LITHUANIAN ENERGY INSTITUTE

ILONA ALIŠAUSKAITĖ-ŠEŠKIENĖ

COMPARATIVE ASSESSMENT OF RENEWABLE ENERGY SOURCES GENERATION TECHNOLOGIES IN HOUSEHOLDS

Doctoral Dissertation
Social sciences, Economics (04S)

2018, Kaunas

Doctoral dissertation was prepared in Lithuanian Energy Institute Laboratory of Energy Systems Research in the period of 2013-2017.

Scientific supervisor:
Prof. Dr. Dalia ŠTREIMIKIENĖ (Lithuanian Energy Institute, Social Sciences, Economics – 04S)

Scientific consultant:
Dr. Tomas BALEŽENTIS (Lithuanian Institute of Agrarian Economics, Technical Sciences, Informatics Engineering – 07T)

LIETUVOS ENERGETIKOS INSTITUTAS

ILONA ALIŠAUSKAITĖ-ŠEŠKIENĖ

ATSINAUJINANČIUS ENERGIJOS IŠTEKLIUS NAUDOJANČIŲ ENERGIJOS GAMYBOS TECHNOLOGIJŲ PALYGINAMASIS VERTINIMAS NAMŲ ŪKIUOSE

Daktaro disertacija
Socialiniai mokslai, Ekonomika (04S)

2018, Kaunas

Disertacija parengta 2013-2017 metais Lietuvos energetikos instituto Energetikos kompleksinių tyrimų laboratorijoje.

Mokslinis vadovas:
Prof. dr. Dalia ŠTREIMIKIENĖ (Lietuvos energetikos institutas, Socialiniai mokslai, ekonomika – 04S)

Mokslinis konsultantas:
Dr. Tomas BALEŽENTIS (Lietuvos agrarinės ekonomikos institutas, Technologijos mokslai, informatikos inžinerija – 07T)

ACKNOWLEDGEMENT

First and foremost, I would like to express my sincere gratitude to my scientific supervisor Prof. Dr. Dalia Štreimikienė for her knowledge, guidance, encouragement, patience and the opportunity – without her continuous support this doctoral dissertation would not have been achievable.

I thank Dr. Tomas Baležentis, my scientific consultant, for his invaluable help, patience, insights and suggestions, I received throughout the research work.

Finally, I want to thank my son – I love you more than anything, you are the one that keeps me trying and hoping.

CONTENTS

LIST OF TABLES

LIST OF FIGURES

SYMBOLS AND ABBREVIATIONS

AC – Avoided cost
AHP – Analytic Hierarchy Process
ANP – Analytic Network Process
ARAS – Additive Ratio Assessment method
ARAS-F – Fuzzy Additive Ratio Assessment method
ARAS-G – Grey Additive Ratio Assessment method
CA – Conjoint analysis
CE – Choice experiment
CO_2 – Carbon dioxide
COPRAS – Complex Proportional Assessment
COPRAS – G - Complex Proportional Assessment of alternatives with Grey criteria
CVM – Contingent valuation method
EDAS – Evaluation Based on Distance from Average Solution
ELECTRE – Elimination and Choice Expressing Reality
EU – European Union
FI – Factor income
FMADM – Fuzzy Multi-Attribute Decision Making
FMODM – Fuzzy Multi-Objective Decision Making
GHG – Greenhouse gas
HP – Hedonic pricing
ICTs – Information and communications technologies
KEMIRA – Kemeny Median Indicator Ranks Accordance
MAUA – Multi-Attribute Utility Analysis
MCDM / MCA – Multi-Criteria Decision Method / Multi-Criteria Analysis
MOORA – Multi-Objective Optimization by Ratio Analysis
MULTIMOORA – Multi-Objective Optimization on the Basis of Ratio Analysis pluss Full Multiplicative form
NAIADE – Novel Approach to Imprecise Assessment and Decision Environments
PROMETHEE – Preference Ranking Organization Method for Enrichment Evaluations
RC – Replacement cost
RES – Renewable energy sources
SAW – Simple Additive Weighting
SMEs – Small and medium enterprises
SWARA – Step-Wise Weight Assessment Ratio Analysis
TC – Travel cost
TOPSIS – Technique for Order of Preference by Similarity to ideal Solution
UK – United Kingdom
VIKOR – VlseKriterijuska Optimizacija I Komoromisno Resenje
WASPAS – Weighted Aggregated Sum Product Assessment
WTP – Willingness to pay

INTRODUCTION

Relevance. While the demand of energy is increasing around the world, the traditional energy resources are depleting and its' acquisition methods are damaging to the environment. Renewable energy sources (RES) are attractive alternative to traditional energy. The issue of RES and its usage promoting is addressed by the European Union long ago and is one of the Lithuanian energy policy objectives set out in the National Energy Strategy and in the Law of Energy of the Republic of Lithuania. Lithuanian RES promotion policy is primarily directed towards the promotion of renewable energy in the manufacturing sector, however, volume of support for specific renewable energy technologies lacks a scientific basis. Energy efficiency policies can be based on direct and indirect price mechanisms, such as subsidies elimination and the integration of external costs in energy prices, which reduce consumption trends in price sensitive sectors and equipment (Štreimikienė, 2002a). The arising external costs while using RES technologies are significantly lower or absent compared with fossil energy. External costs mean an external damage to the environment caused by burning traditional fuels (coal, oil, natural gas). Unfortunately, this particular damage, external cost (externalities), is not reflected in the prices of traditional fuels and ultimate consumer of traditional energy products, however, does not pay these costs or does not compensate people for harm done to them, they do not face the full cost of the services they purchase, i.e. their energy use is being implicitly subsidized, thus energy resources are not allocated efficiently. Scientists agree – underestimating external costs prevents penetration of RES technologies into the market on a large scale (Klevas, Štreimikienė, 2006).

According to economic theory, the main goal of the promotion of RES is to integrate the external benefits of renewables into the price of energy produced from RES. Identifying these benefits and selecting the appropriate support measures is a complex scientific task. Furthermore, it is important to know the attitudes of energy consumers since their attitudes are the foundations of their resulting behavior. Thus, while promoting the use of renewables and their technology, opinions of households, their priorities and the key factors that determine their choice between different energy production technologies must be considered. Assessment of households' willingness to pay (WTP) is being applied in the world for external benefits determination. This particular method allows to evaluate external benefits of RES technology as well as to justify their subsidies while considering the priorities of society and consumers' willingness to pay and promote specific RES technologies.

Moreover, although renewable energy is the inevitable choice for sustainable economic growth, many factors still need to be taken into consideration when investing in a renewable energy technology. Moving towards a sustainable future requires policy actions that solve existing problems without creating new ones and sustainability assessment of renewable energy technologies could be the key for reaching that goal successfully. Properly conducted sustainability assessment of RES technologies can prevent potential barriers or limit them while implementing and using RES technologies, also creating an opportunity to prepare for possible consequences arising from feasible disadvantages of RES.

The problem of research: Forming policy for the promotion of RES based on subsidies and incentives is impossible if consumers' opinion and their preferences for RES technologies are unknown. Consumers are involved in implementing the objectives of Lithuanian RES energy policy, yet their opinion has not been investigated and taken into consideration. In Lithuania issues discussed in scientific literature mostly deal with RES and their technologies promotion on the supply side, for instance (Klevas & Štreimikienė, 2006) dedicated particular part of the their book "Basics of Lithuanian energy economy" for analyzing the promotion of renewable energy economy, including the financial and economic promotion measures, (Katinas, Markevicius, Erlickyte, & Marciukaitis, 2008) examined the ways in which assistance can be maximized to infiltrate RES Lithuanian electricity sector and their potential impact on the environment, (Čiegis & Zeleniūtė, 2008) discussed the economic development aspect of sustainability of Lithuania, (Galinis, Lekavičius, & Miškinis, 2010) analyzed the wider exploitation of RES, (Streimikiene, Balezentis, Krisciukaitienė, & Balezentis, 2012) clarified the multiple criteria decision system, choosing the most sustainable energy technologies, (Gaigalis, Markevicius, Katinas, & Skema, 2014) outlined the analysis of RES promotion in Lithuania in compliance with the EU strategy and policy. However, the issue of RES technology assessment in the world is addressed much more versatile. A strong correlation between environmental attitude and ecological behavior intention has been established – it is important to know the attitudes of energy consumers since their attitudes are the foundations of their resulting behavior (Ek, 2005; Stigka, Paravantis, & Mihalakakou, 2014). Number of studies published over the last years focusing on consumers' preferences towards renewables has increased steadily, thus resulting in a flood of data (Sundt & Rehdanz, 2015). Valuation methods and survey types can vary widely. For instance, (Wood, Kenyon, Desvousges, & Morander, 1995) in their work have analyzed WTP among several key customer segments one of which was residential. (Hanley & Nevin, 1999) used WTP method as suitable in order to estimate "of either an individual's willingness to pay for an improvement in the quality or quantify of some environmental good". (Roe, Teisl, Levy, & Russell, 2001) designed their survey to elicit consumer's WTP for changes in environmental characteristics of residential electricity service using price and environmental disclosure statements. (Ek, 2005) analysed electricity consumers' attitudes towards wind power. (Bergmann, Hanley, & Wright, 2006) used the choice experiment method to estimate people's preferences over environmental and social impacts of hydro, on-shore and off-shore wind power and biomass in Scotland. (Borchers, Duke, & Parsons, 2007) presented findings of a contingent choice experimental design used to estimate consumer preferences and WTP for voluntary participation in green energy electricity programs. (Banfi, Farsi, Filippini, & Jakob, 2008) used a choice experiment method to evaluate consumers' WTP for energy-saving measures in Switzerland's residential buildings. (Bergmann, Colombo, & Hanley, 2008) in their investigation used choice experiment method while focusing on differences in preferences between urban and rural residents. (Longo, Markandya, & Petrucci, 2008) investigated WTP of United Kingdom energy users for different characteristics of energy programs that stimulate the production of renewable energy by using choice experiment. (Zografakis et al., 2010) conducted a contingent valuation method study to analyze and to evaluate the citizens' public acceptance and WTP for renewable energy sources in Crete. (Zorić & Hrovatin, 2012) in their study analyzed WTP in Slovenia for electricity generated from RES. (Guo et al., 2014) in order to assess the value of renewable electricity and obtain information on consumer preferences, estimated WTP of Beijing, China, residents for renewable electricity. (Štreimikienė & Baležentis, 2014) in their pilot study on assessment of WTP in Lithuanian households used choice experiment method in order to provide main drivers of WTP for renewables. (Akcura, 2015) analysed households' preferences and WTP under a mandatory scheme where all households contribute compared to a voluntary scheme where only those who wish to pay to support renewables do so. Therefore, **the main problem** is to assess households’ attitudes towards RES technologies (precisely, the so-called microgeneration technologies – renewable energy generation technologies that are installed in households) as well as criteria according to which households choose to install renewable energy technologies at home.

Object of dissertation – renewable energy cogeneration technologies in households.

Purpose statement – to carry out comparative assessment of RES generation technologies (microgeneration) in Lithuanian households. The latter includes a comprehensive assessment – the best setting of microgeneration technologies according to households’ preferences, households’ willingness to pay for individual (thus separate) microgeneration technologies, as well as multi-criteria evaluation of microgeneration technologies based on other important economic, social and environmental criteria. The purpose statement is being pursued by analyzing the following tasks:

1) Literature review, systematization of market failures and RES barriers that hinder RES development and establishment of evaluation criteria of WTP and multiple-criteria methods for RES technologies applied in households (microgeneration technologies), thereby justifying them and selecting evaluation indicators;
2) Developing a model for the evaluation of RES technologies applied in households (microgeneration technologies) and their application instrumentation;
3) Application of developed model for comparative assessment of RES technologies in Lithuanian households which consists of: collecting empirical data for the multi-criteria assessment and WTP for RES technologies applied in households (microgeneration technologies);
4) Preparing a questionnaire for assessing energy consumers WTP for RES technologies applied in households (microgeneration technologies) and performing the assessment;
5) Preparing a questionnaire for expert examination intended for multi-criteria assessment;
6) Performing multi-criteria evaluation of RES technology based on households WTP for RES technology and the results of experts’ evaluation;
7) Summarizing the results of comparative assessment of RES technologies applied in households (microgeneration technologies) in Lithuania;
8) Based on the results of the research, make recommendations on the application of the model and its improvement.

Practical value. Comparative assessment of microgeneration technologies would allow the state to choose a rational policy for the use and promotion of RES – to allocate funds for promotion among technologies, to form priority promotion areas, to establish the amount of support, subsidies, for different RES technologies applied in households.

After reviewing over 200 literature sources, it has been concluded that method for comparative assessment of RES technologies used and recommend by many researchers is Multi-Criteria Decision Method (MCDM) or Multi-Criteria Analysis (MCA). MCDM is an appropriate choice for solving complex problems. A large number of external variables play a relevant role in orienting decision making and while some of these variables can be manipulated by numerical models, such as cost–benefit analysis, market penetration strategies and environmental impacts, other factors dealing with social and cultural context, political drawbacks and aesthetic aspects, can be assessed only in a qualitative way or with subjective judgment. Therefore, MCDM can give the decision maker considerable help in the selection of the most suitable RES technologies. However, while considering the fact decision makers have wide options of many different techniques, which more or less has equal weight, one can say it can be compensated by its ability to deal with complex problems, nonetheless, nowadays, it might be not enough to decide between trade-offs alternative sources in order to choose the most beneficial one. It is highly important to know the attitudes of electricity consumers as well – since they are paying for RES promotion. Thus, in this dissertation, MCA method is being "backed up", with additional analysis, revealing the needs and uprights of society, i.e. WTP – besides the parameters describing RES technology, households' WTP criteria was included in MCDM, reflecting households' preferences for RES technologies. WTP integration in MCA will suggest the best result which would satisfy decision maker and would be made by taking into account residents opinion.

Methodology. In addition to the analysis of scientific literature different programs were used in this dissertation: factorial design was conducted using R statistical program, program STATA was used for performing WTP method and Excel was used for MCA as well as for performing Monte Carlo method.

Dissertation structure. The thesis consists from three parts. In the first part „The theoretical justification of comparative assessment“ the importance of renewable energy sources (RES) while implementing energy development goals is validated, RES barriers are analyzed and systematized and sustainability assessment of RES technology is substantiated and summarized simultaniously with possible research methods needed in order to conduct sustainability assessment itself.

The second part of dissertation „Methodology for comparative assessment of renewable microgeneration technologies in households“ describes the possible research methods and examines the applicable methodology for households willingness to pay (WTP) for RES technologies and multi-criteria development methods (MCDM) for comparative assessment of RES technologies as well as particular RES technologies, that are possible to install in households, thus, microgeneration technologies, are being sampled as an object of research. Summary of WTP and MCDM conducted studies is also being provided in this part.

In the third part "Application of model for comparative assessment of renewable microgeneration technologies in Lithuanian households" the research conducted from WTP and MCDM is described along with the instruments used to carry it out, as well as the results of households' willingness to pay is presented and the ranking of microgeneration technologies is accomplished.

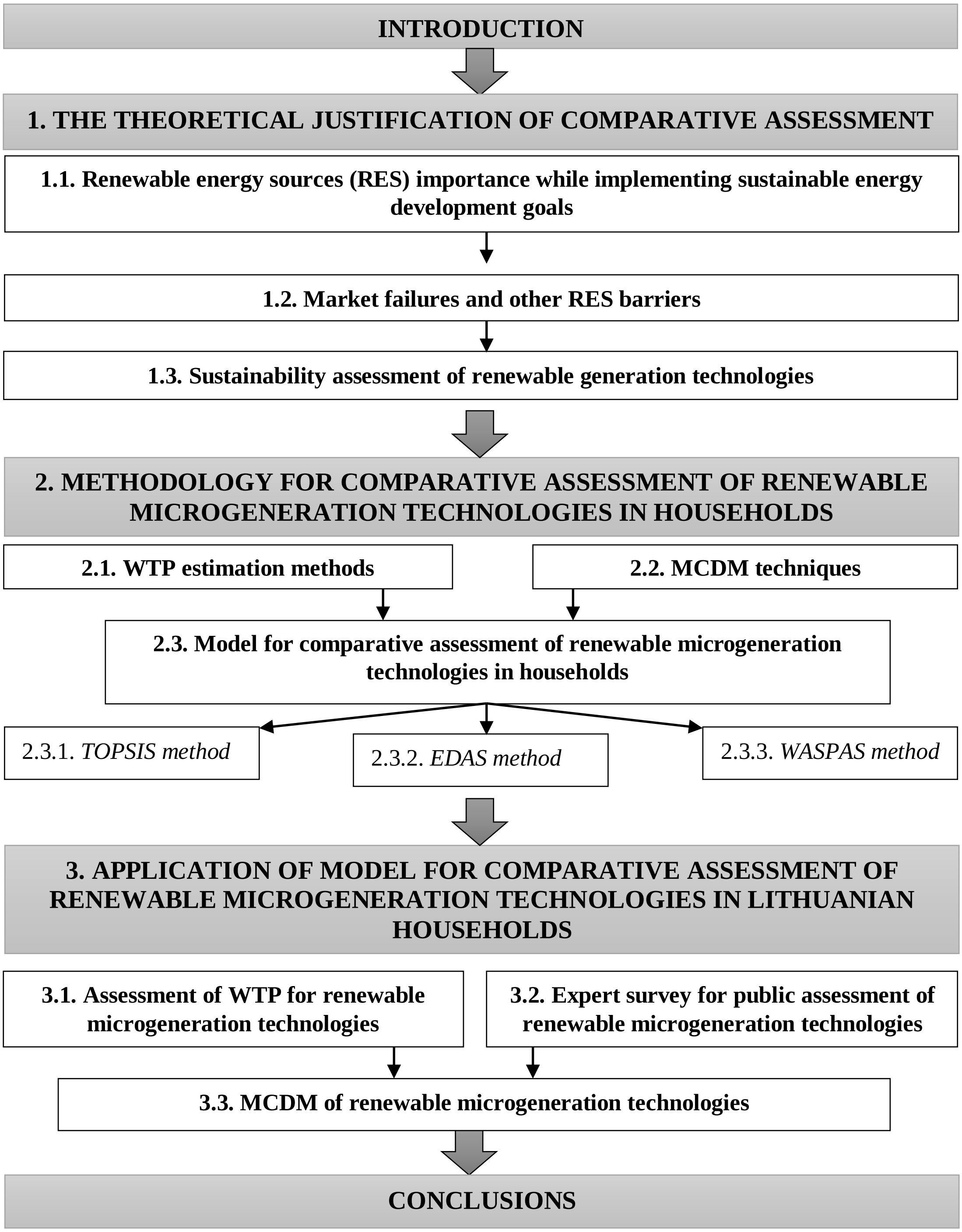


Figure 1. Dissertation scheme

Source: Created by author

Scientific novelty:

- The main criteria for comparative assessment of microgeneration technologies were analysed and systematized;
- The theoretical model for comparative assessment of renewable energy technologies in households (microgeneration technologies) was created capturing household attitudes towards RES technologies and the main criteria according to which households choose to install renewable energy technologies at home;
- The model was implemented by developing a multi-criteria assessment methodology for RES technologies, which consists of WTP and MCDM, allowing comparing and ranking RES technologies, thereby considering public preferences and determining directions of government support for RES technologies.
- The prepared methodology was applied for assessment of renewable energy technologies in Lithuanian households for the first time, providing valuable insights in Lithuanian households' willingness to pay for RES technologies embedded in their houses (microgeneration technologies).

Defensive statements of dissertation:

1. Consumers’ wealth, education and age affects their WTP for RES technologies in households:
    a) Consumers with higher income tend to pay more for RES technologies in their households;
    b) Younger residents tend to pay more for RES technologies in their households;
    c) Residents with higher education tend to pay more for RES technologies in their households.
2. Lithuanian households have relatively little WTP for RES technologies, while comparing it with other Western European countries.
3. Multi-criteria decision method (combined of WTP and MCDM) allows comparing and gathering RES technologies, while considering the preferences of society and determining directions of government support for RES technologies.

1. THE THEORETICAL JUSTIFICATION OF COMPARATIVE ASSESSMENT

1.1. Renewable energy sources (RES) importance while implementing sustainable energy development goals

While the world situation is changing faster than political realities, one of the most important elements of economic development has become a smart, sustainable and inclusive growth (European Commission, 2013). The concept of sustainable development is characterized by an approach to planning and decision-making, which aims to effectively and permanently reduce social and economic disparities and to protect the environment (Tvarios plėtros politika ir vadovas, 2006), while the concept of sustainable growth means "building a resource efficient, sustainable and competitive economy, exploiting Europe's leadership in the race to develop new processes and technologies, including green technologies, accelerating the roll out of smart grids using ICTs (information and communications technologies), exploiting EU-scale networks, and reinforcing the competitive advantages of our businesses, particularly in manufacturing and within our SMEs (small and medium enterprises), as well through assisting consumers to value resource efficiency" (European Commission, 2010). Such an approach is believed to be helpful for European Union (EU) prosper in a low-carbon, resource constrained world while preventing environmental degradation, biodiversity loss and unsustainable use of resources (European Commission, 2010).

The concept of ecologically sustainable development has been spoken for the first time in 1972 in Stockholm at the United Nations Conference on the Environment, in which the relationship between economic development and its impact on the environment was recognized and the term "ecological development" was proposed. In 1987 United Nations World Commission on Environment and Development headed by Norwegian Prime Minister Gro Harlem Brundtland, presented a report entitled "Our Common Future", in which sustainable development issues and policy changes were discussed, and sustainable development was defined as development that meets the needs of the present without compromising the ability of future generations to meet their own needs (Brundtland et al., 1987). The provisions of sustainable development were finally agreed upon in 1992 in United Nations conference on Environment and Development, which was held in Rio de Janeiro, and in which sustainable development was validated at the highest level as a fundamental long-term development of society ideology (Čiegis & Zeleniūtė, 2008).

Many principles of sustainable development are often divided into three aspects: environmental, economic and social. Environment is an indispensable basis for a sustainable development, economics is a measure to achieve sustainable development, good life for all (social aspect) is the aim of sustainable development. Implementation of these economic, social and environmental objectives of sustainable development plays a crucial role in energy (Štreimikienė, 2002a). Energy issues are "a fundamental component of the conceptual and strategic discussions on sustainable development worldwide" (International Atomic Energy Agency, 2006). In order energy to maintain and consolidate sustainable development, the energy development itself must be sustainable (Štreimikienė, 2002a). Sustainable energy means the production and consumption of energy that ensures long-term human development goals in all the social, economic and environmental aspects (Štreimikienė, 2002a).

Energy has become a crucial element for sustainable development and well-being of any country in modern era (Ahmad & Tahar, 2014) – economies are closely linked with energy and depend on it. Still, relatively recently countries around the world have considered their main challenges are sufficient production and consumption of energy (Reddy, Williams, & Johansson, 1997). Until 1997 “energy policy mainly aimed at realizing an affordable, reliable and secure energy system in order to maximally facilitate energy intensive industrial processes” (Negro, Alkemade, & Hekkert, 2012). Only in 1997 the participants of Structural Convention on Climate Change in Japan, Kyoto, signed the Kyoto Protocol, which establish the obligation of countries to suppress global warming (Streimikiene, 2002). In the year 2000 United Nations and the World Energy Council published the survey named "Energy and the Challenge of Sustainability", where it was observed that the key attribute of the modern energy system unsustainability – world's population unequal access to commercial energy and environmental, economic and geopolitical energy discontinuity results that will affect the future. Around that time, when the dispute between Russia and Ukraine arouse over natural gas and the war in Iraq happened it became clear energy systems of different countries depend too heavily on each other which is extremely dangerous (Negro et al., 2012). Thus, it can be emphasized energy production and consumption is closely linked with all the global economic, social and environmental development (Klevas & Štreimikienė, 2006).

Energy is an essential factor in overall efforts to achieve sustainable development (Vera & Langlois, 2007). World countries, in order to realize sustainable development in the field of energy, usually face three main challenges:

1. Energy availability. Only 20% the world's population consumes 80% of energy produced in the world (United Nations Development Programme, 2000). The fact, that around two billion people in developing countries do not use commercial energy, is a concern, since in the future, there will be rising social unrest and political instability in these countries, which can have a direct impact on the economic and social stability of global economy and transition countries (Klevas & Štreimikienė, 2006). The population support systems are necessary to establish in order to ensure the availability of energy to low-income families. A well-functioning and commerce based global energy market would serve for all countries and people's interests (Štreimikienė, 2002a).
2. Power supply. This is an opportunity to use various forms of energy, at any time and in sufficient quantities and at reasonable prices (Klevas, Štreimikienė, 2006). Energy security plays a decisive role in the economy of any country, because uneven distribution of fossil fuels, which in many countries is based on the energy system, determine development of economies and ensure the welfare of the population of individual countries (Štreimikienė, 2002b).
3. The reduction of energy production and consumption negative impact on the environment or renewable energy. Continues use of fossil resources which cause environmental, ecological and technological problems. The development and implementation of technologies, that reduce carbon dioxide emissions, are absolutely necessary measures for reducing pollution, for example: setting the pollution tax or emissions trading (Štreimikienė, 2002b).

Hence the main goal of sustainable energy development ensuring energy production and consumption would guarantee the long-term human development, economic growth and ecological sustainability, while maintaining stable institutions that will ensure global security (Štreimikienė, Čiegis, & Jankauskas, 2007). Therefore, the objective of sustainable energy policy, in order to achieve main sustainable energy development goals, is to ensure (Čiegis, 2004):

- High-quality energy services accessible to every inhabitant of the world;
- The security of energy supply in the short, medium and long term;
- Well-balanced energy network systems that optimize the system's efficiency and cooperation;
- Increasing the efficiency of energy production and consumption, particularly in countries in transition;
- A permanent reduction of the environmental impact of energy, development and adaptation of green technology, moving from pollution-intensive technology (which governs greenhouse gas and other emissions) to less polluting technologies and more use of renewable energy resources.

Defining the core of the energy policy to help achieve a more sustainable energy future is also possible (Štreimikienė, 2002a):

1. Energy security and safety. It is necessary to increase energy security and safety firstly by ensuring energy safety and efficiency, multiplying variety of fuels in use, diversifying energy supply and maintaining strategic and commercial reserves as well as promoting research and development in the area of new technologies and renewable energy sources.
2. Energy production and efficiency. Energy efficiency policies can be based on direct and indirect price mechanisms, such as subsidies elimination and the integration of external costs in energy prices, which reduce consumption trends in price sensitive sectors and equipment (Štreimikienė, 2002a). However, efficiency policies can overcome market failure even without changing the pricing structure, for instance by introducing efficiency standards and labeling equipment and products. Also, legislative provisions, adequately inform users, planners, policy-makers, well-motivated operators and adequate paying for energy systems play a crucial role in the successful implementation of energy efficiency improvement measures (Štreimikienė, 2002a).
3. Economically based energy pricing, while eliminating subsidies and integrating external costs. Energy pricing is crucial in reducing the environmental impact of energy consumption and ensuring energy efficiency improvement measures, however the consideration of all the generation, transmission, distribution and consumption costs is needed in order to guarantee the total efficiency of the economy.
4. Energy market opening, liberalization and economic efficiency growth. The liberalization of the energy market ensures the efficiency of economic growth in the energy sector and contributes to the implementation of sustainable energy development goals (Štreimikienė, 2002b).
5. The new technology research and development of cleaner fossil fuels, renewable energy resources. Research and development of renewable resources, plays a crucial role in ensuring sustainable energy development goals, but such research is necessary to implement institutional support (Štreimikienė, 2002b).

In 2008 European Commission has set targets for the year 2020, 2030 and 2050 that should be achieved through sustainable energy policy (European Commission, 2008). A binding set of laws was developed – “The EU climate and Energy package”. Its’ aim was to ensure that European Union would fulfill its ambitious climate and energy targets, referred as the "20-20-20" targets, for the year 2020 (Roos, Soosaar, Volkova, & Štreimikienė, 2012):

- cut greenhouse gas (GHG) emissions, which include carbon dioxide (CO_2), methane, nitrous oxides, chlorofluorocarbons and water vapor which, upon release, contribute to heating up the lower layers of the atmosphere (Karakosta, Pappas, Marinakis, & Psarras, 2013), by 20% compared to 1990;
- establish a 20% share for renewable energy in final energy consumption (Fig. 2., Fig. 3.) and the share of biofuels up to 10% in transport fuels;
- achieve a 20% reduction in energy consumption by 2020 (to improve energy efficiency).

The above-mentioned targets represent an integrated approach to climate and energy policy, which aims to combat climate change, improve the EU’s energy security and to strengthen its competitiveness.

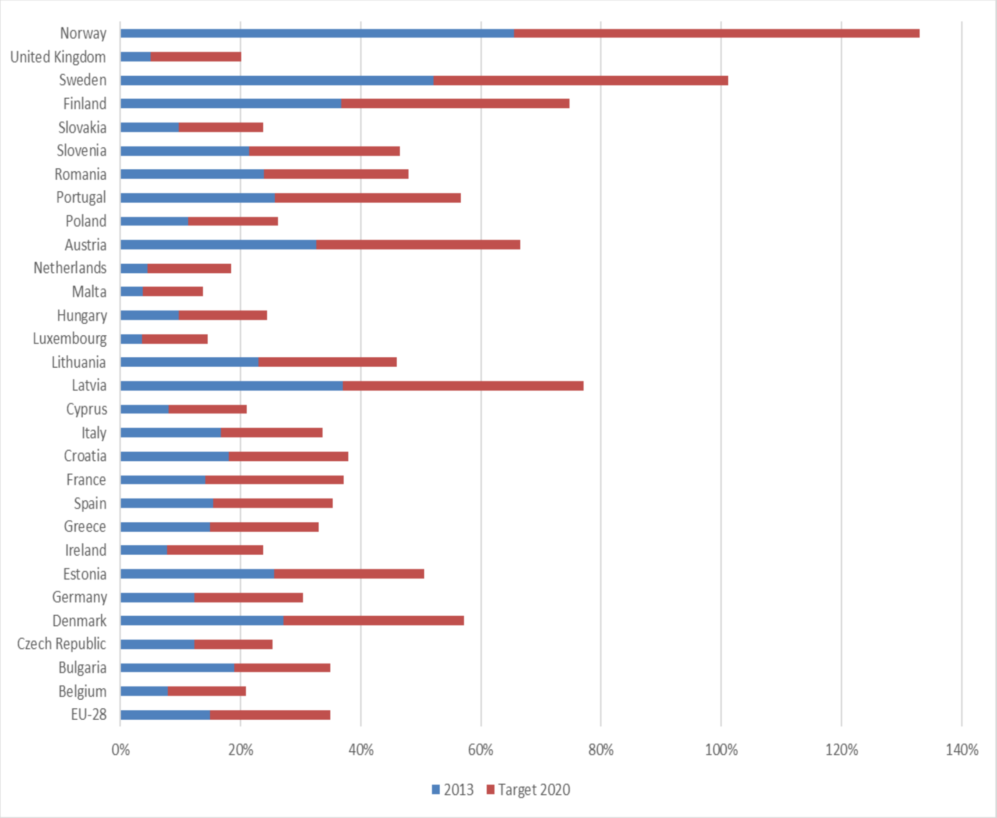


Figure 2. Share of renewable energy in gross final energy consumption

Source: Created by author (EUROSTAT data)

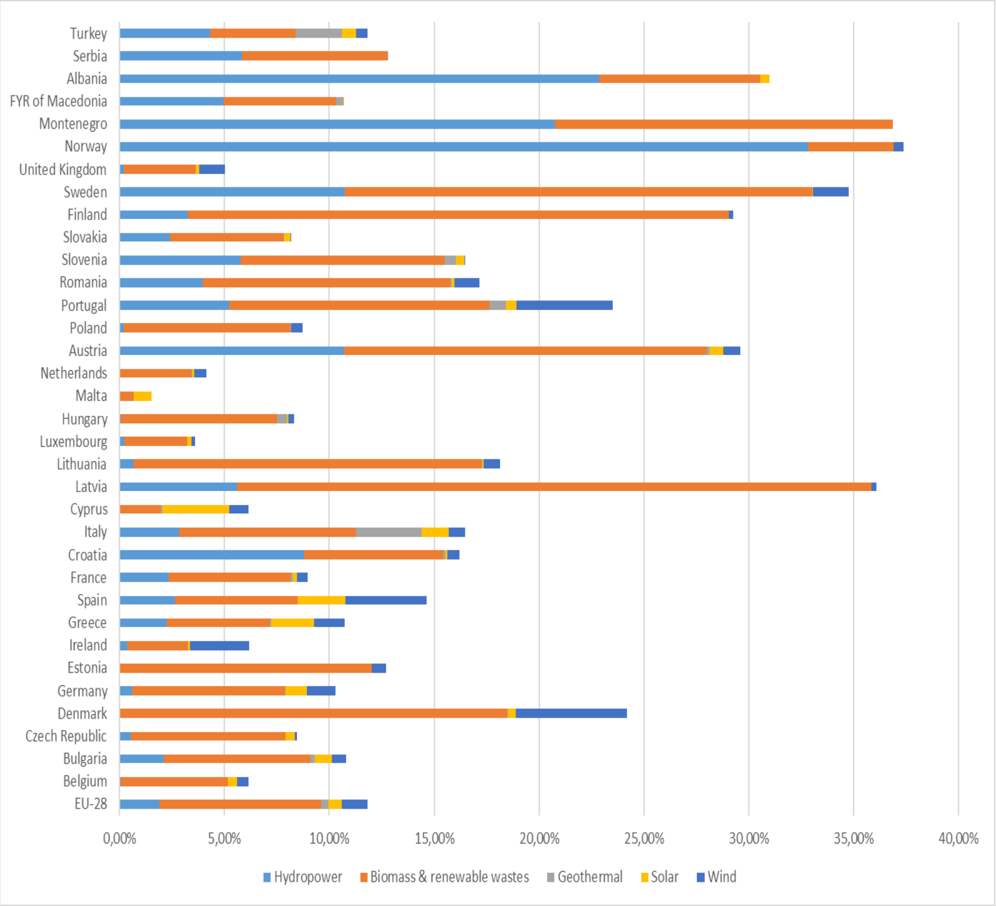


Figure 3. Share of renewables in gross inland energy consumption, 2013

Source: Created by author (EUROSTAT data)

EU leaders are committed to the implementation of European Commission's proposal for 2030 – to reduce GHG emissions by 40% (indicators compared with the ones of year 1990). It is expected that in accordance with this agenda, in 2030 the EU's share of the energy produced from renewable resources, will be 27%, at the same time EU's economic and energy system will become more competitive, secure and sustainable. EU plans that by 2050 GHG emissions will be reduced to a large extent, but the implementation of this objective is a serious challenge for the existing energy systems, since the energy sector is responsible for about 80% of all EU emissions (Nacionalinis atsinaujinančių išteklių energijos veiksmų planas, 2010).

EU's long-term scenario, in order to implement sustainable energy, should be the change of current energy sources with RES, because it is impossible to ensure sustainable development without transferring the global energy system into a cohesive (Štreimikienė et al., 2007). Therefore, RES and its technologies are identified as a means to reduce the impact of the energy system on the global climate and to reduce the dependence of national energy systems on foreign oil and gas (Negro et al., 2012). Renewable energy means aerothermal, hydrothermal and ocean energy, hydropower, biomass, biogas, including landfill and sewage treatment plant gas, as well as other renewable non-fossil resources energy, the technological use of which is available now or will be available in the future (Lietuvos Respublikos Seimas, 2011). RES accumulates the essential qualities inside itself for which these resources has become the research center of attention of all sustainable energy development (Klevas & Štreimikienė, 2006):

- RES means the inexhaustibility of their use;
- in terms of nature processes circulation, RES means the fact that technological progress is oriented to the human activities harmony with natural nature processes circulation;
- made progress was immense in technical sense and only because of high cost of energy, RES is produced of, these sources cannot go to the market on a larger scale.

The issue of RES was addressed in the EU long time ago. In 1995 in White Paper "An energy policy for the European Union" the importance of RES technologies is stated in order to achieve one of the main goals of energy policy – security of supply. RES helps to achieve greater energy efficiency. In 1997 in the White Paper "Energy for the future: renewable sources of energy" the attention is drawn to the fact, that renewable energy sources represent an unacceptably modest contribution to the whole Community's energy balance, particularly in the view of its possible technical potential. In 2009 in White Paper "Adapting to climate change: Towards a European framework for action" was noted that one of the most important European economic recovery plan targets – EU investment in low-carbon technologies, such as promoting greater energy efficiency and introducing and exploiting green products.

Another important document indicating the significance of RES is Green Paper featured in the late 1996 – "Energy for the future: renewable sources of energy". This paper argues that strategic objective of energy policy is to promote the use of RES thus implementing the environmental challenges, increasing employment and ensuring sustainable regional development. In 2000 in Green Paper "Towards a European strategy for the security of energy supply" the emphases are laid that, RES is a key tool in the fight against global warming. In 2005 Green Paper "on energy efficiency or doing more with less" appeared. The main its objective was to identify barriers for use of energy-saving options, and submit suggestions on how these barriers can be overcome. In 2006 in Green Paper "A European strategy for sustainable, competitive and secure energy" the question was raised how to prepare a long-term, safe and reliable investment system, which enables to develop renewable energy use in Europe. In 2007 in Green Paper "Adapting to climate change in Europe - options for EU action" was noted that in order to adapt to climate change, it is necessary to take many steps, one of which is improvement of world's resources knowledge, including renewable energy sources, their flows and availability. In 2010 in Green Paper "EU development policy in support of inclusive growth and sustainable development" was stressed that exploiting countries potential of RES, firstly a qualified labor force is required. In 2013 in Green Paper "A 2030 framework for climate and energy policies" the importance of earliest possible moment to develop an energy strategy for 2030 is highlighted. One of the reasons for which is ensuring a competitive economy and a reliable energy system. Therefore, clear formulation of objectives for 2030 would greatly contribute in achieving those goals, as it is expected that the need for efficient and low-carbon technology would greatly increase in the future thus encouraging research, development and innovation along with possibility for new employment and economic growth.

Number of other legislative acts in the field of renewable energy resources exist in EU. The latest EU directives on RES can be seen in Table 1.

Table 1. Recent European Parliament directives on RES

Directives	Objective
Directive 2001/77/EC of the European Parliament and of the Council of 27 September 2001 on the promotion of electricity produced from renewable energy sources in the internal electricity market	The purpose of this Directive is to promote an increase in the contribution of renewable energy sources to electricity production in the internal market for electricity and to create a basis for a future Community framework thereof.
Directive 2003/30/EC of the European Parliament and of the Council of 8 May 2003 on the promotion of the use of biofuels or other renewable fuels for transport	This Directive aims at promoting the use of biofuels or other renewable fuels to replace diesel or petrol for transport purposes in each Member State, with a view to contributing to objectives such as meeting climate change commitments, environmentally friendly security of supply and promoting renewable energy sources.
Directive 2006/32/EC of the European Parliament and of the Council of 5 April 2006 on energy end-use efficiency and energy services and repealing Council Directive 93/76/EEC (Text with EEA relevance)	The purpose of this Directive is to enhance the cost-effective improvement of energy end-use efficiency in the Member States by: • providing the necessary indicative targets as well as mechanisms, incentives and institutional, financial and legal frameworks to remove existing market barriers and imperfections that impede the efficient end use of energy; • creating the conditions for the development and promotion of a market for energy services and for the delivery of other energy efficiency improvement measures to final consumers.
Directive 2009/28/EC of the European Parliament and of the Council of 23 April 2009 on the promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC (Text with EEA relevance)	This Directive establishes a common framework for the promotion of energy from renewable sources. It sets mandatory national targets which specify what share of gross final energy consumption and energy consumed in transport sector shall consist of renewable energy. It also establishes rules relating to renewable energy, which regulate statistical transfers between Member States, common projects of Member States and projects between Member States and third parties, guarantees of origin, administrative procedures, information and training, as well as access to the electricity grid. It establishes sustainability criteria for biofuels and bioliquids.
Directive 2009/72/EC of the European Parliament and of the Council of 13 July 2009 concerning common rules for the internal market in electricity and repealing Directive 2003/54/EC (Text with EEA relevance)	This Directive establishes common rules for the generation, transmission, distribution and supply of electricity, together with consumer protection provisions, with a view to improving and integrating competitive electricity markets in the Community. It lays down the rules relating to the organization and functioning of the

	electricity sector, open access to the market, the criteria and procedures applicable to calls for tenders and the granting of authorizations and the operation of systems. It also lays down universal service obligations and the rights of electricity consumers and clarifies competition requirements.

Source: Created by author "EUR-Lex" access to European Union law http://eur-lex.europa.eu/

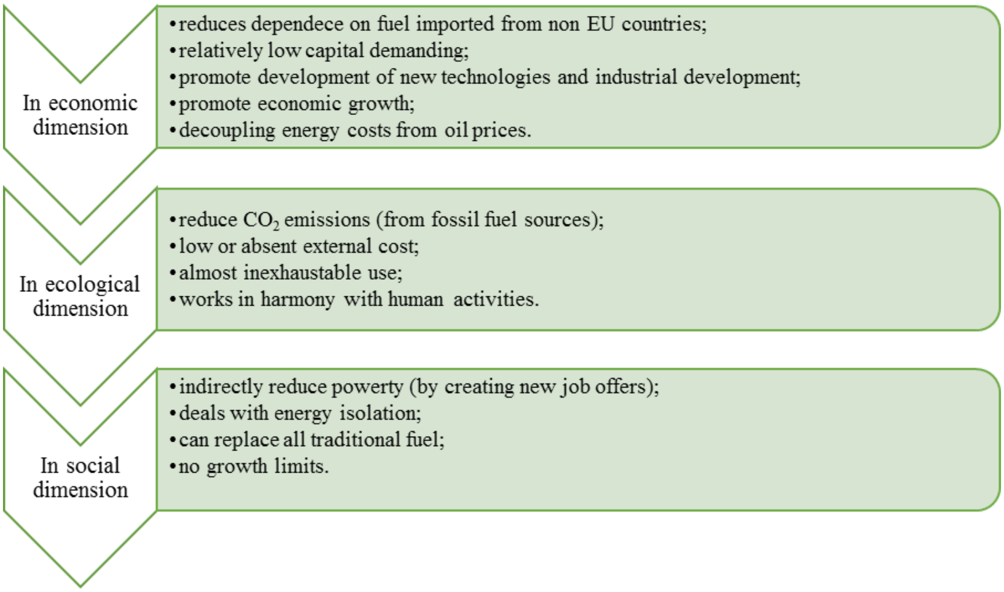
RES development is an attractive alternative to traditional energy as fossil fuel burning significantly increases environmental pollution and accelerates global warming, causing more natural disasters. Economic theories emphasize the importance of renewable resources as having no limits of growth, countervailing most maneuverable type of capital (Klevas & Štreimikienė, 2006). The emphases should be laid on dual external benefit that RES technology can offer:

- Not only RES technologies help to solve the problems of climate change, these technologies make it possible to deal with the energy isolation and economic problems, and also indirectly reduce poverty by making a positive effect on the country's level of employment and creating new job opportunities. RES technologies promote industrial development, economic growth and development of new technologies (Klevas & Štreimikienė, 2006). RES can also be suitable for less developed countries as relatively low capital demanding and decentralized options (Karakosta et al., 2013).
- The arising external costs while using RES technologies are significantly lower or absent compared with fossil energy. External costs mean an external damage to the environment caused by burning traditional fuels (coal, oil, natural gas).

Unfortunately, this particular damage, external cost, or so-called externalities, is not reflected in the prices of traditional fuels (Bridges, Felder, McKelvey, & Niyogi, 2015; Streimikiene & Alisauskaite-Seskiene, 2014). According to (Owen, 2006), ultimate consumer of traditional energy products, however, does not pay these costs, or does not compensate people for harm done to them, they do not face the full cost of the services they purchase, i.e. their energy use is being implicitly subsidized, thus energy resources are not allocated efficiently. Therefore, underestimating external costs prevents penetration of RES technologies into the market on a large scale (Klevas & Štreimikienė, 2006). Furthermore, although the deployment of RES, which was aided by national policy incentives, such as the feed-in-tariff, and mechanisms of the Kyoto protocol, such as the Clean Development Mechanism, has been large during the last decade (Karakosta et al., 2013), and the environmental benefits of renewable energy are obvious and many countries have included RES investments in their strategy towards reducing dependence on oil and gas imports and the respective price volatilities, as well as mitigating GHG emissions (Menyah & Wolde-Rufael, 2010). Consequently, fossil fuel generated energy-efficient systems cheapness does not let to displace conventional energy kind from dominant positions (Klevas & Štreimikienė, 2006).

In order to boost the popularity of renewable energy, the world's governments develop and implement a variety of mechanisms to promote new technology developers, producers and investors to become involved in renewable energy generation market (Klevas & Štreimikienė, 2006). It usually takes the form of financial, institutional, or educational aid (White, Lunnan, Nybakk, & Kulisic, 2013). In most cases governments provided financial support may consist of introducing subsidization schemes, grants, and/or feed-in tariffs/quota systems (White et al., 2013). The most popular and widely used RES promotion method is to encourage the setting of tariffs (support is given to all energy producers using RES) and targeted investment (that is, one-time support). According to (Mountford, 2000) RES technologies and their subsidies, as well as energy efficiency and conservation measures promotion, are the only ones justified in subsidizing energy (Mountford, 2000). Renewable energy subsidies are justified in order to align with the environmental impact of different alternatives, as above-mentioned external costs are not sufficiently integrated in energy prices (Štreimikienė et al., 2007).

All in all, it can be said, RES and their technologies are highly important to sustainable development, moreover, sustainable development cannot be achieved without use of RES. Furthermore, scientists define these two concepts (sustainability and renewable energy) as twin concepts, which "emerged as a defining imperative of humanity that is situated at the nexus of science, technology, culture, economics, policy and the environment" (Mardani, Jusoh, Zavadskas, Cavallaro, & Khalifah, 2015). "These twin concepts are both framed as a means to mitigate the negative impacts of natural resource depletion, energy consumption, water consumption and climate changing GHG emissions associated anthropogenic activities" (Mardani et al., 2015). Thus, in my opinion, the tightness of RES technologies and sustainable development can be described and demonstrated best through three different dimensions – economic, ecological and social, which tightly relate to each other and intervene:



In economic dimension

- reduces dependece on fuel imported from non EU countries;
- relatively low capital demanding;
- promote development of new technologies and industrial development;
- promote economic growth;
- decoupling energy costs from oil prices.

In ecological dimension

- reduce CO_2 emissions (from fossil fuel sources);
- low or absent external cost;
- almost inexhaustable use;
- works in harmony with human activities.

In social dimension

- indirectly reduce powerty (by creating new job offers);
- deals with energy isolation;
- can replace all traditional fuel;
- no growth limits.

Figure 4. RES and their technology importance for sustainable development

Source: Created by author

1.2. Market failures and other RES barriers

Although RES deployment has been mainly focused on achieving environmental goals, its potential contribution to energy security went not unnoticed, highlighting the potential of RES to improve the security of energy supply in consuming countries (Francés, Marín-Quemada, & González, 2013). RES provides many additional advantages – it allows creating new vacancies in the production, transportation, construction and operation chain, reduces the cost of imported energy sources and also reduce country's energy dependence (Galinis et al., 2010). According to (Verbruggen et al., 2010), renewable energy sources and technologies are diverse, and their future depends on a variety of circumstances. Furthermore, they are not limited by the resources, but the technological, economic and political factors, thus it is important to define each of these factors' potential (scientists use word "potential" in a mean of something that can develop or become actual) (Verbruggen et al., 2010):

- "Market potential: the amount of renewable energy output expected to occur under forecast market conditions that are shaped by private economic agents and are regulated by public authorities" (Verbruggen et al., 2010). It is based on expected private income and expenses and estimated in private prices (including the calculation of subsidies and taxes) and private discount rates. As the world countries differ in their economic context and policies, thus market potential of each country is different. In assessing the market potential there always remains a certain level of uncertainty, since it is impossible to predict what the reaction is going to be towards certain political instruments, future costs, prices and consumer preferences (Verbruggen et al., 2010).
- "Economic potential: the amount of renewable energy output projected when all (social and private) costs and benefits related to that output are included" (Verbruggen et al., 2010). In realizing the economic potential, negative external costs and co-benefits of all energy users and of other economic activities are priced, while social discount rates are used to balance the interests of consecutive human generations (Verbruggen et al., 2010). So far, this potential is aspirational. In order to implement this potential one of the first steps should be public prosperity in the long term and the internalization of external costs, which means external cost effects compensation by the effort or expense of phenomenon (traditional fuel burning) which caused these costs. Internalization of external costs into the full energy production cost is of high importance in the energy sector since it could increase the attractiveness of using RES for energy generation (Štreimikienė & Ališauskaitė-Šeškienė, 2013) and is considered an efficient policy instrument for reducing negative impacts on energy supply and use (Rafaj & Kypreos, 2007). Internalization advantage in this case should be reflected in energy fuel prices paid by end users (Verbruggen et al., 2010). As well as in the case of market potential forecast, a certain level of uncertainty remains while forecasting economic potential due to yet fully untested scale of negative effects caused by external costs and pricing of this scale (Verbruggen et al., 2010).
- Sustainable development potential: required amount of renewable energy produced when the implementation of sustainable development is being done in all three aspects: environmental, economic and social (Verbruggen et al., 2010). In this case the separation between economic and political components is needed in order to

stress the importance of political aspect – “when public governance is more directed to developing RES, the environmental, economic and social interests can be better balanced and integrated” (Verbruggen et al., 2010).
- “Technical potential: the amount of renewable energy output obtainable by full implementation of demonstrated and likely to develop technologies or practices” (Verbruggen et al., 2010).

External costs are not the only obstacles that wider integration of RES in the total energy sector. RES has to overcome environmental, socio-economic, technical and institutional barriers (Mourmouris & Potolias, 2013). And, like potentials, these barriers are “contextual and dynamically evolving over time, difficult to identify accurately” (Verbruggen et al., 2010). Rapid diffusion of RES in the electricity power sector is crucial if the EU wants to fulfill its 2050 CO_2 reduction commitments” (Eleftheriadis & Anagnostopoulou, 2015), yet above-mentioned barriers impede the penetration of RES into the market. Thus, identifying and alleviating all barriers that hinder the development of RES is a necessity for successful deployment of these technologies (Eleftheriadis & Anagnostopoulou, 2015).

Two different scientific paradigms explaining slow diffusion of RES technologies exist (Negro et al., 2012). The first one, neo-classical economic paradigm, argues that market failures are the main reason of slow RES diffusion. Often proposed solutions for it is getting the prices right (with help of various tax incentives and subsidies), as well as public research and development (R&D) subsidies (Negro et al., 2012). Lack of investment funds can be one of the main limiting factors in addressing the broader problem RES (Galinis et al., 2010), therefore encouraging tariffs (support, given to all energy producers using RES) also may become the solution. Nevertheless, market failure approach is particularly weak in identifying where above-mentioned subsidies should go, and what their level should be (Negro et al., 2012).

Neo-classical view is being challenged by the second scientific paradigm which highlights the importance of systematic innovation – it is believed that innovation speed, direction and success are strongly influenced by the environment in which this innovation developed (Negro et al., 2012). This environment is called the innovation system, technological innovation system or ecosystem, thus, scientists, supporting this approach, argue there may exist many other weaknesses in the system (apart from market imperfections) that hinder the rapid development and diffusion of innovation (Negro et al., 2012).

Market barriers and market failures, however, are identified usually as the main brake for the development of RES. Furthermore, types of these barriers that hinder the development of RES infrastructures can be categorized in various ways, for instance – technical and non-technical barriers, societal, administrative or financial barriers (Boie, Fernandes, Frías, & Klobasa, 2014). More general way of grouping barriers is their distribution into (Štreimikienė & Pareigis, 2007):

- commercial – this kind of barriers are a result of competitiveness of new technologies and traditional technologies;
- price distortions – due to existing subsidies and unequal tax burden on renewable energy technologies compared to traditional (conventional) technologies;
- market failures – in terms of RES provided public benefit and negative external effects of traditional energy resources;

- market barriers, such as inadequate information, access to capital constraints, exchange with initiatives between home owners and tenants and high transaction rates by making small purchases, as well as institutional barriers. Anything that slows the rate at which the market for a technology expands can be referred to as a market barrier (Owen, 2006).

In order to compete with traditional technologies, such as the use of nuclear and fossil fuel, RES have to overcome two major commercial barriers: poor infrastructure and lack of economies of scale in the production of the traditional technologies (Štreimikienė & Pareigis, 2007). Infrastructure barriers often come with significant financial expenditure, given the substantial costs associated with the upgrades of high voltage and retail electricity networks (Martin & Rice, 2012).

Most of RES benefits consist of public goods, such as pollution reduction and environmental benefits for society. However, users who buy green energy and pay for it has to breathe the same air as all consumers buying cheaper energy (Štreimikienė & Pareigis, 2007). Difficulty occurs when not all the market participants, energy consumers, are willing to pay for such public goods, hence, heavier tax burden goes to consumers, who willingly pay for green energy.

Although public awareness of RES can offer multiple benefits, as it can contribute to the social acceptance of projects based on these energy sources and to overall improvement of consumers' energy behavior (Karytsas & Theodoropoulou, 2014), however, RES technologies also face barriers in market transactions – consumers don't have enough information, given by energy supply companies, about energy sources and their emissions to the atmosphere. In addition, RES projects and firms implementing it are generally small, it has less resources compared to large companies (Štreimikienė & Pareigis, 2007). Thus, the ability of these companies to negotiate with customers and major market participants, to participate in lobbying and to carry weight in market procedures as well as participate in industry forums, determining rules of marketing, is rather low (Štreimikienė & Pareigis, 2007).

Barriers can be classified in a general way. Different types of market barriers and measures that can be enabled to alleviate them are summarized in Table 2. (International Energy Agency, 2003):

Table 2. Types of market barriers and measures that can alleviate them

Barriers	Key characteristics	Typical measures
Uncompetitive market price	Scale economies and learning benefits have not yet been realized	• Learning investments • Additional technical development
Price distortion	Costs associated with incumbent technologies may not be included in their prices; Incumbent technologies may be subsidized	• Regulation to internalize external costs or remove • subsidies • Special offsetting taxes or levies • Removal of subsidies
Information	Availability and nature of a product must be understood at the time of investment	• Standardization • Labelling • Reliable independent information sources • Convenient & transparent
Transactions costs	Costs of administering a	

	decision to purchase and use Equipment (overlaps with ‘‘Information’’ above)	calculation methods for decision making
Buyer’s risk	• Perception of risk may differ from actual risk (e.g. ‘pay-back gap’) • Difficulty in forecasting over an appropriate time period	• Demonstration • Routines to make life-cycle cost calculations easy
Finance	• Initial cost may be high threshold • Imperfections in market access to funds	• Third party financing options • Special funding • Adjust financial structure
Inefficient market organization in relation to new technologies	• Incentives inappropriately split—owner/designer/ user not the same • Traditional business boundaries may be inappropriate • Established companies may have market power to guard their positions	• Restructure markets • Market liberalization could force market participants to find new solutions
Excessive/inefficient regulation	Regulation based on industry tradition laid down in standards and codes not in pace with developments	• Regulatory reform • Performance based regulation
Capital stock turnover rates	Sunk costs, tax rules that require long depreciation & inertia	• Adjust tax rules • Capital subsidies
Technology-specific barriers	Often related to existing infrastructures in regard to hardware and the institutional skill to handle it	• Focus on system aspects in use of technology • Connect measures to other important business issues (productivity, environment)

Source: (International Energy Agency, 2003)

However, this particular list of barriers along with typical measures that can alleviate them is not comprehensive, therefore is not meant to suggest that the individual barriers are tight categories (International Energy Agency, 2003).

Since different types of barriers are closely relative – other categorizations are possible (Müller, Brown, & Ölz, 2011):

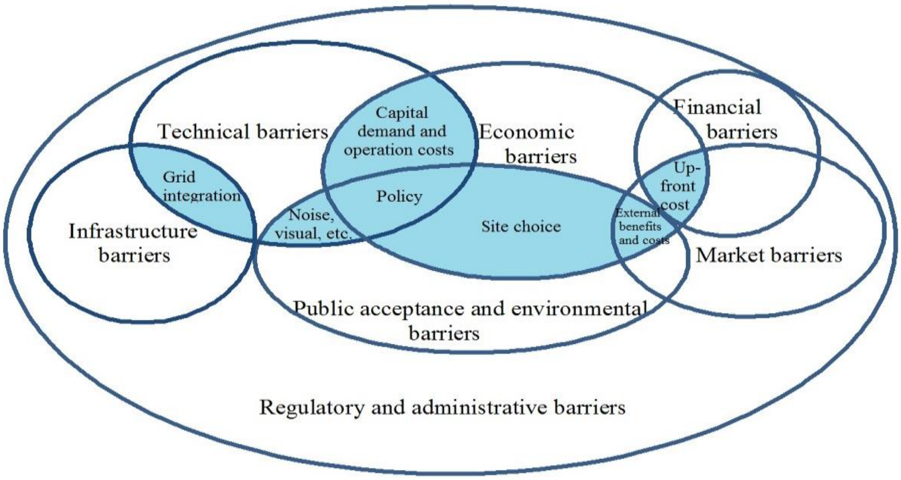


Figure 5. Barriers to renewable energy development

Source: (Müller et al., 2011)

According to (Müller et al., 2011), “an economic barrier is present, if the cost of a given technology is above the cost of competing alternatives, even under optimal market conditions”. As can be seen in Fig. 5., blue color areas are problems, which happens when two barriers overlap, e. g. side choice problem occurs because of economic and public acceptance and environmental barriers, grid integration problem occurs because of technical and infrastructure barriers, capital demand and operation costs problem occurs when technical and economic barriers overlap. In other words, all of these problems, which may occur, demand certain policy measures in order to be solved. Policy itself is neither problem nor a barrier – it is a toll for solving a problem. (Müller et al., 2011) stress the direct connection between technological maturity and economic barriers, and categorize all other types of barriers as non-economic:

Table 3. Barriers of RES technology

Barriers	Key characteristics
Techno-economic barriers	Relate to the direct costs of a certain technology in comparison to competing technologies, given the internalization of all external costs and ideal framework conditions.
Non-economic barriers	Relate to factors that either prevent deployment of RES technology all together (no matter how high the willingness to pay) or lead to higher costs than necessary or distorted prices. Further differentiation of barriers is possible: – regulatory and policy uncertainty barriers; – institutional and administrative barriers; – market barriers; – financial barriers; – infrastructure barriers; – lack of awareness and skilled personnel; – public acceptance and environmental.

Source: (Müller et al., 2011)

Regulatory and policy uncertainty barriers mostly appear in cases of bad policy design or discontinuity and/or insufficient transparency of policies and legislation (Müller et al., 2011). Institutional and administrative barriers include the lack of strong institutions, clear responsibilities and complicated or slow procedures (Müller et al., 2011). Müller, Brown, & Ölz attribute to market barriers "inconsistent pricing structures hat disadvantage renewables, asymmetrical information, market power, subsidies for fossil fuels, and the failure of costing methods to include social and environmental costs". Financial barriers, according to above-mentioned scientists, may be associated with an absence of adequate funding opportunities and financing products for renewable energy. Infrastructure barriers mainly center on the flexibility of energy system and public acceptance and environmental barriers linked to experience with planning regulations and public acceptance of RES (Müller et al., 2011). As for lack of awareness and skilled personnel – these non-economic barriers relate to insufficient knowledge and insufficient numbers of skilled workers (Müller et al., 2011). Different categorization of RES barriers is possible because different types of barrier are closely relative.

All economic processes are strongly influenced by current energy system, thus the aim to revolutionize the whole energy system, would cause the wave of changes in all other economic processes, while transitioning to green energy consumption. Transition from traditional energy to renewable energy consumption should be very gradual, and for every barrier to overcome different measures are being offered. Scientists Karakosta, Pappas, Marinakis, & Psarras suggest classifying barriers by the specific RES technology, as well as systematize drivers that hamper those barriers (Karakosta et al., 2013):

Table 4. Barriers and drivers of RES technology

RES technologies	Barriers	Drivers
Biomass gasification (Biomass CHP (Combined Heat and Power) poplar/ Straw)	• Lack of internalization of external costs in power generation • Lack of effective policies to improve energy security and reduce CO2 emissions • Low conversion efficiency • Transportation cost • Feedstock availability (competition with industry and biofuels for feedstock, and with food and fiber production for arable land) • Lack of supply logistics • Risks associated with intensive farming (fertilizers, chemicals, biodiversity)	• Prospective energy price development • Security of selling electricity (feed-in laws) • Diversification of energy sources, energy import dependency • Diversification of farmers' income • Land use competition (e.g. crops): transport biofuels, bio based materials, food, nature conservation • European policy framework supporting CHP
Molten carbonate fuel cells fed with wood gas (Fuel cells MCFC)	• High cost of fuel cell stack and reformer • Lifetime, degradation due to material science issues • Reliability not yet proven • Many competitors	• High electric efficiency • Energy security • Low criteria pollutant emissions • Reduced vibration, high power to heat ratio

Offshore wind farms	• Lack of incentive schemes • Impacts of variability on power system reliability • Access to transmission • Perceived visual and ecological impacts • Structure of conventional electricity markets	• Increased performance and reliability • Technology advances • Larger turbines (when installed offshore) • Increased manufacturing capacity
Solar photovoltaics (PV)	• High production costs • Low energy density (low efficiency and low number of operating hours per year) • Intermittent source in an electricity grid	• Favorable regulatory framework • Instrument for climate change policy • Decentralized distribution system • Technological and cross-sectorial spillovers • Competitive and dynamic market • Active role of venture capital
Solar thermal power plants	• High capital costs • Limited potentials to connect South Europe and North Africa with Central Europe by use of high voltage direct current line	• Objective of security of supply • Enforced direct market support for RES (feed-in-laws) • Preferring non-intermittent electricity suppliers • Advanced side applications and side products • Increasing demand for local added value • Aiming at conflict neutral technologies

Source: (Karakosta et al., 2013)

According to above-mentioned scientists RES technologies can be categorized into five main (Table 4.):

1) Biomass gasification – Combined Heat and Power (CHP) plants can use biomass for power generation, along with heat. Biomass CHP plants are considered mature technologies and short rotation coppiced poplar and straw can be used as fuel for the gasification process. Scientists stress "this specific technology faces specific barriers for deployment, which are related to the lack of effective policies to promote it, the lack of internalization of external (transportation) costs, the feedstock availability and the risks of intensive farming". Next to this they emphasize "feed-in laws provide secure selling perspectives, it could raise the farmers' income and it can certainly contribute to energy diversity and independence".
2) Molten carbonate fuel cells fed with wood gas – Molten Carbonate Fuel Cells (MCFC) belong to the high-temperature fuel cells and are used for electricity heat in residential and commercial applications – feeding them with wood gas constitutes a renewable source for electricity production (Karakosta et al., 2013). Emphasize is

maid, “use of MCMF produces moderate chemical waste, which is relatively less when feeding then with wood gas. The technology chain involves plant construction and operation, gas drilling and pipelines, as well as wood gas logging and transport. The use of wood gas also requires acceptance of wood harvest and transport.” As it is depicted in Table 4., “high costs and performance degradation are certainly blocking the deployment of this technology, although the favourable policies and the high efficiency makes MCMF a promising technology”.

3) Offshore wind farms – scientists stress, “increased performance, capacity and reliability of offshore wind farms has made them an attractive option for increased use, while the lack of incentives, the difficulty in getting access to transmission, the ecological impacts from the deep sea installations and the current structure of electricity markets are hindering their further deployment” (Karakosta et al., 2013)
4) Solar photovoltaics – “wafer-based crystalline silicon currently represents the main technological route for the production of Photovoltaics (PV) modules”. One type of these technologies is used in solar plants or buildings while others are mostly used on buildings. According to scientists, although PV installations have low energy density with high intermittency and comparatively high production costs, in most countries a favorable legal framework exists, such as feed-in tariffs along with instruments for climate change which promote such decentralized RES (Karakosta et al., 2013).
5) Solar thermal power plants – Karakosta, Pappas, Marinakis, & Psarras concludes “chemical waste produced is of medium level and the public acceptance is generally good, although the historic experience is limited. The visual impact can be significant, but minimal if the plant is installed in remote areas”. Scientists also stress “it can enhance the security of supply and, when coupled with thermal storage to produce electricity in the absence of solar irradiation, can become an almost non-intermittent electricity supplier”.

Often cases occur when barriers overlap, interact and influence the decision to invest in new technologies. The following example for that is situation when technological barriers, production costs, and large-scale implementation limitations become main reasons for the small share of wind and tidal energies from the world’s total energy mix (Hadian & Madani, 2015). Consequently, identifying and alleviating all barriers that hinder the development of RES becomes a high importance for successful deployment of these technologies (Eleftheriadis & Anagnostopoulou, 2015). All things considered, it seems reasonable to assume that, because of different RES and their technology, used in different countries, as well as their usage intensity, countries economic environment, market potential, market failures and other barriers for development of RES, different measures should be applied for mitigation of RES barriers while specific situation is being considered.

Increased utilization of RES would solve many essential challenges in the world – ecological crisis, social tensions, unemployment and economic stagnation, however, market failures and other RES barriers are basically the main reason utilization of RES is still far from its potential at global scale (Dombi, Kuti, & Balogh, 2014). One might not forget, such a major barrier as the timing of RES targets and the uncertainty regarding future targets (Jacobsen, Pade, Schröder, & Kitzing, 2014), not to mention, conventional fossil fuels, including oil, coal, and natural gas, continue to dominate the market due to its low cost and high availability, while at the same time challenging the principles of sustainability (Evans, Strezov, & Evans, 2009).

1.3. Sustainability assessment of renewable generation technologies

"Efficient production, distribution and use of energy resources and provision of equitable and affordable access to energy while ensuring security of energy supply and environmental sustainability are some of the energy policy objectives towards a sustainable energy system" (Doukas, Andreas, & Psarras, 2007).

Countries are supporting investments in renewable energy by many different types of support schemes and with different levels of support (Jacobsen et al., 2014).

Furthermore, cooperation and coordination across countries can contribute to a more efficient expansion of renewable generation in Europe and can therefore reduce the costs of compliance with the 2020 renewable targets (Jacobsen et al., 2014). Yet fighting barriers is not enough. In order to mitigate the barriers or circumvent them, the feasibility of energy alternatives in different regions should be considered, as not all energy sources are accessible in all regions due to different physical, technological, legal and institutional barriers (Hadian & Madani, 2015). Development goals may also vary by regions, therefore utilization of RES needs to meet local conditions, including available resources, such as labor supply, knowledge and infrastructure (Dombi et al., 2014).

Unfortunately, not only RES technologies have above-mentioned advantages (great potential for sustainability, technically feasible, economically viable, socially acceptable alternative to traditional fuels), they have their own disadvantages as well (Dombi et al., 2014; Stigka et al., 2014). Furthermore, common features to all RES are their already mentioned usually higher cost and the fact none of them is solely beneficial for the environment (Kosenius & Ollikainen, 2013). And although four of most common sources (wind power, hydropower, energy from wood and energy from crops) can replace CO_2 emissions in different degrees (Kosenius & Ollikainen, 2013), unintended consequences emerging from the increased use of renewables exist, especially with respect to their effects on other valuable natural resources (e.g., water and land) in the long run (Hadian & Madani, 2015). According to (Hadian & Madani, 2015), such RES as hydropower and biomass, affect water more than the others and additionally, the production of some energy (like ethanol and biomass) requires large land areas. These secondary impacts on water and land can establish barriers to sustainable development as the pressure on a major component of the ecosystem (e.g., land, water) can eventually yield to the failure of that component and even to the collapse of the whole system due to the strong interrelations of ecosystem components (Hadian & Madani, 2015). Wind power can also cause negative landscape effects and is detrimental to bird and bat populations (Kosenius & Ollikainen, 2013). Furthermore, bioenergy crop production (such as corn, wheat or barley for ethanol) is a source of nutrient leaching and it reduces biodiversity (Kosenius & Ollikainen, 2013; Lankoski & Ollikainen, 2011). Yet "in rural areas, bioenergy crop projects may create new income sources and employment which replaces traditional agricultural jobs and improves the declining profitability of agriculture" (Kosenius & Ollikainen, 2013). Zografakis et al. (2010) suggested a clear systematized list of RES advantages and disadvantages:

Table 5. Advantages and disadvantages of RES

Advantages	Disadvantages
• Decrease of environmental impacts from the over exploitation and use of fossil fuels • Increase of the security of energy supply • Reduction of the oil dependence and of oil contribution to national accounts balance • Benefit for tourism development through cleaner environment • Improvement of quality of life due to pollution reduction • Development of local know how on RES technologies • Creation of new vacancies	• Visual pollution, especially for wind energy • Increased installation cost • Fluctuations in their production availability

Source: (Zografakis et al., 2010)

However, regarding the ecological problems, world has crossed or at least has come close to that border where the space for the long-run survival of the human civilization is doubtful (Dombi et al., 2014; Meadows, Randers, & Meadows, 2004). Humanity stands before two intrinsically linked global challenges – development and climate change (Yadoo & Cruickshank, 2012), and scientists agree – ultimately, there is no alternative other than replacing traditional energy sources with renewables (Hadian & Madani, 2015). "Renewable energy is the inevitable choice for sustainable economic growth, for the harmonious coexistence of human and environment as well as for the sustainable development" (Peidong, Yanli, Yonghong, Lisheng, & Xinrong, 2009). Although the development of industrialized nations has been the major contributor to increased GHG emissions (and therefore climate change) – the poorest countries, which have emitted the least GHG, will be impacted the most severely by climate change and will be the least able to withstand weather-related shocks (Klein, Schipper, & Dessai, 2005; Yadoo & Cruickshank, 2012; Zerriffi & Wilson, 2010). Nevertheless, if those countries were to follow the same development paths as today's industrialized countries, global GHG emissions would rise even more sharply, therefore current energy trajectory needs a reverse (Yadoo & Cruickshank, 2012). According to (Hofman & Li, 2009), sustainability can be seen as a final goal – a balance of social and economic and environment, and a sustainable energy sector has to be in balance between energy production and consumption. Furthermore, within the environmental tolerance limits, it has no or minimal impact on environment and gives the opportunity to country to employ its social and economic activities (Hofman & Li, 2009).

Rationalization of consumption, more efficient energy usage and a new energy structure are needed to be achieved in the same time in order to shift the structure of energy system towards sustainability, therefore, more intensive use of RES is a highly important aspect (Dombi et al., 2014). And vice versa – one of the major aspects for nearly any renewable energy project realization is sustainability (Wimmler, Hejazi, de Oliveira Fernandes, Moreira, & Connors, 2015).

Many factors need to be taken into consideration when investing in a renewable energy technology and lessons can be learnt from sustainable development when selecting the optimal solution for supplying clean energy – not all renewable energy technologies may always provide the most sustainable option, bearing in mind certain specific area (Luong, Liu, & Robey, 2012). The important goal is trying to find the right balance between economic, social and environmental aspects of sustainable development, which together act as guiding principles to ensure that factors which are considered for a renewable energy technology is relevant for sustainable development (Luong et al., 2012). Sustainability assessment ensures that the selected RES technology would be a sustainable option (Luong et al., 2012). According to (Carrera & Mack, 2010), sustainability concept itself is already tied to the idea, that holistic technological impact assessment is possible only by incorporating long-term perspective, which means that assessment of energy technologies should not only be guided by short-term economic gains but must also take into consideration its repercussions on inter- and intra-generational equity. Consequently, concept of sustainability is an integrative precondition for the assessment of energy technologies (Carrera & Mack, 2010) and sustainability assessment can be used as a tool, helping decision-makers and policy-makers decide, which actions they should and should not take in an attempt to make society more sustainable (Devuyst, Hens, & De Lannoy, 2001). (Ness, Urbel-Piirsalu, Anderberg, & Olsson, 2007) supplemented and extended this characterization noting that the purpose of sustainability assessment is to provide decision-makers with an evaluation of global to local integrated nature–society systems in short and long-term perspectives in order to assist them to determine which actions should or should not be taken in an attempt to make society sustainable. The aim of sustainability assessment also can be described as an attempt to maintain "that plans and activities make an optimal contribution to sustainable development" (Verheem, 2002). Most precised definition of sustainability assessment was suggested by (Pope, Annandale, & Morrison-Saunders, 2004). These scientists noted most sustainability assessment "definitions are sufficiently generic to describe a broad range of different processes, many of which have indeed been called 'sustainability assessment' or some similar term in the literature". They clarified the term in a mean, when it fulfils "its potential as a tool for promoting sustainability". Scientists offered to separate to different terms, whereas the term sustainability assessment "should assess whether or not an initiative is sustainable, and not simply assess direction to target" and the term "assessment for sustainability requires a clear concept of sustainability as a societal goal, defined by criteria against which the assessment is conducted and which effectively separate sustainable outcomes from unsustainable ones" (Pope et al., 2004).

Moving towards a sustainable future requires policy actions that solve existing problems without creating new ones (Gohari et al., 2013; Hadian & Madani, 2015; Hjorth & Madani, 2014) and sustainability assessment of renewable energy technologies could be the key for reaching that goal successfully. Properly conducted sustainability assessment of RES technologies can prevent potential barriers or limit them while implementing and using RES technologies, also creating an opportunity to prepare for possible consequences arising from feasible already mentioned disadvantages of RES (357isauskaitė -Šeškienė, 2016).

"The implementation of successful renewable energy that is sustainable in time, especially at the community level, has been related to more open and participatory processes where views, expectations and framings from different stakeholders become integrated" (Mardani et al., 2015).

Various tools and methods for sustainability assessment of RES technologies exist as well as there are many renewables which differ in their environmental and economic impacts, their stage of technology development and their technologies itself (Kosenius & Ollikainen, 2013; Turkenburg et al., 2000). (Ness et al., 2007) developed a holistic framework, according to which, tools of sustainability assessment are divided into three categorization areas:

1) indicators and indices, which are further divided into non-integrated and integrated. It is a simple tool, allowing one to evaluate economic, social and environmental country's development goals. When indicators are aggregated in some manner, resulting measure becomes an index;
2) product-related assessment tools with major focus on flows in connection with production and consumption of goods and service. Tools in this category evaluate resource use and environmental impacts along the production chain or through the life cycle of the product;
3) integrated assessment, which is a collection of tools usually focused on policy change or project implementation. Project related tools are used for local scale assessments, whereas the policy related focus on local to global scale assessments. This particular assessment consists of the wide-array of tools for managing complex issues. "There are many examples of integrated assessments of major environmental problems, but also established tools such as Multi-Criteria Analysis (MCA), Risk Analysis, Vulnerability Analysis and Cost Benefit Analysis (CBA), that do not necessarily pertain directly to only sustainability issues, but can be extended to a variety of other problem areas across disciplinary thresholds" (Ness et al., 2007).

(Bebbington, Brown, & Frame, 2007) stressed the need, which is widely recognized, for individuals, organizations and societies to find models, metrics and tools for articulating the extent and the ways in which current activities are unsustainable. (Böhringer & Jochem, 2007) discussed about three central issues, which concerns sustainable development indices. Thirst issue is that one should be conscious about the themes determining the thematic aggregation method and units determining technical aggregation method while selecting appropriate indicators. Secondly, weighting and normalization of these indicators should be treated in transparent way with proper sensitivity analysis. And thirdly, it must be ensured, that input indices (variables) would be commensurable.

(Gasparatos, 2010) noted the importance of distinction between the notions of a sustainability assessment evaluation tool and a sustainability assessment evaluation framework. According to him, frameworks are integrated and structural procedures, akin to protocols, which contain a number of prescribed stages that ought to be followed in order to meet a pre-determined objective. A key element of such assessment frameworks is comparison of different project or policy alternatives based on their impacts to the environment. Such assessment frameworks do not specify different analytical tools that must be used for the analysis of different alternatives. (Gasparatos, 2010) suggested the definition of evaluation tool would mean the various analytical techniques that can be used to conduct analyses and comparisons within frameworks. "Such tools attempt to understand a system and offer information in a format that can assist the decision-making process" (Gasparatos, 2010). Furthermore, according to the assumptions of sustainability assessment tools and their valuation perspective, sustainability assessment tools were categorized into two broad categories:

1) reductionist tools. Their advantage lies in their ability to measure the performance of projects by reducing and integrating their diverse aspects to a small set of numbers. This category of tools can be divided into three others: monetary (e.g. Willingness to Pay (WTP), Cost Benefit Analysis (CBA), Whole Life Costing),

biophysical (e.g. Material Flow Analysis, Ecological Footprint, Energy Accounting) and indicator list/composite indices;

2) non-reductionist tools. Under which Multi-Criteria Analysis (MCA) falls.

(Singh, Murty, Gupta, & Dikshit, 2012) provided an overview of various sustainability indices applied in sustainability domain, however the selection of indices depends heavily on the country in which they will be applied (Booysen, 2002), not to mention sustainability requirements may be viewed differently across countries (Böhringer & Jochem, 2007). Furthermore, different sustainability evaluation tools make different assumptions on what is important to measure and how to measure it and so the outcome of such sustainability evaluations is far from value-free and neutral (Gasparatos, 2010). Therefore, "it is justified to claim that when a certain tool is chosen as a yardstick to measure the performance of a project, at the same time a value-laden evaluation perspective is inevitably also chosen" (Gasparatos, 2010). And though, according to (Gasparatos & Scolobig, 2012), there is no shortage of sustainability assessment tools, however, guidelines and criteria on how to choose between these tools are lacking. Often a variety of criteria can be applied to identify the suitability and sustainability of technologies, whereas no ideal family of criteria has been defined in the literature (Wimmler et al., 2015).

Some scientists (Beccali, Cellura, & Mistretta, 2003; Dombi et al., 2014; Pohekar & Ramachandran, 2004; Qin, Huang, Chakma, Nie, & Lin, 2008; J. Wang, Jing, Zhang, & Zhao, 2009; Wimmler et al., 2015) propose MCA method as the appropriate one for sustainability assessment. Multi-Criteria Analysis became increasingly popular in decision-making for sustainable energy because of multi-dimensionality of the sustainability goal and the complexity of socio-economic and biophysical systems (J. Wang et al., 2009). The concept of multi-criteria sustainability assessment for evaluating energy systems in regards of sustainability was developed by (Afgan & Carvalho, 2002). According to them, energy system is a complex one with respective structure – it may interact with its surrounding by utilizing resources, exchanging conversion system products, utilizing economic benefits from the conversion process and absorbing the social consequences of the conversion process. Therefore, depending on the problem, energy system can be defined by different boundaries. While sustainability indicators take into account economic and environmental resources parameters, (Afgan & Carvalho, 2002) have presented selection of criteria and options for new and renewable technologies assessment, which was based on the analysis and synthesis of parameters under information deficiency method. In their analysis indicators represented measure of different interactions between energy system and its surroundings. Thus, multi-criteria evaluation of new and renewable technologies established a measuring parameter, comprised of different above-mentioned interactions of system and its surroundings, demonstrated the potential analysis of complex systems and it was intended for use in the evaluation of different option of power plants (Afgan & Carvalho, 2002).

According to (Beccali et al., 2003), "in a decisional process the making of choices derives from complex hierarchical comparisons among alternative options, which are often based on conflictual criteria". A large number of external variables play a relevant role in orienting decision-making and while some of these variables can be manipulated by numerical models, such as cost–benefit analysis, market penetration strategies and environmental impacts, other factors dealing with social and cultural context, political drawbacks and aesthetic aspects, can be assessed only in a qualitative way or with subjective judgment (Beccali et al., 2003). Therefore, MCDM "gives the decision-maker considerable help in the selection of the most suitable innovative technologies in the energy sector, according to preliminary fixed objectives" (Beccali et al., 2003).

(Pohekar & Ramachandran, 2004) suggest multi-criteria decision-making method as a solution for problems involving conflicting and multiple objectives. According to these scientists, MCA method can provide solutions to increase complex energy management options, whereas traditional single criteria approach is normally aimed at identifying the most efficient options at a low cost. (J. Wang et al., 2009) describe MCA method as "a form of integrated sustainability evaluation", that can be used to eliminate the difficulty – "it is an operational evaluation and decision support approach that is suitable for addressing complex problems featuring high uncertainty, conflicting objectives, different forms of data and information, multi interests and perspectives, and the accounting for complex and evolving biophysical and socio-economic systems".

Although, according to (Carrera & Mack, 2010), above-mentioned MCA approach mainly focuses on technical aspects of energy systems, it also takes into consideration social indicators such as new vacancies, space required and health effects on the surrounding population. However, these scientists noted, nevertheless MCA method has been applied in numerous publications, "while this approach provides some theoretical groundwork, it is somewhat sparse and actually lacks a basic definition of sustainability". Furthermore, according to (Hadian & Madani, 2015), variety of sustainability assessment methodologies have been presented in energy system planning, which reflects the fact this particular field has correctly realized the complexity of the problem and identified the proper framework for developing long-term energy plans and assessing energy sustainability. Nonetheless, significant differences between the study results indicate the inconsistency in the assumptions and methods applied in the previous studies. This discrepancy, according to (Hadian & Madani, 2015), appears due to three major limitations:

1) Different notions of optimality. Because of different notions of optimality, various multi-criteria assessment methods result in different optimal outcomes (Madani, Sheikhmohammady, Mokhtari, Moradi, & Xanthopoulos, 2014) and rankings of energy alternatives, which make study results highly sensitive to the choice of multi-criteria assessment method. Therefore, (Hadian & Madani, 2015) note, there is a need to develop a more robust assessment procedure, which minimizes the results' sensitivity to the analyst's choice of multi-criteria assessment method.
2) Uncertainty in performance values. Energy planning studies usually use different methods, which provide deterministic output despite uncertain input information, thus hiding risks associated with study results. (Hadian & Madani, 2015) stress "there is need to develop a method which considers the uncertainties involved and inform the decision makers about the uncertainties' impacts on the assessment of the results and their robustness".
3) Lack of reliable aggregating index. There is a lack of reliable aggregating indicator, which can provide useful quantitative information for policy makers – different sustainability indicators provide valuable information. However, their focus is normally limited on particular aspect of sustainability, making them ineffective for sustainability evaluation.

Use of MCA proponents claim this method provides a systematic, transparent approach that increases objectivity and generates results that can be reproduced, while opponents state method is prone to manipulation, is very technocratic, and provides a false sense of accuracy (Janssen, 2001).

According to (Kocaoglu, Daim, Iskin, & Alizadeh, 2015), an appropriate portfolio of energy resources selection is a complicated and multidimensional problem, which is also affected by numerous factors stemming from multiple perspectives including technical, economic, environmental, social and political, each energy resources have varying degrees of appropriateness for different regions and energy systems. Therefore, choosing sustainability assessment method is a highly important aspect as well. However, in most cases choice of sustainability assessment evaluation tool is made by analysts without taking into consideration the values of the affected stakeholders (Gasparatos, 2010). Furthermore, even though sustainability assessment of energy systems is commonplace, it oftentimes fails to account for social repercussions and long-term negative effects and benefits of energy systems (Carrera & Mack, 2010) and the choice of sustainability assessment tools can entail various ethical and practical repercussions (Gasparatos, 2010).

A strong correlation between environmental attitude and ecological behavior intention has been established – it is important to know the attitudes of energy consumers since their attitudes are the foundations of their resulting behavior (Ek, 2005; Stigka et al., 2014). According to (Stigka et al., 2014), in democratic societies, inputs to the planning and decision-making process include not only expert opinions, but public feelings and perceptions as well, the problem being that rational individual behavior may conflict with the common good and prevent the efficient use of public resources. “Nowadays most of the citizens expect, more than in the past, their government or administration not only to warn them of major environmental–energy–climate problems, but also to prepare them for enacting timely policy responses” (Zografakis et al., 2010).

Consequently, not only societies need sustainability assessment of renewable energy technologies – it needs to assess the trade-offs between alternative sources in order to choose the most beneficial one (Kosenius & Ollikainen, 2013). Although, over the years, there has been an increase in public awareness of the adverse environmental effects of the consumption of fossil fuels (Stigka et al., 2014), nonetheless, in order to make socially optimal renewable energy investment, external costs and benefits of renewables, which may appear, need to be taken into account (Bergmann et al., 2006). What is more, some benefits and costs of renewables and their technology do not have monetary values, therefore, different economic valuation techniques were derived in order to evaluate them (Menegaki, 2008). Ultimately, societies must develop a good understanding of the environmental impacts and especially, the marginal rate of valuation between different kind of energy sources and between different types of renewables (Kosenius & Ollikainen, 2013).

Assessment of willingness to pay (WTP) “calculates the financial contribution people are willing to make in order to prevent or remedy environmental damage” (Stigka et al., 2014). Although this integrated assessment method answers the question, what premium are energy customers willing to pay for environmentally friendly energy, it “should not be interpreted as actual willing to pay but rather as an index of consumer’s relative preferences for certain outcomes over other outcomes” (Wood et al., 1995). Households satisfaction with renewable energy and WTP have significant impact on state policies aiming to promote renewable energy sources (Georgescu & Herman, 2014; Lungu, Dascalu, Caraiani, & Balea, 2014; Streimikienė & Mikalauskiene, 2014). According to (Lungu et al., 2014), “given that renewable energy use is in an early stage and that it can influence the consumer behavior in a way to increase the market performance, development of new strategies orientated to sustainable energy consumption can have a positive impact if properly explained in terms of consumer demand". Furthermore, as consumers become more environmentally conscious and willing to pay a higher price for green energy – utilization of RES becomes ever more widespread (Ek, 2005). And once the benefits of renewables will be recognized by a larger percentage of population – cost of renewable energy technologies will drop (Menegaki, 2008). Moreover, because many renewable energy resources throughout Europe are concentrated by their nature in remote areas, WTP can be also used as a tool for planning the development of renewables in remote communities (Hanley & Nevin, 1999). Such remote communities, with low population densities, limited conventional energy sources, lack of infrastructure, low levels of economic activity, physical access constraints and long distances to external markets, could benefit through the generation of local income and employment while using a strategy to meet their energy demand as much as possible from local renewable sources (Hanley & Nevin, 1999).

Assessment of WTP for climate change mitigation measures is one the main aspects currently world's focus is concentrated on (Štreimikienė & Griškaitė-Šeškienė, 2014). In general, consumers' voluntary renewable energy purchases through green power marketing are highly important, when it comes to policy mechanisms that can support renewable generation sources (Wiser, Pickle, & Goldman, 1998). In many countries energy production is based on a variety of energy sources (including solid mineral fuels, oil, gas, nuclear power and RES) and is an important contributor to economic development (Stigka et al., 2014). Examinations of voluntary contributions for the energy generated from RES have already received a lot of attention (Zorić & Hrovatin, 2012). "As renewable energy activities grow and require more funding, the tendency in many countries is to move away from methods that let taxpayers carry the burden of promoting renewables, towards economic and regulatory methods that let energy consumers carry the burden" (Turkenburg et al., 2000). Concept that consumers share responsibility for pollution and its cost has been increasingly accepted (Dincer, 2000). In some jurisdictions, the prices of many energy resources have increased over the last decades, in part to account for environmental costs (Dincer, 2000). Therefore, in terms of highly important and still growing societies influence on political decisions considering ecological issues, particularly green energy and their technologies, it can be said, whereas already mentioned MCA method is created for decision-makers, WTP approach is designed for consumers to express their decisions. All in all, collection of individuals' willingness to pay for the reduction or prevention of environmental damages defines the benefits of an environmental policy (Stavins, 2007).

Based on the previously examined studies, author has concluded advantages and disadvantages of MCA and WTP methods:

Table 6. Advantages and disadvantages of MCA and WTP methods

	TYPES
	Multi-Criteria Analysis (MCA)
Cited authors	(Afgan & Carvalho, 2002; Beccali et al., 2003; Bergmann et al., 2006; Dombi et al., 2014; Ek, 2005; Gasparatos, 2010; Hadian & Madani, 2015; Janssen, 2001; Madani et al., 2014; Menegaki, 2008; Pohekar & Ramachandran, 2004; Qin et al., 2008; Stigka et al., 2014; J. Wang et al., 2009; Wimmler et al., 2015)
Advantages	• Popular because of multi-dimensionality of sustainability goal and the complexity of socio-economics and biophysical systems;

	• Its' indicators represent measure of different interactions between energy system and its surroundings; • Demonstrates the potential analysis of complex systems • Helps to assess factors dealing with cultural and social; context, political drawbacks and aesthetic aspects – those, who can be assessed only in qualitative way or subjective judgment; • It is considerable help for decision makers while selecting the most suitable innovative technologies in the energy sector, according to preliminary fixed objectives; • It is as a solution for problems involving conflicting and multiple objectives-can provide solutions to increase complex energy management options, whereas traditional single criteria approach is normally aimed at identifying the most efficient options at a low cost; • Is suitable for addressing complex problems featuring high uncertainty, conflicting objectives, different forms of data and information, multi interests and perspectives, and the accounting for complex and evolving biophysical and socio-economic systems; • Takes into consideration some social indicators, e.g. new vacancies, space required and health effects on surrounding population; • Provides a systematic, transparent approach that increases objectivity and generates results that can be reproduced.
Disadvantages	• Lack of private input and opinion – attitudes of energy consumer are not included; • External costs and benefits of renewables are not taken into account; • Though MCA provides a theoretical groundwork, it is somewhat sparse – lacks a basic definition of sustainability • Mainly focuses on technical aspects of energy systems; • Because different notions of optimality various multi-criteria assessment methods result indifferent optimal outcomes • Study results are highly sensitive to the choice of multi-criteria assessment method; • Hides the risk associated with study results, i.e. provides deterministic output despite uncertain input information; • A lack of reliable aggregating indicator, which can provide useful quantitative information for policy makers – different sustainability indicators provide valuable information; • However, their focus is normally limited on particular aspect of sustainability, making them ineffective for sustainability evaluation; • Method is prone to manipulation, is very technocratic, and provides a false sense of accuracy.
Scope	Usually used in decision-making for sustainable energy. Originally was intended for use in the evaluation of different option of power plants.
	Willingness to pay (WTP)
Cited authors	(Adamowicz, Louviere, & Williams, 1994; Bergmann et al., 2006; Boxall, Adamowicz, Swait, Williams, & Louviere, 1996; Georgescu & Herman, 2014; Hanley & Nevin, 1999; Kosenius & Ollikainen, 2013; Lungu et al., 2014; Menegaki, 2008; Roe et al., 2001; Stigka et al., 2014; Streimikienė & Mikalauskiene, 2014; Štreimikienė & Baležentis, 2014; Wood et al., 1995;

	Zografakis et al., 2010)
Advantages	• Takes into account attitudes of energy consumers; • Takes into account external costs and benefits of renewables; • Has significant impact on state policies aiming to promote RES; • Helps energy consumers, households, to become more conscious; • The larger percentage of population recognizes the benefits of renewables, the more quicker cost of renewable energy will drop; • Can be used as a tool for planning renewables in remote communities.
Disadvantages	• Significant differences can be found between values derived from two different WTP methods while applying them to the same target group of respondents.
Scope	Calculates the financial contribution people are willing to make in order to prevent or remedy environmental damage. This financial contribution is interpreted as an index of consumer's relative preferences for certain outcomes over other outcomes.

Source: Created by author

As it is clarified – appraising energy technologies in terms of their sustainability is already a complex task, considering the series of uncertainties and implications that have to be encountered so as to obtain realistic and transparent results (Doukas et al., 2007), not to mention determination on what sustainability assessment method to use. Thus, considering the basis of all analyzed theory and Table 6., it becomes clear, both methods has its' own pros and cons. However, because energy consumers' behavior and attitudes is one of determinant elements towards RES technology and RES consumption, as they interfere in energy policy widely firmly nowadays, in my opinion, it is necessary to combine MCA and WTP methods. More explicitly – MCA method needs to be "backed up", with additional analysis, revealing the needs and uprights of society (Ališauskaitė -Šeškienė, 2016), thus one of its elements should consists estimated WTP. That way, to my mind, decision makers will be able perform sustainability assessment while taking into account opinion of home owners. After all – one of the principal aims of MCA approaches is to help decision makers organize and synthesize gathered information "in a way which leads them to feel comfortable and confident about making a decision, minimizing the potential for post decision-regret by being satisfied that all criteria or factors have properly been taken into account" (Belton & Stewart, 2002). Therefore, I expect, WTP integration within MCA will suggest the best result which would satisfy decision-maker and would be made by taking into account residents' opinion.

2. METHODOLOGY FOR COMPARATIVE ASSESSMENT OF RENEWABLE MICROGENERATION TECHNOLOGIES IN HOUSEHOLDS

2.1. WTP estimation methods

Number of studies published over the last years focusing on consumers’ preferences towards renewables has increased steadily, thus resulting in a flood of data (Sundt & Rehdanz, 2015). Furthermore, these studies vary widely not only in the energy-related characteristics they analyze and geographical location, but also different WTP valuation techniques employed (Fig. 6) (Johnson, Nemet, & Nemet, 2010; Menegaki, 2008; Streimikienė & Mikalauskiene, 2014; Sundt & Rehdanz, 2015). (Menegaki, 2008) has grouped all the studies of renewable energy evaluation into five main methods, depending on the research field from where the research is launched: stated preference techniques, revealed preference techniques, financial option theory, emergy analysis and economic but not welfare-based oriented methods. Financial option theory – portfolio analysis valuates projects in line with their anticipated risks and returns. These approaches valuate renewables not on the basis of their stand-alone cost, but on the basis of their overall portfolio cost with expected portfolio risk. Method of emergy analysis is used rather in economical engineering for determining net value of environmental projects to human society. And other economic but not welfare-based oriented methods are “various other economic methods and techniques which do not fall under above groups and are not welfare-based either” (Menegaki, 2008), whereas two first methods, stated and revealed preferences, are intended for energy consumers’ willingness to pay for renewable energy and their technologies evaluation.

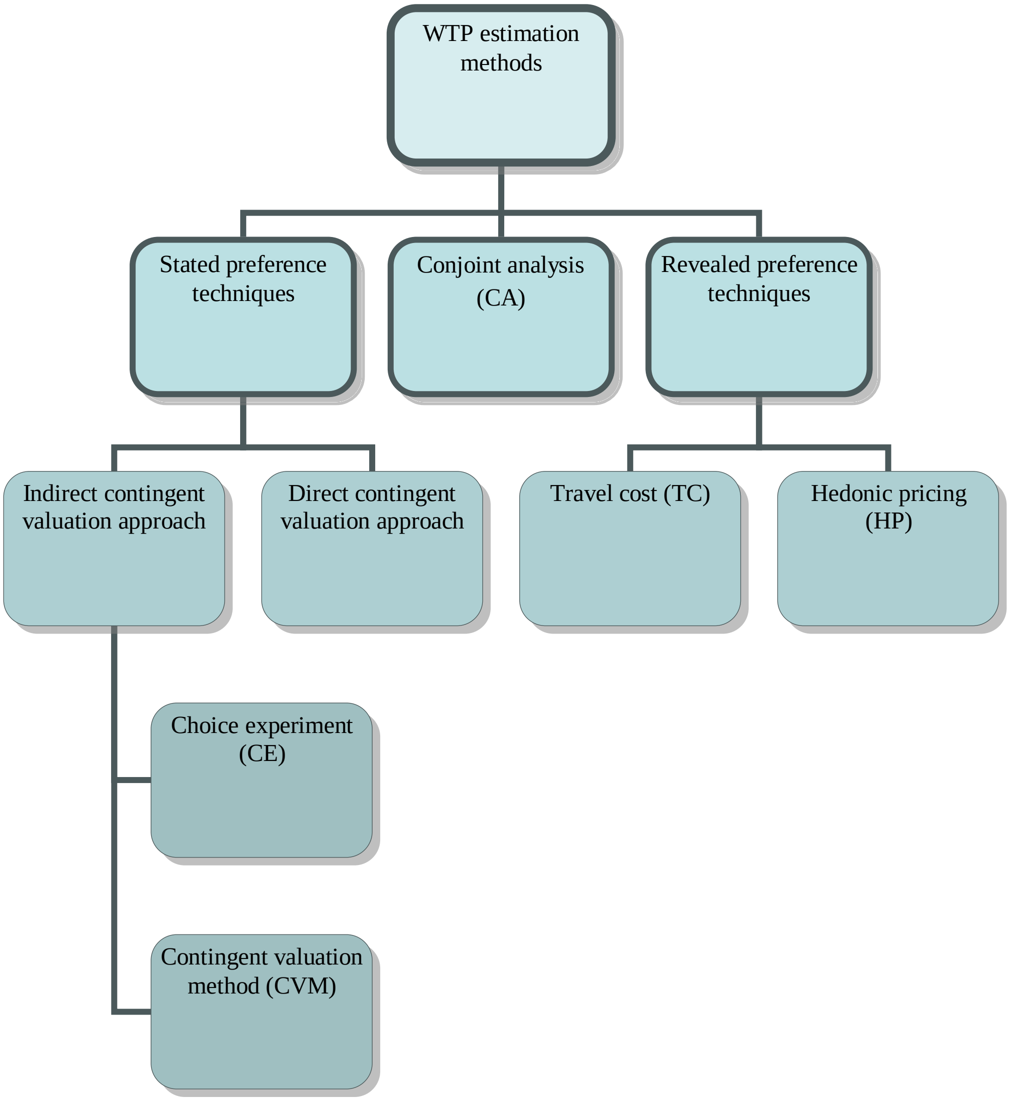


Figure 6. Methods to assess WTP

Source: Created by author

However, as can be seen in (Fig. 6), three principal techniques exist in the field of WTP valuation – Stated preference techniques, Revealed preference techniques and Conjoint analysis. Stated preference and Revealed preference techniques are based on Random utility theory. Only relatively recently (Louviere, Flynn, & Carson, 2010) demonstrated, conjoint analysis (CA) doesn’t belong to Random utility theory and evolved out of the theory of “Conjoint measurement”, which is “purely mathematical and concerned with the behavior of number systems and not the behavior of humans or human preferences”. Until that and sometimes nowadays, academics and practitioners seemed have confused CA and CE methods and often considered CA as a special case of choice experiment (CE) (sometimes visa versa), which considers as Stated preference technique. (Louviere et al., 2010) suggested, while both of CE and CA methods use experimental design to assess WTP, however, one of main differences is, CA "methods depend on orthogonal arrays of attribute level combinations as ways to sample profiles from full factorial arrays of attribute levels", while Stated preference methods do not have this limitation. Thus, considering all controversy, related to CA method, author of dissertation decided conjoint analysis is not most reliable method while performing WTP estimation.

Stated preference method, originated in mathematical psychology (Acito & Jain, 1980), is based on respondent's choice from hypothetical choice set (Adamowicz et al., 1994) or his direct answer, whereas information for the analysis of Revealed preference techniques is given out by markets, as produced by consumers' actual decisions (Menegaki, 2008; Štreimikienė & Baležentis, 2014). Revealed preference techniques was pioneered by American economist Paul Samuelson and is used for comparing the influence of policies on consumer behavior (Štreimikienė & Baležentis, 2014). Examples of this techniques are Travel cost and Hedonic pricing, which assume, preferences of consumers can be revealed by their purchasing habits (Menegaki, 2008; Štreimikienė & Baležentis, 2014). Other scientist, (De Groot, Wilson, & Boumans, 2002) suggested there might be more divided economic valuation methods into four groups, each with its own repertoire of associated measurement issues: direct market valuation, indirect market valuation, contingent valuation and group valuation. According to scientists, in case where there are no explicit markets for services, one must resort to more indirect means for assessing values. Scientists have noted, a variety of valuation techniques to establish WTP exists:

1) Avoided Cost (AC): services allow society to avoid costs that would have been incurred in the absence of those services, e.g. flood control (which avoids property damages) and waste treatment (which avoids health costs) by wetlands.
2) Replacement Cost (RC): services could be replaced with human-made systems, e.g. natural waste treatment by marshes which can partly be replaced with costly artificial treatment systems.
3) Factor Income (FI): many ecosystem services enhance incomes, e.g. natural water quality improvements which increase commercial fisheries catch and thereby incomes of fishermen.
4) Travel Cost (TC): use of ecosystem services may require travel. These costs can be seen as a reflection of an implied value of the service, e.g. in recreation areas that attract distant visitors whose value placed on that area must be at least what they were willing to pay to travel to it.
5) Hedonic Pricing (HP): service demand may be reflected in the prices people will pay for associated goods, e.g. housing prices at beaches exceed prices of identical inland homes near less attractive scenery.

One of the first comparative applications of Stated preference approach was made by (Adamowicz et al., 1994). Scientists used a Stated preference model and a Revealed preference model in their study while combining them both. The analysis showed, both, "hypothetical" Stated preference and "actual behavior" Revealed preference, techniques "provides evidence that the underlying preferences are in fact similar". However, (Banfi et al., 2008) have noted, nevertheless both, Revealed and Stated preference, methods are used to evaluate WTP, they preferred Stated preference method, namely choice experiment, due to small size of energy-efficient houses' market (thus revealed preference data is only scarcely available) and because Stated preference method made it possible to compare the willingness to pay of people who have already experienced the additional comfort benefits of energy-saving measures with those who do not have such information. Other scientists support this idea as well. According to (Claudy, Michelsen, & O'Driscoll, 2011), in theory either method could be used to estimate WTP, however, if target households surveyed group consists of a small number, it is very difficult to apply a revealed preference method, while stated preference methods, on the other hand, are more feasible in a case like that.

While comparing Stated and Revealed preference techniques it can be firmly said, Stated preference techniques are more suitable for WTP for renewable energy resources for climate change mitigation measures (e.g. for the particularity of promotion of RES related to impact of global climate change) (Štreimikienė &127Ališauskaitė-Šeškienė, 2014). Revealed preference techniques, requires a well-developed market for green energy and, because it relates to a specific area, is designed for assessing the environmental pollution reduction and benefits improvement of natural environment quality (Herbes, Friege, Baldo, & Mueller, 2015; Štreimikienė & Ališauskaitė-Šeškienė, 2014). Since climate change is a global phenomenon, both, Travel cost and Hedonic pricing, methods cannot assess the benefits of global climate change mitigation in a particular area (Štreimikienė & Ališauskaitė-Šeškienė, 2014).

Stated preference techniques are based on the notion not only consumers are interested in energy – they are interested in the modes that energy is produced as well (Štreimikienė & Baležentis, 2014). Two main methods of this technique were derived by (Wood et al., 1995) – direct and indirect contingent valuation method. Direct contingent valuation approach is used while asking survey respondents outright how much value they place on a given good. However, scientists noticed, this form of questioning presents biases, as respondents may have an incentive to either over- or under-report their true WTP, depending on how the questions are worded. In order to assess respondents' WTP while minimizing some of above-mentioned biases, (Wood et al., 1995) propose to use an indirect approach. In their research, scientists stressed "indirect approach is more effective than asking direct WTP questions because goods or products are described as a collection of attributes and respondents must carefully weigh the trade-offs between attributes". That way, they added, "because the product is not explicitly identified, and respondents are asked to state their preferences for attribute level, respondents' incentive to over- or under-report their true WTP minimize".

One of indirect contingent valuation approaches is contingent valuation method (CVM). The idea of CVM practice is to ask each respondent a closed form question, whether they would accept to pay a given amount to obtain a given change in their status quo, thus the answers to particular question obtained are of "yes" or "no" type (Christiaensen & Sarris, 2007). This particular method is employed to analyze public attitudes towards the use of RES for energy production (Stigka et al., 2014), therefore it is suitable for the estimation of consumers' WTP for renewable energy and the factors that effect it, for the evaluation and choice among various alternative renewable energy choices (e.g. wind, hydro biomass) and for the examination of the form of payment (whether collective or private) (Menegaki, 2008).

Another indirect contingent valuation method, choice experiment (CE), or what some researchers call, discrete choice experiment, was initially developed by (Louviere & Hensher, 1982). In CE respondents are asked to select their preferred alternative from a given set of choices and are typically asked to perform a sequence of such choices, i.e. respondents make trade-offs between all attributes across each alternative, and are expected to choose their most preferred alternative (Campbell, Hutchinson, & Scarpa, 2008). CE confronts "respondents with multiple questions in the following form: do you prefer A or B, where A and B are described by the level of the characteristics of a good or service" (van Putten, Lijesen, Özel, Vink, & Wevers, 2014). Thus, method of choice experiment is well suited to the elicitation of trade-offs between different RES technology described in questionnaire (Kosenius & Ollikainen, 2013).

According to scientists (Boxall et al., 1996), although both, CVM and CE, methods required individuals to state their preferences for environmental qualities, nonetheless significant differences were found between values derived from these two methods. Furthermore, (Boxall et al., 1996) noted, CE have advantages over CVM methods because of already mentioned CVM questionnaire and inaccuracy of information arising from it, while applying the choice experiment method on the other hand relies on the representation of a choice situation, thus "it relies less on the accuracy and completeness of any particular description of the good or service, but more on the accuracy and completeness of the characteristics and features used to describe the situation". Experimental aspect of CE is actually what makes an advantage. This particular advantage derives from the fact experimental design procedures are used to make packages of attributes which reflect different states of the environment and individuals are being asked to choose preferred alternative from a choice set made up of a set of different packages (Boxall et al., 1996).

Valuation methods and survey types can vary widely. For instance, (Wood et al., 1995) in their work have analyzed WTP among several key customer segments one of which was residential. (Hanley & Nevin, 1999) used WTP method as suitable in order to estimate "of either an individual's willingness to pay for an improvement in the quality or quantify of some environmental good". (Roe et al., 2001) designed their survey to elicit consumer's WTP for changes in environmental characteristics of residential electricity service using price and environmental disclosure statements. (Ek, 2005) analyzed electricity consumers' attitudes towards wind power. (Bergmann et al., 2006) used the choice experiment method to estimate people's preferences over environmental and social impacts of hydro, on-shore and off-shore wind power and biomass in Scotland. (Borchers et al., 2007) presented findings of a contingent choice experimental design used to estimate consumer preferences and WTP for voluntary participation in green energy electricity programs. (Banfi et al., 2008) used a choice experiment method to evaluate consumers' WTP for energy-saving measures in Switzerland's residential buildings. (Bergmann et al., 2008) in their investigation used choice experiment method while focusing on differences in preferences between urban and rural residents. (Longo et al., 2008) investigated WTP of UK energy users for different characteristics of energy programs that stimulate the production of renewable energy by using choice experiment thereby stressing the fact stated preference studies on WTP for security of energy supply generally focus on short-term security of supply (black-outs), rather than on price volatility or long-term security of supply. (Zografakis et al., 2010) conducted a CVM study to analyze and to evaluate the citizens' public acceptance and WTP for renewable energy sources in Crete. (Zorić & Hrovatin, 2012) in their study analyzed WTP in Slovenia for electricity generated from RES. (Guo et al., 2014) in order to assess the value of renewable electricity and obtain information on consumer preferences, estimated WTP of Beijing, China, residents for renewable electricity by employing CVM method. (Štreimikienė & Baležentis, 2014) in their pilot study on assessment of WTP in Lithuanian households used CE method in order to provide main drivers of WTP for renewables. (Akcura, 2015) analyzed households‘ preferences and WTP under a mandatory scheme where all households contribute compared to a voluntary scheme where only those who wish to pay to support renewables do so.

Table 7. Summary of WTP studies carried out with different types of analysis

	Study	**Type of analysis to assess respondents WTP**	**Target segments**	**Target renewable source technology/ electricity services**	**State/Region**	**Model estimating WTP**
1.	(Wood et al., 1995)	CA	Residential, farm, small commercial, large commercial and industrial	Different energy mixes used to generate electricity	United States	Probit model
2.	(Hanley & Nevin, 1999)	Direct contingent valuation	Remote community	Three-turbine wind farm, small-scale hydro scheme and biomass development	Scotland	None (stated WTP)
3.	(Roe et al., 2001)	CA	Households	Residential electricity services	United States	Linear model
		Hedonic pricing	Households	Residential electricity services	United States	Hedonic regression (linear ordinary least squares)
4.	(Nomura & Akai, 2004)	Direct contingent valuation	Residents from large cities (owners of telephone)	Electricity generated from photovoltaic and wind power systems	Japan	None (stated WTP)
5.	(Ek, 2005)	CE	House owners	Hydro power, biomass power, solar power and wind power	Sweden	Probit model
6.	(Borchers et	CE	New Castle	Different	United States	Non-linear

	al., 2007)		County, Delaware residents	renewable energy programs		probability model
7.	(Bergmann et al., 2008)	CE	Rural and urban households	Hydro power, on-shore and off-shore wind power and biomass production	Scotland	Logit model
8.	(Longo et al., 2008)	CE	Residents of Bath	Hypothetical program that promotes RE production	England	Random utility model
9.	(Banfi et al., 2008)	CE	House owners and apartment tenants	Air renewal (ventilation) systems for energy saving	Switzerland	Logit model
10.	(Bollino, 2009)	CVM	Households	Electricity generated from RES	Italy	Probit model
11.	(Zografakis et al., 2010)	CVM	Residents of Crete	RES project	Greece	Logistic regression
12.	(Scarpa & Willis, 2010)	CE	Households	Solar photo-voltaic, micro-wind power, solar thermal, heat pumps, biomass boiler and pellet stoves	UK	Logit model
13.	(Claudy et al., 2011)	CVM	Residents	Wood pellet boilers, small wind turbines, solar panels, solar water heaters	Ireland	Probit model
14.	(Zorić & Hrovatin, 2012)	CE	Residents	Electricity generated from RES	Slovenia	Tobit model
15.	(Aravena, Hutchinson, & Longo, 2012)	CVM	Residents	Electricity generated from RES	Chile	Discrete choice random utility model
16.	(Kosenius & Ollikainen,	CE	Residents	Wind power, hydro power,	Finland	Logit model

	2013)			energy from crops and wood		
17.	(Guo et al., 2014)	CVM	Residents of Beijing	Electricity generated from RES	China	Logit model
18.	(Bigerna & Polinori, 2014)	CVM	Households	Electricity generated from RES	Italy	Logistic regression
19.	(Štreimikienė & Baležentis, 2014)	Direct contingent valuation	Households	Electricity degenerated from RES	Lithuania	Non-parametric regression
20.	(Oberst & Madlener, 2014)	CE	Households	Wind power, solar power, biomass	Germany	Logit model
21.	(Akcura, 2015)	CVM	Households	Electricity generated from RES	UK	Probit model
22.	(Chan, Oerlemans, & Volschenk, 2015)	CVM	Households	Electricity generated from RES	South Africa	Tobit model
23.	(Dagher & Harajli, 2015)	CVM	Residents	Electricity generated from RES	Lebanon	Tobit model
24.	(Grilli, Balest, Garegnani, & Paletto, 2015)	CVM	Residents	Hydro power, biomass	Italian Alps	Tobit model
25.	(Yamamoto, 2015)	Direct contingent valuation	Households with PV-systems adoption	Photovoltaic system	Japan	None (stated WTP)
26.	(Jung, Kim, & Lee, 2015)	CVM	Residents	Renewable energy	South Korea	Regression model
27.	(Morita & Managi, 2015)	CA	Residents	Electricity generated from solar and wind power	Japan	Logit model
28.	(Sun, Yuan, & Xu, 2015)	CVM	Households	Smog mitigation	China	Probit model and interval regression
29.	(Vecchiato & Tempesta, 2015)	CE	Residents of Veneto	Different renewable energy mixes	Italy	Logit model
30.	(Lee & Heo, 2016)	CVM	Residents	Electricity generated from solar	South Korea	Logistic regression

				and wind power		

Source: Created by author

As can be seen from Table 7., the majority of scientists preferred CE or CVM methods in order to estimate consumers WTP, however only few of them ((Scarpa & Willis, 2010), (Claudy et al., 2011), (Štreimikienė & Baležentis, 2014), (Oberst & Madlener, 2014), (Lee & Heo, 2016)) investigated WTP for microgeneration technologies, i.e. renewable energy generation technologies – technologies that are installed in households. It can be linked to the fact the uptake of microgeneration technologies in most European countries remains low in general despite major policy and marketing efforts (Claudy, Michelsen, O'Driscoll, & Mullen, 2010), which indicates home owners' WTP for microgeneration technologies "is significantly lower than actual market prices, posing a serious challenge for policy makers and marketers" (Claudy et al., 2011). Over the years social acceptance of renewable energy innovation has often been discussed in the context of large renewable technology projects, acceptance having been seen as rather passive consent by the public (Sauter & Watson, 2007), however, microgeneration at the level of households is an interesting subject because of its large potential, the possibly limited control by market players and grid operators and the current lack of continuous metering of residential and small business consumers (Van der Veen, Reinier AC & De Vries, 2009). According to (Sauter & Watson, 2007), renewable energy technologies, applied in households, do not only impact in individuals' environments, e.g. noise or spoiling the landscape, but also necessitate their active acceptance in terms of the willingness to install these technologies in their homes. These particular technologies, microgeneration technologies, are defined as renewable energy generation technologies, that are installed in householdes, such as (Scarpa & Willis, 2010; Willis, Scarpa, Gilroy, & Hamza, 2011):

- solar photovoltaic (PV) – solar roof panels, comprising thin layers of semiconductor material, convert sunlight to electrical energy. Output is determined by the area of the panels, their efficiency, and the brightness of natural light available;
- micro wind – a roof or pole mounted turbine converts kinetic energy of wind to electrical energy. Output is determined by turbine size and wind speed;
- solar thermal – a roof, shade structure or other location absorb solar energy mounted collectors (panels), heat water or other fluids, and can also power solar cooling systems. Solar thermal systems differ from PV systems, which generate electricity rather than heat. Output is determined by the area of the panels, their efficiency, and the bringhtness of natural light available;
- heat pumps – thermal roof panels use sunlight to heat water. Output is a function of available sunlight, panel area and panel efficiency;
- biomass boilers and pellet stoves – usually wood chips or pellets, and used for space heating and hot water needs. Requires space for boiler and fuel storage.
- small scale CHP – this concept means combined heat and power generation systems with electrical power less than 200 kW (Streimikiene & Baležentis, 2013). Although technically CHP is not a "renewable", it is assigned to renewable technology because of its' potential to save significant amounts of energy and reduce carbon emissions (Claudy et al., 2010). This type of technology can be divided into mini-CHP and micro-CHP. Mini-CHP is taken to be in the range of a few kilowatts to 100 kW and may serve a group of dwellings or a commercial site,

whereas micro-CHP is suitable to serve a single dwelling and has no agreed size limit, but 10 kW of electrical power might be appropriate (Streimikiene & Baležentis, 2013).

Several small scale CHP compete on the market (Alanne & Saari, 2004; De Paepe, D'Herdt, & Mertens, 2006; Streimikiene & Baležentis, 2013):

- Reciprocating engines – a power plant based on a reciprocating engine consists of a reciprocating engine (diesel, gas or multiple fuel) and a generator linked to the engine. However, they are noisy and not very attractive alternative for residential applications;
- Stirling engines – is also a reciprocating engine, but contrary to conventional diesel and gas engines its cylinder is closed, and combustion takes place outside the cylinder. Furthermore, they have lower noise production and are very applicable to residential buildings. However, their low efficiency supports their use as backup power supplies rather than one in continious use.
- Fuel cells – produce electricity electrochemically, by combining hydrogenand atmospheric oxygen. Not only this technology has very low emission rate, it is also noiseless, reliable and modular. However, fulle cell plant costs can be up to three times higher than reciprocating engines and thus it is an important drawback.
- Micro-turbines – gas turbines with electrical power generation from 25 kW to 250 kW. Micro-turbine plants are quite low noise and small size, they are more environmentally friendly than reciprocating engines, yet their electrical efficiency is low and they are expensive.

Back in 2010 researchers (Claudy et al., 2010) provided all RES technologies will have an increasingly important role to play in the nearest future, as they provide a great potential to contribute to the reduction of GHG emissions, ease fossil fuel dependency and stabilize energy costs. Microgeneration technologies in particular have the potential to contribute favourably to energy supply (Allen, Hammond, & McManus, 2008), furthermore – it could fundamentally change the relationship between energy companies and consumers (Watson, 2004) by literally turning the system upside down: as at least partial shift would be performed from an electricity system based on central power stations (like nuclear, coal or big natural gas-based power plants) to small-scale power generation at the domestic level (Sauter & Watson, 2007). In that case, consumers would become energy suppliers in their own right, however, a pre-condition for this change is the diffusion of microgeneration technologies into the market which will depend on consumers' acceptance of microgeneration technologies (Watson, 2004), i.e. their willingness to pay for RES technologies in their households. Unfortunately, despite major marketing and public policy efforts, the diffusion of these particular technologies in most European countries is slow, thus microgeneration technologies can be referred as resistant innovations – they face slow take up times as they require consumers to alter their existing belief structures, attitudes, traditions or entrenched routines significantly (Claudy et al., 2010; Garcia, Bardhi, & Friedrich, 2007). Furthermore, deployment of renewable energy in the residential sector also depends on consumers‘ intentions to adopt a technological innovation (Sardianou & Genoudi, 2013). And while classical economic theory suggest that individuals make consumption decisions that maximize their welfare given the capital constrained derived demand function, demand for one good or service occurs as a result of the demand for another intermediate/final good or service, and thus consumers usually think of themselves as a central actor in a decision process (Lancaster, 1966; Sardianou & Genoudi, 2013).

All in all, it can be stressed understanding of consumer' preferences and WTP for RES technology, thus microgeneration technology, becomes even more important because of additional energy markets open for competition and public policy continues to explore further introduction of RES into energy generation mix (Borchers et al., 2007). Microgeneration still is the growing trend and public opinion towards it is crucial (that has been emphasized by (Sauter & Watson, 2007), (Wüstenhagen, Wolsink, & Bürer, 2007), (Allen et al., 2008), (Van der Veen, Reinier AC & De Vries, 2009), (Willis et al., 2011), (Sardianou & Genoudi, 2013)) – after all, balancing market depends on the behavior of market participants (Van der Veen, Reinier AC & De Vries, 2009).

Knowing more about consumers' attitudes towards green energy is highly important as well as information about the foundations of these attitudes (Ek, 2005).

In many cases results of studies of WTP vary widely, which, according to (Kraeusel & Möst, 2012), is the result of different methodologies and intermittent preferences of customers (Kraeusel & Möst, 2012; Poortinga, Steg, Vlek, & Wiersma, 2003). And although most of existing research generally supports that people are willing to pay extra for renewable energy (Akcura, 2015; Bigerna & Polinori, 2014; Borchers et al., 2007; Nomura & Akai, 2004), zero WTP or negative WTP may exist as well.

Negative WTP indicates respondents should be compensated in order to choose to use a product with the particular attribute (James, Rickard, & Rossman, 2009), while zero WTP means respondent does not have to be paid for using such products nor is he willing to sacrifice to procure a good. However, some scientists exclude negative WTP, although that may lead to erroneous conclusions about the net social benefits of the proposed change (Hanley, Colombo, Kriström, & Watson, 2009). Furthermore, in the survey, it would be more exact to leave that econometric estimation of possible negative WTP, as it testifies the low or no interest of households (Christiaensen & Sarris, 2007) and "consequently, if there is not sufficient consumer willingness to pay, public funding is needed to support RES development" (Bigerna & Polinori, 2014). Thus, negative WTP can contribute to government's decision about the size of compensation in order to encourage consumers to use RES technologies. However, "if consumers take into account the environmental issues and consider that promoting RES will mitigate environmental damage, they are likely to attach a positive value to RES" and positive consumers thinking towards RES technologies may influence their willingness to pay by augmenting the premiums they are willing to pay for such new technology (Bigerna & Polinori, 2014). Thus, the need for public funding might be reduced over time (Bigerna & Polinori, 2014).

WTP is considered as a means of capturing public preferences for climate strategies, especially in relatively localized settings (Johnson et al., 2010). Environmental attitudes and beliefs are common explanatory elements in WTP surveys, while others include income, education and political views (Johnson et al., 2010). Although not all the above-mentioned research authors investigated and specified determinants or socio-demographic factors in their study, which affected people's WTP the most, many of those determinants can be seen summarized in the table below:

Table 8. Common determinants or socio-demographic factors affecting people's WTP

Determinants Study	Health effects	Environmental effects	Political views	Gender	Marital status	Education	Age	Vacancies	Income	Equipment use restrictions	Price	Contract terms	Race	Environmental organization affiliation	Geographical place of residence
(Wood et al., 1995)	*	*						*		*					
(Roe et al., 2001)		*		*		*	*		*		*	*	*	*	*
(Ek, 2005)						*	*		*					*	
(Borchers et al., 2007)				*			*				*				
(Bergmann et al., 2008)		*				*	*	*	*		*				
(Longo et al., 2008)				*	*	*	*		*		*	*		*	
(Bollino, 2009)				*		*	*	*	*						*
(Claudy et al., 2011)				*			*								*
(Zorić & Hrovatin, 2012)		*		*		*	*		*		*				*
(Aravena et al., 2012)				*			*		*		*			*	
(Kosenius & Ollikainen, 2013)		*		*			*	*	*						*
(Guo et al., 2014)				*		*	*		*					*	
(Bigerna & Polinori, 2014)				*		*	*		*						
(Štreimikienė & Baležentis, 2014)				*		*	*	*	*						
(Oberst & Madlener, 2014)				*	*		*	*	*		*				
(Akcura, 2015)				*			*		*					*	
(Chan et al., 2015)		*		*			*		*						
(Dagher & Harajli, 2015)			*	*	*	*	*	*	*			*		*	
(Grilli et al., 2015)		*		*			*		*					*	
(Yamamoto, 2015)				*		*	*		*						
(Jung et al.,				*		*	*								

2015)															
(Morita & Managi, 2015)				*		*	*								*
(Sun et al., 2015)							*		*						
(Vecchiato & Tempesta, 2015)				*			*								*
(Lee & Heo, 2016)				*		*	*		*						

Source: Created by author

Furthermore, when choosing between two methods, used by the majority of scientists, CE and CVM, in order to estimate consumers WTP for microgeneration technology, attention should be drawn CVM is considered rather as a relic – a while ago environmental valuation studies have been dominated by the CVM, which lasted for almost 20 years, nowadays CE is dominating in this area (Navrud & Bråten, 2007). And while applying stated preference choice experiment method, attributes of microgeneration technology play a crucial role.

Table 9. Summary of attributes used in studies

Attributes Study	Capital cost	Installation cost	Investment risk	Maintenance cost	Payback period	Net electricity cost (or monthly electricity bill)	Annual energy saving	Recommended by	CO_2 reduction (contribution to climate	Degree of electricity self-supply	Social impacts (e.g. create new local employment		Contract length	Air pollution	Landscape impact	Wildlife impact	Annual length of electricity shortages	Certification of origin	Minimum distance from houses	Size of the installed device	Inconvenience of system
(Borchers et al., 2007)						*	*														
(Bergmann et al., 2008)						*					*			*	*	*					
(Longo et al., 2008)						*			*		*						*				
(Scarpa & Willis, 2010)	*			*		*	*	*					*								*
(Koseniuss & Ollikainen, 2013)						*			*		*					*					
(Oberst & Madlener, 2014)		*	*		*	*			*	*	*										
(Vecchiato &						*												*	*	*	

Tempesta, 2015)																					

Source: Created by author

Estimation of WTP relies on the theory of random utility models (Train, 2009). Let $j = 1, 2, \ldots, n$ index the decision makers and $i = 1, 2, \ldots, m$ index the alternatives considered. Each decision maker assigns a certain probability to the i-th alternative, U_{ij}. Alternative i is preferred over the i'-th one if $U_{ij} > U_{i'j}, i \neq i'$,.yet the latter values are not observed. Instead, the attributes of each alternative, $\mathbf{x}_{ij}$, and decision maker, $\mathbf{s}_j$, are observed. Therefore, the representative utility is defined as a function of the observed variables, i.e. $V_{ij} = V\left(\mathbf{x}_{ij}, \mathbf{s}_j\right)$. Given the analyst cannot account for all the factors affecting the utility, a random error ε_{ij} captures the disturbances due to the unobserved factors so that $U_{ij} = V_{ij} + \varepsilon_{ij}$. Accordingly, the probability of choosing the i-th alternative by the j-th decision maker is defined as follows:

$$\begin{aligned} P_{ij} &= \Pr\left(U_{ij} > U_{i'j}, i \neq i'\right) \\ &= \Pr\left(V_{ij} + \varepsilon_{ij} > V_{i'j} + \varepsilon_{i'j}, i \neq i'\right) \qquad , \\ &= \int_{\varepsilon} I\left(\varepsilon_{i'j} - \varepsilon_{ij} < V_{ij} - V_{i'j}, i \neq i'\right) f\left(\varepsilon_j\right) d\varepsilon_j \end{aligned} \tag{1}$$

where $I(\cdot)$ is the indicator function and $f(\cdot)$ is the density function. Assuming the representative utility is linear in parameters $\boldsymbol{\beta}$, one can define the following model: $U_{ij} = \boldsymbol{\beta}\mathbf{x}_{ij} + \varepsilon_{ij}$. The logit model then estimates the probability of choosing the i-th alternative by the j-th decision maker is defined as follows:

$$P_{ij} = \frac{\exp\left(\boldsymbol{\beta}\mathbf{x}_{ij}\right)}{\sum_{i'=1}^{m} \exp\left(\boldsymbol{\beta}\mathbf{x}_{i'j}\right)}. \tag{2}$$

In order to account for varying preferences of the decision makers, coefficients $\boldsymbol{\beta}$ can be allowed to vary across decision makers. This is known as the mixed logit models (McFadden & Train, 2000; Revelt & Train, 1998). Let $\boldsymbol{\beta}_j$ be the random vector of regression coefficients and $f\left(\boldsymbol{\beta}_j \mid \boldsymbol{\theta}\right)$ be the underlying density function with parameter vector $\boldsymbol{\theta}$. For the mixed logit model, the probability of choosing the i-th alternative by the j-th decision maker becomes

$$P_{ij} = \int \frac{\exp\left(\boldsymbol{\beta}\mathbf{x}_{ij}\right)}{\sum_{i'=1}^{m} \exp\left(\boldsymbol{\beta}\mathbf{x}_{i'j}\right)} f\left(\boldsymbol{\beta} \mid \boldsymbol{\theta}\right) d\boldsymbol{\beta}. \tag{3}$$

In case each decision maker faces several experiments indexed over $t = 1, 2, \ldots, T$, a panel structure can be imposed. Let y_{ijt} equal unity if decision maker j chooses alternative i during the t-th experiment and zero otherwise. Then, the probability of observing a certain pattern of choices is defined as follows (Train, 2009):

$$S_j = \int \prod_{t=1}^{T} \prod_{i=1}^{m} \left(\frac{\exp\left(\boldsymbol{\beta}\mathbf{x}_{ij}\right)}{\sum_{i'=1}^{m} \exp\left(\boldsymbol{\beta}\mathbf{x}_{i'j}\right)} \right)^{y_{ijt}} f\left(\boldsymbol{\beta} \mid \boldsymbol{\theta}\right) d\boldsymbol{\beta}. \tag{4}$$

Parameters $\boldsymbol{\theta}$ can be estimated via simulated maximum likelihood procedure, which seeks to maximize the following log-likelihood function:

$$SLL = \sum_{j=1}^{n} \ln \left[\frac{1}{R} \sum_{r=1}^{R} \prod_{t=1}^{T} \prod_{i=1}^{m} \left(\frac{\exp\left(\boldsymbol{\beta}_j^r \mathbf{x}_{ij}\right)}{\sum_{i'=1}^{m} \exp\left(\boldsymbol{\beta}_j^r \mathbf{x}_{i'j}\right)} \right)^{y_{ijt}} \right], \tag{5}$$

where $r = 1, 2, \ldots, R$ is the index of draws from $f\left(\boldsymbol{\beta}_j \mid \boldsymbol{\theta}\right)$. This procedure can be implemented in lines with (Hole, 2007).

The estimated coefficients of the mixed logit model can be applied to derive the measures of WTP for certain features of the alternatives. Assuming that a (fixed) cost variable is included in the model, the expected WTP can be estimated via

$$E\left(WTP_k\right) = -\frac{E\left(\beta^k\right)}{\beta^{\mathrm{c}}}, \tag{6}$$

where k denotes the k-th attribute and β^c is the coefficient associated with a cost variable

$$E\left(W^*\right) = -\frac{E\left(\boldsymbol{\beta}\right)\mathbf{x}^*}{\beta^{\mathrm{c}}}. \tag{7}$$

Furthermore, the model can be used to estimate the change in welfare associated with the choice of a certain alternative defined in terms of a set of attribute values $\mathbf{x}^*$. Given the preferences of consumers represented by set of regression coefficients and the reference alternative defined by attribute values $\mathbf{x}^0$, the change in welfare can be measured as a ratio of the difference in utilities over the negative of the coefficient of a coefficient (Bennett & Blamey, 2001; Bergmann et al., 2008):

$$E\left(\Delta W^{*,0}\right) = \frac{E\left(\boldsymbol{\beta}\right)\mathbf{x}^0 - E\left(\boldsymbol{\beta}\right)\mathbf{x}^*}{\beta^{\mathrm{c}}}, \tag{8}$$

where $\boldsymbol{\beta}$ is the vector of coefficients of the mixed logit model.

2.2. MCDM techniques

Implementation of new and innovative energy technologies is a key mean towards a sustainable energy system – energy sector and its contribution to the greenhouse effect play a major role in the policy for a sustainable development, therefore efforts towards a sustainable energy system are progressively becoming an issue o concern and of paramount importance for most politicians and decision makers (Doukas et al., 2007). In recent years, due to increasing energy demand, use of renewable energy technologies has grown dramatically, naturally number of different MCA techniques has grown as well. Furthermore, "MCDM has been one of the fastest growing areas of operational research, as it is often realized that many concrete problems can be represented by several (conflicting) criteria" (Bashiri, Badri, & Hejazi, 2011).

(Doukas et al., 2007) presented direct and flexible multi-criteria decision making (MCDM) approach. (Zangeneh, Jadid, & Rahimi-Kian, 2009) proposed a model for evaluation and ranking of various distributed technologies in Iran. (Oberschmidt, Geldermann, Ludwig, & Schmehl, 2010) elaborated a multi-criteria methodology – PROMETHEE (Preference Ranking Organization Method for Enrichment Evaluations) – by assigning criteria weights depending on the actual development phase of a certain technology for the performance assessment of energy supply technologies. (Shen, Lin, Li, & Yuan, 2010) used a fuzzy Analytic Hierarchy Process (FAHP) in order to reveal the suitable RES for the purposes of meeting goals that pertain to energy, the environment, and the economy in Taiwan. (Streimikiene et al., 2012) in their study applied two different MCA methods, Multi-Objective Optimization on the Basis of Ratio Analysis pluss Full Multiplicative form (MULTIMOORA) techniques and Technique for Order of Preference by Similarity to ideal Solution (TOPSIS), for more robust assessment of most sustainable electricity production technologies. (Balezentiene, Streimikiene, & Balezentis, 2013) offered offers a multi-criteria decision making framework for prioritization of energy crops based on fuzzy MULTIMOORA method which enables to tackle imprecise information. (Stein, 2013) in his research proposed a model, built by using Analytic Hierarchy Process (AHP), that ranked renewable and other technology for electricity production. (Ren, Fedele, Mason, Manzardo, & Scipioni, 2013) in their paper developed as sustainability assessment method to rank the prior sequence of biomass-based technologies for hydrogen production by using novel fuzzy Multi-Criteria Decision Making (FMCDM) method which allows multiple groups of decision-makers to use linguistic variables to assess the biomass-based technologies. (van de Kaa, Rezaei, Kamp, & de Winter, 2014) decided to choose AHP in order to rank photovoltaic (PV) technological systems because this particular method, as a robust MCDM method, is used to compare factors and technological designs and to structure this decision-making situation. Furthermore, according to scientists, "because the AHP method uses simple scoring questions and a schematic overview of the factors, it is very useful in situations with respondents who are not familiar with the underlying theoretical concepts of the decision-making situation". (Troldborg, Heslop, & Hough, 2014) because of MCA's attractiveness yet uncertainty considering its input information, decided to develop and apply a MCA for a national-scale sustainability assessment and ranking of eleven renewable energy technologies in Scotland. (Zhao & Guo, 2014) proposed fuzzy multi-attribute decision making approach (fuzzy entropy-TOPSIS) for selecting the proper green supplier of thermal power equipment in China. (Luthra, Kumar, Garg, & Haleem, 2015) identified twenty-eight barriers for adoption of renewable and sustainable energy technologies in India. Scientists used Analytic Hierarchy Process (AHP) as an appropriate methodology, which works as a multi-attribute decision-making methodology – it is a decision support tool that uses a multilevel hierarchical structure of objectives, criteria, sub-criteria and alternatives.

According to (Mardani et al., 2015), although all of these methods are mainly aimed at making decision-making process better informed and more formalized, nevertheless, a number of them have been designed for a particular problem, hence they are inapplicable to other problems. However, two broad categories of MCA can be distinguished – classical MCA and fuzzy MCA (Mardani et al., 2015). MCDM is considered as a complex decision-making tool involving both quantitative and qualitative factors (Mardani, Jusoh, & Zavadskas, 2015), yet at the same time these several different criteria (qualitative and quantitative) may affect each other mutually when evaluating alternatives, which may make the selection process complex and challenging (Vahdani, Hadipour, Sadaghiani, & Amiri, 2010). In many cases the decision maker has inexact information about alternatives in respect to an attribute. Thus, classical MCDM methods cannot effectively handle problems when information is imprecise, whereas fuzzy set theory is a powerful tool to handle imprecise data. Fuzzy MCDM (FMCDM) was proposed by (Zadeh, 1975), who suggested key elements in human thinking are not numbers but labels of fuzzy sets. Therefore, classical MCDM problems are the ones, among which the ratings and the weights of criteria, are measured in crisp numbers, and FMCDM problems are the ones, among which the ratings and the weights of criteria evaluated on imprecision, subjective and vagueness are usually expressed by linguistic terms and then set into fuzzy numbers (Y. Wang & Lee, 2007). Various classification of MCA methods exists (Liou & Tzeng, 2012; Mardani et al., 2015; Mardani et al., 2015; E. K. Zavadskas & Turskis, 2011), however, scientists distinguish these methods as main for MCA:

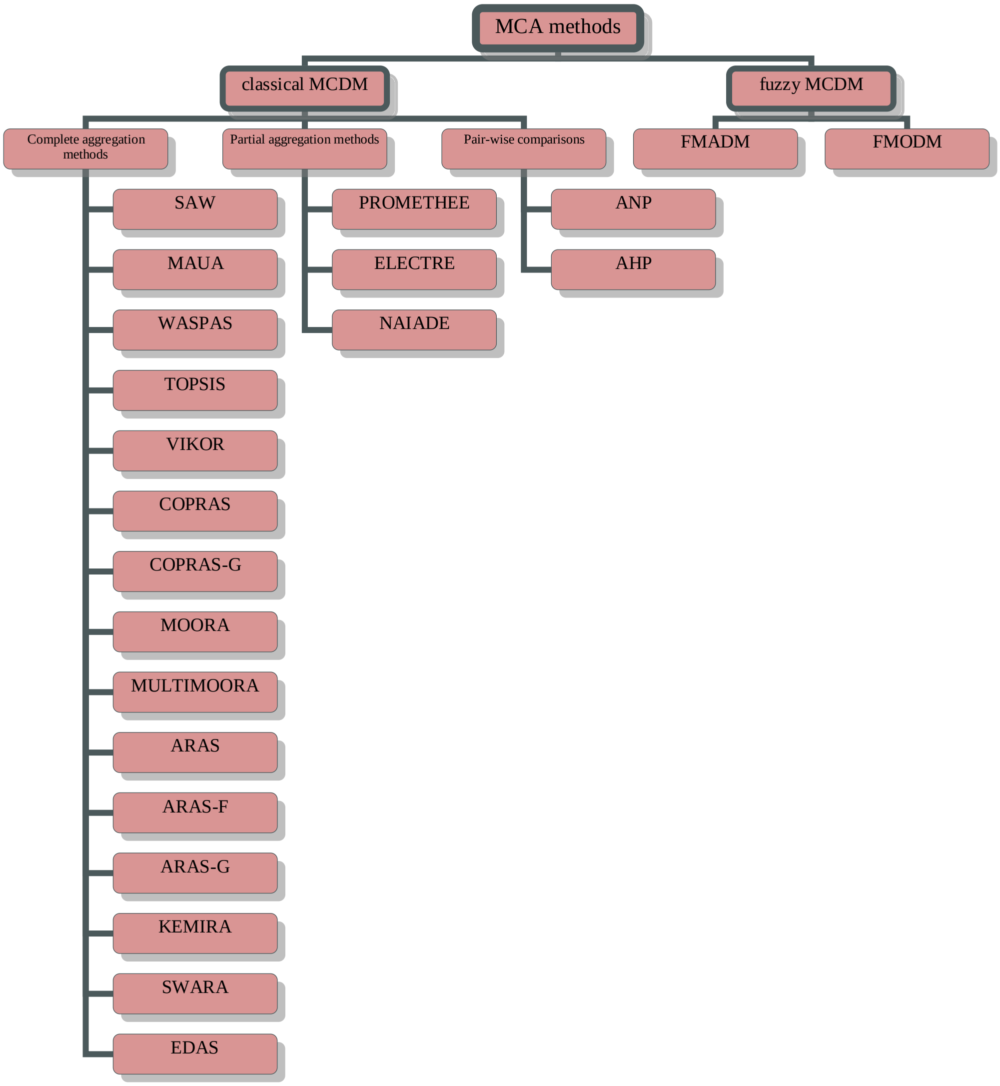


Figure 7. Different methods for Multi-Criteria Analysis

Source: Created by author

As can be seen in Fig. 7, three main methods can be distinguished among classical MCDM:

– complete aggregation methods, which include already mentioned TOPSIS and MULTIMOORA and others – Simple Additive Weighting (SAW) (MacCrimmon, 1968), Multi-Attribute Utility Analysis (MAUA) (Keeney & Raiffa, 1976), Weighted Aggregated Sum Product Assessment (WASPAS) (E. Zavadskas, Turskis, Antucheviciene, & Zakarevicius, 2012), VlseKriterijuska Optimizacija I Komoromisno Resenje (VIKOR) (Mavi, Farid, & Jalili, 2012; Opricovic & Tzeng, 2004), multiple criteria Complex Proportional Assessment (COPRAS) (E. Zavadskas, Kaklauskas, & Sarka, 1994), Complex Proportional Assessment of alternatives with Grey criteria (COPRAS-G) (Liou, Tamošaitienė, Zavadskas, & Tzeng, 2015), Multi-Objective Optimization by Ratio Analysis (MOORA) (Brauers & Zavadskas, 2006), Additive Ratio Assessment method (ARAS) (E. K. Zavadskas & Turskis, 2010), Fuzzy Additive Ratio Assessment method (ARAS-F) (Turskis & Zavadskas, 2010a), Grey Additive Ratio Assessment method (ARAS-G) (Turskis & Zavadskas, 2010b), Kemeny Median Indicator Ranks Accordance (KEMIRA) (Krylovas, Zavadskas, Kosareva, & Dadelo, 2014), Step-Wise Weight Assessment Ratio Analysis (SWARA) (Keršuliene, Zavadskas, & Turskis, 2010); Evaluation Based on Distance from Average Solution (EDAS) (Keshavarz Ghorabaee, Zavadskas, Olfat, & Turskis, 2015);

- partial aggregation methods, which not only include higher mentioned PROMETHEE but Elimination and Choice Expressing Reality (ELECTRE) (Figueira, Mousseau, & Roy, 2005) and Novel Approach to Imprecise Assessment and Decision Environments (NAIADE) (Munda, 2005) as well;
- pair-wise comparisons – Analytic Network Process (ANP), Analytic Hierarchy Process (AHP).

Whereas, fuzzy MCDM can be categorized into fuzzy multi-attribute decision making (FMADM) and fuzzy multi-objective decision making (FMODM). According to (Mardani et al., 2015), the objective of FMADM is finite and implicit, whereas the objective of FMODM approach is infinite and explicit, thus in FMADM decision maker's objectives are unified under decision maker's utility, which is dependent upon the selection criteria, while in FMODM objectives of decision makers (optimal resource utilization and quality) improvement remain explicit and are assigned with fuzzy weights that reflect their relative significance. All in all, these scientists stress, most important benefit of FMCDM methods is their capability of considering many selection criteria.

2.3. Model for comparative assessment of renewable microgeneration technologies in households

Comparative assessment of renewable microgeneration technologies will consist from two parts. First part will be assessment of WTP – which will reflect the opinion of households – thus the opinion of energy consumers. In order to conduct WTP among energy consumers first of all researcher needs to select particular technologies that will be analyzed. In this case the choice has been made to select these particular microgeneration technologies, which are most commonly used Lithuanian households: solar thermal, solar panel, biomass boiler and micro wind. In order to design an unlabelled discrete choice experiment with two generic alternatives (and an opt-out choice) second step should be made in the investigation – to select the attributes for choice experiment. This particular task is rather difficult, because not only researcher has to decide upon the number of it but also to select attributes that best describe the good to be evaluated (Longo et al., 2008). According to researchers, the number of attributes and levels usually needs to be limited – as well as the number of possible hypothetical scenarios, which depends on the number of attributes and levels. According to (Longo et al., 2008), in order to identify the preferences of respondents for a high number of hypothetical scenarios it is necessary to survey large number respondents, nonetheless it is also important to keep choice experiment exercise relatively simple and minimize the cognitive burden the respondent has to bear. Given that researchers (Longo et al., 2008; Oberst & Madlener, 2014; Scarpa & Willis, 2010) usually includes in their survey 4-7 attributes and 2-5 levels, the attributes that will be included in the survey of this dissertation will consist of:

1) installation costs;
2) monthly energy bill;
3) length of the warranty period;
4) inconvenience of system;
5) degree of possibility for sharing.

Each of them will have four levels. As regards the inconvenience of system, the four levels correspond to special circumstances associated with different technologies of energy generation, i.e. climatic conditions and the time of the day (daylight requirement), the need for additional fuel, generation of noise during the operation, and none of these. The attribute of sharing possibility captures the preferences of inhabitants in regard to cooperative use of renewable energy sources.

Second part of comparative assessment research will be adapting MCA for particular selected technologies. In order to do that the expert (politicians, businessmen and academics) survey will be completed – they will be asked to assess the same microgeneration technologies based on environmental, social, economic, energy, technology and political criteria according to Likert scale. According to the literature analysis (Kocaoglu et al., 2015; Mourmouris & Potolias, 2013; Oberst & Madlener, 2014), the following criteria were distinguished (Table 10.)

Table 10. Criteria and indicators for MCDM

CRITERIA	**Indicators** of the criteria	
	Sustainability indicator	**Resilience indicator**
ENVIRONMENTAL	• Noise pollution • CO_2 emissions in the atmosphere • Land use requirement	• Climate resilience
SOCIAL	• Level of public resistance/opposition • Job creation • Social benefits	
ECONOMICAL	• Investment cost • Operation and maintenance cost • Payback period	• Sensitivity to fuel price fluctuation
ENERGETIC		• Market concentration on supply
TECHNOLOGICAL	• Market size (domestic) • Market size (potential)	• Technological maturity • Innovative ability
POLITICAL		• Contributes to the development of the country’s energy independence

Source: Created by author

Thus, each expert will rank particular technology according to seventeen indicators. All these criteria can be classified as negative and positive. Negative criteria include: noise pollution, CO_2 emissions in the atmosphere, land use requirement, level of public resistance, operation and maintenance cost, sensitivity to fuel price fluctuation, market concentration on supply – the higher their score is, the more damage they cause. Positive criteria include: climate resilience, job creation, social benefits, investment cost, payback period, market size (domestic), market size (potential), technological maturity, innovative ability, contribution to the development of country's energy independence – the higher their score is, the better their indicators are.

In order to determine the compatibility of expert opinions OWA (Ordered Weighted Average) method (Yager, 2004) will be used. OWA operator is used for the elimination of exemptions after which expert answers are compatible. It reduces the importance of extreme ratings and thus increases the robustness of the results as well. OWA operator has, therefore, been applied in research focused on a number of areas (Emrouznejad & Marra, 2014).

(Yager, 2004) defined the OWA operator for an n-dimensional argument set $(a_1, a_2, \ldots, a_n)$ as a mapping $F: \Re^n \rightarrow \Re$ with weight vector $W = (w_1, w_2, \ldots, w_n)$, $\sum_i w_i = 1$, $w_i \in [0,1], i = 1, 2, \ldots, n$:

$$F_W(a_1, a_2, ..., a_n) = \sum_{i=1}^{n} w_i b_i , \tag{9}$$

where b_i is the i-th largest element of $(a_1, a_2, \ldots, a_n)$.

The weight vector can be established by considering the following procedure:

$$w_i = Q(1/n) - Q((i-1)/n), i = 1, 2, ..., n, \tag{10}$$

where $Q(y)$ is a non-decreasing relative quantifier (Zadeh, 1983):

$$Q(y) = \begin{cases} 0, & y < a, \\ \dfrac{y-a}{b-a}, & a \le y \le b, \\ 1, & b < y. \end{cases} \tag{11}$$

Parameters a and b govern the degree of coverage of the ordered set of arguments and the following combinations of (a, b) might be applied: "most" – (0.3, 0.8), "at least half" – (0, 0.5), and "as many as possible" – (0.5, 1). In this paper, we apply the first term.

Consequently, expert assessments and the measure of WTP will be aggregated into a single decision matrix which then will serve as a basis for MCDM. The latter analysis will be carried out by three different techniques (TOPSIS, EDAS and WASPAS), on the basis of 17 indicators plus one additional – WTP, which will reflect energy consumers opinion upon particular microgeneration technology. All the three MCDM techniques require setting the weight vectors, which represent the importance of the criteria considered in the analysis. There are different approaches towards setting of these weights. For instance, one might assume equal weights and thus put no additional importance on either of the criteria. Also, an expert survey could be used to populate the weights. However, one of the most important questions in the MCDM is the robustness of the results (ranking). Therefore, in this dissertation (Baležentis & Streimikiene, 2017) and (Awasthi & Baležentis, 2017) will be followed and Monte Carlo stimulation will be applied in order to check the robustness of the results without ex-ante knowledge of the underlying weights of the criteria.

Assuming the criterion weights are perturbed, the random numbers from the uniform distribution will be drawn independently for each criterion. Thereafter, the generated vector will be normalized with respect to the sum of the individual weights. As a result, the normalized weights sum up to unity and indicate the relative importance of the criteria. This procedure will be repeated 5000 times in order to check if the final ranking of the alternatives is highly dependent on the weight vector. To sum it up, using Monte Carlo simulation method sensitivity analysis is carried out, which examines if the final result would change in case minor preferences or input data changes (Awasthi & Baležentis, 2017; Baležentis & Streimikiene, 2017; Simanavičienė & Ustinovičius, 2011). Thus, public impacts can be assessed by the virtue of expert assessment. Such an approach will allow to account for country-specific issues when comparing different microgeneration technologies.

Consequently, model of comparative assessment of microgeneration technologies in households can be seen in Fig. 8, where the data that was collected is shown in blue dotted line, everything else is generated and the final result of this particular model is ranking of microgeneration technologies.

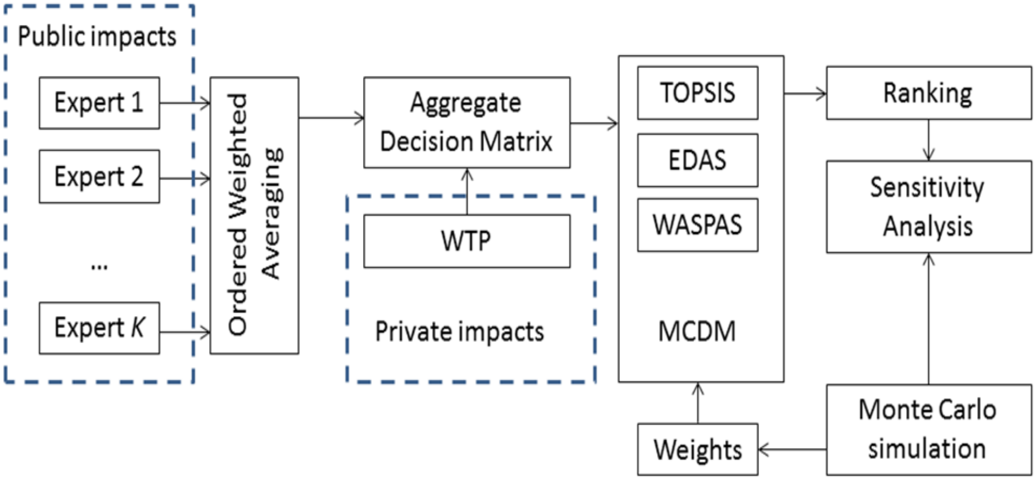


Figure 8. Model for comparative assessment of renewable microgeneration technologies in households

Source: Created by author

In this research the assumption has been made that index $i = 1, 2, \ldots, m$ is associated with alternatives (i.e. microgeneration technologies), whereas index $j = 1, 2, \ldots, n$ represents criteria considered in the analysis. Therefore, the decision matrix representing information about the multiple renewable energy generation options comprises elements x_{ij}. The set of criteria is divided into the two sub-sets, namely set B comprising benefit criteria (these criteria are to be maximized) and set C comprising cost criteria that are to be

)

minimized. In order to ensure smooth operation of the MCDM techniques, criteria with negative values has been transformed:

$$x_{ij} = x_{ij}' + \left|\min_i x_{ij}'\right| + \min_i \left|x_{ij}'\right|, \tag{12}$$

where x_{ij}' is the initial value of the j-th criterion for the i-th alternative, when the j-th criterion involves negative values. The second term on the right-hand side of Eq. 12 implies that the values become non-negative, whereas the third term pushes them away from the zero value. Such a setting allows the resulting elements of decision matrix, x_{ij}, to be meaningfully aggregated by multiplicative utility functions. The decision matrix can then be fed into the MCDM techniques as depicted in Fig. 8.

Three higher mentioned MCDM techniques (TOPSIS, EDAS and WASPAS) have been applied in order to ensure the robustness of results.

2.3.1. TOPSIS method

First, the TOPSIS technique proceeds by normalizing the initial decision matrix by means of vector normalization:

$$x_{ij}^* = w_j \frac{x_{ij}}{\left(\sum_{i=1}^{m} x_{ij}^2\right)^{1/2}} \quad , \tag{13}$$

where w_j denotes the weight associated with the *j*-th criterion, such that $\sum_j w_j = 1$. Therefore, the weighted normalized decision matrix comprises elements $x_{ij}^{\text{å}}$.

The weighted normalized decision matrix is then employed to identify the two ideal solutions, i.e. the positive-ideal solution A^* and the negative-ideal solution A^-. Specifically, the positive ideal solution comprises the maximal (resp. minimal) values of the benefit (resp. cost) criteria, whereas the negative ideal solution is represented by the minimal (resp. maximal) values of the benefit (resp. cost) criteria:

$$A^* = \left\{\left(\max_i v_{ij} \,\middle|\, j \in B\right), \left(\min_i v_{ij} \,\middle|\, j \in C\right), j = 1,2,\cdots,n\right\} = \left\{v_1^*, v_2^*, \cdots, v_n^*\right\}, \tag{14}$$

$$A^- = \left\{\left(\min_i v_{ij} \,\middle|\, j \in B\right), \left(\max_i v_{ij} \,\middle|\, j \in C\right), j = 1,2,\cdots,n\right\} = \left\{v_1^-, v_2^-, \cdots, v_n^-\right\}, \tag{15}$$

where $B \in \left\{j = 1,2,\cdots,n\right\}$ and $C \in \left\{j = 1,2,\cdots,n\right\}$ are sets of benefit and cost criteria, respectively.

The position of each alternative with respect to the two ideal solutions is evaluated by means of the Euclidean distance:

$$S_i^* = \sqrt{\sum_{j=1}^{n} \left(v_{ij} - v_j^*\right)^2}, \text{ for } i = 1, 2, \cdots, m, \tag{16}$$

$$S_i^- = \sqrt{\sum_{j=1}^{n} \left(v_{ij} - v_j^-\right)^2}, \text{ for } i = 1, 2, \cdots, m, \tag{17}$$

where v_j^* and v_j^- represent the coordinates of the ideal solutions. The two measures obtained by Eq. 16 and 17 are further aggregated by constructing the relative closeness indices:

$$C_i = \frac{S_j^-}{S_j^* + S_j^-}, \tag{18}$$

where $C_i \in \left[0;1\right]$ with $i = 1, 2, \cdots, m$. As the relative measure in Eq. 18 indicates the relative distance to the negative ideal solution, higher value thereof implies better performance of an alternative.

2.3.2. EDAS method

The EDAS technique was proposed by (Keshavarz Ghorabaee et al., 2015). (Trinkūnienė et al., 2017) applied the technique for assessment of contractors. In addition, the EDAS technique has also been extended into the fuzzy environment (Stanujkic, Zavadskas, Ghorabaee, & Turskis, 2017). The EDAS technique relies on measurement of distances of the alternatives from the average solution (hypothetic alternative). The coordinates of the average solution are defined as follows:

$$AV = \left\{ \left(\frac{1}{m} \sum\nolimits_{i=1}^{m} x_{ij} \right), j = 1, 2, \cdots, n \right\} = \left\{ AV_1, AV_2, \cdots, AV_n \right\}. \tag{19}$$

The computation proceeds by calculating the distances of each alternative from the average solution. The two mutually exclusive distances (“positive” and “negative” ones) are calculated. For benefit (resp. cost) criteria, “positive” distance becomes positive in case the observed value exceeds (resp. is lower than) the average value for a certain criterion. The opposite logics hold for the “negative” distance. Therefore, the “positive” distance for each alternative and criterion is obtained as follows:

$$\begin{aligned} PD_{ij} &= \frac{\max\left\{0, x_{ij} - AV_j\right\}}{AV_j}, j \in B, \\ PD_{ij} &= \frac{\max\left\{0, AV_j - x_{ij}\right\}}{AV_j}, j \in C. \end{aligned} \tag{20}$$

As regards the “negative” distances, the underlying computations are given as follows:

$$ND_{ij} = \frac{\max\left\{0, AV_j - x_{ij}\right\}}{AV_j}, j \in B,$$

$$ND_{ij} = \frac{\max\left\{0, x_{ij} - AV_j\right\}}{AV_j}, j \in C. \tag{21}$$

The distances based on Eq. 20-21 are dimensionless numbers as they are normalized by the coordinates of the average solution. The distances obtained by Eq. 20-21 are then aggregated for each alternative by taking the importance of each criterion in to account:

$$\begin{aligned} SP_i &= \sum_{j=1}^{n} w_j PD_{ij}, \\ SN_i &= \sum_{j=1}^{n} w_j ND_{ij}, \end{aligned} \tag{22}$$

where w_j is the weight of the *j*-th criterion with $\sum_j w_j = 1$. Then, the weighted aggregate distances are normalized with respect to the maximal values:

$$\begin{aligned} SP_i^* &= SP \big/ \max_i SP_i, \\ SN_i^* &= 1 - SN_i \big/ \max_i SN. \end{aligned} \tag{23}$$

Finally, the utility of each alternative is calculated by considering the average of the two normalized weighted aggregate distances for each alternative:

$$A_i = \frac{1}{2}\left(SP_i^* + SN_i^*\right). \tag{24}$$

Therefore, alternatives with higher values of A_i are preferred.

2.3.3. WASPAS method

The method of weighted aggregated sum/product assessment (WASPAS) was proposed by (Chakraborty & Zavadskas, 2014). It has been employed for construction planning problems (E. K. Zavadskas, Antucheviciene, Kalibatas, & Kalibatiene, 2017) and extended into the fuzzy environment (Ghorabaee, Zavadskas, Amiri, & Esmaeili, 2016; E. K. Zavadskas, Antucheviciene, Hajiagha, & Hashemi, 2014). The WASPAS technique relies on both additive and multiplicative utility functions.

For the WASPAS method, the normalized decision matrix is obtained by applying the linear normalization:

$$\begin{aligned} x_{ij}^* &= \frac{x_{ij}}{\max_i x_{ij}}, \forall j \in B, \\ x_{ij}^* &= \frac{\min_i x_{ij}}{x_{ij}}, \forall j \in C, \end{aligned} \tag{25}$$

where x_{ij}^* stands for the normalized rating of the i-th alternative according to the j-th criterion.

The additive utility function is applied in order to aggregate the normalized ratings for each alternative:

$$S_i = \sum_{j=1}^{n} w_j x_{ij}^* \tag{26}$$

where w_j is the weight of the j-th criterion, $\sum_j w_j = 1$.

Similarly, the multiplicative utility function is defined to appraise utility of each alternative:

$$P_i = \prod_{j=1}^{n} \left(x_{ij}^*\right)^{w_j} . \tag{27}$$

The values of additive and multiplicative utility functions yielded by Eq. 26-27 are then combined into a single measure of utility:

$$Q_i = \lambda S_i + (1-\lambda) P_i . \tag{28}$$

Without loss of generality, we choose $\lambda = 0.5$, which implies equal importance of the additive and multiplicative utility functions. Attention should be paid to the fact the alternatives are ranked in descending order of Q_i.

To sum up, the research of this dissertation consisted from two parts – WTP, which reflects the opinion of households upon microgeneration technologies and MCDM. WTP is performed by using discrete choice experiment, while second part of the research also includes experts' opinion on the impact of microgeneration technologies in the environmental, social, economical, energetic, technological and political aspects after which MCDM is applicable and the stability of results verified by employing Monte Carlo simulation. Detailed instrumentation for evaluating microgeneration technologies is illustrated in Fig. 9.

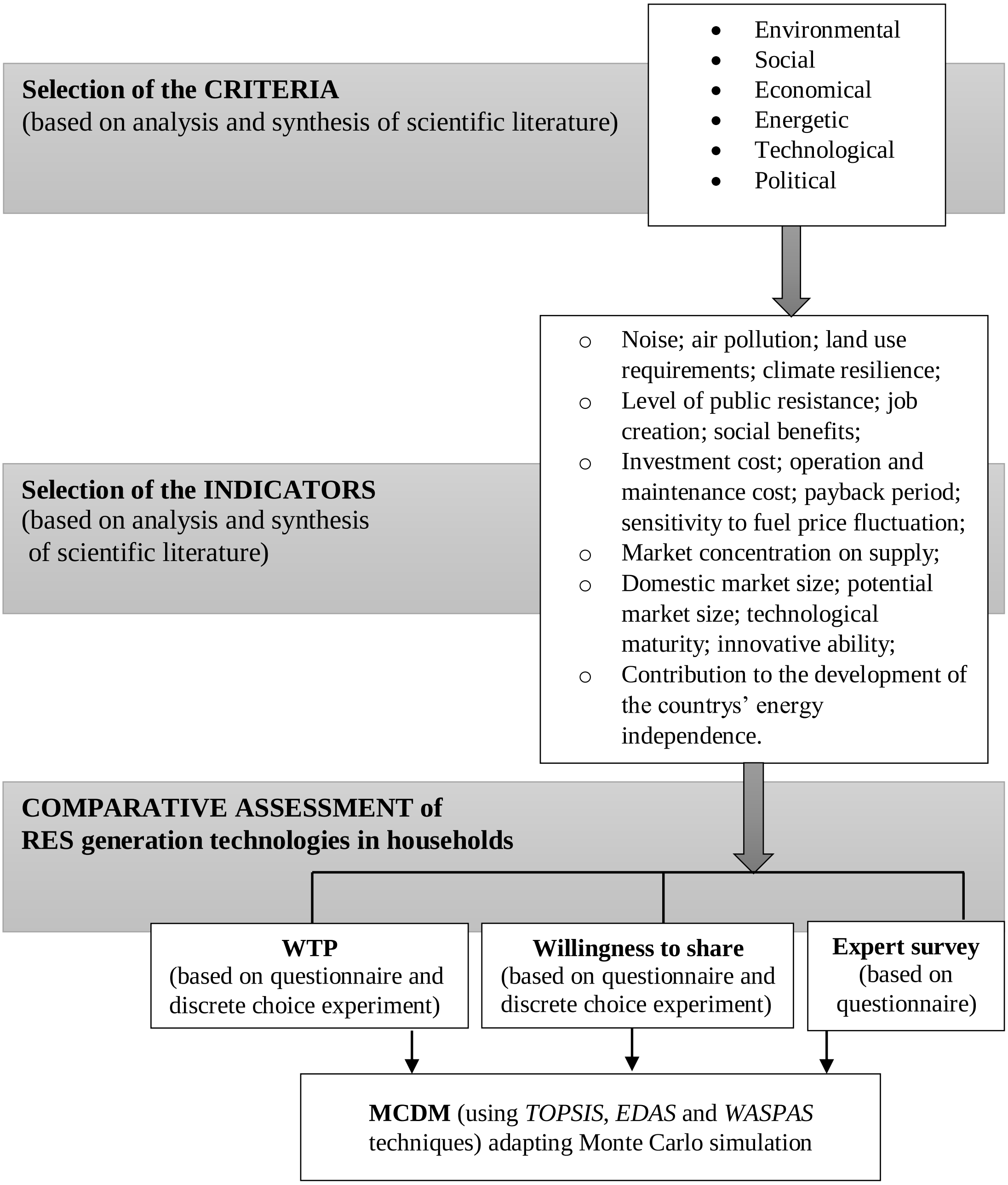


Figure 9. Instrumentation for evaluating RES technologies applied in households (microgeneration technologies)

Source: Created by author

3. APPLICATION OF MODEL FOR COMPARATIVE ASSESSMENT OF RENEWABLE MICROGENERATION TECHNOLOGIES IN LITHUANIAN HOUSEHOLDS

3.1. Assessment of WTP for renewable microgeneration technologies

An unlabelled discrete choice experiment with two generic alternatives (and an opt-out choice) was designed in order to conduct WTP among energy consumers for solar thermal, solar panel, biomass boiler and micro wind technologies. The options, possible for each attribute is given in table below:

Table 11. Attributes and their levels used in discrete choice experiment

Attribute	Level 1	Level 2	Level 3	Level 4
1. Installation costs, EUR	1500	3000	4500	6500
2. Monthly bill, EUR/month	16	30	35	38
3. Length of the warranty period, years	2	5	10	13
4. Requirements for operation	Weather	Fuel	Noise	None
5. Degree of possibility for sharing	Very low	Low	Moderate	High

Source: Created by author

The questionnaire survey was carried out in order to identify the preferences on renewable energy sources and sharing thereof. The factorial design was prepared in accordance with (Fedorov, 1972) and comprised 40 alternatives representing the full factorial design of 5^4 alternatives. Two questionnaires were distributed (APPENDICES “Questionnaire A”, “Questionnaire B”) each of them containing 20 alternatives (Wheeler, 2004). Respondents had to choose among two alternatives, i.e. 10 choice experiments per questionnaire. In addition, they were allowed to choose the *status quo* option.

Questionnaires were completed by respondents in the April – June period of 2016. The target group of respondents concluded individual house owners living in Kaunas or Kaunas region. Another requirement for respondents was that they didn’t use microgeneration technologies in their house. Sample size was computed according to Paniotto formula, on the basis of which, sample had to be concluded not less than 99 respondents. 104 respondents completed the questionnaires thereby carrying out 1040 choice experiments in total.

Primarily respondents were asked to answer short questions that revealed the socio-demographic characteristics:

- 46% of respondents were women and 54% were men;
- 69% of respondents were married, 11% – separated, 11% – single, 3 % –widowed, 7% – cohabiting;
- 3% of respondents were 22 years old and younger; 18% – 23-34 years, 41% – 35-44, 33% – 45-65 and 5% of respondents were 65 years and older;
- 8% of respondents were unemployed, 4% – students, 36% working in public sector, 44% working in private sector and 9% were entrepreneurs;
- 10% of respondents specified their revenues per month were less than 300 EUR, 13% – 300-500 EUR, 35% – 501-1000 EUR, 23% – 1001-1500 EUR, 14% – 1501-

2000 EUR, 3% – 2001-3000 EUR and 3% of respondents specified their revenues per month were more than 3000 EUR;

- 10% of respondents specified their education as upper secondary, 13% – were graduated and 77% were post-graduate;
- 5% of respondents specified their household consist of 1 person, 32% – of 2 persons, 28% – of 3 persons, 30% – of 4 persons and 6% – of more than 4 persons;
- 12% of respondents specified they live in a cottage, while other 88% respondents specified their living place as individual house;
- 2% of respondents indicated they do not own cars, 3% of respondents indicated they own 1 car, 51% – 2 cars and 10 – 3 cars and more;
- 4% of respondents specified the size of their living place is less than 80 sq. m., 38% – 80-120 sq. m., 38% – 121-200 sq. m. and 19% – more than 200 sq. m.;
- 70% of respondents appeared to be the house that they live in owners, while 30% of respondents did not own the right to the house that they live in;
- 24% of respondents pointed out they solve their housing issues on their own, 76% - consults with their spouse or partner;
- 4% of respondents specified they pay for electricity during cold season 0-20 EUR per month, 58% – 21-50 EUR, 31% – 51-100 EUR, 4% – 101-200 EUR, 1% – 201-300 EUR and 3% – 301-400 EUR;
- 15% of respondents specified they pay for electricity during southern season 0-20 EUR per month, 51% – 21-50 EUR, 30% – 51-100 EUR and 4% – 101-200 EUR;
- 2% of respondents specified they pay for heating during cold season 0-20 EUR per month, 7% – 21-50 EUR, 33% – 51-100 EUR, 50% – 101-200 EUR, 8% – 201-300 EUR and 1% – 301-400 EUR;
- 51% of respondents specified they pay for heating during southern season 0-20 EUR per month, 38% – 21-50 EUR, 8% – 51-100 EUR, 2% – 101-200 EUR and 1% – 201-300;
- 3% of respondents specified they pay for electricity and heating 0-20 EUR per month on average, 4% – 21-50 EUR, 18% – 51-100 EUR, 57% – 101-200 EUR, 13% – 201-300 EUR, 4% – 301-400 EUR and 1% – over 400 EUR;
- 7% of respondents specified they are not familiar with microgeneration technologies and 93% of respondents pointed out they are familiar with renewable (microgeneration) technologies, from latter:
  - 85% of respondents specified they have heard about solar thermal and 14% of respondents have not;
  - 74% of respondents specified they have heard about solar panel and 26% of respondents have not;
  - 71% of respondents specified they have heard about biomass boilers and 29% of respondents have not;

    - 75% of respondents specified they have heard about micro wind and 25% of respondents have not.
- 12% of respondents specified they would not like to replenish their existing heating and electricity systems with renewable ones and 88% specified they would like to replenish their existing heating and electricity systems with renewable ones. From latter:
    - 50% of respondents specified they would agree to share energy from their renewable energy technology with their neighbor and 38% – they would not.

Applied LSD (Least Significant Difference) test conducted using R statistical program showed that the difference of average WTP among respondents which are distributed between seven different groups of income is not significant, although averages are different. This outcome may be received due to limited number of respondents – for some income groups only few respondents attributed themselves. Thus, it can be emphasized, consumers' wealth didn't affect their WTP for RES technologies in households in this particular research.

In the second part of questionnaire household owners were presented with the sets of alternative combinations of attributes of particular microgeneration technologies and asked to choose the one more preferred alternative form each set of two. As it continued, repeated choices of household owners from sets of alternatives revealed the trade-offs they are willing to make between attributes and thus between 4 different microgeneration technologies (Scarpa & Willis, 2010).

In order to account for differences in tastes, a mixed logit model with opt-out was employed. Installation costs were chosen as a fixed parameter thus ensuring higher stability of the model and more reasonable estimation of the WTP. The remaining parameters were included as random ones assuming normal distribution. Installations costs, monthly bill, and warranty period entered into the model as continuous variables, whereas operation requirements and degree of sharing (see Table 12.) – as dummy variables (no special requirements for operation and very low possibility for sharing were taken as base levels).

As per suggestion of mixed logit model with opt-out was estimated, which allowed for the dependent variable (Table 12.). Likelihood ratio tests confirmed the presence of non-zero standard deviations as parameters of the underlying distributions of the random coefficients. Therefore, there are significant differences in tastes of the respondents in regard to the effects the decision variables. Further manipulations with distributions of the parameters did not render any decisive changes in the results of the estimation.

The significant coefficients in Table 12. have expected signs: negative coefficients near costs of installation indicate that respondents are less willing to choose alternatives associated with higher investment requirements. The same holds for monthly bill, yet the same absolute increase in monthly bill has a higher effect if compared to installations costs. Increase in warranty period positively affects the probability of choosing the corresponding alternative. Finally, the presence of additional requirements for operation decreases the attractiveness of the alternative. More specifically, noise appeared as the most undesirable feature. Considering variation in tastes, monthly bill showed insignificant coefficient for the model thus implying no differences in the effect of changes in monthly payments upon the choice of energy source across the respondents. As regards the remaining variables, the differences in preferences were observed for at least one level of each attribute.

Table 12. Results of the estimation of the mixed logit model

Variable	Coef.	SE	z-value	Sig.
Mean				
Costs	-0.00104	0.000143	-7.27	***
Bill	-0.09366	0.015	-6.24	***
Warranty	0.250422	0.056134	4.46	***
Req1	-1.26372	0.387759	-3.26	***
Req2	-1.77965	0.280422	-6.35	***
Req3	-3.0829	0.586121	-5.26	***
Share2	0.176686	0.361369	0.49	
Share3	-0.11903	0.380056	-0.31	
Share4	0.242231	0.325592	0.74	
Standard deviation				
Bill	-0.00782	0.021144	-0.37	
Warranty	0.217705	0.048313	4.51	***
Req1	0.293656	0.536862	0.55	
Req2	0.068448	0.794067	0.09	
Req3	-1.63493	0.707709	-2.31	**
Share2	-0.37285	0.411201	-0.91	
Share3	0.402816	0.644225	0.63	
Share4	1.655886	0.36495	4.54	***
	N	1402		
	LR $\chi^2(8)$	45.86		
	p-value	0.000		
	LL	-311.723		

Notes: (i) *** (**) denotes significant coefficients at the level of significance of 1% (5%); (ii) *Req1* to *Req3* correspond to the first three levels of requirements for operation in Table 11.; (iii) *Share2* to *Share4* correspond to the last three levels of degree of possibility for sharing in Table 11.
Source: Created by author

The possibility for sharing appeared to be insignificant. Therefore, the respondents were not considering it as a criterion for the choice of the energy source. This can be explained by certain factors pertinent to Lithuanian context. The negative experience from collectivisation often dampers the initiatives of cooperation in multiple areas. On the other hand, land market distortions following de-collectivisation rendered fragmented and, sometimes, highly heterogeneous neighbourhoods, where cooperation is not that welcome. Therefore, the reasons behind the resistance against sharing of energy generation facilities deserve further research.

Inclusion of monetary variables in the mixed logit model allowed valuing the attributes. Results are presented in Table 13. The increase in monthly bill by 1 EUR requires decrease in installation costs of 90 EUR on average in order to maintain the same level of utility. This figure captures both: the expected time of operation and implicit discount rate. The increase in warranty period of one year is worth 241 EUR. The respondents were eager to pay 2973 EUR in order to avoid noise related to operation of the energy generation facility. Confidence intervals (CI) for the aforementioned attributes indicated significant WTP, whereas the estimates for possibility of share include zero values. This once again suggests the respondents attributed no clear value to possibility for sharing of the energy generation.

Table 13. Estimates of the WTP for different attributes

	Bill (EUR)	Warranty (years)	Requirements for operation			Possibility for sharing		
			Weather	Fuel	Noise	Low	Moderate	High
$E(WTP_k)$	-90	241	-1219	-1716	-2973	170	-115	234
CI	-107	161	-1919	-2315	-4144	-507	-827	-368
	-73	322	-518	-1117	-1802	848	598	836

Notes: (i) *CI* stands for the 95% confidence interval based on the delta method; (ii) Requirements for operation are compared to case of no requirements; (iii) Degrees of possibility for sharing are compared to very low possibility.
Source: Created by author

Four selected microgeneration technologies, commonly used in Lithuania and many other European countries, were further considered in terms of welfare changes: solar thermal, biomass boiler, solar panel, micro wind. Following Eq. (7), biomass, solar, and wind plants were compared to solar panel. Table 14. presents the description of each of the four technologies. The last row in table below presents the changes in welfare as measured in monetary terms.

Table 14. Changes in welfare associated with different microgeneration technologies

Technology	Solar thermal	Biomass boiler	Solar panel	Micro wind
$E(WTP)$, EUR	1363	-507	3363	-2597
$E(\Delta W^{\text{solar panel}})$, EUR	-2001	-3870		-5960
$E(WTP)$, EUR/month	15	-6	37	-29
$E(\Delta W^{\text{solar panel}})$, EUR/month	-22	-43		-66

Source: Created by author

Thus, it can be emphasized solar panels for electricity generation appeared as the most desirable microgeneration technology for Lithuanian energy consumers. The change of the latter technology into any other would render a negative change in welfare. Micro wind appeared as the least attractive option worth around 6 thousand EUR less than the base option of solar panel. Indeed, much of this change can be attributed to the presence of noise during operation of this particular technology. Similarly, biomass boilers require certain fuels for operation and are less preferred by the dwellers.

3.2. Expert survey for public assessment of renewable microgeneration technologies

Twelve experts (3 politicians, 3 businessmen and 6 academics) have completed the questionnaire survey (APPENDICES "Expert Questionnaire"). They were asked to assess the same microgeneration technologies as household owners based on environmental, social, economic, energy, technology and political criteria according to Likert scale (a five-point system):

1. Totally disagree
2. Disagree
3. Difficult to say
4. Agree
5. Fully agree

Experts have ranked solar thermal, solar panel, biomass boilers and micro wind technology according to seventeen indicators. Thus, they were asked to complete four of tables like the one presented below.

Table 15. Questions regarding expert evaluation on microgeneration technology

No.	*Factors that impact particular technology*	*Assessment level*				
		Disagree			*Agree*	
1.	*Particular technology* use generate noise	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
2.	*Particular technology* use contributes to the growth of CO_2 emissions in the atmosphere	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
3.	*Particular technology* needs extra land and distort the landscape	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
4.	*Particular technology* is resistant to climate change and extreme meteorological phenomena	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
5.	*Particular technology* is badly appreciated in society	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
6.	*Particular technology* creates additional jobs (directly and indirectly)	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
7.	*Particular technology* use has a positive impact on the social progress of the entire region	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
8.	*Particular technology* cost is constantly decreasing	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
9.	*Particular technology* is characterized by high operating and maintenance costs	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
10.	*Particular technology* has a short payback period	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
11.	*Particular technology* price is sensitive to energy and fuel price fluctuations	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
12.	High concentration of *particular technology* in the market negatively affects the stability of the system	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
13.	*Particular technology* is in great demand on the local market	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
14.	*Particular technology* is in great demand on the global market	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
15.	*Particular technology* is technologically mature and widespread in the global market	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
16.	Technological improve of *particular technology* is possible	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
17.	*Particular technology* use contributes to the development of country's' energy independence	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐

Source: Created by author

3.3. MCDM of renewable microgeneration technologies

In order to aggregate the expert ratings in a more robust manner, the OWA operator was applied, for all 17 factors (criteria) and WTP results (as it was indicated as the 18th criteria). Within the next step aggregate decision matrix was formed:

Table 16. Aggregate Decision Matrix

Microgeneration technologies	Indicators								
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Solar thermal	1.40	1.23	1.73	3.30	1.80	4.00	3.07	3.73	1.57
Solar panel	1.00	1.23	2.97	3.30	2.00	4.00	3.80	4.40	1.57
Biomass boiler	2.00	1.80	1.80	4.23	1.57	4.23	4.00	3.23	3.30
Micro wind	4.23	1.40	3.97	3.57	2.80	4.00	3.90	3.97	2.40

sequel of Table 16.

Microgeneration technologies	Indicators								
	10	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**
Solar thermal	2.80	2.00	2.13	1.97	3.57	3.73	4.07	4.23	4466.6788
Solar panel	2.57	1.90	3.30	2.23	3.90	3.90	4.73	4.73	2596.75
Biomass boiler	2.97	3.13	1.40	3.47	3.73	4.07	4.00	4.57	6467.1894
Micro wind	2.73	2.47	3.80	2.97	4.07	4.23	4.40	4.73	506.80192

Source: Created by author

Comparative assessment, conducted with MCDM and backed up with WTP, was carried out with three different methods (TOPSIS, EDAS and WASPAS). The TOPSIS method yielded rather uncertain results for the best performing technology. Indeed, both solar thermal and biomass boiler microgeneration technologies showed the highest probabilities of acquiring the first rank indicating the most preferable alternative. However, the probability of such event for solar thermal technology exceeded 0.5 (i.e. 0.51), whereas that for the biomass boiler technology fell below this value (i.e. 0.44). Therefore, the choice of the most preferable alternative appeared to be highly dependent on the choice of the weighting vector when the TOPSIS technique was applied. Looking closer at the results of the Monte Carlo simulation indicates that the solar thermal technology had the highest probabilities of being attributed with ranks 1 and 2 (0.51 and 0.47, respectively), whereas the biomass boiler technology showed a much wider range of ranks. More specifically, the latter technology showed the highest probability of being attributed with rank 1, yet probabilities of 0.26 and 0.30 were also observed for ranks of 2 and 3. Therefore, the biomass boiler technology might appear as the second or even the third most preferable technology depending on the weighting vector. The solar panel technology showed clearly increasing probabilities as the ranks descended from 1 to 3, with probability of appearing as the third most preferable alternative equalling 0.69. Finally, wind microgeneration technology appeared as the least preferable one irrespectively of the changes in the weighting vector. Fig. 10 presents the distribution of ranks rendered by the Monte Carlo simulation for the TOPSIS technique.

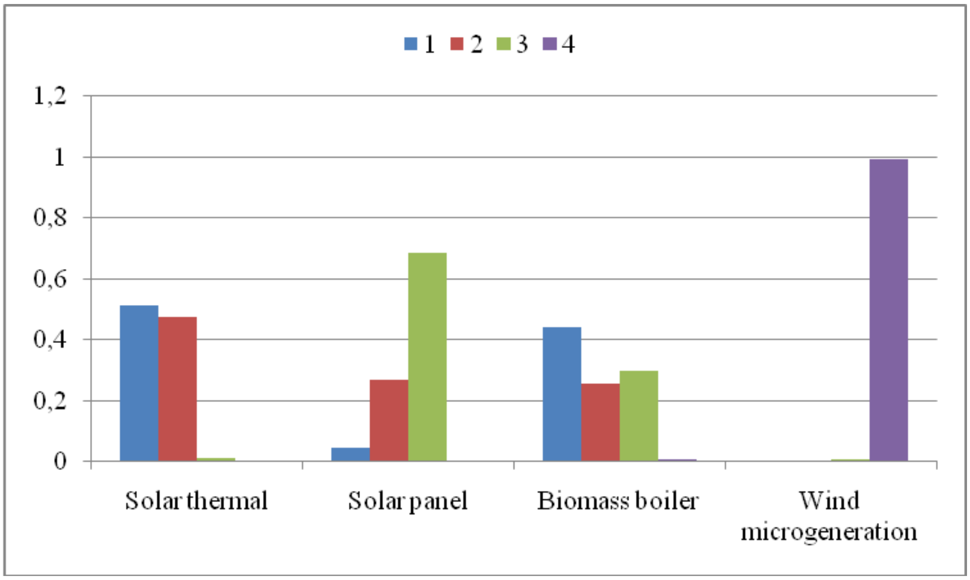


Figure 10. Relative frequency of attribution of certain ranks for the TOPSIS technique under the Monte Carlo simulation (*N* = 5000)

Source: Created by author

Biomass boiler turned out to be the most preferable energy generation technique according to the aggregation defined by the EDAS technique. Indeed, the Monte Carlo simulation yielded probability of such a ranking of 0.63. Solar thermal energy generation technology came next with probability of 0.67. The changes in the weighting vector caused solar thermal energy generation appearing as the most preferable alternative with probability of 0.25. Therefore, the latter alternative might become more appealing if the importance of criteria is altered. The solar panel technology showed the highest probability to be attributed with the rank of three (0.71). Wind microgeneration technology appeared as the least attractive one with probability of more than 0.99. Fig. 11 presents the results of the Monte Carlo simulation for the EDAS technique.

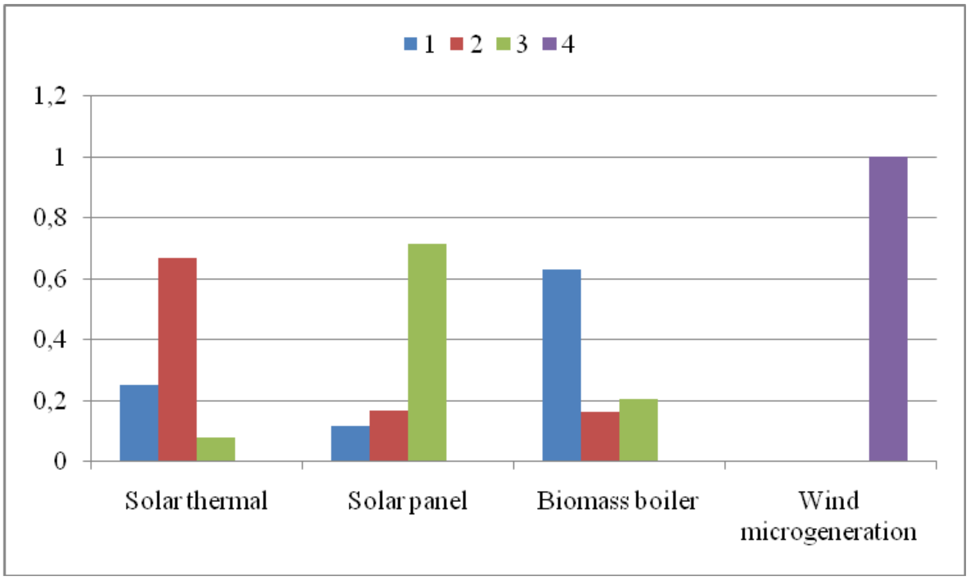


Figure 11. Relative frequency of attribution of certain ranks for the EDAS technique under the Monte Carlo simulation (*N* = 5000)

Source: Created by author

Results for the WASPAS technique are similar to those obtained for the EDAS. In case of WASPAS, the biomass boiler appeared as the most desirable alternative with probability of 0.59. The solar thermal plants were placed as the second best alternative with probability of 0.61 (based on the Monte Carlo approach). Anyway, the probability of the solar thermal plants being the best option was 0.18. The probabilities of being the best and second-best alternative for the solar panel were 0.22 and 0.23, respectively. For the latter microgeneration technology, the highest probability was that of being ranked as the third-best alternative (0.54). As it was the case with the previous techniques, the wind microgeneration technology turned out to be the least favourable alternative. Fig. 12 presents the results of the Monte Carlo simulation for the EDAS technique.

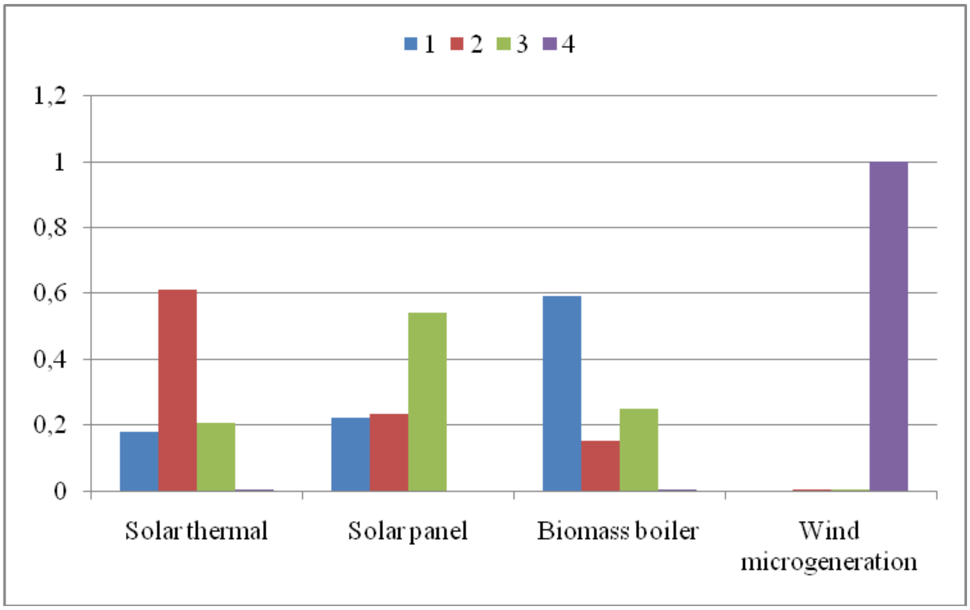


Figure 12. Relative frequency of attribution of certain ranks for the WASPAS technique under the Monte Carlo simulation (N = 5000)

Source: Created by author

Thus, while summarizing the results of comparative assessment of RES technologies applied in households (microgeneration technologies) in Lithuania, presented in Table 17., it can be said, comparative assessment, combined of WTP and MCDM, displayed matching results – biomass boilers and solar thermal were ranked as the best microgeneration technology.

Table 17. Results of comparative assessment of microgeneration technologies

MCDM method	TOPSIS				EDAS				WASPAS			
Particular technology / Ranks	Solar thermal	Solar panel	Biomass boiler	Micro wind	Solar thermal	Solar panel	Biomass boiler	Micro wind	Solar thermal	Solar panel	Biomass boiler	Micro wind
1	**0.5142**	0.0450	0.4408	0.0000	0.2506	0.1170	**0.6324**	0.0000	0.1816	0.2244	**0.5940**	0.0000
2	0.4740	0.2700	**0.2558**	0.0002	**0.6682**	0.1686	0.1630	0.0002	**0.6114**	0.2340	0.1544	0.0002
3	0.0114	**0.6850**	0.2978	0.0058	0.0808	**0.7144**	0.2042	0.0006	0.2064	**0.5416**	0.2512	0.0008
4	0.0004	0.0000	0.0056	**0.9940**	0.0004	0.0000	0.0004	**0.9992**	0.0006	0.0000	0.0004	**0.9990**
Stability	51.42	68.5	44.08	99.4	66.82	71.44	63.24	99.92	61.14	54.16	59.4	99.9
Given ranks	1	3	2	4	2	3	1	4	2	3	1	4

Source: Created by author

However, two of MCDM methods (EDAS and WASPAS) showed all in all biomass boilers were assigned with the best (no. 1) rank and solar thermal technologies were ranked as the second best. Analysis completed by TOPSIS technique demonstrated solar thermal technology where ranked as the best one, and biomass boilers were ranked as second best. These unequal outcomes linked to the different methods of particular techniques – TOPSIS and EDAS rely on the reference point approach, i.e. TOPSIS considers the ideal and anti-ideal solutions as the two reference points, whereas EDAS takes the sample average as a reference point. The WASPAS technique relies on multiplicative and additive utility functions. Furthermore, results obtained by all three methods showed micro wind technology in 99 % with all Monte Carlo simulations was ranked as the least good and solar panel were assigned with rank no. 3 in 44-63% with all Monte Carlo simulations. Thus, by changing weights of different indicators (criteria) 5000 times (enabling Monte Carlo method) micro wind technology persists as the most poorly ranked one.

CONCLUSIONS

- Literature review has suggested each state has its own RES promotion methods and apply them in different ways. Therefore, using the good practice, it would be possible to complete the analysis of RES technology, and to identify main RES technologies preferred by households thereby suggesting directions for subsidies in order to promote RES in Lithuania. RES has to overcome various barriers and because of their ability to evolve over time – many their identification ways are possible. The essential branches for which barriers can be attributed are environmental, socio-economic, technical and institutional. However, because market failures (which means in terms of RES provided public benefit and negative external effects of traditional energy resources) are one of the main brakes hindering the development of RES, the more general way, suggested by scientists, is to group them into three main groups: commercial, price distortions, market failures and market barriers. Properly conducted sustainability assessment of RES technologies can prevent potential barriers or limit them.

  Various tools and methods for sustainability assessment of RES technologies exist. Assessment of households' willingness to pay (WTP) for external benefits determination is being applied in the world. Based on the literature survey the following criteria for WTP analysis was established: installation costs, monthly bill, length of the warranty of period, requirements for operation and degree of possibility for sharing. Regards to multi-criteria decision method (MCDM), which also was suggested by many scientists as the appropriate one for sustainability assessment, following criteria (indicators) were included in the analysis, representing public impacts: noise, air pollution, land use requirements, climate resilience, level of public resistance, job creation, social benefits, investment cost, operation and maintenance cost, payback period, sensitivity to fuel price fluctuation, market concentration on supply, domestic market size, potential market size, technological maturity, innovative ability, contribution to the development of the country's energy independence. Integrated application of higher mentioned criteria allows to comprehensively evaluate microgeneration technologies.

- Developed model comprises the two main parts: econometric model for estimation of WTP and expert survey, which are being aggregated by applying MCDM framework for comprehensive analysis of both private and public impacts. Econometric model relies on mixed logit model. MCDM framework involves the three MCDM techniques (TOPSIS, EDAS and WASPAS) and Monte Carlo simulation. Monte Carlo allows checking the robustness of ranking of microgeneration technologies compared.

- In order to assess the possibilities of development of microgeneration technologies in Lithuania the following technologies were analyzed: solar thermal, biomass boiler, solar panel, micro wind. Questionnaire survey involving the discrete choice experiment was completed, which allowed estimating the WTP econometrically. Secondly, an expert survey was carried out in order to evaluate the public impacts of microgeneration technologies.

- In order to assess energy consumers WTP for RES technologies, thus microgeneration technologies, applied in households the questionnaire survey was carried out (APPENDICES "Questionnaire A", "Questionnaire B"). Repeated choices of household owners from sets of alternatives revealed the trade-offs they are willing to make between attributes and thus between 4 different microgeneration technologies, which have been selected for the research as the most commonly used in Lithuanian households, i.e. solar thermal, solar panel, biomass boiler and micro wind. Although microgeneration technology is still the growing trend and most of existing research generally supports that people are willing to pay extra for renewable energy, the research showed, in Lithuania, however, this is not the case. WTP analysis showed Lithuanian households would pay extra only for solar panel and solar thermal technologies. In other cases (biomass boilers and micro wind) they prefer to be compensated in order to choose the particular technology. Solar panels for electricity generation appeared as the most desirable microgeneration technology for Lithuanian energy consumers. The change of the latter technology into any other would render a negative change in welfare. Micro wind appeared as the least attractive option worth around 6 thousand EUR less than the base option of solar panel. Indeed, much of this change can be attributed to the presence of noise during operation of this particular technology. Similarly, biomass boilers require certain fuels for operation and are less preferred by the dwellers. Nevertheless, study proved it is possible to conduct Lithuanian households' attitudes towards renewable energy and measures should be taken to help improve users' perspective towards them.

- In order to conduct comparative assessment of microgeneration technologies in Lithuania by using MCDM, a questionnaire for expert examination (APPENDICES "Expert Questionnaire") was prepared and expert survey was completed. They were asked to assess the same microgeneration technologies as household owners based on environmental, social, economical, energetical, technological and political criteria according to Likert scale. All in all, particular microgeneration technologies were ranked according to the 17 factors that impact solar thermal, solar panel, biomass boilers and micro wind technologies.

- Multi-criteria evaluation (MCDM) of RES technology based on households WTP for RES technology and the results of experts' evaluation was performed: expert assessments and the measure of WTP was aggregated into a single decision matrix which served as a basis for MCDM, which was carried out by three different methods (TOPSIS, EDAS and WASPAS), on the basis of 17 indicators plus one additional – WTP, that reflected energy consumers opinion upon particular microgeneration technology. Different weights for different indicators (and thus – different criteria) were generated 5000 times (enabling Monte Carlo method) in order to check the robustness of the results without ex-ante knowledge of the underlying weights of the criteria.

- While summarizing the results of comparative assessment of RES technologies applied in households (microgeneration technologies) in Lithuania it can be said, comparative assessment, combined of WTP and MCDM, displayed matching results – biomass boilers and solar thermal were ranked as the best microgeneration technology. However, two of MCDM methods (EDAS and WASPAS) showed all in all biomass boilers were assigned with the best (no. 1) rank and solar thermal technologies were ranked as the second best. Analysis completed by TOPSIS technique demonstrated solar thermal technology where ranked as the best one, and biomass boilers were ranked as second best. These unequal outcomes linked to the different methods of particular techniques – TOPSIS and EDAS rely on the reference point approach, i.e. TOPSIS considers the ideal and anti-ideal solutions as the two reference points, whereas EDAS takes the sample average as a reference point. The WASPAS technique relies on multiplicative and additive utility functions. Results obtained by all three methods showed micro wind technology in 99 % with all Monte Carlo simulations was ranked as the least good and solar panel were assigned with rank no. 3 in 44-63% with all Monte Carlo simulations. Thus, by changing weights of different indicators (criteria) 5000 times (enabling Monte Carlo method) micro wind technology persists as the most poorly ranked one.

- Based on the results of the research, recommendations on the application of the model and its improvement is maid:
    - The amount of microgeneration technology subsidies can be determined based on WTP value. If WTP is high for particular technology – this technology will be bought willingly by consumers, and thus, the subsidy program can be more easily implemented in this case;
    - Since the research of dissertation demonstrated different methods and weights yield different results, it is therefore recommended to use the Monte Carlo method while performing comparative assessment of RES technologies and not rely solely on one multicriteria assessment method;
    - Whereas the state must also take into account the public interest, revealed by experts, and the private interest, disclosed by WTP, it would be advisable for the state to subsidize microgeneration technologies based on the results of the WTP study and MCDM.

REFERENCES

Acito, F., & Jain, A. K. (1980). Evaluation of conjoint analysis results: A comparison of methods. *Journal of Marketing Research,* 106-112.

Adamowicz, W., Louviere, J., & Williams, M. (1994). Combining revealed and stated preference methods for valuing environmental amenities. *Journal of Environmental Economics and Management, 26*(3), 271-292.

Afgan, N. H., & Carvalho, M. G. (2002). Multi-criteria assessment of new and renewable energy power plants. *Energy, 27*(8), 739-755.

Ahmad, S., & Tahar, R. M. (2014). Selection of renewable energy sources for sustainable development of electricity generation system using analytic hierarchy process: A case of Malaysia. *Renewable Energy, 63,* 458-466.

Akcura, E. (2015). Mandatory versus voluntary payment for green electricity. *Ecological Economics, 116,* 84-94.

Alanne, K., & Saari, A. (2004). Sustainable small-scale CHP technologies for buildings: The basis for multi-perspective decision-making. *Renewable and Sustainable Energy Reviews, 8*(5), 401-431.

Itališauskaitė-Šeškienė, I. (2016). Multi-criteria decision analysis methods aiming to evaluate renewable energy sources technology. *13th Annual International Conference of Young Scientists on Energy Issues (CYSENI 2016), Kaunas, Lithuania, May 26–27, 2016.Kaunas: LEI, 2016,* 36-45.

Allen, S., Hammond, G., & McManus, M. C. (2008). Prospects for and barriers to domestic micro-generation: A United Kingdom perspective. *Applied Energy, 85*(6), 528-544.

Aravena, C., Hutchinson, W. G., & Longo, A. (2012). Environmental pricing of externalities from different sources of electricity generation in Chile. *Energy Economics, 34*(4), 1214-1225.

Awasthi, A., & Baležentis, T. (2017). A hybrid approach based on BOCR and fuzzy MULTIMOORA for logistics service provider selection. *International Journal of Logistics Systems and Management, 27*(3), 261-282.

Balezentiene, L., Streimikiene, D., & Balezentis, T. (2013). Fuzzy decision support methodology for sustainable energy crop selection. *Renewable and Sustainable Energy Reviews, 17,* 83-93.

Baležentis, T., & Streimikiene, D. (2017). Multi-criteria ranking of energy generation scenarios with Monte Carlo simulation. *Applied Energy, 185,* 862-871.

Banfi, S., Farsi, M., Filippini, M., & Jakob, M. (2008). Willingness to pay for energy-saving measures in residential buildings. *Energy Economics, 30*(2), 503-516.

Bashiri, M., Badri, H., & Hejazi, T. H. (2011). Selecting optimum maintenance strategy by fuzzy interactive linear assignment method. *Applied Mathematical Modelling, 35*(1), 152-164.

Bebbington, J., Brown, J., & Frame, B. (2007). Accounting technologies and sustainability assessment models. *Ecological Economics, 61*(2), 224-236.

Beccali, M., Cellura, M., & Mistretta, M. (2003). Decision-making in energy planning. application of the electre method at regional level for the diffusion of renewable energy technology. *Renewable Energy, 28*(13), 2063-2087.

Belton, V., & Stewart, T. (2002). *Multiple criteria decision analysis: An integrated approach* Springer Science & Business Media.

Bennett, J., & Blamey, R. (2001). *The choice modelling approach to environmental valuation* Edward Elgar Publishing.

Bergmann, A., Colombo, S., & Hanley, N. (2008). Rural versus urban preferences for renewable energy developments. *Ecological Economics, 65*(3), 616-625.

Bergmann, A., Hanley, N., & Wright, R. (2006). Valuing the attributes of renewable energy investments. *Energy Policy, 34*(9), 1004-1014.

Bigerna, S., & Polinori, P. (2014). Italian households' willingness to pay for green electricity. *Renewable and Sustainable Energy Reviews, 34*, 110-121.

Böhringer, C., & Jochem, P. E. (2007). Measuring the immeasurable—A survey of sustainability indices. *Ecological Economics, 63*(1), 1-8.

Boie, I., Fernandes, C., Frías, P., & Klobasa, M. (2014). Efficient strategies for the integration of renewable energy into future energy infrastructures in Europe–An analysis based on transnational modeling and case studies for nine European regions. *Energy Policy, 67*, 170-185.

Bollino, C. A. (2009). The willingness to pay for renewable energy sources: The case of Italy with socio-demographic determinants. *The Energy Journal, 30*(2), 81-96.

Booysen, F. (2002). An overview and evaluation of composite indices of development. *Social Indicators Research, 59*(2), 115-151.

Borchers, A. M., Duke, J. M., & Parsons, G. R. (2007). Does willingness to pay for green energy differ by source? *Energy Policy, 35*(6), 3327-3334.

Boxall, P. C., Adamowicz, W. L., Swait, J., Williams, M., & Louviere, J. (1996). A comparison of stated preference methods for environmental valuation. *Ecological Economics, 18*(3), 243-253.

Brauers, W. K. M., & Zavadskas, E. K. (2006). The MOORA method and its application to privatization in a transition economy. *Control and Cybernetics, 35*(2), 445.

Bridges, A., Felder, F. A., McKelvey, K., & Niyogi, I. (2015). Uncertainty in energy planning: Estimating the health impacts of air pollution from fossil fuel electricity generation. *Energy Research & Social Science, 6*, 74-77.

Brundtland, G., Khalid, M., Agnelli, S., Al-Athel, S., Chidzero, B., Fadika, L., . . . de Botero, M. M. (1987). Our common future (\'Brundtland report\').

Campbell, D., Hutchinson, W. G., & Scarpa, R. (2008). Incorporating discontinuous preferences into the analysis of discrete choice experiments. *Environmental and Resource Economics, 41*(3), 401-417.

Carrera, D. G., & Mack, A. (2010). Sustainability assessment of energy technologies via social indicators: Results of a survey among European energy experts. *Energy Policy, 38*(2), 1030-1039.

Chakraborty, S., & Zavadskas, E. K. (2014). Applications of WASPAS method in manufacturing decision making. *Informatica, 25*(1), 1-20.

Chan, K., Oerlemans, L. A., & Volschenk, J. (2015). On the construct validity of measures of willingness to pay for green electricity: Evidence from a south African case. *Applied Energy, 160*, 321-328.

Christiaensen, L. J., & Sarris, A. (2007). *Rural household vulnerability and insurance against commodity risks: Evidence from the united republic of Tanzania* Food & Agriculture Org.

Čiegis, R. (2004). *Ekonomika ir aplinka: Subalansuotos plėtros valdymas*. Kaunas: Vytauto Didžiojo universitetas.

Čiegis, R., & Zeleniūtė, R. (2008). Lietuvos ekonomikos plėtra darnaus vystymosi aspektu. *Taikomoji Ekonomika: Sisteminiai Tyrimai, 2*(2), 11-28.

Claudy, M. C., Michelsen, C., & O'Driscoll, A. (2011). The diffusion of microgeneration technologies–assessing the influence of perceived product characteristics on home owners' willingness to pay. *Energy Policy, 39*(3), 1459-1469.

Claudy, M. C., Michelsen, C., O'Driscoll, A., & Mullen, M. R. (2010). Consumer awareness in the adoption of microgeneration technologies: An empirical investigation in the republic of Ireland. *Renewable and Sustainable Energy Reviews, 14*(7), 2154-2160.

Dagher, L., & Harajli, H. (2015). Willingness to pay for green power in an unreliable electricity sector: Part 1. the case of the Lebanese residential sector. *Renewable and Sustainable Energy Reviews,*

De Groot, R. S., Wilson, M. A., & Boumans, R. M. (2002). A typology for the classification, description and valuation of ecosystem functions, goods and services. *Ecological Economics, 41*(3), 393-408.

De Paepe, M., D'Herdt, P., & Mertens, D. (2006). Micro-CHP systems for residential applications. *Energy Conversion and Management, 47*(18), 3435-3446.

Devuyst, D., Hens, L., & De Lannoy, W. (2001). *How green is the city? sustainability assessment and the management of urban environments*. New York: Columbia University Press.

Dincer, I. (2000). Renewable energy and sustainable development: A crucial review. *Renewable and Sustainable Energy Reviews, 4*(2), 157-175.

Dombi, M., Kuti, I., & Balogh, P. (2014). Sustainability assessment of renewable power and heat generation technologies. *Energy Policy, 67*, 264-271.

Doukas, H. C., Andreas, B. M., & Psarras, J. E. (2007). Multi-criteria decision aid for the formulation of sustainable technological energy priorities using linguistic variables. *European Journal of Operational Research, 182*(2), 844-855.

Ek, K. (2005). Public and private attitudes towards "green" electricity: The case of Swedish wind power. *Energy Policy, 33*(13), 1677-1689.

Eleftheriadis, I. M., & Anagnostopoulou, E. G. (2015). Identifying barriers in the diffusion of renewable energy sources. *Energy Policy, 80*, 153-164.

Emrouznejad, A., & Marra, M. (2014). Ordered weighted averaging operators 1988–2014: A citation-based literature survey. *International Journal of Intelligent Systems, 29*(11), 994-1014.

The EU climate and energy package, (2008).

EUROPE 2020: A strategy for smart, sustainable and inclusive growth, COM (2010) 2020 final, (2010).

European Commission. (2013). *The European union explained: Europe 2020: Europe's growth strategy*. Luxembourg: Publications Office of the European Union. doi:10.2775/39976

Evans, A., Strezov, V., & Evans, T. J. (2009). Assessment of sustainability indicators for renewable energy technologies. *Renewable and Sustainable Energy Reviews, 13*(5), 1082-1088.

Fedorov, V. V. (1972). *Theory of optimal experiments* Elsevier.

Figueira, J., Mousseau, V., & Roy, B. (2005). ELECTRE methods. *Multiple criteria decision analysis: State of the art surveys* (pp. 133-153) Springer.

Francés, G. E., Marín-Quemada, J. M., & González, E. S. M. (2013). RES and risk: Renewable energy's contribution to energy security. A portfolio-based approach. *Renewable and Sustainable Energy Reviews, 26*, 549-559.

Gaigalis, V., Markevicius, A., Katinas, V., & Skema, R. (2014). Analysis of the renewable energy promotion in Lithuania in compliance with the European Union strategy and policy. *Renewable and Sustainable Energy Reviews, 35,* 422-435.

Galinis, A., Lekavičius, V., & Miškinis, V. (2010). Atsinaujinančių energijos išteklių platesnio naudojimo kryptys. *Mokslas ir technika, 6,* 4-6.

Garcia, R., Bardhi, F., & Friedrich, C. (2007). Overcoming consumer resistance to innovation. *MIT Sloan Management Review, 48*(4), 82.

Gasparatos, A., & Scolobig, A. (2012). Choosing the most appropriate sustainability assessment tool. *Ecological Economics, 80*, 1-7.

Gasparatos, A. (2010). Embedded value systems in sustainability assessment tools and their implications. *Journal of Environmental Management, 91*(8), 1613-1622.

Georgescu, M., & Herman, E. (2014). Social corporate responsibility regarding household consumer satisfaction with the electric power supply services. *Amphitheatre Economic, 16*(35), 123-137.

Ghorabaee, M. K., Zavadskas, E. K., Amiri, M., & Esmaeili, A. (2016). Multi-criteria evaluation of green suppliers using an extended WASPAS method with interval type-2 fuzzy sets. *Journal of Cleaner Production, 137,* 213-229.

Gohari, A., Eslamian, S., Mirchi, A., Abedi-Koupaei, J., Bavani, A. M., & Madani, K. (2013). Water transfer as a solution to water shortage: A fix that can backfire. *Journal of Hydrology, 491,* 23-39.

Grilli, G., Balest, J., Garegnani, G., & Paletto, A. (2015). Exploring residents' willingness to pay for renewable energy supply: Evidences from an italian case study. *Available at SSRN 2669975,* Guo, X., Liu, H., Mao, X., Jin, J., Chen, D., & Cheng, S. (2014). Willingness to pay for renewable electricity: A contingent valuation study in Beijing, China. *Energy Policy, 68,* 340-347.

Hadian, S., & Madani, K. (2015). A system of systems approach to energy sustainability assessment: Are all renewables really green? *Ecological Indicators, 52,* 194-206.

Hanley, N., Colombo, S., Kriström, B., & Watson, F. (2009). Accounting for negative, zero and positive willingness to pay for landscape change in a national park. *Journal of Agricultural Economics, 60*(1), 1-16.

Hanley, N., & Nevin, C. (1999). Appraising renewable energy developments in remote communities: The case of the North Assynt estate, Scotland. *Energy Policy, 27*(9), 527-547.

Herbes, C., Friege, C., Baldo, D., & Mueller, K. (2015). Willingness to pay lip service? applying a neuroscience-based method to WTP for green electricity. *Energy Policy, 87,* 562-572.

Hjorth, P., & Madani, K. (2014). Sustainability monitoring and assessment: New challenges require new thinking. *Journal of Water Resources Planning and Management,*

Hofman, K., & Li, X. (2009). Canada's energy perspectives and policies for sustainable development. *Applied Energy, 86*(4), 407-415.

Hole, A. R. (2007). Estimating mixed logit models using maximum simulated likelihood. *Stata Journal, 7*(3), 388-401.

International Atomic Energy Agency. (2006). *Brazil: A country profile on sustainable energy development*. Vienna: International Atomic Energy Agency.

International Energy Agency. (2003). *Creating markets for energy technologies*. Paris: Organization for Economic Cooperation and Development/International Energy Agency. doi:10.1787/9789264099647-en

Jacobsen, H. K., Pade, L. L., Schröder, S. T., & Kitzing, L. (2014). Cooperation mechanisms to achieve EU renewable targets. *Renewable Energy, 63*, 345-352.

James, J. S., Rickard, B. J., & Rossman, W. J. (2009). Product differentiation and market segmentation in applesauce: Using a choice experiment to assess the value of organic, local, and nutrition attributes. *Agricultural & Resource Economics Review, 38*(3), 357.

Janssen, R. (2001). On the use of multi-criteria analysis in environmental impact assessment in the netherlands. *Journal of Multi-Criteria Decision Analysis, 10*(2), 101-109.

Johnson, E., Nemet, G. F., & Nemet, G. (2010). Willingness to pay for climate policy: A review of estimates.

Jung, W., Kim, T., & Lee, S. T. (2015). The study on the value of new & renewable energy as a future alternative energy source in Korea.

Karakosta, C., Pappas, C., Marinakis, V., & Psarras, J. (2013). Renewable energy and nuclear power towards sustainable development: Characteristics and prospects. *Renewable and Sustainable Energy Reviews, 22*, 187-197.

Karytsas, S., & Theodoropoulou, H. (2014). Socioeconomic and demographic factors that influence publics' awareness on the different forms of renewable energy sources. *Renewable Energy, 71*, 480-485.

Katinas, V., Markevicius, A., Erlickyte, R., & Marciukaitis, M. (2008). Governmental policy and prospect in electricity production from renewables in Lithuania. *Energy Policy, 36*(10), 3686-3691.

Keeney, R. L., & Raiffa, H. (1976). Decision analysis with multiple conflicting objectives. *Wiley& Sons, New York,*

Keršuliene, V., Zavadskas, E. K., & Turskis, Z. (2010). Selection of rational dispute resolution method by applying new step-wise weight assessment ratio analysis (SWARA). *Journal of Business Economics and Management, 11*(2), 243-258.

Keshavarz Ghorabaee, M., Zavadskas, E. K., Olfat, L., & Turskis, Z. (2015). Multi-criteria inventory classification using a new method of evaluation based on distance from average solution (EDAS). *Informatica, 26*(3), 435-451.

Klein, R. J., Schipper, E. L. F., & Dessai, S. (2005). Integrating mitigation and adaptation into climate and development policy: Three research questions. *Environmental Science & Policy, 8*(6), 579-588.

Klevas, V., & Štreimikienė, D. (2006). *Lietuvos energetikos ekonomikos pagrindai*. Kaunas: Lietuvos energetikos institutas.

Kocaoglu, D. F., Daim, T. U., Iskin, I., & Alizadeh, Y. (2015). Technology assessment: Criteria for evaluating a sustainable energy portfolio. In T. U. Daim (Ed.), *Hierarchical decision modeling: Essays in honor of dundar F. kocaoglu* (pp. 3-34). Switzerland: Springer International Publishing. doi:10.1007/978-3-319-18558-3

Kosenius, A., & Ollikainen, M. (2013). Valuation of environmental and societal trade-offs of renewable energy sources. *Energy Policy, 62*, 1148-1156.

Kraeusel, J., & Möst, D. (2012). Carbon capture and storage on its way to large-scale deployment: Social acceptance and willingness to pay in Germany. *Energy Policy, 49*, 642-651.

Krylovas, A., Zavadskas, E. K., Kosareva, N., & Dadelo, S. (2014). New KEMIRA method for determining criteria priority and weights in solving MCDM problem. *International Journal of Information Technology & Decision Making, 13*(06), 1119-1133.

Lancaster, K. J. (1966). A new approach to consumer theory. *The Journal of Political Economy*, 132-157.

Lankoski, J., & Ollikainen, M. (2011). Biofuel policies and the environment: Do climate benefits warrant increased production from biofuel feedstocks? *Ecological Economics, 70*(4), 676-687.

Lee, C., & Heo, H. (2016). Estimating willingness to pay for renewable energy in south korea using the contingent valuation method. *Energy Policy, 94*, 150-156.

Lietuvos Respublikos atsinaujinančių išteklių energetikos įstatymas, (2011).

Liou, J. J., Tamošaitienė, J., Zavadskas, E. K., & Tzeng, G. (2015). New hybrid COPRAS-G MADM model for improving and selecting suppliers in green supply chain management. *International Journal of Production Research*, 1-21.

Liou, J. J., & Tzeng, G. (2012). Comments on “Multiple criteria decision making (MCDM) methods in economics: An overview”. *Technological and Economic Development of Economy, 18*(4), 672-695.

Longo, A., Markandya, A., & Petrucci, M. (2008). The internalization of externalities in the production of electricity: Willingness to pay for the attributes of a policy for renewable energy. *Ecological Economics, 67*(1), 140-152.

Louviere, J. J., Flynn, T. N., & Carson, R. T. (2010). Discrete choice experiments are not conjoint analysis. *Journal of Choice Modelling, 3*(3), 57-72.

Louviere, J. J., & Hensher, D. A. (1982). *Design and analysis of simulated choice or allocation experiments in travel choice modeling*

Lungu, C. I., Dascalu, C., Caraiani, C., & Balea, E. C. (2014). Econometric approach of the scenarios regarding the impact of the consumer’s empowerment and companies’ responsibility for environment sustainability on the electricity market performance. *Amfiteatru Economic, 16*(35), 187-200.

Luong, S., Liu, K., & Robey, J. (2012). Sustainability assessment framework for renewable energy technology. *Technologies for Sustainable Built Environment Centre.Reading: Informatics Research Centre*, 1-8.

Luthra, S., Kumar, S., Garg, D., & Haleem, A. (2015). Barriers to renewable/sustainable energy technologies adoption: Indian perspective. *Renewable and Sustainable Energy Reviews, 41*, 762-776.

MacCrimmon, K. R. (1968). *Decisionmaking among multiple-attribute alternatives: A survey and consolidated approach* DTIC Document.

Madani, K., Sheikhmohammady, M., Mokhtari, S., Moradi, M., & Xanthopoulos, P. (2014). Social planner’s solution for the Caspian Sea conflict. *Group Decision and Negotiation, 23*(3), 579-596.

Mardani, A., Jusoh, A., MD Nor, K., Khalifah, Z., Zakwan, N., & Valipour, A. (2015). Multiple criteria decision-making techniques and their applications–a review of the literature from 2000 to 2014. *Economic Research-Ekonomska Istraživanja, 28*(1), 516-571.

Mardani, A., Jusoh, A., & Zavadskas, E. K. (2015). Fuzzy multiple criteria decision-making techniques and applications–Two decades review from 1994 to 2014. *Expert Systems with Applications, 42*(8), 4126-4148.

Mardani, A., Jusoh, A., Zavadskas, E. K., Cavallaro, F., & Khalifah, Z. (2015). Sustainable and renewable energy: An overview of the application of multiple criteria decision making techniques and approaches. *Sustainability, 7*(10), 13947-13984.

Martin, N. J., & Rice, J. L. (2012). Developing renewable energy supply in Queensland, Australia: A study of the barriers, targets, policies and actions. *Renewable Energy, 44*, 119-127.

Mavi, R., Farid, S., & Jalili, A. (2012). Selecting the construction projects using fuzzy VIKOR approach. *Journal of Basic and Applied Scientific Research, 2*(9), 9474-9480.

McFadden, D., & Train, K. (2000). Mixed MNL models for discrete response. *Journal of Applied Econometrics*, 447-470.

Meadows, D., Randers, J., & Meadows, D. (2004). *Limits to growth: The 30-year update* Chelsea Green Publishing.

Menegaki, A. (2008). Valuation for renewable energy: A comparative review. *Renewable and Sustainable Energy Reviews, 12*(9), 2422-2437.

Menyah, K., & Wolde-Rufael, Y. (2010). CO 2 emissions, nuclear energy, renewable energy and economic growth in the US. *Energy Policy, 38*(6), 2911-2915.

Morita, T., & Managi, S. (2015). Consumers' willingness to pay for electricity after the great east japan earthquake. *Economic Analysis and Policy, 48*, 82-105.

Mountford, H. (2000). Experiences with reforming energy subsidies. *UN-ECEIOECD Workshop on Enhancing the Environment by Reforming Energy Prices, Czech Republic*, 14-16.

Mourmouris, J., & Potolias, C. (2013). A multi-criteria methodology for energy planning and developing renewable energy sources at a regional level: A case study Thasos, Greece. *Energy Policy, 52*, 522-530.

Müller, S., Brown, A., & Ölz, S. (2011). *Renewable energy. policy considerations for deploying renewables* International Energy Agency.

Munda, G. (2005). A NAIADE based approach for sustainability benchmarking. *International Journal of Environmental Technology and Management, 6*(1-2), 65-78.

Navrud, S., & Bråten, K. G. (2007). Consumers' preferences for green and brown electricity: A choice modelling approach. *Revue D'Économie Politique, 117*(5), 795-811.

Negro, S. O., Alkemade, F., & Hekkert, M. P. (2012). Why does renewable energy diffuse so slowly? A review of innovation system problems. *Renewable and Sustainable Energy Reviews, 16*(6), 3836-3846.

Ness, B., Urbel-Piirsalu, E., Anderberg, S., & Olsson, L. (2007). Categorizing tools for sustainability assessment. *Ecological Economics, 60*(3), 498-508.

Nomura, N., & Akai, M. (2004). Willingness to pay for green electricity in japan as estimated through contingent valuation method. *Applied Energy, 78*(4), 453-463.

Oberschmidt, J., Geldermann, J., Ludwig, J., & Schmehl, M. (2010). Modified PROMETHEE approach for assessing energy technologies. *International Journal of Energy Sector Management, 4*(2), 183-212.

Oberst, C., & Madlener, R. (2014). Prosumer preferences regarding the adoption of micro-generation technologies: Empirical evidence for german homeowners.

Opricovic, S., & Tzeng, G. (2004). Compromise solution by MCDM methods: A comparative analysis of VIKOR and TOPSIS. *European Journal of Operational Research, 156*(2), 445-455.

Owen, A. D. (2006). Renewable energy: Externality costs as market barriers. *Energy Policy, 34*(5), 632-642.

Peidong, Z., Yanli, Y., Yonghong, Z., Lisheng, W., & Xinrong, L. (2009). Opportunities and challenges for renewable energy policy in china. *Renewable and Sustainable Energy Reviews, 13*(2), 439-449.

Pohekar, S., & Ramachandran, M. (2004). Application of multi-criteria decision making to sustainable energy planning—a review. *Renewable and Sustainable Energy Reviews, 8*(4), 365-381.

Poortinga, W., Steg, L., Vlek, C., & Wiersma, G. (2003). Household preferences for energy-saving measures: A conjoint analysis. *Journal of Economic Psychology, 24*(1), 49-64.

Pope, J., Annandale, D., & Morrison-Saunders, A. (2004). Conceptualising sustainability assessment. *Environmental Impact Assessment Review, 24*(6), 595-616.

Qin, X., Huang, G. H., Chakma, A., Nie, X., & Lin, Q. (2008). A MCDM-based expert system for climate-change impact assessment and adaptation planning–a case study for the georgia basin, canada. *Expert Systems with Applications, 34*(3), 2164-2179.

Rafaj, P., & Kypreos, S. (2007). Internalisation of external cost in the power generation sector: Analysis with global multi-regional MARKAL model. *Energy Policy, 35*(2), 828-843.

Reddy, A. K. N., Williams, R. H., & Johansson, T. B. (1997). *Energy after RIO: Prospects and challenges*. New York: United Nations Publications.

Ren, J., Fedele, A., Mason, M., Manzardo, A., & Scipioni, A. (2013). Fuzzy multi-actor multi-criteria decision making for sustainability assessment of biomass-based technologies for hydrogen production. *International Journal of Hydrogen Energy, 38*(22), 9111-9120.

Revelt, D., & Train, K. (1998). Mixed logit with repeated choices: Households' choices of appliance efficiency level. *Review of Economics and Statistics, 80*(4), 647-657.

Roe, B., Teisl, M. F., Levy, A., & Russell, M. (2001). US consumers’ willingness to pay for green electricity. *Energy Policy, 29*(11), 917-925.

Roos, I., Soosaar, S., Volkova, A., & Štreimikienė, D. (2012). Greenhouse gas emission reduction perspectives in the baltic states in frames of EU energy and climate policy. *Renewable & Sustainable Energy Reviews, 16*(4)

Sardianou, E., & Genoudi, P. (2013). Which factors affect the willingness of consumers to adopt renewable energies? *Renewable Energy, 57*, 1-4.

Sauter, R., & Watson, J. (2007). Strategies for the deployment of micro-generation: Implications for social acceptance. *Energy Policy, 35*(5), 2770-2779.

Scarpa, R., & Willis, K. (2010). Willingness-to-pay for renewable energy: Primary and discretionary choice of British households' for micro-generation technologies. *Energy Economics, 32*(1), 129-136.

Shen, Y., Lin, G. T., Li, K., & Yuan, B. J. (2010). An assessment of exploiting renewable energy sources with concerns of policy and technology. *Energy Policy, 38*(8), 4604-4616.

Simanavičienė, R., & Ustinovičius, L. (2011). Daugiatikslių sprendimo priėmimo metodų jautrumo analizė taikant Monte Karlo modeliavimą. *Informacijos Mokslai, 56*

Singh, R. K., Murty, H., Gupta, S., & Dikshit, A. (2012). An overview of sustainability assessment methodologies. *Ecological Indicators, 15*(1), 281-299.

Stanujkic, D., Zavadskas, E. K., Ghorabaee, M. K., & Turskis, Z. (2017). An extension of the EDAS method based on the use of interval grey numbers. *Stud.Inf.Control, 26*(1), 5-12.

Stavins, R. N. (2007). Environmental economics. *National Bureau of Economic Research Working Paper Series, Working paper 13574*

Stein, E. W. (2013). A comprehensive multi-criteria model to rank electric energy production technologies. *Renewable and Sustainable Energy Reviews, 22,* 640-654.

Stigka, E. K., Paravantis, J. A., & Mihalakakou, G. K. (2014). Social acceptance of renewable energy sources: A review of contingent valuation applications. *Renewable and Sustainable Energy Reviews, 32,* 100-106.

Streimikiene, D. (2002). Kyoto protocol and implications of Lithuanian commitments. *Organizacijų Vadyba: Sisteminiai Tyrimai, ,* 263-273.

Štreimikienė, D. (2002a). Tvari energetikos plėtra. *Aplinkos Tyrimai, Inžinerija Ir Vadyba, 1*(19), 20-29.

Štreimikienė, D. (2002b). Vietiniai ir globaliniai darnios energetikos plėtros politikos įgyvendinimo Lietuvoje aspektai. *Energetika,* (1), 53-60.

Streimikiene, D., & Alisauskaite-Seskiene, I. (2014). External costs of electricity generation options in Lithuania. *Renewable Energy, 64,* 215-224.

Štreimikienė, D., & Ališauskaitė-Šeškienė, I. (2013). Elektros energijos gamybos šaltinių išorinių kaštų Lietuvoje vertinimas. *Energetika, 59*(1)

Štreimikienė, D., & Ališauskaitė-Šeškienė, I. (2014). Lietuvos gyventojų pasirengimo mokėti už atsinaujinančius energijos išteklius vertinimas. *Energetika, 60*(3)

Štreimikienė, D., & Baležentis, A. (2014). Assessment of willingness to pay for renewables in Lithuanian households. *Clean Technologies and Environmental Policy, 17*(2), 515-531.

Streimikiene, D., & Baležentis, T. (2013). Multi-criteria assessment of small scale CHP technologies in buildings. *Renewable and Sustainable Energy Reviews, 26,* 183-189.

Streimikiene, D., Balezentis, T., Krisciukaitienė, I., & Balezentis, A. (2012). Prioritizing sustainable electricity production technologies: MCDM approach. *Renewable and Sustainable Energy Reviews, 16*(5), 3302-3311.

Štreimikienė, D., Čiegis, R., & Jankauskas, V. (2007). *Darnus energetikos vystymasis.* Vilnius: Vilniaus universiteto leidykla.

Streimikienė, D., & Mikalauskiene, A. (2014). Lithuanian consumer's willingness to pay and feed-in prices for renewable electricity.

Štreimikienė, D., & Pareigis, A. R. (2007). Atsinaujinančių energijos išteklių naudojimo skatinimas Lietuvoje. *Ūkio Technologinis Ir Ekonominis Vystymas, 13*(2), 159-169.

Sun, C., Yuan, X., & Xu, M. (2015). The public perceptions and willingness to pay: From the perspective of the smog crisis in china. *Journal of Cleaner Production,*

Sundt, S., & Rehdanz, K. (2015). Consumers' willingness to pay for green electricity: A meta-analysis of the literature. *Energy Economics, 51,* 1-8.

Train, K. E. (2009). *Discrete choice methods with simulation* Cambridge university press.

Trinkūnienė, E., Podvezko, V., Zavadskas, E. K., Jokšienė, I., Vinogradova, I., & Trinkūnas, V. (2017). Evaluation of quality assurance in contractor contracts by multi-attribute decision-making methods. *Economic Research-Ekonomska Istraživanja, 30*(1), 1152-1180.

Troldborg, M., Heslop, S., & Hough, R. L. (2014). Assessing the sustainability of renewable energy technologies using multi-criteria analysis: Suitability of approach for national-scale assessments and associated uncertainties. *Renewable and Sustainable Energy Reviews, 39*, 1173-1184.

Turkenburg, W. C., Beurskens, J., Faaij, A., Fraenkel, P., Fridleifsson, I., Lysen, E., . . . Sinke, W. C. (2000). Renewable energy technologies. In J. Goldemberg (Ed.), *World energy assessment: Energy and the challenge of sustainability* (pp. 219-272) United Nations Development Programme.

Turskis, Z., & Zavadskas, E. K. (2010a). A new fuzzy additive ratio assessment method (ARAS-F). case study: The analysis of fuzzy multiple criteria in order to select the logistic centers location. *Transport, 25*(4), 423-432.

Turskis, Z., & Zavadskas, E. K. (2010b). A novel method for multiple criteria analysis: Grey additive ratio assessment (ARAS-G) method. *Informatica, 21*(4), 597-610.

United Nations Development Programme. (2000). *Energy and the challenge of sustainability*. New York: World Energy Assessment.

Vahdani, B., Hadipour, H., Sadaghiani, J. S., & Amiri, M. (2010). Extension of VIKOR method based on interval-valued fuzzy sets. *The International Journal of Advanced Manufacturing Technology, 47*(9-12), 1231-1239.

van de Kaa, G., Rezaei, J., Kamp, L., & de Winter, A. (2014). Photovoltaic technology selection: A fuzzy MCDM approach. *Renewable and Sustainable Energy Reviews, 32*, 662-670.

Van der Veen, Reinier AC, & De Vries, L. J. (2009). The impact of microgeneration upon the dutch balancing market. *Energy Policy, 37*(7), 2788-2797.

van Putten, M., Lijesen, M., Özel, T., Vink, N., & Wevers, H. (2014). Valuing the preferences for micro-generation of renewables by househoulds. *Energy, 71*, 596-604.

Vecchiato, D., & Tempesta, T. (2015). Public preferences for electricity contracts including renewable energy: A marketing analysis with choice experiments. *Energy, 88*, 168-179.

Vera, I., & Langlois, L. (2007). Energy indicators for sustainable development. *Energy, 32*(6), 875-882.

Verbruggen, A., Fischedick, M., Moomaw, W., Weir, T., Nadaï, A., Nilsson, L. J., . . . Sathaye, J. (2010). Renewable energy costs, potentials, barriers: Conceptual issues. *Energy Policy, 38*(2), 850-861.

Verheem, R. (2002). Recommendations for sustainability assessment in the Netherlands. *Commission for EIA.Environmental Impact Assessment in the Netherlands.Views from the Commission for EIA In,*

Wang, J., Jing, Y., Zhang, C., & Zhao, J. (2009). Review on multi-criteria decision analysis aid in sustainable energy decision-making. *Renewable and Sustainable Energy Reviews, 13*(9), 2263-2278.

Wang, Y., & Lee, H. (2007). Generalizing TOPSIS for fuzzy multiple-criteria group decision-making. *Computers & Mathematics with Applications, 53*(11), 1762-1772.

Watson, J. (2004). Co-provision in sustainable energy systems: The case of micro-generation. *Energy Policy, 32*(17), 1981-1990.

Wheeler, R. E. (2004). Comments on algorithmic design. *Vignette Accompanying Package AlgDe,*

White, W., Lunnan, A., Nybakk, E., & Kulisic, B. (2013). The role of governments in renewable energy: The importance of policy consistency. *Biomass and Bioenergy, 57,* 97-105.

Willis, K., Scarpa, R., Gilroy, R., & Hamza, N. (2011). Renewable energy adoption in an ageing population: Heterogeneity in preferences for micro-generation technology adoption. *Energy Policy, 39*(10), 6021-6029.

Wimmler, C., Hejazi, G., de Oliveira Fernandes, E., Moreira, C., & Connors, S. (2015). Multi-criteria decision support methods for renewable energy systems on islands. *Journal of Clean Energy Technologies, 3*(3)

Wiser, R., Pickle, S., & Goldman, C. (1998). Renewable energy policy and electricity restructuring: A California case study. *Energy Policy, 26*(6), 465-475.

Wood, L. L., Kenyon, A. E., Desvousges, W. H., & Morander, L. K. (1995). How much are customers willing to pay for improvements in health and environmental quality? *The Electricity Journal, 8*(4), 70-77.

Wüstenhagen, R., Wolsink, M., & Bürer, M. J. (2007). Social acceptance of renewable energy innovation: An introduction to the concept. *Energy Policy, 35*(5), 2683-2691.

Yadoo, A., & Cruickshank, H. (2012). The role for low carbon electrification technologies in poverty reduction and climate change strategies: A focus on renewable energy mini-grids with case studies in nepal, peru and kenya. *Energy Policy, 42,* 591-602.

Yager, R. R. (2004). Generalized OWA aggregation operators. *Fuzzy Optimization and Decision Making, 3*(1), 93-107.

Yamamoto, Y. (2015). Opinion leadership and willingness to pay for residential photovoltaic systems. *Energy Policy, 83,* 185-192.

Zadeh, L. A. (1975). The concept of a linguistic variable and its application to approximate reasoning—I. *Information Sciences, 8*(3), 199-249.

Zadeh, L. A. (1983). A computational approach to fuzzy quantifiers in natural languages. *Computers & Mathematics with Applications, 9*(1), 149-184.

Zangeneh, A., Jadid, S., & Rahimi-Kian, A. (2009). A hierarchical decision making model for the prioritization of distributed generation technologies: A case study for Iran. *Energy Policy, 37*(12), 5752-5763.

Zavadskas, E. K., Antucheviciene, J., Hajiagha, S. H. R., & Hashemi, S. S. (2014). Extension of weighted aggregated sum product assessment with interval-valued intuitionistic fuzzy numbers (WASPAS-IVIF). *Applied Soft Computing, 24,* 1013-1021.

Zavadskas, E. K., Antucheviciene, J., Kalibatas, D., & Kalibatiene, D. (2017). Achieving nearly zero-energy buildings by applying multi-attribute assessment. *Energy and Buildings, 143,* 162-172.

Zavadskas, E. K., & Turskis, Z. (2010). A new additive ratio assessment (ARAS) method in multicriteria decision-making. *Technological and Economic Development of Economy, 16*(2), 159-172.

Zavadskas, E. K., & Turskis, Z. (2011). Multiple criteria decision making (MCDM) methods in economics: An overview. *Technological and Economic Development of Economy, 17*(2), 397-427.

Zavadskas, E., Kaklauskas, A., & Sarka, V. (1994). The new method of multicriteria complex proportional assessment of projects. *Technological and Economic Development of Economy, 1*(3), 131-139.

Zavadskas, E., Turskis, Z., Antucheviciene, J., & Zakarevicius, A. (2012). Optimization of weighted aggregated sum product assessment. *Elektronika Ir Elektrotechnika*, *122*(6), 3-6.

Zerriffi, H., & Wilson, E. (2010). Leapfrogging over development? promoting rural renewables for climate change mitigation. *Energy Policy, 38*(4), 1689-1700.

Zhao, H., & Guo, S. (2014). Selecting green supplier of thermal power equipment by using a hybrid mcdm method for sustainability. *Sustainability, 6*(1), 217-235.

Zografakis, N., Sifaki, E., Pagalou, M., Nikitaki, G., Psarakis, V., & Tsagarakis, K. P. (2010). Assessment of public acceptance and willingness to pay for renewable energy sources in Crete. *Renewable and Sustainable Energy Reviews, 14*(3), 1088-1095.

Zorić, J., & Hrovatin, N. (2012). Household willingness to pay for green electricity in Slovenia. *Energy Policy, 47*, 180-187.

LIST OF AUTHOR'S PUBLICATIONS

Štreimikienė, Dalia; Ališauskaitė-Šeškienė, Ilona. Elektros energijos gamybos šaltinių išorinių kaštų Lietuvoje vertinimas // Energetika = Power engineering = Энергетика / Lietuvos mokslų akademija. Vilnius: Lietuvos mokslų akademijos leidykla. ISSN 0235-7208. 2013, t. 59, Nr. 1, p. 11-19. [Academic Search Complete; IndexCopernicus; Inspec].

Štreimikienė, Dalia; Ališauskaitė-Šeškienė, Ilona. Sustainability assessment of renewable electricity generation technologies // Practice and research in private and public sector - 2013 [elektroninis išteklius] : 3rd international scientific conference proceedings, April 11-12, 2013 / Mykolas Romeris University. Faculty of Economics and Finance Management. Vilnius: Mykolo Romerio universitetas. ISSN 2029-7378. 2013, p. 156-164. [Business Source Corporate Plus].

Štreimikienė, Dalia; Ališauskaitė-Šeškienė, Ilona. Lietuvos gyventojų pasirengimo mokėti už atsinaujinančius energijos išteklius vertinimas // Energetika = Power engineering = Энергетика / Lietuvos mokslų akademija. Vilnius: Lietuvos mokslų akademijos leidykla. ISSN 0235-7208. 2014, t. 60, nr. 3, p. 169-183. [Academic Search Complete; IndexCopernicus; Inspec].

Štreimikienė, Dalia; Ališauskaitė-Šeškienė, Ilona. Willingness to pay for renewable electricity and feed-in-prices in Lithuania // Practice and research in private and public sector - 2014 [elektroninis išteklius]: 4th international scientific conference proceedings, May 14-15, 2014 / Mykolas Romeris University. Vilnius: Mykolo Romerio universitetas. ISSN 2029-7378. 2014, p. 48-56.

Ališauskaitė-Šeškienė, Ilona. Renewable energy sources technology assessment and promotion // The 11th international conference of young scientists on energy issues, CYSENI [elektroninis išteklius]: Kaunas, Lithuania, May 29-30, 2014 / Lithuanian Energy Institute. p. 27-37.

Štreimikienė, Dalia; Ališauskaitė-Šeškienė, Ilona. External costs of electricity generation options in Lithuania // Renewable energy. Kidlington: Pergamon-Elsevier Science. ISSN 0960-1481. 2014, Vol. 64, p. 215-224. [Science Citation Index Expanded (Web of Science)].

Ališauskaitė-Šeškienė, Ilona. Barriers and market failures that influence the development of renewable energy sources // The 12th international conference of young scientists on energy issues, CYSENI: Kaunas, Lithuania, May 27-28, 2015 [elektroninis išteklius] / Lithuanian Energy Institute. Kaunas: LEI. p. 1-9.

Ališauskaitė-Šeškienė, Ilona. Multi-criteria decision analysis methods aiming to evaluate renewable energy sources technology // The 13th international conference of young scientists on energy issues, CYSENI: Kaunas, Lithuania, May 26-27, 2016 [elektroninis išteklius] / Lithuanian Energy Institute. Kaunas: LEI. p. 45-54.

Štreimikienė, Dalia; Ališauskaitė-Šeškienė, Ilona. Comparative assessment of external costs and pollution taxes in Baltic States, Czech Republic and Slovakia. E&M Economics and Management = E&M Economie a management. Liberec: Technická Univerzita v Liberci, 2016, Vol. 19, no. 4. p. 4-18. ISSN: 1212-3609; DOI: 10.15240/tul/001/2016-4-001.

The evaluation of Lithuanian households’ willingness to pay for microgeneration technology // The 14th international conference of young scientists on energy issues, CYSENI: Kaunas, Lithuania, May 25-26, 2017 [elektroninis išteklius] / Lithuanian Energy Institute. Kaunas: LEI.

APPENDICES

Questionnaire A

This questionnaire is for residents living in individual houses. The purpose of the questionnaire is to determine the preferences of the population for the selection and installation of renewable energy sources (RES) technologies in their own homes, considering the following priorities: installation cost, average monthly energy bill, length of the warranty period, requirements for operation, degree of possibility for sharing.

By answering short questions that reveal the socio-demographic characteristics, type of housing, knowledge about RES and their technologies, on the following pages you will have to choose between different hypothetical renewable energy technologies for individual homes. Each scenario for choosing renewable energy technologies is described in five features that you will need to select. Pairs of selected renewable energy technology selection scenarios are different from each other in two or more attributes.

1. **GENDER:**
   1. woman
   2. man

2. **MARITAL STATUS:**
   1. married
   2. separated
   3. single
   4. widowed
   5. cohabiting

3. **AGE:**
   1. under 23
   2. 23-34
   3. 35-44
   4. 45-65
   5. over 65

4. **EMPLOYEE STATUS:**
   1. unemployed
   2. student
   3. working in public sector
   4. working in private sector
   5. entrepreneur

5. **REVENUES PER MONTH:**
   1. less than 300 EUR
   2. 300 – 500 EUR
   3. 501 – 1000 EUR
   4. 1001 – 1500 EUR
   5. 1501 – 2000 EUR
   6. 2001 – 3000 EUR
   7. over 3000 EUR

6. EDUCATION:

1. elementary
2. upper secondary
3. graduation
4. post-graduate

7. YOUR HOUSEHOLD CONSISTS OF:

1. 1 person
2. 2 persons
3. 3 persons
4. 4 persons
5. more than 4 persons

8. TYPE OF HOUSE:

1. cottage
2. individual house

9. NUMBER OF CARS:

1. 0
2. 1
3. 2
4. 3 and more

10. SIZE OF THE LIVING SPACE:

1. less than 80 sq. m.
2. 80-120 sq. m.
3. 121-200 sq. m
4. more than 200 sq. m.

11. DO YOU OWN THE RIGHT TO THE HOUSE IN WHICH YOU LIVE?

1. yes
2. no

12. YOU SOLVE YOUR HOUSING ISSUES:

1. on your own
2. having consulted to your spouse/partner

13. HOW MUCH DOES YOUR ELECTRICITY COST PER MONTH AT AN AVERAGE DURING COLD SEASON?

1. 0-20 EUR
2. 21-50 EUR
3. 51-100 EUR
4. 101- 200 EUR
5. 201-300 EUR
6. 301-400 EUR
7. over 400 EUR

14. HOW MUCH DOES YOUR ELECTRICITY COST PER MONTH AT AN AVERAGE DURING SOUTHERN SEASON?

1. 0-20 EUR
2. 21-50 EUR
3. 51-100 EUR
4. 101- 200 EUR
5. 201-300 EUR
6. 301-400 EUR
7. over 400 EUR

15. HOW MUCH DOES YOUR HEATING COST PER MONTH AT AN AVERAGE DURING COLD SEASON?

1. 0-20 EUR
2. 21-50 EUR
3. 51-100 EUR
4. 101- 200 EUR
5. 201-300 EUR
6. 301-400 EUR
7. over 400 EUR

16. HOW MUCH DOES YOUR HEATING COST PER MONTH AT AN AVERAGE DURING SOUTHERN SEASON?

1. 0-20 EUR
2. 21-50 EUR
3. 51-100 EUR
4. 101- 200 EUR
5. 201-300 EUR
6. 301-400 EUR
7. over 400 EUR

17. HOW MUCH DOES YOUR ENERGY (EKLECTRICITY AND HEATING) COST PER MONTH AT AN AVERAGE?

1. 0-20 EUR
2. 21-50 EUR
3. 51-100 EUR
4. 101- 200 EUR
5. 201-300 EUR
6. 301-400 EUR
7. over 400 EUR

18. ARE YOU FAMILIAR WITH RENEWABLE ENERGY TECHNOLOGIES (MICROGENERATION TECHNOLOGIES)?

1. Yes
2. No

19. IF YES, THEN WHICH ONES?

1. solar thermal
2. solar panel
3. biomass boilers

4. micro wind

20. WOULD YOU LIKE TO REPLENISH YOUR EXISTING HEATING AND ELECTRICITY SYSTEMS WITH RENEWABLE ENERGY TECHNOLOGIES?

1. Yes
2. No

21. IF YOU ANSWERED "YES" TO THE 20TH QUESTION, THEN WOULD YOU PLEASE ANSWER IF YOU WOULD AGREE TO SHARE ENERGY FROM YOUR RENEWABLE ENERGY TECHNOLOGY WITH YOUR NEIGHBOR?

1. Yes
2. No

22. SUPPOSE YOU NEED TO BUY A BOILER COSTING ~ 1550 EUR, WHICH WILL HEAT ABOUT 120 SQUARE METERS HOUSE. HOW MUCH MORE WOULD YOU AGREE TO PAY FOR IT, SO THAT 50% OF ANNUAL ENERGY IN YOUR HOUSE WOULD BE MADE UP OF RENEWABLE ENERGY SOURCES?

____

Scenarios for installing renewable energy technologies in an individual house

Scenarios for renewable energy sources technologies for individual houses are described below by the following attributes:

1) **Installation cost**

~1500 EUR; ~3000 EUR; ~4500 EUR; ~6500 EUR

2) **Monthly energy bill (during cold and southern season)**

~16 EUR/month; ~30 EUR/month.; ~35 EUR/month.; ~38 EUR/month

3) **Length of the warranty period**

2 years; 5years; 10 years; 13 years

4) **Special installation conditions and inconvenience of system**

the amount of energy produced directly correlates with the time of day and meteorological conditions; purchase of additional fuel technology is needed; the operating technology causes extremely high noise; none

5) **Degree of possibility for sharing**

very small opportunity; little opportunity; on average possible; the biggest opportunity

Please choose among two hypothetical alternatives for the use of renewable energy technology

The following 10 tables describe the hypothetical renewable energy (microgeneration) technologies for individual houses. Each table presents two renewable energy technologies to choose, which one is preferable. Compare only the two renewable energy technologies, presented in each table. Do not differentiate between technologies in different tables.

Option no.1: Compare alternative A with alternative B

Attributes	**Alternative A**	**Alternative B**
Installation cost, EUR	~4500	~6500
Monthly energy bill (during cold and southern season), EUR/month	~30	~38
Length of the warranty period, years	2	10
Special installation conditions and inconvenience of system	none	purchase of additional fuel technology is needed
Degree of possibility for sharing	very small opportunity	very small opportunity

1) Which alternative for renewable energy technology you prefer more? ☐**A** ☐**B**

2) If you had to choose between alternative A, B and opt-out choice, when none of renewable energy technologies would be installed in your home, what would you choose?

☐**A** ☐**B** ☐ **Opt-out choice**

Option no.2: Compare alternative C with alternative D. Do not compare your choices with previous ones

Attributes	**Alternative C**	**Alternative D**
Installation cost, EUR	~3000	~1500
Monthly energy bill (during cold and southern season), EUR/month	~38	~30
Length of the warranty period, years	5	13
Special installation conditions and inconvenience of system	the amount of energy produced directly correlates with the time of day and meteorological conditions	none
Degree of possibility for sharing	very small opportunity	very small opportunity

1) Which alternative for renewable energy technology you prefer more? ☐**C** ☐**D**

2) If you had to choose between alternative C, D and opt-out choice, when none of renewable energy technologies would be installed in your home, what would you choose?

☐C ☐D ☐ Opt-out choice

Option no.3: Compare alternative E with alternative F. Do not compare your choices with previous ones

Attributes	**Alternative E**	**Alternative F**
Installation cost, EUR	~1500	~4500
Monthly energy bill (during cold and southern season), EUR/month	~38	~16
Length of the warranty period, years	10	5
Special installation conditions and inconvenience of system	the amount of energy produced directly correlates with the time of day and meteorological conditions	the operating technology causes extremely high noise
Degree of possibility for sharing	little opportunity	the biggest opportunity

1) Which alternative for renewable energy technology you prefer more? **☐E ☐F**

2) If you had to choose between alternative E, F and opt-out choice, when none of renewable energy technologies would be installed in your home, what would you choose?

☐E ☐F ☐ Opt-out choice

Option no.4: Compare alternative G with alternative H. Do not compare your choices with previous ones

Attributes	**Alternative G**	**Alternative H**
Installation cost, EUR	~1500	~3000
Monthly energy bill (during cold and southern season), EUR/month	~38	~30
Length of the warranty period, years	2	5
Special installation conditions and inconvenience of system	none	the operating technology causes extremely high noise
Degree of possibility for sharing	the biggest opportunity	on average possible

1) Which alternative for renewable energy technology you prefer more? **☐G ☐H**

2) If you had to choose between alternative G, H and opt-out choice, when none of renewable energy technologies would be installed in your home, what would you choose?

☐G ☐H ☐ Opt-out choice

Option no.5: Compare alternative I with alternative J. Do not compare your choices with previous ones

Attributes	**Alternative I**	**Alternative J**
Installation cost, EUR	~1500	~3000
Monthly energy bill (during cold and southern season), EUR/month	~35	~30
Length of the warranty period, years	13	2
Special installation conditions and inconvenience of system	the operating technology causes extremely high noise	the operating technology causes extremely high noise
Degree of possibility for sharing	on average possible	little opportunity

1) Which alternative for renewable energy technology you prefer more? ☐**I** ☐**J**

2) If you had to choose between alternative I, J and opt-out choice, when none of renewable energy technologies would be installed in your home, what would you choose?

☐**I** ☐**J** ☐ **Opt-out choice**

Option no.6: Compare alternative K with alternative L. Do not compare your choices with previous ones

Attributes	**Alternative K**	**Alternative L**
Installation cost, EUR	~4500	~1500
Monthly energy bill (during cold and southern season), EUR/month	~38	~38
Length of the warranty period, years	13	5
Special installation conditions and inconvenience of system	the operating technology causes extremely high noise	the amount of energy produced directly correlates with the time of day and meteorological conditions
Degree of possibility for sharing	on average possible	little opportunity

1) Which alternative for renewable energy technology you prefer more? ☐**K** ☐**L**

2) If you had to choose between alternative K, L and opt-out choice, when none of renewable energy technologies would be installed in your home, what would you choose?

☐**K** ☐**L** ☐ **Opt-out choice**

Option no.7: Compare alternative M with alternative N. Do not compare your choices with previous ones

Attributes	**Alternative M**	**Alternative N**
Installation cost, EUR	~4500	~6500
Monthly energy bill (during cold and southern season), EUR/month	~35	~38
Length of the warranty period, years	2	2

Special installation conditions and inconvenience of system	the amount of energy produced directly correlates with the time of day and meteorological conditions	the operating technology causes extremely high noise
Degree of possibility for sharing	on average possible	little opportunity

1) Which alternative for renewable energy technology you prefer more? ☐**M** ☐**N**

2) If you had to choose between alternative M, N and opt-out choice, when none of renewable energy technologies would be installed in your home, what would you choose?

☐**M** ☐**N** ☐ **Opt-out choice**

Option no.8: Compare alternative O with alternative P. Do not compare your choices with previous ones

Attributes	**Alternative O**	**Alternative P**
Installation cost, EUR	~6500	~3000
Monthly energy bill (during cold and southern season), EUR/month	~35	~38
Length of the warranty period, years	2	2
Special installation conditions and inconvenience of system	the operating technology causes extremely high noise	purchase of additional fuel technology is needed
Degree of possibility for sharing	the biggest opportunity	very small opportunity

1) Which alternative for renewable energy technology you prefer more? ☐**O** ☐**P**

2) If you had to choose between alternative O, P and opt-out choice, when none of renewable energy technologies would be installed in your home, what would you choose?

☐**O** ☐**P** ☐ **Opt-out choice**

Option no.9: Compare alternative R with alternative S. Do not compare your choices with previous ones

Attributes	**Alternative R**	**Alternative S**
Installation cost, EUR	~1500	~6500
Monthly energy bill (during cold and southern season), EUR/month	~30	~16
Length of the warranty period, years	5	5
Special installation conditions and inconvenience of system	purchase of additional fuel technology is needed	none
Degree of possibility for sharing	on average possible	the biggest opportunity

1) Which alternative for renewable energy technology you prefer more? ☐**R** ☐**S**

2) If you had to choose between alternative R, S and opt-out choice, when none of renewable energy technologies would be installed in your home, what would you choose?

☐**R** ☐**S** ☐ **Opt-out choice**

Option no.10: Compare alternative T with alternative U. Do not compare your choices with previous ones

Attributes	**Alternative T**	**Alternative U**
Installation cost, EUR	~3000	~3000
Monthly energy bill (during cold and southern season), EUR/month	~16	~35
Length of the warranty period, years	10	13
Special installation conditions and inconvenience of system	purchase of additional fuel technology is needed	the amount of energy produced directly correlates with the time of day and meteorological conditions
Degree of possibility for sharing	on average possible	the biggest opportunity

1) Which alternative for renewable energy technology you prefer more? ☐**T** ☐**U**

2) If you had to choose between alternative T, U and opt-out choice, when none of renewable energy technologies would be installed in your home, what would you choose?

☐**T** ☐**U** ☐ **Opt-out choice**

Choice motivation

1. Have the choices been clear to you? ☐ Yes ☐ No
2. Was it difficult to answer the questions??

☐ No

☐ Yes → What were the biggest difficulties when comparing two alternatives?

____

____

☐ I have evaluated alternatives according to all attributes

☐ I have evaluated alternatives according only to one attributes → Which one?

☐ Installation cost, EUR

☐ Monthly energy bill (during cold and southern season), EUR/month

☐ Length of the warranty period, years

☐ Special installation conditions and inconvenience of system

☐ Degree of possibility for sharing

4. By rating attributes from 1 to 5, where 1 stands for the key criterion, and 5 is the least important, consider the following attributes when choosing an alternative for renewable energy technologies for individual homes:

______ Installation cost, EUR
______ Monthly energy bill (during cold and southern season), EUR/month
______Length of the warranty period, years
______Special installation conditions and inconvenience of system
______Degree of possibility for sharing

5. Can you explain the reasons for your attribute ranking?

____

____

Questionnaire B

This questionnaire is for residents living in individual houses. The purpose of the questionnaire is to determine the preferences of the population for the selection and installation of renewable energy sources (RES) technologies in their own homes, considering the following priorities: installation cost, average monthly energy bill, length of the warranty period, requirements for operation, degree of possibility for sharing.

By answering short questions that reveal the socio-demographic characteristics, type of housing, knowledge about RES and their technologies, on the following pages you will have to choose between different hypothetical renewable energy technologies for individual homes. Each scenario for choosing renewable energy technologies is described in five features that you will need to select. Pairs of selected renewable energy technology selection scenarios are different from each other in two or more attributes.

1. **GENDER:**
   1. woman
   2. man

2. **MARITAL STATUS:**
   1. married
   2. separated
   3. single
   4. widowed
   5. cohabiting

3. **AGE:**
   1. under 23
   2. 23-34
   3. 35-44
   4. 45-65
   5. over 65

4. **EMPLOYEE STATUS:**
   1. unemployed
   2. student
   3. working in public sector
   4. working in private sector
   5. entrepreneur

5. **REVENUES PER MONTH:**
   1. less than 300 EUR
   2. 300 – 500 EUR
   3. 501 – 1000 EUR
   4. 1001 – 1500 EUR
   5. 1501 – 2000 EUR
   6. 2001– 3000 EUR
   7. over 3000 EUR

6. **EDUCATION:**
   1. elementary

2. upper secondary
3. graduation
4. post-graduate

7. YOUR HOUSEHOLD CONSISTS OF:

1. 1 person
2. 2 persons
3. 3 persons
4. 4 persons
5. more than 4 persons

8. TYPE OF HOUSE:

1. cottage
2. individual house

9. NUMBER OF CARS:

1. 0
2. 1
3. 2
4. 3 and more

10. SIZE OF THE LIVING SPACE:

1. less than 80 sq. m.
2. 80-120 sq. m.
3. 121-200 sq. m
4. more than 200 sq. m.

11. DO YOU OWN THE RIGHT TO THE HOUSE IN WHICH YOU LIVE?

1. yes
2. no

12. YOU SOLVE YOUR HOUSING ISSUES:

1. on your own
2. having consulted to your spouse/partner

13. HOW MUCH DOES YOUR ELECTRICITY COST PER MONTH AT AN AVERAGE DURING COLD SEASON?

1. 0-20 EUR
2. 21-50 EUR
3. 51-100 EUR
4. 101- 200 EUR
5. 201-300 EUR
6. 301-400 EUR
7. over 400 EUR

14. HOW MUCH DOES YOUR ELECTRICITY COST PER MONTH AT AN AVERAGE DURING SOUTHERN SEASON?

1. 0-20 EUR
2. 21-50 EUR

3. 51-100 EUR
4. 101- 200 EUR
5. 201-300 EUR
6. 301-400 EUR
7. over 400 EUR

15. HOW MUCH DOES YOUR HEATING COST PER MONTH AT AN AVERAGE DURING COLD SEASON?

1. 0-20 EUR
2. 21-50 EUR
3. 51-100 EUR
4. 101- 200 EUR
5. 201-300 EUR
6. 301-400 EUR
7. over 400 EUR

16. HOW MUCH DOES YOUR HEATING COST PER MONTH AT AN AVERAGE DURING SOUTHERN SEASON?

1. 0-20 EUR
2. 21-50 EUR
3. 51-100 EUR
4. 101- 200 EUR
5. 201-300 EUR
6. 301-400 EUR
7. over 400 EUR

17. HOW MUCH DOES YOUR ENERGY (EKLECTRICITY AND HEATING) COST PER MONTH AT AN AVERAGE?

1. 0-20 EUR
2. 21-50 EUR
3. 51-100 EUR
4. 101- 200 EUR
5. 201-300 EUR
6. 301-400 EUR
7. over 400 EUR

18. ARE YOU FAMILIAR WITH RENEWABLE ENERGY TECHNOLOGIES (MICROGENERATION TECHNOLOGIES)?

1. Yes
2. No

19. IF YES, THEN WHICH ONES?

1. solar thermal
2. solar panel
3. biomass boilers
4. micro wind

20. WOULD YOU LIKE TO REPLENISH YOUR EXISTING HEATING AND ELECTRICITY SYSTEMS WITH RENEWABLE ENERGY TECHNOLOGIES?

1. Yes
2. No

21. IF YOU ANSWERED “YES” TO THE 20TH QUESTION, THEN WOULD YOU PLEASE ANSWER IF YOU WOULD AGREE TO SHARE ENERGY FROM YOUR RENEWABLE ENERGY TECHNOLOGY WITH YOUR NEIGHBOR?

1. Yes
2. No

22. SUPPOSE YOU NEED TO BUY A BOILER COSTING ~ 1550 EUR, WHICH WILL HEAT ABOUT 120 SQUARE METERS HOUSE. HOW MUCH MORE WOULD YOU AGREE TO PAY FOR IT, SO THAT 50% OF ANNUAL ENERGY IN YOUR HOUSE WOULD BE MADE UP OF RENEWABLE ENERGY SOURCES?

____

Scenarios for installing renewable energy technologies in an individual house

Scenarios for renewable energy sources technologies for individual houses are described below by the following attributes:

1) **Installation cost**

~1500 EUR; ~3000 EUR; ~4500 EUR; ~6500 EUR

2) **Monthly energy bill (during cold and southern season)**

~16 EUR/month; ~30 EUR/month.; ~35 EUR/month.; ~38 EUR/month

3) **Length of the warranty period**

2 years; 5years; 10 years; 13 years

4) **Special installation conditions and inconvenience of system**

the amount of energy produced directly correlates with the time of day and meteorological conditions; purchase of additional fuel technology is needed; the operating technology causes extremely high noise; none

5) **Degree of possibility for sharing**

very small opportunity; little opportunity; on average possible; the biggest opportunity

Please choose among two hypothetical alternatives for the use of renewable energy technology

The following 10 tables describe the hypothetical renewable energy (microgeneration) technologies for individual houses. Each table presents two renewable energy technologies to choose, which one is preferable. Compare only the two renewable energy technologies, presented in each table. Do not differentiate between technologies in different tables.

Option no.1: Compare alternative A with alternative B

Attributes	**Alternative A**	**Alternative B**
Installation cost, EUR	~4500	~6500
Monthly energy bill (during cold and southern season), EUR/month	~35	~30
Length of the warranty period, years	5	5
Special installation conditions and inconvenience of system	none	purchase of additional fuel technology is needed
Degree of possibility for sharing	little opportunity	the biggest opportunity

1) Which alternative for renewable energy technology you prefer more? ☐**A** ☐**B**

2) If you had to choose between alternative A, B and opt-out choice, when none of renewable energy technologies would be installed in your home, what would you choose?

☐**A** ☐**B** ☐ **Opt-out choice**

Option no.2: Compare alternative C with alternative D. Do not compare your choices with previous ones

Attributes	**Alternative C**	**Alternative D**
Installation cost, EUR	~3000	~4500
Monthly energy bill (during cold and southern season), EUR/month	~35	~16
Length of the warranty period, years	13	13
Special installation conditions and inconvenience of system	purchase of additional fuel technology is needed	none
Degree of possibility for sharing	little opportunity	little opportunity

1) Which alternative for renewable energy technology you prefer more? ☐**C** ☐**D**

2) If you had to choose between alternative C, D and opt-out choice, when none of renewable energy technologies would be installed in your home, what would you choose?

☐**C** ☐**D** ☐ **Opt-out choice**

Option no.3: Compare alternative E with alternative F. Do not compare your choices with previous ones

Attributes	Alternative E	Alternative F
Installation cost, EUR	~6500	~6500
Monthly energy bill (during cold and southern season), EUR/month	~38	~35
Length of the warranty period, years	13	10
Special installation conditions and inconvenience of system	none	none
Degree of possibility for sharing	on average possible	on average possible

1) Which alternative for renewable energy technology you prefer more? ☐**E** ☐**F**

2) If you had to choose between alternative E, F and opt-out choice, when none of renewable energy technologies would be installed in your home, what would you choose?

☐**E** ☐**F** ☐ **Opt-out choice**

Option no.4: Compare alternative G with alternative H. Do not compare your choices with previous ones

Attributes	Alternative G	Alternative H
Installation cost, EUR	~3000	~4500
Monthly energy bill (during cold and southern season), EUR/month	~38	~16
Length of the warranty period, years	10	2
Special installation conditions and inconvenience of system	none	purchase of additional fuel technology is needed
Degree of possibility for sharing	the biggest opportunity	little opportunity

1) Which alternative for renewable energy technology you prefer more? ☐**G** ☐**H**

2) If you had to choose between alternative G, H and opt-out choice, when none of renewable energy technologies would be installed in your home, what would you choose?

☐**G** ☐**H** ☐ **Opt-out choice**

Option no.5: Compare alternative I with alternative J. Do not compare your choices with previous ones

Attributes	Alternative I	Alternative J
Installation cost, EUR	~3000	~4500
Monthly energy bill (during cold and southern season), EUR/month	~16	~30
Length of the warranty period, years	2	10
Special installation conditions and	the amount of	the amount of energy

inconvenience of system	energy produced directly correlates with the time of day and meteorological conditions	produced directly correlates with the time of day and meteorological conditions
Degree of possibility for sharing	on average possible	the biggest opportunity

1) Which alternative for renewable energy technology you prefer more? □**I** □**J**

2) If you had to choose between alternative I, J and opt-out choice, when none of renewable energy technologies would be installed in your home, what would you choose?

□**I** □**J** □ **Opt-out choice**

Option no.6: Compare alternative K with alternative L. Do not compare your choices with previous ones

Attributes	**Alternative K**	**Alternative L**
Installation cost, EUR	~6500	~4500
Monthly energy bill (during cold and southern season), EUR/month	~30	~35
Length of the warranty period, years	13	10
Special installation conditions and inconvenience of system	the amount of energy produced directly correlates with the time of day and meteorological conditions	the operating technology causes extremely high noise
Degree of possibility for sharing	little opportunity	very small opportunity

1) Which alternative for renewable energy technology you prefer more? □**K** □**L**

2) If you had to choose between alternative K, L and opt-out choice, when none of renewable energy technologies would be installed in your home, what would you choose?

□**K** □**L** □ **Opt-out choice**

Option no.7: Compare alternative M with alternative N. Do not compare your choices with previous ones

Attributes	**Alternative M**	**Alternative N**
Installation cost, EUR	~4500	~6500
Monthly energy bill (during cold and southern season), EUR/month	~38	~16
Length of the warranty period, years	13	13
Special installation conditions and inconvenience of system	purchase of additional fuel technology is	the amount of energy produced directly correlates with the

	needed	time of day and meteorological conditions
Degree of possibility for sharing	the biggest opportunity	very small opportunity

1) Which alternative for renewable energy technology you prefer more? ☐**M** ☐**N**

2) If you had to choose between alternative M, N and opt-out choice, when none of renewable energy technologies would be installed in your home, what would you choose?

☐**M** ☐**N** ☐ **Opt-out choice**

Option no.8: Compare alternative O with alternative P. Do not compare your choices with previous ones

Attributes	**Alternative O**	**Alternative P**
Installation cost, EUR	~3000	~1500
Monthly energy bill (during cold and southern season), EUR/month	~16	~16
Length of the warranty period, years	13	10
Special installation conditions and inconvenience of system	the operating technology causes extremely high noise	the operating technology causes extremely high noise
Degree of possibility for sharing	the biggest opportunity	very small opportunity

1) Which alternative for renewable energy technology you prefer more? ☐**O** ☐**P**

2) If you had to choose between alternative O, P and opt-out choice, when none of renewable energy technologies would be installed in your home, what would you choose?

☐**O** ☐**P** ☐ **Opt-out choice**

Option no.9: Compare alternative R with alternative S. Do not compare your choices with previous ones

Attributes	**Alternative R**	**Alternative S**
Installation cost, EUR	~1500	~3000
Monthly energy bill (during cold and southern season), EUR/month	~16	~30
Length of the warranty period, years	2	10
Special installation conditions and inconvenience of system	none	none
Degree of possibility for sharing	on average possible	little opportunity

1) Which alternative for renewable energy technology you prefer more? ☐**R** ☐**S**

2) If you had to choose between alternative R, S and opt-out choice, when none of renewable energy technologies would be installed in your home, what would you choose?

☐**R** ☐**S** ☐ **Opt-out choice**

Option no.10: Compare alternative T with alternative U. Do not compare your choices with previous ones

Attributes	**Alternative T**	**Alternative U**
Installation cost, EUR	~3000	~1500
Monthly energy bill (during cold and southern season), EUR/month	~35	~35
Length of the warranty period, years	5	2
Special installation conditions and inconvenience of system	none	purchase of additional fuel technology is needed
Degree of possibility for sharing	very small opportunity	the biggest opportunity

1) Which alternative for renewable energy technology you prefer more? ☐**T** ☐**U**

2) If you had to choose between alternative T, U and opt-out choice, when none of renewable energy technologies would be installed in your home, what would you choose?

☐**T** ☐**U** ☐ **Opt-out choice**

Choice motivation

1. Have the choices been clear to you? ☐ Yes ☐ No
2. Was it difficult to answer the questions??

☐ No
☐ Yes → What were the biggest difficulties when comparing two alternatives?

____

____

☐ I have evaluated alternatives according to all attributes
☐ I have evaluated alternatives according only to one attributes → Which one?

☐ Installation cost, EUR
☐ Monthly energy bill (during cold and southern season), EUR/month
☐ Length of the warranty period, years
☐ Special installation conditions and inconvenience of system
☐ Degree of possibility for sharing

4. By rating attributes from 1 to 5, where 1 stands for the key criterion, and 5 is the least important, consider the following attributes when choosing an alternative for renewable energy technologies for individual homes:

______ Installation cost, EUR
______ Monthly energy bill (during cold and southern season), EUR/month
______Length of the warranty period, years

______Special installation conditions and inconvenience of system
______Degree of possibility for sharing

5. Can you explain the reasons for your attribute ranking?

____

____

Expert Questionnaire

Dear Expert,

My name is Ilona Alisauskaite-Seskiene. I am a 4th year Ph.D. student of economics in Lithuanian Energy Institute, Laboratory of Energy Systems Research. My mentor is Ph.D. Dalia Streimikiene. I am currently working on research, the purpose of which is to identify the best renewable energy technologies in households. In order to achieve this goal, it is necessary to adapt the multi-criteria decision method (MCDM) to the selected technologies (solar thermal, solar panel, biomass boilers, micro wind), based on which the state could choose the optimum policy for the use and promotion of renewable energy, allocate incentives between technologies that use renewable energy sources (RES) and form priority incentive areas.

Multi-criteria decision method will include experts' assessment of higher mentioned RES technology, a study of households' willingness to pay (WTP) for RES technologies and a study on the willingness to share the energy produced from RES technologies. Such an investigation has not been carried out in Lithuania so far.

We kindly ask experts to evaluate each technology (solar thermal, solar panel, biomass boilers, micro wind) on the basis of environmental, social, economical, energetic, technological and political criteria according to the following indicators:

CRITERIA	**Indicators** of the criteria	
	Sustainability indicator	**Resilience indicator**
ENVIRONMENTAL	• Noise pollution • CO_2 emissions in the atmosphere • Land use requirement	• Climate resilience
SOCIAL	• Level of public resistance/opposition • Job creation • Social benefits	
ECONOMICAL	• Investment cost • Operation and maintenance cost • Payback period	• Sensitivity to fuel price fluctuation
ENERGETIC		• Market concentration on supply
TECHNOLOGICAL	• Market size (domestic) • Market size (potential)	• Technological maturity • Innovative ability
POLITICAL		• Contributes to the development of the country's energy independence

1. Noise pollution – noise of the technology that is being used.
2. CO_2 emissions in the atmosphere – this indicator reflects the impact of global climate change, which is influenced by atmospheric CO_2 amount (most often expressed as GHG emissions (in grams) per unit of energy in gCO_2/kWh).

3. Land use requirement – area of land needed to install the technology
4. Climate resilience – shows how much energy technology is resistant (able to withstand) unpredictable climate change and extreme weather events in the future.
5. Level of public resistance/opposition – use of certain energy systems may not be acceptable to all citizens, i.e. some technologies can be evaluated unfavourably by society and vice versa.
6. Job creation – many people can be employed in the design, construction, installation and operation of energy supply systems. Sustainable energy systems create jobs and improve people's quality of life.
7. Social benefits – describes the social progress that has taken place in the region due to the technology used.
8. Investment cost – if the cost of technology decreases, this technology will be more attractive.
9. Operation and maintenance cost – this is the cost for the operation and maintenance of the technology, for example, additional fuel purchased, technology maintenance costs, etc.
10. Payback period – short time span that the installed technology installed pays off.
11. Sensitivity to fuel price fluctuation – sensitivity of technology price to fluctuations in energy and fuel prices.
12. Market concentration on supply – how much technology concentration in the market affect the reliability of the supply, for example, the more solar thermal technology there is in the market, the less supply is stable and requires more storage and reserve capacities.
13. Market size (domestic) – means potential demand in local markets: the bigger it is, the better technology costs and the improvement of technology is higher.
14. Market size (potential) – means potential demand in global markets: the bigger it is, the better, as it can achieve economies of scale and this leads to falling prices.
15. Technological maturity – the maturity of technology and the extent to which technology is prevalent in the marketplace.
16. Innovative ability – flexibility of the technology and the ability to be improved.
17. Contributes to the development of the country’s energy independence – whether technology contributes to the development of energy independence.

All these indicators can be classified as negative and positive. Negative criteria include: noise pollution, CO_2 emissions in the atmosphere, land use requirement, level of public resistance, operation and maintenance cost, sensitivity to fuel price fluctuation, market concentration on supply – the higher their score is, the more damage they cause. Positive criteria include: climate resilience, job creation, social benefits, investment cost, payback period, market size (domestic), market size (potential), technological maturity, innovative ability, contribution to the development of country’s energy independence – the higher their score is, the better their indicators are.

During this questionnaire survey, competent persons and experts will be questioned, thus your opinion is of great value. Your participation in the study is confidential and the answers to the questions will be analysed and used in the dissertation.

Emphasis is being laid four technologies **(solar thermal, solar panel, biomass boilers, micro wind)**, intended for use in individual houses or cottages, were selected for the evaluation. Based on the above statements, we kindly ask you to evaluate them on a five-point system using this scale:

1. Totally disagree
2. Disagree
3. Difficult to say
4. Agree
5. Fully agree

We kindly ask you to evaluate RES technologies according to the following indicators, which are characterized by the selected criteria:

No.	*Factors that impact* ***solar thermal***	*Assessment level*				
		Disagree			*Agree*	
1.	Solar thermal use generate noise	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
2.	Solar thermal use contributes to the growth of CO$_2$ emissions in the atmosphere	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
3.	Solar thermal needs extra land and distort the landscape	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
4.	Solar thermal is resistant to climate change and extreme meteorological phenomena	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
5.	Solar thermal is badly appreciated in society	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
6.	Solar thermal creates additional jobs (directly and indirectly)	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
7.	Solar thermal use has a positive impact on the social progress of the entire region	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
8.	Solar thermal cost is constantly decreasing	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
9.	Solar thermal is characterized by high operating and maintenance costs	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
10.	Solar thermal has a short payback period	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
11.	Solar thermal price is sensitive to energy and fuel price fluctuations	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
12.	High concentration of solar thermal in the market negatively affects the stability of the system	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
13.	Solar thermal is in great demand on the local market	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
14.	Solar thermal is in great demand on the global market	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
15.	Solar thermal is technologically mature and widespread in the global market	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
16.	Technological improve of solar thermal is possible	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐

17.	Solar thermal use contributes to the development of country’s energy independence	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐

No.	*Factors that impact* ***solar panel***	*Assessment level*				
		Disagree			*Agree*	
1.	Solar panel use generate noise	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
2.	Solar panel use contributes to the growth of CO_2 emissions in the atmosphere	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
3.	Solar panel needs extra land and distort the landscape	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
4.	Solar panel is resistant to climate change and extreme meteorological phenomena	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
5.	Solar panel is badly appreciated in society	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
6.	Solar panel creates additional jobs (directly and indirectly)	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
7.	Solar panel use has a positive impact on the social progress of the entire region	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
8.	Solar panel cost is constantly decreasing	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
9.	Solar panel is characterized by high operating and maintenance costs	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
10.	Solar panel has a short payback period	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
11.	Solar panel price is sensitive to energy and fuel price fluctuations	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
12.	High concentration of solar panel in the market negatively affects the stability of the system	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
13.	Solar panel is in great demand on the local market	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
14.	Solar panel is in great demand on the global market	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
15.	Solar panel is technologically mature and widespread in the global market	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
16.	Technological improve of solar panel is possible	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
17.	Solar panel use contributes to the development of country’s energy independence	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐

No.	*Factors that impact* ***biomass boiler***	*Assessment level*	
		Disagree	*Agree*

1.	Biomass boiler use generate noise	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
2.	Biomass boiler use contributes to the growth of CO_2 emissions in the atmosphere	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
3.	Biomass boiler needs extra land and distort the landscape	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
4.	Biomass boiler is resistant to climate change and extreme meteorological phenomena	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
5.	Biomass boiler is badly appreciated in society	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
6.	Biomass boiler creates additional jobs (directly and indirectly)	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
7.	Biomass boiler use has a positive impact on the social progress of the entire region	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
8.	Biomass boiler cost is constantly decreasing	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
9.	Biomass boiler is characterized by high operating and maintenance costs	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
10.	Biomass boiler has a short payback period	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
11.	Biomass boiler price is sensitive to energy and fuel price fluctuations	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
12.	High concentration of biomass boilers in the market negatively affects the stability of the system	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
13.	Biomass boiler is in great demand on the local market	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
14.	Biomass boiler is in great demand on the global market	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
15.	Biomass boiler is technologically mature and widespread in the global market	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
16.	Technological improve of biomass boiler is possible	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
17.	Biomass boiler use contributes to the development of country’s energy independence	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐

No.	*Factors that impact **micro wind***	*Assessment level*				
		Disagree			*Agree*	
1.	Micro wind use generate noise	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
2.	Micro wind use contributes to the growth of CO_2 emissions in the atmosphere	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
3.	Micro wind needs extra land and distort the landscape	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐

4.	Micro wind is resistant to climate change and extreme meteorological phenomena	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
5.	Micro wind is badly appreciated in society	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
6.	Micro wind creates additional jobs (directly and indirectly)	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
7.	Micro wind use has a positive impact on the social progress of the entire region	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
8.	Micro wind cost is constantly decreasing	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
9.	Micro wind is characterized by high operating and maintenance costs	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
10.	Micro wind has a short payback period	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
11.	Micro wind price is sensitive to energy and fuel price fluctuations	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
12.	High concentration of micro wind in the market negatively affects the stability of the system	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
13.	Micro wind is in great demand on the local market	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
14.	Micro wind is in great demand on the global market	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
15.	Micro wind is technologically mature and widespread in the global market	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
16.	Technological improve of micro wind is possible	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
17.	Micro wind use contributes to the development of country’s energy independence	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐

I would like to get acquainted with the research results	Yes ☐	No ☐

Please send a completed application form by e-mail: i.alisauskaite@gmail.com. If you have any questions, please do not hesitate to contact via e-mail or phone number +370 699 07556, and I will answer them by providing all the necessary information you need. I sincerely thank you for your time, cooperation and answers.