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# Analysis of energy development sustainability: The example of the lithuanian district heating sector

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ABSTRACT

Today, sustainable energy development is one of key issues on European development agenda. The article describes one of sustainable energy development promoting tool - the eco-labelling scheme for district heating and cooling systems elaborated within the framework of Intelligent Energy for Europe program project "Ecoheat4cities" and partially funded by European Agency for Competitiveness and Innovation. The scheme is based on measured energy and environmental performance data of the district heating and cooling system and considers primary non-renewable energy usage together with the share of renewable energy and carbon dioxide emissions calculated using life-cycle analysis methodology. The "power bonus" approach is used for performance indicators of the heat generated in cogeneration installations. An analysis of a number of Lithuanian district heating companies using elaborated labelling criteria shows positive trends towards fulfilling Lithuania's energy policy goals. The labelling scheme gives opportunity for policy makers and urban planners to compare different heat supply options and decide upon exploiting district heating advantages and benefits for reaching EU energy and environment policy goals.

## 1. Introduction

Common understanding of sustainable energy is provision of energy that meets the needs of the present without compromising the ability of future generations to meet their needs (Renewable, 2004). Two main trends in development of sustainable energy technologies are wider use of renewable energy sources and increasing energy efficiency. The first trend means replacement of fossil fuels with renewable energy sources such as wind, solar, hydro, and geothermal energies as well as biomass, which is the main renewable source in Nordic countries. The second trend, which is considered to be even more important, is raising energy efficiency in whole energy supply chain leading to reduced extraction, transporting and conversion as well as supply losses coupled with higher efficiency in consumers' installations.

The shortcomings of the use of fossil fuel becomes more evident due to declining global resources, political dictatorship of exporters, as well as the impact of increased greenhouse gases emissions on climate change.

Biomass is the main renewable energy source, widely used in Lithuania, where besides above mentioned reasons, biofuel production also contributes to the development of regional economics, creates new jobs and reduces energy generation costs. The use of RES is constantly growing, so the demand for biomass also increases. This demand fosters the need for new policies, legislation, rising of awareness and creating new opportunities for forestry and agriculture sectors. Thus, one can clearly see that security of energy supply and climate change prevention are the main driving forces for bioenergy market development. Methodological background for sustainable technological development includes environmental, economic and social aspects of energy sector in various governing levels.

Energy criteria for sustainable development were formulated by several global and European energy agencies (IAEAI, 2005), which involved development guidelines and methodology for impact assessment in social, economic and environmental dimensions. For the purpose of this work several criteria were analysed, which are most closely related to the use of biofuel and energy efficiency measures in autonomous and district heating (DH) technologies. Primary non-renewable energy factor, carbon dioxide emission factor and renewable and recycled energy factor were selected as best describing purposes of this investigation i.e. data availability, transparency, explicitly and public acceptance.

The paper deals with sustainability criteria, which is used for labelling purposes of DHC systems with the aim to promote sustainable development and enlarge public acceptance of DH, which is considered as the most efficient and environment friendly type of heat supply within towns and other densely populated areas. Scores used for

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**Nomenclature**

| | |
|---|---|
| CHP | Combined heat and power |
| DH | District heating |
| DHC | District heating and cooling |
| DHS | District heating system |
| EU | European Union |
| GHG | Greenhouse gases |
| IEE | Intelligent Energy for Europe |
| LNG | Liquefied natural gas |
| RES | Renewable energy sources |
| RES-E | Renewable energy sources for heat generation |
| RES-H | Renewable energy sources for heat generation |

*Symbols*

| | |
|---|---|
| $E$ | energy |
| $Q$ | heat |
| $K$ | emission coefficient |
| $R$ | renewable and surplus heat fraction |
| $\beta$ | ratio of any specified energy to total heat |
| $EP$ | energy performance indicator |
| $ES$ | energy source indicator |
| $f$ | factor |
| *ref* | reference |
| $s$ | power loss index |
| $\sigma$ | power-to-heat ratio |
| $\eta$ | efficiency |

*Indexes*

| | |
|---|---|
| *aux* | auxiliary |
| *hn* | heating network |
| *cond* | in condensation mode |
| *hp* | heat producer |
| *chp* | combined heat and power |
| *Hi* | heating value |
| *del* | delivered |
| *ng* | natural gas |
| *dh* | district heating |
| *nren* | non-renewable |
| *el* | electricity |
| *P* | primary energy |
| *ext* | external |
| *R* | renewable and surplus heat |
| *F* | fuel |
| *ref* | reference |
| *i* | index for energy carrier |

labelling are related to reference system, where above indicators meet minimal efficiency and environmental requirements which mean that such system meets the goals of EU 2020 energy policy. An analysis covers a number of Lithuanian DH companies. There are no district cooling networks in the country at present.

Geographic location and climate conditions make Lithuania highly dependent on DH generation and supply effectiveness as widely developed DH sector covers heating needs of about half of population and up to 90% of heat demand in public and residential houses of largest cities. The main goals of Lithuania's heat sector are to ensure reliable, secure and qualitative heat supply to all consumers with the least costs; to promote competition between various types of fuel and heat generation technologies; to improve the efficiency of heat generation, transmission and consumption; to promote wider use of indigenous fuel, biomass and other renewables; and to reduce negative impact to the environment (Ministry of Energy, 2016). Recently not secure natural gas supply from single Russian supplier has fostered DH conversion to biomass fuel as the most urgent priority, thus adding to implementation of nearly all above defined goals. At the same time, the new liquefied natural gas (LNG) terminal started operating in 2014 in the Baltic Sea port Klaipeda thus increasing supply security and bargaining power of Lithuanian natural gas importers. Lithuania's Government supports these actions via use of EU Structural Funds for modernization of existing and construction of new biomass boiler-houses and CHP plants, also via establishment of biomass fuel trading system as well as via establishing of new extended environmental requirements in national legislation.

## 2. Background

Energy consumption is increasing fast due to growing energy demand in all countries and especially in those that are developing, which also leads to growing energy costs and growing GHG emissions. Another factor is diminishing fossil fuel resources. Those two factors have raised global interest in the use of renewable energy sources and in the design of sustainable energy systems, which use renewable sources (Baños et al., 2011).

The new concept of sustainable development came into practice in planning and reforming of energy sector as a response to political and economic challenges faced during the past decades. It includes social, economic and environmental issues as well as development of techniques for decision-making process because traditional approach involving just economic or just environmental factors appeared to be non-effective for sustainability assessment of energy systems. Such situation led to the need of applying multi-criteria approach for analysis of complex systems, using a number of indicators for assessment of various aspects which are important for the future decision-making (Tsoutsos et al., 2009; Bazmi and Zahedi, 2011). These energy policy solutions, that meet sustainability requirements would help in selection of desirable sustainable and feasible technological solution (Häyhä et al., 2011).

Among the most informational criteria for selecting the most advanced energy generators, using renewable and hybrid energy sources, energy generation costs and $CO_2$ emissions are considered as the most important criteria (Goodbody et al., 2013). Implementation of such energy systems requires also technological assessment to define specific mix of resources, technologies and capacities for specific solution. Well-designed energy generating system using efficient technologies, should be the lowest costs solution, as well as reliable and sufficient to maintain appropriate living standards of consumers (Yılmaz and Selim, 2013). Various forms of broadening scope, primarily by focusing on electricity production by building combined heat and power plants, or using the alternative value of the technical system for new applications were investigated for DH systems in Sweden (Magnusson, 2012). Particular focus was made on strategic planning in district heating sector due to the fact that increased recovery of excess heat from CHP generation and industrial processes has the potential to reduce primary energy demand (Persson and Werner, 2012). Danish investigation shows that increased share of renewable energy sources reduces $CO_2$ emissions in the Danish building stock, while at the same time increasing flexibility of the energy system. Their economic model calculates the potentials and costs of connection to expanded district heating networks depending on supply technology. At the same time $CO_2$ emissions, fuel consumption and socio-economic costs can be reduced by expanding district heating (Möller and Lund, 2010).

Energy efficiency improvement defined via demand-side energy savings is not less important, as social aspect such as reduction of