fig. 7. Geothermal Power Plant

Lithuanian Power Plant is the largest national thermal power plant (Fig. 6). The facilities of the power plant include the main building, which contains the energy equipment, hydrotechnical buildings, as well as auxiliary buildings and structures. The auxiliary buildings host the chemical water treatment plant, the electrolysis plant, the compressor room, laboratories, the physical plant, as well as administrative and household premises. Three chimneys (one of 150 metres and the other two of 250 metres) of the power plant are also important structures. They ensure pull and dissipate emitted gasses. The power plant mainly runs on boiler oil and natural gas. When Ignalina Nuclear Power Plant will be closed in 2010, this power plant will be the main electricity producer and supplier in Lithuania.

The geothermal Power Plant was constructed in 2004 (Fig. 7) seeking to continue industrial geothermal research, as well as to develop technologies for tapping of underground resources and make integrated use of them in economic activities. Facilities of the company include: the building of Klaipėda geothermal power plant used for activities and the first geothermal bores made in Lithuania, in 1989. Geothermal bores reach geothermal water of a temperature of 40°C, which is then heated up to 70°C and supplied to centralised urban networks. Operating efficiency of the power plant depends on the price of natural gas and on fixed prices for procurement of the produced heat. Despite complicated operating conditions, activities of the geothermal power plant are considered very promising and its development is actively promoted.

This research has an aim to measure the utility level and adjusted market value of Lithuanian energy companies, which use traditional and alternative energy resources, applying the Decision Support System for Measurement of Effect of Environment Factors on Value of Energy Companies developed by the authors. It is difficult to appraise objects, which are basically different although operate in the same sector. However, multiple criteria analysis methods are a good choice in order to analyse and assess objects with rather different parameters. Quantitative data of the analysed energy objects are shown in Table 4.

Table 4. Quantitative data of the analysed energy sector objects

Quantitative data of objects	Kruonis PPHPP	Kaunas HPP	Lithuanian PP	Geothermal PP
Rated capacity, MW	900	100.8	1,800	35
Production cost (energy price) cnt/kw	22	9	31	12
Company's value (replacement cost), thousand LTL	1,852,000	147,600	1,495,700	29,950

4.1. Creation of the criteria system

The research is based on the results obtained through use of the expert method of criteria assessment. In prepared questionnaires, expert groups assessed the impact of environment factors on activities of the selected energy sector objects. Objective results were ensured by forming expert groups from representatives of different social groups: specialists of energy companies, managers, CEOs; two expert groups included residents who own property close to energy objects. A total of six expert groups took part in the survey. Questionnaires for the expert evaluation were prepared in such way as to achieve maximum assessment of indicators within components of the Analysis Model for Environment Factors. Qualitative criteria which define environment factors of the analysed objects and quantitative criteria which define the actual data were selected for measurement of the utility degree and market value of the objects. The experts used a table to set the values of macro, meso and microenvironment criteria which affect the value of the four specified objects. Weights of the criteria are assessed using conditional measurement units: points between 1 and 10 in this particular case. The experts gave more points to these criteria which they consider to have bigger weight, to be more "influential", and make bigger impact on the end result of valuation. The utility level and market value of the selected objects were measured based on qualitative criteria assessed by the experts and quantitative criteria describing the objects.

First, experts helped to set priorities of all determined criteria, i.e. the criteria were ranked on a scale between 1 and 29. Reliability of the research was verified by calculating the degree of opinion coincidence of expert groups. During the research, each expert group submitted assessments of the four analysed energy objects. The results of expert assessment were processed and summarised in the table of criteria values and weights. The ranking and weights of criteria determined during expert assessment are provided in Table 5.

4.2. Measuring the utility degree and market value

The priority and weight of variants of the analysed objects depend, directly and proportionally, on a criteria system which adequately defines the alternatives, as well as on values and weights of the criteria. The utility level shows the level of goals achieved by stakeholder groups. Considering the utility degrees of analysed real estate alternatives, the value of a specific object/alternative is measured. The utility degree and market value are measured for each object using the calculation sequence presented in subchapter 4.2 and formulas (1) through (12). Although values of criteria which, according to the value, affect the elements specified in the Analysis Model for Environment Factors are assessed by experts, this information, however, can change due to the impact of stakeholder groups who may influence decisions by their goals and ability to achieve them. Therefore, expert groups, which represent certain stakeholders, assessed possible degree of stakeholder influence as well.

The main window of the Decision Support System for Measurement of Effect of Environment Factors on Value of Energy Companies (ESIAPVN-DS) is shown in Fig. 8. ESIAPVN-DS system work on address of internet network http://193.219.145.33/elektra/default.aspx.

Table 5. Measurement of values and weights of qualitative and quantitative criteria

	x_i	Description	Unit	Weight of criteria (1st to 4th expert groups)	+ –	Ranking average (assessment by 1st to 6th expert groups)				Sum of criterion ranking
						Kruonis PHPP	Kaunas HPP	Lithuanian PP	Geothermal PP	
Qualitative criteria										
Macroenvironment criteria	1	EU regulation of electricity-related activities	points	0.049	+	29	31	29	32	121
	2	Internal (national) policy towards this sector	“	0.023	+	20	15	17	14	66
	3	Relations with national authorities	“	0.027	+	17	17	19	16	69
	4	Trends of economic change	“	0.028	+	24	18	26	17	85
	5	Changes of consumption	“	0.03	+	22	19	26	18	85
	6	Investment conditions	“	0.047	+	34	30	29	20	113
	7	Public attitude towards activities	“	0.047	+	22	30	30	29	111
	8	Change of industrial technology	“	0.047	+	29	29	29	31	118
	9	Development of alternative energy sources	“	0.034	+	20	22	17	25	84
	10	Environmental regulations	“	0.049	+	27	31	19	32	109
Mesoenvironment criteria	11	Legal regulation of activities	“	0.03	+	20	19	22	18	79
	12	Municipal influence	“	0.027	+	25	17	23	15	80
	13	Legal basis for infrastr. develop.	“	0.023	+	15	15	18	15	63
	14	Profitability degree	“	0.055	+	29	35	16	29	109
	15	Competitive environment	“	0.011	-	8	7	11	11	37
	16	Introduction of environment-friendly technologies	“	0.034	+	22	22	22	24	90
	17	Dependence on resource provision	“	0.013	–	13	8	43	12	76
	18	Integration into internat. structures	“	0.019	+	14	12	19	18	63
	19	Degree of corporate social responsibility	“	0.038	+	23	24	24	24	95
	20	Degree of external pollution effect costs	“	0.011	–	7	7	36	7	57
Microenvironment criteria	21	Taxation base level	“	0.042	–	32	27	26	26	111
	22	Conditions to fund development projects	“	0.034	+	23	22	21	23	89
	23	Price of raw materials and energy resources	“	0.014	–	11	9	37	13	70
	24	Experience of CEOs	“	0.061	+	40	39	40	41	160
	25	Supply of qualified specialists	“	0.053	+	33	34	35	36	138
	26	Price of labour resources	“	0.05	–	32	32	27	17	108
	27	Readiness to select and use innovations	“	0.052	+	32	33	32	33	130
	28	Cooperation with science establishments	“	0.027	+	20	17	25	31	93

Continuation of **Table 5**

	x_i	Description	Unit	Weight of criteria (1st to 4th expert groups)	+ –	Ranking average (assessment by 1st to 6th expert groups) Kruonis PHPP	Kaunas HPP	Lithuanian PP	Geothermal PP	Sum of criterion ranking
	29	Influence of stakeholder groups	“	0.028	–	18	18	18	18	72
		Total amount of rankings		1,0		661	639	736	645	2,681
Quantitative criteria										
	1	Production cost (energy price)	cnt/ kwh	0.2	–	**22**	**9**	**31**	**12**	
	2	Company's value	LTL	0.3	+	**1,852,000**	**147,600**	**1,495,700**	**29,950**	
	3	Company's rated capacity	MW	0.5	–	**900**	**100.8**	**1,800**	**35**	
		Total amount of rankings		1,0						

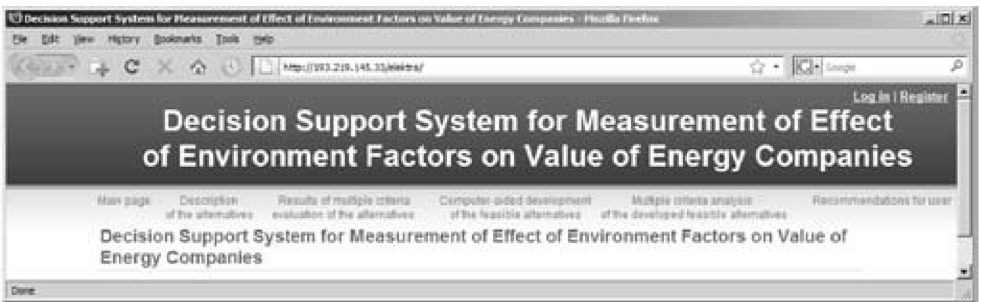


Fig. 8. The main window of ESIAPVN-DS system

Table 6 presents the calculations for the utility degree and market value of the analysed energy objects, i.e. Kruonis Pumped-storage Hydroelectric Power Plant, Kaunas Hydroelectric Power Plant, Lithuanian Power Plant and Geothermal Power Plant, which were performed using the Decision Support System for Measurement of Effect of Environment Factors on Value of Energy Companies developed in Vilnius Gediminas Technical University.

Having assessed the determined values of indicators, it can be noted that experts attributed the biggest weight to the following indicators: the experience of top managers, staff qualification, EU regulation of activities, cooperation with science establishments and environmental regulations. The social role of energy companies also carries a considerable weight. In future, during the improvement of studies of environment factors, this indicator can be analysed more thoroughly dividing it into more specific components. Using the unique decision support system for the measurement of the utility degree and market value of objects, which was developed in Vilnius Gediminas Technical University, it is possible to measure the ratio of ranks of each selected criterion, that clearly defines each object by showing its differences compared to the best alternative.

It is continued by measurement of indicator weights and making a normalised decision-making matrix. Obviously, Kaunas Hydroelectric Power Plant has the highest utility degree and the first priority. This result was determined by the use of renewable sources, high profit margin, environmental aspect (not affected by external pollution costs), favourable public opinion on activities and low production costs. The Geothermal Power Plant comes as the second alternative which has a considerable potential of renewable energy sources independent of seasonal variations, favourable public opinion and opinion of stakeholder institutions about activities, high social responsibility level and innovativeness.

When the best alternative is set, then the adjusted object's market value is calculated using the formulas (10) through (12). The company's replacement cost, which differs from the market value, is taken as the initial value. Energy objects usually have higher replacement cost than the obtained income capitalisation value or possible sales price. Using the intelligent software for the processing of multiple criteria analysis results, we obtained the number of approximations and the adjusted market value of objects. Tables 7–10 show the results of market value measurement of energy objects.

Table 6. Initial data and results of multiple criteria evaluation of the alternatives

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	0,056	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. structures	+	points	0,019	0,0042 AVG MIN	0,0036 AVG MIN	0,0057 AVG MIN	0,0054 AVG MIN

Continuation of **Table 6**

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. structures	+	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%

5. Recommendations

The problem is how to define an efficient energy sector enterprises 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 sector enterprises 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 11) shows how changes in the micro, meso and macroenvironment and the extent to which the goals pursued by various interested parties are satisfied cause corresponding changes in the value and utility degree of energy sector enterprises. 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 sector enterprises versions allowing to find an optimal combination of different interested parties goals pursued, micro-, meso- and macroenvironment conditions and finances available.

Table 7. The result of market value measurement for Kruonis Pumped-storage Hydroelectric Power Plant

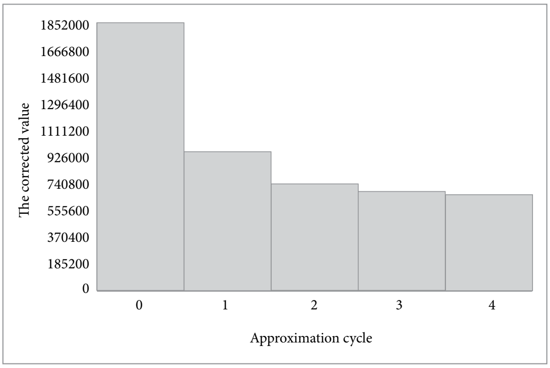
Calculation by approximation cycles in market value measurement	**Diagram of approximation cycles in market value measurement**	**Result**
1,852,000 41% 881,312.5 27.54% 638,640.62 9.5% 577,972.65 2.62% 562,805.66 0.67%		Considering weights of qualitative and quantitative criteria of environment factors, the market value of Kruonis HAE adjusted through five approximation cycles makes up **LTL 562,805.664 thousand**. This value is close to the obtained income capitalisation value specified in Table 4. Such result shows that property development costs fail to repay the object's utility.

Table 8. The result of market value measurement for Kaunas Hydroelectric Power Plant

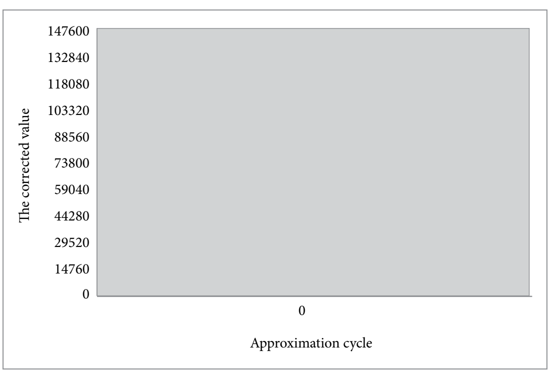
Calculation by approximation cycles in market value measurement	**Diagram of approximation cycles in market value measurement**	**Result**
147,600 0% 147,600		Whereas this object obtained the highest utility degree during the related measurement, the object's market value is not adjusted: it coincides with the property development cost and is close to the obtained property income capitalisation value. The adjusted market value of Kaunas HE is **LTL 147,600 thousand.**

Table 9. The result of market value measurement for Lithuanian Power Plant

Calculation by approximation cycles in market value measurement	Diagram of approximation cycles in market value measurement	Result
1,495,700 41.08% 881,312.5 17.43% 727,715.62 5.28% 689,316.4 1.39% 679,716.6 0.35%		Measurement of the utility level has shown that this alternative is ranked the lowest. The price of energy resources, environmental aspects and high production costs made the biggest negative impact in the measurement of the market value of Lithuanian Power Plant. Thus the adjusted market value obtained through approximation cycles makes up **LTL 679,716.602 thousand.** The obtained market value is almost twice lower than the object's replacement cost and 8.7% lower than the obtained income capitalisation value.

Table 10. The result of market value measurement for the Geothermal Power Plant

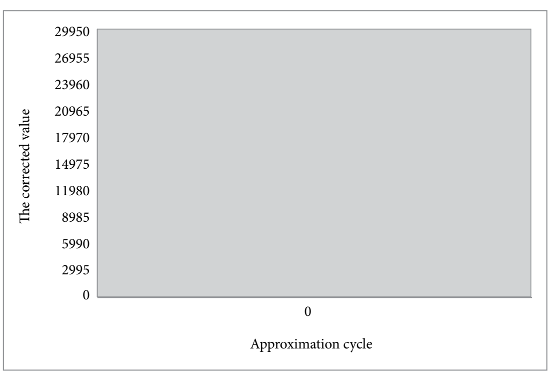
Calculation by approximation cycles in market value measurement	Diagram of approximation cycles in market value measurement	Result
29,950 0% 29,950		This object received the second utility priority during measurement of the utility degree. Its market value is not adjusted: it coincides with the property development cost and is close to the obtained property income capitalisation value. The adjusted market value of the Geothermal Power Plant is **LTL 29,950 thousand**.

Table 11. Recommendations in the ESIAPVN-DS system

Qualitative and quantitative description of the alternatives							
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%)(0,137%)	31 (3,23%)(0,043%)	29 (10,34%)(0,137%)	32 (0%)(0%)
Internal (national) policy towards this sector	+	points	0,023	20 (0%)(0%)	15 (33,33%)(0,207%)	17 (17,65%)(0,11%)	14 (42,86%)(0,266%)
Relations with national authorities	+	points	0,027	17 (11,76%)(0,086%)	17 (11,76%)(0,086%)	19 (0%)(0%)	16 (18,75%)(0,137%)
Trends of economic change	+	points	0,028	24 (8,33%)(0,063%)	18 (44,44%)(0,336%)	26 (0%)(0%)	17 (52,94%)(0,4%)
Changes of consumption	+	points	0,03	22 (18,18%)(0,147%)	19 (36,84%)(0,298%)	26 (0%)(0%)	18 (44,44%)(0,36%)
Investment conditions	+	points	0,047	34 (0%)(0%)	30 (13,33%)(0,169%)	29 (17,24%)(0,219%)	20 (70%)(0,888%)
Public attitude towards activities	+	points	0,047	22 (36,36%)(0,462%)	30 (0%)(0%)	30 (0%)(0%)	29 (3,45%)(0,044%)
Change of industrial technology	+	points	0,047	29 (6,9%)(0,088%)	29 (6,9%)(0,088%)	29 (6,9%)(0,088%)	31 (0%)(0%)
Development of alternative energy sources	+	points	0,034	20 (25%)(0,23%)	22 (13,64%)(0,125%)	17 (47,06%)(0,432%)	25 (0%)(0%)
Environmental regulations	+	points	0,049	27 (18,52%)(0,245%)	31 (3,23%)(0,043%)	19 (68,42%)(0,905%)	32 (0%)(0%)
Legal regulation of activities	+	points	0,03	20 (10%)(0,081%)	19 (15,79%)(0,128%)	22 (0%)(0%)	18 (22,22%)(0,18%)
Municipal influence	+	points	0,027	25 (0%)(0%)	17 (47,06%)(0,343%)	23 (8,7%)(0,063%)	15 (66,67%)(0,486%)
Legal basis for infrastr. develop.	+	points	0,023	15 (20%)(0,124%)	15 (20%)(0,124%)	18 (0%)(0%)	15 (20%)(0,124%)
Profitability degree	+	points	0,055	29 (20,69%)(0,307%)	35 (0%)(0%)	16 (118,75%)(1,764%)	29 (20,69%)(0,307%)
Competitive environment	-	points	0,011	8 (12,5%)(0,037%)	7 (0%)(0%)	11 (36,36%)(0,108%)	11 (36,36%)(0,108%)
Introduction of environment-friendly technologies	+	points	0,034	22 (9,09%)(0,083%)	22 (9,09%)(0,083%)	22 (9,09%)(0,083%)	24 (0%)(0%)
Dependence on resource provision	-	points	0,013	13 (38,46%)(0,135%)	8 (0%)(0%)	43 (81,4%)(0,286%)	12 (33,33%)(0,117%)
Integration into internat. structurestūras	+	points	0,019	14 (35,71%)(0,183%)	12 (58,33%)(0,299%)	19 (0%)(0%)	18 (5,56%)(0,029%)
Degree of corporate social responsibility	+	points	0,038	23 (4,35%)(0,045%)	24 (0%)(0%)	24 (0%)(0%)	24 (0%)(0%)
Degree of external pollution effect costs	-	points	0,011	7 (0%)(0%)	7 (0%)(0%)	36 (80,56%)(0,239%)	7 (0%)(0%)
Taxation base level	-	points	0,042	32 (18,75%)(0,213%)	27 (3,7%)(0,042%)	26 (0%)(0%)	26 (0%)(0%)
Conditions to fund development projects	+	points	0,034	23 (0%)(0%)	22 (4,55%)(0,042%)	21 (9,52%)(0,087%)	23 (0%)(0%)
Price of raw materials and energy resources	-	points	0,014	11 (18,18%)(0,069%)	9 (0%)(0%)	37 (75,68%)(0,286%)	13 (30,77%)(0,116%)
Experience of CEOs	+	points	0,061	40 (2,5%)(0,041%)	39 (5,13%)(0,084%)	40 (2,5%)(0,041%)	41 (0%)(0%)
Supply of qualified specialists	+	points	0,053	33 (9,09%)(0,13%)	34 (5,88%)(0,084%)	35 (2,86%)(0,041%)	36 (0%)(0%)
Price of labour resources	-	points	0,05	32 (46,88%)(0,633%)	32 (46,88%)(0,633%)	27 (37,04%)(0,5%)	17 (0%)(0%)
Readiness to select and use innovations	+	points	0,052	32 (3,12%)(0,044%)	33 (0%)(0%)	32 (3,12%)(0,044%)	33 (0%)(0%)
Cooperation with science establishments	+	points	0,027	20 (55%)(0,401%)	17 (82,35%)(0,6%)	25 (24%)(0,175%)	31 (0%)(0%)
Influence of stakeholder groups	-	points	0,028	18 (0%)(0%)	18 (0%)(0%)	18 (0%)(0%)	18 (0%)(0%)
Company's income capitalisation value	-	thousand LTL	0,9	1852000 (98,38%)(23,912%)	147600 (79,71%)(19,373%)	1495700 (98%)(23,818%)	29950 (0%)(0%)
Company's rated capacity	+	MW	0,9	900 (100%)(24,305%)	100,8 (1685,71%) (409,706%)	1800 (0%)(0%)	35 (5042,86%) (1225,647%)
Production cost (energy price)	-	cnt/kwh	0,9	22 (59,09%)(14,362%)	9 (0%)(0%)	31 (70,97%)(17,248%)	12 (25%)(6,076%)

* – The sign "*" indicates that a greater (less) criterion value corresponds to a greater significance for a user (stakeholders)

Table 11 provides extensive information about the quantitative effect of environment factors on value of energy companies. Last columns of the matrix provided in Table 11 give information about possibilities to increase the value of energy companies. Let us take production costs (cnt/kwh) of the Lithuanian Power Plant as an example. This cell of the matrix provided in Table 11 shows that:

- Production cost of Lithuanian Power Plant is 31 cnt/kwh. It is the highest production cost among the compared alternatives (22 cnt/kwh for Kruonis HAE, 9 cnt/kwh for Kaunas HE and 12 cnt/kwh for Geothermal Power Plant).
- Calculations show that theoretically this production cost may be improved by 70.97%.
- Improvement of production cost by 70.97% in Lithuanian Power Plant means a 17.24% increase of its market value.

Let us take another example from legal regulation of activities of the Geothermal Power Plant (Table 6):

- Experts gave 18 points to legal regulation of activities of the Geothermal Power Plant (the lowest result among all analysed power plants).
- Calculations show that the legal regulation of activities may be improved by about 22%.
- Improvement of 22% in legal regulation of activities of the Geothermal Power Plant means a 0.18% increase of its market value.

Table 12 provides information about criteria that have the greatest influence on the ranking of energy companies.

Table 12. TOP 3 object criteria that have the greatest influence on the ranking

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 income capitalisation value	98%	24%
2	Company's rated capacity	100%	24%
3	Production cost (energy price)	59%	14%
Kauno HPP			
1	Company's rated capacity	1686%	410%
2	Company's income capitalisation value	80%	19%
3	Price of labour resources	47%	1%
Lietuvos PP			
1	Company's income capitalisation value	98%	24%
2	Production cost (energy price)	71%	17%
3	Profitability degree	119%	2%
Geothermal PP			
1	Company's rated capacity	5043%	1226%
2	Production cost (energy price)	25%	6%
3	Investment conditions	70%	1%

6. Conclusions

1. The developed Analysis Model for Environment Factors of electricity companies, which incorporates information and intelligent technology, allows analysing corporate environment and value affecting factors, as well as to assess environment efficiency, the related stakeholder groups which want to achieve their goals, and the entire external macro, meso and microenviroment which that the environment and the stakeholder groups. The authors supplemented the Analysis Model for Environment Factors of electricity companies by the criterion of corporate social responsibility as a promising factor which affects company's value.

2. Assessment of special-purpose property of infrastructure companies must include the analysis of factors which define compliance with environmental requirements and norms, as well as the measurement of weights of such factors and their influence on operating efficiency and, respectively, on the value.

3. When solving tasks related to the valuation of special-purpose property of energy sector, an effective instrument can be a value analysis model which matches corporate economic goals, corporate environmental responsibility from social, ecologic and economic perspective, as well as influence of environment factors on corporate property.

4. Valuation methods which are deemed traditional fail to account for the entire set of value affecting criteria. These methods set value of an energy company as a sum of separate complexes of facilities (using the replacement cost approach) or the transformed value of forecast cash flows based on subjective assumptions (using the income capitalisation or other economic methods). Thorough assessment of environment factors helps to improve objectiveness of assumptions; it also facilitates assessment of the utility level of the analysed objects and, respectively, adjustment of the value.

5. Multiple criteria analysis methods, which incorporate the use of intelligent support systems, enable a broader perspective, through the use of simple instruments, on the market value measurement process of objects operating in various branches; it also facilitates the assessment of a larger variety of value affecting factors and their linking with constantly changing environment factors thus monitoring changes of value. The developed Decision Support System for Measurement of Effect of Environment Factors on Value of Energy Companies (ESIAPVN-DS) facilitates the measurement of the utility level and market value of the analysed objects, as well as the analysis of factors which may affect the value, at the same time searching for solutions to eliminate negative effect of factors or to identify the strengths.

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APLINKOS VEIKSNIŲ POVEIKIO ENERGETIKOS SEKTORIAUS ĮMONIŲ VERTEI NUSTATYMAS: ANALIZĖS MODELIS IR METODAS

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Santrauka

Energetikos įmonių turto valdymo, disponavimo turtu praktiniams uždaviniams spręsti reikalinga tikroji šių įmonių turto vertė. Tradiciniai praktikoje taikomi turto vertinimo metodai pagrįsti turto sukūrimo sąnaudų ar veiklos finansinių rodiklių analize, jie neįvertina daugelio vertę veikiančių aplinkos veiksnių įtakos. Siekiant padidinti vertės nustatymo objektyvumą, pasiūlytas taikyti energetikos įmonių aplinkos veiksnių tyrimo modelis, kurio elementų analizė leidžia įvairiais aspektais pažvelgti į šių įmonių turto vertę ir įvertinti vertės kitimo priežastis. Sukurtas modelis leidžia analizuoti įmonės aplinką, vertinti jos efektyvumą, aplinką ir suinteresuotas grupes veikiančią išorinę makro-, mezo- ir mikroaplinką kaip visumą. Naudojantis rodiklių, apibūdinančių analizuojamo sektoriaus aplinką, sistema, pasiūlyta infrastruktūros įmonėms vertinti, taikyti daugiakriterine analize paremtus metodus. Siekiant nustatyti aplinkos veiksnių tyrimo modelio veiksmingumą, išspręstas praktinis uždavinys – taikant modelį ir remiantis daugiakriterinės analizės metodais nustatytas pasirinktų elektros energetikos įmonių naudingumo laipsnis ir rinkos vertė.

Reikšminiai žodžiai: aplinkos veiksniai, daugiakriterinė analizė, energetika, ekologija, infrastruktūra, modelis, vertinimas.

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