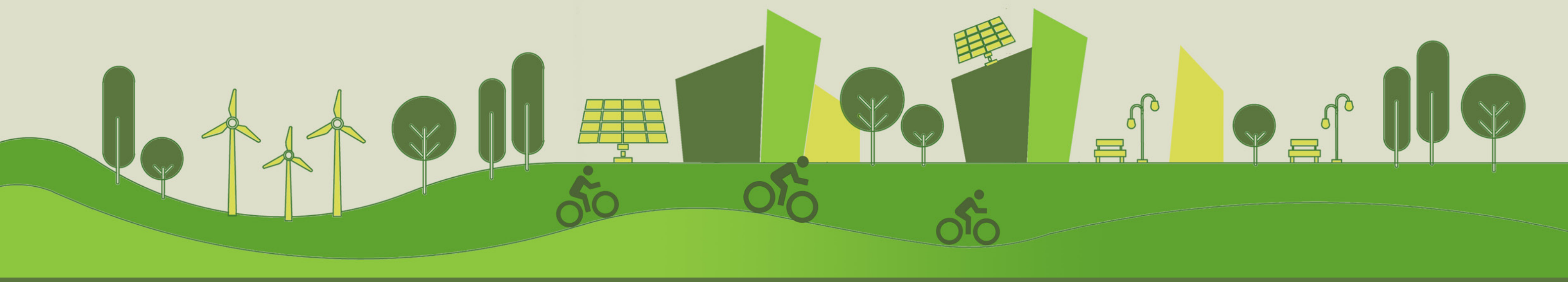
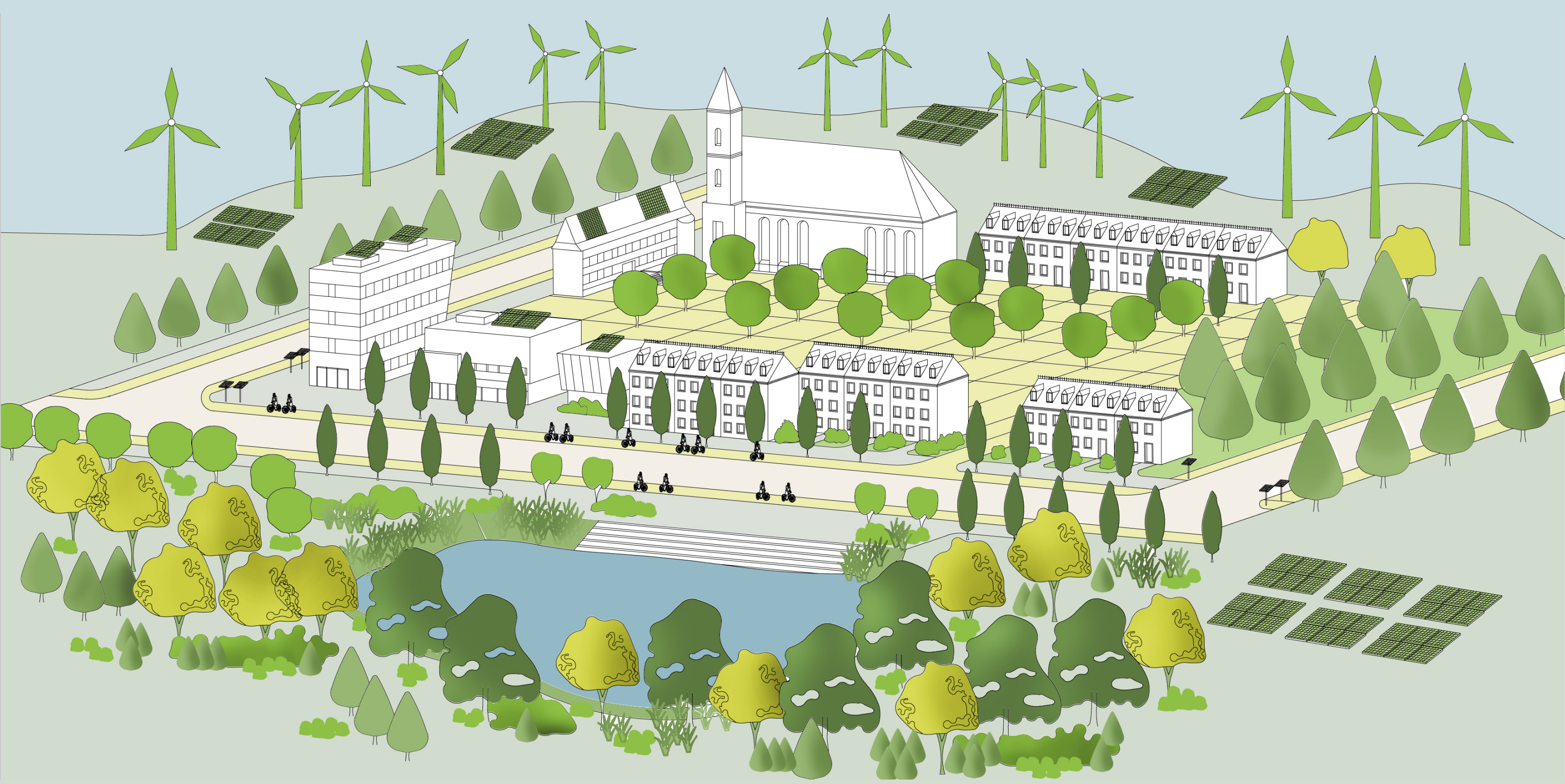


The project entitled „EDINA – Energy-efficient development of special revitalisation zones and urban areas".

IMPROVING THE ENERGY EFFICIENCY OF RESIDENTIAL BUILDINGS IN REVITALISATION AREAS TOOLKIT



Supported by:

Federal Ministry for Economic Affairs and Climate Action

on the basis of a decision by the German Bundestag

European Climate Initiative EUKI

IRMiR Institute of Urban and Regional Development

FPE Energy Conservation Foundation

IWO

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European Climate Initiative EUKI

IRMiR INSTYTUT ROZWOJU MIAST I REGIONÓW

FPE FUNDACJA POSZANOWANIA ENERGII

IWO

Project: "EDINA – Energy-efficient development of Special Revitalisation Zones and urban areas"

IMPROVING THE ENERGY EFFICIENCY OF RESIDENTIAL BUILDINGS IN REVITALISATION AREAS

TOOLKIT

The project is part of the European Climate Initiative (EUKI). EUKI is a project financing instrument by the German Federal Ministry for Economic Affairs and Climate Action (BMWK). The main aim of EUKI is to support cooperation on climate matters within the European Union (EU) in order to reduce greenhouse gas emissions.

Warsaw, January 2022

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DISCLAIMER: The savings presented in the text that can be achieved by retrofitting the various elements in the example development project are only valid for the specific characteristics described in App. 1.

Supported by: Federal Ministry for Economic Affairs and Climate Action on the basis of a decision by the German Bundestag

European Climate Initiative EUKI

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TABLE OF CONTENTS

Appendix 1

INTRODUCTION

List of abbreviations

u.o.r.	Polish Revitalisation Act (Journal of Laws of the Republic of Poland 2021, item 485)
MRHM	Municipal register of historical monuments
MRP	Municipal Revitalisation Programme
LRP	Local revitalisation plan
LSDP	Local spatial development plan
RA	Revitalisation area
SRZ	Special Revitalisation Zone

INTRODUCTION

The Polish Institute for Urban and Regional Development, together with its partners, the Polish Energy Conservation Foundation and the Initiative Wohnungswirtschaft Osteuropa (IWO) e.V. – Housing Initiative for Eastern Europe, has launched the project entitled "Energy-efficient development of Special Revitalisation Zones and urban areas (EDINA)".

The project consists of a series of measures designed to improve energy efficiency in buildings located in revitalisation areas in Poland. This toolkit is one of the outcomes of the project. It explains various opportunities for using tools to support the projects of private companies that are planning to retrofit residential buildings in revitalisation areas.

The toolkit emerged from a series of workshops held between 12 February and 12 March 2021. These were attended by representatives from cities with Special Revitalisation Zones (Bytom, Łódź, Kalisz, Opole Lubelskie, Ośno Lubuskie, Płock, Polkowice, Świnoujście, Włocławek) as well as representatives from foundations dealing with energy efficiency, from the Polish Ministry of Development Funds and Regional Policy and from the Polish Ministry of Climate and Environment. The following road map provided the overall structure for the workshops:

ROAD MAP

Fig. 1. Road Map
Source: Polish Institute of Urban and Regional Development.

The workshops focused on examples of good practice for energy efficiency in Germany and Poland. They were in two parts, the first of which focused on challenges and solutions common to both countries. This part of the workshops was geared towards enabling the participants to first introduce and identify energy efficiency challenges and measures in Polish towns and cities and then compare and contrast them with the presentation given by the German project partner. This enabled them to determine what inspiration from Germany would be useful for the cities in view of their revitalisation efforts and the underlying conditions in Poland. Towns and cities were looking for inspiration for:

a. Retrofitting densely packed inner-city buildings (laid out in a grid pattern), including improving their heat management and adapting them to climate change (Łódź),modernizacji obiektów zabytkowych z uwzględnieniem odnawialnych źródeł energii i termomodernizacji,
b. Retrofitting historical buildings, including using renewable energy sources and thermal upgrading,
c. Design solutions for greening within an existing mediaeval urban layout and improving the thermal protection of historical buildings (Włocławek),
d. Consolidating disparate ownership arrangements in order to implement joint energy efficiency measures,
e. Harnessing the energy potential of rivers for urban development,
f. Projects for educating residents in heat management,
g. Encouraging people to switch to a different heat source,
h. Rules for organising and running energy cooperatives.

In the second part, the workshop participants identified their cities' energy efficiency priorities. Most people felt that relevant activities in the revitalisation areas related primarily to thermal upgrading and replacing existing heat sources with more efficient ones. Towns and cities are also beginning to implement mobility and blue-green infrastructure projects, both of which are issues that affect revitalisation areas as well as the town or city as a whole. As revitalisation areas located in historical town and city centres share similar characteristics, the challenges identified by the cities relate mainly to the historical structure of listed buildings. The workshop participants described their cities' approaches to varying levels of funding depending on the scope and type of the work being carried out under grants awarded in Special Revitalisation Zones.

The second part of the workshops also served to determine the costs required during the renovation process for improving energy efficiency and to link the improvement of a building's energy balance with other elements of the revitalisation process – with the programme itself (assessment, objectives, projects), resolutions (on renovation grants) and other solutions adopted in the municipality (e.g. a boiler replacement scheme). These issues are thus afforded particular attention in the toolkit.

Poland's revitalisation areas span over 1.2 million hectares and are home to more than 6 million people. Since they mostly cover town and city centres, the low energy efficiency of old housing stock (both publicly and privately owned) is by far the biggest problem inside them. In terms of pursuing Poland's long-term renovation strategy, therefore, guidance on making buildings in revitalisation areas more efficient can be regarded as a priority.

The EDINA project is part of the European Climate Initiative (EUKI) of the German Federal Ministry of Environment, Nature Conservation and Nuclear Safety (BMU). The main aim of EUKI is to support cooperation on climate matters within the European Union (EU) in order to reduce greenhouse gas emissions.

Inspiration from Germany for Polish towns and cities

Revitalising a historical town centre – the example of Eberswalde

Objective: to refurbish a historical town centre

Eberswalde's climate targets for 2030

- Renewable energy sources adopted by municipal companies (from 1999 onwards),
- Energy-efficient street lighting,
- Refurbishment of public buildings (mainly historical ones),
- Adding more cycle lanes and pedestrian paths,
- Greenery schemes,
- Criteria for sustainable public procurement,
- Reaching an agreement on climate protection with the housing industry,
- Installing solar panels on the roofs of historical buildings.

Framework conditions

The town council designated a 59.5-hectare area as an intervention site in 1992. All of the buildings in the old town are built on stilts as a result of the poor soil conditions. The network of streets has remained largely unchanged since the town was founded despite 35% of its buildings being destroyed during World War II.

The old buildings, streets and squares are characterised by their historical urban layout. With the help of urban development funds from the federal and federal state government as well

as its own resources, the town council is encouraging locals to get involved in refurbishing the historical town centre, Schicklersche Vorstadt and Bahnhofsvorstadt.
The local government's attitude is characterised by an integrated approach to urban revitalisation, energy efficiency and strategies for adapting to climate change. Its activities have included introducing innovative technologies for use inside the renovated buildings.

Achievements

- The town square has been doubled in size compared to the pre-war period, and historical buildings in the town centre have been refurbished. For example, the town's oldest half-timbered house, which used to be home to the "Adler" pharmacy, has been renovated,
- Sustainable mobility has been embraced (fewer traffic jams, introduction of green, electric public transport and electric charging stations with the option of feeding electricity back into the municipal grid); a multi-storey cycle park near the rail station is encouraging the use of more environmentally friendly means of transport,
- A community education centre – Amadeu Antonio – has been set up (to develop public participation and community projects).

Drawing inspiration from eco-friendly investments in the historical town centre

The Paul-Wunderlich-Haus ("Paul Wunderlich House") was built on what was then Pavillonplatz, a square adjacent to the market square, in 2007. It is one of the most modern and energy-efficient public administration buildings in Germany and provides space for 550 staff of Barnim district council as well as hosting exhibitions of works by Eberswalde-born artist Paul Wunderlich.

The importance of integrating the project into Eberswalde's historical town centre, which still bore the scars of the Second World War, was highlighted during the design stage. Four buildings are grouped around the former Pavillonplatz and form a vibrant town centre together with the market square. The pioneering architecture is also characterised by its use of sustainable materials and a particularly high level of energy efficiency – it consumes less than 100 kilowatt hours of primary energy per square metre of floor space per year. The building has held Germany's gold seal of quality for sustainable construction since January 2009.

Source:
https://www.eberswalde.de/start/stadtentwicklung/konzepte
https://www.energiewendebauen.de/projekt/gebaeudeensemble-nutzt-erdreich-als-waerme-und-kaeltequelle
https://www.barnim.de/de/verwaltung-politik/paul-wunderlich-haus.html
https://www.energiewendebauen.de/projekt/gebaeudeensemble-nutzt-erdreich-als-waerme-und-kaeltequelle

Photo 1. Paul-Wunderlich-Haus
Source: Polish Institute of Urban and Regional Development.

The “Adler” pharmacy building

The “Adler” pharmacy building in Eberswalde was built in the first half of the 17th century, with evidence suggesting that a pharmacy had been based there since 1623. The “Adler” pharmacy building was given a new lease of life as the town’s museum, tourist information centre and cultural office in 1997 following extensive renovation. This work was supported by EUR 1.6 million in EU funding and the town’s own contribution of EUR 300,000.

Source: https://www.architektur-bildarchiv.de/image/Museum-Adler-Apotheke-Eberswalde-38500.html

Photo 2. The “Adler” pharmacy building
Source: Polish Institute of Urban and Regional Development.

Sustainable mobility

The town of Eberswalde recently built its first multi-storey cycle park with space for over 600 bicycles. Uniquely, the structure was built entirely of wood and spans roughly 1,300 square metres. Some 300 cubic metres of softwood in all was used to construct the two-storey building, which also has a green roof and photovoltaic system. The cycle park includes parking bays and boxes for electric vehicles, such as cargo bikes and bicycles with trailers, as well as a charging point for them. The town of Eberswalde received funding from the EU’s Regional Development Fund and the Ministry of Infrastructure and Planning of the federal state of Brandenburg to run a pilot project for timber construction and cycling promotion, with an investment value of around EUR 2.2 million. With its new cycle park, the city wants to make its contribution to sustainable development. The town's mayor stressed the uniqueness of the project in his statement: "It's the first cycle park in Germany to be made more or less exclusively of wood. The fact that we can provide commuters at the station with an environmentally friendly way to get to and from Berlin makes us as a town very proud." Source: https://www.lbholzbb.de/presse_aktuelle_nachrichten.php?id=1871

Photo 3. The wooden cycle park
Source: Polish Institute of Urban and Regional Development.

Photo 4. Electric charging station capable of feeding electricity back into the municipal grid
Source: Polish Institute of Urban and Regional Development.

The view from Poland's towns and cities

Włocławek: "This is an important example as far as the city of Włocławek is concerned in terms of the development of the inner-city space with the construction of new facilities, the development of waterfront areas and environmentally friendly solutions, including transport (such as cycle parking and municipal car charging stations)."

Kalisz: "Like many Polish towns and cities, Kalisz is struggling with too much car traffic. The problem is particularly severe in the city centre, where the historical street layout cannot cope with the excessive number and demands of car drivers. The issue is both too many cars and not enough parking spaces. However, the most significant disadvantage of using petrol and diesel cars is the pollution they emit. This is why I'm interested in sustainable mobility in Eberswalde. The second interesting issue is the retrofitting of historical buildings in the town centre. Kalisz's revitalisation area includes a group of buildings that are on the municipal register of historical monuments. This imposes certain restrictions on the possibilities for using new technologies in retrofits and thermal upgrades. The potential for using alternative energy sources for historical buildings is also interesting." alternatywnych źródeł energii dla budynków historycznych".

Płock: "Of all the solutions introduced in Eberswalde, those worth looking into in more detail as far as our city is concerned include the measures relating to sustainable mobility: the construction of multi-storey cycle parks where people can leave their bikes in lockable boxes, the purchase of electric vehicles for office work and the construction of municipal charging stations. Using the first floor of the office buildings as shops was also an interesting solution, meaning that the buildings also serve a purpose outside office hours (at least to some extent)."

Zawiercie: "They are comprehensive urban redevelopment solutions. Both are examples of the modern, energy-efficient construction and thermal upgrading of historical buildings harnessing renewable energy sources."

"An example of the coherent redevelopment of a town, using solutions that encourage residents to behave in an environmentally conscious way and that minimise the burden on the environment: a hub that promotes cycling, taking the train and using electric vehicles."

Poznań University of Economics and Business – Sławomir Palicki: "One has to appreciate its pro-environmental message, how it's setting out to make cycling more popular and how it's succeeding in building an identity and a modern, transformative image of the town."

CZĘŚĆ I

The importance of improving the energy efficiency of buildings

CZĘŚĆ I

The importance of improving the energy efficiency of buildings

I.1 What impact do towns and cities have on climate change?

Around 55% of people in the world live in towns and cities. United Nations data (from 2018) suggests that the global urban population will grow to hit some 6.7 billion by 2050.

PEOPLE LIVING IN URBAN AND RURAL AREAS (IN MILLIONS); PERCENTAGE OF PEOPLE LIVING IN URBAN AREAS

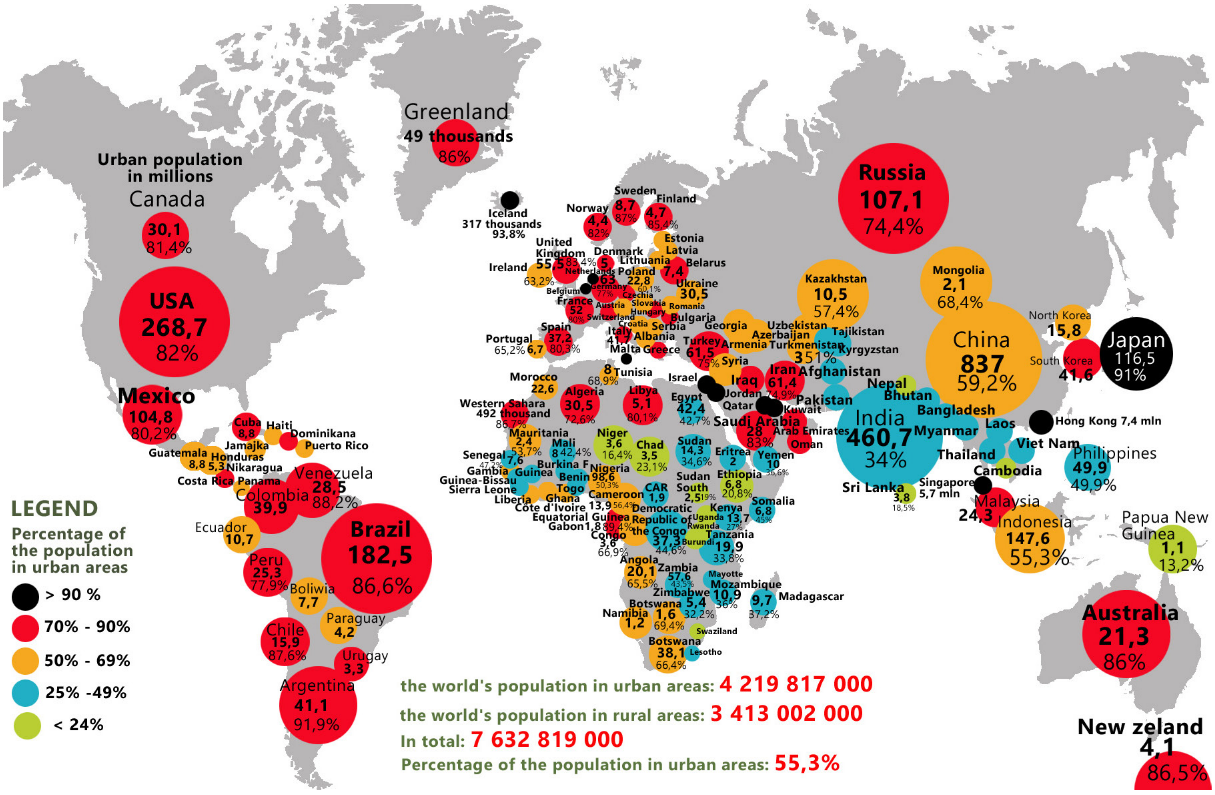


Fig. 2. People living in urban and rural areas in millions; percentage of people living in urban areas
Source: own research by the Polish Institute of Urban and Regional Development based on data from the United Nations, Population Division, Department of Economic and Social Affairs, World Urbanization Prospects: The 2018 Revision, File 1: Population of Urban and Rural Areas at Mid-Year (thousands) and Percentage Urban, 2018, POP/DB/WUP/Rev.2018/1/F01; https://population.un.org/wup/Download.

POPULATION GROWTH IN URBAN AREAS 1950–2050

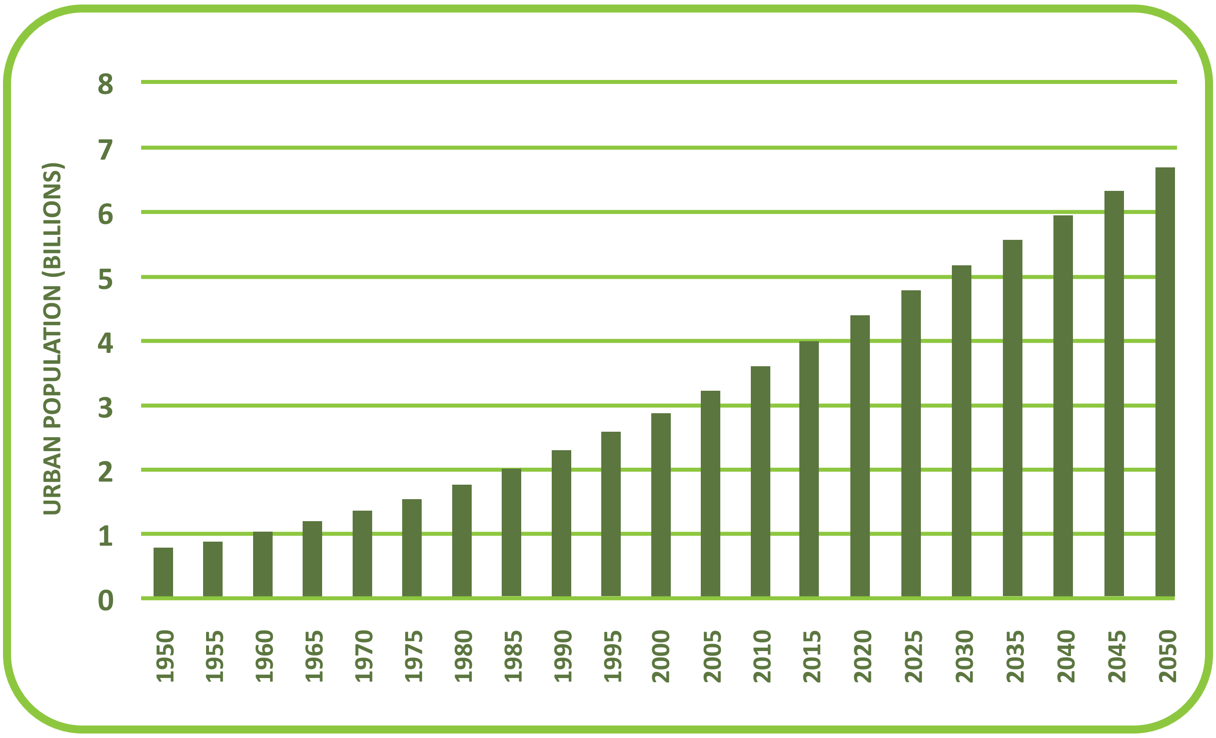


Fig. 3. Population growth in urban areas 1950–2050
Source: Opracowanie własne – Instytut Rozwoju Miast i Regionów na podstawie danych z United Nations, Population Division, Department of Economic and Social Affairs, World Urbanization Prospects: The 2018 Revision, File 3: Urban Population at Mid-Year by Region, Subregion, Country and Area, 1950-2050 (thousands); https://population.un.org/wup/Download.

Rapid urban growth brings both costs and benefits. The increased concentration of people in towns and cities and the drive to generate growth in them have a significant impact on the environment, including the depletion of natural resources and changes in the climate such as global heating and heavy rainfall. Towns and cities are responsible for 75% of global energy consumption and 80% of greenhouse gas emissions. At the same time, emissions from towns and cities are lower than their respective national average.

Saving energy, energy efficiency and the use of renewable energy in cities are challenges that affect a great many areas. Neither is there a one-size-fits-all solution that would suit every single town and city. Instead, the best possible package of solutions needs to be put together in each location based on the available resources, urban structures, skills and capacities. This is the job not only of town and city authorities but also of all sectors – businesses, non-governmental organisations and the locals themselves. At international level, therefore, towns and cities are seen as being the places where society has the greatest expectations for climate action and where cutting-edge environmental solutions are created. A range of strategies are emerging for safeguarding environmental security, such as water, energy, waste and flood protection. Despite the changes that are beginning to take place in towns and cities, forecasts based on their current energy requirements demonstrate an urgent need for a whole range of solutions.

Trends in primary and final energy demand

This text is based on the publication entitled Energy Technology Perspectives 2020 by the International Energy Agency (Energy Technology Perspectives 2020, The International Energy Agency, 2020:78–84).

The International Energy Agency (IEA) was set up in 1975 on the basis of Implementing Agreements, which constituted the practical implementation of Chapter VII of the Agreement on an International Energy Program. These Implementing Agreements form part of a scheme set up to support the idea of organising and strengthening international cooperation in the area of energy technologies, research into these technologies and how they are to be developed and deployed. Energy Technology Perspectives 2020 is a major new IEA publication focusing on the technologies required and opportunities available for achieving international climate and sustainable energy objectives. The report provides important analysis and advice on the clean energy technologies that the world needs in order to meet its net-zero emissions targets.

Trends in primary energy demand

Under the Sustainable Development Scenario, global primary energy demand will increase only slightly between 2019 and 2070, whereas the global population is set to be 35% higher and the economy about 3.5 times bigger than today (Table 1). Compared to the near-40% increase in global primary energy demand in the Stated Policies Scenario, the degree to which economic growth is decoupled from energy demand represents a significant break with past trends.

“Primary energy” means the state that energy is in before it is transformed in any way by humans. Some energy is transformed in power plants, refineries, heating plants and other conversion processes. “Final consumption” refers to the consumption of energy and raw materials after deducting conversion and distribution losses.

		Scenario based on sustainable development	Scenario based on sustainable development	Scenario based on stated policies
	2019	**2040**	**2070**	**2070**
Coal	3,783	1,309	696	3,188
Oil	4,523	3,000	1,156	4,778
Natural gas	3,336	3,056	2,048	4,786
Nuclear power	728	1,140	1,472	1,101
Renewable energy sources	2,220	5,325	9,905	6,013
Hydropower	371	585	840	716
Modern bioenergy	935	2,365	2,948	2,252
Traditional biomass use	588	0	0	287
Solar power	118	1,156	3,414	1,283
Wind power	123	759	1,564	845
Other renewable sources	86	461	1,140	630
Total	**14,590**	**13,830**	**15,278**	**19,865**
Net CO_2 emissions ($MtCO_2$)	**36,064**	**16,834**	**0**	**35,737**

Table 1. Change in global primary energy demand under the Sustainable Development Scenario 2019–2070
Source: own research based on Energy Technology Perspectives 2020, pp. 78–81; https://www.iea.org/reports/energy-technology-perspectives 2020.

The Sustainable Development Scenario anticipates a sharp increase in the use of clean energy sources in the years to 2070. These currently account for 20% of global energy demand. This percentage doubles to around 40% in the Stated Policies Scenario and rises even further – to around 75% – in the Sustainable Development Scenario (Figure 4).

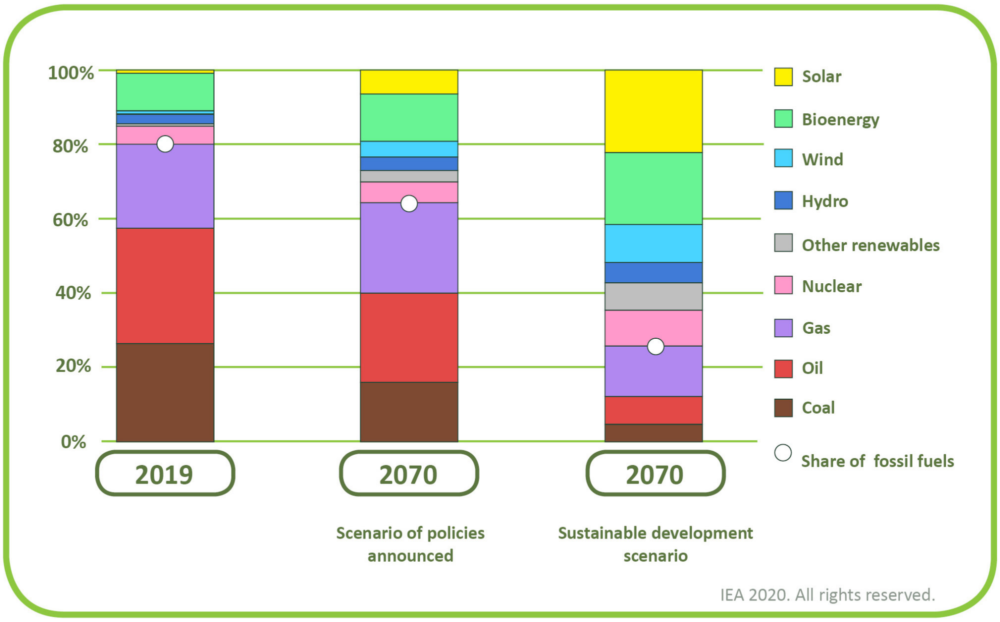


Fig. 4. Change in global primary energy demand under the Sustainable Development Scenario 2019–2070
Source: own research based on Energy Technology Perspectives 2020, pp. 78–81; https://www.iea.org/reports/energy-technology-perspectives-2020.

With fossil fuel consumption set to fall sharply, the share of the total energy mix attributable to renewables will increase from 15% in 2019 to over 60% in 2070 under the Sustainable Development Scenario. Solar power will become the largest source of primary energy.

Trends in final energy demand

			Scenario based on sustainable development	Scenario based on sustainable development	Scenario based on stated policies
	2000	2019	2040	2070	2070
Industry	2,054	3,278	3,162	3,077	4,513
Transport	1,961	2,865	2,537	2,461	3,923
Buildings	2,345	3,087	2,648	2,868	4,193
Other	950	1,153	1,310	1,081	1,639
Total	**7,310**	**10,384**	**9,657**	**9,486**	**14,269**
Coal	732	1,327	824	398	1,326
Oil	3,292	4,048	2,823	1,099	4,561
Natural gas	1,104	1,659	1,357	426	2,362
Electricity	1,076	1,943	2,909	4,507	4,004
Heat	240	312	272	187	356
Hydrogen	0	0	98	539	91
Ammonia	0	0	18	133	9
Bioenergy	859	1,035	1,035	1,315	1,285
“Synthetic fuels”	0	0	32	254	0
“Other renewable sources”	7	60	290	629	275
Total	**7,310**	**10,384**	**9,657**	**9,486**	**14,269**
“Demand for hydrogen”		94	290	1,199	229

Table 2. Change in global final energy demand by fuel and sector under the Sustainable Development Scenario 2019–2070
Source: Own research based on Energy Technology Perspectives 2020, pp. 82–84; https://www.iea.org/reports/energy-technology-perspectives-2020.

Total global demand for final energy under the Sustainable Development Scenario is set to flatten out in the early 2020s, before declining steadily over the forecast period. By 2070, it will be nearly 10% lower than in 2019 and more than 30% lower than in the Stated Policies Scenario thanks to significant energy efficiency gains, particularly in the years to 2040. Under the Sustainable Development Scenario, demand for oil and gas will decline most sharply in relative terms, slumping by over 70% between 2019 and 2070 in each case. Demand for heating inside buildings and for process heat in industry will also fall as technologies such as heat pumps are used more efficiently.

Electricity consumption will increase the most in absolute terms, more than doubling by 2070. This is followed by hydrogen, which will begin to be used as a fuel in the 2020s and will primarily be adopted by the transport and industrial sectors. Synthetic liquid fuels – hydrocarbons that are derived from hydrogen generated from electricity and CO2 – will start to power HGVs and aircraft in the 2020s. By 2070, the amount of synthetic fuel being consumed will be equivalent to 5 million barrels per day (mb/d) and will meet some 40% of the demand for aviation fuel.

FINAL ENERGY DEMAND BY FUEL (Mtoe)

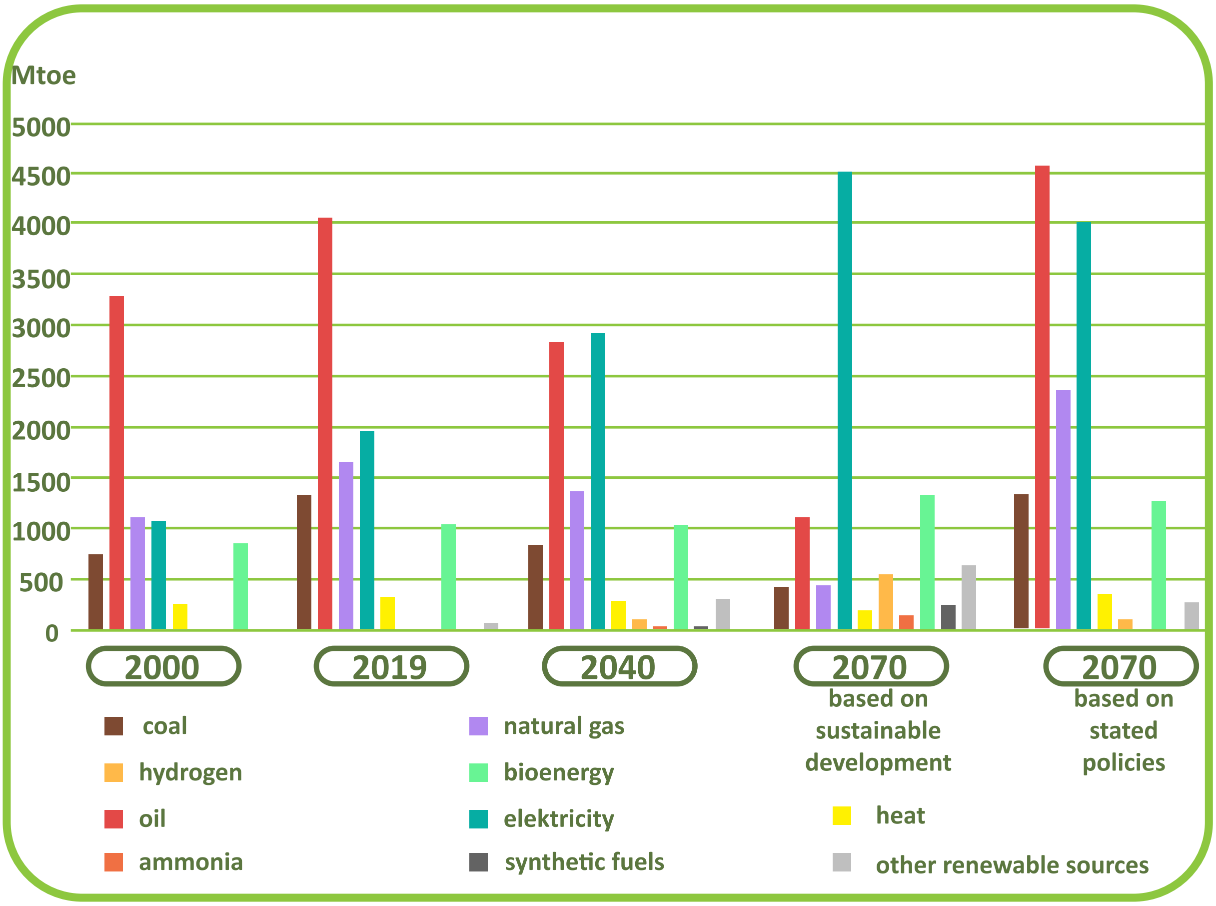


Fig. 5. Final energy demand by fuels - change in global final energy demand by fuel and sector under the Sustainable Development Scenario 2019–2070

Source: own research based on Energy Technology Perspectives 2020, pp. 82–84; https://www.iea.org/reports/energy-technology-perspectives-2020.

Although the transport sector will see the largest drop in fossil fuel consumption (primarily petroleum), it will also fall in the industrial and building sectors. Electricity will become the main source of energy in all three sectors (Figure 6). In the transport sector, the combined total for all hydrogen fuels (hydrogen, ammonia, synthetic hydrocarbons) will meet a third of the total energy demand in 2070, almost on a par with electricity. Great emphasis is being placed on efforts to reduce carbon emissions. Some towns and cities are devising their own solutions to this problem, while others are collaborating in networks such as the C40 initiative (a network of global megacities taking action to reduce greenhouse gas emissions).

CHANGE IN GLOBAL FINAL ENERGY DEMAND BY FUEL AND SECTOR UNDER THE SUSTAINABLE DEVELOPMENT SCENARIO 2019–2070

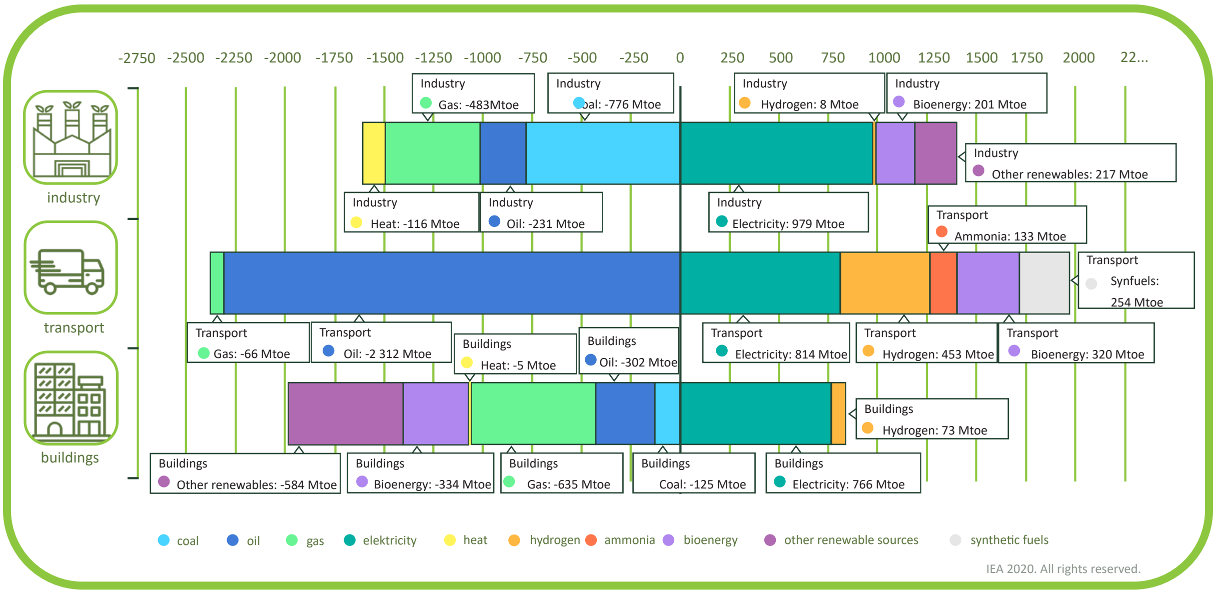


Fig. 6. Change in global final energy demand by fuel and sector under the Sustainable Development Scenario 2019–2070
Source: own research based on Energy Technology Perspectives 2020, pp. 82–84; https://www.iea.org/data-and-statistics/charts/change-in-global-final-energy-demand-by-fuel -and-sector-in-the-sustainable-development-scenario-2019-2070. Źródło: https://www.iea.org/reports/energy-technology -perspectives-2020.

C40 **is a global network connecting up 97 of the world's largest cities, which are working together to respond to the challenge posed by climate change. Representing more than 700 million citizens and a quarter of the global economy, the city mayors who make up the C40 alliance are committed to meeting the most ambitious targets under the Paris Climate Agreement at local level.**

The impact of their collective efforts can be demonstrated in figures:

- There are now 66,000 electric buses on the streets of the C40 cities (compared to 100 in 2010);
- 24 of the C40 cities have committed to generating 100% of their power from renewable sources by 2030 (compared to 5 cities in 2010);
- 18 of the C40 cities have banned or significantly reduced the use of single-use plastic packaging (compared to 2 cities in 2010);
- 17 of the C40 cities restrict access by petrol and diesel cars (compared to six cities in 2010);
- 82 of the C40 network cities operate urban cycling systems (compared to 21 cities in 2010).

C40 – a Knowledge Hub

As well as collaboration through sharing technological solutions, C40 is also geared towards supporting other cities. A special grant programme that the network offers is benefiting 17 cities in the Global South by helping them to take action to mitigate climate change.

C40 also provides an extensive database of examples of good practice and guidance on various aspects of emission reduction, greenhouse gas emissions and the use of renewables.

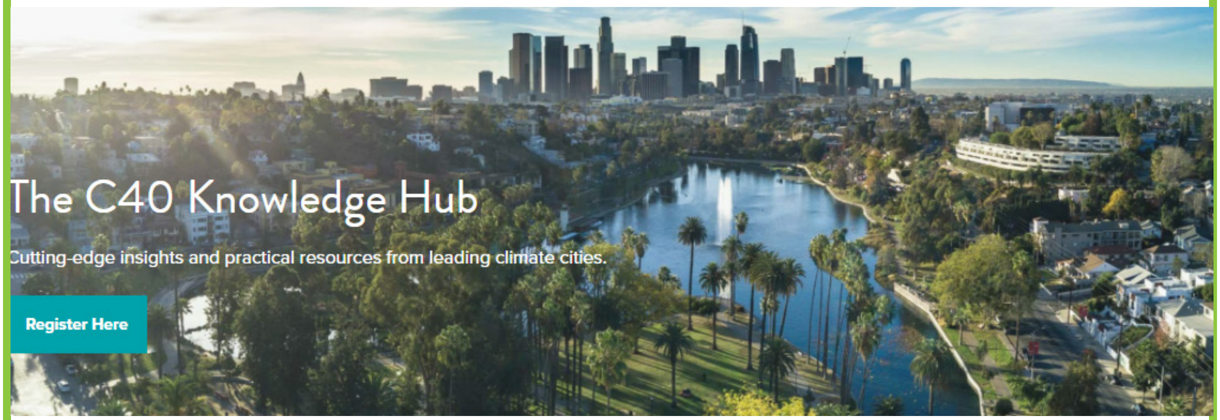
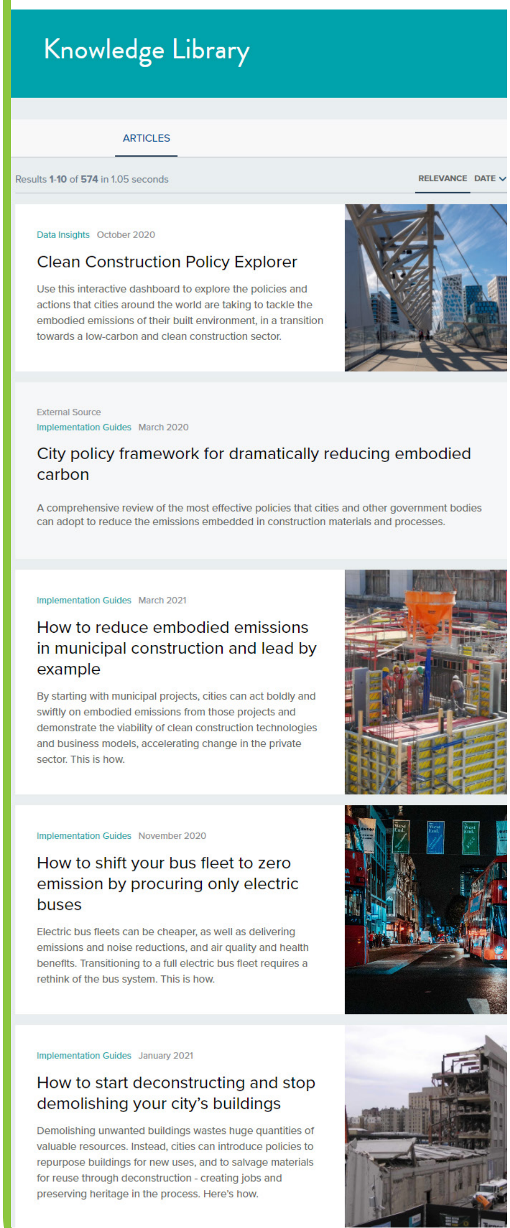


Fig. 7. The C40 Knowledge Hub
Source: https://www.c40knowledgehub.org/s/?language=en_US [dostęp: 1.04.2021].



The C40 network also identifies and categorises the measures being taken by cities, mainly in Europe and North America, that can inspire others. Every solution is assessed in terms of its potential to reduce CO_2 emissions, its ease of implementation, its cost-effectiveness and its feasibility. Seven groups of such solutions have been identified. Alongside tailored public procurement, zoning, tax mechanisms and investments in state-of-the-art transport and greening, two other important elements relate to the energy efficiency of buildings:

- Regulations for newbuilds,
- Making existing buildings more energy-efficient (including comprehensive thermal upgrades to public buildings and promoting competitions for technological solutions to improve the energy efficiency of public buildings).

I.2 How do buildings contribute to energy consumption and CO2 emissions?

According to data from the European Commission, residential and other buildings account for 40% of the EU's total energy consumption and some 36% of all its CO2 emissions. Detailed research conducted while devising the framework for the 2015 Paris Climate Agreement shows that heating and cooling are responsible for nearly 50% of final energy consumption in the EU, 80% of which is attributable to buildings. Considering that the building sector alone makes up 50% of the total demand for materials, that buildings are responsible for 33% of waste production and water consumption, and that 80% of today's buildings will still be in use by 2050, it becomes clear that taking action regarding buildings is a priority for tackling the climate challenges.

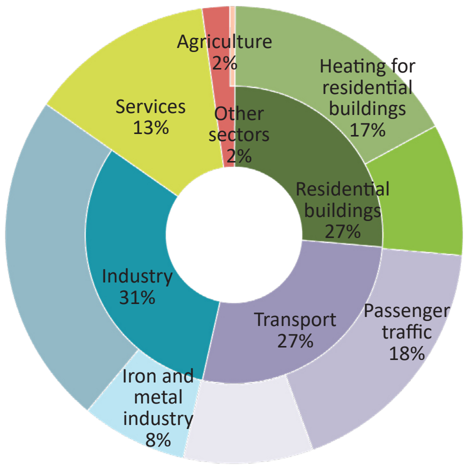
The authorities in towns and cities can make an important contribution to improving their inhabitants' quality of life by backing various environmentally friendly solutions. Towns and cities also influence the attitudes of homeowners and landlords to a large degree through various grant programmes. Municipal environmental policies can also be reflected in introducing appropriate rules on spatial planning or adopting local laws with an impact on climate issues (e.g. banning coal-fired boilers and fireplaces and offering grants for replacing heat sources).

As the owners of buildings (serving both residential and public purposes), town and city authorities are also able to exert significant influence on market conditions through targeted measures such as the use of public procurement, energy-efficient renovation work and considering the whole life cycle of a building. One such example is Oslo, where an invitation to tender for the redevelopment of one of the city's streets resulted in the world's first-ever zero-emission building site. The change can also be seen in the King's House project in Brighton & Hove, which involved removing 1,000 staff along with all the furniture and equipment from the city's largest office building. Instead of throwing all the fixtures and fittings away, however, as would have been done in the past, locals, organisations and community groups were given the opportunity to come and pick them up. A total of 150 tonnes of materials were reused with an equivalent value of GBP 150,000, although the additional benefits gained from reusing these materials are hard to measure in monetary terms.

The burden that energy consumption places on the climate varies between EU countries. For example, a study from Germany showed that residential buildings are responsible for 27% of energy consumption in the country.

GERMANY – CROSS-SECTORAL OVERVIEW

MAJOR ENERGY END-USERS, ECONOMIC SECTORS, 2018



SIX MAJOR CO2 EMITTING END-USERS, 2018

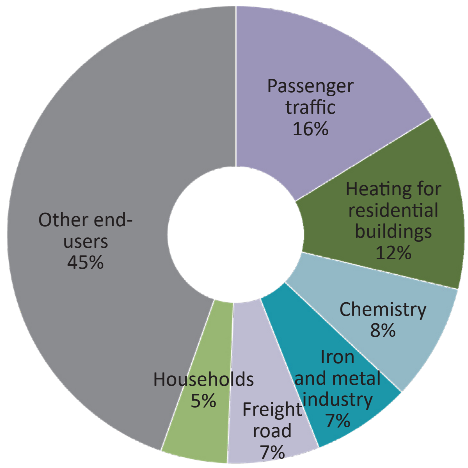
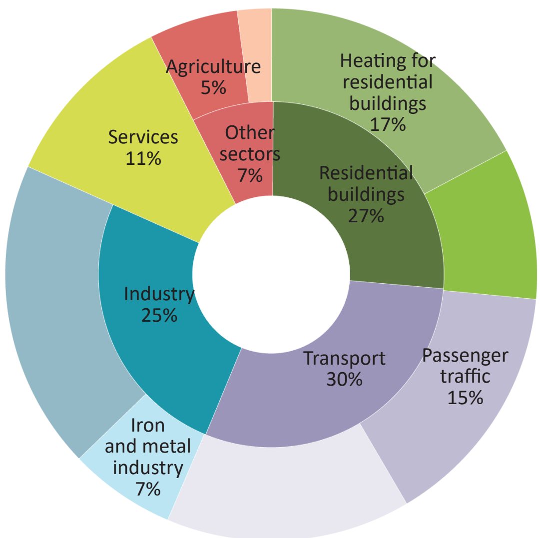


Fig. 8. A cross-sectoral overview of Germany
Source: own research based on the Energy Efficiency Indicators, The IEA; https://www.iea.org/reports/energy-efficiency-indicators.

POLAND – CROSS-SECTORAL OVERVIEW

MAJOR ENERGY END-USERS, ECONOMIC SECTORS, 2018



SIX MAJOR CO2 EMITTING END-USERS, 2018

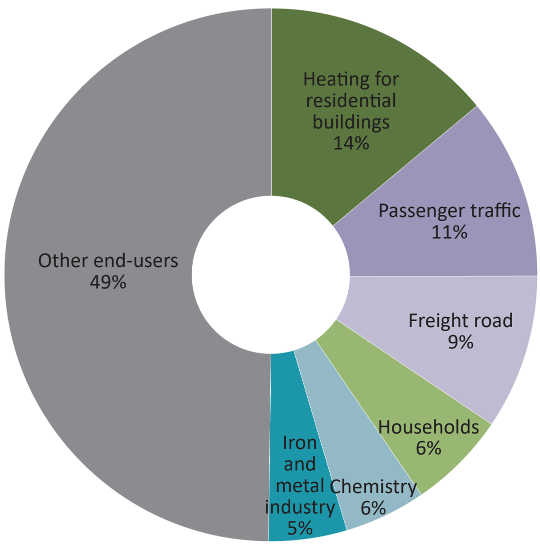


Fig. 9. A cross-sectoral overview of Poland
Source: own research based on the Energy Efficiency Indicators, The IEA; https://www.iea.org/reports/energy-efficiency-indicators.

The variation is due to the quality of the building materials used, the insulation technologies deployed, the air-tightness of the windows and the efficiency of the heating system. National long-term renovation strategies are thus being devised in every EU country in line with their specific characteristics. Basing itself on the World Health Organization's 2009 guidelines, the European Parliament stated in its directive on improving the energy performance of buildings that this is directly linked to our well-being and living comfort. Buildings with a better energy performance offer a higher level of comfort and improved health for their residents. By contrast, thermal bridges, inadequate insulation and unwanted draughts can cause damp. It must therefore be ensured that buildings are fully and consistently insulated and that the temperature on their internal surfaces does not fall below the dew point. This means a need to move away from focusing on the building envelope and towards making sure that any thermal upgrades cover all the building's technical systems, including heating, cooling and using energy for lighting and ventilation.

I.3 Where does heat escape from a building?

As well as being an environmental problem, energy consumption also places significant strain on household budgets. With energy costs rising, insulating a building is one way to save money in the future. To do so, the main causes of heat loss in residential buildings must first be identified.

WHERE HEAT IS LOST FROM A LOW-RISE BUILDING

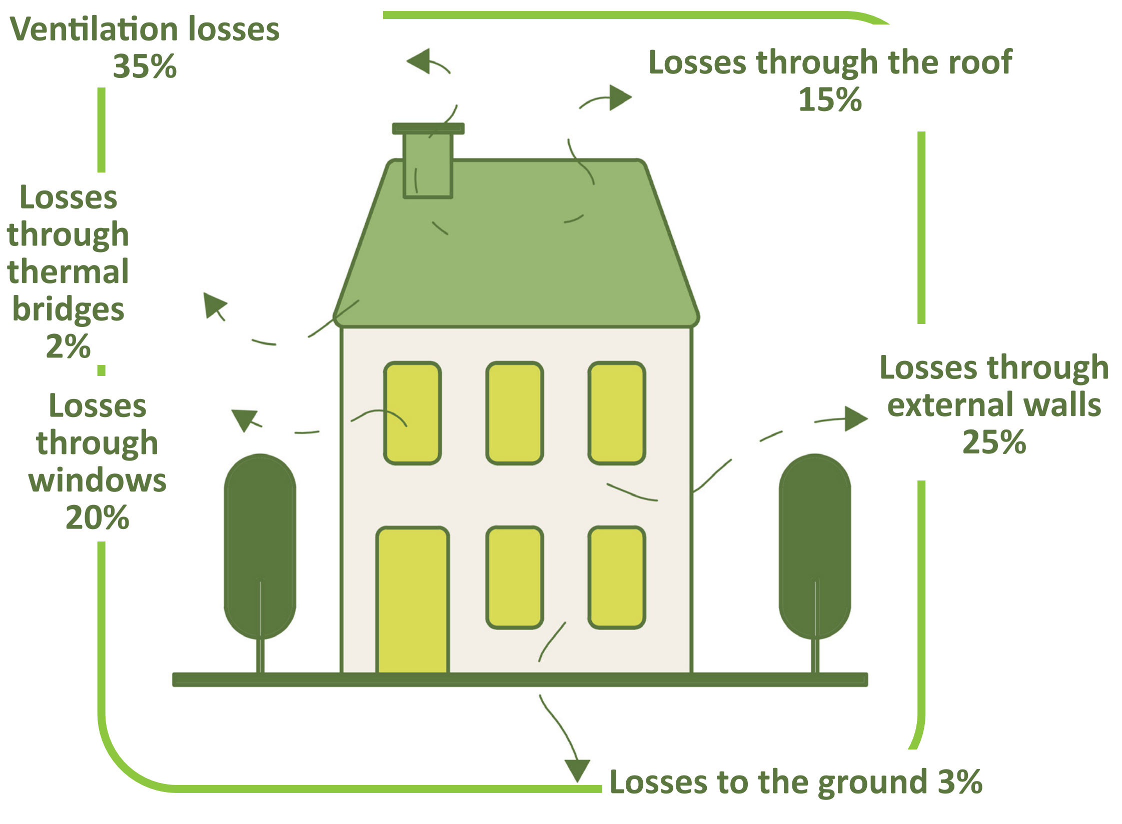


Fig. 10. Where heat is lost from a low-rise building
Source: own research based on data from the Polish Energy Conservation Foundation.

Most buildings in Poland lack adequate insulation against heat escaping from rooms. Previous building regulations set only lax requirements, and even these were often circumvented. Nowadays, therefore, the main routes for heat loss are external walls, ceilings, attics and flat roofs. The poor thermal quality of windows, air escaping through windows, and inefficient heating systems also pose significant problems. This provides various channels through which heat can escape.

MINIMUM AND MAXIMUM HEAT LOSS

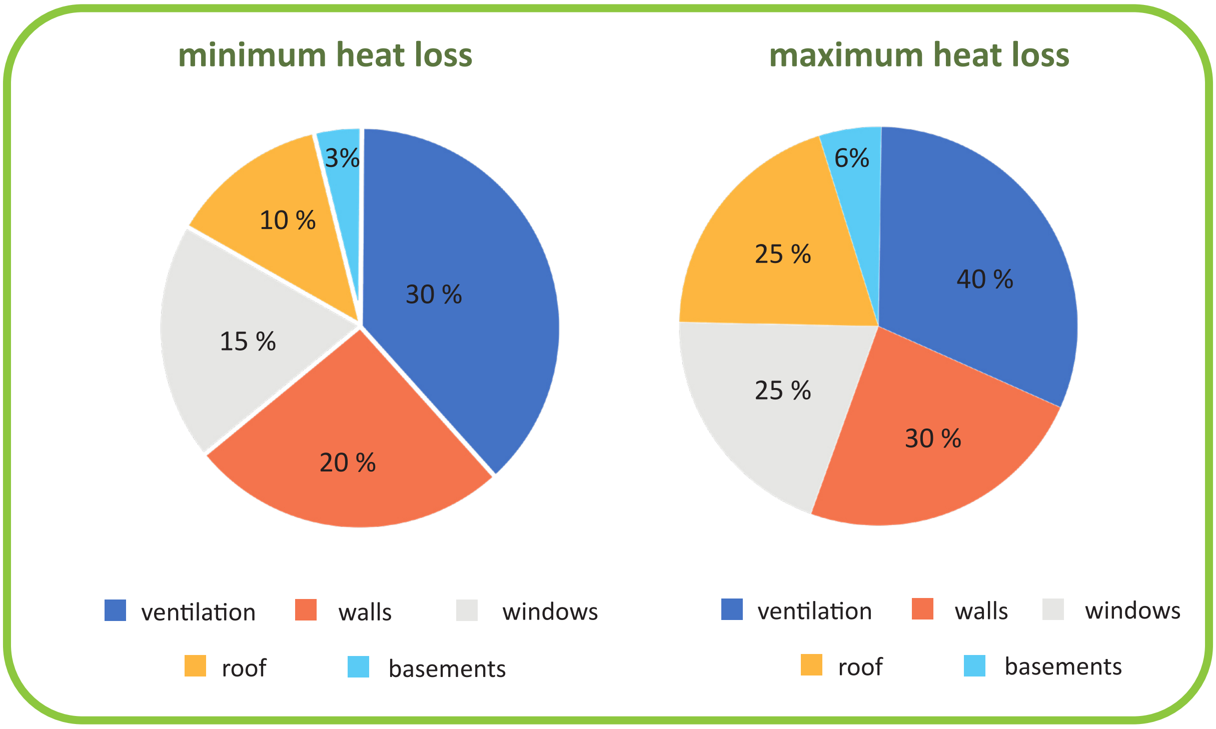


Fig. 11. Minimum and maximum heat loss
Source: own research based on Robakiewicz M., Panek A., 2020, Termomodernizacja, NAPE, Warsaw, p. 5.

I.4 Why should energy efficiency improvement efforts focus on revitalisation areas?

In March 2021, the European Commission published a renovation strategy for improving the energy performance of buildings. The Commission aims to increase renovation rates at least twofold over the next ten years. This is intended to improve quality of life for the people living in and using the buildings, reduce greenhouse gas emissions in Europe, and promote digitalisation and the recycling of materials. No fewer than 35 million buildings could be renovated and up to 160,000 green jobs created in the construction sector by 2030.

Although buildings account for roughly 40% of energy consumption in Europe, only around 1% of them will receive a comprehensive thermal upgrade in any given year. At the same time, nearly 34 million Europeans cannot afford to heat their home. The “Renovation Wave” is a public policy that encourages energy-efficient renovation, the fight against energy poverty, the promotion of people’s health and well-being, and lower energy costs. The strategy is targeting the decarbonisation of heating and cooling, the battle against fuel poverty and poor energy quality in residential buildings, and the refurbishment of public buildings such as schools, hospitals and administrative buildings. The Commission is proposing to remove barriers along the entire renovation chain – from project conception through to financing and completion – with various policy measures, funding tools and instruments for technical assistance. The renovation strategy thus aligns with the core tenets of the revitalisation process that is being pursued in run-down residential areas of Polish cities. This means that the revitalisation process has to encompass projects that promote energy-efficient renovation but that also, and in particular, tackle the issue of energy poverty amongst residents of the revitalisation area (RA) and improve their quality of life.

The various member states are devising their own long-term renovation strategies in response to the Commission’s actions. The public consultation on Poland’s draft document closed on 26 February 2021. Data on the energy efficiency of Polish buildings shows the scale of the challenge in hand. Buildings constructed before 1970, i.e. those with the worst energy performance, account for 44% of all residential buildings and accommodate 47.5% of the Polish population. Restricting the analysis to buildings owned by the local authority reveals that as many as 80% of them were erected before 1970.

MUNICIPAL HOUSING AS A PERCENTAGE OF TOTAL HOUSING STOCK

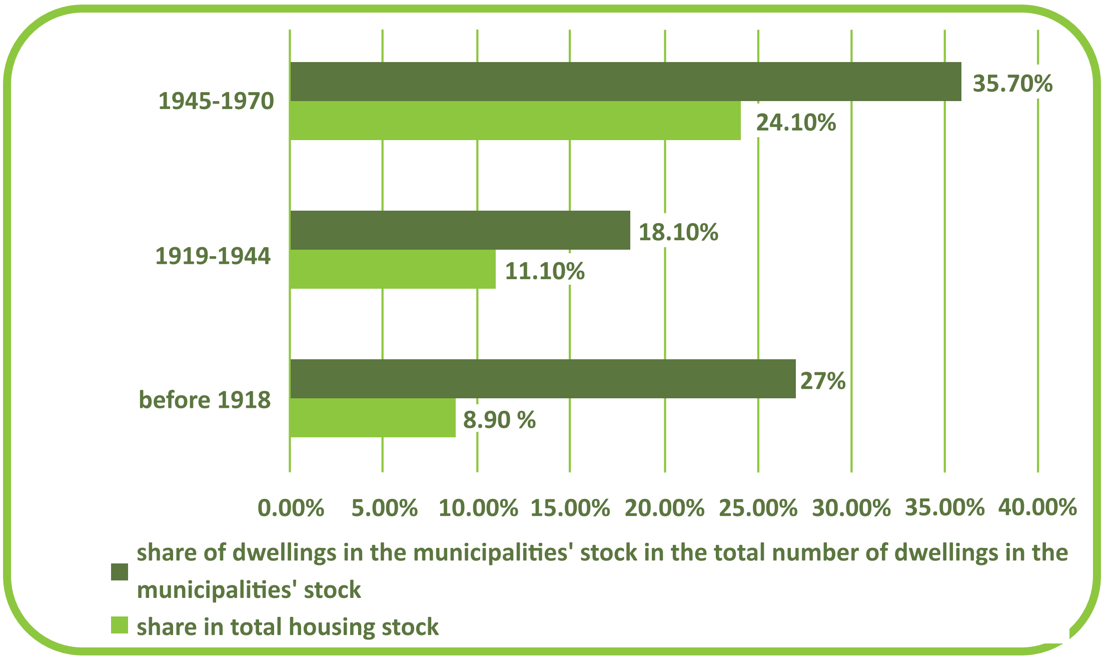


Fig. 12. Municipal housing dating from various periods as a percentage of the total municipal housing stock and as a percentage of the overall housing stock.
Source: Muzioł-Węcławowicz A., Nowak K., 2018, Mieszkalnictwo społeczne. Raport o stanie polskich miast, OPM IRMiR, Warsaw, p. 70.

Contrasting these figures with the technical condition of Poland's municipal buildings makes the scale of the challenge even more apparent.

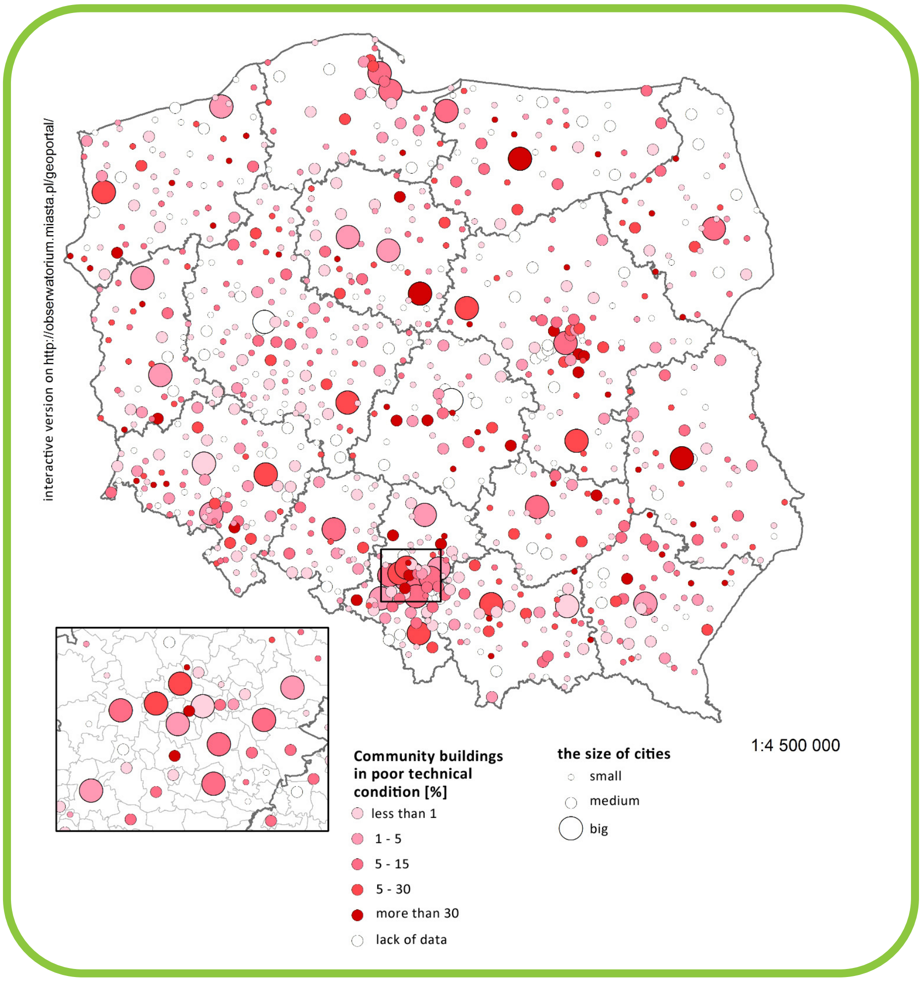


Fig. 13. Technical condition of municipal buildings in Poland.
Source: Muzioł-Węcławowicz A., Nowak K., 2018, Mieszkalnictwo społeczne. Raport o stanie polskich miast, OPM IRMiR, Warsaw, p. 71.

Most buildings in a poor condition – both publicly and privately owned – are located in areas that Polish towns and cities have chosen for their revitalisation measures. Housing has to form an important part of revitalisation efforts.
This requirement was voiced very clearly at the third Polish Metropolitan Revitalisation Congress (Revitalisation and housing. Efforts to meet residents' basic needs, Gdańsk, 22 and 23 June 2020):

„People spend about 80% of their time at home. Home is therefore where the vast majority of their basic needs are met, including biological and physiological ones. But home is more than that: it is also a retreat, a refuge, the focus of domestic life, a place to spend time with one's family, somewhere to work. It plays a huge role in everyone's lives. It is therefore extremely important that decision-makers focus their attention on a public policy at government and local authority level that is aimed at meeting the needs of all citizens, from different social groups, including the underprivileged and poor. Observing the facts and analysing official documents makes it clear that housing policy varies in these specific areas that are affected by various crises, including negative social, spatial/functional and technical developments (the "revitalisation areas"). Since revitalisation programmes at municipality level do not include this sectoral policy in their considerations, housing is relegated to secondary or even tertiary status. This should not be the case – as a horizontal policy, revitalisation policy must also encompass these responsibilities of the municipality itself and set objectives and priorities for all stakeholders (including developers, investors and other private- and public-sector operators)."

With air quality problems present across the board in the revitalisation areas, thus exerting a direct impact on the health of the people in RAs, particular priority in the revitalisation process should be given to finding environmentally friendly solutions, including in housing.

Land for residential use makes up 83.67% of the space in RAs designated in cities and 76.32% of the space in these areas in rural municipalities (Spadło, 2020: 60). At the same time, the results of an ongoing evaluation (Jadach-Sepioło 2021) show that, although revitalisation is inextricably linked in Poland with the need to improve residents' quality of life – very often including significant housing problems that have been worsening for decades – such projects make up only about 10–15% of all revitalisation initiatives. The study also found that these projects mainly involve renovating communal areas, whilst comprehensive refurbishment remains rare. In addition, only a handful of municipalities are making use of statutory tools (twelve Polish municipalities have set up a Special Revitalisation Zone, and only five local authorities have begun to devise a local revitalisation plan) that enable support to be provided by private companies with plans to modernise buildings located in revitalisation areas. The following section of the toolkit outlines the residential development work being undertaken in the Special Revitalisation Zones.

Part II

The energy efficiency standard of retrofitting

Part II

The energy efficiency standard of retrofitting

II.1 Energy demand versus occupant comfort and health

When talking about a retrofit, it is important to consider not only energy savings but also, and in particular, the purposes for which energy is supplied to the building. Having a clear understanding of these purposes should keep us away from inefficient measures that, although they may result in savings, would also make rooms less comfortable or increase the risk of illness due to insufficient ventilation, for example.

By supplying energy to a building, we hope to keep the air inside a suitable temperature and clean (via ventilation and heating incoming air), provide hot water for washing, ensure adequate lighting and power household appliances.

Let us now consider in more detail the issues relating to the supply of heat energy providing thermal comfort, clean air and hot water.

Air temperature

Let us assume that an apparent temperature of 20–21°C is considered comfortable. But what exactly does "apparent temperature" mean? Essentially, it can be assumed to be the average of the air temperature and the surface temperature of the surrounding parts of the building envelope. For example, if we were near a window with an internal surface temperature of about 16°C and in air with a temperature of 20°C, we would feel an apparent temperature of about 18°C between these two elements. This suggests that insufficiently insulated external walls not only make more heat "escape" but also make us feel cold – despite the air being 20°C – due to the low surface temperature. In the same way, underfloor heating will increase the apparent temperature; a warm floor (around 25°C) will produce a comfortable-feeling 20–21°C even if the air temperature is 18–19°C. Needless to say, some people will also be comfortable at a temperature a few degrees lower or higher than the assumed 20–21°C. If we decide to turn the temperature down to 17°C in winter, we can expect our heating bills to be about 20% lower; similarly, maintaining a constant 23°C in winter will add around 20% onto our bills.

Air exchange

Besides thermal comfort, air quality – i.e. ensuring adequate ventilation – is also an important factor. An air flow of 30–50 m3/h per person or 0.5 to 1.0 air changes per hour throughout the entire volume of the house is considered ideal. This figure is based on the need to remove pollutants that are emitted indoors as a result of our activities and our simply being present inside the building. Inside a building, there will be an increase in the carbon dioxide content and a reduction in the oxygen content of the room air, an increase in the amount of water vapour and the emission of a very large number of chemical pollutants of various kinds from furniture, cleaning products, carpets, wallpaper, etc. Since a deterioration in air quality is hard to detect (unlike temperature, which we feel immediately if it is too low or too high), this poses an even greater danger. It can cause ill health as well as serious health problems due to mould forming (as a result of excessive moisture in the air, i.e. a lack of effective ventilation removing moisture to the outside) or to interference with heating appliances (gas oven, water heater, fireplace). In other words, proper ventilation is not only a question of smells but also, and in particular, of health, and it is essential not to cut corners in this area.

Heating system

A heating system is responsible for heating the ambient air and keeping rooms at a comfortable temperature. Polish regulations require every building intended for permanent human habitation to have such a system. Most single-family dwellings are equipped with central water heating – a two-pipe gravity heating system or, increasingly, a closed system with pump circulation. The heat for the system is usually supplied by a boiler powered by natural gas, for example. The temperature of the water supplying the radiators can be pre-set on the boiler (known as "quality control" or "weather control") depending on the current temperature of the air outside. An internal central heating system transfers the heat to the radiators, which then radiate it out into the rooms. Since how much heat a room requires generally depends not only on the current outside air temperature but also on factors such as occupant preferences, additional indoor heat sources and extra heat from sunlight, a thermostatic valve is fitted to the radiators to control heat distribution on each. The energy consumed (in this case gas) is always measured at the point where the system enters the building and may include cooking and hot water preparation as well as heating in this case.

This kind of heating system compensates for heat lost as a result of:

- Heat penetrating external walls – typically around 20–30%,
- Heat penetrating the roof – typically around 10–25%,
- Heat penetrating windows – typically around 15–25%,
- Heat being lost into the ground or an unheated cellar – typically around 3–6%,
- Heating ventilation air – usually around 10–40%.

As well as lost heat, heat can also be gained indoors in a number of ways:

- From sunlight,
- From the presence and day-to-day activities of the occupants.

Although this latter heat gain is considered a benefit when heating, occupants will effectively still have to pay for this energy when settling their electricity or gas bill.

When the temperature outside is low, it can be assumed that all of the heat gains can be used indoors to increase the air temperature. The hotter it is outdoors, i.e. the lower the heat demand, the less of the heat gains can be utilised. In a well-insulated building, the heat gains will be sufficient to keep the indoor temperature at +20°C even when it is around +5°C outside; in an old, unrenovated building, by contrast, the heating would already have had to have been switched on when it dropped to +12–15°C outside.

Bearing in mind that we cannot always make full use of heat gains, the difference between heat losses and heat gains represents the amount of heat required at any given time to ensure the necessary air temperature indoors. This energy has to be supplied by a radiator, underfloor heating system or the draught from a fireplace, oven, etc. However, it is not the same quantity of energy that we pay for. To calculate this, it is necessary to go back to the source of the energy supplying the building in question. If this is a natural-gas-fired boiler, it can be assumed that the efficiency at which heat is generated is equal to the efficiency of the boiler (i.e. 50–95%). In other words, some of the heat produced by burning the gas will “escape” together with the flue gases.

By way of an aside, it is worth noting that cooling the flue gases excessively causes condensation to build up, which can destroy an unsuitable chimney or boiler.

This results in losses:

- Associated with heat being transported from the boiler to a room; these losses are particularly “severe” if the pipes run through unheated rooms – typically 95%,
- Associated with the heat supply not being regulated precisely, e.g. heating south-facing rooms too much, as north-facing ones will be under-heated if the heating is turned down – typically around 93%,
- Associated with the use of heat inside a room, taking into account factors such as the location of the radiators and whether they are obscured or covered by anything (they will ideally be underneath the windowsill and kept completely free) – typically around 95%.

This gives the boiler and central heating system a total efficiency level of anywhere between around 40% and over 80%. This figure translates directly into heating costs.

ILLUSTRATION OF HEAT LOSSES AND GAINS AS WELL AS USEFUL AND FINAL ENERGY DEMAND

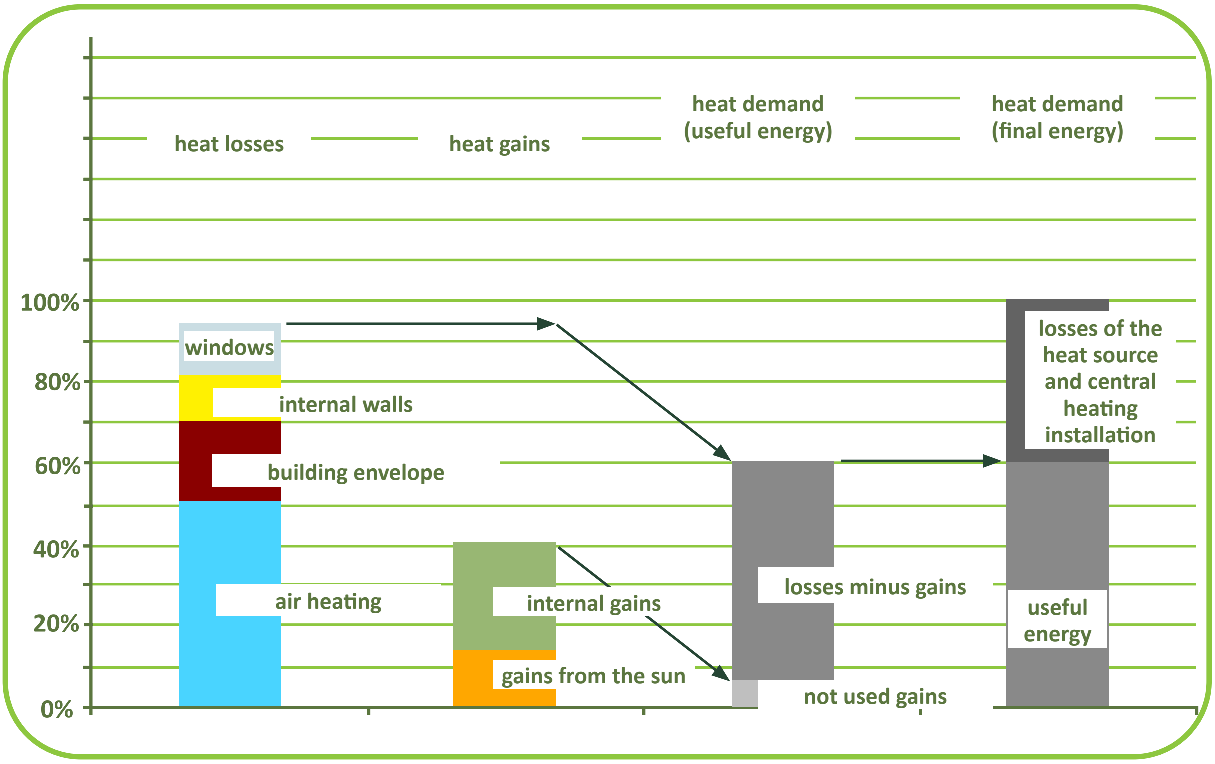


Fig. 14. Illustration of heat losses and gains as well as useful and final energy demand for an example flat in a 2000s building.

Water heating system

Energy is also needed in order to prepare hot water. The corresponding heat source can be integrated into the central heating system, or a standalone appliance can be used. How much heat will be required for this purpose will depend on the amount of hot water consumed and the efficiency of the boiler/heater and the overall system. Simply heating one cubic metre of water (1,000 litres) from 10°C to 55°C requires some 50 kWh of energy. Unfortunately, the way in which heat is used to heat water makes the boiler and the system as a whole much less efficient than in the case of central heating. A standard system that is several decades old will usually be no more than around 30% efficient. This means that over half of the heat is lost – a significant amount – and more than 150 kWh of energy is required to heat the one cubic metre from the earlier example. A modern, highly efficient central hot water system can double this overall efficiency (boiler plus system) to around 60–70%.

II.2 What is involved in retrofitting a building?

When carrying out a retrofit project, the current situation should first be analysed. In other words, the thermal comfort conditions for users inside the building should be checked alongside its compliance with the applicable technical and construction regulations. After that, the next step is to choose the retrofitting solutions to implement and produce a timetable for doing so. The technical and energy efficiency standard achieved will ultimately depend on the correct planning and implementation of the retrofitting process.

In planning a retrofit project, a list of criteria should be prepared, including:

- The intended level of insulation for the building envelope,
- The quality and energy efficiency of the installation systems,
- The impact of the building on the environment,
- Ensuring air parameters conducive to the health of users,
- Effectiveness and sustainability of the construction materials and installation systems used,
- Making allowances for changes to the use of the building,
- Ensuring the ease of use of devices and economic operation of the installation systems,
- Economic efficiency of activities carried out,
- Adapting the building to the needs of the disabled.

Energy consumption inside buildings can be significantly reduced, not only by increasing the thermal insulation of the building envelope but also by controlling heating, ventilation, air-conditioning and lighting systems in the correct way. Another aspect involves adapting the intensity of the technical systems to the requirements at any given moment.

The energy demand of a building depends on numerous parameters, including the thermal insulation of the building envelope, the type of heating and ventilation system used, the flow of ventilation air, the amount of heat gained from sunlight, what the building is used for and the general parameters inside the building (temperature, relative humidity), etc. Although some of these parameters will be influenced by the building's occupants during its use, others will depend on its technical condition.

The thermal insulation of the envelope is an important factor in assessing the energy quality of a building. This is not necessarily an easy task, even if building plans are to hand, as the envelope will not always have been constructed in line with them. Some parts of the envelope may also have been retrofitted or rebuilt after the building entered use, and these changes will not always have been included in its technical documentation. Another key aspect is how the thermal properties of building materials change over time. The thermal resistance of a material will typically decrease over a building's lifetime. The rate of this change depends on a number of factors, such as the type of material, its exposure to external agents, the influence of the internal environment, ongoing maintenance work or unforeseen failures or faults.

There are several ways to assess the level of thermal protection. This can be done based on:

- Existing technical documentation,
- Site inspections,
- Catalogue data and legal regulations,
- Measurements.

The first of these methods involves consulting technical documentation to find out about the construction of the building envelope and the materials used. If these documents are available, they will be the main source of information on the envelope's construction. Knowing what materials were used makes it possible to determine the heat transfer coefficient (U-value) of an opaque envelope section in accordance with the current standard.

A site inspection will indicate whether the documentation available on a building reflects its actual condition. Visiting a building in situ will usually make it easy to check whether it has undergone any significant changes during its use and make it possible to verify the condition of the construction and insulation materials. If the building's current condition is in line with the blueprints, they can be used for further work. If any discrepancies are identified, additional tests should be carried out to estimate the actual thermal insulation of the envelope. In the event of gaps in the documentation, measurements and/or excavation work should be performed during the site inspection to examine the construction of the envelope.

Heat transfer coefficients through the building's envelope can also be estimated based on the technology that it employs or the year it was constructed. Specific technologies are usually described in building catalogues, which also state the heat transfer coefficients of the building envelope. Buildings that enter use at different times must comply with the thermal protection stipulations enshrined in the relevant legislation, standards or technical requirements.

The last of these methods involves taking specialist measurements using appropriate instruments. These can be used not only to measure the heat transfer coefficient but also to assess how damp a certain part of the building envelope is. A method known as thermography is often used, which allows the thermal quality of the building envelope and the continuity of the insulation to be assessed.

Another aspect is assessing the technical condition of the heating, ventilation and cooling systems. Any appraisal of existing condition should be broken down into the following stages: assessing the technical condition of the system; verifying the design assumptions and settings of the automatic control system; and any structural and organisational constraints with an impact on retrofitting. A technical condition assessment will also include evaluating how leak-tight the system is (whether any air or water can escape), evaluating the condition of the thermal insulation, and checking the cleanliness of heat transfer surfaces and the condition of actuators and mechanical parts. Verifying the design assumptions and settings of the automatic control system also includes checking whether the actual parameters comply with those calculated in the blueprints. The following elements should be verified: the supply air parameters; the heating/cooling power (overall and in each room); the volume flow rate (overall and per person); the diagrams of system operation time; the settings and strategies for the automatic control system; and the option of regulating heating/cooling power and volume flow rate in individual zones of the building depending on the usage profile.

Any plans to retrofit systems must take account of the building's construction and factors including the options for routing pipes or ventilation ducts, the restrictions imposed by a division into fire zones and the availability of energy carriers (energy sources and connections).

The technical condition of the lighting system and the lighting conditions of the rooms inside a building should be checked regularly – at least once every five years – while the building is in use. How often the technical condition of the system and the lighting conditions are to be checked should depend on factors including what the premises are used for and what lighting solutions are employed, including the types of light fixture and light source. An analysis of the technical condition of the lighting system being used should also serve to assess the energy efficiency standard in terms of its current level and potential for improvement. Such an assessment will be necessary when drawing up energy performance certificates and preparing a building retrofit project. The verification should start with a review of the technical documentation and should check the types, wattages and number of light fittings and light sources in each room as well as how these light sources are distributed. Retrofitting the system will involve replacing faulty light fittings with new ones, adapting the system in line with current regulations and requirements and adjusting the lighting power.

When assessing the technical condition of the hot water system, particular focus should be placed on the following elements: the equipment used to prepare the hot water; the hot water system piping and circulation piping; the thermal insulation; the fittings; the taps; the validity of the verification of the water meters installed on the hot water system piping; and compliance with technical requirements relating to reducing microbiological hazards in the hot water system. Particular attention should be paid during the technical inspection of the hot water system to achieving the required hot water temperature both at the point where it is prepared and at the furthest draw-off points in the system. The effectiveness of the hydraulic balancing of the individual circulation circuits will also need to be checked, as this has a direct impact on keeping the hot water supplied to users at the correct temperature. Assessing the technical condition of the hot water system and the equipment used in hot water preparation can underpin an analysis of the options for retrofitting the system in terms of the conditions required for the efficient use of energy carriers and for reducing water consumption.

The main element of an analysis of options for improving the energy efficiency standard of cold and hot water supply systems as well as sewerage systems carrying domestic sewage and rainwater in buildings and on the premises will be an assessment of their technical condition.

The following should be included in an analysis of the technical condition of water supply systems: determining the condition of the materials used to make the individual components of the system; determining the capacity of valves and taps in order to estimate the degree of change in system capacity; determining the level of noise generated by the system; inspecting the readings on water meters (both main and for each occupant) in order to estimate the scale of water leaks in the system; and inspecting how pipes are attached to the fixed elements of the building.

If a building is to be comprehensively retrofitted, it must be brought in line with the applicable technical and building regulations. Any improvement in the technical standard should be integrated into an improvement in energy efficiency. Without a doubt, a comprehensive retrofit offers the advantage of potentially achieving significant energy and emissions savings as well as avoiding additional costs resulting from issues such as timing individual retrofit measures poorly. A retrofit can improve not only the look of a building but also the health of its occupants or its accessibility for people with disabilities. The functional layout of a building can also very often be improved or extra floor space gained based on a detailed case study.

II.3 The technical standard of retrofitting

Retrofitting a building is a complex process and one that requires engagement from the investor, the energy auditor, the designer and the building's user if it is to work.

The issues relating to the technical standard of retrofitting in the broad sense include the following:

- Technological aspects: the set and description of retrofit projects,
- Procedural aspects: the principles for conducting an energy audit and carrying out construction work,
- Verification aspects: assessing the effects of the retrofitting work carried out.

Understanding all of the issues involved in retrofitting work geared towards making buildings more energy-efficient also requires at least a basic knowledge of the terminology used. This applies, for example, to the difference between the terms "useful energy", "final energy" and "primary energy". In the paragraphs that follow, an attempt has been made to include some of the most important information about the technical standard of retrofitting in general.

II.4 What different types of energy are there inside a building?

Energy can take the form of heat, chemical energy, nuclear energy, light energy, mechanical work or electricity. In discussing buildings and how to make them more energy-efficient, we will be restricting ourselves to heat and electricity. When assessing the energy performance of a building, we will be using the terms "useful energy", "final energy" and "non-renewable primary energy" for these types of energy. The Polish regulations governing the methodology for determining the energy performance of a building or part thereof and energy performance certificates state the following:

- Useful energy
  a. when heating a building or part thereof – the energy that is transferred from the building or part thereof to its surroundings by infiltration or with the ventilation air, minus the heat gains,
  b. when cooling a building or part thereof – the heat gains minus the energy that is transferred from a building or part thereof to its surroundings by infiltration or with the ventilation air,

c. when preparing domestic hot water – the energy that is transferred from a building or part thereof to its surroundings together with the wastewater,

- Final energy – energy that is supplied to a building or part thereof for its technical systems,
- Non-renewable primary energy – energy contained in fossil energy resources that has not been converted or transformed.

The figure below (Figure 15) illustrates the sequence for calculating the various types of energy and for how that energy is supplied.

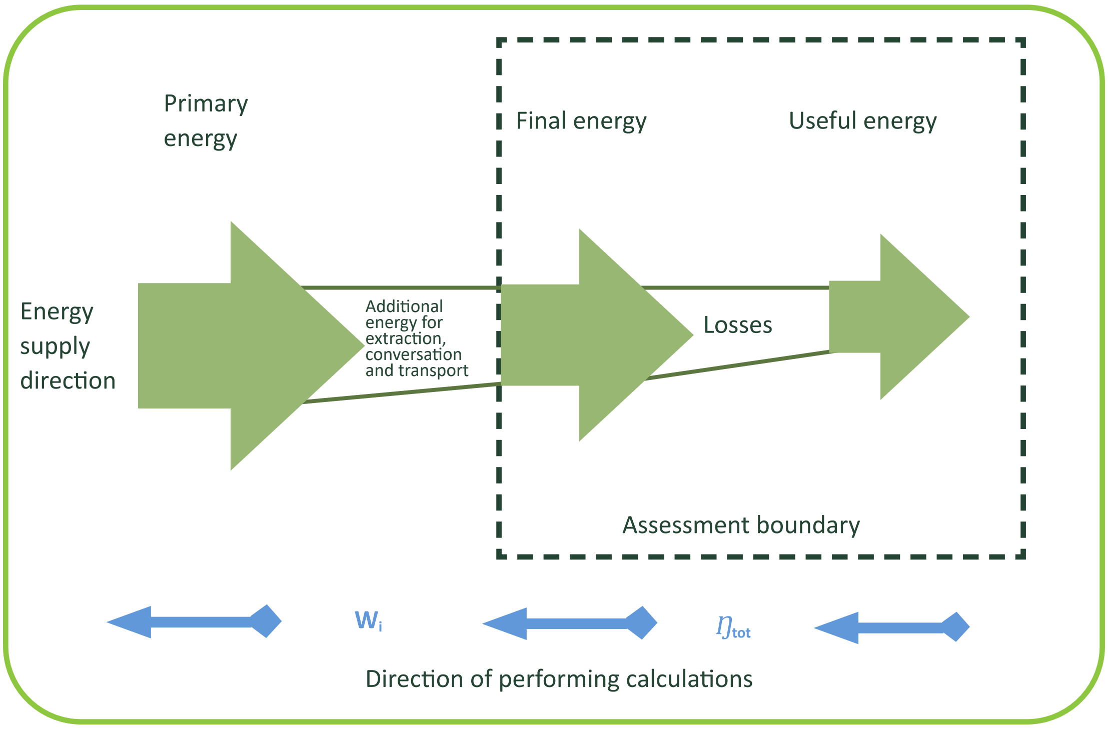


Fig. 15. Sequence for calculating and supplying energy within the framework of determining a building's energy performance
Source: Polish Energy Conservation Foundation.

The useful energy demand is determined based on the thermal balance of the relevant space and takes into account internal gains, solar gains, heat lost through infiltration and ventilation, and the utilisation factor for heat gains in heating mode or heat losses in cooling mode. To calculate final energy demand, the useful energy demand is divided by the overall system efficiency tot, which is the product of four partial seasonal efficiency factors: generation, transmission, accumulation, and regulation and utilisation. The non-renewable primary energy demand is calculated as the product of the final energy demand and the non-renewable primary energy input factor w_i.

Measures to reduce the demand for useful energy for heating or cooling a building involve retrofitting the building envelope, both externally and internally, and upgrading the ventilation system.

Reducing final energy demand requires making the building's technical systems more efficient. This can be done by using an energy source with a higher generation efficiency, reducing heat transfer or storage losses, or employing more efficient automation systems.

Alongside measures designed to reduce the useful or final energy demand, the non-renewable primary energy demand can also be modified by changing the fuel or energy source supplied to the building. The amount of this energy will depend on the input factor for non-renewable primary energy and its standard values as shown in Figure 16.

STANDARD VALUES FOR THE NON-RENEWABLE PRIMARY ENERGY INPUT FACTOR

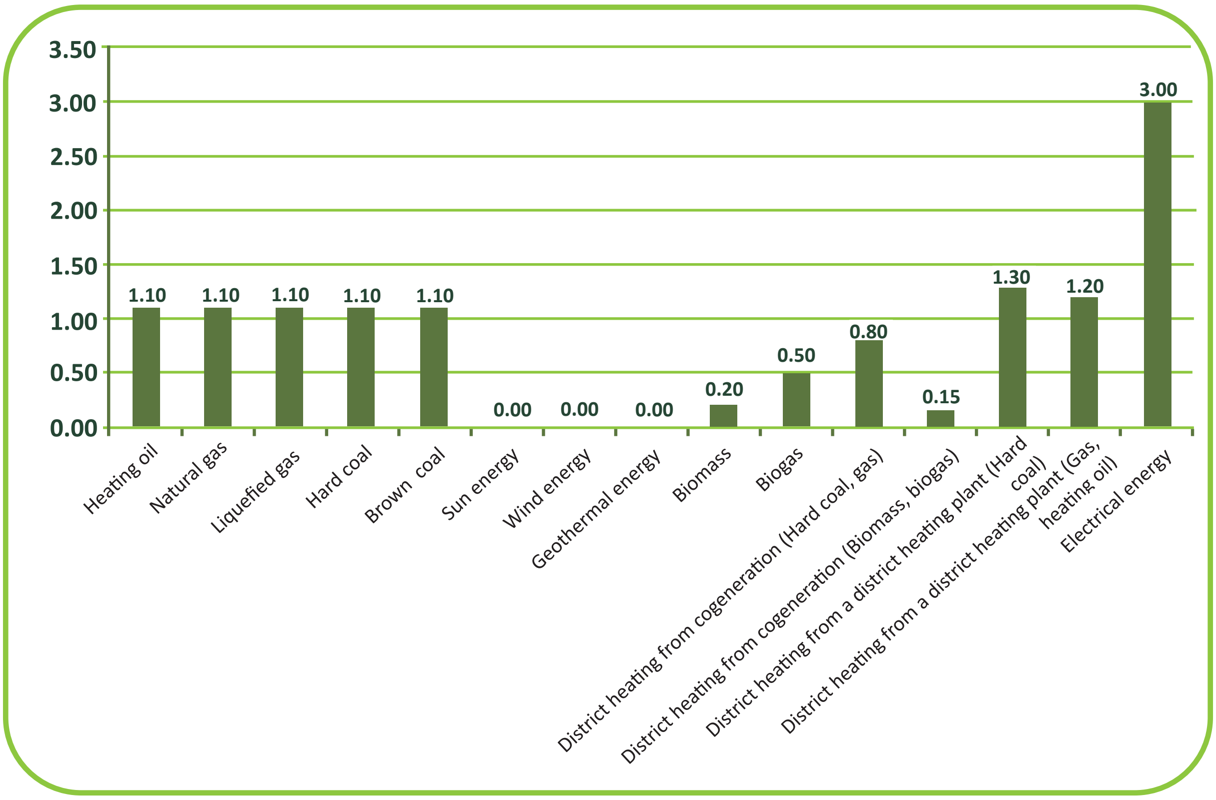


Fig. 16. Standard values for the non-renewable primary energy input factor in accordance with the regulations governing the methodology for determining a building's energy performance
Source: Polish Energy Conservation Foundation.

In the case of fossil fuels burnt directly in situ and standard district heating systems without combined heat and power (CHP), the wi values are greater than one. Renewable sources have a wi of zero. For renewable fuels and district heating networks with CHP, the values are less than one. At 3.0, system electricity has the highest value.

II.5 What is an energy audit?

A basic definition of an energy audit can be found in the standard PN-EN 16247-1:2012 Energy audits – Part 1: General requirements. This states that an energy audit involves systematically monitoring and analysing the energy used and consumed by a property, building, system or organisation in order to identify and report on energy flows and the potential to make energy efficiency improvements. Under this definition, an audit encompasses the whole range of activities relating to examining, analysing and assessing the energy efficiency of not only buildings and their component parts but also processes, transport and organisation. In addition, the standard defines an energy audit report as a study containing a summary of opportunities for energy efficiency improvements and a proposed timeline for implementing these measures.

The procedure for performing energy audits of buildings, for example, is described in detail in the regulations on the detailed scope and forms of energy audits (Journal of Laws 2009, no. 43, item 346; Journal of Laws 2015, item 1606; Journal of Laws 2020, item 879) and relates to projects geared towards reducing the energy demand of a building for heating and the preparation of hot water as well as replacing heat sources inside the building. Since the system for supporting thermal upgrading has been running in Poland for over 20 years now, energy auditors are familiar with the process for choosing retrofit projects based on the procedure described in the regulations mentioned above.

If there are plans for a more extensive retrofit of a building than that stipulated in the Polish Act on Supporting Thermal Upgrades and Renovation, a procedure based on the regulations defining the scope and forms of energy audits can be adopted in order to select the best solutions as there is no strictly defined form that such an audit should take. However, an audit conducted in this way will not be able to help secure a thermal upgrade or renovation reward. Various financial support programmes require an energy audit to be conducted in accordance with the methodology set out in the regulations on the detailed scope and forms of energy audits even though the scope of the subsidy is broader than that stipulated in the Polish Act on Supporting Thermal Upgrades and Renovation. An energy auditor must be tasked with the audit.

II.6 What types of audit are there?

Poland has several types of audit that are carried out for specific purposes; these are described below.

An **energy audit (thermal upgrading)** is a study that specifies the scope and the technical and economic parameters of a thermal upgrade project and that indicates the ideal solution, taking particular account of the costs of delivering this project and the energy that could be saved, while also constituting the premises for a construction project. It works on the basis of the Polish Act of 21 November 2008 on Supporting Thermal Upgrades and Renovation and the central register of building emissions (Journal of Laws 2021, items 554, 1162, 1243). Energy audits of buildings are to be performed in accordance with the regulations issued by the Polish Minister of Infrastructure on 17 March 2009 governing the detailed scope and forms of energy audits and parts of renovation audits, audit report templates and the algorithm for assessing the profitability of a thermal upgrade project (Journal of Laws 2009, no. 43, item 34), taking into account the relevant amendments (Journal of Laws 2015, item 1606, and Journal of Laws 2020, item 879). Buildings undergo energy audits in order to identify potential energy savings and choose the most appropriate retrofit option when the building's manager or owner is applying for a thermal upgrade reward. One might also be required as part of specific programmes supporting energy efficiency. The thermal upgrade reward, which is granted for implementing a thermal upgrade project, allows the investor to repay some of the loan taken out for the project.

The second type of audit is a **renovation audit**, which specifies the scope and the technical and economic parameters of a renovation project, while also constituting the premises for a construction project. It works on the basis of the Polish Act of 21 November 2008 on Supporting Thermal Upgrades and Renovation and the central register of building emissions (Journal of Laws 2021, item 554). Renovation audits of buildings are to be performed in accordance with the regulations issued by the Polish Minister of Infrastructure on 17 March 2009 governing the detailed scope and forms of energy audits and parts of renovation audits, audit report templates and the algorithm for assessing the profitability of a thermal upgrade project (Journal of Laws 2009, no. 43, item 34), taking into account the relevant amendments (Journal of Laws 2015, item 1606, and Journal of Laws 2020, item 879). Buildings undergo renovation audits in order to identify potential energy savings and choose the most appropriate retrofit option for improving the building's technical condition and when the building's manager or owner is applying for a renovation reward. The renovation reward, which is granted for implementing a renovation project, allows the investor to repay some of the loan taken out for the project provided that it involves renovating a multi-family dwelling that fulfils the criteria set out in the Act and the project meets the conditions set out in the Act regarding reducing energy demand and the cost of the renovation.

An **energy efficiency audit** is carried out in accordance with the Polish Energy Efficiency Act (Journal of Laws 2021, items 468, 868). It includes an analysis of energy consumption and determines the technical condition of a property, technical equipment or system. It is used as a basis for drawing up a list of measures for improving the energy efficiency of the property, technical equipment or system, assessing the economic feasibility of individual measures and estimating the energy savings that can be achieved. The energy efficiency audit also forms the basis for applying for "White Certificates". These attest to energy savings and can be traded on the energy exchange.

A **company energy audit** aims to provide detailed and verified calculations of proposed energy efficiency measures and furnish information on potential energy savings within a company. It works on the basis of the Polish Energy Efficiency Act of 20 May 2016 (Journal of Laws 2021, items 468, 868). A company energy audit must be performed by all large businesses that employed over 250 staff in the previous two years or that meet the financial criteria (annual sales of more than EUR 50 million and income of more than EUR 43 million). The company energy audit includes an overview of all its energy management activities and, on this basis, indicates how it can achieve cost-effective energy and cost savings and make its production more competitive.

II.7 How can the standard of a building be defined after retrofitting?

The rules governing the design of buildings in Poland are set out in Polish Construction Act of 7 July 1994 (Journal of Laws 2020, item 1333, as amended) and, in particular, are enshrined in the regulations on the technical requirements to be met by buildings and their location. These regulations provide a set of guidelines for all aspects related to designing, constructing and operating a building and the technical systems installed therein.

The **Technical Requirements** contain a section devoted to guidelines for reducing energy demand in buildings – Section X. Energy conservation and thermal insulation. As well as reducing energy demand, however, the regulations also make reference to maintaining thermal comfort (reducing the risk of overheating premises) and visual comfort (access to daylight).

Meeting the requirements for the thermal protection of a building mainly means ensuring that the thermal insulation (U-value) of an envelope section is adequate and that the non-renewable primary energy demand input factor does not exceed its maximum value. The maximum U-values for individual parts of a building envelope are given in Annex 2 to the regulations. Table 3 shows the values in force for example envelope sections as of 31 December 2020.

Envelope section type and temperature in room	Heat transfer coefficient $U_{C(max)}$ [W/(m²K)]
External walls (t_i≥16°C)	0.20
Roofs, flat roofs and ceilings under unheated attics or over passageways (t_i≥16°C)	0.15
Flooring on the ground (t_i≥16°C)	0.30
Windows (except skylights), balcony doors and transparent surfaces that do not open (t_i≥16°C)	0.9
Skylights (t_i≥16°C)	1.1

Table 3. Values for the maximum heat transfer coefficients of an example building envelope
Source: Polish Energy Conservation Foundation.

The maximum primary energy value is calculated as the sum of the partial values for heating, ventilation and domestic hot water and cooling (if there is a cooling system in the building) and lighting (in non-residential buildings).

These values will vary by building type; examples of the values applicable from 31 December 2020 are given in Table 4.

Partial value for primary energy [kWh/(m²rok)]	Type of building		
	Public use	Shared housing	Multi-family dwelling
Heating, ventilation and domestic hot water	45	75	65
Cooling	$25 \cdot A_{f,C}/Af^{*)}$		$5 \cdot A_{f,C}/Af^{*)}$
Lighting, depending on its operating time t_0	25 at $t_0 < 2{,}500$ h/year 50 at $t_0 \geq 2{,}500$ h/year		0

*) $A_{f,C}$ – cooled area, A_f – total temperature-controlled area

Table 4. Partial primary energy values in example building types
Source: Polish Energy Conservation Foundation.

Ever-lower heat transfer coefficients bring the problem of heat dissipation and thus the risk of premises overheating. Requirements have thus been stipulated regarding the reduction of solar gains through transparent partitions. Under the specifications, the product of the total solar energy transmittance of the glazing – g_n – and the radiant reduction factor due to the sun protection equipment used – f_C, must not exceed 0.35 in summer. This effect can be achieved by using appropriate glazing with selective coatings or fixed or movable sunshades. There is a wide range of possibilities, and a solution should be chosen on a case-by-case basis.

Another parameter to be taken into account is the air-tightness of the building, as this will affect the unwanted and uncontrolled flow of air into it from outside. This phenomenon can increase energy demand. The regulations recommend a maximum air permeability value n50 of 3.0 1/h in buildings with gravity or hybrid ventilation and 1.5 1/h in buildings with mechanical ventilation or air conditioning. It is also recommended that an air-tightness test be carried out once the building has been constructed.

In addition to structural aspects, the energy demand of a building is also influenced by what technical systems it uses. The Technical Requirements cover:

- The minimum thickness of the thermal insulation used for distribution pipes and components in central heating systems, domestic hot water systems (including circulation pipes) and air cooling and heating systems,
- The minimum heat recovery efficiency of a mechanical supply and exhaust ventilation system with heat recovery,
- The maximum power of corresponding fans used inside a ventilation and air-conditioning system,
- The requirement to use controllable fans to adjust their air output in line with usage needs in the case of hybrid ventilation, mechanical ventilation and supply/exhaust ventilation systems.

Some of the Technical Requirements are even more lenient than the restrictions imposed by European legislation, such as the Ecodesign Directive for ventilation equipment, where the minimum efficiency level for heat recovery is higher than that specified
in the Technical Requirements. Provided that appropriate certified ventilation equipment is used , therefore, the basic requirements of Polish building regulations will be met.

A retrofit of an existing building does not need to meet all the requirements applicable to newbuilds. The only criteria are usually not exceeding the maximum heat transfer coefficients in the retrofitted parts of the building envelope and adapting the building's technical systems in line with the current technical and building regulations. When designing a building retrofit project, however, there is nothing to prevent stricter criteria from being applied in order to achieve a better energy result while maintaining or even improving the level of indoor comfort.

II.8 The process steps involved in retrofitting a building

Before retrofitting an existing building, the appropriate scope of the improvements should be determined. The scope of the work to be done can be split into several stages depending on the objective and the accuracy of the analyses. Potential activities include:

- An energy survey of the building,
- An initial energy audit,
- An energy audit of the building (for renovation, thermal upgrading, energy efficiency),
- The retrofit project itself.

Table 5 below describes the objective and scope of these activities.

Name	Objective	Scope
Energy survey of the building	Assessing the energy efficiency of the building based on the stocktake carried out and identifying options for improving this situation by making the proposed improvements.	• A quantitative assessment consisting in drawing up and analysing the energy balance of the building using the consumption method. • Verifying the amount of thermal output (for heating and hot water preparation) and electrical power ordered. • A qualitative assessment in three categories: external envelope elements, internal systems, energy carriers and other media. • A final evaluation comparing the current condition of the element in question with the situation post-retrofit that would technically be possible as proposed in the so-called scoring catalogue.
Initial energy audit	Supporting the investor at the investment planning stage and estimating the underlying figures to help them choose an investment strategy.	• Determining the estimated investment costs of the proposed retrofitting work. • Determining the expected energy and operating cost savings associated with the proposed improvements. • Verifying the ability of the investment to meet the requirements of the Polish Act on Supporting Thermal Upgrades and Renovation. • Verifying the investor's financial capacity in relation to the proposed retrofitting work.

Energy audit of the building	Defining the financial and operational scope of an investment required to reduce heating bills and for heating rooms and water, making use of support from existing financial schemes.	• Assessing the current technical condition of the building and its systems. • Determining the building's energy performance. • A list of retrofitting and/or renovation improvements included in the retrofit project. • A technical description of the retrofit project to be carried out. • An economic assessment and selection of the most suitable retrofit option. • Preparing the documentation required to apply for funds from financial support schemes.
Retrofit project	Identifying and describing detailed structural and building solutions associated with the retrofitting improvements revealed in the energy audit.	• Describing the technical condition of the building with regard to the planned retrofitting improvements. • A detailed description of the technical solutions earmarked for implementation in the energy audit. • A description of the scope of the planned construction work. • A list of materials required to carry out the retrofit.

Table 5. A description of the process steps involved in retrofitting a building
Source: Polish Energy Conservation Foundation.

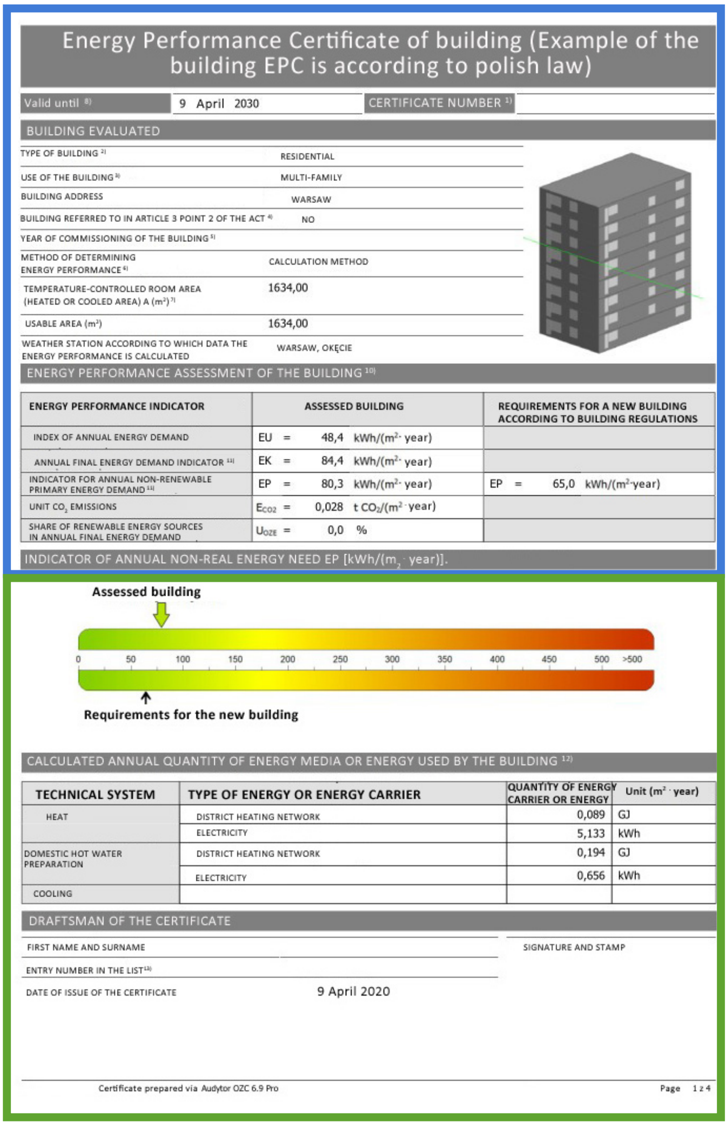
The scope of the individual process steps involved in retrofitting a building can vary depending on the condition of the building, the quality of the documentation and how much retrofit work is required. Before choosing the most suitable option, however, appropriate analyses must be carried out and the work itself must be planned well if the expected savings in energy demand are to be made.

II.9 What is an energy performance certificate for a building?

An energy performance certificate is a document comprising energy demand indicators for heating, domestic hot water, lighting and cooling. The document is issued by an authorised expert and contains basic data and indicators on the thermal protection of the building and the energy demand inside it as well as an assessment of the energy quality level by comparing the indicators against benchmarks.

Depending on the specific requirements, the calculations on an energy performance certificate are made for the building as a whole, for a part of the building constituting a self-contained entity in technical and utilities terms, or for a residential unit. However, a part of the building constituting a self-contained entity in technical and usage terms is a part with a single usage function different from the rest of the building and whose structural and installation solutions allow it to function independently (e.g. a residential building that has commercial premises on the ground floor).

It should also be noted that the energy demand calculations applied in the energy performance certificate system are performed based on standard building use and using standard climate data. This means that the results of the final energy demand calculations will differ from the actual energy consumption measured over a given financial year. It can therefore be said that the energy performance certificate system should be used to compare buildings with one another or to identify how retrofit work can deliver savings in relative terms rather than to determine actual energy demand and the associated costs.



Energy Performance Certificate of building (Example of the building EPC is according to polish law)

Valid until [8]	9 April 2030	CERTIFICATE NUMBER [1]	

BUILDING EVALUATED

TYPE OF BUILDING [2]	RESIDENTIAL
USE OF THE BUILDING [3]	MULTI-FAMILY
BUILDING ADDRESS	WARSAW
BUILDING REFERRED TO IN ARTICLE 3 POINT 2 OF THE ACT [4]	NO
YEAR OF COMMISSIONING OF THE BUILDING [5]	
METHOD OF DETERMINING ENERGY PERFORMANCE [6]	CALCULATION METHOD
TEMPERATURE-CONTROLLED ROOM AREA (HEATED OR COOLED AREA) A (m^2) [7]	1634,00
USABLE AREA (m^2)	1634,00
WEATHER STATION ACCORDING TO WHICH DATA THE ENERGY PERFORMANCE IS CALCULATED	WARSAW, OKĘCIE

ENERGY PERFORMANCE ASSESSMENT OF THE BUILDING [10]

ENERGY PERFORMANCE INDICATOR	ASSESSED BUILDING	REQUIREMENTS FOR A NEW BUILDING ACCORDING TO BUILDING REGULATIONS
INDEX OF ANNUAL ENERGY DEMAND	EU = 48,4 kWh/(m^2· year)	
ANNUAL FINAL ENERGY DEMAND INDICATOR [11]	EK = 84,4 kWh/(m^2· year)	
INDICATOR FOR ANNUAL NON-RENEWABLE PRIMARY ENERGY DEMAND [11]	EP = 80,3 kWh/(m^2· year)	EP = 65,0 kWh/(m^2·year)
UNIT CO_2 EMISSIONS	E_{CO2} = 0,028 t CO_2/(m^2· year)	
SHARE OF RENEWABLE ENERGY SOURCES IN ANNUAL FINAL ENERGY DEMAND	U_{OZE} = 0,0 %	

INDICATOR OF ANNUAL NON-REAL ENERGY NEED EP [kWh/(m_2· year)].

CALCULATED ANNUAL QUANTITY OF ENERGY MEDIA OR ENERGY USED BY THE BUILDING [12]

TECHNICAL SYSTEM	TYPE OF ENERGY OR ENERGY CARRIER	QUANTITY OF ENERGY CARRIER OR ENERGY	Unit (m^2 · year)
HEAT	DISTRICT HEATING NETWORK	0,089	GJ
	ELECTRICITY	5,133	kWh
DOMESTIC HOT WATER PREPARATION	DISTRICT HEATING NETWORK	0,194	GJ
	ELECTRICITY	0,656	kWh
COOLING			

DRAFTSMAN OF THE CERTIFICATE

FIRST NAME AND SURNAME	SIGNATURE AND STAMP
ENTRY NUMBER IN THE LIST [13]	
DATE OF ISSUE OF THE CERTIFICATE	9 April 2020

Certificate prepared via Audytor OZC 6.9 Pro — Page 1 z 4

Data on a building subject to assessment

Fig. 17. Specimen energy performance certificate for a building
Source: Polish Energy Conservation Foundation.

Energy performance indicators

Fig. 18. Scope of the content to be shown on the energy performance certificate for a building
Source: Polish Energy Conservation Foundation.

II.10 What is the difference between an energy audit and an energy performance certificate?

The main difference between an energy audit and an energy performance certificate is the purpose for which they are carried out. An energy audit is performed in order to choose the most suitable set of retrofitting tasks and forms the basis for obtaining subsidies for the planned work (e.g. the thermal upgrade reward in the case of a thermal upgrade audit or “White Certificates” in the case of an energy efficiency audit). By contrast, the energy performance certificate is an energy assessment of an existing building in which measures that could improve its energy performance must be included, although their impact is not specified in detail. The former document only needs to be drawn up once, while the latter is valid for ten years. The energy performance certificate is an essential document required in order to sell or rent out a building or other premises.

II.11 How can the results of a retrofit be verified?

A retrofit is geared primarily towards reducing energy demand and thus reducing the costs of the building's heating and electricity supply. Carrying out an energy audit before undertaking a retrofit project is designed to determine the savings resulting from the proposed measures. Construction work is then carried out based on the retrofit project, for which the audit will have supplied the underlying premises. An assessment of the effects can be split into several stages:

- Verifying whether work was done correctly,
- Analysing the results obtained from a computational perspective,
- Analysing the results obtained from a measurement perspective.

Verifying whether the work was done correctly must also include checking whether the construction and installation work was performed in line with the retrofit project. This applies in particular to the scope of the work, the materials used and their parameters. It may emerge during construction work that some steps cannot be carried out, which will influence whether or not the desired energy efficiency level of the building can be achieved. Extra steps may also need to be added in that were not previously envisaged in the retrofit project. Checking the scope of the measures against the original assumptions is therefore essential.

Another important step is to check whether the specifications of the materials, building components or equipment used matches the underlying premises of the design. Here too, there may be an issue if elements with parameters (e.g. heat transfer coefficient) worse or better than those assumed were used during construction work.

Whereas the scope of the work and the specifications for the materials and equipment used in construction can be verified using the documentation provided, verifying the quality and correctness of the work carried out is not so easily done. This is primarily the responsibility of the site manager, who is in charge of the construction work carried out. They are tasked with checking that individual construction measures are carried out in accordance with the state of the art. Unfortunately, errors in construction do occur in practice despite a site manager being present. There are various tests that can be carried out by specialist companies or energy auditors in order to check whether this has happened. These tests include:

- Thermal imaging – infrared thermography is a technique that enables temperature fields to be visualised and logged on the surface of the objects being tested by detecting the infrared radiation emanating from them; the measurement produces a so-called thermogram, i.e. an image in which the temperature field is represented by a selected palette of colours or in shades of grey; this makes it possible to identify where heat is escaping from a room, e.g. due to gaps in the layer of insulation;
- Air-tightness tests – these serve to calculate the air permeability of a building (n50 value) and check whether it meets accepted requirements; they may also be used to detect, document and eliminate leaks causing the unwanted infiltration of outside air;
- Heat flux density tests – these measurements are carried out to determine the thermal resistance of a certain part of the building envelope and thus make it possible to determine whether it meets the expected requirements after retrofitting.

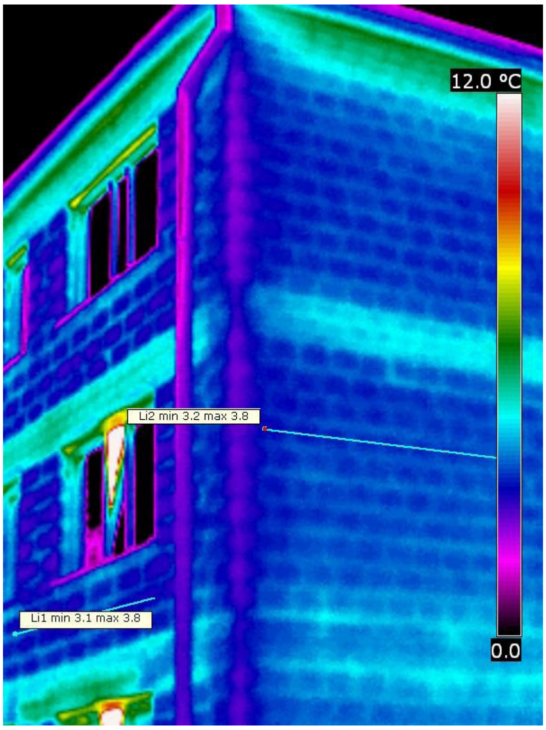


Photo 5. Thermal image of an example building
Source: Polish Energy Conservation Foundation.

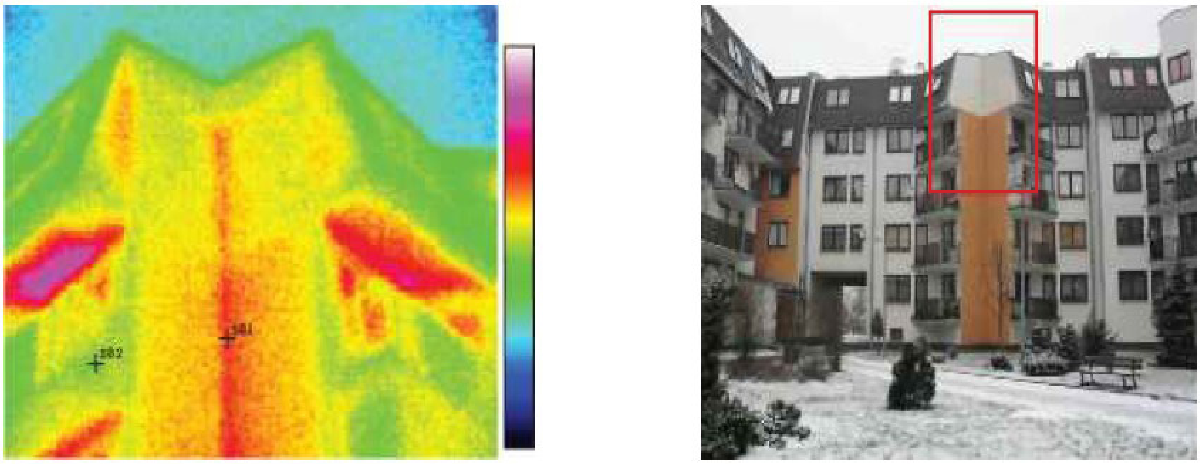


Photo 6. Thermogram showing heat lost through an internal corner
Source: Polish Energy Conservation Foundation.

After verifying whether the work was done correctly, it may emerge that the scope or parameters of the materials or equipment used have changed and that the energy and cost savings identified in the pre-retrofit audit are no longer valid. A post-retrofit energy audit should be carried out in this case in order to determine what the reduction in energy demand will be based on the actual building work carried out. This audit also forms part of various financial support schemes, where it is an essential prerequisite confirming that the work was carried out in line with the investment objectives.

However, the best way to verify the effects achieved is by using a measurement method. This involves recording energy consumption after a building has been retrofitted and comparing the results with the values logged before the retrofit. Depending on what the retrofit measures set out to achieve, it may be possible to determine the pre-retrofit benchmarks using heating or electricity bills. However, several important elements must be borne in mind in the case of a measurement method. Firstly, it is recommended that energy consumption measurements taken before and after the retrofit relate to the system or installation that was retrofitted. This will furnish data on the energy consumed by a specific system and, unlike collective meters, avoids any measurement uncertainties caused by potential changes in consumption levels in other systems. This will apply, for example, to work that reduces the demand for heating but in a building where there is a shared heating meter for the heating system and domestic hot water preparation. The amount of heat consumed by each of the two systems will need to be separated out in order to verify the effects achieved.

Another important element is normalising heat consumption measurements based on actual weather data. This is especially the case if the energy demand for heating falls. The amount of heat required to heat a room depends largely on the outside air temperature, which varies from year to year (and season to season). Figure 19 below shows the heating degree days[1] for the years 2010–2020 as well as standard meteorological data for Warsaw.

1 The number of heating degree days depends on the average outside temperature in each month and the number of days per year on which the heating is operating.

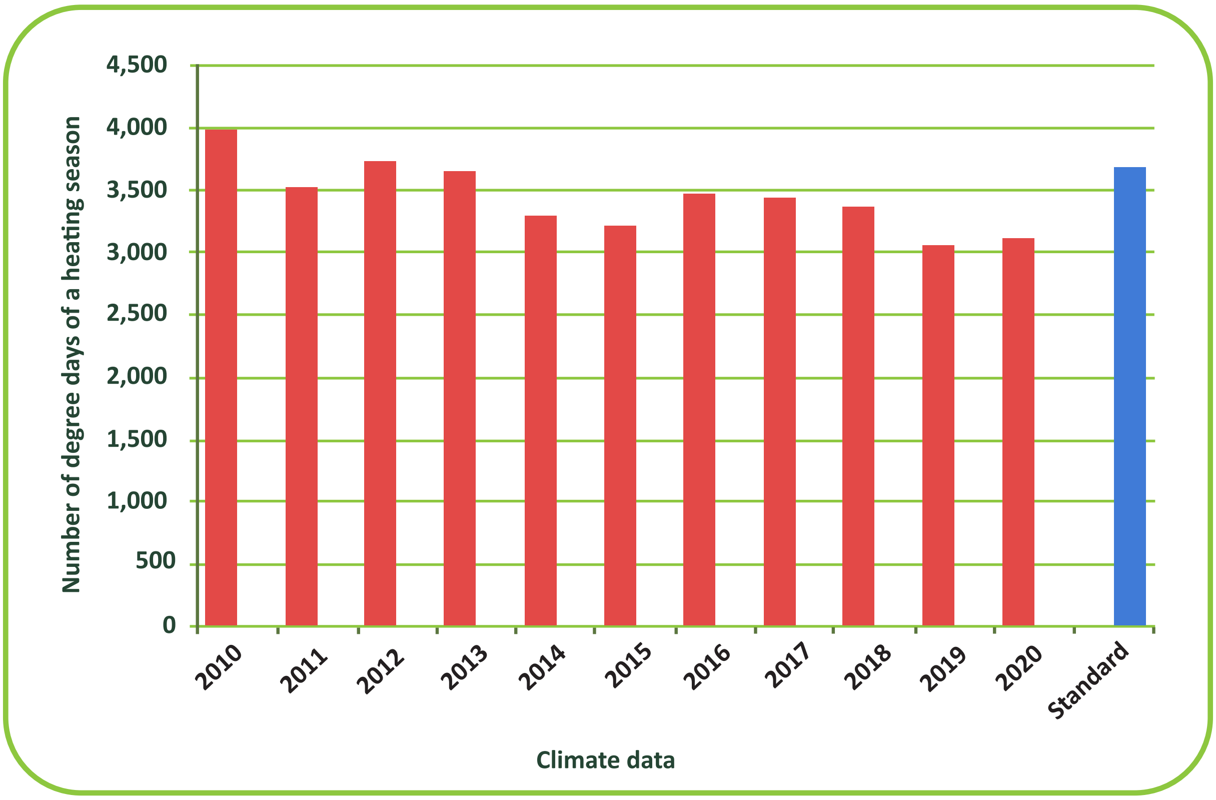


Fig. 19 Heating degree days for Warsaw
Source: Polish Energy Conservation Foundation.

The figure shows that the number of heating degree days can vary considerably – by more than 20% in some cases – from one year to the next. This also applies to differences between the actual outside temperature in a given measurement year and the standard data used for calculations in energy audits. In order to be able to compare whether and by how much heating demand has fallen, therefore, the consumption measurements must be compared against benchmark or baseline climate data – normalised, in other words.

When verifying the effects measured, it is also important to carry out a check in the next few years after completing the retrofit. Verification is most commonly done three to five years after the building work was completed. The thermal characteristics of the building and the regulation of its systems will change post-retrofit. It may take as much as a year to “learn” how to operate the building again, adjust its systems and change the habits of its users or residents. Measurements taken during the first year after the work was carried out may therefore not be reliable. There have been cases where the heat consumption of a building has actually increased in the first year following a thermal upgrade. Only after adjusting the systems and “teaching” users how the retrofitted building will respond to their actions did energy consumption fall in subsequent years to the level envisaged in the energy audit.

It is clear that verifying the effects of a retrofit comprises several steps that can be dealt with separately. However, taking all of them together will generally ensure that the anticipated savings can be made.

II.12 How can a building envelope be retrofitted?

External walls

The retrofit solution used for the building envelope must be tailored to the design of each individual section of it.

External walls can be classified as follows (Figure 20):

- Single-skin – comprising masonry made of a single material,
- Double-skin – comprising masonry and an insulation layer,
- Triple-skin – comprising masonry, an insulation layer and a curtain wall; there may be several centimetres of air between the insulation and the external masonry,
- External façades made of prefabricated elements,
- Timber-framed.

TYPES OF EXTERNAL WALLS

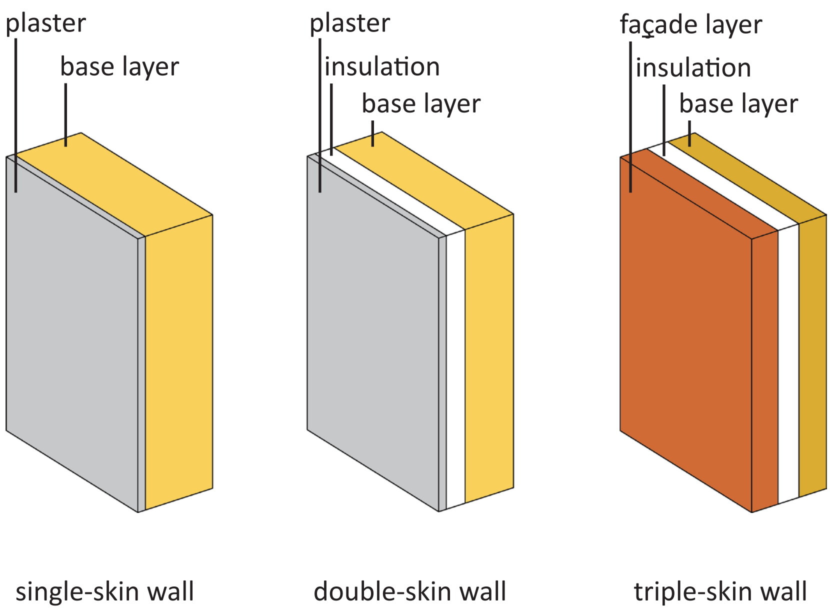


Fig. 20. Types of external wall (single-skin, double-skin, triple-skin)
Source: Polish Energy Conservation Foundation.

When retrofitting external walls, it is important to consider not only thermal insulation aspects but also solutions that can boost the building's energy performance. These days, the finishing elements for external walls can include solar panels.

The most important parameter for the retrofit process is the thermal insulation of the wall, which must meet the requirements of the applicable regulations. The maximum values for heat transfer coefficients are stipulated in the regulations issued by the Polish Minister of Transport, Construction and Maritime Economy on 5 July 2013 amending the regulations on the technical requirements to be met by buildings and their location.

How an external wall is to be retrofitted depends mainly on its construction. The most common ways to retrofit external walls are described below.

"Light-wet" method

The light-wet method involves affixing thermal insulation made from a particular insulation material to the external wall surface, placing a layer of plastic mesh reinforcement embedded in an adhesive on top and then applying a thin-coat render. It is generally used when retrofitting buildings with a single-skin wall.

However, double-skin walls can also be retrofitted using the light-wet method, in which case the old insulation layer must be removed and the wall must be insulated after the surface underneath has been reinforced.

"Light-dry" method

The light-dry method involves attaching impregnated, well-dried wooden slats to the outside of the building wall (metal profiles must not be used as water vapour can condense on them, making the insulation material and the building walls damp). Boards of mineral wool are used to insulate the walls. After putting the insulation boards in place, a layer of highly vapour-permeable polyethylene film is applied, followed by a spacer grid also made from wooden slats. This creates a ventilation gap, which should be between 20 and 30 mm wide. Meshes or grilles are installed at the inlet and outlet of the ventilation gap in order to prevent insects and rodents from getting in.

Double façade

When retrofitting a building, a double façade can be positioned either next to or offset from its external wall.

The use of both types of double façade avoids having to change the standard use of the premises. This solution makes it possible not only to increase the insulation of the external walls but also to change (adapt) the parameters of the translucent and opaque elements of the façade in line with the building's requirements.

In the case of a double façade next to the building's external wall, most of the work is carried out on the outside of the building using an aluminium structure fixed to the ceilings. New windows are inserted into this structure and fixed in place using special profiles. Once the windows have been installed, the thermal insulation and façade panels are fitted. The old window frames are not removed until after the external façade is finished. This work can be done while the building is not in use, minimising any inconvenience to its occupants. Elements that improve the energy performance of the building, such as solar panels, can be used as façade panels, while this solution also allows external active shading systems to be installed.

In terms of the technology, installing a double façade positioned a certain distance from the building is similar to installing one next to its external wall. In structural terms, such a façade can also be designed as a self-supporting system (i.e. it has its own structure and does not weigh down the building's structure once installed; the second façade is attached to the building).

A double façade brings several benefits: it can increase the impermeability of the structure, reduce the impact of noise and pollution and, in the case of façades not positioned adjacent to the retrofitted building wall, create additional space for running utility pipes, for instance.

When choosing a method for retrofitting external walls, local framework conditions must be taken into account alongside additional requirements arising from conservation regulations, for example. If thick insulation cannot be used, another option is modern insulation materials that enable a higher level of thermal resistance to be achieved with a much thinner layer of material thanks to their low thermal conductivity coefficient values. Such materials include aerogels and vacuum insulated panels (VIPs).

EXAMPLE OF THE EFFECT OF RETROFITTING EXTERNAL WALLS ON THE DEMAND FOR USEFUL ENERGY FOR HEATING AND RETROFIT COSTS BASED ON THE BUILDING DESCRIBED IN APPENDIX 1, "EXAMPLE OF A RETROFITTING ANALYSIS ON A MULTI-FAMILY DWELLING".

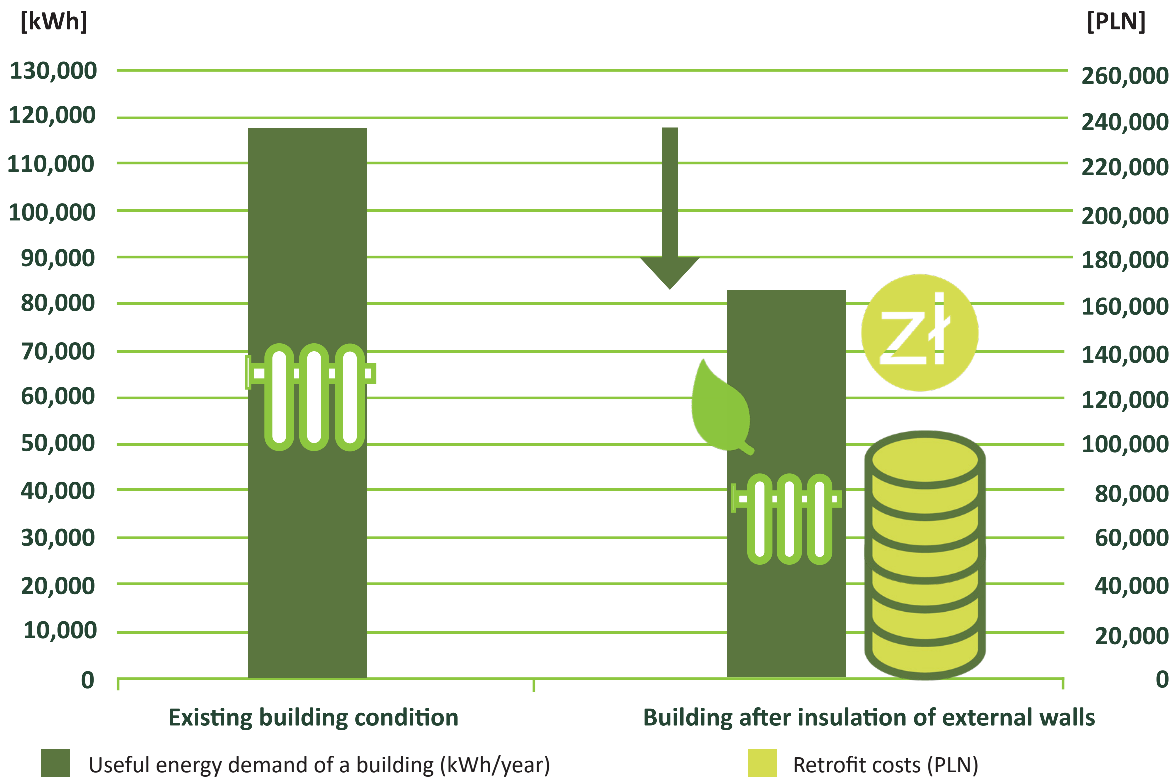


Fig. 21. Example of the effect of retrofitting external walls on the demand for useful energy for heating and retrofit costs (see Appendix 1 for more information on the assumptions used in the calculations)
Source: Polish Energy Conservation Foundation.

Roofs and ceilings

Ceilings in a building can be divided into:

- Flat roofs and roofs,
- Intermediate floors.

The heat transfer coefficients of the roof and flat roofs should meet the minimum requirements under the current thermal protection regulations for buildings.
How roofs or ceilings are to be retrofitted depends on their design and intended use. The most common ways to retrofit ceilings are described below.

Adding acoustic insulation to intermediate floors

Intermediate floors serve a dual purpose: they separate a storey from the storey above while also forming the floor for the upper storey.

Adding proper acoustic insulation to the intermediate floors means removing materials from the structural layer of the floor. This is therefore done while the building is being comprehensively retrofitted.

All materials used in the acoustic insulation layer must have a dynamic stiffness value that has been tested and declared by the manufacturer. No polystyrene (EPS) or extruded polystyrene (XPS) should be used for the acoustic insulation layer as the dynamic stiffness of these materials is not monitored during their manufacturing process.

Insulating ceilings above unheated spaces

The most beneficial way to reduce heat loss through the ceiling above an unheated space in a building being retrofitted is to lay thermal insulation on the side of the unheated space. The layer of insulation is fixed in place using hooks or steel mesh. On the side of the unheated space, the insulation can either be left uncovered or can be covered with aluminium foil, plaster, etc.

Active ceilings

It is also possible to route systems in the ceilings as part of the retrofit. Low-temperature underfloor and ceiling heating is used in residential units and offices. It mainly uses water as the heat transfer medium, in a similar way to surface cooling systems.

The advantage of surface heating systems is that they can maintain a temperature 2–3 K lower than in rooms with convection heating, with no adverse impact on thermal comfort for users. Reducing the losses associated with the transmission of the heat carrier allows the cost of the energy consumed to be cut by between 15% and 20%.

There are two types of ceiling cooling system: convection and radiant.
It is possible to find a suitable system for all ceiling structures and construction methods. The individual components of the cooling system, i.e. the cooling ducts and mats, are sometimes placed directly into the plaster and sometimes under the plasterboard of the suspended ceiling. Alternatively, they can be suspended in the form of metal panels.

An installation system that uses active heating and/or cooling can be implemented when a building is undergoing a comprehensive retrofit.

Flooring on the ground

Insulating foundation or basement walls reduces the amount of heat lost to the ground. There will be no need to insulate foundation walls if their masonry is made of a material with a low heat transfer coefficient. If the foundations are to be insulated, they must first be exposed. In the case of unheated basements, the foundation insulation does not need to reach as far down as the footing itself. The insulation should be laid at least 50 cm deep. Full-height wall insulation is recommended in energy-efficient buildings. New damp-proofing must also be installed in addition to the thermal insulation.

Insulating the flooring on the ground without removing any old layers

If the flooring on the ground can be insulated without removing any old layers, it must be borne in mind that adding insulation and making a new sub-floor complete with flooring will reduce the height of the room.

The internal and entrance doors will need to be shortened or replaced post-retrofit. This kind of solution brings benefits as it does not require any interference with the existing floor structure or incur any additional costs for removing the old floor layers.

Before carrying out a retrofit of this kind, an expert's report will be required in order to determine whether the existing floor can bear the loads associated with the new floor layers.

Insulating the flooring on the ground after removing the old layers

If the layers of the existing flooring on the ground cannot be kept, they must be removed and a new floor laid. The old horizontal floor insulation protecting the building from moisture coming up from the ground must be replaced or repaired when re-laying the floor.

Roofs and flat roofs

The methods for retrofitting typical structures involve adding a layer of thermal insulation and, if necessary, a vapour-proof and/or vapour-permeable film.

The simplest way to retrofit a ventilated flat roof is to add a layer of thermal insulation in the form of a loose insulating material such as granules of rock or glass mineral wool, cellulose insulation or polystyrene granules. The material is inserted into the ceiling using pneumatic equipment, and sight glasses are used to check whether the layer is distributed correctly and evenly.

How a flat roof should be insulated depends on how it is used. A distinction can be made between roofs where access is required occasionally (e.g. for emergency repairs to maintenance-free technical equipment, repairs to roofing/lining), roofs designed to accommodate people regularly (e.g. servicing and maintaining air-conditioning equipment), and roofs actually intended for use by people (e.g. terraces, green roofs). The appropriate insulation material and additional layers of waterproofing, vapour-proofing, slope and top protection for the structure must be chosen in view of this distinction. If the retrofit will not impact on the use of the roof, removing the old insulation layer can be assumed to be the best option.

Insulating the roof above an unused attic (without modifying the attic's function) can be done by laying insulation material directly onto the attic ceiling. Several layers of boards of insulating material are generally used, varying the position of the joins so as to eliminate any thermal bridges. Potential insulation material includes mineral wool, self-extinguishing polystyrene, compressed reed and polyurethane foam. A finishing layer is not usually required when using boards for this type of insulation.

A timber-framed roof, e.g. over an attic that is in general use, can be insulated by laying a layer of material above, between or under the rafters.

Laying insulation above the rafters is awkward and is only to be recommended if the top layer of the roof is being modified. There is usually already some insulation between the rafters and, if the existing layers are not thick enough to permit the required thickness of additional insulation to be laid, placing additional layers underneath them will suffice. Insulating boards are fixed in place using long nails. Several layers of boards are generally used, varying the position of the joins so as to eliminate any thermal bridges. Potential thermal insulation material includes mineral wool, self-extinguishing polystyrene, compressed reed and polyurethane foam. A vapour-proof film should be laid underneath (particularly if the structure is not ventilated), and the surface should be finished with plaster, plasterboard or another material.

RETROFITTING A VENTILATED FLAT ROOF

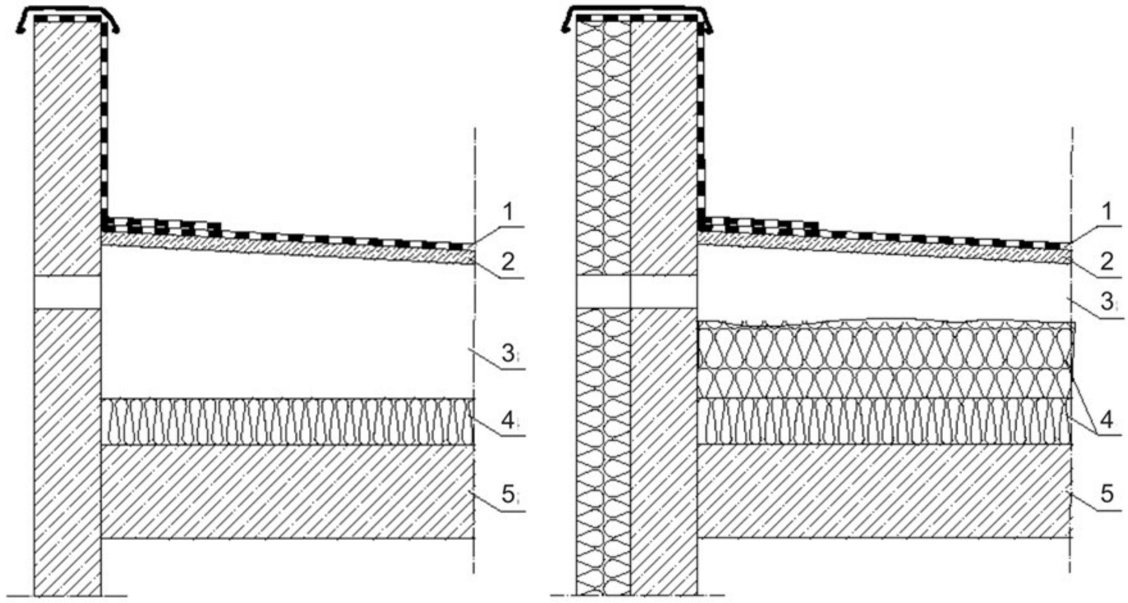


Fig. 22. Retrofitting a ventilated flat roof: 1 – top protective layer, 2 – structural layer, 3 – air cavity, 4 – thermal insulation, 5 – ceiling
Source: Polish Energy Conservation Foundation.

RETROFITTING A SOLID FLAT ROOF

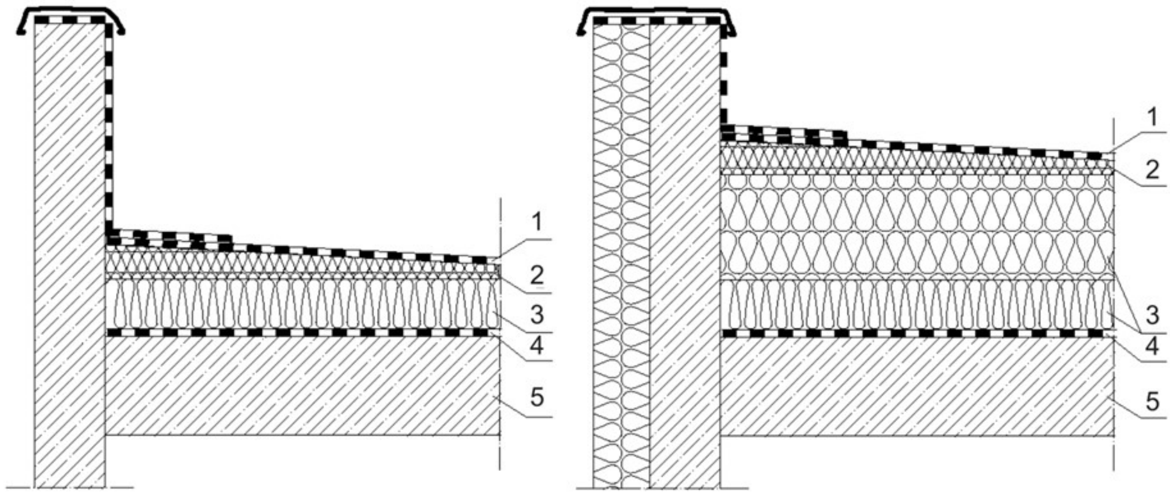


Fig. 23. Retrofitting a solid flat roof: 1 – top protective layer, 2 – sloping layer, 3 – thermal insulation, 4 – vapour-proofing, 5 – ceiling
Source: Polish Energy Conservation Foundation.

RETROFITTING A ROOF ABOVE AN UNUSED ATTIC

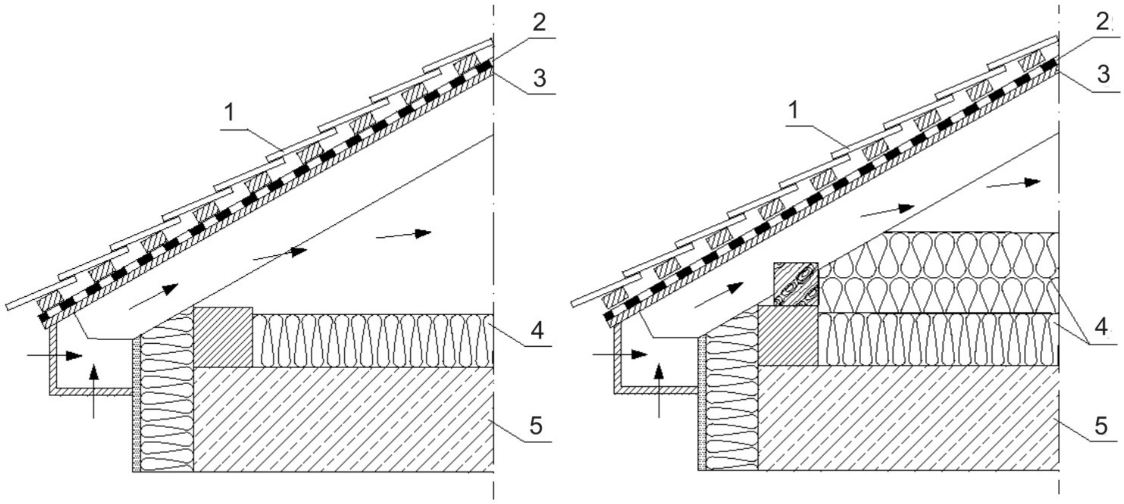


Fig. 24. Retrofitting a roof above an unused attic: 1 – roofing (tiles), 2 – water- and wind-proofing, 3 – soffit, 4 – thermal insulation, 5 – ceiling
Source: Polish Energy Conservation Foundation.

RETROFITTING A ROOF ABOVE AN ATTIC IN GENERAL USE

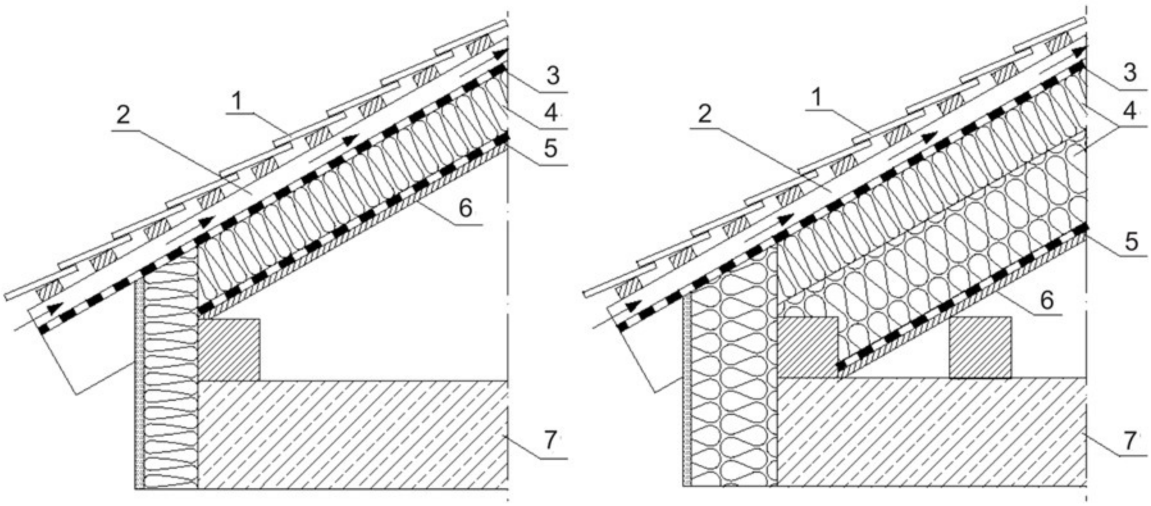


Fig. 25. RETROFITTING A ROOF ABOVE AN ATTIC IN GENERAL USE: 1 – roofing (tiles), 2 – ventilation gap (2–3 cm wide), 3 – vapour-permeable film, 4 - thermal insulation, 5 - vapour-proof membrane (only in "wet" rooms), 6 – finish (e.g. wood), 7 – ceiling
Source: Polish Energy Conservation Foundation.

EXAMPLE OF THE EFFECTS OF RETROFITTING THE ROOF, THE CEILING ABOVE THE CELLAR AND THE CEILING ABOVE THE PASSAGEWAY FOR CARS LEADING INTO THE COURTYARD BASED ON THE BUILDING DESCRIBED IN APP. 1, "EXAMPLE OF A RETROFITTING ANALYSIS ON A MULTI-FAMILY DWELLING"

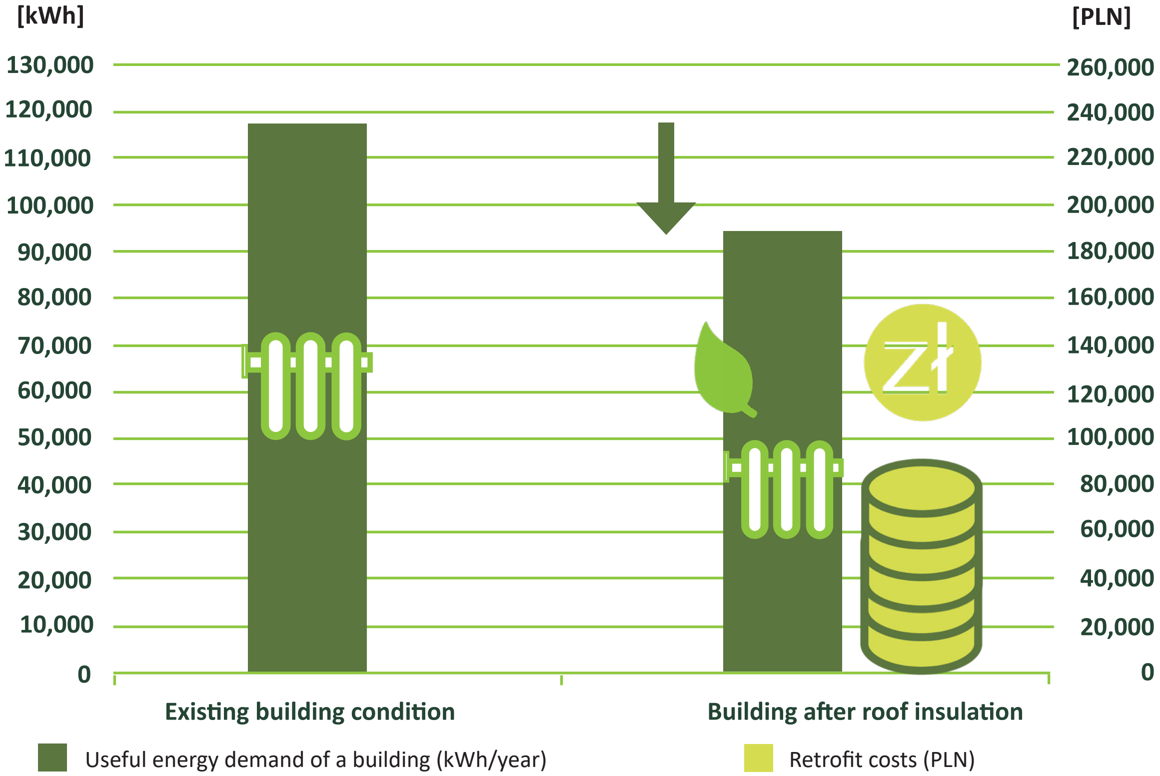


Fig. 26. Example of the effect of retrofitting the roof on the demand for useful energy for heating and retrofit costs (see Appendix 1 for more information on the assumptions used in the calculations)
Source: Polish Energy Conservation Foundation.

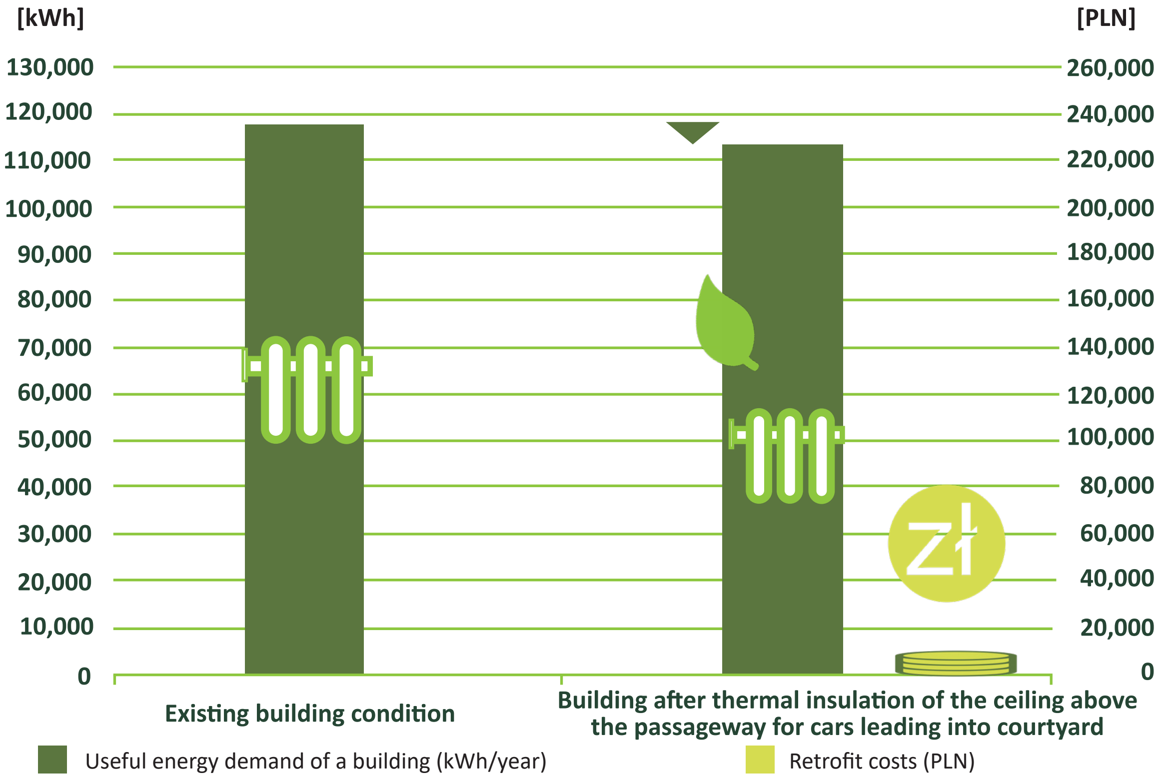


Fig. 27. Example of the effect of retrofitting the ceiling above the passageway for cars leading into courtyard on the demand for useful energy for heating and retrofit costs (see Appendix 1 for more information on the assumptions used in the calculations)
Source: Polish Energy Conservation Foundation.

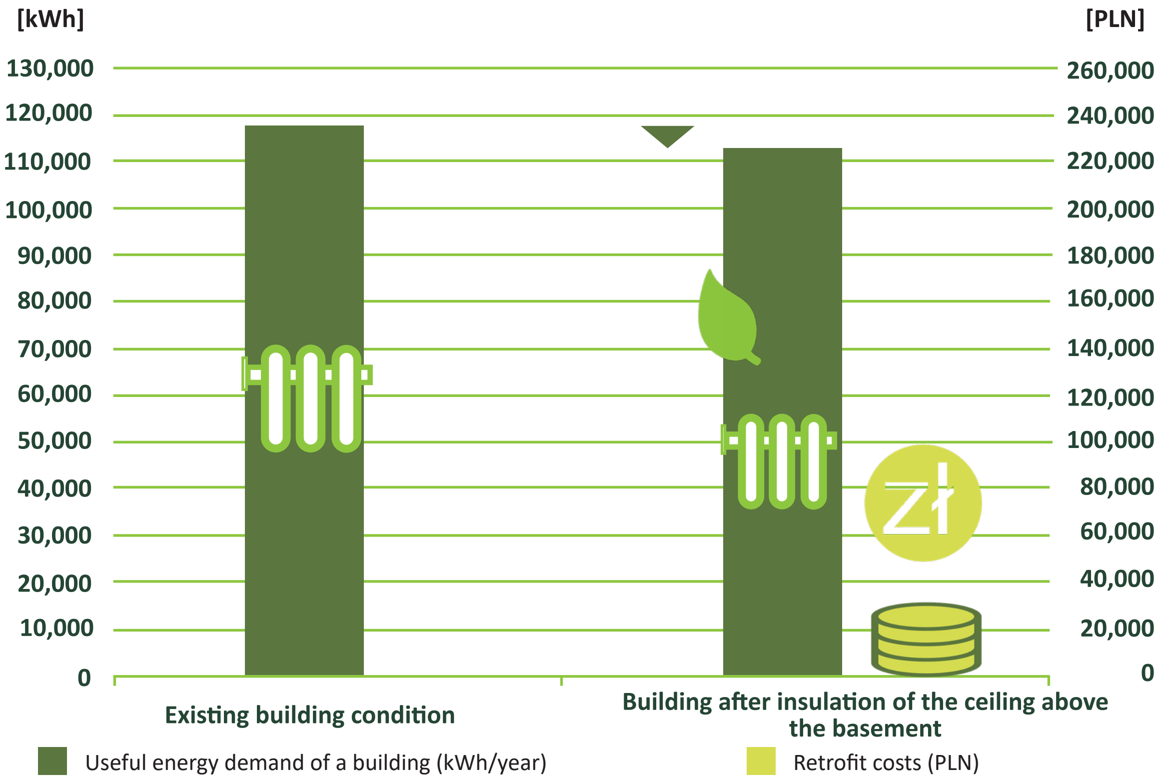


Fig. 28. Example of the effect of retrofitting the ceiling above the cellar on the demand for useful energy for heating and retrofit costs (see Appendix 1 for more information on the assumptions used in the calculations)
Source: Polish Energy Conservation Foundation.

Windows and other transparent sections of the building envelope

The design of transparent building envelope sections can vary considerably, thus significantly influencing the building's energy demand as a result of the variation in how much heat is lost, how much solar heat is gained, the role of daylight in the consumption of electricity for lighting and the associated generation of internal heat gains. Four basic parameters need to be taken into account in order to fully determine the impact of transparent building envelope sections on its energy performance: the heat transfer coefficient, air-tightness, solar energy transmittance and visible light transmittance.

Windows can vary in terms of both their design and their materials, with the type of glazing used playing the largest role in determining energy efficiency. The basic solution employed nowadays involves packets of glazing consisting of two or three panes of glass joined in the factory, with the space between each pane being filled with air or a noble gas. Glass with a low-emission coating is a crucial factor in determining a window's characteristics, as it retains thermal radiation emitted from inside the building while remaining highly permeable to solar radiation. This means that double-glazed windows made of low-emission glass have a better heat transfer coefficient than triple-glazed ones made of ordinary glass. Another factor influencing the characteristics of glazing is the type of spacer used. This spacer is often made of materials with a high heat transfer coefficient (e.g. aluminium), which produces thermal bridges. Materials with more favourable properties (e.g. plastic) can be used to reduce the impact of such bridges. The second extremely important element is the type and design of the window frame used. Nowadays, one can find window frames made of wood, plastic or aluminium. The various materials differ mainly in terms of their appearance and their durability and maintenance characteristics. Although higher energy efficiency can generally be achieved using plastic frames, similar performance levels can also be obtained with other materials.

EXAMPLE OF THE EFFECTS OF RETROFITTING WINDOWS AND DOORS BASED ON THE BUILDING DESCRIBED IN APPENDIX 1, "EXAMPLE OF A RETROFITTING ANALYSIS ON A MULTI-FAMILY DWELLING"

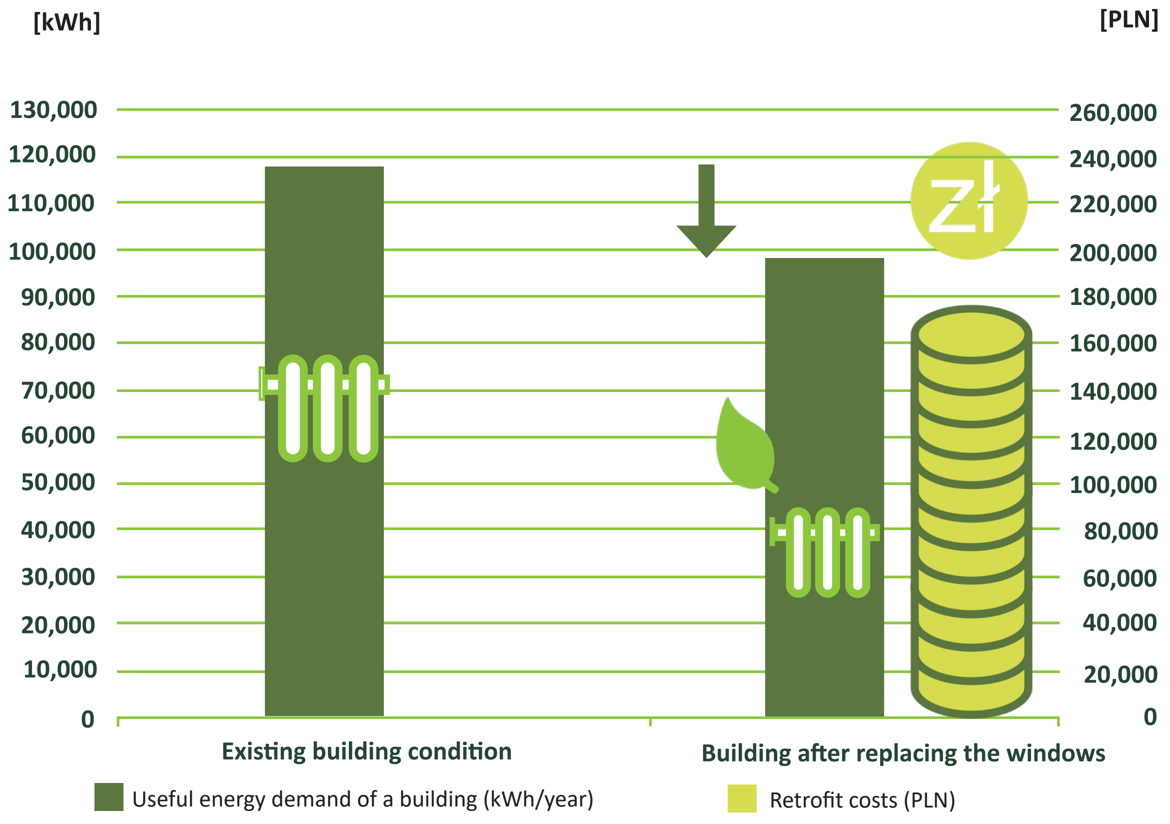


Fig. 29. Example of the effect of retrofitting windows on the demand for useful energy for heating and retrofit costs (see Appendix 1 for more information on the assumptions used in the calculations)
Source: Polish Energy Conservation Foundation.

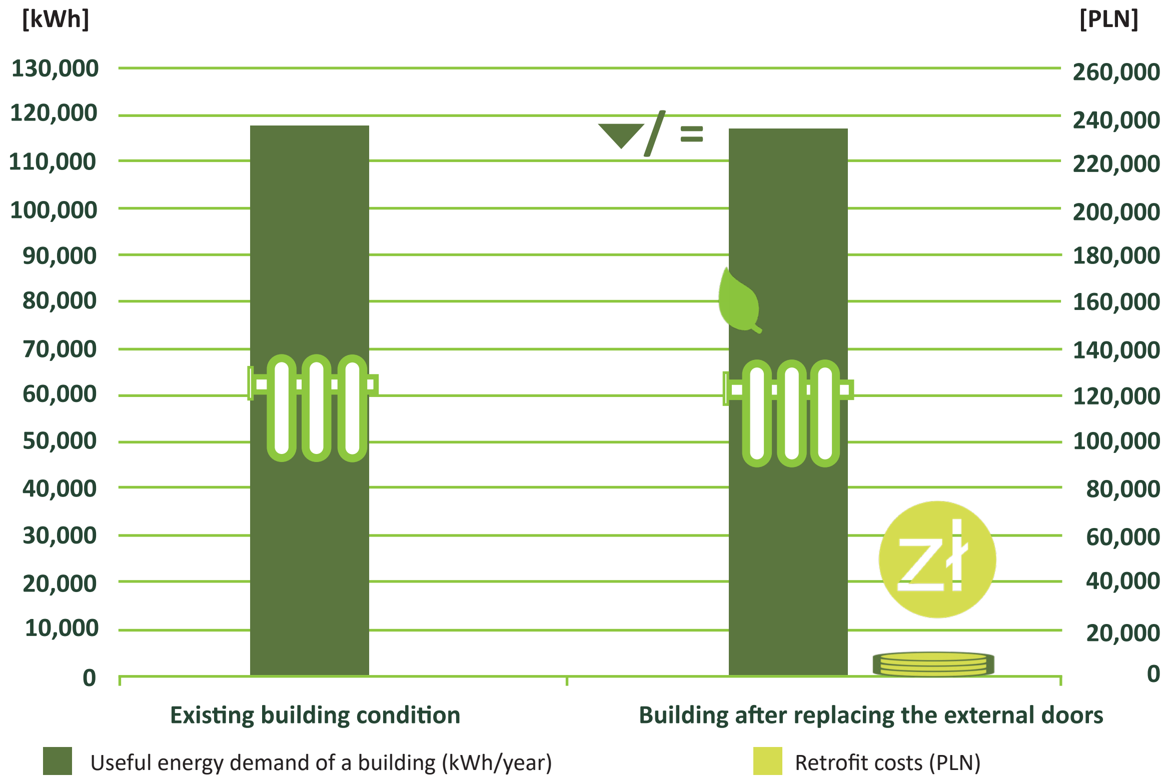


Fig. 30. Example of the effect of retrofitting external doors on the demand for useful energy for heating and retrofit costs (see Appendix 1 for more information on the assumptions used in the calculations)
Source: Polish Energy Conservation Foundation.

Photo 7. Retrofit of the façade of a building in Łódź, including replacing the window frames
Source: city of Łódź.
Photo 8. Retrofit of the façade and window frames of a building in Kalisz
Source: city of Kalisz.

Shading elements

Transparent sections of a building envelope allow solar radiation to penetrate inside. Although this boosts the building's energy performance by providing welcome heat gains in winter and harnessing the potential of natural light, it also increases the risk of the building overheating as a result of unwanted heat gains in summer. Sunshades enable a comfortable indoor environment to be ensured all year round while reducing energy requirements. How effective a shading element will be depends on its design and position – shades fitted to the outside of a building are much more effective than those installed inside. Shading elements can also be integrated with photovoltaic cells.

II.13 How can a ventilation system be retrofitted?

“Ventilation” means the exchange of air inside a room or rooms. Air that has been polluted (by water vapour, odours, CO2) or depleted of oxygen has to be removed and replaced by clean air from outside. Ideally, air should be supplied to “clean” rooms (living room, bedroom) and removed from “dirty” ones (toilet, bathroom, kitchen), thus preventing air from the kitchen or toilet from entering living spaces. It must be borne in mind that the purpose of ventilation is to ensure clean, healthy and comfortable conditions inside the home, so any savings in this area should be made very carefully. A ventilation system that does not work properly will not only produce smoky and unpleasant smells but will also increase air humidity. This will lead to mould, the risk of carbon monoxide poisoning or ill health and disease symptoms.

Natural ventilation is the most popular system in use today. It is based on two mechanisms that cause air to move: thermal buoyancy (linked with the difference in air density inside and outside) and wind pressure. This produces different principles for the operation of natural ventilation in winter and summer. At temperatures below +12°C, the forces generating air movement should be sufficient for air to flow into the rooms through window ventilators and/or gaps in the frames and then be removed through the exhaust ducts in the kitchen, bathroom and toilet. When the temperature outside is higher, air is mainly exchanged inside rooms by opening windows.

Like any system designed to ensure user comfort, ventilation comes at a cost, mainly for the heat required to heat the air in winter. This heat is usually supplied by the heating system, which also compensates for any heat lost through the walls or roof. The amount of energy consumed by a ventilation system will also depend on the energy required to induce air flow (fan drives). A distinction is made between natural, mechanical and hybrid ventilation depending on the mode of action of the individual forces that induce this air flow. Although changing a ventilation system can often be fairly difficult, this does not mean that it is impossible. For example, switching from natural to mechanical ventilation is a relatively simple process that usually involves installing appropriate vents, exhaust grilles and extractor fans. Installing mechanical supply and exhaust ventilation in a building is much more difficult as new ducts will need to be constructed (often horizontally, distributing air across the floor) and a supply and exhaust ventilation unit will need to be placed in a suitable position. However, this ventilation system is able to offer the highest levels of comfort (e.g. air filtration) and the most efficient way of recovering heat from the air that is extracted.

As the amount of heat required for ventilation depends largely on the airflow, it is worth adjusting this airflow dynamically in line with demand, i.e. increasing it when necessary and reducing it when demand falls. The humidity of the air inside a residential building is a good indicator of its ventilation requirements (greater humidity should mean an increase in airflow and vice versa). Similarly, good results can be achieved in office or commercial buildings by controlling the airflow rate based on CO2 concentration levels. “On-off” controls or controls that depend on the time of day/night can be used as a last resort.

Significant amounts of heat are dissipated with the air removed from rooms. Using this waste heat to heat outdoor air (or cool it in summer) is a very common way of reducing heat consumption in mechanical ventilation systems. Various pieces of equipment can be used for heat recovery, such as plate heat exchangers, rotary heat exchangers or systems using an intermediate medium. Nowadays, heat can also be recovered from the air extracted by a mechanical ventilation system, where it feeds the heat pump used to heat domestic water.

The electrical equipment inside the ventilation system should be highly efficient and thus with low specific energy consumption values. How much electricity the drive systems consume will depend on several factors: the efficiency of the motor, choosing a suitable motor (in terms of its power), the control method used, and appropriate maintenance and operation.

Ventilation systems will only run correctly if the equipment is supervised and operated properly. Mechanical ventilation devices such as ventilation units, fans and air ducts should be installed in such a way that they can be regularly inspected, maintained, repaired or replaced.

When upgrading a ventilation system from natural to mechanical, it is worth focusing particularly on the following:

- The noise level (especially the air flow in living areas),
- The cost of replacing/cleaning filters,
- How the ventilation system interacts with fireplaces and other open-flued appliances,
- The possibility of air flowing from clean rooms (e.g. bedrooms) into dirty ones (e.g. kitchen, toilet) and compliance with the specifications for openings: with a surface area over 80 cm^2 in doors to rooms and over 220 cm^2 in doors to bathrooms and toilets,
- Ease of access to the ventilation unit and fans and for inspections of the air ducts,
- The possibility of draining condensation from the heat recovery system.

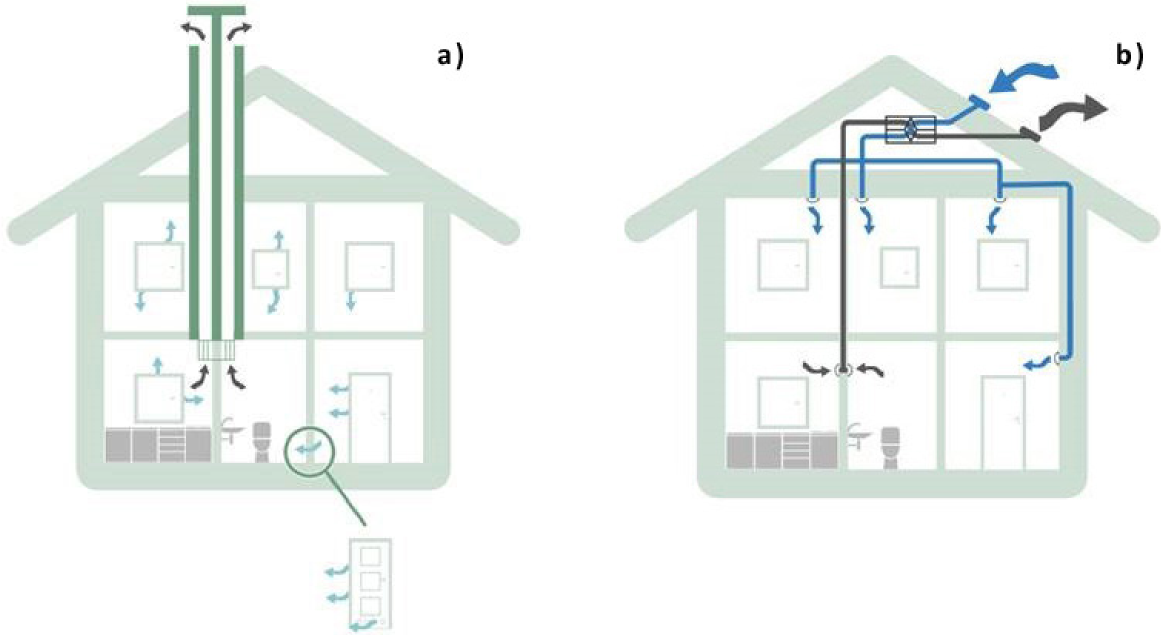


Fig. 31. a) Diagram showing how gravitational and mechanical ventilation works, b) Diagram showing how mechanical supply and exhaust ventilation with heat recovery works
Source: Polish Energy Conservation Foundation.

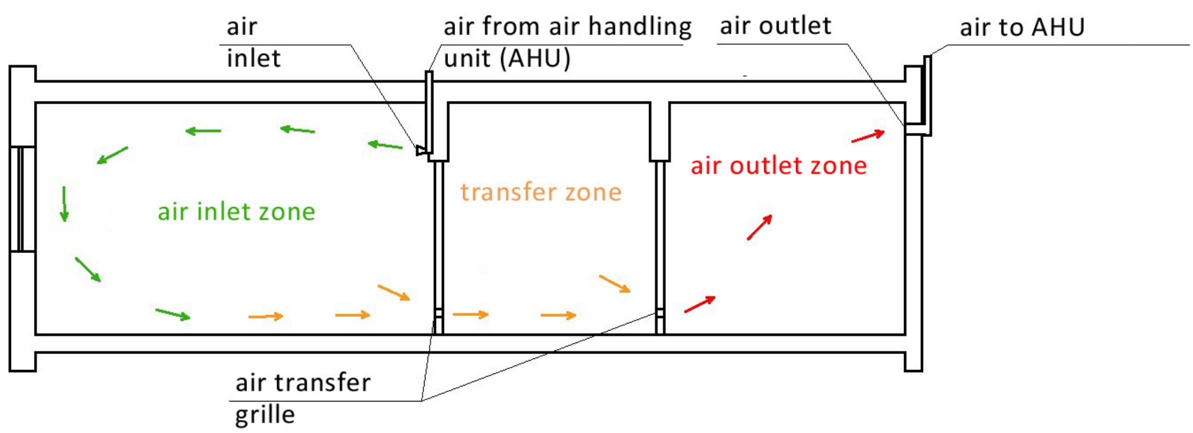


Fig. 32. Diagram showing the air flow directed inside a building
Source: Passive House Institute, Darmstadt.

II.14 How can a central heating system be retrofitted?

Retrofitting a central heating system can incorporate the following measures:

- Sealing the system,
- Decommissioning the central venting network and replacing the expansion tank,
- Repairing or supplementing the thermal insulation or laying new thermal insulation,
- Installing thermostatic valves,
- Installing installing riser regulators,
- Cleaning the system (water or chemical flushing),
- Adjusting the system and adapting it to lower heating requirements,
- Replacing radiators with more efficient ones,
- Switching to lower parameters for the medium used,
- Setting up zones,
- Reducing heating in rooms used only temporarily,
- Reducing heating for a specific period of time (depending on the thermal inertia of the rooms),
- Changing the heating system.

The heating systems used inside buildings can be divided into local, central and remote heating systems depending on the location of the heat source.

In a local heating system, the heat source is located right inside the room to be heated. Traditional local heating systems include various types of appliance capable of burning solid fuel. This type of equipment offers limited scope for controlling its capacity and is subject to restrictions geared towards reducing the emission of pollutants into the atmosphere. Retrofitting a local heating system usually means replacing it with a central heating system, which requires pipes to be laid to all consumers inside the building. Central heating systems have a single heat source supplying heat to several flats or groups of rooms inside the building being heated. They use systems to distribute heat in a building through a network of pipes and heating elements using different media such as hot or warm water and steam at various pressures.

The advantages of central heating systems are that they require fewer heat sources than a local heating system. This means fewer chimneys or ducts for the flue air, more efficient heat generation and thus less emission of pollutants into the environment. They also eliminate the need to supply fuel to individual heat sources, as is the case with local heating, make control more efficient and improve the user-friendliness and maintenance of the heating system. The main disadvantages of a central heating system are the requirement for a system of sharing heating costs, higher installation costs in some cases, and increased heat losses in the central heating system network.

The demand for heating power can be defined as the maximum heat loss of the rooms. Heating systems are designed in consideration of the "design external temperature", i.e. under the conditions that will ensure that an appropriate room temperature is maintained during the coldest time of the year. Heating systems are regulated based on adjusting their thermal output to the amount of power required to heat the building, which changes as the outside air temperature changes. The need for control thus results from a desire to keep rooms at a comfortable temperature as well as reduce heating costs. Pre-regulation (appropriate pre-setting of radiator valves or riser or zone shut-off valves) ensures the temperature distribution envisaged in the design and the heat carrier flows under design conditions (occurring only a few days a year) as well as the heating power of the selected radiators. Operating controls guarantee an indoor temperature that suits users' preferences despite (daily, yearly) fluctuations in the temperature outside. This consists in adjusting the thermal output of both the entire system and individual radiators to the demand for room heating at that precise moment.

The electrical equipment inside the heating system should be highly efficient and thus with low specific energy consumption values. How much electricity the drive systems consume will depend on several factors: the efficiency of the motor, choosing a suitable motor (in terms of its power), the control method used, and appropriate maintenance and operation of the equipment.

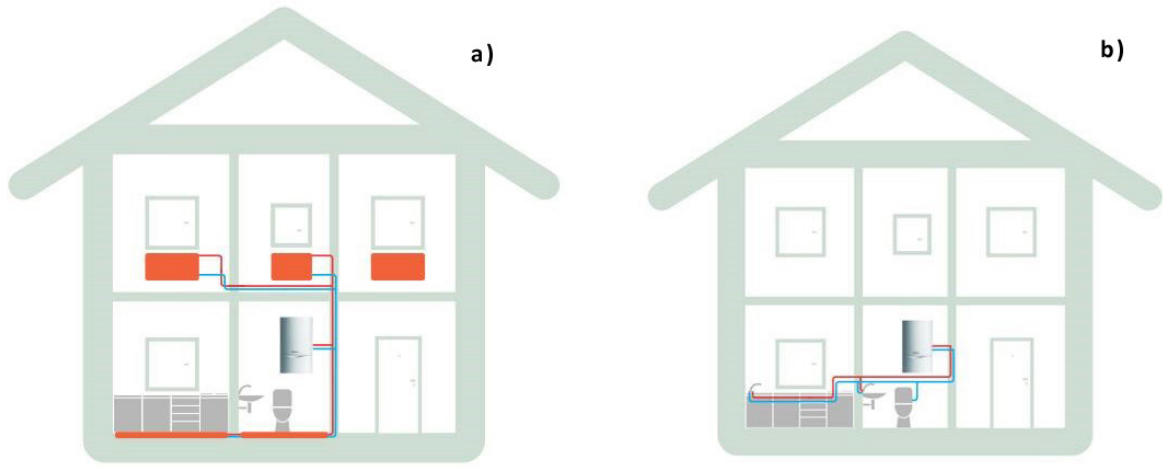


Fig. 33. Functional diagram of a combi boiler, a) – central heating system, b) – domestic hot water system
Source: Polish Energy Conservation Foundation.

INSTALLING A WATER AND CENTRAL HEATING SYSTEM PRIOR TO INSULATION

Photo 9. Installing a water and central heating system prior to insulation; the photograph shows a special fastening system using hard foam insulation that eliminates the risk of gaps forming and the insulation layer thinning
Source: Polish Energy Conservation Foundation.

THREE-DIMENSIONAL VISUALISATION OF THE HEATING SYSTEM

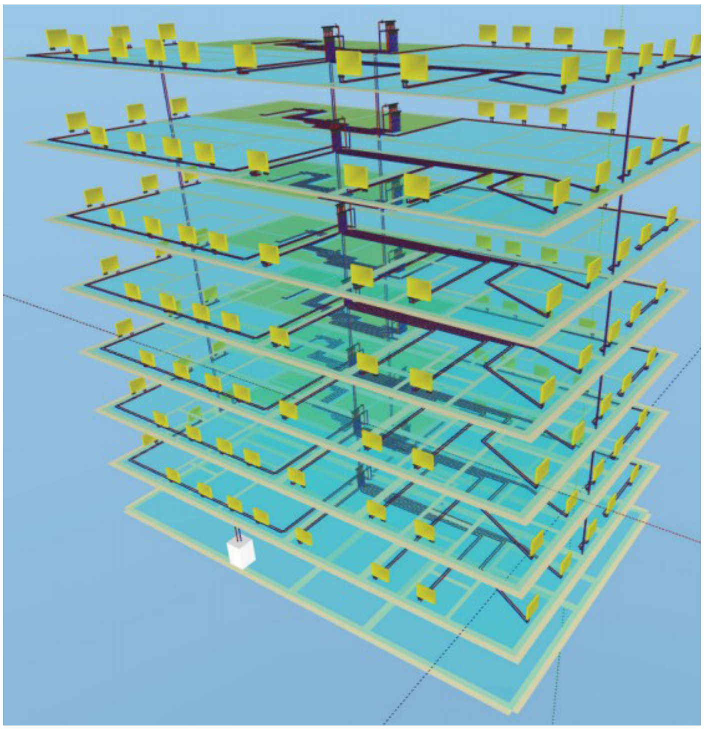


Fig. 34. Three-dimensional visualisation of the heating system using Audytor CO software 6.0
Source: Polish Energy Conservation Foundation.

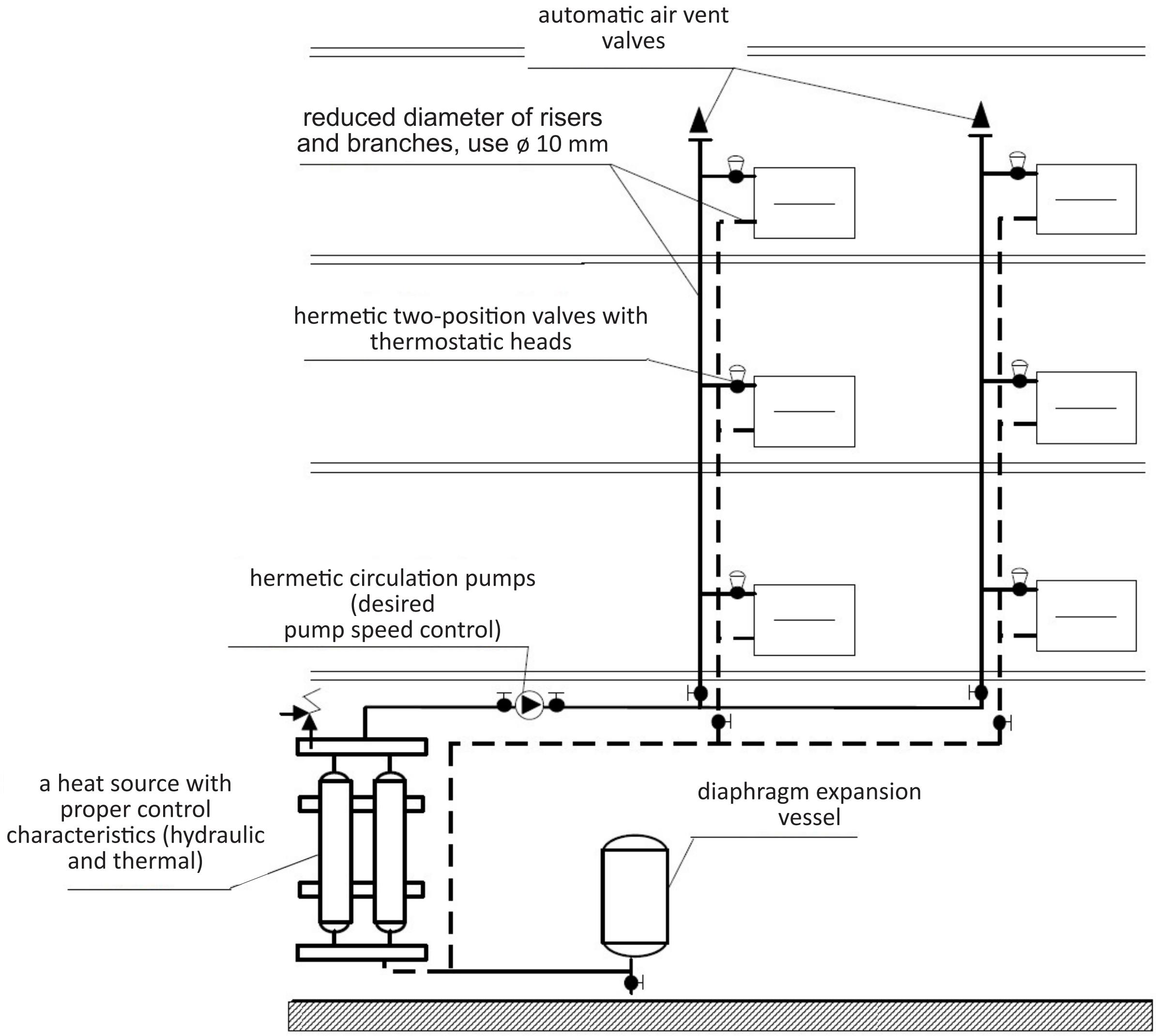


Fig. 35. Diagram showing the typical installation of a two-pipe hydronic central heating system with a closed, bottom-distribution system
Source: Paweł Kędzierski.

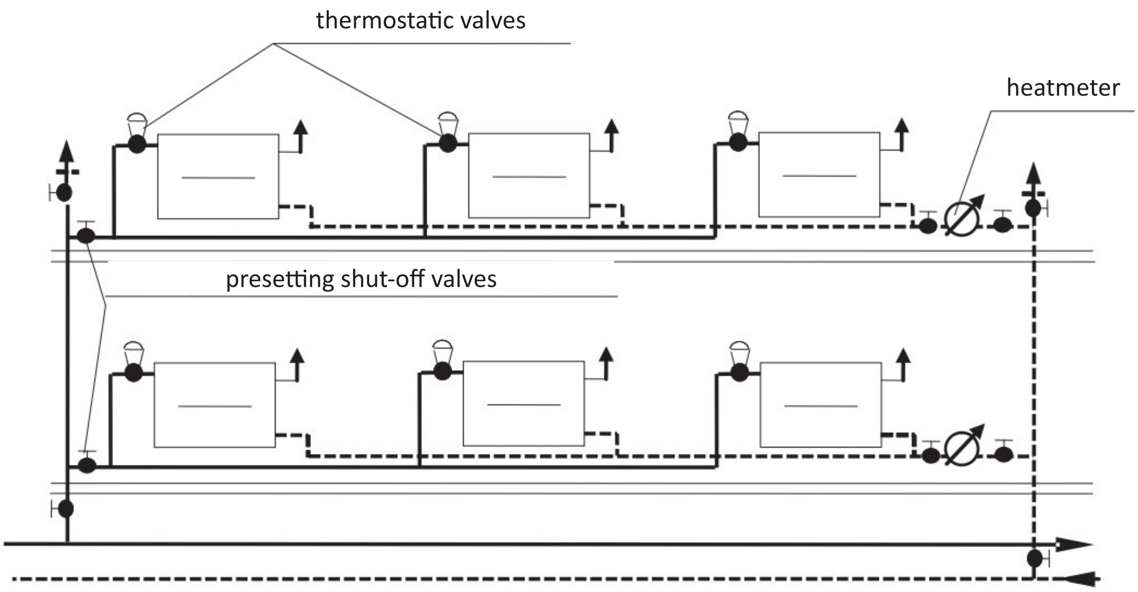


Fig. 36. Diagram showing the installation of a horizontal two-pipe heating system
Source: Paweł Kędzierski.

II.15 How can a cooling system be retrofitted?

A retrofit of a cooling system should start with an analysis of the scope for reducing heat gains, both those from solar radiation and those generated internally (e.g. from appliances, equipment or lights). Reducing heat gains can enable the amount of energy required for cooling to also be reduced. An analysis of this system will not be straightforward, however. This is because using external shading elements, for example, may actually cause the lighting system to consume more energy, which may increase rather than reduce the building's total energy demand. Such analyses should be carried out on each potential option individually and employ methods that analyse the demand of all systems in the building on an hourly basis.

Another way is to use passive cooling systems. These include night flushing, where air is circulated through the building at night when the air outside is cooler than that inside the building. This lowers the temperature of the inner layers of the building envelope, increasing the possibility of heat accumulating inside the building's envelope and structural elements the following day. This means that any increase in room air temperature caused by heat gains (internal or external) is significantly lower than if no night flushing had occurred. If the heat capacity of these elements is not sufficient, it can potentially be increased by erecting solid partition walls or using phase change materials (PCMs). This then makes it possible to ensure acceptable microclimate conditions in rooms without the need for active cooling.

As with other systems, a retrofit of an existing system will need to include ensuring that it is air-tight, repairing or supplementing the thermal insulation or laying new thermal insulation, fitting control valves and cleaning the system. The following steps will also be required: adjusting the system and adapting it in line with the reduced heat demand; replacing equipment with more efficient models; changing the parameters of the medium used; setting up zones; reducing cooling in rooms used only temporarily; reducing cooling for a specific period of time (depending on the thermal inertia of the rooms); or switching to a different cooling system.

When replacing cooling equipment, attention should be paid to its efficiency and how much energy it consumes. The right equipment will also need to be selected and its output regulated. In addition, cooling equipment is available that makes use of a phenomenon known as "free cooling", i.e. exploiting low air temperatures outdoors to generate heat gains indoors. Harnessing this technology can make the cooling equipment more efficient.

II.16 How can a domestic water heating system be retrofitted?

Measures for retrofitting a domestic water heating system include:

- Switching the heat source from single- to dual-function,
- Replacing faulty appliances,
- Replacing leaky pipes,
- Repairing or insulating pipes,
- Reducing circulation time (using thermostatic valves or time-controlled pumps),
- Installing devices to reduce hot water consumption (aerators),
- Installing residential hot water meters.

When choosing a technical solution for saving water and energy, care should be taken to ensure that the components used in the system comply with the relevant product standards, possess valid hygienic certificates and are approved for use in construction. An important factor in the operation of water supply systems is the correct choice of taps, which should be installed above the corresponding sanitary appliances, i.e. the washbasin tap above the washbasin etc.

Opportunities for saving water and energy include the following design solutions used in taps: aerators, flow restrictors, flow regulators and pressure reducers. Solutions that aim to reduce the amount of time that water flows without being used are another option. With a two-handle mixer, for instance, the user has to use trial and error to set the desired temperature of the water flowing out of the spout once the cold and hot water valves have been opened. Only after they have done this can they actually make use of the water flowing out, e.g. to wash their hands. The alternative is to use a thermostatic mixer. This allows the desired temperature of the mixed water to be set in advance, even before the water valve is opened, using a calibrated temperature knob. The mixer valve can then be opened and the water – at its pre-set temperature – can be used straight away.

Suitable materials should be used for installation. For example, plastic pipes have better insulation properties than traditional materials (steel, copper). However, all types of piping should be insulated to reduce heat transfer losses in domestic hot water.

In the case of systems that heat water centrally for the whole or part of a building, calculations will need to be made for the circulation pipes once the diameters of the supply pipes – i.e. the distribution pipes, risers and connections to the points of use – have been determined. Water is circulated through these pipes in order to ensure the correct temperature upstream of the tap valves. These pipes and the hot water storage tanks should be insulated to reduce the heat lost from the system.

The hot water supply system must be equipped with efficient drive units (pumps), whose power rating should be chosen accordingly.

EXAMPLE OF THE EFFECT OF RETROFITTING A DOMESTIC WATER HEATING SYSTEM ON THE DEMAND FOR FINAL ENERGY FOR HEATING AND RETROFIT COSTS BASED ON THE BUILDING DESCRIBED IN APPENDIX 1, "EXAMPLE OF A RETROFITTING ANALYSIS ON A MULTI-FAMILY DWELLING"

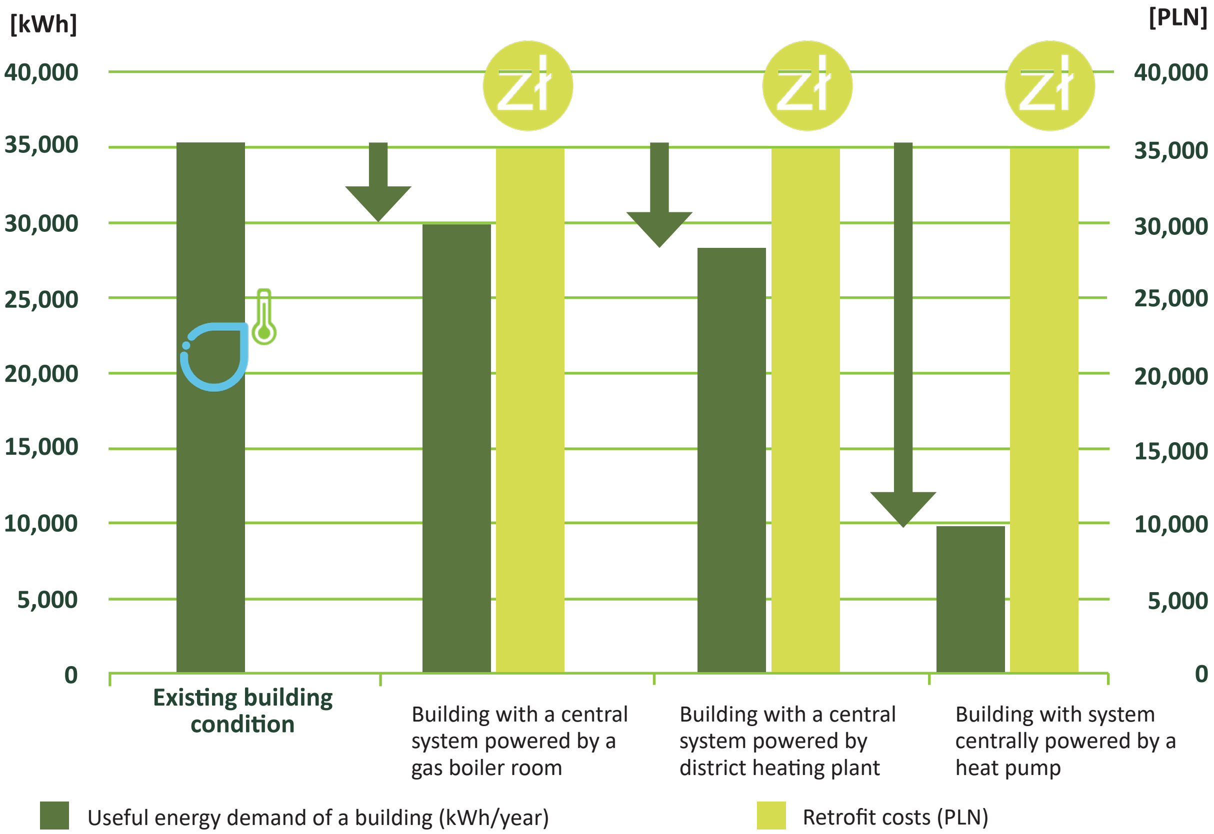


Fig. 37. Example of the effect of retrofitting a domestic water heating system on the demand for final energy for heating and retrofit costs (see Appendix 1 for more information on the assumptions used in the calculations)
Source: Polish Energy Conservation Foundation.

II.17 How can a heat source be retrofitted?

The main ways to make heat sources more efficient are to retrofit or replace them. A heat source can be retrofitted if it is still operational. This may involve repairing faulty components and/or retrofitting the source with an automatic control system. It may not be possible to retrofit the heat source in the case of a comprehensive retrofit project that significantly reduces energy demand. In this case, a new source should be selected whose capacity is in line with the building's new requirements. The first step is to determine the availability of energy sources and carriers. Replacing the heat source may require laying a new connection to the building. The source should be chosen in consideration of local requirements (e.g. emissions, availability of space and energy carriers) and investment and operating costs. The new source will need to be adapted to the building's energy requirements and possess an automatic control system. A new heat source will have to be chosen when switching from a local to a central heating/hot water/cooling system, and the same factors should be considered as when replacing a source. Heat sources should have a high level of energy efficiency (efficiency of energy generation).

Replacing the source and thus the fuel can lead to energy costs increasing despite the building requiring less energy overall, if the energy carrier comes at a higher unit price, for instance. Heat sources should be retrofitted with the understanding and consent of all the people who use the building, especially in residential properties.

The use of renewable energy sources in the new supply system should be considered when carrying out a comprehensive retrofit, and these sources should be chosen based on their availability and potential installation location. Possible sources for highly built-up areas include solar panels, solar thermal collectors and heat pumps. The renewable energy sources chosen should be of an appropriate size so that the benefits of such a system are maximised.

DIAGRAM SHOWING HOW A HEAT PUMP WORKS

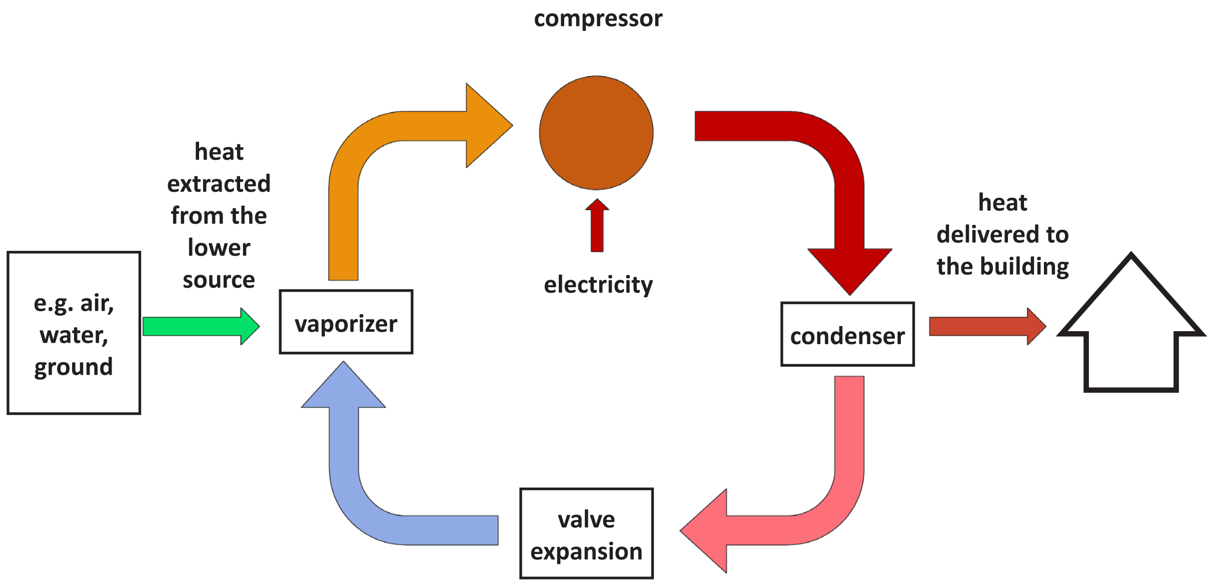


Fig. 38. Diagram showing how a heat pump works
Source: Polish Energy Conservation Foundation.

DIAGRAM SHOWING AN EXAMPLE OF A PHOTOVOLTAIC SYSTEM CONNECTED TO THE GRID

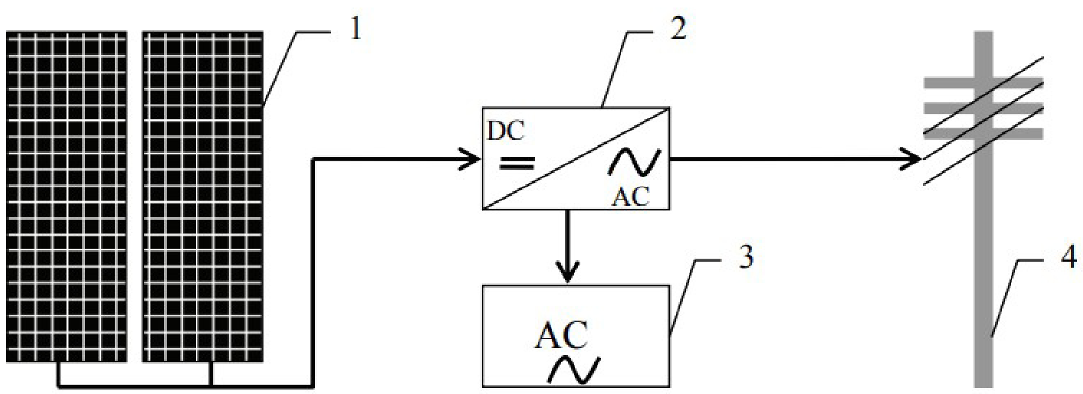


Fig. 39. Diagram showing an example of a photovoltaic system connected to the grid, where: 1 – solar panels, 2 – inverter, 3 – AC receiver, 4 – electricity grid
Source: Polish Energy Conservation Foundation

EXAMPLE OF THE EFFECT OF RETROFITTING A CENTRAL SYSTEM ON THE DEMAND FOR FINAL ENERGY FOR HEATING AND RETROFIT COSTS BASED ON THE BUILDING DESCRIBED IN APPENDIX 1, "EXAMPLE OF A RETROFITTING ANALYSIS ON A MULTI-FAMILY DWELLING"

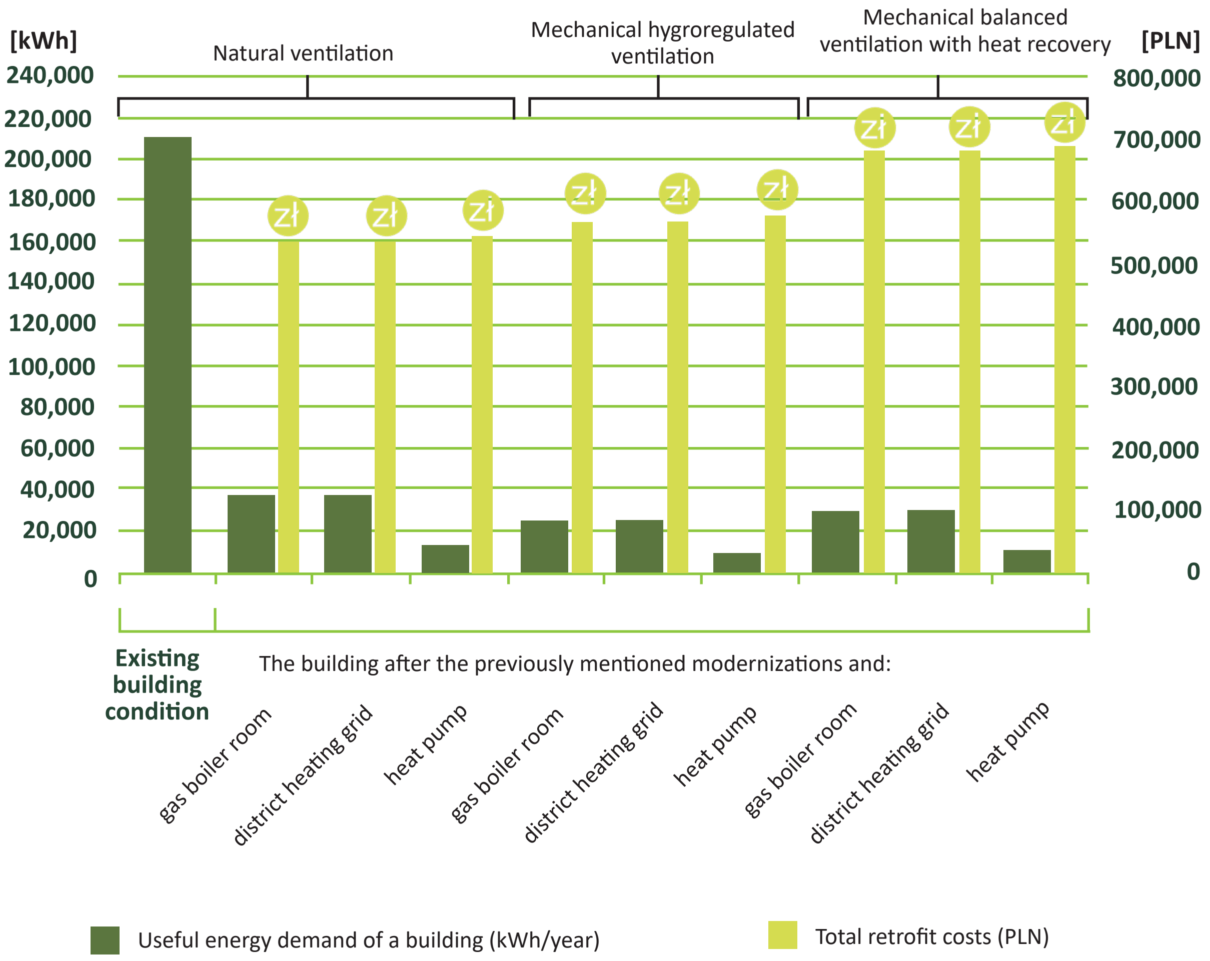


Fig. 40. Example of the effect of retrofitting a central system on the demand for final energy for heating and retrofit costs (see Appendix 1 for more information on the assumptions used in the calculations)
Source: Polish Energy Conservation Foundation.

II.18 Sources of funding for thermal upgrading measures

There are currently several financial instruments in Poland that can subsidise building retrofit projects.

The most popular include:

- The Thermal Upgrading and Renovation Fund,
- The "White Certificates" system,
- The "Clean Air" programme,
- The "Stop Smog" programme,
- The thermal upgrade allowance,
- The "My Electricity" programme.

These financial instruments are described in brief below.

Thermal Upgrading and Renovation Fund

The Thermal Upgrading and Renovation Fund is a programme geared towards making Poland's building stock more energy-efficient. This support system has been running in Poland for over 20 years without major changes and is set out in the Polish Act on Supporting Thermal Upgrades and Renovation. It allows some of the costs of thermal upgrade, renovation and low-emission projects to be reimbursed. The programme is intended to support projects designed to bring about improvements, amongst other things, that reduce the demand for energy for heating domestic water and for supplying heat to residential buildings, shared housing and buildings that are owned by local authorities and used for performing their public duties.

Support is provided in the form of a so-called reward, i.e. repayment of some of the loan taken out to finance the project. This repayment is made from the resources held by the Thermal Upgrading and Renovation Fund, which is operated by the state-owned development bank Bank Gospodarstwa Krajowego (BGK) and funded from the state budget.

The thermal upgrade reward will be granted if certain criteria are met:

- The annual energy demand in buildings in which only the heating system is being retrofit falls by at least 10%, or
- The annual energy demand in other buildings falls by at least 25%, or
- Primary energy losses in local heating networks and the local heat sources feeding them fall by 25%, or

- A technical connection to a centralised heat source established in conjunction with the decommissioning of a local heat source reduces annual heating costs by at least 20%, or
- An energy source is converted to a renewable source, or high-efficiency combined heat and power (CHP) is used.

An additional criterion is that a loan for at least 50% of the costs of the thermal upgrade project must be taken out from a bank that has an agreement with BGK.

The thermal upgrade reward amounts to 16% of the costs incurred in implementing the thermal upgrade project. It will be upped to 21% of the total costs if the micro-installation of a renewable energy source with a maximum power of at least 1 kW for a single-family dwelling or 6 kW for another building type is carried out in the building at the same time as the thermal upgrade.

In addition, investors undertaking a thermal upgrade project that involves establishing an additional connection between the texture layer and the structural layer of layered external walls in large-panel-system buildings are entitled to additional support in the amount of 50% of their costs for drawing up technical documentation regarding the selection and placement of metal anchors, purchasing metal anchors for use in concrete intended to strengthen the connections between the layers of multi-layer panels, preparing holes and installing the metal anchors.

It is also possible to apply for a renovation reward from the Thermal Upgrading and Renovation Fund, although these are only available for renovation projects involving a multi-family dwelling that has been in use since before 14 August 1961. A renovation audit must be carried out before this renovation reward can be obtained. As with an energy audit, this must demonstrate the energy savings and include energy demand calculations for this purpose.

Under the Polish Act on Supporting Thermal Upgrades and Renovation, the renovation of a building can include the following types of work:

- A general renovation of the building (without renovating actual premises);
- Replacing windows and renovating balconies, even if these are for the exclusive use of the owner of the premises;
- Redeveloping a building resulting in its improvement;
- Fitting out a building with the systems and equipment required in the buildings currently entering use in accordance with the technical and building regulations.

The renovation reward is available to investors who are private individuals, housing associations in which a majority of members are private individuals, housing cooperatives or social housing associations. Here too, the renovation bonus will be granted if the loan taken out for the renovation work is 50% (at least) of the total project costs, and the bonus will cover 15% of the costs of the renovation project.

The renovation bonus may cover 50% of the renovation project costs if all of the following criteria are met:

- The investor is a municipality or a company under commercial law that is wholly owned by a municipality; and
- All the residential units inside the building form part of the municipality's housing stock; and
- The building is situated in an area where restrictions or bans on the operation of fuel-burning systems are in force; and
- The renovation audit demonstrates that, once the renovation project is complete, the building elements being renovated will meet the minimum energy and thermal insulation requirements that have applied to buildings since 31 December 2020; and
- Either before or as part of this renovation project, the building has been or is to be technically connected to a centralised heat source in conjunction with the decommissioning of a local heat source, or a full or partial conversion to renewable energy sources has taken or is to take place, or high-efficiency CHP has been or is to be used, or the heat source has been or is to be converted to one that meets low-emission standards.

In addition, if the building being renovated is listed in the register of historical monuments or is located in an area listed in this register, the renovation reward will amount to 60% of the costs of the renovation project up to a maximum of the amount of the loan taken out to realise the project. The criterion about meeting the minimum requirement for buildings in terms of energy savings and thermal insulation applicable as of 31 December 2020 will not apply in the case of such buildings if the renovation audit demonstrates that it cannot be fulfilled.

"White Certificates" system

Another financial support scheme involves applying for energy efficiency certificates under the so-called White Certificates scheme. Such schemes are geared towards encouraging investors to make investments in improving the energy efficiency of equipment, properties and processes by giving them financial rewards in the form of tradable property rights. The amount of the financial rewards depends on the amount of energy saved as a result of the corresponding investments. As entities operating on the energy market are obliged to submit a certain number of white certificates to the president of the Polish Energy Regulatory Office (ERO), continuous demand for them is ensured on the Polish Power Exchange (TGE) and the price is determined in accordance with to the laws of supply and demand. An alternative option to purchasing white certificates and redeeming them with the president of the ERO involves paying substitution fees in an amount determined by the maximum stock market price.

Energy efficiency audits are geared primarily towards identifying the savings on the basis of which energy efficiency certificates (white certificates) are to be issued. Importantly, the value of the certificates depends exclusively on the extent of the savings achieved (measured in energy units), meaning that their market value may exceed the amount spent on the investment.

To be eligible for white certificates, a retrofit project can be any of those mentioned in the list published in the announcement by the Polish Minister of Energy on 23 November 2016 regarding the detailed list of projects designed to improve energy efficiency, including thermal upgrading measures. Specifically, these are:

- Insulating walls, ceilings, flooring on the ground, foundations, roofs or flat roofs,
- Retrofitting or replacing window and door frames,
- Retrofitting the heating system or domestic water heating system,
- Retrofitting the ventilation and air conditioning system,
- Retrofitting the lighting system or replacing it with an energy-efficient one.

One or several projects of the same type that qualify under a particular category included in the announcement can be submitted in one application. A project or projects of the same type must deliver at least 10 toe (approximately 116 MWh) of annual energy savings, else the application will not be considered.

“Clean Air” programme

A new version of the “Clean Air” programme – “Clean Air 2.0” – was launched on 15 May 2020 with much-simplified procedures, followed on 21 October 2020 by an increase in the amount of subsidies available. In the new incarnation of the programme, recipients were divided into two income groups, one for basic and one for increased subsidy levels. The annual income of a recipient in the basic subsidy group cannot exceed PLN 100,000 from multiple sources, regardless of the average monthly income of each member of their household.

For the group of recipients eligible for higher subsidies, the average monthly income per household member cannot exceed PLN 1,400 in a multi-person household and PLN 1,960 in a single-person household.
Subsidies are available for implementing projects that involve removing an inefficient solid-fuel heat source and purchasing and installing an air- or ground-source heat pump – either for just heating or for heating and hot water – or another heat source.

Besides replacing a heat source, subsidies are also available for:

- Removing an existing central heating or hot water system and purchasing and installing a new one (including solar thermal collectors),
- Purchasing and installing a micro photovoltaic system,
- Purchasing and installing a mechanical ventilation system with heat recovery,
- Purchasing and installing insulation for the windows, external doors, garage doors/gates or other parts of the building envelope (including removal),
- Documentation related to the above: the energy audit (insofar as the building envelope is insulated), project documentation, expert's reports.

W zależności od przynależności do grupy dochodowej i zakresu przedsięwzięć modernizacyjnych maksymalna kwota dotacji może wynosić od 10 000 zł nawet do 37 000 zł.

"Stop Smog" programme

A further programme for promoting thermal upgrade projects is entitled "Stop Smog". It is designed for people living in energy poverty who own or co-own single-family dwellings as well as for municipalities carrying out low-emission projects in single-family dwellings that form part of the municipality's housing stock. Although the programme is implemented by the municipalities, a county, a group of several municipalities or a metropolitan association may also be a party to the agreement on behalf of the municipalities.

The "Stop Smog" programme provides support for projects including:

- Decommissioning high-emission heat sources or replacing them with low-emission ones,
- Carrying out thermal upgrades to a building,
- Connecting a building to a district heating or gas network,
- Installing a renewable energy source,
- Reducing the amount of energy a building needs for heating and domestic water heating.

Funding is provided in the form of a grant amounting to up to 70% for municipalities with up to 100,000 inhabitants and less than 70% for municipalities with more than 100,000 inhabitants. At the same time, the average cost of a low-emission project in one building – or, if the building comprises two units, in one unit – may not exceed PLN 53,000.

Thermal upgrade allowance

The thermal upgrade allowance was introduced on 1 January 2019 by means of the Polish Act of 9 November 2018 Amending the Act on Personal Income Tax and the Act on Lump-Sum Income Tax Levied on Certain Individual Income. This support scheme is designed for taxpayers who own or co-own single-family dwellings.

The thermal upgrade allowance permits expenses of up to PLN 53,000 that are incurred for thermal upgrade work to a single-family dwelling to be deducted from the basis for a person's tax assessment. This applies to improvements that reduce the demand for energy for heating and domestic hot water, establishing a technical connection to a centralised heat source in conjunction with the decommissioning of a local heat source, replacing some or all energy sources with renewable sources, or using high-efficiency CHP.

The following are deemed tax-deductible expenses:

- Those listed in the annex to the Polish regulations defining the list of types of construction material, equipment and services related to the implementation of thermal upgrade projects;
- Those associated with a thermal upgrade project to be completed within the next three years;
- Those recorded on an invoice issued by a person subject to goods and services tax who is not exempt from this tax;
- Those that have not already been subsidised from the resources of the Polish National Fund for Environmental Protection and Water Management or from voivodeship-level environmental protection and water management funds or that have not already been reimbursed to the taxpayer in any form;
- Those that have not been included in tax-deductible costs, deducted from income under the Polish Act on Lump-Sum Income Tax Levied on Certain Individual Income, or claimed by the taxpayer in conjunction with their use of tax allowances within the meaning of the Polish Tax Ordinance.

The tax-deductible thermal upgrade allowance of up to PLN 53,000 is available to each taxpayer individually, meaning that married taxpayers are able to claim a joint allowance of up to PLN 106,000. This limit covers all the thermal upgrade projects being implemented by a particular taxpayer in buildings that they own or co-own. In other words, the allowance is not ring-fenced for a specific investment.

"My Electricity" programme

The final scheme of note is "My Electricity", which aims to increase the production of electricity from micro photovoltaic systems. It is open to private individuals who generate electricity for their own needs and who have signed a comprehensive agreement regulating the feed-in of the electricity generated by their micro system to the grid. In order to apply for subsidies, the installation project must have been completed before the application is submitted. Investment costs that are not covered by the support scheme are tax-deductible. Subsidies are provided in the form of a grant of up to 50% of the qualifying costs up to a maximum of PLN 5,000 per project. Recipients under the "My Electricity" programme can also claim other forms of subsidy such as the "Clean Air" scheme and the thermal upgrade allowance.

II.19 Using a 1970s residential building as an example of the possible scope of thermal upgrading measures

The typical scope of thermal upgrading measures includes:

- Insulating external walls,
- Insulating the roof,
- Insulating the flooring or ceiling above an unheated cellar,
- Replacing windows,
- Installing a mechanical ventilation system with heat recovery,
- Retrofitting the central heating system,
- Replacing the boiler or another heat source,
- Replacing taps,
- Retrofitting the domestic water heating system,
- Fitting a control and regulation system,
- Fitting systems that make use of renewable energy sources – solar panels or solar thermal collectors.

Carrying out the above tasks will significantly reduce heat loss and hot water consumption and will make the central heating and hot water system more efficient. The estimated energy demand for a 1970s residential building can thus be reduced by around 80%.

The steps to take to achieve this include:

- Insulating external walls with polystyrene or mineral wool approximately 20 cm thick;
- Insulating the attic floor with mineral wool approximately 35 cm thick, or converting the attic into usable space by insulating its roof with a similar layer of insulation, bearing in mind that this part of the building envelope should be protected against water vapour getting in;
- Insulating the ceiling in the cellar (ground floor, insulation board approximately 15 cm thick) or insulating the cellar walls (including checking and potentially improving the waterproofing of the walls in the ground);
- Replacing the windows, e.g. with triple-glazed windows with a U-value of 0.9 W/m2·K, which can also be fitted with blinds to prevent heat loss during winter nights and overheating on summer days;
- Sealing gravity ventilation ducts and installing a mechanical ventilation system,
  - such as a supply/exhaust ventilation system with heat recovery (air supply to the rooms, air outflow from the kitchen, bathroom and toilet, plus a heat exchanger allowing the air flowing in to be heated by the heat from the air flowing out),
  - or humidity-controlled mechanical ventilation (fitting humidity-controlled ventilators in windows or walls, fitting humidity-controlled exhaust grilles in toilets, kitchens and bathrooms, fitting extractor fans at the ends of ventilation ducts),
- Replacing or overhauling the central heating system, including adjusting the radiators, forcing heating water to circulate using a circulation pump, installing thermostatic valves, replacing any open expansion tanks with closed or diaphragm ones, insulating pipes (especially any that pass through unheated spaces);
- Replacing the boiler, e.g. with a condensing boiler suitable for the new heating load and fitted with appropriate controls and instruments;
- Replacing taps with single-lever mixers, including a number of thermostatic taps, complete with flow limiters and aerators;
- Retrofitting the hot water distribution system and replacing the heat source used to heat water (this can be linked up with the new central heating boiler and the two systems integrated), insulating water distribution and circulation pipes;
- Enabling the system and boiler to temporarily switch off the system or lower the preset indoor air temperature, introducing weather-based regulation of radiator flow temperature;
- Considering installing a renewable heat source such as solar panels or solar thermal collectors.

II.20 Examples of measures from Germany

“Märkische Scholle” housing cooperative, Berlin-Lichterfelde, revitalisation of housing dating from 1930

Märkische Scholle is a housing cooperative, which means that all its members hold shares in it. They elect their representatives every five years, and these representatives meet once a year: “The duties of the representatives come with significant responsibility: they elect the Supervisory Board, adopt the annual financial statements, decide on dividend payouts and approve the actions of the Board of Directors and Supervisory Board.” (https://www.maerkische-scholle.de/organe.html)

“The Supervisory Board advises, supports and monitors the work of the Management Board and thus serves as a company’s oversight body. The members of the Supervisory Board appoint the Management Board in accordance with the Articles of Association. The Supervisory Board and Management Board engage in intensive discussions and consult in detail on decisions relating to cooperative policy.” (https://www.maerkische-scholle.de/organe.html)

The Management Board is responsible for the cooperative’s activities. The current (2021) members of the Management Board are Margit Piatyszek-Lössl (Commercial Director) and Jochen Icken (Technical Director). (https://www.maerkische-scholle.de/organe.html)

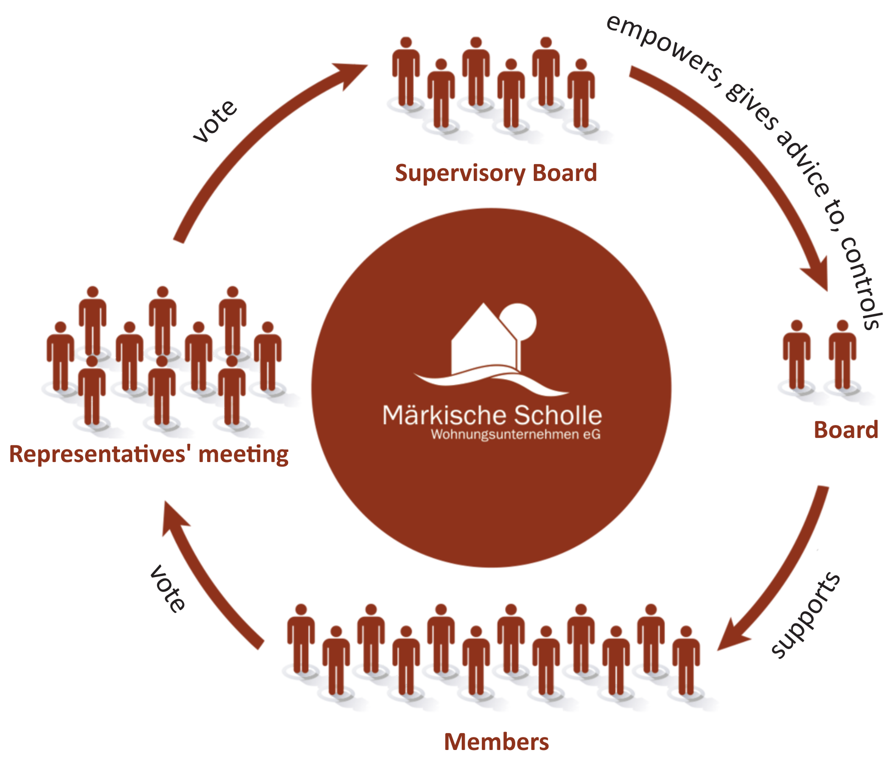


Fig. 41. Diagram of the cooperative’s activities
Source: https://www.maerkische-scholle.de/organe.html.

The Märkische Scholle cooperative has 5,000 members and 30 employees.
(https://www.maerkische-scholle.de/wohnbezirke.html)

The Weimar Republic was founded in the wake of the First World War. The shortage of housing prompted the passing of the "Reichsheimstättengesetz" (an act on the provision of housing for returnees). War veterans were offered a loan from the government and a cheap plot of land to build on. On 4 August 1919, "Märkische Scholle, Landsiedlungsgenossenschaft vom Reichsbund der Kriegsbeschädigten, Kriegsteilnehmer und Kriegshinterbliebenen e.G.m.b.H." ("land settlement cooperative of the imperial association of war wounded, war veterans and those left dependent by the war") was founded with the aim of building housing on the outskirts of Berlin, especially for war veterans.

Märkische Scholle changed its strategy in the wake of hyperinflation in 1924, currency reform and the introduction of a property tax intended to promote housebuilding. Its Articles of Association were amended as follows: "The object of the company is to promote the construction of small flats. The purpose of the cooperative is geared towards building and procuring healthy and suitably fitted-out small flats for those of small means at affordable prices." (Articles of Association, 1925). The cooperative thus switched its focus to renting out flats.
(https://www.maerkische-scholle.de/historie.html)

Nowadays, Märkische Scholle's core values are:

- Affordable rents,
- The right to housing for life,
- Co-determination,
- Cooperative living.

(https://www.maerkische-scholle.de/leitbild.html)

The cooperative's main aims are:

- A form of living and coexistence that is fair to all families and generations,
- Building and renovating to save energy and resources.

(https://www.maerkische-scholle.de/leitbild.html)

The Lichterfelde estate – existing buildings (initial situation):

- A 1930s development providing an affordable, family-friendly place to live,
- Simple architecture, few frills, straightforward construction, small rooms,
- 450 flats were built in the 1930s,
- A further 400 were added in the 1960s,
- Problems: thin walls, uninsulated ceilings, old windows and doors that let heat escape, wasting energy.

(https://ezeit-ingenieure.de/projekt/sanierung-und-dachgeschossneubau-wohnanlage)
(https://ezeit-ingenieure.de/projekt/sanierung-ausbau-nahwaermenetz-lichterfelde-sued)

TYPICAL PLAN OF A FLAT

Fig. 42. Typical plan of a flat
Source: presentation by deematrix Energiesysteme GmbH/Axel Popp: Technical paper: TOP 2014/03 eTank – Der Erdwärmespeicher, slide 31.

Energy concept, energy system, energy saving, problem with energy storage

The extremely compact design enables the heating demand (excluding hot water) to be cut from its original level of some 175 kWh/m² per year to approximately 33 kWh/m² per year without needing to use excessively thick insulation. The old roof space was demolished and replaced with a new prefabricated-timber superstructure. The heat transfer coefficient (U-value) of the façade ranges from 0.13 W/(m²·K) (timber construction) to 0.21 W/(m²·K) (existing building). The windows have a Uw value of less than 1.0 W/(m²·K), while the roof has a U-value of either 0.1 or 0.16 W/(m²·K). The cellar ceiling is fitted with spray foam insulation, which improves the U-value from 0.9 to 0.26 W/(m²·K).

By harnessing smart technology and using a low-temperature heating system for the building, the usable output of the liquid-based solar thermal collector system can be increased significantly (from around 300 kWh to more than 650 kWh per square metre per year). Surplus and low-temperature yields from the solar thermal collector system are fed into a ground-source heat storage tank (the “eTank”) that has been set up adjacent to the buildings. If required, these yields are also used to heat the water in the heating system to the required heating temperature with the aid of (cascaded) heat pumps. High-temperature solar energy yields are fed directly into the heating system or the stratified heat storage tank for water.

A controlled ventilation system supplies fresh air to the flats via external wall-mounted diffusers. Exhaust air is fed into the cellar through the existing chimneys, where the energy from it is recovered by the air-source heat pump and supplied to the heating and hot water system highly efficiently all through the year.

A dynamic energy manager (DEM) controls all the energy flows. Heat is exchanged using radiators and, in the attic, underfloor heating. The energy required to power the geothermal heat pump is generated by a photovoltaic system up to 80 m² in size on the roof of the building. (https://ezeit-ingenieure.de/projekt/sanierung-und-dachgeschossneubau-wohnanlage)

LOCATION OF UNDERGROUND STORAGE SYSTEMS

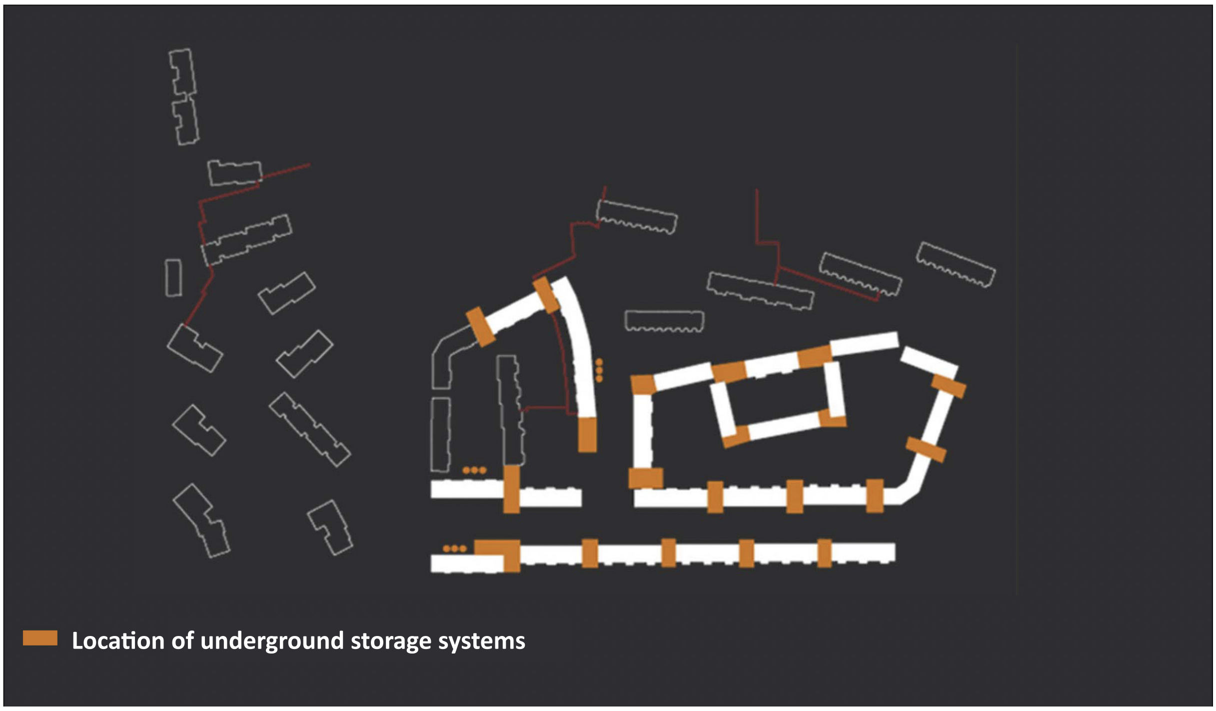


Fig. 43. Location of underground storage systems
Source: presentation by deematrix Energiesysteme GmbH/Axel Popp: Technical paper: TOP 2014/03 eTank – Der Erdwärmespeicher, slide 32.

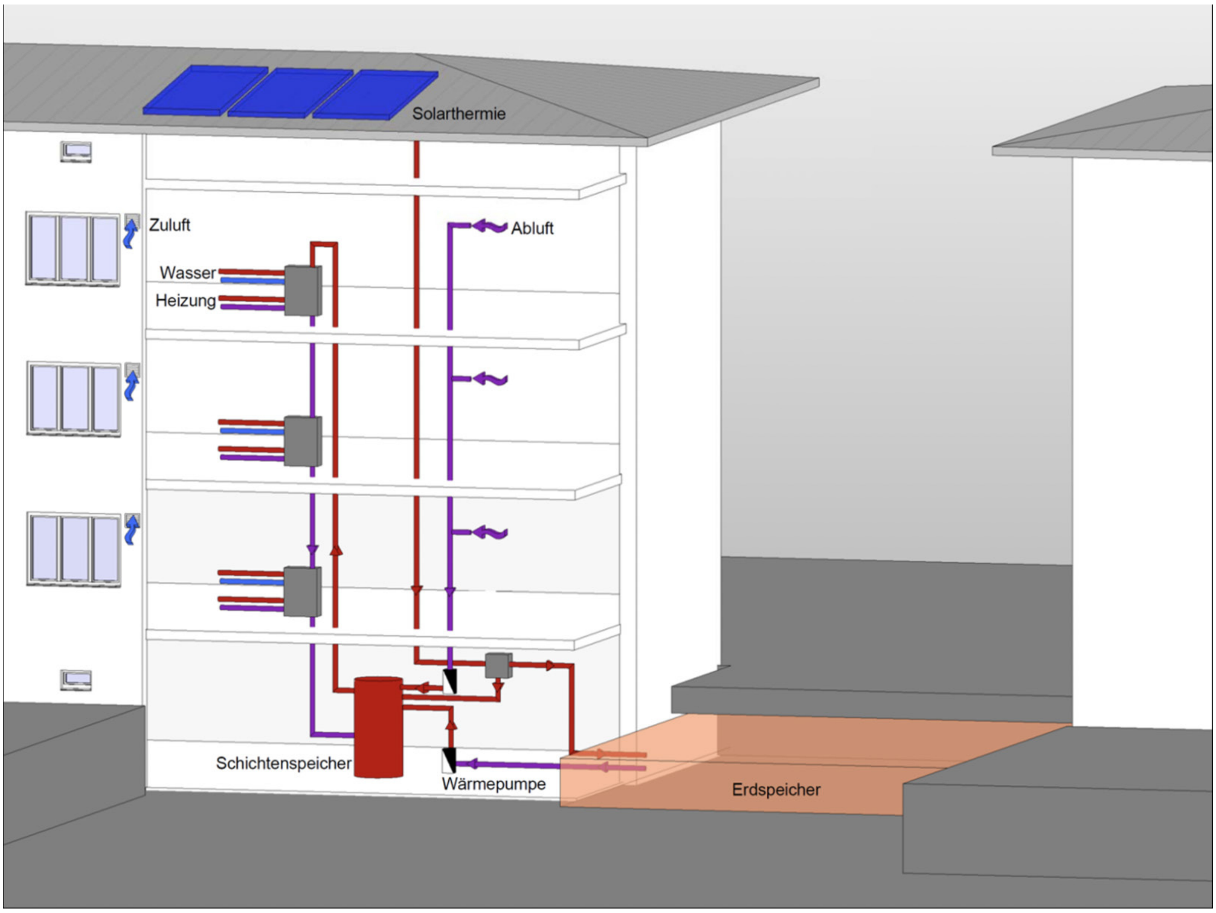


Fig. 44. Location of underground storage systems
Source: presentation by deematrix Energiesysteme GmbH/Axel Popp: Technical paper: TOP 2014/03 eTank – Der Erdwärmespeicher, slide 33.

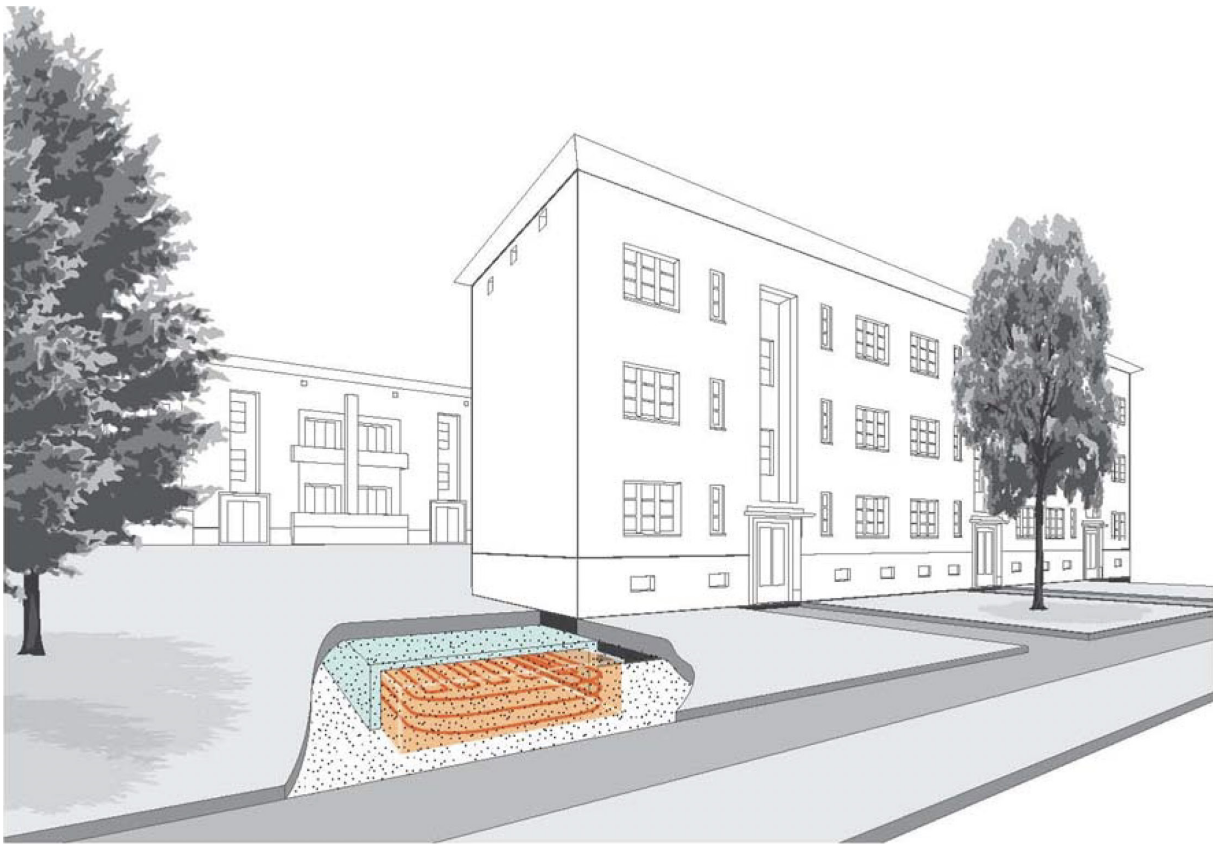


Fig. 45. Location of underground storage systems
Source: presentation by deematrix Energiesysteme GmbH/Axel Popp: Technical paper: TOP 2014/03 eTank – Der Erdwärmespeicher, slide 7.

Energy efficiency has improved thanks to solar and heating technologies that are more efficient. Primary energy demand has fallen from 210 kWh/m² to 30 kWh/m² per year (https://www.boell.de/de/2019/03/05/innovative-technik-wenig-kosten-fuer-die-mieterinnen), while operating costs and emissions have dropped by almost EUR 0.85/m².

Assistance with relocation for residents, public consultation, updates on renovation work, support schemes

Residents were notified in advance about the planned construction works and given assistance while they were moved temporarily to other flats in the cooperative. Their belongings (e.g. furniture) were stored elsewhere, with the cooperative covering storage costs.

Sources of funding, support

Retrofit cost: EUR 80 million

Funding:

- Slight rent increase (approximately EUR 2/m² for the "Kaltmiete" and EUR 1/m² for the "Warmmiete")[2],
- EUR 740,000 from the German Federal Ministry for the Environment's Environmental Innovation Programme.[3]

Certificates and reviews of the estate's level of innovation

"This renovation project won the BUND Environmental Award in the 'Economy and Innovation' category in November 2014. It was also honoured by Berlin-based KlimaSchutzPartner in 2015." (https://www.berlin-spart-energie.de/projekt/maerkische-scholle-saniert-841-wohnungen-in-lichterfelde-sued-169.html)

In addition, the project scooped the 2017 Heat Pump City Award, presented by the European Heat Pump Association, as well as the 2016 TGA Award.

2 The German rental system distinguishes between "Kaltmiete" ("cold rent"), which is the administrative rental charge with separate additional charges for rubbish collection, cleaning, heating, and water, and "Warmmiete" ("warm rent"), which is all costs added together.

3 https://www.boell.de/de/2019/03/05/innovative-technik-wenig-kosten-fuer-die-mieterinnen

Max-Steenbeck-Gymnasium school, Cottbus

Details of the building:

- Building constructed from prefabricated concrete panels ("Plattenbauweise", or large panel system-building),
- Year of completion: 1973,
- Feasibility study: retrofitting to "Passivhaus" standard with the highest possible economic efficiency, taking account of operating costs over 30 years.

Surface area of school building and sports hall:

- Total floor area (in accordance with DIN 277): 10,863 m²,
- Net heated floor area (for non-residential buildings in accordance with DIN 277): 9,509 m²,
- Total volume of rooms: 40,954 m³,
- Workstations (or number of pupils or people): 600 people,
- Form Factor (A/V ratio) of the building (before/after retrofitting, if applicable): 0.33 (before); 0.35 (school building) m²/m³.

(https://web.archive.org/web/20180315134705/https://projektinfos.energiewendebauen.de/projekt/energetische-sanierung-einer-plattenbau-typenschule)

Retrofit

Implementation period:

- 2008: retrofitting to "Passivhaus" standard,
- 2010–2012: carrying out the retrofit, October 2012: activities resume,
- 2015–2016: monitoring and optimisation – regulating the temperature, the operating time of the ventilation system, the pumps and the artificial lighting.

Costs:

- Retrofit cost: EUR 12.8 million,
- Cost of building structures: EUR 460/m², building services EUR 254/m² plus taxes.

Objectives and challenges:

- Automatic ventilation system with heat recovery,
- Ensuring a basic level of fresh air (important in view of the coronavirus pandemic),
- Ensuring ventilation at a level of 20 m³/h per person while keeping C02 concentration below 1,000 ppm – supplemented in part by window ventilation,
- There is often no space for ventilation systems during a retrofit,
- Increasing the mechanical air exchange would pose additional problems (noise, large duct cross-sections, draughts, costs, energy consumption, dehumidification),

- Less than 34 kWh/m2/year for heating and mechanical ventilation,
- First retrofit of this type of building to “Passivhaus” standard.

Solutions employed:

- Ground-source heat storage,
- Geothermal energy for use in winter and summer,
- Harnessing heat fed back from the heating system,
- Harnessing geothermal energy for ventilation,
- Supplying a low-temperature heating system using heat fed back from a higher-temperature system,
- Six central ventilation systems fitted with heat recovery,
- Thermal insulation 30 cm thick for the outer and ground wall.

Key energy values			
Key demand values			
	after retrofit	before retrofit	
Demand for heating (useful energy demand)	26.30 (school building)	260.90 (school building)	kWh/m²/year
Total primary energy	45.2	217.4	kWh/m²/year
Energy parameters: consumption			
	after retrofit	before retrofit	
Total final energy – electricity	14.7		kWh/m²/year
Final energy – heat	22.5	133.20 (school building)	kWh/m²/year
Primary energy – heat		93.20 (school building)	kWh/m²/year
Primary energy – total	29,90 (school building); 22,60 (sports hall)	132.10 (school building)	kWh/m²/year
	after retrofit	before retrofit	
Ventilators and pumps	5.3		kWh/m²/year
Electrical energy required for lighting	5.6		kWh/m²/year

Table 6. Energy data
Source: https://web.archive.org/web/20180315134705/https://projektinfos.energiewendebauen.de/projekt/energetische-sanierung-einer-plattenbau-typenschule.

Photo 10. Max-Steenbeck-Gymnasium school building, Cottbus
Source: Polish Institute of Urban and Regional Development.

Photo 11. Extraction and supply of air from/to a room
Source: Polish Institute of Urban and Regional Development.

Photo 12. Room with computers and desks designed to reduce computer noise
Source: Sanierung Max – Steenbeck – Gymnasium Cottbus. Schlussbericht, Cottbus, September 2015: p. 31; https://web.archive.org/web/20180315134705/https://projektinfos.energiewendebauen.de/projekt/energetische-sanierung-einer-plattenbau-typenschule.

Photo 13. Heating manifold for radiators and ventilation with flow meters
Source: Polish Institute of Urban and Regional Development

Photo 14. Physics classroom with soundproof panels in the ceiling and retractable media
Source: Sanierung Max – Steenbeck – Gymnasium Cottbus. Schlussbericht, Cottbus, September 2015: p. 32; https://web.archive.org/web/20180315134705/https://projektinfos.energiewendebauen.de/projekt/energetische-sanierung-einer-plattenbau-typenschule.

PART III

Basic information on the Special Revitalisation Zones

PART III

Basic information on the Special Revitalisation Zones

III.1 Why are the Special Revitalisation Zones being created in towns and cities?

The Special Revitalisation Zone (SRZ) is a specific area that can either cover the whole revitalisation area or just a part of it, i.e. include one or more revitalisation sub-areas in a given town or city. An SRZ has an impact on ownership arrangements within its area and allows the municipality to use various tools to make essential revitalisation projects included in the Municipal Revitalisation Programme (MRP) easier to implement. The corresponding resolution lasts for ten years but cannot be extended, a move that is designed to encourage efficient proceedings.

In most of the towns and cities where SRZs were established, the main aim was to promote the renovation of private buildings using grants for owners of the properties where revitalisation projects would be carried out. The range of tools used has since expanded. Płock, for example, is making active use of the right of first refusal to increase the municipal housing stock in the revitalisation area, which is enabling tenants to be rehoused in the immediate vicinity of the buildings being renovated. Six cities are currently working on affordable rental housing projects inside their SRZ. In Włocławek, an urban design and architectural competition has been announced for redeveloping the zone of affordable rental housing indicated in the MRP. The solutions put forward constitute a substantive contribution to the planned change in the local spatial development plan. Słupsk, Łódź and Świnoujście are working on changes to their local spatial development plans (LSDPs) or on establishing local revitalisation plans (LRPs) so that affordable rental housing can be created there. Kalisz has begun to develop an LRP, while Płock has amended its local zoning plan. Some cities are also considering loosening their administration requirements for rehoming people for renovation purposes.

III.2 How many Special Revitalisation Zones have already been established in Poland?

SRZs can only be created in municipalities that made provision for this instrument in their MRPs. There were just under 300 MRPs in force in Poland at the end of 2020. Although 32 of these programmes envisaged setting up an SRZ, only 12 towns and cities ultimately received one.

Municipalities in which a planned SRZ has actually been established	Municipalities whose MRP envisages setting up an SRZ
Bytom Kalisz Łódź Malczyce Opole Lubelskie Ośno Lubuskie Polkowice Płock Świnoujście Waganiec Włocławek Słupsk	Bieruń Gdańsk Gorzów Wielkopolski Jarocin Kazimierz Dolny Koluszki Kościan Kościerzyna Leszno Piła Poznań Pułtusk Ruda Śląska Rumia Sejny Starachowice Stargard Starogard Gdański Szczawno-Zdrój Szydłowiec Wałbrzych Wołomin

Table 7. Special Revitalisation Zones in Poland – existing and planned
Source: Polish Institute of Urban and Regional Development.

The town of Żyrardów has not been included in the table. On 28 January 2021, the town council adopted the Municipal Revitalisation Programme for the town of Żyrardów for the years to 2030,[4] which also envisages setting up an SRZ.

Two SRZs were established in 2017, i.e. the second year of the Polish Revitalisation Act being in force. The next five were initiated in 2018 and the next four – Malczyce, Waganiec, Włocławek and Świnoujście – in 2019. Although no more SRZs were created in 2020, both Słupsk and Żyrardów are planning one for 2021.

A few more municipalities are currently deciding on whether to set up an SRZ. An evaluation of the revitalisation system
in Poland reveals that they are being prompted by the ease with which EU funds can be obtained and the system that encourages these funds to be spent within a short period of time. This in turn is leading municipalities to prefer straightforward projects. As it takes time to carry out revitalisation using all of the tools introduced in the Polish Revitalisation Act, such as clarifying the legal status of abandoned properties and enforcing the right of first refusal, a number of

4 http://rewitalizacja.zyrardow.pl/gminny-program-rewitalizacji-uchwalony [accessed on 10 February 2021].

municipalities are considering making use of SRZs in the future. By contrast, one reason for SRZs being used so rarely as a way of subsidising the renovation of privately held assets is the limited budget available to the municipalities. As they can already access EU funds for simple revitalisation projects, municipalities choose the most urgent tasks to work on. The limited time horizon of an SRZ after its introduction (no more than ten years) also makes it tempting to defer any decision on potentially setting one up in order to be able to make full use of the tools that it offers in the future (i.e. if the budgetary situation of local authorities improves or when funds will be available for complex revitalisation projects, e.g. related to rented accommodation or setting up a system of grants for renovating private buildings located inside an RA). Taking the towns and cities that have already established SRZs as an example, however, it is clear that some local governments have become effective users of the various tools available under the Polish Revitalisation Act (u.o.r.).

Characteristics of the SRZs designated in Kalisz, Łódź, Bytom, Włocławek, Świnoujście, Płock, Polkowice, Ośno Lubuskie and Opole Lubelskie

In most of these cities, SRZs have been designated in run-down inner-city areas, which is why densely packed historical buildings are usually the dominant feature. The revitalisation area in **Kalisz** has the most buildings in the municipal register of historical monuments (MRHM) per square kilometre. The buildings inside this area are over 100 years old on average, and their technical condition is characterised by significant shortcomings, a high percentage of outdated coal-fired heating systems and low energy efficiency, resulting in high heat losses. There are 1,791 buildings inside the revitalisation area, most of which are residential. These buildings have a diverse make-up and include both tenements and multi-family dwellings (blocks of flats) in the various neighbourhoods. They also vary in terms of their number of floors (two to four) and technical condition (very good to very poor – in the case of buildings requiring urgent

Photo 15. Photo 16. Historical residential buildings in the Kalisz SRZ
Source: Kalisz city council.

Photo 17. Ulica Sienkiewicza in Łódź's revitalisation area
Source: Łódź city council.

Also facing a huge challenge is the city of **Łódź**, which has over 10,000 properties within its SRZ. The revitalisation area, which corresponds to the Łódź metropolitan area, is home to as many as 3,800 street-facing tenements that are also listed buildings. Łódź's revitalisation area is also very diverse in terms of its buildings: there are tenements, blocks of flats and estates made up of single-family homes. Almost the entire revitalisation area consists of densely packed, municipally owned buildings in a poor technical condition. Unfortunately, the low level of innovation in Poland's energy sector means that outdated and environmentally unfriendly solutions are still being employed. This is also being felt **in Łódź**, which has never been supported by a system-wide solution for connecting its centre and its expanding suburbs to a district heating network. There is therefore a high intensity of harmful emissions close to the ground throughout the revitalisation area.

Włocławek's revitalisation area has also been established in the oldest historical part of the city, where over 50% of the buildings are in a poor or mediocre technical condition and require comprehensive renovation. The buildings have dilapidated roofs and walls, with flats plagued by damp and mould. Although the revitalisation area is equipped with all the necessary utilities (water, sewerage and energy), only some of the buildings are connected or are capable of being connected to the district heating or gas network. Most residents therefore use boilers fuelled by coal and other products not intended for this purpose. In addition, the revitalisation area has only a small amount of green space. Green spaces in cities absorb carbon dioxide, offset some of the hydrocarbons emitted from vehicles' fuel tanks, retain rainwater and create areas of shade. Not having any will significantly reduce locals' quality of life.

Photo 18. The revitalisation area in Włocławek
Source: Włocławek city council.

The technical deterioration of its historical buildings is also a challenge for **Płock**. The "Stare Miasto, Kolegialna" revitalisation sub-area lacks a comprehensive approach to renovating its historical buildings, including thermal upgrading, due to limited financial resources and a shortage of replacement premises. Not all buildings are equipped with technical infrastructure (central heating, gas). Local boilers and household boilers used for heating pollute the air and necessitate the presence of utility rooms (units) in the space, which impair its quality. The situation in Płock's other revitalisation sub-areas (Dobrzyńska, Skarpa and Radziwie) is somewhat different. The building stock is dominated by pre-1989 examples, some of which – belonging to housing associations – have already undergone a thermal upgrade. The Radziwie sub-area is dominated by single-family dwellings built in the second half of the 20th century, most of which are heated using traditional, inefficient solid fuels that pollute the environment.

Photo 19. Photo 20. Historical buildings in the revitalisation area in Płock
Source: Płock city council.

Photo 21. The Bobrek revitalisation area in Bytom
Source: Bytom city council.

What makes **Bytom**'s revitalisation area unique is its high concentration of municipal buildings. Most of these are over 100 years old, have not seen adequate investment, and often do not meet modern standards in terms of their utilities. Only 161 out of a total of over 13,000 premises have a central water heater, and no fewer than 55% of all municipal buildings lack a gas heating system. This is particularly the case in sub-area 8 (Bobrek), where all of the municipal buildings lack a gas system and use tiled coal-fired boilers for heating instead. There are also single-family dwellings built after the Second World War, while the northern part of the district is home to early 20th- century buildings known as "familoki" ("family blocks of flats"). One in every five buildings owned by the municipality is in a poor or very poor state of repair. The city centre and the Rozbark sub-area are dominated by old tenements built before World War II, when the area was still part of Germany. Part of the Śródmieście Północ area contains around a dozen single-family dwellings with a "Finnish"-type wooden construction that were built in the post-war period.

Many of the residential buildings in **Świnoujście** were constructed before 1970. They make up 43.5% of the city's total stock of residential buildings and are generally in a good technical condition. Although most have been renovated, some still require retrofitting, e.g. to make them more energy-efficient.

Photo 22. Buildings in Świnoujście
Source: Świnoujście city council.

The revitalisation area in **Ośno Lubuskie** lies almost entirely within the boundaries of the town's historical urban layout as listed in the register of historical monuments. The actual buildings are very diverse, however: there are mainly two- and three-storey multi-family tenement flats situated in densely packed street-facing buildings and single-family dwellings situated along the historical building line, with a few detached houses. The area also contains some large-panel-system buildings. By contrast, modern buildings make up only a small part of the area. Many buildings do not meet energy efficiency standards, and the lack of a centralised district heating system is a problem. With many of the families living in the revitalisation area being poor and having a low level of environmental awareness, they will often burn waste and poor-quality fuels. Environmentally friendly heating systems are the exception rather than the rule.

Photo 23. Buildings inside the RA in Opole Lubelskie
Source: Opole Lubelskie town council.

Photo 24. Buildings in Ośno Lubuskie
Source: Ośno Lubuskie town council.

However, the significant percentage of green spaces and recreational areas (about 25%) is having a positive impact on the quality of the environment within the revitalisation area.

The revitalisation area in **Opole Lubelskie** is likewise characterised by diversity in land use. It is dominated by single- and multi-family dwellings, which make up nearly 41% of the area. Most of the buildings are old, historical stock; they are often in a poor technical condition and require renovation, retrofitting and upgrading as well as technical solutions that will enable them to be used efficiently in terms of energy efficiency and environmental protection. As part of its revitalisation activities, the municipality of **Opole Lubelskie** has established a programme for renovating tenements, comprising an architectural and construction concept for renovating its tenements and devising conceptual solutions for building façades, damp-proofing, thermal upgrading, replacing window and door frames, roofing, railings and lighting, and adapting entrances to the needs of the disabled and other people requiring assistance.

The buildings in **Polkowice**'s revitalisation area are atypical, as it mainly comprises modernist blocks of flats managed by a housing cooperative. As in other Polish towns and cities, one of the problems identified in Polkowice's MRP is the emissions generated close to the ground through the use of outdated heating systems and low-quality heating fuel. The housing stock in the revitalisation areas of Polish towns and cities is diverse in terms of its ownership, building type and technical condition. What is common to all municipalities, however, is the need to improve energy efficiency due to the problem posed by emissions close to the ground in revitalisation areas, which are related to how their buildings are heated (local boiler rooms, individual boilers). These factors mean that the revitalisation areas usually record the most severe breaches of air quality standards in the town or city in terms of the concentration of total particulate matter PM2.5 and PM10 as well as benzo[a]pyrene. This problem is being recognised not only by city leaders but also by the residents themselves. In **Kalisz**, for example, around 50% of respondents from all stakeholder groups said that air pollution from coal-fired boilers was a significant or very significant problem in the revitalisation area.

The SRZ in the **municipality of Waganiec** was set up to cover the entire revitalisation area and is divided into three sub-areas: Waganiec (consisting of two sub-municipalities, Waganiec I and Waganiec II), Sierzchowo and Wólne. All of the sub-areas feature a particularly high degree of rural residential and economic development. Based on the information contained in the MRP for 2016–2025, traditional solid-fuel boilers are the main source of exhaust gas emissions generated close to the ground. These boilers can be powered by various fuels, including coal, eco-pea coal, coal dust and wood. Differing amounts of ash, other waste and flue gases are produced depending on the type of fuel. A small percentage of buildings compared to the total number of buildings in the individual sub-area are connected to the district heating network. People in the sub-areas are also seeing their quality of life affected by their limited access to the sewage network and district heating network, requiring them to use domestic septic tanks and treatment plants and use gas or electricity to heat their water.

The **municipality of Malczyce** is made up of nine sub-municipalities: Malczyce, Mazurowice, Chomiąża, Rachów, Rusko, Wilczków, Kwietno, Dębice, Chełm and two localities: Szymanów and Zawadka, both included in the Chełm sub-municipality. The SRZ covers seven streets in the village of Malczyce (Dworcowa, 1 Maja, Mazurowicka, Mylna, Polna, Henryka Sienkiewicza and Romualda Traugutta). This area is home to a dense concentration of buildings and shared flats in need of repair and retrofitting. According to the MRP for the Malczyce municipality for 2016–2022, the revitalisation area covers 0.86% of the municipality and houses 25.72% of its population. It is home to 58 pre-1945 multi-occupancy dwellings, as many as 35 (over 60%) of which are in the revitalised area. The percentage of shared dwellings is as high as 11% in the revitalisation area compared with 2.58% in the municipality as a whole. The percentage of homes without access to technical and sanitary facilities is 0.42% in the municipality but as much as 2% inside the RA. Over half of these buildings located in the revitalisation area require a thermal upgrade. The municipality of Malczyce is home to a group of residential buildings that use a high percentage of coal-based fuels for heating purposes.

The SRZ in **Słupsk** was established by way of Słupsk city council resolution no. XXXVII/573/21 of 24 November 2021 on the establishment of a Special Revitalisation Zone in the revitalisation area of the city of Słupsk. The SRZ covers the revitalisation area designated by Słupsk city council resolution no. XXIII/276/16 of 30 March 2016. The tools available inside the SRZ are grants for the owners and perpetual users of all types of property, regardless of the purpose they serve. The right of first refusal and the ban on issuing zoning decisions in the revitalisation area expired on 7 June 2018. Subsidies of up to 50% of the net expenses incurred are available for necessary expenses within the rules of SRZ grants. The level of the grant, i.e. the maximum grant per property, is capped at PLN 100,000. The call for applications for grants inside the SRZ is announced within 14 days of the city of Słupsk's budget for the relevant financial year being adopted. The deadline for submitting applications for grants inside the SRZ is at least 30 days after the call is announced.

Photo 25. Buildings in Słupsk
Source: Słupsk city council.

III.3 What scope of work can attract subsidies in grant programmes for renovation work in Special Revitalisation Zones?

The municipality may provide the owners or perpetual users of properties located inside its SRZ area with a grant to carry out construction work consisting of renovation or redevelopment as well as to perform conservation and restoration work in an amount not exceeding 50% of the necessary expenses provided that the properties in question are not in the register of historical monuments. However, these activities must help to implement the revitalisation projects included in the relevant MRP.

The definitions of the terms "redevelopment" and "renovation" can be found in the provisions of the Polish Act of 7 July 1994 – Construction Law (Journal of Laws 2020, items 1333, 2127, 2320; Journal of Laws 2021, items 11, 234, 282). Specifically, paragraphs 7a and 8 of Article 3 state:

- redevelopment – the execution of construction work resulting in a change in the usage or technical parameters of an existing property, excluding its characteristic parameters such as its volume, building surface, height, length, width or number of floors,

- renovation – the execution inside an existing building of construction work consisting in restoring its original state rather than ongoing maintenance, with the use of construction products other than those originally used being permitted.

Conservation and restoration tasks, by contrast, are deemed to be those referred to in Article 3 paragraphs 6 and 7 of the Polish Act on the Protection and Care of Historical Monuments (Journal of Laws 2020, items 282, 782, 1378):

- conservation tasks – activities aimed at preserving and strengthening the substance of a historical monument, thus stopping the processes causing its destruction, and documenting these activities,

- restoration tasks – activities aimed at showcasing the artistic and aesthetic value of the historical monument, including, if necessary, completing or reconstructing parts thereof, and documenting these activities.

Despite the many renovation challenges identified in revitalisation areas, a limited list of tasks can be funded under the SRZ renovation grant programme. The specific scope of work that can be covered by a grant is defined by the appropriate provision of Article 77 of the Polish Act on the Protection of Historical Monuments. The grant programme for renovation work in SRZs thus most commonly covers the following expenses in municipalities' day-to-day practice:

Types of investment under Article 77 of the Act on the Protection of Historical Monuments that are eligible for a grant as part of an SRZ	
Relating to properties listed in the MRHM	**Relating to other properties**
— Protecting, preserving and strengthening the substance of the historical monument, — Stabilising the structure of the historical monument's component parts or restoring them, — Refurbishing or completing plaster and architectural facings or reconstructing them, — Restoring destroyed parts of the historical monument, — Refurbishing or completely restoring windows, including jambs and shutters; external door frames and doors, roof trusses, roofing, gutters and drainpipes, — Retrofitting the electrical system in wooden historical monuments or in historical monuments that have original wooden elements and accessories, — Providing an anti-moisture system, — Completing the ground plan of defence architecture and archaeological historical monuments, — Showcasing existing original elements of a historical park or garden layout, — Purchasing maintenance and construction materials required to carry out work on a historical monument listed in the register, — Purchasing and installing burglary, fire and lightning protection systems.	— Refurbishing or completing plaster and architectural facings or reconstructing them, — Refurbishing or completely restoring windows, including jambs and shutters, external door frames and doors, roof trusses, roofing, gutters and drainpipes, — Providing an anti-moisture system, — Purchasing and installing burglary, fire and lightning protection systems.

Table 8. Types of investment eligible for a grant as part of an SRZ
Source: Polish Institute of Urban and Regional Development.

Although this scope is broad, it does not always suit the specific characteristics of the individual area or the objectives of the town or city. The relevant resolutions thus contain provisions that regulate in detail the scope of the work being subsidised as well as the level of subsidy. Most municipalities (Płock, Kalisz, Polkowice, Ośno Lubuskie, Świnoujście) adopted the 50% maximum limit for necessary expenditure as stipulated in the Polish Revitalisation Act. In Łódź, the level of subsidy varies depending on whether the property in question is deemed historical. This is a direct result of the city's development strategy and the requirement to protect the historical value of the Łódź metropolitan area, which forms part of this strategy. By contrast, two other cities have applied detailed rules tailored to the specific features of their revitalisation areas that had previously been identified in their MRPs.

In Włocławek, a call for proposals was announced while the MRP was being prepared. The projects submitted included four properties whose owners were planning the comprehensive redevelopment of the buildings, including renovating structural elements and internal systems. These investments are geared towards enabling businesses to operate and improving the quality of residents' lives and the conditions for doing business. Another project planned in the MRP is called "Renovation Grants" and consists of subsidies (up to 50%) for renovation and investment activities in properties covered by the SRZ. Four options for the work have been taken into consideration.

The following work in the communal areas of the buildings are envisaged for the "Investing with Class", "Step-by-Step Renovation" and "Showcase+" projects:

1. Construction work allowing the building to be made use of;
2. Installation work on the water and sewage networks in accordance with the technical design, on the valves shutting off individual measuring points and, in the case of sewage, on a tee positioned vertically in front of the premises;
3. Installation work on the gas network, up to the shut-off valve of the measuring point as in point 2;
4. Installation work on the electrical network, to protect the internal system of the premises as in point 2;
5. Installation work on the central heating network, up to the shut-off valve of the internal energy consumption point of the premises system as in point 2;
6. Installation work, including installing a rainwater drainage system leading to a collector;
7. Installation work on the low-voltage network up to the consumption socket in the premises;
8. Comprehensive landscaping of the area around the property.

The scope of work adopted applies to all properties located in the SRZ, including those listed in the register of historical monuments. The "History Pays Off" programme is designed for historical buildings for which the list of work has to be expanded. It will subsidise all of the activities listed in Article 77 of the Polish Act on the Protection and Care of Historical Monuments. The "Investing with Class" programme, by contrast, involves extensive investment geared towards eliminating threats to life and property. Due to the run-down state of housing in central Włocławek, the maximum level of subsidies is set at 50% of necessary expenditure. This comprehensive renovation is intended to provide the greatest possible momentum for change in terms of developing the revitalisation area. Its effects are already visible, not only in the fabric of the city but also in the minds of locals, who are beginning to see the positive changes.

III.7 How often is renovation work subsidised in the Special Revitalisation Zones?

Among the tools an SRZ offers, municipalities frequently make use of grants for renovation or reconstruction and for conservation and restoration work in buildings that are not listed in the register of historical monuments. These are provided for in as many as eleven out of the twelve resolutions on setting up an SRZ and are accompanied by detailed rules on awarding grants for construction work comprising renovation or redevelopment as well as for conservation and restoration work in relation to properties not listed in the register of historical monuments on behalf of owners or perpetual users of properties inside the SRZ. To date, a total of 22 calls for proposals have been announced in eight of these cities, with a total of 180 grants awarded in those that have made their decision.

Municipality	Number of calls for proposals	Number of grants awarded
Kalisz	3	36
Łódź	5	57
Ośno Lubuskie	1	6
Płock	4	44
Polkowice	3	7
Włocławek	3	28
Malczyce	2	2
Słupsk	**1**	**0**
Total	**22**	**180**

Table 9. Level of subsidy and the scope of necessary expenses within the rules of SRZ grants
Source: Jadach-Sepioło A., Kułaczkowska A., 2019, Specjalna Strefa Rewitalizacji w praktyce, Polish Institute of Urban and Regional Development, Warsaw, pp. 32–33.

PART IV

How can municipalities support efforts to make residential buildings in their revitalisation area more efficient?

PART IV

How can municipalities support efforts to make residential buildings in their revitalisation area more efficient?

IV.1 What are the main efficiency measures that municipalities are carrying out?

Most buildings in Poland without thermal insulation were constructed before 1989 and are characterised by their outdated, coal-fired heating systems. This type of housing is concentrated in revitalisation areas, creating a high demand for thermal upgrading measures as part of the revitalisation process. Thermal upgrading is geared towards making improvements that help to reduce energy demand for heating rooms and preparing domestic hot water. Thermal upgrading measures are being carried out in single-family dwellings, shared housing and public buildings owned by local authorities. In practice, there are three levels of thermal upgrade.

TABLE 13. LEVELS OF THERMAL UPGRADE INSIDE A BUILDING

Level of thermal upgrade inside building	Measures to achieve the desired level of retrofit
Minor thermal upgrade	• Retrofitting or replacing the heat source
Medium thermal upgrade	• Retrofitting or replacing the heat source • Replacing windows and doors or insulating external walls
Comprehensive thermal upgrade	• Partially or completely replacing the heat source and using renewable energy sources or high-efficiency CHP • Replacing central heating and domestic hot water systems, including their insulation • Replacing the external frames of windows and doors • Insulating all internal parts of the building envelope (façades, flat roof and ceiling/floor) • Renovating balconies

Table 10. Levels of thermal upgrade inside a building
Source: Rynek Instalacyjny, Polish Institute for Renewable Energy (IEO), NAPE.

In practice, thermal upgrading measures usually involve public buildings and housing stock owned by municipalities and housing cooperatives. They primarily include retrofitting or replacing heat sources as well as replacing the frames on windows and doors and insulating external walls (medium thermal upgrade). The extensive nature of the thermal upgrading measures in these buildings is thanks to the good availability of funding schemes for them, including voivodeship-level environmental protection funds, BGK and EU funds.

The most common work done on private properties involves a minor thermal upgrade, i.e. merely retrofitting the heat source or heating system. However, this solution only achieves a small reduction in final energy demand (approximately 10%).

The extent of the renovation work undertaken by the owners of private properties is largely determined by what financial support schemes are available. At local level, the most common form of support provided to residents by municipalities are targeted subsidies (also known as "environmental grants") that enable them to replace low-efficiency solid-fuel heating systems with more environmentally friendly solutions. Schemes that support wall insulation and the use of renewable sources (e.g. solar panels) are less common in relative terms.

However, financial support schemes should primarily encourage the owners of buildings to undertake comprehensive thermal upgrades. Besides replacing the heating source, these should also include insulating external walls and replacing window and door frames as a bare minimum.

This has been confirmed by the findings of scientific studies. Analyses carried out in Wrocław on the types of heat source used in residential buildings reveal that the buildings with an environmentally unfriendly heat source are also normally the oldest buildings, which also require thermal upgrading (insulating walls and replacing windows). The main recommendation made by this study of Wrocław tenements is therefore to combine thermal upgrade programmes with schemes supporting the decommissioning of solid-fuel heat sources.[5]

5 Baborska-Narozny M., Szulgowska-Zgrzywa M., et al., 2018, Ciepło w domu gdy zimno na dworze, Wrocławska Rewitalizacja, Wrocław, http://cieplozimno.pwr.edu.pl/ – project entitled "Density of the distribution of solid-fuel heat sources compared with the age, type and function of the building fabric and residents' attitudes towards changes in the heating system in the city of Wrocław."

IV.2 How can energy efficiency measures for residential buildings inside a Special Revitalisation Zone be coordinated?

Buildings located in an SRZ and included in a renovation programme may have inefficient heat sources that need replacing. If so, appropriate measures must be considered when planning the renovation. First of all, the amount of work required to switch the heat source to one that is ultimately to provide both heating and domestic hot water should be taken into account. The internal consumer systems may need to be built from scratch or extensively retrofitted depending on their current condition. The technical and economic framework conditions for carrying out this work will determine which specific solutions will be applied to the heat source. One important consideration at this stage is whether centrally fed district heating systems will be an option. If not, individual (residential) heat sources powered by electricity or gas should be considered.

The next step is to analyse the possibility of using various heat sources and what levels of efficiency these would bring:

- A boiler (local, individual) using the most environmentally friendly, efficient and available fuels,
- A hybrid source, using renewable heat and heat recovery (e.g. combining a conventional source with photovoltaic cells and a heat pump),
- Connecting to a district or local heating network.

The analysis should take into account a large number of aspects such as: the possibility of finding the source; how inconvenient it will be for residents to operate; the availability of fuel; ongoing operational issues; expenses and costs; and safety.

The most efficient option in an urban area with a district heating network will be to connect the building to that network. As a first step, therefore, the grid operator should be contacted in order to find out the technical connection criteria.

It must also be borne in mind that an entity holding legal ownership of a building that is not connected to the district heating network or equipped with an individual heat source but that is located in an area where the technical conditions for drawing heat from the district heating network are in place is under a conditional obligation to connect to that network.

Replacing a heat source in a property located in an area where an energy-efficient district heating system is in operation is deemed to be a special case.

An energy-efficient district heating or cooling system is defined as one that uses at least the following to achieve its heating or cooling:

1. 50% energy from renewable sources, or
2. 50% waste heat, or
3. 75% heat from CHP, or
4. a 50% combination of energy and heat as specified to in points 1 to 3.

The circumstances surrounding the operation of such a system impose certain obligations on both its operator and the owner of the property. In particular, connecting to an energy-efficient network is free of charge.

One important aspect to be borne in mind when planning to connect buildings in an SRZ to a district heating network is the intended number of properties to be connected. Issues associated with connecting to the district heating or gas network should be considered at the same time and in a targeted way, regardless of the timetable for undertaking renovation work for retrofitting individual buildings. In particular, it must be remembered that the energy company (i.e. the network operator) is required to consider both the target capacity and the network route in terms of the scale and distribution of consumption points. The network implementation schedule must also account for the land use planned inside the SRZ. The first steps often involve upgrading pavements and traffic routes, landscaping or greening. Since underground infrastructure should be redeveloped and new systems constructed before moving on to measures like these, all conceptual and design work must be carried out in good time. The design process for underground linear infrastructure can be complex and lengthy. A large number of crossings and collisions with other infrastructure are inevitable, particularly in city centres – which is where SRZs are usually located. This requires agreements to be reached with all the various operators and sophisticated design solutions to be found. A separate aspect is the issue of land ownership, which involves both obtaining licences for setting up the infrastructure and then establishing easements on these properties.

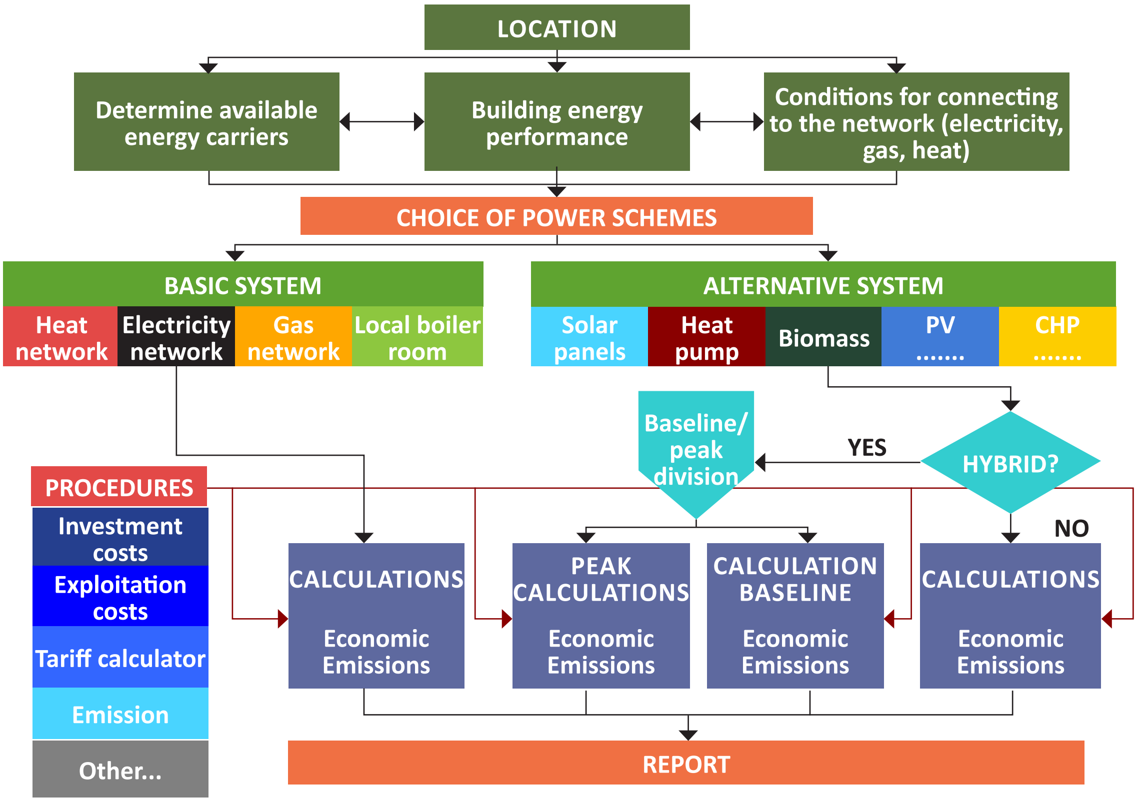


Fig. 46. Flowchart for selecting an energy supply system
Source: fpe.org.pl/NowyEkspert.

Coordinating the various works in an appropriate fashion may prove so complicated that it prevents the most effective solutions from being implemented for reasons associated with the property or results in an unjustified increase in costs. In view of these circumstances, it is a good idea to conclude a long-term agreement with the network operators if the intention is to connect a large number of properties inside the SRZ to the district heating or gas network. One example of this could be the agreement signed between Veolia Energia Łódź and the city of Łódź, which paves the way for planned, coordinated action to connect entire areas of the city to the grid. The benefits associated with acquiring new heat consumers may persuade the supplier to contribute to the investments required to adapt each building so that it can receive the heat. This may provide an additional source of funding for revitalisation projects. It is important to bear the available technologies in mind when planning to connect properties to a district heating or gas network. Trenchless technologies will be an option if the building to be connected to the network is located in an area that has already been revitalised and if the district heating or gas network has to run through an area that has already been redeveloped and, for example, is covered by a guarantee or is still within its "useful life". One example of this could be the connection of the Cloth Hall building in Kraków to the district heating network, where the network was laid beneath the surface of the central market square (Rynek Główny) using guided drilling technology.

IV.3 Can grants for renovation work within a Special Revitalisation Zone be put towards making buildings more energy-efficient?

Yes. Grants in SRZs can support measures geared towards making buildings more energy-efficient. According to data from the "National Energy Efficiency Action Plan for Poland 2017", the biggest cause of heat loss in buildings is heat escaping through parts of the envelope, particularly through glazing (windows and doors). This accounts for as much as 60–70% of the building's total energy balance. Ventilation is in second place in terms of loss. Renovation work geared towards making the building more energy-efficient as simply as possible should therefore reduce heat losses while maximising the benefits of the energy consumed.

The document recommends making improvements to existing buildings, including the following retrofit steps:

- "Windows and doors – using energy-efficient frames,
- External walls – adequate insulation of the walls,
- Roof – proper roof insulation,
- Flooring on the ground – adequate insulation for the flooring on the ground,
- Thermal bridges – adopting solutions that minimise thermal bridges."[6]

These are deemed necessary expenses eligible for a subsidy as part of renovation work inside an SRZ.

IV.4 How can the costs of investing in energy efficiency improvements in Special Revitalisation Zones be covered?

If the SRZ in question contains a large percentage of historical buildings that are included in the general register and the municipal register of historical monuments, and if there is a large cluster of problems associated with the large number of solid-fuel boilers being used for heating, it is a good idea to instigate an extensive campaign of renovating private buildings using three support instruments:

- Grants for renovation work in an SRZ envisaged under the Polish Revitalisation Act,
- Grants available under Article 81 of the Polish Act on the Protection of Historical Monuments for carrying out conservation, restoration or construction work on monuments entered in the general register or the municipal register of historical monuments,

6 https://www.gov.pl/web/klimat/krajowy-plan-dzialan-dotyczacy-efektywnosci-energetycznej, pp. 119–120 [accessed on 10 February 2021].

- Environmental protection grants available under the Polish Environmental Protection Act that are designed to reduce emissions close to the ground and improve energy efficiency.

Combining these three support instruments will generate synergy effects. The short list of necessary expenses that can be subsidised inside an SRZ essentially restricts renovation projects in that SRZ to minor thermal upgrades.

Achieving the objectives of improving the energy performance of buildings in an SRZ means improving its energy parameters and making other improvements that will reduce heat loss inside it and make it more air-tight by making use of the list of necessary expenses under the Polish Act on the Protection of Historical Monuments. Specifically:

a. With regard to the windows and doors – using energy-efficient frames,
b. With regard to the roof – proper roof insulation,
c. With regard to the external walls – adequate insulation of the walls and adopting solutions that minimise thermal bridges.

As the short list of renovation expenses that can be financed using SRZ-related and conservation grants is much longer in the case of environmental subsidies, this opens up the possibility of establishing connections to a network (e.g. gas, central heating), converting heating systems, replacing heating sources and carrying out a thermal upgrade to the building.

The programme of targeted grants that supports the decommissioning of coal-fired boilers in private properties, amongst other things, follows the procedure provided for in Article 403 paragraph 4 of the Polish Environmental Protection Act.[7] The specific rules of the programme apply throughout the municipality and should relate in particular to:

1) Entities not deemed part of the public finances sector, including:
    1. oprivate individuals,
    2. housing associations,
    3. legal entities,
    4. entrepreneurs;

2) Entities from the public finances sector that are municipality- or district-level legal entities.

Assuming that the highest concentration of coal-fired boilers is usually to be found in densely packed inner-city developments inside the revitalisation area (and the SRZ), one basic instrument for reducing the problem of emissions close to the ground as part of the revitalisation process would be a programme of targeted grants for decommissioning solid-fuel boilers and funding environmentally friendly heating sources.

7 Act of 27 April 2001 – Environmental Protection Law (Journal of Laws 2020, items 1219, 1378, 1565, 2127, 2338).

A comparison between the subject of the support and the scope of the regulations governing the corresponding grant tools is provided below.

	Grant within a Special Revitalisation Zone	Conservation grants available to a municipality, the executive board of a voivodeship and the conservator of historical monuments at voivodeship level	Environmental grants
Subject of support	• Properties entered in the municipal register of historical monuments, except for those included in the register of historical monuments maintained by the competent voivode, • Other properties.	• Properties included in the register of historical monuments maintained by the competent voivode, • Properties entered in the municipal register of historical monuments.	• All properties, unless the municipality declares a specific type of development ineligible for support in a resolution setting out its rules for awarding grants.
Scope of application of the regulations	The territory covered by the SRZ as contained within the boundaries of the revitalisation area	The territory of the whole municipality	The territory of the whole municipality
Types of expenditure supported	The list in Article 77 of the Polish Act on the Protection of Historical Monuments	The list in Article 77 of the Polish Act on the Protection of Historical Monuments	An extensive list of works in the fields of environmental protection and water management, as determined by the municipality

Table 11. Comparison of the scope of the regulations governing the grant tools available at local level
Source: Polish Institute of Urban and Regional Development.

Combining grant instruments in SRZs is therefore justified by the need to support the comprehensive renovation work being done on buildings there, covering both aesthetic aspects and energy efficiency in the broad sense.

Offering a nuanced range of instruments to support the renovation of private properties is also a response to the recommendation made by the study of tenements in Wrocław on the types of heat source used in residential buildings. This identified a need to link thermal upgrade schemes to programmes geared towards decommissioning solid-fuel heat sources in the oldest urban buildings that also require a thermal upgrade (insulating walls and replacing windows). More information on funding thermal upgrading measures is presented in the subsection entitled "Sources of funding for thermal upgrading measures".

IV.5 Are environmental grants available for all types of property in a municipality?

Polish environmental protection law stipulates that ring-fenced environmental protection and water management subsidies ("environmental grants") are designed to cover some or all of the costs of investments undertaken by: 1) entities not deemed part of the public finances sector (private individuals, housing associations, legal entities, entrepreneurs); 2) entities from the public finances sector that are municipality- or district-level legal entities.

It should therefore be acknowledged that any work carried out on properties owned by these entities will be eligible for environmental protection subsidies in accordance with the local regulations.

In some cases, however, municipalities will issue resolutions specifying (shortening) the list of property types eligible for an environmental grant. It is therefore up to the municipality to decide whether all types of development located on its territory and within the boundaries of its SRZ will be able to access environmental grants

Some towns and cities award grants to the owners and perpetual users of all types of property, regardless of the purpose they serve (Słupsk, Żyrardów).

Others focus exclusively on residential buildings or specify what type of residential building (multi- or single-family) is covered by its support programme. In Bytom, Kalisz and Polkowice, for instance, support is ring-fenced for residential buildings, although the particular type is not specified in detail. Grants in Łódź are only available for developments involving multi-family dwellings, whereas Włocławek's programme only covers single-family homes. In Płock, meanwhile, owners of properties serving either a residential or a commercial purpose are able to apply for subsidies.

IV.6 To what extent is renovation work eligible for funding from a grant for replacing heat sources?

Reimbursements under environmental grant programmes are usually given to entities that have invested in more environmentally friendly solutions for supplying heat by decommissioning their coal-fired boilers and, for example, connecting to a district heating network, replacing their boilers with gas- or oil-fired ones or using electricity. Some local authorities include investments based on renewable energy sources in their subsidy programme. These can include the installation of solar thermal collectors, solar panels or heat pumps (Polkowice, Słupsk). A detailed breakdown of what is eligible for a grant in individual towns and cities is given in the table below.

	Type of building	Grant available for	Amount of subsidy	
			%	PLN
Bytom	Residential	1) Replacing the windows, 2) Installing systems based on renewable energy, 3) Installing a central heating system on the premises if connecting to a district heating network.	60%	- max. 7,200 for a boiler, installation of central heating - max. 9,000 for renewable energy sources
Kalisz	Residential	1) Purchasing a boiler or radiators, 2) Installing or purchasing radiators if connecting to a district heating network, 3) Purchasing a heat pump.	x	- 6,000 for decommissioning a solid-fuel heat source - 3,000 for connecting to the sewage network
Łódź	Residential Multi-family	1) Connecting to the district heating network, 2) Connecting to the district gas network, 3) Installing an individual electric heating source.	80%	- max. 7,000 per premises (replacing heating) - max. 50,000 per building (connecting to the district heating network)
Płock	Residential and service buildings	1) Switching to a gas-fired boiler, 2) Switching to an oil-fired boiler, 3) Connecting to the district heating network, 4) Switching to electric heating, 5) Installing a heat pump.	80%	- 100 for decommissioning a boiler, - 200 per kilowatt of heating power installed
Polkowice	Residential	1) Switching to a modern energy source (oil-fired/electric boiler, renewable energy), 2) Connecting to the district heating network.	60%	- max. 10,000 for a single-family home, - max. 7,000 for premises in a multi-family home
Słupsk	Properties within the city limits	1) Connecting to the district heating network, 2) Switching to renewable energy (heat pump, solar thermal collectors, solar panels), 3) Switching to a gas-fired boiler, 4) Switching to an oil-fired boiler, 5) Switching to electricity.	50%	- max. 5,000 for connecting to the district heating network or using renewable energy - max. 3,000 per premises for switching to electricity

Włocławek	Single-family dwellings	1) Switching to a gas-fired boiler, 2) Switching to an oil-fired boiler, 3) Switching to electricity, 4) Connecting to the district heating network.	x	4,000
Żyrardów	Properties heated by a solid-fuel heat source	1) Switching to a gas-fired boiler, 2) Switching to an oil-fired boiler.	up to 100% of the costs of a new boiler.	5,000
Malczyce	Replacing heat sources in single- and multi-family dwellings and residential units inside multi-family dwellings, boiler rooms	1) Switching to gas-fired boilers, 2) Switching to boilers powered by light fuel oil, 3) Switching to electric boilers, 4) Switching to solid-fuel or biomass boilers that meet the criteria for a class 5 boiler as a bare minimum (in accordance with the standard PN-EN 303-5:2012) and are equipped with an automatic fuel feeder.	up to 50% of the eligible costs.	- up to max. 10,000 for a single-family home - up to max. 5,000 for a home in a multi-family block of flats - in the case of a boiler room supplying heat to a multi-family dwelling, the limit of the eligible costs for such a system will be determined based on the number of flats that it serves; specifically, it will be this number multiplied by PLN 4,000.

Table 12. Scope of the regulations governing the principles of targeted environmental grants in selected towns and cities
Source: Polish Institute of Urban and Regional Development.

The value of any subsidy is calculated as a percentage of the eligible costs incurred up to a maximum threshold set at a certain amount; this arrangement was applied by Bytom, Łódź, Płock, Polkowice, Słupsk and Żyrardów. In Kalisz and Włocławek, the level of subsidy is expressed as a specific amount.

Some towns and cities choose to stipulate additional criteria for obtaining a grant. For instance, the resolution governing the rules for awarding grants in Żyrardów contains a provision obliging the entities granted financial support to maintain the environmental impact of their investment for at least five years. Polkowice's regulations, by contrast, oblige the investor to repay the grant – with interest – if they install an additional source of heating that does not meet the criteria specified in the regulations within 36 months of receiving the grant.

IV.7 Can environmental grants and grants within a Special Revitalisation Zone be claimed at the same time in order to subsidise renovation work?

If a property is eligible both on the grounds of being located in an SRZ and because improvements in its energy performance are planned, there is nothing to prevent both subsidy sources from being put towards renovation work for the same overall investment. There is no risk of the same costs being funded twice as the list of works eligible for an SRZ subsidy is separate and omits the kinds of retrofitting geared towards improving energy efficiency that are available under the environmental grant programme.

In practice, however, the instigation by the investor of the process for obtaining subsidies (whether this is as part of an SRZ or under an environmental grant) significantly reduces the time actually required to complete the construction work. This is due to the specific characteristics of the budgetary resources included in the financing of private investments, which are subject to the "annuality principle".

This means that a private investor seeking subsidies from public funds for retrofitting work is required to plan their renovation work in one-year cycles. In the case of a property requiring a wide range of retrofitting and installation work to be undertaken, this makes it very difficult to effect a comprehensive investment within a single building season given how long it takes to obtain grants.

In practice, therefore, investors will generally stagger their property renovation activities. This staggered approach both makes the work being carried out more efficient and enables optimum use to be made of all grant sources available at local level.

Staggering work in the correct way allows both programmes of grants – those available in an SRZ and those awarded for environmental purposes – to be combined seamlessly. The diagram below shows a potential sequence of activities. In the first stage, ongoing repairs and renovation should be carried out in order to make the building safe to use. If enough money is available for any additional work, these renovation measures should be complemented by thermal upgrading measures involving improving the thermal insulation of the building envelope (insulating and replacing windows) and improving the efficiency of technical systems (central heating, domestic hot water, ventilation), including regulating energy sources. Replacing existing energy sources with more efficient ones or installing renewable energy sources can then be considered in the next stage. This should be done after any thermal upgrades are complete to avoid a situation where the new energy source that has already been selected ends up being oversized in relation to the now-reduced demand following the thermal upgrades. Last but not least come measures to improve the aesthetics and functionality of the building's surroundings. The aim should be to arrive at a situation where an energy-efficient and safe-to-use building is located in a user-friendly environment.

From the perspective of the substantive criteria for accessing the grant programme in an SRZ, a public entity should check whether the property has previously undergone an energy retrofit in terms of its heating source. If it has, it will be entitled to proceed to the aesthetics stage available within the framework of the SRZ solutions.

One important element in the staggered planning of measures to make buildings more energy-efficient is to adopt a hierarchy for carrying out these measures: from those that are simplest and most necessary through to those that are the most complex and expensive as well as the additional measures relating to the building's surroundings.

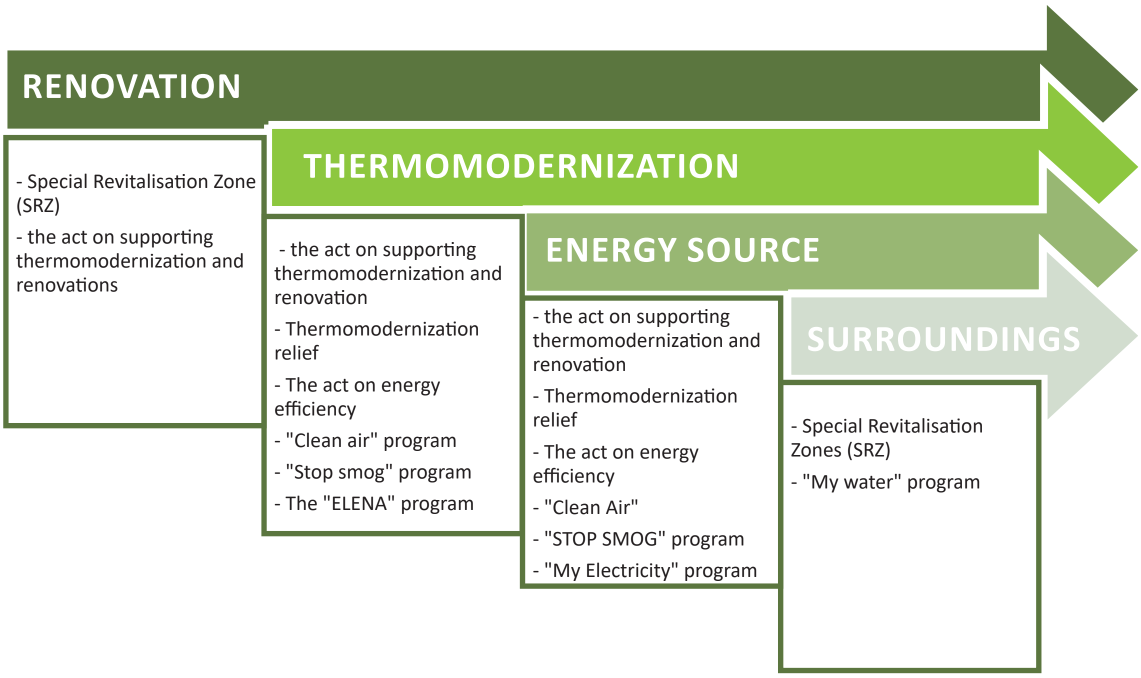


Fig. 47. Staggered planning of measures for making buildings more energy-efficient
Source: Polish Institute of Urban and Regional Development.

IV.8 How can a programme of renovation work in a Special Revitalisation Zone be planned so as to incorporate energy efficiency improvements?

Based on municipalities' current practice, it would appear possible to combine different grant programmes as part of processes to renovate private properties. Investors usually decide for themselves on the suitable source for their subsidies, taking account of the scope of the work to be carried out.

When designing the support tools to be available inside an SRZ, however, the public entity should plan out their use in advance, also taking energy efficiency aspects into account. Tools are planned out at the level of the provisions of an MRP. The process of planning a renovation programme within an SRZ should therefore include the following steps:

1. Incorporating environmental objectives into the action streams in the MRP.
2. Defining a programme of renovation grants in the SRZ as a revitalisation project included in the MRP, covering improvements to energy efficiency and a reduction in emissions close to the ground,
3. Declaring the establishment of an SRZ in the MRP records,
4. Adopting a resolution to establish an SRZ with a renovation programme,
5. Introducing a complementary instrument in the form of an environmental grant programme to support the implementation of thermal upgrade projects and efforts to replace existing heat sources with environmentally friendly ones.

One example of such an approach to renovation being adopted in an SRZ can be found in Płock. As part of its operational objective C.1.1., "Improving the technical condition of buildings, the standard of space and the quality of the environment", the Płock Revitalisation Programme includes a project entitled "Improving the standard of living and energy efficiency of properties in central Płock". At the level of its MRP, therefore, strictly renovation-related issues have been combined with elements of energy efficiency improvement, enabling several sources of financing to be combined at the implementation stage. The description of this revitalisation project in the Płock Revitalisation Programme includes the following passage:

The project involves carrying out construction work comprising renovation or redevelopment as well as conservation and restoration work at properties that are not entered in the register of historical monuments but that are located within the Special Revitalisation Zone, including work intended to improve energy efficiency and associated with the reduction of emissions close to the ground by decommissioning inefficient heat sources. The project will be implemented in partnership with the owners and perpetual users of the properties located within the Special Revitalisation Zone, who will be awarded grants from the city of Płock's budget in accordance with the principles set out in the resolution establishing the Special Revitalisation Zone as well as grants for replacing heat sources. Implementing the project will allow housing stock and public buildings that have depreciated in value to be renovated and the quality of life of the people living in the revitalised area to be significantly improved. The buildings' operating costs will be reduced and air quality increased."

IV.9 Can a renovation programme in a Special Revitalisation Zone be subsidised with third-party funds?

The revitalisation system in Poland only allows external financial support to be given to revitalisation projects included in the MRP. Public- and private-sector resources (e.g. external stakeholders, property owners) are expected to be involved.

The question of diversifying sources of funding for revitalisation work thus relates only to revitalisation projects included in the MRP, which are generally financed using various resources:

- The EU's cohesion policy under the European Social Fund, the European Regional Development Fund and the Cohesion Fund,
- National and regional policies and instruments (government programmes, environmental protection funds, credit- and asset-based instruments offered by funds and banks),
- Private sources of funding.

With regard to SRZs, meanwhile, there is no need to estimate in the MRP what resources are in line to be committed using the tools of the zone (i.e. the SRZ). This is mainly because there is no option to obtain external subsidies (e.g. under the EU's Cohesion Policy) to cover the costs of using tools within an SRZ. The Polish Public Finance Act clearly defines whether grants are an option and, if so, where they can come from (Article 126). Grants are defined as monetary resources subject to specific accounting rules that are drawn from the government budget, the budgets of local authorities and ring-fenced government funds allocated on the basis of this

Act, separate acts or international agreements for funding or subsidising the implementation of public works.

The main source of funding for the costs incurred by the SRZ tools is thus the municipality's own budget.

If there is no option to subsidise an external grant programme for renovating private properties, the only way to alleviate the burden on the municipal budget is to lower the cap on project funding in the respective resolution – from a maximum of 50% of necessary expenditure to, say, 30% or 20%.

More information on funding thermal upgrading measures is presented in the subsection entitled "Sources of funding for thermal upgrading measures".

IV.10 Does making buildings more efficient help to reduce energy poverty?

Revitalisation areas in Poland are usually set up in inner-city areas and city centres that are facing a raft of social problems associated with poverty and technical problems resulting from sub-standard, often historical buildings that tend to be amongst the oldest in the city. The main environmental problem in areas like this is seasonal air pollution caused by emissions from domestic heating appliances.

Energy poverty is a complex problem that generally results from low income, high energy costs or living in a building with a low level of energy efficiency.

Public entities' revitalisation measures are frequently geared towards improving housing conditions in the municipal building stock and include comprehensive retrofitting of municipal buildings in order to improve their thermal performance. The revitalisation measures in multi-family dwellings often see coal-fired boilers replaced by central heating, thus improving their technical condition as well as residents' safety and quality of life. Investing in a thermal upgrade can thus have an impact not only on the building's technical problems but also on environmental problems in terms of reducing emissions close to the ground as well as social problems in terms of providing residents with a better quality of life and health. It should therefore be acknowledged that a policy of revitalisation is a good solution to the problem of fuel poverty caused by inadequate housing conditions.

However, changing a home's heating source by switching away from coal makes it more expensive to heat. Achieving genuine results in terms of reducing energy poverty thus means not only securing financial support for replacing heating sources but also providing additional compensation for the higher cost of using energy carriers other than solid fuel. A cushioning scheme, enabling residents to obtain an allowance to cover higher heating costs after switching away from a solid-fuel heat source, should be offered to the lowest-income households. Rising energy costs can pose a significant problem to residents of a revitalisation area, who are very often facing many complex social problems at the same time. It therefore makes sense for an educational programme on saving energy to form part of broader social and professional awareness-raising activities for residents at risk of energy poverty.

IV.11 What kind of inspiration do Polish cities need in order to speed up the process of improving energy efficiency in their revitalisation areas?

The opinions of the cities, which were garnered during a series of workshops forming part of the project entitled "Energy-efficient development of Special Revitalisation Zones and urban areas (EDINA)", identified a number of guidelines required in order to speed up the process of improving energy efficiency in revitalisation areas. These relate in particular to issues associated with:

a. Retrofitting densely packed inner-city buildings (laid out in a grid pattern), including improving their heat management and adapting them to climate change (Łódź),
b. Retrofitting historical buildings, including using renewable energy sources and thermal upgrading,
c. Design solutions for greening within an existing mediaeval urban layout and improving the thermal protection of historical buildings (Włocławek),
d. Consolidating disparate ownership arrangements in order to implement joint energy efficiency measures,
e. Harnessing the energy potential of rivers for urban development,
f. Projects for educating residents in heat management,
g. Ways to encourage residents to switch heat source,
h. Rules for organising and running energy cooperatives.

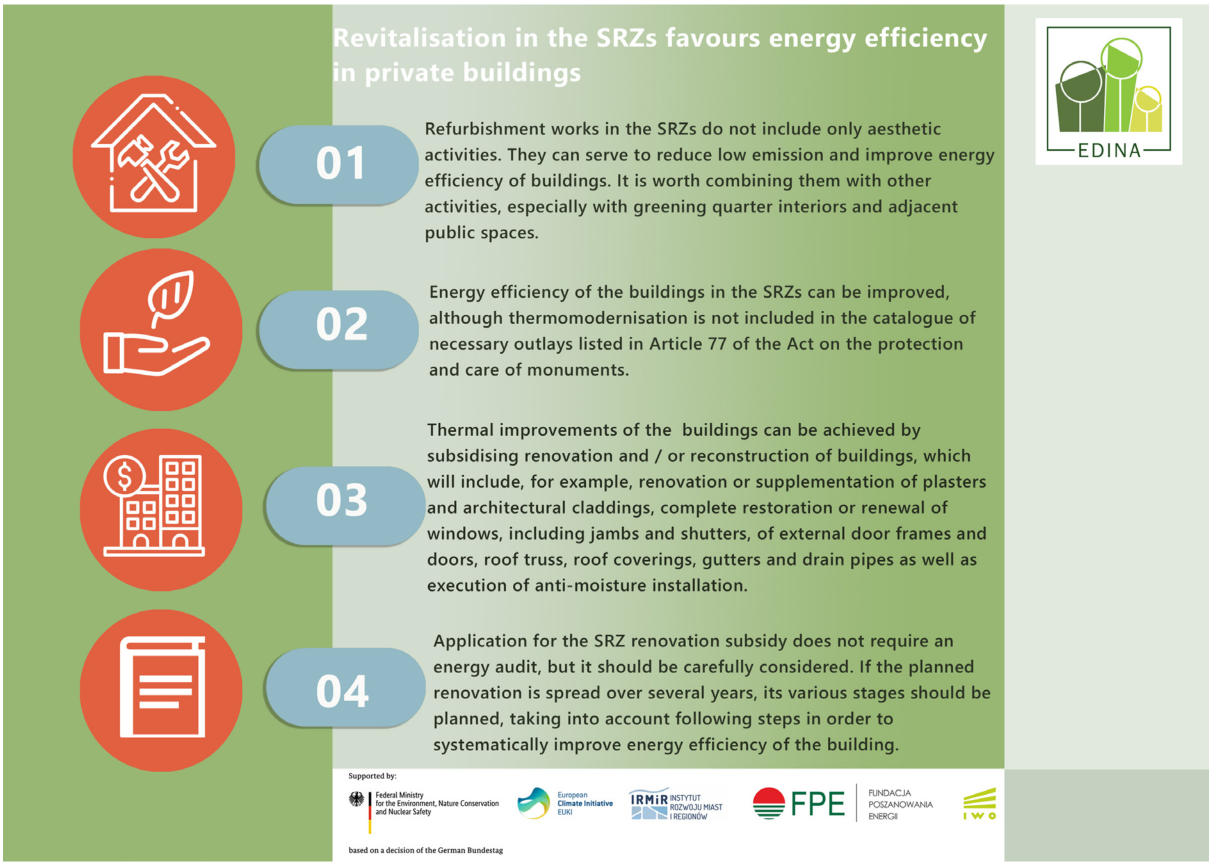


Fig. 48. Revitalisation inside an SRZ promotes energy efficiency improvements in private buildings.
Source: Polish Institute of Urban and Regional Development.

Potsdam's garden city – the Drewitz estate (Gartenstadt Drewitz) – rebuilding the centre and the garden city concept in Drewitz, a district dominated by large-panel-system buildings

A garden city – the Drewitz estate (Gartenstadt Drewitz)

Overarching aim:

- To establish Potsdam's first zero-emission district; in other words, to transform the district in a climate-friendly and socially responsible way by creating energy-efficient buildings, introducing attractive green spaces on the estate in line with the "garden city" model, and promoting eco-mobility and a high level of satisfaction and buy-in amongst residents.

Specific objectives

Energy-efficient retrofitting; ensuring social rents; transforming street spaces into parks; building new affordable housing. The entire redevelopment of the estate is to be done with broad-based citizen participation. The activities planned are designed to boost development in this district plagued by social and urban challenges.

Modelling the approach

An integrated approach to the revitalisation programme. An integrated approach to energy efficiency as part of a large-scale retrofit of buildings constructed between 1986 and 1991 and a landscaping plan (the “master plan”) including public spaces, communications, parking spaces, areas for recreation, green spaces, landscaping the model neighbourhoods, linking up the various neighbourhoods, lighting, the main traffic artery.

Framework conditions

The Drewitz housing estate is situated on the south-eastern outskirts of Potsdam. It dates from the late 1980s, making it one of the last new estates to be built in the former East Germany. Together with its neighbouring district of Am Stern to the north, it was included in the “Soziale Stadt” (“socially integrated city”) urban development programme. The estate is dominated by five-storey large-panel-system buildings and is currently home to some 5,300 people living in around 3,000 flats across an area of 37 hectares.

Developing the idea – towards the energy transition and climate protection

IThe idea of Gartenstadt Drewitz was born in 2009 as part of a German government competition entitled “Energy-efficient rehabilitation of large housing estates based on integrated urban development concepts”. The initial concept, created on behalf of the housing association ProPotsdam and given the working title of “Gartenstadt Drewitz – powerful energy, green energy”, was modified in 2011 following extensive consultations with local stakeholders, particularly residents and Potsdam’s first-ever elected estate council. The “Masterplan Gartenstadt Drewitz” master plan identifies key development milestones and objectives and sets out spatial planning and transport measures. A participatory approach was also devised to ensure that local stakeholders could have their say and encourage them to get involved in the project’s next planning and implementation stages. The solutions for land use and the original garden city concept that had been developed were expanded in 2013 to include energy transition and climate protection issues as part of an integrated energy and climate protection concept. This integrated energy and climate protection concept now forms the basis for the additional measures to be taken between 2025 and 2050 in order to make the district green and zero-emission.

Achievements

The amount of green space in the district has already increased threefold since 2009 thanks to the project and is continuing to grow year on year. The renovation of the buildings is reducing the need for energy, most of which may be replaced by “green heating” and “green electricity” in the future.

As a one-of-a-kind project in the federal state of Brandenburg, the Gartenstadt Drewitz project and the associated energy transformation of this large housing estate have attracted significant attention. Drewitz is a pilot project for the "energy-efficient transformation of urban districts" as well as a study accompanying the "Energy-efficient urban rehabilitation" programme run by the bank KfW. The Gartenstadt Drewitz project won the German Municipal Climate Protection Prize in 2014.

Drawing inspiration from eco-friendly investments on a large housing estate

Prior to the energy efficiency measures, energy had been supplied from a central heating network (97%). Energy savings were only achieved through thermal upgrades.

Energy saved through thermal upgrades to buildings

		2010		2013 (implementation of renovation plan starts)		2016 (implementation of renovation plan ends)	
Primary energy	MWh	24,100	(112%)	21,471	(100%)	15,705	(73%)
Final energy	MWh	31,621	(104%)	30,369	(100%)	29,220	(96%)
CO_2 emissions	t	9,586	(104%)	9,196	(100%)	7,482	(81%)

Table 13. Energy saved through thermal upgrades to buildings for the years 2010 (baseline), 2013 and 2016 (start and end of implementation of renovation plan)
Source: Abschlussbericht Sanierungsmanagement Potsdam-Drewitz, http://www.stattbau.de/fileadmin/downloads/170815_abschlussbericht-sanman_potsdam_web.pdf.

Solutions employed for supplying energy to buildings

- Central heating network combined with renewable energy sources (wind, solar) and combined heat and power (CHP) based on natural gas (97%),
- Electricity,
- Natural gas,
- Fuel oil.

Solar and other technological innovations deployed in retrofitted buildings

- Konrad-Wolf-Allee 14-24: solar thermal collectors,
- House at Robert-Baberske-Str. 5: solar power,
- Fritz-Lang-Str. 10-12: solar power within the framework of the citizens' energy association (Potsdamer Bürger-Solar GbR),
- Single-family homes on Priesterweg and Sternstraße: individual solar panels,
- Schiller-Gymnasium Potsdam: "Hamster" fuel cell project,
- ProPotsdam: purchasing green energy.

Aims of the concept:

- To integrate thermal energy storage systems with district heating,
- To increase the proportion of district heating made up by biogas and CHP,
- To continue enhancing district heating by integrating CHP units,
- To increase the use of renewable energy by using solar panels and solar thermal collectors to generate electricity.

The comprehensive investments reduced coal consumption by 3,575 t/year and cut CO_2 emissions

		2010		2013 (implementation of renovation plan starts)		2016 (implementation of renovation plan ends)	
CO_2 emissions	t	9,586	(104%)	9,196	(100%)	7,482	(81%)

Table 14. Energy saved through thermal upgrades to buildings for the years 2010 (baseline), 2013 and 2016 (start and end of implementation of renovation plan)
Source: Abschlussbericht Sanierungsmanagement Potsdam-Drewitz, http://www.stattbau.de/fileadmin/downloads/170815_abschlussbericht-sanman_potsdam_web.pdf

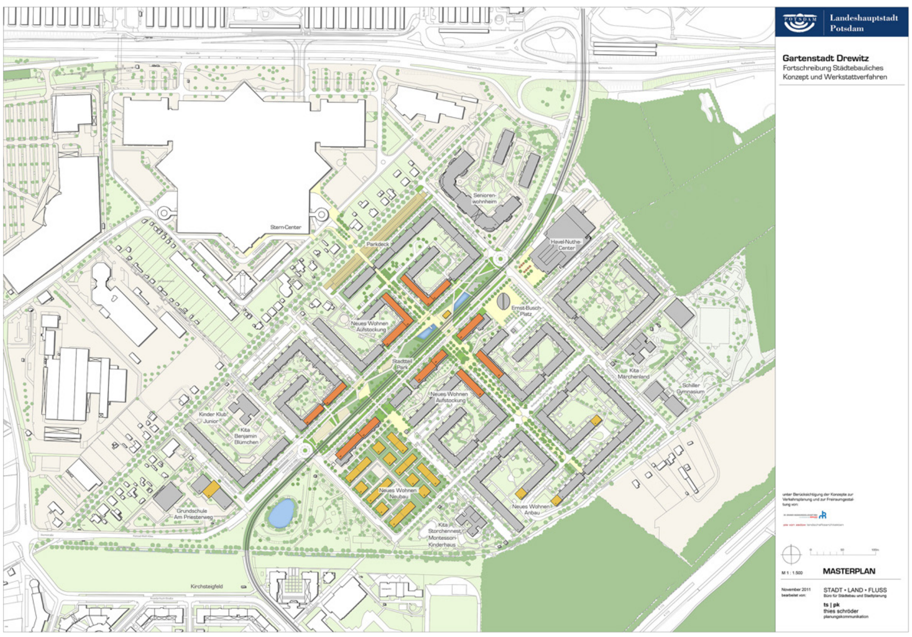


Fig. 49. Master plan for Potsdam-Drewitz
Source: https://www.potsdam.de/gartenstadt-drewitz.
http://www.stattbau.de/fileadmin/downloads/170815_abschlussbericht-sanman_potsdam_web.pdf

Photo 26. The main thoroughfare of Konrad-Wolf-Allee
Source: Polish Institute of Urban and Regional Development.

Photo 27. Greening the pedestrian zone along Konrad-Wolf-Allee
Source: Polish Institute of Urban and Regional Development.

Photo 28. Retrofitted façade of a block of flats
Source: Polish Institute of Urban and Regional Development.

Photo 29. Green inner courtyard in the neighbourhood being redeveloped
Source: Polish Institute of Urban and Regional Development.

The view from Poland's towns and cities

Płock: „This project provides an apt demonstration of how to make fairly unattractive housing estates full of blocks of flats resident-friendly. Highly appealing public spaces, giving priority to pedestrians and public transport. At the same time, the standard of the semi-private spaces (courtyards) have been improved using environmentally friendly solutions (rainwater management)."

„The example set by the Drewitz district can be an inspiration for the work being done on the estates in our city that are dominated by large-panel-system buildings, including those inside the revitalisation area. Applying the garden city idea to such an estate could be one answer to the 'concrete jungle' that you see spreading everywhere and the fact that space is always being taken up by cars. Creating shared spaces, which several housing associations are doing, as well as the solutions that Drewitz is employing to reduce car traffic (charging for parking, building cycle shelters) would seem to be worth exploring in more detail. Besides the thermal upgrading measures undertaken in Drewitz and the installation of solar panels on the buildings, another potential source of inspiration could be getting the educational institution (located on the estate) involved in the life of the estate, as it provides a space for leisure, entertainment and socialising."

Zawiercie: „As well as some interesting solutions for making the buildings more energy-efficient, another good example is how the town's main street has been redeveloped into an attractive green space where residents can integrate and spend their free time."

"A comprehensive, multi-faceted approach to creating an attractive, resident-friendly housing estate while minimising its environmental impact. Besides the thermal upgrades to the buildings on the estate, a lot of thought has also gone into the location of the facilities serving residents' basic needs and the most favourable traffic and transport system."

Łódź: „This case study is valuable to us in two ways: firstly, as an example of how to revitalise a large area successfully (making comprehensive changes to the entire estate) and, secondly, as an inspiration for introducing blue-green solutions right at the heart of the estate. This significantly boosts locals' well-being, increases social participation and helps to combat the effects of climate change."

Włocławek: „The large-panel-system buildings that dominate the estate are characteristic of former Eastern Bloc towns and cities. So the pioneering work done there – such as using the land on the estate more attractively and giving it more green space in line with the 'garden city' model, separating out model courtyards, introducing climate-friendly mobility and technical infrastructure, sorting out parking spaces and focusing on developing social infrastructure – is relatively easy to carry out and can give some direction to the changes being implemented on this type of estate."

Polish Ministry of Climate and Environment – Patrycja Ciechańska: „I think that the revitalisation of this estate was the most comprehensive project of its kind that I encountered during this visit. As well as undertaking thermal upgrades to buildings, creating green-blue infrastructure, turning a section of road into green spaces for recreation and providing public transport services, it also addressed social issues such as working to strengthen the local community, focusing on education and combating unemployment."

Poznań University of Economics and Business – Sławomir Palicki: „I found this to be one of the largest-scale projects, not only in terms of the size of the area and the investments being made in the work but also in terms of the 'breadth' and 'depth' of the issues tackled. There was coordination (links) between the social, communication and spatial aspects as well as the technical and organisational aspects (this is what I mean by 'breadth'). At the same time, the 'depth' was reflected in the approach being taken to the transformations at the assessment and design stage of the processes – from the socio-demographic assessment through to the economic (cost) dynamics and the technical and technological solutions employed to meet the low-emission requirements. I was impressed by how problems and needs were assessed, supported by a really extensive analysis of the options that took all the possible permutations into account. The results of the measures taken were similarly impressive. I'd probably say that the 'Garden City' Potsdam-Drewitz project made the most positive impression on me out of everything I saw during the study visit."

List of tables, figures and photographs

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APPENDIX 1

Example of a retrofitting analysis on a multi-family dwelling

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Example of a retrofitting analysis on a multi-family dwelling

The multi-family dwelling being analysed is located in Poznań and was built in the 1930s. It was constructed using traditional technology and has three floors above ground and a cellar. The usable space in the residential part is 540 m2 out of a total of 580 m2. The building comprises 12 residential units used by 48 tenants. Figures 1, 2 and 3 show various views of the building as well as a typical floor plan.

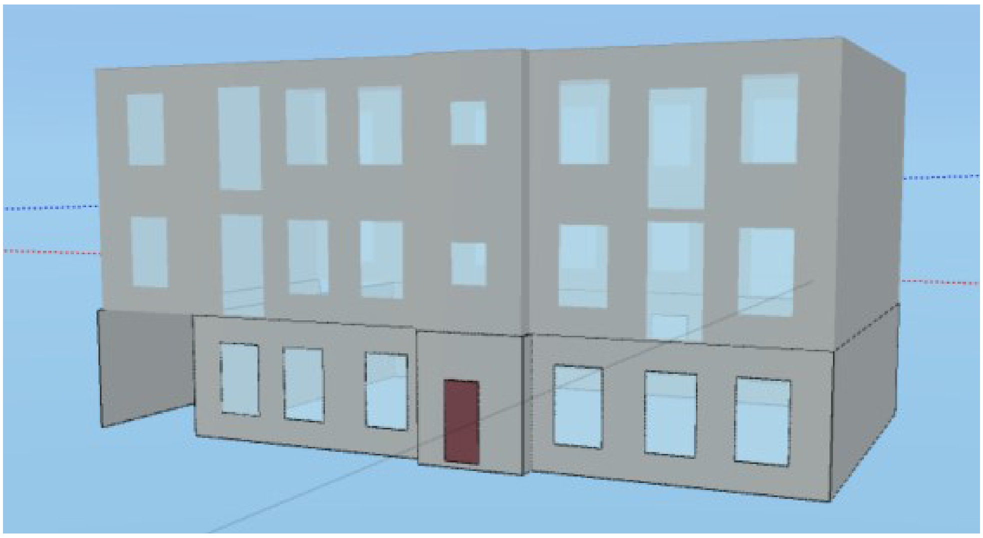

Figure 1. View from the north side – model created using Audytor OZC 7.0Pro
Source: Polish Energy Conservation Foundation

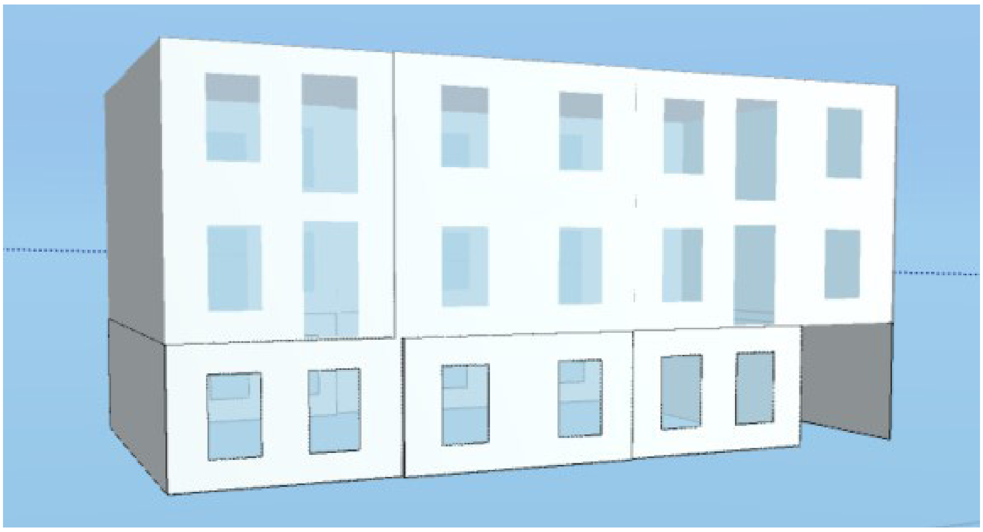

Figure 2. View from the south side – model created using Audytor OZC 7.0Pro
Source: Polish Energy Conservation Foundation

Figure 3. Typical floor plan – model created using Audytor OZC 7.0Pro
Source: Polish Energy Conservation Foundation

The building adjoins other similarly shaped townhouses on the west and east sides. The windows are on the south and north sides, and the entrance to the building is on the north side. The external walls are made of ceramic brick, and the ceiling above the cellar is ceramic as well, while the roof has a wooden structure. There are wood-frame windows inside the residential units, the stairwell and the cellar. The external doors leading to the stairwell are made of wood.

Coal-fired boilers are used to heat the building. A coal price of PLN 0.15/kWh (for final energy) has been used for calculation purposes. The hot water required by residents is prepared individually in electric heaters. An electricity price of PLN 0.65/kWh (for final energy) has been used for calculation purposes. The building uses a natural system of gravity ventilation, with an air flow of 1,250 m3/h.

The annual demand for heating over a standard season and the final and primary energy demand figures for heating were calculated based on the regulations governing the methodology for determining a building's energy performance.[1] Peak heating power for the building was calculated in accordance with the standard PN-EN 12831 "Heating systems in buildings. Method for calculation of the design heat load".[2] The calculations also factored in multi-year climate data on average monthly outdoor temperatures and average monthly solar radiation intensity values based on the information published on the website of the Polish Public Information Bulletin (Biuletyn Informacji Publicznej – BIP). All calculations were performed using the computer software
Audytor OZC 7.0Pro.

1. Assessing the current technical condition of the building

The heat transfer coefficients of the building envelope are higher than those currently stipulated in the regulations on the technical requirements to be met by buildings and their location [3].

The analysis is proposing the following retrofit measures for the building envelope in order to improve energy efficiency: insulating the external walls above ground and at ground level; insulating the ceiling above the passageway for cars leading into the courtyard; insulating and repairing the roof; and replacing windows and external doors leading into the stairwell. A summary of heat transfer coefficients is shown in Table 1.

Since the building is not a historical building, there are no restrictions preventing its external walls from being insulated. Façades of historical buildings must be renovated in compliance with the guidelines issued by the monument conservation officer.

HEAT TRANSFER COEFFICIENTS OF THE BUILDING ENVELOPE

Part of envelope	U, W/(m²K)	
	Current	Required*
External walls	1.17	0.20
Ceiling above cellar	1.15	0.25
Ceiling above passageway for cars leading into courtyard	1.25	0.15
Roof	1.27	0.15
Wood-frame window, on premises	2.60	0.90
External door, wooden	5.10	1.30

Table 1. Heat transfer coefficients of the building envelope
*) – values required in accordance with the regulations [3]

The individual residential heating systems are outdated and in a very poor technical condition as well as posing a risk to occupant safety. The analysis envisages removing the individual residential heat sources and building a central heating system supplied by a local heat source. The three most common heat sources will be considered – an on-site gas boiler, a district heating substation and an air source heat pump.

Table 2 shows the efficiency levels of the existing heating systems. [1].

EFFICIENCY OF THE HEATING SYSTEM

No.	Description	Energy coefficient values	Description of solutions adopted
1	Heat generation	0.80	Coal-fired boilers
2	Heat transfer	1.00	Local heating
3	Regulation and utilisation	0.70	Boiler heating
4	Heat accumulation	1.00	Lack of buffer tank
5	Overall system efficiency	0.56	-
6	Accounting for breaks in heating over a week	1.00	n/a
7	Accounting for breaks in heating over a day	1.00	n/a

Table 2. Efficiency of the heating system

Heat generation in the boilers is inefficient, and the equipment itself is outdated. In order to make the heating work better and improve thermal comfort, the individual heat sources are to be removed and replaced by a central heating system. Changing the heating system will make the premises safer to use, improve thermal comfort for residents and reduce pollutant emissions at local level.

The hot water required by residents is prepared individually in electric heaters. Table 3 shows the efficiency levels of the existing domestic water heating systems.

EFFICIENCY OF THE DOMESTIC WATER HEATING SYSTEM

No.	Description	Energy coefficient values	Description of solutions adopted
1	Heat generation	0.96	Electric storage heater
2	Heat transfer	0.80	Water heating for a group of hot water points at one site
3	Heat accumulation	0.80	Accumulation tank, manufactured 2001–2005
4	Utilisation	1.00	Electric storage heater
5	Overall system efficiency	0.61	Water heating for a group of hot water points at one site

Table 3. Efficiency of the domestic water heating system

The analysis envisages retrofitting the water heating system, which will involve removing existing systems and building a central circulating hot water system equipped with individual water meters and supplied from a newly designed dual-function heat source.

The residential units are ventilated by gravitational means via exhaust grilles. Fresh air comes in through gaps in doors and windows. Three options for retrofitting the ventilation system have been analysed. The first involves leaving the existing natural ventilation as is, installing window ventilators and replacing the windows inside the units. The second would be to replace the natural ventilation with a mechanical ventilation system, replace the windows in the premises and install humidity-controlled window ventilators.The third, which is the most difficult option to implement, would see the existing natural ventilation system replaced by a mechanical supply and exhaust ventilation system fitted with heat recovery.

Table 4 shows the results of calculations of the heating demand and the heat load of the building in its current condition.

DEMAND FOR USEFUL ENERGY FOR HEATING AND POWER REQUIRED FOR HEATING – BUILDING IN ITS CURRENT CONDITION

No.	Description	Unit	Value
1	Demand for useful energy for heating	GJ/year	423.15
2	Demand for useful energy for heating	kWh/year	117,542
3	Power required for heating	MW	0.062

Table 4. Demand for useful energy for heating and power required for heating – building in its current condition

The high level of energy and power required for heating is due to the poor thermal insulation inside the building envelope and the type of ventilation system employed.

2. Retrofitting the building envelope

The first step in retrofitting a building should include improving the thermal insulation of the building envelope. The tables below present an assessment of the cost-effectiveness of the measures analysed based on assumed gross average market prices for energy and technology. The calculations followed the process set out in the regulations on the detailed scope and forms of the energy audit.[5][6] Calculations are carried out based on the situation before retrofitting (values with index 0) and after retrofitting (values with index 1) in order to determine the annual energy savings. The thermal resistance of each part of the building envelope must first be established. The heat transfer coefficient U of the part is determined on this basis, followed by the amount of heat required in a year to cover the loss through infiltration Q. The next step is to calculate how much power would be required to cover the loss through infiltration q. The annual cost savings ΔOru are then calculated based on the figures for Q and q and the price of the energy source (standing and variable charges). The simple payback time SPBT depends on the cost of implementing the improvements Nu and the total annual cost savings ΔOru.

2.1. Insulating external walls

The analysis envisages insulating the external walls above ground with polystyrene 13 cm thick and with a heat transfer coefficient of 0.031 W/mK. This will enable this part of the building envelope to achieve the required heat transfer coefficient after its retrofit.

Area for calculating heat loss			**380 m²**	
Area for calculating cost **Add. insulation:λ=0,031 W/(mK)**			**400 m²**	
No.	**Explanation**		**Current situation**	**Situation after retrofit**
1	Thickness of additional layer of thermal insulation; g	m		0.13
2	Increase in thermal resistance ΔR	(m²*K)/W		4.19
3	Thermal resistance R	(m²*K)/W	0.855	5.05
4	U_0, U_1	W/m²*K	1.170	0.198
5	Q_{0U}, Q_{1U}	GJ/year	149.22	25.26
6	q_{0U}, q_{1U}	MW	0.017	0.003
7	Annual cost savings ΔOru	PLN/year		5,206
8	Unit price of improvements	PLN/m²		260.00
9	Cost of implementing improvements Nu	PLN		104,000
10	SPBT=NU/ΔOru	years		20.00

The total cost of insulating the external walls amounts to PLN 104,000, with a simple payback time of 20 years.

2.2 Insulating the ceiling above the passageway for cars leading into the courtyard

The analysis envisages insulating the ceiling above the passageway for cars leading into the courtyard with polystyrene 23 cm thick and with a heat transfer coefficient of 0.039 W/mK. This will enable this part of the building envelope to achieve the required heat transfer coefficient after its retrofit.

Area for calculating heat loss			**32,0 m²**	
Area for calculating cost				
Add. insulation: λ**=0,039 W/(mK)**			**32,0 m²**	
No.	**Explanation**		**Current situation**	**Situation after retrofit**
1	Thickness of additional layer of thermal insulation; g	m		0.23
2	Increase in thermal resistance ΔR	(m²*K)/W		5.90
3	Thermal resistance R	(m²*K)/W	0.803	6.70
4	U_0, U_1	W/m²*K	1.246	0.149
5	Q_{0U}, Q_{1U}	GJ/year	13.38	1.60
6	q_{0U}, q_{1U}	MW	0.002	0.0002
7	Annual cost savings ΔOru	PLN/year		495
8	Unit price of improvements	PLN/m²		210.0
9	Cost of implementing improvements Nu	PLN		6,720
10	SPBT=NU/ΔOru	years		13.60

The total cost of insulating the ceiling above the passageway for cars leading into the courtyard amounts to PLN 6,720, with a simple payback time of 13.6 years.

2.3 Insulating the roof

The analysis envisaged insulating the roof by spraying it with a layer of PUR foam insulation with a thickness of 23 cm and a heat transfer coefficient of 0.039 W/mK. This will enable this part of the building envelope to achieve the required heat transfer coefficient after its retrofit.

Area for calculating heat loss			**220,0 m²**	
Area for calculating cost			**230,0 m²**	
Add. insulation:λ=0,039 W/(mK)				
No.	**Explanation**		**Current situation**	**Situation after retrofit**
1	Thickness of additional layer of thermal insulation; g	m		0.23
2	Increase in thermal resistance ΔR	$(m^2*K)/W$		5.90
3	Thermal resistance R	$(m^2*K)/W$	0.786	6.68
4	U_0, U_1	W/m^2*K	1.272	0.150
5	Q_{0U}, Q_{1U}	GJ/year	93.92	11.05
6	q_{0U}, q_{1U}	MW	0.011	0.0013
7	Annual cost savings ΔOru	PLN/year		3,481
8	Unit price of improvements	PLN/m^2		390.0
9	Cost of implementing improvements Nu	PLN		89,700
10	SPBT=NU/ΔOru	years		25.80

The total cost of insulating and renovating the roof amounts to PLN 89,700, with a simple payback time of 25.8 years.

2.4 Insulating the ceiling above the cellar

The analysis envisages insulating the ceiling above the cellar with polystyrene 10 cm thick and with a heat transfer coefficient of 0.031 W/mK. This will enable this part of the building envelope to achieve the required heat transfer coefficient after its retrofit.

Area for calculating heat loss			**200,0 m²**	
Area for calculating cost			**210,0 m²**	
Add. insulation:λ=0,031 W/(mK)				
No.	**Explanation**		**Current situation**	**Situation after retrofit**
1	Thickness of additional layer of thermal insulation; g	m		0.10
2	Increase in thermal resistance ΔR	$(m^2*K)/W$		3.23
3	Thermal resistance R	$(m^2*K)/W$	0.870	4.10
4	U_0, U_1	W/m^2*K	1.149	0.244
5	Q_{0U}, Q_{1U}	GJ/year	37.02	4.10
6	q_{0U}, q_{1U}	MW	0.004	0.0005
7	Annual cost savings ΔOru	PLN/year		638
8	Unit price of improvements	PLN/m^2		150.0
9	Cost of implementing improvements Nu	PLN		31,500
10	SPBT=NU/ΔOru	years		49.40

The total cost of insulating the ceiling above the cellar amounts to PLN 31,500, with a simple payback time of 49.4 years.

2.5 Replacing the windows

The analysis envisaged replacing the building's windows with new ones with a heat transfer coefficient U of 0.9 W/(m²·K) and fitting ventilators inside them. If the individual heat sources (coal-fired boilers) are to be left in situ, the air for combustion should be supplied through an additional duct.

Area for calculating heat loss and cost		**110,0 m²**		
No.	**Explanation**	**Unit**	**Current situation**	**Situation after retrofit**
1	Heat transfer coefficient of windows U	W/(m²*K)	2.6	0.90
2	Q_0, Q_1	GJ/year	238.86	176.10
3	q_0, q_1	MW	0.0285	0.0210
4	ΔOrok + ΔOrw	PLN/year		2,636.0
5	Unit replacement cost	PLN/m²		1,600.0
6	Replacement cost N_{WIN}	PLN		176,000
7	SPBT	years		66.80

The total cost of replacing the windows and fitting ventilators amounts to PLN 176,000, with a simple payback time of 66.8 years.

2.6 Replacing the external doors

The analysis envisaged replacing the external doors with new ones with a heat transfer coefficient U of 1.3 W/m²K.

Area for calculating heat loss and cost		**3,0 m²**		
No.	**Explanation**	**Unit**	**Current situation**	**Situation after retrofit**
1	Heat transfer coefficient of doors U	W/(m²*K)	5.1	1.30
2	Q_0, Q_1	GJ/year	2.40	0.76
3	q_0, q_1	MW	0.00071	0.00025
4	ΔOrok + ΔOrw	PLN/year		57
5	Unit replacement cost	PLN/m²		2,000.0
6	Replacement cost N_{DO}	PLN		6,000
7	SPBT	years		104.7

The total cost of replacing the doors amounts to PLN 6,000, with a simple payback time of 104.7 years.

Summary of retrofit measures for the building envelope

Table 5 lists the individual retrofit measures for the building envelope that will make the building more energy-efficient. The energy demand and simple payback times for the building were determined based on calculations performed in accordance with the regulations governing the methodology for determining a building's energy performance.[1]

SUMMARY OF THE EFFECTS OF RETROFITTING THE BUILDING ENVELOPE				
No.	Description	ZUseful energy demand of the building after a certain retrofit measure kWh/year	Total costs PLN	SPBT years
0	Building in its current condition	117,542	0	-
1	Building after insulating the external walls	83,109	104,000	20.1
2	Building after insulating the ceiling above the passageway for cars leading into the courtyard	114,270	6,720	13.7
3	Building after insulating the roof	94,521	89,700	26.0
4	Building after insulating the ceiling above the cellar	113,324	31,500	49.8
5	Building after replacing the windows	99,672	176,000	65.7
6	Building after replacing the external doors	117,163	6,000	105.5

Table 5. Summary of the effects of retrofitting the building envelope

Insulating the external walls and insulating the ceiling above the passageway for cars leading into the courtyard are the most effective individual measures (i.e. have the shortest simple payback times). Insulating the roof would cut the energy demand for heating the building more than insulating the ceiling over the unheated cellar would. The greatest energy savings could be achieved by insulating the external walls, although this step would incur the second-highest investment costs. When planning a comprehensive retrofit, all the measures analysed must be taken into account. If an investor does not have the funds for a comprehensive retrofit, the next stages of the project must be planned accordingly.

3. Retrofitting the ventilation system

After insulating the building envelope, the next step should be to upgrade the ventilation system. Below is an assessment of the cost-effectiveness of the measures analysed based on assumed gross average market prices for energy and technology. The calculations followed the process set out in the regulations on the detailed scope and forms of the energy audit.[5][6]

They were based on the building's full energy balance in view of the desire to account for the variability of air flows in the case of ventilation system upgrades.

3.1. Humidity-controlled ventilation

The table below lists the results of analysing the increases in the building's energy efficiency after upgrading the ventilation system and replacing the windows. The energy demand and simple payback times for the building were determined based on calculations performed in accordance with the regulations governing the methodology for determining a building's energy performance.[1]

No.	Explanation	Unit	Current situation	Situation after retrofit
1	Transfer coefficient of windows U	W/(m2*K)	2.6	0.9
2	Q_0, Q_1	GJ/year	423.15	317.40
3	q_0, q_1	MW	0.062	0.064
4	ΔOrok + ΔOrw	PLN/year		4,441.5
5	Unit replacement cost	PLN/m²		1,800.0
6	Replacement cost N_{WIN}	PLN		198,000
7	SPBT	years		44.60

The total cost of replacing the ventilation system amounts to PLN 198,000, with a simple payback time of 44.6 years.

3.2 Mechanical supply and exhaust ventilation system with heat recovery

Below are the results of analysing the increases in the building's energy efficiency after upgrading the ventilation system and replacing the windows. The energy demand and simple payback times for the building were determined based on calculations performed in accordance with the regulations governing the methodology for determining a building's energy performance.[1] The analysis considered a change from the natural ventilation system to a mechanical supply and exhaust ventilation system with heat recovery. This option was assessed together with window upgrades for the building being analysed. If the individual heat sources (coal-fired boilers) are to be left in situ, the air for combustion should be supplied through an additional duct.

No.	Explanation	Unit	Current situation	Situation after retrofit
1	Transfer coefficient of windows U	W/(m2*K)	2.6	0.90
2	Q_0, Q_1	GJ/year	423.15	348.95
3	q_0, q_1	MW	0.062	0.0540
4	ΔOrok + ΔOrw	PLN/year		3116.40
5	Cost of installing ventilation	PLN/m^2		168,000
6	Cost of replacing windows	PLN		154,000
7	SPBT	years		103.30

The total cost of replacing the ventilation system amounts to PLN 322,000, with a simple payback time of 103.3 years.

3.3. Summary of measures for retrofitting the ventilation system

Table 6 lists the individual retrofit measures for the ventilation system. The energy demand and simple payback times for the building were determined based on calculations performed in accordance with the regulations governing the methodology for determining a building's energy performance.[1]

SUMMARY OF THE EFFECTS OF RETROFITTING THE VENTILATION SYSTEM				
No.	Description	Energy demand of the building after a certain retrofit kWh/year	Total costs PLN	SPBT years
0	Building in its current condition	117,542	0	-
1	Building after replacing the windows	99,956	176,000	66.80
2	Building fitted with a humidity-controlled ventilation system and after replacing the windows	88,167	198,000	44.60
3	Building fitted with a supply and exhaust ventilation system with heat recovery	96,931	322,000	103.30

Table 6. Summary of the effects of retrofitting the ventilation system

A building fitted with a mechanical ventilation system with humidity-controlled ventilators offers the shortest simple payback time and requires the least useful energy for heating.

4. Retrofitting the domestic water heating system

Retrofitting the domestic water heating system would involve removing the individual electric heaters, laying hot water and circulation pipes, insulating the system, fitting individual water meters, and installing control valves and a hot water storage tank complete with accessories. Three central sources of power for the system were analysed: a gas boiler, a district heating substation and an air source heat pump. The results summarised below do not include the cost of the heat source itself or the fixed costs associated with supplying the energy, both of which have been included in the analysis of retrofitting the heating system. The analysis assumes final energy prices of 0.25 PLN/kWh for gas, 0.22 PLN/kWh for district heating and 0.65 PLN/kWh for electricity.

Description	Unit	Situation before retrofit	Situation after retrofit		
		Individual systems	Gas boiler	District heating substation	Heat pump
Annual demand for useful energy	kWh/year	21,679	17,343	17,343	17,343
Efficiency of the domestic water heating system	-	0.614	0.578	0.612	1.768
Annual demand for final energy	kWh/year	35,285	30,005	28,338	9,809
Variable charge	PLN/kWh	0.65	0.25	0.22	0.65
Annual variable charge	PLN/year	22,935	7,501	6,234	6,376
Total energy/heating costs	PLN/year	22,935	7,501	6,234	6,376
Cost of retrofitting systems	PLN	-	35,000	35,000	35,000
Simple payback time	year	-	2.27	2.10	2.11

Changing the individual sources of domestic hot water would significantly reduce annual energy demand and energy costs. This reduction in energy demand would be due to the use of individual water meters, which would cut overall hot water consumption. The simple payback time irrespective of the heat source would be similar for all options and less than three years in each case.

5. Retrofitting the central heating system

Retrofitting the central heating system would involve the following: installing horizontal pipes and risers; insulating the system; installing residential manifolds; installing radiators equipped with thermostatic valves; installing control valves and other fittings; hydraulic regulation of the central heating system; and installing a central heat source complete with fittings and automation. The results of the analysis for changing the central heating system are presented below and take all the retrofit measures described above into account.

They also include the results for the existing building, in which the requisite standard conditions for ensuring the required temperature in the residential units were not met before the retrofit. When the temperature indoors is reduced below standard levels, this is usually because tenants are trying to economise or are having problems regulating their individual heat sources, such as coal-fired boilers. A similar situation can be observed with the use of heat sources such as individual electric heaters, where a lowering of the temperature is very often associated with a desire to spend less on energy. Lowering the indoor temperature to an extreme can damage tenants' health. This option was added to illustrate the significant difference between the energy demand for heating in a building where the requirements of the current regulations are met and in one where the temperature level is not maintained. Energy calculations must always be based on a building that is being used properly, i.e. in accordance with the current standards and regulations. Even if it is established that the requisite temperature level in a building is not being maintained, therefore, any calculations and any statements on the effects of retrofitting must be based on a compliant building.

The analysis assumes final energy prices of 0.15 PLN/kWh for coal, 0.25 PLN/kWh for gas, 0.22 PLN/kWh for district heating and 0.65 PLN/kWh for electricity. The analysis also includes the standing charges for heat sources (gas boiler, district heating substation and heat pump). The corresponding results are given below.

Description	Unit	Existing building	Existing building in which the required temperature is not being maintained	Building with natural ventilation			Building with humidity-controlled ventilation			Building with mechanical supply and exhaust ventilation with heat recovery		
				Gas boiler	District heating substation	Heat pump	Gas boiler	District heating substation	Heat pump	Gas boiler	District heating substation	Heat pump
Demand for useful energy for heating	kWh/year	117,542	95,094	28,744	28,744	28,744	19,408	19,408	19,408	22,986	22,986	22,986
Power consumption	MW	0.062	0.059	0.02	0.02	0.02	0.03	0.03	0.03	0.02	0.02	0.02
Efficiency of central heating system	-	0.56	0.56	0.78	0.77	2.20	0.78	0.77	2.20	0.78	0.77	2.20
Demand for final energy for heating	kWh/year	209,896	169,812	36,984	37,390	13,087	24,972	25,246	8,836	29,575	29,900	10,465
Unit price of fuel/ heat	PLN/kWh	0.15	0.15	0.25	0.22	0.65	0.25	0.22	0.65	0.25	0.22	0.65
Standing charge	PLN/month	0		201.79	312.17	20.68	201.79	416.23	20.68	201.79	299.16	20.68
Subscription	PLN/month	0		19.50	0.00	4.72	19.50	0.00	4.72	19.50	0.00	4.72
Annual heating cost	PLN/year	31,484	25,472	9,245.96	8,225.86	8,506.29	6,242.90	5,554.12	5,743.47	7,393.73	6,577.99	6,802.23
Annual variable charge	PLN/year	0	0	2,421.53	3,746.03	248.12	2,421.53	4,994.71	248.12	2,421.53	3,589.95	248.12
Annual standing charge	PLN/year	0	0	233.95	0.00	56.68	233.95	0.00	56.68	233.95	0.00	56.68
Total energy costs	PLN/year	31,484	25,472	11,901.44	11,971.89	8,811.08	8,898.37	10,548.84	6,048.26	10,049.20	10,167.93	7,107.03
Retrofit cost	PLN	0	0	535,520	535,520	542,720	564,720	564,720	574,320	680,620	680,620	687,520
SPBT	years			27.4	27.4	23.9	25.0	27.0	22.6	31.8	31.9	28.2
Final energy	kWh/(m^2/year)	422.7	353.6	115.5	113.3	39.5	94.8	92.4	32.1	102.7	100.4	35.0
Primary energy	kWh/(m^2/year)	580.8	504.7	135.0	100.6	126.8	122.8	94.1	115.4	134.1	103.3	126.4

Changing the individual heating sources would significantly reduce the annual energy demand and energy costs in the case of a comprehensive retrofit of the building. The simple payback time irrespective of the heat source would be similar for all options and between 22.6 and 31.9 years in each case. The building's final and primary energy demand after retrofitting would be significantly lower than beforehand. A building with humidity-controlled ventilation and a heat pump as its heat source would boast both the lowest operating costs and the shortest simple payback time. By contrast, the highest operating costs would be incurred by a building with natural ventilation and a district heating substation as its heat source, and the longest simple payback time would be required in a building fitted with a mechanical supply and exhaust ventilation system with heat recovery and a district heating substation as its heat source. The decision to use a particular heat source will be based on the conditions on the ground and the availability of the energy carrier. It must be remembered that the prices of energy carriers and technical solutions will need to be applied to each investment individually. The results shown are merely exemplary values for the building analysed.

6. List of tables and figures

7. Bibliography

[1] Regulation of the Minister of Infrastructure and Development of 27 February 2015 on the methodology for determining the energy performance of a building or part of a building and energy performance certificates.
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[6] Ordinance of the Minister of Infrastructure and Development of 18 May 2020 amending the Ordinance on the detailed scope and form of the energy audit and part of the renovation audit, the templates of the audit fiches, and the algorithms for assessing the profitability of a thermomodernisation project.

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