Hibrid system energetic performances evaluation composed by vapor compression heat pump used in building heating and dailly hot water

Evaluarea performantelor energetice a sistemului hibrid compus din pompa de caldura cu compresie de vapori utilizata in incalzirea cladirilor si apa zilnica

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Abstract

This paper addresses the topic of wide interest, regarding the positive impact to environment by using renewable energy resources, in terms of building heatinf thermal agent and daily hot water preparation. Thus, a hydraulic scheme is proposed which consists of an air-water heat pump and a gas boiler that takes over the additional load in the conditions of external temperatures for which the heat pump cannot satisfy the entire needs of the consumer. In the first part of the analysis, the calculation procedure is structured with the necessary equations for the energy evaluations specific to each type of system, thus being possible to calculate the thermal input brought by each equipment. The method also summarizes the procedure for establishing Meteo data for the heating season, respectively for the entire year in terms of daily hot water consumption. The data thus structured are used to construct BINs that contain a number of hours characterized by an average temperature over the entire subinterval. After establishing the working procedure and the BIN database, in the last part of the material two examples were proposed, for both situations in which an air-to-water heat pump of known dimensions is evaluated for establishing the energy coverage of a known consumer. The two examples address both heating and hot water consumption.

Key words: hibrid system, heat pump

1. Introduction

The implementation of the use of renewable sources is currently an intensely pursued objective in the context in which the use of hydrocarbon-based sources must be minimized as much as possible. This field includes the use of solar energy for the production of heat and electricity, the use of wind energy for the production of electricity, the use of biomass and biogas and the use of compression or absorption heat pumps to extract energy from the outside environment (air, apa, sol). The present paper follows a series of concerns in the field of the use of renewable resources, especially solar energy and the energy of the external environment. Some of the previous concerns in this field are mentioned in the bibliography of the paper.

The paper has a practical character, namely the presentation of the steps and steps to be performed to evaluate the energy contribution that a certain source system using the heat pump can offer to a specific consumer defined by its type and size. The previous papers mentioned in the bibliography substantiate the procedure presented in this paper.

The procedures presented take into account the fact that throughout the use of the compression heat pump, its coefficient of performance, COP, is variable depending on the temperatures of cold and hot environments and also the thermal power delivered to the pump condenser is variable depending on the electric power, absorbed at the heat pump compressor. One assumption used in the procedures is the constant value of the average temperature differences at the heat pump evaporator and condenser, Δt_{VP} and Δt_{CD}, respectively.

The procedures involve the construction of BIN type outdoor temperature ranges and the establishment within each such range of the COP of the heat pump and the electrical power used. At each BIN type interval, the thermal powers delivered by the heat pump and the classic source, the thermal power plant, are established in order to cover the necessary thermal power of the consumer. The energy performance of the heat pump is represented by 2 parameters, namely an average value of the COP of the heat pump and the value of the thermal energy delivered by the heat pump during the operation period.

2. **The procedure for evaluating the performance of the heat pump for heating the spaces of a residential type consumer.**

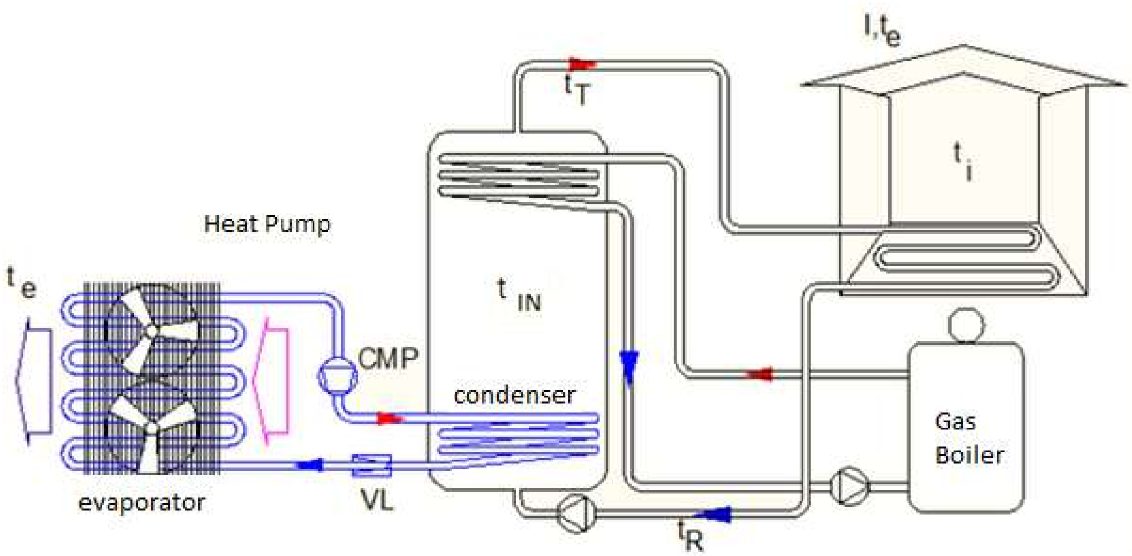

Fig.1

The description of the energy performance evaluation procedure will refer to the case of an air-water heat pump, in which the outside temperature intervenes both in the case of evaluating the thermal power delivered by the heat pump and in the case of evaluating the consumer's heat demand for space heating.

a. Input data :
   - Known data (proposed) : Δt_{VP} = 5 ºC, Δt_{CD} = 5 ºC, M = 0.958 si N = 1.5321;
   - Datasheet heat-pump parameters :COP_0, θ_{VP0}, θ_{CD0}, P_{CD0}, η_{EL};
   - Building thermal characteristics : Φ_{INC0}, t_{T0}, t_{R0}, t_{i0}, t_{e0}:

b. Building thermal heat power evaluation and external themperature dependant thermal adjustment equations:

$$H_{INC} = \frac{\Phi_{INC0}}{(t_{i0} - t_{e0})} \tag{1}$$

$$\Phi_{INC} = H_{INC} \cdot (t_{i0} - t_e) \tag{2}$$

$$t_T = \frac{t_{T0} - t_{e0}}{t_{i0} - t_{e0}} \cdot t_{i0} - \frac{t_{T0} - t_{i0}}{t_{i0} - t_{e0}} \cdot t_e \tag{3}$$

$$t_R = \frac{t_{R0} - t_{e0}}{t_{i0} - t_{e0}} \cdot t_{i0} - \frac{t_{R0} - t_{i0}}{t_{i0} - t_{e0}} \cdot t_e \tag{4}$$

c. Heat pump condenser and evaporator mathematical model equations:

$$\begin{aligned} \varepsilon_{VP}^{C} &= \frac{\theta_{VP} - \Delta t_{VP} + 273.15}{\theta_{CD} - \theta_{VP} + \Delta t_{VP} + \Delta t_{CD}} \\ \varepsilon_{VP\_iz}^{*} &= M \cdot \varepsilon_{VP}^{C} - N \end{aligned} \tag{5}$$

$$\eta_{iz} = \frac{COP_0 - \eta_{EL}}{\varepsilon_{VP\_iz\_0}^{*} \cdot \eta_{EL}} \tag{6}$$

$$\begin{aligned} EER &= \varepsilon_{VP\_iz}^{*} \cdot \eta_{iz} \cdot \eta_{EL} \\ COP &= \left(1 + \varepsilon_{VP\_iz}^{*} \cdot \eta_{iz}\right) \cdot \eta_{EL} \end{aligned} \tag{7}$$

$$P_{EL} = \frac{P_{CD}}{COP} \tag{8}$$

$$\begin{aligned} P_{VP} &= P_{EL} \cdot EER \\ P_{CD} &= P_{EL} \cdot COP \end{aligned} \tag{9}$$

d. Based on known catalog conditions of the heat pump (COP_0, θVP_0, θ_{CD0}, P_{CD0}, η_{EL}) the refrigeration efficiency Carnot de calcul, εCVP0 is established, using the relation (51) in these conditions and further computational isentropic refrigeration, $\varepsilon * _{VP\_iz\_0}$, using the relation (5_2). Also, the isentropic efficiency of the compressor, η_{iz}, is further determined using the relation (6) and the catalog electric power of the heat pump using the relation (8) in catalog conditions.

e. Determining the outside temperature for which the heat pump manages to fully cover the heat required for heating the building spaces. This temperature is distinguished by the fact that it leads to equal values for the thermal power delivered by the heat pump condenser with the power needed to heat the building spaces: $P_{CD} = \Phi_{INC}$, ensuring the thermal balance of the heated spaces on the normal indoor temperature, t_{i0}. In order to determine the thermal power delivered by the condenser, the relation (9_2) will be used, where the COP of operation of the heat pump is established using the relations (5) and (7) where in the relation (5) it will be: θ_{VP} = tem, and $\theta_{CD} = t_{m0}$, where $t_{m0} = (t_{T0} + t_{R0}) / 2$. The relationship (2) will be used to determine the required heat flow of the consumer. We propose a graphical method for determining the external equilibrium temperature, t_{eE}, by the intersection of the P_{CD} curves with Φ_{INC}, established graphically by points.

f. The following is the setting of the BIN outdoor temperature ranges. The outside equilibrium temperature, teE, divides the division of BIN intervals into 2 zones. Zone 1 of BIN intervals characterized by $t_e < t_{eE}$ outdoor temperatures and zone 2 of BIN intervals characterized by $t_e > t_{eE}$ outdoor temperatures. In zone 1 of BIN intervals the heat pump will absorb from the network an electric power equal to the catalog electric power of the heat pump but will provide the condenser with a thermal power lower than the power required by the consumer, the difference being covered by the boiler. In zone 2 BIN intervals the heat pump will absorb from the network a lower electric power than the catalog electric power by the intervention of the frequency converter and will deliver to the condenser a thermal power equal to the power required by the consumer. It is established for each BIN interval from zone 1 and from zone 2 the average external temperature of the respective BIN interval, tem. In the case of this paper, the determination of BIN intervals was done using a Meteo database. For a representative calendar year, the database contains 8760 temperature values corresponding to each hour and characterized by average hourly temperatures. The heating season corresponds to all the subperiods in which the average temperature for 3 days has a value of less than 12 ºC. Thus, a smaller number of hourly data is obtained, corresponding only to the heating period. Furthermore, the totality of the hours retained for the heating period, lead to the construction of the BIN intervals necessary to evaluate the operation of the heat pump. The construction of BIN intervals can be done by two methods.

Method 1 is represented by a number of predefined intervals. Each subinterval having the same length, established between the maximum, t_{e_max} and minimum temperatures, t_{e_min}, of the heating period, for a given number of necessary subintervals, according to the equation:

$$\Delta t_e = \frac{t_{e\_\max} - t_{e\_\min}}{n_i} \qquad (10)$$

In which Δt_e represents the temperature step of each subinterval.

Method 2 is represented by a number of equal sub-intervals for which the temperature step is this time predetermined and the number of sub-intervals being calculated according to the equation:

$$n_i = \frac{t_{e\_\max} - t_{e\_\min}}{\Delta t_e} \qquad (11)$$

Both methods generate BIN intervals, characterized by an average temperature between the ends of the subintervals calculated with the temperature step set according to Method 1 or predetermined by Method 2. Obviously each BIN will contain all the hours in the database, related to the heating period, which have as temperature hourly average, a value within its characteristic temperature subinterval.

g. To determine the effective operation of the heat pump within the BIN intervals in zone 1, proceed to each of the BIN intervals in this zone as follows:

- It is proposed a degree of energy coverage for the heat pump, GAPC:
- The temperature of the warm environment is determined according to the relation

$$\theta_{CD} = 0.5 \cdot GA_{PC} \cdot t_T + \left(1 - 0.5 \cdot GA_{PC}\right) \cdot t_R \tag{12}$$

- The operating COP of the heat pump is established according to relations (5) and (7);
- It is established the thermal power yielded by the heat pump to the P_{CD} condenser and the heat demand of the house, Φ_{INC}, at the external temperature, tem, according to relations (9_2) and (2);
- Calculate the energy coverage of the heat pump, GAPC:

$$GA_{PC} = \frac{P_{CD}}{\Phi_{INC}} \tag{13}$$

- Returning with the value resulting from the application of the relation (13) for the GA_{PC} in the relation (12) is obtained in this way a rapidly recurring convergent series of GA_{PC} values.
- - The final value obtained for the energy coverage degree, GA_{PC}, has previously calculated the value of EER and COP, and the powers of P_{CD}, P_{VP}, P_{EL} and Φ_{INC},
- - The energies corresponding to the respective BIN intervals are further established:

$$\begin{aligned} E_{CD} &= \Delta\tau_{BIN} \cdot P_{CD} / 1000 \\ E_{VP} &= \Delta\tau_{BIN} \cdot P_{VP} / 1000 \\ E_{EL} &= \Delta\tau_{BIN} \cdot P_{EL} / 1000 \\ E_{INC} &= \Delta\tau_{BIN} \cdot \Phi_{INC} / 1000 \end{aligned} \tag{14}$$

- We can also define a green energy coverage :

$$GA_{VP} = \frac{P_{VP}}{\Phi_{INC}} \tag{15}$$

h. To determine the effective operation of the heat pump within the BIN intervals in zone 2, proceed to each of the BIN intervals in this zone as follows:
- The thermal power delivered to the condenser of the heat pump, P_{CD}, is established as equal to the required thermal flow of the consumer, Φ_{INC},
- The operating COP of the heat pump is established according to relations (5) and (7);
- The electric power absorbed from the network is established according to the relation (8);
- The degree of energy coverage, GA_{PC}, is 1 and based on the relation (91) the thermal power absorbed at the vaporizer, P_{VP} is established;
- The energies corresponding to the respective BIN intervals are further established using the relations (14) and the degree of green energy coverage according to the relation (15);
- Finally, it is established by summing up the situation at the level of the entire cold season of the year regarding the energies: total thermal energy necessary for the consumer, $E_{INC\text{-}year}$, total thermal energy delivered by the heat pump, $E_{CD\text{-}year}$, total electricity absorbed by mains heat pump, $E_{EL\text{-}year}$, the total thermal energy absorbed by the heat pump evaporator, $E_{VP\text{-}year}$ and the total thermal energy supplied by the boiler, $E_{CT\text{-}an}$. It also shows the degrees of annual energy coverage, $GA_{PC\text{-}year}$, $GA_{VP\text{-}year}$, $GA_{CT\text{-}year}$.

3. Procedure for evaluating the performance of the heat pump for the preparation of hot water for the consumption of a residential consumer.

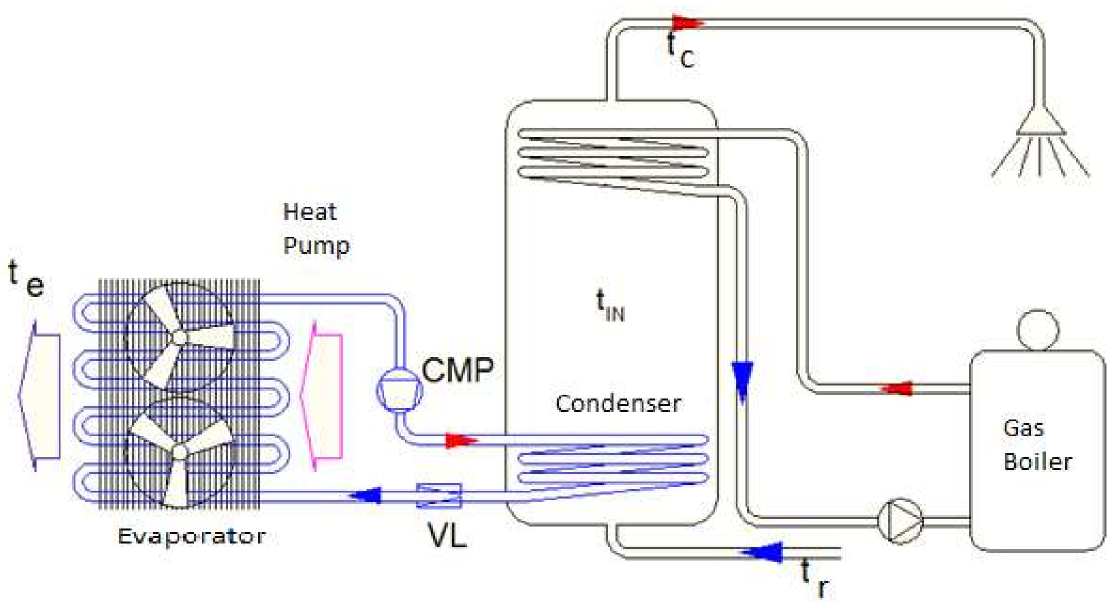

Fig. 2

The description of the energy performance evaluation procedure will refer to the case of an air-to-water heat pump, in which the outside temperature intervenes in the case of the evaluation of the thermal power delivered by the heat pump.

a. Input data:
   - Known parameters : Δt_{VP} = 5 ºC, Δt_{CD} = 5 ºC, M = 0.958 si N = 1.5321;
   - Heat pump datasheet known parameters :COP_0, θ_{VP0}, θ_{CD0}, P_{CD0}, η_{EL};
   - Building thermal characteristics : G_{ACC}, t_{ac}, t_{ar} :

b. Building thermal heat power evaluation and external themperature dependant thermal adjustment equations:

$$H_{ACC} = 1.163 \cdot G_{ACC} \quad (1)$$

$$\Phi_{ACC} = H_{ACC} \cdot (t_c - t_r) \quad (2)$$

c. Heat pump evaporation and condensing thermal power evaluation equations :

$$\varepsilon_{VP}^{C} = \frac{\theta_{VP} - \Delta t_{VP} + 273.15}{\theta_{CD} - \theta_{VP} + \Delta t_{VP} + \Delta t_{CD}}$$
$$\varepsilon_{VP\_iz}^{*} = M \cdot \varepsilon_{VP}^{C} - N \quad (3)$$

$$\eta_{iz} = \frac{COP_0 - \eta_{EL}}{\varepsilon_{VP\_iz\_0}^{*} \cdot \eta_{EL}} \quad (4)$$

$$EER = \varepsilon_{VP\_iz}^{*} \cdot \eta_{iz} \cdot \eta_{EL}$$
$$COP = \left(1 + \varepsilon_{VP\_iz}^{*} \cdot \eta_{iz}\right) \cdot \eta_{EL} \quad (5)$$

$$P_{EL} = \frac{P_{CD}}{COP} \quad (6)$$

$$P_{VP} = P_{EL} \cdot EER$$
$$P_{CD} = P_{EL} \cdot COP \quad (7)$$

d. Based on the knowledge of the catalog conditions of the heat pump (COP0, θ_{VP0}, θ_{CD0}, P_{CD0}, η_{EL}) the refrigeration efficiency Carnot de calcul, ε^{C}_{VP0} is established, using the relation (3_1) in these conditions and further the isentropic refrigeration efficiency of calculation, $\varepsilon^{*}_{VP\_iz\_0}$, using relation ($3_2$). Also, the isentropic efficiency of the compressor, η_{iz}, is further determined using the relation (4) and the catalog electric power of the heat pump using the relation (6) in catalog conditions.

e. Determining the outdoor temperature for which the heat pump manages to fully cover the heat required for the preparation of hot water for the building. This temperature is distinguished by the fact that it leads to equal values for the thermal power delivered by the heat pump condenser with the power required to heat the building spaces: $P_{CD} = \Phi_{ACC}$. To determine the thermal power delivered by the condenser we will use the relation (7_2) where the COP of operation of the heat pump is established using the relations (3) and (5) where in the relation (3) we will have: $\theta_{VP} = t_e$, and $\theta_{CD} = (t_c + t_r)/2$.
The relationship (2) will be used to determine the required heat flow of the consumer. We propose a graphical method for determining the equilibrium external temperature, t_{eE}, by the intersection of the P_{CD} curves with Φ_{ACC}, established graphically by points.

f. Next is the evaluation of the BIN intervals of the external temperature. The equilibrium external temperature, teE, divides the division of BIN intervals into 2 zones. Zone 1 of BIN intervals characterized by $t_e<t_{eE}$ outdoor temperatures and zone 2 of BIN intervals characterized by $t_e>t_{eE}$ outdoor temperatures. In zone 1 of BIN intervals the heat pump will absorb from the network an electric power equal to the catalog electric power of the heat pump but will provide the condenser with a thermal power lower than the power required by the consumer, the difference being covered by the boiler. In zone 2 BIN intervals the heat pump will absorb from the network a lower electric power than the catalog electric power by the intervention of the frequency converter and will deliver to the condenser a thermal power equal to the power required by the consumer. It is established for each BIN interval from zone 1 and from zone 2 the average external temperature of the respective BIN interval, tem. And in the case of preparing hot water for consumption, the procedure for establishing the BIN intervals is based on the hourly data generated with the help of the Meteo database. Also, the two methods described above for the heating system can be applied exactly for hot water. The specification that needs to be made represents the full use of the hours in the generated database, the period of use of hot drinking water being all year round.

g. To determine the effective working mode of the heat pump within the BIN intervals in zone 1, proceed to each of the BIN intervals in this zone as follows:
   - We propose a heat pump coverage energy ratio, GA_{PC}:
   - We evaluate condensing energy by :

$$\theta_{CD} = 0.5 \cdot GA_{PC} \cdot t_c + \left(1 - 0.5 \cdot GA_{PC}\right) \cdot t_r \tag{8}$$

- We establish COP with equations (3) si (5);
- We establish condensing thermal power, P_{CD}, and building power demand according external temperature, t_e, with equations (7_2) si (2);
- Coverage energy ratio is again evaluated with:

$$GA_{PC} = \frac{P_{CD}}{\Phi_{ACC}} \quad (9)$$

- Re turning with the value resulting from the application of relation (9) for GA_{PC} in relation (8) is obtained in this way a rapidly recurring convergent series of GA_{PC} values.
- The final value obtained for the energy coverage degree, GA_{PC}, has previously calculated the value of EER and COP, and the powers of P_{CD}, P_{VP}, P_{EL} and Φ_{ACC},
- The energies corresponding to the respective BIN intervals are further established:

$$\begin{aligned} E_{CD} &= \Delta\tau_{BIN} \cdot P_{CD} / 1000 \\ E_{VP} &= \Delta\tau_{BIN} \cdot P_{VP} / 1000 \\ E_{EL} &= \Delta\tau_{BIN} \cdot P_{EL} / 1000 \\ E_{ACC} &= \Delta\tau_{BIN} \cdot \Phi_{ACC} / 1000 \end{aligned} \quad (10)$$

- Can be defined an coverage green energy ratio:

$$GA_{VP} = \frac{P_{VP}}{\Phi_{ACC}} \quad (11)$$

h. To determine the effective operation of the heat pump within the BIN intervals in zone 2, proceed to each of the BIN intervals in this zone as follows:

- The thermal power delivered to the condenser of the heat pump, P_{CD}, is established as being equal to the required thermal flow of the consumer, Φ_{ACC},

- The operating COP of the heat pump is established according to relations (3) and (5);

- The electric power absorbed from the network is established according to the relation (6);

- The degree of energy coverage, GA_{PC}, is 1 and based on the relation (7_1) the thermal power absorbed at the vaporizer, P_{VP} is established;

- The energies corresponding to the respective BIN intervals are further established using the relations (10) and the degree of green energy coverage according to the relation (11);

- Finally, it is established by summation, the situation at the level of the entire cold season of the year in terms of energy: total thermal energy required by the consumer, $E_{INC-year}$, total thermal energy delivered by heat pump, $E_{CD-year}$, total electricity absorbed by mains heat pump, E_{EL-an}, the total thermal energy absorbed by the heat pump evaporator, E_{VP-an} and the total thermal energy provided by the thermal power plant, $E_{CT-year}$. The results of the annual energy coverage, $GA_{PC-year}$, $GA_{VP-year}$, $GA_{CT-year}$ also result

4. Examples

In order to have a more correct understanding of the calculation procedures, the following is an example of a calculation for the procedure of space heating and hot water preparation. It is considered a residential building located in the town of Toplita.

On the heating side of the spaces, this building is characterized by a computational heat demand Φ_{INC0} = 200000 W. The central heating installation was dimensioned at the nominal parameters of the thermal agent t_{T0} = 90ºC, t_{R0} = 70ºC. The normalized indoor temperature is t_{i0} = 20ºC, and the calculated outdoor temperature is t_{e0} = -21ºC. The heat pump is characterized by COP_0 = 2.5, θ_{VP0} = 2 ºC, θ_{CD0} = 60 ºC, P_{CD0} = 150000 W, η_{EL} = 0.95.

For the effective application of the procedure for evaluating the energy performance of the use of the heat pump, a calculation program was built in SCILAB. According to the presented data, the value of t_{eE} = - 8.78 ºC resulted in the case of heating the building spaces, for the external equilibrium temperature.

Next can be graphically followed the simulation results.

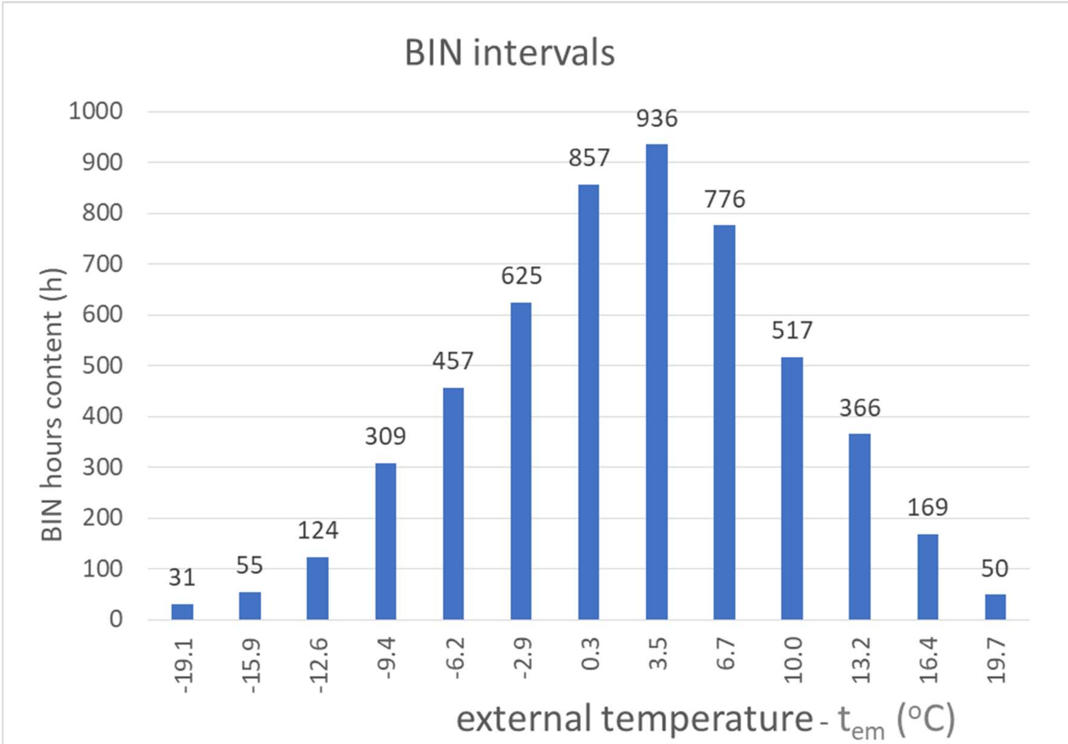
BIN intervals
BIN hours content (h)
1000
900
800
700
600
500
400
300
200
100
0
31
55
124
309
457
625
857
936
776
517
366
169
50
-19.1
-15.9
-12.6
-9.4
-6.2
-2.9
0.3
3.5
6.7
10.0
13.2
16.4
19.7
external temperature - t_{em} (^oC)

Fig.3

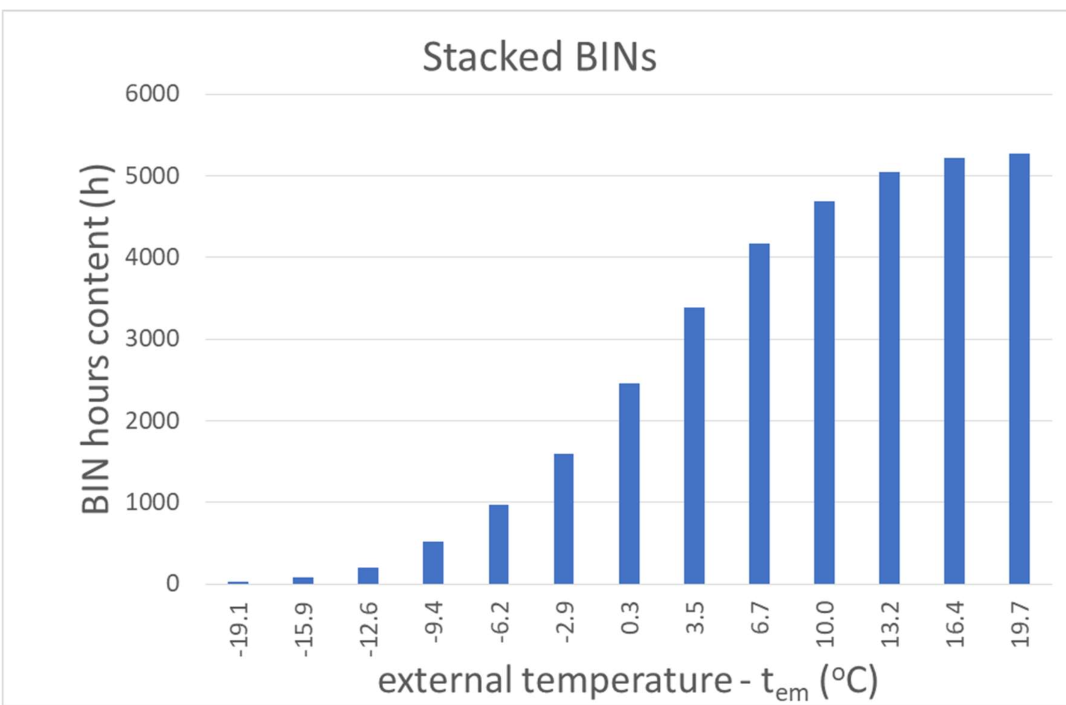
Stacked BINs
BIN hours content (h)
6000
5000
4000
3000
2000
1000
0
-19.1
-15.9
-12.6
-9.4
-6.2
-2.9
0.3
3.5
6.7
10.0
13.2
16.4
19.7
external temperature - t_{em} (^oC)

Fig.4

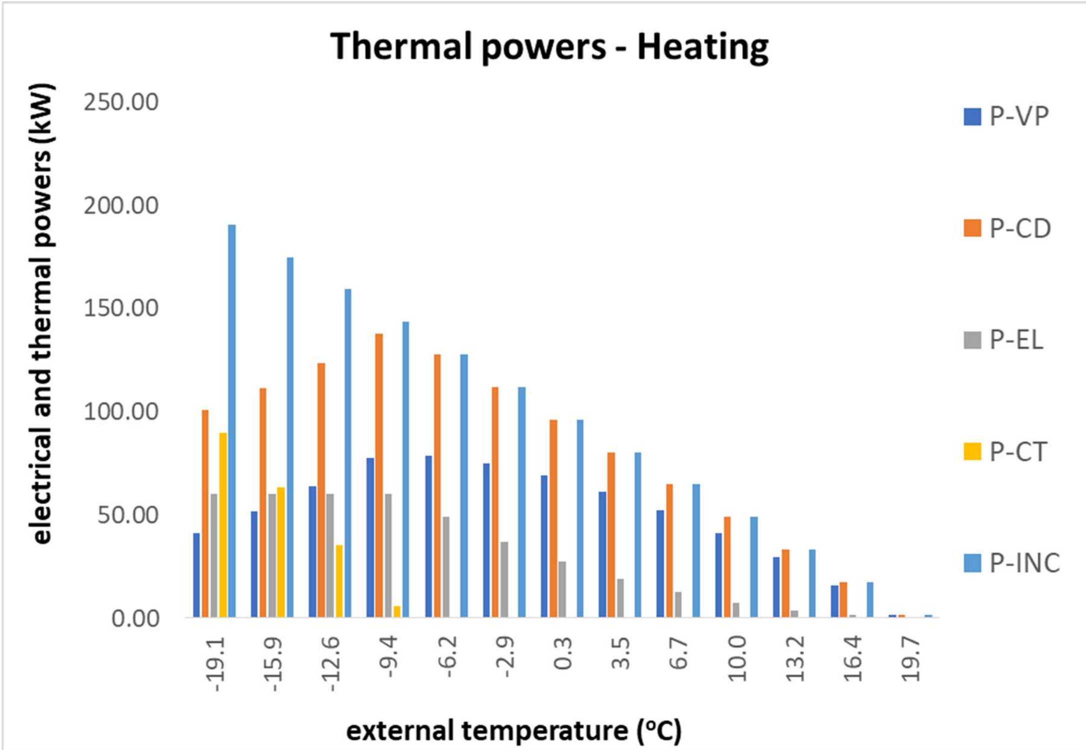
Thermal powers - Heating
electrical and thermal powers (kW)
250.00
200.00
150.00
100.00
50.00
0.00
-19.1
-15.9
-12.6
-9.4
-6.2
-2.9
0.3
3.5
6.7
10.0
13.2
16.4
19.7
external temperature (°C)
P-VP
P-CD
P-EL
P-CT
P-INC

Fig.5

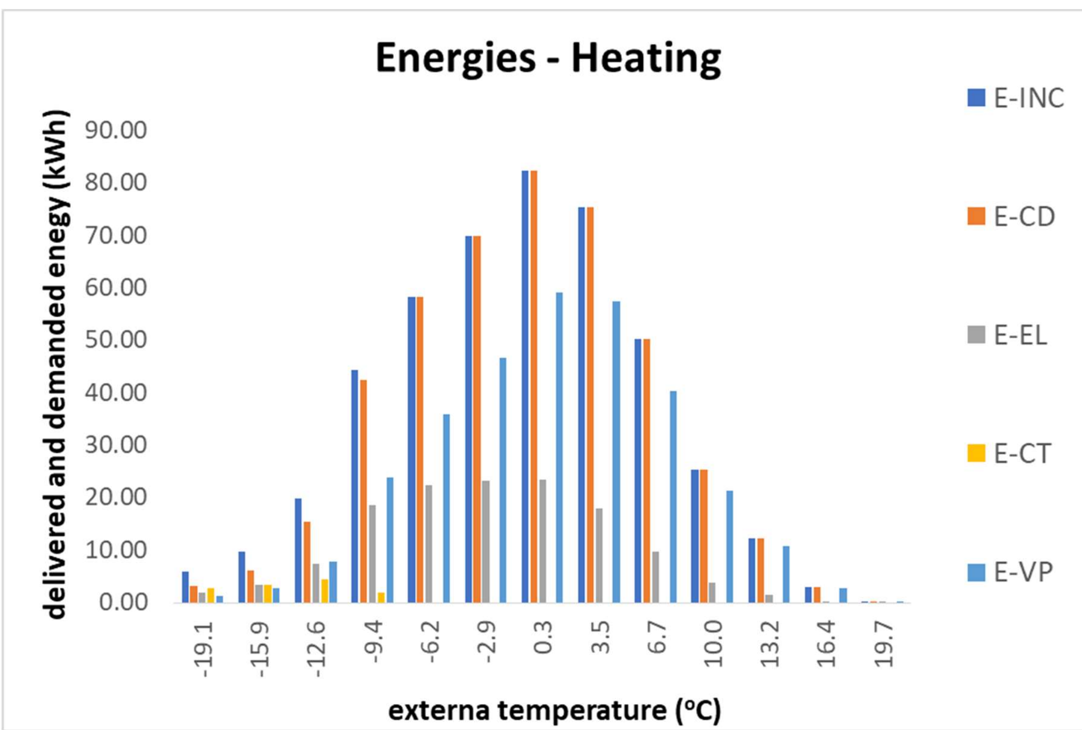
Energies - Heating
delivered and demanded enegy (kWh)
90.00
80.00
70.00
60.00
50.00
40.00
30.00
20.00
10.00
0.00
-19.1
-15.9
-12.6
-9.4
-6.2
-2.9
0.3
3.5
6.7
10.0
13.2
16.4
19.7
externa temperature (°C)
E-INC
E-CD
E-EL
E-CT
E-VP

Fig.6

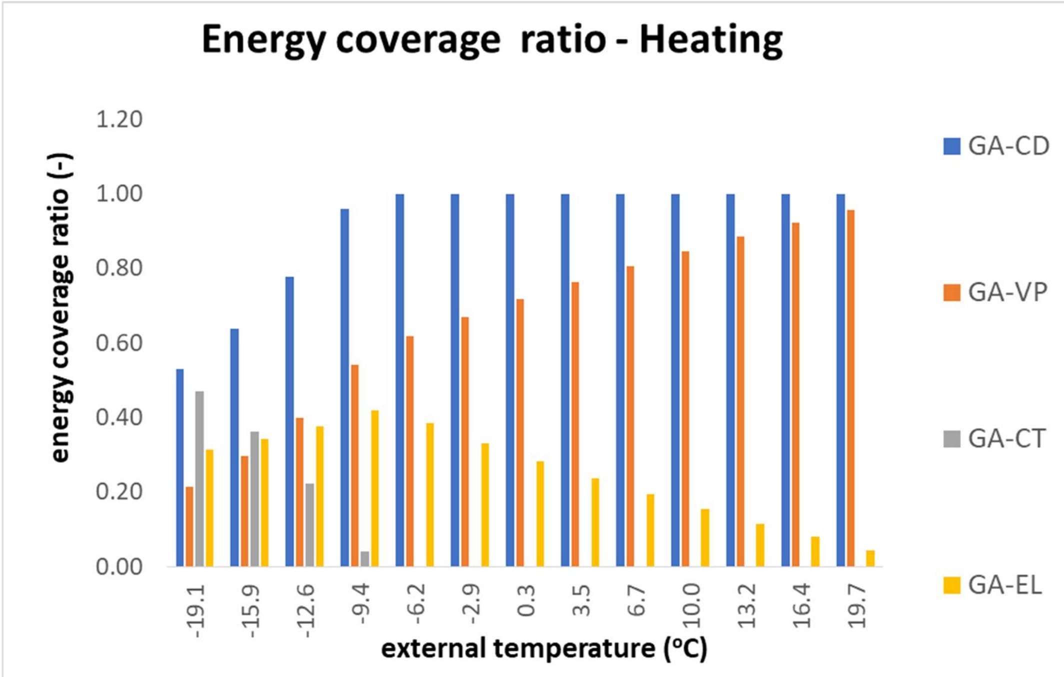
Energy coverage ratio - Heating
energy coverage ratio (-)
1.20
1.00
0.80
0.60
0.40
0.20
0.00
-19.1
-15.9
-12.6
-9.4
-6.2
-2.9
0.3
3.5
6.7
10.0
13.2
16.4
19.7
external temperature (°C)
GA-CD
GA-VP
GA-CT
GA-EL

Fig.7

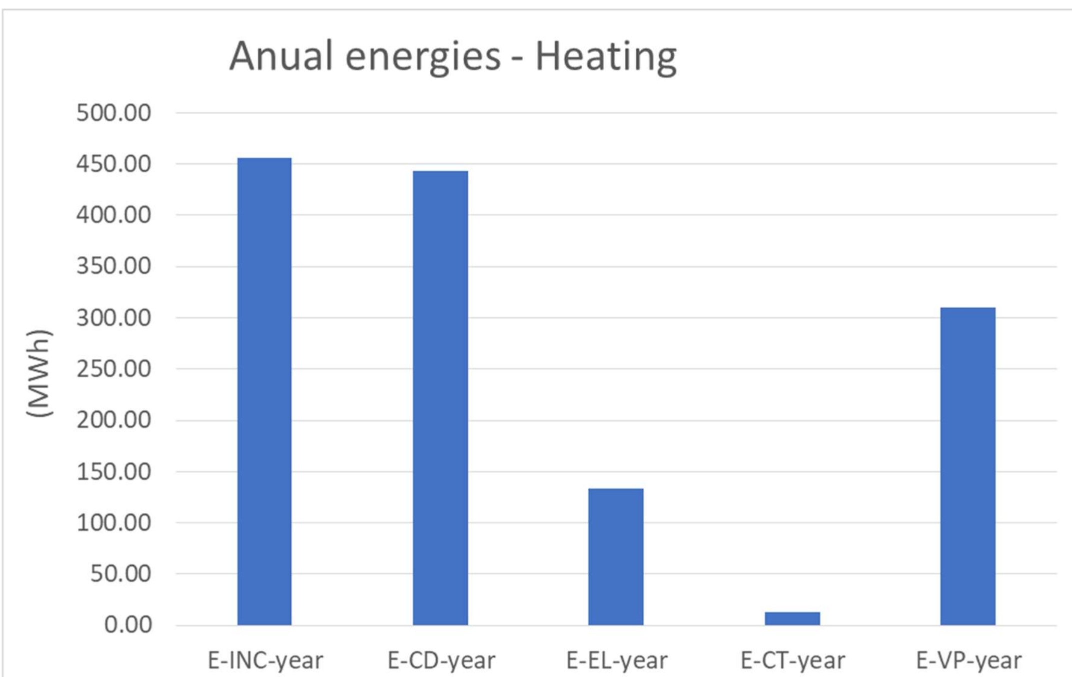
Anual energies - Heating
(MWh)
500.00
450.00
400.00
350.00
300.00
250.00
200.00
150.00
100.00
50.00
0.00
E-INC-year
E-CD-year
E-EL-year
E-CT-year
E-VP-year

Fig.8

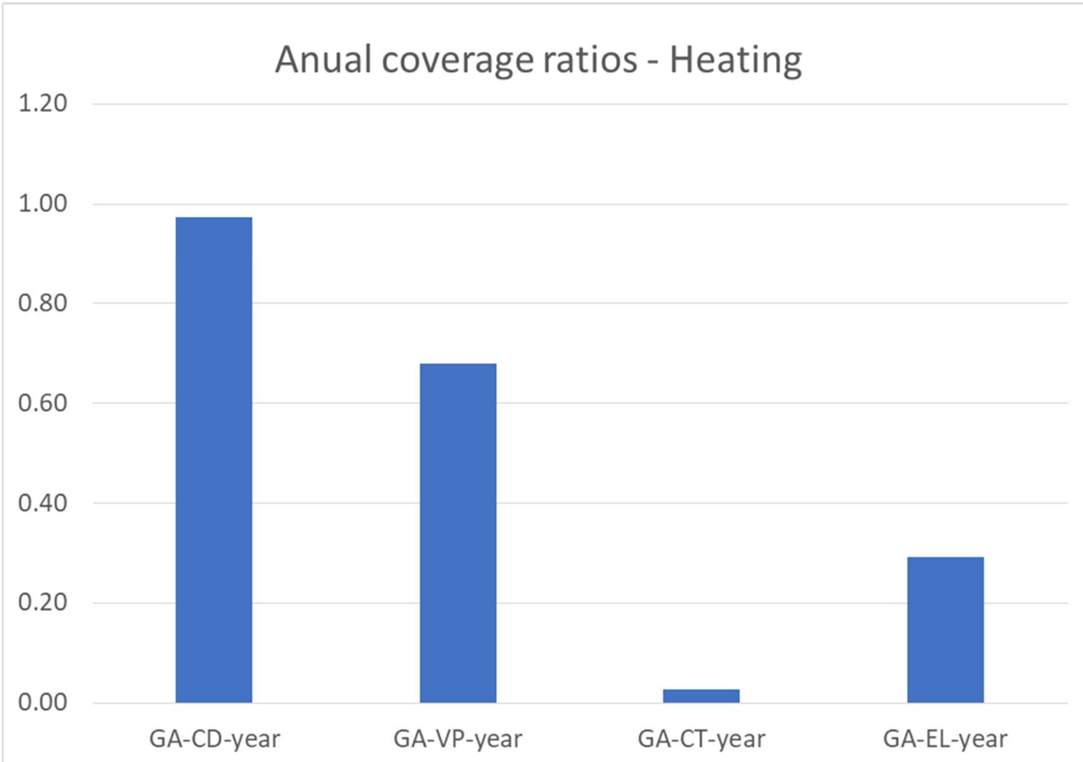

Fig.9

On the hot water supply side, this building is characterized by a consumption of hot water consumption of 110 /persons.day, in the building living 120 people. The hot water preparation installation was dimensioned at the nominal parameters of the thermal agent t_c = 55 °C, t_r = 10 °C. The heat pump is characterized by COP_0, = 2.5, θ_{VP0} = -5 °C, θ_{CD0} = 60 °C, P_{CD0} = 12000 W, η_{EL} = 0.95, Toplita locality. BIN data for the whole year are used to calculate the heat demand, the total number of hours being 8760.

For the effective application of the procedure for evaluating the energy performance of the use of the heat pump, a calculation program in SCILAB was built, as in the case of space heating. According to the presented data, the value of teE = +5.68 °C resulted in the case of preparing the hot water for consumption related to the building.

Simulation results graphics.

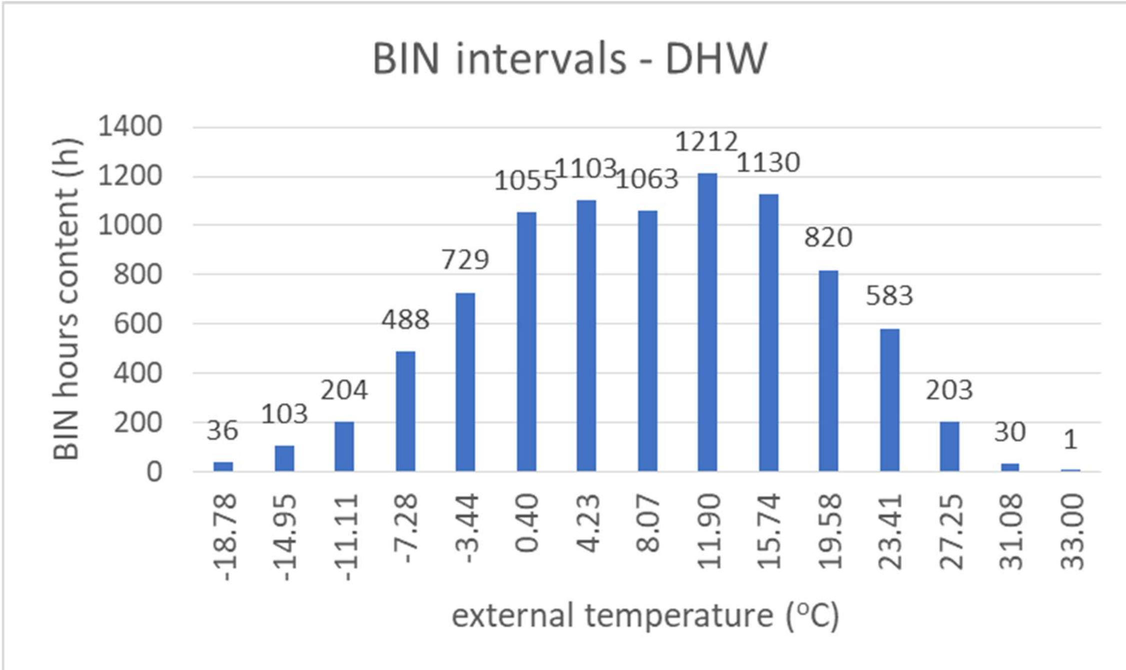
BIN intervals - DHW
BIN hours content (h)
1400
1200
1000
800
600
400
200
0
36
103
204
488
729
1055
1103
1063
1212
1130
820
583
203
30
1
-18.78
-14.95
-11.11
-7.28
-3.44
0.40
4.23
8.07
11.90
15.74
19.58
23.41
27.25
31.08
33.00
external temperature (°C)

Fig. 10

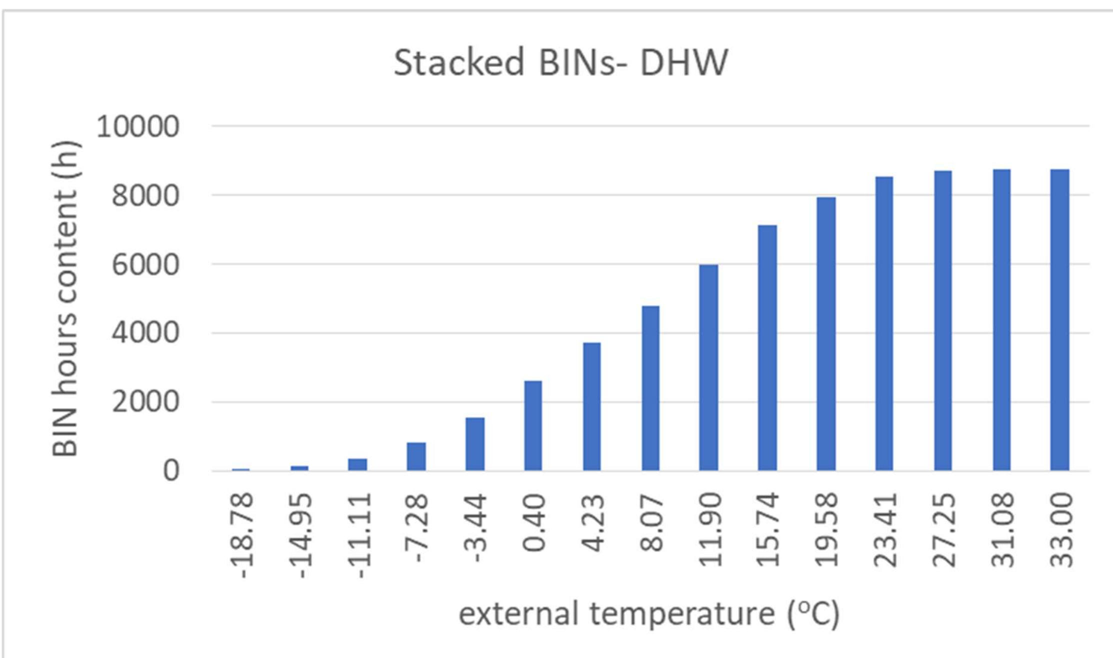
Stacked BINs- DHW
BIN hours content (h)
10000
8000
6000
4000
2000
0
-18.78
-14.95
-11.11
-7.28
-3.44
0.40
4.23
8.07
11.90
15.74
19.58
23.41
27.25
31.08
33.00
external temperature (°C)

Fig. 11

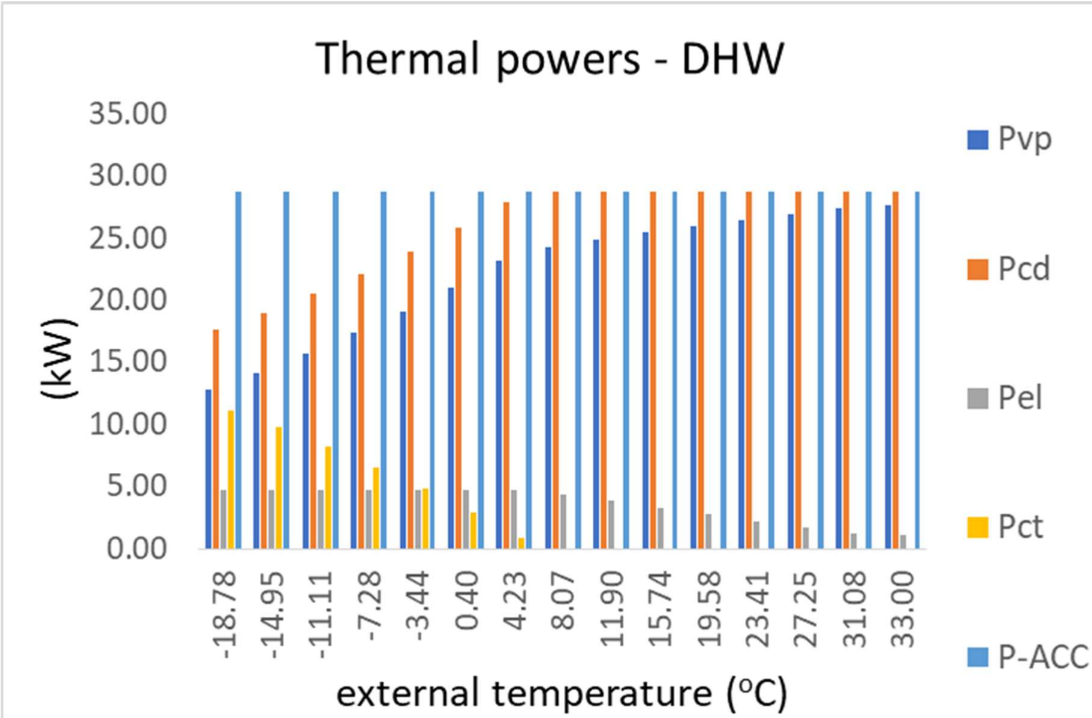
Thermal powers - DHW
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
(kW)
-18.78
-14.95
-11.11
-7.28
-3.44
0.40
4.23
8.07
11.90
15.74
19.58
23.41
27.25
31.08
33.00
external temperature (°C)
Pvp
Pcd
Pel
Pct
P-ACC

Fig. 12

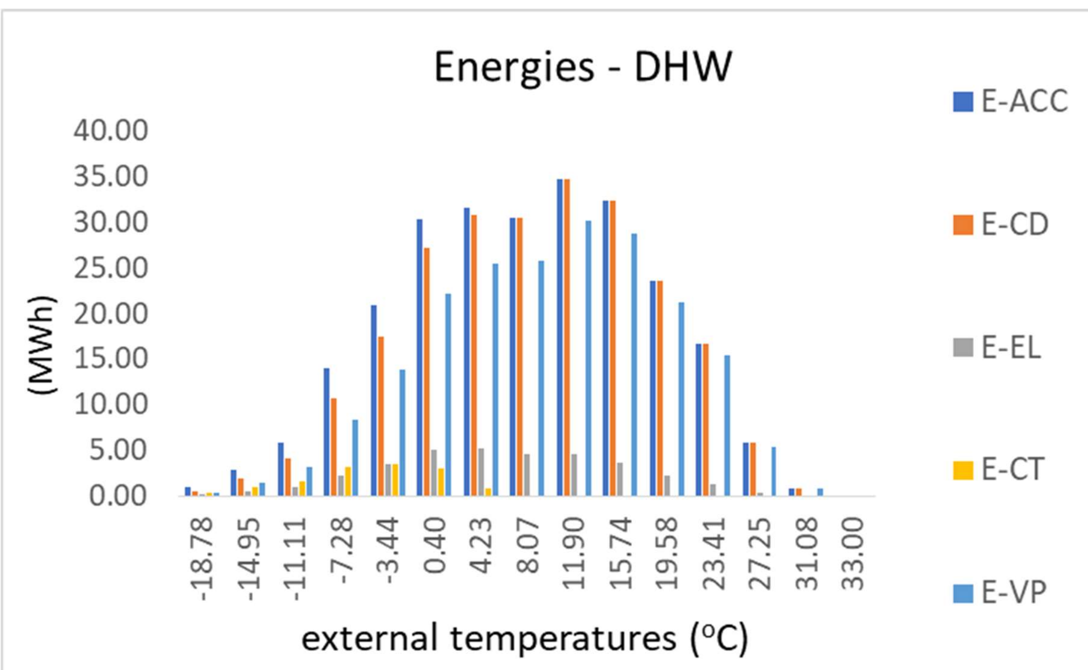
Energies - DHW
40.00
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
(MWh)
-18.78
-14.95
-11.11
-7.28
-3.44
0.40
4.23
8.07
11.90
15.74
19.58
23.41
27.25
31.08
33.00
external temperatures (°C)
E-ACC
E-CD
E-EL
E-CT
E-VP

Fig. 13

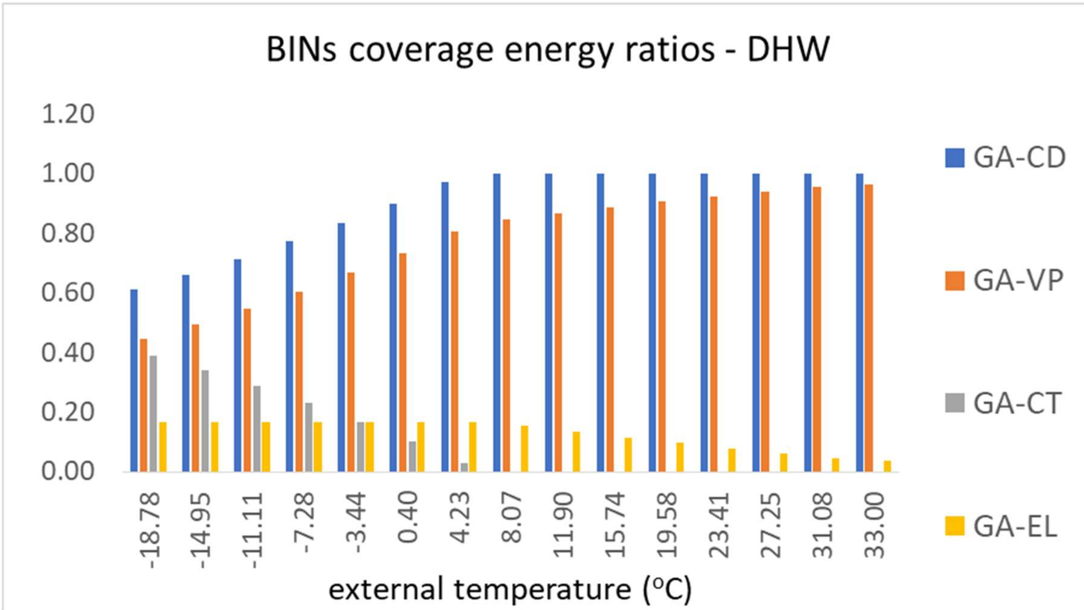
BINs coverage energy ratios - DHW
1.20
1.00
0.80
0.60
0.40
0.20
0.00
-18.78
-14.95
-11.11
-7.28
-3.44
0.40
4.23
8.07
11.90
15.74
19.58
23.41
27.25
31.08
33.00
external temperature (°C)
GA-CD
GA-VP
GA-CT
GA-EL

Fig. 14

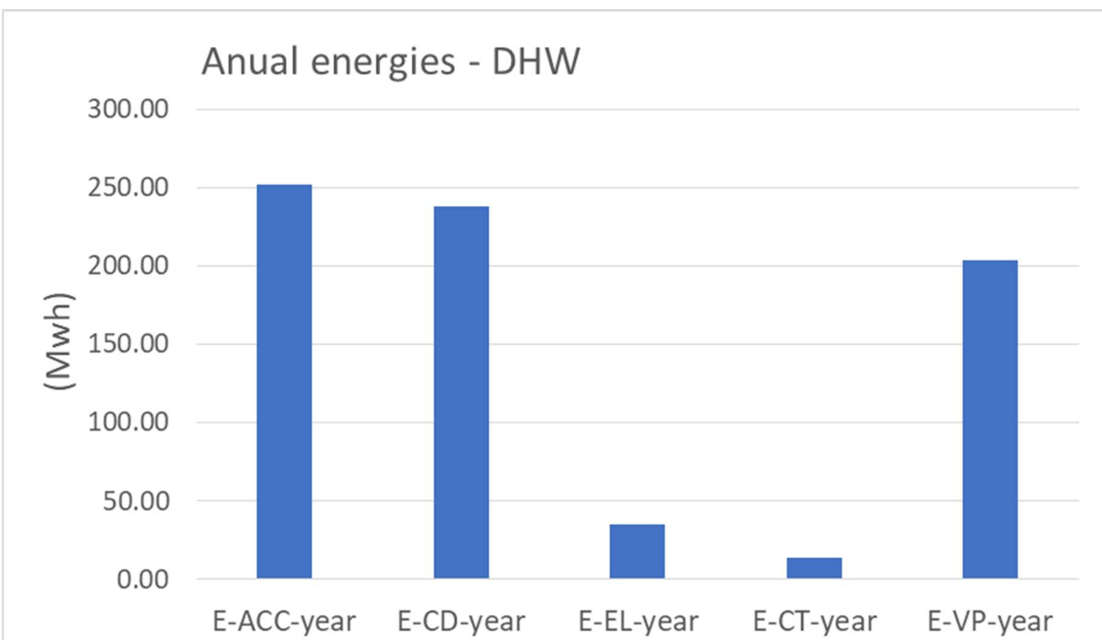
Anual energies - DHW
300.00
250.00
200.00
150.00
100.00
50.00
0.00
(Mwh)
E-ACC-year
E-CD-year
E-EL-year
E-CT-year
E-VP-year

Fig. 15

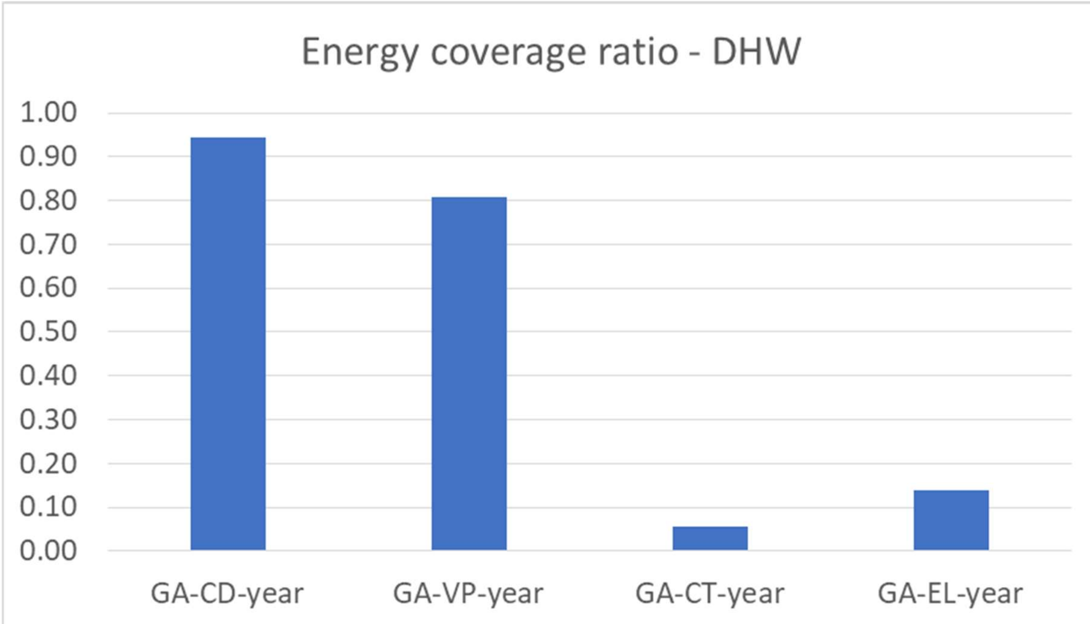

Fig. 16

5. Conclusions

For the effective application of the procedure for evaluating the energy performance of the use of the heat pump, a calculation program in SCILAB was built, as in the case of space heating. According to the data presented, the value of t_{eE} = +5.68 ^{o}C, as presented from the beginning, for the external equilibrium temperature for the building, resulted in the preparation of hot drinking water related to the building. a heat pump in a hybrid system next to a thermal power plant, for servicing a central heating installation of a building's spaces and separately for servicing a domestic hot water preparation installation.

There are 4 basic steps:

- determination of the equilibrium outside temperature (which involves an iterative calculation),
- construction of BIN outdoor temperature ranges;
- establishing the energy inputs brought by the heat pump within the BIN intervals characterized by outside temperatures lower than the outside equilibrium temperature (involves an iterative calculation);
- establishing the energy inputs brought by the heat pump within the BIN intervals characterized by outdoor temperatures higher than the outside equilibrium temperature;
- the annual balance of the energy contributions brought by the heat pump;

Taking into account the series of calculations to be performed and taking into account the iterative determinations to be made in the mentioned steps, the use of an automatic calculation program is absolutely necessary. We mention the fact that it is possible to use the excel work environment even if certain stages are solved a little slower. In the final stage, the energies provided by the heat pump, by the environment from which the heat is extracted, by the thermal power plant using fossil fuel are cumulated throughout. The total electricity consumption is also evaluated and it is related to the necessary energy consumption of the consumer.

Nomenclature:

t_{i0} – interior standard temperature, °C;
t_{e0} – exterior calculation standard temperature, °C;
t_{T0} – maximum heating agent calculation temperature, °C;
t_{R0} – maximum return heating agent temperature, °C;
t_{m0} – average thermal agent calculation temperature, °C;
t_T – heating agent out temperature, °C;
t_R – return heating agent temperature, °C;
t_e – external temperature, °C;
t_{em} – BIN average temperature, °C;
t_{eE} – balance external temperature, °C;
t_c – daily hot water set temperature, °C;
t_r – water source cold temperature, °C;
Δt_{VP} – evaporator logarithmic average temperature difference, °C;
Δt_{CD} – condensing logarithmic average temperature, °C;
θ_{VP0} – datasheet known evaporation environment temperature, °C;
θ_{CD0} – datasheet known condensing environment temperature, °C;
θ_{VP} – evaporation environment temperature, °C;
θ_{CD} – condensing environment temperature, °C;
G_{ACC} – daily hot water flow rate, l/h;
P_{VP} – evaporation thermal power, W;
P_{CD} – condensing thermal power, W;
Φ_{INC} – building heating demand, W;
Φ_{INC0} – maximum building heating demand, W;
Φ_{ACC} – daily hot water heating demand, W;
P_{EL} – compressor electrical power, W;
E_{VP} – evaporation thermal energy, kWh;
E_{CD} – condensing thermal energy, kWh;
E_{EL} – electrical energy, kWh;
E_{INC} – heating energy, kWh;

E_{ACC} – daily hot water heating energy, kWh;
H_{INC} – building heat transfer coefficient, W/K;
H_{ACC} – consumer daily hot water heat transfer coefficient, W/K;
$\Delta\tau_{BIN}$ – BIN interval number of hours, h;
ε^{C}_{VP} – Carnot efficiency, -;
$\varepsilon^{*}_{VP\_iz}$ – calculated isentropic efficiency, -;
$\varepsilon^{*}_{VP\_iz\_0}$ – datasheet isentropic efficiency of heatpump , -;
EER – energy efficiency ratio, -;
COP – coefficient of performance, -;
COP_0 – heat pump datasheet coefficient of performance, -;
η_{iz} – isentropic compressor efficiency, -;
η_{EL} – compressor electrical drive efficiency, -;
GA_{PC} – heat pump coverage energy ratio, -;
GA_{VP} – heat pump coverage green energy ratio, -;
M, N – constants, -;

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