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The effect of energy efficiency improvements on the development of 4th generation district heating

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Abstract

Article is about development scenarios for the Latvian district heating system in which a policy instrument for energy efficiency improvement is used to achieve a higher share of renewable energy. The system dynamics model was used to determine whether it is possible to use energy efficiency policy to accelerate a shift from fossil fuels to renewables in district heating. In addition, the task was to determine measures which would help to remove barriers for renewable resource technology implementation. Six different development scenarios were viewed in the article. Results reveal that increased energy efficiency at heat source have no direct impact on fossil energy and renewable energy ratio. By increasing energy efficiency it is only possible to vary renewable energy share between different renewable technologies. It is possible to reach 40 % biomass energy share and 30 % solar energy share in 2030 when policy is used only for biomass technologies, but 20 % biomass energy share and 50 % solar energy share could be achieved by implementing policy only for solar technologies. The main barrier for switching from fossil energy to renewable energy is a lot of new gas boilers which were installed during reconstructions at many heat sources in the past few years. It is possible to reach even 97.47 % renewable energy share in district heating in 2030 if the service life for gas boilers is reduced to 5 years.

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Keywords: district heating; energy efficiency; 4th generation district heating; renewable energy

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1. Introduction

Technical, economic and environmental aspects of district heating and cooling are being studied in scientific papers more and more often [1]. Special attention is given to efficiency of different technical solutions at all district heating stages – at heat source [2], at heat network [3] and at end users [4]. Targets for improvement of energy efficiency are set at the European Union (EU) level [5] and they are supported in every country with roadmaps. In Latvia energy efficiency strategy provides measures at heat end users and at energy conversion sector [6]. Largest energy efficiency potential can be found in district heating systems, apartment buildings, municipal buildings and public institutions which are also part of district heating systems.

Energy efficiency is accented as one of the most important factors in the concept of 4^{th} generation district heating (4GDH) [7]. Based on the concept, renewable energy and excess heat are used at the heat source. Most common renewable energy sources by different authors are heat pumps [8], biomass cogeneration (CHP) plants [9], and solar collectors with seasonal storage [10]. All technological solutions which are implemented in district heating systems have a high energy efficiency level [11]. Every EU country has its own implementation rate for renewable energy technologies. Denmark has the most ambitious target – 100 % renewable energy by year 2060 [12]. Many scientists in the EU are modeling district heating systems to determine how high a renewable energy share will be both in the short and long term [8].

Implementation of renewable energy technologies in district heating systems is not an easy or straight forward process because it comes with many different barriers [13] which could be technical, economic, social, political, or environmental in nature.

There are many studies about implementation of renewable energy technologies in district heating, but there are not so many studies about barriers that arise when integrating renewable technologies in systems. The aim of this research is to use system dynamic modeling to determine possible development scenarios for district heating in Latvia both in the short and long term based on implementation of the 4GDH concept. System dynamic model will be used to determine whether it is possible to increase the renewable energy share by implementing policy which increases energy efficiency. In addition to renewable energy share the aim is to find measures which could help to remove barriers that prevent implementation of renewable energy technologies.

2. Methodology

System dynamic model was developed in "Powersim Studio 8" software. The model was designed to study implementation of 4GDH. System dynamic model consists of several parts including heat source, heat transmission and heat end user and it consists of many stocks, flows and feedback interactions and has been presented in [14].

The model's heat source part consists of several possible heat production technologies – gas combustion boilers and biomass combustion boilers both of which are currently used in Latvian district heating as well as solar collectors with seasonal storage and heat pumps which are considered as future district heating technologies. Other heat source technologies could be added to the model. The heat source part generates deterioration of technologies as well as installation of new capacities for technologies which results in a gradual shift from one technology to another. The initial technology capacity is 875 MW from which 80 % are gas combustion boilers but 20 % are biomass combustion boilers. Solar and heat pump share is taken 0.001 %. Total capacity and distribution comes from actual situation in Latvian district heating boiler houses. Shift from one technology to another is based on economic reasons and the main indicator is the heat tariff. Technologies for which service life have come to an end, are replaced by the ones with the lowest heat tariff. Installed amount is described by logical function [15]. More similar heat tariffs for different technologies more evenly installed capacity is spread between technologies.

Heat tariff is made based on heat tariff calculation methodology confirmed by the Latvian Public Utilities Commission (PUC) [16]. It includes fuel costs and loan repayments, thereby considering and comparing most important costs for different heat production technologies.

System dynamic model also includes heat losses (8 %, low-temperature networks) as well as changes in heat demand from end users side based on historical data. Forecasts for technology costs, fuel costs, electricity costs and heat demand, comes from historical data [17] as well as from other researchers [18].