

Projekt zintegrowany LIFE "Śląskie. Przywracamy błękit". Kompleksowa realizacja programu ochrony powietrza dla województwa śląskiego realizowany jest przy dofinansowaniu z Programu LIFE Unii Europejskiej oraz Narodowego Funduszu Ochrony Środowiska i Gospodarki Wodnej.

LIFE20 IPE/PL/000007 - LIFE-IP AQP-SILESIA-SKY

SUSTAINABLE CONSTRUCTION MODELS IN THE 'SILESIA. BLUE SKY RESTORED' PROJECT

A comprehensive assessment of a building's environmental impact using a full life-cycle analysis



"Silesia. Blue sky restored."
Silesian Voivodeship
2026

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Województwo
Śląskie

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Figure 1 Implementation example for sustainable construction principles (source: generated by AI)



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1. About the LIFE integrated project 'Silesia. Blue Sky Restored'. Comprehensive implementation of the Air Protection Programme for the Silesian Voivodeship

'Silesia. Blue Sky Restored' is Europe's largest air protection project, and it covers the entire Silesian Voivodeship.

Coordinating Beneficiary – Silesian Voivodeship

Co-beneficiaries – 83 partners, including:

- 74 gminas of the Silesian Voivodeship
- 4 subregional associations of the Silesian Voivodeship
- Inter-Municipal Association for Ecology in Żywiec
- Institute of Fuel and Energy Technology
- Silesian University of Technology
- Silesian Botanical Garden Associations Union
- European Grouping of Territorial Cooperation TRITIA

The project's period of implementation is 1 January 2022 - 31 December 2027.

The project is co-financed by the European Union's LIFE Programme – a programme of actions for the environment and climate – and the National Fund for Environmental Protection and Water Management.

The primary objective of the project is the efficient and effective implementation of the Air Protection Programme for the Silesian Voivodeship (hereinafter referred to as APP), which was adopted by Resolution No. VI/21/12/2020 of 22 June 2020 by the Silesian Voivodeship Assembly.

The main objective of the project is consistent with the overarching objective of the APP, i.e. the development and implementation of remedial measures that will lead to an improvement in air quality, which in turn will reduce the adverse impact of air pollution on the health and lives of the inhabitants of the Silesian Voivodeship. The measures taken as part of the project will enable a significant acceleration in the replacement of low-power (below 1 MW) solid fuel heating devices in the municipal and residential sector, which is the main source of the problem situation in the voivodeship.

Other project objectives include:

- developing institutional capacity, a regional advisory support system and a regional information platform to improve air quality (creating a local network of competent eco-advisers at local, municipal and sub-regional level);
- developing know-how, tools, methods and demonstration activities that can strengthen the implementation of the APP and the European Green Deal both in the Silesian Voivodeship, neighbouring cross-border regions and throughout Poland;



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- raising awareness among various target groups about low emissions and preventive measures, taking into account their financial efficiency, both in the Silesian Voivodeship and across borders;
- transferring good practices to other regions of Poland and Europe.

Implementing the project will also achieve the following specific objectives:

- increasing the effectiveness of legislative solutions (the Anti-Smog Resolution) forcing the replacement of obsolete, inefficient heating devices;
- implementing effective pollution control mechanisms at local government level and developing good practices in this area;
- developing good practices in investment planning at the municipal level;
- implementing methods for optimal improvement of energy efficiency and rational investment in public facilities;
- supporting local authorities in their efforts to improve air quality and adapt to climate change by improving the quality of public spaces and increasing the proportion of green spaces in urban areas.

Total project value: EUR 16,515,020 (approx. PLN 76 million), including:

- LIFE funds (60%): EUR 9,908,979 (approx. PLN 45.6 million)
- NFOŚiGW (National Fund for Environmental Protection and Water Management) funds (35%): EUR 5,780,243 (i.e. PLN 25,883,350)
- Total own contribution of all partners (5%): EUR 825,798 (approx. PLN 3.8 million)
 - of which the Silesian Voivodeship's own contribution: EUR 412,121 (approx. PLN 1.9 million).



Figure 2 Project Activity Flowchart



Projekt zintegrowany LIFE "Śląskie. Przywracamy błękit". Kompleksowa realizacja programu ochrony powietrza dla województwa śląskiego realizowany jest przy dofinansowaniu z Programu LIFE Unii Europejskiej oraz Narodowego Funduszu Ochrony Środowiska i Gospodarki Wodnej.

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2. Measure C.3. Development of Models to Reduce Environmental Impact in Public Buildings

The purpose of this measure is to develop models, i.e. optimal organisational, legal and investment solutions for improving energy efficiency and reducing the environmental impact of public buildings (SCM – sustainable construction models).

The tasks comprising the measure include:

- development by the Silesian University of Technology of an energy consumption survey template for buildings in the municipalities participating in the project;
- analysis of surveys of submitted buildings (over 150 buildings submitted);
- monitoring of 27 facilities involving the measurement of their energy consumption (in the categories of administration, education and culture);
- analysis of monitoring data;
- developing rules and recommendations for SCM implementation during expert workshops;
- development by the Silesian University of Technology of sustainable construction models for the buildings in question, taking into account the above-mentioned categories;
- selection of five buildings to implement sustainable construction models;
- implementation of measures in five buildings (one in each subregion and one owned by the Silesian Voivodeship);
- pilot preparation of conceptual documents as part of long-term development of measures in the context of climate neutrality – implementing sustainable construction models in the border area;
- replication of solutions.

The monitoring of 27 buildings based on which sustainable building models were developed included the following:

- Monitoring conducted for all buildings:
 - local meteorological conditions (temperature, wind speed and insolation) – external measurement;
 - temperature measurement in selected rooms;
 - CO₂ concentration level indoors;



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- measurement of parameters indicating the intensity of building use, such as door opening counters, entry and exit counters, etc. (depending on the nature of the building and installation options).
- For buildings equipped with air conditioning systems:
 - meter for measuring electricity consumed by air conditioners.
- Measurement of the total amount of energy consumed for heating and usable hot water supply. Monthly measurement:
 - for coal-fired boilers – total weight of coal burned, together with a document provided by the supplier specifying the type and calorific value of the coal;
 - for oil-fired boilers – the volume of oil burned, with the calorific values declared by the manufacturer;
 - for the district heating network – the total amount of energy purchased from the supplier according to the heat meter;
 - for a gas-fired boiler – the total volume of gas consumed;
 - for a heat pump – the total amount of electricity used to drive the pump;
 - measurement of instantaneous heat output for heating and usable hot water – a heat meter on the receiving side of the installation or two meters if it is possible to measure the heat supplied for usable hot water separately.
- For PV panels or solar collectors:
 - measurement of the amount of electricity generated in the case of PV panels, and a heat meter in the case of thermal collectors.

Sustainable construction models will enable the identification of key measures and tools to be implemented across various types of facilities (administrative, educational and cultural) that will reduce the negative impact of buildings on the environment. In addition to developing guidelines and theoretical models, they will be **implemented for demonstration** purposes – testing, evaluation and presentation of results **in five buildings in the Silesian Voivodeship** (the sites will be selected based on recommendations and guidelines developed by the Silesian University of Technology). For this purpose, **nearly EUR 0.5 million has been allocated to each building** in the ‘Silesia. Blue Sky Restored’ project.



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3. Sustainable construction issues

What is sustainable construction?

Sustainable construction is an approach to designing, erecting and operating buildings in a way that minimises negative environmental impact while ensuring a high quality of life for the buildings' users. This involves strategies to use natural resources efficiently, reduce CO₂ emissions, as well as promote healthy and comfortable living and working spaces.

Sustainable construction is not only about eco-friendly solutions, but also long-term savings, improved comfort of living and responsibility for future generations.

Key elements of sustainable construction

➤ Energy efficiency

- Using energy-saving technologies (e.g. heat pumps, photovoltaic panels and energy management systems).
- Thermal insulation and airtightness of buildings to reduce heat loss.
- Using renewable energy sources.

➤ Water management

- Collecting and reusing rainwater and grey water.
- Installing water-saving fittings (e.g. aerators, dual flush systems).

➤ Eco-friendly building materials

- Using renewable and low-carbon raw materials (e.g. wood from certified plantations, concrete mixed with fly ash).
- Recycling and reusing building materials.



Figure 3 Implementation example for sustainable construction principles (source: generated by AI)



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➤ **Indoor environmental quality**

- High indoor air quality (mechanical ventilation with heat recovery, air filters).
- Using non-toxic materials (e.g. paints and varnishes with low volatile organic compound content).
- Natural lighting and acoustics to improve user comfort.

➤ **Minimising construction waste**

- Prefabricated building components to reduce waste.
- Sorting and recycling construction waste.

➤ **Green infrastructure**

- Green roofs and walls to support thermal insulation and improve air quality.
- Biodiversity around buildings (e.g. rain gardens, flower meadows, tree plantings).

➤ **Transport and mobility**

- Designing housing estates that are friendly to pedestrians and cyclists.
- Proximity to public transport and electric vehicle charging infrastructure.



Figure 4 Implementation example for sustainable construction principles (source: generated by AI)

A **green building**, or more precisely, a sustainable building, is therefore an economical, comfortable structure developed with respect for the natural environment. Its underlying principles include:

- Efficient use of resources, especially non-renewable energy and water.
- Ensuring a healthy and comfortable environment for the building's users.
- Responsibility in relation to the surroundings and location of the building.
- Flexibility and options to readapt the building, and its systems and equipment as a way to conserve resources and save money.



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- Using building management systems to monitor and control equipment and systems to minimise the consumption of energy and other resources.
- Minimising the amount of waste produced and recycling.
- Avoiding toxic and other harmful emissions.
- Using environmentally friendly construction materials, i.e. those that meet at least one of the following criteria:
 - ✓ they are made from recycled materials, agricultural waste
 - ✓ no natural resources are exploited in their production
 - ✓ the negative environmental impact of their manufacture, destruction or repair is minimised



Figure 5 Implementation example for sustainable construction principles (source: generated by AI)

- ✓ energy and water are used economically in their production
- ✓ they contribute to a healthy and safe indoor environment
- ✓ they have been produced locally.

Sustainable construction and the *Green City* concept

Green City is an urban planning concept that aims to create cities that are friendly to people and the environment by managing resources sustainably, using green infrastructure, and employing technologies that limit negative impacts on the climate. Their purpose is to improve the quality of life for residents, reduce CO₂ emissions, and adapt to climate change.

3.1. Key features of *Green Cities*

- **Sustainable mobility**
 - Developing public transport and cycling paths.
 - Promoting electric vehicles and charging stations.



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- Zero-emission zones and restrictions on car traffic in city centres.
- **Green infrastructure**
 - Creating parks, green roofs and walls.
 - Protecting green spaces and biodiversity.
 - Rain gardens and retention basins for managing rainwater.
- **Energy efficiency**
 - Using renewable energy sources (photovoltaics, geothermal energy and wind turbines).
 - Passive and zero-emission buildings.
 - Smart energy management systems in buildings.
- **Circular economy**
 - Minimising waste and promoting recycling.
 - Reusing rainwater and grey water.
 - Local production and short supply chains.
- **Climate change adaptation**
 - Urban cooling systems (e.g. shaded areas, fountains).
 - Flood protection through water retention and permeable surfaces.
 - Strategies for preventing heat islands in cities.
- **Community and environmental education**
 - Educational programmes for residents and businesses.
 - Citizen participation in urban planning.
 - Initiatives to support the local economy and urban agriculture.

3.2. Examples of *Green Cities* around the world:

- **Copenhagen (Denmark)** – a climate-neutral city prioritising cyclists.
- **Singapore** – extensive green infrastructure and eco-friendly construction.
- **Freiburg (Germany)** – a model eco-city with the Vauban district as an example of sustainable planning.



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4. Underlying principles, advantages and disadvantages of using sustainable construction elements.

4.1. Comprehensive thermal modernisation principles:

Comprehensive thermal modernisation of a building comprises measures to improve energy efficiency, reduce heat loss and operating costs. This involves:

- ✓ **Insulation of external partitions**
 - Outer walls – insulation with polystyrene, mineral wool or other insulating materials.
 - Roof/flat roof – insulation preventing heat loss through the upper part of the building.
 - Ceilings and floors on the ground – thermal insulation of the lower parts of the building.
- ✓ **Replacement of window and door frames** – installing windows and doors with superior insulation properties (e.g. triple-glazed windows, doors with low heat transfer coefficients).
- ✓ **Modernisation of the heating system**
 - Replacing the boiler with a more efficient one (e.g. gas condensing boiler, heat pump, biomass boiler).
 - Optimising the heating system (modernising radiators and central heating installations).
 - Installing smart heat management systems (thermostats, weather automation).
- ✓ **Modernisation of the ventilation system** – installing mechanical ventilation with heat recovery (recuperation) to reduce heat loss.
- ✓ **Modernisation of the usable hot water (UHW) system** – replacing obsolete heaters with energy-efficient devices (UHW heat pumps, solar collectors).
- ✓ **Use of renewable energy sources (RES)** – installing a photovoltaic system for electricity generation.
- ✓ **Optimisation of electricity consumption**
 - Replacing existing lighting with energy-efficient LEDs.
 - Using smart energy management systems.
- ✓ **Benefits of comprehensive thermal modernisation:**
 - Reduced heating costs (by as much as 50-70%).



Województwo
Śląskie

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- Improved thermal comfort in the building (no draughts or cold walls).
- Reduced CO₂ emissions and improved environmental performance of the building.
- Higher property value thanks to improved energy efficiency.
- Funding opportunities through programmes such as Clean Air or EU funds.

4.2. Advantages and disadvantages of certain elements of sustainable construction

1. Green walls:

✓ Advantages of green walls:

- Improved air quality – plants absorb pollutants and produce oxygen, contributing to cleaner air.
- Temperature regulation – green walls reduce the urban heat island effect and insulate buildings, lowering temperatures in summer and reducing heat loss in winter.
- Aesthetics and improved well-being – green walls create a welcoming environment, reduce stress and improve the mood of those using the space.
- Enhanced biodiversity – they create habitats for insects, birds and other organisms, supporting the local ecosystem.
- Reduced noise – the layer of vegetation absorbs sound, improving indoor and outdoor acoustics.
- Higher property value – greenery on buildings attracts investors' attention and enhances the prestige of the location.
- Retention system – reuse of rainwater.

✓ Disadvantages of green walls

- High installation cost – green wall systems, especially those with automatic irrigation, can be expensive.
- Maintenance and upkeep – they require regular care, fertilisation and irrigation system checks, generating additional costs.
- Risk of damage to the façade – poorly designed system may cause moisture to build up in the walls and damage the structure of the building.



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2. Green roofs

✓ Advantages of green roofs:

- Improved air quality – roof vegetation filters pollutants and produces oxygen.
- Temperature regulation – green roofs insulate buildings, lowering temperatures in summer and reducing heat loss in winter.
- Reduced urban heat island effect – covering roofs with vegetation helps lower temperatures in cities.
- Rainwater collection and retention – green roofs reduce the amount of water run-off into the drainage system, which limits the risk of flooding.
- Improved aesthetics and psychological comfort – roofs covered with vegetation provide attractive and relaxing spaces.
- Enhanced biodiversity – they create habitats for insects, birds, and small animals.
- Protection of roofing – vegetation protects the roof from weather conditions, extending its service life.
- Can serve as usable space – intensive roofs can be used to create gardens, terraces or recreational areas.

✓ Disadvantages of green roofs

- High installation cost – requires appropriate preparation of the building structure and water drainage system.
- Structural load – green roofs can be heavy, requiring the building to be reinforced.
- Maintenance and care – intensive roofs require regular watering, fertilising and pruning of plants.
- Possible drainage problems – improperly designed systems can lead to waterlogging and leaks.

3. Heat pumps draw heat from the surrounding space (air, water or ground) and transfer it to the building's heating system.

✓ Types:

- Air source heat pumps – the most commonly used type, draw heat from the outside air.
- Ground source heat pumps – utilise thermal energy stored in the ground (require a horizontal collector or vertical probes).



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Śląskie

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- Water heat pumps – draw energy from groundwater or surface water (less commonly used).

✓ Advantages:

- Very high efficiency (COP 3-5, i.e. 1 kWh of electricity provides 3-5 kWh of heat).
- Low operating costs.
- No exhaust emissions at the place of use.

✓ Disadvantages:

- High purchase and installation costs.
- They require access to electricity.

4. **Biomass-fired boilers** burn renewable organic materials, generating heat for heating buildings and usable water.

✓ Types:

- Pellet-fired boilers – automatic, convenient to use, and highly efficient.
- Wood and wood chip-fired boilers – require manual fuel feeding, but are cheaper to operate.

✓ Advantages:

- High energy efficiency.
- Low operating costs compared to gas or heating oil.

✓ Disadvantages:

- They require space for storing fuel.
- Exhaust emissions, although significantly lower than from coal.

5. Use of **photovoltaic panels**

✓ Advantages:

- savings on electricity bills
- energy independence
- long service life—panels typically last 25–30 years, and their efficiency declines slowly and gradually
- low operating costs—panels are virtually maintenance-free, requiring only occasional cleaning and inspection



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✓ Disadvantages:

- dependence on weather conditions
- need for adequate installation space
- decline in efficiency over time—although the panels are durable, their efficiency gradually decreases (approx. 0.5–1% per year)
- dependence on billing systems (e.g., net billing)—the method used to bill for surplus electricity
- disposal at the end of the service life

6. Less popular in Poland, but still used, are **solar collectors**, which capture solar energy and convert it into heat for usable water heating or supplementary heating.

✓ Types:

- Flat solar collectors – cheaper, but less efficient in winter.
- Tubular vacuum collectors – more expensive, but more effective in colder months.

✓ Advantages:

- No operating costs after installation.
- Long service life (up to 25-30 years).
- No CO₂ emissions.

✓ Disadvantages – weather-dependent (lower efficiency in winter).

7. **Geothermal energy** – utilises heat from the Earth's crust to heat buildings and domestic water.

✓ Advantages:

- Very low operating costs
- Always available regardless of the weather.
- No CO₂ emissions.

✓ Disadvantages:

- High infrastructure construction costs.
- Needs to be located in areas rich in geothermal resources.

8. **Waste heat and renewable energy-based heating systems** recover heat from industrial processes, ventilation systems or sewage systems and use it to heat buildings.



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- ✓ Advantages:
 - High energy efficiency.
 - Can be integrated with municipal district heating networks.
- ✓ Disadvantages:
 - Requires sophisticated infrastructure.
 - Limited availability for individual buildings.

9. Heat source selection depending on the building:

- ✓ The most effective solution for single-family homes:
 - Heat pumps (low operating costs, no emissions).
 - Biomass-fired boilers (for those who prefer solid fuels).
 - Solar collectors (excellent as a backup for UHW).
- ✓ Best for large buildings and housing estates:
 - Geothermal energy (for suitable locations).
 - Waste heat and district heating networks (where available in the region).

10. Types and applications of cooling sources

- ✓ **Air conditioning (compressor systems)** – air conditioners use a refrigerant to extract heat from the room and release it outside.
- Types:
 - Split and multi-split – for flats, small offices, individual indoor and outdoor units.
 - VRF/VRV – for larger buildings; the system allows for simultaneous cooling and heating of different zones.
 - Central systems – used in large commercial facilities, often combined with ventilation systems.
- Advantages:
 - Effective and rapid cooling.
 - Temperature control in different rooms.
 - Heating option during winter (heat pumps).



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- Disadvantages:
 - High electricity consumption.
 - May cause draughts and desiccate the air.
- ✓ **Heat pumps with cooling function (reversible operation)** – the heat pump can operate in cooling mode, transferring heat from the building to the outside.
- Types:
 - Air source heat pumps – the simplest to install, work well in temperate climates.
 - Ground source heat pumps – they use the coolness of the ground (so-called passive cooling), which is highly energy efficient.
- Advantages:
 - Low operating costs, especially with passive cooling.
 - Can be used to heat the building in winter.
 - Quiet operation.
- Disadvantages:
 - High installation cost.
 - In the case of air pumps – lower efficiency at very high temperatures.
- ✓ **Free cooling (passive cooling – without a compressor)** – utilises cool outside air or cold stored in the ground/water to lower the temperature in the building.
- Types:
 - **Night ventilation** – the building is cooled at night by air exchange.
 - **Water cooling with cold storage** – using cool water from natural sources (e.g. rivers, lakes, deep wells).
 - **Ground cooling** – a system of heat exchangers in the ground, often used with heat pumps.
- Advantages:
 - Very low operating costs.
 - An environmentally friendly and effective solution.
 - No noise or negative impact on air quality.



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- Disadvantages:
 - Limited effectiveness during very hot periods.
 - Requires a well-designed ventilation system or access to cooling sources.
- ✓ **Absorption and adsorption cooling systems (trigeneration)** utilise waste heat (e.g. from industrial processes or solar collectors) for cooling.
- Advantages:
 - Can be integrated with district heating systems.
 - Highly efficient in large buildings.
 - Environmentally friendly – allows for the utilisation of waste heat.
- Disadvantages:
 - High capital expenditure.
 - Cost-effective mainly in large commercial facilities.

11. Cooling source selection:

- ✓ For single-family houses and flats:
 - Heat pump with cooling function (in modern installations).
 - Split air conditioner (in the absence of a heat pump).
 - Free cooling with night ventilation (for passive houses).
- ✓ For offices and small commercial properties:
 - VRF/VRV air conditioning systems (with the option to control different zones).
 - Free cooling combined with mechanical ventilation.
- ✓ For large commercial and industrial buildings:
 - Absorption/adsorption cooling (if waste heat is available).
 - Water cooling or trigeneration (for large shopping centres, office buildings).

The choice of cooling source in a building depends on several factors, such as the purpose of the building, its size, cooling demand, energy efficiency, as well as investment and operating costs. The key criteria for selecting a cooling source are:

- Building area – larger buildings require more advanced cooling systems.



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- Cooling demand – depends on the number of users, insolation and technology in the building.
- Energy efficiency – choosing solutions with low energy consumption is a sensible option.
- Capital expenditure and operating costs – some solutions require a higher initial expenditure but are cheaper to operate.
- Energy source – if the building has access to renewable energy sources, it is worth considering, for example, operating a heat pump in cooling mode.

12. Advantages of energy management systems (EMS). Energy management systems are advanced technological solutions that monitor, control and optimise energy consumption in buildings, industry and urban infrastructure. They offer a number of benefits:

✓ Energy savings and lower operating costs

- Reduced energy consumption – smart control of heating, ventilation, lighting and other systems can reduce consumption by as much as 20-30%.
- Lower bills – thanks to automatic adjustment and detection of inefficient appliances.
- Improved energy tariff management – adjusting energy consumption hours to benefit from lower rates.

✓ Optimised operation of building systems

- Automatic adjustment of HVAC (heating, ventilation, air conditioning) parameters to actual demand.
- Smart lighting management, e.g. motion and light intensity sensors.
- Real-time coordination of equipment operation to avoid peak power consumption.

✓ Support for sustainable development and ecology

- Reduced CO₂ emissions – limiting the use of fossil fuels contributes to climate protection.
- Integration with renewable energy sources (RES) – EMS enables the effective use of photovoltaics, heat pumps and energy storage facilities.
- Optimised water and heat consumption – managing other resources in the building as well.

✓ Improved monitoring and analysis of energy data

- EMS enable real-time monitoring of energy consumption.



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- With reports and analyses, better decisions can be made regarding investments in energy efficiency.
- Ability to detect faults and leaks in the system.
- ✓ User comfort and process automation
 - Smart systems adjust temperature, ventilation and lighting to users' preferences.
 - Remote control and management via mobile applications or web platforms.
 - Can be integrated with smart home and smart city systems.
- ✓ Increase in property value and compliance
 - Buildings with energy management systems have a higher market value.
 - Improving energy efficiency makes it easier to obtain environmental certificates (e.g. BREEAM, LEED).
 - It helps meet energy efficiency standards, e.g. EPBD (Energy Performance of Buildings Directive).
- ✓ Enhanced energy security
 - EMS helps minimise the risk of blackouts by balancing the load on the grid.
 - The systems can work with energy storage facilities, increasing independence from electricity suppliers.
 - Detecting anomalies in the energy system helps avoid breakdowns and costly downtime.

5. Principles concerning the Sustainable Construction Models developed during expert workshops.

5.1. General comments

1. Every building and its location are unique to a certain extent, and therefore the optimal solution for energy supply is different in each case. However, many contractors prefer typical and standardised solutions.
2. Due to the high cost of modernisation works and their significant impact on subsequent building operating costs, it is strongly recommended that a team be appointed to act on behalf of the investor and ensure that the contractor carries out the modernisation works in a manner that is



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optimal for a given site. In addition to construction specialists and others involved in renewable energy issues, the team should also include a person specialising in greenery.

3. Before commencing modernisation, it is advisable to conduct annual monitoring of heat and electricity consumption, which will allow for better selection of the size and type of equipment (a detailed description of the annual monitoring process is provided in the description of Activity C.3. of this study, as well as in the monitoring report [14] and the recommendations regarding monitoring [17]).
4. Buildings subject to monument conservation (historic monuments), as a separate category of structures, require individual and special consideration. Although they are considered individually, they can also be modernised in accordance with the principles defined as Sustainable Building Models. The rules concerning modernisation, thermal modernisation, the introduction of RES, green roofs, etc., are included, among others, in a document developed as part of the project 'Silesia. Blue Sky Restored' [8].
5. Before obtaining a building permit, the architectural and construction design should be preceded by the preparation of a functional and spatial programme together with a concept taking into account renewable energy sources, and the performance of pre-design studies in the following areas: principles of designing energy-efficient and environmentally friendly buildings, principles of green architecture, sustainable construction and universal design. The designs should take into account local conditions, the location of the plot, the location of watercourses, so-called ecological extensions, local infrastructure, and general natural conditions, including the microclimate.

5.2. Energy demand

1. Heat demand depends on the building's structure, its surroundings, and how it will be used in the future. Each of these factors can be influenced to some extent by the building manager.
2. One method to reduce energy demand is to shield the building from the wind, which can be achieved by using protective vegetation (according to the typology recommendations prepared by the Silesian Botanical Garden Associations Union as part of the 'Silesia. Blue Sky Restored' project [18]) and by using earth embankments with cover or low-rise vegetation. Naturally, both must be part of the development plan for the area surrounding the building.
3. A significant way to reduce the energy required to cool a building is to shade it with deciduous trees, which help cool it in summer while allowing solar energy to enter in winter. Detailed guidelines concerning species are included in the typology prepared by the Silesian Botanical Garden Associations Union [18].



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Śląskie

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4. When planning the modernisation of a building, one needs to consider the possibility of changing its functional layout so that rooms intended for permanent human occupancy are located primarily on the south side, and auxiliary rooms on the north side.
5. An effective means of reducing heat demand is to use forced ventilation with heat recovery. In buildings with gravity ventilation, air exchange is usually too low when the building is in use and too high when the building is not in use. The signal controlling the intensity of circulation should be the measurement of CO₂ in rooms (taking into account the requirements specified by the Construction Law).
6. Human thermal comfort depends primarily on air temperature, wall temperature and humidity. Increasing humidity during winter, apart from its positive health effects, also makes it possible to lower the temperature and thus reduce the demand for heating. One of the recommended methods for increasing air humidity is to introduce plants into staff rooms [19].
7. Efforts should be made to reduce the amplitude of environmental factors (air humidity, temperature, solar radiation intensity and wind speed).
8. A significant reduction in heat demand can be achieved by using conservatories and winter gardens, which can be used as staff areas, promotional areas, etc.
9. Green walls, which significantly improve the thermal insulation of a building, should be created using plants that do not damage plaster. Where possible, it is advisable for the green wall to have its own supporting substructure.
10. Green roofs are recommended; they can be created using drought-resistant perennial plants, such as epiphytic mosses in northern and/or shaded locations (extensive roofs), while intensive green roofs (shrubs and trees) are recommended over extensive ones in other cases. Attention should be paid to the size and type of the root system and waterproofing. A feasibility study must precede implementation [16].
11. It is recommended to install screens that limit the penetration of solar radiation into rooms, protect against overheating, and heat loss.
12. Thermal modernisation of a building should involve not only improving the insulation of walls, but also that of windows and doors.

5.3. Sources of heat

1. If the building has access to a district heating network, this should be considered as the primary source of heat. Heat sources for the district heating network will undergo an energy transition, ultimately leading to heat consumption without a carbon footprint.



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2. If the building's location does not allow for heat to be drawn from the district heating network, heat pumps should be considered first, with ground source heat pumps being strongly recommended over air source heat pumps if the location allows. When installing a heat pump, it is advisable to introduce photovoltaic panels.
3. Bio-mass fired boilers can be planned as an alternative to heat pumps or as a peak source. Low-maintenance biomass pellet boilers that meet eco-design requirements are particularly recommended.

5.4. Sources of cooling

1. Except for very specific cases where waste heat is available, justifying the use of adsorption chillers, compressor units are the primary source of cooling. However, it is important to carefully consider whether air conditioning is truly necessary and whether thermal comfort can be achieved with passive methods.
2. First, a central source of cooling should be considered, with the cooling distributed via chilled water to rooms where cooling is necessary. A central cooling source allows for the use of cold storage.
3. For user comfort, individual air temperature control should be used in each room.

5.5. Sources of electricity

1. Due to their social function, public buildings should have a secure supply of electricity by being connected to the power grid. It is not advisable to plan buildings in an off-grid system.
2. The primary source of electricity generated in the building itself are photovoltaic panels, which can also be installed on green roofs with an additional raised support structure, enabling the functional implementation of green roofs. Where car parks or other small architectural structures are present, they should also be used for the installation of photovoltaic panels, provided they are not located in shaded areas. When installing panels on sloping roofs and façades, attention should be paid to the aesthetic aspect; the use of 'solar planes' is recommended.
3. The optimal angle for positioning photovoltaic panels depends on the building's function. For example, school buildings consume electricity mainly in the morning, and energy demand is reduced in summer due to the holiday break. Hence, the optimal positioning of the panels is eastwards. Where the goal is to maximise the use of electricity for own needs without selling it to the grid, this entails different angles for the optimal positioning of the panels in both planes. This applies primarily to flat roofs.



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4. It is recommended to consider photovoltaic panels in hybrid (water-cooled) PVT technology, using waste heat for UHW production or ground heat regeneration.

5.6. Energy storage facilities

1. In buildings where PV panels are installed, it is advisable to use electricity storage facilities. The size of the storage facility should be selected based on measurements of the electricity flow through the building.
2. In buildings equipped with heat pumps, it is reasonable to use heat storage facilities that allow for the storage of heat in an amount corresponding to the daily consumption on a typical day during the heating season. The heat pump can fill the storage tank during periods of high availability of electricity from renewable energy sources. However, the possibilities of connecting an RES installation to an existing building should be analysed, especially in view of factors that preclude the implementation of a storage facility, such as the high temperature of the circulating medium in the heating system.
3. In buildings equipped with central air conditioning and cooling distribution using chilled water, it is advisable to use cold storage facilities with a capacity corresponding to the cooling consumption on a typical day during the summer season.

5.7. Modernisation of energy management systems

1. Smart energy management systems.
2. Automatic control of heating, ventilation, and lighting.
3. Integration with energy storage facilities (e.g. lithium-ion batteries).
4. The ability to control thermal conditions in the building by zone.

5.8. Rainwater:

1. It is recommended to use rainwater for watering green roofs, greenery surrounding buildings, cooling PVT panels, and securing grey water reservoirs.

5.9. Education:

2. Separate building operating instructions should be prepared for the manager and user, explaining the solutions used and the correct ways to use them.



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5.10. Further comments:

1. When planning vegetation, species with low allergenic risk and low invasive potential should be selected.
2. The use of anti-smog murals and anti-smog paints should be considered, especially for promotional purposes on empty walls of the building.
3. Apply the principles of circular architecture, including the use of demolition waste in the planned modernisation.

6. Reduction in annual carbon dioxide emissions

6.1. Calculation model

In order to calculate the annual CO₂ emissions of a given building, it is necessary to perform a number of preliminary calculations. Emissions generated by a building depend on the consumption of electricity, district heating and fuel. The installation of new equipment in the building also involves certain emissions. Each building, due to its function, structure and location, requires a different amount of energy. The options for installing renewable energy sources vary depending on the building. Demands and capabilities fluctuate over time due to weather conditions, operating modes, and the presence of people. For this reason, it has been proposed that calculations be performed at hourly intervals. The basis for the calculations is the instantaneous (hourly) energy balance. A distinction is made here between two balances – heat and electricity – which are interrelated. The calculations are carried out for a period of one year. Values such as emissions and energy consumption are ultimately added up.

First, the conditions for installing a photovoltaic system are determined for a given building.

The number of photovoltaic panels is calculated using data on the available roof area. The angle of inclination of the panel and the azimuth it faces are also determined. Using PVGIS, annual data on the intensity of solar radiation falling on a given installation can be generated. Next, annual weather data is collected from the nearest station of the Institute of Meteorology and Water Management (IMGW). Annual data is also collected from the power system on the instantaneous (hourly) share of renewable sources and data on instantaneous electricity prices on the balancing market (purchase/sale prices for commercial customers). Due to availability reasons, the data comes from 2020.

In order to calculate the hourly electricity balance, it is necessary to determine the power consumed and generated. The power consumption is the sum of the heat pump power, the power consumed for utility purposes, and the air conditioning power. The power of the heat pump is calculated based on the instantaneous heat demand, which consists of two components: heat used for heating and heat for



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usable hot water preparation. Heat used for heating is calculated using empirical functions developed based on energy monitoring data. Heat for usable hot water is calculated from weekly consumption profiles, which are also prepared based on monitoring data. In the case of electrical power for utility purposes, weekly consumption profiles are also used. The power for air conditioning purposes is determined from empirical functions, similarly to the heating power. The power generated by the PV system is determined based on data on the instantaneous intensity of solar radiation and other weather data using the correlation formulas described in the references. The difference between the power generated and consumed is the value of energy taken from or fed into the grid. It is assumed that consumption data collected from monitoring will be used without creating weekly profiles and empirical functions. However, this is not possible due to ongoing measurements and the lack of data for the entire heating season.

Since power exchange with the electricity system involves financial losses, certain methods of compensation have been provided for. First, if the building shows an energy deficit on an annual basis (after summing up), the power of the biomass-fired boiler (as a fraction of the heat pump power) is selected iteratively so that the deficit is minimised. Another undesirable factor is the lack of daily electricity balancing, e.g. in a situation where there is excess power generation from photovoltaics during the day and simultaneous power consumption by the heat pump at night. short-term heat storage in a water tank heated by the heat pump using surplus power has been proposed. Its capacity is also selected iteratively.

Hourly data on energy consumption from the grid allows for the estimation of CO₂ emissions generated by non-renewable energy sources connected to the power system (using the aforementioned instantaneous data on the share of renewable sources), which is then summed up on an annual basis. In addition, emissions associated with power consumption from the heating system (if any) are added. The annual emissions are also supplemented by CO₂ emissions spread over a period of 20 years associated with the construction and installation of new equipment, such as photovoltaic panels, biomass-fired boilers and heat pumps.

Calculations can be performed for a number of modernisation options. The developed calculation algorithm allows for the selection of four types of photovoltaic cells (monocrystalline, HIT, polycrystalline, CIGS), two types of heat pumps (air and ground source) and the inclusion or exclusion of functionality related to the selection of a biomass-fired boiler. For each building, the calculation yields 16 modernisation variants. Avoided annual CO₂ emissions are used as the criterion for evaluating the proposed variants in terms of their compliance with the design specifications.

6.1.1. Instantaneous building energy balance

The basic equation for the calculations carried out is the energy balance equation. It is solved for the heat needed to heat the building (CH) and prepare usable hot water (UHW), as well as for the electricity needed for domestic use, heating and air conditioning. The energy balance for heat can therefore be presented as follows:



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$$\dot{Q}_{in}(\tau) = \dot{Q}_{co}(\tau) + \dot{Q}_{cwu}(\tau) \quad (1)$$

where $\dot{Q}_{in}$ denotes heat supplied (by the heating device), $\dot{Q}_{co}$ denotes heating expenditure, and $\dot{Q}_{cwu}$ denotes usable hot water preparation. These values represent thermal outputs expressed in kW and are specific to a given moment in time τ . Internal heat generation has been omitted. The instantaneous heating power values are calculated based on the temperature difference between the set internal temperature and the external temperature using an empirical function, whereby the functional relationship between the set temperature difference and the heat output is determined based on the monitoring data collected so far, as described in section 4.3. This approach is physically justified, as heat losses, both heat transfer through external partitions to the ground and losses from ventilation, are functions of the temperature difference. Consumption for usable hot water is also calculated using a model based on data collected from monitoring to date, with the proviso that it is only a function of time (day of the week and hour), as described in the section ‘Usable hot water’.

The momentary energy consumption for heating purposes must be covered by a heat source. For buildings connected to the district heating network, we assume that it will be zero-emission after 2050 [13], therefore, the installation of new heat sources is not assumed. For buildings not connected to the district heating network, it is assumed that heat sources may include an air-source heat pump, a ground-source heat pump, or a biomass boiler. The electrical power of a heat pump can be calculated as:

$$N_{el,pc}(\tau) = \frac{\dot{Q}_{in}(\tau)}{COP_{pc}(\tau)} \quad (2)$$

where COP_{pc} stands for the energy efficiency coefficient of a heat pump. It is calculated on an instantaneous basis as a function of prevailing conditions and the pump’s load relative to its nominal capacity, according to the methods described by Marsik et al. [10] and Qian et al. [12], for air-source and ground-source heat pumps, respectively. The nominal power of the heat pump is defined as the maximum annual heat output, without specifying a particular model of the device, which constitutes a significant simplifying assumption.

The biomass boiler was treated solely as an additional heat source.

$$\dot{Q}_{in}(\tau) = \dot{Q}_{pc}(\tau) + \dot{Q}_{kb}(\tau) \quad (3)$$

where indices “pc” and “kb” stands for hat pump and biomass boiler respectively.



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The capacity of the biomass boiler is selected through an iterative process. If the calculation results show an annual surplus of electricity generated, the boiler is not considered. However, if an annual shortfall occurs, the boiler's capacity is gradually increased until the shortfall is eliminated. Additionally, the possibility of installing a buffer tank to store heat produced by the heat pump in the event of excess electricity production during the heating season has been considered. This is a method of short-term energy storage. The size of the tank is selected iteratively to minimize overproduction and shortfalls on a daily basis—excess electricity generated by the PV system during the heating season is not sold to the grid but is used by the heat pump to heat the tank. It is assumed that water serves as the storage medium. “Charging” the tank causes the temperature of the medium to rise, while discharging causes it to fall, according to the energy balance equation:

$$U_{2,zb} = U_{1,zb} + \int_{\tau_2}^{\tau_1} \dot{Q}_{pc}(\tau) + \dot{Q}_{out}(\tau) d\tau \quad (4)$$

where U is internal energy; indices 1 and 2 denote the start and end of charging/discharging, respectively. The internal energy can be expressed as:

$$U_{zb} = V_{zb} \rho_{zb} C_w t \quad (5)$$

where V is volume, ρ is density and C_w represents heat capacity of water. The storage tank volume is determined iteratively to minimize excess electricity production.

Finally, the balance equation for electricity takes the following form:

$$N_{el,siec}(\tau) = N_{el,pc}(\tau) + N_{el,uz}(\tau) + N_{el,klim}(\tau) - N_{el,gen}(\tau) \quad (6)$$

where the instantaneous powers N are expressed in kilowatts and the subscripts denote, respectively: grid—the grid, gen—local generation from renewable energy sources, pc—heat pump, uz—energy consumption for domestic purposes, klim—energy consumption for air conditioning. The power drawn from the grid is the resultant value. Generation from renewable energy sources depends on the technology used and is calculated using meteorological data and data from the PVGIS system [4] as described in the next chapter.



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6.1.2. Energy generation

Photovoltaic panels are considered to be the main source of renewable energy. In general, four variants of photovoltaic panels with different cell technologies are envisaged, without specifying a particular manufacturer. The cells are:

1. Monocrystalline
2. HIT (Heterojunction with Intrinsic Thin Layer)
3. Polycrystalline
4. CIGS (copper, indium, gallium, selenide).

The instantaneous power of a photovoltaic installation is determined based on data on insolation and other weather data.

$$N_{el,pv}(\tau) = G_i(\tau) \cdot A_{pv} \cdot n_{pv} \cdot \eta_{el,pv}(\tau) \quad (7)$$

where $N_{el,pv}$ denotes the power of the installation in W, G_i is the intensity of solar radiation in W/m^2 , A_{pv} is the panel area, n_{pv} is the number of panels in a given section of the installation, and $\eta_{el,pv}$ is the instantaneous efficiency of the panel. The G_i values are derived from the PVGIS [4] for the selected location. This tool requires information about the angle of inclination of the panel to the horizontal plane and their azimuth. For flat roofs, the optimal angle and azimuth indicated by the PVGIS is adopted. For buildings with sloping roofs and containing sloping roof sections, these data were estimated based on photographs of buildings, satellite images and survey data.

The number of panels depends on the roof area of the building, with the area of a single panel being identical to the area of the panels tested by Paudyala et al. [11] (1.66, 1.67, 1.63, and 0.94 m^2 for monocrystalline, HIT, polycrystalline, and CIGS panels, respectively). It is assumed that sloping roofs will be fully covered (panels laid on the roof surface) and flat roofs will be half covered (which is a significant simplifying assumption of the presence of other installations on flat roofs and the fact that panels positioned at an angle to the surface must be spaced apart). The efficiency of a panel is a function of its temperature [5]:

$$\eta_{el,pv}(\tau) = \eta_{el,pv,nom} \cdot [1 - \beta_{pv}(t_{pv}(\tau) - t_{st})] \quad (8)$$

where $\eta_{el,pv,nom}$ is the nominal efficiency of the panel, β_{pv} is the temperature coefficient, t_{st} is the reference cell temperature, and t_{pv} is the instantaneous temperature. The instantaneous temperature can be estimated using the correlation developed by Skoplaki et al. [15]:



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$$t_{pv}(\tau) = t_{zew}(\tau) + G_i(\tau) \frac{0.25}{5.7 + 3.8w_w(\tau)} \quad (9)$$

where t_{zew} is the current outside temperature and w_w is the wind speed in m/s.

Snowfall was also taken into account in the calculations. In the event of precipitation according to IMGW measurement data, it is assumed that the power of the photovoltaic panels is 0. The parameters of the panels adopted as baseline (according to [11]) are presented in Table 1 Overview of baseline parameters for photovoltaic panels Table 1.

Table 1 Overview of baseline parameters for photovoltaic panels

Panel type	β_{pv}	$\eta_{el,pv,nom}$	H, m	L, m
Monocrystalline	-0.0027	0.194	1.675	0.992
HIT	-0.0024	0.194	1.59	1.053
Polycrystalline	-0.0028	0.163	1.64	0.992
CIGS	-0.0026	0.138	1.19	19

6.2. Energy demand

The methodology for calculating energy demand is described in detail in the document 'Report on the energy monitoring of buildings' [14]. It should be noted that the data comes from the period 2024-2025 and is not identical to the data from surveys indicated by building users based on readings from previous years.

6.3. Calculation of emissions

6.3.1. Emissions associated with the installation of new energy sources

Building photovoltaic systems, heat pumps, or biomass-fired boilers entails additional CO₂ emissions. These arise during the production and extraction of the raw materials needed to build the individual devices, as well as during their transport and installation. The life cycle analysis (LCA) method was used to estimate these emissions.



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In order to calculate emissions associated with building photovoltaic systems, the results of studies by Imran et al. [7] and Barrou [1] were used. These researchers indicate the CO₂ emissions associated with the production of photovoltaic panels and entire systems. Emissions in relation to kW of installed power are shown in Table 2.

Table 2 Overview of emissions associated with the construction of PV systems [7, 1].

Panel type	For the panel, kgCO ₂ /kW	For the system, kgCO ₂ /kW
Monocrystalline	1220	1280
HIT	612	682
Polycrystalline	757	824
CIGS	634	715

Emissions associated with the construction of heat pumps (air and ground source) and biomass boilers are calculated using the dependencies published by Caduff et al. [2]. These dependencies allow the mass of the equipment to be estimated based on its power, the mass of individual raw materials used in its production in relation to the calculated mass, and finally the mass subject to the given processes. The results are multiplied by the emissions specific to the raw materials/processes, using data obtained from the GABI libraries [6].

It should be noted that emissions associated with the construction of new equipment are, in a sense, one-time emissions. The desired result is annual emissions. For this reason, it is assumed that one-time emissions associated with the construction of facilities are spread over a period of 20 years.

6.3.2. Network emissions

Drawing power from the national electricity grid and heat from local heating systems involves CO₂ emissions. It can be assumed that, in line with climate policy goals, these systems will be zero-emission from 2050 [13], which would put emissions at 0 kg/kWh. On the other hand, these assumptions will not be met in the near future, and the estimation of emissions generated by buildings is valuable information for further analysis.

Similar to other calculations, emissions were estimated on an hourly basis using data for the base year. Public data from Polskie Sieci Elektroenergetyczne (PSE, Polish Power Grid) was used [3]. PSE data contains information on generated power and its sources on an hourly basis. This allows for the calculation of the fraction of total power generated by non-renewable sources. The product of the non-renewable fraction and the average emissions per unit of energy from non-renewable sources published by the National Centre for Emissions Balancing and Management [9] is the estimated instantaneous CO₂ emissions per kWh:



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$$m_{CO_2/kWh}(\tau) = \frac{N_{n-ren}(\tau)}{N_{n-ren}(\tau) + N_{ren}(\tau)} \cdot W_{em,kobize} \quad (10)$$

where N_{n-ren} is power generation from non-renewable sources (MW), N_{ren} is power generation from renewable sources (MW), and $W_{em,kobize}$ is average emissions per unit of energy generated in Poland from non-renewable sources, amounting to 788 kg CO₂/MWh. It is assumed that power generation from renewable sources does not involve emissions.

CO₂ emissions associated with energy consumption from local heating networks were estimated at 111.26 kg CO₂=GJ according to the KOBiZE report [9].

These values refer to units of energy. Since the calculations are based on power values, it is assumed that the power during a given hour is constant, so the energy consumed from the grid is the product of power and time. Data on the amount of CO₂ emitted in individual hours are summed up for the entire year.

$$m_{CO_2,el,rok}(\tau) = \sum_{i=1}^{8760} E_{el}(\tau) m_{CO_2/kWh}(\tau) \quad (11)$$

where $E_{el}(\tau)$ is the energy consumed in a given hour of the year in kWh ($E_{el}(\tau) = N_{el,siec}(\tau)$), assuming constant power in a given hour).

6.3.3. Emissions related to fuel combustion

Emissions related to fuel combustion are estimated on the basis of KOBiZE data, which show the amount of CO₂ emissions per unit of energy from a given fuel for a given type of building. These values are presented in Table 3. They are specific to the category 'institutions/commerce/services'.

Table 3 Overview of emission indicators for selected fuels

	Emisja CO ₂ kg/GJ
Olej opałowy	77.75
Gaz ziemny	55.39
Węgiel kamienny	94.25



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These values are multiplied by the annual energy consumption for heating in a given building, taking into account the heat consumption for usable hot water preparation:

$$m_{CO2,el,rok}(\tau) = \sum_{i=1}^{8760} Q_{in}(\tau) W_{pal} \quad (12)$$

where W_{pal} is the emission factor for a given fuel, $Q_{in}(\tau)$ is the energy consumed for heating purposes in a given hour, expressed in GJ.

6.4. Calculation results

Calculations using the described model were performed for 27 selected buildings in 16 different modernisation variants. The variants differ in terms of the use of different types of photovoltaic cells, air or ground source heat pumps, and the installation or non-installation of a biomass-fired boiler. The variants are summarised Table 4. It should be noted that these are calculation variants, not necessarily feasible in practice (e.g. possible technical problems with the installation of PV panels on roofs or ground source heat pumps in densely built-up areas). In addition, it is not recommended to modernise heat sources in buildings supplied from the district heating network, as according to climate policy assumptions, these systems will be zero-emission starting in 2050 [13]. The calculations carry a degree of uncertainty due to the assumptions made and the lack of measurements for a full heating season.

Table 4 Overview of calculation variants

Variant/Sheet	PV cell type	Heat pump type	Can a biomass-fired boiler be installed?
1	Monocrystalline	Air source	Yes
2	HIT	Air source	Yes
3	Polycrystalline	Air source	Yes
4	CIGS	Air source	Yes
5	Monocrystalline	Ground source	Yes
6	HIT	Ground source	Yes
7	Polycrystalline	Ground source	Yes
8	CIGS	Ground source	Yes
9	Monocrystalline	Air source	No
10	HIT	Air source	No
11	Polycrystalline	Air source	No
12	CIGS	Air source	No



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13	Monocrystalline	Ground source	No
14	HIT	Ground source	No
15	Polycrystalline	Ground source	No
16	CIGS	Ground source	No

Due to the large number of variants, the results are shown in charts. The chart in Figure 6 shows the differences in CO₂ emissions after the implementation of a given variant in relative terms (i.e. per square metre of floor area), while the chart in Figure 7 shows the same differences in absolute terms. Figure 8 shows the emissions associated with the implementation of each variant.

As can be seen, the differences are minor. The values for the best variants (in terms of avoided emissions) are presented in Table 5 and Table 6, in relative and absolute terms, respectively. The tables are arranged according to the amount of emissions avoided.

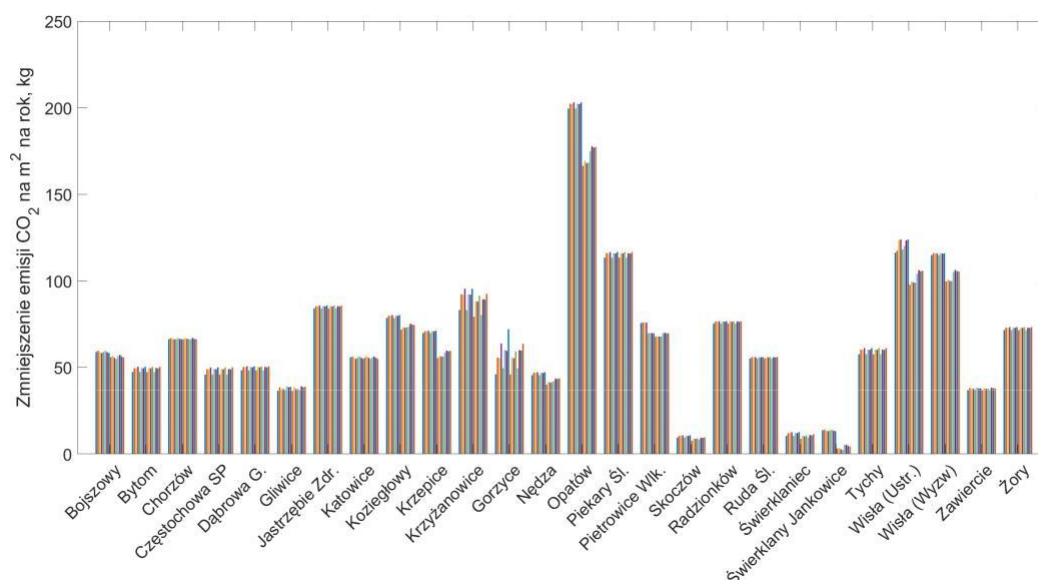


Figure 6 Relative (per unit of area), annual, avoided CO₂ emissions for each calculation variant.



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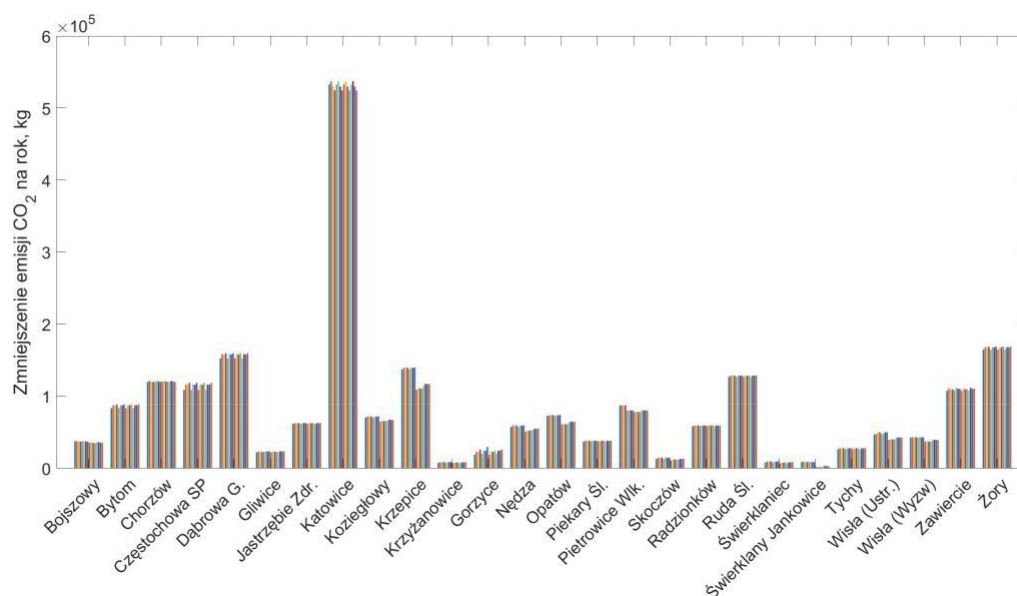


Figure 7 Annual CO₂ emissions avoided for each calculation variant.



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Table 5 Avoided annual CO₂ emissions in relation to the building area and emissions associated with the construction of the installation in relation to the building area for the most favourable variant. Arranged according to avoided emissions.

Nr	Subregion	Fuel	Name	Emissions avoided kg/m ² /year	Installation construction emissions kg/m ²	Var.
14	Nortch	Coal	Opatów	203.06	61.61	2
24	South	Gas	Wista (Ustr.)	123.89	47.54	4
16	Central	District heating network	Piekary Śl.	116.68	47.13	2
25	South	Gas	Wista (Wyzw)	116.03	39.78	4
11	West	Gas	Krzyżanowice	95.42	178.98	4
7	West	District heating network	Jastrzębie Zdr.	85.73	25.17	6
9	North	Gas	Koziegłowy	80.27	29.56	4
19	Central	District heating network	Radzionków	76.67	24.03	2
17	West	Gas	Pietrowice Wlk.	75.95	8.08	4
27	West	District heating network	Żory	73.31	26.32	4
12	West	Coal	Gorzyce	72.11	248.09	4
10	North	Heating oil	Krzepice	71.18	26.77	8
3	Central	District heating network	Chorzów	67.03	19.82	4
23	Central	District heating network	Tychy	61.15	49.72	4
1	Central	Heating oil	Bojszowy	59.66	22.86	4
8	Central	District heating network	Katowice	56.31	11.04	4
20	Central	District heating network	Ruda Śl.	56.02	13.86	4
5	Central	District heating network	Dąbrowa G.	50.64	35.36	4
2	Central	District heating network	Bytom	50.36	41.30	4
4	North	District heating network	Częstochowa SP	50.08	58.28	4
13	West	Coal	Nędza	47.27	28.68	2
6	Central	Gas	Gliwice	39.11	54.32	4
26	Central	Gas	Zawiercie	38.36	30.52	4
22	West	Gas	Świerklany Jankowice	14.03	10.80	2
21	Central	Gas	Świerkianiec	12.69	34.90	6
18	South	Gas	Szczółw	10.81	25.58	4



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Table 6 Avoided annual CO₂ emissions in absolute terms and emissions associated with the construction of the installation for the most favourable variant. Arranged according to avoided emissions.

Nr	Subregion	Fuel	Name	Emissions avoided kg/m ² /year	Installation construction emissions kg/m ²	Var.
8	Central	District heating network	Katowice	537150.60	105284.33	2
27	West	District heating network	Żory	169041.44	60686.21	4
5	Central	District heating network	Dąbrowa G.	159860.07	111629.96	4
10	North	Heating oil	Krzepice	140018.51	52657.32	4
20	Central	District heating network	Ruda Śl.	128925.28	31907.46	4
3	Central	District heating network	Chorzów	121465.53	35907.88	2
4	North	District heating network	Częstochowa SP	118808.93	138263.71	4
26	Central	Gas	Zawiercie	111671.97	88841.56	6
2	Central	District heating network + gas	Bytom	88926.17	72930.58	4
17	West	Gas	Pietrowice Wlk.	87571.49	9320.74	4
14	North	Coal	Opatów	74117.73	22486.74	4
9	North	Gas	Koziegłowy	72242.13	26600.53	4
7	West	District heating network	Jastrzębie Zdr.	63014.45	18501.21	4
13	West	Coal	Nędza	59792.90	36277.35	4
19	Central	District heating network	Radzionków	59599.35	18679.96	4
24	South	Gas	Wista (Ustr.)	50242.94	19278.66	4
25	South	Gas	Wista (Wzw)	43280.34	14838.08	2
16	Central	District heating network	Piekary Śl.	38506.14	15551.83	4
1	Central	Heating Oil	Bojszowy	37953.25	14544.68	2
12	West	Coal	Gorzyce	29665.64	102061.02	8
23	Central	District heating network	Tychy	28250.43	22969.96	4
6	Central	Gas	Gliwice	23854.61	33132.46	6
18	South	Gas	Skoczów	15106.18	35739.50	4
21	Central	Gas	Świerklaniec	9809.59	26985.48	4
22	West	Gas	Świerklany Jankowice	9134.53	7031.12	2
11	West	Gas	Krzyżanowice	8891.37	16677.60	4



Województwo
Śląskie

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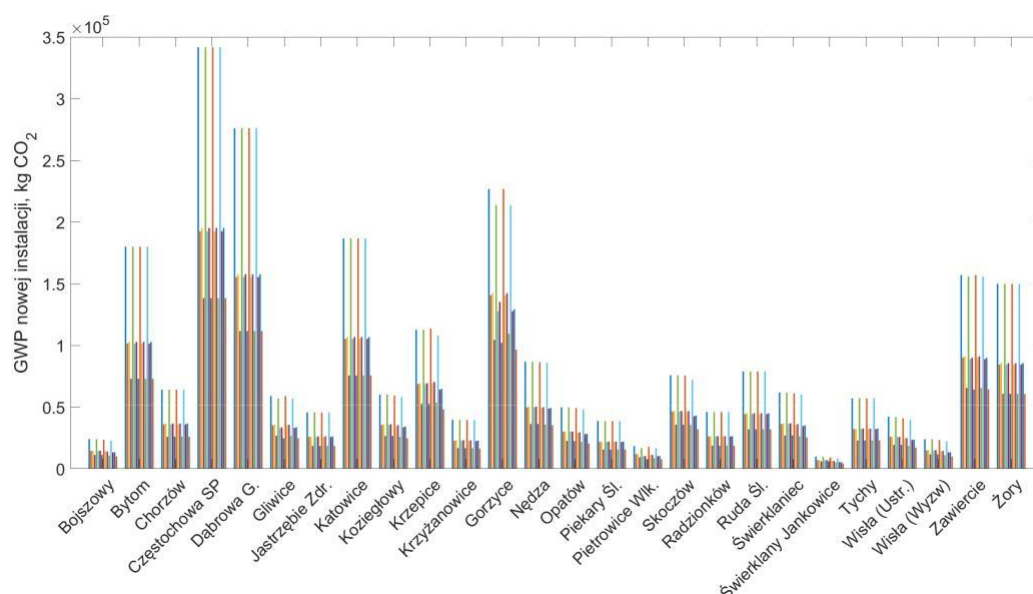


Figure 8 CO₂ equivalent associated with the construction of the installation for each calculation variant.

7. Sustainable Construction Models for 9 existing sectoral facilities: administration, education and culture

7.1 Assessment of the feasibility of implementing Sustainable Building Models in selected facilities

On 26 and 27 March 2025, an expert panel comprising specialists in the fields of energy, architecture and green spaces developed Sustainable Building Models. The participants had the opportunity to familiarise themselves with the building profiles. During the discussion, the possibility of implementing individual, established principles of Sustainable Building Models was explored using the example of the 9 buildings mentioned above. As the SCM principles are described in detail in Chapter 4, the results of the discussion are presented in tabular form in Table 7.

The general comments apply to all buildings. Energy management systems can also be implemented in all cases. The remaining points were considered feasible (or not) taking into account the location of the building, its surroundings, expansion possibilities, plot size and connection to the district heating network. In addition, due to the function of the building, the requirements for thermal comfort were assessed differently. The scope of implementation is also necessarily smaller in historic buildings.



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Table 7 Implementation of sustainable building models in selected facilities. The items in the table refer to the sub-sections of a given subchapter.

		Bytom	Krzepice	Nędza	Skoczów	Katowice	Żory	Pietrowice Wlk.	Opatów	Świerklaniec
5.2 Energy Demand										
	1	✓	✓	✓	✓	✓	✓	✓	✓	✓
	2	✓	✓	✓	✗	✗	✓	✗	✗	✓
	3	✓	✓	✓	✗	✗	✓	✗	✗	✓
	4	✓	✗	✓	✗	✗	✗	✗	✗	✗
	5	✓	✓	✓	✓	✓	✓	✓	✓	✓
	6	✓	✓	✓	✓	✓	✓	✓	✓	✓
	7	✓	✓	✓	✓	✗	✓	✗	✗	✓
	8	✗	✓	✓	✗	✗	✓	✗	✗	✓
	9	✓	✓	✓	✓	✓	✓	✓	✓	✓
	10	✓	✓	✓	✗	✓	✓	✗	✗	✗
	11	✗	✓	✓	✗	✗	✓	✓	✓	✓
	12	✓	✓	✓	✓	✓	✓	✓	✓	✓
5.3 Heat sources										
	1	✓	✗	✗	✗	✓	✓	✗	✗	✗
	2	✗	✓	✓	✓	✗	✗	✓	✓	✓
	3	✗	✓	✓	✓	✗	✗	✓	✓	✓
5.4 Cooling sources										
	1	✓	✗	✓	✓	✓	✓	✓	✓	✓
	2	✓	✗	✓	✓	✓	✓	✓	✓	✓
	3	✓	✗	✓	✓	✓	✓	✓	✓	✓
5.5 Electric power sources										
	1	✓	✓	✓	✗	✓	✓	✓	✓	✓
	2	✓	✓	✓	✗	✓	✓	✓	✓	✓
	3	✗	✓	✓	✗	✗	✓	✗	✗	✗
	4	✗	✓	✓	✗	✗	✗	✓	✓	✓
5.6 Rainwater										
	1	✓	✓	✓	✓	✓	✓	✓	✓	✓
5.7 Education										
	1	✓	✓	✓	✓	✓	✓	✓	✓	✓
5.8 Energy storage facilities										
	1	✓	✓	✓	✗	✗	✓	✓	✓	✓
	2	✗	✓	✓	✓	✗	✓	✓	✓	✓
	3	✓	✗	✓	✓	✗	✓	✓	✓	✓
5.9 Modernisation of energy management systems										
	1	✓	✓	✓	✓	✓	✓	✓	✓	✓
	2	✓	✓	✓	✓	✓	✓	✓	✓	✓
	3	✓	✓	✓	✓	✓	✓	✓	✓	✓
	4	✓	✓	✓	✓	✓	✓	✓	✓	✓

7.2. Sustainable building models

7.2.1. Model 1: Krzepice – Adam Mickiewicz Primary School No. 1 (education)

The building is located at. A. Mickiewicza 13/17, 42-160 Krzepice (Figure 9 and Figure 10), situated in the northern subregion of the Voivodeship. The building attracted considerable interest from the Expert



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Panel owing to its location and large plot size. According to survey data (Table 8), the complex of buildings has a usable area of 1,967 m², is heated with 52,000 litres of fuel oil per year, and has a total annual energy consumption of 577,634.33 kWh, including 563,333.33 kWh for heating. The building is partially insulated with 40 mm thick polystyrene foam. Modernisation of heat sources and installation of renewable energy sources could lead to a reduction in annual CO₂ emissions of 140,018.51 kg/year.

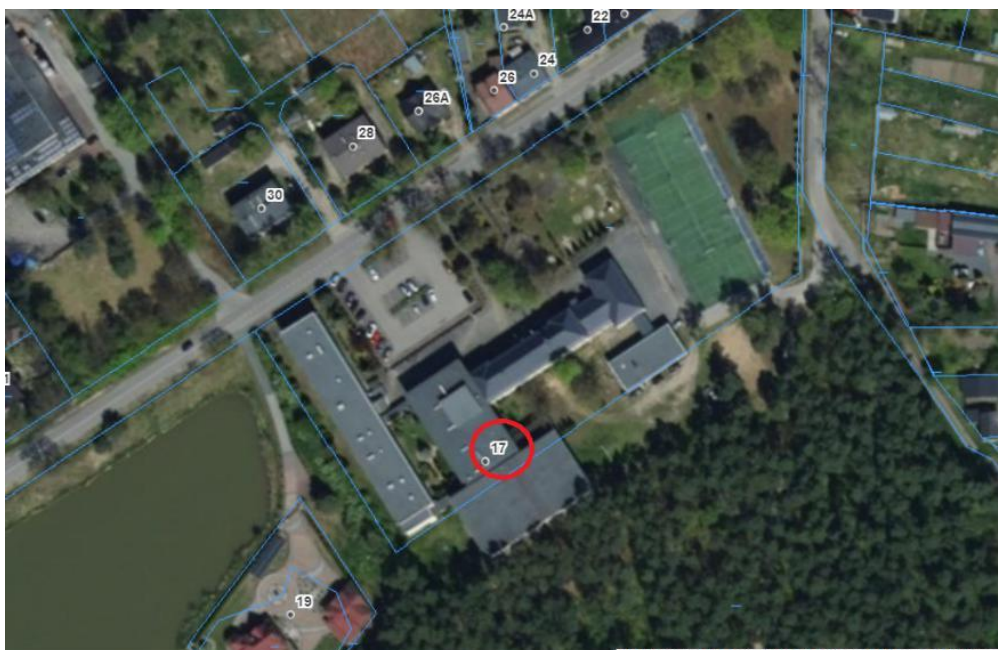


Figure 9 School building in Krzepice, location (source: Geoportal)

Table 8 Survey data for the building in Krzepice.

City	Krzepice
Subregion	North
Function	Education
Address	Krzepice, Mickiewicza 13/17
Heat source	heating oil
Usable area	1967 m ²
Air conditioning (number of units)	no
Mechanical ventilation	no
Electricity consumer units	electric water heaters: 3, refrigerators: 1, computer hardware: 2 servers + 49 computers
Wall thickness	0.41 m (brick), 0.32 m (hollow brick)
Wall material	brick, hollow brick
Insulation	polystyrene foam
Insulation thickness	40 mm
Roof type	flat
Attic/roof insulation	polystyrene foam, 20 mm
Floor insulation	no
Window frames	PVC



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Figure 10 School buildings in Krzepice, photograph.

When implementing the sustainable model for this building, particular attention should be paid to the following aspects:

- Energy demand
1. Heat demand depends on the building's structure, its surroundings, and how it will be used in the future. Each of these factors can be influenced to some extent by the building manager.
 2. Reducing the impact of environmental factors by shielding the building from the wind, which can be achieved by using protective vegetation (according to the typology recommendations or low). Naturally, both must be part of the development plan for the area surrounding the building.
 3. Shading with deciduous trees, which help cool the area in summer, while allowing solar energy to flow in during winter. Detailed guidelines concerning species are included in the typology prepared by the Silesian Botanical Garden Associations Union [18].
 4. Use of forced ventilation with heat recovery. In buildings with gravity ventilation, air exchange is usually too low when the building is in use and too high when the building is not in use. The signal controlling the intensity of circulation should be the measurement of CO₂ in rooms (taking into account the requirements specified by the Construction Law).
 5. Increasing humidity during winter, apart from its positive health effects, also makes it possible to lower the temperature and thus reduce the demand for heating. One of the recommended methods for increasing air humidity is to introduce plants into staff rooms [19].



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6. Efforts should be made to reduce the amplitude of environmental factors (air humidity, temperature, solar radiation intensity and wind speed).
7. Consider the use of conservatories and winter gardens, which can serve as staff areas, promotional areas, etc.
8. Implementing green walls. Green walls, which significantly improve the thermal insulation of a building, should be created using plants that do not damage plaster. Where possible, it is advisable for the green wall to have its own supporting substructure.
9. Green roofs are recommended; they can be created using drought-resistant perennial plants, such as epiphytic mosses in northern and/or shaded locations (extensive roofs), while intensive green roofs (shrubs and trees) are recommended over extensive ones in other cases. Attention should be paid to the size and type of the root system and waterproofing. A feasibility study must precede implementation [16].
10. It is recommended to install screens that limit the penetration of solar radiation into rooms, protect against overheating, and heat loss.
11. Thermal modernisation of a building should involve not only improving the insulation of walls, but also that of windows and doors.

- Sources of heat

1. Heat pumps should be considered first, with ground source heat pumps being strongly recommended over air source heat pumps if the location allows. When installing a heat pump, it is advisable to introduce photovoltaic panels.
2. Bio-mass fired boilers can be planned as an alternative to heat pumps or as a peak source. Low-maintenance biomass pellet boilers that meet eco-design requirements are particularly recommended.

- Sources of electricity

1. Due to their social function, public buildings should have a secure supply of electricity by being connected to the power grid. It is not advisable to plan buildings in an off-grid system.
2. The primary source of electricity generated in the building itself are photovoltaic panels, which can also be installed on green roofs with an additional raised support structure, enabling the functional implementation of green roofs. Where car parks or other small architectural structures are present, they should also be used for the installation of photovoltaic panels, provided they are not located in shaded areas. When installing panels on sloping roofs and façades, attention should be paid to the aesthetic aspect; the use of 'solar planes' is recommended.
3. The optimal angle for positioning photovoltaic panels depends on the building's function. For example, school buildings consume electricity mainly in the morning, and energy demand is reduced



Województwo
Śląskie

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in summer due to the holiday break. Hence, the optimal positioning of the panels is eastwards. Where the goal is to maximise the use of electricity for own needs without selling it to the grid, this entails different angles for the optimal positioning of the panels in both planes. This applies primarily to flat roofs.

4. It is recommended to consider photovoltaic panels in hybrid (water-cooled) PVT technology, using waste heat for UHW production or ground heat regeneration.

- Rainwater

1. It is recommended to use rainwater for watering green roofs, greenery surrounding buildings, cooling PVT panels, and securing grey water reservoirs.

- Education

1. Separate building operating instructions should be prepared for the manager and user, explaining the solutions used and the correct ways to use them.

- Energy storage facilities

1. When PV panels are installed, it is advisable to use electricity storage facilities. The size of the storage facility should be selected based on measurements of the electricity flow through the building.
2. When heat pumps are installed, it is advisable to use heat storage tanks that allow heat to be stored in an amount corresponding to daily consumption on a typical day during the heating season. The heat pump can fill the storage tank during periods of high availability of electricity from renewable energy sources. However, the possibilities of connecting an RES installation to an existing building should be analysed, especially in view of factors that preclude the implementation of a storage facility, such as the high temperature of the circulating medium in the heating system.

- Modernisation of energy management systems

1. Smart energy management systems.
2. Automatic control of heating, ventilation, and lighting
3. Integration with energy storage facilities (e.g. lithium-ion batteries).
4. The ability to control thermal conditions in the building by zone.

- Further comments

1. When planning vegetation, species with low allergenic risk and low invasive potential should be selected.
2. The use of anti-smog murals and anti-smog paints should be considered, especially for promotional purposes on empty walls of the building.



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3. Apply the principles of circular architecture, including the use of demolition waste in the planned modernisation.

7.2.2. Model 2: Żory – Primary School No. 4 (education)

The building is located at Boryńska 38C, 44-240 Żory (Figure 11 and Figure 12). It is in the western subregion of the voivodeship. According to survey data (Table 11Table 9), the building complex has a usable area of 2,305.7 m², is heated by a district heating network, and has a total annual energy consumption of 415,442.33 kWh, including 373,833.33 kWh for heating. The building is not insulated. Modernisation of heat sources and installation of renewable energy sources could lead to a reduction in annual CO₂ emissions of 169,041.44 kg/year.



Figure 11 School building in Żory, location (source: Geoportal)



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Table 9 Survey data for the building in Żory.

City	Żory
Subregion	West
Function	education
Address	Żory, Boryńska 38c
Heat source	district heating network
Usable area	2305,7 m ²
Air conditioning (number of units)	1, central
Mechanical ventilation	no
Electricity consumer units	Segments A, B: Flat reinforced concrete roof, covered with roofing felt. Segments D, E: Flat reinforced concrete, covered with polystyrene roofing felt.
Wall thickness	n.d.
Wall material	brick
Insulation	none
Insulation thickness	n.d.
Roof type	Segments A, B: Flat reinforced concrete roof, covered with roofing felt. Segments D, E: Flat reinforced concrete, covered with polystyrene roofing felt.
Attic/roof insulation	no
Floor insulation	no
Window frames	wooden



Figure 12 School buildings in Żory, photograph.

When implementing the sustainable model for this building, particular attention should be paid to the following aspects:

- Energy demand
1. Heat demand depends on the building's structure, its surroundings, and how it will be used in the future. Each of these factors can be influenced to some extent by the building manager.



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2. Reducing the impact of environmental factors by shielding the building from the wind, which can be achieved through the use of screening vegetation (according to the typology recommendations prepared by the Silesian Botanical Garden Association as part of the "Silesia: Restoring the Blue" project [18]) as well as through earthen embankments with vegetation (ground cover or low-growing plants). Of course, both must be part of the land-use plan for the area surrounding the building.
 3. Shading with deciduous trees, which help cool the area in summer, while allowing solar energy to flow in during winter. Detailed guidelines concerning species are included in the typology prepared by the Silesian Botanical Garden Associations Union [18].
 4. Use of forced ventilation with heat recovery. In buildings with gravity ventilation, air exchange is usually too low when the building is in use and too high when the building is not in use. The signal controlling the intensity of circulation should be the measurement of CO₂ in rooms (taking into account the requirements specified by the Construction Law).
 5. Increasing humidity during winter, apart from its positive health effects, also makes it possible to lower the temperature and thus reduce the demand for heating. One of the recommended methods for increasing air humidity is to introduce plants into staff rooms [19].
 6. Efforts should be made to reduce the amplitude of environmental factors (air humidity, temperature, solar radiation intensity and wind speed).
 7. Consider the use of conservatories and winter gardens, which can serve as staff areas, promotional areas, etc.
 8. Implementing green walls. Green walls, which significantly improve the thermal insulation of a building, should be created using plants that do not damage plaster. Where possible, it is advisable for the green wall to have its own supporting substructure.
 9. Green roofs are recommended; they can be created using drought-resistant perennial plants, such as epiphytic mosses in northern and/or shaded locations (extensive roofs), while intensive green roofs (shrubs and trees) are recommended over extensive ones in other cases. Attention should be paid to the size and type of the root system and waterproofing. A feasibility study must precede implementation [16].
 10. It is recommended to install screens that limit the penetration of solar radiation into rooms, protect against overheating, and heat loss.
 11. Thermal modernisation of a building should involve not only improving the insulation of walls, but also that of windows and doors.
- Sources of heat
1. Heat pumps should be considered first, with ground source heat pumps being strongly recommended over air source heat pumps if the location allows. When installing a heat pump, it is advisable to introduce photovoltaic panels.



Województwo
Śląskie

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2. Bio-mass fired boilers can be planned as an alternative to heat pumps or as a peak source. Low-maintenance biomass pellet boilers that meet eco-design requirements are particularly recommended.

- Sources of cooling

1. Except for very specific cases where waste heat is available, justifying the use of adsorption chillers, compressor units are the primary source of cooling. However, it is important to carefully consider whether air conditioning is truly necessary and whether thermal comfort can be achieved with passive methods.
2. First, a central source of cooling should be considered, with the cooling distributed via chilled water to rooms where cooling is necessary. A central cooling source allows for the use of cold storage.
3. For user comfort, individual air temperature control should be used in each room.

- Sources of electricity

1. Due to their social function, public buildings should have a secure supply of electricity by being connected to the power grid. It is not advisable to plan buildings in an off-grid system.
2. The primary source of electricity generated in the building itself are photovoltaic panels, which can also be installed on green roofs with an additional raised support structure, enabling the functional implementation of green roofs.
3. Where car parks or other small architectural structures are present, they should also be used for the installation of photovoltaic panels, provided they are not located in shaded areas. When installing panels on sloping roofs and façades, attention should be paid to the aesthetic aspect; the use of 'solar planes' is recommended. The optimal angle for positioning photovoltaic panels depends on the building's function. For example, school buildings consume electricity mainly in the morning, and energy demand is reduced in summer due to the holiday break. Hence, the optimal positioning of the panels is eastwards. Where the goal is to maximise the use of electricity for own needs without selling it to the grid, this entails different angles for the optimal positioning of the panels in both planes. This applies primarily to flat roofs.

- Rainwater

1. It is recommended to use rainwater for watering green roofs, greenery surrounding buildings, cooling PVT panels, and securing grey water reservoirs.

- Education

1. Separate building operating instructions should be prepared for the manager and user, explaining the solutions used and the correct ways to use them.

- Energy storage facilities



Województwo
Śląskie

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1. When PV panels are installed, it is advisable to use electricity storage facilities. The size of the storage facility should be selected based on measurements of the electricity flow through the building.
2. When heat pumps are installed, it is advisable to use heat storage tanks that allow heat to be stored in an amount corresponding to daily consumption on a typical day during the heating season.
3. The heat pump can fill the storage tank during periods of high availability of electricity from renewable energy sources. However, the possibilities of connecting an RES installation to an existing building should be analysed, especially in view of factors that preclude the implementation of a storage facility, such as the high temperature of the circulating medium in the heating system.

- Modernisation of energy management systems

1. Smart energy management systems.
2. Automatic control of heating, ventilation, and lighting.
3. Integration with energy storage facilities (e.g. lithium-ion batteries).
4. The ability to control thermal conditions in the building by zone.

- Further comments

1. When planning vegetation, species with low allergenic risk and low invasive potential should be selected.
2. The use of anti-smog murals and anti-smog paints should be considered, especially for promotional purposes on empty walls of the building.
3. Apply the principles of circular architecture, including the use of demolition waste in the planned modernisation.
4. Applying the principles of circular architecture, including the use of demolition waste in the planned modernisation.

7.2.3. Model 3: Skoczów – Special School Complex (education).

The building is located at Mickiewicza 12, 43-130 Skoczów (Figure 13 and Figure 14). It is in the southern subregion of the voivodeship and is administered by the voivodeship authorities. Without a doubt, the represents a challenge in terms of implementing SCM due to its historic nature and location.



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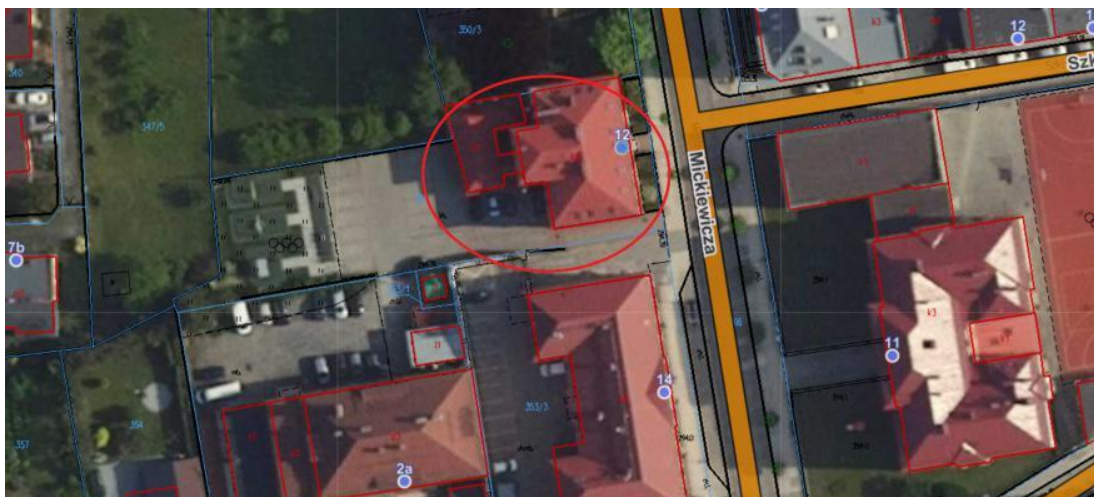


Figure 13 School building in Skoczów, location (source: Geoportal)



Figure 14 School building in Skoczów, photograph.

According to survey data (Table 10), the building complex has a usable area of 1,397 m², is heated with 8,186.82 m³ of natural gas per year, and has a total annual energy consumption of 79,068.73 kWh, including 72,771.73 kWh for heating. The building is insulated with 40 mm thick polystyrene foam. Modernising heat sources and installing renewable energy sources could lead to a reduction in annual CO₂ emissions by 15106.18 kg/year.



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Table 10 Survey data for the building in Skoczów.

City	Skoczów
Subregion	South
Function	education
Address	Skoczów, Mickiweicza 10
Heat source	gas
Usable area	1397 m ²
Air conditioning (number of units)	no
Mechanical ventilation	yes
Electricity consumer units	lighting, computers
Wall thickness	ground floor: 74 and 64, upper floors: 50
Wall material	brick
Insulation	none
Insulation thickness	n.d.
Roof type	sloping, tiled
Attic/roof insulation	no
Floor insulation	no
Window frames	old type, wooden

When implementing the sustainable model for this building, particular attention should be paid to the following aspects:

- Energy demand

1. Heat demand depends on the building's structure, its surroundings, and how it will be used in the future. Each of these factors can be influenced to some extent by the building manager.
2. Use of forced ventilation with heat recovery. In buildings with gravity ventilation, air exchange is usually too low when the building is in use and too high when the building is not in use. The signal controlling the intensity of circulation should be the measurement of CO₂ in rooms (taking into account the requirements specified by the Construction Law).
3. Increasing humidity during winter, apart from its positive health effects, also makes it possible to lower the temperature and thus reduce the demand for heating. One of the recommended methods for increasing air humidity is to introduce plants into staff rooms [19].
4. Efforts should be made to reduce the amplitude of environmental factors (air humidity, temperature, solar radiation intensity and wind speed).
5. Implementing green walls. Green walls, which significantly improve the thermal insulation of a building, should be created using plants that do not damage plaster. Where possible, it is advisable for the green wall to have its own supporting substructure.
6. Thermal modernisation of a building should involve not only improving the insulation of walls, but also that of windows and doors.



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- Sources of heat

1. Heat pumps should be considered first, with ground source heat pumps being strongly recommended over air source heat pumps if the location allows. When installing a heat pump, it is advisable to introduce photovoltaic panels.
2. Bio-mass fired boilers can be planned as an alternative to heat pumps or as a peak source. Low-maintenance biomass pellet boilers that meet eco-design requirements are particularly recommended.

- Sources of cooling

1. Except for very specific cases where waste heat is available, justifying the use of adsorption chillers, compressor units are the primary source of cooling. However, it is important to carefully consider whether air conditioning is truly necessary and whether thermal comfort can be achieved with passive methods.
2. First, a central source of cooling should be considered, with the cooling distributed via chilled water to rooms where cooling is necessary. A central cooling source allows for the use of cold storage.
3. For user comfort, individual air temperature control should be used in each room.

- Rainwater

1. It is recommended to use rainwater for watering green roofs, greenery surrounding buildings, cooling PVT panels, and securing grey water reservoirs.

- Education

1. Separate building operating instructions should be prepared for the manager and user, explaining the solutions used and the correct ways to use them.

- Energy storage facilities

1. When PV panels are installed, it is advisable to use electricity storage facilities. The size of the storage facility should be selected based on measurements of the electricity flow through the building.
2. When heat pumps are installed, it is advisable to use heat storage tanks that allow heat to be stored in an amount corresponding to daily consumption on a typical day during the heating season. The heat pump can fill the storage tank during periods of high availability of electricity from renewable energy sources. However, the possibilities of connecting an RES installation to an existing building should be analysed, especially in view of factors that preclude the implementation of a storage facility, such as the high temperature of the circulating medium in the heating system.



Województwo
Śląskie

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LIFE20 IPE/PL/000007 - LIFE-IP AQP-SILESIA-SKY

- Modernisation of energy management systems

1. Smart energy management systems.
2. Automatic control of heating, ventilation, and lighting.
3. Integration with energy storage facilities (e.g. lithium-ion batteries).
4. The ability to control thermal conditions in the building by zone.

- Further comments

1. When planning vegetation, species with low allergenic risk and low invasive potential should be selected.
2. The use of anti-smog murals and anti-smog paints should be considered, especially for promotional purposes on empty walls of the building.
3. Apply the principles of circular architecture, including the use of demolition waste in the planned modernisation.

7.2.4. Model 4: Katowice – Marshal's Office (administration)

Located at Henryka Dąbrowskiego 23, 40-035 Katowice (Figure 15 and Figure 16), the building dates back to the 1950s and is listed in the Municipal Register of Monuments. It is located in the central subregion of the Voivodeship. The location of the building at Plac Chrobrego in the centre of Katowice eliminates any solutions that would interfere with the building's surroundings.



Figure 15 Marshal's Office building in Katowice, location (source: Geoportal)



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Figure 16 Marshal's Office building in Katowice, photograph. (Jan Mehlih, GFDL, Creative Commons Attribution ShareAlike 2.5)

According to survey data (Table 11), the building complex has a usable area of 9,540 m², is heated by a district heating network, and has a total annual energy consumption of 1,426,095.12 kWh, including 865,458.12 kWh for heating purposes. The building is not insulated. Modernising heat sources and installing renewable energy sources could lead to a reduction in annual CO₂ emissions by 537150.60 kg/year. The building already has green walls and over 50 AC units installed. This is the largest of the buildings submitted to the Project.

Table 11 Survey data for the building in Katowice.

City	Katowice
Subregion	Central
Function	administration
Address	Katowice, Henryka Dąbrowskiego 23
Heat source	district heating network
Usable area	9540 m ²
Air conditioning (number of units)	260 (int.) / 50 (ext.)
Mechanical ventilation	no
Electricity consumer units	3 emergency water heaters, coolers: 15, computer hardware: 40 servers, 500 computers
Wall thickness	n.d.
Wall material	brick
Insulation	sandstone panel
Insulation thickness	n.d.
Roof type	flat
Attic/roof insulation	wool 20 cm
Floor insulation	no
Window frames	PVC



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When implementing the sustainable model for this building, particular attention should be paid to the following aspects:

- Energy demand

1. Heat demand depends on the building's structure, its surroundings, and how it will be used in the future. Each of these factors can be influenced to some extent by the building manager.
2. Use of forced ventilation with heat recovery. In buildings with gravity ventilation, air exchange is usually too low when the building is in use and too high when the building is not in use. The signal controlling the intensity of circulation should be the measurement of CO₂ in rooms (taking into account the requirements specified by the Construction Law).
3. Increasing humidity during winter, apart from its positive health effects, also makes it possible to lower the temperature and thus reduce the demand for heating. One of the recommended methods for increasing air humidity is to introduce plants into staff rooms [19].
4. Implementing green walls. Green walls, which significantly improve the thermal insulation of a building, should be created using plants that do not damage plaster. Where possible, it is advisable for the green wall to have its own supporting substructure.
5. Green roofs are recommended; they can be created using drought-resistant perennial plants, such as epiphytic mosses in northern and/or shaded locations (extensive roofs), while intensive green roofs (shrubs and trees) are recommended over extensive ones in other cases. Attention should be paid to the size and type of the root system and waterproofing. A feasibility study must precede implementation [16].
6. Thermal modernisation of a building should involve not only improving the insulation of walls, but also that of windows and doors.

- Sources of heat

1. Retaining the district heating network as a heat source. Heat sources for the district heating network will undergo an energy transition, ultimately leading to heat consumption without a carbon footprint.

- Sources of cooling

1. Except for very specific cases where waste heat is available, justifying the use of adsorption chillers, compressor units are the primary source of cooling. However, it is important to carefully consider whether air conditioning is truly necessary and whether thermal comfort can be achieved with passive methods.



Województwo
Śląskie

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2. First, a central source of cooling should be considered, with the cooling distributed via chilled water to rooms where cooling is necessary. A central cooling source allows for the use of cold storage.
3. For user comfort, individual air temperature control should be used in each room.

- Sources of electricity

1. Due to their social function, public buildings should have a secure supply of electricity by being connected to the power grid. It is not advisable to plan buildings in an off-grid system.
2. The primary source of electricity generated in the building itself are photovoltaic panels, which can also be installed on green roofs with an additional raised support structure, enabling the functional implementation of green roofs.
3. Where car parks or other small architectural structures are present, they should also be used for the installation of photovoltaic panels, provided they are not located in shaded areas. When installing panels on sloping roofs and façades, attention should be paid to the aesthetic aspect; the use of 'solar planes' is recommended.

- Rainwater

1. It is recommended to use rainwater for watering green roofs, greenery surrounding buildings, cooling PVT panels, and securing grey water reservoirs.

- Education

1. Separate building operating instructions should be prepared for the manager and user, explaining the solutions used and the correct ways to use them.

- Energy storage facilities

1. When PV panels are installed, it is advisable to use electricity storage facilities. The size of the storage facility should be selected based on measurements of the electricity flow through the building.
2. When heat pumps are installed, it is advisable to use heat storage tanks that allow heat to be stored in an amount corresponding to daily consumption on a typical day during the heating season. The heat pump can fill the storage tank during periods of high availability of electricity from renewable energy sources. However, the possibilities of connecting an RES installation to an existing building should be analysed, especially in view of factors that preclude the implementation of a storage facility, such as the high temperature of the circulating medium in the heating system.

- Modernisation of energy management systems

1. Smart energy management systems.
2. Automatic control of heating, ventilation, and lighting.



Projekt zintegrowany LIFE "Śląskie. Przywracamy błękit". Kompleksowa realizacja programu ochrony powietrza dla województwa śląskiego realizowany jest przy dofinansowaniu z Programu LIFE Unii Europejskiej oraz Narodowego Funduszu Ochrony Środowiska i Gospodarki Wodnej.

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3. Integration with energy storage facilities (e.g. lithium-ion batteries).
4. The ability to control thermal conditions in the building by zone.

- Further comments

1. When planning vegetation, species with low allergenic risk and low invasive potential should be selected.
2. The use of anti-smog murals and anti-smog paints should be considered, especially for promotional purposes on empty walls of the building.
3. Apply the principles of circular architecture, including the use of demolition waste in the planned modernisation.

7.2.5. Model 5: Pietrowice Wielkie – Community Services Centre (administration)

The building is located at 1 Maja 1, 47-480 Pietrowice Wielkie (Figure 17 and Figure 18). It is a former railway station building from 1855, located on the active section of the LK177 line, and is in the western subregion of the voivodeship.



Figure 17 Community Services Centre building in Pietrowice Wielkie, location (source: Geoportal)



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Figure 18 Community Services Centre building in Pietrowice Wielkie, photograph.

According to survey data (Table 12), the building complex has a usable area of 1,153 m², is heated with 34,825 m³ of natural gas per year, and has a total annual energy consumption of 342,892.56 kWh, including 309,555.55 kWh for heating. The building is insulated with 50 mm thick polystyrene foam. Modernising heat sources and installing renewable energy sources could lead to a reduction in annual CO₂ emissions by 87,571.49 kg/year.

Table 12 Survey data for the building in Pietrowice Wielkie.

City	Pietrowice Wielkie
Subregion	West
Function	aministration
Address	Pietrowice Wielkie 1-go Maja
Heat source	gas
Usable area	1153 m ²
Air conditioning (number of units)	2
Mechanical ventilation	yes
Electricity consumer units	
Wall thickness	0.24-.0.74 m
Wall material	brick
Insulation	polystyrene, wool, PE panel
Insulation thickness	10-20 cm
Roof type	sloping and flat
Attic/roof insulation	yes
Floor insulation	n.d.
Window frames	PVC



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When implementing the sustainable model for this building, particular attention should be paid to the following aspects:

- Energy demand

1. Heat demand depends on the building's structure, its surroundings, and how it will be used in the future. Each of these factors can be influenced to some extent by the building manager.
2. When planning the modernisation of a building, one needs to consider the possibility of changing its functional layout so that rooms intended for permanent human occupancy are located primarily on the south side, and auxiliary rooms on the north side.
3. Use of forced ventilation with heat recovery. In buildings with gravity ventilation, air exchange is usually too low when the building is in use and too high when the building is not in use. The signal controlling the intensity of circulation should be the measurement of CO₂ in rooms (taking into account the requirements specified by the Construction Law).
4. Increasing humidity during winter, apart from its positive health effects, also makes it possible to lower the temperature and thus reduce the demand for heating. One of the recommended methods for increasing air humidity is to introduce plants into staff rooms [19].
5. Implementing green walls. Green walls, which significantly improve the thermal insulation of a building, should be created using plants that do not damage plaster. Where possible, it is advisable for the green wall to have its own supporting substructure.
6. Green roofs are recommended; they can be created using drought-resistant perennial plants, such as epiphytic mosses in northern and/or shaded locations (extensive roofs), while intensive green roofs (shrubs and trees) are recommended over extensive ones in other cases. Attention should be paid to the size and type of the root system and waterproofing. A feasibility study must precede implementation [16].
7. It is recommended to install screens that limit the penetration of solar radiation into rooms, protect against overheating, and heat loss.
8. Thermal modernisation of a building should involve not only improving the insulation of walls, but also that of windows and doors.

- Sources of heat

1. Heat pumps should be considered first, with ground source heat pumps being strongly recommended over air source heat pumps if the location allows. When installing a heat pump, it is advisable to introduce photovoltaic panels.
2. Bio-mass fired boilers can be planned as an alternative to heat pumps or as a peak source. Low-maintenance biomass pellet boilers that meet eco-design requirements are particularly recommended.



Województwo
Śląskie

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- Sources of cooling

1. Except for very specific cases where waste heat is available, justifying the use of adsorption chillers, compressor units are the primary source of cooling. However, it is important to carefully consider whether air conditioning is truly necessary and whether thermal comfort can be achieved with passive methods.
2. First, a central source of cooling should be considered, with the cooling distributed via chilled water to rooms where cooling is necessary. A central cooling source allows for the use of cold storage.
3. For user comfort, individual air temperature control should be used in each room.

- Sources of electricity

1. Due to their social function, public buildings should have a secure supply of electricity by being connected to the power grid. It is not advisable to plan buildings in an off-grid system.
2. The primary source of electricity generated in the building itself are photovoltaic panels, which can also be installed on green roofs with an additional raised support structure, enabling the functional implementation of green roofs.
3. Where car parks or other small architectural structures are present, they should also be used for the installation of photovoltaic panels, provided they are not located in shaded areas. When installing panels on sloping roofs and façades, attention should be paid to the aesthetic aspect; the use of 'solar planes' is recommended.
4. It is recommended to consider photovoltaic panels in hybrid (water-cooled) PVT technology, using waste heat for UHW production or ground heat regeneration.

- Rainwater

1. It is recommended to use rainwater for watering green roofs, greenery surrounding buildings, cooling PVT panels, and securing grey water reservoirs.

- Education

1. Separate building operating instructions should be prepared for the manager and user, explaining the solutions used and the correct ways to use them.

- Energy storage facilities

1. When PV panels are installed, it is advisable to use electricity storage facilities. The size of the storage facility should be selected based on measurements of the electricity flow through the building.
2. When heat pumps are installed, it is advisable to use heat storage tanks that allow heat to be stored in an amount corresponding to daily consumption on a typical day during the heating season. The



Województwo
Śląskie

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heat pump can fill the storage tank during periods of high availability of electricity from renewable energy sources. However, the possibilities of connecting an RES installation to an existing building should be analysed, especially in view of factors that preclude the implementation of a storage facility, such as the high temperature of the circulating medium in the heating system.

- Modernisation of energy management systems

1. Smart energy management systems.
2. Automatic control of heating, ventilation, and lighting.
3. Integration with energy storage facilities (e.g. lithium-ion batteries).
4. The ability to control thermal conditions in the building by zone

- Further comments

1. When planning vegetation, species with low allergenic risk and low invasive potential should be selected.
2. The use of anti-smog murals and anti-smog paints should be considered, especially for promotional purposes on empty walls of the building.
3. Apply the principles of circular architecture, including the use of demolition waste in the planned modernisation.

7.2.6. Model 6: Bytom – Youth Culture Centre No. 2 (culture)

The building, located at Księdza Jerzego Popiełuszki 9, 41-906 Bytom (Figure 19 and Figure 20), is a modernist-style building dating back to the 1950s, situated in the central subregion of the voivodeship.



Figure 19 Youth Culture Centre No. 2 building in Bytom, location (source: Geoportal)



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Figure 20 Youth Culture Centre No. 2 building in Bytom, photograph

The building has a usable area of 1,765.89 m², is uninsulated, and has PVC windows installed. The building is located on the outskirts of the city and has a large plot of land. The building is heated with natural gas, consuming 18,003 m³ per year, and has a total annual energy consumption of 306,011.22 kWh, including 290,582.22 kWh for heating. The location of the building – the Karb district – is severely affected by mining damage. Information included in the survey are presented in Table 13. Modernising heat sources and installing renewable energy sources could lead to a reduction in annual CO₂ emissions by 88926.17 kg/year.

Table 13 Survey data for the building in Bytom

City	Bytom
Subregion	Central
Function	culture
Address	Bytom, Popietuszeki 9
Heat source	district heating network
Usable area	1765.89 m ²
Air conditioning (number of units)	no
Mechanical ventilation	no
Electricity consumer units	water heaters: 3, refrigerators: 2, computers: 8 + 1 server
Wall thickness	Basement walls 1 brick thick – 25 cm (0.25 m), the walls of the above-ground storey are 1.5 bricks thick, 38 cm (0.38 m). The facade is made with lime and cement plaster.
Wall material	brick
Insulation	none
Insulation thickness	
Roof type	multi hipped wooden roof, concrete ceilings
Attic/roof insulation	none
Floor insulation	floor on joists (partially)
Window frames	PVC



Projekt zintegrowany LIFE "Śląskie. Przywracamy błękit". Kompleksowa realizacja programu ochrony powietrza dla województwa śląskiego realizowany jest przy dofinansowaniu z Programu LIFE Unii Europejskiej oraz Narodowego Funduszu Ochrony Środowiska i Gospodarki Wodnej.

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When implementing the sustainable model for this building, particular attention should be paid to the following aspects:

- Energy demand

1. Heat demand depends on the building's structure, its surroundings, and how it will be used in the future. Each of these factors can be influenced to some extent by the building manager.
2. Reducing the impact of environmental factors by shielding the building from the wind, which can be achieved through the use of screening vegetation (according to the typology recommendations prepared by the Silesian Botanical Garden Association as part of the "Silesia: Restoring the Blue" project [18]) as well as through earthen embankments with vegetation (ground cover or low-growing plants). Of course, both must be part of the land-use plan for the area surrounding the building.
3. Shading with deciduous trees, which help cool the area in summer, while allowing solar energy to flow in during winter. Detailed guidelines concerning species are included in the typology prepared by the Silesian Botanical Garden Associations Union [18].
4. When planning the modernisation of a building, one needs to consider the possibility of changing its functional layout so that rooms intended for permanent human occupancy are located primarily on the south side, and auxiliary rooms on the north side.
5. Use of forced ventilation with heat recovery. In buildings with gravity ventilation, air exchange is usually too low when the building is in use and too high when the building is not in use. The signal controlling the intensity of circulation should be the measurement of CO₂ in rooms (taking into account the requirements specified by the Construction Law).
6. Increasing humidity during winter, apart from its positive health effects, also makes it possible to lower the temperature and thus reduce the demand for heating. One of the recommended methods for increasing air humidity is to introduce plants into staff rooms [19].
7. Efforts should be made to reduce the amplitude of environmental factors (air humidity, temperature, solar radiation intensity and wind speed).
8. Consider the use of conservatories and winter gardens, which can serve as staff areas, promotional areas, etc.
9. Implementing green walls. Green walls, which significantly improve the thermal insulation of a building, should be created using plants that do not damage plaster. Where possible, it is advisable for the green wall to have its own supporting substructure.
10. Green roofs are recommended; they can be created using drought-resistant perennial plants, such as epiphytic mosses in northern and/or shaded locations (extensive roofs), while intensive green roofs (shrubs and trees) are recommended over extensive ones in other cases. Attention should be paid to the size and type of the root system and waterproofing. A feasibility study must precede implementation [16].



Województwo
Śląskie

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11. It is recommended to install screens that limit the penetration of solar radiation into rooms, protect against overheating, and heat loss.
12. Thermal modernisation of a building should involve not only improving the insulation of walls, but also that of windows and doors.

- Sources of heat

1. Retaining the district heating network as a heat source. Heat sources for the district heating network will undergo an energy transition, ultimately leading to heat consumption without a carbon footprint.

- Sources of cooling

1. Except for very specific cases where waste heat is available, justifying the use of adsorption chillers, compressor units are the primary source of cooling. However, it is important to carefully consider whether air conditioning is truly necessary and whether thermal comfort can be achieved with passive methods.
2. First, a central source of cooling should be considered, with the cooling distributed via chilled water to rooms where cooling is necessary. A central cooling source allows for the use of cold storage.
3. For user comfort, individual air temperature control should be used in each room.

- Sources of electricity

1. Due to their social function, public buildings should have a secure supply of electricity by being connected to the power grid. It is not advisable to plan buildings in an off-grid system.
2. The primary source of electricity generated in the building itself are photovoltaic panels, which can also be installed on green roofs with an additional raised support structure, enabling the functional implementation of green roofs.
3. Where car parks or other small architectural structures are present, they should also be used for the installation of photovoltaic panels, provided they are not located in shaded areas. When installing panels on sloping roofs and facades, attention should be paid to the aesthetic aspect; the use of solar planes' is recommended.

- Rainwater

1. It is recommended to use rainwater for watering green roofs, greenery surrounding buildings, cooling PVT panels, and securing grey water reservoirs.

- Education

1. Separate building operating instructions should be prepared for the manager and user, explaining the solutions used and the correct ways to use them.



Województwo
Śląskie

Projekt zintegrowany LIFE "Śląskie. Przywracamy błękit". Kompleksowa realizacja programu ochrony powietrza dla województwa śląskiego realizowany jest przy dofinansowaniu z Programu LIFE Unii Europejskiej oraz Narodowego Funduszu Ochrony Środowiska i Gospodarki Wodnej.

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- Energy storage facilities

1. When PV panels are installed, it is advisable to use electricity storage facilities. The size of the storage facility should be selected based on measurements of the electricity flow through the building.
2. When heat pumps are installed, it is advisable to use heat storage tanks that allow heat to be stored in an amount corresponding to daily consumption on a typical day during the heating season. The heat pump can fill the storage tank during periods of high availability of electricity from renewable energy sources. However, the possibilities of connecting an RES installation to an existing building should be analysed, especially in view of factors that preclude the implementation of a storage facility, such as the high temperature of the circulating medium in the heating system.

- Modernisation of energy management systems

1. Smart energy management systems.
2. Automatic control of heating, ventilation, and lighting.
3. Integration with energy storage facilities (e.g. lithium-ion batteries).
4. The ability to control thermal conditions in the building by zone.

- Further comments

1. When planning vegetation, species with low allergenic risk and low invasive potential should be selected.
2. The use of anti-smog murals and anti-smog paints should be considered, especially for promotional purposes on empty walls of the building.
3. Apply the principles of circular architecture, including the use of demolition waste in the planned modernisation.

7.2.7. Model 7: Nędza – multifunctional building (culture) .

The building, located at ul. Sportowa 10, 47-440, Nedza (Western subregion), is a two-storey building with a flat roof, with a usable area of 1,265 m², heated with coal at a rate of 15 tonnes per year. Annual energy consumption is 128,625 kWh, of which 87,500 kWh is used for heating. It is located in a rural area, close to two large sports fields.



Projekt zintegrowany LIFE "Śląskie. Przywracamy błękit". Kompleksowa realizacja programu ochrony powietrza dla województwa śląskiego realizowany jest przy dofinansowaniu z Programu LIFE Unii Europejskiej oraz Narodowego Funduszu Ochrony Środowiska i Gospodarki Wodnej.

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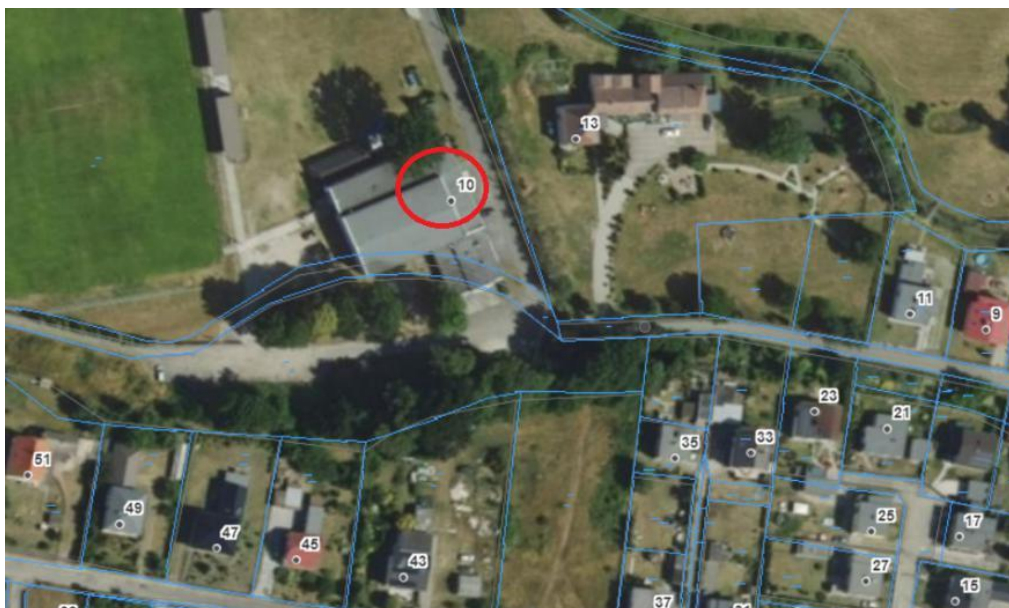


Figure 21 Multifunctional building in Nędza, location (source: Geoportal).



Figure 22 Multifunctional building in Nędza, photograph.

Modernising heat sources and installing renewable energy sources could lead to a reduction in annual CO₂ emissions by 59792.90 kg/year. The building is insulated with a thin layer of polystyrene foam



Projekt zintegrowany LIFE "Śląskie. Przywracamy błękit". Kompleksowa realizacja programu ochrony powietrza dla województwa śląskiego realizowany jest przy dofinansowaniu z Programu LIFE Unii Europejskiej oraz Narodowego Funduszu Ochrony Środowiska i Gospodarki Wodnej.

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(according to survey data, 0.12 cm, probable error). Information included in the survey are presented in Table 14

Table 14 Survey data for the building in Nędza.

City	Nędza
Subregion	West
Function	culture
Address	Nędza, Sportowa 10
Heat source	coal
Usable area	1265 m ²
Air conditioning (number of units)	no
Mechanical ventilation	no
Electricity consumer units	water heaters: 10 (including 6 boilers), refrigerators: 4, washing machines: 2, dryers: 2, sauna, computers; always on 1
Wall thickness	0.38 m
Wall material	brick + cinder block
Insulation	polystyrene foam
Insulation thickness	12 cm
Roof type	flat
Attic/roof insulation	wool 15 cm
Floor insulation	no
Window frames	PVC

7.2.8. Model 8: Opatów, Municipal Public Library (culture)

The building, located at ul. Tadeusza Kościuszki 1, 42-152 Opatów, is situated in the northern subregion of the voivodship, within the centre of a small town near the main road. The building is insulated with 12 cm thick polystyrene foam. It was built in 1909, but there is no information regarding its presence in the register of monuments.



Figure 23 Municipal Public Library in Opatów, location (source: Geoportal)



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Figure 24 Municipal Public Library in Opatów, photograph

According to survey data (), the building's usable floor space is 738 m² and it is heated with coal at a rate of 20 tonnes per year. Total annual energy consumption is 142,696.67 kWh, including 116,666.67 kWh for heating. According to calculations, modernising heat sources and installing renewable energy sources could lead to a reduction in annual CO₂ emissions of 74,117.73 kg/year, which represents the highest result per unit of area (203.6 kg/m²) among the buildings considered.

Table 15 Survey data for the building in Opatów

City	Opatów
Subregion	North
Function	administration
Address	Opatów, Kościuszki 1
Heat source	coal
Usable area	365 m ²
Air conditioning (number of units)	no
Mechanical ventilation	no
Electricity consumer units	water heaters: 1, computers: 6 (always on)
Wall thickness	n.d.
Wall material	brick, stone
Insulation	polystyrene foam
Insulation thickness	12 cm
Roof type	sloping
Attic/roof insulation	no
Floor insulation	polystyrene foam, 10 cm
Window frames	PVC



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When implementing the sustainable model for this building, particular attention should be paid to the following aspects:

- Energy demand

1. Heat demand depends on the building's structure, its surroundings, and how it will be used in the future. Each of these factors can be influenced to some extent by the building manager.
2. When planning the modernisation of a building, one needs to consider the possibility of changing its functional layout so that rooms intended for permanent human occupancy are located primarily on the south side, and auxiliary rooms on the north side.
3. Use of forced ventilation with heat recovery. In buildings with gravity ventilation, air exchange is usually too low when the building is in use and too high when the building is not in use. The signal controlling the intensity of circulation should be the measurement of CO₂ in rooms (taking into account the requirements specified by the Construction Law).
4. Increasing humidity during winter, apart from its positive health effects, also makes it possible to lower the temperature and thus reduce the demand for heating. One of the recommended methods for increasing air humidity is to introduce plants into staff rooms [19].
5. Implementing green walls. Green walls, which significantly improve the thermal insulation of a building, should be created using plants that do not damage plaster. Where possible, it is advisable for the green wall to have its own supporting substructure.
6. It is recommended to install screens that limit the penetration of solar radiation into rooms, protect against overheating, and heat loss.
7. Thermal modernisation of a building should involve not only improving the insulation of walls, but also that of windows and doors.

- Sources of heat

1. Heat pumps should be considered first, with ground source heat pumps being strongly recommended over air source heat pumps if the location allows. When installing a heat pump, it is advisable to introduce photovoltaic panels.
2. Bio-mass fired boilers can be planned as an alternative to heat pumps or as a peak source. Low-maintenance biomass pellet boilers that meet eco-design requirements are particularly recommended.

- Sources of cooling

1. Except for very specific cases where waste heat is available, justifying the use of adsorption chillers, compressor units are the primary source of cooling. However, it is important to carefully consider whether air conditioning is truly necessary and whether thermal comfort can be achieved with passive methods.



Projekt zintegrowany LIFE "Śląskie. Przywracamy błękit". Kompleksowa realizacja programu ochrony powietrza dla województwa śląskiego realizowany jest przy dofinansowaniu z Programu LIFE Unii Europejskiej oraz Narodowego Funduszu Ochrony Środowiska i Gospodarki Wodnej.

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2. First, a central source of cooling should be considered, with the cooling distributed via chilled water to rooms where cooling is necessary. A central cooling source allows for the use of cold storage.
3. For user comfort, individual air temperature control should be used in each room.

- Sources of electricity

1. Due to their social function, public buildings should have a secure supply of electricity by being connected to the power grid. It is not advisable to plan buildings in an off-grid system.
2. The primary source of electricity generated in the building itself are photovoltaic panels, which can also be installed on green roofs with an additional raised support structure, enabling the functional implementation of green roofs.
3. Where car parks or other small architectural structures are present, they should also be used for the installation of photovoltaic panels, provided they are not located in shaded areas. When installing panels on sloping roofs and façades, attention should be paid to the aesthetic aspect; the use of 'solar planes' is recommended.
4. It is recommended to consider photovoltaic panels in hybrid (water-cooled) PVT technology, using waste heat for UHW production or ground heat regeneration.

- Rainwater

1. It is recommended to use rainwater for watering green roofs, greenery surrounding buildings, cooling PVT panels, and securing grey water reservoirs.

- Education

1. Separate building operating instructions should be prepared for the manager and user, explaining the solutions used and the correct ways to use them.

- Energy storage facilities

1. When PV panels are installed, it is advisable to use electricity storage facilities. The size of the storage facility should be selected based on measurements of the electricity flow through the building.
2. When heat pumps are installed, it is advisable to use heat storage tanks that allow heat to be stored in an amount corresponding to daily consumption on a typical day during the heating season.
3. The heat pump can fill the storage tank during periods of high availability of electricity from renewable energy sources. However, the possibilities of connecting an RES installation to an existing building should be analysed, especially in view of factors that preclude the implementation of a storage facility, such as the high temperature of the circulating medium in the heating system.



Województwo
Śląskie

Projekt zintegrowany LIFE "Śląskie. Przywracamy błękit". Kompleksowa realizacja programu ochrony powietrza dla województwa śląskiego realizowany jest przy dofinansowaniu z Programu LIFE Unii Europejskiej oraz Narodowego Funduszu Ochrony Środowiska i Gospodarki Wodnej.

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4. In buildings equipped with central air conditioning and cooling distribution using chilled water, it is advisable to use cold storage facilities with a capacity corresponding to the cooling consumption on a typical day during the summer season.

- Modernisation of energy management systems

1. Smart energy management systems.
2. Automatic control of heating, ventilation, and lighting.
3. Integration with energy storage facilities (e.g. lithium-ion batteries).
4. The ability to control thermal conditions in the building by zone.

- Further comments

1. When planning vegetation, species with low allergenic risk and low invasive potential should be selected.
2. The use of anti-smog murals and anti-smog paints should be considered, especially for promotional purposes on empty walls of the building.
3. Apply the principles of circular architecture, including the use of demolition waste in the planned modernisation.

7.2.9. Model 9: Świerklaniec – Sports Centre (culture)

The building is located at Leśna 5, 42-622 Nowe Chechło (Swierklaniec gmina), and is in the central subregion of the voivodeship. The building dates back to the 1950s, is not insulated, and is situated in a suburban area.

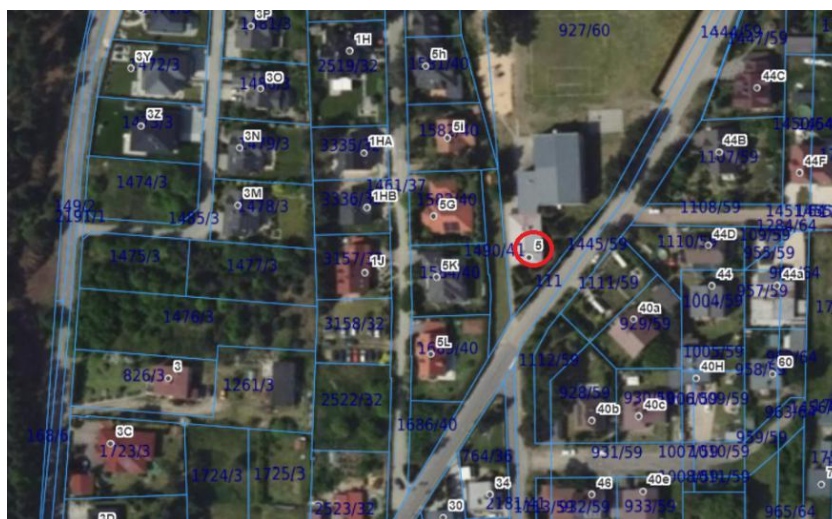


Figure 25 Culture facility in Świerklaniec, location (geoportal)



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Figure 26 Building in Świerklaniec, photograph.

The complex of buildings has a usable area of 690 m². Gas heating, with an annual consumption of 13,000 m³ per year, annual energy consumption is 123,264.80 kWh, including 115,564.80 kWh for heating purposes. Calculations have shown that CO₂ emissions can be reduced by up to 9,809.59 kg/year. Information included in survey are presented in Table 16.

Table 16 Survey data for the building in Świerklaniec.

City	Świerklaniec
Subregion	Central
Function	administration
Address	Świerklaniec, Nowe Chechło, Leśna 5
Heat source	gas
Usable area	773.3 m ²
Air conditioning (number of units)	4
Mechanical ventilation	no
Electricity consumer units	refrigerators: 2
Wall thickness	0.35 m
Wall material	brick
Insulation	none
Insulation thickness	
Roof type	flat and sloping
Attic/roof insulation	no
Floor insulation	
Window frames	PVC

When implementing the sustainable model for this building, particular attention should be paid to the following aspects:



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- Energy demand

1. Heat demand depends on the building's structure, its surroundings, and how it will be used in the future. Each of these factors can be influenced to some extent by the building manager.
2. Reducing the impact of environmental factors by shielding the building from the wind, which can be achieved both through the use of windbreak vegetation (according to the typology recommendations prepared by the Silesian Botanical Garden Association as part of the "Silesia: Restoring the Blue" project [18]) as well as through earthen embankments with vegetation (ground cover or low-growing). Of course, both must be part of the land-use plan for the area surrounding the building.
3. Shading with deciduous trees, which help cool the area in summer, while allowing solar energy to flow in during winter. Detailed guidelines concerning species are included in the typology prepared by the Silesian Botanical Garden Associations Union [18].
4. Use of forced ventilation with heat recovery. In buildings with gravity ventilation, air exchange is usually too low when the building is in use and too high when the building is not in use. The signal controlling the intensity of circulation should be the measurement of CO₂ in rooms (taking into account the requirements specified by the Construction Law).
5. Increasing humidity during winter, apart from its positive health effects, also makes it possible to lower the temperature and thus reduce the demand for heating. One of the recommended methods for increasing air humidity is to introduce plants into staff rooms [19].
6. Efforts should be made to reduce the amplitude of environmental factors (air humidity, temperature, solar radiation intensity and wind speed).
7. Consider the use of conservatories and winter gardens, which can serve as staff areas, promotional areas, etc.
8. Implementing green walls. Green walls, which significantly improve the thermal insulation of a building, should be created using plants that do not damage plaster. Where possible, it is advisable for the green wall to have its own supporting substructure.
9. It is recommended to install screens that limit the penetration of solar radiation into rooms, protect against overheating, and heat loss.
10. Thermal modernisation of a building should involve not only improving the insulation of walls, but also that of windows and doors.

- Sources of heat

1. Heat pumps should be considered first, with ground source heat pumps being strongly recommended over air source heat pumps if the location allows. When installing a heat pump, it is advisable to introduce photovoltaic panels.



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2. Bio-mass fired boilers can be planned as an alternative to heat pumps or as a peak source. Low-maintenance biomass pellet boilers that meet eco-design requirements are particularly recommended.

- Sources of cooling

1. Except for very specific cases where waste heat is available, justifying the use of adsorption chillers, compressor units are the primary source of cooling. However, it is important to carefully consider whether air conditioning is truly necessary and whether thermal comfort can be achieved with passive methods.
2. First, a central source of cooling should be considered, with the cooling distributed via chilled water to rooms where cooling is necessary. A central cooling source allows for the use of cold storage.
3. For user comfort, individual air temperature control should be used in each room.

- Sources of electricity

1. Due to their social function, public buildings should have a secure supply of electricity by being connected to the power grid. It is not advisable to plan buildings in an off-grid system.
2. The primary source of electricity generated within the building itself is photovoltaic panels, which can also be installed on green roofs using an additional elevated support structure that enables the functional implementation of green roofs. If there are parking lots or other small architectural structures, they should also be used to mount photovoltaic panels, provided they are not located in shaded areas. When installing panels on sloped roofs and facades, attention should be paid to aesthetics; the use of "solar panels" is recommended. Where car parks or other small architectural structures are present, they should also be used for the installation of photovoltaic panels, provided they are not located in shaded areas. When installing panels on sloping roofs and façades, attention should be paid to the aesthetic aspect; the use of 'solar planes' is recommended.
3. It is recommended to consider photovoltaic panels in hybrid (water-cooled) PVT technology, using waste heat for UHW production or ground heat regeneration.

- Rainwater

1. It is recommended to use rainwater for watering green roofs, greenery surrounding buildings, cooling PVT panels, and securing grey water reservoirs.

- Education

1. Separate building operating instructions should be prepared for the manager and user, explaining the solutions used and the correct ways to use them.



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- Energy storage facilities

1. When PV panels are installed, it is advisable to use electricity storage facilities. The size of the storage facility should be selected based on measurements of the electricity flow through the building.
2. When heat pumps are installed, it is advisable to use heat storage tanks that allow heat to be stored in an amount corresponding to daily consumption on a typical day during the heating season.
3. The heat pump can fill the storage tank during periods of high availability of electricity from renewable energy sources. However, the possibilities of connecting an RES installation to an existing building should be analysed, especially in view of factors that preclude the implementation of a storage facility, such as the high temperature of the circulating medium in the heating system.

- Modernisation of energy management systems

1. Smart energy management systems.
2. Automatic control of heating, ventilation, and lighting.
3. Integration with energy storage facilities (e.g. lithium-ion batteries).
4. The ability to control thermal conditions in the building by zone.

- Further comments

1. When planning vegetation, species with low allergenic risk and low invasive potential should be selected.
2. The use of anti-smog murals and anti-smog paints should be considered, especially for promotional purposes on empty walls of the building.
3. Apply the principles of circular architecture, including the use of demolition waste in the planned modernisation.

8. Circular architecture – complete building life cycle.

Circular architecture is an approach to designing, constructing and operating buildings according to the principles of the circular economy. This involves minimising waste, maximising the use of recycled materials and designing buildings in such a way that they can be easily modified, dismantled and reused.



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Main principles of circular architecture:

1. Waste minimisation – buildings are designed to reduce the consumption of new raw materials and facilitate their recycling at the end of their service life.
2. Reuse of materials – e.g. bricks, timber, concrete or steel can be used in new structures after appropriate treatment.
3. Modularity and flexibility – buildings are designed so that, instead of being demolished when no longer needed, they can be easily modified or expanded.
4. Sustainable materials – components with a low carbon footprint, recycled or biodegradable materials are used.
5. Energy efficiency – energy-saving technologies and renewable energy sources are utilised.

Application examples of circular architecture:

- **Office buildings made from recycled materials**, e.g. The Edge building in Amsterdam, which utilises modular solutions.
- **Modular houses** can be dismantled and moved to another location, minimising loss of materials.
- **Recycling building materials**, e.g. old bricks can be reused in new buildings instead of producing new ones.

Why is circular architecture important?

- Reduces CO₂ emissions and raw material consumption.
- Minimises construction waste.
- Extends the service life of materials and facilities.
- Reduces the costs of operating and demolishing buildings.

8.1. Application of circular architecture principles to the analysed implementation cases of Sustainable Construction Models

For existing buildings that were constructed according to traditional principles but will eventually be demolished, circular architecture principles focus mainly on selective demolition, reusing materials, and minimising waste. Thus, a number of key principles should be highlighted:



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1. Material audit and digital documentation. Prior to demolition, an audit of building materials should be performed to determine which components can be reused or recycled. Advanced technologies, such as 3D scanning and BIM (Building Information Modelling), can help identify valuable materials and their location within a building.
2. Selective dismantling instead of demolition. Instead of standard demolition, the building should be dismantled in stages to maximise the recovery of raw materials. This includes, among other things:
 - ✓ dismantling windows, doors, floors
 - ✓ selectively removing electrical and plumbing systems
 - ✓ recovering structural elements (steel, wood, concrete).
3. Reusing and recycling materials
 - Wood can be restored and used in new buildings or for furniture.
 - Steel and aluminium can be remelted and used in new projects.
 - Concrete and brick can be crushed and used as a road foundation or to produce new building materials.
 - Glass can be remelted into new glass panels.
4. Using materials in temporary structures
 - ✓ modular pavilions
 - ✓ shelters
 - ✓ urban infrastructure facilities (e.g. shelters, benches, fences).
5. Establishing local building material exchanges. Material exchange platforms can be established in cities. This approach is particularly popular in Scandinavian countries, where a central register of building materials is maintained.
6. Waste minimisation and responsible disposal. Materials which cannot be reused should be disposed of in line with circular economy principles, e.g. through recycling, composting (for certain organic materials) or conversion into new products.



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