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Research paper

Mathematical Models for Determination of Specific Energy Need for Heating and Cooling of the Administrative Building

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Abstract

According to the building energy balance, most of the resources are spent on maintaining a comfortable indoor microclimate. To estimate the energy resources rational use and to determine building energy efficiency, specific indicators are used per unit area and/or volume.
In this paper, a comparative analysis of various approaches to determination of energy need for heating and cooling that have been used or are introduced in Ukraine and the peculiarities of different climatic data application is carried out. The differences in application of considered methods are established. The analysis of various averaging time intervals (monthly, daily average and hourly) for climatic parameters change in dynamic models during the heating period application influence on heating and cooling load change is carried out. Specific energy need has been established according to different methods and a comparison with the current normative values in Ukraine has been made.

Keywords*: cooling, climatic data, dynamic modes, energy need, energy efficiency indicators, heating, heat losses, mathematical model, solar heat gains.*

1. Introduction

The problems of buildings efficient energy use and providing comfortable indoor microclimate conditions have become nationally important. In June 2017, the Law of Ukraine "Energy Efficiency of Buildings" was adopted [1]. Much attention is paid to the buildings energy need for heating while energy needs for cooling requires more attention. One of the indicators for heating energy effective use is the value per unit of area and/or volume. Similar indicators for building air conditioning system in Ukraine have not been introduced. Depending on the tasks being solved, the following calculation methods and models can be used to determine the energy needs: stationary, quasi-stationary and dynamic. Standards for the calculation of buildings energy performance [2-5], which were used in Ukraine up to 2015, allow to calculate the annual energy need for heating and don`t take into account energy needs for cooling.
Standard [6] provides two methods for calculating buildings energy need for heating and cooling: quasi-stationary and dynamic. On the basis of the first one, the national method for calculating DSTU B.A.2.2-12: 2015 [7], based on the determination of monthly indicators (quasi-stationary method of calculation), has been introduced to replace the standard DSTU_N B.A.2.2.5: 2007 [4]. In this regard, standard [5] has gained the development, the standard [8] has been introduced. The second method [6] is based on a simplified hourly calculation method for heating and cooling energy need (five resistances one capacity model 5R1C).
Standard values of the specific characteristics of the building energy use are also revised, including the heating, cooling and domestic hot water production [8].
The building annual energy need for heating and/or cooling is determined by the method [7]:

$$Q_0^{year} = \sum_{i=1}^{n} Q_{HC.nd.i}, \tag{1}$$

i – serial number of heating/ cooling month,
n – number of heating months,
$Q_{HC.nd}$ – monthly energy need for heating/ cooling, kWh.

$$Q_{HC.nd} = Q_{HC.tr} + \eta_{HC.gn} Q_{HC.gn}, \tag{2}$$

$Q_{HC.tr}$ – monthly total heat transfer by transmission and ventilation, kWh,
$Q_{HC.gn}$ – monthly total heat gains in heating/cooling mode, kWh,
$\eta_{HC.gn}$ – dimensionless monthly heat/cool gains utilization factor.

$$Q_{HC.hr} = Q_{tr} + Q_{ve}, \tag{3}$$

Q_{tr} – heat transfer by transmission, kWh,
Q_{ve} – heat transfer by ventilation, kWh.

$$Q_{H.gn} = Q_{int} + Q_{sol}, \tag{4}$$

Q_{int} – amount of internal heat gains, kWh,
Q_{sol} – amount of solar heat gains, kWh.

$$Q_{tr} = H_{hr}(\theta_{int} - \theta_e)t, \tag{5}$$

H_{hr} – total zone heat transfer coefficient by transmission, W/K,
θ_{int} – building zone set-point temperature for heating, °C,
θ_e – average monthly outside air temperature, °C,
t – month duration for which the calculation is made, h.

$$Q_{ve} = H_{ve}(\theta_{int} - \theta_e)t, \tag{6}$$

H_{ve} – total heat transfer coefficient by ventilation, W/K.

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The second standard approach [6] requires the creation or use of existing programs for implementation of this method. Fig. 1 shows a simplified scheme for the method implementation for a certain building zone that includes external walls, window openings and ventilation, which are characterized in the circuit by conduction units H_{op}, $H_{tr.w}$, H_{ve}, respectively.

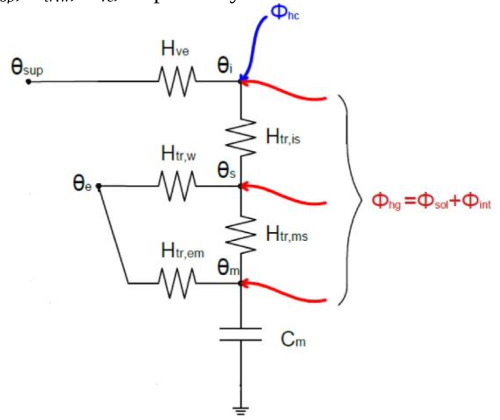


Fig. 1: Model of five resistances and one capacity (5R1C) [10]

The energy need for heating is based on the calculation of the heating level, $\Phi_{HC.nd}$, for each hour to be delivered to the internal air temperature node, θ_{air}, to maintain a certain set-point temperature. The set-point temperature is an average weighted value of internal air temperature and radiant temperature.

Heat transfer by ventilation, H_{ve}, is directly connected to internal air temperature node, θ_{air}, and the node that corresponds to supply air temperature, θ_{sup}. Heat transfer by transmission is divided into two parts: the first one is through fenestration surfaces, like windows, $H_{tr.w}$, that do not have thermal mass, the second one is through opaque surfaces H_{op}, that have thermal mass, and, in its turn, is divided into two parts: $H_{tr.em}$ and $H_{tr.ms}$. Solar (Φ_{sol},) and internal heat gains (Φ_{int}) are distributed between the internal air temperature node, θ_{air}, the central node, θ_s (mixture of θ_{air} and mean radiant temperature θ_r) and the node representing the building mass, θ_m. The thermal mass is reflected by the specific heat, C_m, located between $H_{tr.ms}$ та $H_{tr.em}$. The coupling by conductivity is determined between the internal air temperature and the central node. The value of the heat flux due to internal sources, Φ_{int}, and the value of the heat flux in the zone of the room due to the sun, Φ_{sol}, are divided between the three nodes: internal air temperature, θ_{air}, and internal nodes, θ_s, θ_m. This scheme is implemented on the basis of standards EN 13790 and EN 13786 [6, 9].

$$H_{tr.is} = h_{is} A_{tot} \tag{7}$$

$$H_{tr.ms} = h_{ms} A_m \tag{8}$$

$$H_{tr.em} = \frac{1}{\frac{1}{H_{op}} - \frac{1}{H_{tr.ms}}} \tag{9}$$

$$H_{tr.1} = \frac{1}{\frac{1}{H_{ve}} + \frac{1}{H_{tr.is}}} \tag{10}$$

$$H_{tr.2} = H_{tr.1} + H_{tr.w} \tag{11}$$

$$H_{tr.3} = \frac{1}{\frac{1}{H_{tr.2}} + \frac{1}{H_{tr.ms}}} \tag{12}$$

$$C_m = \sum k_j A_j \tag{13}$$

$$\Phi_{m.tot} = \Phi_m + H_{tr.em}\theta_e + \frac{H_{tr.3}\left(\Phi_{st} + H_{tr.w}\theta_e + H_{tr.1}\left(\frac{\Phi_{ia}+\Phi_{HC.nd}}{H_{ve}} + \theta_{sup}\right)\right)}{H_{tr.2}} \tag{14}$$

$$\theta_m = \frac{\theta_{m,t} + \theta_{m,t-1}}{2} \tag{15}$$

$$\theta_{m,t} = \frac{\theta_{m,t-1}\left(\frac{C_m}{3600} - 0,5(H_{tr.3} + H_{tr.em})\right) + \Phi_{m.tot}}{\frac{C_m}{3600} + 0,5(H_{tr.3} + H_{tr.em})} \tag{16}$$

$$\theta_s = \frac{H_{tr.ms}\theta_m + \Phi_{st} + H_{tr.w}\theta_e + H_{tr.1}\left(\frac{\Phi_{ia}+\Phi_{HC.nd}}{H_{ve}} + \theta_{sup}\right)}{H_{tr.ms} + H_{tr.w} + H_{tr.1}} \tag{17}$$

$$\theta_{air} = \frac{H_{tr.is}\theta_s + H_{ve}\theta_{sup} + \Phi_{ia} + \Phi_{HC.nd}}{H_{tr.is} + H_{ve}} \tag{18}$$

Φ_{ia}, Φ_m, Φ_{st} – internal and solar radiation heat gains are distributed between the 3 nodes, θ_{air}, θ_s, θ_m;
$\Phi_{m.tot}$ – total heat flow, W;
h_{is} – heat transfer coefficient between the internal air temperature node, θ_{air}, and central node, θ_s, has a fixed value $h_{is} = 3,45\ \frac{W}{m^2K}$;
h_{ms} – heat transfer coefficient between the nodes *m* and *s*, has a fixed value $h_{ms} = 9,1\ \frac{W}{m^2K}$;
A_m – effective mass area, m^2;
A_j – area of the j-element, m^2;
A_{tot} – the area of all external enclosures of the building, m^2;
C_m – internal heat capacity, J/K;
k_j – internal heat capacity per unit area of the j-element of the building, $J/(m^2 \cdot K)$;
$H_{tr.is}$ – coupling by conductivity between node *s* and inside air temperature, W/K
$H_{tr.1}$, $H_{tr.2}$, $H_{tr.3}$ – conductivity of conditional nodes 1, 2, 3, W/K

An alternative option is to use existing software products. The most commonly used among them are EnergyPlus, eQUEST, TRNSYS. The EnergyPlus software product (E+) uses the best approaches of the two well-known programs DOE-2 and BLAST, the calculation methods of which are close to European standards [11]. In contrast to the above-mentioned method, E+ separately takes into account the heat capacity of external and internal enclosures. In the simulation of heat flows through translucent elements of building surfaces, E+ uses a window calculation subroutine [12], a slab pre-processor subroutine [13] is used to calculate the slab on grade, which allows to perform detailed calculations.

The article [10] compares model 5R1C with TRNSYS model for Palermo, Venice, Vienna and Helsinki for heating and cooling purposes. The difference in energy need for heating does not exceed 9%, energy need for cooling difference is up to 27%. Such difference led to an increase in the number of resistances and capacities in the new German standard [14].

E + software uses climatic data from the IWEC (International Weather for Energy Calculations) file for the typical year of a particular city [15] (available from DOE and E+ websites). For the territory of Ukraine, two IWEC climatic files are available – for Kyiv and Odessa – which have the averaged characteristics of each of the two temperature zones. IWEC 2 set has weather files for the 41 Ukrainian cities, but they are fee-based resources that restricts their use (sold by ASHRAE). To calculate solar heat gains on vertical surfaces the position of the sun relative to the horizon during the year and its change during the day is needed to be used. E+ uses several techniques for recalculating solar heat gains on vertical surfaces.

Consequently, since the above dynamic methods are not yet widely used in Ukraine, the purpose of the work is to study the features of the application and comparison of different methods for calculating building energy need for heating and cooling for the purpose of buildings energy efficiency determination. Tasks include:
1) analysis of the peculiarities of meteorological data in the form of typical year and regulatory climatic values and other input data use for the applied methods of determining the annual energy need

according to DSTU B A.2.2-12: 2015, EN 13790, EN 13786, E + software;
2) creation of a monthly quasi-stationary calculation model according to the national method of calculation DSTU B.A.2.2-12: 2015 and determination of energy needs for heating and cooling;
4) creation of a dynamic simplified hourly model based on EN 13790, EN 13786 and calculation of heating/cooling energy need;
5) calculation of energy need for heating and cooling in a dynamic mode based on the created model in the E + software;
6) comparison of the obtained results.

2. Input Data

For a detailed study of buildings energy performance by dynamic methods it is considered sufficient to choose a representative room for calculations [16, 17]. Similarly, calculations may also be made for other premises, the difference of which is only in the orientation and solar heat gains to the space [17].
The object of the study is a room in the building of the 1970s typical construction. Room dimensions are 5.5×6.1 m, floor-to-ceiling height is 3.2 m. It has one exterior wall (5.5×3.2 m) with an exterior window (5×2.5 m). The exterior wall has the thermal resistance R = 0.8 (m^2·K)/W (one-brick wall). The outer window is a double-glazed system with wooden frame. Interior walls are built with half-brick (δ = 0.125 m). Ceiling and floor construction is reinforced concrete slab (δ = 0.2 m). Ventilation is natural; air exchange rate is 1 h^{-1}. The building is located in Odessa. The design internal air temperature is 18°C. The heating system is ideal load air system. Solar heat gain coefficient of fenestration surfaces in the room is 0.56. This coefficient was calculated in E+ software according to the type of glazing. Heating is available 24 hours per day and seven days per week during the heating season. Air conditioning is available from 8:00 to 18:00. Due to the lack of normative period for air conditioning use, three summer months were calculated in the paper. A representative room is considered with orientations to the S and N.

3. Research Results

3.1. Analysis of the Climatic Characteristics Used In Calculating Energy Need for Heating/Cooling at Different Bases of Climatology

The normative climatic data in Ukraine include the average monthly values of the external air temperature and solar heat radiation falling on the vertical and horizontal surfaces, which is sufficient in the stationary and quasi-stationary methods of calculation [18]. When calculating the building energy need for heating and/or cooling by dynamic methods, hourly climatic values are needed. The paper analyzes and compares the normative climatic data in Ukraine and the international weather file IWEC for use during energy need for heating/cooling determination.
The model created in E+ software environment, performs the most detailed calculation and requires a larger number of input climatic parameters (all of the above parameters). The simplified hourly model 5R1C does not take into account wind speed and direction, relative humidity, barometric pressure, with the increase of nodes number in the model these parameters can be taken into account. Monthly calculation method according to DSTU B A.2.2-12-12: 2015 takes into account the same package of climatic parameters as the 5R1C model in the monthly view. To compare differences in the calculation methodology, the models' settings were reduced to an equal number of input climatic parameters.
During the calculations, climatic hourly values from the IWEC were used [15], which include the dry-bulb temperature, relative humidity, wind speed and direction, barometric pressure, direct (expressed through direct normal), and diffuse solar radiation on horizontal (diffuse horizontal) surface and so on.

The IWEC weather file is developed as part of the research project RP-1015. The procedure for obtaining data was based on the choice of a typical year for the 18-year sequence of hourly weather data. The E + software uses the IWEC weather file with the "EPW" extension. In order to compare the data of the current climatology in Ukraine and the international hourly weather IWEC file they have to be represented in the same time intervals and appropriate calculations have to be carried out. To calculate solar heat gains, the position of the sun to the horizon during the year and change during the day has to be used; the hourly solar heat gains received per unit of surface of each orientation are averaged monthly.
Software products that use climatic data of the typical year IWEC (for example, E+) contain built-in conversion techniques from simplified to advanced ones. In the created model on E+ base the detailed method of calculation "Full interior and exterior with reflection" is used.
Current approaches applied in Ukraine for energy need for heating determination use climatic data from building climatology standard [7, 18]. The use of IWEC file in other approaches, other than the E+ software, has difficulties with information presentation format.
In Ukraine, the simplified hourly dynamic method of calculation based on the European standard EN 13790 [6] has come into force, which takes into account in its calculations the total solar heat gains to space, but there are no normative hourly climatic data for calculating building energy need in Ukraine. When using dynamic models based on the simplified hourly calculation method 5R1C the classical technique of converting solar heat gains to vertical surfaces of different orientations which is given in Duffy's papers can be used [19]. In this technique it is assumed that the diffuse component of solar radiation equally falls on all surfaces and it does not take into account reflected solar radiation from the ground surface. Therefore, while using a simplified hourly method, this feature of converting IWEC file data can make the difference between the results of energy consumption for heating/cooling purpose.
E+ software was used to compare the methods for converting solar heat gains to the vertical surfaces of the IWEC climatic file. The average monthly values derived from the classical hourly Duffy calculation method [19] and the calculation results in the EnergyPlus software product are quite close, the average difference is 5%, the maximum difference in the results in the winter period was 8%, in the summer – up to 15% [20].
Fig. 2 shows a graph of changes in the average monthly values of external air temperature and solar radiation on vertical surfaces, calculated on the basis of the national calculating methodology DSTU B A.2.2-12: 2015 [7] (marking: S Normative climate data, N Normative climate data), also the values calculated by the E+ program on the IWEC database (marking: S IWEC, N IWEC) are given.

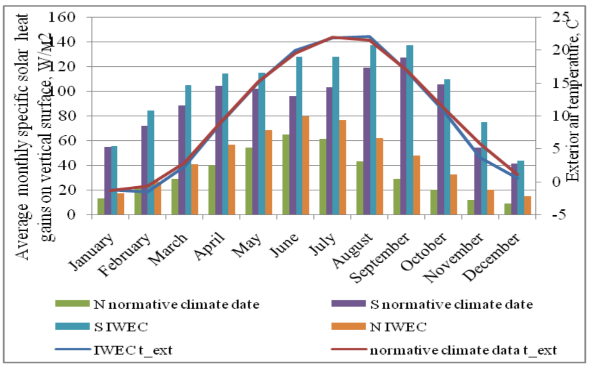


Fig. 2: Average monthly climatic data from normative documents of Ukraine and the international weather file for Odessa

The external air temperature profile for two climatological bases is almost the same. Solar heat gains values are significantly different from those adopted in Ukraine. For Odessa this difference is up to

30% for the summer months, and for the winter period this difference is 50% for the N and 15% for the S.

E + uses in calculations an IWEC climatic data file created for a particular city. The difference in the climatic values of regulatory documents in force in Ukraine and IWEC values should make a difference in the results of calculating the buildings energy efficiency.

3.2. Application of Different Methods for Calculation of Energy Need for Heating and Cooling

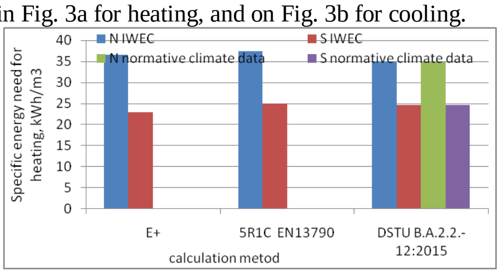
The space energy need for heating and cooling was calculated according to the IWEC climatic data to bring the analysis to identical input conditions and included transmission heat losses, ventilation heat losses and solar heat gains to the zone (in all methods for determining energy need, solar heat gains to the space was determined using the same technique proposed in E+ Full interior and exterior with reflection"). Two extreme cases of determining the energy need for heating/cooling are considered: for southern (S) and northern (N) orientation, because the difference in climatic values of solar radiation for the southern and northern orientations significantly changes the value of the energy need for heating and cooling, which is derived from the energy balance of the space with the appropriate orientation of the exterior walls and translucent elements of building envelope.

Models based on the monthly method of calculation according to DSTU B.A.2.2-12: 2015 [6] are implemented in the Microsoft Excel environment, the model based on EN 13790 and EN 13786 [6, 9] is implemented on the basis of Mathcad.

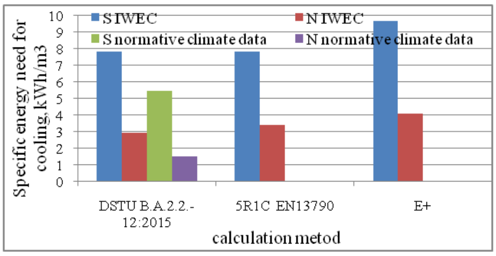
For existing climatology in Ukraine [18], the energy need for heating is calculated in all cities; the energy needed for cooling is calculated only for cities in the southern regions, provided the outside temperature is above 21°C. According to the national methodology for calculating DSTU B.A.2.2-12: 2015 [7], the energy need for cooling is calculated provided that the temperature of the air in the room is 25°C, which coincides with the European standards regarding the microclimate, this standard [7] gives the specification of the internal air temperature, depending on the purpose of the premises, for administrative buildings this temperature is 24°C. According to the standard [7], the duration of the cooling period should not exceed 2000 h/year, which is adhered to in the climatology of Ukraine [17].

In order to compare the methods discussed, the calculation of energy need was carried out for the city of Odessa with a moderately continental climate, which allowed calculating the energy need for heating and cooling.

The calculation of the annual heating and cooling energy need in the monthly basis (national method of calculation according to DSTU BA.2.2-12: 2015) and using hourly intervals (E + and 5R1C) is carried out. Specific characteristics of the calculated energy need values, obtained by the considered methods, are presented in Fig. 3a for heating, and on Fig. 3b for cooling.



a)



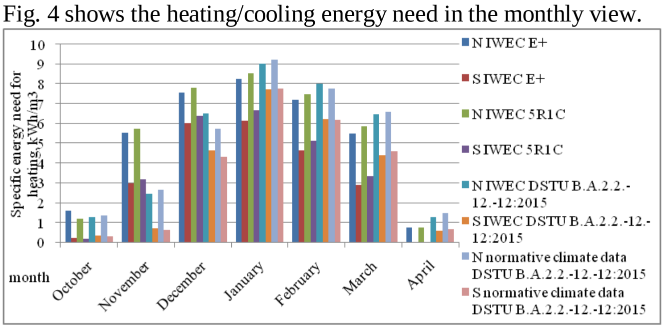
b)

Fig. 3: Annual specific energy need for heating (a) and cooling (b) for a building in Odessa according to different methods and weather databases

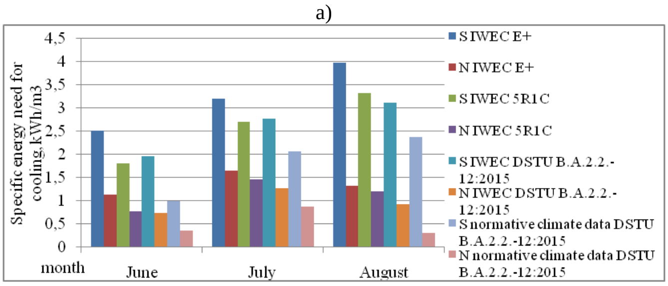
Fig. 3 shows not only a comparison of different methods for calculating the specific energy need for the same input climatic parameters (IWEC data by the method of recalculation given by E+), but also their difference in case of normative climatic data use adopted in Ukraine. Energy need for heating and cooling calculated based on E+ is chosen as a reference value for calculating differences in the results of calculations according to given approaches.

The difference in energy need for heating values is higher for southern oriented zone than for northern oriented zone. Quasi-stationary monthly calculation method according to DSTU B.A.2.2-12: 2015 gives a discrepancy with E+ in the winter period 4% for the north, 8% for the south. The dynamic methods E+ and 5R1C give the value of the heating energy need, the difference of methods is up to 9% for the south, and 2% for the north. In the summer period, solar heat gains to the zone of the building is a major part of the overall energy balance. For the cooling mode, the national method of calculating according to DSTU BA.2.2-12: 2015 also has the largest difference with E+, but towards reduction, which is connected with the approaches of taking into account the heat accumulation properties of the fences, the difference is 18% for the S and 28% for the N. Dynamic methods E + and 5R1C have a difference of 16-18% for all orientations. The 5R1C model considers building thermal massiveness through one reduced node of the internal and external enclosures, unlike E+, where those enclosures are divided. A significant percentage of the discrepancy between dynamic models indicates the need to develop models for calculating energy need for cooling [6] operating in Ukraine.

Fig. 4 shows the heating/cooling energy need in the monthly view.



a)



b)

Fig. 4: Chart of the specific energy need for heating (a) and cooling (b) of a building located in Odessa, depending on the month

In general, the lowest values of the monthly energy need for heating have the results based on E+, rather close values are obtained on the basis of the 5R1C model, the average monthly difference of the received calculations is 4-8% for the N and the S. The average monthly discrepancy in the calculation of DSTU B A.2.2-12-12: 2015 according to the IWEC with the results obtained on the basis of the model E+ is 14% for the N and 30% for the S. For calculating energy need based on climatology, the difference is the same as for IWEC data. The national method of calculation has the greatest value for the heating needs using IWEC climatic data, as compared to other considered methods.

In the summer months of the year when determining the cooling energy need, the divergence comparing to E+ methods is 18% based on the 5R1C model for N and S orientations; 28% (N) and 18% (N) - DSTU B A.2.2-12: 2015 according to the IWEC. According to the data from climatology, the difference based on DSTU B.A.2.2-12: 2015 is even greater (40% - S, 55% - N).

The energy need for cooling by the national method of calculation [7] is the lowest, compared with other methods, which are due to the heat-inertia features of the enclosures in each of the methods described above.

As the first measure of increasing the buildings energy efficiency in Ukraine, the thermo-modernization of buildings is considered, where the consumption of the building is analyzed annually/seasonally. The next step in improving energy efficiency is to regulate the amount of heating during the day, which reduces the energy consumption during non-working hours or hours of peak solar activity. The analysis of methods for solving such problems is carried out on the basis of dynamic models. In this work, two dynamic models are considered based on the 5R1C model and the E + software product.

Tendencies in the behavior of heating energy need graphs for hourly dynamic modeling using E+ and 5R1C are almost the same. Fig. 5 gives the data of the hourly calculation according to the 5R1C model of the specific energy need for the heating of the room oriented to the S. The hourly results are obtained: using hourly values of climatic data from the IWEC, averaging from these data to the monthly intervals of the heating season and based on the average monthly climatic standards in force in Ukraine.

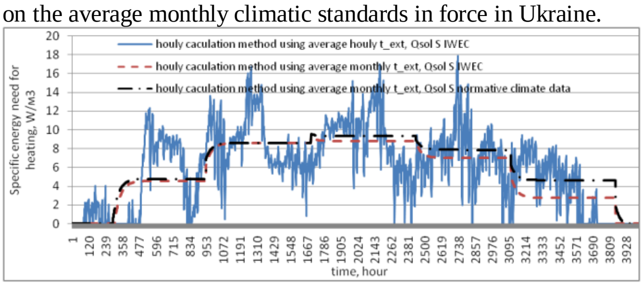


Fig. 5 Hourly change of specific energy need for heating during the heating period for the space in Odessa according to 5R1C model for different climatology databases

The results of hourly energy need for heating using monthly values of weather conditions by 5R1C model have a smooth transition between months, which is due to the heat-inertial features of the building envelope. The average monthly and annual energy consumption based on hourly calculation of heating load is almost the same as the hourly calculation results for average daily and average monthly values of t_{ext} and Q_{sol}.

The calculation using average monthly climatic data in Ukraine gives higher specific values due to the differences in the climatic characteristics of the databases analyzed above.

The model based on the hourly values of t_{ext} and Q_{sol} provides an opportunity to analyze the energy need when adjusting the heating system during the day. Hourly changes in the level of heating are significant. So, in the hours of a high level of solar activity, the heating system energy consumption is lowered or it can be even switched off. This is typical for the off-season period, as well as for the anomalous climatic values of February (the lowest temperatures and the highest values of solar activity for the winter months).

3.3. Analysis of the Specific Indicators of Energy Need for Heating and Cooling Using Different Mathematical Models

On the basis of the above methods of energy need for heating and cooling calculation, specific indicators of building energy performance are established as an average for S and N orientations (Table 1). For energy certification of buildings, modern normative values are used, for comparison, for educational establishments located in the II climatic zone, the regulatory value of energy need is 28 kWh/m^3 [5]. For existing old buildings without thermal upgrade, normative values are selected for buildings of the 70s [3], this value is 32 kWh/m^3.

For old buildings, the norms of energy consumption for heating are higher compared to the current standards, due to the increased requirements for the thermal characteristics of building envelope during the construction/design phase. There are no normative values of cooling energy need in Ukraine. When calculating with the use of dynamic methods of 5R1C and E +, the specific energy need for cooling and heating is slightly higher compared to the quasi-stationary according to DSTU B.A.2.2-12:2015, which is explained by simplifications when taking into account heat-inertia features of the building envelope.

Table 1: Indicators of the specific energy need for heating and cooling obtained by different calculation methods (average for southern and northern orientation)

Specific energy need of the building, kWh/m^3					
heating			cooling		
DSTU B.A. 2.2-12: 2015	5R1C	E+	DSTU B.A. 2.2-12: 2015	5R1C	E+
30	31	30	5.4	5.7	6.9

4. Conclusion

The paper analyzes and compares the normative climatic data used in Ukraine and the international weather file of IWEC when used to determine the energy need for heating. The normative climatological data used in Ukraine shows the average monthly values of the external air temperature and solar heat gains on the vertical and horizontal surfaces, which is sufficient in the stationary and quasi-stationary methods of calculation. The international climatic weather file for the considered city of Ukraine almost does not differ from the average monthly values of the outside air temperature from the normative climatology of Ukraine.

The solar heat gains to the vertical and horizontal surfaces according to the IWEC file are significantly different from the current climatology in Ukraine. The difference in solar radiation for Odessa is about 30% for summer months, for winter period it is 50% for the N and 15% for the S.

The work compares the calculation of energy need for heating and cooling by three methods (two dynamic [6, 11] and one quasi-stationary [7]). Calculation according to the method [7] has the greatest difference in comparison with the results of the simulation in E+ both in heating and cooling modes. The energy need for heating by quasi-stationary monthly method of calculation according to DSTU B.A.2.2-12: 2015 gives a discrepancy with E + in the winter period around 4% for the N and 8% for the S. The dynamic methods based on E+ and 5R1C give the value of energy need for heating, the difference of methods is up to 9% for the S, and 2% for the N. For the cooling mode, the national method for calculating DSTU B.A.2.2-12-12: 2015 has the largest difference with E+, but towards the reduction, which is related to the approaches to taking into account the heat accumulation properties of the enclosures, the difference is 18% for the S and 28% for the N. In the winter it is 12% for the N, 28% for the S.

The dynamic methods E+ and 5R1C give almost the same value of energy need for heating, the difference is up to 4-8% for all orientations, for cooling mode it is 16-18% for all orientations. Model

5R1C takes into account the massiveness of the building through one reduced node of the internal and external enclosures, unlike E+, where the nodes of these enclosures are separated. A significant percentage of the discrepancy between dynamic models indicates the need to develop models for calculating energy need for cooling [6, 7] applicable in Ukraine.

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