KĘSTUTIS BIEKŠA

ENERGY ECONOMIC MODEL FOR GREEN SETTLEMENTS

SUMMARY OF DOCTORAL DISSERTATION

SOCIAL SCIENCES, ECONOMICS(04S)

Kaunas
2015

KAUNAS UNIVERSITY OF TECHNOLOGY

LITHUANIAN ENERGY INSTITUTE

Kęstutis Biekša

ENERGY ECONOMIC MODEL FOR GREEN SETTLEMENTS

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

2015, Kaunas

The Doctoral dissertation was prepared at the Lithuanian Energy Institute, the Laboratory of Renewable Energy and Energy Efficiency during 2008–2013.

Scientific Supervisor:
Dr. Habil. Valentinas KLEVAS (Lithuanian Energy Institute, Social Sciences, Economics – 04S).

Lithuanian language editor:
Stefanija SKEBIENĖ (Lithuanian Energy Institute)
English language editor:
Julija VASILENKO-MASKVYTĖ (Lithuanian Energy Institute)

The Dissertation Defence Board of Economics Science Field:
Prof. Dr. Habil. Zigmas LYDEKA (Vytautas Magnus University, Social Sciences, Economics – 04S);
Prof. Dr. Bronius NEVERAUSKAS (Kaunas University of Technology, Social Sciences, Economics – 04S);
Prof. Dr. Violeta PUKELIENĖ (Vytautas Magnus University, Social Sciences, Economics – 04S);
Prof. Dr. Vytautas SNIEŠKA (Kaunas University of Technology, Social Sciences, Economics – 04S) – chairman;
Prof. Dr. Gražina STARTIENĖ (Kaunas University of Technology, Social Sciences, Economics – 04S).

Official opponents:
Prof. Dr. Habil. Jonas ČEPINSKIS (Vytautas Magnus University, Social Sciences, Economics – 04S);
Dr. Arvydas GALINIS (Lithuanian Energy Institute, Social Sciences, Economics – 04S).

The official defence of the dissertation will be held at 10 a. m. on December 4, 2015 at the public session of the Board of Economics Science Field in the Session Hall of the Central Building of the Lithuanian Energy Institute.

Address: Breslaujos st. 3-202, 44403 Kaunas, Lithuania.
Tel. (370) 37 300042, fax. (370) 37 324144, e-mail: doktorantura@ktu.lt

The Summary of the Doctoral Dissertation was sent out on 4 November, 2015. The dissertation is available at the libraries of Kaunas University of Technology (K. Donelaičio st. 20, Kaunas) and Lithuanian Energy Institute (Breslaujos st. 3, Kaunas).

KAUNO TECHNOLOGIJOS UNIVERSITETAS
LIETUVOS ENERGETIKOS INSTITUTAS

Kęstutis Biekša

ŽALIŲJŲ GYVENVIEČIŲ ENERGETINIO ŪKIO MODELIS

Daktaro disertacijos santrauka
Socialiniai mokslai, ekonomika(04S)

2015, Kaunas

Daktaro disertacija rengta 2008-2013 metais Lietuvos energetikos instituto Atsinaujinančių išteklių ir efektyvios energetikos laboratorijoje.

Mokslinis vadovas:
Habil. dr. Valentinas KLEVAS (Lietuvos energetikos institutas, socialiniai mokslai, ekonomika – 04S).

Lietuvių kalbos redaktorė:
Stefanija SKEBIENĖ (Lietuvos energetikos institutas)
Anglų kalbos redaktorė:
Julija VASILENKO-MASKVYTĖ (Lietuvos energetikos institutas).

Ekonomikos mokslo krypties daktaro disertacijos gynimo taryba:
Prof. habil. dr. Zigmas LYDEKA (Vytauto Didžiojo universitetas, socialiniai mokslai, ekonomika – 04S);
Prof. dr. Bronius NEVERAUSKAS (Kauno technologijos universitetas, socialiniai mokslai, ekonomika – 04S);
Prof. dr. Violeta PUKELIENĖ (Vytauto Didžiojo universitetas, socialiniai mokslai, ekonomika – 04S);
Prof. dr. Vytautas SNIEŠKA (Kauno technologijos universitetas, socialiniai mokslai, ekonomika – 04S) – pirmininkas;
Prof. dr. Gražina STARTIENĖ (Kauno technologijos universitetas, socialiniai mokslai, ekonomika – 04S).

Oficialieji oponentai:
Prof. habil. dr. Jonas ČEPINSKIS (Vytauto Didžiojo universitetas, socialiniai mokslai, ekonomika – 04S);
Dr. Arvydas GALINIS (Lietuvos energetikos institutas, socialiniai mokslai, ekonomika – 04S).

Disertacija bus ginama viešame ekonomikos mokslo krypties daktaro disertacijos gynimo tarybos posėdyje, kuris įvyks 2015 m. gruodžio 4 d., 10 val. Lietuvos energetikos instituto Posėdžių salėje.

Adresas: Breslaujos g. 3-202, 44403 Kaunas, Lietuva.
Tel. (370) 37 300042, fax. (370) 37 324144, e-mail: doktorantura@ktu.lt

Disertacijos santrauka išsiųsta 2015 m. lapkričio 4 d. Su disertacija galima susipažinti Kauno technologijos universiteto (K. Donelaičio g. 20, Kaunas) ir Lietuvos energetikos instituto (Breslaujos g. 3, Kaunas) bibliotekose.

INTRODUCTION

Relevance of the research

The protection of nature, historical and cultural values found the resonance and confirmation in the sustainable development concept and in the majority of the 21st century ideas about the future of the new way of life. These ideas have revealed practically themselves in the movement for creation of global eco-villages. This movement is a local initiative activity with the main goal to create unpolluted and green environment, to foster community spirit and promote green economic development. The main aim altogether emphasising the actuality of this scientific work is to connect various research results into a united and practically applied model of green settlements that covers criteria of sustainable development.

The movement of eco-villages or green settlements is driven by group leaders of local communities with the aim to pursue the main objectives: to create better, healthier, eco-friendlier lifestyle conditions fostering social and community lifestyle and encourage the development of ecological permaculture and nature economy. The development of such settlements uses the bottom-up approach; however, currently, there are no directives and legal norms, which regulate the development of green settlements.

The use of green energy is not a priority issue in the project of green settlements developed by local communities; however, these settlements form a separate group, where the thermal and electrical energy production and consumption are considered. The main aspect of formation of the energy economy model of green settlements is the optimal use of RES (Renewable Energy Sources) and effective energy consumption.

The energy model of green settlements is a formation of electric and thermal energy production and consumption scenarios, where the use of local and renewable resources is considered. In formation of the energy model for green settlements, it is assumed that the share of RES should be no less than that in the Directive for promotion of use of renewable energy sources. However, the perspective development of green settlements cannot stop before 2020. In the optimal case, an assumption is accepted that the model of green settlements in the future must be based on 100 % of the use of RES. However, this technical target is just a guideline, because other factors like economic, social and environmental also need to be considered. Therefore, the development of green settlements is a continuous process without an end like the cycles of nature, where one form changes the other. For this reason, it is important to scientifically justify the systematic use of renewable resources, the reserves and waste management using resource flow analysis. It is necessary to develop a secondary use of materials (reuse), where toxic waste is involved in technical (anthropogenic) and biological (ecosphere) cycles.

Investigation level of the scientific problem. The problem is related to the direction of the development of modern energy economy and the issues of sustainable development when long-term and continuous development of the society does not have to confront the primary life status, which continuously maintains self-regulated mechanisms. Energy is needed for operation of the cycle of ecosystem, and this energy comes mostly from the sun. In the society of material flow where one lives, one element is lacking: these are decomposers, which can break down useful components closing the material cycle and create a waste-free cycle (Juknys, 2005).

The research object is the production of materials, products and energy in a “closed” cycle, where there is almost no waste, and where the produced waste is recycled. Therefore, not only the efficient use of products and materials is important, but also the ecology of components used in the production of these materials and the recycling possibilities. A systematic aspect is important in the circular economy cycle, where there is a need to analyse the resources and the amount of energy and its flow in order to manage and control energy distribution in an attempt to decrease the amount of waste and to turn waste into useful materials. Development of the energy economy according the principles of circular economy requires the use of various local and renewable energy resources (Pledger, 2013). The concept of circular economy is investigated by (Wijkman, 1998), (Rockstrom, 2010), (Stahel, 2010), (Braungart, 2002).

Green settlement is related primarily to the understanding of ecosystem approach and holistic approach to the formation of ecologic lifestyle. Living organisms and their environmental interactions in the nature are interdependent processes that work together ensuring the life and convenience of the system (Palojarvi, 2013). Therefore, the development of the model of green settlements is intended to preserve the entity of the nature and to emphasize the dependent position for each of its parts and for human as well (Kalenda, 2007).

There is a need for versatile model in the formation of energy economy of green settlements, according to the background of circular economy. The most important issue, which emphasizes the actuality of this research work, is to link various research studies and results into a single and practically applied model of green settlements covering sustainable development aspects. Green settlement, first of all, is a community, which attempts to unite the aspects of sustainable development in the economic, social and ecological environment, fostering a holistic and eco-friendly lifestyle. Green settlement is a living laboratory, where ecological innovations are created and the solutions are accepted ensuring the sustainable development in the sector of civil engineering, energy use, waste and wastewater management, transport organization, agricultural and food production, the culture of consumption (Palojarvi, 2013).

A new concept of economic development is associated with the new criteria, which give the meaning to human and nature interaction. Economist Jackson in the book "Prosperity without growth" argues that well-being and a better quality of life are possible in another economic dimension, where communities and their created social capital but not the capital, net added value or gross domestic product are the main driving force. Welfare of a new economy driven by the green capital will be developed using smart management and control methods in accordance with the ideas of sustainable development concept.

There is a need for the holistic approach to the system in order to reach sustainability in the society, where the system works as an ecological loop in the nature, where plants produce oxygen and other materials needed for animals, and animals produce carbon dioxide and residues needed for plant growth. Sustainable energy economy has to be balanced with the natural environmental cycles, and at the same time, it has to be connected with other regions without harming the environment. This is a step forward to becoming a green energy economy that emphasises principles of sustainability yet avoids becoming an autarky economy.

The essence of green capitalism is discussed by Henderson and Meadows in their scientific articles. Interpretation of the concept of sustainable development using green environmental indicators is examined by Wijkman, Rees, Fullerton, Stavins, George, Postel, Wackernagel, Bartelmus, Joy E. Hecht, Costanza and by other scientists in their research work.

Green villages have to become a new economic force in the development of acceptable RES usage scenario in the community level and together can synthesize various funding mechanism and preconditions for the rational implementation of the renewable technologies. The purpose of creation of the energy model of a green village is to represent the regional (on the elderate or community level) energy economy through creation of a scheme of a working energy economy showing the functioning of the energy sector and its characteristics. The main purpose of creation of the energy model of a green settlement is to examine the behaviour of energy economy in the regional context (neighbourhoods, elderate, community) under different region of the energy state of the system and the external conditions

A green settlement is like a living laboratory, where ecological innovations are created, and the solutions are accepted ensuring the sustainable development in the sector of civil engineering, energy use, waste and wastewater management, transport organization, agricultural and food production, the culture of consumption (Palojarvi, 2013). Therefore, the process network analysis method (PNS) is applied for the research in this "laboratory". PNS method is associated with a creation of algorithm of branch-and-bound method, which helps to conceptualize the present situation and to forecast options of feasible decisions, also to support the identification of the kind of information is needed in order to evaluate the consequences of decision-making.

The research problem: how to establish a sustainable energy economic model, where a constant and long-term social development will not confront the primary life status, which is supported by continuous self-regulatory cyclic mechanism associated with long-term economic and energy sector objectives according to principles of circular economy.

The object of scientific research: the theoretical and practical application of the concept of energy economic model of an existing settlement including the development of energy economic scenarios and preparation of specific energy economy development program for a certain region. A model could practically help new communities to increase the share of use of local and renewable energy resources.

The aim of the scientific research: to analyse the dissemination of energy flows in the region in different energy economic systems, to develop energy economic models for settlements according to the principles of sustainable development. Evaluate energy economic model for a settlement according to social, environmental and economic aspects, analyse the best practical application examples of development of green settlements and evaluate possibilities to supply the thermal and electrical energy to the green settlements.

The objective of the development of the **E**nergy **E**conomic **M**odel for **G**reen **S**ettlement (EEMGS) is the preparation of the action program for redevelopment of energy economic model in the context of the green settlement concept and the preparation of calculation models using step-by-step methods in order to reach the maximal level of RES usage.

In order to achieve the research aim, **the following research tasks** have been formulated:

Unit 1: theoretical section

1. To analyse theoretical background and assumptions of determination of the development of green settlements.
2. To validate the transformation concept of energy economic model of a green settlement.

Unit 2: model formation section

3. To analyse the implementation conditions of the concept for the green settlement structure and to select a rational transformational model.
4. To evaluate the method for energy economy development, its formation and forecasting by selecting the method for formation of the energy sector model of green settlements.
5. To develop and adapt the concept of energy economy model of a green settlement under practical application conditions.

Unit 3: model implementation and realization of calculation section

6. To analyse the status quo of energy economic model of a green settlement (region) and the development of energy economy structure.

7. To form a vision of development of green settlements in the medium and long-term perspective as a green, smart, balanced program to use renewable energy in a maximal efficient way, providing analysis and calculations that show the share of optimal achievable use of RES, and to present conclusions and outcomes.

The structure of the thesis: the dissertation consists of the **introduction,** where the main elements are arranged briefly describing the content and practical value of the dissertation.

In the first part of the dissertation, analyses of the theoretical guidelines are presented. The theoretical concept of energy economic model for green settlements is formed as a possibility to synthesise the social and territorial dimensions, thus realising the objectives of sustainable development.

In the second part of the dissertation, analyses of the methodological concept for an investigation based on the literature review are presented, and a formed paradigm and basic guidelines for formation of the green settlement concept are provided. The calculation method is theoretically validated and adapted as the most suitable for achieving the defined target. The presumptions for developing of scenarios are formed.

In the third part of the dissertation, basic presumptions permitting the definition of the use of RES from the economic viewpoint within the background of achieving the solidarity obligations in the community of the green settlement are analysed. The geographical location, the stock of natural resources (agricultural and land tenure and others), the potential of renewable energy resources in the specific communities of Riese and Avizieniai elderates are analysed, and the development model of energy systems using RES technologies is formed. The energy economic development models are formed. The models create a background for development of a sustainable green settlement and show the trends for development of energy economy in the region. Energy economic models are evaluated according to the process network synthesis method, and the optimal development scenario using RES and local energy resources is selected. Investigated development scenarios of energy economic models allow to develop the model of green settlement and validate the concept of inexhaustible energy resources.

The methods of research: analysis and systematic literature review in the scientific work are done in order to create a background for the theoretical and methodological concept. The following methods for investigation are applied: qualitative and quantitative comparative analysis, analysis of sustainable development indicators in the economic, ecological and social environment, energy levelised cost method adjusting the methodology of enhanced economic analysis, sustainable process index method evaluating the impact to environment of energy systems using ecological footprint method.

The scientific novelty and theoretical significance of the work as well as author's contribution to the field of research is determined by the following obtained research results. The novelty consists of the aspects below:

The program and calculation model for reformation of energy economic for green settlements are prepared, where the main substance is the supply of energy resources in the regional energy economy and the forecast of the perspective for development of energy economy and the optimal use of local and renewable resources.

Implementation of territorial principles for the development of RES simultaneously with the use of other energy resources is a prerequisite for the assimilation of development of green settlements and promotion of the use of RES.

The designed model of energy economic for a green settlement is allowed to synthesize technological, economic and social achievements to reach the common objective in the community.

Scientific and practical value of the work can be grounded on possible implementation areas of the model using theoretical and practical aspects. **The value**: the work has been summarised using specific investigations and versatile theoretical analysis, and the suitable development model for development of different type of green settlements has been proposed in order to meet the energy demand using only RES and other local energy resources. **Scientific value**: to form presumptions for promotion of sustainable development of green settlements and to evaluate the actual promotion mechanisms. Reasonably estimate according to sustainable development principles and to realize the usefulness of RES from the social, economic and ecological viewpoint. **Practical application**: the method and calculation program can be adapted for establishing many similar green settlements. The methodology of green settlement can become a motivation for solidarity of human actions.

The research results: the research results are approved at the international conferences and published in articles. Summarized theoretical guidelines validating the new model of human and nature interactions, detailed calculations and evaluations of energy economy in specific regions oriented to reach 100 per cent of energy supplied by RES. The prepared program and calculation method can serve as prototypes for establishing new communities of green settlements and continuously and sustainably pursuing recognized objectives, efficiently using local and renewable resources that meet communities' energy demand.

The structure of the dissertation: the dissertation consists of introduction, three parts, conclusions, list of references and annexes. The volume of the work is 165 pages. There are 56 tables and 24 figures in the dissertation. The list of references consists of 183 titles.

Content of the dissertation

REVIEW OF THE DISSERTATION CONTENT

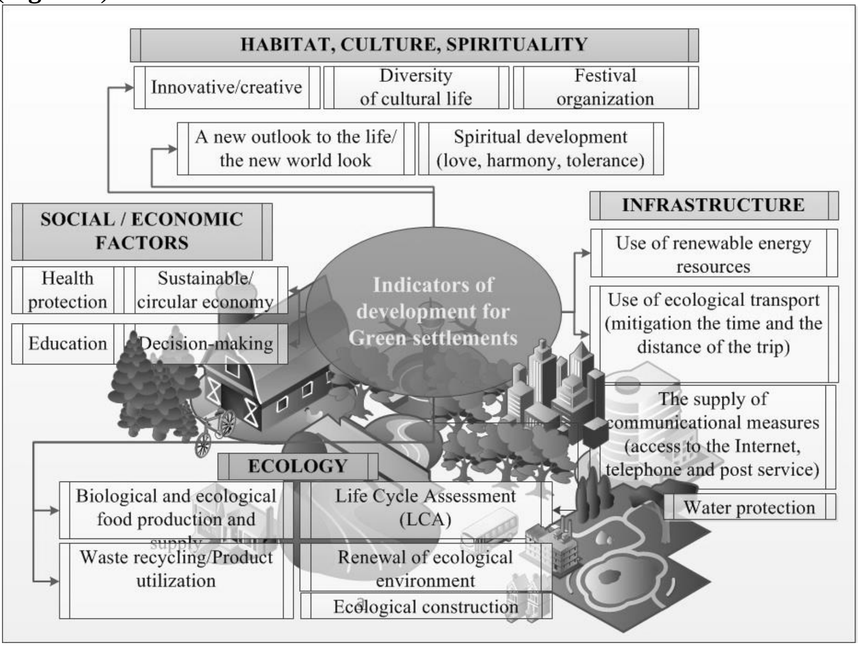
Chapter 1. Formation of the reconstruction model of energy economy of the territorial unit.

The first chapter of the dissertation focuses on the theoretical issues of sustainable development concept, its characteristics and indexes. The formation of the concept of energy economic model for a green settlement has been described, and a typical model of green settlement has been created giving possibilities to form principles of energy economy model for green settlements. The main development trends of urban and rural development definitions have been described as creating principles for development of the model of energy economy for a green settlement using urban and rural development models.

1.1. Formation of the methodology of energy economy development according to territorial aspects in the context of sustainable development.

The real debate about sustainable development has started with the Club of Rome, where status quo of the global humanity was analysed, and the report "Limits to growth" was published by Medouz in 1972. This report was later criticized as a too pessimistic and even misleading one; however, it has set a background for the concept of sustainable development. Economic growth is very important and desirable; however, the population growth, resource exploitation and the increase of production cannot be unbounded; therefore, it is necessary to immediately take actions for regulating these processes (Juknys, 2005). Today, more than twenty-five years later, discussions about the sense, limitations and possibilities of this phenomenon are still taking place. Wijkman, Jemeson and other authors are concerned that the phenomenon of sustainable development is theoretically and methodologically an uncertain thing. Therefore, the development should not be separated from fostering self-management, cultural knowledge and knowledge that can harmonize the action for sustainable development (Paulauskas, 1999). Sustainable development ideas and their application aspects for economic development and growth including the evaluation of ecological and social environment indicators were investigated by many scientists Wijkman, Rees, Fullerton, Stavins, George, Postel, Wackernagel, Bartelmus, Joy E. Hecht, Costanza. Economic and environmental aspects of sustainable development in Lithuania were analysed in the scientific articles by Buračas, Čepinskis, Čiegis, Melnikas, Pranulis, Rajeckas, Rinkevičius, Rutkauskas, Štreimikienė. Klevas and Paulauskas stated that the development based on economic criteria should be changed by the sustainable development, leading to the new stage of development from renewable to sustainable energy economy. Other scientists named this phase the third industrial revolution (Rifkin, 2012), prosperity without growth (Jackson, 2009) or the society of green capital (Meadows, 1992). They confirm that the welfare could be created using smart management methods, where the driving force will be knowledge and communication components.

The title "Eco village" was officially accepted by the UN in 1998. An eco village or a green settlement is a small community with a population from several to several hundred people, who attempt to prove that their lifestyle in harmony with nature is not only possible but is even healthier and more significant. An eco village is a sustainable settlement, where the balance between nature cycles and human activities predominates. An eco village is a green settlement, where local and renewable energy resources are used. Nowadays, according to sustainable development model, applying informational and communicational technologies, and according to cultural, aesthetic and ethnic criteria, the green settlement is a habitat, where traditions and spirituality are complimenting the technologies and development. The model of a green settlement is created using ecological and spiritual, economic and technological indicators according to cultural, ecological and spiritual aspects. Indicators of development of a green settlement are described and showed in the picture below (**Figure 1**).



Source: (Jackson, 2002)

Figure 1. The typical model of a green settlement

Nowadays, the slogan "Return to the nature" is not just a revival of a primitive lifestyle or an autarky economy. Unlike this slogan, the development trend of new technologies is taking actions to avoid competition with nature and refuse a wish "to defeat the nature". It emphasises the circular economy, where production of goods, products and energy is done in the closed cycle without waste, as waste is recycled. Therefore, embodied energy and products in the production cycle and primary ecological aspects and recycle possibilities are significant. A systematic aspect is very important in the circular economy, because it helps to manage and control the distribution of energy through analysing the amount of raw materials and energy and its flows, and it tries to decrease waste amount and to convert waste into valuable materials. Development of energy economy in accordance with circular economy principles needs to use various local and renewable energy resources (Pledger, 2013).

The movement of eco communities in Lithuania and other countries is rapidly expanding. Usually, they are constructed as single and self-sufficient farmsteads, which are promoting environmentally friendly lifestyle, and rarely –

a group of homesteads, which form a separate group of farmstead. Several of them have already been constructed in Lithuania, those are: Vepriai, Šventasodžio and Voškonių eco villages and several communities such as Kruno, Melkio and Suknių. Similar eco villages have been constructed in Latvia (Rožkalni, Dziesmas, Zaki un citi zveri, Jaunpeibalga), in Poland (Lublin eco community Lasi Kozlowieckie), in Finland (Kangasala, Vihti, Numela), in Sweden (Suderbyno eco community in Gotland, Charlottendal community), in Germany (Zegg eco village). Eco villages began to settle at the end of the 20th century, e.g., Zegg eco villages in Germany were settled in 1991. Suderbyrn and Charlottendal eco villages have only been settled 15 years ago; Kangasalan eco village was settled in 1997. Eco villages were launched in Latvia and Lithuania around 2008. All the above-mentioned eco villages have the same development trends: buildings were constructed using ecological materials, according to the rules agreed upon with the fellows of the community. Almost all the above-mentioned eco communities actively participate in the Global Ecovillage Network (GEN) and actively share information, exchange the best practices and carry out joint projects promoting a sustainable lifestyle. Analysis of strengths and weaknesses has shown the opportunities and threats of development of energy sector (**table 1**) and help to select the optimal method for formation of the energy sector structure of green settlements.

Table 1. SWOT analysis of a green settlement

Strengths	**Weaknesses**
Education of community. Encouragement of the sharing and circular economy. Reduction of consumption and environmental pollution. Promotion of use of renewable energy resources.	The picture of a closed green settlement community is mainly unacceptable. Another interpretation is that the green settlement has its own target group, which does not have to comply with the opinion of the majority. The procedures of accepting new members, described in the guidelines of local community, create a "filter" for unacceptable members. However it creates a negative opinion about green communities.
Alternative development of traditional settlements under the sustainable development concept, transforming the existing infrastructure and adapting it according to the model of a green settlement. Development of the use of RES technologies. Promotion of organic farming.	Development of green settlements by means of the cultural-social aspect is not classified as urban growth expansion. The development opportunities of green settlements in urban and high-density areas are not investigated. Therefore, development of energy economy may not meet the criteria of sustainable development. Private ownership of land and increase of land as real estate's value may become an obstacle to developing green settlements. The original concept of green settlements emphasizes the natural economic activity (autarky), which may be unacceptable for the majority of people, because it does not follow the modern economic trends.

Social factors and “top down” approach enable development of green settlements, which are primarily promoting eco ideas. While the social aspects prevail, the most attention is paid to environmental protection, energy and economy sectors. Usually ideas of green settlements are implemented in remote villages; however, the increased environment pollution, lack of drinking water and food resources, and overpopulation have encouraged transformations of urban areas. Gradually, traditional urban planning principles undertake green settlement ideas, as they create a harmonious living environment and promote clean energy technologies.

1.2. The concept of reformation model of energy economic for a settlement

Theoretical interpretation of sustainable development concept has switched to the evaluation of RES application opportunities, according to territorial aspects, which analyses National RES development goals. Established RES objectives help to promote ideas for further formation of green settlements, because usually, besides the main socially oriented driving force, the second major aspect is the development of energy economy. The EU energy policy represents ambitious targets, but it requires large investments. Lithuanian energy sector is positioned to achieve several major national strategic projects, and all together, it requires large investments as well. However, financial and human resources, as well as availability of fossil and renewable resources, are the main weak points, which undermine the possible fulfilment of the EU and national policy objectives. Energy system is efficient if the investment is giving economic payback in a short term. However, the development of RES is inconceivable without financial support so far. The promotion of RES is possible from the point of view of total costs, including external costs, such as environmental and correction of market errors. The next weak point is that the size of implementation of energy policy programs in the regional (local) environment is not clear. These problems can be solved through integration of regional development resources in the regional development strategy applying RES technologies.

Lithuania has to follow the goals of energy sector delegated by EU Directives, which presently have almost been achieved (The Ministry of Energy, 2012). However the development of green settlements has not been regulated by law so far, and usually, green regions are developed by initiatives of the local community. The essential principles for development of these settlements are as follows: fostering of organic agriculture (permaculture) and ecological lifestyle, construction of eco-friendly houses in a healthy and natural environment distant from urban areas. Energy supply in the formation of eco settlements is not a primary task; however, the provision of energy resources is a fundamental factor for sustainable development of a green settlement. There are already many practical application examples, which prove that the supply of energy using 100% of RES is possible. One of the primary goals for energy economy development of a green settlement is to bring energy consumers closer to energy producers. A conception to use passive energy is a prerequisite, but not a sufficient one. Energy production using RES must be promoted using smart technologies, where consumers can produce more energy than they consume, but in addition, the use of renewable energy resources must be promoted. An effective RES uptake method, which helps to escape from the market failures, is the creation and development of bioregions, which are interconnected with a development concept of green settlements. An uptake of local resources is based on methodology of circular economy, where every region has its own and specific local resources and can establish a specific environment for conversion of these resources and show the real environmental and social values.

Smart grid technologies reduce energy losses, increase the use and the amount of different RES technologies, and provide possibilities for consumers to actively participate in the energy market. The amount of energy raw materials and local energy resources is influenced by geographical and physical characteristics.

The model of energy economy development for a green settlement can be created using these urban and rural development models:

1. Green communities or eco communities – a group of people, usually consisting of several families up to several hundred people, who are trying to reach a common objective to create a living area where eco-friendly living ideas (permaculture, use of RES, reduction of mobility, sharing concept) are developed.
2. Eco village is a residential area consisting of a few up to hundred hectares, where several buildings (farms) or a group of buildings are located, forming the rural landscape, and where eco community promotes environmentally friendly living traditions.
3. Green settlements – are a united group of eco villages, where the eco community is trying to develop economic and social activities in accordance with the principles of eco life. These settlements often use the common regulations, which define activities and trends of eco life within the community, and which must be followed by all residents of the community.
4. Green urban areas – these are usually the territories of towns and cities, where a natural development and sustainable human and economic activity are approached.
5. Green Cities – these are living areas (mostly in the existing cities, but can be new cities as well), where economy is interacting with ecosystem in a sustainable way. Green cities usually have several “green zones” which are merged into one area, which has the urban like infrastructure, but where activities are taking place in the harmony of ecosystem.

Chapter 2. Formation of the model structure for a green settlement

This chapter describes the formation of the model structure of a green settlement, analysis of different modelling programs and selection of suitable and optimal modelling method for formation of energy economy of a green settlement. The selected method of PNS is described. The territorial, physical and other characteristics of the selected region are analysed.

2.1. Formation of energy economic structure for a green settlement

The nature is a perfect example of waste-free technologies; meanwhile, in an artificially created economy called the antroposphere, the products and energy flow, exploitation of fossil raw materials also stimulates the production of waste, which increases the environment pollution. However, it is not possible to recycle the products (energy) by 100%, so the main purpose is to reduce the use of energy resources or to use primary resources more efficiently, promote the use of renewable energy resources, choose and use ecological products and technologies with embodied intermediate eco products and eco energy. Therefore, every region has specific conditions (geographical, physical, social, economic, etc.), so the development of energy economy in the region is a specific task; consequently, every region could have a distinctive environment for the assimilation of resources (Birekland, 2008). However, the economy cannot be developed in autarky system, so the sustainability can be achieved if the circular economy model is applied. Regions cannot be separated from the other regions and natural environment, because processes influence the ecosystem. So the main purpose of this research is to find the best energy economic model in accordance with sustainable development aspects.

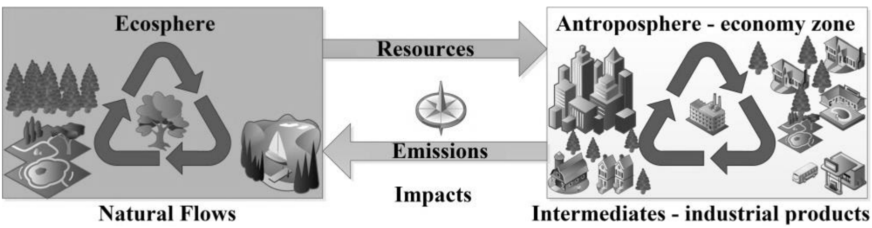


Figure 2. Relationship of economy and natural cycles

Ecological settlement is a living territory, where the main development purpose is not a form or build-up of the area, but the management and organization of urban social dimensions. The development of ecological settlement is managed through a variety of land use, environmental, institutional, social, technological and economic policies. There are many examples of practical application of a green settlement in a form of eco village (Kangasala Communal Village in Finland, Suderbyn permaculture eco village in Sweden, Kovcheg eco village in Russia, ZEGG and Sieben Linden eco communities in

Germany) or a part of the city (Hammarby sjostad in Sweden, Freistad city in Austria, Masdar city in the United Arab Emirates), where sustainable development ideas are implemented in accordance with creation of eco lifestyle.

The development of a green settlement is not a finite process, but it is an endless and circular development, where one form changes into another, where a qualitative and quantitative variation is approached (**Figure 2**). Therefore, it is important to find the systematic and resource inventory management of resource flows. The development of a green settlement should be a diverse process based on a circular economy model, where the activities in the anthroposphere and ecosphere should be balanced.

The model is understood as a particular object, process or the analogue of phenomena reflecting interest of the original features and characteristics that may, under certain conditions, replace the original system (Valkauskas, 2011). The model is used to study situations and objects or represent and predict processes; consequently, the model as it is referred to is a reflection of artificial or real image, which enables to analyse certain properties of the original system (Boguslauskas, 2007). The model is called modelling or the analysis of object or system, when it is difficult to carry out investigations in reality. Creation of a model algorithm is a mathematical econometric task, when alternating various parameters, the status of the simulated object is characterized, and provides results of the chosen objective function, which allows getting data and information about the real behaviour of the system under certain conditions, and finally, determine the changes needed for model and later on, to real system in order to improve its functionality.

2.2. Process network synthesis method

Energy process network system (PNS) analysis method is designed for investigation of energy flow in the region. It investigates local available energy resources, energy generation technologies, defines energy users and evaluates energy flows. PNS helps to set up a structure for regional energy economy and evaluates the potential energy economy scenarios. The quality of scenario depends on information about energy demand in the region, as well as on the technological, economic and social aspects.

PNS method is based on P-graph structure as unique bipartite graph representing the structure of a process system. In P-graph, the operating units are denoted by horizontal bars, and their input and output materials – by solid circles. A P-graph is a directed graph presented in **Figure 3**. The direction of the arcs is the direction of the material flows in the network. It is directed to an operating unit from its input materials and from an operating unit to its output materials. P-graph is a bipartite graph. One set of nodes (horizontal bars) represents the operating units, and the other (solid circles) – the material streams. Relations of the operating units are realized through material streams.

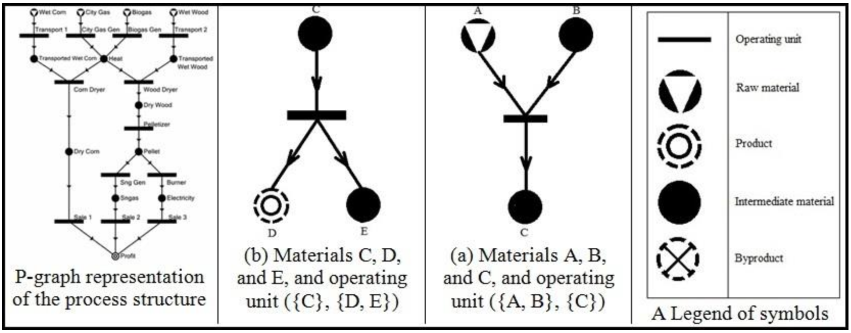


Figure 3. Principle of PNS structure using P-graph method

In P-graph representation, there are arcs from each input material (stream) to the operating unit consuming it, and from each operating unit, to its output materials (streams). In the table below, in column (a), an example is shown, where in one operating unit, two separate materials are produced (main product D and by-product E). Intermediate product can be treated as by-products and can be used by other operating units or disposed as a waste product. In column (b), it is shown as a single operating unit, receiving material (raw resources) A and by-products from other processes B as its inputs, produces material, which is subsequently fed to another operating unit, where material C (by-product) is generated.

Process network synthesis method is optimizing the material and energy flows in the region. The main aim is to find an optimal energy track from the transformation of raw materials (energy sources) to generation of final product (electricity, heat power). A method requires the optimization of process structures as well as the optimization of continuous material and energy flows (Narodoslawsky, 2011). A method can be applied for investigation of material and energy flow in the region as well as for optimization of regional scenario of RES application. The following information, such as available regional fossil and local energy resources, infrastructure, material and energy flows from industry, agricultural and other activities, prices and costs for resources, investment and operating costs of energy supply, distribution, production and storage technologies, final products, sub-products and services provided by network, is considered in the optimal energy process network system.

2.3. Evaluation of supply of green energy to the region energy economy

2.3.1. Formation of the structural schema of the energy economy

The maximal energy structure includes the following resources: (1) agricultural field/meadow (energy plants (miscanthus, sudangras, other sorts of grass, short rotation plants (lot. Salix viminalis), sunflowers, rape, maize material is rapeseed, sunflower seed)); (2) agricultural wood (input material – woodchips); agricultural meadow (input material – grass silage); livestock input (input material – manure); (3) cattle; (4) cropland.

The following operating units were taken into account: (1) drying and pressing plant seeds (output material – plant oil, press cake); (2) chopping and drying wood and wood residues; (3) briquetting wood saw; (4) green bio refinery GBR (output – milk and amino acids); (5) pelletizer of wood residues; (5) fermentation and biogas production; (6) centralized heat production using biomass at central biomass boilers and suing organic Rankine cycle (ORC) technology; (7) wood gasification (output – heat, synthetic gas, electricity); (8) burning biogas at CHP plant using micro gas turbine (MGT) and biogas generator (output – heat and electricity); (8) biogas cleaning and making synthetic biogas SNG; (9) RES technologies: wind and solar energy (thermal and PV models). The primary energy sources in PNS structure are: net electricity from the grid, natural gas, wood and wood residues, wood logs, crops, grass silage, energy grass and plants, water, manure from the cattle, horses and pigs, other types of fossil (coal), RES, such as wind and solar energy. The existing state of energy infrastructure is presented in **Figure 4**.

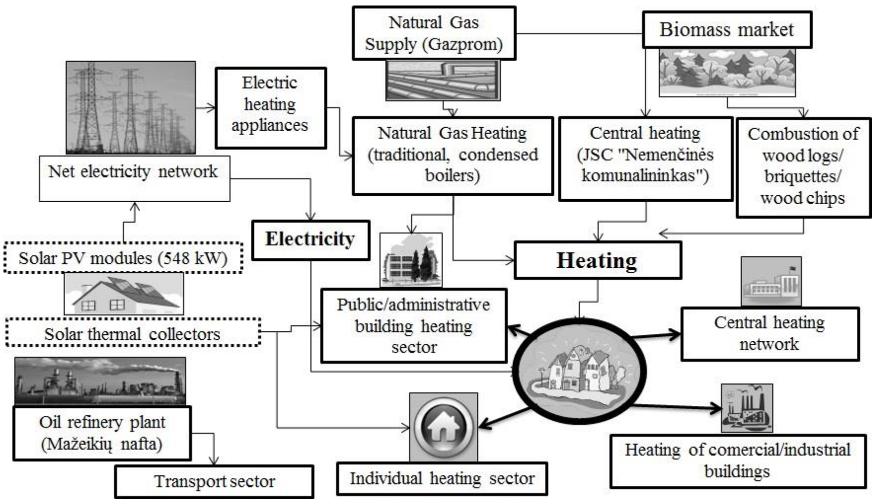


Figure 4. Principle of PNS structure using P-graph method

Application of technologies, such as chopping and drying of biomass, pyrolysis, micro gas turbine, refinery, methanation, provides new energy resources, such as wood briquettes and pellets, wood chips, choral coal, liquid synthetic oil, natural synthetic gas, biogas are sub-products, which have a higher calorific value than the initial biomass product.

According to survey results, done in the investigated communities, around 50-80 % of consumers use natural gas boilers, and about 30 % use biomass burning boilers in the centre of community village called D. Riese. 70 % of households prepare hot water using electric boilers, and around 30 % use natural gas boilers. Transport system is based on a mixture of public and private vehicles. There is a municipality bus system, which operates in the region. However, car and bus infrastructure is based on using fossil fuel (diesel, gasoline, and liquid natural gas). There is no train or tram infrastructure in the region.

2.3.2.Evaluation of the use of energy production technologies

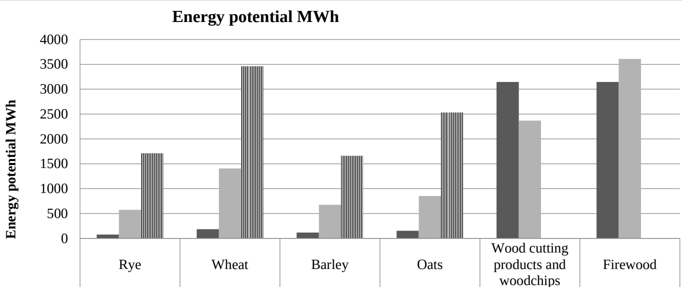
The current energy system in Lithuania is based on using both energy resources: fossil and renewable. Electricity is supplied through a district network, and about 9.6 % of electricity is produced using RES (25.9 GWh), and according to the information from Lithuanian Statistics and Ministry of Energy, in the beginning of 2013, there were around 627 kW of installed capacity of solar PV system. This makes about 548 MWh of produced electricity per year. However, household sector involves 28 % from the total electricity demand. Other sectors, such as industry and business (33.30 %), retail and social (35.90 %), agricultural and other sector (2.6 %) also use electricity. Total electricity demand is 31064 MWh. The heat energy demand is distributed as follows: (1) central heating district system (DH) and decentralized heating systems. DH uses only natural gas for preparation of heat. Total supplied heat amount in DH system is around 5059 MWh. This is around 10 % from the total heat demand (49214 MWh). Household sector consumes around 32.5 % of heat energy (21118 MWh), and around 70 % of heat energy is produced using biomass, mainly fire wood, wood and wood residues. Industry and business sector uses around 11395 MWh, social and agricultural sector uses 11147 MWh of heat energy. There is no information about distribution of fuel for preparation of heat energy in these sectors; therefore, it is assumed that 20 % of heat energy is produced using natural gas, and 80 % is produced using mainly biofuel. Subsequently, the target to produce no less than 80 % of heat in decentralized system using RES has already been achieved.

The scenario for development of regional energy economy based on using local and renewable energy resources and RES technologies was created. Most of consumers in the decentralized heating system are already using biomass; the priority is given to increasing of the efficiency of using biomass technologies and to supplying biomass using local energy resources. Consequently, the use of straw and producing straw pallets, producing wood pellets and wood chips from local wood, wood residues and energy plants were emphasized. Biogas production technology is also described, because after cleaning, it can be used as a substitute of natural gas and can be supplied to gas network for heating purposes. Substitution by natural gas will guarantee a constant and secure supply of energy. Biomass production and creation of biomass storage infrastructure can also secure constant energy supply. Proposed bio refinery technology called GBR (Green biorefinery) showed advantages of applied projects in Austria. During the GBR process, valued food additives, such as amino acid and lactic acid from the grass and grass silage, were produced.

2.3.3. Assessment of green energy potential

Energy yield of biomass is calculated multiplying the land area by the average yield of crops per land plots according to the used technology. The average yield capacity and energy values of crops are recalculated according to data taken from the Ministry of Energy final report (the Ministry of Energy of the Republic of Lithuania, 2009). Nowadays, energy corn and energy plant (sorghum) used for biogas production can generate about 54-61 MWh per ha. The average energy value in the bioethanol production using sugar beets is around 40 MWh per ha, using seed corns – 23 MWh per ha and grain is 15 MWh per ha. Rape and sunflowers used for biodiesel production can generate 15 MWh of energy per ha (Rees, 1996). Comparing derivative products, such as synthetic natural gas from biomass, the energy value is around 8200 kWh per ton of biomass. It seems that processes of energy conversion, such as pyrolysis, methanation, refinery, are more advanced and favourable for energy production compared with a direct burning of biomass.

Energy values were analysed, taking into account that biomass from crops, straw and wood cutting can be burnt in biomass boiler house, and the total amount of energy produced is presented in **Figure 5**. The energy value of crops (average is around 4 kWh/t of crops) is naturally not so big as it is mentioned in Wolfgang Urban presentation (Rees, 1996), but RES are treated as zero CO_2 emissions. Straw potential is the same (4 kWh/t), but the yield is 3-4 times bigger. Wood potential is logically the most promising, because wood is not treated as food, and it has already been extensively used as biomass by users. Energy value of wood residues and firewood depends on moister and the type of trees, but the average is around 2.4 kWh/m^3 or 4.02 kWh/t.



	Rye	Wheat	Barley	Oats	Wood cutting products and woodchips	Firewood
Aera of agricultural land and forests, ha	77	186	118	153	3145	3145
Energy potential of biomass, MWh/year	574	1.406	676	852	2368	3608
Energy potential of straw MWh/year	1710	3461	1660	2531		

Figure 5. Energy potential in the region

The total energy produced by using local available biomass, is around 9484 MWh, where wood biomass accounts for around 2368 MWh, and firewood – 3608 MWh in both communities. Comparing the demand of energy, there is a potential to cover half of primary energy needs for heating in the region if energy consumption value in buildings is 145 kWh/m^2 per year or can cover total heat energy needs of the commercial and public sector.

Chapter 3. The stages of energy economic scenarios for green settlements and their evaluation

3.1. Characteristic of the territorial unit

Regional projects run by local communities have strong local administration support to implement practical ideas using "bottom-up" development approach. Suburban communities of Vilnius region municipality, Riese and Avizieniu communities were chosen for investigation (**Figure 6**). Communities are situated in Vilnius region, which covers the territory of 2129 km^2. The population of Vilnius region municipality is 99900 inhabitants (Statistics Lithuania, 2011). District is divided into 23 communities.

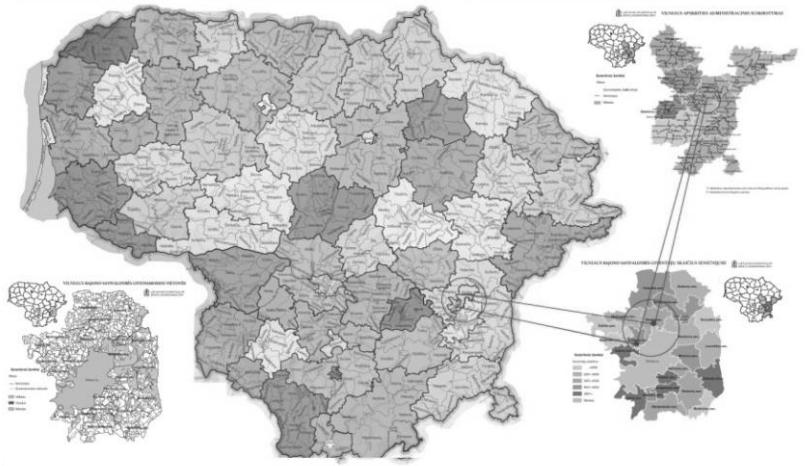


Figure 6. Investigated territory

The territory of Riese communities covers 10222 ha, and Avizieniu community – 4500 ha. Land allocated for natural meadows and grazing occupies about 5092 ha (62 %) of the territory; arable land occupies about 59 % (8233 ha) of the territory. Forests, water bodies, infrastructure and built up territory occupy around 21 % (3344 ha) of the territory in both communities. Forests account for about 18 % of the territory in Riese community and around 29 % in Avizieniu community. The territory not used for its direct purpose accounts for about 62 %

(5092 ha) in both communities (National land service, 2011). Therefore, the land available for growing crops and energy plants for energy production can be taken from the land allocated to agricultural purpose minus gardens but plus natural meadows and grazing land plots and other types of land.

There are around 11061 inhabitants that live in both communities or around 4.36% (96484) from the total inhabitants of Vilnius region (Statistics Lithuania, 2011). The average household consist of 2.5 inhabitants (National Land Service, 2011). The number of households in both communities is 4424 or 4.37% from the total number of households in Vilnius region. The total heated area in buildings accounts for 389 thous. m^2 in both communities.

The average energy consumption rate per household in Vilnius region is about 11 MWh per annum, and the average normative energy value is 177 kWh/m^2. Energy demand for residential and other type of buildings according to different normative energy values is presented in the table below (**Table 2**).

Table 2. Energy demand for residential houses in communities

			Heat demand (norm value 225 kWh/m^2)		Heat demand (norm value 145 kWh/m^2)		Heat demand (norm value 120 kWh/m^2)	
Region	Residents	House holds	Living dwellings	Total	Living dwellings	Total	Living dwellings	Total
			MWh	MWh	MWh	MWh	MWh	MWh
Vilnius	96484	38594	295046	661571	199320	446928	157358	352838
Riešė	4216	1686	12892	28908	8710	19529	6876	14514
Avižieniai	6845	2738	20932	46935	14141	31707	11164	25032
Total	11061	4424	33824	75843	22850	51236	18040	40450

Energy user groups were investigated according to the heating system installed in houses also using the report (the Ministry of Energy of the Republic of Lithuania, 2009). Energy needs for heating, lightning and other purposes (operation of equipment, devices, industrial service, hospital, etc.) are investigated according to the groups of buildings. The groups of buildings are: (a) residential buildings; (b) administrative and public buildings; (c) commercial and industrial; (d) agricultural premises and farmer households. Information about primary energy needs (heating, preparation of hot water, electricity) for living residences, public houses and other premises is calculated according to legislative norms for energy demands and consumption in buildings. Old buildings have a value of energy consumption around 225 kWh per 1 m^2 per year. Buildings built after 1992 have RSN norms with a value of 145 kWh per 1 m^2. New buildings built according to new RSN norms have value of around 120 kWh per 1m^2. Low energy houses consume around 85 kWh per 1 m^2, and passive houses – around 30 kWh per 1m^2. The distribution of heating systems is presented in **Table 3**.

Table 3. Distribution of heating system to residential houses in communities

Community	Natural gas, m^2	Electric boilers, m^2	Biomass boilers, m^2	Liquid fuel boilers, m^2	District heating users, m^2	**Total area, m^2**
Vilnius	89035	37802	385254	2573	49772	**1311314**
Riešė	3891	1652	16834	112	18971	**57299**
Avižieniai	6317	2682	27332	183	30801	**93030**
Total in communities	10208	4334	44166	295	49772	**150329**

The largest group of buildings are individual residential houses. The total area of individual dwellings is five times larger than the residential area. It should be noted that biomass is the dominant in the heating system because of large distribution of group named "other", which are mainly decentralized gas stoves and firewood stoves. Heat energy balance is presented in **Table 4** and electricity balance in **Table 5**.

Table 4. Heat energy balance

Type of energy and energy fuel	**Riešė**	**Avižieniai**	**Total**
Central heating system	553	4506	5059
Natural gas	553	4506	5059
Biomass	0	0	0
Residential sector	8049	13068	21118
Natural gas	422	685	1106
Biomass	5598	9090	14688
Other fuel	2029	3294	5323
Public house sector	3686	7461	11147
Natural gas	2949	5969	8918
Biomass	737	1492	2229
Business and industry sector	3768	7627	11395
Natural gas	377	763	1139
Biomass	3391	6864	10255
Agricultural sector	164	332	495
Natural gas	16	33	50
Biomass	147	298	446
Total consumption of heat energy	**16220**	**32994**	**49214**
Natural gas	4317	11955	16272
Biomass	9875	17744	27619
Other fuel	2029	3294	5323

Table 5. Electricity balance

Type of energy and energy fuel	**Riešė**	**Avižieniai**	**Total**
Consumption of electricity MWh	**11840**	**19224**	**31064**
Households	3339	5421	8760
Business and industry	3942	6402	10344
Public service	4251	6902	11153
Agriculture	213	346	559
Street lighting	96	153	249

The investigated region has centralized heating network consisting of five boilers with total installed 2,343 MW capacities, which use natural gas. The annual produced amount of heat energy is around 5059 MWh, and the supplied amount of energy is around 4506 MWh, whereas the consumption of natural gas is 695 thous. m^3 of natural gas. The loss in the decentralized heating system is 11 %. Total heated area of buildings is 49772 m^2. The average energy consumption rate is 152 kWh/m^2.

Energy demand for industry and agricultural premises is calculated according to data for energy and fuel distribution by sector (Statistics Lithuania, 2011). The share of industry of final energy and fuel consumption was 19.2 %, agriculture – 2.4 %, commercial and public sector – 12.4 %, whereas household sector – 32.5 %. Consequently, the final consumption of heat energy in the investigated community is as follows: residential – 21118 MWh, agriculture – 495 MWh, commercial and public sector – 11395 MWh, and public service – 11147 MWh.

3.2. General features of energy economy development stages

The energy economy development stages are investigated using PNS method referring to the best practices in the EU (mainly in Austria). Formation of energy economy development stages is carried out under the following conditions: (1) Analysis of the current situation in the energy sector gradually reducing the use of fossil fuel and increasing the use of RES, according to the renewable energy development plan of Vilnius region. (2) The aim of the development of energy economy stages by 2020 in the region is to encourage producing the major part of energy using RES. (3) The formation of the development of energy economy sectors in the long period is performed trying to use more RES and the surplus or waste energy in the electricity and district heating sector by adapting the energy economy planning tools, such as smart energy technologies.

3.2.1.Selection and short description of development scenarios

The following scenarios were formed: (1) the status quo, which analyses existing energy economic structure from 2008 up to 2013; (2) a short-term up to year 2020 energy economy scenario, which analyses the energy economy development perspectives; (3) a vision scenario of energy economic development, which analyses the beyond year 2030 with the objective to form a sustainable green settlement as a green, smart balanced program to use renewable energy in a maximal efficient way, providing analysis and calculations that show the share of optimal achievable use of RES and provide conclusions and outcomes.

3.2.2.Evaluation criteria

Energy economic development stages are assessed by technological, economic, social and ecological (environmental) indicators. Technological indicators are heat energy and electricity consumption and production, and the share of RES from the total primary energy consumption. Technological indicators of RES are the most important evaluation criteria. Economic indicators are the amount of investment needed and net added value in the region. Ecological indicator is evaluated using sustainable process (SPI) index, which assesses the global land area required to meet the energy needs. Energy economic stages are evaluated by maximizing technological, economic and social indicators and minimizing the ecological indicator; the function can be written as follows:

$$f_{opt}(Scen)_i^{n=3} = f_{\max}[(a_1)(b_1)] + f_{\max}[(a_2)(b_2)] + f_{\max}[(a_3)(b_3)] + f_{\min}[(a_4)(b_4)])$$

where w_{opt} – evaluated stage; $Scen_i$ – chosen stage; a_i – the value of analysed indicator; b_i – the importance of analysed indicator; n – the amount of evaluated stages.

The objective of the modelling is to create an optimum energy economic sector structure using the indicators described in the formula. PNS helps to investigate local available energy resources, energy generation technologies, defines energy users, evaluates energy flows, enables to set up a structure for regional energy economy and evaluates the potential energy economy scenarios. The quality of scenario depends on information about energy demand in the region, as well as on the technological, economic and social aspects.

3.3. Evaluation of scenarios

The energy infrastructure is mostly based on the use of fossil fuel. However, the biomass energy penetration level is in the range from 30% to 80% depending on the source information. Nevertheless, most of resources' sources are imported from other regions. The main focus of PNS analysis is to develop regional energy economy infrastructure which can support energy needs using RES, can generate additional energy amount and will increase the regional added net value. 65 materials and sub-products and 44 energy production technologies (operating units) were investigated. Maximal structure (**Figure 7**) of PNS model consists of 23 available energy production technologies which use 39 primary and secondary materials. PNS algorithm has excluded 25 energy production technologies and 28 primary materials and sub-products. The main criteria of modelling energy economy scenarios are the balance of energy flow, the payout period and energy prices. It is important to choose the adequate capacity of production, to evaluate investment and operating costs.

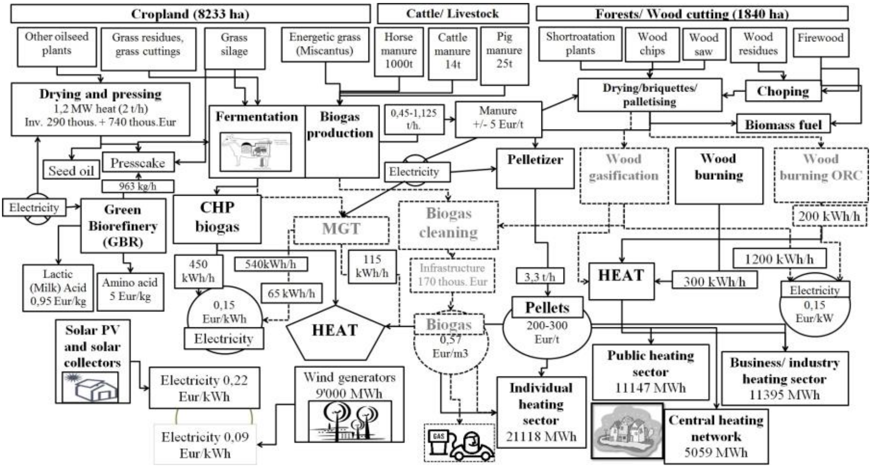


Figure 7. Maximum structure of regional energy system

Flow network of raw material, intermediate and final products for energy production was set up for evaluation of different regional energy economy scenarios. PNS program were used to figure out all possible solutions in the energy conversion process, also to find the optimal energy model. Optimal scenario is based on the energy economy model, where efficiently used resources can produce energy in the most economical way, and when sustainable flow of products and sub-products is taken into consideration.

First of all, the status quo of regional energy economy was analysed. Next, the energy structure was changed following trends and obligations to fulfil the requirements of RES directives in order to reach the optimal regional energy economy. The formation of scenarios is based on assumptions that regional energy economy will be developed using RES technologies in the district heating network. Since most of consumers in decentralized heating system are using biomass already the priority is given to increase the efficient of using biomass technologies and to supply biomass using local energy resources. Consequently the use of straw and producing straw pallets, producing wood pellets and wood chips from local wood, wood residues and energy plants were emphasized. Biogas production technology is also described because after cleaning it can be used as a substitute of natural gas and can be supplied to gas network for heating purposes. Substitution to natural gas will guarantee a constant and secure supply of energy. As well biomass production and creation of biomass storage infrastructure can also secure the constant energy supply. Proposed bio refinery technology called GBR (Green biorefinery) is showed advantages of applied projects in Austria. During the GBR process a valued food additive such as amino acid and lactic acid from the grass and grass silage were produced.

Optimization of energy model was carried out by changing quantitative criteria or the amount of primary material and qualitative criteria or economic factors of RES production technologies, i.e. change the price for material and final products and applying different feed tariff for a final energy products. PNS showed that the economically beneficial to supply cleaned SNG to natural gas network is when the price of biogas is three times higher than now (2,09 Lt/m3 or 0,61 EUR/ m3). The next scenario was formed with the lowest feed in price for RES technologies. Biogas is economically reasonable to burn it in the heat boilers and to produce heat energy. However if the quantity of primary biogas resources (especially waste from meat rendering process, waste oil, cattle manure) is sufficient the biogas can be used at CHP plant. In the case of expensive natural gas, it is recommended to use cheaper energy resources, which can be found in abundance in the region. In this case, it is proposed to produce around 28 % of energy using natural gas, and 72 % using biomass (wood chips produced using local resources). If the prices of natural gas increase by 30 % up to 0.78 Eur/m^3, it is recommended to refuse the use of natural gas and to use other resources in the district heating system. At a lower price of natural gas (<0.5 Eur/m^3, which is 1.7 EUR/m^3) and in the case the fuel price is unchanged (~ EUR 60 Eur/t or 210 EUR/t), natural gas can be used as the main fuel for the district heating and industry. Naturally the best scenario is to produce energy with the cheapest energy resources but what to do if these resources are limited. PNS can help to distribute limited resources in energy network with best economic factors. However RES nowadays usually with an exception of biofuel can't guarantee the lowest produces energy prices. Therefore in both scenarios energy produced by wind generators and solar PV systems were treated as supplementary because of high investment costs and always was included in the model because of large production rate.

The influence on climate (represented by the fossil C sector) is strong in all technologies. There is a large pressure for the natural gas technology so far, however renewable technologies also have strong influence on the environment. For example, in the production process of wind turbines and photovoltaic panels, a lot of energy is used in the production of steel elements. Another reason is that the current energy system is still mostly based on fossil fuel, and the energy input into production and manufacturing of equipment also causes pressures in this category.

The production of photovoltaic models has quite a high pressure on the environment as well. Especially the emissions to water are prominent as a result of the complex chemical process needed to produce the semiconductor wafers. It should be noted that the carbon emission pressure predominantly comes from the production of frames for PV modules, because they are made of steel.

RES technologies such as wind generators, solar PV systems and solar collectors have been treated as supplementary energy resources so far. Usually, they can provide energy flow, which is not constant during daytime or a month and is unevenly dispersed through the year. Consequently, the main problem of RES is to capture and store the energy and to secure the constant energy flow. This can be achieved either through implementing storage technologies (boilers, accumulators) or through integrating the smart technologies (smart grids). The latter option is more promising, because it solves several problems. Firstly, it saves money, because smart grid technologies are based more on improvement of software. Secondly, it has a positive environment aspect. Smart grids use existing infrastructure, and this probably will not harm environment as much as it could, should the demand for accumulation equipment increase. The third positive thing is that using RES, the distribution of energy flow to costumers is as good as using fossil fuel. Fourth is that energy generator facilities stand nearby the end-users, and the loss of energy in the distribution path is less than that when one big energy power source is allocated. Finally, the fifth argument is that decentralized energy generation does not need to keep large constant energy reserves for balancing a network.

Chapter 4. Conclusions

1. “Return to the nature” is not just a revival of a primitive lifestyle – it is the development trend where new technologies are taking actions to avoid competition with nature and refuse a wish “to defeat the nature”. Ecologization of settlements in the local region is connected to understanding the principles of ecological cycles to ensure environmental integrity emphasising harmonization of human activities with nature. Holistic approach to green energy economy of settlements is forming an environment similar to that of the Earth ecological system, where material, social and emotional capital is performing. Accumulation and (or) consumption of these capitals is related to the rational, emotional and spiritual wisdom; therefore, natural resources in green settlements are used responsibly and sustainably.
2. Depletion of energy resources and the increase of its prices have negative impact to economic and social life. Economic activities create pollutions, which dissipate in the ecosystem far away from emitting sources. Negative impacts to ecosystem have adverse effect to human life conditions, therefore the essential principles of economic transformation is the reuse of resources, primary energy savings and replacement of fossil resources. The process of transformation the energy economy of existing settlements to green settlements is understating as ecologazation of a certain living territory, rapidly growing use of RES technologies changing opportunities to use primary resources for energy production influence the transformation of use of energy resources.
3. A green settlement model involves the formation of a complex analysis of the RES technology that provides a systematic approach to renewable technologies in the regions. Successful development of energy economy of a

green settlement depends on the local community and the region where they live. A pattern of green settlement is formed with rural landscape elements developing city like infrastructure and reconciling agriculture and other economic sector activities. Energy economy of a green settlement depends on its people and the territory. The community is the economic strength of a green village, which creates social capital and trust and cherishes the surrounding environment. A green energy farm village formed the most acceptable in the case of RES uptake of synthesizing various RES technologies and creating conditions for the rational implementation of renewable technologies.

4. Energy process network system (PNS) analysis method is designed for investigation of energy flows in the region. PNS method is adapted to work with computers called "PNS-Studio" and a web based program "RegiOpt-CP" is available for free online. PNS method is associated with a creation of algorithm of branch-and-bound method, which helps to conceptualize the present situation and to forecast options of feasible decisions, also to support the identification of the kind of information is needed in order to evaluate the consequences of decision-making. PNS helps to set up a structure for regional energy economy and evaluates the potential energy economy scenarios. It helps to investigate local available energy resources, energy generation technologies, defines energy users, evaluates energy flows, enables to set up a structure for regional energy economy and evaluates the potential energy economy scenarios. PNS method referring to the best practices in the EU (mainly in Austria).
5. The balance of energy flow is achieved by combining activity of economic sectors. The first is to secure the use of energy power of centralized heating and business/industry enterprises. Agricultural products and their waste utilized for energy production have an impact on supply and demand of agricultural products. Emerged new market of energy products is increasing the prices of agricultural products, reducing the supply of food and increasing the competitiveness of products. RES used for energy production is also used for other economic activities such as agriculture; therefore, RES should be balanced with the other economic activities, and energy resources should not compete with agricultural resources.
6. In the case of expensive natural gas, it is recommended to use cheaper energy resources, which can be found in abundance in the region. In this case, it is proposed to produce around 28 % of energy using natural gas, and 72 % using biomass (wood chips produced using local resources). If the prices of natural gas increase by 30 % up to 0.78 Eur/m^3, it is recommended to refuse the use of natural gas and to use other resources in the district heating system. At a lower price of natural gas (<0.5 Eur/m^3, which is 1.7 EUR/m^3) and in the case the fuel price is unchanged (~ EUR 60 Eur/t or 210 EUR/t), natural gas can be used as the main fuel for the district heating and industry. *Status quo*

analysis showed that the region has favourable conditions to reach planned RES targets. Development of RES technologies is related to the increase of efficiency of energy use and the implementation of new technologies. Theoretically an amount of biomass energy (5975 MWh) will be enough to cover 12.21 % of a total heat energy demand in the region and will be cover 100 % of heat energy demand in the central heating system (5059 MWh). In case of local shortages of biofuels, it is recommended to replace the growing demand for biofuels by imported biofuel or biofuel manufacture using fast-growing plant biomass.

7. The formation of the development of energy economy sectors in the long period is performed trying to use more RES and the surplus or waste energy in the electricity and district heating sector by adapting the energy economy planning tools, such as smart energy technologies. Improvement of the efficiency of energy production using RES has to be achieved by reducing the use of fossil fuel in the energy sector. Analysis of regional energy economy showed that the use of biomass and biofuel resources is the most effective instrument for optimal use of RES in the region ensuring sustainable energy supply. Biogas production technologies have especially good conditions, where produced synthetic biogas is used for heat and electricity production and can be used as a fuel for transport purposes and as an alternative replacing the use of natural gas.
8. *Status quo* analysis showed that economic added value is received outside the region, because activities conducted in the energy sector are organized outside the region. Resources used for energy production are mainly imported or transported from other regions. RES can be developed only under the natural market conditions without exceptions and without various compensatory or support mechanisms. Technologies using RES compete with technologies based on fossil resource combustion; therefore, the increase of efficiency of RES technologies and diversified RES resources decreases the electricity cost, while it becomes equal and competitive to energy produced using fossil resources. Once the maximum price values have been reached, further development of traditional energy based on fossil resources is economically useless.
9. A systematic and sustainable approach during the formation of the green settlement model provides an opportunity to implement larger power generation technological projects using RES by optimizing energy economy processes and taking into account the sustainable development criteria. The model of a green settlement involves the formation of a complex analysis of RES technologies, which gives the model a systematic approach to RES technologies in the regions. Energy and other projects in the region should not be an obstacle to promoting the 100 % use of RES.

Chapter 5. References

1. Aleknavičius, P., Valčiukienė, J. Kaimiškojo kraštovaizdžio raidos ypatumai Vilniaus miesto įtakos zonoje. *Vandens ūkio inžinerija*, 2011, 38(58), p. 32-41.
2. Braungart, M., McDonough, W. *Cradle to cradle: Remaking the way we make things*. North point press, 2002. 193 p. ISBN 0-86547-587-3.
3. Birkeland, J. Positive development from vicious circles to virtuous cycles through built environment design. 2008, London, Streling VA, 408 p., ISBN 978-1-84407-578-2.
4. Čiegis, R. *Darnus ekonomikos vystymasis*. Šiaulių universitetas. 2008. 204 p. ISBN 978-9986-38-881-4.
5. Čiegis, R. *Gamtos išteklių ir aplinkos ekonomika*. Klaipėda, 2009, p. 771. ISBN 978-9955-18-375-4.
6. Henderson, H. *Ethical markets: growing the green*. Chelsea Green Publishing, 2006, 300 p., ISBN 978-1-933392-23-3.
7. Juknys, R. *Aplinkotyra*. Vytauto Didžiojo universitetas, 2005, p. 334, ISBN 9955-12-115-7.
8. Kalenda, Č. *Ekologinė etika*. Rosma. ISBN 978-9986-00-509, p. 171.
9. Lietuvos Respublikos energetikos ministerija. *Lietuvos Respublikos energetikos ministerijos 2010 metų ataskaita*. Vilnius.
10. Lietuvos Respublikos žemės ūkio ministerija. *„Žalioji knyga". Lietuvos kaimo ateitis*. Lietuvos agrarinės ekonomikos institutas. 2010, 33 p., ISBN 978-9955-481-18-8.
11. Lietuvos Respublikos nekilnojamo turto registre įregistruotų statinių apskaitos duomenys 2011 m. sausio 1 d. Nacionalinė žemės tarnyba. [interaktyvus] [žiūrėta 2012-09-20]. Prieiga per internetą: http://www.nzt.lt
12. Meadows, D., et al. *Beyond the limits: global collapse or a sustainable future*. Earthscan Publications, 1992, p. 300, ISBN 0-930031-55-5.
13. Palojarvi, A., Pyysiainenas, J., Saloranta, M. *Experiences with Ecological Technologies and Practices*. BMK leidykla, 2013, p. 122, ISBN 978-609-8080-74-2.
14. Paulauskas, S. *Savivaldos dialektika*. Klaipėda: Klaipėdos universiteto leidykla, 1999. 251 p. ISBN 9986-505-8-8.
15. Pledger, S. The circular economy. Prezentacija konferencijoje „Ecovillages for sustainable rural development", 2013 m. spalis, Druskininkai. Agrarinės ekonomikos institutas.
16. Rees, W., Wackernagel, M. Urban ecological footprints: why cities cannot be sustainble – and why they are a key to sustainability. *Environmental Impact Assess Rev*, 1996, 16, p. 223–248.
17. Rifkin, J. *Trečioji pramonės revoliucija*. Eugrimas, 2012, p. 336, ISBN 978-609-437-148-6.

18. Rockstrom, J., Folke, C., et al. Resilience thinking: integrating resilience, adaptability and tranfomability. Ecology and Society, 2010, 15(4), 20, [interaktyvus] [žiūrėta 2012-02-12]. Prieiga internete: http://www.ecologyandsociety.org/vol15/iss4/art20
19. Stahel, R., Walter. The performance economy. Palgrave-MacMillan, London, 2010. p. 349. ISBN 978-0-230-58466-2.
20. Stoglehner, G., Narodoslawsky, M. How sustainable are biofuels? Answers and further questions arising from an ecological footprint perspective. *Bioresource technology*, 2009, 100, p. 3825-3830.
21. Stoglehner, G. Ecological footprint - a tool for assessing sustainable energy supplies. Journal of Cleaner Production, 2003, 11, p. 267-277.
22. *Statistical Yearbook of Lithuania 2009*. Vilnius, Statistic Lithuania, 2010, 704 p. ISSN 2029-3631.
23. Valkauskas, R. *Duomenų analizės įvadas*. Vilniaus universitetas, 2011, p. 156, ISBN 978-9955-634-47-8.
24. Wijkman, A. Sustainable development – challenges and prospects. Regeringsuppdrag. Forskning till stöd för hållbar utveckling. Bilaga 1. Forskningsrådsnämnden, FRN-rapport 1998, 12, p. 9-27.

Chapter 6. List of scientific publications

Publications corresponding to the list of Thomas Reuters Web of Science database

1. Klevas V., **Bieksa K.**, Murauskaite L. Innovative method of RES integration into the regional energy development scenarios. *Energy Policy*, 2014, 64, p. 324-336, ISSN 0301-4215.

Peer-reviewed articles referred in international databases

1. Klevas V., **Biekša K.,** Klevienė A., Bubelienė J., Stankevičius M**.** Energetikos raidos darnumo vertinimo metodologijos principai. *Energetika*, 2010, 56(2), p. 92-102, ISSN 0235-7208, [INSPEC, Index Copernicus].
2. Murauskaitė L., Klevas V.**, Biekša K**. Centralizuoto šilumos tiekimo sistemos reformavimo prielaidos Lietuvoje. *Taikomoji ekonomika: sisteminiai tyrimai*. 2013, 7(1), p. 191-208, ISSN 1822-7996, [Business Source Complete (EBSCO), CEEOL, Index Copernicus].

Publications in other periodicals and articles collections

1. **Biekša K.,** Klevienė A**.** Analysis of energy accounting methods of sustainable energy economy. *6th Annual Conference of Young Scientists on Energy Issues CYSENI 2009,* Kaunas, Lithuania, 28–29 May, 2009. Kaunas: LEI, 2009, p. 202-211, ISSN 1822-7554, (INSPEC).

2. Klevas V.**, Biekša K**. Atsinaujinančių energijos gamybos technologijų darnusis vystymasis pagal proceso tinklinės analizės metodą. *Šilumos energetika ir technologijos-2013: konferencijos pranešimų medžiaga, Kauno technologijos universitetas, 2013 m. sausio 31 d. – vasario 1 d*. Kaunas: Technologija, 2013, p. 45-50, ISSN 2335-2477.

Publications in Proceedings of Conferences

1. **Biekša K**. Sustainable development of regional energy system using process network synthesis method. *10th Annual International Conference of Young Scientists on Energy Issues (10 CYSENI anniversary)*: Kaunas, Lithuania, May 29-31, 2013, Kaunas: LEI, 2013, p. 253-263, ISSN 1822-7554.
2. **Biekša K.**, Klevienė A. Regional energy economy development scenarios in Lithuania from the ecological footprint perspective. *8th International Conference of Young Scientists on Energy Issues CYSENI 2011,* Kaunas, Lithuania, May 26-27, 2011. Kaunas: LEI, 2011, p. 151-160, ISSN 1822-7554.
3. **Biekša K.**, Klevienė A. Strategic self-management: comparison of energy accounting methods for energy price evaluation of the Lithuanian energy sector. *7th Annual Conference of Young Scientists on Energy Issues CYSENI 2010*, Kaunas, Lithuania, May 27-28, 2010. Kaunas: LEI, 2010, p. 193-203, ISSN 1822-7554.
4. Klevas V., **Biekša K.**, Klevienė A., Stankevičius M. Regional approach of sustainable energy development. 11th IAEE European Conference on Energy Economy, Policies and Supply Security: Surviving the Global Economic Crisis. Vilnius, Lithuania, August 25-28, 2010. International Association for Energy Economics, Cleveland OH, 2010, p. 1-10, ISSN 1559-792X.

Articles in National conference proceedings

5. Klevas V.**, Biekša K**. Atsinaujinančių energijos gamybos technologijų darnusis vystymasis pagal proceso tinklinės analizės metodą. *Šilumos energetika ir technologijos 2013: konferencijos pranešimų medžiaga*, Kauno technologijos universitetas, 2013 sausio 31 – vasario 1 d. Kaunas: Technologija, 2013, ISSN 2335-2477.
6. **Biekša K.,** Klevienė A. Analysis of energy accounting methods of sustainable energy economy. *6th Annual Conference of Young Scientists on Energy Issues CYSENI 2009*, Kaunas, Lithuania, 28-29 May, 2009. Kaunas: LEI, 2009, p. 202-211, ISSN 1822-7554.

Popular scientific articles and conference proceedings

1. **Biekša K.,** Energetikos strategija nuosavame kieme. *Namas ir aš,* 2013, 4, p. 32-36, ISSN 1648-4150.
2. **Biekša K**. *Mokyklų ekologinio pėdsako skaičiavimo metodikos pristatymas*. Pranešimas konferencijoje: Švietimas tvariam vystymuisi ugdant pasaulio pilietį, 2013 m. lapkričio 20 d., Vilnius, VšĮ Lietuvos vaikų ir jaunimo centras. Prieiga internete: www.lvjc.lt/ekopedsakas/Ekologinis%20pedsakas aprasymas.pdf
3. **Biekša K**. *Ugdymo įstaigų atliktų ekologinio pėdsako rezultatų pristatymas ir analizė.* Pranešimas ugdymo įstaigų vadovų forume „Darni mokykla“, 2014 m. balandžio 15 d., Vilnius, VšĮ Lietuvos vaikų ir jaunimo centras. Prieiga internete: www.lvjc.lt/ekopedsakas/Pedagogika_ekologinis_pedsakas1.pdf

Information about the author of the dissertation

Name: Kęstutis Biekša
Contact: kestuts@hotmail.com

Academic background:

2008-2014	PhD studies at Lithuanian Energy Institute, Laboratory of Regional Energy Development,
1997-2000	Royal Institute of Technology, Land and water department, Stockholm, Sweden, Master of environmental engineering and sustainable infrastructure,
1995-1997	Vilnius Gediminas Technical University, Faculty of Civil Engineering, Department of Construction Technology and Management, Master of Civil Engineering,
1990-1995	Vilnius Gediminas Technical University, Faculty of Civil Engineering, Department of Construction Technology and Management, Bachelor of Civil Engineering.

Work experience:

2014-current	Chief specialist at the Ministry of Energy of the Republic of Lithuania, Heat energy and energy efficiency division.
2013-2014	Freelance energy and environmental consultant
2005-2013	Project administrator at JSC “Sweco Lietuva”, Division of Water Design
2003-2005	Project manager at JSC “Eksponentė” and public institution “Strategic Self-Management Institute”

2001-2002 Project manager at JSC “Carl Bro (Grntmij Lietuva)
1999-2001 Project manager at NGO “Ecologia”
1994-1997 IT and sales manager at JSC “Bijoresta”

Field of scientific interest: Energy economics, regional development of renewable energy technologies, environmental assessment of energy processes using ecological footprint method.

Membership: European Association of Environmental and Resource Economists

REZIUMĖ

Mokslinio tyrimo aktualumas. Siekis išsaugoti žmogaus gyvenamąją aplinką bei istorijos ir kitas vertybes rado atgarsį ir patvirtinimą ekonomikos darnios raidos koncepcijoje bei daugumoje XXI a. naujųjų idėjų apie ateities gyvenseną. Jos praktiškai ėmė reikštis pasauliniame ekologinių gyvenviečių kūrimosi judėjime. Šis judėjimas – tai vietinių iniciatyvų ir grupės lyderių inicijuojama veikla, kurios pagrindinis tikslas – gyvenimas švarioje, ekologiškoje aplinkoje, puoselėjant bendruomeniškumą ir socialinį bendrumą, skatinant ekologiško ūkio raidą. Svarbiausias klausimas, kartu išryškinantis ir šio darbo aktualumą - susieti įvairių tyrimų rezultatus į vieningą, praktiniu požiūriu pritaikomą energetinio ūkio pertvarkymo į į žaliųjų gyvenviečių energetinį ūkį koncepciją, aprėpiančią darnios raidos aspektus.

Efektyvus atsinaujinančių energijos išteklių (AEI) naudojimo būdas, padedantis išvengti rinkos klaidų, yra bioregionų sukūrimas ir plėtra, kuri yra susijusi su žaliųjų gyvenviečių raidos koncepcija, kurioje bendruomenės raida grindžiama cirkuliacinės ekonomikos konceptualiomis nuostatomis. Kiekvienas regionas, turintis savitus vietinius išteklius, gali sukurti savitą aplinką šiems ištekliams pasisavinti (Birekland, 2008), todėl įvertinusi AEI potencialą, galima sukurti savitą aplinką energijos ištekliams naudoti, kuo mažiau pakenkiant gamtinei ir gyvenamajai aplinkai bei sumažinant atliekų susidarymą, parodant tikrąją aplinkos ir socialinę vertę. Cirkuliacinės ekonomikos cikle svarbus yra sistemiškumo aspektas, kai reikia išsamiai išanalizuoti išteklių bei energijos kiekius ir srautus, kad būtų galima valdyti energijos pasiskirstymą, siekiant sumažinti atliekų kiekius arba atliekas paverčiant naudingomis medžiagomis. Plėtojant regiono energetinį ūkį pagal cirkuliacinės ekonomikos principus reikia naudoti kuo įvairesnius vietinius ir AEI (Pledger, 2013).

Žaliųjų gyvenviečių energetinio ūkio modelis formuojamas pagal elektros energijos ir šilumos energijos gamybos ir vartojimo etapus, optimaliai panaudojant vietinius ir AEI. Formuojant žaliosios gyvenvietės energetinį ūkį daroma prielaida, kad AEI ir energijos išteklių dalis turi būti ne mažesnė nei numatyta ES direktyvose dėl AEI naudojimo. Optimaliu atveju siekiama visiškai atsisakyti naudoti iškastinį kurą, pakeičiant jį AEI. Energetinio ūkio pertvarka turi būti planuojama, organizuojama ir skatinama įvairiomis ekonominėmis, socialinėmis bei aplinkosauginėmis priemonėmis, veikiančiomis pagal „iš viršaus į apačią“ (angl. *top down*) arba „iš apačios į viršų“ *(angl. bottom up*) principus. Žaliųjų gyvenviečių plėtra – procesas, neturintis pabaigos arba raida spirale, kai viena forma keičia kitą, kai vyksta kokybiniai ir kiekybiniai pokyčiai. Todėl svarbu išsiaiškinti sistemiškumą arba išteklių atsargų valdymą, atliekant išteklių srautų analizę. Taip pat būtina plėtoti antrinį medžiagų ir netoksiškų atliekų panaudojimą techniniame (antropogeninis) ir biologiniame (ekosferos) cikluose, skatinti efektyvų išteklių naudojimą bei taupymą. Žaliųjų gyvenviečių plėtra turi būti įvairiapusė, nes cirkuliacinės ekonomikos atveju atsiranda biologinių, technologinių ir kultūrinių procesų įvairovė. Be to, turi būti skatinamas AEI ir vietinių energijos išteklių naudojimas.

Mokslinė problema ir jos ištyrimo lygis.

Pradiniu impulsu žaliosios gyvenvietės teorinėms nuostatoms formuotis yra darniosios plėtros koncepcija, kuri analizuoja ekonominės, socialinės aplinkos ir gamtos santykių problemas, siekiant patenkinti dabartinius visuomenės poreikius, nemažinant ateinančių kartų galimybių tenkinti savo poreikius (Wijkman, 1998). Nagrinėjant darnios plėtros koncepciją ir pritaikant jos idėjas praktikoje pastebėta, kad būtinos tam tikros transformacijos pačioje darnios raidos koncepcijoje, papildant racionalia, emocine ir dvasine visuomenės išmintimi. Šiuolaikinės ir sparčiai besiplėtojančios informacinės technologijos leidžia formuoti praktinius scenarijus, organiškai susiejančius technologinius pasiekimus su žmonių visuomenės raidos poreikiais (Bizzarri, 2011). Tačiau vis labiau aiškėja, kad būtent žmogaus pažiūrų sistema keistina, nes technologijų pažanga gerokai lenkia žmogaus ekologinį išsilavinimą ir požiūrį, ir vis dar išlikusį įsisenėjusį žalingą norą „nugalėti gamtą“. Darni raida tapo šių laikų iššūkiu visose veiklos srityse, apimant švietimo, ekonominę, socialinę ir ekologinę aplinką. Ypač svarbi yra ateities kartų apsirūpinimo energijos ištekliais, išsaugant gyvenamąją aplinką, problema.

Mokslinėje literatūroje darni ekonomikos raida dažniau yra siejamas su „žaliojo“ kapitalo sąvokomis, o nauja ekonomikos raidos koncepcija – su naujų kriterijų iškėlimu, kurie naujai įprasmina žmogaus ir gamtos sąveiką. Ekonomistas T. Jackson knygoje „Gerovė be augimo“ (2009) teigia, kad gerovė ir geresnė gyvenimo kokybė yra įmanoma kitoje ekonominėje erdvėje, kurioje pagrindinė varomoji jėga yra ne tik kapitalas, kuriantis pridėtinę vertę, o bendruomenės ir jų kuriamas socialinis kapitalas. Naujoje „žaliuoju“ kapitalu grindžiamoje ekonomikoje gerovė bus kuriama taikant išmanius valdymo metodus ir laikantis darnios raidos koncepcijos idėjų. „Žaliojo“ kapitalizmo esmė yra diskutuojama (Henderson, 2006), (Meadows, 1992) moksliniuose straipsniuose. Pastaruoju laikotarpiu vis didesnį svorį įgauną cirkuliacinės ekonomikos koncepcija, kurios esminis teiginys – siekiant tvarumo visuomenėje reikia holistinio požiūrio į gamybinę sistemą, kuri turi veikti panašiai kaip veikia Žemės ekologinė sistema (Stahel, 2010). Susiformavęs požiūris į raidą nesuabsoliutinant augimo arba materialumo, orientuojamasi į socialiniais principais paremtą plėtrą. Ekonominio augimo suabsoliutinimas pernelyg dažnai užmaskuota forma „pateisina“ aplinkos besaikį niokojimą. Žanas Žakas Ruso (*Jean-Jacques Rousseau*) jau XVIII a. perspėjo, kad žmogus turi atsitokėti ir pradėti mąstyti apie civilizacijos raidos kryptį, apie savo gyvensenos pobūdį ir prasmę. Šiais laikais jo paskelbtas „grįžimo į gamtą“ šūkis nėra primityvaus gyvenimo būdo atgaivinimas, o adekvatesnis jo supratimas. Tai naujausių technologijų pritaikymu pagrįsta žmonių bendruomenės raidos kryptis, išvengiant rungtyniavimo visų su visais ir atsisakymas noro „nugalėti gamtą“ (Rifkin, 2012).

Vietovės energetikos ūkio plėtrą pagal cirkuliacinės ekonomikos principus, panaudojant kuo įvairesnius vietinius ir AEI nagrinėja (Pledger, 2013). Cirkuliacinę ekonomiką ir koncepciją „nuo lopšio iki lopšio“ (angl. *cradle to cradle*) nagrinėja (Wijkman, 1998; Rockstrom, 2010; Stahel, 2010; Braungart, 2002. Tačiau įvairios teorinės nuostatos turi įgyti tam tikrą „laboratorinį“ patikrinimą ir įvairių koncepcijų sintezės galimybę. Šiuo teoriniu pagrindu ir buvo formuojama žaliųjų gyvenviečių sukūrimo ir plėtojimo idėja. Žalioji, arba ekologinė, gyvenvietė visų pirma susijusi su ekologinės sistemos raidos dėsnių supratimu ir holistiniu požiūriu į ekologinės gyvensenos formavimą. Gamtoje gyvi organizmai ir jų aplinkos sąveikos yra tarpusavyje susiję procesai, kurie veikia kartu ir vieni kitus, palaikydami gyvybę ir užtikrindami sistemos tikslingumą (Palojarvi, 2013). Todėl plėtojant žaliosios gyvenvietės modelį pirmiausiai yra siekiama išsaugoti aplinkos vientisumą ir pabrėžti kiekvienos jos dalies, taip pat žmogaus, priklausomą padėtį (Kalenda, 2007). Žaliųjų gyvenviečių plėtra neatsiejama nuo vietinių ir AEI naudojimo, todėl technologijų, naudojančių vietinių ir AEI, skatinimas turi tapti prioritetine energetikos ūkio sritimi. Žaliosios gyvenvietės turėtų tapti nauja ekonomine jėga, kurioje bendruomenės formuotų priimtiniausią AEI įsisavinimo scenarijų, kartu galėdamos sintezuoti įvairias finansavimo priemones ir prielaidas racionaliam AEI technologijų įgyvendinimui.

Pagrindinis žaliosios gyvenvietės energetinio modelio sudarymo tikslas – išnagrinėti vietovės energetinio ūkio veikimą esant skirtingoms to regiono energetinės sistemos būsenoms ir išorinėms sąlygoms. Energetiniam ūkiui sukurti yra naudojamos įvairios planavimo priemonės ir valdymo modeliai. Vienas iš jų – procesų tinklinės sintezės (toliau – PTS) metodas (angl. *process network synthesis method*). PTS metodas randa optimalius sprendinius pagal sprendinių medžio sudarymo algoritmą, kuris padeda suvokti esamą energetinio ūkio situaciją ir numatyti galimus sprendimų variantus, įvertinant turimą ir trūkstamą informaciją.

Mokslinio darbo problema – suformuoti darnią energetinio ūkio struktūrą taip, kad nuolatinė ir ilgalaikė visuomenės plėtra nekonfrontuotų su pirmine gyvosios gamtos būsena, kurią nuolatos palaiko cikliškai veikiantys savireguliacijos mechanizmai, susieti su ilgalaikiais ūkio ir energetikos sektoriaus tikslais, pagal cirkuliacinės ekonomikos principus.

Tyrimo objektas – vietovės energetinio ūkio struktūros formavimo teorija ir praktinis energetinio ūkio struktūros rekonstravimo ilgalaikėje perspektyvoje modelis, apibendrinta sistema teorinių pažiūrų į bendruomenių energetinio ūkio transformavimą, susiejant su ilgalaikiais šalies ūkio ir energetikos tikslais, pagal cirkuliacinės ekonomikos principus, kad nuolatinė ir ilgalaikė bendruomenės ūkio raida ir gyvensena nekonfrontuotų su pirmine gyvosios gamtos būsena, kurią nuolatos palaiko cikliškai veikiantys savireguliacijos mechanizmai.

Mokslinio darbo tikslas – suformuoti vietovių energetinio ūkio ekologizavimo koncepcijų ir ilgalaikės plėtros modelį, kuris praktiškai padėtų besikuriančioms žaliųjų gyvenviečių bendruomenėms nuosekliai ir darniai siekti užsibrėžtų tikslų, pamažu vis didesniu mastu panaudojant vietinius ir AEI bendruomenės energijos poreikiams tenkinti.

Tyrimo metodai. Siekiant sukurti teorinę žaliosios gyvenvietės rekonstrukcijos koncepciją, tyrimui atlikti buvo taikyti šie metodai: kokybinė ir kiekybinė palyginamoji analizė, darniosios plėtros rodiklių analizė ekonominėje, ekologinėje ir socialinėje aplinkoje, ekonominis sugretinamos energijos kainos metodas, tinklinės regiono energetinio ūkio sistemos sudarymo metodas, tvaraus proceso indeksas, įvertinantis energetikos sistemos poveikį aplinkai ekologinio pėdsako metodu.

Darbo apribojimai ir tolesnių tyrimų kryptis. Parengta gyvenviečių (vietovių) energetinio ūkio pertvarkos programa ir pritaikytas skaičiavimo metodas leidžia spręsti regiono apsirūpinimo energijos ištekliais (vietiniais ir AEI) problemas bei padeda parengti energetinio ūkio modernizavimo schemas (vietinių ir AEI, sumaniųjų tinklų technologijų panaudojimas, taupant pirminius energijos išteklius, efektyviai paskirstant ir naudojant galutinę energiją), ekologizuojant energetinį ūkį ir formuojant energetinio ūkio plėtros etapus, optimizuojant AEI ir vietinių energijos išteklių naudojimą.

Teritorinio AEI panaudojimo principais parengta žaliųjų gyvenviečių energetinio ūkio plėtros programa skatina naudoti AEI, neatsisakant naudoti kitus vietinius energijos išteklius.

Suformuota energetinio ūkio nuoseklios plėtros struktūra, sudaro sąlygas siekti vieningų žaliosios gyvenvietės bendruomenės tikslų, sintezuojant technologinius, ekonominius ir socialinius pasiekimus.

Atliktas tiriamasis darbas analizuoja esamos arba naujai kuriamos (planuojamos) gyvenvietės (vietovės) energetinio ūkio struktūrą, jos formavimosi teorines bei praktines plėtros prielaidas, pasiūlant tinkamą energetinio ūkio raidos struktūrą ir plėtros etapus, siekiant optimaliai panaudoti regione esančius AEI ir kitus vietinius energijos išteklius.

Mokslinis pritaikymas: formuojant žaliųjų gyvenviečių energetinio ūkio struktūrą, įvertintas ir realizuotas vietinių ir AEI visuomeninis naudingumas socialiniu, ekonominiu, aplinkosauginiu požiūriais.

Praktinis pritaikymas: naudojant procesų tinklinės analizės metodą formuojama ekologinio energetinio ūkio struktūra ir parenkamas optimalus energetinio ūkio plėtros variantas, kuris yra tinkamas žaliųjų gyvenviečių energetinio ūkio, kuriame skatinama žaliosios gyvenvietės kūrimosi idėja, formavimui, motyvuojant bendruomeninę žmonių veiklą. Energetinio ūkio ekologizavimo etapai sudaromi pagal darnios raidos metodologinius principus ir sprendžia esamų gyvenviečių apsirūpinimo šilumos ir elektros energija galimybes, analizuojant energijos srautus ir jų pasiskirstymo regione ypatybes, siekiant ateityje apsirūpinti energija naudojant AEI nenaudojant iškastinio kuro.

UDK 620.9:502.131.1+330.34:502.131.1] (043.3)
SL344. 2015-10-22, 2,75 leidyb. apsk. l. Tiražas 60 egz. Užsakymas 368.
Išleido leidykla „Technologija“, Studentų g. 54, 51424 Kaunas
Spausdino leidyklos „Technologija“ spaustuvė, Studentų g. 54, 51424 Kaunas