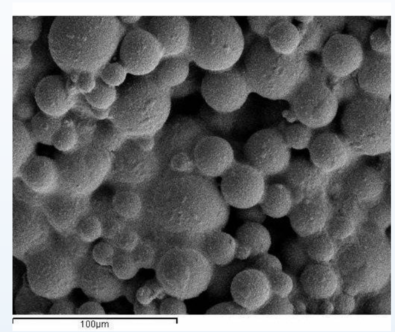
Issues of modelling PCM: A case study in EnergyPlus Simulation

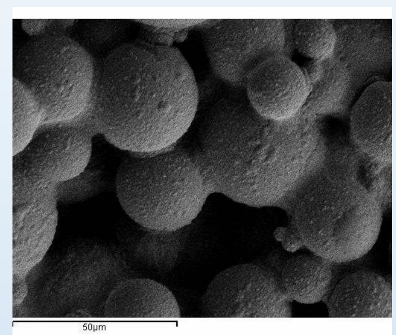
Dr David Tetlow
University of Nottingham
The Mark Group

Presentation Content

1. Phase Change Materials
   – Definitions ,
   – Applications,
2. Energy Plus
   – Simulation process,
   – Systems currently utilising the software,
   – Layout & options,
   – PCM incorporation
3. Case Study
   – PCMs in a simple *Solid Brick* building
4. Q & A

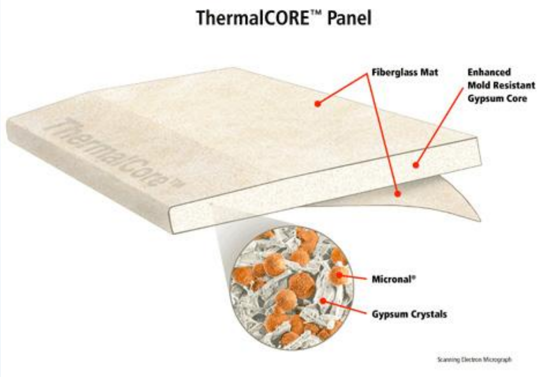
Phase Change Materials





‘Unique materials that store/release heat in latent form as they change phase from solid to liquid and vice versa’

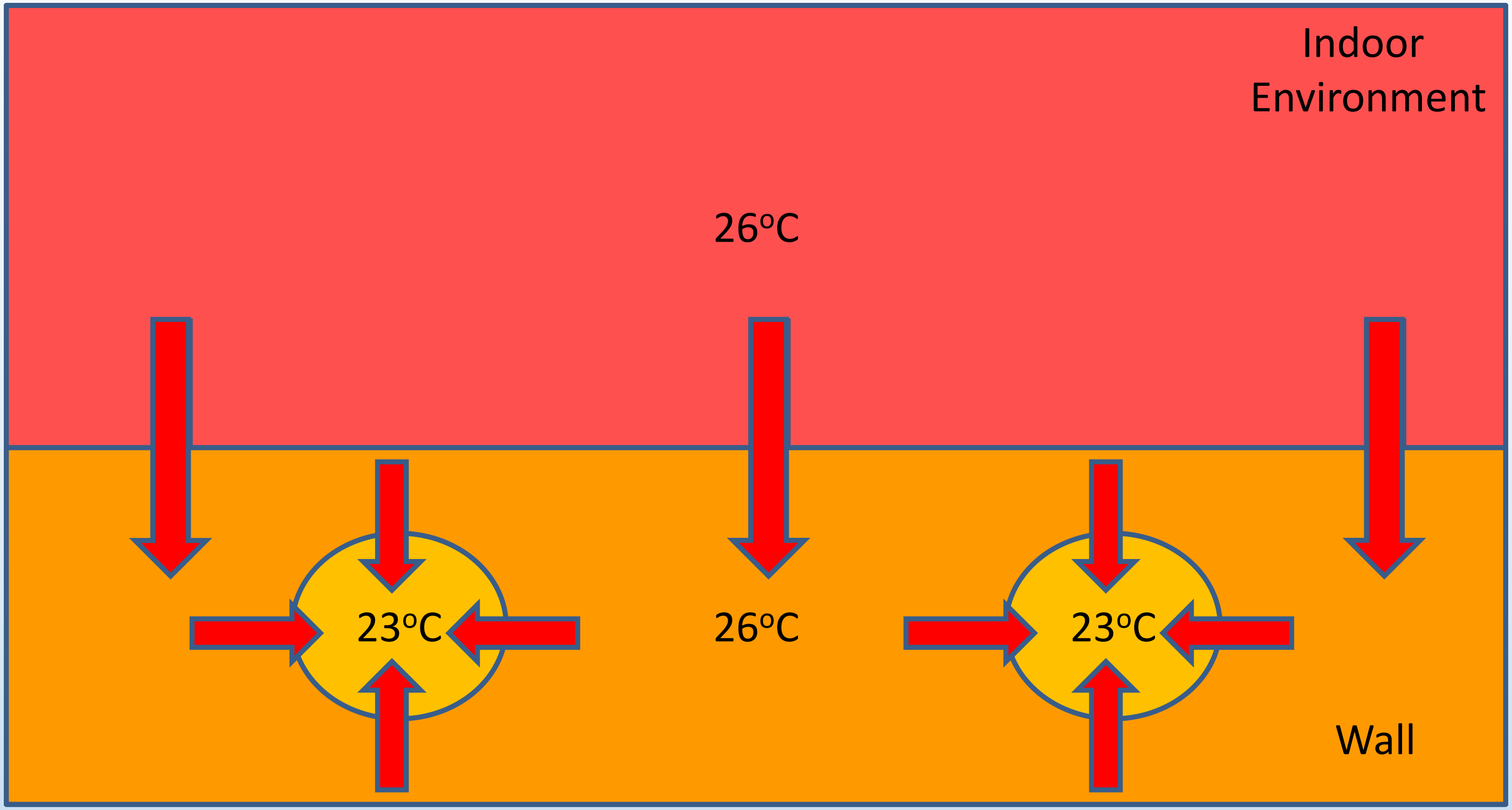
PCM Applications



Clothing, Air Conditioning, Building Materials...........

Any overheating control system

PCMs in Action



PCM -23 melting point reached

PCM Thermal Properties

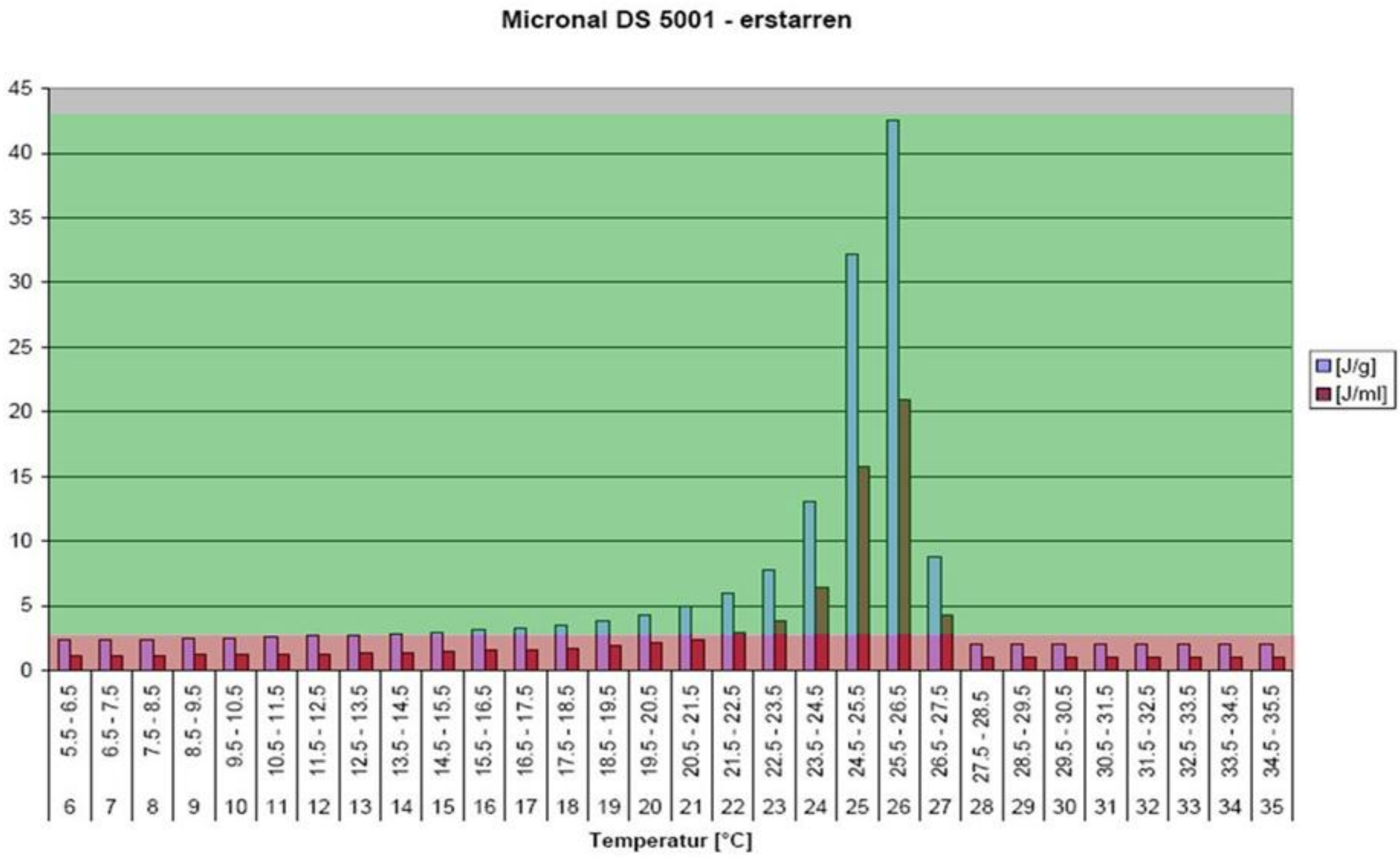
Thermal Conductivity / k-Value (W/m.K)

Density / ρ-Value (kg/m^3)

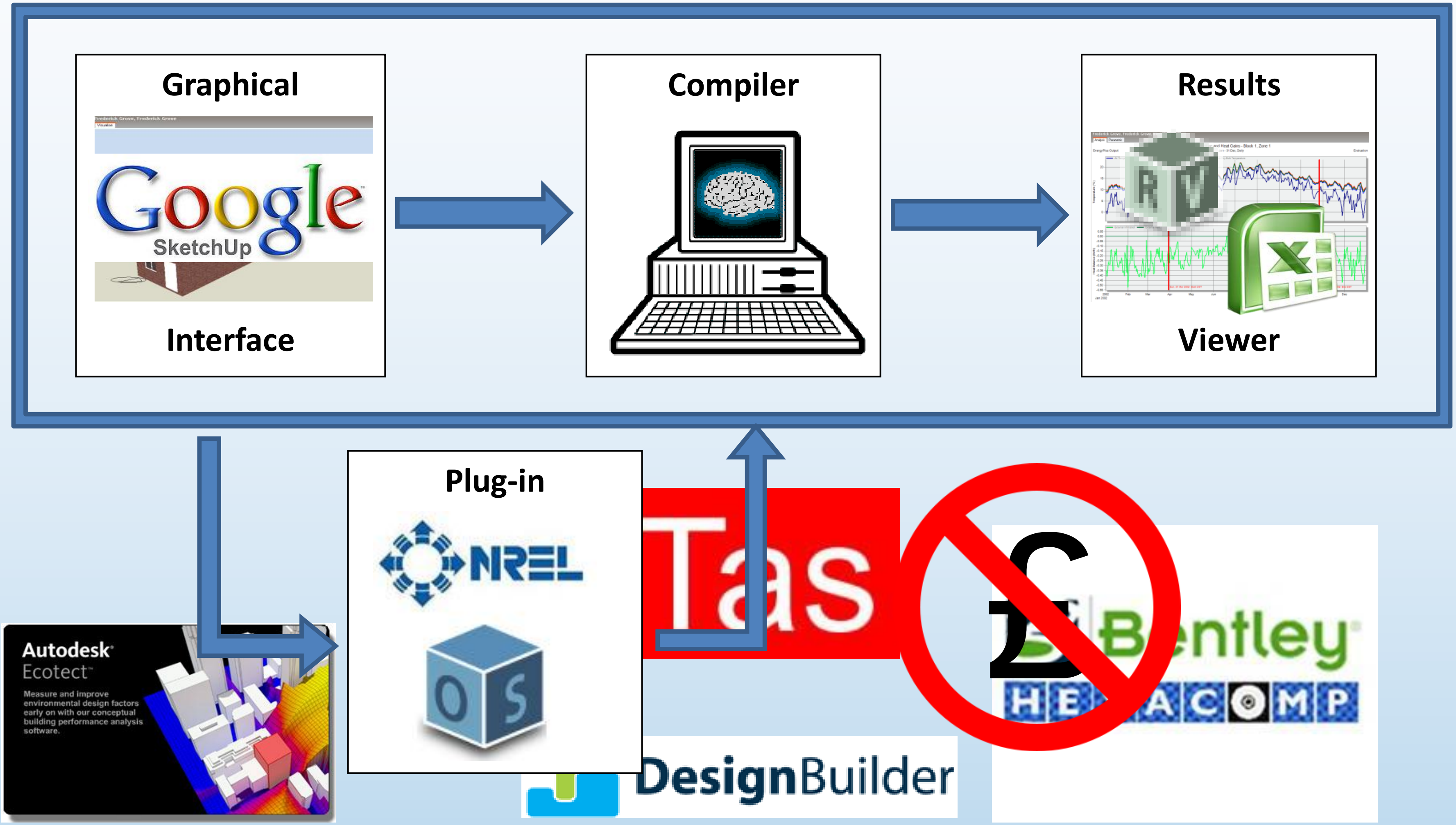
Specific Heat Capacity / C-Value (J/kg.K)

Enthalpy and Heat of Fusion (J/kg)

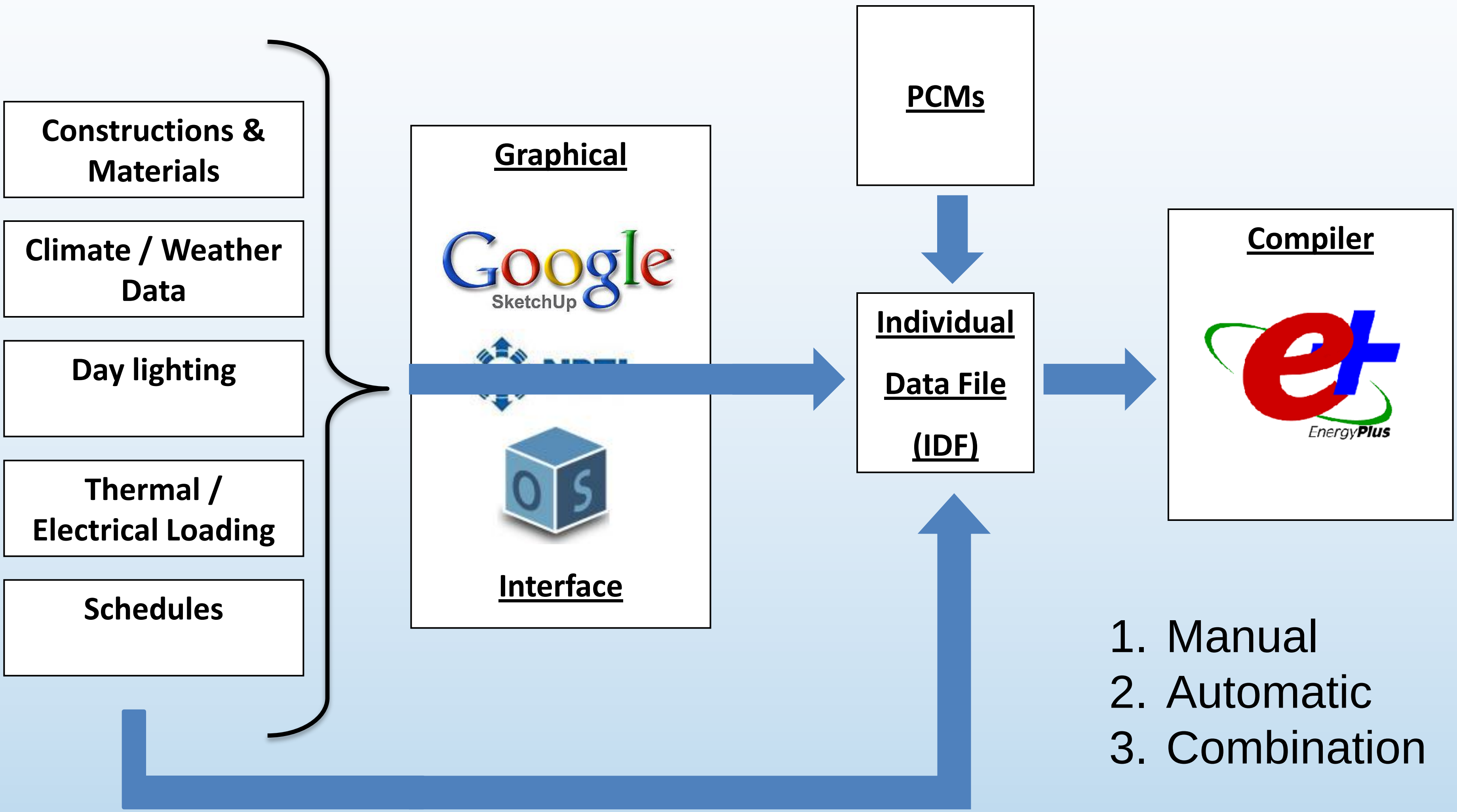
Octadecane (26^{o}C MP)



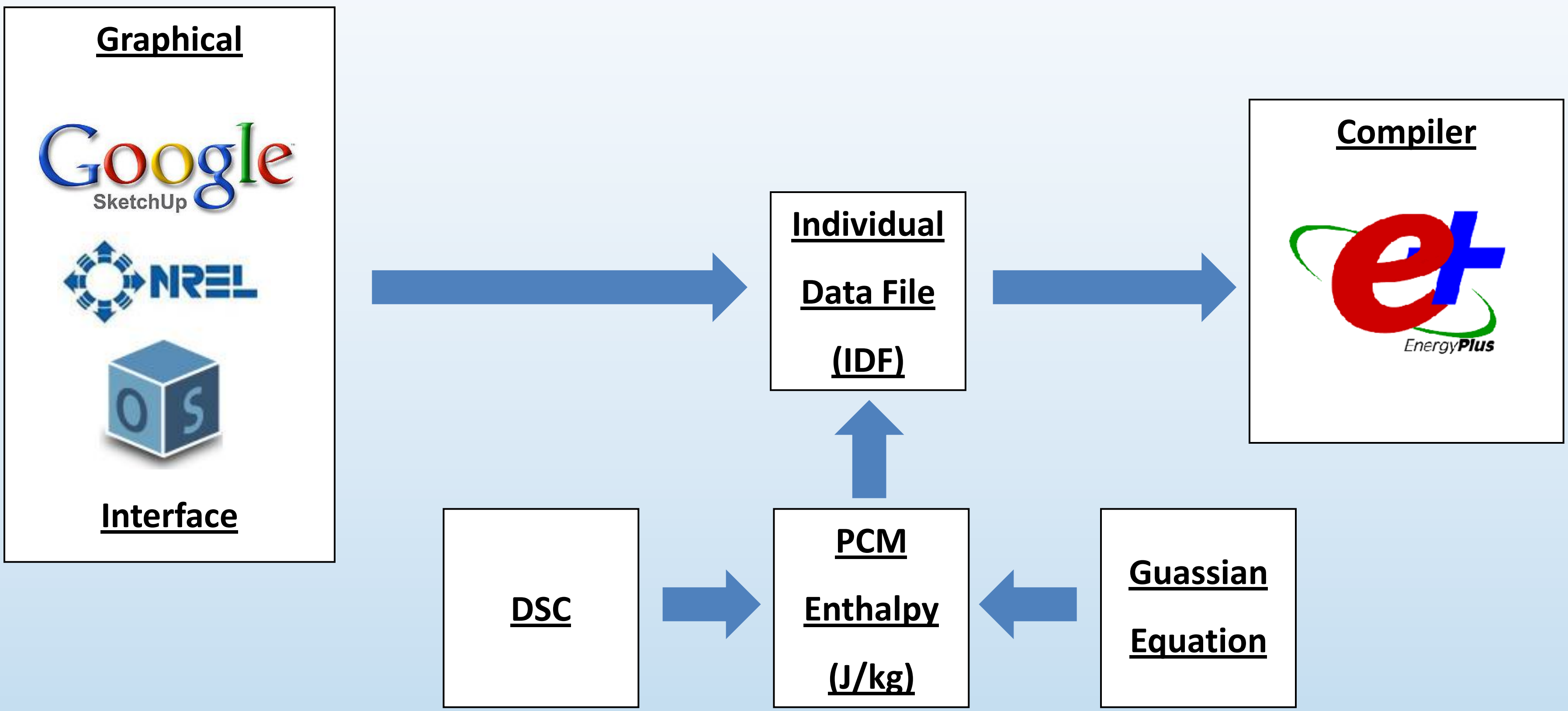
EnergyPlus – Simulation Process

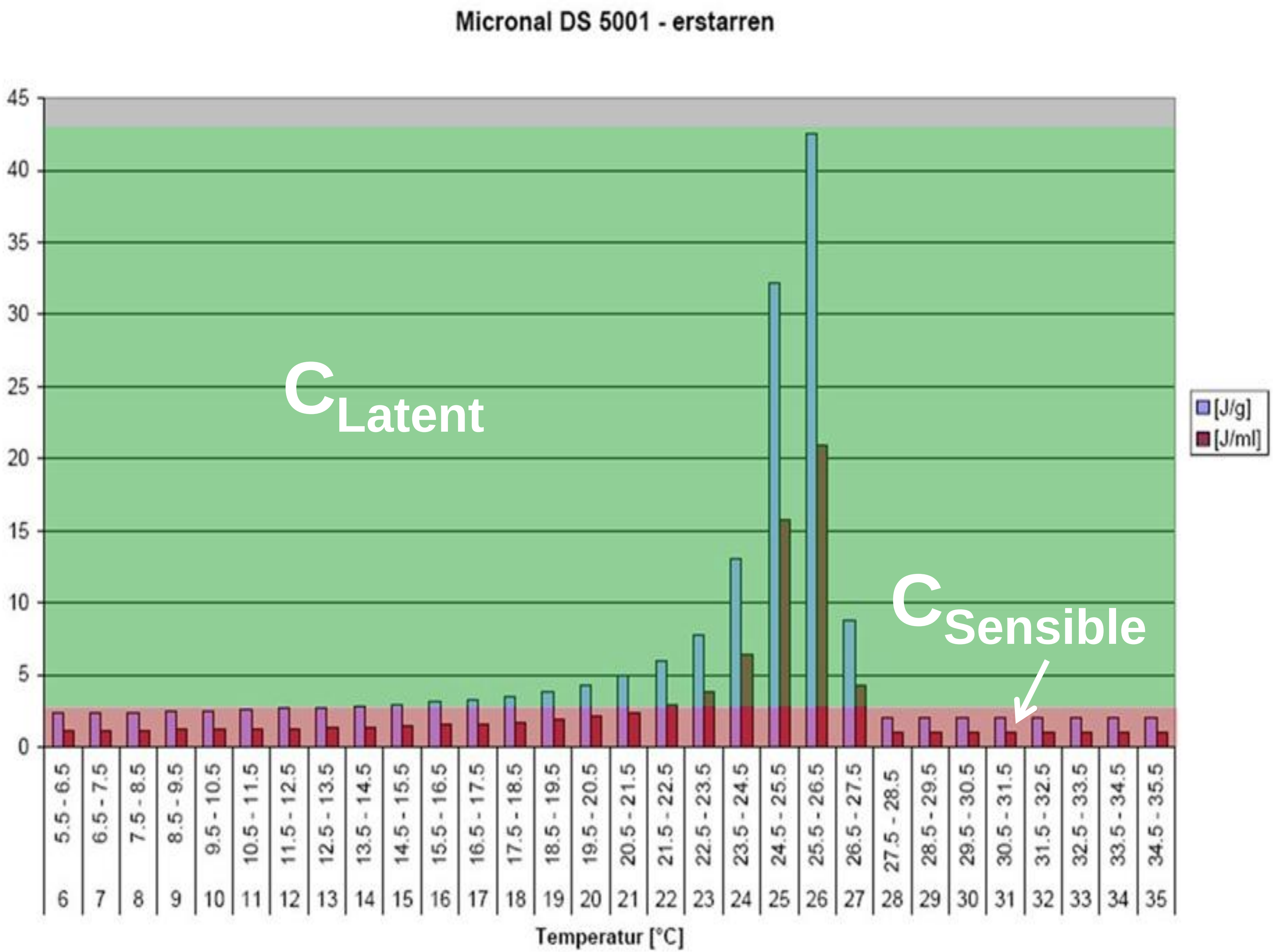


EnergyPlus – Simulation Process



EnergyPlus - PCM Incorporation





Micronal DS 5001 - erstarren
45
40
35
30
25
20
15
10
5
0
C Latent
C Sensible
[J/g]
[J/ml]
5.5 - 6.5
6
6.5 - 7.5
7
7.5 - 8.5
8
8.5 - 9.5
9
9.5 - 10.5
10
10.5 - 11.5
11
11.5 - 12.5
12
12.5 - 13.5
13
13.5 - 14.5
14
14.5 - 15.5
15
15.5 - 16.5
16
16.5 - 17.5
17
17.5 - 18.5
18
18.5 - 19.5
19
19.5 - 20.5
20
20.5 - 21.5
21
21.5 - 22.5
22
22.5 - 23.5
23
23.5 - 24.5
24
24.5 - 25.5
25
25.5 - 26.5
26
26.5 - 27.5
27
27.5 - 28.5
28
28.5 - 29.5
29
29.5 - 30.5
30
30.5 - 31.5
31
31.5 - 32.5
32
32.5 - 33.5
33
33.5 - 34.5
34
34.5 - 35.5
35
Temperatur [°C]

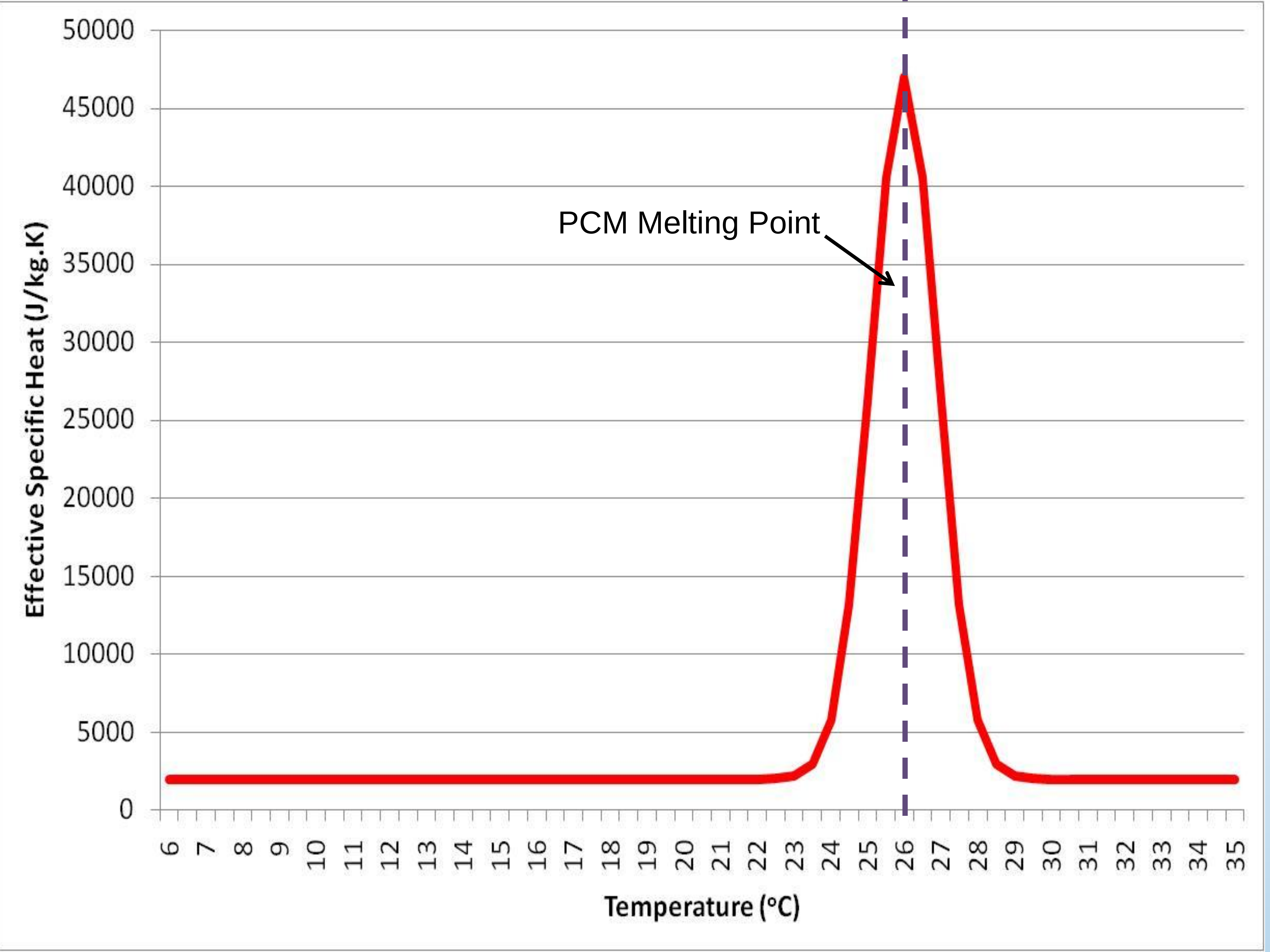
EnergyPlus - PCM Incorporation

$$C_{eff} = C_{Sensible} + C_{Latent}$$

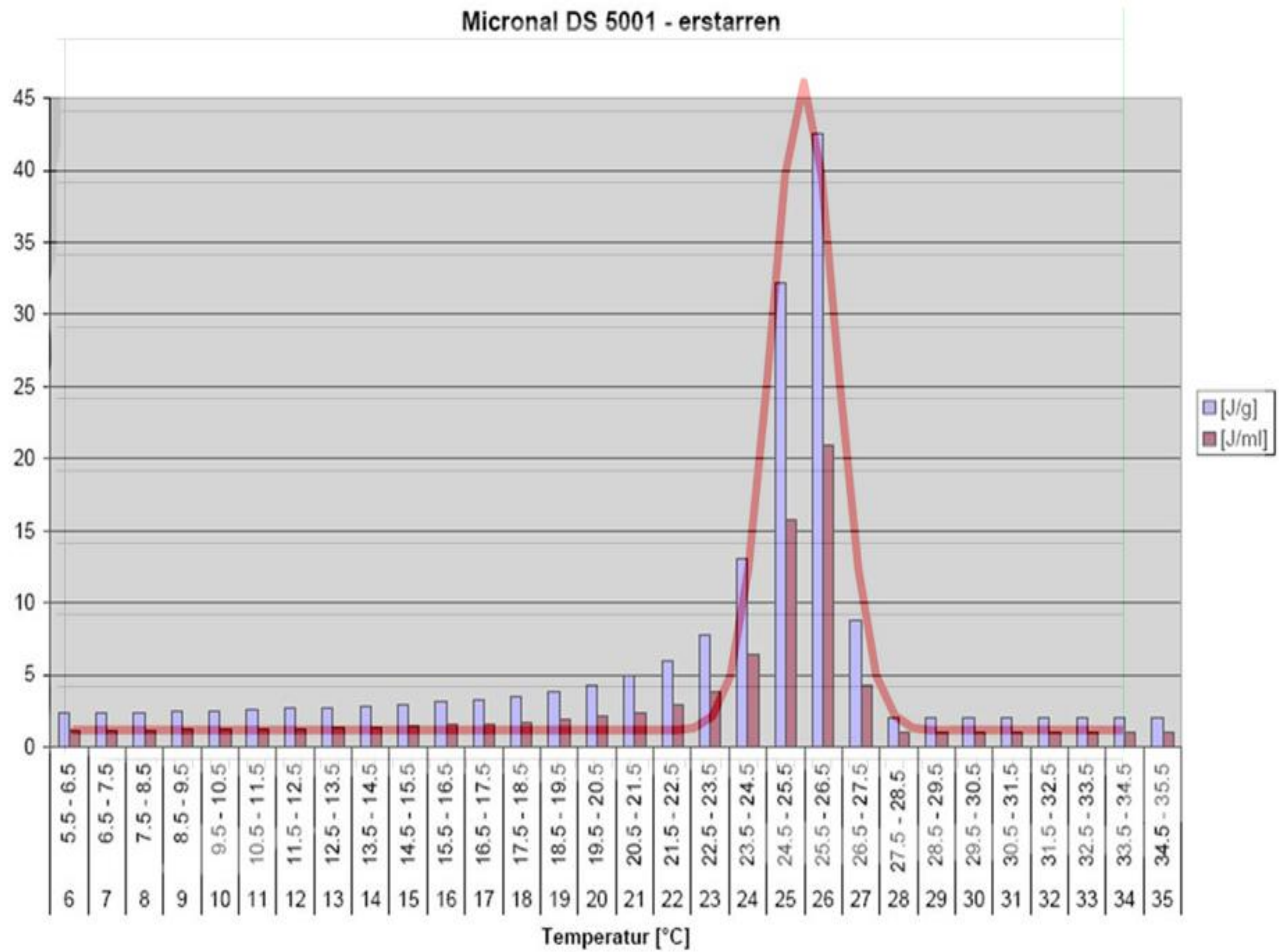
$$C_{Latent} = Ae^{-0.5\left(\frac{T - T_{mp}}{B}\right)^2}$$

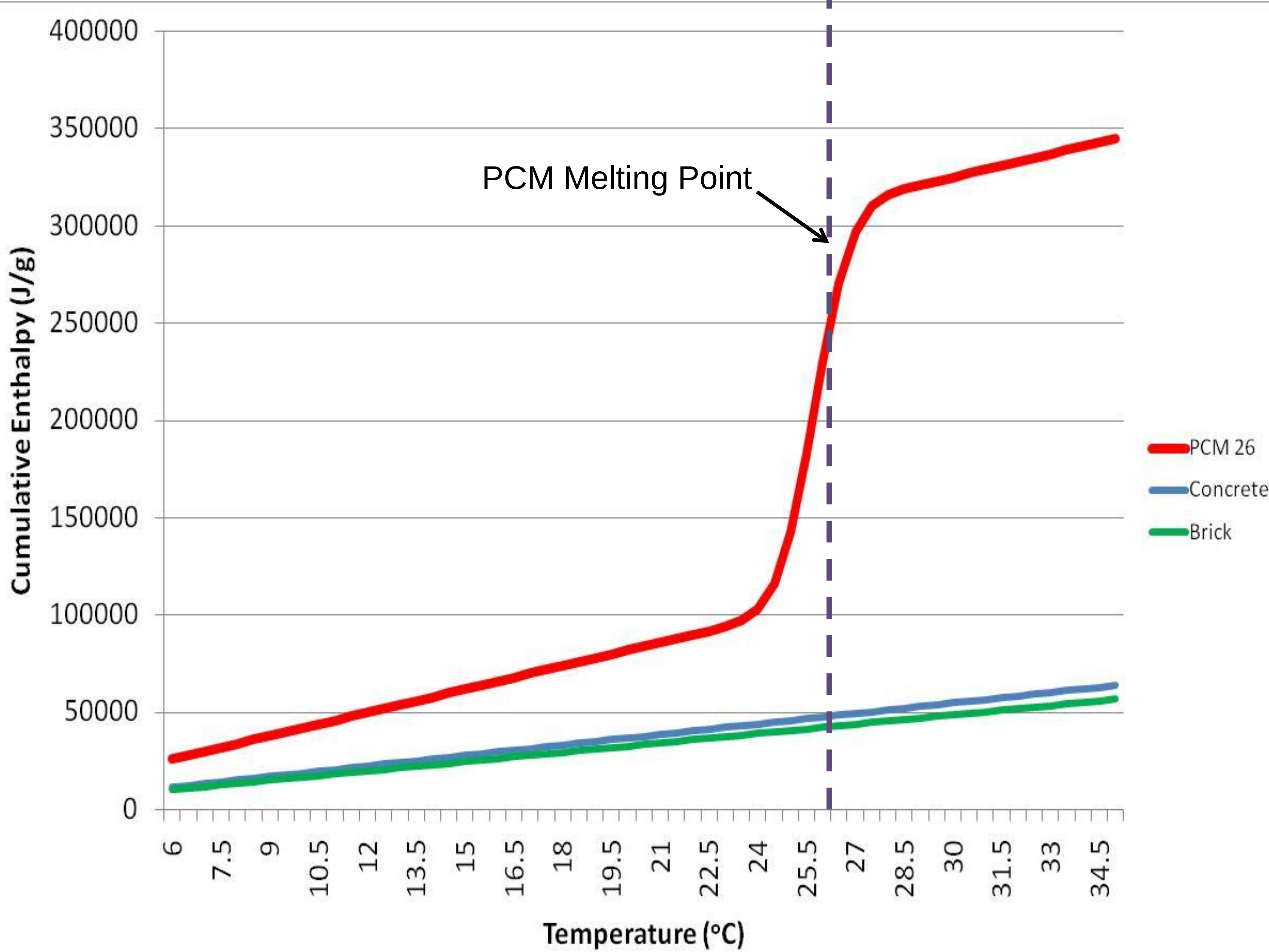
A = Enthalpy Coefficient (~ half PCM Heat of Fusion)

B = Melting Width Coefficient (Purity ~ 0.1 – 1.0)



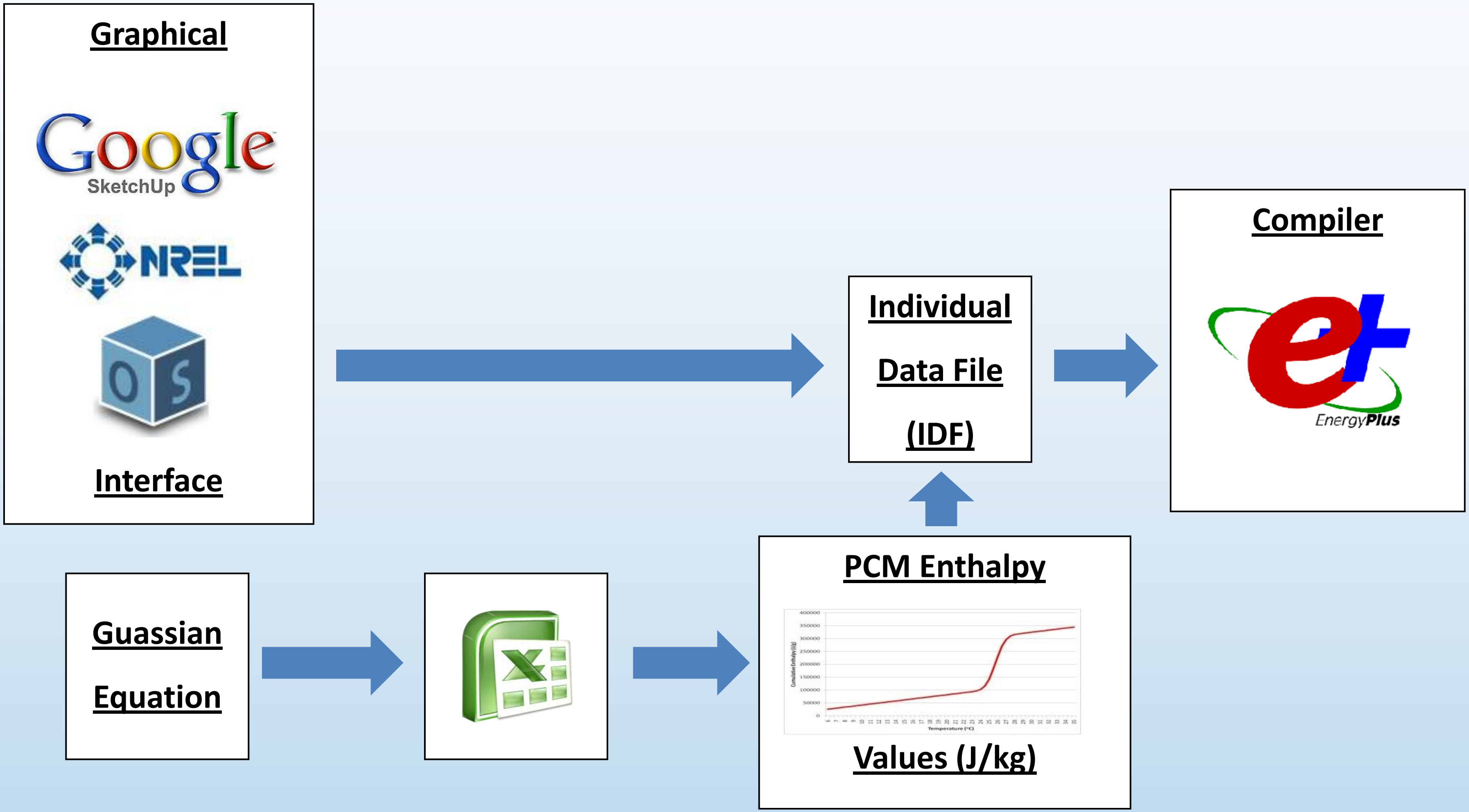
Effective Specific Heat (J/kg.K)
50000
45000
40000
35000
30000
25000
20000
15000
10000
5000
0
PCM Melting Point
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
Temperature (°C)


Micronal DS 5001 - erstarren
45
40
35
30
25
20
15
10
5
0
[J/g]
[J/ml]
5.5 - 6.5
6.5 - 7.5
7.5 - 8.5
8.5 - 9.5
9.5 - 10.5
10.5 - 11.5
11.5 - 12.5
12.5 - 13.5
13.5 - 14.5
14.5 - 15.5
15.5 - 16.5
16.5 - 17.5
17.5 - 18.5
18.5 - 19.5
19.5 - 20.5
20.5 - 21.5
21.5 - 22.5
22.5 - 23.5
23.5 - 24.5
24.5 - 25.5
25.5 - 26.5
26.5 - 27.5
27.5 - 28.5
28.5 - 29.5
29.5 - 30.5
30.5 - 31.5
31.5 - 32.5
32.5 - 33.5
33.5 - 34.5
34.5 - 35.5
6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35
Temperatur [°C]



PCM Melting Point
Cumulative Enthalpy (J/g)
400000
350000
300000
250000
200000
150000
100000
50000
0
6
7.5
9
10.5
12
13.5
15
16.5
18
19.5
21
22.5
24
25.5
27
28.5
30
31.5
33
34.5
Temperature (°C)
PCM 26
Concrete
Brick

EnergyPlus - PCM Incorporation



Case Study – Building Simulation Parameters

1. Simple (225mm) solid brick building (*Constructions & materials*)
   - Roof and Floor: insulated to Building Regulation standard U-Values
   - Ventilation and Air tightness: Openstudio Defaults
   - Walls insulated internally with *Mineral Fibre*, U-Values:
     - Before: 3.0 $W/m^2.K$
     - After: 0.3 $W/m^2.K$

2. PCM Parameters
   - Thermal (k, Cs, ρ, etc): based on BASF Micronal PCM
   - Incorporated into 12.5mm of Finishing Plaster
   - Simulated at 3 separate melting points: 18^oC, 22^oC, 26^oC

Case Study – Building Simulation Parameters

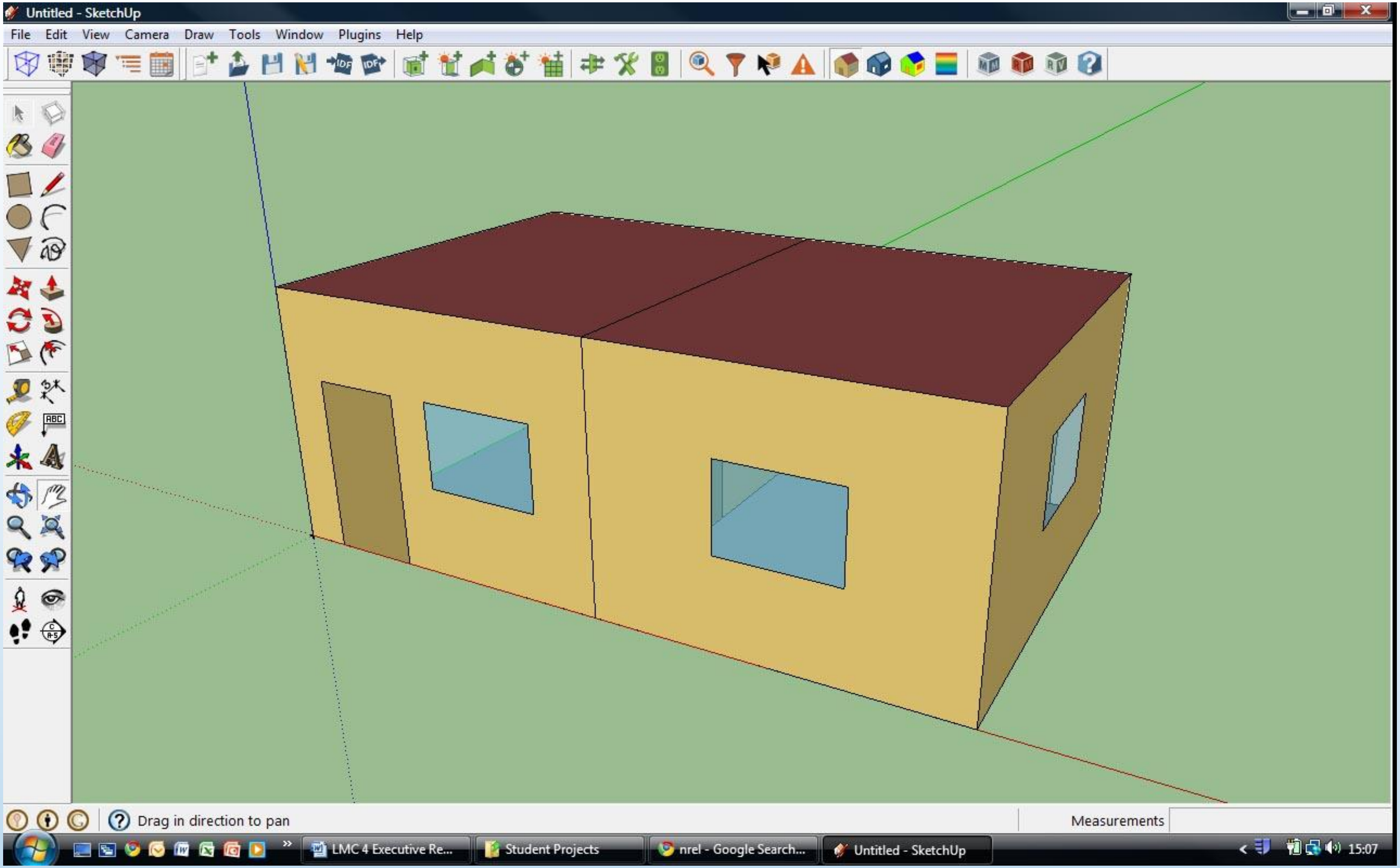
3. Location: London (*Climate*)

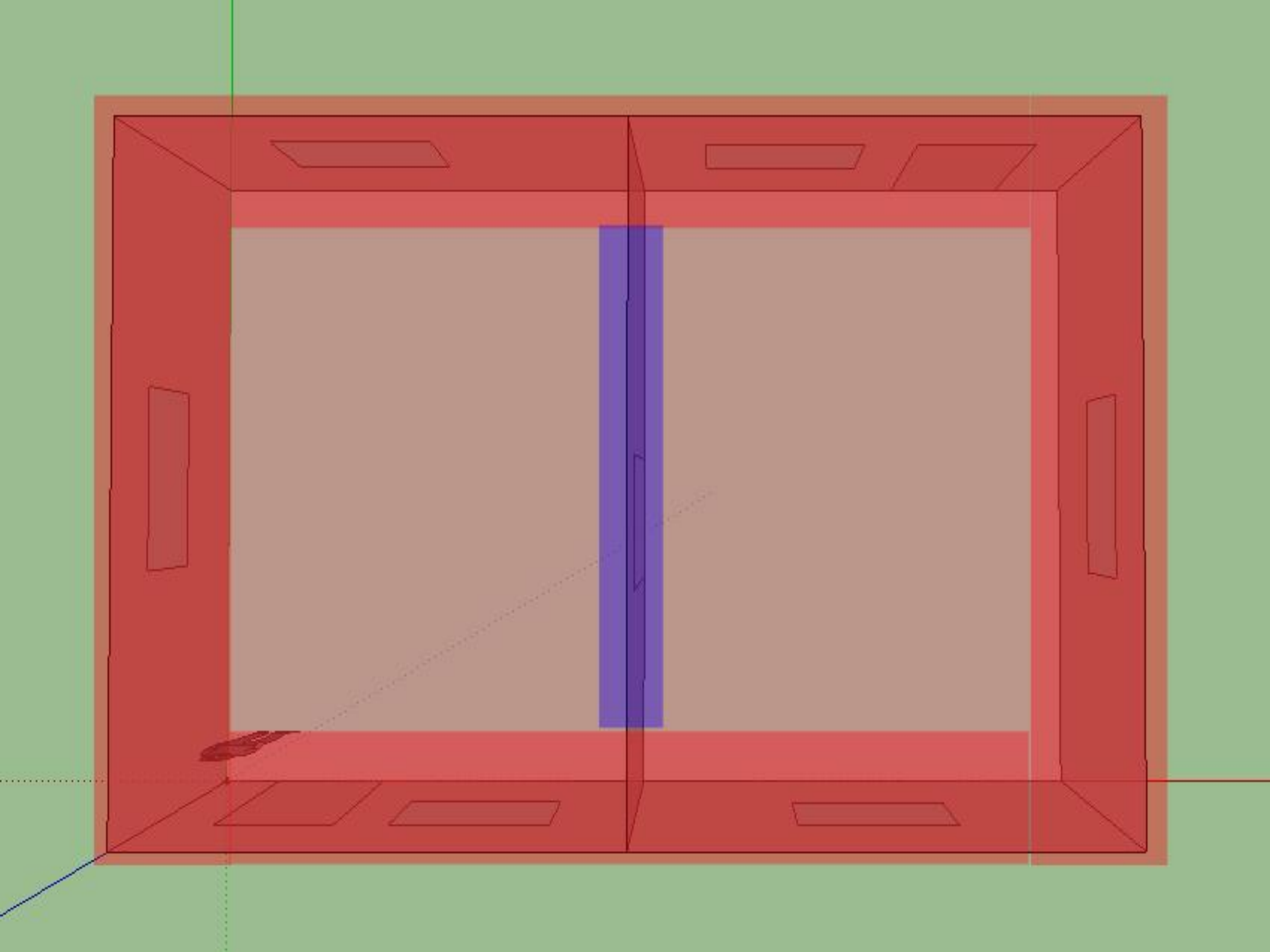
4. Hot Period: 1st – 15th July (*Weather conditions*)

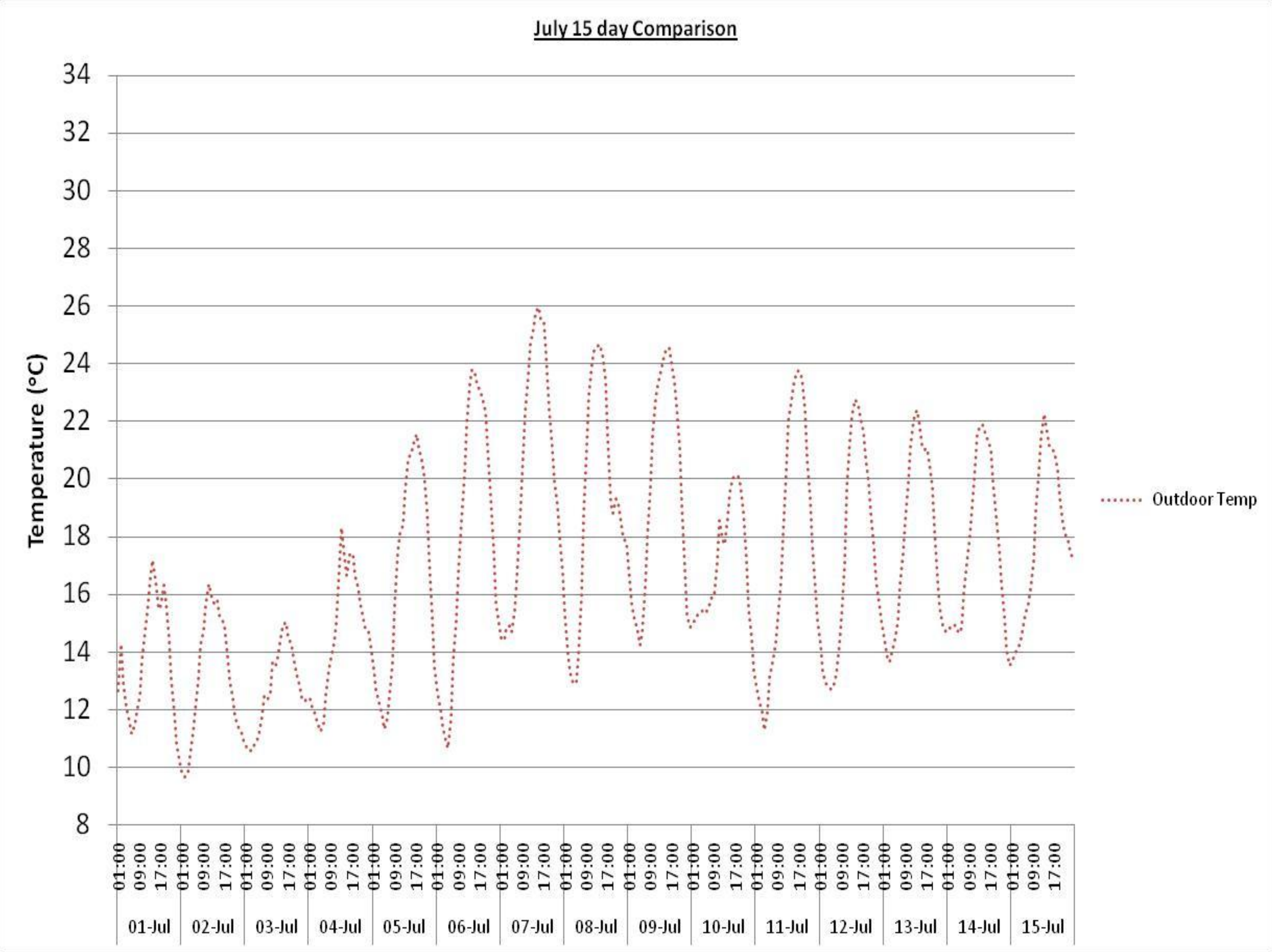
5. Occupied: Day time (*Openstudio default Schedules*)

6. Gains: Electrical, Lighting, Solar, and People (*Openstudio default Thermal Loading*)

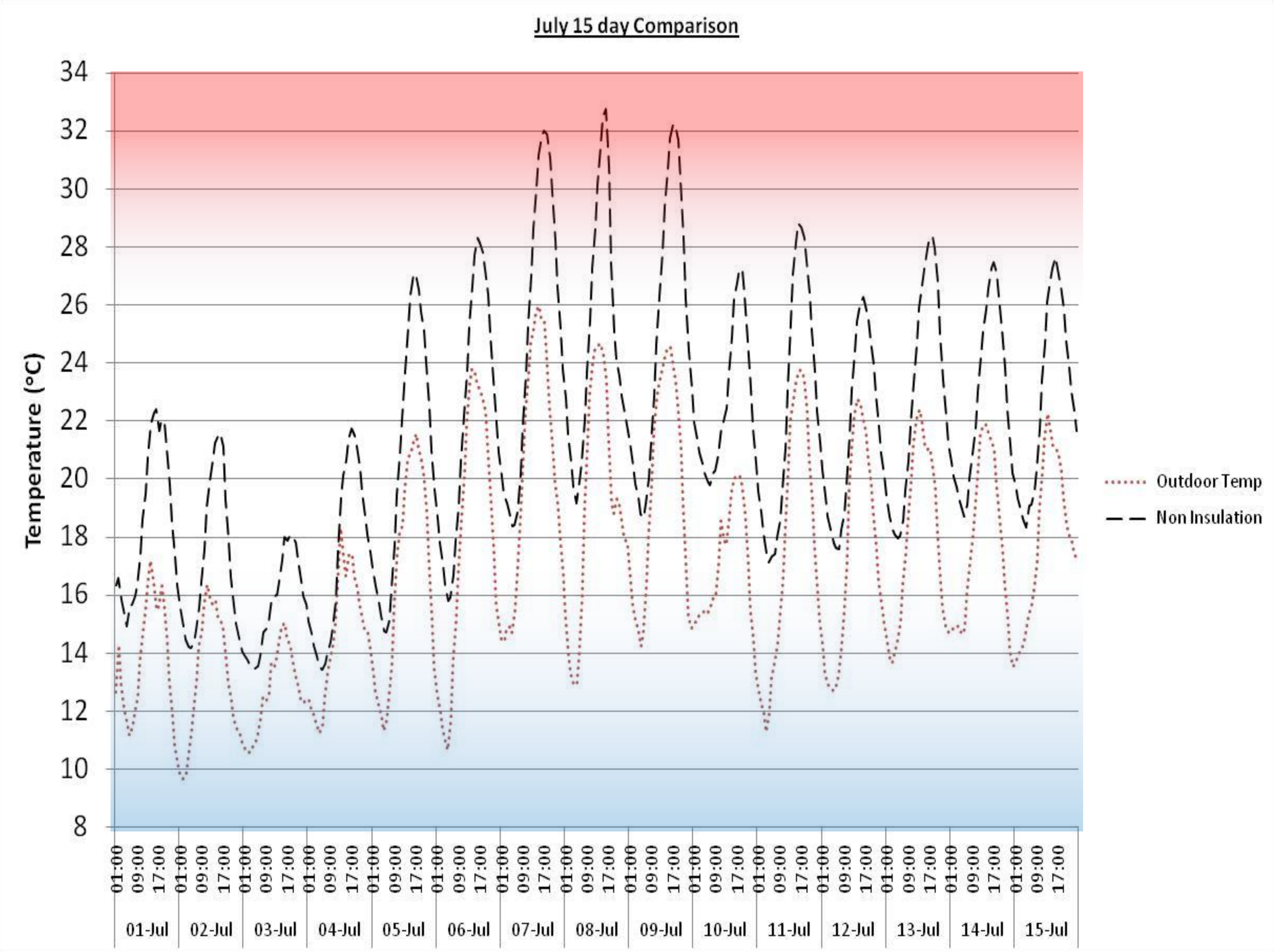
Case Study – Building Simulation



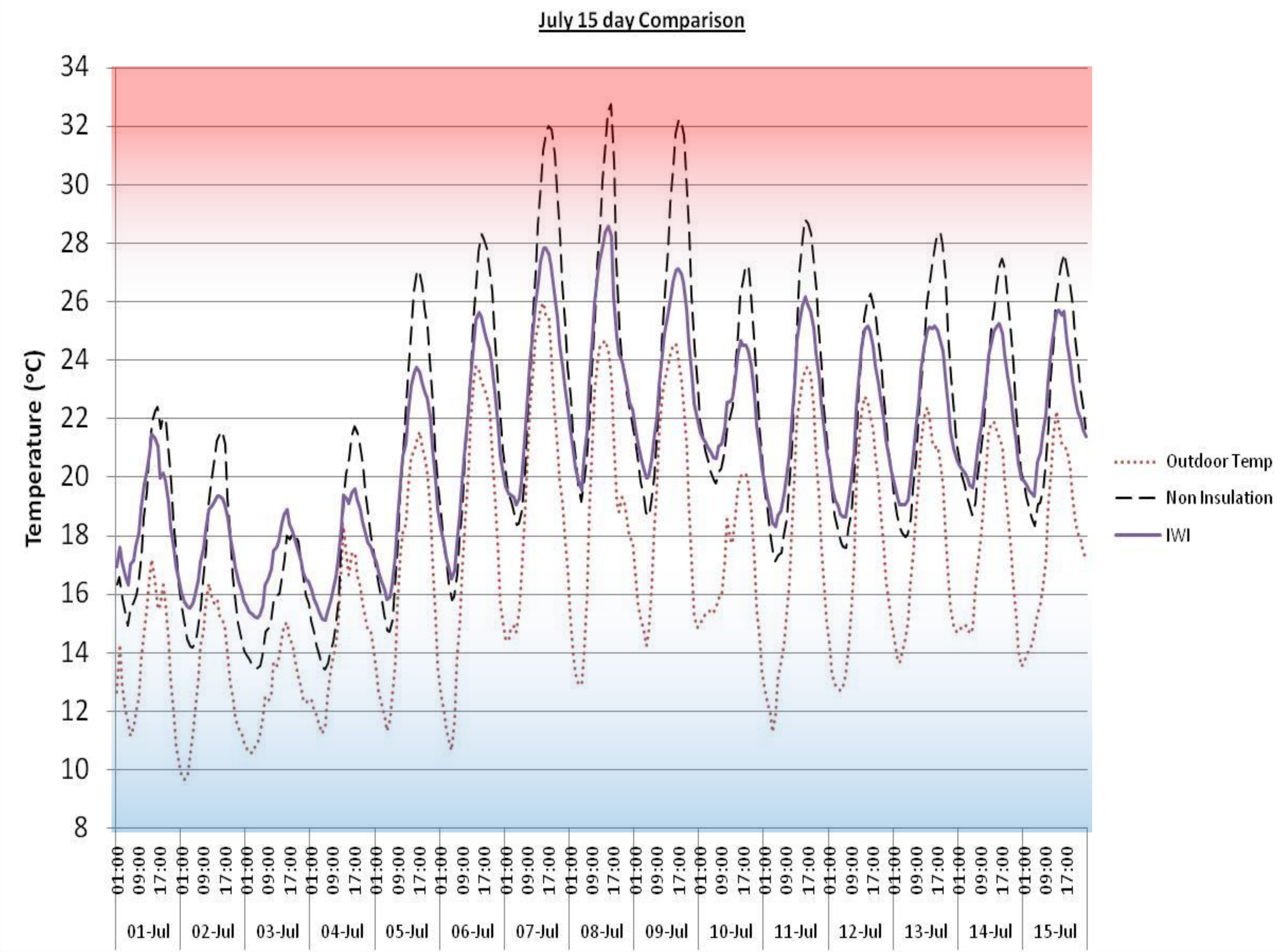




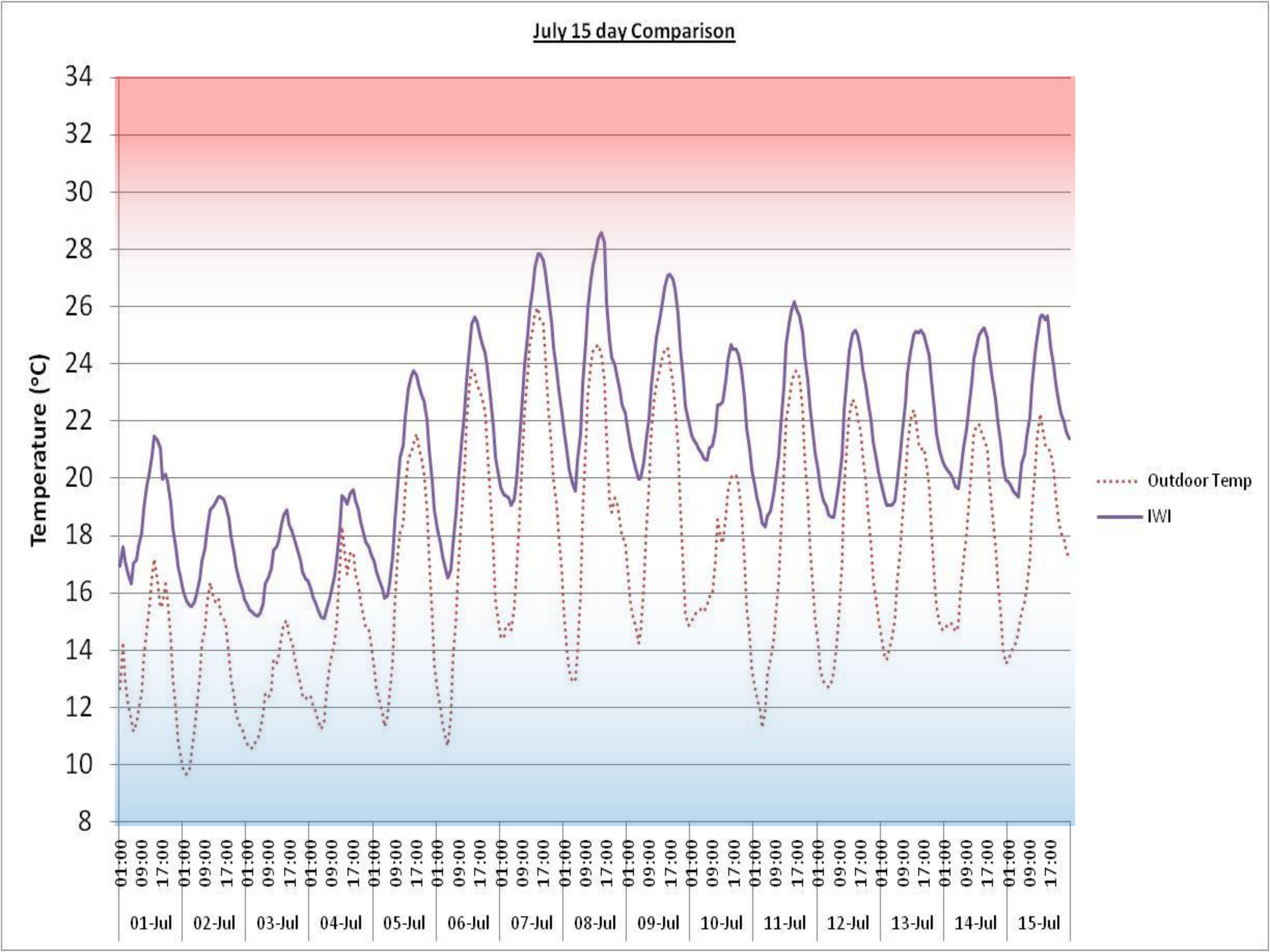
July 15 day Comparison
Temperature (°C)
34
32
30
28
26
24
22
20
18
16
14
12
10
8
01:00
09:00
17:00
01-Jul
02-Jul
03-Jul
04-Jul
05-Jul
06-Jul
07-Jul
08-Jul
09-Jul
10-Jul
11-Jul
12-Jul
13-Jul
14-Jul
15-Jul
Outdoor Temp



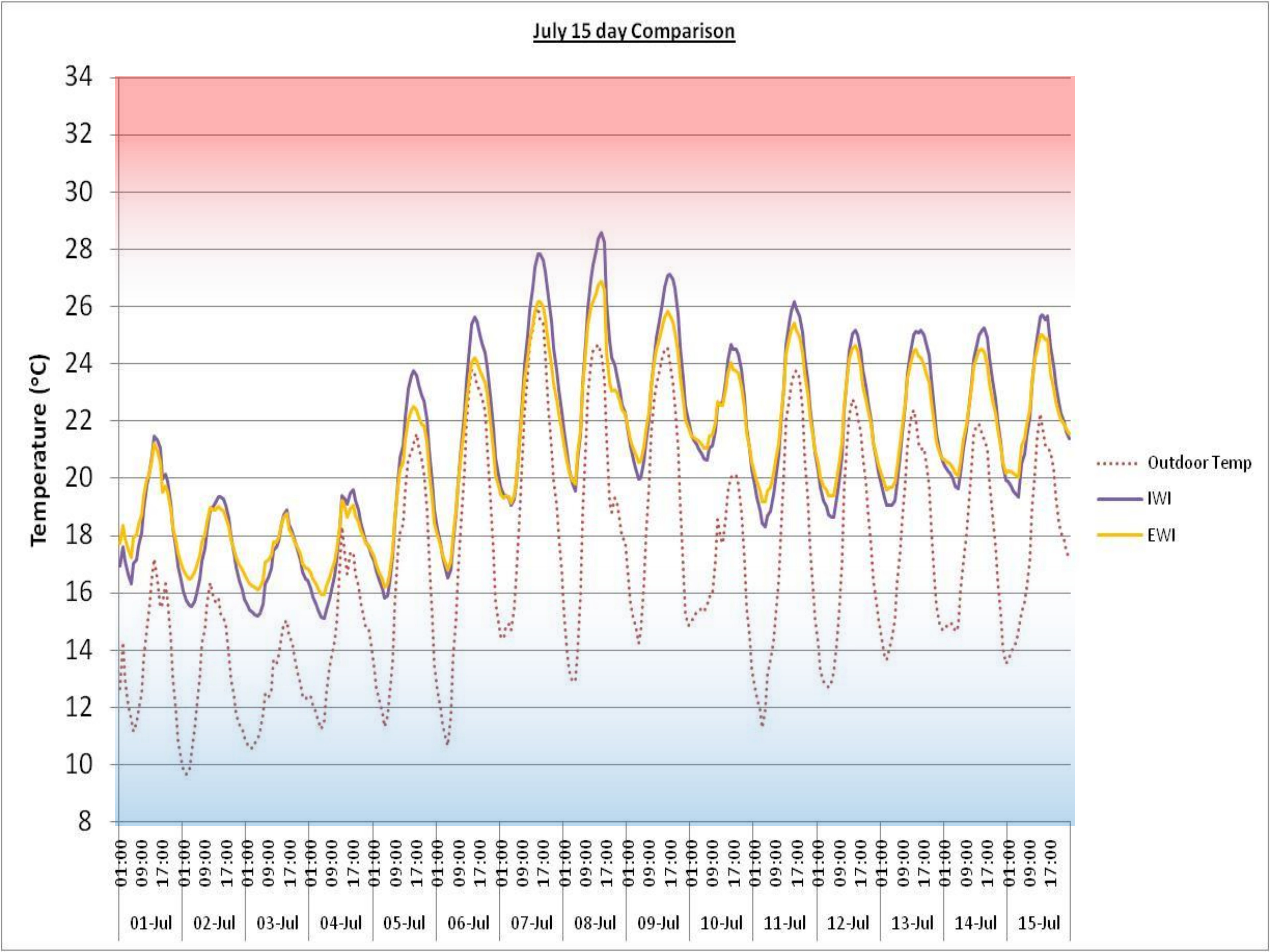
July 15 day Comparison
Temperature (°C)
34
32
30
28
26
24
22
20
18
16
14
12
10
8
01:00
09:00
17:00
01-Jul
02-Jul
03-Jul
04-Jul
05-Jul
06-Jul
07-Jul
08-Jul
09-Jul
10-Jul
11-Jul
12-Jul
13-Jul
14-Jul
15-Jul
Outdoor Temp
Non Insulation



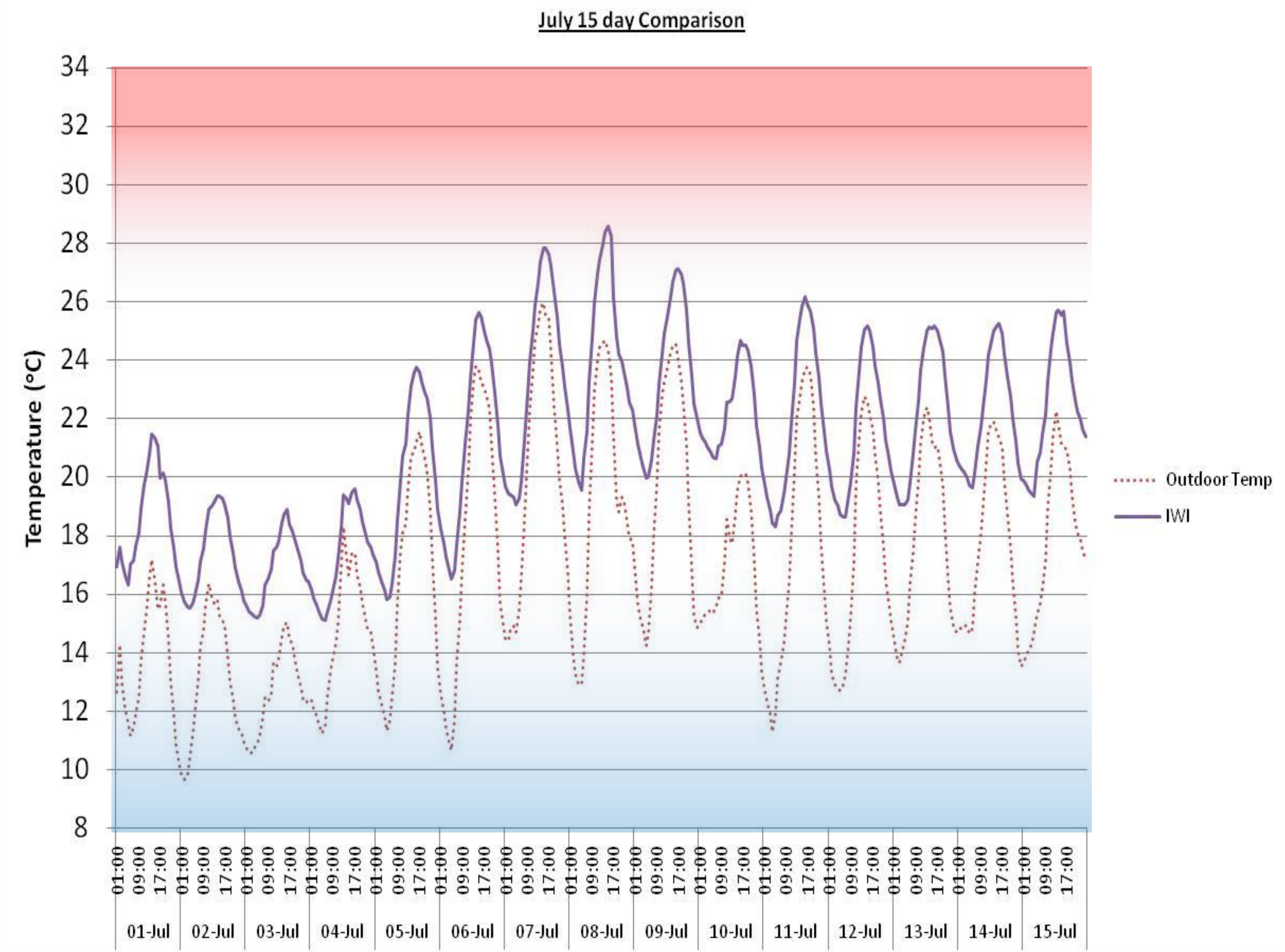
July 15 day Comparison
Temperature (°C)
34
32
30
28
26
24
22
20
18
16
14
12
10
8
01:00
09:00
17:00
01-Jul
02-Jul
03-Jul
04-Jul
05-Jul
06-Jul
07-Jul
08-Jul
09-Jul
10-Jul
11-Jul
12-Jul
13-Jul
14-Jul
15-Jul
Outdoor Temp
Non Insulation
IWI

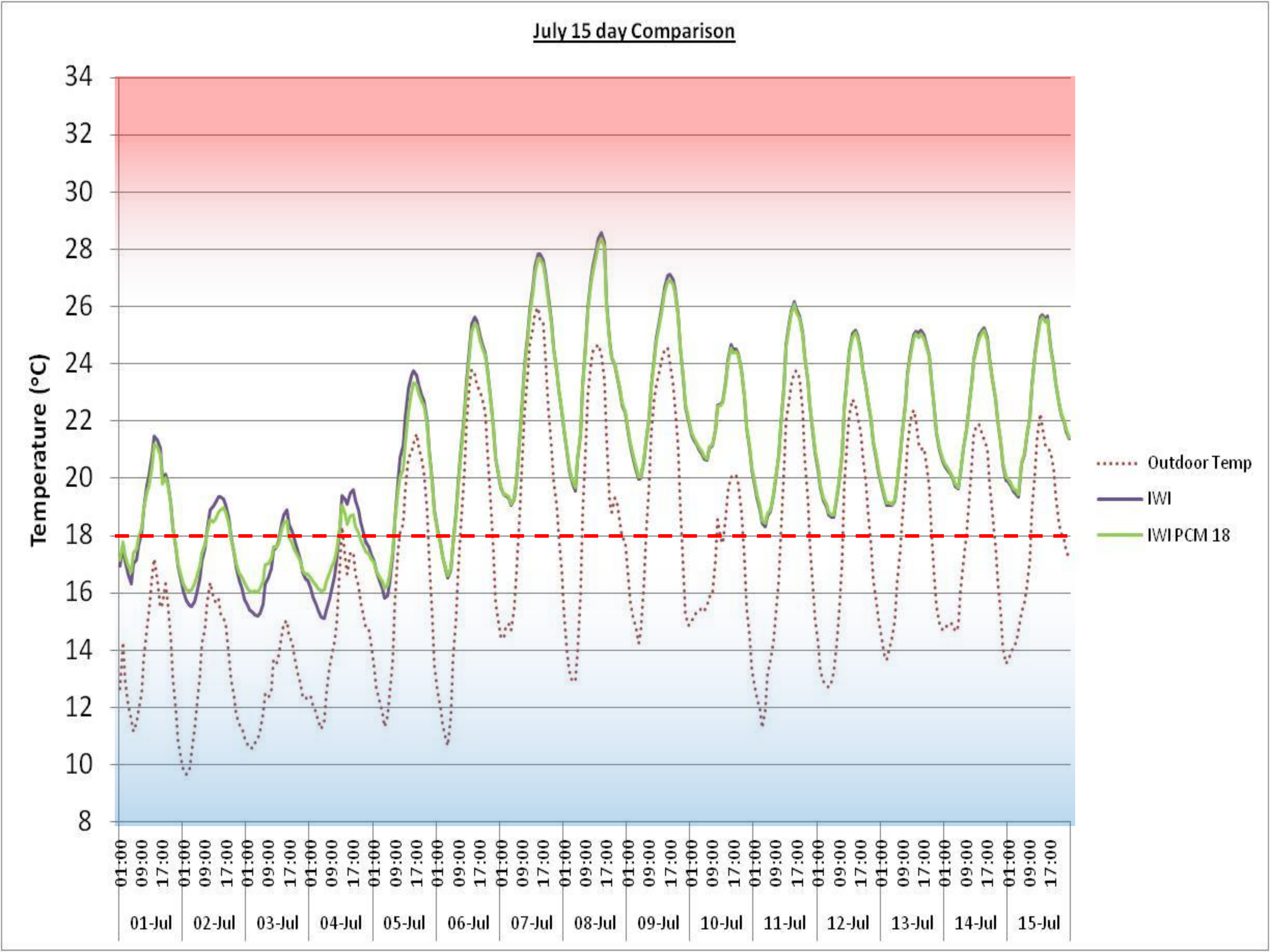


July 15 day Comparison
Temperature (°C)
34
32
30
28
26
24
22
20
18
16
14
12
10
8
01:00
09:00
17:00
01-Jul
02-Jul
03-Jul
04-Jul
05-Jul
06-Jul
07-Jul
08-Jul
09-Jul
10-Jul
11-Jul
12-Jul
13-Jul
14-Jul
15-Jul
Outdoor Temp
IWI

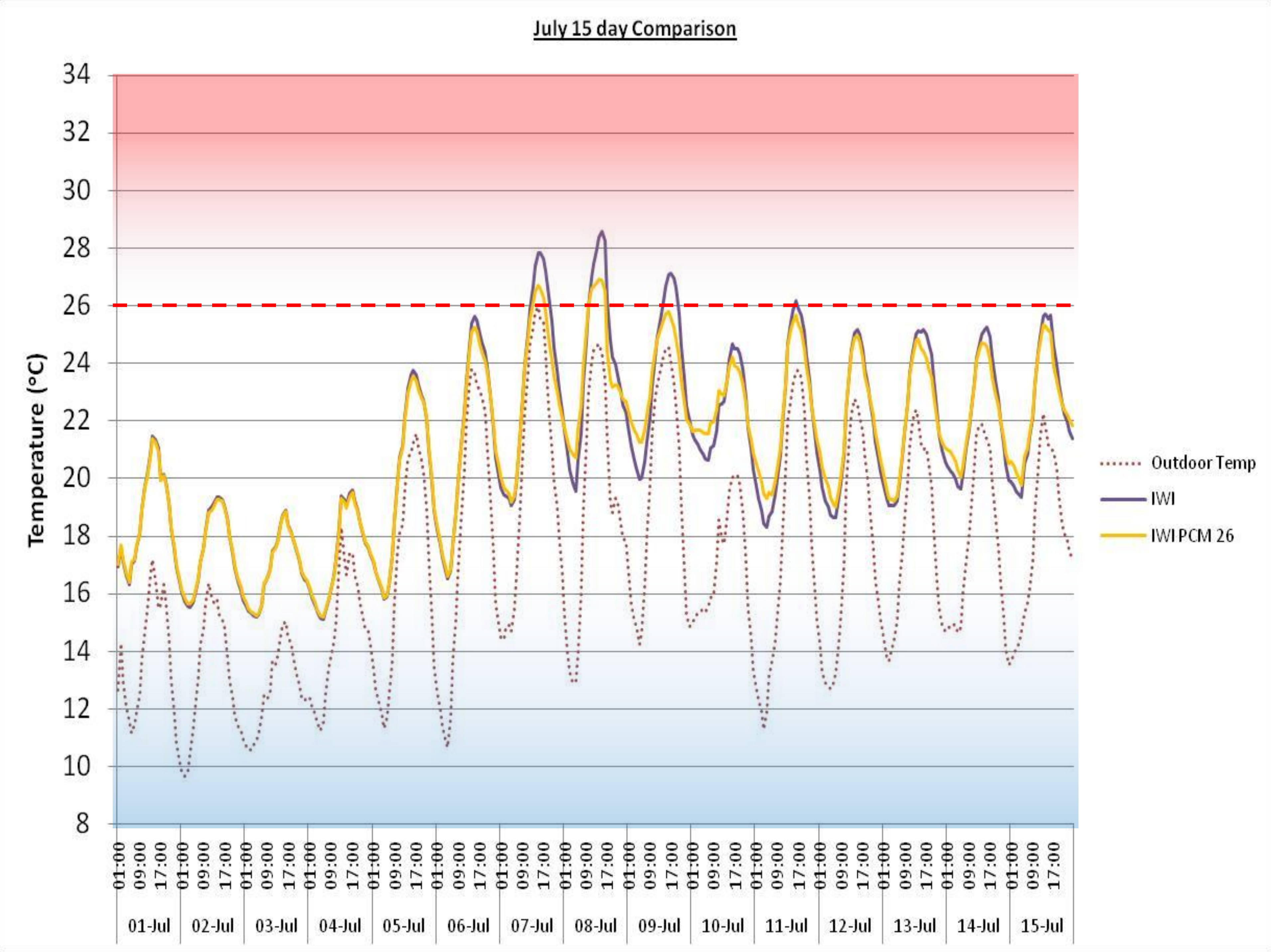


July 15 day Comparison
Temperature (°C)
34
32
30
28
26
24
22
20
18
16
14
12
10
8
01:00
09:00
17:00
01-Jul
02-Jul
03-Jul
04-Jul
05-Jul
06-Jul
07-Jul
08-Jul
09-Jul
10-Jul
11-Jul
12-Jul
13-Jul
14-Jul
15-Jul
Outdoor Temp
IWI
EWI

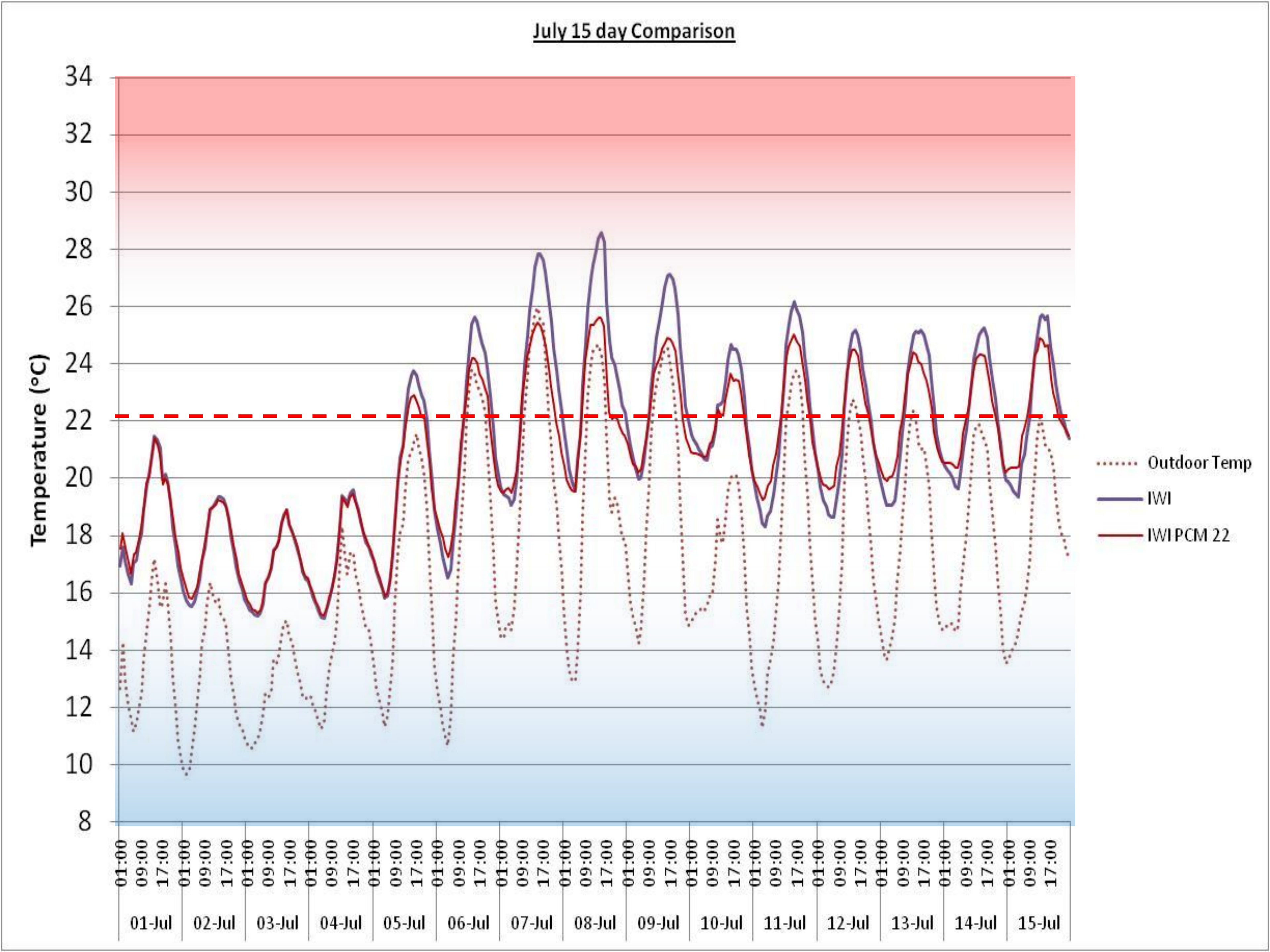

July 15 day Comparison
Temperature (°C)
34
32
30
28
26
24
22
20
18
16
14
12
10
8
01:00
09:00
17:00
01-Jul
02-Jul
03-Jul
04-Jul
05-Jul
06-Jul
07-Jul
08-Jul
09-Jul
10-Jul
11-Jul
12-Jul
13-Jul
14-Jul
15-Jul
Outdoor Temp
IWI

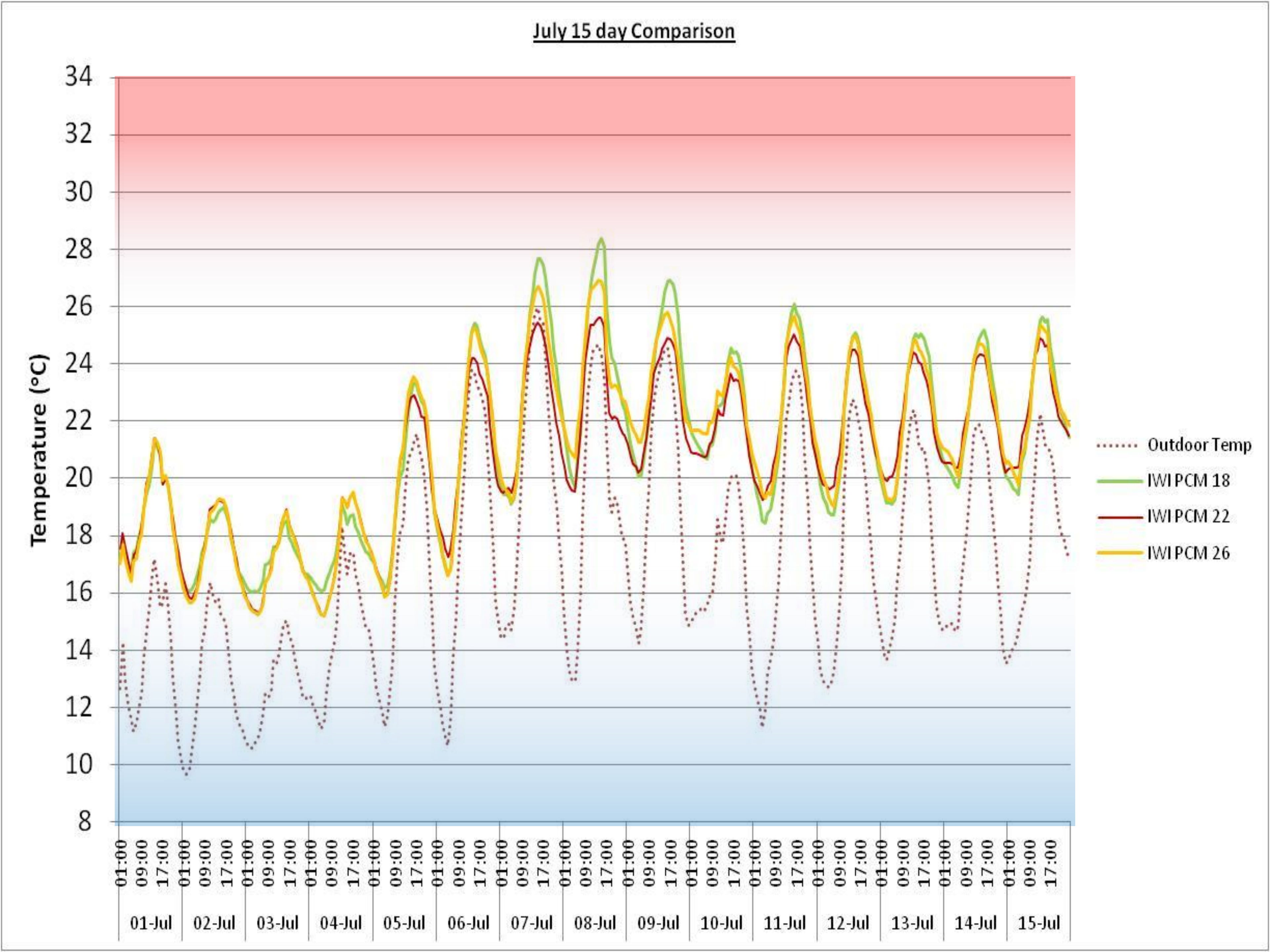


July 15 day Comparison
Temperature (°C)
34
32
30
28
26
24
22
20
18
16
14
12
10
8
01:00
09:00
17:00
01-Jul
02-Jul
03-Jul
04-Jul
05-Jul
06-Jul
07-Jul
08-Jul
09-Jul
10-Jul
11-Jul
12-Jul
13-Jul
14-Jul
15-Jul
Outdoor Temp
IWI
IWI PCM 18



July 15 day Comparison
Temperature (°C)
34
32
30
28
26
24
22
20
18
16
14
12
10
8
01:00
09:00
17:00
01-Jul
02-Jul
03-Jul
04-Jul
05-Jul
06-Jul
07-Jul
08-Jul
09-Jul
10-Jul
11-Jul
12-Jul
13-Jul
14-Jul
15-Jul
Outdoor Temp
IWI
IWI PCM 26


July 15 day Comparison
Temperature (°C)
34
32
30
28
26
24
22
20
18
16
14
12
10
8
01:00
09:00
17:00
01-Jul
02-Jul
03-Jul
04-Jul
05-Jul
06-Jul
07-Jul
08-Jul
09-Jul
10-Jul
11-Jul
12-Jul
13-Jul
14-Jul
15-Jul
Outdoor Temp
IWI
IWI PCM 22



July 15 day Comparison
Temperature (°C)
34
32
30
28
26
24
22
20
18
16
14
12
10
8
01:00
09:00
17:00
01-Jul
02-Jul
03-Jul
04-Jul
05-Jul
06-Jul
07-Jul
08-Jul
09-Jul
10-Jul
11-Jul
12-Jul
13-Jul
14-Jul
15-Jul
Outdoor Temp
IWI PCM 18
IWI PCM 22
IWI PCM 26

Case Study Conclusions

1. Under the simulations limitations, PCMs reduced the impact of overheating, provided that:
   – The melting point is set to an appropriate value, i.e. In the centre of the comfort zone
   – A suitable quantity of PCM is used

2. If available results from a Differential Scanning Calorimeter (DSC) should be used in the simulation to improve accuracy

3. PCMs should not be considered as a full solution to overheating, in certain circumstances alternative cooling would be required

QUESTIONS???

Software Sources:

http://openstudio.nrel.gov/

(***NOTE***: ensure you follow the user documentation)

http://sketchup.google.com/

http://apps1.eere.energy.gov/buildings/energyplus/

Contact:

David.tetlow@nottingham.ac.uk

David.tetlow@markgroup.co.uk