

## DETERMINANTS OF SUSTAINABLE DEVELOPMENT OF DISTRICT HEATING SYSTEMS

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**Abstract:** The heating sector, which accounts for half of the EU's final energy consumption, still relies heavily on fossil fuels. This results in the emission of greenhouse gases and other pollutants into the atmosphere. For this reason, the European Union has, for several years, been pursuing a climate and energy policy which, in the area of district heating, is intended to make it more efficient and sustainable. This means introducing low-carbon technologies and reducing fossil fuel consumption in favour of renewable energy sources. Modern efficient district heating systems should guarantee a reliable heat supply while reducing environmental impact. The article discusses the main factors important for the sustainable development of district heating. The potential and importance of the heating sector in the European Union member states was presented. Then, the factors affecting the development of this sector are shown and the directions of transformation of district heating systems with the use of renewable energy sources are discussed. It also presents the current structure of fuels consumed by the district heating sector in Europe and its projected development with the use of high-efficiency cogeneration and various renewable energy sources.

**Keywords:** district heating; fuel mix, renewable energy sources; decarbonisation

### 1. INTRODUCTION

In recent years, the issues of energy security, energy savings and energy efficiency, as well as the development of new energy technologies, have occupied an important place in discussions on economic development, increased competitiveness and environmental protection in EU countries and around the world. While the energy sector, including district heating, determines socio-economic development, it also affects the environment and climate change on a global scale. In order to counteract these phenomena, the European Union has been pursuing a rigorous climate and energy policy within its sustainable development strategy for several years. The main elements of this strategy in the area of district heating are efficient use of energy, development of renewable energy sources (RES) and cogeneration, reduction of greenhouse gas emissions, and implementation of energy-saving technologies in buildings (European Commission, 2016; Ministry of Climate and Environment, 2021). The European Green Deal, adopted in 2019 by the European Commission, is a

continuation of environmental protection and climate change measures. This is a new development strategy whose main objective is to achieve net zero greenhouse gas emissions in 2050, with economic growth decoupled from the use of natural resources (European Commission, 2019). This involves the decarbonisation of the energy sector (electricity and heating), the deployment of low-carbon technologies and the reduction of fossil fuel consumption in favour of renewable energy sources.

**2. THE STATE OF DISTRICT HEATING IN THE EUROPEAN UNION COUNTRIES**

The heating and cooling sector represents half of the energy consumption in the EU, being supplied 75% by fossil fuels (European Commission, 2016). The volume of gross heat generation in EU countries in 2018 is shown in Figure 1.

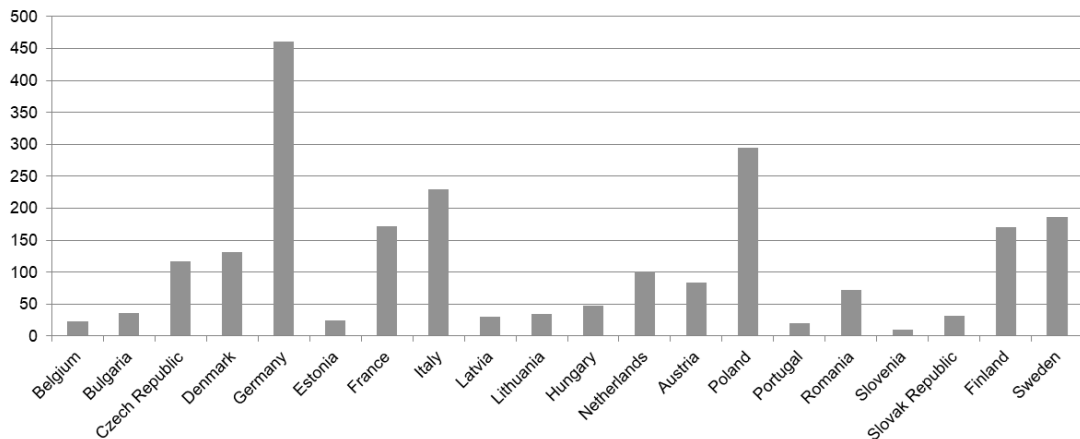


Fig. 1. Gross heat generation in EU countries in 2018 [PJ]

Source: own elaboration according to the European Commission, *EU energy in figures*, 2020

Depending on the customer group, the share of thermal energy demand is different. In the residential sector, most heat is consumed for space heating, while in industry electricity and heat are used for process heating (Figure 2).

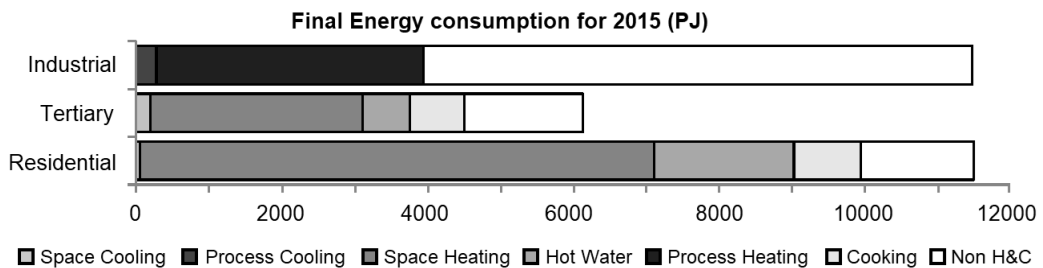


Fig. 2. Shares of final energy demand per end user in EU Member States

Source: according to Kavvadias et al., 2019

The residential, alone, is responsible for 54% of heating and cooling energy consumption, followed by services at 21% and industry at 24%. Consequently, heat supply to buildings and industry has been identified as a key pillar of European energy policy, which aims to achieve a climate-neutral Europe by 2050 (Kavvadias et al., 2019). Heat supply in different EU countries depends on geographical location, climatic conditions and availability of energy sources (Talebi et al., 2019). Heat for municipal needs is produced in centralized sources (district heat), or in individual sources or small local

generating units, e.g. community boiler houses. District heating is particularly dominant in northern MS due to lower outdoor temperatures. Today, more than 60 million EU citizens use district heating on a daily basis. The highest percentage of citizens using district heating is in Denmark, Estonia, Latvia, Lithuania, Poland, Sweden and Finland (Figure 3).

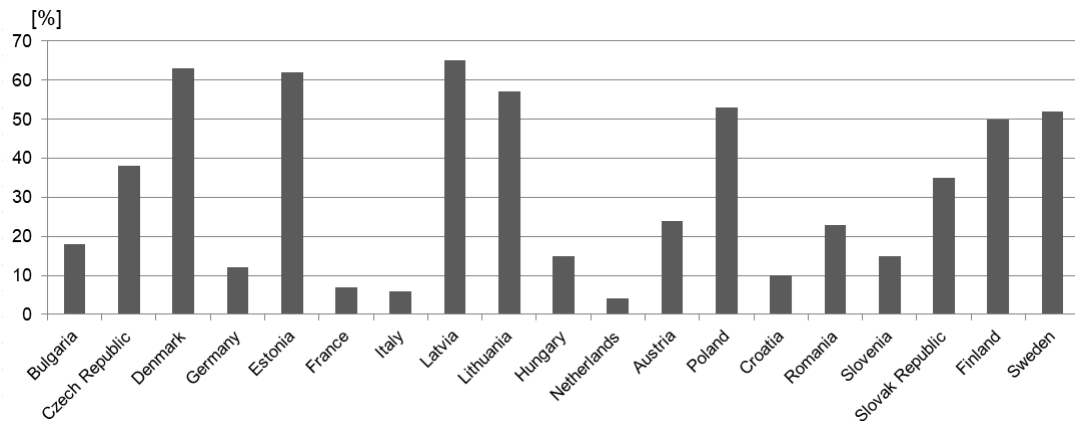


Fig. 3. Percentage of citizens served by district heating in selected EU countries

Source: <https://www.euroheat.org/wp-content/uploads/2016/03/2015-Country-by-country-Statistics-Overview.pdf>

The largest district heating systems in the EU are found in cities such as Warsaw, Berlin, Hamburg, Helsinki, Stockholm, Copenhagen, Paris, Prague, Sofia, Bucharest, Vienna and Milan (Werner, S., 2017). The district heating potential in each country (installed heating capacity and length of district heating network) is shown in Figure 4.

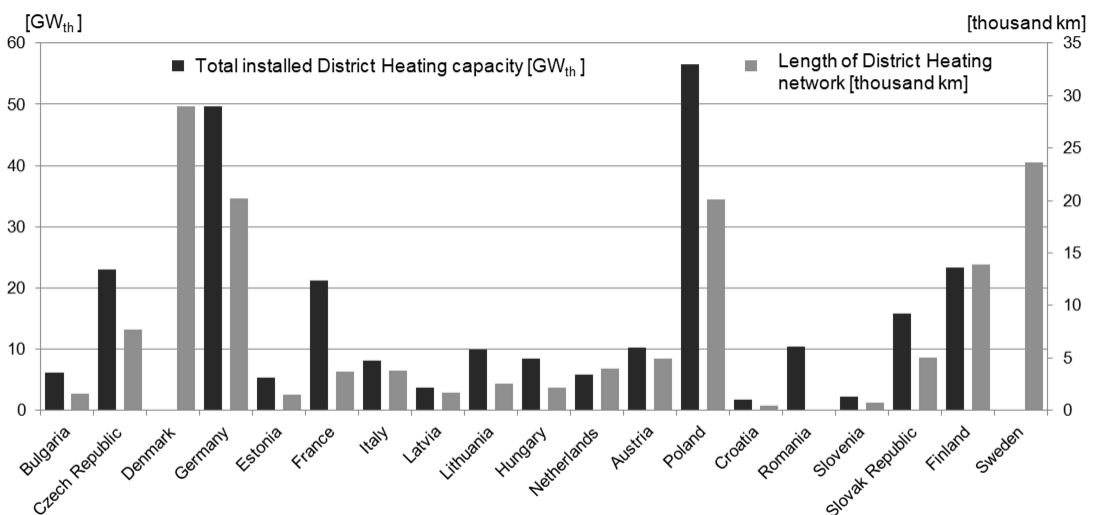


Fig. 4. The potential of district heating systems in selected EU countries

Source: <https://www.euroheat.org/wp-content/uploads/2016/03/2015-Country-by-country-Statistics-Overview.pdf>

An important indicator characterizing national heat sectors is the efficiency of heat supply, defined as the ratio between the delivered useful heating energy to the final energy consumption (Kavvadias et al., 2019). In a significant part of the EU Member States, this ratio is still relatively low - below 70%, as shown in Figure 5.

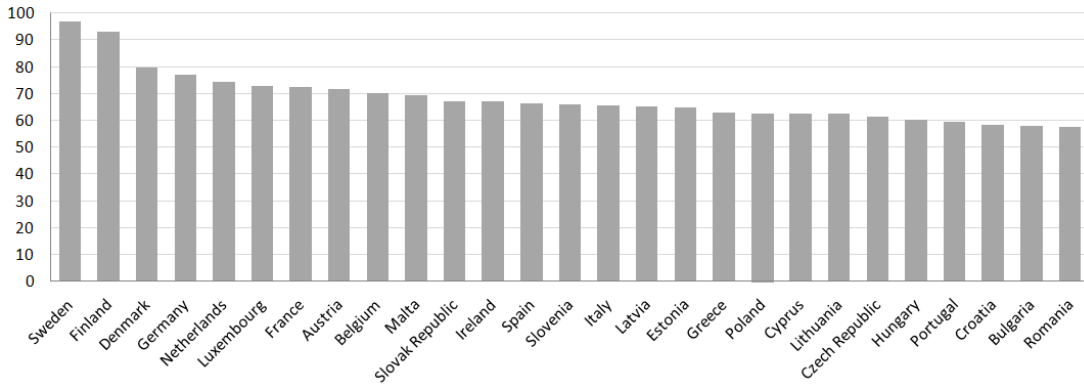


Fig. 5. Overall national heating supply efficiencies in EU countries [%]

Source: according to Kavvadias et al., 2019

The Scandinavian countries are leaders in terms of the efficiency of heating systems, the size of the share of households connected to these systems, as well as the use of modern, sustainable energy solutions (Upgrade DH, 2019). Some countries in the Baltic, Eastern and Southeastern Europe have inefficient district heating systems, designed for high temperatures and inefficient building stock. These countries need to modernize district heating systems and improve their efficiency. This can be achieved with new generation units, access to renewables, efficient distribution infrastructure, high-efficiency buildings that can use low-temperature supplies (Mathiesen et al., 2019).

### 3. DIRECTIONS OF CHANGES IN DISTRICT HEATING

The complexity of factors currently influencing the development and direction of change in the district heating sector is shown in Figure 1 (Wrzalik, 2021).

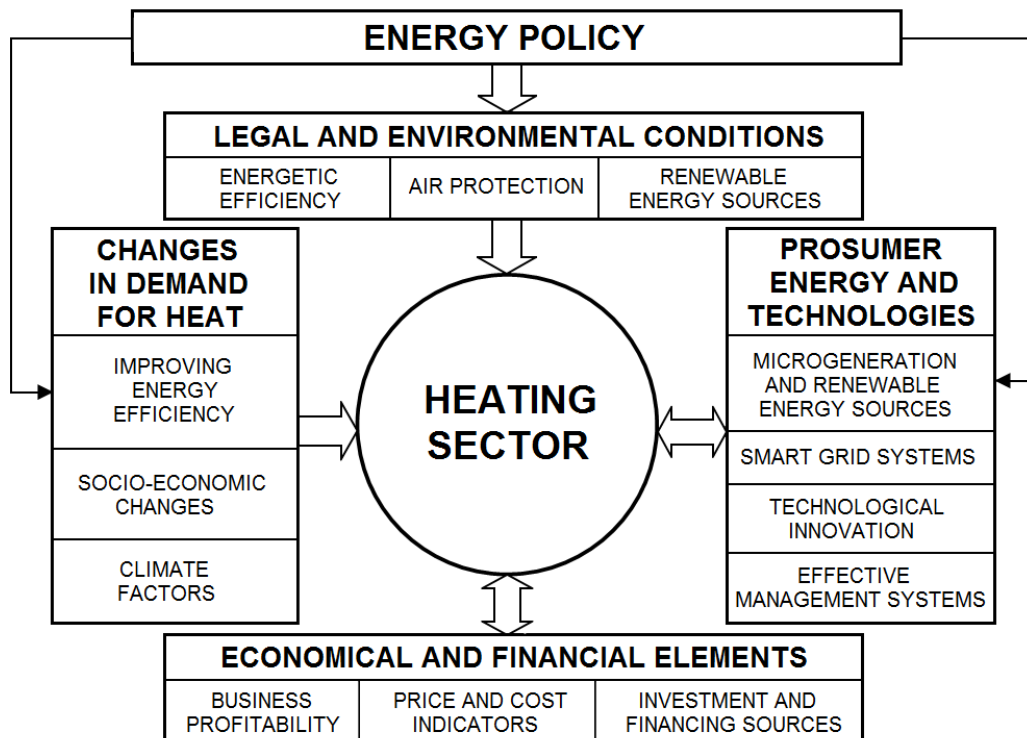


Fig. 6. Factors influencing the directions of changes in the heating sector

Source: Source: own elaboration

Successful transformation and decarbonisation, improvement of energy security and efficiency, as well as ecological indicators in the field of heat supply require comprehensive modernisation and implementation of innovative technological solutions by heating companies. Innovations in district heating must cover two areas: technical infrastructure (heat sources and district heating networks) and management of the heat generation and transmission system (Wrzalik, 2019).

The future of heat supply systems is 4GDH and 5GDH - low temperature district heating networks integrated into sustainable energy systems using renewable energy sources and heat storages (Lund et al., 2021). The 4GDH and 5GDH systems provide heat supply to low-energy buildings from district heating systems with low network losses. Their important feature is the use of low-temperature renewable heat sources integrated into the operation of intelligent energy systems. The latest generation district heating systems conceptually depicted in Figure 7 identifies possible pathways for decarbonising of the heating sector.

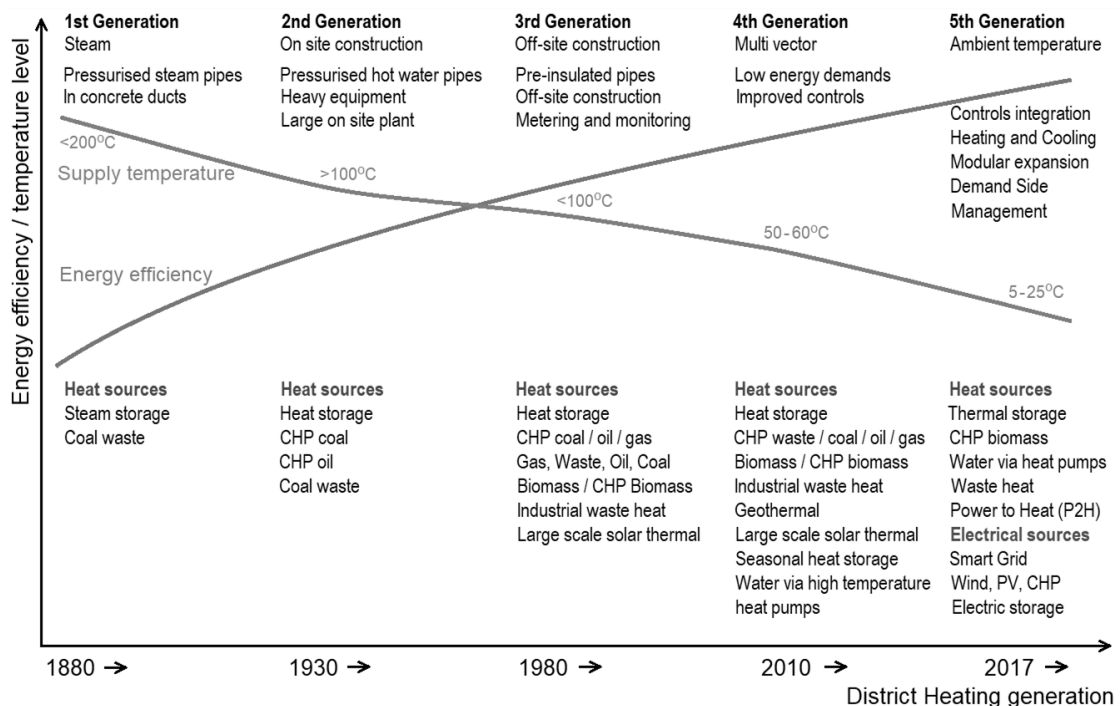


Fig. 7. Heat network trends to lower distribution temperatures and higher efficiency

Source: according to [https://www.icax.co.uk/image\\_Fifth\\_Generation\\_Heat\\_Networks.html](https://www.icax.co.uk/image_Fifth_Generation_Heat_Networks.html) and Lund et al., 2021

The advantages of low temperature district heating (LTDH) include efficiency (low heat losses), reduced greenhouse gas emissions, flexibility to use multiple renewable heat sources, increased use of heat storage, and improved power to heat ratio in cogeneration systems (Bach et al., 2016; Talebi et al., 2016; Imran et al., 2017; Werner, S., 2017; Bamisile et al., 2020; Lund et al., 2021).

Ultimately, district heating systems should be integrated with other parts of the energy system (smart grids). This happens through flexible production in combined heat and power (CHP) plants complementing fluctuating renewable electricity production; use of waste heat from industry and services; and use of electricity in large-scale heat pumps and electric boilers during hours of high variable renewable energy production (Mathiesen et al., 2019).

#### 4. RENEWABLE ENERGY SOURCES IN THE FUEL MIX OF DISTRICT HEATING

The way in which heat is generated, its availability and its use affect the quality of life of society, the environment and the economy. The contribution of coal and other fossil fuels in combustion processes causes significant emissions to the atmosphere. It is therefore a priority for the European Union to implement a strategy that will make heating more efficient and sustainable. The current diversity of fuels (fuel mix) used in the thermal power sector of the EU countries is presented in Figure 8.

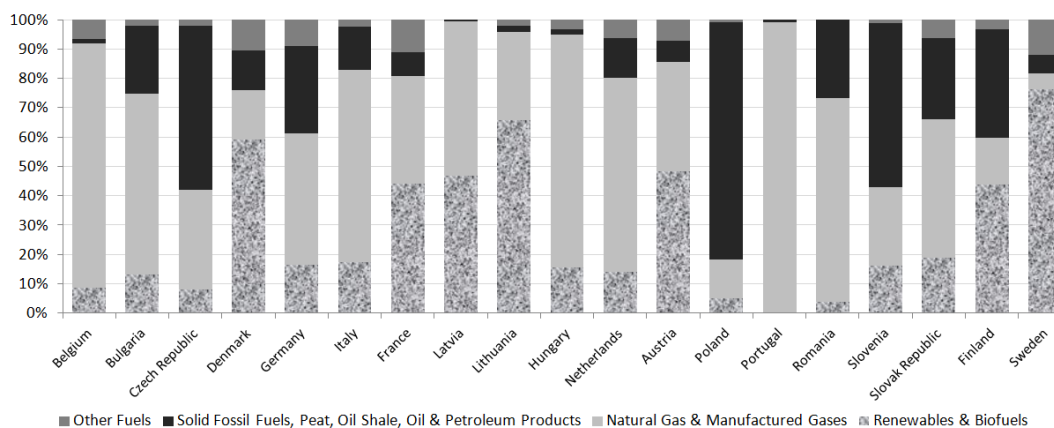


Fig. 8. Fuel mix in the thermal power sector in selected EU countries in 2018 [%]

Source: own elaboration according to the European Commission, *EU energy in figures*, 2020

Only a few countries have exploited their renewable resource potential in district heating. Countries with a significant share of RES include Denmark, Sweden, Lithuania, Latvia, Finland, France and Austria (IRENA, 2017). Increasing the use of renewable energy sources is one of the most important objectives of European energy policy. The projected development of district heating in Europe using high-efficiency cogeneration and various renewable energy sources is shown in Figure 9.

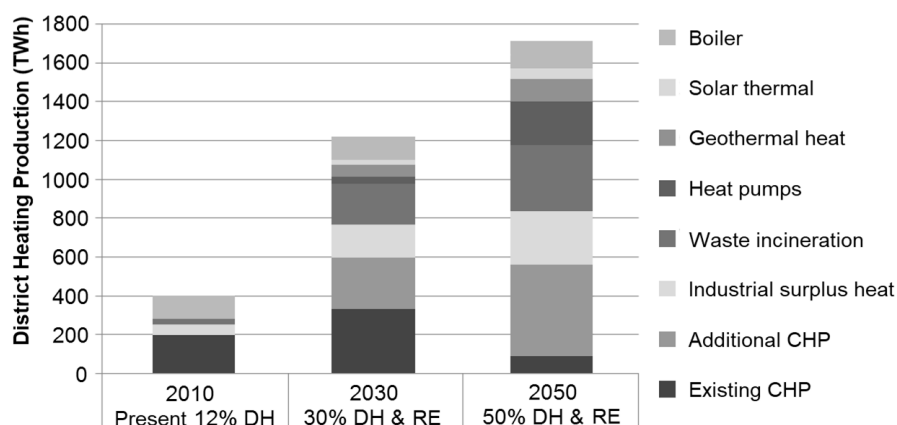


Fig. 9. District heating production for the entire EU27 energy system from 2010 to 2050

Source: Euroheat&Power, 2012

The main energy carrier that allows to increase the share of renewable energy sources in heating is biomass, although it has limitations related to its sustainable acquisition. There is also significant potential for geothermal, biogas and solar energy in EU countries, which will grow in popularity as the cost of obtaining them decreases (IRENE, 2017). The growth of geothermal heating plants in Europe is shown in Figure 10.

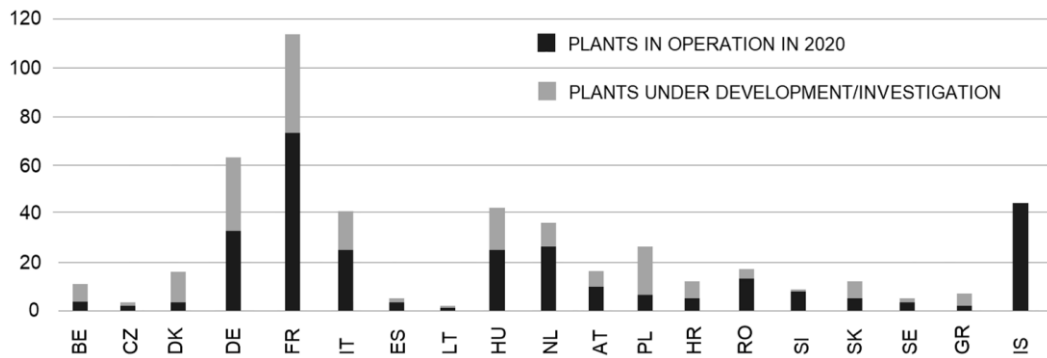


Fig. 10. Number of geothermal heating plants in Europe: installed, planned, in development  
Source: own elaboration according to EGEC, 2021

The potential of RES in district heating and their efficiency is growing rapidly with the development of heat storage technologies, both in multi-day and seasonal cycles. Seasonal storage is primarily used to store surplus energy from renewable sources and from cogeneration units produced during the summer season.

## 5. CONCLUSION

For many years, the European Union has been promoting district heating as a means of reducing carbon emissions and increasing energy efficiency. The policy of decarbonisation and reduction of greenhouse gas emissions forces a move away from fossil fuels towards renewable energy sources. Supporting this process is the directive on renewable energy sources adopted as part of climate policy, the so-called "RED II Directive". Therefore, in the next several years, the heating sector in many EU countries will be an area of accelerated technological changes and transformation of district heating systems towards efficient and low-emission systems with an increasing share of energy from renewable sources. A switch to renewable energy sources for district heating can help meet rising urban energy needs, improve efficiency, reduce emissions and provide cost-effective temperature control. Efficient district heating systems 4GDH and 5GDH can play a key role in the energy transition towards a low-carbon economy. Flexible integration of the power and heat sectors should contribute to both renewable energy integration and decarbonisation.

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