# Heat Balances by using heat pumps


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**The methodology of heat balance calculation can be different. We use dynamic (detailed) simulations, quasi-stationary methods - monthly method, correlation (static) day-stage method with a fixed heating period length, and also dynamic methods with a specified time step - a simple hourly method. The main aim of this work is to use and demonstrate the importance of the new hour method (EN ISO 52016-1) in comparison with the commonly used monthly method. The energy requirements for heating, cooling and hot water production are calculated using the Simulation 2018 software with an hourly step. Using the heat pump with an hourly step is calculated energy intensity model house.**

Nowadays, the construction of new houses and reducing their energy intensity is becoming an increasingly discussed topic. From 2020, a new EU directive will be in force – it mandates the construction of environmentally friendly buildings and contains stricter requirements for the energy performance of buildings. It will be an obligation to design such a house. The key aim of this diploma work is to point out to the importance of the hourly method, which works according to EN ISO 52016-1 – It calculates more accurate values by using hour time step and this is the way to move the building into higher energy category.

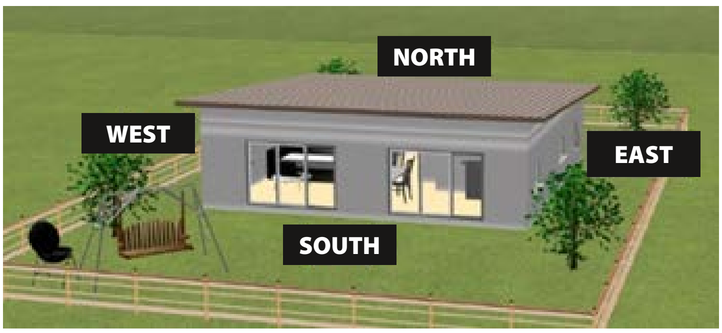
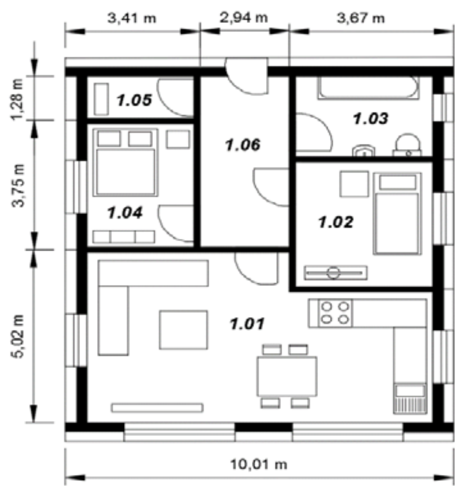



**Figure 1.** Model house.

## Methodology of this work

### *1. Model house*

The first step of this work is a simple design of a house in two climatic areas (one warmer and one colder) according to the principles of low-energy house design. The building has a compact shape, high-quality materials are used, it is suitably oriented to the cardinal points (p.o. large windows are oriented to the south side because of solar gains, rooms like technical room or laundry are on the north side of house).



Simulation 2018 software is used for energy analysis of the model house, this SW works with a new hourly calculation model according to Articles 6.5.6 to 6.5.13 of EN ISO 52016-1. This model is based on re-compilation and solution of the system of balance equations in individual time steps, taking into account the energy balance at the level of the zone (room) and at the level of partial constructions. At least five balance equations corresponding to the number of nodes in the structure model (from 5 to 30) shall be compiled for each "opaque" structure, depending on its composition. For "translucent" structures, a two-node model is used.

## *2. Design of a heat source power*

The heat source power is based on the external calculation temperature and the associated heat loss consisting of the passage of heat and ventilation. Climatic data were provided by SHMU institute. Both the hourly and monthly methods are used to demonstrate the difference in the performance regime over the selected 4 days in each season. The theoretical required heat output is determined as the difference between heat loss and heat gain. The value of heat loss is calculated for each hour of the day and heat gains (indoor and solar) are evaluated by Simulation 2018 based on location, altitude, building orientation, used materials, house occupants and other factors. The theoretical heat source power calculated in this way does not take into account heat accumulation!

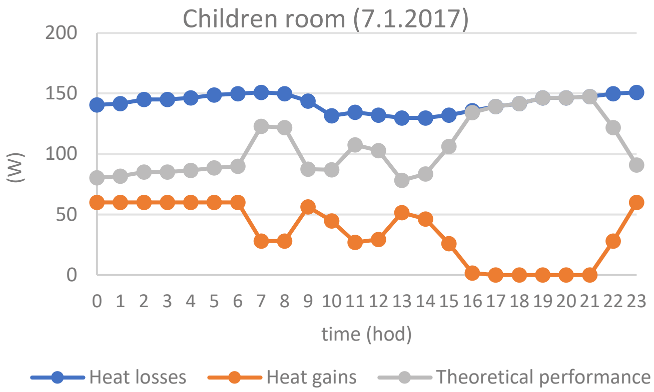



**Figure 2.** Theoretical heat source power.

However, Heat accumulation is taken into account:

- in the building construction - the specific heat capacity, the thermal conductivity and the density of each layer of material are specified;
- room equipment - according to EN ISO 52016-1 standard value of 10 000 J/(m²K) is assumed for common rooms - if the value is set to 0, the state for a completely empty room would be calculated;
- in the air.

Calculation in the software run in the "free float" mode, that means without the providing heat/cold from the source (the indoor air temperature therefore depends only on the boundary conditions). The output of the calculation is a protocol containing a graph of the resulting temperature in the room (reaction of the room) to the boundary conditions, which are mentioned heat gains, outdoor temperature and ventilation.

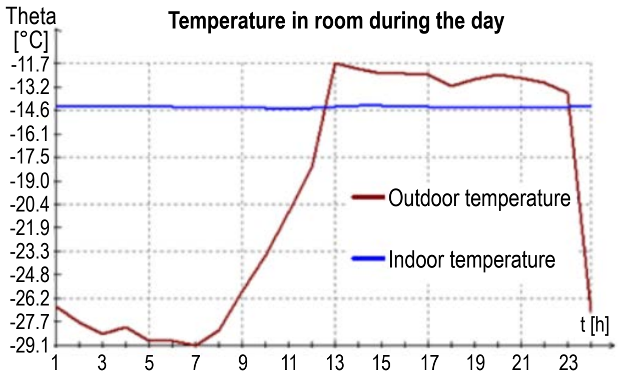



**Figure 3.** Course of outdoor and indoor temperature.

The heat required to heat the mass of the room air is determined from the calorimetric equation:

$$Q = m_{vz} \cdot c_p \cdot (t_v - t_n) \text{ (kJ)}$$

It takes into account the amount of air in the room ($m_{vz}$) that will need to be heated (cooled), the heat capacity of the air ($c_p$) at given conditions and pressure 101.3 kPa and of course the temperature difference (resulting room temperature $t_v$ – designed temperature $t_n$). This calculation is performed for each temperature throughout the day.

The heat output of the heat/cold source calculated from the calorimetric equation can be entered into the software. After its installation we get a graph of the resulting temperature in the room and it is possible to find out whether the heat source is oversized, sufficient or it is necessary to increase it. Of course, it will be oversized because of the heat accumulation from heating process. The heat output values are optimized so that the resulting room graph shows the design temperature in the room.

### *3. Calculation of building energy demands*

The hourly and monthly method is again used to calculate the energy demands for heating, cooling and hot water production throughout the year. Regarding the hourly method, the same procedure as explained in the design of the heat source (where 4 days were selected to determine the required heat source output) is applied, but by this way every room and every day is analysed hourly for both selected temperature regions. EN 15316-3-1 is used to determine the annual energy demand for water heating.

### *4. Calculation of energy intensity*

The global indicator of energy intensity is primary energy entering to the transformation process – kWh/(m²/year), which is largely dependent on the selected heat source. The technologies compared are heat pumps (colder region - ground/water, warmer region - air/water) and electric boiler with cooling circuit. The primary energy consumption is determined by:

- by SPF pursuant to Decree no. 324/2016 Z.z.
- using the SCOP
- hourly step with the corresponding heating coefficient

An example hourly calculation for warmer region:

The selected air-water heat pump from the manufacturer Protherm - Genia Air Split is 5 kW. To calculate hourly energy consumption, it is necessary to know the COP / EER value at each hour of the year at a given hourly temperature. The subsequent hourly heat / cold consumption will be determined by the equation below.

$$\text{hourly energy consumption(kWh)} = \frac{\text{hourly energy demand (kWh)}}{\text{COP/EER}}$$

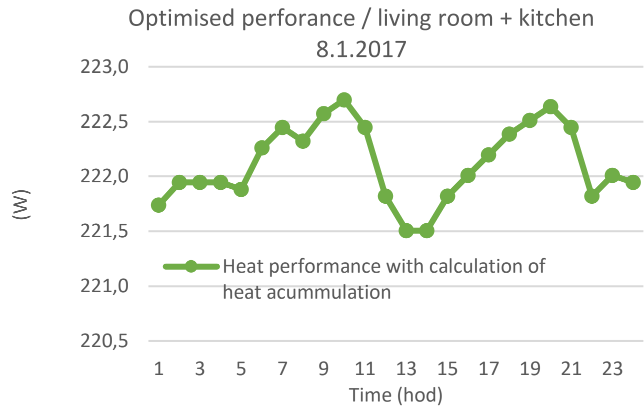



**Figure 4.** Resulting optimized required heat source power (heat accumulation taken into account).

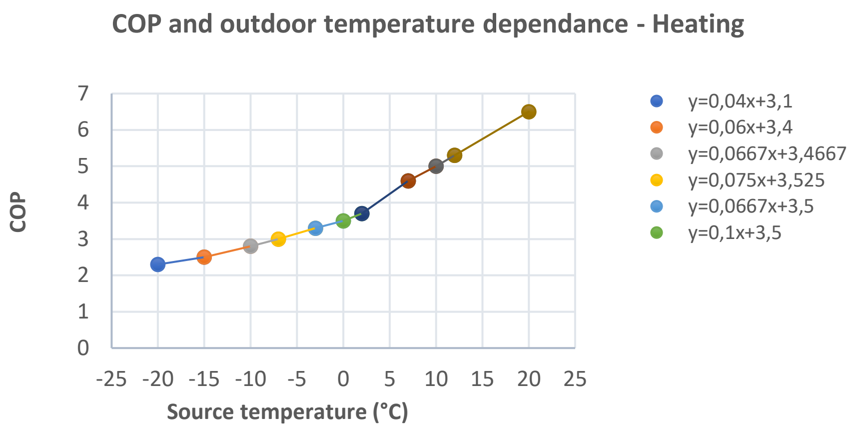



**Figure 5.** COP/EER dependence on outside temperature.

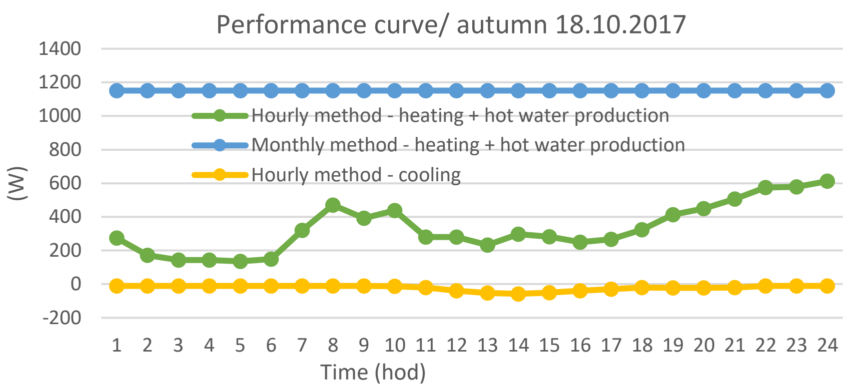



**Figure 6.** The resulting heat output curves on the selected autumn day.

The information datasheet shows the COP coefficient dependence on the outside temperature – COP is given for temperatures –20, –15, –10, –7, –3, 0, 2, 7, 10, 12, 20°C. I consider the system temperature at the outlet of 35°C, when operating the pump in heating mode - the model house has low temperature floor heating.

When hot water is heating, an outlet temperature of 55°C is considered. The cooling coefficients of the EER are used for temperatures of 15, 20, 25, 35, 46°C. The other COP/EER values are derived using linear dependencies (**Figure 5**) between them according to EN 14825. The total energy consumption of the house is calculated, multiplied by the primary energy factor. According to Decree no. 324/2016 Z.z , PEF value for electricity is 2.2. The result is a global indicator of primary energy in kWh/m².year, which determines the classification of the building into the energy class.

## Results

### *1.Heat source power*

**Figure 6** shows the resulting heat output power curves of the whole house with water heating on a selected autumn day in warmer region calculated with an hourly step compared to the power calculated by the monthly method. The monthly method based on the average temperature indicates only the need for heating, while the detailed hourly method shows, besides heating also the need for cooling during the lunch hours.

### *2. Energy demands and energy intensity*

The difference between the heating and cooling energy needs of a model house calculated by the hourly and monthly method reaches up to 20%. The procedure with an hourly calculation step is more accurate, more flexible, and does not need much more input data. The hourly method analyses in detail the solar and indoor gains, ventilation and, in particular, the heat accumulation, which is taken into account in the building construction, furniture and equipment in the room and in the air. The monthly method according to EN ISO 13790 with an adaptation factor provides a rough estimate based on conventional assumptions, which may, in some cases, suit but do not allow to optimize heat pump solutions in more detail. The hourly method, an hourly step, allows more detailed access to a building requiring both heating and cooling. In the monthly calculation, it is also difficult to check the need for cooling in the months when it is still heating. The lowest value of primary energy consumption is demonstrated by the hourly calculation method. This principle is suitable for heat pumps as it more precisely takes into account the calculation with the corresponding COP in relation to

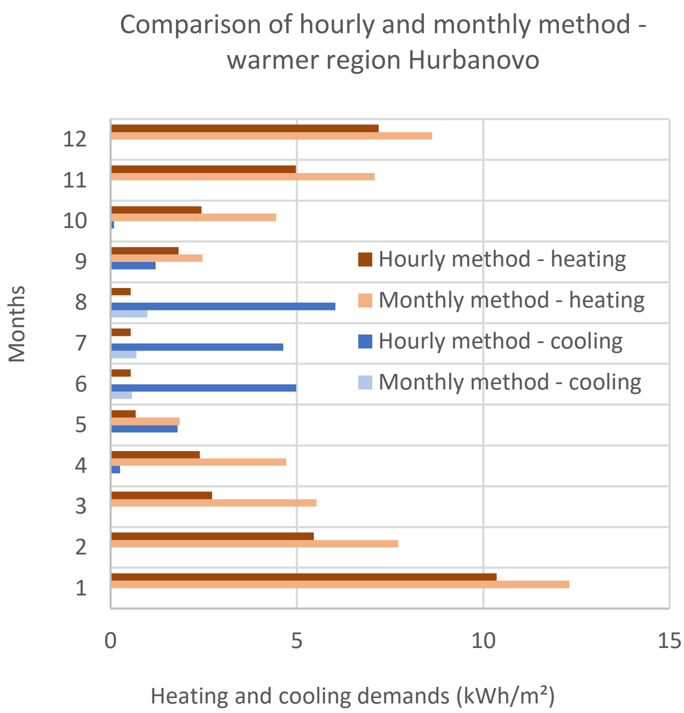
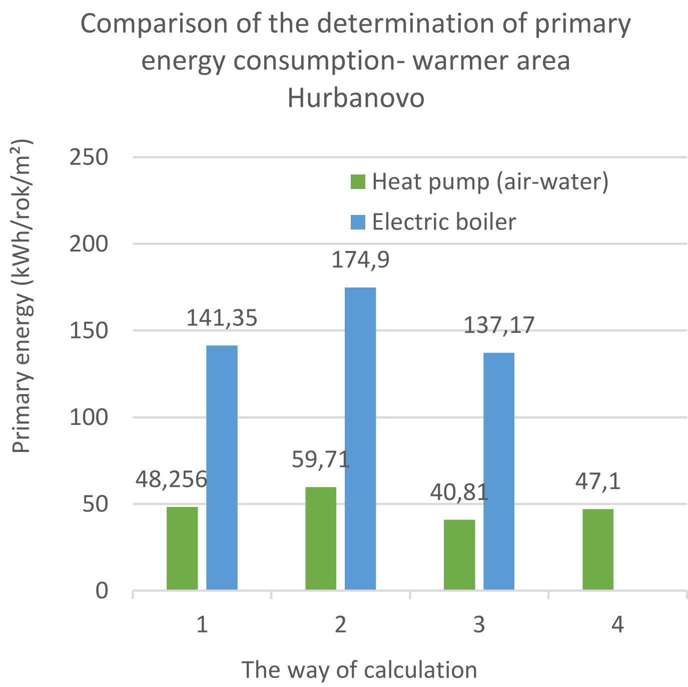



**Figure 7.** Comparison of energy requirements in kWh/m² per year calculated by monthly and hourly method. The figure shows not only the lower energy demand calculated by the hourly step, but also the cooling demand in April, May, September, which remained hidden using the monthly method.




| | |
|---|---|
| 1 - Decree no. 324/2016 Z.z. Hourly method | 2 - Decree no. 324/2016 Z.z. Monthly method |
| 3 - Hourly calculation | 4 - Calculation with SCOP |

**Figure 8.** Comparison of energy intensity expressed in primary energy in kWh/m² per year calculated by monthly and hourly method shows high consumption for electric boiler and lowest consumption calculated per hour.

*Table 9. The resulting comparison of energy intensity. A house with a heat pump is classified in a higher energy class as opposed to a house with an electric boiler, which moves the house to class B.*

| Hurbanovo - warmer region | | | | | | | |
|---|---|---|---|---|---|---|---|
| The way of determination of energy consumption | The way of determination of energy demands | Energy demand for heating (kWh/rok/m$^2$) | Energy demand for hot water production (kWh/rok/m$^2$) | Energy demand for cooling (kWh/rok/m$^2$) | Source of heat | Primary energy consumed (kWh/rok/m$^2$) | Building category |
| Order 324/2016 Z.z. | Order 324/2016 Z.z. Hourly method | 39.74 | 23.95 | 18.98 | Heat pump air-water | 48.256 | A0 |
| | | | | | Electric boiler | 141.35 | B |
| | Order 324/2016 Z.z. Monthly method | 54.76 | 23.95 | 2.25 | Heat pump air-water | 59.74 | A1 |
| | | | | | Electric boiler | 174.9 | B |
| Hourly calculation | Hourly method | 39.74 | 23.95 | 18.98 | Heat pump air-water | 40.81 | A0 |
| | | | | | Electric boiler | 137.17 | A1 |
| Calculation with SCOP | Hourly method | 39.74 | 23.95 | 18.98 | Heat pump air-water | 47.1 | A0 |

the outside temperatures for each hour of the year. The COP is calculated per hour and depends on the load rate and temperature of the low potential heat source.

## Discussion

This diploma work shows that, in contrast to the monthly method, the hour method is a more accurate way to determine the energy requirements (energy needs) of a building. The difference between heating needs is up to about 20%. Also, the monthly method is not able to accurately describe the building's cooling needs. The hourly method analyses in detail processes in the building, i.e. solar and indoor gains, ventilation and especially heat accumulation. Another big difference is the power mode of the heat source, where there is also a significant difference between the methods used.

Difference of primary energy consumption as a global indicator between hourly calculation method and monthly method according to Decree no. 324/2019., in both cases (both cold and warm areas) reaches a lower value of about 15%.

The difference in primary energy consumption between the hourly calculation and the SCOP calculation is about 13% lower. The hourly method is important for heat pumps because the calculation by the hourly step more accurately takes into account the COP corresponding to the given temperature conditions, i.e. the load rate and the source temperature. The calculation by seasonal heating or cooling coefficient, similar to the monthly method according to the Decree, is less accurate.

When calculating with the monthly method, it is difficult to check the need for cooling, for example, in April, May, September, when there are still heating requirements. A building without cooling may seem better. The hourly step can also calculate the need for cooling and maintain the internal environment parameters when calculating the energy performance of a building.

## Conclusion

The above results and the way of determining both the energy demands and the energy intensity with an hourly step contribute to the specification of the requirements for heating, cooling, water heating and significantly help in the correct design of technical equipment of buildings, especially heat pumps with possible use of photovoltaic electricity. The hourly method, an hourly step, allows for a more specific approach to a building requiring both heating and cooling. The task for the future will be to improve the calculation methodology, to beat up and automate the calculation and to gradually introduce it into a practice. ■