Shading Effect of Alley Trees and Their Impact on Indoor Comfort

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The Issue

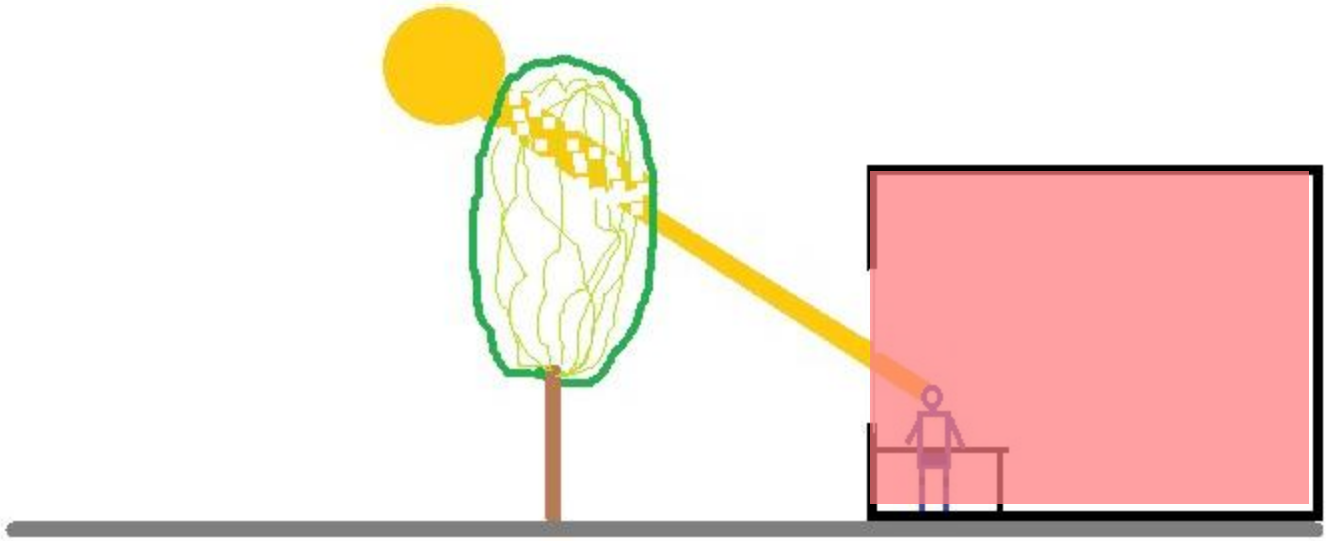
UHI **energy efficiency**

- Urban heat island → summer heat stress → health problems
- Trying to create a tolerable indoor comfort → mechanical cooling → drastic increase of electricity-use during the summer period
- EU aims to mitigate energy consumption in building sector (EPBD recast: nZEB, EED)
- Green Infrastructure development goals (EU Biodiversity Strategy 2020)

Analysis

Aims:

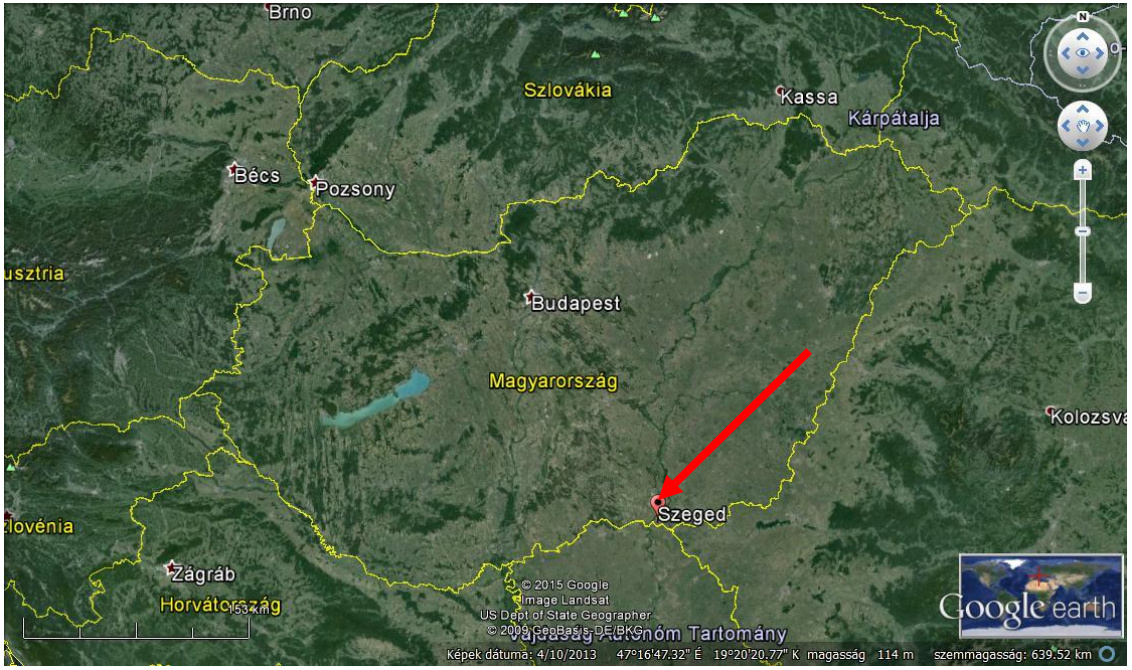
- investigate the importance of shading effect of alley trees on indoor thermal comfort
- analyse species-dependence of the effect
- form a base for targeted model development/ adaptation (e.g. i-Tree)



Field measurements

Study area:

Szeged (Hungary)



Tree species:

Sophora japonica

Tilia cordata

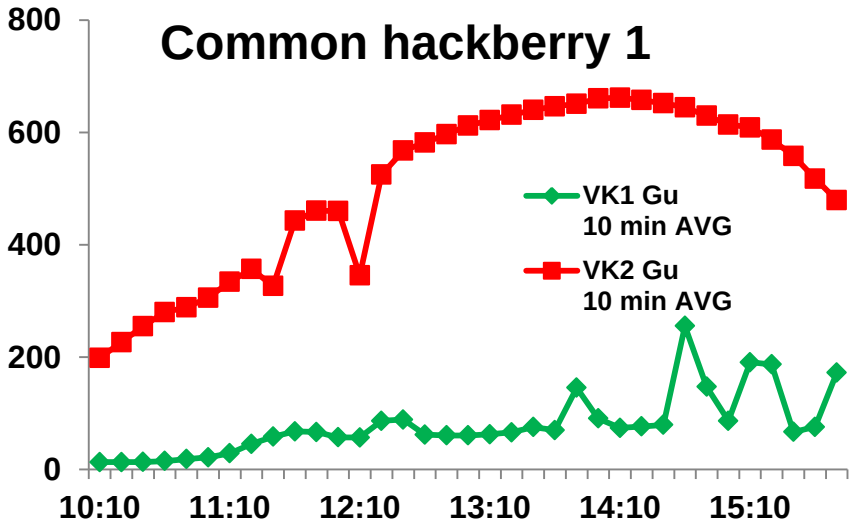
Celtis occidentalis

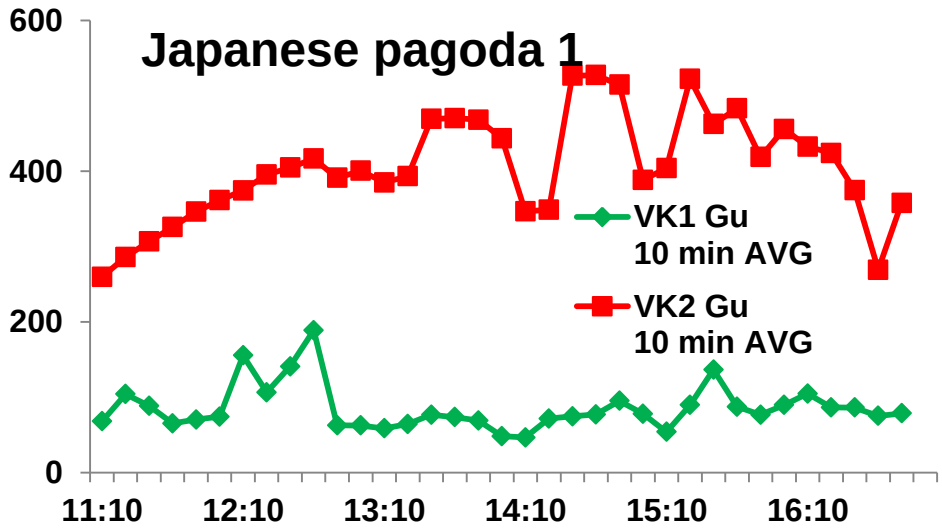
Field measurements

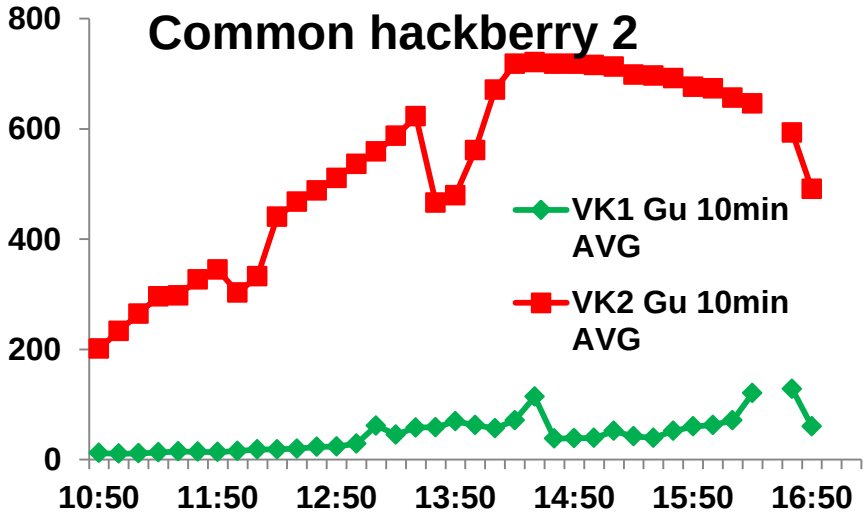
Transmissivity measurements:

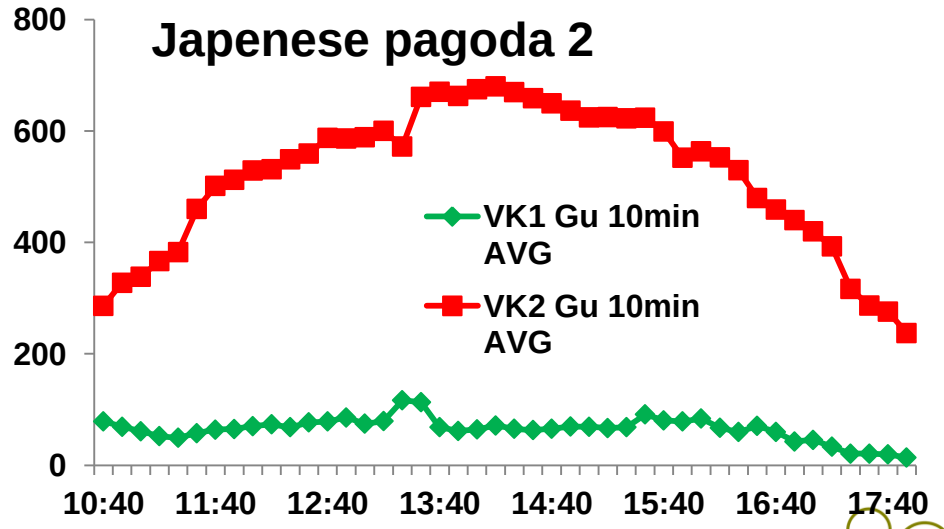
- the indicator of shading effect (ratio of irradiance (shortwave radiation) in shaded and reference point)
- Measurements were made for vertical plane
- Kipp&Zonen CNR 1,2 pyranometers
- 3*2 measurement days

Results I.

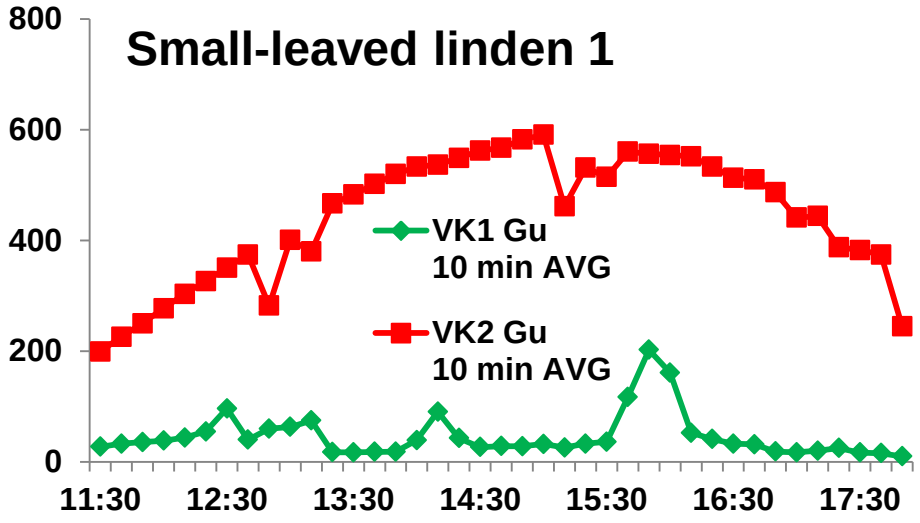

Common hackberry 1
800
600
400
200
0
10:10
11:10
12:10
13:10
14:10
15:10
VK1 Gu
10 min AVG
VK2 Gu
10 min AVG

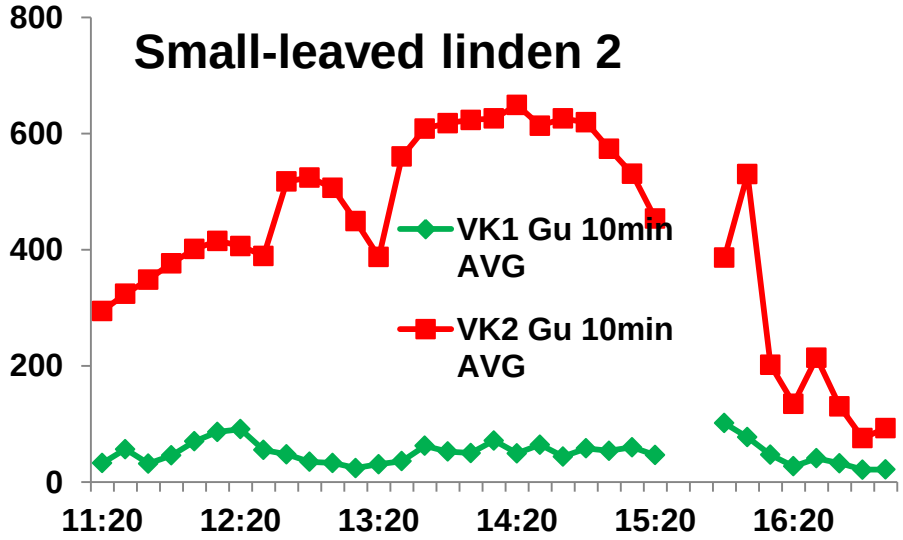

Japanese pagoda 1
600
400
200
0
11:10
12:10
13:10
14:10
15:10
16:10
VK1 Gu
10 min AVG
VK2 Gu
10 min AVG


Common hackberry 2
800
600
400
200
0
10:50
11:50
12:50
13:50
14:50
15:50
16:50
VK1 Gu 10min
AVG
VK2 Gu 10min
AVG


Japenese pagoda 2
800
600
400
200
0
10:40
11:40
12:40
13:40
14:40
15:40
16:40
17:40
VK1 Gu 10min
AVG
VK2 Gu 10min
AVG

Results II.





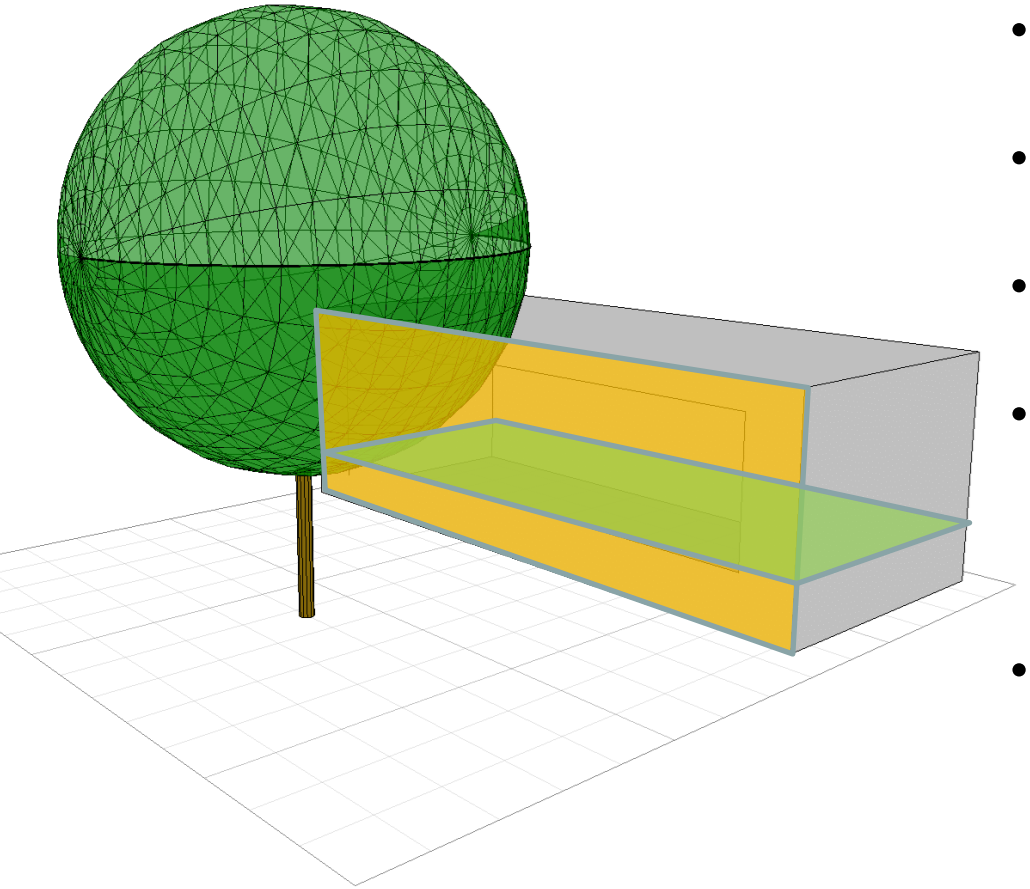
	T (%)	σ (%)
Celtis occ.	**11,3**	7,5
Sophora j.	**16,6**	7,6
Tilia cord.	**12,0**	7,6

- high variability of transmissivity values
- influence of tree condition
- considerable differences between species in radiance transmissivity

→effects on indoor thermal comfort

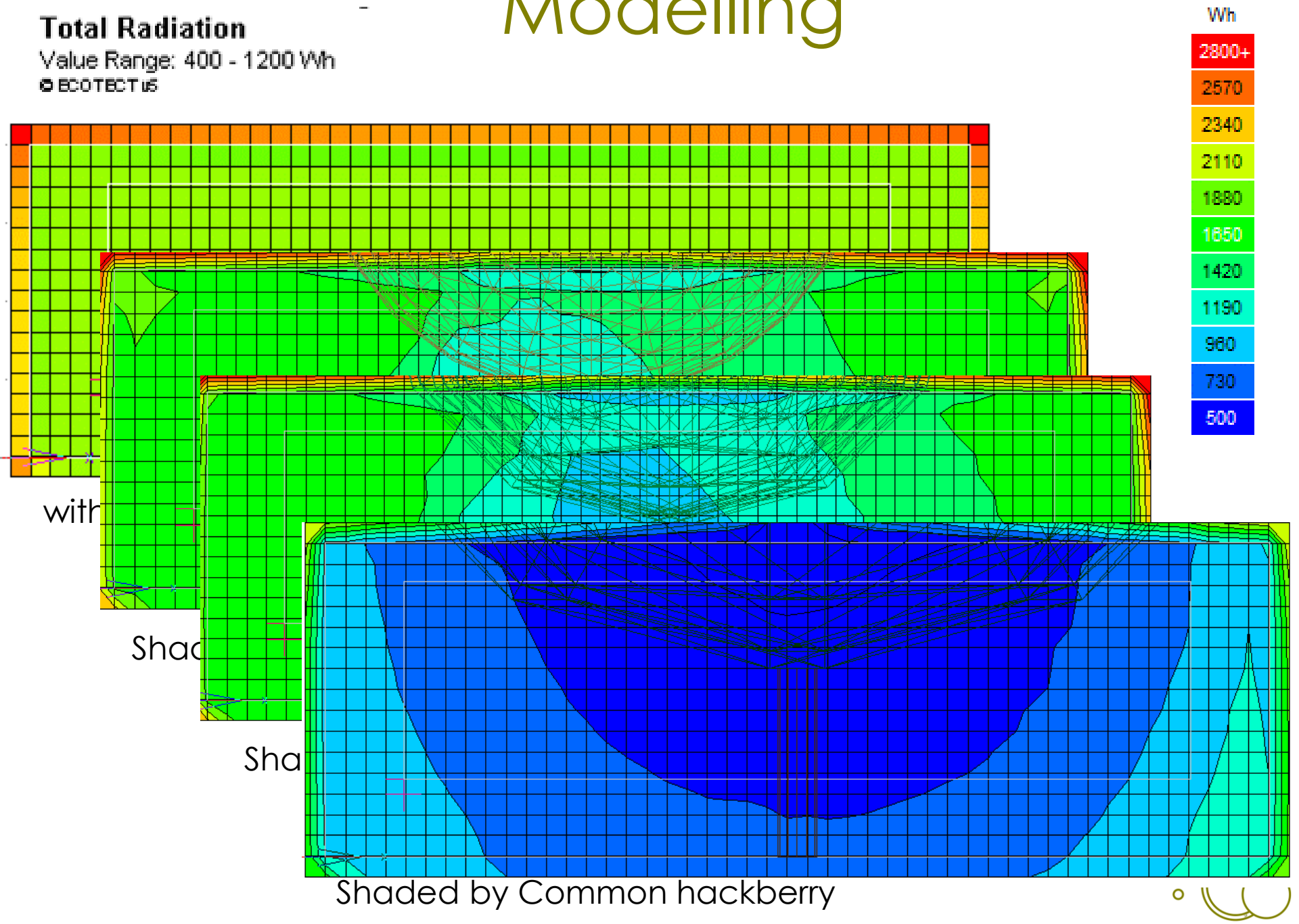
Modelling

- *Modelling was carried out with Autodesk ECOTECT software.*
- *Aim is to give more general approach of the shading effect of alley trees.*
- *measurements were carried out on an ideal model*



- **The model** consists of a cubic room: 12 x 6 x 4 m.
- **Wall:** thin brick structure covered with plaster.
- **Windows:** double glazed, timber framed.
- **Tree:** spherical polygons, material transparency is taken from the pyranometer measurements.
- **Modelling day:** typical summer day (16th July).

Modelling


Total Radiation
Value Range: 400 - 1200 Wh
ECOTECT v5
Wh
2800+
2570
2340
2110
1880
1650
1420
1190
960
730
500
with
Shad
Sha
Shaded by Common hackberry

Results

Cumulative value of solar gain on vertical surface [kWh]				
	Case without tree	*Shadowed by Common hackberry*	*Shadowed by Japanese pagoda*	*Shadowed by Small-leaved lime*
Average	1,98	0,81	1,60	1,49
Minimum	1,72	0,46	1,18	1,05
Maximum	2,00	1,28	1,92	1,90
Rate of reduction in per cent	0%	60%	19,30%	24,80%

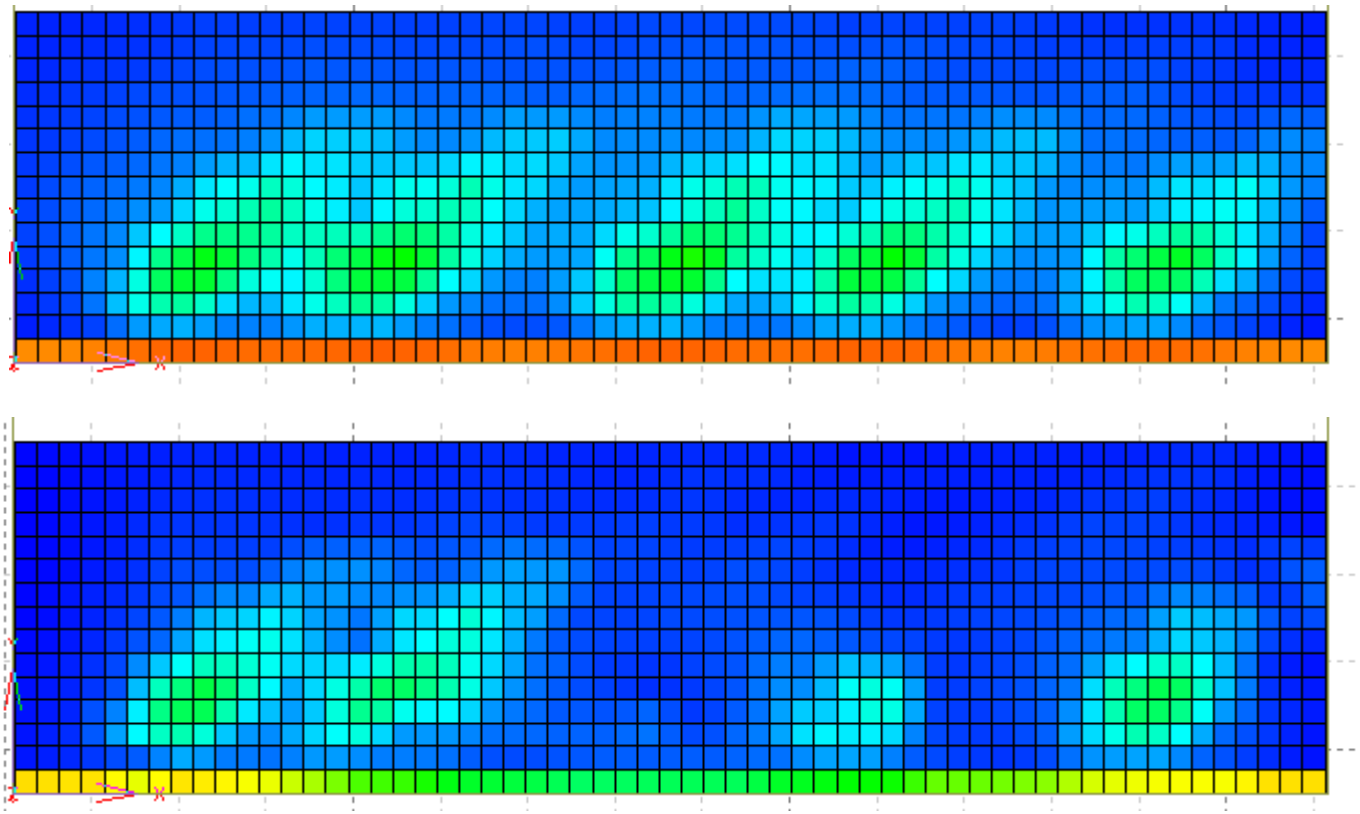
Modelling

Tilia cord.

Total Radiation

Value Range: 400 - 1200 Wh

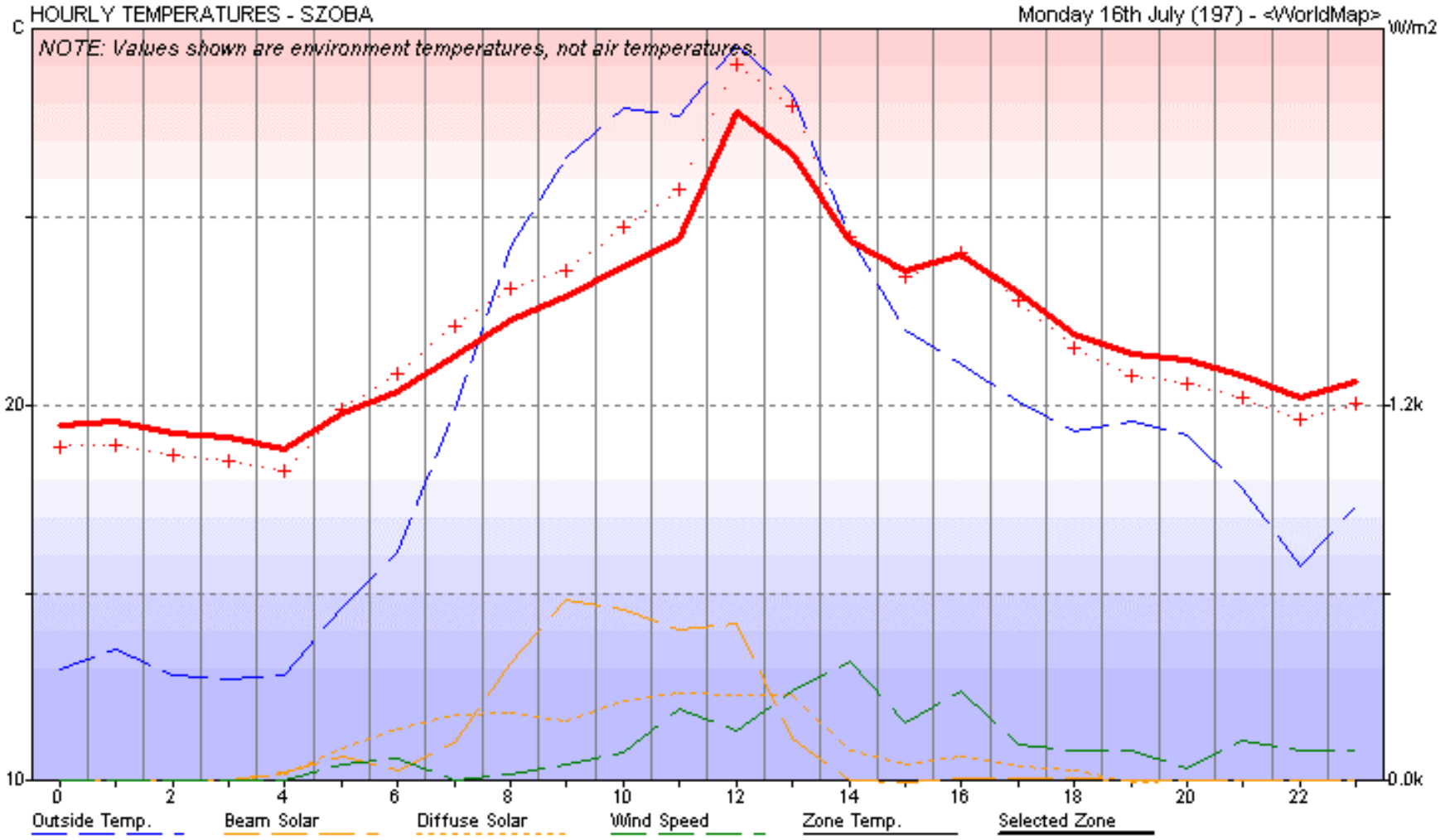
© ECOTECT 6



Results

Cumulative value of solar gain on horizontal surface [kWh]				
	Case without tree	*Shadowed by Common hackberry*	*Shadowed by Japanese pagoda*	*Shadowed by Small-leaved lime*
Average	0,74	0,52	0,67	0,60
Minimum	0,46	0,46	0,46	0,46
Maximum	1,99	0,97	1,79	1,74
Rate of reduction in per cent	0%	29%	9%	18%

Results


HOURLY TEMPERATURES - SZOBA
Monday 16th July (197) - <World Map>
C
W/m2
NOTE: Values shown are environment temperatures, not air temperatures.
20
10
1.2k
0.0k
0
2
4
6
8
10
12
14
16
18
20
22
Outside Temp.
Beam Solar
Diffuse Solar
Wind Speed
Zone Temp.
Selected Zone

Results

Investigating indoor temperatures

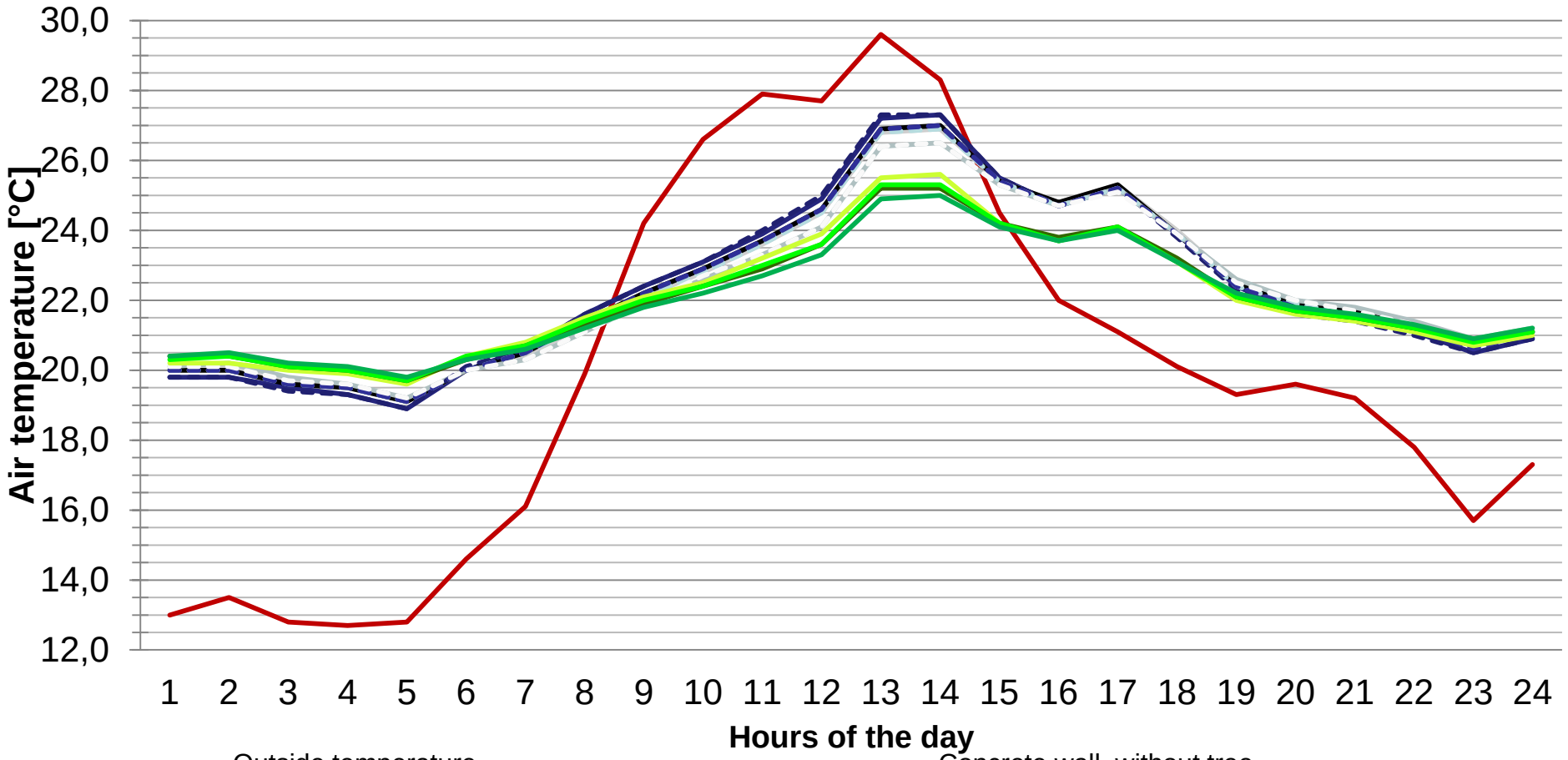
- **Three wall types:**

	heavy-weight	leight-weight
insulated	Concrete wall with 18 cm thermal insulation. U-value: [0.17 W/m^{2}K]	Wooden wall with 16 cm thermal insulation. U-value: [0.18 W/m^{2}K]
not insulated	Brick wall, plastereed, U-value: [1.01 W/m^{2}K]	

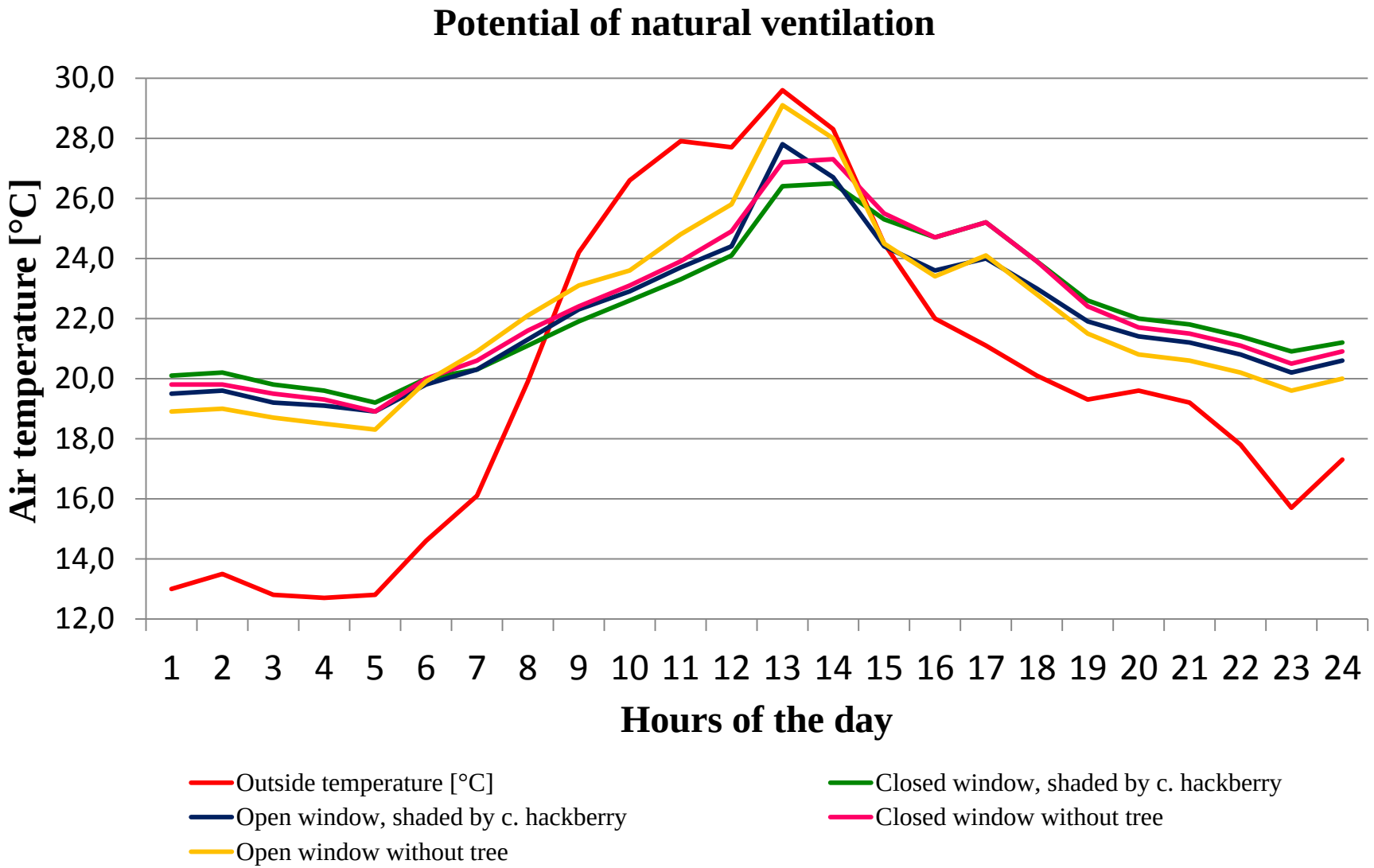
- **Window opening scenarios**

Results

Indoor air temperatures in different cases (structures and shading scenarios) on a tipical summer day



Results


Potential of natural ventilation
Air temperature [°C]
30,0
28,0
26,0
24,0
22,0
20,0
18,0
16,0
14,0
12,0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
Hours of the day
Outside temperature [°C]
Closed window, shaded by c. hackberry
Open window, shaded by c. hackberry
Closed window without tree
Open window without tree

Summarising results

- Trees have an important role in mitigating total radiation on building facades and indoor surfaces
- The effectivity of shading depends mainly on vertical transmissivity, which is a species-dependent characteristic of trees.
- A tree in front of the building
  - ***Diminishes the total irradiance on vertical surface up to 60%.***
  - ***mitigates indoor temperature by $\Delta T_{air,max}$=0,6-0,8°C.***
  - ***Imporves the potential of natural ventilation.***

The operating hours of air conditioning device are mitigated / or even the installation can be avoided

Discussion and further plans

- further measurements and model-based assessments from different study areas (species, climatic ciurcumstances and modelling contexts)
- go on with further transmissivity measurements of different species
- Verifing the model-based results with indoor measurements.

- planting guide: model-based impact assessments of trees of different species, direction and distance to building
- urban-scale (spatial) assessments

Thank you for your attention!