



Potential energy and ecological effects of reducing energy consumption when heating residential buildings in Poland

Piotr Lis¹

ABSTRACT:

The communal and living sector, a sub-sector with the majority share of residential buildings, on average accounts for approximately 41% of the total energy consumption in the European Union. Due to this fact, the buildings sector has a significant potential for improving the energy efficiency of existing buildings and thus significantly reducing the emission of air pollutants. One way is through thermal modernization. This article presents the expected energy and environmental effects of measures that modify existing residential buildings to conform to the requirements expected to come into force in Poland in 2021. It has been assumed that the energy demand for heating buildings will be limited to 55 kWh/(m²year) for multi-family residential buildings and 60 kWh/(m²year) for single-family residential buildings. The calculations show that it is possible to reduce the energy consumption of heating residential buildings by over 70%, which will result in a reduction of total air pollutant emissions from home heating when compared to 2011.

KEYWORDS:

energy consumption; heating buildings; air pollutant emissions; residential buildings

1. Introduction

Recent years have seen several dominant and interdependent trends in the discussion of economic development: increased demand for energy resulting from development, coupled with the simultaneous depletion of non-renewable fuels and the search for sources to meet the growing need, while reducing the emission of pollutants.

Because of a constant increase in energy demand, it is considered that energy efficiency can become an alternative and essential source of energy and, at the same time, help reduce the emissions of air pollution arising in its production. The search for the greatest opportunities for energy savings and efficiency should focus on the areas where energy consumption is highest.

The dominant role here is played by the communal and living sector, to the extent that it is the sub-sector of buildings with a majority share of residential buildings. Buildings, on average, account for approximately 41% [1, 2] of total energy consumption in the European Union. The most significant purpose of energy use in households in Poland was space heating, the share of which was 66.4% in 2016 [3]. Solid fuels and district heating are clearly dominant in space heating [4].

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.

¹ Czestochowa University of Technology, Faculty of Infrastructure and Environment, ul. J.H. Dąbrowskiego 73, 42-201 Czestochowa, e-mail: piolis@is.pcz.pl, orcid id: 0000-0002-5310-0895

2. Aim, definitions, and methods

The article aims to estimate the possibilities of reducing energy consumption for heating residential buildings and thereby reduce emissions of air pollutants in the whole country. The article presents the expected energy end ecological effects of measures limiting the E_{KH} index - the final energy consumption values for heating residential buildings to the level of $55\div 60$ kWh/(m²·year). The explanations of the index type and its values are presented below.

In Poland, the methodology of determining the energy performance of a building has been presented in the Regulation of the Minister of Infrastructure and Development on the methodology of determining the energy performance of a building or a part of a building and energy performance certificates [5].

In the article, the main focus is on heating a building. For this reason, the basic figure from which the discussion has started is E_{KH} index for the annual final energy demand for building heating, which is the quotient of the annual final energy demand delivered to the building for the heating system $Q_{k,H}$ and the area of the building with controlled air temperature A_r .

Also, attention should be paid to the use of the above mentioned energy demand for the energy performance of buildings. These are calculated values and should be included in the theoretical ones. The exception is the use of energy performance in energy consumption that is the actual quantity that is obtained by direct or indirect measurement. In the case of GUS statistics on space heating, they refer to the energy consumption for this purpose (actual value) and not to the energy demand (theoretical value). The latter concept is undefined and absent from the GUS studies, e.g. [6]. Correctly calculated values of the annual demand of $Q_{k,H}$ and the related E_{KH} index should be as close as possible to the value of the annual energy consumption of C_H and the related unitary annual final energy consumption index for the heating of a building designated as E_{KCH} . The E_{KCH} index is the quotient of the annual final energy consumption supplied to a building for the heating system C_H and the area of the building with controlled air temperature (heated area) A_r . Due to the availability of statistical data, the calculation simplifies the assumption that the area of a building or flat with controlled air temperature (heated area) A_r is equal to the usable area A_u .

The range of index E_{KH} values ($55\div 60$ kWh/(m²·year)) indirectly results from the fact that since 2021 Poland will be subject to a requirement concerning the maximum value of the EP_{H+W} index of the annual calculation demand of a building for non-renewable primary energy for heating and hot water production at the level of 65 kWh/(m²·year) for multi-family residential buildings and 70 kWh/(m²·year) for single-family residential buildings [7]. In the presented analyses, the baseline value for their conduct was the already mentioned E_{KH} coefficient of final energy consumption for heating, i.e. a value that does not take into account the energy consumption for hot water production. For this reason, the range of its values obtained after reducing the EP_{H+W} index by 10 kWh/(m²·year) has been assumed. In a simplified way, it was assumed that such a value would correspond to the energy consumption for hot water production.

Considerations and analyses carried out later in this paper refer to the year 2011 since in that year, the National Census (abbreviated to NSP 2011) was conducted. Details of the statistical research methodology applied by the Central Statistical Office are described at the beginning of each source item with the data of the Central Statistical Office used by the author of the article, and additionally in [6]. For air pollutant emissions, the available output data is for households, not for residential buildings. For this reason, it was necessary to introduce the concept of a household to the considerations. Groups of people living together in an apartment and jointly maintaining themselves [8].

3. Energy characteristics of residential buildings

In 2011, there were 6,047,100 buildings with at least one flat in Poland, of which 5,542,600 were residential [9]. The main focus is on the group of occupied and heated dwellings, and

in principle, on the dwellings located there, as they contribute to the analyzed energy consumption for space heating. There were 5,182,330 such facilities in Poland. The quantitative characteristics of the buildings and apartments located there are presented in Table 1.

In this time, there were 12,060,000 apartments in occupied and heated residential buildings with a usable area 868 mln m² (484 mln m² in single-family and 384 mln m² in multi-family buildings) [9, 12]. 4.81 million of these apartments were in single-family buildings and 7.25 million in multi-family buildings [9, 12]. These apartments were used by 13,568,000 households [9, 10]. Energy consumption in households (including passenger cars in operation) reached the level of 1117 PJ [11] with the dominant share of heating amounting to 68.8% [11].

Table 1

Occupied and heated buildings and apartments constructed in Poland in various periods

The construction period	Occupied and heated buildings [9]		Occupied apartments in occupied and heated buildings [10]		Usable area A _U occupied apartments in occupied and heated buildings [12]		EK _{H+W} [13]	EK _{GH} (own elaboration based on [10, 12, 14])
	[Thous.]	[%]	[mln]	[%]	[Thous. m ²]	[%]	[kWh/(m ² ·year)]	[kWh/(m ² ·year)]
before 1918	404.61	7.81	1.12	9.25	68346.09	7.87	>300	321.89
1918-1944	809.22	15.61	1.39	11.54	94086.82	10.84	260÷300	255.08
1945-1970	1363.48	26.31	3.02	25.05	182847.98	21.06	220÷260	224.23
1971-1978	654.03	12.62	2.03	16.84	127816.06	14.72	190÷220	197.59
1979-1988	753.79	14.55	2.12	17.57	160657.69	18.51	140÷190	
1989-2002	670.65	12.94	1.47	12.16	134916.96	15.54	125÷160	157.90
2003-2007	321.47	6.20	0.55	4.57	59469.97	6.85	90÷120	
2008-2011	205.08	3.96	0.36	3.01	39942.52	4.60		
Total	5182.33	100.00	12.06	100.00	868084.10	100.00	-	-

“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” [11].

The energy performance of the buildings and apartments located there are presented in Tables 2 and 3.

Table 2

Index of energy consumption for heating of occupied and heated buildings and apartments used in Poland to 2011 inclusive (own elaboration based on [9, 12, 14, 15])

Quantity	Index of energy consumption for heating		Index of energy consumption for heating [kWh/(m ² ·year)]
	In single-family buildings [kWh/(m ² ·year)]	In multi-family buildings [kWh/(m ² ·year)]	
Weighted average	243.94	163.91	208.51

Table 3

Energy consumption for heating of occupied and heated buildings and apartments used in Poland to 2011 inclusive (own elaboration based on [9, 12, 14, 15])

Quantity	Energy consumption for heating		Energy consumption for heating [TWh/year]
	In single-family buildings [TWh/year]	In multi-family buildings [TWh/year]	
Total	118	63	181

4. Energy and ecological effects of increasing the thermal insulation of external partitions in heating residential buildings

The calculations used a simplified methodology and were based on the data concerning the total energy consumption for heating in buildings and usable areas of apartments located therein. The differences between these calculated values of specific annual energy consumption and the previously adopted levels of reduction to 55 kWh/(m²·year) and 60 kWh/(m²·year) were the basis for estimating the energy-saving potential in this respect presented in Table 4.

Table 4

Energy saving potential for heating residential buildings as a result of reduction of specific energy demand for heating to the level of 60 kWh/(m²·year) for single-family buildings, 55 kWh/(m²·year) for multi-family buildings

Reduction of energy consumption for heating				Reduction of total energy consumption for heating	
In single-family buildings		In multi-family buildings			
[TWh]	[%]	[TWh]	[%]	[TWh]	[%]
88.98	75.40	41.86	66.45	130.84	72.29

This value of reduction of total energy consumption for heating (72.29%) 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 (Table 5).

Table 5

Annual reduction of air pollutant emissions from the heating and the total in households (own elaboration based on [16, 17])

Specification of emission	Reduction of air pollutant emissions from household due to reduction of energy demand for heating in households [housand 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	57.12	10.82
Emission of nitrous oxide	202.81	46.54	0.74
Emission of methane	1835.16	71.33	5.16
AIR EMISSION OF SELECTED POLLUTANTS			
Emission of nitrogen oxides NO _x	48.80	41.55	5.74
Emission of sulfur oxides SO _x	158.44	72.29	17.41
Emission of ammonia NH ₃	0.37	45.03	0,14
Emission of non-methane volatile organic compounds	74.29	32.38	11.39
Emission of carbon monoxide CO	1172.69	62.59	40.22
Dust emission PM ₁₀	75.00	68.26	30.58
Dust emission PM _{2.5}	44.35	66.37	29.29
Emission of total suspended dust	119.35	67.55	26.58

5. Conclusions

Simple calculations show that as a result of adjusting the energy demand for heating in residential buildings to the level of 50÷60 kWh/(m² year), the demand in existing residential buildings may be reduced by an average of approx. 72.3% as compared to the situation in 2011. For single-family buildings, these savings amounted to 75.4%, and for multi-family buildings to 66.4%. The disclosed disproportion between single and multi-family housing is caused by higher financial resources allocated in thermal modernization programs for multi-family residential buildings. The potential for annual energy savings in terms of the analyzed reduction of its consumption to heat buildings was 130.8 TWh/year. Considering that in 2014 the total final energy consumption in Poland amounted to 531.4 TWh [18], the estimated energy savings account for 24.6% of the said consumption.

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

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 apartments from about 30% to about 70% (Table 5), 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 5) 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.

Reduced energy consumption for heating also means lower costs and thus an economic effect. This can significantly affect the availability of an efficient and environmentally friendly heating system. Its cost and reduced heat demand, together with significantly reduced heating costs, maybe more attractive for a larger number of residents. This will help to reduce the recent phenomenon of energy poverty.

However, the achievement of the estimated results in a satisfactory scale and over time should be the subject of far-reaching state intervention.

Acknowledgements

The material was prepared as part of the statutory research of the Czestochowa University of Technology BS/PB-401-301/18 task 6.

References

- [1] Peryt S., Asztemborski B., Efektywność wykorzystania energii w latach 2004-2014, GUS Departament Produkcji, Krajowa Agencja Poszanowania Energii S.A., Warszawa 2016.
- [2] Lis P., Cechy budynków edukacyjnych a zużycie ciepła do ogrzewania, Seria Monografie nr 263, Wydawnictwo Politechniki Częstochowskiej, Częstochowa 2013.
- [3] Peryt S., Wnuk R., Berent-Kowalska G., Walkowska K. - under the direction, GUS Departament Przedsiębiorstw, Krajowa Agencja Poszanowania Energii S.A., Efektywność wykorzystania energii w latach 2006-2016, GUS, Warszawa 2018.
- [4] Tkaczyk W., Kozieł A., Mikołajuk H. - under the direction, GUS - Departament Produkcji, Ministerstwo Energii, Agencja Rynku Energii S.A. (ARE S.A.), Zużycie energii w gospodarstwach domowych w 2012 r., GUS, Warszawa 2012.
- [5] Rozporządzenie Ministra Infrastruktury i Rozwoju z dnia 27 lutego 2015 r. w sprawie metodologii wyznaczenia charakterystyki energetycznej budynku lub części budynku oraz świadectw charakterystyki energetycznej, Dz.U. 2015, poz. 376 z późn. zm..
- [6] Kacperczyk G., cooperation: Mikołajuk H. - under the direction, Gilecki R., Hassman-Udrycka H., Kacprowska J., Parciński G., Szymańska M., Zasady metodyczne sprawozdawczości statystycznej z zakresu gospodarki paliwami i energią oraz definicje stosowanych pojęć, GUS Departament Statystyki Gospodarczej, Warszawa 2006.
- [7] Obwieszczenie Ministra Infrastruktury i Rozwoju z dnia 17 lipca 2015 r. w sprawie ogłoszenia jednolitego tekstu Rozporządzenia Ministra Infrastruktury w sprawie warunków technicznych, jakim powinny odpowiadać budynki i ich usytuowanie, Dz.U. 2015, poz. 1422 z późn. zm.

- [8] Główny Urząd Statystyczny, Portal informacyjny. Pojęcia stosowane w statystyce publicznej, Access to the website: stat.gov.pl/metainformacje/slownik-pojec/pojecia-stosowane-w-statystyce-publicznej/103,pojecia.html 01.03.2019, GUS, Warszawa 2019.
- [9] Matulska-Bachura A. - under the direction, Andrusiuk K., Dec A., Knyszewska E., Przybylska M., Różańska M., Sobczyk M., Mieszkania. Narodowy Spis Powszechny Ludności i Mieszkań 2011 (including file: <https://stat.gov.pl/spisy-powszechny/nsp-2011/nsp-2011-wyniki/mieszkania-narodowy-spis-powszechny-ludnosci-i-mieszkan-2011,18,1.html>), GUS, Warszawa 2011.
- [10] Matulska-Bachura A. - under the direction, Andrusiuk K., Dec A., Knyszewska E., Przybylska M., Różańska M., Sobczyk M., Zamieszkane budynki. Narodowy Spis Powszechny Ludności i Mieszkań 2011 (including file: <https://stat.gov.pl/spisy-powszechny/nsp-2011/nsp-2011-wyniki/zamieszkane-budynki-nsp-2011,15,1.html>), GUS, Warszawa 2011.
- [11] Tkaczyk W., Kozieł A., Mikołajuk H. - under the direction, GUS - Departament Produkcji, Ministerstwo Energii, Agencja Rynku Energii S.A. (ARE S.A.), Zużycie energii w gospodarstwach domowych w 2015 r., GUS, Warszawa 2015.
- [12] Matulska-Bachura A. - under the direction, Andrusiuk K., Knyszewska E., Przybylska M., Różańska M., Sobczyk M., Warunki mieszkaniowe gospodarstw domowych i rodzin, Narodowy Spis Powszechny Ludności i Mieszkań 2011, GUS, Warszawa 2014.
- [13] Mańkowski S., Szczechowiak E., Zintegrowany system zmniejszenia eksploatacyjnej energochłonności budynków, Strategiczny projekt badawczy, Zadanie badawcze nr 2. Tom I, część A: Uwarunkowania przekształceń w budownictwie, Warszawa - Poznań 2013.
- [14] Lis P., Estimated potential for energy savings in heating residential buildings in Poland, E3S Web of Conferences 49, 00068 2018, eISSN: 2267-1242, Access to the website: <https://doi.org/10.1051/e3sconf/20184900068>.
- [15] Úrge-Vorsatz D., Wójcik-Gront E., Tirado Herrero S., Labzina E., Foley P., Impact on the labour market of the deep energy modernization program of buildings in Poland, The Center for Climate Change and Sustainable Energy Policy, European Climate Foundation, Central European University, Hungary, Budapest 2012.
- [16] Bochenek D. - under the direction, Bancarzewska M., Górska A., Karczewska K., Lizuraj M., Pawłowska T., Reńska A., Sulik J., Wojciechowska M., Wrzosek A., Zagórska K., Zieleźny K., Ochrona środowiska, GUS, Warszawa 2013.
- [17] Departament Badań Regionalnych i Środowiska GUS, Rachunki ekonomiczne środowiska, GUS, Notatka informacyjna. Załącznik nr 1 Rachunki emisji do powietrza, Access to the website, <http://stat.gov.pl/obszary-tematyczne/srodowisko-energia/srodowisko/rachunki-ekonomiczne-srodowiska,7,1.html> 12.04.2017, GUS, Warszawa 2016
- [18] Departament Produkcji GUS, Wydział Bilansów Paliw, Surowców i Materiałów, Energia, Access to the website: <https://stat.gov.pl/files/gfx/portalinformacyjny/pl/defaultaktualnosci/5485/1/4/1/energia2016.pdf>, GUS, Warszawa 2016.

Potencjalne efekty energetyczne i ekologiczne zmniejszenia energochłonności ogrzewania budynków mieszkalnych w Polsce

STRESZCZENIE:

Poszukiwania największych możliwości w zakresie oszczędności i efektywnego wykorzystania energii powinny skupić się tam, gdzie występuje największe zużycie energii. Dominującą rolę odgrywa tutaj sektor komunalno-bytowy w części stanowiącej subsektor budynków z wielościanowym udziałem budynków mieszkalnych. Budynki odpowiadają przeciętnie za około 41% łącznego zużycia energii w Unii Europejskiej. To zużycie energii przekłada się również na emisję setek milionów ton zanieczyszczeń powietrza. W pracy przedstawiono przewidywane energetyczne ekologiczne efekty działań, które dostosowują istniejące budynki mieszkalne do wymagań obowiązujących w Polsce od 2021 roku. Przyjęto ograniczenie zapotrzebowania na energię do ogrzewania budynków do poziomu 55 kWh(m²rok) dla budynków mieszkalnych wielorodzinnych i 60 kWh(m²rok) dla budynków mieszkalnych jednorodzinnych. Z przeprowadzonych obliczeń wynika, że możliwa jest redukcja zużycia energii do ogrzewania budynków mieszkalnych o ponad 70% w stosunku do stanu z 2011 roku, co spowoduje zmniejszenie ogólnej emisji zanieczyszczeń powietrza z gospodarstw domowych z tytułu ogrzewania mieszkań do około 70% w zależności od rodzaju zanieczyszczeń.

SŁOWA KLUCZOWE:

zużycie energii; ogrzewanie budynków; emisja zanieczyszczeń powietrza; budynki mieszkalne