A satellite view of Earth from space, showing a curved horizon and a vast expanse of white clouds over a dark landmass. The image is used as a background for the presentation slide.

**TRANSSOLAR KLIMAENGINEERING**

Technologies for energy efficient design  
and thermal comfort in buildings  
Stuttgart - Munich - New York

# **WAS BEDEUTET BEHAGLICHKEIT? ERFARHUNGEN AUS ASIEN UND EUROPA**

**15. OKTOBER 2015  
WOLFGANG KESSLING**







# Zero Carbon Operation

Sustainable Cooling of Greenhouses  
in the Tropics



**Client**

NParks, Singapore

**Gardens by the Bay**

Landscape: Grant Associates, Bath

**Cooled Conservatories**

Architect: Wilkinson Eyre, London

**MEP**

CPG, Singapore and A10, London



# Prototype Glasshouses for Cooled Conservatories, Singapore

Architect  
Nirmal Kishnani, CPGreen

Client  
NParks, Singapore

**The Flower dome: cooled dry Mediterranean biome**

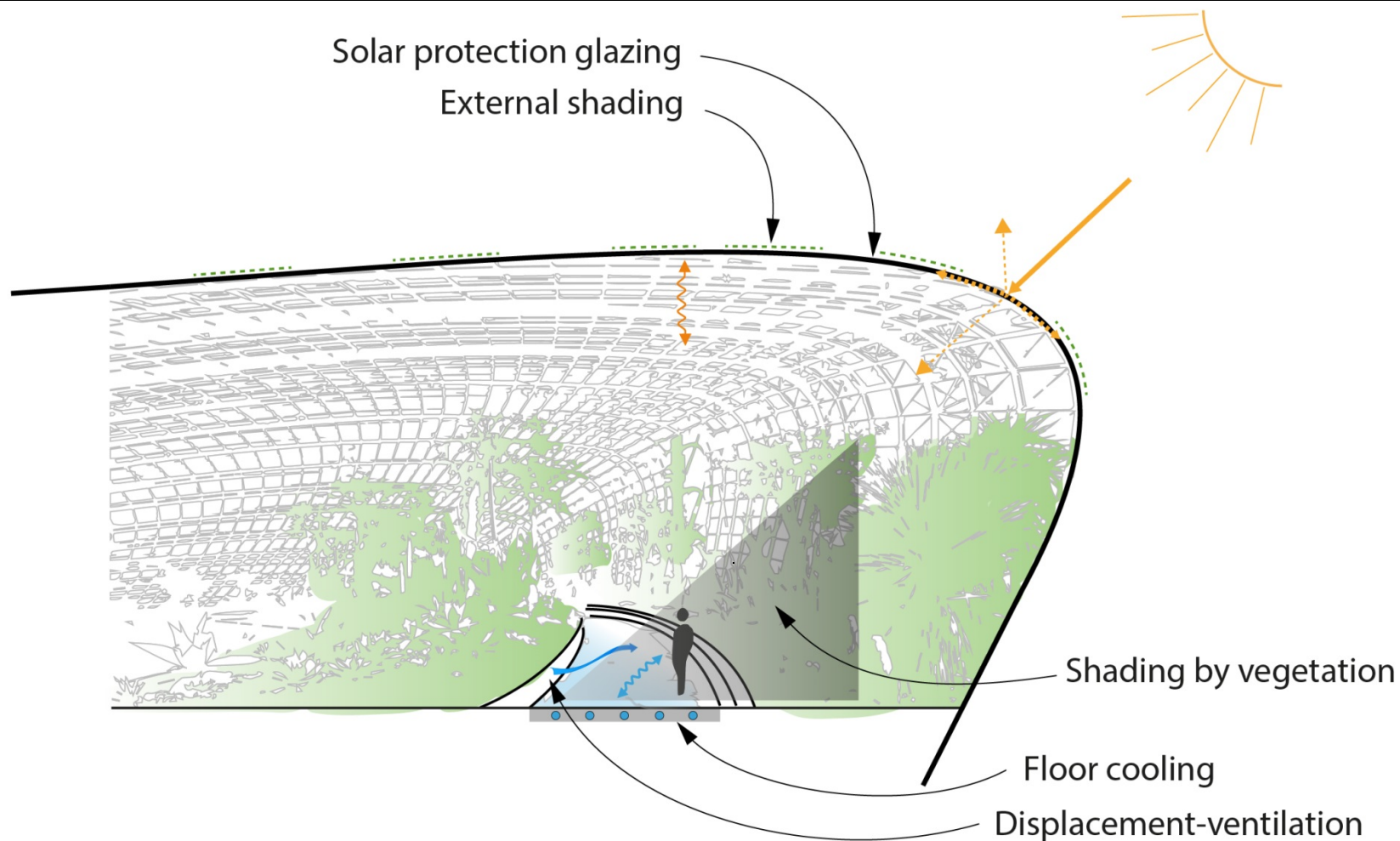






Source: Grant Associates

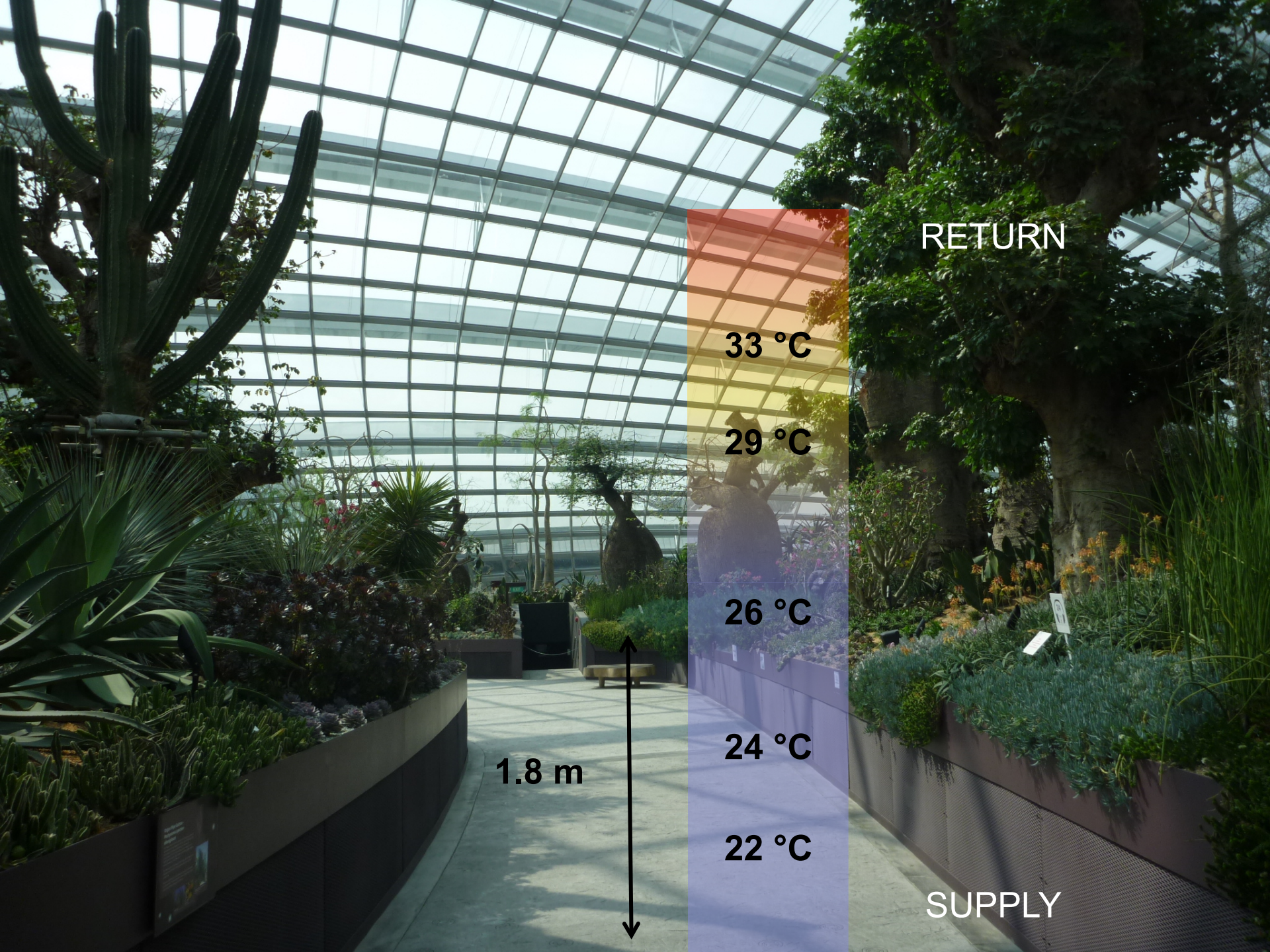
## Operative Temperature - a measure for human comfort



When designing for comfort consider air temperature and radiant environment.



Controlling radiant temperature can create a more comfortable, draft free environment that is energy efficient.



RETURN

33 °C

29 °C

26 °C

24 °C

22 °C

SUPPLY

1.8 m

# The Cloud Forrest: Tropical Montagne Cloud Forest



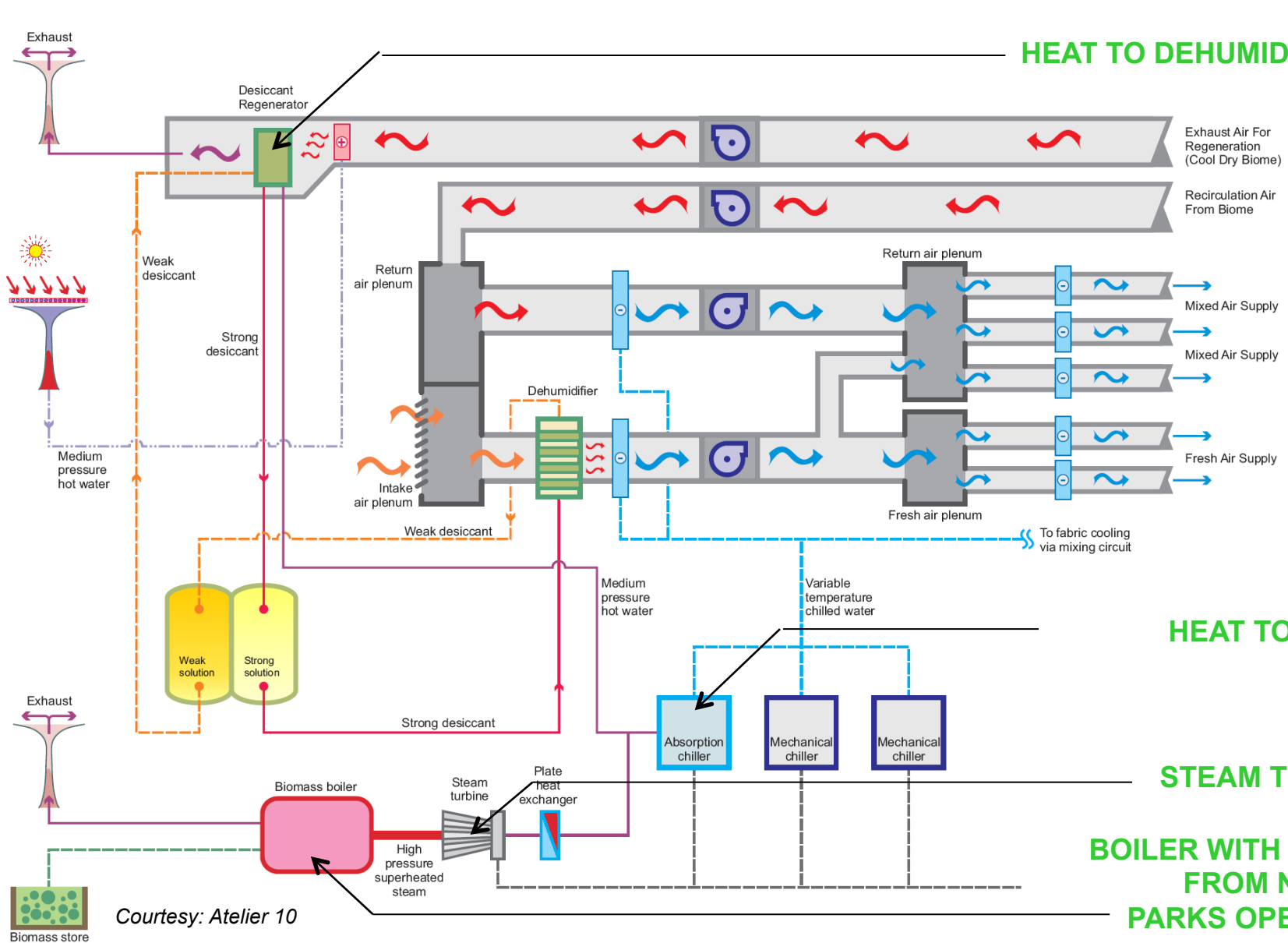




Source: facebook images, Soh Huiwen





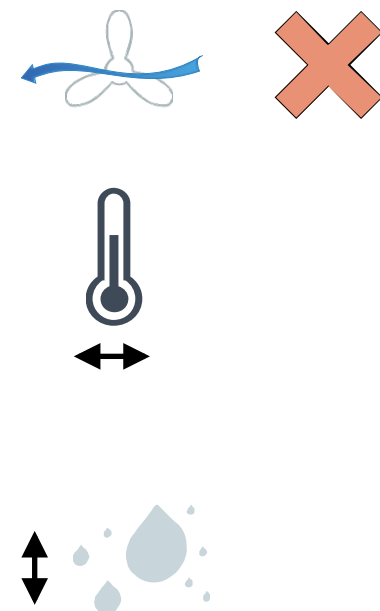
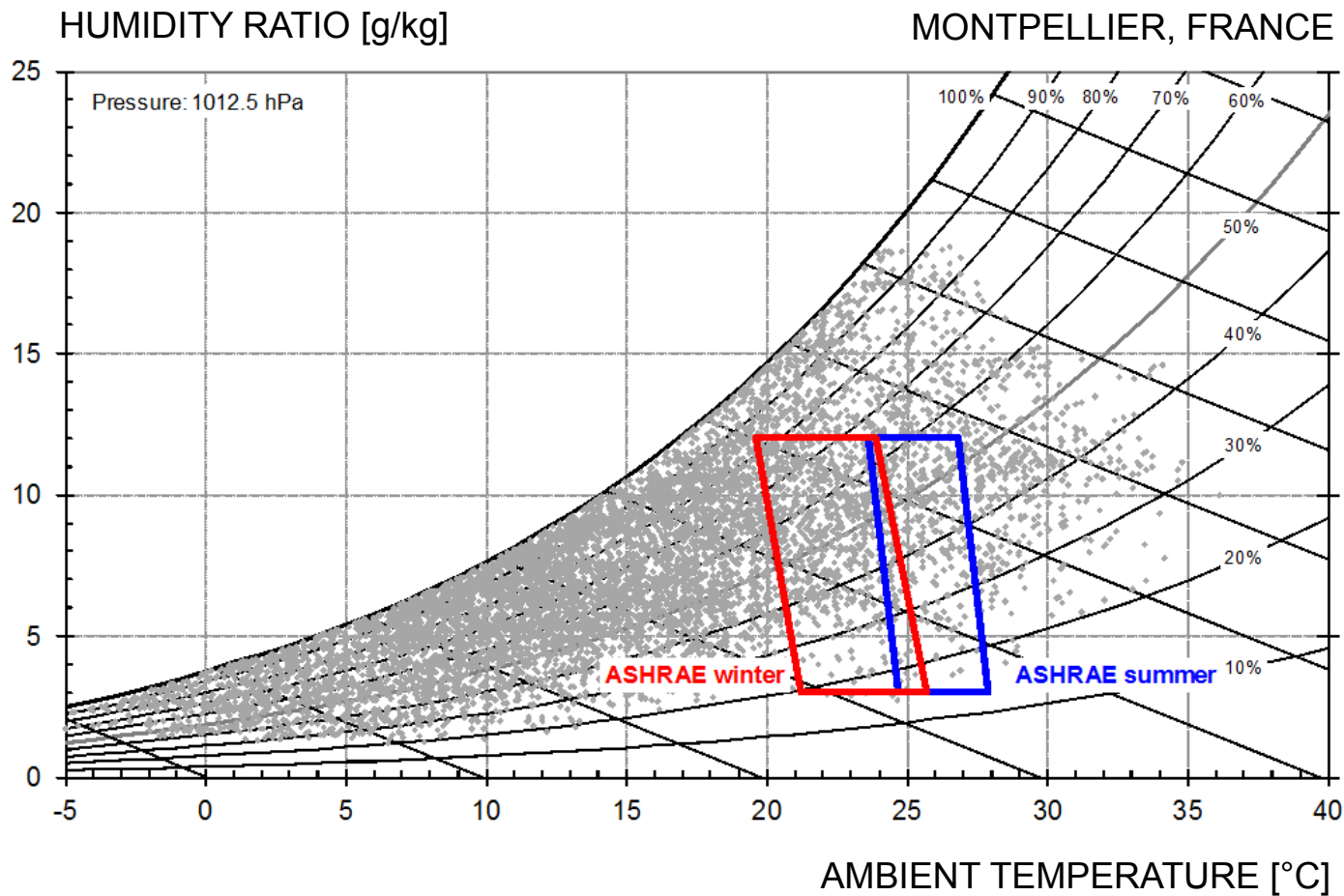




The way  
we  
define  
comfort  
...

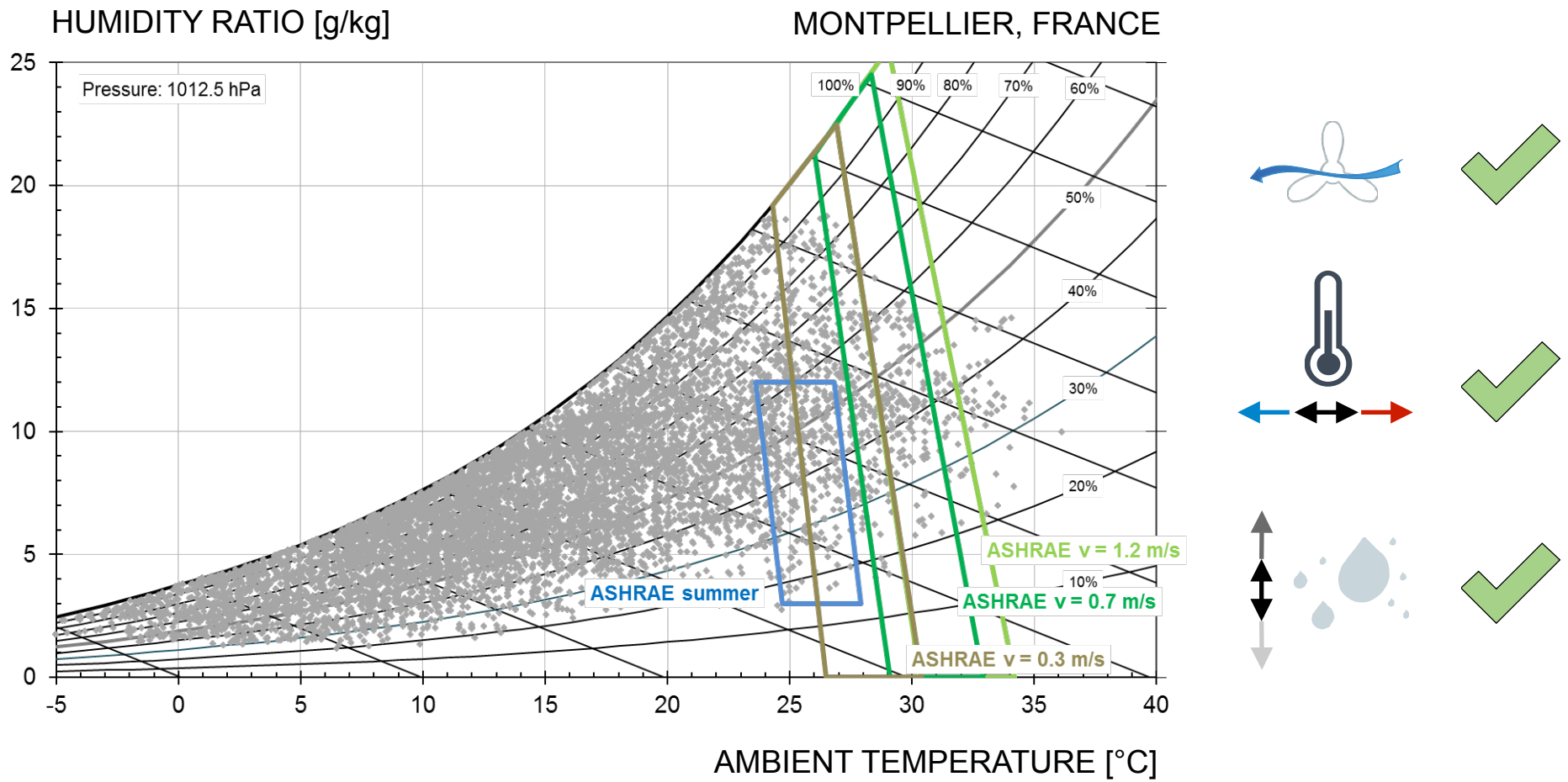


ASHRAE Standard 55 for comfort air conditioning



➡ Tight temperature and humidity range as a consequence of no air movement

# ASHRAE Standard 55-2013, comfort air conditioning with elevated air speed



➡ Extended temperature and humidity range as a consequence of air movement

# Comfort with elevated air speed

Sustainable Cooling Concepts for the Tropics



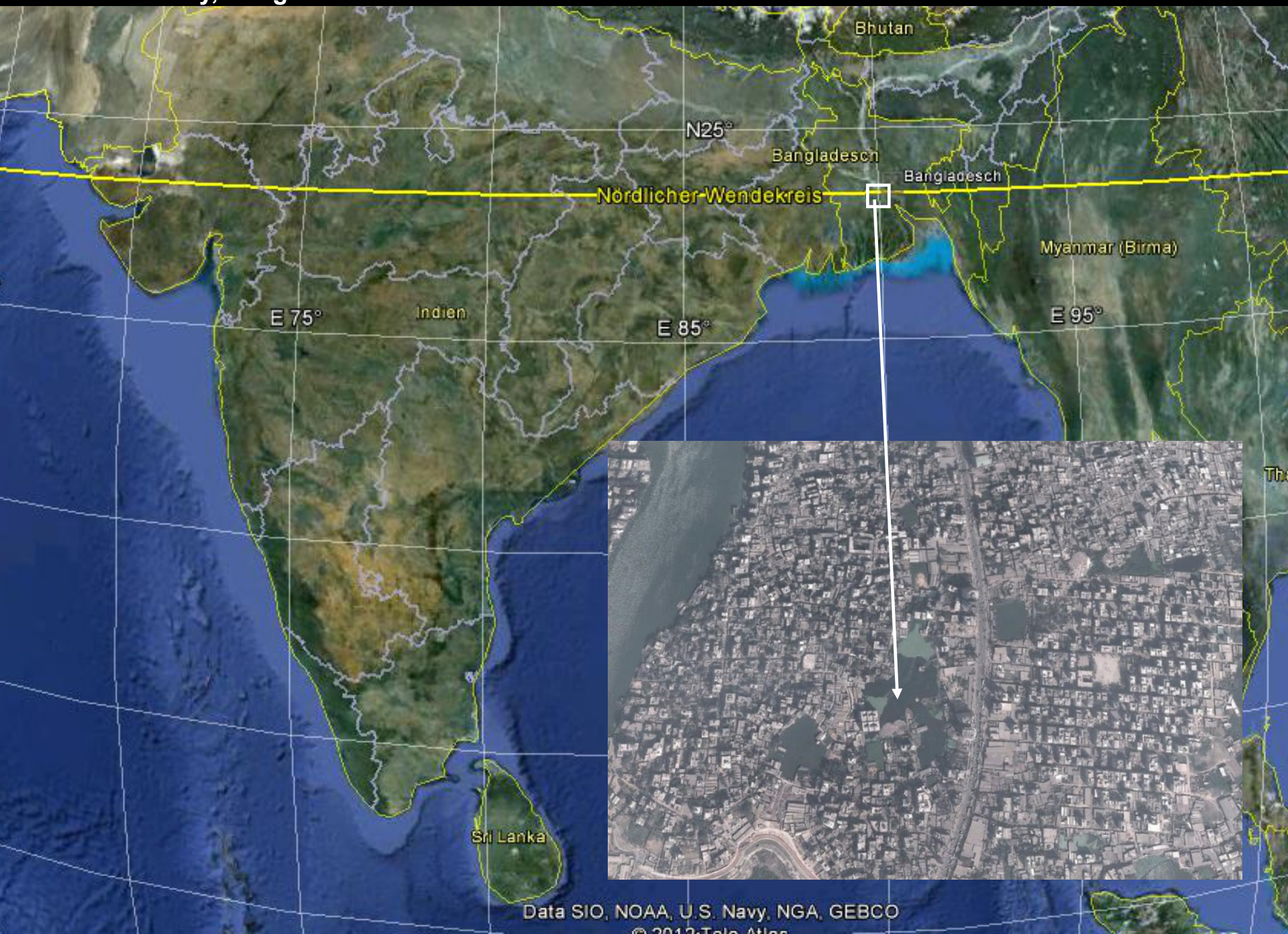
**BRAC University, Bangladesh**

**Client**

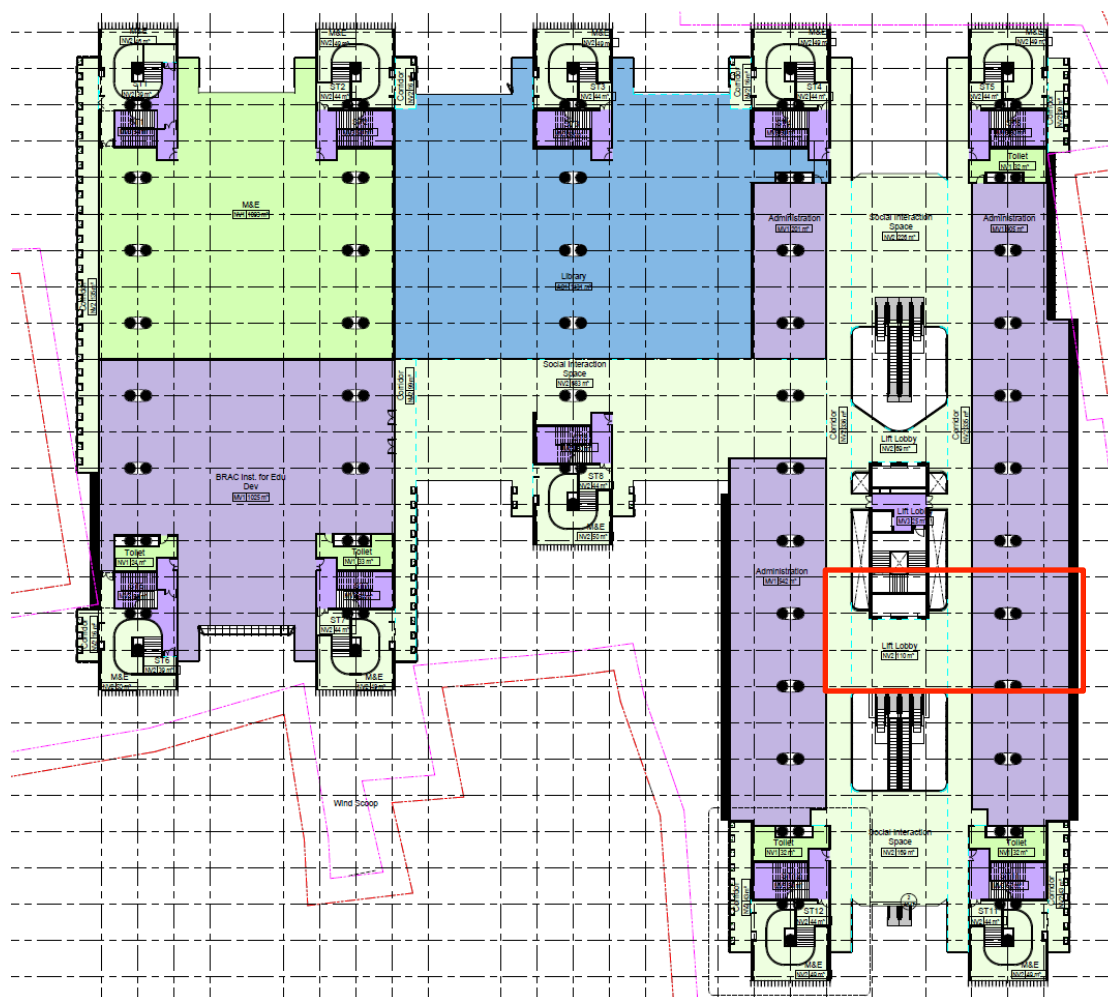
BRAC, Bangladesh

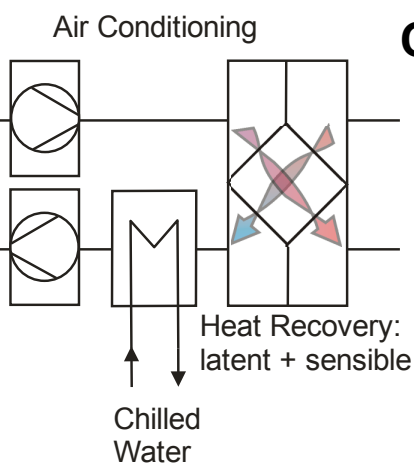
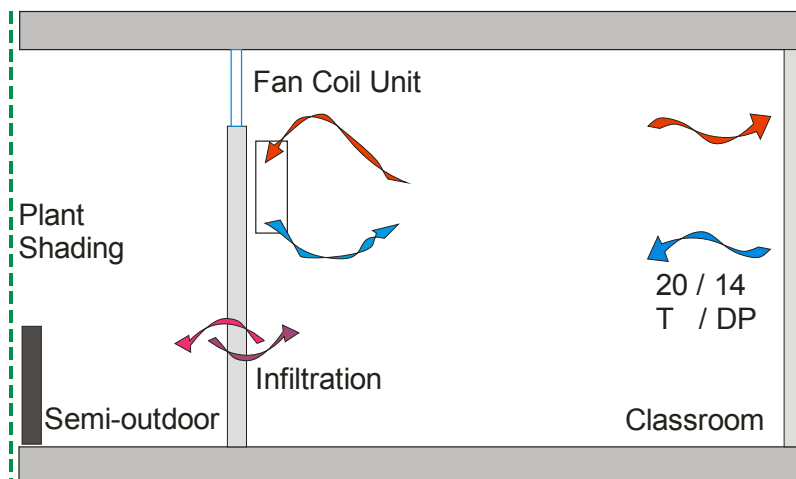
**Architect**

WOHA, Singapore



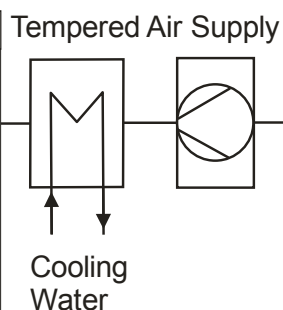
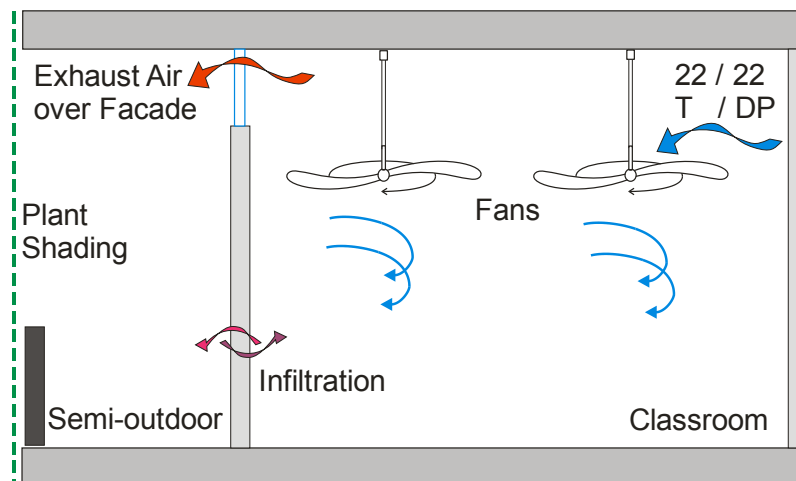






## Conventional design V1 of AC System

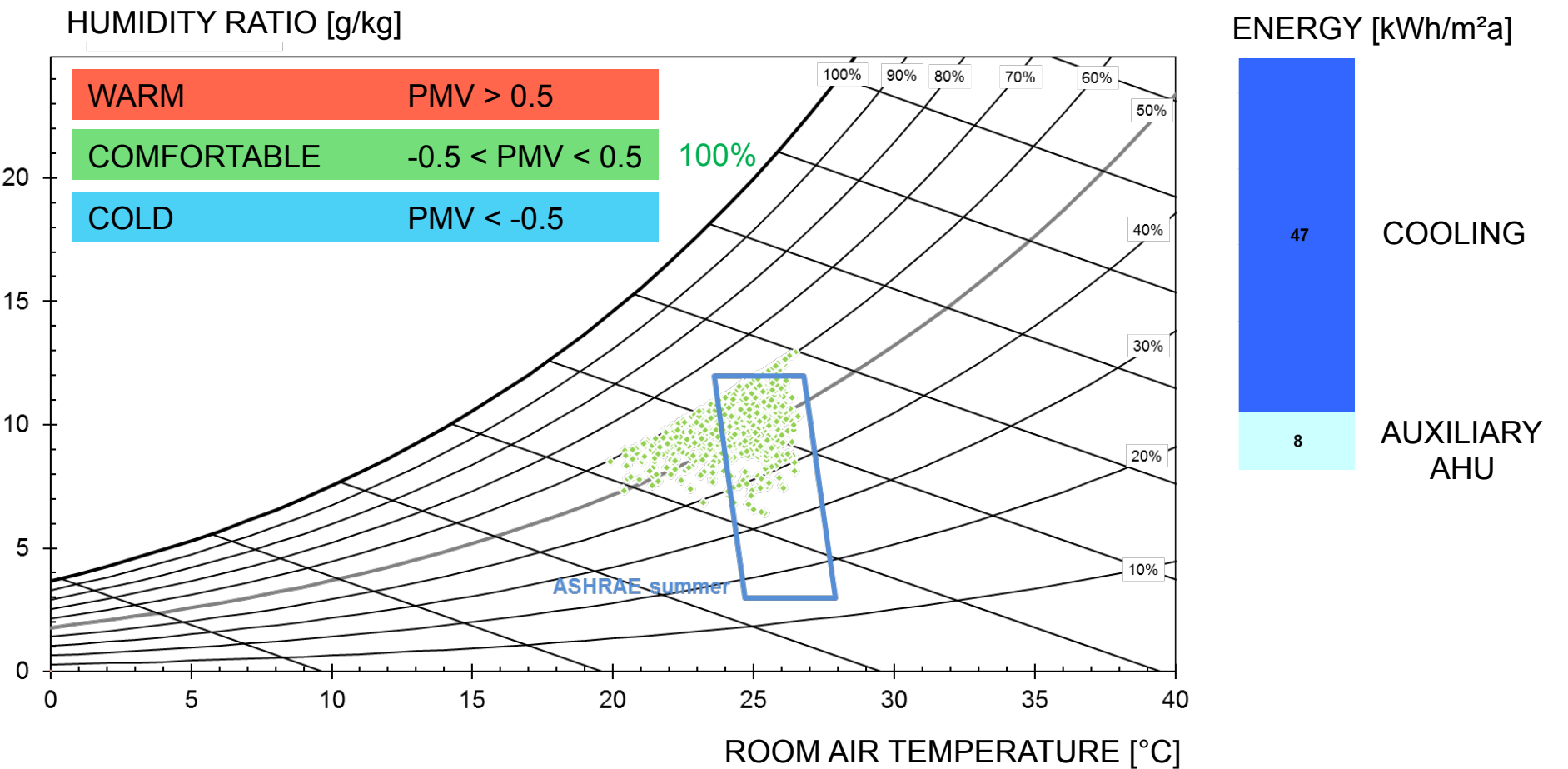
Infiltration: 0.2 /h  
cooling: max. 26 °C



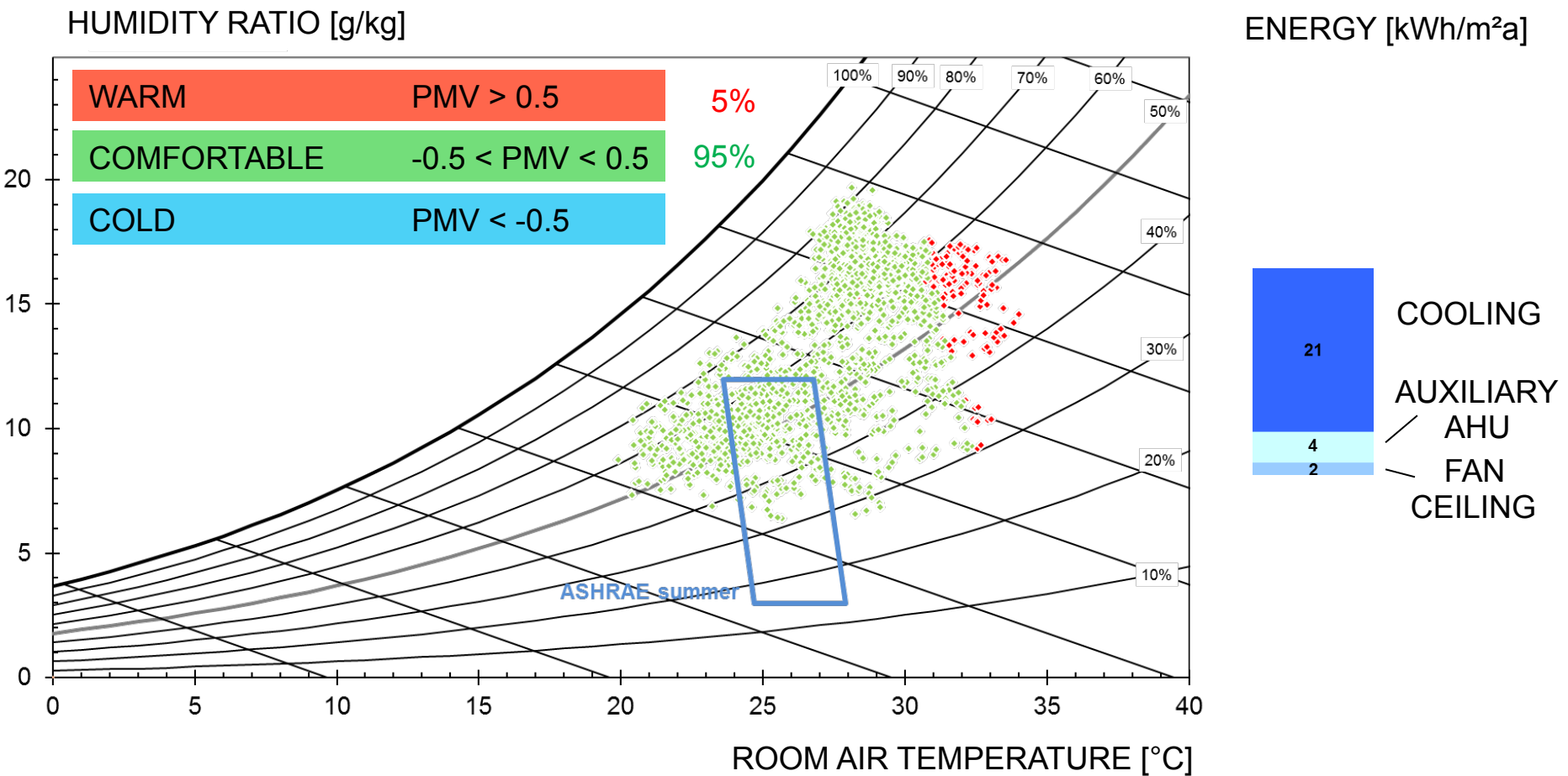
## Hybrid design V2 with tempered air

Infiltration: 0.2 /h  
no cooling

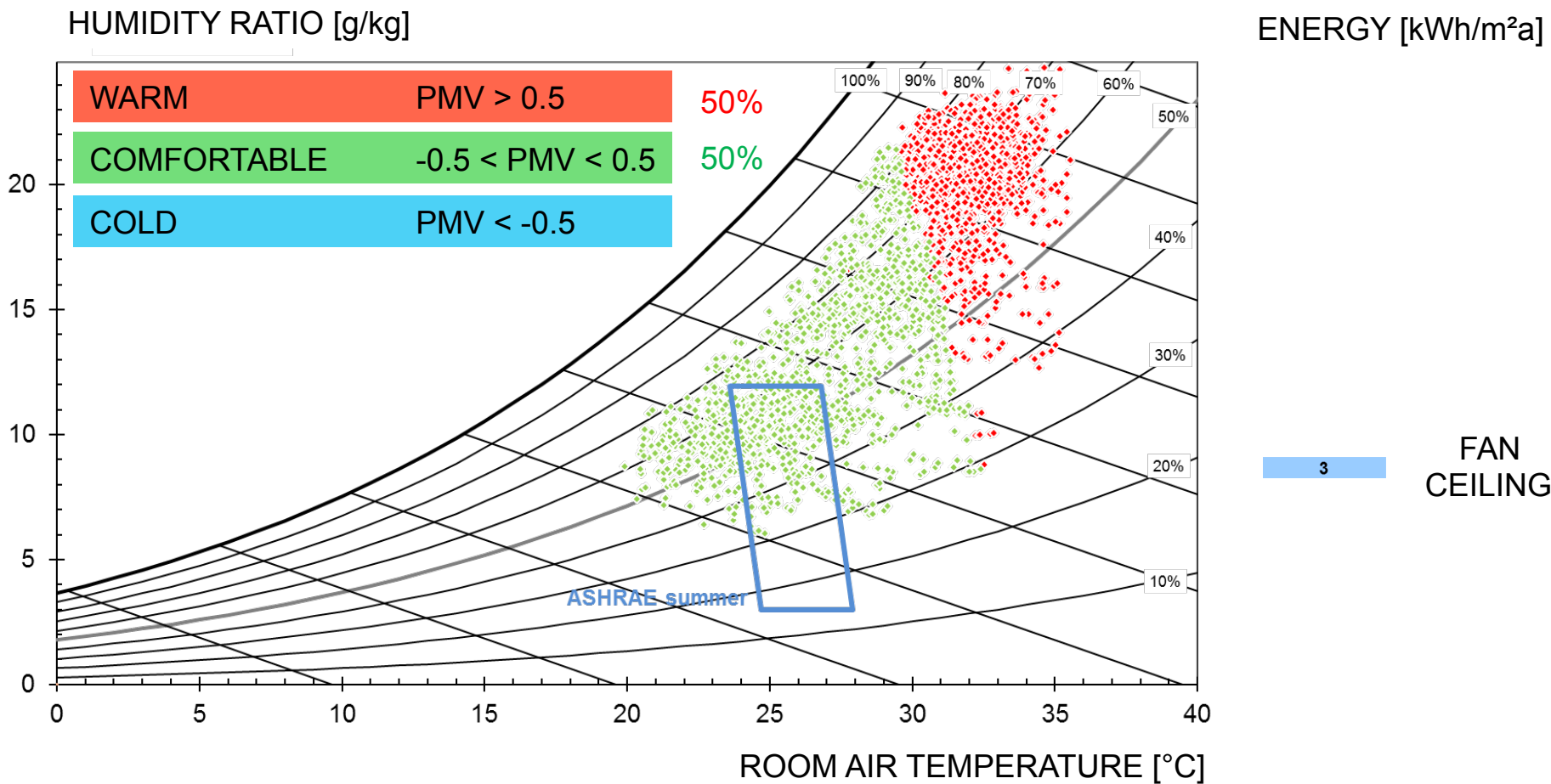
Conventional air conditioning



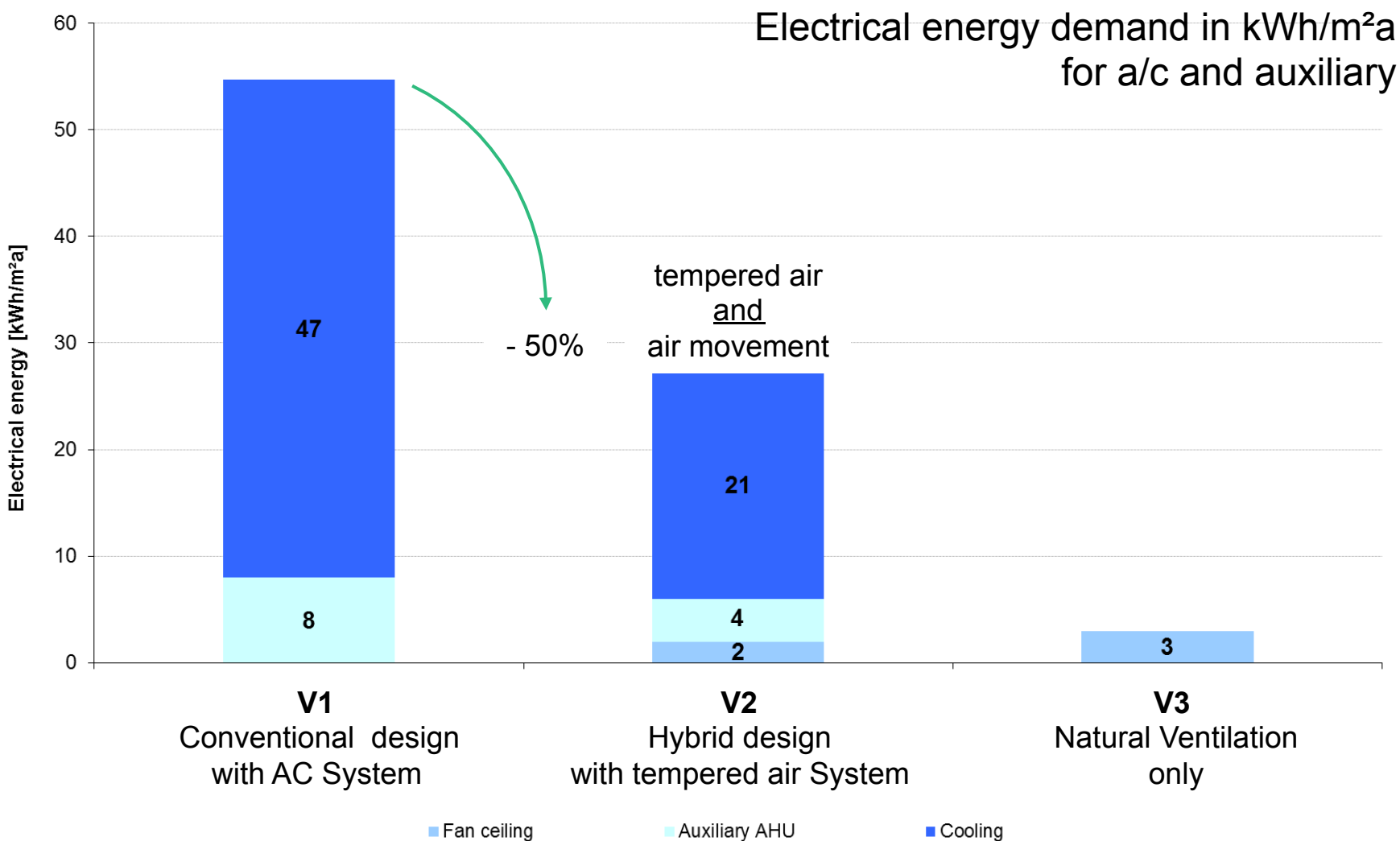
Hybrid ventilation with tempered air



Natural ventilation with ambient air



Comparison of concepts, Comfort and Energy in office



same comfort but 50 % energy savings V2 to V1

... has  
significant  
impact

Buildings designed  
for adaptive  
comfort consume

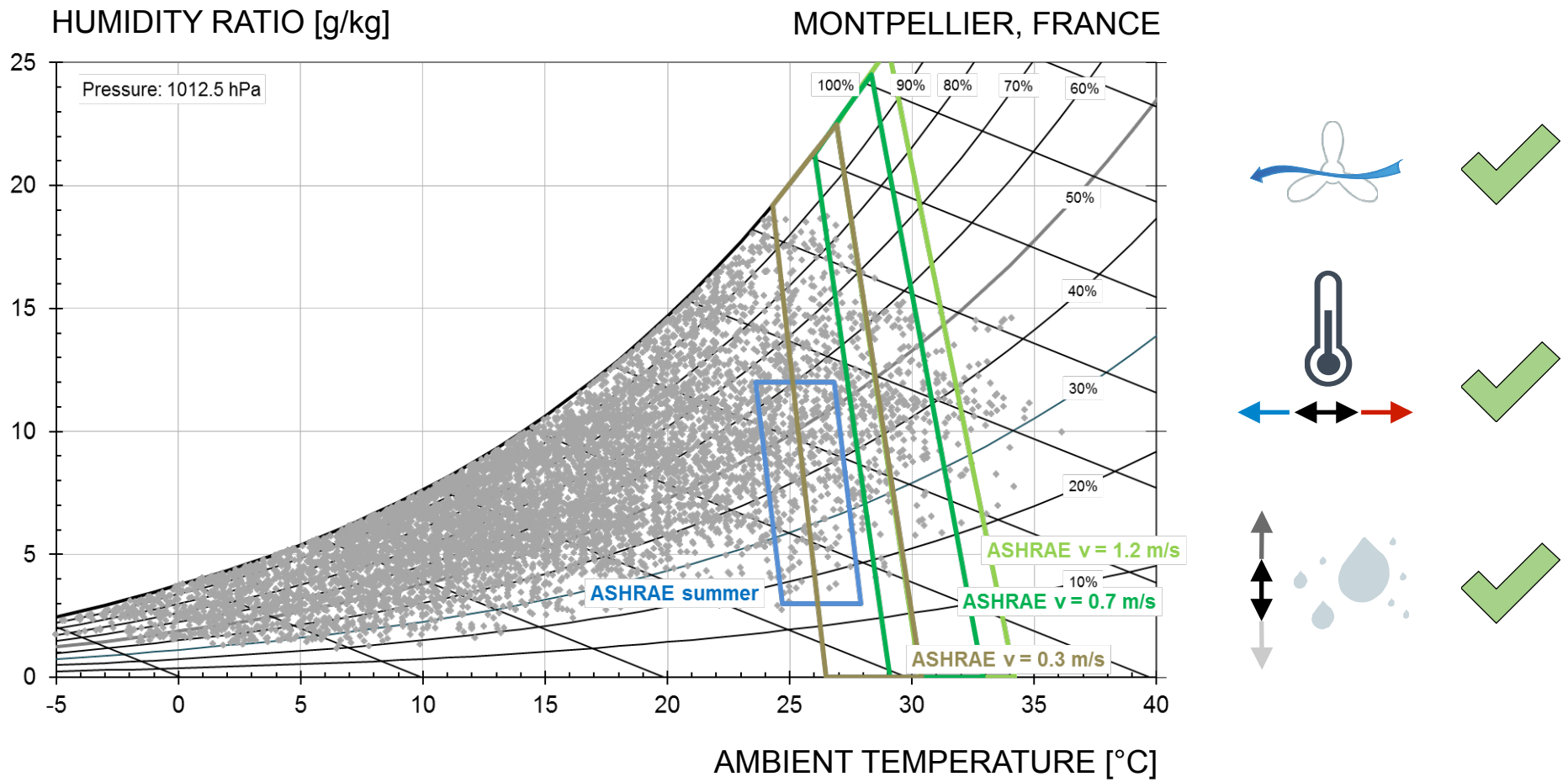
50%

less energy



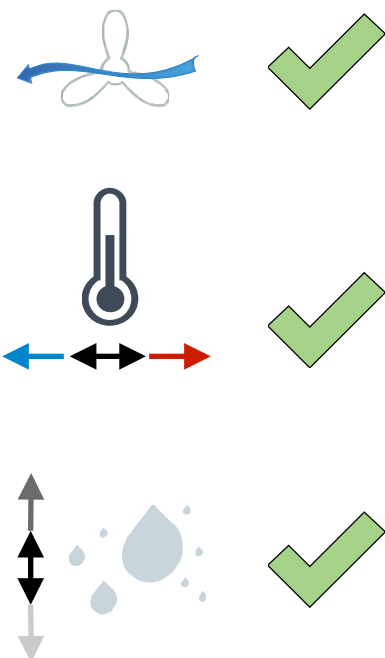
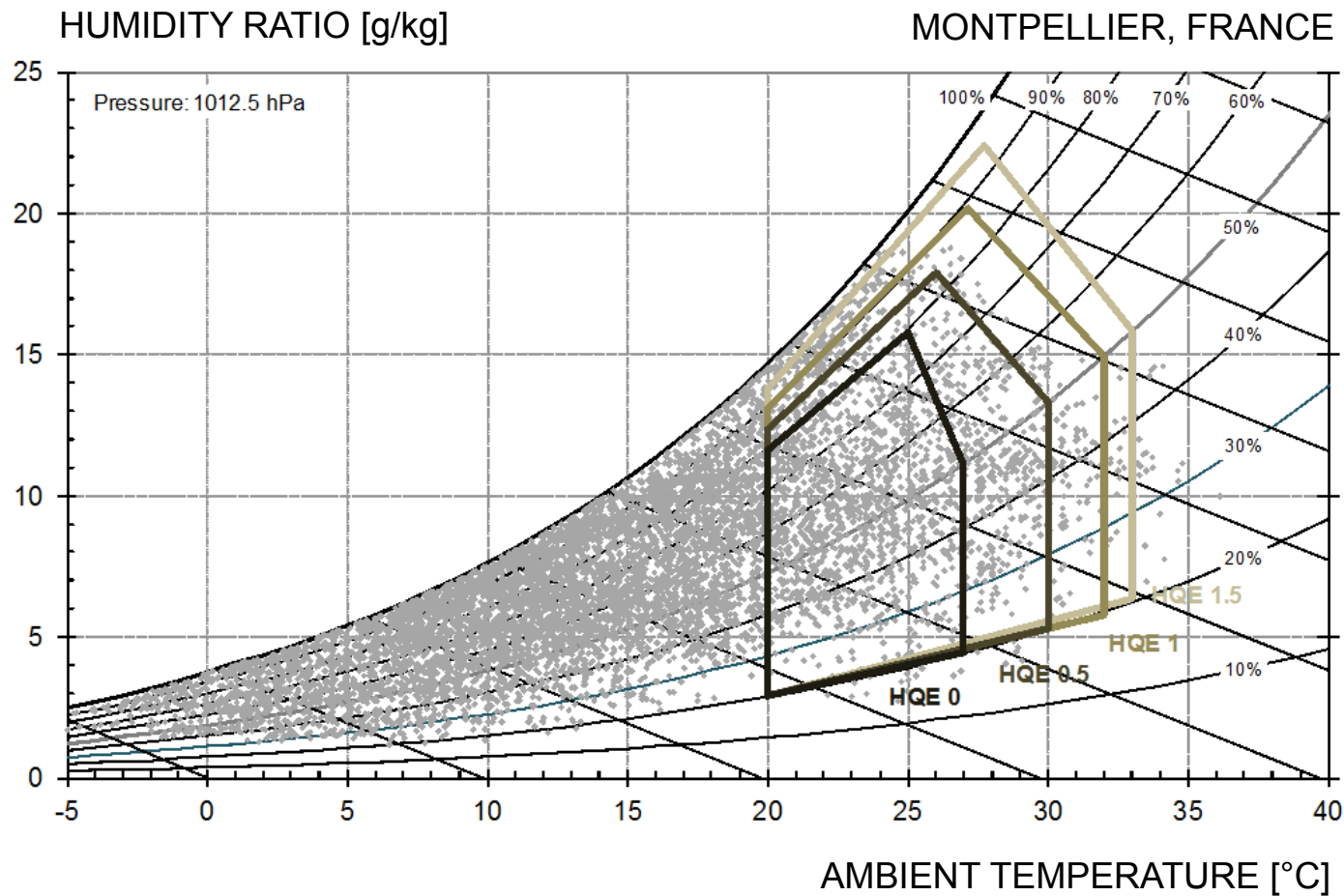


ASHRAE Standard 55-2013, comfort air conditioning with elevated air speed



➡ Extended temperature and humidity range as a consequence of air movement

# French HQE: Certification for High Environmental Quality Buildings



➡ Extended temperature and humidity range as a consequence of air movement

# High Comfort Low Energy

## Context Sensitive Comfort Strategies for Mediterranean Climate



### **Client**

LUMA Foundation, Arles

### **Tower Building**

Architect: F.O.Gehry, Los Angeles

### **Existing Buildings**

Architect: Annabelle Selldorf, New York





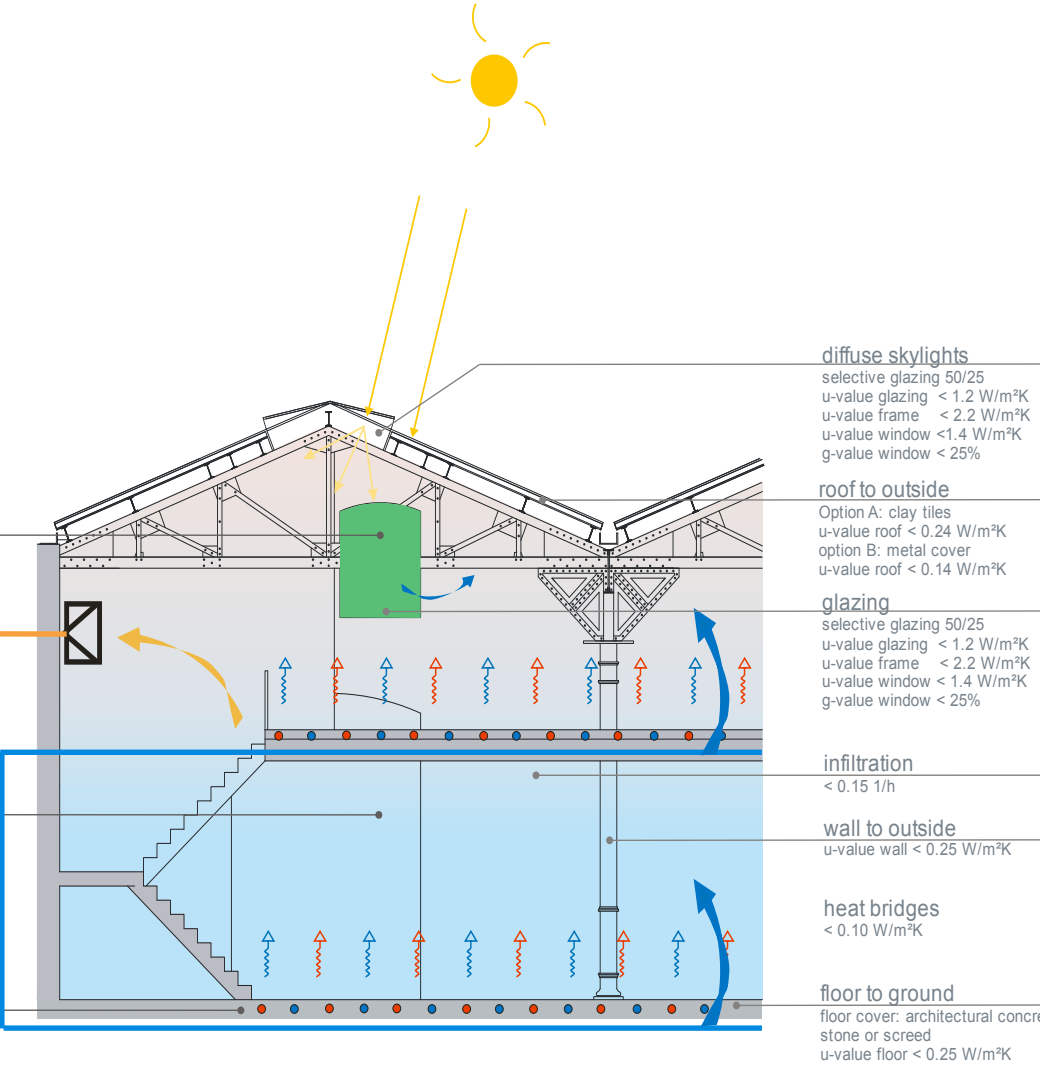
**mech. vent. not in operation in 2014**

nat. vent. ground floor 0.95 1/h\*K (3.35 m clear ceiling height)  
nat. vent. mezzanine 0.65 1/h\*K (4.35 m clear ceiling height)  
facade openings with automated operation on BMS  
south: ground floor > 1-2 m² & mezzanine > 14 m²  
north: ground floor > 4-6 m² & mezzanine > 14 m²  
roof: >10 m²

mech. vent. 4'000 m³/h  
2'000 m³/h ground floor + 2'000 m³/h mezzanine  
T supply summer 18°C  
T dew point 12°C  
T supply winter 20°C

mechanical ventilation/  
displacement with heat recovery

floor heating & cooling



Begin of refurbishment 6<sup>th</sup> of March 2014, Les Forges





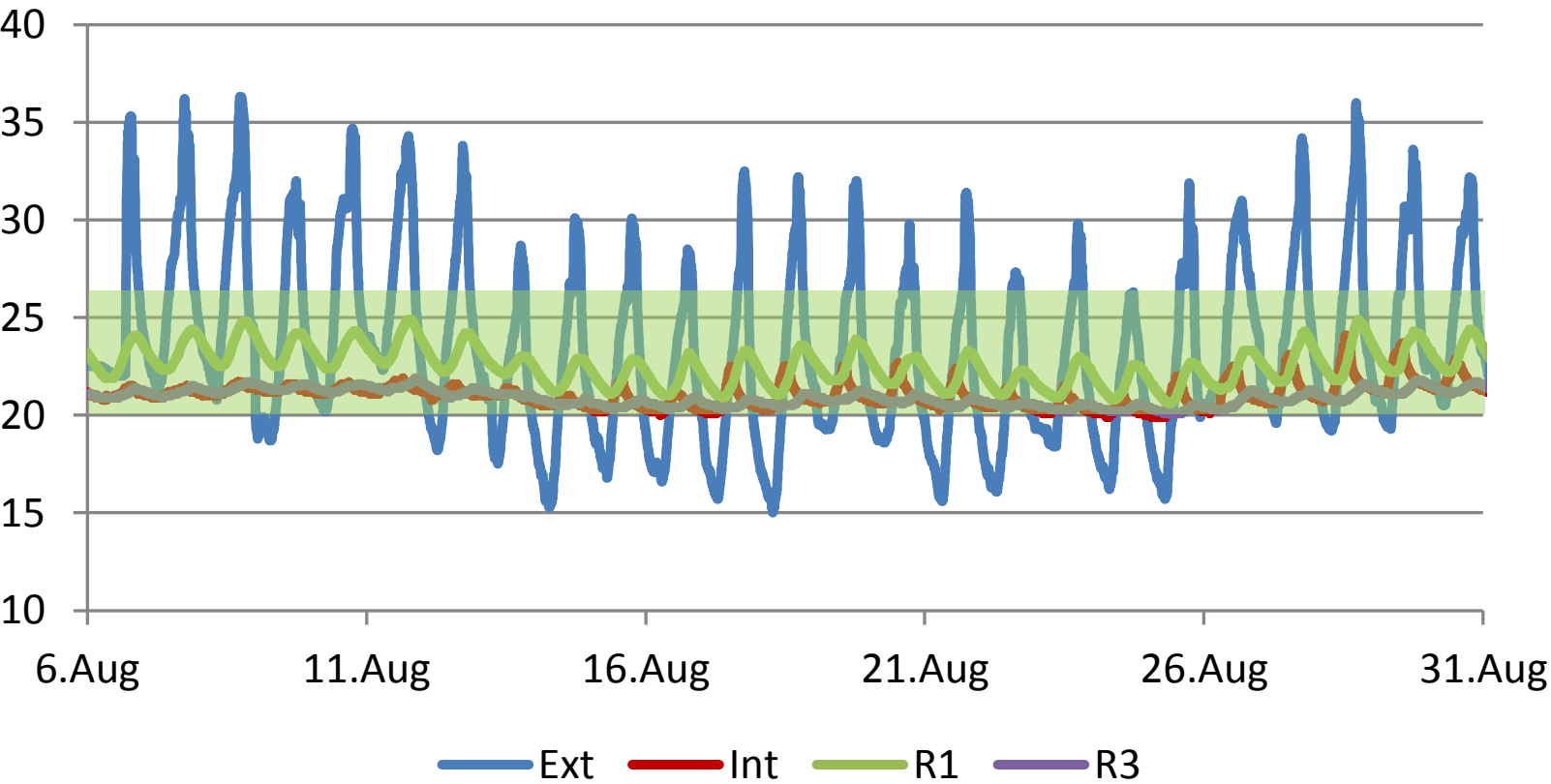


ETIENNE BONNET

# Outside & floor temperatures [°C]



Temperature [°C]



Parc des Ateliers

26/12/2014



Parc des Ateliers

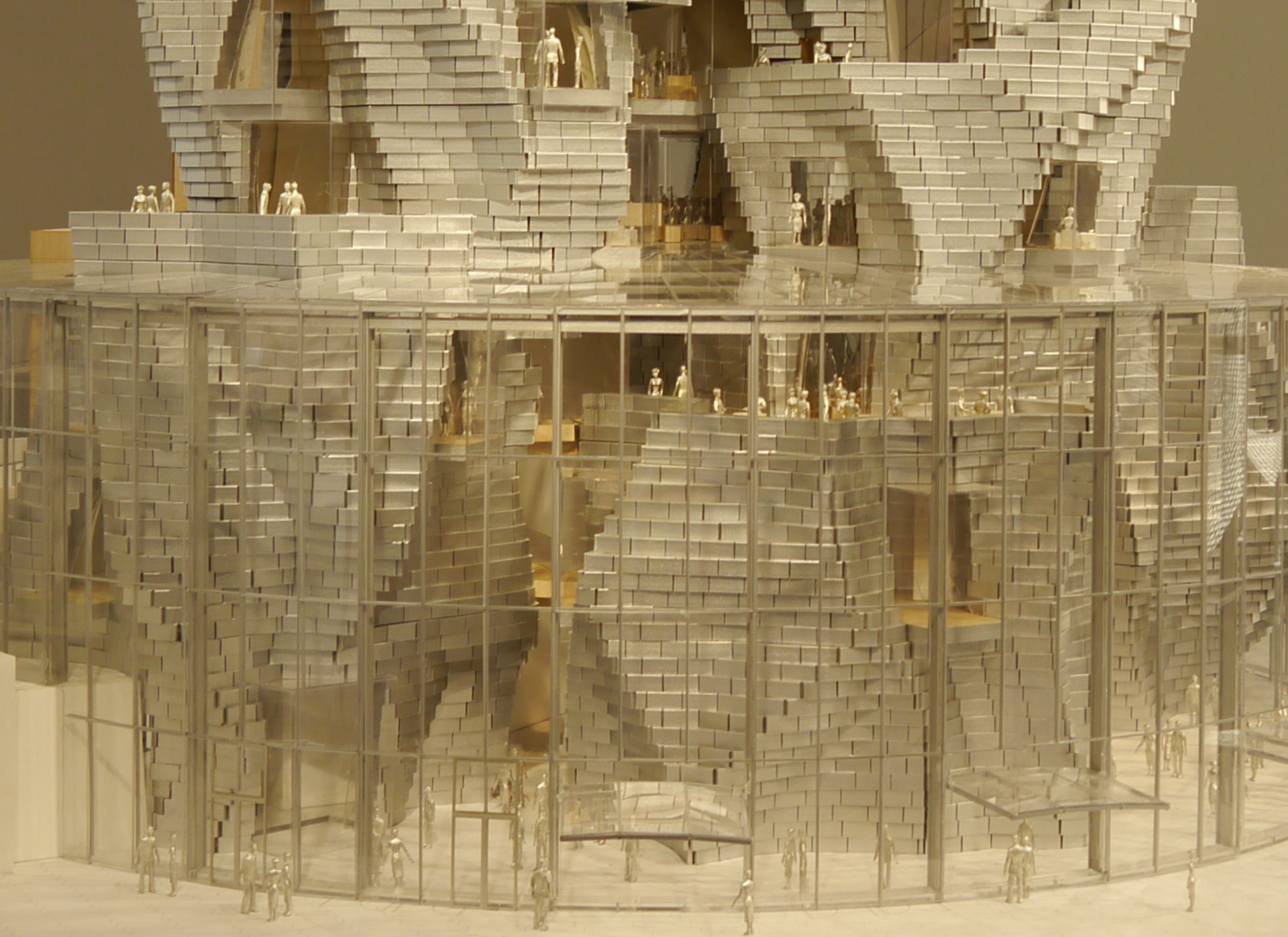
02/06/2015



Parc des Ateliers

18/08/2015







# Why to design for Outdoor Comfort?



very strong heat stress

strong heat stress

moderate heat stress

no thermal stress

slight cold stress

moderate cold stress



Reduce heat stress

# Comfort in the Urban Space

## Performing landscapes for liveable cities



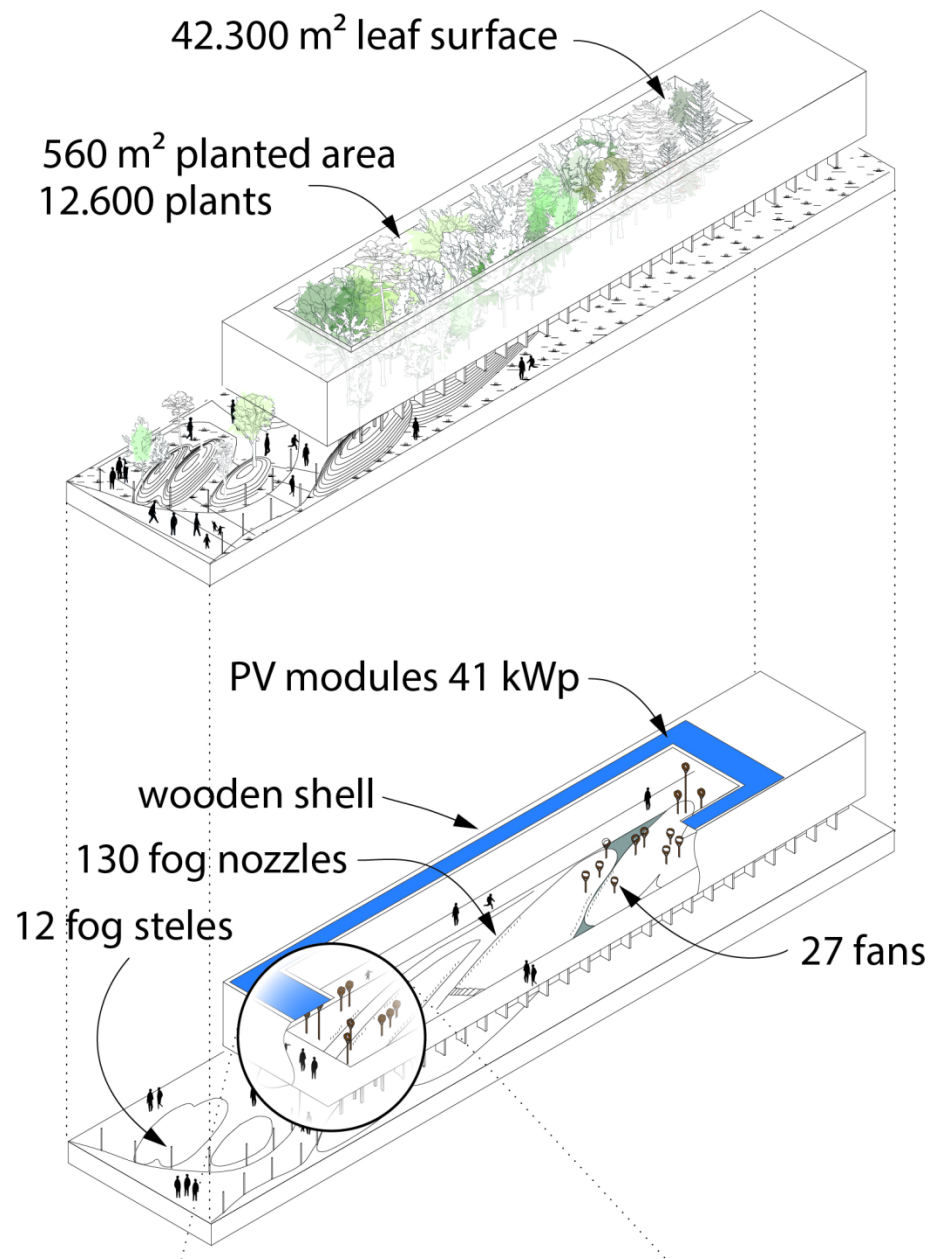
### Client

WKO Vienna  
Austrian Pavilion, EXPO 2015, Milano

### Team.Breathe.Austria

Concept, Landscape and Architecture:  
Prof. Klaus K. Loenhardt, Agency in Biosphere,  
Hohensinn Architektur, LANDLAB,  
i\_a&I, TU-Graz, Lendlabor, Graz  
Mist and fan system: rain time, Vienna

## Elevated air speed and dry mist to create comfort in outdoor environment



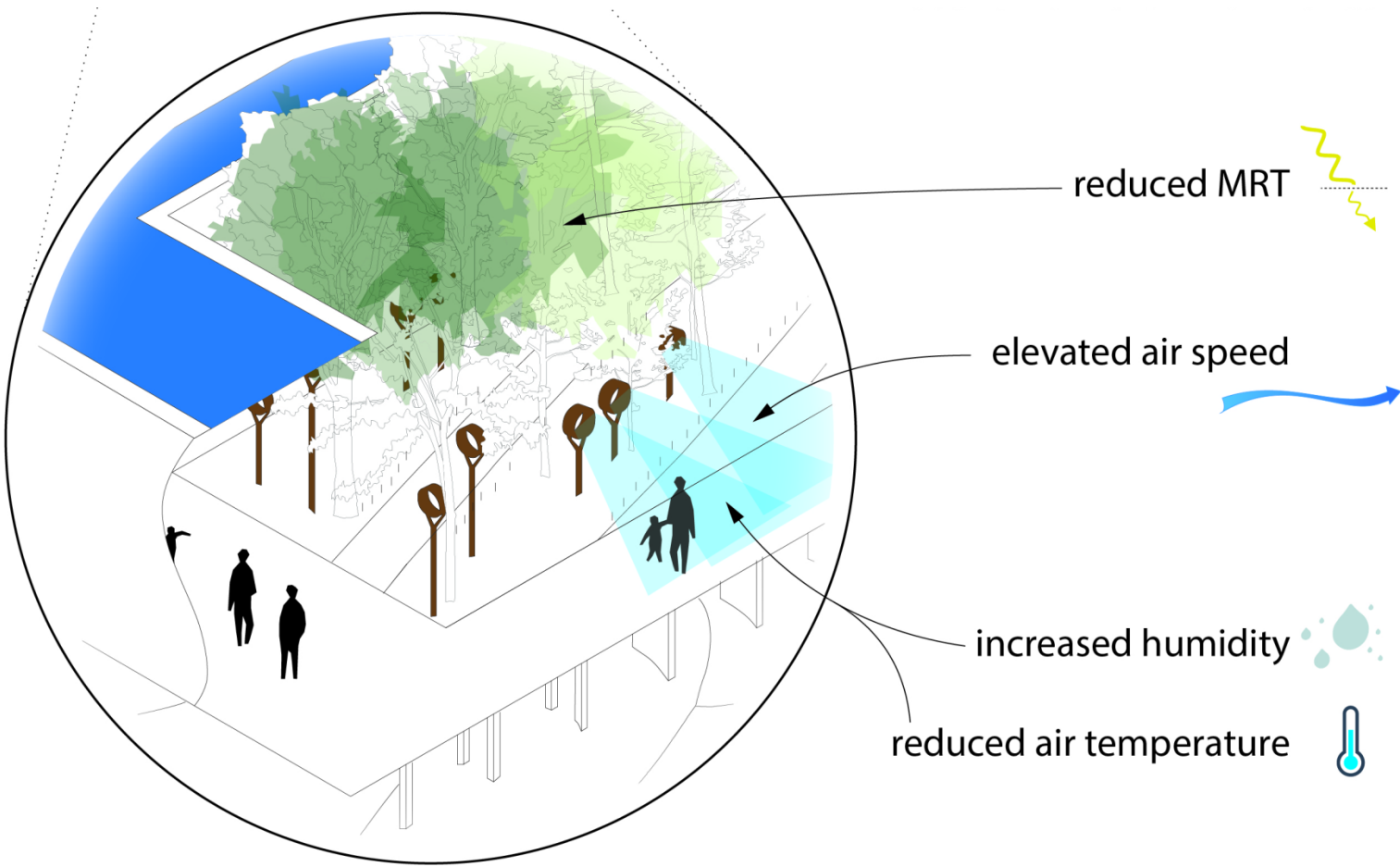
### VEGETATION

Large and dense trees can provide excellent shade. If well irrigated leave surface temperatures will remain close to ambient air temperatures even when exposed to intense solar radiation. So rich vegetation will keep the mean radiant temperature (MRT) significantly lower as typical building materials.

### TECHNOLOGIE

Fans in combination with high pressure misting system can provide efficient adiabatic cooling effects perceived at the position of human beings.

Elevated air speed and dry mist to create comfort in outdoor environment



Elevated air speed and dry mist to create comfort in outdoor environment



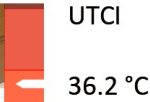
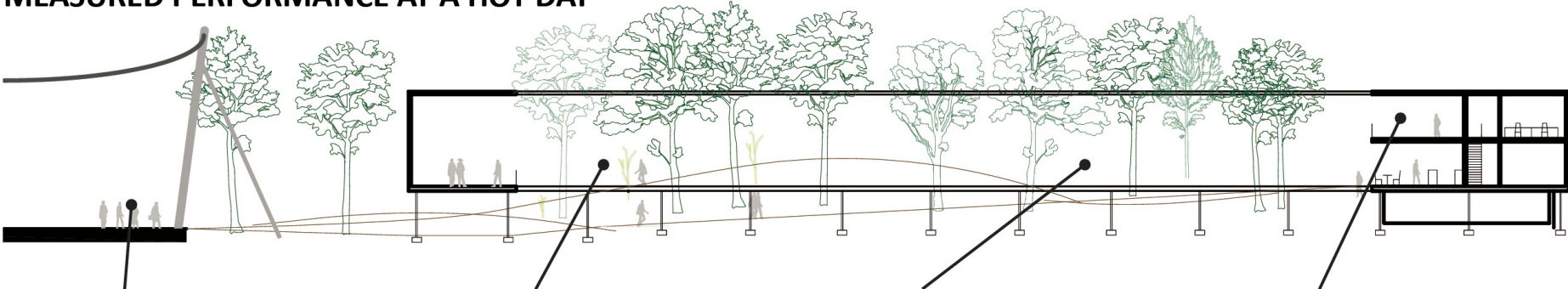
Elevated air speed and dry mist to create comfort in outdoor environment



Elevated air speed and dry mist to create comfort in outdoor environment

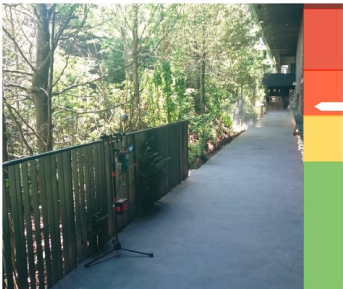


MEASURED PERFORMANCE AT A HOT DAY



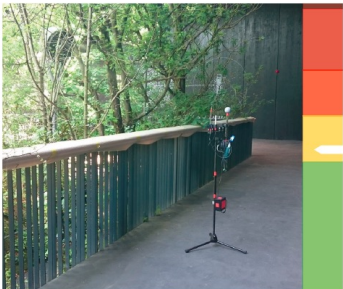
Shade, EXPO Pathway

Air temperature:	34.5 °C
Relative humidity:	44.0%
Mean Radiant Temperature:	38.4 °C
Air velocity:	0.3 m/s



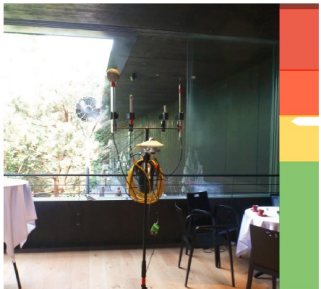
Shade, Vegetation

Air temperature:	32.5 °C
Relative humidity:	50.0%
Mean Radiant Temperature:	32.5 °C
Air velocity:	0.3 m/s



Shade, Dry Mist Fans

Air temperature:	27.0 °C
Relative humidity:	74.0%
Mean Radiant Temperature:	34.3 °C
Air velocity:	2.6 m/s



VIP-Lounge

Air temperature:	31.0 °C
Relative humidity:	61.0%
Mean Radiant Temperature:	31.0 °C
Air velocity:	1.8 m/s

# EXPO2015: AUSTRIAN PAVILION





plane für  
“high comfort - low energy”

1 reduziere den Verbrauch  
2 optimiere die Effizienz  
3 ersetze fossile Brennstoffe

nutze die natürlichen  
Ressourcen des Standortes

denke in größeren Maßstäben  
berücksichtige Mobilität

vereinbare nachhaltige Ziele

“dream big”

thermischer Komfort, Tageslicht  
exzellente Frischluft

aber schaffe hohen Komfort  
der technischen Systeme  
durch erneuerbaren Energien

Sonne, Tageslicht, Wind,  
Geothermie, Wasser

vom Gebäude zum Masterplan  
ganzheitliche Lösungen

Reduziere Primärenergie

„maximize impact“