



BEST PRACTICES for your house



Thermal modernisation in a trio with a heat pump and a photovoltaic installation –
how to ensure a warm and clean house

Investment in Wojciech's house

Under the technical supervision of Prof. Jacek Smółka, Ph.D. (Eng)

#SilesiaBlueSkyRestored



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ABOUT THE “SILESIA. BLUE SKY RESTORED” PROJECT

Starting from January 1st, 2022, the Silesian Voivodeship has been implementing a LIFE integrated project called “Silesia. Blue Sky Restored” whose main goal is smooth and effective implementation of the air protection programme for the Silesian Voivodeship and the anti-smog resolution.

The scope of the project covers the whole Silesian Voivodeship and all residents, engages 84 partners, including as many as 74 Silesian municipalities and cities. The total value of the project is € 16 515 020. The activities related to the project have already been recognised twice - the Silesian Voivodeship was awarded the title of the Energy Transformation Leader and won the 2022 WPROST Innovator Award.

The project includes both soft activities and investments, including the ones aimed at improving the energy efficiency of public buildings or increasing green areas by developing post-industrial areas.

ENVIRONMENTAL CONSULTANTS IN THE SILESIA VOIVODESHIP

As part of the project, a group of 74 representatives of municipalities was created, the so-called environmental consultants, who work locally within a municipality. In the municipalities that do not have their own environmental consultant, residents are supervised by sub-regional environmental consultants. Their role is to provide consultancy services for residents and initiate and coordinate local activities aimed at improving air quality.

The scope of the environmental consultants’ activities is broad and includes:

- assistance in obtaining funding - they help residents receive funding for replacing the heating source and improving the energy efficiency of buildings,
- technical consultancy - they provide professional advice on the replacement of the heating source improvement of energy efficiency,
- education in society - they educate residents on the improvement of air quality,
- initiating eco-friendly activities - they initiate and coordinate local activities and investments aimed at improving air quality and reduction of greenhouse gas emissions,
- inspections and compliance with regulations - they actively participate in the inspections of furnaces for compliance with the anti-smog resolution and the prohibition of waste disposal by burning,
- supporting local administration - they assist in obtaining external financial support for municipalities within the scope of environmental activities.

The full list of environmental consultants can be found at:
przywracamylekit.slaskie.pl/ekodoradcy

INVESTMENT IN WOJCIECH'S HOUSE

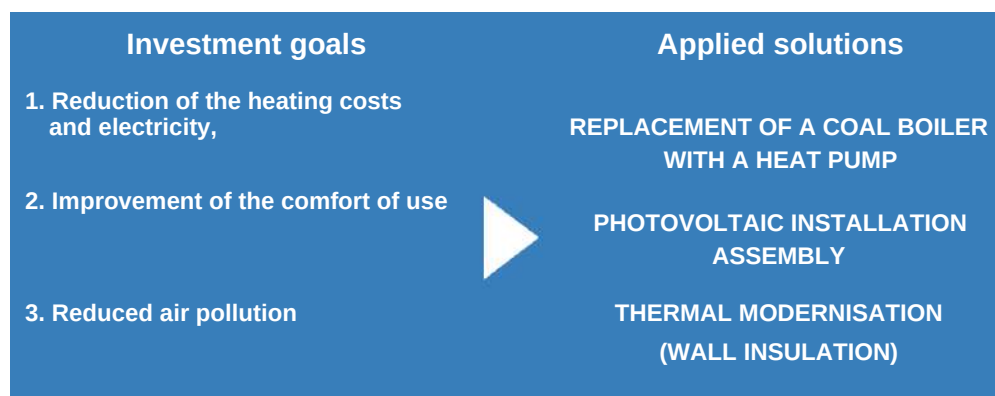
In winter, late autumn or early spring we think about what we can do to make our house warm, without spending too much money on heating. The high prices of coal or natural gas can take up a lot of the home budget. Wojciech had a similar dilemma – he lives in a village called Szymocice, in Racibórz county, and previously used coal to heat his single-family house.



Technical conditions before the investment

Building type	single-family detached house
Year built	1980
Usable floor area	170 m ²
Estimated annual building heating needs	±37 400 kWh (220 kWh/m ² x 270 m ²)
Number of floors	3 (including the basement)
Basement	full (under the whole building), unheated basement
Exterior walls construction technology	slag concrete block, 38 cm thick, uninsulated walls
Roof area	136 m ²
Roof construction	hip roof
Roofing material	torch-on membrane over full form-work
Window technology	PVC single-chamber
Heating source prior to the investment	top-loading coal boiler with the power of 21 kW (class 3)
Room heating type	panel radiators
Water heating method prior to the investment	boiler with a coil pipe (when the heating season ends – an electric heater)
Number of residents	1
Average annual hot utility water consumption	20 m ³
Average air temperature in the building during winter	23 °C

The assessment of his own financial resources and the possibility of achieving the investment goals affected the selection of the applied technological solutions. Wojciech considered a pellet boiler to heat the building, but eventually chose a heat pump. Moreover, Wojciech decided that it would be economically reasonable to equip the house with a photovoltaic installation and that the building would undergo thermal modernisation with wall insulation. The main investment related to the replacement of the heating system and installation of photovoltaic panes was completed in 2022. A year later – in the autumn of 2023 - Wojciech insulated the walls.



His main motivation to make changes was savings on the house maintenance costs. Thermal modernisation of the walls and the replacement of the old coal boiler with a heat pump, partially powered with photovoltaic panels, helped reduce the heating bills. The heat pump is also easy to use, as it completely eliminates the user's role related to supplying coal to the house, and then to the boiler, removal of ash, as in the case of a coal boiler. All he has to do to enjoy a warm house is set the right temperature on the controller. By making the decision to replace the coal boiler with an eco-friendly solution, such as the heat pump, Wojciech also contributed to ensuring proper air quality in the region.

Thanks to the electricity produced in his own photovoltaic installation, electric devices, including the heat pump, can be powered directly by that installation on sunny days. Such integration of modern and green solutions for house allowed for a significant reduction of consumption of the energy needed to heat the house and power electric devices.

It is also important to mention that the thermal modernisation and the heat pump and photovoltaic installation increased the value of the property.

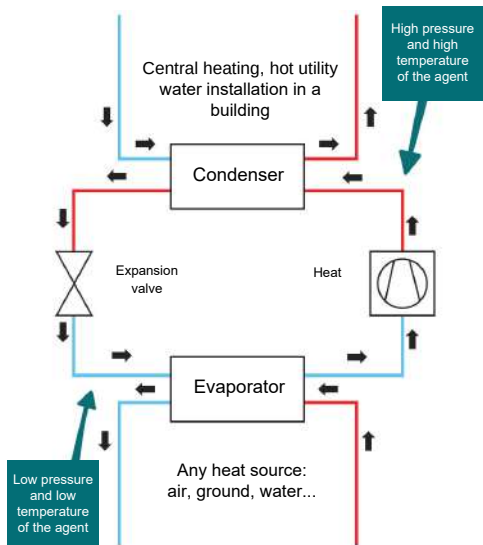
Are you considering a similar investment in your single-family house? If the answer is yes, read our publication and learn more about the steps you can take, not only to save money on bills, but also contribute to blue sky restoration in the Silesian Voivodeship!



APPLIED SOLUTIONS

Heat pumps

A heat pump is a device which produces heat for a central heating system and/or hot utility water installation while using the heat obtained from the environment (air, ground or water) and electricity used to power a compressor.



Heat pumps used in houses, even though there are several types, have four basic elements:

- Evaporator (heat exchanger) is a component in which the heat from outside is collected to a working agent (a special fluid) flowing inside the pump system compressor. The heat supplied the working agent fluid evaporates and flows into the compressor in the form of gas.
- The compressor is an element in which the working agent in the form of gas is compressed, which raises its pressure and temperature.
- Condenser (heat exchanger) is a component in which the working agent transfers the heat to the heat agent – water. As a result of the

heat transferred, the working agent condensates and flows to the expansion valve in liquid form.

- The expansion valve is an element that reduces the pressure and temperature of the working agent which flows into the evaporator in liquid form.

Usually, a heat pump is comprised of the so-called inside and outdoor unit. The outdoor unit collects the heat from the outside to the working agent

with lower temperature, and transfers the heat in the indoor unit to the working agent with higher temperature to the heating agent in the house installation. There are heat pumps in which these elements are placed in one external casing.

How does a heat pump work?

The construction and operation of a heat pump is similar to a refrigerator, where we transfer the heat from the inside of the fridge compartment outside to the kitchen space, thanks to a compressor. Depending on the type of the heat pump, heat is collected from the air, ground or water and transferred to the heating system, also thanks to a compressor, powered with an engine, which is powered with electricity.

Inside a heat pump, at the first stage, the working agent in liquid form with low pressure and low temperature collects heat from outside, where it is warmer (air, ground, water), and changes to gas in the heat pump's evaporator. At the second stage, the working agent in gas form inside the compressor raises its pressure and temperature. At the third stage, the working agent in gas form with high pressure and temperature transfers the heat to cooler water in the heating system and changes to liquid in the heat pump's condenser. At the last, fourth, stage, the working agent in liquid form in the expansion valve lowers its pressure and temperature. In this way the thermodynamic cycle ends and the first stage of the heat pump operation starts.

➤ A heat pump in a standard building of 100 m² requires about 3,000-4,000 kWh per year, to meet all heating needs, out of which about 2,000-3,000 kWh is the need for heat for central heating, while about 1,000 kWh is the need for heat for hot utility water circulation. These are estimated values which differ, depending on several factors, such as the building's heating needs, which depend mainly on the building's energy standard, energy tariff, number of residents, their lifestyle, etc.

➤ A heat pump has a long life expectancy because it usually lasts for around 20-25 years. Similarly to other heating devices, its high performance requires regular (usually annual) maintenance inspections.

➤ A heat pump is more effective when used with low-temperature heating, e.g. underfloor heating.

➤A heat pump ensures proper thermal comfort in a building, also at lower outside temperatures. It is equipped with an electric system supporting its operation which turns on when the outside temperature is below the optimum temperature for the evaporator to work. In such a situation, the costs of its operation are slightly higher.

Types of heat pumps

Heat pump types differ, depending on the lower heat source. Usually, heat pumps, as the lower heat source, use: air, ground, surface water, groundwater.



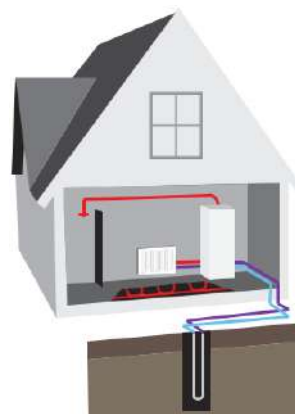
Air source heat pump

in which the heat for the evaporator is absorbed from air outside



Ground source heat pump

in which the heat for the evaporator is absorbed from the ground horizontal collector system



Ground source heat pump

in which the heat for the evaporator is absorbed from the ground vertical collector system



Water source heat pump

in which the heat for the evaporator is absorbed from surface water



Water source heat pump

in which the heat for the evaporator is absorbed from ground water

Heat pump type	How it works	Characteristics compared to other types of heat pumps
Air-air	They absorb the heat from air outside and transfer the heat at higher temperature directly to the inside of the building using ventilators placed in outdoor units.	+ integrated heating, ventilation and cooling systems (free air conditioning in rooms in summer when powered by a photovoltaic installation with appropriate power) + no medium (e.g. water) which reduces heat loss + lower costs + it does not require central heating installation, so it is perfect for buildings where its installation is impossible or cost-ineffective (e.g. summer cabins) - less efficient at lower temperatures - cannot produce hot utility water (an additional unit must be purchased) - relatively loud - lower comfort of use compared to water installations (e.g. underfloor heating)
Air-water	They absorb the heat from air outside and transfer the heat at higher temperatures to water-based systems, e.g. radiators or underfloor heating. Can be used to heat hot utility water.	+ relatively easy installation + multifunctionality (house, utility water heating, air conditioning) - less efficient at lower temperatures - relatively low cost - requires more space for installation



Heat pump type	How it works	Characteristics compared to other types of heat pumps
Ground-air	They absorb the heat from the ground and transfer the heat at higher temperature directly to the inside of the building using ventilators placed in outdoor units.	+ high efficiency + stable, regardless of the outside temperature + quiet and maintenance-free + ability to cool the building on hot days - high initial investment costs - requires expensive boreholes (for vertical collectors) or excavation (for horizontal collectors)
Ground-water	They absorb the heat from the ground and transfer the heat at higher temperature to water-based systems, e.g. radiators or underfloor heating. Can be used to heat hot utility water.	+ high efficiency + stable, regardless of the outside temperature + quiet and maintenance-free + multifunctionality (house, utility water heating, air conditioning) - high initial investment costs - requires expensive boreholes (for vertical collectors) or excavation (for horizontal collectors)
Water-water	They absorb the heat from underground or surface water and transfer the heat at higher temperature to water-based systems, e.g. radiators or underfloor heating. Can be used to heat hot utility water.	+ high efficiency + stability depends on the temperature and the stream of underground or surface water + quiet and maintenance-free + ability to cool the building on hot days - high initial investment costs - requires clean ground water

Benefits of installing a heat pump – summary

Characteristics	Benefits
Do not emit harmful exhaust gas	Eco-friendly
Cheaper to maintain than traditional heating systems	Energy saving
Require minimum maintenance and repairs	Comfort
Eliminate the risk of fire, explosion or carbon monoxide poisoning	Safety
Can heat rooms and utility water and cool rooms	Multifunctionality
Easy to install, long lifespan	Easy installation, long lifespan

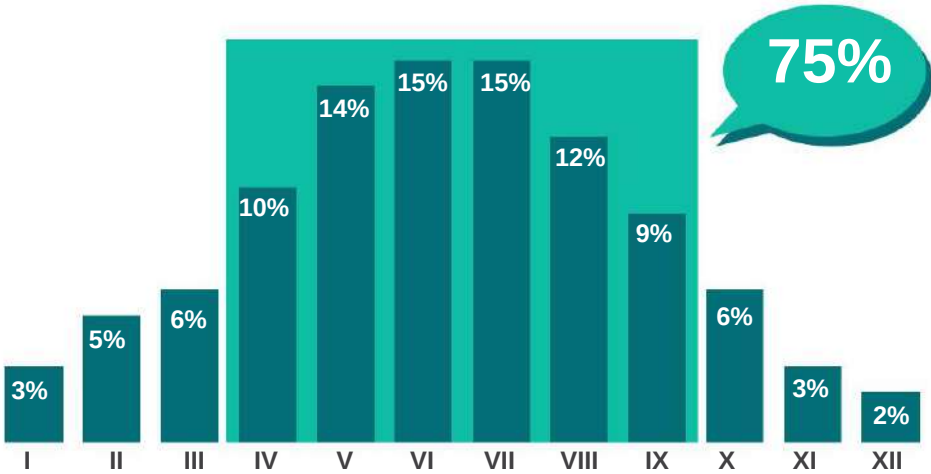


Photovoltaic panels

To minimise the costs of heating, preparing hot utility water and building cooling on hot days, it is worth considering an installation integrating a heat pump and a photovoltaic installation. This solution allows for the use of the energy from solar radiation to directly power a heat pump with free electricity. This solution is 100% green. Any possible energy surplus produced by the photovoltaic installation on sunny days can be stored in the form of heat in the utility water reservoir or sold to the power grid.

Most energy produced by the photovoltaic installation is dependent on the proper direction of photovoltaic panels in relation to sunrays and their inclination angle. In countries located north of the equator, including Poland, the biggest yield of the energy produced by photovoltaic panels is obtained when they are directed to the south. The optimal inclination angle of photovoltaic panels in our latitude is 30-40°. At https://re.jrc.ec.europa.eu/pvg_tools/en/ production of energy in actual photovoltaic installations with different power ranges located in many cities in Poland and other countries is monitored and archived, while the estimated distribution of energy production in photovoltaic installation in individual months is shown in the chart below:

Annual energy yield [%]



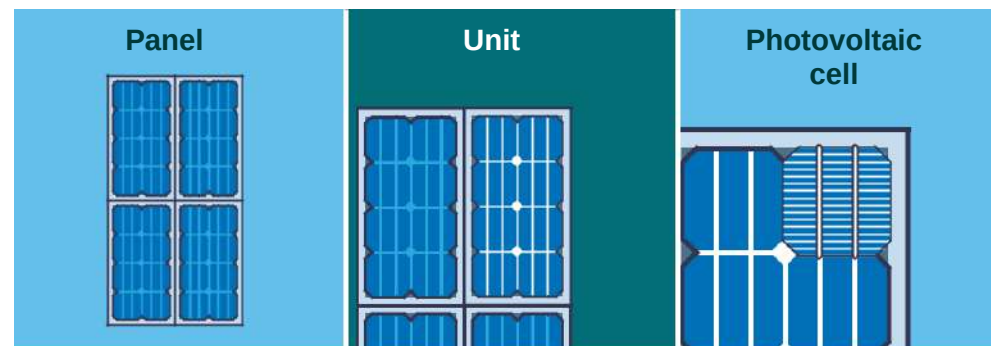
Photovoltaic panels are usually installed on the roofs of buildings. If the roof construction makes it impossible to install the panels, due to insufficient load-bearing capacity or inadequate roof position in relation to the cardinal points, the photovoltaic installation is placed on the ground using special constructions. Such installations are least frequent on the walls of buildings.

How does a photovoltaic installation work?

- Sunrays falling on the semiconductor panel in the photovoltaic cells, force the electrons out of their orbits in atoms, stimulating their movement which generates electric current flow.
- As a result, the so-called direct current is produced which cannot be used to power other devices in a house.
 - Using wires, direct current is transported to the inverter, where the energy produced is transformed into alternating current.
- After the energy is transformed, it is sent to the electrical installation in a house to power devices. Electricity surplus reaches the external power grid, moving through the bidirectional power meter.

A photovoltaic installation is comprised of photovoltaic panels (also called PV panels), an inverter, a bidirectional meter, wiring, as well as assembly and safety elements.

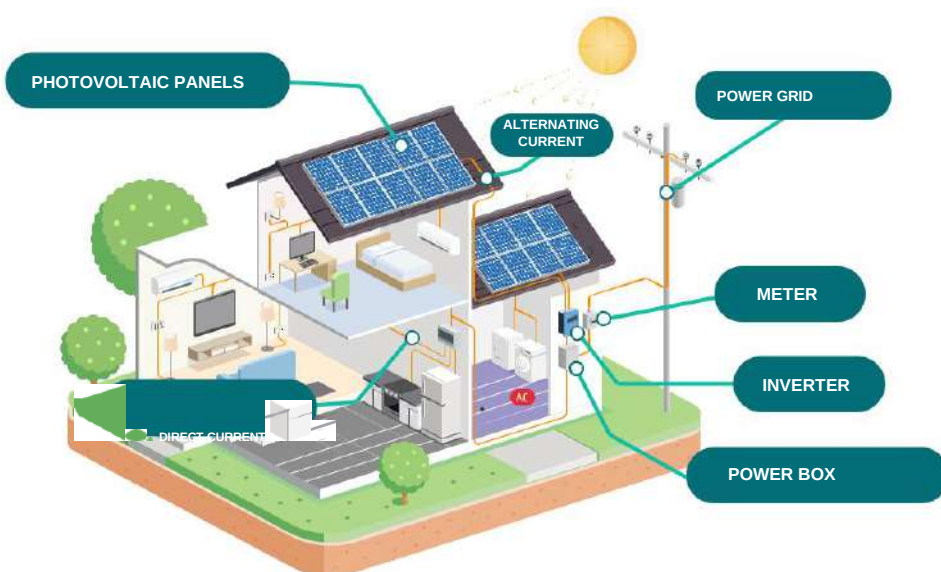
The most important elements of a photovoltaic installation are photovoltaic panels. They are made of photovoltaic cells, i.e. small semi-conductive elements, in which light-activated photovoltaic phenomenon occurs. The cells are connected in parallel in sets, called units, which when placed in one casing create photovoltaic panels.



The inverter is the heart of the photovoltaic installation. It transforms direct current produced by photovoltaic panels to alternating current. It also controls the whole installation to optimise energy production.

It particularly reduces voltage in situations when it is too high and turns on power supply if a failure is detected.

The bidirectional power meter measures electricity produced by the installation and then transferred to the power grid (in the so-called on-grid systems if it is connected to the external power grid). Moreover, the meter measures the electricity drawn from the power grid when the current needs of a household are higher than the electricity produced by the photovoltaic installation.



➤Positioning of the photovoltaic panels in the east-west direction increases the energy yield by approx. 10-15%, however, it also allows for an increased electricity self-consumption (using it in the household instead of releasing it to the power grid) using the hourly billing system.

➤It is assumed that the minimum inclination of photovoltaic panes in Poland is 10°, so the panels can self-clean (e.g. when it rains).

➤When planning a PV installation you should remember that the units and their construction add weight to a roof which must be handled by the roof truss. A single photovoltaic installation unit weights about. 16-20 kg. An installation with the power of 5 kWp can weigh up to 400 kg.

➤A photovoltaic installation can be also combined with the so-called energy storage or batteries which allow for gathering energy surplus and then using it when the amount of energy produced is insufficient. These types of systems require installation of hybrid inverters, more expensive than the ones in on-grid installation.

➤The whole photovoltaic installation operation is safe for the environment. It is all because of the fact that electricity production using a photovoltaic installation does not emit harmful chemical compounds. As a result, by using this solution, we contribute to the improvement of air quality in the region.

➤Most elements of a photovoltaic installation are recyclable, so up to 90% of materials can be recycled. In addition, the components are easy to maintain and repair, they last for up to 30 years.

How to specify the required power of photovoltaic panels

One of the most important issues to consider is determination of the household's needs in terms of the amount of electricity that the photovoltaic panels should produce. A well-designed photovoltaic installation should produce approximately the amount of electricity that we use annually. It is simple when we have been living in the house for a few years because we can specify energy consumption precisely. It is more difficult when we are moving to a new house. In this case, we need to calculate the estimated annual energy consumption. It depends on several factors.

The most important ones are: the number of residents, whether they work from home or not, the scope of use of the installed electrical devices. Moreover, we need to consider the following issues: heating method (e.g. are we going to use a heat pump?), air conditioning (e.g. are we going to cool the house on hot days?), house ventilation (e.g. are we going to use heat recovery ventilation?) and electric vehicle charging (e.g. are we going to charge an electric vehicle, bicycle or scooter using our own electrical installation?).

It is estimated that energy consumption in a typical household is:

- 2,800 kWh/year, for 2 adults and 1 child
- 4,200 kWh/year, for 2 adults and 2 children
- 5,600 kWh/year, for 2 adults and 3 children

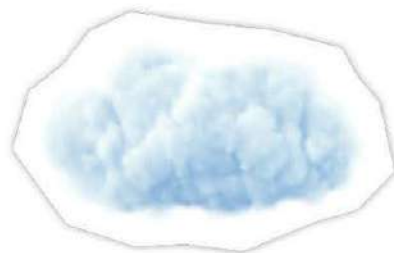
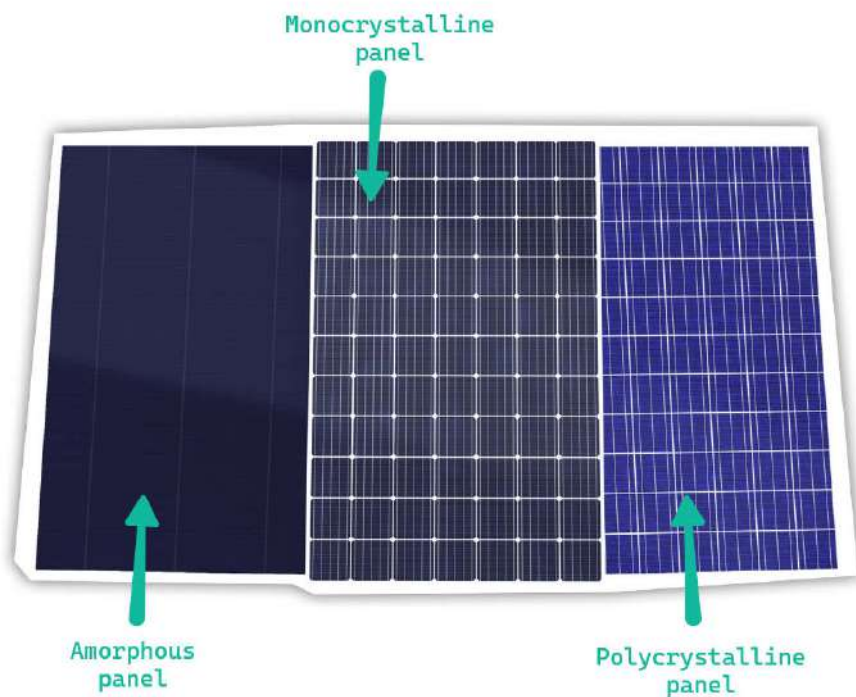
It is assumed that for every 1000 kWh we need about 1.25 kWp of the photovoltaic installation power.

And what area on the roof or a special construction do we need? The area required for a photovoltaic installation with the power of 1 kWp is around 5.5-6 m², which means that a PV installation with the maximum power of 4 kWp requires around 22-24 m², while a PV installation with the maximum power of 8 kWp covers around 44-48 m². Additionally, we must take into consideration the fact that the distance between the units and the roof edges cannot be less than approx. 0.5-1.0 m, and 0.4-1.0 m from the lightning protection installation.



Types of photovoltaic panels

Currently, we can choose between three main types of photovoltaic panels:



The table below presents the benefits of specific types of photovoltaic panels.

Type of photovoltaic panels	Characteristics
Amorphous panel	• unlike mono- and polycrystalline panels, which are comprised of a set of connected cells, the whole amorphous unit is a single photovoltaic cell • the cells are thin and elastic, so they can be installed on surfaces with a specific curvature • relatively cheap due to a relatively small amount of silicon used • low performance
Monocrystalline panel	• the cells are made of many small silicon crystals • the cells are black • high performance • more expensive compared to polycrystalline panels • smaller installation area with a specific power compared to an installation made of polycrystalline panels • long lifespan
Polycrystalline panel	• the cells are made of homogeneous silicon crystal with an ordered structure • the cells are blue • average performance • less expensive compared to monocrystalline panels

Benefits of installing photovoltaic panels – summary

Characteristics	Description	Benefits
They produce electricity that can be used in a household, and the surplus can be sold.	A photovoltaic installation helps lower electricity bills by up to 70%, although usually the value is much lower.	Lower bills for
They use an unlimited solar energy source	A photovoltaic installation allows for partial independence from external factors affecting the electricity prices. Moreover, the feeling of energy safety can increase the purchase of an energy storage.	Energy independence
They contribute to reduction of greenhouse gas emissions	Electricity production of solar radiation increases the share of clean energy in a household.	Positive effects on the environment
They have a positive effect on the house's image	A photovoltaic installation makes a building more attractive for potential buyers. A study carried out in the United States showed that a photovoltaic installation increases the value of a property by approx. 4-5%.	Increases property value
They are not harmful to the environment	A photovoltaic installation is not loud and does not have a negative impact on the health and well-being of humans or animals.	Comfort of use

Thermal modernisation of a building

What affects the energy efficiency of a building

1 The construction and shape of a house

Houses with basic and simple shapes have the best heating properties because a lot of heat is lost in corners and at the bends of dividing structures. The roof is another element of a building that may cause big heat loss. The highest level of energy efficiency can be achieved with a roof with the simplest shape possible, i.e. a gable or pent roof.

2 Building materials

Building materials (e.g. brick, concrete) used in the exterior dividing structures of a building have low isolation parameters, therefore the use of layered walls comprised of construction and insulating layers is a better solution, ensuring improved reduction of heat loss.

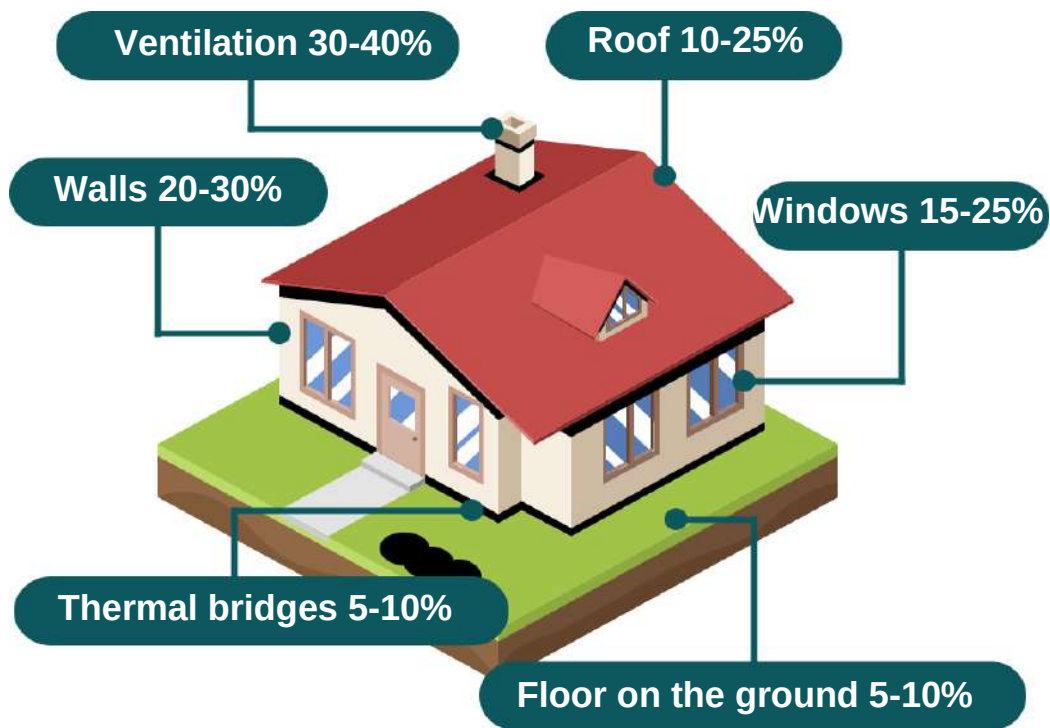
3 Insulation materials

The insulating layer in the dividing structure reduces the effect of the environment on the heat loss inside the building. It is important to remember that the insulation material has two functions – thermal and acoustic insulation. It is possible to use many types of insulation materials with different properties preventing the heat loss in a building and at the same time affecting the building's comfort of use.

4 Thermal conductivity index (lambda)

It is a parameter determining the thermal conductivity of a material. It is usually marked with the Greek symbol lambda (λ), and its value is stated in W/(m*K) (watts per meter-kelvin), showing how much heat flows in one second through 1 m² of a homogeneous material which is 1 m thick, with a temperature difference of 1 kelvin. The higher the value of this index, the more a given material is useful for insulation.

A building loses heat in many ways, which is shown in the infographic below.



- **Ventilation** – in the process of removing contaminated air from a room (e.g. steam, carbon dioxide) fresh air is supplied from outside, which must be reheated.
- **Roof** – usually the roof has the largest exterior dividing structure in terms of surface. According to the laws of physics, heated air which is lighter than cool air moves up, while heat gets outside through the roof.
- **Walls** – they constitute big exterior surface of a building. Walls in older houses usually are not well-insulated due to the lack of such requirements in construction regulations at that time.

- **Windows** – because of the window construction the values of heat resistance are the lowest compared to other dividing structures. Especially in the case of old windows heat loss may be big. The heat may escape through the leaks resulting from improperly adjusted window frames, through old sealing or gaps in places where they connect with plaster. Despite their small role in the whole exterior surface of a house, heat loss through windows is significant.
- **Thermal bridges** – places in exterior dividing structures through which the heat escapes from the house. They form in places made from low-quality material, where adjacent surfaces connect and in all leaks.
- **Floor on the ground** – contact with humid and cool ground causes more loss, although not as much as in the case of the roof.

➤ In order to assess the building's needs for energy and specify the scope of works necessary to reduce those needs, an energy audit is carried out. Such an analysis uses data on the building construction (roof, walls, windows, foundations), building location, ventilation and the system used to heat the building and hot utility water.



➤Energy standards for houses are set by the heat transfer coefficient (U) for individual dividing structures in the building. According to the currently applicable norms (specified in the Ordinance of the Minister of on the technical conditions that must be met by buildings and their location), the coefficient cannot be lower than: 0.15 W/(m²K) for roofs and flat roofs, 0.20 W/(m²K) for exterior walls, 0.30 W/(m²K) for floors on the ground, 0.90 W/(m²K) for vertical windows, 1.10 W/(m²K) for roof windows and 1.30 W/(m²K) for exterior doors.

The value of this coefficient includes the insulating properties of walls measured using the mentioned thermal conductivity index and wall thickness and thermal diffusivity index which specify the conditions for the exchange of heat between a wall and the heated air from outside and between a wall and the air surround the building.

In practice the value of the thermal conductivity index has the biggest impact on the insulating properties of a dividing structure and the index should be as low as possible, and the dividing structure should be as thick as possible.

Low thermal conductivity index means that a building releases the heat slower during winter and absorbs it slower during summer. As a result, the costs of heating and air conditioning are lower. These values must be taken into consideration when planning thermal modernisation, if we are going to apply for funding from outside sources.

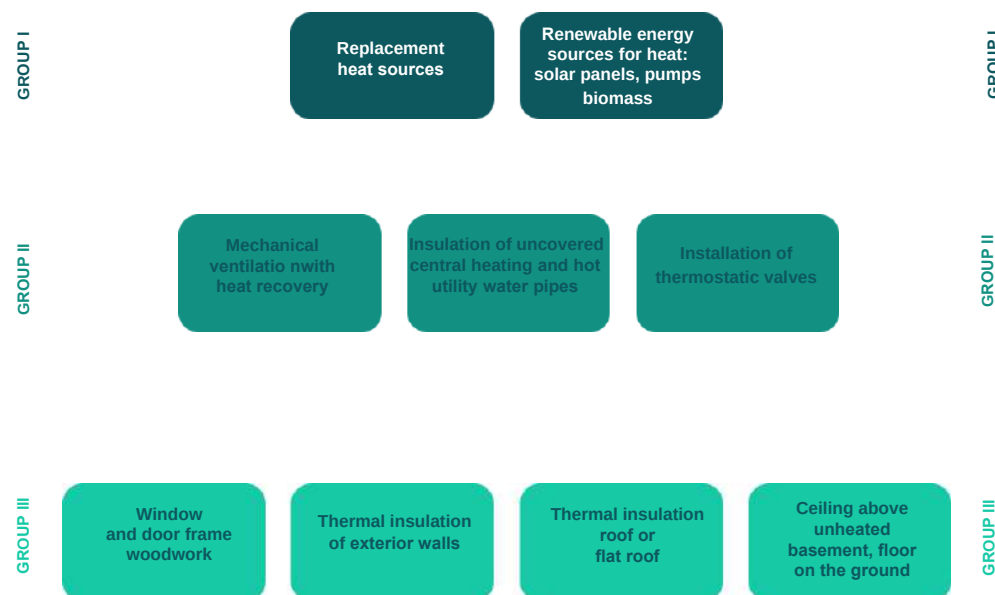
➤The best way to reveal the sources of heat loss in a building is thermographic inspection. Based on a photo taken with a special camera we can check if the dividing structures provide good insulation from outside and detect thermal bridges. Such inspection is recommended also after completing thermal modernisation. We can then assess if the contractor properly completed the modernisation works, i.e. if the insulation layer was applied correctly, there are no gaps or thermal bridges.

The scope of thermal modernisation of a building

The scope of thermal modernisation of a building may differ.

Thermal modernisation level	Activities aimed at achieving the desired level of thermal modernisation
Basic thermal modernisation	modernisation or replacement of the heating system, including replacement or modernisation of the heat source
Moderate thermal modernisation	- modernisation or replacement of the heating system, including replacement or modernisation of the heat source - replacement of window and door frame woodwork - insulation of exterior walls - roof insulation
Comprehensive thermal modernisation	- modernisation or replacement of the heating system, including replacement or modernisation of the heat source - use of renewable energy sources - modernisation or replacement of the hot utility water system - replacement of window and door frame woodwork - insulation of all exterior dividing structures (facades, flat roofs, ceiling/floor) - removal of thermal bridges (heat loss locations) - modernisation of the ventilation system

The path to comprehensive thermal insulation leads through completion of three groups of activities, presented in the infographic below.



Benefits of thermal modernisation of a building

The benefits of thermal modernisation include:

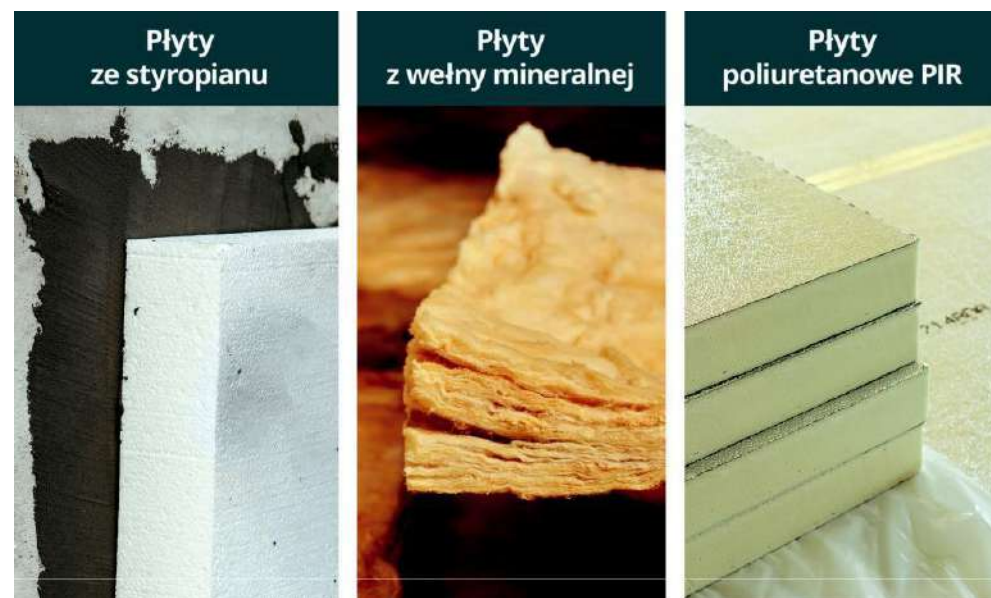
- ➔ Reduced consumption of the energy needed to heat a building and prepare hot utility water, and the costs related to the use of the building in a way ensuring a healthy microclimate in a house;
- ➔ Reduced negative impact of a building on the environment thanks to decreased heating needs in the heating season and reduced consumption of the energy used to prepare hot utility water, and fewer fossil fuels burnt and limited emissions of pollutants (e.g. ash) and greenhouse gases to the air.
- ➔ Improved quality of internal environment and residents' living comfort, including temperature and humidity of the air inside, the speed of airflow between rooms, noise and air pollution;

➔ Increased value of the property thanks to improved aesthetics and functionality of the building;

➔ Longer lifespan of the building related to additional works which are often undertaken, e.g. strengthening of the elements of the roof construction during its insulation or replacement of the roofing material.

Review of the insulation materials currently used in exterior walls

The primary role of the materials used for thermal insulation is proper heat loss prevention. Moreover, selection of a specific material should also include their price, resistance, comfort of use and acoustic insulation. Apart from the popular materials, such as styrofoam and mineral wool, in recent years new materials have emerged made from new raw materials, e.g. polyurethane boards (PIR).



Selection of a specific insulation material should consider its technical characteristics, including thermal conductivity index (the lower its value, the better insulating properties of a material), fire resistance, vapour permeability, acoustic insulation, physicochemical properties and the ease of workability.

The table below summarises basic types of insulation materials that are currently used to insulate exterior walls of buildings.

Type of material	Thermal conductivity index λ [W/(mK)]	Characteristics
Styropian	0,031 – 0,045	+ low weight + low water absorption + relatively low price (compared to other insulation materials) + easy of workability - poor fire resistance - low sensitivity to mechanical damage - vapour permeability - low level of acoustic insulation
Wetna mineralna	0,030 – 0,043	+ great fire resistance + high vapour permeability + good acoustic insulation + good elasticity - high porosity that can cause humidity absorption

Type of material	Thermal conductivity index λ [W/(mK)]	Characteristics
Polyurethane boards PIR	0,023 – 0,029	+ great fire resistance + low water absorption + high stiffness + good resistance to adverse weather + high level of acoustic insulation - relatively high price (compared to other insulation materials)



Technical solutions used in Wojciech's house

Air-water heat pump

Let's take a closer look at Wojciech's air-water heat pump. It is comprised of two units: an outdoor and indoor one. The outdoor unit is placed outside the building.

The outdoor unit is connected to the pipe system with the indoor unit, i.e. the one which is placed in the house. The components of the indoor unit include: a heat exchanger, a compressor, valves and a water reservoir. Its dimensions do not exceed the size of an average refrigerator, however, it is necessary to create a space for it in the house. The indoor unit was placed in the basement, so it would not take up the usable floor area in the main part of the house.

If a house does not have a basement or an attic, the indoor unit can be placed in a proper recess or in any other place with enough space. You can also consider purchasing a heat pump in which the indoor unit is integrated with the outdoor unit.

Technical specification of Wojciech's heat pump:

Heat power	12 kW
Coefficient of performance (COP) of the heat pump*	5
Indoor unit dimensions (width/height/depth)	130.5 X 129.5 x 52 cm
Outdoor unit dimensions (width/height/depth)	600 X 1800 x 650 mm
Indoor unit weight	195 kg
Outdoor unit weight	110 kg
Energy efficiency class	A++

* result for intake air temperature 7° C and water temperature upon release from the heat pump at 35°C, according to the EN 14511 standard.

The value of COP at the level of 5 means that for every electricity unit used the heat pump produces 5 heat units.

Photovoltaic installation

In his house Wojciech installed 12 photovoltaic panels. They were placed on the ground and directed to the south. This solution allowed for optimisation of electricity production from solar energy. The panels are positioned in such a way as to ensure as many sunrays fall on their surface during the day as possible. It was impossible to place all panels to the south on the hip roof, therefore they were installed on a supporting construction on the ground.



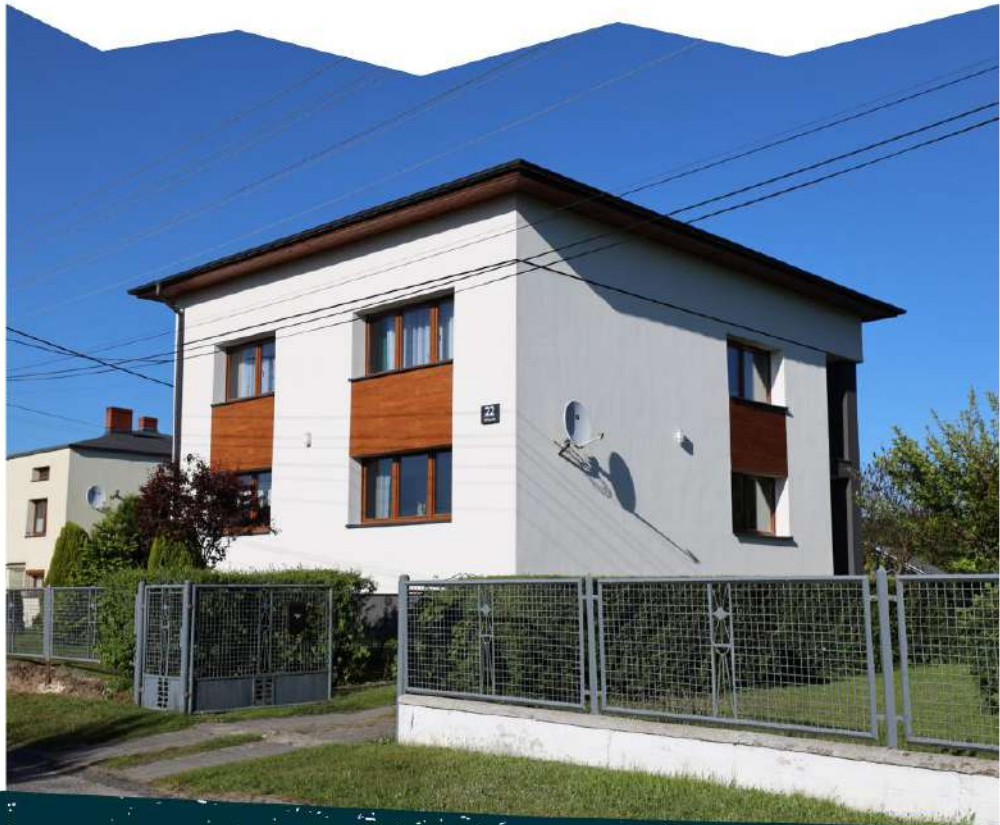
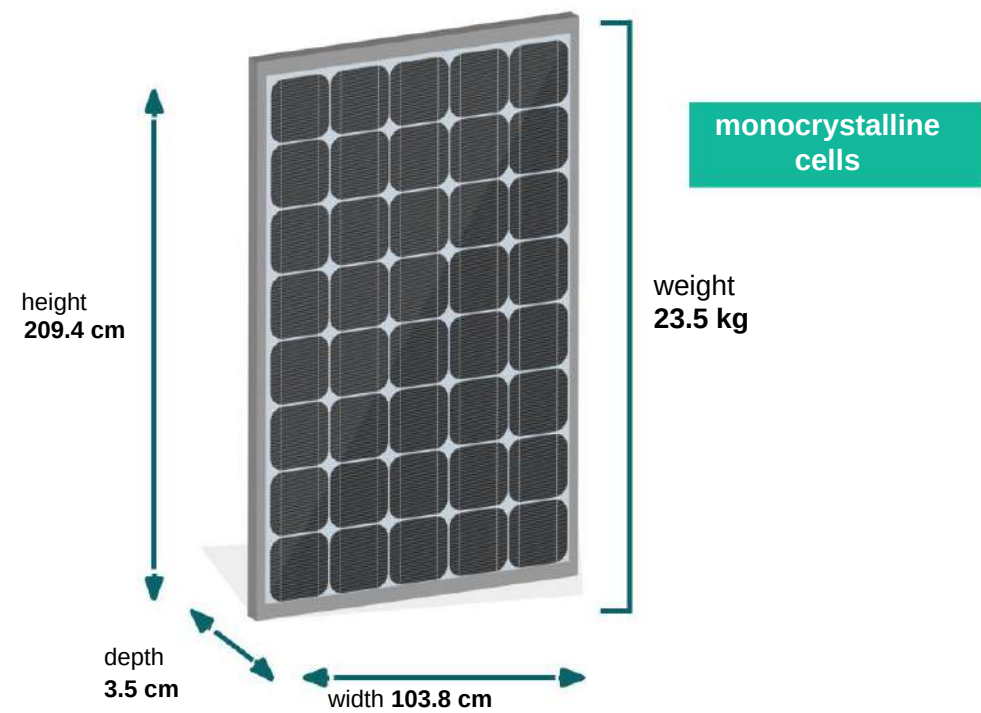
Wojciech chose a photovoltaic installation with the following technical characteristics:

Installation power	5.52 kWp
Single panel power	460 W
Performance	21.16%
Cell type	Monocrystalline

Thermal modernisation (wall insulation)

Wojciech decided to insulate the exterior walls of the building by himself, by doing the renovation. He insulated the walls in ETICS, a system in which a special thermal insulation material is affixed to the building exterior, and then covered with mortar (reinforced layer). The next step was covering the mortar with thin-layer plaster.

The main insulation layer selected by Wojciech during the thermal modernisation works included styrofoam sheets with a thickness of 15 cm and thermal conductivity index of 0.038 W/(mK). The thermal modernisation works improved the building's thermal insulation, significantly reducing the heat loss. As a result, the heat pump does not have to operate with full power to maintain a stable, convenient temperature in Wojciech's house.



EXPERT'S VIEW: ON GREEN HOME TECHNOLOGIES

"The consumption of energy needed to heat a building depends on its condition and heating and ventilation systems used. However, regardless of whether a building is new or have been used for some time, the most important thing is proper insulation of walls, roof, windows and floors, as well as reduction of loss related to room ventilation. Once the heat loss is reduced following thermal modernisation, one can focus on the selection of the proper type and power of the heat source and installation of central heating which ensures a convenient and financially viable indoor temperature of 20-21°C in the heating season. The whole process should be managed by a person who is trained in this field, e.g. an environmental consultant, due to the high investment costs and the complexity of technical issues.

The materials available for wall insulation ensure a significant reduction of the heat loss because their conductivity indexes are slightly different. Therefore the selection of a given material, with properly selected thickness of the insulation layer, may depend on the technical parameters, such as the acoustic insulation, vapour permeability and the total cost of thermal modernisation using a given insulation material.

A heat pump is a device which is a very efficient heat source, provided that it operates at a small temperature differences between the building's interior and exterior. Taking into consideration the conditions in Poland, a ground-water heat pump is a good choice because the ground temperature at appropriate depth is above zero and almost fixed during the heating season, but due to the financial reasons the most popular choice is an air-water heat pump. In both cases a heat pump is the most efficient when combined with low-temperature underfloor heating. If traditional radiators are used, we should remember about appropriate heating surface, to ensure the desired room temperature.

A photovoltaic installation produces electricity on sunny days, which during this period translates into significantly lower electricity bills. During the winter season, this type of installation can only partially power a heat pump, and in turn reduce the costs of heating using this type of heat source."

Prof. Jacek Smółka, Ph.D. (Eng)

Silesian University of Technology
Faculty of Energy and Environmental Engineering
Department of Thermal Technology



THE COST OF THE INVESTMENT, SAVINGS AND FUNDING

How much money did Wojciech spend to complete his investment?

Technologies	Cost incurred	Funding amount	Cost minus funding
Purchase and assembly of the photovoltaic installation	PLN 38,000	PLN 56,000	PLN 54,000
Purchase and installation of the heat pump	PLN 40,000		
Cost of the insulation materials used in the walls	PLN 32,000		
Installation of the the insulation materials used in the walls	PLN 0 (on one's own)	PLN	PLN
TOTAL	PLN 110,000	PLN 56,000	PLN 54,000

In relation to the investment Wojciech incurred the total cost of PLN 110,000, out of which the purchase and installation of the photovoltaic panels was PLN 38,000, the purchase and installation of the heat pump was PLN 40,000, while the cost of the insulation materials used in the walls was PLN 32,000. After completing the investment and submitting appropriate documents and with the assistance of an environmental consultant, Wojciech received a partial refund of the costs in the form of funding under the Clean Air program for the whole thermal modernisation program amounting to PLN 56,000.

To sum up, the final cost of the investment related to the purchase and installation of the photovoltaic panels, the heat pump and purchase of the insulation materials used in the walls, after receiving the refund of the costs in the form funding, was PLN 54,000.

Funding options are popular, so we recommend contacting an environmental consultant appointed for a given municipality. An environmental consultant will inform you about the current and future funding opportunities for the purposes related to thermal modernisation.

How have the costs related to heating, preparation of hot utility water and energy consumption changed?

2023 was the first full year the new heating installation (related to house heating) and photovoltaic installation (related to electricity production) were used. It was not until November in 2023 that Wojciech insulated the walls, so it slightly affected the reduced building's heating needs, considering the whole year.

The savings are shown in the comparison of the costs that would be generated if the coal boiler was still in use and the actual costs incurred while using the modernised heating system and electricity production using the photovoltaic installation.



Cost type	Hypothetical costs in 2023 if the old installation was still in use	Actual costs incurred in 2023 while using the new installation
Coal cost (7 x PLN 2,137/tonne – averaged price for 2023)	around PLN 15,000	-
Electricity production costs	PLN 1,500	PLN 9,500 (including the heat pump operation)
Cost of heating utility water	- (included in the coal cost)	- (included in the costs of electricity used by the heat pump and solar collectors)
Coal boiler maintenance cost	PLN 300	-
Heat pump inspection cost	-	PLN 350
TOTAL	PLN 16,800	PLN 9,850

By investing in the photovoltaic panels and the heat pump Wojciech saved PLN 6,950 in 2023 (PLN 16,800 – 9,850) on the costs related to heating the house, preparing hot utility water and energy consumption. Wojciech also noticed that in the first months following insulation of the walls the total energy consumption, whose significant part is produced by the heat pump, was reduced by approx. 25-30%. In the coming years it will bring measurable savings on the total costs of central heating, hot utility water and electricity.

All this means that the costs incurred in relation to the investment can pay off after 5-6 years, not to mention the comfort of use, reduction of the risk of lack of availability and coal price fluctuations, as well as environmental protection.



Wojciech's savings

PLN 6,950 saved in 2023 on the costs related to heating the house, preparation of hot utility water and energy consumption.



THE PROS AND CONS OF THE INVESTMENT



Financial aspect

Pros	Cons
• Use of free solar energy, resulting in lower bills for electricity, heating the house and utility water (in the case of photovoltaic installation and a heat pump). • Possibility of partial independence from external electricity providers (in the case of photovoltaic installation). • Heating optimisation thanks to a high level of automation (in the case of a heat pump). • Higher value of the building related to the use of modern technological solutions (in the case of a heat pump and photovoltaic installation). • Long lifespan with proper maintenance and repairs (in the case of a heat pump and photovoltaic installation). • Possibility to obtain funding for the investment (in the case of a heat pump and photovoltaic installation). • Higher rating of the tourist attractiveness of a given location which may contribute to the municipality's higher revenue from tourism (in the case of a heat pump and photovoltaic installation).	• High initial cost of the investment (in the case of a heat pump and photovoltaic installation). • High dependency of electricity production on weather conditions (in the case of photovoltaic installation). • Lower performance of an air source heat pump at very low temperatures outside the building (in the case of a heat pump).



Financial aspect

Pros	Cons
• Possibility to obtain electricity without polluting the environment (in the case of photovoltaic installation). • Possibility to heat the house without polluting the environment- (in the case of a heat pump).	• (in the case of a heat pump) Interference with the environment in the case of water and ground source heat pumps



Health aspect

Pros	Cons
• Contributing to reduction of the level of pollution in the environment, which will result in lower incidence rate for conditions caused by air pollution (in the case of a heat pump and photovoltaic installation). • Protection against the risk of carbon monoxide emission and explosion while using boilers powered with fossil fuels (in the case of a heat pump).	• (in the case of a heat pump) Noise created by the pump when it is working

Pros

- Cleanliness in the building resulting from the use of a clean heat source (in the case of a heat pump).
- Great comfort of use related to the high level of automation and no need to perform physical maintenance of the device (in the case of a heat pump).
- Possibility to use it to cool the building on hot days (in the case of a heat pump).

Cons

- When installed on the roof, with low load-bearing capacity it may be necessary to strengthen the construction of the roof (in the case of photovoltaic installation).
- Some people claim that it disrupts building's aesthetics (in the case of the photovoltaic installation).



STEPS REQUIRED TO COMPLETE A SIMILAR INVESTMENT

Step	Description	
1	First contact with an environmental consultant on the "Silesia. Blue Sky Restored" project who: - assess the building's needs for heat energy, - presents possible technological solutions including the investment goals, - specifies estimated costs related to the investment while using different technological solutions, - specifies available funding resources.	☐
2	Independent review of the advantages and disadvantages of individual technological solutions in relation to the cost of the investment and selection of the technological solution.	☐
3	Second contact with the environmental consultant who adjusts the parameters of use of the selected technological solution to the needs of the household.	☐
4	Market research on the companies offering the selected technological solutions, including initial verification (among family members, friends, etc.) and their reliability.	☐
5	Collecting quotations from the companies for installation, an analysis of the agreement and warranty terms and conditions.	☐
6	Selection of the best proposal.	☐

Step	Description	
7	Contacting the company that presented the best proposal and informing it about the decision.	☐
8	Following positive results of the verification of the reliability of the selected company, signing an agreement with the company on completion of the investment.	☐
9	Third contact with the environmental consultant who helps prepare proper documents that must be submitted to the entity providing funding (before the investment is completed, during or after its completion).	☐
10	After the investment is completed, thorough review of the conditions of use and maintenance of the installation, explanation of possible doubts in this matter.	☐
11	Submission of documents enabling funding for the completed investment to the entity providing the funding.	☐
12	Within 14 days of launching the installation, application submitted to the Central Emission Register of Buildings (https://ceeb.gov.pl/).	☐
13	If the costs related to the thermal modernisation were not funded from a different source, deduction from personal income tax (PIT), in the calendar year following completion of the investment, of the costs incurred in relation to the investment as part of the tax relief for thermal modernisation.	☐



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Office of the Marshall of Silesia Department
of Regional Projects Regional Centre for
Environmental Information

main office address: ul. Dąbrowskiego 23, 40-037 Katowice
mailing address: ul. Ligonja 46, 40-037 Katowice
phone: +48 (32) 77 40 554 | e-mail: przywracamyblekit@slaskie.pl
przywracamyblekit.slaskie.pl



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LIFE integrated project "Silesia. Blue Sky. Restored". Comprehensive implementation of the Air Protection Program for the Silesian Voivodeship funded by the EU's LIFE programme and the National Fund for Environmental Protection and Water Management.
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