PAST, PRESENT AND FUTURES OF DISTRICT HEAT SUPPLIERS, WITH SPECIAL REGARD TO HUNGARIAN DISTRICT HEAT SUPPLIERS - LITERATURE REVIEW

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Abstract: *In recent years, many researchers displayed interest in the different types of social innovations. In the current research, the author does not aim at creating a new definition, but at examining the possibilities to generate social innovations in the case of district heat suppliers by accepting the previously created definitions. In the case of district heat suppliers, three levels of social innovations can be distinguished and the current research aims at presenting how they have been realized worldwide for almost 140 years. Its methodology includes bibliography research based on seconder research methods and its result is a summary which helps make the heat supplier systems of different generations from the 19th-21st centuries transparent. The purpose of the present study is to examine the changes in the district heating systems of the world by examining international literature with the methods of literature review. District heating systems are grouped based on the following aspects: the role of heating systems in the given country, price level / price regulation, the technical and technological characteristics of heating systems and the share of renewable energy sources. The study emphasizes several times the related current conditions and characteristics in Hungary. The results of this literature review prove to be an important tool for the author's further research.*

Keywords: *District heat supply; District heat producers; District heat suppliers; technological and ecological environment; social innovation.*

JEL Classification: *K32.*

1. Introduction

The roots and the first forms of central heating can be found in the ancient times. Karner (2003), however, points out that, contrary to the general belief that district heating could be linked to the Romans, this way of heating was known also in the capital city of Mesopotamia and similar procedures to central heating were used in ancient China as well. In ancient times and in the Middle Ages, many inventions came to be used independently by many different peoples and groups at almost the same time, so central heating is likely to be similar. In the Roman Empire, the ancestor of the today underfloor heating was used to ensure the temperature of the baths, but similar technical implementations were used to supply other buildings as well. In 13 BC Pallio Vitrovius, Roman architect, presented the heating system of the imperial palace.

Like many ancient discoveries, central heating was forgotten or played a minor role in the Middle Ages. However, some records from the 15th century mention the district heating of baths. Subsequently, the technical development of the industrial revolution provided the opportunity for this type of heating to spread.
In the 1790s, waste heat from English factories was transported via underground pipelines to heat public baths and since the middle of the 19th century "apartments heated from long distance" has been spread in several European (London, Paris, Hamburg, Dresden) and American (New York, Boston) cities.
“Social innovation provides new or original solutions to solve the problems of a community with the aim of improving its well-being” (Kocziszky, Veresné and Balaton, 2017). Through reaching the goals to improve the quality of life, heat suppliers implement social innovations by their products (heat and hot water supply), by the applied technologies and by implementing them in consumer-friendly services (Süveges, 2019). It was, however, realized in different ways during the centuries. The current study aims at describing the heating generations of the 19th-21st centuries by analyzing the international literature. The basis of the comparison as the possibilities to generate social innovations are the technical and technological characteristics of district heating.

2. Literature review

Based on the examination of the international literature, I classified the heat supply systems operating in different countries according to the following criteria:

1) Main reasons and historical roots of the development of heat supply
2) Prices of district heating
3) Generations of heating systems and their technical and technological characteristics
4) Proportion of renewable energy sources in the total heat supply capacity.

2.1. Main reasons and historical roots of the development of heat supply

Kádárné (2010) explained that in different parts of the world, district heating systems had developed from different motivations and with different technical and technological conditions. The Association of Hungarian District Heat Suppliers classifies the systems of European countries into four groups:

1) Northern Europe: Sweden, Finland, Denmark and Iceland, where the role of this heating method is constantly appreciated for its positive effects on the protection of the environment and climate. In these countries, it is also an important instrument of the energy policy and it is continuously improved. Accordingly, the proportion of district heating in apartment heating is extremely high. In Denmark, it is over 60% and up to 98% in some major cities. Denmark is considered to be a model country from several aspects due to the leading-edge technologies (Vanhoudt, Oevelen and Johanson, 2019; Nielsen, 2019) and to the high utilization rate of geothermal energy (Margaryan, Dyrelund and Hansen, 2019).

2) Austria and Germany, where gas and district heat suppliers are organized into holding companies owned by local municipalities and the development of heat suppliers is an integral part of urban environmental programs (Kádárné, 2010). The proportion of heat supply out of heating systems is much lower in this group than in the previous one.
3) The proportion of district heat in the group including France, Italy, the United Kingdom and certain parts of the Netherlands is low (5%) and there is no great tradition of this heating method. However, the governmental energy strategies of these countries also include district heating projects with low carbon dioxide emission, both for the general public and for other users (Webb and Bush, 2019). In the case of Italy, the use of water with lower temperatures can be observed in the heat supply (Kádárné, 2010), which is considered by many to be a significant way of future development of district heating (Jensen, 2019). The initial low share of district heating, of course, has the advantage of providing opportunity to increase the role of renewable energy sources. In France, for example, the share of this energy source has doubled in five years and is expected to increase to five times compared to its 2013 value by 2030 (Perrin, 2018). Especially in the northern and eastern metropolitan areas of the country, an increase in utilization is expected with the use of further synergies (Boysen, 2018). Ireland has similar conditions, where there is no historical tradition of large-scale district heating, the rate is only 1% like in much warmer countries in Europe like Greece, Cyprus and Malta, however, more and more countries consider district heating to be an opportunity to meet their energy policy and environmental goals (Gartland, 2018).
4) Newly acceded Member States of the European Union, all of which have experienced "a period of rapid and forced industrialization" (Kádárné, 2010, p.23). As these countries have a district heat ratio exceeding the EU-15 average, they are often of lower quality in technical implementation (like thermal insulation) and in technology due to the historical aspects of their construction and have considerable potential for development.

In the European Union, on average, district heating accounts for about 10% of heating, similarly to the world average, but significant differences can be observed among countries (Werner, 2016).

2.2. Classification based on the prices of heat supply

There are other options of grouping in addition to the above described one. One such research material of relevance, also conducted by Werner (2016) and being part of the research on the future role of district heating, compared the price levels of European heat suppliers and created the following groups based on prices:

1) Countries with high price: Denmark, Slovakia, Germany, Norway and Sweden,
2) Countries with low price: Iceland , Bulgaria, Switzerland, Poland and Hungary,

3) Countries with high district heating prices compared to the disposable income: Slovakia, Estonia, Latvia, Lithuania. (Interestingly, Hungarian district heating is generally associated with high prices in the mind of the individuals (Németh, 2008), but this statement cannot be justified either in absolute or relative terms based on the research results.)

In their study, Kácsor, Kerekes and Mezősi (2019) grouped European heat supply systems according to the type of district heating system in the country. Based on their summary research, two groups can be distinguished:

1. In most Western European countries, "there is no explicit price regulation system, any abuse of a dominant position is detected or sanctioned by the competition authorities through ex-post procedures… .. the pricing model used here leave it to the competition among heating modes and competition for consumers to determine district heating prices and district heat suppliers may not use their position improperly"(Kácsor, Kerekes and Mezősi, 2019 p. 8)
2. "Ex-ante price regulation" by regulators responsible for regulating and supervising energy markets is common in Eastern European countries (Kácsor, Kerekes and Mezősi, 2019, p. 9).

District heating used in Hungary can be classified into the price regulation systems of the Eastern European countries based on the procedures applied by the regulatory system. This is well illustrated by several events like the 2011 Freezing of Service fees. The Act XXIX of 2011 on the Amendment of the Energy Related Laws Frose on Retail Prices and Prices of Institutions Treated Separately as of March 31, 2011. It is the Minister of National Development who is responsible for setting prices of heat sold to the public and to institutions treated separately as the highest official price. Also included in 2012 are the Transformation of the energy support system and in 2013 the Utility price cuts. As a result of the price cuts in district heating, the total savings of 20% were realized by consumers on the whole in more stages.

At this moment, the Hungarian district heating regulation consists of three parts, which are as follows:

1) Prices for residential district heat services
2) Prices applied by heat suppliers
3) Subsidies for district heat suppliers

2.3. Generations of heating systems and their technical and technological characteristics

One of the most frequently mentioned elements in the international literature analyzing district heating is the generation-by-generation comparison of heating systems (Lygnerud, 2019). Several researchers have dealt with this topic, among which the study by Lund, Werner, Wiltshire, Svendsen Thorsen, Hvelplund and Matthiesen (2014) is outstanding. Its main assumption is that district heating and cooling systems will play a major role in the sustainable energy systems in the future, by reaching up to 100% renewable rate. In order to achieve this, however, significant improvements are needed compared to the current situation. The different generations have been characterized by a number of aspects which can be grouped into three groups. The main findings of their study are summarized in the Table 1. In

both the United States and European countries, first generation heating systems were based on similar technology, characterized by technically inefficient operation and high network losses. The heat-conveying of the second generation systems was water at temperature of 100ºC at high pressure and all systems built from the 1930s used this technology until the 1970s. This was typical of the heating systems of the countries of the Soviet bloc. Construction was characterized by low quality and there was no possibility / need to regulate or change the amount of heat used.

Table 1: Generations of heating systems and their technical and technological characteristics

	Generations of heating systems			
Evaluation criteria	**First generation**	**Second generation**	**Third generation**	**Fourth generation**
Period	1880-1930	1930-1980	1980-2020	2020-2050
Heat-conveying	Steam	Mostly pressurized hot water (above 100ºC)	Mostly pressurized hot water (below 100 º C)	Low temperature water (30-70ºC)
Serviced buildings, needs	Blocks of flats and the buildings of the tertiary sector in cities	Blocks of flats and the buildings of the tertiary sector, typical size is 200-300 kWh/m^2	Blocks of flats and the buildings of the tertiary sector and detached homes, typical size is 200-300 kWh/m^2	Existing buildings with lower heat demand (50-150 kWh/m^2) and small scale (<25 kWh/m^2) new users
Heating in the apartments	Radiators using high temperature water (90ºC) or steam	Radiators using high temperature water (90ºC)	Radiators using medium temperature water (70º C) and underfloor heating	Radiators using low temperature water (50º C) and underfloor heating
Basis of thermal energy	Carbon	Oil, natural gas	Natural gas, biomass, renewable energy sources	Renewable energy sources

Source: Own compilation based on Lund, Werner, Wiltshire, Svendsen Thorsen, Hvelplund and Matthiesen (2014)

Third-generation heating systems including solutions from the late '70s and early' 80s are often referred to as "Scandinavian district heating technology" because many of the components used in district heating have been manufactured in the Nordic countries. These systems and technical solutions are used in the former Soviet Union Member States and in Central and Eastern Europe, but the systems

currently being built in China, Korea, USA and Canada also belong to this generation.
Besides technical and technological basis, the authors also reviewed motivation factors that are summarized below.

Table 2: Generations of heating systems and motivation factors

	Generations of heating systems			
Evaluation criteria	**First generation**	**Second generation**	**Third generation**	**Fourth generation**
Period	1880-1930	1930-1980	1980-2020	2020-2050
Primary motivation of the society and the consumers	Convenience and risk reduction	Fuel reduction, lower costs	Security of supply	Recognition of the role of district heat supply in the fossil energy carriers freedom
Justification and aim of the investments and their motivation from decision making side	Minimizing the subsistence costs per consumers	Advantages of cost reduction derived from cogeneration	Taking into account reduced payback time	Choosing projects with longer payback time

Source: own compilation based on Lund, Werner, Wiltshire, Svendsen Thorsen, Hvelplund and Matthiesen (2014)

The development of the first generation heating systems from the consumers' point of view was mainly motivated by comfort and safety factors and the aim was to replace the individual heating systems and boilers in the private homes, which were then able to produce hot water in a less safer way and they often exploded. The second-generation systems were motivated by social reasons that differed from country to country, but in general the main goal was to reduce the level of resources used and increase comfort. The motivation factors of the currently used third generation systems are not different from the previous generations on the substance, with the addition of the increasing presence of renewable energy sources for environmental reasons (Lund, Werner, Wiltshire, Svendsen Thorsen, Hvelplund and Matthiesen, 2014).
Currently, the vast majority of district heating companies in the world, including Hungary, belong to the third generation systems. The authors argue that the same applies for district cooling systems, that is, the technologies and motivations appropriate to the third generation are in use and valid here.
Of course, it should be added that district cooling does not have such a history than heating. It first appeared in the literature in the '90s. In the case of district cooling, the United States played a pioneering role, where there were 1,000 such systems in

operation three decades ago. Japan is also outstanding and district cooling has an increasing appearance also in European countries (Karner, 2003).
Not surprisingly, the Danish have already made specific steps towards the fourth generation, with the redesign of the existing 90oC system in a suburb of Copenhagen, where the introduction of a low-temperature system of 50-55oC was decided in the case of 1,500 households (Hog and Moos, 2018). This will not be the first such system for newly built homes where district heating systems were developed based on the fourth generation approach (Horsen, Gudmundsson, Hansen, 2016). Technically and technologically, the aim is to reach the fourth level when the systems built on renewable energy base operating with high efficiency and low losses contribute significantly to the achievement of environmental objectives. The success of the new generation is based on the change in the motivation and decision-making system of consumers and service providers and producers and the shift towards long-term, environmentally sustainable solutions.
In the case of fourth generation district heating, I accept the authors' definition that the 4th Generation District Heating (4GDH) system is consequently defined as a coherent technological and institutional concept, which by means of smart thermal grids assists the appropriate development of sustainable energy systems. 4GDH systems provide the heat supply of low-energy buildings with low grid losses in a way in which the use of low-temperature heat sources is integrated with the operation of smart energy systems. The concept involves the development of an institutional and organizational framework to facilitate suitable cost and motivation structures. (Lund, Werner, Wiltshire, Svendsen Thorsen, Hvelplund & Matthiesen, 2014, p. 10).
I think that grouping the heating systems by generations, in addition to describing the current situation, also sets the future by describing development and motivation perspectives. The timeliness of the paper has been confirmed, as due to the changes in the Earth's climate and in order to prevent further problems, heat suppliers play an important role therefore the situational picture of the companies operating in Hungary provides the basis for further development opportunities.

2.4. Proportion of renewable energy sources in the total heat supply capacity
Although all countries have third generation heating systems, it does not imply that the countries are on the same level on the path toward fourth generation systems. This is illustrated in Figure 1, showing the share of renewable energy sources in heating and cooling in different countries of the European Union.
From the Figure 1, the following statements can be made about the energy mix:

1) Different countries have different levels of share of renewable energy in the total energy use in the field of heat supply.
2) In the last few years, the largest change in the proportion could be experienced in the Baltic States. In this change, the relative rearrangement of the fuel price and the increase in gas prices played an important role.
3) Other measures, mainly tax and administrative reduction measures, have been taken to orient energy use towards biomass and biogas-based heat production, such as halving the VAT on biomass in Latvia or exempting

large-scale plants fueled by biomass and biogas from environmental charges in Lithuania.

4) Large-scale growth over the past years is not expected to remain unchanged in the coming period due to the high aid component and the decrease in energy prices (Kácsor, Kerekes and Mezősi, 2019)

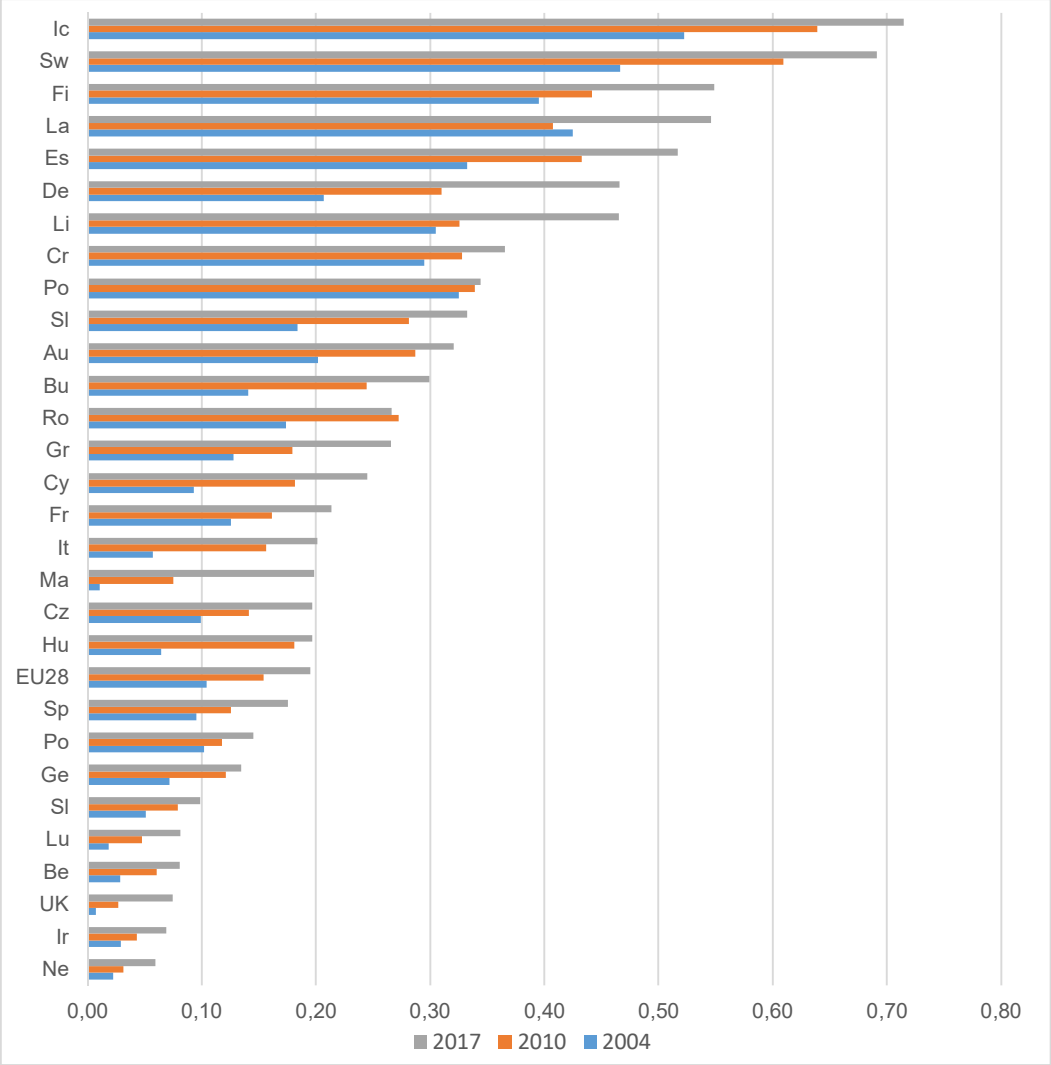

Figure 1: Proportion of renewable energy sources in total heat supply capacity in the 28 Member States of the European Union 2004-2017
Source: Own compilation based on Eurostat, [nrg_ind_ren]

3. Summary

The purpose of this study was to provide a brief summary of the past, the present and the potential future development opportunities of district heat suppliers. Based on the examination of the most important international literature in this field, heat suppliers were examined based on different grouping possibilities. For the future, fourth generation heating / cooling systems relying on renewable energy sources can play a key role in achieving climate protection goals. This study provides a good basis for the author's further research works.

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Bio-note:

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