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Pathway and restriction in district heating systems development towards 4th generation district heating

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ABSTRACT

This article analyses the indicators that describe the overall efficiency of the district heating system and restrictions for its transition towards a 4th generation district heating system. The object of this case study is a district heating company with a modern biomass combined heat and power plant – "Fortum", in Jelgava. Possible development scenarios for the district heating company moving towards a 4th generation district heating system were analysed. The scenarios were compared via technological, economic and bioeconomic indicators and evaluated for their restrictions for limiting long-term sustainable development. The scenarios which include production of new biomass products (bio-oil) are the most sustainable solutions that allow to increase the added value from 58 €/t_{wood} to 80 €/t_{wood}. The heat tariff was analysed in order to identify the economic feasibility of the development scenarios. Reducing tariffs by improving district heating's operation is the only unsustainable solution for the district heating company because it reduces the company's possibility to invest in future developments. It is concluded that bioeconomic development scenarios can support sustainability of the district heating systems. Development decisions need to be taken in due time before the consumption decreases because of energy efficiency measures.

1. Introduction

The future district heating (DH) system is smarter and more sustainable by using low carbon technologies at all stages – heat production, transmission and final consumption [1]. DH will also be integrated in the overall energy system by so increasing its flexibility [2]. The DH integrated with cooling systems has strong potentials in future energy systems, but additional efforts are needed to identify, assess and implement these potentials [3]. The future prospects for DH and cooling systems in the world are connected with the following challenges: to communicate more efficiently the DH business concept; to implement a new vision for the DH that goes beyond a fossil free fuel mix; to introduce new technologies for using low temperature heat sources [4].

However, the DH systems may face problems regarding consumption decrease. This may be due to the increasing number of end users who choose to retrofit their buildings [5]. Improvements in efficiency by the end users will result in more specific transmission losses, lower linear heat density and higher distribution costs [6]. The concept of the 4th Generation District Heating (4GDH) requires synergy between energy conservation and the expansion of district heating [1].

A significant amount of thermal energy in Europe is produced by cogeneration of heat and power (CHP) plants [7]. The annual overall efficiency values proposed in the Energy Efficiency Directive are 80% (for combined cycle gas turbines with heat recovery and steam condensing extraction turbines) and 75% (for all other cogeneration technologies covered by the Directive) [8]. The latest CHP technologies are competitive – a well-designed CHP system can increase the annual overall efficiency value up to over 80% in small-scale [9] and up to 90% in large-scale cogeneration [10]. A reduction from heat consumption due to energy efficiency measures will lead to either production decrease of electricity or, in certain situations, electricity may be produced by condensation, by so lowering the economic feasibility of the CHP plant [11]. Several studies have been devoted to determining the optimal capacity [12] and operation requirements of CHP [13].

While modelling, certain requirements have been set to minimize the initial and operating costs of the energy supply system, however the optimal operation strategy is determined by using

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indicators [14]. Using the smart energy system approach, a 100% renewable energy system is possible without consuming an unsustainable amount of bioenergy [15]. In recent years the amount of CHP plants that use renewable fuels, particularly biomass, has increased in Latvia and in Europe overall. From the environmental standpoint, it lowers greenhouse gas emissions (GHG). It also decreases the transmission and distribution costs of electricity, and increases energy independence, consequently making the energy system more sustainable. An additional argument is that biomass is a good alternative to fossil fuels because of the lower heat tariff and higher cost-effectiveness, compared to individual heating technologies [16]. The use of biomass in DH should correspond to the principles of sustainable bioeconomy and circular economy [17]. Further in the article are analysed new indicators that identify the use of biomass and agree with the sustainable bioeconomy principles. A large number of scientific articles have explored the technological, economic, environmental and institutional impacts and indicators of using cogeneration in the DH system [3]. These indicators can be compared for the use of cogeneration at the national level [18] and between different countries [19].

The tariff is one of the most important indicators regarding the economic efficiency of DH [20]. Scientists suggest reconsidering the price structure of DH systems because a price intervention could bring results, which are more coherent in reducing the heat energy demand by retrofitting buildings [21]. The research process aims to analyse the interplay between the tariff regulation and energy efficiency goals while also providing information on regulations that correspond with the policy design [22].

For better comparison and analysis, it is important to classify the development scenarios of DH systems based on their characteristics and sustainability aspects. By understanding which indicators are important and how they interact, it is possible to identify the opportunities for improving existing systems.

Although there are several models dedicated to the analysis of the DH system in transition towards 4GDH, indicators that comprehensively describe the efficiency of the overall system have not been studied sufficiently. The main aim of this research is to analyse the possible development scenarios towards a 4GDH system, by comparing the technological, economic and bioeconomic indicators, while evaluating barriers and restrictions that limit long-term sustainable development of the DH system.

2. Methods

The 4GDH concept provides development of combined heat and power (CHP) technology as one of the more flexible and essential for future [23]. However, the heat usage will decrease when the process of retrofitting energy ineffective housing accelerates and the DH system is upgraded to 4GDH including other heat sources (solar, heat pumps), heat storage devices and a smart heating grid.

This decrease of demand can be compensated by attracting new already existing customers (local DH systems with less efficient, often fossil energy heat source) or industrial customers (preferably integrated with the CHP plant), introducing district cooling and, where possible, supporting new housing developments. In case a decrease in demand happens faster than the new developments, the CHP plant may become uncompetitive. Therefore, it is important to choose indicators that allows predicting competitiveness of the DH system by coupling with low emission strategy towards providing smart solutions.

2.1. Selection of research indicators

Several often used indicators and some relatively new indicators have been selected in Fig. 1 to describe the DH system's performance.

The main goal of this research is to identify the most economically feasible solutions for developing the current DH system towards 4GDH and a smart energy system based on a coherent modernization approach. The coherence of this approach is expressed by the developing synergies between three different parts of DH: heat source, networks and end-users. This means that the changes at each stage will have an impact on the overall system development.

The European Union countries apply different approaches when assessing the efficiency of cogeneration units [24]. The overall annual efficiency of cogeneration is the ratio between all annual energy outputs and all annual energy inputs into the plant during the reporting period (year) [25]:

$$\eta_{CHP} = (Q_{CHP} + E_{CHP})/f_{CHP} \tag{1}$$

where Q_{CHP} – the useful thermal energy, MWh per year; E_{CHP} – annual amount of produced electricity from cogeneration, MWh per year; f_{CHP} – annual fuel energy flows entering the system. If

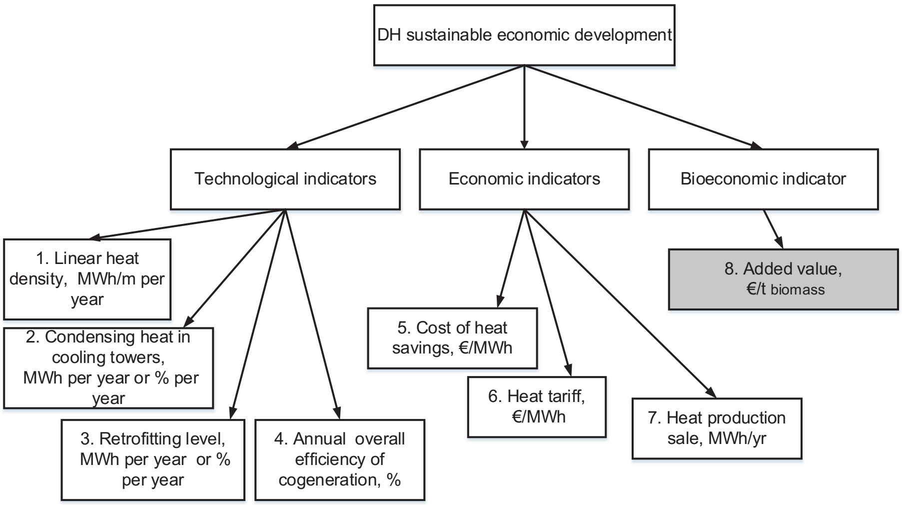

Fig. 1. Selection of indicators.