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DYNAMIC METHOD FOR CALCULATING ENERGY NEED IN HVAC SYSTEMS

Summary

In this paper the new dynamic method for calculation of energy for heating, cooling and mechanical ventilation is presented. The method is based on a combination of the simple hourly method, from EN ISO 13790, and a modification of the existing calculation procedure for determination of the energy need for mechanical ventilation, described in Algorithm for calculation of the energy need for HVAC systems. Developed method, incorporated in Croatian national Algorithms used for energy certification of buildings, enables the determination of the hourly energy need for heating and cooling which includes all energy flows that occur during the air conditioning process (moistening, dehumidifying, etc.). Simulations are performed for a Croatian reference dwelling, equipped with two different HVAC systems. The results are compared against those obtained from the quasi-steady state monthly method, also described in Algorithms. The comparison proved that the application of the quasi-steady state method would preclude the correct calculations in buildings with air conditioning.

Key words: *energy need for heating and cooling, HVAC systems, energy performance certification of buildings, simple hourly method*

1. Introduction

One of the main goals of the Directive on energy performance of buildings (EPBD), 2010/31/EU, is the reduction of the primary energy consumption in buildings that accounts for 40% of total consumption in the EU. The Directive prescribes setting up a common procedure for energy performance calculation provided within a number of CEN standards. One of them is HR EN ISO 13790 "Thermal performance of buildings – Calculation of energy use for space heating and cooling" [1]. Standard covers three types of methods: a fully prescribed monthly method, a fully prescribed simple hourly method and calculation procedure for detailed dynamic simulation methods. The most popular was the monthly method, but over the years, it was pointed out that the application of the monthly method can preclude the correct calculations in various types of buildings [2], [3], especially in buildings with air conditioning. Authors in [2] state that simple hourly method [1] or detailed simulation methods should be used for calculation of energy use for heating and cooling of office buildings. Likewise, in [3] authors reveal that the application of the quasi steady-state method is unreliable for determining energy need in school buildings.

The existing hourly method described in the Croatian national Algorithm is very simplified and easy to use, but has proved to be insufficiently accurate. The calculation procedure for the simple hourly method given in HRN EN ISO 13790 [1] is due to dynamic interactions complicated, but however suitable to apply in spreadsheets.

After introducing the simple hourly method in the Croatian national Algorithm, the new approach for determining the energy need for mechanical ventilation was developed by authors. The new methodology is rather complicated as it requires iterative procedure for determining the energy need for mechanical ventilation and the energy need for heating and cooling.

As opposite to the models described in [4], [5] which calculate indoor temperature and relative humidity, taking into account moisture transfer through building envelope and moisture gain from internal sources (people), the proposed method takes into account dehumidifying effect on air handling units coolers (when the cooling water temperature is below the external air dew point). This effect increases the energy need for cooling, especially analysing low temperature cooling.

In the paper, this new methodology is described and case study of the energy needs for a Croatian reference dwelling equipped with two different HVAC systems is presented. The results are compared against those obtained by the existing methodology carried out on the monthly basic.

2. Methods

2.1 Simple hourly method

The main goal of the simple hourly calculation [1] method is to take into account the influence of hourly and daily variations in weather, operations (solar blinds, thermostats, needs, occupation, accumulation, etc.) and their dynamic interactions on heating and cooling energy need keeping extra input, compared to the monthly calculation method, to a minimum. The simplicity of the method is maintained through the calculation of the heat transfer coefficients and the internal and solar heat gains as done in the monthly method.

2.1.1 Description of the 5R1C model

HRN EN ISO 13790 standard presents a full description of a simple hourly method based on an equivalent resistances and one capacitance (5R1C) network model of a building (zone). The thermal-electrical analogy is based on the similarity between electric current and heat flux.

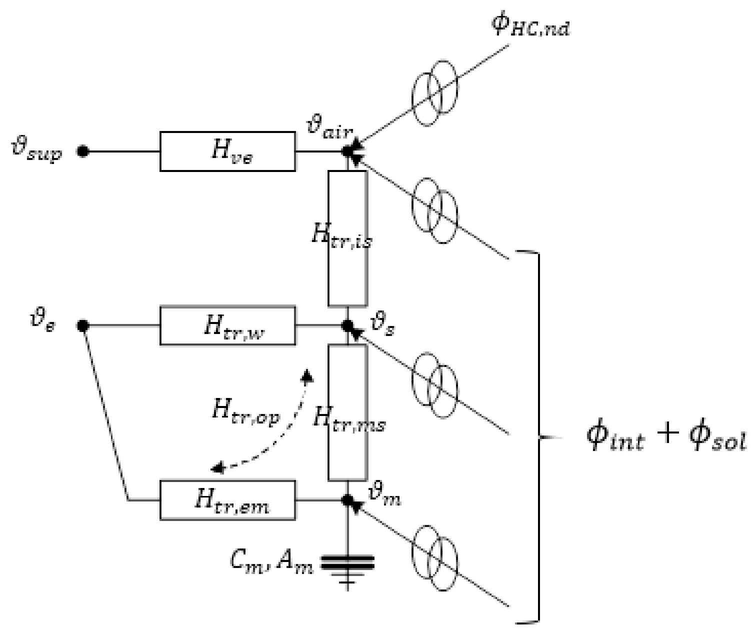

Fig. 1 5R1C thermal model of building [1]

The heating or cooling power ($\phi_{HC,nd}$) is supplied to or extracted from the internal air node (ϑ_{air}) to maintain a certain set-point indoor air temperature: $\vartheta_{int,H,set}$ for heating or $\vartheta_{int,C,set}$ for cooling.

The heat flow rates due to internal heat sources (ϕ_{int}) and due to solar heat sources (ϕ_{sol}) are split into three parts. These are: ϕ_{ia}, ϕ_{st} and ϕ_{m}, connected to the indoor air (ϑ_{air}), the internal surface (ϑ_{s}) and the thermal mass (ϑ_{m}) temperature nodes, respectively.

The heat transfer coefficient by ventilation (H_{ve}) is connected with the supply air temperature (ϑ_{sup}) and the internal air temperature. For the purposes of the energy performance certification of buildings in Croatia where energy need for heating or cooling ($\phi_{HC,nd}$)should obtain energy requirements of HVAC and room system mutually, the supply air temperature (ϑ_{sup}) is equal to the external air temperature (ϑ_{e}).

$H_{tr,w}$ is the transmission heat transfer coefficient for windows and doors, taken as having zero thermal mass. The transmission heat transfer coefficient for opaque elements ($H_{tr,op}$) is split into the external ($H_{tr,em}$) and the internal ($H_{tr,ms}$) part, connected to the single thermal capacity (C_m), representing the building (zone) thermal mass. The internal air node (ϑ_{air}) and the internal surface node (ϑ_{s}) are connected through the coupling conductance.

2.1.2 Calculation of the "new" heat transfer coefficients

The internal part ($H_{tr,ms}$) of the transmission heat transfer coefficient for opaque elements ($H_{tr,op}$) is calculated as

$$H_{tr,ms} = h_{ms} \cdot A_m \quad \text{[W/K]} \tag{1}$$

where:

- h_{ms} is the heat transfer coefficient between nodes m and s, with fixed value of 9.1 W/m^{2}K
- A_m is the effective mass area expressed in square meters, obtained from Table 1.
- A_f is the conditioned floor area calculated considering external dimensions, expressed in square meters

Table 1 Default values for dynamic parameters [1]

Class of building's thermal mass	Am (m^2)
Very light	2.5·Af
Light	2.5·Af
Medium	2.5·Af
Heavy	3.0·Af
Very heavy	3.5·Af

The external part ($H_{tr,em}$) of the transmission heat transfer coefficient for opaque elements ($H_{tr,op}$) is calculated as

$$H_{tr,em} = \frac{1}{\dfrac{1}{H_{tr,op}} - \dfrac{1}{H_{tr,ms}}} \quad \text{[W/K]} \tag{2}$$

The thermal coupling conductance that connects the internal air node (ϑ_{air}) and the internal surface node (ϑ_{s}) is obtained by

$$H_{tr,is} = h_{is} \cdot A_{tot} \quad \text{[W/K]} \tag{3}$$

where:

- h_{is} is the heat transfer coefficient between internal air node (ϑ_{air}) and the internal surface node (ϑ_s), with a fixed value of 3.45 W/ m^{2}K
- A_{tot} is the area of all surfaces facing the building zone, equal to $A_{at} \cdot A_f$, [m^2]
- A_{at} is the dimensionless ratio between the internal surface area and the floor area, equal to 4.5, [-]

2.1.3 Calculation of the heat flows from the internal and solar heat sources

The heat flow rates from internal (ϕ_{int}) and solar (ϕ_{sol}) heat sources are split between the indoor air (ϑ_{air}), the internal surface (ϑ_s) and the thermal mass (ϑ_m) temperature nodes as follows:

$$\Phi_{ia} = 0.5 \cdot \Phi_{\text{int}} \quad [\text{W}] \tag{4}$$

$$\Phi_m = \frac{A_m}{A_{tot}} \cdot \left(0.5 \cdot \Phi_{\text{int}} + \Phi_{sol}\right) \quad [\text{W}] \tag{5}$$

$$\Phi_{st} = \left(1 - \frac{A_m}{A_{tot}} - \frac{H_{tr,w}}{9{,}1 \cdot A_{tot}}\right) \cdot \left(0.5 \cdot \Phi_{\text{int}} + \Phi_{sol}\right) \quad [\text{W}] \tag{6}$$

2.1.4 Determination of the air temperature for given ϕHC,nd

The solution is based on a Crank-Nicholson scheme considering a time step of one hour. The temperatures are the average over one hour except for $\vartheta_{m,t}$ and $\vartheta_{m,t-1}$ which are instantaneous values at time *t* and *t-1*.

For a given time step, $\vartheta_{m,t}$ is calculated at the end of the time step from previous value $\vartheta_{m,t-1}$ by:

$$\vartheta_{m,t} = \frac{\vartheta_{m,t-1} \cdot \left[\frac{C_m}{3600} - 0.5 \cdot \left(H_{tr,3} + H_{tr,em}\right)\right] + \Phi_{m,tot}}{\frac{C_m}{3600} + 0.5 \cdot \left(H_{tr,3} + H_{tr,em}\right)} \quad [°\text{C}] \tag{7}$$

with:

$$\Phi_{m,tot} = \Phi_m + H_{tr,em} \cdot \vartheta_e + H_{tr,3} \cdot \frac{\Phi_{st} + H_{tr,w} \cdot \vartheta_e + H_{tr,1} \cdot \left(\frac{\Phi_{ia} + \Phi_{HC,nd}}{H_{ve}} + \vartheta_{\text{sup}}\right)}{H_{tr,2}} \quad [\text{W}] \tag{8}$$

$$H_{tr,1} = \frac{1}{\frac{1}{H_{ve}} + \frac{1}{H_{tr,is}}} \quad [\text{W/K}] \tag{9}$$

$$H_{tr,2} = H_{tr,1} + H_{tr,w} \quad [\text{W/K}] \tag{10}$$

$$H_{tr,3} = \frac{1}{\frac{1}{H_{tr,2}} + \frac{1}{H_{tr,ms}}} \quad [\text{W/K}] \tag{11}$$

For the considered time step, the average values of nodes temperatures are given by:

$$\vartheta_m = \frac{\vartheta_{m,t} + \vartheta_{m,t-1}}{2} \quad [°C] \tag{12}$$

$$\vartheta_s = \frac{H_{tr,ms} \cdot \vartheta_s + \Phi_{st} + H_{tr,w} \cdot \vartheta_e + H_{tr,1} \cdot \left(\vartheta_{sup} + \frac{\Phi_{ia} + \Phi_{HC,nd}}{H_{ve}} \right)}{H_{tr,ms} + H_{tr,w} + H_{tr,1}} \quad [°C] \tag{13}$$

$$\vartheta_{air} = \frac{H_{tr,is} \cdot \vartheta_s + H_{ve} \cdot \vartheta_{sup} + \Phi_{ia} + \Phi_{HC,nd}}{H_{tr,is} + H_{ve}} \quad [°C] \tag{14}$$

2.1.5 Calculation procedure

For each hour the actual internal temperature (ϑ_{air}) and the actual heating or cooling need ($\phi_{HC,nd}$) is calculated using step wise procedure.

Step 1: Check if cooling or heating is needed.

Take $\phi_{HC,nd}=0$ and calculate the internal air temperature (ϑ_{air}) according to the equations in the previous chapter.

Name the resulting ϑ_{air} as $\vartheta_{air,0}$ ($\vartheta_{air,0}$ is the temperature of free floating conditions).

If $\vartheta_{int,H,set} \leq \vartheta_{air,0} \leq \vartheta_{int,C,set}$ no heating or cooling is required so $\phi_{HC,nd,ac}=0$ and $\vartheta_{air,ac}=\vartheta_{air,0}$, and no further calculations are needed.

If not apply step 2.

Step 2: Choose the set-point and calculate the heating or cooling need.

If $\vartheta_{air,0} > \vartheta_{int,C,set}$, take $\vartheta_{air,set}=\vartheta_{int,C,set}$ and $\phi_{HC,nd}=\phi_{HC,nd,10}=-10 \cdot A_f$.

If $\vartheta_{air,0} < \vartheta_{int,H,set}$, take $\vartheta_{air,set}=\vartheta_{int,H,set}$ and $\phi_{HC,nd}=\phi_{HC,nd,10}=10 \cdot A_f$.

Apply equations in the previous chapter and name the resulting ϑ_{air} as $\vartheta_{air,10}$.

Calculate unrestricted heating or cooling need ($\phi_{HC,nd,un}$) to reach the required set-point temperature by:

$$\Phi_{HC,nd,un} = \Phi_{HC,nd,10} \cdot \frac{\vartheta_{air,set} - \vartheta_{air,0}}{\vartheta_{air,10} - \vartheta_{air,0}} \quad [W] \tag{15}$$

Step 3: Check if available cooling or heating power is available.

If unrestricted heating or cooling need ($\phi_{HC,nd,un}$) is between $\phi_{H,max}$ (maximum heating power) and $\phi_{C,max}$ (maximum cooling power) the actual heating or cooling power has been determined $\phi_{HC,nd,ac}=\phi_{HC,nd,un}$.

If the previous condition has not been satisfied the actual heating or cooling power is determined by maximum available heating or cooling power.

To obtain the actual internal air temperature, the equations in the previous part should be applied again using heating or cooling power ($\phi_{HC,nd}$) equal to $\phi_{HC,nd,ac}$.

2.2 New approach in calculating the energy need for mechanical ventilation

Primary objective of the Algorithm for calculation of the energy need in HVAC systems [6] is the determination of the energy need for mechanical ventilation, which includes all energy flows that occur during the air conditioning (moistening, dehumidifying, etc.), not only air exchange rates. In the Algorithm [6], the calculation procedures for 12 different schemes are provided, thus covering all the basic combinations of the air conditioning treatment.

The new methodology for determining the energy need for mechanical ventilation [6], [7], [8], [9], [10] has been introduced in the Algorithm, because the previously described method was only able to estimate the energy need on the monthly basis. In the previous method, all the dynamic parameters of the building envelope were contained in the utilization factor $\eta_{H,gn}$. For example, a utilization factor for the internal and solar heat gains takes into account the fact that only part of these gains are utilized to decrease the energy need for heating, the rest causes an increase of the internal temperature above the set-point. This approach, for calculations of the energy need on the hourly basis, has not been proven as sufficiently accurate.

The new method enables the use of the demonstrated simple hourly method in the calculations of the HVAC systems. Essentially, these new approach, which enables the calculation energy need of HVAC systems on the hourly basic, does not distinguish much from the previously described procedure, still in use for calculation of energy needs of HVAC systems on the monthly basis.

2.2.1 Description of the new approach

Strictly speaking, monthly and hourly methods distinguish only in the determination of the necessary enthalpy difference and in the determination of energy need for the mechanical ventilation.

The necessary enthalpy difference for covering the heat losses/gains is calculated as

- For monthly method (heating)

$$\Delta h_{opt} = \frac{3600}{t} \cdot \frac{Q_{tr} + Q_{ve,\inf} + Q_{ve,win} - \eta_{H,gn} \cdot Q_{H,gn}}{\rho_a \cdot \dot{V}_{mech,sup}} \cdot k_v \quad \text{[kJ/kg]} \tag{16}$$

- For monthly method (cooling)

$$\Delta h_{opt} = \frac{3600}{t} \cdot \frac{Q_{C,gn} - \eta_{C,ls} \cdot \left(Q_{tr} + Q_{ve,\inf} + Q_{ve,win}\right)}{\rho_a \cdot \dot{V}_{mech,sup}} \cdot k_v \quad \text{[kJ/kg]} \tag{17}$$

- For hourly method (heating)

$$\Delta h_{opt} = \frac{3600}{t} \cdot \frac{Q_{H,gn} - Q_{H,ve,mech}}{\rho_a \cdot \dot{V}_{mech,sup}} \cdot k_v \quad \text{[kJ/kg]} \tag{18}$$

- For hourly method (cooling)

$$\Delta h_{opt} = \frac{3600}{t} \cdot \frac{Q_{C,gn} - Q_{C,ve,mech}}{\rho_a \cdot \dot{V}_{mech,sup}} \cdot k_v \quad \text{[kJ/kg]} \tag{19}$$

The energy need for the mechanical ventilation is obtained from

- For monthly/hourly method (heating)

$$Q_{H,ve,mech} = \frac{\rho_a \cdot \dot{V}_{mech,sup} \cdot \left(h_{out} - h_e - \Delta h_{opt}\right) \cdot t}{3600} \quad \text{[kW]} \tag{20}$$

- For monthly method (cooling)

$$Q_{C,ve,mech} = \frac{Q_{C,gn} \cdot k_v - Q_{cool}}{\eta_{C,ls}} - \left(Q_{tr} + Q_{ve,\inf} + Q_{ve,win}\right) \cdot k_v \quad \text{[kW]} \tag{21}$$

- For hourly method (cooling)

$$Q_{C,ve,mech} = \frac{\rho_a \cdot \dot{V}_{mech,sup} \cdot \left(h_e - h_{out} - \Delta h_{opt}\right) \cdot t}{3600} \quad [\text{kW}] \tag{22}$$

In the above equations the required input parameters in the monthly method are building physics and meteorological data, making the method very simple to use. Due the reason that required input parameters in the hourly method are the results of other calculations (simple hourly method) iterative procedures are necessary, making the method more complicated to use.

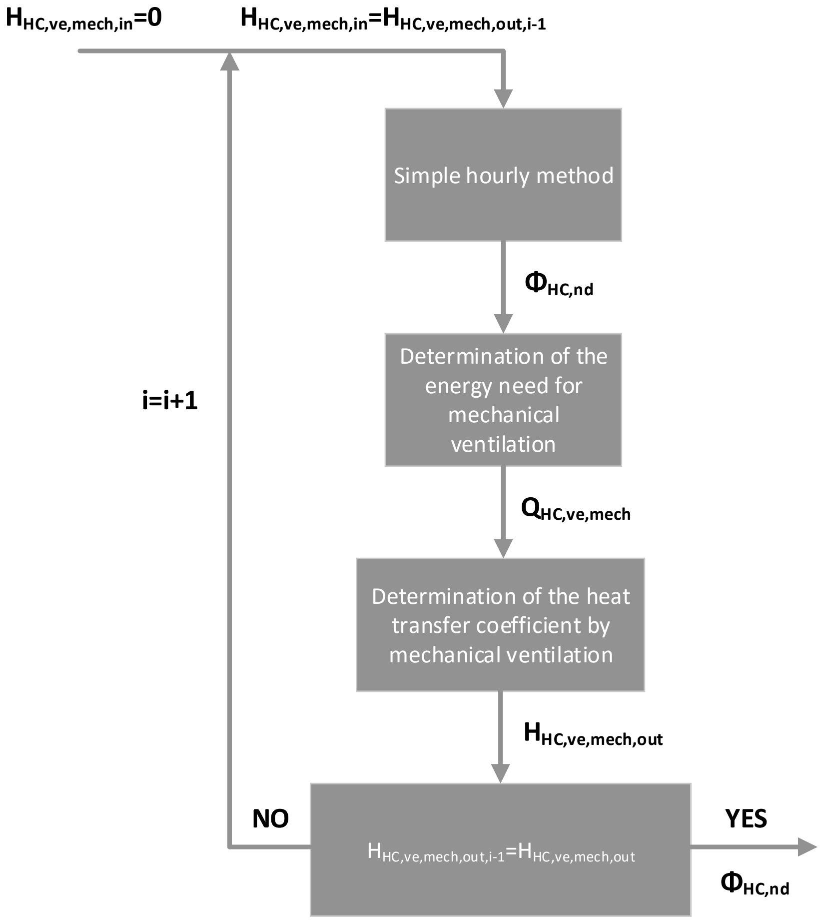

Fig. 2 Algorithm for determining the heat transfer coefficient by mechanical ventilation

In the first step, the energy need for heating or cooling without the need for mechanical ventilation is calculated. After that, the energy need for mechanical ventilation and heat transfer coefficient by mechanical ventilation $H_{HC,ve,mech,out}$, containing all the required energy flows for supply air treatment, is determined. With the determined $H_{HC,ve,mech,out}$ the energy need for heating or cooling is being recalculated and the new $H_{HC,ve,mech,out}$. The procedure is repeated until the heat transfer coefficients of the former and current step are equalized.

2.2.2 Calculation of the energy need for the mechanical ventilation

In the following text the calculation of the energy need for the mechanical ventilation of a simple scheme is being explained (Fig. 3).

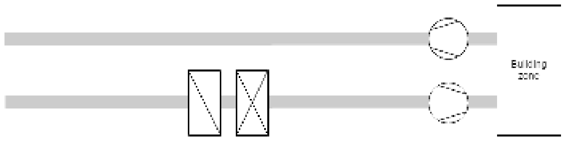

Fig. 3 HVAC scheme (Scheme 4 in Algorithm [2])

The calculation of the energy need for the mechanical ventilation starts with determining the enthalpy of the outdoor and indoor air and calculating the required enthalpy difference for covering the heat losses/gains.

$$h_e = 1.01 \cdot \vartheta_e + x_e \cdot \left(2501 + 1.86 \cdot \vartheta_e\right) \quad \text{[kJ/kg]} \tag{23}$$

$$h_{pom} = 1.01 \cdot \vartheta_{int} + x_{mech,sup} \cdot \left(2501 + 1.86 \cdot \vartheta_{int}\right) \quad \text{[kJ/kg]} \tag{24}$$

$$\Delta h_{opt} = \frac{3600}{t} \cdot \frac{Q_{HC,gn} - Q_{HC,ve,mech}}{\rho_a \cdot \dot{V}_{mech,sup}} \cdot k_v \quad \text{[kJ/kg]} \tag{25}$$

Then, the enthalpy of the supply air is determined.

$$h_{mech,sup} = h_{pom} \pm \Delta h_{opt} \quad \text{[kJ/kg]} \tag{26}$$

After knowing the state of the supply air after the each component in air handling unit the energy consumption of heater/cooler and the energy need for mechanical ventilation is being calculated as

$$Q_{heater/cooler} = \max\left(0; \left|\frac{\rho_a \cdot \dot{V}_{mech,sup} \cdot \left(h_{mech,sup} - h_e\right) \cdot t}{3600}\right|\right) \quad \text{[kW]} \tag{26}$$

$$Q_{HC,ve,mech} = \frac{\rho_a \cdot \dot{V}_{mech,sup} \cdot \left(h_{mech,sup} - h_e \mp \Delta h_{opt}\right) \cdot t}{3600} \quad \text{[kW]} \tag{27}$$

$$H_{HC,ve,mech} = \frac{1000 \cdot Q_{HC,ve,mech}}{\left(\vartheta_{\text{int}} - \vartheta_e\right) \cdot t} \quad \text{[W/K]} \tag{27}$$

3. Calculation example

The Calculation procedure is applied to the examples of two different HVAC systems (*Schemes 4 and 8 in Algorithm*) [6]. The first analyzed system (Fig. 3) consist of air handling unit equipped with air filter, heater, cooler. The second analyzed system (Fig. 4) consists of the same air handling unit with additional heat recovery unit.

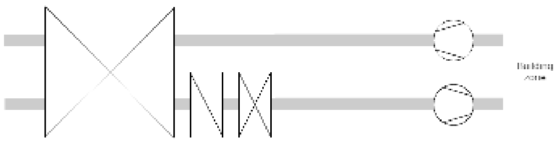

Fig. 4 HVAC scheme (Scheme 8 in Algorithm [2])

Previously mentioned HVAC systems are used for space heating and cooling purposes in the reference (typical) dwelling house assumed to be insulated with 10 cm of EPS. The overall surface area of the dwelling is A=120 m^2 and heated (cooled) surface area is A_k=110 m^2. It has been assumed that heat transfer coefficient by infiltration and window opening accounts for $H_{ve,inf+win}$=44.3 W/K (n=0.5 h-1). In the provided calculation example, the constant supply air flow rate of 482.6 m^3/h has been selected. In the example the climatic data for the City of Zagreb are being used.

4. Results and discussion

Fig. 5, 6 and 7 present calculation results of hourly energy need for heating and cooling of two analyzed HVAC systems for the characteristic day in a month. Fig. 8 shows the effect of the dehumidification on increasing the overall hourly energy need. Fig. 9 and 10 present the comparison of the monthly energy need of the analyzed HVAC systems obtained by monthly and hourly method.

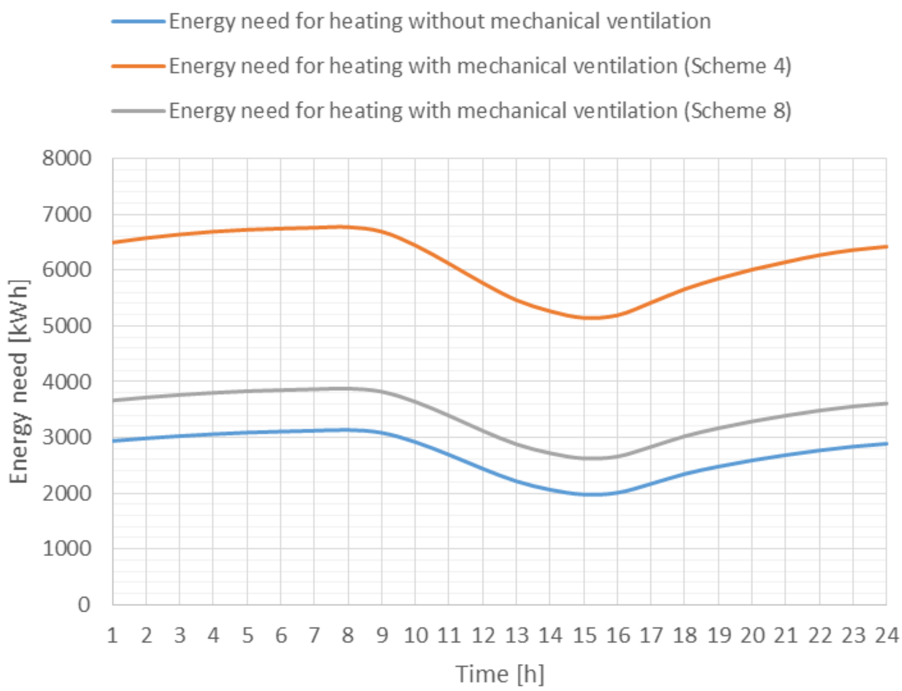

Fig. 5 Energy need for heating – January

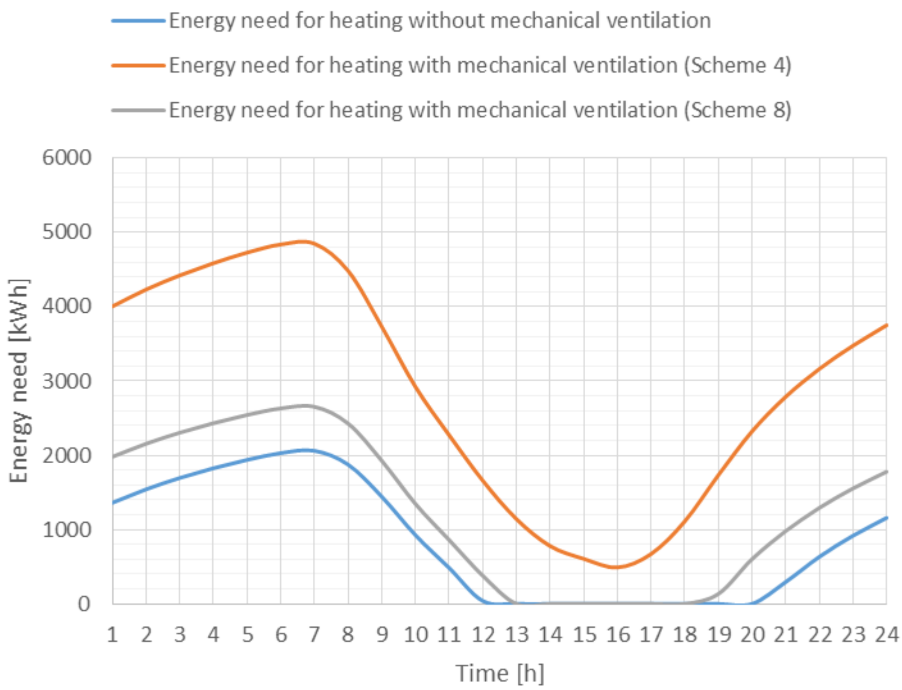

Fig. 6 Energy need for heating – March

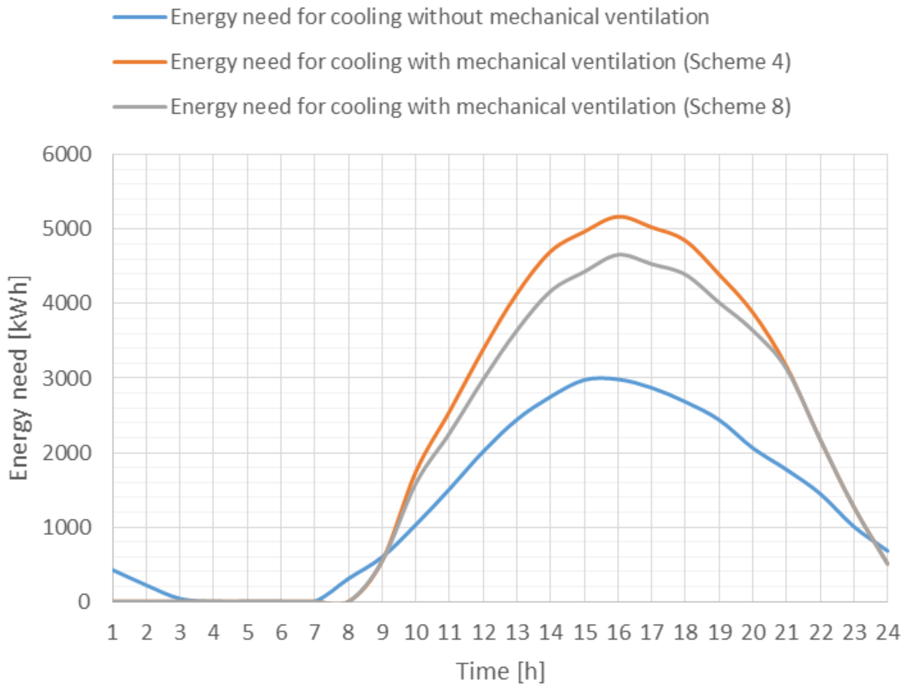

Fig. 7 Energy need for cooling – July

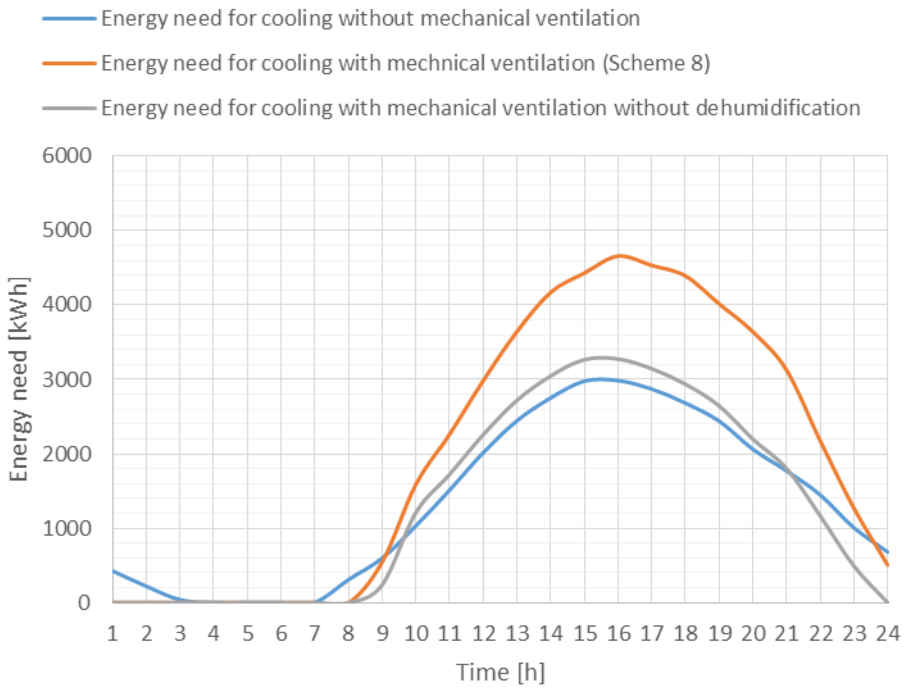

Fig. 8 Energy need for cooling – July

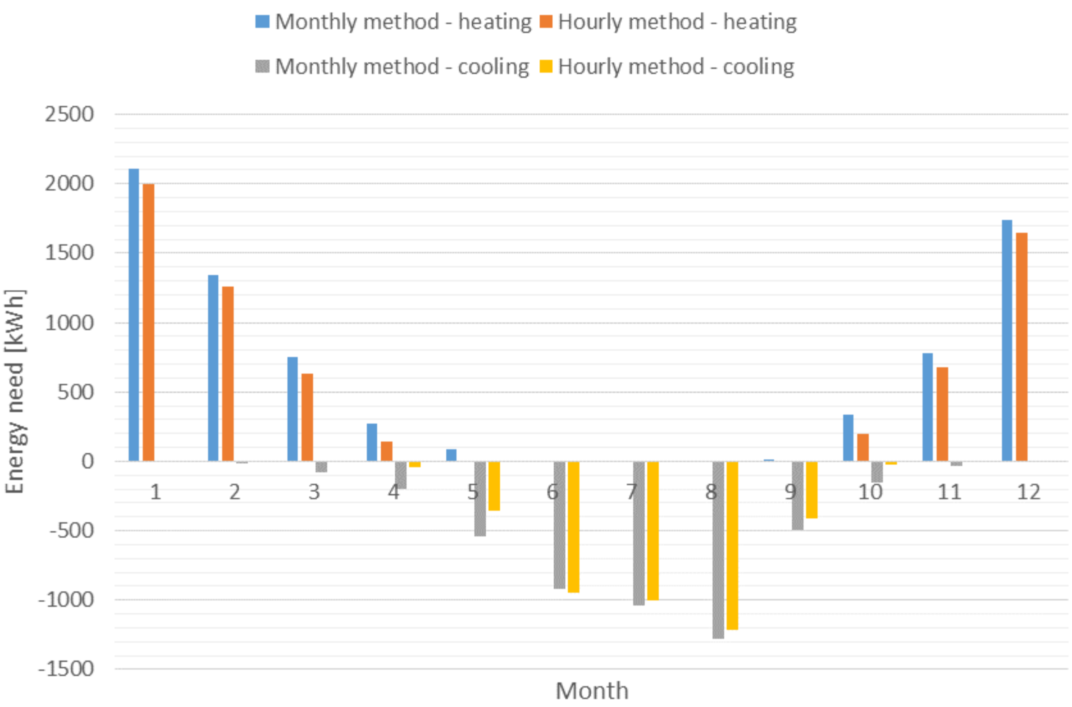

Fig. 9 Monthly energy need for heating/cooling (*without mechanical ventilation*)

Table 2 Comparison – Monthly and hourly energy need for heating/cooling (*without mechanical ventilation*)

Energy need [kWh]	Heating		Cooling	
Month	**Monthly method**	**Hourly method**	**Monthly method**	**Hourly method**
January	2104	2002	3	0
February	1343	1261	13	0
March	755	628	76	0
April	273	138	196	46
May	90	0	539	355
June	0	0	922	944
July	0	0	1038	1001
August	0	0	1277	1218
September	1	0	497	416
October	339	195	155	23
November	775	682	31	0
December	1740	1650	4	0
Annually	7419	6556	4751	4004

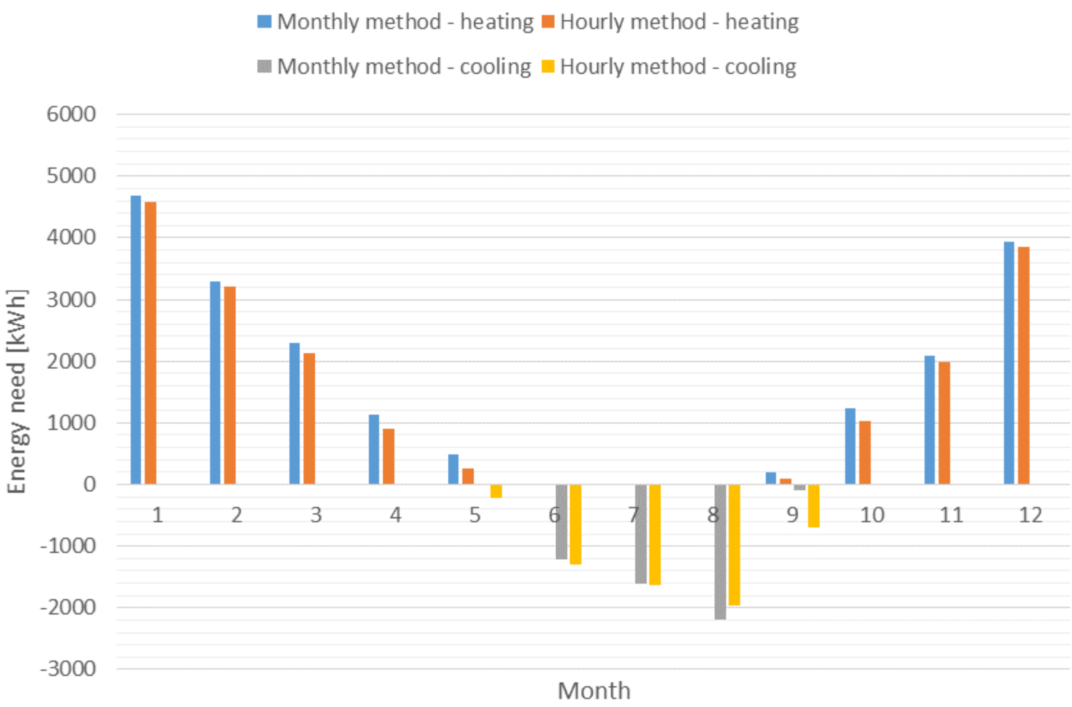

Fig. 10 Monthly energy need for heating/cooling (*Scheme 4*)

Table 3 Comparison – Monthly and hourly energy need for heating/cooling (*Scheme 4*)

Energy need [kWh]	**Heating**		**Cooling**	
Month	**Monthly method**	**Hourly method**	**Monthly method**	**Hourly method**
January	4680	4578	0	0
February	3289	3208	0	0
March	2288	2131	0	0
April	1138	903	0	0
May	484	264	0	213
June	0	0	1213	1303
July	0	0	1618	1626
August	0	0	2190	1973
September	192	95	94	686
October	1245	1034	0	0
November	2083	1986	0	0
December	3936	3846	0	0
Annually	19335	18045	5115	5801

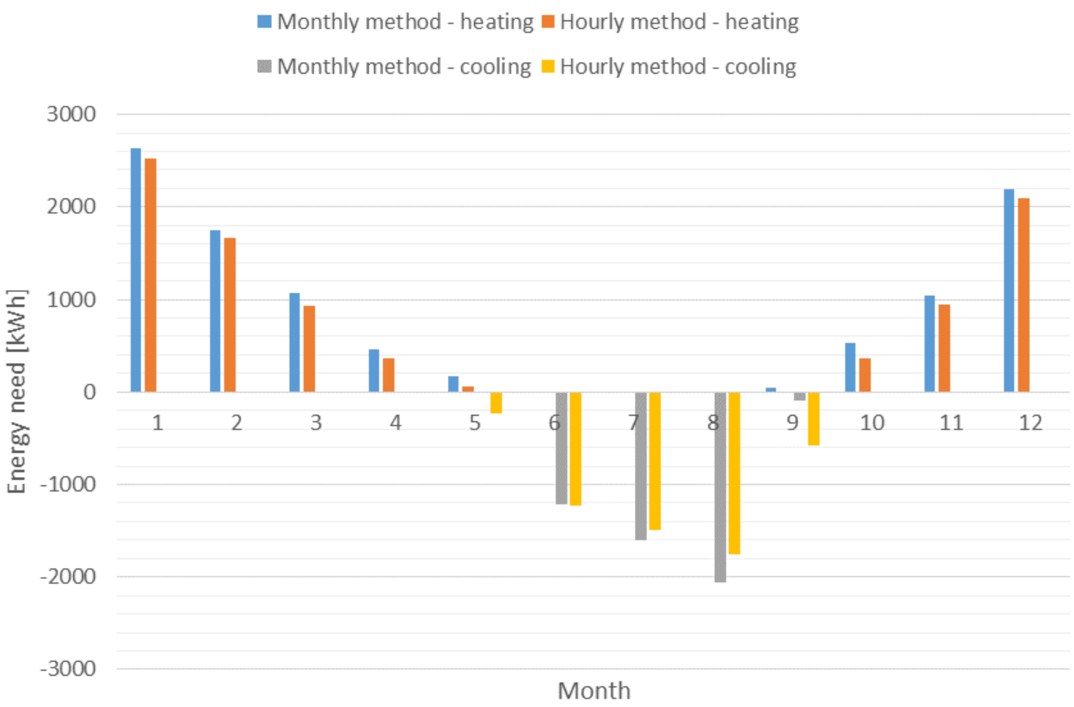

Fig. 11 Monthly energy need for heating/cooling (*Scheme 8*)

Table 4 Comparison – Monthly and hourly energy need for heating/cooling (*Scheme 8*)

Energy need [kWh]	**Heating**		**Cooling**	
Month	**Monthly method**	**Hourly method**	**Monthly method**	**Hourly method**
January	2529	2631	0	0
February	1661	1742	0	0
March	929	1071	0	0
April	361	454	0	0
May	53	173	0	225
June	0	0	1213	1224
July	0	0	1599	1486
August	0	0	2056	1761
September	0	41	94	574
October	364	529	0	0
November	951	1048	0	0
December	2101	2191	0	0
Annually	8949	9880	4962	5270

As Figs 9, 10 and 11 and Tables 2, 3 and 4 show, monthly and hourly method predict similar energy need for heating/cooling (differences on annual basis 6-16%). Greater differences occur in the transitional period (up to 100%) where the monthly method clearly overestimates the energy need for heating [11], [12]. Furthermore, in some months, due to averaging of the climate data (especially moisture content), the energy need for cooling obtained by two methods distinguish a lot. This is also the main reason why monthly method has a limited accuracy in the calculations of building energy needs, especially buildings equipped with air conditioning system.

Table 5 Comparison – Annually energy need for heating/cooling (*Scheme 4 and Scheme 8*)

Energy need [kWh]	Heating		Cooling	
Month	**Scheme 4**	**Scheme 8**	**Scheme 4**	**Scheme 8**
Annually	18045	9880	5801	5270

Table 5 shows the benefits from installing heat recovery system. In the present case, by employing the heat recovery system, energy need for heating and cooling decreases 45.2% and 9.2%, respectively. These numbers confirm the fact that heat recovery represents well-known solution to reduce annual energy demand in buildings equipped with air ventilation systems.

5. Conclusion

The new methodology for the calculation of the energy need for heating and cooling, incorporated in Croatian national Algorithms is presented. The simple hourly method from HRN EN ISO 13790 standard and the new approach for determining the energy need for mechanical ventilation, that enables the use of the simple hourly method in calculation of HVAC systems, is described.

The results of calculations performed for the reference Croatian dwelling equipped with two different HVAC systems are shown and the importance of employing heat recovery systems is analysed. Also, the increase of energy need due to the dehumidification has clearly been demonstrated.

Furthermore, the comparison against the results of the energy need obtained by monthly method has been carried out. The performed comparison proved that the monthly method is not sufficiently accurate to determine the energy need for cooling, due to the averaging of the climate data, especially moisture content.

NOMENCLATURE

$H_{tr,em}$	External part of the transmission heat transfer coefficient, [W/K]
$H_{tr,is}$	Thermal coupling conductance, [W/K]
$H_{tr,ms}$	Internal part of the transmission heat transfer coefficient, [W/K]
$H_{tr,op}$	Transmission heat transfer coefficient for opaque elements, [W/K]
h_{is}	Heat transfer coefficient between nodes air and s, [W/m^{2}K]
h_{ms}	Heat transfer coefficient between nodes m and s, [W/m^{2}K]
A_{at}	Dimensionless ratio between the internal surface area and the floor area, [-]
A_f	Conditioned floor area, [m^2]

A_m	Effective mass area, [m^2]
A_{tot}	Area of all surfaces facing the building zone, [m^2]
ϕ_{int}	Internal heat sources, [W]
$\phi_{HC,nd}$	Energy need for heating/cooling, [W]
ϕ_{sol}	Solar heat sources, [W]
ϑ_{air}	Internal air temperature, [°C]
ϑ_m	Node m temperature, [°C]
ϑ_s	Node s temperature, [°C]
Q_{tr}	Heat transfer by transmission, [kWh]
$Q_{ve,inf}$	Heat transfer by ventilation due to infiltration, [kWh]
$Q_{ve,win}$	Heat transfer by ventilation due to window opening, [kWh]
$Q_{HC,ve,mech}$	Energy need for mechanical ventilation, [kWh]
$Q_{HC,nd}$	Energy need for heating or cooling, [kWh]
$\eta_{H,gn}$	Utilization factor for heat gains, [-]
$\eta_{C,ls}$	Utilization factor for heat losses, [-]
k_v	Heat load part covered by mechanical ventilation, [-]
h_e	External air enthalpy, [kJ/kg]
h_{out}	Outlet air enthalpy, [kJ/kg]
h_{pom}	Indoor air enthalpy reduced to the supply air moisture content, [kJ/kg]
$h_{mech,sup}$	Supply air enthalpy, [kJ/kg]
$V_{mech,sup}$	Air flow rate, [m^3/h]
x_e	External air moisture content, [kg_w/kg_{air}]
$x_{mech,sup}$	Supply air moisture content, [kg_w/kg_{air}]

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