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COMPARATIVE ANALYSIS OF TWO METHODOLOGIES FOR CALCULATING ENERGY PERFORMANCE AND ENERGY DEMAND: A CASE STUDY OF THE MUNICIPAL OFFICE AND VILLAGE ADMINISTRATION BUILDING

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Abstract

In response to increasingly stringent European Union directives and national regulations on the energy performance of buildings, reliable and interpretable energy assessment methods are essential, particularly for public utility buildings due to their large floor areas and significant contribution to national energy demand. This study compares regulatory calculation results obtained for an administrative public utility building using two frameworks: the energy performance certificate (EPC) procedure and the energy audit methodology. The objective is to quantify methodological discrepancies and to indicate which model assumptions most strongly affect ventilation–related losses and the resulting energy indicators. For the investigated building, the ventilation heat loss coefficient determined within the audit methodology was 37% higher than that obtained under the EPC procedure, which translated into an over 31% higher useful energy demand for heating and ventilation. The audit–based EU and EK indicators were higher than those calculated within the EPC framework, while the EP indicator remained at a comparable level, indicating that differences in methodological assumptions can substantially alter the distribution of useful and final energy components without necessarily producing a proportional change in primary energy. The reported differences should be interpreted as consequences of distinct regulatory algorithms and input treatment (including ventilation and infiltration air flow rates and system efficiency assumptions) rather than as evidence of divergence from actual operational energy use, as measurement–based validation was not performed. The findings support a more cautions interpretation of EPC and audit outputs and underline the need for broader case samples and operational data to generalise results.

Keywords: building heat balance, energy demand, energy efficiency, Energy Performance Certificate, Energy audit, Energy performance indicators

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1. INTRODUCTION

The evolving National and European Union Standards concerning the reduction of energy consumption have necessitated extensive research and analysis of numerous facilities within the construction sector. Increasingly stringent regulations regarding building commissioning and rental have prompted a reassessment of existing buildings for economic reasons. In this context, the concepts of energy consumption and energy balance are crucial in defining energy efficiency. Energy efficiency is determined as the ratio of the energy saved to that consumed or forecasted. The primary objective of productive energy use is to reduce consumption during the phases of operation, production and service management in buildings. (Markiewicz–Zahorski et al. 2021)

Low heat consumption indicators for space heating necessitate the use of materials and products that facilitate the minimization of energy consumption costs. An energy-efficient building is generally defined as one that consumes approximately 70 kWh/m^2 per year (Dz.U.2022.1225), whereas the average single-family building in 2024 exhibits an energy consumption level of 161.7 kWh/m^2 (bankier.pl). Numerous factors influence the maintenance of energy efficiency at levels specified in relevant standards.

An additional advantage of energy-efficient buildings is their environmental sustainability which supports the European Union's climate policy through the reduction of greenhouse gas emissions. Human activities should be conducted with environmental awareness, as the production and utilization of thermal or electrical energy contribute to pollution in the natural environment. Implementing energy-efficient solutions in the construction sector indirectly enhances building safety. Energy conservation, the use of renewable energy sources and the efficient management of energy resources exert a positive influence on the ecosystem and contribute to the sustainable development of the built environment. (Kaczmarczyk 2025)
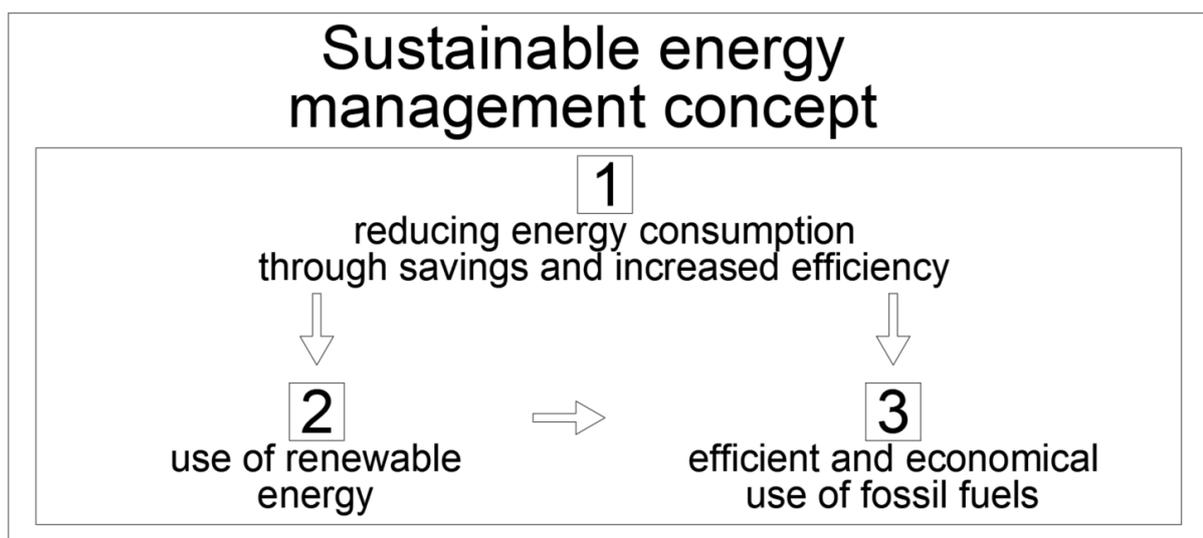

Fig. 1. Sustainable Energy Management Framework [own elaboration]

In every building structure a construction-energy framework is established. Determining the energy balance of a building involves identifying both energy losses and gains. Within building facilities an equilibrium of the energy balance is maintained – energy losses are compensated by the supplied energy. Consequently reducing energy losses directly decreases the amount of energy

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required for supply. Such losses are primarily caused by insufficient airtightness, ventilation inefficiencies and thermal transmission through the building envelope. Air and heat leakage constitute the main factors of energy loss are closely related to the airtightness and thermal insulation properties of the building layers. The final outcome of the energy balance depends on internal heat gains which are influenced by the building's usage, equipment and location. Heating, ventilation, plumbing, electrical, gas and water supply systems all contribute to the overall energy demand which represents the principal component of the building's energy balance. (Kowalski and Szałański 2017)
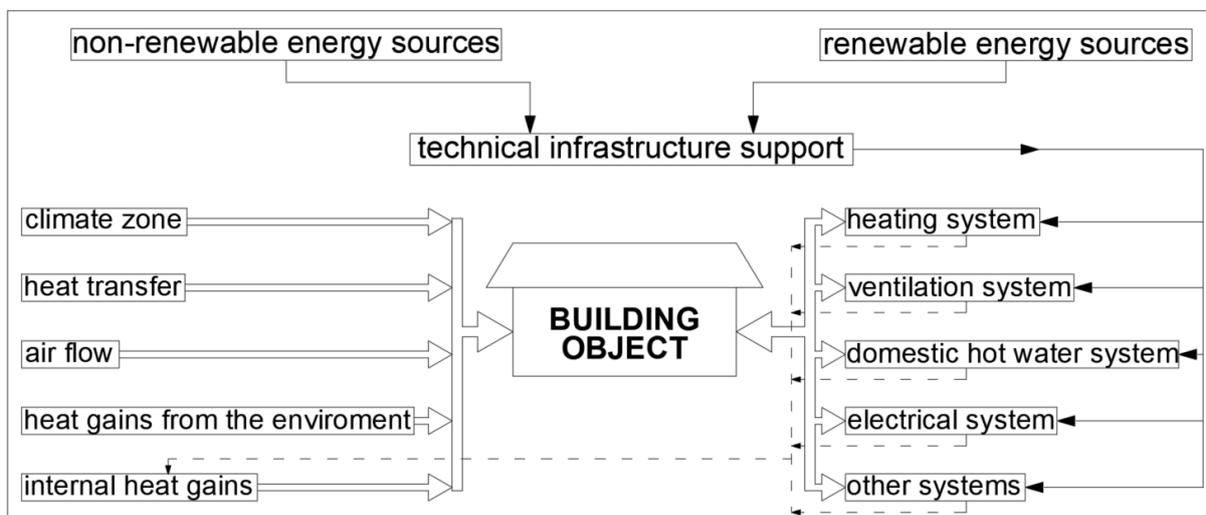

Fig. 2. Energy Demand of the Building [own elaboration]

The energy demand required to use the building is included in the energy performance certificate. This document is required when purchasing a building or premises and is intended to indicate to the buyer the operating costs of the purchased property. The Building Law Act of 7 July 1994 as amended (Dz.U.1994.89.414), has undergone numerous amendments, which incorporate EU Directives on energy performance. One of the most important was the Regulation of the Minister of Infrastructure and Development of 27 February 2015 on the methodology for determining the energy performance certificates (Dz.U.2015.376). The latest amendment to the above Regulation entered into force 28 March 2023, changing the values of the non-renewable primary energy consumption coefficient and the templates for energy performance certificates.

The energy performance certificate is determined by the annual primary energy demand indicator. The methodology for calculating energy performance takes into account the amount of useful energy consumed, final energy and losses from the efficiency of installation systems and primary energy. The calculations also include energy losses resulting from transmission, the type of energy carrier and generation losses. After calculating the annual non-renewable primary energy demand indicator EP, the tested object or part thereof can be assessed. The lower the EP value expressed in $kWh/(m^2 \cdot year)$, the higher the efficiency and environmentally friendly energy use. New buildings intended for human habitation must have an EP index lower than the limit value. For single-family buildings, the EP must not exceed 70 $kWh/(m^2 \cdot year)$, while the values for multi-family residential buildings cannot exceed 65 $kWh/(m^2 \cdot year)$ for collective housing 75 $kWh/(m^2 \cdot year)$ and public buildings, depending on the type of function they perform, these values range from 45 to 70 $kWh/(m^2 \cdot year)$ (Dz.U.2022.1225). The EP indicator is influenced by many factors. To calculate this indicator, the thermal insulation of the

building's external partitions, external window and door frames, ventilation, renewable energy production installations, the location of the building and the presence of thermal bridges are taken into account. (Kwiatkowski and Rucińska 2020) The final energy indicator EK, which relates to the demand for ventilation, cooling, heating and domestic hot water, is a parameter of the energy efficiency of a building. Energy charges for the above-mentioned demand calculations is the EU indicator, which relates to useful energy. The relationship between all three energy-dependent indicators is shown in Figure 3. This is a diagram of the energy cycle from the raw material to the end user of the building.
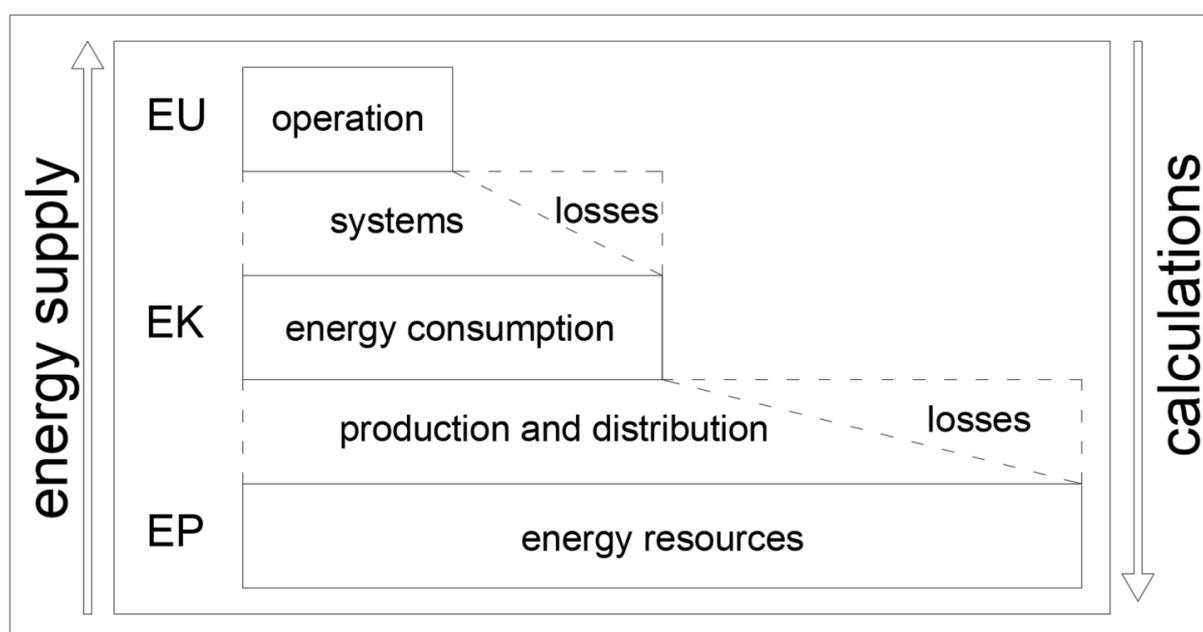
Fig. 3 Interpretation of Useful Final and Primary Energy [own elaboration]

The calculation of energy demand is based on climate data and the method of use of the building or part thereof. Based on information about the type of building, a method for calculating energy performance depending on actual energy performance depending on actual energy consumption was determined. The energy performance certificate takes into account all the indicators listed above and the annual energy consumption per square metre of the building in question. The last significant change in the regulations concerning energy performance certificates was the amendment of 28 April 2023 (Dz.U.2023.697). The changes have made it necessary to have this document in certain cases. At present, an energy performance certificate is required when selling or renting a building or part of a building, after completion and acceptance of a newly constructed building and for public buildings. When selling or renting a building or premises, the property owner is required to provide the buyer or tenant with a current energy performance certificate. This generates additional costs for owner is required to provide the buyer or tenant with a current energy performance certificate. In the case of a newly constructed building, the owner is exempt from the obligation to obtain an energy performance certificate for a residential building up to 70 m^2 built for their own use. Buildings occupied by public administration or judicial authorities with a usable area of more than 250 m^2 should have this document displayed in a place visible to visitors. The same obligation applies to the owner or manager of buildings with a usable area of more than 500 m^2 that are open to the public. There are exceptions to the obligation to

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have energy performance certificates. Failure to comply with the obligation to have an energy performance certificate may result in a fine.

An energy audit is an analysis of a building and its systems in order to identify irregularities that increase maintenance costs. The detailed scope of the audit and audit templates can be found in the Regulation of the Minister of Infrastructure and Development of 3 September 2015 (Dz.U.2015.1606), which is an amendment to the Regulation of the Minister of Infrastructure of 17 March 2009 on the detailed scope and forms of energy audits and parts of renovation audits, audit card templates, and the algorithm for assessing the profitability of thermal modernisation projects (Dz.U.2009.43.346). The first stage of the audit involves a preliminary energy audit, i.e. a one-day observation, which allows the source of inappropriate energy management to be located. Heating and ventilation systems as well as the location and position of the facility are taken into account. Then, based on the calculations, a list of gains and losses is drawn up. The next stage of the full audit is an assessment of the condition of the building and equipment based on an on-site inspection. The poor technical condition of the building may contribute to an increase in heating energy demand and consequently, maintenance costs. Next, in extended audit, solutions are identified to improve energy consumption and the need for thermal modernisation work leading to savings is indicated. (Michalak et al. 2023)

2. THERMAL CALCULATION METHODS

2.1. Energy Performance Certificate (EPC) Calculation Methodology

Calculations carried out using the methodology for preparing the energy performance of a building and the energy performance certificate in the Regulation of the Minister of Infrastructure and Development of 27 February 2015, as amended by the Regulation of the Minister of Development and Technology of 28 March 2023. At the initial stage, the heat transfer coefficients of building partitions in direct contact with external conditions are determined.

First, the heat loss coefficient due to transmission H_{tr} is determined which depends on the types of thermal bridges and the heat transfer coefficients of the building's thermal envelope. Subsequently, the heat loss coefficient associated with ventilation from the heated zone H_{ve} is evaluated using on formula 2.1, which accounts for the thermal capacity of air as well as the individual contributions of ventilation airflow components k with the heated zone.

$$H_{ve} = \rho_a \cdot c_a \cdot \sum_k b_{ve.k} \cdot V_{ve.k.n} \left[\frac{W}{K}\right] \qquad (2.1)$$

Where:
$\rho_a \cdot c_a = 1200$ [J/(m³·K)] – heat capacity of air
$b_{ve.k}$ [-] – temperature correction factor for the outdoor air stream depending on the outdoor air stream identifier k
$V_{ve.k.n}$ [m³/s] – external air stream k in the heated zone

The values of the time-averaged external air flow $V_{ve.k.n}$ depend on the flow identifier k, which in turn results from the type of ventilation and the manner of use and airtightness of the building. In a public building that is not in use 24 hours a day, the time share of mechanical ventilation fans β (if any) is also taken into account.

The time-averaged outdoor air flow $V_{ve.l.n}$ is determined using formula 2.2 for gravity ventilation. The time-mean outdoor air flow takes into account the basic outdoor air flow and the area of the heated

zone. The basic external air flow $V_{ve.l.s}$ during the use of a public building is determined on the basis of the Regulation (Dz.U.2015.376).

$$V_{ve.l.n} = V_{ve.l.s} \cdot A_{f.s} \left[\frac{m^3}{s \cdot m^2}\right] \tag{2.2}$$

Where:

$V_{ve.l.s}$ [m³/s] – basic external air flow during building use

$A_{f.s}$ [m²] – heated area

The average additional flow of outside air entering through leaks V_{inf} in m³/h was determined. In the case of gravity ventilation, it was assumed that no building airtightness test was performed. In the modernised building, the air exchange rate of 0.2 h^{-1} is specified on the basis of the Regulation on the methodology for determining energy performance. The volume of the heated zone V in m³ is based on the building design.

The next parameters considered, which are necessary for calculations using the energy performance methodology, are heat gains $Q_{H.hg}$ in kWh/year, determined as the sum of internal heat gains Q_{int} in kWh/year and solar heat gains Q_{sol} in kWh/year. Monthly internal heat gains are governed by the heat load, which is selected according to the functional use of the spaces. Another part of the building, which is the Community Centre, is considered a building intended for catering purposes.

The final stage of calculations resulting from energy performance calculations is to calculate the annual final energy demand supplied to the analysed building for the heating system $Q_{K.H}$, which is determined on the basis of formula 2.3. The coefficient $\eta_{H.tot.CO}$ is the product of the average seasonal efficiencies of the components comprising the entire heating system. The total efficiency factor $\eta_{H.tot.CO}$ is composed of the following components: $\eta_{H.g}$ – efficiency of heat generation by the boiler; $\eta_{H.d}$ – efficiency of heat distribution in the central heating system; $\eta_{H.e}$ – efficiency of heating system control and $\eta_{H.s}$ – efficiency of heat storage (accumulation).

$$Q_{K.H} = \frac{Q_{H.nd}}{\eta_{H.tot.CO}} \left[\frac{kWh}{year}\right] \tag{2.3}$$

Where:

$Q_{H.nd}$ [kWh/year] – annual heat demand for useful energy for heating and ventilation

$\eta_{H.tot.CO}$ [%] – total efficiency of the heating system

In addition to the heating system, the building has a domestic hot water preparation system, which must be taken into account in energy performance calculations. Formula 2.4 is used to obtain the annual demand for useful energy for domestic hot water preparation $Q_{W.nd}$. The main factor determining the useful energy demand for domestic hot water V_{Wi}.

$$Q_{W.nd} = \frac{V_{Wi} \cdot A_f \cdot c_w \cdot \rho_w \cdot (\theta_w - \theta_0) \cdot k_R \cdot t_R}{3600} \left[\frac{kWh}{year}\right] \tag{2.4}$$

Where:

V_{Wi} [dm³/m²·doba] – unit demand for hot water

$c_w = 4.19$ [kJ/(kg·K)] – specific heat capacity of water

$\rho_w = 1000$ [kg/m³] – density of water

$\theta_w = 55$ ℃ – domestic hot water temperature

$\theta_w = 10$ ℃ – cold water temperature

k_R [-] – reduction factor taking into account breaks in building use

t_R [day/year] – number of days of hot water system usage per year

One of the final calculations required for the determination of the energy performance indicators is the annual final energy demand for domestic hot water preparation $Q_{K.W}$, which is calculated using equation 2.5. One component of this calculation is obtained using formula 2.1.4, while the other component represents the average annual total efficiency of the domestic hot water preparation system $\eta_{W.tot.CWU}$. The total efficiency factor is composed of the following elements: $\eta_{W.g}$ – heat generation efficiency; $\eta_{W.d}$ – heat distribution efficiency and $\eta_{W.s}$ – heat storage efficiency.

$$Q_{K.W} = \frac{Q_{W.nd}}{\eta_{W.tot.CWU}} \left[\frac{kWh}{year}\right] \tag{2.5}$$

Where:
$Q_{W.nd}$ [kWh/year] – total annual final energy demand for domestic hot water preparation
$H_{W.tot.CWU}$ [%] – total efficiency of the domestic hot water system

To determine the EP and EK values using the energy performance method, the following calculations of annual final energy demand for: lighting must be taken into account $Q_{K.L}$, primary energy demand for heating the building $Q_{P.H}$, primary energy demand for domestic hot water preparation $Q_{P.W}$ and primary energy use to for lighting $Q_{P.L}$. Formulas 2.6, 2.7 and 2.8 show their complexity for the methodology using energy performance certificate calculations.

$$EP_{CH.E} = \frac{Q_{P.H} + Q_{P.W} + Q_{P.L}}{A_f} \left[\frac{kWh}{m^2 \cdot year}\right] \tag{2.6}$$

$$EK_{CH.E} = \frac{Q_{K.H} + Q_{K.W} + Q_{K.L} + E_{el.pom}}{A_f} \left[\frac{kWh}{m^2 \cdot year}\right] \tag{2.7}$$

$$EU = \frac{Q_{H.nd} + Q_{W.nd}}{A_f} \left[\frac{kWh}{m^2 \cdot year}\right] \tag{2.8}$$

Where:
$Q_{P.H}$ [kWh/year] – annual primary energy demand for heating and ventilation purposes
$Q_{P.W}$ [kWh/year] – annual primary energy demand for domestic hot water
$Q_{P.L}$ [kWh/year] – annual primary energy demand for built-in lighting
$Q_{K.L}$ [kWh/year] – annual final energy demand for built-in lighting
$E_{el.pom}$ [kWh/year] – auxiliary energy demand

2.2. Methodology for calculating the energy audit

An energy audit is carried out in order to find the most optimal solution for a thermal modernisation project. The audit is not limited to presenting energy indicators. It includes proposals for measures to improve the energy efficiency of the building, as well as a technical and economic analysis. (Adamczyk and Dylewski 2020)

In the Regulation of the Minister of Infrastructure of 17 March 2009 (Dz.U.2009.No 43.346 as amanded) on the detailed scope and forms of energy audits and parts of renovation audits, audit card templates, as well as the algorithm for assessing the profitability of thermal modernisation projects, the methodology for determining the audit, like the energy performance, is based on the input data of the analysed public building. The initial information to be entered into the audit includes general data

about the building, technical and construction documentation, and descriptions of installations. Next proceed to the thermal calculations of the existing condition. (Barwińska–Małajowicz et al. 2023)

Within the energy audit methodology, the heat loss coefficients due to transmission are determined in the same manner as in the energy performance methodology. However, the calculation of the heat loss coefficient due to ventilation in the audit methodology is carried out using Equation 2.9. The heat loss coefficient for ventilation differs in that, instead of the time-averaged external air flow used in the characteristics, the average value of the flow rate over time is used, which depends on the air flow through the heated space $\dot{V}$ [m³/s].

$$H_{ve} = \rho_a \cdot c_a \cdot \dot{V} \ [\frac{W}{K}] \tag{2.9}$$

Where:
$\dot{V}$ [m³/s] – air flow through the heated space

The total internal heat gains Q_{int} expressed in kWh/year and the solar heat gains Q_{sol} expressed in kWh/year are determined in the same manner as in the energy performance certificate methodology. The above–mentioned parameters are governed by the same boundary conditions and assumption as those adopted for the energy performance certificate calculations.

Compared to the energy performance, the $\eta_{H.tot.CO}$ coefficient will change due to the fact that additional components are taken into account in the energy audit. Additional elements supplementing the calculation of the heating system efficiency are: heating break during the week w_t and heating break during the day w_d.

Another element is domestic hot water system. The total efficiency of the domestic hot water systems according to the Regulation of the Minister of Infrastructure and Development of 3 September 2015 (Dz.U.2015.1606) amending the Regulation of 17 March 2009 (Dz.U.2009.346), reference should be made to the Regulation on the preparation of certificates (Dz.U.2015.376). Efficiency has the same component values and to obtain the annual final energy demand $Q_{K.W}$ expressed in kWh/year should be substituted for the efficiency values $\eta_{W.tot.CWU}$ and the useful energy demand for domestic hot water preparation $Q_{W.nd}$ in formula 2.4. The main factor determining the demand for domestic hot water is changing. Formula 2.11 for the annual demand for useful energy for domestic hot water preparation in relation to energy performance takes a different form. The factors based on the above standard are subject to change. To determine formula 2.11 for DHW demand in the energy audit methodology, use standard PN-EN 15316-3-1:2008 and determine the daily DHW demand (2.10).

$$V_{CWU} = V_{wi} \cdot A_f \cdot k_R \ [\frac{dm^2}{day}] \tag{2.10}$$

$$Q_{W.nd} = V_{CWU} \cdot c_w \cdot \rho_w \cdot (\theta_w - \theta_0) \cdot k_R \cdot t_R [\frac{kWh}{year}] \tag{2.11}$$

After calculating the above-mentioned requirements based on standards and regulations, the values of the EU useful energy, EK final energy and EP primary energy indicators were calculated. The calculation of indicators using the energy audit method is slightly different. In this method, not only the cooling system was omitted, but also the annual energy consumption associated with the lighting installation and technical systems of the building as shown in formulas 2.12–2.14. The primary energy indicator EP expressed in kWh/(m²·year) has two significant components of the annual demand for non-renewable primary energy: for the heating system $Q_{H.nd}$ and for domestic hot water $Q_{W.nd}$ stated in kWh/year. The final energy parameter EK reported in kWh/(m²·year) in the energy audit

methodology, compared to the energy performance, has only two components of final energy: for heating the building $Q_{K.H}$ and for domestic hot water preparation $Q_{K.W}$ stated in kWh/year. The components of the useful energy indicator EU given in kWh/(m²·year)] remained unchanged in relation to the energy performance, while the values were modified as a result of the application of a different calculation methodology.

$$EP_A = \frac{Q_{P.H} + Q_{P.W}}{A_f} \left[\frac{kWh}{m^2 \cdot year}\right] \tag{2.12}$$

$$EK_A = \frac{Q_{K.H} + Q_{K.W}}{A_f} \left[\frac{kWh}{m^2 \cdot year}\right] \tag{2.13}$$

$$EU = \frac{Q_{H.nd} + Q_{W.nd}}{A_f} \left[\frac{kWh}{m^2 \cdot year}\right] \tag{2.14}$$

3. BUILDING ANALYSIS AND RESULTS OF CALCULATION

In order to compare energy consumption values, calculations were made for a selected public building using both the energy performance certificate methodology and the energy audit methodology. Table 1 shows the preliminary data used in the calculations.

Table 1. Input parameters of analysed building

General data of building question		
1	Building purpose	Public utility
2	Building construction/technology	Traditional, brick
3	Building type	Existing
4	Number of storeys	3
5	Building volume [m³]	6726
6	Usable floor space [m²]	1318,09
7	Usable area with regulated temperature A_f [m²]	1311,10
8	Number of commercial premises	1
9	Number of people using the building	350
10	A/V shape factor	0,4

The verified administrative and utility building serves several public functions. The attic and first floor rooms have been adapted for use by the Municipal and Village Councils. The ground floor houses utility rooms and the Community Centre hall, which are rented out for special events. On the north side, there is a staircase visible in Fig. 4. The three-storey building is made of aerated concrete blocks, has a multi-pitched roof insulated with mineral wool and PVC window frames. The building is used by 350 people and has a usable area of over 1300 m². The usable area requires an energy performance certificate.

Based on an on-site inspection, the technical condition of the building was assessed and the systems installed in the building were identified. The building has a two-pipe central heating system connected to a gas boiler located in the boiler room in the basement. The heating medium is supplied through galvanised steel pipes from the outside to the panel radiators. Domestic hot water is

prepared by a gas boiler, which charges a hot water tank equipped with a circulation system also located in the boiler room. The building is ventilated by gravity through air inlets also located in the boiler room. The building is ventilated by gravity through air inlets located in the windows, while exhaust air is removed through gravity ventilation ducts. The building is lit by standard and compact fluorescent lamps.

Fig. 4 North Elevation of the Administrative and Utility Building Under Discusion [own elaboration]

3.1. RESULTS OF ENERGY PERFORMANCE CHARACTERISTICS

In this section, the calculation procedure applied to the above–described administrative and service building, performing a public utility function, is presented. The reported results include the building's energy performance characteristics as well as the values obtained from the performed calculations carried out in accordance with the methodology described in Section 2.1. The presented calculation procedure constitutes the basis for further analysis and discussion of the results in the subsequent sections of the paper.

The analysed building has gravity ventilation, therefore the average basic external air flow V_0 and the average additional external air flow entering through leaks V_{inf} are taken into account in the calculation of the average flow. In the case in question, the building is divided into two parts. One part serves as a community centre, so the basic flow was assumed to be catering. The other part of the building is an office, so the values for an office were adopted.

To calculate the heat loss coefficient for ventilation H_{ve}, the building was calculated as an entire. The results of the heat loss coefficient for ventilation of the building in question are shown in Table 2, compiled on the basis of data contained in the Regulation (Dz.U.2015.376). The total heat loss through ventilation was determined and a value of 1632.18 W/K was determined and a value of 1632.18 W/K was obtained. To gain the heat loss value from ventilation, the air flow V [m^3] was used, taking into

account the air flow from natural ventilation V_0 and the average additional external and infiltrating air flow V_{inf}.

Table 2. Determination of the time-averaged air volume flow rate $V_{ve.k.n}$ [m³/h] and the heat loss coefficient due to ventilation H_{ve} [W/K]

Heat loss values through ventilation										
A_f [m²]	V [m³]	β [-]	$V_{ve.1}$ [m³/h]	$b_{ve.1}$ [-]	$V_{ve.2}$ [m³/h]	$b_{ve.2}$ [-]	$V_{ve.3}$ [m³/h]	$b_{ve.3}$ [-]	$V_{ve.4}$ [m³/h]	$b_{ve.4}$ [-]	H_{ve} [W/K]
1311.10	6726.00	0.30	8071.20	0.30	1345.20	0.30	1614.24	0.70	1345.20	0.70	1632.18

Further parameters required for the application of the energy performance methodology include the heat gains $Q_{H.hg} = 100\ 369.17$ kWh/year, which are calculated as the sum $Q_{int} = 65\ 465.85$ kWh/year and $Q_{sol} = 34\ 903.33$ kWh/year. Monthly internal heat gains are determined by the heat load assigned in accordance with the functional use of the office premises. Another part of the building, which is the Community Centre, is considered a building intended for catering purposes.

Based on the calculated parameters for the analysed building, the annual heat demand for heating and ventilation $Q_{H.Nd}$ can be established. The total amount of heat transferred from the heated zone is the sum of the heat resulting from transmission and the heat from ventilation in a given month. The annual demand for heating and ventilation after summing up the individual months is 172 846.68 kWh/year.

Table 3. Determination of the time-averaged air volume flow rate $V_{ve.k.n}$ [m³/h] and the heat loss coefficient due to ventilation H_{ve} [W/K]

Monthly energy demand for heating and ventilation $Q_{H.nd.s} = Q_{H.ht.s} - Q_{H.gn.s} \cdot \eta_{H.gn.s}$ [kWh/month]												Annual energy demand for heating and ventilation $Q_{H.nd}$ [kWh/year]
I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	
293 62.80	29 299.14	18 799.09	10 219.11	4 939.42	578.57	0.00	563.31	5 854.83	15 418.28	27 778.67	30 033.46	172 846.68

The following efficiencies were taken into account: generation from gas condensing boilers $\eta_{H.g} = 0.92$; heat transfer of water central heating with insulated pipes, fittings and equipment in the heated space $\eta_{H.d} = 0.96$; heating systems control with panel radiators $\eta_{H.e} = 0.874$ and heat accumulation due to the lack of a buffer tank $\eta_{H.s} = 1.00$. The product of the above efficiencies is equal to $\eta_{H.tot.CO} = 0.772$. Taking this relationship into account, the annual final energy demand for heating and ventilation $Q_{K.H}$ according to formula 2.3 is 223 918.79 kWh/year.

The unit domestic hot water demand for the analysed case amounts $V_{Wi} = 0.35$ dm³/(m²·day). The calculated DHW temperature θ_W is set at 55 ºC, while the water temperature before heating θ_0 is assumed to be 10 ºC. The annual final energy demand for domestic hot water preparation $Q_{W.nd}$, calculated using Equation 2.4, amounts to 6 140.71 kWh/year.

The last thermal energy that should be included in the final energy calculations is the annual useful energy demand for domestic hot water preparation, which amounts to 10 261.89 kWh/year [2.5]. The formula should take into account the average annual total efficiency of the domestic hot water preparation system, which consists of the following efficiencies: heat generation for gas-fired

condensing boilers $\eta_{W.g} = 0.88$; heat transfer for central water heating distributed to 30 hot water consumption points $\eta_{W.d} = 0.80$ and heat accumulation due to the presence of storage heaters $\eta_{W.s} = 0.85$. The product of the above efficiencies is equal to $\eta_{W.tot.CWU} = 0.598$.

Within the energy performance methodology the EP and EK indicators requires consideration of the annual final energy demand for: lighting $Q_{K.L} = 73\ 407.94$ kWh/year; primary energy demand for heating $Q_{P.H} = 248\ 228.16$ kWh/year primary energy demand for domestic hot water preparation $Q_{P.W} = 12\ 053.76$ kWh/year and primary energy use to for lighting $Q_{P.L} = 183\ 519.85$ kWh/year. After inserting the annual requirements and taking into account the heated area, the total energy demand indicators: primary EP is 338.50 kWh/(m^2·year), the final energy value EK is 235.42 kWh/(m^2·year) and the useful energy value EU is 136.52 kWh/(m^2·year).

The formulas for energy indicators in their original form the 2015 Regulation (Dz.U.2015.376) take into account the annual demand for the following systems: heating, heating and ventilation, domestic hot water, cooling, lighting and technical. In the analysed example, the building does not have a cooling system, so this component has been omitted from formulas 2.6–2.8.

3.2. RESULTS OF THE ENERGY AUDIT

The building under investigation has already undergone thermal modernisation in 2023, so while the determination of heat loss coefficients through transmission does not differ from that used in the energy performance methodology, when calculating the heat loss coefficient for ventilation in the audit methodology, formula 2.9 should be used. This resulted in total heat loss through ventilation $Q_{H.ve}$ of 213 359.48 kWh/year.

Table 4. Determination of the ventilation heat loss coefficient H_{ve} [W/K] based on the audit

heat loss values through ventilation					
θ_e [ºC]	V_i [m^3]	basic hygiene requirements		ventilation heat loss calculations	
		n_{min} [h^{-1}]	V_{min} [m^3/h]	V [m^3/h]	H_{ve} [W/K]
-20,00	6726,00	1,00	6726,00	8743,80	2242,00

The total internal heat gains amount to $Q_{int} = 65\ 236.14$ kWh/year. Gains from solar radiation depend on the same conditions as in the energy certificate and are at the same level, amounting to $Q_{sol} = 34\ 903.33$ kWh/year.

The tested building was constructed of aerated concrete blocks, therefore it is treated as a heavy building, additionally, the device has a five-day operating mode during the week $w_t = 0.85$. The daily value $w_d = 0.88$ also depends on the function of the building and, due to the eight-hour operation, the daily break is 16 hours. After conversion, the total efficiency of the heating system $\eta_{H.tot.CO}$ is 0.577. The annual final energy demand for heating and ventilation is 394 009.31 kWh/year.

Compared to the values obtained within the energy performance methodology, the parameters used for the determination of the domestic hot water system components change only slightly. The annual final energy demand equals $Q_{K.W} = 9\ 424.18$ kWh/year. The unit demand for DHW is $V_{Wi} = 0.4$ [dm^3/(m^2·day)], which is determined on the basis of the type of building and the correction factor for interruptions in use $k_R = 0.75$. The normative data relating to office buildings concerning the unit demand for DHW can be found in the standard. (PN-EN 15316-3:2008)

The primary energy indicator EP reported as 340.52 kWh/(m^2·year) consist of two significant components the annual non-renewable primary energy demand for the heating system $Q_{H.nd} = 227\ 498.52$ kWh/year and for domestic hot water $Q_{W.nd} = 5\ 639.43$ kWh/year. Within the energy

audit methodology, the final energy indicator EK = 307.71 kWh/(m^2·year) includes only final energy demands for heating $Q_{K.H}$ = 394 009.31 kWh/year and for domestic hot water preparation $Q_{K.W}$ = 9 424.18 kWh/year. The useful energy indicator amounted to EU = 177.82 kWh/(m^2·year).

4. ANALYSIS OF THE HEAT ENERGY CONSUMPTION BALANCE OF THE EXAMINED FACILITY

Energy calculations were carried out for the investigated public utility building within two parallel calculation frameworks: the methodology for preparing the building Energy Performance Certificate (EPC) and the energy audit methodology using the applicable standards. The comparison is methodological in nature and addresses differences in calculated results arising from differing parameter definitions and underlying assumptions in the two approaches. It does not include validation of the results against metered data of actual operational energy consumption.

After determining heat losses due to transmission and ventilation and accounting for internal heat gains and solar gains, the annual useful energy demand for space heating and ventilation $Q_{H.nd}$ expressed in kWh/year, was established. The value of $Q_{H.nd}$ calculated accordance with the EPC methodology (Dz.U.2015.376 as amended) amounted to 172 846.68 kWh/year, whereas the value determined within the energy audit framework (Dz.U.2017.1912 as amended) amounted to 227 498.52 kWh/year. The difference in this parameter results from the different procedure used to determine the ventilation heat loss coefficient, H_{ve} stated in W/K, which governs the total ventilation heat losses $Q_{H.ve}$ [kWh/year], which in turn affects the result of the energy demand for heating and ventilation $Q_{H.nd}$ reported in kWh/year, these, in turn, indirectly affect the energy indicators EK and EP.

The total ventilation heat losses ventilation $Q_{H.ve}$ expressed in kWh/year, are calculated in both approaches using an analogous monthly scheme (with the same climatic data for Krosno and the same time horizon). The differences arise at the stage of determining the ventilation heat loss coefficient H_{ve} stated in W/K. Under the EPC energy performance methodology (Dz.U.2015.376 as amended), the above parameter is determined using Equation 2.1. The adopted components of the time–averaged outdoor air flow rate $V_{ve.k.n}$ reported in m^3/h – including the infiltration air flow component and the temperature correction factors for outdoor air – are provided in Table 2. Using this approach, the ventilation heat loss coefficient was obtained as H_{ve} = 1632.18 W/K. In contrast, the audit methodology does not employ the time-averaged outdoor air flow rate; instead, it expresses H_{ve} as a function of the volumetric air flow rate $\dot{V}$ expressed in m^3/s derived from 2.9, adopted from PN–EN ISO 13789. The corresponding standard–based calculation of the ventilation heat loss coefficient used in energy audits yields H_{ve} = 2242.00 W/K. The implications of this difference, together with other parameters dependent on H_{ve} are shown in Figure 5.

Methodological differences between the EPC energy performance assessment and the energy audit are also evident in the determination of the final energy demand for domestic hot water (DHW) preparation $Q_{K.W}$ reported in kWh/year. The overall efficiency of the DHW system is determined in the same manner in both approaches and equals $\eta_{H.tot.CWU}$ = 0.598. The key differences in the calculation of the annual useful energy demand for DHW $Q_{W.nd}$ expressed in kWh/year, stem from the determination of the main input component. In the EPC framework, the unit daily demand V_{Wi} stated in dm^3/(m^2·day) is taken from the Regulation (Dz.U.2015.376 as amended), whereas in the audit approach normative values from PN-EN 15316–3:2008 were adopted and used to determine the daily DHW volume V_{CWU} reported in dm^3/day.
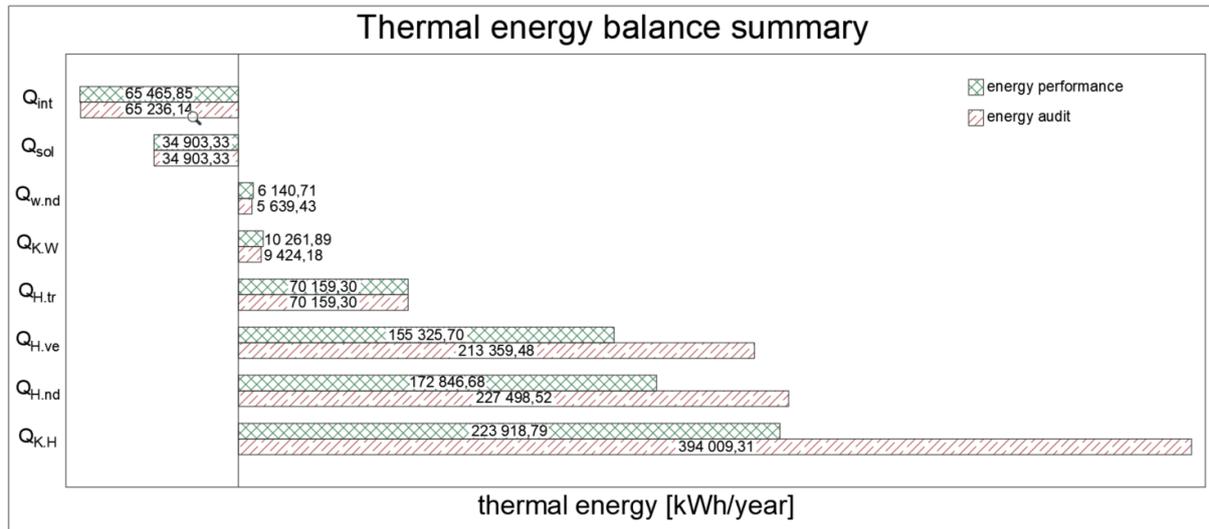
Fig. 5. Thermal Energy Balance Summary of a Public Utility Building Based on Audit Findings and Energy Performance Characteristics [own elaboration]

The thermal energy balance energy balance data were prepared based on the applicable standards and regulations and the results are presented in Figure 5 as a comparison between the energy audit and the energy performance assessment. Both solar gains and internal gains remain at a similar level in the two approaches. The largest discrepancies between the audit–based results and the energy performance assessment occur in the ventilation heat losses, which subsequently leads to differences in the heating demand, is illustrated in Figure 5. The observed difference in the useful energy demand for space heating $Q_{H.nd}$ resulting from the different treatment of ventilation heat losses in the EPC methodology, amounts to 76% of the corresponding value obtained using the energy audit methodology. This outcome follows from the distinct approaches adopted in the two methods for defining the ventilation air flow rate and the ventilation heat loss coefficient H_{ve} expressed in W/K.

The calculation procedure applied in both the energy performance assessment and the energy audit includes the determination of total ventilation heat losses and the annual useful energy demand for domestic hot water (DHW) preparation, which affects the resulting energy indicators. When analysing individual indicators, only the useful energy indicator EU is based on an unchanged formulation in both methods. In the audit methodology, the primary energy calculation does not include the lighting demand, while in the final energy calculation the lighting demand and auxiliary energy for technical systems are omitted. Figure 6 illustrates the differences in the energy indicators depending on the applied methodology. The useful energy indicator EU obtained under the energy performance methodology is lower than the audit result by 41.30 kWh/(m^2·year) whereas the difference in the final energy indicator EK equals 72.28 kWh/(m^2·year). The primary energy indicator EP is very similar in both approaches; the value calculated within the energy performance framework is only slightly higher than obtained using the audit methodology with a difference of only 2.03 kWh/(m^2·year).

COMPARATIVE ANALYSIS OF TWO METHODOLOGIES FOR CALCULATING ENERGY PERFORMANCE
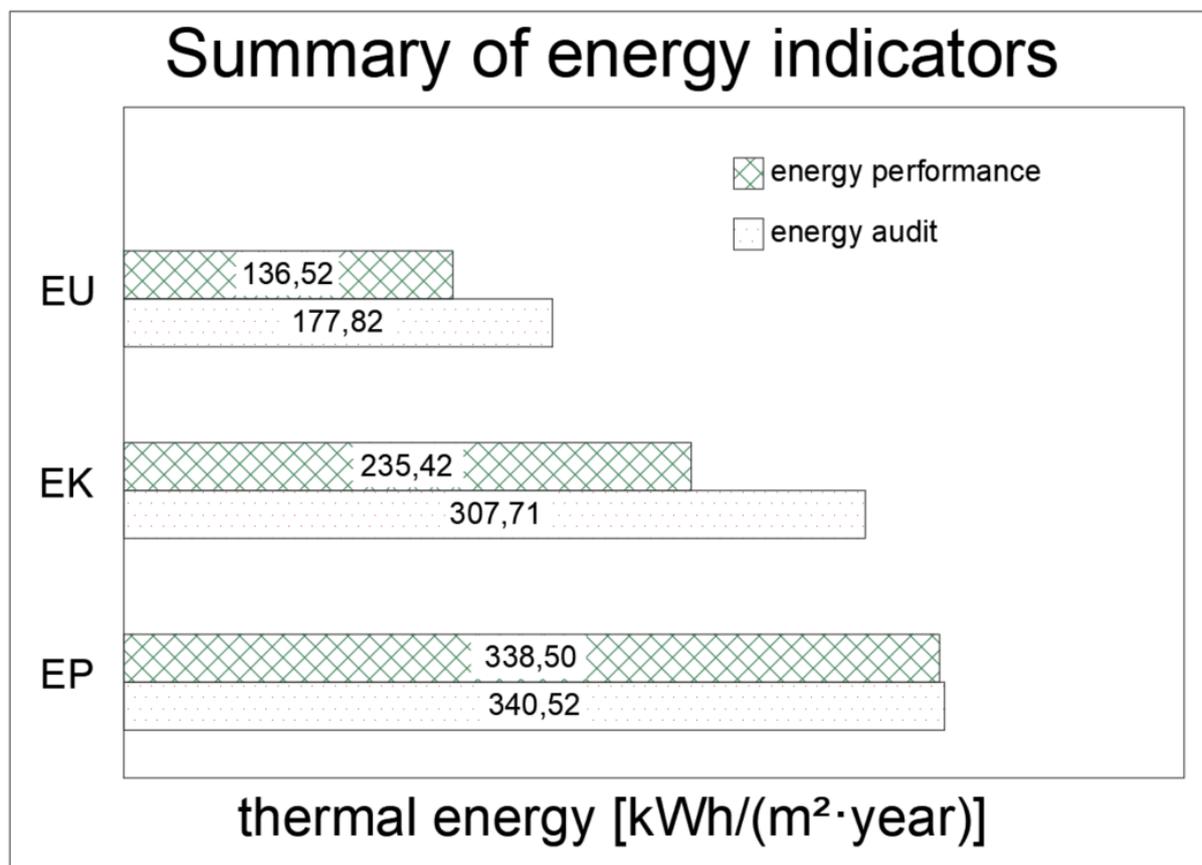AND ENERGY DEMAND: A CASE STUDY OF THE MUNICIPAL OFFICE AND VILLAGE ADMINISTRATION BUILDING

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Fig. 6 Energy Demand According to the Selected Methodology

4.1. Uncertainly and Sensitivity Analysis

This study presents a comparison of calculated results obtained using two regulatory – defined approaches. It should be noted, however, that no formal uncertainty analysis or sensitivity analysis was performed to quantify the impact of variations input parameters and calculation assumptions on the results.

In particular, the influence of uncertainty and variability in the following assumptions on $Q_{H.ND}$, $Q_{K.H}$, $Q_{K.}W$ and the indicators EU, EK and EP was not assessed. Fixed values were adopted for the investigated case and no sensitivity assessment was performed with respect to the following inputs: the assumed ventilation air flow rates, the level and treatment of infiltration and the overall system efficiency values (including the components affecting efficiency within the audit methodology).

Within the EPC calculation methodology, an increased volumetric air flow rate – augmented by the infiltration air flow component – was adopted for the determination of the ventilation heat loss coefficient H_{ve} expressed in W/K. This treatment follows from the need to account for the lower energy balance obtained when applying the standard EPC framework compared with the energy audit approach. If identical air flow rates were used in both approaches, the discrepancies in ventilation–related heat loss results would be even more pronounced, which further highlights the distinct nature of the assumptions embedded in each methodology.

Using equation 2.3, the annual final energy demand for space heating and ventilation $Q_{K.H}$ was determined based on the overall efficiency of the heating system. The overall efficiency was assumed as 77.20% within the energy performance (EPC) framework, whereas for the energy audit it equalled 57.70%. The difference between the overall heating efficiencies $\eta_{H.tot.CO}$ in the two approaches results from additional components included in the audit methodology. In particular, daily and weekly heating interruptions reduce $\eta_{H.tot.CO}$. The reduced $\eta_{H.tot.CO}$ together with the higher useful energy demand for space heating and ventilation $Q_{H.nd}$ expressed in kWh/year affects the resulting final energy demand $Q_{K.H}$ reported in kWh/year. Therefore $Q_{K.H}$ obtained in the energy audits is 1.76 times higher than that calculated using the EPC methodology.

Consequently although the direction of the observed differences between the EPC and audit approaches is justified by the differing methodological definitions and assumptions, the magnitude of these differences should be interpreted with caution, as it may be sensitive to the adopted parameters and their plausible variants.

4.2. Limitations of the study

The study is a single–case analysis of one public utility building. Therefore, the results should be interpreted as conclusions for the investigated facility and as an illustration of the influence of the chosen calculation methodology on the outcome, rather than as a basis for generalisation to the broader population of public buildings.

The manuscript exhibits a limited degree of originality in terms of proposing new methods or concepts. It does not introduce a new model or algorithm; instead, its contribution lies in comparing two existing, regulatory –defined calculation approaches (energy performance certification versus energy audit) and identifying which methodological elements (including the treatment of H_{ve}, infiltration and system efficiencies) generate discrepancies in $Q_{H.nd}$, $Q_{K.H}$, $Q_{K.w}$ and the indicators EU, EK and EP.

An additional limitation is the lack of validation of the calculated results against operational data (e.g. metered energy consumption) and the absence of an uncertainty analysis (Section 4.1.). Accordingly, the observed differences should be interpreted as methodological differences within regulatory calculation frameworks, rather than as a measure of actual building energy use under real operating conditions.

5. COCLUSION

In the analysed public utility building, it was demonstrated that the algorithm used to determine the ventilation–related heat loss coefficient in the energy audit methodology differs from the approach applied in the energy performance certificate (EPC) procedure, resulting in discrepancies in the calculated outcomes. These differences arise from divergent assumptions and from the treatment of selected components of the energy balance (including, inter alia, ventilation and infiltration air flow rates as well as system efficiency values). Importantly, this study is limited to a comparison of regulatory calculation results obtained using the two methodologies. For the investigated building, the EU and EK indicators derived from the audit methodology were higher than those obtained within the EPC procedure, whereas the EP indicator remained at a comparable level. This indicates that, for the same building and input data, methodological differences can materially affect the structure of useful and final energy components without necessarily inducing a corresponding change in the primary energy indicator.

In the investigated case, the ventilation heat loss coefficient determined using the audit methodology was 37% higher than that obtained using the EPC procedure, which translated into an over

31% higher useful energy demand for heating and ventilation in the audit compared with the EPC. These results should be interpreted as a consequence of differing methodological assumptions and computational algorithms rather than as evidence discrepancies between EPC outputs and actual operational energy use, as no measurement–based validation was conducted. For the analysed building, this implies that the EPC procedure and the energy audit may yield different estimates of the energy demand for heating and ventilation, which is relevant when comparing results and when selecting a document for an informational versus retrofit–oriented purpose. Generalisation of these observations requires a broader sample of buildings and verification of calculated results against operational data.

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