Indoor-outdoor cooling potential of nature-based solutions

An application to university campus retrofit

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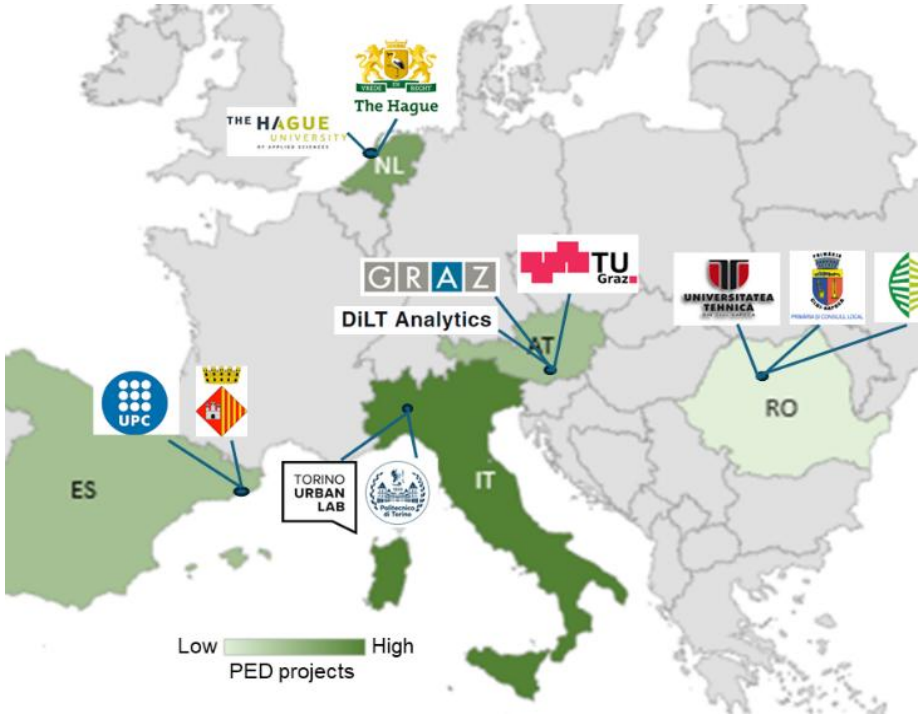
Introduction



DUT Driving Urban Transitions

Co-funded by the European Union

eduPED

EDUcational campuses as drivers for **P**ositive **E**nergy **D**istricts

- To **accelerate the transition** to Positive Energy Districts (**PED**s) in urban areas.
- Applying **morphology approach** for **energy-positive regeneration and refurbishment**
- **Leveraging on educational institutions** with sizeable built assets in cities as the drivers, orchestrators, and knowledge hubs for upscaling PED Urban Living Labs.

Introduction

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EDUcational campuses as drivers for **P**ositive **E**nergy **D**istricts

University Campuses as **Living Labs**

- **Reduce Energy** consumption
- Optimise **renewable energy generation** and flexibility
- Improve **climate adaptation**

Introduction

eduPED

EDUcational campuses as drivers for **P**ositive **E**nergy **D**istricts

University Campuses as **Living Labs**

- **Reduce Energy** consumption
- Optimise renewable energy generation and flexibility
- Improve **climate adaptation**

Nature-Based Solutions (NBS)

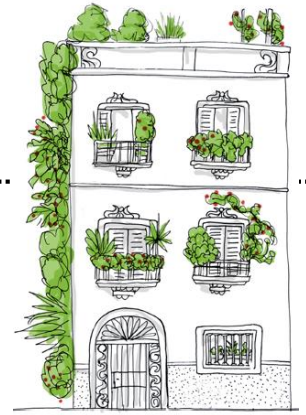
Objective

To quantify **the global cooling potential of NBS** applied to building retrofits at the **building and the district scales**, considering their **dual impact on the indoor and outdoor thermal environment**.

Nature-Based Solutions

Scale of aplication

Buildign scale



District scale

Impacts

INDOOR THERMAL COMFORT
COOLING ENERGY DEMAND

Indoor

Radiant temperatures
Air temperature

OUTDOOR THERMAL COMFORT (OTC)
URBAN HEAT ISLAND (UHI)

Outdoor

Radiant temperature
Ambient temperature
Humidity
Wind speed

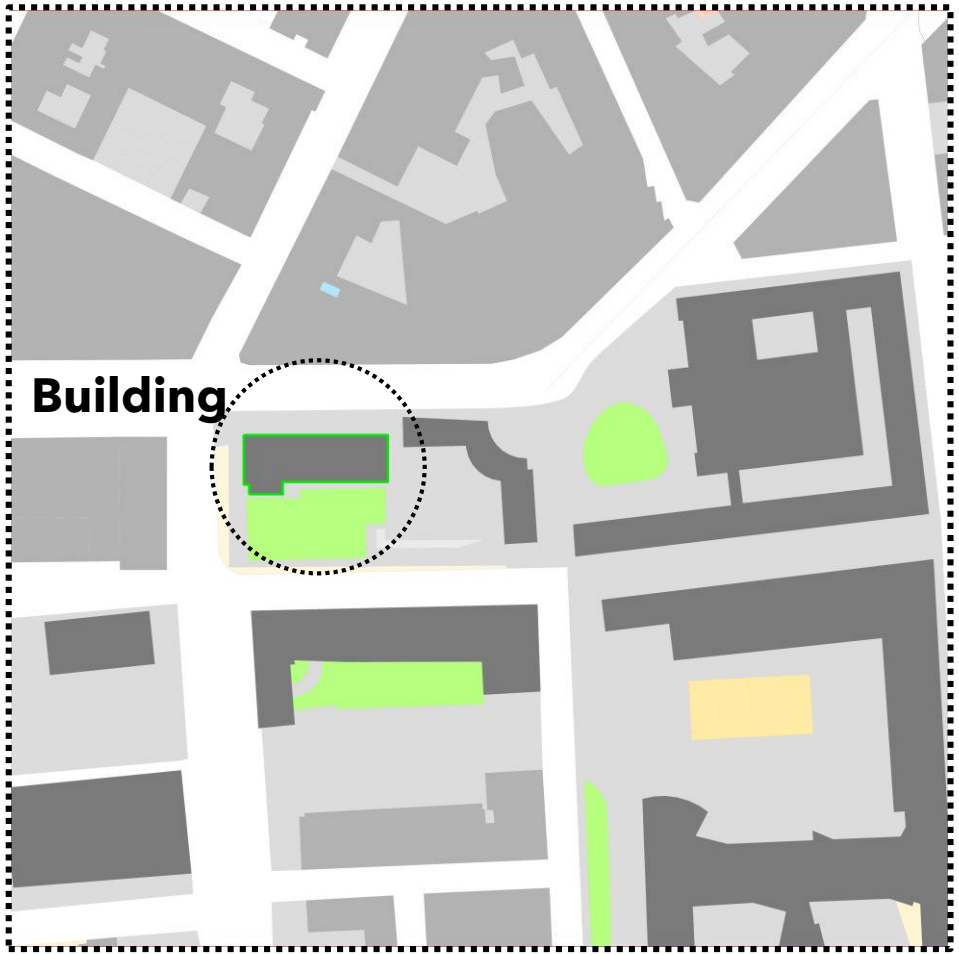
Image source: PROGRAMA D'IMPULS DE LA INFRAESTRUCTURA VERDA URBANA, Ajuntament de Barcelona

Case study: UPC campus and district in Terrassa

Building

Library

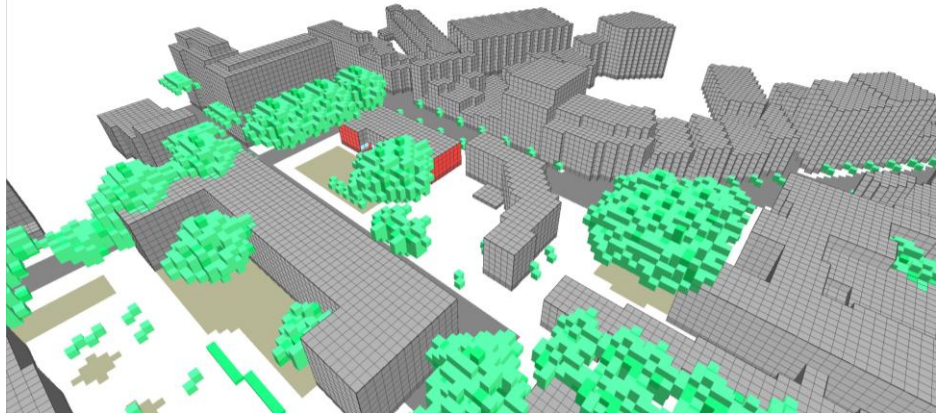
District



Methodology

ENVI _MET

Outputs



/ Atmosphere
- Ambient temperatura
- Mean Radiant Temperature
- Humidity
- Wind speed

/ Biomet
- PET Physiological Equivalent temperature

Outdoor

UHI
OTC

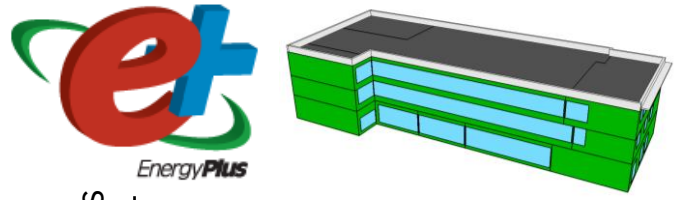
/ Buildings / Dynamic

Wall Surface temperatures (OUTSIDE)

/ Atmosphere

Ambient temperature

Boundary conditions



Outputs

NBS scenarios :
- Green Façades (GF)
- Green Roofs (GR)

Scale of aplication:
- Building
- District

Meteorological data: Typical day of August
(based on the last 10 years data)

Simulation time: 42h

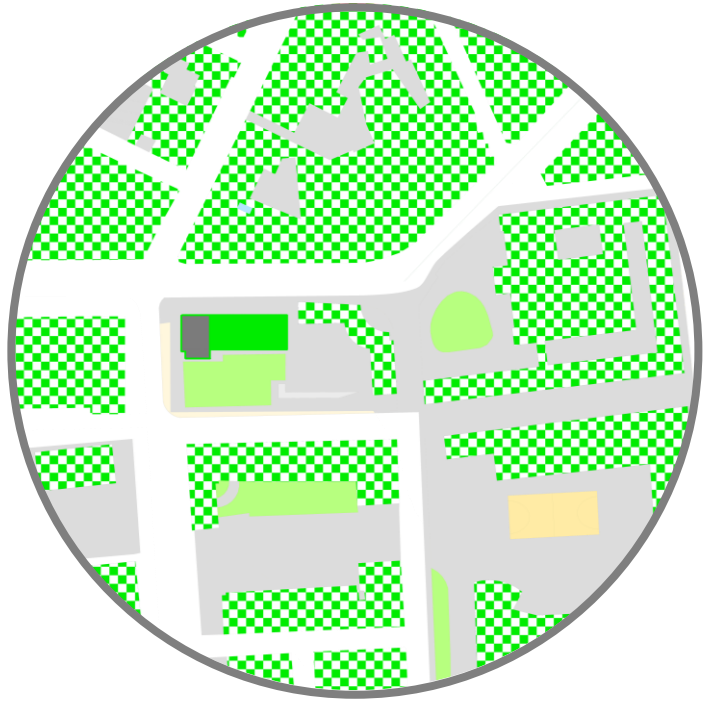
Indoor

THERMAL COMFORT
- Mean Radiant Temperature
- Air temperature
- Operative temperature

ENERGY
- Cooling energy

Methodology

Scenarios:

	Library GF	District GF	District GF + GR
			
NBS :	**Green Façade (GF)**	**Green Façade (GF)**	**Green Façade (GF) + Green Roof (GR)**
Scale:	**Building** 100 % opaque wall	**District** 50% building facades	**District** 50% building facades 50 % Roof surface (flat roofs)

RESULTS

Outdoor

OUTDOOR THERMAL COMFORT (OTC)
URBAN HEAT ISLAND (UHI)

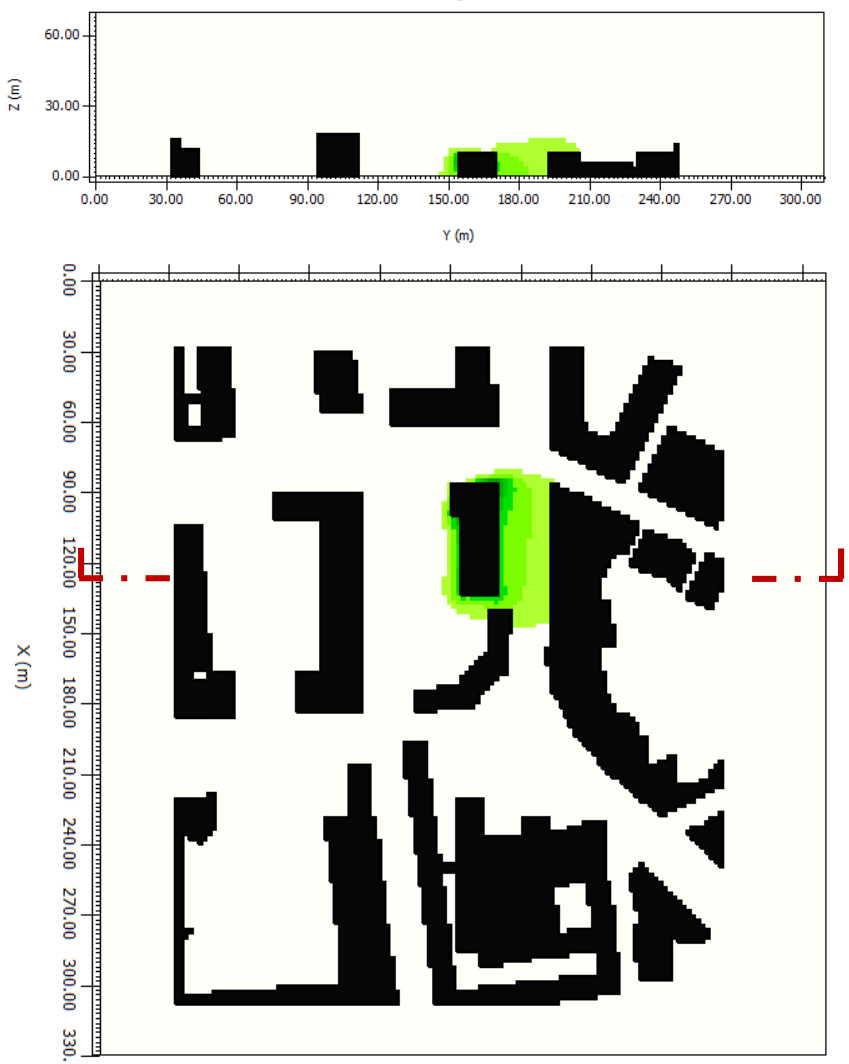
Indoor

INDOOR THERMAL COMFORT
COOLING ENERGY DEMAND

Outdoor Absolute difference **P**otential **A**ir **T**emperature:

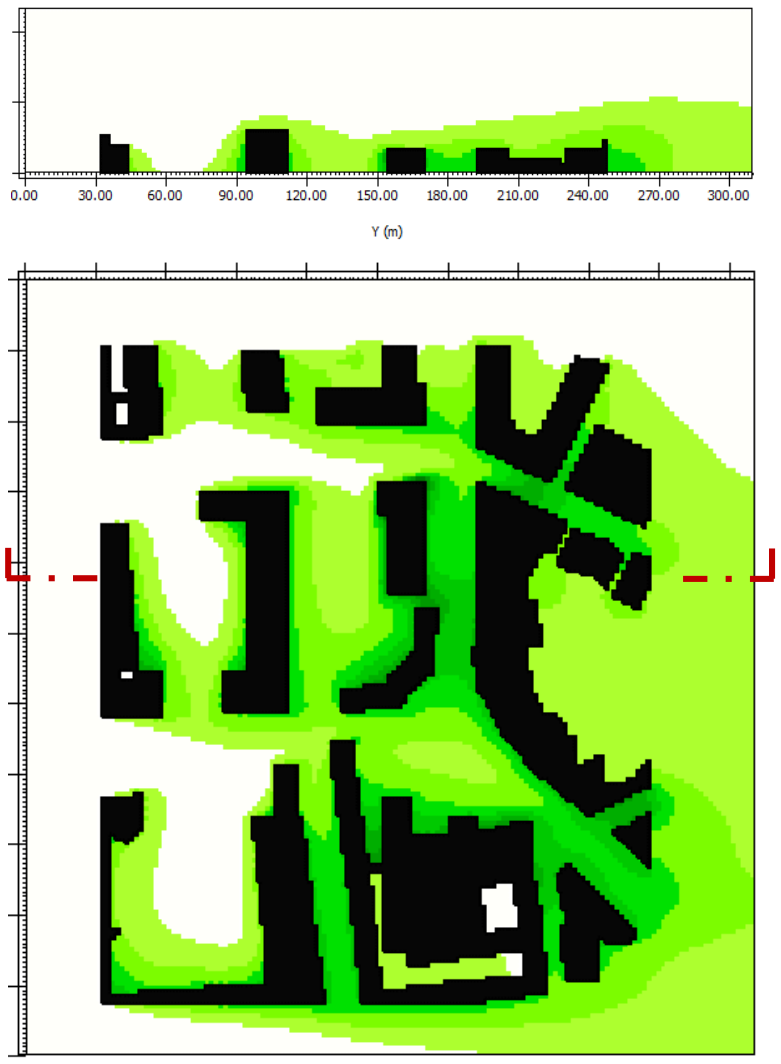
Typical August day | **h**19:00 | **k**=6=5m

Base Case – Library GF



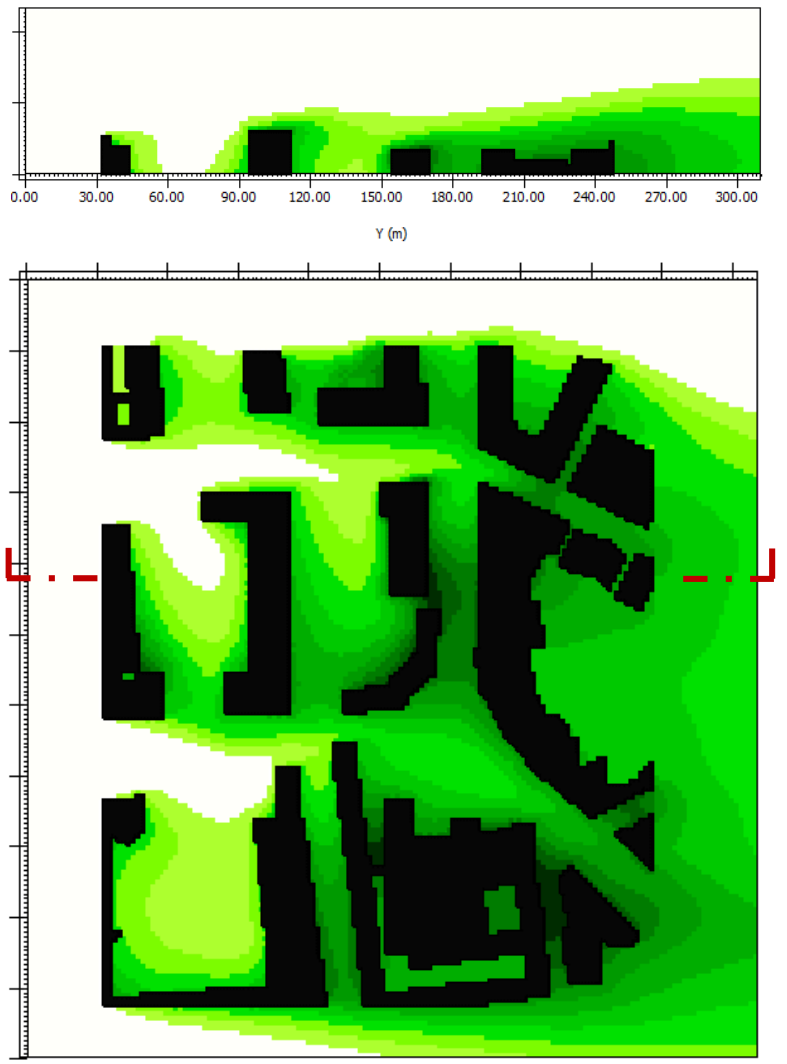
min 0.00 K | **max** 0.13 K

Base Case – District GF



min 0.00 K | **max** 0.31 K

Base Case – District GF + GR



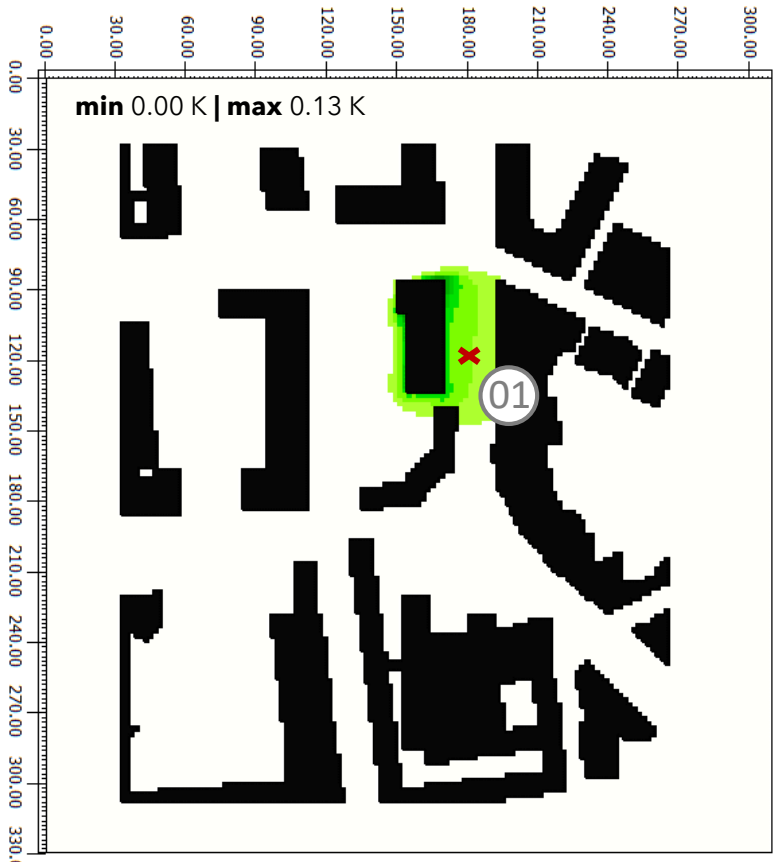
min -0.01 K | **max** 0.50 K

below 0.06 K
0.06 to 0.12 K
0.12 to 0.18 K
0.18 to 0.24 K
0.24 to 0.30 K
0.30 to 0.36 K
0.36 to 0.42 K
0.42 to 0.48 K
0.48 to 0.54 K
above 0.54 K

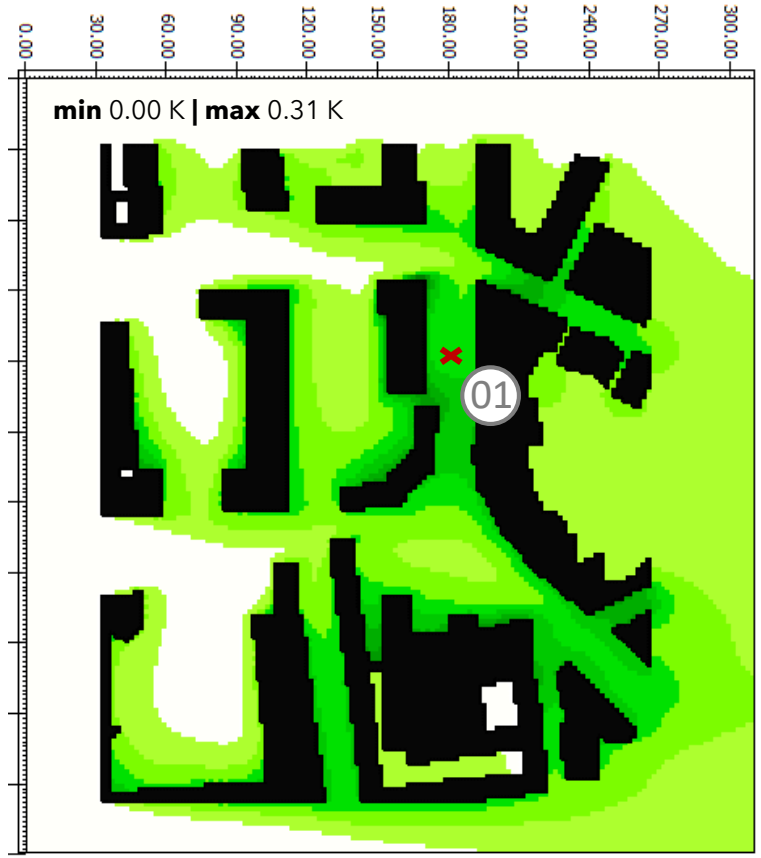
Outdoor Absolute difference **P**otential **A**ir **T**emperature:

Typical August day | **h**19:00 | **k**=6=5m

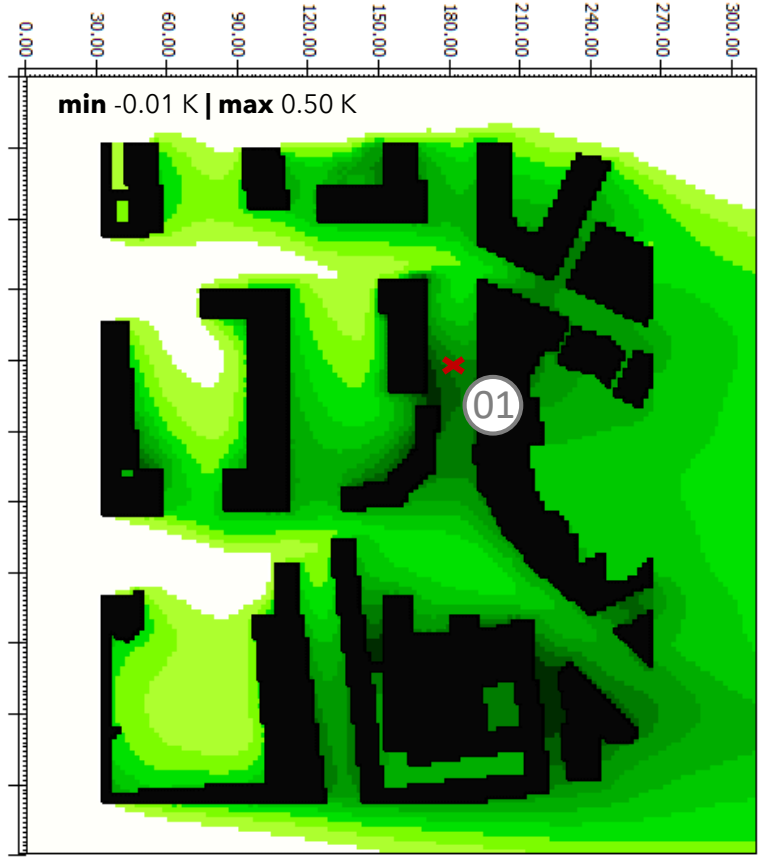
Base Case – Library GF



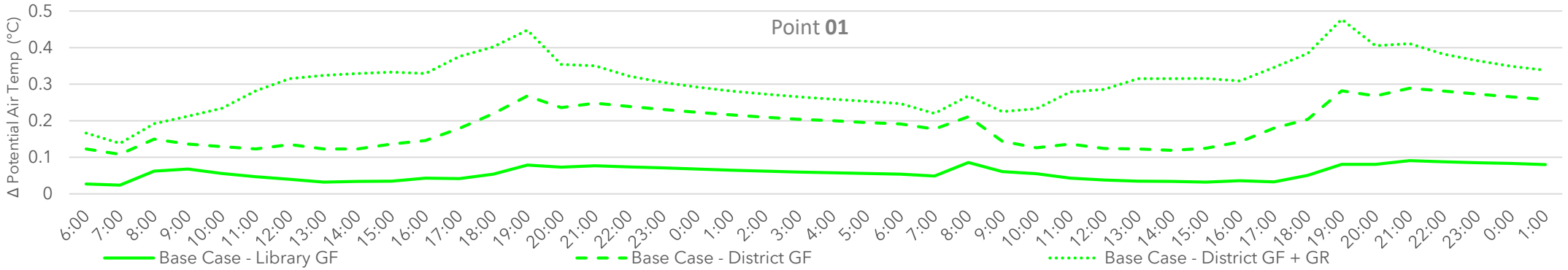
Base Case – District GF



Base Case – District GF + GR



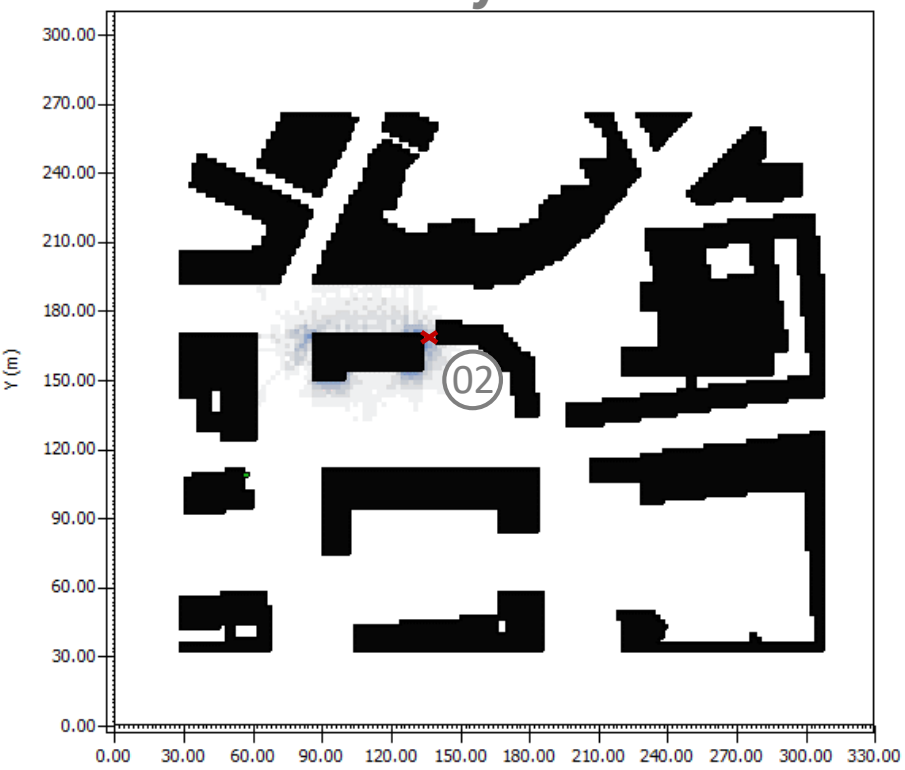
below 0.06 K
0.06 to 0.12 K
0.12 to 0.18 K
0.18 to 0.24 K
0.24 to 0.30 K
0.30 to 0.36 K
0.36 to 0.42 K
0.42 to 0.48 K
0.48 to 0.54 K
above 0.54 K



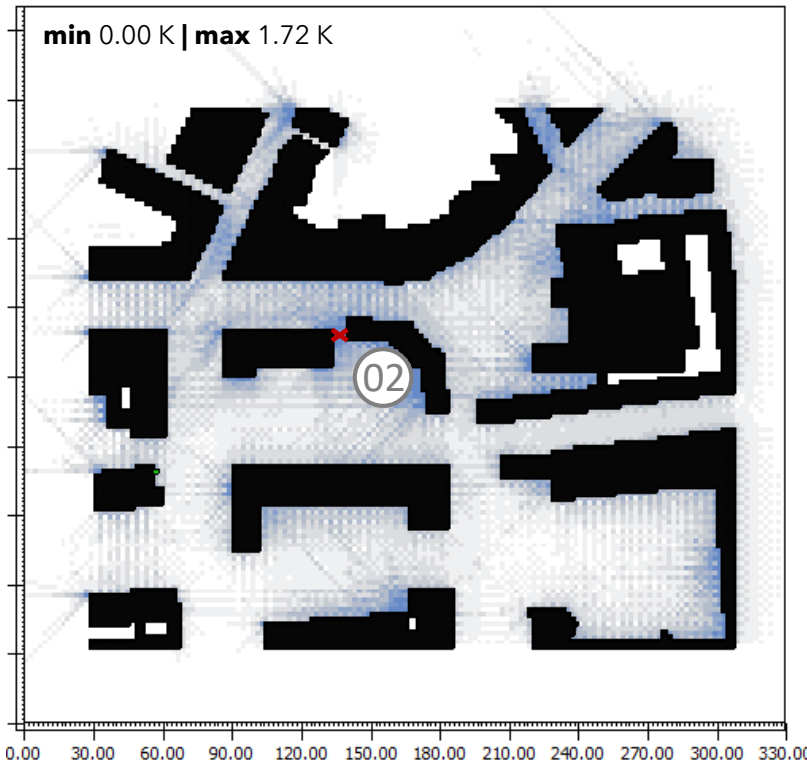
Outdoor Absolute difference **M**ean **R**adiant **T**emperature:

Typical August day | **h**19:00 | **k**=3=1.40m

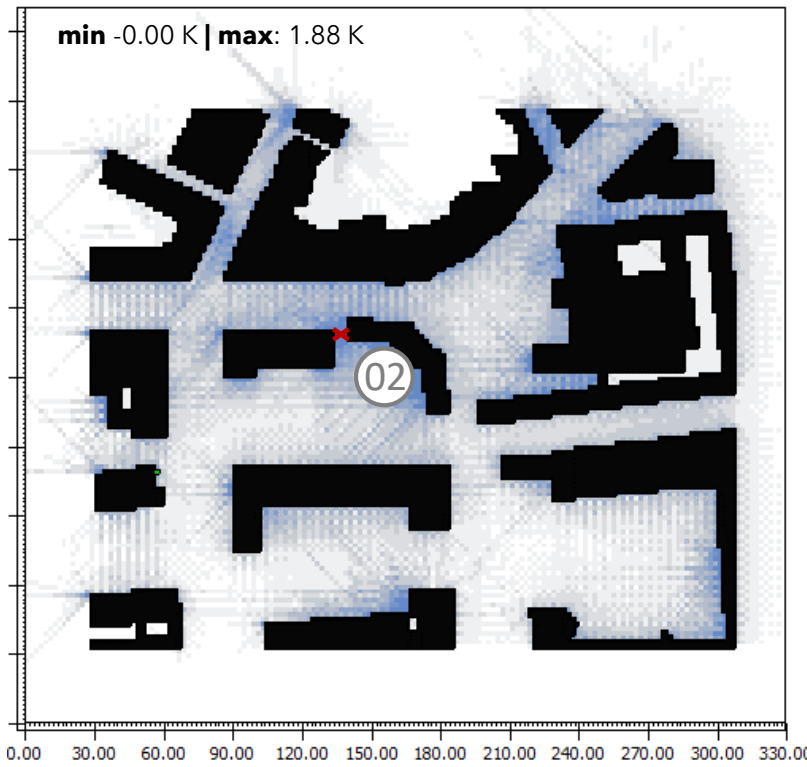
Base Case – Library GF



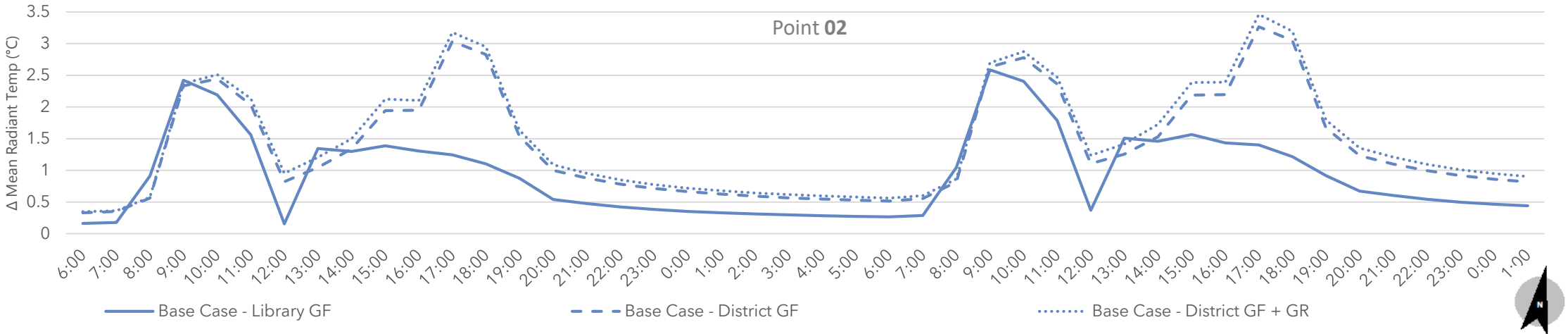
Base Case – District GF



Base Case – District GF + GR



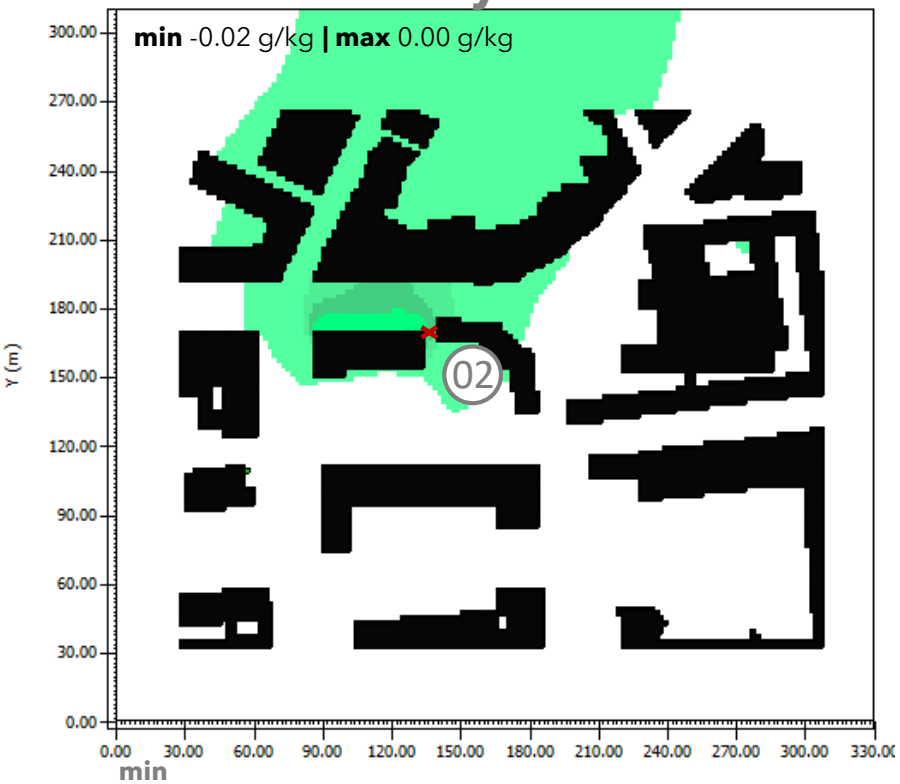
below 0.20 K
0.20 to 0.40 K
0.40 to 0.60 K
0.60 to 0.80 K
0.80 to 1.00 K
1.00 to 1.20 K
1.20 to 1.40 K
1.40 to 1.60 K
1.60 to 1.80 K
above 1.80 K



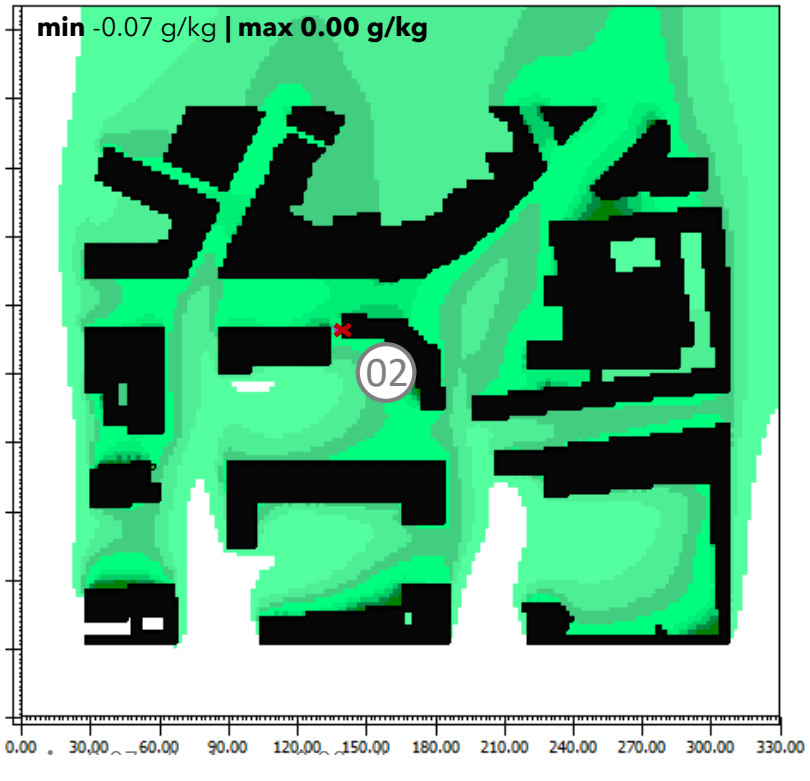
Outdoor Absolute difference **S**pecific **H**umidity:

Typical August day | **h**19:00 | **k**=3=1.40m

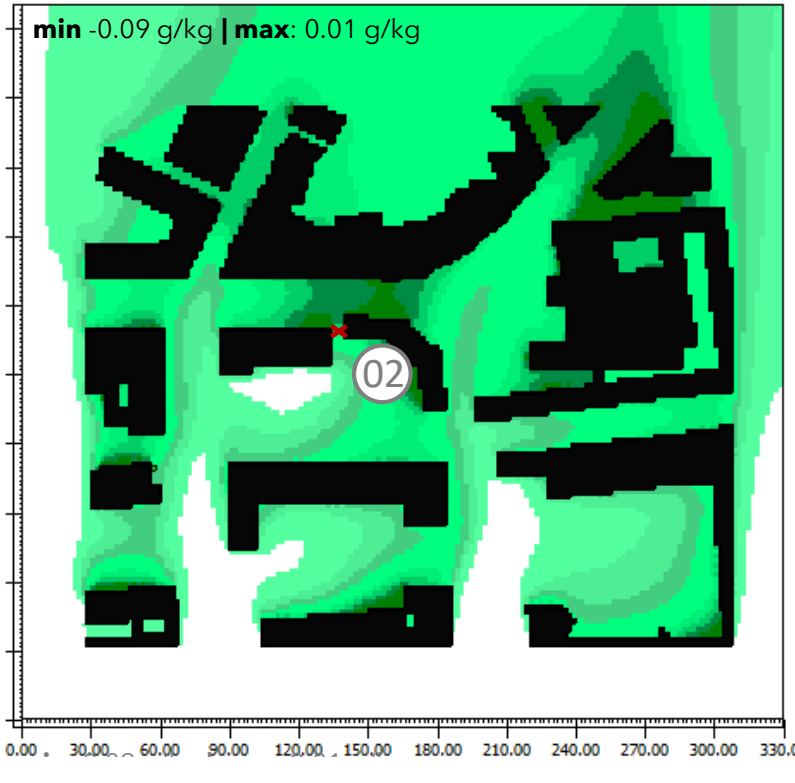
Base Case – Library GF



Base Case – District GF

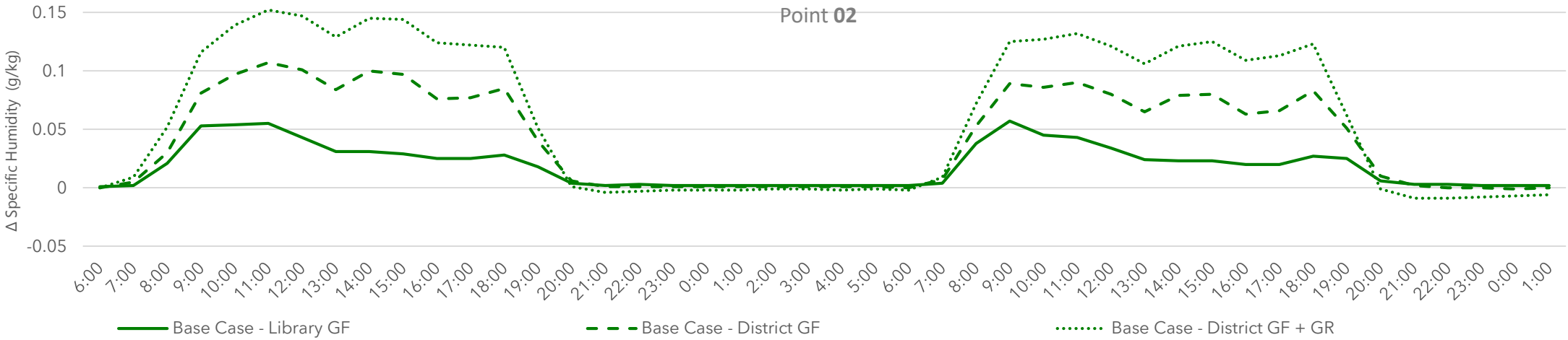


Base Case – District GF + GR



min

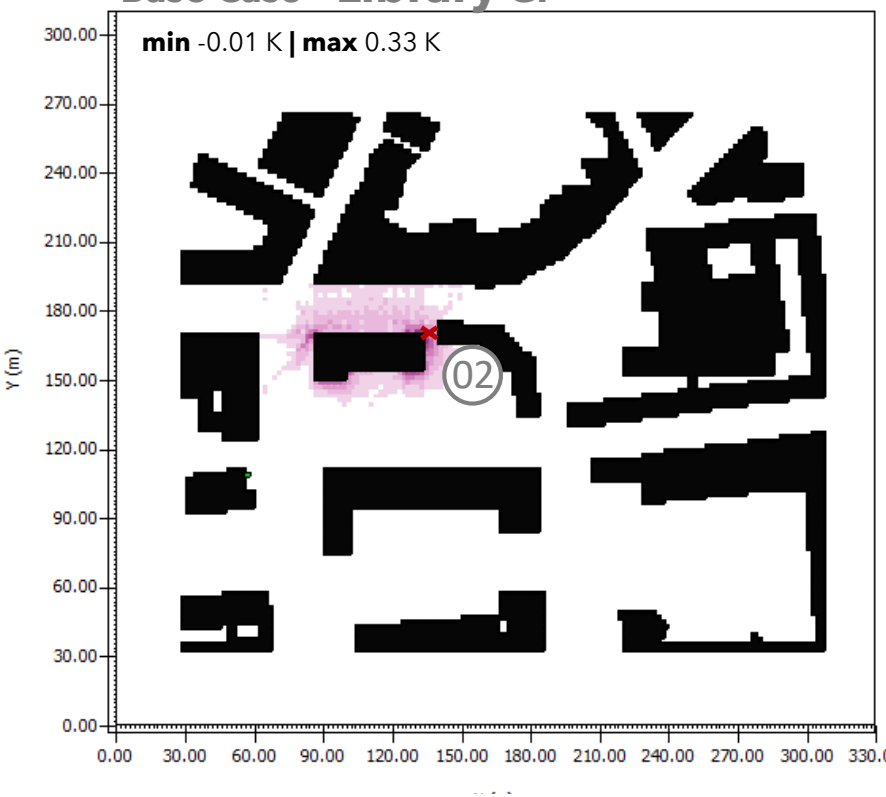
- above 0.08 g/kg
- 0.08 to 0.07 g/kg
- 0.07 to 0.06 g/kg
- 0.06 to 0.05 g/kg
- 0.05 to 0.04 g/kg
- 0.04 to 0.03 g/kg
- 0.03 to 0.02 g/kg
- 0.02 to 0.01 g/kg
- 0.01 to 0.00 g/kg
- below 0.00 g/kg



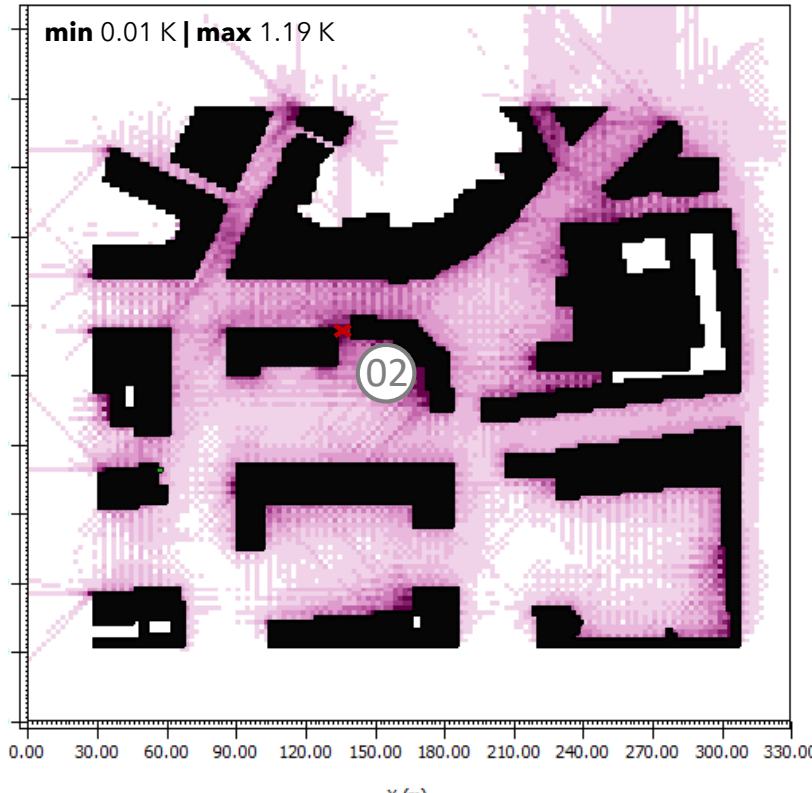
Outdoor Absolute difference **P**hysiological **E**quivalent **T**emperature:

Typical August day | **h**19:00 | **k**=3=1.40m

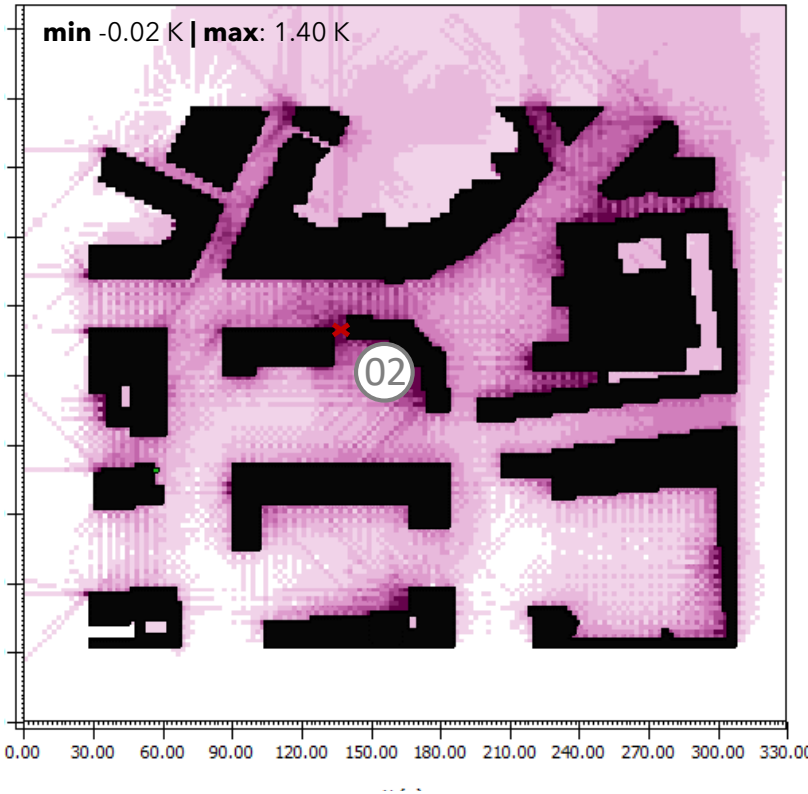
Base Case – Library GF



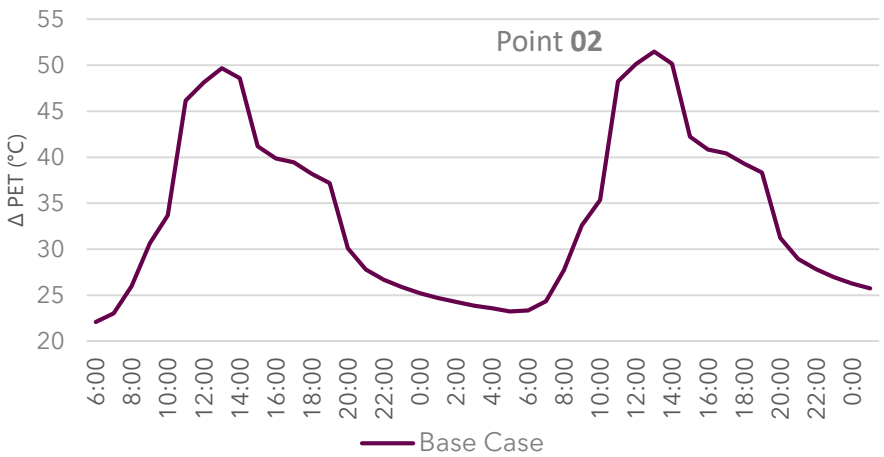
Base Case – District GF

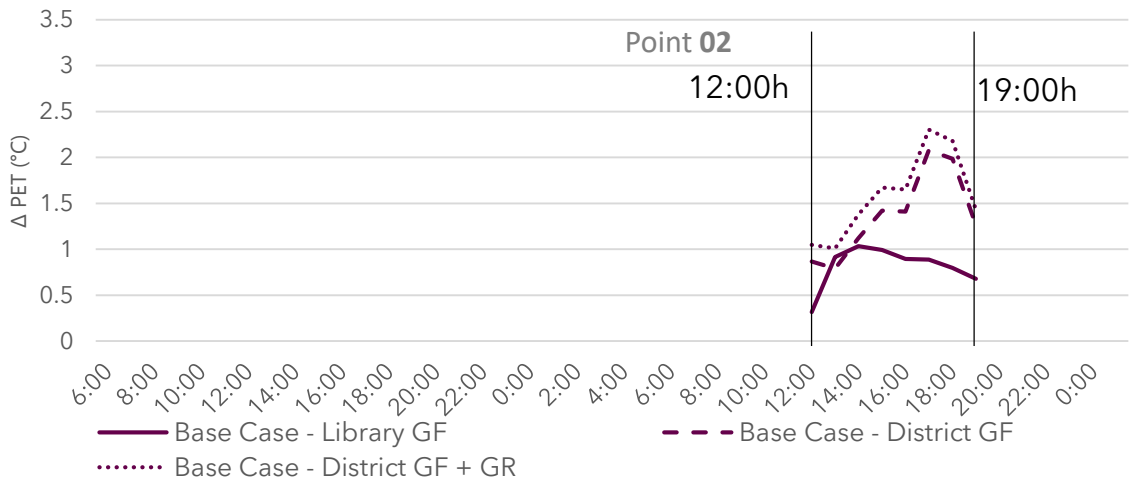


Base Case – District GF + GR

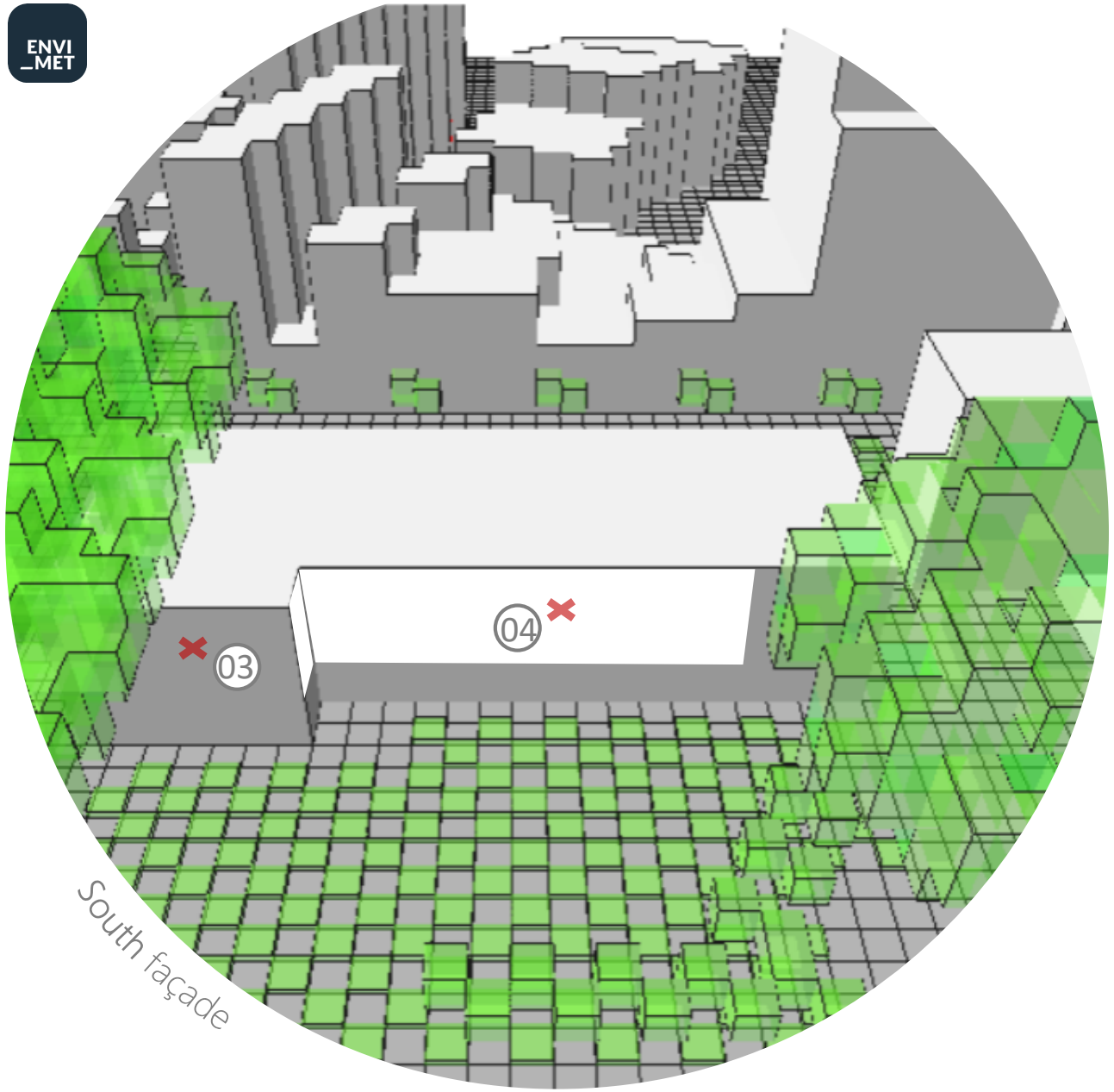


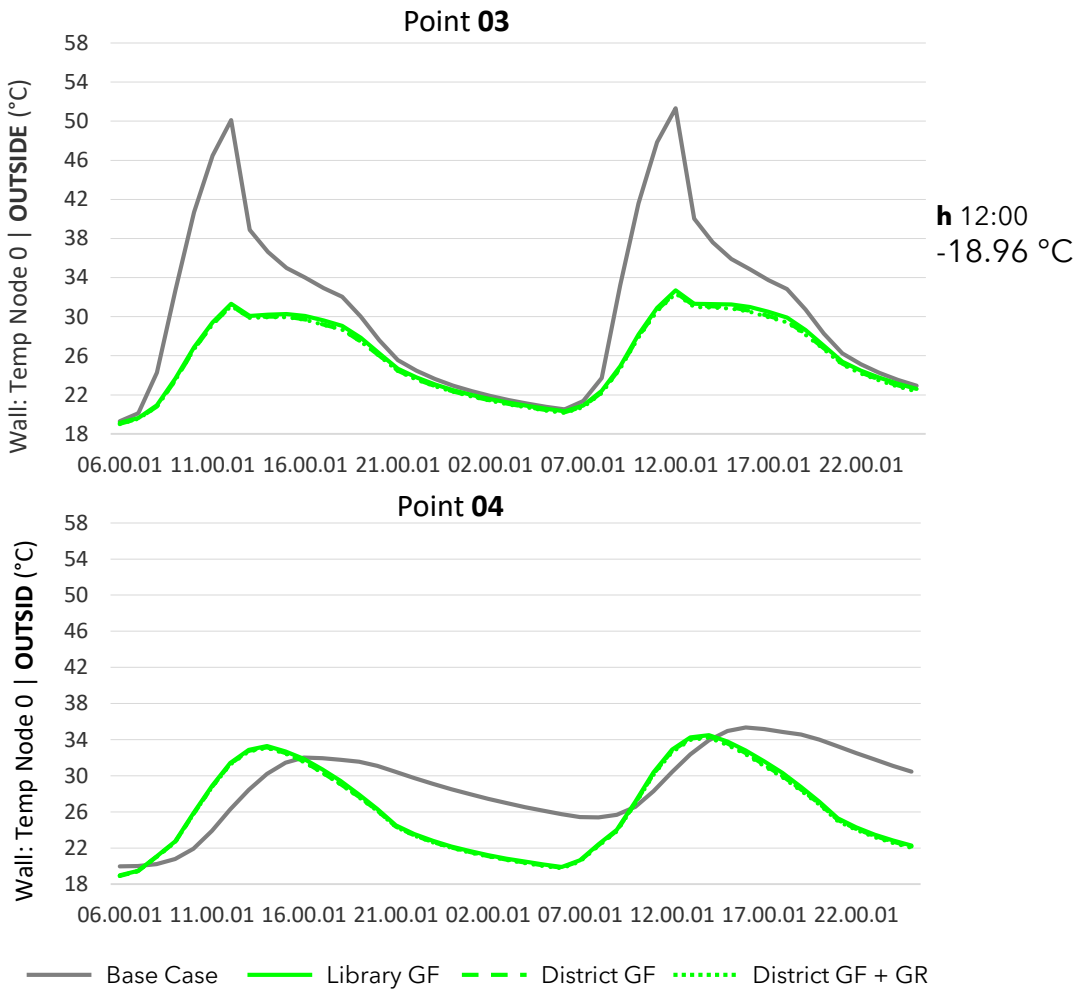
below 0.15 K
0.15 to 0.30 K
0.30 to 0.45 K
0.45 to 0.60 K
0.60 to 0.75 K
0.75 to 0.90 K
0.90 to 1.05 K
1.05 to 1.20 K
1.20 to 1.35 K
above 1.35 K





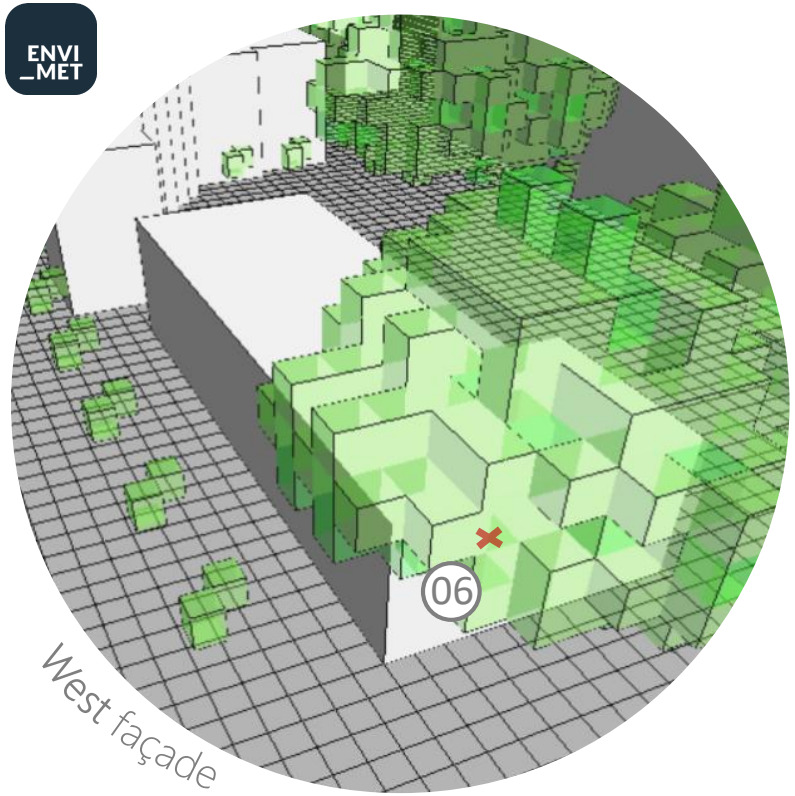
Building Wall: Temperature Nodes | **OUTSIDE**

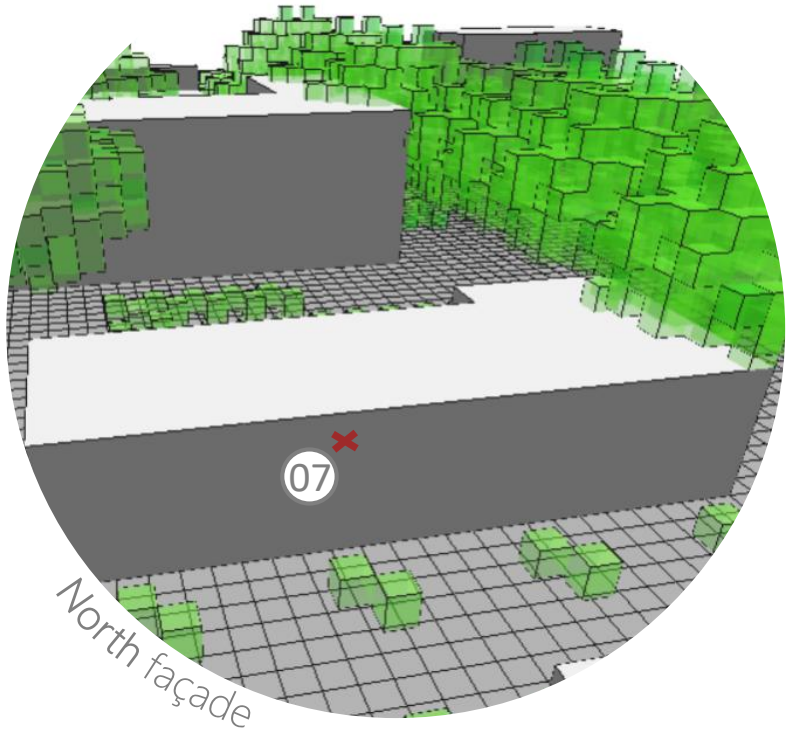


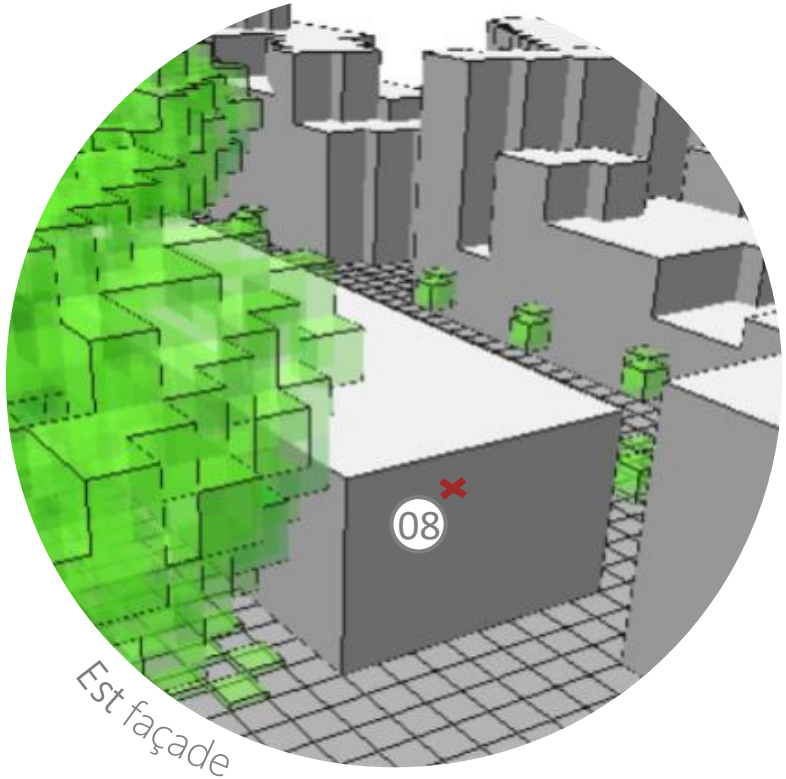


h 12:00
-18.96 °C

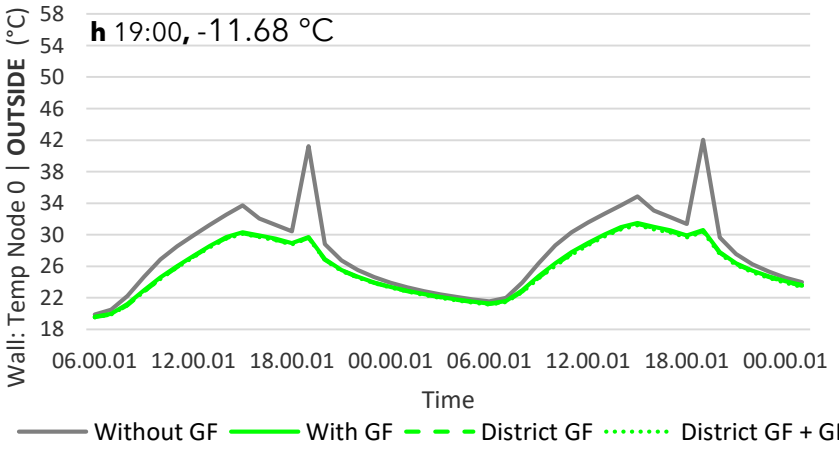
Building Wall: Temperature Nodes | **OUTSIDE**



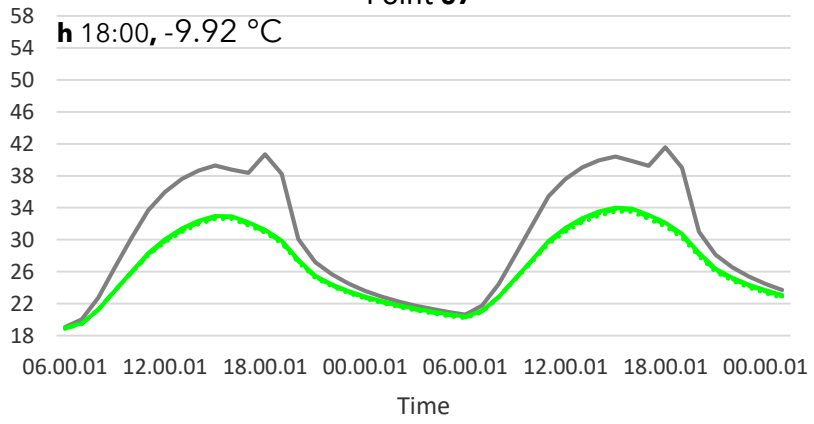




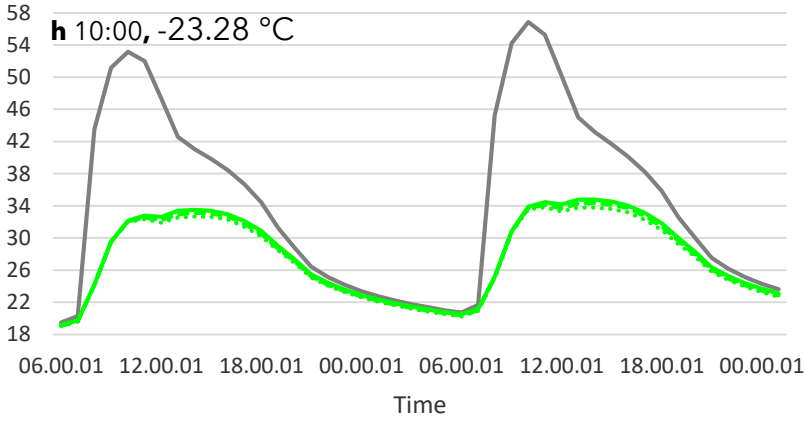
Point **06**



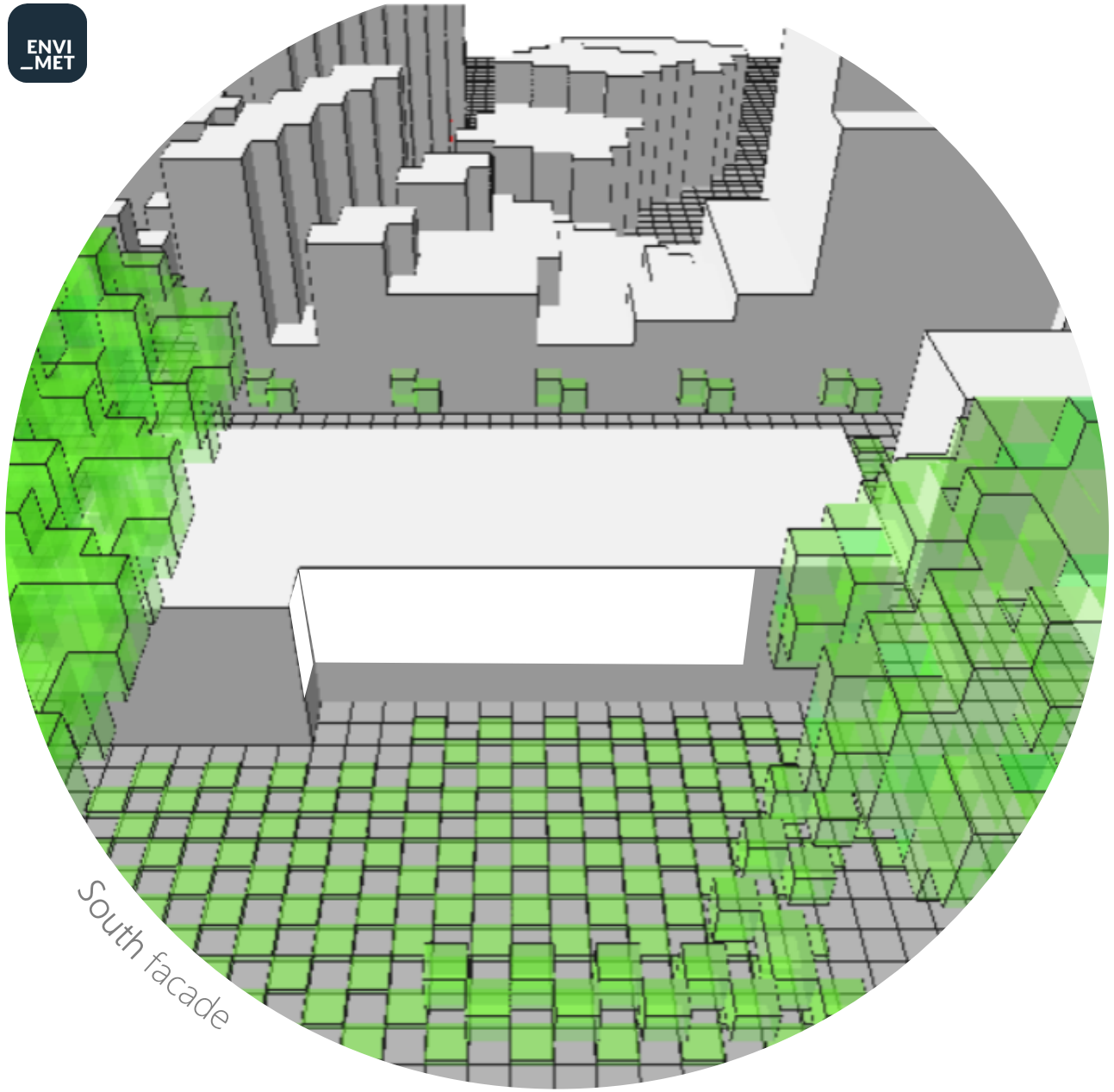
Point **07**

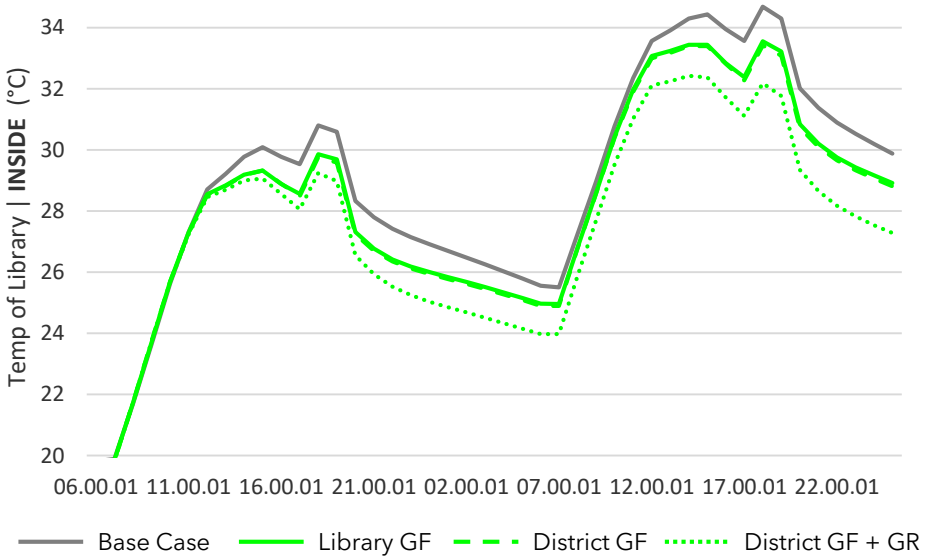


Point **08**



Building Temperature of Library | **INSIDE**



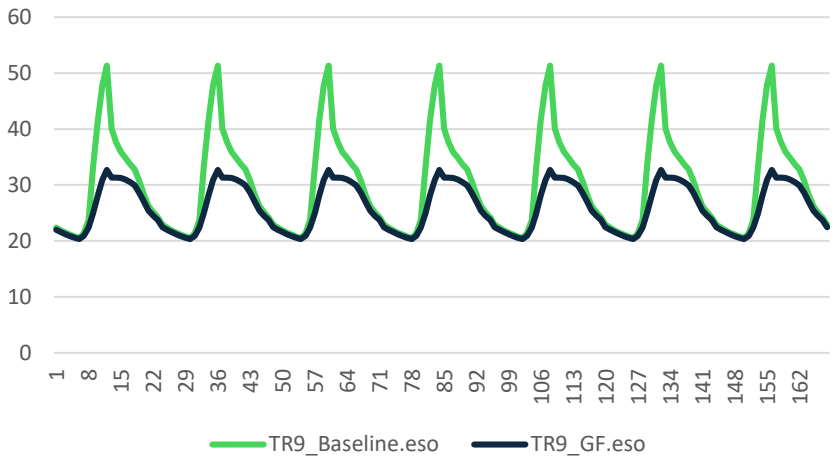


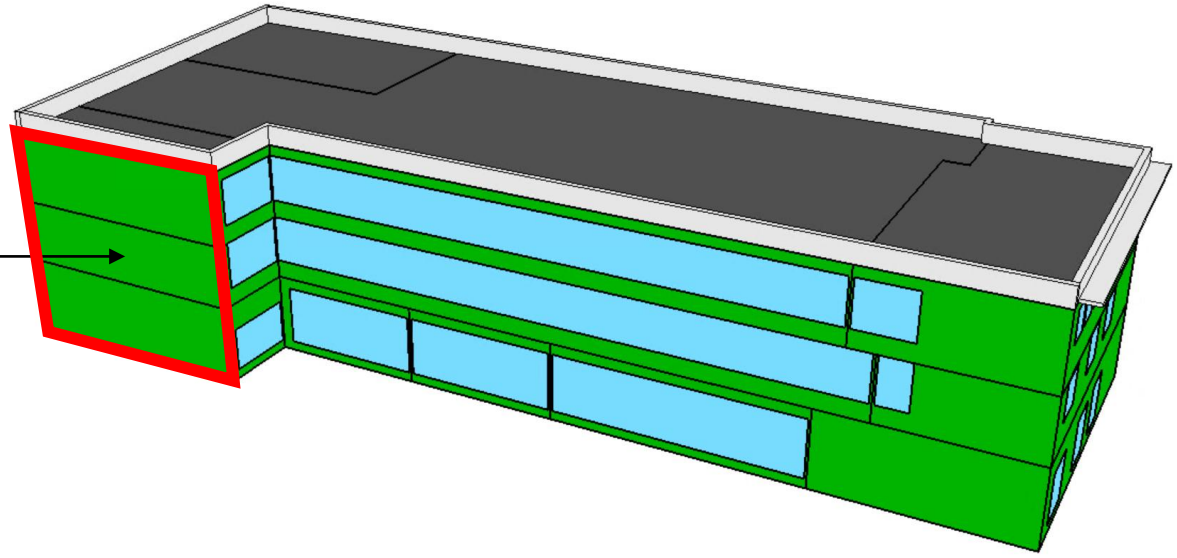
h 18:00
Base Case – **Library GF (District GF)** → -1.27 °C

h 18:00
Base Case – **District GF + GR** → -2.50 °C

"**Other side coefficient**" object used to feed the hourly wall surface temperature calculated by ENVImet as **boundary conditions for EnergyPlus calculation**

Wall: Temperature Nodes | **OUTSIDE**





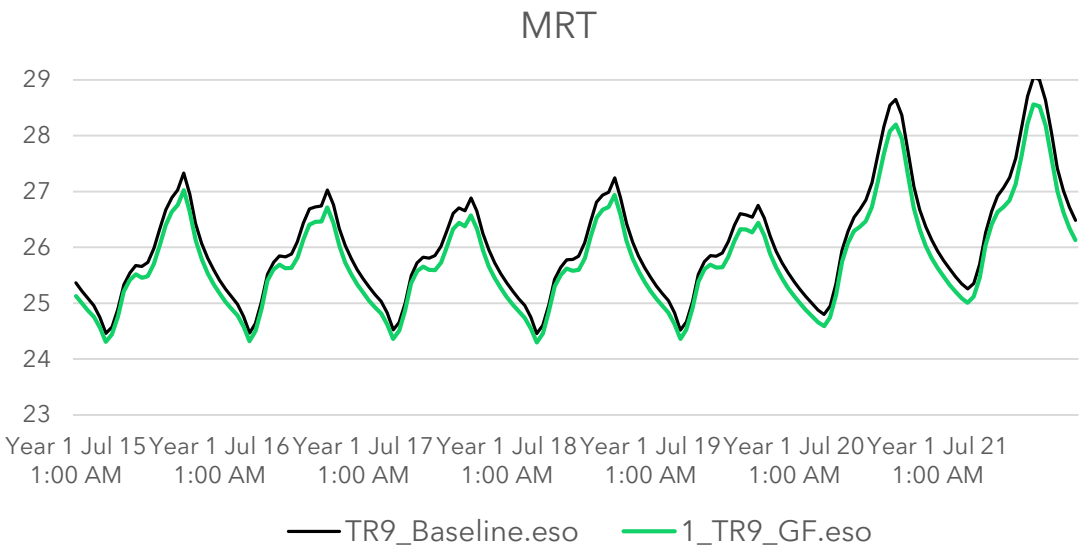
Llimitations of the "Other side coefficient" approach:

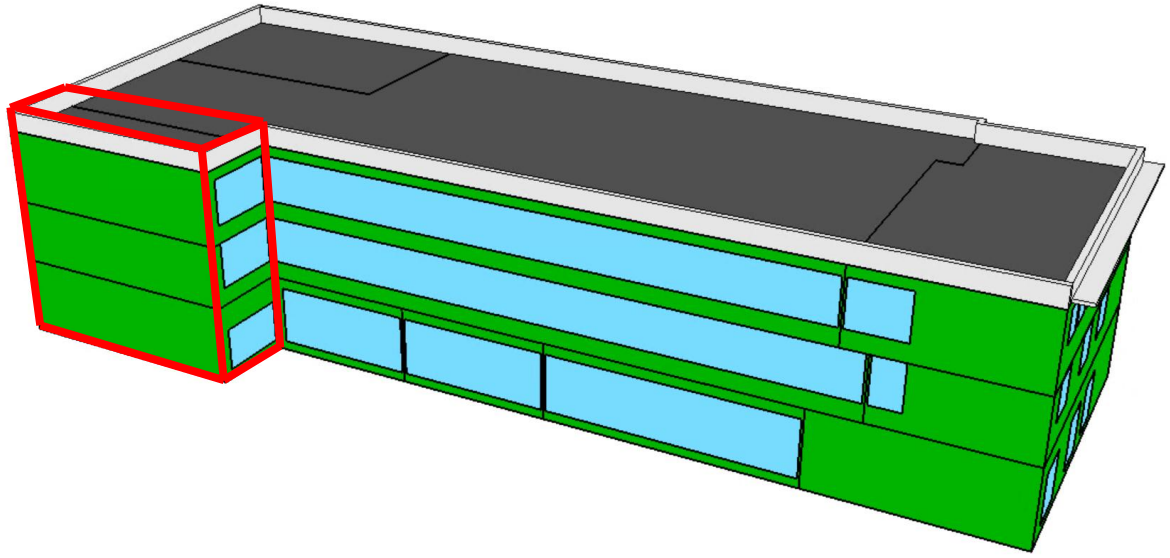
- It cannot be applied to windows
- **It cannot be applied to walls including windows**

Building Indoor thermal conditions

"**Other side coefficient**" object used to set the hourly wall surface temperature calculated by ENVImet as **boundary conditions for EnrgyPlus calculation**

Mean Radiant Temperature | **INSIDE***





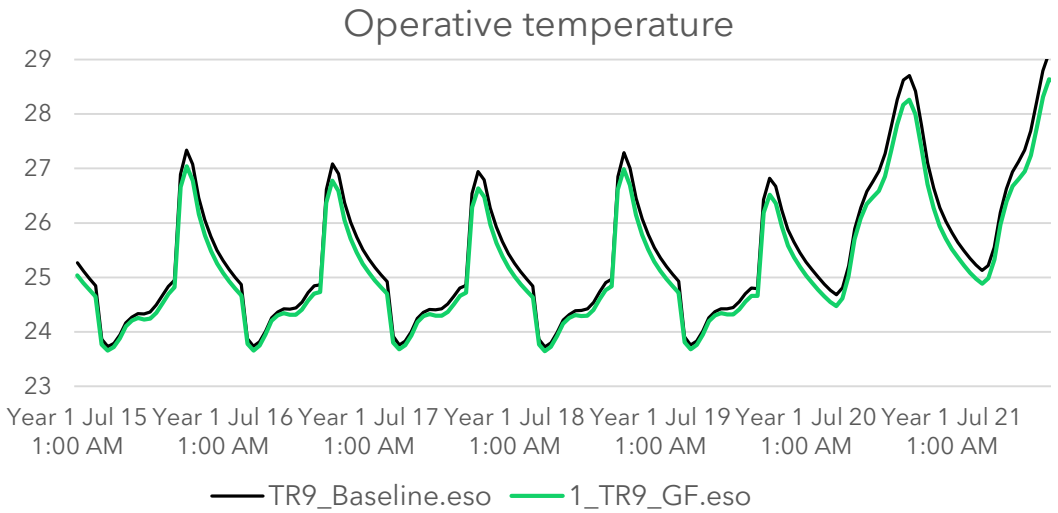
Base Case – **Library GF** → -0,4 °C (Max)

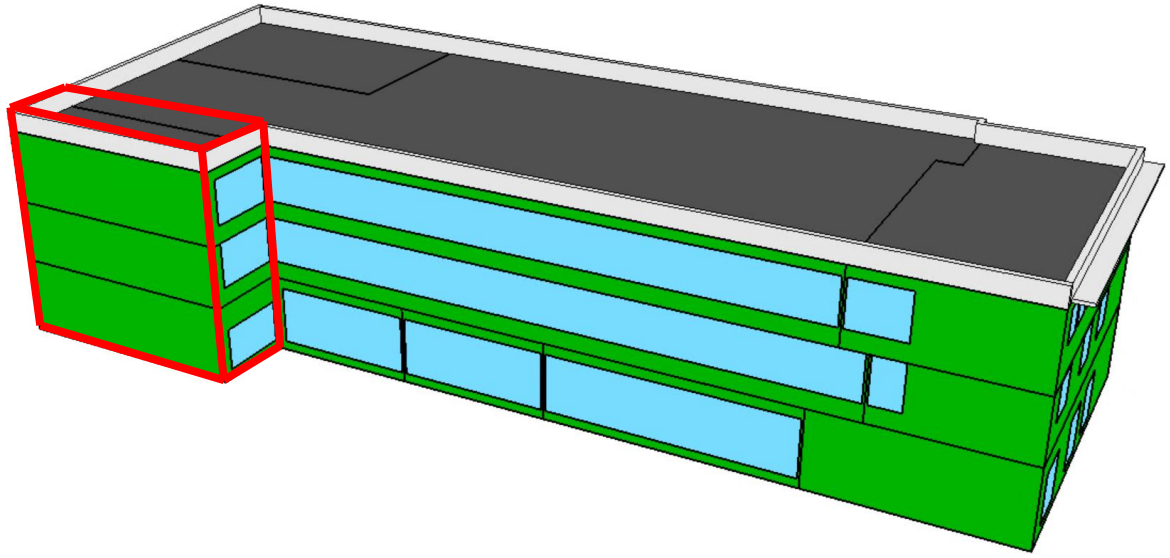
*Results for 1 Zone, with GF on the southern façade. The wall has 5cm thermal insulation

Building Indoor thermal conditions

"**Other side coefficient**" object used to set the hourly wall surface temperature calculated by ENVImet as **boundary conditions for EnrgyPlus calculation**

Operative Temperature| **INSIDE***





Base Case – **Library GF** → -0,5 °C (Max)

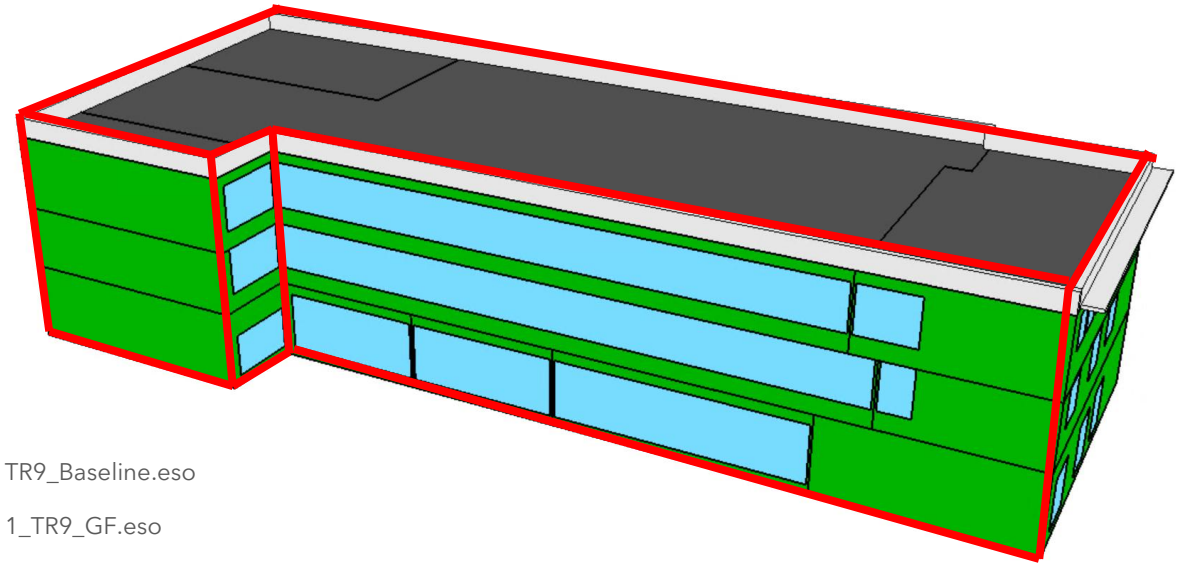
*Results for 1 Zone, with GF on the southern façade. The wall has 5cm thermal insulation

Building Energy

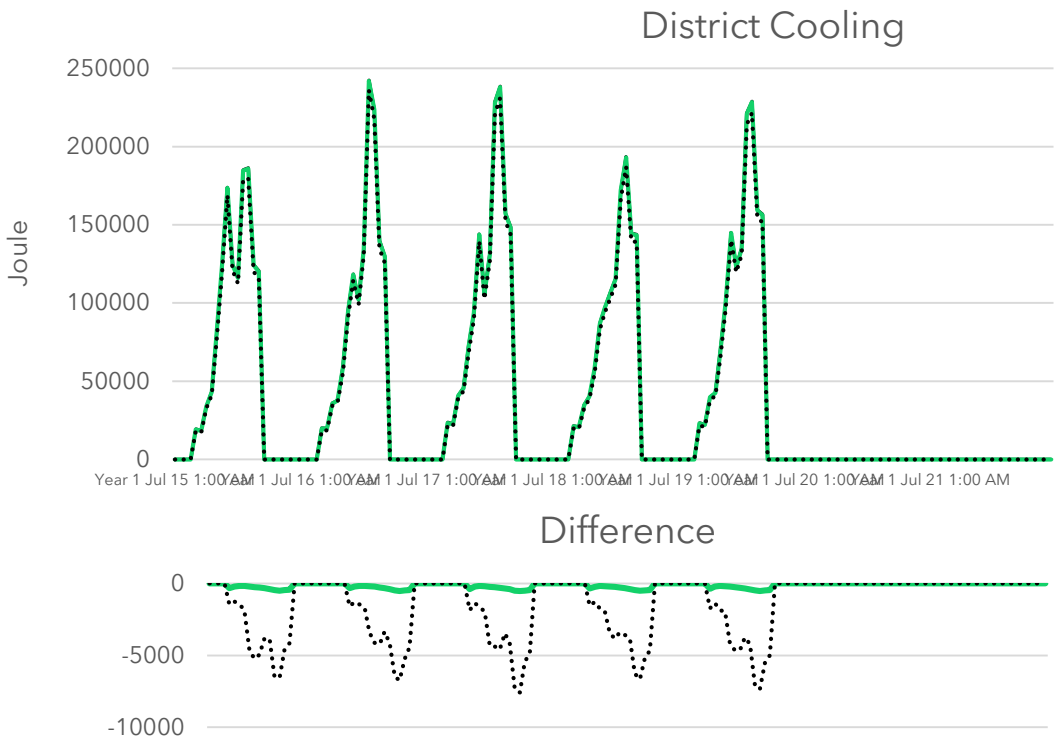
"**Other side coefficient**" object used to set the hourly wall surface temperature calculated by ENVImet as **boundary conditions for EnrgyPlus calculation**

+

Morphed weather file, to include the beneficial effect of district-scale NBS applications on air temperature (UHI)



District Cooling | **Buildings**



TR9_Baseline.eso

1_TR9_GF.eso

1_TR9_GF_DistrictMicroclimate.eso

-3% Distric cooling reduction

Conclusions

Outdoor

- District-scale applications of GF and GR can contribute to mitigate UHI. The maximum positive impact is up to 0,5 °C reduction in the evening.
- GF have positive impact on street-level thermal conditions, reducing MRT by up to 3,5 °C and PET by 2 °C.

Indoor

- The outside wall surface temperature is reduced by up to 20 °C, but the impact on indoor operative temperature is limited to 0,5 C*
- The UHI mitigation entails a small reduction in cooling energy for the library buildings by 3%

*Preliminary results

Future work

ENERGYPLUS-ENVImet : Complete the study and improve the coupling methodology

Urban microclimate simulations: Explore other models (Vertical City Weather Generator)

Nature- base solutions: Explore different systems (green walls)

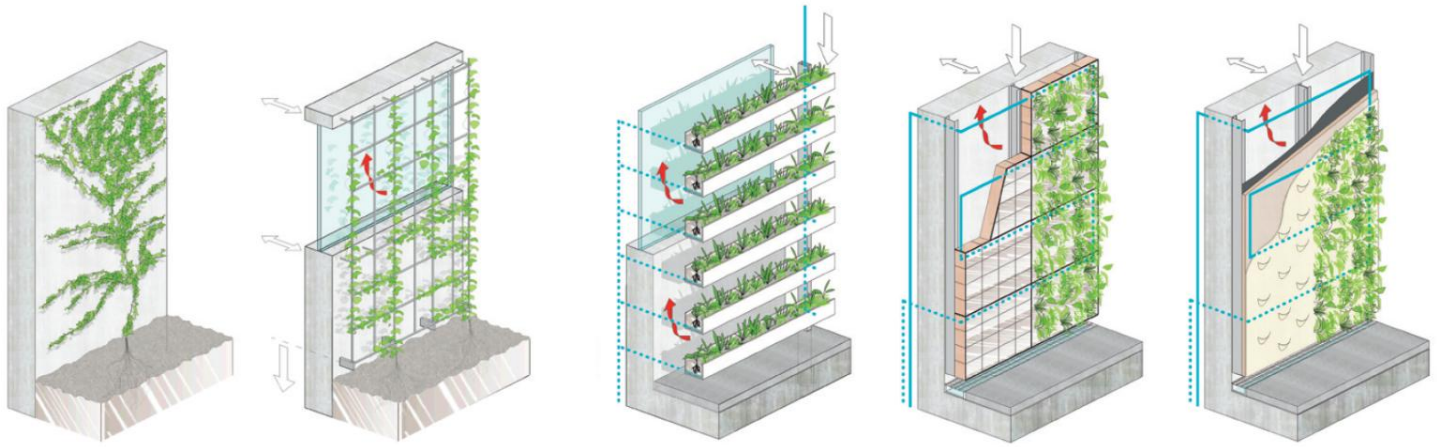


Image source: Nicole Pfoser (2024), Green Facades. DETAIL PRACTICE.

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Thank you!

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