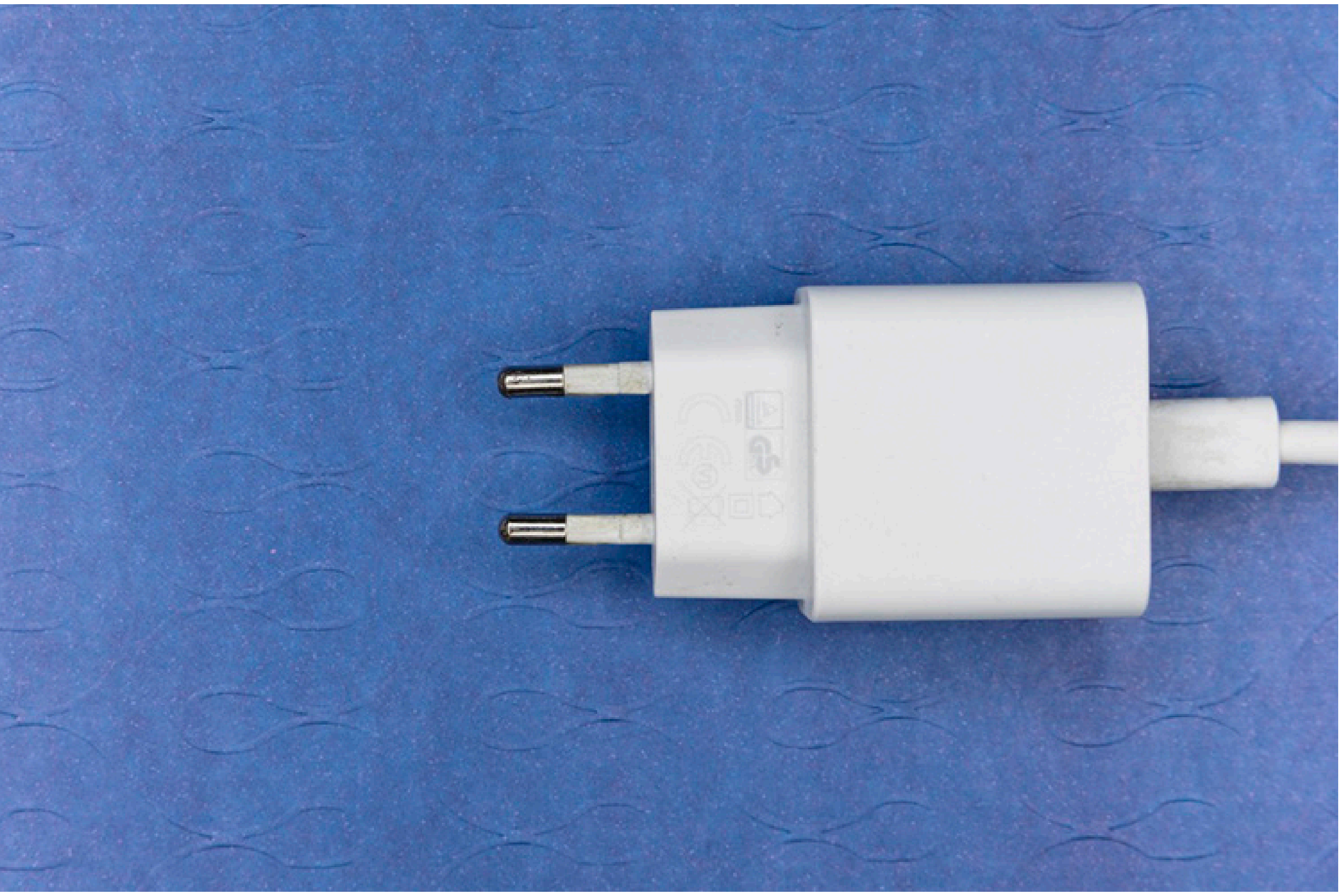

Heat electrification in Poland

The path to clean heat

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Forum Energii is a think tank focused on the energy sector. Our mission is to create the foundations for an effective, safe, clean, and innovative energy sector based on data and analyses.

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Preface

The transformation of district and individual building heating is inevitable. It is forced by fundamental factors such as the need to fight for climate and environmental protection, the reduction of fossil fuels in energy processes, and progress in heating techniques and materials. It is important to understand the challenges ahead and manage them in a way that achieves the greatest possible benefits while minimising the costs that accompany any change.

The main direction of modernisation of the heating system is electrification, the process of replacing fossil fuels with a higher form of primary energy, i.e., electricity. This is what we are dealing with in the report. We point out the technologies and potential benefits of using them in modernisation, as well as the limitations to be faced. Electrification, however, is not only a change of primary energy source but also an accompanying paradigm shift in the functioning of the entire heating sector. The previous model of the heating sector consisted of the simple production of heat to meet the current demand of the consumer. However, in the near future, it will be replaced by a multifunctional model based on a flexible response to external factors such as the wholesale price of electricity, access to energy surpluses, and consumer preferences regarding the level of thermal comfort. Following changes in the electricity market, a transformation is also taking place in the heating sector. This transition will be characterised by the emergence of 'heating prosumers,' who operate in a similar way to those in the electricity sector.

Electrification of district heating will entail further changes. The use of electrical devices for the production of heat (mainly heat pumps) will enable district heating entities to offer power system balancing services and energy storage, as well as the use of low-temperature waste and renewable energy sources for affordable heating. The European Commission has recognised the advantages of heat electrification in strategic documents on the integration of EU sectors and hydrogen policy.

The extensive use of heat pumps means not only improving the energy efficiency of the entire area of heat supply but also the possibility of a significant increase in the share of renewable energy in the heat flow. It is also an opportunity to get rid of smog quickly.

I encourage you to read this report and familiarise yourself with the benefits of electrification of district heating in Poland and proposals on how to overcome barriers to the development of this technology.

I wish you a pleasant read.

Dr Joanna Maćkowiak-Pandera
President of Forum Energii

1. Analysis background. Why is heating electrification inevitable?

One-third of final energy in Poland is used for heating buildings and making hot water. Half of the heat generated in individual heating sources comes from burning coal. Three-quarters of district heating systems are fuelled by coal, and small systems depend almost entirely on this fuel.

The heating sector in Poland is at a crossroads. Maintaining the current fuel and technological structure and the related business models is a thing of the past. This is due to technical progress, climate policy, and the end of cheap and good quality coal reserves in Poland. The traditional use of coal as a fuel for heating, however, has no future if we want to improve air quality and reduce carbon dioxide (CO_2) emissions. Fossil fuels in heating must be replaced by clean sources of heat. By 2030, coal should be eliminated from individual household heating. In district heating, this will probably happen a few years later, but here too the change is inevitable due to the shrinking supply of domestic coal, the rising costs of CO_2 emissions and the inefficiency of traditional heating installations.

This raises the important question of what other heating technologies can be used to help achieve climate neutrality. Current trends show that a whole range of energy sources will be used in the future, with a strong emphasis on renewable energy and energy recovered from other processes. Fossil fuels such as coal and gas will be replaced by:

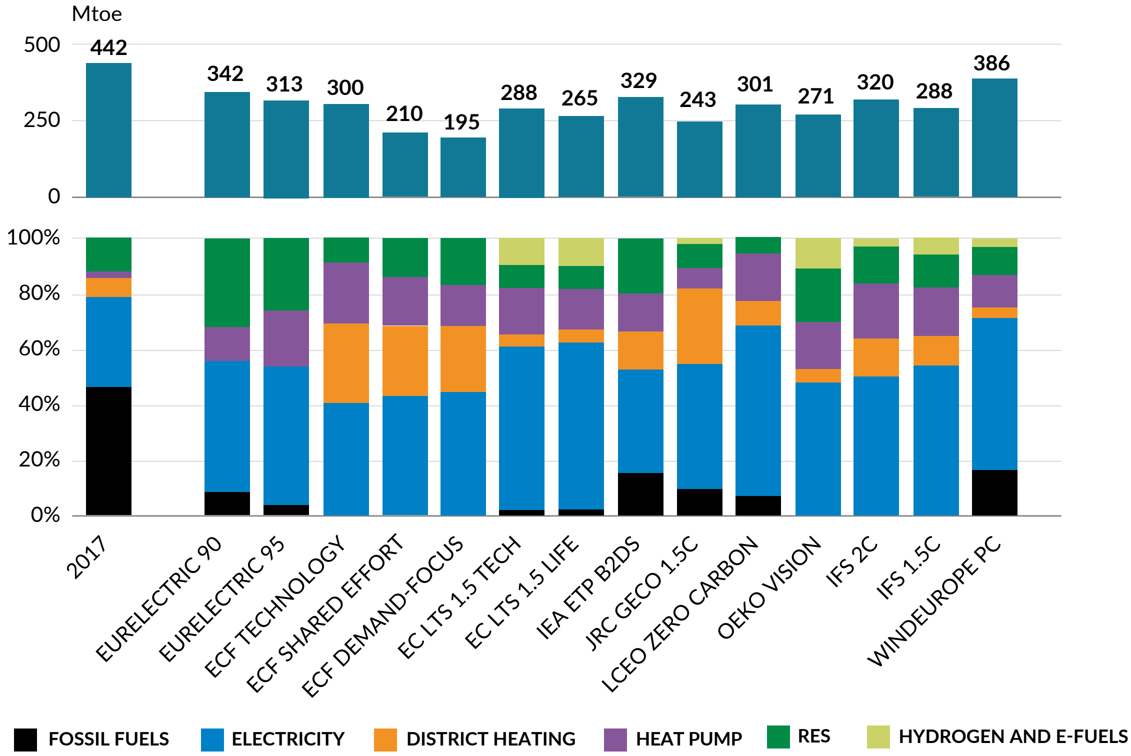
- electricity, where heat pumps allow for the use of renewable heat sources,
- local biomass and biogas feeding small district heating networks,
- geothermal sources supplying low-temperature district heating networks,
- solar thermal in individual building heating and district heating,
- waste heat from technical processes,
- energy from municipal and industrial waste,
- green hydrogen from surplus electricity from renewable energy sources (RES) supplying cogeneration units.

All these technologies can be used in district heating. However, in the case of individual households, the choices will be narrower and limited to heating with electricity, solar energy and, to a small extent, biomass. Natural gas will gradually disappear, displaced by emission-free heat sources. It should also be remembered that, in the future, the energy standards for buildings will be much stricter than those today and primary energy consumption will fall by 60-80%. Under such conditions, energy from external sources will only serve to reheat buildings to maintain thermal comfort, not to provide continuous heat. The energy efficiency of buildings is therefore the foundation for a cost-optimal transformation of heating.

A comparison of decarbonisation scenarios for the EU, carried out by different research centres, shows a significant role for electricity for heating buildings. Analyses show that, in individual EU countries, between 10% and 35% of boilers or heating cookers (for oil, coal, and gas) must be replaced by emission-free heat sources by 2030 in order to achieve a 50% reduction in CO_2. The main replacement technologies will be heat pumps and district heating powered by low- or zero-emission energy[1]. If higher carbon reduction targets are adopted, the replacement rate will need to be even higher.

1 *Towards net-zero emissions in the EU energy system by 2050*, Joint Research Centre, 2020, https://publications.jrc.ec.europa.eu/repository/bitstream/JRC118592/towards_net-zero_emissions_in_the_eu_energy_system_-_insights_from_scenarios_in_line_with_2030_and_2050_ambitions_of_the_european_green_deal_on.pdf.

Figure 1: Final energy consumption and mix of heat sources in buildings in the EU-28, in scenarios achieving at least a 90% reduction of CO_2 emissions by 2050



Source: Joint Research Centre, 2020.

Electrification and energy efficiency will be the two main strategies for decarbonisation of the entire heating sector.

The process of decarbonising the economy will cause heating and the electricity system to be increasingly interconnected. On the one hand, the replacement of fossil fuels (primarily coal) with electric heating sources will increase the consumption of electricity coming from the national power system. However, heat pumps, due to their high process efficiency, will reduce this increase in demand more than other equipment such as combustion boilers or electric boilers. On the other hand, the use of electric heating devices may increase the flexibility of the demand side and thus strengthen the stability of national power system operation with a high share of variable RES (PV, wind farms). If heat consumers are rewarded for flexibility and provide demand response services, this will allow optimal use of the network infrastructure and avoid unnecessary costs of developing electricity networks. Therefore, the key to integrating electrified heating into the power sector is to take advantage of the thermal storage properties of buildings and manage the operation of heating devices smartly. In addition, remote control of heating devices in reaction to current conditions on the power system will make it possible to increase the use of RES on the system and avoid the costs of building new generation capacities and modernising power networks.

Flexibility in heating will allow for more stable operation of the national power system and increase the share of RES in electricity production.

- Highly energy-efficient houses are good heat accumulators, which allows heating devices to be switched off for a few hours during peak demand for electricity, without the residents losing heat comfort.
- Heat storage systems for heat pumps should be a standard solution in district heating and non-district heating.

2. Main conclusions and recommendations

Heat electrification is a major project that requires education, mobilisation of financial resources, and legislative changes. Below, we present the key actions that will accelerate this process, support the decarbonisation of heating, and improve air quality in Poland.

Reduce energy consumption of buildings

Improving the energy efficiency of buildings is the foundation for an effective transformation of heating, as it ensures that the costs of heating are minimised. An ambitious building strategy should be developed and implemented, with specific objectives for reducing final energy consumption for heating purposes and establishing standards for achieving them. Analyses carried out by Forum Energii[2] indicate the possibility of reducing the primary energy consumption of all existing buildings by 60-80% by 2050 compared to the current situation.

Phase out coal from heating

The development of clean heating technologies will not be possible without legally binding deadlines for banning the use of coal for heating purposes. Household heating in Poland, which uses low-quality coal and waste fuels, is not only a source of CO_2 emissions but also a source of toxic smog. Therefore, coal should be completely phased out of domestic heating by 2030 and district heating by 2035. Adopting these targets will allow the whole sector to be on the path to full decarbonisation by 2050.

Integrate district heating with the national power system

Heating devices powered by electricity can support national power system balancing due to their ability to work flexibly. Intelligent control of heat sources and use of heat storage systems can make production independent of current heat demand and adapt it to the current needs of the power system. This will strengthen the stability of grid operations throughout the entire power system. This is particularly important due to the growing trend of energy production from variable RES.

Promote electric heating devices

The development of flexible electricity tariffs will generate real cost savings for consumers using electric heating devices. Moreover, demand control (DSR) of many users of heating devices will reduce the costs of balancing power system operations, while bringing in additional revenue from the new system service.

When designing new buildings, it is important to remember the EU objective of climate neutrality in all heating and cooling. Already in the coming years, buildings put into service should be powered by zero-emission heat sources. This will avoid future expenditures for the modernisation of heating systems. However, in the case of existing facilities, it will be necessary to replace the source of heat with zero-emission systems and to adapt internal installations. This will incur additional costs, so it will be necessary to implement appropriate aid programmes for building owners.

2 *Clean heat 2030* | *Strategy for heating*, Forum Energii, 2019, https://www.forum-energii.eu/en/analizy/czyste-cieplo-2030.

Heating as a service—have heating companies install heat pumps

The RES Directive indirectly imposes an obligation on heating companies to increase the share of RES and waste heat supplied heat by 1.1 to 1.3 percentage points per year. To meet the obligations, district heating companies may extend their activities to include the installation of heat pumps for individual customers, e.g., in the ESCO formula (ESCO - Energy Services Company, remunerated by savings on energy costs). The production of heat by the installed devices should be counted towards the required annual increase in the share of energy from RES in the district heating company. This will expand the operating activities of the enterprises and accelerate growth of the share of energy from RES in the national balance sheet. Moreover, the professional operation of numerous heating companies may lead to economies of scale, allowing for the standardisation of devices, a reduction of production costs of heat pumps (CAPEX), and thus the cost of house heating. Such a service could be used by households that do not have the possibility to connect to the heating network and by buildings constructed in areas not served by district heating networks.

Change the factor of non-renewable primary energy W_i

The technical conditions for buildings in force since 2021 will result in restrictive energy requirements for new and modernised buildings. Meeting them requires, in many cases, the use of renewable energy sources as renewable heat in buildings. A solution could be to install heat pumps that provide renewable heat. However, their use depends on the size of the W_i factor used to calculate the energy consumption of a building. The value of the coefficient, which is derived from the “coalification” of the production mix in the National Power System, has not been updated for years, which is to the detriment of electric heating technologies. Taking into account the constantly growing share of energy from RES in the national power system, the size of the W_i coefficient should be reduced and updated to give a stronger stimulus to the heat electrification process. Expert calculations indicate that it should have a value no greater than 2.5. Today, it is 3.0.

Ensure competitive balance in the heating equipment market

The ETS (CO_2 emissions trading system) does not, in principle, cover heating equipment below 20 MWt used for individual heating. However, electric heating devices (including heat pumps) participate in the ETS indirectly, as they use electricity from the national power system, the price for which includes CO_2 costs. This inflates the operating costs of such devices compared to gas or coal boilers, for example. Therefore, it is necessary to achieve a level playing field in the heating equipment market. This can be done through an appropriate tax policy, such as reducing VAT for installations with a lower impact on the climate and environment.

Encourage the wide-spread use of low-temperature heat

The efficient use of heat pumps, renewable energy (solar, geothermal) and waste heat from technical processes requires a reduction in the temperature of the heating medium. The lower the temperature, the more of that cheap primary energy can be used. Consideration should therefore be given to making it compulsory to design heating installations in new buildings with water temperatures no higher than 55^{0}C or even lower. This will increase the efficiency of heat pumps and the share of heat from RES. Additionally, it is worth allocating a part of the subsidy pool, e.g., in the Clean Air Programme, to the modernisation of internal installations enabling the reduction of the heating agent temperature.

Strengthen R&D activities

Heat pumps appeared on the Polish market about 50 years ago, in the 1970s. Their mass commercialisation took place 20 years ago. It is therefore a relatively young industry that benefits from the progress made in the areas of efficiency, mechanics, hydraulics, and IT. To meet the new challenges requires a combination of scientific and industrial potential. Poland has industrial capital in the form of many innovative companies with experienced scientific staff. It is worth using these national resources to develop products that could become an export commodity creating high-margin jobs.

Increase public awareness and expertise

The electrification of district heating can be accelerated if the awareness of its benefits among potential investors increases. It may be particularly economically attractive for households to use a heat pump and its installations for heating and cooling their homes. However, it is necessary to create an advisory network at the municipal level to support residents with technical, organisational, and economic knowledge in this area.

Rapid progress in the technological development of heat pumps also requires building designers and installers to stay abreast of the latest knowledge. Meanwhile, there is currently no national educational programme in this area. There are too few technical schools and universities dedicated to heating technologies. Therefore, a barrier to the development of heat pump technology in Poland may turn out to be less a lack of equipment on the market but rather a shortage of qualified staff. Appropriate training programmes should therefore be created and specialist education should be provided.

Establish financing mechanisms for electrification of district heating

A significant barrier to low-carbon heating for an average household is the lack of sufficient capital resources to carry out deep thermal modernisation of the building and change the heating source. In addition to the existing subsidy programmes and tax relief, new mechanisms supporting the transformation of the heating system should be sought. These may include developing ESCO services, tax incentives, dedicated energy tariffs, and the like. Poland can also take advantage of the funding provided through the EU Recovery Fund for the development of low-emission heat sources.

3. Policy developments relevant for heat electrification

Work is speeding up on translating the goal of climate neutrality in 2050 into specific legislative initiatives at the EU level. Ambitions for the 2030 goals are also increasing, as presented by the European Commission in their *Impact Assessment on Stepping up Europe's 2030 Climate Ambition* (Table 1).

Table 1: European Union's 2030 objectives: current state and proposals by the European Commission

Objectives	Current objective	Proposal for amendment
Reduction of greenhouse gas emissions compared to 1990	40%	55%
Energy efficiency improvements compared to the 2007 forecast	32.5%	39-40%
Share of renewable energy sources in gross final energy consumption	32%	38-40%

Source: *Impact Assessment on Stepping Up Europe's 2030 Climate Ambition*, 2020.

The European Commission points to the leading role of buildings on the way to climate neutrality and the reduction of greenhouse gas emissions. At EU level, as many as 75% of buildings are energy inefficient, which contributes to increased fuel consumption and environmental pollution. Currently, only 1% of buildings in the EU are thermally upgraded every year[3]. To meet the targets set for 2030, the renovation rate must be tripled. The European Commission is preparing a process to revise relevant directives and sub-targets as part of the EU's "Renovation Wave". The policy package contains a number of legislative initiatives that will lead, among other things, to an improvement in the energy efficiency of buildings and an increase in the share of heat from renewable sources. In addition, the package envisages closer integration of individual heating systems with the power system. In its strategy for sector integration[4], the European Commission talks about the leading role of heat pumps in the building sector. Managing the operation

3 https://eur-lex.europa.eu/resource.html?uri=cellar:749e04bb-f8c5-11ea-991b-01aa75ed71a1.0001.02/DOC_1&format=PDF
4 https://ec.europa.eu/energy/sites/ener/files/energy_system_integration_strategy_.pdf

of many heat pumps, depending on the situation in the Polish power system, will allow for an increase in the share of energy from RES variables in the future and, at the same time, for more stable operation of the energy system.

Extending the European Emissions Trading System to the buildings sector

An important instrument for the implementation of climate policy in the European Union is the Emissions Trading System (EU ETS). Until now, this tool has been associated with the energy sector and the largest players in the energy and fuel markets. In the next decade, however, attention will be redirected to the end of the energy transformation chain, i.e., to end users. As part of revising the ETS Directive, the European Commission is currently considering expanding the EU ETS to include the entire building sector.

The European Commission points to possible solutions such as:

- extending the ETS to more sectors,
- establishing an emissions trading system for the buildings sector, separate from the ETS,
- setting a mandatory price for CO_2 emissions (e.g., application of a carbon tax).

If adopted, the extension of the ETS to the buildings sector would result in the loss of fossil fuels' privileged position as individual heating sources from the lack of the burden of environmental costs.

The second direction of change is to accelerate the reduction of CO_2 emission allowances on the market. As a result, allowance prices could rise to EUR 76 in 2030[5]. This means a threefold increase from current prices, likely making the use of fossil fuels unprofitable. These measures are intended to support the achievement of the EU's ambitious climate change targets.

Integrating Heating with the energy system[6]

In July 2020, the European Commission adopted its Sector Integration Strategy. This document sets out the path of development, among others, for the heating sector. Electrification will pave the way for changes in the way heat is generated. Electricity used for heating is to be produced from renewable sources. The European Commission assumes that heat pumps will be the key technology that will allow for the integration of systems. In 2030, about 40% of residential buildings and 65% of commercial buildings are to be equipped with heat pumps. In 2050, this will be 50-70% and 80%, respectively[7].

The strategy for linking sectors is based on three pillars:

- energy efficiency and the use of local energy resources,
- electrification of the building and transport sectors,
- clean fuels (green hydrogen, biofuels, biogas—where electrification is difficult).

More RES in heating

Large reductions of CO_2 emissions are not possible without, at the same time, increasing the share of RES in the energy system. The share of renewable sources is expected to increase in 2030 from the existing target of 32% to as much as 38-40%. It is necessary to carry out this shift to lower emissions and higher RES in the district heating sector faster than the rates foreseen in the current provisions of the RES Directive[8] (1.1%-1.3% y/y). This is a great challenge for heating companies, but also an opportunity to expand and add new business activities in the area of buildings that

5 *Zmiana celów redukcyjnych i cen uprawnień do emisji wynikająca z komunikatu „Europejski Zielony Ład"*, Krajowy Ośrodek Bilansowania i Zarządzania Emisjami, 2020, https://www.kobize.pl/pl/article/life-climate-cake-pl-aktualnosci/id/1642/zmiana-celow-redukcyjnych-i-cen-uprawnien-do-emisji-wynikajaca-z-komunikatu-seuropejski-zielony-lad.

6 *Powering a climate-neutral economy: An EU Strategy for Energy System Integration, European Commission, 2020*, https://ec.europa.eu/energy/sites/ener/ files/energy_system_integration_strategy_.pdf.

7 https://ec.europa.eu/energy/sites/ener/files/energy_system_integration_strategy_.pdf

8 Directive 2018/2001 of the European Parliament and of the Council of 11 December 2018 on the promotion of the use of energy from renewable sources.

are beyond the traditional reach of district heating networks (e.g., the aforementioned installation of heat pumps to meet the required objective of increasing the production of heat from RES).

Improving energy efficiency

Achieving the objective of reducing CO_2 emissions requires improving energy efficiency throughout the entire value chain, from primary energy source to end user. Therefore, in the European Commission's view, the reduction of energy consumption (compared to the 2007 forecast) must increase from the current target of 32.5% to 39-40%. Mass building energy renovation, with particular emphasis on the most energy-intensive buildings, is to be at the heart of the measures. All steps taken should be based on the principle of 'energy efficiency first', taking full advantage of cost-effective energy savings in buildings. Amendments to the Energy Efficiency Directive (EED[9]), the Energy Performance of Buildings Directive (EPBD[10]) and an appropriate framework for financing projects are supposed to deliver the required step-change in building renovation.

Decarbonising buildings

The EPBD sets the objective of decarbonising buildings in the European Union. According to it, all new buildings from 2021 must have almost zero energy consumption. The directive also introduces the obligation to develop national long-term strategies for renovating buildings. It is expected that the annual rate of renovation will increase to 3% of the total national rate for renovating the building stock. It will also be necessary to set a minimum level of energy efficiency for buildings undergoing renovation. A consequence of the directive is the need to increase the flow of thermal energy from low-emission sources for buildings put into operation from 2021. The revision of the directive is intended to strengthen the role of energy efficiency certificates, lead to the spread of building automation systems, and implement requirements for the development of nearly zero-energy buildings.

4. Energy efficiency as a priority

As explained above, decarbonisation of heat will require significant improvements in the energy efficiency of buildings. Analyses indicate that there is significant potential for reducing the final energy consumption of buildings in Poland[11]. There is much to be done in the single-family house segment[12] In particular. Thermomodernisation of buildings will reduce emissions, as the demand for heat will be reduced and the efficiency of heating systems will also improve[13]. It will also increase the heat storage capacity in buildings, thus ensuring greater flexibility of the heating system. Additionally, large-scale heat storage (e.g., underground heat accumulators) may complement the heating systems. This increases the system's ability to absorb surplus heat energy and, at the same time, improves the flexibility of the heating system, thus supporting the operation of the national power system.

Experience shows that environmental, energy, and economic objectives can be achieved more effectively and at lower cost if the policies and regulations delivering on them are focused on both supply-side and demand-side solutions. Prioritising energy efficiency where it is socially more cost-effective will achieve more added value than investments focused solely on the generation side and energy and fuel infrastructure[14]. This philosophy of action has been adopted in other countries through the 'energy efficiency first' principle. It is also a central pillar of European energy and climate policy.

9 Directive 2018/2002 of the European Parliament and of the Council of 11 December 2018 amending Directive 2012/27/EU on energy efficiency (EED Energy Efficiency Directive).

10 Directive 2018/844 of the European Parliament and of the Council of 30 May 2018 amending Directive 2010/31/EU on the energy performance of buildings and Directive 2012/27/EU on energy efficiency (EPBD Energy Performance of Buildings Directive).

11 *Financing renovation of buildings in Poland*, Buildings Performance Institute Europe, 2018, http://bpie.eu/wp-content/uploads/2018/06/merged-1.pdf.

12 *Energy efficiency in Poland*, Institute of Environmental Economics, 2018, https://ibs.org.pl/app/uploads/2018/04/KK_IES_Przeglad2017_EN_160x230mm_2018_06_28_web.pdf.

13 Most heating systems can operate more efficiently at lower flow temperatures. This applies to both fossil fuels and heating systems based on renewable fuels.

14 R. Cowart, *Unlocking the promise of the Energy Union: "Efficiency first" is key*, Brussels 2014, https://www.raponline.org/knowledge-center/unlocking-the-promise-of-the-energy-union-efficiency-first-is-key/.

Numerous studies have been conducted on the ideal technology mix for decarbonising heat. Most, if not all of them, agree that, without energy efficiency, the total cost of decarbonising heat will be significantly higher. Energy efficiency reduces heat demand, which in turn ensures a building can be heated at a lower cost through a heating system with a smaller capacity. Reducing heat demand also delivers substantial cost savings for additional generation capacity if all or a large part of heat is electrified.[15]

In 2019, the International Energy Agency (IEA)[16] published a report on the critical role of buildings in the energy transformation that identifies three main strategies:

- To create sufficiency by avoiding unnecessary energy demand and technology investment through strategic planning, building design and energy technology measures that address the underlying need for energy use. These measures should at least maintain or even improve service levels in buildings.
- To deliver radical advances in energy efficiency through building fabric improvements and efficient appliances.
- To deliver decarbonisation by replacing carbon-intensive technologies with high-performance, low-carbon solutions.

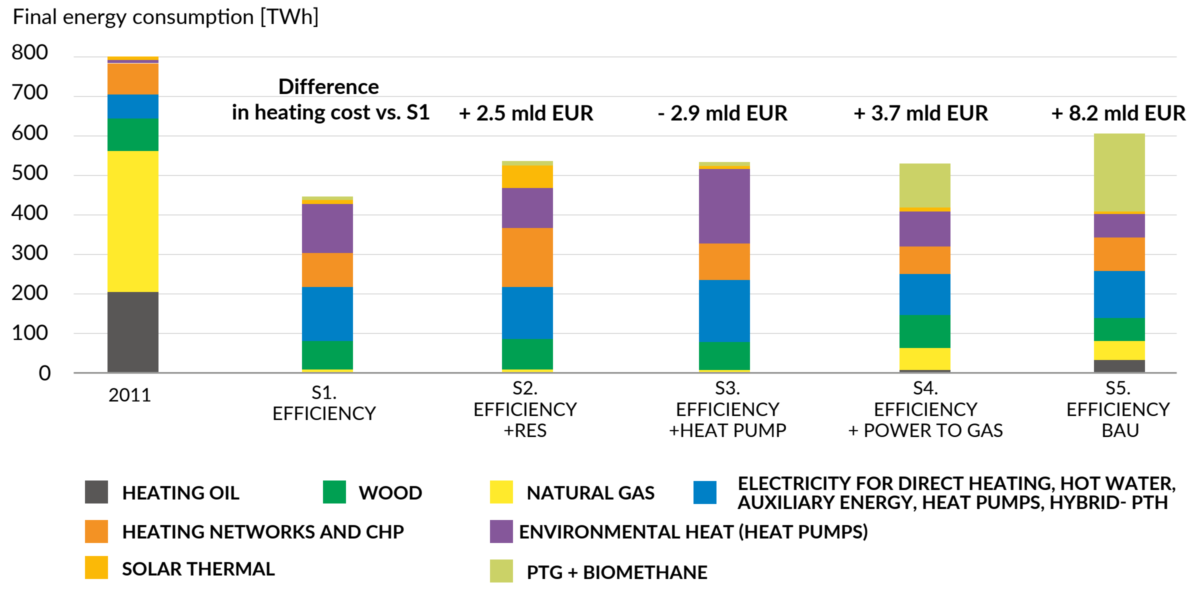
Adoption of the above strategies will make it possible to avoid excessive energy consumption in buildings and to select appropriate generation sources without the risk of overinvestment, while maintaining a high level of thermal comfort. Less energy-intensive buildings enable more efficient operation of the heating network at lower temperatures of the heating medium. It also allows the use of low-temperature heat sources such as geothermal energy, solar energy, industrial waste heat, and large-scale heat pumps.

Eurelectric[17], an association for the electricity industry, recently presented a decarbonisation pathway from a European Union perspective. This analysis shows that energy efficiency can be the main source of reducing CO_2 emissions in buildings. The next step is to electrify heat with heat pumps. Heat Roadmap Europe's modelling[18] of the optimal balance between heat consumption savings and the supply of clean heat (in four EU countries—the Czech Republic, Croatia, Romania, and Italy) shows that by improving energy efficiency, final energy consumption can be reduced by up to 50% in some countries. It is also recommended that the remaining heat demand should be met by low-carbon sources such as district heating and heat pumps.

These findings are mirrored by national studies. For example, a study commissioned by Agora Energiewende[19] also presents insightful results. It compares several scenarios leading to climate neutrality in Germany's heat supply by 2050, differing in the degree of energy efficiency improvement and the technological mix of the heat sources used. The results of the analysis showed that, in a scenario in which the predominant energy supply option is heat pumps (S2), the annual cost of heat supply is EUR 2.9 billion lower than in the reference scenario (S1. Efficiency). The most expensive scenario turned out to be the one that assumed maintaining the current rate of building renovation and using large amounts of green hydrogen and biomethane (S5) to achieve the environmental targets.

15 Eyre, N., & Baruah, P. (2015). Uncertainties in future energy demand in UK residential heating. *Energy Policy*, *87*, 641-653.
16 *The Critical Role of Buildings*, IEA, France 2019, https://www.iea.org/publications/reports/PerspectivesfortheCleanEnergyTransition/.
17 *Decarbonisation pathways*, Eurelectric, Brussels 2019, https://cdn.eurelectric.org/media/3457/decarbonisation-pathways-h-5A25D8D1.pdf.
18 Hansen et al., 2016.
19 *Building sector Efficiency: A crucial Component of the Energy Transition, Fraunhofer IEE I Consentec*, Agora Energiewende, Berlin 2018, https://www.agora-energiewende.de/en/publications/building-sector-efficiency-a-crucial-component-of-the-energy-transition/.

Figure 2: Change in heat consumption of buildings in the 2050 scenarios (vs. 2011) and the difference in annual cost compared to the reference scenario (S1) in Germany



Source:Agora Energiewende, 2019.

5. The benefits of heat electrification

The choice of the right heating technology depends on many factors. Social, environmental, and economic aspects and its impact on the energy sector must be taken into account. In order to identify the optimal technology mix and clean heating strategy for a given country, the following criteria need to be taken into account:

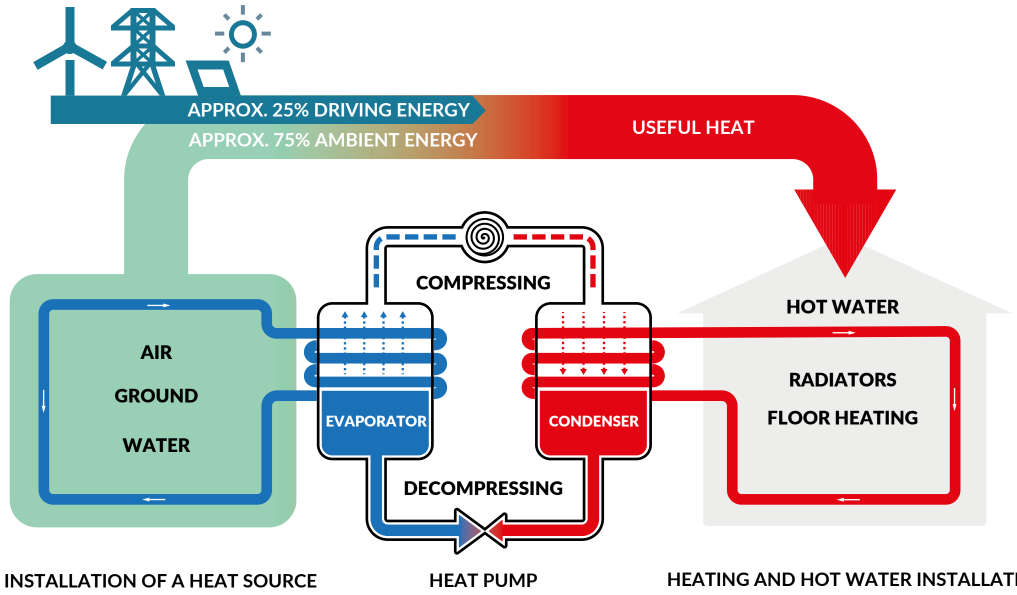
- ensuring high energy efficiency of the heat generation process,
- minimising the cost of domestic clean heating,
- reducing the environmental and climate impact,
- taking advantage of the potential for integration of heating into the national power system and balancing the impact of variable RES,
- exploiting the high growth potential of clean heating technologies and increasing market demand,
- using economies of scale to improve market competitiveness,
- focusing on well-established technological solutions and, at the same time, tapping into the great potential for innovation.

Of the many existing heat generation technologies, in principle, only compressor-based heat pumps fully comply with these criteria. The trends in the number of pumps installed indicate that the market is beginning to appreciate the advantages of this type of heating in households.

Heat pumps are heating devices powered by ambient heat. The energy source can be waste heat, surface water, ground heat, or air.

Compressor heat pumps are most commonly used. The driving force for transporting heat from the environment to the internal heating system is electrical energy. Ambient heat is a generally available, renewable resource, so it is not included in the energy consumption balance. The efficiency of these devices is determined in relation to the electricity used. In practice, 3 to 5 times more heat energy is obtained than electricity drawn from the power system. In the case of solutions using heat and cold at the same time, this value can reach a range of 6 to 8 units. High efficiency of the device translates into low operating costs.

Figure 3: Diagram of heat pump operation



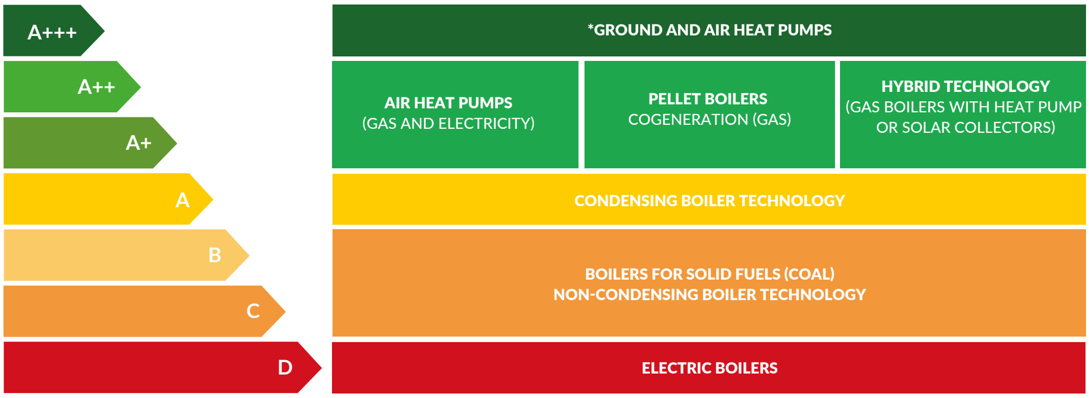
Source: PORT PC.

Efficiency of heating sources

A tool for comparing the efficiency of heating devices (up to 70 kW heating power) are energy labels. Labelling heating appliances allows consumers to compare the energy consumption of different heating systems. The least efficient appliances are marked in red (class D) and the most economical in green (class A+++). According to the announcements of the European Commission and the European Parliament, only heating devices using RES (of classes higher than A+)[20] will be supported.

20 *Mapa drogowa dotycząca przygotowania i wdrażania studiów wykonalności inwestycji badawczo-rozwojowych i innowacyjnych (ang. Business Technology Roadmaps – BTR) dla branży producentów niskoemisyjnych urządzeń grzewczych do 2030 roku*, MPiT, 2019.

Figure 4: Energy classes of heating devices



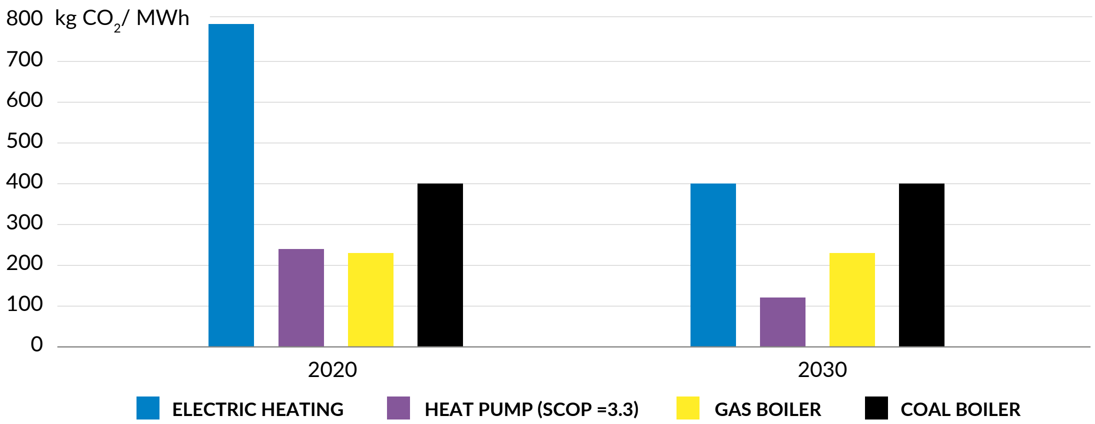
*Class A+++ 35°C from 2019 also for the best brine and air/water heat pumps.
Source: PORT PC, 2020[21].

Comparing the technologies of heating electrification, a significant difference can be observed between the energy class of heat pumps and electric boilers. Both devices are in extreme positions. An electric boiler, despite low losses in energy conversion (efficiency close to 100%), is powered by electricity, so its energy class reflects the national electricity mix. Meanwhile, heat pumps, processing ambient heat, are 3-5 times more efficient than conventional electric heaters. This is the most effective technology available for individual consumers.

Environmental benefits of heat pumps

In Poland, of the available heating technologies, heat pumps and gas boilers result in the lowest CO_2 emissions. Replacing coal boilers with heat pumps provides immediate benefits in terms of reducing dust, sulphur, and nitrogen oxides and carbon dioxide emissions. Given our current national energy mix, a house heated by a heat pump emits 40% less carbon dioxide than a house heated by coal. However, the CO_2 emissions of electric boilers are equal to those of the national power system, which translates into the highest carbon intensity among the available heating technologies. The planned development of renewable energy in Poland will result in a significant reduction in carbon dioxide emissions and lower the carbon intensity of electricity. This means that, in 2030, heat pumps will be even more environmentally friendly and also deliver higher carbon savings compared to gas boilers. The CO_2 emissions of heat pumps compared to coal and gas boilers will be 84% and 50% lower, respectively (Figure 5).

Figure 5: CO_2 emissions of heating devices depending on the share of energy from RES in the national power system

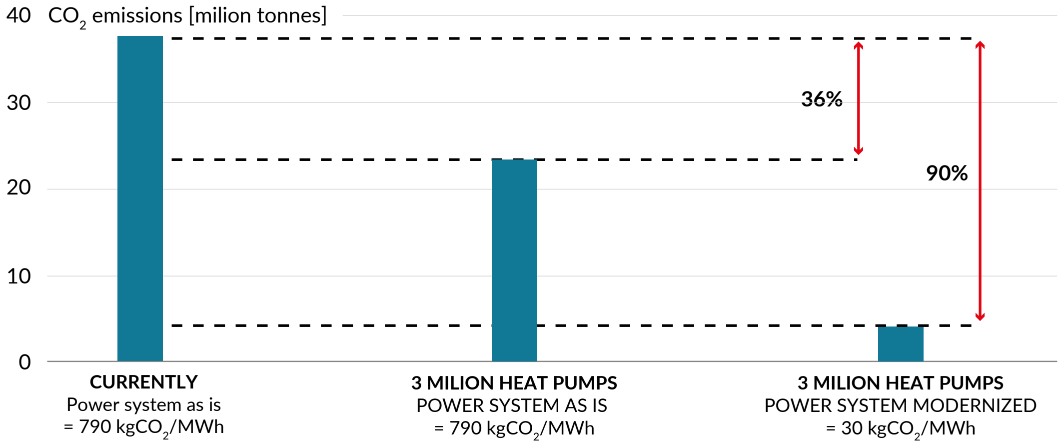


*CO_2 emissions taking into account the efficiency of heating systems.
Source: Own study based on PORT PC data

21 *Scenariusze elektryfikacji ogrzewania w budynkach jednorodzinnych w Polsce do 2030 roku*, PORT PC, 2020.

As mentioned above, just changing the power supply of a single-family residence from a coal-fired boiler to a heat pump reduces carbon dioxide emissions by about 40%. In Poland, there are about 3 million buildings heated by boilers and coal furnaces. Equipping them all with heat pumps would reduce annual national CO_2 emissions by about 13 million tonnes (i.e., 36% of emissions from buildings heated individually). This is a net result assuming the current mix of generation facilities in the national power system and an increase in CO_2 emissions due to additional production of electricity needed to drive heat pumps. Assuming the continuation of the national power system decarbonisation process, which is expected to lead to a reduction in electricity emissions equal to about 30 kg CO_2/MWh in the 2040s, the effect of replacing coal heating will be even greater, as annual CO_2 emissions will fall by about 32 million tonnes (i.e., by 90% compared to the current emissions from individually heated buildings). This shows how important it is to decarbonise the electricity sector and electrify district heating in parallel.

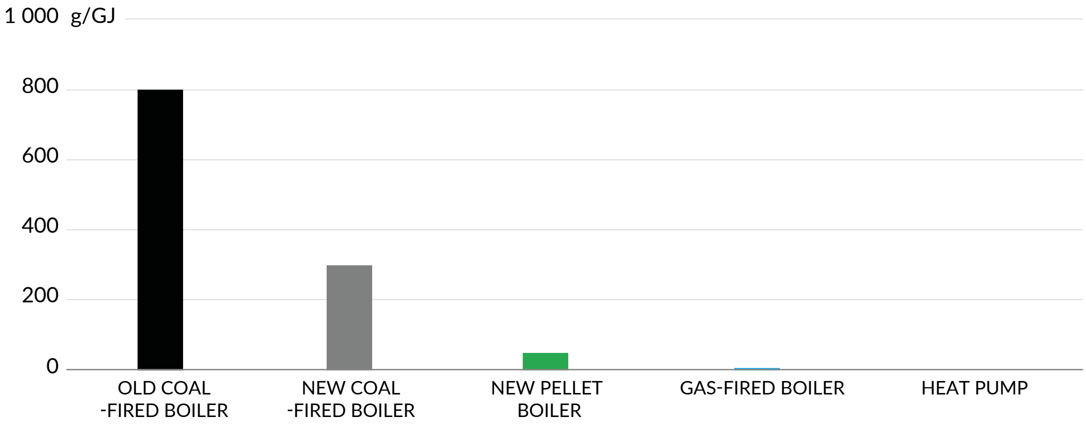
Figure 6: Current CO_2 emissions from households and emissions after the installation of 3 million heat pumps and after reduction of coal in the electricity mix



Source: Own study.

An additional benefit of heat electrification is it eliminates local emissions of air pollutants such as PM_{10}, $PM_{2.5}$, and B(a)P, which come from individual heating sources burning solid fuels. This is particularly important in areas struggling with high levels of smog.

Figure 7: Direct particulate emissions (PM_{10} and $PM_{2.5}$) from various heat sources



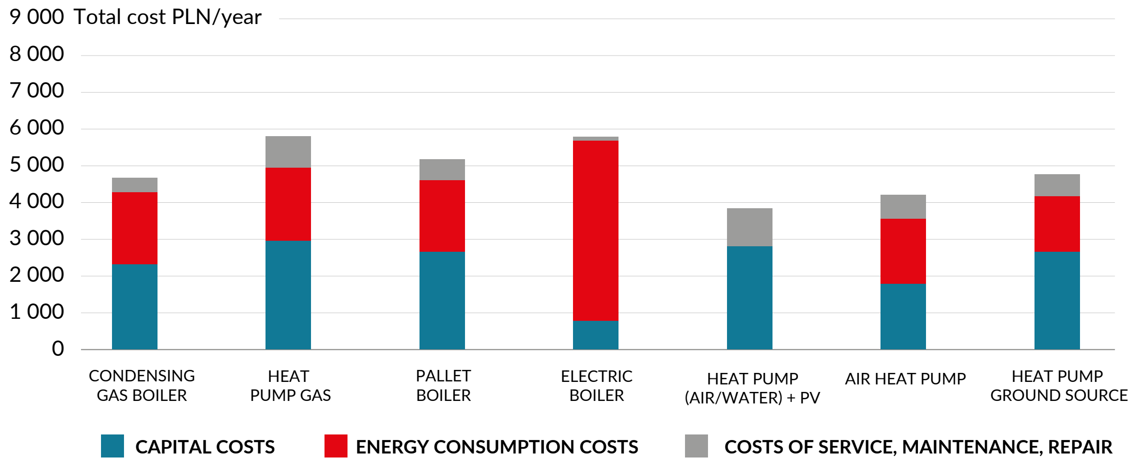
Source: NFOŚiGW.[22]

22 *Czyste Ciepło w twoim domu*, Narodowy Fundusz Ochrony Środowiska i Gospodarki Wodnej.

Heating costs

Looking through the lens of capital costs, the cheapest source of heat is an electric boiler. For a house with a floor area of 150 m^2, the installation of this type of boiler costs about PLN 6,000. However, unit operating costs (i.e., the cost of electricity) are quite high, which is why this solution may only be cost-effective in facilities with low heat demand[23]. Therefore, taking into account all the costs (investment outlay plus service and energy consumed), heat pumps, especially those coupled with photovoltaics, are much more advantageous (Figure 8). Although the upfront investment barrier of about 25-30 thousand PLN (without PV) is quite high from the perspective of the building owner, the possibility of obtaining co-financing from financial support programmes increases the attractiveness of the investment. It is also worth noting that trends in the technological development of heat pumps and photovoltaics indicate great potential for further cost reduction.

Figure 8: Total annual cost of heating a house using various heat sources



Source: PORT PC.

An additional and increasingly important advantage of heat pumps is the possibility to use them as cooling devices during the summer heat. Cooling can be provided by some heat pump technologies without investment in an air conditioning system.

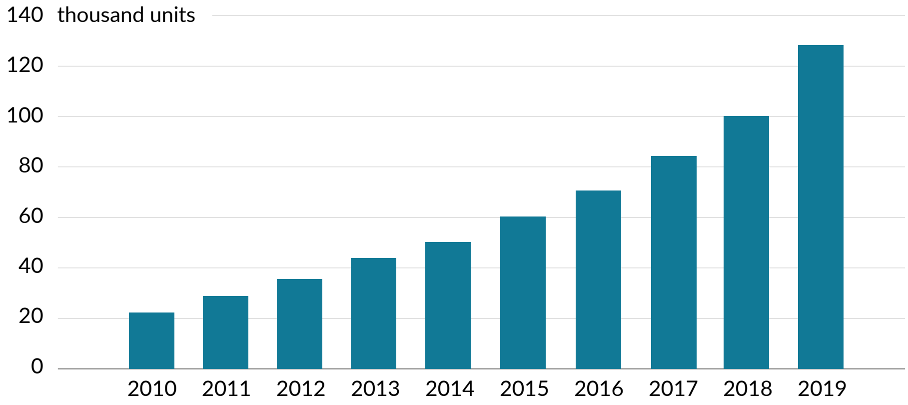
National market trends

The dynamics in the domestic heat pump market indicate the growing attractiveness of heat electrification. Poles increasingly choose a heat pump for space heating and as a source of domestic hot water in their homes. According to estimates by PORT PC[24] in 2019, almost a quarter of new single-family buildings use this technology. This is a huge increase compared to 3% of the market in 2011. This reflects the global trend towards electrification of heating. As energy demand from new buildings continues to drop, this will drive an even higher rate of heat pump use in new buildings going forward.

23 *Scenariusze elektryfikacji ogrzewania w budynkach jednorodzinnych w Polsce do 2030 roku*, PORT PC, 2020, https://portpc.pl/scenariusze-elektryfikacji-ogrzewania-w-budynkach-jednorodzinnych-w-polsce-do-2030-roku/.

24 *Rynek pomp ciepła w 2019 roku i w perspektywie do roku 2030*, PORT PC, 2020, http://portpc.pl/rynek-pomp-ciepla-w-polsce-w-2019-roku-i-w-perspektywie-do-roku-2030/.

Figure 9: Total number of heat pumps installed in Poland



Source: PORT PC.

However, despite the significant growth of installed heat pumps, Poland is still in the initial phase of using this technology compared to other EU countries. Almost 14 million pumps are already operating in Europe. With 11.8 heat pump units installed per 1,000 households, Poland is 18th among the 21 European countries covered by the EHPA (European Heat Pumps Association) study.

It is worth noting, however, that the largest Polish companies in the heating sector that produce boilers for solid fuels are changing to the production of low-emission heating appliances, such as heat pumps or waste-heat recovery systems. This is an indication of a growing trend and major change in the market. The National Renewable Energy Action Plan[25] published in 2010 assumed the amount of energy from heat pumps to reach 4.94 PJ/year by 2020. This forecast has been surpassed by a factor of two and actual energy delivered via heat pumps is equivalent to 9.92 PJ/year[26].

According to PORT PC analyses, in 2030, 1.5 million heat pumps may be used for central heating in Poland. This will make it possible to produce about 60 PJ of heat from RES, i.e., almost twice the current heat flow from renewable sources in district heating systems.

Rozwój pomp ciepła niesie ze sobą szereg korzyści w postaci poprawy jakości powietrza, wzrostu efektywności energetycznej oraz zwiększenia udziału energii odnawialnej w ciepłownictwie. Aby lepiej wykorzystać wymienione zalety i przyspieszyć rozwój tej technologii w kraju, potrzebne są odpowiednie działania legislacyjne, bodźce finansowe oraz edukacja społeczeństwa.

6. Integrating electrified heat into the national power system

Flexibility of demand is the essence of cost optimisation

Electrification of the heating sector in Poland means an increase in demand for electricity of 20-30 TWh by 2050[27]. Given the lack of a power transformation strategy, the challenge will be to adapt distribution networks to these additional loads and to ensure adequate generation capacity in the power system. The use of electric heating sources capable of responding to the current balance of energy supply and demand may significantly reduce the costs of power system operation and the costs related to the absorption of increasing amounts of energy from variable RES. The flexibility of consumers and effective demand-side management (DSR) reduces the need for peak capacity, and

25 https://www.ebb-eu.org/legis/ActionPlanDirective2009_28/national_renewable_energy_action_plan_poland_pl.pdf
26 Heating electrifiaction scenarios – PORTPC 2020 Raport https://portpc.pl/pdf/raporty/01-70_Raport_2020_P.pdf.
27 https://www.forum-energii.eu/pl/analizy/czyste-cieplo-2030

therefore reduces expenditure for power generation capacity and for the expansion and upgrade of power grids. It also reduces the operational cost of electrifying heating as it allows heating systems to be run at a lower cost — if time-of-use tariffs are coupled with the flexible operation of heating.

Demand management and flexible operation of heat pumps (in households and district heating plants) to react to fluctuations in load on the power grid enables an increase in the share of variable RES in the power system and reduces curtailment. Moreover, the flexibility of demand allows for an increase in the number of heat pumps installed without increasing the power capacity in the system (thanks to obtaining a low load factor from heating devices).

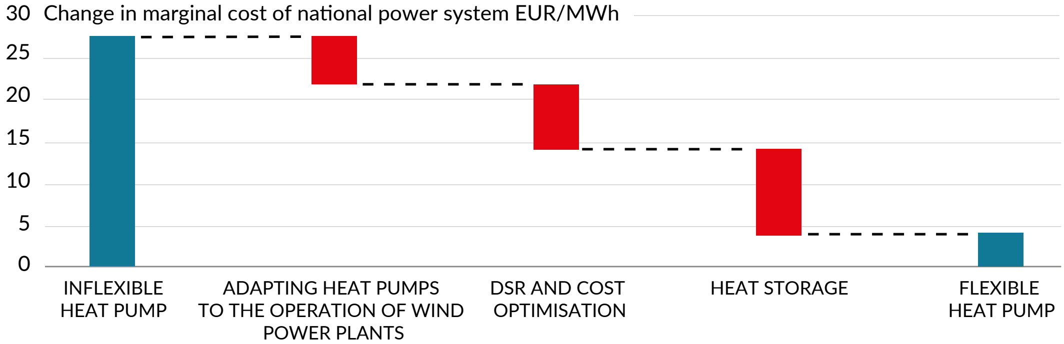
Recent analysis[28] has shown that the flexible operation of heat pumps in a system with a high share of wind energy significantly reduces the marginal electricity system cost of covering an additional MWh of the heat pumps' electricity consumption. This is for three reasons:

- First, the load from the heat pumps coincides relatively well with the production of wind energy, thus avoiding curtailment of wind farms.
- Second, flexible control of heat pumps enables cost optimisation while meeting the needs of both markets—heat and electricity.
- Third, the possibility of storing thermal energy and using the thermal inertia of buildings allows for cost-optimal operation of generation sources in the power system.

Taken together, the combination of wind power, system-friendly heat pump technology, and thermal storage can almost completely mitigate the additional costs of electricity consumed by heat pumps.

Modelling of the Danish power system has shown that the highest expenditure comes from the connection of inflexible heat pumps, as they create additional load that cannot be offset through demand response—this may be around EUR 27.5/MWh at the margin. However, if operation of the pump is matched to the supply of wind farms, costs are optimised, and energy storage is used, the incremental marginal cost can be reduced to just about 4 EUR/ MWh (Figure 10).

Figure 10: Marginal cost in the Danish power system as a result of connecting an inflexible heat pump and its change as a result of cost optimisation of heat production



Source: O. Ruhnau, L. Hirth, A. Praktiknjo, 2019[29].

In the past, most of the attention has been paid to the flexibility of electricity systems, leaving aside the flexibility potential of the heating sector. However, as the integration of both sectors increases, the importance of flexible heating becomes much more important. Heating systems that use electricity as the main or a significant source of energy can bring a number of benefits to the electricity system. These benefits fall into three groups (Figure 11):

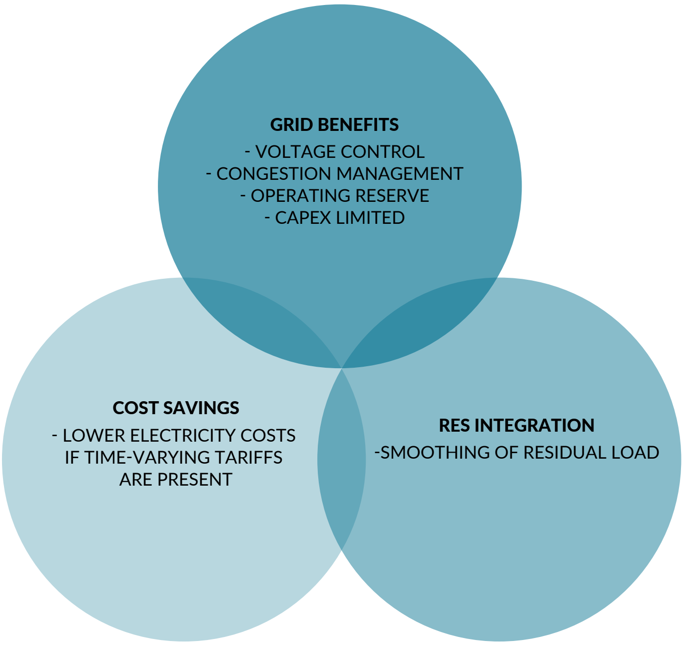
28 O. Ruhnau, L. Hirth, A. Praktiknjo, *Heating with wind: Economics of heat pumps and variable renewables*, Leibniz Information Centre for Economics – ZBW, Hamburg 2019.

29 O. Ruhnau, L. Hirth, A. Praktiknjo, *Heating with wind: Economics of heat pumps and variable renewables*, Leibniz Information Centre for Economics – ZBW, Hamburg 2019.

- benefits for electricity networks,
- lower heating costs,
- increases in share of RES on the power system.

In a system with a high share of variable RES, district heating networks and heat pumps operating in energy-efficient buildings may adapt their operation to the current situation in the national power system, thus reducing the system balancing costs. It should be emphasised that storing thermal energy contained in hot water or in the structure of buildings is much cheaper than storing electricity.[30] Analyses indicate that storing energy in the form of heat is 100 times cheaper in terms of capital expenditure per unit of storage capacity than storing electricity.[31]

Figure 11: Benefits of flexible heating



Source: D. Fischer, H. Madani, 2017[32].

Reduction of peak power demand in the national power system

Making the operation of heating devices independent of the current demand for heat is a necessary condition for reducing the peak load on the energy system, and thus also for reducing financial expenditure for new generation capacity and network modernisation. This will be achieved by improving the energy efficiency of buildings and the widespread use of heat storage facilities.

Heat stores and efficient buildings allow for flexible use of heat pumps. In other words, they are controlled by an energy aggregator, who switches them off for several hours during peak periods in the power system, without residents losing thermal comfort at any time of the year.

30 Zhai, Z., Abarr, M. L. L., Al-Saadi, S. N. J., & Yate, P. (2014). Energy storage technologies for residential buildings. *Journal of Architectural Engineering, 20*(4), B4014004.

31 Lund, H.et al. (2016) Energy Storage and Smart Energy Systems. International Journal of Sustainable Energy Planning and Management 11, pp. 3-14

32 D. Fischer, H. Madani, *On heat pumps in smart grids: A review*, "Renewable and Sustainable Energy Reviews" 2017, 70(C), 342-357.

Data on standard user practices in the UK show that if 20% of all buildings were equipped with heat pumps, this would increase peak loads by 14%[33]. To avoid such an increase in load, it is crucial to change the operating profile of heat pumps. It is therefore necessary for them to operate flexibly on a daily basis and to be optimised to meet both consumer preferences (i.e., a specific room temperature at a given time) and power system needs. Optimal operation of heating devices can be achieved to a greater extent through the use of heat storage. Heat storage devices can enable load management over the course of a day, with several hours of heat supply being stored, or seasonal storage of heat over a period of several weeks.

In many European countries, a significant number of heat pumps work with local hot water storage tanks[34]. The walls of the building and the hot water tank can be treated as a daily heat storage device. If buildings are upgraded to a higher energy efficiency standard, heat pumps can operate even more flexibly, which allows for further reductions in the peak demand for electricity. The volatility of energy prices and the growing need for flexibility and potential opportunities to provide system services for balancing the national power system indicate that investments in heat storage will be increasingly profitable.

Numerous examples show that the potential for flexibility on the demand side is high. Even without a hot water tank, pumps used in energy-efficient buildings can be switched off for several hours without affecting thermal comfort[35]. This is shown by examples from various European countries:

- Denmark – heat pumps can be switched off for 5 to 6 hours at an outdoor temperature of 5°C and 2 to 3 hours at an outdoor temperature of -12°C.
- Switzerland – heat pumps can be switched off in all houses for more than 6 hours, and in the best insulated buildings for up to 12 hours.
- Austria – the shutdown time for temperatures above -7°C is 5 to 10 hours[36].
- UK – standard construction of a building with a moderate level of insulation can maintain thermal comfort for 2 hours after switching off the heat pump, even without a storage tank.[37]
- Norway, Sweden, Denmark, Germany, and Austria–studies involving 80,000 customers indicate that the best insulated buildings can maintain thermal comfort for 5 hours without heating at an outdoor temperature of 0°C.[38]

Larger district heating systems also have great potential for flexibility.[39] It is possible to store the heat supplied to the district heating network in a heating medium or an additional heat store. It is also possible to use the thermal inertia of buildings as additional energy stores. All these elements are usually used for daily balancing of the district heating network.[40]

Figure 12 shows sample load curves on the energy system when there is a lack of flexibility of heating devices and when their operation is optimised for the current situation on the power system. Morning peaks reduce because of the use of wind energy over night to preheat buildings and evening peaks are reduced through the use of solar energy during the day.

33 In this study, some of the heat pumps analysed operated under the assumption that the house was heated continuously, while for others, the house was only heated at certain times when necessary. J. Love, A. Z. Smith, S. Watson, E. Oikonomou, A. Summerfield, C. Gleeson, R. Lowe, *The addition of heat pump electricity load profiles to GB electricity demand: Evidence from a heat pump field trial*, "Applied Energy" 2017, 204, 332-342.

34 D. Fischer, H. Madani, *On heat pumps in smart grids: a review*, Renewable and Sustainable Energy Reviews 2017, 70(C), 342-357.

35 Arteconi, N. J. Hewitt, F. Polonara, Domestic demand-side management (DSM): Role of heat pumps and thermal energy storage (TES) systems, "Applied Thermal Engineering" 2013, 51(1-2), 155-165.

36 A. Arteconi et al, 2013.

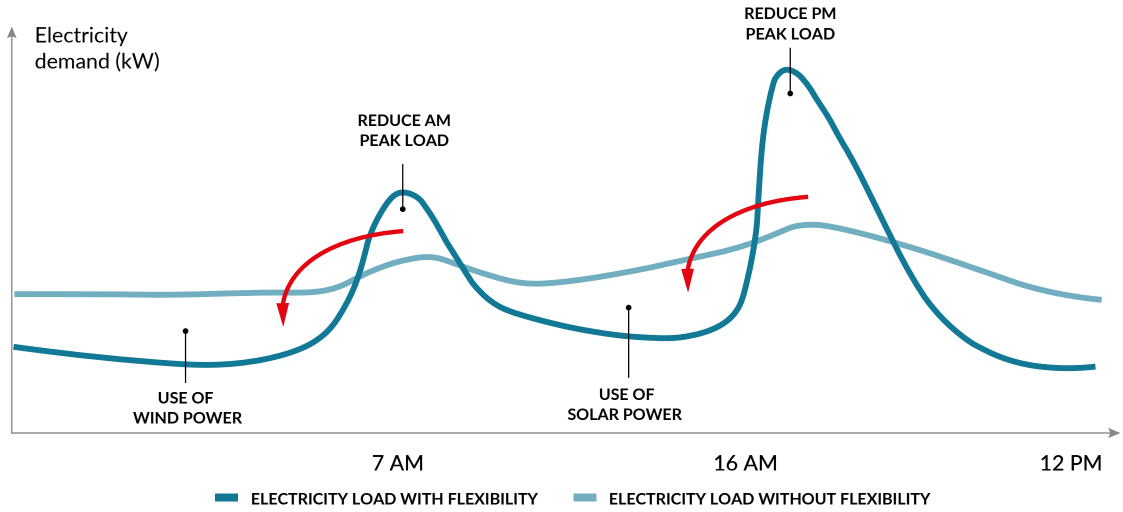
37 *IEA HPT Programme Annex: Heat pumps in smart grids; UK executive summary*, Delta Energy & Environment, Edinburgh 2018, https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/680514/ heat-pumps-smart-grids-executive-summary.pdf.

38 UK homes losing heat up to three times faster than European neighbours; https://www.tado.com/t/en/uk-homes-losing-heat-up-to-three-times-faster-than-european-neighbours/.

39 K. M. Luc, A. Heller, C. Rode, Energy demand flexibility in buildings and district heating systems – a literature review, "Advances in Building Energy Research" 2019, 13(2), 241-263.

40 Vandermeulen, B. van der Heijde, L. Helsen, Controlling district heating and cooling networks to unlock flexibility: A review, "Energy" 2018, 151, 103-115.

Figure 12: Flexibility of heat load



Source: Regulatory Assistance Project, 2020.

The extent to which flexibility from heating sources is needed and achievable depends on a number of factors, including daily and seasonal patterns of renewable energy production, energy performance of buildings, the availability of tanks for heat storage and the like. This also requires intelligent controls that operate the heat pumps in response to signals such as energy prices. However, the acceptance by building occupants of a flexible form of heating system operation is crucial.

Short-term heat storage

Storing energy in the form of heat can increase the current flexibility of the system in a more cost-effective way than storing electricity. Research is being carried out to improve heat accumulators. High expectations are associated with phase-change accumulators, which use materials that change their state of aggregation. This results in higher energy densities at a certain volume. Just like normal accumulators, they are charged with a heat pump or direct electrical heating during off-peak hours and discharged when heat is needed to heat the building. In the energy system, this reduces the power demand during peak periods is reduced. The only electricity consumption results from operation of the central heating pump, which is necessary for the circulation of water in the heating system. This uses a lot less energy, however, than the heating device itself.

Studies have shown that properties with a thermal storage system and heat pumps consumed on average 85% of electricity during off-peak periods, and only 15% during the on-peak period. This was done while maintaining the thermal comfort of households[41]. It is worth noting that thermal storage systems in many countries are still at an early stage of commercialisation. It can be assumed that with the ongoing technological progress and the reform of the electricity market (dynamic prices, possibility of providing balancing services), the popularity of these devices will increase. In some countries, the installation of heat accumulators is systematically supported. For example, Scotland and Germany provide dedicated financial support for investors who build them[42].

41 T. Shepherd, *Various heating solutions for social housing in North Lincolnshire: Ongo Homes*. Technical Evaluation Report. NEA Technical Innovation Fund. Newcastle upon Tyne, 2018, https://www.sunamp.com/wp-content/uploads/2019/04/CP780-TIF-REPORT-Aug-18-FINAL-1.pdf.

42 Heat batteries to be included in Home Energy Scotland loans, 2018, https://www.power-technology. com/news/heat-batteries-included-home-energy-scotland-loan-scheme/.

Seasonal thermal energy storage

In addition to short-term storage systems, there is a need for seasonal heat storage because of the significant seasonal variation in heat demand. Seasonal storage is more complex because a seasonal storage system requires access to a larger area and involves more complex construction work. However, seasonal heat storage is critical for the successful decarbonisation of district heating. Seasonal thermal storage devices allow for a reduction of electricity consumption by heat pumps during the period of increasing demand for heating in winter. In this case, the pumps work with the accumulator, usually acting as a supplementary source of energy, and thermal energy is drawn from the accumulator. The source of heat energy directed to seasonal accumulators can be solar farms, large-scale heat pumps, and cogeneration units.

Seasonal accumulators can be earthen storage tanks, deep wells, and underground water tanks. Large-scale accumulators are usually integrated within district heating networks[43]. In Europe, large-scale seasonal storage of thermal energy has been operating since the 1970s and the first pilot projects were caried out in Sweden[44]. One of the largest storage projects in the world are being implemented in Denmark[45].

Figure 13: Solar farm (20,000 m^2) with a heat accumulator

Source: Arcon Sunmark. Battery in Nykøbing Sjælland, Denmark.

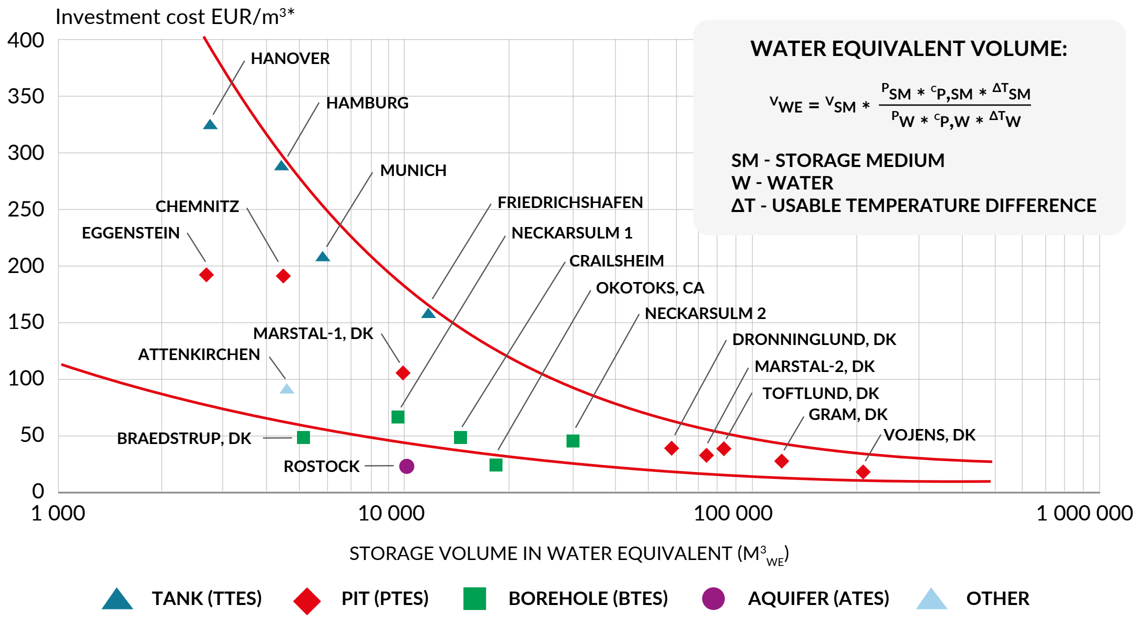
Depending on local conditions and technical solutions, the costs of storage technology can vary considerably. However, as the scale increases, the expenditure per unit of additional storage capital converges (Figure 14)..

43 T. Shepherd, *op. cit.*

44 D. Mangold, L. Deschaintre, *Seasonal thermal energy storage: Report on state of the art and necessary further R+D*, IEA: Solar Heating & Cooling Programme, Paris 2015, http://task45.iea-shc.org/data/sites/1/publications/IEA_SHC_Task45_B_Report.pdf.

45 P. Eames, D. Loveday, V. Haines, P. Romanos, *The future role of thermal energy storage in the UK energy system: An assessment of the technical feasibility and factors influencing adoption.* (Research report), London 2014, https://ukerc.ac.uk/publications/the-future-role-of-thermal-energy-storage-in-the-uk-energy-system/.

Figure 14: Unit investment expenditure of large-scale heat storage facilities



$$v_{WE} = v_{SM} * \frac{\rho_{SM} * c_{P,SM} * \Delta T_{SM}}{\rho_{W} * c_{P,W} * \Delta T_{W}}$$

*Course EUR of 2017.
Source: A.J. Kallesøe, T. Vangkilde-Pedersen, 2019 [46].

Seasonal green hydrogen storage

Green hydrogen is obtained by electrolysis using electricity from RES. In the future, once green hydrogen production technology is fully commercialised, this gas can be used in cogeneration units for district heating. Green hydrogen could support the needs of the national power system, while also producing heat for district heating. Supporting the national power system will be a priority, unlike at present when the operation of generating units is subordinated to the needs of heat consumers. Future temporary imbalances between heat supply and demand should be compensated by heat accumulators as much as possible.

The UK and the Netherlands, which have extensive gas distribution networks, have found that, in the context of the full decarbonisation of heat, a small share of hybrid systems may become economically viable[47]. Such a hybrid system would include a heat pump with less capacity than needed during the coldest day of the year and a peak load boiler based on zero-emissions gas. On cold days, which may coincide with high electricity demand, gas heating is used to supplement the heat pump. This reduces electricity demand and the heat pump capacity needed. However, for these systems to be zero-emission in the future, they need to be prepared for the use of environmentally-neutral gas, such as hydrogen or biogas (stored seasonally). The adoption of such solutions is a matter of a local economic analysis, examining the profitability of building a system that operates on the basis of two heating devices, a heat pump and a gas/hydrogen boiler. The bulk of heating needs would still be provided by electricity via heat pumps but, on the coldest days of the year, a back-up system provides supplementary heat. Hybrid systems are more expensive than a stand-alone heat pump because of the additional equipment needed. For this reason, it is likely that hybrid systems will play a relatively small role overall, and will only be deployed in areas with electricity network constraints where it is cheaper to deploy hybrid systems than upgrade the electricity network.

46 A.J. Kallesøe, T. Vangkilde-Pedersen (ed.), Underground Thermal Energy Storage (UTES) – state-of-the-art, example cases and lessons learned. HEATSTORE project report, GEOTHERMICA – ERA NET Cofund Geothermal, 2019.

47 Strbac et. al., and Government of the Netherlands, *Klimaatakoord (Climate agreement)*, The Hague 2018, https://www.klimaatakkoord.nl/ documenten/publicaties/2019/06/28/klimaatakkoord.

7. New business models

There are many potential business models that could be used for heat electrification. Below, we present the most important ones.

Dynamic electricity prices

Variable energy prices encourage customers to shift their electricity consumption from periods with high prices—and higher unit CO_2/MWh emissions due to the dispatch of increasingly carbon-intensive generation resources—to periods with lower prices and lower emissions) This means that dynamic tariffs create incentives not only to optimise heating and system costs, but also indirect incentives to reduce emissions[48].

Electricity tariffs may be designed to make the most efficient use of the existing energy system infrastructure. This will also make it possible to reduce the operating costs of district heating companies while reducing the costs of the electricity system. This is a situation that benefits all parties: energy companies, network operators, and final consumers.

Experience shows that customers are willing to shift their consumption to cheaper hours of the day if offered appropriate financial incentives. For example, in the electric car segment, research shows that price is crucial when vehicle owners decide to recharge their cars at home[49]. A recent UK study on the impact of variable prices on the behaviour of energy consumers showed that they shift around 70% of their energy consumption away from peak hours[50]. Similar behaviour can be expected in the area of electric heating.

Dynamic tariffs can have many forms. They start with simple solutions such as a daytime and night-time tariff or weekday and weekend tariff. The consumer pays a variable, pre-determined charge, the amount of which is based on historical energy consumption patterns, for specific periods of time. At the other end of the range of offers for consumers are real-time energy prices, determined on the basis of the prevailing conditions on the power system. Another emerging form of tariff is a discount during peak hours: Consumers who choose this tariff receive a partial refund if they avoid using electricity during peak hours, but are charged a uniform price, whether they consume electricity during peak periods or at other times of the day.

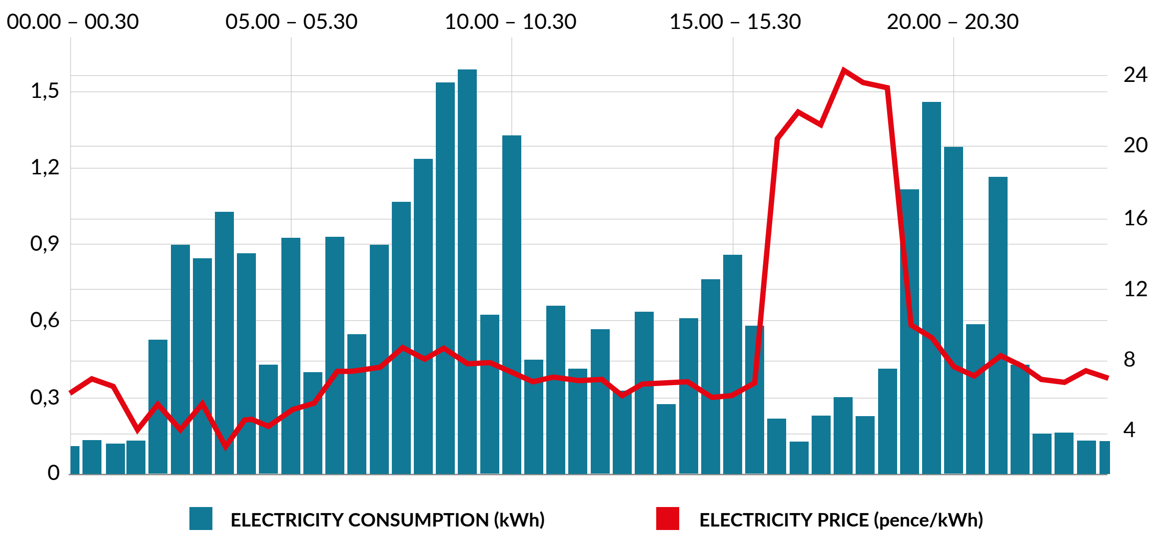
Here is one example of a tariff differential over time. The Octopus Agile tariff in the UK offers customers half-hourly prices. The supplier sets daily rates based on a formula that depends on the half-hourly wholesale electricity price. The company then communicates the rates to end consumers via a smartphone app every day at 16:00. This gives them enough time to plan their electricity use for the next day. A precondition for subscribing to this tariff is to have a smart meter that takes half-hourly consumption measurements and sends them to the supplier for billing. An additional function of the tariff is to inform the consumer when the selling price of electricity falls below zero. If customers consume energy during these periods, they are rewarded for it. Consumers can either plan their consumption profile manually or have messages sent directly to properly programmed smart appliances. Figure 15 shows the load profile of a household with a heat pump and Octopus Agile tariff over 24 hours. The low electricity consumption is clearly visible at the peak, when the energy price is highest.

48 Farnsworth, D., Shipley, J., Lazar, J., & Seidman, N. (June 2018). *Beneficial electrification: Ensuring electrification in the public interest*. Montpelier, VT: Regulatory Assistance Project. Source: https://www.raponline.org/wp-content/ uploads/2018/06/6-19-2018-RAP-BE-Principles2.pdf.

49 *Project report: Consumers, vehicles and energy integration*, Projekt PPR917, TRL, Berkshire 2019, https://trl.co.uk/ sites/default/files/CVEI%20D5.3%20-%20Consumer%20Charging%20Trials%20Report.pdf.

50 J. Hildermeier, C. Kolokathis, J. Rosenow, M. Hogan, C. Wiese, A. Jahn, *Start with smart: Promising practices for integrating electric vehicles into the grid*, VT: Projekt w ramach pomocy regulacyjnej, Montpelier 2019, https://www.raponline.org/knowledge-center/start-with-smart-promising-practices-integrating-electric-vehicles-grid/.

Figure 15: Example of time-varying tariff and load shifting of heat pump consumption



Source: Regulatory Assistance Project, based on Octopus Agile tariff data and energy consumer load profile, 2020.

It is not yet certain to what extent heat pump users will be willing to respond to dynamic pricing and whether they will shift their heat demand over time. This depends primarily on the construction of the entire heating system and the ability of the building to store heat. Experience from Denmark, which consists of testing automatic responses to price signals on the demand side (heat pumps), shows that consumers respond to these signals if the system is properly automated.

Danish eFlex project

In 2011-2012, DONG Energy Eldistribution carried out a trial project in which it tested consumer reactions to price incentives. The aim of the project was to identify the most effective incentives for heat pump users, triggering a demand-side response that would defer energy consumption and avoid network costs.

The households were equipped with a heating automation system with an integrated control unit that switched the heat pump off at periods of peak demand and turned it back on afterwards. Participants were able to set maximum break periods, minimum heat comfort levels and pre-set the parameters to be controlled by the automation. One of the parameters was the current energy price, another was the share of wind energy in the system. It was also possible to choose a parameter combining both factors.

Energy prices were based on three elements: Nord Pool's day-ahead wholesale electricity market prices, the 3-step grid tariff, and taxes and charges. The system also allowed users to bypass the automation at any time.

The results of the project have shown that there is considerable potential for managing the load on heat pumps. The reduction of peak power in the group of tested equipment was 30%.

The study confirmed that households respond to economic stimuli and are open to automation based on price signals. For only about 1% of the time, or approximately every 3 months, customers used the automation bypass function.

An appropriate pricing policy is an important element in the desired operation of heating devices. However, its effectiveness will be limited if it is not accompanied by technical solutions (such as automated load control systems) enabling customers to react easily and effectively to incentives. On the other hand, the implementation of sophisticated automation solutions and heating technologies will not bring benefits without dynamic energy prices. Experience to date shows that progress in both areas must be interrelated.

Heating as a service

Households normally pay for the amount of fuel used, such as kilowatt-hours of electricity or gas, litres of heating oil, and a fixed fee for using the infrastructure to maintain the desired indoor temperature. End users are concerned about thermal comfort and not about the type of energy, whether gas, electricity, or hot water from a district heating network. Meeting this expectation was the basis for a new approach called 'heat as a service', i.e., a model in which a household agrees with an energy service provider on a specific level of thermal comfort at a specific price[51]. Customers can decide what thermal comfort means to them, e.g., by choosing at which hours of the day they would like to have a given temperature in specific rooms. The energy service provider installs the heating system, operates it, and ensures the fulfilment of the customers' expectations in return for agreed charges.

This business model can be compared to a contract for unlimited broadband access in which the speed and reliability of the connection are agreed in the contract, but the amount of data used does not affect the cost. The customer is paying for a reliable and fast broadband connection.

The issue of ownership of heating equipment is also a contractual one. The energy service provider may be the owner of the heating system and apply a similar approach to leasing a car in which the customer agrees to the contract period and a fixed monthly payment, but the car is not owned by the customer at the end of the contract period.

The authors of this report are convinced that the business model of 'heat as a service', adopted by commercial heating companies, may become a basis for the dissemination of heat pumps in individual households. Many buildings will never be connected to district heating networks for technical or cost reasons, but they should still be of interest to these companies. The decommissioning of obsolete fossil fuel boilers and their replacement with heat pumps, offered under the ESCO formula, may be a significant extension of companies' operations and contribute to increasing the share of heat from RES, thus contributing to the national target.

The professional operation of heating companies and the economies of scale achieved in this huge market, which includes 3 million buildings, will translate into the standardisation of solutions, more advanced heat pump technologies and, finally, into lower capital expenditure, which will result in a lower price of the service offered to customers.

The updated strategy for district heating is expected to take into account the social, environmental and economic benefits of this type of business model and provide an incentive to develop appropriate legislative solutions dedicated to licensed district heating companies.

Currently, there are already some variants on the heat-as-a-service business models on the European market (Table 2). They can potentially be adapted to the specific situation in Poland.

51 *Heat as a Service: An Introduction*, Energy Systems Catapult, Birmingham 2019, https://es.catapult.org.uk/wp-content/uploads/2019/06/SSH2-Introduction-to-Heat-as-a-Service-1.pdf.

Table 2: Market models of district heating services

Business model	How does it work?
Asset Leasing	The service provider charges a fixed monthly fee for the lease of the heating device. The fee includes routine maintenance and repairs. Examples: • The Netherlands – the company Feenstra offers boiler rental. • Denmark – the company OK offers leasing of heat pumps.
Asset leasing with savings effect	Similar to the asset leasing, but with some efficiency guarantees. Example: • Denmark - Best Green reimburses customers for the cost of electricity used by heat pumps.
Energy payment plan	An alternative way of paying for energy that does not include the heating device. Examples: • UK - Energy Systems Catapult, a payment model for agreed heating hours or payment for customer-controlled energy consumption. • Spain – the company Naturgy offers combined energy supply and maintenance services for a fixed monthly fee.
Heat production as a service	The service provider leases the heating device and also supplies the fuel. Customers are charged per unit of heat generated. Examples: • Germany - Thermondo and Viessmann offer this kind of service with gas boilers.
Thermal comfort as a service	The service provider leases the heating device. Customers are charged for thermal comfort, not for the heat generated. Example: • The Netherlands – the company Eneco, using heat pumps, offers

Source: Delta EE, 2019 [52].

Balancing of the power supply system (through aggregators)

At the current level of heating and information technology (ICT), there is no way that individual households can become active participants in the energy market on their own. To enable them to provide system services such as energy balancing, intermediaries—such as aggregators—are needed to act on behalf of a group of households. An aggregator can benefit from distributed energy resources from a large number of consumers. The main advantage of aggregation is that it gives customers the opportunity to participate in different markets (e.g., electricity and gas) by gaining local flexibility, shifting load hours, and generating services that benefit the network and the electricity system as a whole. The role of aggregators is crucial for creating demand-side flexibility, especially in the building sector, as individual customers are usually small entities whose priority is to obtain reliable and cheap services with the least effort on their part.

52 *Heat as a service*, Delta EE, 2019, https://www.delta-ee.com/images/Infographics/HaaS_Infographic_Final.pdf.

The market for demand-side management services is still small and at an early stage of development, both in terms of technology and customer involvement. According to a recent study[53], the status of this market is as follows:

- The size of the EU household demand-side management market is less than 1.5 GW of electricity capacity. This is not much compared to conventional power generation and the asset base that can easily be used in the DSR service.
- 16 companies currently offer 30 commercial demand-side management projects for households in nine EU markets; another 30 trial projects are close to commercialisation.
- Today, Voltalis dominates the management of energy consumption in the residential market, controlling almost 1 GW of power.
- New technology platforms are being created that cooperate with existing aggregators and energy suppliers.

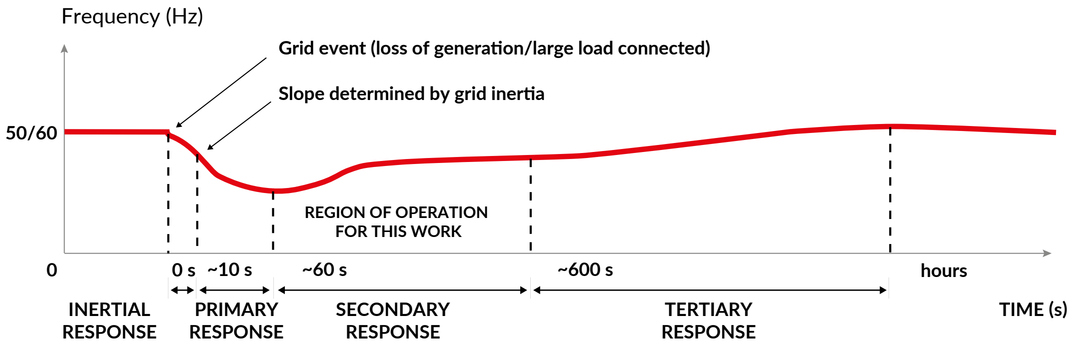
According to the International Renewable Energy Agency (IRENA)[54], residential aggregators usually only include distributed photovoltaics and energy storage facilities in their portfolio. Meanwhile, they have the ability to create demand-side flexibility from a much wider portfolio of residential assets, including power-to-heat solutions, electric vehicles or smart energy devices. However, this is still in the experimental phase.

We are convinced that the planned changes to the rules of the balancing market in Poland, which increase the number of groups of participants allowed to balance the system, will accelerate the development of DSR services.

In practice, there are three levels of power system response services (Figure 16). These are:

- Primary response, which is activated almost in real-time. It allows for automatic load adjustment, so that the frequency can be controlled within a few seconds of the interference.
- Secondary response, which is activated in a second step within 10 minutes and allows a return to the standard frequency value in the system.
- Tertiary response is activated in the next step, which maintains frequency stability for the longer time necessary to address the root cause of the imbalance in the system.

Figure 16: Types of response services



Source: State Grid Electric Power Research Institute, 2020.[55]

53 J. Hughes, Residential demand response: releasing great potential in the next 5 years, 2019, https://www.delta-ee.com/delta-ee-blog/residential-demand-response-releasing-great-potential-in-the-next-5-years.html.

54 Demand-side flexibility for power sector transformation, IRENA, 2019, https://www.irena.org/publications/2019/Dec/Demand-side-flexibility-for-power-sector-transformation.

55 Z. Wu, W. Gao, T. Gao et. al., *State-of-the-art review on frequency response of wind power plants in power systems*, Journal of Modern Power Systems and Clean Energy 2018, 6, 1-16, https://link.springer.com/content/pdf/10.1007/s40565-017-0315-y.pdf

Commercially active aggregators can offer secondary and tertiary response services using heat pumps[56]. This means that some kind of control over the operation of heat pumps is needed. There are two options in this respect:

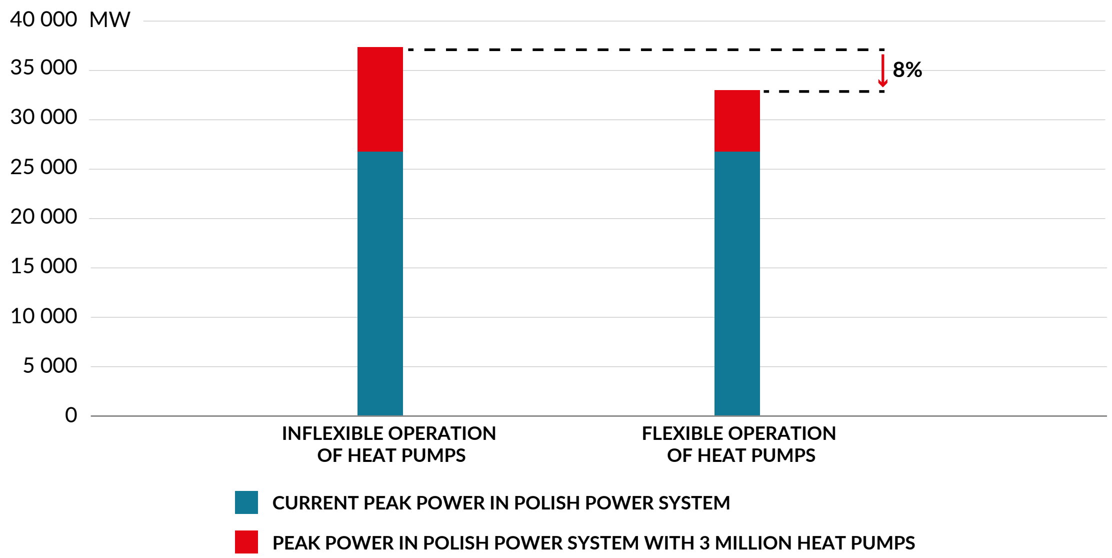
- Direct control, which consists of a compressor in the heat pump directly controlled by a signal from the generator. This type of control is faster and more accurate than indirect control. The main disadvantage is that the heat pump has to be prepared for external control, which is not possible for most currently manufactured pumps.
- Indirect control, which takes place mainly by controlling the heating temperature with a temperature sensor. In this way, the heat pump operation and power level can be influenced.

National flexibility potential of heat pumps (DSR)

Due to the lack of sufficient experience with demand-side management in district heating, as well as the initial phase of its electrification process and the development of heat accumulators, it is only possible to roughly estimate the benefits for the power system that come from the remote control of heat pumps.

For the purposes of this report, we assumed that 3 million detached houses in Poland would be equipped with a heat pump. This would increase the national power system peak load by about 10 GWe (assuming the maximum household demand is 3.3 kW). From the experience of the Danish Dong Energy eFlex project, it is known that about 30% of the heat load can be shifted by optimising the operation of heat pumps, without the loss of thermal comfort by the building's residents. Therefore, effective management of heat pumps can reduce demand for power by 3 GWe (up to 7 GWe), or 8% of total national power system peak power (Figure 17). This is such a large potential that it is worth striving for by preparing appropriate action plans and legislative solutions.

Figure 17: Reduction of peak power in the national power system as a result of heat pump operation management



Source: Own study.

56 Innovation landscape brief: Aggregators, IRENA, 2019, https://www.irena. org/-/media/Files/IRENA/Agency/Publication/2019/Feb/IRENA_Innovation_Aggregators_2019.PDF?la=en&hash=EB86C1C86A7649B25050F57799F2C0F609894A01.

8. Summary. What do we gain?

Heat electrification based on the use of energy obtained from renewable sources, although it seems a long way off, would allow Poland to take a huge step into the future.

Environmental and climate protection

Modernisation of buildings in Poland and electrification of heat will enable rapid improvement of air quality and, at the same time support, the process of decarbonising heating. The transformation of the entire individual heating system may completely eliminate the demand for coal from households and small consumers, which currently amounts to 12 million tonnes per year.

Increase in the share of energy from RES

Heat pumps should support national RES targets, as set out in the Renewable Energy Directive. Unfortunately, Poland did not achieve the target set by the EU for 2020, so efforts should be made to achieve the new target set for 2030. The greatest potential for energy from renewable sources for individual heating lies precisely in heat pumps and partly in biomass and solar heating. An increase in the share of energy from renewable sources means simultaneously strengthening energy security and reducing fuel imports.

Energy efficiency of buildings

It is important to support both improved energy efficiency in buildings and electrification of heat in conjunction. This will allow for increased energy performance while reducing capital expenditure. Heat pumps work more efficiently in well-insulated buildings. Efficient buildings, in turn, enable more flexible operation of heat pumps and increase the potential for system services. Efficient facilities also minimise the power requirements of heat pumps and, consequently, the amount of additional electricity and capital expenditure needed.

Reduction in energy intensity

Heat pumps provide energy savings and are therefore a qualified (preferred) technology under Article 7 of the Energy Efficiency Directive[57]. According to this Article, Member States are obliged to reduce their final energy consumption by 0.8% annually between 2021 and 2030. The implementation of heat pumps together with the thermal upgrades to buildings can help to close the energy inefficiency gap in the economy.

It is also worth adding that the installation of heat pumps in new buildings, instead of heating systems based on fossil fuels, will make it possible to meet the requirements of the Energy Performance of Buildings Directive more effectively.

Reduction of heating costs

With the progressive implementation of heat pumps, more advanced dynamic electricity tariffs should be introduced.

There are already multi-zone tariffs in Poland that can and should be linked to the introduction of heat pumps to optimise heating costs. The remuneration of system services based on the control of heat pump operation may reduce the demand for peak capacity and expenditures for construction of new generation capacities in the power system. The balancing services should further contribute to reducing the cost of heating for households.

57 Commission Recommendation of 25 September 2019 on transposing the energy savings obligations under the Energy Efficiency Directive, 2019, https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32019H1658&from=EN.

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Heat electrification in Poland.
The path to clean heat

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