Good heating practices from Denmark and Germany

Conclusions for Poland

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1. Foreword

Changes in the heating sector are fundamental for the improvement of air quality in Poland. However, our heating supply sector has been drifting for years. On the one hand, the decision-makers are afraid to talk about cost increases and the need to support the poorest people. On the other hand, Polish heating sector is an exceptionally difficult puzzle – it is heterogeneous, it has diversified ownership and production structures and a different level of technical advancement. We should not exclusively concentrate on heating systems, because these are mainly individual heating sources, which contribute to the emergence of smog.

The entire discussion on energy sector and heating sector in our country is unfortunately still subordinate to mining affairs. Mining is important, but the energy sector cannot be developed through one sector, especially when it has an influence on the entire economy. We have reached the point in which we have the worst air quality in the European Union. As many as 36 out of 50 of the most polluted cities in Europe are located in Poland. This has to change in the future.

Discussions with people who have a direct influence on the future of the national heating sector have been the inspiration to create this report. Many of them are convinced that the discussion on Polish heating should be started anew. A review of the best technologies available in the 21st century is necessary. It is vital to analyse both the good as well as the bad experiences of other countries.

We have decided to learn from the experiences of Denmark and Germany. We have checked their achievements in the improvement of air quality and modernization of the heating sector. We have chosen these two countries due to their similarities to Poland. They are located in a similar climate zone, take advantage of expanded heating networks and for years their heating sector has relied primarily on coal.

In the present study, we try to bring our readers closer to the outline of the history of changes in the sector in Denmark and Germany. We show the importance of long-term vision, specific aims and mechanisms motivating engagement and appropriate evaluation of environmental costs in this process.

We hope that this report will become an inspiration in the important discussion on solving the problem of smog and the modernization of the Polish heating sector and will allow Polish decision-makers to believe that changes are not only necessary, but also feasible.

Yours faithfully,
Joanna Maćkowiak-Pandera
President of Forum Energii

2. Introduction

The aim of this report is to present the experiences of the heating sector in Denmark and Germany over the last 30 years. This may provide impetus to a national discussion on the most modern technologies available and regulatory solutions. The report is part of the “Clean Heat” project implemented by Forum Energii, the main task of which is to support the actions connected with the improvement of air quality in Poland through changes in the heating sector.

We decided to mention the examples of Denmark and Germany due to the following reasons:

- In the past their heating systems were strongly dependant on coal.
- Over the last few years they have significantly changed their heating sectors, which has contributed to the improvement in air quality.
- They are located in a similar climate zone and have well-developed heating networks.

The area of heating supply is understood as both system heat and individual heating installations in buildings that are not connected to urban networks. An integral part of the discussion on the heating sector is the improvement of energy efficiency. The modernization of heat sources cannot begin without radical improvement in the energy standards of buildings. Heating networks are treated as a source that should be particularly taken care of. System heat will help to solve the problem of smog, but at the same time Polish heating systems have to be effective and offer heat at a reasonable price.

In this report we describe how Denmark and Germany managed to eliminate coal from households. How was the problem of energy poverty solved? Which incentives were used for the development of clean heat sources? We also show how the heating sector helps to balance the power system through cogeneration.

3. Comparison

Poland, Germany and Denmark demonstrate a number of similarities with regard to the use of coal in the past and to the development of heating systems. However, their experiences have been different in the recent years. This is due to the fact that their energy systems differ with regard to size, emissivity and attitude to fossil fuels. A synthetic comparison of key macroeconomic indicators is displayed below.

Tab. 1. Three countries at a glance (2016).

	Denmark	Germany	Poland
Energy sector			
Generation of electricity	30.5 TWh	649.1 TWh	166.6 TWh
Electricity share from RES in the electricity production	60.5%	29.9%	14.0%
Electricity share from cogeneration in the electricity production	39.4%	13.5%	16.6%
System heat generation	38.0 TWh	130.4 TWh	81.3 TWh
Heat share from RES in the system heat generation	50.0%	14.2%	7.6%
Heat share from RES in the system heat generation	67%	83%	60%
Economy			
Energy consumption GDP (toe /Mil EUR'10)	66.4	111.1	231.2
Emissivity GDP (tCO_2/Mil EUR'10)	153.3	290.0	747.6
Goals and strategies 2030			
National reduction of CO_2 vs 1990	Discussion	55% - 56%	
Energy share from RES in the stream of primary energy	35%		?
Energy share from RES in the stream of primary energy	50% from wind	65%	
Goals and strategies 2050			
National reduction of CO_2 vs 1990	80%- 95%	80%- 95%	
Energy share from RES in the stream of primary energy (Pe)/ final energy (Fe)	100% (Pe)	60% (Fe)	
Energy share from RES in the stream of primary energy (E)	100%	60% (E+H)	?
Energy share from RES in the stream of heating energy (H)	100%	60% (E+H)	
Reduction of primary energy vs. 2008		50%	

The examples of Denmark and Germany very clearly illustrate to what extent Poland differs from European leaders who are our base for comparison. The areas of strategic planning, setting long-term aims and consistency in their achievement are considered as a particular handicap in Poland. Unfortunately, there is still no defined national power or heating policy in a time horizon of two or three decades. As a result, we risk wasting time, the slowing down of investments in the area of heating supply as well as the ineffective spending of money.

4. Conclusions for Poland

Both countries analysed have different experiences, resources and technologies. They differ in attitude towards the transformation of the heating sector. It is not possible to copy their solutions, but it is worth getting to know them and getting inspired. Below, we present the most important conclusions to be drawn for Poland following an analysis of the transformation models of the heating sector in Denmark and Germany.

Planning

Long-term strategy and goals

It is crucial to set long-term goals for the Polish heating sector until 2030 and 2050. These should include social consultations and, due to a long-term perspective, agreements between the main political parties. This strategy should refer to European regulations and reflect mega trends and phenomena at macro-level. The lack of a national heating policy means the increase of legislative risk, higher cost of capital and the slowing down of investments in power generation assets.

Planning of heating supply

Local Spatial Management Plans should separate the areas with types of heating supply sources defined by local authorities. This will allow for the optimization of financial expenditures for the development of infrastructure and more social benefits.

Environmental education and communication

The state should educate the society not only with regard to the level of air pollution, but also inform them about necessary actions. Modern communication is needed in order to pass the knowledge about the prevention of threats and protection of health as well as to provide opportunities to reduce air pollution. It is also essential to inform the citizens about the need for investment and technological actions and about the government's plans and implemented regulations.

External costs

It is vital to develop the methodology for calculating external costs (health and environmental costs) for heating projects. In Denmark, the methodology for calculating external costs has been made uniform, and input data for calculations (unit costs of pollution groups for different categories) is subject to periodic updates and is published by the government agenda. It is necessary to include the impact of technology on health and environment, i.e. social and economic cost, when making a decision about the choice of heating and power projects.

Industrial strategy

A well-prepared strategy for the modernization of the heating supply sector may be beneficial not only from the environmental, but also from the macroeconomic point of view of the state. The allocation of funds for efficiency understood as reduction of heat energy consumption and an increase of heat share from RES should be connected with the concept of the development of national industry producing devices for the heating sector and small power energy.

Resources

Energy efficiency and standards of buildings

If there is a failure to improve energy efficiency, the costs of transforming the heating sector will be too high, and environmental effects will be delayed. Buildings use about 30% of final energy, and national fuel import, mostly from Russia, is growing. The promotion of energy efficiency in the existing buildings is fundamental as are mandatory reinforced standards for new buildings. As a comparison, Germany has implemented zero-energy standard for new buildings since 2021. A strategy to reduce primary energy demand by 80% is implemented in the existing buildings up to 2050. The “Flat+” program implemented in Poland, which is to help the citizens to solve housing problems, should promote ambitious standards of energy efficiency. It may drive Polish innovations and become a part of the new industrial policy.

A shift from solid fuels to heating of individual buildings

Both Denmark and Germany abandoned coal combustion in households, because individual stoves are the main reason for smog. In both countries, biomass and gas are gradually being abandoned as well.
Heating networks, heat pumps, renewable sources and partially gas are alternatives to coal. Poland needs to develop a strategy to abandon the use of coal in households by 2030 or 2035, otherwise the air quality will not improve.

The future of biomass

The change in attitude towards the use of biomass is becoming gradually more visible both in Germany and Denmark. It is not a neutral fuel for the environment - in terms of emissivity, origin and availability. The production of biomass for energy purposes is a competition for agricultural crops, which should be given priority. This is why biomass has a perspective in small and local CHP plants and heating stations. The combustion of biomass in large power stations has no future. A discussion on the combustion of biomass in stoves (as a substitute for coal) should be held. It is certainly a better alternative to coal waste, but its combustion in small stoves causes emissions of many harmful substances. This is due to the low efficiency of equipment and lack of possibility to maintain appropriate emission standards. Denmark faced just such a problem.

Funding

Effective use of public measures

Polish governments support thermo-modernisation, coal, RES, 5th generation coal stoves, development of heating networks, diversification of gas sources and many other projects connected with the heating sector and energy sector. In the meantime, some of these actions are mutually exclusive. Funding should support a uniform national strategy or a wide range of regional strategies and commonly-accepted long-term goals.

Circulation of funds in a closed circulation system

Modernization of the heating sector is connected to large expenditures. This is why it will be important to source new funding in the future. The first possible step is to use revenues from the sales of CO_2 emission rights - their price increased up to about 25 Euro per tonne in 2018 (after correction, it decreased up to 18 Euro per tonne) and further increases should be expected. With current annual emissivity of power and heating sectors at the level of 153.7 million tonnes of CO_2 , PLN 12 billion is needed - those funds should be wholly spent on the heating sector and low-emission energy sector. Similar solutions are applied in Germany and Denmark. Funds from the sales of emission rights are used to eliminate its sources. In Germany, 100% of revenues from CO_2 auctions are spent on power and pro-climate projects. In Denmark, the revenues generated by coal tax that charges different types of primary energy to different extents (fuels, electricity, heat) are almost totally allocated to support modernization of the energy sector and the heating sector.

Energy poverty

Sensitive social groups which are prone to energy poverty should continue to be protected. The support programmes developed in Poland should be coherent with directions of planned transformation of heating supply area. They cannot only be a reaction to current pressing problems.

Technology

Connecting heating sectors with power engineering

Heating sector may help to balance the energy system. Both Denmark and Germany are working on relevant solutions. It is also worth tapping this potential in Poland. Modern heating stations equipped with flexible cogeneration units, heat pumps, electric boilers and heat accumulators may stabilize (balance) the work of the National Power System.

Electrification of the heating sector

Electrification of the heating sector, may be an alternative for Polish households. The energy system of the future will be characterized by a huge amount of cheap electricity from RES. Where the tariff is flexible and prices of electricity reflect the demand, the wide use of heat pumps will be possible. This is already a real perspective in the near future.

Use of surplus energy

Surplus energy originating from industrial processes, discharges from waste water treatment plants, from air conditioning and cooling devices should be treated as national power resources. Its role in the heating sector should grow steadily. System mechanisms and regulatory frameworks promoting this type of energy should be formed. It is connected with the change in the philosophy of heating companies (decentralization and diffusion of energy sources, bi-directional thermal energy flows) and change of network performance parameters and transition to low-temperature levels.

Support of development of 4th and 5th generation heating networks (4G and 5G)

Low-temperature networks: 4G and 5G allow for an easier and more effective absorption of energy from RES and surplus energy. Decrease of temperature of working medium in heating systems should be a constant process andshould be an integral part of projects for development of heating companies. Mechanisms and regulatory framework, which will facilitate and stimulate this process, should be formed.

5. Denmark

5.1. History of changes in the energy sector

The Danish energy sector started to change in the mid-seventies after the very first oil crisis. Western Europe was shocked by the crisis which gave rise to the reflection that fossil fuels resources wre not limitless, and that the prices are shaped by the international market pushing up energy costs in unexpected situations. Those who learned the lesson, decided to solve the problem by adapting the future power policy. Within just a quarter of the century, Danish energy sector and heating sector have been entirely altered. Energy efficiency, cogeneration in the energy sector and renewable energy were of primary importance. Figure 1 shows the decisive steps of this process.

Figure 1 Key stages of development of the energy sector in Denmark.

1973 – Oil crisis
- Starting discussions on fuel independence

1979 – The First Energy Plan and the First Heating Act
- Start reducing oil consumption and petroleum in energy sector and heating sector
- Introduction of the obligation to connect buildings to heating networks

1981 – Development of National Heating Plans
- Dividing into areas with defined energy sources for heating purposes

1986 – Parliament's decision on energy planning
- Withdrawal from considerations about the construction of a nuclear power plant
- Excluding coal from energy plans
- Strengthening the role of small CHP plants as a base for the power system
- Further taxation of liquid fuels and electricity for heating purposes

1990 – Amendment to the Heating Act
- Strengthening the role of biomass and gas cogeneration
- Introduction of guidelines for self-government authorities regarding the use of cogeneration in local heating companies

1992 – Introduction of environmental taxes as instruments for shaping the energy mix.
- Introduction of support systems for the development of cogeneration, heating networks and RES

1993 – Political agreement on the strategy of using biomass for energy purposes
- Further support for the development of CHP plants and heating networks

2008 – Agreement on energy policy 2008-2011
- Strong support for the development of wind energy and other RES

2012 – Agreement on the Energy Plan 2012-2020
- Road map and action plan for the development of RES, wind energy and energy systems

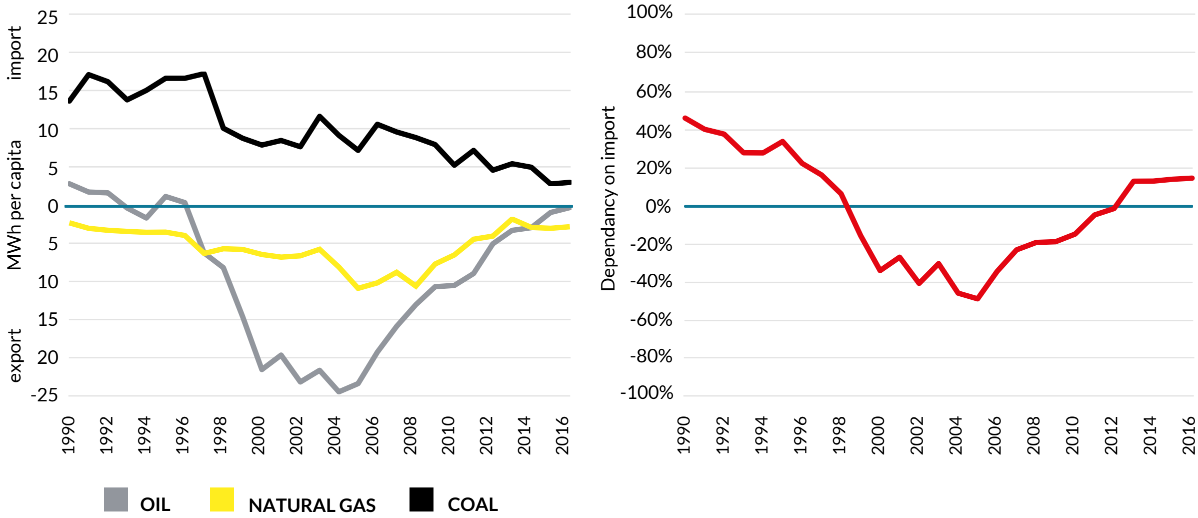
2018 – Agreement on the Energy Plan 2018-2030
- Update of goals and action plans
- Adoption of national goals for 2030 and maintenance of goals for 2050

Source: Own analysis on the basis of State of Green, White papers for a green transformation, 2016.

5.2. Opening balance

From the beginning of the 1990s until now, Denmark has been self-sufficient with regard to its natural gas supply and petroleum. The country became the exporter of net energy for many years to come thanks to the increase of resources extraction in the 1990s. However, again Denmark became an importer of net energy due to a further drop in extraction. In2016, dependence on energy import was 13.9%, which is a good result when it is taken into account that the EU average exceeded 53%. Denmark compensated the drop in petroleum and gas extraction by increasing the generation of electricity from local renewable sources (mainly from wind, biomass and sun).

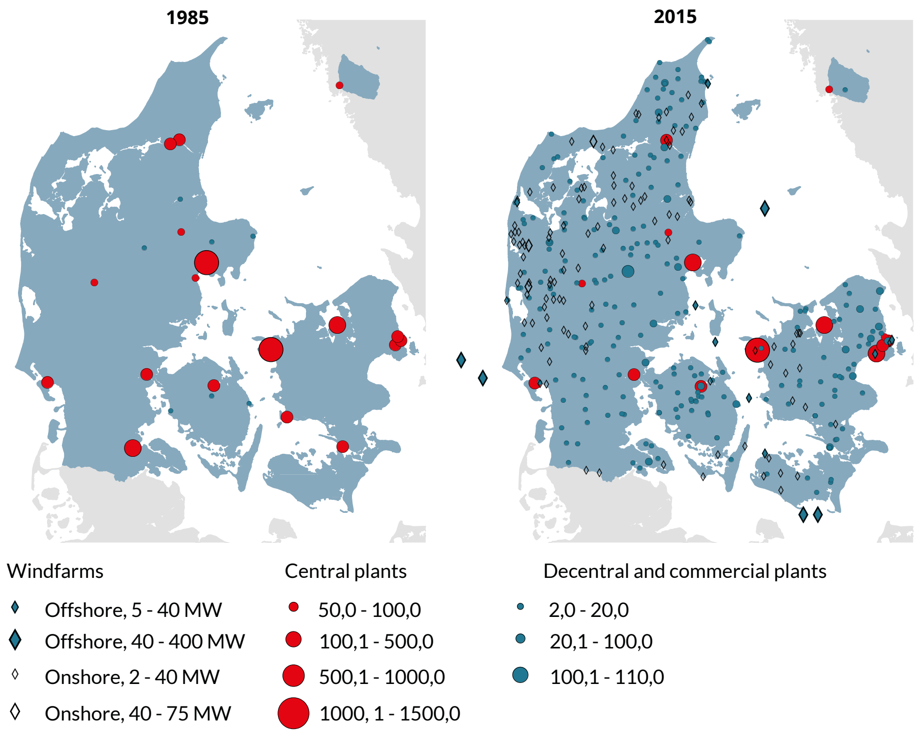
Figure 2 Net import of coal, petroleum and natural gas per habitant and the level of net import dependence.



Source: Own analysis on the basis of DG ENER of the European Commission

After the oil crisis, a wide range of regulations were implemented aimed at the increase in the the energy efficiency and making the country independent of fossil fuels import, starting with petroleum and coal. The dynamic development of renewable energy sources, dispersed cogeneration sources of heating systems brought a revolutionary transformation of the energy landscape in the country within a quarter century.

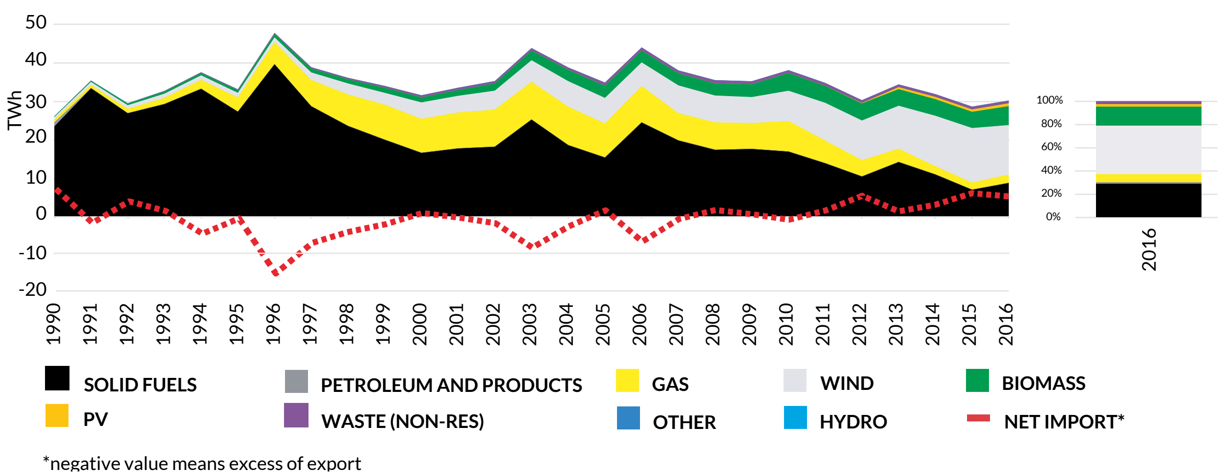
Figure 3 Transition from strongly centralized to decentralized energy system in Denmark.



Source: Energinet

Figure 4 illustrates the change of structure of electricity generation sources in Denmark and the structure of generation in electricity sector. Since the 1990's the energy sector has seen a transition from coal to energy from wind in the energy sector. The drop in the generation of electricity visible in the whole period results from the decrease of its export and drop in the generation in gas-fired CHP plants replaced by cheap energy from wind farms.

Figure 4 Generation of electricity divided into sources and production structure in 2016

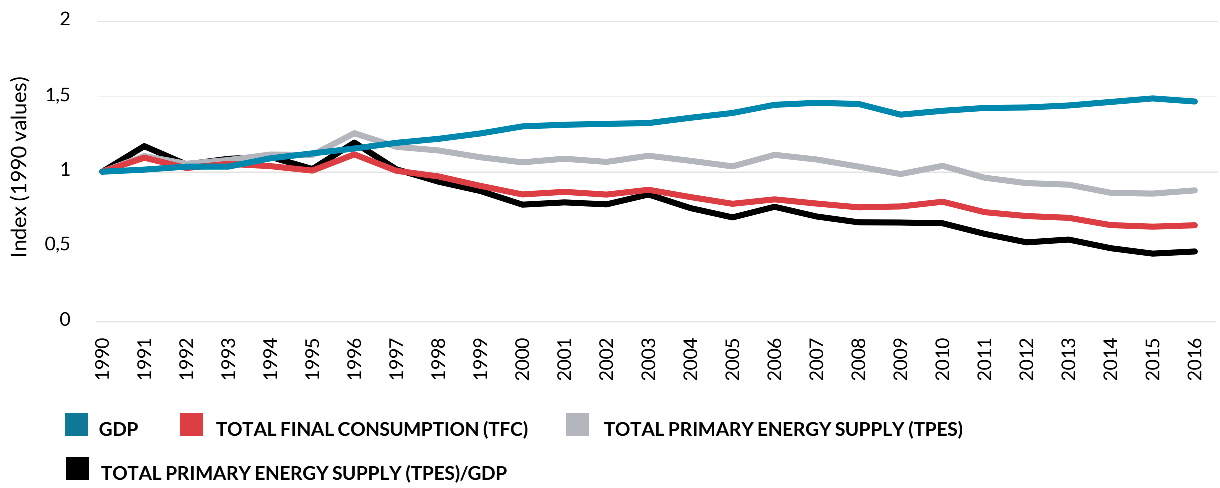


Source: Own analysis on the basis of DG ENER of the European Commission

The share of energy from renewable sources in the generation of electricity is high - it reaches about 60%. The share of coal keeps falling even though it still covers about 30% of annual demand. Currently, no coal-fired units are being built. Since 2016 two large cogeneration units for biomass have appeared. By 2020 one more unit should be built, which will allow for a reduction in coal consumption.

In addition to increasing the use of energy with RES, the second pillar of the energy and heating sector transformation is the improvement of energy efficiency. The economic growth has been accompanied by a decrease in demand for primary energy for over a decade. This is the effect of modernization of generation industry programmes and increase in productivity without growth in energy demand.

Figure 5 Basic energy efficiency indicators in Denmark.

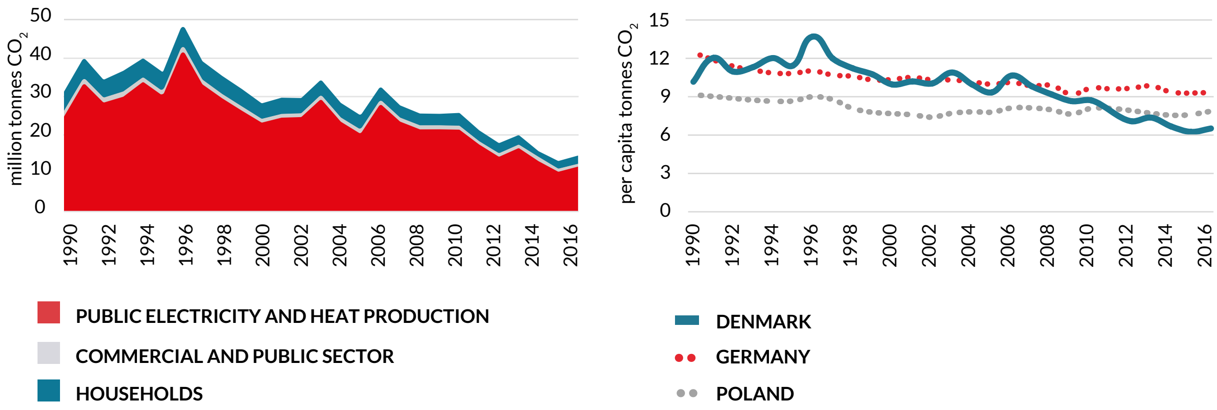


Source: Own analysis on the basis of DG ENER of the European Commission and data of Eurostat.

Reduction of greenhouse gases emissions

CO_2 emissions and climate changes are the key issues in state policy. Figure 6 demonstrates that CO_2 from the energy sector (energy, district heating and individual heating) in Denmark decreased by 34% by 2015 (in comparison to 1990) despite the increase in population and constant economic growth. This decrease is a consequence of the development of wind energy and continuous modernization and development of the heating sector, which uses more and more energy from RES, from municipal surplus and waste energy. The drop in emissions is also a derivative of the reduction in electricity exports.

Figure 6. Change in CO_2 emissions from energy sector and change in CO_2[1] emissions per habitant.



Source: Own analysis on the basis of DG ENER of the European Commission

One of the strongest incentives enforcing the reduction of CO_2 emissions is the so-called coal tax. In Denmark, fossil fuels (used both for the needs of CHP plants, as well as individual heating) are subject to a CO_2 tax (an average of about EUR 23 per tonne of CO_2 emitted).

According to COWI, in terms of fuel energy, the CO_2 tax is respectively:

- Natural gas: **4.7 EUR/MWh (5.5 PLN/GJ)**
- Petroleum: **6 EUR/MWh (7 PLN/GJ)**
- Coal: **16 EUR/MWh (18.6 PLN/GJ)**
- Biomass: **0 EUR/MWh (0 PLN/GJ)**

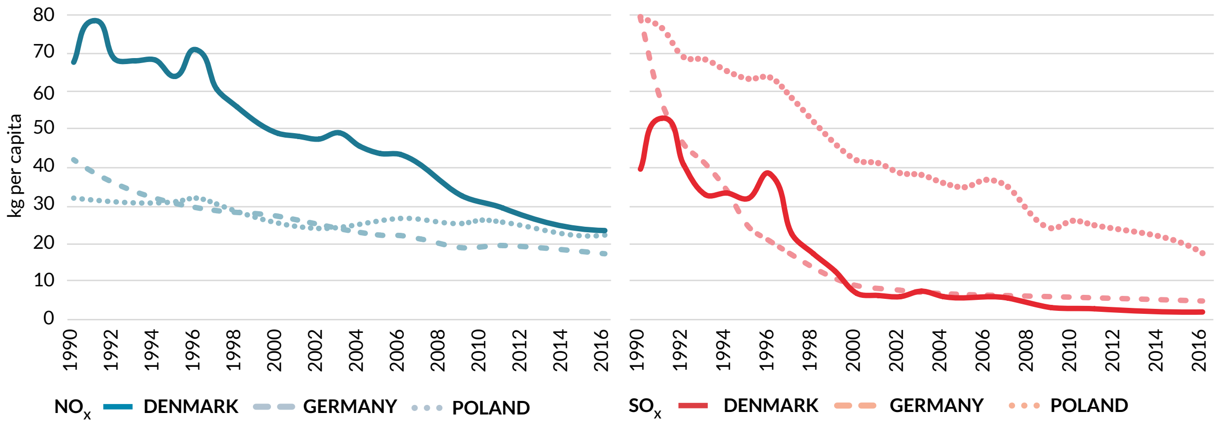
This tax is sometimes adjusted, along with a change in the level of ambition of climate policy.
In Denmark, biomass plays a key role as a fuel in the energy sector. Of the nine large CHP plants in Denmark, four plants have already passed from coal or natural gas to co-production with the use of biomass. Two plants are currently undergoing reconstruction, and the next one is to be transformed by 2023. The main goal that accompanies the modernization of the heating sector is the total abandonment of coal fuel by 2030. Combustion of a large amount of biomass is being highly criticised. Not only is the impact on the climate important, but the method of obtaining biomass and the impact on nature. The view that biomass is a transitional fuel is becoming more and more established. Works on the completely zero-emission and environmentally neutral target model are under way.

1 The emission concerns the generation of electricity and heat as well as commercial and housing sectors.

Reduction of nitrogen oxides and sulphur oxides

The main source of nitrogen oxides (NO_x) is combustion of fossil fuels, biomass and emissions from vehicles.

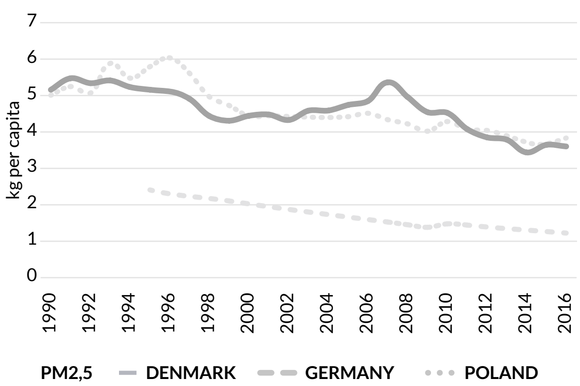
Figure 7 Emissions of NO_x and SO_x per habitant in Denmark.



Source: Own analysis on the basis of DG ENER of the European Commission

Despite the high efficiency of the energy system, NO_x emissions remain at a high level. One of the main reasons is the combustion of biomass in the energy sector and individual households. The combustion of biomass, even in professional heating stations, emits three times more NO_x than the combustion of coal and gas (unless installations for reduction of emissions are applied). It should be highlighted that all biomass units should meet the standards resulting from MCP (Medium Combustion Plants) and IED (Industrial Emissions Directive) Directives. Therefore, centralized heat plants are definitely more environmentally friendly than individual pellet boilers or even gas boilers. A considerable drop in NO_x emission was observed in1989 after the implementation of new standards for plants with thermal power above 25 MW.

Figure 8. Emission of particulate matter in Denmark.



Source: Own analysis on the basis of DG ENER of the European Commission

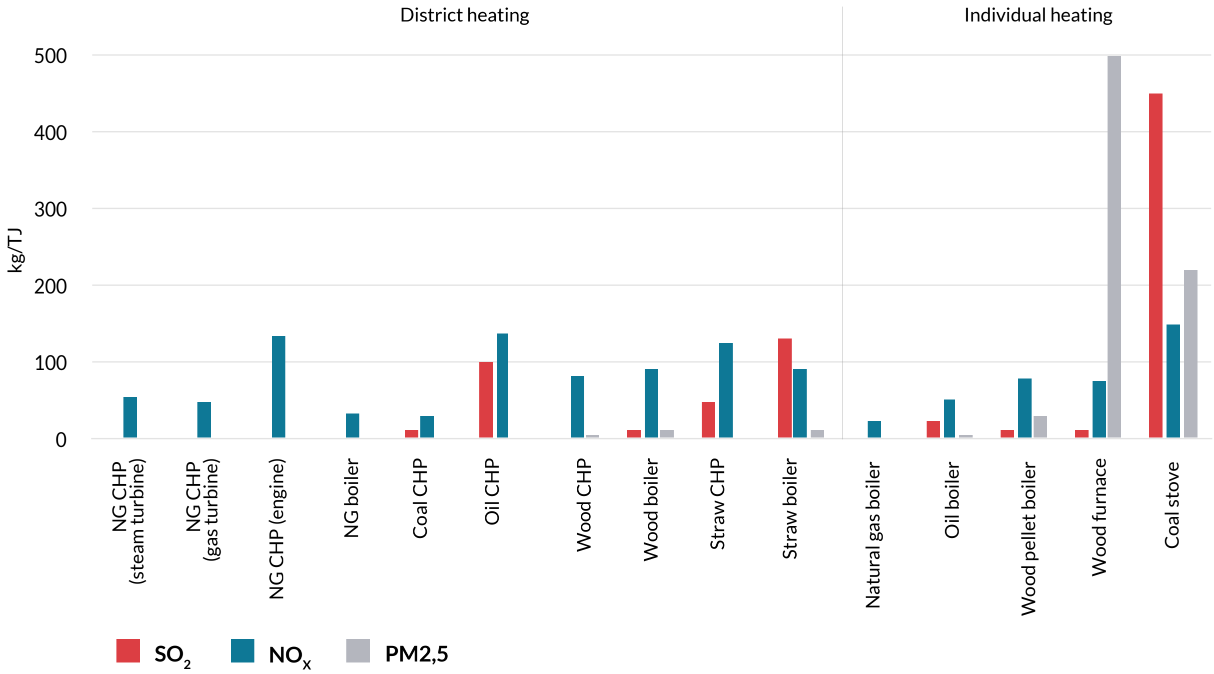
The decrease in sulphur oxide emissions (SO_x) is the effect of a wider gas introduction and actions undertaken as part of EU policy (Implementation of LCP/IED and MCP Directives) requiring the construction of more and more effective flue gas desulphurisation systems. The Directive on sulphur content in liquid fuels has additionally contributed to the reduction of contamination level.

Reduction of fine particulate matter (PM) emission

Particulate matter (PM 2.5) are very small particles present in the atmosphere which easily penetrate the bloodstream of human beings. They are extremely harmful to human health. Fine particulate matter is released into the air by the combustion of fossil fuels, but it can also be released by natural sources. The chart indicates that PM 2.5 emission has slightly decreased since 1990, but it is still too high.

Emissions of particulate matter are strongly dependent on the type of fuel and the fuel-combusting device. In the case of natural gas, emission almost does not occur. A certain emission level is generated by the combustion of coal, oil, straw and wood in heating units. The highest emissions come from stoves and boilers in individual buildings. Biomass is often considered to be an environmentally friendly fuel, but in fact its combustion in domestic boilers can cause much larger environmental pollution with PM 2.5 than combustion of oil or high-grade coal (Figure 9).

Figure 9. Emission indicators (kg / TJ in fuel) for different production technologies.



Source: COWI

Wood stoves in Denmark

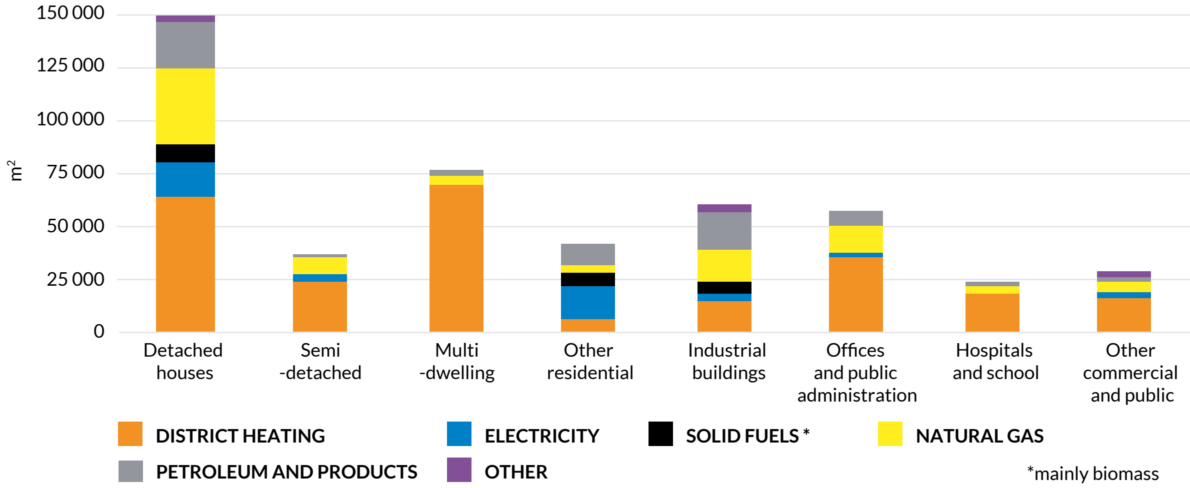
More than 10% of Denmark's heat demand in 2016 was met by home wood stoves.
The Environment Agency carried out a number of campaigns aimed at withdrawing obsolete stoves installed before 1980 and increasing the social awareness regarding the impact of stove operation on the quality of emitted fumes.
As a result of an educational campaign and financial incentives in the form of subsidies for the purchase of new stoves (approximately EUR 300) about 20,000 stoves were scrapped, out of 800,000 in total.

In addition, a number of legislative actions have been taken over the past 10 years, e.g. permission to sell only stoves with an acceptable (maximum) level of particulate, carbon monoxide and hydrocarbon emissions.

5.3. Heating supply sector

The most important source of heating in Denmark is district heating. As many as 64% of households are connected to heating networks, and in cities up to 98%. If it is not possible to connect to the heating network, gas is the option, and in rural areas - biomass boilers, heat pumps and oil- or gas- fired boilers.

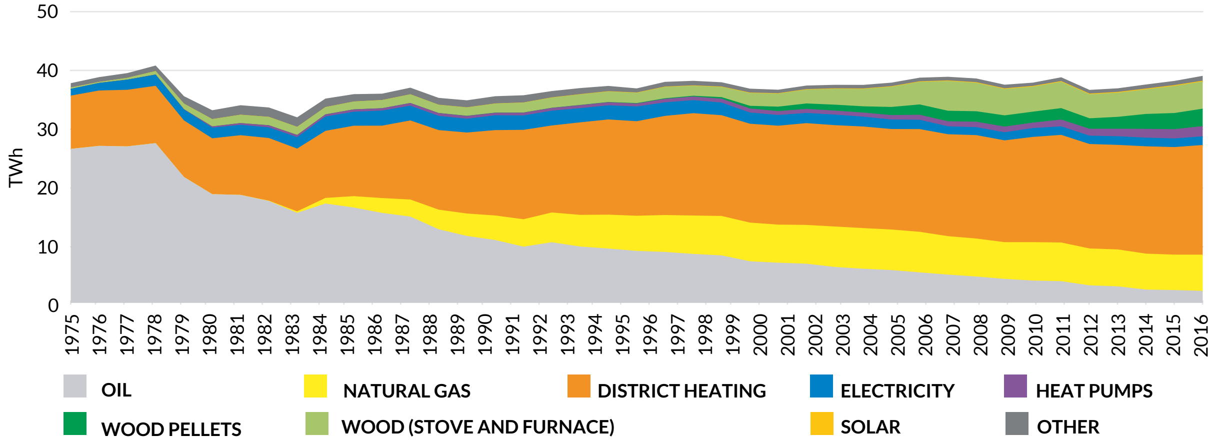
Figure 10. The usable area is heated by means of the main heat sources at individual consumers.



Source: Own analysis on the basis of Energistyrelsen and IEA

The total households' demand for heat and its supply, with division into types of fuels, is shown in Figure 11. The extent to which oil crises affected the level of energy consumption and the decline in the use of heating oil for gas and district heating is evident. The chart shows both district network and individual installations in households (excluding services and industry).

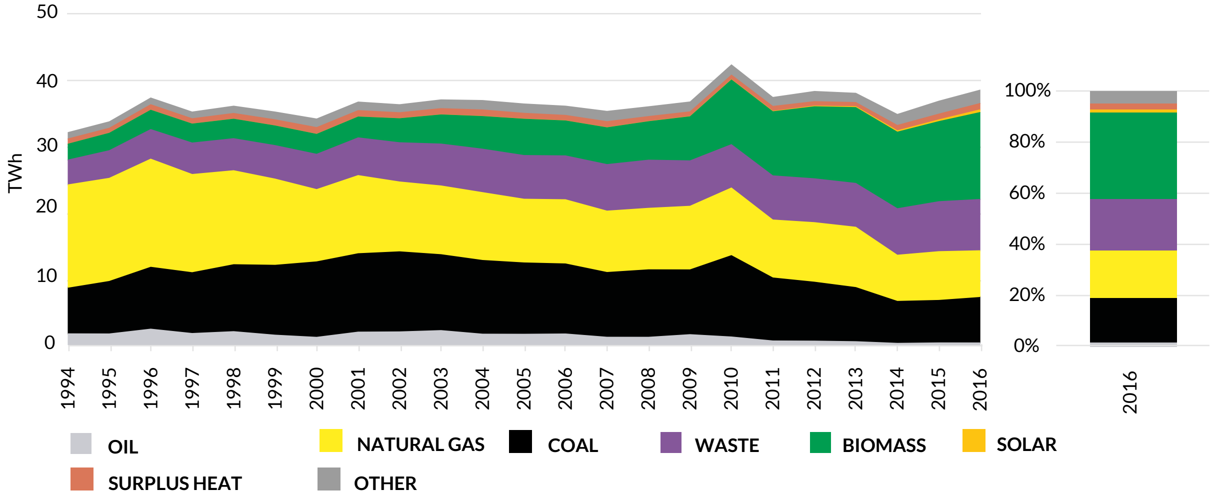
Figure11. Heat demand in Danish households according to heat source



Source: Own analysis on the basis of Energistyrelsen

In urban heating systems (Figure12), there has also been a decrease in oil consumption in favour of biomass and municipal waste, used primarily in units operating at the basis of the load. Natural gas still plays an important role in the heating sector in Denmark, but due to high taxes, it is losing its importance.

Figure 12. Generation of district heating and fuel structure of district heating.



Source: Danish Energy Agency

In Denmark there are over 400 heating companies owned by heat consumers (cooperatives), municipalities or in some cases private enterprises.

Basic information on the heating sector in Denmark (2015):

- 30 780 km - length of network
- 64% - share of district heating in total heat demand
- 57% - share of cogeneration in the national generation of electricity
- 69% - share of heat from cogeneration in the stream of district heating
- 50% - share of RES in district heating
- about 8.3 kWh - average heat consumption per person per year
- about EUR 2.5 billion/year - revenues from sales of heat

Waste management companies

In Denmark, there are about 25 plants generating energy from waste. The vast majority of these plants are co-owned by many municipalities. All plants supply heating companies with district heating. Heat from waste incineration plants covers about 20% of the total Danish heat consumption. Some plants generate energy in cogeneration units.

The high share of heat supplied from plants generating energy from waste results from significant regulatory support and broad public acceptance for this technology. Since the beginning of the development of Danish heating systems, municipal waste has been perceived as resources (fuel), and national waste management plans favoured the recovery of energy instead of its storage. Even the latest waste management plan is actually called a resource plan.

Cogeneration from gas

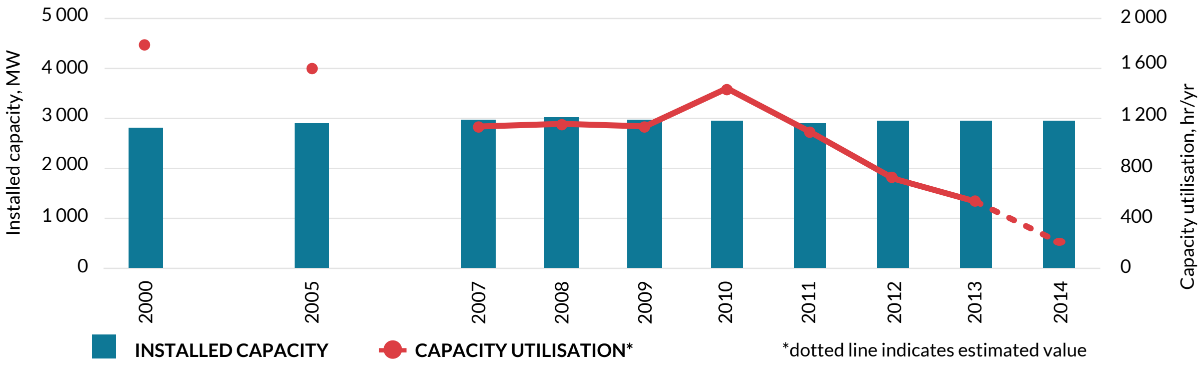
In Danish heating sector, gas units (2,800 MWe) work mainly during the periods of high energy prices on the stock exchange, guaranteeing coverage of operating costs.

It can be said that the era of gas (and coal) CHP plants is slowly disappearing in Denmark. The once very strong support mechanisms for gas units, will cease to apply as of 2019, which may reduce the available capacities due to the lack of coverage of fuel costs, taxes and fees for CO_2 emissions through revenues from the sales of electricity. The policy of withdrawing from the combustion of fossil fuels inthe heating sector prevents investors from building new capacities. Due to the growing energy gene-

Figure 13. Waste incineration plants in Denmark

Source: Own analysis on the basis of COWI ration in wind farms and the drop in wholesale energy prices, the operating time of gas units is significantly reduced. They only operate during peak power demand in the energy system. In 2016, the average time of using all (10 GWe) cogeneration units was 2,500 h/year, and for biomass units it amounted to 4,400 h/year.

Figure 14. Installed capacity of gas cogeneration units and decreasing time of capacity utilization.



Source: own analysis on the basis of data presented by Per Kristensen during a conference in Warsaw on 17 January 2018.

The uncertain future of small heating systems in Denmark

At the beginning of the 1990s, many small towns established their own heating systems. With no access to a gas distribution network and due to the high individual costs of oil boilers, the heating network with the use of natural gas cogeneration was considered to be a cheaper solution. An incentive for consumers to connect to the network was a low heat price guaranteeing an annual saving in heating costs of 20% in relation to alternative sources. Often, 150 to 400 apartments were connected to such a network.

The increase in the costs of purchase of natural gas and decrease in revenues from electricity sales from cogeneration units have caused these systems to start generating losses.

Temporary subsidy programmes allowed for further activity, but payment of these benefits will end in 2018, so heat prices will be increasing.

The Danish government is considering the implementation of financial programmes in order to cover the costs of closing the most deficit heating systems.

5.4. National strategies and goals for 2020-2050

Denmark's power strategy is always the subject of multilateral arrangements between stakeholder groups and the political consensus of the ruling party and opposition parties. It guarantees legislative stability and high efficiency in achieving the assumed goals. In 2012, after agreement negotiations were concluded between all political parties, the Energy Agreement document was signed, with specific goals and actions until 2020 and in the perspective of 2050. The table below presents the goals set in the Agreement of 2012 and updates of 2018.

Tab. 2. Main goals of the Energy Agreement

Goal/year	2013-2016	2020	2030	2035	2050
General goal Reduction of CO_2 (vs 1990)		**34%**			Total independence of Denmark from fossil fuels
Energy from RES		**35%** of share In entire primary energy			**100%** RES for all sectors
Electricity		**50%** of energy from wind in total consumption	Total withdrawal from coal	**100%** RES	**100%** RES
District heating sector			Total withdrawal from coal and oil	**100%** RES	**100%** RES
Individual heating sector	The use of gas stoves and oil stoves has been prohibited since 2013 In new buildings and since 2016 In the existing buildings, located in the area of heating network				
Energy efficiency		Reduction of primary energy consumption by 4% and net energy By 12% (vs 2006)			
Transport		**10%** RES from biofuels			

Source: IEA and analyses of Forum Energii

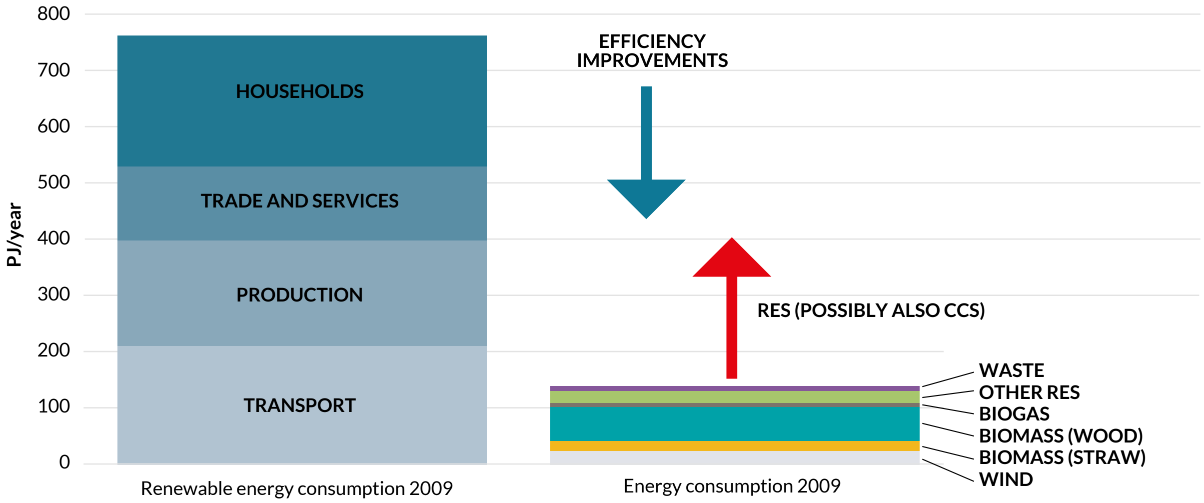
The Energy Agreement is based on two pillars:

I. Increased share of RES in the energy sector, heating sector and transport

II. Increased energy efficiency

The share of individual pillars in achieving final goals is subject to on-going amendments to energy policy, in the event of appearance of new fundamental phenomena in macroenvironment that require such changes. Figure 15 symbolically illustrates the mechanism of achieving the final goal, which is the achievement of climate neutrality by affecting both pillars of energy policy.

Figure 15. The two pillars of the energy transformation in Denmark.



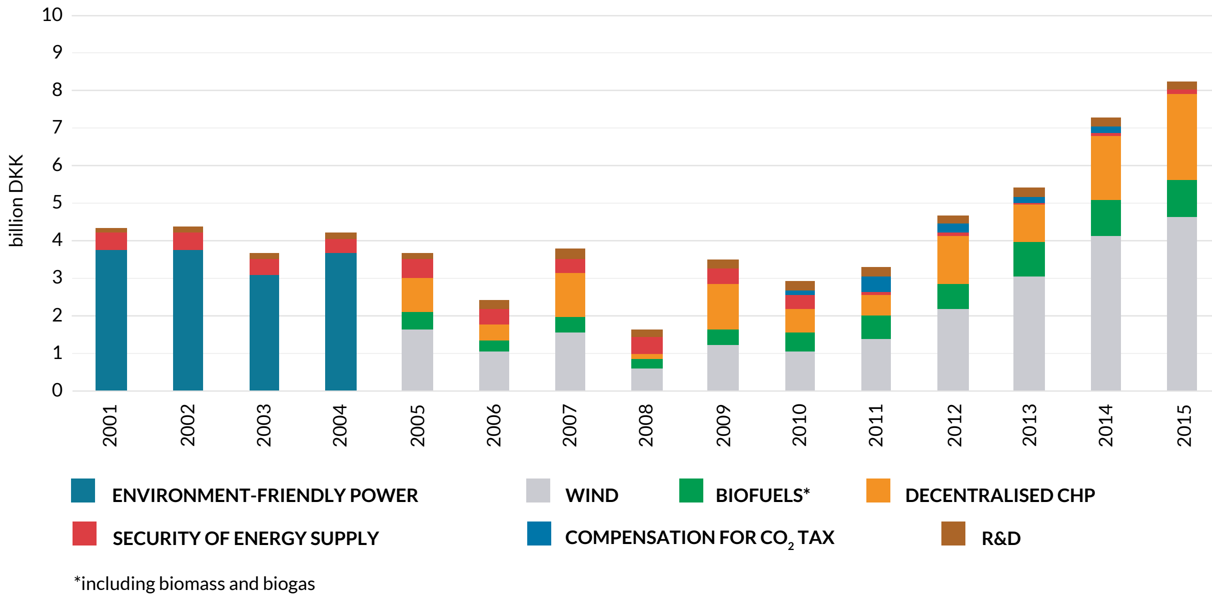
Source: Government of Denmark 2011, Energy Strategy

Major operational goals of the Agreement of 2012:

- Construction of the next 1500 MW onshore farms and 1800 MW offshore farms
- Development of strategies for buildings to increase energy efficiency
- Conversion of all combined CHP plants from coal to biomass
- Support of the development of local heat sources in RES (biomass and geothermal energy)
- Introduction of tax mechanisms and subsidies in order to increase the use of RES in the industry
- Development of intelligent networks
- Development of a financing mechanism for activities related to low-emission transformation (e.g. transfer of CAPEX expenditures to DNO tariffs, redirection of part of revenues from "carbon taxes" and excise tax for modernization activities).

In July 2018, the new Danish government signed another Energy Agreement introducing amendments to the previous one, resulting from changes in the market situation and the growing costs of the RES support system transferred to final consumers (Figure 16).

Figure 16. The cost of the RES support system in Denmark.



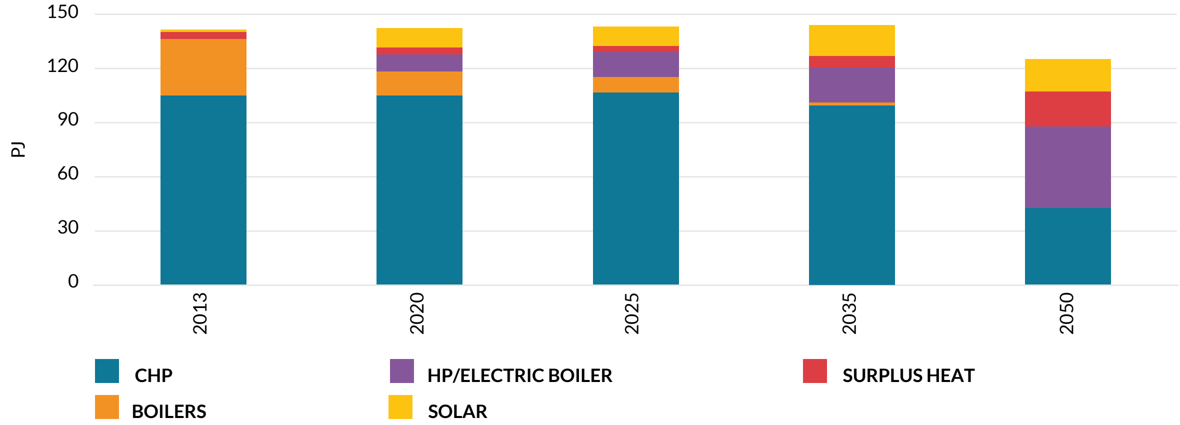
Source: Own analysis on the basis IEA

Basic directions of changes to the new Agreement:

- Marketing of RES technologies through the introduction of auction mechanisms as a substitute for guaranteed subsidies.
- Bringing in the market for heating by eliminating the obligation to connect to district heating ne-tworks and wider application of the TPA principle, especially for renewable energy sources
- Reduction of the tax imposed on electricity for heating purposes in order to create incentives for installing (individual and collective) heat pumps.
- Reduction of the taxes imposed on waste energy in order to enable its use inthe heating sector.
- Further development of onshore farms (+2.4 GW by 2030).

It should be emphasized that the goals set out in the Agreement of 2012, such as the withdrawal from coal in the heating sector until 2030, or total independence from fossil fuels in 2050, remain in force. Analysing the provisions of the current Agreement, it is expected that the district heating in 2050 will come from solar sources, from recovered energy (waste), from electricity (heat pumps and electric boilers) and from biomass cogeneration units (Figure 17).

Figure 17. The structure of district heating generation in Denmark (2013-2050).



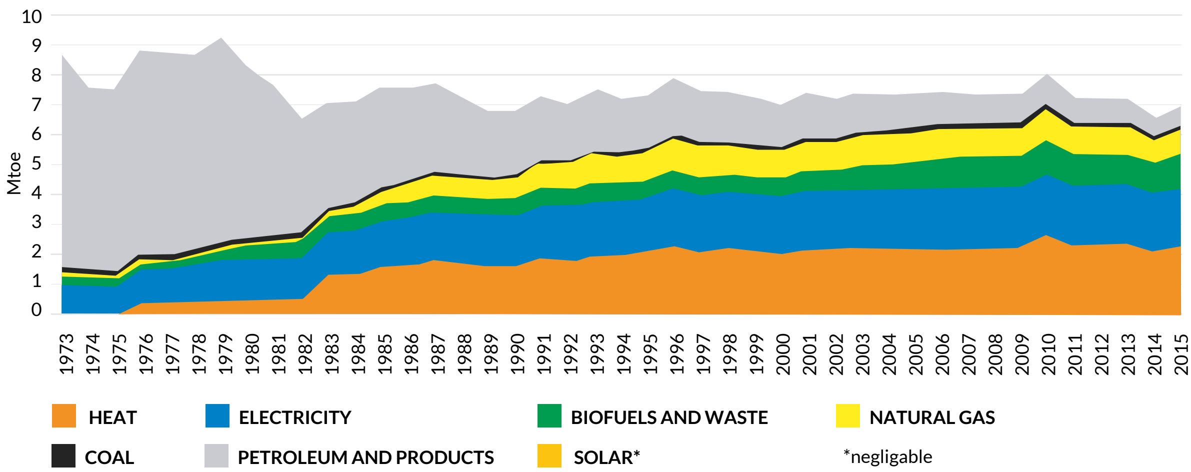
Source: Ole Odgaard, DEA, Conference Warsaw 2018

Energy efficiency

Energy efficiency in Denmark has been increasing for many years thanks to the consistent policy of the authorities and the application of tax incentives and support mechanisms. There has been a permanent separation of economic growth from final energy consumption for over a decade. In the period from 2005 to 2015, there was a decrease in final energy consumption by 11% despite constant GDP growth. Denmark, under the arrangements with the EU, declared the objective of a reduction (2006-2020) of primary energy consumption by 14.5%. The energy consumption of Denmark's GDP is among the lowest in the EU and amounts to 66 toe/million (to compare: Germany 111, Poland 231 toe/million EUR'2010).

The industry, which increased energy efficiency by 25% (2005-2015), has a large share in improving this indicator. This is the effect of modernization and increase in energy consumption from RES. Among households and in services, energy efficiency improved by about 5.6% in the last 10 years.

Figure 18. Final energy consumption in the household and service sector.



Source: IEA Denmark 2017

The policy of Denmark is oriented towards achieving the goals set by the EU. The ministries and local administration implement appropriate action plans for this purpose. In 2017 Denmark forwarded the National Action Plan on energy efficiency to the European Commission.

National Action Plan on energy efficiency

Denmark will reduce primary energy consumption by 14.5% by 2020 compared to 2006. and DNO distribution companies (heating, gas, electricity) have to annually reduce the level of energy sold by1.5% as a result of actions increasing the efficiency. In addition, DNOs are subject to Compulsory Energy Efficiency Systems. According to the Energy Agreement of 2012, all DNOs must annually reduce the final energy consumption from 2.6% to 3%. The goal is set for each year. For example, in 2016, 43% of reduction target was for industry, 29% for households, and 19% for the service sector.

Obligatory national efficiency goals have generated a number of new types of services and business models. Recognizing activities in the area of efficiency as a priority, staff in competent offices was strengthened and the Energy Efficiency Centre was established in order to better monitor and support the activities. High taxes on energy from non-renewable sources also stimulate the modernization of buildings to reduce operating costs. In addition, in 2014, the Building Renewal Strategy was developed, which will consequently reduce energy consumption by 35%.

Building Renewal Strategy

Activities regarding all buildings:

- Tightening energy standards, excluding windows
- Tightening energy standards for windows
- Improving energy standards for installations in buildings
- Ensuring compliance with provisions regarding buildings
- Introducing voluntary energy classes for the existing buildings
- Tightening high energy standards for new buildings
- Improving the flow of information and communication with regard to energy efficiency
- Commitments for energy companies to improve energy efficiency
- Ensuring an effective energy labelling system for buildings
- Providing analytical support in the process of preparing thermal modernization of buildings
- Providing effective financing mechanisms for thermo-renovation
- Development of a comprehensive policy for construction

Activities aimed at single-family buildings:

- Strengthening thermal renovation operations through the "Better House" program
- Increased use of heat from RES instead of heat from oil and gas

Activities aimed at multi-family, service and administrative buildings:

- Development and implementation of a public tender model for a guaranteed level of energy reduction
- Thermal modernization of municipal buildings
- Thermal modernization of private buildings for rent, housing co-operatives and associations of house owners
- Thermal modernization of buildings for commercial rent
- Actions undertaken in order to improve the energy efficiency of public buildings, as a model for owners of other buildings

Actions aimed at strengthening competence and innovations in order to accelerate the growth of energy efficiency:

- Strengthening education and developing competences in the field of energy efficiency
- Strengthening research and development programmes and launching demonstration projects in the area of energy efficiency

Source: IEA Denmark 2017

"Better House" program

The programme was introduced on 1 January 2014 in order to promote the energy efficiency of individual residential buildings. As part of this programme, the points of complex service offering expert advises to the house owners were created. The programme concentrates on all forms of energy consumption, i.e. heating, cooling, heating of water and lighting. As part of this programme, training for architects, engineers, contractors, energy consultants and designers is provided. Additionally, the programme focuses on financing mechanisms for property owners.

Source: IEA Denmark 2017

5.5. Main stakeholders of the energy sector and their competences

Stakeholder	Competences
Ministry of Energy, Enterprises and Climate	This is, among other things, responsible for climate strategies and policies of the broadly understood energy sector.
Danish Energy Agency (Energistyrelsen, DEA)	Monitors the energy market and the energy resources market. Publishes price forecasts of resources and energy, CAPEX and OPEX values for various types of technologies as well as external energy costs. This information is used to perform analyses of socio-economic costs and profitability analyses of new projects in the energy sector.
The Danish Energy Regulatory Office	The scope of rights and responsibilities is similar to the Polish ERO.
The Energy Board of Appeal	A final administrative appeal body with regard to the decisions of public authorities.
Danish Climate Change Council	An independent body of experts that advises on transformation issues towards a low-emission society.
The Energy Board	An independent advisory body composed of representatives from science and industry. Supports the work on the Energy Agreement. Develops suggestions for energy policies.
Regional and urban self-government authorities	Regional authorities play an important role in implementing national energy and climate change policies by creating local urban and industrial development plans. Local authorities are responsible for energy projects (wind energy, biomass, biogas and photovoltaic) and for district heating. Many municipalities are also the owners of local heating and power companies.

Particular attention should be paid to the high competences of regional and urban local government authorities, which guarantee that energy projects are adapted to the national strategy of development and environmental protection.

Planning of heating networks in municipalities

Each area of the municipality is divided into energy regions. On the basis of the analysis of the availability of district heating or natural gas, an administrative decision is made as to which areas should be supplied with district heating or gas. In rural areas, more individual solutions, such as oil heating and biomass and heat pumps are usually permitted.

External costs of emissions

The Danish Energy Agency (DEA) publishes a report containing the socio-economic costs of energy for different types of fuel, technology and level of energy use (large power stations, heating networks, final users). Moreover, DEA publishes general emission factors and costs of emissions to the environment (NO_x, SO_x and PM 2.5) based on current health costs as well as typical capital expenditure (CAPEX) of various technologies. The calculation of external costs must be included in the calculation of socio-economic costs, which are a permanent element of the feasibility studies of new energy projects. The methodology and data published by the DEA ensure that all project calculations are subject to objective evaluation, and local authorities select and accept projects on the basis of comparable analyses. The Table below shows example values of external costs published by the DEA. The external costs of pollutant emissions are about three times lower in the case of municipal heating stations than in individual households. This is due, among other things, to the type of technology, greater dispersion of pollution, the quality of environmental protection devices and distances from settlements.

Tab. 3. External costs of pollutant emissions depending on the source (EUR / kg)

Costs of emissions	SO_x	NO_x	PM2.5
Individual households	3.9	2.4	11.1
Industrial combustion installations	1.8	1.3	3.6
Large combustion installations (district heating)	1.3	0.9	3.1

Source: Assumptions for socio-economic calculations in the energy sector, Danish Energy Agency

Gas enterprises

The Danish TSO (transmission system operator) Energinet bears full responsibility for the supply of natural gas to Denmark and is the owner of the natural gas transmission system and two gas storage facilities. Energinet is owned by the Ministry of Energy, Enterprises and Climate. The natural gas distributors in Denmark were until recently divided into three gas companies: HMN, Danish Gas Distribution (DGD) and Nature Energy. HMN is owned by 57 municipalities, and Nature Energy is owned by eight municipalities. Until recently DGD belonged to the Danish energy company Ørsted (formerly DONG Energy), but is currently owned by Energinet (owned by the state). Energinet plans to take over two other natural gas distribution companies (HMN and Nature Energy).

Energy enterprises

- TSO (Energinet) is responsible for the entire electricity transmission system and it ensures security of energy supply. It does not have its own generation units.
- **Energy producers** - the main producers are CHP plants and wind farms. Centralized CHP plants are owned by Ørsted or local heating companies. Decentralized CHP plants are usually owned by local multi-utility companies.

5.6. Law shaping the heating sector

The Heating Supply Act

The Heating Supply Act of 1979, as amended, is the foundation for the operation and development of heating networks. Its main unchanging principles are as follows:

- Security of energy supply
- Minimizing the impact on the environment
- Energy efficiency
- Reduction of CO_2 emissions.

The stability of the provisions of the Act makes it possible to implement capital-intensive heating investments with a long payback period. According to the document, the city council, in cooperation with public utilities and other stakeholders, is responsible for planning heat supply for the municipality area.

General goals of heat supply planning:

- Promoting heating at the lowest socio-economic costs
- Supporting the most environmentally friendly form of heating
- Reducing dependence on supplies of petroleum and other fossil fuels.

Two regulations have a particularly significant impact on heating systems: the regulation on the approval of heating projects[2] and the regulation on connections. According to the first of them, the municipality approves projects concerning the construction or extension of heating systems. **One of the basic criteria for the evaluation and acceptance of projects is the result of a socio-economic analysis.** As part of the standardized method of analysis, a comparison of costs related to the project and costs of impact on society and the environment is carried out. As a result of the analysis, local authorities accept a project that is more beneficial from a social and economic perspective.

Requirement to connect to the heating network

In some regions in Denmark buildings must be connected to the heating network or natural gas network. The municipality decides on the obligatory connection. It does not oblige a tenant to use heat from heating systems, but it means that even without using heat, tenants have to pay fixed fees related to the readiness to supply heat. In March 2018, the government announced that it would abolish the obligation to connect in order to allow for greater market play of alternative sources of heat supply. However, in heating areas where there is no obligation to connect, some suppliers offer connection discounts and lower energy costs in the initial period in order to make their offer more attractive and increase the number of heat consumers.

Support mechanisms for cogeneration

The basic support mechanism for a CHP plant is the power fee (readiness to work) paid by the TSO. The fees are paid to hundreds of Danish cogeneration units (most of them are small plants). As of 2019, the support

2 BEK No. 825 af 24/06/2016"; in Danish "Projektbekendtgørelsen"

system based on power fees will end.
In the case of biomass cogeneration units, a bonus for the price of electricity is paid (around EUR 20/kWh). The support mechanism was approved until May 2019. The system is expected to continue.

Building regulations

Building regulations are of great importance for the development of heating systems, as they enforce heating installations in existing or new buildings to use non-fossil fuels or district heating.

The Electricity Supply Act

The Act is used when planning medium and large CHP plants, i.e. plants with capacities above 25 MW.

5.7. Heat price

The price of heat in Denmark is high in comparison to Germany and Poland, but given the high energy efficiency and the level of affluence, it is a relatively lower expense in the budget of an average household in Denmark.

Tab. 4. Average heat price for the consumer, excluding VAT (in EUR/kWh)

Indicator	Denmark	Germany	Poland
Average heat price in 2015 (EUR/kWh)	80	74	50
Average net income (EUR)	31,518	23,476	6,393

Source: COWI

5.7.1 Key factors affecting district heating prices in Denmark

The effect of the scale of heating companies

The Heating Act of 1979 introduced the obligation to create a national heating development plan. At the same time, it introduced the concept of "power zones", under which the municipal authorities decided on the type of heat supply (district heating or individual gas heating). Furthermore, since the 1990's administrative decisions have been made to replace heating stations with CHP plants and to replace fuel from coal and oil with gas and biomass. As a result of the policy of local authorities, heating companies began to develop intensively, which allowed for the optimization of the costs of heat generation.

Form of the ownership

The majority of heating companies are owned by heat consumers (cooperatives) or municipal authorities. This allows for transparent business activity and cost control.

The cost formula - non-profit

Heating companies have a right to recover all costs incurred (including capital costs), but no right to generate profits. A potential profit is reinvested in the development or improvement of efficiency. Additional revenues (financial surpluses) from the sales of electricity reduce the heat price in the next settlement period (or increase it if the CHP plant generates losses, e.g. as a result of negative prices on the energy exchange). The tariff system allows for repayment of loans taken for reconstruction and modernization of the property, thanks to the share of the fixed fee at the level of 25-30% (the rest is a variable fee). In Denmark, the regulator does not approve heat tariffs. It checks them only in the case of disputes. The regulator is obliged to conduct analyses and set benchmarks for use in heating entities.

Low capital costs

Heating companies owned by the municipality enjoy high creditworthiness, which significantly reduces the cost of loans. In addition, banks established by municipalities operating on the financial market offer long-term investment loans with very low interest rates (such as mortgage loans).

Minimization of social costs

The municipal authorities only approve those projects that are characterized by the best socio-economic effects. Most often, district heating is the cheapest option.

Support mechanisms

Investment support for biomass heating stations and CHP plants (since 1981), for cogeneration energy (since 1984), for the extension of heating networks (since 1994) allowed for maintaining the price of district heating at a competitive level.

Higher tax (since 1977) on fossil fuels (gas, coal, oil) and carbon tax on CO_2 emissions (since 1992) caused heat from individual sources consuming fossil fuels to be more expensive than district heating, which indirectly contributed to the development of heating systems and cost reduction.

There are no heating systems without heat accumulators in Denmark. Its ownership allows cogeneration units to balance the energy market and derive additional financial benefits fromthis, consequently lowering the heat price.

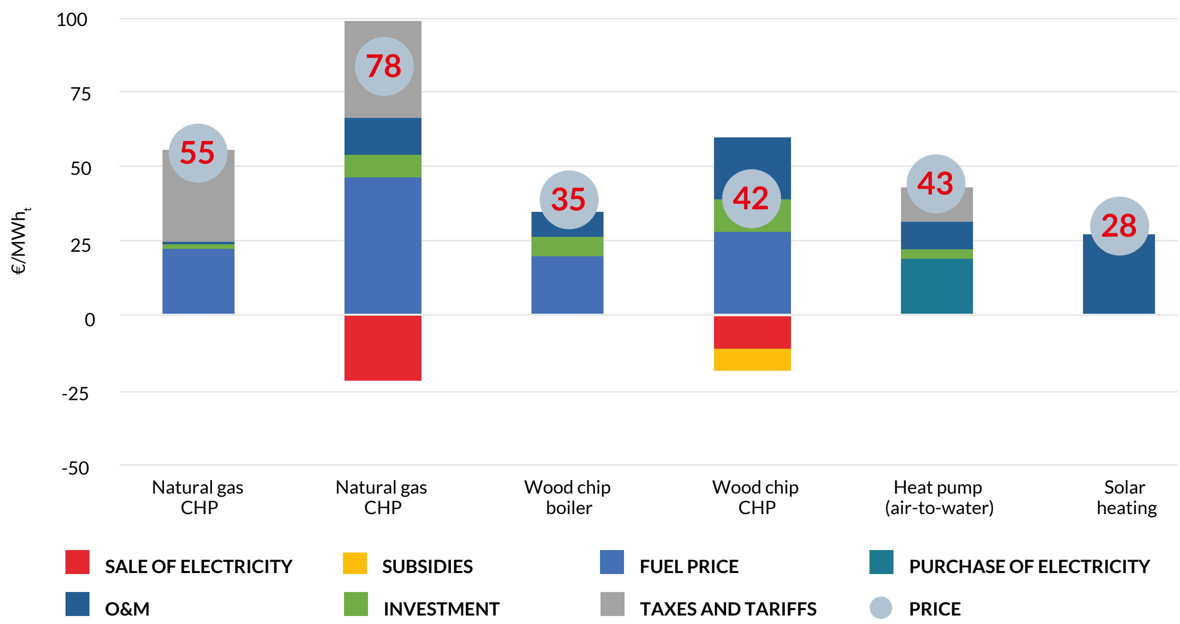
Funds for the modernization of the energy sector "circulate in a closed circuit"

Subsidies for the development of heating systems and cogeneration systems or RES come first of all from the so-called carbon taxes, so they are neutral for the state budget.
The funds obtained in this way are practically fully reinvested into ventures reducing the consumption of fossil fuels. This internal circulation of money will continue until the last tonne of fossil fuel is combusted.
A similar solution in Poland could be the management of revenues from entitlements to CO_2 emissions.

The cost of district heating generation

The chart in Figure 19 illustrates the structure of heat generation costs invarious technologies. As can be seen, the state's tax policy strongly affects the price diversification of final consumers, discouraging further use of gas for heating purposes.

Figure 19. The structure of heat costs from various generation sources.[3].



Source: COWI

The lowest heat prices are from biomass boilers and solar sources. The heat price from solar sources depends almost exclusively on investment costs (variable costs are negligible). However, if the true price of solar

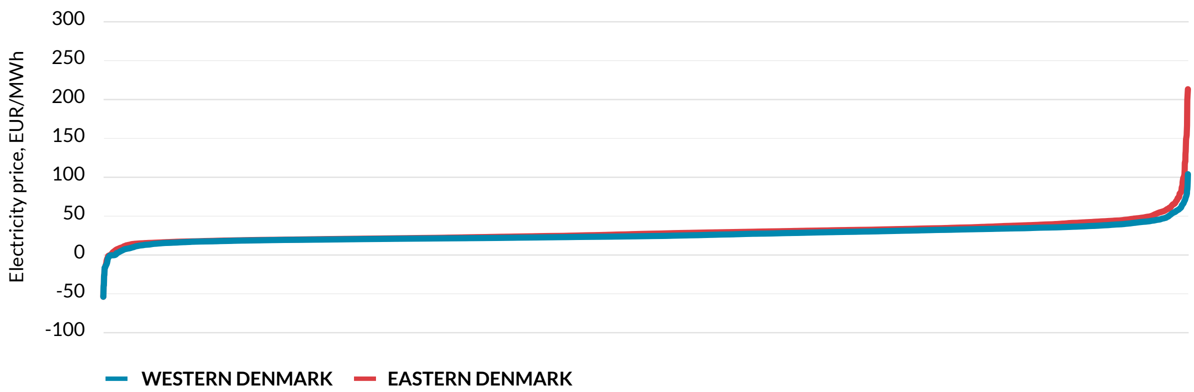
3 The dot on the chart shows the result price (cost minus income, including taxes and subsidies). Fixed cost was "changed" for working time = 5,000 h/year. The adopted price of electricity is EUR 27/MWh.

heat for the consumer is to be calculated, the construction costs of the heat accumulator and the costs of an additional heat source, e.g. a biomass boiler (which is often practised) should be added.
A heat pump can also be an attractive source of power, but it will depend on the state policy and future taxes imposed on electricity for heating purposes.

High electricity taxes in Denmark mean that the heat price generated by it is not the most attractive (especially in the case of an electric boiler). Recently, the Danish government proposed to reduce the tax on electricity used for heating purposes by approximately EUR 20/MWh, which will reduce heat generation costs by about EUR 6/MWh, making heat pumps able to compete with biomass installations.

The highest heat price is from gas cogeneration units. Without a subsidy system as of 2019 and at low electricity prices, it is not competitive in relation to other sources. With the electricity price higher than EUR 37/MWh, cogeneration may become an attractive option (it is worth adding that the wholesale electricity price exceeded EUR 37/MWh for only about 1000 hours in 2017).

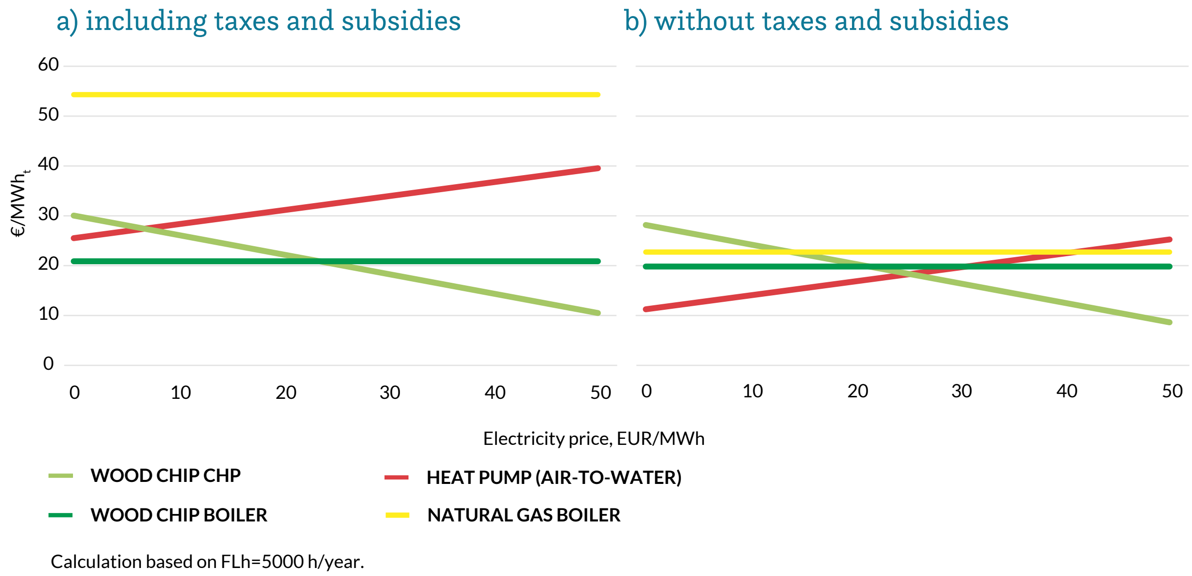
Figure 20. An ordered chart of wholesale electricity prices in Denmark



Source: Energinet

Due to the high dynamics of the daily electricity price changes in Danish heating companies, most often not only cogeneration units are built, but also generation sources that use electricity for heat production (so-called Power-to-Heat). Depending on the level of wholesale electricity prices, these sources which ensure the lowest variable heat costs are activated. The next chart shows the sensitivity of variable costs of various sources to changes in the electricity price, taking into account the impact of taxes.

Figure 21. Variable cost of heat generation as a function of changes in electricity prices

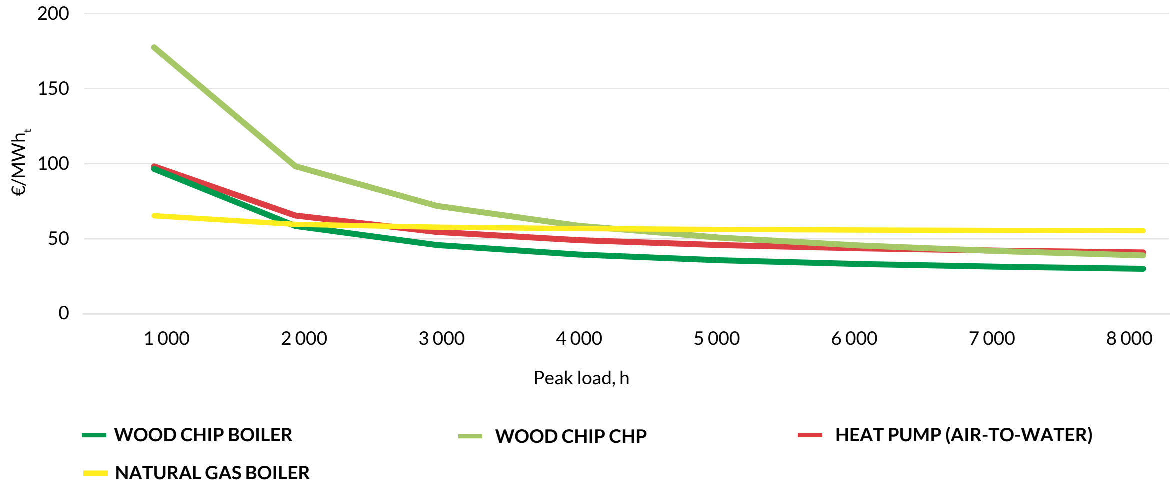


Source: COWI

As can be seen from chart "a", when the wholesale electricity price increases, the biomass price from the CHP plant decreases, so that after reaching the threshold of 22 EUR/kWh, it becomes the cheapest source. Conversely, if the wholesale electricity price drops below 8 EUR/MWh, the cost of heat generation in cogeneration becomes higher than in the heat pump. As mentioned earlier, the government reduced the taxation of electricity supplying the heat pumps by 50% (in comparison to the tax imposed on electricity for other purposes). It is expected that the tax will be further reduced in order to implement the strategy for the development of heat pumps, which will contribute to the increase of competitiveness of pumps towards biomass installations. In chart "b", which shows the heat prices without taxes and subsidies, it can be seen that the heat pump becomes the cheapest option when the wholesale electricity price drops below 25 EUR/kWh. In turn, a gas boiler is still the most expensive option.

For the sake of completeness, it is still necessary to look (Figure 22) at the level of heat prices depending on the working time of generation units with full capacity and including taxes, fixed costs, i.e. capital costs and investment costs (converted into an annual cost including the life of the generation unit).

Figure 22. Heat price including fixed costs, taxes and subsidies.



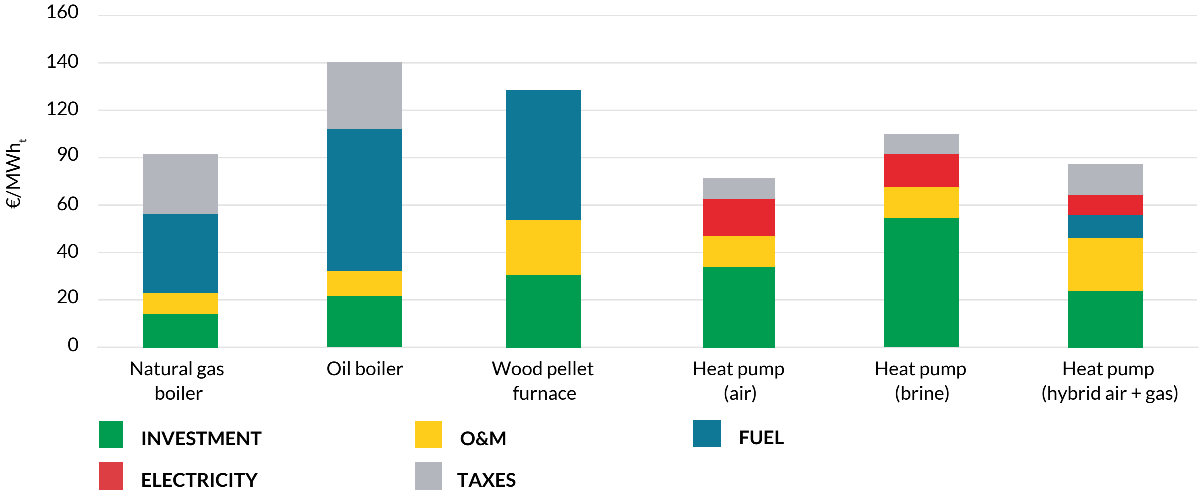
Source: COWI

The greater the number of working hours with full load, the lower the heat price due to the lower share of the fixed cost in the energy stream. Investment costs for gas boilers are low, so the number of working hours at full load is not of great importance, as in the case of other installations. New, capital-intensive units are expected to work with a full load of at least 4-5,000 h/year, which in practice only happens in biomass CHP plants (which will allow this unit to produce heat at a competitive price against a gas boiler). However, given the expected reduction in electricity taxation for heating purposes, it is expected that heat pumps will become competitive and popular, especially in small heating companies. Biomass units will still be an attractive price source of heat for many years, but it should be remembered that in Denmark biomass is beginning to be treated as a transition fuel used until the introduction of more environmentally neutral RES.

Individual heating

In Denmark, pellet boilers, gas boilers and oil boilers are used as the power source for individual buildings. In accordance with the policy of limiting the use of fossil fuels for heating purposes, the last two technologies are gradually eliminated by administrative injunctions or gas and oil taxes. Recently, there has been an incentive in the form of limiting the taxation of electricity used for heating purposes (as described earlier). As can be seen in Figure 23, in the case of heating individual households, which cannot be connected to the heating network, the most advantageous is heat pump heating. This is a new situation resulting from the development of technology and decrease in investment costs as well as tax limits. The applied incentives are expected to increase the number of heat pumps used. At the same time, there is a discussion on the impact on the environment of the use of biomass (pellets) in boilers in individual buildings.

Figure 23. The total cost of heat generation, individual heating[4]

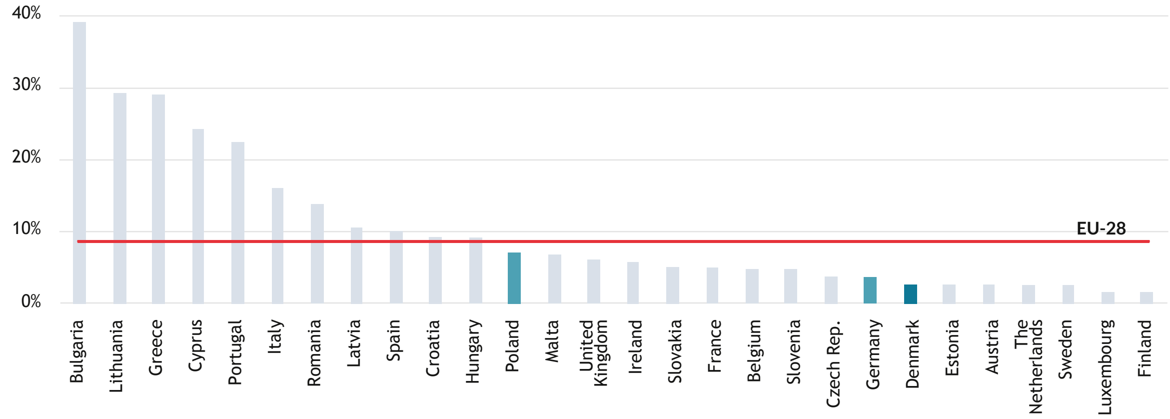


Source: COWI

5.8. Support for sensitive customers

According to the EU statistics, Denmark belongs to countries with a relatively low percentage of people affected by energy poverty. However, this phenomenon exists and the problem is recognized and remedial actions are taken.

Figure 24. Participation of people in society who cannot maintain a satisfactory temperature in their home

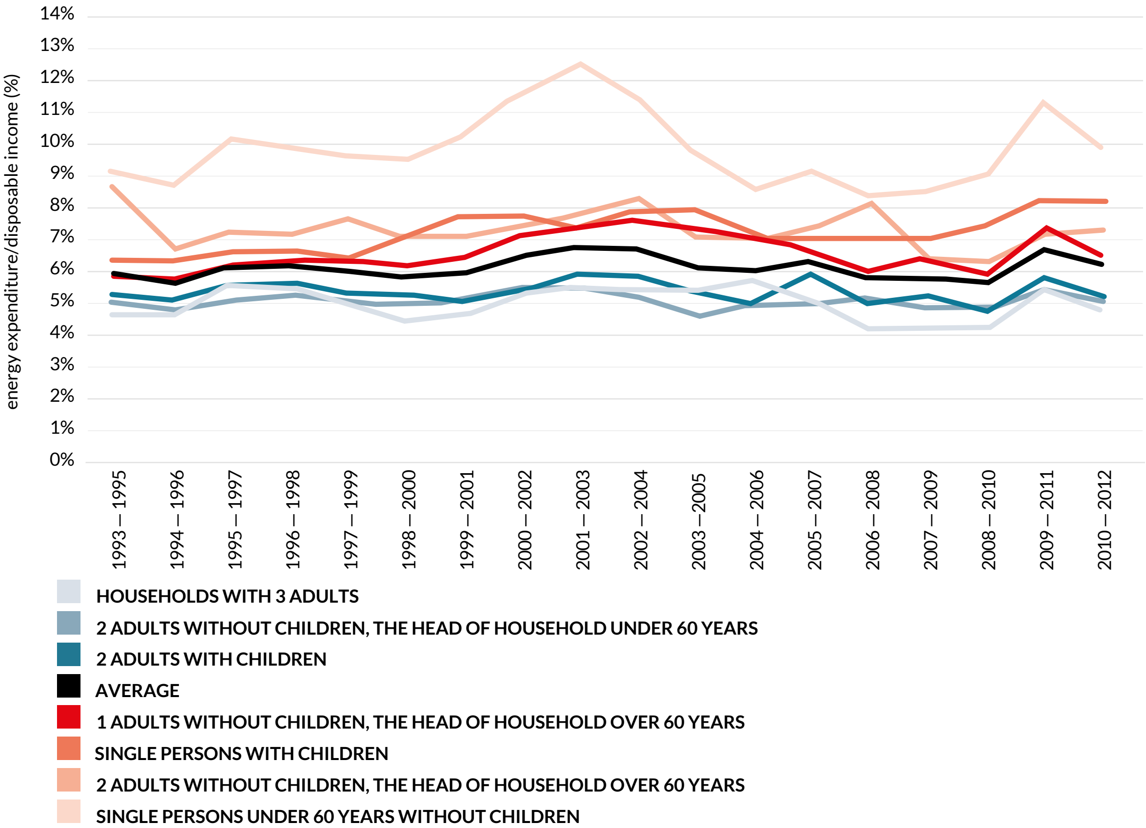


Source: Own analysis on the basis of Eurostat, 2016.

The progressing liberalization of the energy market, the dynamics of price changes and the increase in resources prices mean that in some social groups the share of energy-related expenditure in the household budget starts to be significantly higher than the national average of between 5% and 6% (Figure 24).

4 Calculation of annual heat energy consumption for 18 kWh; fixed cost spread over a period of 20 years

Figure 25. The share of energy expenditure in the home budget in various social groups



Source: Energy poverty in Denmark, Aalborg University

An important element in the fight against energy poverty is consultancy services in the area of energy saving. Most heating companies offer their consumers free energy optimization service. This includes a consultant's visit in the apartment to assess the heating installation, and advice on how to make a better use of it. Such action is also in the interest of the heating company, as it allows for the optimization of the operation of the heating network. The advantage is therefore mutual.

In Denmark, numerous heat cost reduction programs have been addressed to sensitive consumers, including:

- Co-financing of thermal modernization of houses - for pensioners and people with low incomes
- Subsidies for owners of oil and wood boilers as an incentive to change to a clean and more efficient heating solution
- The possibility ofleasing heat pumps instead of buying them.

Experiences show that these programs have been successful, considering the number of people willing to get rid of old inefficient heating devices. Currently, five Danish companies offering heat pumps receive subsidies to try out pump leasing methods.

5.9. **Summary**

- Denmark's energy policy, agreed among all political parties, aims at making the country completely independent from the import of fossil fuels by 2050.
- Consistent implementation of the energy policy assumptions and the introduction of effective support mechanisms led to a complete transformation of the Danish energy sector in the short term (1980-2005). The adopted model of dispersion of the generating base has resulted in the creation of over four hundred small CHP plants spread throughout the country.
- The continued transformation of the energy sector aims at the complete replacement of coal with biomass in CHP plants and further development of wind farms. These units, supported by photovoltaic sources, will ultimately constitute the generation base of the energy system.
- Due to the decision to abandon fossil fuels, it was decided to end support mechanisms for cogeneration coal and gas units. Existing coal units are currently being rebuilt into biomass units. Gas units mainly function as balancing units for the energy system, generating revenues from the sales of electricity at peak demand and high wholesale prices. The average time of using the power (full time operation) of gas cogeneration units fell below 1,000 hours a year.
- The Danish energy system maintains the stability of work with the share of energy from wind farms in total consumption, reaching over 50%. CHP plants equipped with flexible cogeneration units, heat accumulators, electric boilers or heat pumps effectively stabilize the operation of the power system
- In Denmark, there is a continuous process of reducing the temperature of the network water. The transition to 4G and 5G low temperature systems will enable efficient use of renewable energy resources (solar and wind) and waste energy (from industry, air conditioning, etc.).
- Support mechanisms and tax policy, originally dedicated to cogeneration and the use of biomass, are now increasingly encouraging the use of electricity for heating purposes and at the same time discouraging the use of fossil fuels.
- The biomass utilization strategy assumes the combustion of pellets in large cogeneration units, whereas local biomass, usually straw, is used in small CHP plants and heating plants.
- The heat supply planning process is characterized by high transparency thanks to social consultations. A key element in the decision making process for the implementation of heating projects is the analysis of the socio-economic costs of the investment project (which includes environmental costs). The process of issuing a permit for the implementation of an investment requires a comparison of the external costs of at least two alternative concepts. Local authorities accept a project that is more beneficial from the perspective of social costs.

6. Germany

6.1. History of changes in the energy sector

Oil crises and growing resistance towards nuclear energy are two engines driving the German transformation of the energy sector. Strong social protests led to the construction of the nuclear power plant in Wyhl being halted in 1973. The suspension of the development of nuclear energy with two oil crises became a strong stimulus to look for alternative ways to develop the sector and industry related to energy. In addition, the 1970s and 1980s were a period of heated debate about the impact of industry and the energy sector on the condition of the environment. Society forced a change in the adopted course of action in the energy sector and social acceptance of the way chosen before a quarter of a century, is still high.

Ground breaking stages of energy transformation are presented in the Figure below.

Figure 26. Key stages of development of the energy sector in Germany

1972	– Publication of the Roman Report "Limits of Growth" • serious debate in Germany on the sufficiency of resources
1973/1975	– Social movement against nuclear power • stopping the construction of the nuclear power
1973/1979	– Oil crises • Act on energy efficiency
1980	– Publication of the book on Energiewende • increase and prosperity without petroleum and uranium
1990	– Reunification of Germany • modernization of the heating sector in Eastern Germany
1991	– Introduction of guaranteed tariffs for energy from RES • the beginning of the new energy sector
1998	– Liberalization of the energy market • freedom to choose an energy supplier • breaking monopolies
2000/2014	– Act on the development of RES and cogeneration • development of distributed energy sector
2011	– The meltdown of the reactor at EJ Fukushima • accelerating the transformation of the energy sector • decision to abandon nuclear energy
2016	– Revision of RES and cogeneration support systems • auction mechanism, more market, lower costs
2022	– Withdrawal from nuclear energy
2030	– Continuation of energy transformation • assumed share of RES in electricity - 65% • assumed reduction of CO_2 emissions - 55%

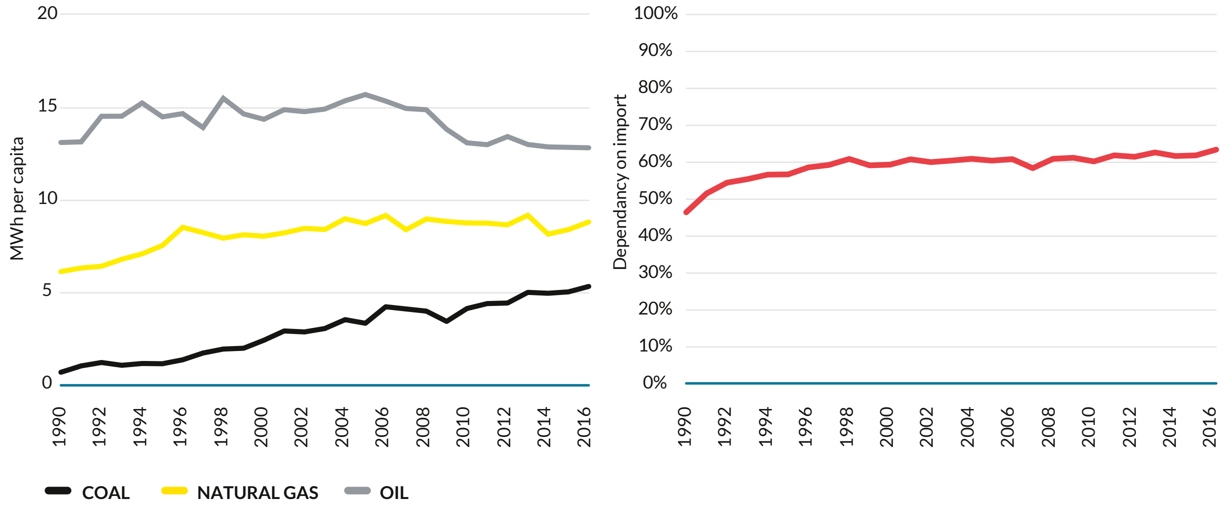
Source: Own analysis on the basis of COWI

6.2. **Opening balance**

The chapter presents the most important changes that have taken place in the last 30 years in the energy sector, and in particular in the heating sector in Germany.

Germany is a country heavily dependent on imported fuels for the energy sector, heating sector and the entire economy. In 2016, the dependence on primary energy import was 63.5% and was 10 percentage points higher than the EU average in 2016. Aiming at the lower resource dependence, as well as keeping in mind the experiences of the oil crises, Germany has been consistently implementing modernization of the energy and heat supply sector since the 1970s. It was decided to intensively develop RES in order to reduce dependence on imports of basic energy resources.

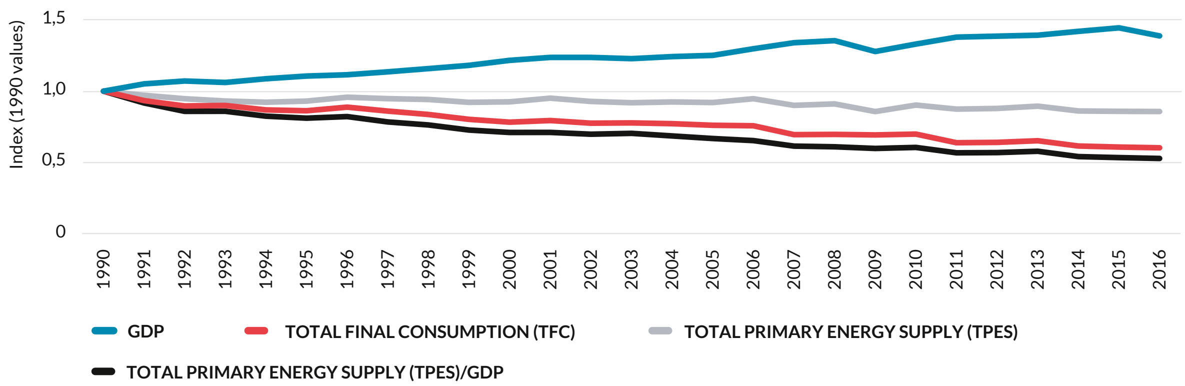
Figure 27. Net import of coal, petroleum and natural gas per habitant and the level of net import dependence in Germany.



Source: Own analysis on the basis of DG ENER of the European Commission

The charts in Figure 28 indicate that the implementation of the goals of the policy to improve the energy efficiency of the economy is slowly achieving results in the form of a decrease in energy consumption of GDP and the amount of primary energy consumed per habitant in Germany.

Figure 28. Energy consumption of GDP and primary energy consumption per habitant[5].



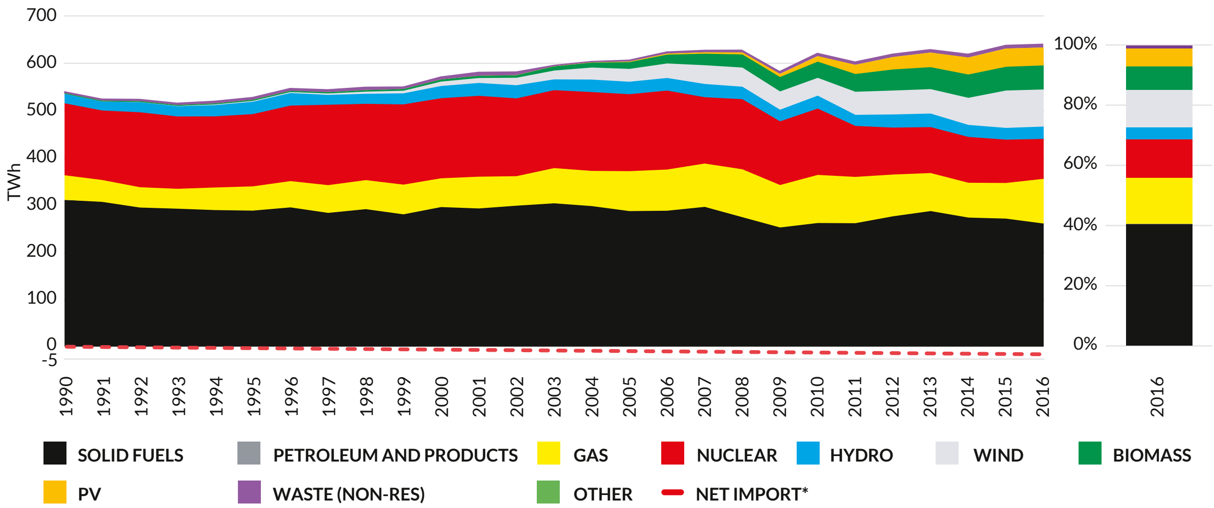
Source: Own analysis on the basis of DG ENER of the European Commission

The next chart shows the generation of electricity by fuel type and technology. The effects of energy sector modernization are visible. They show a systematic increase in the share of energy from RES, which replaces the withdrawn nuclear power plants (the last of which will stop operating in 2022). Due to the good economic

5 It includes fuels (the same as in primary energy generation) and electricity and heat.

situation and the growing demand for electricity, the work of coal-fired power plants has remained practically unchanged for years and faces criticism regarding the efficiency of energy transformation mechanisms.

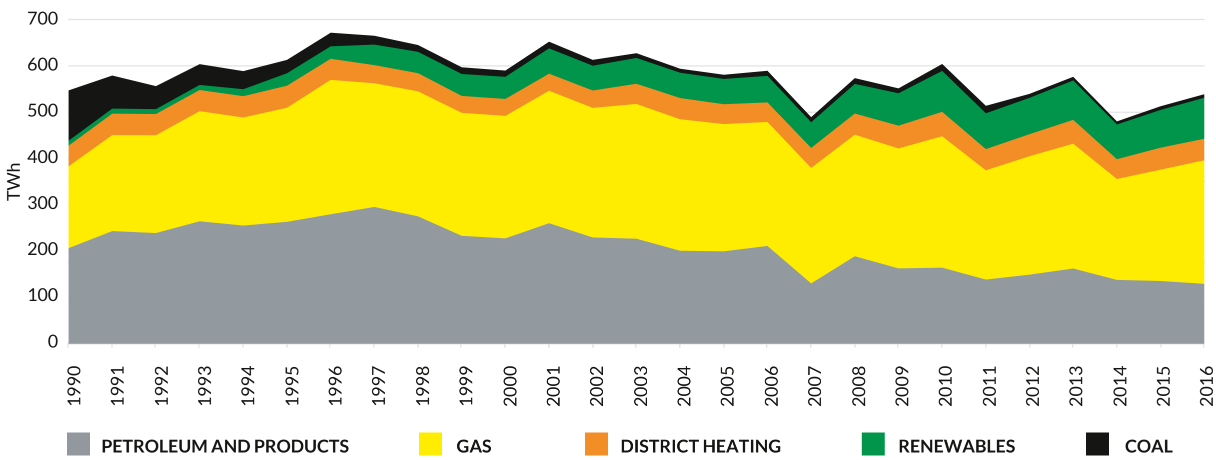
Figure 29 Generation of electricity divided into sources and energy generation structure in 2016. [6]



Source: Own analysis on the basis of DG ENER of the European Commission

The level of energy consumption in German households (excluding electricity) is shown in Figure 30. As you can see, the use of petroleum in relation to RES is falling and the consumption of final energy is gradually decreasing. Coal has been almost completely withdrawn from the heating sector.

Figure 30. Final energy consumption (excluding electricity consumption) in households divided into types of energy sources.



Source: Own analysis on the basis of AGEB

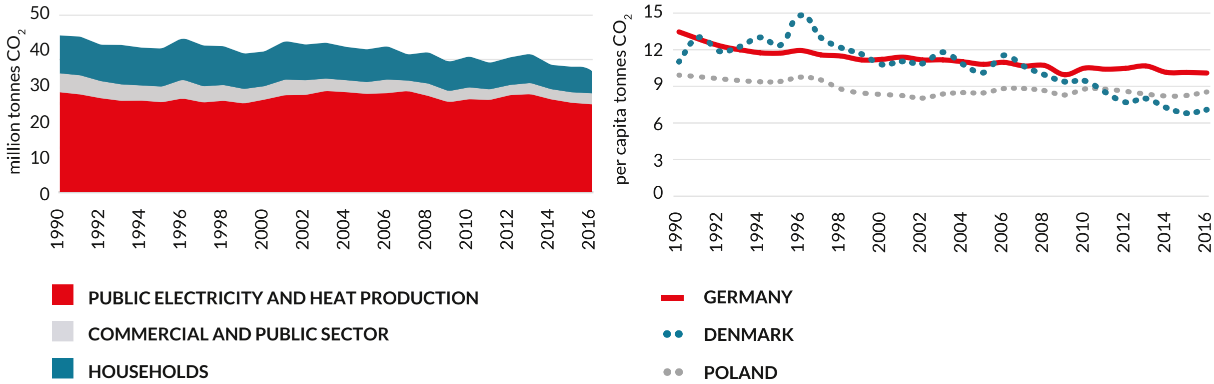
6 Negative means the advantage of export.

Reduction of greenhouse gases emissions

In contrast to Denmark, where heating networks are developing intensively, in Germany, the improvement of air quality was achieved thanks to the development of a vast natural gas network and reduction of coal combustion in cities, especially in individual buildings.

There has been a decrease in CO_2 emissions due to the development of wind and solar energy and the use of biomass. Biomass is consumed in low power cogeneration units operating mainly in the baseload. However, variable RES (photovoltaic and wind) are balanced by conventional generating units.

Figure 31. Changes in CO_2 emissionsfrom the energy, heat and services sectors.



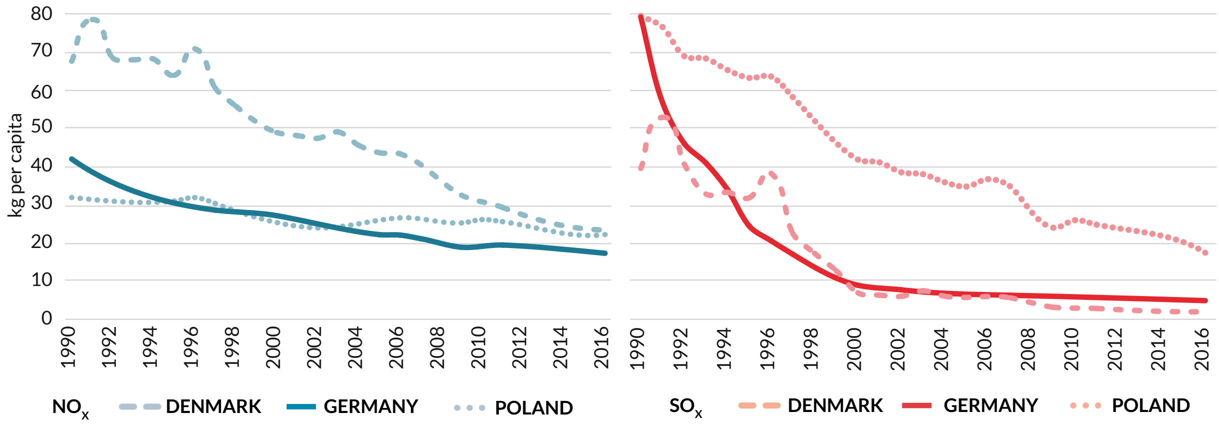
Source: Own analysis on the basis of DG ENER of the European Commission

Germany constantly strives to increase the power installed in RES by implementing climate obligations. The currently supported and developed field of action is the use of the heating sector as a kind of energy storage and stabilizer of the power system. Due to the flexible use of heat pumps and electric boilers or cogeneration units, depending on the current needs of the power system, heating sector offers balancing services.

Reduction of nitrogen oxides and sulphur oxides

An almost 60% reduction of nitrogen oxide emissions, which occurred in recent years, is the effect of reducing emissions in road transport as well as the energy sector and heating sector. This is the result of the implementation of European regulations and the introduction of increasingly restrictive standards. The decrease in SOx emissions is primarily the result of actions taken after the reunification of Germany, which led to a significant reduction in the number of boiler houses and small brown-coal-fired stoves. The improvement of energy efficiency in buildings and development of heating systems led to general improvement of air quality, especially in the eastern part of the country (taking into account the initial level of pollution).

Figure 32 NO_x and SO_x emissions per habitantin Germany.

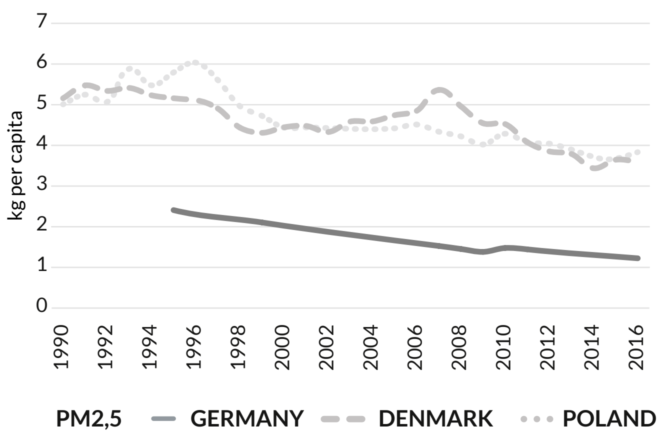


Source: Own analysis on the basis of DG ENER of the European Commission

Reduction of fine particulate matter (PM) emission

The low level of PM 2.5 emissions (about 65% lower than in Denmark in 2016) is to a great extent the result of the modernization of the energy sector and heating sector. In 1993, sulphur oxide emission limits were significantly tightened. Power stations for hard and brown coal could meet these standards by building high-efficiency flue gas desulphurisation installations. The units which could not meet the restrictive limits were closed. As a result of modernization, the air quality improved and PM emissions decreased. An additional reason for reducing pollution by fine dust is the increased use of gas for heating individual buildings, in favour of withdrawing biomass (in contrast to Denmark, where 800,000 biomass stoves are still installed, although this number is falling).

Figure 33. Emission of particulate matter in Germany.



Source: Own analysis on the basis of DG ENER of the European Commission

6.3. Heating supply sector

In Germany, there are about 340 companies which provide heat energy via heating networks. Diverse forms of ownership are observed. These are mainly companies (in whole or in part) owned by municipalities, but also private companies privatized during the liberalization of the energy market, in the 1990s.

In order to ensure the protection of consumers and continuous and high-quality services, all district heating suppliers in Germany are subject to the provisions of the Regulation on General Conditions for Heat Supply. A municipality may require investors to use a heating network in a given area for heating purposes.

The gas boilers are still used in 50% of individual buildings, but in recent years there has been an increase in the use of heat pumps, system heat and biomass.

The use of heat from RES in buildings

In 64.6% of 110,000 new residential buildings completed in 2017 use RES, and in 43.3% of new buildings, RES installations are the basic source of energy.

District heating - basic figures:

- 21 300 km - length of heating network
- 9% - share of district heating in total heat demand
- 17% - share of cogeneration in the national generation of electricity
- 83% - share of heat from cogeneration in the stream of district heating
- 15% - share of RES in district heating

Source: Data from Euroheat and Power study, 2017.

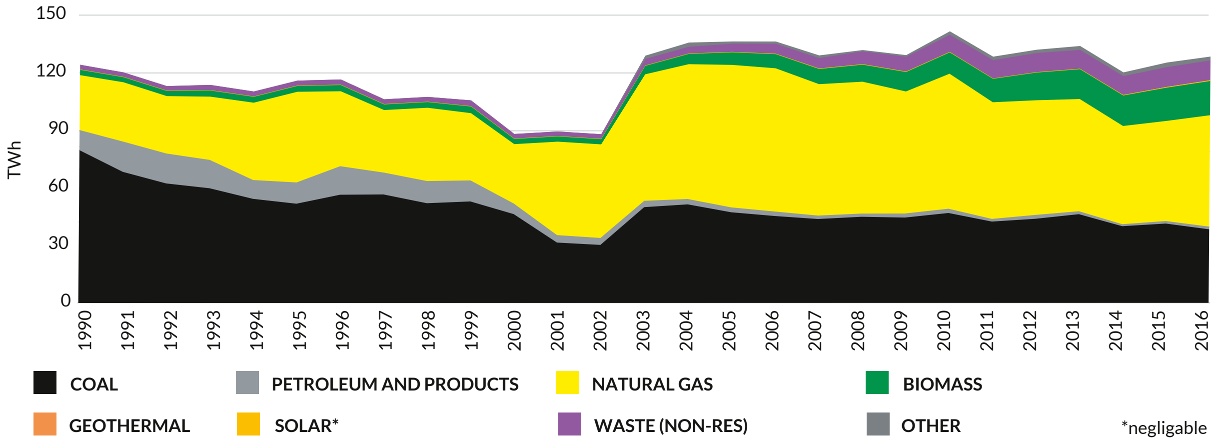
In Germany, 13.8% of occupied apartments are connected to system heat sources[7]. There is a significant difference in this respect between the former areas of West and East Germany. In the West, the share of heating sector is about 9%, and in the East it is about 30%. The main reason for this differentiation is the policy that the GDR authorities were conducting in the area of building a central heating network in cities. At that time, the popular fuel for municipal heating stations was brown coal. Where there was no municipal network, lignite briquettes or even brown coal were used in individual stoves. After the reunification of Germany, a large-scale infrastructure modernization program was started. The distribution networks of natural gas were, among other things, expanded, which allowed for the transition from brown coal to gas heating and a radical improvement in air quality.

The next Figure shows the generation of district heating divided into primary energy sources. The visible downward trend in 1990-2002 is the result of the improvement of energy efficiency resulting from the thermal modernization of buildings and heating networks (mainly in the former GDR).

In this area of system heating, the share of renewable energy is about 13%. It is expected that the 14% share of heat from RES in the entire heat stream in 2020 will be achieved. For comparison, the percentage of heat from RES in the total heat energy stream in Denmark in 2016 was 39.6% and in Poland 14.3%.

7 Euroheat and Power 2017 study

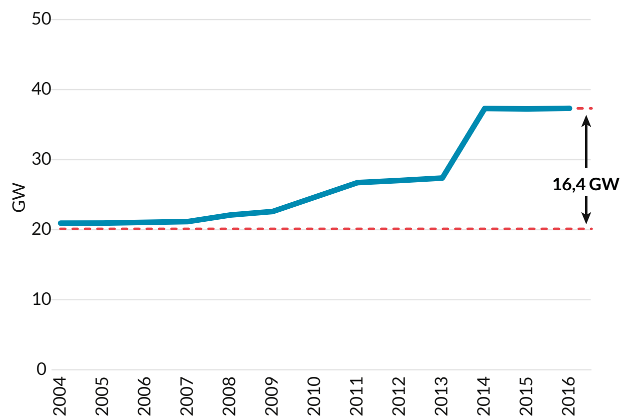
Figure 34. Generation of district heating divided into fuels and share of individual fuels in 2016.[8]



Source: Own analysis on the basis of DG ENER of the European Commission

The Cogeneration Support Act sets the goal to obtain the level of electricity generation from co-generation at the level of 110 TWh by 2020 and 120 TWh by 2025 (for comparison, generation in 2016 was 89 kWh). Thanks to the effective support mechanisms, the increase in cogeneration capacity has been recorded since 2004 at the level of 17 GWe (Figure 35).

Figure 35. Electric power installed in CHP plants in Germany



Source: Own analysis on the basis of Eurostat

6.4. National strategies and goals for 2020 - 2050

Germany, like Denmark, aims at achieving the full climate neutrality of the energy sector by 2050. The process is not easy due to the strong dependence of the economy on conventional coal-based energy sector and decisions on switching off zero-emission nuclear power stations. Exclusion of such a powerful generation base from exploitation is associated not only with engineering challenges, but also with the need to solve social problems that may arise in the case of the absence of reasonable alternatives in the labour market. So far, transformation has been taking place with the acceptance of the majority of the population, although the national goal of reducing CO_2 emissions for 2020 probably will not be achieved. However, the government is trying to maintain a consensus on the “Energiewende”, which is why the pace of action is not falling down. There is a discussion about next milestones - e.g. Goals for 2030.

8 The change in 2002/2003 results from the change in the method of calculating the amount of heat.

The Table below shows the goals set as part of adopted strategies and operational policies in recent years.

Tab. 6. Main goals with regard to climate, energy from RES and energy efficiency

Objective/year	2020	2022	2030	2040	2050
Reduction of CO_2 emissions in Germany in relation to 1990.	**40%**		**55%- 56%**	**70%**	**80%- 95%**
Reduction of CO_2 - energy sector	→	→	**62%- 61%** 175-183 mln t	→	→
Reduction of CO_2 - buildings	→	→	**67%- 66%** 70-72 mln t	→	→
National reduction of primary energy consumption in relation to 2008.	**20%**	→	→	→	**50%**
Buildings, Reduction of primary energy vs 2008	**20%**	→	→	→	**80%**
Country Reduction of gross electricity	**10%**	→	→	→	**25%**
RES share in the final energy consumption	→	→	→	→	**60%**
RES share in electricity	**35%**	→	**65%**	→	→
RES share in heat	**14%**	→	→	→	→
RES share in transport	**10%**	→	→	→	→
Share of nuclear energy	→	**0%**			

Source: Own analysis

Climate Action Plan 2050 (CAP)

In 2016, the government published a document that outlined strategies to achieve the goals set in the Paris Agreement. The Climate Action Plan (CAP) describes a map of actions to achieve the long-term goal of full neutrality in terms of greenhouse gases in Germany by the middle of the century. The document was widely consulted and contains many suggestions made by German federal states, municipalities, associations and citizens.

CAP defines goals and tools, which should be used in six areas:

- Energy sector
- Construction andbuildings
- Transport
- Industry and services
- Agriculture
- Forests and use of arable lands

The energy sector focuses on three strategic actions:

- **Reduction of energy demand** in all sectors of economy andelimination of fossil fuels
- Direct use of energy from RES, avoiding energy losses in energy conversion processes (i.e. solar energy for heating is better than heat from cogeneration or biomass heating stations)
- **Use of electricityfrom RES** in the most effective way inthe heating sector andindustry (e.g. Power-to-Heat) and transport (e.g. e-mobility, Power-to-Gas)

The German government assumes that the energy sector will be environmentally neutral in 2050 and it builds a strategy for other areas of the economy and areas of life based on this.

In the field of power engineering, the most important activities are:

- The need to increase the flexibility of the energy sector in the entire value chain
- The need to develop intelligent energy networks and to prepare for increased and variable electricity flows, among others as a result of the development of RES, e-mobility and electric heating
- The need for gradual withdrawal from conventional energy while respecting the interests of social groups affected by this process (additional negotiations with the European Commission are also planned to accept public aid, for example related to the transformation of mining regions and the creation of new workplaces)

The most important conclusions in the area of biomass use:

- The priority of using agricultural lands for food production purposes instead of using it to grow energy crops
- Halting the development of energy plantations at the current level
- Targeting biomass and biofuels primarily for use in air and sea transport to include these sectors in the process of reducing CO2 emissions
- The use of biomass only in dispersed local CHP plants and industry. Increased use of waste biomass from the agricultural industry, processing industry and municipal waste streams
- Biomass inthe heating sector will be a complementary fuel, as the remaining part of the heat stream will come from electricity generated in emission-free sources and other RES.

The following priorities have been specified for buildings:

- Improvement of energy efficiency and increased use of RES for heating purposes
- Development of low temperature, multi-directional [9]fourth and fifth generation networks (4G and 5G) for easier use of heat from RES and waste.

9 It is envisaged that heat energy will be sent not only to buildings, as it is now, but also from buildings that surrender the surplus of energy produced by them to the network. The energy can be, for example, heat coming from cooling the server room.

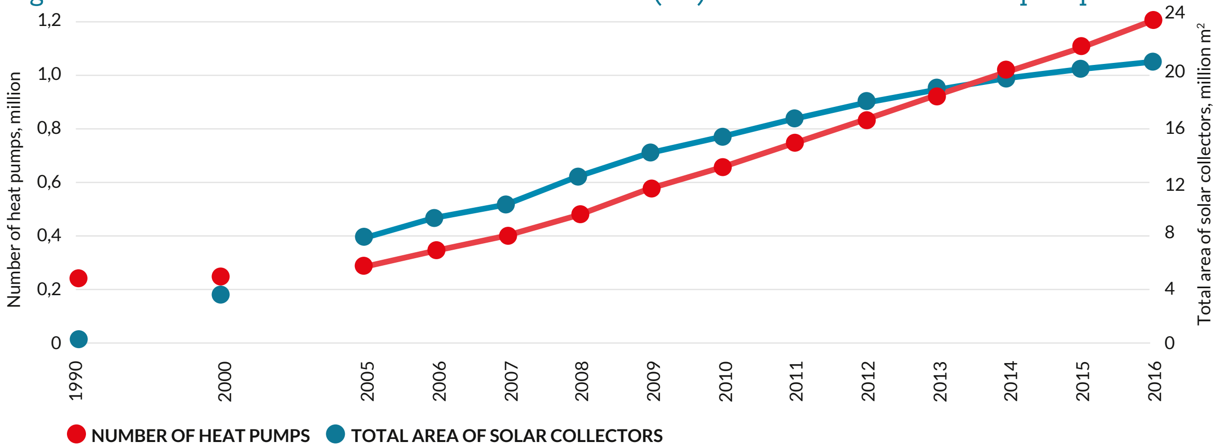
- Development of ICT technologies for buildings
- Multidimensional planning, including not only the technique, but also the quality of life and work of residents of buildings

The most important activities resulting from the priorities for buildings are as follows:

- New buildings will be completed in the zero-energy standard since 2021.
- Systematic reduction of the use of fossil fuels for heating purposes
- Implementation of mechanisms supporting the use of RES and waste energy inthe heating sector
- In the area of existing buildings, the implementation of system mechanisms supporting the change of heating sources from fossil fuels to energy from RES in order to lead to a zero-energy standard in 2050.
- Supporting the process of combining sectors (the so-called sector coupling): i.e. the heat sector, buildings sector, transport sector, industry sector and energy sector
- Improvement of awareness andeducation of society

As a result of the policy of RES development and alternative heat sources, which has been implemented for years, the share of heat pumps and solar panels in heating of buildings is growing dynamically. In 2016, the power of heat pumps exceeded 10 thousand MWt, and solar panels - 13.4 thousand MWt (Poland: 1.5 thousand MWt of solar collector power). The total area of collectors in Germany in 2016 was around 20 million m², or 37% of the total area of panels in Europe.

Figure 36. Growth of the surface of solar collectors (m²) and the number of heat pumps.



Source: Own analysis on the basis of BMWI

National Action Plan on Energy Efficiency (NAPEE)

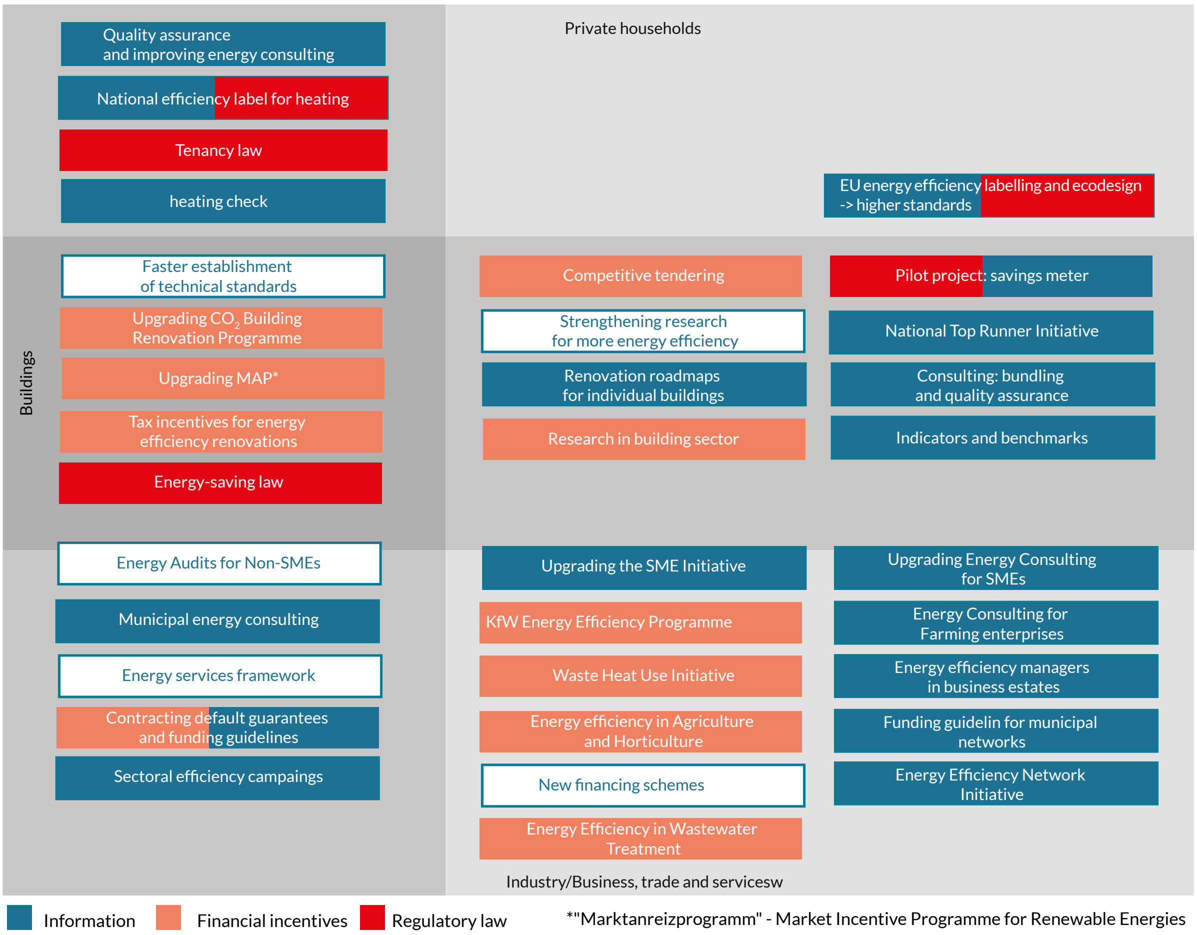
Energy efficiency is the main pillar of energy transformation. One of the most important activities is to improve the energy efficiency of buildings. The German government has developed a number of strategies and action programs to achieve the goals.

In 2014, the NAPEE, a guidance document indicating strategies for future activities, based on three main pillars, was adopted:

- Intensifying activities for the energy efficiency of buildings
- Establishment of an industry branch and a business model based on the efficiency requirement from energy efficiency
- Increasing individual responsibility for energy efficiency

NAPEE sets out suggestions and directions for action in many interdependent areas and establishes the most important legislative and financial initiatives. What is more, it indicates the areas of innovation and R&D activities. The illustration below shows the area of necessary activities.

Figure 37. Short-term measures and long-term work processes as part of the NAPEE



Source: Ministry of Economy and Energy, NAPEE

Goals to improve energy efficiency by 2050

In accordance with the NAPEE, national primary energy consumption should decrease by 50% compared to 2008.

National electricity consumption should fall by 25% by 2050, despite the increase of electricity consumption for heating purposes and transport.

Primary energy consumption in buildings should be reduced by 80% in 2050.

Energy Efficiency Strategy for Buildings

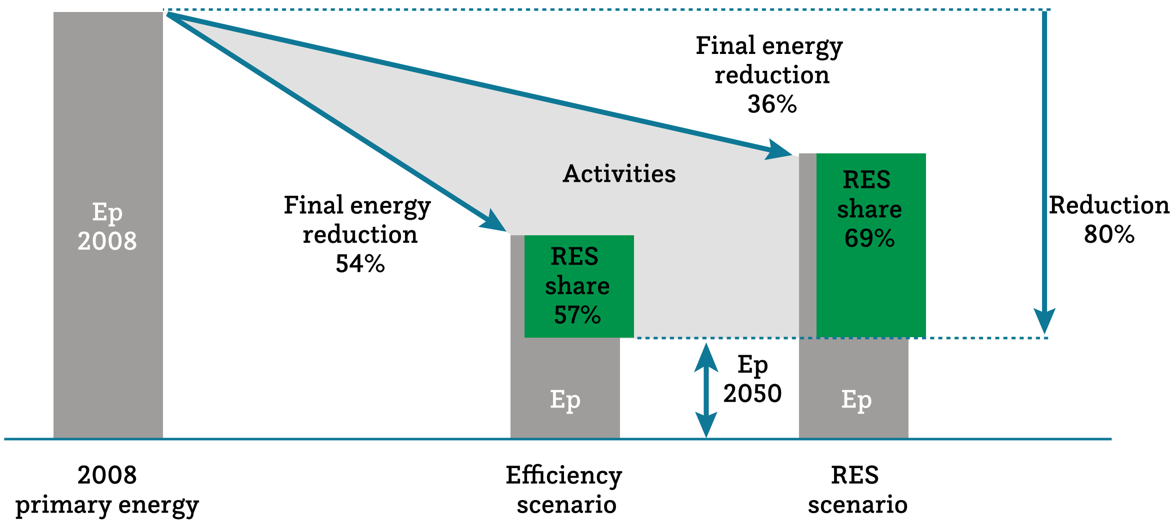
Strategy for buildings was adopted in 2015. The document contains the results of analyses of three scenarios of activities in the area of buildings (scenario: Reference, Energy Efficiency (EE) and Renewable Energy (RES) along with the analysis of energy, environmental and financial effects. Only two scenarios - EE and RES - allow the government to achieve the goal of reducing primary energy consumption at 80% in 2050 (compared to 2008). The goal may be achieved as a result of connecting two groups of activities:

- Reduction of final energy consumption (thermal modernization of buildings)
- Increase of share of energy from RES in the heating of buildings.

As shown in Figure 38, the assumed goal (80%) can be achieved by undertaking, with varying intensity, energy efficiency measures and increasing the share of RES. In the RES scenario, the improvement of energy efficiency and the reduction of final energy is only 36%, but the share of RES increases to 69%. However, in the EE scenario, the reduction in final energy consumption is 54%, and the RES share may be lower and amounts to 57%. In both cases, the goal of 80% reduction in primary energy consumption is achieved.

The following figure demonstrates the concept of the conducted analyses.

Figure 38. Scenarios for achieving the 80% primary energy reduction goal by 2050.



Source: Forum Energii

The results of scenario analyses became the basis for further legislative works implementing the Energy Efficiency Strategy for Buildings.

In order to achieve climate change goals, greenhouse gas emissions in the construction sector will have to be reduced by 70-72 million CO_2. Building regulations are already ensuring very low energy consumption for new buildings, and in many German cities the standard for passive houses is required for buildings built on land purchased from the municipality.

As of 2021, the zero-energy standard will apply to all new buildings in Germany

Paradox of a person renting a flat

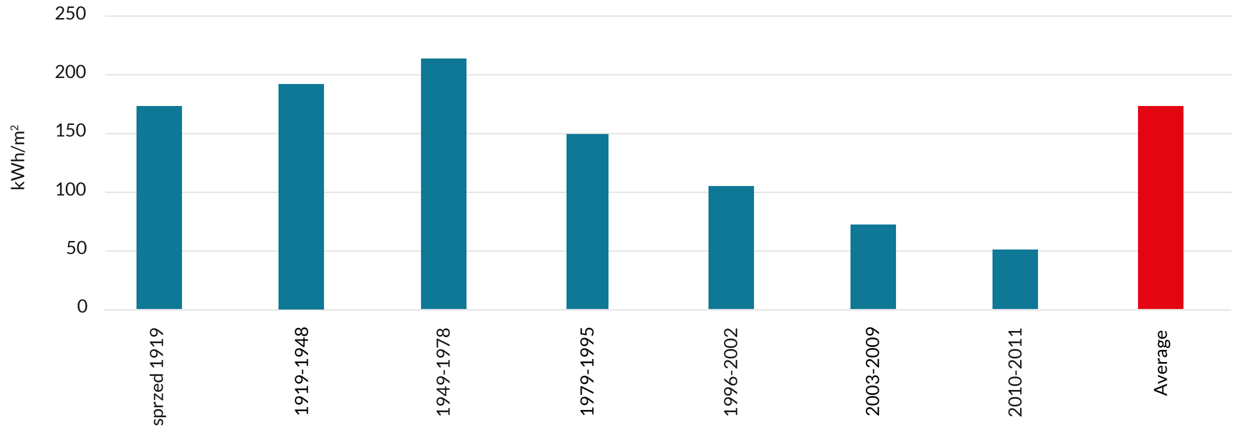
Many building owners carry out renovations only with the minimum energy efficiency standards, without applying for the implementation of thermal renovation deeper than that required under construction law. The lack of interest of the building owners results from the simple fact that according to standard rental contracts, the heating costs are covered by the tenant. For the owner, this cost is neutral and does not constitute a stimulus for investment activities. In Germany, this is a huge problem, as the rent of apartments is more popular than their purchase (about 57% of apartments are rented). The problem has been noticed - various actions have been taken, e.g. in the form of information campaigns or low-interest loans, which aim at encouraging the owners to improve the energy standards of existing buildings.

6.5. Law shaping the heating sector

The regulation on energy saving (EnEV)

The first Energy Saving Act dates back to 1976. It was assumed then that "you should not use more energy for heating buildings than you need". In the last version (2016), the document defines standards for the insulation of building elements and the maximum primary energy consumption for heating purposes, both in new buildings and renovated buildings. It is 75% lower than in the mid-1970s. In the long-term perspective, as stated above, it continues to fall. The Act also requires the issuance an "energy passport" for new buildings confirming the "energy class" (similar to that issued for household appliances). The share of energy from RES is also defined in the building permit for a new building.

Figure 39. Average final energy consumption per unit of building space, depending on the construction year



Source: Federal Ministry of Economy and Energy of Germany, 2014.

Support mechanisms of energy efficiency in buildings

- efficiency standards
- reimbursement programs
- consultancy and tax programs supporting RES
- preferential loans for single-family houses:
    - up to EUR 100,000/house, if built in a higher energy standard
    - up to EUR 4,000 for professional supervision over a comprehensive project for the renovation and modernization of the energy installation
- the funding program offered by the Federal Ministry of Economy and Energy, which encourages wider use of renewable energy inthe heating sector and replacement of old gas and oil boilers

RES Promotion Act inthe heating sector (EEWärmeG)

The aim of the Act is to promote renewable energy sources for the generation of heat and cooling purposes. The Act provides that a certain percentage of energy used must come from renewable sources, depending on the source. The requirements apply to new and renovated buildings. A mandatory share of energy from RES is also imposed on new single-family houses:

- Solar panels: 15% (about 4% of roof surface), or
- Biomass heating: 50% or
- Heat pump: 50%

In addition, there is an obligation to prove that the new heating system meets the requirements for the amount of energy from RES by the user/owner. For example, in the case of a biomass-fired boiler, evidence is required that the device uses the actual amount of fuel, e.g. in the form of a confirmation of purchase.

The Act on Renewable Energy Sources in the Energy sector (In German: EEG)

The Act on RES specifies future goals and principles of support of this industry and gives priority to electricity from RES. In the latest version of the EEG, electricity generation in renewable sources should reach the following ceilings:

- 40 to 45% at the latest before 2025.
- 55 to 60% at the latest before 2035.
- at least 80% at the latest before 2050.

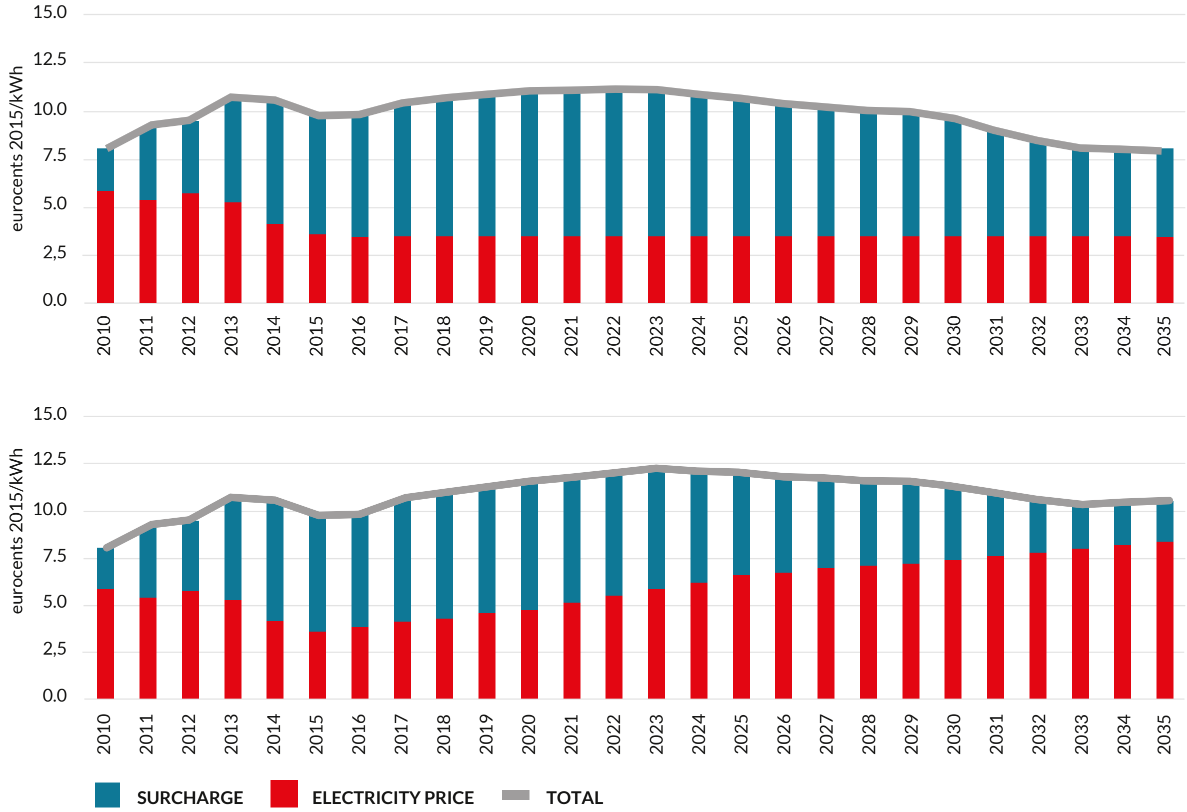
Furthermore, the Act states that the share of electricityfrom RES should amount to at least 18% of the total gross energy consumption by 2020.

In the case of power stations built before 2014, the generation unit operator receives a fixed price for the supplied electricity from the TSO (Feed-in-Tariff-FiT). Units released after 2014 receive a premium that compensates for the difference between the price of energy sold on the market and the cost of production (CfD). Compensation for RES are calculated by the TSO and transferred to energy consumers in the form of an EEG fee. Energy-intensive industries are partially exempt from EEG. In 2016, the auctions for RES were implemented in order to reduce the costs of support mechanism.

The Figures below show the simulations of the EEG fee in the situation of a constant price of electricity at the level that is maintained in 2015 and in the situation of the expected increase in the wholesale price of energy. In the case of higher energy prices, the subsidies for RES producers will be lower due to the specificity of differential contracts (CfD). In both cases it can be seen that from 2022, the burdens resulting from the agreements concluded with energy suppliers from RES will be reduced due to the beginning of the process of terminating expensive 15-year renewable energy support contracts concluded in previous years.

Figure 40. The sum of the wholesale price of electricity and average renewable energy subsidies

a) at a fixed energy price, b) with increasing energy price



Source: Agora Energiewende

Interesting conclusions can be drawn from the analyses of the Ministry of Energy of Germany, comparing investment expenditures on RES and their impact on the growth of domestic trade (multiplier effect). As shown in the Table, in 2016 investment expenditures and annual internal turnover as a result of previous investments in RES are at a comparable level. It is worth noting the impact of biomass technologies (mainly used inthe heating sector) on the growth of turnover on the internal market. This is due to the fact that the cost of variable use of biomass installations is higher than, for example, photovoltaic cells. The variable cost, i.e. the cost of biomass for the installation operator, is also the income for the biomass vendor. Such stimulated trade will continue throughout the life cycle of the generation unit.

Tab. 8. Comparison of investment expenditures for RES in Germany with the domestic turnover generated by them in 2016.

Investment expenditures (mld €)									
Hydro power plants	Wind farms		Photovoltaics	Solar (heat) energy	Geothermal sources	Biomass			Total
	Land	Marine				Power generation	Heat generation		
0.03	6.8	3.3	1.6	0.7	1.2	0.3	1.2		15.1
Multiplier effect - domestic turnover (€ bn)									
Hydro power plants	Wind farms		Photovoltaics	Solar (heat) energy	Geothermal sources	Biomass			Total
	Land	Marine				Power generation	Heat production	Fuels	
0.2	1.9	0.4	1.5	0.3	1.2	4.6	3.1	2.6	15.6

Source: RES in Figures

Cogeneration Act („Kraft- Wärmekopplungsgesetz", KWKG)

The Act sets the goal of obtaining the level of electricity generation from cogeneration at the level of 110 kWh by 2020 and 120 kWh by 2025 (for comparison, production in 2016 was 89 kWh). The Act introduces a tender procedure for units with a capacity of 1 to 50 MW_e. The winning projects will receive a fixed bonus (cogeneration allowance) to the price of electricity sold on the energy market.

The levels of cogeneration allowance for installations with a capacity of 2 to 50 MW_e are presented below.

Unit power kW	Allowance for a professional CHP plant eurocent / kWh	Allowance for selfproducers eurocent/kWh
Up to 50	8	4
From 50 to 100	6	3
From 100 to 250	5	2
From 250 to 2000	4.4	1.5
2,000 and more	3.1	1

In the case of replacing coal as a fuel in a CHP plant, the cogeneration allowance increases by 0.6 eurocent/kWh. The duration of the guaranteed tariffs varies depending on the level of investment and is as follows:

- For new and modernized units (modernization cost> 50% of the new unit), the allowance can be obtained for the first 30,000 working hours in full load.
- For modernized units (modernization cost = 25%-50% of the new unit), the allowance can be obtained for 15,000 working hours in full load.
- For modernized units (modernization cost: from 10% to 25% of the new unit), the allowance can be obtained for 10,000 working hours in full load.

It should be emphasized that the allowance cannot be granted to a new unit (belonging to an entity other than one operating on the local heat market), when the heating system is a high efficiency system and the new cogeneration unit displaces the existing unit from the market. This provision is aimed at a real increase in the generation of electricity in cogeneration (in the case of displacing the existing cogeneration unit by the new one, generation increase would be zero) and the introduction of protection for a local heating company against not always positive effects of competition in the small heat market.

Financial support for heating networks

Aiming at the further development of heating systems as a tool to improve air quality, subsidies for the construction of new heating networks were introduced, depending on its size:

- For heating network diameter ≤ DN 100 support up to 40% of investment expenditure
- For heating network diameter> DN 100 support up to 30% of investment expenditure

The support may be granted only to the so-called effective heating systems. Effective systems are those in which the share of energy from cogeneration is greater than 75% or the total share of heat energy from cogeneration, RES and waste heat is at least 50%, with at least a 25% share of heat generated in cogeneration. The maximum funding available for each project is EUR 20 million.

Financial support for the construction of heat accumulators.

Financial support for the construction of a heat accumulator can be obtained for up to 30% of the total investment cost, but not exceeding EUR 10 million. The condition is that:

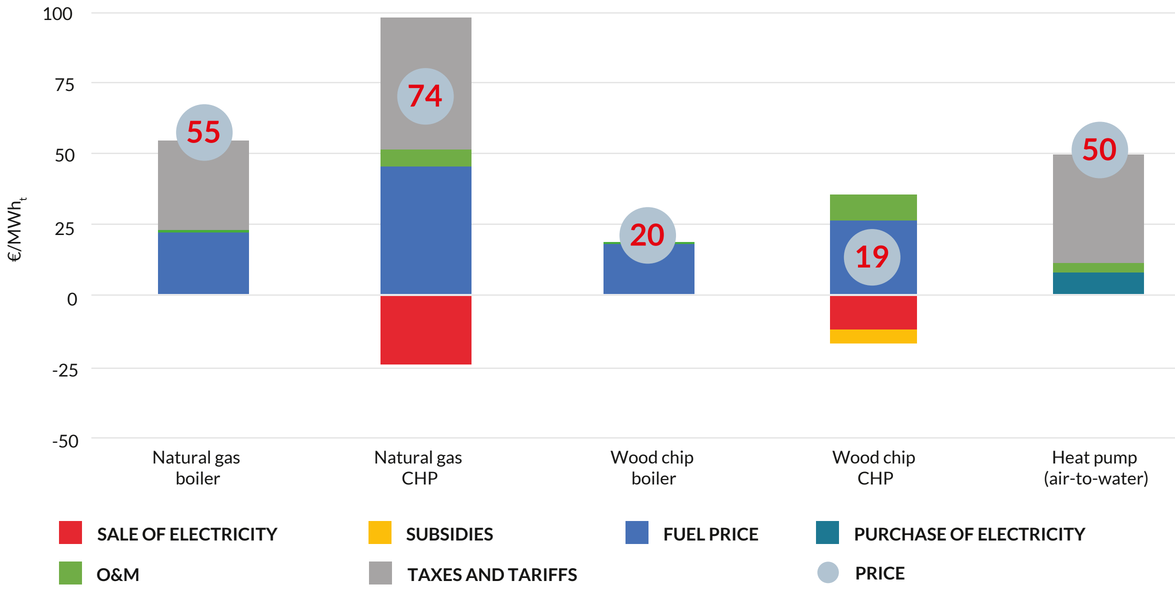
- the share of heat from cogeneration was at least 50% or 25% of heat from cogeneration and 25% of waste heat from industrial plants
- heat losses would be lower than 15 W/m^2
- an accumulator was larger than 50 m^3

6.6. Heat price

System heating (district heating)

In Germany, support mechanisms inthe heating sector differ slightly from those in Denmark. The energy taxation is also different, a fact reflected in the levels of heat prices in local heating systems. Figure 41 illustrates the structure of district heating generation costs in various technologies. Generation in small biomass units is most favourable. Heat pumps would be an attractive option if not for taxes and other fees of the energy price. It is expected that the taxation of natural gas will increase in the following years, which may further adversely affect the cogeneration heat price.

Figure 41. The cost of heat generation from various sources along with the cost structure.[10].



Source: COWI

Price regulation of district heating

Contracts for the supply of district heating are usually multi-annual contracts (10 years) with a fairly complex formula for indexation of prices as a result of changes in resources prices, generation costs, taxes, etc. Any adjustment of the heat price takes place through mutual negotiations and agreements. Due to the dominant position of heating companies on local markets, the issue of heat prices is a common subject of discussions and public debates.

10 The dot on the graph shows the result price (cost minus income, including taxes and subsidies). Fixed cost was "changed" for working time = 5,000 h/year. The adopted price of electricity is EUR 27/kWh.

The heat price for the final recipient consists of three main elements:

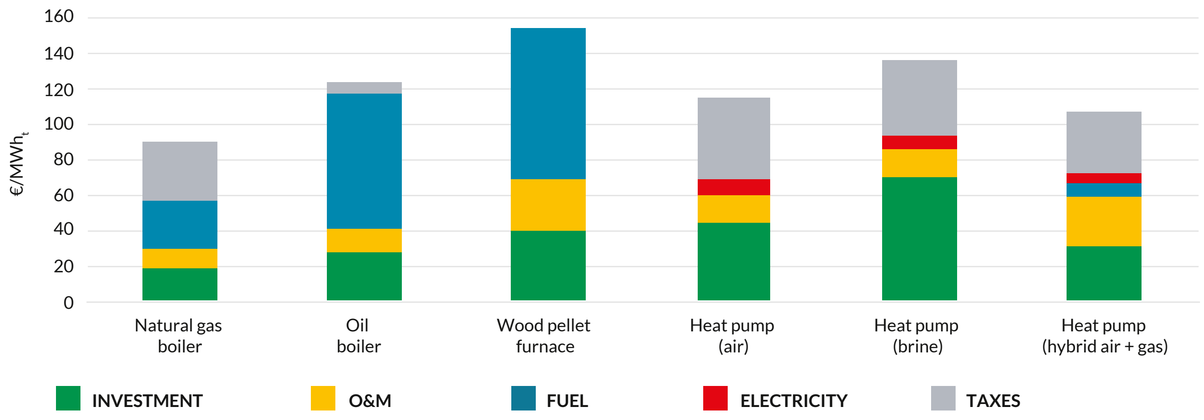
- Fixed fee - charged irrespective of consumption, in order to cover the costs of investment, operation and maintenance of infrastructure. The fixed fee is about EUR 20 - 30 per year per kW of connection power
- The variable fee - the fee for consumed energy is about 60 - 100 EUR/MWh (average approx. 80 EUR/kWh)
- Service fee - charged by some suppliers, for measuring heat consumption about 100 - 200 EUR/year

For example: for an average flat (70-80 m²) with a 15 kW connection and an annual consumption of 15 thousand kWh, the annual heat cost is about EUR 1575. (fixed fee = 25 EUR/kW, in the case of a multi-family residential this fee is lower).

Individual heating

In Germany, gas boilers are the most popular source of heat in individual buildings. Due to the high taxation and costs of electricity, individual heat pumps do not currently compete with natural gas. However, heat pumps are a good solution in comparison to fuel oil boilers and wood pellets. It is worth noting that the grid operator can apply lower electricity fees if it is entitled to turn off the heat pump to a max. 2 hours in the period of peak demand for power in the system. The discount awarded by the operator can even reduce the variable cost of heating up to 20%. This discount was included in the chart of variable heat generation costs in various sources.

Figure 42. Cost of heat generation, individual heating[11]



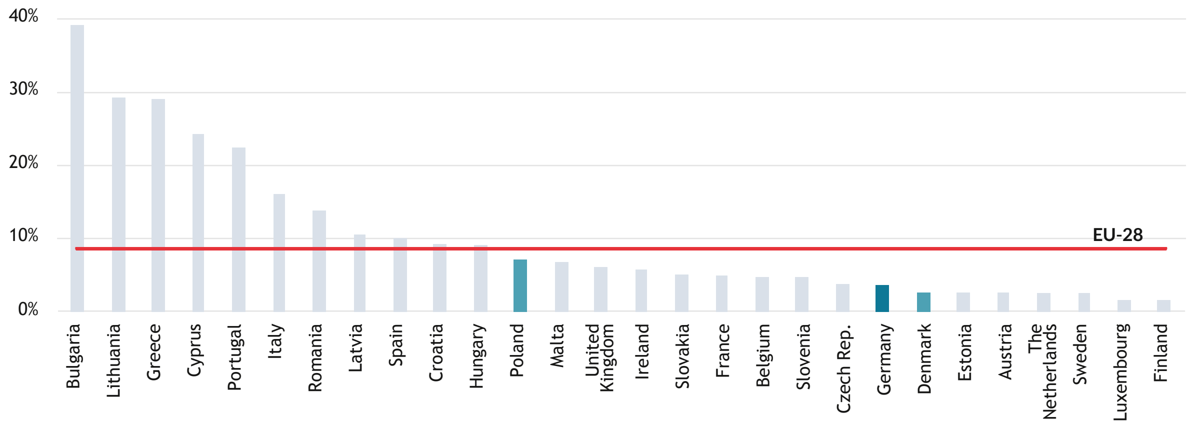
Source: Own analysis on the basis of COWI

11 Calculation for 18 MWh of annual heat consumption. Fixed cost over a period of 20 years.

6.7. **Support for sensitive customers**

The phenomenon of energy poverty in Germany involves about 3%-4% of citizens (slightly more than in Denmark). It places Germany at the forefront of European countries with the lowest percentage of citizens affected by this problem.

Figure 43. Participation of people in society that cannot maintain a satisfactory temperature in their home



Source: Own analysis on the basis of Eurostat

In Germany, residents with low incomes are supported by co-financing the cost of renting a flat and the cost of energy. The heating surcharge for eligible persons is a maximum of EUR 3/m² of "living space of appropriate size".

The concept of "living space of appropriate size" varies from region to region: about 45 m² is usually considered suitable for a single-person household, and 60 m² for a double-person household. The financial resources for support are covered by the federal budget. The process is managed by the Federal Labour Office.

In addition, heating companies offer heating audits and ESCO services that lead to the reduction of cost for heating buildings. What is more, they run educational campaigns aimed at increasing the awareness of heat consumers.

6.8. **Summary**

- The energy policy of Germany, agreed among all political circles, aims to achieve the goal of reducing CO2 emissions by a level of 85-90% by 2050 (vs 1990).
- Increased energy efficiency of buildings is one of the pillars of the energy policy. The mechanisms leading to achieving the national goal of 80% reduction of primary energy consumption by buildings by 2050 are being implemented. This goal is to be achieved by increasing the use of energy from RES

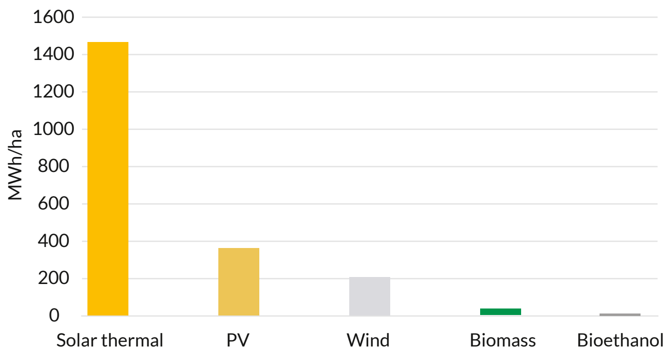
for heating purposes in buildings (57-69% share) and reducing final energy consumption (from 54-36% vs 2008).

- In accordance with the adopted strategy for buildings, all new buildings must meet the standard of zero-energy buildings as of 2021.
- The introduction of guaranteed tariffs for RES and cogeneration has contributed to the rapid development of these technologies. In 2000-2016, the installed electric power in cogeneration increased from 24 GWe to 37 GWE. The share of RES in electricity generation currently exceeds 30%.
- It is expected that cogeneration units will be used to balance the energy system, which is supplied primarily from wind farms and solar farms in 2050. Power batteries and Power-to-Heat technologies will play an important role. In the heating sector, it is expected that large energy flows from RES and heat pumps will be used, which will also be used to balance the energy system.
- The Cogeneration Act has implemented a subsidy mechanism (CAPEX) for the construction of heating networks and heat accumulators in order to develop heating systems and CHP plants effectively cooperating with the energy system.
- Despite the current large share of biomass - the development of this source of energy will be limited in the future. The national policy of using biomass puts emphasis on the use of arable land areas for food, not energy. The development of energy plants, apart from those currently functioning, is not expected. The criteria for the protection of biodiversity and the origin of biomass are also important.
- The use of gas in the heating sector of individual buildings results in the achievement of very low average national concentrations of PM 2.5 (about three times lower than in Denmark and Poland).
- In accordance with the adopted energy policy, the strategy for energy efficiency improvement and strategy for buildings and other directional governmental documents, all activities in these areas should be correlated with incentives stimulating the development of innovation and domestic industry.

7. Key technologies

The discussion on energy security and independence from the import of resources shed a new light on renewable energy sources. According to the analyses of the International Renewable Energy Agency (IRENA), virtually every country in the EU has local RES energy resources able to cover the demand for all domestic primary energy with a great deal of excess. When planning the development of the heat supply sector, it is worth taking the potential of available RES resources into account in order to use them in the most effective way. Figure 44 shows the energy efficiency of 1 ha of land when different technologies for processing primary renewable energy into usable energy are applied.

Figure 44. Annual energy generation from 1ha of land



Source: Own analysis on the basis of Per Alex Sorensen, Planenergi: "Experience with solar thermal in Denmark".

Heat storages

RES variables are characterized by very low generation costs, but at the cost of their variable work. The development of energy storage technologies is important. Inthe heating sector, heat accumulators, which can mitigate the current or almost seasonal imbalance of supply and demand in the heat market, can help.

Daily heat storage

Short-term storages are used to optimize the operation of a CHP plant, providing the opportunity to increase electricity generation during daily peak demand in the energy system (and in the period of higher energy prices). Surplus heat, as unusable during the day, is stored in the accumulator for use in the evening and at night, when the heat demand increases. In the evening and at night, the wholesale price of electricity decreases at the same time, worsening the profitability of the cogeneration unit operation. If the drops in electricity prices are high, it pays to turn off the unit and supply the heat consumers only with the energy stored in the accumulator, possibly with the support of a heat pump or an electric boiler. In Denmark, virtually all CHP power plants are equipped with heat accumulators. The largest one has the capacity of 70,000 m^3 (about 3.5,000 MWh).

Seasonal heat storage

These storages are primarily used to accumulate surplus of energy from renewable sources (currently mainly solar farms) and surplus of heat energy from cogeneration units generated in the summer season. The heat accumulated in this way is used in autumn and winter when the demand for heating energy increases. The currently largest accumulator in Vojens has a capacity of 203,000 m^3.

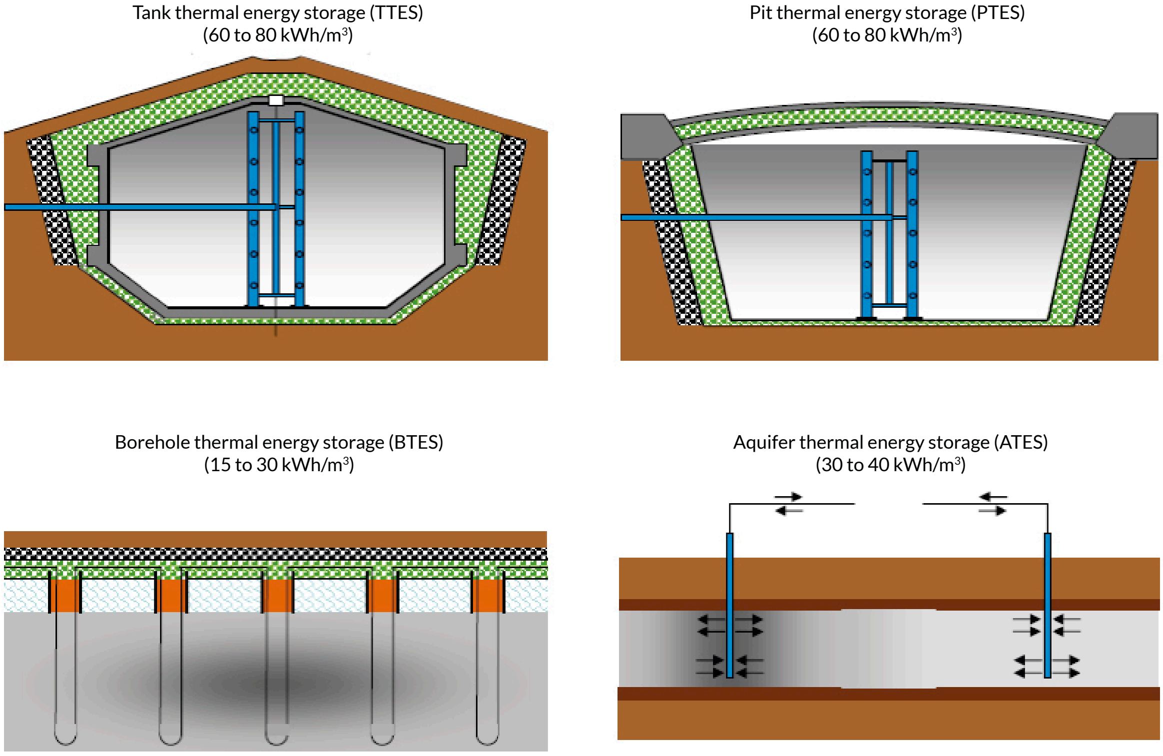
Figure 45 Daily heat accumulator in Nykøbing Sjælland

Source: Arcon Sunmark

The construction of the accumulator is not too complex. Simply put, it is a well thermally insulated hole in the ground. If there are favourable ground conditions and no need for heavy foundations, the storage is a relatively inexpensive solution. The unit expenditure is about 20 EUR/m^3 (while the short-term storage costs about 400-500 EUR/m^3).

In practice, various methods of seasonal heat storage are used. It is shown in Figure 46. Currently, the most popular are Pit Thermal Energy Storage (PTES).

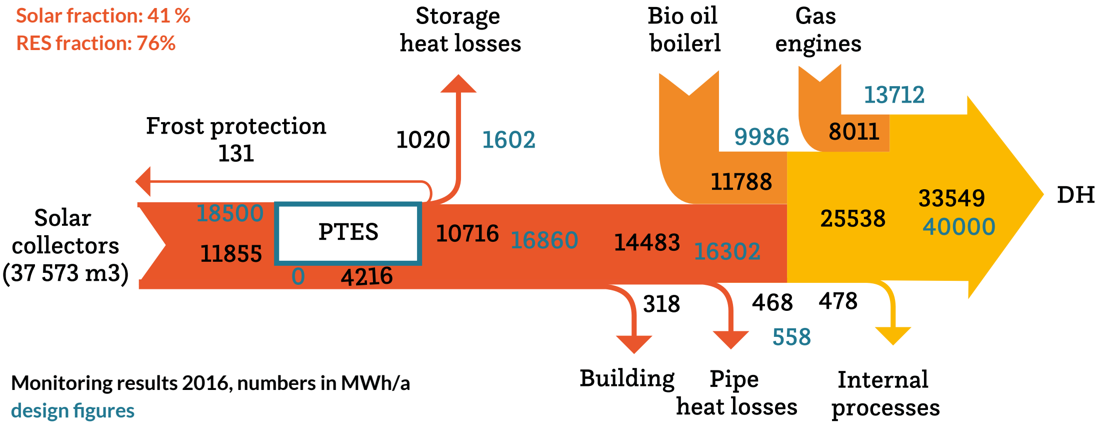
Figure 46. Examples of solutions for seasonal heat storage



Source: Energistyrelsen

The construction of each storage is always preceded by a thorough analysis of the profitability of the project in connection with the work of the entire set of devices that the heating company has at its disposal. One of the important factors influencing the analysis results is the energy efficiency of the tank. The practice shows that it is high reaching up to 90%. Figure 47 shows the flow of heat energy streams (including also losses) inthe heating company in Dronninglund. According tothe Figure, the share of heat fromsolar panels was around 41% during the year thanks to the use of a heat accumulator.

Figure 47. Planned and actual heat energy streams

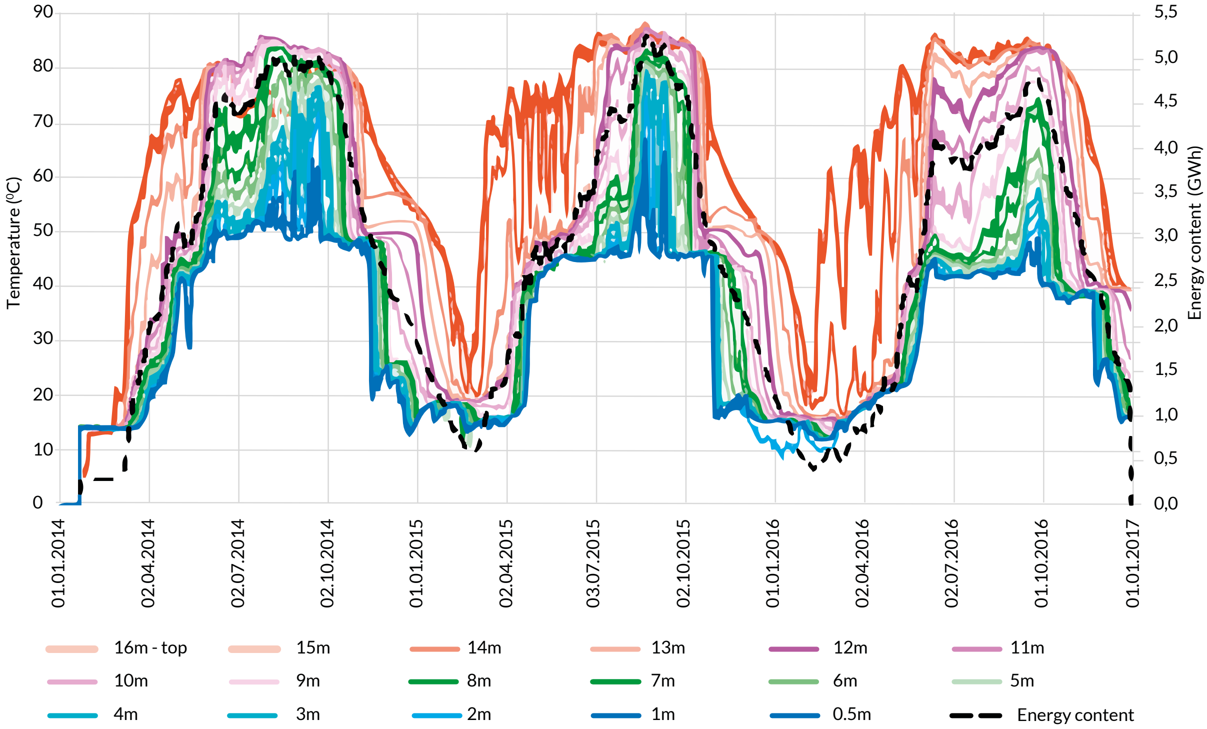


Source: Arcon Sunmark

Experiences from the three years of operation (2014-2016) confirmed the high energy efficiency of the tank at the level of 90%. The maximum storage temperature was 89 degrees C, and the minimum was 12 degrees C.

The next Figure shows the seasonal cycles of charging and discharging the accumulator.

Figure 48. Cycles of accumulator operation



Source: Arcon Sunmark

Photographs from the construction site show the subsequent stages of accumulator construction and its structural elements. The total cost of accumulator construction amounted to EUR 2.27 million.

Figure 49. Stages of heat accumulator construction

Source: Arcon Sunmark

Other heat storage technologies mentioned in the introduction, such as ATES and BTES, are less popular due to higher capital expenditure and achieve lower thermal powers.

Heating with solar energy

The cost of solar heating is always strongly dependent on CAPEX capital expenditure, as OPEX operational variable costs are at a very low level. Solar technologies are always part of a larger set of generation devices in a heating station, because they cannot ensure uninterrupted supply of heat throughout the year. Frequent completion of solar sources are heat pumps, biomass units or gas boilers. In most companies that use solar heat sources there are daily or seasonal heat accumulators. The largest solar farm in Denmark has an area of 156 thousand m^2. In Vojens in Denmark there is a farm with an area of 70,000 m^2 and the largest accumulator with a volume of 203,000 m^3. Solar energy accounts for 45% of the total heat generation. Heat price is approximately EUR 42/MWh (source: Arcon Sunmark).

Tab. 9. Example calculation of farm production costs with a solar panels area of 10,000 m^2

Purchase of land 3 ha	EUR 50 000
Solar modules, pipelines, heat exchangers, working medium, pumps etc.	EUR 1,850,000
Fencing and preparation of land	EUR 50,000
Transmission pipelines	EUR 300,000
Control and Measurement Instruments and Automation	EUR 100,000
Consulting, expertises	EUR 40,000
Total	**EUR 2,390,000**
Generation of heat	5,000 MWh/year
Annual capital costs	EUR 119,000/year
Renovations	EUR 5,000/year
Total generation cost	EUR 124,000/year
Unit generation cost	**EUR 24.9/MWh**

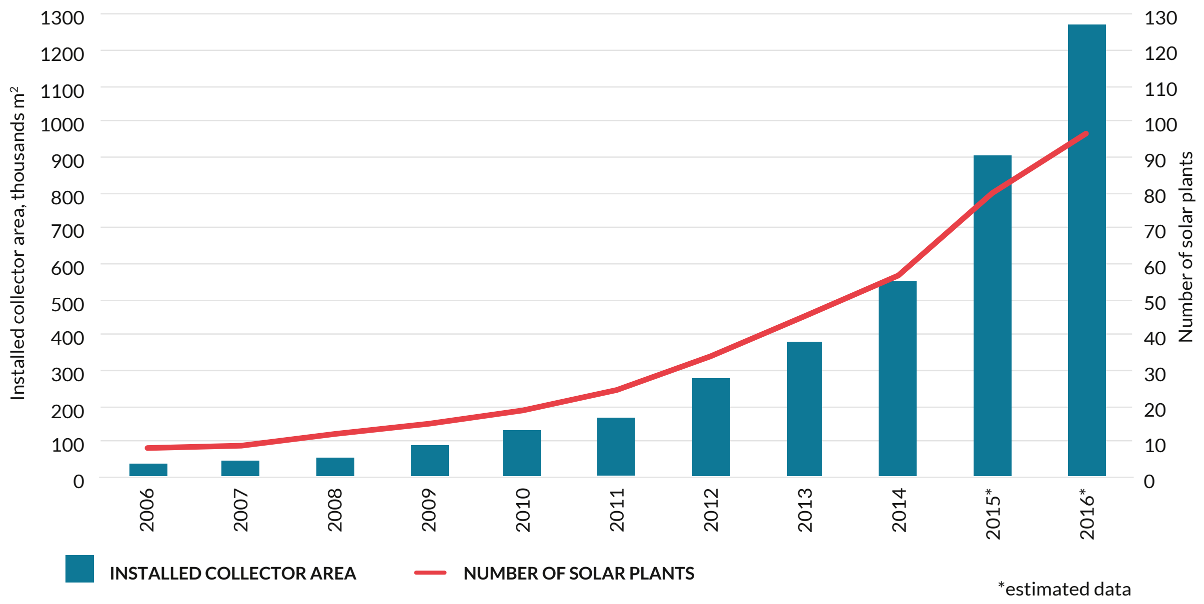
Source: Per Kristensen, conference Warsaw 17.01.2018

Increasing efficiency of devices and decrease in CAPEX expenditure increase interest in the use of solar energy inthe heating sector. Even in Denmark, a country seemingly with low insolation, there is a rapid increase in installed power in solar sources (Figure 50).

Figure 50. Nykøbing Sjælland Farm 20.084 m^2

Source: Arcon Sunmark

Figure 51 Development of solar heating in Denmark



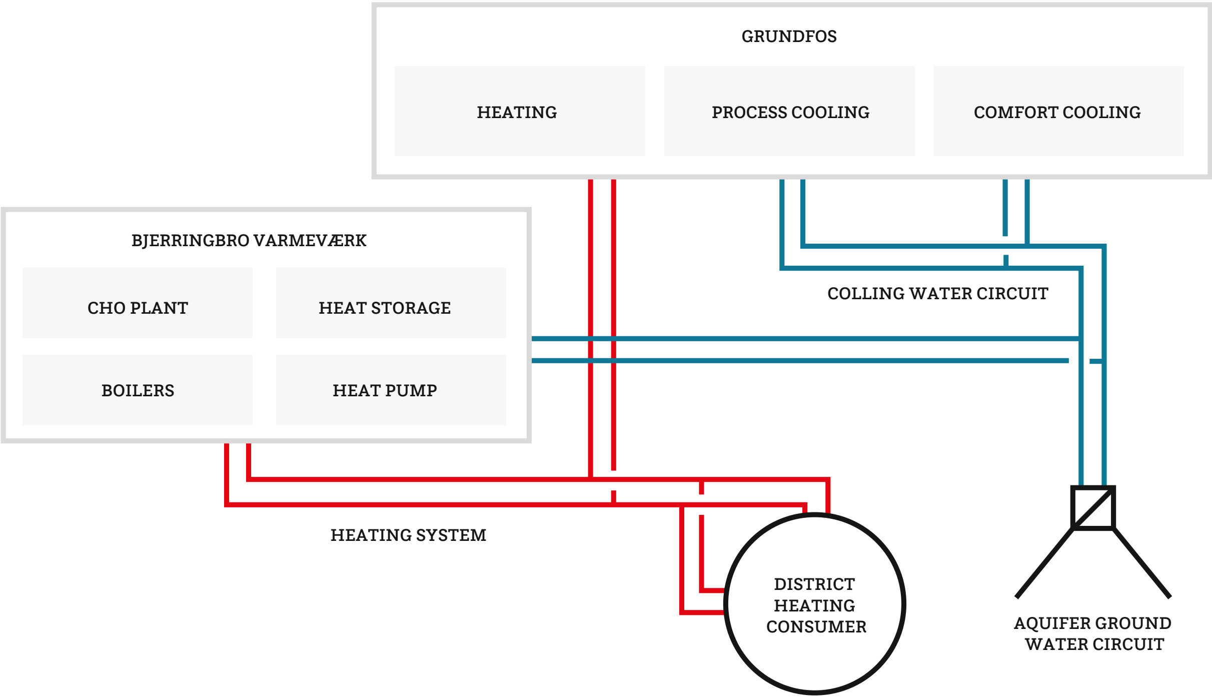
Source: own analysis on the basis of data presented by Per Kristensen during a conference in Warsaw on 17 January 2018

Heat pumps

These are an effective way to use waste energy (heat energy from industrial processes, air conditioning, etc.) to produce useful thermal energy. Air heat pumps are a fairly popular solution, especially at low power. Unfortunately, their efficiency depends on the ambient temperature. Inthe case of using the heat pump inwinter, the COP drops to a level equal to 1, corresponding to the efficiency of the electric boiler, which drastically increases the cost of production. That is why other heat sources witha higher energy potential are being sought for. It can be waste heat from industry, from wastewater treatment plants or heat previo-usly stored in seasonal accumulators.

An example of using waste heat with the use of heat pump is Bjerringbro in Denmark where heat pumps with a capacity of 2 MW use waste heat from Grundfos production plant and process it into heat, which can be used in a heating network. The two-stage process allows for a higher temperature - from about 38°C to 68°C. In the summer, surplus of residual heat is stored in brine accumulators to be used by heat pumps in the winter.

Figure 52. Heat pump work system in Bjerringbro, Denmark

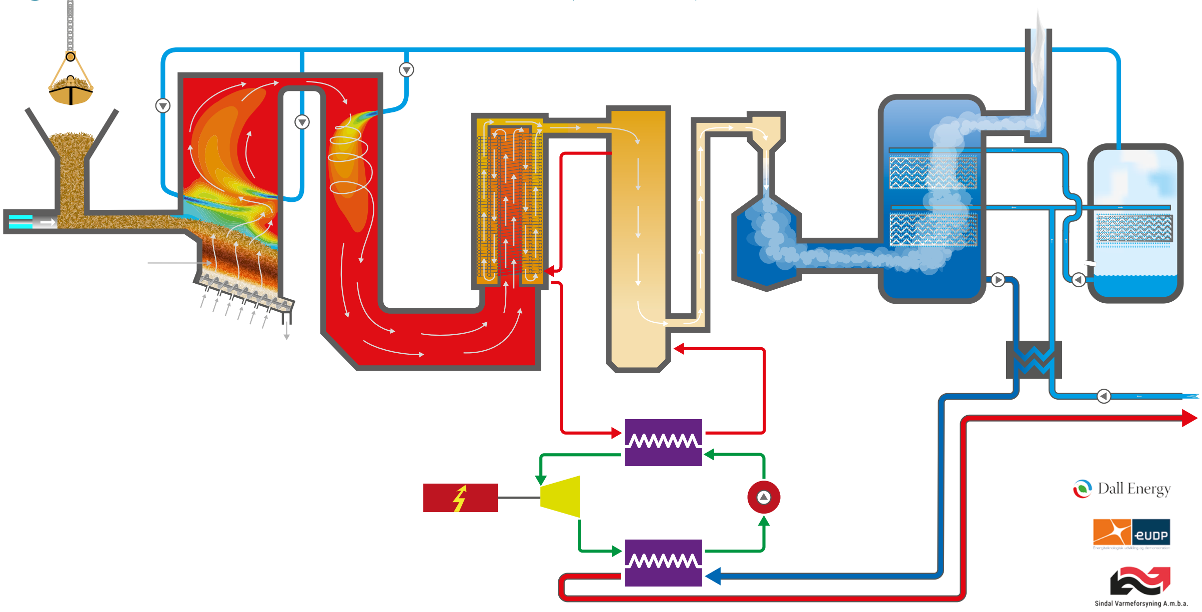


Source: Own analysis on the basis of COWI

Cogeneration from biomass

Cogeneration from biomass is used in medium and high power heating systems and due to economies of scale. Biomass units should be characterized by a high working time during the year, due to the high level of CAPEX (the lowest for pellet boilers, and the highest for boilers burning straw). Both in Denmark and in Germany, the current support mechanisms encourage the construction of small CHP plants using local biomass resources. An interesting project is a heating unit put into operation in summer 2018 in Sindal in Denmark, which is characterized by high work flexibility (15%-100% capacity) and a high tolerance for changing biomass type. Good technological parameters have been achieved thanks to the use of gasification technology that supplies thermal energy to a cogeneration unit operating in the ORC system (Organic Rankine Cycle). The decision to implement the investment resulted from: higher taxes and the increasing price of gas used for heating and the availability of cheaper local waste biomass (straw, gardening waste, wood chips). The construction of a water vapour condenser, with the flue gases, allows for the thermal power to the municipal network to be increased. It is expected that the new investment will reduce the heat price for households in the future, which currently amounts to about EUR 60/MWh (PLN 70/GJ). It is worth noting that the project in Sindal is a model example of the use of national engineering thought and the potential of local, small enterprises that produce equipment for the heating sector and energy sector.

Figure 53. Heating station scheme in Sindal (Denmark)



Source: Jens Dall, Dall Energy

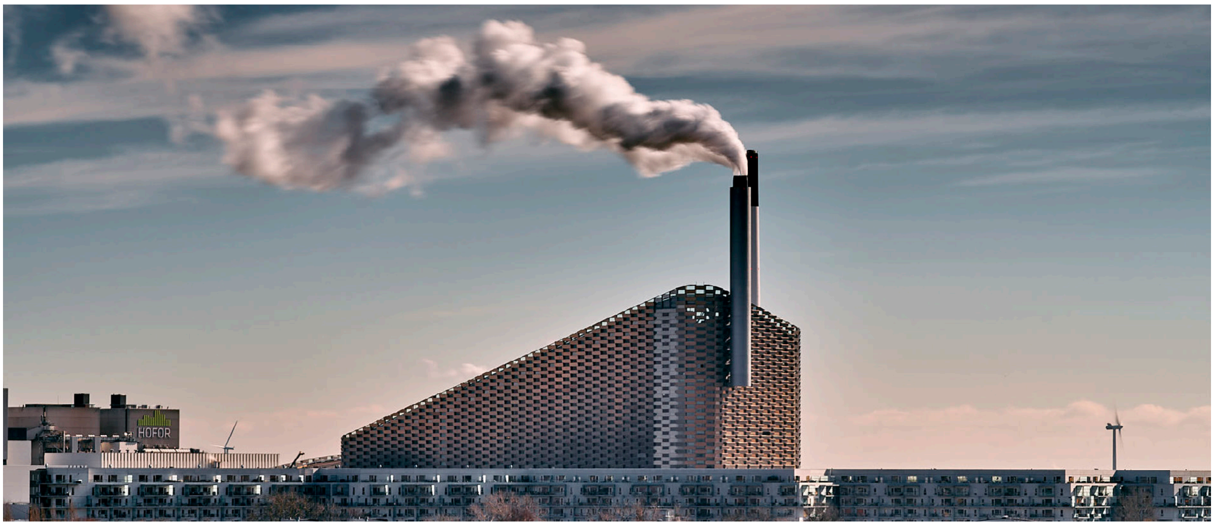
Basic data

- Thermal power: 5 MW
- Electric power: 0.8 MW
- Overall efficiency: 90%
- Change of power (real) 15%-100%
- Exhaust fumes temperature: 40 degrees C
- Fuel moisture: 20%- 60%
- Temperature of district heating water: 40 degrees C/80 degrees C
- CAPEX: EUR 9 mln
- Source for all-year work (existing gas engine - peak work)

Energy generation from municipal solid waste

The Plant for Thermal Treatment of Municipal Waste (PTTMW) is a very popular source of heat and electricity. Thanks to the high technical level and high quality environmental protection devices, they are usually accepted by local communities. In Denmark and Germany, many such plants were established at a time when the waste management requirements and the scope of the obligation to recover and recycle valuable fractions were not so strongly set by the EU. In accordance with current EU policy, waste management should focus first on minimizing the volume of waste, then on recovery and re-use. At the next-to-last stage energy is recovered in thermal utilization plants, and the last one - small quantities that have not been used in the whole chain of operations. As a result of implementing the above-mentioned principles in many EU countries, including Germany and Denmark, municipal waste to PTTMW has become a scarce resource sought out of the local community, even on the European market (import of waste e.g. from Sweden to Germany or Denmark). Therefore, before making a decision about the construction of PTTMW, it is very important to balance the stream of resources with accuracy, taking into account the impact of future policies in this area.

Figure 54. Copenhagen - municipal CHP plant with a ski track on the roof.

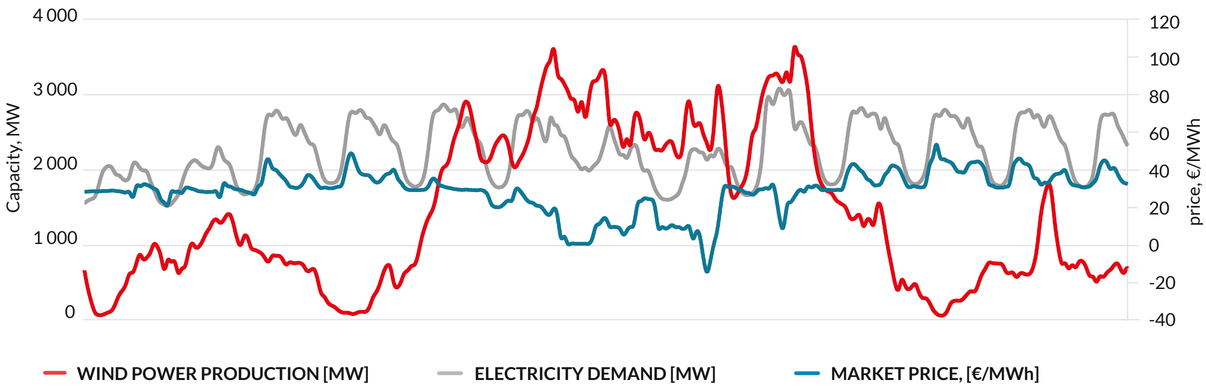


Source: Christoffer Regild

Integration of the heating sector with the power grid

The increase in the share of RES variables (wind farms and photovoltaics) forces a change in the rules of functioning of other energy market participants. The key word describing the new phenomenon is “flexibility”. A flexible response to momentary changes in electricity generation (resulting from the unstable work of RES variables) by other elements of the energy system, i.e. primarily through conventional thermal units (power stations and CHP plants) and secondly by energy consumers, are expected. Dynamic changes in wholesale electricity prices (Figure 55) have resulted in CHP plants ceasing to be must-run plants (working with extortion), but rather becoming active participants in the energy market, offering system balancing services.

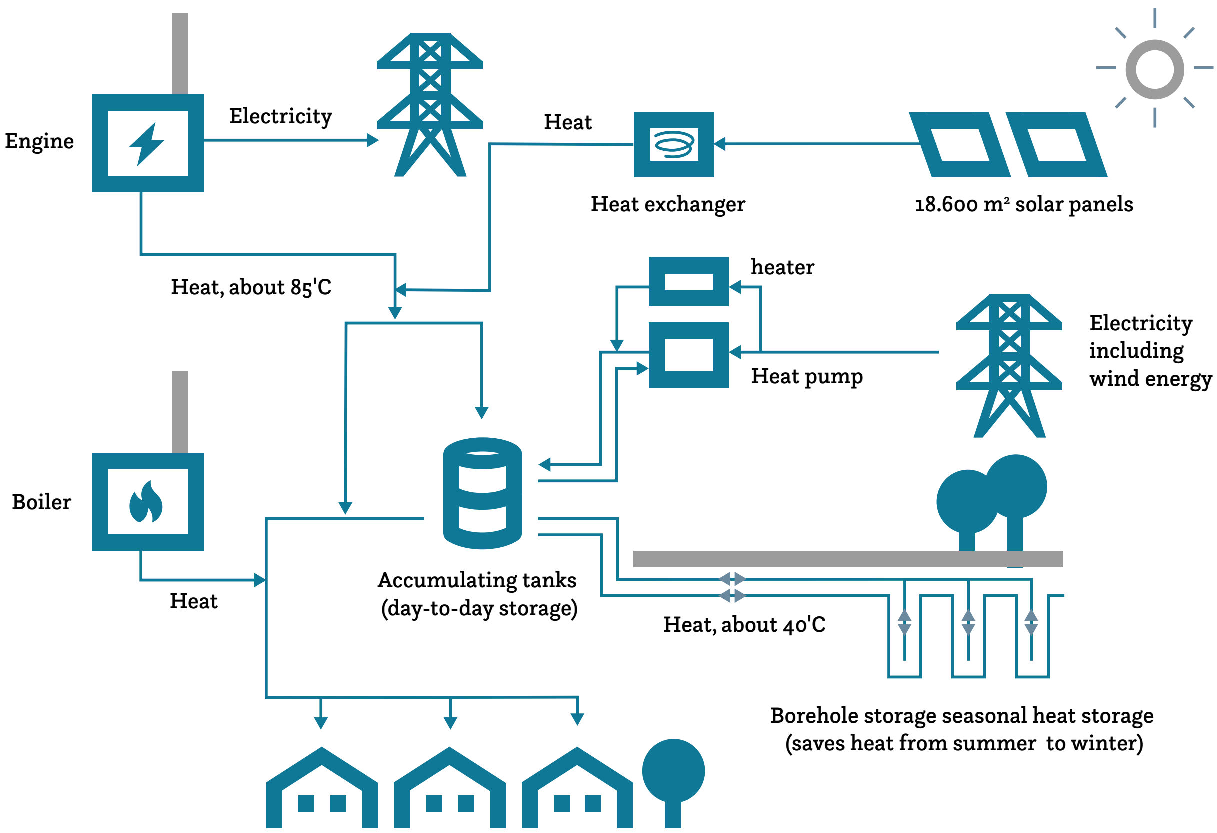
Figure 55. Market price, electricity generation from wind energy and electricity demand in the western part of Denmark in two weeks of April 2017.



Source: Energinet

The new market quality forced retrofitting of the CHP plant with new generation devices, such as heat pumps or electric boilers or reserve gas boilers, additionally supported by heat accumulators. Figure 56 shows a schematic set of devices included in the CHP plant actively cooperating with the electricity market.

Figure 56. Scheme of Braedstrup CHP plant



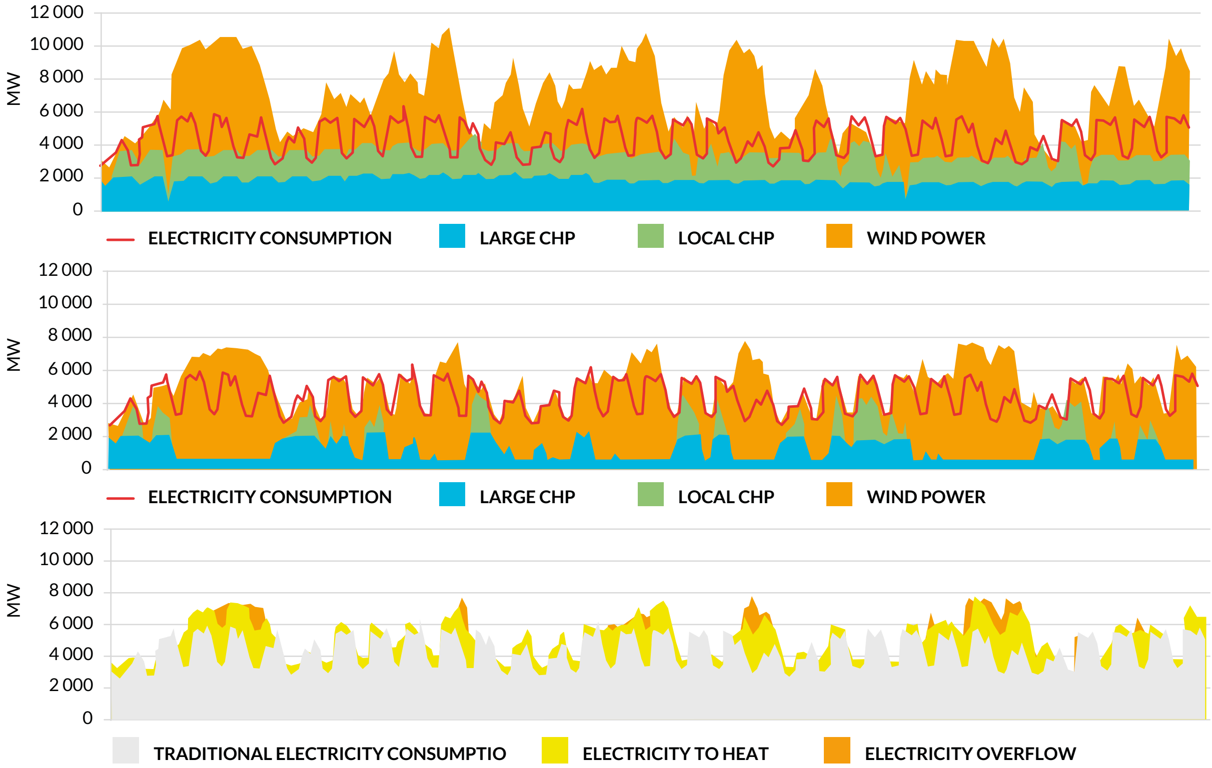
Source: Braedstrup

In the case of low electricity prices, heat is produced in electric boilers or heat pumps. And vice versa, when prices are high, a cogeneration unit is started up. Solar heat sources complement the manufacturing devices. Heat accumulators act as a buffer which enables the supply to be balanced with the demand of the local heat market.

At present, the process of adjusting taxes on electricity is underway, so as to encourage both heating companies and individual households to use heat pumps and electric boilers on a larger scale. It is expected that with the increase in the number of electrical devices for heat generation and the development of ICT, the transmission system operator using aggregators managing distributed devices (Virtual Power Plant) will be able to balance the power system more effectively. The following charts illustrate how heating and cooling systems equipped with heat pumps, electric boilers, heat accumulators and flexible cogeneration units can balance the energy system.

The first chart in Figure 57 shows the balance of electricity in the situation of large wind farm production and the operation of CHP plants in the extortion mode by local heat markets. The second chart presents a flexible reaction of cogeneration units, i.e. reduction of production and temporary shutdown. The heat is produced in electric boilers and heat pumps. The last chart is the balance of supply and demand and the balance of surplus energy that can be used to produce heat or for export.

Figure 57. Simulation of balancing the Danish power system by the heating sector



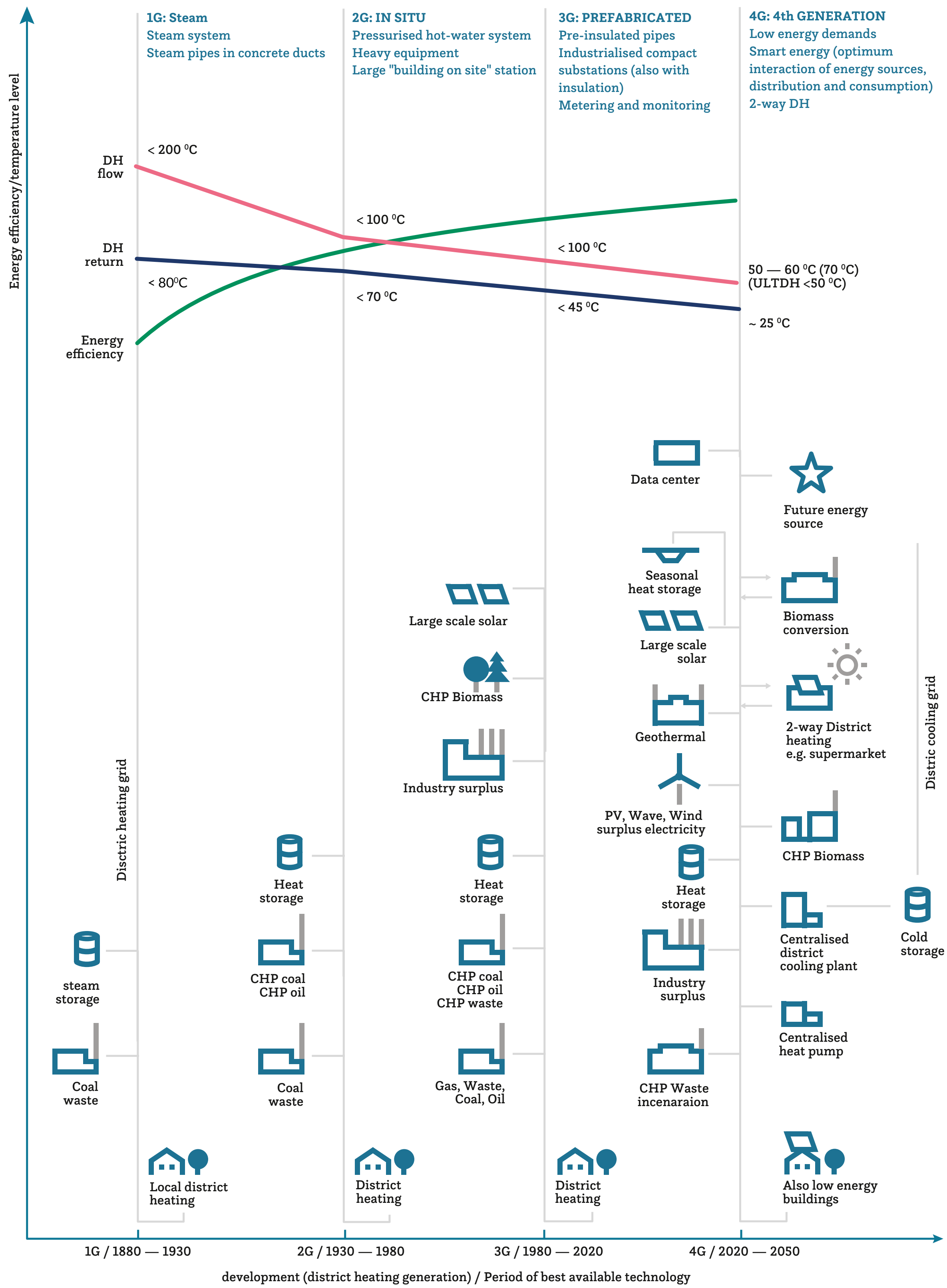
Source: Ramboll www.pfbach.dk

A time will come when heating companies will cease to just be the suppliers of the product in the form of heat, but will rather start to shape new business models based on guarantees of thermal comfort of customers and energy services.

4G heating systems

Figure 58 shows the stages of transformation of Danish heating. As you can see, along with the technological progress, the efficiency of the systems increases and the temperature of the network water is reduced. So-called 4G low-temperature networks - the fourth generation - are an opportunity to increase the share of renewable sources in heat generation and low-energy waste energy (from industry, server houses, sewage treatment plants, etc.). Reduction of the temperature of the medium in the system additionally reduces energy losses, especially during the summer, but it is also a serious engineering challenge related to the adaptation of existing heating systems, heat distribution centres and the method of heating at final users. It is a long-term process. However, if we want to switch to zero-emission heat from renewable sources, we should gradually prepare heating networks to operate with lower temperatures of the working medium during modernization and development works. It should also be remembered that in the future buildings will be less energy-intensive, so a low-temperature network will be the right solution for them. When preparing the national strategy for thermal modernization of buildingsin Poland (in accordance with the EU requirements presented in the Winter Package), it is worth preparing a strategy for the heating sector including the development of the 4G network.

Figure 58 Stages of transformation of the Danish heating sector



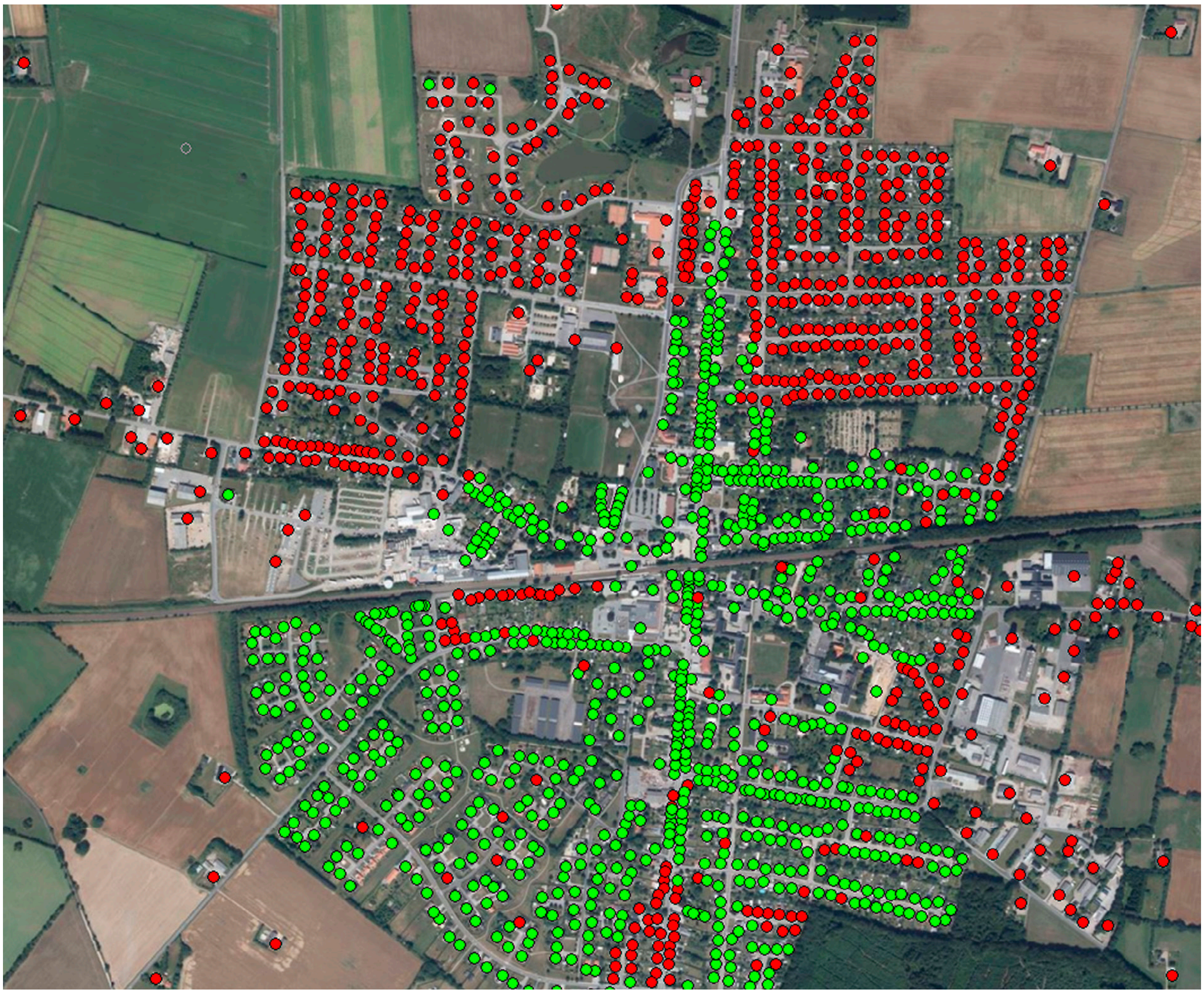
Source: Aalborg University

Planning of network development

The collected data on the consumption and type of fuel are invaluable from the point of view of energy planning. In Denmark, such information is collected in a central database. Heating companies can use them to plan the expansion and modernization of the network. Along with GIS mapping, data on energy needs are an invaluable tool for assessing the cost-effectiveness of connecting specific areas/buildings to heating networks.

The attached visualization shows the recipients already connected to the heating network (green) and buildings not using the heating network (red). Such a clear picture of the situation makes it easier for a heating company to identify areas worth focusing on when planning new connection campaigns and investments.

Figure 59. Recipients using the heating network (green) andrecipients not using heating network (red)



Abbreviations

RES – renewable energy sources
GDP – gross domestic product
EUR – euro, €
DG ENER Directorate – General for Energy
CDGU – centrally dispatched generating units
PM – particulate matter
IEA – International Energy Agency
DNO – Distribution network operator
TPA – third party access
DEA – Denmark Energy Agency
NAP – National action plan
DERO – The Danish Energy Regulatory Office
DGD – Danish Gas Distribution
TSO – Transmission system operator
CHP – plant
HP – Heat pump
EU – European Union
EU-28 – 28 Member States of the European Union
NPP – Nuclear power plant
GDR – German Democratic Republic
CAP – Climate Action Plan
ICT – Information and communication technologies
NAPEE – National Action Plan on Energy Efficiency
R&D – research and development
PE – primary energy
Regulation on Energy Saving
HA – Home appliances
CfD – Contract for Difference
REA – Renewable Energy Act
FiT – Feed-in-tariff
DN – Nominal diameter
ESCO – Energy Saving Company
TTES – Tank Thermal Energy Storage
PTES – Pit Thermal Energy Storage
BTES – Borehole Thermal Energy Storage
ATES – Aquifer Thermal Energy Storage
COP – Coefficient of Performance
ORC – Organic Rankine Cycle
PTTMW – The Plant for Thermal Treatment of Municipal Waste
GIS – Geographic Information System

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Notes

Notes

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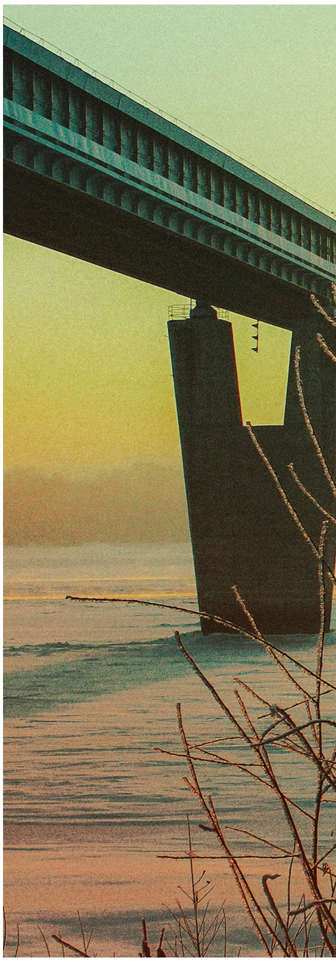
Good heating practices from Denmark and Germany

Conclusions for Poland



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