LITHUANIAN ENERGY INSTITUTE

LINA MURAUSKAITĖ

DIVERSIFICATION OF RENEWABLE ENERGY SOURCES FOR DISTRICT HEATING SYSTEM

Doctoral dissertation
Social Sciences, Economics (04S)

2016, Kaunas

UDK 620.97 + 697.3](043.3)

Doctoral dissertation was prepared in Lithuanian Energy Institute, Laboratory of Renewable Energy and Energy Efficiency during the period of 2011–2016. The studies were supported by Research Council of Lithuania.

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ISBN 978-609-02-1249-3

LIETUVOS ENERGETIKOS INSTITUTAS

LINA MURAUSKAITĖ

ATSINAUJINANČIŲ ENERGIJOS IŠTEKLIŲ DIVERSIFIKAVIMAS CENTRALIZUOTO ŠILUMOS TIEKIMO SISTEMOJE

Daktaro disertacija
Socialiniai mokslai, ekonomika (04S)

2016, Kaunas

UDK 620.97 + 697.3](043.3)

Disertacija rengta 2011–2016 metais Lietuvos energetikos instituto Atsinaujinančių išteklių ir efektyvios energetikos laboratorijoje. Mokslinius tyrimus rėmė Lietuvos mokslo taryba.

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ABBREVIATIONS

CHP – combined heat and power
CO_2 – carbon dioxide
DH – district heating
EC – European Commission
EU – European Union
EUR – euro
GDP – gross domestic product
GHG – greenhouse gas emissions
IEA – International Energy Agency
IRR – Internal Rate of Return
JEREMIE – Joint European Resources for Micro to Medium Enterprises
JESSICA – Joint European Support for Sustainable Investment in City Areas
ktoe – kilotonne of oil equivalent
kW – kilowatt
kWh – kilowatt hours
LCoE – modified Levelised Cost of Energy
LDHA – Lithuanian District Heating Association
LEA – Lithuanian Energy Agency
LEIF – Lithuanian Environmental Investment Fund
LNG – liquefied natural gas
MW – megawatt
MWh – megawatt hours
NCECP – National Commission for Energy Control and Prices
NPV – Net Present Value
OECD – Organization for Economic Cooperation and Development
RES – renewable energy sources
SWOT – strengths, weaknesses, opportunities and threats
TPA – third party access
VAT – value added tax

DEFINITIONS

District heating – an infrastructure for distributing heat generated in a centralized location for residential and commercial heating requirements such as space heating and water heating. District heating system comprises generation, transmission, and consumption.

Method – a particular form of procedure for accomplishing or approaching something, especially systematic or established.

Methodology is the interconnection of research, analysis, and methods of practical calculation, as well as the whole of assumptions, which allow justifying diversification of RES technologies and sources in DH system. The methodology consists of three stages, which comprise 1) theoretical insights; 2) territorial dimension (context of city/town sustainable development); 3) tools (methods) for practical calculation and the implementation of the system of preconditions.

Natural RES, such as solar and geothermal energy, do not use any source of solid or liquid fuel; therefore, a stable price is guaranteed in a long-term perspective.

INTRODUCTION

Relevance of the research. District heating (further DH) is one of the most important energy sectors in Lithuania, which influences economic growth, competitiveness, energy supply, and energy efficiency of the country. DH sector is closely related to the household expenses, where the share of cost for the heat consumption is disproportionately high compared with the average household income. Therefore, the DH systems are an especially important macroeconomic problem, posing great difficulties for economic development. Their maintenance costs are not only directly related to the production and transportation but also VAT exemptions, subsidies for investments, compensation for the poorest sections of the population, etc. Even more damage is caused by the decline of investments due to people's low expectations, fear for the future and, therefore, excessive saving. It should be added that due to the one-sided understanding of economic policy, which is only related to the short-term reduction of heat price, subsidies for the investment of biomass encourage disproportionate, excess use of the capital in heat production sector; excess capacities have increased several times.

Although DH systems encompass more than 50 per cent of heat sector, DH problems have to be solved by the state; DH difficulties, an increase of the price are in the Government's spotlight. DH fuel costs constitute about 50-70 per cent of the total cost; therefore, the main question is fuel prices. For this reason, all the attention is directed to the cheapest type of fuel at the period. During 26 years of independence, reforms have been associated with changes in the type of fuel due to the changes of price of one or another type of fuel. Currently, an intensive promotion of biomass is taking place.

Expansion of biomass boilers in DH sector enabled to reduce heat prices for consumers. However, in the long run, the increase in the biomass price is expected, which will be influenced by a sharp rise in demand.

DH, as the heat supply system, conceptual argumentation of advantages is based on the infrastructure that enables the use of diversified fuel; among other benefits, a variety of fuel types would be the basis for security of energy supply and long-term stability of energy price. This particular possibility of the utilization of DH infrastructure can lead to a renaissance of DH systems in foreign countries. This is related to the recent adoption of EU directives. Directive 2012/27/EU has a target to reduce EU primary energy consumption by 20% by 2020 and to reduce greenhouse gas emissions (further in the text GHG emissions) by 80-95% by 2050, compared to 1990. These objectives are promoting the development of renewable energy sources (further RES) technologies in Lithuania. According to Directive 2009/28/EB on the promotion of the use of energy from RES, the Republic of Lithuania must ensure that the share of energy from RES will be not less than 23% in gross final consumption of energy by 2020 (20% in electricity sector, 60% in heat production, 10% in transport). The Lithuanian goal of 23% had already been reached at the end of 2014. However, due to the fact that there is a standard overlap of fundamentally different types of RES, in the RES concept, biomass becomes the main accent of restructuring heat production.

However, this type of fuel also affects atmospheric pollution. Thus, taking into account future additional obligations of Paris Agreement on GHG emission reductions, there is a necessary breakthrough of the use of other types of RES technologies, such as solar and geothermal energy. Therefore, it is relevant to analyse diversified RES for the production of heat in DH system, including mostly untapped RES, such as solar and geothermal energy.

Although a lot of research has been done in respect to RES; however, some uncertainties, which need to be identified and solved by energy policy makers by determining the reliable directions on how to develop RES sector in future, remain. Due to international discussions for more than two decades it is considered that a unified and long-term economic policy for RES sector development needs to be developed. Most of the debates arise due to fragmentation and transformation of RES support measures. The newest EU document (EU, 2014) proclaims that even Government support and funding is a significant factor that promotes the development of RES technologies in adverse market conditions, but the different support of RES technologies is often unbalanced. Government support may have different forms; however, only some of them are currently used in Lithuania, which basically repeat instruments and financial mechanisms that are used in foreign countries. Structural Funds are one of the most important sources of funding for RES technologies. Commitments for the promotion of RES under the EU Directives have a significant impact in Lithuania. For example, state subsidies for investments are regarded as the simplest form of support that enables rapid popularity of renewable energy technologies, if the grant is large enough. The incentive schemes were widely used in many countries of various support organizations in the past. However, it was observed that this does not encourage project developers to choose economically optimal technologies, and often unreasonably expensive plants are installed, operational rates of which are not always justified. The essential deficiency of this type of promotion is a lack of connection with the achievement of external benefit, which is understandable as a contribution to solving the problems of sustainable development of environmental, social, supply of energy resources of future generations and other aspects.

External benefit evaluation of renewable energy is one of the most difficult problems of the economic theory. An economic policy that is formed on the basis of assessment is a complex system, where a balance of three aspects of sustainability is needed: environment, economy, and social life. A contemporary generation has a challenge not only to cope with problems of energy supply without leaving them for another generation to solve but especially with the growing threat of climate change. Deployment of RES technologies receives a special attention because the main cause of pollution is identified by burning fossil fuel. However, a good performance and well-balanced RES policy need efforts from stakeholders with different interests and market participants.

DH infrastructure is suitable for reaching strategic energy goals of the state, such as integration of local and RES, utilization of municipal waste for generation of heat and electricity, diversification of fuel sources due to the security of energy supply, implementation of district cooling for buildings, integration of industrial waste heat to DH networks, effective production of electricity in cogeneration, reduction of environmental pollution and GHG emissions, etc. DH enables the use of diversified fuel sources, and this could be the basis for security of energy supply and **stabilisation of energy prices**. One of the main important problems is that DH, which dominates in the supply of heat, is oriented toward short-term cheapness of heat.

Therefore, this results in a massive introduction of new equipment into DH systems due to significant changes in fuel prices. The recent example is a sharp increase in the price of natural gas, which has determined the massive use of biomass boilers.

The main issue in Lithuanian DH sector is based on the dominant position of only one type of fuel source, which has to dominate in DH balance due to the lowest price in a short term. Therefore, solar and geothermal energy on a large scale has a very low possibility to be used in a very well extended infrastructure of DH.

Another issue is a mismatch in the interests of consumers and producers in DH. Financially, DH systems are not concerned about partial heat production on the consumption side, for example, by using systems of solar collectors and others. Residents that receive subsidies for the renovation of multifamily buildings and for the development of RES will at large affect savings of heat energy. A massive disconnection from DH system is not only unbalancing the DH network but also raising the price for the rest of consumers. The massive renovation of multifamily buildings will significantly reduce the amount of consumed heat energy; for this reason, the price for DH will noticeably increase. When evaluating the development of RES in multifamily buildings, it is important to take into account the size of support and possible consequences for the system of DH. The examples of northern European countries, which are in a similar climatic zone, show that such type of problems could be successfully solved by economic and other measures, which are based on the status of natural monopoly. One of the most important preconditions is territorial planning of energy development, whereas the implementation of plans can be a basis for the diversification of fuel sources in heat sector in case of avoiding excess investment.

Municipalities should be a connecting link in the practical implementation of national RES energy goals. The role of municipalities for the development of RES is regulated in detail in Law on Energy from Renewable Sources. However, the implementation of this law on the municipal level does not progress in practice. RES Development Action Plans have been developed only by few municipalities, but such claim at municipal councils has been stalled. According to the existing situation, it can be stated that problems and failures in case of municipal involvement in the planning of RES refer to the short-term, fragmented solutions.

***Investigation level of the scientific problem*.** There are very few empirical economics papers written on DH, as noted by Linden & Peltola-Ojala (2010). Economic approach for DH as a natural monopoly problem is a basis for research and solutions. One of the above-mentioned reasons from the economic perspective is that DH systems are not treated as natural monopolies or pricing, which encourage producing and supplying the maximum amount of heat energy. The monopoly of DH is formed due to the nature of the infrastructure. Therefore, it is determined by pricing, regulatory and infrastructure planning peculiarities, which have to be analyzed and evaluated. Basically, it is still unrealized and impracticable intention of Law on Heat: the special plans of heat sector aim at harmonizing interests of the state, municipalities, energy companies, individuals and legal parties or groups supplying heat to the consumers and energy sources for heat production.

There have been attempts to analyze problems of RES integration into energy sector in several researches in Lithuania. Some authors analyse sustainable development aspects (Čiegis, Grundey, & Štreimikienė, 2005; Čiegis & Štreimikienė, 2005); promotion of RES in Lithuania (Katinas & Markevičius, 2006; Štreimikienė & Pareigis, 2007). However, DH is usually analysed in engineering field of scientific papers related mainly to combined heat and power plants (Lund, Šiupšinskas, & Martinaitis, 2005; Rasburskis & Lund, 2007; Streckienė, Martinaitis, Andersen, & Katz, 2009), or policy aspects of DH (Katinas & Markevičius, 2006; Klessmann, Held, Rathmann, & Ragwitz, 2011; Konstantinavičiūtė, 2011).

Lithuanian authors' research shows that dynamic changes of energy and industry have significantly influenced operation of DH systems (total heat consumption decreased, some industries and individual customers disconnected from the DH systems, new customers developed, automated consumer substations were implemented, etc.) (Kaliatka et al., 2008). A retrospective analysis of the evolution of the heat sector in Lithuania is examined by (Lukoševičius & Balaišytė, 2011a; Marcinauskas & Korsakienė, 2011).

A retrospective analysis of the heat sector development in Lithuania is examined by Marcinauskas and Korsakienė (2011) in a historical-expert review, and by Lukoševičius and Balaišytė (2011a) in their study. The latter authors, Lukoševičius and Balaišytė (2011), emphasise that proposals of changes in DH sector were based not on economic calculations or international practice, but on the episodic restructuring of heat sector, which confused the legal-economic system. Therefore, a series of legal disputes were caused, but essential problems of heat supply were insufficiently addressed.

An important aspect to be considered is that many authors link the achievement of sustainable development goals to the territorial aspect, i.e. it is perceived that there is an insufficient achievement of results of sustainable development on the state level. If initially the concept of sustainable development was directed at the state level through Agenda 21 resulting from the 1992 Rio Summit, then now, a growing number of experts recognize that on the local scale; municipalities, cities or metropolitan regions are suitable for mobilizing actors and solving challenges of sustainable development, including a wider use of RES (Camagni, 2002; Tanguay, Rajaonson, Lefebvre, & Lanoie, 2010).

The results of international scientific papers, mainly from Scandinavian countries, in recent years aim at analysing and designing the 4th generation DH (Lund et al., 2014), which is characterized by low temperature DH (Gadd & Werner, 2014), the use of smart DH network (Brand, Calvén, Englund, Landersjö, & Lauenburg, 2014; Lund et al., 2014; Mathiesen et al., 2015).

It should be noted that questions of DH companies on a natural monopoly aspect have been scarcely analysed both in Lithuania and in foreign countries. A natural monopoly is an economic category, whose operation on market conditions cannot be considered as free market economy controlled power system without control and regulation. On the one hand, the natural monopoly status determines the whole system of economic laws based on regulatory, pricing tools and methods; on the other hand, a variety of measures and reforms in post-Soviet legacy were necessary, which shocked the whole system by permanent changes in the price of fuels and the consequent power generation convergence with the wrong (unrelated to the monopolistic nature DH) interpretation of the problems and solutions. DH systems, despite their monopoly position, have become profit-making organizations. Historical aspects of natural monopoly concept and its regulation are analysed in (Depoorter, 1999; Magnusson & Palm, 2011; Mosca, 2008). Pricing of DH in different countries is analysed in (Björkqvist, Idefeldt, & Larsson, 2010; Difs & Trygg, 2009; Li, Sun, Zhang, & Wallin, 2015). Regulatory issues are analysed by (Lukoševičius & Werring, 2011; Wissner, 2014).

Economically regulated pricing is analysed by (Aronsson & Hellmer, 2009; Valiukonis, Lukoševičius, Gudelis, & Čirgelienė, 2008) and typically used in countries, where reforms take place, and there is no a well-established infrastructure, and the dominance of monopolies is strong in energy sectors.

Economic principles of regulated price formation theoretical foundations are presented in Valiukonis et al. (2008) study, which provides elements of possible pricing alternatives on the basis of the World Bank study, which are widely applied in the energy sector.

The regulation itself may not represent the main or the only reason why DH in transition economies is less efficient than, for example, in Western Europe (Poputoaia & Bouzarovski, 2010). Despite the government policy efforts, accepted legislated base and programs for the enhancement of the use of RES, due to the expensiveness of alternative energy technologies and various constraints, the total contribution to development is modest.

In recent years, the consumption of fossil fuel and the mitigation of climate changes have become major challenges all over the world. To engage in these challenges, many countries are pursuing the research, development, and demonstration of RES. In the past few years, RES have rapidly developed all over the world. RES have become important alternative energy sources to realize energy diversification. In the 21st century, political support for renewable energies has been growing continuously both on the national and international levels.

Significant changes in energy sector after 2006: it was a natural gas price boom, increase of social and political pressure for fast developments in clean energy, and financial crisis, which requires adequate government measures to stimulate the economy. However, decisions of heat sector are usually aimed at the short-term competitiveness of price, without assessing long-term benefits of the possibility of stabilizing heat prices, thus the cheapest type of fuel has a dominant position in a short term.

The industry of renewables could be important for generating employment and stimulating growth (Marques, Fuinhas, & Pires Manso, 2010). Investment in RES may bring considerable profits, so more and more enterprises will be involved in this field. The increased use of RES in the heat market can significantly alleviate the negative effects of high-energy costs on the national economy. Successful commercialisation of indigenous, non-fossil energy resources is expected to promote regional economic development and employment, help to increase national energy security and reduce a substantial portion of the increasing trade deficit necessity to import fossil fuels (Katinas & Markevičius, 2006).

According to Klessmann et al. (2011), “success includes implementing effective and efficient policies that attract sufficient investments, reducing administrative and grid related barriers, especially in currently less advanced countries, dismantling financial barriers in the heat sector, realising sustainability standards for biomass, and lowering energy demand through increased energy efficiency efforts”.

An important question is the selection of research models and feasibility analysis. EnergyPRO is typically used for techno-economic analysis of simulating cogeneration plants and DH systems with multiple energy producers (Fragaki & Andersen, 2011; Rasburskis & Lund, 2007; Streckienė et al., 2009). Other types of projects, e.g. solar collectors and heat pumps, can also be analysed and detailed by means of the software (Nielsen & Möller, 2012).

Most of the environmental problems that society faces today have their origin in urban areas; therefore, they must combine commitment and capacity for innovation to solve them (Pereira & Azevedo, 2011). Because cities are different in the size of their territory, a number of inhabitants, environment, political and social-cultural conditions, the local government of each city together with society should find an individual way of sustainable development. In view of the growing complexity of managing the rapidly evolving urban environment and cities in Europe, there is a need for integrated approaches that assist city planners, developers and councillors in unsustainability of the current model of urban development (Rotmans & Asselt, 2000; Walton & El-Haram, 2005; Xing, Horner, El-Haram, & Bebbington, 2009). The most important thing is the participation of city inhabitants, representatives of business and other sectors in urbanized life aspects, because cities, in a sense, are products of their inhabitants (R Čiegis & Česonis, 2004).

To summarize the investigation level of the scientific problem, it can be stated that in spite of the ongoing development of renewable energy, there is a lack of unified methodology, which facilitates solving DH problems from a theoretical base to the practical implementation, and allows reasonable diversification of RES. In the scientific literature, there is a lack of economic knowledge-based methodological principles, which would allow the use of diversified RES technologies in DH systems on producer and consumer sides in terms of the aspect of urban sustainable development.

The scientific problem of the research: how to theoretically justify the concept of integration of diversified RES technologies into DH sector on consumer and producer sides?

The object of the research: the use of diversified RES (based on the example of solar and geothermal energy) technologies in district heating (DH) systems on the demand and supply sides within the frame of cities sustainable development.

The aim of the research**:** to develop justification methodology of the integration of diversified RES (based on the example of solar and geothermal energy) technologies into DH systems on the producer and consumer sides in terms of sustainable development of cities.

The main tasks of the research**:**

1. To examine and systematise the main characteristics determining the problems of the DH and their social, environmental, and economic consequences in terms of sustainable development.
2. To investigate DH as natural monopoly based on economic theory and related theoretical and practical issues of DH long-term planning, reforming, pricing, and financing; and economic opportunities for their solution.
3. To inspect and systematise the impact of legal regulation on the use of RES, and to formulate prerequisites for the use of diversified RES technologies in DH system.
4. To analyse theoretical essence and evaluation issues of the external benefit for the use of RES in DH sector and to formulate research concept for diversification of RES in DH.
5. To develop a system of preconditions of integration of diversified RES technologies on production and consumption side using DH infrastructure in the cities/towns sustainable development context.
6. To analyse and to evaluate possibilities of diversification of RES technologies (based on the example of solar and geothermal energy) in production and consumption sectors on the territorial aspect, i.e. on city/town level.

Research methods. In order to achieve the aim and tasks of the research, systematic and comparative analysis and synthesis of scientific literature, strategic and legislative acts are used. The methodology formation is done by using theoretical insight generalization, simulation, and logical analysis methods. The empirical study is performed using statistical and logical analysis. Technical simulation of diversification of RES technologies (based on the example of solar and geothermal energy) in DH system is done by using EnergyPRO software; economic evaluation is carried out using modified levelized cost of energy (LCoE) method.

Sources used in the scientific research**.** In the process of accomplishing this dissertation, a number of Lithuanian and foreign authors' monographs, research results, scientific publications, statistics, conference papers and various scientific recommendations have been analysed.

The novelty of the scientific research and fields of its application:

- Problems of DH development are evaluated and based on the status of DH as a natural monopoly and experience of foreign countries, which are highlighted by the comparative analysis according to selected segments (regulation of monopolies, pricing, etc.).

- The concept of the use of currently largely untapped diversified technologies of RES (based on the example of solar and geothermal energy) is done, on the basis of long-term municipal energy planning.
- The system of preconditions for potential possibilities of the use of RES (on the example of solar and geothermal energy) is formed on demand and supply sides on a territorial basis, i.e. city/town level.
- Methodological principles of long-term diversification of RES sources in DH systems are developed seeking the economically justified increase of the use of solar and geothermal energy technologies on the producer and consumer sides in terms of sustainable development of cities, based on the experience of Scandinavian and other countries. The transition from fossil fuel based DH systems is based on original principles for the diversified use of RES, not only biomass.

Potential areas of practical application of the work. Adapting formed methodological principles in Lithuania for a broader use of RES in DH sector, possibilities of the use of solar and geothermal energy are evaluated on the demand and supply sides. Developed methodological principles enable to justify the formation of a long-term potential of diversified RES in Lithuania, and to finance RES technologies that currently are not widely used.

The dissertation results may be used when considering planning documents of urban energy, which are related to the DH sector. The assumptions and recommendations enable the interested parties to make decisions that will allow stabilising heat prices for consumers in the long term.

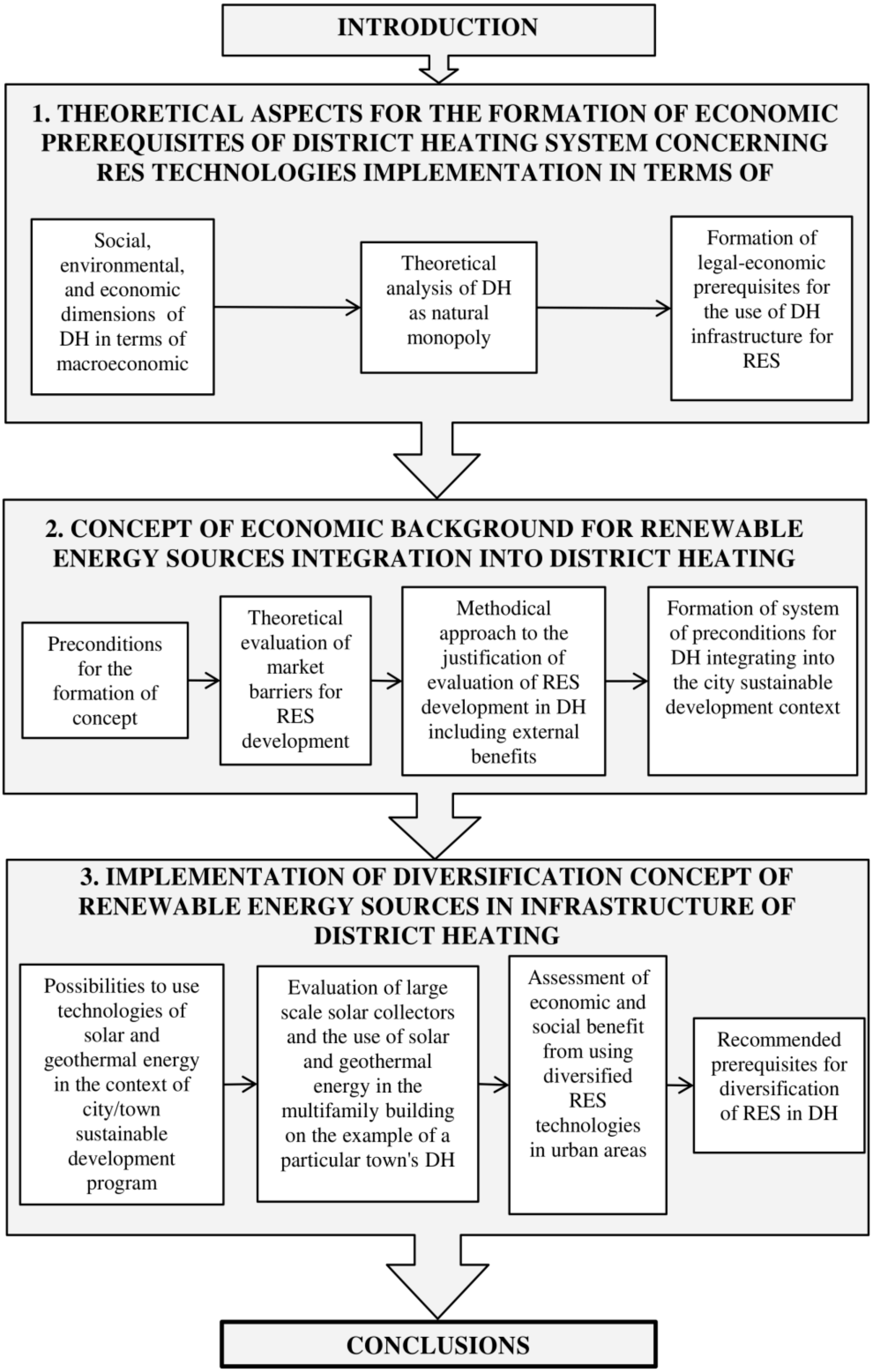
The key findings were presented at Lithuanian and international scientific conferences, as well as in the scientific journals.

The structure, as well as the logical composition of the thesis, has been determined by the tasks of the research (see the scheme below). The accomplishment of the tasks is represented in three parts of the dissertation.

The first part of the dissertation consists of the analysis of the main characteristics determining the problems of the DH and their social, environmental, and economic consequences in terms of sustainable development. Particular attention is given to issues of reforms in Lithuanian DH sector. Investigation of DH as a natural monopoly in terms of economic theory and economic opportunities for their solution, such as pricing and financing schemes, is performed. Moreover, the impact of legal regulation on the use of RES is analysed, and prerequisites for the use of diversified RES technologies in DH system are presented.

The second part of the dissertation is devoted to the formation of preconditions for the concept of economic background for RES integration into DH. A theoretical study of market barriers for the wider use of RES is conducted; moreover, the significance of the external benefit for the use of RES in DH sector is theoretically based.

The third part of the dissertation evaluates possibilities of diversification of RES technologies (based on the example of solar and geothermal energy) in production and consumption sectors on the territorial aspect, i.e. on city/town level. Recommended prerequisites for diversification of RES in DH are given.


INTRODUCTION
1. THEORETICAL ASPECTS FOR THE FORMATION OF ECONOMIC PREREQUISITES OF DISTRICT HEATING SYSTEM CONCERNING RES TECHNOLOGIES IMPLEMENTATION IN TERMS OF
Social, environmental, and economic dimensions of DH in terms of macroeconomic
Theoretical analysis of DH as natural monopoly
Formation of legal-economic prerequisites for the use of DH infrastructure for RES
2. CONCEPT OF ECONOMIC BACKGROUND FOR RENEWABLE ENERGY SOURCES INTEGRATION INTO DISTRICT HEATING
Preconditions for the formation of concept
Theoretical evaluation of market barriers for RES development
Methodical approach to the justification of evaluation of RES development in DH including external benefits
Formation of system of preconditions for DH integrating into the city sustainable development context
3. IMPLEMENTATION OF DIVERSIFICATION CONCEPT OF RENEWABLE ENERGY SOURCES IN INFRASTRUCTURE OF DISTRICT HEATING
Possibilities to use technologies of solar and geothermal energy in the context of city/town sustainable development program
Evaluation of large scale solar collectors and the use of solar and geothermal energy in the multifamily building on the example of a particular town's DH
Assessment of economic and social benefit from using diversified RES technologies in urban areas
Recommended prerequisites for diversification of RES in DH
CONCLUSIONS

1. THEORETICAL ASPECTS FOR THE FORMATION OF ECONOMIC PREREQUISITES OF DISTRICT HEATING SYSTEM CONCERNING RES TECHNOLOGIES IMPLEMENTATION IN TERMS OF SUSTAINABLE DEVELOPMENT

This chapter defines factors that are determining the characteristics of the district heating (further DH) and social, environmental, and economic dimensions in terms of macroeconomics. Characteristics of DH as a natural monopoly in terms of economic theory are described. Features of DH pricing based on sustainable development are investigated. The impact of legal regulation on the use of renewable energy sources (further RES) is analysed.

This PhD thesis is based on heterodox economics rather than conventional economics. Heterodox economics provides an alternative approach, which includes historical and social factors into the analysis. Heterodox economics refers to methodologies that are considered outside the conventional or “mainstream“ economics (Faber, 2008). Ecological economics is only a few decades old and it is a leading contender among heterodox economic schools (Gowdy & Erickson, 2005; Spash & Ryan, 2012), which became as alternative to neoclassical economics.

A fundamental objective of ecological economics is economic theory and practice based on physical reality (laws of physics, especially laws of thermodynamics) and the knowledge of biological systems. The main goal of it is development of human well-being, which is achieved through planning for the sustainable development of ecosystems and societies. Spash (2013) explains that modern ecological economics arose partially from a crisis in environmental economics in late 1980‘s. Plumecocq (2014) after analysis of more than 6000 papers emphasizes that the discourses of ecological economics and environmental economics became closer over time. However, Gendron (2014) highlights that the aim of a heterodox economics of the environment is not so much to integrate the economy and the environment, but rather to understand how a specific social concern, the environment, is leading to an institutional transformation of the economic system. He shows that sustainable development relies on the green economy, where poor and mistaken public policies are leading to externalities and consequently fostering a “brown”, i.e. ecologically intensive economy.

Ecological economics also use the specific methodology, based on epistemology approach. This PhD thesis use ecological economists, such as Spash (2012), understanding of methodology. As the example, the definition of the methodology is provided from online encyclopedia and Lithuanian author Gintalas (2011) approach.

Table 1.1. Definition of the term "methodology"

Author	Definition
Spash, 2012	Methodology is used in two senses referring to (i) the principles and practices that underlie research in a discipline or subject area, and (ii) the appropriateness of the methods. This requires general principles about the formation of knowledge in practice and so becomes interrelated with the theory of knowledge (i.e. epistemology); in economics, methodology is often used as synonymous with epistemology.
www.encyclopedia.com	The term methodology may be defined in at least three ways: (1) a body of rules and postulates that are employed by researchers in a discipline of study; (2) a particular procedure or set of procedures; and (3) the analysis of the principles of procedures of inquiry that are followed by researchers in a discipline of study.
Gintalas, 2011	The main task of the methodology is creation and development of the ways, procedures, and tools system of scientific knowledge. The knowledge of methodology include: 1) what ways and tools of scientific knowledge should be used to investigate a specific object; 2) what cognitive tools or techniques are required to perform certain procedures of research; 3) what content of specific tools and techniques that are used in researching a particular object reveals its consistent pattern; 4) how methods are related to cognitive function, moving the knowledge from specific to abstract and vice versa.

The term "methodology" requires a specific definition, because there are many controversial definitions on the same term. Therefore methodology of this dissertation is divided into three levels:

1) theoretical insights;

2) territorial dimension (context of city/town sustainable development);

3) scientific tools (methods) for practical calculation and the implementation of the system of preconditions.

The methodology is the interconnection of research, analysis, and methods of practical calculation, as well as the whole of assumptions, which allow justifying of diversification of RES technologies and sources in DH system. The methodology comprises of three levels, such as economic theory, analytical research based on territorial dimension, and system of preconditions/scientific tools for practical implementation.

1.1. Social, environmental, and economic dimensions of DH in terms of macroeconomic

1.1.1. Potential possibilities and peculiarities of DH to solve problems of sustainable development

Problems associated with the use and application of sustainable development indicators primarily come from an overly broad definition of sustainable development that derives various interpretations, the lack of standard and universal classification methods or approaches to designing sustainable development indicators, especially at the municipal level, and restrictions originated from the accessibility of data that prevent their quantification and the specific qualification of indicators (Tanguay et al., 2010).

Sustainable development as global empiric phenomena was developing gradually and was influenced by various processes and environment dimensions. Analysis of the evolution of sustainable development conception may be divided in a number of dimensions, which correspond to sustainable development conception, with the main criteria of periodicity. The above proposition can be considered to have three stages (R Čiegis & Česonis, 2004):

a) two dimensions sustainability – economic and environmental;

b) three dimensions sustainability – economic, social and environmental; first time mentioned the concept of sustainability in Brundtland report (1987);

c) four dimensions sustainability – economic, social, environmental and political. The fourth dimension also called organization (institutional) dimension (Remigijus Čiegis, Ramanauskienė, & Martinkus, 2009; Labuschagne, Brent, & van Erck, 2004; Singh, Murty, Gupta, & Dikshit, 2012). However, it should be noted that each definition has its approach. In the case of DH, sustainable development unthinkable without the security of energy supply and social equality, therefore political dimension is seen as overarching of other dimensions. Four dimensions could be showed in sustainability criteria tetrahedron, as it is in Figure 1.1.

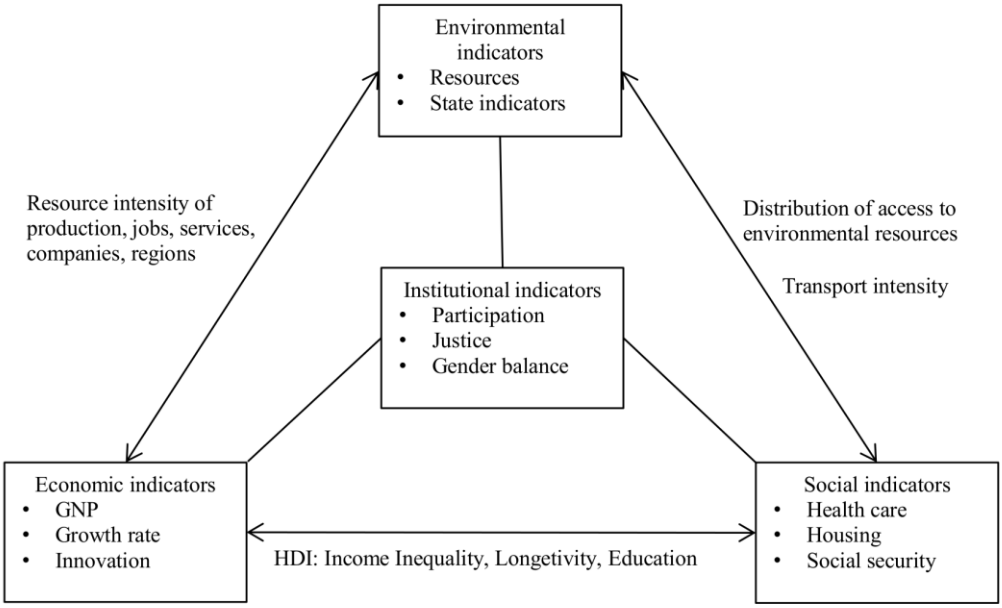


Figure 1.1. Tetrahedron framework of sustainable development indicators (Labuschagne et al., 2004)

Limitation of economic growth indicators for welfare and progress of mankind have had impact for the formation process of sustainable development conception. The rapid growth of economy in the 20th century more evidently revealed global problems of modern world, which damage the environment, lead to poverty, wars, and conflicts. Advanced abilities are the necessary condition for solving those problems.

If the concept of sustainable development was initially directed at nations through Agenda 21 resulting from the 1992 Rio Summit, a growing number of experts recognize that it is at the local scale, i.e. at the level of municipalities, cities or metropolitan regions, that the challenges are best expressed and that actors must be mobilized (Camagni, 2002; Tanguay et al., 2010).

The European Association for the Environment Agency constantly alerts to the growing urbanisation and the unsustainability of the current model of development. As a result of increasing urbanisation, Europe is one of the most urbanized continents of the Earth, since about 75% of the population lives in urban areas. However, the urban future of Europe is an issue of great concern, because in 2020 approximately 80% of Europeans will live in urban areas. In several countries, it may be achieved even at 90% or more (Pereira & Azevedo, 2011). Urban development has special importance within the broader context of sustainability. In view of the growing complexity of managing the rapidly evolving urban environment and cities in Europe, there is a need for integrated approaches that assist city planners, developers and councillors in this undertaking (Rotmans & Asselt, 2000; Walton & El-Haram, 2005; Xing et al., 2009).

When cities present proper densities and planning, they demonstrate to be the most efficient way of life. Then the recognition of the necessary accountability of cities is clear. Because most environmental problems that society faces today have their origin in urban areas, they must combine commitment and capacity for innovation to solve them (Pereira & Azevedo, 2011). Cities are diverse in their size of territory, population, environment, political, and social-cultural conditions. Therefore an individual way of sustainable development should be found by the local authorities of each city together with society. The participation of local communities, representatives of business, and other sectors in urbanized life aspects is the most essential, because cities, in a manner, are products of their inhabitants (R Čiegis & Česonis, 2004).

Strategic planning in urban areas is a continuous process that creates an opportunity for the various interest groups to be involved in the planning and implementation of development. A strategic plan is the basis for the development of management and planning systems that are based on principles of sustainable development, democracy, and market economy. Moreover, a strategic plan enables a more rational allocation of limited resources of the budget and better coordination as well as implementation of the various sectoral programs. The major advantage of strategic planning is focus on the most important issues and the most perspective tasks, based on in-depth knowledge of current situation and future trends.

However, integration of sustainable energy projects, e.g. RES technologies may be successful after reliable methodological assessment of the positive effect of such projects for solving social, economic, rural development problems in a regional development context. Scientific problem is to define the economic background for policies and measures aiming to sustainable energy development (Klevas, 2010).

Majority of the investors during the search of investment location usually analyse strategic plans and this is one of the most important factors for choosing a place for investments or at least choosing possible options. The importance of sustainable development and principles of sustainability are starting to be understood in Lithuania, and the implementation process has started, but during this process a lot of uncertainties were observed. The issue is a misconception about strategic planning of sustainable development principles in cities, the absence of a united methodology for strategic planning processes of sustainable development (R Čiegis & Česonis, 2004).

Strategic planning enables the use of modern DH infrastructure as a tool for implementing environmental, social, and economic development of heat energy in a most advanced way for society. Figure 1.2 shows the fundamental idea of contemporary DH, which is the use of local (produced at municipal level) heat and prioritise fuel sources that emit heat under the production process and waste it under normal circumstances. The infrastructure of DH is based on a closed and well insulated pipe network for supply and return of heat energy. DH is the most sustainable heating solution, because it enables the use of locally generated heat and fuel sources, which under normal conditions would be wasted or remained unused. Moreover, the high level of efficiency is usually achieved in DH in order to save primary energy resources.

European generation of DH is mainly based on recycled heat from CHP, wasted heat from industrial processes, and waste incineration for the reduction of GHG emissions and lower demand of primary energy. Other generation of DH is based on the direct use of RES (geothermal, solar energy, biomass) and fossil fuel for the peak demand.

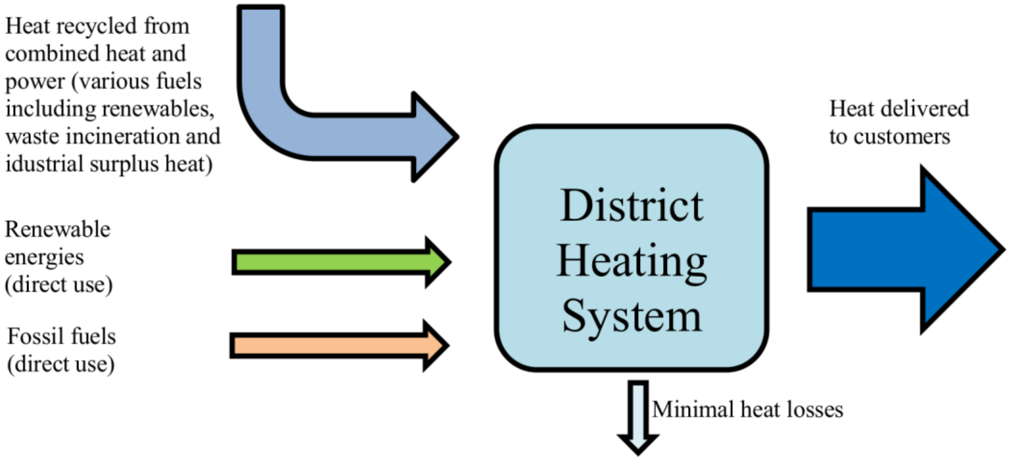


Figure 1.2. Fundamental idea of district heating (Frederiksen & Werner, 2014)

One of the main advantages of DH system is local pollution prevention and control. The decrease of particles, SO_x and NO_x and other local pollutants by the use of DH infrastructure is possible due to centralised chimneys, which are usually located outside the city and exhaust emissions higher than individual boilers. Centralised system of DH enables the use of more efficient pollution prevention and control measures that could be achieved due to economies of scale.

Another advantage is the increase of energy security due to the use of DH. The EU imports 54% of the total primary energy sources from outside its territory. According to Euroheat & Power, even in the most optimistic scenarios, the rose between 56% and 60% is expected by 2020, and to as high as 70% by 2030.

Past crises of natural gas, notably in 2006-2007 and 2009, have made the vulnerability of the energy supply system obvious. In several countries and cities, DH systems were able to considerably ease the situation by switching to alternative fuels.

Moreover, DH infrastructure creates flexibility and sustainability of fuel mix. DH infrastructure enables the introduction of various fuel mix (renewable, fossil, waste energy, etc.); therefore, high flexibility rate could be achieved. The integration of a new type of fuel or energy might be done with minimal requirement from operator. In comparison with individual boilers, no measures for customers are needed during the fuel switching process.

Large scale integration of RES is possible in DH system. The main demand of heat energy concentrates in urban areas; therefore the use of RES might be complicated in case of the use of biomass, because of logistics, emissions, and space. Furthermore, DH system enables the integration of various combustible RES, such as straw, wood waste as well as municipal waste and sewage sludge. Diverse use of RES in DH, such as solar and geothermal energy, can be more efficient due to expanding range of techniques and economies of scale.

1.1.2. Issues of reforms in Lithuanian DH and characteristics of consequences for economy

Evaluation of current conditions and problems of contemporary DH in Lithuania is inherent from the main unsolvable problems of DH systems' development. The historical approach may reveal the origin of the problems and consequences of the decisions taken, assess the achievements and mistakes, draw conclusions. DH systems of Lithuania were developed during the era of planned economy. The majority of DH systems in larger cities were designed and constructed more than 40 years ago in Lithuania and in other Baltic states. Kaliatka et al. (2008) emphasize that dynamic changes of the energy sector and industry have significantly influenced operation of DH systems (total heat consumption decreased, some industries and individual customers disconnected from the DH systems, new customers developed, automated consumer substations were implemented, etc.).

A retrospective analysis of the heat sector development in Lithuania is examined by Marcinauskas and Korsakienė (2011) in a historical-expert review, and by Lukoševičius and Balaišytė (2011a) in their study. The following is a systematic scientific approach to the periodization of reforms in heat sector during the last two decades.

After Lithuania regained its independence in 1990, most of DH companies were owned by "Lietuvos energija", AB until 1997. Decisions for heat pricing and technical-organisational changes were coordinated between administration of companies and central management bodies. Before DH holding was transferred to municipalities in 1997, conditions of heat sector had been deteriorated; many local boilers had been demolished; a significant number of heat consumers had been lost; heat load had been decreased notably, etc. The situation differed from municipality to municipality, but it was difficult from an economic and technical viewpoint in many cases. Central administration hardly participated in DH policy making, therefore municipalities had to make essential decisions on their understanding and responsibility regarding further activities of DH companies.

1997 was a year in which *assets of DH companies were transferred to municipalities' ownership* according to Resolution of Reorganisation of Special Purpose Company Lietuvos energija, AB (1997). *Financial liabilities* were allocated proportionally to transfers of assets; *unreasonably low heat prices* were maintained; decentralized management that had been problematic for smaller companies was transferred as well.

2000–2003 was a period of *lease or privatisation of DH companies*. During this period, management rights were transferred to private operators in 12 municipalities, including Vilnius and other major cities. After the adoption of the Law on Heat Sector in 2003, *stabilisation period began in the DH sector*. Implementing legislation that regulated activities of heat sector in various aspects was adopted. The heat price was determined in accordance with objective criteria when heat price is higher than cost. During this period, restructuring of leased DH companies was implemented; obsolete assets were improved; a number of employees was optimized; efficiency of heat supply was increased; and heat production plants that use biomass were developed.

2006–2008 was a period when *the price of fossil fuel (natural gas) rose dramatically*. Therefore, the prices of heat energy increased and the search of "culpable" started. Due to this issue, efforts to tighten control measures were experimented, the economic motivation of the principles of heat pricing was lacking in DH sector. The period of "popular" political decision began since 2009 in DH sector. Lukoševičius and Balaišytė (2011a) emphasises that proposals of changes in DH sector were based not on economic calculations or international practice, but on the episodic restructuring of heat sector, which confused the legal-economic system. Therefore a series of legal disputes were caused, but essential problems of heat supply were solved insufficiently.

The price of natural gas increased approximately four times during the period 2003–2013 in Lithuania, *the price of biomass* rose about two times during the same period (Figure 1.3). The share of RES in fuel structure of Lithuanian DH sector expanded more than seven times during the last decade (from 7.2 per cent in 2003 to 53.4 per cent in 2015) due to the implementation of EU Directives obligations, EU support for RES, and relatively cheaper biomass. Natural gas price increased rapidly in the period 2007–2008 and recalculation of heat prices was delayed; therefore heat suppliers suffered from more than 67 million euro loss, which was included in the components of heat price in later years as uncovered fuel costs. The increase in natural gas prices not only rose the price of DH, but also increased Lithuania's energy dependency on a single natural gas supplier, Russia's Gazprom. However, higher prices of fuel do not mean that it must be completely refused for use and only cheaper biomass could be the only option in a rather difficult situation. The considerable increase in demand for biomass would cause price spikes inevitably in the coming heating seasons. Liquefied Natural Gas (LNG) terminal that started operation in December 2014 will stabilise gas prices in Lithuania, therefore scenarios of the use of gas might and should appear in the strategic plans of towns.

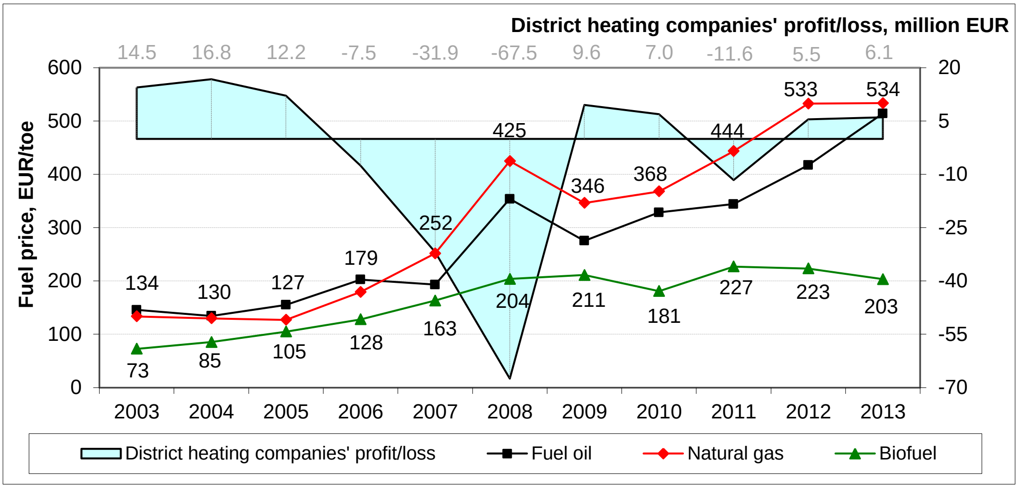


Figure 1.3. Operating results of heat supply and dynamics of fuel prices in Lithuania 2003-2013 (NCECP; LDHA, 2014)

The final prices of natural gas are regulated by National Commission for Energy Control and Prices (NCECP), therefore small customers pay a higher price for fuel due to a larger price share of gas transportation (gas suppliers incur higher costs during transportation of fuel to small objects). As a result, the smaller the city that is burning natural gas (or has many small boilers), the higher the costs for fuel. If biomass as an alternative is preferred, it will require considerable investments in biomass boilers. Therefore, it is expected that the state will promote the use of RES in heat sector and will contribute to the investment subsidies or soft loans. The need to reduce the consumption natural gas is limited due to the largest DH companies (in Vilnius, Kaunas, and Panevėžys), which operates gas-fired cogeneration plants. The adaptation of technologies for the use of biomass in major cities of the country would be uncoordinated with the LNG terminal in Lithuania, because of reduction in consumption and longer payback period for the investments that was made.

Law on Heat Sector (2003a) contains a provision about separation of accounting of costs of heat production and heat supply that has created conditions for competition in heat sector. Independent producers of heat can connect to the heat networks if they provide a cheap and high-quality supply of heat.

The prices of heat sector are influenced by price regulation that is one of the forms of subsidies and hence leads to internal cross-subsidisation, when small consumers payments are lower than the market price would be, as described by Lithuanian Free Market Institute (2006). The result of such policy in the natural gas sector is that relatively more consumers have refused DH services and have chosen an individual gas heating; this resulted in diminished competitiveness of DH sector.

Price compensation is another form of subsidies, which remained in heat sector. Dynamics of compensation for heating and hot water since 2003 is shown in Figure 1.4. The main problems are related with consumers, which receive compensation for heating; they are not interested neither in saving of heat energy nor in modernising and optimising the living space. This type of social behaviour becomes a burden on the budget from which compensation for heating is paid. Moreover, neighbours of persons that receive benefits in multifamily buildings have difficulties because those persons tend to use more energy and avoid saving measures, especially related to investments. Lithuanian Free Market Institute (2006) states that due to this reason heat demand is relatively increasing, especially among insolvent consumers. The problem is particularly acute when joint owners are trying to reach an agreement for the modernisation of the multifamily building, which would help to reduce heat loss and hence expenditures for heat energy. When part of the multifamily building owners receives compensation for heating and others do not receive, then it is difficult to reach an agreement; the main reason is that those receiving compensation are not interested in reducing heat loss. The above discussed problems require regulatory changes in relations between joint owners.

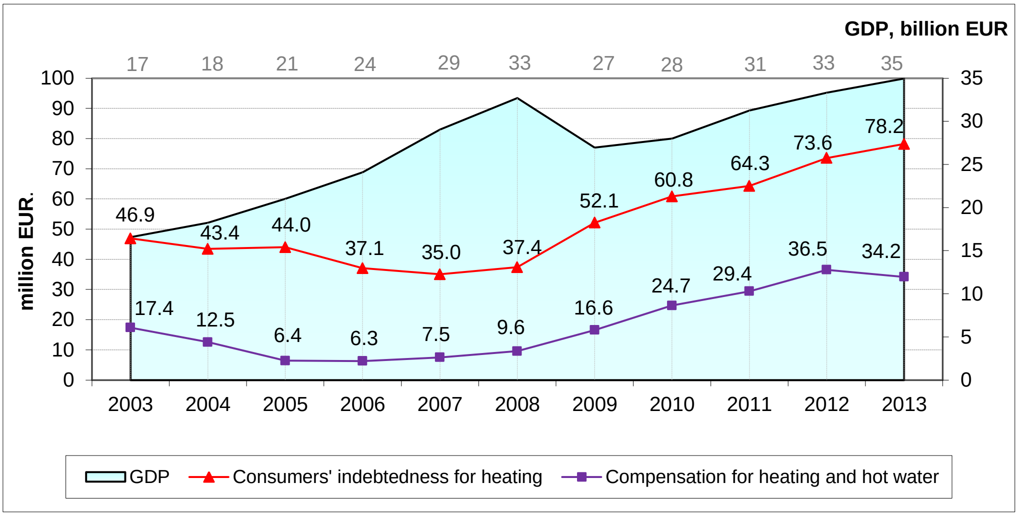


Figure 1.4. Consumers‘ indebtedness for heating, compensation for heating and hot water, and GDP 2003-2013 (Statistics Lithuania; LDHA, 2014)

Figure 1.4 shows the comparative analysis of consumers' indebtedness for heating, compensation for heating and hot water, and GDP, which indicates the economic level of the national economy. As shown in Figure 1.4, during the period of economic growth in 2003-2007 both the indebtedness of consumers and compensation for heating from the state had tendency to decline. After the financial crisis in 2008, the economy of the country was in decline; therefore indebtedness of consumers and compensation for heating is growing every year. Indebtedness of consumers has doubled to 78.2 million euro since 2006. Compensations from state budget during the period 2006–2012 increased from 6.3 to 36.5 million euro, i.e. about 6 times, and started to slight decrease in 2013. This burden to the state budget could be reduced by the modernisation of old and energy inefficient multifamily buildings. The appropriate use of the EU Structural Funds and modernisation of multifamily buildings would enable to achieve long-term effects, such as savings of compensations for heating and environmental benefit.

The consumption of heat energy in Lithuania is influenced by Value Added Tax (VAT) reduction, i.e. 9 per cent VAT rate. VAT exemptions suppress market signals that the use of energy resources should be reduced and more efficient. However, the cancellation of the VAT exemption will increase financial burden for low-income consumers, what is likely to cause higher demand for compensation for heating or disconnection from the DH system.

The increase in fuel prices will influence higher expenditures for DH and growing demand for social compensations for heating; also a greater burden for the state and for all taxpayers.

Current state aid for DH has the following characteristics (Lukoševičius, 2011):

- Individual social support is given mostly for heating old, energy-inefficient buildings, and discourages their renovation, because social payments are not associated with energy savings;
- A preferential 9% rate of value-added tax (VAT) rate is applied to all amount of heat that is consumed by the households. Therefore 12 percentage points (from the standard VAT rate of 21%) support mostly gets owners of large flats (presumably potentially richer residents) and energy-intensive buildings. This is unfair to both social solidarity and economic terms.
- The beneficiaries of the social compensation for heating often prevent energy-saving initiatives, because their payments for heating have a little dependency on the quantity of thermal energy consumption.

Social compensation for heating and VAT exemption will only increase with fuel prices and will discourage renovation of apartment buildings; therefore the more rational use of the taxpayers' contributions to state budget should be taken.

In summary, the problems of Lithuanian heat sector are a heritage of planned economy, threatening economic and social problem in recent times. The sharp increase in gas prices highlighted and exacerbated these problems; the solution of which is still delayed. The further direction could be found comparing with advanced systems of foreign countries. Switching of fuel type does not mean a decision, at least the long-term. A series of measures that are linked to each other is the path, which should be carried out in stages.

The use of RES for the production of DH energy would enable to diversify the fuel and energy sources. However, there is a need to solve the problems of independent heat producers' connection to the DH network by regulation of thermal energy that is made from RES.

The social compensations for DH do not encourage the efficient consumption of heat energy in Lithuania because it is not related to the consumption of thermal energy and energy savings. Social policy decisions with unstable energy policy distort market signals to the consumers. Compensation for the consumption of heat energy reduces the need to save and use the energy more efficient, how it would be in a market economy.

In summary, it can be stated that DH systems are an important macroeconomic issue, posing great difficulties for economic development. Their maintenance costs are not only directly related to the production and transportation, but also VAT exemptions, subsidies for investments, compensation for the poorest sections of the population. Even more damage cause people's expectations for investments, fear for the future and therefore excessive saving. Subsidies for the investment of biomass encourage disproportionate, excess use of the capital in heat production sector; excess capacities are increased several times.

1.2. Theoretical analysis of DH as natural monopoly

1.2.1. Comparison of DH reformation conceptions in foreign countries and Lithuania

Nowadays the main goal for the use of DH energy is the cheap price of heat for consumers, while for the supplier of DH is financial self-sufficiency in obtaining profits. DH companies now operate as profit seeking companies in Lithuania, but due to monopoly position it has exclusive rights, such as adequate rate of return and calculation of price on a monthly basis.

Firstly, it should be defined what is the progress of the DH sector. A priori is considered that the DH systems in Lithuania are well developed. Physically, according to potential opportunities of DH, it is an advanced heating system. However, the comparison with foreign countries shows that DH systems require further development in Lithuania.

The analysis of Denmark and other countries, especially Northern Europe, highlighted several key points. Firstly, it is a stable heat price for consumers, which is achieved by the fuel that contains a considerable variety of RES. Secondly, constantly developing DH system, which is already the fourth generation of the technological structure.

The dissertation examines the field that regards direction towards more diversified renewable technologies in the fuel balance of DH system. It should be noted that the reforms of the DH sector cover a wide range of related technical, legal, economic and organizational measures, which has its own aspects in individual countries.

However, the basis of all reforms and improvement of the technologies is the fact that DH is a natural monopoly, rather than market economy enterprises.

The Scandinavian countries, as well as Lithuania, have a well-developed DH infrastructure and long-term experience of planning and legal regulation.

Lithuanian DH sector face challenges not only in recent years. After the adoption of the Law on Energy from Renewable Sources (2011) and EU Structural Support period 2007-2013, there was no stable state policy on DH. Support was given for small scale biomass boilers up to 5 MW capacity and competition on the production side of DH was encouraged by Law on Heat Sector (2003a). On the other hand, pricing was not favourable for municipalities' producers, especially in the largest Lithuanian cities; therefore many small private investors started a business at producing heat in small biomass boilers. An example of successful energy policy and strategic planning could be Denmark.

According to Sperling et al. (2011), the transition period of an energy system based on fossil fuel technologies and centralisation in Denmark started since the 1970s. One of the main results was long-term energy planning, which had been influenced by an open and flexible political process. The introduction and dissemination of cogeneration (CHP) technology, as well as DH, wind energy, and biogas, were priorities for support from targeted programmes. Denmark's first overall energy plan "Danish energy plan" was enacted in 1976. The plan was intended to lay the basis for a long-term energy policy. The public policy in Denmark has a regulatory approach with a specific heating law, including tariff regulation, zoning, etc. DH has a strong position in the Danish heat market. As demonstrate Danish Energy Authority (2005), two major issues in the Danish law (Act on heat supply) have large effects on the market. First, since 1982 there is an obligation to connect new and existing buildings to public supply. Second, since 1988 there has been a ban on installing electrical heating in new buildings and since 1994 there has been a ban on installing electrical heat systems in existing buildings with water based central heating. In comparison to Lithuania, there is no existing ban for electric heating or the use of natural gas in buildings; therefore DH should compete with alternatives on the market conditions.

An important role is given to municipalities in Denmark. As stated by Niels and Meyer (2014), heat planning was introduced in 1979, and it was mandatory for municipalities to establish a heat plan in accordance with specific rules given by the Ministry of Energy. Strategic municipal heat planning was successful in the 1980s, but became less effective after the revision of the Heat Supply Act in 1990, as argue Sperling and Möller (2012). The first Danish Heat Supply Act of 1979 had the requirement to designate geographical heat supply areas; responsibility was given to the municipalities together with counties, and local utility companies. As a result, heat supply made a transition from individual forms of heating, such as oil boilers or electric heating, to more efficient and collective forms, such as DH and natural gas. After the establishment of well-defined heat supply areas, most municipalities restricted themselves to acting as project authorities that would approve single heat supply projects without having long-term aspects in mind. Municipalities still have the authority to devise heat plans in Denmark, which nowadays mainly contain general objectives and can be the basis for initiating specific heat supply projects. In general, overall municipal heat planning has been given lower priority in many municipalities during the last two decades. In Lithuania, municipality role in DH sector usually is defined by the decision of DH price in small municipalities for a 3-5 years period. Zoning of DH areas in cities/towns of Lithuania is still seldom. Decisions, however, also require clear support and guidelines from the central level, which should set the frame for strategic municipal energy planning in general, and municipal heat supply and demand planning in particular.

Nielsen and Möller (2013) state that since the late 1970s Danish energy administration has been using a geographical database for heat demand and supply. Authors express their opinion that geographical database could be a base for a future stabilisation of state policy for DH. After each change of government, there is a tradition in Lithuania to change National Energy Strategy, there is no available geographical database. A lack of stable strategic planning and more active role of municipalities are the key elements that should be improved in the nearest future.

Denmark's price regulation on DH was introduced with the Heat Supply Act of 1979. The fact that DH in Denmark supplies a large number of individual houses, together with the option of mandatory connection, gives it a dominating position in the heat market and a natural monopoly. Therefore the act specifies that DH must be operated as a non-profit activity, with cost-based pricing. Nowadays in Denmark DH is owned by consumer cooperatives or municipal utilities. On the contrary, in Lithuania DH companies are mainly owned by municipalities or private investors.

Sweden has an extensive DH sector. DH accounts for about 40 % of the heating market in Sweden. The change in the fuel mix has been impressive: compared to 1970, when oil was the main fuel, oil accounts for only a few per cent today. More than 62 % of DH fuel today is biomass (Di & Ericsson, 2014). The main key forces for the transition from oil to biomass are favourable public policies such as the introduction of a carbon tax in 1991 and the Tradable Renewable Electricity Certificates scheme in 2003. Compare to Lithuania, the main force to make the transition from natural gas based DH to biomass based DH is support from EU funds and requirements of RES Directive. The lack of long-term energy policy creates the situation when support is concentrated only till 2020 in Lithuania.

The Swedish DH market is already deregulated in the sense that companies may charge the price they see fit (unless they are municipal administrations). It is also deregulated in the meaning that any company wishing to enter the market by starting a DH business may do so, provided relevant permits, etc. can be granted by the authorities. On the other hand, DH is not deregulated since all companies are vertically integrated and when a local de-facto monopoly for DH has been established no competition exist in that specific DH market (Westin & Lagergren, 2002). In Lithuania, DH production should work on market conditions, but is still regulated by National Commission for Energy Control and Prices.

Denmark and Sweden are small and have a well-developed DH infrastructure. Lithuania was part of the Soviet Union, and DH was monopolized during that times. Nowadays a competitive market in DH sector is encouraged by Law on Heat Sector and support is given mainly from EU Structural Funds.

Environmental benefits of DH are integrated as a part of public policy in Denmark and Sweden. On the other hand, Finland has chosen less sustainable development of DH.

DH has a stable pricing policy in Finland. Most fuel prices have risen steeper than the price of DH since 2004. One reason why the DH sector has managed this well is the diversified use of fuels, another is the increase in the use of peat and waste wood, and a third is wide spread use of coal (Havskjold & Sköldberg, 2009). Figure 1.5 shows prices of DH and fuels in heat production of Finland during the last decade. The prices of fossil fuels increased after 2011 due to implemented environmental taxes. Finland, as well as Denmark and Sweden, use high environmental taxes for fossil fuel with an exception for CHP. Lithuania is not going the same direction at the moment; on the contrary, feed-in tariff for electricity from CHP has decreased during recent years.

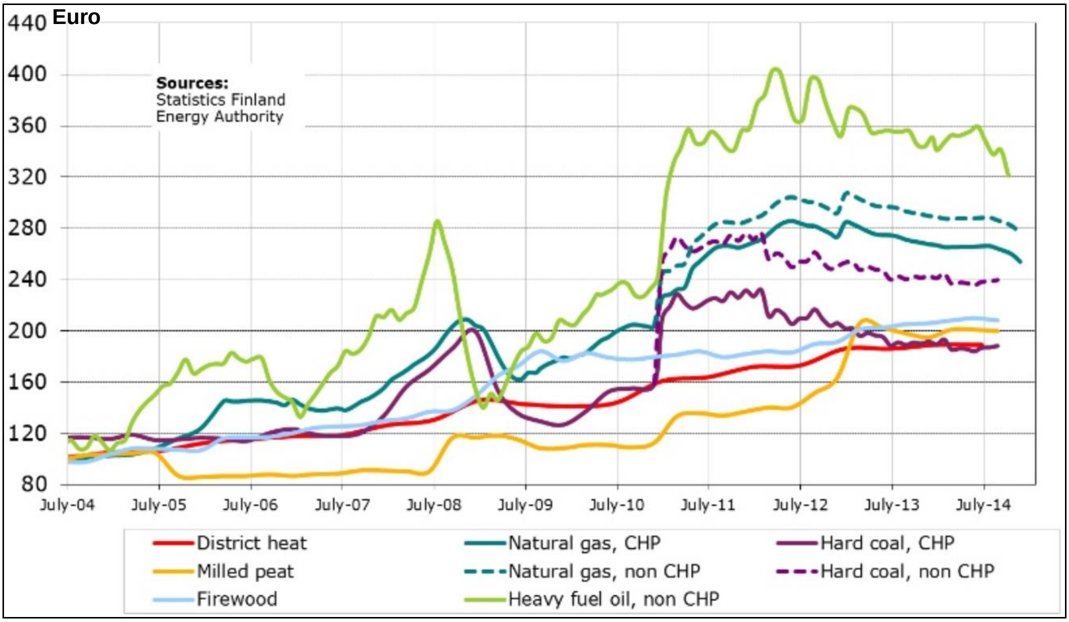


Figure 1.5. Prices of district heating and fuels in heat production of Finland, 2004-2014

As reported by Wessberg (2002), DH production originated in Finland in the 1950s. Following the initiative, integrated heat and power production has become a significant element of energy production in Finland. Centralised heat production using water boilers started simultaneously with the integrated production. DH almost became a fashion in Finnish municipalities during the 1970s after the oil crisis. From the policy perspective of market deregulation and industry restructuring, the results are encouraging. The electricity market restructuring, which started in 1999 and affects DH markets only indirectly, has lowered DH prices (Linden & Peltola-Ojala, 2010). In Lithuania, lower feed-in tariff for electricity from CHP also had the indirect effect to DH prices, but negative.

To summarise, Denmark has a heat zoning, many decentralised DH plants, and working on a non-profit basis. RES integration is based on taxation of fossil fuels; therefore, preeminent position of RES is even without the support for investment or operation. Sweden has chosen deregulated market of DH, but has the influence for the market by taxation for fossil fuel. Finland has chosen less sustainable DH sector, which is based on diversification (both RES and fossil fuel). The preeminent position has a lower price. All three countries have high energy and environmental taxes.

Methodological principles of internalization of the influence of externalities. Fossil fuel “cheapness” occurs due to the fact that external costs are not included in the price. For example, in Denmark external costs were integrated into the price of fossil fuel as taxes in 1975. The evolution of Denmark energy system from fossil fuel to 100 per cent RES in 2050 is shown in Figure 1.6.

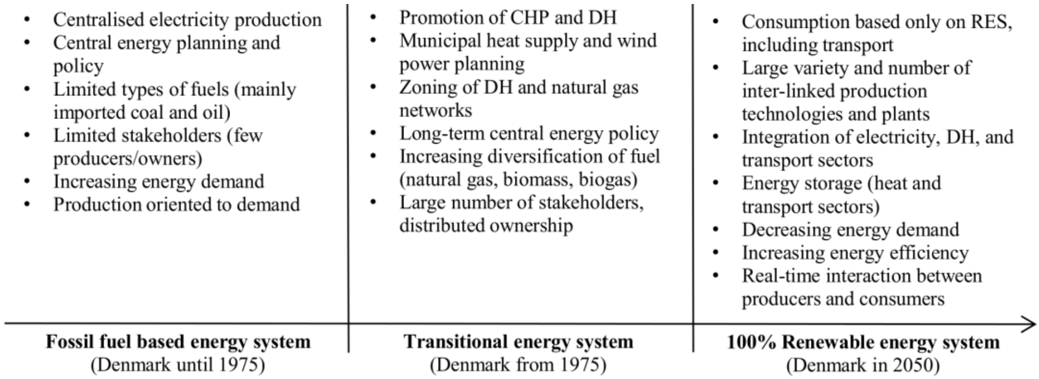


Figure 1.6. Denmark evolution from fossil fuel based energy system to 100 per cent RES

Denmark decision to give priority for energy savings and a diversified energy supply was made before more than 30 years, including the use of RES. Initiatives of energy policy were launched, including a concentration on CHP production, heat planning in municipalities and on developing a grid of natural gas in the whole country (Sperling et al., 2011). Moreover, Denmark greatly improved the efficiency of the building sector and launched the support for RES, research and development of new energy technologies that are environmentally friendly, as well as ambitious to introduce and use green taxes. Along with the production of oil and gas from the North Sea, the new policy determined that Denmark made transition from being a main importer of oil in 1970's to being more than self-sufficient in energy at the end of the XX century. The increased use of RES with a gradual reorganisation of the energy supply and the energy policy has launched the base for Denmark to set ambitious targets for the reduction of GHG emissions and for the use of RES in 2050. The comparison of Denmark and Lithuania long-term policy of DH is presented in the next table. The tax system is related only to the heating price. RES support system is limited to DH.

Table 1.2. Comparison of Denmark and Lithuania long-term policy of district heating

	Denmark	**Lithuania**
Long-term strategy	100 per cent of RES in 2050	23 per cent of RES for total consumption of energy in 2020
Tax system for heating price **RES support system** **- For producers** **- For consumers**	Taxes for fossil fuels Programs of the cities	No taxes for fuels Support measures are aimed at implementation of EU directives
Infrastructure	District heating – Non-profit organisations Regulated by antimonopoly law Binomial tariff	District heating – Profit seeking organisations Monomial tariff, controlled by NCECP
Interaction between consumers and producers	Scenarios method	

According to OECD (2013), while ex-tax gas prices in Denmark are close to those found in other EU countries, their final retail price is the highest among OECD member states due to high taxes. In 2010, the percentage of taxes on natural gas prices for households amounted to 50.6% in Denmark. DH customers pay a reduced fee for energy delivered from CHP plants.

In conclusion, the natural preeminent position of RES in Denmark DH system is created by long-term energy policy, which incorporates externalities of fossil fuel into price under the different taxes. Therefore, non-exhaustible RES could compete on market conditions even without intervention from the state. State policy plays a key role in decision making of the country for the future perspectives on the use of diversified RES sources.

Long-term political ambitions in renewable energy technology utilization are shown in Figure 1.7.

Lithuania is in the second generation of DH. The use of heat accumulation and large scale solar collectors is just a theoretical possibility at the moment.

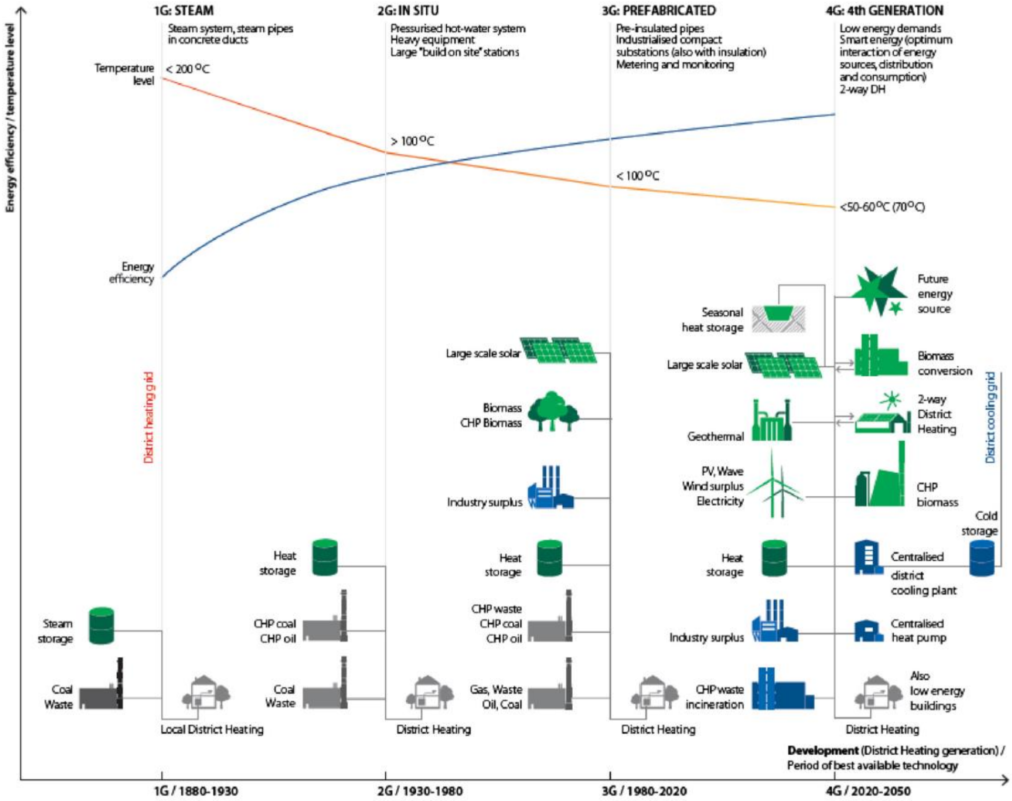


Figure 1.7. Four generations of district heating (Lund et al., 2014)

Utilisation of RES in the production of DH energy would allow diversifying the fuel and energy sources. Moreover, utilisation of diversified RES in the production of heat energy must be enhanced by other measures than the existing ones. Feed-in tariff example for solar PV expansion in Lithuania might be an example of the power of support measures for immature technologies to take part in the market. Moreover, declining cost of solar PV, called a Swanson's law, predicted 20% price declines for every doubling of installed capacity. The evolution of solar PV cell cost during the last two decades is presented in Figure 1.8. Similar effect is expected to solar collector due to the high impact of China, which produces major part of solar collectors at lowest cost.

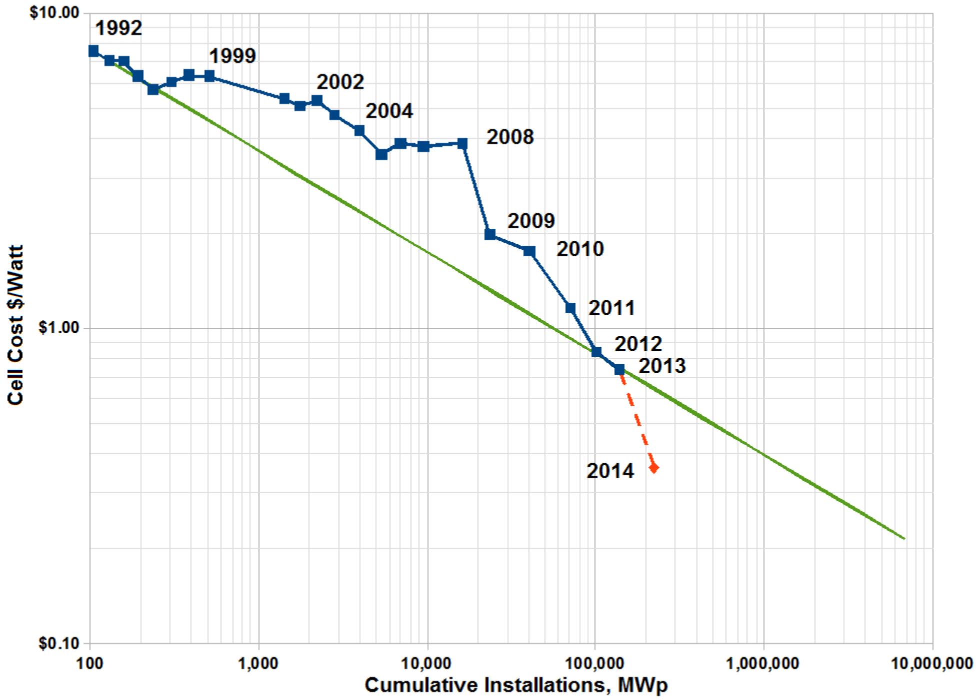


Figure 1.8. Swanson's Law on solar PV cell cost and cumulative installation

Management aspect is not less important. The territorial government departments, such as municipalities or their energy development agencies, have to be managers and organizers that are responsible for the implementation of a territorial district, city, region commitments, and at the same time on state obligations.

The comparison with the case of Denmark might show possible directions of further development of DH sector by the use of diversified RES.

1.2.2. Characteristics of DH as natural monopoly in terms of economic theory

One of the key issues from the economic point of view is that DH systems are not treated as natural monopolies. Therefore pricing is a consequence, which aims at promoting to produce and supply the maximum amount of heat energy. This problem is relevant at the moment, but the solution is based on microeconomic comprehension about the competition on the production side. However, such attitude leads to excess investments, which are attracted by massive subsidies. The prerequisites that are needed for more successful decision making is based on the analysis, which reveals the economic meaning of natural monopoly and approaches, which might enable a natural monopoly as a significant tool for development of RES, reaching environmental and other goals. DH as a natural monopoly was scarcely analysed in scientific researchers. The main authors that analysed this issue are

(Magnusson & Palm, 2011; Söderholm & Wårell, 2011; Wårell & Sundqvist, 2009; Westin & Lagergren, 2002; Wissner, 2014). Further analysis is mainly based on these authors' approach.

History of the concept of natural monopoly is provided in Mosca (2008) study. Depoorter (1999) explains dilemma of the concept of natural monopoly from the public policy perspective, when a decision between economies of scale and competition should be made. A scientific approach to DH infrastructure as a ***natural monopoly*** is twofold. Some would presume that the whole DH production system is to be considered a natural monopoly, while others would limit the monopoly to the DH distribution grids. The conception of natural monopoly represents a challenging regulation dilemma. A traditional definition, as it is defined in (Elsner, Heinrich, & Schwardt, 2015), is that natural monopoly was considered to occur in cases where economies of scale exist. This means that a single company can supply the market at the lowest cost, compare with several companies. Scale economies are considered as a barrier to entry the market; due to the monopoly power, a natural monopoly is seen as a market failure, therefore, the intervention of the government is required (in the forms of nationalization, regulation, or antitrust). DH is one example of a public utility that is usually characterised by having substantial sunk costs due to large infrastructures.

The main features of a public utility are performing an essential public service and requiring regulation from the government due to nature of a monopoly. The operation of public utilities mainly consists of three elements: production, transmission, and distribution. In the case of a natural monopoly, only one company supplies the entire demand of the market at a lower price than two or more companies, because competition creates a potential loss of efficiency to society. The majority of public utilities are vertically integrated, especially in energy sector. Vertical separation (*unbundling*) aims at separating three elements of public utilities into competitive elements and natural monopolies.

However, as noted by Grohnheit and Mortensen (2003), DH is not considered by none of the EU directives on liberalisation, such as electricity and gas markets. Nonetheless, the DH as a system offers the possibility for competition between fuels and technologies on the market for space heating and hot water. Author agree with Rezaie and Rosen (2012) opinion, that one of the main advantages of large DH system is environmental benefits from the perspective of industry, government, and society.

Unlike the situation in electricity and gas market, EU recognition of DH expansion is mainly included as part of the measures aimed at reducing emissions of greenhouse gases by the impact on global warming. DH lower priority in the EU legislation is seen because any cross-border transactions with DH exist in the EU and that the DH in most EU countries represents a relatively small part of the heat market. Therefore, the DH has not a significant part of the energy market in general, as it has in the case in the Nordic and Baltic countries.

Competition in the electricity sector is considered suited for the production and sales. However, the case of DH is more complicated. Electricity markets are mainly national or even cross-national (with existing impediment of the distribution systems), thus, the meeting of suppliers and consumers is organised on functioning markets, such as NordPool. DH markets are local, mainly for one city/town; therefore, **DH markets are limited geographically**.

Wissner (2014) in his recent study argues that DH sector is different from the electricity and gas sectors. Direct competition between DH suppliers scarcely occurs due to the reason that DH systems are predominantly designed as isolated systems that are not interconnected with each other. The local scale of DH systems means that the choice of customers between different DH producers is limited. Moreover, there is no wholesale market for DH mainly due to technological limitations. Therefore, regulation of the DH sector is necessary, particular in terms of pricing.

Natural monopoly might also be created by economies of scope in case of multi-product companies, despite the non-existent economies of scale in terms of the production of goods separately. The examples of DH system for this fact are production of electricity in combined heat and power (CHP) plant and/or district cooling. CHP production due to its complexity is more likely to be considered as a natural monopoly than a simple DH system, but the electricity as a product can apparently be generated and sold in competition with other companies.

The DH system is recognised today as integrated monopolies (production, distribution, and sales). Since there are significant economies of scale in the DH as well as DH markets are local, it may be most efficient that operations are conducted by only one operator, i.e. a monopoly. When it is most efficient to engage in an activity as a monopoly activity it should be classified as a natural monopoly. Neo-classical economics defines natural monopoly as the situation where a company can produce the entire quantity of a product that is in demand on the market at a lower cost, than two or more companies can. Therefore, public utility services of DH require government intervention. Westin and Lagergren (2002) emphasise that regulation of *market imperfections* might be the limited entry of DH companies by means of concession in order to provide public utility services. Another type of regulation is **monopoly pricing**, where the transfer of *wealth* is made from consumers to DH producer.

Allocative inefficiency occurs when DH consumers do not pay an efficient price, and it is caused by monopoly pricing, which creates a situation of substitutes' consumption at higher prices. The internal inefficiency of monopolistic DH company occurs due to the minimal external pressure on cost-minimisation. However, the latter statement is debatable, because monopolistic DH company might be highly interested in cost-minimisation in order to gain maximum profits.

Cross-subsidisation means that DH company (public or private) that operates both in a competitive market and non-competitive market, or a market with imperfect competition, could use its market power on the market with little or no competition, to subsidize business in the competitive market. In other words, cross-subsidies mean the use of profits from one product to finance losses from another product. Westin and Lagergren (2002) provide an example of Swedish Competition Authority criticism to DH/electricity utilities about cross-subsidisation and the generated economic inefficiencies due to this reason.

The main methods for regulating natural monopolies are cost-based regulation and incentive-based control. Cost-based regulation is when the monopolist will get coverage for their costs and obtain a reasonable return on invested capital. An incentive-based regulation aims to provide the monopolist incentive to operate efficiently. The simplest form of incentive-based regulation is a price cap regulation. The issues of allocative and internal inefficiency of natural monopoly might be solved by the regulator, which control DH prices from a *public interest* perspective. The problem occurs due to the reason of which price would allow for efficiency. Sappington and Weisman (2016), who analysed price regulation in the USA, give an example of the electricity sector in California. A significant number or utilities were regulated with a price cap in 2000. Wholesale electricity prices dramatically increased and created a situation of huge financial losses for electricity companies. As noted by Sarkar (2016), an example of the electricity sector in California shows benefit to consumers from price cap regulation, because consumers are protected from short-term market forces and unreasonably high prices.

The two overall objectives of the regulation for natural monopolies in general are (1) to ensure efficient use of existing infrastructure and services and (2) ensure optimum incentives to invest in new infrastructure and service development. Price regulation of a natural monopoly might lead to the decrease of necessary investments and maintenance of DH system. However, the example of the opening in electricity market shows that cost-plus pricing system protected producers and motivated them to maintain systems up to date. On the contrary, the focus on the pressure on prices and the reduction of costs, as well as uncertainty of the market development, determines a low willingness to invest in new production facilities.

Entry regulations or ownership as regulatory tools. Li et al. (2015) argue that bidding helps to develop a competitive market environment. However, bidding according to marginal costs is rarely possible due to imperfect information and alternatives of DH. Auctions refer to bidding, i.e. operators who wish to transfer heat through a bottleneck can bid on the capacity and the highest willingness to pay will thus purchase the right to transfer. Bidding in the case of the DH market might be a vertical separation of DH company. The ownership of DH infrastructure might be operated by the municipality. The drawback of public control of the DH infrastructure is limited incentives for the efficient operation; therefore, the DH price could be too high. Publicly owned assets have lower incentives for cost reduction or improvement of quality.

Deregulation through third party access. Deregulated DH market has different approaches. DH market is deregulated in Sweden from the perspective that DH is sold at market prices (Magnusson, 2012). However, the DH market is not deregulated in the case of vertical integration. Deregulation might also be defined as privatization of public operations. Privatization can be seen as deregulation of publicly owned DH monopoly; the government can control the prices in these industries, but after privatization, the prices are usually more market oriented.

Third party access (TPA). The concept of TPA appears in different contexts and sometimes with different meanings. TPA is the right of a producer or other owners of DH to gain access to the DH network on non-discriminatory conditions and thereby supply the heat. Söderholm and Wårell (2011) emphasise the importance of increasing the competition in the market and gives a description of TPA as a tool of opening DH network for competition by separating production and retail parts of DH. The example of the electricity market revealed that ownership unbundling reduces discrimination among companies and improve allocative efficiency, but it weakens incentives to invest (Gugler, Rammerstorfer, & Schmitt, 2013). The liberalised electricity market is associated with lower prices (Hyland, 2016); successful electricity market reform in Nordic electricity market with increased competition and decreased prices (Amundsen & Bergman, 2006) are the main arguments for the introduction of TPA in DH market. However, as it was previously mentioned, electricity and DH markets have significant differences. Therefore, the TPA in DH sector might not be successful in the case of increasing competition and thus decreasing price. The main reason is that DH markets are local and limited geographically; hence, competition would be only between few companies.

The introduction of TPA to heating networks, for example, would enable residual heat producers to sell excess heat and to have access to a distribution network for DH. Excess heat from industrial processes, or industrial residual heat, also called waste heat from the industry. Industrial residual heat may be the waste heat of various industrial processes, various industry sectors. The largest producers of industrial waste heat for DH might be paper pulp industry, chemical industry and the mining and steel industries, but there are also examples of engineering and foundry industries supplying surplus heat to the DH network. The use of waste heat in DH saves the environment because otherwise it would be wasted to the air or to the lake. Waste heat means heat that is a by-product of various industrial processes and which thus is completely emission-free. In connection with the energy efficiency of industrial processes often increases opportunities to utilize more heat that can be used to DH and gains competitive pricing position compared with other heating alternatives.

The ***pricing*** of a DH market can be described as the natural monopoly pricing in economic theory (Elsner et al., 2015; Söderholm & Wårell, 2011). Figure 1.9 shows pricing of DH as a natural monopoly, which is based on the assumptions that DH has economies of scale and charges the same price for all units of heat. Long-run average costs (LRAC) are large at minimal quantity (Q) due to large fixed costs compared to their variable costs. Therefore, LRAC exceeds marginal costs (MC) over a wide range of Q. If the state encourages more companies to enter the market and open up the natural monopoly, LRAC will rise for every new company, resulting in that society as a whole is wasting its resources. Price (P) will exceed marginal revenue (MR) because natural monopoly company must lower P to sell an additional unit of heat. Figure 1.9 shows the relationship between demand (D) for heating and MR. Prices of DH is limited by prices of alternative heating methods, this is the D curve. MR can become negative; then the total revenue decreases. Further discussion is divided into two parts; firstly, pricing of natural monopoly is detailed, the later opening of DH market and its effect on price is presented.

The DH company chooses to produce heat until their MR equals MR, but the price will instead occur on the basis of consumers' willingness to pay for this quantity, i.e. the price is determined based on D curve. Efficient production Q_c is reached with the socially-optimum price P=MC. However, in such situation DH company makes a loss, because P_c is below LRAC. Efficient production for socially-optimum price requires subsidies for the producers and increases the final price for customers.

Maximising profit for the DH company is possible at the production level Q_m, where MR=MC and price level P_m. Monopoly profit is shown by a rectangular area "afgP_m". Monopoly price P_m evidently creates inefficiency with substantially lower production level Q_m than in the case of socially-optimum price. Suppose that DH company lowers the price a bit under the monopoly price P_m. The consumer surplus increases while profit decreases. A profit-maximising company would not implement such a change, but a DH company owned by the municipality in which it operates may not be pure profit maximisation; it is prepared to accept a lower profit for the customers to get a larger consumer surplus. Figure 1.9 shows such situation at point "d", where DH company sets fair-return price P=LRAC and receives a reasonable return on capital. The reason for lowering the price is explained by the D curve, which is different in the short term compared to the long term and more specifically, that the slope is steeper in the short term. Customers of DH have difficulties to switch between alternatives in the short term (such as geothermal heating), but the flexibility is greater in the long term. This means that the demand curve is flatter in the long term, or in other words, that the price elasticity is higher. A DH company with a long-term pricing strategy will then set a lower price than a DH company with a short-term pricing strategy.

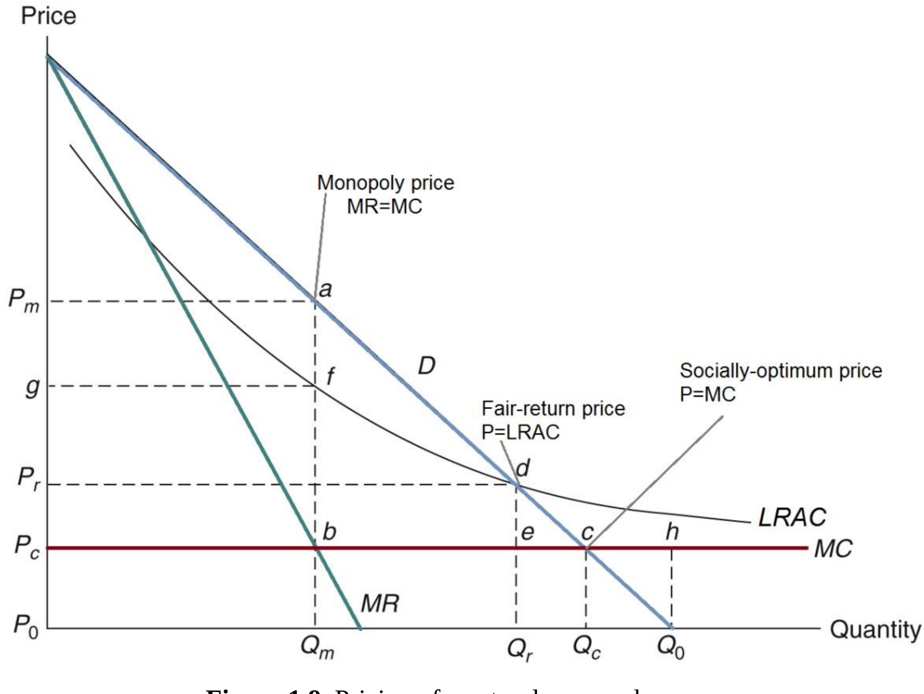


Figure 1.9. Pricing of a natural monopoly

As noted by Wårell and Sundqvist (2009), it is important for DH company to take into consideration relationship between the increase in price and reduction in sales. The rise of price in case of CHP, when DH company produce both electricity and heating, subsequently affects not only decrease of heat production but also the lower generation of electricity and lower revenues from electricity sales. Therefore, the rise of DH price influence lower revenues from two separate products (Werner, 2009).

The DH network is a natural monopoly, thus, the production of hot water is the only level at which competition could be considered. In this case, several companies compete to supply hot water to the network owner, who could be either a vertically integrated DH company, or just a network owner. However, there are factors that create difficulties in organizing the production of DH in this way. One factor is that there are probably significant synergies or economies of scope between the hot water production and distribution of DH. The hot water should be preferably produced in close connection to the DH network because it is relatively costly to transport. The DH network must also have the capacity to always supply enough hot water. Another factor is the presence of sunk costs, which means that DH boiler is difficult to move once installed. Although the investment risk can be reduced by producing electricity (which can be sold to another location), DH is a market where entry is associated with high costs, which limits competition. DH markets are geographically isolated and most DH markets are quite small, pays entry probably not in most places.

An important exception is industrial plants that are producing waste heat (Münster et al., 2012). The use of industrial waste heat increases efficiency and reduces emissions, also helps to improve the quality of the environment (Rezaie & Rosen, 2012). This situation is not about the new entry, but about a potential supplier of heat, which already exists in the DH area and has its main business in another market. If the waste heat is economically profitable to use (sufficient temperature and close to the DH network), the question arises about the price of the waste heat. In the typical case of a seller (waste heat producer) and a buyer (DH supplier) is a range of possible prices from about zero to the cost of DH supplier to self-produce hot water. The price has only the function that determines the distribution of the proceeds between the parties. The problem is that it requires some investment for the transaction to take place, to connect the waste heat to the network and probably also in terms of adjustments to the DH company's other sources of heat.

The above arguments indicate that the TPA can be an expected result in stronger negotiating position for industrial waste heat producers. However, it is unlikely that competition with the entry of new producers of heat will occur. It is, therefore, unclear whether TPA would lead to lower prices for DH (Magnusson & Palm, 2011).

The regulation provides similar incentives for productivity improvements as product competition between several companies in a market, where production technology allows multiple companies to compete with each other for customers (Grohnheit & Gram Mortensen, 2003). The competition in the case of DH market is usually limited to the few companies' competition (oligopoly). Oligopoly could create cartel and 'tacit inclusion' could lead to overpricing (Perdiguero Garcia, 2010). The regulation can, therefore, be considered as a substitute for the competition that's not working for a natural monopoly - both regulatory and competitive pressure on firms to act effectively and thereby increases the wealth produced in the market. One advantage of competition is that it runs largely to general legislation on contracts, while the price regulation is explicit and industry-specific. This suggests that price regulation should primarily be used where the elements of natural monopoly are significant, i.e. where some form of competition is particularly difficult to achieve. If it is possible to divide up the production of a natural monopoly vertically and separating it out, or the part of the business that is the core in the natural monopoly, then a price regulation in principle limited to these, and competition may advise otherwise. The idea is that regulation restricted to activities where there is a particularly strong argument for regulation.

To sum up, the TPA impact on the decrease of DH prices is still a disputable question. The practice of different pricing strategies in each municipality and DH market opening for the competition is concurrent processes. Wårell and Sundqvist (2009) emphasise that economically efficient market is not necessary a market with the lowest possible price. The price level should be close to marginal costs.

EU legislation for unbundling of electricity and gas sectors allow Member States to choose between regulated TPA and negotiated TPA. Both approaches might be applicable for DH sector, as well as single buyer model and extended producer market that are discussed by Wårell and Sundqvist (2009); Söderholm and Wårell (2011).

1) Regulated Third Party Access. Regulated TPA means full access to DH network; the network owner has an obligation to allow access for different producers. Network operations required in a regulated TPA need to be regulated and the conditions of access to the network are determined in advance. The network owner is obliged to provide access to the network if these conditions are met, and is entitled to charge a specific network charge from the heat suppliers who are interested in the use of the network for DH supplies.

The access to the DH network in case of regulated TPA is ex-ante regulated, as described by (Söderholm & Wårell, 2011). Such regulation means that determining of access conditions is done prior to giving access to the network.

Regulated TPA, both on the producer market and the customer market, has been introduced in the Nordic electricity market and in the European natural gas market. Opening to competition both production and trade through a regulated TPA is the creation of a separate producer and customer market. In a DH market with a regulated TPA production and trade, the customer has an opportunity to choose one of the recognised suppliers that should provide hot water for heating.

It is not considered absolutely necessary to implement a vertical separation of production, network operation, and trade at introduction of regulated TPA; but in practice, the DH companies distinguishing network operations from the business activities, production, and trade, that competition on equal terms could be achieved. That has been done in the electricity and natural gas markets.

The main advantage of regulated TPA is increased competition in the DH market. Full access to DH network can lead to greater efficiency due to higher competition. The main limitation is a non-discriminatory competition of several companies because DH market is local and thus relatively small compared to electricity or gas markets, where regulated TPA was implemented successfully. The price of DH after introducing TPA is difficult to predict (Wårell & Sundqvist, 2009).

The effect of regulated TPA in DH market is hardly predictable in comparison with differences between electricity and gas markets. The positive impact of regulated TPA was higher in the electricity market, while the effect on the European natural gas market was less positive (Growitsch & Stronzik, 2014). Minor competitive effects, an increase in administrative costs and similar price level are the main issues for regulated TPA in DH market (Wårell & Sundqvist, 2009).

2) Negotiated Third Party Access. Negotiated TPA means that the DH companies are obliged to negotiate with other actors requesting access. The main difference between the negotiated TPA from a regulated TPA is that access is negotiated between network owner and producer. This provides the opportunity to take into account local conditions for DH business. It is not necessary for the DH companies to separate production and trade from network operations in the case of negotiated TPA. However, they are not deemed to involve a significant competitive disadvantage to producers, who request access to the network. Generally, a negotiated TPA is not a condition for market opening in the same degree as a regulated TPA. The real possibilities for an outsider operator to establish itself in the market depend on how the regulations and the prospects for a negotiated TPA are looking. But regardless of how a negotiated TPA design gives the incumbent greater control over the conditions for access to the network than in the case with the other models for TPA. Another decisive factor in competitive conditions is the degree of separation between production / trade and network. The stronger degree of separation provides better conditions for a functioning of the market opening than a slight distinction. Therefore, it cannot be stated that such a strong separation as possible is desirable from a comprehensive perspective because separation may have other negative effects, e.g. reduced system optimization and increased administrative costs.

The access to the DH network in case of negotiated TPA is ex-post regulated, as described by (Söderholm & Wårell, 2011). This is the main difference from regulated TPA. Determining of access conditions DH network is negotiated between two stakeholders. Because the negotiated DH system means that network owners are obliged to negotiating with a potential new supplier of heat, this is an element of negotiated TPA to the production market.

The situation of today, however, shows that the existing DH company has a much stronger bargaining position compared to the other party. This is because there is no obligation from the DH company to get along with the new producer. The DH business, basically always, is integrated within the company, i.e. network owner is also a producer and is also the operator of the sales. Moreover, in the negotiated system there is no right for a new producer to establish agreements directly with customers, i.e. the level of trade is not covered by the negotiated TPA. Therefore, the negotiated system has the limited ability to a customer market where DH customers can choose between different actors. However, it would be possible under the current DH system to extend the negotiated TPA on the production side in order to give both parties more equally strong negotiating terms, and also trading activity is the subject to a negotiated TPA.

3) Single-buyer Model. A single-buyer form means that all eligible consumers in DH network shall have the right to negotiate contracts with all DH producers and independent producers. The DH network is owned by only one company, which sells heat to consumers. The final price consists of negotiated price, transportation and system costs. The main difference between the negotiated TPA from a single-buyer model is that trade market of a single-buyer model is regulated in such a way that there is only one player who has the right to enter into agreements with customers. Therefore, the consumer market is non-existent, only a producer market (Wårell & Sundqvist, 2009).

DH producers and independent producers are responsible for the quality of heat that is supplied to DH network, such as proper temperature level and pressure at the delivery point. "Single-buyer" company is responsible for the agreement with the customer and DH producers. Moreover, it takes liability for the quality of product to customers, metering, and billing of heat energy. The product includes security of supply, production (i.e. to secure reserves and peak production), pressure, maintenance and modernisation of the network, as well as losses in the network.

The advantages of a single-buyer model are similar to the negotiated TPA. Transportation and system costs are negotiated for each DH system separately, thus, market transparency and efficiency of costs increase. Moreover, the potential producers do not sell heat directly to consumers but to "single-buyer", which is the owner of DH network. The producer of industrial waste heat this single-buyer model might be beneficial due to the low marginal cost of heat production, because heat otherwise would be wasted to the environment. The disadvantages of a single-buyer model are related to increased burden of costs for the DH network and limited competition due to potential oligopoly in the market (Söderholm & Wårell, 2011).

An Extended Producer Market was initially suggested by Wårell and Sundqvist (2009); Söderholm and Wårell (2011) as a supplement form of increasing competition and the opening of DH market, in addition to previously discussed regulated TPA, negotiated TPA and single-buyer model. The extended producer market requires at least partly unbundling or vertical separation of DH companies. Moreover, heat energy as a product is traded between DH producers and DH network operator. The efficiency of this form of DH market is higher due to increased market transparency. Extended producer market differs from the electricity market, such as Nord Pool, in a manner of increased transparency and informational efficiency of DH market. Financial separation of DH production and transmission activities by separate accounts is preferable. Furthermore, competitiveness of DH market is increased by the accessibility of information for the new producers of heat about DH system costs and transactions, as well as DH price control for this form of DH market.

The advantages of an extended producer market, as provided by Söderholm and Wårell (2011), are more competition, better operation, and increased efficiency in DH market. The sole company that owns DH network creates conditions for lower costs of maintaining the system, also ensure better investments, and the use of advanced technologies in a DH system. Informational efficiency of DH market could be ensured by providing comprehensive information about DH system costs and transactions according to separated DH production and transmission activities; therefore, consumer confidence of DH market is also increased.

The disadvantages of an extended producer market, as stated by Söderholm and Wårell (2011), are a separation of DH production and transmission activities, and the obligatory disclosure of investments and transactions. The problem arises especially for a small size DH company, which has only a few employees, due to the reason that additional requirement for information might be a burden, both financially and workforce. On the other hand, the main advantage of extended producer market is increased transparency and informational efficiency.

Extended producer market in every DH system should work as a platform where buyers and sellers of DH could be met in a non-discriminatory manner. Transparency of costs and transactions is necessary to enable extended producer market. The efficiency of the market might be reached when pricing is close to the marginal cost. Competition of the market could be limited in the case when municipally owned DH companies have other interests than just increase competition in DH market.

The main issue of TPA in DH sector is that DH markets are local and limited geographically. The limited size of DH system and thus limited number of potential competitors on the production for heat energy distinguish DH market from electricity and gas markets, where TPA in the case of unbundling was required by EU legislation. The DH network is still considered as a natural monopoly, while production of heat might be opened for competition of existing or new producers of heat. TPA and extended producer market with proper legal regulation could be the solution for increased competition and transparency of DH market, especially in large DH system. The challenge is that TPA can have small positive effects on competition and at the same time make it more difficult to operate the integrated DH business in a cost effective manner. The potential prerequisites for diversified RES penetration are presented at the end of this chapter.

1.2.3. Features of DH pricing, support, and financing schemes for RES support in DH sector

Among the most important prerequisites for the unhindered development of RES technologies into DH fuel energy balance is pricing and financial support.

Pricing is determined by three main methods in the energy sector. *Market-based pricing* is applied to the areas which are dominated by reasonable and rational competition. This method is mostly combined with various regulatory elements: antimonopoly supervision for dominant market players; the use of state support for infrastructure development; determination of various tasks, standards of quality and reliability, etc. This pricing is typical for the electricity production sector, DH activities in areas where are strong and rational alternative options of heating (Sweden, Finland). *Political-social pricing* is focused on the consumer's solvency and is applied in countries that are governed by "planned economy" basis or this governance has a significant impact on the poor sections of the population (in developing countries), which is unable to pay the actual price, etc. This pricing is based on the product or service grant instead of other sources, such as state or municipal budgets or other operating incomes (China, Russia). *Economic regulated pricing* is a mechanism of monopoly regulation, which is applied in free-market countries, when interests of the sides involved in the process are coordinated, because it cannot be guaranteed by the free market or other economic measures. This pricing is typical in countries where reforms take place and there is no well-established infrastructure, and dominance of monopolies is strong in energy sectors (Aronsson & Hellmer, 2009; Li et al., 2015; Valiukonis et al., 2008).

Economic principles of regulated price formation are presented in Table 1.3. Valiukonis et al. (2008) provided elements of possible pricing alternatives on the basis of the World Bank study, which are widely applied in the energy sector.

Table 1.3. Alternatives of price formation based on regulation by economic principles (Valiukonis et al., 2008)

	1 alternative	**2 alternative**	**3 alternative**	**4 alternative**
Pricing principle	According to the costs of services	Incentive based		
Costs	Accounting data	Standard costs	Future costs	Reasonable costs
Profit linking	With turnover	With capital		
Groups of consumers/tariffs	Single tariff	Differentiated tariff		
Price linking	Fixed fee, linked with the area, volume, etc.	Linked with a use (singe-component)	Linked with a use (double-component)	Linked with a use and quality (triple-component)
Application of tariff	Equal for a city/town, municipality, state, etc.	Equal for each enterprise	Equal for each system	
Accounting	Production site	Heat substation of the building	Heat substation of the flat	Combined
Compensation volume	Full	Partial	Not compensated	
Form of social support	Financing through the supply company	Funding from the local budget	Funding from the central budget	Combined
Price administration	Municipal regulation	Central regulation	Shared responsibility	
Tariff correction	Procedures of the hearing, deliberation, etc.	Automatic conversion formula		

DH pricing principles in Europe and Asia methodologically may be divided into three groups (according to Lukoševičius and Balaišytė (2011b); Marcinauskas and Korsakienė (2012)):

1. The first method consists of an annual review of DH price components and new socio-political pricing for the following year; this method in the literature is called "**cost+profit**". The annual revision of costs and adjustment of prices according to the actual data of companies is applied in countries, where the DH is subsidized by the municipal or state budget or from revenue of electricity sales (Russia, China). Disadvantages associated with the method are long-term investment planning and the guarantee of return on investment, because savings or efficiency results next year and are included in the price for consumers. Heating companies for energy, material, and financial cost estimation requires a lot of precise normative indicators, which should be constantly adjusted according to changes in the market. Heat suppliers have no interest in cutting costs, because it may lack the funds for maintenance, for the necessary investments in order to ensure the reliability and efficiency of heat supply. According to Gudzinskas et al. (2011), this method was applied in Lithuania till 2003, but such pricing became unsuitable when private capital entered Lithuanian DH sector, because it has a natural desire to earn higher profits. Experience has shown that it is difficult to determine the necessity for costs professionally and objectively. Usually, it causes a lot of disputes between the heat suppliers, municipalities, regulators, consumer's advocates.

2. The second method determines that correction of heat prices could be done just after a significant change in any component of the cost (for example, fuel, taxes, etc.). This economic pricing is based on market relations; the method is called "**price cap**". Heating prices are limited by relationships with customers, and the maximum amount of profit is controlled by market surveillance authorities (Western European countries). The price of heat by this method is only converted from fuel prices and inflation indices. Interfere is usually avoided with the operations of companies if they are working effectively. Price regulation can be carried out by the energy regulator or the heat supply market.

Resvik (2011) distinguishes four heat price regulation and control principles: political price regulation, heavy touch and light touch price regulation, and pricing based on alternatives, which are detailed in Table 1.4. These principles differ in Europe: northern European countries tend to use light touch regulation or pricing primarily based on alternatives, economies in transition use heavy touch price regulation, and political price regulation are mainly used in Russia and Eastern Europe.

Table 1.4. Principles of the district heating prices' regulation and control (Resvik, 2011)

Basically political price regulation	**Heavy touch price regulation (ex-ante)**	**Light touch regulation (ex-ante/post)**	**Pricing primarily based on alternatives**
DH prices are based on normative costs but decided with political consideration and subsidies.	State regulator finally approves DH prices. In some countries, political consensus is needed.	DH prices decided by the company but controlled by regulator/competition office.	DH prices are set against customer's next best alternative.
No or strictly limited profit making.	Strong cost and profit monitoring and restriction of allowed returns.	Lightly regulated profit making. Focus on cost plus pricing principle.	Profits are based on market conditions.
Russia, Romania, Belorussia, and Ukraine	Estonia, Latvia, Lithuania, Poland, Hungary, Slovakia, Bulgaria	Finland, Germany, Czech Republic, Netherlands and Denmark	Sweden and Norway

3. The third method differs because the long-term (basic) stable cost structure determination is done for the period of regulation (3 or more years) with periodic correction of separate components when there are significant changes. This **combined pricing method** is applied in transition economies of the EU Member States (Estonia, Latvia, Lithuania, Poland, and beginning in Ukraine). This method seeks to harmonize DH sector economic basis with changing indicators of economies in transition (inflation, wages, fuel markets, the structure of consumers, etc.), and technical changes in DH systems (introduction of new equipment, efficiency gains as the DH system upgrades, etc.). Heat suppliers have the opportunity to get profit for operational efficiency gains during regulation period, therefore, it is the interest in cutting costs. Received profit is transferred to consumers through the price of heat at the beginning of the next regulatory period. The long-term (basic) price of heat is determined after analysis of heat production, supply, and selling expenses for each DH company.

The comparison of different approaches to tariff regulation is shown in Table 1.5 below. The main difference with the above analysed methods is substitution and benchmarking regulatory options. Substitution encourages cost reduction, but not necessarily price reduction. The question about improving the competitiveness also remains open for this method. Benchmarking (or yardstick) regulation approach allows the company to set tariffs that are related not only to its own costs but also to the costs incurred by other companies in providing DH. Competition is encouraged for cost savings even with companies, which operate not on the same local market.

Table 1.5. Comparison of different approaches to tariff regulation (IEA, 2004)

Priorities	Regulatory options			
	Cost-plus	Substitution	Price-cap	Benchmarking
Covering operational costs	+	?	+	+
Covering capital costs	+	?	+	+
Improving competitiveness	-	+	+	+
Encouraging cost reduction	-	+ (but not necessarily price reduction)	+	+
Encouraging energy efficiency	-	+	+	+
Simplicity of implementation	+	?	-	-

Notes:
+ Tariff meets the priority
- Tariff does not meet the priority
? It depends on the implementation details or the situation. For example, cost-plus tariffs usually favour investment, but only if return on capital is included if the tariff structure

World Bank, International Energy Agency, World Energy Council recommendations for economies in transition are long-term pricing method for the non-efficient post-soviet energy sector.

A comparative analysis of heating prices and control system in regulated DH sector (Denmark), unregulated DH sector (Finland), and countries in economic transition (Lithuania, Poland, and Russia) are presented in Table 1.6. The key finding is that monitoring and control are necessary for all types of DH market (either of the antimonopoly agency or regulatory bodies), as well as approval of the final price.

Table 1.6. Pricing and supervisory system of district heating in different countries (Lukoševičius and Balaišytė, 2011b)

Principles of district heating pricing	**Denmark** DH sector is regulated	**Finland** DH sector is unregulated	**Lithuania** Country in economic transition	**Poland** Country in economic transition	**Russia** Country in economic transition
Methodology	DERA	Non existing	NCECP	ERO	FST
The price of heat is set by	Company	Company	NCECP	ERO	FST
Regulatory period, year	Undetermined	Undetermined	3-5	1-5	At least 1
Recalculation of heat price	-	-	Monthly	Yearly	Yearly
Normative profit	0 per cent	Unregulated	5 per cent by WACC	Reasonable	15 per cent of costs
Approval of final price	DERA	Antimonopoly agency	NCECP	ERO	Municipa-lity
Monitoring and control	DERA	Antimonopoly agency	NCECP and municipality	ERO	FST
Investigate complaints	Antimonopoly energy council	Court	Court	Court	FST

Notes: ERO – Energy Regulatory Office; FST – Federal Service of Tariffs; NCECP - National Commission for Energy Control and Prices; WACC – Weighted Average Cost of Capital

Recently comprehensive scientific research concerning regulated, deregulated, and integrated approach to market was presented by Li et al. (2015). This research aims at providing insights into developing an advanced pricing mechanism for DH systems from the economic point of view. Table 1.7 below shows the main issues and advantages/disadvantages of each of the market type. Comparing with pricing that is used in Lithuania, the closest type of market is an integrated model of the competitive and regulated market. The increase of the competition between DH producers and promoting effective resource allocation is encouraged by this type. However, it is based on a number of assumptions, which usually differs from engineers, economists, and politicians' points of view.

Table 1.7. Concepts of pricing for district heating (Li et al., 2015)

Type of market	Pricing method	Price component	Key issue	Characteristic
Regulated market	Cost-plus	•Operational cost •Annual depreciation •Permitted profit	•Determining permitted profit	**Advantage** •Simple, flexible and ease of administration **Disadvantage** •DH companies have incentives to inflate costs •Undermining suppliers′ incentives to reduce costs and upgrade technologies
Deregulated market	Marginal cost	•Cost of one more unit of generation •Marginal variable cost and depreciation of fixed cost	•Allocating the joint cost •Short-run marginal cost/long-run marginal cost	**Advantage** •Suppliers are motivated to reduce costs, promote efficiency, and invest in infrastructure and equipment •Precisely presenting the variation of production costs and effectively reflecting the effects of market on heat production •Varying across DH systems and through seasons **Disadvantage** •Difficult to calculate •Likely to under- or over-recover costs over time •Tightly related to the marginal cost of electricity
	Incremental cost approach	•Operational costs of the existing system •Discounted costs of future changes	•Integrating the current and future cost	**Advantage** •Preserving the basic aim of marginal-cost pricing, while avoiding over- or under-pricing •Eliminating unjustified surpluses or losses for suppliers •Self-sustaining and self-financing **Disadvantage** •Uncertainties due to unpredictable development in technologies and/or new constraints •Implying an increase in production
	Shadow price	•Willingness to pay for an extra unit of heat production when the market is in equilibrium	•Market in equilibrium	**Advantage** •Reflecting resource prices at the market equilibrium •May include the investment cost of potential new plants •Can be used to decide system behaviours resulting from changes in boundary conditions and to indicate the relationship of the costs in continuous time periods **Disadvantage** •Difficult to determine in practice
Integrated model of competitive and regulated market	Equivalent marginal cost pricing	•Short- and long-run marginal cost	•Short-run prices are determined through bidding •DH capacity is regulated by the Heating Capacity Cost Reference •Exergy is used as the common standard to measure heat	**Advantage** •Promoting efficiency in the DH market •Ensuring investments •Enabling the comparison of heating production in different ways •Increasing the competition between DH producers and promoting effective resource allocation **Disadvantage** •Based on a number of assumptions •Over complicated for non-professionals

In summary, in the scientific literature exist three main pricing methods: market based (liberal), political-social, and economic regulatory pricing. Pricing policies in heat sector can be conditionally divided into the "cost + profit" approach, the "price cap" method, and a long-term (base) promotional pricing method. Review of the heat pricing in Baltic countries and in Nordic countries allowed to define the main heat pricing trends. Denmark has regulated DH sector, municipal heat sector planning and mandatory consumer connection to the DH network in licensed areas. Heat price reflects the cost incurred by heat companies, which are non-profit utilities in Denmark. Sweden and Finland have deregulated DH sector, heat prices are based on market conditions; connection to the DH network is optional. Lithuania, Latvia, Estonia, Poland apply long-term promotional pricing in order to promote necessary investments in DH sector.

Support schemes of RES in DH sector. DH infrastructure is rational for the use of solar and geothermal energy, which would be beneficial for the massive use of RES. Therefore it is the need of the implementation of legal and economic mechanisms and the use of existing DH infrastructure. Table 1.8 presents EU countries' funding schemes for RES support in DH sector.

Table 1.8. The funding schemes in the EU for RES in DH sector in 2013 (CEER, 2015)

	No support schemes in place	**General taxation paid by all citizens**	**Through specific non-tax levies like PSOs paid by all customers via electricity bills**	**Other**
Austria	x			
Belgium		x		
Czech Republic				x
Denmark			x	
Estonia	x			
Finland				x
France		x		
Germany			x	
Greece				x
Hungary				x
Ireland		x		
Italy				x
Lithuania				x
Luxembourg		x	x	
Netherlands			x	
Norway			x	
Poland	x			
Portugal		x		
Romania	x			
Spain		x		
Sweden	x			
UK		x		

The majority of European countries RES funding schemes are financed through general taxes. The last category "Other" consist of funding, which is not included in general taxes or paid by all customers via electricity bills, such as investment aids from different funds, grants. Lithuania supports heat from RES, which is included into regulated heat price; heat pumps are supported by the preferential tariff of electricity.

Lithuania is promoting the use of indigenous, renewable and waste energy resources by financial measures. However, there is no direct support for RES in DH. Sources of financial support are (Konstantinavičiūtė, 2011):

- Exemption from pollution taxes;
- The Lithuanian Environmental Investment Fund;
- EU Structural Funds for 2007-2013;
- Lithuanian Rural Development Programme for 2007-2013;
- The Fund of the Special Programme for Climate Change.

However, none of these instruments has been able to sufficiently accelerate the introduction of renewable energies in the heat market.

RES development in DH sector from 2007 to 2014 has increased about 3 times in Lithuania. RES in DH sector consist mainly of biomass and insignificant share of municipal waste. The share of biomass in DH was more than 50 per cent in 2015, and increase up to 70 per cent is forecasted by 2020. All assumptions are now subordinated in one type of RES, which is biomass.

RES development in DH sector is financed by the EU Structural Funds (Table 1.9), Lithuanian Environmental Investment Fund (LEIF), and Special Climate Change Programme.

Table 1.9. Support from 2014-2020 EU Structural Funds (LR Ministry of Energy, 2015)

Support measures for heat sector	**billion Euro**
1. „Modernization and development of cogeneration“ (Vilnius/Kaunas major projects)	233
2. „Promotion of small capacity biomass cogeneration“	32,4
3. „Modernization and development of the heat supply network“	69,5
4. „Modernization of fossil fuel boilers“	15

The table above shows the source of funds, in particular, structural funds, by 2020. The explanation of such situation is provided in Table 1.10, which consist of support schemes in Lithuania.

Table 1.10. RES support schemes in Lithuanian DH sector

Support scheme		Description
Price-based mechanism	Purchase of heat produced from RES (from heat producers)	The support is given for the purchase of heat, which is produced from RES. Heat suppliers are required to purchase all heat from independent heat producers, which is produced from RES cheaper and meets the quality, supply reliability, and environmental requirements. It is not applicable in the case of RES produced exceeds consumer demand.
Subsidy	Investment subsidy from LEIF	LEIF support is given for the projects, which reduces the long-term environmental damage. It includes a change of heat source from fossil fuel to biomass.
Tax regulation mechanism	The exemption from pollution tax	Biofuels and biogas producers, which produce heat, are exempt from pollution tax.

Cheapness and apparent economic advantage of heat, which is produced from biomass, is due to subsidies for biomass. However, under this system, other renewable technologies have almost no ability to compete in the market.

The following characterizes the forms of investment support, which can be very different, while Structural Funds in Lithuania is basically appointed only one form of subsidy. New EU program documents related to the support of RES technology issues notes that direct grants distorts the market relations and makes economic damage in the long term, because the energy infrastructure change is a complex process. More rational forms of financial support exist in foreign practice (Figure 1.10).

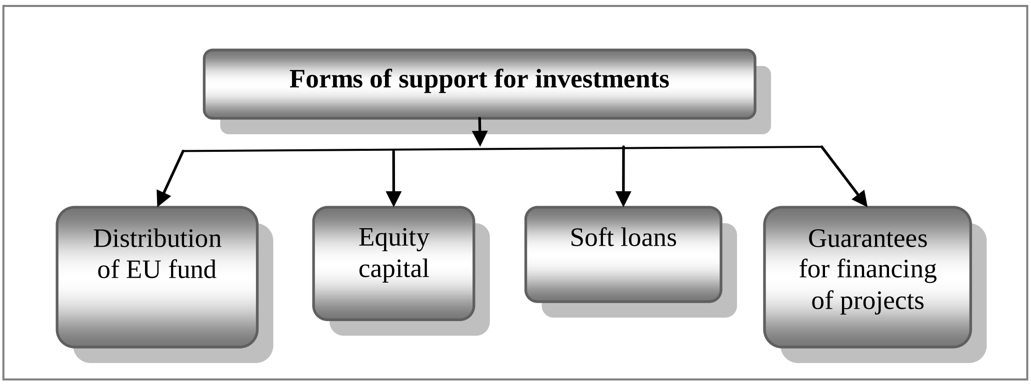


Figure 1.10. Forms of support for investments

Meanwhile, the use of solar and geothermal energy on a larger scale would be very favourable in DH infrastructure. DH enables the diversified use of fuels, which would be the basis for security of energy supply and energy price stability. One of the main drawbacks is that the dominant heat supply for DH systems is targeted to the short-term cheapness of heat. Therefore, massive introduction of new expensive equipments is noticed every time of significant changes in the price of the fuel.

Another problem is conflict of interests between the consumers and DH as the heat suppliers. It is evident that residents which receive subsidies for building renovation and installation of RES achieved significant heat energy savings. But a number of disconnected apartments from DH system have grown, which not only unbalance heat supply network but also increase the price of heat to other consumers. Heat network transmission losses should still pay less than the number of heat consumers.

Financing schemes for RES support in DH sector. After the review of the main forms of support for investments, it is important to analyse potential financing schemes, which may hasten diversified RES penetration into the market. Integration of renewable energy projects (such as solar collectors) into DH systems may create an external positive effect to the whole society concerning environmental and other regional development goals. Consumers' need for hot water or space heating is satisfied without burning natural gas or biomass, therefore the pollution is avoided. Moreover, import of natural gas from Russia is reduced and the forest conservation is increased.

Measures that could give greater opportunities for the use of solar and geothermal energy in the DH system are the promotion of the competition and support schemes that enable competitiveness. Energy, which is produced by consumers, can participate in the competitiveness process if this issue is treated on the state level, i. e., minimize investments and costs in the macroeconomic context. In this regard the short study of the financial system and opportunities for improvement is given.

Heat producers that use RES technologies have no direct subsidy, such as feed-in tariff. However, subsidies for investment and soft loans for RES heat technologies are provided by the Lithuanian Environmental Investment Fund (LEIF). In 2012, EUR 5.7 million of subsidies were offered from LEIF to finance biomass projects. Subsidies decreased to EUR 3.1 million in 2013 financing period for biomass projects.

Subsidies for the heating sector were also provided from EU Structural Funds for the period of 2007–2013. Lithuania has implemented the Promotion of Cohesion programme. Subsidies under the measure "Utilisation of RES for the production of energy" were provided under the mentioned programme. Beneficiaries were asking for 164 million euro during the 2012 year, but finally, only 29 financial agreements for a total value of 61.9 million euro was signed. The amount of subsidy varied from 29 thousand euro to 5 million euro with the intensity of fifty per cent. The remaining amount of financial resources must be covered by the private investors by using their own financial resources or loans. Governmental assistance is not foreseen for the implementation of the measure. Several examples of co–financed biomass related projects by various sources of financing exist; however, typical financial instruments, such as subsidy and loan, are dominated. The fourth largest city of Lithuania Siauliai in 2010 started to build a combined cycle heat and power plant, fuelled by biomass. The support from EU Structural Funds was 5.2 million euro. The heating company used about quarter million euro of private financial sources for the project. Moreover, additional financial sources of 10 million euro were received from the European Investment Bank as a loan. Scandinavian banks SEB bank and Swedbank provided a syndicated loan of more than 13.6 million euro.

Tax incentives for the utilisation of RES in the heating sector are not provided, except excise tax that has an exception for biomass.

European countries use various financial sources and different incentives mechanisms to support energy from RES. However, traditional financing sources and incentives are used in Lithuanian RES sector because of the lack of knowledge, shortage of experience, and unstable regulation of RES sector.

Possibilities to use innovative financial sources and incentives for the wider finance of RES sector in Lithuania are presented further.

JESSICA initiative is a Joint European Support for Sustainable Investment in City Areas. The initiative has been launched by the European Investment Bank, in cooperation with the Council of Europe Development Bank and the European Commission. Support is given to sustainable urban development and regeneration through financial engineering instruments such as stock capital, loans, and warranties. Since the beginning of 2008 Lithuanian Ministry of Finance together with European Investment Bank analysed possibilities of JESSICA implementation in Lithuania. The decision was made that JESSICA funds will be allocated to the sector of old multi-apartment buildings, which were built before 1993. The agreement was reached that funds should be directed to the implementation of energy efficiency measures. Therefore, JESSICA Holding Fund was established. The contribution committed into JESSICA Holding Fund is 227 million euro and consisted of European Regional Development fund (127 million euro) and National funding (100 million euro) for the improvement of financing conditions for multi-apartment building, higher education schools, and students' dormitories. European Investment Bank selected three banks (namely, Swedbank, SEB bank and Siauliu bank) in Lithuania, which finance projects. Banks are able to finance up to 100 per cent of construction costs. Soft loans are provided for 20 years period with 3 per cent fixed interest rate. JESSICA Holding Fund foresees to support various activities related to renovation and reconstruction of the building. RES technologies also could be funded by soft loans from this fund for the installation of RES in the buildings. This alternative source of finance should be used more widely in Lithuania.

JEREMIE (Joint European Resources for Micro to Medium Enterprises) Holding Fund was established at the end of 2008 in Lithuania after Ministries of Finance and Economy and European Investment Fund reached an agreement for the establishment of JEREMIE Holding Fund. The total sum of 210 million euro was directed to this fund. Financing is provided to small and medium enterprises via financial intermediaries in a form of venture capital and guarantees. JEREMIE can support improved access to finance in urban areas.

Overview of different sources of finance for DH suppliers and consumers revealed that market is ready to finance implementation of RES alternatives in DH sector of Lithuania.

1.3. Formation of legal-economic prerequisites for the use of DH infrastructure for RES diversification

In recent years, the consumption of fossil fuel and the mitigation of climate changes have become major challenges for governments all over the world. To engage these challenges, many countries are pursuing the research, development, and demonstration of RES (Shen, Lin, Li, & Yuan, 2010). In the past few years, RES have got rapid development all over the world. RES have become important alternative energy sources to realize energy diversification. During the last few years, political support for renewable energies has been growing continuously both at the national and international level.

Looking at the energy use after 2006, it was a price boom of natural gas, increase of social and political pressure for fast development in clean energy, and financial crisis, which requires adequate government measures to stimulate the economy. The industry of renewables could be important to generate employment and to stimulate growth (Marques et al., 2010). Investment in RES may bring considerable profits, so more and more enterprises will be involved in this field (Abdmouleh, Alammari, & Gastli, 2015). The increased use of RES in the heat market can significantly alleviate the negative effects of high-energy costs on the national economy. Successful commercialisation of indigenous, non-fossil energy resources is expected to promote the development of regional economy and employment, help to increase national energy security and to reduce a substantial portion of the increasing trade deficit necessity to import fossil fuels (Katinas & Markevičius, 2006).

The main factor limiting further renewable energy growth in DH is high investment costs and constrains of legal regulation. In 1997, European Union issued a White paper for the development of RES, and formulated the target - renewable energy would account for 12% of total EU energy consumption by 2010 and would account for 50% of energy source composition in EU by 2050. Actually it was only during the beginning of the 21st century, when some countries or political blocs (as is the EU case) began to set targets for renewable energy and to define policy measures for the sector (Boyu, 2011; Marques et al., 2010; Štreimikienė, Burneikis, & Punys, 2005). In 2007, EU leaders agreed to an integrated climate and energy policy to combat climate change. The EU's 20-20-20 targets envisage the reduction of greenhouse gas emissions by 20%, the increase in energy efficiency by 20%, and the share of energy from renewable source at least 20%.

Main EU Directives that have an impact on DH sector are as follow:

- Directive 2009/28/EC of the European Parliament and of the Council on the *promotion of the use of energy from renewable sources* and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC (23 April 2009);

- Directive 2009/29/EC of the European Parliament and of the Council amending Directive 2003/87/EC so as to *improve and extend the greenhouse gas emission allowance trading scheme* of the Community (23 April 2009);
- Directive 2010/31/EU of the European Parliament and of the Council on the *energy performance of buildings* (9 May 2010);
- Directive 2010/75/EU of the European Parliament and of the Council on *industrial emissions* (integrated pollution prevention and control) (24 November 2010).
- Directive 2012/27/EU of the European Parliament and of the Council on *energy efficiency*, amending Directives 2009/125/EC and 2010/30/EU and repealing Directives 2004/8/EC and 2006/32/EC (25 October (2012)).

Most experience in supporting RES is offered to the electricity sector. In contrast, no legislative framework at EU level was available in the heating sector before the implementation of Directive 2009/28/EC, where DH is recognized as a promising technique for reaching overall strategic energy goals: safety of energy supply by increasing independence from imported energy resources, wider use of waste energy from industries and integration of RES into energy supply infrastructures. Necessary preparations are conducted in all EU countries by implementing this Directive. The tremendous development of RES in Lithuania is foreseen in DH sector, mainly based on the use of biomass.

The Renewable Energy Sources Directive 2009/28/EC, which entered into force in June 2009, transforms binding targets into a legislative framework: the European target of 20% RES in the gross final consumption of energy is divided into binding national targets for the EU-27 member states. After one year, by July 2010, member states were required to present National Action Plans of RES (NREAPs) that fixes specific objectives for each member state in the use of RES for each sector, including heating. All 27 NREAPs had been published by January 2011, which seems quick compared to the implementation of other EU legislations, e.g. Directive 2004/8/EC on cogeneration or Directive 2006/32/EC on energy end-use efficiency, as noted by Klessmann et al. (2011). According to the NREAP, Lithuania has quite ambitious plans to increase RES in the heating sector from 27 per cent in 2005 to 39 per cent in 2020. Taking into account technological possibilities of DH sector and economic advantage, heat production from RES should be increased by not less than 50 per cent. Whether the proposed actions will be sufficient to actually achieve these targets remains to be seen.

Management of energy demand is encouraged in Directive 2010/31/EU. EU members should use the available funds and funding, such as the European Regional Development Fund, for increasing energy efficiency and using renewable energy in the housing sector. According to this Directive, all new buildings have to be nearly zero-energy buildings by 31 December 2020. New buildings occupied and owned by public authorities have to be nearly zero-energy buildings after the end of 2018. The requirements of this Directive will affect not only construction sector and the price of new houses but also existing buildings that are subject to major renovation and should, therefore, meet minimum energy performance requirement. Looking in the long perspective on the influence of Directive 2010/31/EU and Directive 2012/27/EU on energy efficiency, it will decrease in the demand side of DH. Therefore heating prices should decrease, but the heat loss in the network could become the main factor for inefficient DH supply.

Later EU Directive 2009/29/EC on the improvement of the greenhouse gas emission trading scheme (ETL) pointed out that free allocation shall be given to DH as well as to high efficiency cogeneration. The basic principle for allocation of ETL should be auctioning from 2013. Directive 2010/75/EU on industrial emissions is important for combustion plants, which are in operation after 1 January 2016. These plants should ensure that emissions into the air from these plants will not exceed the emission limit values. The main threat of this prohibition is for Vilnius and Kaunas CHP plants, which are dependent on combustion of natural gas. Without costly investments in flue-gas cleaning devices mentioned CHP will not be able to be in operation and supply heat for two biggest Lithuania cities. As an alternative could be biomass cogeneration plants. However, the case of Kaunas city revealed that it is difficult to deal with municipality politicians, who in 2011 summer agreed on a detailed plan of new modern CHP, but at the end 2011 changed their minds. Strategic city heating projects should be a priority for each city, and the politicians should bring all efforts to make them clear and stable.

The Energy Efficiency Directive 2012/27/EU establishes a set of binding measures for reaching EU 20% energy efficiency target by 2020. EU countries were required to transpose the Directive's provisions into their national laws by 5 June 2014. Lithuania has not achieved this requirement. The project of the Law of Energy Efficiency was presented to the Parliament on April 2014, but the final decision is still unknown. The main national measures, suggested by the Directive 2012/27/EU, and related with DH sector are high efficiency cogeneration, renovation of 3 % share of public buildings, and 1.5 % energy savings per year for energy distributors or retail energy sales companies. The level of savings could be reached by other measures as well, such as improving the efficiency of heating systems, installing double glazed windows or insulating roofs.

The further development of RES in DH market is enhanced by EU Directives but limited by price. As noted by (Menz & Vachon, 2006), the prices of traditional energy sources do not include the environmental costs. Prices fail to reflect the real costs of their use, when compared to the ones of renewable energy, giving the idea that prices of clean energy are not competitive in the short term. Chang et al. (2009) study the interrelationship among prices, income, and renewables. The authors conclude that countries with high economic growth deal better with high energy prices (related to the use of renewable energy), because it is easier to support the high costs connected with these technologies (Marques et al., 2010). Consequently, high investment costs are one of the factors that limit further renewable energy growth, but looking in the long term perspective even in Lithuania it could be beneficial.

The increased spread of anomalous weather in recent times has led to active public discussions about climate protection. The greenhouse gas emissions can be reduced by increasing the share of RES in the heat market, similar to the effect already initiated in the electrical power market. However, a similarly strong impulse in public policy for the heat market is still lacking. Moreover, in the current labour market, it should not be forgotten that the increased use of RES creates employment while simultaneously reducing fossil fuel imports. Legislation to promote RES in the heat market thereby creates a fourfold dividend:

(1) contributes to the protection of climate and resources,

(2) reduces the dependence on imports,

(3) strengthens regional value added,

(4) creates future-assured employment (Nast, Langniß, & Leprich, 2007).

A very large potential in the heat market still remains to be developed. The dividend is therefore correspondingly large. EU Directives that have an impact on DH sector have to be the main road for further development on the use of RES. The targets that were set in NREAP have to be followed, but it is necessary to create strong national legislation framework and accessibility to finance RES in DH.

Many states in Eastern and Central Europe, as well as Lithuania, possess extensive DH networks that were constructed during the days of communist rule in order to provide a universally accessible energy service. But the post-communist transition was marked by the exacerbation of the sector’s numerous technical, economic, regulatory and environmental problems, accompanied by its abandonment in favour of alternative methods of heating (Poputoaia & Bouzarovski, 2010).

Government policy for promoting renewable energy was formulated during 10 years (1990–2000), as noted by Katinas & Markevičius (2006). The policy was revised during 5 year periods for comprehensiveness, coordination, and market development. A strategy to promote the use of alternative energy sources such as biomass, small hydro power, biogas, wind energy, etc. has been adopted. Promotion of local and RES usage and energy efficiency is established in the Law on Energy of the Republic of Lithuania as priority objectives of energy sector regulation. In Lithuania the promotion of renewables’ use is based on the main legislation acts, as follows:

- Law on Energy of the Republic of Lithuania (2002);
- Law on Electricity of the Republic of Lithuania (2000);
- Law on Heat Sector of the Republic of Lithuania (2003a);
- Law on Energy from Renewable Sources of the Republic of Lithuania (2011);
- National Energy Independence Strategy (2012);
- National Strategy for the Development of Renewable Energy Sources (2010b).

The Law on Energy states that energy companies, which supply heat to apartment buildings, supply the heat to flats if users do not wish otherwise. The increasing DH prices and low income of apartment buildings owners cause discussions about how to become independent from DH companies. There are several cases, widely announced in media, how people after long bureaucracy procedures were enabled to change the type of heating to the individual. Results are contradictory, one of them proud to be independent, other honestly say it is costly than DH. It should be noted that if one of the owners of apartment building disconnects from DH, others have to pay more for heat loss. The situation may become very difficult after the larger scale of such independency from DH. The infrastructure of DH that was created for a long time and control of the pollution in the cities would only be just fruitless efforts.

The main legislation act for DH is Law on Heat Sector. This law provides competition in the heating sector, purchase of heat from independent producers, detailed explanation of the heat contracts cancellation of user initiative, the license of heat supply, pricing of heat, etc. Heating prices are regulated by The National Control Commission for Prices and Energy, therefore profit of heat supply companies is limited. This causes the inability of investments in new heating devices that uses RES as a fuel. Sources of possible financial support in Lithuania are given at previous subsection. Lithuanian Law on Heat Sector states that heat production is based on the competition between heat producers. The heat supplier is obliged to connect all heating devices of independent heat producers that were installed to replace fossil fuel plants. Priority is given for the purchase of renewable heat. Heat suppliers (owned by municipality of private investors) must purchase all heat from RES produced by independent heat producers, which is cheaper than the heat produced by the heat supplier and which satisfy quality, supply security and environmental requirements, unless the supply of RES heat produced by independent heat producers exceeds the consumers' heat demand. If heat is produced from RES by two or more independent producers, priority is given to the lower price. Heat suppliers must not discriminate independent heat producers when operating, maintaining, managing, and developing the heat transmission network.

The Law on Energy from Renewable Sources is mainly driven by EU Directive 2009/28/EC. This law repeats goals that were set in mentioned Directive. It aims to ensure sustainable energy supply, promote the further use of renewable energy technologies and their development, especially in regard to the environment (climate change). The Law on Energy from Renewable Sources frames an opportunity to significantly reduce costs of producing hot water in apartment buildings using RES technologies, such as solar collectors. However, the pricing of produced heat is unfavourable for independent heat producers, because DH suppliers have to buy energy made from RES at the lowest price. Consequently, hot water that is prepared using solar collectors has to be used by its owners. Finally, the main problem of the Law on Energy from Renewable Sources is still lacking executive acts that limit further investments in renewable energy.

As indicated in the Lithuanian National Renewable Energy Action Plan (2010a), the National Strategy for the Development of Renewable Energy Sources (2010b), among other priorities of the development of energy from RES it is envisaged utilisation of the existing DH infrastructure and further development of necessary infrastructure while creating conditions for the development of diversified RES. It is predicted that biomass to be consumed in the DH sector should become the main contributor to the increase in the consumption of RES. Taking into account technological possibilities of the DH sector and economic advantage, heat production from RES in this sector should be increased by no less than 60 % by 2020.

Lithuanian Energy Agency (LEA) is responsible for the coordination of research, development, and implementation of renewable energy projects. Under instructions of the Ministry of Energy, LEA deals with drafting the National Energy Program, other programs regarding the improvement of efficient use of local, renewable and waste energy resources, organisation of their implementation, updating and revision, preparation of legal, economic and organisational energy efficiency measures for the enhancement of national energy policy implementation.

Situation in the DH sector in Lithuania is similar to other transition countries and has similar problems, such as follows:

- Very high consumption of thermal energy – more than 200 kWh/m^2 annually;
- Renovation of building goes very slowly;
- Most heat consumers have no individual regulation, so heating bills do not correspond to their living standard;
- Heat supply volume has been reduced several times from design conditions, therefore many equipment and pipelines are oversized;
- "Old" facilities and schemes are modernized or replaced slowly;
- Low efficiency, poor quality standards, high heat prices;
- Disappointment with such situation forms negative attitude regarding DH (Lukoševičius, 2011).

As the result of such situation, main regulatory problems in Lithuania can be pointed out:

- Destructive competition with gas heating (incorrect pricing policy);
- Planning/zoning of cities still seldom;
- Unregulated disconnections, causing problems of DH in some cities;
- New obligations to DH sector are not supported by required financial resources;
- Approval and financing of investment are unpredictable;
- Lots of speculations and populist decisions in the DH sector (Lukoševičius, 2011).

DH and cogeneration policy frameworks in Lithuania consist of *secure market-oriented* energy policies. Such policies promote liberalisation, competition and customer choice. Therefore it separates monopolistic from competitive activities for privatisation, also harmonises liberalisation of CHP and electricity markets. Moreover, policy aimed at the *development of long-term and local energy strategies and promotion of DH and cogeneration* (World Energy Council, 2004). However, long term strategy and/or planning for the development of DH is still missing in Lithuania. The decisions mainly aim at the short-term competitiveness of price, without evaluation of the long term benefits or possibility to stabilise the price of heat.

DH and cogeneration regulatory goals in Lithuania are (World Energy Council, 2004):

1. *Enhance regulatory regimes*: have regulator reporting to President, Parliament and Government; control monopolistic generators; undertake independent audits of regulated companies and regulator.

2. *Foster competition*, *access to grids*: set regulated prices, price caps, taking into account depreciation; reduce barriers to third-party access to market so as to allow customer choice.

3. *Secure cost-covering*, *market-oriented prices*, *tariffs*: reschedule or incorporate old company debt into tariffs or solicit government support.

Consistent policy package is the key to cause a development of renewable energy in DH that is required to meet ambitious targets. The Law on Energy from

Renewable Sources gave the beginning for national legislative framework on the use of renewable energy. As mentioned earlier, the main problem of this law is still lacking executive acts that limit further investments in renewable energy.

Table 1.11 gives an overview of the major RES administrative and legal barriers in EU based on a summary of various studies in Klessmann et al. (2011) research. The second column shows the available policy responses to address these barriers. The implementation of these policy features varies strongly across European member states.

Table 1.11. Common RES administrative and legal barriers and policy responses (Klessmann et al., 2011)

Barrier	Options for policy response
Inefficient administrative procedures (high number of authorities involved, lack of coordination among authorities, lack of transparent procedures, long lead times, high costs for applicants, etc.)	Improving and streamlining administrative procedures towards transparent and non-discriminatory processes ("one-stop shop" approach for applications, maximum response periods for authorities, clear guidelines and capacity building for civil servants, limiting administrative requirements to the relevant elements, simplified procedures for small plants, etc.).
RES not or insufficiently considered in spatial planning	Improved spatial planning rules; Definition of RES priority areas; Information and capacity building for local authorities; Participation and/or compensation options for local communities.
No or insufficient standards and codes for RES equipment (specifications not well defined, not expressed in EU/international standards, etc.)	Improvement of technical specifications and codes; Implementation of EU/international standards and certifications.
Tenancy law and ownership law impede the development of building-integrated RES technologies	Implementation of RES-use obligations; Adapt tenancy and ownership law to facilitate RES deployment (facilitating cost sharing, provision of energy services etc.).

The accelerated deployment of RES for heating purposes is too important to allow it to depend on strongly varying public budgets. A subsequent goal is to charge polluters for the necessary additional financing for renewable energy installations. Those groups which bring fossil fuels into circulation or which use them should be burdened, as was argued by Nast et al. (2007).

According to Klessmann et al. (2011), "critical success factors include implementing effective and efficient policies that attract sufficient investments, reducing administrative and grid related barriers, especially in currently less advanced countries, dismantling financial barriers in the heat sector, realising sustainability standards for biomass, and lowering energy demand through increased energy efficiency efforts".

Figure 1.11 illustrate key principles in order to reforming DH with the status of natural monopoly to a direction that DH infrastructure could be appropriately used for penetration of renewable technologies on a large scale, which is based on the analysis of the 1st chapter of the dissertation.

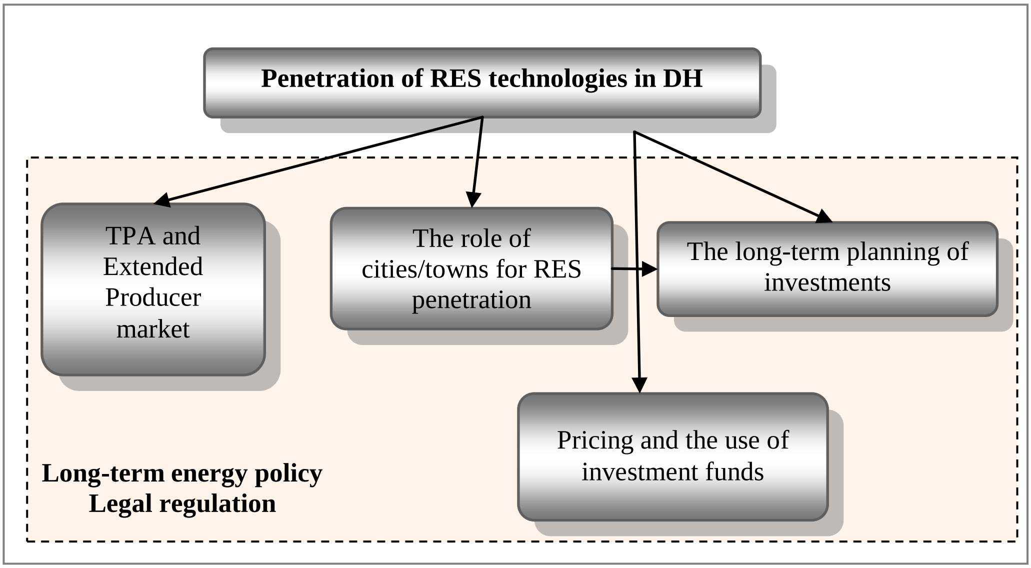


Figure 1.11. Reforming DH as natural monopoly in order to use renewable technologies on a large scale

Regulation itself may not represent the main or the only reason why DH in transition economies is less efficient than, for example, in Western Europe (Poputoaia & Bouzarovski, 2010). Despite the efforts of government policy, accepted legislated base and programs for enhancement of the use of RES, due to expensiveness of alternative energy technologies and various constraints, total contribution to development is not impressive.

It is increasingly recognized that an integrated complex of environmental, social and economic policies is easier implemented in cities and districts. Public expenditure and funding from Structural Funds should, where possible, allow achieving more than one policy objective of sustainable development. Sustainable development of energy at regional level requires support measures for organizing and implementing institutions. Municipalities can play an important role in promoting assumptions of sustainable energy development, because the local government performs a number of functions in the energy sector, and these opportunities should be used.

2. CONCEPT OF ECONOMIC BACKGROUND FOR RENEWABLE ENERGY SOURCES INTEGRATION INTO DISTRICT HEATING SYSTEM

2.1. Preconditions for the formation of concept

The essential issue of DH sector in Lithuania at the moment is competition between heat suppliers in a short period of time when only one type of fuel has a preeminent position (biomass at the moment). Such public policy does not encourage the integration of more diversified RES, such as solar collectors or heat pumps, in the DH sector.

The basic aspects of this chapter are as follows:

- Diversification of RES is necessary for reaching stable long-term price;
- Natural RES, such as solar and geothermal energy, do not use any source of solid or liquid fuel, therefore a stable price is guaranteed for the long-time.

Decisions that might have the best long-term effect, considering price, environmental and other social costs, might not be the best if the only price of the short-term period is taken as the main factor. Therefore this chapter aims at methodology formation for diversified RES integration into DH system in terms of sustainable development of cities.

Demand for diversified RES technologies is restricted by slow demand rates. Progressive technologies may have the economic background for the successful development only in the case of high demand. The main challenge is increasing public interest, which may be expressed through continuous supply of energy resources in the future, solving social and environmental problems, and also the inability of the private sector to invest under current conditions. However, the awareness of energy consumers usually contains just fragments in comparison to the full effective knowledge, which forms demand based on public benefit.

Programmes of regional energy might be effective after organizational changes and the use of various financing forms of technologies integration by using Structural Funds. However, integration of RES may be more successful after reliable methodological assessment of positive effect for solving social, economic, development problems in a regional development context. The scientific and practical problems are being solved while evaluating links between energy development and economic growth with providing possibilities to solve social and energy security problems.

Organizational forms are exceptionally important for diversified RES implementation on a wider scale. These are various regional or municipal programmes, which include RES projects to solve energy supply, environmental, and social problems in rural areas as well as many other functions in the context of sustainable development. The exchange of best practices, based on sustainable energy aspects, is the cornerstone of development promotion of the projects at local level.

Integration of diversified energy projects into regional development process may create external positive effect concerning environmental and other regional development goals. Sustainable energy investment projects, characterised by a positive local environmental development impact, can be brought up to the level of implementation using contribution not only from Structural Funds, but also from other regional/public sources of finance.

The demand to form a common energy policy with an economic support system for RES as one of the compounds is notified for several years already. It is not possible without unified approach to the perspectives of the use of different types of fuels and energy sources in making strategic decisions as well as implementing them (Dusonchet and Telaretti, 2010b).

The essential condition is to distinguish two main groups of support concerning RES:

a) Energy producers and suppliers; they must integrate RES into energy system in order to compete with main types of fuel, such as natural gas or coal;

b) Energy consumers; they require additional support for RES and establishment of infrastructure; demand is limited by factors, such as acceptable price and security of energy supply.

However, the use of RES is related to additional public benefit, which is not evaluated in individual business decision-making.

RES include the following main qualities:

– RES means inexhaustibility of their use, which means possibility to provide future generations with energy sources;
– Implementation of RES means that technological progress is directed towards the harmony of human activity with natural processes.

It is necessary to analyse economic support forms for creation and mastering of diversified RES technologies to make them competitive with technologies of traditional fuels and make them sensible according to actual purpose, need, and possible effect. In principle, support schemes should provide the same RES compatibility conditions, but do not protect them against other sorts of energy and technologies.

Economic and financial support for RES certainly does not depend on intrinsic goals that are pursued by a competitive market. For example, implementation of RES may increase the security of energy supply for the company, district or even region. Projects carried out for RES implementation provide improved comfort and have effects on new jobs, dispersed across the community both socially and spatially, and involving small and medium size enterprises.

Development of RES is a part of the implementation of climate change policies, improving energy efficiency and ensuring the security of energy supply. The most important is recognition that they all are necessary elements of sustainable energy future that will not be delivered by market forces alone. Many of the benefits of RES are the public benefits that accrue to everyone. For example, those who have chosen RES reduce pollution for everyone and provide the environmental benefit to the entire society. However, a customer who is willing to pay more for electricity from RES still has to breathe the same air as the neighbour who might choose not to pay more.

Employment, fuel diversity, price stability, and other indirect economic benefits of RES are being provided for the society as well. For example, for a large industrial customer, it may be more meaningful to risk moving to another region in response to increases in fuel prices rather than to pay more for RES to stabilize regional prices. While this strategy may benefit the individual firm, it is likely to damage the long-term economic competitiveness of the region. In the same way, firms that can transfer the increase in energy costs to customers may also lack the incentive to diversify fuel sources, even though investment in RES would stabilize prices over the longer term.

Creation of competitive energy market is favourable for the increase in economic growth; however, security of energy supply, mitigation of environmental impact and energy affordability are the targets of sustainable energy development, which can be achieved only by implementation of Government rational energy policy. Sustainable development needs organizing institutions, stakeholders, support measures, etc. The most important thing is to understand that the main essence of all EU directives, policies and measures is to overcome energy market failures: regulation of monopolies in the energy sector, dealing with energy externalities, energy affordability, asymmetry of information, and energy security. Implementation of diversified RES technologies is the necessary element of strategy for sustainable development.

It is evident that the main stakeholders in this process are market forces. However, state, municipalities, nongovernmental organizations, consulting firms may play a considerable role as a connecting, integrating and promoting chain between the financing organizations and energy consumers (Vos and Savin, 2012).

EU Structural Funds have a significant role in this field; however, their distribution needs more rationality and more orientation towards sustainable development. The EU policy for sustainable energy represents ambitious targets and requires tremendous investments. The gap between objectives and available resources is the main weak point, which undermines the possible fulfilment of the EU policy objectives (EC, 2014). A further weak point concerns the fact that the size and the impact of integration and implementation of EU energy policies and related programmes into the regional and local environment are uncertain. A possible solution to this problem can come from the involvement of the regional development resources and the Structural Funds into the energy policy related objectives and programmes (Antinucci et al., 2002). The sustainable energy objectives may be reasonably integrated into the regional development strategy in an overall vision of a sustainable development for the region.

Talking about the perspectives of the use of main type of RES, solar energy, it is evident that the main market is on the consumers' side. The most important problem, determining the slow absorption process of solar energy on the side of the consumer is the lack of knowledge and organisation, deterrent amount of investments, and especially the differences between energy suppliers and consumers in the DH sector.

It has to be noted that technology development is noticeably one step ahead the general level of society's education and its susceptibility to innovation, in economic terms, the demand for new technologies, innovative forms of financing, and forms of management organization. For example, the sustainable development of the DH sector is an integral part of smart grids that are based on the idea of developing information and communication technologies. It is the reorganization of the electricity and heating systems, based on technologies and innovations, the main idea of which is to develop sustainable cooperation between producer and consumer, giving more opportunities for users to be in the electricity and DH market. Development of smart grids would promote the use of RES and also promote not only the liberalization of the electricity, but also of the DH market. The reorganized system of DH market would stimulate the efficiency of consumption and production of electricity and DH, decrease the negative influence of the environment, motivate the creation of new workplaces, and reduce the prices of energy.

A new educational conception is needed, directed at the development of mentality of the society for sustainable development. Moreover, the concept of sustainable development determines the boundaries and absolute limits, and restrictions placed on the influence of current technologies on environmental sources and the necessity to absorb the effects of human activity (Klevas et al., 2009).

The task of diversified RES evaluation extends knowledge and answers to more than one question on the economic theory. In the presence of global risks of climate change, the questions arise: what is the essence of technical progress in the presence of exhausting energy sources, and how the economic theory and policies have to be transformed? Because of the fluctuation of natural gas prices, the development of economics becomes more problematic and difficult to forecast, and the combustion of energy sources is certainly accepted as an incentive of the global climate changes. Therefore, the necessity of the use of diversified RES, as widely as possible, is undoubted.

In this context, the solidity of a knowledge-based economy concept emerges. One of the main science roles is to give information, which enables the formation of the development of policy in a decision making process. It is necessary to essentially improve scientific perception, based on scientific researches, and to raise the scientific competence of a country.

The preparation of research methodology concept for the development of diversified RES in DH and assumptions are defined in Figure 2.1 below. Territorial prospective RES planning concept is based on the methodological justification of external benefit evaluation after the realization of assumptions of external benefit.

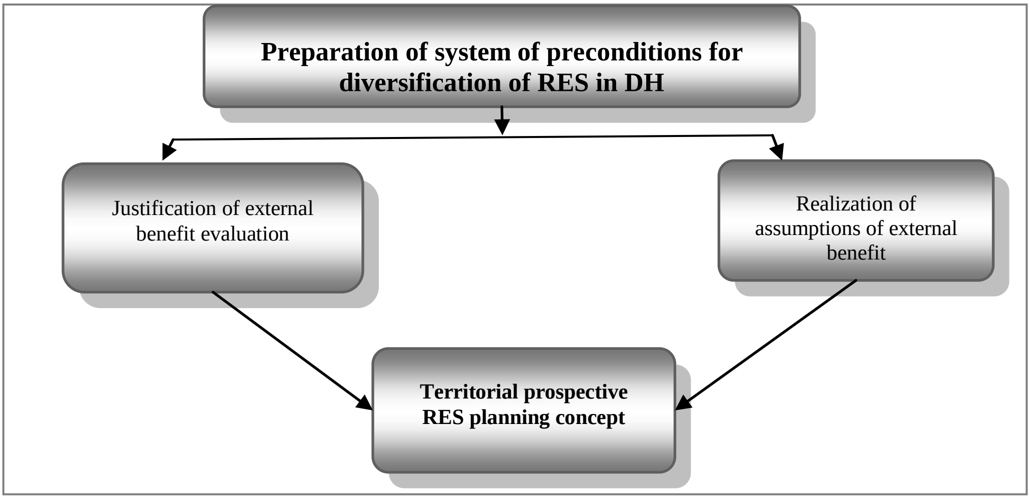


Figure 2.1. Preparation of system of preconditions for diversification of RES in DH

Extended financing of environmentally friendly technologies by using diversified RES is necessary seeking to overcome heat energy market failures and barriers. The EU Structural Funds are very effective financial channels from this point of view. These funds can be used effectively to overcome a set of market failures by financing innovations and developing new environmentally friendly technologies.

The main trends of investigation related to RES economic support are as following:

a) Analysis of the RES according to different aspects of benefits, which participate in the economic process and reflection of this feature in economic estimations.
b) Analysis of barriers, which suspends wider development of RES sector.
c) Evaluation of prerequisites for diversified RES development based on externalities.
d) Organizational role of cities, which enable evaluation and financing on a wider scale.

2.2. Theoretical evaluation of market barriers for RES development

2.2.1. Classification of RES according to different aspects of benefits

The primarily task is to determine the object of the research. RES is an exceptionally wide object (see Figure 2.2) to be feasible for analysis of all possible types of RES, their application, availability to use technologies, and particularly their utility. Moreover, dynamics of utilisation for each type of RES is different, especially reduction in the cost of technology during the time. Therefore the initial objective is to transpose all discussions into a certain plane, which is defined by consolidated rules and economic laws, and to find a common denominator of different opinions. This means that single facts should be integrated into the logical chain of actions and consequences, i.e. into the chain which is based on economic laws.

The utility of RES differs from fossil fuel, such as oil and gas. The main difference is that RES ensure that future generations will be supplied with energy sources. This substantial advantage is not methodologically assessed, but it is one of the fundamental accents of the concept of sustainable energy development, as described in the first chapter. Renewal, as an exclusive feature of these energy sources, is important for classification.

Figure 2.2 shows RES classification scheme, which displays social utility categories under the particular type of RES.

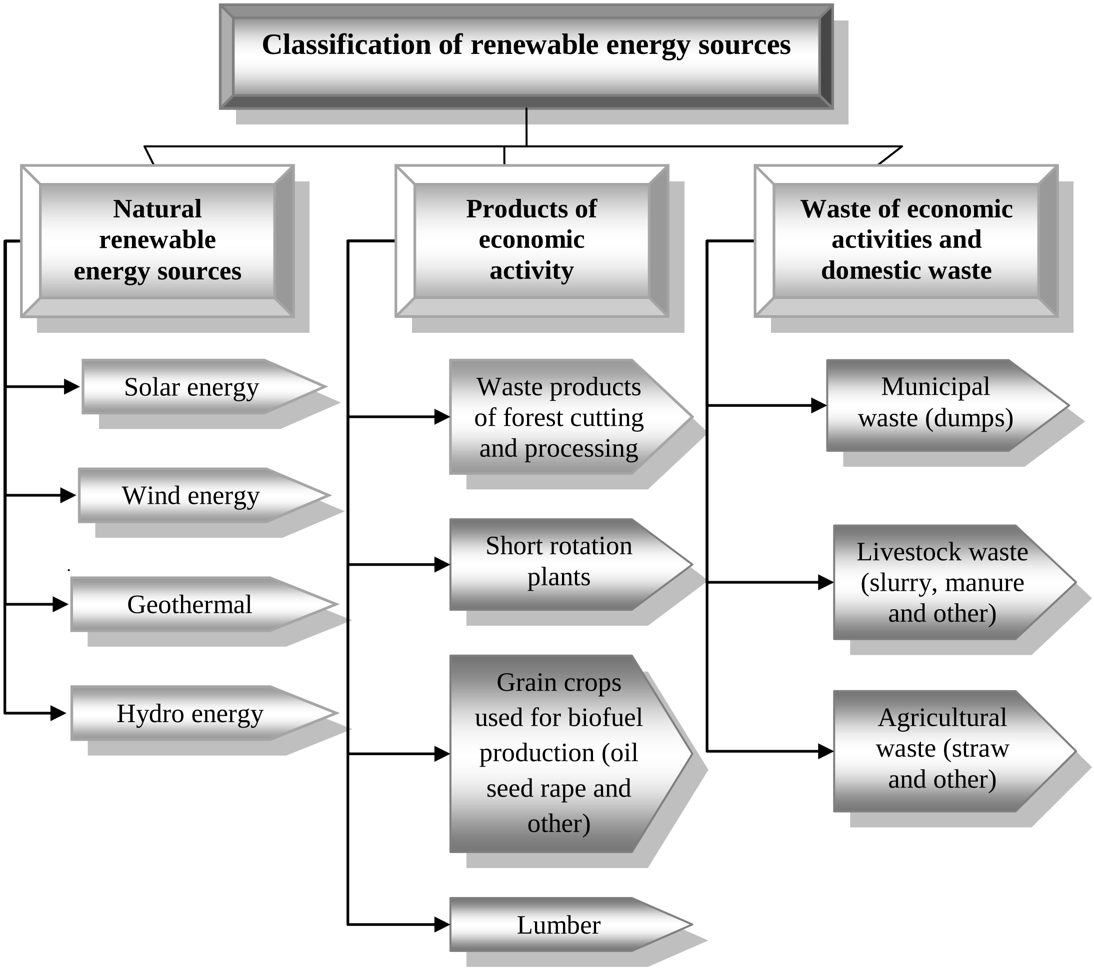


Figure 2.2. Principle scheme of RES classification

As it is seen from classification in Figure 2.2, RES are grouped into three main types:

- the first or the basic type of RES is a phenomenon existing in the nature that is renewables, which can gradually change exhaustive energy resources during a long time, for example, oil and gas. This type is solar, wind, hydro, and geothermal energy;
- the second type is energy resources received as a result of economic activity. Their conditional renewal depends on continuity of the economic activity. Moreover, in all cases it should be noted multifunctional resources, for example, utilisation of lumber;
- the third type is the utilisation of waste from economic activity and municipal waste. When RES technologies are used, then waste utilisation is a valuable tool for solving environmental problems. The exploitation for energy needs in this case is rather limited due to limits of industry or EU regulation for reducing the amount of municipal waste.

RES support scheme should be differentiated in accordance to social benefit it can provide:

- natural RES mean that their utilisation is not exhaustive; this gives the possibility for future generations to self-provide with energy resources; however, it is necessary to bear in mind that renewal is different;
- in the case of circulation of natural processes, it means that technological progress is oriented towards harmonisation of human activity with a circulation of natural processes.

In the framework of this thesis, research object is **natural RES**, namely solar and geothermal energy, which is currently simply to use in DH system; but wide utilisation of natural RES gives an opportunity for future generations to ensure themselves with energy resources.

The consensus of the motivation of RES suppliers and consumers is the essential problem both from the scientific and practical point of views. Under the normal market conditions this does not cause a problem, however, RES is a specific resource. Problem is that business is interested in the high price of purchased energy and development of infrastructure by using state funds. The industry has emerged in some market segments (for example, small-scale hydro energy and wind energy). Meanwhile, consumers seek for lower prices and this aim contradicts to the aim of energy suppliers. Therefore questions arise: how to balance demand with supply or who pays premiums to tariffs? Moreover, it is necessary to clearly identify reasons why business has to be supported.

The task to be accomplished in theoretical context is formulated as following: to prepare a theoretically-based systematic approach, which is committed to motivating the use of RES. One of the main roles of science is to provide information, which allows sophisticated development of policy in decision making process. For this reason it is essential to fundamentally improve scientific understanding and long-term assessment, which is based on scientific research; moreover, to improve State's competence by new research schemes, which would allow receiving answers to questions that remain in shadow when RES support schemes are transposed from international practice. During transpose of RES support schemes from international practice, State's economic status in society's evolution process is considered insufficiently.

Evaluation of RES development in DH could be based on different modelling tools and calculation methods. The following sections present a methodological approach to the diversified RES integration in DH with a combination of modelling tools and LCoE method.

2.2.2. Market barriers for RES development related with external costs (non)evaluation

The external costs occur when producing or consuming a good or service imposes a cost upon a third party. If there are external costs in consuming a good (negative externalities), the social cost will be greater than the private cost. The existence of external costs can lead to market failure. This is because the free market generally ignores the existence of external costs or externalities, as shown in Figure 2.3.

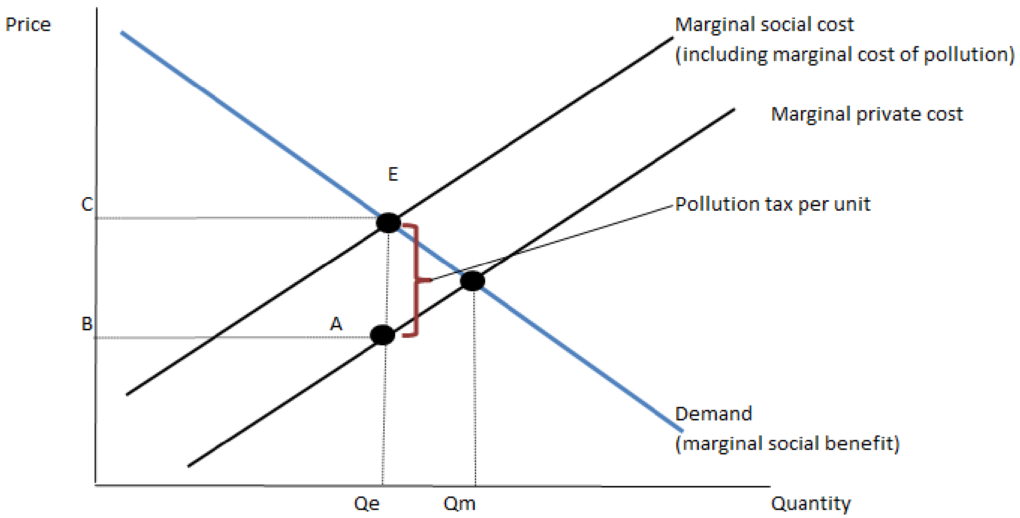


Figure 2.3. Externalities that result from the difference in private and social costs

The existence of external costs has implications for product prices, output levels, resource usage, and competition. When significant external costs are associated with a good (or service), then the price of the good is too low (because external costs are not being paid) and its output level is too high, relative to the socially efficient rate of output for the good. The bottom line, when costs and prices do not include external costs, the market will not produce a socially efficient result.

External costs are not reflected on income statements of companies or in decisions of consumers. However, external costs remain costs to society, regardless of who pays for them: producers or consumers. Social costs include both: the more tangible private costs and any external costs to society, which arise from the production or consumption of a good or service. Social costs differ from private costs; for example, a producer can avoid the cost of air pollution and allow production of the company to imposes costs (health or environmental degradation) on other parties that are adversely affected by the air pollution.

The main concept is externalities, i.e. the negative effects that arise from some activity, which are not included in the cost for the activity, but which affect some third party. If the cost of such effects is not taken into account, suboptimal consumption of the commodity or service will occur. This situation was principally propounded by Pigou (1920) , and as examples, he points out that the air pollution from a factory raises the cost for laundry for the people living in the proximity, or that sparks from the railway can cause fires in surrounding woods. The concept of externalities that was introduced by Pigou (1920) further developed in the 60ies and 70ies and refers to a situation in which one party’s utility or production function depends on (real) variables that are chosen by another party without regard to the impact of that choice on the first party.

The market inability to incorporate the external costs according to Pigou’s view is a failing. Therefore, the Government should rectify the situation by taxing the activity that increases the external cost, and the polluter should pay. Pigou’s examples mainly concern effects on neighbours, even if he also expresses concerns about how natural resources are used. The main disadvantage of this line is the difficulty of how to put a value on external effects. However, Pigou lays the foundation for environmental taxes and fees, mainly by claiming that over-consumption will occur if a product/service is not priced adequately to include all costs and that the Government should intervene to rectify such situation. The guiding principle of environmental taxes is that the polluter should pay. Pigou is also a starting point for all efforts to estimate external costs for various activities.

Ownership line was introduced by Coase (1960) and criticises Pigou’s desire to internalise external cost by means of taxes. Coase instead wants to internalise external effects by taking the problem back to the parties involved. By negotiation of “allowances” to use various resources, the problems of effects between neighbours could be solved. Coase does not state who should pay since the result is the same in the end. This presupposes equal partners, apparent effects, and involved parties. The Government should not interfere; the involved parties should deal with the issue since they have the greatest knowledge of the situation, which means lower costs. The most important objections to Coase are that environmental problems affect many people, transaction costs could be high, and coming generations cannot participate in the negotiation. Still, trade in carbon dioxide emission allowances, for example, has a bearing on these lines of thought, e.g. that the involved parties have the greatest knowledge about how to tackle the problem and thus facilitate work load of the Government. The introduction of property rights for a clean environment and subsequent trading of pollution rights will induce an efficient use of pollutants. When such property rights do not exist, government intervention is required, for example through taxes, subsidies, or tradable emission permits. The biggest differences between Coase's theory and today's carbon dioxide emission allowance trading programme are that the Government regulates the emissions by putting a cap on them and that the transactions are between the causes instead of between the cause and the affected parties.

However, both economic theories refer significant market barriers and market failures that will limit the development of renewables unless special policy measures are enacted to encourage that development. These hurdles can be grouped into four categories (Li et al., 2015; Owen, 2006; Resch et al., 2008; Wissner, 2014):

1. Commercialisation barriers faced by new technologies competing with mature technologies (undeveloped infrastructure and lack of economies of scale);
2. Price distortions from existing subsidies and unequal tax burdens between renewables and other energy sources;
3. Failure of the market to value the public benefits of renewables;
4. Market barriers such as inadequate information, lack of access to capital, "split incentives" between owners and tenants, and high transaction costs for making small purchases.

More detailed characteristics of market barriers and typical measures to facilitate with them are presented in Table 2.1.

Table 2.1. Types of market barriers and measures for facilitating them (IEA, 2003)

Barrier	Key characteristics	Typical measures
Uncompetitive market price	Scale economies and learning benefits have not yet been realised	• Learning investments • Additional technical development
Price distortion	Costs associated with incumbent technologies may not be included in their prices; incumbent technologies may be subsidised	• Regulation to internalise 'externalities' 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	•Standardisation •Labelling •Reliable independent information sources •Convenient & transparent calculation methods for decision making
Transactions costs	Costs of administering a decision to purchase and use equipment (overlaps with "Information" above)	
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 organisation 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 liberalisation 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)

Because of these market barriers presented above, renewables will be unable to compete on a level playing field with conventional generation until new policies are adopted to internalize the public costs of these fossil fuel sources. Competitive issues arise at the individual level of the company, as well as across states or nations; failure to pay for external costs would provide those firms or nations with a competitive advantage over producers who are paying the external costs associated with the production of their products. Emission fees or caps on total pollution, with tradable emission permits, are examples of ways to internalize the costs of pollution, creating a more level arena for renewables. Policy makers should look for ways to make firms and consumers 'internalize' or take into account the external costs they create when they make production and consumption decisions.

A successful example of internalizing external costs due to the pricing of fuel policy and implementation of the long-term energy strategy was in Denmark. During the 1970s and 1980s, taxes were applied to fuels used in heat generation with the objective of encouraging the use of environmentally friendly energy and efficient energy utilisation. Biomass and biogas were exempted from taxes. As could be seen from Figure 2.4, the variable part of DH price was depending on taxes of fuel types.

Employment, fuel diversity, price stability, and other indirect economic benefits of renewables also accrue to society as a whole.

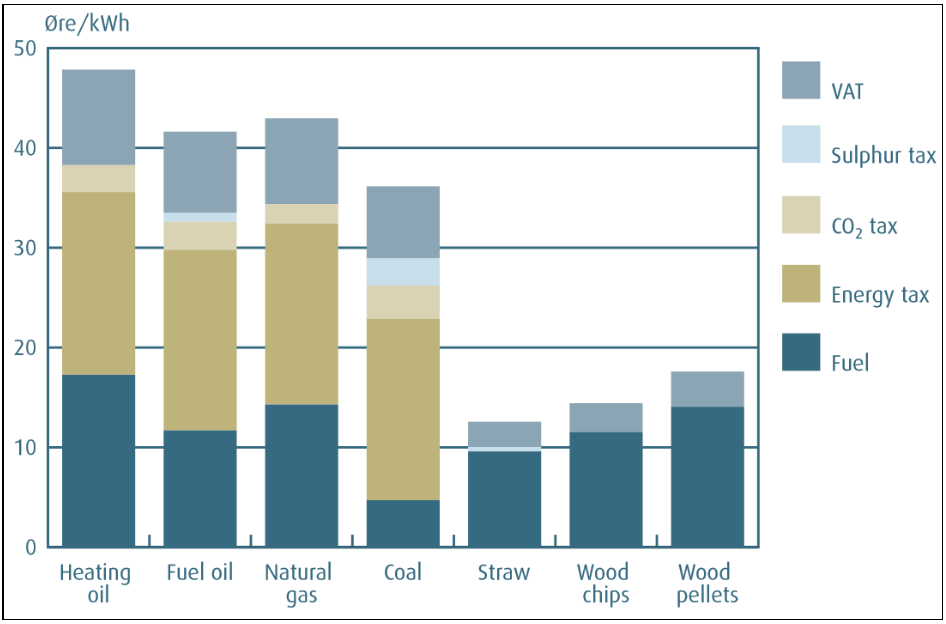


Figure 2.4. Fuel costs for district heating production in Denmark in 2002 (Danish Energy Authority, 2005)

According to Danish energy planning and state policy, oil, and natural gas had high taxes because the Danish government supported production in CHP instead of boilers and encouraged people not to use natural gas for individual heating, but to connect to DH network. Therefore the competitive price of DH occurred. The main reason was that fuel, used for the production of electricity, did not have the taxes on natural gas. Denmark continues high environmental and CO_2 taxes nowadays. In Lithuania, there are no high taxes for fossil fuel; therefore diversification of fuel sources in DH requires additional support from the state budget or EU funds.

The main conclusion is that energy and environmental taxes are based on economic theory, and they are not the artificial increase of price level. However, in the case of Lithuania, the introduction of such taxes is scarcely possible, especially in the short term. Therefore the solution is sought from the perspective of social benefit, with regard to demand of consumers.

It can be stated that reduction of external costs is associated with the promotion of renewables. The most considerable and rational measure is diversified RES integration by the use of the infrastructure of DH within the framework of cities/towns programs. This would allow successful use for the most of the measures, which are described in Table 2.1. The majority of these measures are not in the competence of DH companies, therefore these issues are the subject of strategic planning. Energy tax for the fossil fuel on the example of Denmark would be very difficult to implement in Lithuania under the present circumstances. An external cost is the category of energy economics. The complexity of assessment methods for external costs is eliminated in further PhD thesis, where the main emphasis is the use of diversified RES technologies based on external benefit.

2.2.3. Economic meaning of the evaluation of external benefit of RES

The need to support RES is defined by the shortcomings of the market, which create unequal conditions for comparability and competitiveness of various types of fuel and energy. There are several reasons why in Lithuania, as in many other countries, solar energy is used distantly. Firstly, the presumption that current situation exists not only because of the lack of economic support. The more significant reasons are a lack of organisation, gaps of public education and dissemination of knowledge in society, also too high expectations of getting the support from the state. Generally, it is operated on standard opinions that are partially right, but more important factors, which vary in time, are not considered. Knowledge is usually concentrated and presented in a narrow approach when some facts are emphasised and some are suppressed. For example, it is assumed that economic potential of energy made from solar thermal energy is poor because of the expensive technologies and inappropriate climatic conditions in Lithuania. This fact is easily denied by the countries with similar climatic conditions, where the development of solar energy is rapidly increasing next to other types of RES.

A breakthrough is noticed even in Lithuania in 2008 - 2011, especially after the feed-in tariffs for the electricity, produced in solar power plants and supplied to networks, were announced. Also, there are many examples that even without the high support from state numbers of consumers install solar energy devices. However, these facts are outside the official statistics yet.

The opportunity of the use of solar energy and the potentially huge consumer market are not getting enough attention in the Government documents. Effective support from the Government forming the basis for a competitive solar energy price is necessary that this type of energy would be used more widely in Lithuania. However, the support does not have to be in direct subsidies or other financing forms that are paid from the budget or by consumers. “Cheapness” or “expensiveness” is more psychological, varying in time concept. Moreover, both cheapness and expensiveness are temporary conceptions that strongly depend on the extent of technology implementation. For example, in Europe an evident trend of decreasing costs of solar hot water systems is observed. The price decreased by 40 % from 1995 to 2006 and reached about 870-1015 €/kW; the forecast is that the price will drop to 435–465 €/kW by 2025. Prices in Lithuania are about 725-900 €/kW at the moment.

From the point of view of RES supply, support measures for technology developers and suppliers mean compensation of social RES production costs as traditional resources are not evaluated correctly because of market errors.

From the approach to RES demand, it should be investigated correct evaluation of social benefits, which may show those advantages, which are not seen in investment decisions, e.g. inexhaustibility and possibility to ensure energy resources for future generations. RES is a wide group of energy resources, and the assessment of these resources depends on its potential, secure and sufficient supply, environmental and renewable characteristics, as well as the impact on the solution of social problems.

The economic theory explains the main reason why there is not enough demand in the market for some products and services, although they are very beneficial for the society. The reason is that the external benefit of the product or service generally is not included in the direct market operations and in prices (Klevas, 2010). It is a particularly important moment in terms of RES. The demand for RES technologies does not indicate the benefit of the society (social benefit), which is gained by using the energy produced from RES. The benefit is dispersed between different users which can be people, future generations, cities, companies. People, even if they do not participate in the market transactions, sometimes can get some product benefit for free. The external environmental benefit of using RES is probably the best example of external benefit. Therefore due to the use of RES for energy production, the negative environmental influence is being reduced, organic fuel resources are being economized, new technologies are being installed, etc. Figure 2.5 shows the curve of “green” (made from RES) energy supply S, that involves the expenditures of producing the “green” energy. The main expenditures cover machinery and equipment, new technologies, employee’s wages, and other expenditures for the training of staff, courses of qualification improvement, etc.

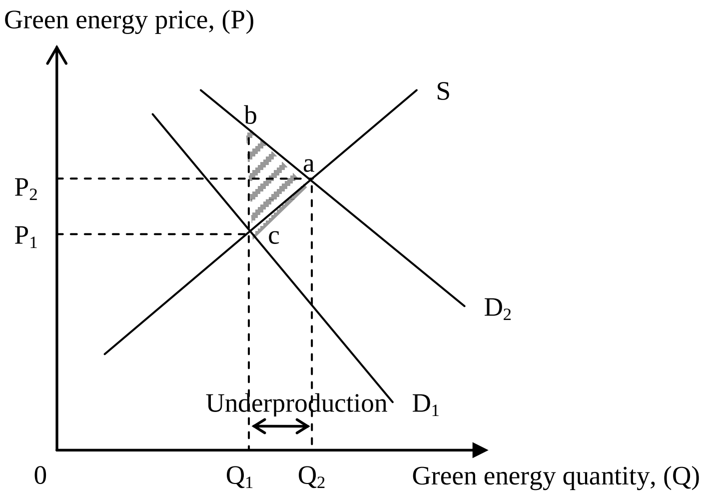


Figure 2.5. The probable influence of external benefit evaluation on RES demand

If the benefit from the „green" energy consumption is unknown or unvalued, consumers will choose the volume of purchased energy by the demand curve D_1. The "green" energy will be bought in smaller amounts than it would be economically reasonable: quantity Q_1 instead of Q_2. However, buying the „green" energy, which is made of RES, reduce the pollution to all residents. Everybody avoids diseases and other negative consequences that emerge from the polluted environment. This benefit is not included in demand D_1. The curve of demand should be D_2, where the external benefit is evaluated. The main problem is to include the benefit into the expression of economic indexes.

The marginal benefit of every additional unit of energy from the quantity of Q_1 to Q_2 exceeds their marginal production costs. The external benefit that is shown in the triangle "abc" is not realized and represents the inefficiency of the market. It should be noted that the benefit is known and declared, but this knowledge is not converted to concrete practical calculating mechanisms. However, only calculations are not enough. It is necessary to significantly increase structural changes in order to initiate the process of RES development. Especially important is that knowledge becomes the main driving force of this process.

Without the state intervention, competitive market will produce "green" energy at the point "c", where the market supply curve S crosses the demand curve D_1. The market equilibrium price P_1 will be at this point and the quantity of produced "green" energy will reach Q_1. However, if not only private but also external benefit is evaluated, the new equilibrium price would be P_2 and the quantity of produced "green" energy would increase to Q_2, where the marginal benefit is equal to the marginal costs. Social benefit is marked in the triangle "abc".

It must be emphasized that the main criterion is not the price of solar collectors and their installation, but also the price of a heating unit that is produced by a solar collector and effectively consumed. It is possible and even necessary to calculate how much the produced heat for the individual-family house or apartment buildings will cost with the chosen type of solar collector. The application of this method allows the estimation of all technical aspects of economic projections to the levelized cost of the heating unit. Initial calculations show that the increasing heat prices make the use of solar collectors for domestic hot water preparation competitive in some cities.

Moreover, if the ecological, economic and social benefit is comprehensively evaluated in a long-term period and on that basis support for consumers producing energy by using solar energy is given, the demand for advanced solar technologies would increase noticeably. These facts certainly cannot determine the choice, although it is necessary to be on a way of objective knowledge and education but not for the presentation of one side information. It is very important in the initial period when the first failures of inadequate decisions can block the way to advanced technologies that the use depends on successful examples.

The background of the research is the following conceptual statements:

- The support of state and private market participants to RES business is considered as correction of market shortcomings to solve sustainable development problems;
- Prices of all energy resources must be based on social costs with assumption that methodologically possible to justify all aspects of the use of fuel and energy: security, environmental, social, and renewability;
- RES benefit can be assessed according to real benefit now and in the future, which is not fixed in investment efficiently, with assumption that various sustainability criteria may have single denominator on single methodological background;
- Justification of RES support measures is based on the comparison of fuel and energy resources used by energy system, on competitive ability, while assessing various sustainable development aspects by a single criterion;
- RES competitive ability is evaluated not in general approach, but in specific territorial environment till certain optimal level, where marginal costs and marginal benefit of all types of energy become equal.

With regard to the definition of the guidelines for sustainable energy development in economic understanding, firstly it should be clearly evaluated current or necessary infrastructure, which is DH system, related to the used type of fuel.

Concerning support measures (Persson & Werner, 2012), they appear as burden measures, financial support, market control, and planning mandates. Burden measures include fiscal and carbon taxes for fossil fuels, giving better opportunities for DH to compete with other heating alternatives. Financial support is mainly investment grants supporting expansion. Market control and supervision may decrease the risk for market abuse, giving customers more confidence to use the technology. Planning mandates can reduce the capacity risk by harmonised extensions, since capacity in both supply and distribution must be available before connection of new customers. To sum up, policy instruments, including taxation, fees, and trading systems are means of internalising external costs.

2.3. Methodical approach to the justification of evaluation of RES development in DH including external benefits

The recommended methodical approach is divided into two basic steps. Firstly, the assessment of the technical possibility to use one or the other technology is done. Then evaluation of the utility of the particular project is done. In the first case EnergyPRO modelling tool is used, and in the second case modified Levelised Cost of Energy (LCoE) method is applied.

Methods that are used in Lithuania and foreign countries evaluate the overall national development of RES and their impact on macroeconomic indicators, based on historical data of the country (or sector). General development trends are taken into account, but benefits of individual projects remain intangible in terms of indicators, which show the economic progress of the country. In order to justify the motivation of RES sector development, it is necessary to form methods, which enable with minimal financial support to achieve maximum benefits for both the beneficiary and the state. Modified LCoE method allows analysis of the economic benefit of selected project for the investor; moreover, the results are linked with macroeconomic indicators by using external parameters. Therefore, the interpolated results might be used for evaluation of the complex effect of the impact of technology or support schemes for the wider use in cities/towns or the country.

Modelling tools for the RES integration in DH. The variety of modelling tools for the analysis of energy sector is increasing every year. According to Connoly et al. (2010) study, *a very high number of users* have the following modelling tools: RETScreen, HOMER, LEAP, BCHP, *energyPRO*. *The high number of users* (up to 1000) have EnergyPLAN, MARKAL/TIMES, *MESSAGE*, ORCED, TRNSYS16, WASP (Table 2.2). Most of these modelling tools are appropriate for modelling regional or national scenarios.

Table 2.2. Modelling tools information and the number of users in terms of downloads/sales (Connolly et al., 2010)

Tool	Organisation	Downloads/sales
Very high number of users		
RETScreen	RETScreen International	>200000
HOMER	National Renewable Energy Laboratory and HOMER Energy LLC	>28000
LEAP	Stockholm Environment Institute	>5000
BCHP Screening Tool	Oak Ridge National Laboratory	>2000
energyPRO	Energi-Og Mijødata (EMD) International A/S	>1000
High number of users		
EnergyPLAN	Aalborg University	100–1000
In*vert*	Energy Economics Group, Vienna University of Technology	100–1000
MARKAL/TIMES	Energy Technology Systems Analysis Program, International Energy Agency	100–1000
MESSAGE	International Institute for Applied Systems Analysis	100–1000
ORCED	Oak Ridge National Laboratory	100–1000
TRNSYS16	The University of Wisconsin Madison	100–1000
WASP	International Atomic Energy Agency	100–1000

Modelling tools are usually classified by the type, such as simulation, scenario-making models, equilibrium or optimisation models, as shown in Table 2.3. Top-down models usually have market equilibrium approach with higher sectoral aggregation and endogenous representation of most macroeconomic parameters like prices and demand elasticities. Bottom-up models usually have optimisation approach with better engineering/technology description and are better for policy analysis involving impact assessment of technology and fuel mix within a sector. The combination of these two approaches is called hybrid models, which incorporate bottom-up technology details within a top-down macroeconomic framework. The following table represents a review of the types of almost 40 different modelling tools, which are commonly used for energy sector analysis.

Table 2.3. Review of the types of different modelling tools (Connolly et al., 2010)

Tool	Type						
	Simu-lation	**Scena-rio**	**Equili-brium**	**Top-down**	**Bottom-up**	**Operation optimis-ation**	**Investment optimisation**
AEOLIUS	Yes	–	–	–	Yes	–	–
BALMOREL	Yes	Yes	Partial	–	Yes	Yes	Yes
BCHP Screening Tool	Yes	–	–	–	Yes	Yes	–
COMPOSE	–	–	–	–	Yes	Yes	Yes
E4cast	–	Yes	Yes	–	Yes	–	Yes
EMCAS	Yes	Yes	–	–	Yes	–	Yes
EMINENT	–	Yes	–	–	Yes	–	–
EMPS	–	–	–	–	–	Yes	–
EnergyPLAN	Yes	Yes	–	–	Yes	Yes	Yes
energyPRO	Yes	Yes	–	–	–	Yes	Yes
ENPEP-BALANCE	–	Yes	Yes	Yes	–	–	–
GTMax	Yes	–	–	–	–	Yes	–
H2RES	Yes	Yes	–	–	Yes	Yes	–
HOMER	Yes	–	–	–	Yes	Yes	Yes
HYDROGEMS	–	Yes	–	–	–	–	–
IKARUS	–	Yes	–	–	Yes	–	Yes
INFORSE	–	Yes	–	–	–	–	–
In*vert*	Yes	Yes	–	–	Yes	–	Yes
LEAP	Yes	Yes	–	Yes	Yes	–	–
MARKAL/TIMES	–	Yes	Yes	Partly	Yes	–	Yes
Mesap PlaNet	–	Yes	–	–	Yes	–	–
MESSAGE	–	Yes	Partial	–	Yes	Yes	Yes
MiniCAM	Yes	Yes	Partial	Yes	Yes	–	–
NEMS	–	Yes	Yes	–	–	–	–
ORCED	Yes	Yes	Yes	–	Yes	Yes	Yes
PERSEUS	–	Yes	Yes	–	Yes	–	Yes
PRIMES	–	–	Yes	–	–	–	–
ProdRisk	Yes	–	–	–	–	Yes	Yes
RAMSES	Yes	–	–	–	Yes	Yes	–
RETScreen	–	Yes	–	–	Yes	–	Yes
SimREN	–	–	–	–	–	–	–
SIVAEL	–	–	–	–	–	–	–
STREAM	Yes	–	–	–	–	–	–
TRNSYS16	Yes	Yes	–	–	Yes	Yes	Yes
UniSyD3.0	–	Yes	Yes	–	Yes	–	–
WASP	Yes	–	–	–	–	–	Yes
WILMAR Planning Tool	Yes	–	–	–	–	Yes	–

EnergyPRO by EMD (EMD International, 2011) modelling software has been used for the technical analysis of potential RES diversification options in DH system; it allows carrying out comprehensive and detailed analyses of energy projects. EnergyPRO is typically used for techno-economic analysis of simulating cogeneration plants and DH systems with multiple energy producers (Fragaki & Andersen, 2011; Rasburskis & Lund, 2007; Streckienė et al., 2009). Other types of projects, e.g. solar collectors and heat pumps, can also be analysed and detailed within the software (Nielsen & Möller, 2012). EnergyPRO provides the user with a detailed financial plan in a standard format. This includes the presentation of the operating results for the project, monthly cash flows and key investment figures such as Net Present Value (NPV), Internal Rate of Return (IRR) and Payback Time (EMD International, 2011). The reason for choosing energyPRO is its ability to model large-scale solar thermal production and to connect DH network. Moreover, energyPRO has an extensive database of hourly data for ambient temperature and solar radiation in different locations of Lithuania.

EnergyPRO evaluates characteristics of the solar collector and its inclination and orientation to the sun, accurately models the hourly amount of produced heat. The formula for a solar collector is as follows:

$$Y = A \cdot \left(\left(I_{beam} \cdot K_{\theta} + \left(I_{diffuse} \right) \cdot K_{60^{\circ}} \right) \cdot \eta_0 - a_1 \cdot \left(T_m - T_a \right) - a_2 \cdot \left(T_m - T_a \right)^2 \right) \qquad (1)$$

where: Y - heat production, [W]; A - solar collector area [m^2]; I_{beam} - beam radiation on a horizontal plane, [W/m^2]; K_{θ} - incidence angle modifier; $I_{diffuse}$ - diffuse radiation on an inclined plane, [W/m^2]; T_m - solar collectors average temperature, [^{o}C], that is an average between the temperature of the cold water entering the collector and the hot water leaving the collector; T_a - ambient temperature, [^{o}C].

The efficiency of the solar collector is defined by three parameters: η_0- intercept (maximum) of the collector efficiency, [-]; a_1 - the first-order coefficient in collector efficiency equation, [$W/(m^2\ ^{o}C)$]; a_2 - the second-order coefficient in collector efficiency equation, [$W/(m^2\ ^{o}C2)$]. The radiation is split into beam radiation and diffuse radiation. Since the diffuse radiation per definition has no incidence angle is used the incidence angle modifier or K_{θ} at 60^{o}.

The use of EnergyPRO modelling tool gives a deeper insight into the use of solar collectors, based on hourly solar radiation and outside temperature. Unfortunately, it shows only classical economic indicators (NPV, IRR, Payback time). For more detailed economic analysis there is a need of unified tools. LCoE might be one of the suitable tools for the comparison of different RES price based on economic assumptions.

Economic analysis with the use of LCOE method

Economic evaluation and the decision-making process are two separate but mutually influencing activities and that the evaluation needs to start at an early stage of the decision-making process in order to be effective. Impacts related to the three dimensions of sustainable development are not captured completely.

Economic evaluation of environmental effect will provide a set of quantitative and qualitative evaluation variables on both positive and negative impacts, that will guide and support policy-makers in taking decisions.

Analytical methods used for environmental effect assessment are usually cost-benefit analysis, cost-effectiveness analysis or multi–criteria analysis. Other methods are also available, such as risk analysis, LCoE, etc.

The first step should be an economic evaluation of environmental effect before the comparison of costs and benefits of a particular project. Social sciences could develop methodologies to manage large multi-disciplinary groups of stakeholders.

Figure 2.6 presents available tools and methods for the economic evaluation of environmental effect.

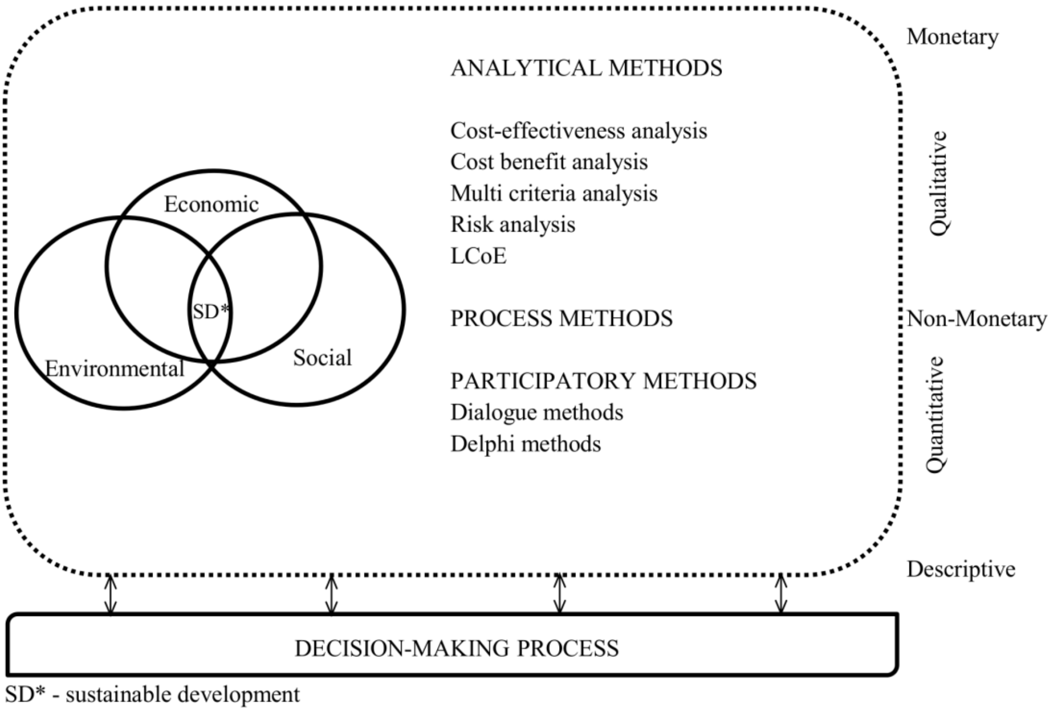


Figure 2.6. Economic evaluation of environmental effects

Cost-benefit analysis entails the monetization of all (or the most important) costs and benefits related to existing public intervention or all viable alternatives at hand. Cost-benefit analysis is mostly used during the appraisal stage of a new intervention. In its most recurrent form, it disregards distributional impacts and only focuses on the selection of the regulatory alternative that exhibits the highest net benefit. Accordingly, the most common methodology in cost-benefit analysis is the "net benefits" calculation, which differs from the "benefit/cost ratio" method that is typically used in cost-effectiveness analysis (being benefit minus costs, rather than benefits divided by costs).

Multi-criteria analysis is a technique to reach a judgement based on an explicit set of objectives and associated criteria. Typically, the multi-criteria analysis will be used to assess and rank alternative options in an impact assessment, or to assess the extent to which a variety of objectives have or not been met, in a retrospective evaluation or fitness check. For example, the criteria chosen could include the impact on the enterprise, the degree of protection of fundamental rights, consumer protection, etc. Multi-criteria analysis is particularly useful when impact assessment has to be reconciled with specific policy objectives, and as such is used as an instrument of ensuring the simultaneous assessment of effectiveness, efficiency, and coherence of policies.

Cost-effectiveness analysis entails that you quantify (not monetize) the benefits that would be generated by one Euro of costs imposed on society. While cost-effectiveness is closely related to cost-benefit analysis, instead of monetised benefits it uses other measures, such as increased life expectancy, educational attainment, emissions abated, etc.

The risk analysis which is inherent in various estimates of costs and benefits should be explicitly recognised and quantified as far as possible as it may have an important bearing on the judgment as regards both the performance of public intervention and ranking of policy options in impact assessments. The influence of the key variables should be investigated by a sensitivity analysis. These variables should be allowed to vary in order to test the robustness of the final and should be linked to the drivers of the problem identified in the problem definition.

Levelized cost of energy (LCoE) is a widely used approach for the comparison of different energy generation alternatives. It is based on the principal that present value of total life–cycle cost is calculated considering the chosen discount rate and then it is allocated per one unit of energy. The LCoE approach is useful to assess the competitiveness of different energy generation options, possible gains for the project developer, and also it helps to make insights into macroeconomic effects (after external data are evaluated). LCoE is the price of energy which has to be set that at the chosen (stated) discount rate, which is equal to capital price, all discounted expenditures are equal to income, and the net present value equals to zero. The general idea of LCoE might be described as the following simplified formula:

$$LCOE = \frac{\text{Lifecycle cost}}{\text{Lifetime energy production}} \quad (2)$$

LCoE is used in the different case studies in largest solar district heating online database (www. http://solar-district-heating.eu). Furthermore, LCoE method enables comparison of existing heating price with alternatives of natural RES, and integration of external benefit effect. This method is appropriate because all main criteria can be concentrated in it, such as NPV (equal to 0) and IRR. The main advantage of this indicator is the possibility of comparison to the competitive price of energy in the market. LCoE shows that the project will have, for example, 10 % IRR (that is determined), if the price of DH (or any other producer/supplier) is not lower than the price that is calculated by the formula:

$$LCOE = \frac{\sum_{i=1}^{i=n} \frac{\left(I_i + O\&M_i - Z_i\right)}{\left(1+r_n\right)^i}}{\sum_{i=1}^{i=n} \frac{G_i}{\left(1+r_n\right)^i}} \qquad (3)$$

where: I_i – capital investments; $O\&M_i$ – annual operational and maintenance costs; Z_i – external benefit of renewable energy (could be negative); n – years of lifetime; i – serial number of the year; G_i – yearly amount of produced and consumed energy; r_n – stated periodic discount rate (discount rate for RES can be lower than for fossil fuel).

Factors that should be considered when analysing LCoE of solar collectors in DH sector are shown in Figure 2.7.

Costs:

- Initial investment or capital cost
- O&M and operating expenses
- Financing costs
- Income taxes
- Property taxes
- Required return on investment

Incentives:

- Incentive revenue

Energy:

- Estimated yearly production
- Annual degradation

Figure 2.7. Factors for the calculation of LCOE

The extended approach of LCoE allows assessing the effect of all currently existing RES support schemes on energy cost. It also enables to compare LCoE and evaluate the investment attractiveness for the investor together with a possible effect on the goals of customers and / or countries.

This method is suitable for the evaluation of a wide spectrum of different options. The result obtained, for example, 1 kWh levelised cost of heat can be compared to officially confirmed DH price, and the feasibility of a project can be decided. The LCoE can be calculated by any of energy development scenarios of the analysed object (multifamily building, house, city, district, etc.). Therefore this method is used to investigate the comparison of diversified RES with the existing DH price.

LCoE is one of the most popular approaches for comparison of different energy generation alternatives on an equal basis. The LCoE is used to assess the competitiveness of different energy generation options, quantifying possible gains for the project developer. The LCoE approach gives an opportunity to quantitatively assess the influence of certain RES support measures on the cost of energy production.

2.4. Formation of system of preconditions for DH integrating into the city sustainable development context

2.4.1. Concept of external benefit for RES technologies

Sustainable energy development, as has been described earlier, means energy production and consumption, which ensures state's and society's long-term aims consistent with social, economic, and environmental dimensions. In other words, this is a reliable energy supply at an affordable price, which causes as the low negative impact on the environment as possible.

RES are more evenly spread in the world compared to organic fuel resources, however, a range of factors (such as competing for land use, environmental restrictions in the area, period of solar and geothermal energy installations) limit the economic potential of natural RES in DH sector. Support for RES is required to promote wider use of renewable energy. Energy market failure is a serious obstacle to promoting development of natural RES in DH sector. The external positive benefit of using RES as a public goodness is not evaluated. These issues are described in more detail in the second chapter. The external benefit is related to the introduction of new technologies, their development, and positive impact on the environment. Subordinating market mechanisms, reducing renewable energy adaptation costs, increasing competitiveness in the market and promoting of development are required to overcome the aforementioned market failures and other market barriers. Therefore subsidies for natural RES can be applied or obligatory purchase quotas for energy produced from natural RES can be introduced in DH sector.

The market does not ensure financing of long-term research and development. New energy technologies are permanently impacted by barriers in all stages of energy innovation chain (from research and development to dissemination of demonstration projects, dissemination of information and technologies).

However, an approach disclosing the principles for assessment methods of research is required. Figure 2.8 shows the distribution of benefits from RES utilisation from consumer's point of view.

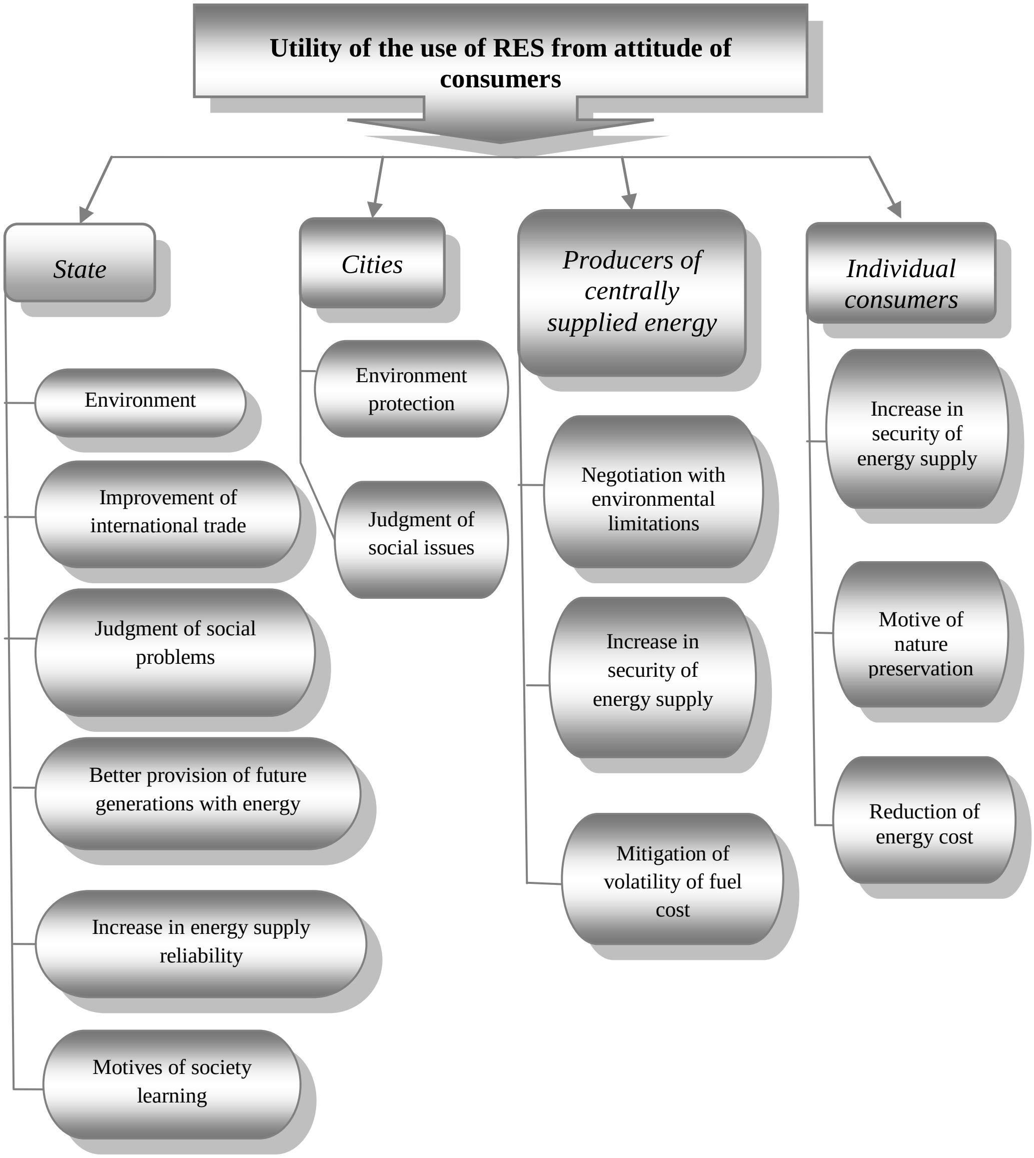


Figure 2.8. Utility of the use of renewables from attitude of consumers

RES have the potential to provide energy services with zero or almost zero emissions of both air pollutants and greenhouse gases. In addition, the greenhouse gas abatement due to a more intensive use of RES would contribute to the achievement of the EU targets, which are related to climate change.

Statistical methods based on the historical data of selected sectors could be used for assessing the development of natural RES and their impact on the macroeconomic indicators. This general trend could not provide deep insight on the actual impact of parameters of a single project. Following general trends can leave benefits of the individual project invisible to the macroeconomic indicators of the country. They neither provide any tools nor techniques enabling optimisation of RES sector development or introduction of support measures for maximizing the macroeconomic benefits with minimum resources. Such assessment is inseparable from the microeconomic analysis of the project chosen by the individual investor (taking into account the economic benefits for the developer), using the external parameters, affecting the macroeconomic indicators. Results obtained in a single project can be interpolated to assess the possible impact of the support scheme on a national level.

2.4.2. Evaluation of external benefit in city programs simultaneously realizing national strategic commitments of RES and environment

A methodology based on the concept that it is a measure to evaluate the energy state and to outline assumptions for prospective planning. There is a misconception that it could be achieved by a single or uniform method and indicator (Klevas, Biekša, Klevienė, Bubelienė, & Stankevičius, 2010). The methodology of municipal energy development can link national policy of sustainable development to local relevant issues. The scenario of local energy development starts from a strategic idea, which establishes links between strategic national and local goals. Municipal energy development enables the municipality to give shape to sustainable, realistic aims within a clearly defined structure. Establishing a local or regional market rather than separate renewable energy projects could help to ensure a market of a sufficient size and enhance competition (Klevas, 2010).

Sustainable development emphasises the integration of economic, social and environmental priorities, and wide participation of stakeholders in the development process. The contemporary concepts of strategic planning can be summarized in three general principles:

1) country ownership and commitment, which implies that the planning processes and targets should be based on a perception of country and what constitutes to its national strategy for sustainable development;

2) comprehensive and coordinated policy process, which means that an effective strategy must be based on reliable information and draw on valid analyses of the likely outcomes of chosen strategy options;

3) targeting, resourcing and monitoring, which are concerned with the measurement and monitoring of development outcomes (Cherp, George, & Kirkpatrick, 2004). In order to know how a society or a process is doing with respect to sustainability, it should be measurable (Özdemir, Härdtlein, Jenssen, Zech, & Eltrop, 2011).

The methodological approach is suitable for sustainability assessment using regional social-economic-environmental indicators, such as increasing of security of energy supply, new jobs, new enterprises, additional economic product, and greenhouse gas reduction (Klevas, 2010).

A strategy for sustainable development comprises, therefore, a set of processes, which seek to integrate the economic, social and environmental objectives of the society. It does not necessarily involve a development plan covering a fixed period of time, nor does it require a separate planning process. The observed strengths of strategic planning in countries in transition included recognition of the social, environmental and economic pillars of sustainable development, high level of governmental ownership, and strong analytical foundations for developing the strategies. The weaknesses included the lack of integration between different themes and sectors, as well as between the local, regional, and national levels of planning, the absence of processes for finding trade-offs and establishing priorities, and ineffective public participation (Cherp et al., 2004). Three issues can be highlighted as the most important for planning success purposes: community participation, interdisciplinarity, and SWOT methodology (Terrados, Almonacid, & Hontoria, 2007).

Lithuanian National Strategy of Sustainable Development (2003b) was adopted in 2003. This strategy includes 6 branches of the economy (transport, industry, energy, agriculture, household, tourism), 4 environmental sectors (air, water, biodiversity, and waste), 4 main social aspects (employment, poverty, and health, education, cultural identity), and regional development issues. All these economic, social, environmental and regional development issues are presented in close integrity. Sustainable development indicators for economic, social and regional development and state of the environment are selected in the strategy for the monitoring of sustainable development; however, this system of indicators was not applied for the analysis of trends and only some targets of sustainable development were set using these indicators (Klevas, 2010).

Division of responsibilities between the central level (government, ministries) and the local level (municipalities of cities) in relation to areas mentioned in the municipal energy plans and strategies may be relevant. In the case of Denmark, local level should implement municipal heat planning in combination with an e.g. strategic municipal energy plan. Local subsidy and tariff schemes that accelerate connection of buildings to DH should be implemented. Also, municipal utility companies as key players must be involved in implementing energy savings in the DH network (R Čiegis & Štreimikienė, 2005).

Figure 2.9 shows how the use of diversified RES affects the sustainable development of DH. The main goals of sustainable development could be implemented in DH by the use of natural RES and dealing with municipal waste. There must be a legal obligation to organise sustainable development of energy at national level distributing indicators at local (cities, districts, regions) level. The only solution in this direction till now was formed DH companies' prospective plans, but they are departmental and not related with common cities or towns, also rural energy problems and possibilities.

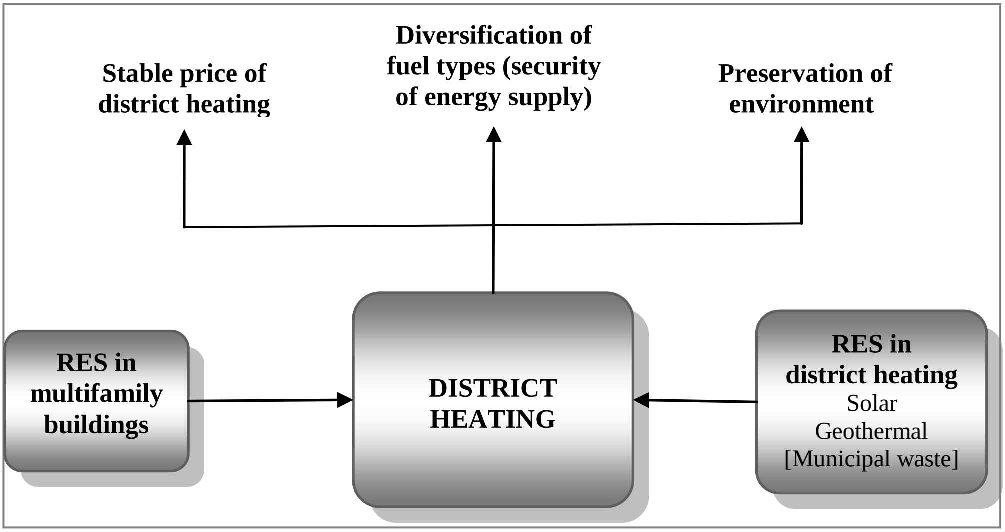


Figure 2.9. Concept of sustainable development of DH by the use of diversified RES

Implementation of the national strategy of sustainable energy should be based on the division of responsibilities that are related to the greater extent of RES and increase of energy efficiency between regions and institutions (Sperling et al., 2011). 2007-2013 Structural Funds programming period was critical in the practice of sustainable energy implementation (Klevas et al., 2010). The next Horizon 2020 period should focus on the region and local sustainable energy programs as a whole.

DH systems have big differences in cities and in towns. In cities, the greater part of heating systems are related with comfort (district heating, electricity or gas heating). In rural areas and small towns dominate boilers of solid fuel and stoves that use local energy sources. Social evaluation of energy sources is one of the most difficult economic problems because the solution is related to indirect and still non-standard evaluation. This is energy saving, an increase of energy efficiency that result in positive social effect. The amount of saving heat is the amount of energy that is replaceable by investments for a long time. This also means abatement of air pollution and solves the question of spending for social needs and health care. Economic evaluation of heat plants is possible just in the concrete environment and can significantly differ in different cities regarding many factors (Klevas et al., 2010).

The absence of a united methodology for the sustainable development of DH, strategic planning processes, and non-standard evaluation of it still is a significant problem that needs further discussion.

DH technology is a promising tool for implementing RES technologies on the supply and demand sides and consequently achieving energy and environment policy goals. DH has various advantages compared to individual heating systems. It is usually more energy efficient due to the simultaneous production of heat and electricity in combined heat and power generation plants, and more flexible for the various fuel sources. However, DH is less attractive for areas with low population densities. Cansino, Pablo-Romero, Román & Yñiguez (2011) emphasises that the importance of DH in EU would justify a more intensive use of RES applied to this type of heating system, and must be considered in the design of energy policies.

The European Union is one of the most active developers of RES promotion methods and support measures. Its initiatives expressed in the Directives to increase the percentage of renewable energy resource in the common energy balance up to 20%, to reduce energy consumption by 20%, to reduce greenhouse gas emissions by 20% up to 2020 would lead to a drastic reduction of EU energy dependence on import.

DH in Lithuania takes a considerable part of the heat market, especially in larger cities; it reveals an important role in the energy supply of cities. DH systems have been developed during the planned economy era. These systems due to energy pricing policy have not always been economically justified. Therefore transition to conditions of the market economy has caused problems for heat suppliers, especially after disconnection of the majority of industries. Designed pipelines became too large in diameter of the current heating demand, which resulted in large heat losses. For example, Gudzinskas and Jakubčionis (2010) showed that due to this reason the heat losses began to significantly rise after renovation (modernisation) of multifamily buildings and energy saving initiatives. Although the process of renovation gains momentum, indicated problem will become more relevant, but a continuation of DH systems is necessary in order to keep air quality in cities (especially during winter time), and to solve social and environmental problems. Demolition of DH systems, as it has happened is some cities, is not the relevant solution. Kveselis, Dzenajavičienė, & Masaitis (2011) observe that considering European energy policy and objectives, it is evident that the DH will remain the major energy-supplying technology for buildings in larger cities and towns.

It should be emphasised that the DH infrastructure is one of the most important preconditions for a broader use of renewable, local resource, and waste energy on a large scale.

The encouragement of energy producers and consumers for efficient use of RES is the major goal of energy policy, as regulated by the Energy Law of the Republic of Lithuania and National Energy Independence Strategy. Promotion of the use of local and RES, as well as energy efficiency are established in the Energy Law of the Republic of Lithuania as priority objectives of the energy sector regulation. Seeking to promote the use of RES, the Ministry of Economy has issued an order for regulating energy purchase.

As IEA (2010) pointed out, RES will have to play a central role in moving the world towards a more secure, reliable and sustainable energy path. The greatest scope for increasing the use of RES in absolute terms lies in the energy sector. Although RES are expected to become increasingly competitive as fossil-fuel prices rise and renewable technologies mature, the scale of government support is set to expand as their contribution to the global energy mix increases. The important role gains national and international regulation of RES.

The forecasts of Lithuania reveal that biomass is the main opportunity for implementation of these plans by 2020 (Table 2.4). It should be noted that the attention for the potential of solar and geothermal energy is inadequately small. Solar energy is a very important RES. However, it is assumed that economic potential of solar energy in Lithuania is rather limited due to its expensive technology and unsuitable climatic conditions. On the other hand, this approach is not entirely justified, because in Lithuania the annual average solar energy is about 1000 kWh/m^2, while in southern Germany – 1260 kWh/m^2, and in northern Germany – 970 kWh/m^2, which means that the climatic conditions for solar energy in Lithuania are similar (LR Ministry of Energy, 2011).

Table 2.4. RES in Lithuania 2009 and projection in 2020 (LR Ministry of Energy, 2011)

RES	2009, ktoe	2009, %	2020, ktoe	2020, %
Solar energy	0	0	1	0
Wind	14	2	99	5
Hydro energy	37	4	59	3
Biofuel	53	6	188	9
Geothermal	5	1	20	1
Biomass	763	88	1626	82
Total	872	100	1993	100

*ktoe – kilotonne of oil equivalent

The analysis of the use of RES dynamics in Lithuania revealed that Lithuania has a relatively high RES potential. The main RES is biomass. However, alternative energy sources are not used sufficiently. In order to increase the use of RES in Lithuania and to pursue the obligations to EU, it is essential to determine the causes that influence the slow development of renewable energy and to identify the main RES utilization problems.

The major part of RES that is used to generate energy in DH sector consists of wood biomass. It is essential to increase the collection of logging residues and to improve the technologies of growing energy crops by substantially expanding the use of biomass resources. However, there are different opinions: the resources of biomass are limited locally; the major part of costs consists of the collection and preparation of biomass for the use. The price of wood that is used as biomass, usually of the kind that is suitable for the construction and the production of furniture, is rising because of the competition. The cost of the collection and preparation of non-merchantable wood is exceptionally high. It is illustrated by the fact that currently a large amount of non-merchantable wood is accumulated, because it is considerably cheaper to make chips from logging than to handle, bundle, and transport the residue of logging.

In most cases, with a few exceptions, the use of natural RES (such as solar collectors) is possible only in conjunction with other energy sources. The comparison of different fuel sources on the basis to supply the entire volume of supply is incorrect.

It can be stated that the potential of the use of solar energy could be considerably larger in households that are in the area of the DH system. Moreover, the use of solar, geothermal, and waste energy potential could be significantly higher in DH systems.

Different generating technologies of DH have a number of benefits. These include energy security, job creation, and long-term price stability. Furthermore, after reliable methodological evaluation of positive impact, the integration of RES could be more successful for solving economic, social, rural development problems in a regional development context. Levelized Cost of Energy method could be used for the future evaluation of how to implement the objectives of the state programs.

Responsibility for fulfilling the Renewable Energy Directive goals lies at the national level, while responsibility for DH is often split between national, regional and local bodies. Principal scheme of diversified RES integration in DH is shown in Figure 2.10.

The principal scheme represents DH as the central infrastructure. Integration of RES on the demand and supply sides of DH may help to reach the state's long-term goal of energy security, energy efficiency, and social problems, which are key elements of external benefit. The important criteria that must be taken in the long-term energy planning are shown on the right. Incorporating externalities into long-term RES energy policy that should be based on continuing researches and development could increase the possibility of developing the economical and sustainable DH system from a societal perspective. The most important role is given to the municipalities, which might use the cities' programs for realising national strategic commitments of RES and environment.

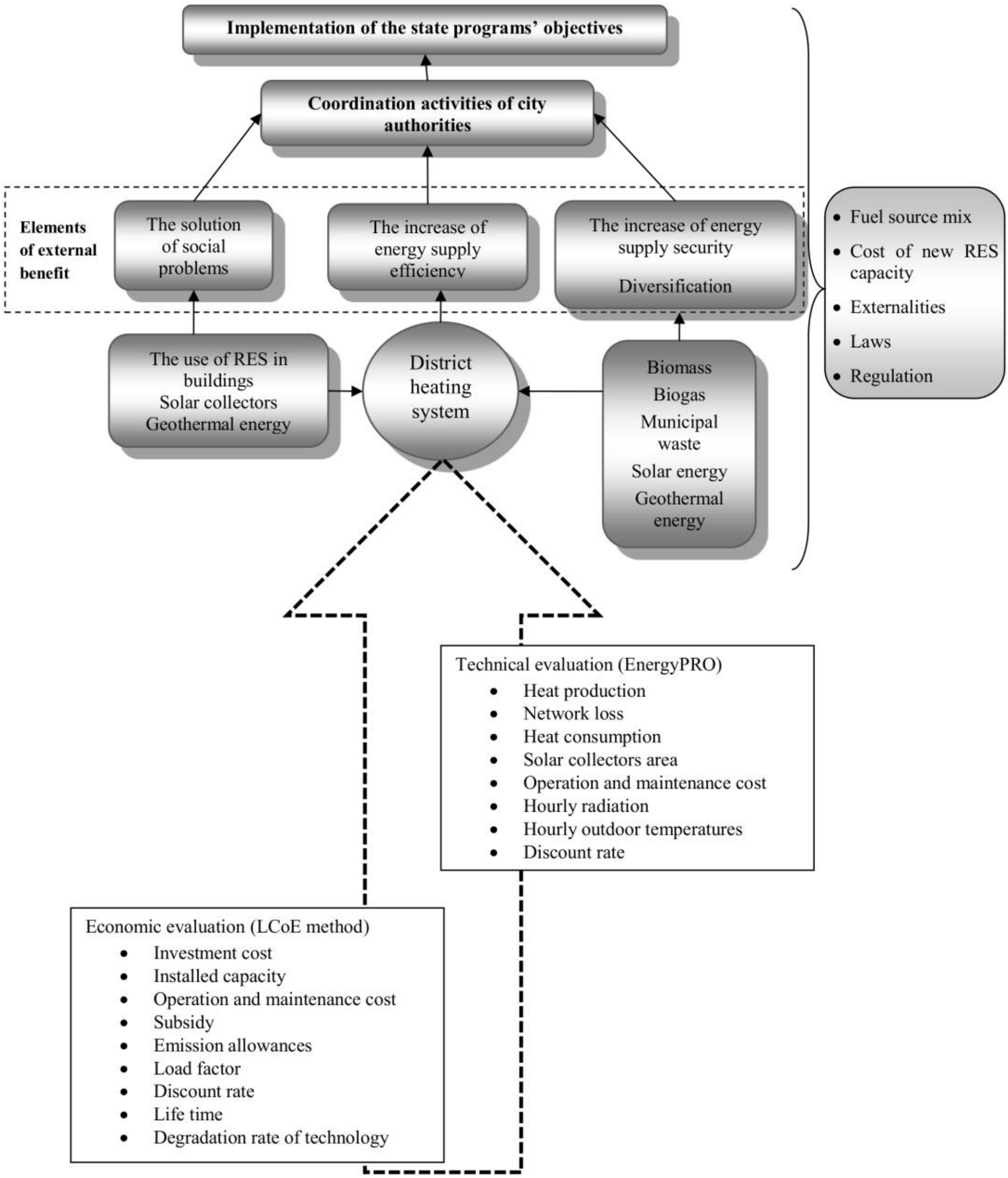


Figure 2.10. Principal scheme of diversified RES integration in DH

3. IMPLEMENTATION OF DIVERSIFICATION CONCEPT OF RENEWABLE ENERGY SOURCES IN INFRASTRUCTURE OF DISTRICT HEATING

Implementation of diversification concept of RES in infrastructure of DH is comprised of verification of selected technical and economic evaluation methods on particular city and the whole of theoretical insights and economic preconditions.

Wide use of RES has many aspects, most important of them are not what measures are used, but what theoretical and motivation background are applied for these measures. On the other hand, it is also evident that not all types of RES and incentives are equivalent. Individual investors are not interested in the consequences that are caused by their activities. State policy theoretically should be focused on the far-sighted balancing of all potential resources. Municipalities probably could realize the objectives of the state, but there is a need to focus on the existing infrastructure. Such infrastructure is electricity and DH networks, and in perspective smart grid technologies that are capable of significantly expansion of the RES utilisation scale.

This chapter is intended for possibilities of diversification of RES technologies (based on the example of solar and geothermal energy) on the demand and supply sides in DH infrastructure. DH infrastructure is suitable for reaching strategic energy goals: the integration of RES into energy supply infrastructure and safety of energy supply by increasing independence from imported energy resources. In order to increase the use of RES in Lithuania, it is essential to determine the causes that influence the slow development of diversified RES and to identify the main RES utilisation problems. The main problem is concentration on only one RES resource (biomass) and lack of diversification in fuel sources of RES. Possibility of different options for the use of more diversified RES, as well as multifamily building renovation, and comparison of different options at unified basis is analysed. The comparison method was used to justify the possibility for the use of diversified RES, such as solar collectors and heat pumps, on DH system's demand and supply sides. Therefore, the case of the use of large scale solar collectors for DH supply during summer time in particular city in Lithuania is analysed. Moreover, diversified RES sources on DH demand side in multifamily building Varėna was calculated on different intensity of possible support schemes by LCoE method.

Significance of DH as an infrastructure for the promotion of RES is undoubted. The lack of diversification of RES in DH sector requires specific attention because natural-gas based production of heat at the moment is transferred to only biomass-based production. Therefore research on diversified RES, such as solar collectors and heat pumps, are presented in the next sections.

3.1. Possibilities to use technologies of solar and geothermal energy in the context of city/town sustainable development program

The main scheme of the evaluation of diversified RES technology could be described in several steps. Firstly, EnergyPRO method is used for the technically possible opportunities and prerequisites for economic competitiveness while integrating RES into DH system on the demand and supply sides. This basis is used for the preparation of a set of possible individual projects, which could be potential elements of DH modernisation. Secondly, these individual projects are evaluated by LCoE method according to external benefit on the state and town level, in accordance with elements of external benefit that are difficult to evaluate. Finally, on the basis of individual and external benefit short-term and long-term prerequisites are constructed for diversified RES integration into DH system within cities/towns programs. City or town current and prospective problems are different; therefore solutions could not be unified and applied on the single basis.

3.1.1. Characteristics of district heating system in particular town

The particular city of Varėna is chosen for further detailed evaluation of possible integration of diversified RES. National Commission for Energy Control and Prices has issued a licence L4-ŠT-35 for „Varėnos šiluma“, UAB in 2004. The licence gives the right to supply heat on the basis of ownership or other legal grounds for controlled heat transfer networks in the territories of Varėna District Municipality that are composed of Varėna town, the village of Matuizos, and railway station of Valkininkai.

The company has 25 shareholders with 913,166 shares. The value of one share is LTL 10. The main shareholder of the company is municipality, which owns 908,157 shares (99.45%). Other shareholders are current or former employees of the company.

"Varėnos šiluma“, UAB thermal energy is supplied for space heating and hot water production. Boiler house in Varėna town was built in 1971. The average age of heating water main pipeline routes is 25 years. The network is operated until now, only a few sections are renovated. The total length of pipelines is 20 071 meters. In 2013 the project "Modernization of the heat supply infrastructure in Varėna" was implemented. The project has renovated 1458.56 m of old heating network. The largest consumer of domestic hot water in Varėna is a residential sector and a number of public places, consuming domestic hot water: Varėna hospital, clinic, two secondary schools, childcare facilities, etc.

Production of DH

Heat for Varėna city's consumers is produced for heating and hot water and supplied by a single central boiler house, which is built on the eastern outskirts of the town (address: Basanavičiaus g. 56, Varėna). Fundamental scheme of boilers in Varėna town is provided in Table 3.1.

Table 3.1. Heat production units in Varėna town

No.	*Boiler*	*The nominal design capacity*	*Fuel*	*Status of boiler*
1.	DKVR-10/13	7.5 MW	Fuel oil	
2.	DKVR-10/13	7.5 MW	Fuel oil	Mothballed
3.	DKVR-10/13	7.5 MW	Fuel oil	Mothballed
4.	KVGM-20	23.3 MW	Fuel oil	
5.	KVGM-20	23.3 MW	Fuel oil	Dismantled
6.	DE-25	9.0 MW	Biomass	
7.	Kaistra 7000	7.0 MW	Biomass	
8.	VHB 4100	4.1 MW	Biomass	Constructed instead of KVGM-20 boiler
Total:		***50.9 MW***		

The main devices of heat generation (see Table 3.1): three steam boilers DKVR-10/13, two water heating boilers KVGM-20, working in fuel oil; steam boiler DE-25, completed with a wood burning furnace; 7 MW water heating boiler Kaistra 7000 with a wood burning furnace. The main fuel for boilers is biomass. New 4 MW wood-fired boiler with a condensing economizer together is finished.

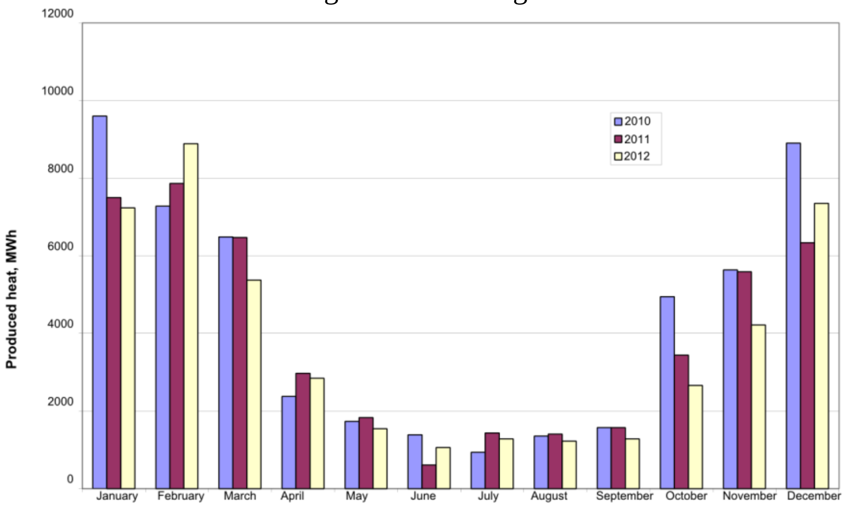


Figure 3.1. The amount of heat produced in the boilers in 2010-2012

Heat demand during heating season is produced by DE-25 Kaistra 7000 boilers, which use biomass as a fuel. Steam boilers DKVR-10/13 are used only for peak load (two of the three boilers are mothballed). KVGM-20 is one of the boilers, which can be produced within the coldest period.

Consumption of DH

„Varėnos šiluma“, UAB has 195 consumers (in Varėna town DH network). In 2012, the company realized 43.71 thousand MWh of thermal energy; from this number 31.36 MWh consumes residential buildings and 12.35 MWh commercial and budgetary institutions. Distribution of realized heat energy by the nature of consumption in presented in Figure 3.2.

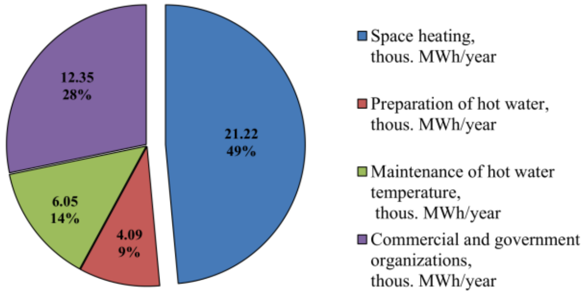


Figure 3.2. Realized amount of heat energy

Heat density of the town is concentrated in several places. Most of the heat energy is consumed in the western and southern parts of the city. The biggest concentration of large users is between Dzūkų and Vytautas street, where the buildings standing total thermal capacity of 11.5 MW, representing 42% of the urban heat flow demand.

The analysis of the data in Figure 3.3 shows that decreasing of technological losses during the 2010-2012 period in the boilers is needed to produce less heat, and the amount of produced heat is about 45 thousand MWh at the end of the period. Heat supplied to a network was about 42 thousand MWh of heat, and heat sold to consumers about 37 thousand MWh. It should be noted that the company's technical-economic indicators in particular have improved after modernization of peak load heating systems of the heating oil tank instead of steam for the use of heating water.

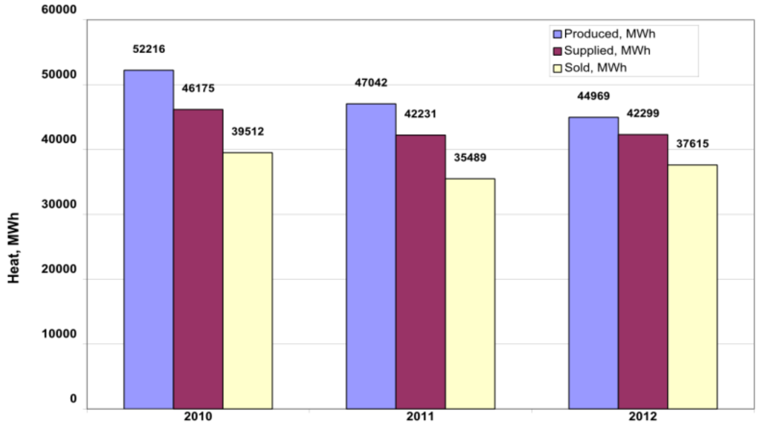


Figure 3.3. Heat losses in production and network in 2010-2012

The dynamics of the losses in the grid is presented in Figure 3.4. The graph shows that the heat loss in Varėna town network during the period 2005-2012 decreased significantly by more than 3 times, from 37 percent to 11.4 percent.

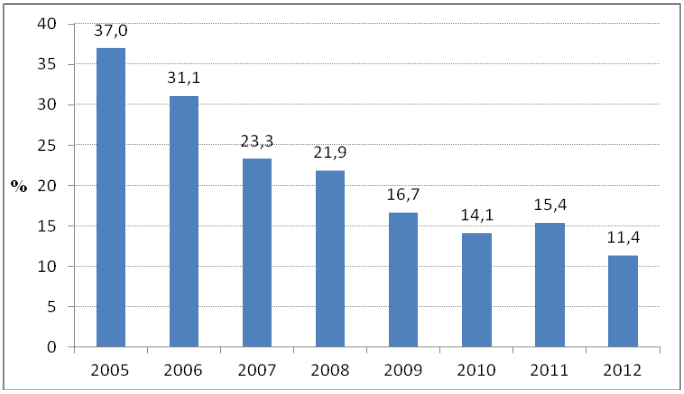


Figure 3.4. Dynamics of heat loss in 2005-2012

DH network of Varėna town is circular, and all major networks are reserved. This provides a high security of heat supply. In case of an accident at any stretch of the heat network, only the insignificant part of consumers feel the heat supply disruptions, but the whole system remains functional. Plan of Varėna DH network is presented in Figure 3.5.

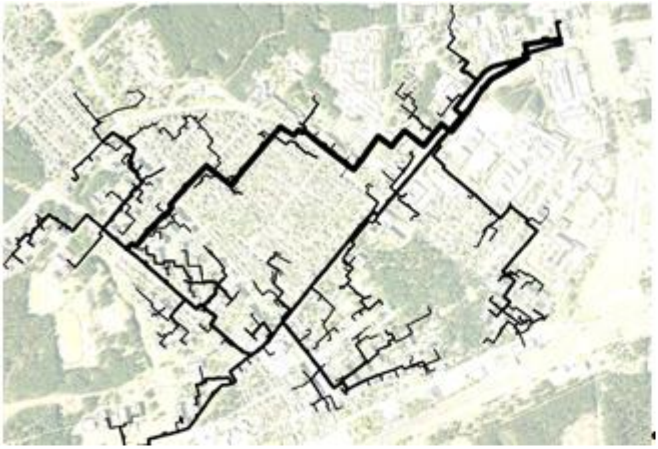


Figure 3.5. District heating network in Varėna town

3.1.2. Evaluation of the use of solar energy for the preparation of hot water in DH system on the example of particular town

Prerequisites for the formation of scenarios

Large scale solar collectors are widespread in Denmark, more than 70 large scale solar collectors' field exist in 2016 (Appendix 1). Online map data may show how effective are solar collectors at the moment (Appendix 2). However, Lithuanian enterprises of solar collectors, which offer information on available prices and the required area of solar collectors, could not be collected through the survey method because of the large scale of the project, which has not been implemented in Lithuania yet. As a result, the initial calculations presented in Appendix 3-5, were carried out with a Danish calculator „f-EASY (SDH)", on the basis of „Varėnos šiluma", UAB data.

Appendix 3 shows preliminary calculations, which are necessary for the solar collectors „Varėnos šiluma", UAB delivered thermal energy. It is amounted to 42.3 thousand MWh and based on real data in 2012. Calculation program „f-EASY (SDH)", designed by Danish company PlanEnergi, estimated 10000 m^2 area of solar collectors, which investment would be approximately 3.3 million euro. These data will be used for future solar system modelling with EnergyPRO 4.2 software.

A calculator „f-EASY (SDH)" estimated 10000 m^2 of solar collector system in practice has already been implemented in Denmark, Torring city. The details of the project, which will be used as a basis for further calculations, is presented in Table 3.2.

Table 3.2. Example from Tørring, Denmark (http://solar-district-heating.eu/)

Solar collectors	10 000 m^2
Cost of land (30 000 m^2)	80 000 euro
Solar collectors (10 000 m^2), pipes, pumps, antifreeze and heat exchangers	2 000 000 euro
Fence, ground shaping etc.	80 000 euro
Heat transfer pipe (1 000 m)	300 000 euro
Control system	80 000 euro
Consultancy	40 000 euro
Total	2 580 000 euro
Calculated production 4.500 MWh/year	
Average 20 year costs of loan: interest rate 5 per cent, inflation 2 per cent, total 6,7 per cent/year	
Yearly capital costs: 2 580 000 euro x 6,7 per cent/year	173 000 euro/year
Maintenance 1 euro/MWh	4 500 euro/year
Total production costs	about 40 euro/MWh

Table 3.2 shows that practical investments in Torring (Denmark) of 10000 m^2 solar energy systems is lower than calculated using a spreadsheet „f-EASY (SDH)“ and consists of 2.5 million euro, excluding costs of land.

Table 3.3 shows assumptions for the solar collectors system in Varėna DH network, which is used with explanations and links to the sources. It is important that for the calculations it is used hourly averages of 20 years (from 1990 to 2010) of solar radiation and outside temperature in Varėna.

Table 3.3. Assumptions for calculations in EnergyPRO 4.2 modelling tool

Assumptions	Explanation
Heat accumulation 1070 m^3	District heating network in Varėna city consists of 1070 m^3
Average 20 year outdoor temperature in Varėna	Average hourly temperature of 1990-2010 is based on CFSR data in EnergyPRO program (Appendix 7)
Average 20 year solar radiation in Varėna	Average hourly solar radiation of 1990-2010 is based on CFSR data in EnergyPRO program (Appendix 6)
Heat price 5.7 €ct/kWh (VAT excluded)	Average heat price of 2013 year (VAT excluded)
Heat demand 42 300 MWh	Average heat demand of 2013 year
Lifetime of solar collectors 20 year	Lifetime of solar collectors based on commonly used duration in financial projects according to data from http://www.solar-district-heating.eu
Interest rate 5 per cent	Interest rate based on the Central Bank of Lithuania statistics http://www.lb.lt/stat_pub/
Inflation rate 2 per cent	Inflation rate based on the European Central Bank prognosis http://www.ecb.int/stats/prices/indic/forecast/
Duration of the loan 15 year	Duration of the loan is based on long-term financing prerequisites
Maintenance for solar collectors 1 euro/MWh	Maintenance for solar collectors are not significant, based on data from http://www.solar-district-heating.eu/

Three main scenarios that are analysed:

Scenario 1. Solar collectors are able to cover all heating demand in the summer time. Land area for solar collectors is available free of cost. Calculation tool "f-EASY (SDH)" estimated of 10000 m^2 solar collectors' area. Investments were modified according market situation and answers from a suppliers' survey. This area of solar collectors that could be connected to Varėna DH will approximately cost about 2.3 million euro.

Scenario 2. Solar collectors are able to cover half of heating demand in the summer time. The area of solar collectors is 5000 m^2. Investments will be approximately about 1.5 million euro.

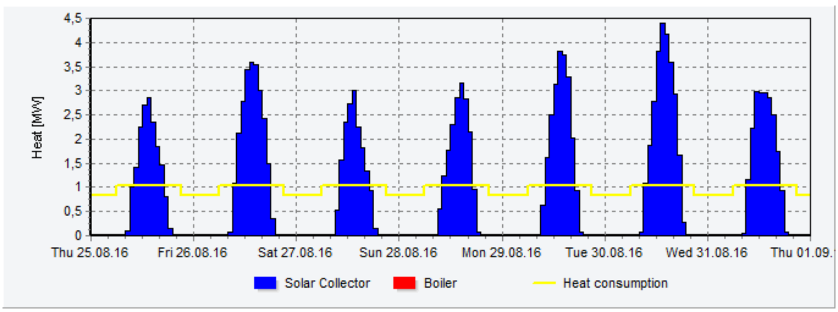
Scenario 3. Solar collectors are placed just on the roofs of administration buildings and boiler houses of Varėna DH Company. The area of solar collectors is 1000 m^2. Investments will be approximately about 0.6 million euro.

The economic feasibility analysis of the chosen solar collectors' area for DH purposes on the supply side in Varėna town is based on net present value (NPV), simple payback time and internal rate of return (IRR). Economy in energyPRO basically is monthly based. Payback time is defined as the month, in which you are able to pay back your loans (the month in which the money in the cash account equals remaining debts in the loans). However, it is not the most suitable criteria for a long term investment. Due to its widespread application, though, it will be used as an indicator in the calculation results. NPV calculation every monthly payment is brought back to Present (start of the Planning period) on a monthly basis. IRR is the discount rate that makes the net present value of all cash flows from a particular project equal to zero. The higher a project's internal rate of return, the more desirable it is to undertake the project. The IRR is found by iterations using Newton’s method. EnergyPRO calculates the Nominal IRR. The difference between the Nominal and the Real IRR is in practice equal to the average inflation in the planning period.

Modelling assumptions are made using various sources, available statistical data, studies, reports, papers, and websites. This research deals with the possibility to install the solar collectors system that is connected directly to DH network in Varėna city. Solar collectors are selected taking into account the intensity of solar radiation and fluctuation of hot water system needs in DH.

Modelling is being done by evaluating the heating demand in Varėna city, working period of flat plate solar collectors in a year, their efficiency. Depending on the solar collectors’ area and heat loss parameters the program calculated the price of hot water made by collector, the payback period of the system, NPV, IRR, etc.

Possibility to use solar collectors for large scale DH supply during summer time in Varėna city (Lithuania) is analysed. Based on the methodology and data described in the beginning of this subsection, three scenarios have been investigated from the business economic point of view. Some main results are discussed in the following diagrams.



Scenario 1

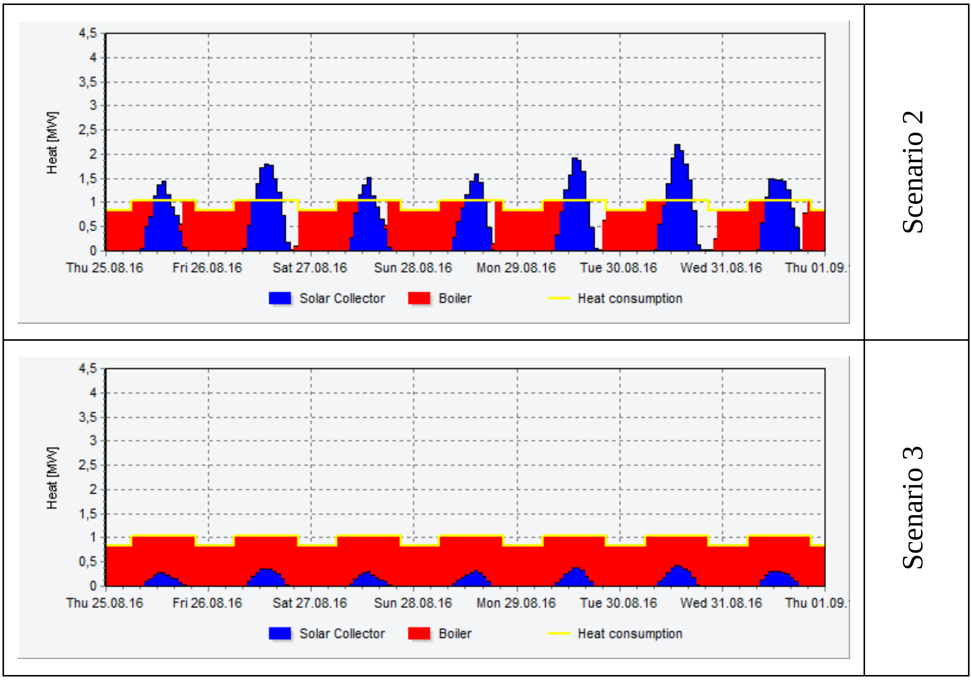


Figure 3.6. Produced heat of solar collectors using energyPRO

Figure 3.6 shows produced heat of solar collectors that was modelled with energyPRO software. Scenario 1: solar collectors are able to produce heat for all heat demand during the end of August. Scenario 2: additional heat production unit (biomass boiler) is used with solar collectors to fulfil heating demand. Scenario 3: solar collectors produce just small part of heating demand. The biggest potential of the efficient use of solar collectors in Lithuania is in the summer time, approximately from the beginning of April to the end of September.

Heat production of 10000 m^2 solar collectors area is only about 9.8 percent of total heat production (scenario 1). The required land area for solar collectors is about 3 or 4 times higher. However, investments in solar collectors are economically feasible and could produce heat during summer time with minimal operation of biomass boiler. The most important factors are sustainable development of the city, fuel savings, and lower environmental pollution.

Calculations of the use of solar collectors showed that payback time is longer than the loan period for scenario 3 and about 14 years for scenarios 1 and 2. The assumption of stable DH price was taken into account. More economically attractive solar collectors' system according this indicator is larger size with lower payback time. However, even a simple indicator shows that investments are risky in all scenarios.

Economic calculations of Net Present Value indicator showed that the most attractive NPV is for the biggest solar collectors' system. The main reason for such result is economy of scale. The new aspect that has not been taken into existing schemes of support in Lithuania is analysis of feed-in tariff for RES in heating sector. Figure 3.7 shows sensitivity analysis of NPV at various feed-in tariff level of DH price for the production of heat by solar collectors. The DH price of Varėna city is selected as a basis (57.4 euro/MWh). Such level feed-in tariff would cover not only production costs of heat from solar collectors, but also bank loan for the investments and minimal profit for heat producers. 20 percent higher and lower feed-in tariff were calculated. Moreover, 10 percent increases and decreases of the investments were also included into calculation. The results revealed that 20 percent lower feed-in tariff gives negative NPV values for solar collectors in all 3 scenarios. Summing up the results, 20 percent lower feed-in tariff is economically unacceptable investment for solar collectors. Scenario 3 with small size of solar collectors is unacceptable even with 20 percent higher feed-in tariff and 10 percent decrease of investments. The current situation in Lithuania shows that small towns already have lower price for DH, and investment in solar collectors is unnecessary and generates financial loss. On the other hand, for more than 10 cities in Lithuania that use natural gas as a fuel for district heating, investments in solar collectors could be attractive.

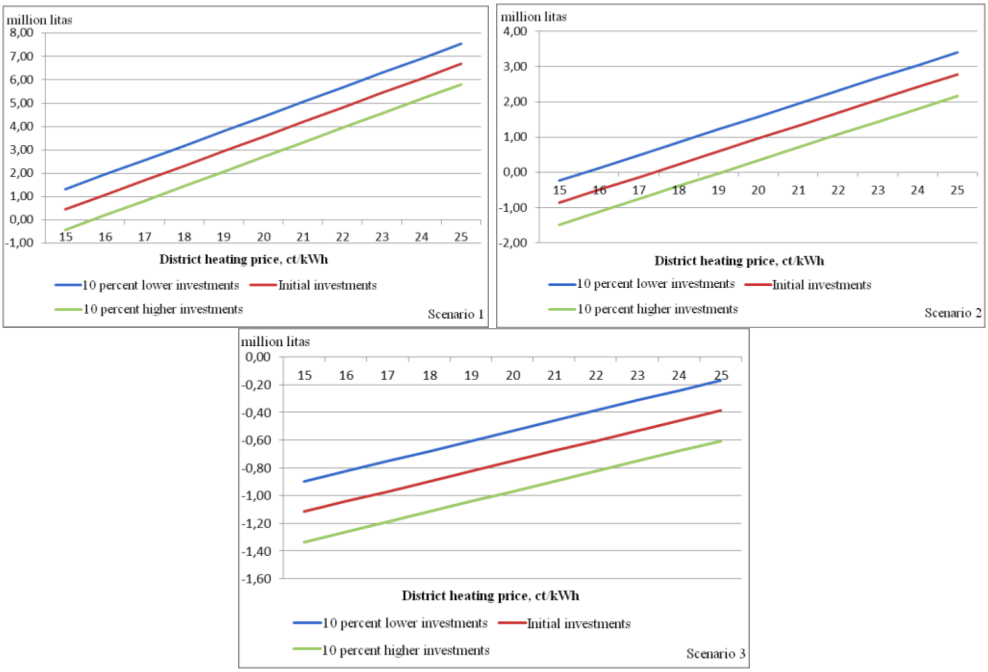


Figure 3.7. Sensitivity analysis of NPV at various investment levels for the production of heat by solar collectors (ct/kWh, excl. VAT)

IRR calculations showed that investment in solar collectors is very risky because IRR varies from 8 percent (scenario 1) to 5.5 percent (scenario 2). The main conclusion is that without government support (for soft loan with 3 percent interest rate or feed-in tariff) investments in solar collectors are financially unacceptable.

Economically attractive investments could be just for cities with DH price over 90 euro/MWh.

Without taking into account external benefit, solar collectors are not economically attractive in case of Lithuania, where biomass boilers (that already had subsidies for investment) is used for heat production. The risk of biomass and other fuel prices, and lower demand of heating after renovation of apartment buildings should be taken into account in further researches.

3.2. Evaluation of large scale solar collectors and the use of solar and geothermal energy in the multifamily building on the example of a particular town‘s DH system

The main question is a competition between the price of self-produced RES energy on the demand side and price of RES DH on the supply side. Therefore, the comparison of LCoE is shown for solar collectors and heat pump on the demand side with different support intensity. Moreover, LCoE of renovation of apartment building is included because of the need to consume energy efficiently and compare the results of various support intensity.

Development of RES in DH requires large investments; however the use of renewable resources in the DH system would let to diversify the fuel mix. Subsidies for investments of solar and geothermal energy technologies would enable to use them in DH system as economically attractive alternatives. State support has an essential role to change situation from moving towards cleaner energy production and diversifying fuel mix in DH sector both the supply and the demand sides.

Previous section presented the results of modelling large scale solar collectors’ field on the supply side of DH in Varėna town. Scenarios were presented that all/half/minority hot water demand during summer time could be covered by solar collectors’ field. The payback time, calculated with energyPRO, was longer than 10 years; therefore this time extended LCoE based calculation has been used for the evaluation process.

Three basic scenarios have been calculated for solar collectors’ field on supply side of DH system (DH_SOL): no subsidy, 30 percent, and 50 percent subsidy for investments of solar collectors’ field, and soft loan with 3 percent fixed interest rate for 20 years period. Scenarios resulted in LCoE for produced heat around 4-6 euro cent per kilowatt hour (average DH price from biomass is 5.8 €ct/kWh in Varėna town in 2014). This result revealed that state support, such as investment subsidies with soft loan, could create a competitive source for biomass boiler during summer time in Varėna town, which already had subsidy from Lithuanian Environmental Investment Fund. The advantage of solar collectors’ field is stable price for DH in long-term period, because no fuel is required. The disadvantage is high investment costs and intermittent production of heat. Therefore solar collectors’ field could not be estimated as the alternative for biomass boiler, but only as complementary installation that enables to fix price for the long-term period, when the price for biomass is expected to increase due to raise in demand.

Calculations of extended LCoE approach have also been applied for the multifamily building in Varėna town, which has already installed solar collectors for the preparation of hot water and heat pumps for the space heating. This five floors multifamily building with 40 apartments is the only one in Lithuania that uses both types of RES technology for heating purposes already. Figure 3.8 shows LCoE analysis of RES scenarios in DH sector on the supply and demand sides, and renovation of multifamily building. Three main scenarios of renovation (REN) were calculated: no subsidy, 30 and 50 percent intensity of subsidy. Furthermore, three additional scenarios were calculated of solar collectors and heat pump (SOL_HP) in multifamily building without subsidy, with 30 and 50 percent intensity of subsidy. Heat pump on the production side of DH in uncompetitive due to high temperature regimes and initial calculations in EnergyPRO program, as it is shown in Appendixes 9-12 on the example of Gargždai town. The comparison of LCoE with various intensity of subsidy reveals that in the case of complete renovation of multifamily building even with fifty percent intensity of subsidy savings in heating cost is higher than the average existing DH price (5.8 €ct/kWh) in Varėna town. Moreover, complete renovation requires large investments. This problem could be solved by separate effective elements of renovation, such as renovation of heating system, replacement of windows, etc. On the other hand, RES on the demand side, such as solar collectors and heat pump, could compete with DH price without any subsidy in Varėna town. It should be noted that even high investment costs in renovation of multifamily buildings in Lithuania is necessary due to very inefficient use of heat energy in multifamily buildings that was built more that 30-40 years ago.

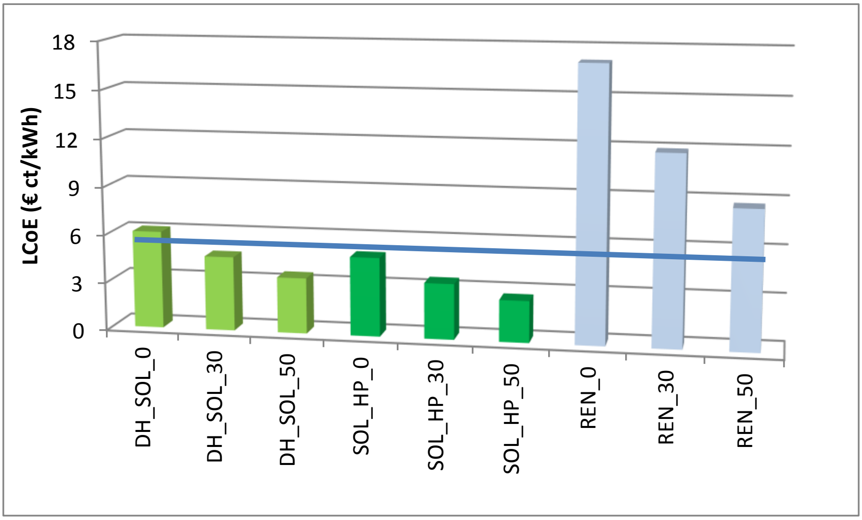


Figure 3.8. LCoE analysis of RES scenarios in DH sector on the supply and demand sides, and renovation of multifamily building (€ ct/kWh, excl. VAT)

Estimation of local and foreign capital investments of solar collectors has also been performed. The results showed that only less than 25 percent of local capital could be used for the installation of solar collectors. Therefore country should take into consideration this drawback and encourage research and development in the field of RES in local scale. Integrated territorial investments could promote the concept of sustainable cities as well as regional growth and development.

Although traditional LCoE is a simplified indicator of the price consumers will pay for generating heat unit from different fuel sources at a given point in time, it could account for externalities in the calculations presented above. An externality is a consequence of an economic activity that is not reflected in the price of that activity. It is important to look at the entire life cycle of a fuel source or generation technology when considering externalities.

3.3. Assessment of economic and social benefits from using diversified RES technologies in urban areas

The stimulation of energy producers and consumers for the use of RES is one of the major goals of energy policy in Lithuania. Policies and measures that aim at enhancing the use of RES are mainly driven by EU policy. Unstable state energy policy and changes of incentive measures destabilize investments initiatives. The lack of both sides economic evaluation is the main challenge during the way to achieve target. Unreasonable huge role is given for biomass in the projections of the use of RES. Biomass is an energy resource that is the result of economic activity and depends on the continuity of economic activity. Meanwhile, the use of an inexhaustible solar and geothermal energy potential is insufficient.

The scientific problem is evaluation of the social benefit of RES that can show the advantages, which is underestimated in investment decisions; for example, RES inexhaustibility and possibility to ensure sufficiency of energy resources for future generations at the same time. Utilization of some of the RES technologies, such as solar energy, also solves environmental issues. Therefore they may be additionally financed from other sources. The main issue is diversity of RES utilization opportunities and incentives. Moreover, it is transfer of their economic interpretations on uniform rules and economic laws into specified dimension, in this case trying to reduce different opinions as much as possible.

Phenomenon of energy is RES that could change exhausted types of energy such as oil, natural gas and could be realized by few types of energy. DH system may use natural RES, such as solar and geothermal energy. On the other hand, social benefit of RES differs from oil and natural gas, because RES guarantee for future generations the supply of energy resources, but this benefit does not have a methodological evaluation. This is one of the main accents of the concept of sustainable energy development.

The external benefit analysis for geothermal heat pump and solar collectors was performed to find their niche in urban and rural areas. The external effect indicators for different scenario cases are shown in Table 3.4. The main indicators were chosen as the most common indicators of investment project, such as new job places, taxes to the state budget, and the use of domestic capital.

Table 3.4. External benefit of using solar and geothermal energy technologies

Indicators	Geothermal heat pump and solar collectors in multifamily building	Solar collectors in district heating system
	126kW	7000kW
Produced, MWh	185	4500
Domestic capital, thousand Euro	25.01	1380.88
Social insurance, thousand Euro	9.27	119.23
Personal income taxes, thousand Euro	3.46	44.46
New job places (man months)	31.9	409.4

Table 3.4 shows the comparison of external benefit using different type and scale of RES. Large scale (10000 m^2) solar collectors are the technology that generates heat mostly during summer period, when combination of geothermal heat pump and solar collectors in multifamily building give effect during the whole year. The main indicators of external benefits are considered as the use of domestic capital, taxes paid to the state budget, and created new job places. Combination of different types of RES may create large external effect and make a significant impact not only to individual consumer of RES, but to the society as well. Therefore the benefit from using RES, especially in urban areas, should be evaluated during decision making. If direct support is applied for RES or environmental technologies, the impact would depend on the volume of support and source of funding. For example, if the direct assistance is financed from the state budget, the promotion measures would increase the budget deficit in addition to the above mentioned positive aspects. It is therefore essential that the promotion would be cost-effective: the benefits exceed the negative effects. Inexhaustible types of RES (such as solar and geothermal energy) enable greater benefit than subsidies it may require while penetration into the market is growing.

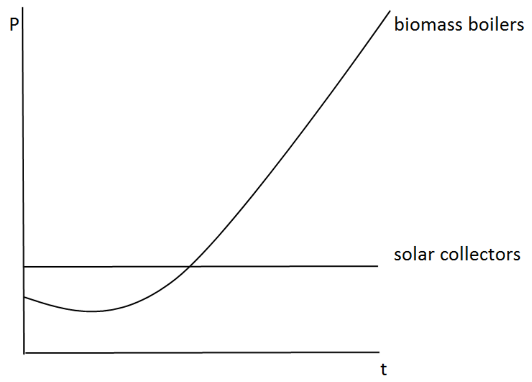


Figure 3.9. Long-term visualisation of price for DH produced by biomass boilers and solar collectors

The main strength of the use of solar collectors is fixed price of thermal energy, as it is schematically shown in Figure 3.9. The main reason for stable price of solar collectors is non-existent cost for fuel because solar collectors use only sun energy. Therefore the price for DH from solar collectors should cover only investment costs. On the other hand, biomass boilers use biomass as a fuel, which is a result of economic activity. Salary has a tendency to increase, intensive use of biomass may cause deforestation, demand for biomass is growing every year, therefore the price for biomass will increase in the future. The question remains on how rapid the increase of biomass price will be.

3.4. Recommended prerequisites for diversification of RES in DH

Long-term energy policy, as presented in Figure 1.11, is a main force to make changes that could incorporate external benefit for the sustainable development of RES and better life of future generations. Potential policy instruments are related with:

- Financial support, such as subsidies for production of DH from RES, feed-in tariffs, and tax incentives for diversified RES. These instruments are usually used for the correction of market prices and diversified RES penetration into the market with the goal of social benefit for the society.
- Direct regulation is related with control and command methods, which requires companies to generate thermal energy from diversified RES.
- Restructured regulation decrease regulatory failures, which creates incorrect signals for the DH market.
- Research and development requires funding from Government for scientists and engineers, who work for creating/improving RES technologies, also support for high-quality laboratories.
- Product standards aims at improvement of products‘ characteristics, which meet a specific standard, such as efficiency of solar collectors.

- Information programs are related mostly with educational campaigns.

Table 3.5. Potential policy instruments to tackle market failures during diversified RES integration in DH system

Market failures / Policy instruments	Externalities of environment	Regulatory failures	DH network externalities	Economies of scale	Market power	Information market failures
Subsidies for production of DH from RES	P		T	T		
Feed-in tariffs for diversified RES	P			T		
Tax incentives for diversified RES	P					
Direct regulation	P					
Restructured regulation		P			P	
Research&Development	P					
Product standards	P					P
Information programs	P					P

P – permanent action
T – temporary action

Table 3.5 shows market failures which occur during diversified RES integration in DH system and potential policy instruments that might be used as permanent or temporary actions to tackle with these market failures. Additional to the market failures that were described during analysis of market barriers for RES development, an information market failure is added, which might be related with generation of RES on the demand side of DH system. If end users have limited information about benefits of RES, the information market failure could possibly occur.

Prerequisites for diversification of RES in DH. As it was shown in Figure 1.11, long-term energy policy and legal regulation is the basis for further penetration of RES technologies in DH. Above proposed potential policy instruments are justified by economic theory due to the status of natural monopoly of DH. Moreover, additional key principles in order to reforming DH that penetration of renewable technologies could be used on a large scale are presented further.

TPA and Extended Producer market. The main issue of TPA in DH sector is that DH markets are local and limited geographically. The limited size of DH system and thus limited number of potential competitors on the production for heat energy distinguish DH market from electricity and gas markets, where TPA in the case of unbundling was required by EU legislation. The DH network is still considered as a natural monopoly, while production of heat might be opened for competition of existing or new producers of heat. TPA and extended producer market with proper legal regulation could be the solution for increased competition and transparency of DH market, especially in large DH system. The challenge is that TPA can have small positive effects on competition and at the same time make it is more difficult to operate the integrated DH business in a cost effective manner.

TPA model might be improved by extended producer market, where external suppliers (both producers and consumers) play a significant role. Extended producer market in every DH system should work as a platform where buyers and sellers of DH could meet in a non-discriminatory manner. Transparency of costs and transactions is necessary to enable extended producer market. The efficiency of the market might be reached when pricing is close to the marginal cost. Competition of the market could be limited in the case when municipal owned DH companies have other interests than just increase competition in DH market.

The role of cities/towns for RES penetration in DH. Connecting link of practical implementation of national RES energy goals should be municipalities. The role of municipalities for the development of RES is regulated in detail in Law on Energy from Renewable Sources. However, the implementation of this law at the municipal level does not progress in practice. Significant issues of legal regulation implementation occur of how to link long-term RES diversification with heat sector strategy and special plans of heat. The role of municipalities should be increased because national goals could be reached just through the territorial units. Active participation of municipalities must be continued, developed, and obligation of the implementation of state goals in the energy sector must occur. For example, DH infrastructure could be used for the use of solar and geothermal energy while the use of RES could be developing on a large scale. Diversification of RES would enable to ensure price stability in the long-term. Therefore extensive training for municipal energy planners should be organised. It is necessary to form not only short-term, but also long-term plans of DH in each of municipalities for the penetration of RES technologies.

The long-term planning of investments. Investments in the energy market have very long-term effects. Therefore the long-term planning is very important. In particular, the task of fulfilling long-term requirements cannot be left to the market forces, which are inactive in this regard. The use of diversified RES will not expand sufficiently on its own accord. For the share of RES to grow within the heat market, the volume of financial aid must also increase until the new technologies can compete in the market without regulatory or financial support. Of course, a new instrument must ensure that the goals defined for expanding RES use in the heat market are achieved in practice. The goals should be achieved at minimum costs. Consequently, there must be minimised not only the direct financial expenditures, but also the administration and inspection efforts.

It is important the role of financing or tax incentives, as well as intermediary institutions of funds‘ distribution (Figure 3.10 and Figure 3.11).

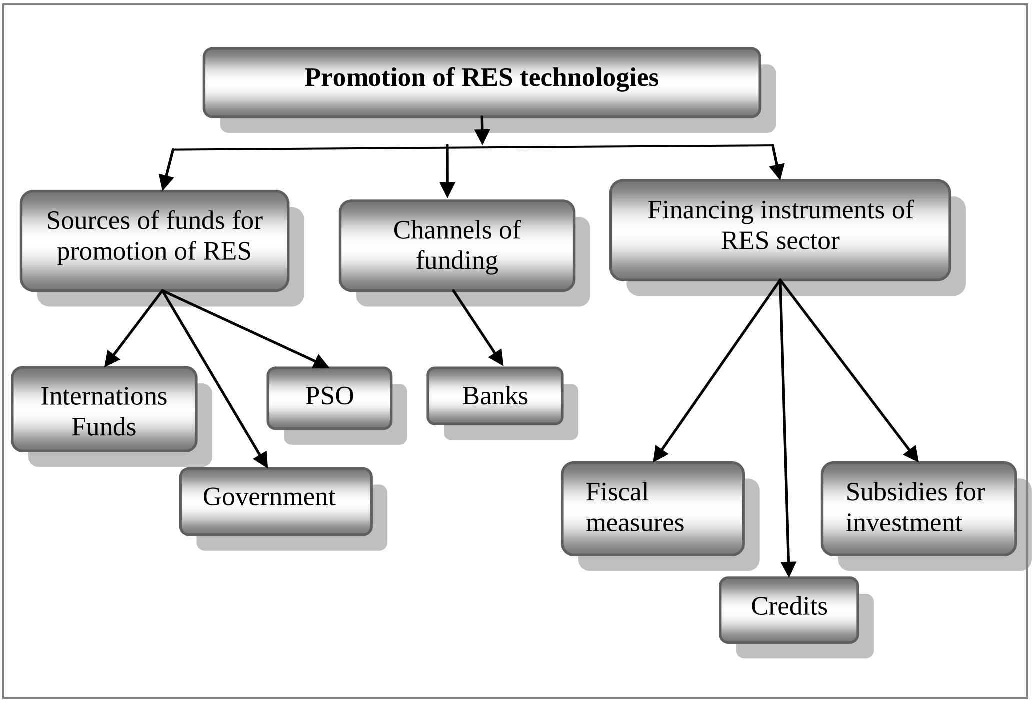


Figure 3.10. Promotion of RES technologies

The issue is evaluation of external impact (benefit) of the use of RES, which leaves a space of uncertainty and subjective interpretations. This responds to the impact evaluation of various RES and energy saving technologies for the GDP, balance of foreign trade in order to create the economic preconditions for the justification of state support.

Meanwhile various types of RES are substantially diverse in different aspects. RES classification according to the nature of renewal is very important to their potential applications in the future and justification of assessment of their economic implementation measures.

The following scheme characterizes the existing funding opportunities for RES support system in Lithuania. Sources of funding during the period 2014–2020 mainly depend on the EU Structural Funds. However, other sources of funding are available, such as Environmental Funds, State Budget, and funding from consumers of energy.

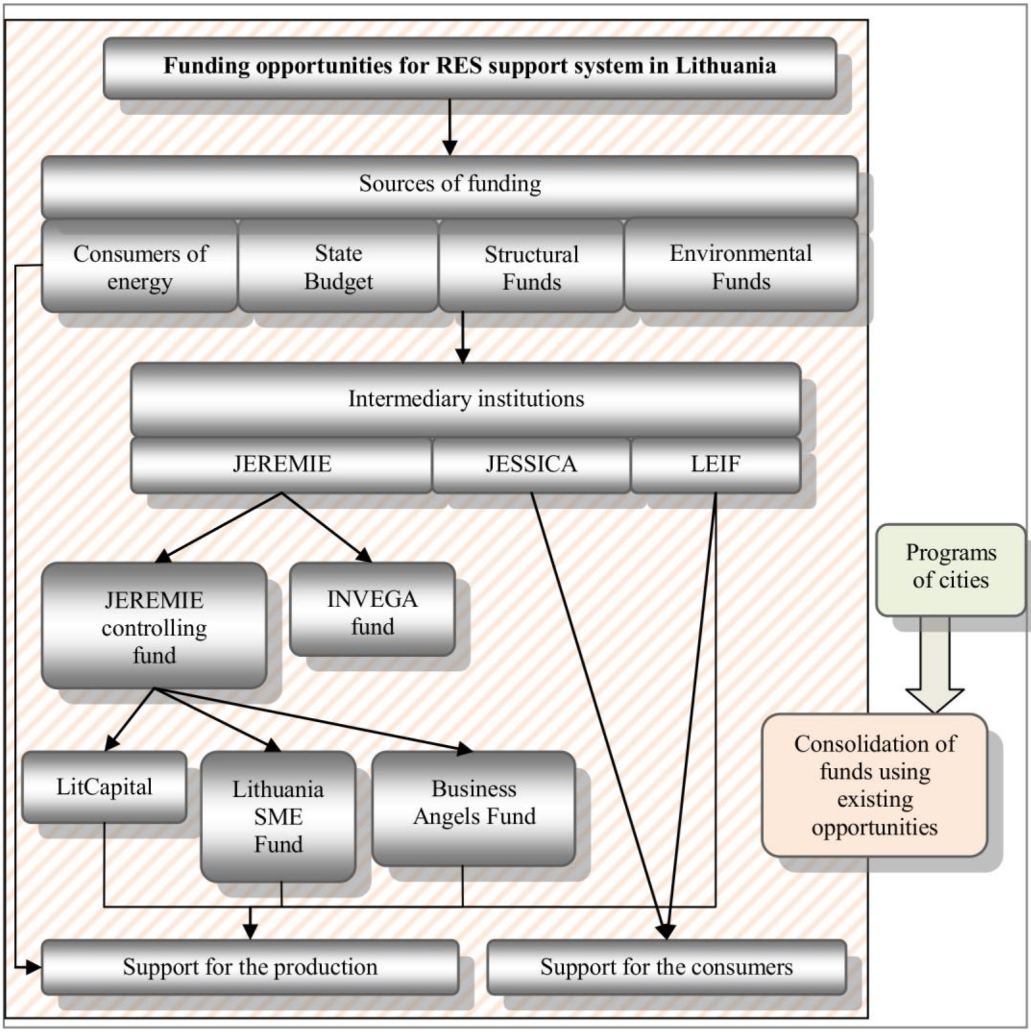


Figure 3.11. System of existing possibilities in Lithuania

Support measures must be considered compatible with the EU competition regulations. Furthermore, the burden imposed on the individual should be examined as well. It is very important to ensure that the financial burden benefits the environment, and that a legally permissible situation exists that does not convert into an extra duty as a result of extensive state regulation, which is possibly illegitimate because of insufficient benefit to the society.

CONCLUSIONS

1. The analysis of literature showed main characteristics of DH, which determine that the state can use DH infrastructure for the implementation of sustainable development principles and the general objectives of the country, such as increase of local and renewable energy sources, utilization of municipal waste, diversification of fuel mix in order to achieve the security of energy supply, installation of district cooling in buildings, efficient generation of electricity from cogeneration, reducing greenhouse gas emissions, etc. However, a retrospective analysis revealed the main problem that due to orientation to one type of fuel, which is the cheapest in the short-term perspective, the penetration of diversified RES into the market is limited in Lithuania. The problems of consumer indebtedness, compensation for heating, and others at macro level have been established, and they increase during economic recession. The analysis of scientific literature has shown that it is important to diversify fuel sources that are used for the production of heat in the long term and to maintain the DH infrastructure.
2. The lack of unified methodology for the use of DH infrastructure for RES diversification on the supply and demand sides is established. The methodology should enable to solve problems from a theoretical base to practical implementation. Therefore, methodology was developed, which is the interconnection of research, analysis, and methods of practical calculation, as well as the whole of assumptions, which allow justifying diversification of RES technologies in the DH system. The developed methodology comprises three levels, such as economic theory, analytical research based on territorial dimension, and a system of preconditions/scientific tools for practical implementation.
3. The analysis of DH as natural monopoly based on economic theory showed that limitations of monopoly can be solved by measures, such as third party access and extended producer market. Based on the foreign comparative analysis, it is established that natural monopoly should be regulated by antitrust legislation through divergent principles of price regulation and control. One of the most important preconditions is a long-term territorial planning of energy development, which enables to diversify fuel sources in DH systems for the implementation of sustainable development principles.
4. The investigation of legal documents in the European Union and Lithuania showed that DH infrastructure is recognized and legally regulated for increase of the use of RES as a favourable instrument to realize energy efficiency, RES development and environmental goals since 2009 on the European level. Essential prerequisites were established that enable diversification of RES technologies in DH systems: long-term planning of investments, organizational role of the cities realizing long-term goals for sustainable development of DH systems, pricing and purposeful use of investment funds, and improvement of extended producer market. It might be stated that essential legal preconditions for diversification of RES technologies in Lithuanian DH sector are sufficient. International comparative analysis revealed

the guidance, the application of which would allow implementing successful reforms in DH sector in order to solve financial problems and realize DH infrastructure as the main tool for diversifying RES.

5. Analysis of economic theory proved that promotion of RES technologies through subsidies for investment should be based on the external benefit of RES. Analysis of the external benefit reveals that in the long-term perspective, various renewable technologies could be evaluated **not as competing with each other, but complementary in fuel mix, while gradually replacing fossil fuels**. According to the theoretical analysis, a research concept is formed, which is based on the evaluation of the external benefit for methodological justification and formation of prerequisites for realization, in order to justify the use of long-term investments for development of diversified RES.
6. System of preconditions of the integration of diversified RES (based on the example of solar and geothermal energy) technologies into DH systems on the producer and consumer sides in terms of sustainable development of cities is developed. The main developed principles show that DH enables the use of diversified RES, which would be the basis for efficiency of energy supply, stability of energy prices and solution of environmental problems. Development of diversified RES in the infrastructure of DH might be realized on city/town level, because urban differences lead to priorities of various types of RES according to the different external benefit levels of different RES types. The essential methodological principle is the evaluation of the external benefit of the use of RES (based on the example of solar energy). On this basis, aggregated evaluation could be carried out as to what size of the composite effect could be expected while increasing the scale of the RES use in DH according to complex scenarios, if confrontation between energy suppliers and energy consumers is avoided.
7. Analysis and empirical research are conducted for natural RES types that are the most difficult to use under current circumstances, such as solar and geothermal energy, the potential of which in Lithuania is huge but scarcely exploited. The analysis of conducted calculations of the particular city data showed that diversified RES technologies (solar collectors and heat pumps) could be competitive in market conditions both on the supply and consumption side, while competitiveness is limited by subsidies for biomass boilers on the production side. A logical matrix is developed, which includes temporary and permanents actions to tackle market failures during diversified RES integration into DH system. Moreover, a system of RES financing options is formed in case of Lithuania because a long-term energy policy is the main factor, which can unite various existing and recommended legal-economic prerequisites and financial mechanisms.

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9. **Murauskaitė L.,** Klevas V. Challenges and options for the interaction of producers and consumers in district heating: a case study in Lithuania. *Proceedings from the 14th International Symposium on District Heating and Cooling (DHC 2014)*, Stockholm, Sweden, September 6–10, 2014. Sweden, 2014, p. 288–294, ISBN 978–91–85775–24–8.
10. **Murauskaitė L.** Coherent policy of renewable energy sources support in Lithuanian district heating sector. *12th International Conference of Young Scientists on Energy Issues (CYSENI 2015)*, Kaunas, Lithuania, May 27–28, 2015. Kaunas: LEI, 2015, p. 73–84, ISSN 1822–7554.

Large scale solar collectors' fields for district heating in Denmark (nominal capacity higher than 700 kW_{th})

Denmark | Any size | Any Coll.sys. | Any Type | Search | 75 Results found.

Plant	Operation Start	Owner	Location	Apert. area in m2	Capacity in kWth	Coll. sys.	Stor. type
Vojens	2012 - extension 2014	Vojens Fjernvarme, DK	Vojens, Denmark	70000	49000	FPC	WTES
Gram	2009	Gram Fjernvarme, DK	Gram, Denmark	44836	31,385	FPC	None
Dronninglund	2014	Dronninglund Fjernvarme	Dronninglund, Denmark	37573	26300	FPC	WTES
Marstal	1996	Marstal Fjernvarme, DK	Marstal, Denmark	33300	23300	FPC	WTES
Ringkøbing	2010 - extension 2014	Ringkøbing Fjernvarmevaerk, DK	Ringkøbing, Denmark	30000	21000	FPC	None
Hjallerup	2015	Hjallerup Fjerrnvarme	Hjallerup, Denmark	21546	15,082	FPC	None
Vildbjerg	2014	Vildbjerg Tekniske Værker	Vildbjerg, Denmark	21244	14900	FPC	
Hadsund	2015	Hadsunds Bys fjernvarmevaerk	Hadsund, Denmark	20513	14,360	FPC	None
Nykøbing Sjælland	2014	Nykøbing Sj. Varmevaerk	Nykøbing Sjælland, Denmark	19925	13900	FPC	
Helsinge	2012 - extension 2014	Helsinge Fjernvarme, DK	Helsinge, Denmark	19588	13700	FPC	None
Gråsten	2012	Gråsten Fjernvarme, DK	Gråsten, Denmark	19017	13312	FPC	None
Braedstrup	2007	Braedstrup Fjernvarme, DK	Braedstrup, Denmark	18612	13027	FPC	BTES
Tarm	2013	Tarm Varmevaerk	Tarm, Denmark	18585	13010	FPC	None
Aulum	2015	Aulum Fjernvarme a.m.b.a.	Aulum, Denmark	16015	11,200	FPC	None
Løgstør	2014	Løgstør Fjernvarmevaerk	Løgstør, Denmark	15500	10900	FPC	
Jetsmark	2015	Jetsmark Energivaerk	Jetsmark, Denmark	15183	10,630	FPC	None
Oksbøl	2010	Oksbøl Varmeværk, DK	Oksbøl, Denmark	14745	10000	FPC	None
Hundested	2015	Hundested Varmevaerk	Hundested, Denmark	14465	10,120	FPC	None
Östervang	2015	Östervang Sjaelland	Östervang, Denmark	14112	9,880	FPC	None
Jægerspris	2010	Jægerspris Fjernvarme, DK	Jægerspris, Denmark	13300	9310	FPC	None
Vrå	2015	Vrå Varmeværk A.m.b.a., DK	Vrå, Denmark	12600	8800	FPC	
Sydlangeland 1	2013	Sydlangeland Fjernvarme	Sydlangeland, Denmark	12512	8758	FPC	None

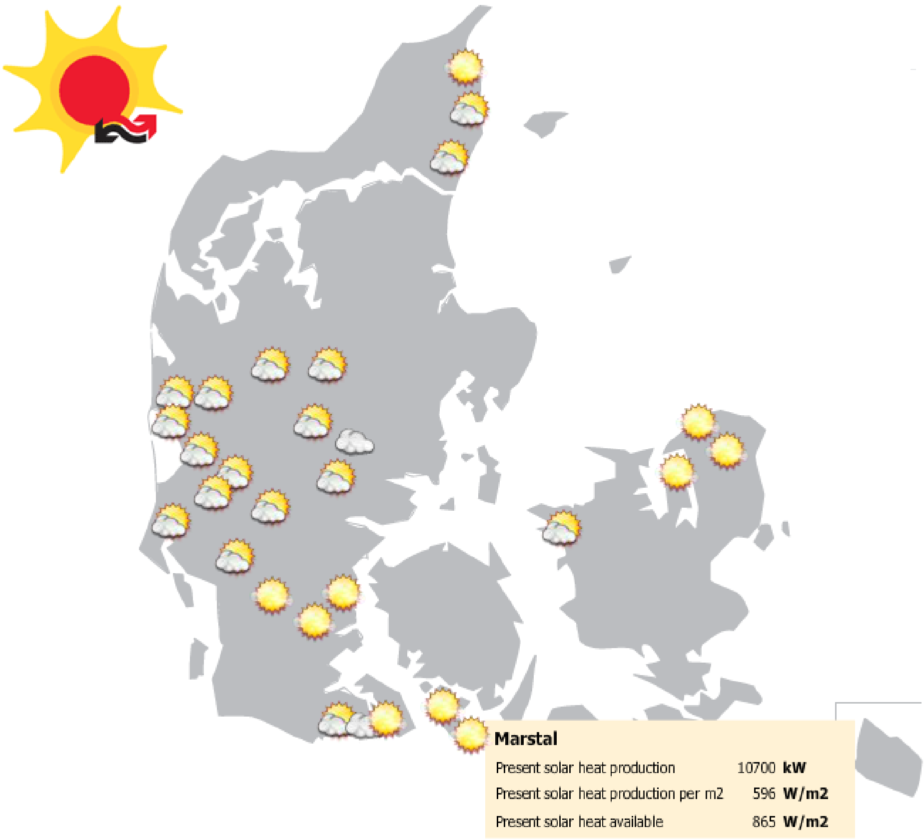
Grenaa	2014	Grenaa Varmeværk	Grenaa, Denmark	12096	8500	FPC	
Veggerløse	2011	Sydfalster Fjernvarme, DK	Veggerløse, Denmark	12075	8500	FPC	None
Hvidebaek	2013	Hvidebaek Varmevaerk	Hvidebaek, Denmark	12000	8400	FPC	None
Sæby	2011	Sæby Fjernvarme, DK	Sæby, Denmark	11921	8300	FPC	None
Toftlund	2013	Toftlund Fjernvarme	Toftlund, Denmark	11000	7700	FPC	None
Svebølle-Viskinge	2011 - extension 2014	Svebølle-Viskinge Fjernvarme, DK	Svebølle-Viskinge, Denmark	10024	7000	FPC	None
Taars	2015	Taars Varmeværk A.m.b.a.	Taars, Denmark	10011	7,000	FPC	None
Broager	2009	Broager Fjernvarme, DK	Broager, Denmark	9988	6992	FPC	None
Løgumkloster 1	2015	Løgumkloster Fjernvarme	Løgumkloster, Denmark	9700	6,800	FPC	None
Hvide Sande	2014	Hvide Sande Fjernvarme A.m.b.A.	Hvide Sande, Denmark	9576	6700	FPC	
Christiansfeld	2013	Christianfeld Varmevaerk	Christianfeld, Denmark	9300	6510	FPC	None
Langå	2015	Langå Varrmevaerk	Langå, Denmark	8505	5,950	FPC	None
Frederiks	2013	Frederiks Varmevaerk	Frederiks, Denmark	8438	5907	FPC	None
Strandby	2008	Strandby Varmevaerk, DK	Strandby, Denmark	8012	5608	FPC	None
Vejby-Tisvilde	2012	Vejby-Tisvilde Fjernvarme, DK	Vejby-Tisvilde, Denmark	8000	5600	FPC	None
Karup	2013	Karup Varmeværk	Karup, Denmark	8000	5600	FPC	None
Soenderborg/Vollerup	2008	Soenderborg Fjernvarme, DK	Soenderborg/Vollerup, Denmark	7681	5400	FPC	None
Gørding	2012	Gørding Varmevaerk, DK	Gørding, Denmark	7400	5200	Unknown	None
Skørping	2012	Skørping Fjernvarme, DK	Skørping, Denmark	7300	5,110	FPC	None
Tørring	2009	Törring Kraftvarmevaerk, DK	Tørring, Denmark	7284	5099	FPC	None
Ærøskøping	1998	Ærøskøping Fjernvarme, DK	Ærøskøping, Denmark	7090	5000	FPC	None
Snedsted (THY)	2015	Snedsted Varmevaerk	Snedsted , Denmark	6500	4,550	FPC	None
Ejstrupholm	2011	Ejstrupholm Fjernvarme, DK	Ejstrupholm, Denmark	6243	4400	FPC	None
Kværndrup	2015	Kvaerndrup Fjernvarme	Kværndrup, Denmark	6242	4,370	FPC	None
Hejnsvig	2010	Hejnsvig Varmeværk, DK	Hejnsvig, Denmark	5763	4000	FPC	None
Aasa	2014	Asaa Fjernvarme A.m.b.a.	Aasa, Denmark	5650	4000	FPC	

Tistrup	2010	Tistrup Varmeværk, DK	Tistrup, Denmark	5400	3780	FPC	None
Ulsted	2006	Ulsted Varmevaerk, DK	Ulsted, Denmark	5012	3500	FPC	None
Ørnhøj-Grønbjerg	2012	Ørnhøj-Grønbjerg Kraftvarmevaerk, DK	Ørnhøj-Grønbjerg, Denmark	5000	3500	FPC	None
Mou	2013	Mou Kraftvarme	Mou, Denmark	4737	3316	FPC	None
Jerslev	2015	Jerslev Kraftvarmevaerk	Jerslev, Denmark	4612	3,230	FPC	None
Tim	2013	Ringkøbing Fjernvarmevaerk	Ringkøbing, Denmark	4235	2965	FPC	None
Haderup	2015	Haderup Kraftvarmeværk, DK	Haderup, Denmark	4234	3000	FPC	
Feldborg	2012	Felborg Kraftvarme, DK	Feldborg, Denmark	4000	2800	FPC	None
Tversted	2013	Tversted Kraftvarmeværk	Tversted, Denmark	4000	2800	FPC	None
Sandved-Tornemark	2013	Sandved-Tornemark Kraftvarmeværk	Sandved-Tornemark, Denmark	3893	2725	FPC	None
Rise	2001	Rise Fjernvarme, DK	Rise, Denmark	3750	2503	FPC	WTES
Skuldelev	2015	Skuldelev Energiselskab a.m.b.a.	Skuldelev, Denmark	3600	2500	FPC	
Gjerlev	2014	Gjerlev Varmeværk A.m.b.a.	Gjerlev, Denmark	3500	2500	FPC	
Sig	2013	Sig Fjernvarme	Sig, Denmark	3479	2435	FPC	None
Öster Hurup	2015	Öster Hurup varmevaerk	Öster Hurup, Denmark	3223	2,260	FPC	None
Ry	1988	Ry Fjernvarme A/S, DK	Ry, Denmark	3040	2128	FPC	None
Hilleroed/Ulleroed	2007	Hilleroed Fjernvarmevaerk, DK	Hilleroed/Ulleroed, Denmark	3007	2105	FPC	None
Insenvad	2014	Ikast El- og Varmeværk A.m.b.a.	Insenvad, Denmark	3000	2100	FPC	
Høje Taastrup	2015	Høje Taastrup Fjernvarme	Høje Taastrup, Denmark	3000	2100	FPC	
Flauenskjold	2014	Flauenskjold Fjernvarme	Flauenskjold, Denmark	2975	2100	FPC	
Skovlund	2012	Skovlund Varmevaerk, DK	Skovlund, Denmark	2970	2100	FPC	None
Nordby	2002	Samsø Energiselskab, DK	Nordby, Denmark	2500	1750	FPC	None
Gl Rye	2014	Rye Kraftvarmeværk A.m.b.a.	Gl Rye, Denmark	2400	1700	FPC	
Dianalund	2011	Filadelfia, DK	Dianalund, Denmark	2000	1400	FPC	None
Hørsholm	2012	Velux	Hørsholm, Denmark	1275	893	FPC	None
Tubberupvænge	1991	Herlev kom. Boligselskab, DK	Tubberupvænge, Denmark	1030	721	FPC	WTES
Saltum	1988	Saltum Fjernvarme A/S, DK	Saltum, Denmark	1005	704	FPC	None

Source: http://solar-district-heating.eu/ServicesTools/Plantdatabase.aspx

APPENDIX 2

Solar collectors online data in Denmark
(example from July 26, 2015 afternoon)



Source: http://www.solvarmedata.dk/

APPENDIX 3

Program “f-EASY (SDH)” data about solar collectors: scenario 1

f-EASY (SDH)

Simple calculator for quick feasibility study of solar district heating

J.E.Nielsen, PlanEnergi *version 0.8* *21/9 2012*

Own or Calc	Parameter	Own input	Value used	Unit
Main inputs				
Own	Total load on network (= annual production)	42.300	42.300	MWh
Own	Solar irradiation on horizontal at location	475	475	kWh/m²
Own	Land area available	30.000	30.000	m²
Own	Price per m² land	-	-	€/m²
Own	Distance to network connection	0,5	0,5	km
Own	Average operating temperature - network side	67	67	°C
Own	Acceptable heat production price	60	60	€/MWh
Main results				
Calc	**Collector area**	-	10.000	m²
Calc	**Land area used**	-	30.000	m²
Calc	**Storage volume**	-	1.277	m3
Calc	**Total investment**		3,3	Mio €
Calc	**Simpel payback time**		16	Years
Detailed inputs				
Calc	Land costs	-	-	mio €
Calc	Transmission heat losses	-	0,6	%
Calc	Costs of transmission piping	-	0,1	mio €
Calc	Costs of collector field per m² (incl. installation)	-	243	€/m²
Calc	Costs of collector field (incl. installation)	-	2,4	mio €
Own	Nominal solar output (Top = 50°C)	4.750,0	4.750	MWh
Calc	Solar output - temperature corrected	-	3.622	MWh
Calc	Solar output - corrected for transmissions losses	-	3.601	MWh
Calc	Solar fraction		9%	-
Calc	Storage volume per collector area	-	0,1	m3/m2
Calc	Store type	None	Steel tank	-
Calc	Storage cost all included	-	0,3	mio €
Calc	Other costs - ground levelling	-	-	Mio €
Calc	Other costs - buildings	-	-	Mio €
Calc	Subtotal		2,9	Mio €
Calc	Other costs - design and optimization	-	0,1	Mio €
Calc	Other costs - misc.	-	0,3	Mio €
Calc	Operational costs - annually	-	0,02	Mio €

APPENDIX 4

Program "f-EASY (SDH)" data about solar collectors: scenario 2

f-EASY (SDH)

Simple calculator for quick feasibility study of solar district heating

J.E.Nielsen, PlanEnergi *version 0.8* *21/9 2012*

Main inputs

Own or Calc	Parameter	Own input	Value used	Unit
Own	Total load on network (= annual production)	42.300	42.300	MWh
Own	Solar irradiation on horizontal at location	475	475	kWh/m²
Own	Land area available	30.000	30.000	m²
Own	Price per m² land	-	-	€/m²
Own	Distance to network connection	0,5	0,5	km
Own	Average operating temperature - network side	67	67	°C
Own	Acceptable heat production price	60	60	€/MWh

Main results

Own or Calc	Parameter	Own input	Value used	Unit
Own	**Collector area**	5.000	5.000	m²
Calc	**Land area used**	-	15.000	m²
Calc	**Storage volume**	-	318	m3
Calc	**Total investment**		1,9	Mio €
Calc	**Simpel payback time**		19	Years

Detailed inputs

Own or Calc	Parameter	Own input	Value used	Unit
Calc	Land costs	-	-	mio €
Calc	Transmission heat losses	-	1,1	%
Calc	Costs of transmission piping	-	0,1	mio €
Calc	Costs of collector field per m² (incl. installation)	-	273	€/m²
Calc	Costs of collector field (incl. installation)	-	1,4	mio €
Own	Nominal solar output (Top = 50°C)	2.375,0	2.375	MWh
Calc	Solar output - temperature corrected	-	1.811	MWh
Calc	Solar output - corrected for transmissions losses	-	1.791	MWh
Calc	Solar fraction		4%	-
Calc	Storage volume per collector area	-	0,1	m3/m2
Calc	Store type	None	Steel tank	-
Calc	Storage cost all included	-	0,2	mio €
Calc	Other costs - ground levelling	-	-	Mio €
Calc	Other costs - buildings	-	-	Mio €
Calc	Subtotal		1,6	Mio €
Calc	Other costs - design and optimization	-	0,1	Mio €
Calc	Other costs - misc.	-	0,2	Mio €
Calc	Operational costs - annually	-	0,01	Mio €

APPENDIX 5

Program “f-EASY (SDH)” data about solar collectors: scenario 3

f-EASY (SDH)

Simple calculator for quick feasibility study of solar district heating

J.E.Nielsen, PlanEnergi *version 0.8* *21/9 2012*

Main inputs

Own or Calc	Parameter	Own input	Value used	Unit
Own	Total load on network (= annual production)	42.300	42.300	MWh
Own	Solar irradiation on horizontal at location	475	475	kWh/m²
Own	Land area available	30.000	30.000	m²
Own	Price per m² land	-	-	€/m²
Own	Distance to network connection	0,5	0,5	km
Own	Average operating temperature - network side	67	67	°C
Own	Acceptable heat production price	60	60	€/MWh

Main results

Own or Calc	Parameter	Own input	Value used	Unit
Own	**Collector area**	1.000	1.000	m²
Calc	**Land area used**	-	3.000	m²
Calc	**Storage volume**	-	12	m3
Calc	**Total investment**		0,6	Mio €
Calc	**Simpel payback time**		34	Years

Detailed inputs

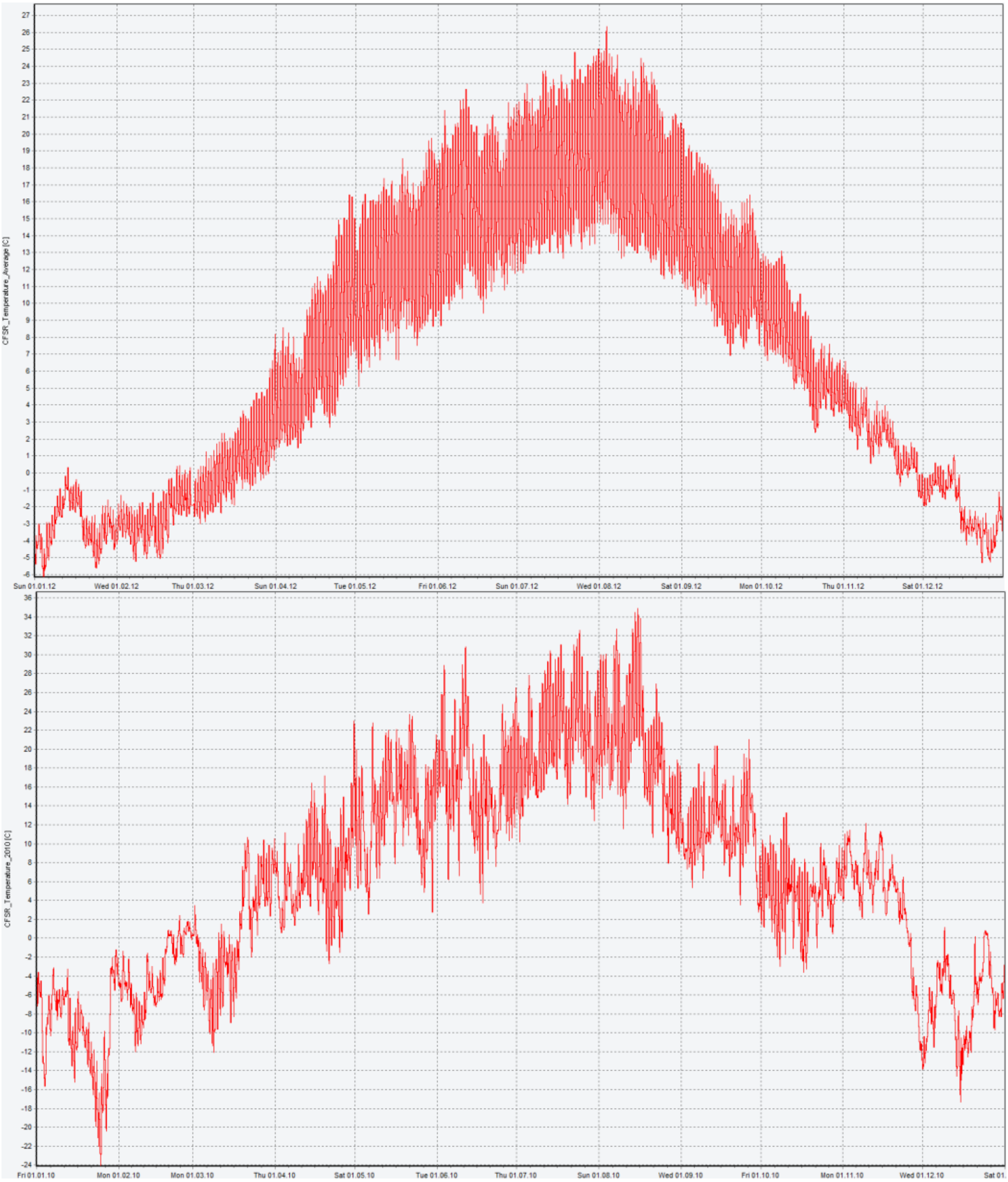
Own or Calc	Parameter	Own input	Value used	Unit
Calc	Land costs	-	-	mio €
Calc	Transmission heat losses	-	5,2	%
Calc	Costs of transmission piping	-	0,0	mio €
Calc	Costs of collector field per m² (incl. installation)	-	342	€/m²
Calc	Costs of collector field (incl. installation)	-	0,3	mio €
Own	Nominal solar output (Top = 50°C)	475,0	475	MWh
Calc	Solar output - temperature corrected	-	362	MWh
Calc	Solar output - corrected for transmissions losses	-	343	MWh
Calc	Solar fraction		1%	-
Calc	Storage volume per collector area	-	0,0	m3/m2
Calc	Store type	None	Steel tank	-
Calc	Storage cost all included	-	0,1	mio €
Calc	Other costs - ground levelling	-	-	Mio €
Calc	Other costs - buildings	-	-	Mio €
Calc	Subtotal		0,5	Mio €
Calc	Other costs - design and optimization	-	0,0	Mio €
Calc	Other costs - misc.	-	0,1	Mio €
Calc	Operational costs - annually	-	0,00	Mio €

APPENDIX 6

Hourly average of solar radiation in Varėna during 20 years (above) and in 2010

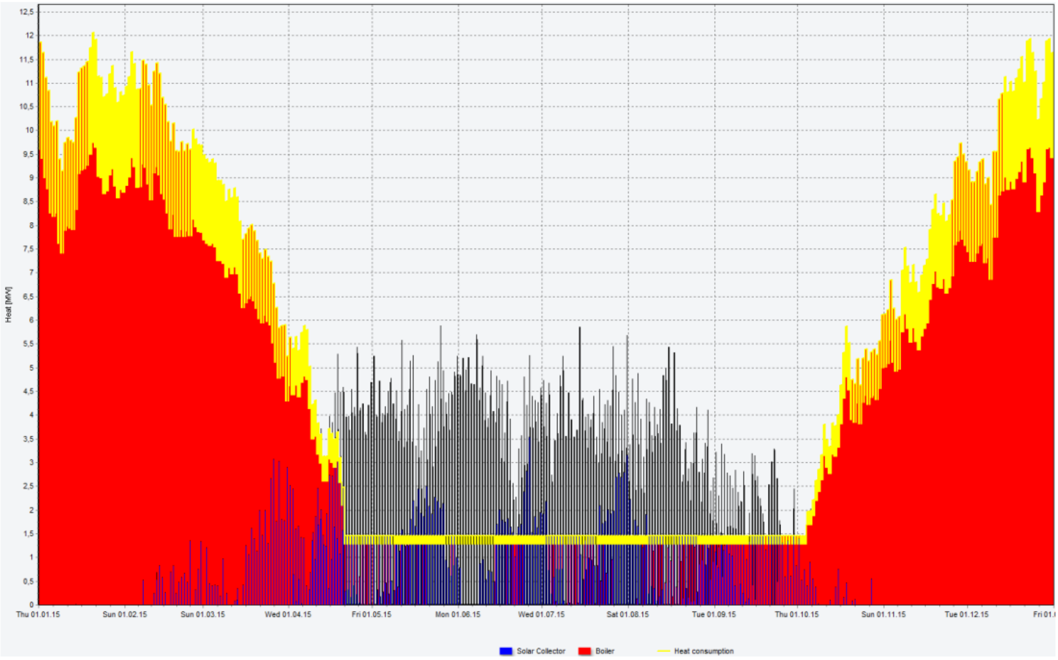
APPENDIX 7

Hourly outdoor temperature in Varėna during 20 years (above) and in 2010



APPENDIX 8

Production of thermal energy by 10 000 m² solar collectors and biomass boilers in Varėna town (EnergyPRO)

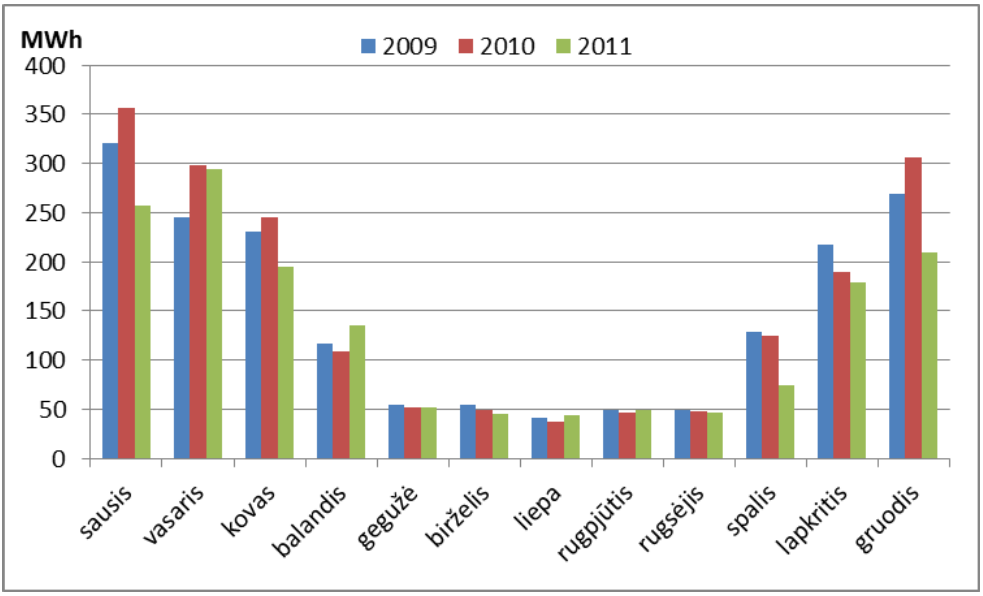


APPENDIX 9

Feasibility analysis of geothermal heating in Gargždai boiler No. 6

APPENDIX 10

Heat consumption in Gargždai boiler No. 6 in 2009–2011, MWh



APPENDIX 11

The assumptions used in the calculations of Gargždai city

- The average 5-year Gargždai outdoor temperature
- Heat price 7.4 EURct/kWh
- Electricity price 11.6 EURct/kWh
- Heat demand 1737.4 MWh
- Geothermal system life time 20 years
- Interest rate 6 per cent
- Inflation rate 2 per cent
- Duration of loan 15 years
- Cost of maintenance for geothermal system 6 EUR/MWh

APPENDIX 12

Financial indicators and sensitivity analysis of Gargždai boiler No. 6

Financial indicators

Simple Payback	16 years 2 months
Net Present Value	0.036 billion Euro
Internal Rate of Return	8.0 per cent

Sensitivity analysis of investments

Variation in investments	Financial indicators	Values
Increase of investment 10 per cent	Simple Payback	18 years 1 month
	Net Present Value	0.005 billion Euro
	Internal Rate of Return	6.6 per cent
Decrease of investment 10 per cent	Simple Payback	14 years 8 months
	Net Present Value	0.070 billion Euro
	Internal Rate of Return	9.7 per cent

APPENDIX 13

Report examples of annual and monthly energy conversion

Energy conversion, annual

Calculated period: 01.2017 - 12.2017

Heat demands:

Heat demand	41.997,9 MWh	
Max heat demand	13,6 MW	

Heat productions:

Solar Collector	4.126,5 MWh/year	9,8 %
Boiler	37.871,3 MWh/year	90,2 %
Total	41.997,9 MWh/year	100,0 %

Peak electric production:

Hours of operation:

	Total [h/Year]	Of annual hours
Solar Collector	2.075,0	23,7%
Boiler	5.162,0	58,9%
Out of total in period	8.760,0	

Turn ons:

Solar Collector	316
Boiler	42

Energy conversion, monthly

Calculated period: 01.2015 - 12.2015

	Total	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Heat demand [MWh]	**41.993,3**	7.930,8	6.953,0	5.694,4	2.129,8	716,6	693,4	716,6	716,6	693,4	2.716,0	5.342,7	7.690,1
Energy unit: Solar Collector													
Heat prod. [MWh]	**4.128,3**	2,6	42,3	237,6	590,5	716,4	699,3	717,0	685,1	361,1	76,3	0,0	0,0
Turn ons	**311**	7	23	31	33	41	39	45	38	30	24	0	0
Operating hours	**2.091**	16	90	206	276	272	267	292	313	241	118	0	0
Full load operating hours	**844**	6	31	61	109	122	123	122	126	107	38	0	0
Energy unit: Boiler													
Fuel consum. [tons]	**13.899,6**	2.910,3	2.536,8	2.003,1	571,2	0,0	0,0	0,0	3,7	121,4	969,0	1.961,2	2.822,9
Fuel consum. [MWh]	**40.169,8**	8.410,7	7.331,3	5.788,9	1.650,9	0,0	0,0	0,0	10,7	350,7	2.800,3	5.667,9	8.158,2
Heat prod. [MWh]	**37.864,9**	7.928,2	6.910,6	5.456,8	1.556,1	0,0	0,0	0,0	10,1	330,6	2.639,7	5.342,7	7.690,1
Turn ons	**44**	0	0	0	7	0	0	0	3	30	4	0	0
Operating hours	**5.206**	744	672	744	447	0	0	0	15	389	731	720	744
Full load operating hours	**1.646**	345	300	237	68	0	0	0	0	14	115	232	334
Fuel consumption: Wood chips													
Fuel consum. [tons]	**13.899,6**	2.910,3	2.536,8	2.003,1	571,2	0,0	0,0	0,0	3,7	121,4	969,0	1.961,2	2.822,9
Fuel consum. [MWh]	**40.169,8**	8.410,7	7.331,3	5.788,9	1.650,9	0,0	0,0	0,0	10,7	350,7	2.800,3	5.667,9	8.158,2
Peak [MW]	**13,747**	13,747	13,260	10,672	6,385	0,524	0,517	0,075	1,105	1,105	6,684	10,970	13,593

APPENDIX 14

Report example of cash flow

Cash Flow, summary

(All amounts in LTL)

	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Revenues										
Revenuesfromsolarcollectors	817.389	817.825	819.217	817.466	817.032	817.089	817.336	818.993	818.224	817.466
Total Revenues	**817.389**	**817.825**	**819.217**	**817.466**	**817.032**	**817.089**	**817.336**	**818.993**	**818.224**	**817.466**
Operating Expenditures										
Operationalcosts_solarcollectors	14.247	14.254	14.279	14.248	14.241	14.242	14.246	14.275	14.261	14.248
Total Operating Expenditures	**14.247**	**14.254**	**14.279**	**14.248**	**14.241**	**14.242**	**14.246**	**14.275**	**14.261**	**14.248**
Net Cash from Operation	**803.142**	**803.570**	**804.938**	**803.217**	**802.791**	**802.847**	**803.090**	**804.718**	**803.962**	**803.217**
Investments										
Investment_solarcollectors	8.900.000	0	0	0	0	0	0	0	0	0
Total Investments	**8.900.000**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Cash From Long Term Financing										
Loan_solarcollectors	8.900.000	0	0	0	0	0	0	0	0	0
Total Cash From Long Term ...	**8.900.000**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Debt service										
Loan_solarcollectors	857.446	857.446	857.446	857.446	857.446	857.446	857.446	857.446	857.446	857.446
Total Debt service	**857.446**	**857.446**	**857.446**	**857.446**	**857.446**	**857.446**	**857.446**	**857.446**	**857.446**	**857.446**
Total Interest on Cash Account	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Cash Surplus	**-54.304**	**-53.876**	**-52.508**	**-54.229**	**-54.655**	**-54.599**	**-54.357**	**-52.728**	**-53.484**	**-54.229**
Cash Account	**-54.304**	**-108.180**	**-160.688**	**-214.917**	**-269.572**	**-324.171**	**-378.527**	**-431.255**	**-484.739**	**-538.968**

	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033
Revenues										
Revenuesfromsolarcollectors	817.121	817.389	817.825	818.993	818.197	817.032	817.089	817.389	817.938	818.224
Total Revenues	**817.121**	**817.389**	**817.825**	**818.993**	**818.197**	**817.032**	**817.089**	**817.389**	**817.938**	**818.224**
Operating Expenditures										
Operationalcosts_solarcollectors	14.242	14.247	14.254	14.275	14.261	14.241	14.242	14.247	14.256	14.261
Total Operating Expenditures	**14.242**	**14.247**	**14.254**	**14.275**	**14.261**	**14.241**	**14.242**	**14.247**	**14.256**	**14.261**
Net Cash from Operation	**802.879**	**803.142**	**803.570**	**804.718**	**803.936**	**802.791**	**802.847**	**803.142**	**803.681**	**803.962**
Investments										
Investment_solarcollectors	0	0	0	0	0	0	0	0	0	0
Total Investments	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Cash From Long Term Financing										
Loan_solarcollectors	0	0	0	0	0	0	0	0	0	0
Total Cash From Long Term ...	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Debt service										
Loan_solarcollectors	857.446	857.446	857.446	857.446	857.446	0	0	0	0	0
Total Debt service	**857.446**	**857.446**	**857.446**	**857.446**	**857.446**	**0**	**0**	**0**	**0**	**0**
Total Interest on Cash Account	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Cash Surplus	**-54.568**	**-54.304**	**-53.876**	**-52.728**	**-53.510**	**802.791**	**802.847**	**803.142**	**803.681**	**803.962**
Cash Account	**-593.536**	**-647.840**	**-701.715**	**-754.443**	**-807.954**	**-5.162**	**797.685**	**1.600.828**	**2.404.509**	**3.208.471**

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SL344. 2016-08-29, 18 leidyb. apsk. l. Tiražas 12 egz. Užsakymas 311.
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