CLIMATE ADAPTATION CONCEPT ON A STADIUM

THE NEW FEYENOORD STADIUM

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P5 PRESENTATION

BACKGROUND

METHODOLOGY

LITERATURE REVIEW

DESIGN EXPLORATION

FINAL DESIGN

CONCLUSIONS

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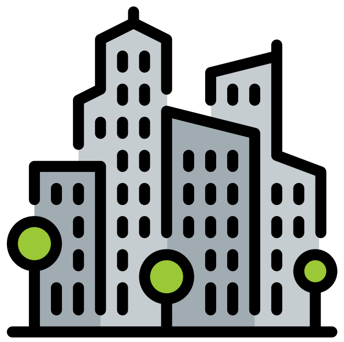
FINAL DESIGN

CONCLUSIONS

BACKGROUND

WHY STADIA?

Most of the existing mitigation and adaptation measures **focus on bigger or smaller scale**



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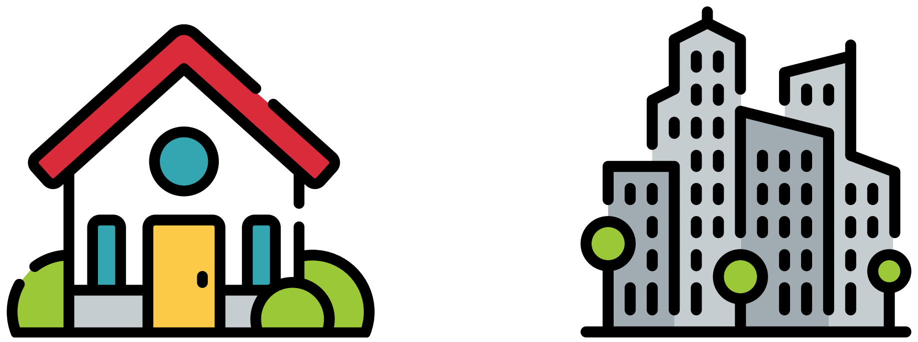
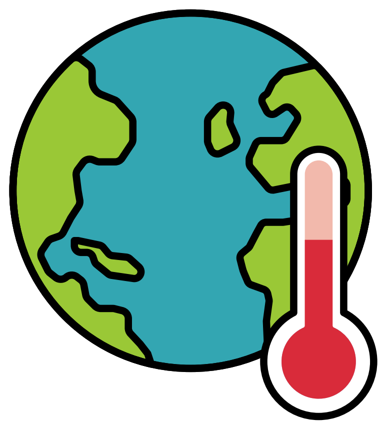
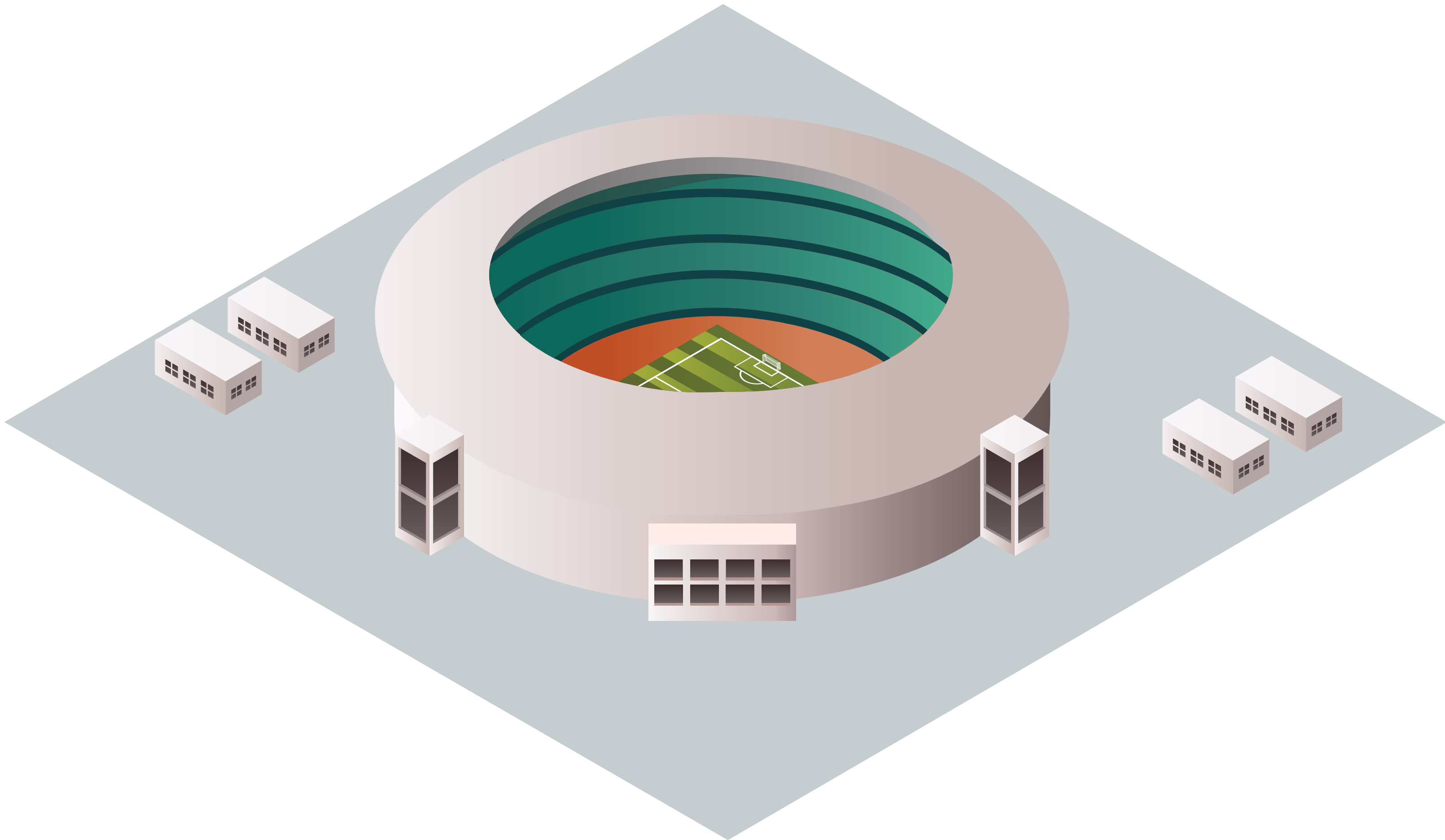


Stadia around the world are designed to be sustainable but **not meant to face climate change**



WHY STADIA?

The practice of almost any sport requires friendly and **comfortable environmental conditions**, cool temperatures and medium humidity levels, as well as satisfactory lighting and ventilation performance (Torsing et al., 2016).



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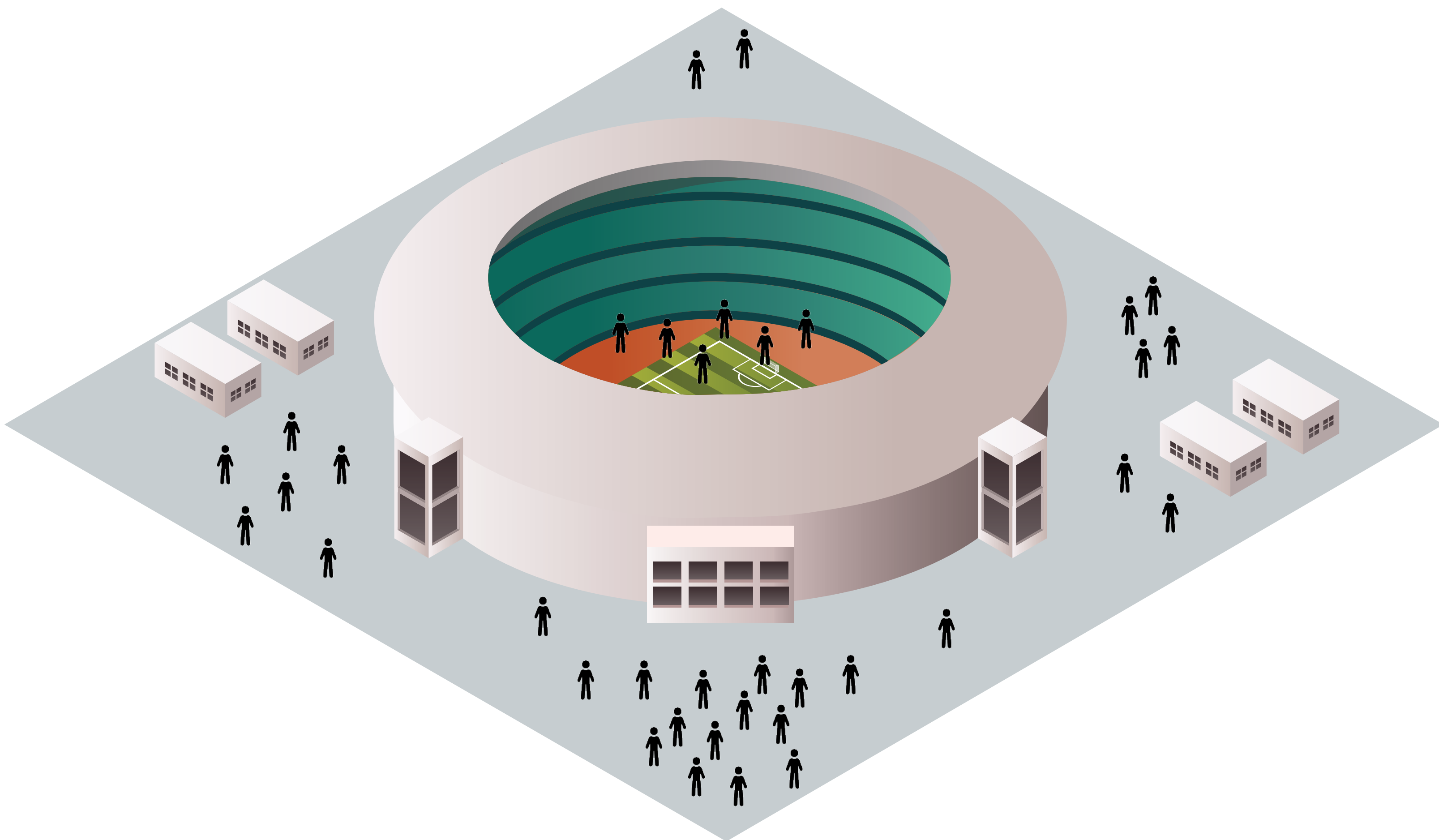
Many **activities**

Many **users** ⟶ Different **requirements**



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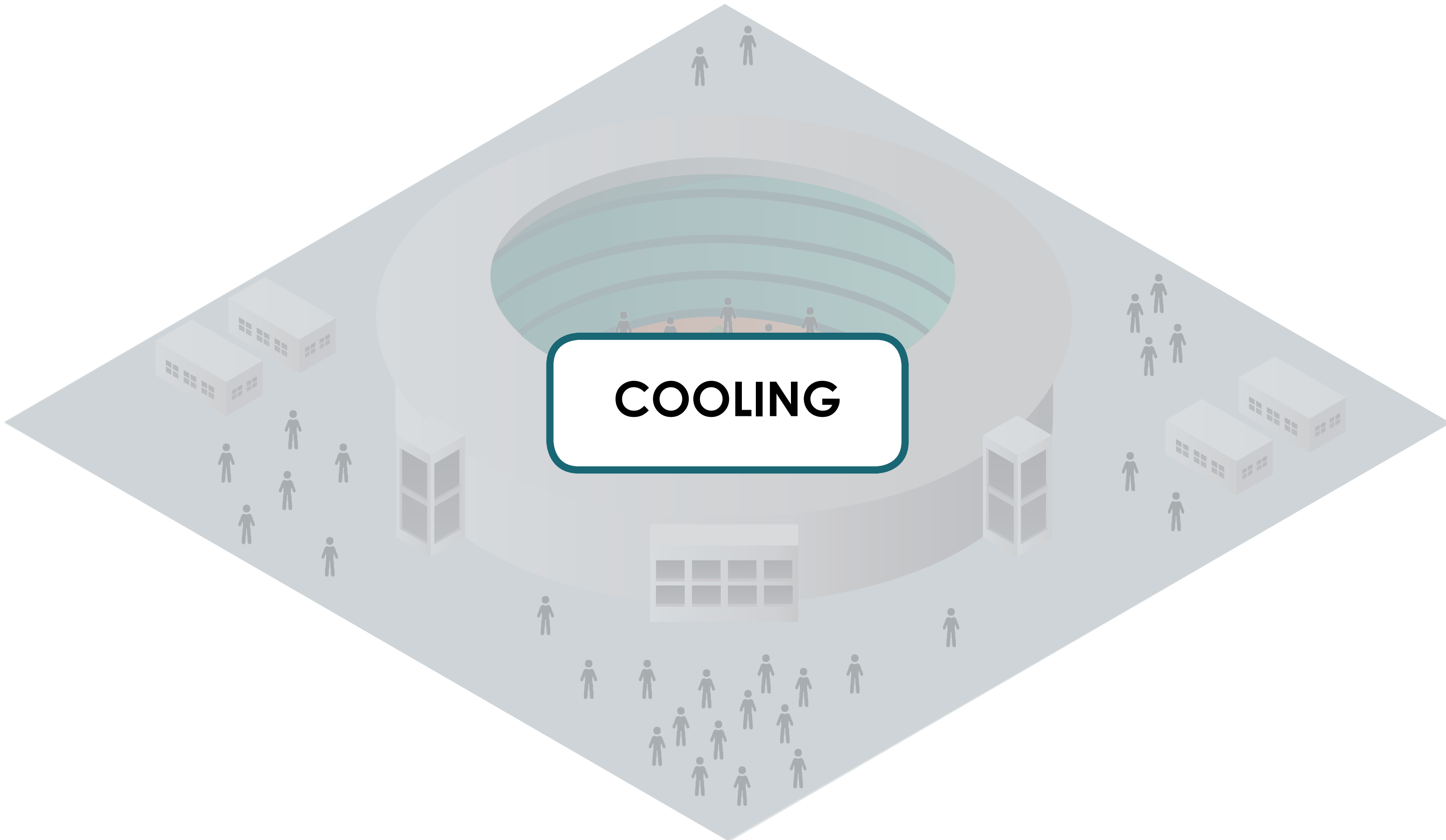
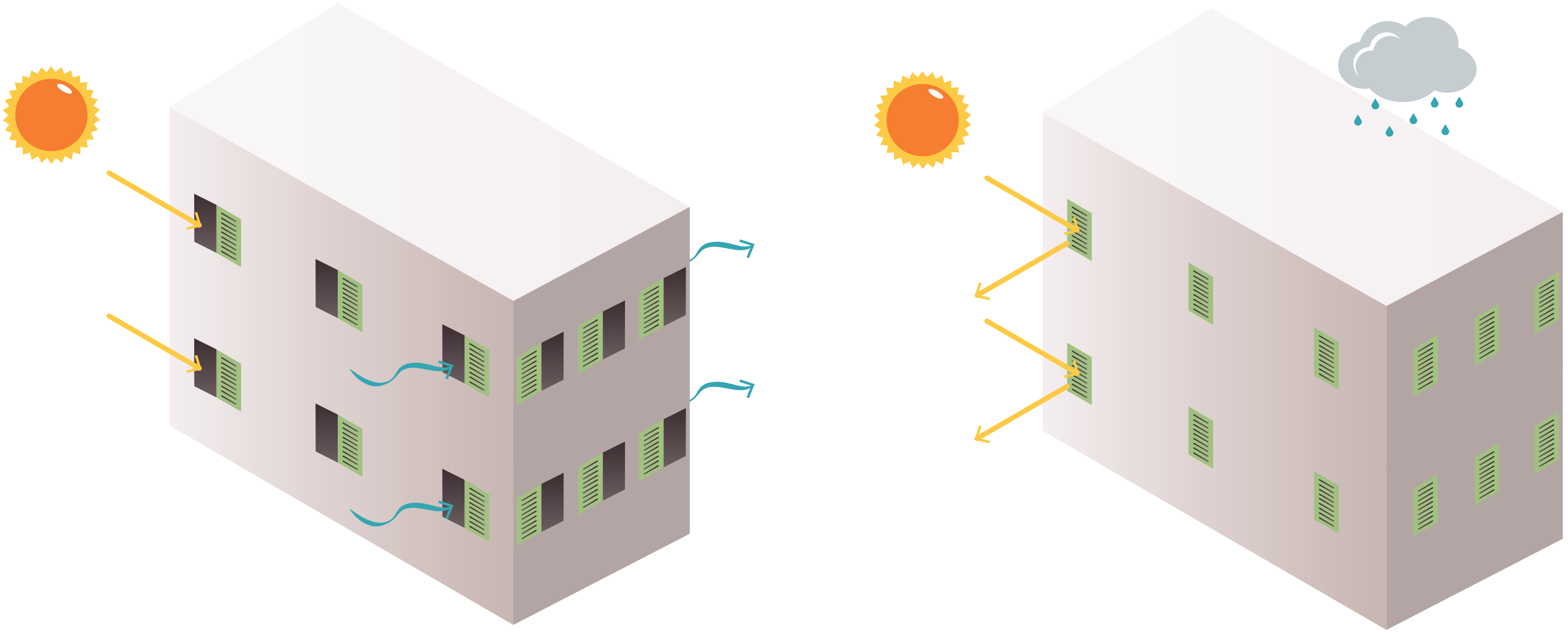


WHY STADIA?

Typical building type



Buildings as *boxes*

- Open if desidered climatic conditions
- Closed if undesired climatic conditions

↓

Control over indoor **thermal comfort** and **micro-climate**

WHY STADIA?

Stadium

Stadia as *semi-outdoor spaces*

↓

Hard to control indoor thermal comfort and micro-climate

WHY STADIA?

Impact on the surroundings, as it is a big infrastructure, with city developing around it.

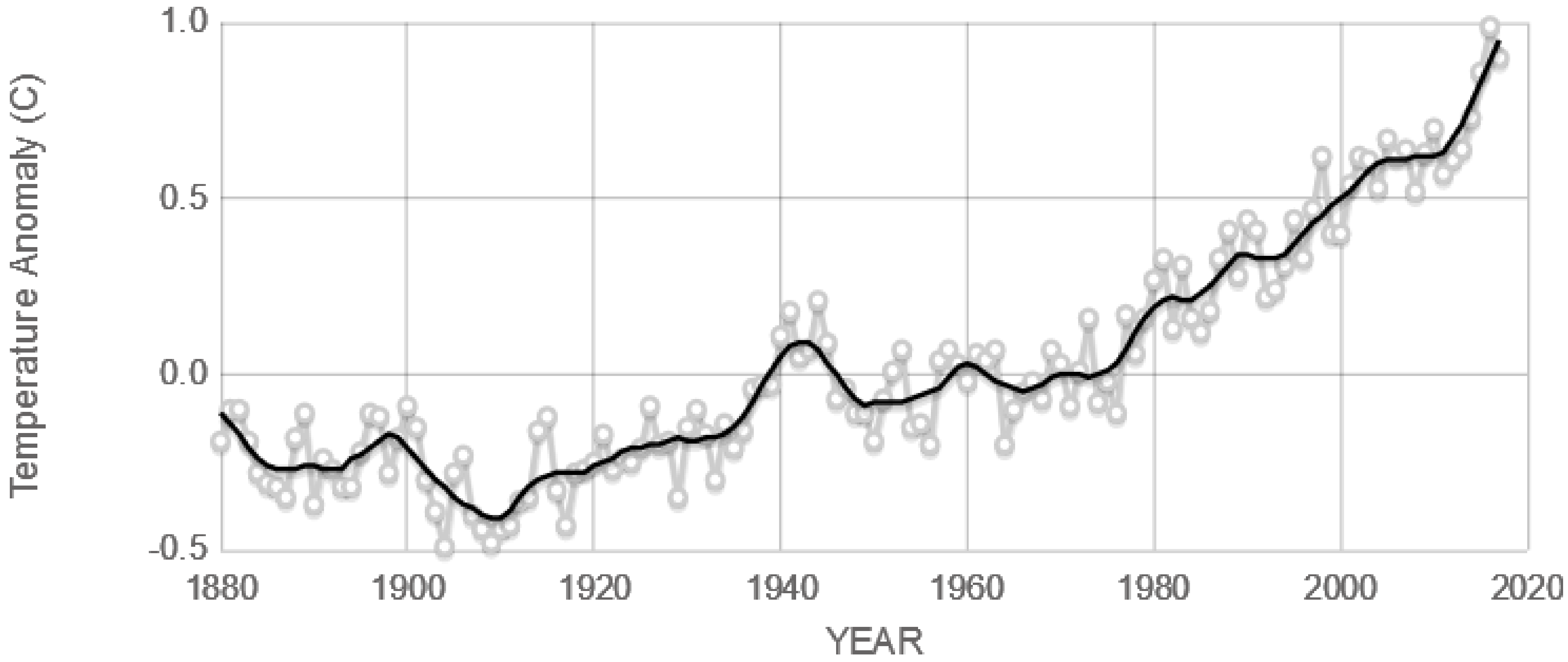
The impacts of climate change are **global** and of **unprecedented scale** (United Nations).

From 1970s temperatures have relentlessly increased, mainly due to CO_2 emissions, which see as main cause the anthropogenic activities.

Shifting weather patterns

- Raising **temperatures**
- Increasing **heat waves**
- Increasing **droughts** periods
- **Extreme** events
- Rising **sea level**
- Risk of **floods**

From 1970s temperatures have relentlessly increased, mainly due to CO_2 emissions, which see as main cause the anthropogenic activities.

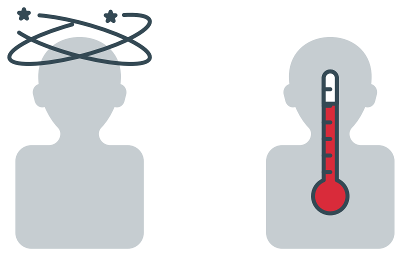


Source: "NASA/GISS", 2018.

Today's average Earth surface temperature is 14 °C.
The goal is to keep global warming of 1.5 °C above pre-industrial levels.

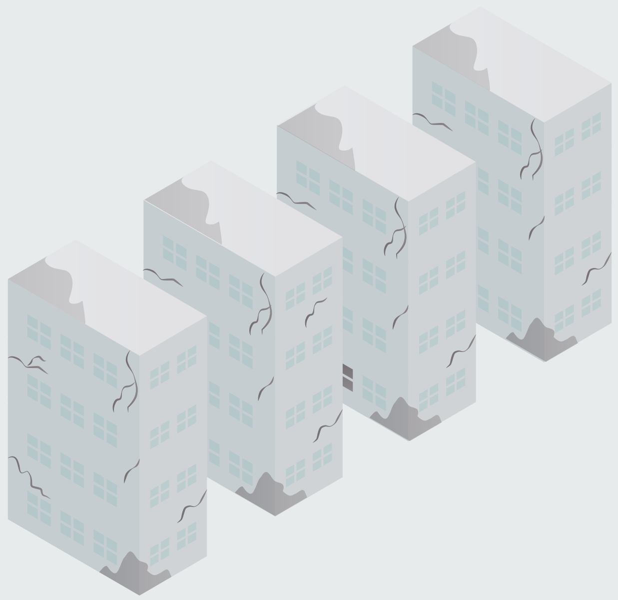
CONSEQUENCES

Human scale



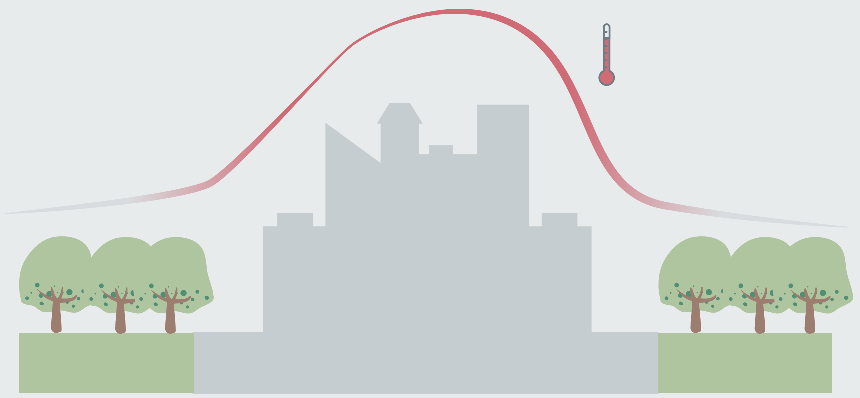
Heat stress risks will increase and thermal comfort will decrease.

Building scale



Buildings are extremely vulnerable to climate change.
- increase in the risk of **collapse**, **declining state** and significant **loss of value**.

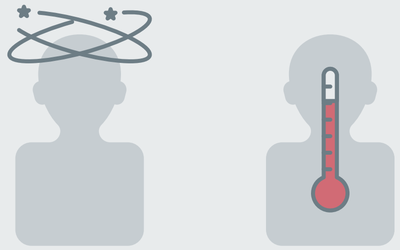
City scale



Urban heat island effect is expected to increase.

CONSEQUENCES

Human scale



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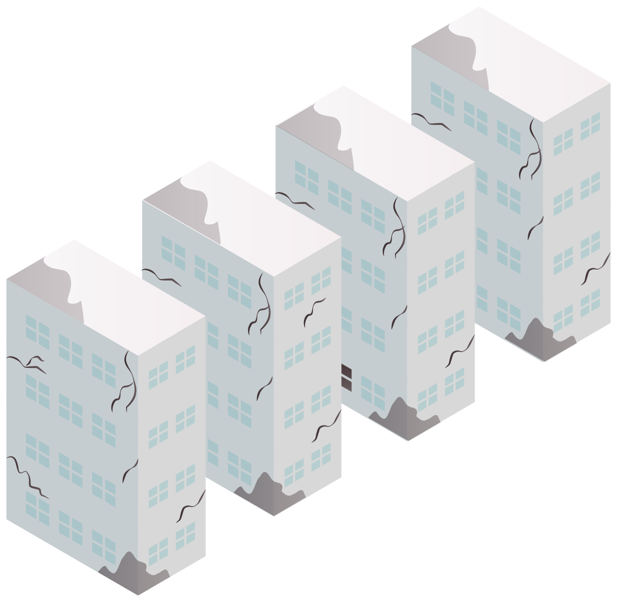

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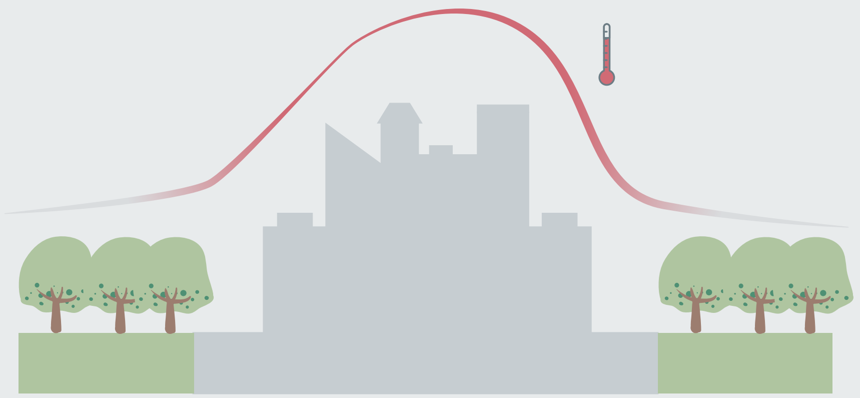

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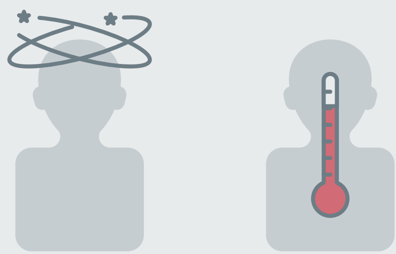

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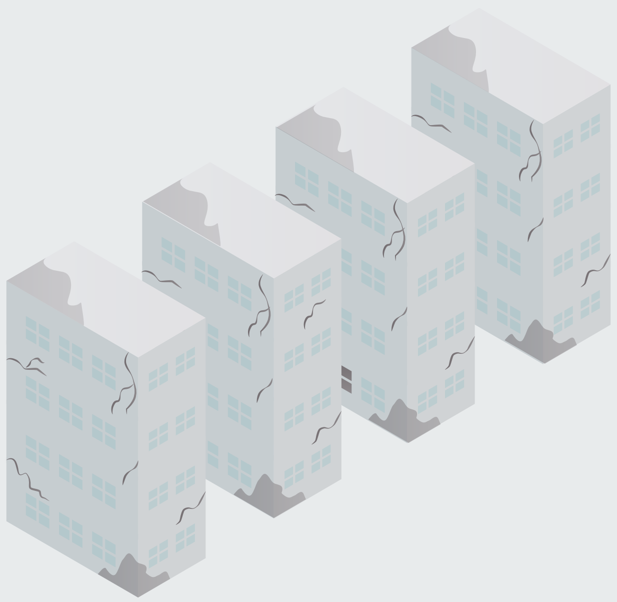

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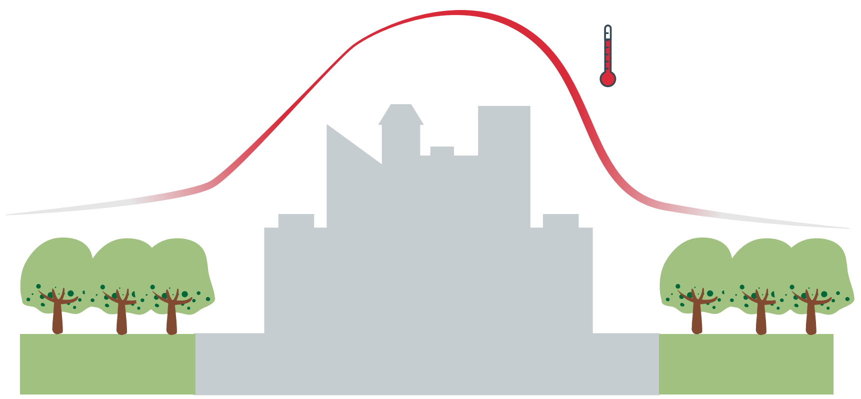


Urban heat island effect is expected to increase.

METHODOLOGY

OBJECTIVE

To design the new **Feyenoord Stadium envelope** to integrate **passive strategies for cooling** to **adapt to climate change**.

- To guarantee **proper livability** of users by creating the desired indoor micro-climate
- To **avoid health risks** and effect of thermal stress
- To entail benefits to the surroundings by **mitigating future UHI**

The proposed solution will define a **design approach model** that can be replicated.

MAIN QUESTION

*How can the **envelope** of a large-scale stadium be designed to integrate **passive strategies to provide cooling** in a future warmer scenario and guarantee a comfortable micro-climate to users, while **reducing the UHI** in the surroundings?*

SUB-QUESTIONS

1 *How are the stadium and its surroundings **affected by climate change**, in particular by **raising temperatures**?*

2 *How do **users' comfort** requirements vary according to the carried-out activity?*

SUB-QUESTIONS

3 *Which are the **parameters** affecting the indoor comfort the most?*

4 *How can the design allow for **shading** in such a way that daylight is still provided?*

5 *How can **natural ventilation** be implemented in the design? What would be the effectiveness of the measure?*

6 *How can **cooling** be provided to the space?*

7 *Which **materials** can be used in the design of the envelope so that the indoor comfort is improved? How they help mitigate UHI in the surroundings?*

DESIGN APPROACH

KNOWLEDGE → **DESIGN EXPLORATION** → **ANALYSIS AND DIGITAL DESIGN** → **COMPARISON AND EVALUATION** → **FINAL DESIGN**

KNOWLEDGE

How are the stadium and its surroundings affected by climate change, in particular by rising temperatures?

How do users' comfort requirements vary according to the carried-out activity?

DESIGN EXPLORATION

Which are the parameters affecting the indoor comfort the most?

ANALYSIS AND DIGITAL DESIGN

Which are the parameters affecting the indoor comfort the most?

COMPARISON AND EVALUATION

How can natural ventilation be implemented in the design? What would be the effectiveness of the measure?

How can cooling be provided to the space?

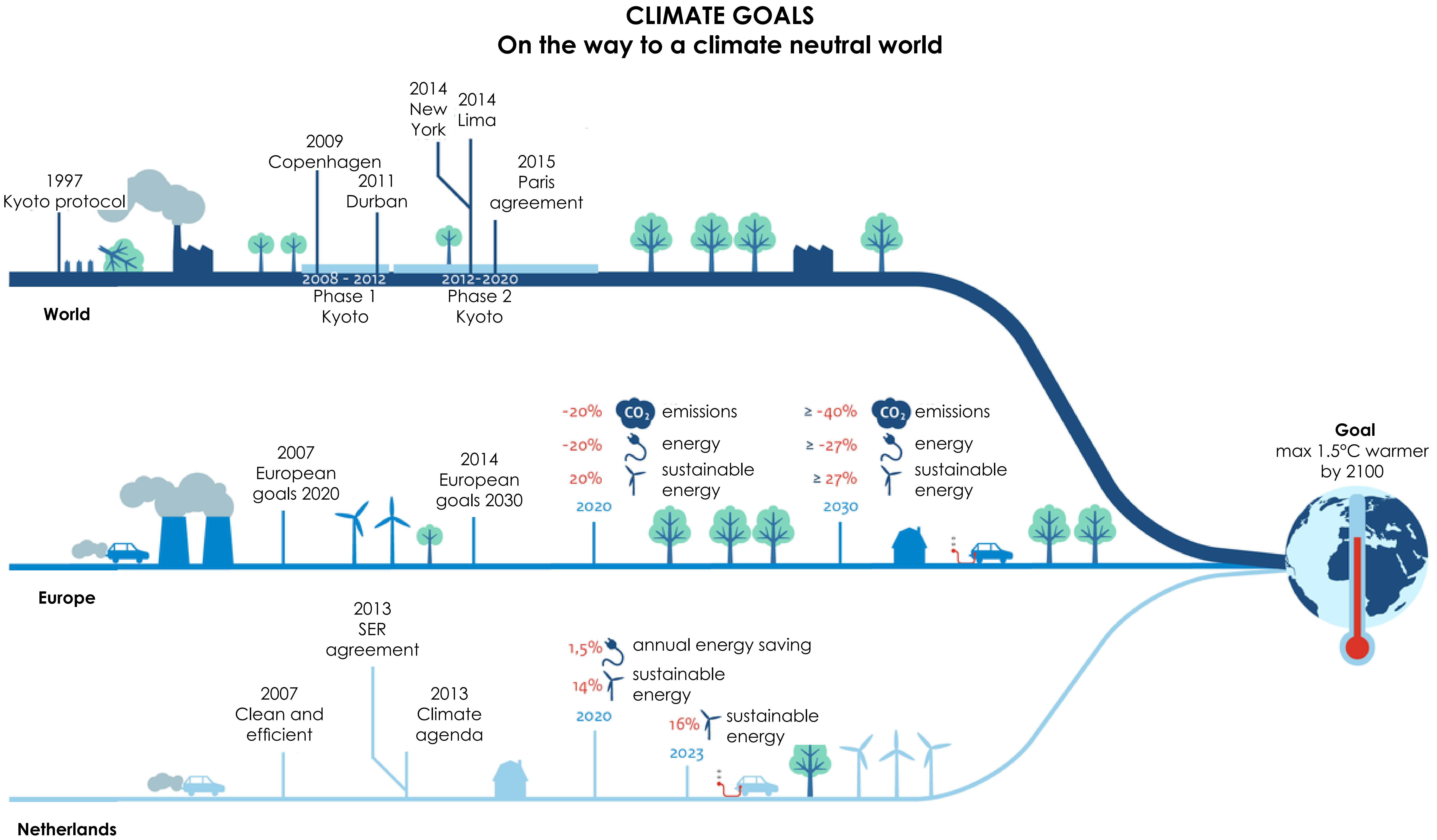
Which materials can be used in the design of the envelope so that the indoor comfort is improved? How they help mitigate UHI in the surroundings?

FINAL DESIGN

How can the envelope of a large-scale stadium be designed to integrate passive strategies to provide cooling in a future warmer scenario and guarantee a comfortable micro-climate to users, while reducing the UHI in the surroundings?

LITERATURE REVIEW

LITERATURE REVIEW

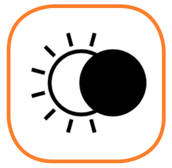


Source: Ministry of infrastructure and water management

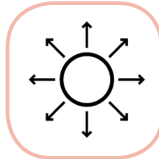
PASSIVE MEASURES


Natural ventilation


Evaporative cooling


Shading


Solar reflectance


Radiative cooling

PASSIVE MEASURES

Natural ventilation

Evaporative cooling

Shading

Solar reflectance

Radiative cooling

DESIGN TO INTEGRATE PASSIVE MEASURES

High albedo

Retractable roof

Thermal mass

Green façade

Cool roof

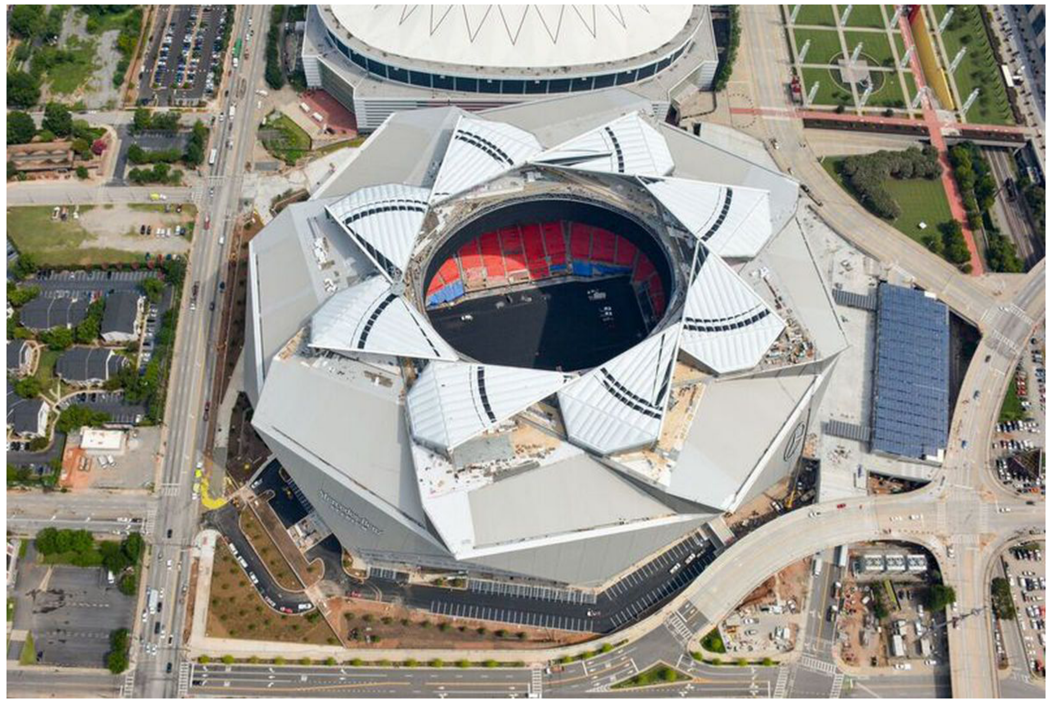
Operable façade

Green roof

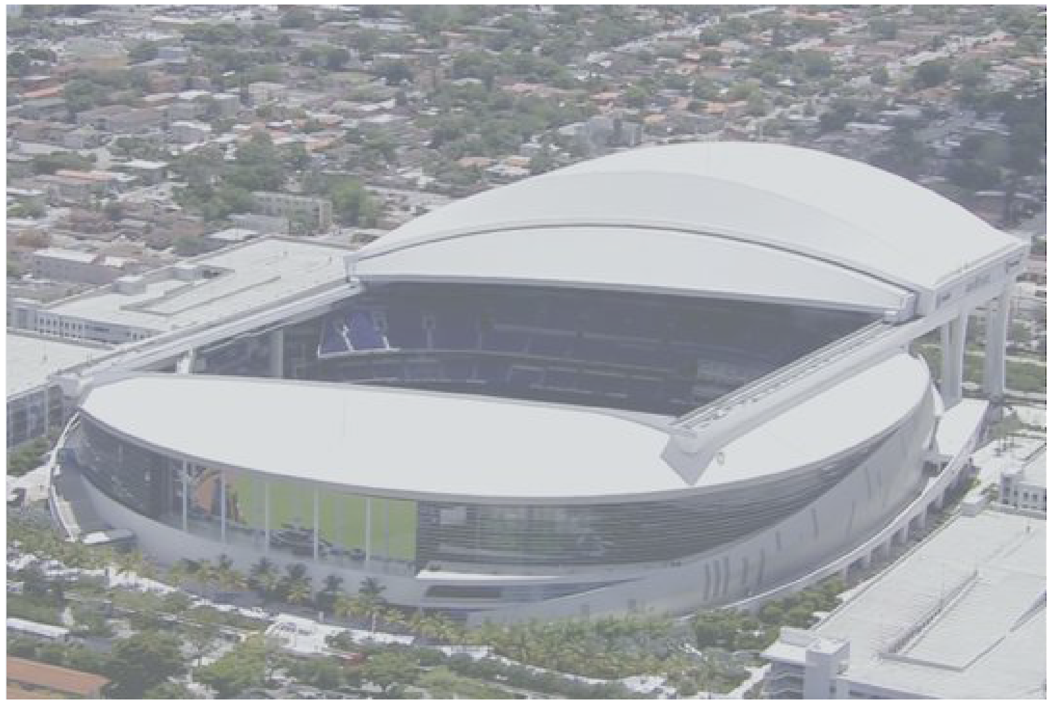
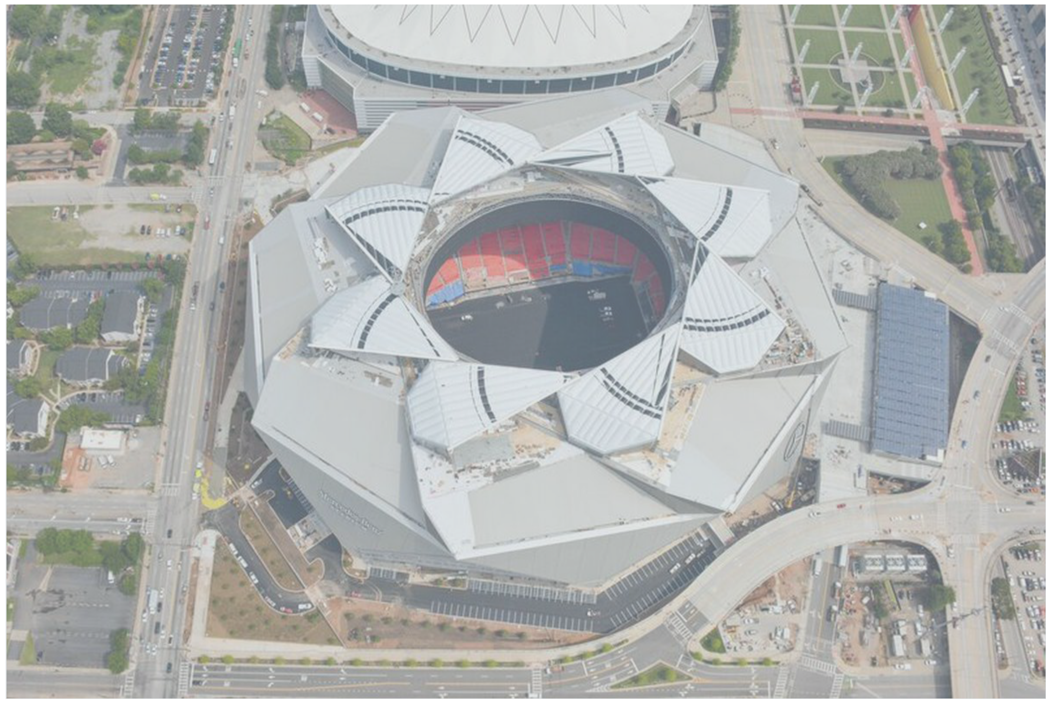
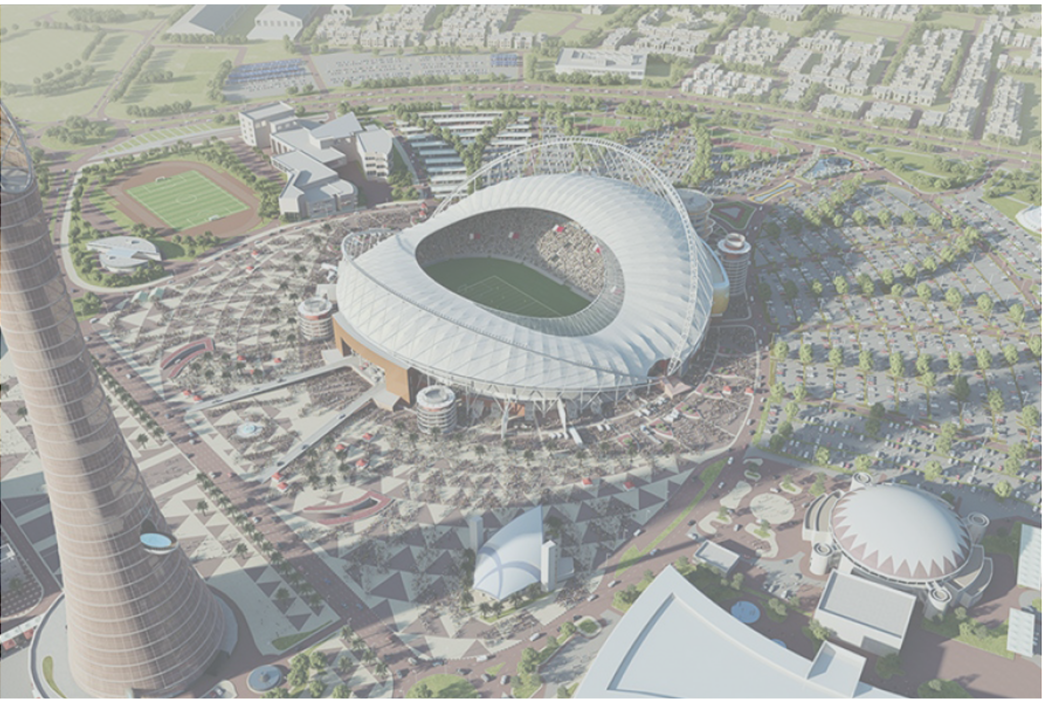
Solar shading

STADIUMS







CLIMATE ADAPTATION?

DESIGN EXPLORATION

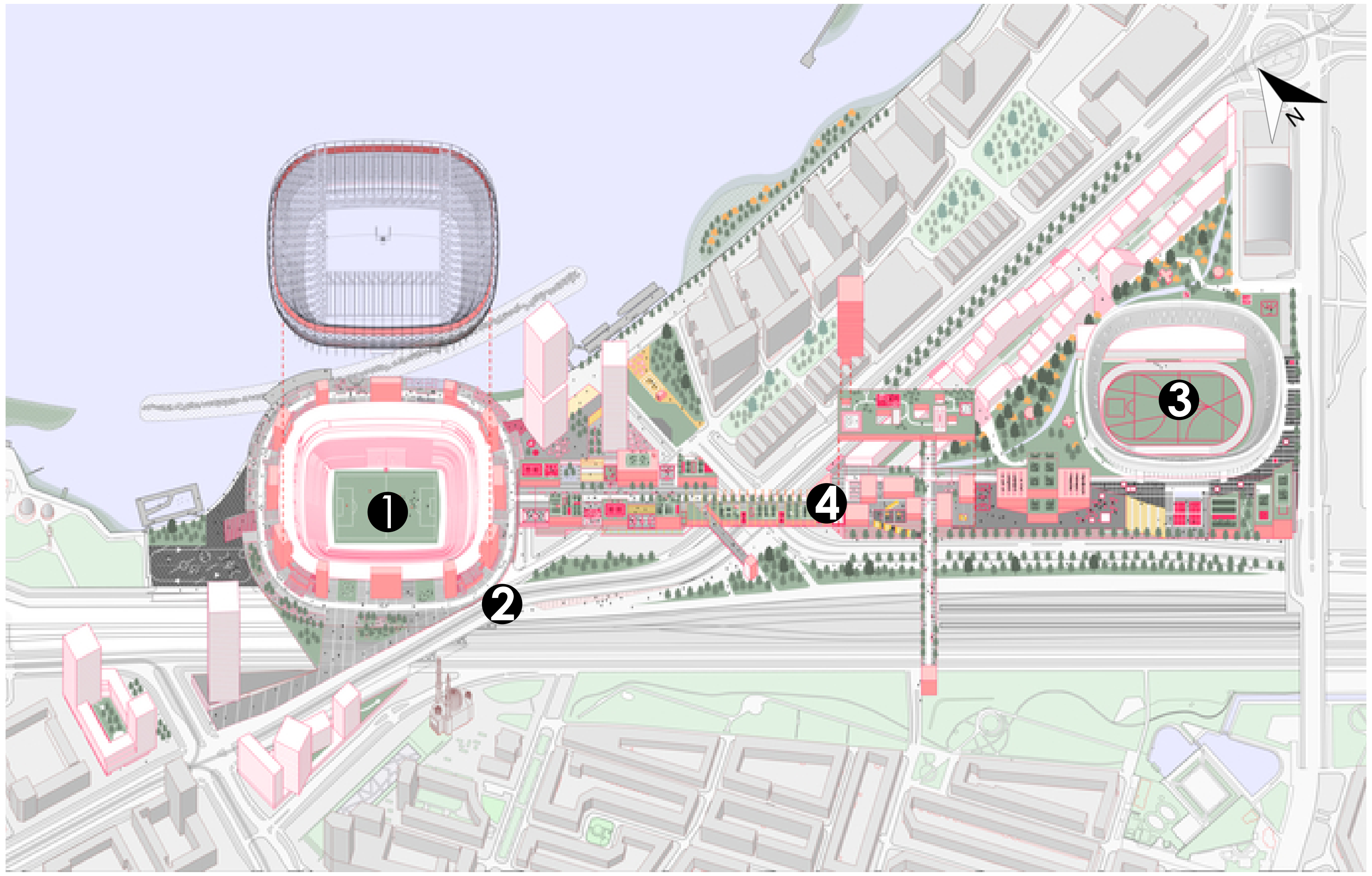
LOCATION

Feyenoord city project is located in the **Feijenoord district**, in the Southern part of Rotterdam, near the Nieuwe Maas.

Source: Google maps

All pictures are taken by the author.

THE PROJECT



Source: OMA, 2018.

❶ **The New Stadium**

❷ **The City Boulevard**

❸ **De Kuip and the Kuip Park**

❹ **The Strip**

Source: OMA, 2018.

CLIMATE ADAPTATION?

Source: OMA, 2018.

Cfb climate (oceanic climate)

- Minimum temperature: **-6**°C
- Maximum temperature: **26**°C (but peaks of **38**°C)
- Average air temperature: approximately **10**°C
- High relative humidity throughout the year, with a mean value of **77.9**%
- Average wind speed: **3.8** m/s
- Prevailing wind direction: **South-West**

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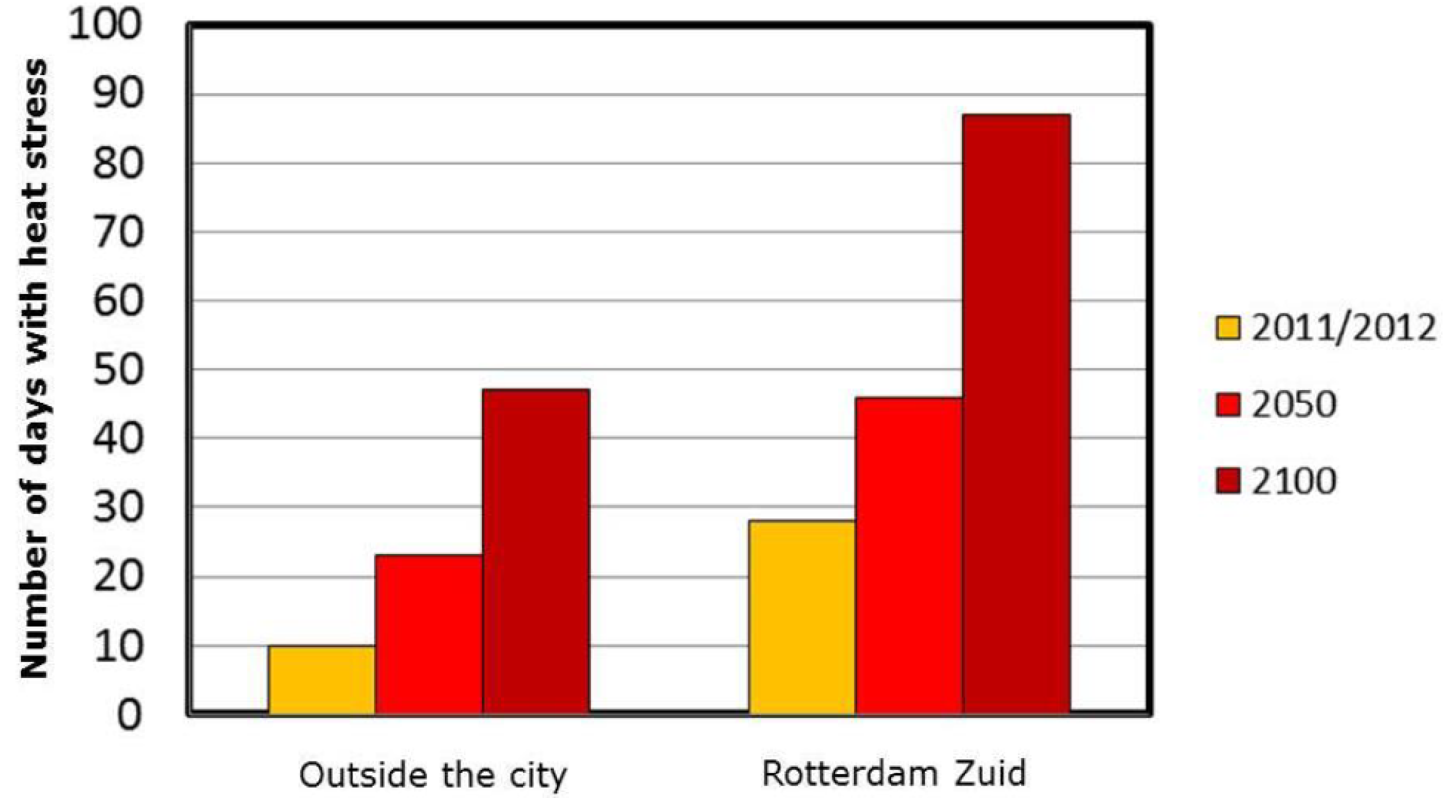


Source: Climate-proof cities final report

PASSIVE MEASURES

Natural ventilation

Evaporative cooling

Shading

Solar reflectance

Radiative cooling

DESIGN TO INTEGRATE PASSIVE MEASURES

High albedo

Retractable roof

Thermal mass

Operable façade

Cool roof

Solar shading

Field

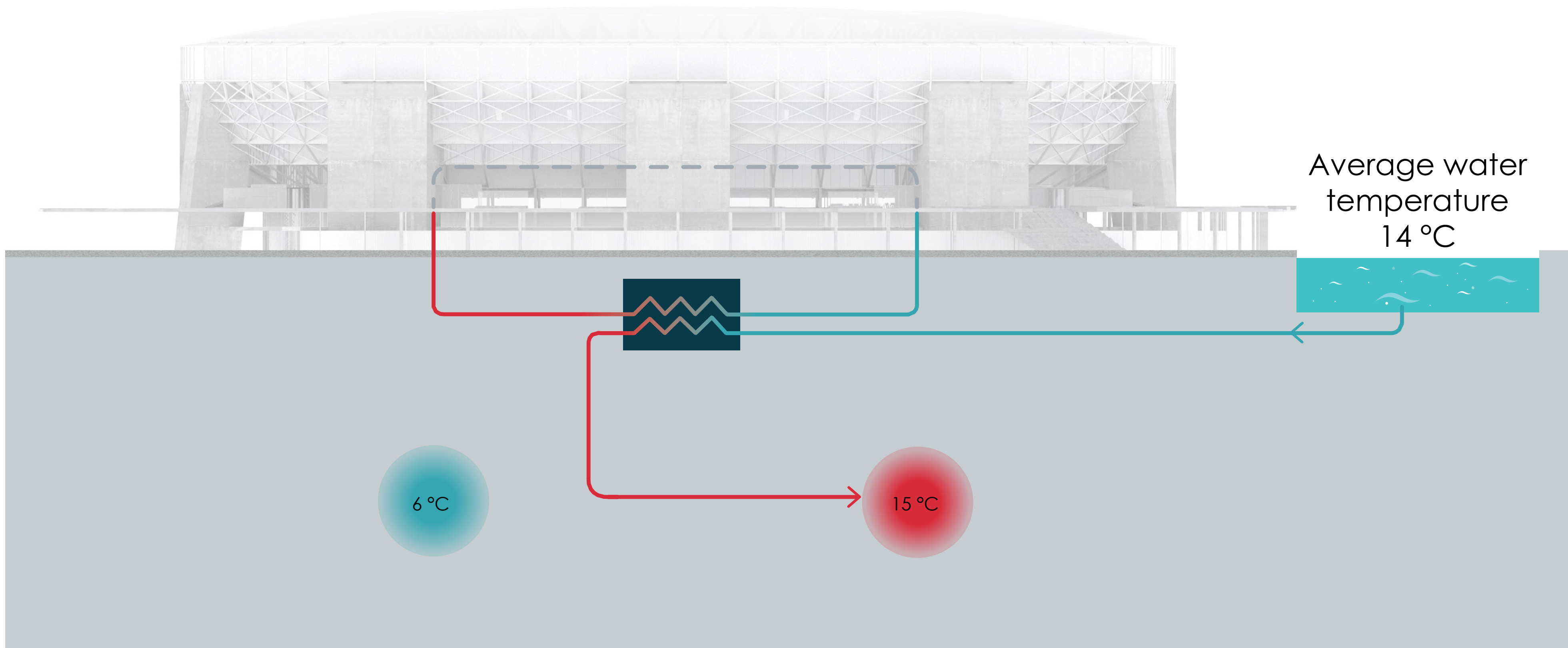
EXTRA MEASURES

ATES + Nieuwe Maas

Solar cooling + Nieuwe Maas

Radiant cooling

Local cooling



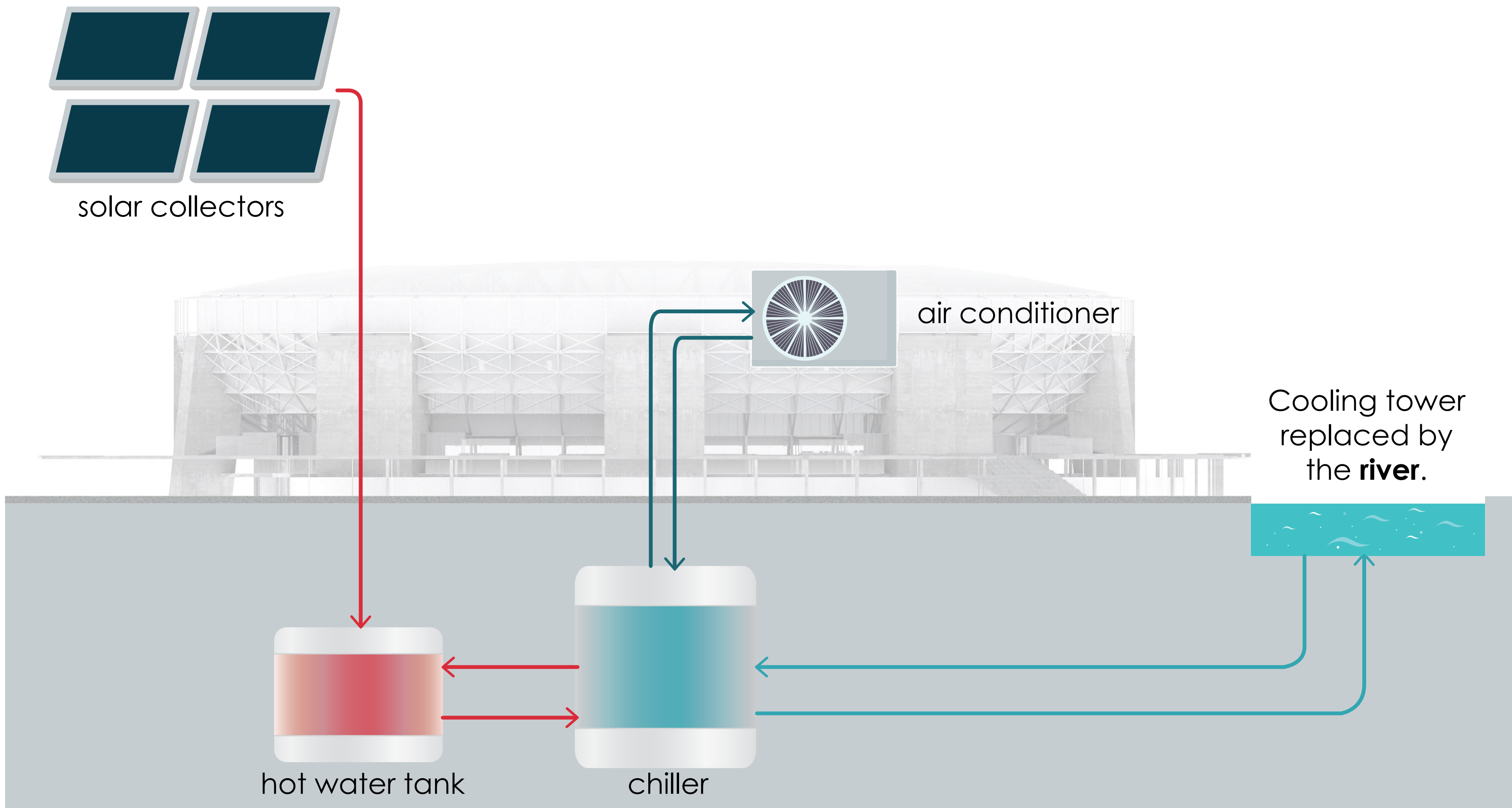
EXTRA MEASURES

ATES + Nieuwe Maas

Solar cooling + Nieuwe Maas

Radiant cooling

Local cooling



EXTRA MEASURES

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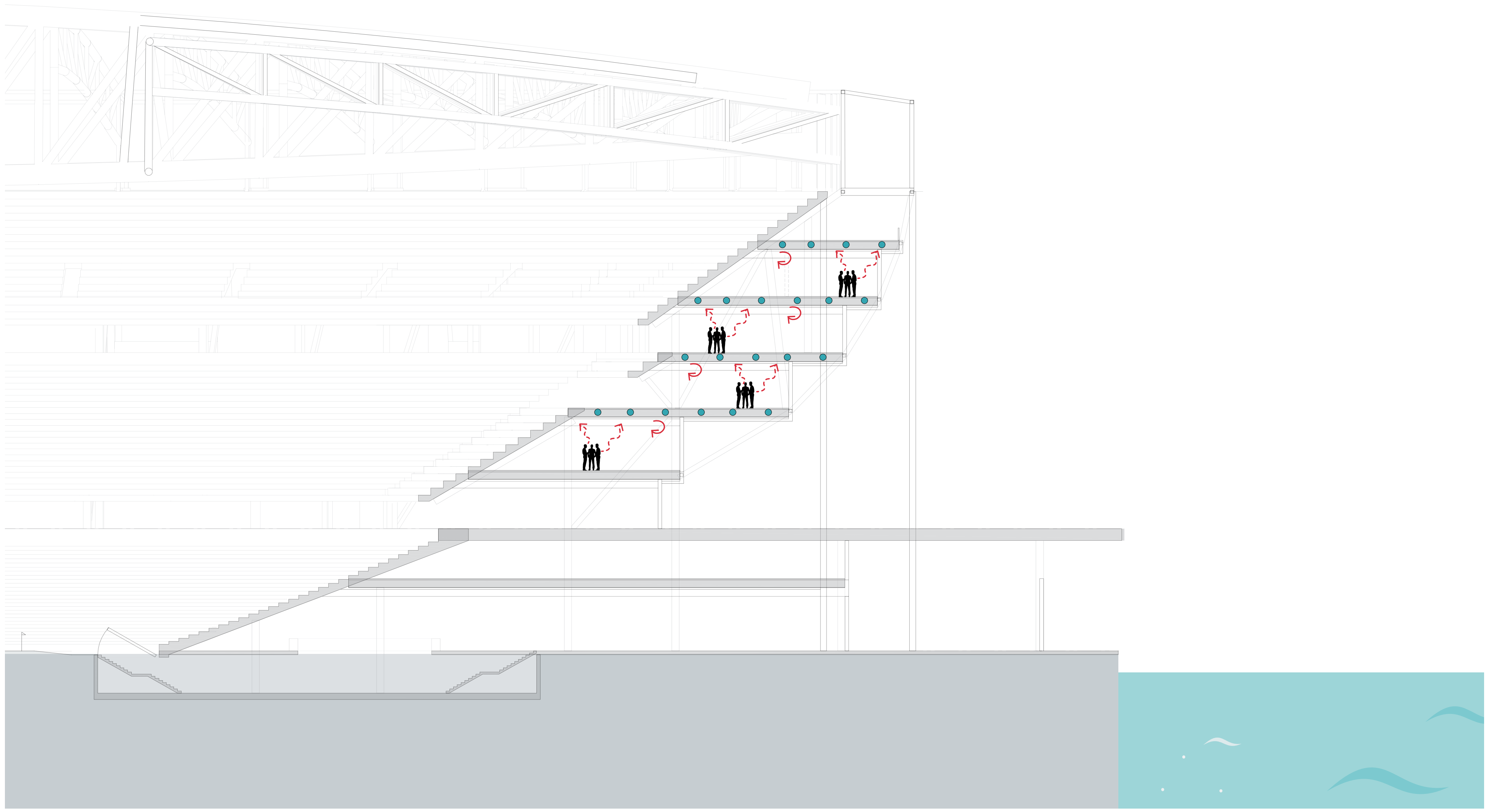
Solar cooling + Nieuwe Maas

Radiant cooling

Local cooling



EXTRA MEASURES

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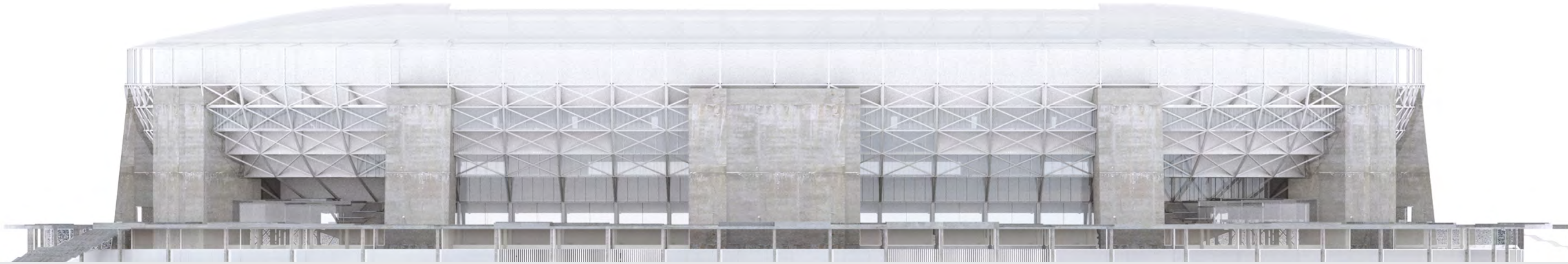
Radiant cooling

Local cooling

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Two activities have been considered:

1) **Football match**;

2) **Concert**.

For both activities, calculations have been performed for four cases:

1) **Winter, MAX** number of people and appliances;
2) **Winter, MIN** number of people and appliances;

3) **Summer, MAX** number of people and appliances;
4) **Summer, MIN** number of people and appliances.

Temperature

MAX	38 °C
MIN	-5 °C

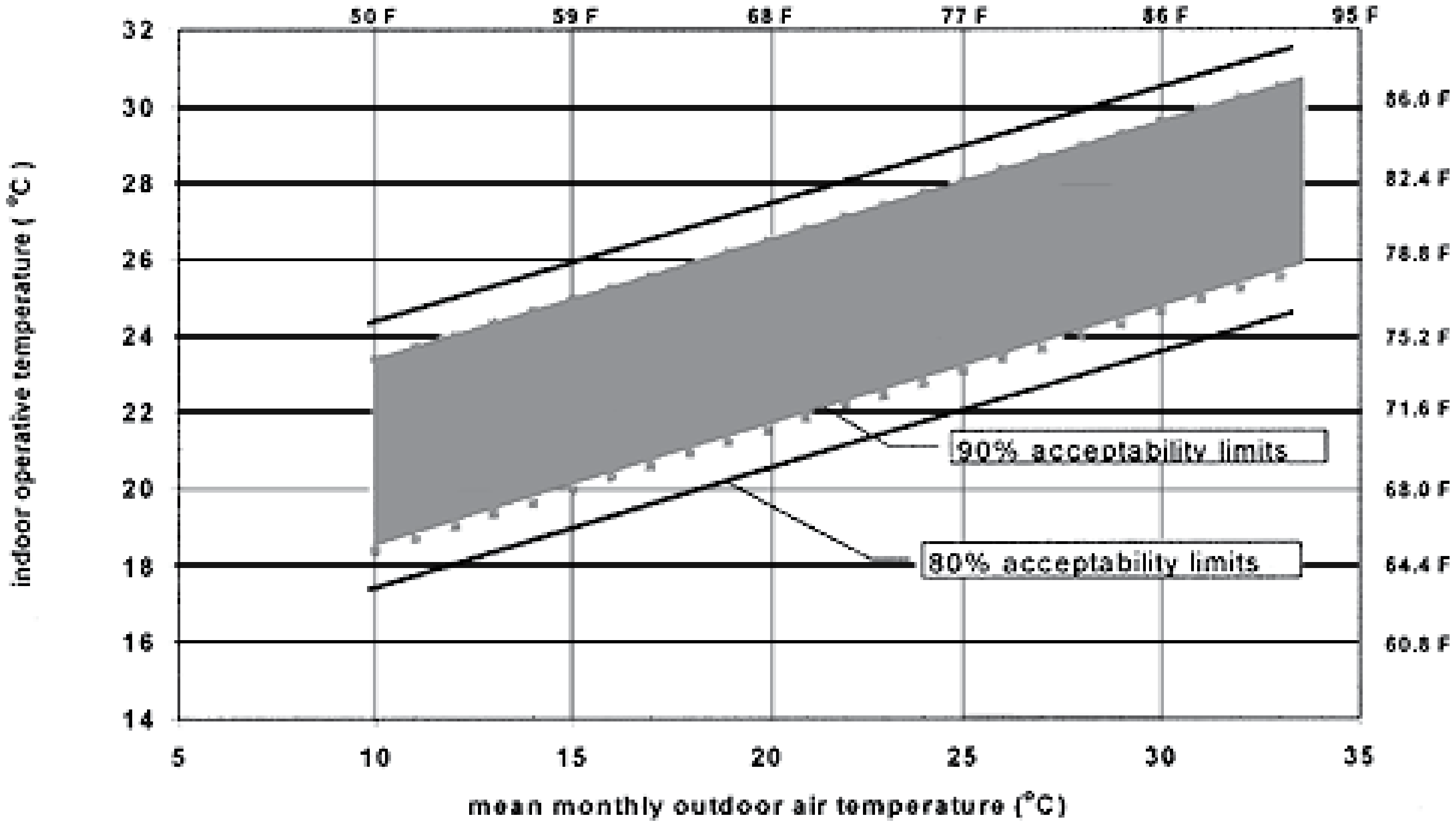
People

MAX	63'000
MIN	5'000

FIFA requires indoor temperature of 20 - 25,5 °C in all hospitality areas of a stadium. These include interior enclosed spaces, spectator tiers, as well as the playing field.

(FIFA. 2011. Football Stadiums: Technical recommendations and requirements - 5th Edition)

Adaptive thermal comfort model



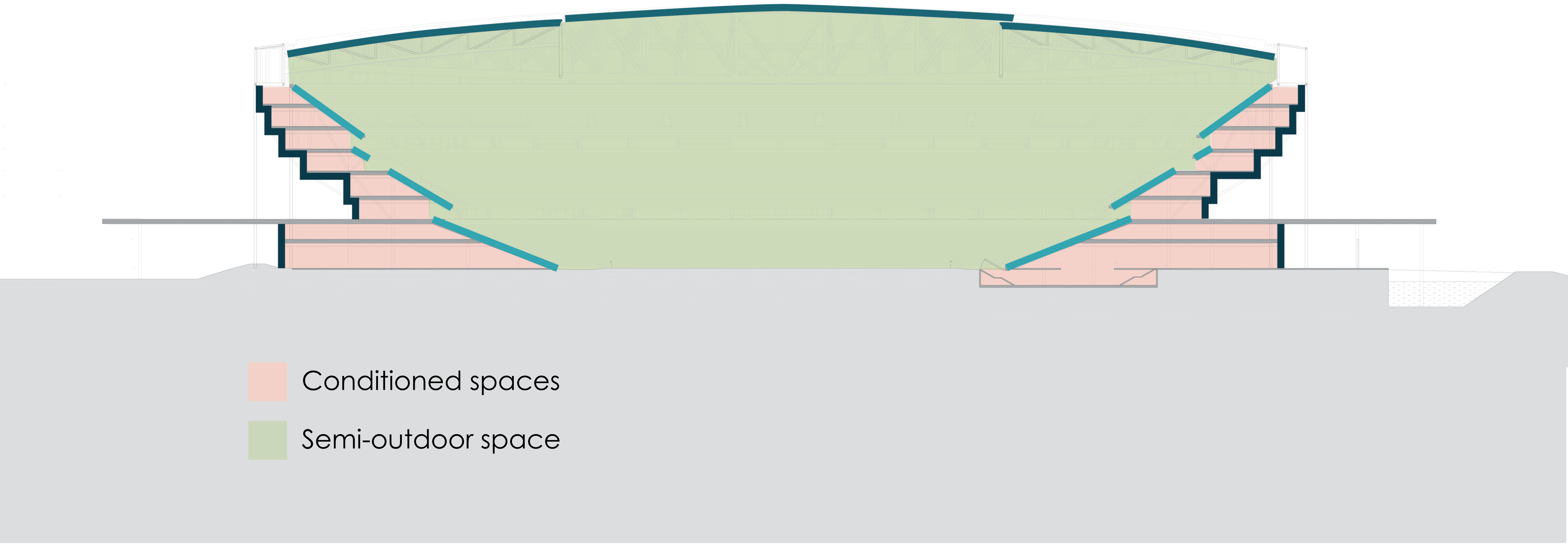
Source: ANSI/ASHRAE Standard 55-2004, Thermal Environmental standard Conditions for Human Occupancy

CONCERT

Concerts usually occur at **nighttime**, they host a **high number of spectators** and the number of appliances within the considered volume can be very high.

Assumptions are made:

- The **roof is closed** for acoustic reasons;
- People perform **heavy activity**;
- **Solar gains are zero** as it is night.

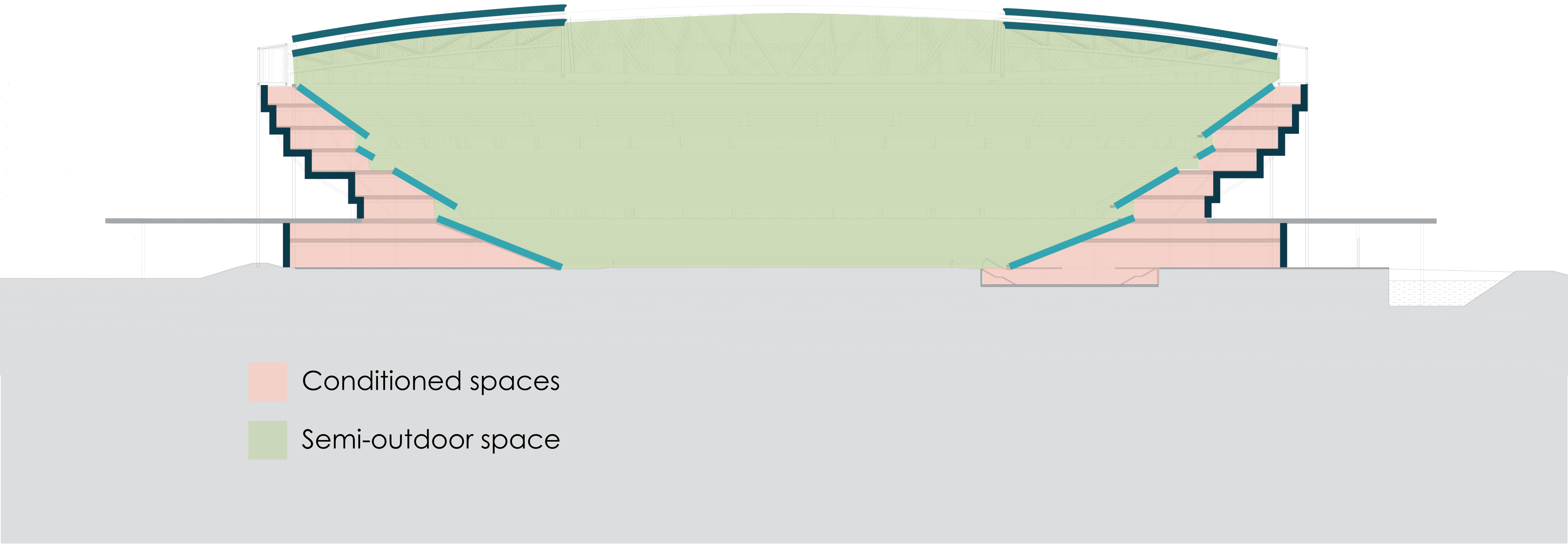


FOOTBALL MATCH

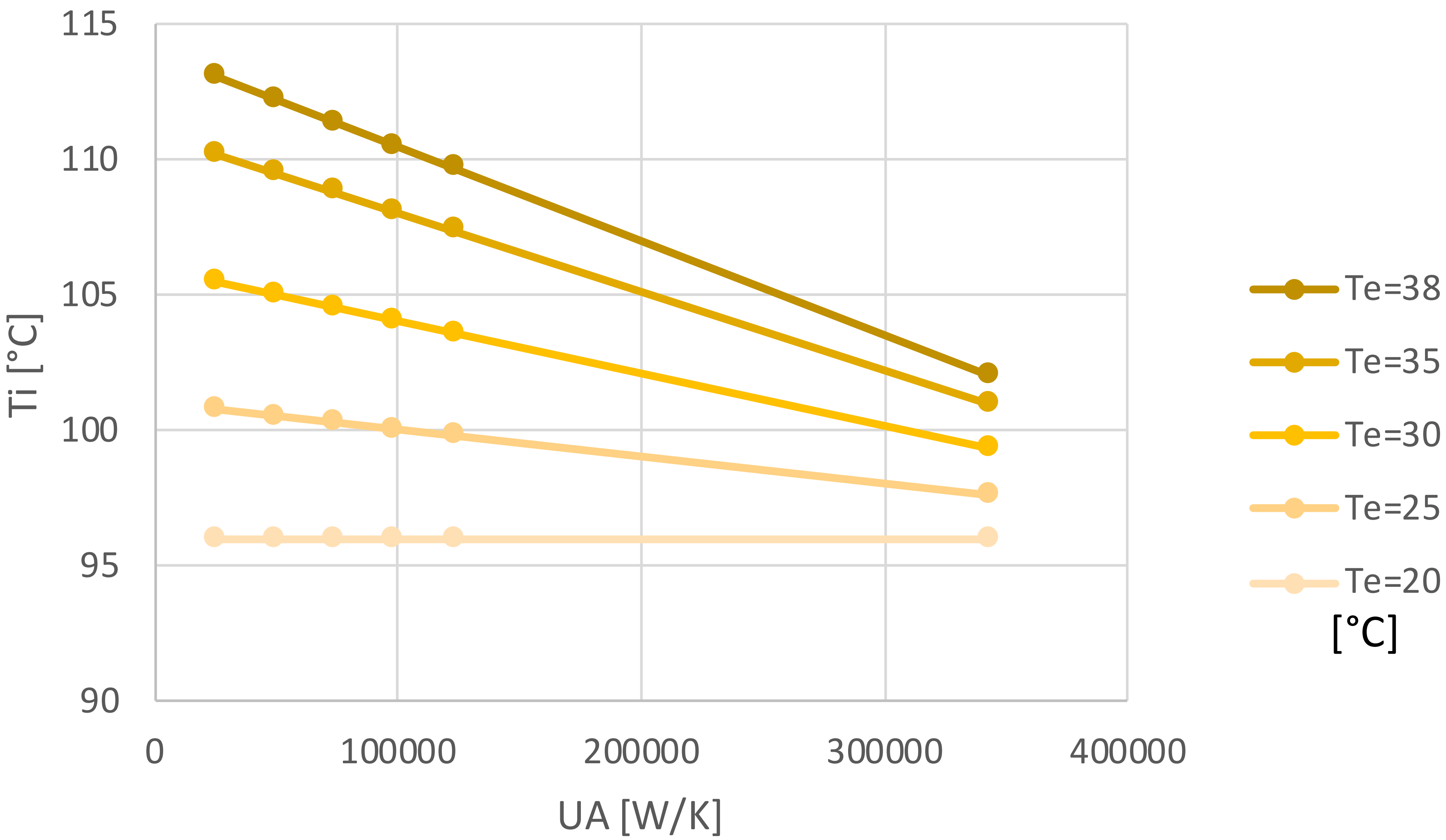
Football matches are usually performed at **daytime**, they host a **high number of spectators** and the number of appliances within the considered volume is not very high.

Assumptions are made:

- The **roof is open** to allow for daylight;
- Spectators are performing **light activity**.



∑UA FAÇADE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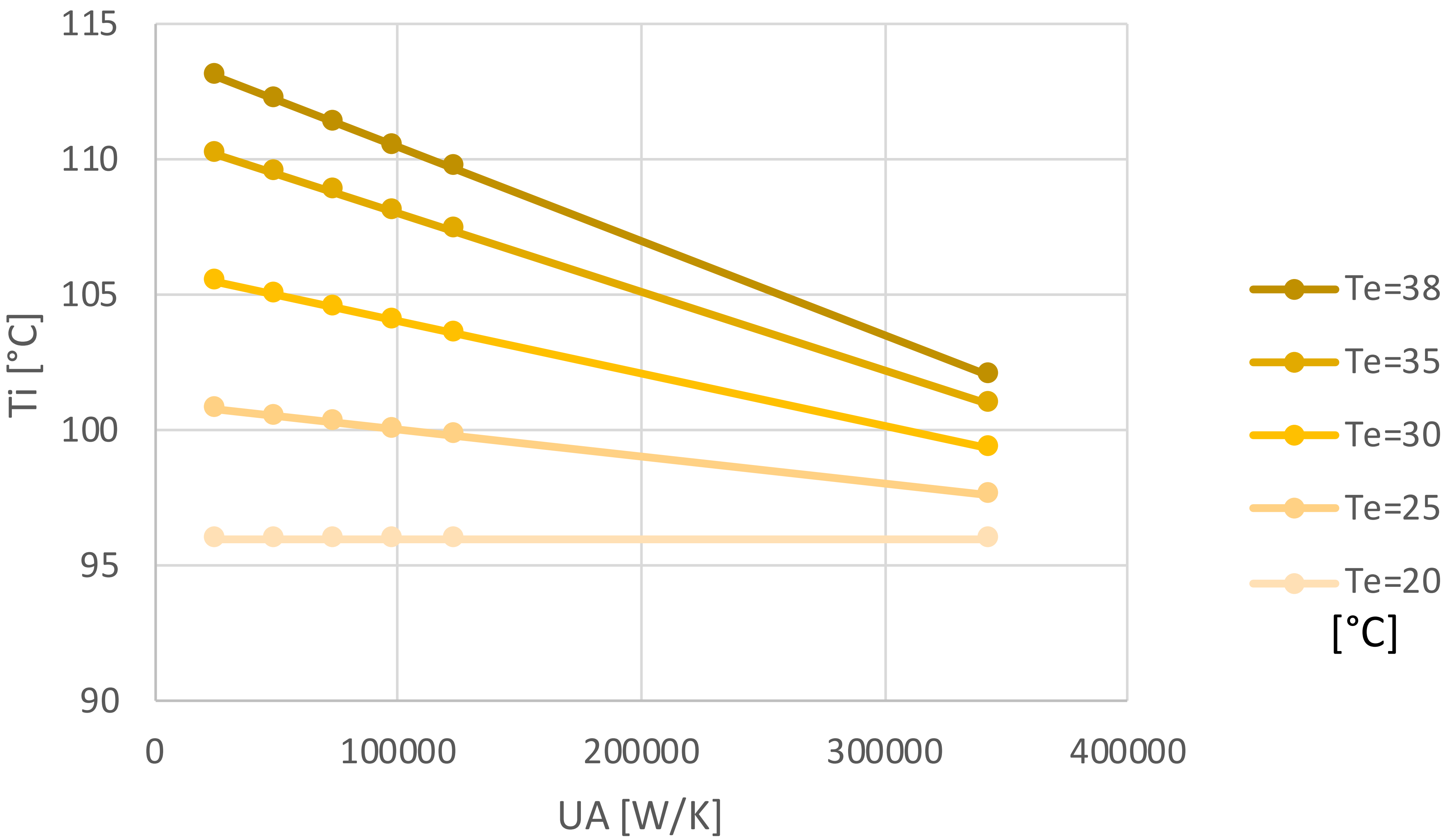
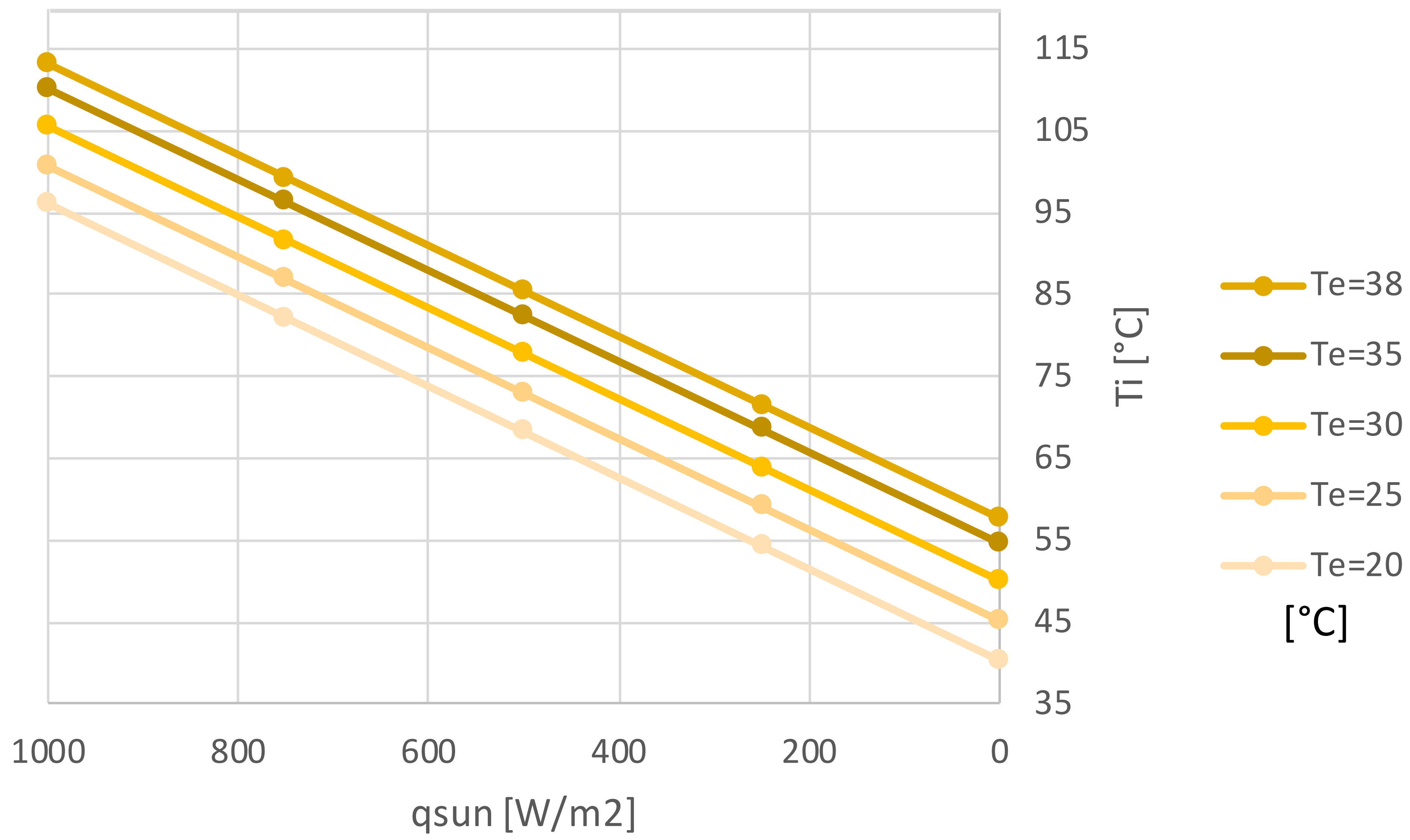


Façade materials to mitigate UHI in the surroundings

SOLAR IRRADIANCE



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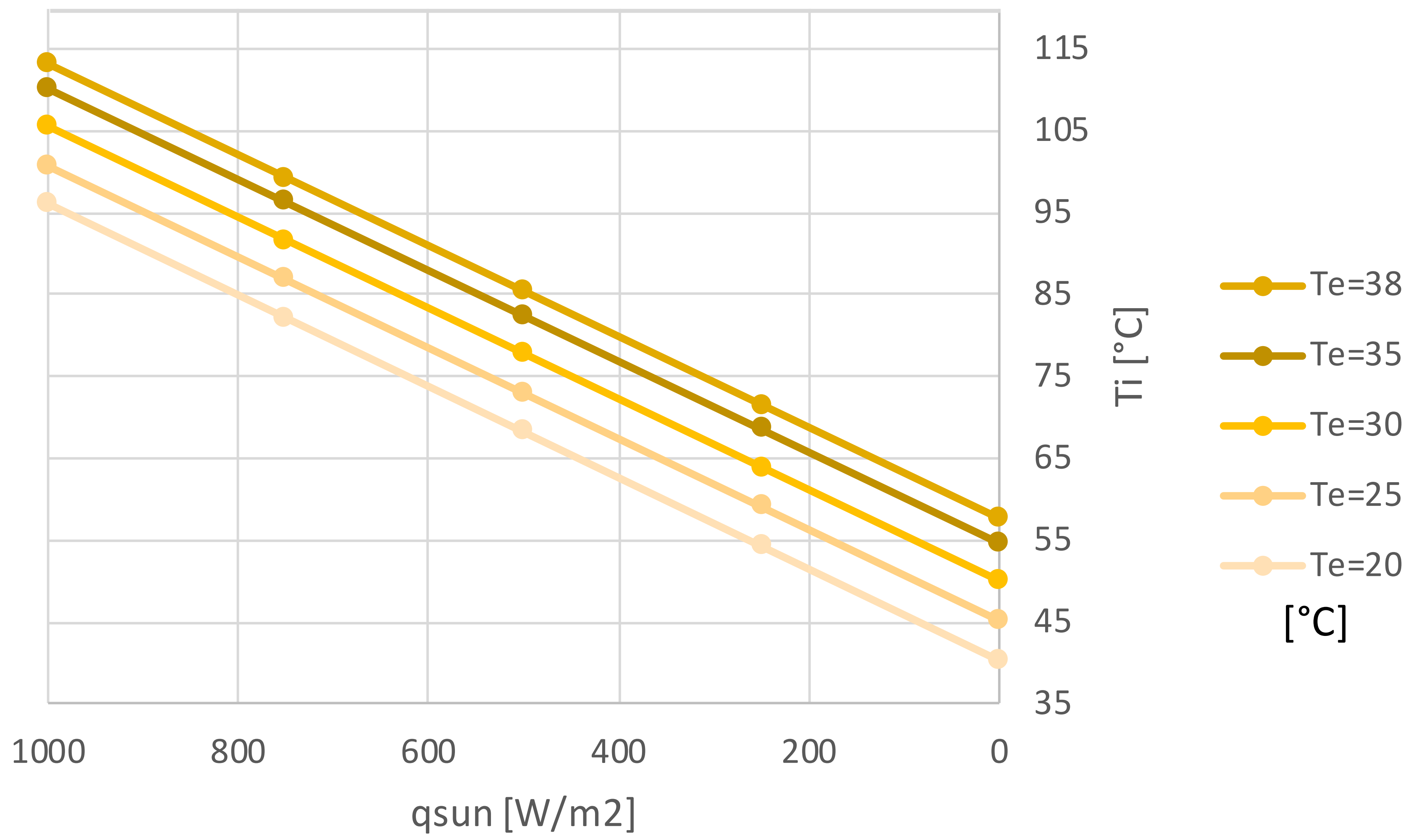
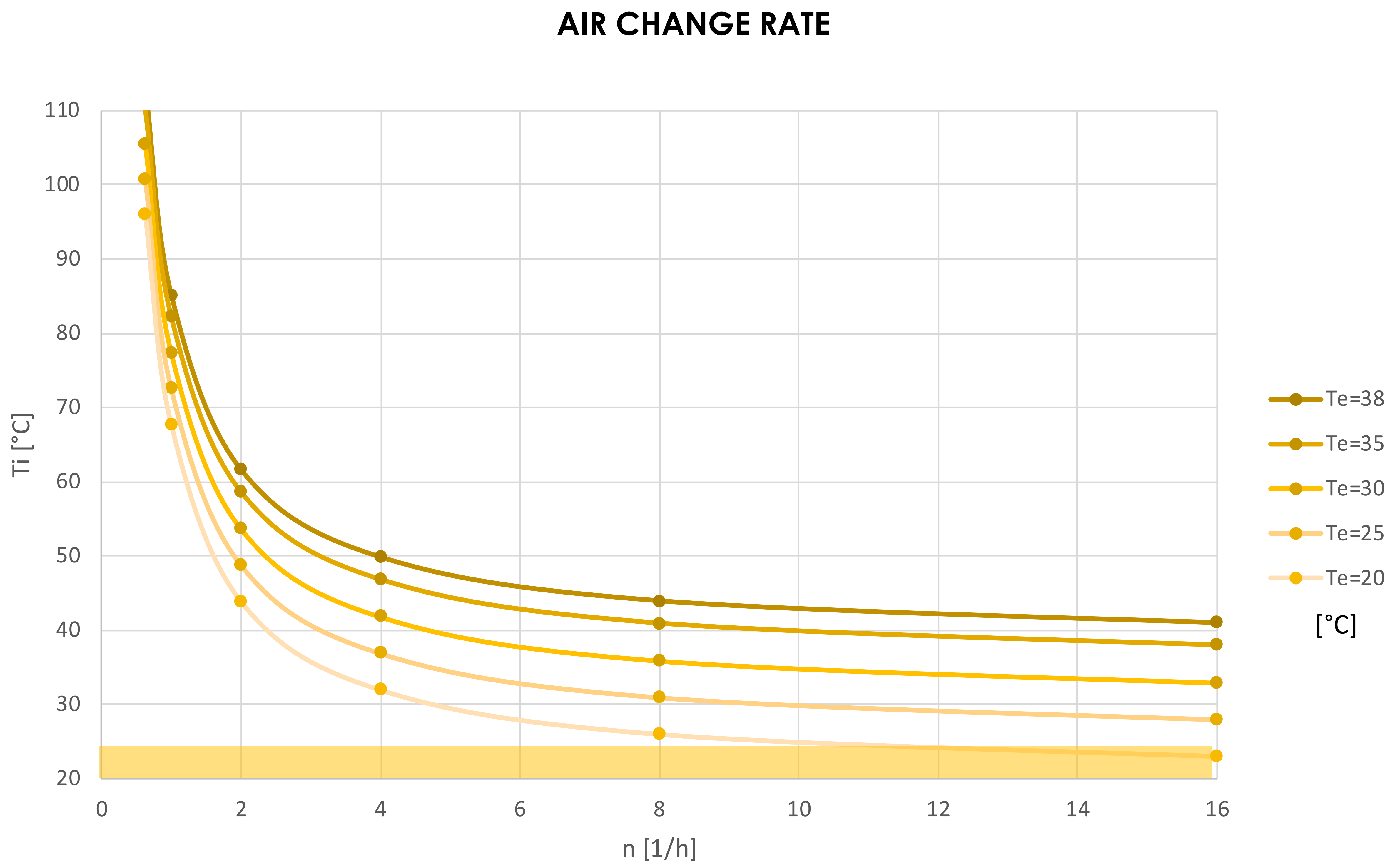


**Solar shading needed
or
less transparent roof**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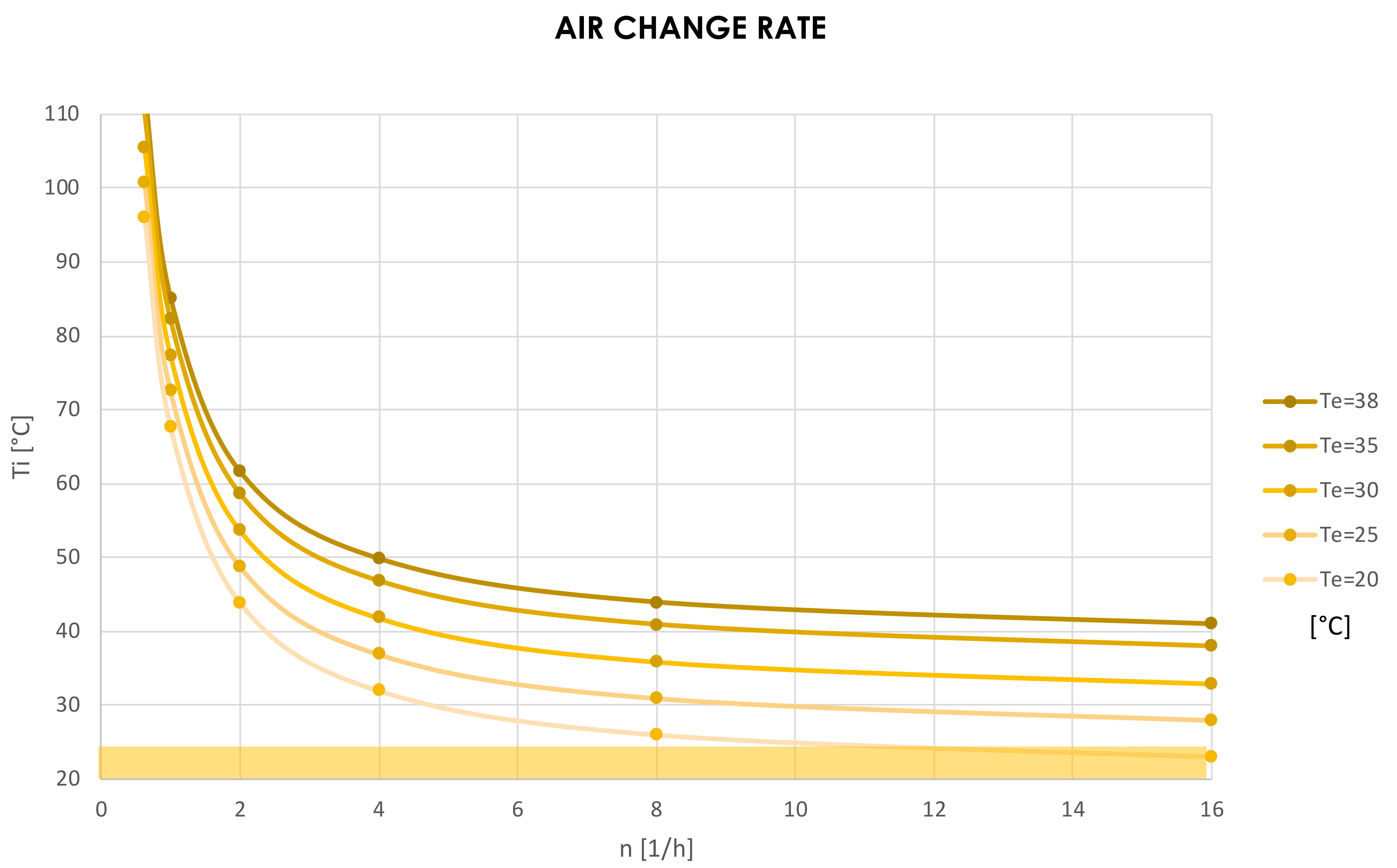
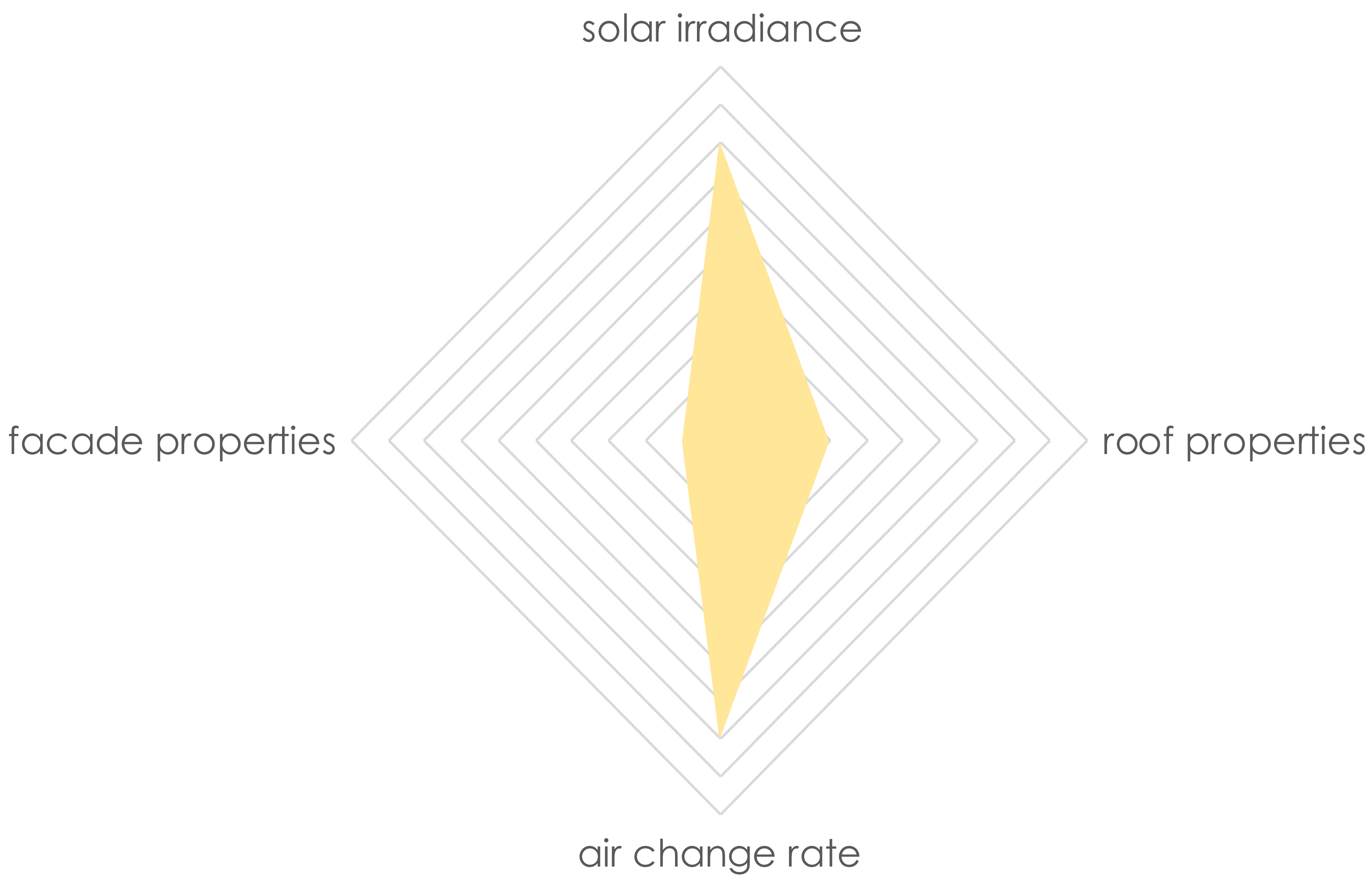
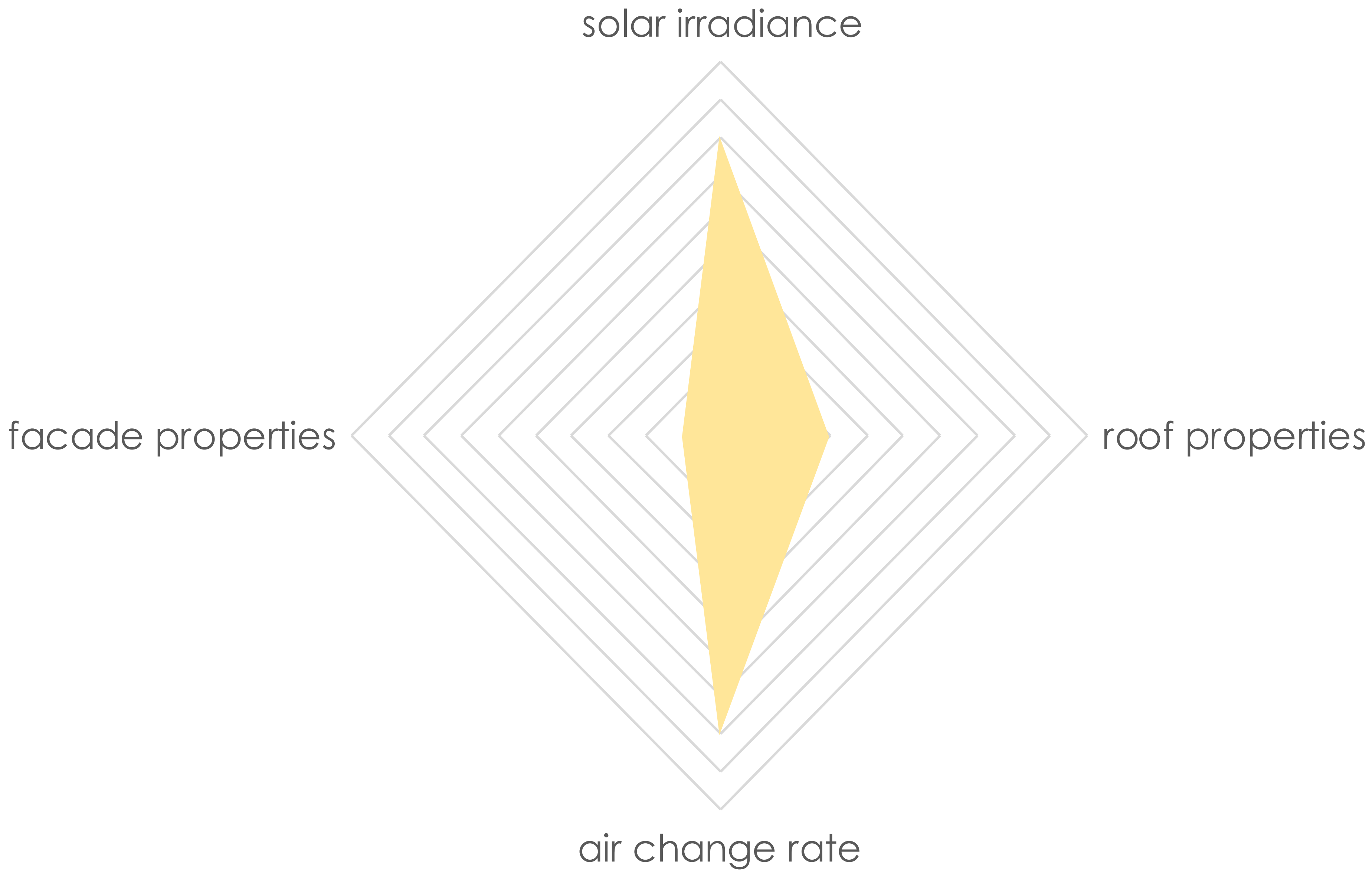


Design for ventilation


solar irradiance
facade properties
roof properties
air change rate

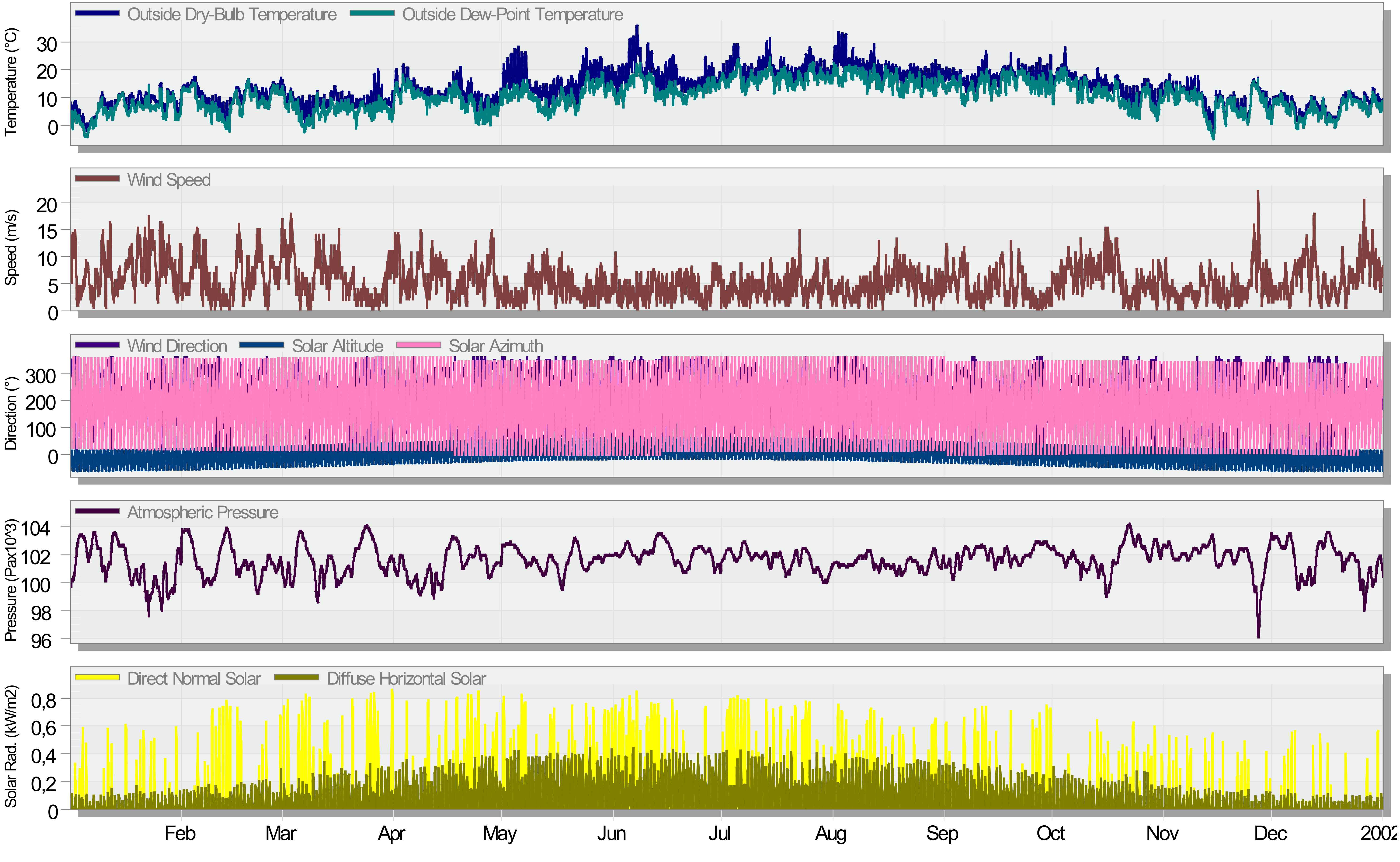


+

Thermal mass
Phase change materials
Ground

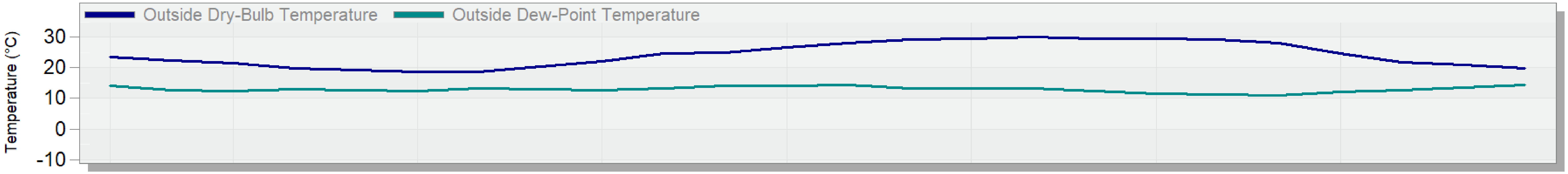
FINAL DESIGN

+ 3°C monthly average

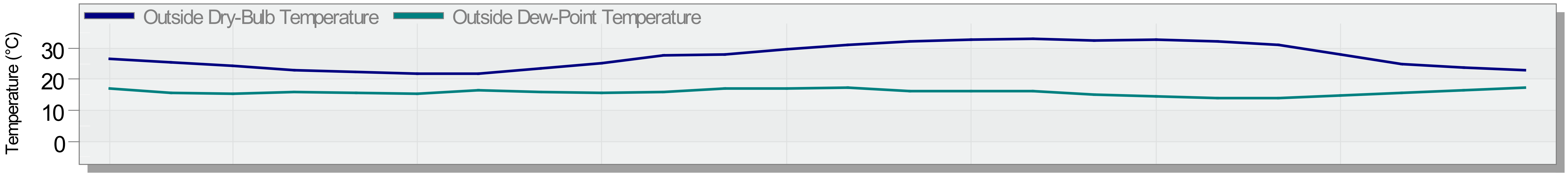


3rd of August

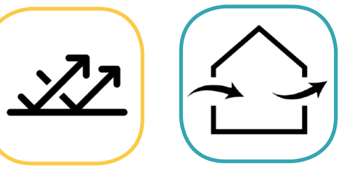
OLD



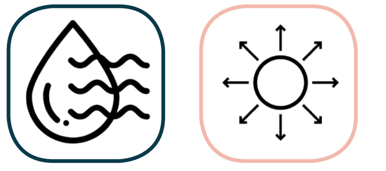
NEW



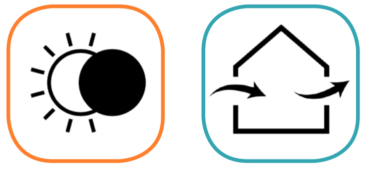
1 FAÇADE



2 CONCOURSES

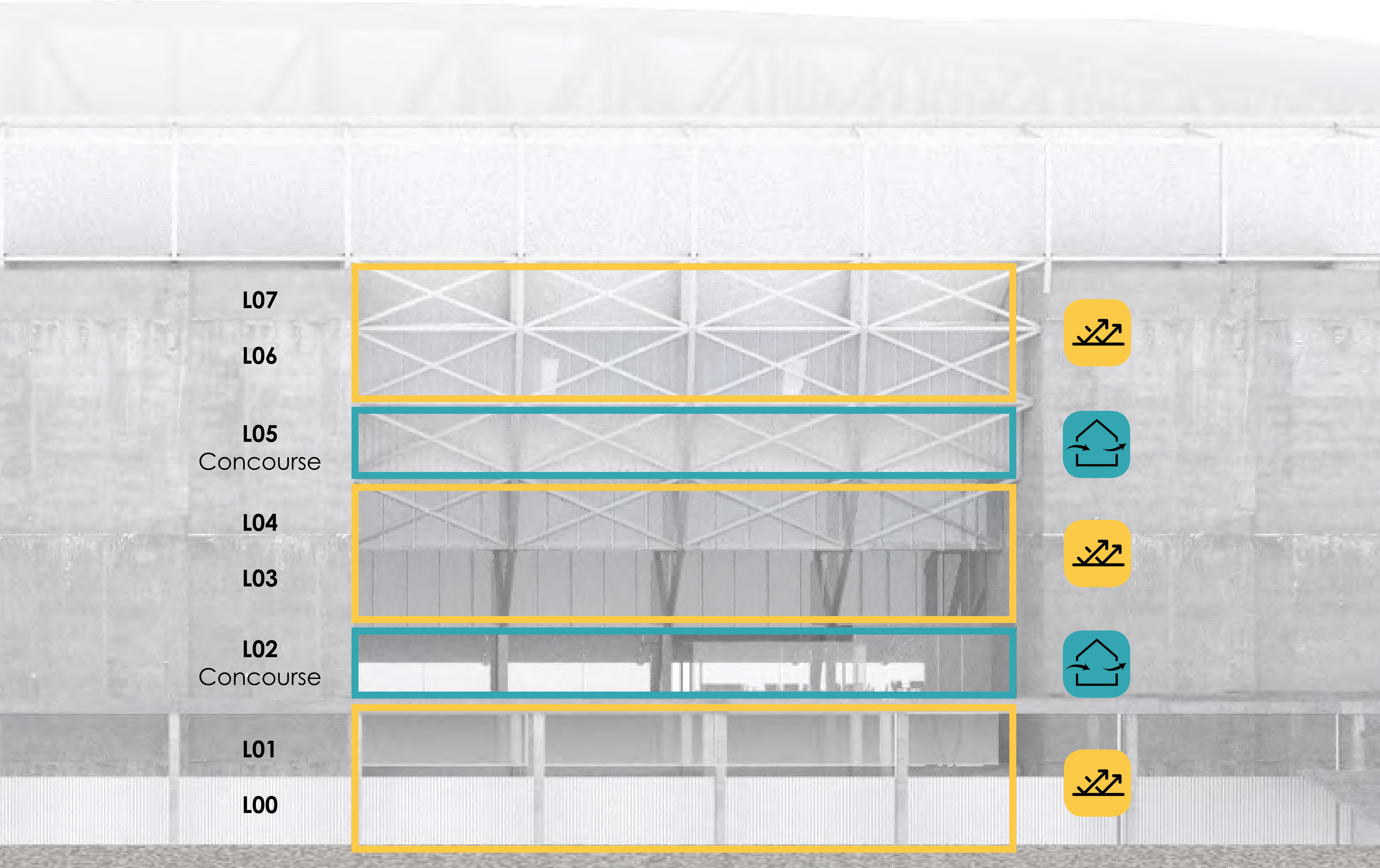


3 ROOF



4 EXTRA MEASURES

1 FAÇADE


L07
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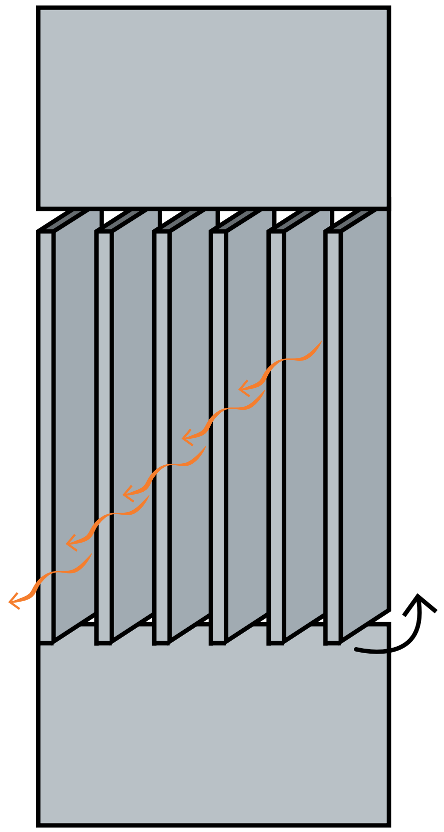
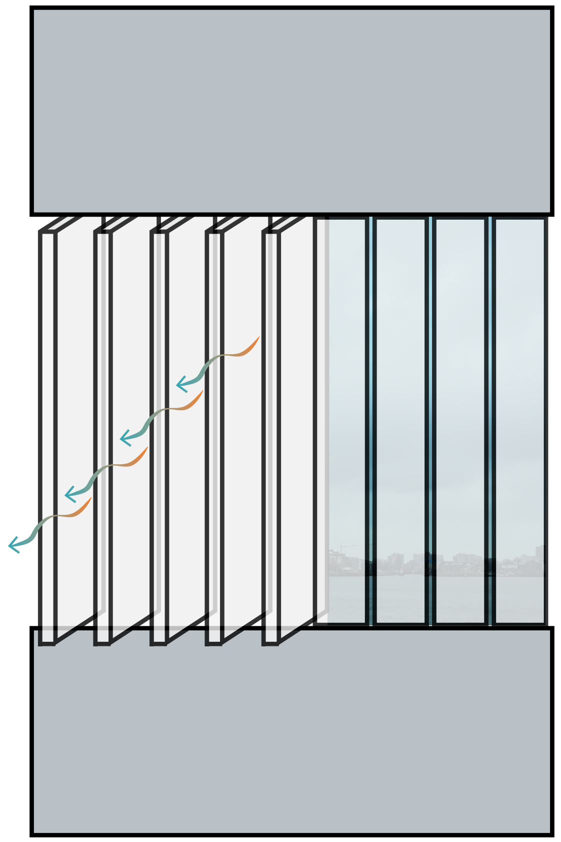
L01
L00

NATURAL VENTILATION



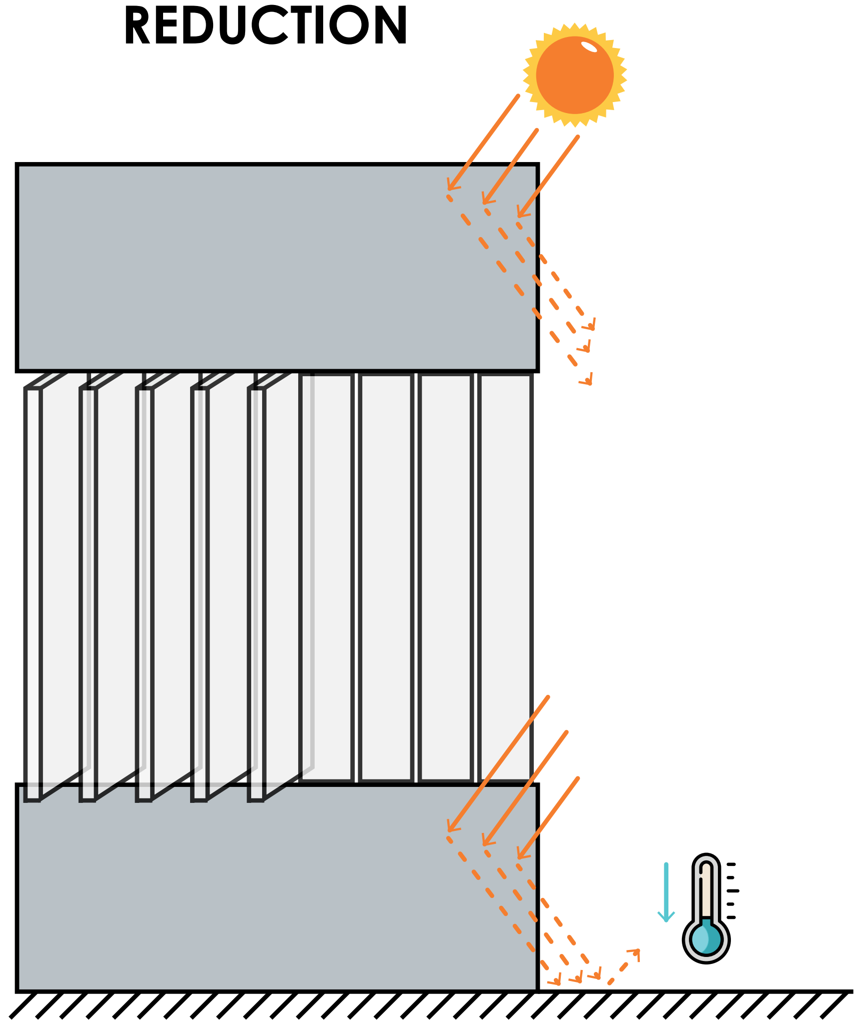
Operable panels
(concourses levels)

COOLING and DAYLIGHT



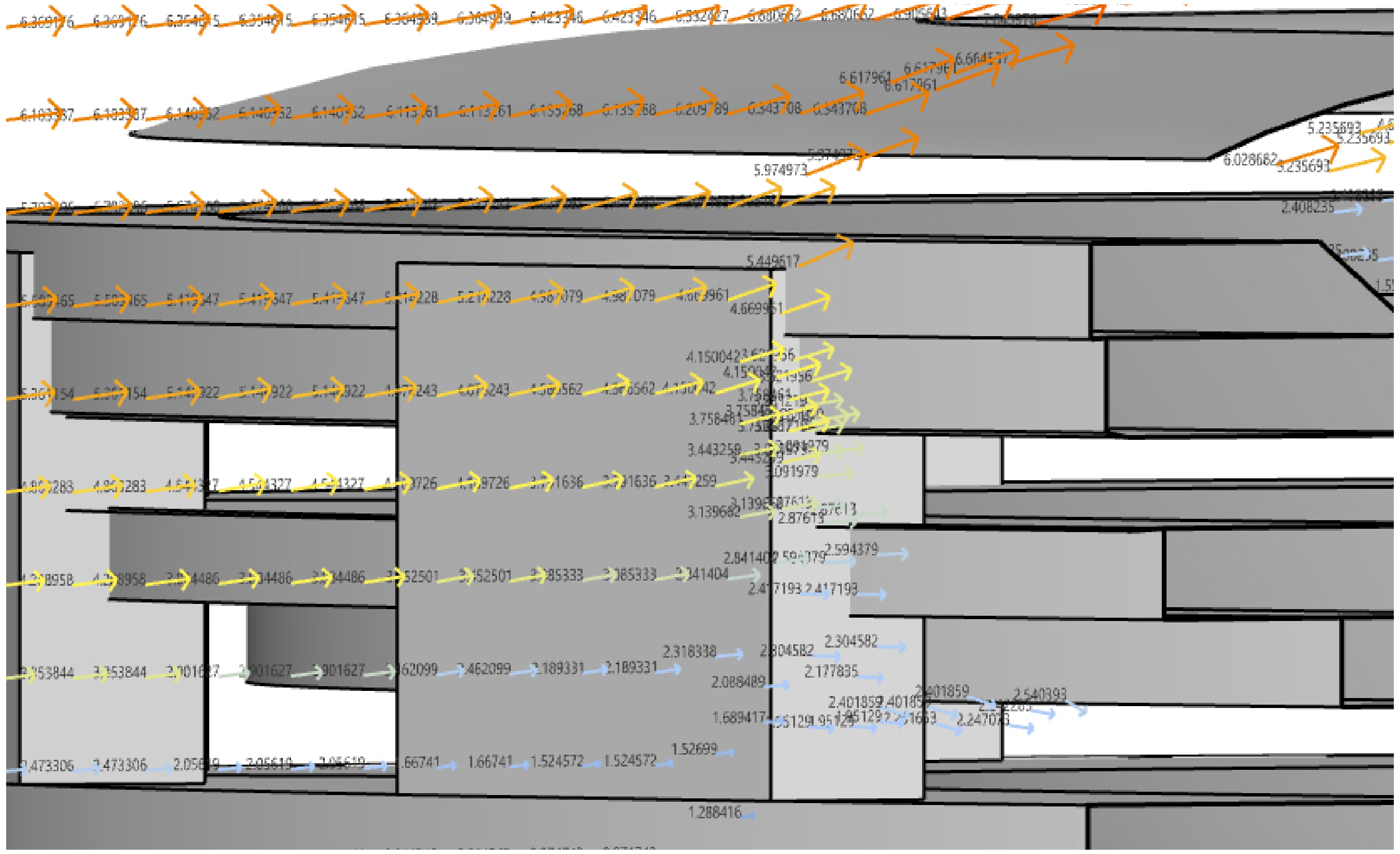
PCM panels

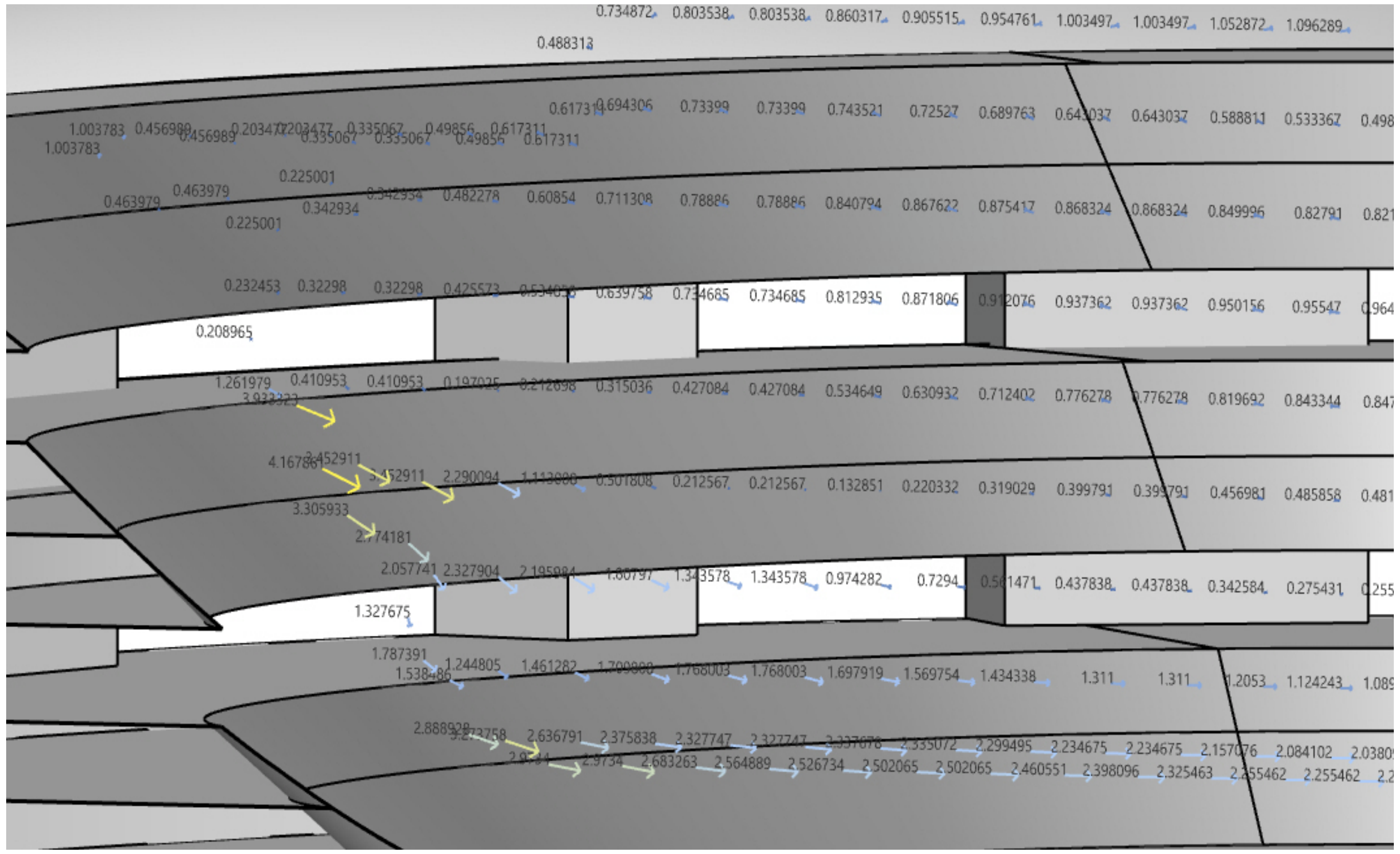
UHI REDUCTION



High albedo materials
(other levels)

CONCOURSES
WIND FLOW





Football match

Match September-May August 3rd	Ventilation ac/h	Max air temperature °C
Basic - stadium	1,3	28,2
Field	0,7	26,5
Tiers	0,7	34,9

Concert

Concert All year August	Ventilation ac/h	Max air temperature °C
Basic - stadium	1,4	28,7
Field	0,7	36
Tiers	0,75	36

Football match

Match September-May August 3rd	Ventilation ac/h	Max air temperature °C
Basic - stadium	1,3	28,2
Field	0,7	26,5
Tiers	0,7	34,9

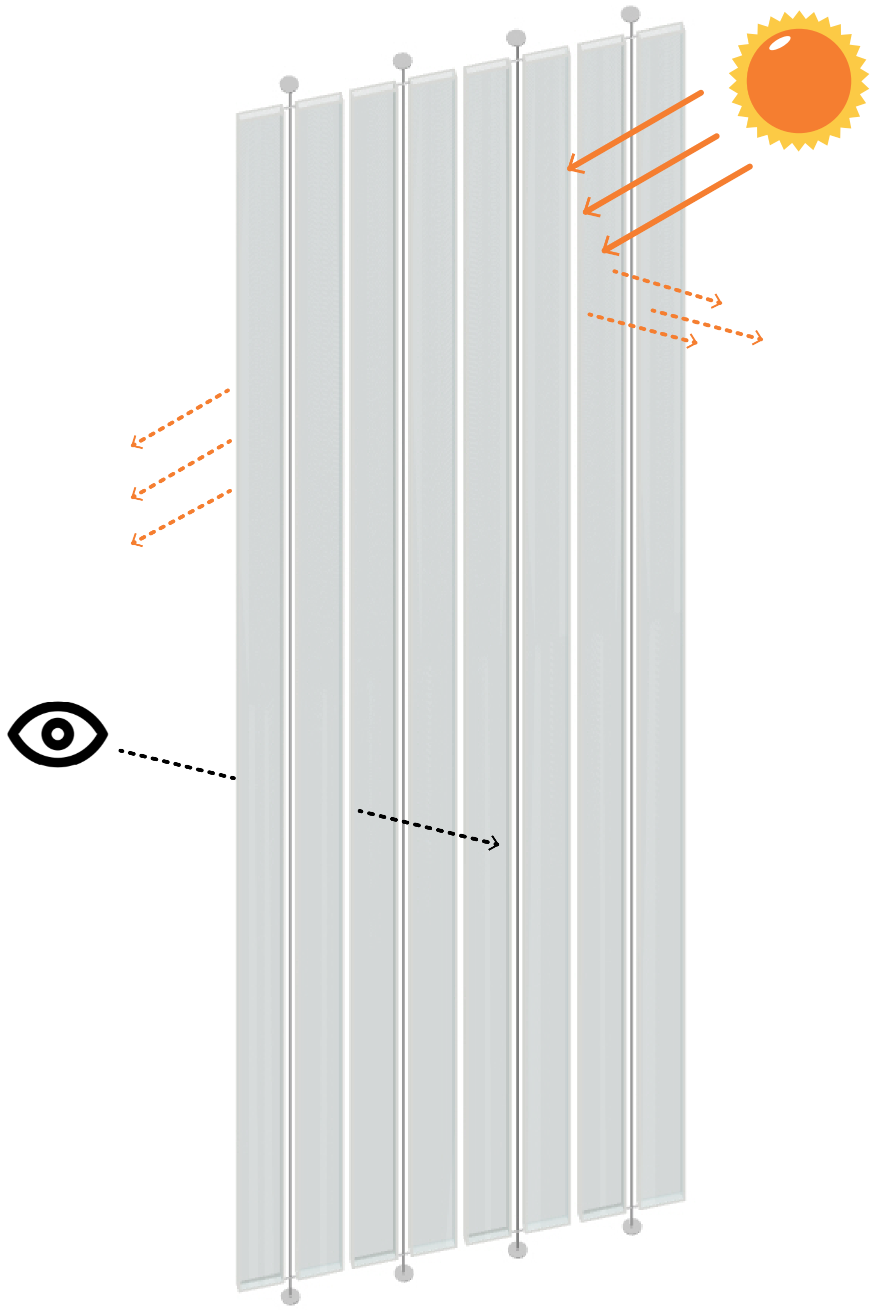
Open concourses - stadium	2,2	28
Field	0,7	26,4
Tiers L02	5,8	34,1

Concert

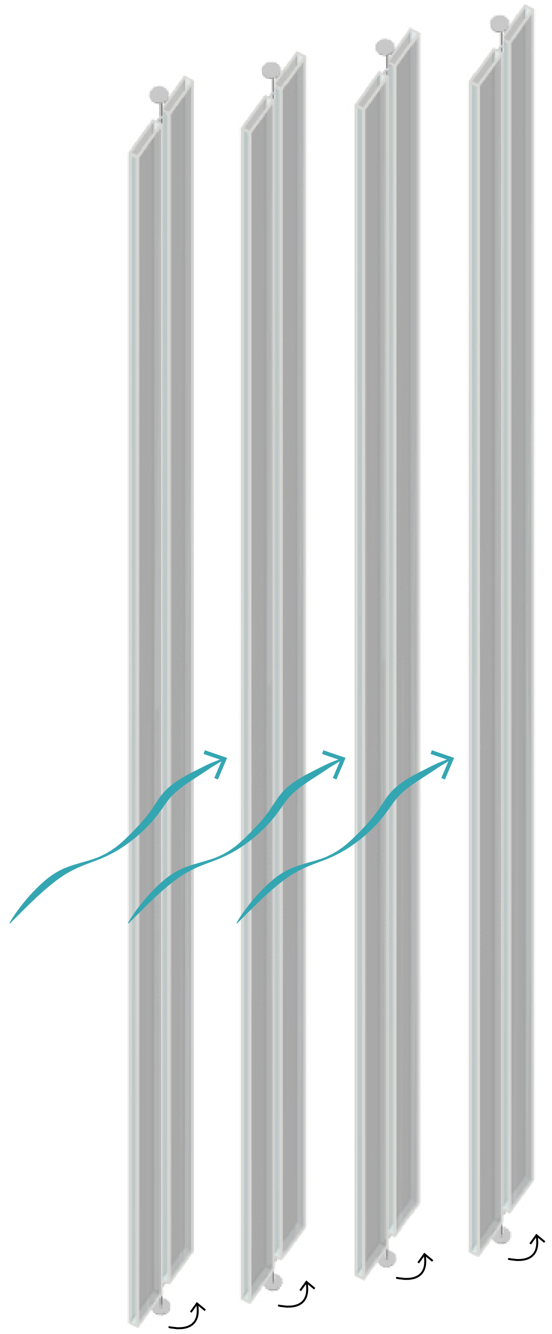
Concert All year August	Ventilation ac/h	Max air temperature °C
Basic - stadium	1,4	28,7
Field	0,7	36
Tiers	0,75	36

Open concourses - stadium	2,2	28,4
Field	4,5	36,1
Tiers L02	5,8	32,8

Closed

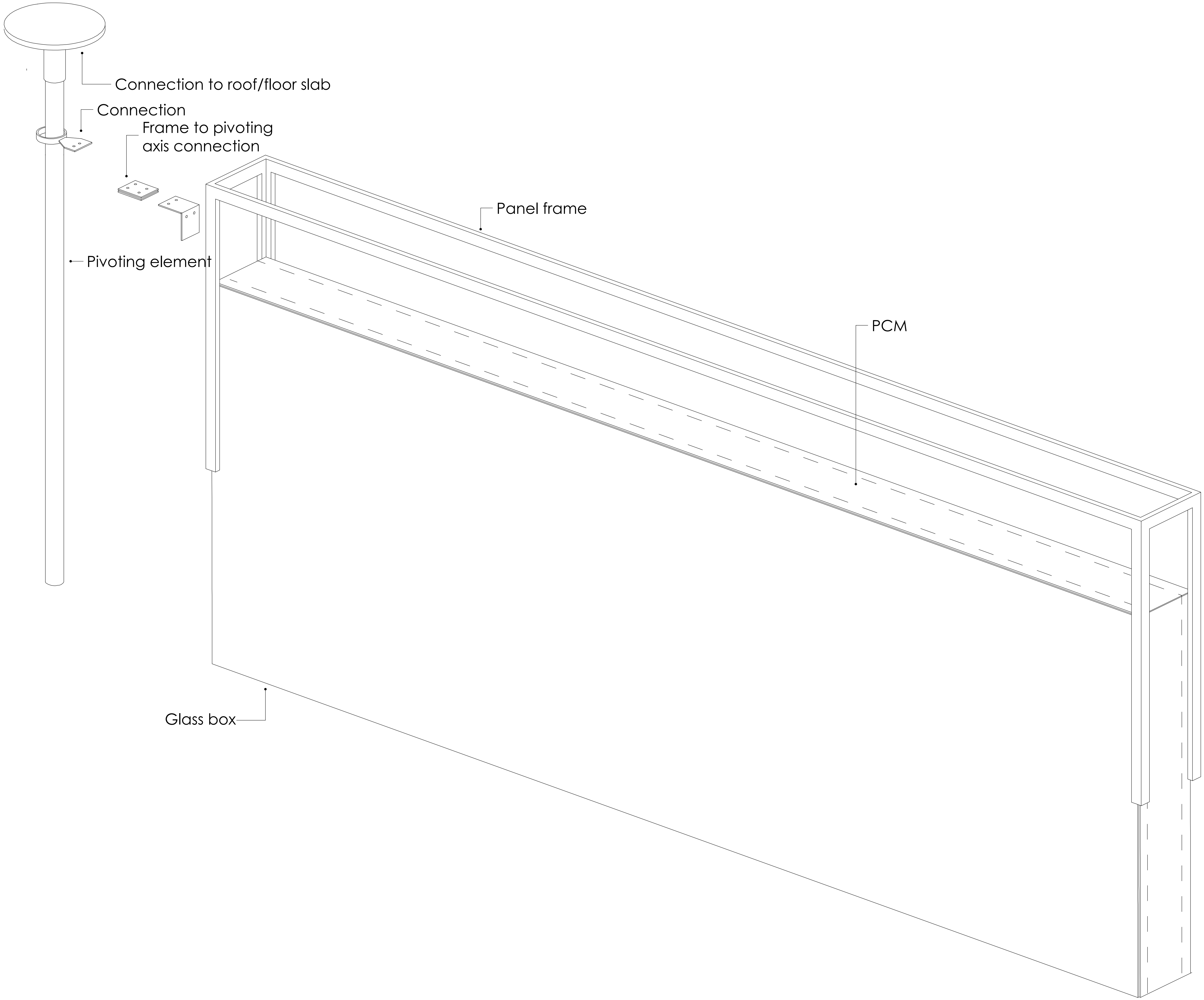


Open



- PCMs are translucent, therefore allow for **daylight** and **view**.
- Outdoor air can only filter through the panels.

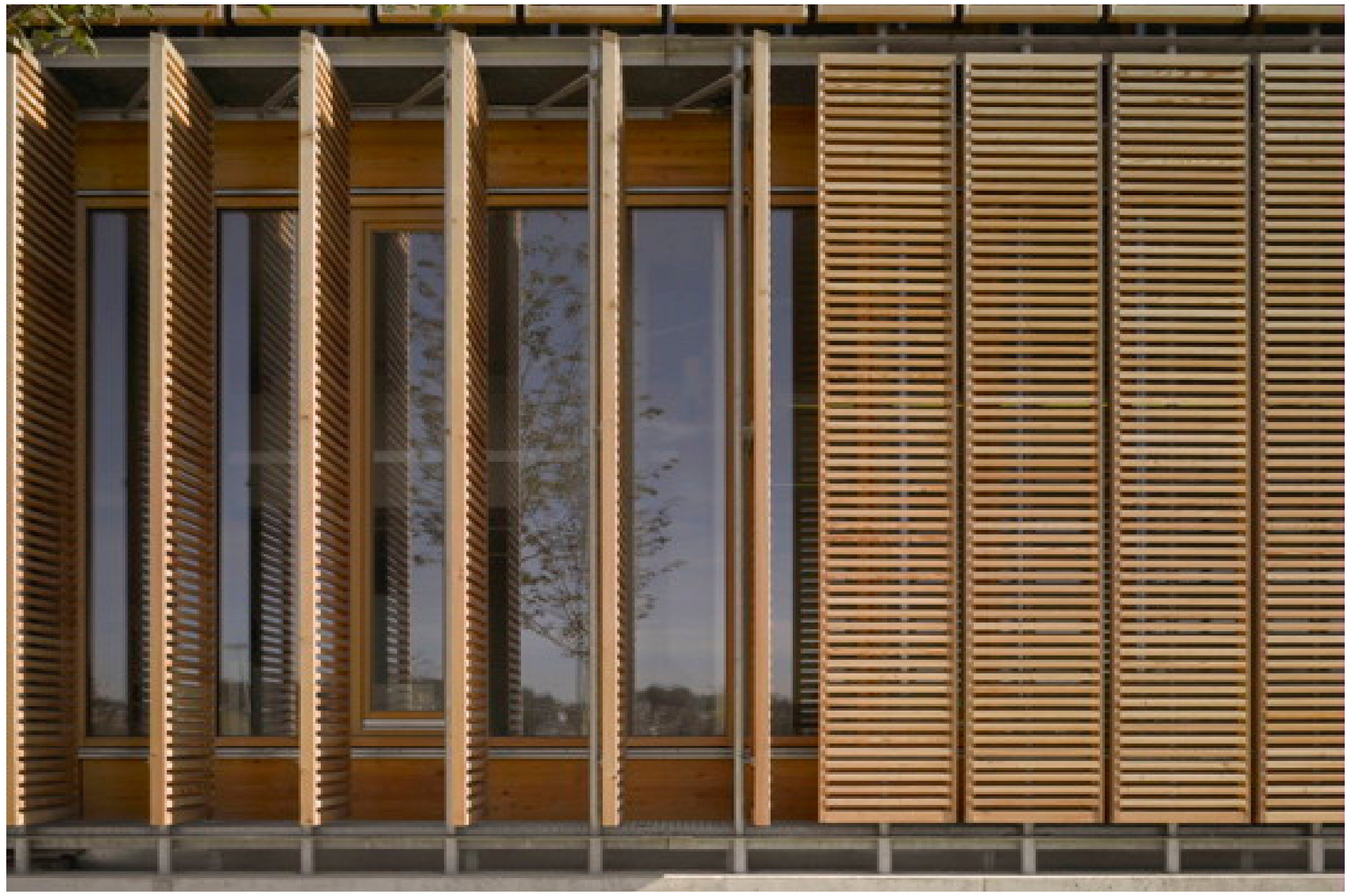
- Façade is fully open and **natural ventilation** occurs.
- PCMs **pre-cool** the air.


Connection to roof/floor slab
Connection
Frame to pivoting
axis connection
Panel frame
Pivoting element
PCM
Glass box

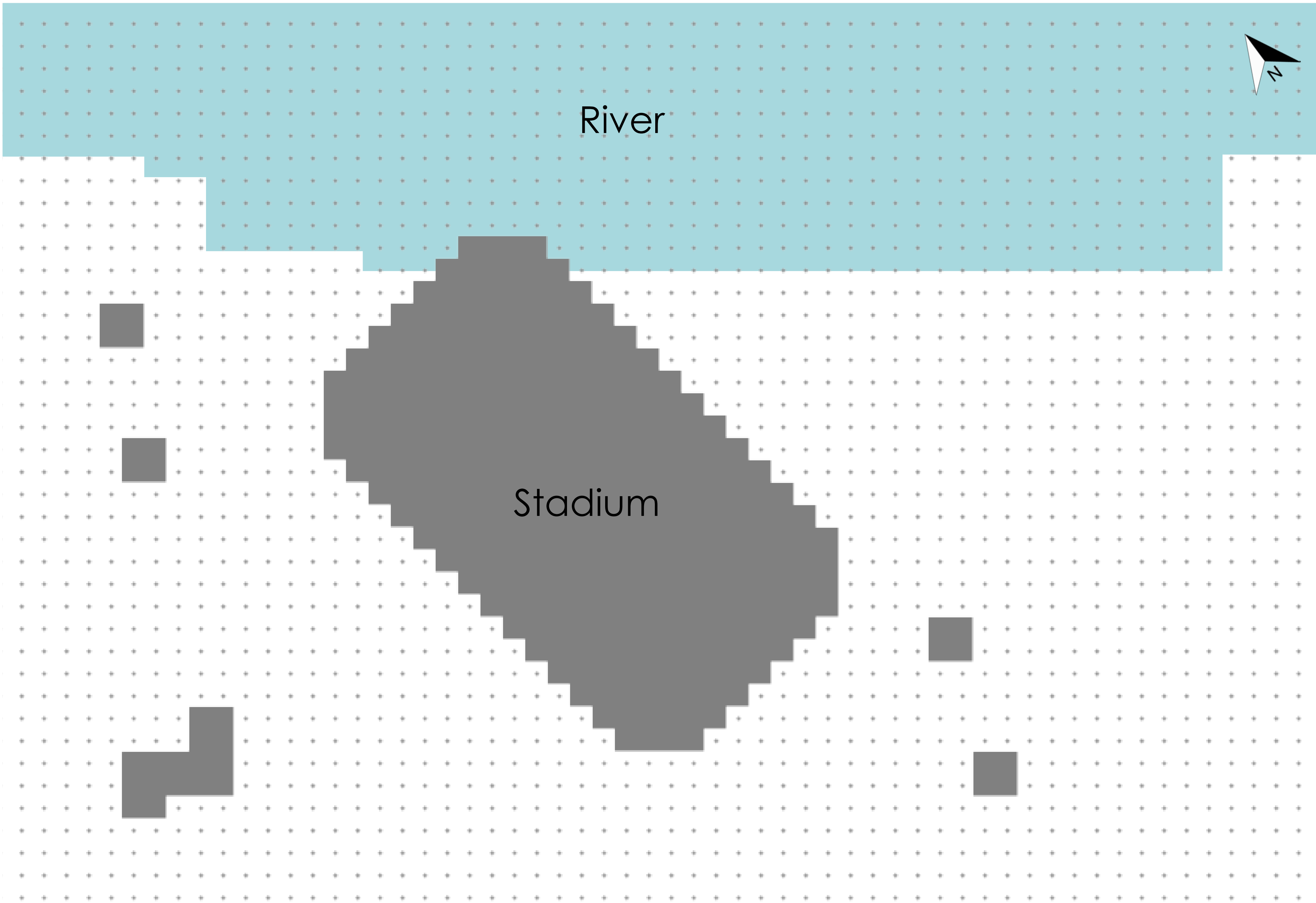
Reference projects

House in Montevideo, Uruguay

Aalen University extension



OTHER LEVELS

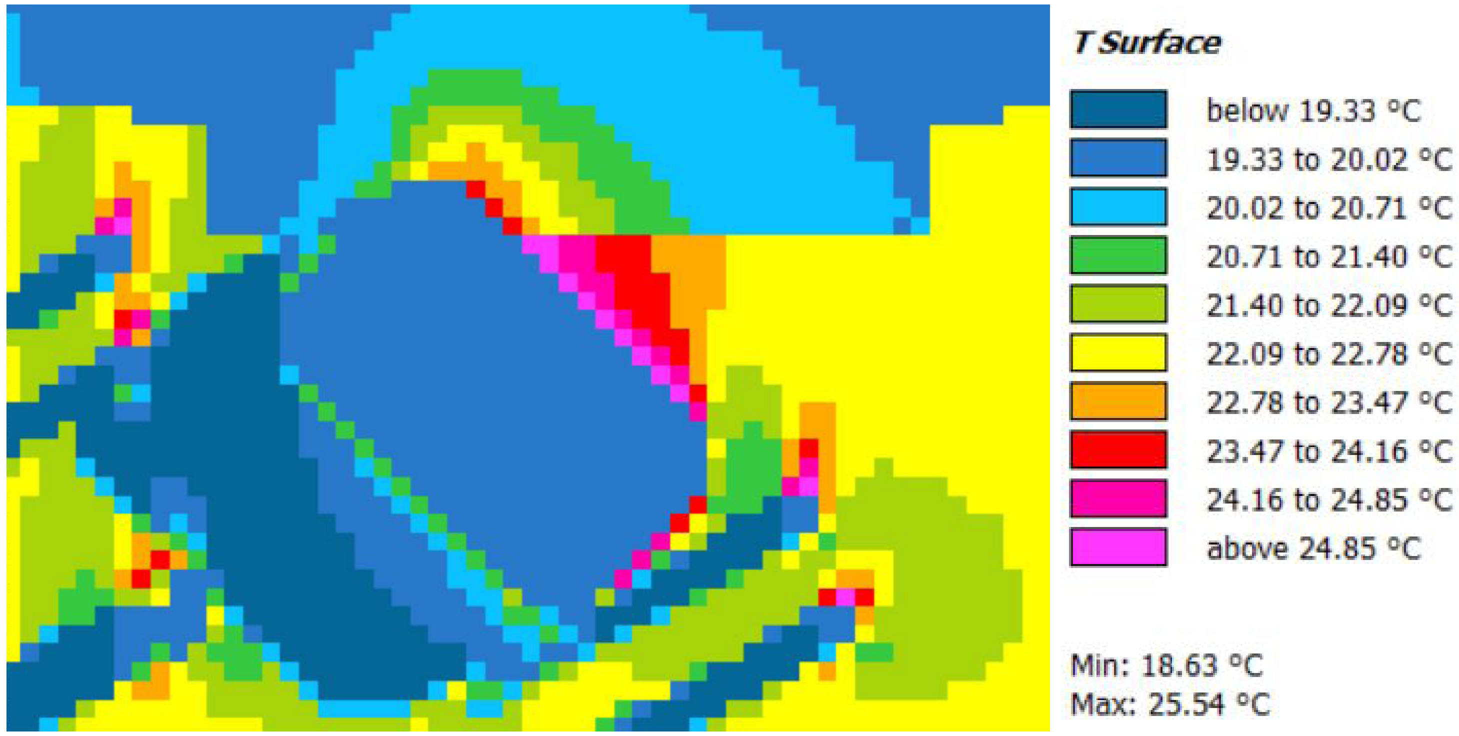


Materials

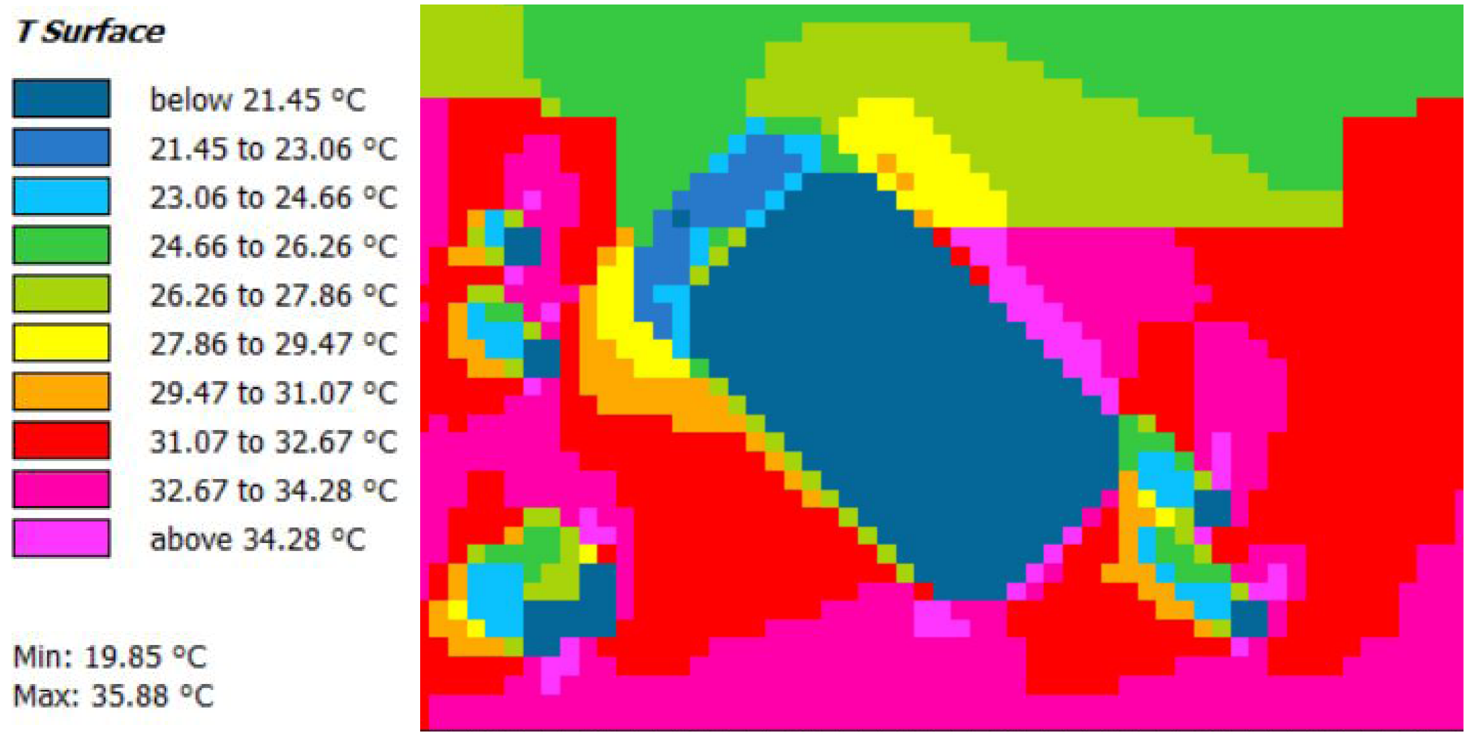
- Basic material
- Aluminium
- White painted wall
- Glass
- Ceramic
- Green

Aluminium

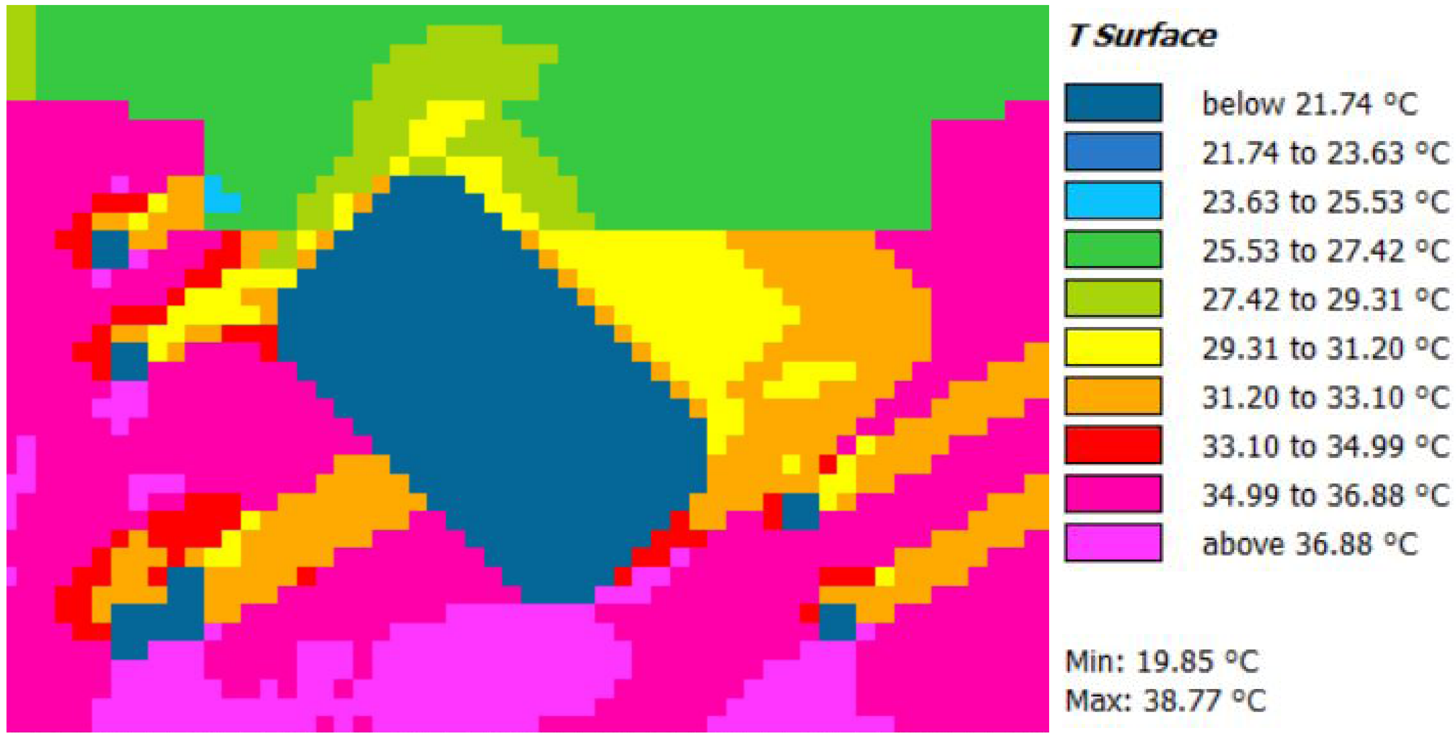
8h



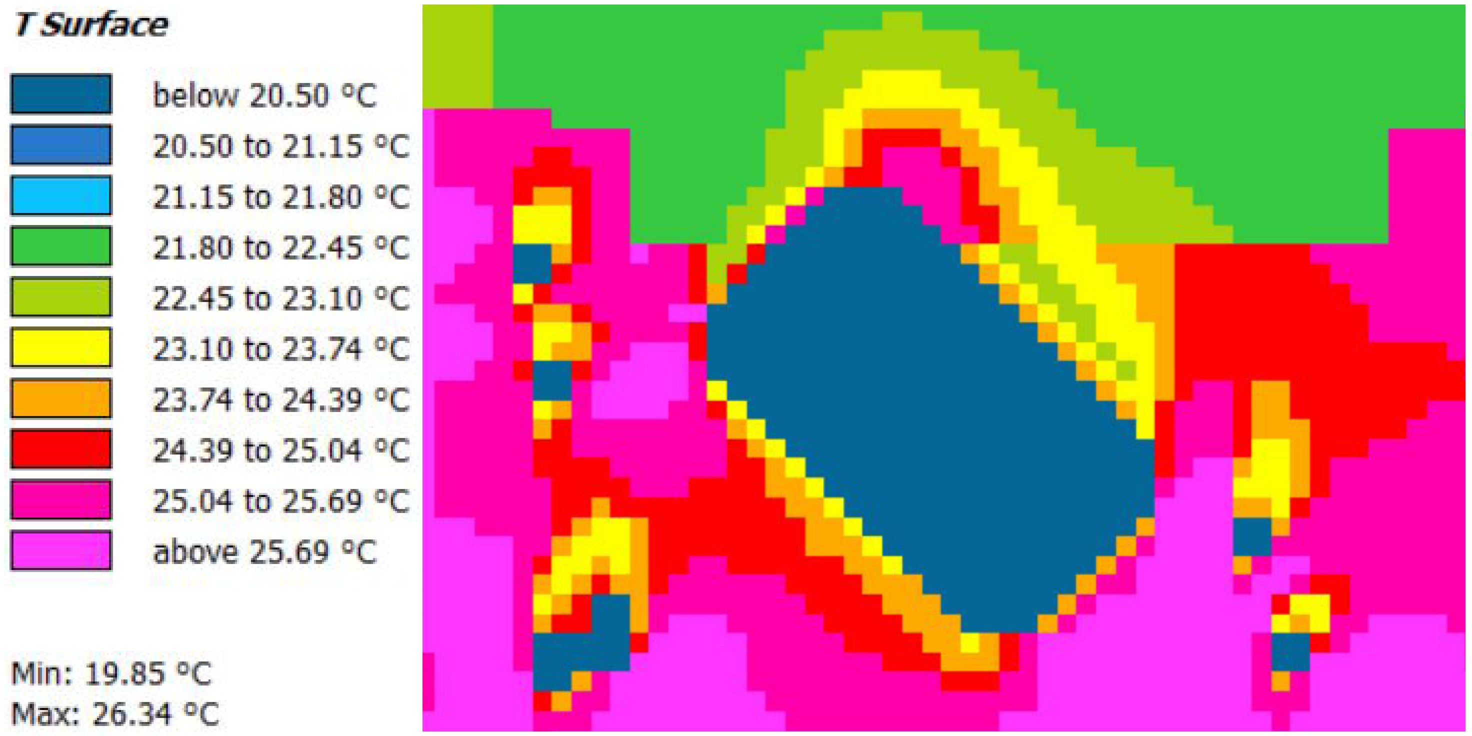
12h



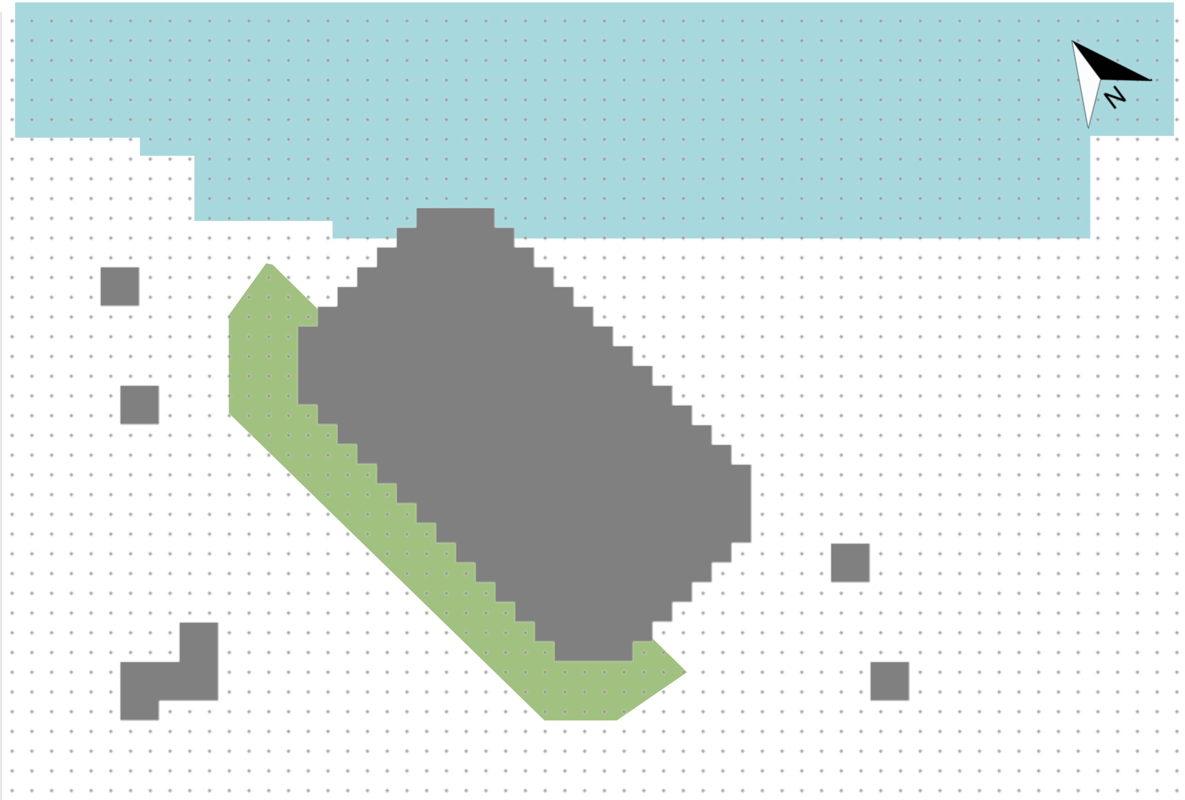
18h



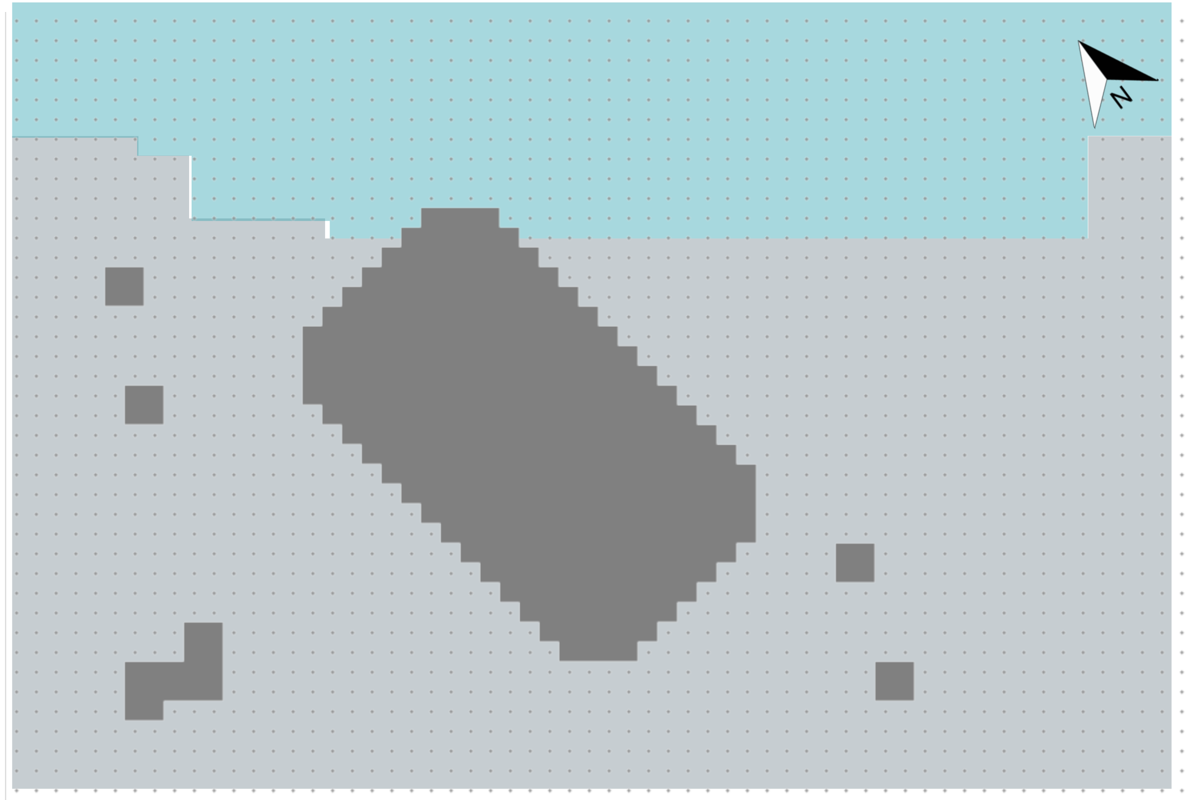
22h



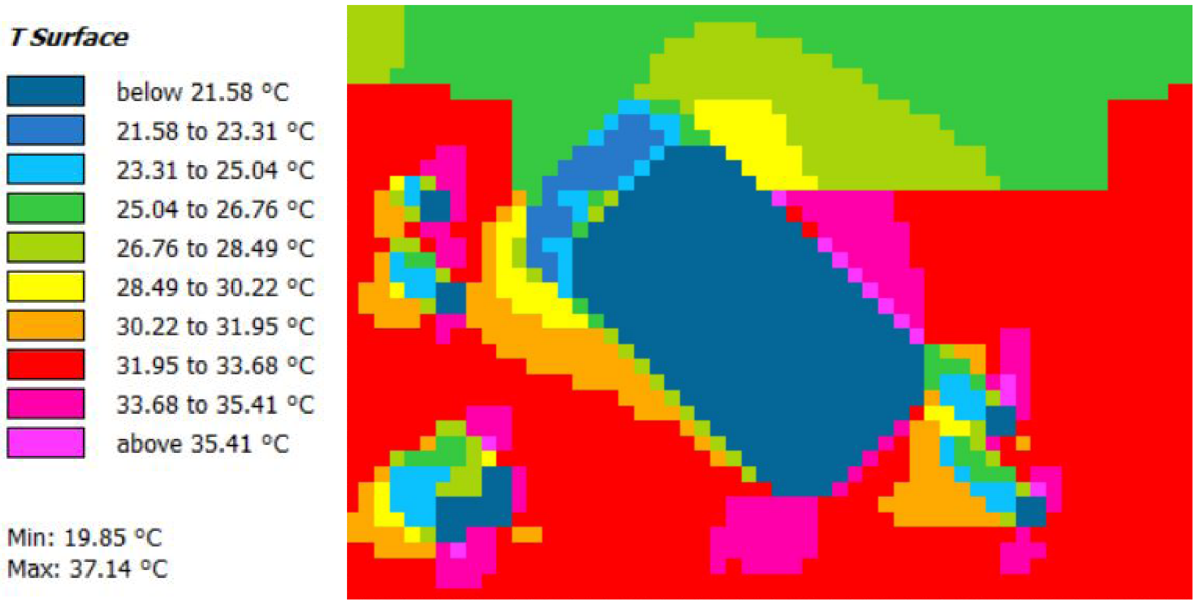
Green

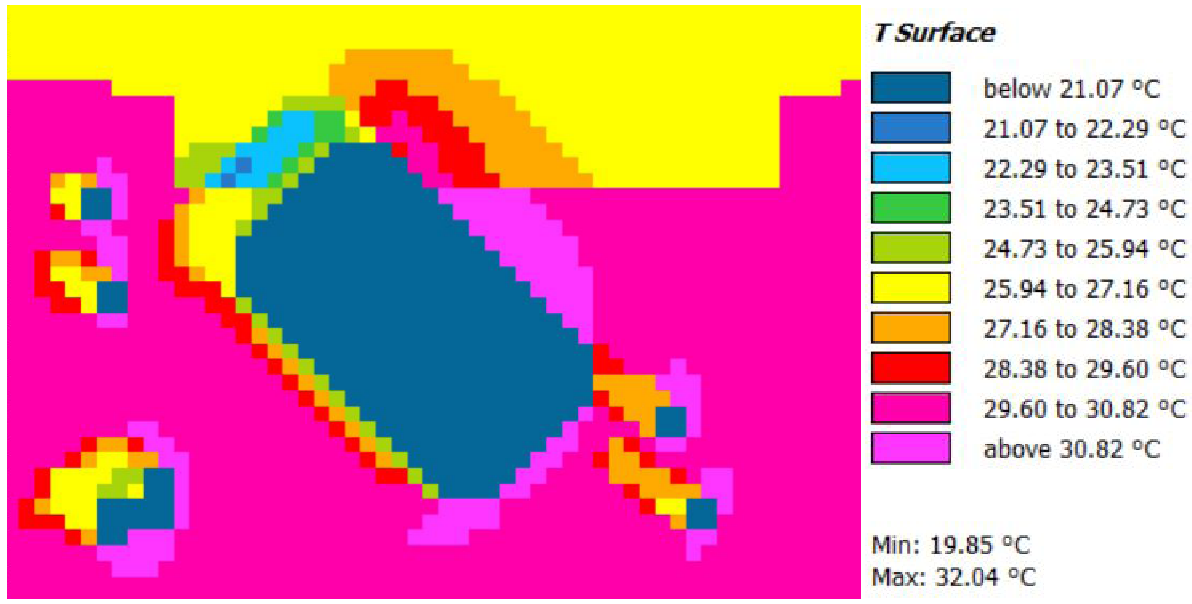


Light coloured concrete



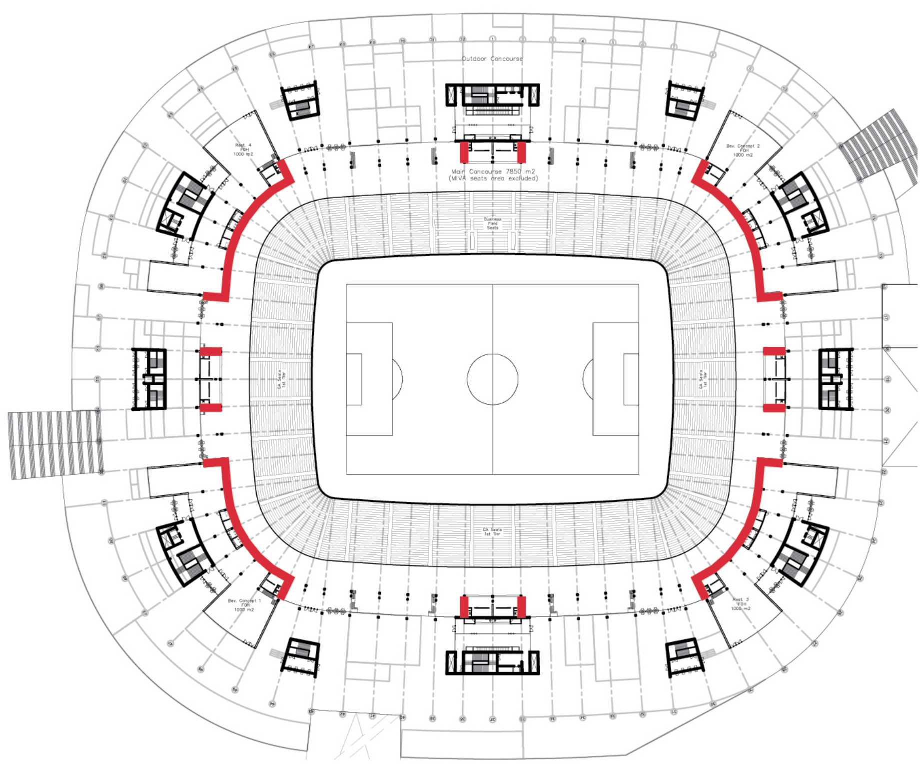
12h



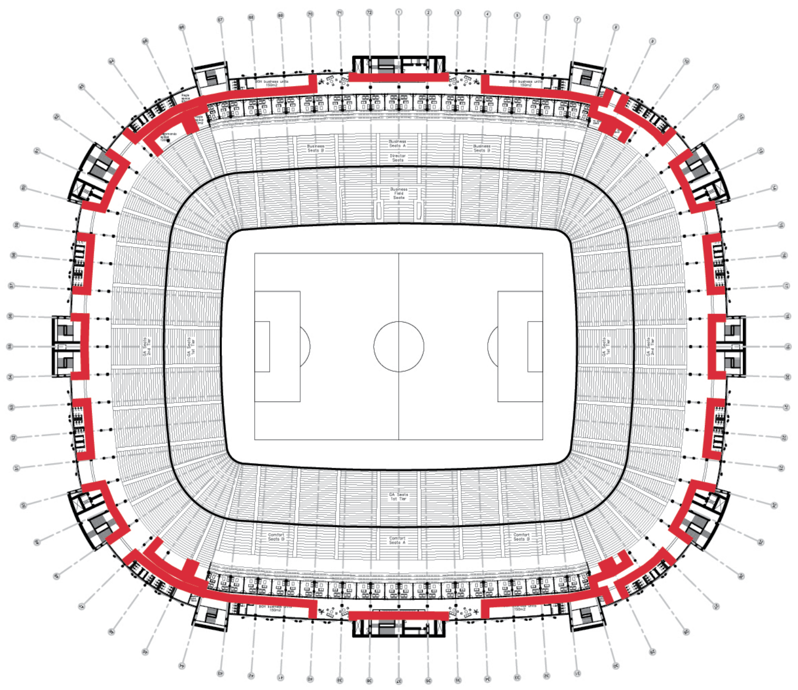


2 CONCOURSES

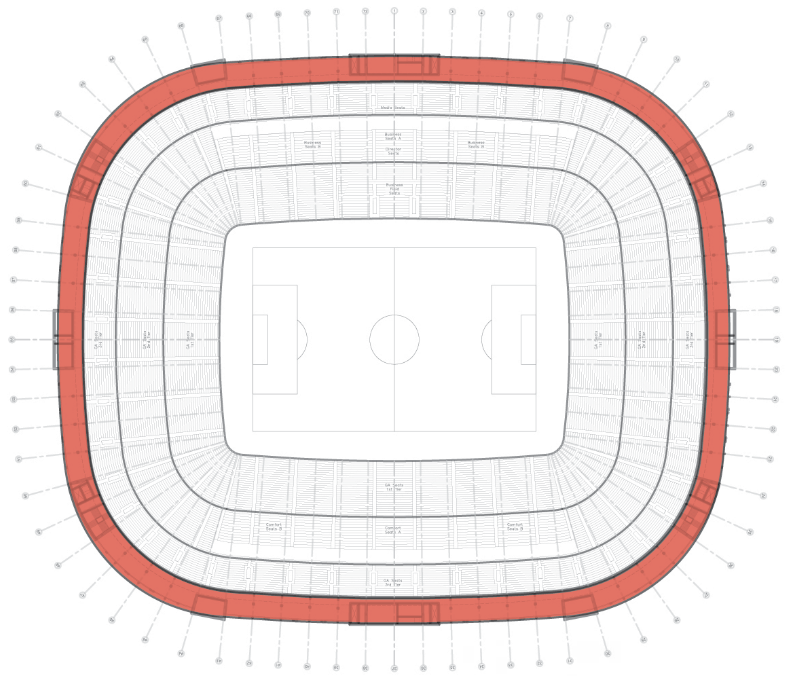
L02



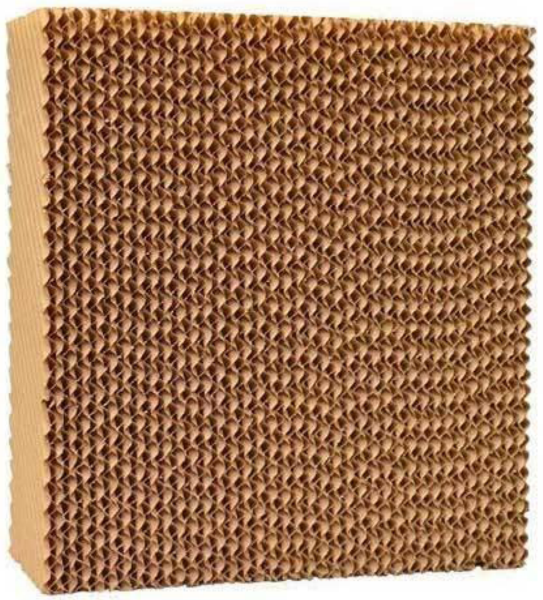
L05

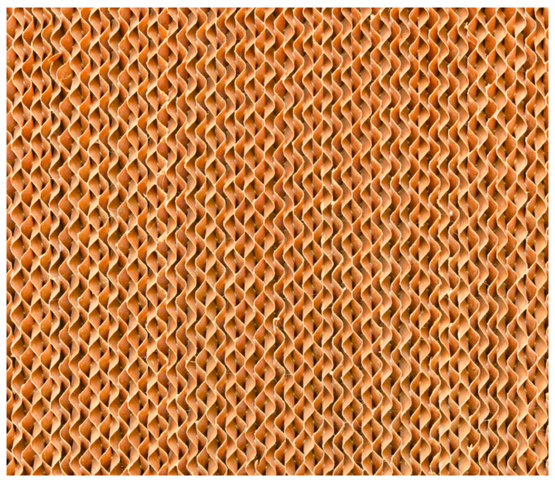


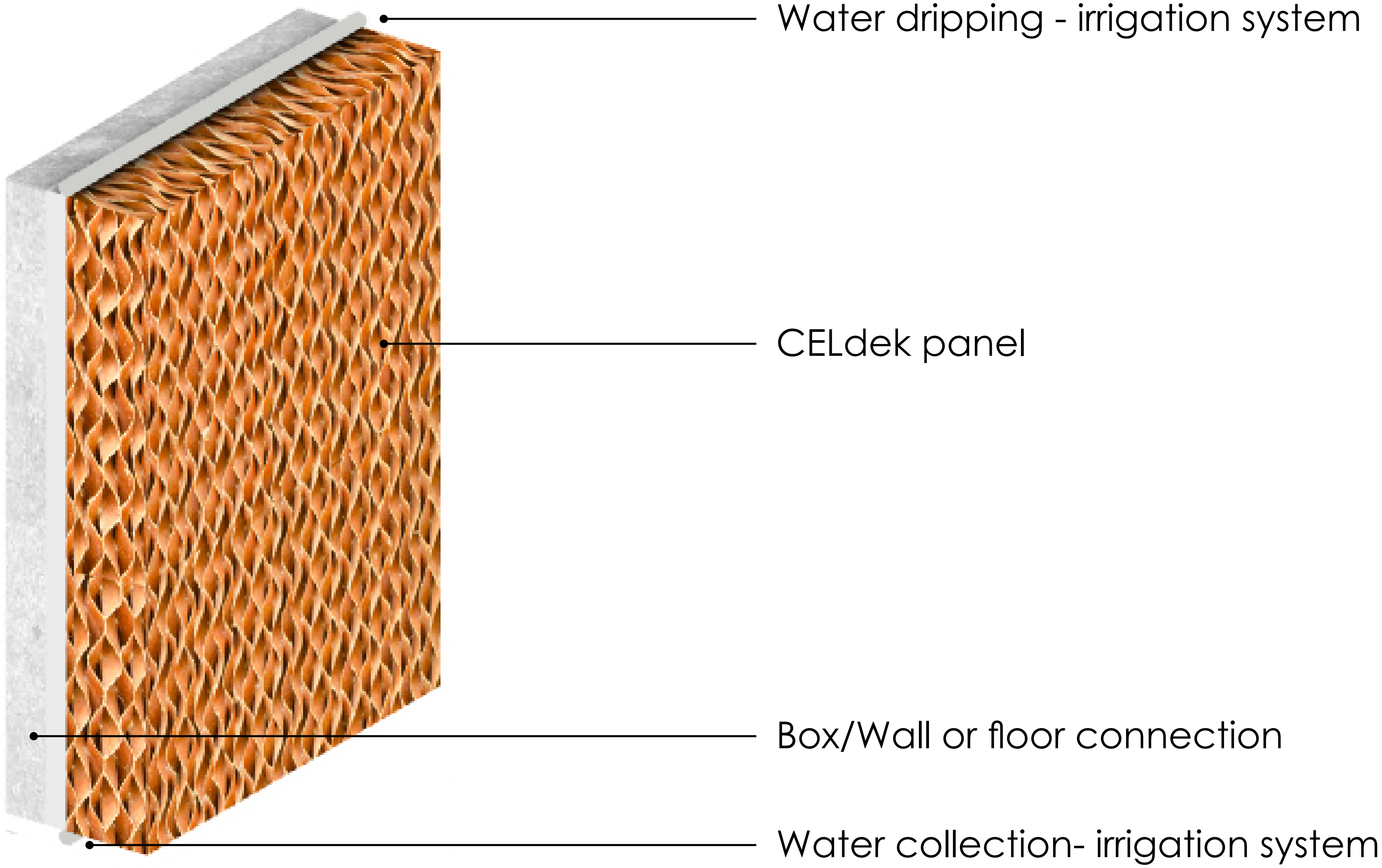
L07

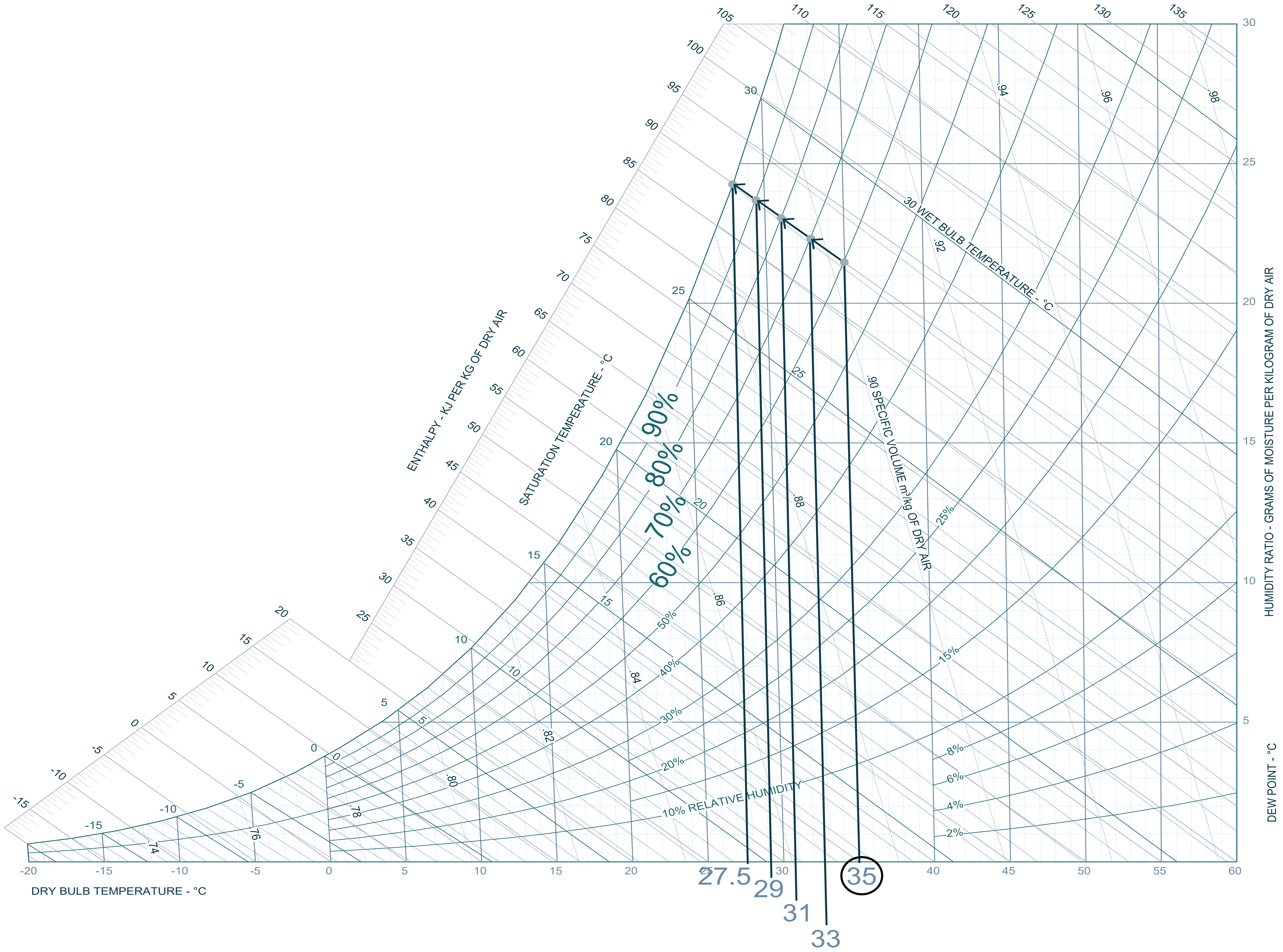


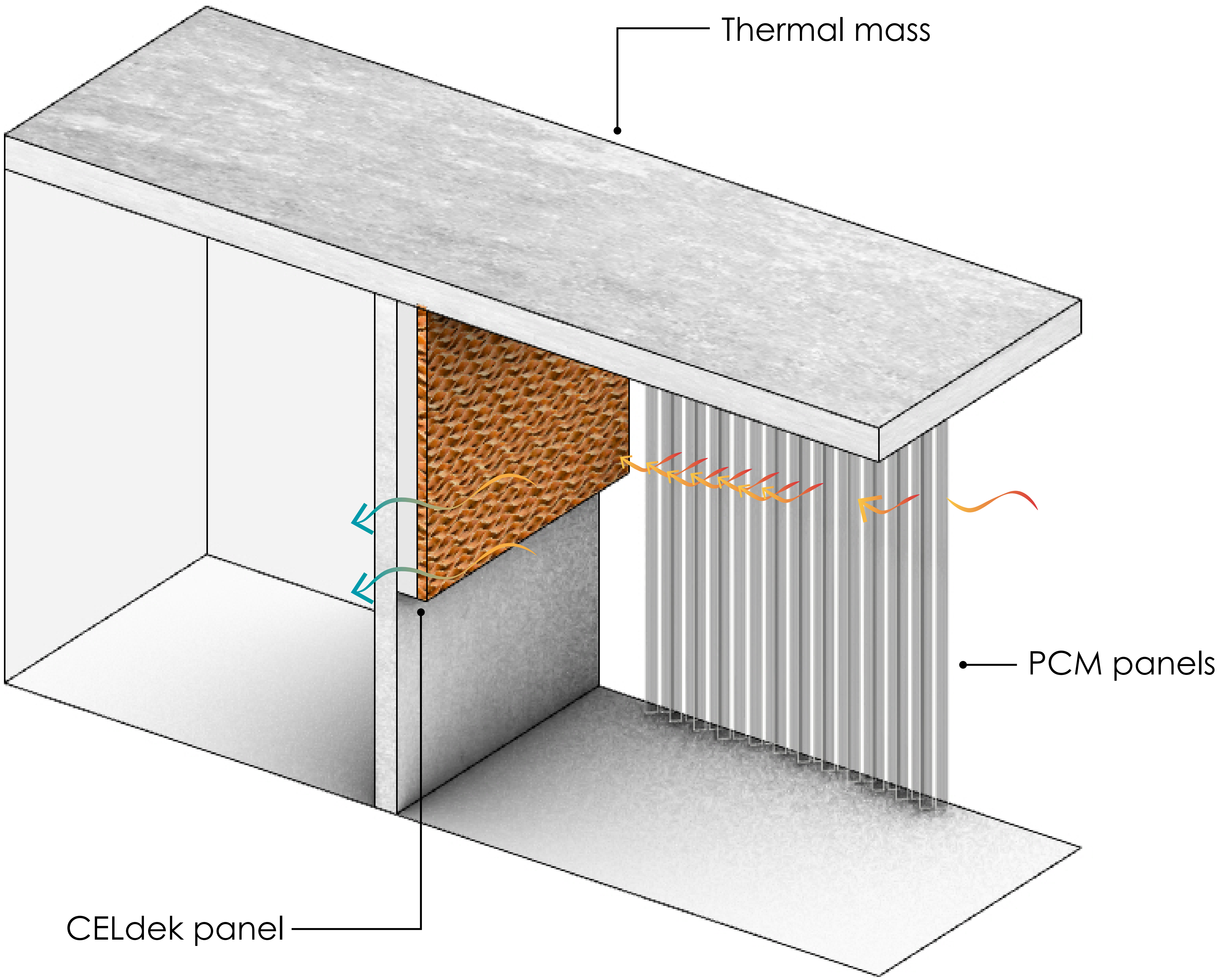
CELdek






Water dripping - irrigation system
CELdek panel
Box/Wall or floor connection
Water collection- irrigation system

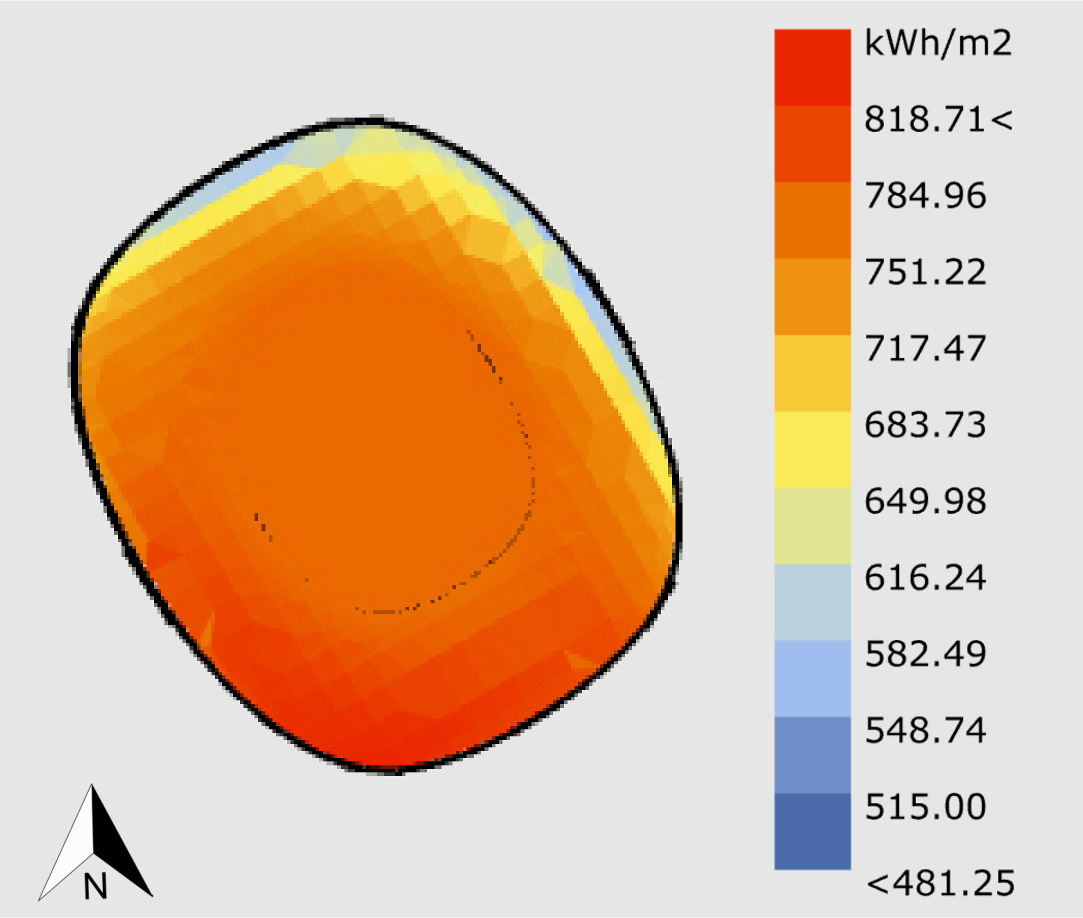

ENTHALPY - KJ PER KG OF DRY AIR
SATURATION TEMPERATURE - °C
30 WET BULB TEMPERATURE - °C
.90 SPECIFIC VOLUME m³/kg OF DRY AIR
HUMIDITY RATIO - GRAMS OF MOISTURE PER KILOGRAM OF DRY AIR
DEW POINT - °C
DRY BULB TEMPERATURE - °C
10% RELATIVE HUMIDITY
90%
80%
70%
60%
50%
40%
30%
20%
25%
15%
8%
6%
4%
2%
27.5
29
31
33
35


Thermal mass
PCM panels
CELdek panel

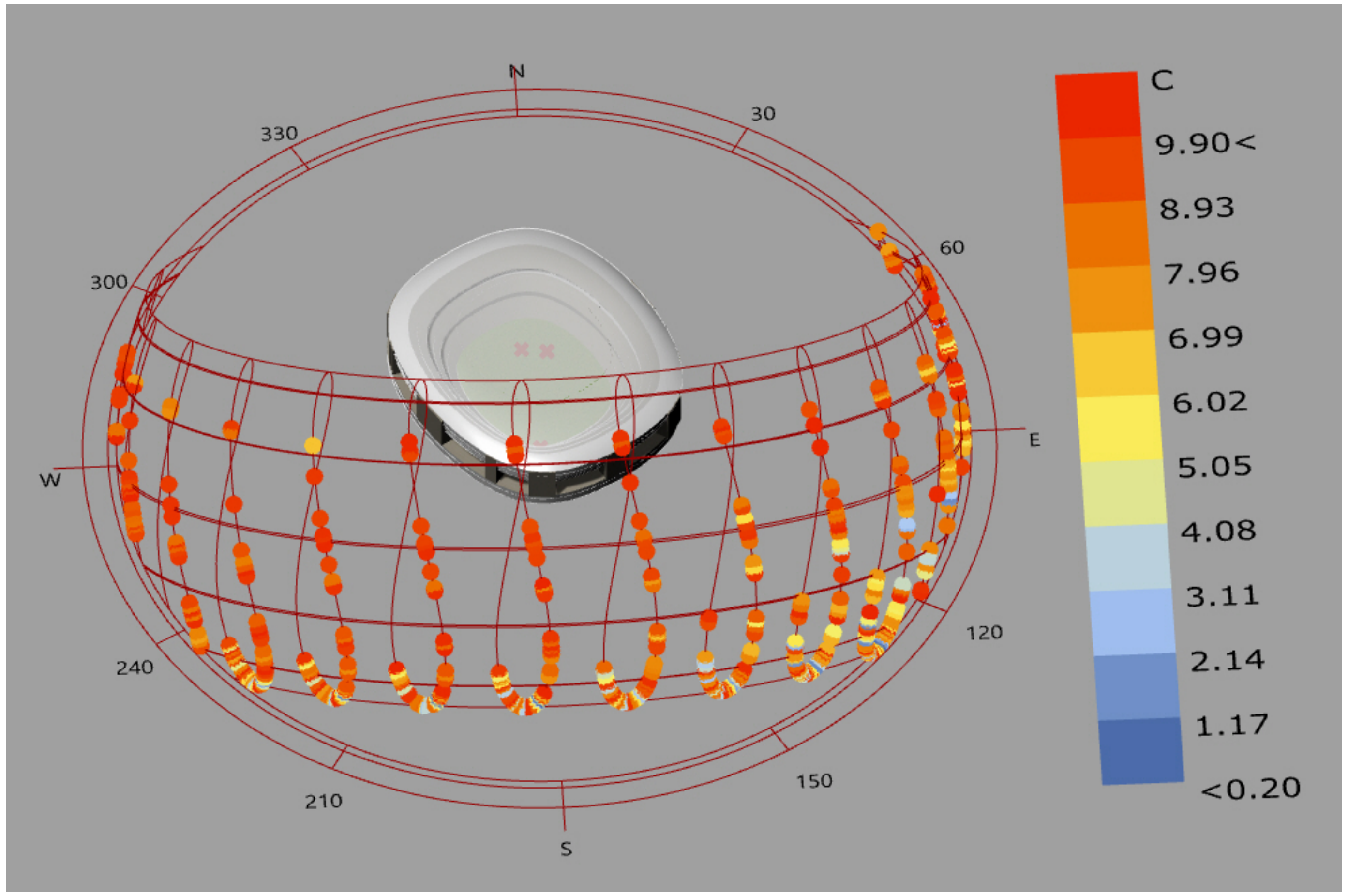
3ROOF

SOLAR ANALYSIS AND SUN-PATH

Spring/Summer

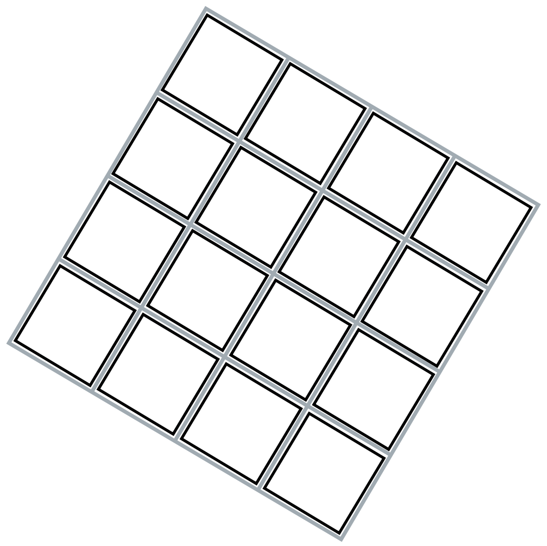


All year



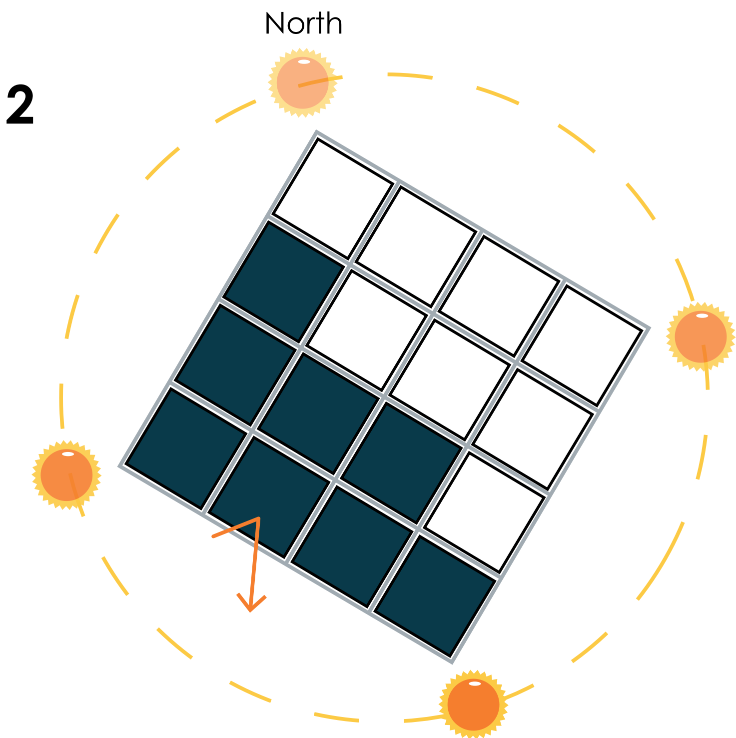
To determine where roof needs to be shaded the most, and where to allow for daylight.

1



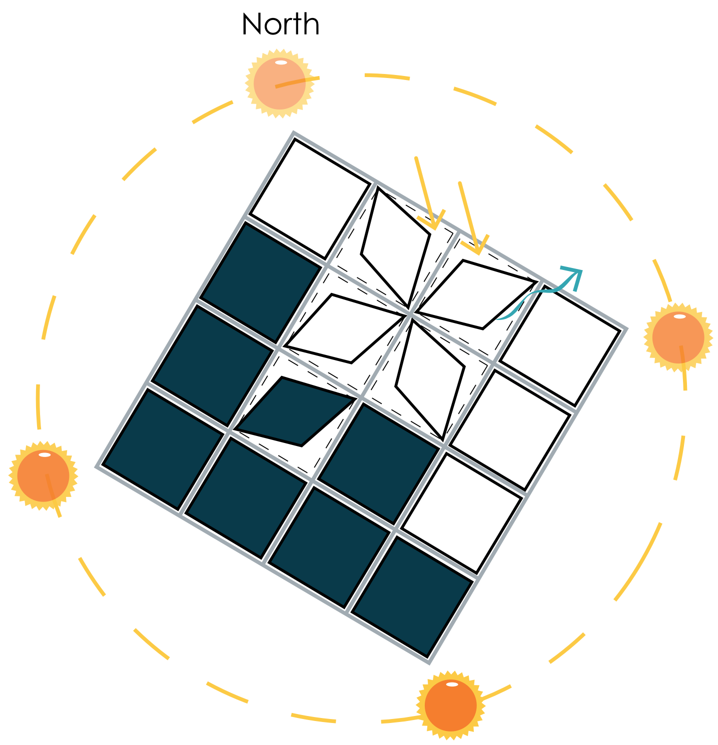
Panels fit the structural grid

2



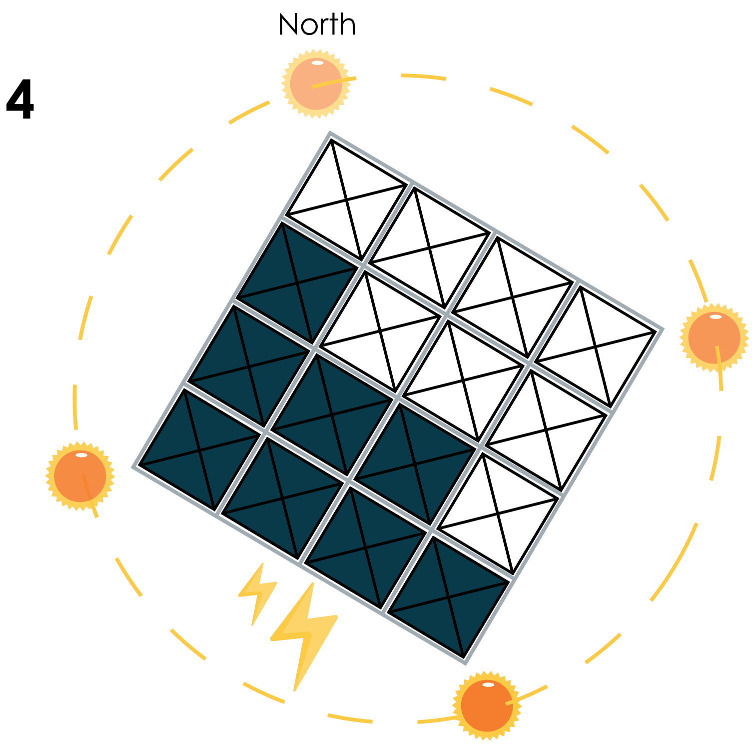
Materials according to the solar analysis

3

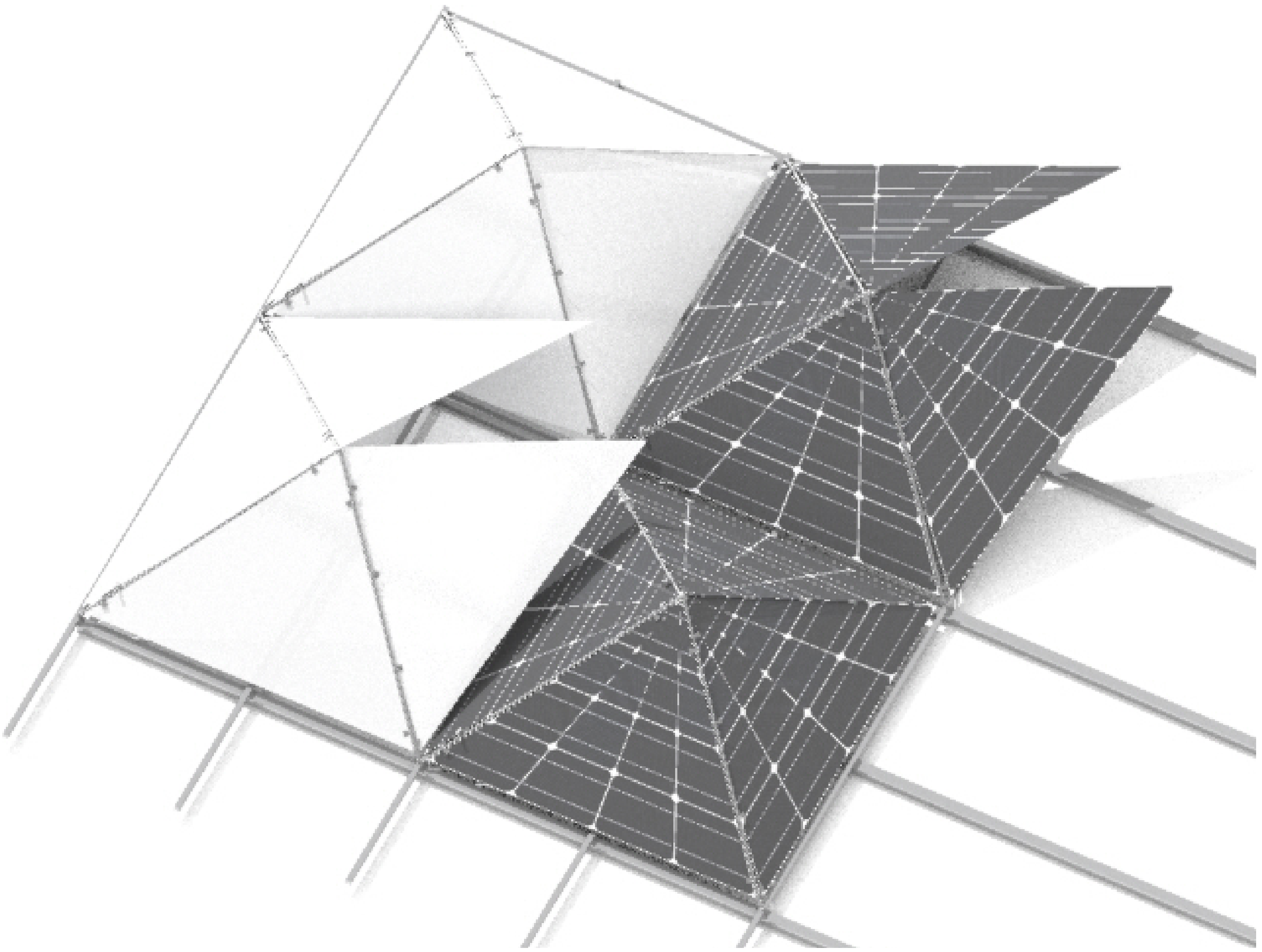


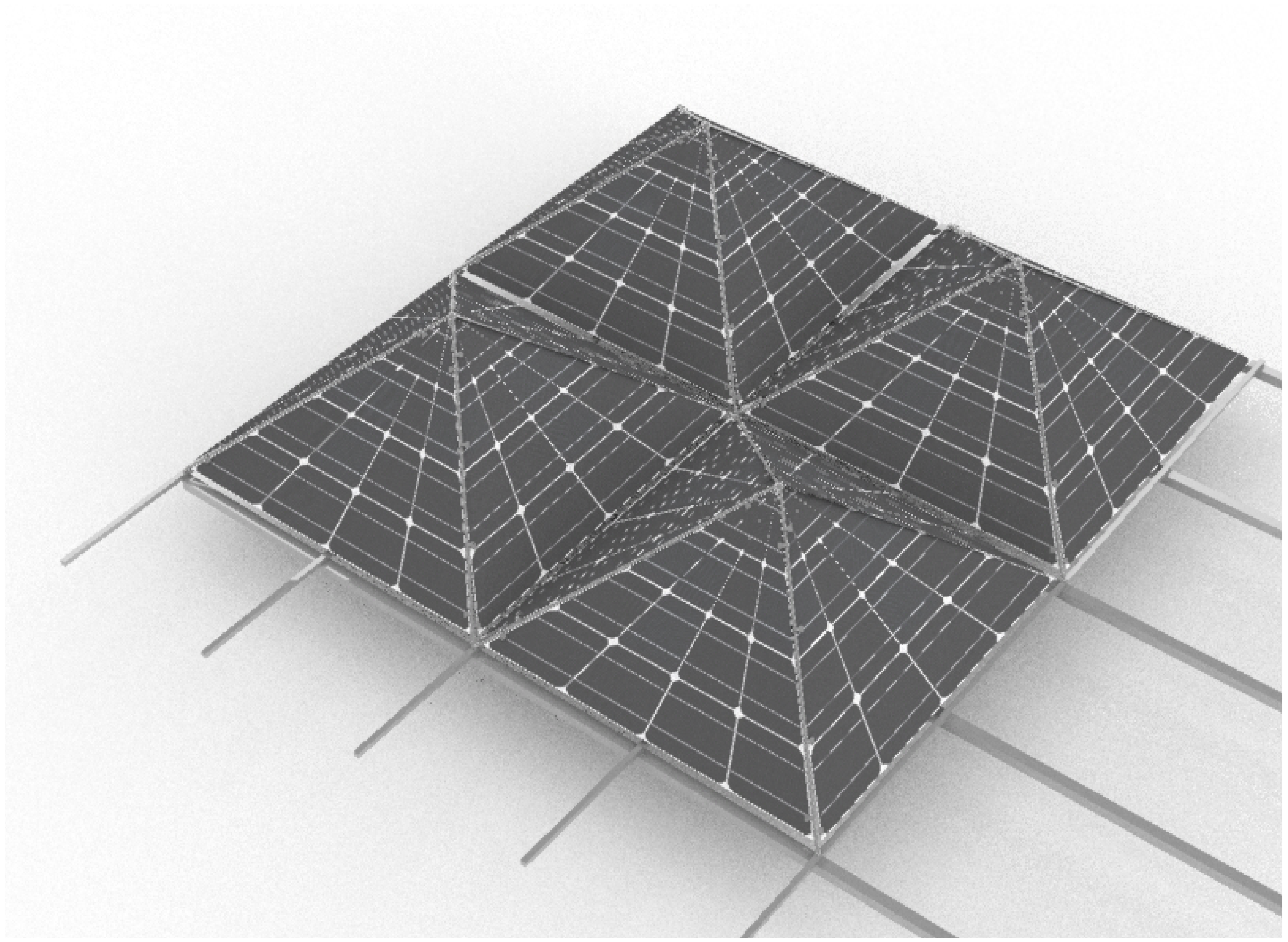
Panel open/closed

4

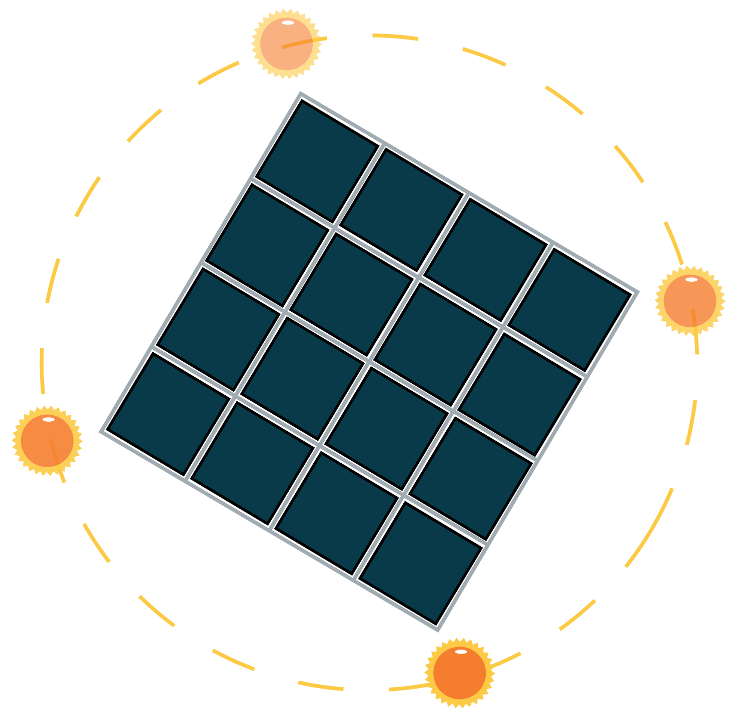


Optimization of the geometry for energy production

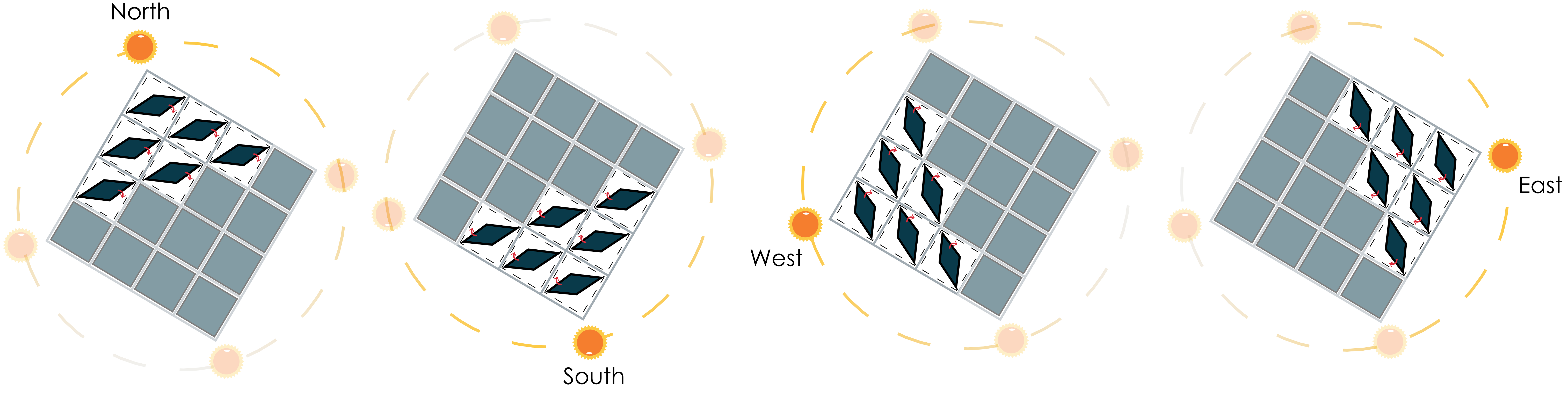


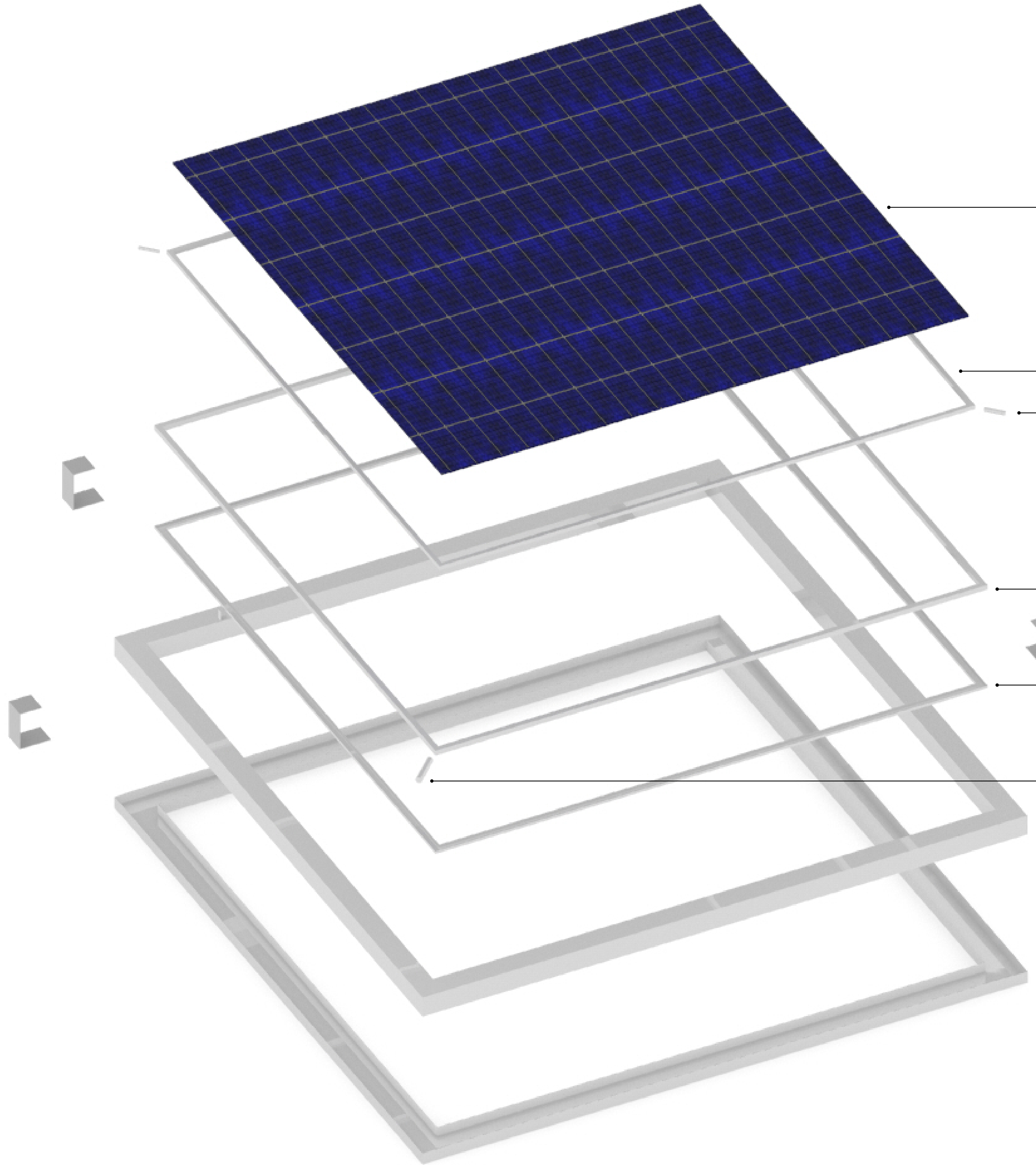


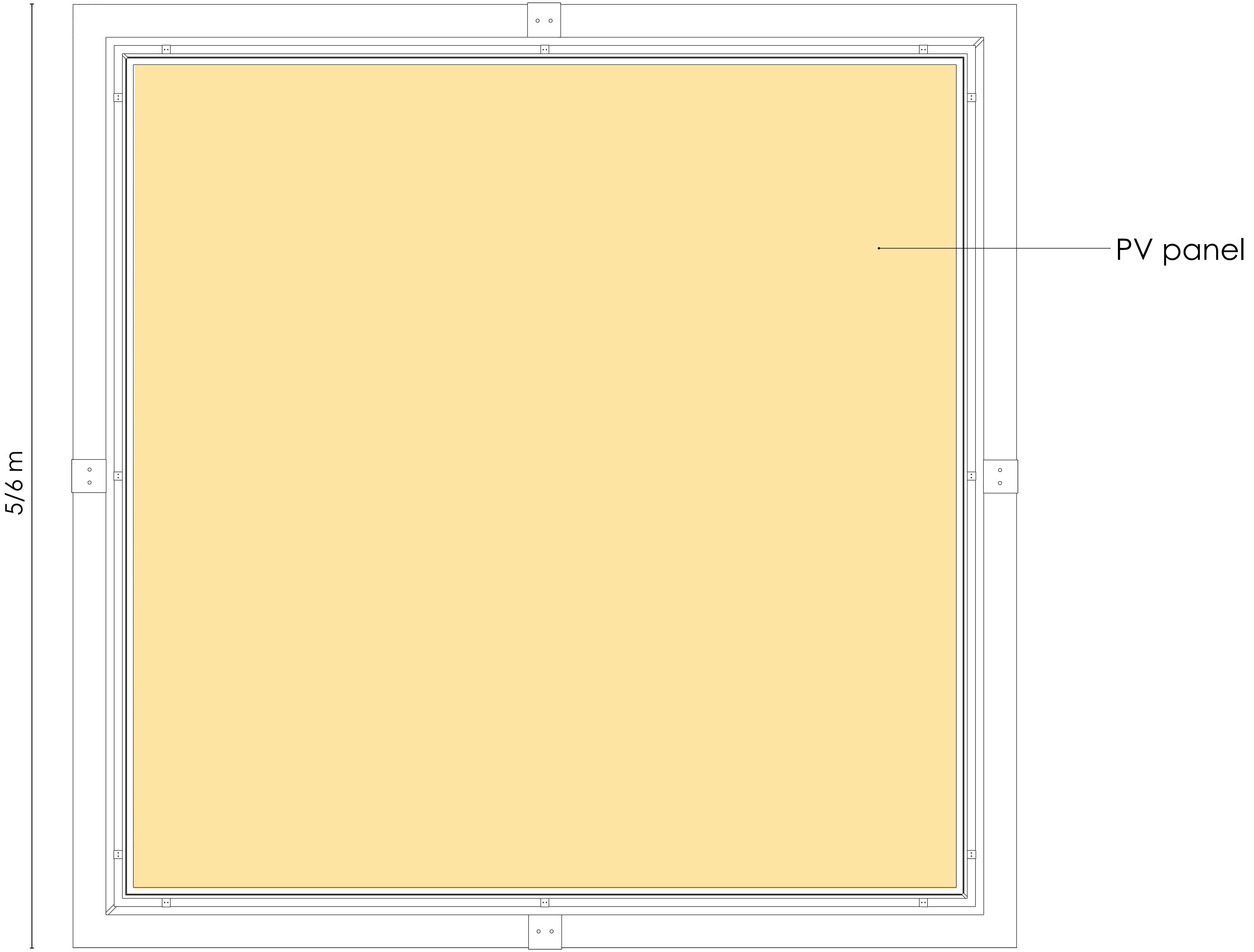
5

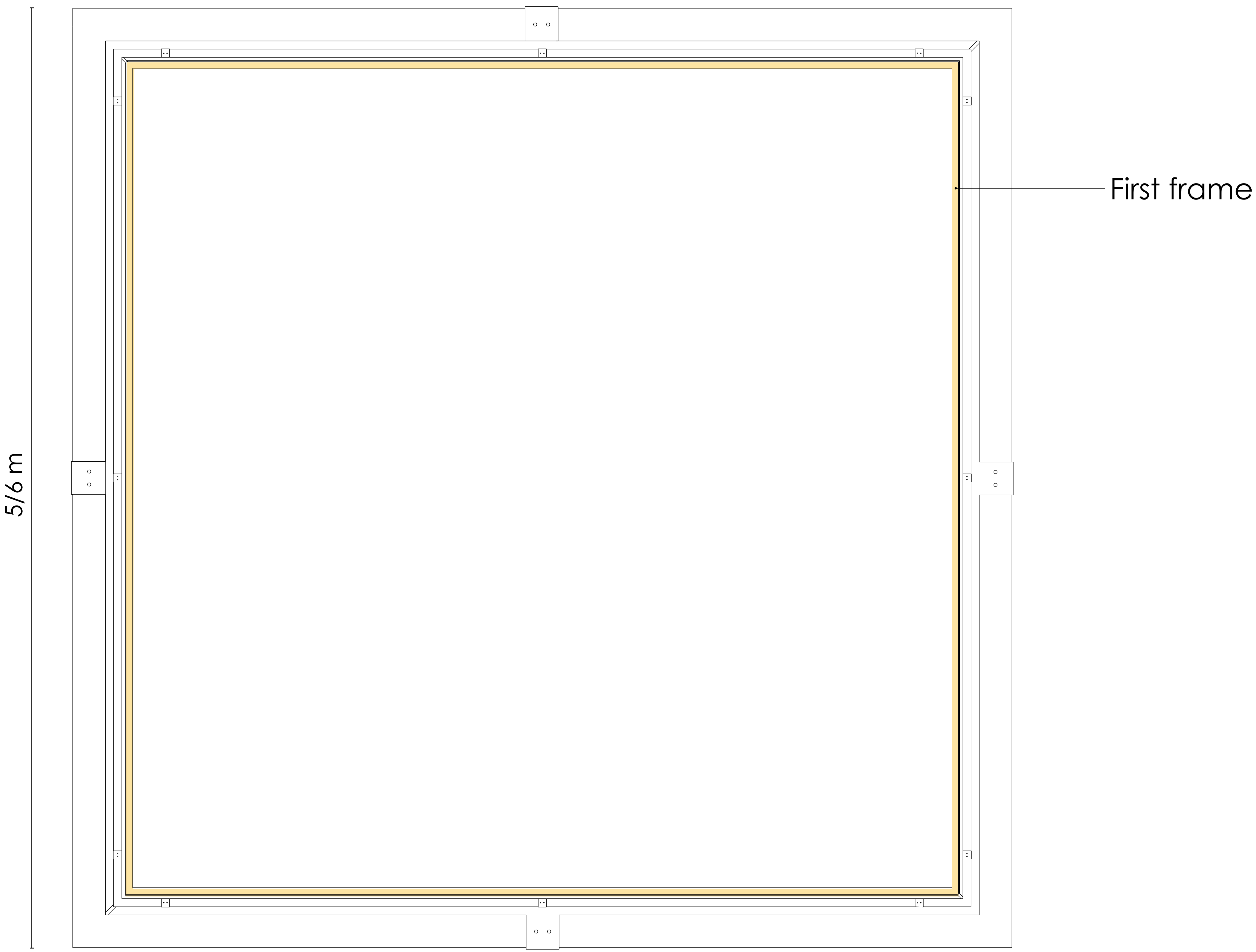


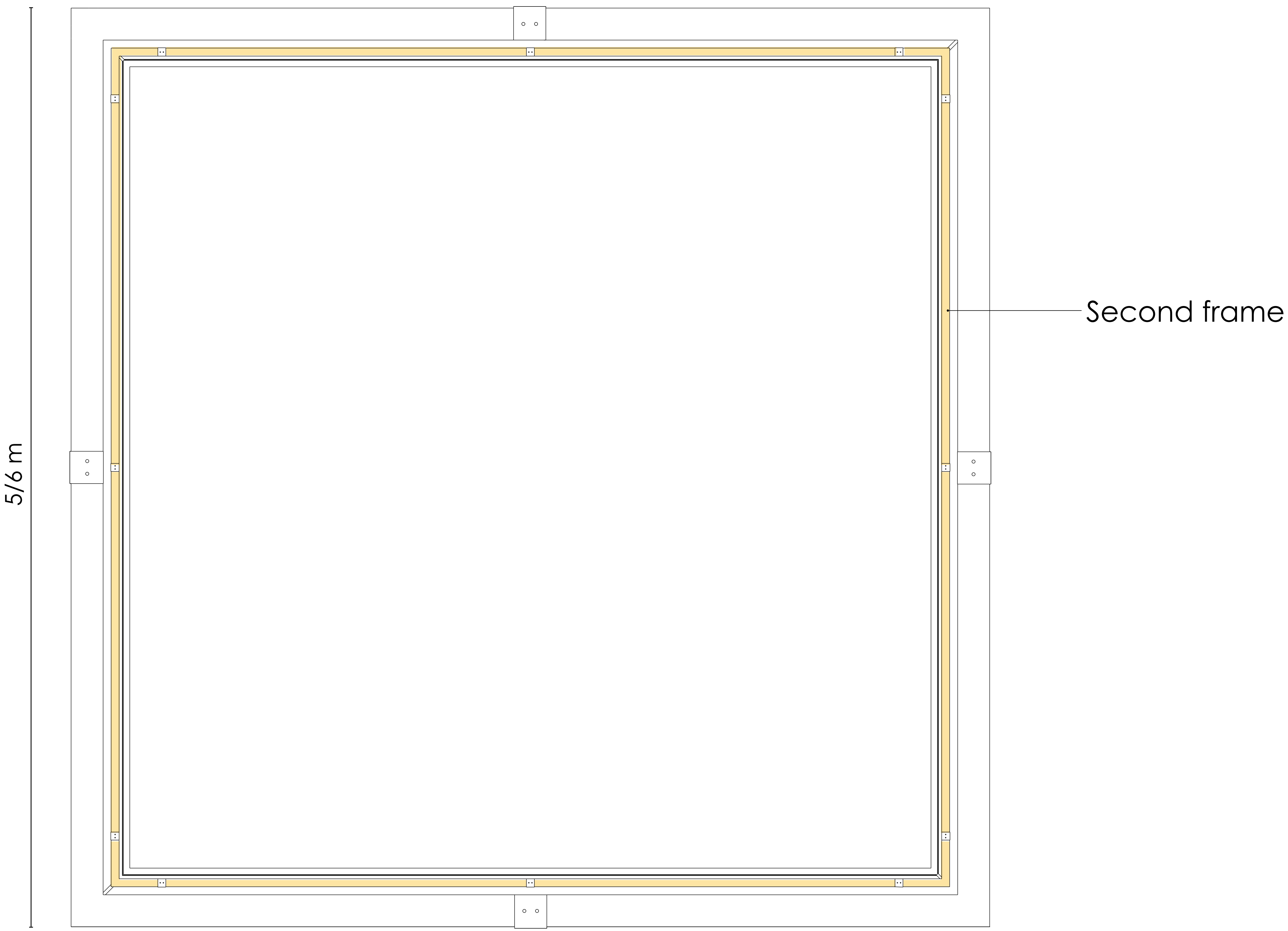
Panels follow the sun

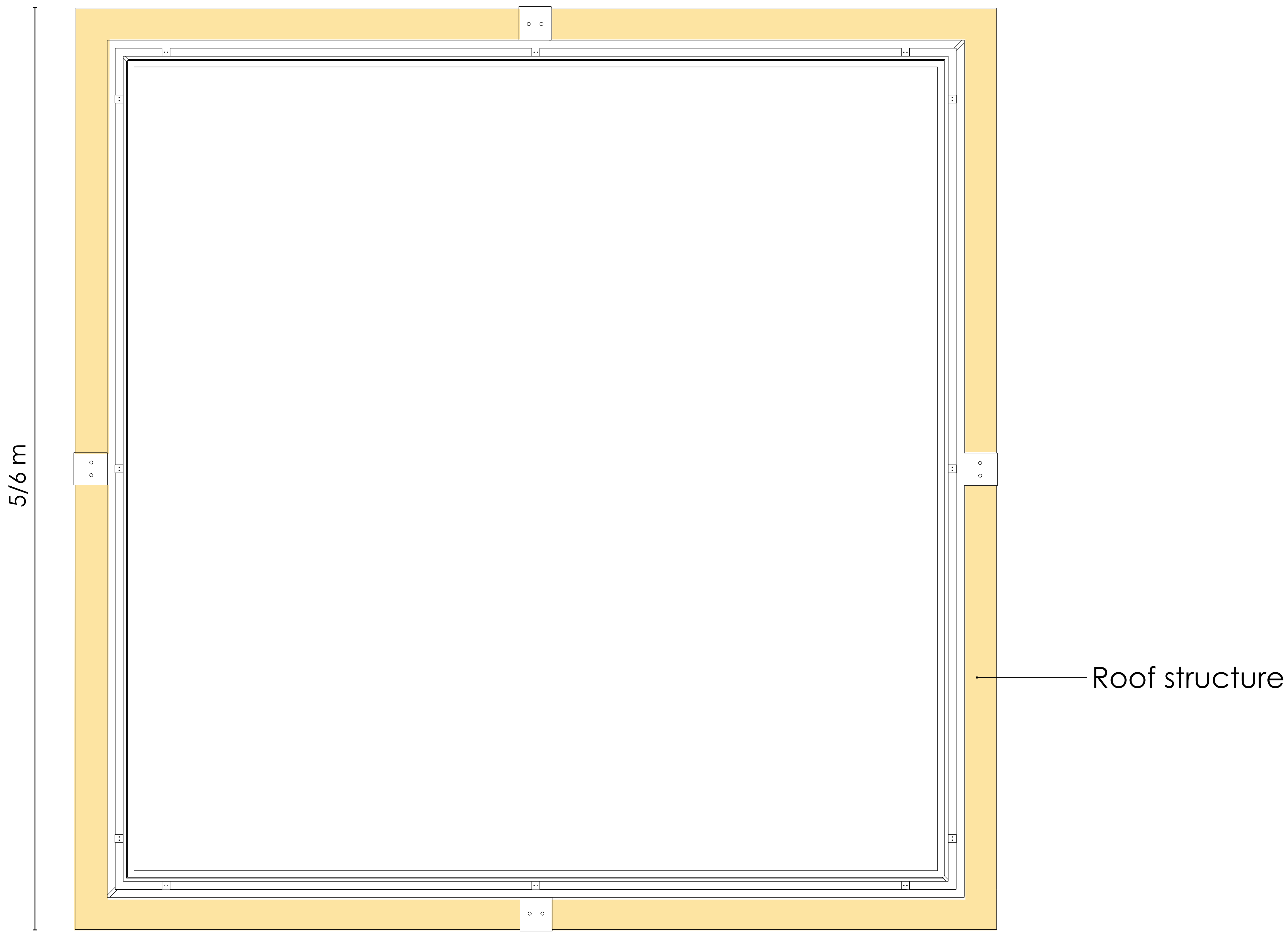


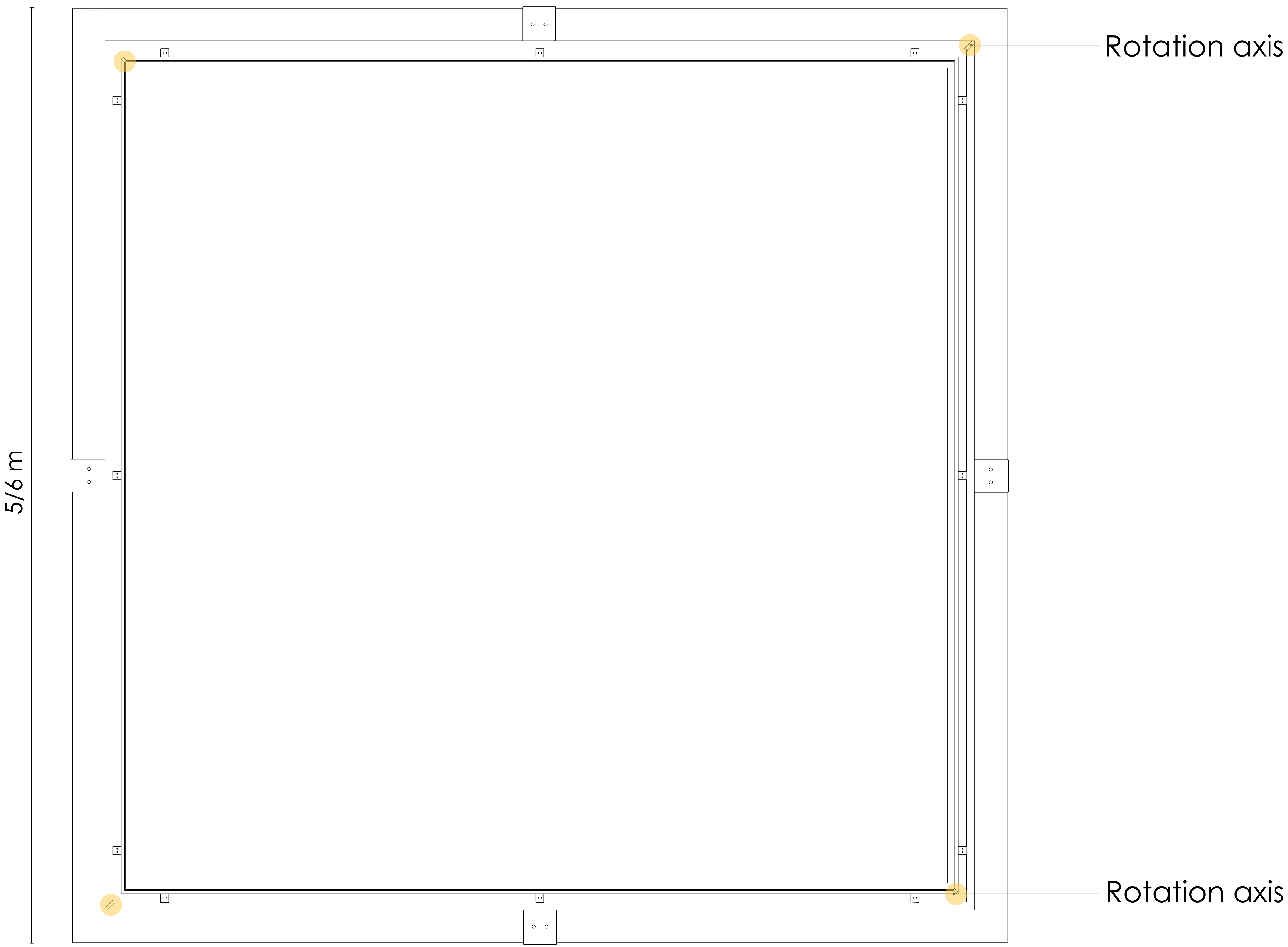

PV panel
First frame
Rotation axis
Second frame
Connection second frame-gutter
Gutter
Rotation axis
Roof structure
Connection structure-gutter
Gutter

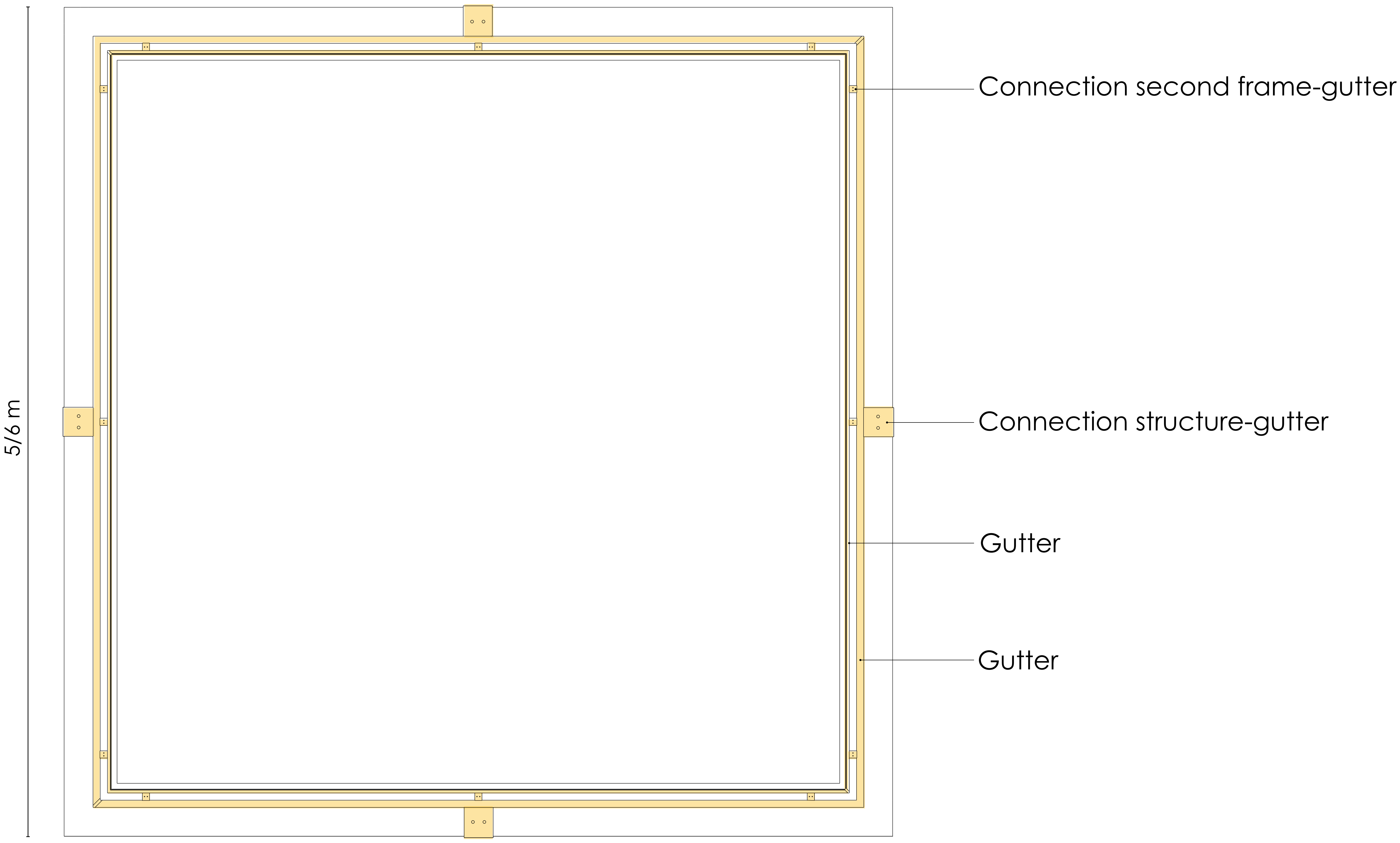

PV panel
5/6 m

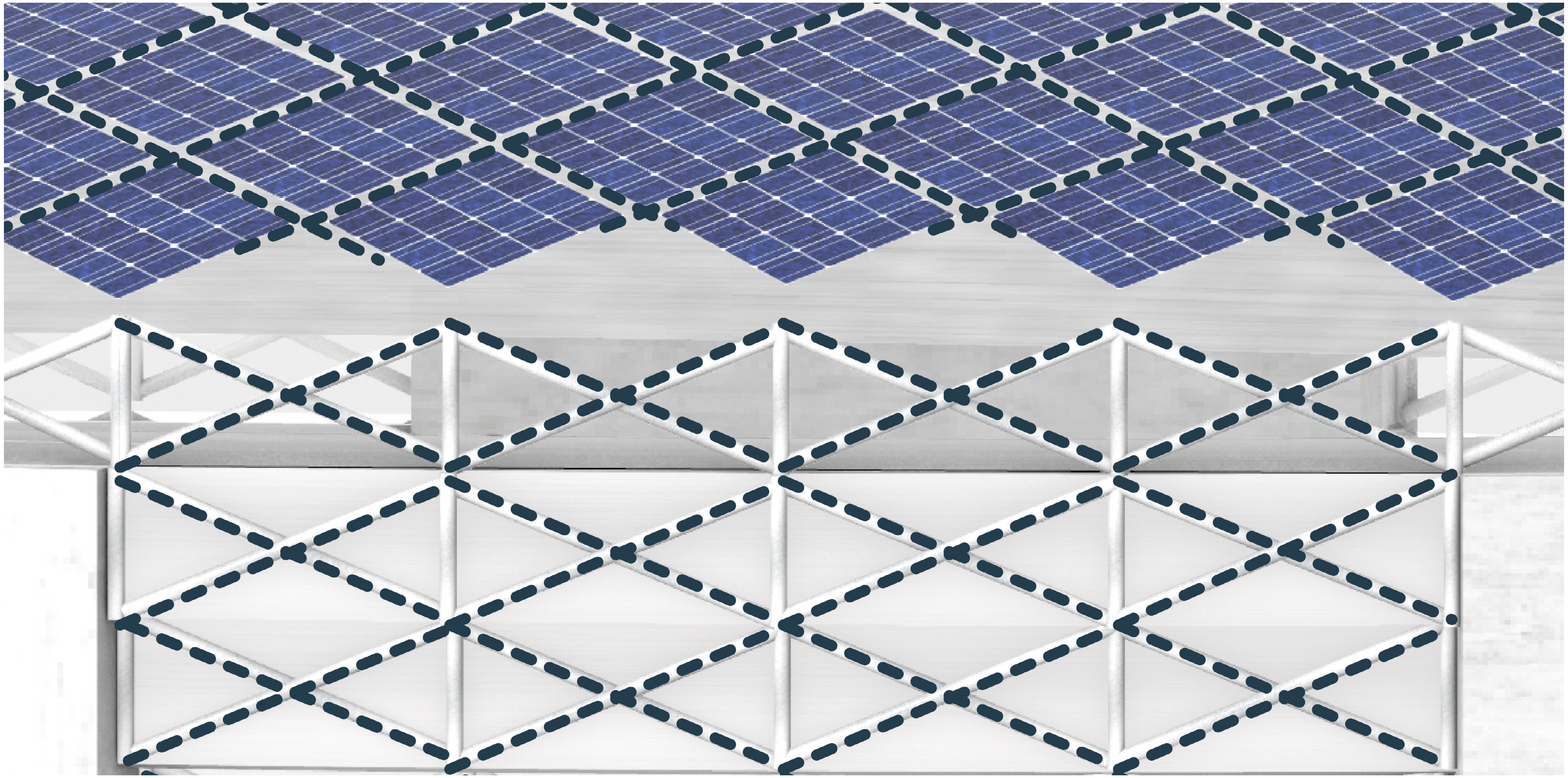

5/6 m
First frame


5/6 m
Second frame


5/6 m
Roof structure


5/6 m
Rotation axis
Rotation axis

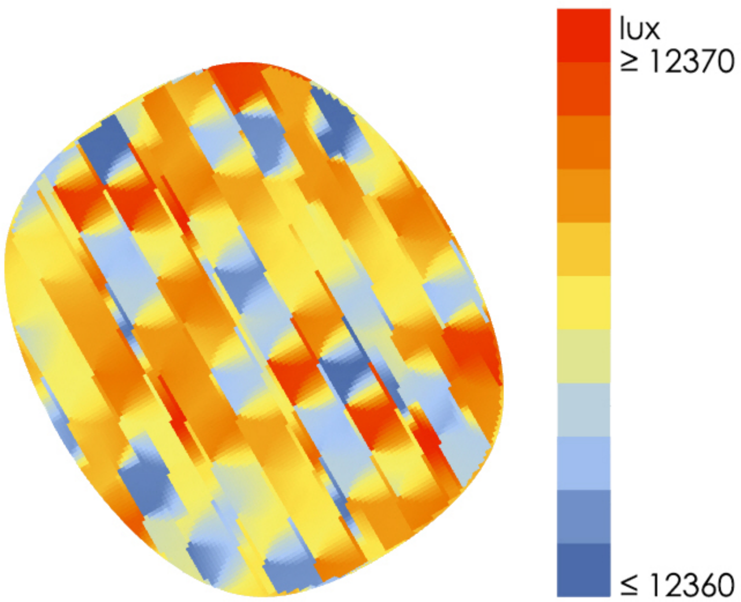

5/6 m
Connection second frame-gutter
Connection structure-gutter
Gutter
Gutter



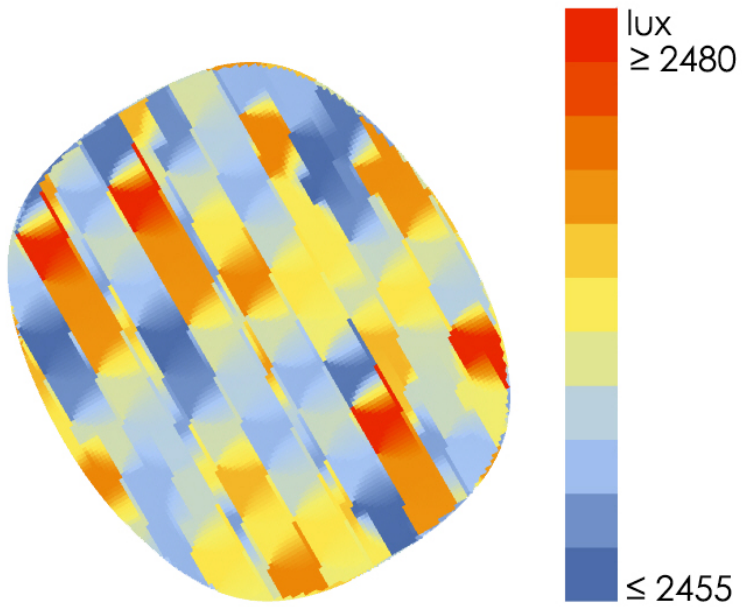
2000 lux

Hourly

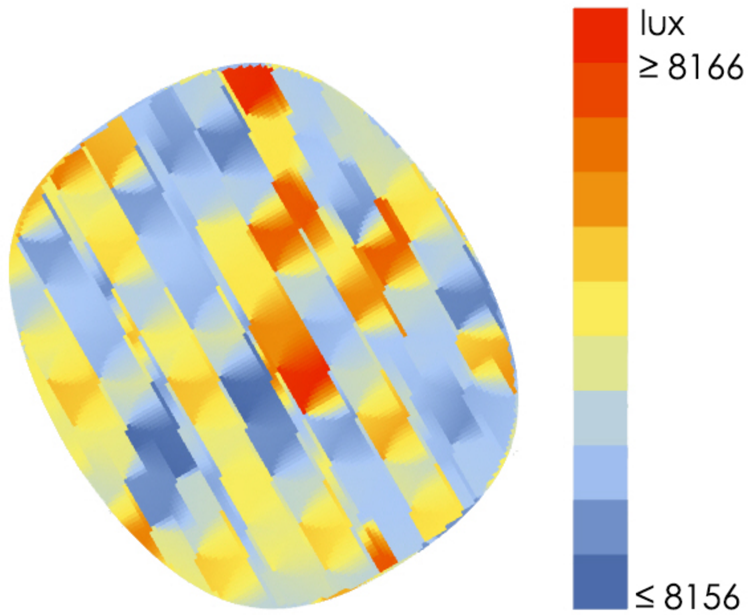
21/06
maximum



21/12
minimum

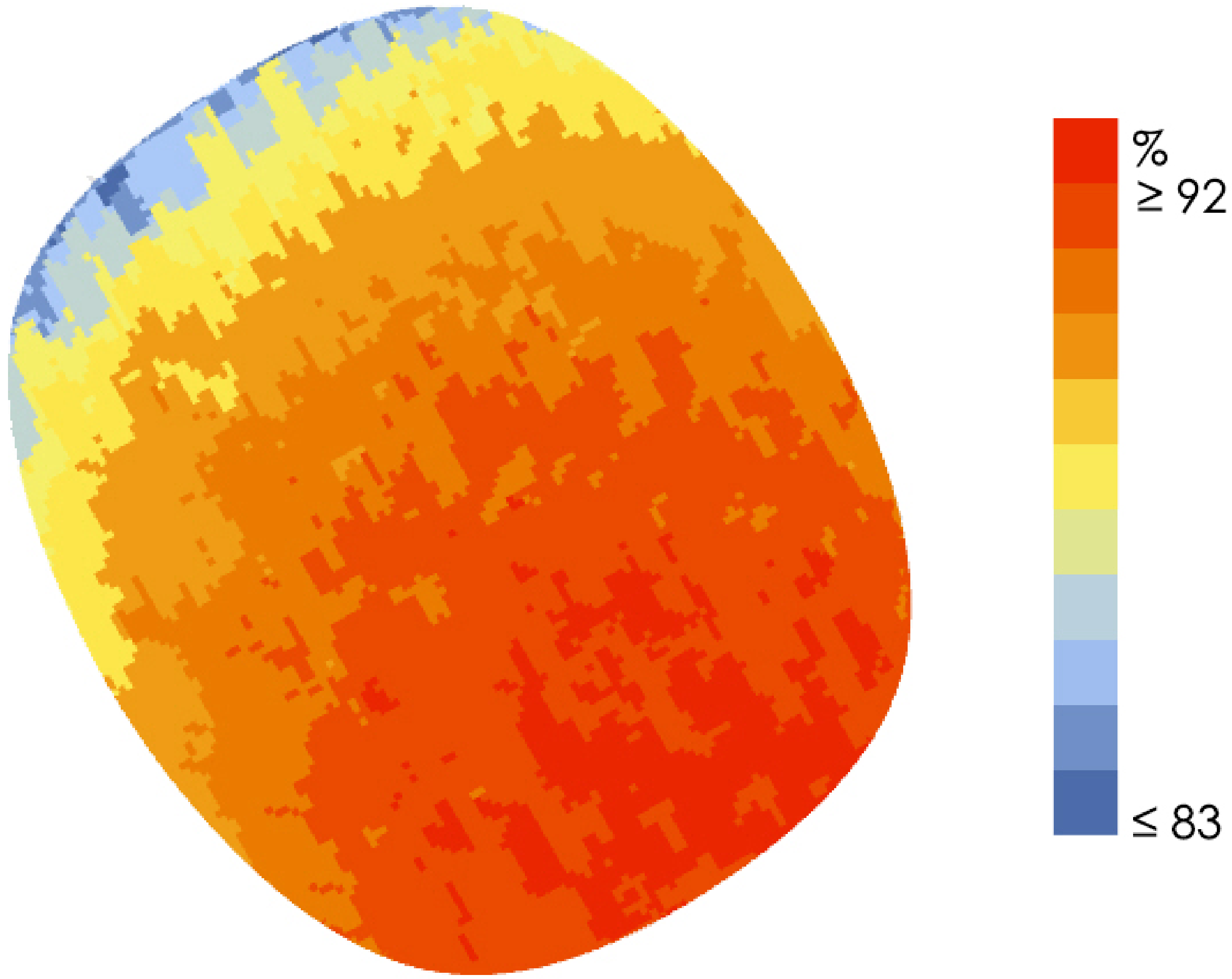


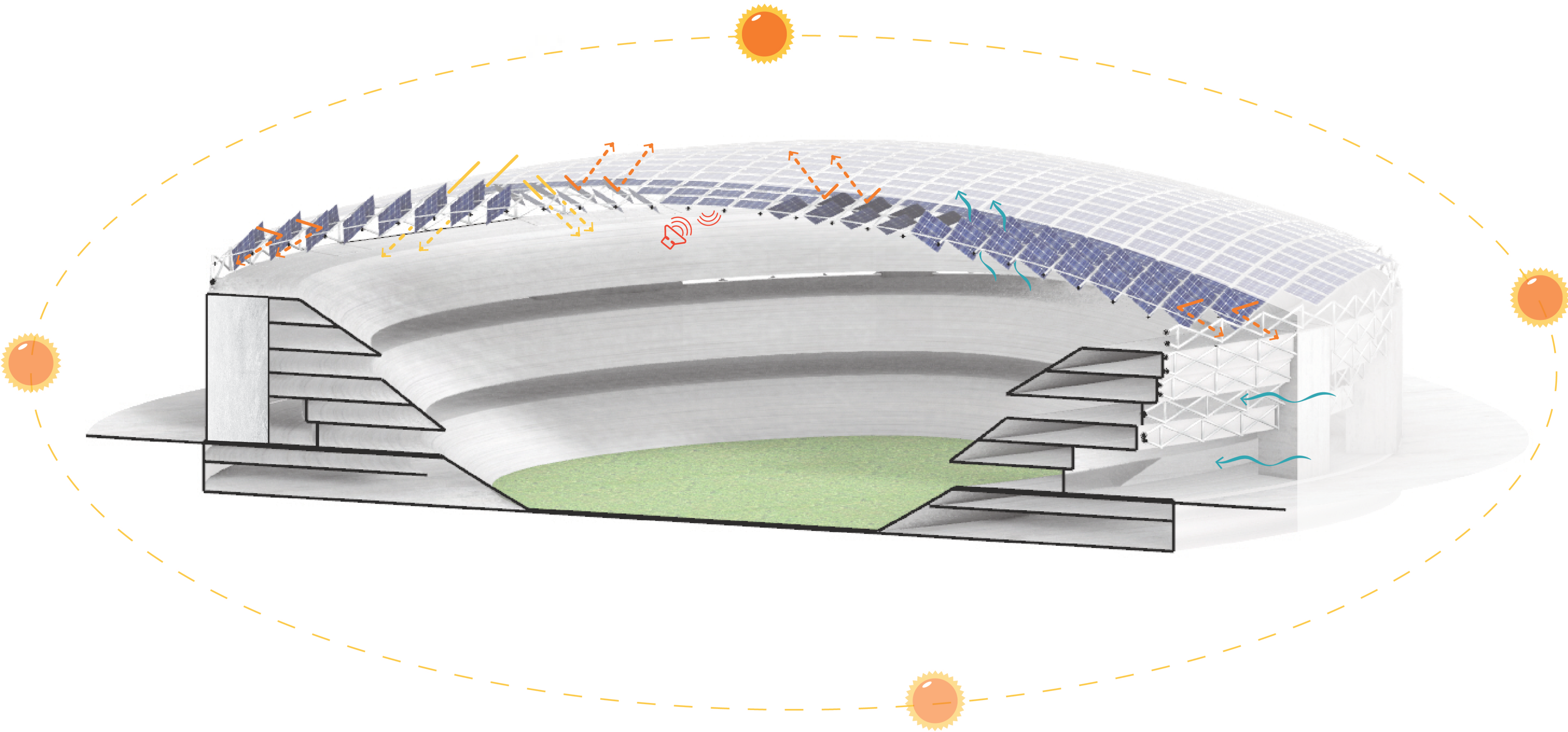
21/03
average



2000 lux

Annual





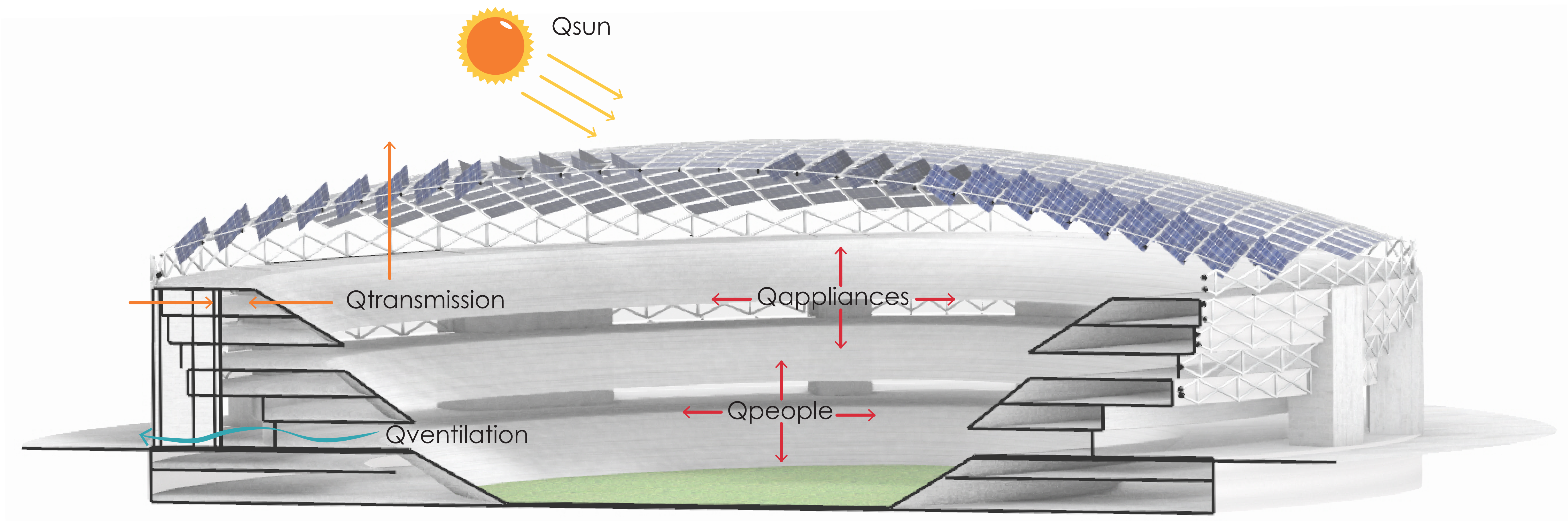
Reference projects

National Stadium Taiwan

Adaptive Solar Façade

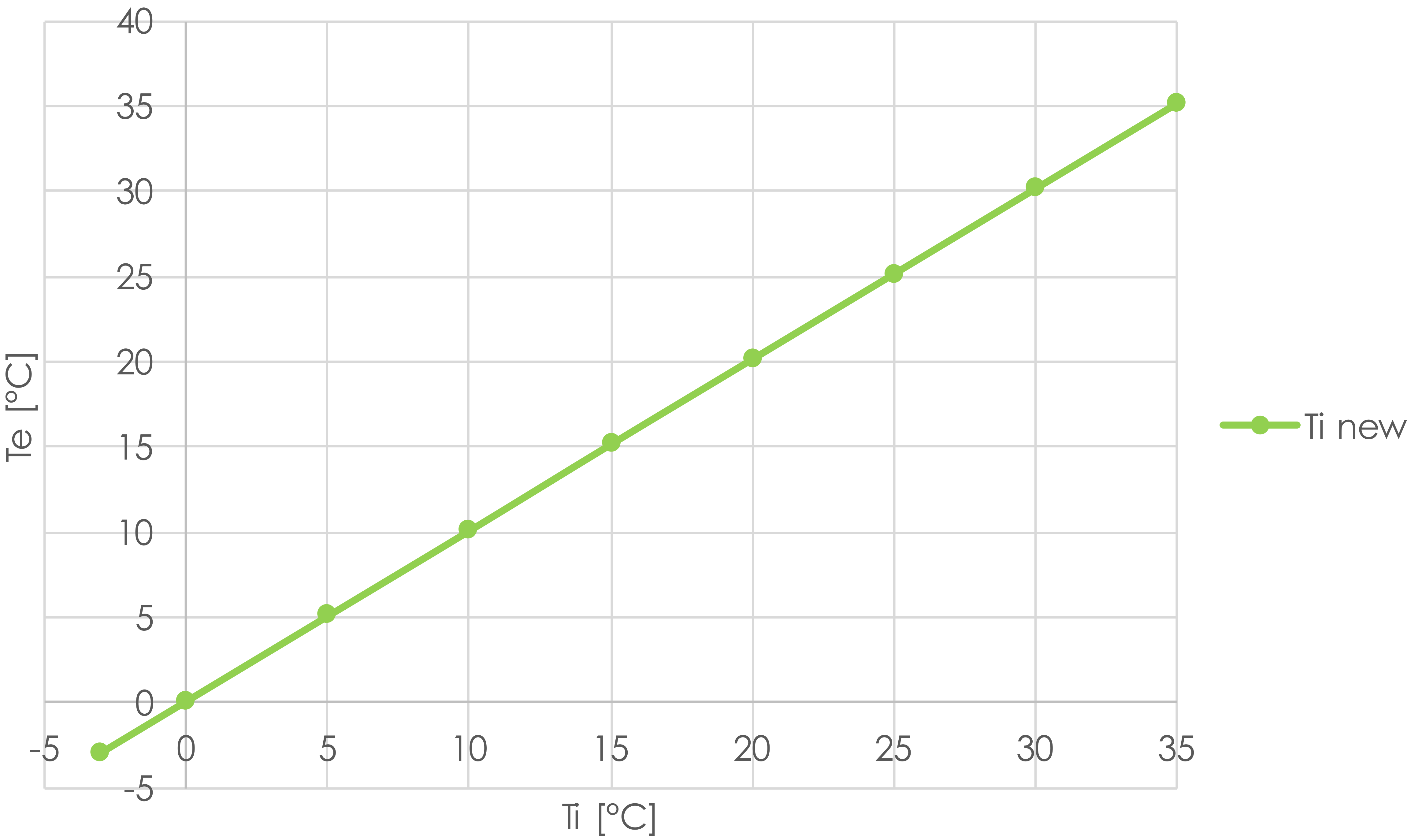
TEMPERATURE

T [°C]	max	35
	min	-3
Solar irradiance[W/m2]	summer	1000
	winter	150
ACH [1/h]	5.8	
Volume [m3]	2347967	
Metabolic rate [W/m2]	Football match	167.4
	Concert	522
New materials	External façade	aluminium
	Roof	PVs



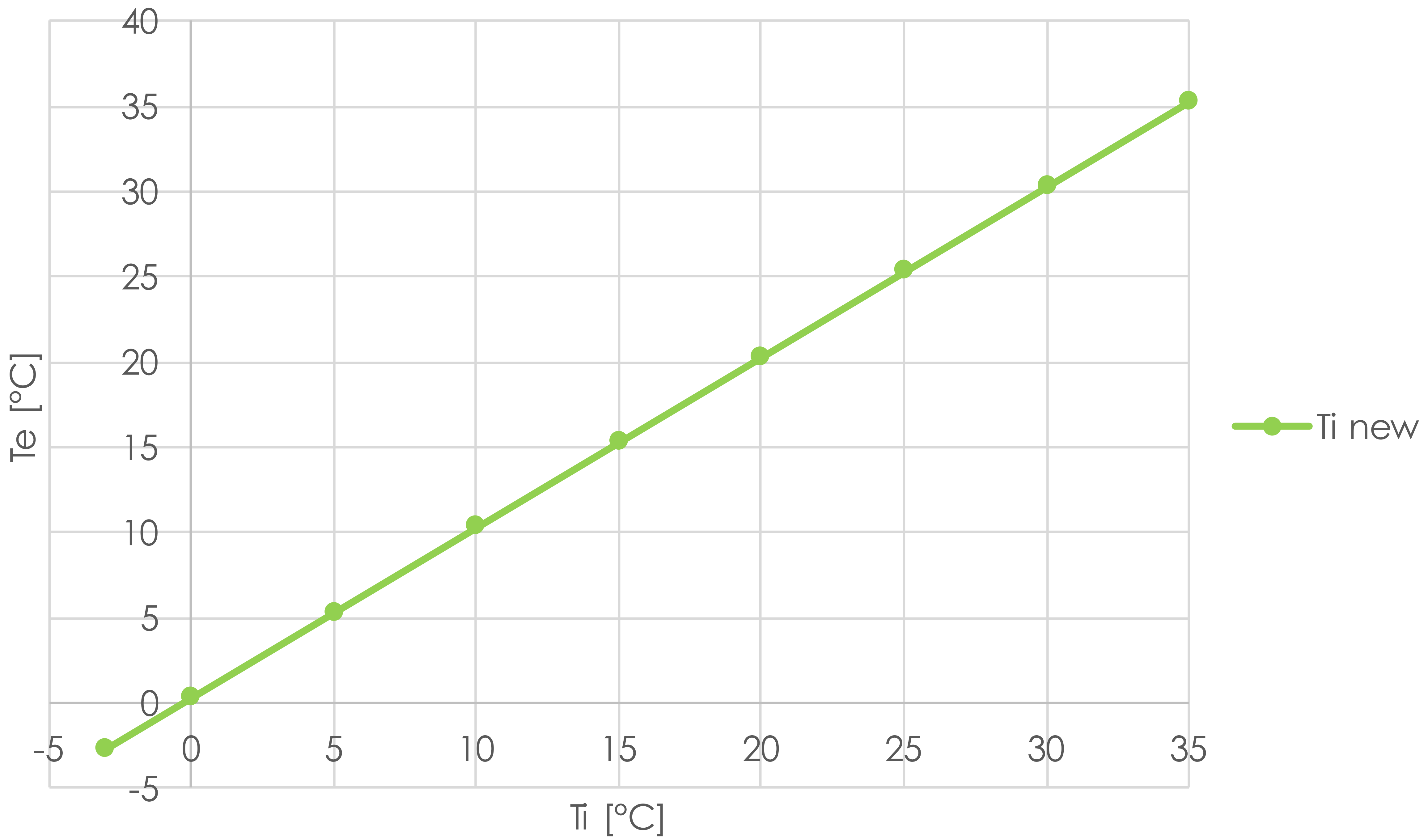
EXTREME TEMPERATURES

Football match



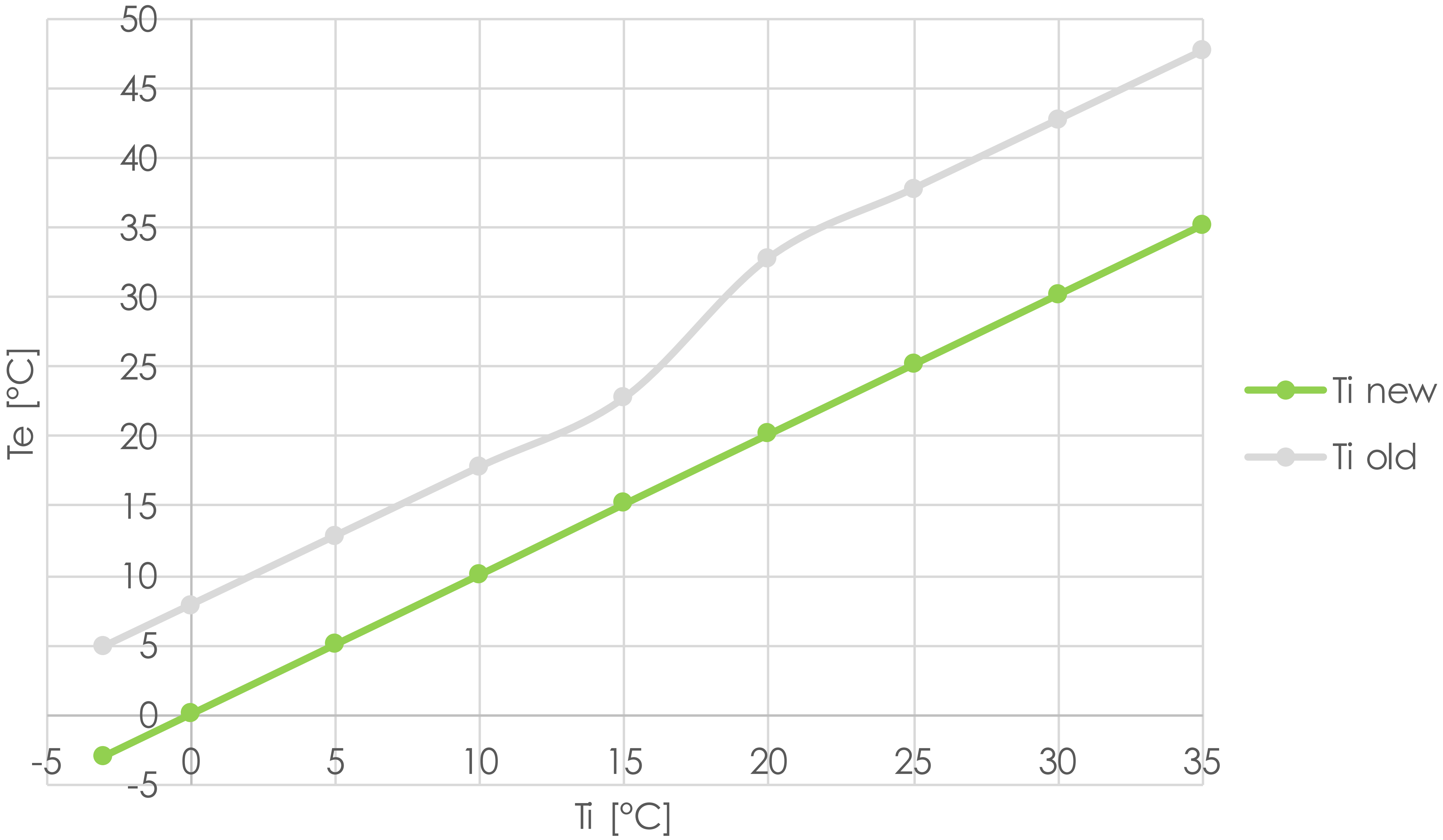
EXTREME TEMPERATURES

Concert



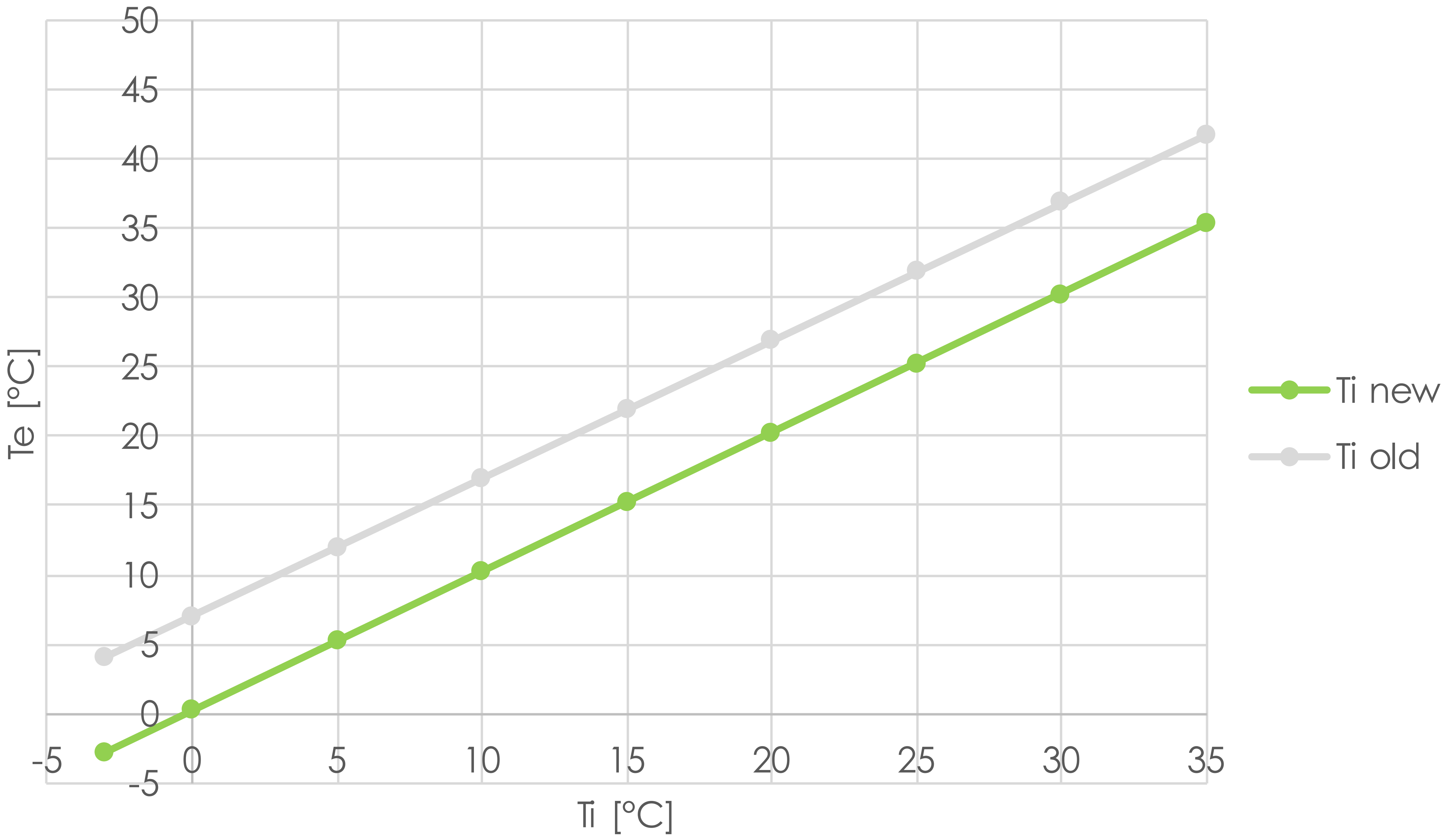
EXTREME TEMPERATURES

Football match

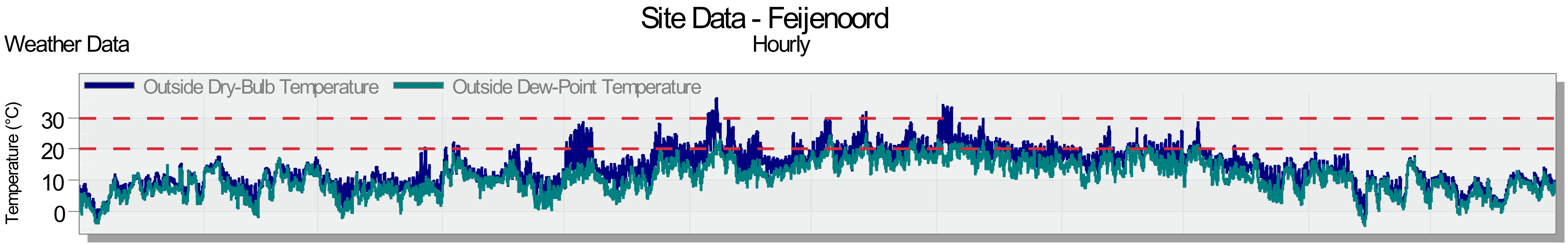


EXTREME TEMPERATURES

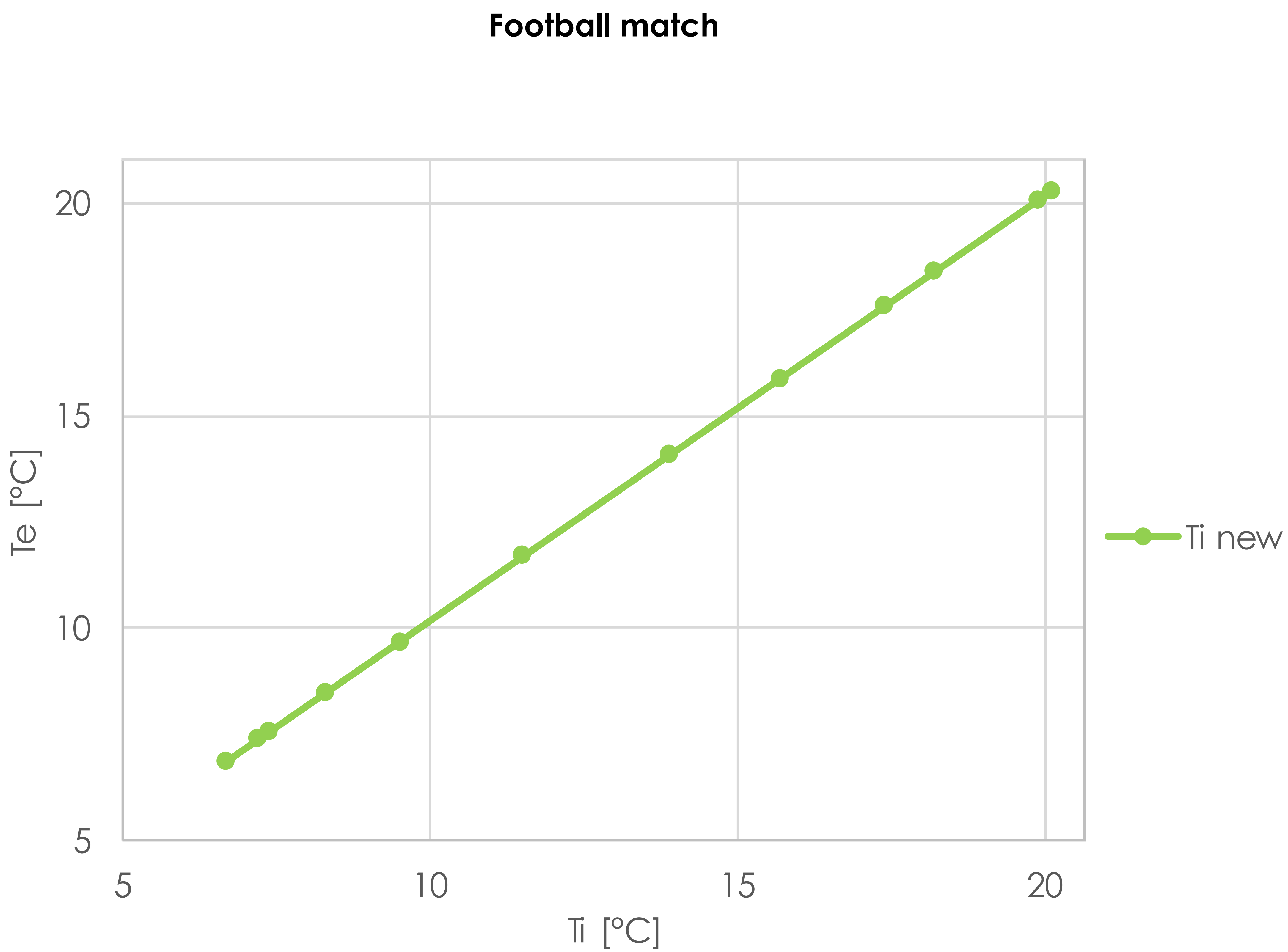
Concert



MONTHLY AVERAGE TEMPERATURE

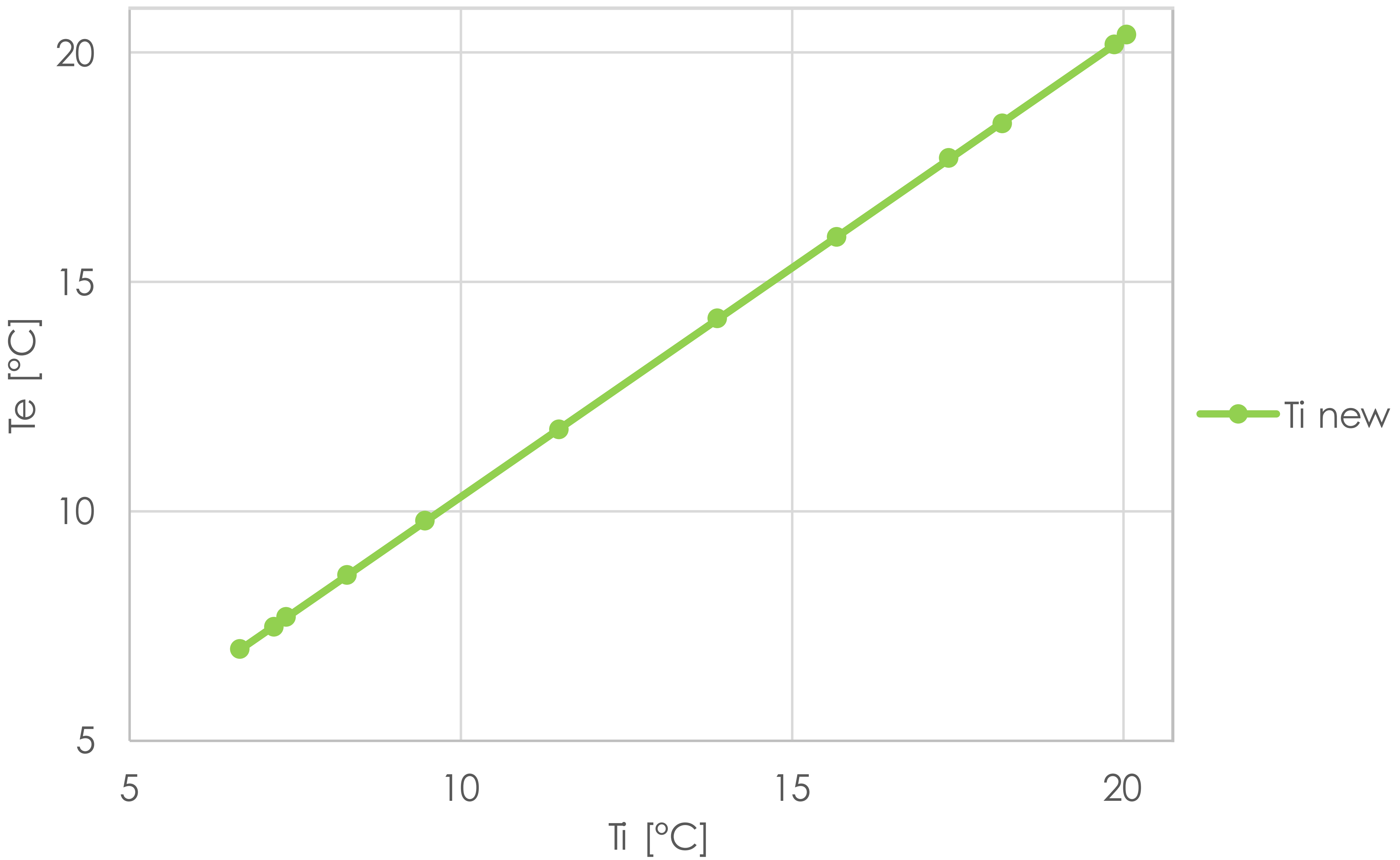


MONTHLY AVERAGE TEMPERATURE

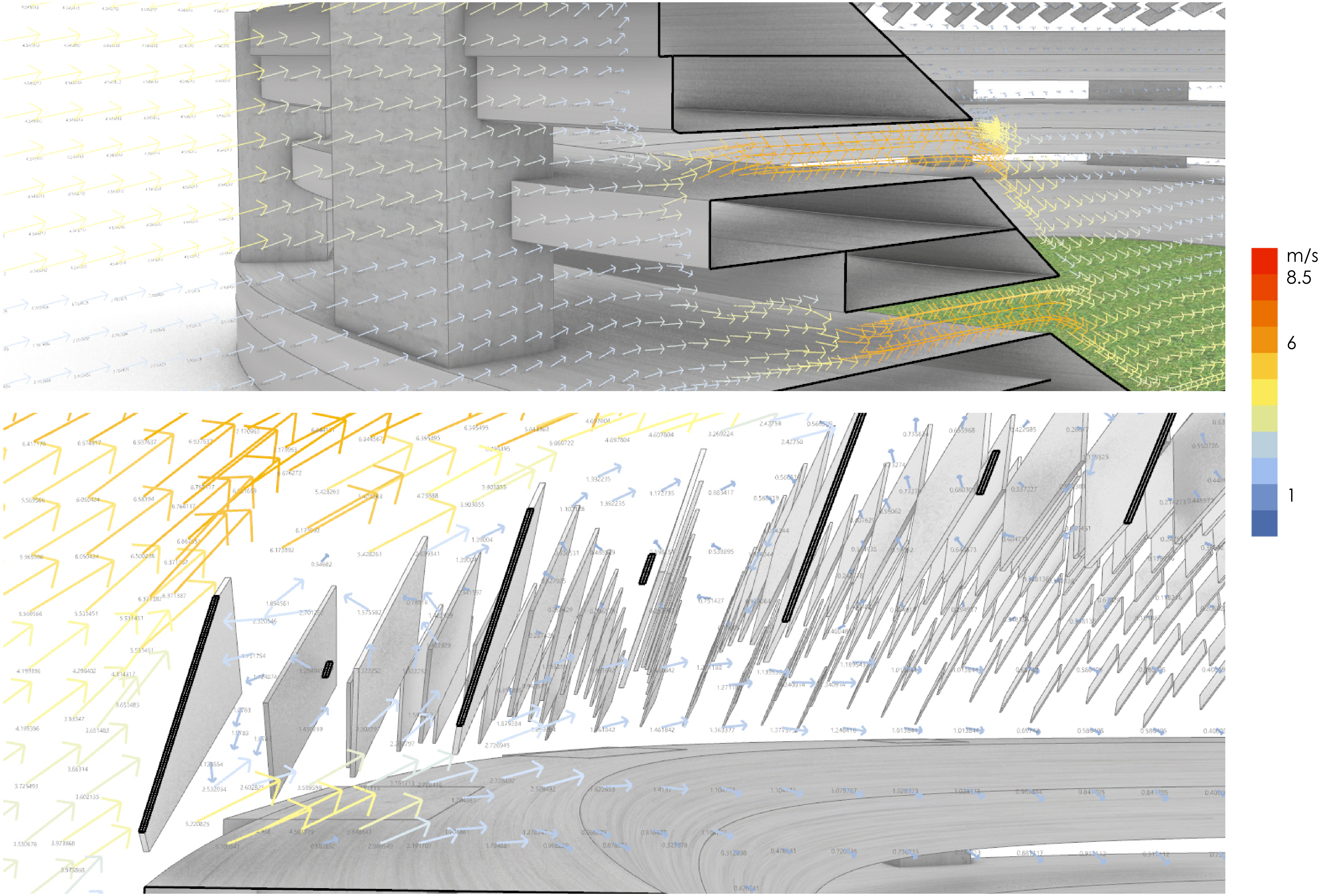


MONTHLY AVERAGE TEMPERATURE

Concert

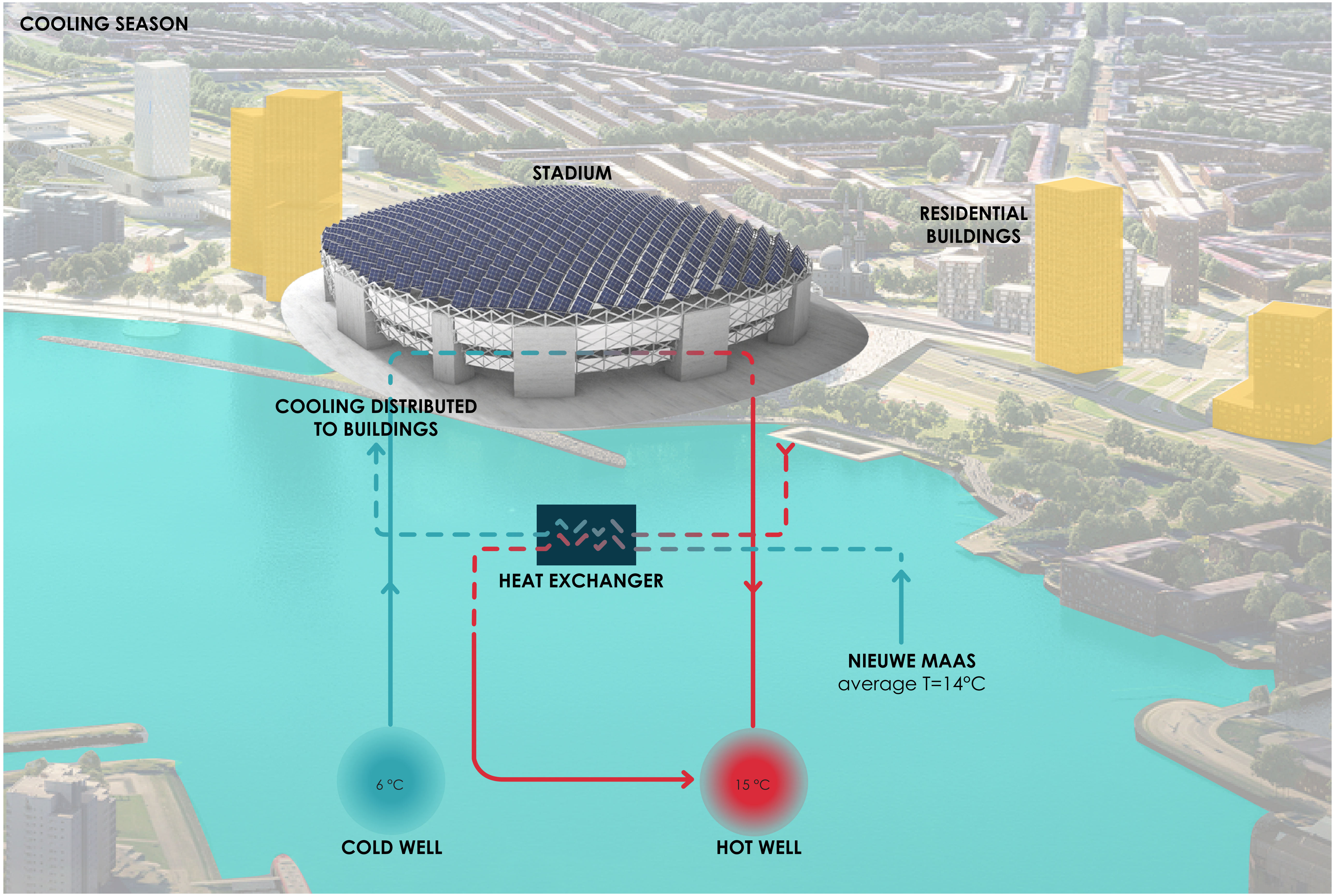


AIR FLOW

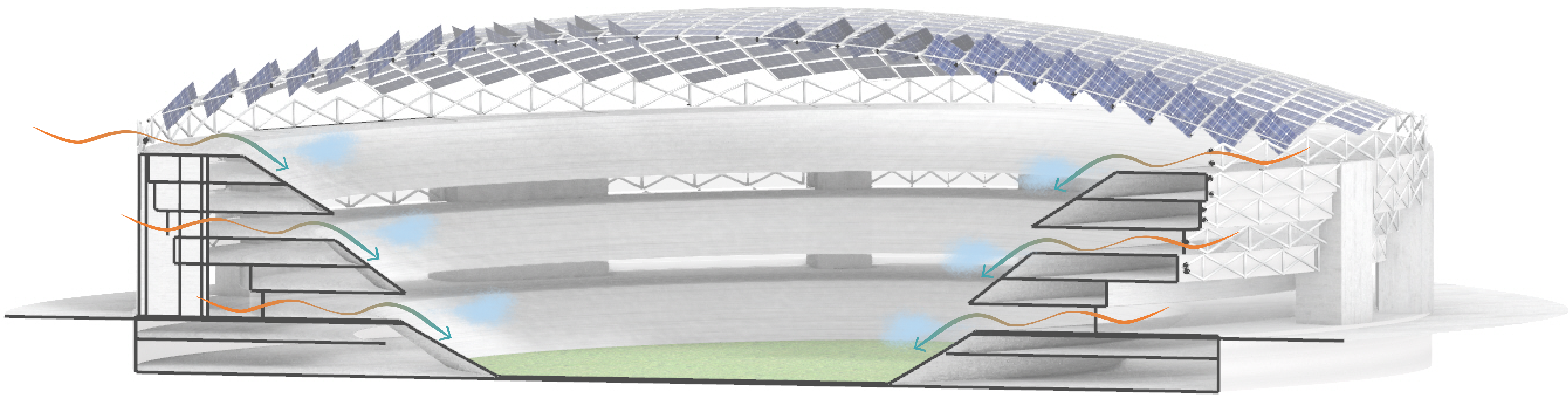


4 EXTRA MEASURES

ATES + NIEUWE MAAS district



LOCAL COOLING



Air nozzles at the top of the tiers in correspondence of the **open levels**.

The **air coming from outside through the concourses mixes with the colder air supplied by the nozzles**.

The design of the new Feyenoord stadium should represent ***a model in terms of design approach*** *to make stadiums around the world adaptable to climate and climate change.*

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1) **Context and site analysis - Local characteristics**

*The design of the new Feyenoord stadium should represent **a model in terms of design approach** to make stadiums around the world adaptable to climate and climate change.*

1) Context and site analysis **- Local characteristics**
2) Objectives **- Starting points**

*The design of the new Feyenoord stadium should represent **a model in terms of design approach** to make stadiums around the world adaptable to climate and climate change.*

1) Context and site analysis - **Local characteristics**
2) Objectives - **Starting points**
3) Parameters - **Boundary conditions**

*The design of the new Feyenoord stadium should represent **a model in terms of design approach** to make stadiums around the world adaptable to climate and climate change.*

1) Context and site analysis **- Local characteristics**
2) Objectives **- Starting points**
3) Parameters **- Boundary conditions**
4) Design **- Smart solution**

*The design of the new Feyenoord stadium should represent **a model in terms of design approach** to make stadiums around the world adaptable to climate and climate change.*

1) Context and site analysis - **Local characteristics**
2) Objectives - **Starting points**
3) Parameters - **Boundary conditions**
4) Design - **Smart solution**
5) Validation

CONCLUSIONS

1 *How are the stadium and its surroundings **affected by climate change**, in particular by **raising temperatures**?*

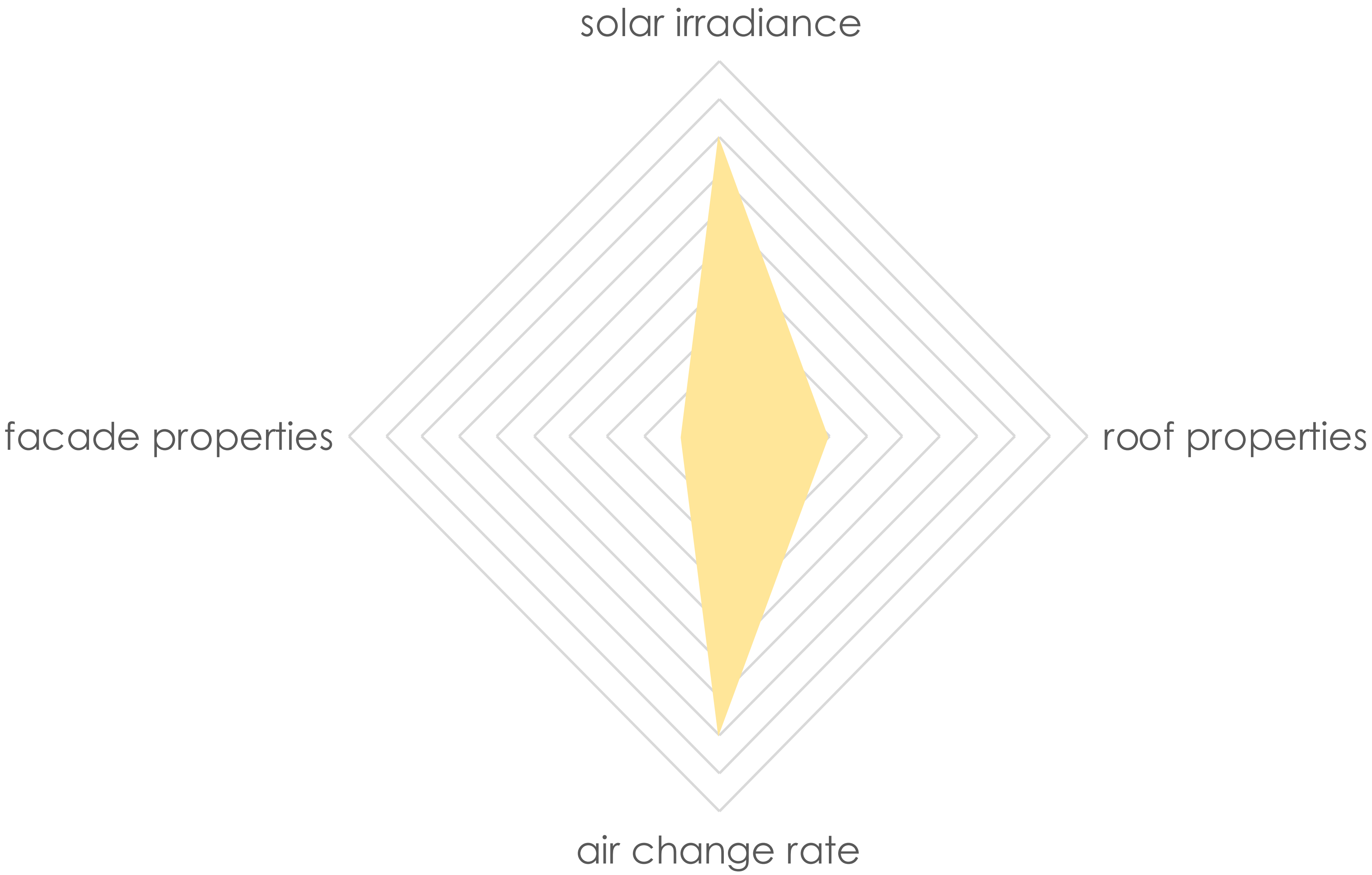
- VULNERABILITY
- HIGHER COOLING DEMAND
- URBAN HEAT ISLAND EFFECT

2 *How do **users' comfort** requirements vary according to the carried-out activity?*

Activity	Users	Heating	Cooling	Air quality	Sun protection	Wind protection	Rain protection	View	Acoustics
Football match	Players	±	++	++	+	±	±	-	-
	Spectators	±	++	+	+	+	+	++	±
Concert	Spectators	±	+	+	+	+	+	++	++

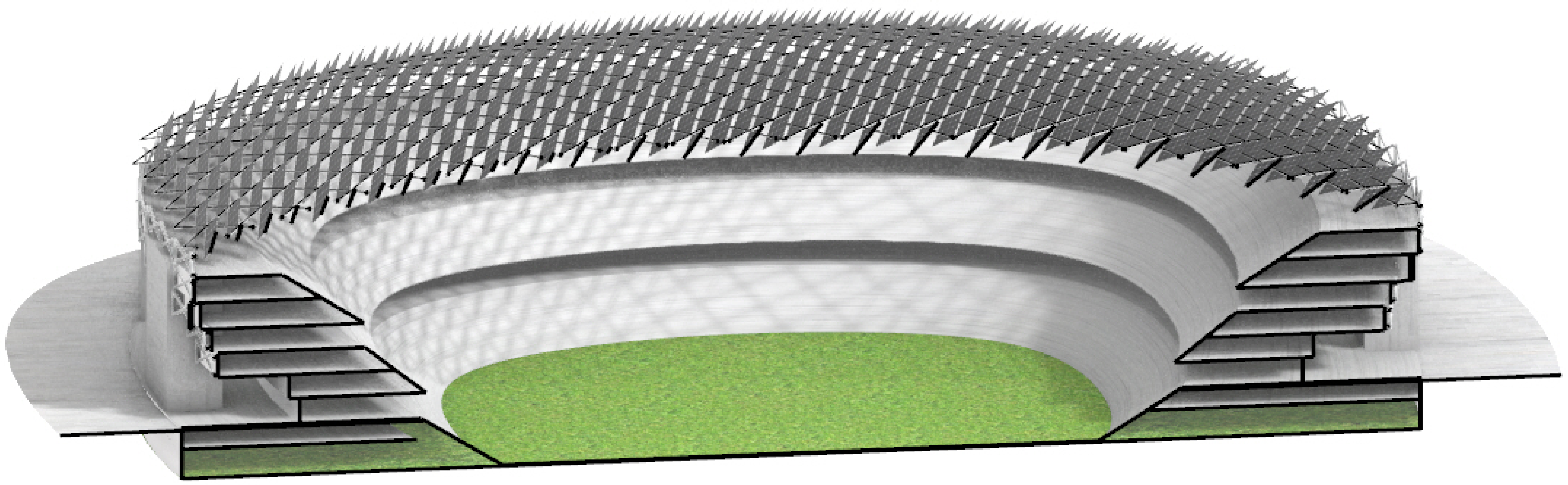
3 *Which are the **parameters** affecting the indoor comfort the most?*

- AIR CHANGE RATE
- SUN



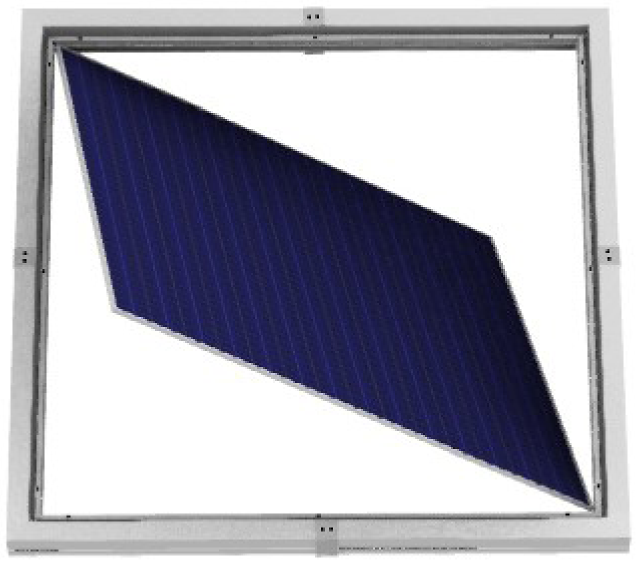
4 *How can the design allow for* ***shading*** *in such a way that daylight is still provided?*

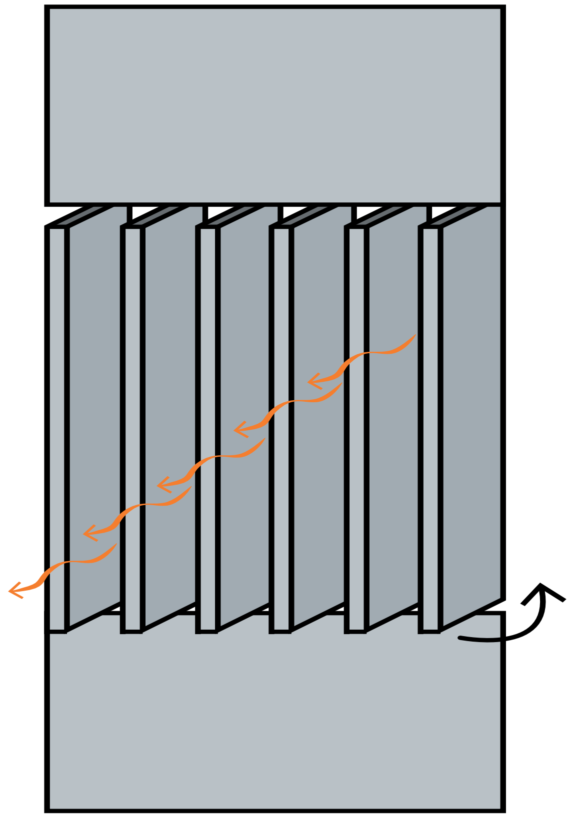
- ORIENTATION
- SOLAR ANALYSIS
- ADAPTIVE SYSTEM



5 *How can **natural ventilation** be implemented in the design? What would be the effectiveness of the measure?*

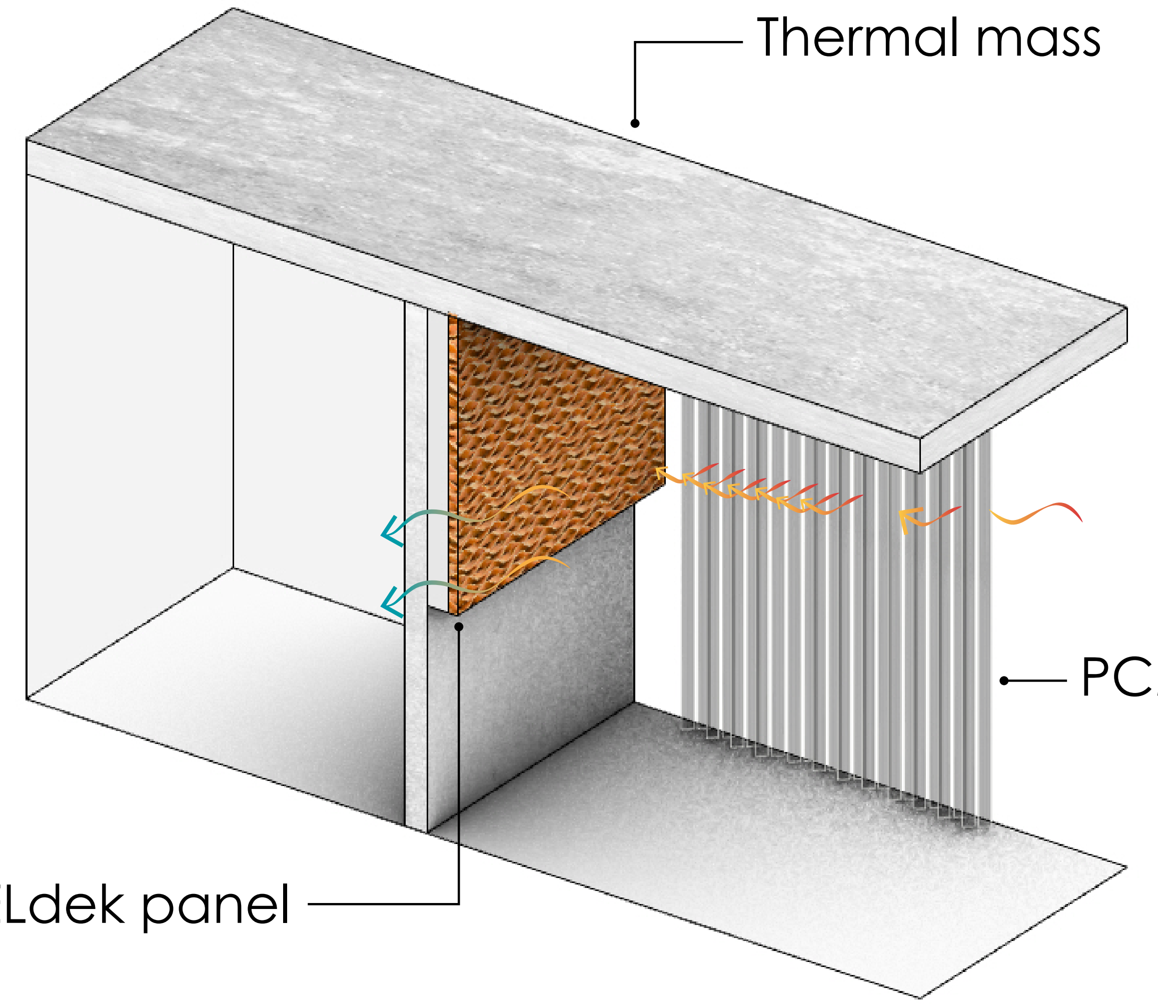
- ORIENTATION
- WIND ANALYSIS





6 *How can **cooling** be provided to the space?*

- **PASSIVE**

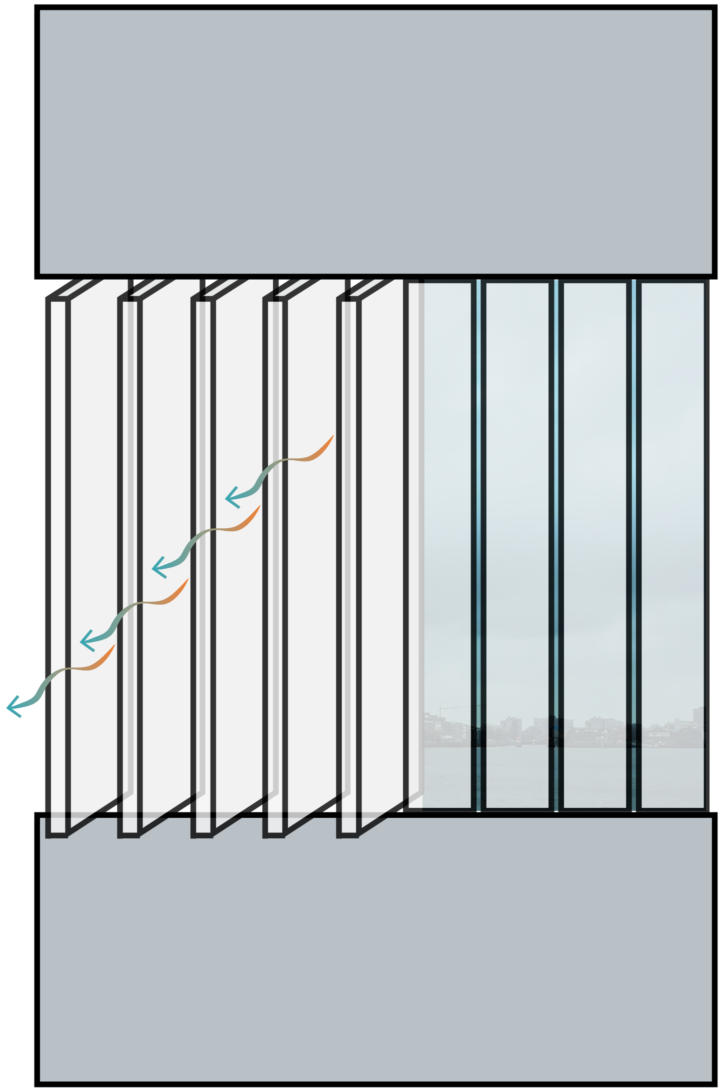


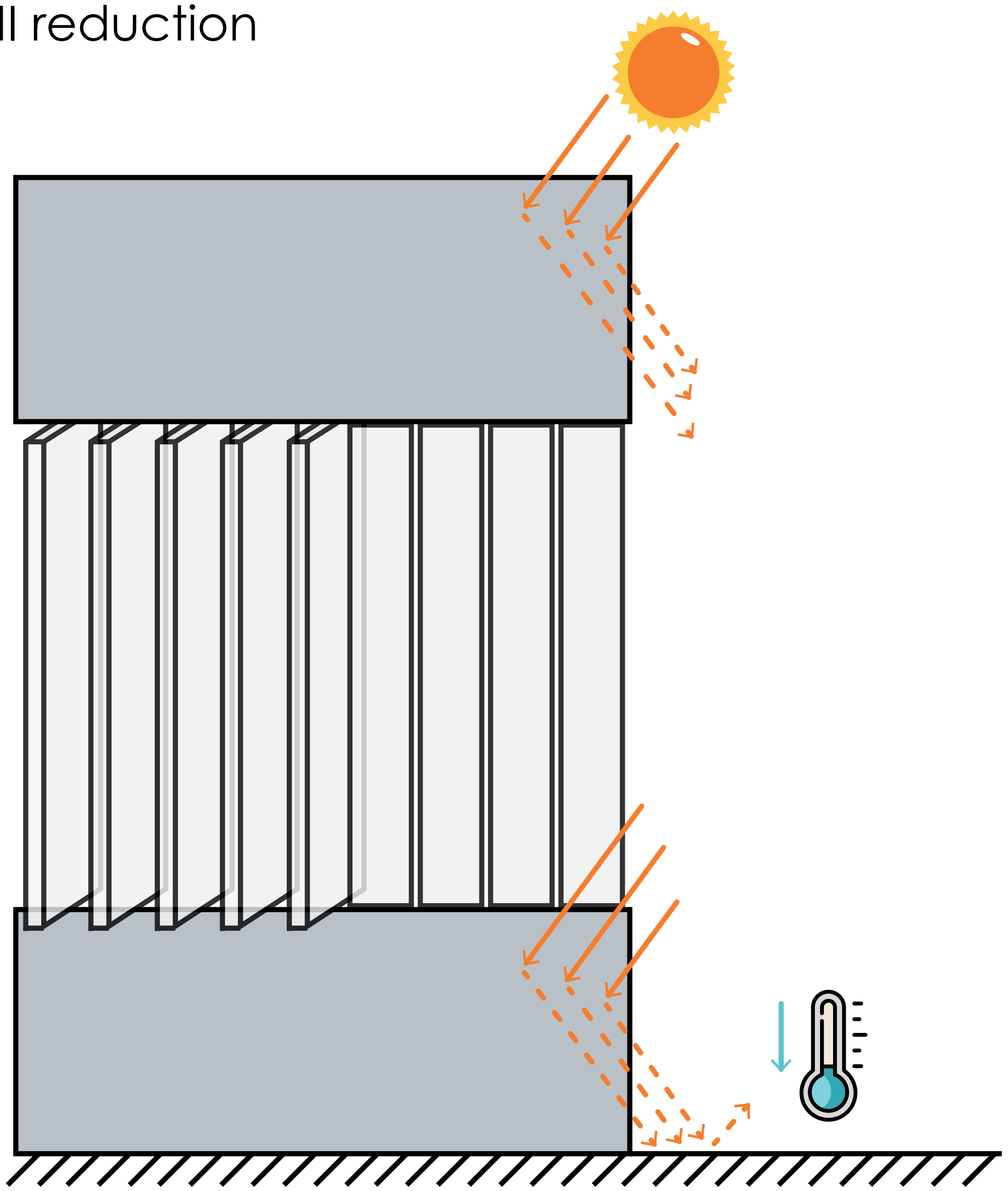
- **ACTIVE**

- ATES
- Local

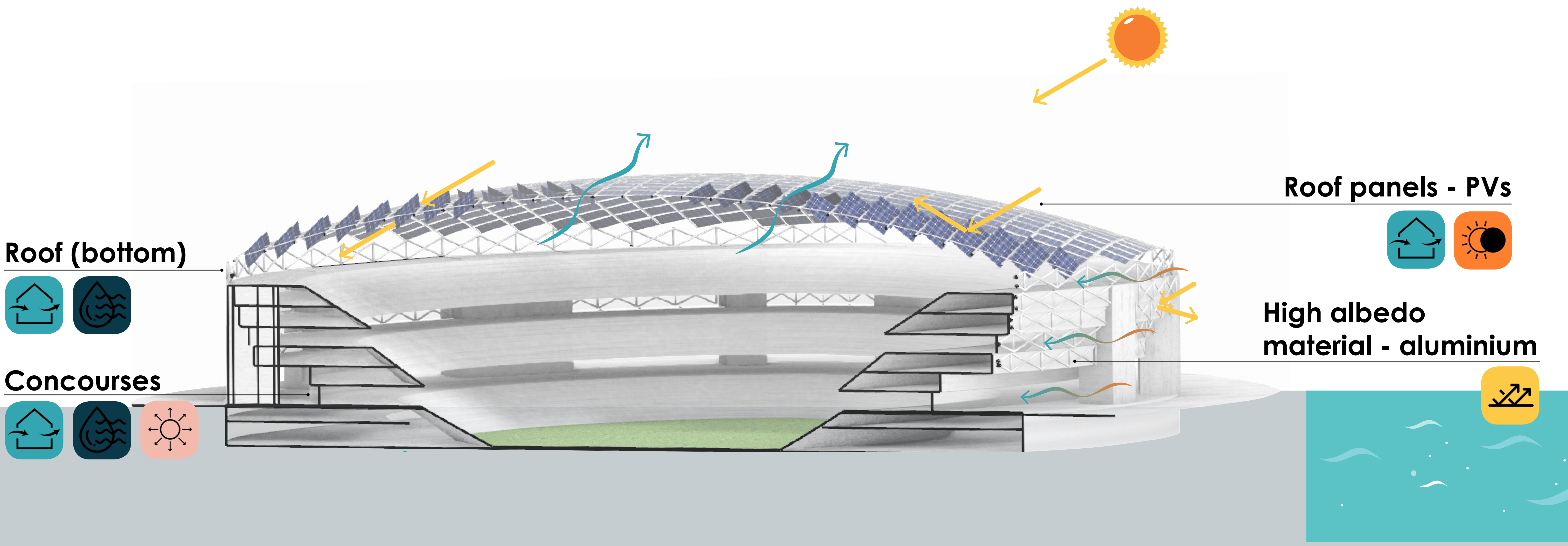
7 *Which **materials** can be used in the design of the envelope so that the indoor comfort is improved? How they help mitigate UHI in the surroundings?*

PCM / Cooling
Aluminium / UHI reduction





*How can the **envelope** of a large-scale stadium be designed to integrate **passive strategies to provide cooling** in a future warmer scenario and guarantee a comfortable micro-climate to users, while **reducing the UHI** in the surroundings?*



1) **Feyenoord project data**
- issues with calculations and simulations: results might not be accurate enough

2) **Feyenoord project is neither complete nor finalized**
- lack of chance to get accurate measurements in site

3) **Climate change data**
- estimation of future temperatures: effect on outcomes

1) **Quality of data**
- get updated information on the project

2) **All parties**
- get information from all the parties involved in the project (advisors, companies, etc...)

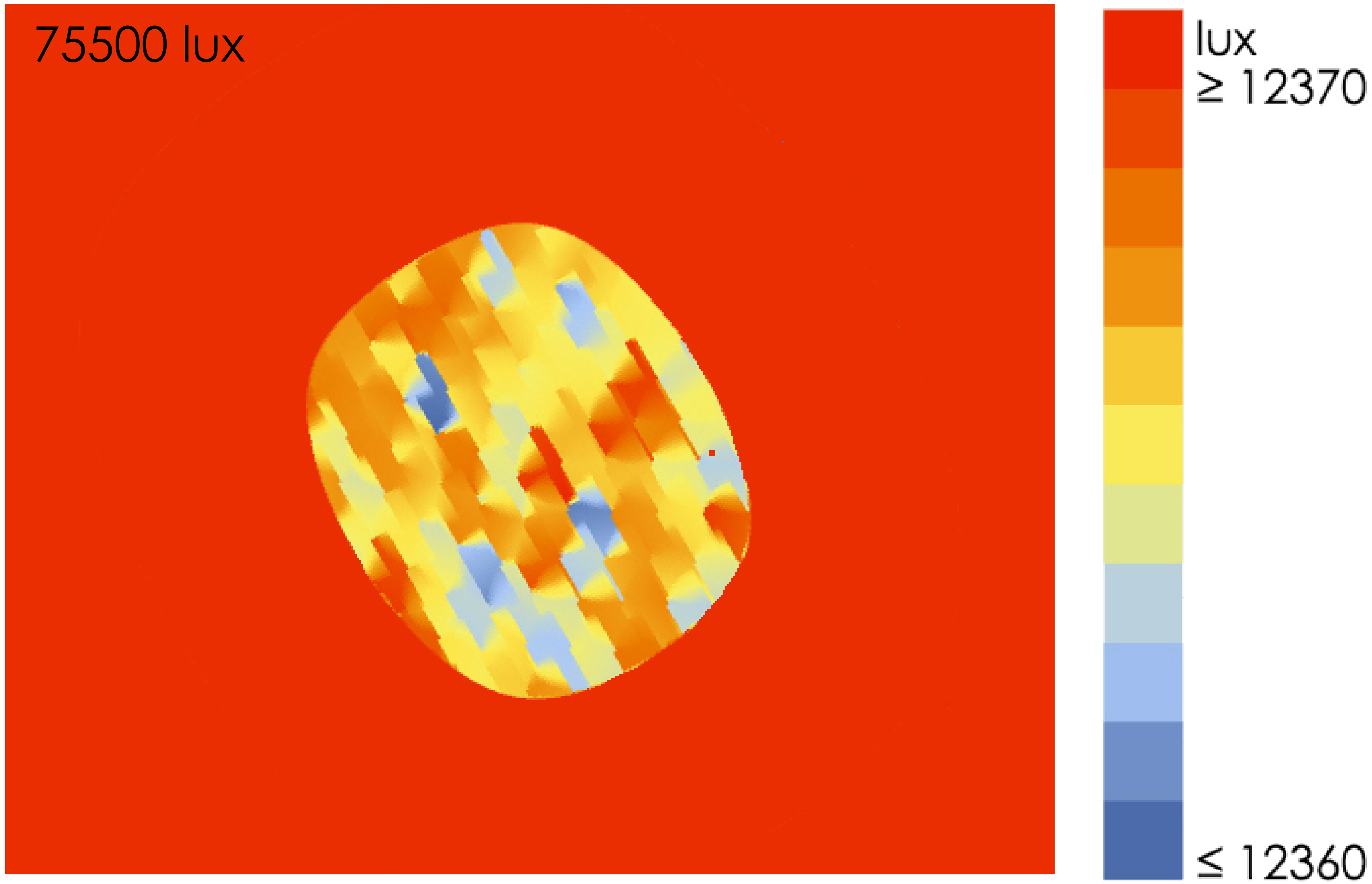

FEYENOORD
F
ROTTERDAM

THANK YOU FOR YOUR ATTENTION

- **Existing researches on climate adaptation**
  - in the case of stadia, a **few examples** exist which were built and designed to fit their context and exploit climate potentials

- **Remarkable example for future stadia design**
  - **climate change adaptability measures** will be fully integrated in the sustainable design of such infrastructures

- **Design by research and research by design method**
  - Pro and cons


75500 lux
lux
≥ 12370
≤ 12360

Requirements	Score
Shading	++
Daylight	++
Acoustics	+
Rain protection	+
Adaptability	++
Visual comfort	±
Ventilation	+
Energy production	++