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Chapter 9

Management aspects of the district heating systems' transformation towards climate neutrality

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9.1. The essence and importance of district heating systems in meeting the demand for heat

A district heating system (DHS) is one of the methods of ensuring thermal comfort in buildings and preparing domestic hot water (DHW). Heat is delivered to heat nodes in buildings via a district heating network, usually supplied with this type of energy from a heating plant or combined heat and power plant (CHP). In some cases, more than one heat source may work for a district heating network, especially when the network has a ring shape. Therefore, generation, transmission, distribution and heat nodes in buildings are combined into one system.

DHS is one of the basic methods of supplying heat to city dwellers in the countries of Northern and Eastern Europe. In the European Union, DHSs are the best developed in countries such as Poland, Germany, the Czech Republic, Slovakia, Sweden, Denmark and Finland. Outside the European Union, DHSs play an important role in meeting the demand for heat from the inhabitants of Russia and China. Figure 9.1 shows the share of DHSs in the total final energy consumption and the share of heat generated from renewable energy sources (RES). It presents the different importance

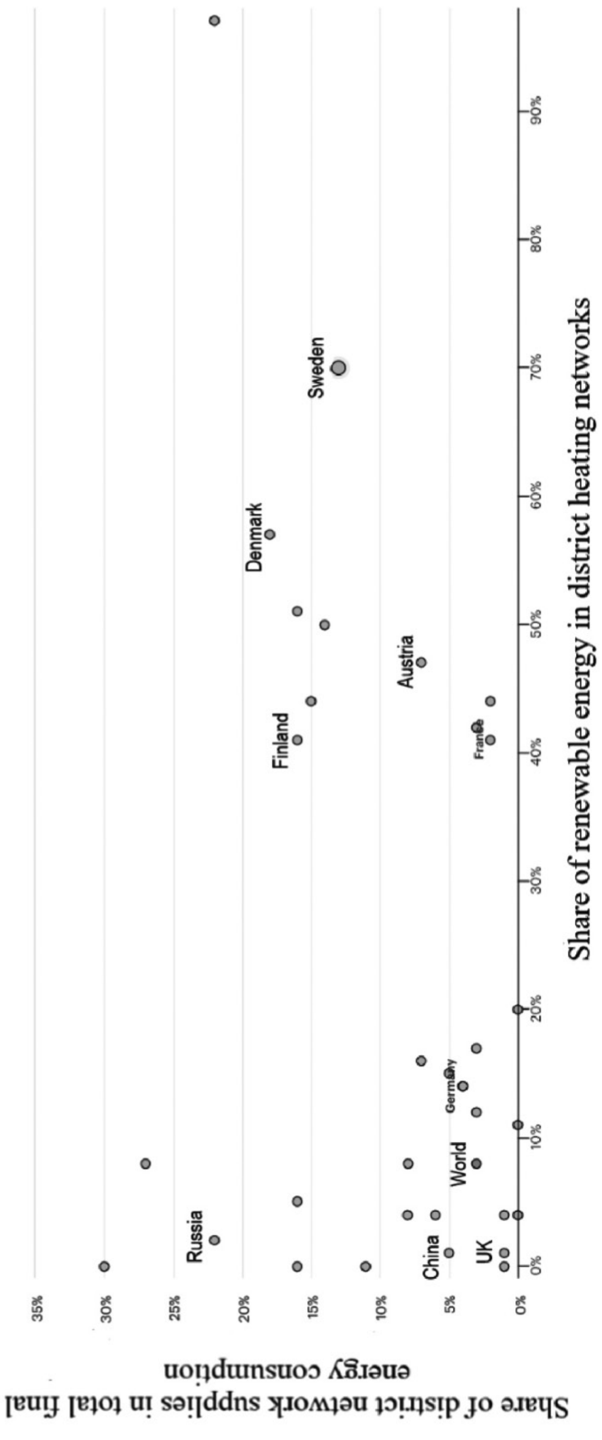

Figure 9.1. The importance of DHSs in selected countries

Source: (Jodeiri, Goldsworthy, Buffa, & Cozzini, 2022).

of DHSs in meeting the demand for heat from the inhabitants of individual countries as well as a different degree of its decarbonisation. The great importance of DHSs in meeting the heat demand is in countries like Russia, Finland, Denmark and Sweden. At the same time, only in the last three has the degree of decarbonisation reflected in the share of renewable energy sources (hereinafter RES) in the heat generation is significant (the share of RES exceeds 40%). However, it should be borne in mind that so far, increasing the share of renewables in DHSs has mostly been limited to the use of forest biomass (less often of agricultural origin) in the production of heat or heat and electricity in CHPs (the example of Finland) (Reda, Ruggiero, Auvinen, & Temmes, 2021). To a much lesser extent, the transition to RES consists in the use of solar or geothermal energy (solar panels, various types of heat pumps), which is related to high temperatures of heat carriers in the existing generation of DHSs (high--temperature systems). The use of biomass as a fuel for the production of heat or heat and electricity is not the most practical solution as, in many cases, it is associated with the over-exploitation of natural forest resources.

DHSs are also relatively well developed in Poland. About 370 companies – operating DHSs in Poland – have a license to generate, transmit, and distribute heat. DHSs are operated by companies in all the largest cities in Poland and many smaller cities. On average, these enterprises satisfy about 60% of urban residents' heat demand while most heat is still produced from hard coal. The structure of fuels used in the Polish DHSs is presented in Figure 9.2.

Since 2002 the share of heat generated from RES has been growing steadily, and is currently still at a very low level of around 11.5%. The heat from RES comes almost entirely from the combustion of biomass, mainly forest biomass. In recent years, the share of heat generated from natural gas has also increased (up to approximately 11.5%), which was associated with the installation of gas engines, most often producing heat and electricity. Recently many companies have also invested in CCGTs (Warsaw, Wrocław, Poznań and others). However, hard coal still has the largest share in the structure of fuels used for heat generation (over 63.8%). In addition, there are still several smaller DHSs in which coal is the sole fuel to generate heat.

The preliminary characteristics of DHSs show that in many countries and cities, they play an important role in meeting the heat demand and, at the same time, still face significant transformation challenges towards climate neutrality. This transformation cannot consist only in constructing biomass boilers or adapting coal boilers to burn this fuel. It is indicated that the combustion of biomass contributes to the devastation of natural forest resources. Therefore, the transformation of DHSs must be based on other technological solutions. In addition, the transformation of DHSs requires using many management and financial tools supporting the development of RES. In particular, implementing modern technological solutions will require changes

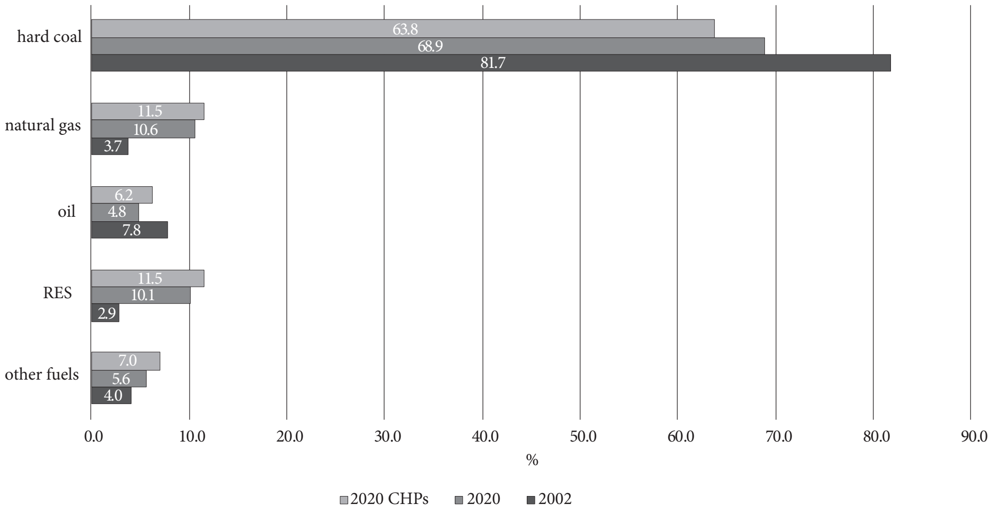

Figure 9.2. The structure of fuels used in the Polish DHSs

Source: (Urząd Regulacji Energetyki [URE], 2022).

in the business models of companies operating DHSs and the development of new services for customers. Therefore, this chapter aims to present the possibilities of using tools from the multi-level perspective and business model theory to assess the state of district heating and the directions of its energy transformation. To achieve the assumed goal, the analysis of the available literature, methods of critical thinking and own research related to the transformation of the district heating sector were used.

9.2. Theoretical assumptions of the Multi-Level Perspective (MLP) in determining the transformation directions of the economy sector

The transformation of DHSs should be understood as a structural change of the entire sector aimed at achieving the goals of climate neutrality, i.e., the state in which carbon dioxide emissions to the atmosphere will be limited to the level that the natural environment can absorb. The transformation of DHSs, therefore, essentially boils down to reducing the emission of carbon dioxide and other pollutants from the combustion of fossil fuels due to the transition to emission-free heat sources, mainly RES. The transformation of DHSs should be viewed from different perspectives; therefore, the analysis of this phenomenon can be performed using a tool known as the Multi-Level Perspective (MLP).

MLP enables the analysis of factors that influence the transformation of a given sector and the links between them. It also reflects the mechanisms and non-linearity of various phenomena (Vähäkari et al., 2020). MLP analysis provides a platform to understand how certain sectors of the economy are being transformed. In the MLP analysis the factors influencing transformation are grouped into three basic categories: **landscape**, **regime**, and **niche**. Within the landscape framework, the socio--technical factors and the links between them which influence or may influence the transformation of the sector are analysed. These factors usually affect the long-term way of doing business in a given sector. Long-term factors include climate change, public awareness change or changes in the regulatory environment. However, there may also be events of an abrupt nature that disrupt business continuity in a given sector and have an immediate impact on how business is done. These phenomena include natural disasters and wars. As a result, there are sometimes opportunities for faster transformation, e.g., by gaining more importance by technologies that have been in a niche so far.

The existing regime, in turn, refers to the existing technologies in a given sector and socio-economic conditions. Thus, the analysis of the existing regime covers the dominant technologies used in the sector, the existing legal regulations and institutional norms, modes of operation and procedures. Under the existing regime, the main actors in the sector, technology producers and decision makers are also analysed. The regime guarantees certain stability of functioning in a given sector as changes taking place in it are slowly.

The last level of the MLP analysis is the one that refers to the niche in which most innovative phenomena develop. Thus, radical innovations develop in the niche that can replace the existing technological regime when the window for change opens. These innovations often develop outside the existing regime in the sector and outside the regulations in force. These innovations result from R&D processes, development of start-ups or experimenting with new business models. The network of connections in the niche is much smaller than in the existing regime and requires mechanisms supporting it.

The factors at the three levels described above are not isolated. On the contrary, there are certain connections and interactions between them. Therefore, all the above factors should be looked at holistically, considering their relations. The emerging weak signals in the landscape or niche can radically change the entire sector. According to the MLP concept, the sector's transformation occurs as a result of pressure on the regime exerted by forces in the landscape, which can create conditions for developing niche technologies and new business models (Reda et al., 2021). These conditions mean that technologies that have so far occupied a niche position in the sector can gain a competitive edge. Companies building business models based on niche technologies can then start a march towards gaining more and more market share. It follows from the above that the MLP analysis also has a time dimension;

therefore, the sector's transformation should be seen as a process. The duration of the transformation process depends, in turn, on the intensity of the impact of factors from the landscape and the niche on the existing institutional and technological regime. The strength of this impact may also vary with time which causes periodic accelerations or delays in the transformation. The idea of the sector transformation process using MLP analysis is presented in Figure 9.3.

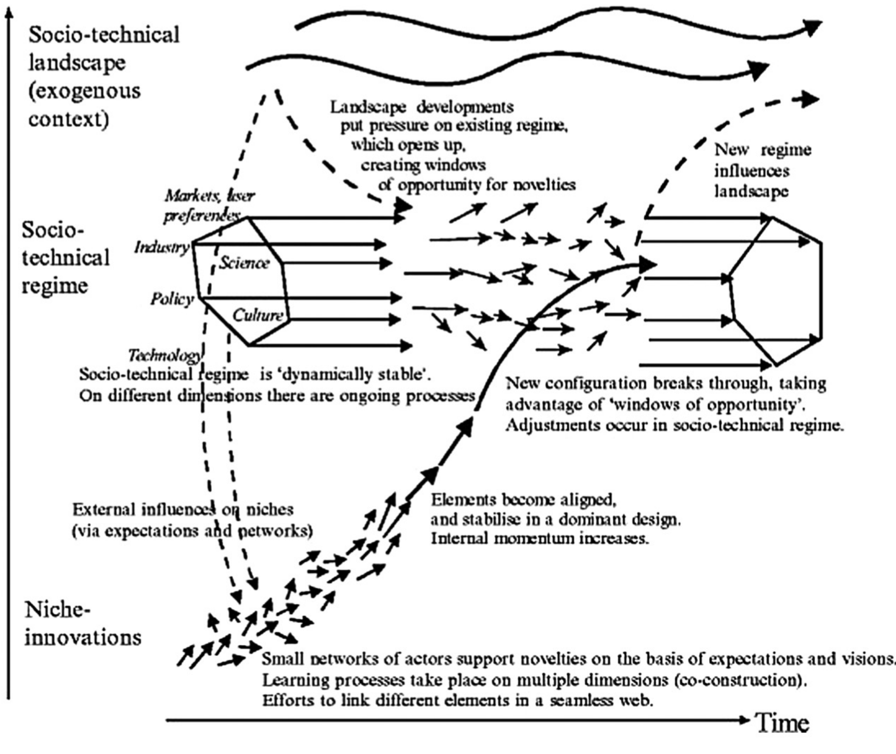

Figure 9.3. The idea of the sector transformation process

Source: (Geels & Schot, 2007).

The course of the sector transformation process does not have to be linear. Depending on the changing strength of the interaction between individual factors from the landscape and the niche, certain changes may occur during this process. For example, over time, technologies that previously did not seem promising may gain a competitive edge. Likewise, the regulatory environment may change over time and favour certain technologies or solutions. These conditions create uncertainty which makes it necessary to identify various transformation scenarios. Many methods can be used to generate and evaluate alternative sector transformation scenarios, such as the Delphi method or other heuristic methods. Defining alternative scenarios of sector transformation is presented in Figure 9.4.

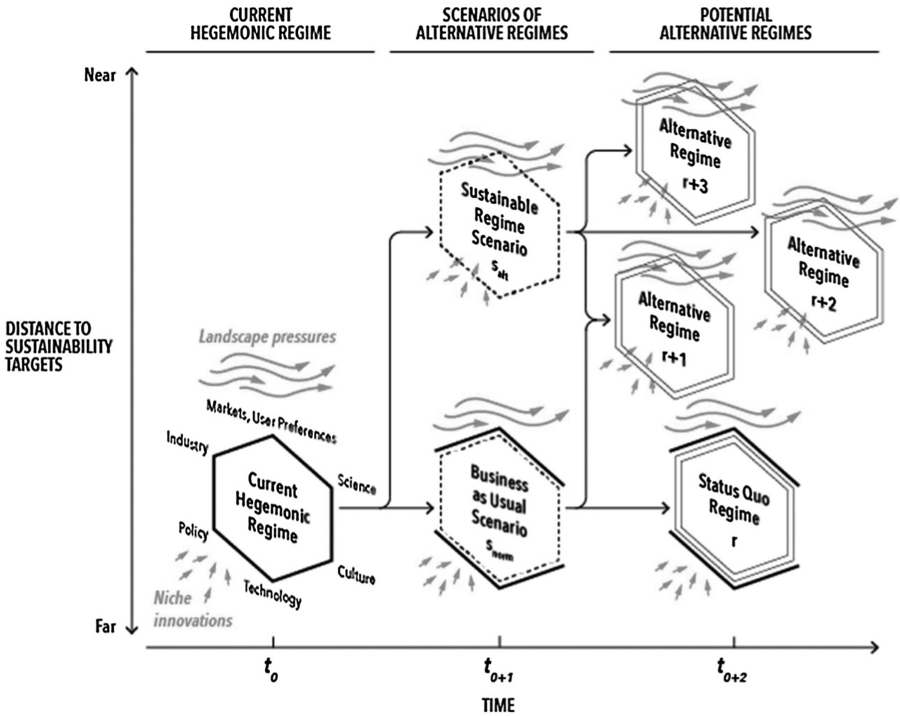

Figure 9.4. Scenarios of the sector transformation

Source: (Vähäkari et al., 2020).

The presented method of MLP analysis, together with the scenario analysis, can also be used to predict the directions of DHSs' transformation. At present, there is no one obvious direction for the transformation of this sector, although the common feature of all potential scenarios will be the reduction of carbon dioxide emissions by increasing the share of RES and waste heat in heat generation. However, this goal can be achieved in several different ways.

9.3. The MLP analysis in planning scenarios of DHS transformation

The analysis of the factors that allow for defining the directions of DHSs' transformation was carried out using MLP analysis. In the following sections the characteristics of the basic factors that were classified into the landscape, regime and niche and which may affect the transformation of DHSs are presented.

In the landscape, the main factors exerting pressure on the DHSs' transformation are related to the climate policy of the European Union and the so-called the Green Deal. These factors include the following.

1. Objectives of the EU climate policy. In 2014 the Council of the European Union adopted goals regarding the climate policy until 2030, while in 2018, the goals related to the share of RES in the overall energy consumption and energy efficiency were increased. At present, the goals regarding the climate policy are as follows (goals to be achieved by the end of 2030):

- a reduction by at least 40% greenhouse gas emissions compared to 1990 levels,
- an increase to at least 32% the share of RES in the final energy consumption,
- and an increase by at least 32.5% energy efficiency.

The 'Fit for 55' package prepared by the European Commission increases the greenhouse gas emission reduction target presented above. Under this proposal, CO_2 emissions should be reduced by 55% by 2030 compared to 1990 levels. In addition, the pool of CO_2 emission allowances allocated to the individual Member States would be reduced by 4.2% annually, which would create additional pressure on the increase of CO_2 emission allowances' price. In addition, the target for the share of RES in final energy consumption rises to 40% and the energy efficiency target rises to 36% for final energy consumption.

All the goals mentioned above also apply to DHSs, a significant emitter of greenhouse gases in Poland – about 63% of heat is produced from hard coal. Moreover, companies selling heat to end users are obliged to fulfil the obligation under Art. 10.1. of the Energy Efficiency Bill (Ustawa z dnia 20 maja 2016), i.e., to implement projects to improve this efficiency at the end user side or to obtain and submit an energy efficiency certificate to the President of the Energy Regulatory Office (ERO) for redemption. The increased energy efficiency target with the presented obligation will increase the costs of companies operating DHSs, negatively impacting the heating price.

2. Limiting free allocation of CO_2 emission allowances for heat generation (Directive (EU) 2018/410). After 2020, the free allocation of CO_2 emission allowances to cover this emission from burning fossil fuels has generally ended, but still, 30% of free allowances will be available to settle CO_2 emissions from heat production. After 2020 the free allocation of CO_2 emission allowances will be allocated to heat production based on the benchmark for heat, the historical level of heat production and the 30% indicator. However, the benchmark for heat was determined at a low level (corresponding to CO_2 emissions from burning natural gas while heat generating). In conjunction with the growing price of CO_2 emission allowances, this factor will constitute another significant impulse to increase the heating price.

3. Inclusion of buildings and road transport in the CO_2 Emissions Trading System (ETS). According to the proposal of the 'Fit for 55' package from 2026, the ETS would cover all fossil fuels used for heating and cooling buildings and used in road transport. The inclusion of buildings and road transport in the ETS is to reduce emissions from these sectors by 43% by 2030 compared to 2005. All emission allowances will be auctioned. It should be added that currently, the ETS covers heat plants or CHPs whose capacity exceeds 20MW in the fuel. The proposed change will therefore be of significant importance for the DHSs.

4. Increasing the share of heat from RES in DHSs. Under the applicable provisions of the Renewable Energy Directive (Directive (EU) 2018/2001), the share of RES in the heating and cooling sector is to increase by at least 1.3% annually (by 1% in DHSs). The 'Fit for 55' package increases the target – the share of heat from RES in DHSs should rise by 2.1% per year – and substantially reduces forest biomass use. The use of forest biomass for heat and electricity generation will be possible at the very end in the hierarchy of handling this raw material which is to limit the exploitation of forests. This means that the increase in the share of RES in DHSs will be possible mainly by using geothermal and solar energy.

5. Changing the definition of 'effective district heating system'. According to the applicable provisions of the Energy Efficiency Directive (Directive (EU) 2018/2002), an effective district heating system can be considered one in which 75% of heat comes from cogeneration or 50% from RES or 50% from waste heat or 50% of heat comes from RES and cogeneration. The 'Fit for 55' package introduces a change in the definition of the effective district heating system. According to the changed definition, an effective district heating system will be one in which:

- 50% of heat comes from RES or
- 50% of the heat comes from waste heat or
- 80% of the heat comes from gas cogeneration or
- 50% of the heat comes from a combination of the above sources, provided that at least 5% of the heat comes from RES.

The new definition of an effective district heating system is to apply from January 1, 2026. Achieving the status of an effective district heating system is important because its absence will give a customer the right to disconnect from DHS after December 31, 2025.

6. Adaptation of heat plants and CHPs to more tightened pollution emission standards. According to the IED Directive (Directive (EU) 2010/75), CHPs and heat plants with a fuel capacity above 50 MW were to comply with the tightened emission standards by January 1, 2016, and under Art. 35 of this Directive, it was possible to postpone the adaptation of heat sources to the new emission standards by the end of December 2022. In turn, heat plants and CHPs with a fuel capacity from 1 to 50 MW (MCP Directive (Directive 2015/2193)) must comply with the tightened emission standards by January 1, 2025 (plants with a nominal thermal power greater than 5 MW) or by January 1, 2030 (plants with a rated thermal power ranging from 1 to 5 MW). The above-mentioned regulations show that in 2020–2030 most heat plants and CHPs will have to undergo a technological transformation. These conditions will lead to a significant increase in heat price from DHSs due to the higher purchase price of low-emission fuels in relation to the price of hard coal and high capital expenditure.

7. Tightened energy standards for buildings. In 2018 an amendment to the EPBD Directive (Directive (EU) 2018/844) was adopted, introducing new energy standards for buildings, including those connected to DHSs. The provisions of this Directive have been transposed into Polish law by the amended Decree of the Minister of Infrastructure of April 12, 2002 (Rozporządzenie Ministra Infrastruktury z dnia 12 kwietnia 2002). In addition to specifying the requirements for thermal insulation, this regulation contains provisions on the compliance of new buildings with the permissible values of the annual demand for non-renewable primary energy EP (kWh/m^2/year). The maximum value of this indicator for domestic hot water, central heating and ventilation is not allowed to exceed 65 for multi-family residential buildings and 45 for public utility buildings from the beginning of 2021, which *de facto* eliminates, in many cases, heat coming from DHSs in Poland generated essentially from hard coal or other fossil fuels. For new buildings to be connected to DHS after 2020, heat nodes must be integrated with dispersed RES, i.e., solar panels or heat pumps powered by photovoltaic electricity. Therefore, the presented regulations affect heat sales and cause an increase in the unit costs of its supply via DHSs.

Additionally, the 'Fit for 55' package introduces the following changes to energy standards for buildings:

- from 2030 all new buildings must be zero-energy (from 2027 public buildings),
- by 2050 all existing buildings must be zero-energy,
- 15% of the worst buildings in terms of energy efficiency must raise their energy standard from level G at least to F by 2027 (public buildings) or by 2030 (residential buildings) (EPC scale from A to G).

These changes are to force the reduction of energy consumption by buildings by increasing their energy efficiency, which will decrease heat sales *via* DHSs and increase heat prices.

8. Equipping buildings with control systems. According to Art. 14 of the amended EPBD Directive (Directive (EU) 2018/844), by the end of 2025, all non-residential buildings with a heat demand above 290 kW are to be equipped with automation and control systems. This is another challenge for heat consumers and companies operating DHSs, which will affect the heat sale and increase the unit costs of its delivery.

Presented above, the most important conditions for running a business in the DHS sector will have a significant impact on:

- competitiveness of heat supplied via DHSs; the price of heat will gradually increase,
- heat sales volume; it will gradually decrease leading to an increase in unit operating costs of DHSs operators, which will translate into further pressure on price increases.

With regard to the second of the above-mentioned issues in Poland, the sales volume of DHSs operators has decreased by approximately 20% over the last 20 years. This decline in heat sales was influenced by two main factors, i.e., thermal modernisation of buildings and global warming. In the future, the decline in the heat sale will significantly deepen, which will be influenced not only by climate change but also by another goal of increasing energy efficiency and the so-called the Green Deal. Achieving the proposed energy effectiveness target (36% increase) by the end of 2030 will no longer be possible only through further thermal modernisation of buildings, as in many cities, the potential for thermal modernisation is running out. This goal will only be achieved through advanced IT control systems and dispersed renewables. Companies operating DHSs will have to implement a number of new solutions and services for heat consumers to increase energy effectiveness.

The existing regime in the DHS sector relates to the use of heat production and distribution technologies, institutional structure, and legal regulations. The characteristics of the existing regime are presented as follows.

Technologies used for the production and distribution of heat. At present, technologies known as second-generation heating are in common use. As part of this technology, heat is produced in central CHPs or heat plants fired by fossil fuels (coal or natural gas), less often by biomass, and sent through district heating networks to heat nodes in buildings. Heat is most often transmitted in the carrier which is water under high pressure and with a supply temperature above 100°C and on the return of the network below 70°C (under the so-called calculation conditions, which most often refer to the outside temperature at the level of minus 20°C). In heat nodes, high parameters of the heat carrier are converted into low parameters adjusted to the possibility of supplying central heating installations in buildings. Due to the carrier's high parameters, it is impossible to integrate RES (energy of the sun or the earth) and waste heat sources with the DHSs. This type of heat sources is usually characterised by low temperatures of the heat carrier (below 65°C). Thus, the technologies currently used allow heat to be transferred only in one direction: from the central CHP or heat plant to the heat substation in the building.

Structure of the DHS market. DHS markets are local due to the limited technical and economic possibilities of heat transmission over long distances. Thus, unlike electricity or natural gas, the transmission of which does not require any intermediate medium, heat transmission is more complex in terms of distribution networks' operations. For this reason, the range of DHSs is limited to highly urbanised areas. The DHS value chain includes heat production, heat transfer and heat trade. In many cases, all these three areas of activity are vertically integrated within one entity (this most often applies to smaller poviat (county) towns). In large agglomerations, separate entities operate in individual sections of the DHS value chain. In Poland, 370 entities operate on the DHS market in various sections of the DHS value chain. Of these entities (URE, 2022):

- 59 entities operate simultaneously in all three sections of the value chain,
- 275 entities operate in the area of heat generation, transmission and distribution,
- 22 entities operate solely in the area of heat generation,
- 14 entities operate in the area of transmission and distribution as well as heat trading.

Over 90% of the enterprises mentioned above operate in smaller county towns. Out of all voivodship cities:

- in five (Białystok, Opole, Łódź, Poznań, Zielona Góra), the DHS market is vertically integrated, which means that one entity is involved in the production of heat, its transmission and distribution;
- in two of them (Katowice, Olsztyn), the DHS market is partially vertically integrated, which means that partially heat is also produced by an entity dealing with heat transmission and distribution and partially by other entities not related to the heat distributor;
- in six of them (Bydgoszcz, Gdańsk, Kielce, Szczecin, Warsaw, Wrocław), heat generation, transmission and distribution are carried out by separate entities not related to each other in terms of capital ties;
- in three cities (Kraków, Lublin, and Rzeszów), heat generation, transmission and distribution are carried out by separate entities not related to each other by capital ties, and more than one entity is active in the heat generation.

In all the cities presented above, one entity operates in the transfer and distribution of heat. Therefore, there is no competition in heat transmission and distribution. Activity in this part of the value chain can be characterised as a natural monopoly.

The role of local authorities on the DHS market. Under the Act on local authorities, their tasks include meeting the community's collective needs, particularly regarding electricity, heat and gas supply (Ustawa z dnia 8 marca 1990). Usually, local authorities entrust the implementation of these tasks to municipal companies established by them or other entities that do not have such a status. According to Art. 19 of the Energy Law Act (Ustawa z dnia 10 kwietnia 1997), the head of the commune, mayor, and city president is obliged to develop draft assumptions for the heat, electricity and gas fuel supply plan. If the plans of energy companies do not ensure the implementation of the developed assumptions, the commune should develop a heat, electricity and gas fuel supply project for the commune or its part (Ustawa z dnia 10 kwietnia 1997, Art. 20). According to the law, local governments should therefore play an important role in meeting the demand for the heat of its residents. In reality, however, local governments are often passive in this area, and their role is limited only to developing the draft assumptions mentioned above. The activity of municipalities in this area increases when there is a real threat to the security of heat supply (e.g., a private entity withdraws from the DHS market).

Regulatory environment of DHS. First of all, the regulations on DHS concern technical aspects related to the security of heat supply and methods of calculating and approving tariffs for heat and transmission services. The latter type of regulation is significant for companies operating DHSs. At present, in Poland, tariffs for heat and transmission services are calculated according to the following methods:

- for heat plants and heat transfer and distribution – cost + return on capital method,
- for CHPs – a method based on reference prices which are average prices of heat from heat plants fired with a specific type of fuel announced by the Energy Regulatory Office for the previous year.

Tariffs for heat and transfer services are approved by the Energy Regulatory Office regardless of their calculation method. It should be added that in other countries, the prices of heat delivered *via* DHSs are regulated according to the price cap method or are even released from the jurisdiction of the market regulator. In some countries, heat prices are also approved by local governments.

Other significant regulations on the DHS market include the obligation to connect buildings to the district heating network if they are within its range and provided that the technical and economic conditions for doing so are met (Ustawa z dnia 10 kwietnia 1997, Art. 7b). A deviation from this rule is possible if the heating price delivered by DHS is higher than the average or the building will be supplied with heat from a heat pump or other electric heating source.

Taking into account the conditions mentioned above, the activity related to the production, transmission and distribution of heat within DHS is a natural monopoly because:

- it is characterised by economy of scale, although it is limited to highly urbanised areas,
- the development of DHS in cities is legally protected against alternative heating methods (Ustawa z dnia 10 kwietnia 1997, Art. 7b),
- activity in the DHS is highly capital intensive,
- heat is one of the basic products needed for human existence; therefore, its demand is inflexible.

The presented picture of the regime is a significant barrier to the transformation of DHSs. Companies operating DHS are taking a defensive position and do not want to allow their current operating model to be endangered by alternative solutions in the field of heat supply. They also do not undertake significant transformation-oriented activities except for investments in central heat sources fired with biomass or natural gas, allowing them to maintain the current regime.

Despite maintaining a monopolistic position on the periphery of the DHS sector, many innovative solutions appear. All of them can be classified as niche. The most important phenomena occurring in the niche include: 1) dynamic development and increase in sales of heat pumps; 2) energy microgrids; 3) digitisation of heating.

1. Dynamic development and increase in sales of heat pumps. Future directions related to the decarbonisation of the DHS will largely rely on electrification and RES. Therefore, heat pumps integrated with renewable electricity sources such as photovoltaics or wind energy will undoubtedly play a fundamental role in the decarbonisation of the DHSs. The heat pump technology currently enables heat production with a temperature of up to 80°C. Air-to-water heat pumps can operate with external air temperatures down to minus 20°C, and the popularity of water-to-water and ground source heat pumps is also growing. The potential capacities that can be obtained from heat pumps are also growing (these capacities are currently up to several dozen MW). The growing popularity of the use of heat pumps for central heating in buildings is illustrated by the sales data presented in Figure 9.5.

Especially dynamic growth of heat pumps' sales has been noticeable since 2015. The annual sales of heat pumps have doubled in 21 EU countries since that year. The increase in sales of air-to-water heat pumps is particularly dynamic. The most significant increases in heat pump sales in 2020 in relative terms were recorded in Poland (increase by 43.8%), Germany (increase by 37.2%) and the Netherlands (increase by 30.5%). In 2020 the markets with the highest sales of heat pumps were

France (394,129 pumps sold), Italy (232,834 pumps sold), Germany (140,390 pumps sold), and Spain (127,856 pumps sold) and Sweden (107,723 pumps sold).

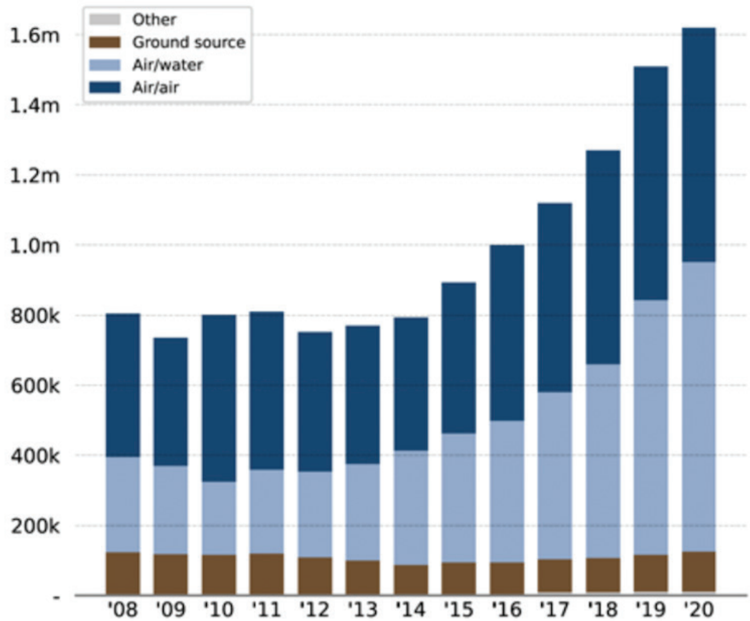

Figure 9.5. Sales volume of heat pumps by type in 21 EU countries

Source: (Nowak, 2021).

2. Energy microgrids. Another interesting solution in the niche of DHSs is energy and area integrated microgrids for heating, cooling and power. Microgrids of this type are integrated through the use of an appropriate ICT layer. As part of the networks in question, there is an area integration of electricity, heat and cold generation sources taking into account various storage technologies and their area balancing. The basic features of this solution include:

- integrating RES and energy storage cooperating with the power, heating and cooling microgrid,
- integrating local automation subsystems to achieve interoperability between individual microgrids and devices generating electricity, heat and cooling,
- microgrid management with the use of a supervisory IT system for control and monitoring, which uses algorithms based on artificial intelligence,
- area energy balancing of the power, heating and cooling microgrids,
- intelligent mechanisms of cooperation between the microgrid and the power system.

Within this type of microgrid, the following devices are integrated:

- photovoltaic-thermal cells (PVT) or photovoltaic cells (PV),
- cascades of reversible water-to-water and air-to-water heat pumps,
- chillers as the peak source of cooling,
- heat recovery systems,
- peak heat sources such as a fuel cell powered by green hydrogen,
- electricity storage in redox and Li-ion technology,
- heat storage in the form of tanks with phase change material (PCM),
- other devices.

The basic target of microgrid management is to maximise its self-balancing and minimise the costs of supplying all connected buildings with energy. The use of artificial intelligence algorithms achieves this goal.

3. Digitisation of heating. Another important direction of innovation is its digitisation which enables the real management of demand for heat by consumers through access to a wide range of information. The role of this type of IT system is to support the improvement of energy efficiency and management of dispersed RES. In particular, the functionalities of this type of solution boil down to:

- integration of the heat node operation with dispersed heat sources (solar panels and/or heat pumps integrated with photovoltaics) aimed at minimising heat consumption from the DHS and thus the costs of heat purchase,
- automatic and remote implementation of the desired temperature settings inside individual rooms in the building,
- 'flattening' the profile of thermal power consumption from the DHS while ensuring thermal comfort in buildings through optimal control of loading and unloading of the storage tanks installed in the heat substation,
- optimisation of the heating curve on the internal central heating system of the building in connection with the way the facility is used and the internal temperature settings on the thermostats,
- remote control of domestic hot water circulation pumps and others and remote control of domestic hot water temperature,
- providing building owners/managers with information on forecasted outdoor temperatures and their expected demand for heat power,
- providing building owners/managers with information on their heat and thermal power consumption in real-time and in different historical time profiles.

IT systems of this type are built in the cloud and container technology. The role of these algorithms is to optimise the heating curve depending on how buildings are used and the operation of heat sources. This type of IT system can be included in the class of Demand Side Management. In the case of DHS, such IT systems contribute to lowering the cost of purchasing heat.

The presented landscape and the changes in the niche of DHS allow for formulating several scenarios of its transformation. These scenarios are presented in Table 9.1.

Table 9.1. Potential scenarios for the transformation of DHSs

Scenario	Characteristics of the scenario
1	2
Conservative	In the conservative scenario, the basic technological system of DHSs remains unchanged; heat is still generated in central CHPs or heat plants and sent via high--parameter networks. Nevertheless, there is a transformation of heat sources in a direction that will enable low-emission or zero-emission fuels. In the first stage, heat sources will be adapted to burn biomass, natural gas and RDF. At this stage, hard coal will be eliminated from DHSs as the fuel with the highest carbon dioxide emission factor. In the second stage, when natural gas can no longer be used and the possibility of burning forest biomass is substantially limited, the CHPs and heat plants would be adapted to burn green hydrogen, which comes from electrolysis processes powered by electricity from RES. Nevertheless, using green hydrogen to generate heat in central CHPs or heat plants may prove uncompetitive in relation to other scenarios. It should be remembered that in this scenario, there are many changes in energy states, the electrolysis process is characterised by low efficiency, and the infrastructure for using hydrogen in DHSs has yet to be built (electrolysers, hydrogen storage, hydrogen transfer networks and finally devices for generating heat from hydrogen). Thus, while the first stage of the DHSs' transformation in this scenario is relatively easy to implement, the competitiveness of heat after the second stage in relation to alternative solutions is questionable.
Realistic	In a realistic scenario, high-temperature DHSs will be transformed into fourth and fifth-generation low-temperature systems. In this type of system, the temperature of the carrier on the supply does not exceed 55–60°C; on the return, it is about 25°C. Lowering the supply and return temperatures to the indicated level would require adapting the infrastructure in buildings to underfloor heating, which is rather difficult and capital-intensive for existing facilities but entirely possible in new facilities. With regard to heat supply to existing buildings, it may be more advantageous to transfer the DHS networks into the low heat source for water-to-water heat pumps installed directly in heat nodes together with peak electrode boilers powered by green electricity. In this situation, the carrier's temperatures on the network's supply side as a low heat source for heat pumps can be even lower than 30°C. Substantially lowering the supply and return temperatures in district heating networks will enable the integration of various RES and waste heat within it. The idea behind this solution is presented in Figure 9.6. As part of the presented idea, the role of the district heating network is also changing, i.e., from the function of heat transfer in one direction (from the central heat source to the heat nodes in buildings) to the function of balancing various RES and waste heat. Due to the low temperatures of the carrier at the supply, dispersed solar panels or larger-scale heat pumps of which low heat sources are water reservoirs can be

1	2
	connected to the district heating network. The district heating network can also be supplied with waste heat sources from the server rooms or, for example, from air--conditioning installations. Finally, the heat surplus from RES installations installed in buildings (solar panels, heat pumps integrated with PV) can be transferred to the heating network. This type of DHS is also easier to integrate with the power system. The district heating network and the heat storage facilities operating within it may become the storage of excess electricity generated during sunny or windy days. On the other hand, heat pumps and heat accumulators installed as part of such a system may participate in the negawatt market (periodical reductions in electricity consumption at the request of the transmission system operator). The presented concept can exhaust the features of a microgrid, and it can also be implemented in the broader dimension, i.e., as a part of larger DHS. Undoubtedly, the management of this type of DHS integrated with various RES and energy accumulators requires appropriate IT solutions.
Radical	In a radical scenario, DHSs lose importance in the long term and are replaced by individual heat sources installed in buildings. These heat sources also include various types of heat pumps (ground, water, air) powered by electricity from photovoltaics installed on the roofs of buildings or from other RES. As peak heat sources, electrode boilers also powered by electricity from RES or green hydrogen boilers are used. It is also possible to install green hydrogen fuel cells in buildings producing heat and electricity simultaneously. Managing these individual heat sources will certainly also require specific IT support.

Source: own study.

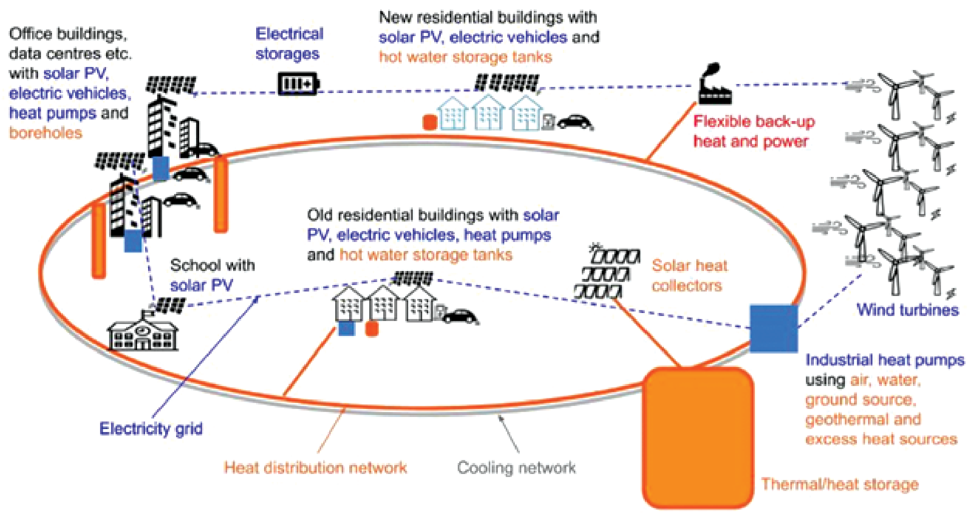

Figure 9.6. Integration of dispersed heat sources within low-temperature DHSs

Source: (Reda et al., 2021).

At the moment, it is difficult to say which direction the transformation of DHS will go. However, the optimal solution seems to be the transformation of DHS from high-temperature to low-temperature (realistic scenario). As presented above, companies operating DHSs will continue to use the heating network, although its role will fundamentally change. In this transformation scenario, central heat sources will be ultimately eliminated from the operation and replaced with dispersed RES. Transformation in other directions is also possible; these changes certainly mean major management challenges for companies, including adapting their business models to new circumstances.

9.4. Business model renewal aimed at transforming DHS

It is now widely accepted that a company's business model reflects a way of generating a satisfactory return on capital for shareholders by generating value for customers (Chesbrough & Rosenbloom, 2002; DaSilva & Trkman, 2014; Magretta, 2002; Teece, 2010; Wierzbiński, 2017). The value created for clients consists of the following basic elements:

- an offer addressed to a specific market segment which should be understood broadly as a set of delivered products, services and experiences and their features, including:
  - the functionality of products/services,
  - innovative products/services compared to the competitive offer,
  - the impact of the product/service on the natural environment,
  - product design,
  - the prestige of possessing or using products/services,
  - brand,
  - a range of complementary products and services,
  - the scope of after-sales service;
- price for products and services compared to the competitive offer; the following forms of providing products and services to customers can be distinguished:
  - sale,
  - leasing,
  - making available it for free with payment for complementary products/services,
  - other forms.

In turn, what part of the generated value will be captured by the enterprise in the form of the profit achieved and the generated rate of return on capital depends on:

- the features mentioned above of the offer which determine the scope of activities and resources necessary for its production,
- the method of providing products/services and selling price,
- the method of organising the internal value chain,
- maintenance and development of key resources for the implementation of activities in the internal value chain,
- relations with external partners,
- the way business is financed.

Some aspects on which value generation for customers and shareholders depends are common. This means that there are feedback relations between them. Thus, it can be concluded that the business model:

- presents a method of generating value for customers and shareholders,
- requires the definition of important components on which the creation of value for customers and shareholders depends, including:
  - features and scope of the offer for specific customer segments,
  - method of making the offer available and selling price,
  - internal value chain,
  - key resources necessary to perform activities within the internal value chain,
  - relations with external partners,
  - method of financing the conducted activity,
- requires the determination of mutual relations between the individual components of the business model.

The presented definition is consistent with the business model's systemic concept and includes a holistic approach features. The systemic and holistic approach fully reflects the essence of the business model and its relationship with creating value for both customers and shareholders. A diagram of such an approach to the business model is presented in Figure 9.7.

The presented idea of the business model can be applied to any company, including those operating DHSs. The business model allows enterprises to stand out in the market and achieve a competitive advantage over other entities. The business model should not be constant but should evolve along with changes in the company's environment or as a result of taking advantage of opportunities appearing in various niches.

Renewal (fundamental change) of the business model is inherent in the essence of strategic management and should also be the domain of companies operating DHSs. The speed and complexity of changes taking place in the economic environment of enterprises force the renewal of the business model, which becomes one

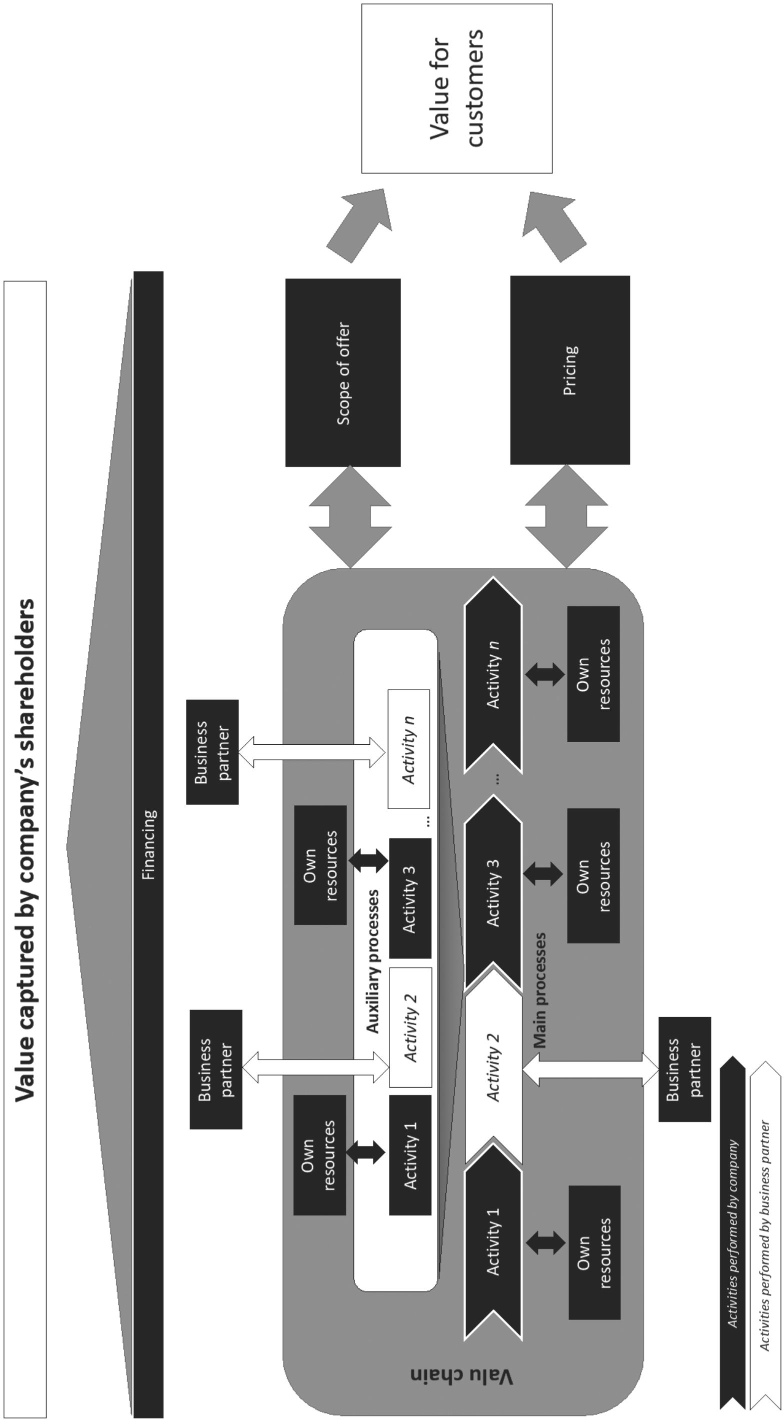

Figure 9.7. Scheme of business model

Source: own study.

of the basic factors of achieving and maintaining a competitive advantage over other entities operating on the market. An innovative product alone or the technology of its production is not enough to achieve success. To achieve success, it is necessary to properly place an innovative product or technology in a business model that will enable effective commercialisation.

The renewal of the business model should be combined with a fundamental change in it, resulting in a completely new way of delivering value to customers or a new way of capturing value by the enterprise for its owners. The renewal of the business model is carried out as part of a specific process in which, in the first place, there is a break with the current way of creating value for customers and owners of the company and replacing it with a completely new approach in this respect (discontinuous change).

The renewal of the business model depends on the changes in the company's external environment. The prerequisites for the start of the renewal are therefore signals about changes in the external environment related to the development of technology, social and cultural changes, and changes in legal regulations. Finally, Basu and Wadhwa (2013) argue that renewal occurs when a business's essence undergoes significant changes. According to these authors, renewal is a process that can significantly impact the enterprise and its long-term prospects of operation. Renewal is associated with fundamental changes to the key attributes of the organisation.

The correct approach to renewing the business model should be considered one that covers at least four essential stages of the process:

- monitoring the determinants of changing the current business model,
- designing and testing a new business model,
- implementation of the new business model,
- improvement of the new business model.

The process of renewing the business model in the context of strategic management is presented in Figure 9.8.

The commencement of work on a new business model is conditioned by certain factors that may occur in the company's environment and structure. The determinants of the need to start working on a new business model can be divided into two groups:

- external determinants resulting in the inconsistency of the current business model with the external environment,
- internal determinants related to the development of new products by the enterprise, production technology, and methods of operation, the commercialisation of which requires the development of a new business model.

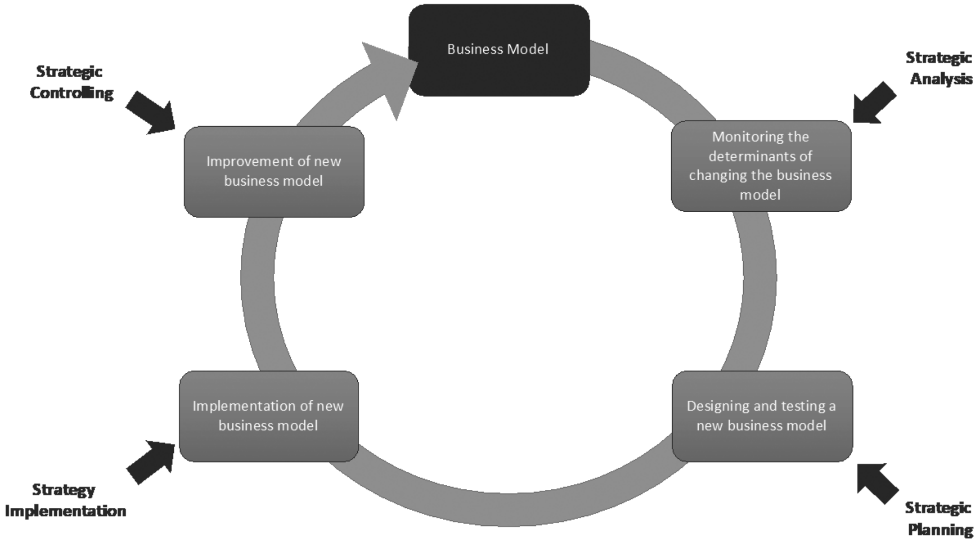

Figure 9.8. The process of renewing the business model

Source: own study.

Identifying an opportunity to create a new business model requires constant monitoring of the determinants included in both groups. The analysis of the environment in the context of the current business model assessment should go beyond the current sector's boundaries and include phenomena occurring in related or potentially related sectors. Extending the analysis of the competitive environment is a key issue because, in many cases, the successful attacks on the competitive position of incumbents came from other sectors or niche parts of the market.

The commencement of work on a new business model may also be conditioned by the development of new products, technologies or methods of operation, which is carried out within the company's organisation. Creating new products, technologies or methods of operation may start the process of defining a new business model. Success depends on the right time (timing) to implement the new business model.

The essential stage in the renewal of the business model is designing its new, innovative version and subjecting it to testing. The design process should define all the essential features of the business model components and the mutual relations between them. The elements of the business model and the relationships between them should be designed in such a way that it is possible to create value for customers and capture a part of the value created by the enterprise. Many tools can be used to design a business model, including a business model map which lists the designed elements and the relationships between them.

The next steps in the renewal of the business model are its implementation on a larger scale and monitoring the performance of the company operating under the new model. Effective implementation of the strategy and business model requires the creation of an appropriate performance monitoring system. The structure of the performance measurement and control system should be adapted to the shape of the business model. Only then can the information obtained from this system help assess the business model, which is the basis for making certain adjustments. It should be noted that in the course of the strategy implementation, these adjustments do not concern a radical change (renewal) of the business model but rather its adaptation to the changing conditions in the environment.

The presented stages of business model renewal relate to existing enterprises that are already operating and exposed to environmental discontinuities. In a few cases, existing enterprises (the so-called incumbents) could renew their business models correctly and at the right time. This is due to many reasons, including but not limited to:

- the success of the current business model which affects the scope of information embedded in the decision-making process (Chesbrough, 2010),
- conflict with the current business model, especially if it involves generating high financial results (Chesbrough, 2010),
- identity trap – the identity of the enterprise limits the possibilities of perceiving strategic options, which makes the enterprise unable to adapt its activities to the changing environment (Bouchikhi & Kimberly, 2003),
- threats of cannibalisation of existing products or operating models.

All the difficulties mentioned above in renewing the business model also apply to companies operating DHSs. Focusing on current activities does not allow companies operating DHSs to see the need to renew their business models. However, this can be done when the company's management can look more broadly at the changes in the environment and niches. The proposed directions for renewing the business model of such companies are presented in Table 9.2.

The renewed business model of companies operating DHSs will threaten the current mode of operation in terms of revenues and financial results. However, transitioning to the new way of creating customer value will be gradual. Companies operating DHSs should start operating under a new business model in separate areas of cities or districts, especially those where new residential and service facilities with a higher energy standard and underfloor heating will be built. Only then the activities under the new business model should be extended to the existing residential, service and other facilities, ultimately covering the entire DHS. The revenue generated under the current business model will therefore decline, but at the same time, the revenue generated from the new way of doing business will grow. The revenue

Table 9.2. Directions for the business model renewal of companies operating DHSs

Business Model Component	Existing Business Model of Companies operating DHSs	Renewed Business Model of Companies operating DHSs (realistic scenario of DHSs' transformation)
1	2	3
Scope of offer	Heat is supplied via a centralised DHSs to the following main groups of consumers: ▪ housing associations and communities, ▪ public institutions, including local governments, ▪ small and medium businesses, to a limited extent, large industrial plants. To a limited extent, these companies provide heating-related services (e.g., maintenance of heat nodes).	In the new business model, the scope of services provided by these companies will include: ▪ provision of balancing services for various dispersed heat sources operating on a common network, ▪ construction and lease of devices for local heat generation in buildings, including heat pumps, solar panels, etc. ▪ aggregation and balancing of electricity used in heat production by heat pumps (receiving surplus electricity from PV panels and selling energy to cover its shortages in heat production by heat pumps) ▪ provision of maintenance services for local heat sources belonging to various entities.
Pricing	The heat and transmission services prices are legally based on the cost-plus method or reference prices. The Energy Regulatory Office approves tariffs for heat and transmission services.	In the new business model, prices will be determined separately for individual services, including: ▪ a fixed monthly fee will be charged for the maintenance of the district heating network, the role of which will change from the transmission to balancing, ▪ there will be a settlement of the monthly balance of heat supplied to a given facility and received from it from a local RES or waste heat source; this balance will be settled not according to prices approved by the ERO but according to negotiated prices, ▪ equipment will be leased at fixed monthly charges for an agreed period that guarantees a specific return on capital, ▪ aggregation of electricity surpluses and shortages will be carried out according to market prices (determined based on quotations on the electricity exchange) ▪ the fee for maintaining local heat sources will be shaped in the course of negotiations.
Value chain	The essential links in the basic process within the value chain are heat generation in central CHPs or heat plants, heat transfer, and heat distribution. As part	The value chain will be fundamentally transformed. The main activities carried out within the value chain include: ▪ maintenance and expansion of the district heating network,

1	2	3
	of the supporting processes, there are activities related to the maintenance of the property, investments, maintenance of IT systems, management activities.	▪ preparation and implementation of investments in local, renewable heat sources as well as waste heat and energy storage ▪ trading electricity for the needs of local heat pumps ▪ balancing and settlement of entities connected to the network from the supplied and received heat ▪ settlement of recipients from other services ▪ management activities.
Main resources	The primary resources include: ▪ devices for heat generation in central CHPs or heat plants ▪ transmission networks ▪ heat nodes in buildings ▪ The primary resources also include employees with competencies in district heating as well as IT systems for the supervision and management of heat sources and networks.	Intangible assets, knowledge and IT systems will be equally crucial as fixed assets. The main resources include: ▪ still, the district heating network but without central heat sources, which, even if they remain, will play an auxiliary role (peak sources) in relation to distributed heat sources ▪ a range of dispersed RES which may be partly owned by companies ▪ IT systems supporting balancing the DHS, trading electricity, settling balances of heat supplied and received from heat sources belonging to prosumers ▪ specialists in the management of dispersed energy systems and electricity trading, as well as specialists in the design and implementation of RES.
Relations with business partners	The main business partners include entities that realise investments in central CHPs or heat plants and networks, maintenance companies, and suppliers of fuels and other utilities. These relations are shaped on the basis of contracts with different time horizons.	The main partners of companies operating DHSs include heat prosumers and entities with excess waste heat that can be introduced into the network. Other key business partners include suppliers of IT systems for managing the dispersed energy system and equipment for RES. These relations will be shaped based on long-term cooperation.
Financing	The activity of companies operating DHS is financed mainly with equity and bank loans. Other financial instruments are used to a limited extent.	The activity of companies operating DHSs will be financed from various sources, including, to a greater extent, subsidies and loans granted by banks involved in the green transformation.

Source: own study.

replacement process must take place gradually so that the financial results generated under the current operating model are used to develop activities under the new business model. However, this process cannot take place too quickly as it may cause difficulties in financing the transition to a new business model and too slowly as this, in turn, exposes companies to the loss of the market, which entities with alternative solutions to DHS will enter. Therefore, it is crucial to properly plan the transition process to a new business model and its effective implementation.

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