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Renewable Energy Sources and Rationalisation of Energy Consumption in Buildings as a Way to Reduce Environmental Pollution

Obnovitelné zdroje energie a racionalizace spotřeby energie v budovách jako způsob snižování znečištění životního prostředí

The combustion of fuels, especially non-renewable ones, is associated with the systematic emissions of harmful substances into the atmosphere, which, in turn, adversely affects the quality of the environment and human health, deteriorates the condition of ecosystems and leads to negative climate changes. The aim of the work is to calculate the expected ecological effects of measures, aimed at reducing the energy demand for existing residential buildings, to a level corresponding to the requirements for the thermal protection of buildings in Poland. It has been estimated that, as a result of reducing the energy consumption for heating in buildings to the level of 65-70 kWh/(m²year), over 70 % in energy savings can be achieved compared to 2011. This will result in a general reduction of pollutant emissions of nearly 70 %.
A comparison was made of low low-stack emission reduction when using modern boilers fuelled by various energy carriers (hard coal, wood, natural gas, heating oil) in an educational building. The renewable energy potential of the European Union was also presented. The possibility of using renewable energy sources are illustrated, including an example of the use of geothermal water for heating public buildings.
Keywords: *environmental pollution, renewable energy sources, rationalisation of energy consumption, buildings, ecological effect*

Spalování paliv, zejména neobnovitelných, je spojeno s trvalým vypouštěním škodlivých látek do ovzduší, což nepříznivě ovlivňuje kvalitu životního prostředí a lidské zdraví, zhoršuje stav ekosystémů a vede k negativním změnám klimatu. Cílem práce je výpočet očekávaných ekologických účinků činností zaměřených na snížení energetické náročnosti stávajících obytných budov na úroveň odpovídající požadavkům na tepelnou ochranu budov v Polsku. Odhaduje se, že v důsledku snížení spotřeby energie na vytápění budov na úroveň 65–70 kWh/(m²rok) ize dosáhnout více než 70 % úspor energie ve srovnání s rokem 2011. Výsledkem bude celkové snížení emisí znečišťujících látek o téměř 70 %.
Bylo provedeno srovnání míry snížení emisí v případě použití moderních kotlů na různé nosiče energie (černé uhlí, dřevo, zemní plyn, topný olej) pro školní budovu. Rovněž byl představen potenciál obnovitelné energie v Evropské Unii. Možnosti využití obnovitelných zdrojů energie jsou ilustrovány mimo jiné na příkladu využití geotermální vody k vytápění veřejných budov.
Klíčová slova: *znečištění životního prostředí, obnovitelné zdroje energie, racionalizace spotřeby energie, budovy, ekologický efekt*

INTRODUCTION

According to data from the Worldwatch Institute, in the USA, the construction and operation of buildings absorbs about 65 % of the total energy consumption [38]. In the European Union, almost 50 % of the final energy consumption is used for heating and cooling, of which 80 % is used in buildings. Buildings are responsible for approximately 36 % of all CO_2 emissions in the EU [9, 15]. Currently, the largest share of the global energy production is non-renewable fuels, the combustion of which is associated with the systematic emissions of harmful substances into the atmosphere. This adversely affects the quality of the environment, deteriorates the condition of ecosystems and leads to negative changes in the Earth's climate. The emission of substances from combustion processes, especially particulate matter or polycyclic aromatic hydrocarbons, also poses a significant threat to human health [17, 18].

In recent years, significant progress has been made in the field of environmental protection, reducing the impact of the economic growth the environment. However, limiting the use of natural resources and reducing emissions still remain a significant challenge in implementing the principles of sustainable development and any zero-emission programme. At the 2019 climate summit, representatives of many countries agreed to initiatives aimed at counteracting climate change, including achieving net zero global carbon dioxide emissions by 2050 [31]. The priority of the

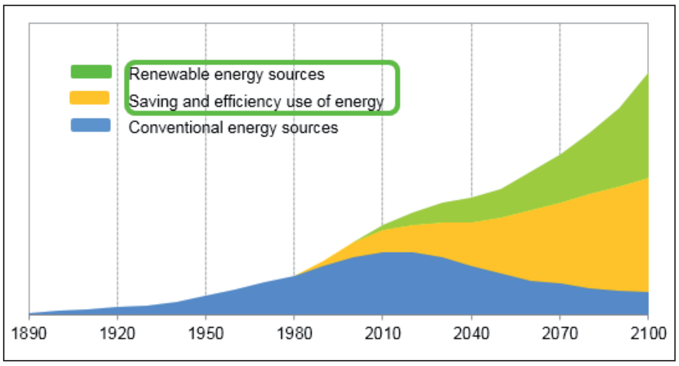


Figure 1 Increase in the global demand for energy and sources of its coverage [33]

European Union's climate and energy policy, valid until 2030, is to reduce greenhouse gas emissions by a minimum of 40 % compared to the 1990 levels, increase the share of energy produced from renewable sources to at least 32 % of the total energy consumption and increase energy efficiency by a minimum 32.5 % [12]. As part of the European Green Deal, the Commission intends to submit a proposal to increase this target level to 50-55 % and also recommends the reduction in greenhouse gas emissions by 80-95 % by 2050 [2, 9]. It is considered that the main way of obtaining clean energy will be through the use of renewable sources and its savings and effective use (Fig. 1.).

A strong stimulus to the development of energy-reducing technology in buildings and to the energy production from renewable sources include, the provisions set down in the Directive on the Energy Performance of Buildings, where all new buildings in the EU member states are obliged, by 31 December 2020, to be classed as nearly zero-energy buildings [9]. Each Member State is committed to establishing a long-term strategy to support the renovation of national housing and non-residential buildings, both public and private, to ensure high energy efficiency and the decarbonisation of those buildings by 2050, enabling the cost-effective conversion of existing buildings into nearly zero-energy consumption buildings [7, 9].

Since the high energy consumption of a large number of buildings is primarily associated with the low thermal insulation of building envelope, thermal modernisation is the first step on the way to reducing energy consumption for heating, and, thus, lowering the level of emissions. In order to reduce energy consumption and emissions, in addition to insulating the building's envelope or replacing the windows and doors, it is also extremely important to reconstruct local boiler houses, replacing boilers with high efficiency models, best powered by gas. Also, the reconstruction of internal heating installations, the insulation of pipes, equipping the installation with measuring elements enabling the weather or time regulation, as well as the liquidation of small local coal heating plants by connecting the buildings to the municipal heating network are all needed. It is estimated that due to the thermal modernisation, the annual energy savings in 2030 may reach approximately 26 % of the consumption in 2013 [21]. The possible potential of the energy savings of the thermal modernisation in buildings as part of individual activities is estimated at: 50-80 % for the modernisation of domestic hot water preparation systems using renewable energy sources, 33-60 % energy savings thanks to the improved thermal insulation of walls, 16-21 % from the modernisation of ventilation systems, 14-20 % from improving the thermal insulation of windows and doors and 10-12 % from regular inspections and repairs of central heating boilers.

Improving the energy efficiency of buildings is also a step on the way to achieving one of the goals of the current Polish climate policy, to achieve an 80 % reduction in greenhouse gas emissions by 2050 [6]. To achieve this target, it is also important to promote and implement environmentally friendly technologies based on renewable energy sources and to increase the use of these types of energy sources (Fig. 2.).

Encouraging the continuous development of technology that produces energy from all types of renewable sources is subject to the provisions set down in the Directive on the Promotion of the Use of Energy from Renewable Sources [8]. Despite almost a four times higher growth in the use of renewable energy compared to the increase in the use of other energy sources over five years, the share of renewable energy in 2018 of the total final energy consumption was only 11 %. The share of renewables in the total final energy consumption in buildings was slightly more favourable, at 13.6 % [31].

AIR QUALITY IN EU COUNTRIES AND POTENTIAL RISKS

The policy of the European Union in the field of reducing the emissions of harmful substances into the atmosphere has brought tangible effects, but the concentrations of air pollutants are still too high. It is estimated that around 95 % of European city inhabitants are exposed to pollutants at concentrations higher than levels considered harmful to their health [4]. The most harmful substance in the air, from the point of view of health protection, is particulate matter [1, 18, 20]. Gaseous pollutants such as nitrogen oxides, sulfur dioxide, carbon monoxide, polycyclic aromatic hydrocarbons and heavy metals are also toxic. The percentage share of the individual sources in the formation of these pollutants in EU countries in 2017 is presented in Table 1 [18, 19]. The low-stack emissions of substances is also troubling, which accumulate around the place of origin. One of the main sources of pollutants are low-efficiency furnaces and boilers fired with coal, wood, biomass, and often waste.

Table 1. Percentage share of the sources in the emissions of the chosen pollutants in EU in 2017 [18, 19]

Sources/Pollutions	$PM_{2,5}$	NO_x	SO_2	CO	VOC
Commercial and household heating	53	7	14	42	26
Heat and electricity production	5	18	48	4	3
Construction and industrial activities	17	15	24	23	41
Road transport	12	39	-	26	11

According to the 2018 WHO (World Health Organization) report, about

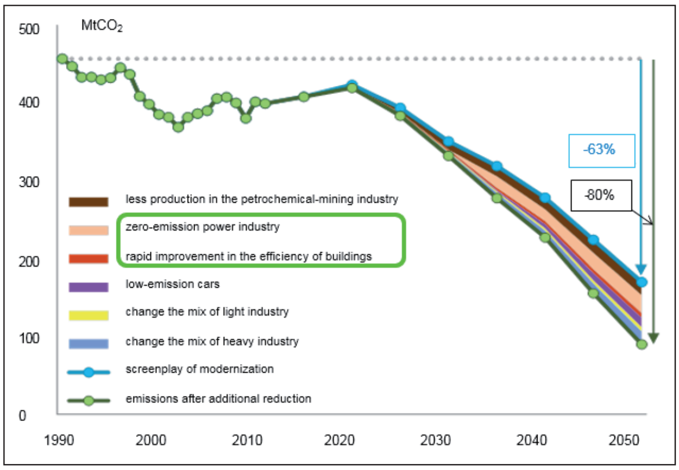


Figure 2 Forecast of greenhouse gas emissions reduction in Poland until 2050 [6]

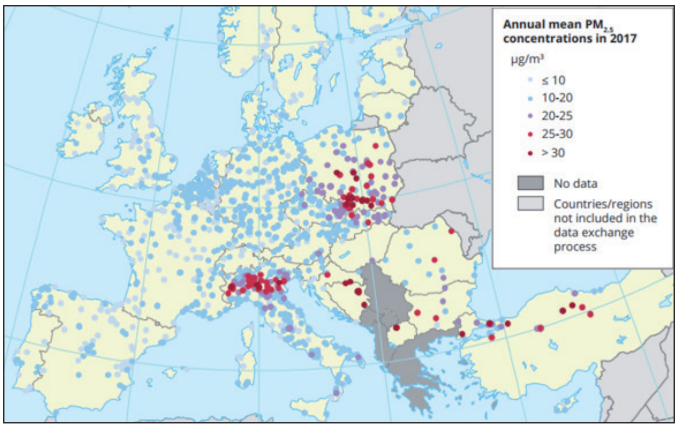


Figure 3 Annual concentrations of PM2.5 in 2017 [4]

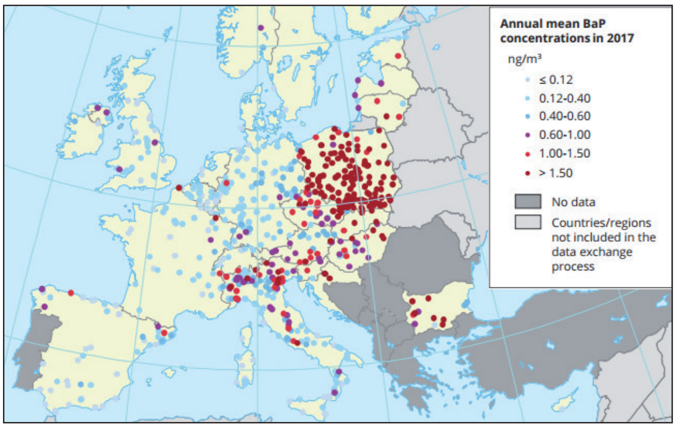


Figure 4 Annual concentrations of B(a)P in 2017 [4]

72 % of Polish, 83 % of Bulgarian and 90 % of Turkish cities exceed the air quality standards related to the limit in the concentration of particular substances [36]. Among the 50 most polluted cities with PM2.5 in the EU, 7 were in Bulgaria (the highest value is 42 μg/m³), 5 in Italy (31 μg/m³), 2 in the Czech Republic (33 μg/m³) and 36 in Poland (41 μg/m³). Since the last report (2019), the situation in Poland has deteriorated in this respect, as there were only 33 Polish cities on the list at that time. Compared to other European Union countries, the air quality in Poland is considered rather dangerous, especially when it comes to the emissions of particulate matter (Fig. 3) or benzo (a) pyrene (Fig. 4) in some areas [4, 34].

The air quality in the Czech Republic is constantly improving and is currently considered to be moderately hazardous. According to the IQAir report, the average annual concentration of PM2.5 in the Czech Republic in 2019 was 14.5 μg/m³ (Fig. 5) [1, 22]. The annual mean concentration of PM2.5 according to the WHO can be harmful if it exceeds 10 μg/m³. The WHO applies stricter emission recommendations than the EU, but they do not possess any legal force.

The cleanest city in Europe was Muonio in Finland, where the average PM2.5 level did not exceed 2 μg/m³ [1]. The WHO believes that concentrations above 10 μg/m³ may already be harmful, and air pollution is the greatest threat to health and life. In Poland, 43,000 deaths are attributed

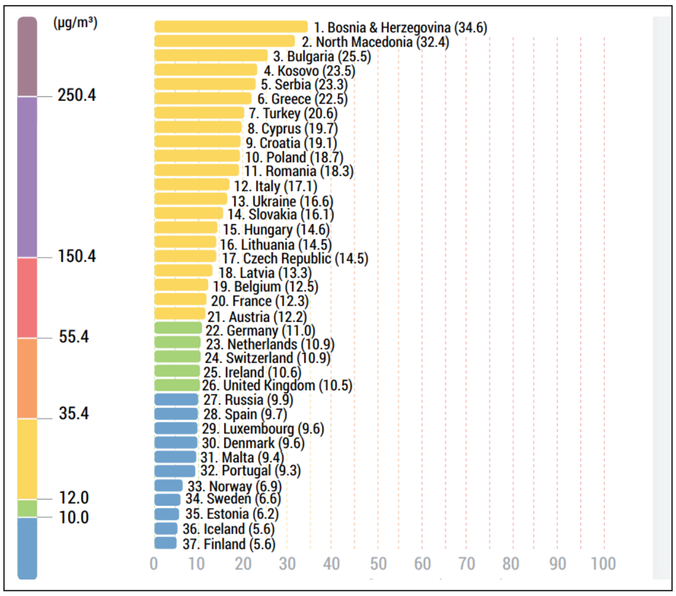


Figure 5 PM 2.5 annual mean concentrations in the individual European countries in 2019 [1]

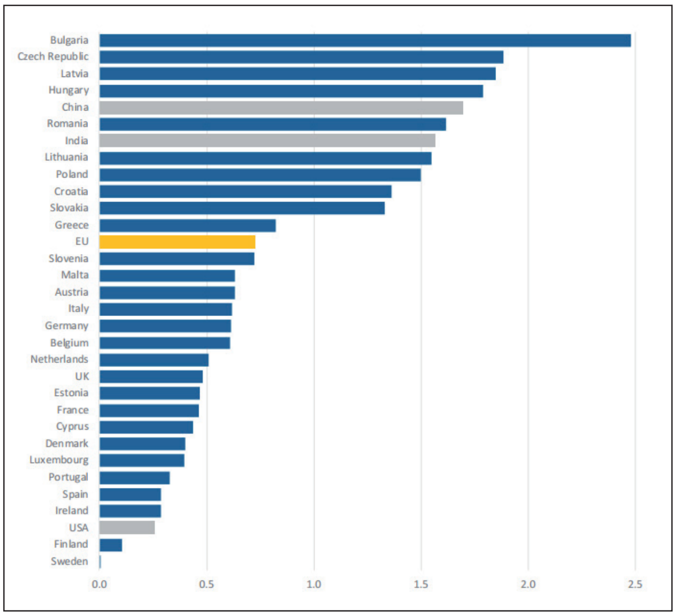


Figure 6 Healthy life years lost due to air pollution per 100 citizens [3]

to exposure to PM2.5 [37], the polluted air in the Czech Republic shortens the lives of 6-8,000 people annually [32]. In the EU, air pollution causes an average of more than 1,000 premature deaths each day, more than ten times the number killed in road accidents [3]. The number of healthy life years lost as a result of the air pollution for one hundred European citizens is shown in Fig. 6.

80% of the premature deaths from air pollution are due to heart disease and stroke. Other causes are cancer and respiratory diseases. Air pollution may cause up to twice as many deaths per year as previously assumed. It is estimated that the emissions of harmful substances into the atmosphere caused 790,000 additional deaths throughout Europe and approximately 8.8 million additional deaths worldwide [25, 26]. EU policies and legislation on clean air requires an improvement in the air quality, similar to the quality recommended by the WHO, using stricter, however, legally non-binding emission recommendations.

THE ECOLOGICAL POTENTIAL OF THERMAL MODERNISATION OF RESIDENTIAL BUILDINGS IN POLAND

The comprehensive and thorough thermal modernisation, leading to a reduction in energy consumption in buildings, at least to the level for which the optimal technical and economic parameters have been defined, should cover the largest possible range of optimal improvements presented, and the level and method of support for the measures should be specified by the state and indicate the scope of the works that the investor must finance from private funds. In addition to the energy effects, the economic effects (resulting from savings in the energy consumption, the development of the economic activity, an increase in the number of new jobs in the areas related to the thermal modernisation), social (resulting from the reduction of energy poverty and social exclusion) and ecological (resulting from the reduction of local air pollution and carbon dioxide emissions leading to climate change, the degradation of ecosystems and affecting human health) are expected after the thermal modernisation. The total economic benefits of investing in the thermal modernisation may exceed 1.5 times the value of the energy savings. Hints to the scale of the potential profits can be obtained by analysing previously conducted thermal modernisation programmes. Under a two-year support programme implemented in the Czech Republic, each 1 Euro invested resulted in 2.47 Euros in budget benefits. In Germany, support for thermal retrofitting and passive houses resulted in budget benefits estimated at 7.2 billion Euros. These countries are more advanced than Poland in the implementation of their thermal modernisation programmes. As part of improving the energy efficiency of buildings, Slovakia has spent 5.5 Euros per person annually, the Czech Republic 2.5 Euros per person, while less than 0.2 Euros per year was spent in Poland [15, 21].

In the European Union, there are approximately 200 million buildings in use (of which, approximately 6 million are located in Poland). The construction and operation of buildings in European Union countries is associated with approximately 40 % of the total energy consumption, but this value is higher in Poland [11, 15, 24]. According to the data given by the Polish National Energy Conservation Agency, the level of unit energy consumption in many buildings in Poland is around 120-300 kWh/(m^2year), while this figure does not exceed 50 kWh/(m^2year) in other European countries [11, 15, 21]. The greatest potential for energy efficiency is found in residential buildings, which are one of the main consumers of energy in the modern economies of developed countries. Buildings constructed in different years have different energy characteristics, and are also powered by energy sources with different levels of efficiency and based on different types of fuel. In Poland, coal is mainly used, while in other European Union countries gas predominates. An analysis into reducing energy consumption in residential buildings, and consequently the emission of pollutants generated during the production, clearly shows the highest efficiency in activities related to spatial heating, accounting for about 60-70 % of the energy intensity of a building and is the direct cause of the relatively high operational energy intensity of these facilities [13, 14]. Such activities may be carried out in the quantitative scope related to the reduction of energy demand for spatial heating by adapting to energy requirements, or in the qualitative scope related to the reduction or elimination of the emissivity of energy generation sources for heating.

In order to determine the estimated level of energy and ecological efficiency of Polish residential buildings, a simplified quantitative characterisation has been made of the potential effects of the activities that reduce the energy consumption for heating residential buildings on a scale of the whole country. The focus was on reducing the energy consumption for the heating of buildings to a value of 70 kWh/(m^2year) in multi-family buildings and 65 kWh/(m^2year) for single-family buildings. These values result from the requirements that will apply from 2021 and omits the estimates of the energy consumption for hot water preparation. Attention was focused on a group of residential buildings that were inhabited and heated. The detailed data on the residential buildings in Poland come from the general population and housing census conducted every 10 years, most recently in 2011, therefore, the efficiency analysis refers to this year [5, 23]. The aforementioned group included 5,182,330 facilities, and the usable floor area of the flats located there was 868,084.1 thousand m^2 in total (Table 2).

Table 2 Residential buildings built in Poland in different years

Construction period of residential buildings	Number of residential buildings		Unit energy consumption for buildings heating	
			single-family	multi-family
	thousand	%	kWh/(m^2year)	
before 1918	404.61	7.81	367.66	264.31
1918-1944	809.22	15.61	306.10	191.31
1945-1970	1363.48	26.31	265.22	172.74
1971-1988	1407.82	27.17	230.25	156.52
1989-2010	1197.20	23.10	183.36	125.67

When estimating the level of the energy consumption for heating buildings, the statistical data of the Central Statistical Office, available in the database in the form of thematic studies or metadata contained in files and other studies were used [5, 23, 27, 29, 35]. The data were identified in terms of suitability for the analysis and served as the input data for the performed calculations. The possible energy savings for heating residential buildings with its reduction to the above-determined level are introduced in Table 3.

Table 3 The potential energy savings by reducing the energy consumption for heating in residential buildings

Construction period of residential buildings	The potential level of reduction in the unit energy consumption of residential buildings heating			
	single-family	multi-family	single-family	multi-family
	kWh/(m^2year)		%	
before 1918	297.66	199.31	81.0	75.4
1918-1944	236.10	126.31	77.1	66.0
1945-1970	195.22	107.74	73.6	62.4
1971-1988	160.25	91.52	69.6	58.5
1989-2010	113.36	60.67	61.8	48.3

After comparing the potential possibilities for reducing the heat consumption in all residential buildings, energy savings of 72.3 % were achieved.

On the basis of the estimated reduction in the energy consumption for heating purposes for residential buildings, the reduction of harmful substance emissions into the atmosphere was estimated. Lowering the energy consumption will reduce the emissions of particulate matter and carbon dioxide, which is particularly harmful to the environment and people. The ecological effects of reducing the energy consumption for heating single-family and multi-family residential buildings to the above-adopted values are presented in Table 4.

Table 4 Reduction of pollutant emissions as a result of the reduced energy consumption for heating in residential buildings

Type of pollution	Pollutant emissions	Emission reduction by	Percentage reduction
	thousands of tonnes		%
Particulate matter $PM_{2.5}$	61.35	41.40	67.5
Particulate matter PM_{10}	103.76	70.02	67.5
Carbon monoxide	1,622.32	1,094.89	67.5
Sulphur oxides	219.18	147.92	67.5
Nitrogen oxides	67.51	45.56	67.5
Polycyclic aromatic hydrocarbons	0.13	0.08	61.5
Carbon dioxide	49,440.57	35,738.35	72.3

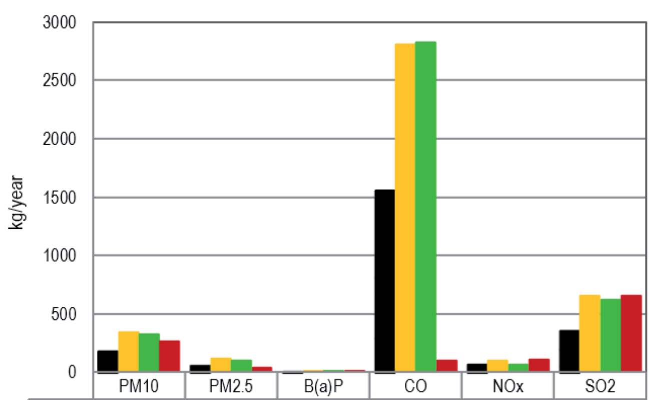
The environmental effect may be increased by modernising heating and ventilation systems in the analysed buildings and replacing the heat source for the heating systems that currently use coal with a source powered by gaseous fuels. This solution is particularly important for buildings built before the 1960s. Connecting the existing buildings to the district's heating network can have a similar effect.

TYPES OF FUELS AND LOW-STACK EMISSION REDUCTION

The elimination of heat sources powered by coal is particularly beneficial for the reduction of particulate matter and benzo(a)pyrene emissions as part of the thermal modernisation. A typical two-story school building, erected using traditional technology, partially with a basement, was selected to analyse the level of low-stack emissions reduction resulting from the use of various variants of energy carriers. The walls were made of solid brick plastered on both sides, its flat roof consisted of a ribbed DZ-4 floor slab, filled with concrete hollow blocks - insulated with reed mats. The windows were made of wood and were double-glazed. The main entrance door was made of uninsulated aluminium profiles, the remaining exterior doors were made of wood. Due to the lack of thermal insulation, the building envelope was characterised by high heat transfer coefficients: U = 1.4 W/(m^{2}K), the flat roof U = 0.68W/(m^{2}K), the ceiling above the basement U = 1.14 W/(m^{2}K), and the ground floor U = 0.73 W/(m^{2}K). The heat transfer coefficient of the windows was 2.6 W/(m^{2}K), external aluminium doors U = 6.0 W/(m^{2}K), and the remaining wooden doors U = 3.5 W/(m^{2}K). The building was heated from its own coal-fired boiler room located on the ground floor. The worn-out boiler, old sectional heaters, ribbed convection heaters (Favier heaters), and the lack of insulation of the pipes caused a very low efficiency of the central heating system, at a level of about 40 %.

A standard comprehensive thermal modernisation project was proposed for the building, consisting of the thermal insulation of the building envelope and the replacement of the windows and doors. Due to the limited possibilities of the investor, as part of the modernisation of the boiler room, it was proposed to replace the old coal-fired boiler with a new higher-efficiency boiler, as well as to use elements of the automatic regulation and control of the system. It was also recommended to modernise the central heating system, hot water heating, to install heating elements with low thermal inertia and thermostatic valves, to install lagging on the central heating pipes, to replace the ineffective electric heaters with a centralised heating from their own boiler room, as well as to increase the heating interruptions. Reducing the heat transfer coefficients of the building envelope by about 60-80 % to the applicable requirements and over 100 % improvement of the heating system efficiency contributed to about 55 % decrease in the energy demand of the building.

The consequence of lowering the heat demand of the considered building was the reduction in the emissions of harmful substances



	PM10	PM2.5	B(a)P	CO	NOx	SO2
coal	187,9	62,6	0,5	1550,6	77,7	361,8
gas	342,6	114,2	0,9	2807,9	100,4	659,9
oil	322,1	97,7	0,9	2822,3	67,3	620,9
wood	264,3	39,9	0,7	97,2	112,8	657,1

Figure 7 Avoided emission from different types of energy carriers

into the atmosphere from the coal combustion process (Table 5). The emission factors were adopted on the basis of the data provided by the National Center for Emissions Management [10]. After the thermal modernisation, the emissions of the particulate matter PM10 and PM2.5 to the atmosphere decreased by about 55 %. The decrease in the emissions of benzo(a)pyrene and other harmful substances was at the same level.

Table 5. Direct emissions and the reduction in the selected pollutants

Type of pollution	Before thermal modernisation	After thermal modernisation
	kg/year	
SO_2	659.9	298.2
NO_x	141.7	64.0
CO	2,828.5	1,277.9
PM10	342.7	154.8
PM2.5	114.2	51.6
B(a)P	0.9	0.4

An analysis was made of the reduction in the low-stack emissions in the case of using gas, oil or wood boilers instead of a coal-fired boiler. The amount of the avoided pollutant emissions from the different energy carriers is shown in Figure 7.

Replacing the boiler with a more efficient coal boiler resulted in a 55 % decrease in the particulate matter emissions, and, in the case of using a gas boiler, an almost 100 % reduction was achieved not only in the particulate matter, but also with the benzo(a)pyrene, carbon monoxide and sulfur dioxide (Table 6).

Table 6 Percentage reduction in direct emissions

Type of pollution	Type of energy carrier			
	Coal	Gas	Oil	Wood
	%			
SO_2	54.8	~100.0	94.1	99.6
NO_x	54.8	70.9	47.5	79.6
CO	54.8	99.3	99.8	3.4
PM 10	54.8	99.9	94.0	77.1
PM 2.5	54.8	99.9	85.5	34.9
B(a)P	54.8	100.0	95.5	77.4

The most appropriate solution to reduce emissions, especially PM10, PM2.5 and B(a)P, would be to combine the comprehensive thermal modernisation of the building with the replacement of a coal-fired heat source with a gas-fired one.

RENEWABLE SOURCES AS MEANS OF ENVIRONMENTAL PROTECTION

An important part of the Clean Energy package presented by the European Commission in 2016 is the creation of a clear path to low- and zero-emission buildings by 2050, and one of the main goals is the development of renewable energy sources. Already, many European Union

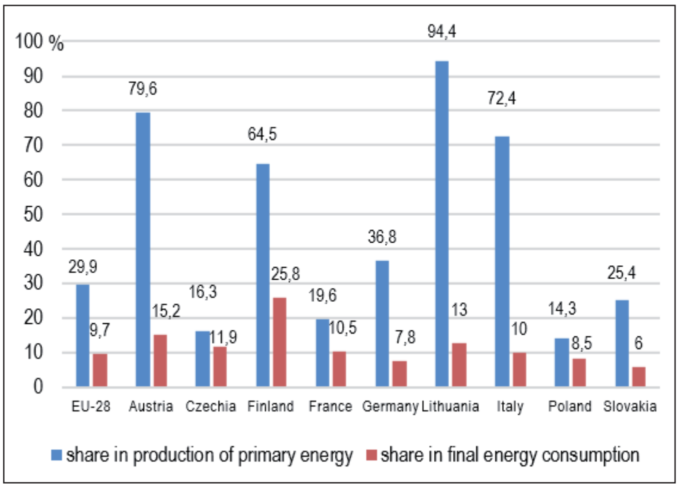


Figure 8 Share of energy from renewable sources in the production of the primary energy and in the final energy consumption [16]

Figure 9 The solar panel system at the specialist hospital in Czestochowa (Viessmann)

countries show a high share of renewable energy sources for obtaining primary energy (Fig. 8), a trend that has been clearly growing in recent years [16].

In Poland, four scenarios for the development of a zero-emission economy by 2050 have been developed [30]. The most favourable scenario seems to assume a 73 % increase in the share of renewable energy sources and the gradual phasing out of coal-based energy. The energy obtained from the renewable sources in Poland in 2018 came mainly from solid biofuels (68.88 %), wind energy (12.55 %) and liquid biofuels (10.33 %). The total energy value of the primary energy obtained from the renewable sources in Poland in 2018 was 367,091 TJ. The structure of the energy production from the renewable sources by the carriers in Poland and other EU countries in 2018 is presented in Table 7 [16]. The differences in the structure of obtaining the energy from the renewable sources in the individual countries are also influenced by the geographic conditions and the possibilities of the resource management.

The energy potential of renewable energy sources in Poland is significant: wind energy - 36.0 PJ, hydropower - 43.0 PJ, energy from biomass - 895.0 PJ, geothermal energy - 1,512.0 PJ and solar energy - 1,340.0 PJ [16].

An example of using solar energy in Poland is the solar panel system in the specialist hospital in Czestochowa. It is the one of largest solar

Table 7 The structure of the energy production from the renewable sources by the carriers [16]

Individual carriers	CZ	FI	IT	DE	FR	PL	EU
Solid biofuels	67.4	73.9	29.5	28.2	41.8	67.9	42.0
Solar energy	4.7	0.0	8.7	9.5	3.9	0.8	6.3
Hydro	3.6	10.9	5.5	4.1	16.6	2.4	11.4
Wind	1.1	3.5	5.7	21.3	8.2	14.0	13.8
Biogas	13.7	1.1	7.2	18.4	3.5	3.1	7.4
Liquid biofuels	4.6	3.1	3.3	7.8	10.2	10.0	6.7
Geothermal energy	-	-	20.7	0.6	1.6	0.2	3.0
Municipal waste	2.1	2.8	3.2	7.5	5.4	1.0	4.4
Heat pumps	2.8	4.7	10.0	2.5	8.9	0.6	4.9

collector installations in Poland (Fig. 8). The solar installation consists of 598 collectors with an area about 1500 m^2. The structure is positioned on three fields located on the roof of the building and directly on the ground level. The solar exchanger technology is based on three buffer tanks, a hot water storage tank, and plate heat exchangers.

The total installed capacity is about 1000 kW. The average daily consumption of hot water by the hospital is about 53 m^3. The collectors cover 51.8 % of the power demand, 32.3 % is guaranteed by the economisers recovering heat from the exhaust, and cooperation with the existing 4 gas and oil steam boilers provides the remaining 15.9 % of the power demand. During sunny weather, the solar installation, together with the economisers, can heat all the water needed for the hospital, with a minimum of sunlight reaching an efficiency of about 84 %.

The energy-saving technology of the economisers will significantly reduce the operating costs of the hospital related to the fees for the energy utilities, resulting in the facility saving up to $85,000 a year. The installation of solar panels in hospitals has become very popular in recent years.

The next example shows the possibility of using unconventional energy sources such as low- and high-temperature geothermal water for heating. In Poland, there are several geothermal plants, i.e., Bańska Niżna, with water temperatures of 60-100°C (capacity - 4.5 MJ/s), Pyrzyce has water temperatures of approx. 60°C (capacity - 15 MJ/s), Mszczonów has water temperatures of approx. 40°C (capacity - 7.3 MJ/s), Uniejów, with water temperatures of approx. 67°C (capacity - 2.6 MJ/s) and Słomniki, with water temperatures of approx. 17°C (capacity - 1 MJ/s). The Słomniki heat-generating plant is Poland's only plant that uses low-temperature heat as a lower source [28]. In Silesia, the largest technical potential of geothermal water exists in reservoirs located in the Miechów trough, in the areas of the Czestochowa and Zawiercie districts, as well as in the Cieszyn district [28].

One example of the potential for utilising low-temperature geothermal water for heat-generating purposes is a deep bore-hole in Poczesna (Czestochowa district) [28]. The pumped water volume flux is 24 m^3/h, 40 m^3/h, 50 m^3/h and 80 m^3/h. The source power is 406 kW, 677 kW, 846 kW and 1,353 kW. For the low-temperature geothermal heat-generating plant in the locality of Poczesna, the following facilities have been assumed to be connected: library – 50 kW, office building – 175 kW, school – 320 kW, health centre - 50 kW, preschool - 105 kW, police station - 44 kW, Poczesna Fire Brigade - 25 kW and church - 50 kW. When heating only part of the above-mentioned facilities, a monovalent system

Figure 10 Czernikowo photovoltaic power plant (Energa)

with a heat pump as the only central heating system supply source can be used. In the event, where the heating of all the buildings is assumed, the thermal power of the geothermal water source under consideration would not be sufficient. An additional heat source could be provided by a gas boiler.

According to data from the Energy Regulatory Office, there are 40 photovoltaic installations in Poland with a capacity of over 1 MW. The largest amount of power does not exceed 3.8 MW. The largest photovoltaic power plant in Poland is located in Czernikowo near Toruń in the northern part of Poland. The choice of the location was determined by factors including the favourable natural conditions, the direct proximity to the end users, the proximity to other renewable energy sources and consistency with the local spatial development plan. The installed capacity of the plant is 3.77 MW. The PV power plant in Czernikowo covers an area of approximately 7.7 ha. The installation consists of about 16,000 panels, each with a capacity of 240 W (Fig. 10).

They cover an area of over 22,500 square meters. The annual electricity production in Czernikowo is estimated at 3,500 MWh. This covers the needs of around 1,600 households. The power plant has a container transformer station, which consists of a low voltage switching station, a transformer chamber and a medium voltage switching station with a control room, as well as an underground cable connection to the 15 kV MV line. Currently, in the Lubuskie Voivodeship, near the Witnica commune, close to the Polish-German border, BayWa r.e. began construction of the largest photovoltaic farm in Poland with a capacity of 64.6 MWp.

In Poland, the largest source of electricity from renewable energy sources is wind. According to the data from the Polish Electricity Networks, the installed capacity of the wind farms is currently close to 6.3 GW. The installed capacity of the wind farms accounts for approximately 65 % of the installed capacity in all types of RES installations. The largest wind farm is located in Margonin in the Wielkopolskie Voivodeship. It consists of 60 wind turbines with a total capacity of 120 MW, which meets the energy needs of 90 thousand households.

Figure 11 The wind farm at Margonin (EDP Renewables Poland)

The power of wind sources in Poland is constantly growing, but photovoltaic installations show much greater dynamics in the development.

CONCLUSION

Compared to other European Union countries, the quality of the outside air in Poland, unfortunately, is not satisfactory. Thus, the gradual adaptation of existing buildings, the exploitation of which is one of the reasons for this state of affairs, to the standards of energy-efficient construction and the introduction of innovative technologies and solutions obviously help to combine the energy and economic effects of reducing the negative impact of the buildings on the environment. Therefore, it is necessary to promote and implement environmentally friendly technologies based on renewable energy sources and to increase the use of these resources. Individual countries can create a legal framework that allows the implementation of international standards of ecological and energy efficiency, because care for the state of the environment and the good health of society, while maintaining the current level of production and standards of living is possible only through the rational management of resources and carrying out pro-ecological projects.

The rationalisation of energy consumption in buildings through thermal modernisation is the basis for reducing low-stack emissions especially in the area where buildings with individual boiler rooms or stoves are located. An analysis of the possibility of reducing the energy consumption of residential buildings and the emissions of pollutants to the atmosphere generated during their production clearly indicates the greatest potential for activities undertaken in regards to heating rooms. The calculations show that, as a result of adjusting the energy demand for residential heating to 65-70 kWh/(m^{2}year), the energy consumption for heating existing residential buildings in Poland can be reduced by an average of around 72 % compared to 2011. Implementing these measures will also reduce air pollutant emissions. Considering the fact that the demand for heating in Poland is about twice as much in comparison with European standards, an improvement in the energy efficiency in this area may result in a reduction in the national energy consumption by over 10 %. This saving would be accompanied by a decrease in the particulate matter and CO_2 emissions on a similar scale. It is estimated that due to the implementation of the EU directives in this area, CO_2 emissions can be reduced by 28 million tonnes per year.

Solid fuels, mainly poor-quality coal and district heating, play a leading role in heating buildings in Poland. Solid fuels are the basic heating energy carrier for single-family houses, and for heat networks for multi-family buildings. The production of district heating takes place in about 75 % of the buildings, also with the participation of coal. However, the centralised production and the use of filters can reduce the negative impact on the environment. The third most used energy carrier is natural gas. This more environmentally friendly fuel is used in 10 % of residential buildings. Natural gas is characterised by about 35 % lower nitrogen oxide emissions and about 97 % lower carbon monoxide emissions. Gas combustion does not properly emit particulate matter, sulfur dioxide and benzo (a) pyrene. Therefore, the solution to the problem of low-stack emissions in cities would be to replace coal boilers with gas boilers or to connect buildings to the network, in addition to a ban on burning wood in open fireplaces. However, in the long term, the conventional power industry based on coal or gas will not be able to meet the growing energy needs due to the limited and fast exhaustion of conventional fuel sources.

Solar radiation, geothermal water, wind and hydroelectricity are widely available renewable energy sources. Renewable energy technology produces clean energy, and the optimal use of these resources minimises the impact on the environment and generates a minimal amount of secondary waste. Supporting the development of renewable energy sources is one of the key elements of sustainable development, contributing to the increase in the energy supply security and economics, as well as the regional and rural development. By reducing the emissions of the pollutants into the atmosphere, climate change is reduced, and the health of society and the state of the natural environment are improved. The production of energy from renewable sources ensures positive environmental effects and, at the same time, contributes to the development of less developed regions.

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