VILNIAUS GEDIMINAS TECHNICAL UNIVERSITY

FACULTY OF ENVIRONMENTAL ENGINEERING

DEPARTMENT OF BUILDING ENERGETICS

Marcos Rodríguez Castro

COMPARISSON OF HEATING AND COOLING CHARACTERISTICS OF AN OFFICE BUILDING BY MADRID AND VILNIUS CLIMATIC ZONES

Final Thesis

Vilnius, 2014

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1.INTRODUCTION

Nowadays, one of the main concerns that we have in our lives is the quality of life, which has resulted in an increasing of the energy consumption over the history. Therefore, the real challenge that we face against is to be able to cover the energy needs and comfort of all over the world, that is what we need to take efficiently advantage of all the energy sources we have.

In this case we are going to study and designing the heating and cooling system of an office building and we will make an energetic comparison of this building between Vilnius (Lithuania) and Madrid (Spain). We will see how different are the climatic conditions and how these conditions make different the normative parameters used in the calculations for the heating and cooling systems.

The main objective of this work is the study and comparison of the energy needed to achieve a comfort temperature inside of an office building in Madrid and Vilnius, and to observe which are the differences between them and what would happen if we build the office building in Vilnius with the normative parameters of Madrid.

For it, we will mainly take into consideration the thermal transmittance of the envelope elements which the building is built with, the heat losses due to ventilation, the heat gains due to internal sources like persons, light, equipment and of course the climatic conditions of each country.

Everything will be done with the normative values found in CTE (*''Código Técnico de la Edificación''*) and in the RITE (*''Reglamento de Instalaciones Térmicas en los Edificios''*), in the case of Madrid. In the case of Vilnius we will take the normative parameters usually accepted and used for the designing of heating and cooling systems.

2.OPERATIVE AND CLIMATIC DATA

First of all we have to say that the main location of our building will be in Madrid. We will calculate the energetic requirements for this case, and later, we will see what is happening if we build exactly the same building in Vilnius, where the low temperatures in winter are much more cold and the high temperatures in summer are milder.

As follows we can see the operative values and climatic data for our two cities.

2.1Madrid

Following the *“Basic Document HE”*, Madrid is in the climatic zone D3, and it has a height around 589 meters over the sea level.

2.1.1Design indoor parameters

In this case, we can see in the paragraph IT 1.1.4 '.1.2 of the RITE, regarding the operational temperature and humidity, in the section "a" is correctly suited to the characteristics of our building so we will use the interior conditions of design that are listed in Table 1.4.1.1.

We can see the table right here, where we can get the next values:

Tabla 1.4.1.1 Condiciones interiores de diseño

Estación	Temperatura operativa °C	Humedad relativa %
Verano	23…25	45…60
Invierno	21…23	40…50

Table 1: Indoor design conditions

Summer:

- **Operative temperature**: 23 °C…25 °C, where we will take then **24 °C**.
- Relative humidity: 45%...60%.

Winter:

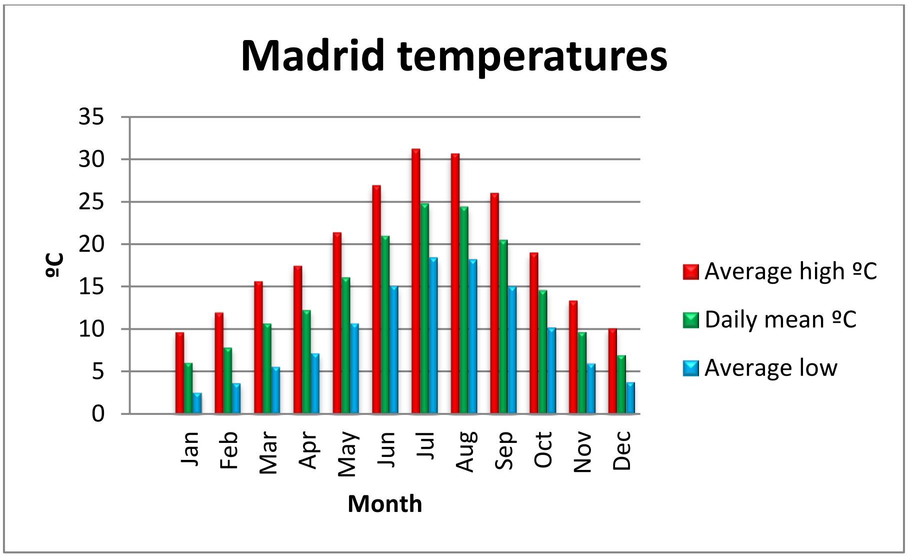
- **Operative temperature**: 21 °C…23 °C, where we will take **22 °C**.
- Relative humidity: 40%...50%.

2.1.2 Design outdoor parameters

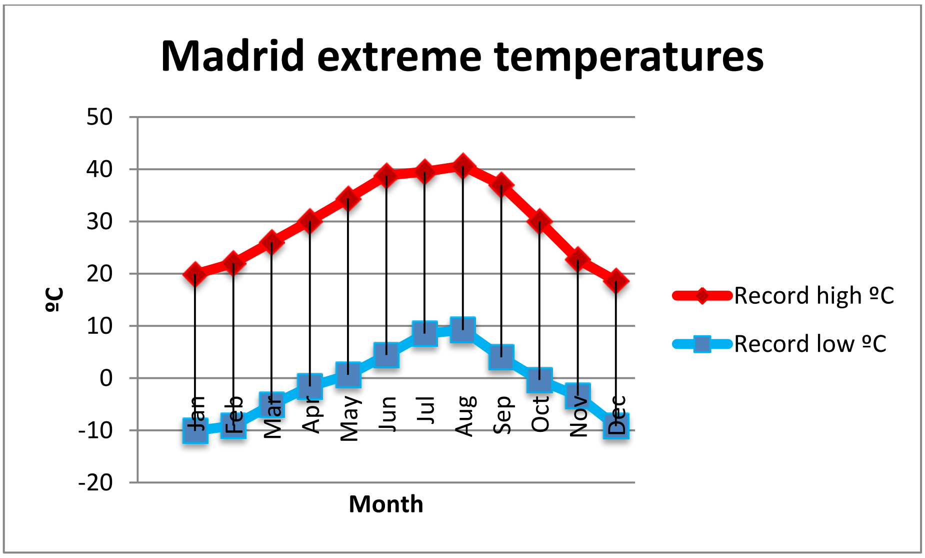
According to data from the UNE 100001:2001 ``*Air Conditioning. Climatic conditions for projects*´´, the maximum average temperature outside for the summer in Madrid is 34 °C, we will take **36 °C** as our designing temperature outside in summer. The average of relative humidity is 43%.

In winter we will take 0 °C, according to the "Basic Document HE" we should take an average outdoor temperatura around 5 °C, but basically we will choose this one in order to cover all the demand. The average relative humidity will be around 70%.

Here we can see two graphs showing the average and extreme temperatures of Madrid which have been taken from *''Agencia Estatal de Meteorología''* website.



Graphic 1: Madrid temperatures



Graphic 2: Madrid extreme temperatures

Winter season (days): 120 from the middle of November until the middle of March.

Average heating season temperature: 8,28 °C

Average annual temperature: 14 °C

2.2Vilnius

2.2.1Design indoor parameters

We will choose the same design temperatures than in Madrid.

In summer we will have a temperature around 24 °C and in winter we will have a design temperature about 22 °C as we can see in the following table.

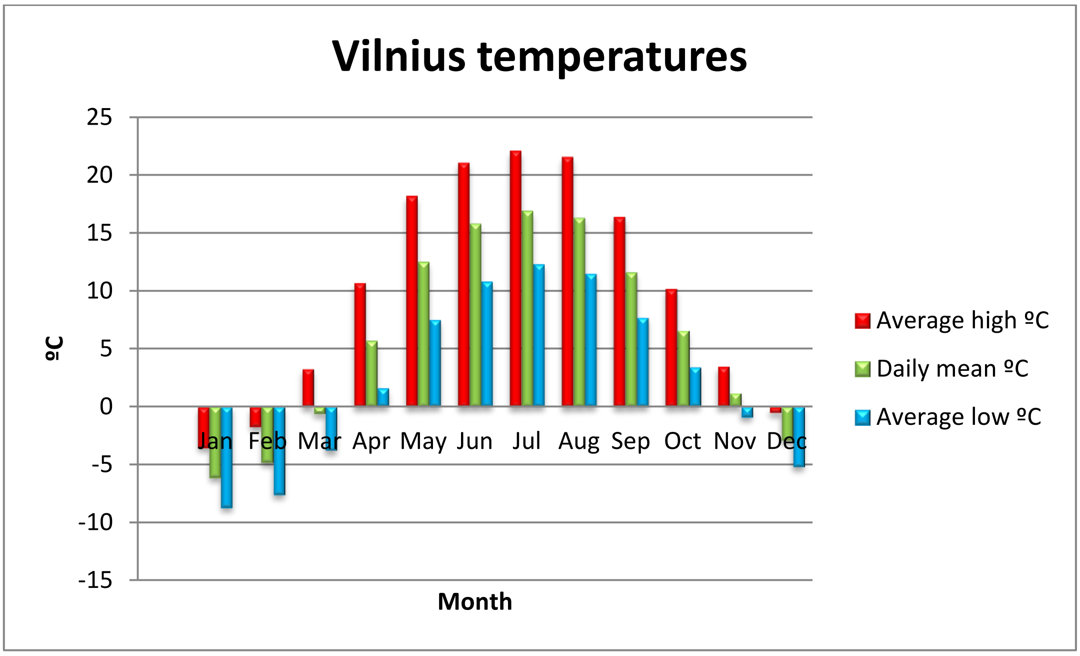
Year period	Indoor air tempetature, ºC	Relative humidity, %	Air flow, m/s
Cold	22±2	40–60	< 0,15
Warm	24,5±1,5	40–60	< 0,25

Table 2: Vilnius design indoor parameters

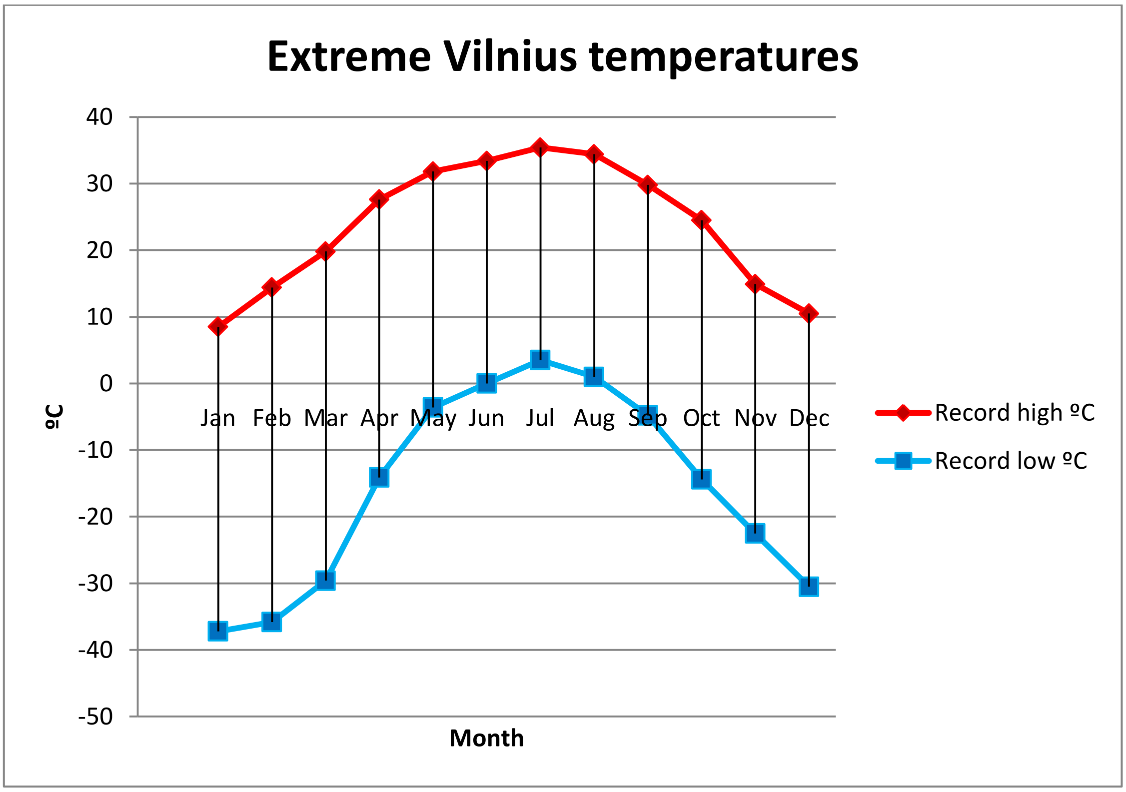
2.2.2Design outdoor parameters

In Winter our designing temperature will be about -25ºC. This temperature is the average between the normative temperatures for light buildings in winter (-27ºC) and massive buildings (-23ºC). We can understand our building as something in the middle because it has its main facade orientated to north built by crystal and the opposite facade will be basically massive concrete wall.

The next charts will show us, as we did before in the case of Madrid, the historical average and extreme temperatures of Vilnius.



Graphic 3: Vilnius temperatures



Graphic 4: Extreme Vilnius temperatures

Winter season (days): 210

Average heating season temperature: -0,5 °C

Average annual temperature: 6,7 °C

3.TECHNICAL DATA

3.1Building characteristics

As we have already said, we will evaluate the thermal loads in an office building.

Our building will have a kind of an ‘’L’’ shape with its main facade orientated to the north. The widest part of our building will be 24 meters long and the narrowest part will be 12 meters long, the length of it will be 39 meters. Our building will have three floors with a total height, over the ground level, of 7.7 meters, with a garage in the basement destined to park the vehicles.

As the first floor is destined to parking of vehicles, there will be no windows. This plant will have two exterior doors, one for the entry of vehicles and another for the output of the same. As we can imagine, we will not cool, either heat the garage, so it will not be a study objective.

The second plant, the ground floor will be the access floor of the building. It will have the main entrance in the corner orientated to the north-east, and the second entrance, which will be a small crystal door, in the facade orientated to the south. The main facade is orientated to the north and it will be built totally with crystal. The total area of this floor will be around 604.26 square meters, to obtain this value we have approximated the corner where there is situated the main entrance as a quarter of circle. We can observe this below in the planes of the building.

The third floor will be built like the second but its height will be half a meter less, what it is 3.60 meters and its area will be 612 square meters.

All the rooms will be conditioned except the bathrooms, and as we can observe, the floors are divided by zones which we will use to calculate air flow rates needed for the building ventilation.

3.1.1Planes

Basement

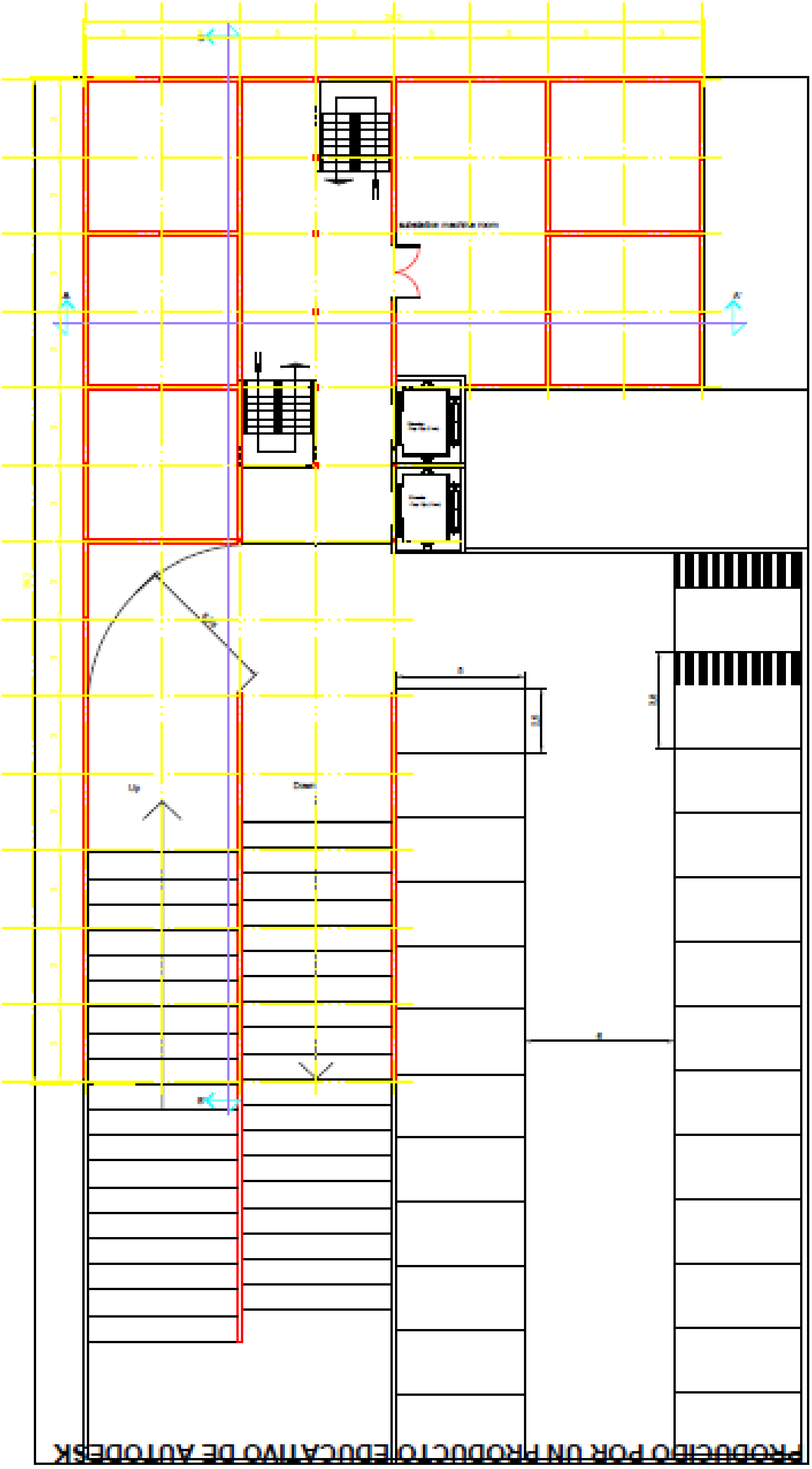
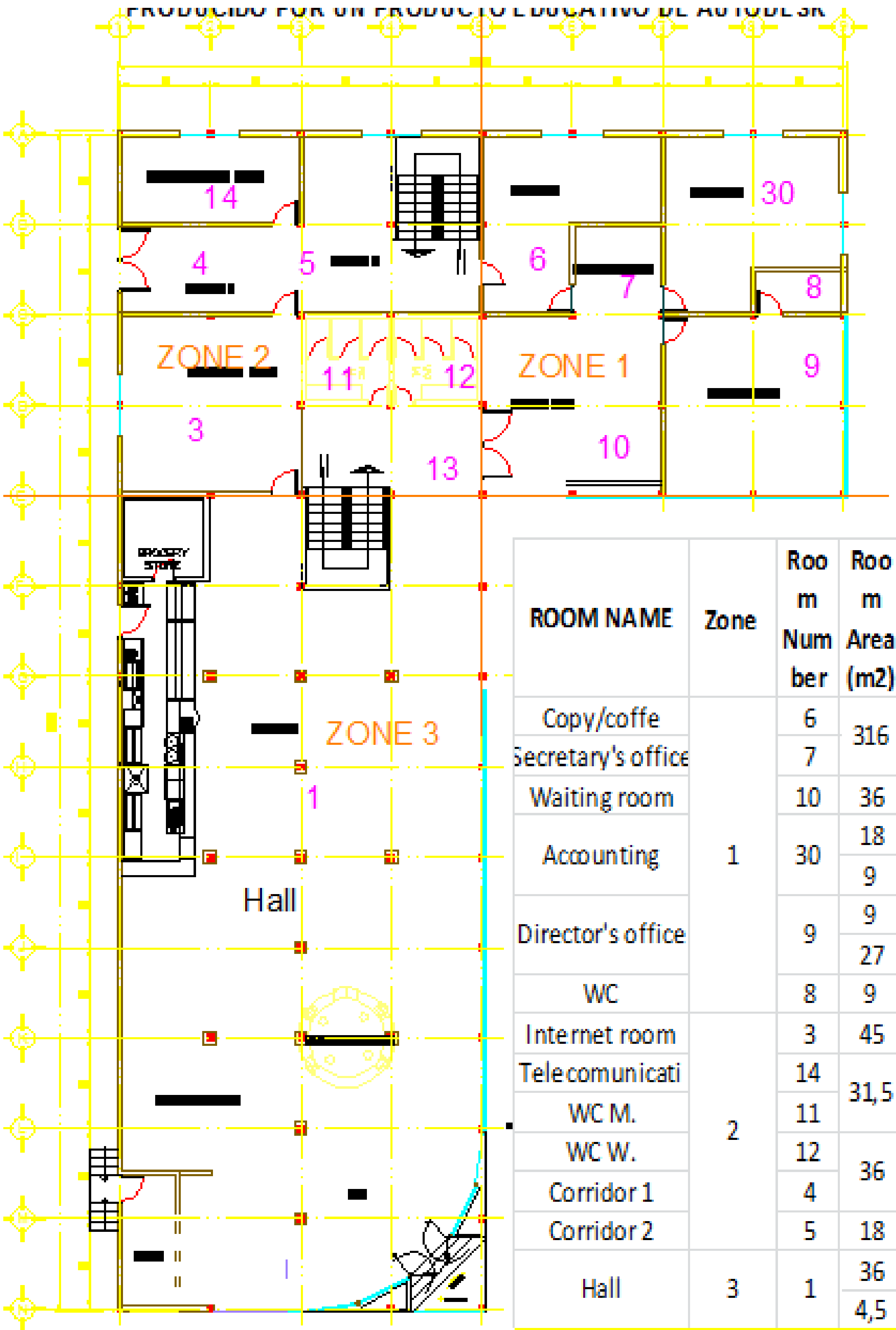


Figure 1: Basement. Zero floor.

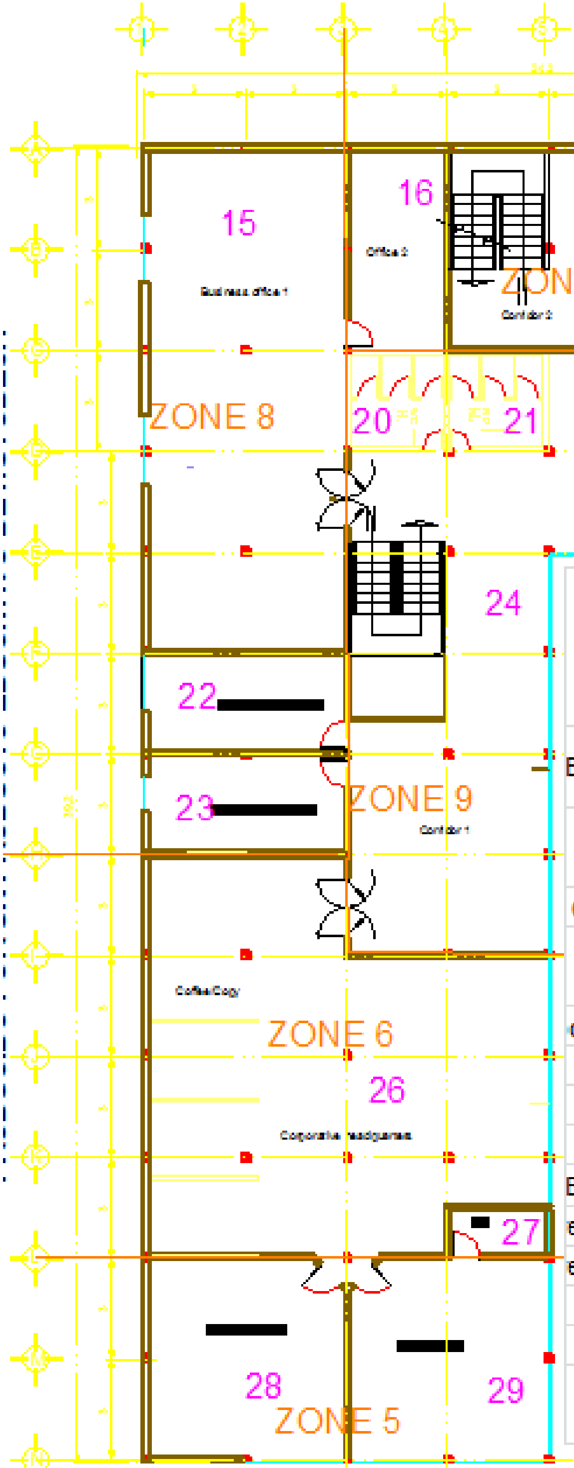
Ground floor

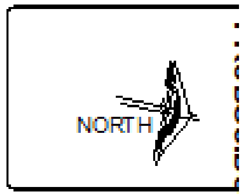


ROOM NAME	Zone	Room Number	Room Area (m2)
Copy/coffe		6	316
Secretary's office		7	
Waiting room		10	36
Accounting	1	30	18
			9
Director's office		9	9
			27
WC		8	9
Internet room		3	45
Telecomunicati		14	31,5
WC M.	2	11	
WC W.		12	36
Corridor 1		4	
Corridor 2		5	18
Hall	3	1	36
			4,5

Figure 2: Ground floor. First floor.

Second floor





ROOM NAME	Zone	Room Number	Room Area (m2)
Business office 2	4	18	90 18
Office 1		19	36
Conference hall	5	28	90
Private office		29	18
orative headqua	6	26	9
WC		27	9
Office 2	7	16	18
Corridor 2		17	18
Business office 1	8	15	108
esentation office		22	
esentation office		23	132
WC M.	9	20	4,5
WC W.		21	36
Corridor 1		24	36

Figure 3: Second floor

3.1.2Areas

The first step is the calculation of the windows, walls, doors and room floor areas. We will do it room by room as follows.

- Windows
  - First floor

Room name	Room number	Area window (m2)
Hall	1	137,35
Internet room	3	4
Telecomunication office	14	4
WC M.	11	0
WC W.	12	0
Copy/coffe	6	4
Secretary's office	7	Included in waiting room
Waiting room	10	24,6
Accounting	30	8
Director's office	9	49,2
Corridor 1	4	0
Corridor 2	5	4
WC	8	0

Table 3: Area windows(first floor)

  - Second floor

Room name	Room number	Area window(m2)
Business office	15	8
Office 2	16	0
Corridor 2	17	0
Business office 2	18	25,6
Office 1	19	32,4
WC M.	20	0
WC W.	21	0
Presentation office 1	22	4
Presentation office 2	23	4

Corridor 1	24	54
Corporative headquarters	26	27
WC	27	0
Conference hall	28	10,8
Private office	29	43,2

Table 4: Area windows(fsecond floor)

The total area of the windows is 444.15 square meters, being the total side area of the building 959.95 square meters.

- Walls
  - First floor

Room name	Room number	Area wall(m2)
Hall	1	119
Internet room	3	20,6
Telecomunication office	14	32,9
WC M.	11	0
WC W.	12	0
Copy/coffe	6	20,6
Secretary's office	7	0
Waiting room	10	0
Accounting	30	35,05
Director's office	9	0
Corridor 1	4	8,3
Corridor 2	5	20,6
WC	8	6,15

Table 5: Area walls(first floor)

  - Second floor

Room name	Room number	Area wall
Business office	15	67,6
Office 2	16	10,8
Corridor 2	17	21,6
Business office 2	18	50
Office 1	19	0

WC M.	20	0
WC W.	21	0
Presentation office 1	22	6,8
Presentation office 2	23	6,8
Corridor 1	24	0
Corporative headquarters	26	43,2
WC	27	5,4
Conference hall	28	32,4
Private office	29	0

Table 6: Area walls(fsecond floor)

The total wall building area is 507.8 square meters.

- Doors

We have just two doors in our building, and these both are located obviously in the ground floor.

These two doors belong, the main entrance to the room number 1, and the second entrance to the corridor 1, which is the room number 4.

Room name	Room number	Area door (m2)
Hall	1	4
Corridor 1	4	4

Table 7: Area doors

- Room floors
    - First floor

ROOM NAME	ROOM NUMBER	AREA FLOOR(m2)
Hall	1	316,3
Internet room	3	36
Telecomunication office	14	18
WC M.	11	9
WC W.	12	9
Copy/coffe	6	27
Secretary's office	7	9

Waiting room	10	45
Accounting	30	31,5
Director's office	9	36
Corridor 1	4	18
Corridor 2	5	36
WC	8	4,5

Table 8: floor areas (first floor)

- Second floor

ROOM NAME	ROOM NUMBER	AREA FLOOR(m2)
Business office	15	90
Office 2	16	18
Corridor 2	17	36
Business office 2	18	90
Office 1	19	18
WC M.	20	9
WC W.	21	9
Presentation office 1	22	18
Presentation office 2	23	18
Corridor 1	24	108
Corporative headquarters	26	131,5
WC	27	4,5
Conference hall	28	36
Private office	29	36

Table 9: floor areas (second floor)

3.2U-values comparison (office building)

In this point we will see how all the normative U-values used in the construction of office buildings are much more high in Madrid than in Vilnius. That is normal because the temperatures are much more cold in winter and we want to isolate our building as much as we can in order to save energy and to pay less money for it.

3.2.1 Madrid U-values

As we said before, Madrid is located in the D3 zone, following this we can obtain in the "CTE" the values of the thermal transmittance of the envelopes of our building.

Here we have a table with the limit values, which we will use in our calculations.

Provincia	Capital	Altura de referencia (m)
Madrid	D3	589

ZONA CLIMÁTICA D3

Transmitancia límite de muros de fachada y cerramientos en contacto con el terreno	U_{Mlim}: 0,66 W/m^{2}K
Transmitancia límite de suelos	U_{Slim}: 0,49 W/m^{2}K
Transmitancia límite de cubiertas	U_{Clim}: 0,38 W/m^{2}K
Factor solar modificado límite de lucernarios	F_{Llim}: 0,28

Cerramientos y particiones interiores	ZONAS A	ZONAS B	ZONAS C	ZONAS D	ZONAS E
Muros de fachada, *particiones interiores* en contacto con *espacios no habitables*, primer metro del perímetro de suelos apoyados sobre el terreno[1] y primer metro de muros en contacto con el terreno	1,22	1,07	0,95	0,86	0,74
Suelos	0,69	0,68	0,65	0,64	0,62
Cubiertas	0,65	0,59	0,53	0,49	0,46
Vidrios y marcos[2]	5,70	5,70	4,40	3,50	3,10
Medianerías	1,22	1,07	1,00	1,00	1,00

Table 10: Madrid thermal transmittance

<u>Thermal transmittance data:</u>

- Windows: 3,50 W/m2K
- Walls: 0,66 W/m2K
- Roof: 0,49 W/m2K
- Indoor floors: 0,64 W/m2K
- Doors: 3,50 W/m2K

Note: notice that the U-value for doors and windows is the same, that is why, as we can guess, the doors of our building are built with the same crystal as windows.

3.2.2 Vilnius U-values

The U-values for the elements constituting the envelope are assumed to be the normative values. No changes were considered due to variable temperature correction coefficient k, since k is approximately equal to 1.

The temperature correction coefficient can be calculated by following expression:

$$k = \frac{20}{(\theta_i - \theta_{e,heating\ season})} \approx 1$$

Where:

$\theta_i = indoor\ design\ temperature\ equal\ to\ building\ room\ temperature, °C$

$\theta_{e,heating\ season} = average\ temperature\ of\ the\ heating\ season, °C$

In our case, as we explained before, the indoor design temperature will be 24°C or 297K and the average of the heating season will be around -25°C, so 248K.

If we introduce these values in the formula above, we can see how we get the k approximately to 1.

In the next table we can see the normative parameters of the thermal transmittance in W/m^{2}K. We will take the those which are in non dwelling-houses, office building column.

Construction element	Index	Dwelling-houses	Non dwelling-houses	
			Office building	Industry buildings
Roofs	r	$U_N = 0{,}16 \cdot \kappa$	$U_N = 0{,}20 \cdot \kappa$	$U_N = 0{,}25 \cdot \kappa$
Ceiling	ce			
Floor above unheated room	fg	$U_N = 0{,}25 \cdot \kappa$	$U_N = 0{,}30 \cdot \kappa$	$U_N = 0{,}40 \cdot \kappa$
Ceiling above non heating basement	cc			
Walls	w	$U_N = 0{,}20 \cdot \kappa$	$U_N = 0{,}25 \cdot \kappa$	$U_N = 0{,}30 \cdot \kappa$
Windows	wd	$U_N = 1{,}6 \cdot \kappa$	$U_N = 1{,}6 \cdot \kappa$	$U_N = 1{,}9 \cdot \kappa$
Doors, gates	d	$U_N = 1{,}6 \cdot \kappa$	$U_N = 1{,}6 \cdot \kappa$	$U_N = 1{,}9 \cdot \kappa$
Thermal bridges	t	$\Psi_N = 0{,}18 \cdot \kappa$	$\Psi_N = 0{,}20 \cdot \kappa$	$\Psi_N = 0{,}25 \cdot \kappa$

Table 11: Vilnius thermal transmittance

Thermal transmittance data

- Windows: 1,6 W/m2K
- Wall: 0,25 W/m2K
- Roof: 0,20 W/m2K
- Indoor floor: 0,20 W/m2K
- Doors: 1,6 W/m2K

4.VENTILATION CHARACTERISTICS

We will design a mechanical ventilation system for our building. We will provide the air with an Air handling Unit with heat recovery. The efficiency of our heat recovery is around 0.7.

In order to design the air flows of supply and exhaust air, we will divide our two floors of the building in different zones, which are showed in the building planes and after we will estimate the amount of persons that there would be in each zone.

We will get two values of the supply air, due to we will calculate these amounts according to the estimated persons of each zone and the floor surface of each zone.

Finally we will choose the biggest one in each zone in order to provide the needed amount in every moment.

4.1Air flows

MADRID

Here we have the air flows that we would use in order to design our building in Madrid. These two tables are European Union norms, so these are used in Vilnius too.

Tabla 1.4.2.1 Caudales de aire exterior, en dm³/s por persona

Categoría	dm³/s por persona
IDA 1	20
IDA 2	12,5
IDA 3	8
IDA 4	5

Table 12: Outdoor air flow rates, (dm^3/s.pers)

Tabla 1.4.2.4 Caudales de aire exterior por unidad de superficie de locales no dedicados a ocupación humana permanente.

Categoría	dm³/(s·m²)
IDA 1	no aplicable
IDA 2	0,83
IDA 3	0,55
IDA 4	0,28

Table 13: Outdoor air flow rates, (dm^3/s.m^2)

First floor

ROOM NAME	ROOM NUMBER	ROOM AREA(m2)	Estimate persons	Air flow acc. to floor area	Air flow acc. to estimated persons	Supply Air flow (m3/h)
Hall	1	316,3	66	945,1044	2970	2970
Internet room	3	36	11	107,568	495	495
Telecomunication office	14	18	10	53,784	450	450
WC M.	11	9		26,892	0	0
WC W.	12	9		26,892	0	0
Copy/coffe	6	27	14	80,676	630	630
Secretary's office	7	9	1	26,892	45	45
Waiting room	10	45	10	134,46	450	450
Accounting	30	31,5	6	94,122	270	270
Director's office	9	36	8	107,568	360	360
Corridor 1	4	18		53,784	0	504
Corridor 2	5	36		107,568	0	
WC	8	4,5		13,446	0	0

Table 14: First floor supply air flow

Second floor

ROOM NAME	ROOM NUMBER	ROOM AREA(m2)	Estimated persons	Air flow acc. to floor area	Air flow acc. to estimated persons	Supply Air flow (m3/h)
Business office 1	15	90	15	268,92	675	675
Office 2	16	18	3	53,784	135	135
Corridor 2	17	36		107,568	0	0
Business office 2	18	90	18	268,92	810	810
Office 1	19	18	3	53,784	135	135
WC M.	20	9		26,892	0	0
WC W.	21	9		26,892	0	0
Presentation office 1	22	18	5	53,784	225	225
Presentation office 2	23	18	5	53,784	225	225
Corridor 1	24	108		322,704	0	504

Corporative headquarters	26	131,5	25	392,922	1125	1125
WC	27	4,5		13,446	0	0
Conference hall	28	36	14	107,568	630	630
Private office	29	36	8	107,568	360	360

Table 15: Second floor supply air flow

<u>Air flows by zones</u>

<u>First floor</u>

<table>
<tr><th>ROOM NAME</th><th>Room Number</th><th>Zone</th><th>Supply Air flow (m3/h)</th><th>Exhaust Air flow(m3/h)</th></tr>
<tr><td>Copy/coffe</td><td>6</td><td>1</td><td rowspan="6">1755</td><td rowspan="6">1827</td></tr>
<tr><td>Secretary's office</td><td>7</td><td>1</td></tr>
<tr><td>Waiting room</td><td>10</td><td>1</td></tr>
<tr><td>Accounting</td><td>30</td><td>1</td></tr>
<tr><td>Director's office</td><td>9</td><td>1</td></tr>
<tr><td>WC</td><td>8</td><td>1</td></tr>
<tr><td>Internet room</td><td>3</td><td>2</td><td rowspan="6">1449</td><td rowspan="6">1377</td></tr>
<tr><td>Telecomunication office</td><td>14</td><td>2</td></tr>
<tr><td>WC M.</td><td>11</td><td>2</td></tr>
<tr><td>WC W.</td><td>12</td><td>2</td></tr>
<tr><td>Corridor 1</td><td>4</td><td>2</td></tr>
<tr><td>Corridor 2</td><td>5</td><td>2</td></tr>
<tr><td>Hall</td><td>1</td><td>3</td><td>2970</td><td>2970</td></tr>
</table>

Table 16: First floor maximum air flows (by zones)

<u>Second floor</u>

<table>
<tr><th>ROOM NAME</th><th>Room Number</th><th>Zone</th><th>Supply Air flow (m3/h)</th><th>Exhaust Air flow(m3/h)</th></tr>
<tr><td>Business office 2</td><td>18</td><td>4</td><td rowspan="2">945</td><td rowspan="2">945</td></tr>
<tr><td>Office 1</td><td>19</td><td>4</td></tr>
<tr><td>Conference hall</td><td>28</td><td>5</td><td rowspan="2">990</td><td rowspan="2">990</td></tr>
<tr><td>Private office</td><td>29</td><td>5</td></tr>
</table>

Corporative headquarters	26	6	1125	1197
WC	27	6		
Office 2	16	7	135	135
Corridor 2	17	7		
Business office 1	15	8	1125	1125
Presentation office 1	22	8		
Presentation office 2	23	8		
WC M.	20	9	504	432
WC W.	21	9		
Corridor 1	24	9		

Table 17: Second floor maximum air flows (by zones)

<u>Total</u>

Supply Air flow (m3/h)	Exhaust air flow (m3/h)
10998	10998

Table 18: Supply and exhaust air flow rates.

<u>VILNIUS</u>

In this case we will show which would be the air flow values we would get using the accurate norms that we have in Vilnius. Even so is basically accepted the European norms that we have used above in the case of Madrid, that is why we are going to obtain the same air flows amount in both cities.

Category	Unit	Rate of outdoor air per person			
		Non-smoking area		Smoking area	
		Typical range	Default value	Typical range	Default value
IDA 1	$m^3.h^{-1}.person^{-1}$ $l.s^{-1}.person^{-1}$	> 54 > 15	72 20	> 108 > 30	144 40
IDA 2	$m^3.h^{-1}.person^{-1}$ $l.s^{-1}.person^{-1}$	36 - 54 10 – 15	45 12,5	72 - 108 20 - 30	90 25
IDA 3	$m^3.h^{-1}.person^{-1}$ $l.s^{-1}.person^{-1}$	22 - 36 6 – 10	29 8	43 - 72 12 - 20	58 16
IDA 4	$m^3.h^{-1}.person^{-1}$ $l.s^{-1}.person^{-1}$	< 22 < 6	18 5	< 43 < 12	36 10

Table 19: Outdoor flow-rates (European norms)

Design air flow rates

Rooms	Supply air flow				Exhaust air flow	
	1 person		$1m^2$ floor*			
	dm^3/s	m^3/h	dm^3/s	m^3/h	dm^3/s.vnt.	m^3/h.vnt.
1	3	4	5	6	7	8
1.Dwelling/residental houses						
1.1. Guestroom	4****	14,4	0,5*	1,8*	-	-
1.2. Bedroom	4	14,4	0,7	2,5	-	-
1.3. Corridor	-	-	-	-	-	-
1.4. Kitchen	-	-	-	-	20/room	72/room
1.7. Bathroom, shower	-	-	-	-	15/ room	54/ room
1.8. WC	-	-	-	-	10/ room	36/ room
Other						
1.9. Stairs	-	-	$0,5\ h^{-1}$	-	$0,5\ h^{-1}$	-
1.10. Storeroom	-	-	0,35	1,3	$0,35/m^2$	$1,3/m^2$
1.11. Basement	-	-	0,2	0,7	$0,20/m^2$	$0,7/m^2$
2. Office buildings						
2.2. Opened office	10	36	1,5	5,4	-	-
2.3. Conference hall	10	36	4	14,4	-	-
2.4. Meeting room	-	-	2	7,2	-	-
2.6. Archive	-	-	$0,35/m^2$	$1,3/m^2$	-	-
2.7. Café/restroom	10	36	5	18	-	-
2.8. Corridor	-	-	0,5	1,8	-	-
2.9. Smoking room/restroom	-	-	$10/m^2$	$36/m^2$	$20/m^2$	$72/m^2$
3. Other buildings						
3.1. Classroom/auditorium	6	21,6	3	10,8	-	-
3.2. Laboratory (students')	6	21,6	3	10,8	-	-
3.5. Meeting hall	8	28,8	6	21,6	-	-
3.6. Sport hall	12	43,2	2	7,2	-	-
3.7. Dinning room	6	21,6	5	18	-	-
3.8. Corridor Hotels	-	-	4	14,4	-	-
4.3. Hotel room	10	36	1	3,6	-	-
4.4. Corridor	10	36	0,5	1,8	-	-
4.5. Hall	10	36	2	7,2	-	-
4.6. Restaurant WC (public) Shower	-	-	-	-	30/ equipment	108/equipment 72/equipment

Table 20: Vilnius design air flow rates

First floor

ROOM NAME	Air flow acc. to floor area	Air flow acc. to estimated persons	Supply Air flow (m3/h)
Hall	5693,4	2376	5693,4
Internet room	194,4	396	396
Telecomunication office	97,2	360	360
WC M.	26,892		
WC W.	26,892		
Copy/coffe	486	504	504
Secretary's office	64,8	36	64,8
Waiting room	810	360	810
Accounting	226,8	216	226,8

Director's office	259,2	288	288
Corridor 1	32,4		32,4
Corridor 2	64,8		64,8
WC	13,446		

Table 21: First flow air flow rates (Vilnius norms)

Second floor

ROOM NAME	Air flow acc. to floor area	Air flow acc. to estimated persons	Supply Air flow (m3/h)
Business office 1	486	540	540
Office 2	129,6	108	129,6
Corridor 2	64,8		64,8
Business office 2	486	648	648
Office 1	129,6	108	129,6
WC M.	26,892		
WC W.	26,892		
Presentation office 1	129,6	180	180
Presentation office 2	129,6	180	180
Corridor 1	194,4		194,4
Corporative headquarters	710,1	900	900
WC	13,446		
Conference hall	518,4	504	518,4
Private office	259,2	288	288

Table 22: Second floor air flow rates (Vilnius norms)

Total

Supply Air flow (m3/h)
12213

Table 23: Supply air flow (Vilnius norms)

As we can see, if we use these accurate data to calculate the air flows in Vilnius, we will obtain an increase around 11% over the air flow that we obtained with the European norms. We are just showing this difference, but we will not take it in account and we assume that the supply and exhaust air flow is the same independent on the city we are.

4.2Heat load

We will calculate the air heater heat power with heat recovery as follows:

$$P_{air\ heater} = 0{,}34 \cdot L_{supply} \cdot (\theta_{supply} - \theta_{outdoor}) \cdot (1 - \eta_r), W$$

Where:

$\eta_r - heat\ recovery\ efficiency$

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First floor

ROOM NAME	Room Number	Zone	Pair heater(W)
Copy/coffe	6	1	3938,22
Secretary's office	7	1	
Waiting room	10	1	
Accounting	30	1	
Director's office	9	1	
WC	8	1	
Internet room	3	2	3251,556
Telecomunication office	14	2	
WC M.	11	2	
WC W.	12	2	
Corridor 1	4	2	
Corridor 2	5	2	
Hall	1	3	6664,68

Table 24: Power air heater (first floor)

Second floor

ROOM NAME	Room Number	Zone	Pair heater(W)
Business office 2	18	4	2120,58
Office 1	19	4	
Conference hall	28	5	2221,56
Private office	29	5	

Corporative headquarters	26	6	2524,5
WC	27	6	
Office 2	16	7	302,94
Corridor 2	17	7	
Business office 1	15	8	2524,5
Presentation office 1	22	8	
Presentation office 2	23	8	
WC M.	20	9	1130,976
WC W.	21	9	
Corridor 1	24	9	

Table 25: Power air heater (second floor)

Total

	Supply Air flow (m3/h)	Exhaust air (m3/h)	P. air heater(W)
TOTAL	10998	10998	24679,51

Table 26: Power air heater Madrid

VILNIUS

First floor

ROOM NAME	Room Number	Zone	P. air heater (W)
Copy/coffe	6	1	8413,47
Secretary's office	7	1	
Waiting room	10	1	
Accounting	30	1	
Director's office	9	1	
WC	8	1	
Internet room	3	2	6946,506
Telecomunication office	14	2	
WC M.	11	2	

WC W.	12	2	
Corridor 1	4	2	
Corridor 2	5	2	
Hall	1	3	14238,18

Table 27: Power air heater (first floor)

<u>Second floor</u>

ROOM NAME	Room Number	Zone	P. air heater (W)
Business office 2	18	4	4530,33
Office 1	19	4	
Conference hall	28	5	4746,06
Private office	29	5	
Corporative headquarters	26	6	5393,25
WC	27	6	
Office 2	16	7	647,19
Corridor 2	17	7	
Business office 1	15	8	5393,25
Presentation office 1	22	8	
Presentation office 2	23	8	
WC M.	20	9	2416,176
WC W.	21	9	
Corridor 1	24	9	

Table 28: Power air heater (second)

<u>Total</u>

	P. air heater (W)
TOTAL	52724,41

Table 29: Power air heater (Vilnius)

4.3 Heat demand and price

We will use the next formula to calculate the heat demand of the ventilation system with heat recovery:

$$Q_V = 0{,}34 \cdot L_{supply} \cdot (\theta_{supply} - \theta_{outdoor,average}) \cdot t_{heat} \cdot n_{heat} \cdot 10^{-3}(1 - \eta_r), kWh$$

Where:

$t_{heat} - heater\ working\ days.\ 120\ days(Madrid); 210\ days(Vilnius)$

$n_{heat} - heater\ working\ hours\ per\ day$ (10 hours)

Cost for heat ventilation:

$$C_{el} = Q_V \cdot c_{heat}, (€/year)$$

$$c_{heat} - 0{,}05 \frac{€}{kWh}\ (Madrid); 0{,}08 \frac{€}{kWh} (Vilnius)$$

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First floor

ROOM NAME	Room Number	Zone	Heat demand (kWh)	Cost (€/year)
Copy/coffe	6	1	2947,22064	147,36 €
Secretary's office	7	1		
Waiting room	10	1		
Accounting	30	1		
Director's office	9	1		
WC	8	1		
Internet room	3	2	2433,346272	121,67 €
Telecomunication office	14	2		
WC M.	11	2		
WC W.	12	2		
Corridor 1	4	2		
Corridor 2	5	2		
Hall	1	3	4987,60416	249,38 €

Table 30: Heat demand and cost (first floor)

Second floor

ROOM NAME	Room Number	Zone	Heat demand Madrid(kWh)	Cost Madrid (€/year)
Business office 2	18	4	1586,96496	79,35 €
Office 1	19	4		
Conference hall	28	5	1662,53472	83,13 €
Private office	29	5		
Corporative headquarters	26	6	1889,244	94,46 €
WC	27	6		
Office 2	16	7	226,70928	11,34 €
Corridor 2	17	7		
Business office 1	15	8	1889,244	94,46 €
Presentation office 1	22	8		
Presentation office 2	23	8		
WC M.	20	9	846,381312	42,32 €
WC W.	21	9		
Corridor 1	24	9		

Table 31: Heat demand and cost (second floor)

TOTAL

	Heat demand (kWh)	**Cost (€/year)**
TOTAL	18469,24934	923,46 €

Table 32: Heat demand and cost (Madrid)

VILNIUS

First floor

ROOM NAME	Room Number	Zone	Heat demand (kWh)	Cost (€/year)
Copy/coffe	6	1	8458,223	676,66 €
Secretary's office	7	1		
Waiting room	10	1		
Accounting	30	1		
Director's office	9	1		
WC	8	1		
Internet room	3	2	6983,456	558,68 €
Telecomunication office	14	2		
WC M.	11	2		
WC W.	12	2		
Corridor 1	4	2		
Corridor 2	5	2		
Hall	1	3	14313,92	1.145,11 €

Table 33: Heat demand and cost (first floor)

Second floor

ROOM NAME	Room Number	Zone	Heat demand (kWh)	Cost (€/year)
Business office 2	18	4	4554,428	364,35 €
Office 1	19	4		
Conference hall	28	5	4771,305	381,70 €
Private office	29	5		
Corporative headquarters	26	6	5421,938	433,76 €
WC	27	6		

Office 2	16	7	650,6325	52,05 €
Corridor 2	17	7		
Business office 1	15	8	5421,938	433,76 €
Presentation office 1	22	8		
Presentation office 2	23	8		
WC M.	20	9	2429,028	194,32 €
WC W.	21	9		
Corridor 1	24	9		

Table 34: Heat demand and cost (second floor)

<u>TOTAL</u>

	Heat demand (kWh)	Cost (€/year)
TOTAL	53004,86	4.240,39 €

Table 35: Heat demand and cost (Vilnius)

5. HEATING CHARACTERISTICS

In this point, we will show the heating characteristics of our building. First of all, we will explain how we have calculated all the aspects step by step, and finally we will give the final results, comparing the energy needed in Madrid, and what would happen, how much would be the energy needed, in Vilnius, if we built the same office building than in Madrid.

5.1Heat losses

Once we have all the areas, we go on with the calculation of the heat losses of the building.

The heat loss of the room is due to two factors. One is the heat loss due to heat transmission through envelopes H_{en} and due to ventilation H_v.

We will calculate the total heat loss coefficient H using the following expression:

$$H = H_{en} + H_v \ (W/K)$$

Where:

Hen – heat loss coefficient due to heat transmission through the envelope, W/K

Hv – heat loss coefficient due to ventilation. W/K

5.1.1Envelopes' heat losses

$$\boldsymbol{H_{en} = \Sigma H_{el} + \Sigma H_{\Psi} + \Sigma H_g \ (\frac{W}{K})}$$

$\Sigma H_{el} - heat\ loss\ coefficient\ of\ the\ envelope\ elements, W/K$
$\Sigma H_{\Psi} - heat\ loss\ coefficient\ of\ the\ thermal\ bridges, W/K$
$\Sigma H_g - heat\ loss\ coefficient\ of\ a\ floor\ on\ the\ ground, W/K$

Where the heat loss through the construction elements can be calculated by following expression:

$$\boldsymbol{H_{el} = U \cdot A \cdot b_u \ W/K}$$

Where:

$U - Heat\ transfer\ coefficient\ of\ the\ envelope\ element, \frac{W}{m^2K}$
$A - area\ of\ the\ element, m^2$
$b_u - correction\ coefficient\ for\ the\ heat\ loss\ to\ the\ unheated\ space$

In the case of the walls, windows, ceilings and roofs, the coefficient b_u=1.

The heat loss coefficient due to thermal bridges can be taken around 10-40% of the heat losses through the elements. In our case we will take:

$$\boldsymbol{H_\Psi = 0,25 \cdot H_{el}}$$

The heat loss coefficient of a floor on the ground will be determined using the same formula that the heat loss through the construction elements but, in this case the coefficient b_u will be 0.5. This coefficient has been calculated estimating a temperature of the garage about 11 °C (average of the outdoor and indoor design temperatures) and using the following expression:

$$b_u = \frac{\theta_i - \theta_a}{\theta_i - \theta_e}$$

Where:

$\theta_i -$ *design indoor temperature*, °C
$\theta_e -$ *design outdoor temperature*, °C
$\theta_a -$ *average temperature between outdoor and indoor*, °C

MADRID

- First floor

Heat losses through the elements

ROOM NAME	ROOM NUMBER	bu	HelWALL(W/K)	HelDOOR (W/K)	HelCEILING(W/K)	HelWINDOW(W/K)	Hel(W/K)
Hall	1	0,5	81,18	14	0	480,725	575,905
Internet room	3	0,5	16,236	0	0	14	30,236
Telecomunication office	14	0,5	24,354	0	0	14	38,354
WC M.	11	0,5	0	0	0	0	0
WC W.	12	0,5	0	0	0	0	0
Copy/coffe	6	0,5	16,236	0	0	14	30,236
Secretary's office	7	0,5	0	0	0	0	0
Waiting room	10	0,5	0	0	0	86,1	86,1
Accounting	30	0,5	23,133	0	0	28	51,133
Director's office	9	0,5	0	0	0	172,2	172,2
Corridor 1	4	0,5	5,478	14	0	0	19,478
Corridor 2	5	0,5	13,596	0	0	14	27,596
WC	8	0,5	4,059	0	0	0	4,059

Table 36: Heat losses through the elements (first floor)

Heat losses through envelopes

ROOM NAME	ROOM NUMBER	Hel(W/K)	Hg(W/K)	HΨ(W/K)	Hen(W/K)
Hall	1	575,905	101,216	143,97625	821,09725
Internet room	3	30,236	11,52	7,559	49,315
Telecomunication office	14	38,354	5,76	9,5885	53,7025
WC M.	11	0	2,88	0	2,88
WC W.	12	0	2,88	0	2,88
Copy/coffe	6	30,236	8,64	7,559	46,435
Secretary's office	7	0	2,88	0	2,88
Waiting room	10	86,1	14,4	21,525	122,025
Accounting	30	51,133	10,08	12,78325	73,99625
Director's office	9	172,2	11,52	43,05	226,77
Corridor 1	4	19,478	5,76	4,8695	30,1075
Corridor 2	5	27,596	11,52	6,899	46,015
WC	8	4,059	1,44	1,01475	6,51375

Table 37: Heat losses through the envelopes (first floor)

- Second floor

Heat losses through the elements

ROOM NAME	ROOM NUMBER	bu	HelWALL(W/K)	HelDOOR (W/K)	HelCEILING(W/K)	HelWINDOW(W/K)	Hel(W/K)
Business office	15	1	44,616	0	44,1	28	116,716
Office 2	16	1	7,128	0	8,82	0	15,948
Corridor 2	17	1	14,256	0	17,64	0	31,896
Business office 2	18	1	33	0	44,1	89,6	166,7
Office 1	19	1	0	0	8,82	113,4	122,22
WC M.	20	1	0	0	4,41	0	4,41
WC W.	21	1	0	0	4,41	0	4,41
Presentation office 1	22	1	4,488	0	8,82	14	27,308
Presentation office 2	23	1	4,488	0	8,82	14	27,308
Corridor 1	24	1	0	0	52,92	189	241,92

Corporative headquarters	26	1	28,512	0	64,435	94,5	187,447
WC	27	1	3,564	0	2,205	0	5,769
Conference hall	28	1	21,384	0	17,64	37,8	76,824
Private office	29	1	0	0	17,64	151,2	168,84

Table 38: Heat losses through the elements (second floor)

<u>Heat losses through envelopes</u>

ROOM NAME	ROOM NUMBER	Hel(W/K)	Hg(W/K)	HΨ(W/K)	Hen(W/K)
Business office	15	116,716	0	29,179	145,895
Office 2	16	15,948	0	3,987	19,935
Corridor 2	17	31,896	0	7,974	39,87
Business office 2	18	166,7	0	41,675	208,375
Office 1	19	122,22	0	30,555	152,775
WC M.	20	4,41	0	1,1025	5,5125
WC W.	21	4,41	0	1,1025	5,5125
Presentation office 1	22	27,308	0	6,827	34,135
Presentation office 2	23	27,308	0	6,827	34,135
Corridor 1	24	241,92	0	60,48	302,4
Corporative headquarters	26	187,447	0	46,86175	234,30875
WC	27	5,769	0	1,44225	7,21125
Conference hall	28	76,824	0	19,206	96,03
Private office	29	168,84	0	42,21	211,05

Table 39: Heat losses through the envelopes(second floor)

- TOTAL

	Hel(W/K)	Hg(W/K)	HΨ(W/K)	Hen(W/K)
TOTAL	2233,013	190,496	558,25325	2981,76225

Table 40: Heat losses coefficients

5.1.2 Ventilation heat losses

Ventilation heat losses can be calculated by following expression:

$$\boldsymbol{H_v = \Sigma H_{ev} + \Sigma H_{nv} + \Sigma H_{in} + \Sigma H_{de}, W/K}$$

Where:

$\boldsymbol{\Sigma H_{ev}}$ $- \, heat\ loss\ due\ to\ mechanical\ ventilation, W/K$
$\boldsymbol{\Sigma H_{nv}}$ $- \, heat\ loss\ due\ to\ natural\ ventilation, W/K$
$\boldsymbol{\Sigma H_{in}}$ $- \, heat\ loss\ due\ to\ cold\ air\ infiltration, W/K$
$\boldsymbol{\Sigma H_{de}}$ $- \, heat\ loss\ due\ to\ external\ door\ opening, W/K$

Heat loss due to mechanical ventilation can be calculated by following expression:

$$\boldsymbol{H_{ev} = 0{,}34 \cdot L_{ev} \cdot (1 - \eta_{hr})}$$

Where:

$L_{ev} - supply\ air\ flow\ by\ mechanical\ ventilation, m^3/h$
$\eta_{hr} - effectiveness\ of\ ventilation\ heat\ recovery\ (recuperation)$

In our case the heat loss due to mechanical ventilation will be 0, because our system is mechanical-balanced.

Heat loss due to cold air infiltration can be calculated by following expression:

$$\boldsymbol{H_{in} = 0{,}34 \cdot L_{in}}$$

$L_{in} - infiltration\ air\ flow, m^3/h$

The air flow of infiltration can be calculated by following expression:

$$\boldsymbol{L_{in} = n_{in} \cdot V_p \cdot \Delta k_c \cdot (1 + \Delta k_b) \cdot \left(1 + k_g\right), m^3/h}$$

Where:

$n_{in} - air\ change\ ratio$
$V_p - volume\ of\ the\ room$
Δk_c
$- \, correction\ coefficient\ depend\ on\ the\ position\ of\ windows\ of angular\ room$
$\Delta k_c = 1{,}2\ in\ one\ wall,\ \ \Delta k_c = 1{,}1\ in\ one\ wall,\ \ \Delta k_c = 1\ in\ another\ way$

$\Delta k_b = correction\ coefficient\ depend\ on\ the\ type\ of\ ventilation$

$k_g - correction\ coefficient\ depend\ on\ the\ position\ of\ the\ room\ in\ the\ building$

$$\boldsymbol{k_g = \| \frac{N}{2} - N_i + 1 \| \cdot \frac{0{,}05}{\sqrt{N}}}$$

Where:

$N - number\ of\ floors\ in\ building$

$N_i - number\ of\ floor, where\ is\ calculated\ room$

$$H_{nv} = 0 \textbf{ because our system is mechanical, and we can despise natural losses}$$

$$H_{de} \approx 0$$

We have decided to despise heat losses due to doors opening because they will be just around 1% out of the total amount of ventilation losses, so it will not introduce important changes in our design.

Necessary data:

n_{in} – 0.2

N – 2

Δk_b - 0.1

Area		Coastal areas	Mainland areas
Level of lee	Keep from wind (in the forest, on the hillside, in the centre of city)	0,3	**0,2**
	Keep from moderately (high buildings, buildings in the city without flora)	0,4	0,3
	Naked (in plain places, in plain places near water or in the fields)	**0,5**	0,4

Table 41:air change ratio

Mechanical balanced ventilation	-0,1
Only exhausted ventilation system	0,1
Other case	0

Table 42:correction coefficient depend on the type of ventilation

- First floor

ROOM NAME	ROOM NUMBER	ROOM VOLUME(m3)	Ni	Kg	ΔKc	ΔKb	Lin(m3/h)	Hin(W/K)	Hv(W/K)
Hall	1	1296,83	1	0,03535534	1,2	-0,1	290,018851	98,6064092	98,6064092
Internet room	3	147,6	1	0,03535534	1	-0,1	27,5073206	9,35248902	9,35248902
Telecomunication office	14	73,8	1	0,03535534	1	-0,1	13,7536603	4,67624451	4,67624451
WC M.	11	36,9	1	0,03535534	1	-0,1	6,87683016	2,33812226	2,33812226
WC W.	12	36,9	1	0,03535534	1	-0,1	6,87683016	2,33812226	2,33812226
Copy/coffe	6	110,7	1	0,03535534	1	-0,1	20,6304905	7,01436677	7,01436677
Secretary's office	7	36,9	1	0,03535534	1	-0,1	6,87683016	2,33812226	2,33812226
Waiting room	10	184,5	1	0,03535534	1	-0,1	34,3841508	11,6906113	11,6906113
Accounting	30	129,15	1	0,03535534	1,2	-0,1	28,8826867	9,82011347	9,82011347

Director's office	9	147,6	1	0,03535534	1,2	-0,1	33,0087848	11,2229868	11,2229868
Corridor 1	4	73,8	1	0,03535534	1	-0,1	13,7536603	4,67624451	4,67624451
Corridor 2	5	147,6	1	0,03535534	1	-0,1	27,5073206	9,35248902	9,35248902
WC	8	18,45	1	0,03535534	1	-0,1	3,43841508	1,16906113	1,16906113

Table 43: ventilation heat losses coefficient (first floor)

- Second floor

ROOM NAME	ROOM NUMBER	ROOM VOLUME(m3)	Ni	Kg	ΔKc	ΔKb	Lin(m3/h)	Hin(W/K)	Hv(W/K)
Business office	15	324	2	0	1,1	-0,1	64,152	21,81168	21,81168
Office 2	16	64,8	2	0	1	-0,1	11,664	3,96576	3,96576
Corridor 2	17	129,6	2	0	1	-0,1	23,328	7,93152	7,93152
Business office 2	18	324	2	0	1,2	-0,1	69,984	23,79456	23,79456
Office 1	19	64,8	2	0	1,2	-0,1	13,9968	4,758912	4,758912
WC M.	20	32,4	2	0	1	-0,1	5,832	1,98288	1,98288
WC W.	21	32,4	2	0	1	-0,1	5,832	1,98288	1,98288
Presentation office 1	22	64,8	2	0	1	-0,1	11,664	3,96576	3,96576
Presentation office 2	23	64,8	2	0	1	-0,1	11,664	3,96576	3,96576
Corridor 1	24	388,8	2	0	1,2	-0,1	83,9808	28,553472	28,553472
Corporative headquarters	26	473,4	2	0	1	-0,1	85,212	28,97208	28,97208
WC	27	16,2	2	0	1	-0,1	2,916	0,99144	0,99144
Conference hall	28	129,6	2	0	1,1	-0,1	25,6608	8,724672	8,724672
Private office	29	129,6	2	0	1,2	-0,1	27,9936	9,517824	9,517824

Table 44: ventilation heat losses coefficient (second floor)

- TOTAL

	Hin(W/K)	Hv(W/K)
TOTAL	325,514583	325,514583

Table 45: infiltration and ventilation total coefficients

5.2 Heat gains

The heat gains Q_{hg} are calculated in two parcels. One refers to the internal heat gains and the other to heat gains due to sun radiation. The heat gains can be calculated by following expression:

$$\boldsymbol{Q_{hg} = Q_{ig} + Q_{sg}, kWh}$$

Where:

$Q_{ig} - the\ internal\ heat\ gains, kWh$

$Q_{sg} - the\ external - solar\ heat\ gains, kWh$

The internal heat gains can be calculated by following expression:

$$Q_{ig} = \Phi_{ig} \cdot t \cdot 24 \cdot 10^{-3}, kWh$$

Where:

$\Phi_{ig} - heat\ gain\ power\ of\ internal\ sources, W$

$t - duration\ in\ days.$

Heat gain power of internal heat sources can be calculated by following expression:

$$\Phi_{ig} = A_p \cdot (q_{el} + q_p), W$$

Where:

$A_p - room\ floor\ area, m^2$

$q_{el} - heat\ gain\ of\ electric\ equipment, W/m^2$

$q_p - heat\ gains\ of\ persons, W/m^2$

	Type of a building	Area per person, A_o, m^2/pr.	Heat gain per person, q_o, W/pr.	Heat gain of persons q_p, W/m^2	Occupancy per day in hours	Heat gains of lighting and other el. equipment q_{el}, W/m^2
1	Living (1-2 floor) buildings	60	70	1,2	12	1,6
2	Multistorey (dweling) houses	40	70	1,8	12	2,4
3	Office buildings	20	80	4	6	2,1
4	Educational buildings	10	70	7	4	1,0
5	Hospitals	30	80	2,7	16	2,4
6	Restauranst, bars, cafe,	5	100	20	3	2,4
7	Supermarkets	10	90	9	4	2,7
8	Sport halls	20	100	5	6	1,0
9	Water pools buildings	20	60	3	4	4,8
10	Culture buildings	5	80	16	3	1,8
11	Garages and industry buildings	20	100	5	6	2,1
12	Storey houses	100	100	1	6	0,6
13	Hotels	40	70	1,8	12	2,4
14	Other	40	70	1,8	12	2,4

Table 46: heat gains by type of building

The external heat gains due to the solar radiation can be calculated by following expression:

$$Q_{sg} = \Phi_{sg} \cdot t \cdot 24 \cdot 10^{-3}, kWh$$

Where:

$\Phi_{sg} - heat\ gain\ power\ of\ solar\ radiation, kW$

$t - the\ duration\ in\ days.$

The heat gain power of solar radiation can be calculated by following expression:

$$\Phi_{sg} = \Sigma(q_{s,j} \cdot g \cdot A_{gl} \cdot a), W$$

Where:

$q_{s,j} - solar\ radiation\ according\ to\ window\ orientation, W/m^2$

$g - solar\ radiation\ transmittance\ coefficient\ of\ glass.$

$A_{gl} - windows'\ glazing\ area, m^2, (0.8 * A_{window})$

$a - shading\ coefficient$

The solar radiation transmittance coefficient of glass varies between 0,5 and 0,9 and usually accepted **as 0,7**.

The shading coefficient varies between 0,2 and 0,7 and usually accepted as **0,5.**

The value of solar radiation varies a lot as we can expect. We will take the following average coefficient depending on the envelope (window) orientation:

$$q_{s,j} = 10\frac{W}{m^2}(north); = 15\frac{W}{m^2}(east\ and\ west); = 25\frac{W}{m^2}(south)$$

MADRID

- First floor

Internal heat gains

ROOM NAME	ROOM NUMBER	ROOM AREA(m2)	qel(W/m2)	qp(W/m2)	Φel(W)	Φpers(W)	Φig(W)
Hall	1	316,3	2,1	4	664,23	1265,2	1929,43
Internet room	3	36	2,1	4	75,6	144	219,6
Telecomunication office	14	18	2,1	4	37,8	72	109,8
WC M.	11	9	2,1	4	18,9	36	54,9
WC W.	12	9	2,1	4	18,9	36	54,9
Copy/coffe	6	27	2,1	4	56,7	108	164,7
Secretary's office	7	9	2,1	4	18,9	36	54,9
Waiting room	10	45	2,1	4	94,5	180	274,5
Accounting	30	31,5	2,1	4	66,15	126	192,15
Director's office	9	36	2,1	4	75,6	144	219,6
Corridor 1	4	18	2,1	4	37,8	72	109,8
Corridor 2	5	36	2,1	4	75,6	144	219,6
WC	8	4,5	2,1	4	9,45	18	27,45

Table 47:internal heat gains (first floor)

External-solar heat gains

ROOM NAME	ROOM NUMBER	WINDOW POSITION	qs,j(W/m2)	AREA WINDOW OUT(m2)	Agl(m2)	Φs,g(W)
Hall	1	N	10	105,575	84,46	295,61
		E	15	31,775	25,42	133,455
Internet room	3	S	25	4	3,2	28
Telecomunication office	14	W	15	4	3,2	16,8

WC M.	11			0	0	0
WC W.	12			0	0	0
Copy/coffe	6	W	15	4	3,2	16,8
Secretary's office	7			0	0	0
Waiting room	10	W	15	24,6	19,68	103,32
Accounting	30	N	10	4	3,2	11,2
		W	15	4	3,2	16,8
Director's office	9	N	10	24,6	19,68	68,88
		E	15	24,6	19,68	103,32
Corridor 1	4			0	0	0
Corridor 2	5	W	15	4	3,2	16,8
WC	8			0	0	0

Table 48:external solar heat gains (first floor)

Second floor

<u>Internal heat gains</u>

ROOM NAME	ROOM NUMBER	ROOM AREA(m2)	qel(W/m2)	qp(W/m2)	Φel(W)	Φpers.surf(W)	Φig(W)
Business office	15	90	2,1	4	189	360	549
Office 2	16	18	2,1	4	37,8	72	109,8
Unnamed/corridor	17	36	2,1	4	75,6	144	219,6
Business office 2	18	90	2,1	4	189	360	549
Office 1	19	18	2,1	4	37,8	72	109,8
WC M.	20	9	2,1	4	18,9	36	54,9
WC W.	21	9	2,1	4	18,9	36	54,9
Presentation office 1	22	18	2,1	4	37,8	72	109,8
Presentation office 2	23	18	2,1	4	37,8	72	109,8
Corridor	24	108	2,1	4	226,8	432	658,8
Corporative headquarters	26	131,5	2,1	4	276,15	526	802,15
WC	27	4,5	2,1	4	9,45	18	27,45
Conference hall	28	36	2,1	4	75,6	144	219,6
Private office	29	36	2,1	4	75,6	144	219,6

Table 49:internal heat gains (second floor)

External-solar heat gains

ROOM NAME	ROOM NUMBER	WINDOW POSITION	qs,j(W/m2)	AREA WINDOW OUT(m2)	Agl(m2)	Φs,g(W)
Business office	15	S	25	8	6,4	56
Office 2	16				0	0
Corridor 2	17				0	0
Business office 2	18	E	15	21,6	17,28	90,72
		W	15	4	3,2	16,8
Office 1	19	N	10	21,6	17,28	60,48
		W	15	10,8	8,64	45,36
WC M.	20			0	0	0
WC W.	21			0	0	0
Presentation office 1	22	S	25	4	3,2	28
Presentation office 2	23	S	25	4	3,2	28
Corridor 1	24	N	10	43,2	34,56	120,96
		E	15	10,8	8,64	45,36
Corporative headquarters	26	N	10	27	21,6	75,6
WC	27			0	0	0
Conference hall	28	E	15	10,8	8,64	45,36
Private office	29	N	10	21,6	17,28	60,48
		E	15	21,6	17,28	90,72

Table 50:external solar heat gains (second floor)

- TOTAL

	Φig(W)	Φs,g(W)	Φhg(W)
TOTAL	7425,53	1574,825	9000,355

Table 51:total heat gains

5.3Heat loads

The heating power P_h, is the necessary power that the furnace must employ in the design case. This design case is as mentioned above an extreme situation, that is, when the outside temperature reaches its design value. The necessary heating power of the furnace is then calculate as the sum of all heat losses in each compartment, and can be calculated by following expression:

$$P_h = \left(H - H_g\right) \cdot (\theta_i - \theta_e) + H_g \cdot (\theta_i - \theta_{eav})$$

$H - total\ heat\ loss\ coefficient, \quad W/K$
$H_g - heat\ loss\ coefficient\ of\ the\ ground\ floor$
$\theta_i - design\ indoor\ temperature, °C$
$\theta_e - design\ outdoor\ temperature, °C$
$\theta_{eav} - average\ annual\ temperature, °C$

MADRID

First floor

ROOM NAME	ROOM NUMBER	Hg(W/K)	H-Hg(W/K)	Ph(W)
Hall	1	101,216	829,443927	19057,4944
Internet room	3	11,52	48,1866545	1152,2664
Telecomunication office	14	5,76	53,1383272	1215,1232
WC M.	11	2,88	2,59791362	80,1940996
WC W.	12	2,88	2,59791362	80,1940996
Copy/coffe	6	8,64	45,5887409	1072,0723
Secretary's office	7	2,88	2,59791362	80,1940996
Waiting room	10	14,4	120,614568	2768,7205
Accounting	30	10,08	74,8274872	1726,84472
Director's office	9	11,52	227,719985	5101,99968
Corridor 1	4	5,76	29,5433272	696,033199
Corridor 2	5	11,52	44,8866545	1079,6664
WC	8	1,44	6,37270681	151,71955

Table 52:heat load (first floor)

Second floor

ROOM NAME	ROOM NUMBER	Hg(W/K)	H-Hg(W/K)	Ph(W)
Business office	15	0	140,9512	3100,9264
Office 2	16	0	20,3544	447,7968
Corridor 2	17	0	40,7088	895,5936
Business office 2	18	0	193,1384	4249,0448
Office 1	19	0	127,50768	2805,16896
WC M.	20	0	6,6132	145,4904
WC W.	21	0	6,6132	145,4904
Presentation office 1	22	0	31,7144	697,7168
Presentation office 2	23	0	31,7144	697,7168
Corridor 1	24	0	273,64608	6020,21376
Corporative headquarters	26	0	219,6382	4832,0404
WC	27	0	6,8706	151,1532
Conference hall	28	0	86,51808	1903,39776
Private office	29	0	179,41536	3947,13792

Table 53:heat load (second floor)

TOTAL

	Ph(W)
TOTAL	64301,4106

Table 54:heat load (Madrid)

VILNIUS

In the case of Vilnius, if we built the same building than in Madrid, we are going to obtain more high heat loads. That is why the outdoor temperature is much lower than in the case of Madrid. The heat losses coefficients will not change because these do not depend on the temperature, and we have to remember that we are working with the same U-values than in Madrid. We have to see what would happen in the case that we built the same building than in Madrid.

First floor

ROOM NAME	ROOM NUMBER	Ph(W)
Hall	1	40532,4694
Internet room	3	2441,02876
Telecomunication office	14	2585,62938
WC M.	11	166,16594
WC W.	12	166,16594
Copy/coffe	6	2274,86282
Secretary's office	7	166,16594
Waiting room	10	5889,2047
Accounting	30	3671,1159
Director's office	9	10879,0953
Corridor 1	4	1476,66438
Corridor 2	5	2285,92876
WC	8	321,54922

Table 55:heat load (first floor)

Second floor

ROOM NAME	ROOM NUMBER	Ph(W)
Business office	15	6624,7064
Office 2	16	956,6568
Corridor 2	17	1913,3136
Business office 2	18	9077,5048
Office 1	19	5992,86096
WC M.	20	310,8204
WC W.	21	310,8204
Presentation office 1	22	1490,5768
Presentation office 2	23	1490,5768
Corridor 1	24	12861,3658
Corporative headquarters	26	10322,9954
WC	27	322,9182
Conference hall	28	4066,34976
Private office	29	8432,52192

Table 56:heat load (second floor)

Total

	Ph(W)
TOTAL	137030,034

Table 57:heat load (Vilnius)

5.4Heat demand

The annual heat demand for this building is the sum of all contributories systems to heating that require to operate. The annual heat demand will be the difference between the average heat consumption and the heat gains during the year. The heat demand Q_h can be calculated by following expression:

$$Q_h = Q_{en,v} - \eta_o \cdot Q_{hg}$$

Where:

$Q_{en,v} - heat\ demand\ to\ compensate\ envelope\ and\ ventilation\ heat\ losses, kWh$

$\eta_o -$
$heat\ gains\ use\ efficiency\ coefficient, recommended: 0{,}8\ (controlled\ according\ outdoor\ temperature)$

$Q_{hg} - heat\ gains, kWh$

The heat demand to compensate envelopes and ventilation heat losses can be calculated by following expression:

$$Q_{en,v} = H \cdot (\theta_i - \theta_{em}) \cdot t \cdot 24 \cdot 10^{-3}, kWh$$

Where:

$H - total\ heat\ loss\ coefficient, W/K$

$\theta_i - indoor\ design\ temperature, °C$

$\theta_{em} - external\ average\ temperature\ of\ calculation(heating\ season)period, °C$

$t - duration\ of\ the\ heating\ season\ in\ days$

The heat gains Q_{hg} are already explained above.

MADRID

First floor

ROOM NAME	ROOM NUMBER	H(W/K)	Qen,v(kwh)	Φhg(W)	Qhg(kwh)	Qh(kwh)
Hall	1	930,659927	36773,7241	2358,495	6792,4656	31339,7516
Internet room	3	59,7066545	2359,22486	247,6	713,088	1788,75446

Telecomunication office	14	58,8983272	2327,28494	126,6	364,608	2035,59854
WC M.	11	5,47791362	216,452087	54,9	158,112	89,9624875
WC W.	12	5,47791362	216,452087	54,9	158,112	89,9624875
Copy/coffe	6	54,2287409	2142,77277	181,5	522,72	1724,59677
Secretary's office	7	5,47791362	216,452087	54,9	158,112	89,9624875
Waiting room	10	135,014568	5334,91164	377,82	1088,1216	4464,41436
Accounting	30	84,9074872	3355,00049	220,15	634,032	2847,77489
Director's office	9	239,239985	9453,23309	391,8	1128,384	8550,52589
Corridor 1	4	35,3033272	1394,96155	109,8	316,224	1141,98235
Corridor 2	5	56,4066545	2228,82998	236,4	680,832	1684,16438
WC	8	7,81270681	308,708172	27,45	79,056	245,463372

Table 60:heat demand (first floor)

<u>Second floor</u>

ROOM NAME	ROOM NUMBER	H(W/K)	Qen,v(kwh)	Φhg(W)	Qhg(kwh)	Qh(kwh)
Business office	15	140,9512	5569,48934	605	1742,4	4175,56934
Office 2	16	20,3544	804,27562	109,8	316,224	551,29642
Corridor 2	17	40,7088	1608,55124	219,6	632,448	1102,59284
Business office 2	18	193,1384	7631,59348	656,52	1890,7776	6118,9714
Office 1	19	127,50768	5038,28746	215,64	621,0432	4541,4529
WC M.	20	6,6132	261,31134	54,9	158,112	134,82174
WC W.	21	6,6132	261,31134	54,9	158,112	134,82174
Presentation office 1	22	31,7144	1253,15012	137,8	396,864	935,658916
Presentation office 2	23	31,7144	1253,15012	137,8	396,864	935,658916
Corridor 1	24	273,64608	10812,7417	825,12	2376,3456	8911,66527
Corporative headquarters	26	219,6382	8678,69598	877,75	2527,92	6656,35998
WC	27	6,8706	271,48214	27,45	79,056	208,23734
Conference hall	28	86,51808	3418,64081	264,96	763,0848	2808,17297
Private office	29	179,41536	7089,34677	370,8	1067,904	6235,02357

Table 61:heat demand (second floor)

TOTAL

	Qh(kwh)
TOTAL	99543,2174

Table 62:heat demand (Madrid)

VILNIUS

First floor

ROOM NAME	ROOM NUMBER	Qen,v(kwh)	Qhg(kwh)	Qh(kwh)
Hall	1	105536,836	11886,8148	96027,3839
Internet room	3	6770,73462	1247,904	5772,41142
Telecomunication office	14	6679,07031	638,064	6168,61911
WC M.	11	621,195404	276,696	399,838604
WC W.	12	621,195404	276,696	399,838604
Copy/coffe	6	6149,53921	914,76	5417,73121
Secretary's office	7	621,195404	276,696	399,838604
Waiting room	10	15310,652	1904,2128	13787,2818
Accounting	30	9628,50905	1109,556	8740,86425
Director's office	9	27129,8143	1974,672	25550,0767
Corridor 1	4	4003,39731	553,392	3560,68371
Corridor 2	5	6396,51462	1191,456	5443,34982
WC	8	885,960952	138,348	775,282552

Table 63:heat demand (first floor)

Second floor

ROOM NAME	ROOM NUMBER	Qen,v(kwh)	Qhg(kwh)	Qh(kwh)
Business office	15	15983,8661	3049,2	13544,5061
Office 2	16	2308,18896	553,392	1865,47536
Corridor 2	17	4616,37792	1106,784	3730,95072
Business office 2	18	21901,8946	3308,8608	19254,8059
Office 1	19	14459,3709	1086,8256	13589,9104
WC M.	20	749,93688	276,696	528,58008
WC W.	21	749,93688	276,696	528,58008

Presentation office 1	22	3596,41296	694,512	3040,80336
Presentation office 2	23	3596,41296	694,512	3040,80336
Corridor 1	24	31031,4655	4158,6048	27704,5816
Corporative headquarters	26	24906,9719	4423,86	21367,8839
WC	27	779,12604	138,348	668,44764
Conference hall	28	9811,15027	1335,3984	8742,83155
Private office	29	20345,7018	1868,832	18850,6362

Table 64:heat demand (second floor)

Total

	Qh(kwh)
TOTAL	308901,997

Table 65:heat demand (Vilnius)

5.5Heat price.

Now, we are going to calculate the heat price that we have to pay for the energy (heat) consumed in our building.

Approximately, the cost for heating season for our building can be calculated by following expression:

$$C_{heat} = \Sigma Q_h \cdot c_{heat}, €$$

Where:

$\Sigma Q_h - the\ heat\ demand\ for\ building, kWh$

$c_{heat} - the\ price\ of\ heat, €/kWh$

MADRID

The price in Madrid is around 0,05 €/kWh.

ROOM NAME	ROOM NUMBER	Cheat(€)
Hall	1	1566,98758
Internet room	3	89,4377231
Telecomunication office	14	101,779927
WC M.	11	4,49812437
WC W.	12	4,49812437

Copy/coffe	6	86,2298387
Secretary's office	7	4,49812437
Waiting room	10	223,220718
Accounting	30	142,388744
Director's office	9	427,526294
Corridor 1	4	57,0991175
Corridor 2	5	84,2082191
WC	8	12,2731686
Business office	15	208,778467
Office 2	16	27,564821
Corridor 2	17	55,129642
Business office 2	18	305,94857
Office 1	19	227,072645
WC M.	20	6,74108698
WC W.	21	6,74108698
Presentation office 1	22	46,7829458
Presentation office 2	23	46,7829458
Corridor 1	24	445,583263
Corporative headquarters	26	332,817999
WC	27	10,411867
Conference hall	28	140,408648
Private office	29	311,751178
TOTAL		**4977,16087**

Table 66: cost for heating season (Madrid)

<u>VILNIUS</u>

The price of the energy in Vilnius is 0,08 €/kWh

ROOM NAME	ROOM NUMBER	Cheat(€)
Hall	1	7682,19071
Internet room	3	461,792913
Telecomunication office	14	493,489529
WC M.	11	31,9870883

WC W.	12	31,9870883
Copy/coffe	6	433,418497
Secretary's office	7	31,9870883
Waiting room	10	1102,98254
Accounting	30	699,26914
Director's office	9	2044,00614
Corridor 1	4	284,854697
Corridor 2	5	435,467985
WC	8	62,0226042
Business office	15	1083,56049
Office 2	16	149,238029
Corridor 2	17	298,476058
Business office 2	18	1540,38447
Office 1	19	1087,19283
WC M.	20	42,2864064
WC W.	21	42,2864064
Presentation office 1	22	243,264269
Presentation office 2	23	243,264269
Corridor 1	24	2216,36653
Corporative headquarters	26	1709,43071
WC	27	53,4758112
Conference hall	28	699,426524
Private office	29	1508,0509
TOTAL		**24712,1597**

Table 66: cost for heating season (Vilnius)

6.COOLING CHARACTERISTICS

The next target is to calculate the cooling power needed in our building. We will compare, as we did before with the heating power, the cooling power in both cities.

In order to do that, we will use a software called ProClim, provided by Swegon. The first step was to divide our building by different zones, in order to calculate the flow rates, so in this point we will go on with the calculation of cooling power.

ProClim web is a program for calculating the heat balance in a room. ProClim web aids the planner by calculating the size of cooling effect required for each room. It is also possible to select a product and calculate the resulting temperature if so desired.

6.1ProClim tutorial

The first sheet, called simple data, shows us the more simple way to calculate the cooling power.

In this sheet we would be able to select briefly the most important parameters for our calculation, as we can see in the next picture.

We will not use this sheet in our procedure, because we want to calculate it more accurately.

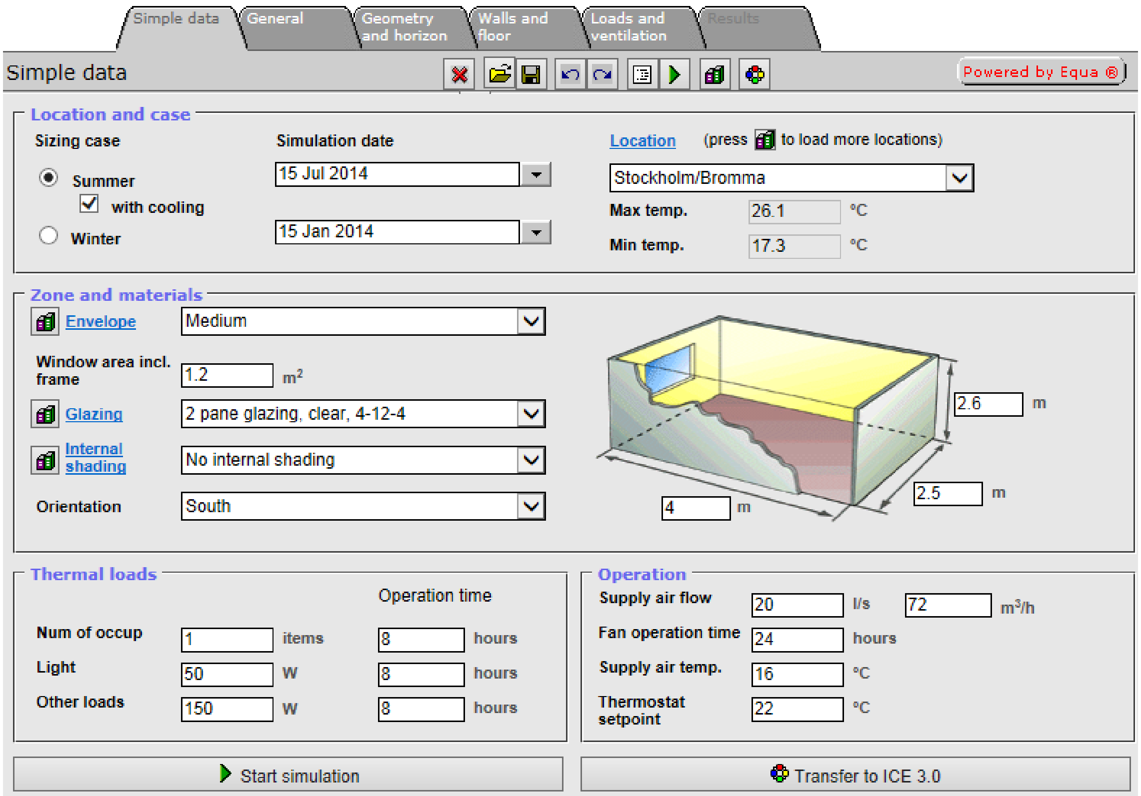


Figure 4: ProClim. Simple data

The next sheet, called General, will be the beginning of our procedure. We will select the sizing case, simulation date and location. Also we will be able to change the maximum and minimum temperatures according to our design.

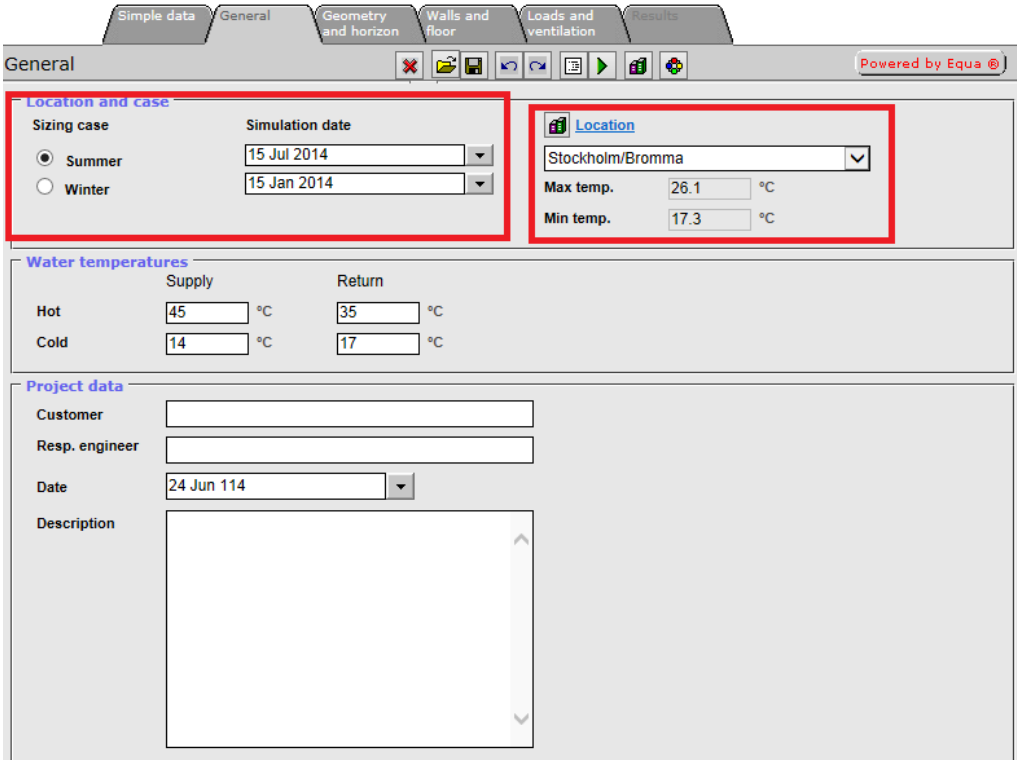


Figure 5: ProClim. General

The next step is to model the geometry and the orientation of our rooms. We can choose the gauges of each zone and how it is orientated.

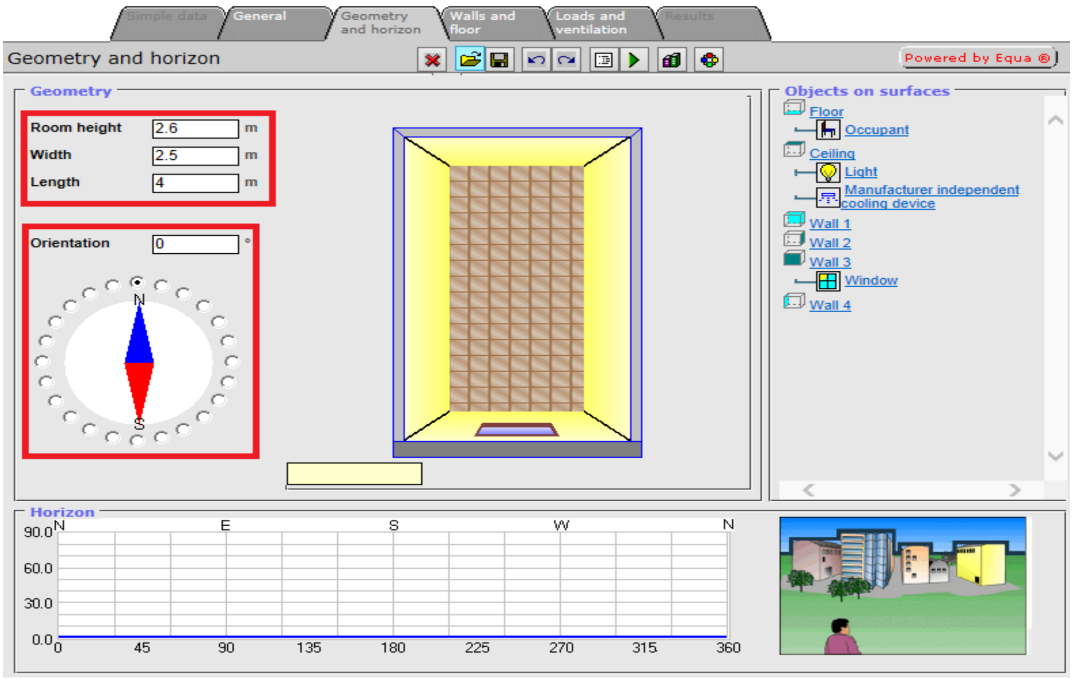


Figure 6: ProClim. Geometry and horizon

After that, in the sheet called walls and floor, we can design each wall, the material of the wall, if there are windows in it, the gauges of each window, the floor, the ceiling, and the power of the cooling device.

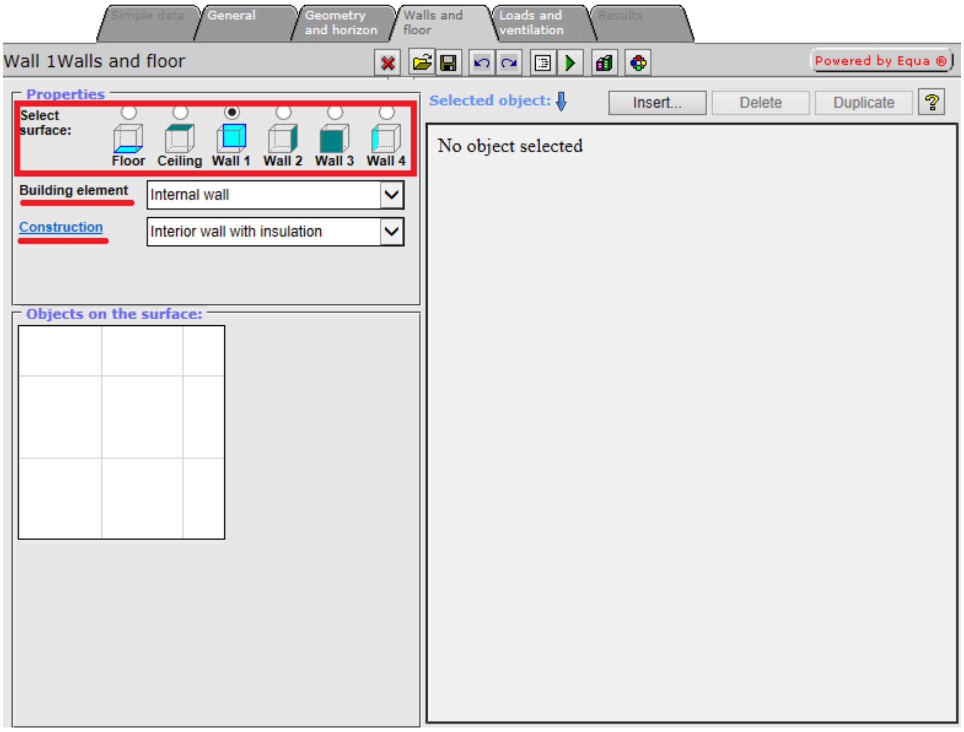


Figure 7: ProClim. Walls and floor

We can add an object, change the building element as follows:

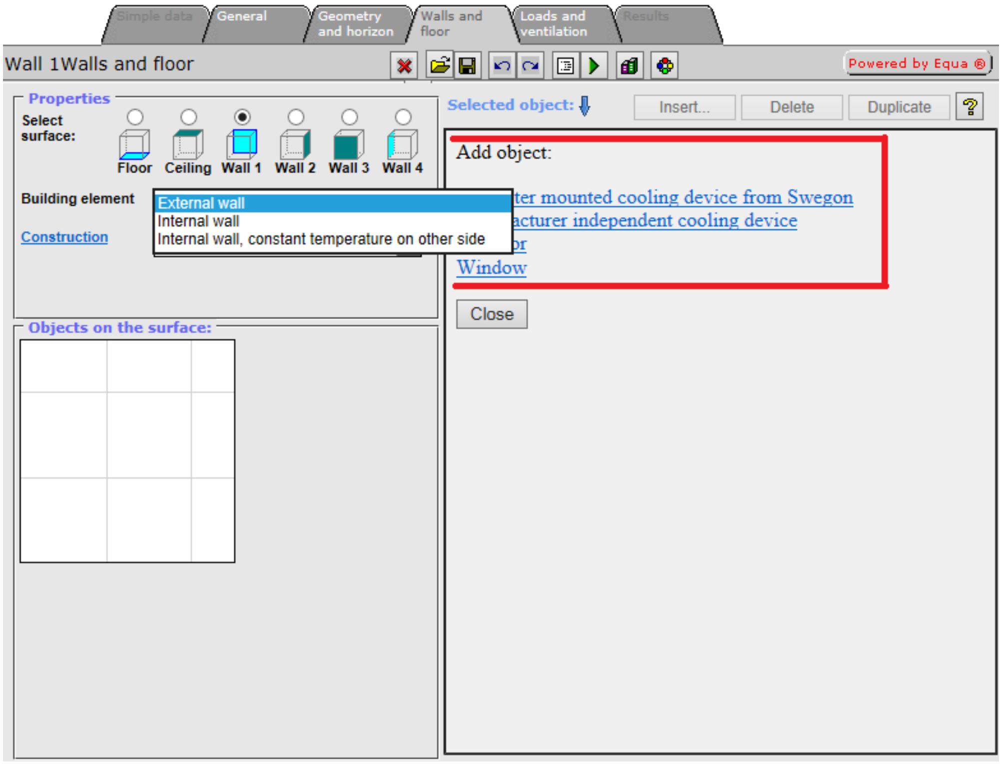


Figure 8: ProClim. Walls and floor

Choose window measures:

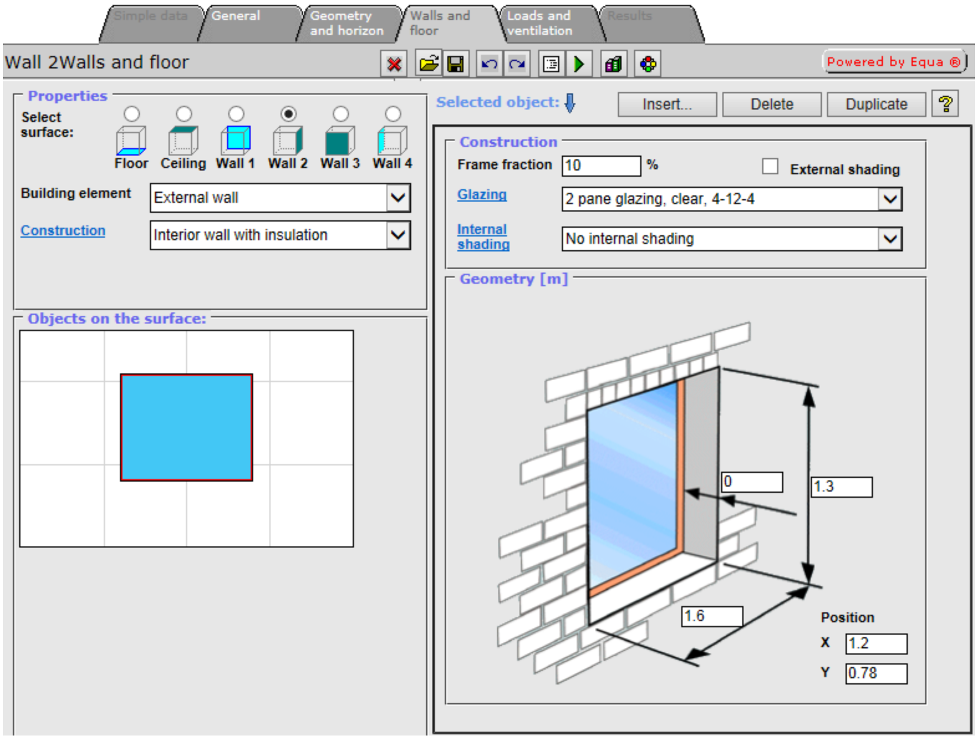


Figure 9: ProClim. Windows measures

Finally, in the last input data sheet, we can choose the heat gains and how much time we should take it in account, the supply and exhaust air flows with the schedules of the fan and chiller as well.

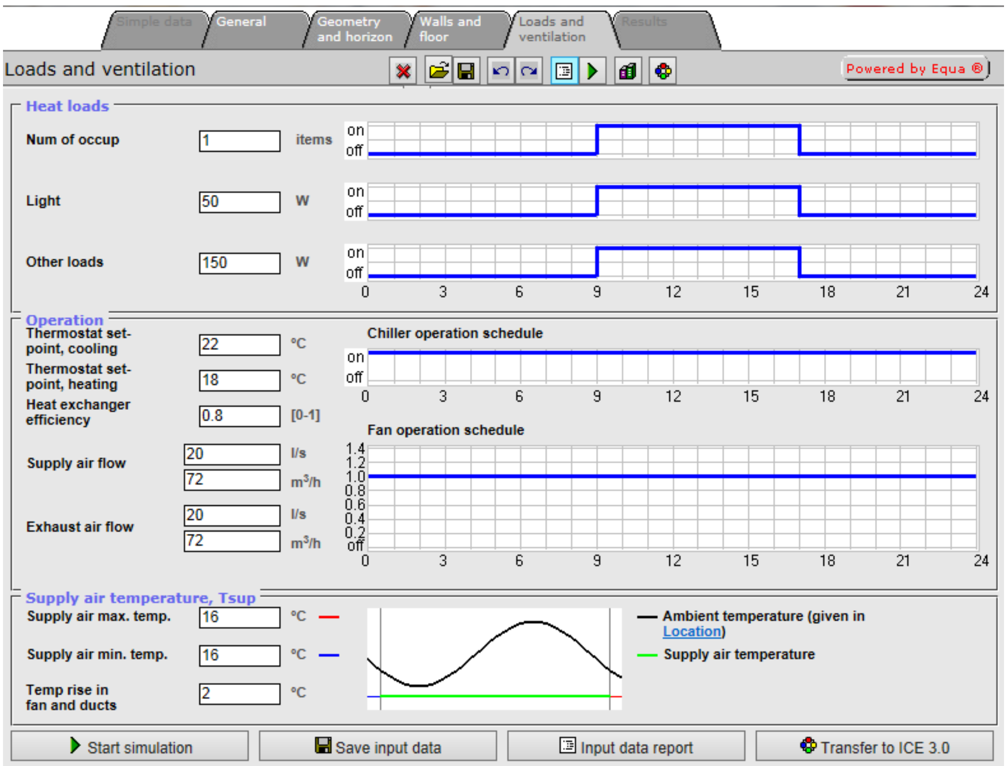


Figure 10: ProClim. Loads and ventilation

The last step is to start the simulation pressing that button and observe the results in the last sheet.

We will be able to observe the following aspects:

- Operative temperature during occupancy
- Maximum cooling power
- AHU temperatures
- Power supplied by plant
- Main temperatures
- Directed temperatures to envelopes
- Heat balance

6.2Cooling loads

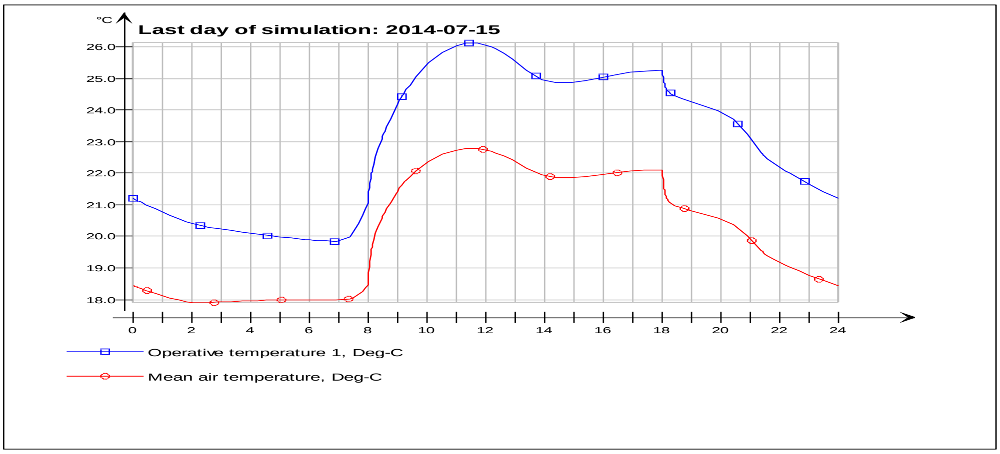
Zone 1

ROOM NAME	Room Number	Zone	Pc Madrid (W)	Pc Vilnius (W)
Copy/coffe	6	1	13080	12510
Secretary's office	7			
Waiting room	10			
Accounting	30			
Director's office	9			
WC	8			

Table 67: Cooling loads (Zone 1)

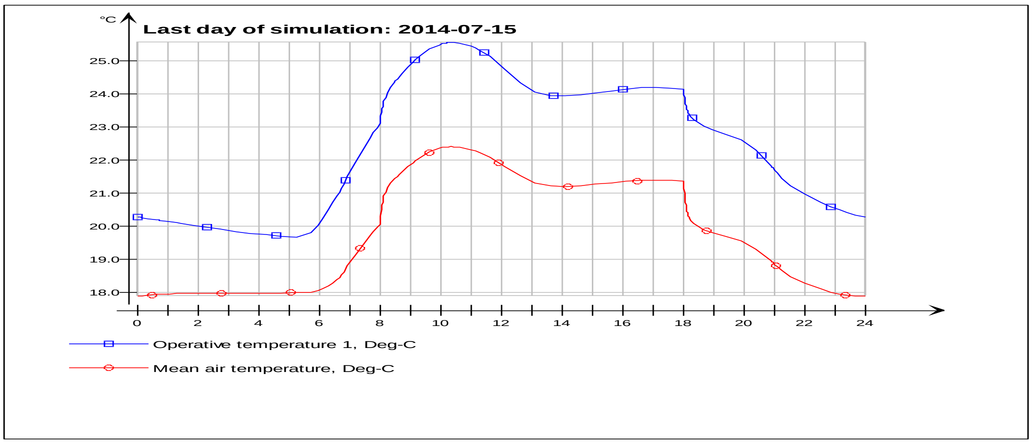
Main temperatures

Madrid



Graphic 5: Main indoor temp. zone 1 (Madrid)

Vilnius



Graphic 6: Main indoor temp.zone 1 (Vilnius)

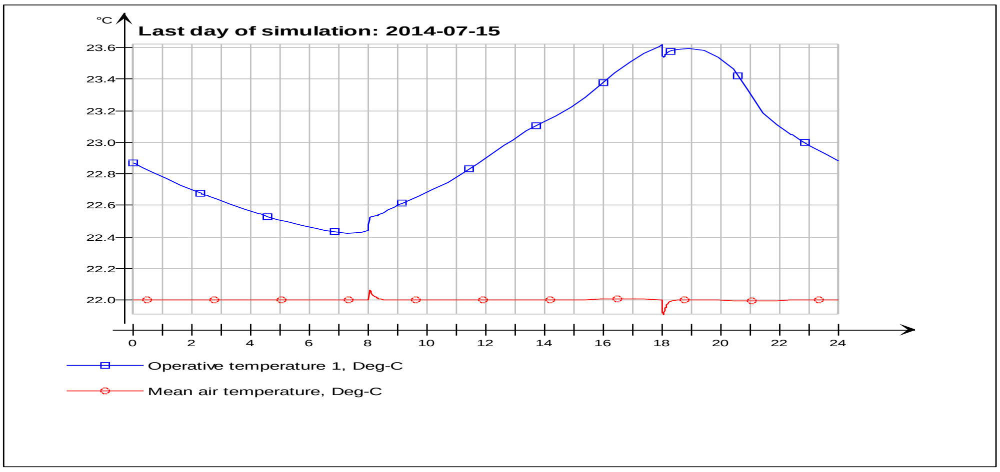
Zone 2

ROOM NAME	Room Number	Zone	Pc Madrid (W)	Pc Vilnius (W)
Internet room	3	2	5345	5188
Telecomunication office	14			
WC M.	11			
WC W.	12			
Corridor 1	4			
Corridor 2	5			

Table 68: Cooling loads (Zone 2)

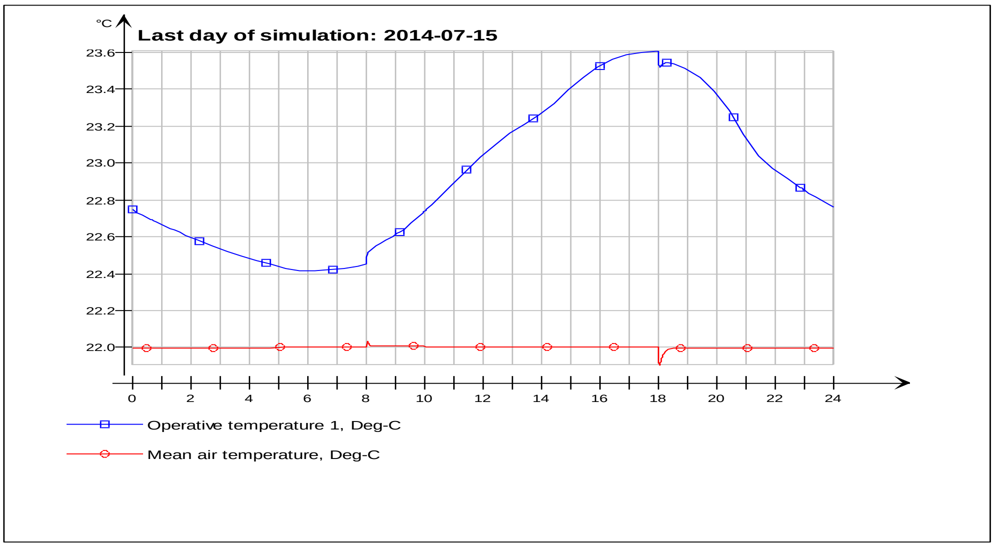
Main temperatures

Madrid



Graphic 7: Main indoor temp.zone 2 (Madrid)

Vilnius



Graphic 8: Main indoor temp.zone 2 (Vilnius)

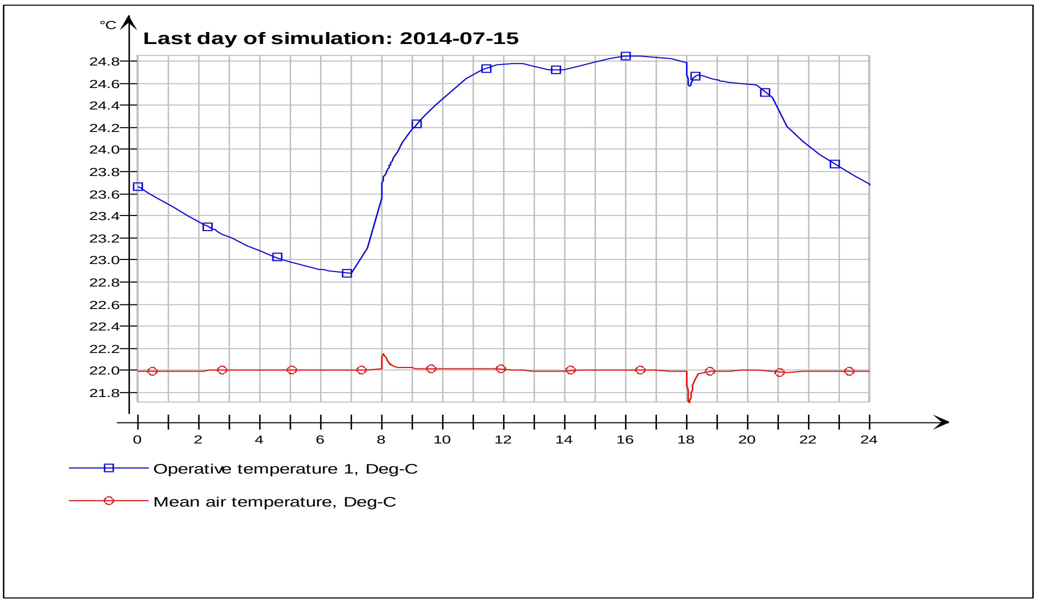
Zone 3

ROOM NAME	Room Number	Zone	Pc Madrid (W)	Pc Vilnius (W)
Hall	1	3	18820	16550

Table 69: Cooling loads (Zone 3)

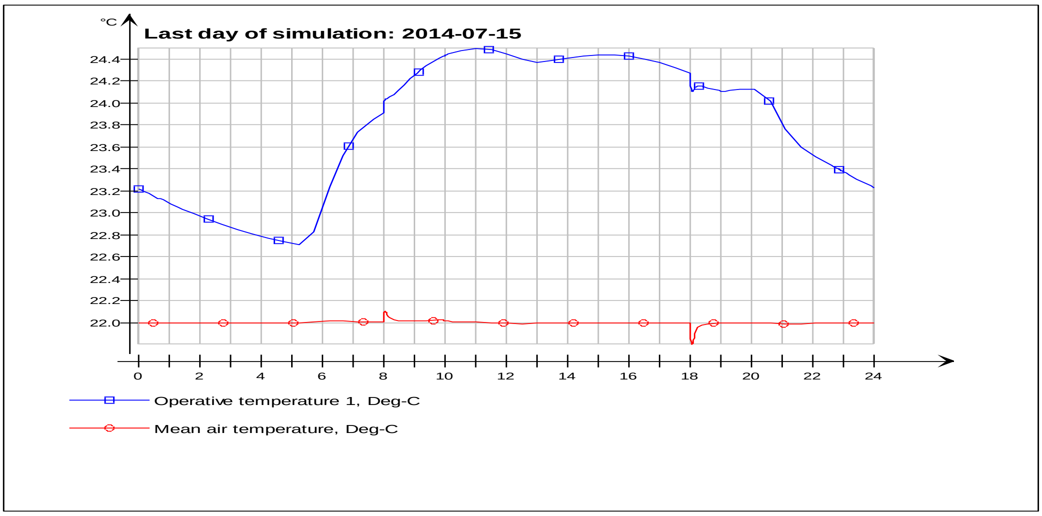
Main temperatures

Madrid



Graphic 9: Main indoor temp.zone 3 (Madrid)

Vilnius



Graphic 10: Main indoor temp.zone 3 (Vilnius)

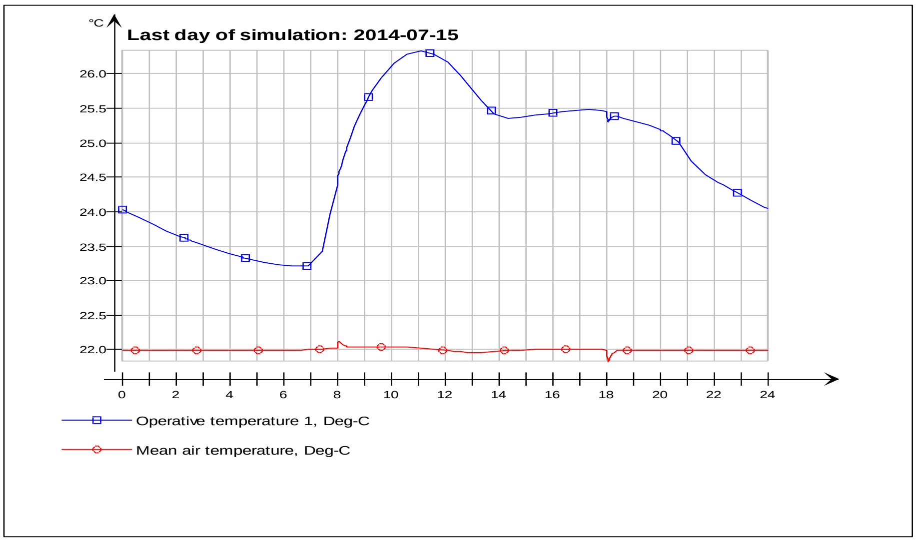
Zone 4

ROOM NAME	Room Number	Zone	Pc Madrid (W)	Pc Vilnius (W)
Business office 2	18	4	10400	9717
Office 1	19			

Table 70: Cooling loads (Zone 4)

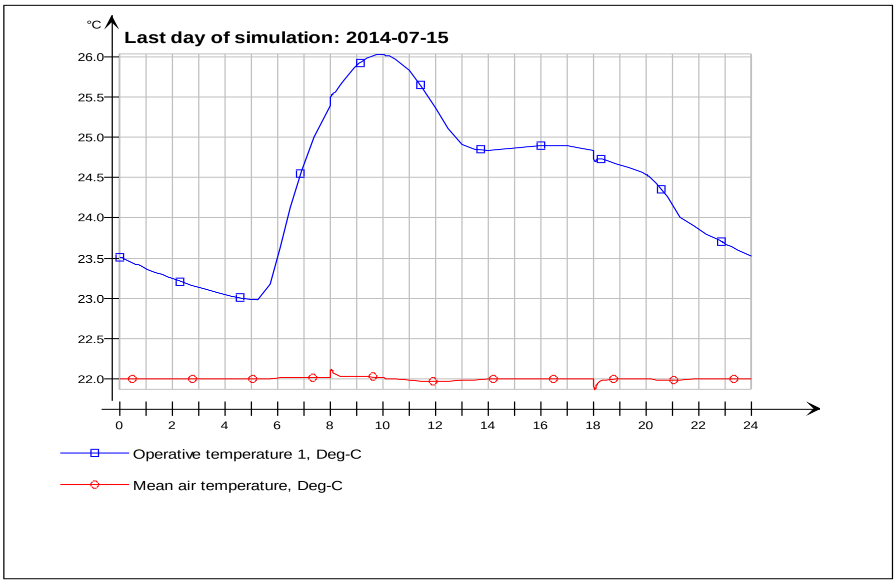
Main temperatures

Madrid



Graphic 11: Main indoor temp.zone 4 (Madrid)

Vilnius



Graphic 12: Main indoor temp.zone 4 (Vilnius)

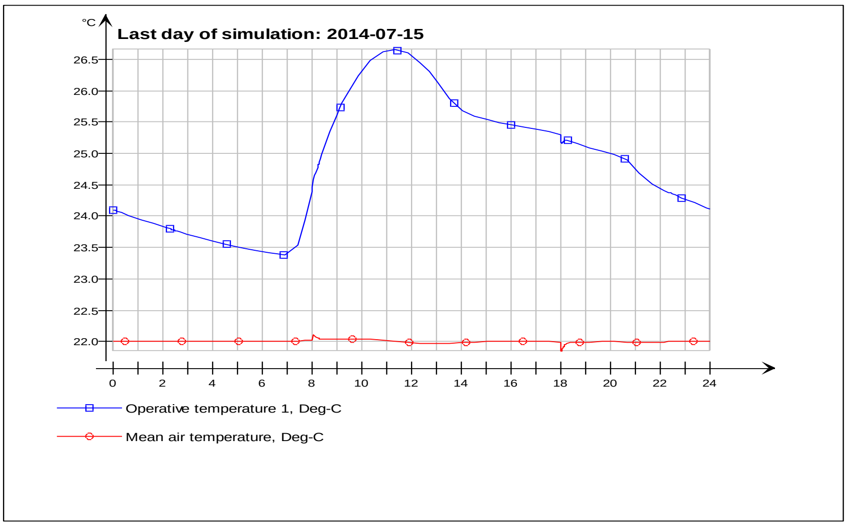
Zone 5

ROOM NAME	Room Number	Zone	Pc Madrid (W)	Pc Vilnius (W)
Conference hall	28	5	10070	9512
Private office	29			

Table 71: Cooling loads (Zone 5)

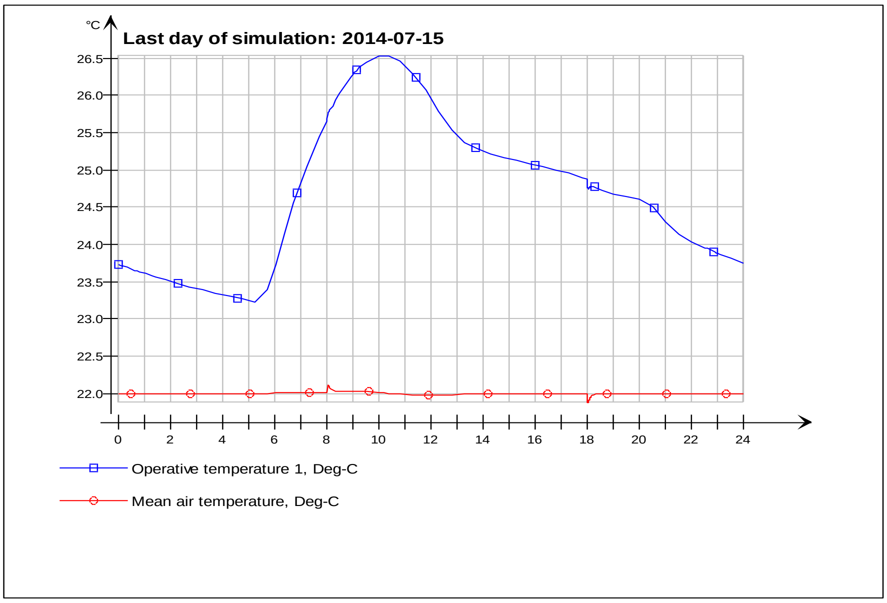
Main temperatures

Madrid



Graphic 13: Main indoor temp.zone 5 (Madrid)

Vilnius



Graphic 14: Main indoor temp.zone 5 (Vilnius)

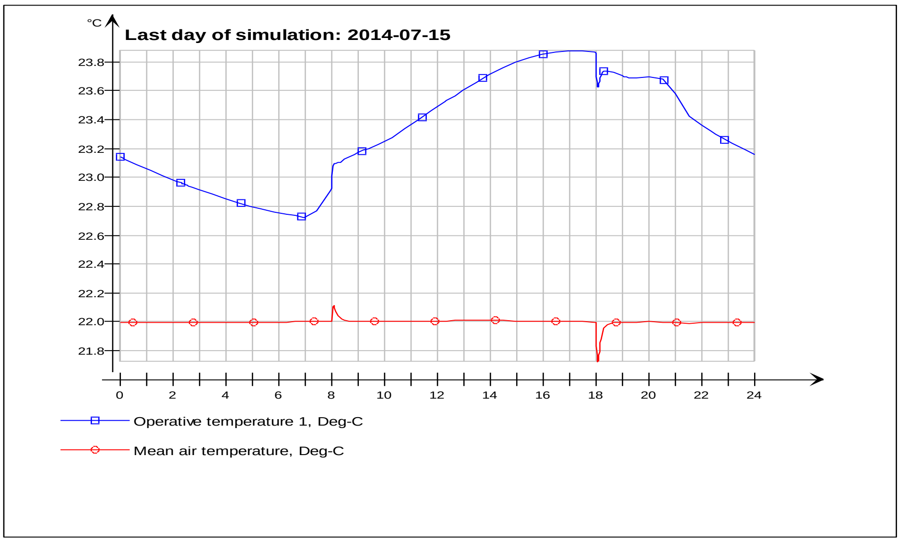
Zone 6

ROOM NAME	Room Number	Zone	Pc Madrid (W)	Pc Vilnius (W)
Corporative headquarters	26	6	5641	4606
WC	27			

Table 72: Cooling loads (Zone 6)

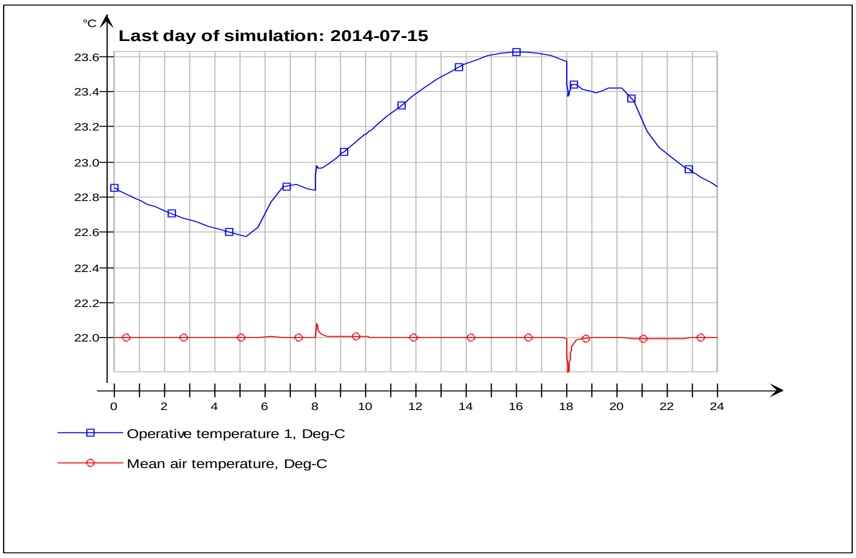
Main temperatures

Madrid



Graphic 15: Main indoor temp.zone 6 (Madrid)

Vilnius



Graphic 16: Main indoor temp.zone 6 (Vilnius)

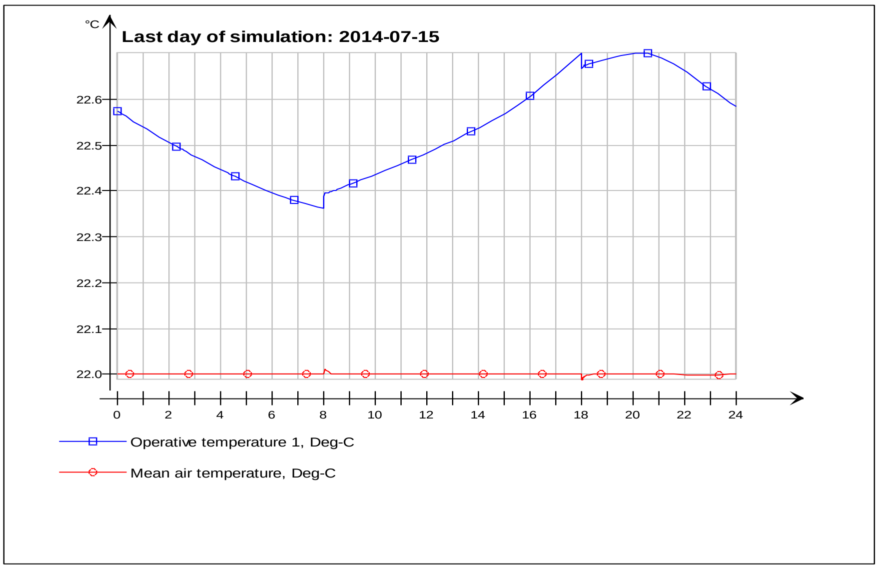
Zone 7

ROOM NAME	Room Number	Zone	Pc Madrid (W)	Pc Vilnius (W)
Office 2	16	7	864,8	734,9
Corridor 2	17			

Table 73: Cooling loads (Zone 7)

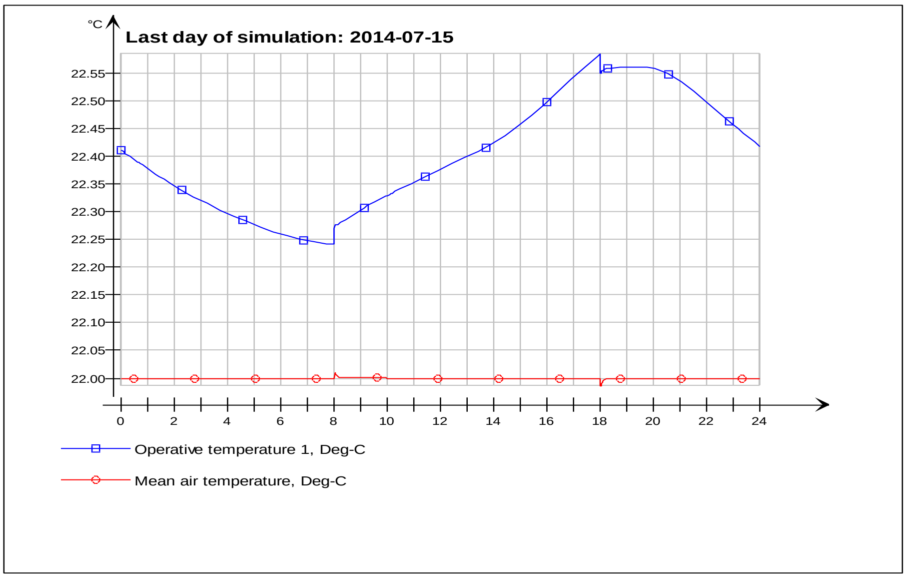
Main temperatures

Madrid



Graphic 17: Main indoor temp.zone 7 (Madrid)

Vilnius



Graphic 18: Main indoor temp.zone 7 (Vilnius)

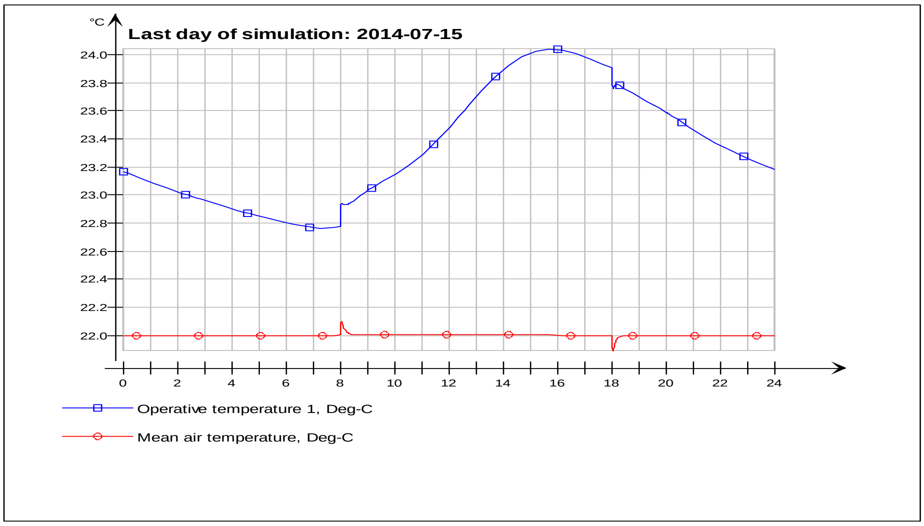
Zone 8

ROOM NAME	Room Number	Zone	Pc Madrid (W)	Pc Vilnius (W)
Business office 1	15	8	5278	6073
Presentation office 1	22			
Presentation office 2	23			

Table 74: Cooling loads (Zone 8)

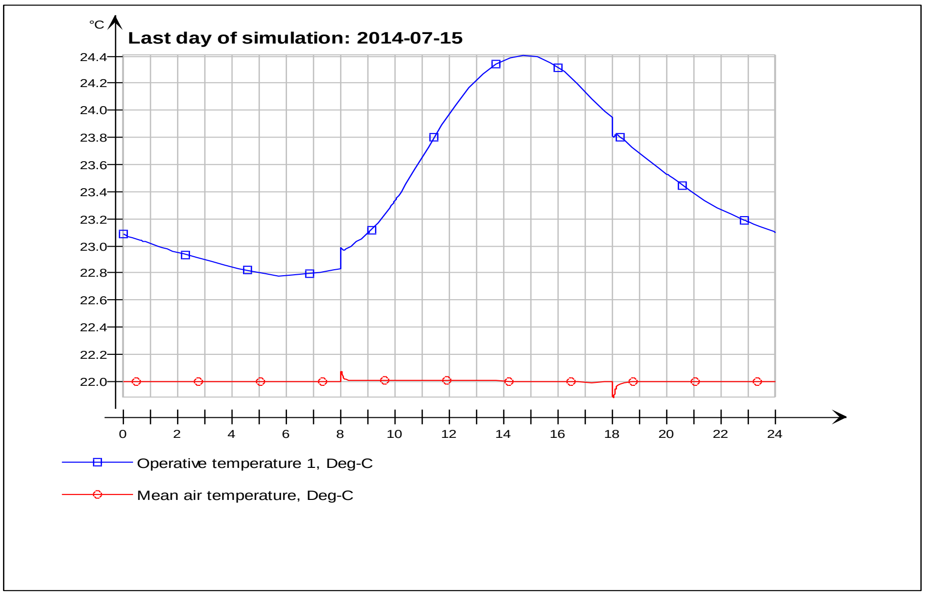
Main temperatures

Madrid



Graphic 19: Main indoor temp.zone 8 (Madrid)

Vilnius



Graphic 20: Main indoor temp.zone 8 (Vilnius)

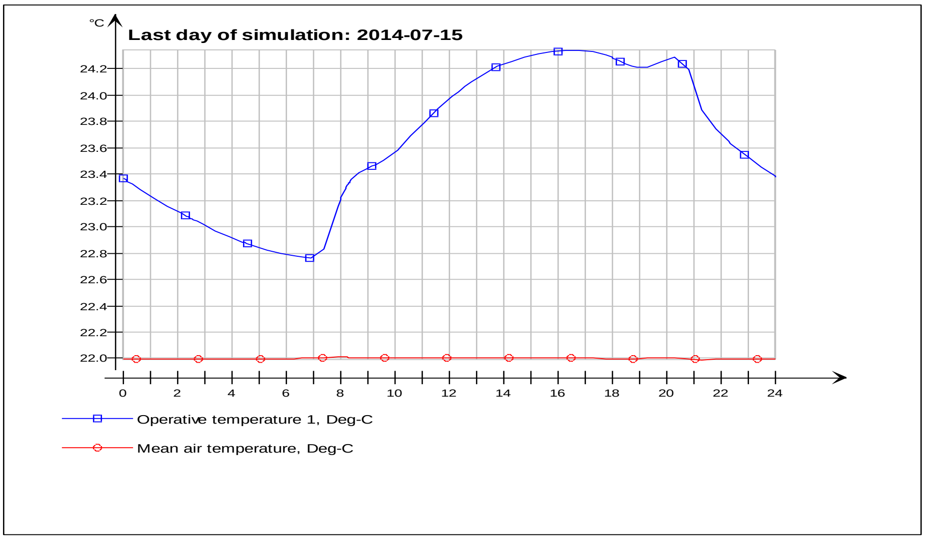
Zone 9

ROOM NAME	Room Number	Zone	Pc Madrid (W)	Pc Vilnius (W)
WC M.	20	9	5180	3636
WC W.	21			
Corridor 1	24			

Table 75: Cooling loads (Zone 9)

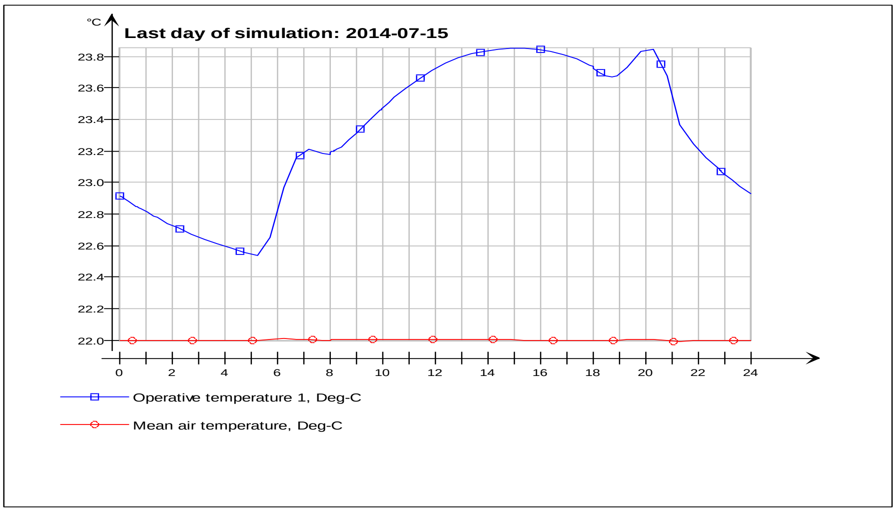
Main temperatures

Madrid



Graphic 21: Main indoor temp.zone 9 (Madrid)

Vilnius



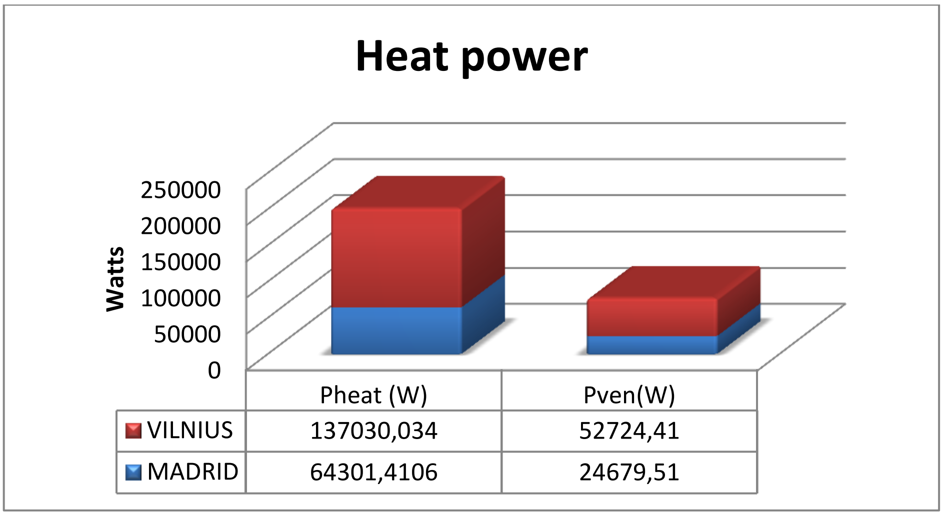
Graphic 22: Main indoor temp.zone 9 (Vilnius)

7.CONCLUSIONS

As we can see, the heat power that we would need in Vilnius is much bigger than the heat power that we are using in Madrid. We could expect this result because the design temperatures gap in winter is much bigger than in Madrid. That is why the U-values used in the envelopes' designing in Vilnius are much bigger in order to compensate these energy requirements.

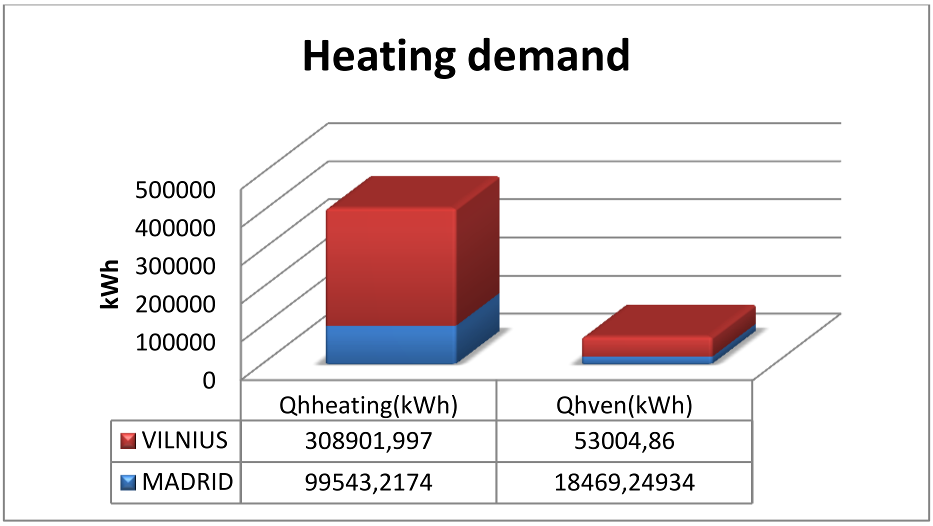
Due to this difference, we can also observe the differences in the heating demand and of course in the price. In the case of the price we can observe a really big difference because the price of the heating in Vilnius is also around 40% higer than in Madrid. This is the main reason to choose another kind of materials and the main reason to do a bit bigger investment in materials and isolations. We will be able to save money and the environment.

Heat power



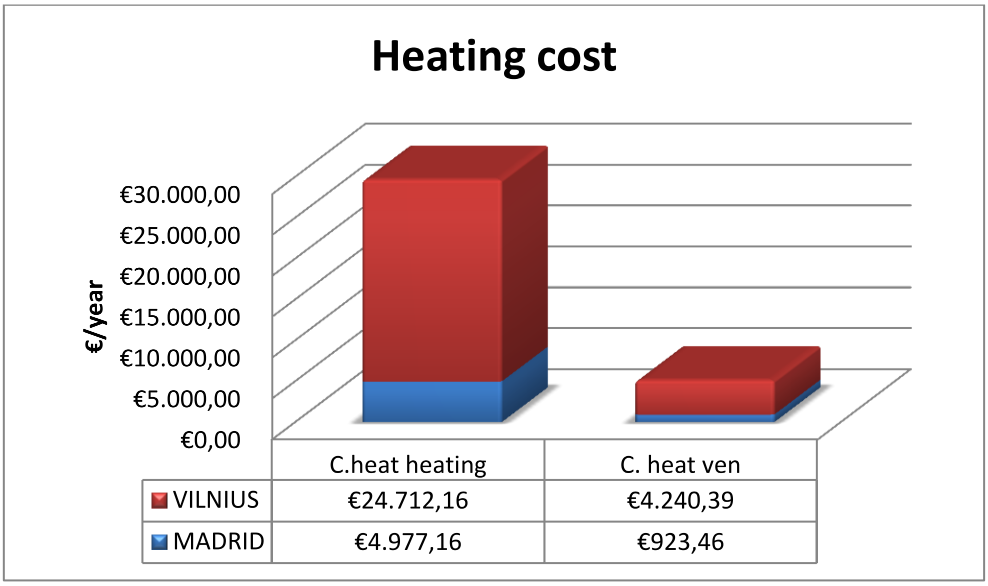
Graphic 23: Heat power

Heat demand



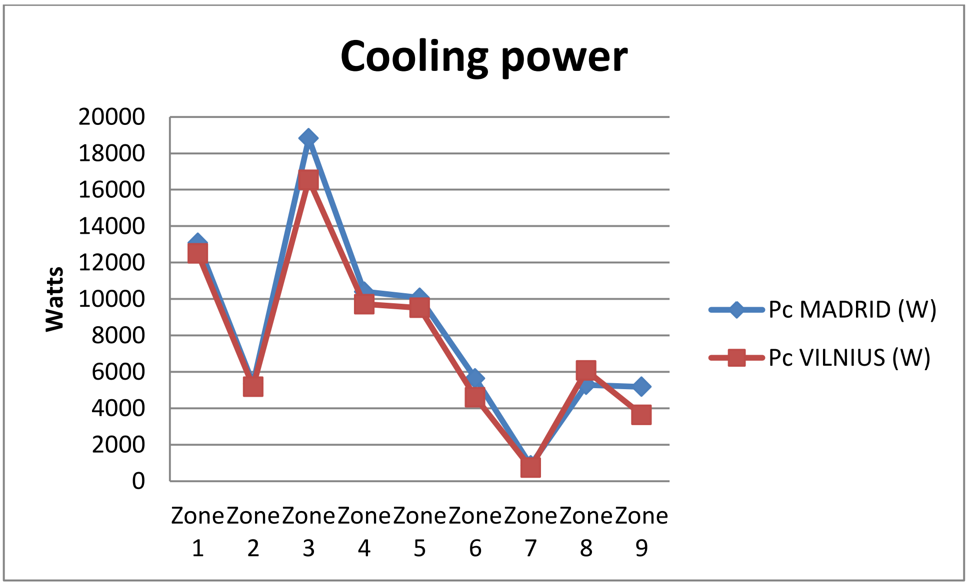
Graphic 24: Heating demand

Heating cost



Graphic 25: Heating cost

Cooling power



Graphic 26: Cooling power

In the chart above we can see the cooling power in each zone of our building. There is no a big difference between Vilnius and Madrid because the characteristics of the day where the simulation has been done are quite similar in both cities. Even so, we can notice how the global power is still higher in Madrid than in Vilnius, originated by the higher temperatures taken in Madrid during the summer period.

REFERENCES

- Climatic data Madrid: www.aemet.es (agencia estatal de meteorología).
- Climatic data Vilnius: World Meteorological Organization (avg high and low) NOAA (sun and extremes)
    - Weatherbase (precipitation and humidity)
    - Statybine klimatologija RSN 156-94
- Basic document HE
- Código Técnico de la Edificación (CTE)
- Reglamento de Instalaciones Térmicas en Edificios (RITE)
- Software Proclim Swegon (http://proclim.equa.biz/ProClimWeb1.14/english/login.html)
- Heating BS 2013
- Ventilation BS 2013

DRAWINGS

ANNEXES

Madrid

Cooling zone 1

Simulation results

Extremes

The zone

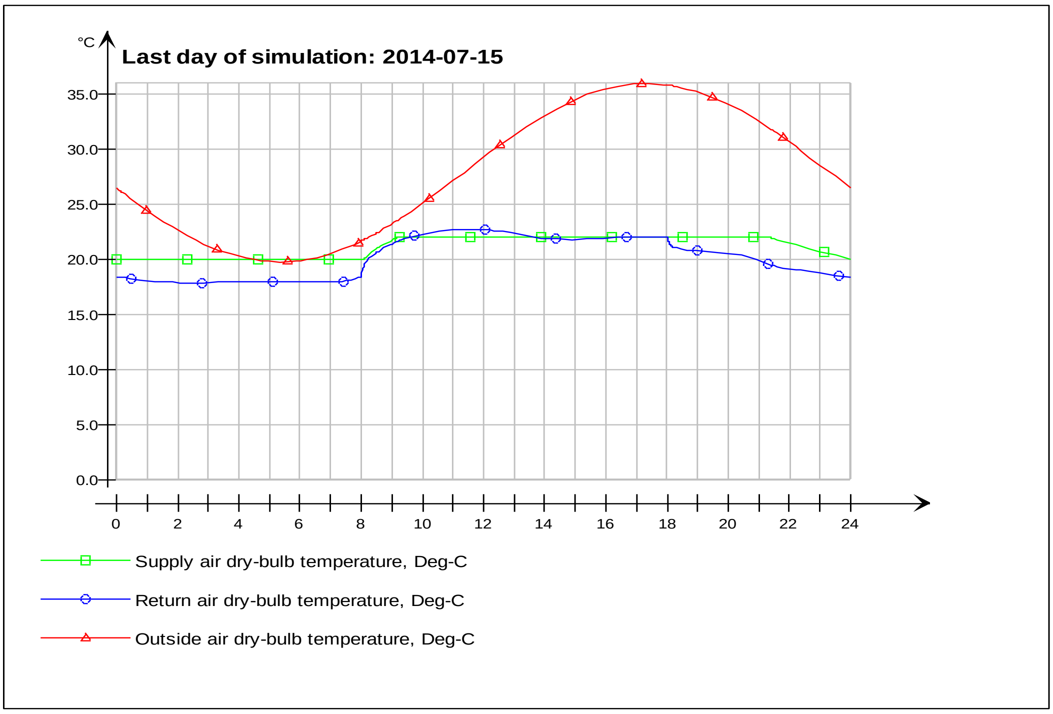
		Value	Occurs at
Operative temperature during occupancy [°C]	min	21.1	8:00
	max	26.1	11:43
Max cooling power [W]	Waterborne	13080.0	11:22
	Airborne*	1544.0	11:22
Max heating power [W]	Waterborne		
	Airborne*	434.2	8:02

*inkl. Infiltration

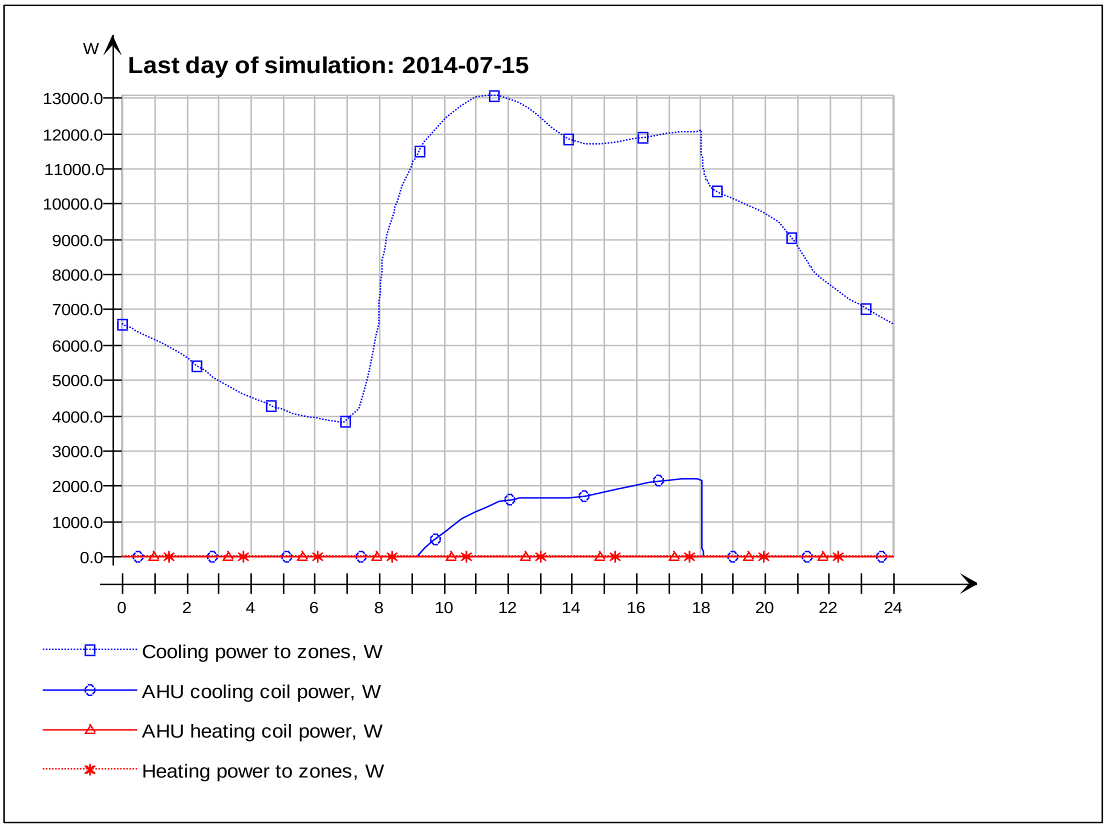
Air handling unit

	Value	Occurs at
Max cooling power [W]	2192.0	17:24
Max heating power [W]	8.4	4:32

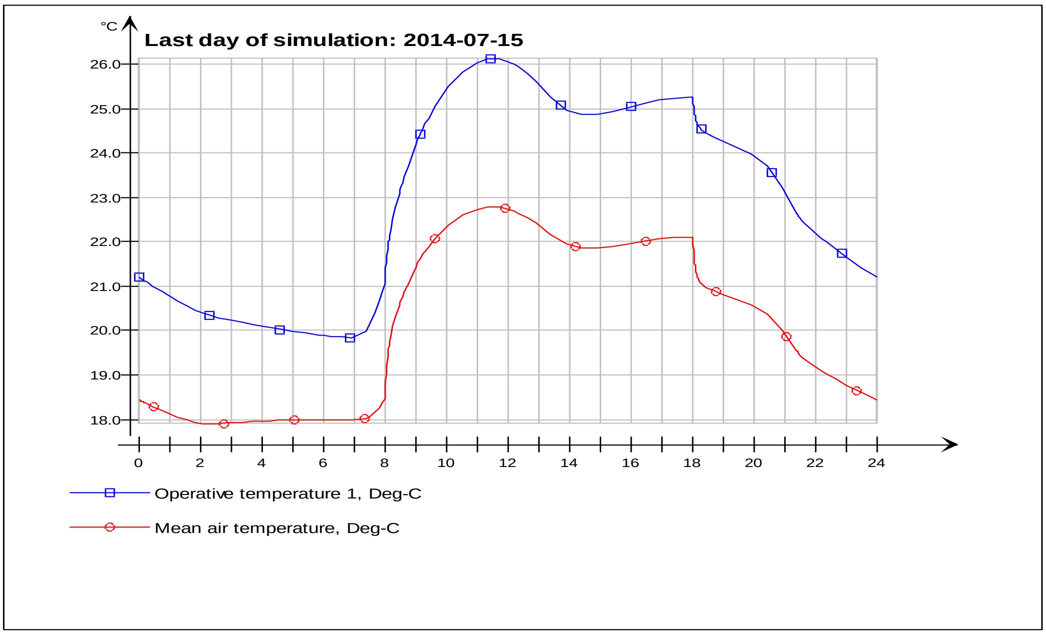
AHU temperatures



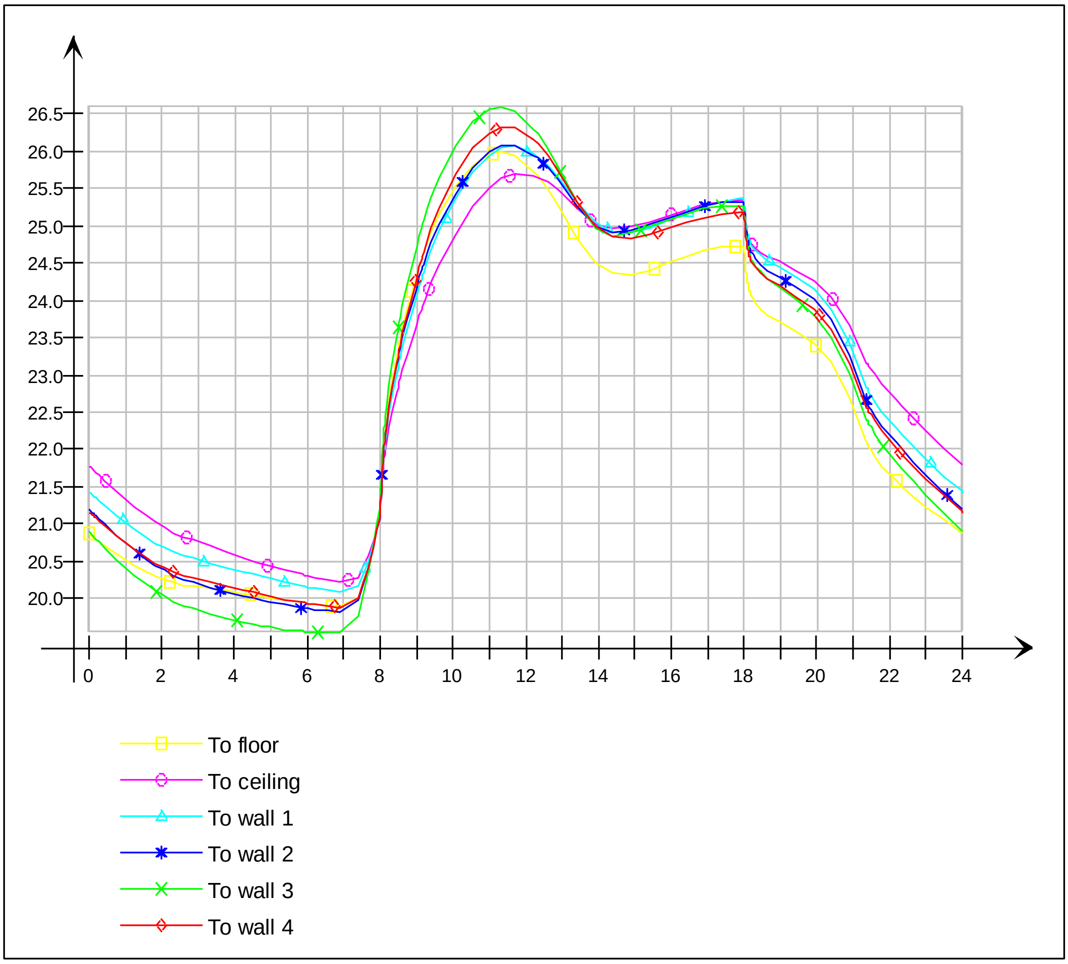
Power supplied by plant



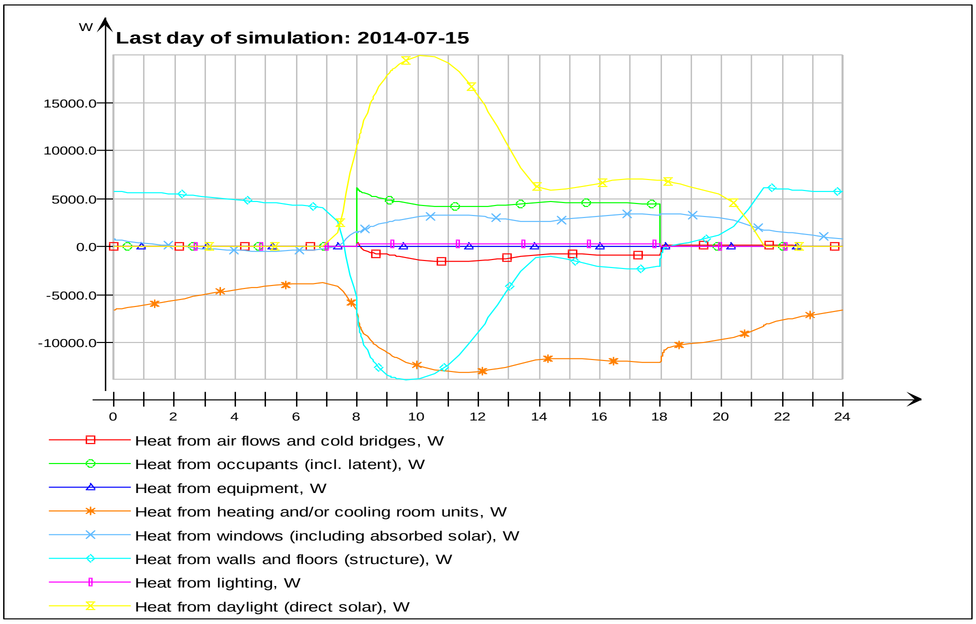
Main temperatures



Directed operative temperatures



Heat balance



Cooling zone 2

Simulation results

Extremes

The zone

		Value	Occurs at
Operative temperature during occupancy [°C]	min	22.4	8:00
	max	23.6	18:00
Max cooling power [W]	Waterborne	5345.0	18:00
	Airborne*	683.9	12:21
Max heating power [W]	Waterborne		
	Airborne*	138.9	18:12

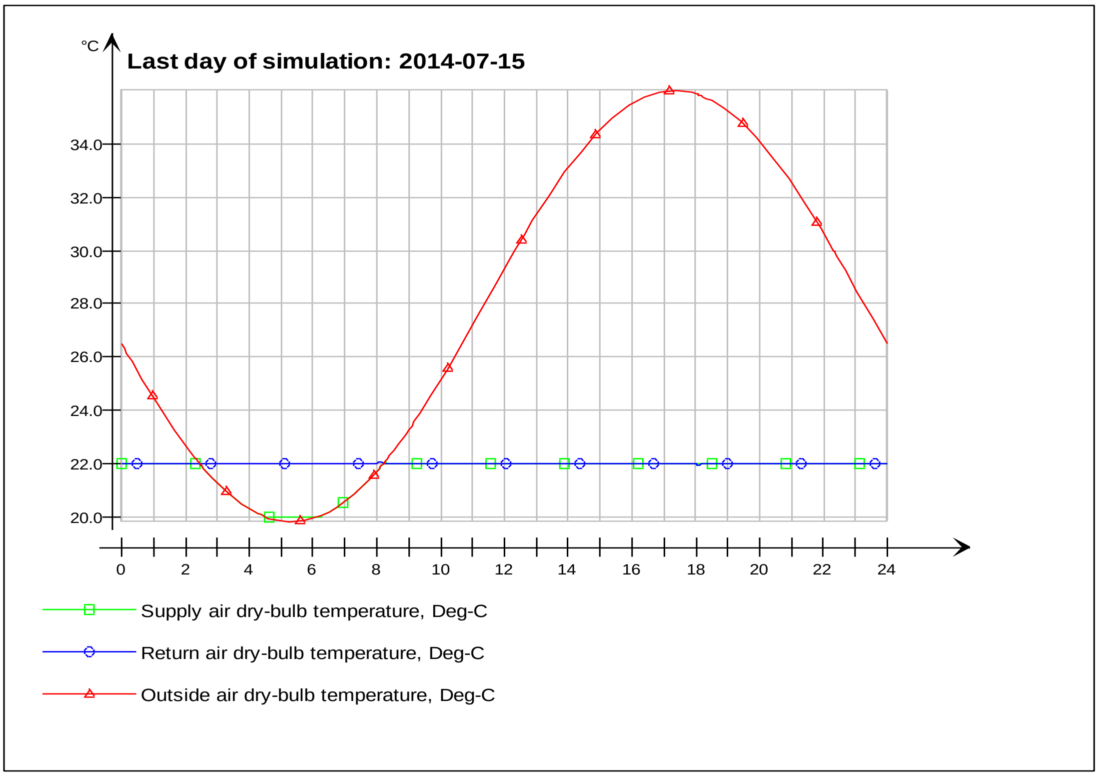
*inkl. Infiltration

Air handling unit

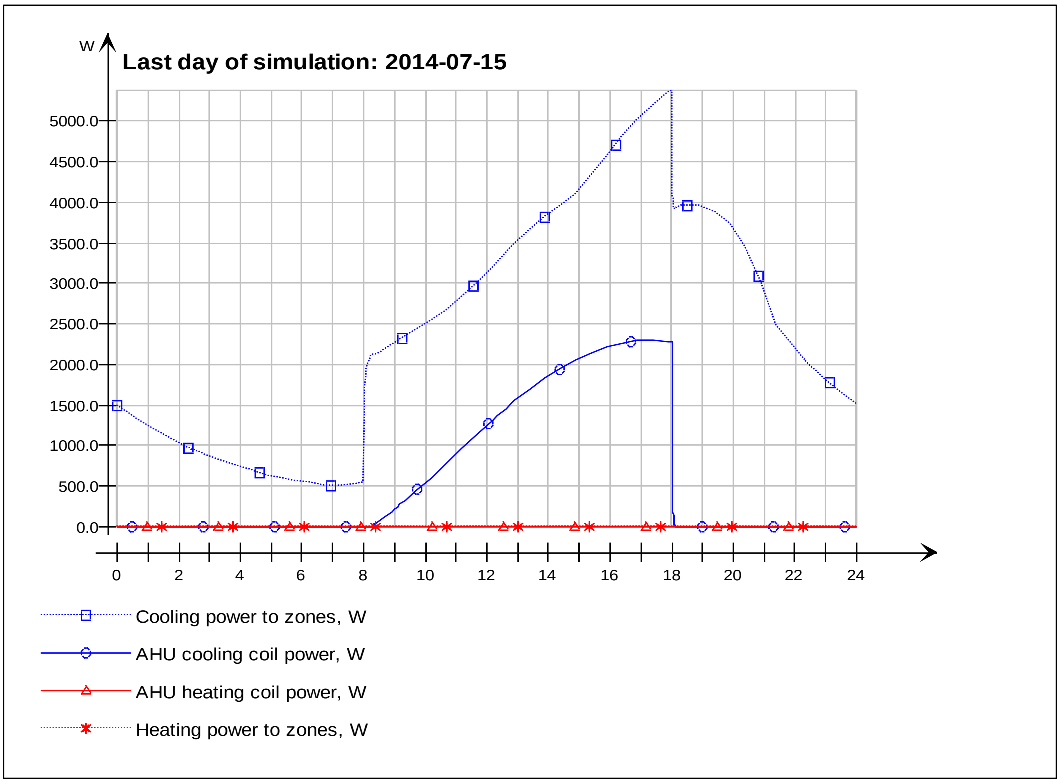
	Value	Occurs at
Max cooling power [W]	2305.0	17:24

Max heating power [W]		

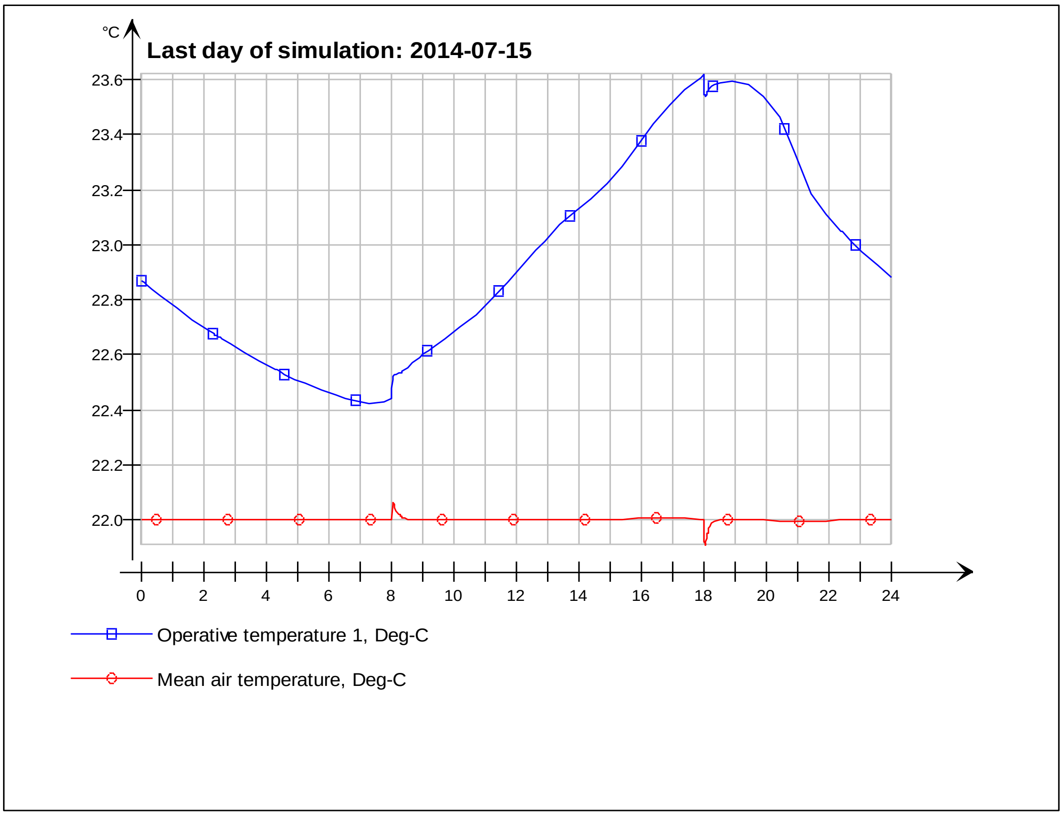
AHU temperatures



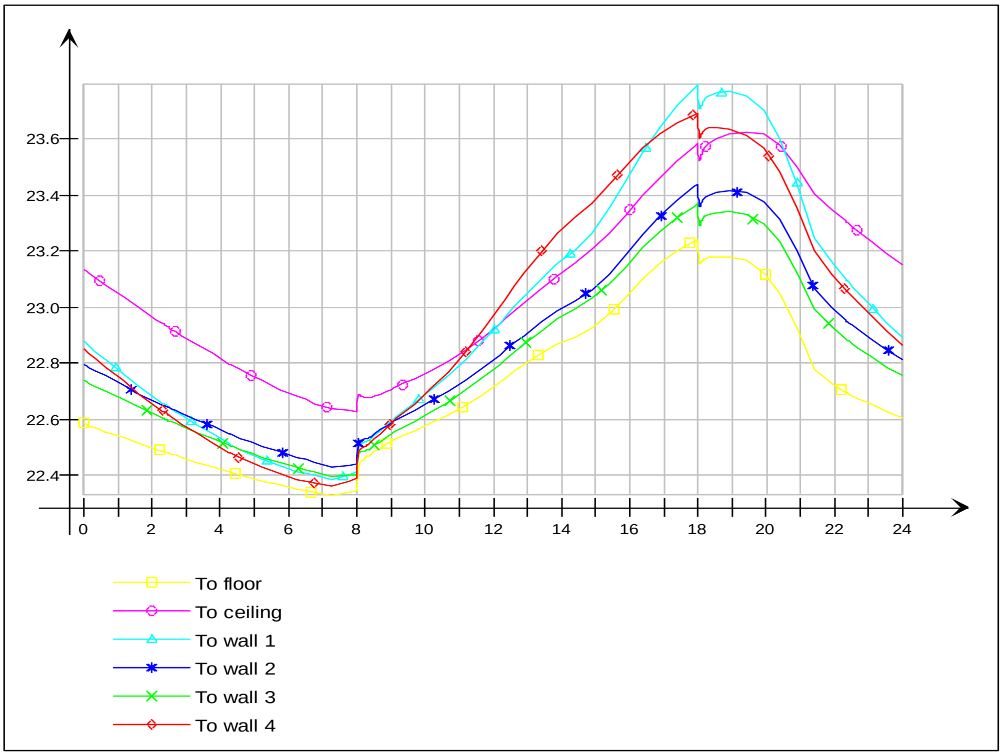
Power supplied by plant



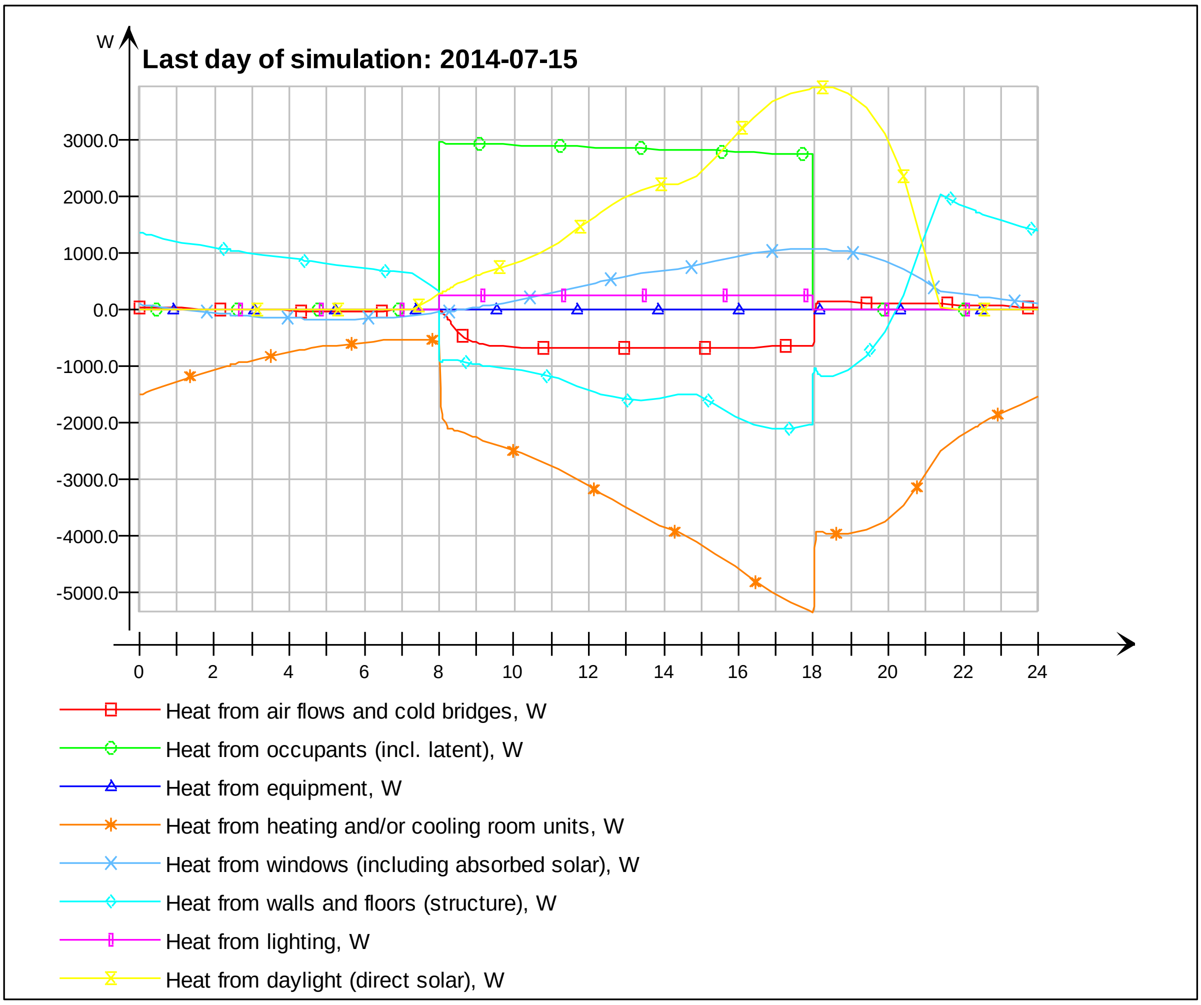
Main temperatures



Directed operative temperatures



Heat balance



Cooling zone 3

Simulation results

Extremes

The zone

		Value	Occurs at
Operative temperature during occupancy [°C]	min	23.6	8:00
	max	24.9	16:28
Max cooling power [W]	Waterborne	18820.0	16:28
	Airborne*	2069.0	11:47

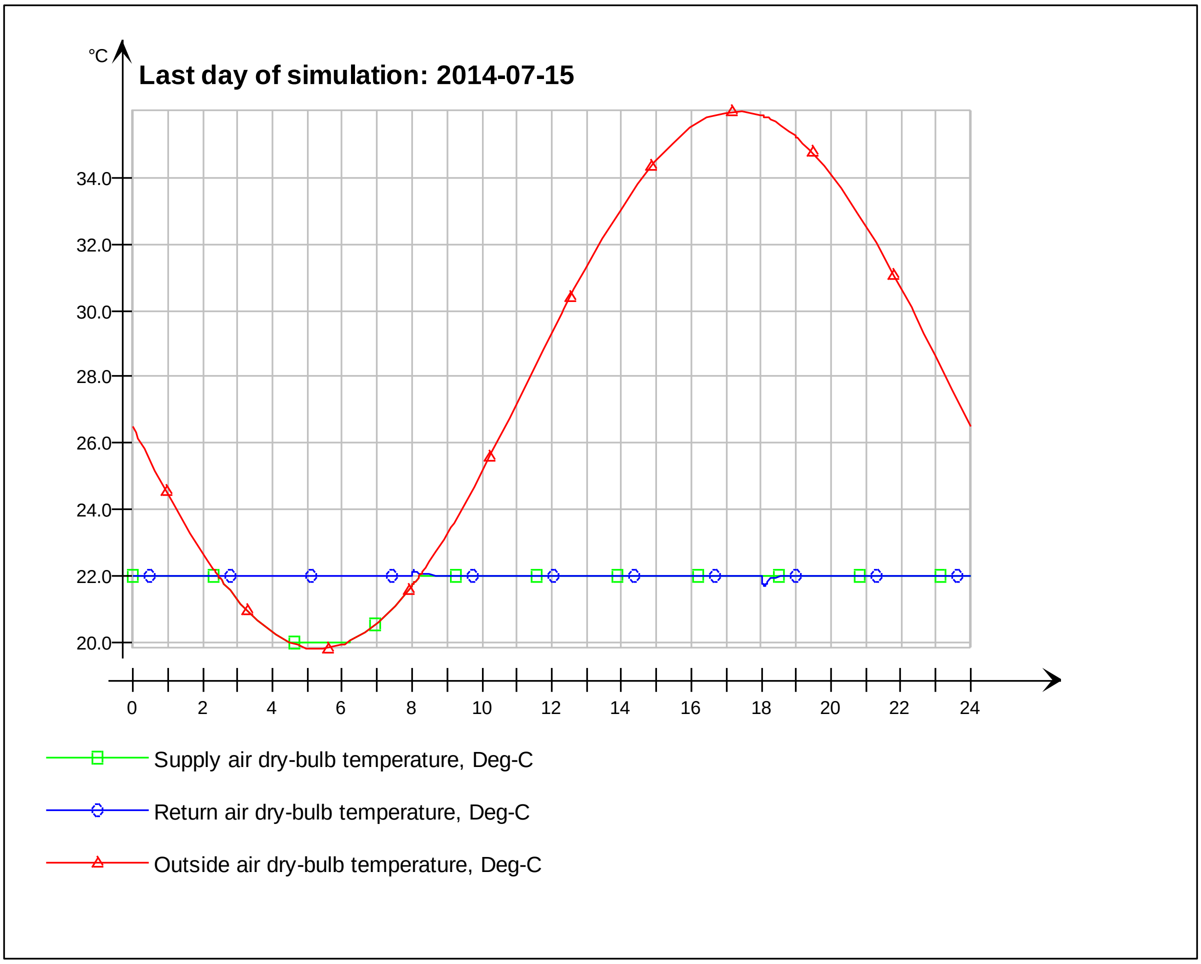
Max heating power [W]	Waterborne		
	Airborne*	194.4	18:10

*inkl. Infiltration

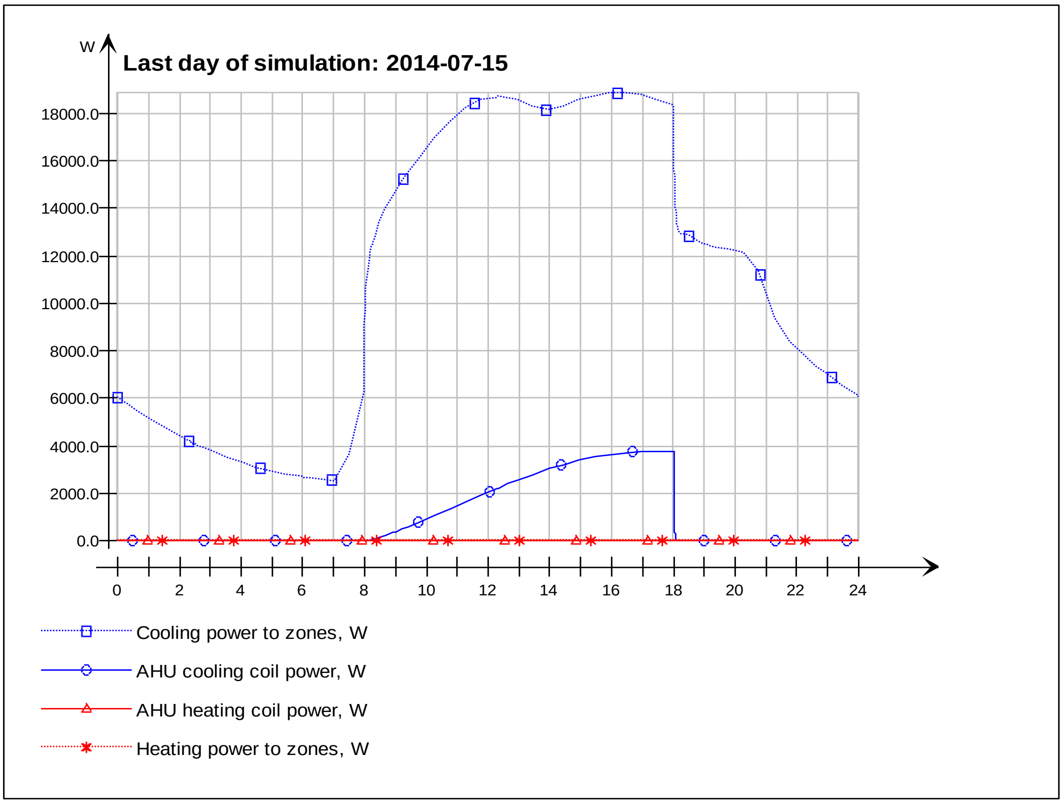
Air handling unit

	Value	Occurs at
Max cooling power [W]	3758.0	17:28
Max heating power [W]		

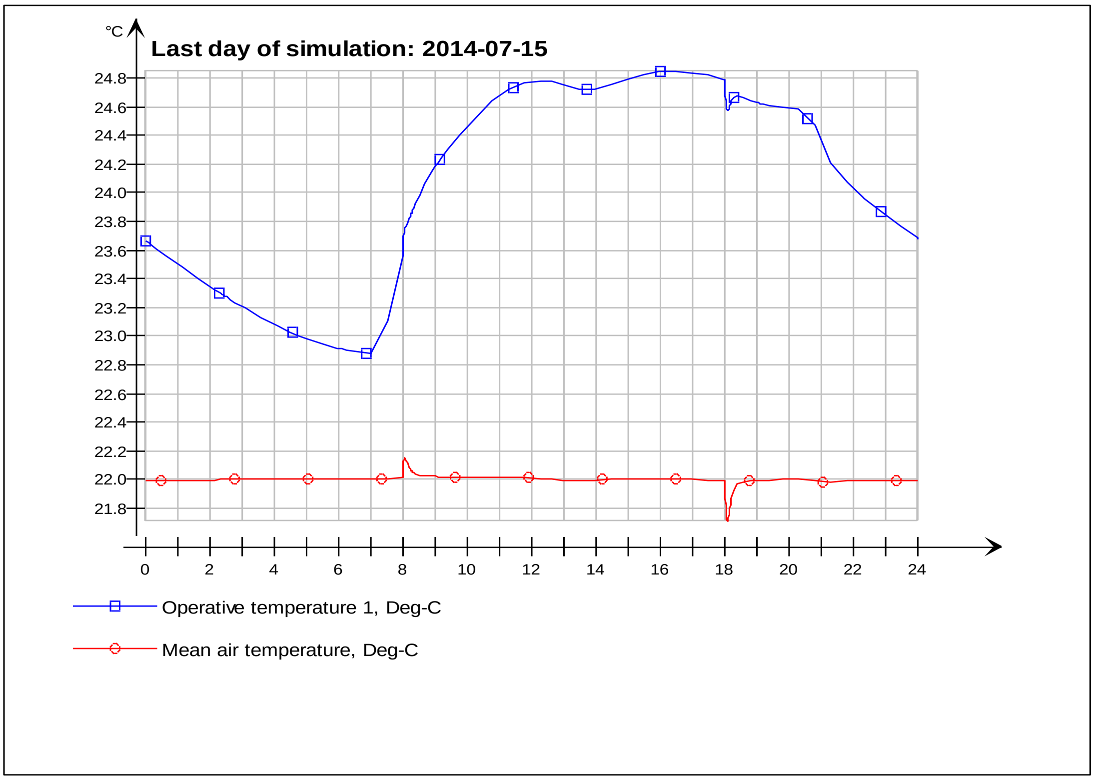
AHU temperatures



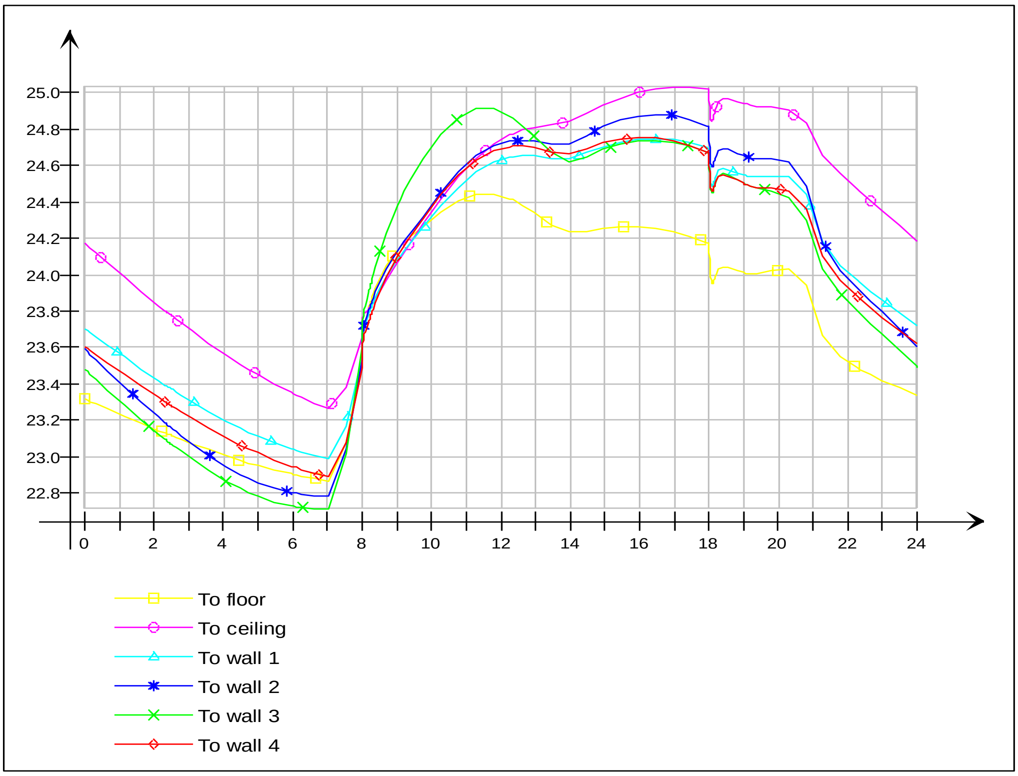
Power supplied by plant



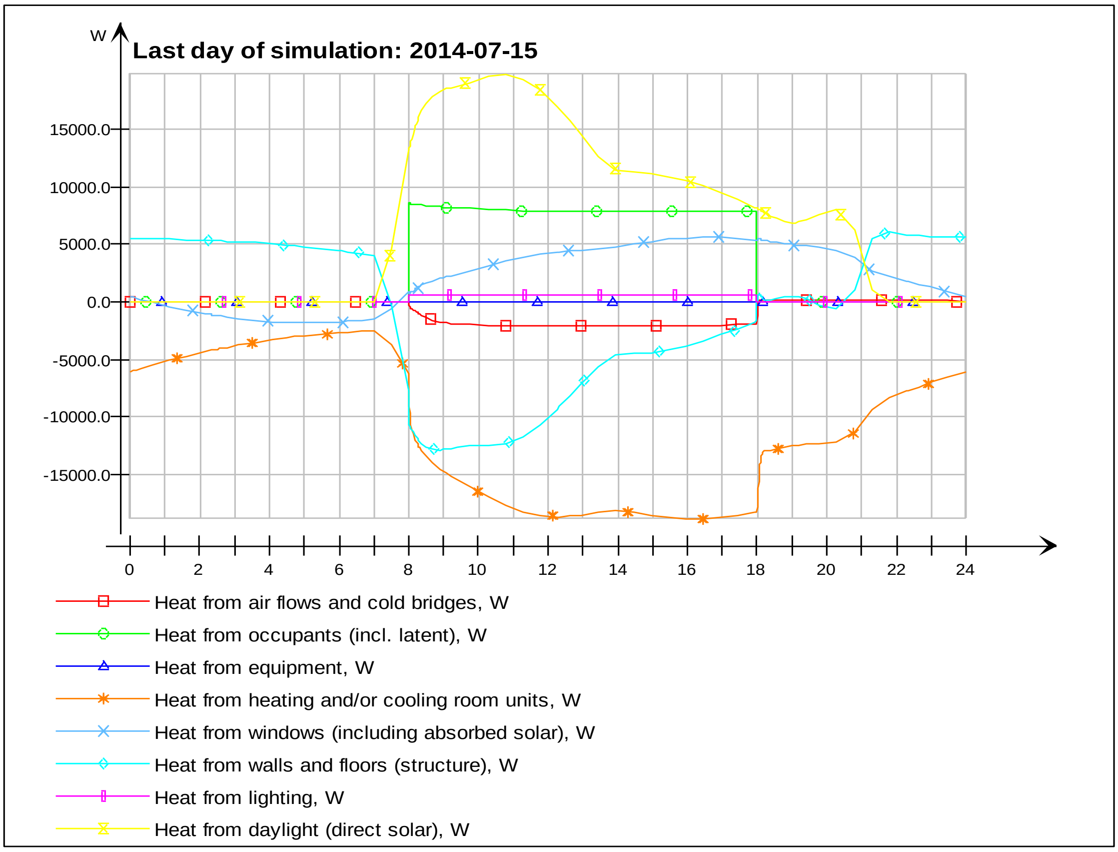
Main temperatures



Directed operative temperatures



Heat balance



Cooling zone 4

Simulation results

Extremes

The zone

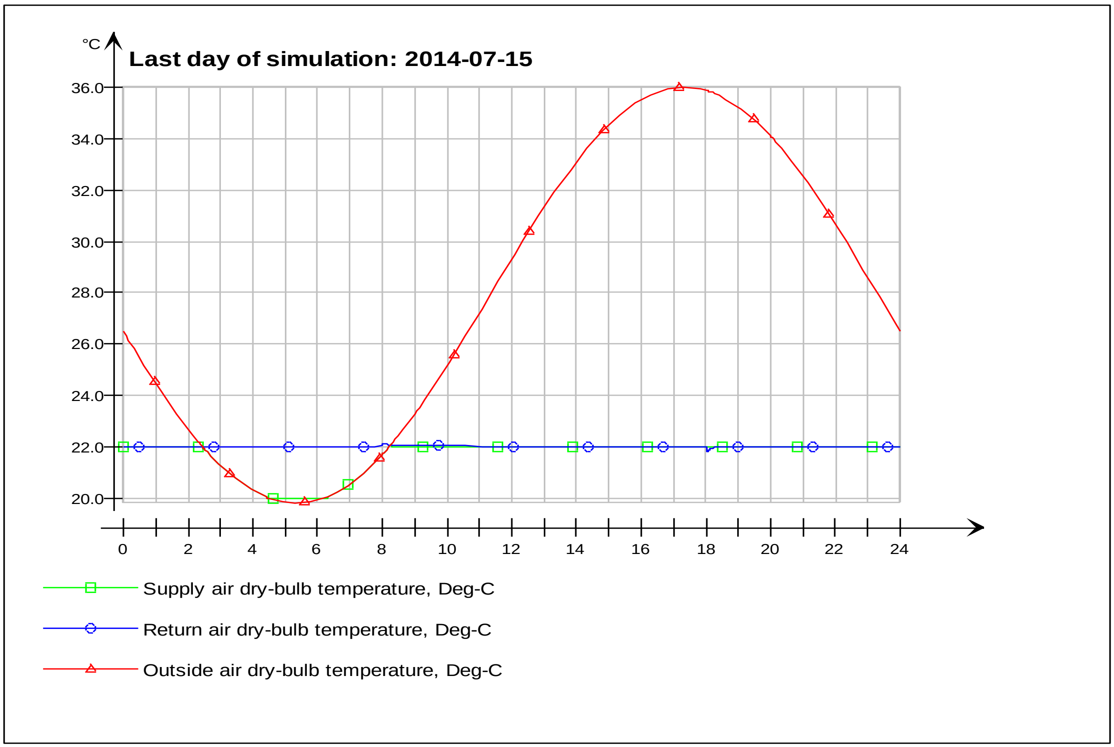
		Value	Occurs at
Operative temperature during occupancy [°C]	min	24.4	8:00
	max	26.3	11:05
Max cooling power [W]	Waterborne	10400.0	11:05
	Airborne*	657.7	11:05
Max heating power [W]	Waterborne		
	Airborne*	81.6	18:11

*inkl. Infiltration

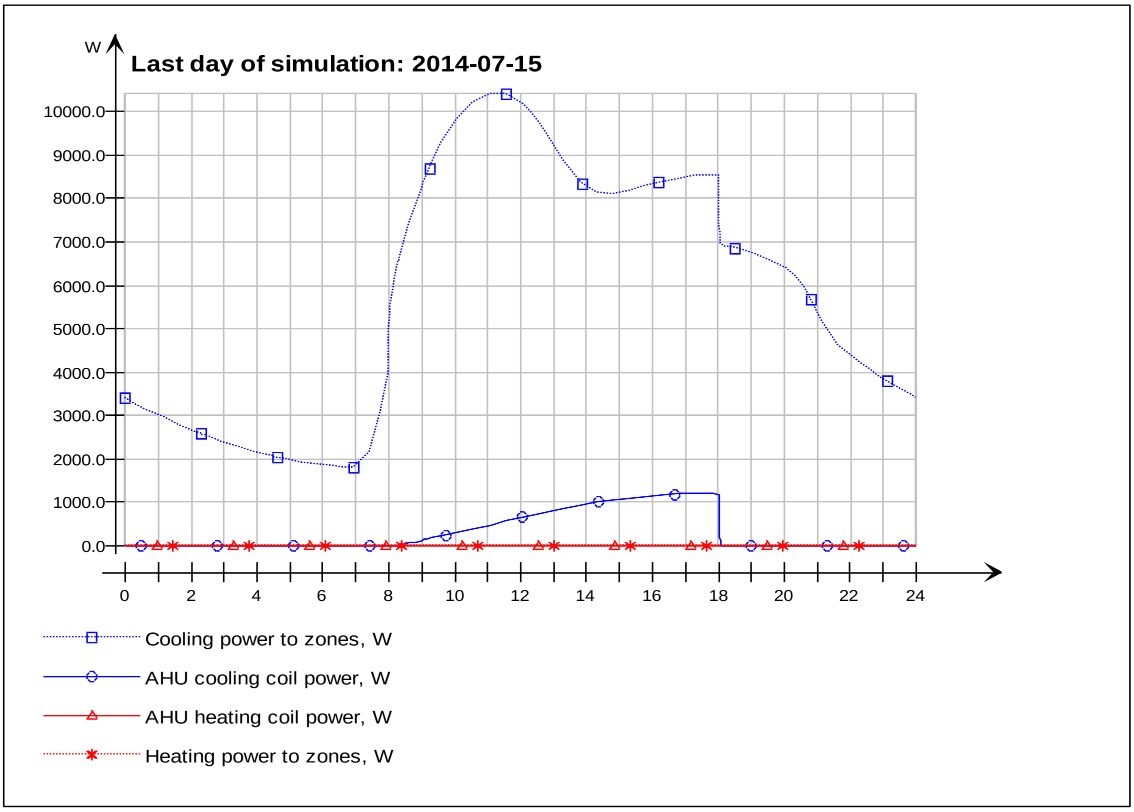
Air handling unit

	Value	Occurs at
Max cooling power [W]	1199.0	17:19
Max heating power [W]		

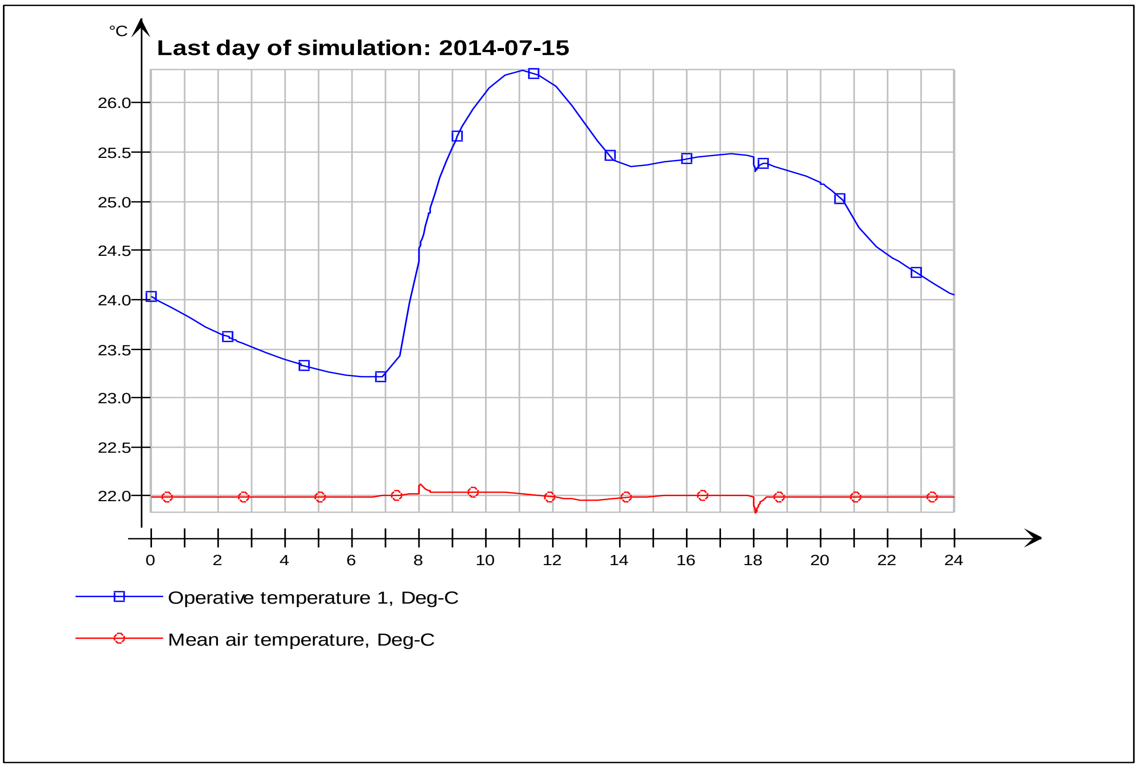
AHU temperatures



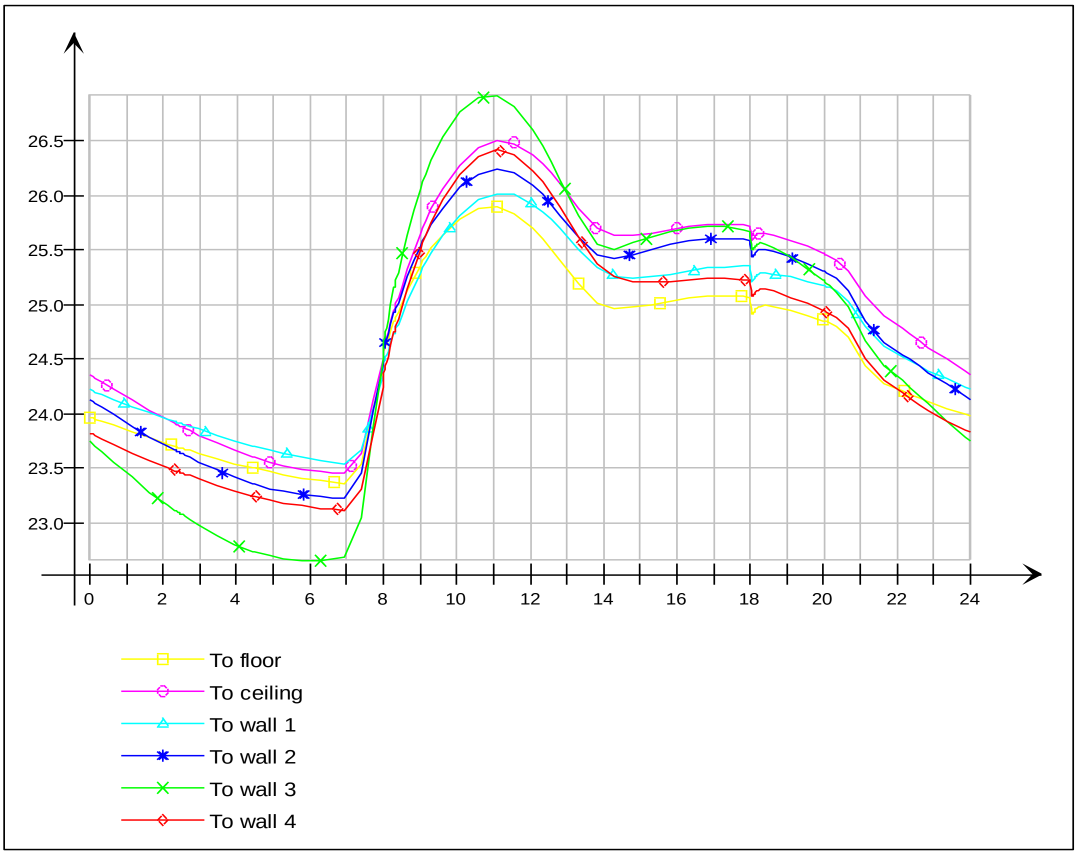
Power supplied by plant



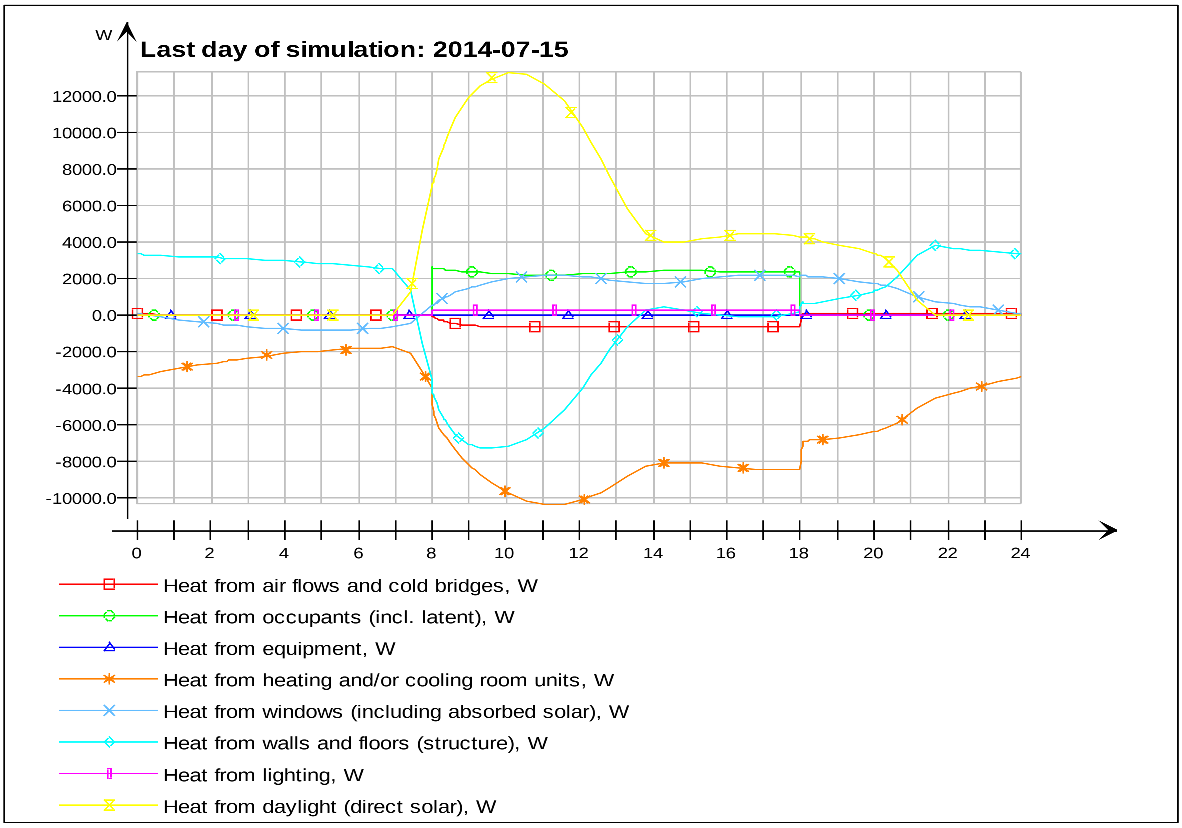
Main temperatures



Directed operative temperatures



Heat balance



Cooling zone 5

Simulation results

Extremes

The zone

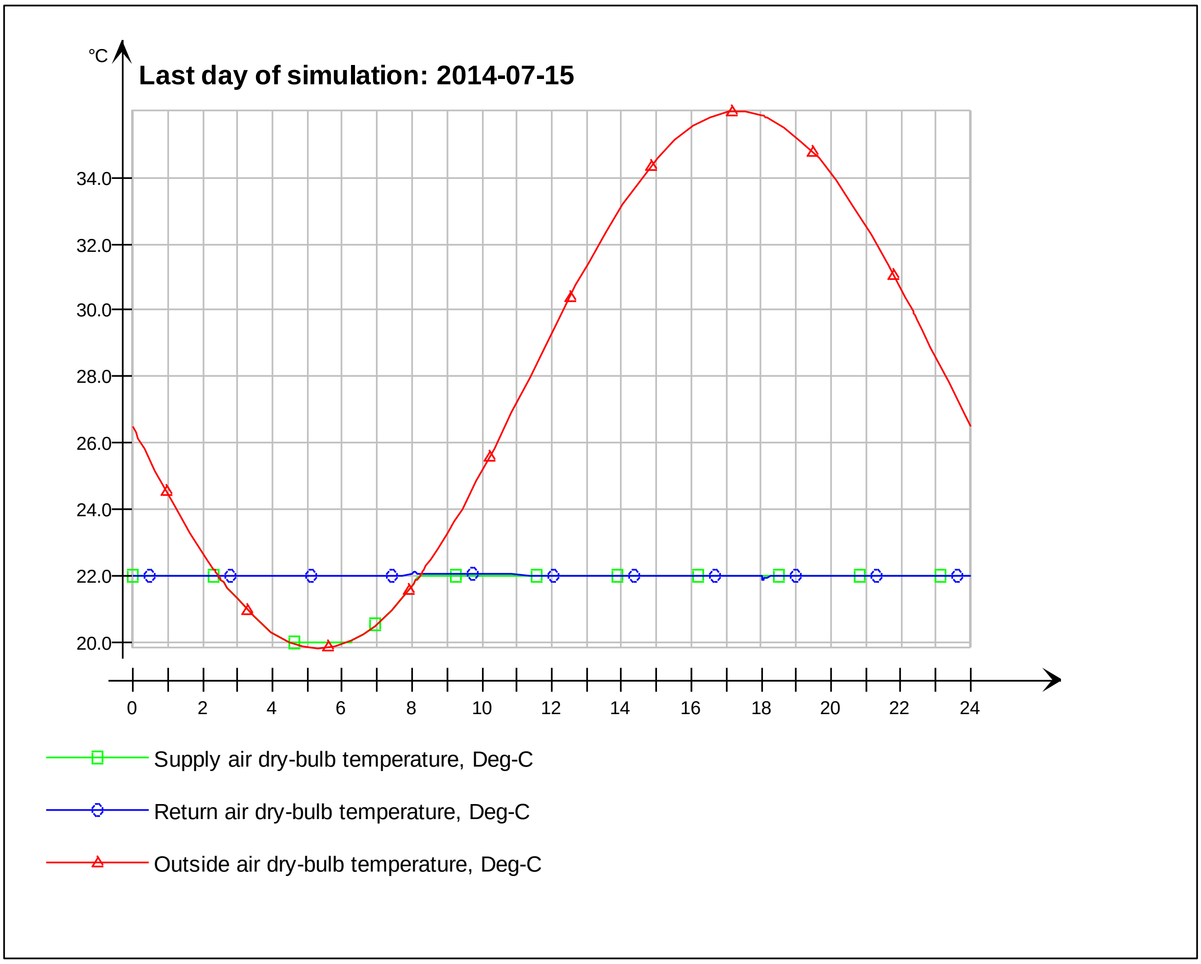
		Value	Occurs at
Operative temperature during occupancy [°C]	min	24.4	8:00
	max	26.7	11:22
Max cooling power [W]	Waterborne	10070.0	11:22
	Airborne*	741.0	11:22
Max heating power [W]	Waterborne		
	Airborne*	20.4	18:15

*inkl. Infiltration

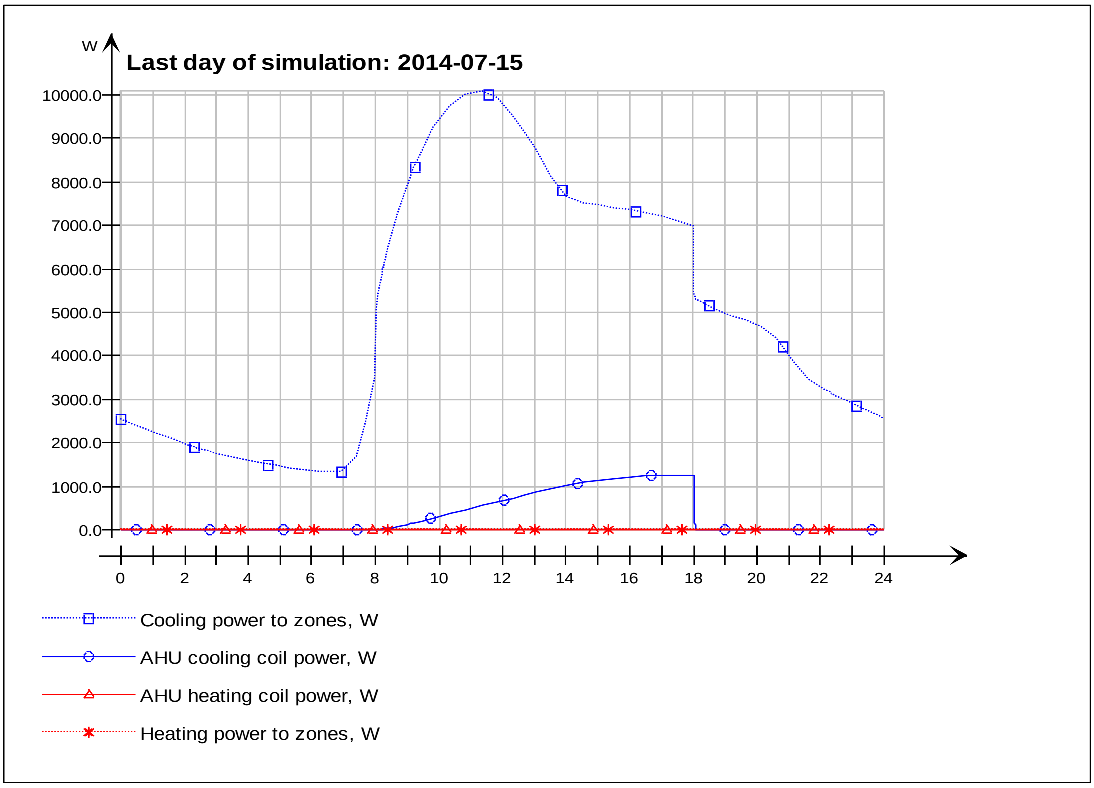
Air handling unit

	Value	Occurs at
Max cooling power [W]	1253.0	17:33
Max heating power [W]		

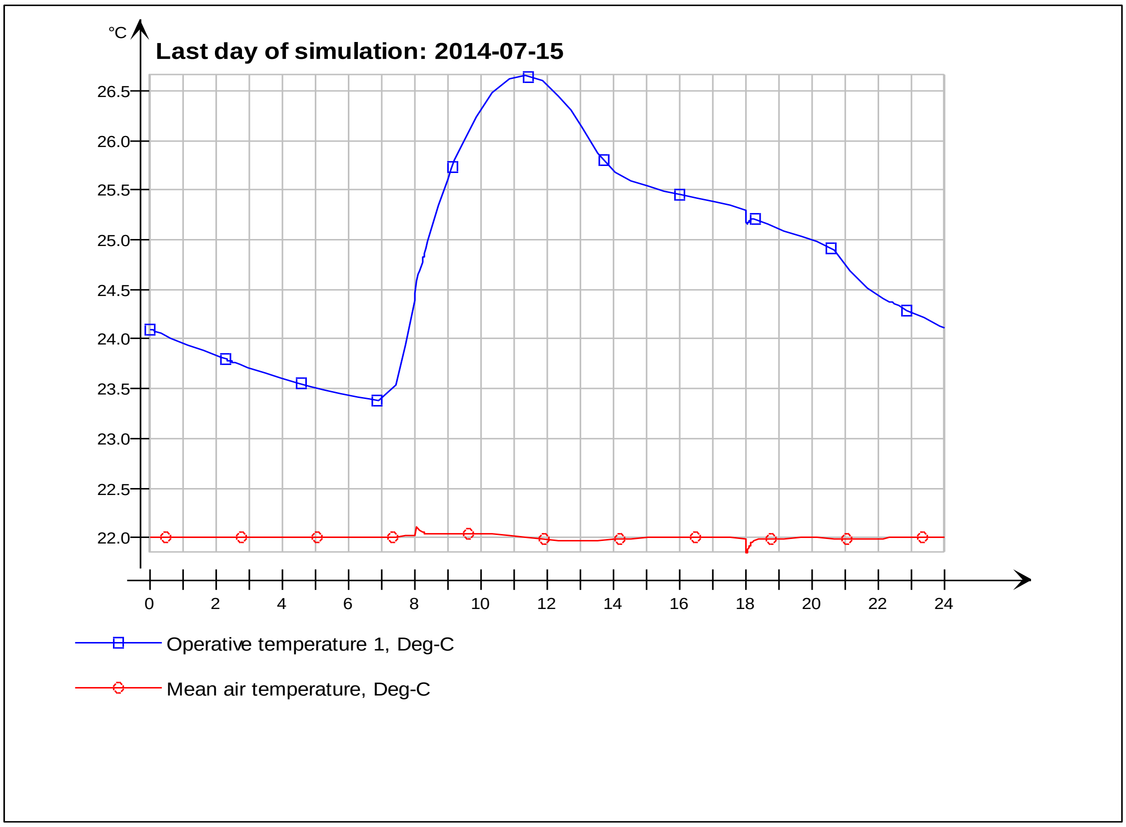
AHU temperatures



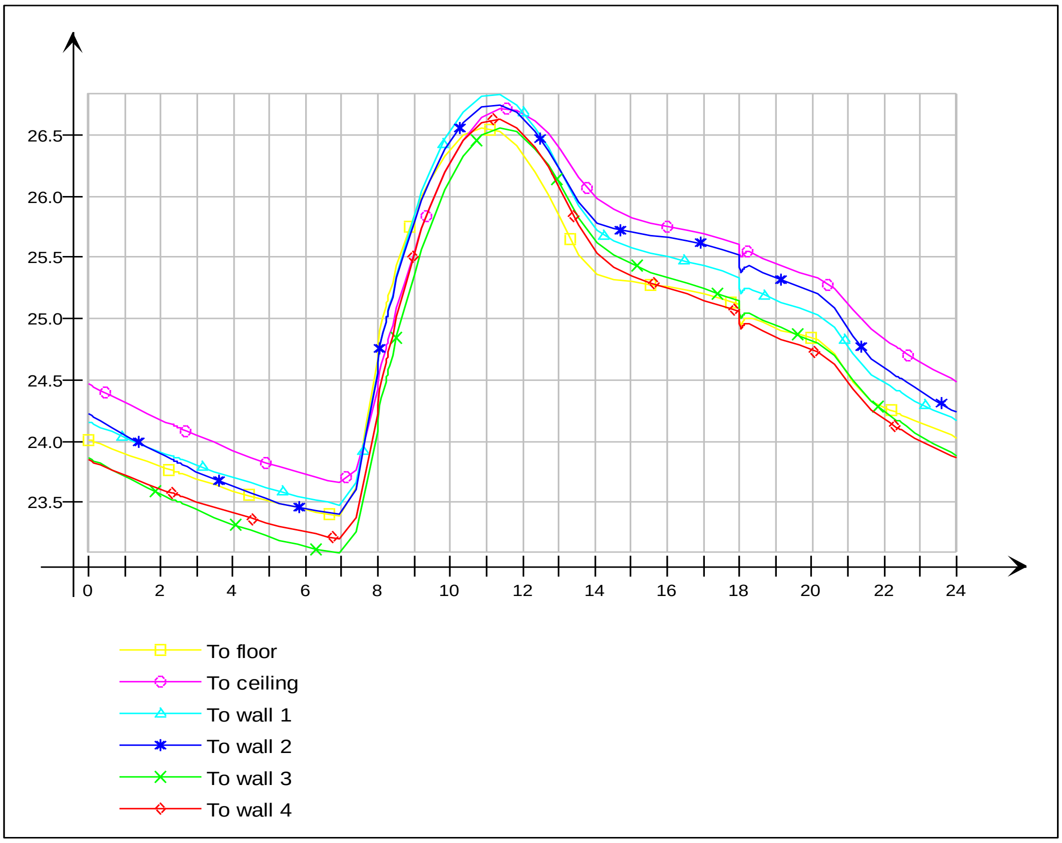
Power supplied by plant



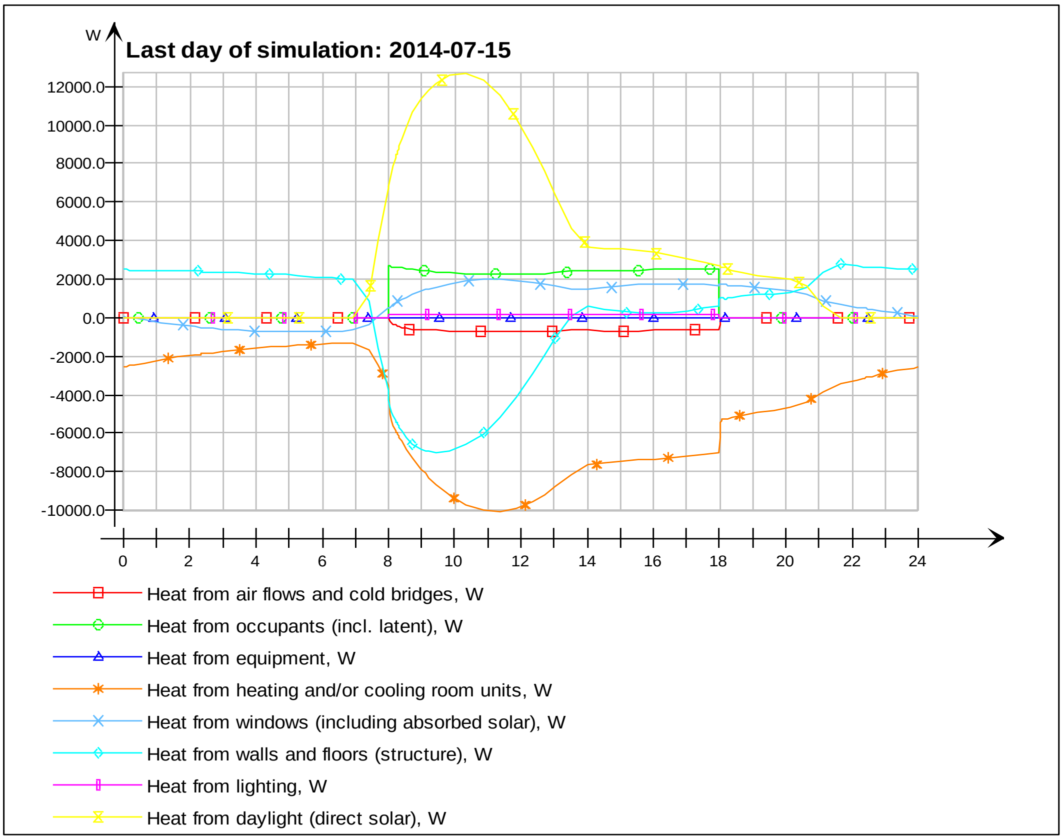
Main temperatures



Directed operative temperatures



Heat balance



Cooling zone 6

Simulation results

Extremes

The zone

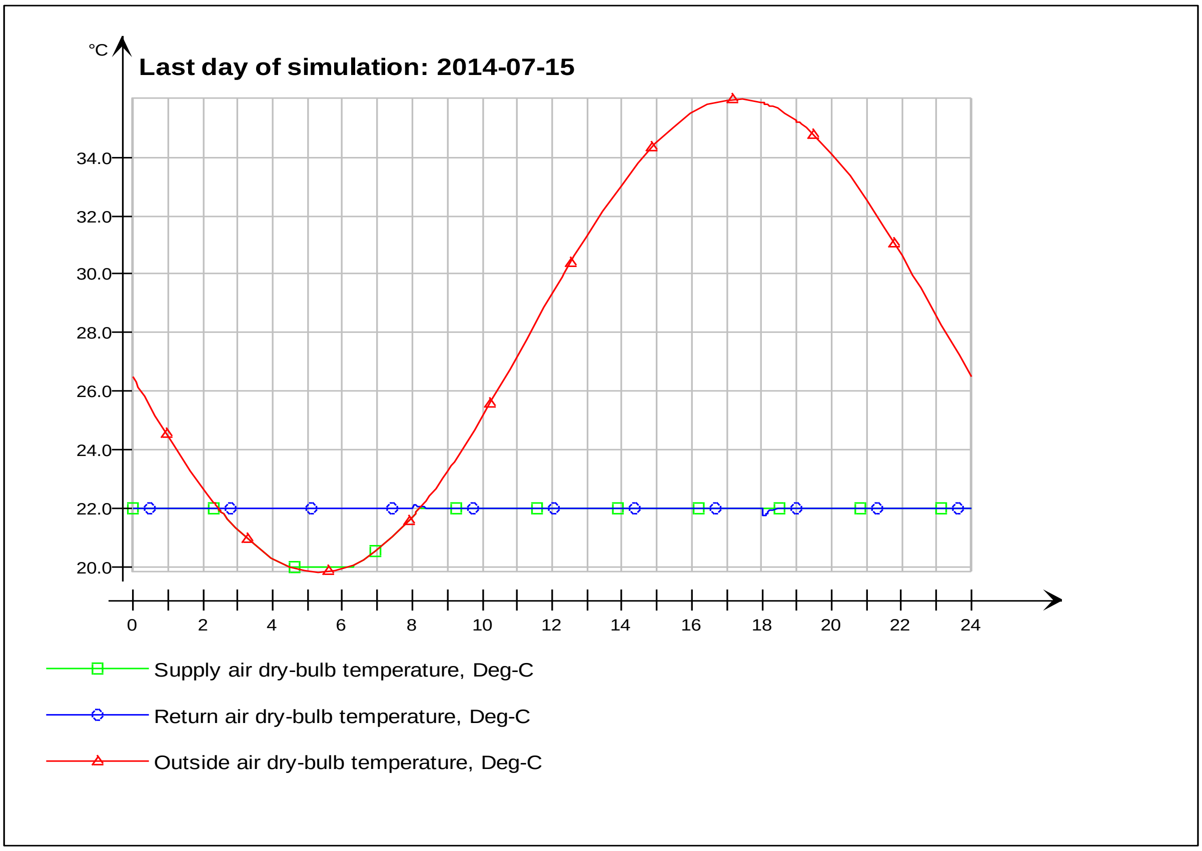
		Value	Occurs at
Operative temperature during occupancy [°C]	min	22.9	8:00
	max	23.9	16:58
Max cooling power [W]	Waterborne	5641.0	16:58
	Airborne*	686.4	9:47
Max heating power [W]	Waterborne		
	Airborne*	77.1	18:10

*inkl. Infiltration

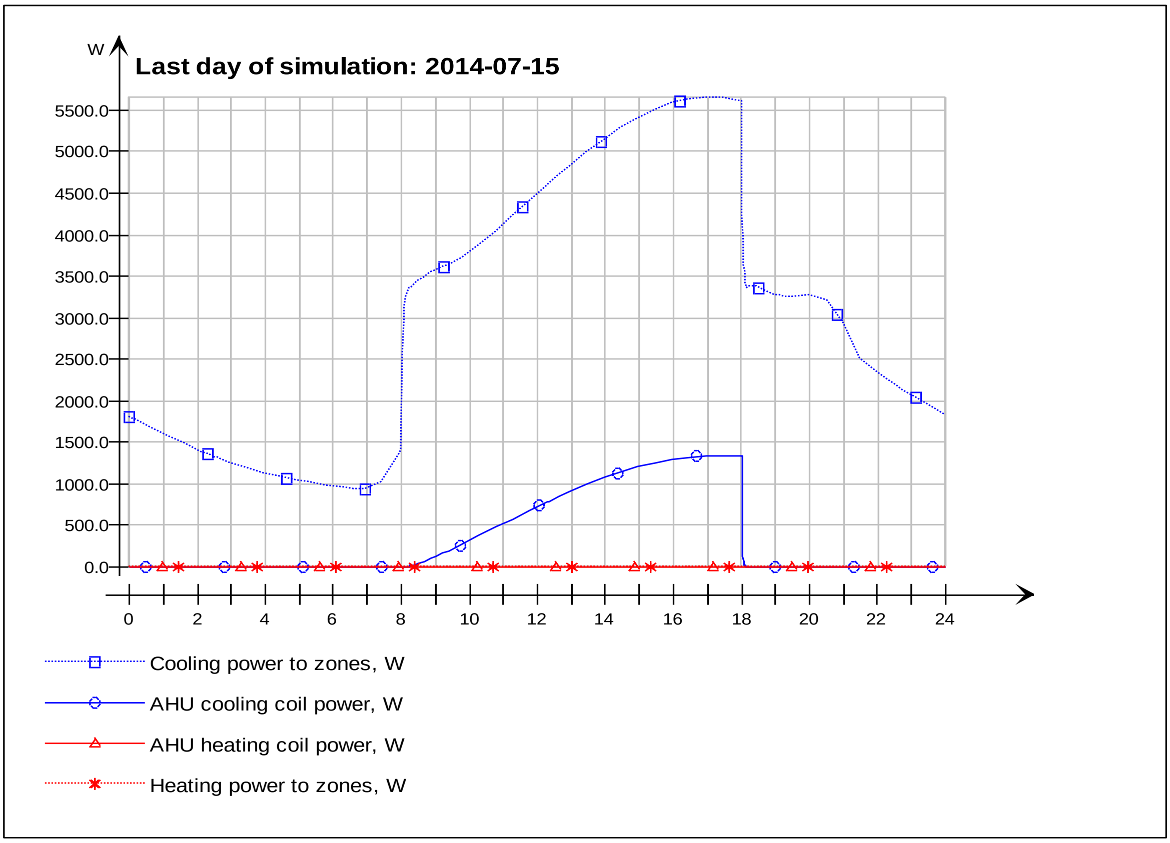
Air handling unit

	Value	Occurs at
Max cooling power [W]	1340.0	17:28
Max heating power [W]		

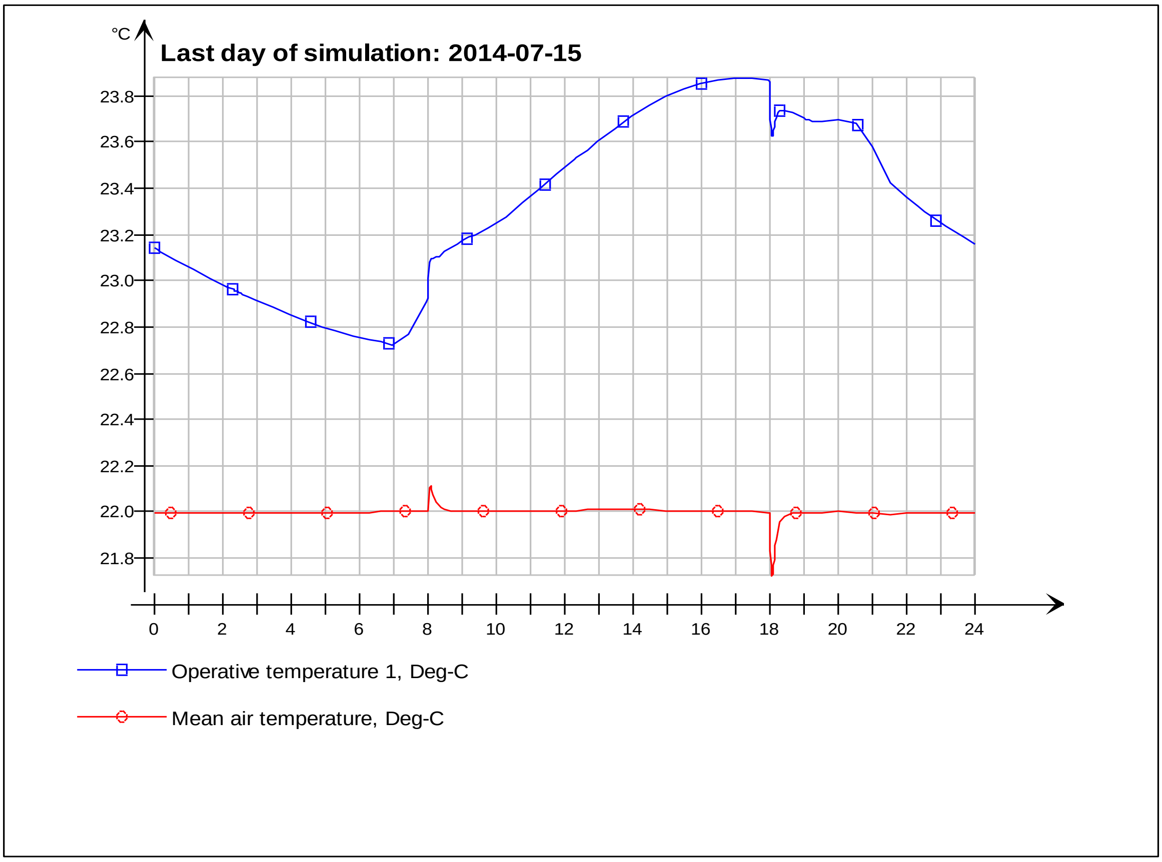
AHU temperatures



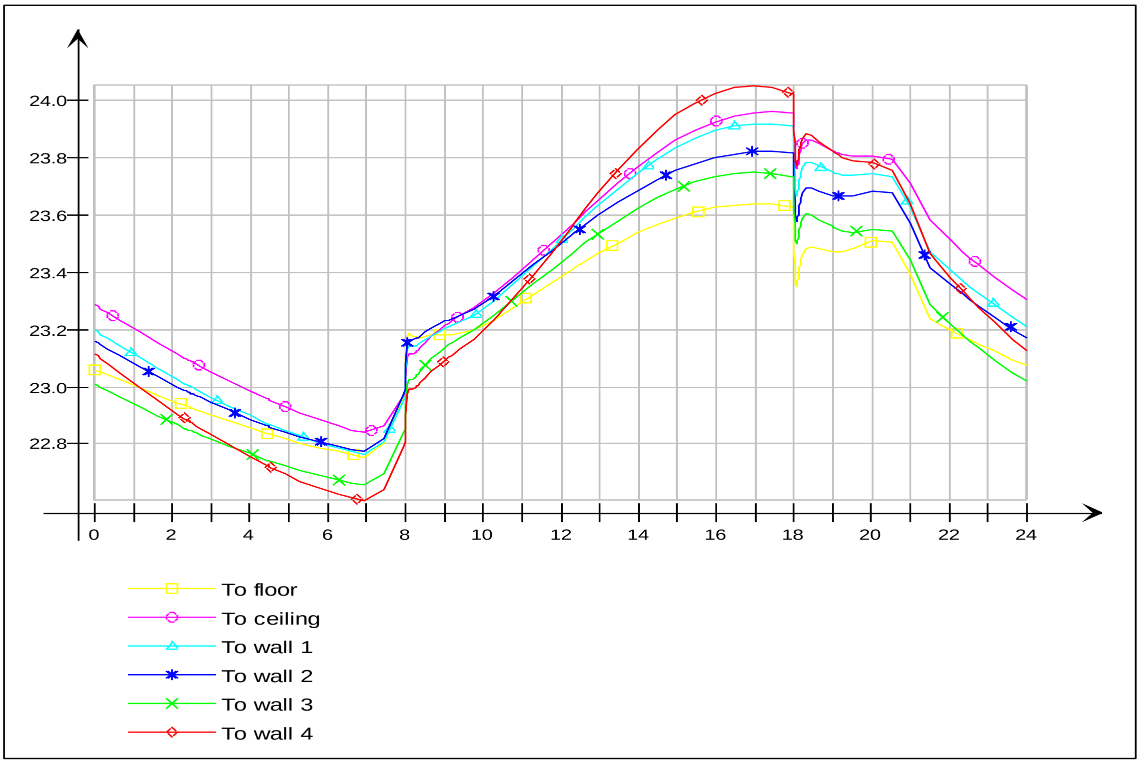
Power supplied by plant



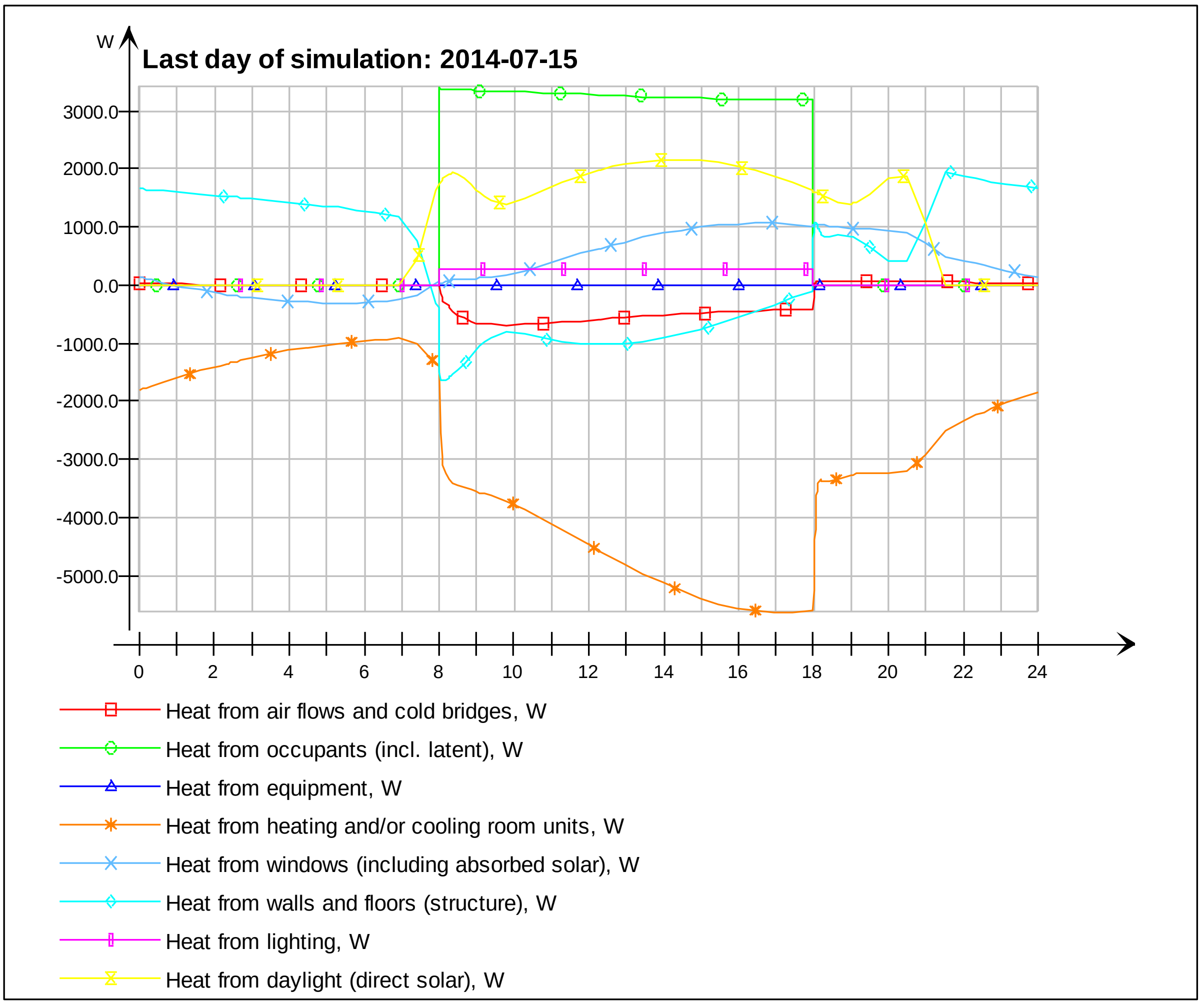
Main temperatures



Directed operative temperatures



Heat balance



Cooling zone 7

Simulation results

Extremes

The zone

		Value	Occurs at
Operative temperature during occupancy [°C]	min	22.4	8:00
	max	22.7	18:00
Max cooling power [W]	Waterborne	864.8	18:00
	Airborne*	101.8	14:02

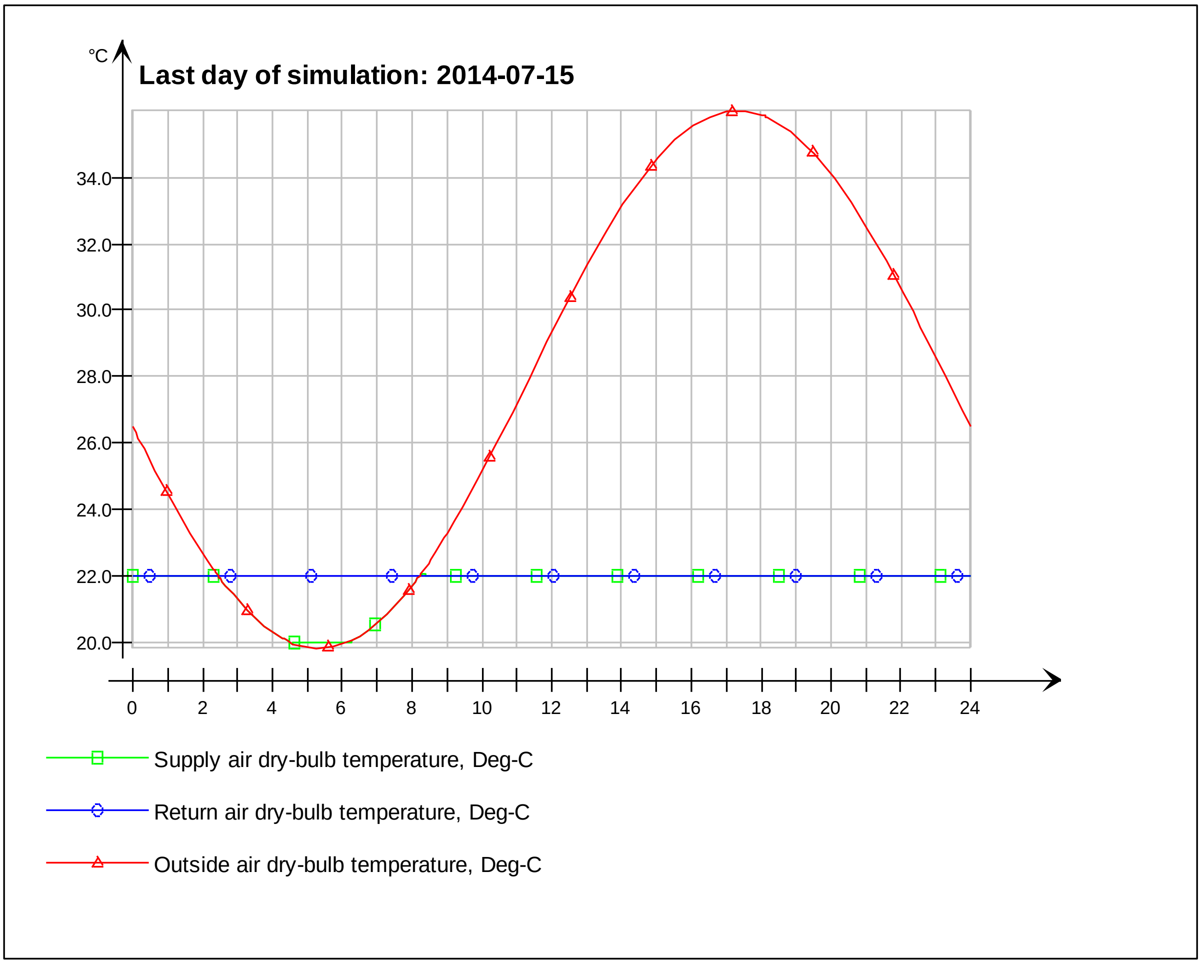
Max heating power [W]	Waterborne		
	Airborne*	50.6	18:11

*inkl. Infiltration

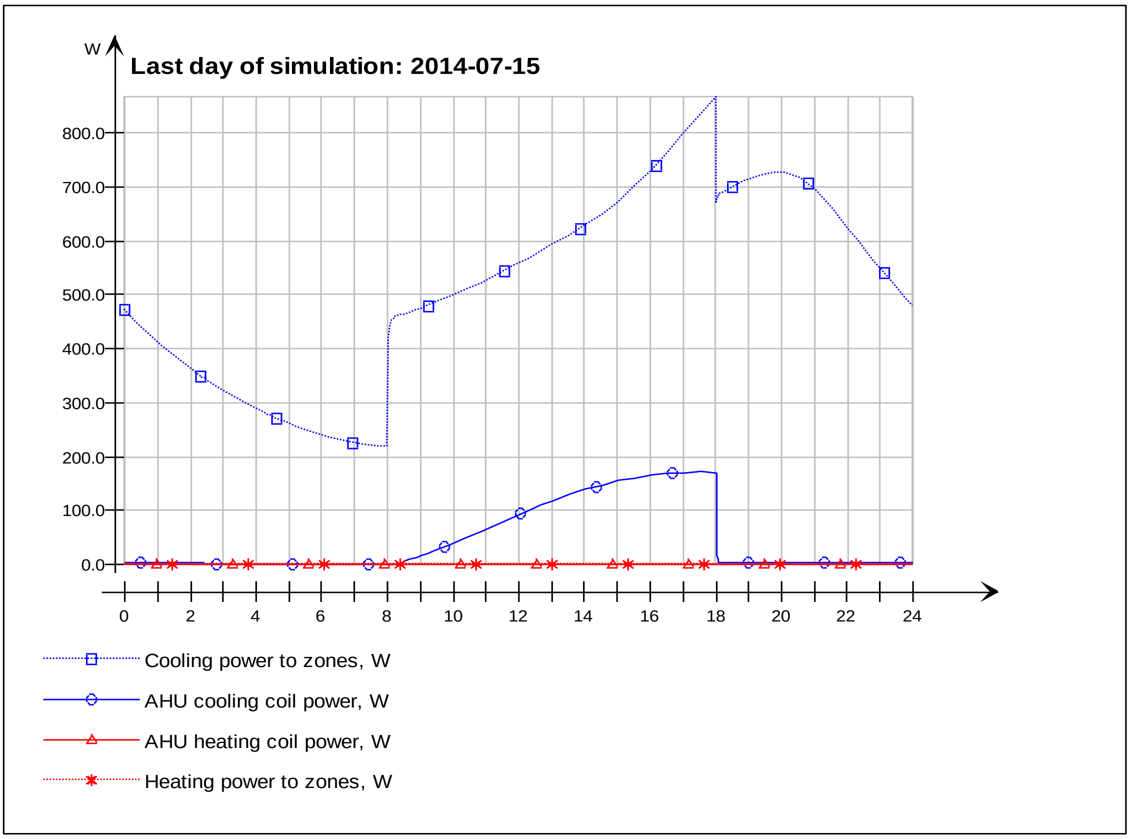
Air handling unit

	Value	Occurs at
Max cooling power [W]	171.0	17:32
Max heating power [W]		

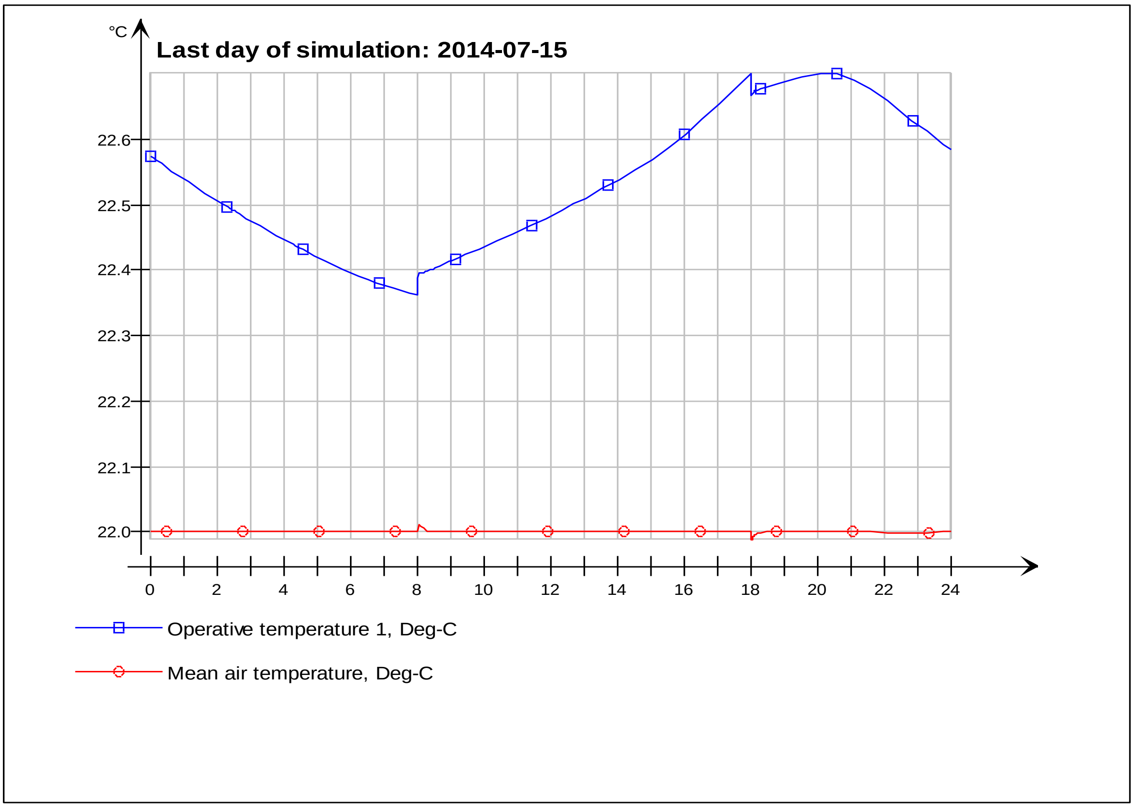
AHU temperatures



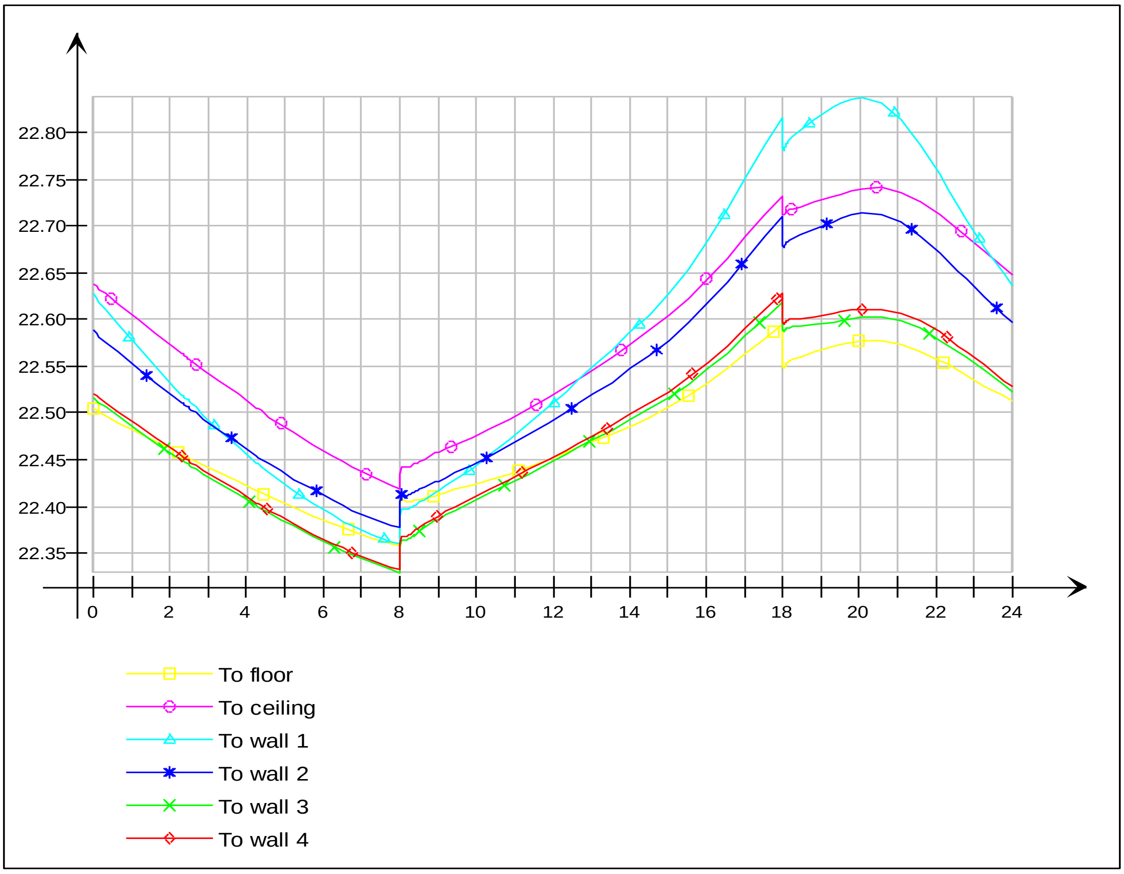
Power supplied by plant



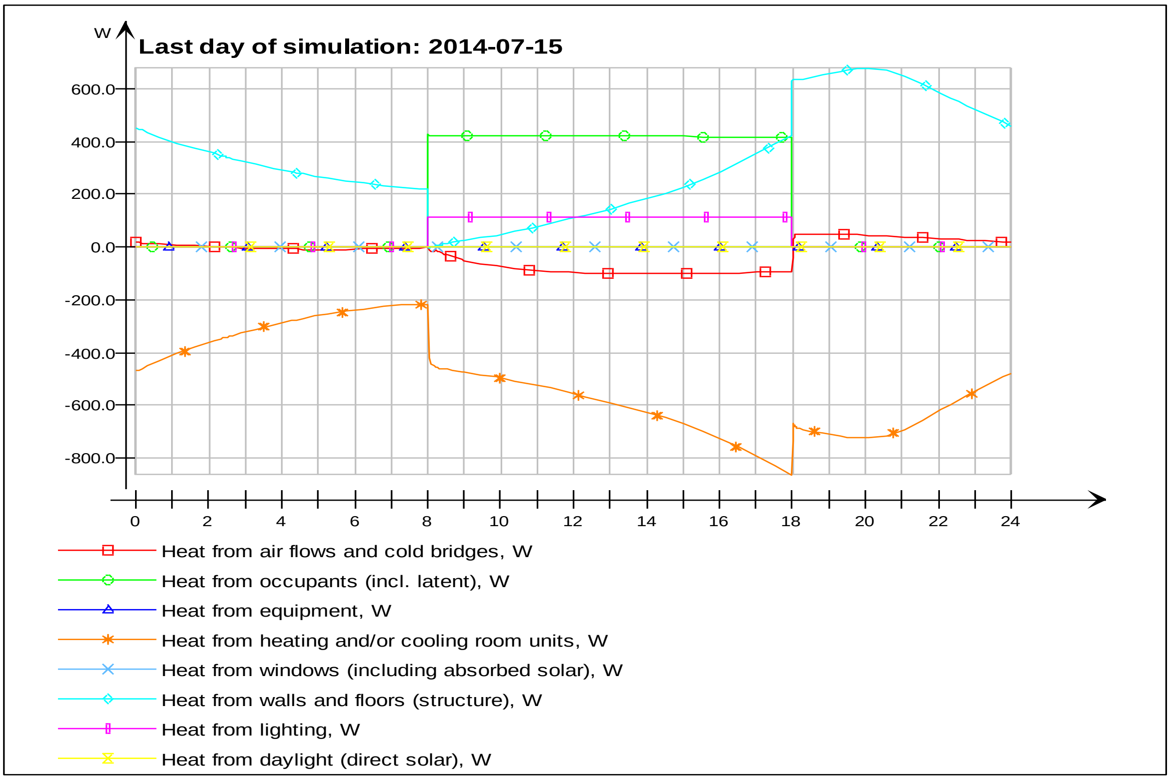
Main temperatures



Directed operative temperatures



Heat balance



Cooling zone 8

Simulation results

Extremes

The zone

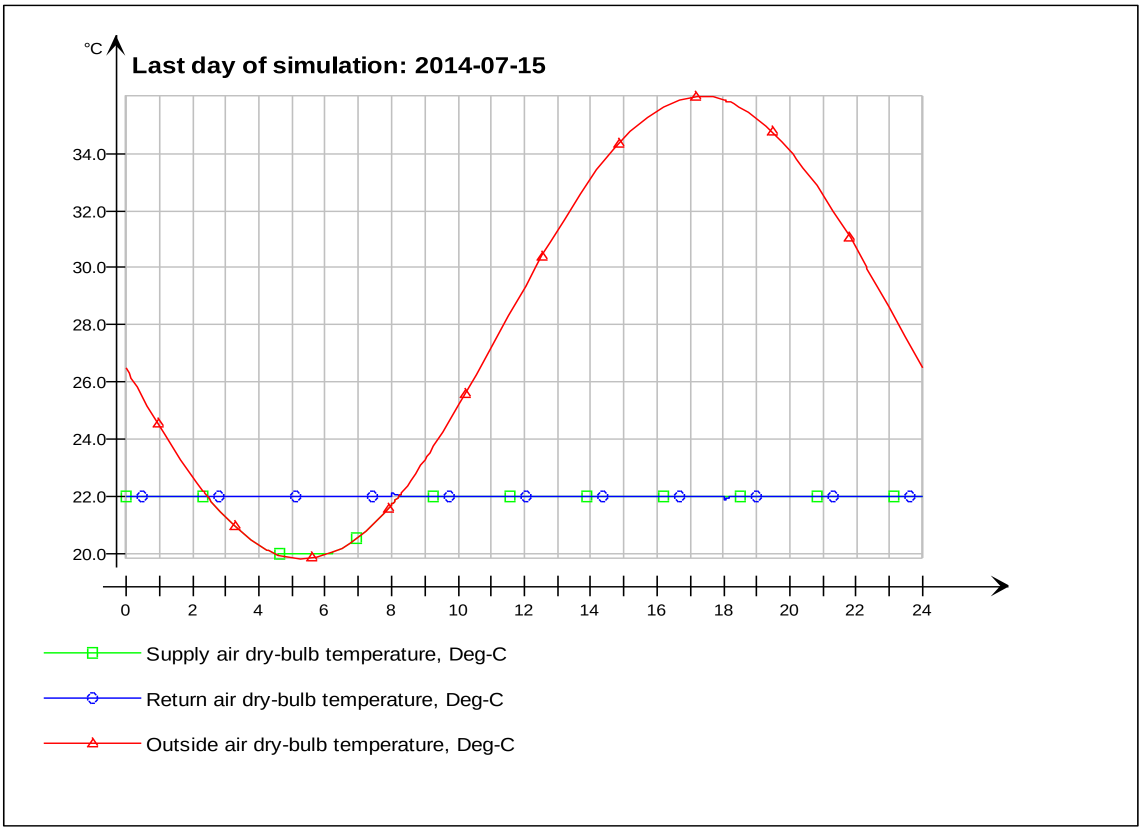
		Value	Occurs at
Operative temperature during occupancy [°C]	min	22.8	8:00
	max	24.0	15:42
Max cooling power [W]	Waterborne	5278.0	15:42
	Airborne*	769.2	13:12
Max heating power [W]	Waterborne		
	Airborne*	94.4	18:13

*inkl. Infiltration

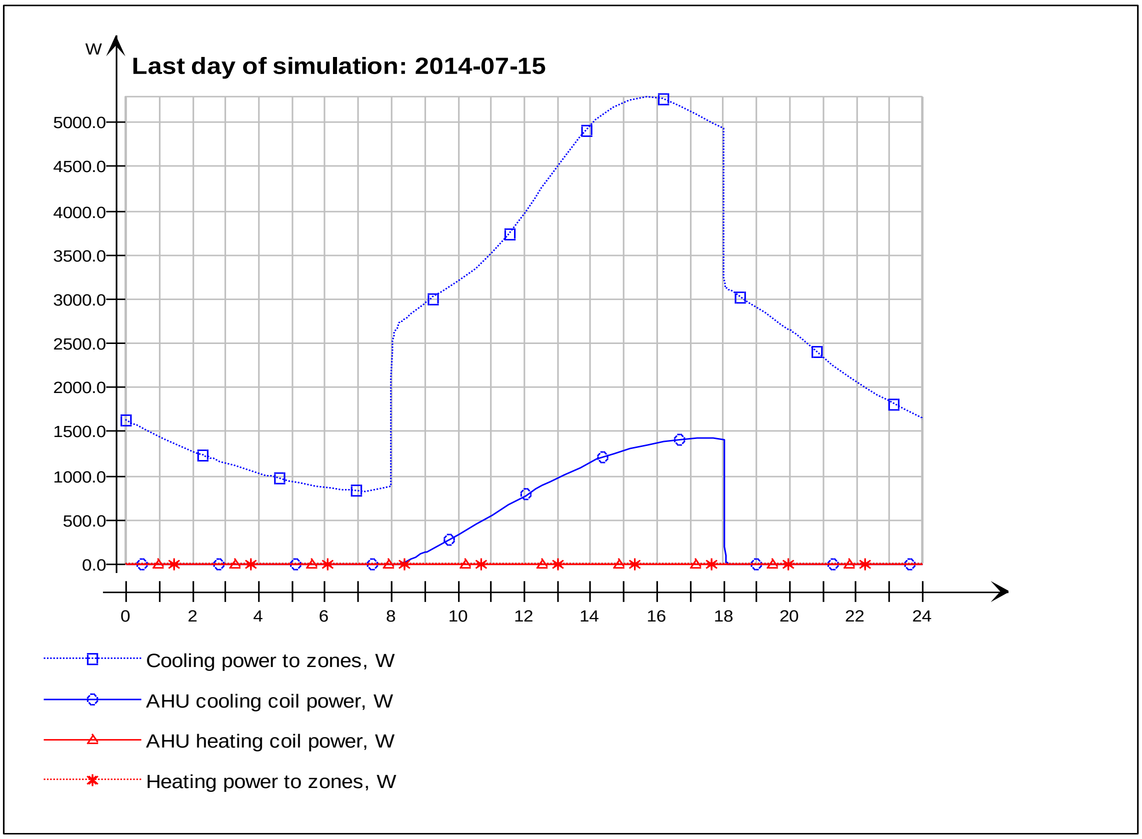
Air handling unit

	Value	Occurs at
Max cooling power [W]	1425.0	17:12
Max heating power [W]		

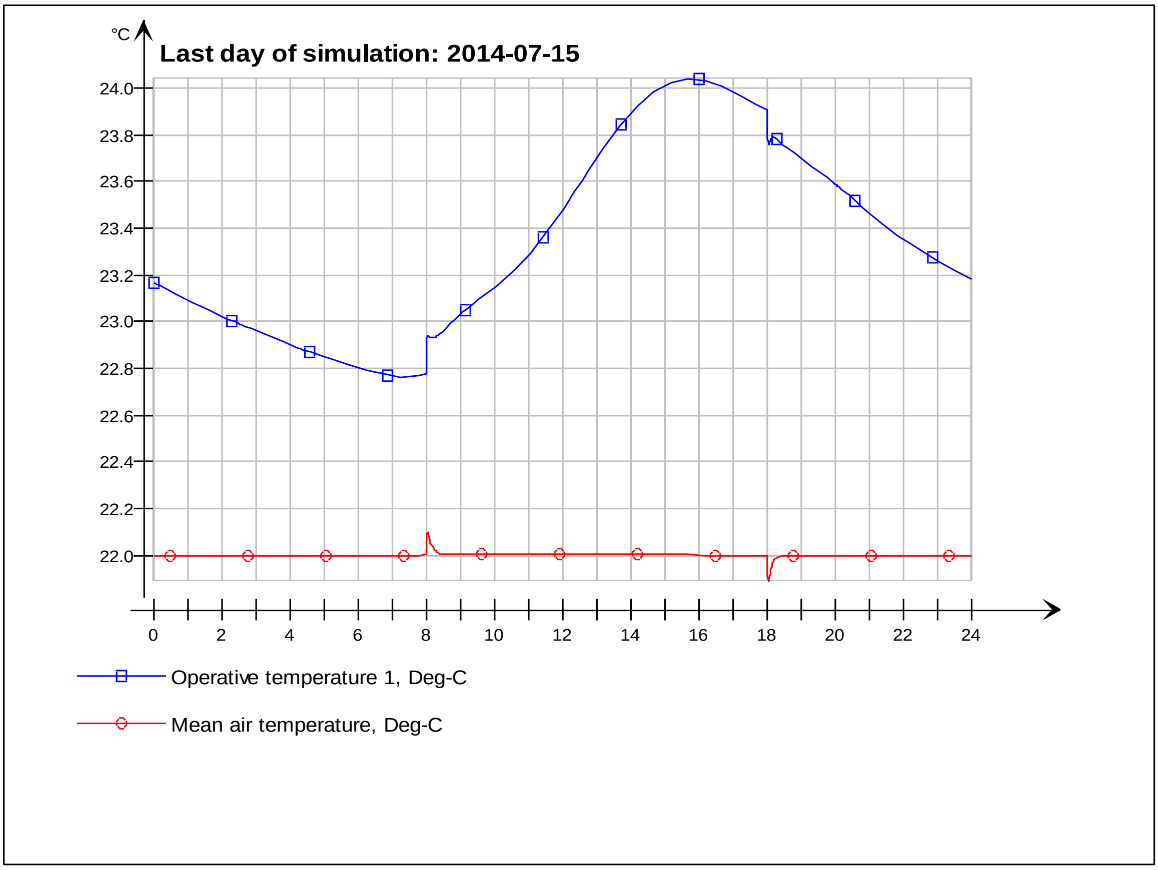
AHU temperatures



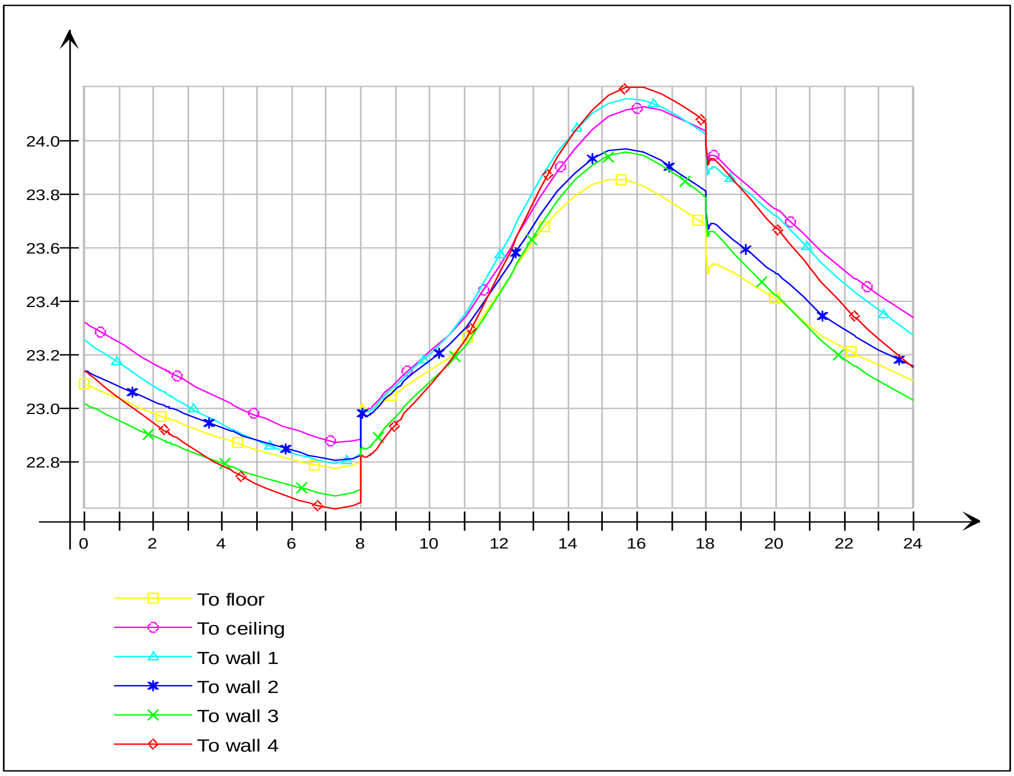
Power supplied by plant



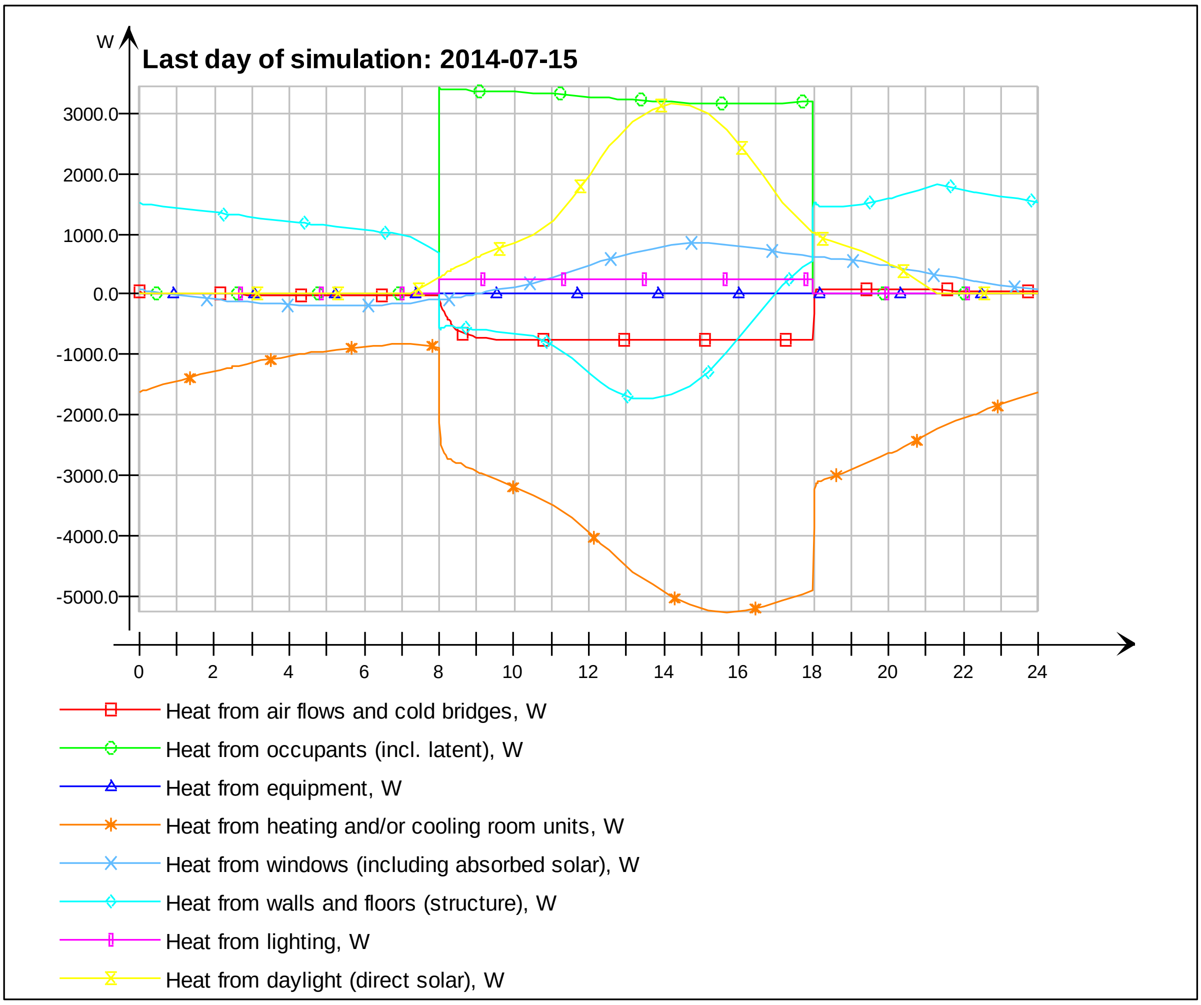
Main temperatures



Directed operative temperatures



Heat balance



Cooling zone 9

Simulation results

Extremes

The zone

		Value	Occurs at
Operative temperature during occupancy [°C]	min	23.2	8:00
	max	24.3	16:17
Max cooling power [W]	Waterborne	5180.0	16:47
	Airborne*	400.1	6:18

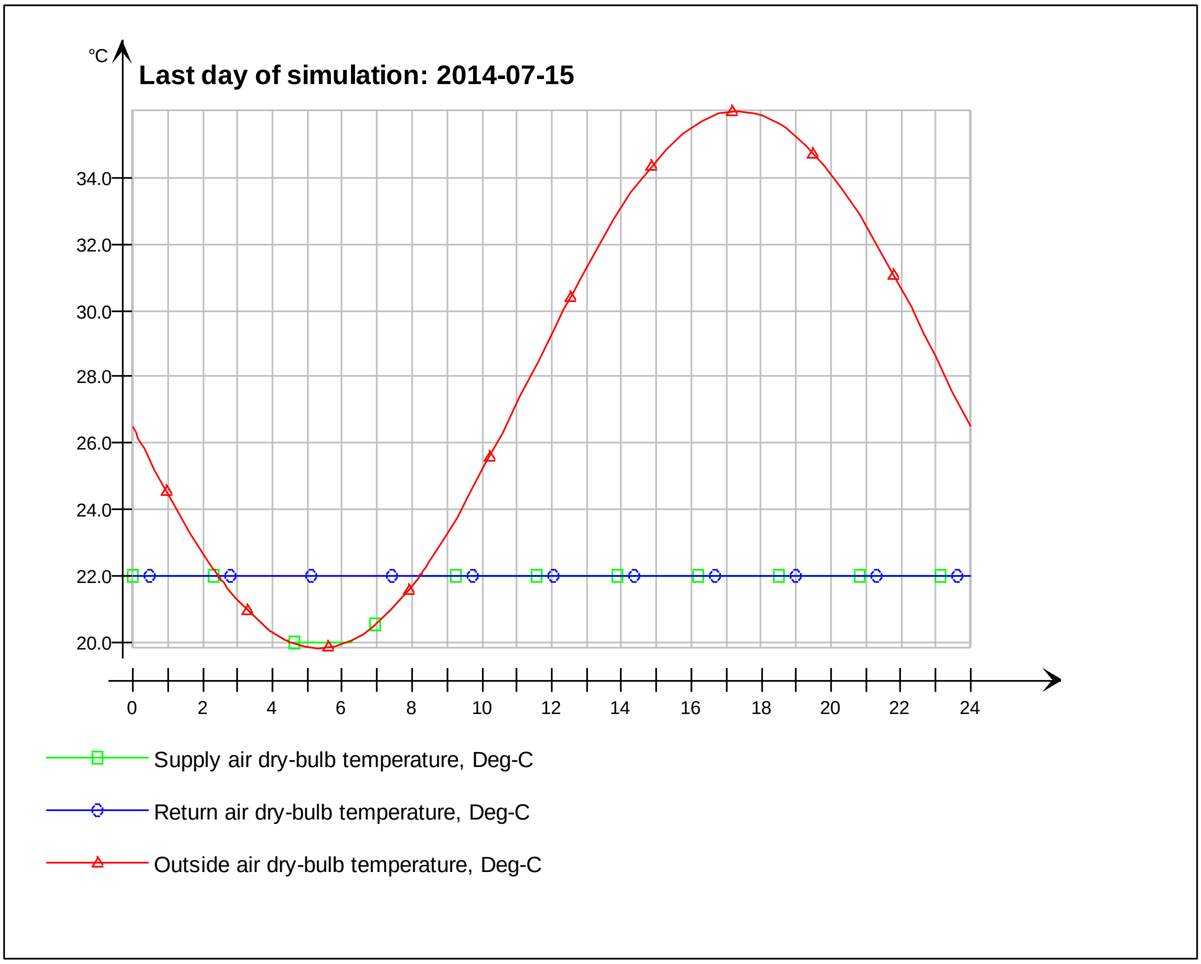
Max heating power [W]	Waterborne		
	Airborne*	54.1	1:09

*inkl. Infiltration

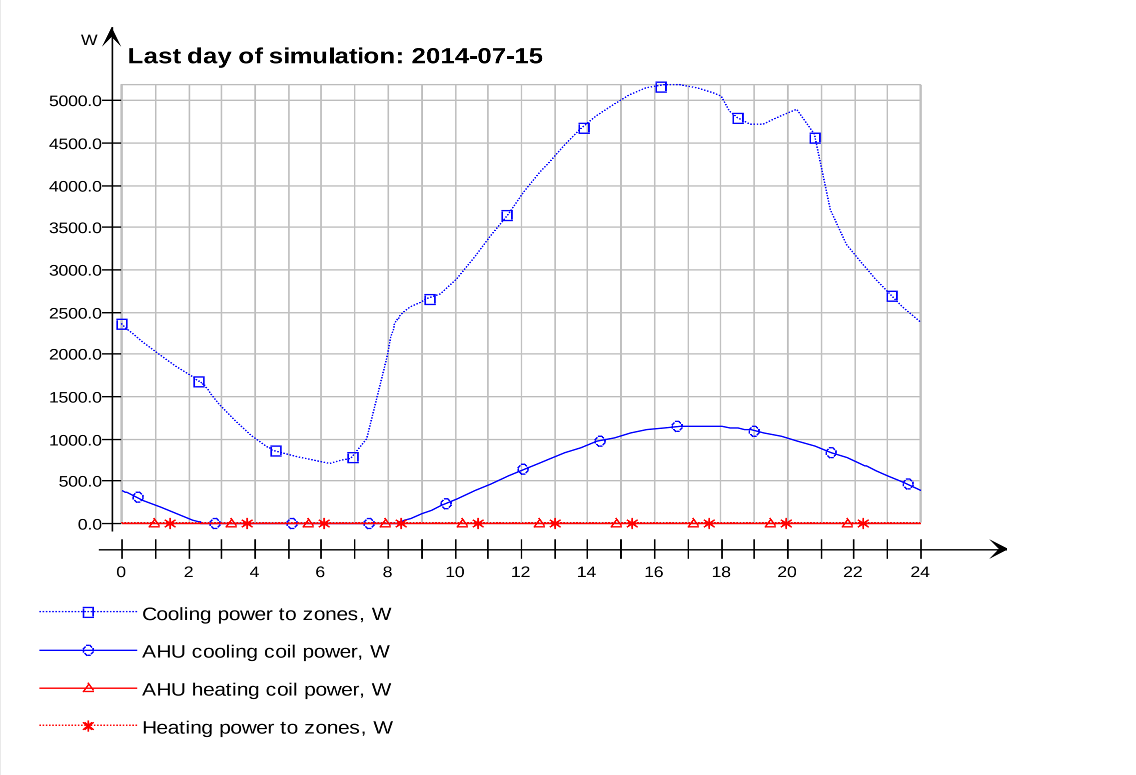
Air handling unit

	Value	Occurs at
Max cooling power [W]	1153.0	17:17
Max heating power [W]		

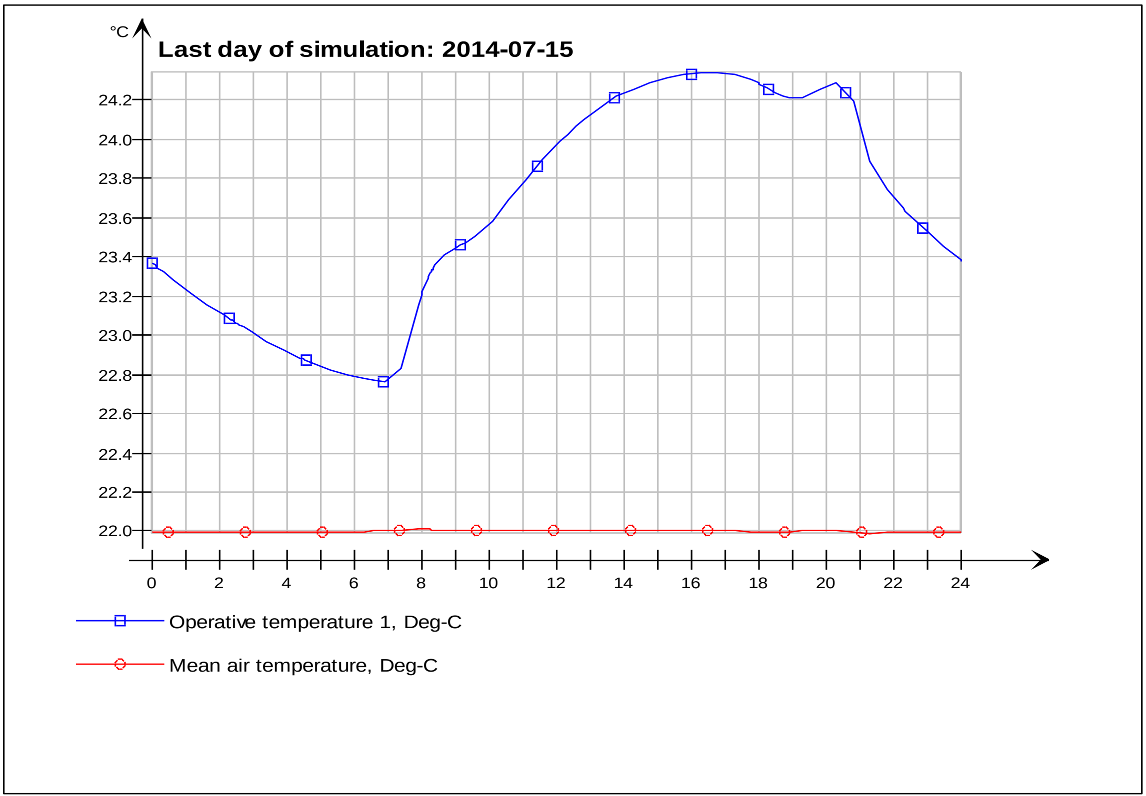
AHU temperatures



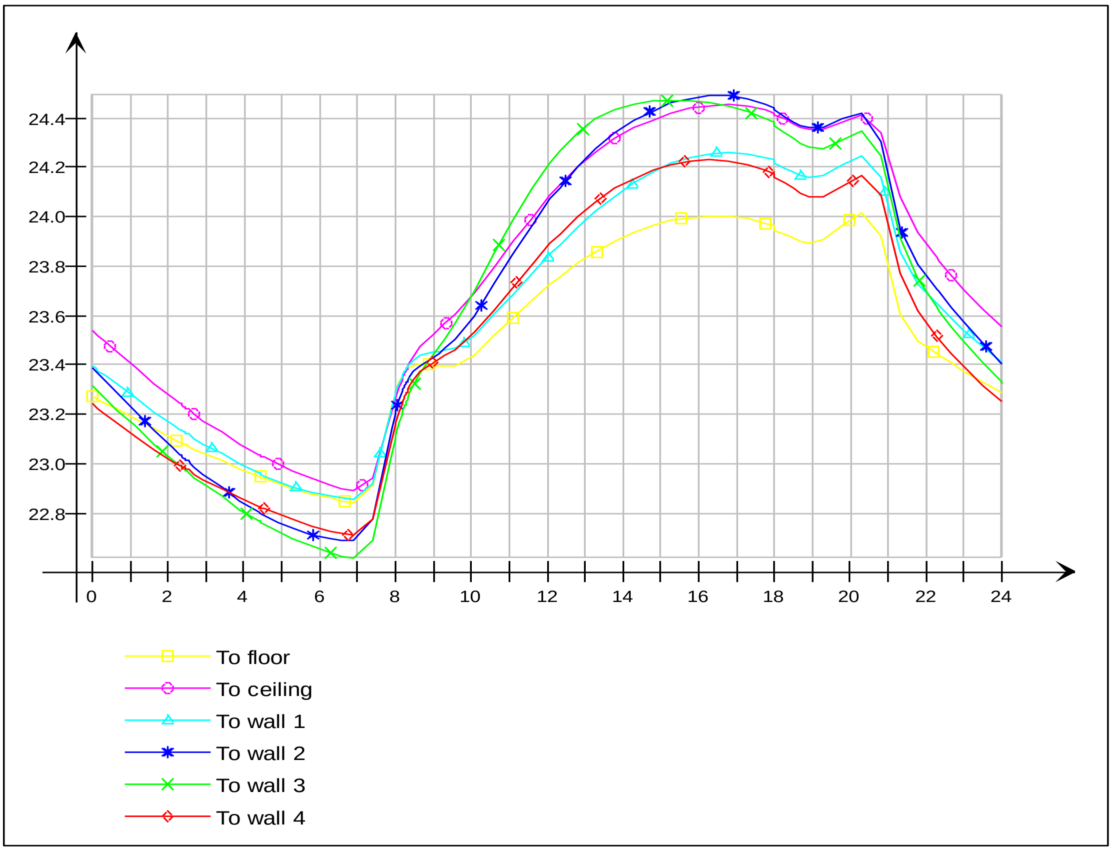
Power supplied by plant



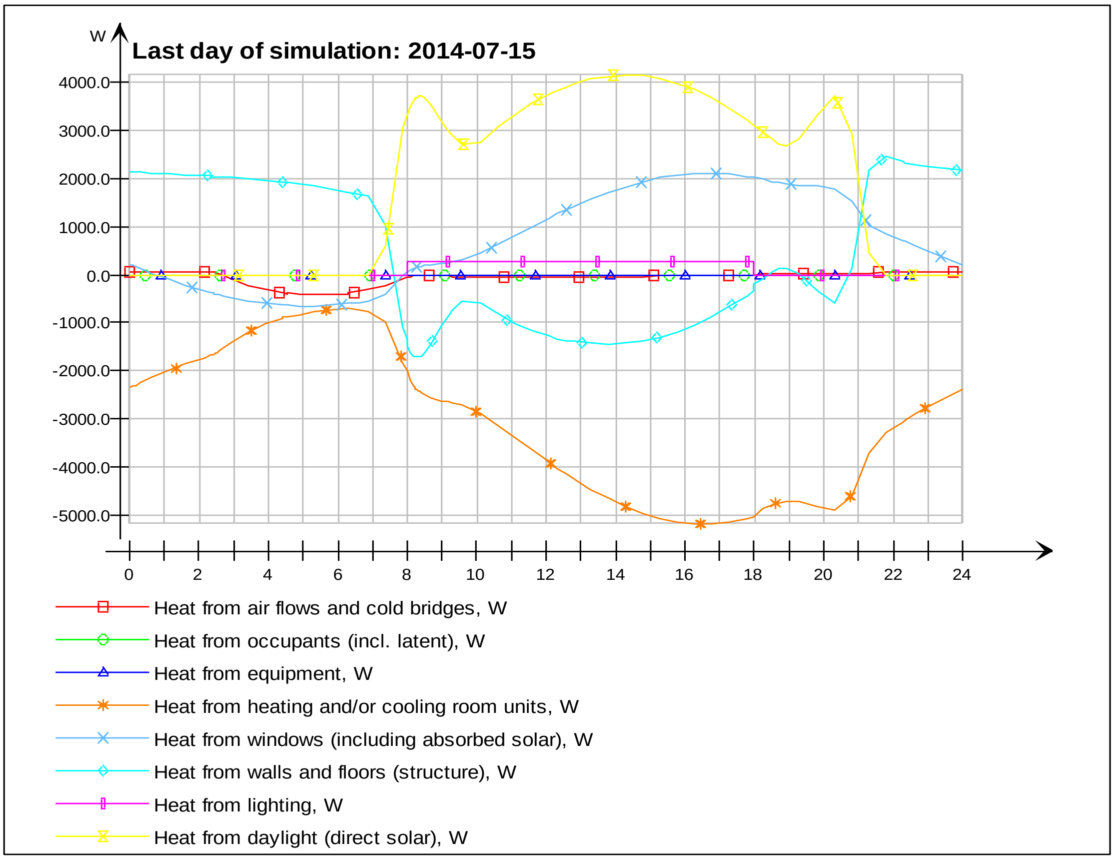
Main temperatures



Directed operative temperatures



Heat balance



Cooling zone 1

Simulation results

Extremes

The zone

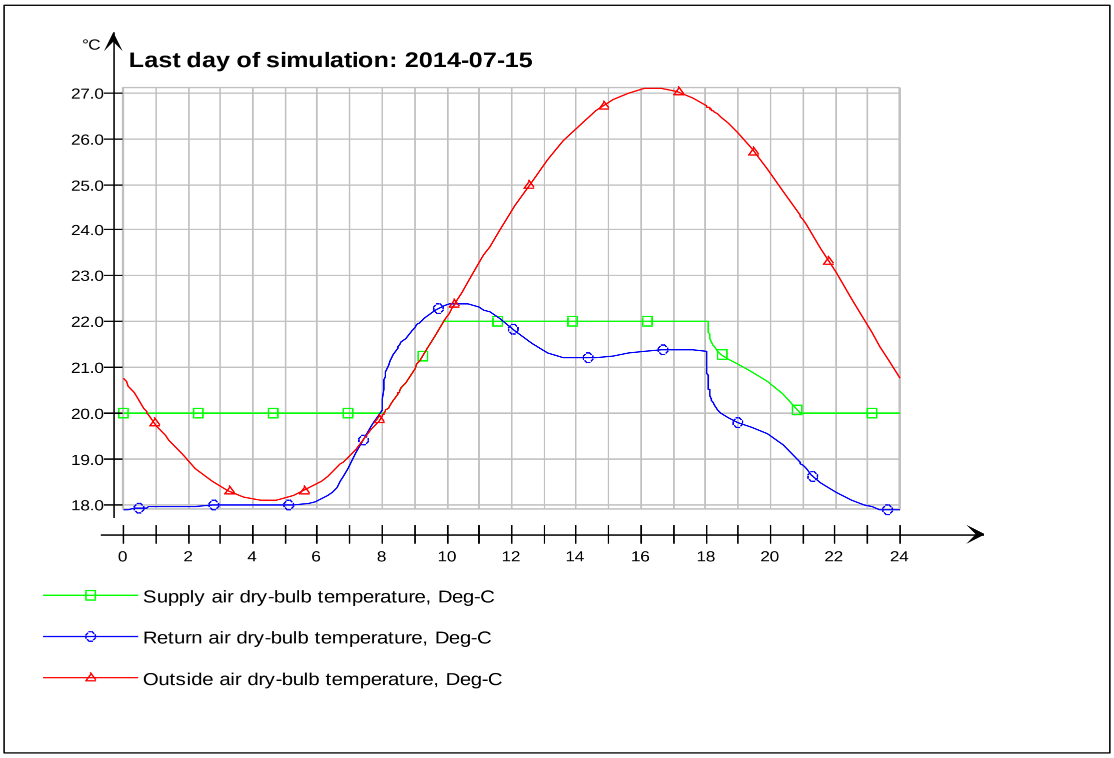
		Value	Occurs at
Operative temperature during occupancy [°C]	min	23.1	8:00
	max	25.6	10:22
Max cooling power [W]	Waterborne	12510.0	10:22
	Airborne*	1638.0	8:54
Max heating power [W]	Waterborne		
	Airborne*	38.1	18:29

*inkl. Infiltration

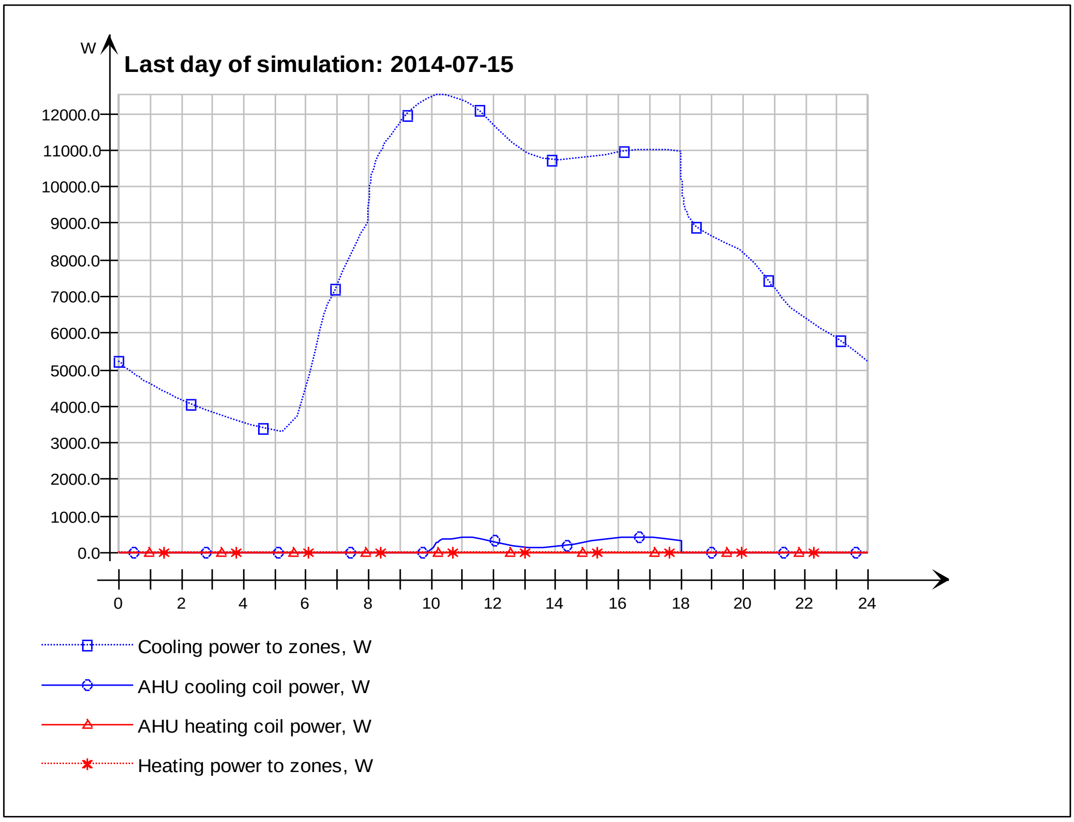
Air handling unit

	Value	Occurs at
Max cooling power [W]	422.9	16:37
Max heating power [W]	8.4	0:47

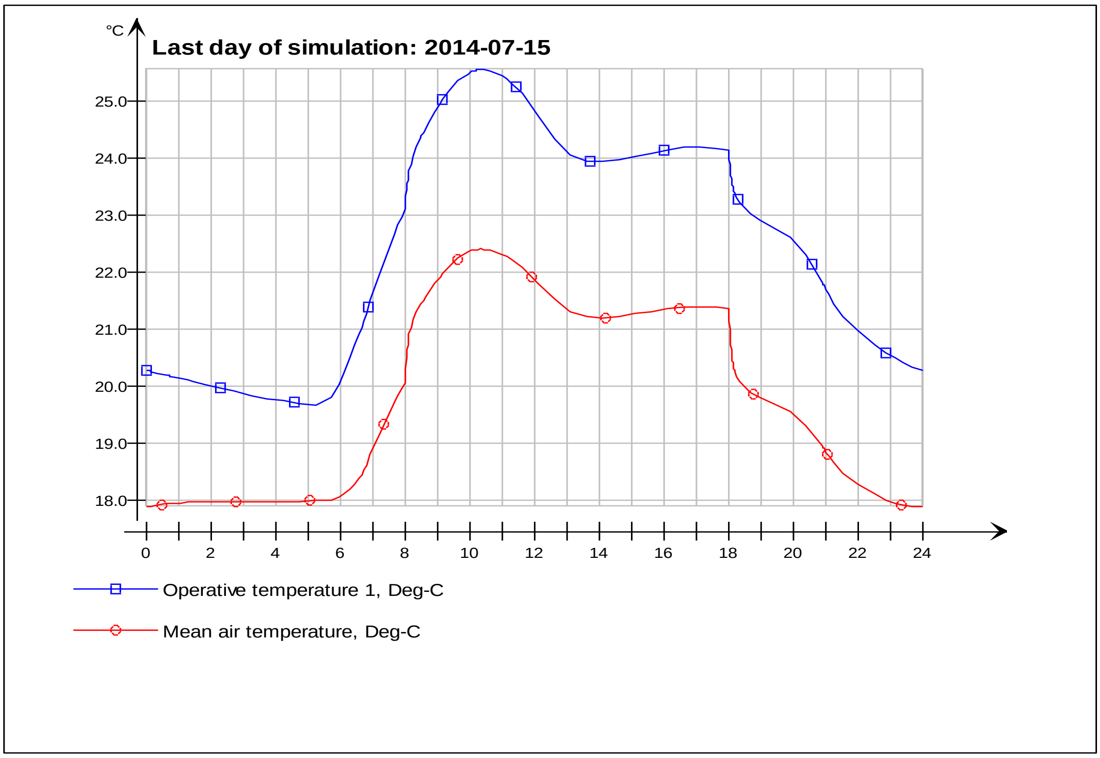
AHU temperatures



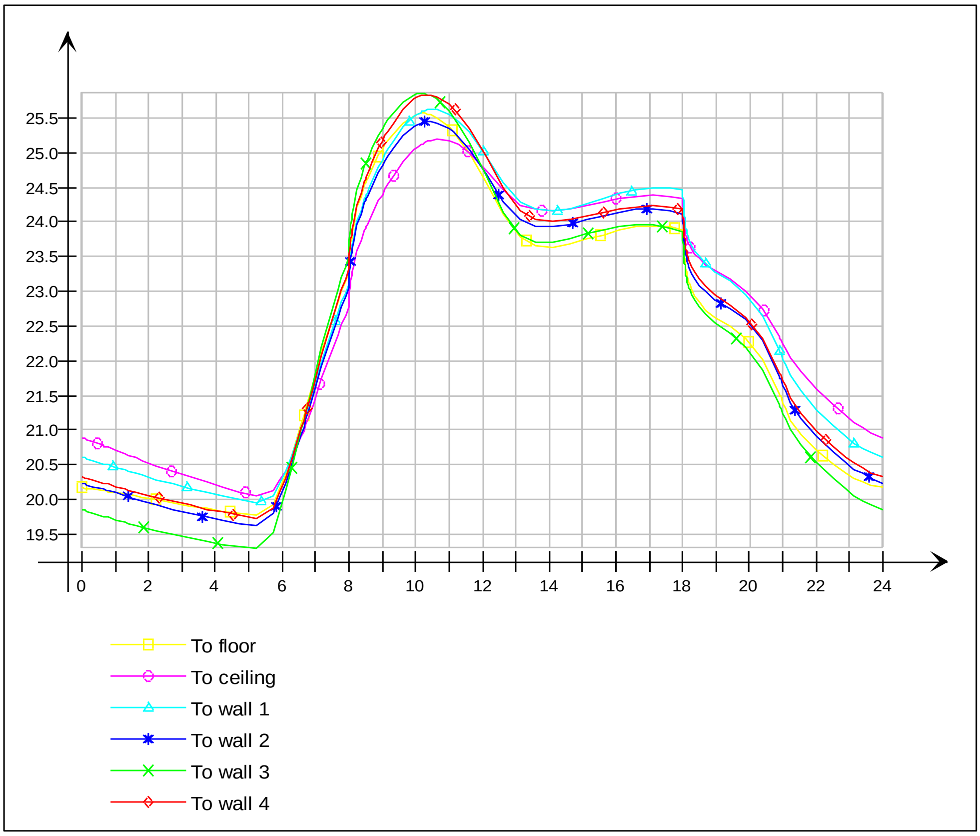
Power supplied by plant



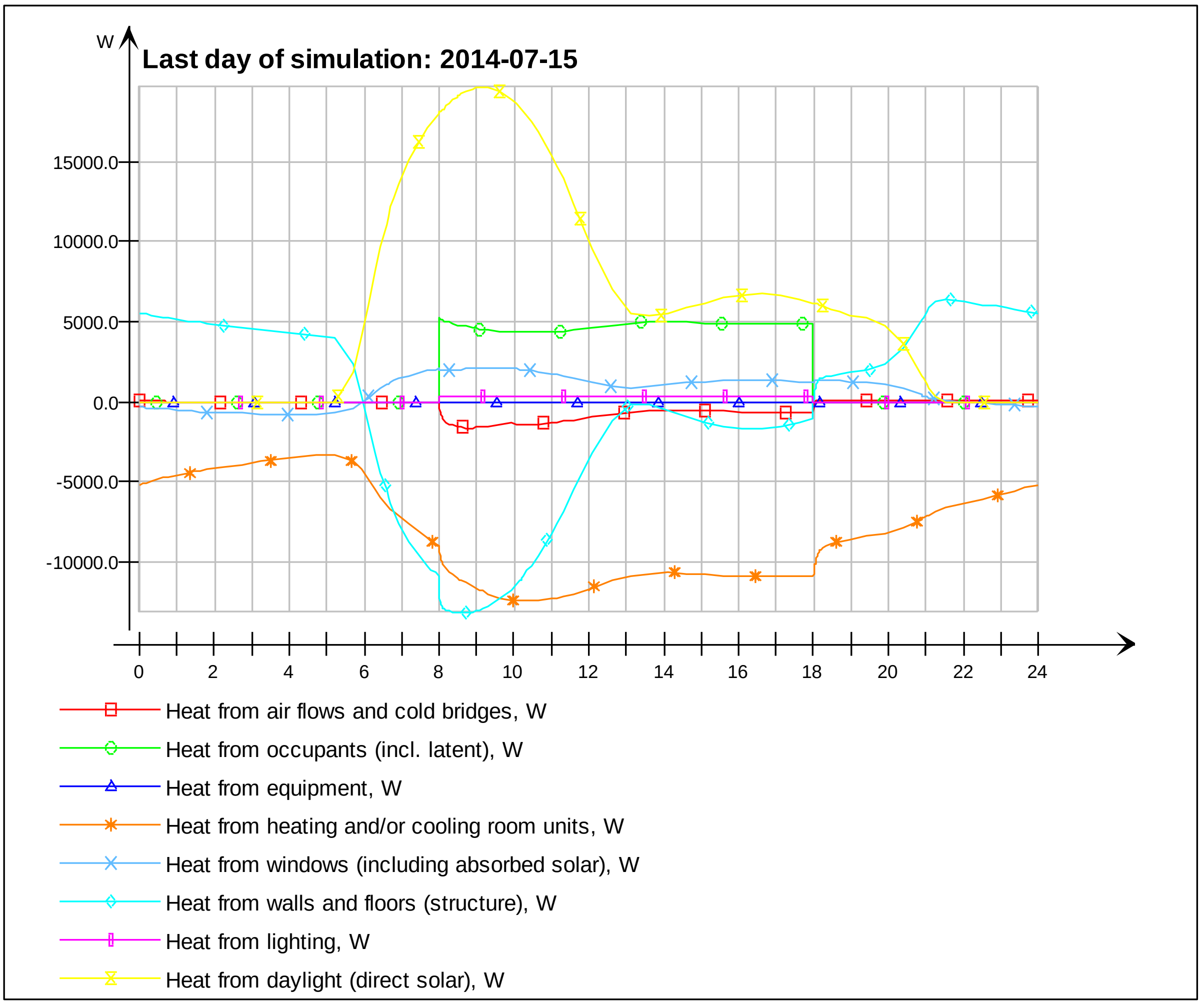
Main temperatures



Directed operative temperatures



Heat balance



Cooling zone 2

Simulation results

Extremes

The zone

		Value	Occurs at
Operative temperature during occupancy [°C]	min	22.4	8:00
	max	23.6	18:00
Max cooling power [W]	Waterborne	5188.0	17:25
	Airborne*	1286.0	8:22

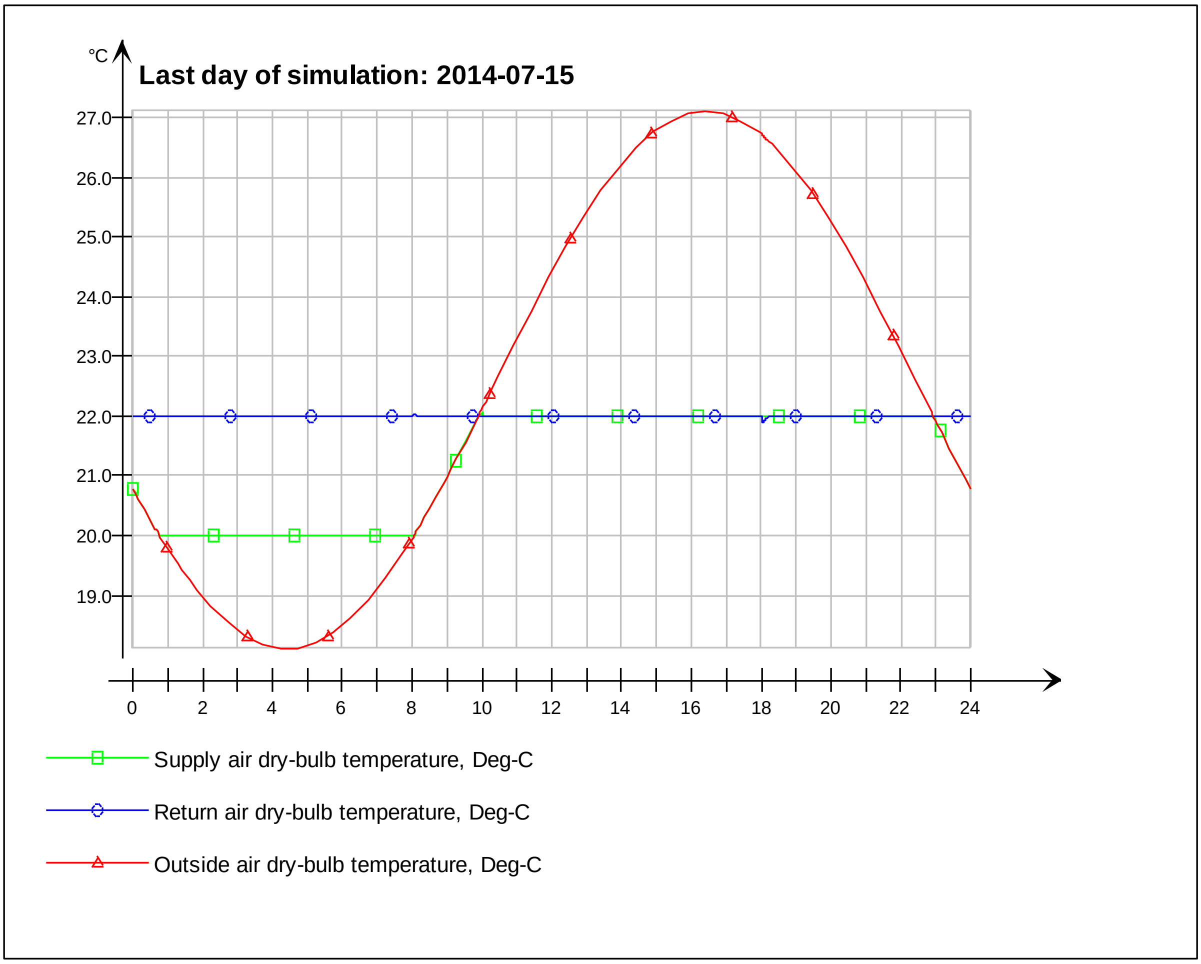
Max heating power [W]	Waterborne		
	Airborne*	40.5	18:11

*inkl. Infiltration

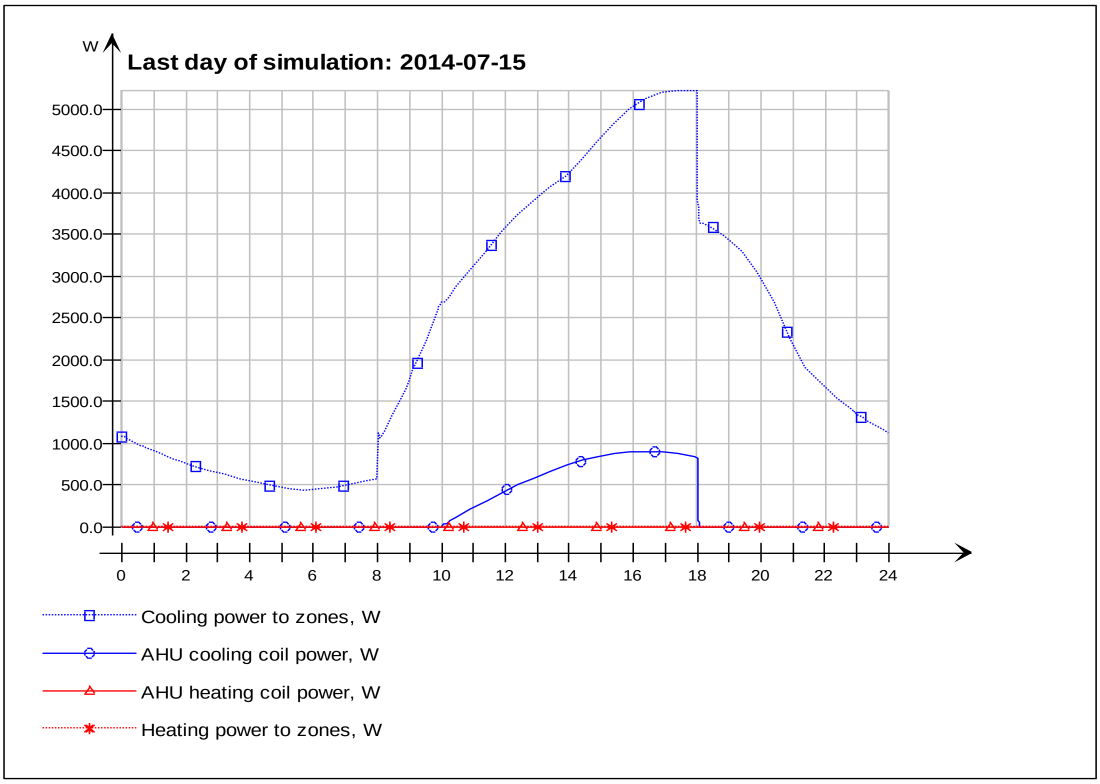
Air handling unit

	Value	Occurs at
Max cooling power [W]	900.5	16:25
Max heating power [W]		

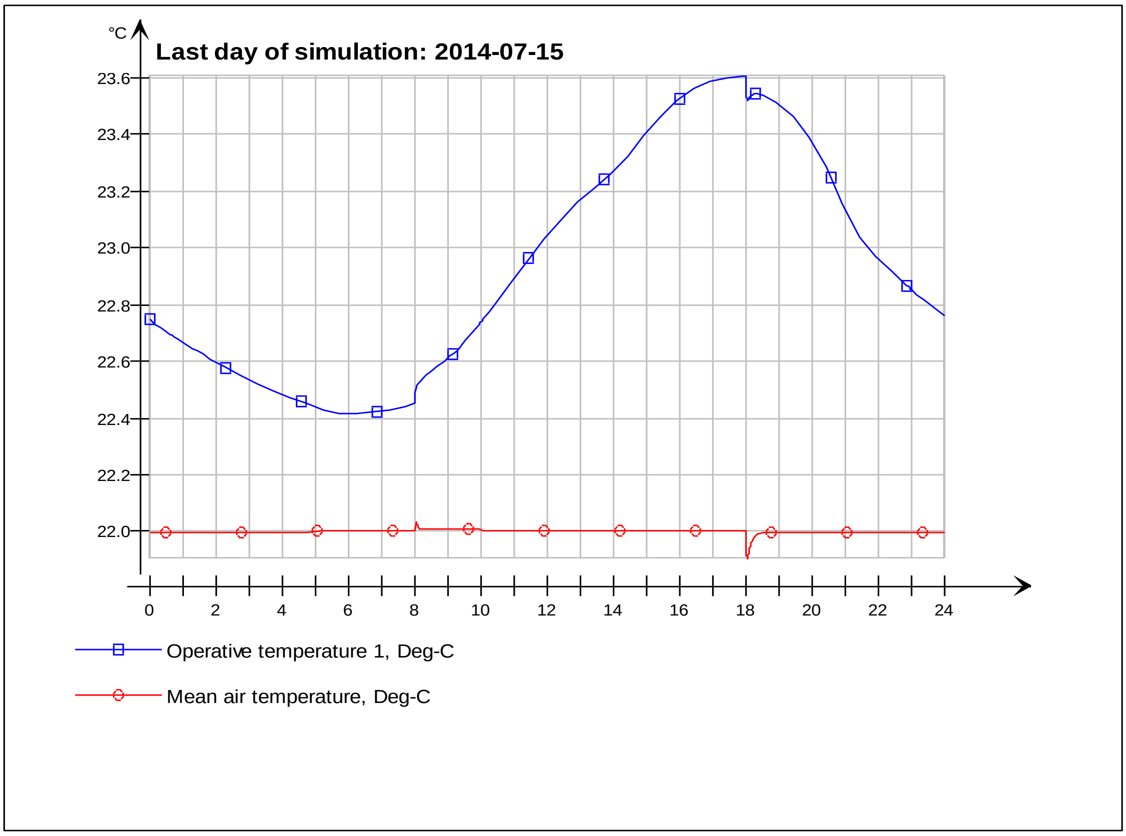
AHU temperatures



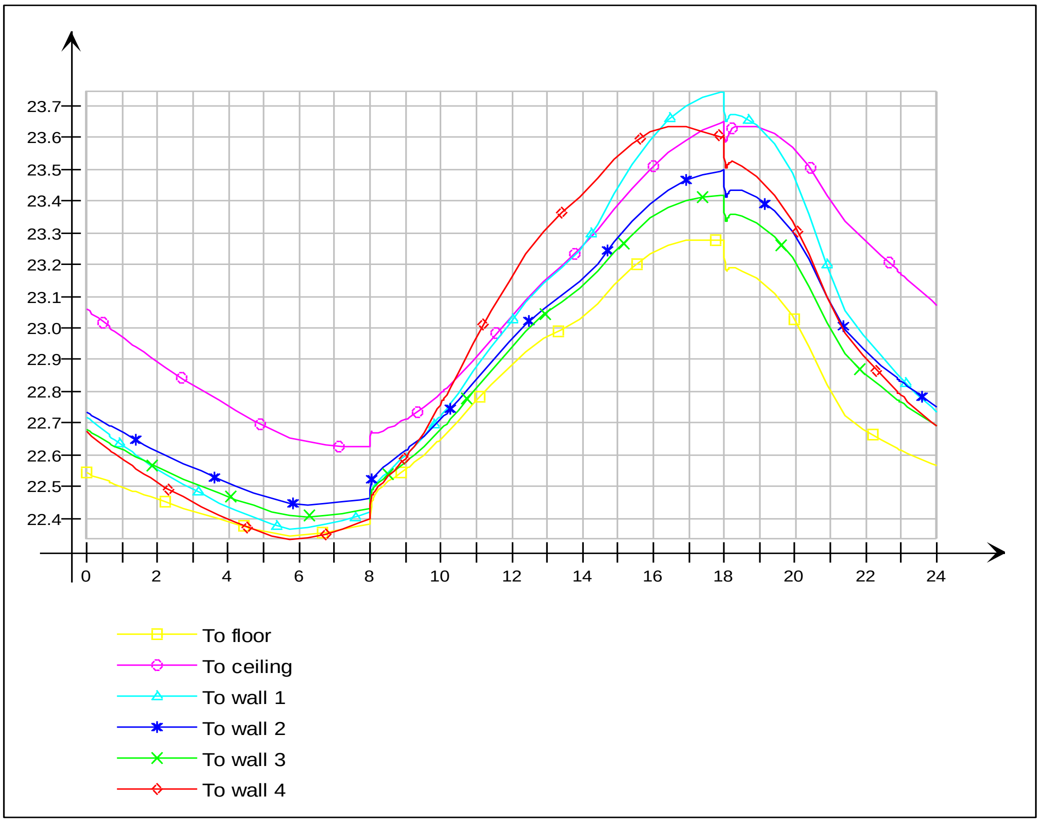
Power supplied by plant



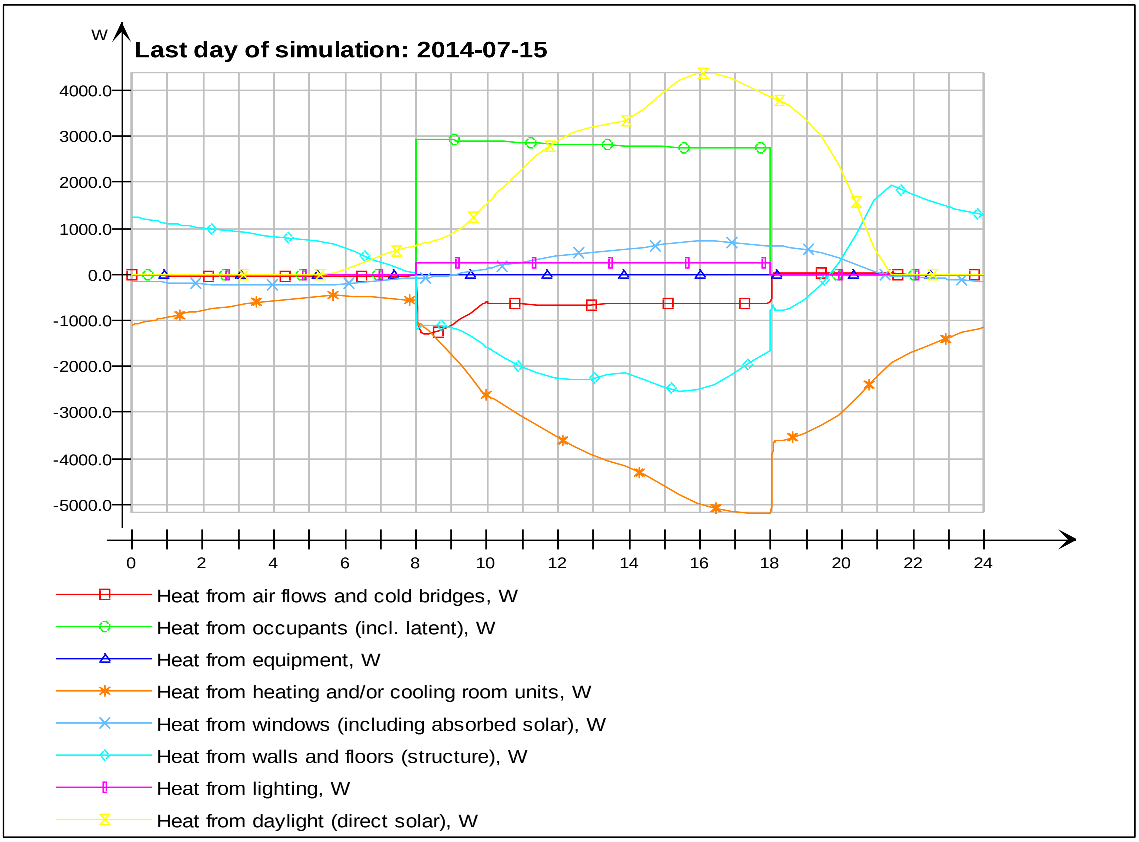
Main temperatures



Directed operative temperatures



Heat balance



Cooling zone 3

Simulation results

Extremes

The zone

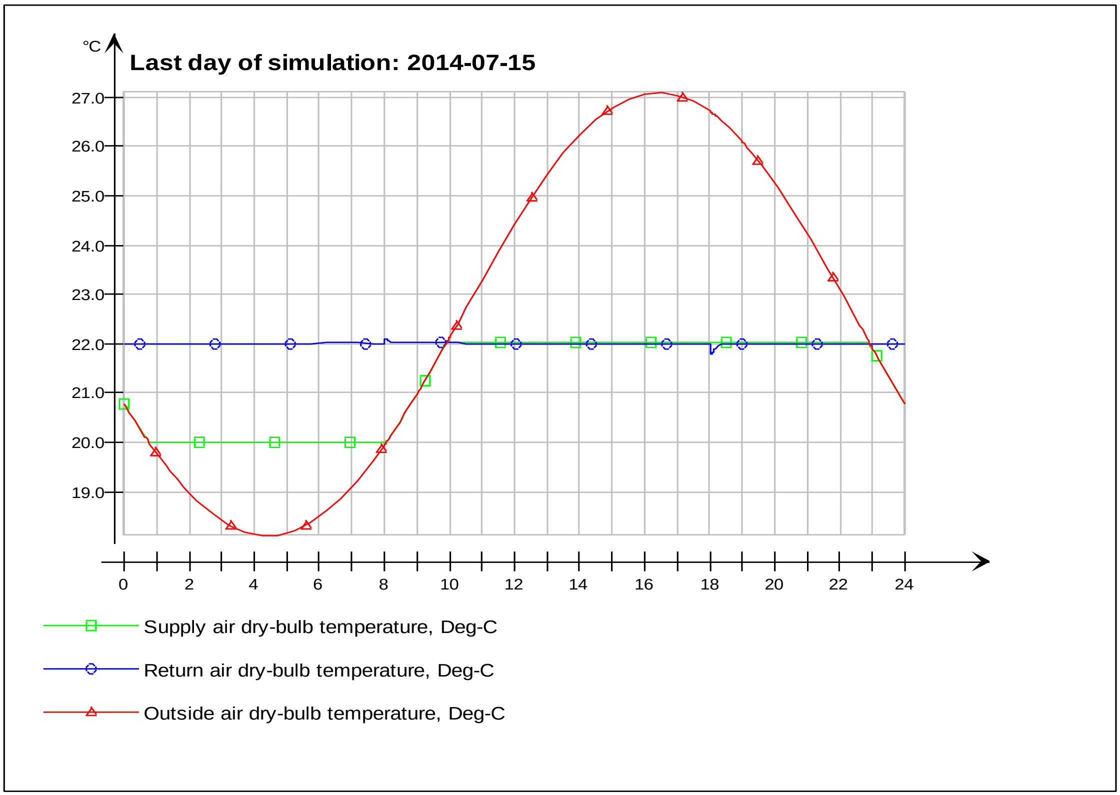
		Value	Occurs at
Operative temperature during occupancy [°C]	min	23.9	8:00
	max	24.5	11:01
Max cooling power [W]	Waterborne	16550.0	11:01
	Airborne*	3119.0	8:20
Max heating power [W]	Waterborne		
	Airborne*	48.8	18:12

*inkl. Infiltration

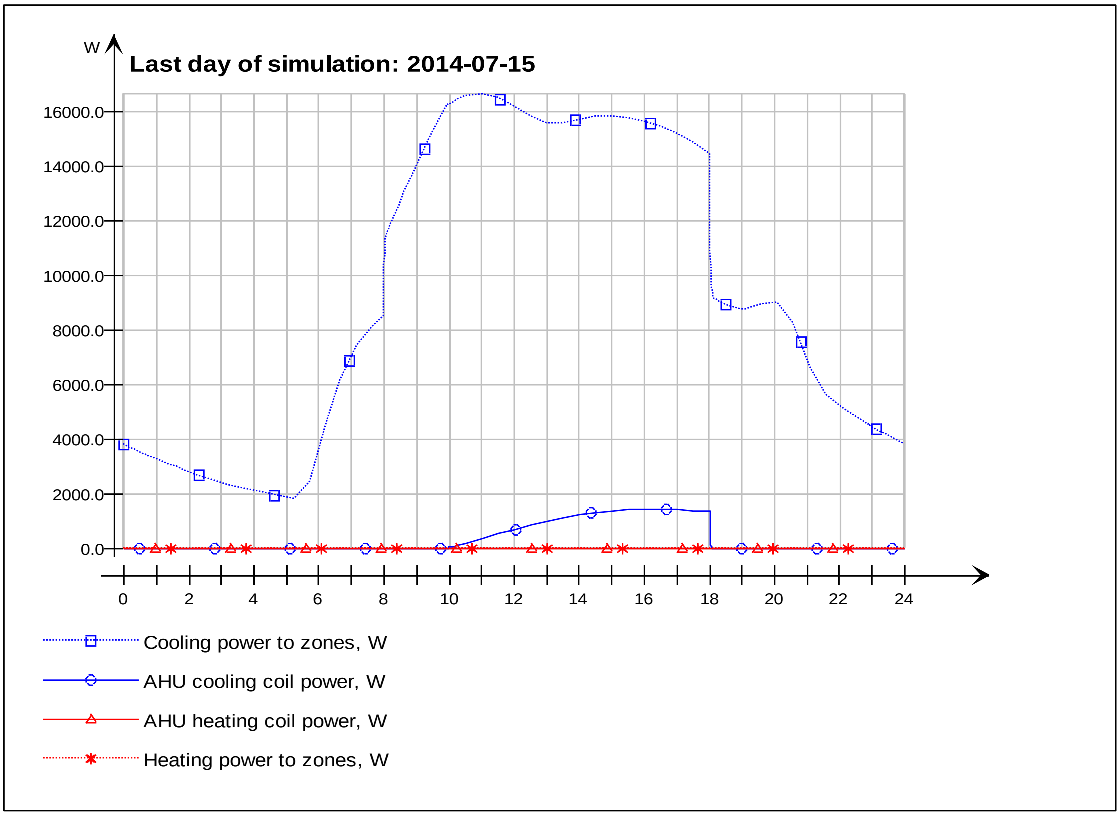
Air handling unit

	Value	Occurs at
Max cooling power [W]	1458.0	16:31
Max heating power [W]		

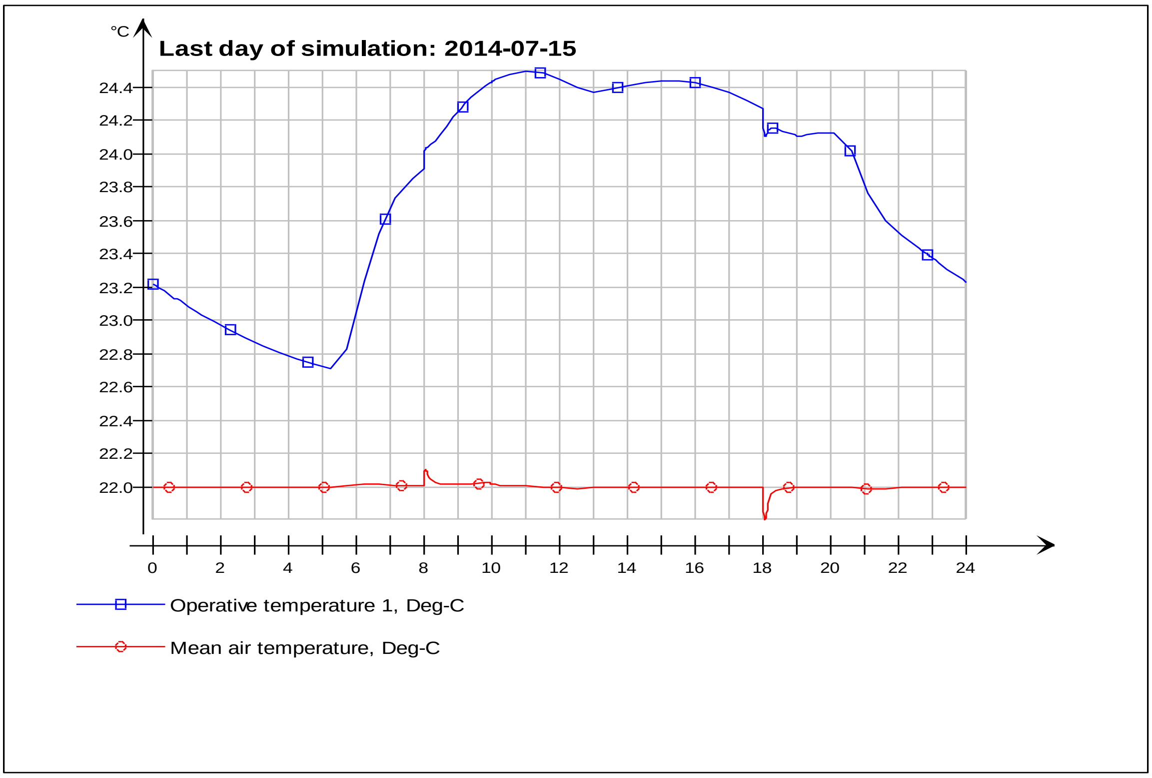
AHU temperatures



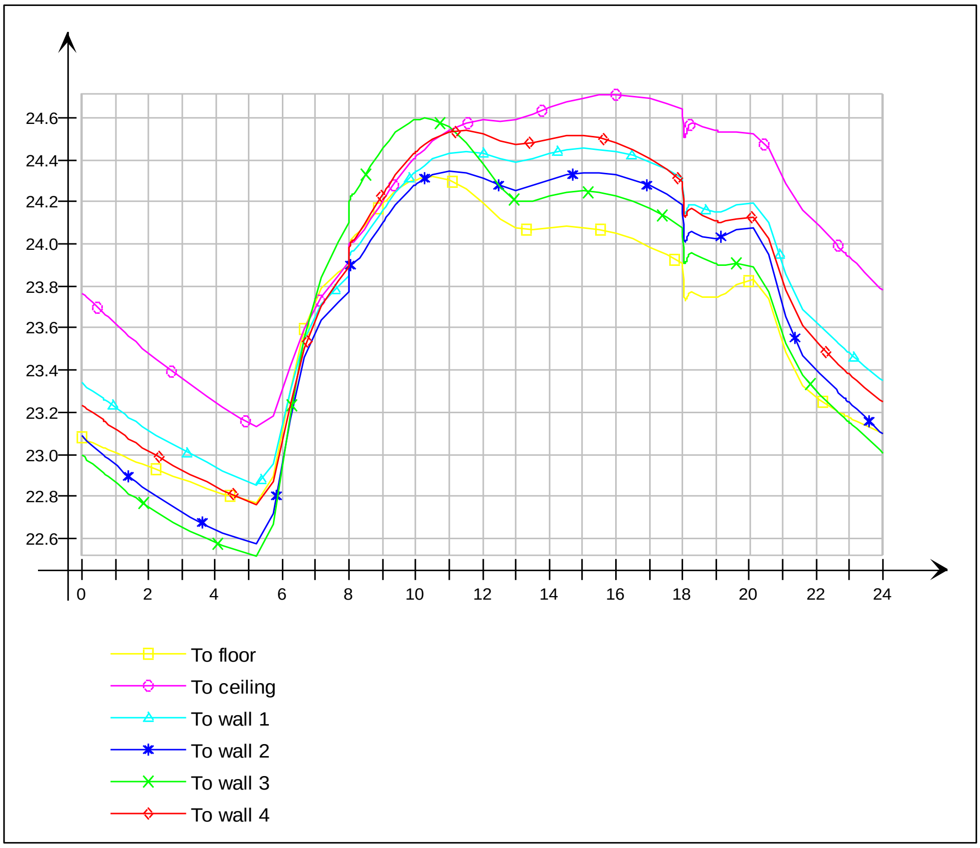
Power supplied by plant



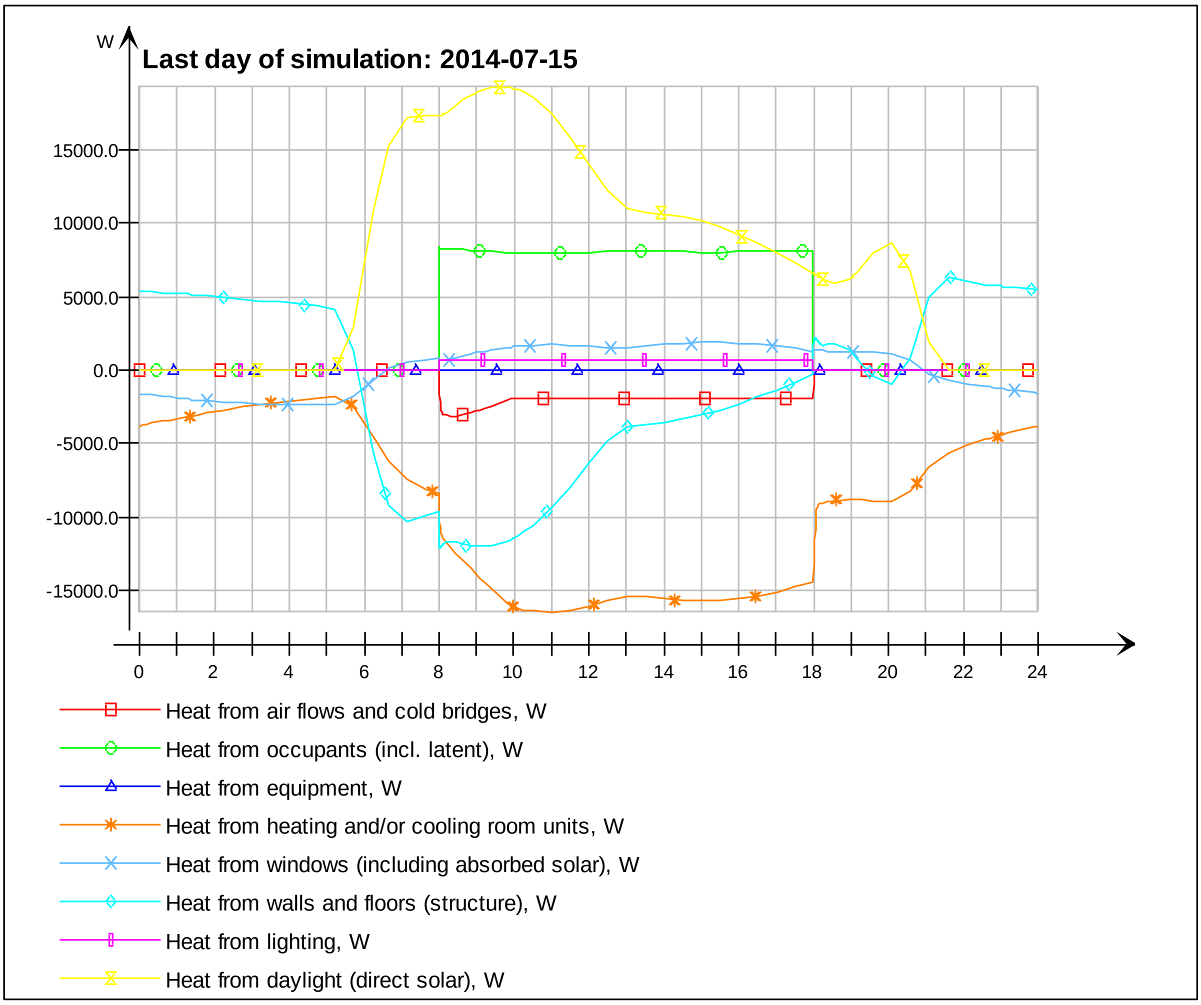
Main temperatures



Directed operative temperatures



Heat balance



Cooling zone 4

Simulation results

Extremes

The zone

		Value	Occurs at
Operative temperature during occupancy [°C]	min	24.8	18:00
	max	26.0	9:57
Max cooling power [W]	Waterborne	9717.0	10:07
	Airborne*	991.6	8:24

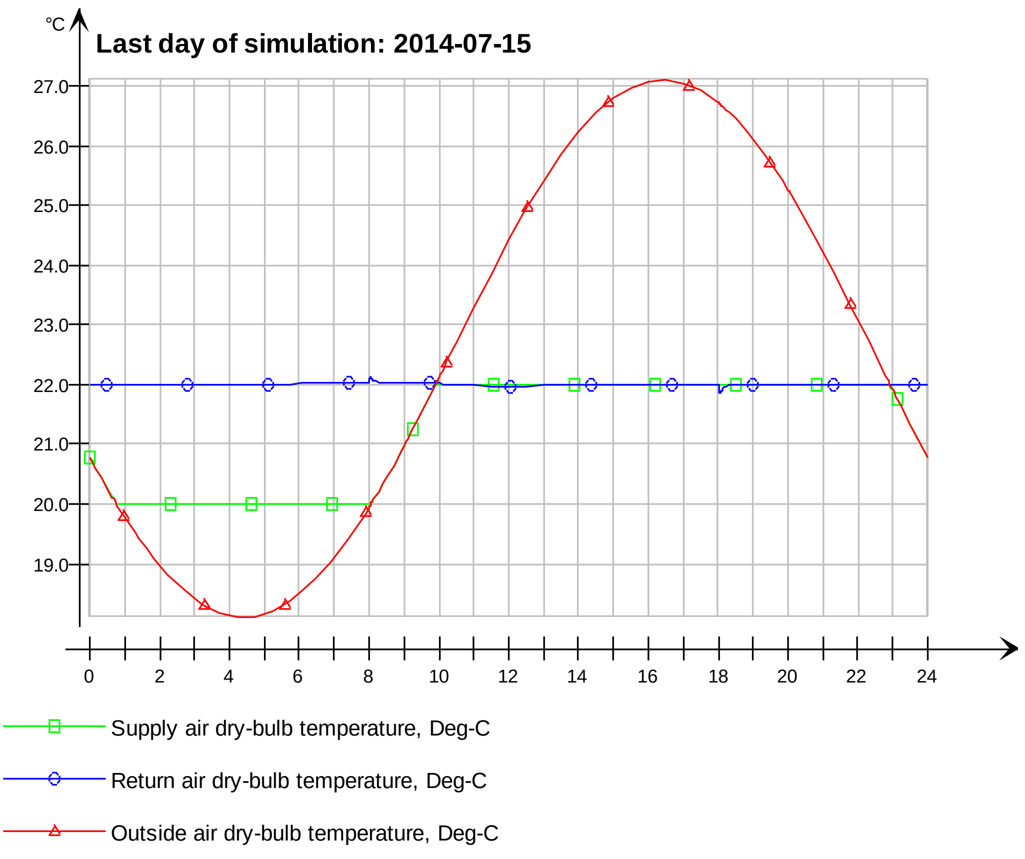
Max heating power [W]	Waterborne		
	Airborne*	20.5	18:12

*inkl. Infiltration

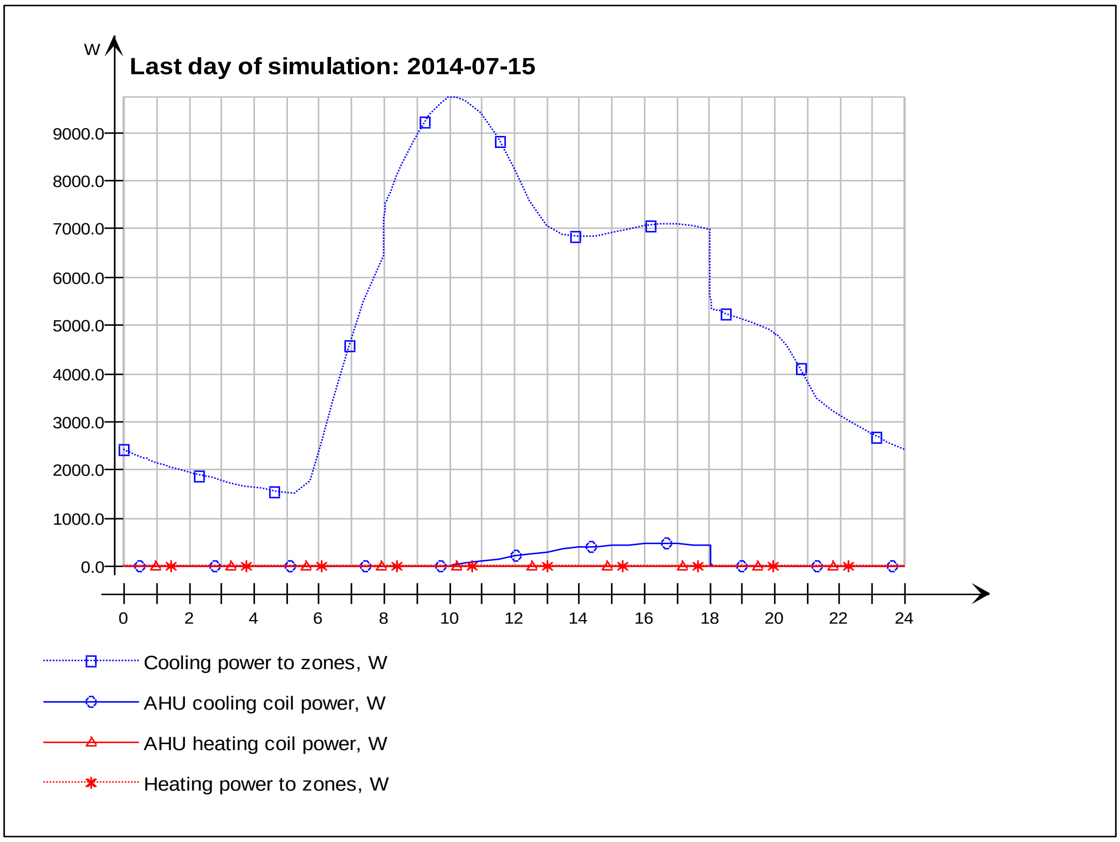
Air handling unit

	Value	Occurs at
Max cooling power [W]	465.8	16:30
Max heating power [W]		

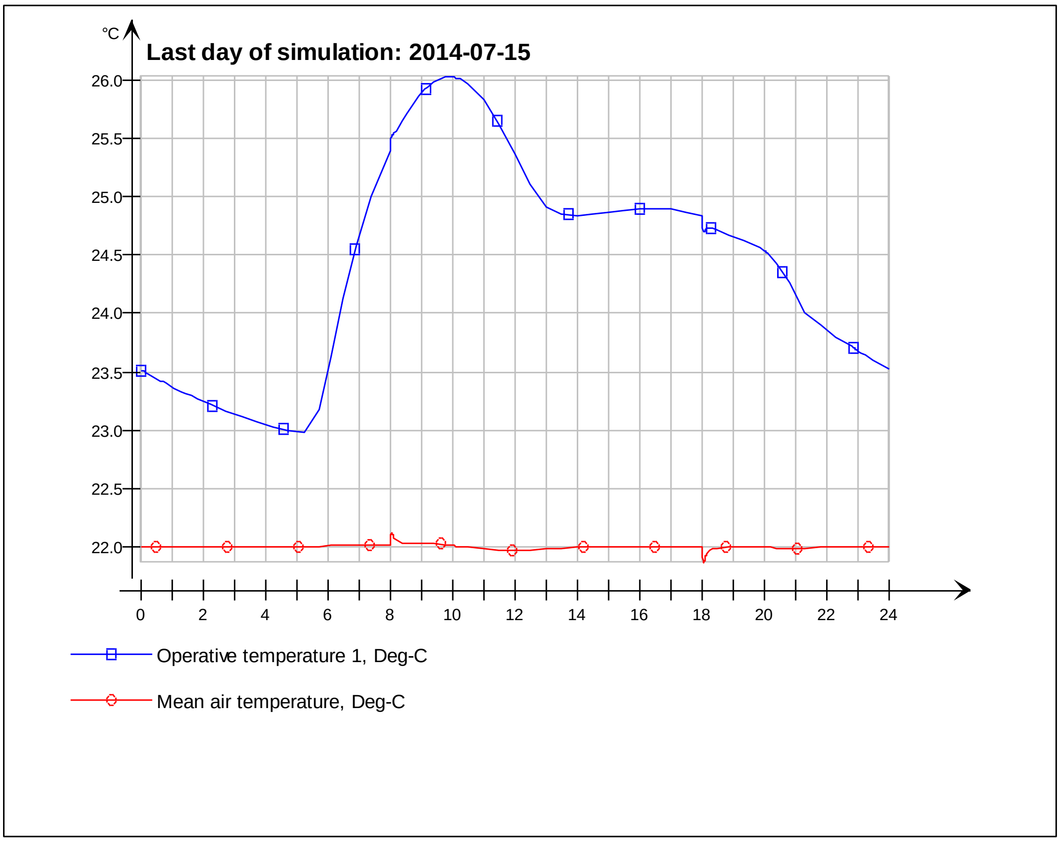
AHU temperatures



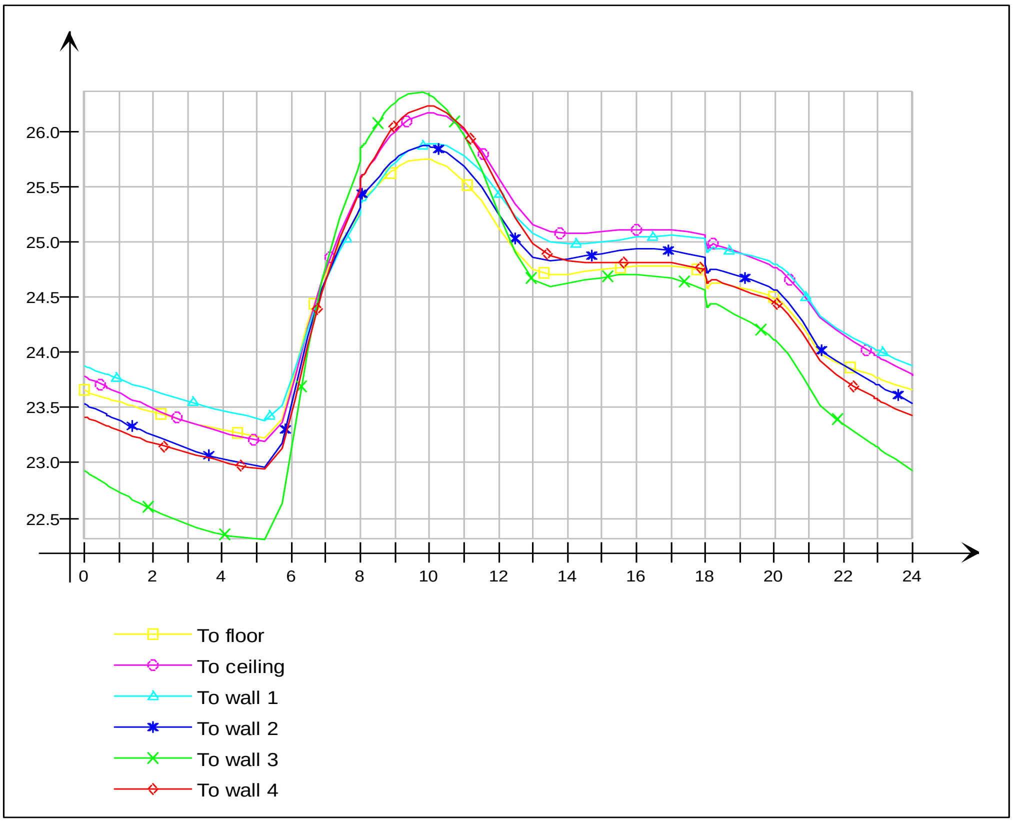
Power supplied by plant



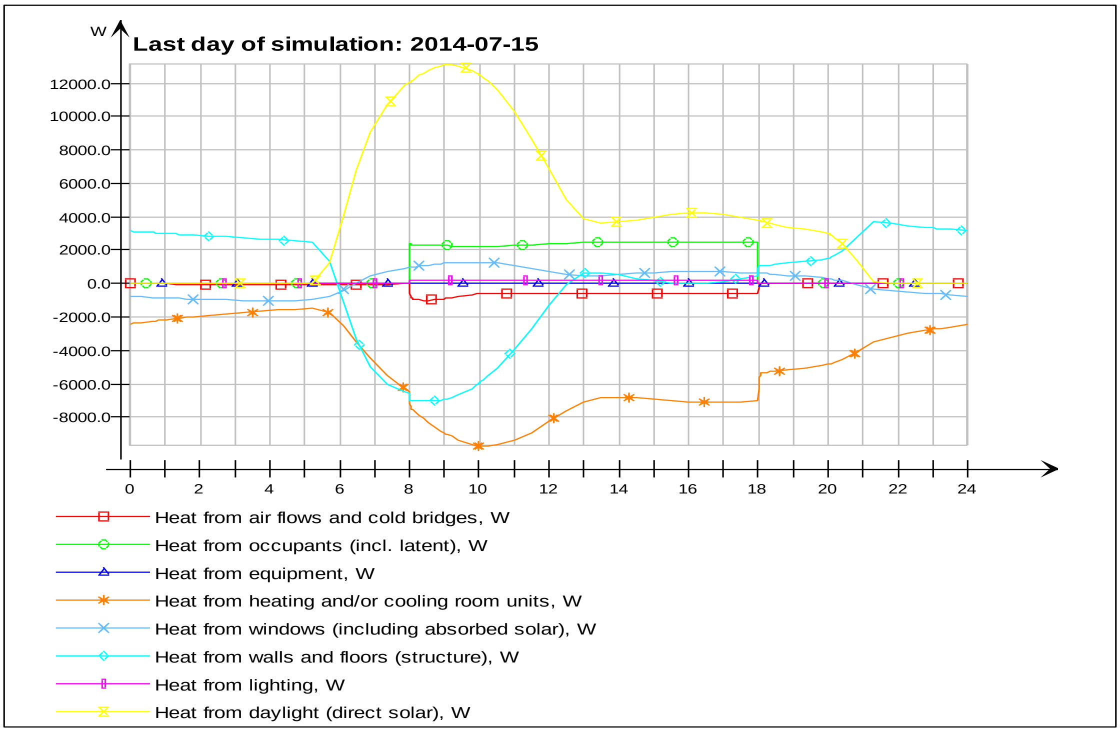
Main temperatures



Directed operative temperatures



Heat balance



Cooling zone 5

Simulation results

Extremes

The zone

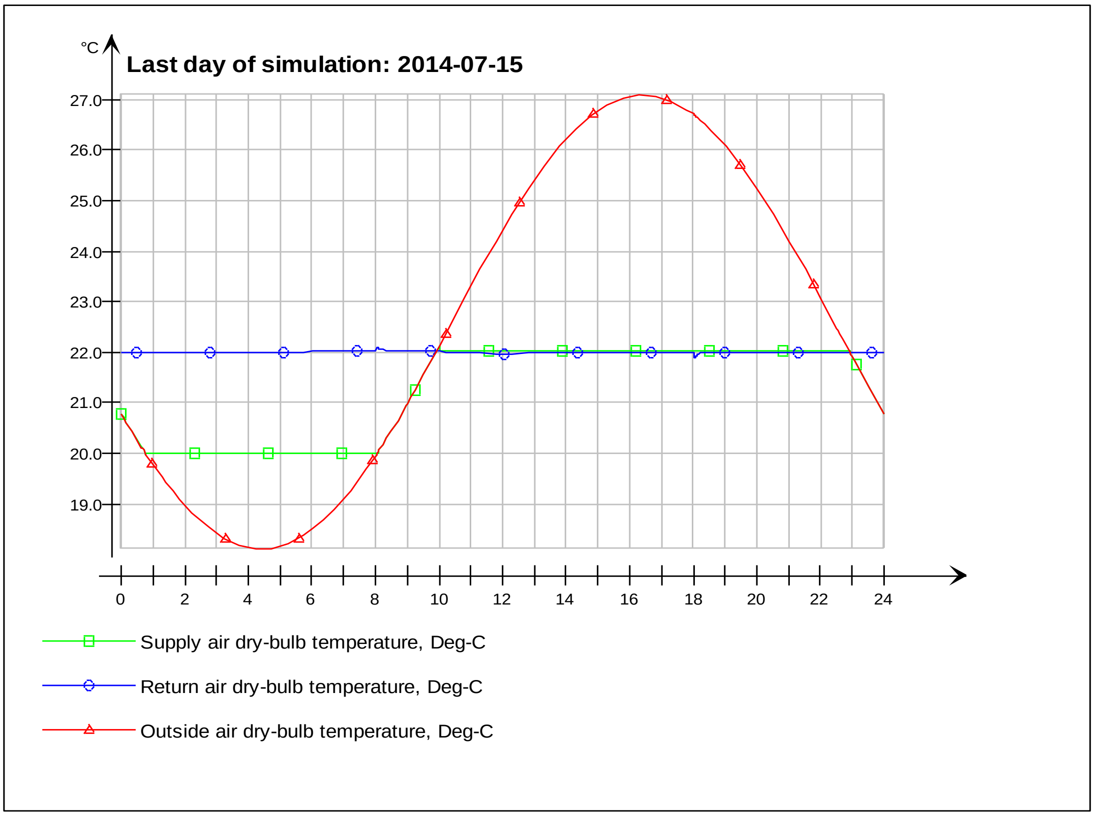
		Value	Occurs at
Operative temperature during occupancy [°C]	min	24.8	18:00
	max	26.5	10:13
Max cooling power [W]	Waterborne	9512.0	10:01
	Airborne*	1132.0	8:21
Max heating power [W]	Waterborne		
	Airborne*	5.1	18:15

*inkl. Infiltration

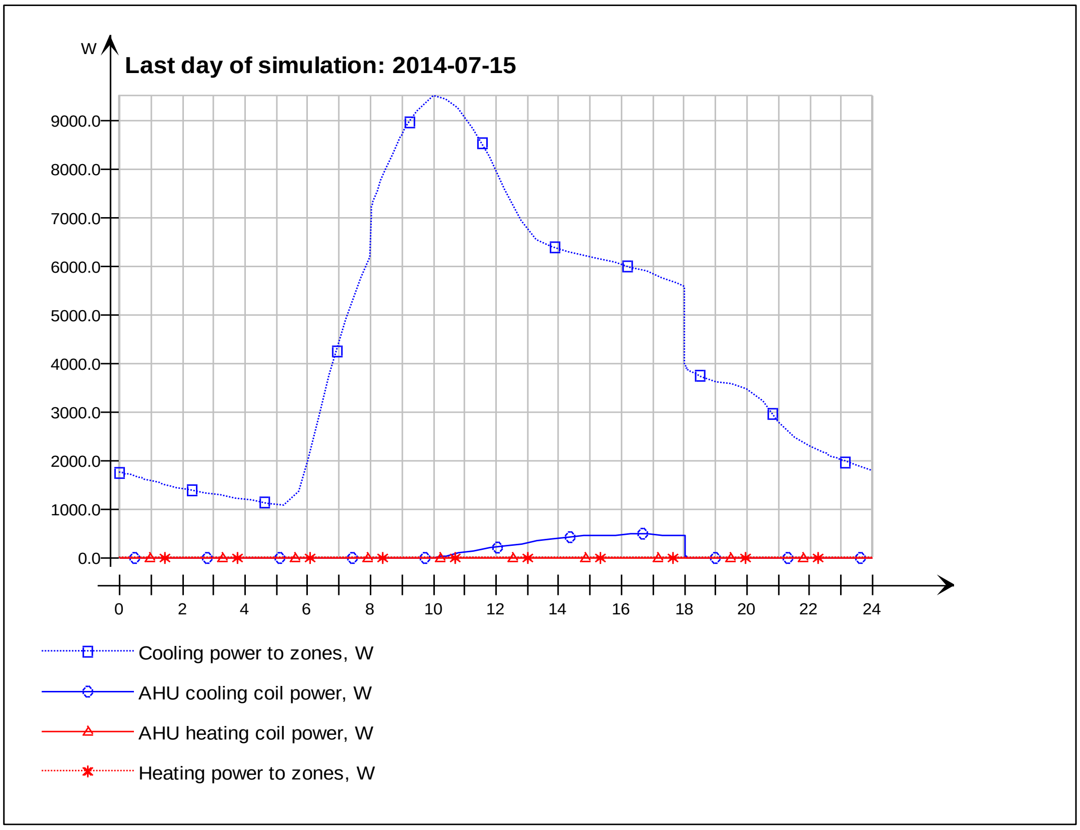
Air handling unit

	Value	Occurs at
Max cooling power [W]	486.5	16:19
Max heating power [W]		

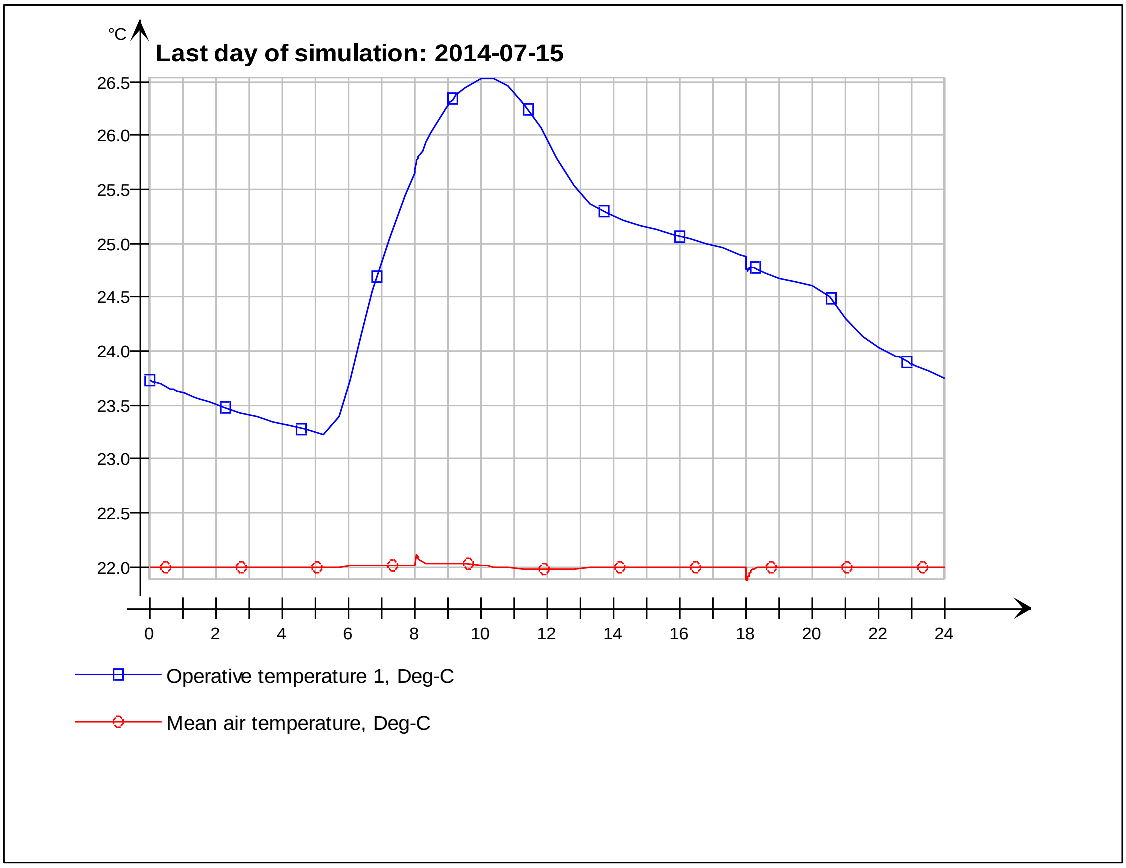
AHU temperatures



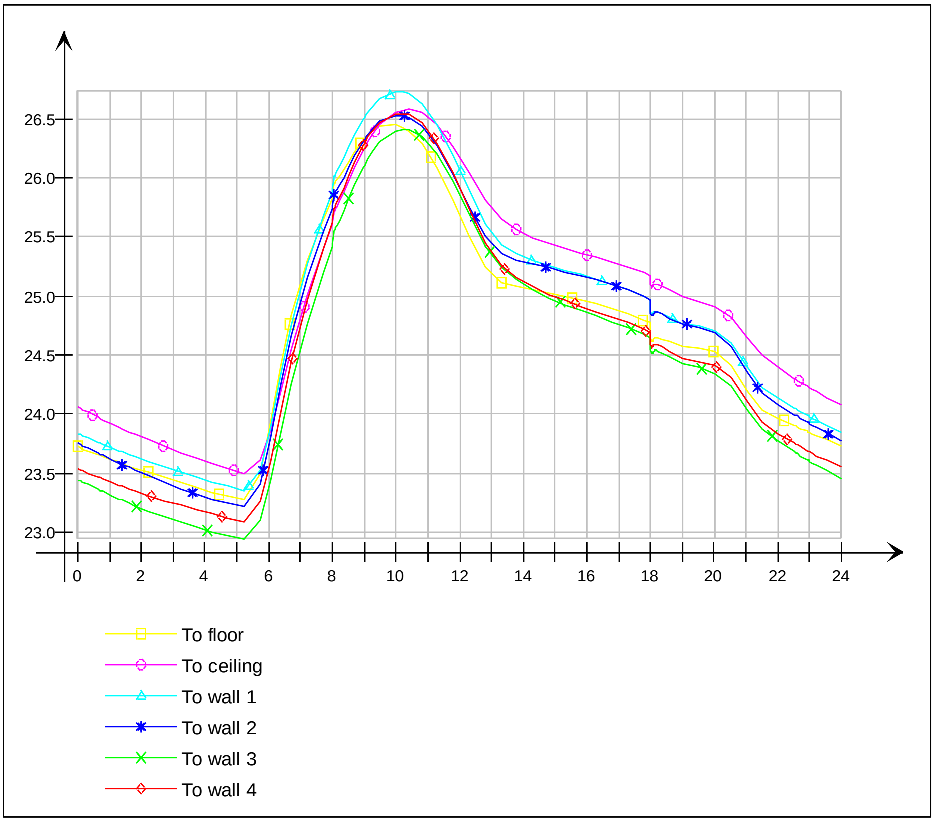
Power supplied by plant



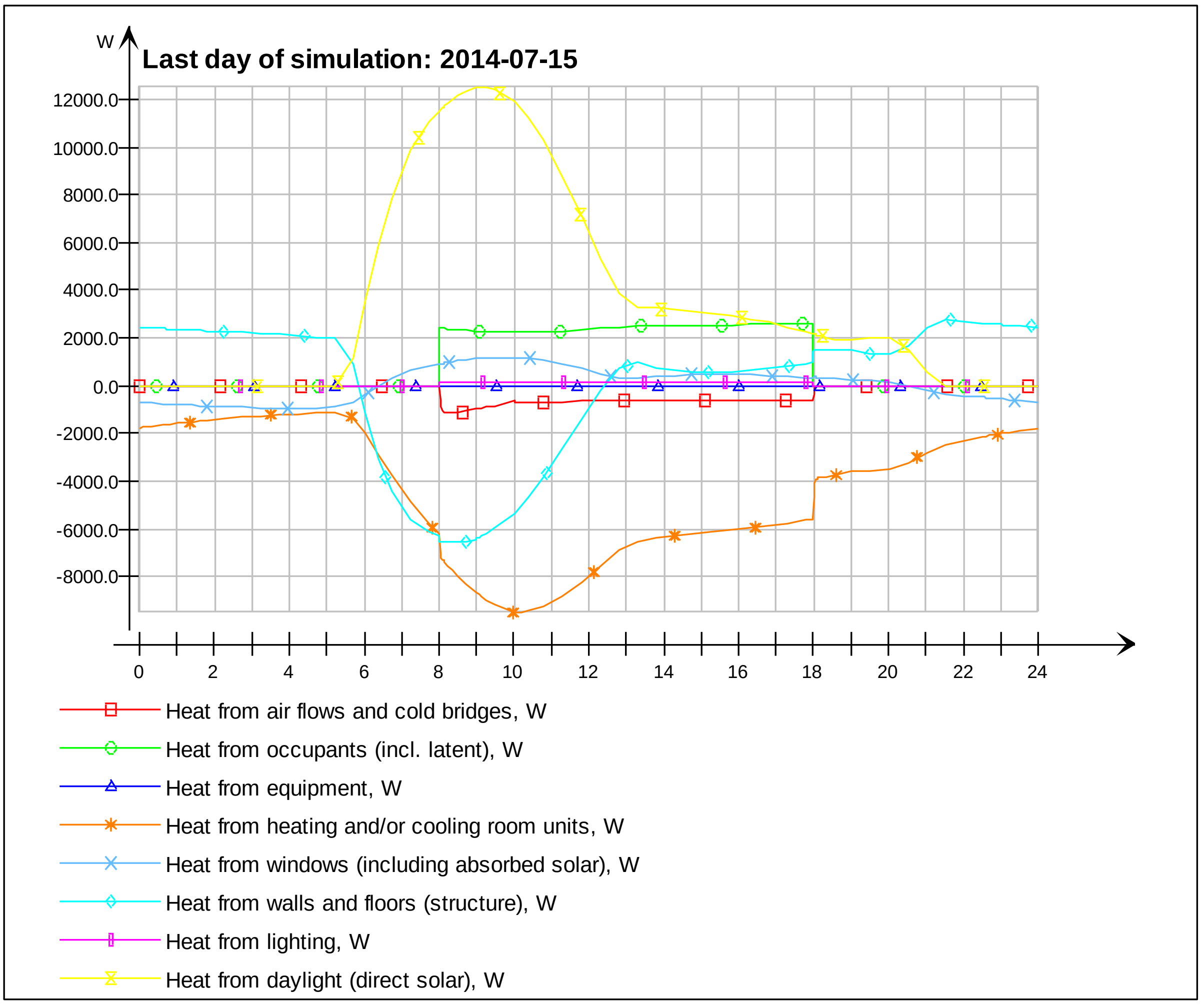
Main temperatures



Directed operative temperatures



Heat balance



Cooling zone 6

Simulation results

Extremes

The zone

		Value	Occurs at
Operative temperature during occupancy [°C]	min	22.8	8:00
	max	23.6	15:53
Max cooling power [W]	Waterborne	4606.0	15:53

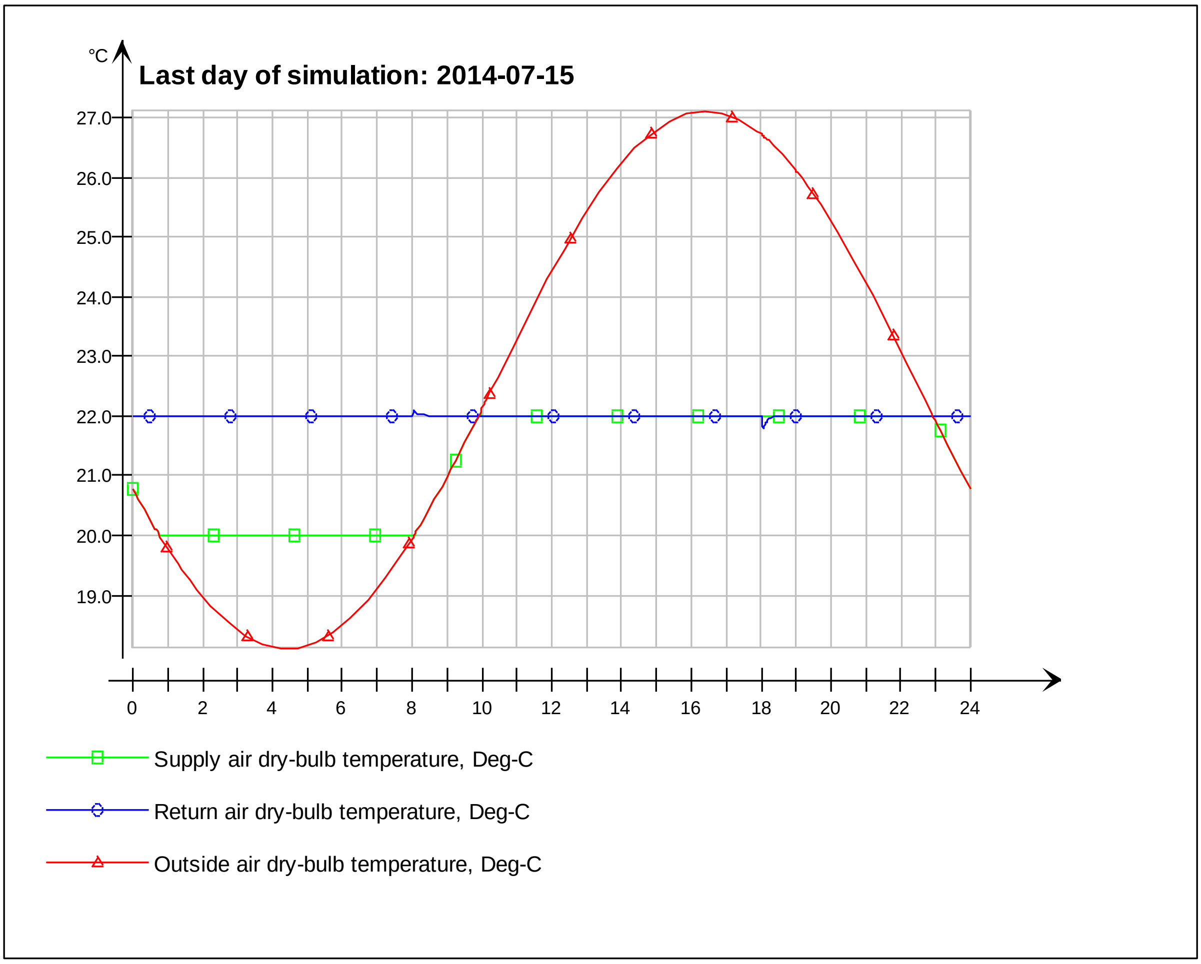
	Airborne*	1187.0	8:21
Max heating power [W]	Waterborne		
	Airborne*	19.4	18:11

*inkl. Infiltration

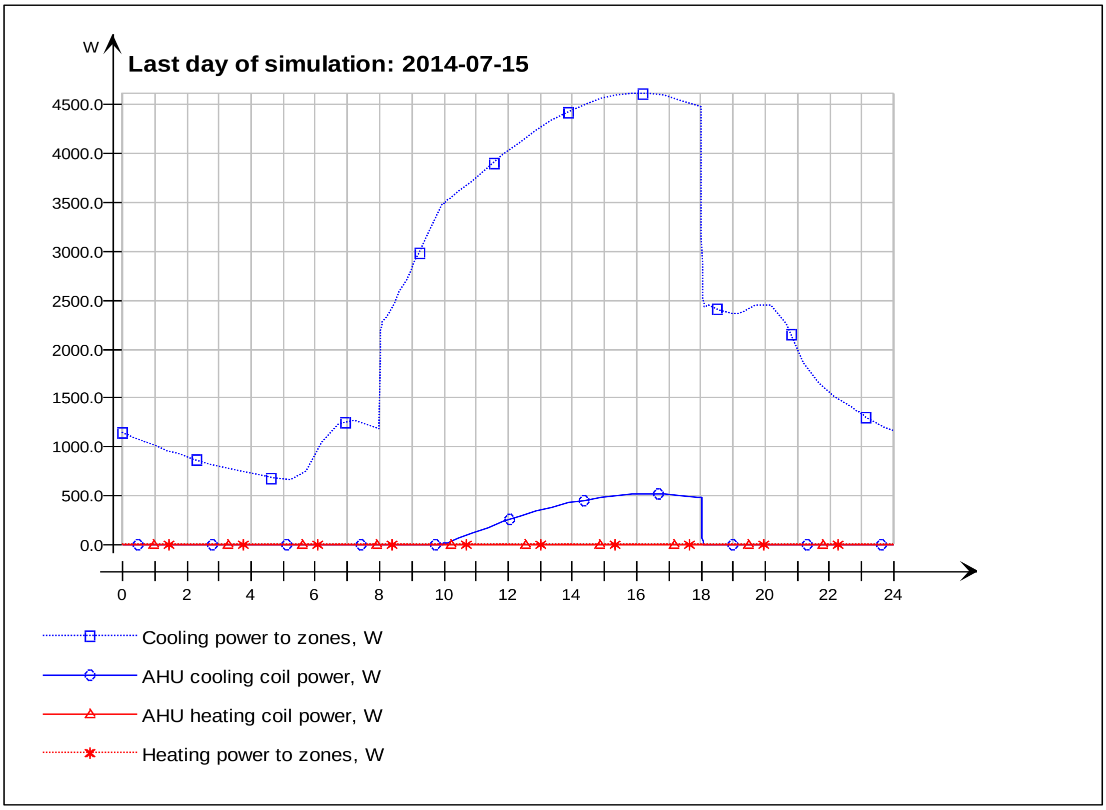
Air handling unit

	Value	Occurs at
Max cooling power [W]	520.7	16:23
Max heating power [W]		

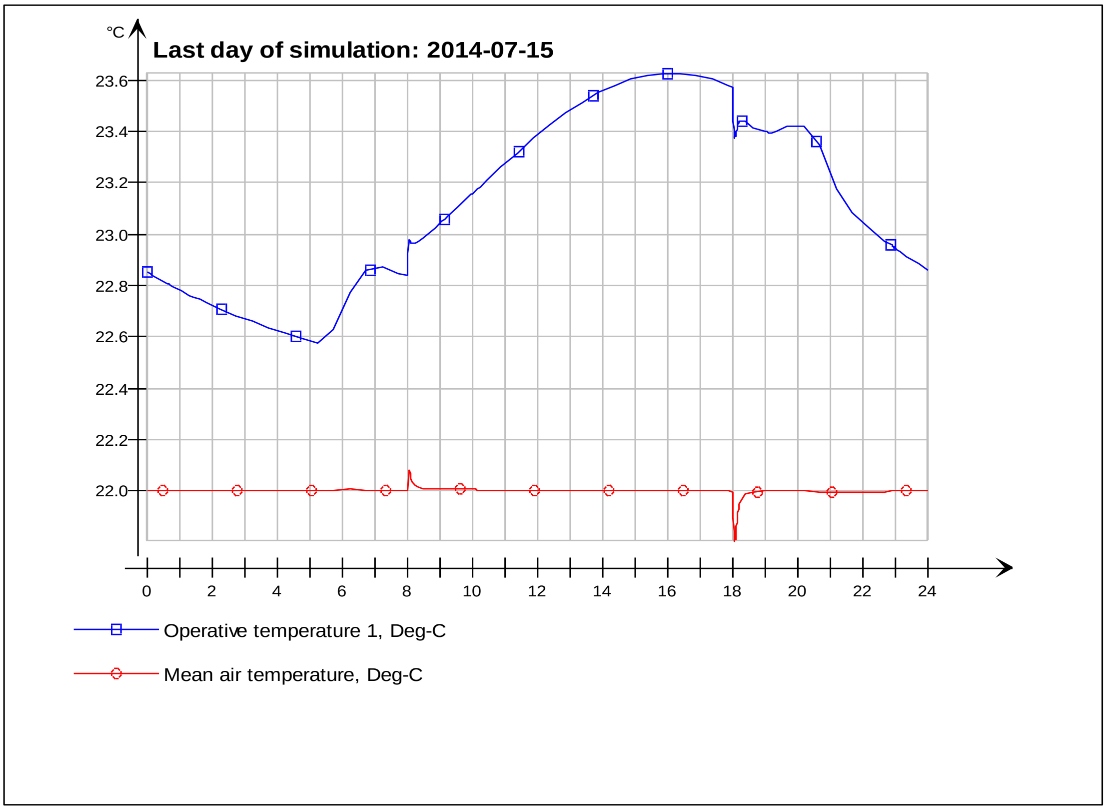
AHU temperatures



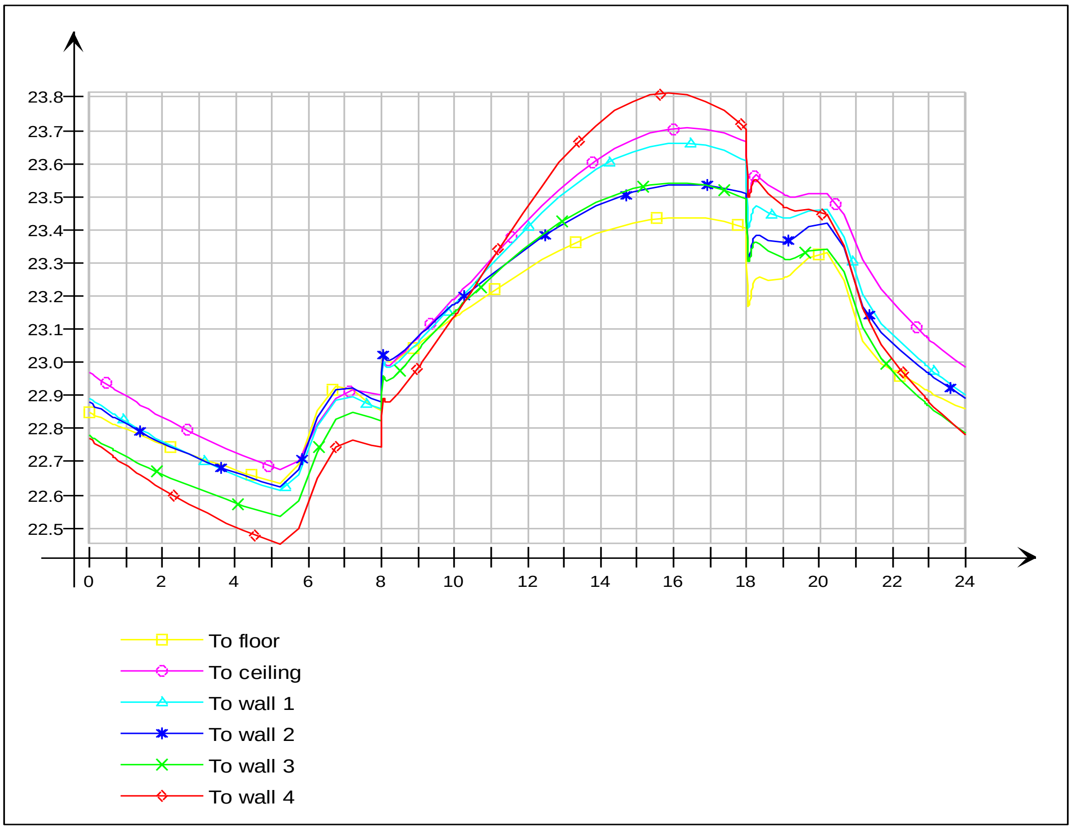
Power supplied by plant



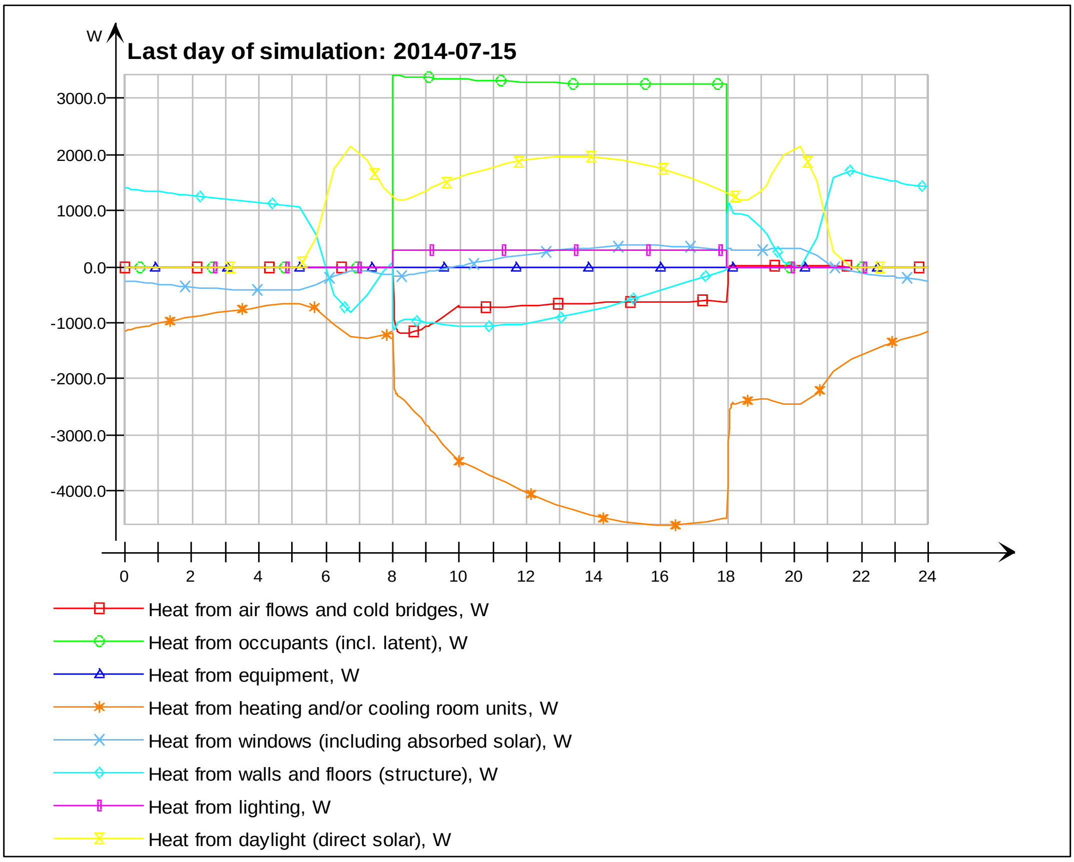
Main temperatures



Directed operative temperatures



Heat balance



Cooling zone 7

Simulation results

Extremes

The zone

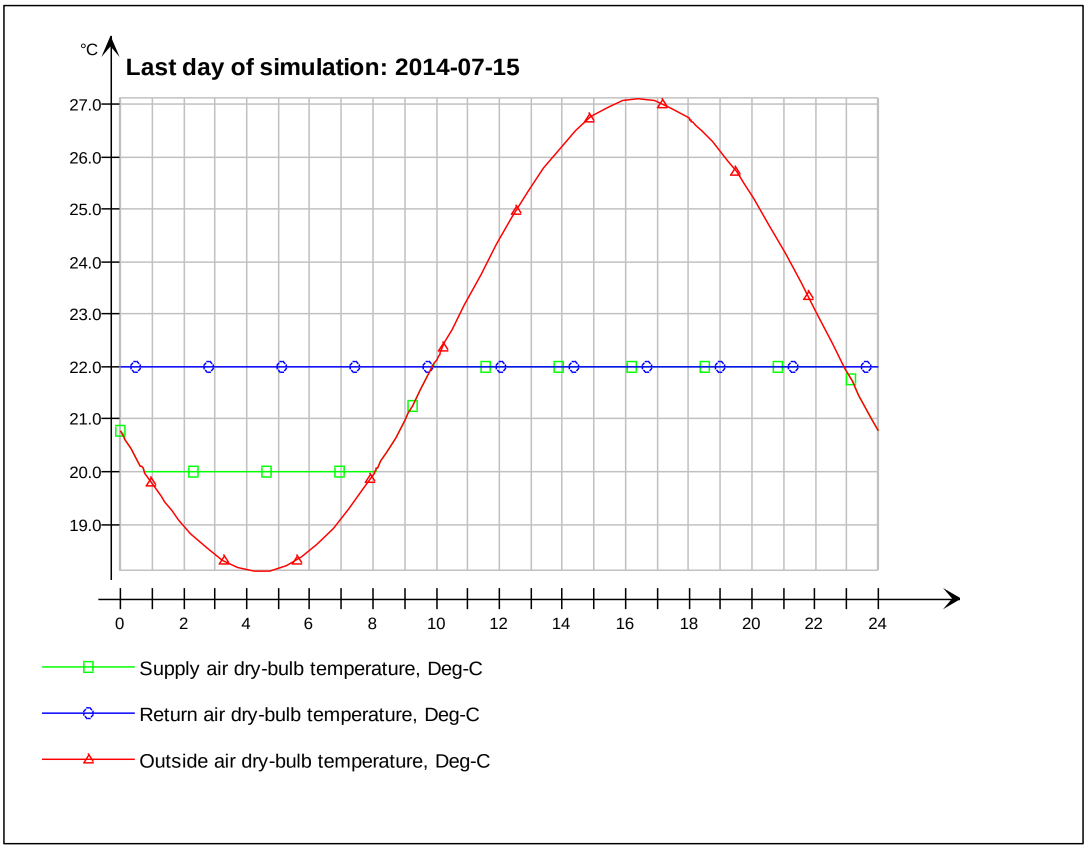
		Value	Occurs at
Operative temperature during occupancy [°C]	min	22.2	8:00
	max	22.6	18:00
Max cooling power [W]	Waterborne	734.9	18:00
	Airborne*	117.5	8:11
Max heating power [W]	Waterborne		
	Airborne*	12.5	18:15

*inkl. Infiltration

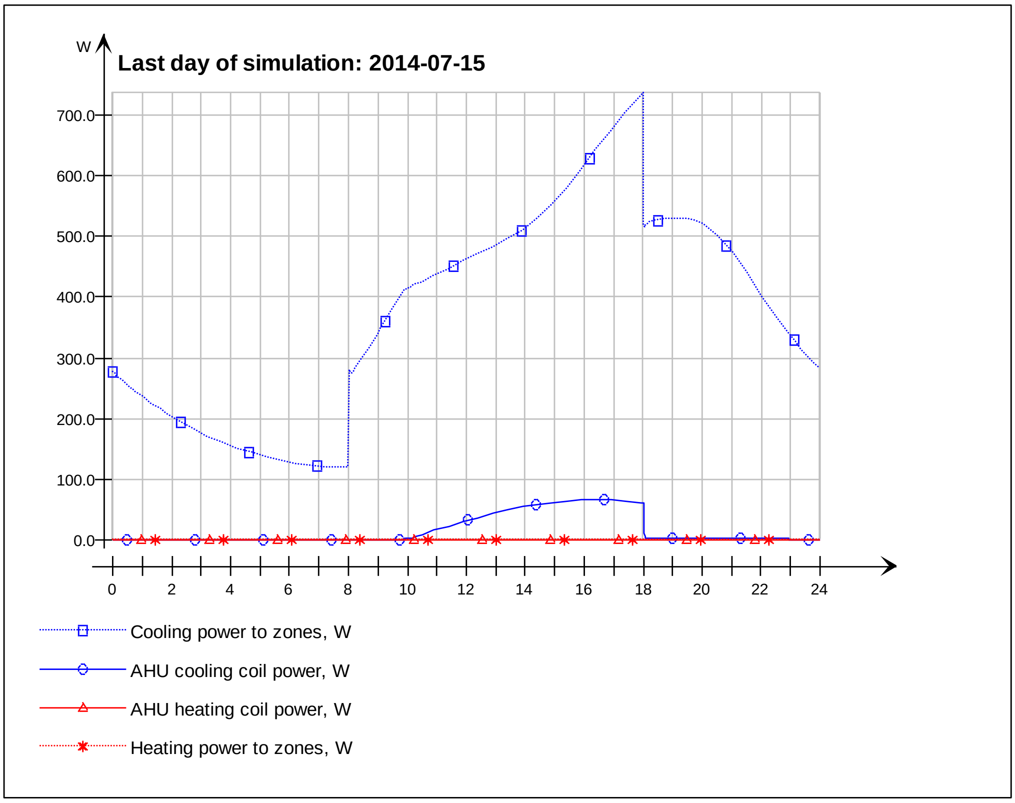
Air handling unit

	Value	Occurs at
Max cooling power [W]	66.5	16:25
Max heating power [W]		

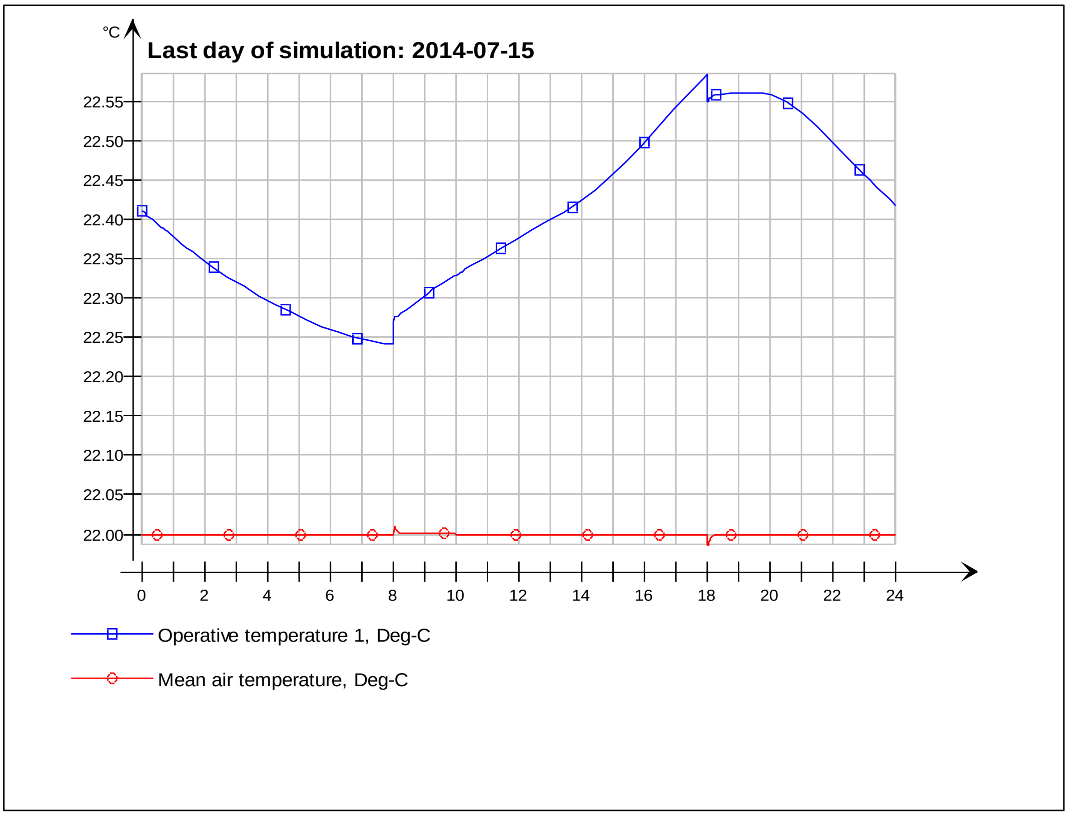
AHU temperatures



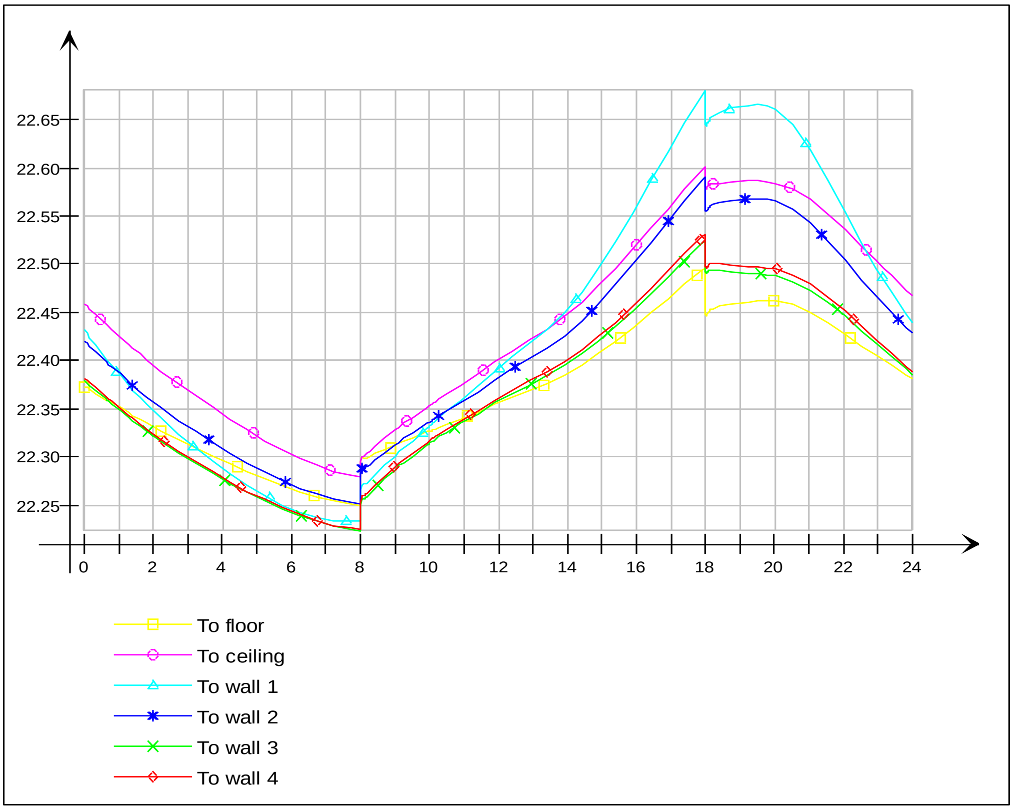
Power supplied by plant



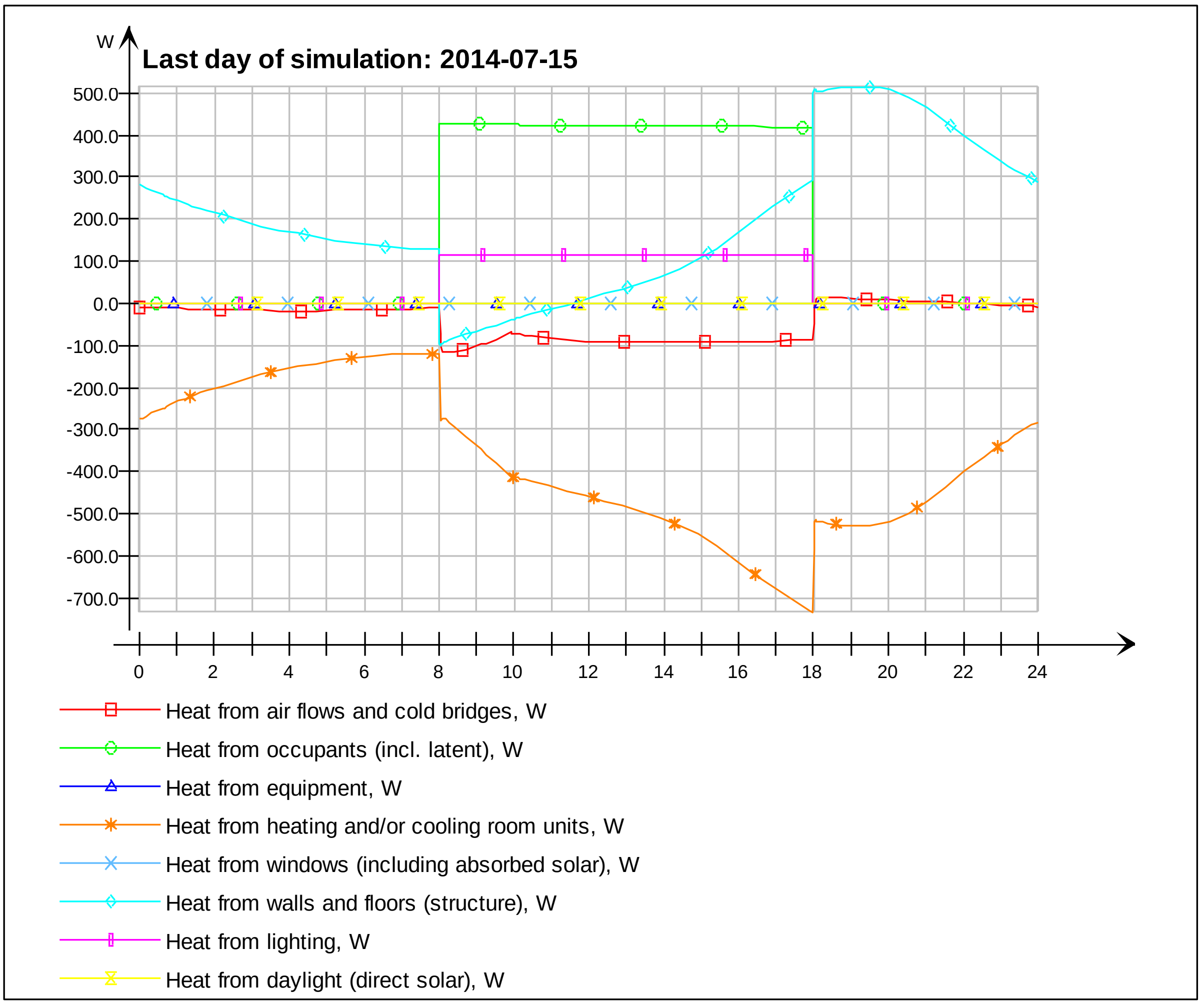
Main temperatures



Directed operative temperatures



Heat balance



Cooling zone 8

Simulation results

Extremes

The zone

		Value	Occurs at
Operative temperature during occupancy [°C]	min	22.8	8:00
	max	24.4	14:44
Max cooling power [W]	Waterborne	6073.0	14:44
	Airborne*	1219.0	8:29

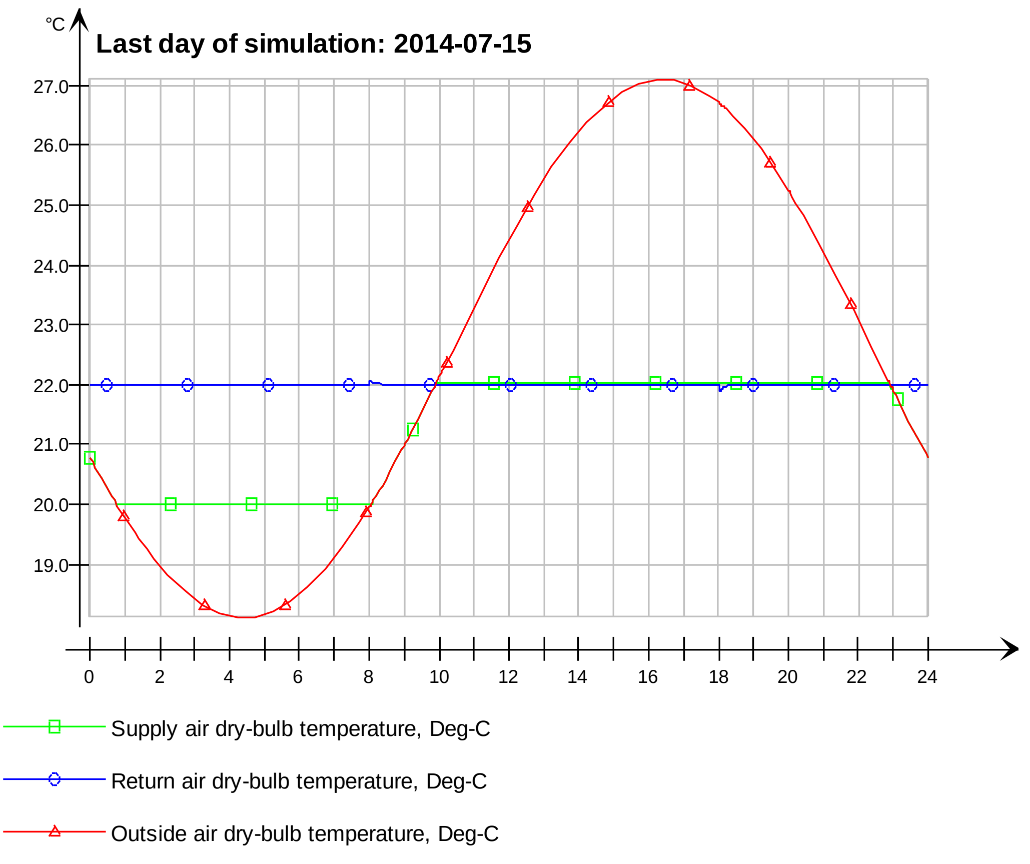
Max heating power [W]	Waterborne		
	Airborne*	23.9	18:13

*inkl. Infiltration

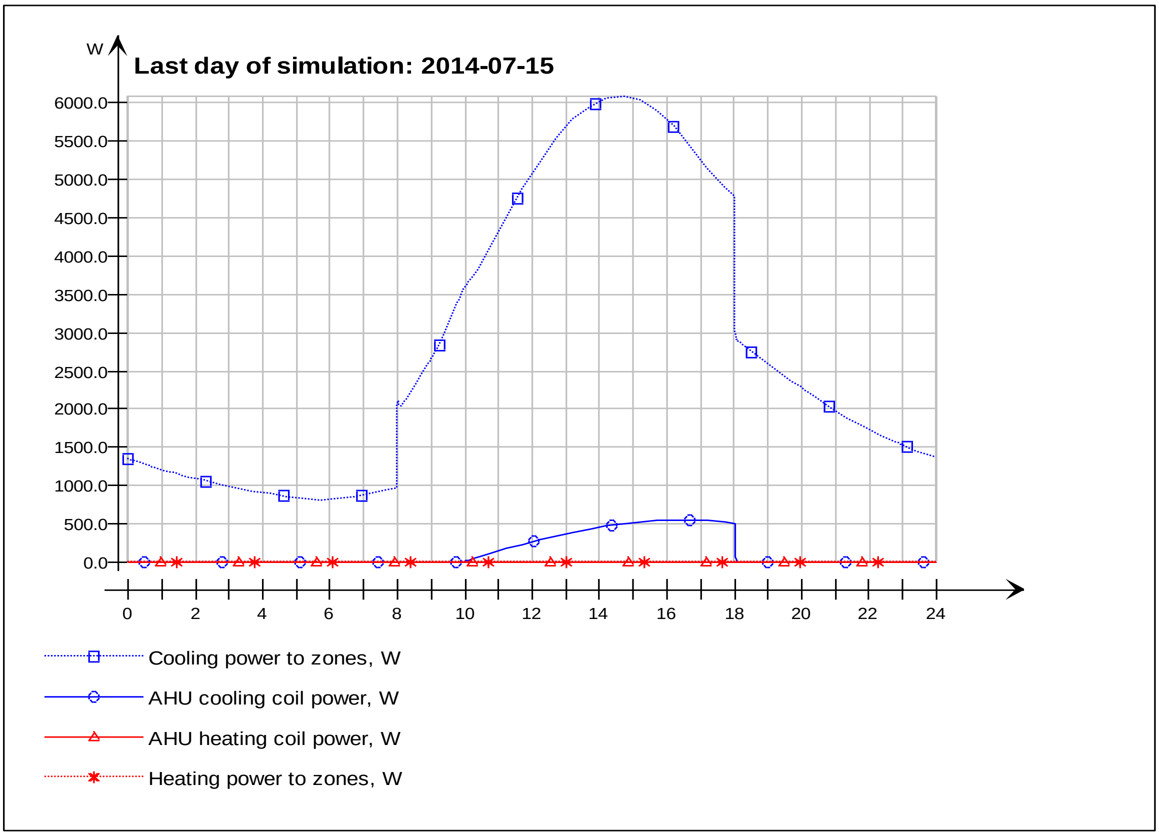
Air handling unit

	Value	Occurs at
Max cooling power [W]	551.5	16:14
Max heating power [W]		

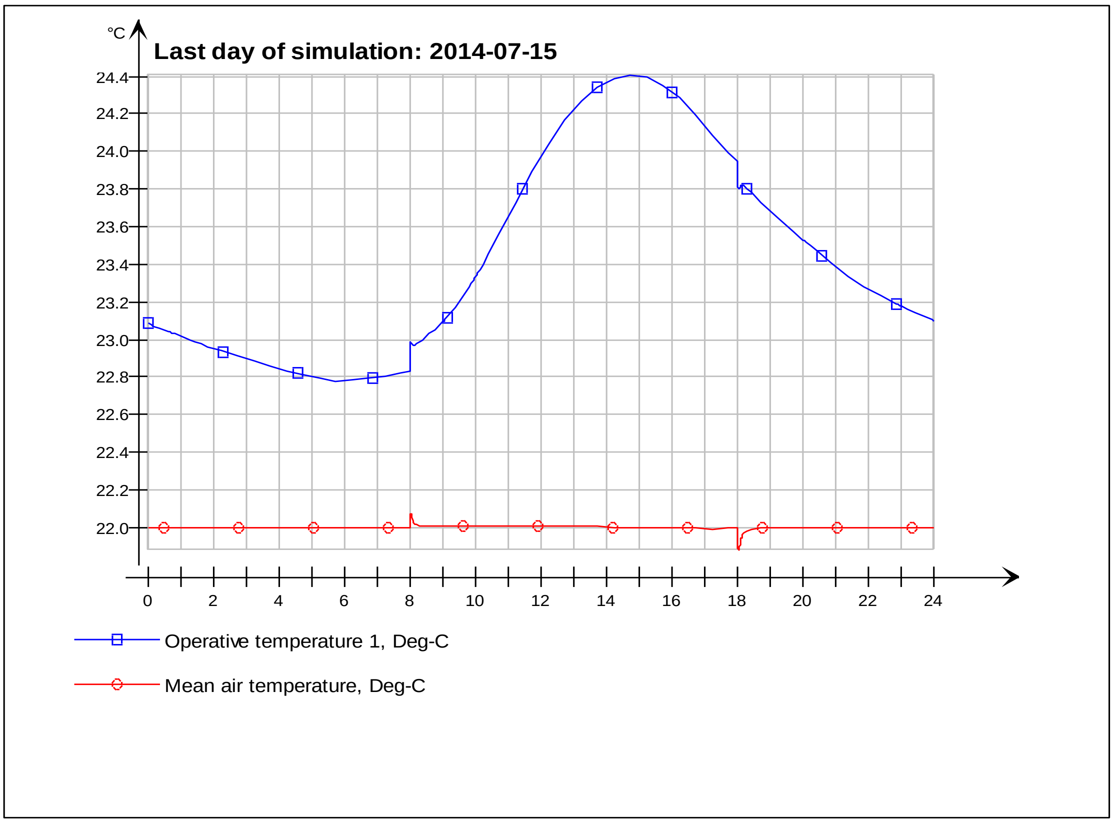
AHU temperatures



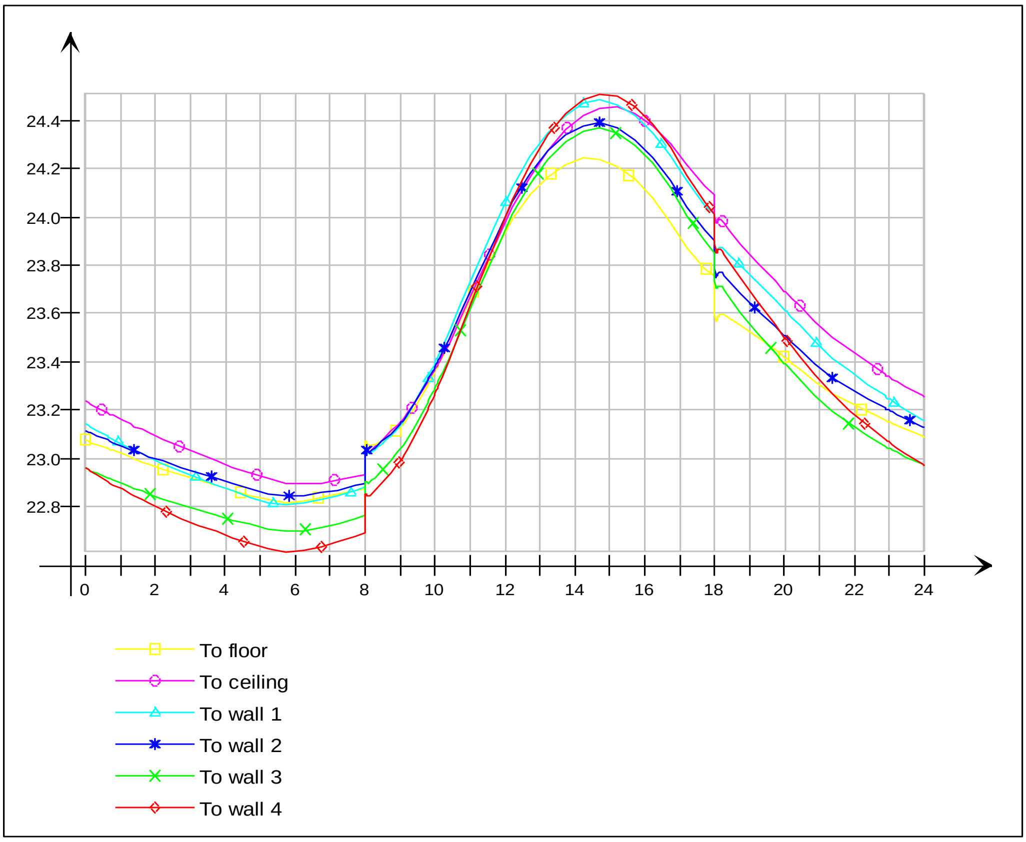
Power supplied by plant



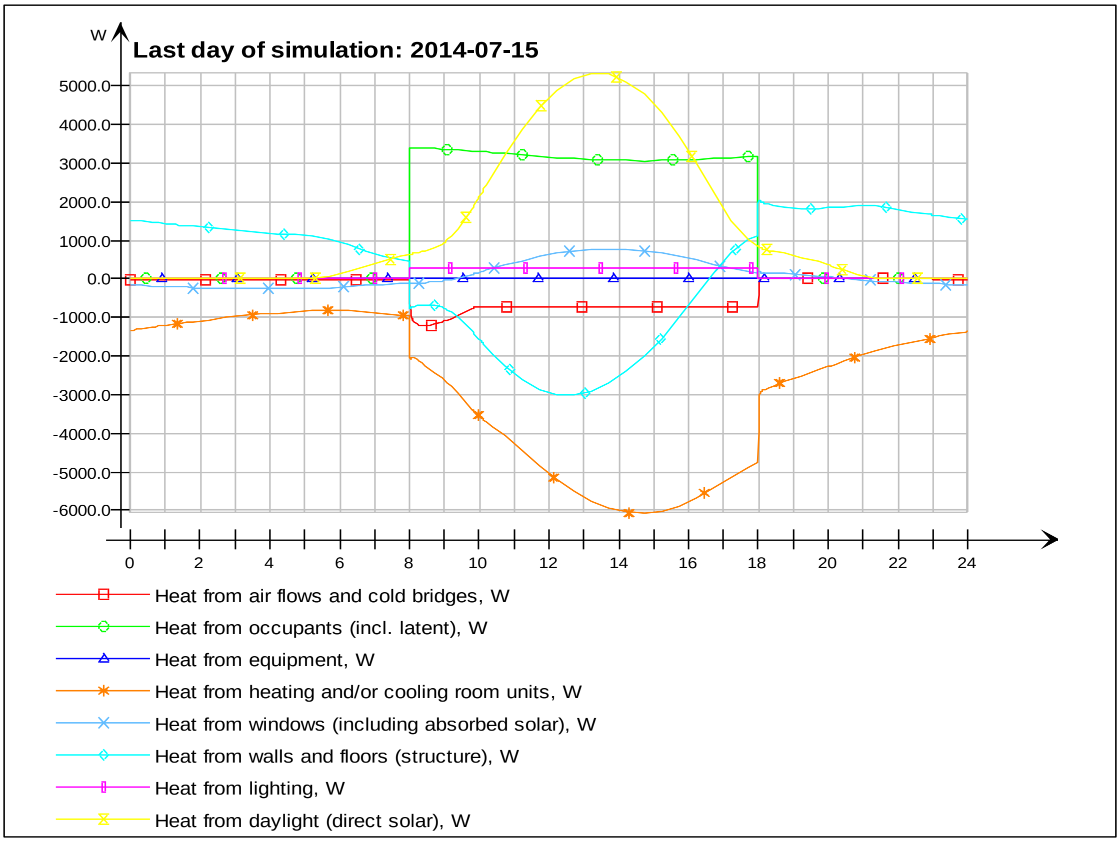
Main temperatures



Directed operative temperatures



Heat balance



Cooling zone 9

Simulation results

Extremes

The zone

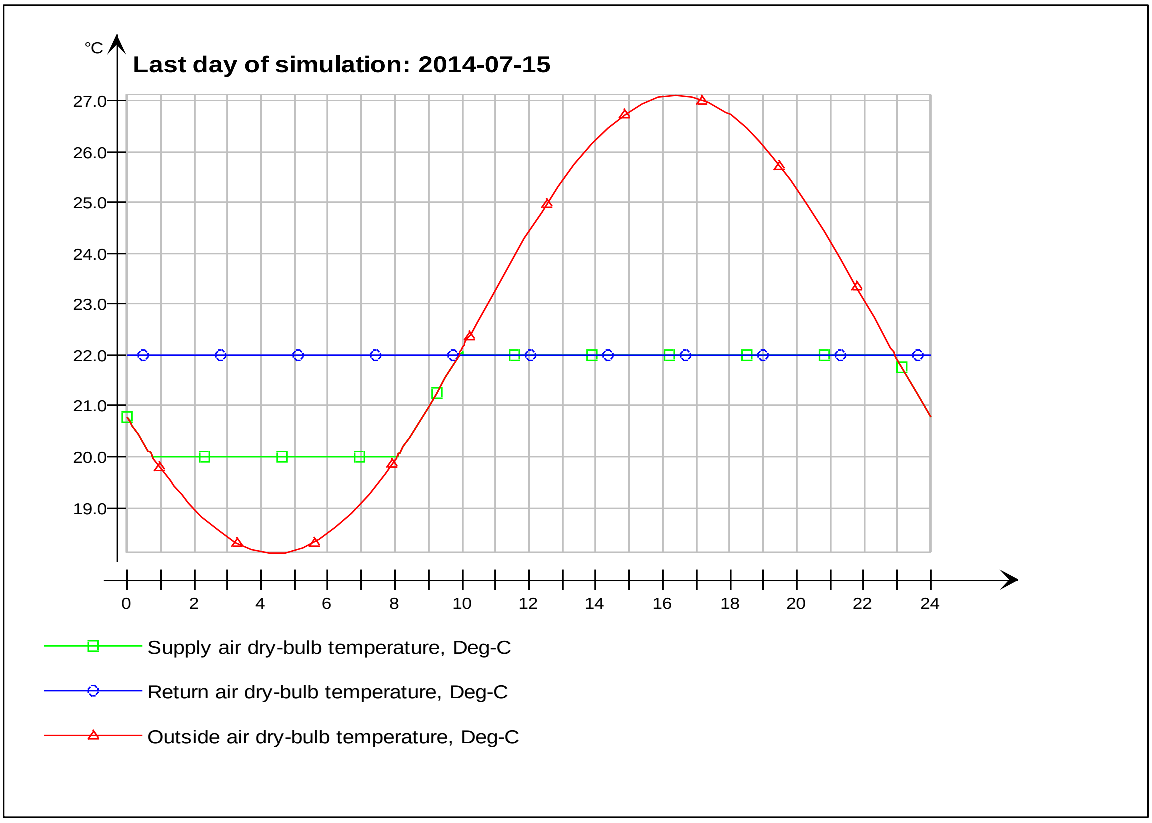
		Value	Occurs at
Operative temperature during occupancy [°C]	min	23.2	8:00
	max	23.9	15:23
Max cooling power [W]	Waterborne	3636.0	15:23
	Airborne*	405.9	8:03
Max heating power [W]	Waterborne		
	Airborne*	40.8	22:58

*inkl. Infiltration

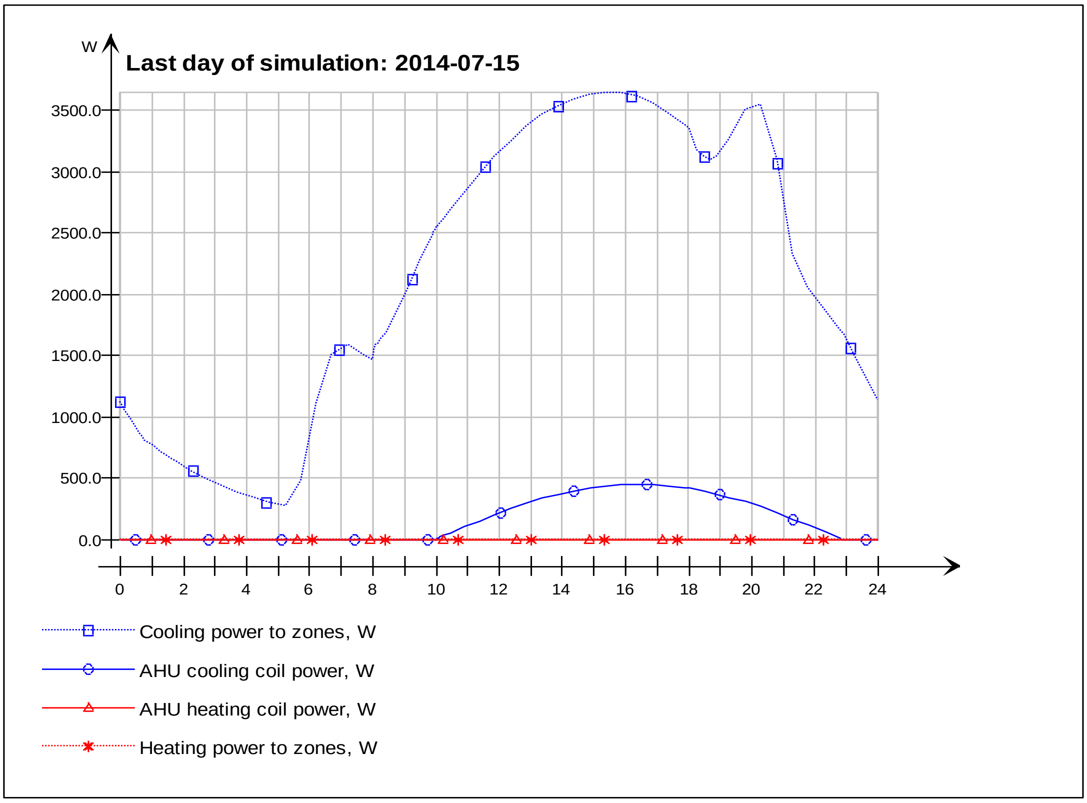
Air handling unit

	Value	Occurs at
Max cooling power [W]	453.7	16:23
Max heating power [W]		

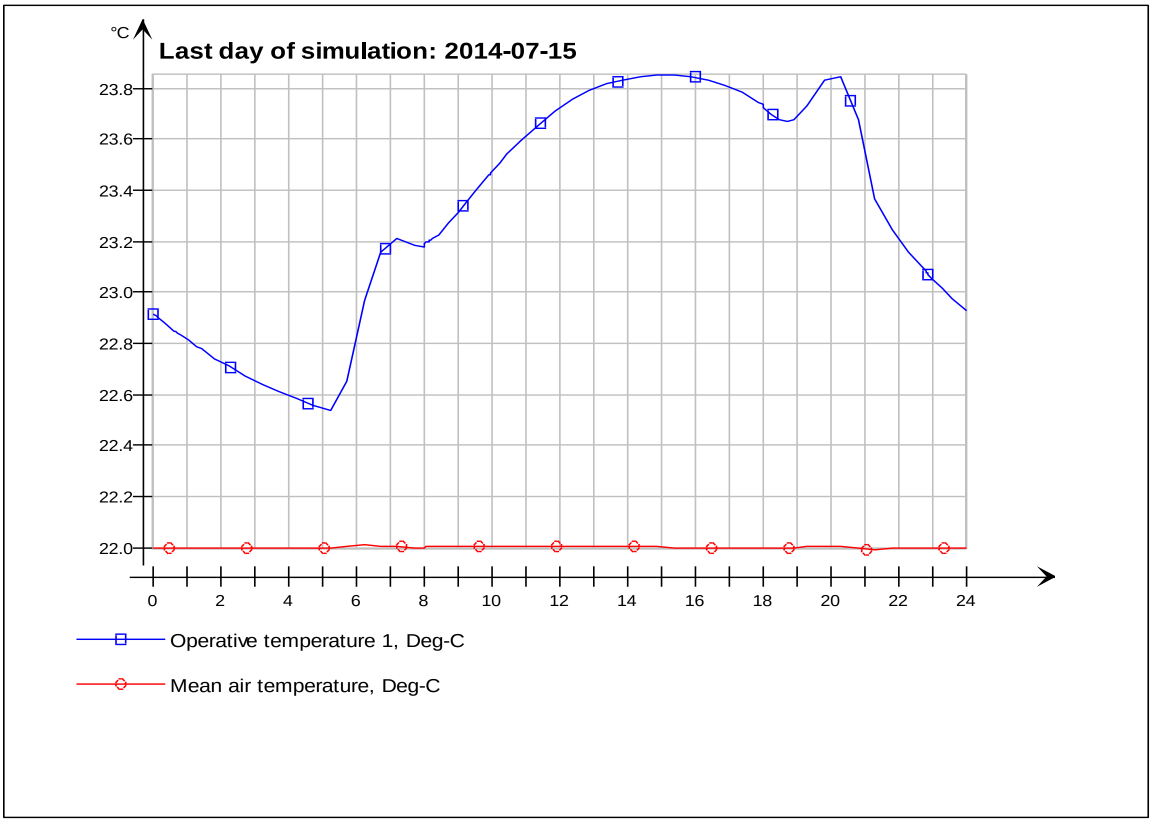
AHU temperatures



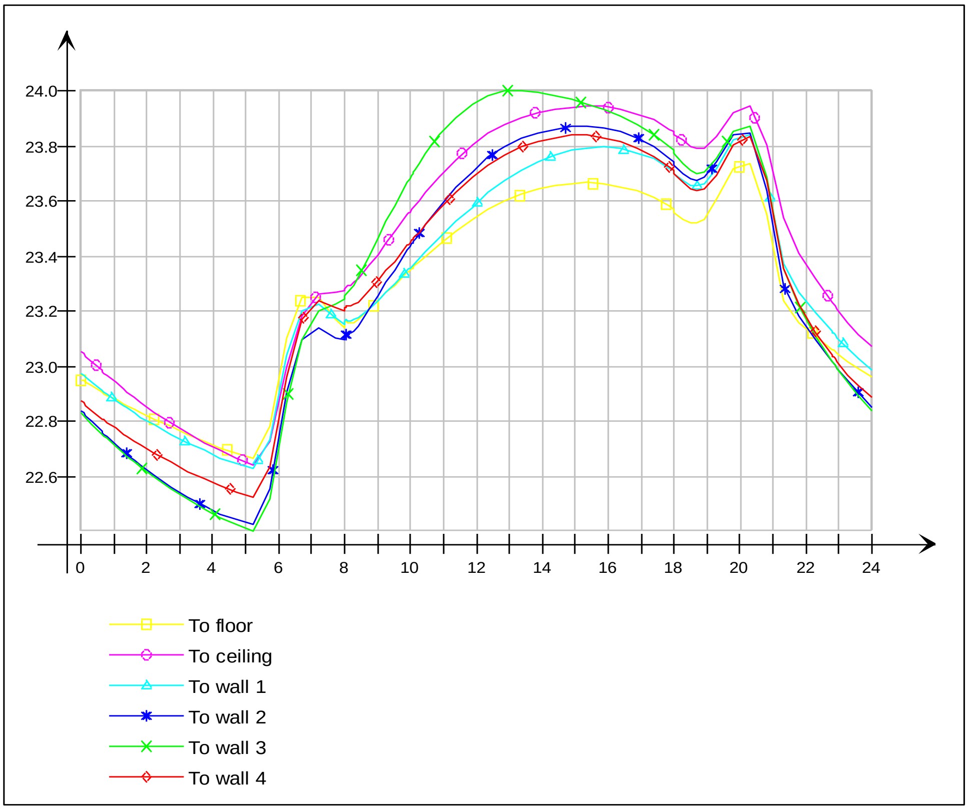
Power supplied by plant



Main temperatures



Directed operative temperatures



Heat balance