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INDRĖ ŠIKŠNELYTĖ

SUSTAINABILITY ASSESSMENT OF ELECTRICITY MARKET MODELS

Summary of Doctoral Dissertation
Social Sciences, Economics (04S)

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ELEKTROS ENERGIJOS RINKOS MODELIŲ DARNUMO VERTINIMAS

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SUMMARY OF DOCTORAL DISSERTATION

INTRODUCTION

Problem formulation: more than 30 years have passed since the publication of the article on energy market restructuring by Schmalensee and Joskow (1983), 25 years since the United Kingdom (UK) began to design its innovative and comprehensive electricity sector privatization, restructuring for competition and regulatory reform program in the energy sector, 22 years since Green and Newbery (1992) published their simulation analysis of market power in the deregulated wholesale electricity markets in England and Wales under alternative market structures, 17 years since Newbery and Pollitt (1997) published their social cost-benefit analysis of the privatization and restructuring program in the UK. Gradually, more and more other countries have followed the UK's lead and introduced comprehensive electricity sector reform programs and, at least in theory, comprehensive electricity sector liberalization principles now apply to all EU countries. Other countries have introduced less comprehensive and consistent reform programs as compared with those in the EU countries. Still the main principles of energy market liberalization have been followed.

Liberalization of electricity market is going on around the world. It began in 1989 in England and in 1992 in the United States. It quickly spread not only in Europe and North America, but also reached South America, Australia, New Zealand and, most recently, some Asian and African countries. During the last 30 years most developed countries have also gone through reasonably comprehensive privatization, restructuring and deregulation programs in sectors that were previously regulated monopolies and/or state-owned: airlines, transportation, telecommunications, natural gas, railroads and other sectors. Although these reforms have not always proceeded without controversy or led to precisely the results predicted, the general trend of public policy has continued to support liberalization and to move forward with additional liberalization reforms in sectors that were once dominated by regulated legal monopolies. Electricity sector liberalization (and natural gas sector liberalization in much of Europe) seems to be different from the trends in these other industries. In many countries electricity sector reforms are incomplete, either moving forward slowly with considerable resistance or

moving backward, despite the success of these reforms in the UK, other EU countries and the Nordic countries, Australia, New Zealand, etc.

Electricity sectors almost everywhere on earth evolved with vertically integrated geographic monopolies that were either state-owned or at high regulation level. The main components of electricity supply – generation, transmission, distribution and retail supply –were integrated within individual electric utilities. These companies in turn had de facto exclusive franchises to supply electricity to residential, commercial and industrial retail consumers within a defined geographic area. The performance of these regulated monopolies varied widely across countries.

Sector performance in developed countries was generally much better than in developing countries (Joskow, 1997; Bacon et al., 2001), but high operating costs, ineffective investments and high retail prices of electric energy stimulated pressures for changes that would reduce electricity costs and retail prices of electric energy. The main reform goal has been to create new institutional arrangements for the electricity sector that provide long-term benefits to society and to ensure that an appropriate share of these benefits are conveyed to consumers through lower prices, reliability of supplies and service quality.

The benefit of electricity reform relies on competitive wholesale markets for power to provide better incentives for controlling operating costs of new and existing generating capacity, to encourage innovation in power supply technologies. Competition in retail market allows consumers to choose the retail power supplier offering the price/service quality combination that best meet their needs and increase competition among electric energy producers and suppliers.

Significant portions of the total costs of electricity supply – distribution and transmission – would continue to be regulated as legal monopolies. Accordingly, regulatory arrangements governing the distribution and transmission networks have generally been viewed as an important complement to the introduction of wholesale and retail competition to supply consumer energy needs.

Regulation of distribution and transmission companies combined with the application of performance-based regulation imposes hard budget constraints on regulated network firms and provides better incentives for them to reduce costs and

improve service quality (Beesley and Littlechild 1989, Joskow 2006, Jamasb et al., 2007).

Although the electricity sector is rather specific and has features that are not typical to other sectors, yet the same economic laws are applied as in other economic activities. The same motives of people prevail in the electricity market – there are those, who produce, supply, transfer or sell electricity and expect to earn as much as possible, and there are others who use electricity and want to buy it as cheaply as possible. Market allows the best match of the desires of two parties, where businesspeople are forced to compete, reduce prices and improve their operational efficiency in order to attract more customers, whereas buyers have the opportunity to choose the suppliers, who are offering the best conditions and can save expenses on electricity consumption.

Looking at the whole country's level of energy, including the electricity sector, objectives in decision-making are multiple and are in conflict with each other: to minimize the costs, minimize the impact on the environment, ensure reliability of energy supply, guarantee energy independence and quality of performance, etc. Therefore, multi-criteria analysis or multi-criteria evaluation, which provide an opportunity to evaluate real importance of the chosen indicators for decision-maker, when economic, environmental, social and other indicators are combined and choose the best solution, taking into account all of them, are applied during the adoption of strategic decisions related to electricity market development. While making decisions in the electricity sector, the most important aspect is as follows: the adopted decisions should coincide with the sector policy objectives.

The concept of "sustainable development" or "sustainability" was first used in early 1980 seeking to imperatively reconcile economic development and environmental protection issues. International organizations use the concept of sustainable development especially to speak about nature preservation. Sustainable development has been defined in many ways, but the most frequently quoted definition is from *Our Common Future*, also known as the Brundtland Report in 1987: "Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (Waheed et al., 2009). Since then sustainable development has become an example of dynamic social, economic, technological and environmental indicators, which allow moving towards a better life. Future generations

having more knowledge, more innovative technologies and different needs will perceive sustainable development goals in their own way based on their cultures and values, since there is no specific sustainability status. Therefore, problems, issues and objectives related to sustainable development must be regularly updated (OECD, 2004).

Appropriate and reliable supply of energy for the affordable price, in safe and environmentally friendly manner and in accordance with social and economic development needs is the main task of sustainable development. Electricity is essential in order to eliminate poverty, improve human welfare and raise the level of living. There are many countries, which do not have a reliable and secure electricity supply; thus, their economic development is very limited. Meanwhile, the degradation of the environment and sustainable development is typical for other countries where electricity is available to everyone. Some authors argue that sustainable development is about achieving a balance between each individual system, such as the environmental, economic and social aspects, over time and spatial horizons that require inter-disciplinary actions in decision-making (Waheed et al., 2009).

Sustainable development is also used as the model of sustainable production and consumption as well as one of the main preventive measures in order to reduce the degradation of the environment (Veleva et al., 2001). Sustainable development "in common sense" constructively matches two issues that contradict each other. For this particular reason, sustainable development has become one of the main criteria and even the evaluation scale today during the adoption of individual decision and formation of country policies.

The level of research of scientific problem: theoretical aspects related to liberalization of electricity market are analysed by many scientists: Armstrong et al., 2006; Stojkovic, 2005; Joskow, 2003; Newbery, 2002; Pažėraitė, 2001 and others. Many different liberal electricity market price formation methods and individual pricing methodologies are analysed (Borenstein, 2005, 2006; Holland et al., 2006; Indounas et al., 2009; Bosco et al., 2006; Haldrup et al., 2006; Braithwait et al., 2007 and others). Although a great number of studies on electricity market liberalization of individual regions and markets can be found in the scientific literature (Hogselius et al., 2010; Bontrum et al., 2008; Tishler et al., 2007; Singh, 2009; Tozzini, 2008; Ishii et al., 2004; Jasmab et al., 2005; Lise et al., 2004 and others); however, there is a lack of studies on

how the selected electricity market organization model affects sustainability. In addition, there is a lack of studies on how a certain region or country forms its energy policy and how the electricity market model applied in a certain country affects sustainability. Finally, there is lack of studies on the methodology, which could be applied in a particular region for the evaluation of the current situation and future prognoses in regard to sustainability aspect.

Scientific problem of the thesis**:** to ascertain what electricity market organization models are the best ones based on the established criteria and how to ascertain them. The main criteria should include the main sustainability aspects (economic, social, and environmental).

The goal of the thesis: to evaluate sustainability of electricity market organization models.

The object of the thesis: electricity market models

The following tasks have been set:

1) To study and systematise scientific literature and empirical studies related to the justification of the opening of electricity market and implementation of possible models in the opened market;
2) To analyse empirical studies dealing with practical examples of the opening of electricity market and introduce the systematised characteristics of electricity markets on the basis of their development;
3) Having systematised scientific literature and empirical studies dealing with the formation of sustainable model, to prepare a theoretical model for organisation of sustainable electricity market;
4) To analyse and systematise scientific literature and empirical studies dedicated to the analysis of instruments, to evaluate sustainability and formulate and test a set of indicators, defining sustainability of electricity market models;
5) By applying the methods of multi-criteria analysis, to develop methodology for evaluation of sustainability on the basis of different electricity market models;
6) On the basis of the methodology created, to evaluate sustainability of the opening models of electricity markets.

Work methods: analysis of scientific literature, documents and statistical data, situational analysis, comparative analysis; the research employs multi-criteria analysis,

expert method of evaluation, conclusion of indices, econometric modelling, model of logistic regression, methods of descriptive statistics (averages, relative and absolute frequencies, dispersion, standard deviation), their calculation and interpretation, correlation analysis, regression analysis, one-factor and multi-factor analysis of variance, analysis of research results and evaluation thereof.

Theoretical work novelty and its meaning:

- The study systematises and summarises scientific literature and empirical studies related to the justification of the opening of electricity market and implementation of possible models in the opened market;
- An original model of sustainable formation of electric market has been developed;
- The main aspects and priorities when evaluating sustainability of energy market organisation models are established on the basis of detailed analysis of the policy of sustainable energy;
- The Electricity Market Opening Index (EMOI) is based on a comprehensive analysis of electricity market models as well as the theoretical and the empirical study of opening the electricity market;
- The system of evaluative criteria of sustainability (Electricity Market Sustainability Index (EMSI)) has been developed on the basis of the analysis of the expert survey and other evaluative criteria of sustainability;
- The importance of sustainability indicators is based on the survey of experts;
- The evaluative methodology designed to evaluate sustainability of electricity market organisation models is based on the comparative analysis of evaluation methodologies used to evaluate sustainability and is also based on an experiment;
- Econometric evaluation model designed to evaluate sustainability of electricity market models is based on evaluation methodology of electricity market models and a set of evaluative indicators of sustainability based on the methods of multi-criteria analysis.

Practical value of work results:

- The evaluation model designed to evaluate the formation of sustainable electricity market and the evaluation model of sustainability of electricity market allows performing the assessment of instruments employed to open the electricity market and supporting the instruments employed to open electricity market in Lithuania as well as other countries;
- The developed model and methodology can be used to analyse the efficiency of opening the electricity market as regards sustainability;
- Based on multi-criteria evaluation methods, the universal (independent from the level of market development) The Electricity Market Opening Index (EMOI) allows determining the level to which the electricity market has been opened.

References: scientific publications of Lithuanian and foreign authors; publications of scientific institutions; legal acts of governmental institutions; the Organisation for Economic Co-operation and Development (OECD), the U.S. Energy Information Administration (EIA); International Energy Agency (IEA); EUROSTAT, other data of statistical databases, etc.

Defended statements:

1. The methodology has been designed to evaluate organisational models of electricity market, which allows performing an extensive evaluation, encompassing all aspects of sustainable development. In case of prediction, there is the basis to construct different scenarios of energy policy which increase the level of credibility.
2. The evaluation methodology, which has been designed for the evaluation of energy market organisation model, provides the basis for the identification of indicators that have the most significant influence on sustainability; also it lays down the premise for the establishment of critical values and possible changes and the analysis of reasons for the changes in sustainability.
3. The methods of multi-criteria analysis allow evaluating different and constantly changing factors that influence sustainability and assure the maximum accuracy of evaluation.

4. The best model of energy market organisation allows ensuring all main objectives of sustainable electricity policy development, which are as important as economic factors and which are based on evaluation of the price of electricity.

Work structure and volume: the paper consists of introduction, theoretical, analytical and research parts, conclusions, list of references and appendices. The volume of the main parts of the paper is as follows: 153 pages, 37 tables, 22 figures, 14 formulas, 10 appendices, 222 references.

The first part of the paper introduces the theoretical aspects of formulation of sustainable electricity market model: the justification of the need to open the electricity market, a detailed introduction of possible organisation models of electricity industry and the process of the opening the electricity market itself, the analysis of the practical implementation of the opening of electricity market, the dynamics of formation philosophies of a sustainable energy policy and the development of an original theoretical model designed to form a sustainable electricity market.

The second part of the paper discusses methodology designed to evaluate sustainability of electricity market models: it introduces evaluation systems of sustainability, application of the methods of multi-criteria analysis and a lot of instruments to support multi-criteria solutions in the electricity sector. This part of the paper also bases methodological access to evaluate sustainability of electricity market models: the selection of evaluative indicators of sustainability of electricity market models is performed and the system to determine the value of indicators is established on the basis of evaluation received from the experts; econometric evaluation model designed to evaluate sustainability of electricity market models is also developed in this part.

The third part of the paper introduces the results and the analysis of sustainability assessment of electricity market models.

Logic scheme of the thesis. A 3-level evaluation system of sustainability of electricity market has been developed:

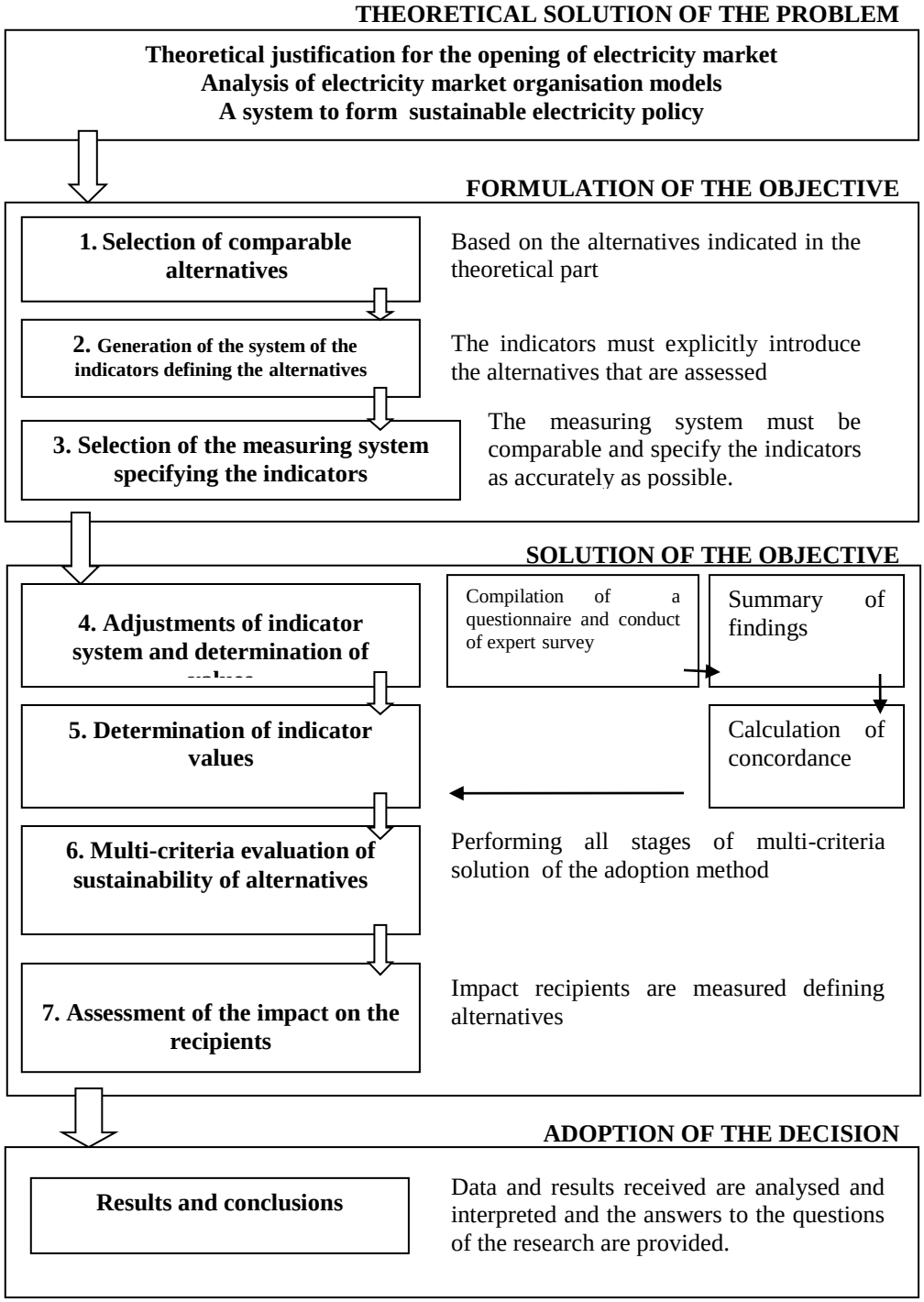


Fig. 1. Logic scheme of the thesis

1. FORMATION OF SUSTAINABLE ELECTRICITY MARKET

Energy plays the main role in all of the aspects of sustainable development and is one of the most essential factors influencing the social development and the economic growth. However, the production of energy and its use influences the quality of environment on all levels: the local, the regional and the global one. In nowadays, the developers of policies are encouraged to evaluate the effect of the strategies created in terms of their effect on sustainable development. For this purpose, international organisations have created and continuously developed the systems designed to form a sustainable policy. This topic has become so relevant that has led to a new discipline to be developed *Sustainability Impact Assessment* (Lee et al., 2000, 2001), the main task thereof is to predict potential economic, environmental and social effects of the developed policy.

The structure of organisation model of electricity industry defined the way it functions and is managed, encompassing production, transmission and distribution. Electricity in the economic system differs from other economic goods, because in the energy system, the coordination of electricity production and consumption in the entire system must be instantaneous. Considering the practical aspect, the industry of electricity in the world is organised on the basis of four market models; they are distinguished on the extent to which the monopolistic power in the model is maintained. The four models of electricity market show how the organisation gradually introduces more options and gradually reduces the extent of monopoly power.

The main characteristics of electricity market organisation models are systematized and introduced in Table 1:

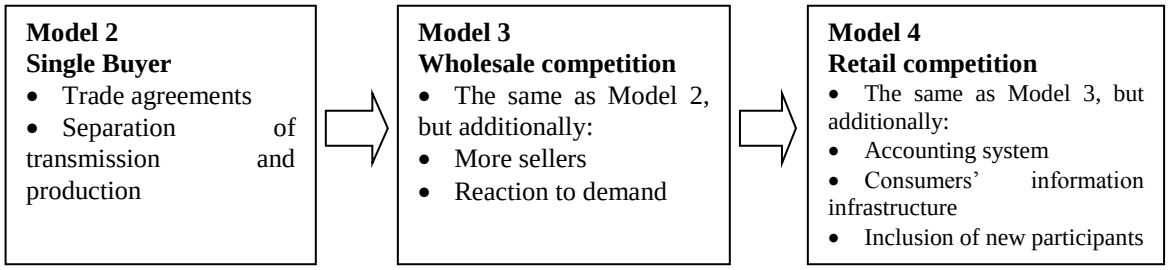
Table 1

Characteristics of the models of electricity markets

	Monopoly	**Single Buyer**	**Wholesale competition**	**Retail competition**
Description	Monopoly in all activity fields	Competition among producers; single buyer	Competition among producers and suppliers; freedom to choose for large consumers	Competition among producers and suppliers; freedom to choose for all consumers
Competition among producers	NO	YES	YES	YES
Competition among suppliers	NO	NO	NO	YES
Wholesalers' right of choice	NO	NO	YES	YES
Retailers' right of choice	NO	NONE	NO	YES

Source: compiled by the author

The state decides which organisational model of electricity market should be selected; however, different models of market organisation demand different structural changes of the sector and reorganisation of the participants in the sector, new institutions, especially creating the wholesale market as well as the changes in the regulatory authorities (Fig. 2).



Source: compiled by the author

Fig. 2. Guidelines of structural and institutional changes

The objective for the opening of electricity market is aimed at creating conditions for competition and effective management of electricity sector; the essence of electricity market is to create uniform and transparent conditions for competition for all electricity producers, suppliers, distributors and users in order to supply the users in the most efficient and the least expensive manner. The opening of electricity market consists of 4 main stages (restructuring, privatization, creation of competition and development), which encompass privatisation of monopolies or creation of budgetary restrictions as

well as the formation of effective mechanisms to achieve the economic efficiency; vertical separation of potentially competitive segments of the market; horizontal restructuring of production segment (ensuring competitiveness of the wholesale market); establishment of independent system operator (to inspect the reliability assurance); development of the trade platform among the producers, distributors and consumers of electricity; competitive and diversified production as well as development of mechanisms stimulating economic, environmental and social efficiency; supply-demand pricing; creation of an independent regulator and the mechanism of transition period of electricity reform.

A number of countries creating policies in a certain sector use indicators in order to monitor the progress of the activities aimed at sustainable development. Having selected a suitable system of formation and reasonably integrated the indicators of sustainable development, it is possible to evaluate the tendencies in spatial and temporal terms; another important aspect, is the necessity to receive an early warning about the policy being developed, because it enables an adequate reaction to the situation. The standard rule for the justification of intervention to the markets should be based on the notion that the general benefit of implementing the measure is higher than the costs of its implementation. However, not all environmental and social effects can be evaluated quantitatively. Effects that contradict each other can be evaluated only be performing qualitative analysis, – it enables decision-making considering a number of indicators that contradict each other. In order to harmonise the policy measures, the methods of multi-criteria decision making (MCDM) are applied; they are extremely useful, when the determination of preferences or their expression are in question.

As it is indicated on the theoretical level, the organisation model of competition in the retail market provides the highest extent to which the mark is opened; it, consequently, influences the efficiency in all fields of activity and correspond to econometric, social and environmental aspects of sustainability to the highest extent. Therefore, the organisational model of competition in the retail market is introduced as the basis for the formation of sustainable electricity market in the country (Fig. 3):

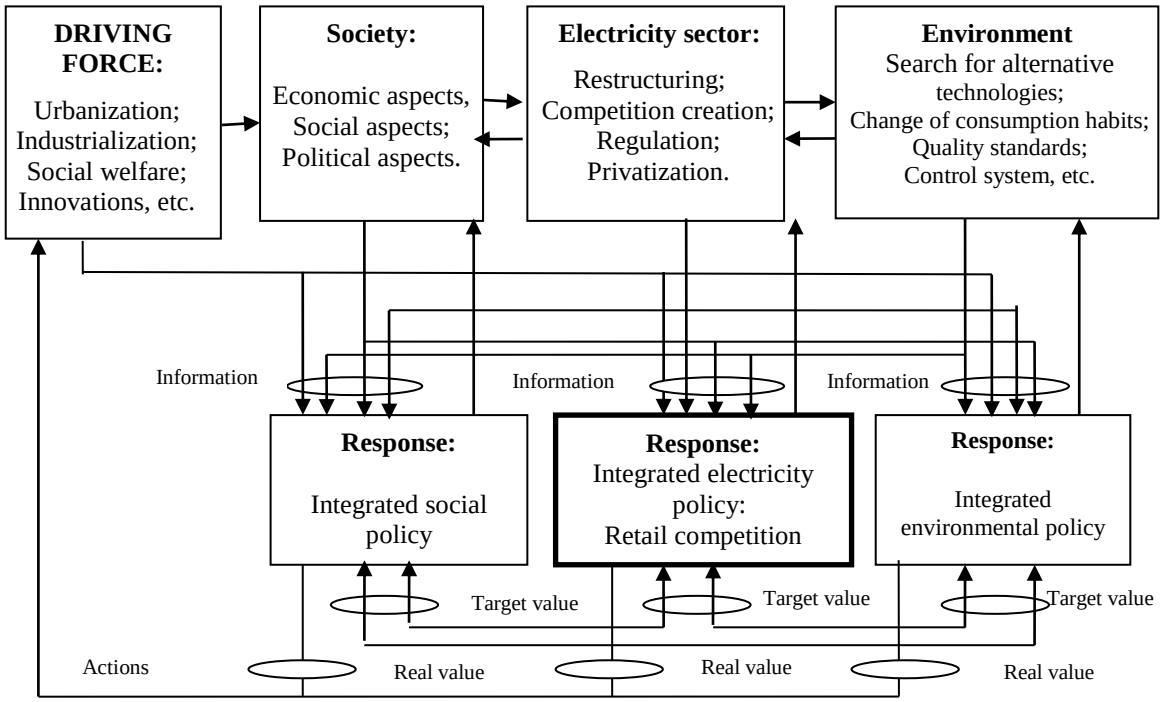


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Fig. 3. Theoretical formation model of sustainable market of electricity

The theoretical model of formation of sustainable electricity market encompasses all stages of opening the market, provides environmental areas that the field influences and defines the most important societal aspects. The model fully integrates all aspects of sustainability and creates the possibility to monitor the changes of the established indicators, compare the actual value of the indicators that has been achieved to the one that has been set and make strategic solutions in order to achieve these indicators.

2. ASSESSMENT METHODOLOGY FOR SUSTAINABILITY OF ELECTRICTY MARKET MODELS

In order to formulate effective evaluation system of sustainability of electricity market models, the thesis justifies the selection of methodological approach of research, defines and systematizes evaluation indicators and introduces expert evaluation as well as methodology of multi-criteria analysis and formulate econometric evaluation model of electricity market models, on the basis of which the research is conducted. The research is conducted on the basis of monitoring various documents of energy policy, expert evaluation, multi-criteria analysis and econometric model of evaluation.

In order to provide a full description and evaluation of sustainability of electricity market models, both quantitative and qualitative methodological approaches are applied and, as Hammersley (1997) states, the aim of these two methodological approaches is to use one research method in order to confirm the results of the other.

The goal of the research: to determine to what extent and which measures of opening the electricity market influence sustainability of electricity market models.

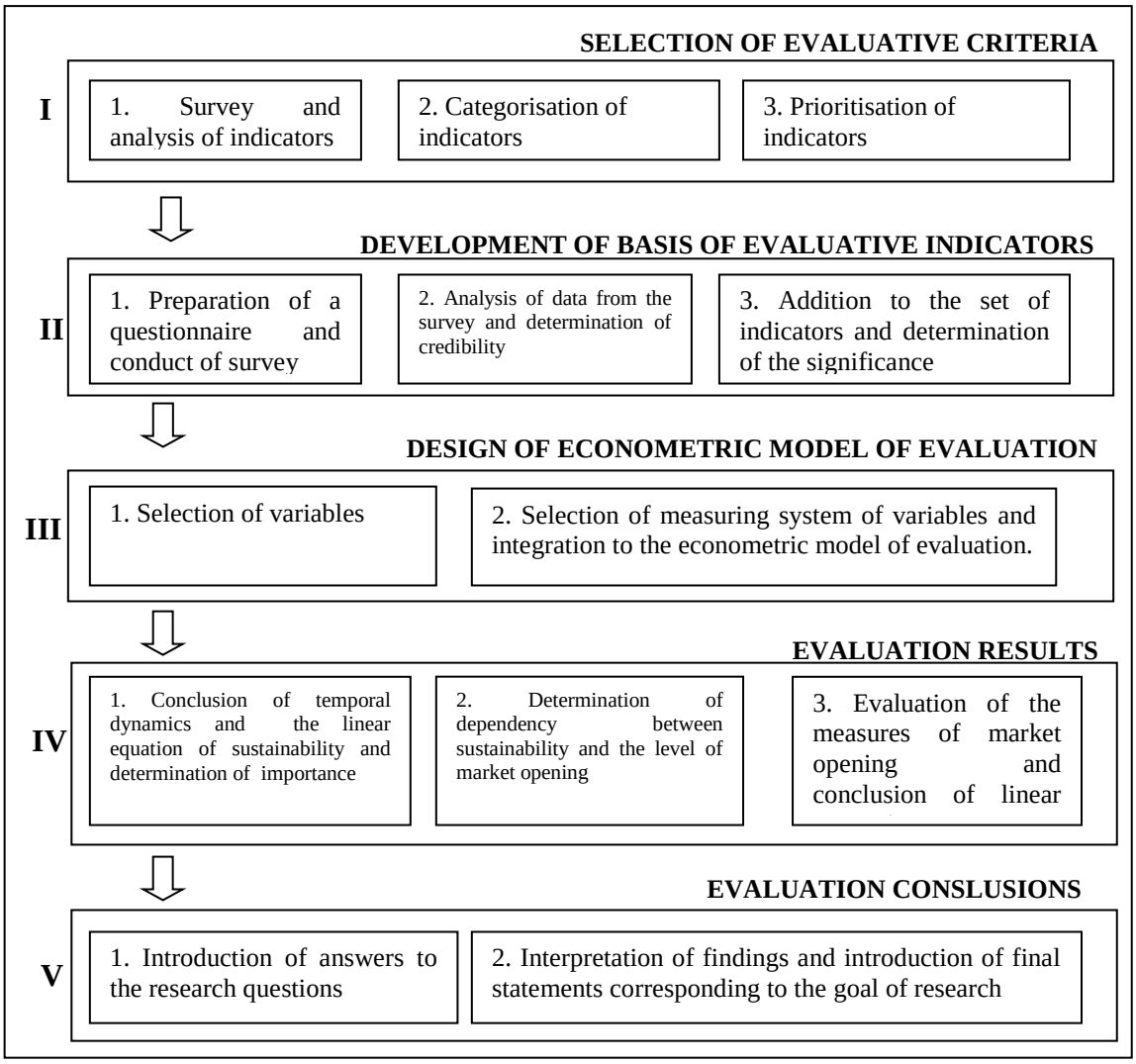
The tasks of the research:

1) To conclude linear equations of sustainability of electricity market over time and determine their statistical significance;
2) To determine the correlation between sustainability of electricity market and the degree to which the market is opened;
3) To determine the correlation and its strength between sustainability of electricity market and each of the variables;
4) To conclude linear regressions of sustainability of electricity market's dependency on the variables.

Research methods: multi-criteria analysis (Weighted Sum Method), where a mono-criterion objective function is concluded having summed up all the objective functions multiplied by weightings), method of the expert evaluation, econometric modelling, logistic regression models, construction of indices, the methods of descriptive statistics (averages, relative and absolute frequencies, dispersion, standard deviation), their calculations and interpretation, correlation analysis, regression analysis, mono-factorial and multi-factorial variance analysis, analysis and assessment of findings of the research.

Research data: data of the Organisation for Economic Co-operation and Development (OECD), the U.S. Energy Information Administration (EIA); International Energy Agency (IEA); EUROSTAT, other data of statistical databases.

Logic scheme of research organisation:



Source: compiled by the author

Fig. 4. Logic scheme of evaluation for sustainability of electricity market models

The set of evaluative criteria designed to evaluate sustainability of electricity market models are based on the analysis of scientific literature and empirical studies (Hirschberg et al., 2007; Ness et al., 2007; Huge et al., 2011; Rovere et al., 2010; Kaygusuz, 2012; Rotmans, 1998; Streimikiene et al., 2008; World Energy Council,

2012; Pope, 2004; Francis, 2001; Roshen et al., 2001; Walker et al., 1999; Rorarius, 2007). Having summarised the results, a set of 16 indicators has been compiled; there are 14 quantitative indicators and 2 qualitative indicators, connecting economic, social and environmental factors of sustainability. Considering the findings of qualitative research (the survey of experts), premises have been laid down to supplement or amend the set of indicators.

The set of indicators has been amended during the survey of the experts (3 indicators have been eliminated) and the importance of evaluative indicators of sustainability of electricity market models has been established (Table 2):

Table 2

EMSI indicators and their significance

Impact area	Indicator	Units of measurement	Target value	Significance
Economic indicators (1/3)				
Growth of economics	Volumes of electricity export	% from the internal production of electricity (net)	+	0.2
	Volumes of electricity import	% from the internal production of electricity (net)	_	0.2
	Intensity of electricity consumption	Btu, 1 USD from the GDP	-	0.2
Competition	Increase of affordability: industrial users	The price of electricity USD/MWh	_	0.2
	Increase of affordability: domestic users	The price of electricity USD/MWh	_	0.2
Σ				**1.00**
Environmental indicators (1/3)				
Impact on the environment	Greenhouse gas emissions (of the energy sector)	CO_2 equivalent, in tons BTU	_	0.3
	The share of renewable energy resources in production of electricity	% from the amount of electricity produced (net)	+	0.25
Efficient use of resources	Recycling	% from the amount of electricity produced (net)	+	0.2
	Loss of provision	% from the amount of electricity used (net)	_	0.25
Σ				**1.00**
Social indicators (1/3)				
Social exclusion	Public health	Dangerous waste from energy sector, CO_2 equivalent thousands of tons per person	_	0.3
	Dependency on import (Energy independence)	Net electricity import, % from the total energy consumption	_	0.35
	Security of supply	Existence of third party access	+	0.2
	Existence of options	Existence of retail competition	+	0.15
Σ				**1.00**

Source: compiled by the author

Econometric model of evaluation has been designed to evaluate the influence of electricity market models on sustainability on the basis of analysis; this model aims at determining which measures of opening the electricity market are the most significant for the sustainability of electricity market.

$$EMSI_e = \alpha + \beta R + \gamma NR + \varepsilon \quad (1)$$

where $EMSI_e$ stands for Electricity Market Sustainability Index, R stands for regulators (indicators that are directly related to opening the market and which reflect the level of market opening); NR stands for non-regulators (independent variables which are not related to the opening of the market); α, β and γ are calculated coefficient vectors and ε is a random variable.

In order to determine the influence of electricity market models on sustainability, the main independent regulators have been selected for research: separation of production and transmission, the access of third parties, competitiveness of wholesale trade, competitiveness of retail trade, regulation quality and the form of property. The main independent non-regulators are the following: the share of hydropower, the share of the nuclear power and the GDP. The share of hydropower and nuclear power allows comparing how the balance structure of electricity fuel influences sustainability, whereas GDP enables evaluation of the size of economy and it has significant influence on energy production and volumes of consumption and other energetic indicators. Table 3 introduces a modified model by F. Steiner, evaluating the effect of measures to open the market on sustainability:

Table 3

Evaluation model of the influence of electricity market models on sustainability

Variables	Measuring
Dependent variables	
Electricity Market Sustainability Index (EMSI)	Electricity Market Sustainability Index (EMSI)
Independent adjustable variables	
Separation of production from transmission **R01**	Dummy variable (1 = separation of accounting or separate companies; 0 = in a different case)
Third party access **R02**	Dummy variable (1 = regulated or agreed access of third parties ; 0 = in a different case)
Competitiveness of wholesale trade **R03**	Dummy variable (1 = the existence of wholesale electricity market; 0 = in a different case)
Competitiveness of retail trade **R04**	Dummy variable (1 = the existence of retail electricity market; 0 = in a different case)
Regulation quality **R05**	Dummy variable (1 = high quality of regulation; 0 = in a different case)
The type of ownership **R06** U1; U2; U3; U4	Discrete variable (0 = public property; 1 = public property mostly; 2 = the amount of public and private property is equal; 3 = private property mostly; 4 = private property)
Independent fixed variables	
Share of the hydropower **N07**	Electricity generated by hydropower sources (%)
Share of the nuclear energy **N08**	Electricity generated by nuclear energy sources (%)
Gross domestic product (GDP) **N09**	GDP (expressed by purchasing power parity in US billion dollars)

Source: compiled by the author

As it has been mentioned already, the opening of electricity market is a gradual process consisting of 4 main stages (restructuring, creation of competitiveness, regulation and privatization), which encompass the measures that are directly related to the instruments implementing these measures: separation of production and transmission, establishment of third party access, assurance of conditions of competitiveness in wholesale market, assurance of conditions of competitiveness in the retail trade, quality of regulation and the form of property. Therefore, all 6 independent adjustable variables, namely separation of production from transmission (R01), the access for the third parties to the power network (R02), competitiveness of wholesale (R03) and retail electricity markets (R04), regulation quality (R05) and the extent of privatization (R06) conclude the Electricity Market Opening Index (EMOI); the higher EMOI, the more open the electricity market is (Table 4):

Table 4

The dynamics of Electricity Market Opening Index (EMOI)

Year/ Country	Australia	US	UK	Canada	Poland	Lithuania	Norway	New Zealand	France	Finland	Sweden	Germany
1990	1	1	6	1	0	0	1	0	0	1	0	2
1991	1	1	6	1	0	0	6	0	0	1	0	2
1992	1	5	6	1	0	0	6	0	0	1	0	2
1993	1	5	6	1	0	0	6	0	0	1	0	2
1994	3	5	7	2	0	0	6	0	0	1	0	2
1995	4	5	8	2	0	1	6	2	0	5	1	2
1996	5	5	8	5	1	1	6	3	0	5	5	2
1997	5	5	8	5	3	1	6	3	0	6	5	2
1998	5	6	8	5	3	1	6	4	0	7	7	7
1999	5	6	9	5	3	1	6	5	0	7	7	7
2000	6	7	9	5	4	1	6	5	0	7	7	9
2001	6	7	9	5	4	2	6	5	0	7	7	9
2002	6	8	9	6	4	5	6	5	0	7	7	9
2003	7	8	9	7	4	5	6	6	0	7	7	9
2004	8	8	9	8	5	6	6	6	0	7	7	9
2005	8	8	9	8	6	6	6	6	4	7	7	9
2006	8	8	9	8	6	7	6	6	5	7	7	9
2007	8	8	9	8	6	7	6	6	6	8	7	9
2008	8	8	9	8	6	6	6	6	6	8	7	9
2009	8	8	9	8	6	6	6	6	6	8	7	9
2010	8	8	9	8	7	7	6	6	6	8	7	9
2011	8	8	9	8	7	7	6	6	6	8	7	9
2012	8	8	9	8	7	7	6	6	6	8	7	9

Source: compiled by the author

In the first stage, Electricity Market Opening Index (EMOI) is concluded on the basis of multi-criteria evaluation methods, which allow determining the extent to which the market is opened. Electricity Market Sustainability Index (EMSI) is based on multi-criteria evaluation method as well. EMSI consists of three groups of indicators, namely the economic, social and environmental ones, the values of which are calculated on the basis of the importance ascribed to each of the selected indicators by experts during the survey. The importance of indicator groups is equal, i.e. each group is equal to 1/3 of the EMSI index. It is also noteworthy that when calculating EMSI, the attention is paid to the analysis on the national level, rather than the comparative international analysis, i.e. EMSI depends on the development of indicators in each analysed country, the economic development of each country, the accessibility of energy resources, etc.

3. EVALUATION RESULTS AND ANALYSIS OF SUSTAINABILITY OF ELECTRICTY MARKET MODELS

Economic analysis of data and interpretation is integral to computerized data analysis that helps to solve various economic-statistical tasks quickly and efficiently. Software packages with integrated methods of mathematical statistics; most of the operations are also formalised which enables accurate and expeditious solution of the applicable tasks. Statistical Package for the Social Sciences (SPSS) is one of the most acknowledged and frequently used software packages of statistical processing of information suitable for various statistical tasks. The main advantage of SPSS is a wide selection of modern methods of statistical analysis and instruments for the visualisation of result analysis (table for data provision, diagrams and distribution curves).

3.1. Linear equations of sustainability of electricity market's temporal dynamics and their statistical significance

In order to form linear equations of temporal dynamics of EMSI (Table 5) which can be applied for the calculation of both EMSI in the assessed period and for future predictions, when the development is stable, processing the data with SPSS.

Table 5

Linear equations of EMSI over the time and their statistical significance

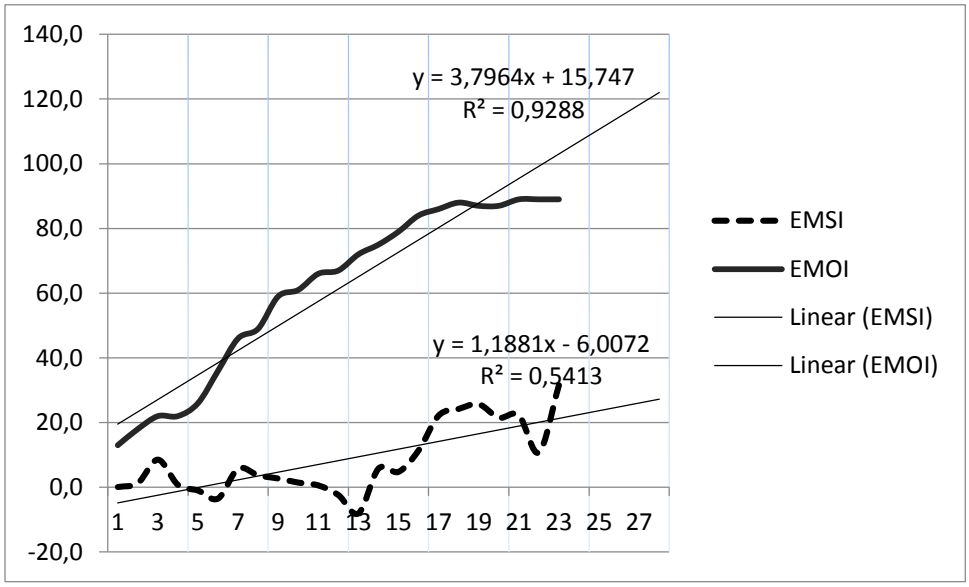
Country	EMSI linear equation	Determination coefficient (R2)	p-value			EMSI linear equation, having removed irrelevant values
			Y (EMSI)	x (years)	constant	
Australia	**y = -0.0042x + 0.0443**	$R^2 = 0.4175$	0.001	0.001	0.005	no insignificant values
US	y = 0.0092x - 1.1203	$R^2 = 0.0132$	0,716	0,716	0,000	-
UK	**y = 0.2661x - 1.0039**	$R^2 = 0.7586$	0.000	0.000	0.027	no insignificant values
Canada	y = 0.0087x + 2.8122	$R^2 = 0.0021$	0.836	0.835	0.000	-
Poland	y = -0.0158x + 0.2258	$R^2 = 0.0688$	0.226	0.226	0.181	-
Lithuania	**y = 0.0492x - 0.1932**	$R^2 = 0.7021$	0.000	0.000	0.043	no insignificant values
Norway	y = -0.0674x - 0.8739	$R^2 = 0.1237$	0.100	0.100	0.097	-
N.Zealand	**y = -0.0051x + 0.0555**	$R^2 = 0.2406$	0.017	0.017	0.039	no insignificant values
France	y = -0.0032x + 0.0876	$R^2 = 0.1612$	0.058	0.058	0.000	-
Finland	y = 0.0262x + 0.0792	$R^2 = 0.3982$	0.001	0.001	0.390	**y = 0.0315x**; R^2 = 0.3761
Sweden	y = 0.0112x - 0.1357	$R^2 = 0.0345$	0.396	0.396	0.424	-
Germany	y = 0.9164x - 4.8171	$R^2 = 0.4259$	0.000	0.001	0.121	**y = 0.5952x**; R^2 = 0.3546
Total	y = 0.099x - 0.4016	$R^2 = 0.0389$	0.001	0.001	0.294	-

Source: compiled by the author

Having processed the data of EMSI linear equations from 12 countries, the general equation has also been concluded. Determination coefficient (R^2) indicates the correspondence of the linear equation to the actual data, i.e. it shows which part of data dissemination can be justified by the linear regression; the closer to 1 is R^2 , the closer to the actual data the equation is. When practically applying the regressive analysis, it is demanded that $R^2 \geq 0.25$, if $R^2 \leq 0.25$, it is very unlikely that linear regression will be suitable. Having received the results, the statistical importance of coefficients is determined. If p-value of the observed importance (hereinafter P) is less than the level of importance α ($p<\alpha$), it can be concluded that the values are significant. If p-value is higher or equal to the selected level of importance ($p\geq\alpha$), the values are insignificant. In this case, the traditional value of importance in research is selected ($\alpha=0.05$): the value analysed is considered to be statistically significant, if its value is lower than the level of importance is lower than 0.05, i.e., $p<0.05$ the value is statistically significant, if $p\geq0.05$, then the value is insignificant. Based on this condition, it can be concluded that the equation of linear regression is applicable to Australia, UK, Lithuania, Finland and Germany, also it can be applied to New Zealand to some extant as well, (R2=0.2406), whereas among the remaining countries, linear regressions of EMSI data are not purposeful and the general equation of all countries is not suitable.

The temporal dynamics of linear regression show that during the investigated period (1990-2012), the dependency of sustainability of electricity market on years (x) in Australia has a tendency of slight decrease (-0.0042x), to grow in UK – (0.2661x), in Lithuania to grow (0.0492x), New Zealand it has a tendency of slight decrease (–0.0051x), in Finland to grow (0.0315x), in Germany to grow (0.5952x). The most significant dependency of sustainability is noticeable in Germany, when analysing Germany's EMSI, the growth of sustainability is noticeable from 2002; before that time, sustainability was practically decreasing, yet from 2002 its growth became steady and the main reason of this can be considered to be the development of the instruments to open the electricity market, including TPA, creation of wholesale and retail competition, high level of privatization and the achievement of high quality assurance.

The comparison of EMOI indices of countries (Table 4) has been conducted in order to reveal whether sustainability of electricity depends on the level of market opening (Fig. 5):



Source: compiled by the author

Fig. 5. The link between EMSI and EMOI

Having concluded temporal dynamics of the linear regressions of EMSI and EMOI, it is visible that during the investigated period (1990-2012), in the analysed countries, electricity market is gradually and stably opened, which influences the growth of sustainability of the market. It has been established that there is direct dependence between EMSI and EMOI: the more open the market, the more sustainable it is.

3.2 Analysis of variables of electricity market models

In the second stage, having established interdependence between EMSI and EMOI, the research based on Steiner's model is conducted, the purpose of which is to reveal how separate instruments used to open the market influence sustainability of electricity market. The econometric evaluation model of the influence of electricity market models on sustainability will be now processed with SPSS software.

The model of linear regression includes the following independent variables: dichotomous (R01; R02; R03; R04; R05); rank (R06) which has been changed into 4 dummy dichotomous variables: U1, U2, U3, U4 (Table 6); Ratio scales (NR07, NR08 and NR09).

Table 6

The values of dummy variables of the rank variable (R06)

Variable (U)	Public property	Mostly public property	The amount of public and private property is equal	Mostly private property	Private property
U1	0	1	0	0	0
U2	0	0	1	0	0
U3	0	0	0	1	0
U4	0	0	0	0	1

Source: compiled by the author

Linear regression based on Steiner's model:

$$EMSI=\alpha + ß_1R_{01} + ß_2R_{02} + ß_3R_{03} + ß_4R_{04} + ß_5R_{05} + ß_{61}U_1 + ß_{62}U_2 + ß_{63}U_3 + ß_{64}U_4 + \gamma_1NR_{07} + \gamma_2NR_{08} + \gamma_3NR_{09} \quad (2)$$

In order to determine the strength of connection between EMSI and each of the variables, the scale of categories (in case of evaluation, 0 and 1 correspond to independent dichotomous R01; R02; R03; R04; R05) employs the comparison of averages, whereas rank (R06) and ration scale ((NR07; NR08; NR09) employs Spearman's correlation coefficient; the scale of values of correlation coefficient is introduced in Table 7:

Table 7

Scale of values of correlation coefficient

Very strong	Strong	Average	Weak	Very weak	No link	Very weak	Weak	Average	Strong	Very strong
from -1 to -0.,8	from -0.8 to -0.6	from -0.6 to -0.4	from -0.4 to -0.1	from -0.1 to 0	0	from 0 to 0.1	from 0.1 to 0.4	from 0.4 to 0.6	from 0.6 to 0.8	from 0.8 to 1

Source: compiled by the author

The strength of correlation of independent variables R06, NR07, NR08 and NR09 has been analysed using Spearman’s coefficient of correlation, which shows what the significance of the change of one variable to the other is. Coefficient was considered statistically important, when the p-value calculated is lower than the selected level of significance 0.05. Table 8 provides statistically significant Spearman’s correlation between the variables of the rank and ordinal scale and EMSI also correlation between the variables themselves:

Table 8

Spearman's correlation between the variables of rank and ordinal scale

Country	Variables	EMSI	R06	NR07	NR08	NR09
Australia	**EMSI**	1.000	-,604(**)	,659(**)		-,619(**)
	R06	-,604(**)	1.000	-,908(**)		,931(**)
	NR07	**,659(**)**	-,908(**)	1.000		-,942(**)
	NR09	-,619(**)	,931(**)	-,942(**)		1.000
US	**EMSI**	1.000				0.110
	R06		1.000	-,759(**)		,840(**)
	NR07		-,759(**)	1.000		-,750(**)
	NR09		,840(**)	-,750(**)		1.000
UK	**EMSI**	1.000	,623(**)	-,415(*)	-,747(**)	,900(**)
	R06	,623(**)	1.000	-,415(*)		,657(**)
	NR07	-,415(*)	-,415(*)	1.000		
	NR08	-,747(**)			1.000	-,771(**)
	NR09	**,900(**)**	,657(**)		-,771(**)	1.000
Canada	**EMSI**	1.000				
	R06		1.000	-,668(**)		,935(**)
	NR07		-,668(**)	1.000		-,681(**)
	NR08				1.000	-,420(*)
	NR09		,935(**)	-,681(**)	-,420(*)	1.000
Poland	**EMSI**	1.000				
	R06		1.000	,549(**)		,889(**)
	NR07		,549(**)	1.000		,449(*)
	NR09		,889(**)	,449(*)		1.000
Lithuania	**EMSI**	1.000	,767(**)	,689(**)	-,464(*)	,932(**)
	R06	,767(**)	1.000	,492(*)		,907(**)
	NR07	,689(**)	,492(*)	1.000	-,490(*)	,672(**)
	NR08	-,464(*)		-,490(*)	1.000	-,435(*)
	NR09	**,932(**)**	,907(**)	,672(**)	-,435(*)	1.000
Norvegija	**EMSI**	1.000		,494(*)		
	NR07	**,494(*)**		1.000		-,888(**)
	NR09			-,888(**)		1.000
N.Zealand	**EMSI**	1.000		,509(*)		-,540(**)
	R06		1.000	-,846(**)		,846(**)
	NR07	**,509(*)**	-,846(**)	1.000		-,866(**)
	NR09	-,540(**)	,846(**)	-,866(**)		1.000
France	**EMSI**	1.000	-,454(*)			
	R06	**-,454(*)**	1.000	-,716(**)		,826(**)
	NR07		-,716(**)	1.000	-,620(**)	-,796(**)
	NR08			-,620(**)	1.000	,484(*)
	NR09		,826(**)	-,796(**)	,484(*)	1.000
Finland	**EMSI**	1.000	,723(**)	-,630(**)	-,535(**)	,784(**)
	R06	,723(**)	1.000			,939(**)
	NR07	-,630(**)		1.000	,632(**)	-0.375
	NR08	-,535(**)		,632(**)	1.000	
	NR09	**,784(**)**	,939(**)			1.000
Sweden	**EMSI**	1.000				
	R06		1.000			,843(**)
	NR07			1.000	-,641(**)	
	NR08			-,641(**)	1.000	-,492(*)
	NR09		,843(**)		-,492(*)	1.000

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Germany	**EMSI**	1.000			-,647(**)	,609(**)
	R06		1.000		-,602(**)	,882(**)
	NR08	**-,647(**)**	-,602(**)		1.000	-,746(**)
	NR09	,609(**)	,882(**)		-,746(**)	1.000
Total	**EMSI**	1.000	,271(**)	-,189(**)	,201(**)	
	R06	**,271(**)**	1.000	-,352(**)		,542(**)
	NR07	-,189(**)	-,352(**)	1.000	-,202(**)	,255(**)
	NR08	,201(**)		-,202(**)	1.000	
	NR09		,542(**)	,255(**)		1.000

Source: compiled by the author
(*) p<0.05
(**) p<0.01

Among the USA, Canada, Poland and Sweden, the correlation of independent variables R06, NR07, NR08, NR09 and EMSI is statistically insignificant, whereas Australia's EMSI heavily influences NR07 (0.659), and NR09 (-0.619); UK influences NR09 (0,9) very heavily, and heavily influences NR08 (-0.747) and R06 (0.623); Lithuanian EMSI influences NR09 (0,932) very heavily and heavily influences R06 (0.767) and NR07 (0.689); Norwegian EMSI has only average influence on NR07 (0.494); EMSI of New Zealand influences NR07 (0.509) and NR09 (-0.540); France's – R06 (-0.454); Finland's EMSI heavily influences NR09 (0.784), R06 (0.723) and NR07 (-0.63); Germany's – NR08 (-0.647) and NR09 (0,609), the weak dependency of the variables of EMSI of all countries is noticed in the case of R06 (0.271) and NR07 (-0.189).

When determining the strength of correlation between dichotomous independent variables (R01; R02; R03; R04; R05) and EMSI, the comparisons of averages are used . Levene's and T-test are performed in a group of countries, separately for each variable (Tables 9-10)

Table 9

Levene's and T-test R01

Country	Levene test		T-test for equal values						
	F	p-value	t	Df (degree of freedom)	p-value	Average difference	Standard deviation	Difference interval, 95% reliability	
								Highest value	Lowest value
Australia	11.682	0.003	0.365	20.852	0.718	0.004	0.012	-0.020	0.029
US	0.183	0.673	1.688	21	0.106	0.623	0.369	-0.144	1.391
Canada	0.025	0.875	-1.562	21	0.133	-1.068	0.684	-2.491	0.354
Poland	10.102	0.005	-0.261	19.023	0.797	-0.032	0.122	-0.287	0.223

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Lithuania	12.800	0.002	-3.542	11.827	**0.004**	-0.488	0.138	-0.789	-0.187
Norway	-	-	1.289	21	0.211	1.689	1.311	-1.036	4.415
N.Zealand	10.803	0.004	-0.791	19.636	0.439	-0.015	0.020	-0.056	0.025
France	1.016	0.325	2.699	21	**0.013**	0.056	0.021	0.013	0.099
Finland	4.589	0.044	-5.496	19.932	**0.000**	-0.365	0.066	-0.503	-0.226
Sweden	7.533	0.012	-0.571	17.634	0.575	-0.068	0.119	-0.318	0.182
Germany	10.044	0.005	-2.129	20.184	**0.046**	-6.777	3.183	-13.413	-0.141
Total	10.003	0.002	-1.845	259.663	0.066	-0.5899	0.3197	-1.2194	0.0396

Source: compiled by the author

Independent variable R01 (Separation of production from transmission) is considered statistically important in Lithuania (p=0.004), France (p=0.013), Finland (p=0.000) and Germany (p=0.046), whereas in other countries, independently from Levene's test (whether the dispersions are equal or different), the independent variable R01 can be considered statistically insignificant. However, separation of production from transmission (R01) is the first necessary step opening the market and implementation of all other measures of market opening are directly dependent on this variable.

Table 10

Levene's and T-test R02

Country	**Levene test**		**T-test for equal values**						
	F	**p-value**	**t**	**Df (degree of freedom)**	**p-value**	**Average difference**	**Standard deviation**	**Difference interval, 95% reliability**	
								Highest value	**Lowest value**
Australia	11.682	0.003	0.365	20.852	0.718	0.004	0.012	-0.020	0.029
US	0.183	0.673	1.688	21	0.106	0.623	0.369	-0.144	1.391
Canada	0.928	0.346	0.042	21	0.967	0.026	0.624	-1.271	1.324
Poland	12.726	0.002	-0.459	17.496	0.652	-0.059	0.128	-0.328	0.211
Lithuania	12.800	0.002	-3.542	11.827	**0.004**	-0.488	0.138	-0.789	-0.187
Norway	-	-	1.289	21	0.211	1.689	1.311	-1.036	4.415
N.Zealand	10.803	0.004	-0.791	19.636	0.439	-0.015	0.020	-0.056	0.025
France	1.016	0.325	2.699	21	**0.013**	0.056	0.021	0.013	0.099
Finland	4.589	0.044	-5.496	19.932	**0.000**	-0.365	0.066	-0.503	-0.226
Sweden	6.144	0.022	-1.013	19.509	0.323	-0.143	0.142	-0.439	0.152
Germany	10.044	0.005	-2.129	20.184	**0.046**	-6.777	3.183	-13.413	-0.141
Total	7.546	0.006	-1.406	262.306	0.161	-0.4613	0.3282	-1.1076	0.1849

Source: compiled by the author

Independent variable R02 (Access of third parties) is considered to be statistically important in Lithuania (p=0.004), France (p=0.013), Finland (p=0.000) and Germany (p=0.046), It is noticeable that statistical significant of variable R02 in the aforementioned countries are identical to the independent variable R01, because the variables in these countries have been introduced together, whereas in other countries,

independently from Levene's test (whether the dispersions are equal or different), the independent variable R02 can be considered statistically insignificant. However, in this case, just like in the case of the independent variable R01, The Access of Third Parties is necessary to open the market, because it constitutes the basis for competition in electricity trade.

Table 11

Levene's and T-test R03

Country	Levene test		T-test for equal values						
	F	p-value	t	Df (degree of freedom)	p-value	Average difference	Standard deviation	Difference interval, 95% reliability	
								Highest value	Lowest value
Australia	4.208	0.053	1.701	16.088	0.108	0.027	0.016	-0.007	0.061
US	0.183	0.673	1.688	21	0,106	0,623	0.369	-0.144	1.391
Canada	0.928	0.346	0.042	21	0.967	0.026	0.624	-1.271	1.324
Poland	29.127	0.000	-0.229	13.513	0.822	-0.036	0.155	-0.370	0.299
Lithuania	25.002	0.000	-3.421	8.994	**0.008**	-0.535	0.156	-0.889	-0.181
Norway	-	-	1.289	21	0.211	1.689	1.311	-1.036	4.415
N.Zealand	10.614	0.004	-0.229	20.765	0.821	-0.005	0.022	-0.051	0.041
France	1.484	0.237	2.929	21	**0.008**	0.062	0.021	0.018	0.105
Finland	4.589	0.044	-5.496	19.932	**0.000**	-0.365	0.066	-0.503	-0.226
Sweden	7.533	0.012	-0.571	17.634	0.575	-0.068	0.119	-0.318	0.182
Germany	10.044	0.005	-2.129	20.184	**0.046**	-6.777	3.183	-13.413	-0.141
Total	10.138	0.002	-1.518	273.829	0.130	-0.4948	0.3259	-1.1364	0.1469

Source: compiled by the author

Independent variable R03 (Competitiveness of the Wholesale Trade) is considered statistically significant in Lithuania (p=0.008), France (p=0.008), Finland (p=0.000) and Germany (p=0.046), whereas in other countries, independently from Levene's test (whether the dispersions are equal or different), the independent variable R03 can be considered statistically insignificant, i.e., it is not credibly different from 0.

Table 12

Levene's and T-test R04

Country	Levene test		T-test for equal values						
	F	p-value	t	Df (degree of freedom)	p-value	Average difference	Standard deviation	Difference interval, 95% reliability	
								Highest value	Lowest value
Australia	9.370	0.006	2.114	16.590	**0.050**	0.034	0.016	0.000	0.067
US	0.208	0.653	-1.713	21	0.101	-0.359	0.209	-0.794	0.077
Canada	17.627	0.000	-6.147	13.153	**0.000**	-3.031	0.493	-4.096	-1.967
Poland	0.028	0.869	1.241	21	0.228	0.657	0.529	-0.444	1.758
Lithuania	3.615	0.071	2.347	21	**0.029**	0.383	0.163	0.044	0.722
Norway	0.235	0.633	-9.832	21	**0.000**	-1.048	0.107	-1.270	-0.826
N.Zealand	-	-	1.289	21	0.211	1.689	1.311	-1.036	4.415

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France	19.390	0.000	0.166	17.406	0.870	0.004	0.024	-0.046	0.054
Finland	2.276	0.146	3.423	21	**0.003**	0.072	0.021	0.028	0.115
Sweden	3.725	0.067	-3.071	21	**0.006**	-0.333	0.108	-0.559	-0.108
Germany	7.533	0.012	-0.571	17.634	0.575	-0.068	0.119	-0.318	0.182
Total	10.044	0.005	-2.129	20.184	**0.046**	-6.777	3.183	-13.413	-0.141

Source: compiled by the author

Independent variable R04 (Competitiveness of the Retail Trade) is considered statistically significant in Australia (p=0.050), UK (p=0.000), Poland (p=0.029), Lithuania (p=0.000), France (p=0.003), Finland (p=0.006) and Germany (p=0.046), whereas in the USA, Canada, the New Zealand, Norway and Sweden, independently from Levene's test (whether the dispersions are equal or different), the independent variable R04 can be considered statistically insignificant.

Table 13

Levene's and T-test R05

Country	**Levene test**		**T-test for equal values**						
	F	**p-value**	**t**	**Df (degree of freedom)**	**p-value**	**Average difference**	**Standard deviation**	**Difference interval, 95% reliability**	
								Highest value	**Lowest value**
Australia	0.637	0.434	7.407	21	**0.000**	0.075	0.010	0.054	0.096
US	0.016	0.899	-1.604	21	0.124	-0.336	0.209	-0.771	0.100
Canada	21.860	0.000	-5.071	17.062	**0.000**	-2.446	0.482	-3.463	-1.428
Poland	0.637	0.434	0.236	21	0.816	0.132	0.561	-1.034	1.298
Lithuania	7.100	0.015	1.454	10.002	0.177	0.285	0.196	-0.152	0.722
Norway	10.261	0.004	-3.719	13.234	**0.003**	-0.480	0.129	-0.758	-0.202
N.Zealand	-	-	1.289	21	0.211	1.689	1.311	-1.036	4.415
France	0.938	0.344	4.393	21	**0.000**	0.096	0.022	0.050	0.141
Finland	1.016	0.325	2.699	21	**0.013**	0.056	0.021	0.013	0.099
Sweden	4.589	0.044	-5.496	19.932	**0.000**	-0.365	0.066	-0.503	-0.226
Germany	7.533	0.012	-0.571	17.634	0.575	-0.068	0.119	-0.318	0.182
Total	15.750	0.001	-2.448	15.656	**0.027**	-8.134	3.323	-15.192	-1.077

Source: compiled by the author

Independent variable R05 (Quality of Regulation) is considered statistically significant in Australia (p=0.000), UK (p=0.000), Lithuania (p=0.000), the New Zealand (p=0.000), France (p=0,013), Finland (p=0.000) and Germany (p=0.027), whereas in the USA, Canada, Norway and Sweden, independently from Levene's test (whether the dispersions are equal or different), the independent variable R05 can be considered statistically insignificant.

Having determined statistical importance of independent variables R01; R02; R03; R04; R05 on EMSI, it can be concluded that the sustainability of electricity markets are significantly affected by all market opening instruments (R01; R02; R03; R04; R05;

R06) in Lithuania, France and Finland, whereas in Germany, statistically important influence is confirmed for all the instruments except R06; it is possible that the significance of R06 is statistically unconfirmed because during the analysed period in Germany, the market has already been highly privatized and it was difficult to determine the differences in analysed values. In UK the statistical importance is confirmed for three measures of market opening, namely R04, R05 and R06, other instruments are difficult to evaluate because of similar period of implementation (Annex 6). In Australia, statistical importance is confirmed for two instruments of market opening, namely R05 and R06; in Poland, statistical importance is confirmed for only one measure, which is R04; however, it is noteworthy that the very existence of an instrument in the country already confirms high level of market opening. In New Zealand, statistical importance is confirmed for R05, which also supports the fact of successful implementation of opening measures.

3.3 Linear regressions of sustainability of electricity market's dependency on the variables

Having determined the strength of correlation between EMSI variables, linear regressions of variables are concluded for each country separately as well as the general equation for all analysed countries. Having evaluated necessary conditions and removed insignificant values, specified values of EMSI are received (Table 14):

Table 14

EMSI linear regression, having removed insignificant variables

Country	EMSI equation, having removed irrelevant variables
Australia	$EMSI=-0.118+0.055*R_{01}+0.07*R_{04}-0.051*R_{05}+0.017*NR_{07}-2.771*10^{-3}*NR_{09}$
US	$EMSI=-0.846-0.715*U_2$
UK	$EMSI=-4.733+2.449*10^{-4}*NR_{09}$
Canada	$EMSI=-37.282+0.391*NR_{07}+3.1215*10^{-4}*NR_{09}$
Poland	$EMSI=0.705+0.78*R_{03}-8.994*10^{-5}*NR_{09}$
Lithuania	$EMSI=-0.095+0.738*R_{04}+2.815*10^{-5}*NR_{09}$
Norway	There are no significant variables in the linear regression equation
N.Zealand	$EMSI=0.018+0.076*R_{01}+0.115*R_{04}-0.067*R_{05}-1.288*10^{-5}*NR_{09}$
France	$EMSI=0.071-0.072*R_{04}$
Finland	$EMSI=2.332-0.082*NR_{08}+1.932*10^{-5}*NR_{09}$
Sweden	There are no significant variables in the linear regression equation

Continued on next page

Germany	EMSI =−22.585+9.828*10^{-4}*NR_{09}
Total	EMSI =0.128+ 4.828*U_4

Source: compiled by the author

As it has been already discussed, Standardized Beta coefficients helps the linear regression to determine which factor has the highest influence on EMSI. Having removed insignificant variables from linear regression of Australia in EMSI equation based on linear regression, the most influential is competitiveness in retail trade – R04 (0.8), the share of hydropower – NR07 (0.666), GDP – NR09 (-0.536), regulation quality – R05 (0.577) and separation of production and transmission – R01 (0.484); in the equation of the USA, only one statistically important variable is confirmed, namely, the level of private property – U2 (-0.618); in UK, there is also one significant variable GDP – NR09 (0.864); in Poland's linear regression in EMSI equation the most influential is GDP – NR09 (-1.166) and competitiveness in wholesale trade – R03 (0.967); in Lithuania's EMSI equation, it is the competitiveness in retail trade – R04 (0.638) and GDP – NR09 (0.45); in New Zealand's EMSI equation it is GDP – NR09 (-1.072), competitiveness in retail trade – R04 (0.801), regulation quality – R05 (-0.481) and separation of production and transmission – R01 (0,458); in France's EMSI equation it is competitiveness in retail trade – R04 (-0.598); in Finland's EMSI equation it is the share of nuclear energy – NR08 (-0.595) and GDP – NR09 (0.544); in Germany's EMSI equation it is GDP – NR09 (0.728); In the general linear regression after elimination of insignificant variables, the most influential on EMSI is private property – U4 (0.464).

Having concluded EMSI linear regressions for the analysed countries and determined the variables which have the greatest influence on regression, it can be claimed that the most significant influence on sustainability of electricity market is the creation of competition in retail trade, qualitative regulation of the market, the share of private property and the growth of GDP in the country. Therefore, it can be concluded that the more open the market, i.e. the selected model of electricity market is of higher degree of opening, the more sustainable it is. There has also been established the interdependence between EMSI and GDP: countries, where the fuel structure is diversified and which influences the use of energy resources, the growth of GDP influences higher sustainability of the market, whereas in countries, where the fuel structure is not diversified, the energy system is based on the use of fossil fuel, the growth of GDP influences the decrease in sustainability.

CONCLUSION

1. The opening of electricity market has created new economic environment in electricity market, which ensures economic growth and serves for the implementation of objectives of efficient development of energy, because the market itself does not guarantee the implementation of the effective concept of development. The electricity market that has been opened creates an option to choose and it generates competitiveness in all areas of the market, influences formation of lower electricity prices and minimization of operational costs as well as efficient implementation of activities in the sector and efficient development in the future.

2. There is a significant difference between the objectives of market opening in developed and developing countries. Developed countries aim at productivity of electricity industry and economic efficiency; in these countries, the need of electric power increases insignificantly, the operation of power system is stable, the aim is to open the electricity market in order for competitive mechanisms to lead to lower costs and lowers prices of electricity. In developing countries, there is an increasing need of electric power, poorly developed system of electricity generation and transmission; therefore, it is expected that the opening of electricity market would attract foreign investments for the development of power systems, remove the deficiencies of electricity and, consequently, revive the economy.

3. Having evaluated the changing environment of electricity system, its non-linearity and feedback, a new theoretical formation model of sustainable energy policy is being introduced. The traditional Unit of Status now includes the components of the Person, the Environment and the System, on the basis of which it is possible to monitor social, environmental and energy policy. The theoretical model of formation of sustainable electricity market encompasses all stages of market opening, provides environmental areas of the fields influenced by the sector and allows integration of societal aspects. The model provides guidelines of policy which encompass comprehensive development: fully integrated aspects of sustainability, monitoring of the change of indicators and directions of strategic solutions.

4. The influence of instruments of sustainable energy policy must include integrated assessment, because the implementation of these instruments can cause

economic, social and environmental effects that contradict each other. The set of 13 indicators to evaluate the sustainability of electricity market models has been formulated on the basis of the analysis of scientific literature, empirical studies and qualitative research (the survey of experts); in the set, there are 11 quantitative indicators and 2 qualitative indicators, encompassing economic, social and environmental aspects of sustainability.

5. The Electricity Market Sustainability Index (EMSI) has been concluded in accordance with the set of indicators and the importance of evaluative indicators determined by the expert survey; the dependence of EMSI on independent variables is analysed on the basis of logistic regression. EMSI index reflect the priority course of energy policy and objectives introduced in the main documents of the policy: Europe 2020, EU Sustainable Development Strategy, the Plan of Implementation of the World Summit on Sustainable Development as well as other international program documents of sustainable development of energy.

Independent variables of the constructed econometric evaluation model are focused on the main regulations of electricity market organisation models (the instruments of market opening); the main independent regulators have been selected for evaluation: separation of production and transmission, third party access, competitiveness in wholesale trade, competitiveness in retail trade, regulation quality and the form of property, whereas the main independent non-regulators include the share of hydropower, the share of nuclear energy and the GDP.

6. Having conducted the evaluation of opening instruments in 1990-2012 and using logistic regression, the methods of descriptive statistics (averages, relative and absolute frequencies, dispersion, standard deviation), correlation, regressive and one-factor and multi-factor analysis of variance, it has been found that in Australia, the most influential on sustainability is the quality of regulation (R05 = 0.8); in the USA, it is the private property – (U2=-0.618); in UK it is the GDP – (NR09=0.864); in Poland it is the GDP (NR09=-1.166); in Lithuania it is the retail competition (R04=0.638); in New Zealand it is the GDP (NR09=-1.072); in France it is retail competition (R04=-0.598); in Finland it is the share of nuclear energy (NR08=-0.595); in Germany it is the GDP (NR09=0.728); in the general linear regression, the most influential factor on the market of electricity market is the share of the private property (U4=0.464). Private ownership is the feature

of electricity market opened to the highest possible level; the basis for the model of competition in retail trade is revealed by the findings of research: the more open the energy market, the more qualifying for sustainability criteria it is.

7. Having conducted empirical research and determined statistical importance of electricity market opening instruments R01, R02, R03, R04, R05 and R06 on EMSI, it can be concluded that in 1990-2012, all instruments of market opening had statistically important effect on sustainability of electricity market in Lithuania. It has been determined that the factor that influenced sustainability in Lithuania's electricity sector in 1990-2012 significantly was the development of retail electricity market and the GDP.

According to statistical analysis, it is impossible to introduce accurate findings on how other instruments like separation of production and transmission activities, competitiveness in wholesale market and third party access to the network as well as privatization have positive effect on sustainability of Lithuania's electricity market, because the effect of these opening instruments is not very significant. In Lithuania, in order to ensure competitiveness of country energetics and implementation of priority objectives of energetics policy in electricity sector, more attention should be paid to the quality of regulation and stimulation of growth of competitiveness, whereas the process of privatization will not necessarily be beneficial to the growth of competitiveness and implementation of priority objectives of energetics policy.

8. Having concluded the assessment of electricity market opening models in 1990-2012 in 12 countries using logistic regression, the methods of statistical description, correlation, regressive one-factor and multi-factor analysis of variance, it has been established that the most influential factor on sustainability of electricity market is the creation of competition, qualitative regulation of the market, the share of the private property and the growth of the GDP in the country. The research has led to the conclusion that the more open the market, the more sustainable it is; therefore, the most sustainable is the organisation model of Retail Competition Market, whereas the organisation model of Wholesale Competition Market does not have a significant influence on sustainability; the model of Single Buyer and Monopolistic market organisation model are inefficient in terms of sustainability; therefore, the countries which aim at sustainable energy policy should not organise the market on the basis of these models.

Having determined the interdependence between the GDP and sustainability, it can be concluded that the countries, where fuel structure is diversified, the growth of the GDP has positive influence on sustainability, whereas in countries, where fuel structure is not diversified, the energy system is based on the fossil fuel and the growth of the GDP has a negative effect on sustainability. The diversification of fuel structure is directly influenced by competition in the market; the more intensive the competition, the more varying the fuel structure; it is directly dependent on the use of renewable energy resources in the energy sector; this dependency confirms once again the need for opening the market and the correspondence between the sustainability of market models and the degree of opening, i.e. the more open the market model, the more sustainable it is.

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DAKTARO DISERTACIJOS SANTRAUKA

Problemos formulavimas: Praėjo daugiau nei 30 metų nuo tada, kai R. Schmalensee ir P.L. Joskow (1983) paskelbė straipsnį apie elektros energijos rinkos restruktūrizavimą, 25 metai nuo tada, kai Jungtinė Karalystė (JK) pradėjo projektuoti inovatyvią kompleksinę energetikos sektoriaus privatizavimo, restruktūrizavimo, konkurencijos ir reguliavimo reformų programą elektros energijos sektoriuje, 22 metai nuo tada, kai R. Green ir D. Newbery (1992) paskelbė alternatyvių elektros energijos rinkos modelių poveikio nereguliuojamoms didmeninėms elektros energijos rinkoms Anglijoje ir Velse modeliavimo analizę, 17 metų nuo tada, kai D. Newbery ir M. Pollitt (1997) pateikė privatizavimo ir restruktūrizavimo programos JK naudos–kaštų analizę, palaipsniui JK pavyzdžiu pradėjo sekti vis daugiau šalių ir pristatė kompleksines elektros energijos sektoriaus reformų programas ir, bent jau teoriškai, nuoseklūs elektros energijos sektoriaus rinkos atvėrimo principai buvo ir yra taikomi visose Europos Sąjungos (ES) šalyse, kituose pasaulio regionuose elektros energijos sektoriaus restruktūrizavimo programos nebuvo tokios išsamios ir nuoseklios kaip ES šalyse, tačiau pagrindinių elektros energijos rinkos atvėrimo principų laikomasi. Elektros sektoriaus rinkos atvėrimas vyksta visame pasaulyje: prasidėjęs 1989 m. Anglijoje, 1992 m. Jungtinėse Amerikos Valstijose, jis išplito ne tik Europoje ir Šiaurės Amerikoje, bet pasiekė ir Pietų Ameriką, Australiją, Naująją Zelandiją bei, pastaruoju metu, kai kurias Azijos ir Afrikos šalis.

Per paskutiniuosius 30 metų išsivysčiusios šalys taip pat įgyvendino privatizavimo, restruktūrizavimo ir reguliavimo panaikinimo programas sektoriams, kurie anksčiau buvo reguliuojamos monopolijos ir/ar valstybinės nuosavybės: oro, transporto, telekomunikacijos, gamtinių dujų, pašto, geležinkelių ir pan. Nors šios reformos ne visada vyko be ginčų ir jų rezultatus buvo galima tiksliai prognozuoti, bendra tendencija išlieka – ir toliau remti rinkos atvėrimą, kurti ir diegti reikalingas priemones monopolijų restruktūrizavimui. Elektros energijos sektoriaus rinkos atvėrimo tendencijos (kaip ir gamtinių dujų sektoriaus daugumoje Europos šalių) skiriasi nuo kitų pramonės šakų. Daugelyje šalių elektros energijos sektoriaus rinkos atvėrimo programa yra neišsami arba juda į priekį labai lėtai dėl didelio pasipriešinimo, netgi kartais juda atgal, nepaisant

šios reformos sėkmės JK, kitose ES ir Skandinavijos šalyse, Australijoje, Naujojoje Zelandijoje ir pan.

Praktiškai visose šalyse elektros energijos sektoriaus veikla išsivystė kaip vertikaliai integruota geografinė monopolija, kuri dažniausiai buvo valstybinė ir aukšto reguliavimo laipsnio. Pagrindiniai elektros energijos komponentai – gamyba, perdavimas, skirstymas ir mažmeninis tiekimas – buvo integruoti į vieną įmonę, kuri turėjo išimtinė teisę tiekti elektros energiją buitiniams, komerciniams ir pramonės vartotojams konkrečiame geografiniame regione. Šių reguliuojamų monopolijų veiklos įvairiose šalyse buvo skirtingos: sektoriaus veikla išsivysčiusiose šalyse iš esmės buvo ženkliai efektyvesnė nei besivystančiose šalyse (P. L. Joskow, 1997; R. W. Bacon ir kt., 2001), tačiau aukštos veiklos sąnaudos, neefektyvios investicijos ir aukštos mažmeninės elektros energijos kainos, skatino ieškoti efektyvesnio elektros energijos rinkos organizavimo būdo, kuris inicijuotų efektyvesnį valdymą, inovatyvias gamybos technologijas, kas sumažintų elektros energijos gamybos sąnaudas ir įtakotų žemesnes elektros energijos kainas.

Pagrindinis elektros energijos reformos tikslas sukurti naujus institucinius susitarimus elektros energijos sektoriui, kurie teiktų ilgalaikę naudą visuomenei ir užtikrinti, kad teikiama nauda būtų perduodama vartotojams per žemesnes kainas, tiekimo patikimumą bei veiklos kokybės užtikrinimą. Elektros energijos reformos nauda remiasi konkurencingos didmeninės elektros energijos rinkos galia efektyviai kontroliuoti sąnaudas, naujus ir esamus elektros energijos gamybos pajėgumus, skatinti inovatyvias technologijas, taip pat ir konkurenciją mažmeninėje rinkoje, kuri leidžia vartotojams pasirinkti mažmeninės elektros energijos tiekėją, siūlantį kainą/paslaugų kokybės derinį, kuris geriausiai atitinka vartotojų poreikius ir sukelia konkurenciją tarp elektros energijos gamintojų it tiekėjų.

Reikšmingą dalį galutinėje elektros energijos sąnaudų sumoje sudaro elektros energijos paskirstymo ir tiekimo sąnaudos, todėl dažniausiai restruktūrizavus elektros energijos sektorių šios veiklos paliekamos teisėtomis monopolijomis. Dėl šios priežasties reguliavimo priemonėms, reglamentuojančioms paskirstymo ir tiekimo tinklus, teikiamas ypatingas dėmesys, papildantis didmeninės ir mažmeninės prekybos konkurenciją patikimai, efektyviai ir kokybiškai aprūpinant vartotojus elektros energija. Paskirstymo ir tiekimo įmonių reguliavimas derinamas kartu su privatizavimu ir remiasi norminiu reguliavimu, kuris numato įmonių finansinių rezultatų apribojimus, kas skatina

įmones mažinti sąnaudas ir gerinti paslaugų kokybę (M. Beesley ir kt., 1989; P.L. Joskow, 2006; T. Jamasb ir kt., 2007).

Nors elektros energijos sektorius yra pakankamai specifinis ir turi kitiems sektoriams nebūdingų bruožų, čia, kaip ir kitose ekonominės veiklos rūšyse, veikia tokie patys ekonomikos dėsniai. Elektros energijos rinkoje veikia tų pačių motyvų vedimi žmonės – vieni, gaminantys, tiekiantys, perduodantys ar parduodantys elektros energiją, tikisi kuo daugiau uždirbti, kiti, vartojantys elektros energiją, nori kuo pigiau jos įsigyti. Rinka sudaro sąlygas geriausiai suderinti abiejų šalių norus, kur verslininkai, norėdami privilioti kuo daugiau pirkėjų, priversti konkuruoti, mažinti kainas ir kelti savo veiklos efektyvumą, o pirkėjai turi galimybę pasirinkti geriausias sąlygas siūlančius tiekėjus, taip pat taupiau vartoti elektros energiją.

Žvelgiant visos šalies lygiu energetikos, tame tarpe ir elektros energijos, sektoriuje keliami tikslai priimant sprendimus yra daugialypiai ir konfliktuoja tarpusavyje: minimizuoti kaštus, minimizuoti poveikį aplinkai, užtikrinti energijos tiekimo patikimumą, užtikrinti energetinį nepriklausomumą ir veiklos kokybę ir t.t. Todėl priimant strateginius sprendimus, susijusius su elektros energijos sektoriaus plėtra taikoma daugiakriterinė analizė arba daugiakriterinis vertinimas, kuris suteikia galimybę įvertinti realią pasirinktų rodiklių svarbą sprendimus priimančiajam, kai yra derinami ekonominiai, aplinkosauginiai, socialiniai ir kt. rodikliai bei parinkti geriausią sprendimą, atsižvelgiant į juos visus. Priimant sprendimus elektros energijos sektoriuje svarbiausiu aspektu galima laikyti tai, kad priimami sprendimai atitiktų sektoriaus politikos tikslus.

„Darnaus vystymosi“ arba „darnumo“ sąvoka pradėta naudoti ankstyvaisiais 1980 m., siekiant imperatyviai suderinti ekonominės plėtros ir aplinkos apsaugos klausimus. Tarptautinės organizacijos naudoja darnaus vystymosi sąvoką ypač kalbant apie gamtos išsaugojimą. Nuo tada, kai 1987 metais, ataskaitoje, pavadintoje „Mūsų bendra ateitis“ Brundtland komisija apibūdino darnų vystymąsi, kaip: "plėtrą, tenkinančią dabarties poreikius ir nekeliančius pavojaus ateities kartų galimybei patenkinti savuosius" (B.Waheed ir kiti, 2009), darnus vystymasis tapo dinamiškas socialinių, ekonominių, technologinių ir aplinkos rodiklių, kurie leidžia šalims judėti link geresnio gyvenimo, pavyzdys. Ateities kartos, turinčios daugiau žinių, inovatyvesnes technologijas ir skirtingus poreikius, darnaus vystymosi tikslus suvoks savaip, atitinkamai pagal savo

kultūras ir vertybes, kadangi nėra konkrečios darnumo būsenos. Būtent dėl šios preižasties su darniu vystymusi susijusios problemos, klausimai ir tikslai, turi būti reguliariai atnaujinami (OECD, 2004).

Tinkamas ir patikimas energijos tiekimas už prieinamą kainą, saugiu ir nekenksmingu aplinkai būdu bei laikantis socialinės ir ekonominės plėtros poreikių yra esminis darnaus vystymosi uždavinys. Elektros energija yra būtina siekiant panaikinti skurdą, gerinti žmogaus gerovę ir pakelti gyvenimo lygį. Yra daug šalių, kurios neturi patikimo ir saugaus elektros energijos tiekimo, tai labai riboja ekonominę plėtrą, tuo tarpu kitose šalyse elektros energija yra prieinama visiems, tačiau tai skatina aplinkos būklės blogėjimą ir prieštaravimą darnaus vystymosi tikslams.

Kai kurie autoriai teigia, kad darnus vystymasis yra pusiausvyros tarp kiekvienos atskiros sistemos, kaip, pavyzdžiui, aplinkosaugos, ekonominių ir socialinių aspektų siekimas, įvertinant laiko ir erdvės horizontus, kurie reikalauja tarpdisciplininių veiksmų sprendimų priėmimo procese (B.Waheed ir kiti, 2009). Darnus vystymasis taip pat yra naudojamas kaip darnaus gamybos ir vartojimo modelis bei kaip viena pagrindinių prevencinių priemonių, siekiant sumažinti aplinkos būklės blogėjimą (V. Veleva ir kt., 2001). Darnus vystymasis „sveiku protu“ konstruktyviai suderina vienas kitam prieštaraujančius klausimus, būtent dėl šios priežasties tiek priimant atskirus sprendimus, tiek formuojant šalies politikas, darnus vystymasis tapo vienas pagrindinių kriterijų ir šiandien dienai netgi vertinimo masteliu.

Problemos ištyrimo lygis: Elektros energijos rinkos atvėrimo teorinius aspektus analizuoja gana daug mokslininkų (M. Armstrong ir kt., 2006; V. Stojkovic, 2005; P. Joskow, 2003; D. Newbery, 2002; A. Pažėraitė, 2001 ir kt.), pateikiama įvairių atvertos elektros energijos rinkos kainos formavimo metodikų, analizuojami atskirų kainodaros metodikų formavimo ypatumai (S.Borenstein, 2005, 2006; S. P. Holland ir kt., 2006; K. Indounas ir kt., 2009; B. Bosco ir kt., 2006; N. Haldrup ir kt., 2006; S. Braithwait ir kt., 2007 ir kt.) literatūroje gausu atliktų elektros energijos rinkos atvėrimo studijų atskirų regionų ir šalių rinkose (P. Hogselius ir kt., 2010; H.J Bontrum ir kt., 2008; A. Tishler ir kt., 2007; A. Singh, 2009; S. Tozzini, 2008; J.Ishii ir kt., 2004; T. Jasmab ir kt., 2005; W. Lise ir kt., 2004 ir kt.), tačiau, kaip įtakoja pasirinktas elektros energijos rinkos organizavimo modelis darnumą, analizių pasigendama; pastebimas trūkumas atliktų studijų būtent apie tai, kaip tam tikro regiono ar šalies formuojama energetikos politika ir

įdiegtas elektros energijos rinkos modelis įtakoja darnumą, ir galimos pritaikyti metodikos apie sektoriaus būklę konkrečiame regione darnumo aspektu tiek esamai situacijai konstatuoti, tiek ir ateities prognozėms sudaryti.

Darbo **mokslinė problema:** nustatyti, kokie elektros energijos rinkos organizavimo modeliai yra geriausi pagal nustatytus kriterijus bei kaip juos nustatyti. Pagrindiniai kriterijai turėtų apimti pagrindinius darnumo aspektus (ekonominius, socialinius, aplinkosauginius).

Darbo tikslas: įvertinti elektros energijos rinkos organizavimo modelių darnumą.

Darbo objektas: elektros energijos rinkų modeliai.

Darbo uždaviniai:

1) išnagrinėti ir susisteminti mokslinę literatūrą ir empirines studijas, skirtas elektros energijos rinkos atvėrimo pagrindimui ir galimų atvertoje rinkoje veikti modelių įdiegimui;
2) išanalizuoti empirines studijas, apimančias elektros energijos rinkos atvėrimo praktinius pavyzdžius, ir susistemintai pateikti elektros energijos rinkų charakteristikas, pagal jų išsivystymo lygį;
3) susisteminus mokslinę literatūrą ir empirines studijas, analizuojančias darnios politikos formavimo sistemos kūrimą, parengti darnios elektros energijos rinkos organizavimo teorinį modelį;
4) išanalizuoti ir susisteminti mokslinę literatūrą ir empirines studijas, skirtas darnumo vertinimo instrumentų analizei bei suformuoti ir patikrinti rodiklių rinkinį, apibūdinantį elektros energijos rinkos modelių darnumą;
5) Taikant daugiakriterinės analizės metodus, sukurti darnumo vertinimo pagal atskirus elektros energijos rinkos modelius metodiką;
6) Remiantis sukurta metodika, atlikti elektros energijos rinkos atvėrimo modelių darnumo vertinimą.

Darbo metodai: mokslinės literatūros, dokumentų, statistinių duomenų analizė, situacijos analizė, lyginamoji analizė, tyrimui atlikti taikyta daugiakriterinė analizė, ekspertinis vertinimo metodas, indeksų konstravimas, logistinės regresijos modeliai, aprašomosios statistikos metodai (vidurkiai, santykiniai ir absoliutūs dažniai, dispersija, standartinis nuokrypis) - jų skaičiavimas ir interpretavimas, koreliacinė analizė,

regresinė analizė, vienfaktorinė ir daugiafaktorinė dispersinė analizė, tyrimo rezultatų analizė ir vertinimas.

Teorinis darbo naujumas ir jo reikšmė:

- Darbe susisteminta ir apibendrinta mokslinė literatūra ir empirinės studijos, skirtos elektros energijos rinkos atvėrimo pagrindimui ir galimų atvertoje rinkoje veikti modelių įdiegimui;
- Sukurtas originalus darnios elektros energijos rinkos formavimo modelis;
- Remiantis detalia darnios energetikos politikos analize, nustatyti pagrindiniai elektros energijos rinkų organizavimo modelių darnumo vertinimo aspektai bei prioritetai;
- Remiantis detalia elektros energijos rinkos modelių analize bei elektros energijos rinkos atvėrimo teorinėmis ir empirinėmis studijomis, sudarytas elektros rinkos atvėrimo indeksas (ERAI);
- Remiantis ekspertų apklausa bei kituose tyrimuose taikomų darnumo vertinimo rodiklių analize, parengta darnumo vertinimo rodiklių sistema (sudarytas elektros rinkos darnumo indeksas (ERDI));
- Remiantis ekspertų apklausa nustatyti darnumo vertinimo rodiklių svoriai;
- Remiantis darnumo vertinimo metodikų lyginamąja analize bei ekspertiniu tyrimu, parengta elektros energijos rinkos organizavimo modelių darnumo vertinimo metodika;
- Remiantis sukurta elektros energijos rinkos modelių vertinimo metodika ir daugiakriterinės analizės metodais suformuotu elektros energijos darnumo vertinimo rodiklių rinkiniu, parengtas elektros energijos rinkos modelių darnumo ekonometrinis vertinimo modelis.

Darbo rezultatų praktinė reikšmė:

- Sukurtas darnios elektros energijos rinkos formavimo modelis bei parengta elektros energijos rinkos organizavimo modelių darnumo vertinimo metodika, leidžia atlikti elektros energijos rinkos atvėrimo priemonių vertinimą bei pagrįsti elektros energijos rinkos atvėrimo Lietuvoje bei kitose šalys priemones;
- Sukurto modelio ir metodikos pagalba galima tirti elektros energijos rinkos atvėrimo efektyvumą darnumo aspektu;

- Remiantis daugiakriteriniais vertinimo metodais sudarytas universalus (nepriklausantis nuo rinkos išsivystymo lygmens) elektros rinkos atvėrimo indeksas (ERAI), leidžiantis nustatyti šalies elektros energijos rinkos atvėrimo laipsnį.

Darbe naudoti literatūros šaltiniai: rašant darbą naudojamasi Lietuvos ir užsienio autorių mokslinėmis publikacijomis; mokslo institucijų leidiniais; vyriausybinių institucijų teisės aktais; Pasaulio Banko, Ekonominio bendradarbiavimo ir plėtros organizacijos (EBPO) (angl. *The Organisation for Economic Co-operation and Development (OECD)*), JAV Energetikos informacijos administracijos (angl. The *U.S. Energy Information Administration (EIA)*); Tarptautinės energetikos agentūros (angl. *International Energy Agency (IEA)*); EUROSTAT ir kitų statistinių duomenų bazių duomenimis bei kitais literatūros šaltiniais.

Ginami teiginiai:

1) Sukurta elektros energijos rinkos organizavimo modelių vertinimo metodika, kuri leidžia atlikti išsamų visus darnaus vystymosi aspektus apimantį vertinimą. Prognozavimo atveju sudarytos sąlygos konstruoti skirtingus energetinės politikos scenarijus, kurie padidina prognozavimo patikimumą.
2) Sukurta elektros energijos rinkos organizavimo modelių vertinimo metodika suteikia galimybę identifikuoti rodiklius, darančius didžiausią įtaką darnumui, nustatyti kritines reikšmes ir galimus pokyčius bei suteikia galimybę analizuoti darnumo kitimo priežastis.
3) Daugiakriterinės analizės metodai, leidžia įvertinti skirtingus ir nuolat kintančius darnumą įtakojančius veiksnius, taip užtikrinat maksimalų vertinimo tikslumą.
4) Geriausias elektros energijos rinkos organizavimo modelis leidžia užtikrinti visus pagrindinius darnaus elektros energijos politikos vystymosi tikslus, kurie yra nemažiau svarbūs už ekonominius, paremtus įtakos elektros kainai vertinimu.

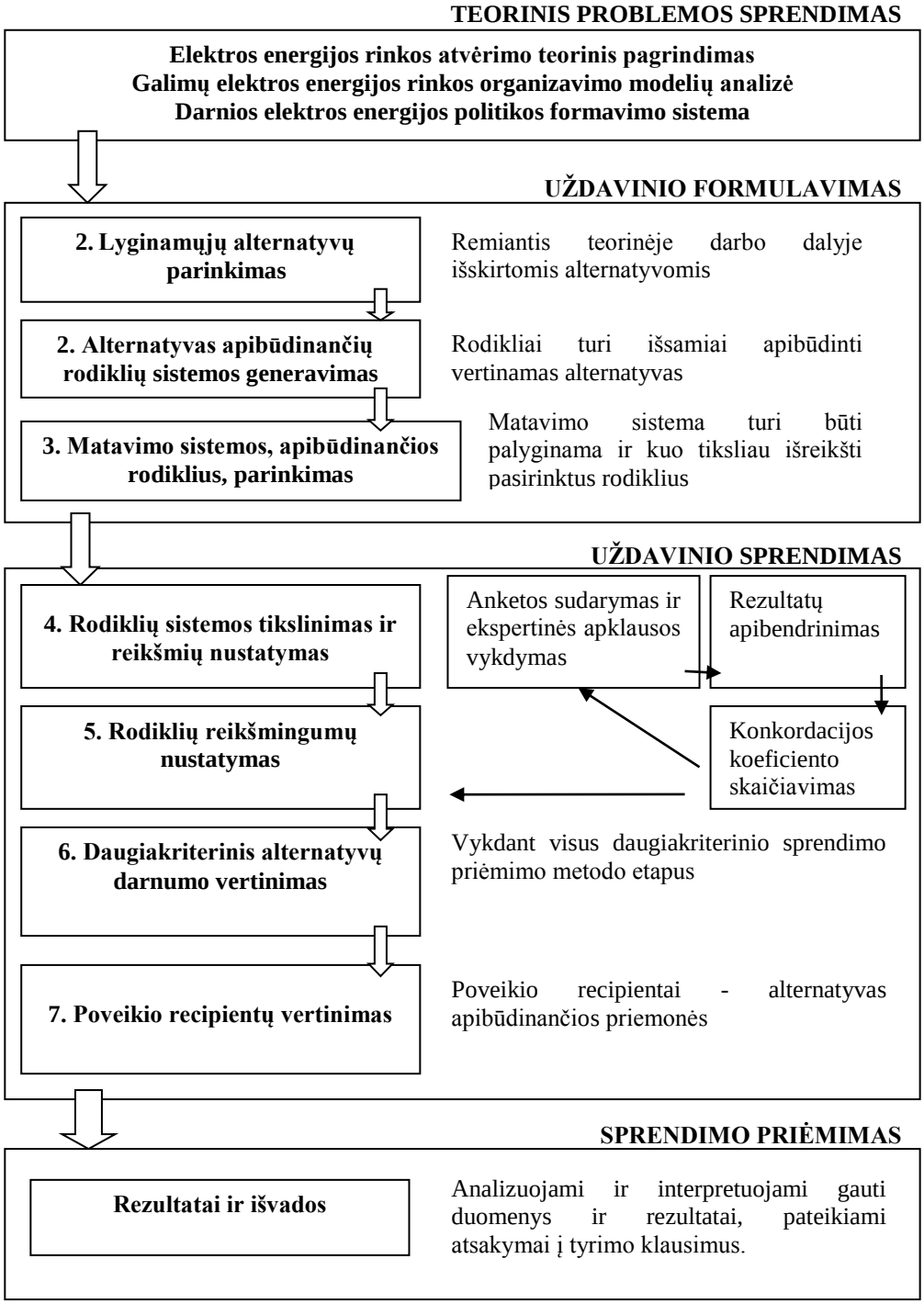
Darbo struktūra: darbą sudaro įvadas, teorinė, analitinė bei tiriamoji dalys, išvados, literatūros sąrašas ir priedai. Pagrindinė darbo apimtis 153 puslapiai, darbe yra 37 lentelės, 22 paveikslai, 14 sunumeruotų formulių, 10 priedų, panaudoti 222 literatūros šaltiniai.

Pirmojoje darbo dalyje pateikiami darnios elektros energijos rinkos formavimo teoriniai aspektai: pagrindžiamas elektros energijos rinkos atvėrimo poreikis, detaliai pateikiami galimi elektros energijos pramonės organizavimo modeliai ir pats elektros energijos rinkos atvėrimo procesas, atlikta elektros energijos rinkos atvėrimo praktinio įgyvendinimo analizė, pateikta darnios energetikos politikos formavimo filosofijų dinamika bei sukurtas originalus darnios elektros energijos rinkos formavimo teorinis modelis.

Antrojoje darbo dalyje pateikiama elektros energijos rinkos modelių darnumo vertinimo metodika: pateikiamos darnumo vertinimo sistemos, daugiakriterinės analizės metodų taikymas bei daugiakriterinių sprendimų paramos instrumentai elektros energijos sektoriuje. Šioje darbo dalyje taip pat pagrindžiama elektros energijos rinkos modelių darnumo vertinimo metodologinė prieiga: atliekamas elektros energijos rinkos modelių darnumo vertinimo rodiklių parinkimas bei formuojama rodiklių reikšmingumo nustatymo, taikant ekspertinį vertinimą, sistema taip pat sukurtas elektros energijos rinkos modelių darnumo ekonometrinis vertinimo modelis.

Trečiojoje darbo dalyje pateikiami elektros energijos rinkos modelių darnumo vertinimo rezultatai ir jų analizė.

Disertacijos loginė schema. Elektros energijos rinkos modelių darnumo vertinimui sukurta trijų lygmenų sistema:



Šaltinis: sukurta autorės

6 pav. Disertacijos loginė schema

IŠVADOS

1. Elektros energijos rinkos atvėrimas sukūrė naują ekonominę aplinką elektros energijos rinkoje, kuri užtikrina ekonominį augimą ir tarnauja efektyvios energetikos plėtros uždaviniams įgyvendinti, kadangi pati rinka savaime negarantuoja efektyvios

plėtros koncepcijos įgyvendinimo. Atverta elektros energijos rinka suteikia galimybę rinktis, o tai sukuria konkurenciją visose rinkos veiklos srityse, įtakoja pigesnių elektros energijos kainų formavimąsi bei veiklos kaštų minimizavimą, efektyvų sektoriaus veiklų planavimą ir tolimesnį efektyvų vystymą.

2. Egzistuoja žymus skirtumas tarp elektros energijos sektoriaus rinkos atvėrimo tikslų besivystančiose ir išsivysčiusiose šalyse. Išsivysčiusios šalys siekia – elektros pramonės produktyvumo ir ekonominio efektyvumo, šiose šalyse elektros energijos poreikis didėja nežymiai, elektros energijos sistema veikia stabiliai, siekiama, kad elektros energijos rinkos atvėrimas per konkurencingus rinkos mechanizmus vestų į mažesnes išlaidas ir žemesnes elektros energijos kainas. Besivystančiose šalims egzistuoja greitai didėjantis elektros energijos poreikis, silpnai išvystyta gamybos ir tiekimo sistema, todėl tikimasi, kad elektros energijos rinkos atvėrimas pritrauks užsienio kapitalą elektros sistemų plėtrai, pašalins elektros energijos trūkumus ir visa tai atgaivins visą ekonomiką.

3. Įvertinus kintančią elektros energijos sistemos aplinką, jos netiesiškumą bei grįžtamąjį ryšį, pateikiamas naujas darnios energetikos politikos formavimo teorinis modelis. Į tradicinės politikos sistemos Būsenos bloką įtraukiamos Žmogaus, Aplinkos ir Sistemos dalys, pagal kurias galima stebėti socialinę, aplinkos apsaugos ir elektros energijos politiką. Sukurtas darnios energetikos politikos formavimo teorinis modelis apima visus elektros rinkos atvėrimo etapus, numato sektoriaus įtakojamų sričių aplinkosaugines sritis ir leidžia integruoti visuomeninius aspektus. Modelis pateikia gaires politikos, kuri apima visapusį vystymąsi: visapusiškai integruoja darnumo aspektus, numato rodiklių kaitos monitoringą ir strateginių sprendimų kryptis.

4. Darnios energetikos politikos priemonių poveikis turi būti vertinamas integruotai, nes šių priemonių įgyvendinimas gali sąlygoti vieną kitam prieštaraujantį ekonominį, socialinį ir aplinkosauginį efektą. Remiantis mokslinės literatūros analize, empirinėmis studijomis ir atlikus kokybinį tyrimą – ekspertų apklausą – suformuotas elektros energijos rinkos modelių darnumo vertinimo 13 rodiklių rinkinys, iš kurių 11 kiekybinių rodiklių ir 2 kokybiniai rodikliai, apimantis ekonominius, socialinius ir aplinkosauginius darnumo aspektus.

5. Remiantis sudarytu rodiklių rinkiniu ir ekspertų apklausos metu nustatytu vertinimo rodiklių reikšmingumu, daugiakriterinės analizės metodais sudarytas elektros

rinkos darnumo indeksas (ERDI), kurio priklausomybė nuo nepriklausomų kintamųjų tiriama logistinės regresijos pagrindu. Suformuotas ERDI indeksas atspindi prioritetines darnios energetikos politikos kryptis ir tikslus pateiktus pagrindiniuose politikos dokumentuose: Europa 2020, ES Darnaus vystymosi strategijoje, Jungtinių Tautų Darnaus vystymosi įgyvendinimo plane ir kt. tarptautiniuose darnaus energetikos vystymosi programiniuose dokumentuose.

Sukonstruoto ekonometrinio vertinimo modelio nepriklausomi kintamieji sutelkti ties pagrindiniais elektros energijos rinkos organizavimo modelių reglamentais (rinkos atvėrimo priemonėmis), vertinimui atrinkti pagrindiniai nepriklausomi reguliatoriai: gamybos ir perdavimo atskyrimas, trečiųjų šalių prieiga, didmeninės rinkos konkurencingumas, mažmeninės rinkos konkurencingumas, reguliavimo kokybė ir nuosavybės forma, tuo tarpu pagrindiniai nepriklausomi nereguliatoriai yra: hidroenergijos dalis, atominės energijos dalis ir BVP.

6. Atlikus elektros energijos rinkos atvėrimo priemonių vertinimą 1990 – 2012 m., naudojant logistinę regresiją, aprašomosios statistikos metodus (vidurkius, santykinius ir absoliučius dažnius, dispersiją, standartinį nuokrypį) koreliacinę, regresinę, vienfaktorinę ir daugiafaktorinę dispersinę analizę, nustatyta, kad Australijos elektros energijos rinkos darnumui didžiausią įtaką turi reguliavimo kokybė (R05 = 0,8); JAV – nuosavybės forma (U2=-0,618); JK – BVP (NR09=0,864); Lenkijos – BVP (NR09=-1,166); Lietuvos – mažmeninė konkurencija (R04=0,638); N. Zelandijos – BVP (NR09=-1,072); Prancūzijos – mažmeninė konkurencija (R04=-0,598); Suomijos – atominės energijos dalis (NR08=-0,595); Vokietijos – BVP (NR09=0,728); Bendroje visų šalių tiesinės regresijos lygtyje, didžiausią įtaką elektros energijos rinkos darnumui turi privačios nuosavybės dalis (U4=0,464). Privati nuosavybė yra aukščiausio laipsnio atvertos elektros energijos rinkos bruožas – Konkurencijos mažmeninėje prekyboje modelio pagrindas – atlikto tyrimo pagrindu prieita išvada: kuo elektros energijos rinka atviresnė, tuo ji labiau atitinka darnumo kriterijus.

7. Atlikus empirinį tyrimą ir nustačius elektros energijos rinkos atvėrimo priemonių R01, R02, R03, R04, R05 ir R06 statistinį reikšmingumą ERDI, galima daryti išvadą, kad elektros energijos rinkos darnumui 1990 – 2012 m. statistiškai reikšmingą poveikį Lietuvoje turėjo visos rinkos atvėrimo priemonės. Nustatyta, kad žymią ir teigiamą įtaką

Lietuvos elektros energijos sektoriaus darnumui 1990 – 2012 m. Lietuvoje turėjo mažmeninės elektros rinkos sukūrimas ir BVP.

Remiantis statistine analize, negalima patikimai nustatyti, kokią teigiamą įtaką Lietuvos elektros energijos rinkos darnumui turi tokios priemonės kaip gamybos ir perdavimo veiklų atskyrimas, didmeninės rinkos konkurencingumas, trečiosios šalies priėjimas prie tinklų bei privatizavimas, kadangi šių rinkos atvėrimo priemonių poveikis darnumui nėra labai žymus. Lietuvoje siekiant užtikrinti šalies energetikos konkurencingumą ir energetikos politikos prioritetinių tikslų įgyvendinimą elektros sektoriuje didesnį dėmesį reiktų skirti reguliavimo kokybei ir mažmeninio konkurencingumo didinimui, tuo tarpu privatizavimo procesas nebūtinai turės teigiamos įtakos konkurencingumo augimui ir energetikos politikos prioritetinių tikslų įgyvendinimui.

8. Atlikus elektros energijos rinkos atvėrimo modelių vertinimą 1990 – 2012 m. 12-oje šalių, naudojant logistinę regresiją, aprašomosios statistikos metodus, koreliacinę, regresinę, vienfaktorinę ir daugiafaktorinę dispersinę analizę, nustatyta, kad didžiausią įtaką elektros energijos rinkos darnumui turi mažmeninės konkurencijos sukūrimas, kokybiškas rinkos reguliavimas, privačios nuosavybės dalis bei šalies BVP augimas. Tyrime prieita išvada, kad kuo rinka atviresnė, tuo ji yra darnesnė, todėl darniausias yra Mažmeninės konkurencijos rinkos organizavimo modelis, tuo tarpu Didmeninės konkurencijos rinkos organizavimo modelis darnumą įtakoja nežymiai, o Vienintelio supirkėjo kaip ir Monopolinis rinkos organizavimo modelis darnumo aspektu yra neefektyvus, todėl valstybės, siekdamos formuoti darnią energetikos politiką šių modelių pagrindu rinkos organizuoti neturėtų.

Nustačius rinkos darnumo ir BVP tarpusavio priklausomybę, prieita išvada, kad šalyse, kuriose kuro struktūra yra diversifikuota, BVP augimas veikia rinkos darnumą teigiamai, tuo tarpu, šalyse, kuriose kuro struktūra nediversifikuota, energetikos sistema paremta iškastinio kuro naudojimu, BVP augimas rinkos darnumą veikia neigiama linkme. Kuro struktūros diversifikaciją tiesiogiai įtakoja konkurencija rinkoje, kuo konkurencija intensyvesnę, tuo ir kuro struktūra yra įvairesnė, tai turi tiesioginę priklausomybę su atsinaujinančių išteklių naudojimu energetikoje, ši priklausomybė dar kartą patvirtina rinkos atvėrimo poreikį ir rinkos modelių darnumą atitinkamai nuo rinkos atvėrimo laipsnio, t.y. kuo rinkos modelis atviresnis, tuo rinka yra darnesnė.

THE LIST OF SCIENTIFIC PUBLICATIONS AND PRESENTATIONS ON THE TOPIC OF DISSERTATION

Publications which are written in scientific information institute (ISI) list

1. Dalia Streimikiene, Indre Siksnelyte (2014) Electricity Market Opening Impact on Investments in Electricity Sector. *Renewable & Sustainable Energy Reviews*. Vol. 29, P. 891–904.
2. Indre Siksnelyte (2013) Sustainability Assessment of Electricity Market Models. *Proceedings of the 6th International Scientific conference. Rural Development 2013.* Vol. 6, Book 1, P. 389-394. ISSN 1822-3230. Thomson Reuters ISI Web of Science (Conference Proceedings Citation Index), Academic Search Complete (EBSCO). ASU Publishing Center.
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1. I. Šikšnelytė (2012) Elektros energijos prekybos scenarijų poveikio elektros energijos kainoms vertinimas. *9th Professor Vladas Gronskas International Scientific Postgraduate and PhD Students Conference "Economy Development: Theory and Practice"*, Kaunas: VU KHF, 6th of December, 2012. P. 156-163. ISBN 978-609-459-130-3.

2. I. Šikšnelytė (2010) Lietuvos elektros energijos rinkos atvėrimo įgyvendinimas. *7th International Scientific Conference "Economy Development: Theory and Practice", 2010. ISBN 978-9955-33-619-8. Kaunas: VU KHF, 9 gruodžio, 2010.*

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4. I. Šikšnelytė (2012) Elektros energijos prekybos scenarijų poveikio elektros energijos kainoms vertinimas. *9th Professor Vladas Gronskas International Scientific Postgraduate and PhD Students Conference "Economy Development: Theory and Practice"*, Kaunas: VU KHF, 6th of December, 2012. ISBN 978-609-459-131-0.
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6. I. Šikšnelytė (2010) Lietuvos elektros rinkos atvėrimo laipsnio įtaka elektros energijos kainoms. *7th International Scientific Conference "Economy Development: Theory and Practice".* Kaunas: VU KHF, 9th of December, 2010.

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