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SimTerm2022 PROCEEDINGS

20th International Conference on Thermal Science and Engineering of Serbia
Niš, Serbia, October 18-21

ENERGY EFFICIENCY ECONOMY ECOLOGY

SimTerm2022

PROCEEDINGS

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Variants for Calculating the Annual Thermal Energy Consumption for Buildings

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Abstract: This paper presents an alternative method for determining the annual consumption of thermal energy for heating of certain buildings. A comparison is made between two methods that have a different approach for selecting input parameters. Arguments are given for the selection of parameters that affect the analysis and are aimed at the effectiveness of use of the facilities and improving energy efficiency. A concrete example for calculation of the annual thermal energy consumption for the building of Faculty of Technical Sciences – Bitola, Republic of North Macedonia, is presented where both methods are applied.

Keywords: Energy consumption, Heat loads Models, Parameters.

1. Introduction

The assessment of thermal energy consumption for heating buildings is an important factor in achieving the required energy efficiency. This data is necessary for the creation of energy infrastructure based on the specific conditions inside and outside the building. Rational use of energy should be correlated with the set energy strategies that depend on the dynamics of climate change at the local and global level [1]. Energy consumption is directly proportional to fuel consumption, but also depends on its availability. The assessment of thermal energy consumption for heating buildings is an important factor in achieving the required energy efficiency. This data is necessary for the creation of energy infrastructure based on the specific conditions inside and outside the building. Rational use of energy should be correlated with the set energy strategies that depend on the dynamics of climate change at the local and global level [1]. Energy consumption is directly proportional to fuel consumption, but also depends on its availability. Also, the detailing of the calculations where specific (refinement) parameters are considered additionally increases the accuracy in determining the annual energy consumption and accordingly the fuel and maintenance costs, the impact on the environment and the improvement of the energy structure in the building. This paper presents a methodology for estimating energy consumption, (Fig. 1) [2], presented through a mathematical model, in which static parameters are considered as average values for certain time intervals. A concrete example is also given for determining the annual energy consumption for the heating of the Faculty of Technical Sciences - Bitola [3].

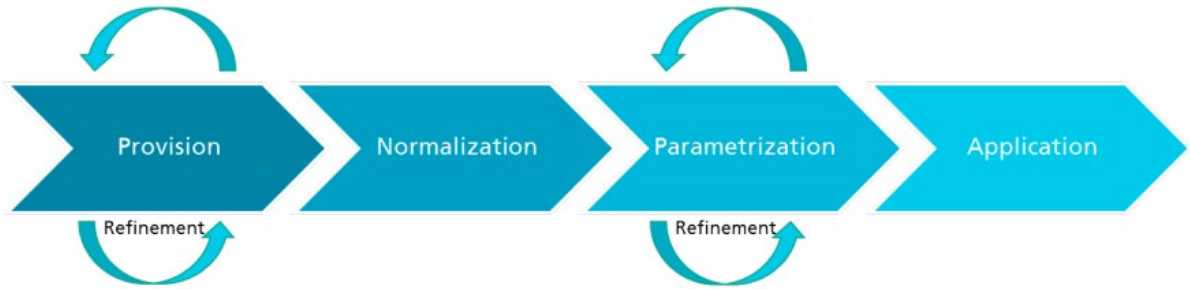

Figure 1. Methodology for predicting thermal energy consumption

2. Defining the model

For predicting the actual consumption of thermal energy, certain influences are taken into account, such as: interruptions of heating for weekends, holidays, night hours, which are inserted in the calculations through correction factors selected from the scientific literature [4]. However, the crucial part in the calculation is outdoor temperature which is specific to a certain area and is determined by statistical analysis of the temperature change in the area over a short and long period of time. The basic expression for calculating the annual thermal energy consumption is (1), [4]:

$$\boldsymbol{Q_g = 24 \cdot Q \cdot z \cdot \frac{t_v - t_g}{t_v - t_{np}} \cdot Y \cdot e_t \cdot e_b} \tag{1}$$

where:

Q_g	-	Annual thermal energy consumption, in $\left[\frac{Wh}{god}\right]$.
Q	-	Total heat loss in the building, in [W].
z	-	Number of days in the heating season,
t_v	-	Internal temperature in the building, in [°C].
t_g	-	Average temperature during the heating season, in [°C].
t_{np}	-	Project outdoor temperature for the specific area where the building is located, in [°C]
$e_t \cdot e_b$	-	Coefficient that considers the cases when the heating system does not work 24 hours a day (e_t) (Table 1), and the heating is interrupted on certain days (Saturday, Sunday and holidays) - operating restrictions, (e_b), (Table 2).
Y	-	Coefficient for the time frame of the impact of adverse conditions that do not affect constantly and at the same time on all rooms in the building and reduce the allowances that are adopted in the transmission losses of the building, (Table 3)

Table 1. Coefficient of temperature limitation e_t

Type of object	$\boldsymbol{e_t}$
hospital	1.0
residential building with heating of all rooms	0.95
residential building with pronounced night heating limitation	0.9
administrative building, and school with two shifts	0.85
school with one shift and high accumulation capacity	0.8
school with one shift and low accumulation capacity	0.75

Table 2. Ccoefficient of operating limitation e_b

Type of object	e_b
buildings with constant heating (hospitals, residential buildings…)	1.00
buildings with limited heating (weekends and holidays)	0.9
schools	0.75

Table 3. Values of factor Y

Conditions	$\boldsymbol{Y}$
normal windy area and sheltered space	0.63
normal windy area and exposed space	0.60
windy area and sheltered space	0.58
windy area and exposed space	0.55

The usual calculation of the annual thermal energy consumption is performed with expression (1). However, each facility has its own specific mode of operation, location and exposure to climatic conditions. This means that additional, specific parameters are needed to complicate and refine the calculation, which will bring the results closer to the real heat consumption.

Firstly, the value of z can be reduced according to the exact number of days for which the given building operates in the heating season (excluding weekends, holidays, and non-working days), whereby the correction coefficient is excluded from the expression (1). Therefore, the newly acquired number of days is determined by the expression (2):

$$z_e = \frac{5}{7} \cdot z - a \tag{2}$$

if the facility does not operate on weekends, while the value a refers to holidays and non-working days.

24· e_t of the equation (1) can be replaced by the average number of heating hours per day during the heating season (x), (3) which causes a temperature drop in the building.

$$\sum_{n=1}^{z_e} x_{nn} = z_e \cdot x \tag{3}$$

where x_{nn} is the number of heating hours in the nth day of the heating season.

The outdoor temperature on a daily, monthly, and annual bases depend on the project temperature for a certain area. Climate changes and global warming are seriously affecting temperatures around the world. Therefore, an analysis of the tendency of temperature increases in the last period compared to previous decades is needed. The average temperature for the heating season of the area where the building is located (t_g), (4) is determined by the dependence:

$$\sum_{n=1}^{z} t_{nn} = z \cdot t_g \tag{4}$$

where t_{nn} is the average temperature on the nth day of the heating season.

The value t_g is taken from the professional literature based on statistical analyzes of temperature changes in a certain area over a longer period of time. However, in recent years there are serious temperature deviations compared to that data, so it is necessary to update the temperature changes.

The factor Y can be compensated in the latest standards which include additions that address the positive and negative impact on the building (intensity and exposure to light, wind, moisture, groundwater, orientation, etc.).

The above arguments transform expression (1) for the calculation of annual thermal energy consumption, giving the following expression (5):

$$Q'_g = \cdot \frac{x \cdot Q \cdot z_e \cdot (t_v - t_g)}{t_v - t_{np}} \tag{5}$$

3. Estimation of Q_g and Q'_g for the building of the Faculty of Technical Sciences - Bitola

In addition, the annual thermal energy consumption is calculated according to equations (1) and (5) for heating the building of the Faculty of Technical Sciences - Bitola. There is a deviation in the obtained results.

The three-storey building (Fig. 2) was built in 1961. The total net area of the building is 5952 m^2 (area of heating space), and the total net volume is 21325 m^3 (volume of heating space), [3].

Faculty of Technical Sciences - Bitola is exposed in a normal windy area. The building usually operates one shift and has a low accumulation capacity. Based on these data, the coefficients from Table 1, 2 and 3 are $e_t = 0.75$, $e_b = 0.75$ and Y= 0.6 respectively. According to the thermal calculation of the heat losses in the premises, segments, and the building as a whole, the standard MKS EN 12831 - 1: 2017, [3] is used as simplified procedure for calculating the heat loads for heating the buildings, $Q = 724823\ W$. The heating season starts on October 15 and ends on April 15, which means z = 182. The adopted internal temperature in the building is $t_v = 19°C$, $t_{np} = -18°C$ [3]. The average temperature in the heating season (according to project data for Bitola) is $t_g = 5°C$) [4]. These values are calculated in equation (1).

Figure 2. Building of the Faculty of Technical Sciences - Bitola

The parameters in equation (5) are determined according to the working regime of the building during the heating season (working days and working hours). Hence, $x = 12\ h$ and $z_e = 120$. Because of the significant deviation of the outdoor temperature due to global warming in relation to the existing values of t_g, a temperature analysis was performed during the heating period for 2017/2018, 2018/2019, 2019/2020 [5]. Fig. 3 shows the temperature changes during the heating season in Bitola.

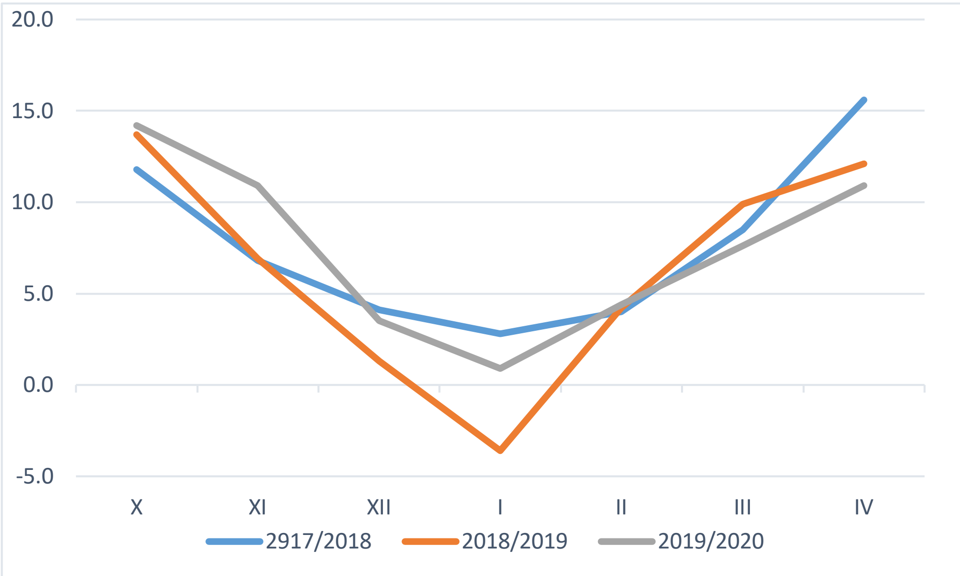

Figure 3. Temperature changes during the heating season in Bitola

The results of the analysis show that the average outdoor temperature in the heating season for the period 2017-2020 is $t_g = 6.5°C$ [3].

Table 4 shows the results of expressions (1) and (5) according to the above methods including the relative and absolute difference.

Table 4. Results for annual thermal energy consumption for the building of Faculty of Technical Sciences – Bitola

Q_g	Q'_g	Difference	%
404310 kWh	353617 kWh	50693 kWh	12.54

4. Conclusion

Accurate predicting and planning of the annual consumption of heat and energy in the facilities, significantly improves the conditions and effectiveness of the operation of the facilities. It enables the adoption of correct conclusions and measures to improve the energy efficiency of the facility, organization of the regime and schedule of use of the premises, regulation and planning of fuel consumption in the heating system. This analysis improves the accuracy of the annual economic plan for determining the financial costs associated with the energy consumption of the facility. By applying the specified method, the accuracy in determining the annual heat consumption is increased, due to the influence of the parameters that apply to each building separately and are determined according to the internal and external conditions.

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