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Reducing energy demand in existing buildings as a tool to reduce air pollution

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Abstract. Buildings, on average, account for approximately 41% of total energy consumption in the European Union. This energy consumption also translates into hundreds of millions of tonnes of emitted CO₂ and other air pollutants. Due to a large share in the total energy consumption, the buildings sector has a significant potential to reduce the energy intensity of building operation, increase the share of renewable energy sources (RES), and thus significantly reduce emission of air pollutants. Existing buildings in Poland, both residential and public, are characterized by high potential in terms of energy and environment. One way to improve the energy efficiency of existing buildings and reduce emissions (in particular greenhouse gases) is through thermos modernization which adapts existing buildings to current and future energy demand requirements. The paper presents the expected environmental effects of measures which adjust the existing residential buildings to the requirements in force in Poland since 2021. It has been assumed that the energy demand for heating buildings will be limited to 55-60 (kWh/(m²year)). The calculations show that such measures will result in a reduction of total air pollutant emissions from households due to the reduction of energy demand for heating of dwellings from about 30% to about 67%, depending on the type of pollution.

1. Introduction

Given the high dependence of the modern world on various forms of energy, the depletion of conventional energy resources and the environmental impact of their processing, the efficient use of energy should be the subject of special measures.

In the European Union, legislative foundations have already been created to take appropriate actions in the form of binding provisions on the need to achieve, by 2020, all EU countries, objectives that are conventionally 3 x 20.

These goals were agreed at the European Council summit in March 2007 and they are:

- reducing CO₂ emissions by 20%,
- increasing the share of energy from renewable sources to 20%,
- increasing energy efficiency by 20%.

Recent years have seen two dominant and interdependent trends in the discussion of economic development problems:

- increase in demand for energy resulting from development with simultaneous depletion of non-renewable fuels and searching for sources to meet the growing needs,
- emission of pollutants and their impact on climate change.



The presence of these thematic currents in a broad debate led the author to carry out considerations and author's simplified quantitative analyses, limited to residential buildings and households. The quantitative analysis was made on the basis of GUS statistical data referring to 2011, when the last National Census was conducted, which were subject to transformations to the form desired by the author. Their partial results in terms of reducing the emission of pollutants into the air as a result of a possible reduction of energy consumption for heating buildings are presented in this paper.

2. Emission of pollutants into the air

Another important aspect of the production of energy from non-renewable fuels using conventional energy technologies is also related to the subject of improving energy efficiency. This aspect is the emission of pollutants into the air. The issue sometimes even seems to dominate over energy efficiency, which is not fully justified in the context of a very broad interdependency.

In the EU, ambitious rules have been set to reduce pollutant emissions. This situation, due to the monoculture of coal in the Polish economy, sets additional difficult goals and tasks for our country. According to the author, these targets are too high in terms of the time of implementation due to the economic and technical tasks necessary to reduce CO₂ emissions into the air which is maintained in Poland at the level of 300 million tones / year (GUS. Information Portal. State and protection of the environment 2016) [1].

There is no doubt that efforts should be made in this direction. However, it is important to quantitative and qualitative manner determine the scope of activities undertaken this route. According to the author, the set emission limits will probably not be met by the use of eco-efficient energy technologies alone, and some opportunities in this respect arise while saving energy and reducing energy consumption (fig. 1 and 2).

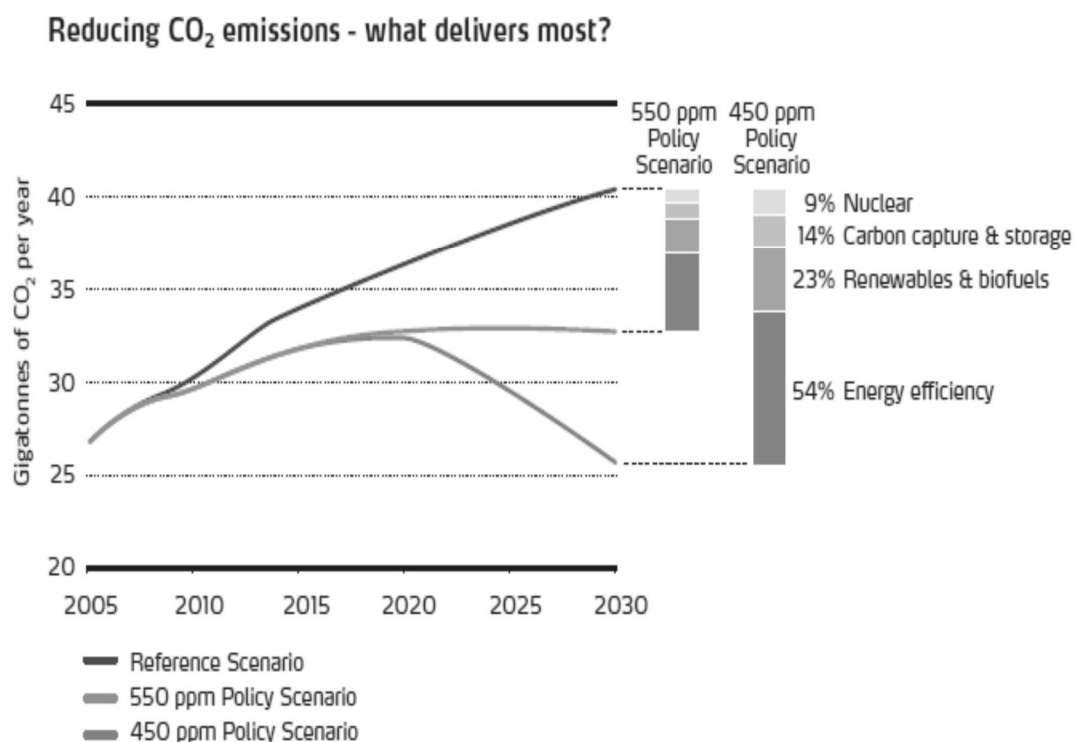


Figure 1. Carbon dioxide CO₂ reduction potentials [2]

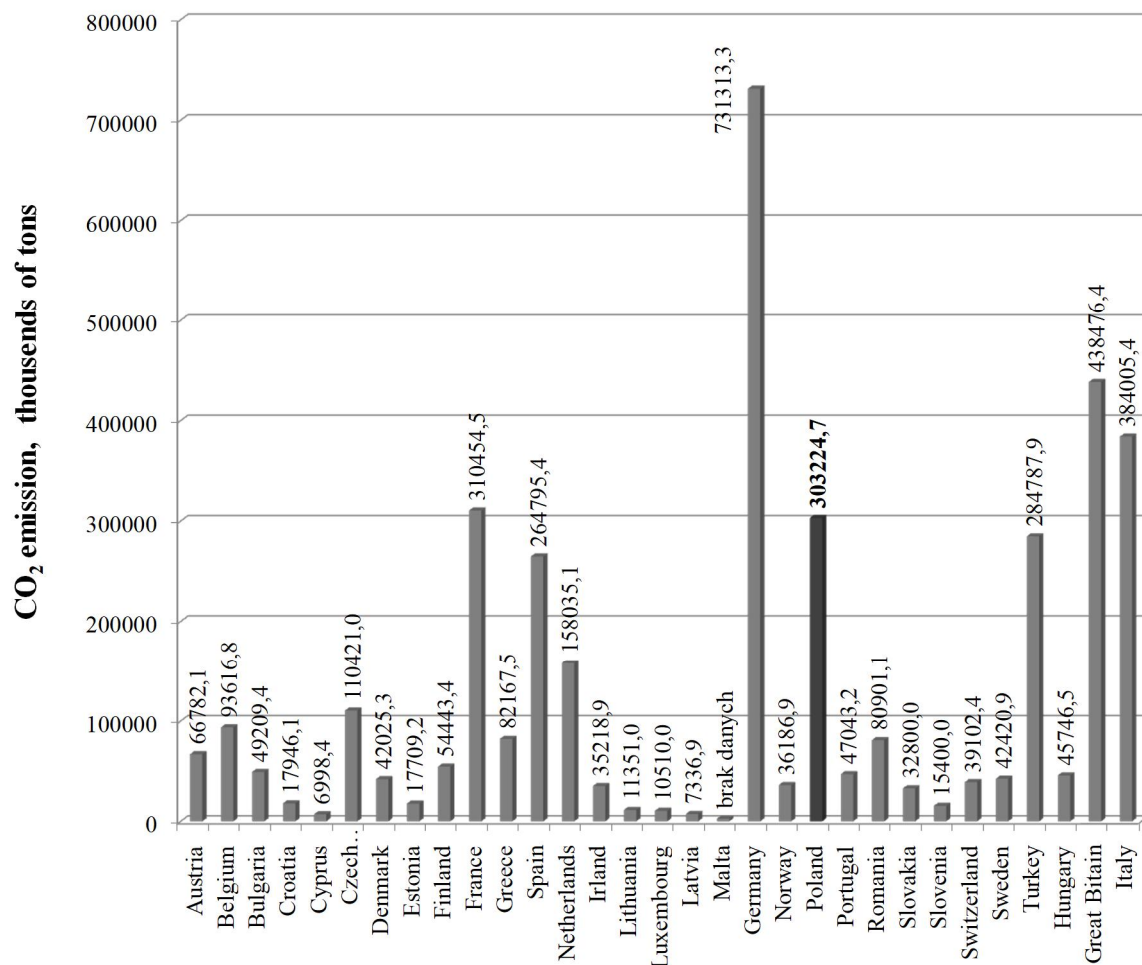


Figure 2. Carbon dioxide CO₂ emissions from fuel combustion [1]

3. Energy consumptions in buildings

The search for the largest opportunities in the use of energy efficient and effective should focus where there is the highest energy consumption. The subsector of buildings with the majority share of residential buildings plays the dominant role here. It is one of the main consumers of energy in the modern economies of developed countries, and above all in the operation phase of these facilities. On average, buildings account for approximately 41% of the total energy consumption in the European Union, which also translates into the emission of hundreds of millions of tons of CO₂ [3,4].

Due to a large share in the total energy consumption, the buildings sub-sector has a significant potential to reduce the energy intensity of building operation, increase the share of RES, and thus significantly reduce emission of, inter alia, CO₂ (Fig. 3).

The quoted data only strengthen the thesis that reducing energy consumption in buildings is very important for rational energy management and reducing emissions of pollutants into the air. Residential buildings (the largest functional group of buildings) play a dominant role in this process and have therefore been the subject of particular attention by the author of this publication. Considerations and analyses carried out later in this paper refer to the year 2011 due to the fact that in that year the National Census (abbreviated to NSP 2011) was conducted.

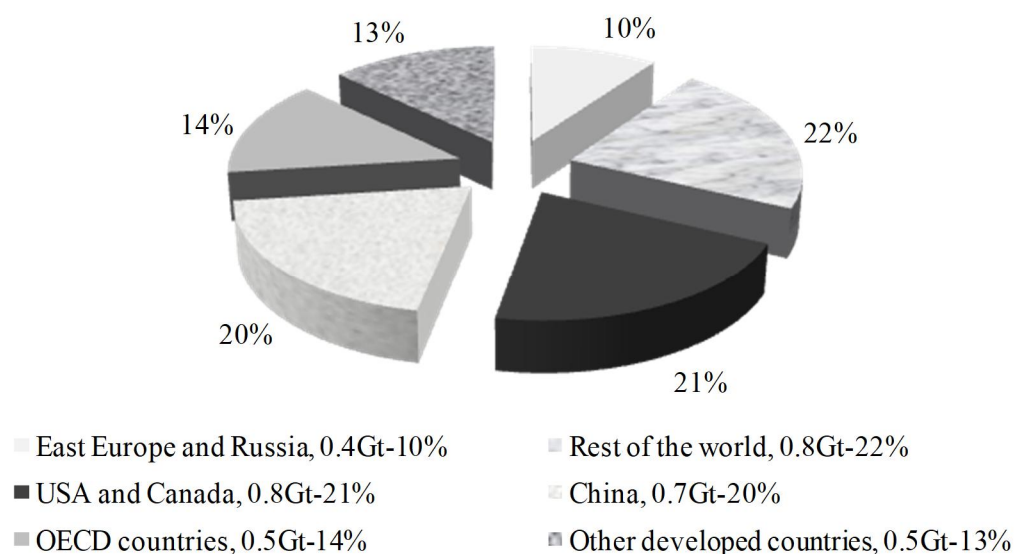


Figure 3. Potential possibilities to reduce CO₂ emissions resulting from the exploitation of buildings [5]

4. Energy consumption in households

In 2011, there were 12,060,000 dwellings in occupied residential buildings (Table 1) which were used by 13,568,000 households [6,7].

Energy consumption in households (including passenger cars in operation) reached the level of 1117 PJ [8] and constituted about 27% of the national energy supply with the dominant share of heating amounting to 68.8% (Fig. 4) [8].

“In terms of volume, solid coal fuels and district heating, which is also produced from these fuels in approx. 75%, played a leading role in space heating” [8]. It should be added that the production of network heat is based in about 75% also on solid coal fuels [8]. Natural gas was the third most used energy carrier. However, only 9.2% of households used this more environmentally friendly fuel than coal as their primary carrier [8].

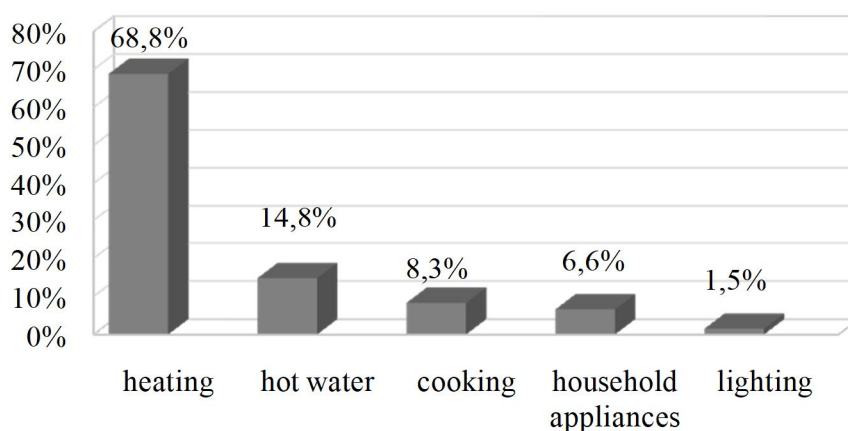


Figure 4. Structure of household energy consumption by purpose [8]

5. Energy efficiency of residential buildings and reduction of air pollutant emissions

The analysis of the possibilities to reduce the energy consumption for heating residential buildings and pollutant emissions inherent thereto in relation to the energy use objectives of buildings clearly shows the greatest potential for measures taken in the scope of space heating.

Table 1. Reduction of energy consumption for heating buildings and flats built in Poland at various times as a result of reduced unit energy demand for heating up to: 60 kWh/(m²year) for single family buildings, 55 kWh/(m²year) for multi-family buildings (own elaboration based on [6,7,8,10]).

The construction period	Energy demand for heating (kWh/(m ² year))		Energy demand for heating after reduction (kWh/(m ² year))		Reduction of energy demand for heating (kWh/(m ² year))	
	in single-family buildings	in multi-family buildings	in single-family buildings	in multi-family buildings	in single-family buildings	in multi-family buildings
before 1918	367.66	264.31	60	55	307.66	209.31
1918-1944	306.10	191.31	60	55	246.10	136.31
1945-1970	265.22	172.74	60	55	205.22	117.74
1971-1988	230.25	156.52	60	55	170.25	101.52
1989-2010	183.36	125.67	60	55	123.36	70.67

Such measures in existing housing may be carried out:

- in terms of (“quantitative”) reduction of energy demand for space heating by adjusting it to future heat and energy requirements,
- in the scope of (“qualitative”) reduction or elimination of emissivity of sources of power generation for heating. This can be achieved by using appropriately cleaner technologies and fuels or by introducing on a large scale renewable energy sources which can be used in our climatic conditions to heat buildings. Such activities contribute to the reduction of the emission of pollutants into the air while limiting the consumption of primary energy for heating. However, they do not affect the final energy consumption
- by optimally combining the activities mentioned above in an optimal way.

In the following, the results of the quantitative analysis of the potential to reduce the energy demand for heating residential buildings are presented by their adaptation to the level 60 kWh/(m²year) and 55kWh/m²year), respectively for multi-family and single-family buildings used in Poland in 2011 (Table 1).

In the next step, a percentage reduction of the total energy demand for heating of the buildings under consideration was assumed at the calculated average level of 72.29% (Table 2). This value allowed for a simplified calculation of the reduction of emissions of selected pollutants to the air as a result of the reduction of energy demand for heating buildings by raising their energy standard. For the calculations, a simplified assumption was made that the percentage reductions in energy demand and pollutant emissions were equal. The calculations were carried out starting from the elaboration of the obtained data concerning the emission of selected pollutants to the air from heating and total in households, and ending with their percentage reduction resulting from the previously calculated reduction of energy demand for heating. Due to editorial limitations, Table 3 and 4 presents only the results of the last stage of calculations for households in 2011 in the form of reduction of the types of emissions to the air considered in the work as a result of reduction of energy demand for heating.

Table 2. Reduction of energy consumption for heating buildings and flats built in Poland at various times as a result of reduced unit energy demand for heating up to: 60 kWh/(m²year) for single family buildings, 55 kWh/(m²year) for multi-family buildings (own elaboration based on [6,7,8,10]).

The construction period	Reduction of total energy consumption for heating (TWh/year)		Reduction of total energy consumption for heating (TWh/year)	Reduction of total energy consumption for heating (% /year)		Reduction of total energy consumption for heating (% /year)
	in single-family buildings	in multi-family buildings		in single-family buildings	in multi-family buildings	
before 1918	11.72	6.34	18.05	83.7	79.2	82.05
1918-1944	12.86	5.70	18.56	80.4	71.3	77.35
1945-1970	20.89	9.54	30.43	77.4	68.2	74.23
1971-1988	27.36	12.97	40.33	73.9	64.9	70.76
1989-2011	16.15	7.31	23.46	67.3	56.2	63.40
TOTAL (AVERAGE)	88,98	41.86	130.84	(75.4)	(66.4)	(72.29)

Table 3. Annual air pollutant emissions from the heating and the total in households (own elaboration based on [11,12])

Specification of emission	Air pollutant emissions from household heating (thousand tons)	Air pollutant emissions from household (thousand tons)	Total air pollutant emissions in Poland (thousand tons)
AIR EMISSIONS FOR GREENHOUSE GAS EXPRESSED CARBON DIOXIDE EQUIVALENT			
Emission of carbon dioxide CO ₂	49440.568	62566.758	330309
Emissions of nitrous oxide	280.575	435.758	27241
Emissions of methane	2538.768	2572.661	35538
AIR EMISSION OF SELECTED POLLUTANTS			
Emissions of nitrogen oxides NO _x	67.506	117.448	851
Emission of sulfur oxides SO _x	219.180	219.180	910
Emissions of ammonia NH ₃	0.510	0.819	270
Emission of non-methane volatile organic compounds	102.769	229.456	652
Emission of carbon monoxide CO	1622.308	1873.686	2916
Dust emission PM ₁₀	103.756	109.877	245
Dust emission PM _{2,5}	61.348	66.813	151
Emission of total suspended dust	141.360	x	414
Emission of dioxins and furans, i-TEQ	134.9	x	269
Emissions of hexachlorobenzene (HCB)	2.8	x	14
Emission of polychlorinated biphenyls (PCB)	0.0004353	x	0.0007246
Emission of polycyclic aromatic hydrocarbons	0.1230266	x	0.1437719

Table 4. Annual reduction of air pollutant emissions from the heating and the total in households (own elaboration based on [11,12])

Specification of emission	Reduction of air pollutant emissions from household due to reduction of energy demand for heating in households (thousand tons)	Reduction of air pollutant emis. from household due to reduction of energy demand for heating in relation to air pollutant emissions from household (%)	Reduction of air pollutant emis. from household due to reduce of energy demand for heating in relation to total air pollutant emissions in Poland (%)
AIR EMISSIONS FOR GREENHOUSE GAS EXPRESSED CARBON DIOXIDE EQUIVALENT			
Emission of carbon dioxide CO ₂	35738.35	53.33	10.82
Emissions of nitrous oxide	202.81	43.45	0.74
Emissions of methane	1835.16	66.60	5.16
TOTAL	37776.33	x	x
AIR EMISSION OF SELECTED POLLUTANTS			
Emissions of nitrogen oxides NO _x	45.56	41.55	5.74
Emission of sulfur oxides SO _x	147.92	72.29	17.41
Emissions of ammonia NH ₃	0.34	45.03	0.14
Emission of non-methane volatile organic compounds	69.36	32.38	11.39
Emission of carbon monoxide CO	1094.89	62.59	40.22
Dust emission PM ₁₀	70.02	68.26	30.58
Dust emission PM _{2,5}	41.40	66.37	29.29
Emission of total suspended dust	95.40	x	24.69
Emission of dioxins and furans, i-TEQ	91.04	x	36.25
Emis. of hexachlorobenzene (HCB)	1.89	x	14.88
Emis. of polychlorinated biphenyls (PCB)	0.000315	x	43.43
Emission of polycyclic aromatic hydrocarbons	0.08	x	61.86
TOTAL	1775.74	x	x

6. Summary

The potential for energy savings in buildings (mainly residential) is estimated at: 33-60% for improving thermal insulation of walls, 16-21% for modernizing ventilation system, 14-20% for improving thermal insulation of transparent partitions, 10-12% for regular inspection and repairs of central heating boilers, 50-80% for modernizing hot water production system with the use of RES [13]. The calculations show that as a result of adjusting the energy demand for heating in residential buildings to the level of 50-60 kWh (m²/(a year)) (based on the requirements in force in Poland since 2021), the demand in existing residential buildings may be reduced by an average of approx. 67% as compared to the situation in 2011.

At the same time, such measures will reduce the overall emissions of air pollutants from households due to the reduction of energy demand for heating of dwellings from about 30% to about 67% (Table 3 and 4), depending on the type of pollutant. In the scale of the whole country, this will

reduce the air pollutant emissions considered in this paper from about 0.7% to about 62% (Table 3 and 4) in comparison to the national emissions of these pollutants in 2011. It should also be noted that the low percentage reduction for domestic emissions is mainly due to the low share of these household emissions in the total Polish air emissions account.

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