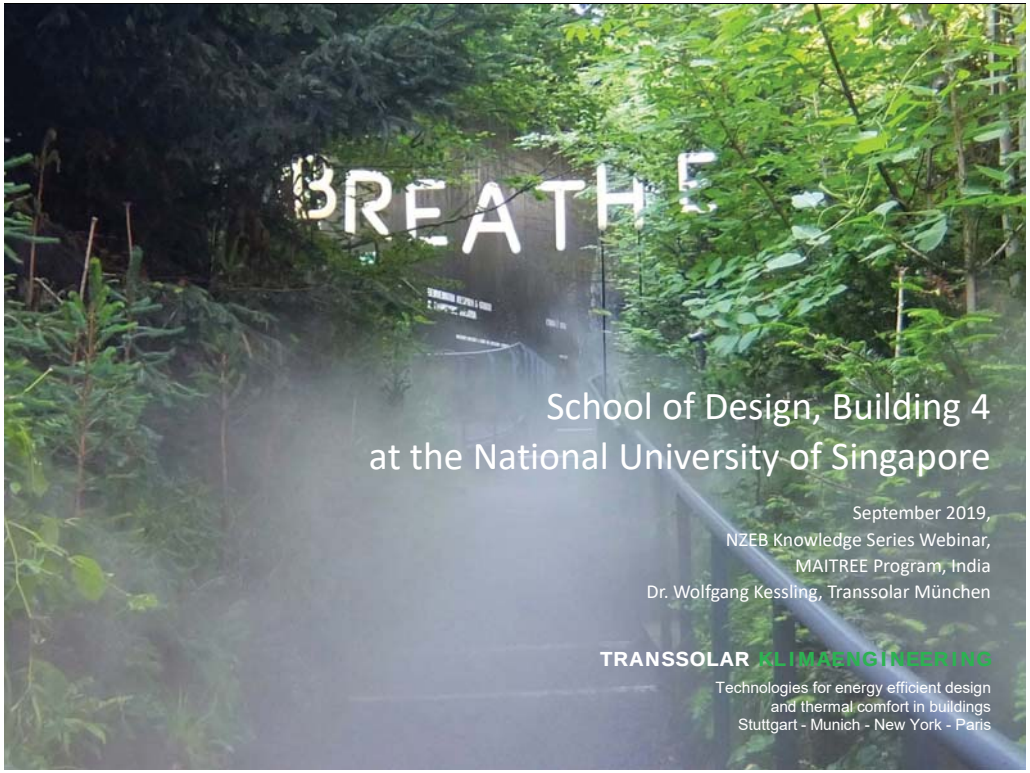


School of Design, Building 4
at the National University of Singapore

September 2019,
NZEB Knowledge Series Webinar,
MAITREE Program, India
Dr. Wolfgang Kessling, Transsolar München

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

SDE4 - Net Zero by Design

Comfortable and Energy Efficient, Building Performance by Design

School of Design at NUS

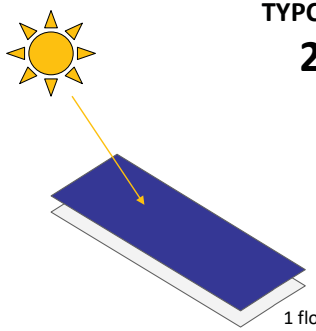
Client
National University Singapore

Architect
Serie Multiply, London and Singapore

MEP and Architects of record
Surbana, Singapore

VISION
high-comfort
net-zero
energy building

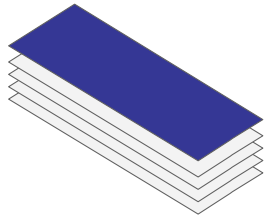
WHAT IS A NET ZERO ENERGY BUILDING?



TYPCIAL PRODUCTION ROOF

260 kWh/m²a

1 floor



4 floors

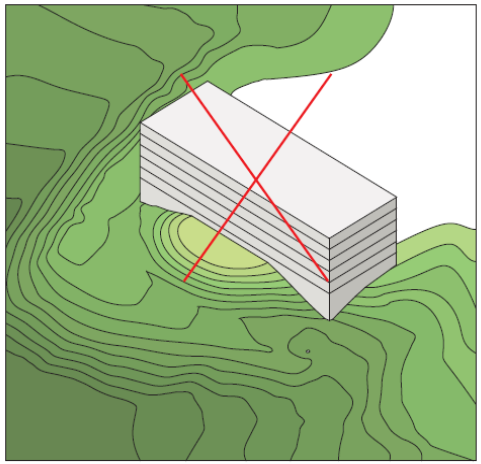
OFFICE, AVERAGE EUI

252 kWh/m²a

OPTIMIZED BUILDING

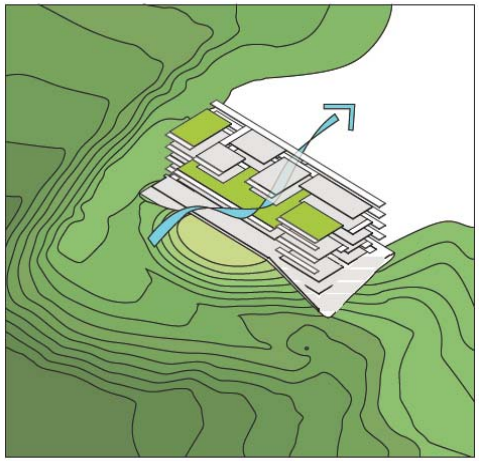
70 kWh/m²a

THE ARCHI-TECTURAL IDEA



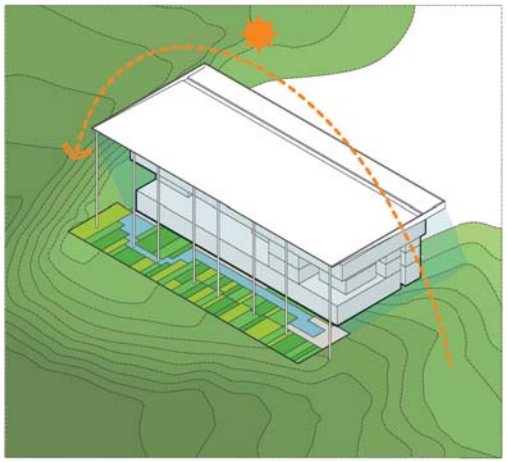
Credits: Serie

Language of stacked planes, platforms and boxes



Credits: Serie

Over-sailing roof, shade …



Credits: Serie

… and renewable electrical energy production

Credits: Serie

Image: Rory Gardiner

Image: Rory Gardiner

Image: Rory Gardiner

Image: Rory Gardiner

Image: Rory Gardiner

Image: Rory Gardiner

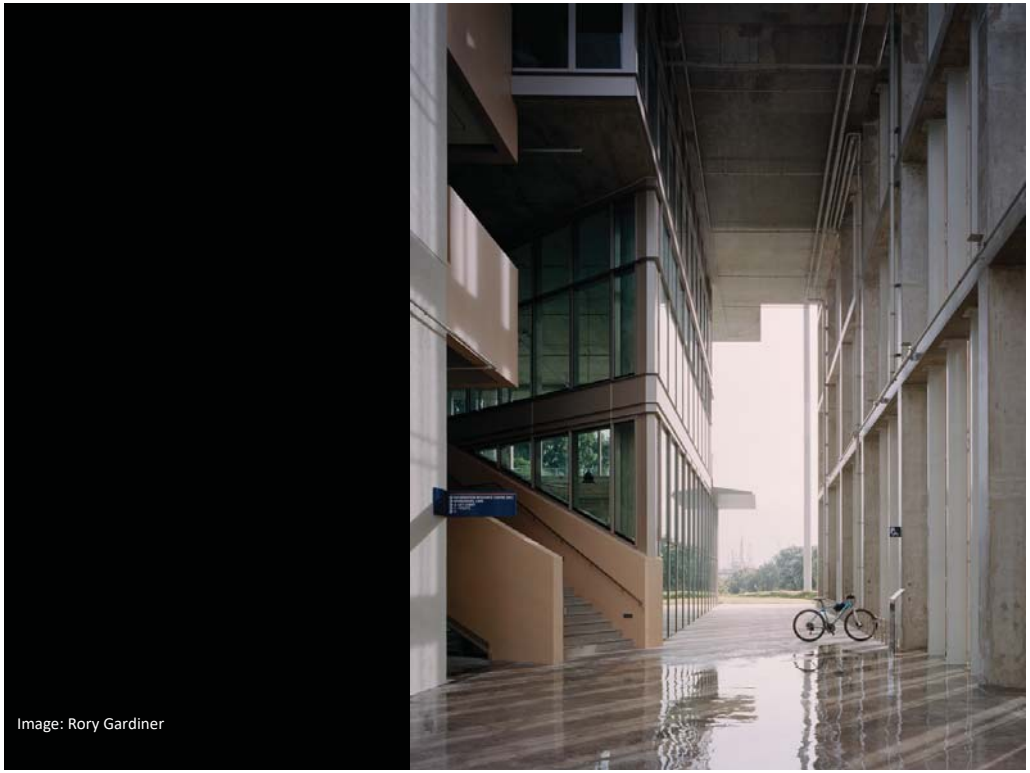


Image: Rory Gardiner

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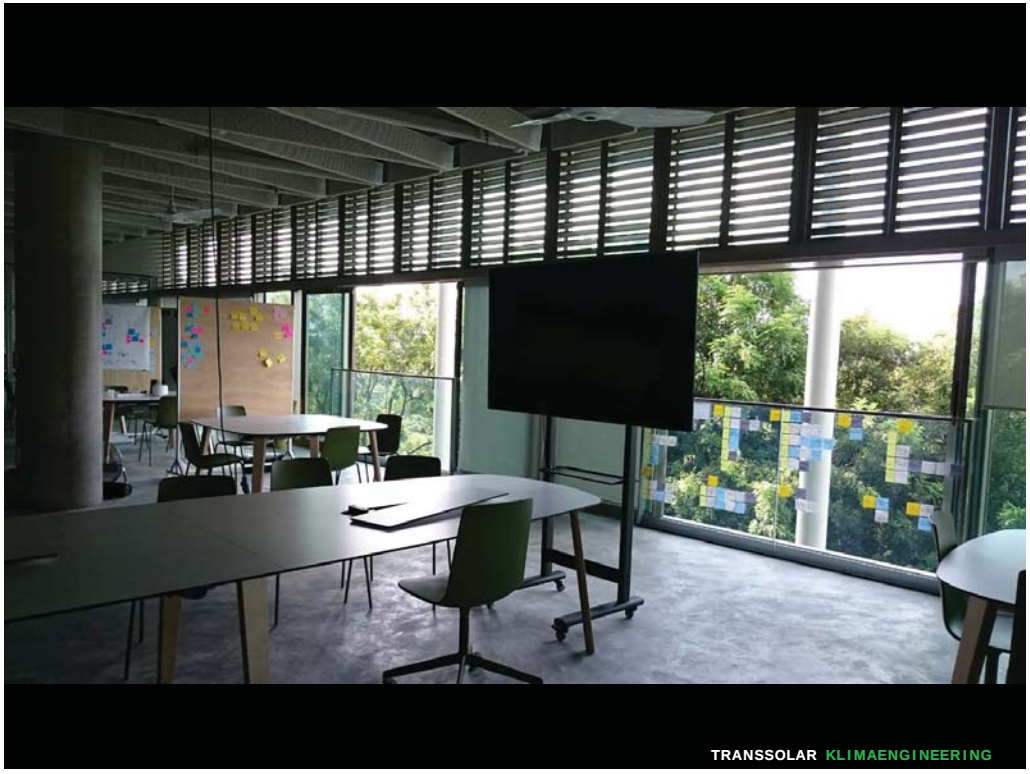
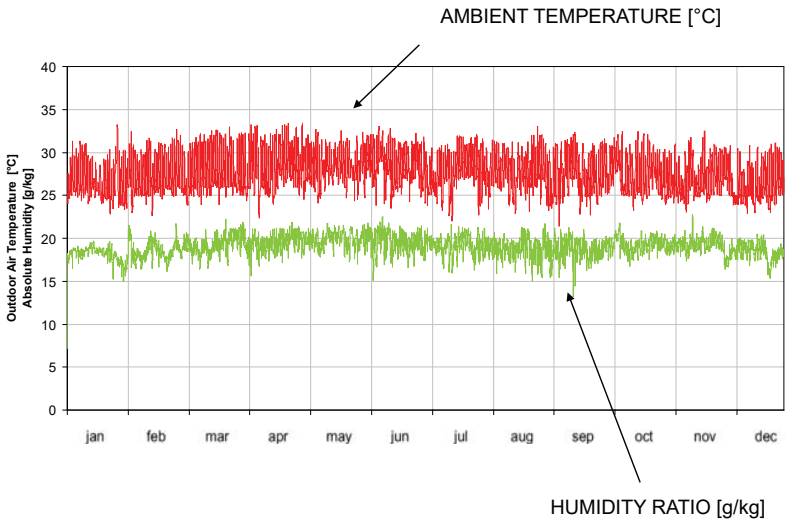
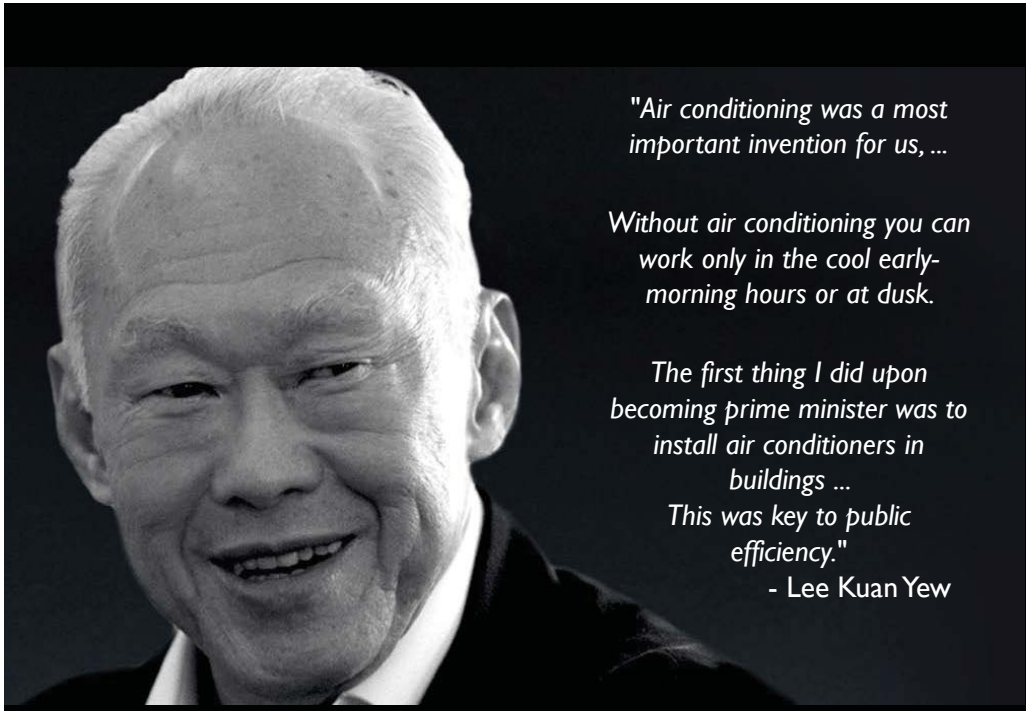


COMFORT
?

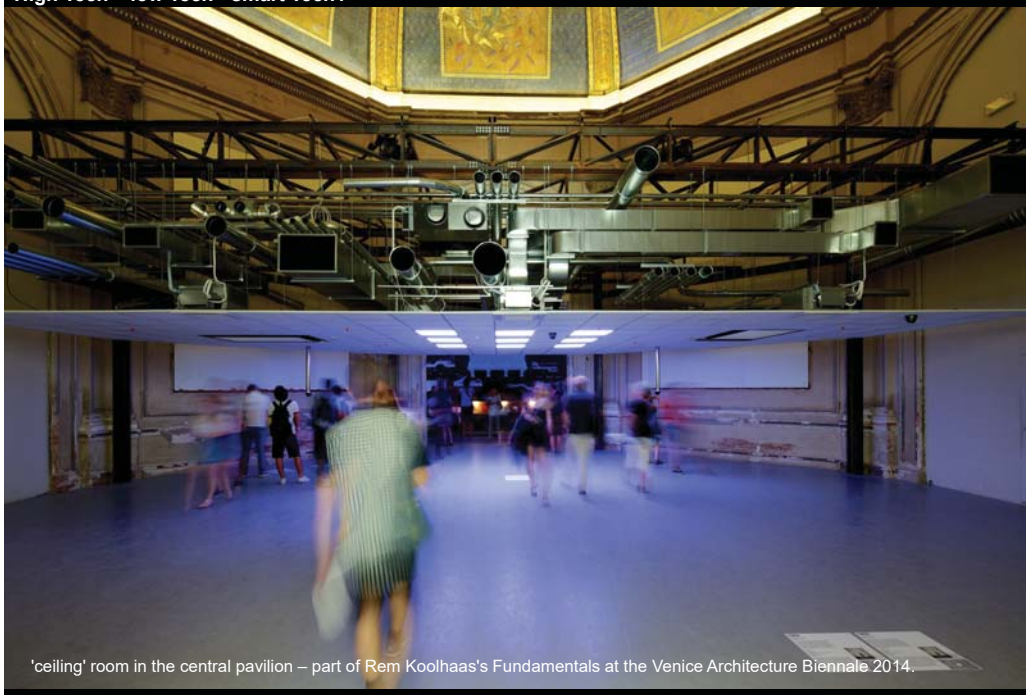
Climate Singapore





Lee Kuan Yew, Singapore Prime Minister (1959 - 1990), The East Asian Way—With Air Conditioning, 2009

High Tech – low Tech - smart Tech?



'ceiling' room in the central pavilion – part of Rem Koolhaas's Fundamentals at the Venice Architecture Biennale 2014.

COMFORT !

Implement adaptive comfort approach

conventional approach

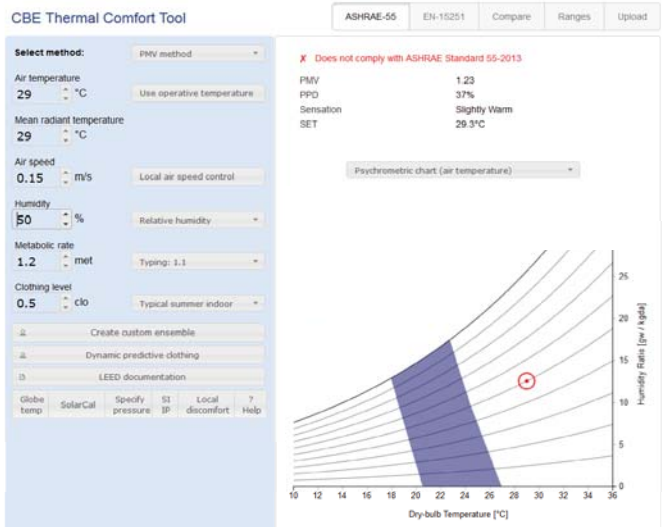
operative Temperature 24°C

adaptive comfort approach

operative Temperature 29°C tempered air + elevated air speed

Thermal comfort comparison with online tool of Berkeley University

Thermal Comfort without elevated air speed



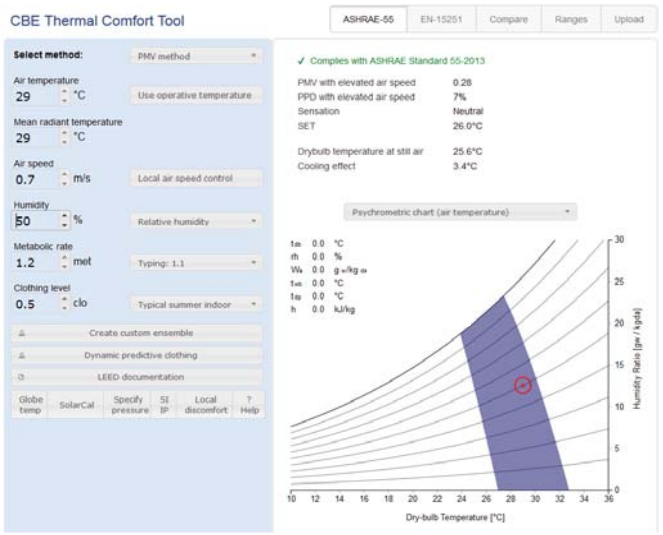
Comfort tool of Center for the Built Environment, University of California Berkeley

Operative Temperature	29°C
Air speed	0.15 m/s
PMV	1.2
SET	29.3

☹

Thermal comfort comparison with online tool of Berkeley University

Thermal Comfort with elevated air speed



Comfort tool of Center for the Built Environment, University of California Berkeley

Operative Temperature	29°C
Air speed	**0.7 m/s**
PMV_{eas}	0.3
SET	26

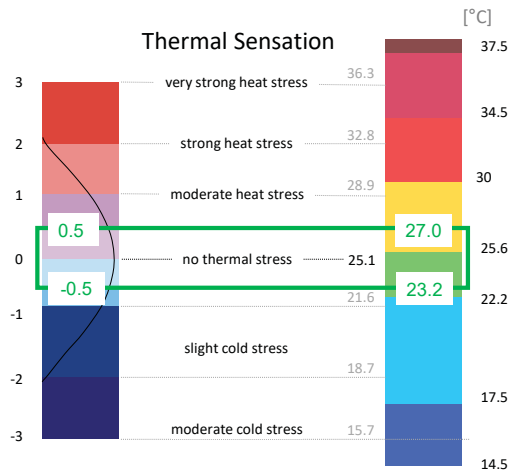
Thermal comfort modelling, ASHRAE Standard 55

Parameter

- Mean Radiation Temperature
- Air Velocity
- Air Humidity
- Air Temperature
- Clothing
- Activity

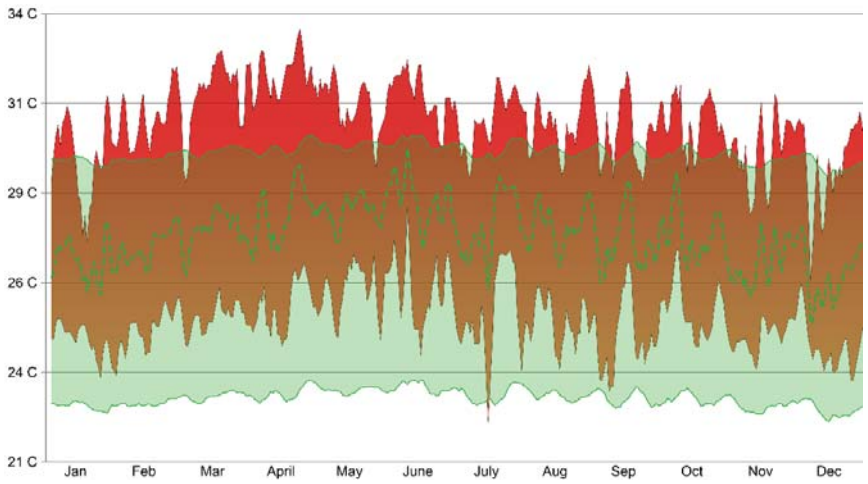
Model Predicted Mean Vote (PMV)

Model Standard Effective Temperature (SET)



Climate Singapore

ADAPTIVE COMFORT RANGES IN SINGAPORE

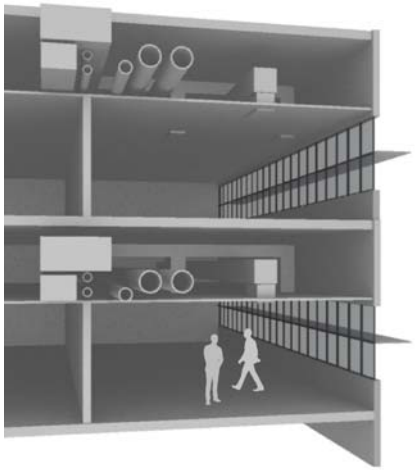


FULL AC vs ADAPTIVE

Basic charactersitics: Conventional Full AC Design versus Adaptive Comfort Design

Full AC

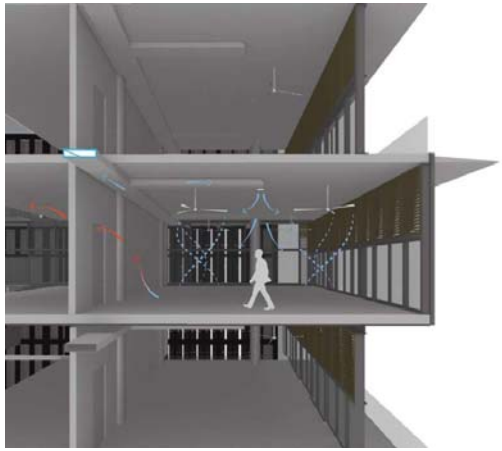
Typical Conventional Design



- fresh air supply with heat recovery to be energy efficient
- return air system for cooling, central mech rooms
- substantial space in false ceiling
- closed façade is required

Adaptive Comfort

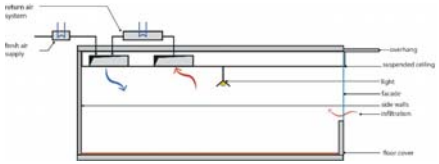
Example: School of Design 4



- supply air system with tempered air
- ceilings fan
- no return air, spill over
- window opening is possible

Comparison: Conventional Full AC Design versus Adaptive Comfort Design

Full AC

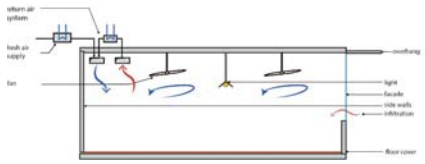


mechanical ventilation:
Tair 15°C
Tdew 12°C
fresh air per person 35m³/h (1.2 ACR)
specific fan power 2 * 2500 Ws/m³

cooling setpoint: operative temperature 24°C
rel. Humidity 60% +/- 5%

return air system: range 4.9 ACR to 0.5

Adaptive Comfort

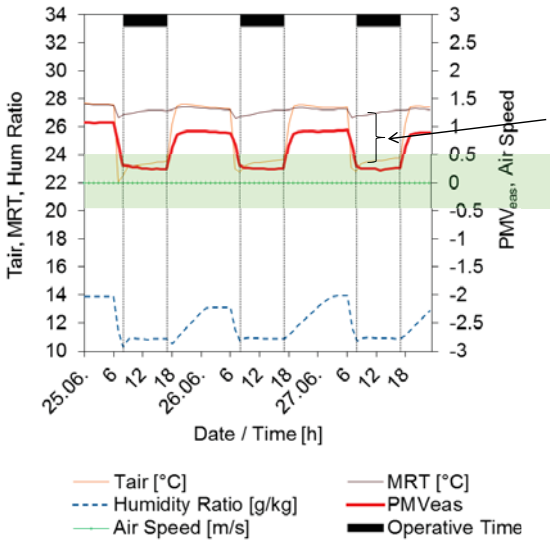


mechanical ventilation:
Tair 18°C
Tdew 18°C
fresh air per person 35m³/h (1.2 ACR)
specific fan power 2 * 2500 Ws/m³

cooling setpoint: operative temperature 29°C
Standard Effective Temp. 27°C
ceiling fan max 1 m/s
rel. Humidity not controlled

return air system range 1.9 ACR to 0

Comfort for design day: Conventional system – Full AC

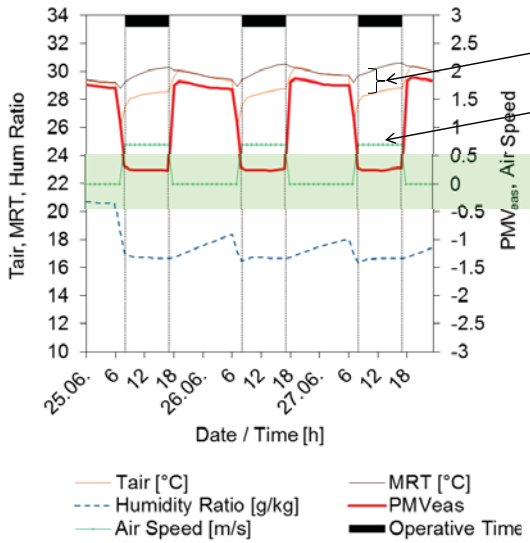


operative temperature ~ 25 °C

high comfortable conditions

low humidity ratio

Comfort for design day: Hybrid system for Adaptive Comfort Design



operative temperature ~ 29 °C

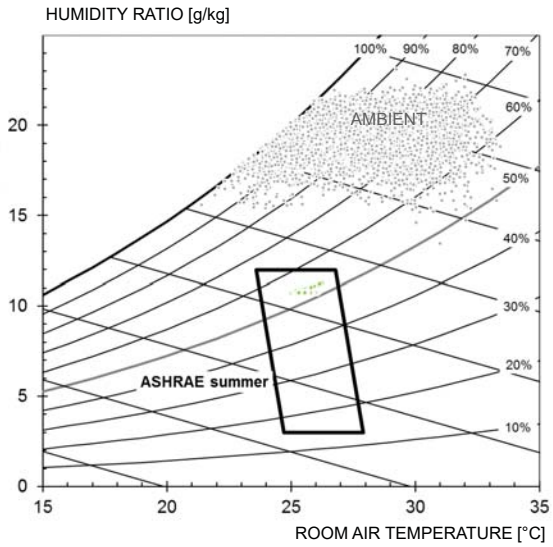
elevated air speed 0.7 m/s

high comfortable conditions

higher humidity ratio

Comfort and energy study for generic university classroom

AC Comfort



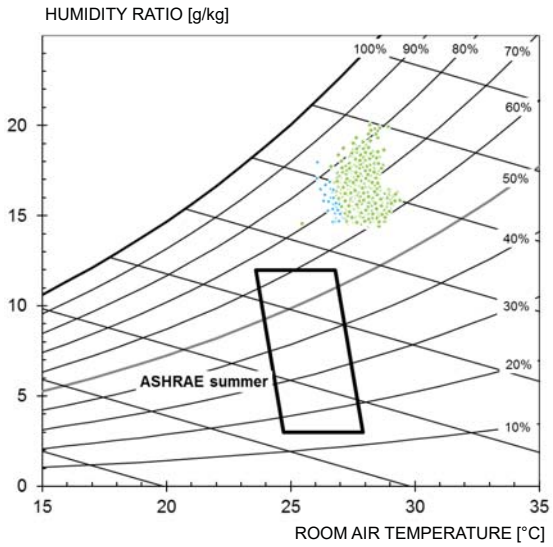
ENERGY [kWh/m²a]

COMFORT

WARM	PMV > 0.5	
COMFORTABLE	-0.5 < PMV < 0.5	100%
COLD	PMV < -0.5	

Comfort and energy study for generic university classroom

Adaptive Tempered Comfort

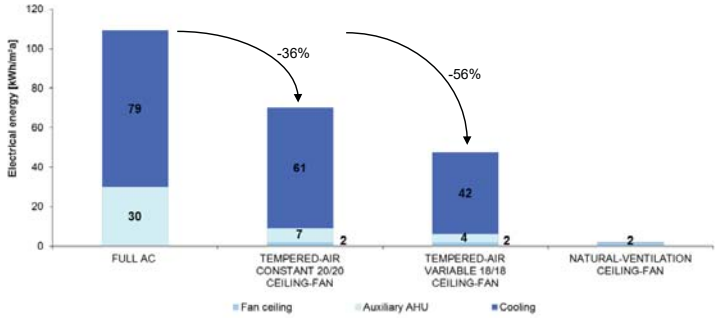


ENERGY [kWh/m²a]

COMFORT

WARM	PMV > 0.5	
COMFORTABLE	-0.5 < PMV < 0.5	98%
COLD	PMV < -0.5	2%

Electrical energy demand for cooling of compared options



DOES ADAPTIVE COMFORT WORK?

Testing of Adaptive Comfort with measurements and perception studies at UWC

Typical classroom at UWC

Occupancy:
24 pupils
1 teacher

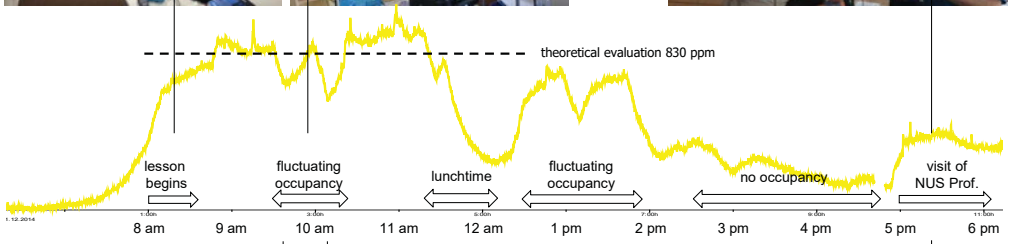
Room characteristics:
area = 72 m²
room height ≈ 2.9 m

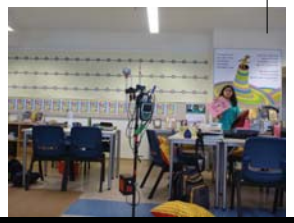
fully air conditioned
supply: 15°C
9 g/kg
exhaust:
spill over into floor

2 ceiling fans

Typical utilization of an UWC classroom

CO_2 concentration as indicator for utilization





Thermal zoning of School of Design building, overview

Photovoltaic
renewable energy

Hybrid Tempered, 26%
library, design studios
Theatre, offices

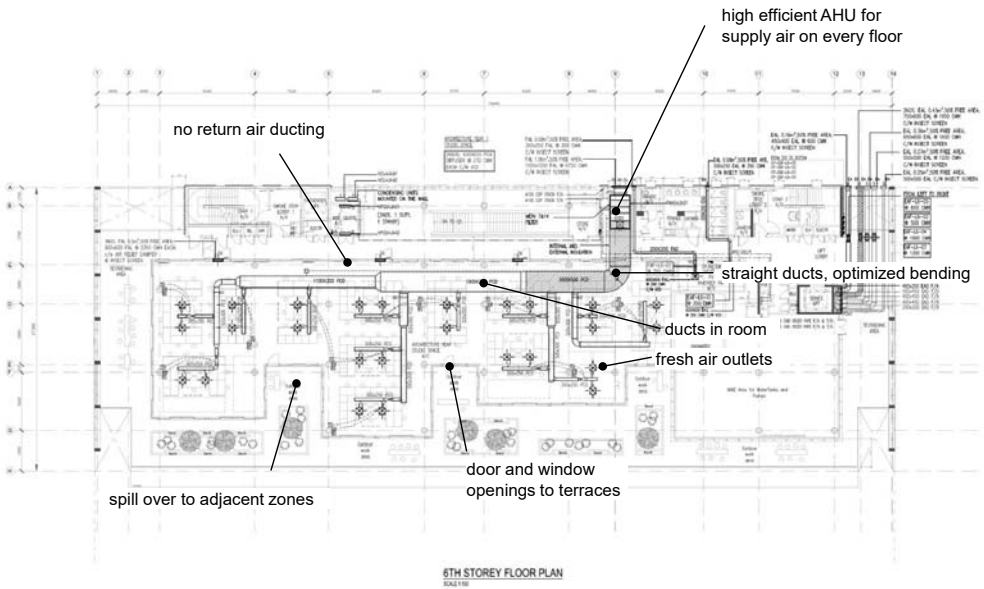
Full AC,17%
green building technology lab
energy lab, computer lab

Natural Cross Ventilated, 46%
with elevated air speed
social Plaza and social
interaction spaces
modeling areas, work shops
smart green home

Circulation
micro climate, wind
vegetation, green and blue

mech and aux rooms 10%

Simple mechanical system, example of drawings SDE4

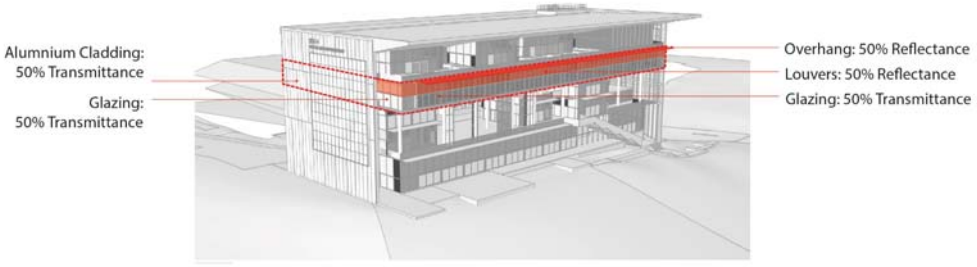


Credits: Surbana

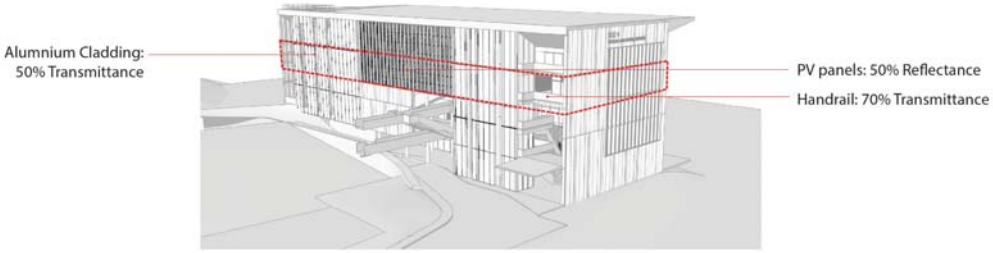
FACADE

Modeling Detail, 5th Floor, status 13th July 2015

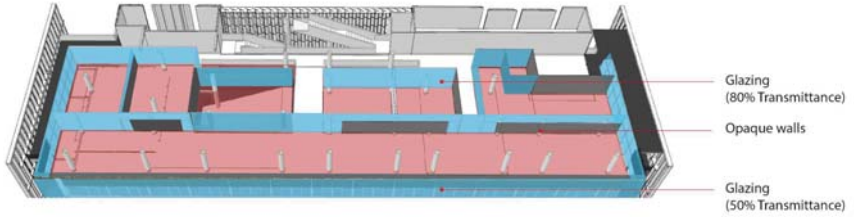
View from South-West



View from North-West



Modeling Detail, 5th Floor, status 13th July 2015



TRANSSOLAR KLIMAENGINEERING

Daylight simulation results UDI, 5th Floor _whole floor with shading, status 13th July 2015

UDI 300-2000lux

UDI >2000lux

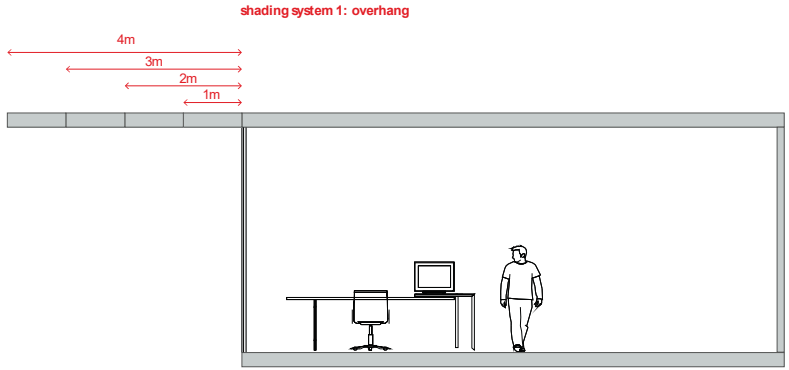
UDI <300lux

LEVEL 5 **ENTIRE FLOOR_WITH SHADING sDA= 47%**

TRANSSOLAR KLIMAENGINEERING

Evaluation of shading systems for glare protection

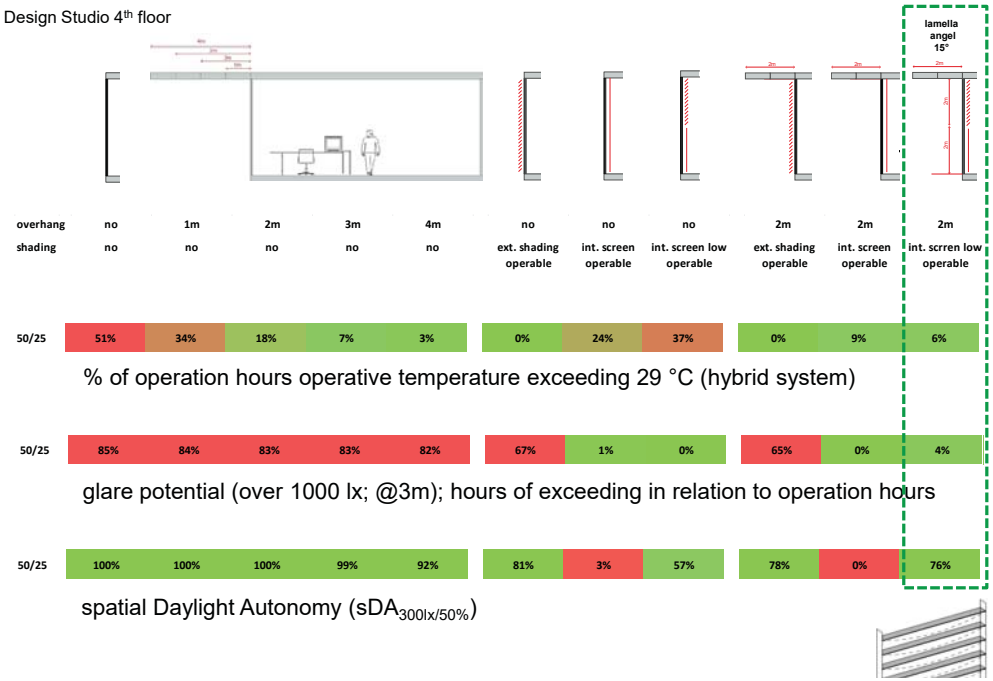
Concept Sketch



TRANSSOLAR KLIMAENGINEERING

Final overview of options to inform the design

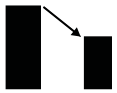
Design Studio 4th floor



PROCESS

Framework for net-zero energy concept

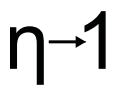
STRATEGY and PROCESS



1

Minimize
Energy Use Intensity by
Optimized Building Layout,
Optimized Operation and
balanced user requirements

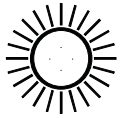
Client
Architects



2

Minimize
Energy Use Intensity by
Optimized Technical Systems

MEP



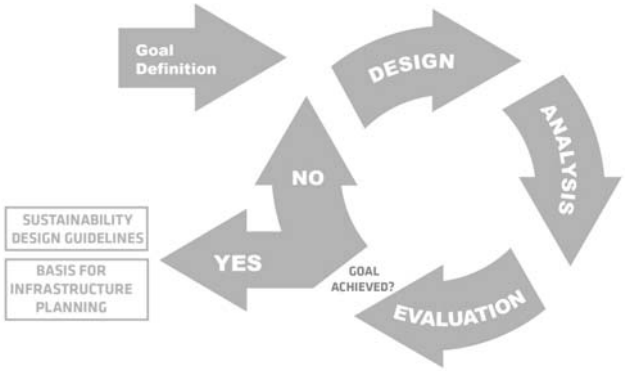
3

Maximize
Renewable Energy Production

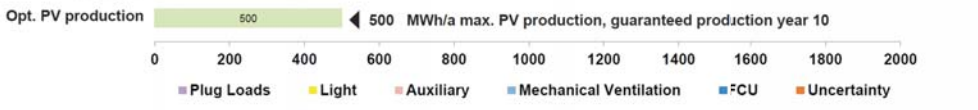
MEP
Architects

Generic Strategy: Iterative Process

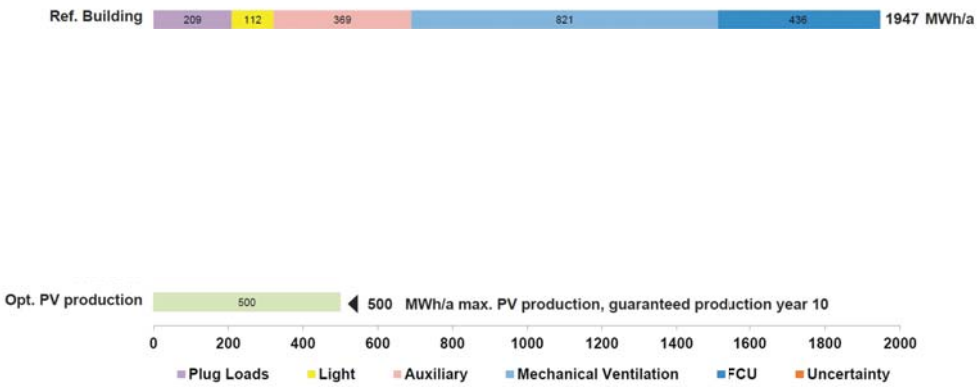
The nature of the set of **multiple requirements** for a sustainable development, with many of them being competitive, requires an **iterative design process** in order to find the best solution. In addition, the multidisciplinary design thinking has to overlap the different scales of the development.



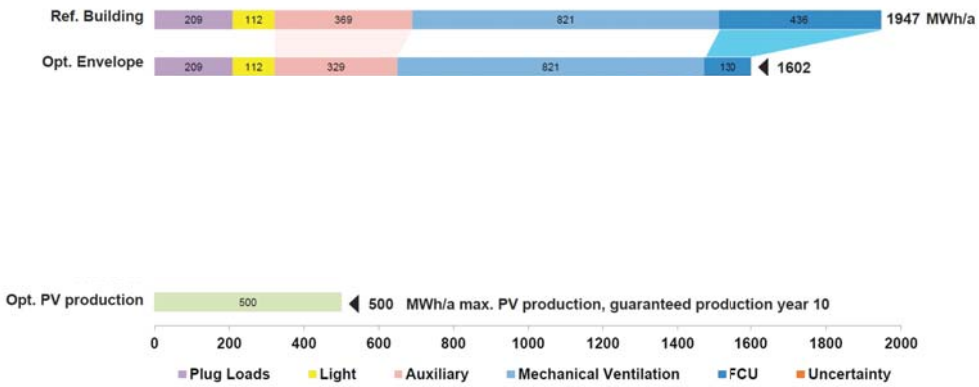
NET ENERGY STORY



⇨ Maximal renewable energy production with PV system defines the available electrical energy to operate the building on net zero.

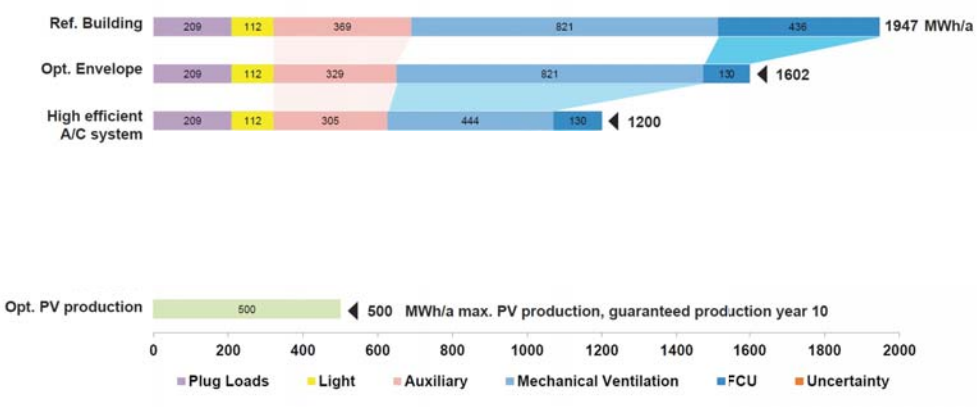


⇨ Challenge the client design brief



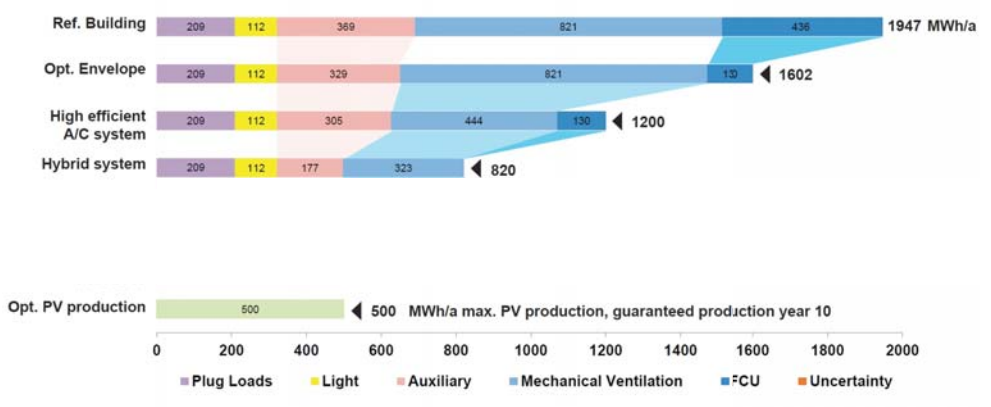
⇨ Optimize the envelope for thermal comfort and energy and glare and daylight

Net Zero Energy story



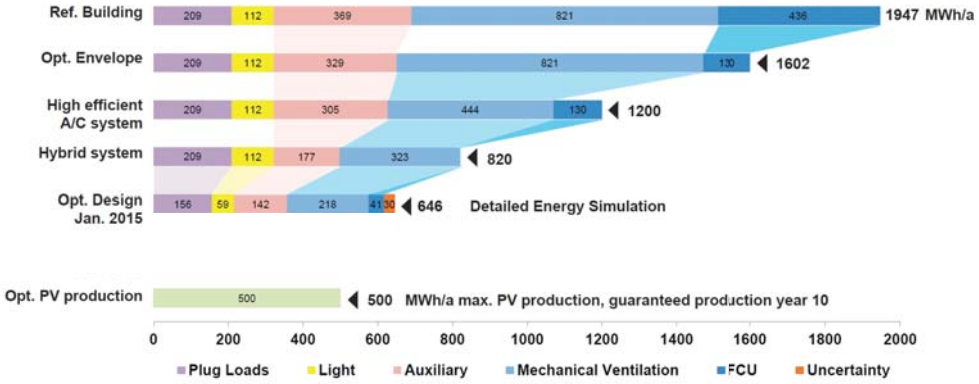
⇨ Maximal energy efficiency of a/c systems

Net Zero Energy story



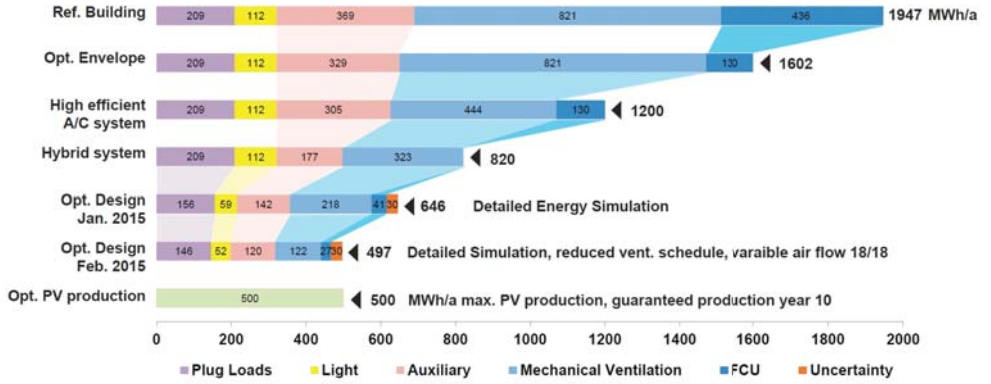
⇨ Design for adaptive comfort with hybrid system
great fresh air, tempered and elevated air speed

Net Zero Energy story



⇨ Get the details right

Net Zero Energy story

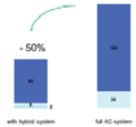


⇨ Inform and improve the building design step by step
with design charrettes

university building
in the tropics…

tempered air and
elevated air speed…

highly comfortable
spaces…



energy efficient and
low investment cost…

100% powered by
photovoltaic on own footprint.

THE BIGGER PICTURE

TRANSSOLAR KLIMAENGINEERING

Illustration: Sean Quinn, Head of Sustainable Design, 10 DESIGN
Source: UN Habitat, State of the World's Cities 2010/2011; McKinsey Global Institute.

Illustration: Sean Quinn, Head of Sustainable Design, 10 DESIGN
Source: Adapted from Architecture 2030. UN Habitat, State of the World's Cities 2010/2011; McKinsey Global Institute.

Growth of the built environment

PACE OF ASIAN DEVELOPMENT

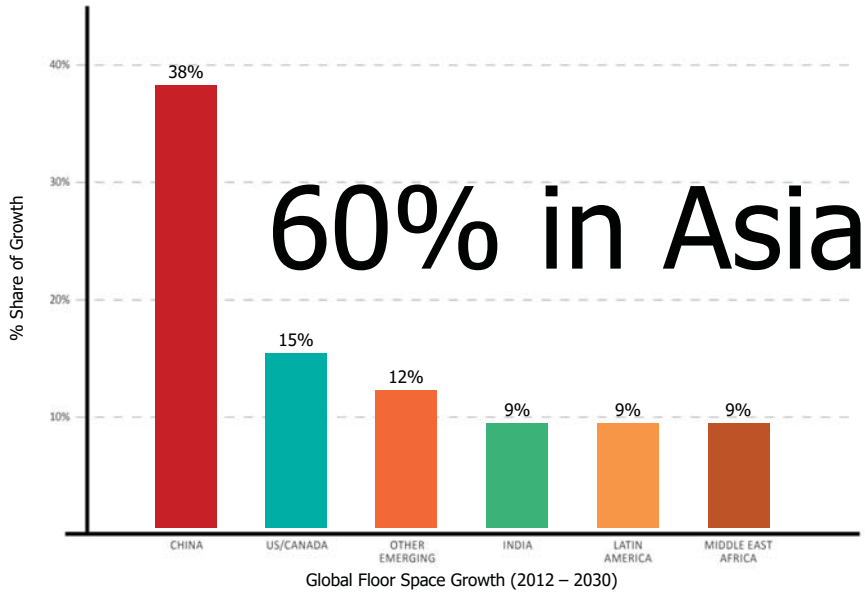
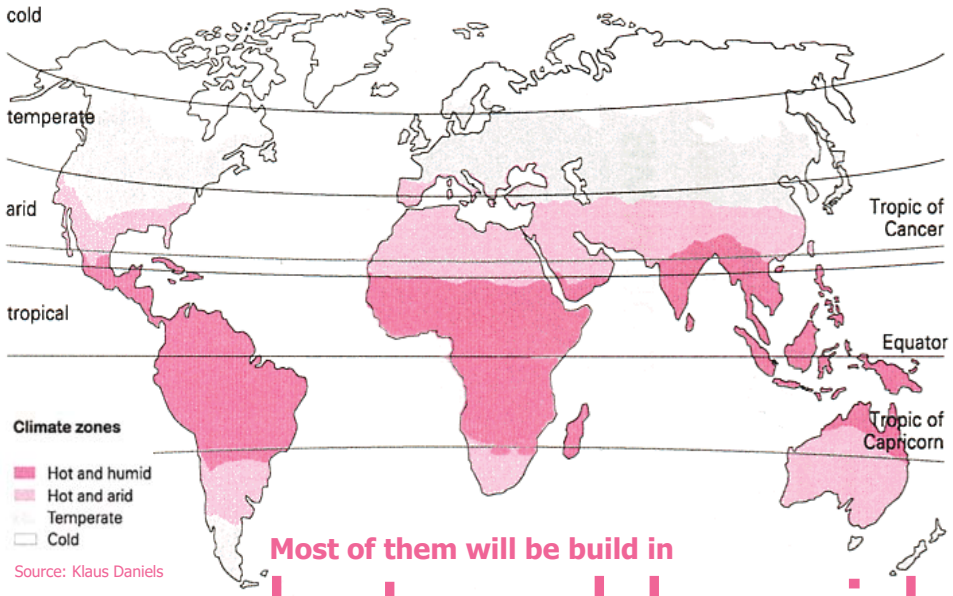


Illustration: Sean Quinn, Head of Sustainable Design, 10 DESIGN
Source: Mckinsey.com,. 'Urban World: Cities And The Rise Of The Consuming Class'. N.p., 2015.

Climate zones



Source: Klaus Daniels

Most of them will be build in

hot and humid climates

The way we design buildings ...

The way we define comfort ...

... has significant impact

Buildings in the Tropics designed for adaptive comfort consume

50%

less energy