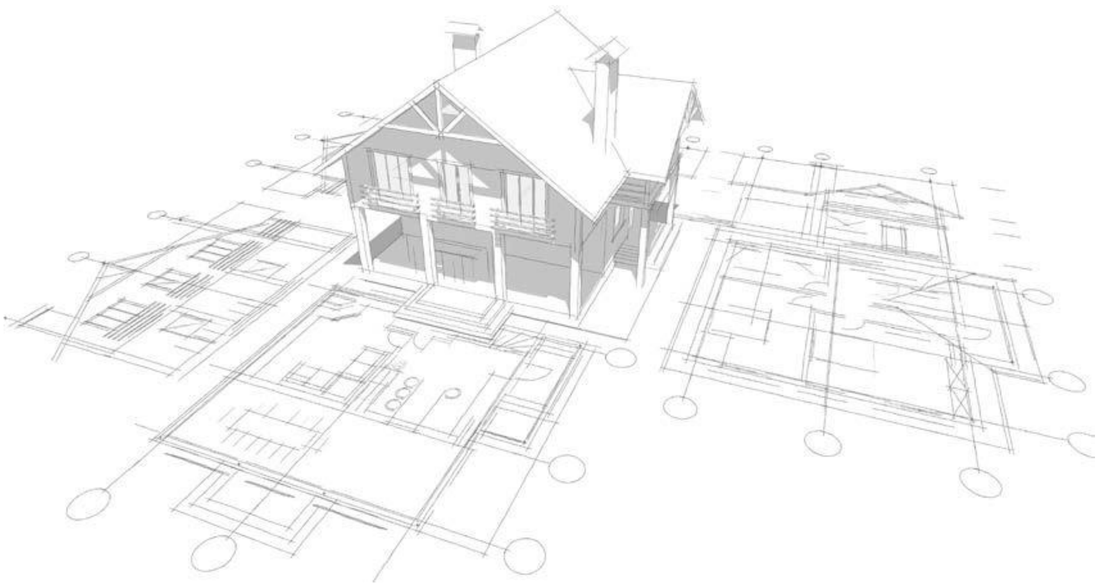
How to meet the requirements that buildings should meet from 2021?

Heating and ventilation in technical conditions



A guidebook for architects, designers and investors

Supporting organizations:

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1 Energy - balance and basic concepts

In compliance with the regulations (and the economic calculation), we strive to reduce the building's energy demand as much as possible. However, in order to be effective, it is worth knowing where the energy in the building comes from, for what purposes it is used, which routes it leaves the house and which technical methods of reducing energy demand are the most effective.

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Challenges of legal requirements

The requirements for energy consumption that must be met by new and modernized buildings are related to legal requirements and global trends. Governments strive to increase the use of renewable energy sources (RES) and continuous improvement of the energy efficiency of the economy, including construction.

Specific requirements are imposed on investors by the Act on RES, energy performance and energy efficiency. These requirements are also included in the regulation on technical conditions, which since 2014 has been gradually setting increasingly higher requirements for thermal insulation of partitions and limits the amount of non-renewable primary energy that buildings can use (the so-called WT 2014, WT 2017 and WT 2021).

We are currently facing another challenge - adapting the construction industry to almost zero-energy standards. The changes in the requirements for buildings that have been introduced over the last few years can be considered radical, especially when one looks at the issue of primary energy demand.

The obligation to perform energy performance certificates for buildings sold or rented, introduced by the Act on the energy performance of buildings in 2009, is another contribution to improving the energy efficiency of buildings. This law also introduced the term nearly zero-energy building (NZEB).

> ***A building with almost zero energy consumption - a building with a decidedly limited demand for primary energy, incl. thanks to the use of high thermal insulation and renewable energy sources. Such a building becomes the applicable standard from 2021.***

Ways of supplying energy to the building

In order to ensure comfort in the building, in the cold period it should be supplied with energy in the form of heat from the outside using a heating device, and in the warm period, energy should be either removed in the form of heat using the ventilation system or cold should be provided. The energy in the building also comes from the penetration of solar radiation through the glazed partitions and from internal gains of heat - from people and devices emitting it. The total heat gains are to cover the losses caused by the heat transfer to the outside through the partitions - walls, roof, floor, doors and windows - and with the ventilation air. In the past, the building used to lose the most heat due to its transmission through partitions, but thanks to improved thermal insulation, these losses were diminished. Currently, heat losses through ventilation are starting to dominate in the heat balance of the building. The way to limit them is to use mechanical ventilation with heat recovery from the exhaust air.

Building cooling is not yet common. One of the methods of limiting excessive temperature outside the heating season is to reduce external gains by ensuring adequate thermal insulation and the use of shutters on the glazing. It is also important to limit internal gains. The heat can be dissipated by using mechanical ventilation in combination with an air ground heat exchanger. Buildings can also be cooled using surface cooling in conjunction with a heat pump. However, a common way to cool buildings is to use air conditioners.

Useful, final and primary energy

To determine the annual non-renewable primary energy (PE) demand, calculate the final energy demand (FE) and take into account the type of fuel or energy carrier consumed by using the non-renewable primary energy input factor (PEFnren). On the other hand, useful energy (UE) and the efficiency of the installation system (η) are used to calculate the annual final energy demand.

ENERGY IN THE BUILDING

The demand for usable energy depends, among others, on the location of the building, the desired temperatures and the energy performance of the facility.
In order to make it possible to compare the amount of energy, the indicators UE, FE and PE were introduced, related to the unit area of the building (expressed in kWh/m^{2}a). The annual calculated demand of the building for non-renewable energy concerns the energy used for heating, ventilation and domestic hot water preparation, possibly cooling (if it is provided in the facility) and lighting (for non-residential buildings).

The results obtained with various heat sources depend on the relation of the coefficient of non-renewable primary energy input and the total efficiency of the entire technical system.
The calculations take into account the annual demand for final auxiliary energy supplied to individual technical systems of the building, which may be very important due to the high coefficient of expenditure on non-renewable primary energy - as much as 3.0 when supplied from the power grid.

Fig. 1. Useful, final and primary energy of the building

We are currently facing another challenge - adapting new facilities to the standards of nearly zero-energy construction

2 Architecture, installations and use of the building - recommendations

Many architectural, installation and functional aspects affect energy consumption in buildings. The implementation of the following recommendations - both at the stage of design and use of the building - will allow not only to plan and build an energy-efficient house, but also to fully use its potential.

Architectural recommendations

- placing the building on the plot with the long side facing south and keeping an open area facing south;
- selection of a simple and compact building body with a low surface-to-volume ratio;
- designing any large glazing in such a way as to provide the possibility of obtaining solar energy during the heating period, and outside of it, do not overheat the rooms, which requires not only the orientation of the building to the south, but also the use of e.g. protruding roof slopes and/or external roller shutters;
- use of load-bearing elements with good insulation and good-quality insulation materials (which allows to reduce the thickness of the walls), as well as windows and doors with low heat transfer coefficients;
- care for high air tightness of the building, which is influenced by the correct joining of structural elements made of various materials and the use of sealing foils;
- location of warm rooms and living rooms to the south, and auxiliary (cool) rooms to the north;
- using more glazing on the south side and less on the north side;
- use of massive components with high heat capacity (floors, walls) for energy storage;
- use of buffer and containment zones.

Installation recommendations

- the use of systems with high efficiency and the use of renewable energy sources, and at the same time ensuring high comfort of use. The efficiency of the heat source is the lowest for solid fuels, higher for gas, and the highest for heat pumps;
- ensuring effective heat transfer from the generation site to the receiver - by means of short, well-insulated sections;
- careful selection of the size of heat storage tanks and the quality of their insulation. Large tanks may have higher losses, but are sometimes necessary to store energy that is cheaper or temporarily available;
- efficient temperature control in rooms - not only to ensure thermal comfort, but also due to energy issues. Paradoxically, heating with wall-mounted radiators has a higher efficiency than surface heaters, because for the latter, the energy calculations carried out in accordance with the current rules do not take into account the fact that it provides comfort at lower temperatures in the rooms;
- use of mechanical ventilation - not only to ensure temperature comfort and provide fresh and filtered air in all weather conditions, but also due to heat recovery from the exhaust air;
- air tightness test of the building.

Operating recommendations

- paying attention to the influence of the way the building is used on its energy efficiency;
- taking into account heat accumulation in the way the building works. In heavyweight buildings, it is more energy-efficient to maintain stable thermal conditions than rapidly increase or lower the temperature;
- full use of mechanical ventilation to ensure an adequate amount of fresh air (avoiding tilting and unsealing windows, the so-called micro-ventilation, when mechanical ventilation is in operation). Any uncontrolled air exchange causes energy losses;
- change of habits - behavior related to the operation of old installations can significantly reduce the energy efficiency of modern systems.

Building requirements

Meeting the requirements of WT 2021 will allow almost zero-energy buildings to be obtained in the future. However, these requirements - especially regarding PE - pose a great challenge for modern construction, as it is necessary to act on a multi-faceted basis. Moreover, in order to meet the requirements of WT 2021, it is necessary to use renewable energy sources.

Thermal insulation in the building

There is no need to convince anyone about the need to insulate a building well. "Good" insulation is associated with the right thickness. With the requirements of WT 2021 and the standard coefficient λ = 0.04 W/mK it exceeds 20 cm. However, we also observe a different trend: a greater variety of insulation materials and the use of technologies with a lower λ with the same type of material, which means that thickness is no longer an indicator of effectiveness. The correctness and tightness of the arrangement are also of key importance. The solution that will reduce the thickness of the insulation are more effective materials, e.g. polystyrene with a conductivity coefficient of 0.031 W/mK.

Installation technologies

The market of heating and ventilation devices is shaped by Directive 2009/125/EC (the so-called ErP), which lays down general principles for setting ecodesign requirements for energy-related products. According to the applicable executive regulations, devices with low energy efficiency are being withdrawn - it has already happened, for gas non-condensing boilers. The tightening of the requirements for the PE index gives more and more importance to energy sources, both for heating (central heating) and preparation of hot water (DHW), as well as for ventilation methods. In order to meet high expectations, it is necessary to combine different activities.

How to meet the requirements of WT 2021 for primary energy (PE)?

Meeting the requirements of WT 2021 is tantamount to obtaining a building with almost zero energy consumption. However, while taking into account the requirements for thermal insulation is relatively easy and unambiguous, meeting the requirements relating to the index of non-renewable primary energy (PE) is complicated and requires a reasonable combination of installation solutions.

Lowering the PE index can be achieved by:
- increased insulation of partitions and air tightness - impact on UE;
- use of high-efficiency heating and ventilation technology - impact on FE;
- use of renewable energy sources, and thus ensuring a low coefficient of non-renewable primary energy expenditure - impact on PE.

From 2021, the primary non-renewable energy (PE) ratio for new and modernized single-family buildings should not exceed 70 kWh/m^{2}a, and for multi-family buildings 65 kWh/m^{2}a.

Table 1. Limiting parameters of the maximum heat transfer coefficients according to WT 2021

No.	Type of partition	Heat transfer coefficient [W/m^{2}K]
1	Outer wall	0.2
2	Roof, flat roof	0.15
3	Floor on the ground	0.3
4	Vertical windows	0.9
5	Roof windows	1.1
6	Exterior doors	1.3

In order to meet the requirements of WT 2021, it is necessary to combine various aspects

- Perfect thermal insulation of external partitions is NOT enough - even if it is much better than required in WT 2021.
- It is NOT enough to use the best conventional technologies, such as gas combustion and low temperature heating.
- Even a combination of very good insulation and a condensing boiler is NOT enough!

The WT 2021 requirements for PE have been defined in such a way that they cannot be met without the use of renewable energy. The use of renewable energy in a building with well-made thermal insulation allows to meet the requirements of WT 2021 and, at the same time, to reduce operating costs and increase the comfort of use.

4 Input data for energy analysis

What solutions should be combined in new as well as in renovated buildings so that the built and equipped house meets the requirements of WT 2021? Instead of theoretical considerations, an analysis of real (in terms of the body) architectural designs was performed. In the case of thermal insulation, boundary conditions were imposed in accordance with WT 2021. Two single-family buildings were analyzed - small (A) and medium (B) and a small multi-family building (6 apartments - C).

We would like to thank the design offices HomeKONCEPT and PRO ARTE for providing building designs for energy analyzes.

Common features of buildings

The following common features were adopted for all analyzed buildings:

- location: III climatic zone - Warsaw. Climatic data were adopted on the basis of typical meteorological years 1971–2000;
- location: on partially sheltered plots of land. On the south side, open space and exposed longer side;
- insulation: achieved minimum thermal parameters of the partitions included in WT 2021;
- air tightness: for gravity ventilation n_{50} = 2.0 1/h, for mechanical ventilation n_{50} = 1.0 1/h;
- average internal temperature: t_w = 20°C.

Table 2 shows that buildings B and C, for which the **surface-to-volume ratio (**shape factor) is the lowest, are geometrically favorable in terms of energy. Building A - although it is the smallest - may have an unfavorable UE index due to the large share of glass partitions. The selection of a building with such a high surface-to-volume ratio for the analysis allows to emphasize the importance of this parameter in meeting the requirements of WT 2021.

Significant, in terms of energy, is also the **share of the window area in relation to the area of the partition** in which they are located. Its higher value is associated with much worse heat transfer coefficients.

Building A (the smallest) has the most glazing in the walls. The use of large glazing requires the fulfillment of a number of conditions, including orientation of the building on the plot and architectural solutions or roller shutters to prevent overheating. In Building B, there is also the issue of windows in the roof, which are less favorable from the point of view of the thermal balance than vertical ones.

Installation variants - basic version

The analyzes adopted were the variants most often planned and used by investors during the construction of the house. Due to the energy carrier, four groups of variants were distinguished:

- **solid fuel**: Variant **1** (coal granulate boiler – eco-pea coal), Variant **2** (biomass boiler - pellets);
- **gas fuel** (high-methane natural gas): Variants **3**, **4** and **5** (with a radiator and surface installation and with the support of solar collectors or an air heat pump for domestic hot water);
- **heat pump**: Variant **6**, **7** and **8** (air, ground and air ones with photovoltaic support);
- photovoltaic-assisted **electric heating**: Variant **9**.

The installation variants with the adopted abbreviation and description are summarized in Table 3.

Table 2. Characteristics of the analyzed buildings

No.	Feature	Unit	Building		
			A	B	C
1	heated surface	m^2	115	252	526
2	heated cubature	m^3	280	646	1475
3	surface-to-volume ratio	–	0.80	0.41	0.33
4	share of the windows	%	24	16.6 (+16.8 roof area)	18

ENERGY ANALYSIS OF BUILDINGS

Building A. HomeKONCEPT 44 G2 with an area of 115 m^2

Fig. HomeKONCEPT Studio

Building B. HomeKONCEPT 35 with an area of 252 m^2

Fig. HomeKONCEPT Studio

Building C. SAN VITO with an area of 526 m^2

Fig. PRO ARTE

Table 3. Installation variants for the analyzed buildings

Variant	Identifier	Description
Variant 1	coal + gravity	automatic coal boiler for eco-pea coal + radiator heating + gravity ventilation
Variant 2	biomass + gravity	automatic boiler for biomass (pellets) + radiator heating + gravity ventilation
Variant 3	gas + gravity	condensing gas boiler + radiator heating + gravity ventilation
Variant 4	gas + mech + floor	condensing gas boiler + surface heating + mechanical ventilation with heat recovery
Variant 5a	gas + solar + mech + floor	condensing gas boiler + surface heating + solar collectors to support domestic hot water preparation + mechanical ventilation with heat recovery
Variant 5b	gas + HP + mech + floor	condensing gas boiler + surface heating + domestic hot water heat pump + mechanical ventilation with heat recovery
Variant 6	HPair + mech + floor	air heat pump + surface heating + mechanical ventilation with heat recovery
Variant 6a	HPair abs+ mech + floor	gas air absorption heat pump + surface heating + mechanical ventilation with heat recovery
Variant 7	HPground + mech+ floor	ground heat pump + surface heating + mechanical ventilation with heat recovery
Variant 8	HPair + mech + floor + PV	air heat pump + surface heating + mechanical ventilation with heat recovery + photovoltaic
Variant 9	electr + PV + mech	electric local space heaters (panel heaters) + mechanical ventilation with heat recovery + photovoltaics

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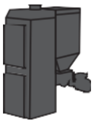
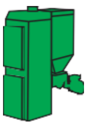
Description of variants

In all variants, the insulation of partitions was assumed to meet the minimum requirements of WT 2021 (see Table 1).



Variant 1: automatic coal-fired boiler + radiator heating and DHW from the boiler + gravity ventilation. It provides relatively low investment costs and low operating costs, although it is associated with the need to prepare a place for fuel storage. This option is also associated with a high inconvenience caused by coal combustion, pollution of the local environment, high CO_2 emissions and impact on the health of users and neighbors - an unacceptable solution from the point of view of the need to reduce low emissions. Often used in the past for WT 2014 and WT 2017.

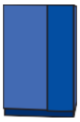


Variant 2: automatic biomass boiler + radiator heating and DHW from the boiler + gravity ventilation. It provides relatively low investment costs and not too high operating costs. It requires a place for biomass storage (and possibly also drying). One of the lowest coefficients of non-renewable primary energy input, PEFnren = 0.2, allows for very low PE values. However, local restrictions on the use of biomass boilers are introduced in urban areas due to their low emissions. A variant rather for rural or suburban areas, with not too densely built-up buildings.

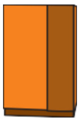
Variant 3: gas condensing boiler + radiator heating and DHW from the boiler + gravity ventilation. It provides relatively low investment costs, not very high operating costs. It is considered to be more pro-environmental than variants with solid fuel combustion. The limitation of application is the lack of universal access to the gas network.

Variant 4: gas condensing boiler + surface heating and DHW from the boiler + mechanical ventilation with heat recovery. It generates higher investment costs (compared to Version 3), but at the same time lower operating costs. It definitely increases the comfort of use (warm floor, preheated ventilation air supply). This variant is considered to be more pro-environmental than solutions based on the combustion of solid fuels, and at the same time is modern. As in the case of Version 3, the limitation of application is the lack of universal availability of the gas network.

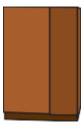
Variant 5: gas condensing boiler + floor surface heating + mechanical ventilation with heat recovery + renewable energy sources supporting DHW preparation. This variant may have two solutions: the use of solar collectors (KS - 5a) or heat pumps (HP - 5b). Generates higher investment costs (use of a separate device for domestic hot water preparation), but lower operating costs (the share of energy for heating domestic hot water is important). It definitely increases the comfort of use. A variant considered to be pro-environmental and modern at the same time. The type of renewable energy used depends on local conditions and user preferences. As in the case of variants 3 and 4, the limitation of application is the lack of universal availability of the gas network.



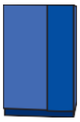
Variant 6: air source heat pump + (under)floor heating and DHW from the heat pump + mechanical ventilation with heat recovery. Occasional shortages of energy obtained by the HP from the air are compensated by the installed heater (e.g. for the temperature below -20°C). It generates higher investment costs, but clearly lower operating costs. Provides high comfort of use and staying indoors. Ecological solution (no pollution at the place of use). Installation of the air source heat pump does not require the administrative procedure.



Variant 6a: gas absorption heat pump + (under)floor heating and DHW from the heat pump + mechanical ventilation with heat recovery. The device is powered by a gas burner, which, by generating heat for the absorption system, allows obtaining renewable energy. Even at the lowest temperatures (down to -30°C), power is provided at the burner of the device, and the efficiency is then similar to that of a gas condensing boiler. This solution generates higher investment costs, but lower operating costs. Provides high comfort of use and of staying indoors. It can be installed outdoors (it does not take up usable space, there is no need to introduce gas into the building). Ecological solution - uses the heat stored in the environment. A solution adequate for medium-sized heating systems (larger single-family buildings, multi-family buildings).



Variant 7: ground heat pump + underfloor heating and DHW from the heat pump + mechanical ventilation with heat recovery. It enables complete coverage of the heating needs of the building. It is associated with high investment costs, but low operating costs. Provides high comfort of use and staying in the room. Ecological solution (no pollution at the place of use). A certain inconvenience is the need to undergo the administrative procedure related to drilling.



Variant 8: air source heat pump + (under)floor heating and DHW from the heat pump + mechanical ventilation with heat recovery + photovoltaic installation (covering 30% of the energy demand for heating). The solution makes it possible to partially cover the heating needs of the building with electricity produced by the own PV installation using the discount principle. It involves high investment costs, which can be reduced by designing the building exactly for this variant and thus avoiding certain solutions that are necessary when using boilers (e.g. chimneys, boiler rooms, etc.). It is distinguished by low operating costs. Provides high comfort of use and of staying indoors. Ecological solution - no pollution at the place of use and limited CO_2 emissions, which results from the efficiency and structure of energy production in the energy system.

Variant 9: heating with electric heaters and electric instantaneous DHW heaters + photovoltaic installation (covering 30% of energy demand for heating) + mechanical ventilation with heat recovery. Economic variant in terms of investment costs of heating devices. However, it requires a large area for a photovoltaic installation, which increases investment costs.

Scan or click:
Adrian Trząski – Requirements for buildings after 2020 - calculation examples for various buildings

Even the best heating device without good regulation of the installation will not provide not only comfort, but also low heating costs

5 Energy analysis in the basic version

For individual installation variants, the value of primary, final and usable energy was calculated – in accordance with the methodology for determining energy performance certificates and using the Audytor OZC 7.0 Pro software. Based on these calculations, it was determined which variants will allow the design and construction of buildings that meet the requirements of WT 2021.

Table 4. List of the efficiency of technical systems and coefficients of non-renewable primary energy input for single-family buildings (according to the regulation on the methodology for determining energy performance - Journal of Laws of 2015, item 376)

Variant	Heat source efficiency		Total efficiency - the product of the efficiency of the source, transmission, accumulation, regulation and use		Non-renewable primary energy input coefficient
	CH	DHW	CH	DHW	PEF_{nren}
1. Automatic coal boiler for eco-pea coal + radiator heating + gravity ventilation	0.82	0.83	0.73	0.56	1.1
2. Automatic biomass (pellet) boiler + radiator heating + gravity ventilation	0.70	0.83	0.63	0.56	0.2
3. Condensing gas boiler + radiator heating + gravity ventilation	0.94	0.85	0.84	0.58	1.1
4. Condensing gas boiler + surface heating + mechanical ventilation with heat recovery	0.94	0.85	0.80	0.58	1.1
5a. Condensing gas boiler + surface heating + solar collectors to support DHW preparation + mechanical ventilation with heat recovery	0.94	0.74	0.80	0.50	1.1 and 0
5b. Condensing gas boiler + surface heating + DHW heat pump + mechanical ventilation with heat recovery	0.94	2.34	0.80	1.59	1.1 and 3.0
6. Air heat pump + surface heating + mechanical ventilation with heat recovery	4.00	2.60	3.41	2.04	3.0
6a. Gas-air source absorption heat pump + surface heating + mechanical ventilation with heat recovery	1.4	1.2	1.2	0.82	1.1
7. Ground heat pump + surface heating + mechanical ventilation with heat recovery	5.00	3.00	4.27	2.04	3.0
8. Air heat pump + surface heating + mechanical ventilation with heat recovery + photovoltaic	4.00	2.60	3.41	2.04	2.1*
9. Electric local space heaters (panel heaters) + mechanical ventilation with heat recovery + photovoltaics	0.99	0.99	0.94	0.65	2.1*

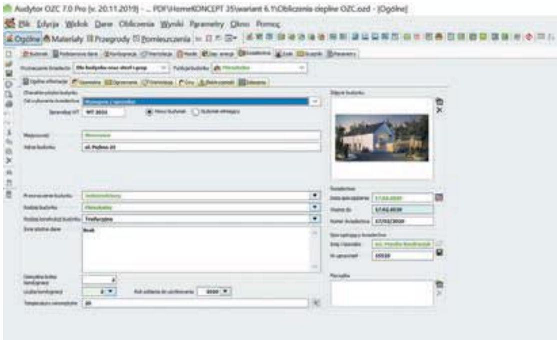
* 30 percent share of PV installations in the supply of electricity for heating and DHW

Efficiency of devices and systems

Table 4 (on the left) presents the efficiency of individual heating devices (CH and DHW) and entire systems for the analyzed variants, as well as the coefficients of non-renewable primary energy expenditure. When analyzing the given efficiencies, one can notice a much higher efficiency of CH systems than DHW ones. For domestic hot water with the use of a solar collector, the efficiency of the system is as high as 50%, although in this case free energy and no emissions are a significant benefit. This has a meaningful impact on the large share of energy for heating domestic hot water. in final energy (EK).
The efficiency of the installation is mainly determined by the efficiency of the source. This can be clearly seen on the example of Variant 2 (biomass + gravity) - showing that biomass boilers have lower efficiency than good coal boilers. This regularity is even better illustrated by variants with heat pumps. However, very low input factors for biomass or solar energy determine low PE values. At the same time, very high coefficients of non-renewable primary energy input in the case of mains electricity use significantly increase the PE value for solutions with heat pumps. This is due to the fact that the Polish energy system is largely based on coal and is diametrically opposed to the systems of other UE countries. It is expected that both the share of RES in electricity generation and the efficiency of its generation and transmission will increase, which will result in the need to change the coefficient of non-renewable primary energy expenditure.

Usable, final and primary energy indicators

Table 5 summarizes the obtained utility, final and primary energy indicators for the analyzed variants and buildings, indicating variants that meet the criterion of the **maximum value of the PE indicator.**



The analyzes were performed using the Audytor OZC 7.0 Pro software

Table 5. List of UE, FE, and PE indicators [kWh/m²a] in the analyzed variants for single-family Building A - 115 m², single family Building B - 252 m² and multi-family Building C - 526 m²

Variant	1	2	3	4	5a	5b	6	6a	7	8	9
Coefficient	**1. Coal + gravity**	**2. Biomass + gravity**	**3. Gas + gravity**	**4. Gas + mech + floor**	**5A. Gas + solar + mech + floor**	**5B. Gas + HP + mech + floor**	**6. HPair + mech + floor.**	**6a. HPabs air + mech + floor**	**7. HPground + mech + floor**	**8. HPair + PV + mech + floor**	**9. Electr + PV + mech**
	Building A – 115 m²										
UE	77	77	77	58	58	58	58	58	58	58	58
FE	114	131	109	93	96	66	26	65	22	26	66
PE	135	40	129	119	87	105	77	84	66	60	146
PE (max.2021)	70										
	Building B – 252 m²										
UE	59	59	59	40	40	40	40	40	40	40	40
FE	96	104	89	71	75	47	21	50	18	21	47
PE	114	34	106	96	62	90	64	66	55	49	109
PE (max.2021)	70										
	Building C – 526 m²										
UE	59	59	59	40	40	40	40	40	40	40	40
FE	91	98	85	68	75	45	19	49	16	19	45
PE	103	25	97	86	56	90	56	63	47	45	105
PE (max.2021)	65										

	condition of max. PE (WT 2021) fulfilled		condition of max. PE (WT 2021) not fulfilled (up to 10% above)		condition of max. PE (WT 2021) not fulfilled (above 20%)

6 Primary energy

The task of the primary energy factor (PE) - as a criterion for meeting the requirements of WT 2021 - is forcing the use of energy from renewable sources, including for heating and hot water preparation in buildings. However, its low value does not automatically mean lower operating costs.

The results of the calculations show that the fulfillment of the conditions of WT 2021 in terms of primary energy (PE) will not be easy or obvious. The shape of the building plays an important role - simple, with a low surface-to-volume ratio, ensures significantly lower energy demand. The analyzed Building A is more geometrically developed, which translates into higher heating needs defined by the UE index - approx. 77 kWh/m^{2}a, while for buildings B and C - approx. 59 kWh/m^{2}a.

Only the variant with a biomass boiler meets the PE requirements in each of the three analyzed buildings. It is a less efficient solution (it can be seen from a higher FE), but a very low coefficient of non-renewable primary energy (0.2) contributes to a very low PE value. Variants 7 and 8 also meet the requirements for each of the three buildings.

Conventional heat sources and renewable energy

Variants based only on classic heat sources, i.e. boilers burning fossil fuels (coal and gas), without the use of renewable energy sources, do not give any building a chance to meet the PE requirements. This also applies to **Variant 4**, based not only on a gas boiler, but also on a surface heating system and mechanical ventilation with heat recovery. The situation is improved by the use of a solar collector for DHW heating. - in the case of buildings B and C it even allows to meet the requirements.

While meeting the minimum requirements for thermal insulation, in the case of Building A, the achievement of the required PE value is guaranteed by **Variant 2 - with a biomass boiler and Variant 7 with a ground heat pump and 8 with an air heat pump and a photovoltaic installation.**

Variant 6 - with an air heat pump for central heating and DHW: with minor changes in Building A, it can meet PE requirements.

Buildings B and C have similar values of PE indexes, which is associated with a similar surface-to-volume ratio. In their case, the PE requirements are met not only by **Variant 2 - with a biomass boiler and 7 - with a ground heat pump and 8 with an air heat pump and photovoltaic installation**, but also **Variant 5a - with a gas boiler and solar collectors, and 6 - with an air heat pump and 6a - with gas absorption heat pump.**

The following variants do not meet the PE value requirements:

- **Variant 1 - with an automatic coal-fired boiler:** due to the relatively low efficiency of the installation and gravity ventilation;
- **Variant 3 - with a gas condensing boiler and gravity ventilation**: PE here is slightly lower than for Variant 1, which is influenced by higher efficiency. Nevertheless, gas and coal are fossil fuels with PEF_{nren} = 1.1;

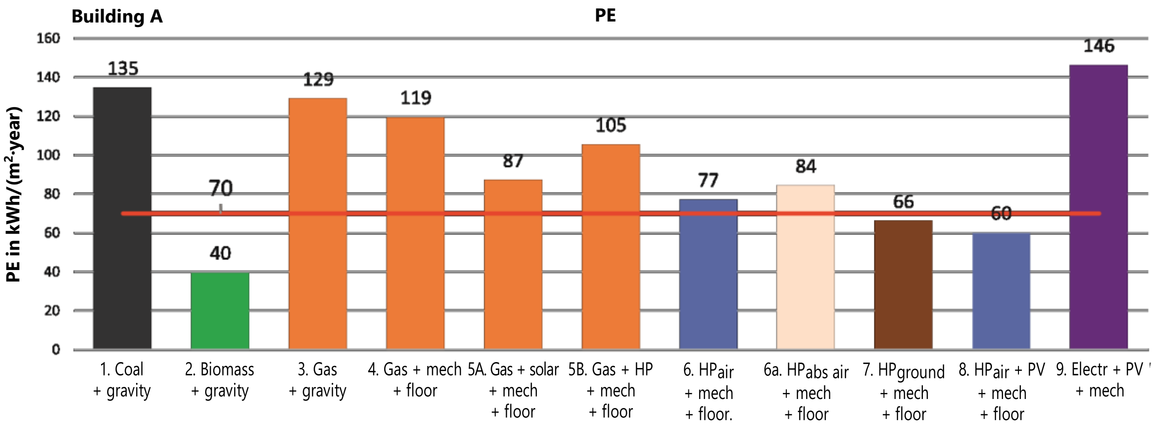


Fig. 2. PE indexes [kWh/m^{2}a] achieved by Building A (single-family building with an area of 115 m^2) for each installation variant

- **Variant 4 - with a gas condensing boiler and mechanical ventilation with heat recovery**: one can see an improvement in the PE index in relation to Version 3, but too small;
- **Variant 5b - with a gas boiler and mechanical ventilation with heat recovery and with the support of a heat pump for DHW heating.**
- **Variant 9 - with electric local heaters, photovoltaics and mechanical ventilation with heat recovery** – even with the real share of PV in the production of energy for heating at the level of 30%, it is not possible to meet the requirements of the technical conditions. It is admittedly completely devoid of a water heating system and central DHW heating (electric heaters and local water heaters with high efficiency are used) but results are still not "within" the required range. Theoretically, in this case, a larger photovoltaic installation with an energy storage can be used, but it is not a realistic solution due to the high financial outlays.

Heat pumps and the PEF_{nren} coefficient

Unfortunately, the required PE value cannot be achieved with the use of an air heat pump (which is a RES) only for DHW purposes. In this case, the PE coefficient will be too high, despite the much higher work efficiency and longer use time than solar collectors. This is related to the use of electricity from the power grid, burdened with a very high coefficient of non-renewable primary energy expenditure (3.0), caused by a large use of coal in the power industry and low efficiency of generation systems.

The same problem occurs when using heat pumps for central heating purposes. and hot water. Among heat pumps powered only by energy from the power grid, only a ground heat pump installation will be able to meet the conditions of WT 2021 in each analyzed building. Gas absorption heat pumps, on the other hand, have a coefficient of PEF_{nren}= 1.1 and can be used in buildings B and C.

The use of a heat pump with a photovoltaic (PV) installation allows to meet the requirements of new technical conditions.

The energy from the photovoltaic installation is taken in 30 percent with the index PEF_{nren} = 0 and in 70 percent with the index PEF_{nren} = 3.0. This is due to the actual self-consumption indicator of energy from the PV installation consumed by heat pumps.

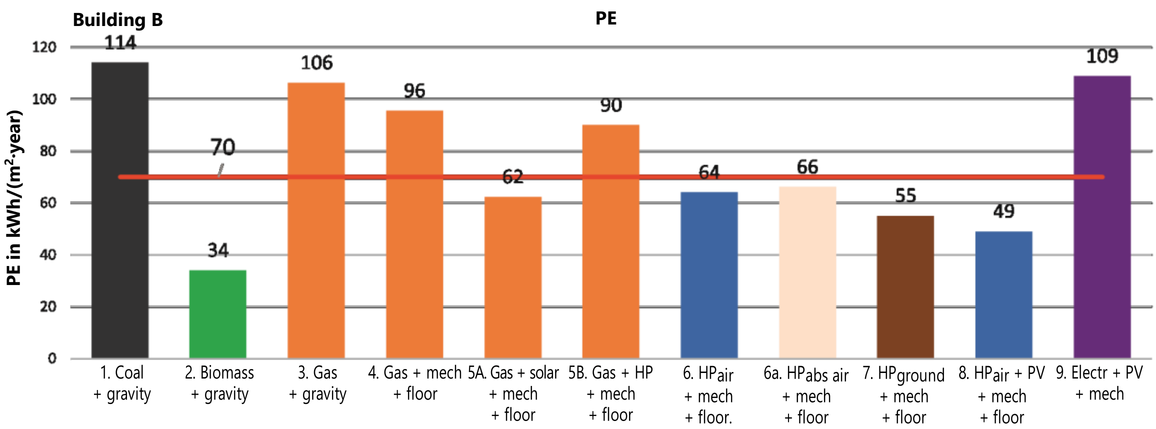


Fig. 3.
PE indexes [kWh/m^{2}a] achieved by Building B (single-family building with an area of 252 m^2) for each installation variant

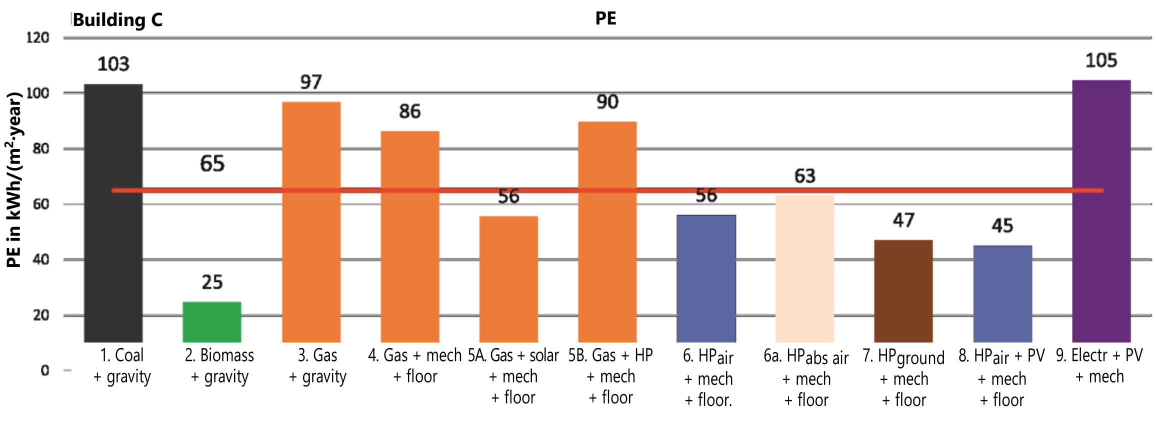


Fig. 4.
PE indexes [kWh/m^{2}a] achieved by Building C (multi-family building with an area of 526 m^2) for each installation variant

7 Final energy

Associated with the energy we pay for - it means the total energy demand taking into account the efficiency of the systems used. For example, we do not incur the costs of purchasing renewable energy from the sun and wind, but it requires the expenditure necessary to obtain it, i.e. the cost of auxiliary energy for pumps. In the case of a photovoltaic installation with a discount system, we recover 80% (installations up to 10 kWp) or 70% (installations from 11 to 50 kWp) of energy given to the power grid.

The cumulative graph of FE indicators for all variants and buildings is shown Fig. 5. There are great similarities in the case of facilities B and C - due to the similar shape, similar values are obtained for the same ventilation systems in both buildings. Building A, due to its less favorable geometry, has a greater need for final energy.
The high degree of technical advancement of the systems is associated with less and less energy demand - it is perfectly visible in the FE indicators. These values are smaller for the successive variants, and the differences between the variants - significant.

Classic systems – a boiler and gravity ventilation

The high FE value for the first three (classic) variants should not be surprising: with an automatic coal boiler, an automatic biomass boiler and a gas condensing boiler (coal + gravity, biomass + gravity, gas + gravity) - at the level of approx. 90 kWh/m^{2}a.
In each of these variants, a commercially available boiler operating with a traditional radiator heating system and gravity ventilation was included. Of course, the variant with the highest efficiency, i.e. the gas condensing boiler (gas + gravity), has the lowest energy requirements, and the variant with the biomass boiler (biomass + gravity) the highest. However, the differences between the three variants are not very big.

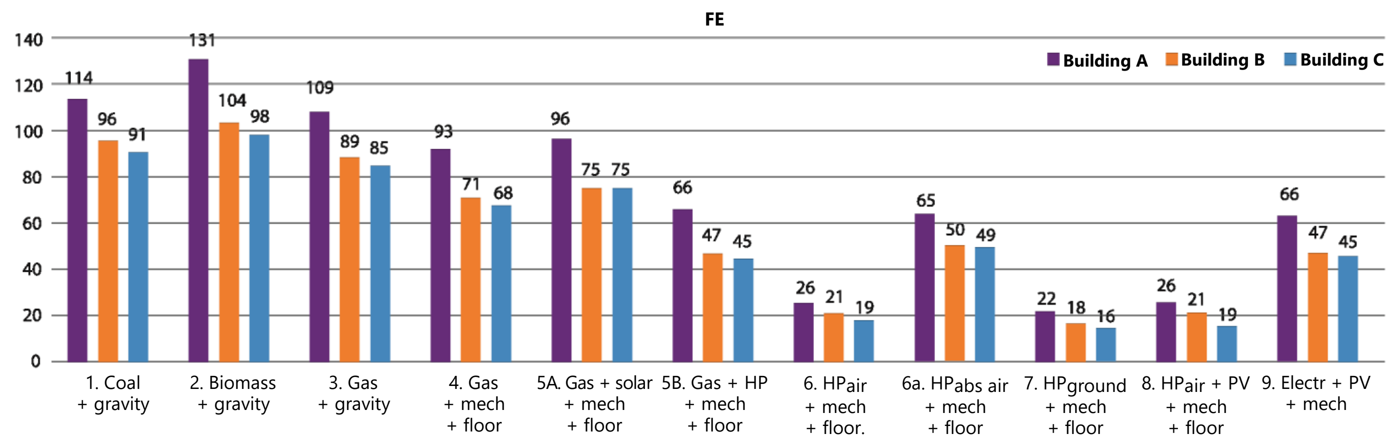
Condensation technique and mechanical ventilation

Another group of variants are more modern solutions using a gas condensing boiler, surface heating and mechanical ventilation with heat recovery. Such a system can be expanded with a device that uses renewable energy for the preparation of DHW. The version with a gas condensing boiler with a heat pump for DHW production has the lowest energy requirement (gas + HP + mech + floor). A large proportion of the energy required for the preparation of DHW translates into savings resulting from the use of a heat pump. The variant with a gas condensing boiler and solar collectors (gas + solar + mech + floor) is less favorable in terms of FE.

Heat pumps

The last group of variants are installations with heat pumps coupled with underfloor heating. A ground source heat pump solution has the lowest final energy requirement. It is clearly smaller than in the case of air source heat pumps.

Fig. 5. Final energy ratio FE [kWh/m^{2}a] for the analyzed variants and buildings



Useful energy

8

The demand for usable energy (UE) is related to the architecture of the building, its tightness and the method of ventilation (gravity, mechanical, mechanical with heat recovery).

In the case of a building with a more complex shape (A), the demand for usable energy (UE) is clearly greater than for buildings with a simpler shape (B and C). Due to the simplicity of the shape, the demand for usable energy is the same for these two buildings. In the case of gravity ventilation, it is approx. 59 kWh/m^{2}a, while ensuring energy recovery from the removed air, thanks to the installation of mechanical ventilation, allows to reduce the UE index to approx. 40 kWh/m^{2}a.

The demand for UE is also related to the tightness of the building. Greater tightness is achieved with the use of controlled (mechanical) ventilation systems and it results in a lower demand for usable energy.

Table 6 shows the share of usable energy for central heating and hot water for Building B.

The difference in the values between the indicators of the demand for useful energy (for gravity and mechanical ventilation) is significant - in the analyzed Building B it is over 30%. Along with the reduction of energy demand for central heating purposes and ventilation, the share of energy for DHW heating increases - from 40.5 to 59.6%.

Table 6. Utility energy demand indicator UE [kWh/m^{2}a] for central heating and hot water on the example of Building B

	Gravity ventilation		Mechanical ventilation	
	Usable energy [kWh/m²a]	**UE share [%]**	**Usable energy [kWh/m²a]**	**UE share [%]**
CH + ventilation	35.3	59.5	16.3	40.4
DHW	24.1	40.5	24.1	59.6
Total	59.4	100	40.4	100

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Investor's guide - Thermomodernization relief

Useful energy "covers" the losses related to the escape of energy from the building - that is, heat transfer and ventilation

9 Conversion of the SCOP factor

on the basis of η_s and η_{wh} coefficients from the heat pump product card according to ecodesign requirements (ErP)

Based on the η_s (eta s) and η_{wh} values (eta wh - only for heat pumps with a built-in DHW tank) declared by the manufacturer in the product card the $SCOP_{CH}$ values related to the operation for CH can be calculated as well as $SCOP_{DHW}$ values related to operation for DHW.

Calculation of the $SCOP_{CH}$ value for heat pump operation for central heating

The heat pump product card includes the η_s values declared by the manufacturers for the design flow temperature of 55°C:

- for a temperate climate (Strasbourg),
- for a cool climate (Helsinki),
- for a warm climate (Athens).

In addition, manufacturers declare the value of η_s for a design supply temperature of 35°C (surface heating) for three climates: temperate, cool and warm.

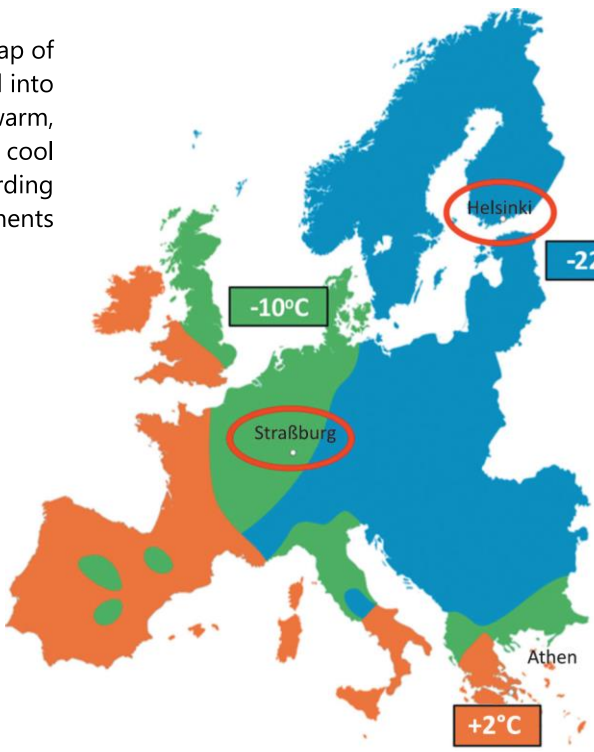

Fig. 6. Map of Europe divided into zones with warm, temperate and cool climate according to ErP requirements

The value of the average seasonal efficiency of heat generation from the energy carrier or energy supplied to the heat source $\eta_{H,g}$ is taken based on the data provided by the manufacturer of the heating equipment, in this case heat pumps. Only in the absence of such data, the values of $\eta_{H,g}$ specified in Tab. 2 of the Regulation on the methodology for calculating the energy performance of a building and a dwelling or a part of a building constituting an independent technical and operational whole and the method of drawing up and specimen energy performance certificates.

Based on the declared values of η_s in the product cards, the **SCOP** value (which is the equivalent of the average seasonal heat generation efficiency $\eta_{H,g}$) can be converted according to each of the given climates and the design supply temperature of 35°C or 55°C according to the following formulas:

- **Brine-to-water and water-to-water heat pumps**

$$SCOP_{PN\ 14825} = (\eta_s + 8\%) \times 2,5$$

- **Air-to-water heat pumps**

$$SCOP_{PN\ 14825} = (\eta_s + 3\%) \times 2,5$$

where:

$SCOP_{PN\ 14825}$ is a seasonal energy efficiency ratio that takes into account the power consumption (energy) by the drive of the ground heat source and the second, peak heating device (electric heater).

The SCOP value calculated on the basis of the PN EN 14825 standard does not include electricity consumption related to the operation of the brine circulating pump, but takes into account the electricity consumption of the electric heater, including defrosting (in the case of an air/water unit).

Calculation example

Example of a **SCOP$_{CH}$** calculation for a 40°C design leaving water temperature using the example data in the air-to-water heat pump design sheet (Table 7):

Table 7. Sample data from the product card of an air-to-water heat pump

Climate type according to ecodesign	η_s in % (35°C)	η_s in % (55°C)
Temperate climate	185	130
Cool climate	170	118

The calculated SCOP values take the values given in Table 8, respectively:

Table 8. SCOP calculated from Table 1 and the corresponding SCOP$_{PN\ 14825}$ formula

Climate type according to ecodesign	SCOP [-] (35°C)	SCOP [-] (55°C)
Temperate climate	4,70	3,33
Cool climate	4,33	3,03

If a design flow temperature of 40°C is assumed (see Fig. 7), the SCOP$_{CH}$ value will be as follows:

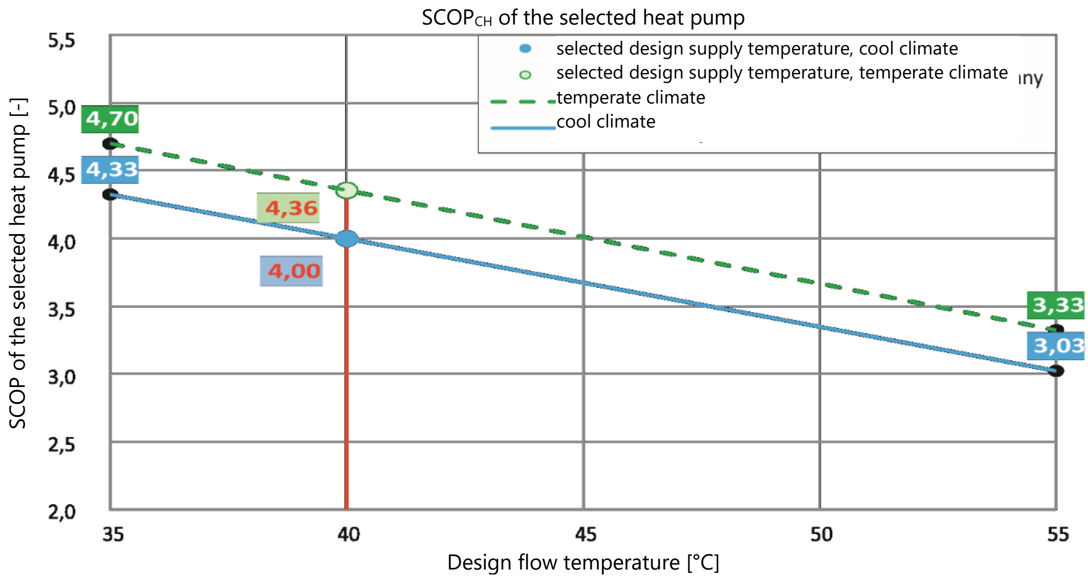

Fig. 7. Calculation of SCOP$_{CH}$ at a design flow temperature of 40°C (for temperate and cool climate)

Scan or click:
A tool for converting SCOP from η_s for air-to-water and brine-to-water heat pumps

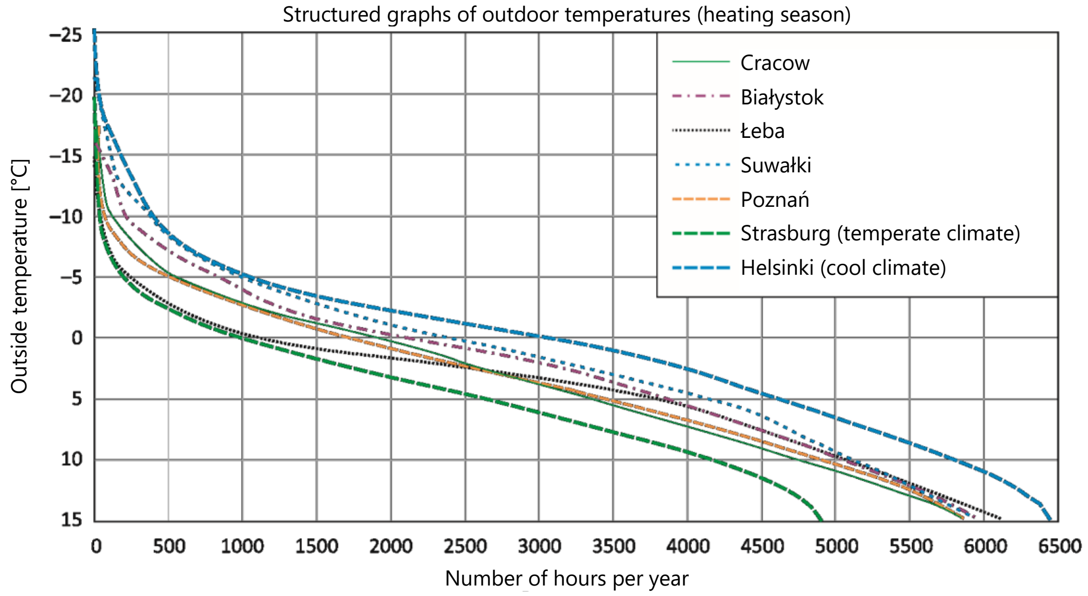

Fig. 8. Comparison of the structured distribution of outdoor temperature in a temperate and cool climate and in five typical climatic locations in Poland from zone I to V - according to the PN EN 12831 standard

- for a temperate climate: $SCOP_{CH}$ = 4.36,
- for a cool climate: $SCOP_{CH}$ = 4.00.

In accordance with the ecodesign (ErP) requirements, the area of Poland is located in a cool climate, despite the fact that for about 8 years the distribution of structured temperatures has placed it in a temperate climate. It should be assumed that due to annual climate variability the $SCOP_{CH}$ value will fluctuate between the $SCOP_{CH}$ value for a cool climate and the $SCOP_{CH}$ value for a moderate climate (i.e. in this case between 4.00 and 4.36).

The graph in Fig. 7 shows that in the case of locations in Poland in the climatic zones I, II, III, the SCOP value will be closer to the $SCOP_{CH}$ of the temperate zone ($SCOP_{CH}$ = 4.36). For climatic zones IV and V closer to the cool climate zone, the $SCOP_{CH}$ value will be closer to the $SCOP_{CH}$ of the cool zone (in this case $SCOP_{CH}$ = 4.00). It should be emphasized that the presented structured graphs of outdoor temperatures for five locations from zones I to V relate to the meteorological years in the range 1971–2000.

Calculating the $SCOP_{DHW}$ value for the heat pump operation in the function of DHW tank charging

The product card of heat pumps with a built-in storage tank includes the values of η_{wh} (eta wh) declared by the manufacturers in the selected DHW consumption profile (most often L or XL with a DHW temperature of 55°C):

- for a temperate climate,
- for a cool climate,
- for a warm climate (not applicable in Poland).

From the η_{wh} value, the SCOP value can be calculated for each of the following climates::

$$\mathbf{SCOP_{DHW} = \eta_{wh} \cdot 2,5}$$

where:

$SCOP_{DHW}$ – seasonal energy efficiency coefficient calculated within the balancing limits of the heat pump installation, taking into account the power consumption (energy) by the drive of the heat source and the power (energy) of the second heating device, and additionally the operation of the charging pump and the losses of the DHW tank, **2.5** - European average value of the input coefficient primary energy in the case of electricity, used in the ecodesign calculation.

An example of **$SCOP_{DHW}$** calculations based on examples of data from the brine-to-water heat pump design sheet is shown in Table 9.

Table 9. Sample data from the product card

Climate type according to ecodesign	η_{wh} in the L DHW consumption profile
Temperate climate	108%
Cool climate	102%

Calculated $SCOP_{DHW}$ values in the case of heat pump operation for hot water in the tank take the values given in Table 10.

Table 10. Calculated $SCOP_{DHW}$ values based on the data in Table 3

Climate type according to ecodesign	$SCOP_{wh}$ [-] in the L consumption profile
Temperate climate	2,72
Cool climate	2,55

If the hot water temperature is lowered by approx. 10°C, from 55°C to 45°C, the SCOP increases by approx. 10%.

Optimization of solutions for Building B

Are the installation variants analyzed so far final, or can there be "something" to be improved within them so that the building in a given variant meets the requirements of WT 2021? Let's check it out! The analysis of possible technical improvements was carried out for Building B, as it is an facility with a simple shape and medium size (252 m^2).

The impact of surface heating, mechanical ventilation and building tightness on energy demand.

First, partial (optimization) analyzes were performed for:

- **Variant 3 (gas + gravity)** – gas condensing boiler with radiator heating and gravity ventilation;
- **Variant 4 (gas + mech + floor)** – gas condensing boiler with surface heating and mechanical ventilation with heat recovery.

Variants 3 and 4 – despite the fact that they are based on the same fuel and heating device - they differ significantly in heating systems, ventilation and tightness of the building. This has an impact on the demand for thermal energy. These differences are visible in the demand of the analyzed buildings for both final and primary energy. They amount to several kWh for final energy and approx. 10 kWh for primary energy.

Table 9 compares the influence of individual elements on PE, FE and UE.

Surface heating is less efficient, which results from the specificity of its regulation, which is also associated with a greater demand for final energy, and consequently for primary energy. The energy calculations do not take into account the actual temperatures in the rooms, and these may be lower for surface heating while maintaining the same or even greater temperature comfort (the analysis showed that in the case of lowering the temperature by 1 K, we obtain savings in the primary energy index at the level of 5 kWh).

Mechanical ventilation with heat recovery means a lower demand for usable energy, which in turn translates into lower final and primary energy consumption. Such ventilation enables the reduction of final energy by nearly 20 kWh (i.e. significantly).

Higher airtightness of the building also reduces the demand for utility energy, and consequently - final and primary energy. However, these differences are clearly smaller (a few kWh) than in the case of using mechanical ventilation with heat recovery.

All these changes contribute to the reduction of energy consumption, with the greatest savings being achieved by introducing heat recovery from ventilation. Savings resulting from the use of surface heating and greater tightness of the building are lower.

Scan or click:
Ewa Zaborowska – Energy performance of multi-family buildings, collective housing and public utility buildings - examples of calculations for 2017 and 2021

Table 11. The impact of the proposed partial improvements on energy demand for Variants 3 and 4 [kWh/m^{2}a]

	Variant 3: gas + gravity	Variant 3 extended: gas + gravity and underfloor heating	Variant 3 extended: gas + gravity and mechanical ventilation	Variant 3 extended: gas + gravity and higher tightness	Variant 4: gas + mech + floor
UE	59.4	59.4	41.3	56.1	40.4
FE	88.5	90.4	70.4	84.5	71.1
PE	106.3	108.4	93.0	101.9	95.5

Table 12. List of individual variants with PE values [kWh/m^{2}a] before and after modification

Coefficient	Variant 3: gas + gravity	Variant 4: gas + mech + floor	Variant 5b: gas + mech + floor + HP	Variant 9: electr + PV + mech
PE before modification	106.3	95.5	90.0	99.0
PE after modification	69.2	68.6	70.0	69.3

Modifications, i.e. meeting the requirements of WT 2021 in terms of costs

The proposed comprehensive solutions concern variants that did not meet the requirements of WT 2021. The easiest way to meet these requirements is in the variant with the lowest non-renewable primary energy demand ratio.

Variant 5b

gas condensing boiler + surface heating and DHW from an air source heat pump + mechanical ventilation with heat recovery

- increasing the efficiency of the recuperator to 90%, and the ventilation system to 75% (85 and 70% were assumed);
- increasing the tightness of the building to n_{50} = 0.9 (assumed 1.0);
- temporary reduction of air exchange - reduction of ventilation at night by 15%;
- use of white internal blinds to improve the heat transfer coefficients;
- improvement of the building's insulation to the value of:
  – roof: 0.106 W/m^{2}K
  (30 cm, λ = 0.039 W/mK),
  – external wall: 0.114 W/m^{2}K
  (30 cm, λ = 0.036 W/mK),
  – floor: 0.096 W/m^{2}K
  (26 cm, λ = 0.036 W/mK).

Variant 4

gas condensing boiler + surface heating + mechanical ventilation with heat recovery

- installation of a solar collector system and shifting to Variant 5a: gas boiler for central heating + solar installation for DHW

Variant 3

gas condensing boiler + radiator heating + gravity ventilation

- improvement of the building's insulation to the value of:
  – roof: 0.132 W/m^{2}K
  (25 cm, λ = 0.039 W/mK),
  – external wall: 0.114 W/m^{2}K
  (25 cm, λ = 0.036 W/mK),
  – floor: 0.131 W/m^{2}K
  (15 cm, λ = 0.036 W/mK);
- installation of solar collectors (50% share in the energy demand for DHW preparation).

> ***Only well-thought-out designs, with a good concept implemented consistently from the very beginning, guarantee the actual achievement of the WT 2021 requirements, without the need to introduce subsequent modifications unreasonably increasing the costs of building a house.***

Variant 9

electric local space heaters (panel heaters) + mechanical ventilation with heat recovery + photovoltaics

The PE indicator was exceeded here by nearly 30 kWh/m^{2}a in relation to the requirements of WT 2021 - they can be met only by applying multidirectional and wide improvements:

- reduction of mechanical ventilation at night by 15%;
- increasing air tightness to n_{50} = 0.7;
- improvement of the building's insulation to the value of:
  – roof: 0.11 W/m^{2}K
  (30 cm, λ = 0.039 W/mK),
  – external wall: 0.114 W/m^{2}K
  (30 cm, λ = 0.036 W/mK),
  – floor: 0.09 W/m^{2}K
  (30 cm, λ = 0.036 W/mK);
- increasing the share of PV to 40% (from 30%), i.e. an additional 10 kW electricity storage.

Variant 1

automatic coal boiler for eco-pea coal + radiator heating + gravity ventilation

It exceeds the required PE value by as much as 44 kWh/m^{2}a. Theoretically, the required PE can be achieved, but it requires a lot of very expensive investments and careful construction of a sealed and highly insulated building and the installation of solar collectors so that they have a 50% share in the energy demand. In practice, however, this has no economic justification and is difficult to implement.

> ***Although it is possible to improve the PE index in such a way that the requirements are met even for the least promising variants, however, these are often improvements that only function theoretically, "on paper" - in fact, such an effect is very difficult to achieve or highly expensive.***

Conclusions from the analysis and tips

1 The extensive surface of the partitions and the large area of glazing not exposed to solar radiation during the heating season contribute to the increase in energy demand. The smallest Building A with an area of 115 m^2 - has, among others for these reasons the highest demand for usable energy (UE).

2 The values of UE, FE and PE indicators are comparable for buildings B and C. This is due to similar surface-to-volume ratios related to the geometrical aspects of the building body.

3 The annual demand for usable energy (UE) is assumed to be the same for all systems in a given building. The UE is related to the energy demand for heating and ventilation. Due to the use of energy recovery from ventilation, in variants 4–9 the UE value is lower than for Variants 1–3 with natural (gravity) ventilation.

4 The value of the final energy index (FE) is the lowest in the case of systems with the highest efficiency, i.e. for heat pumps, which results in low operating costs of these devices.

5 The primary energy index (PE) is determined by: technical equipment of the building (type of heating device and ventilation method), efficiency of devices and the use of renewable energy sources (reducing the input of non-renewable primary energy).

6 The type of ventilation used has a significant impact on the PE index. **Mechanical ventilation with heat recovery makes it easy to meet the requirements.** Moreover, the more efficient the heat recovery system, the greater the reduction of PE demand. However, it should be borne in mind that the higher the recovery efficiency, the more the demand for auxiliary energy to drive the fans increases, which in turn reduces the expected effect. For these reasons, an optimal solution should be sought between efficiency and auxiliary energy.

7 Method of preparing DHW has a great influence on the PE index - demand for non-renewable primary energy. The insulation of houses built according to WT 2021 is so high that DHW may constitute up to 50% or more of the demand for non-renewable energy.

8 A significant share of DHW in the primary energy demand of the building, it limits the impact of saving measures on this indicator in terms of ventilation and thermal insulation of partitions.

9 Another problem to be solved is the fact that the total efficiency of the DHW installation is relatively low. It is therefore necessary to ensure high partial efficiencies, which is of particular importance in the case of multi-family buildings, mainly in terms of transmission efficiency.

10 The greater efficiency of the surface heating installation results from the fact that it allows to maintain a lower temperature in the room while maintaining the comfort of use. However, in standard energy calculations it is not taken into account and standard temperatures are

Final energy is best known to us - it's the energy we pay for assumed, which paradoxically depreciates a more efficient heating system.

11 In the case of Variants 5a and 5b, there is a large difference in the final energy demand (FE). Although for the preparation of DHW heat pumps consume electricity, their use is more advantageous from an energy point of view than solar collectors. Heat pumps are more efficient and have a longer working time. However, the situation changes dramatically when analyzing the primary energy index (PE). A heat pump in a classic solution uses mains electricity which is based on burning coal with low efficiency. The consequence is a high share of primary non-renewable energy. The advantage of solar collectors, taking into account the PE, is that they use solar energy, i.e. they are not burdened with CO_2 emissions, which translates into a clearly lower value of primary energy despite a smaller share in the preparation of DHW.

12 Energy efficiency regulations are structured in such a way that it is often impossible to meet the requirements with conventional solutions, even under very strict standards. Only the use of renewable energy - of course, under the other conditions - can guarantee the fulfillment of the WT 2021 requirements.

13 Replacing a conventional fuel (coal, gas) boiler with a biomass boiler significantly reduces the PE index, ensuring that the required value is almost always achieved, even with a lower biomass boiler efficiency. However, the operation of a biomass boiler may be more expensive than other considered solutions.

14 The use of compressor heat pumps does not always guarantee the achievement of the required PE level. However, given the current conditions, it is one of the cheapest methods of preparing DHW in residential buildings. The use of a photovoltaic (PV) installation supporting the supply of electricity for heating purposes reduces PE. It is assumed that providing 30% of energy from a photovoltaic installation for heat pumps is realistic (analyzes were made for this share of PV energy).

15 Gas air source heat pumps also deserve attention. They are "on the frontier of conventional technologies" - they use fossil fuel, ie gas, but also environmental heat to provide heat for building heating and domestic water. GAHP efficiency is described as GUE (Gas Utilization Efficiency), this indicator informs about the amount of energy produced by the device related to the value of energy in the fuel supplied to the burner. The device obtains renewable energy with the use of gas, which ensures a low coefficient of non-renewable primary energy input PEF_{nren} = 1.1, and not 3.0, as is currently the case with the use of electricity. This guarantees relatively low values of PE indexes, at the level of the use of an installation based on a ground compressor pump. At the same time, the obtained FE indicator is much lower than when using a gas boiler, and similar to the value for a gas boiler with a HP for DHW. The gas absorption heat pump can also be a solution for modernized buildings connected to the gas network, due to the high power supply parameters of the installation - up to 65°C. This allows to work with existing radiator installations and significantly increases the efficiency of the heat source - reducing gas consumption, and most importantly: it allows to meet the requirements of WT 2021. The main "problem" is the power of the devices offered, which will work in medium and large single-family houses, and, above all, in multi-family houses, but for small houses, the device will be oversized. With regard to the objects analyzed in the publication: the pump will work well in a multi-family building, it can also be used in building.

WT 2021 ... and what's next?

Nearly zero-energy buildings do not constitute the final standard for general construction. In the longer term, these standards will evolve towards zero-energy construction (zero demand for non-renewable primary energy thanks to the use of RES) and plus-energy construction (giving back more energy than it consumes) and distributed energy based on RES. Thanks to increasing the thickness of the insulation and the use of new insulation materials, the heat transfer coefficients of the partitions will also be improved. The transmission coefficients for windows and doors can still be improved. The weak links are the connections of the frames with the glazing unit, the frames themselves and the embedment of windows (they should be installed in the insulation zone).

In the case of installation techniques, we will observe changes towards increasing the market share of CO_2-free heating equipment, which will mean an increase in the share of devices using electricity, which will increasingly come from renewable sources - mainly solar and wind energy.

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