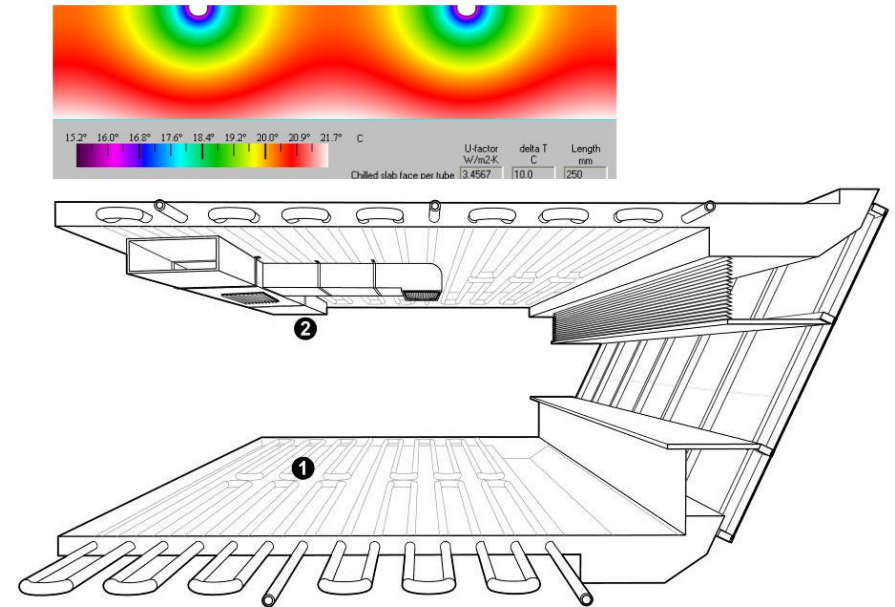
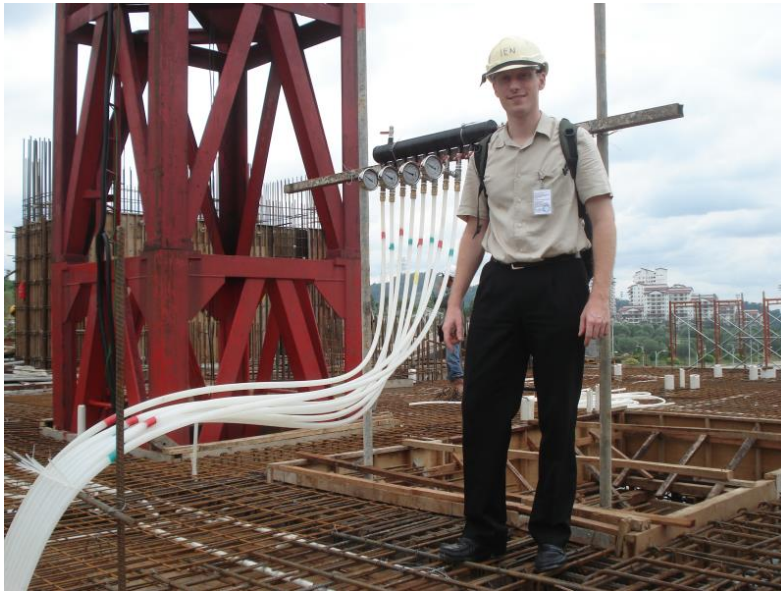


# Innovative Solutions for Energy Efficient Buildings



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# Energy Efficient Buildings with Good Payback time

Case studies from the South East Asian countries



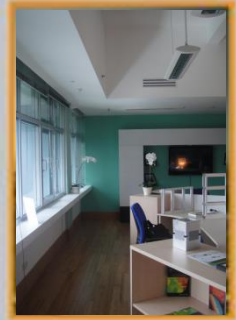
LEO Building



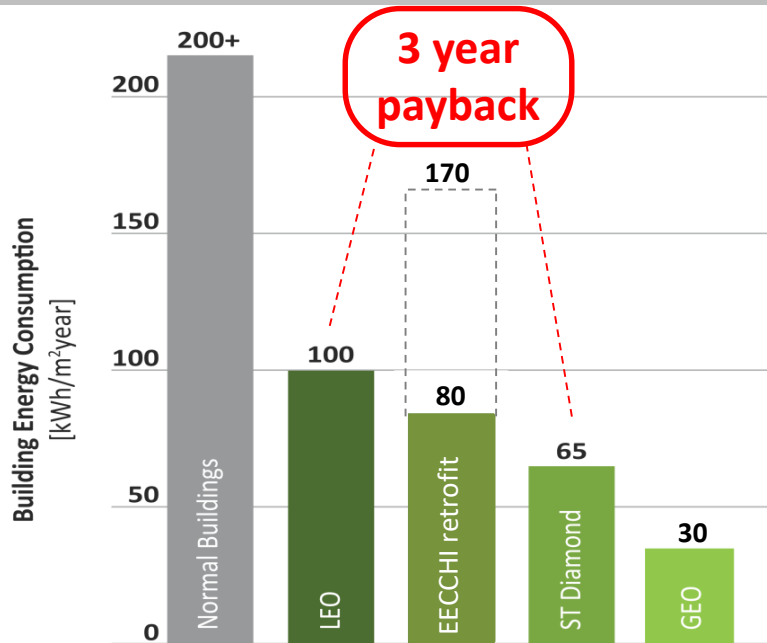
GEO Building



ST Diamond Building



EECCHI retrofit



## Energy Consumption of Green Office Buildings

Measured data for New and Retrofitted Buildings by IEN Consultants

Completed year: 2004 2010 2010 2007

Low energy bill (2017): yes ? yes yes



# Buildings & Energy

Buildings are like a leaky bucket with lots of unnecessary wastages

**ENERGY SUPPLY**  
(renewable) energy



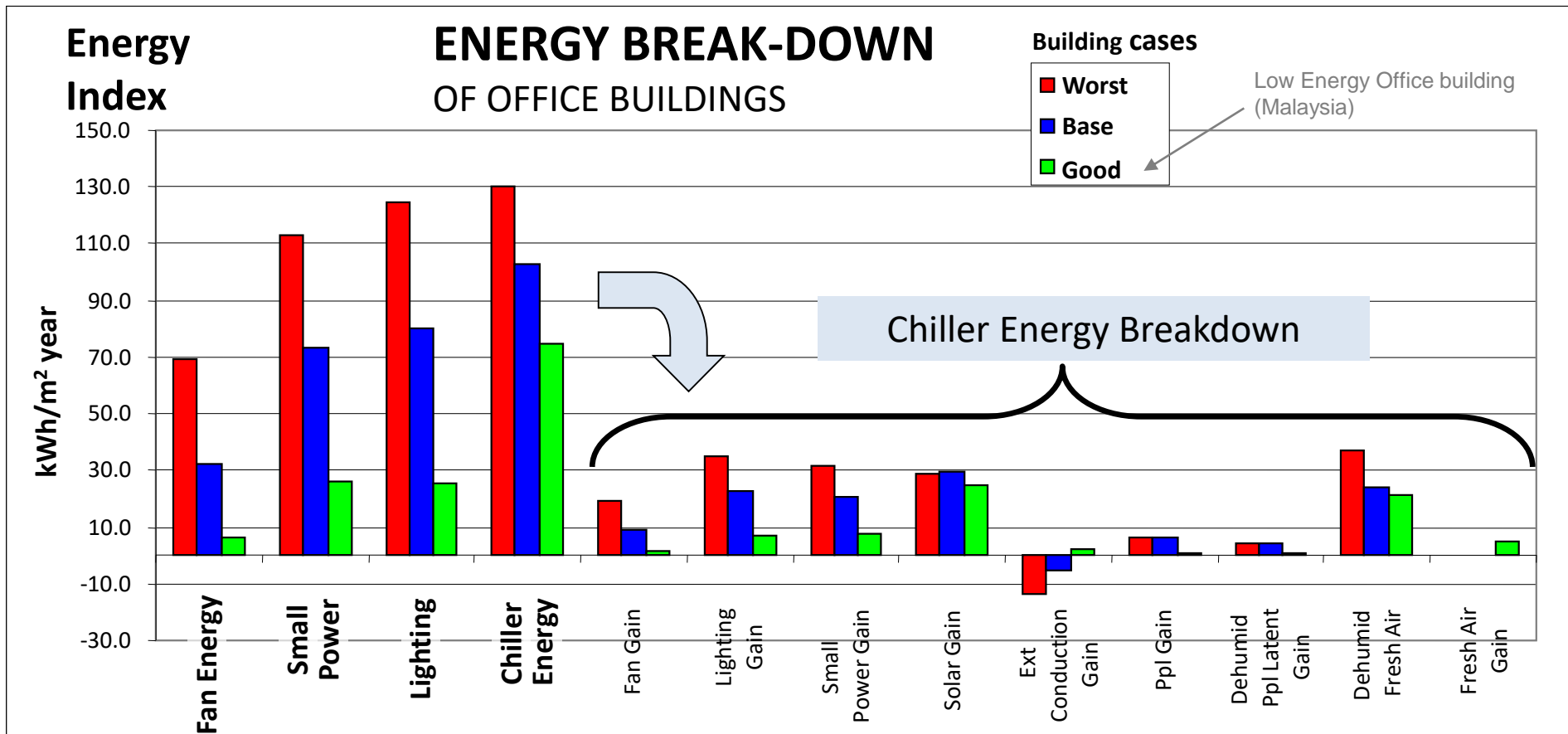
**ENERGY STORAGE**  
electric cars/batteries/thermal

**ENERGY DEMAND**

**ENERGY  
WASTAGE**

Let's plug the holes!

Ask not just for an energy efficient cooling system,  
but also “**Why do I need cooling in the first place?**”



## Case study



Green Energy Office building (Greentech Malaysia) in Bangi, Malaysia:

## GEO BUILDING



# GEO Building (formerly ZEO) in Malaysia

## Key data:

- Gross Floor Area: 4,000 m<sup>2</sup>
- Energy Index: 64 kWh/m<sup>2</sup>/year (excl. PV)
- Energy Index: 30 kWh/m<sup>2</sup>/year (incl. PV)
- Additional construction cost: 18% (excl. PV)
- Additional construction cost: 33% (incl. PV)



Greentech Malaysia office, Bangi, Malaysia (Occupation Oct 2007)

## EE Features:

- Daylighting (almost 100%)
- EE lighting + task lights
- EE office equipment
- EE server room
- Floor slab cooling
- EE ventilation
- Controls & Sensors
- Double glazing
- Insulation

# Energy Design Concepts of GEO Building

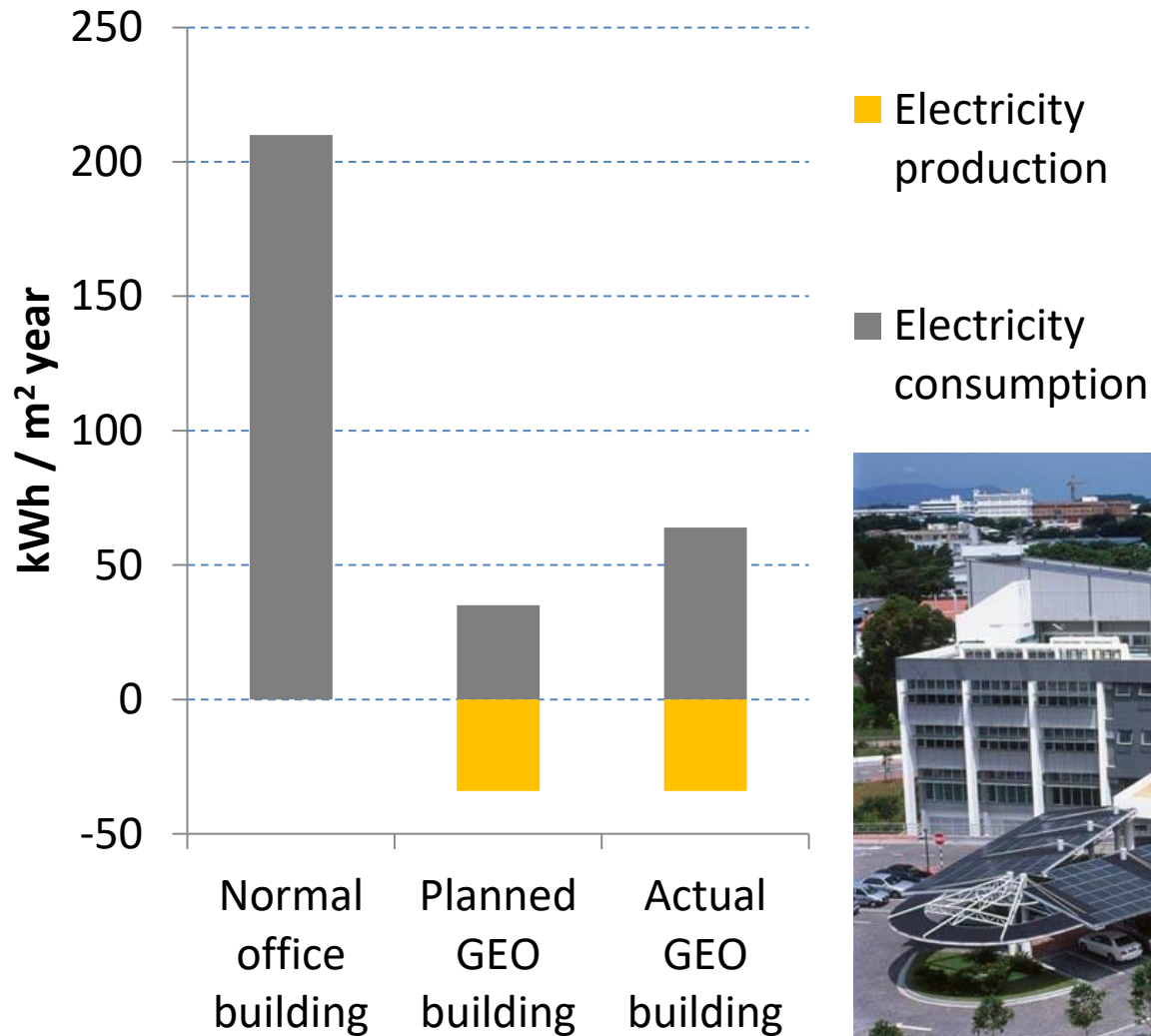
## Concept no. 1

Zero Energy Building

## Concept no. 2

Shift load to the night,  
hence, reducing peak  
demand for power utilities

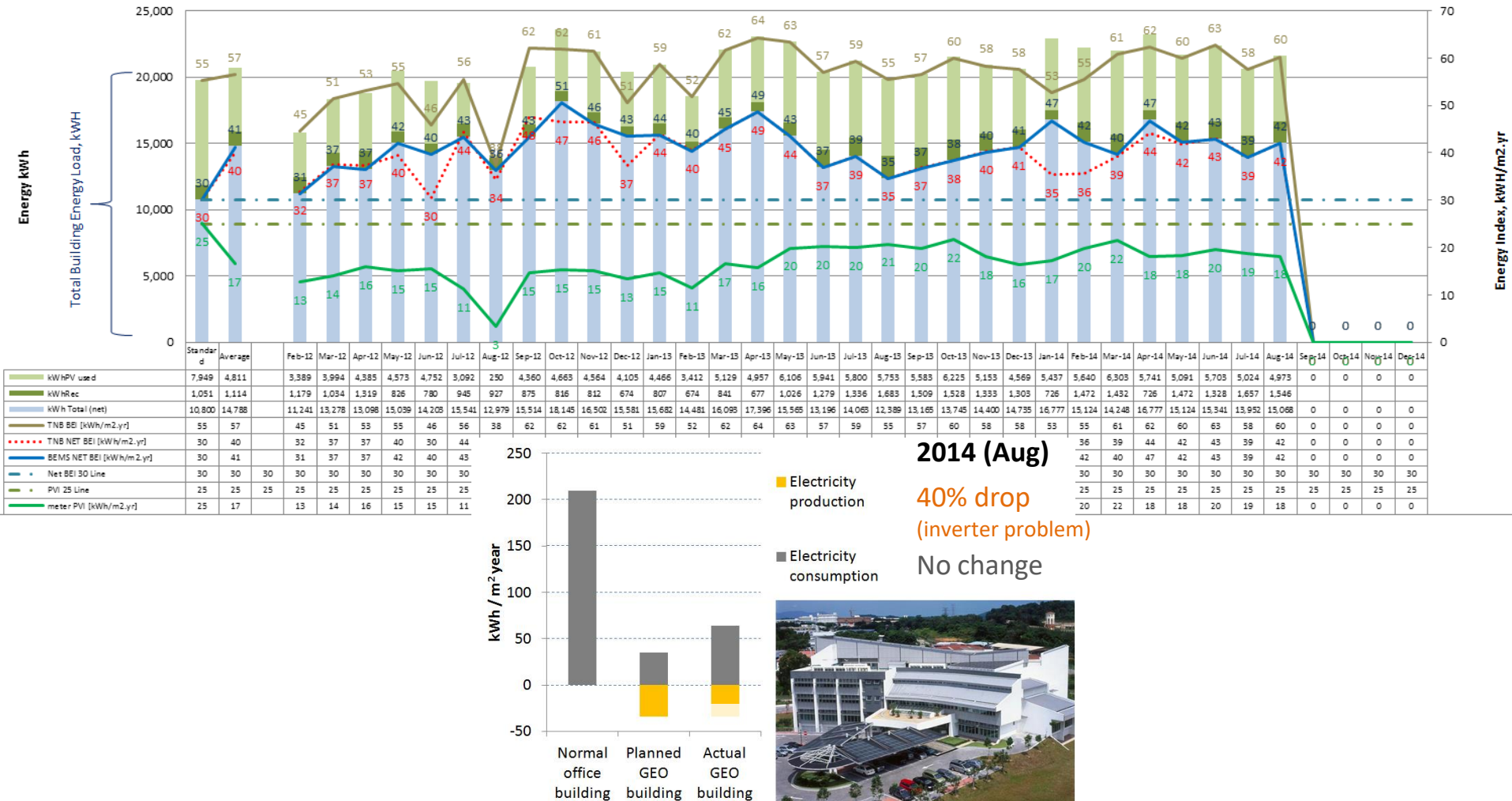
# Concept no. 1: Zero Energy Building





# GEO building: Energy measurements

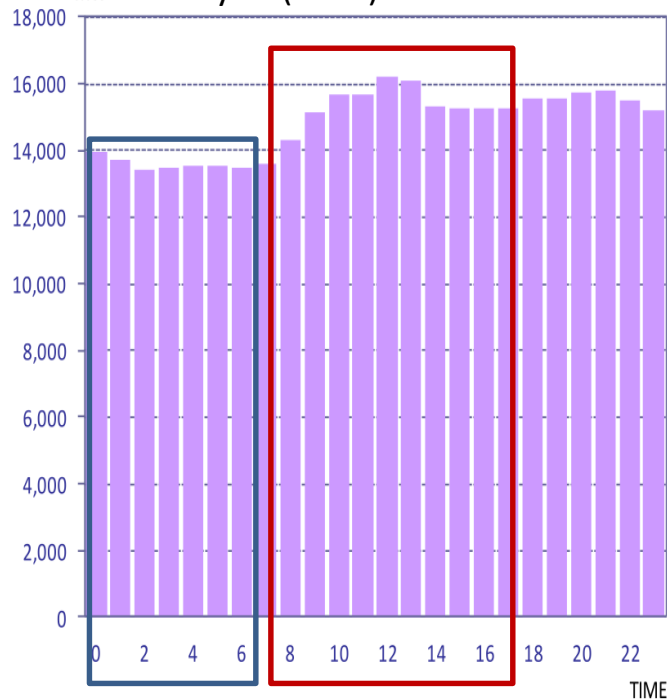
Graph 1 : GEO Building Energy Usage & Generation Performance, 2012-2014(Aug)



# Concept no. 2: Shift load to the night

## Electricity demand curve

Malaysia (2012)



**BUY**

electricity  
from the  
grid

**SELL**

electricity  
to the  
grid

**How?**

Thermal  
storage

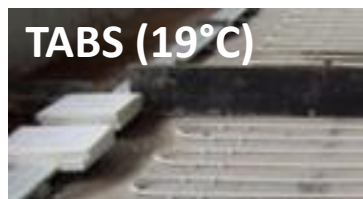
Solar  
PV

## Building integrated photovoltaic (91 kW<sub>p</sub>)



## Floor slab cooling (18°C) and Phase Change Material tank (10°C)

TABS (19°C)



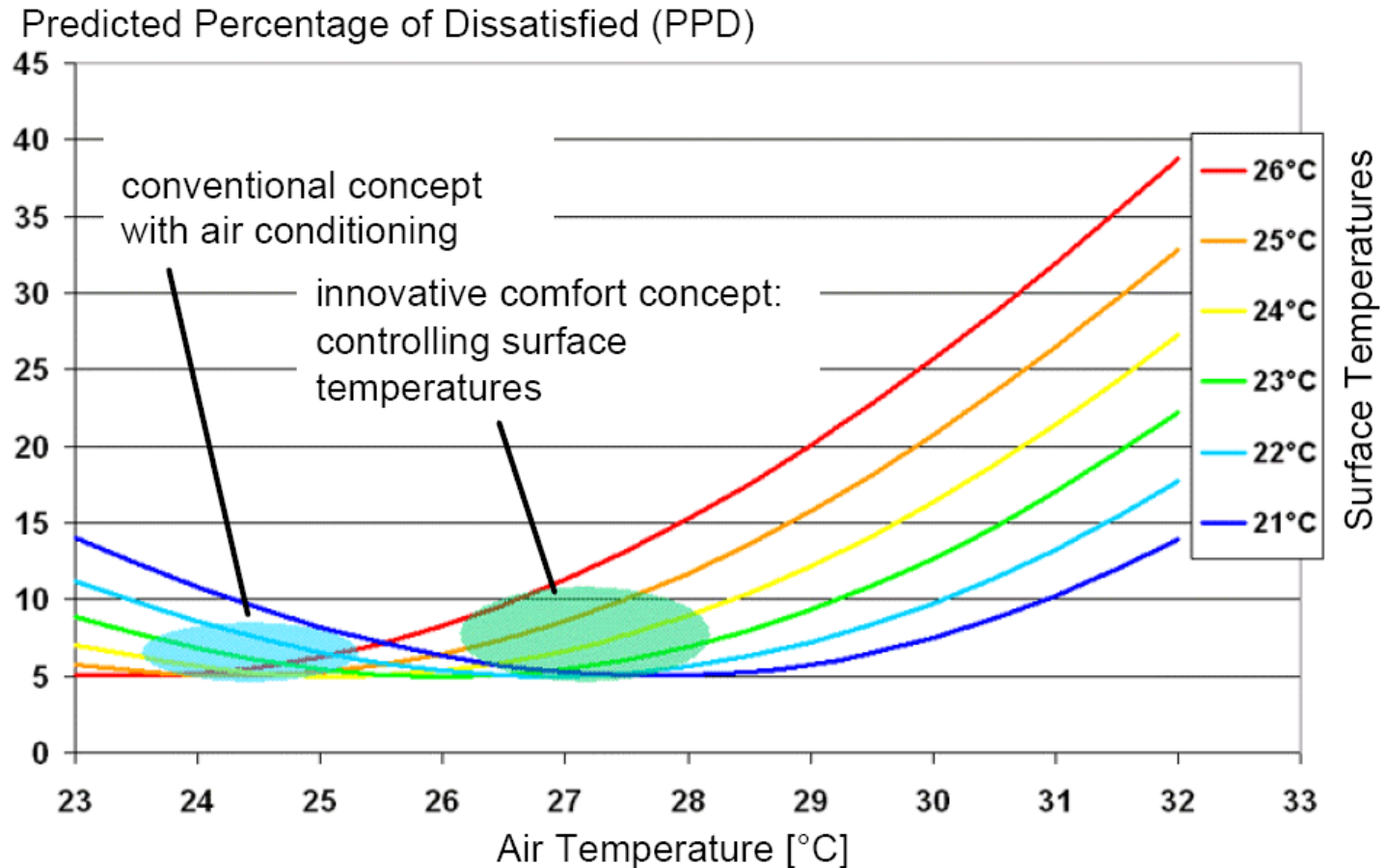
PCM tank



PCM flatice-10



# Radiant Cooling allows Higher Air Temperature

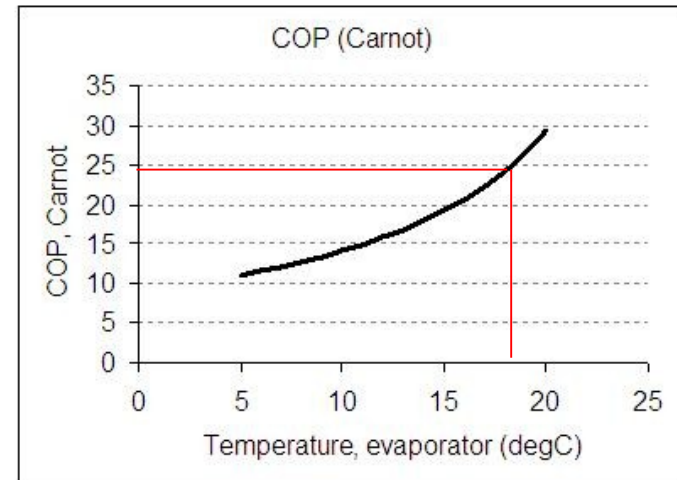


Predicted percentage of dissatisfied (PPD) according to Prof. O. Fanger  
different surface temperatures; no direct radiation  
office work, light clothing air velocity 0.15 m/s; humidity 11 g/kg

# Efficient High Temperature Cooling

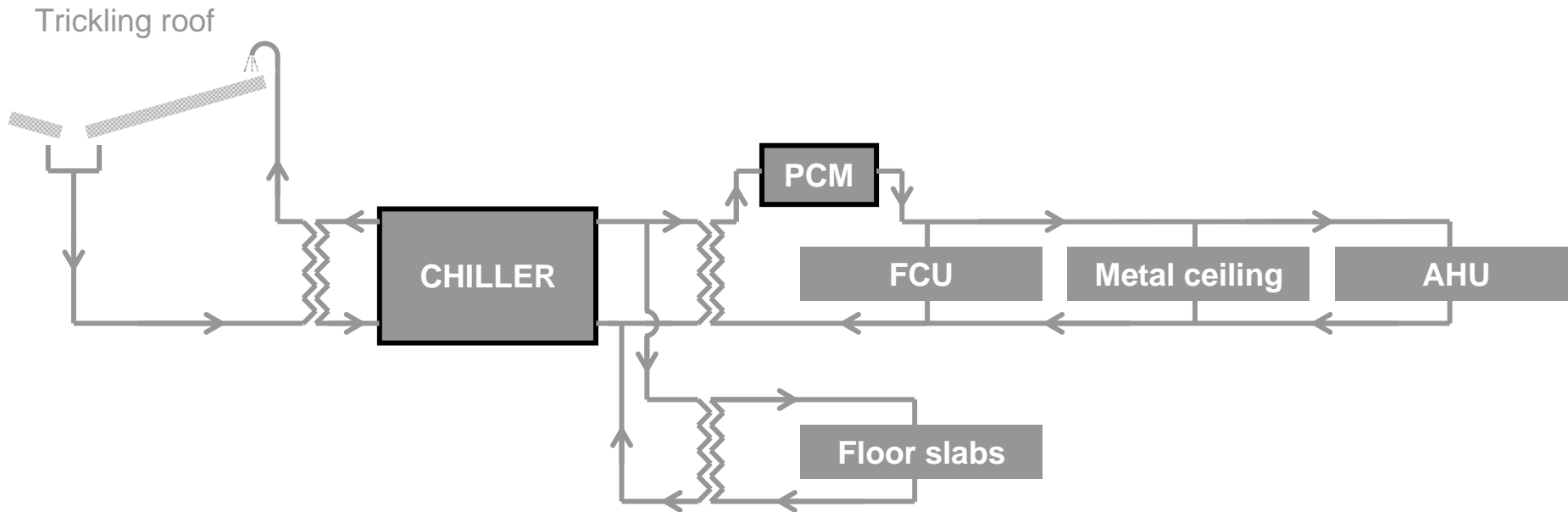
$$\text{COP}_{\text{refrigerator}} = \frac{T_c}{T_H - T_c}$$

- 2 Chillers:
  - a) High Temperature cooling (18°C) for Floor Slab Cooling system (**very high COP possible**)
  - b) Conventional chiller (7°C) for fresh supply
- Chiller Operation Primarily at Night (lower temperature at condensing side → **higher COP**)
- Chillers only supply cooling to thermal storages, hence, **maximum COP** for chiller operation can be ensured at all times. NB. Maximum COP is at part load (~75% load)



*The COP increases with increasing temperature of the evaporator, for example for high temperature cooling at 18°C instead of at the conventional 7°C. Here, the theoretical maximum COP (Carnot) is shown for a constant condenser temperature of 30°C*

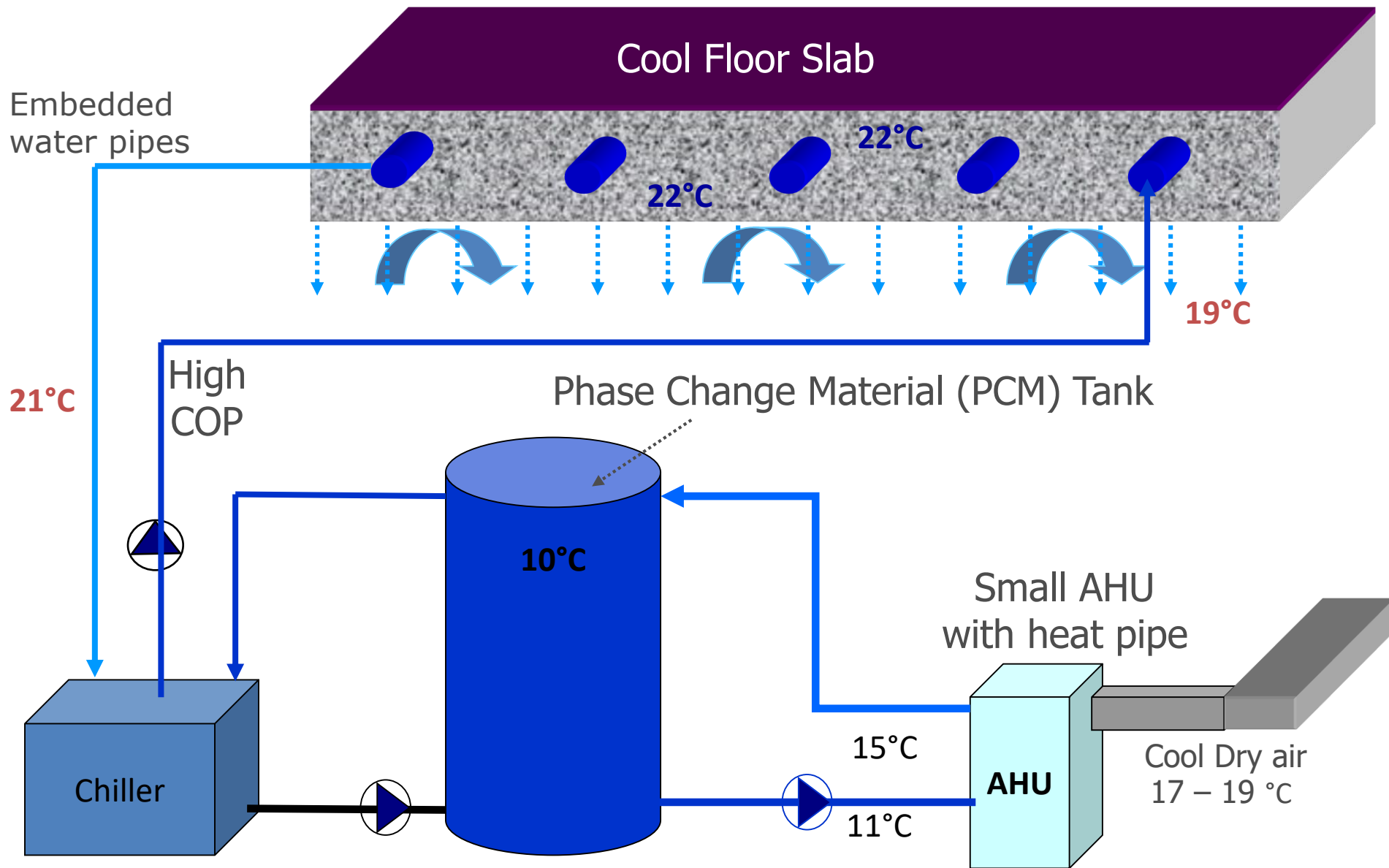
# GEO building



PCM:	Phase Change Material (thermal storage tank with “10°C ice”)
FCU:	Fan Coil Units
Metal ceiling:	Radiant cooling metal ceiling
AHU:	Air handling unit
Floor slabs:	Concrete floor and ceiling slab cooling (TABS, thermally activate building structure)
Trickling roof:	7° tilt flat roof flooded with condenser water at night to eject heat (replaces cooling tower)



# Cooling Storage in Floor Slabs and PCM Tank

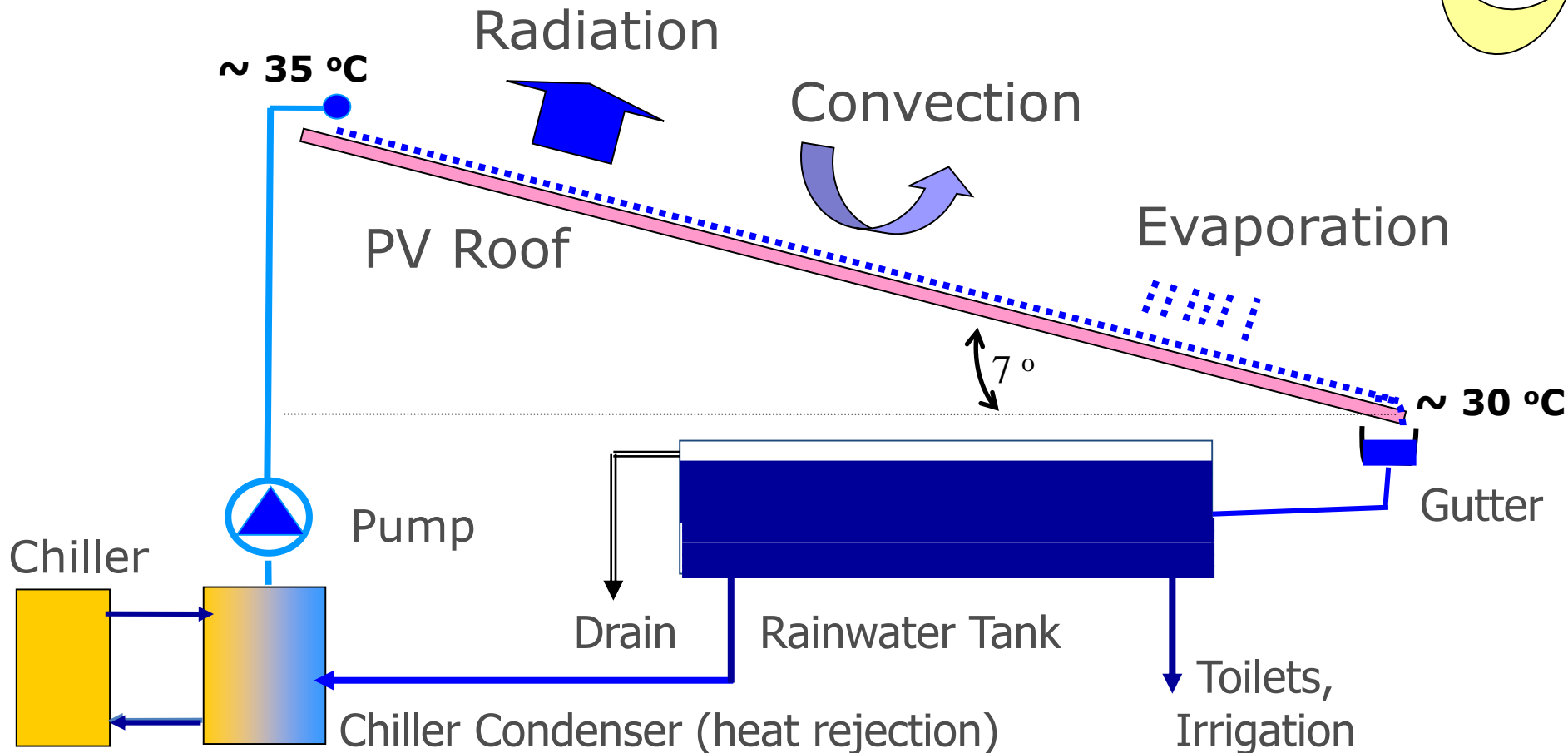
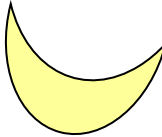


# Rainwater Collection and River Roof

(alternate cooling tower)

~ 25 °C  
~ 95% RH

Sky Radiant Temperature  
**10 – 20 °C at night**



# The River Roof of GEO Building

to be operated at night only

## Video 1:

Gutter for 'cooling tower' water & rainwater



River roof GEO building, Malaysia



Video link:

<https://www.youtube.com/watch?v=h8gC4dlB330>

## Video 2:

Manifold splashing water onto PV roof



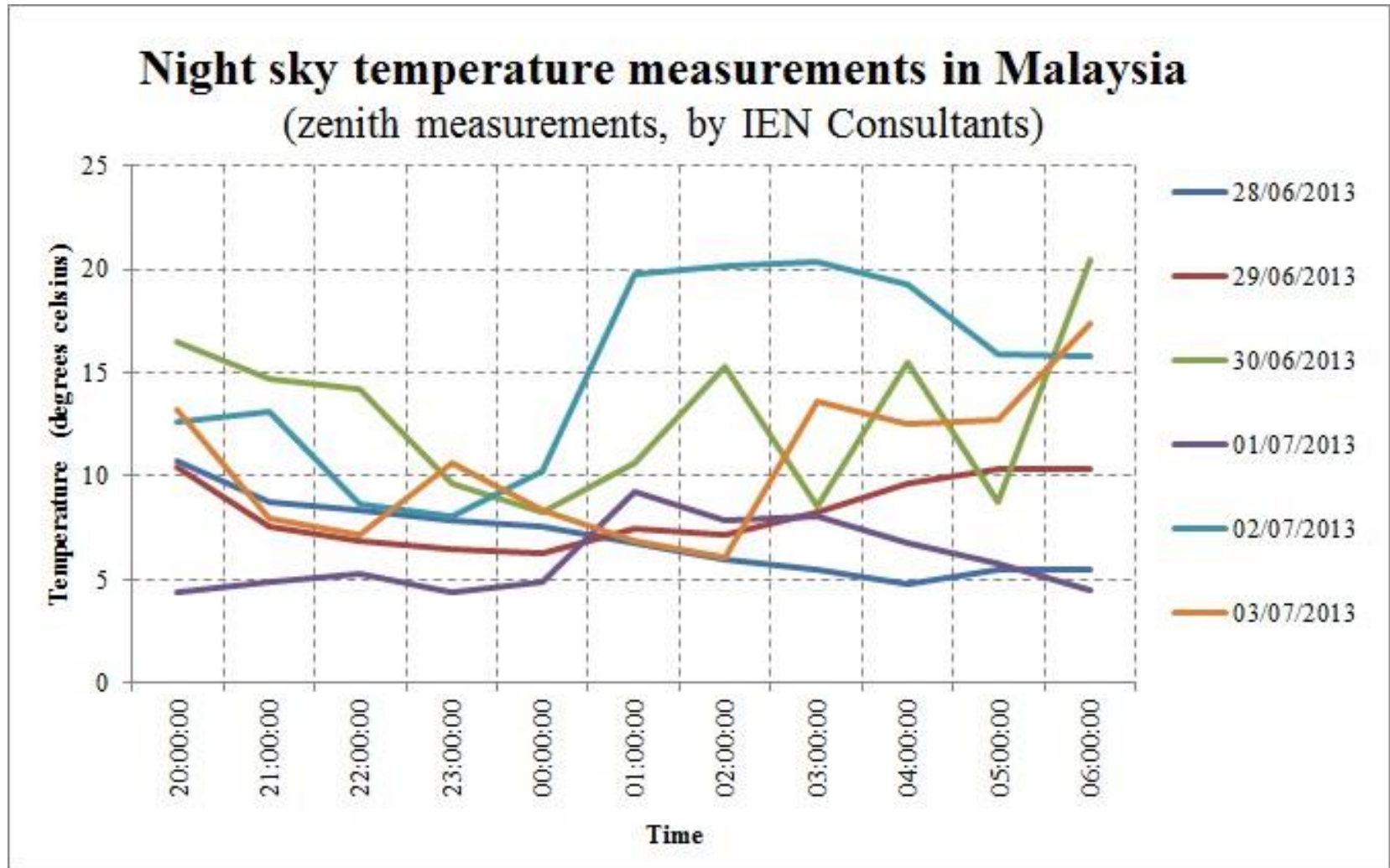
Manifold for river roof at GEO building, Malaysia



Video link:

[https://www.youtube.com/watch?v=nb\\_JntSXoiA](https://www.youtube.com/watch?v=nb_JntSXoiA)

# River roof cooling primarily through sky radiation



# Phase Change Material Tank

- Melting point: 10°C
- Total storage capacity: 580 kWh
- Charged with 7°C water (night time)
- Used for dehumidification of air: 19 → 8 g/kg



Dimensions: ~ 3 x 3 x 2.5 meters



# GEO building: Floor Slab Cooling

- PEX pipes
- Embedded in concrete slab
- Supply temperature: 18-20°C
- Return temperature: 22-24°C
- Night time operation only



# Energy Model for Concrete Floor Slab Cooling

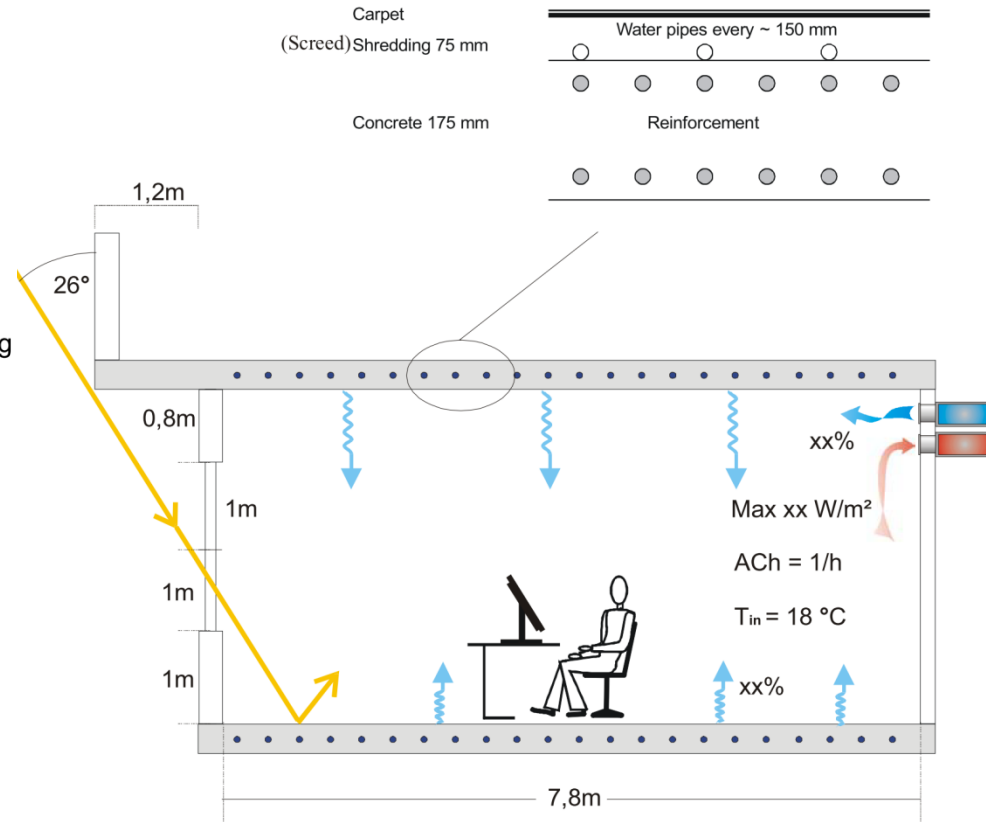
## GEO Building

### Computer modeling of GEO Building

by Transsolar using TRNSYS

#### boundary conditions

floor area and volume	95 m <sup>2</sup> / 356 m <sup>3</sup>
length facade:	12.2 m
depth:	7.8 m
height:	3.75 m without suspended ceiling
facade:	
50 % opaque	20 cm leightweight concrete
50 % glazings with frames	sun protection glazings
	50 % light transmission
	25 % SHGC
	Ug-value = 1.1 W/m <sup>2</sup> /K
shading overhang	1.2 m
Orientation	South
humidity capacity of surface	5 x air humidity capacity



# Energy Model for Concrete Floor Slab Cooling

## GEO Building

### Computer modeling of GEO Building

by Transsolar using TRNSYS

#### Occupation

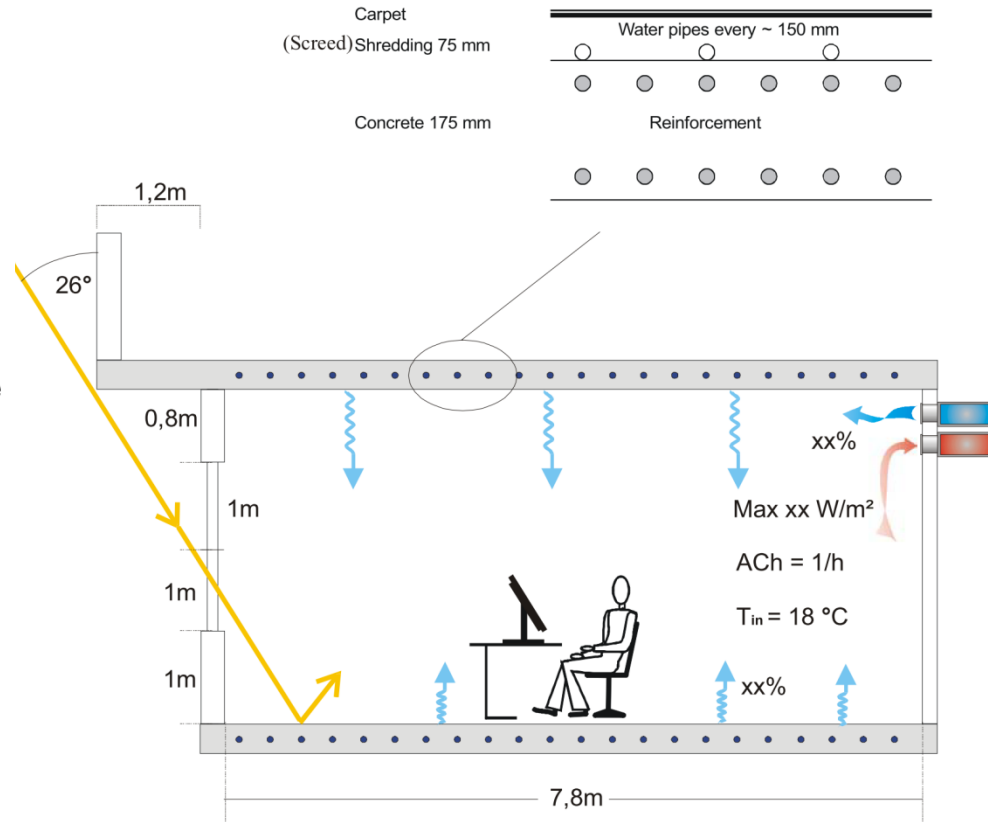
Persons 10 with 75 W sensible heat gain from 8 am to 5 pm  
 PC 10 with 31 W,  
 variant: 10 with 100 W

#### Mechanical ventilation

Airchange 1/h starts 2 h before operation time and stops 1 h after operation time  
 Inlet air temperature 18 °C  
 Inlet air absolute humidity 8.5 g/kg  
 recycling air at night 0.1 1/h to keep 75 % relative air humidity

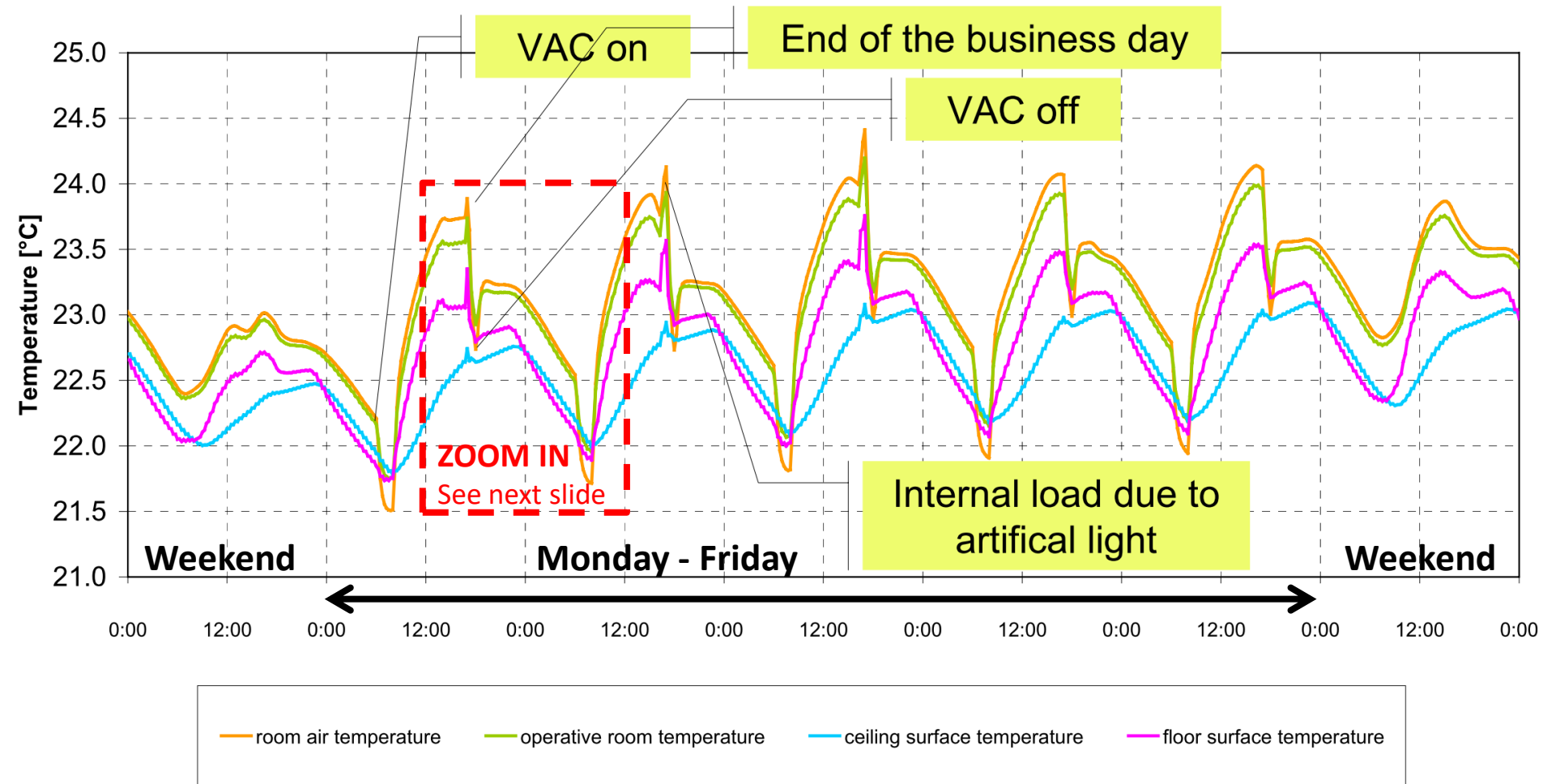
#### Slab cooling

Operation time 10 pm to 8 am  
 Inlet fluid temperature 20 °C  
 Mass flow 12 kg/m<sup>2</sup>/h  
 Pipe dimension 20x2 mm, distance: 15 cm  
 active area 80 %



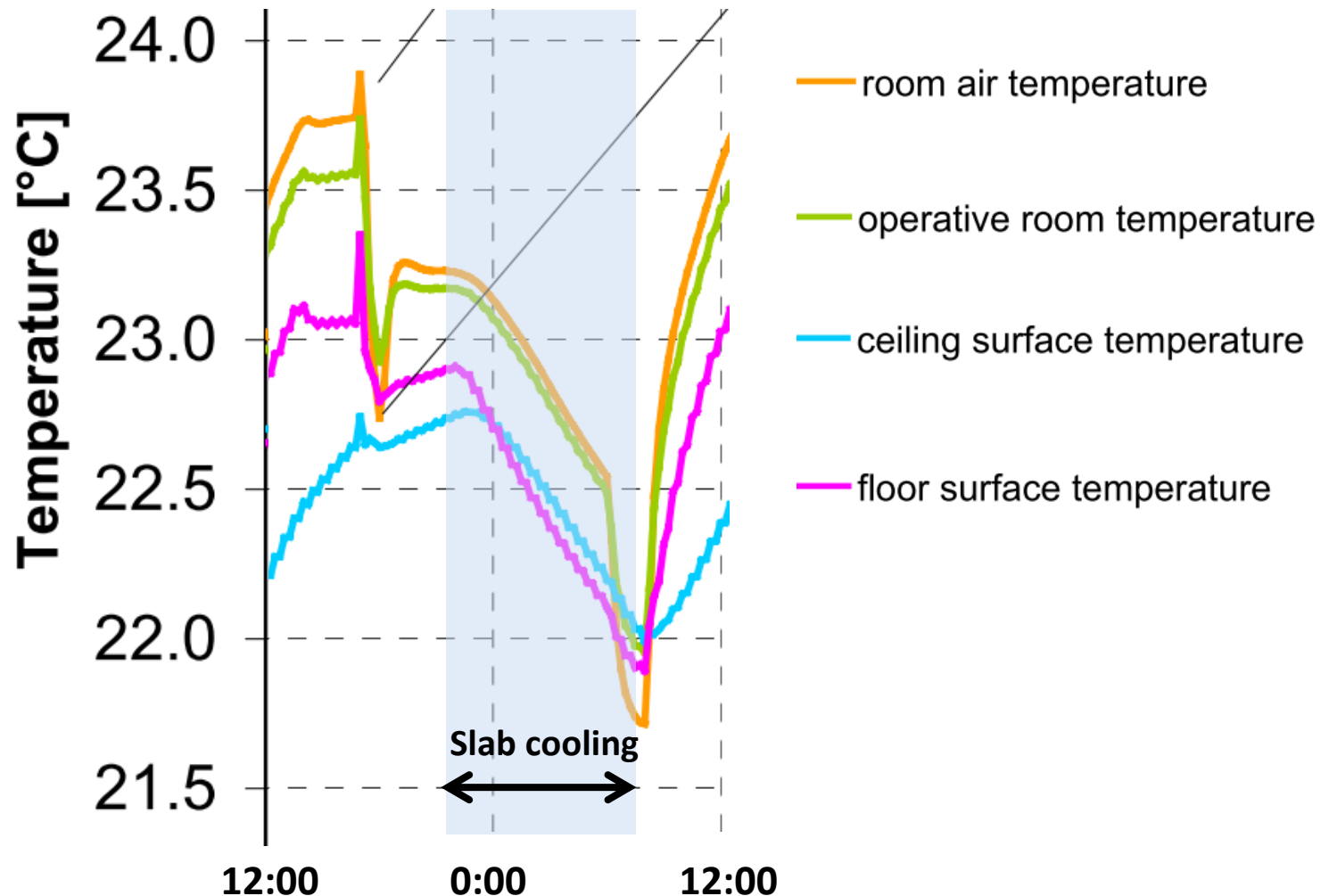
# Energy Model for Concrete Floor Slab Cooling

Slab cooling 10 pm – 8 am



# Energy Model for Concrete Floor Slab Cooling

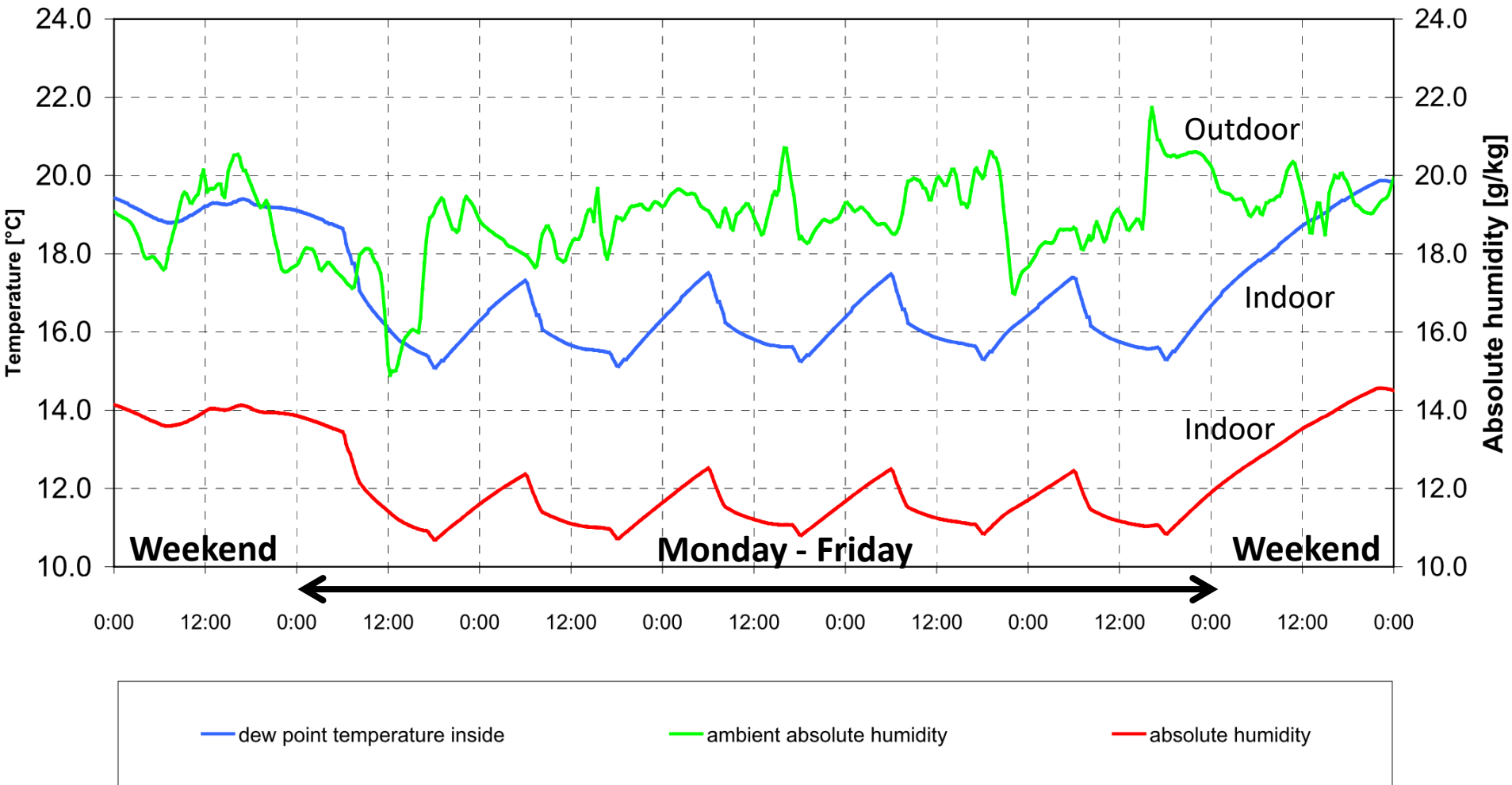
Slab cooling 10 pm – 8 am





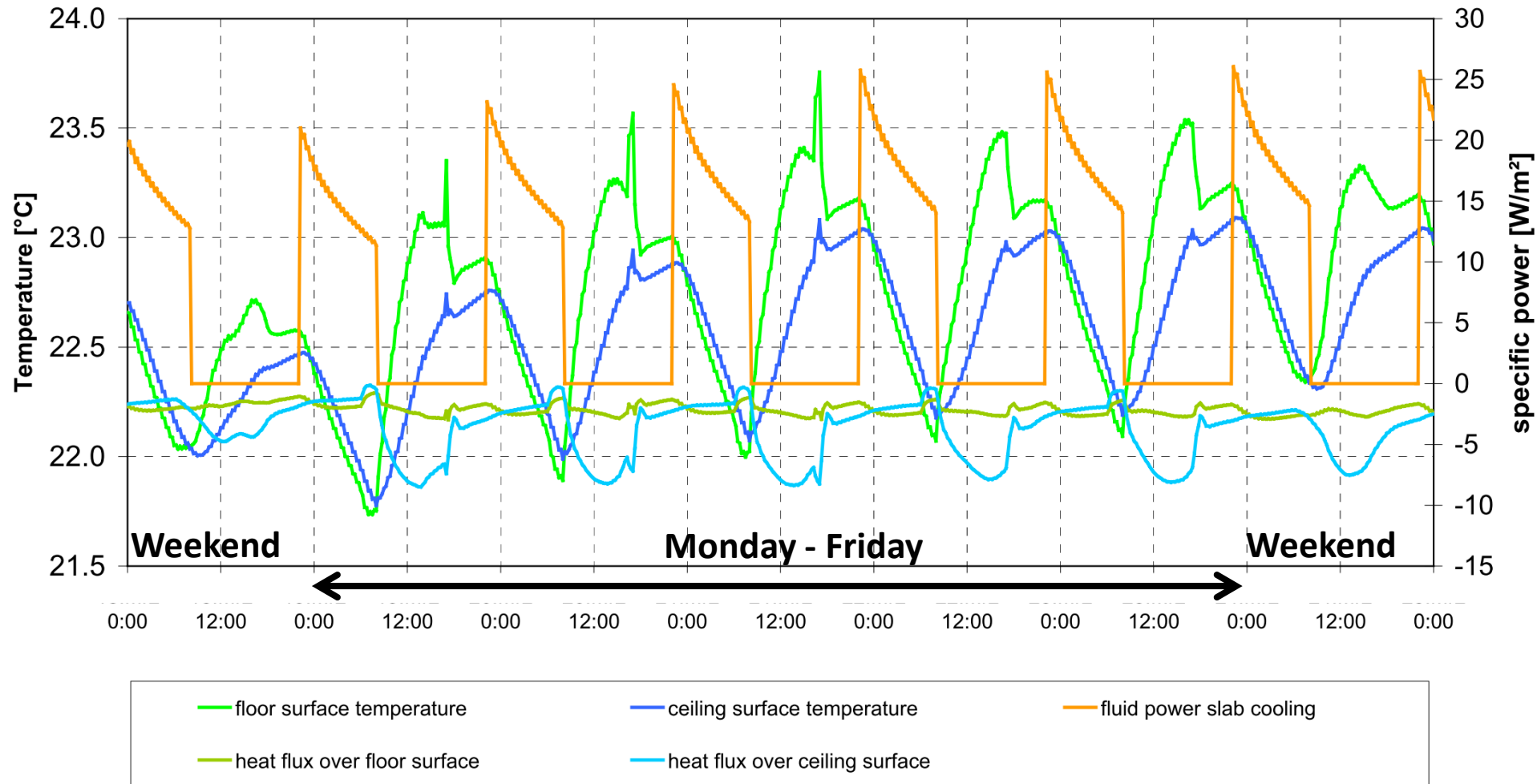
# Energy Model for Concrete Floor Slab Cooling

Slab cooling 10 pm – 8 am



# Energy Model for Concrete Floor Slab Cooling

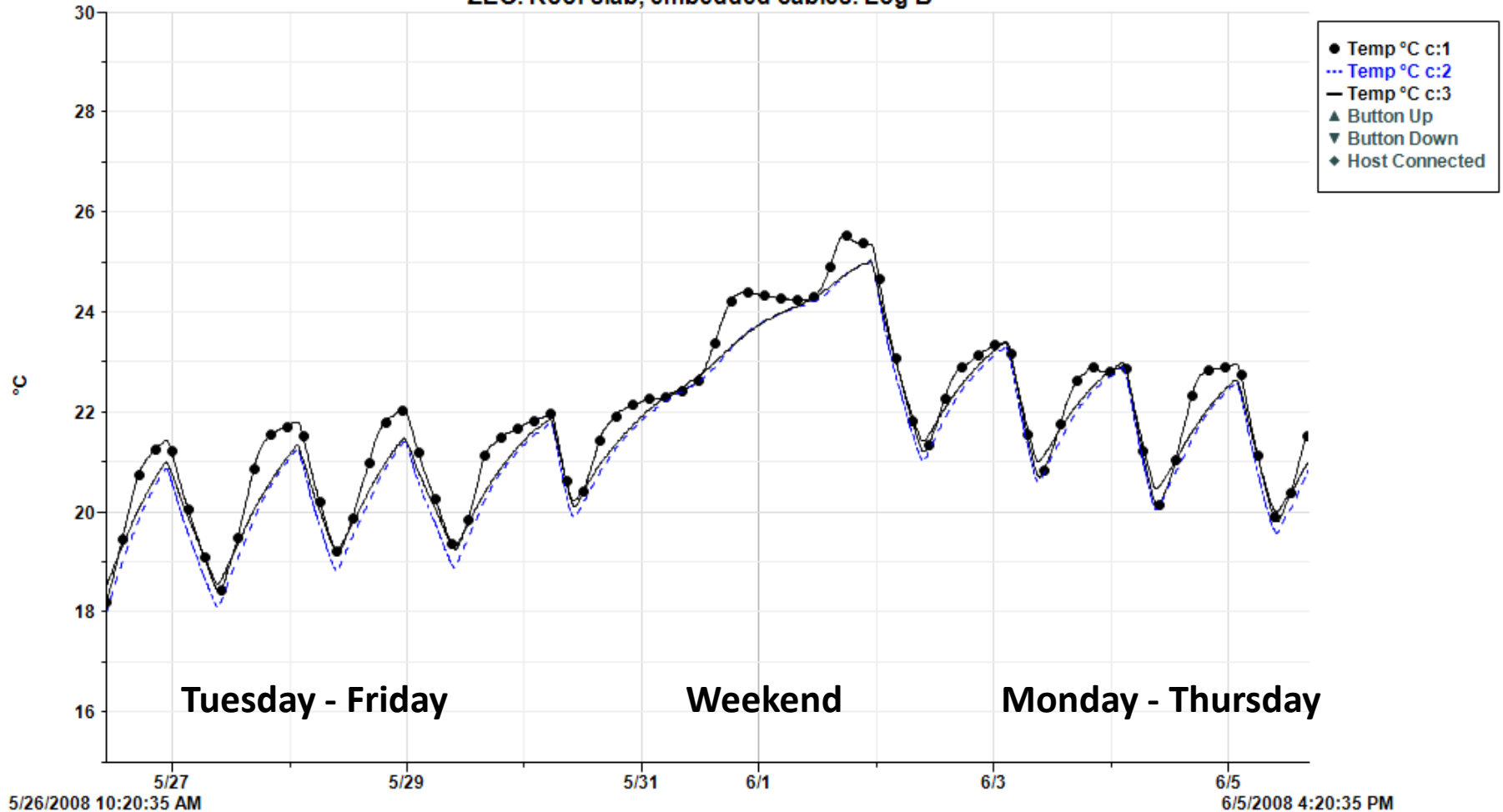
Slab cooling 10 pm – 8 am



# Measured Concrete Slab Core Temperature

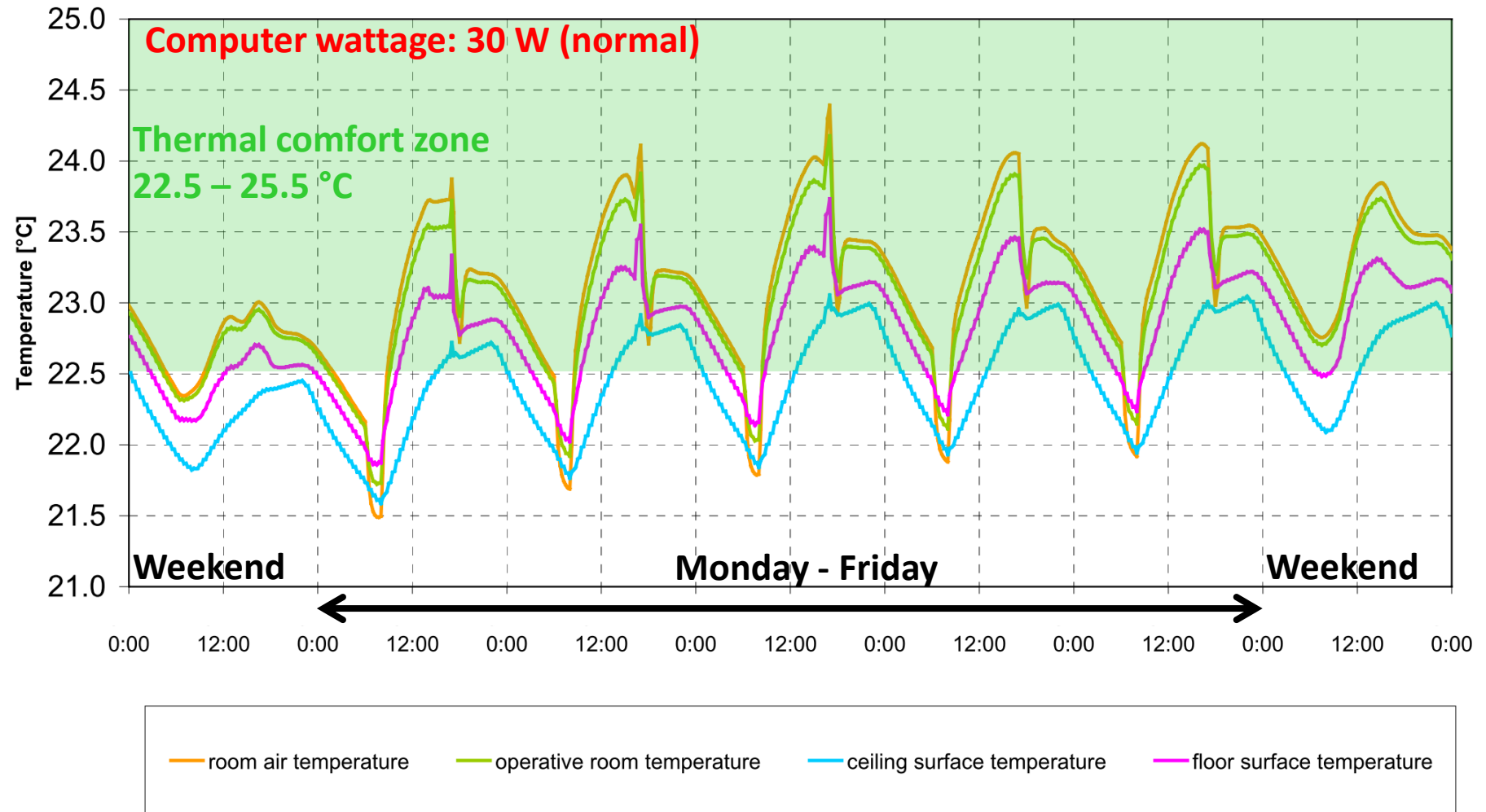
Roof slab of GEO Building

ZEO. Roof slab, embedded cables. Log B



# Thermal Comfort for Concrete Floor Slab Cooling

Slab cooling 10 pm – 8 am



# Measured Temperature for Open Plan Office

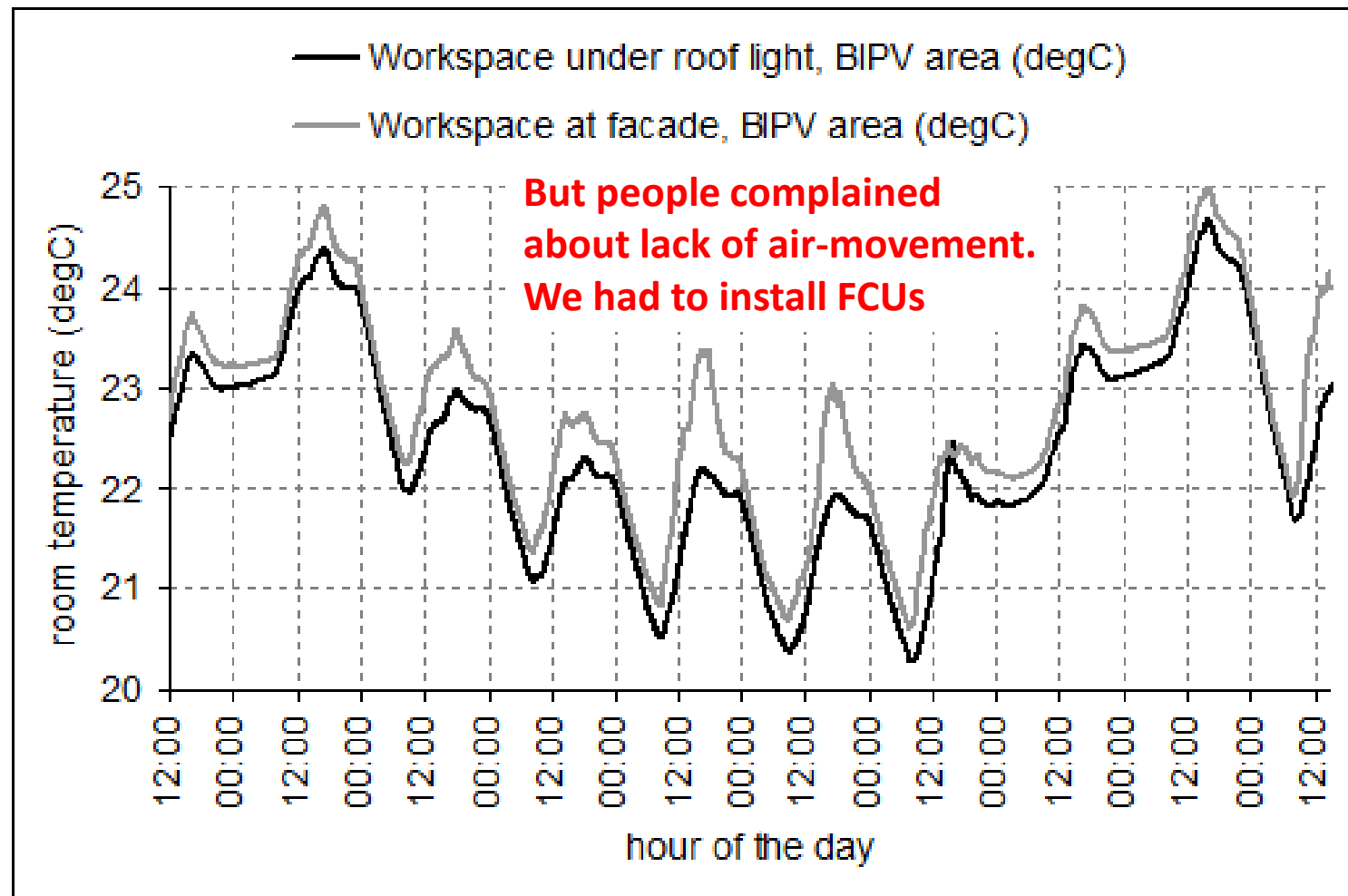


Figure 13: Temperature measured in each workstation from 1 – 10 March 2008



# Measured Dew Point Temperature for Open Plan Office

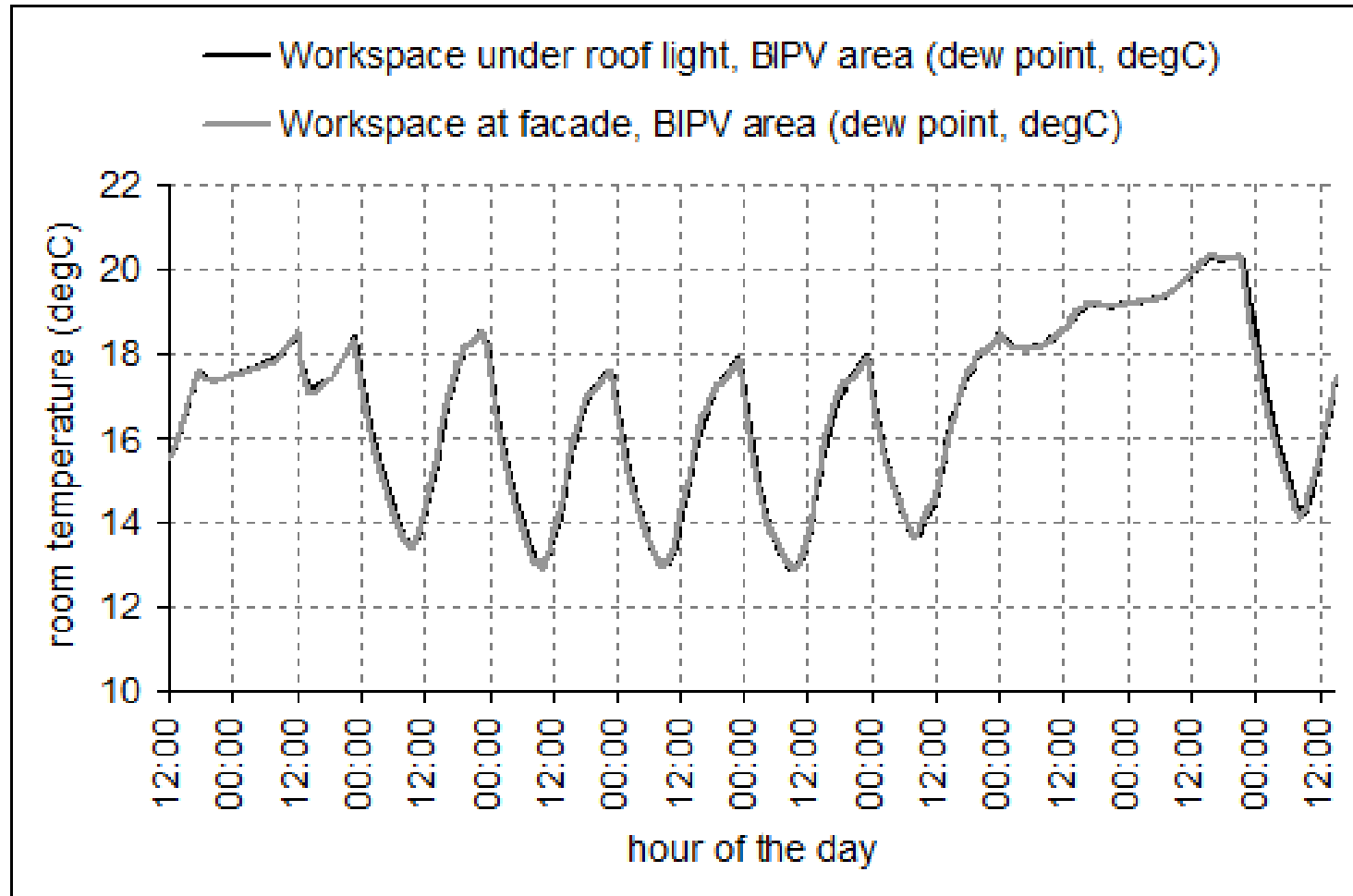
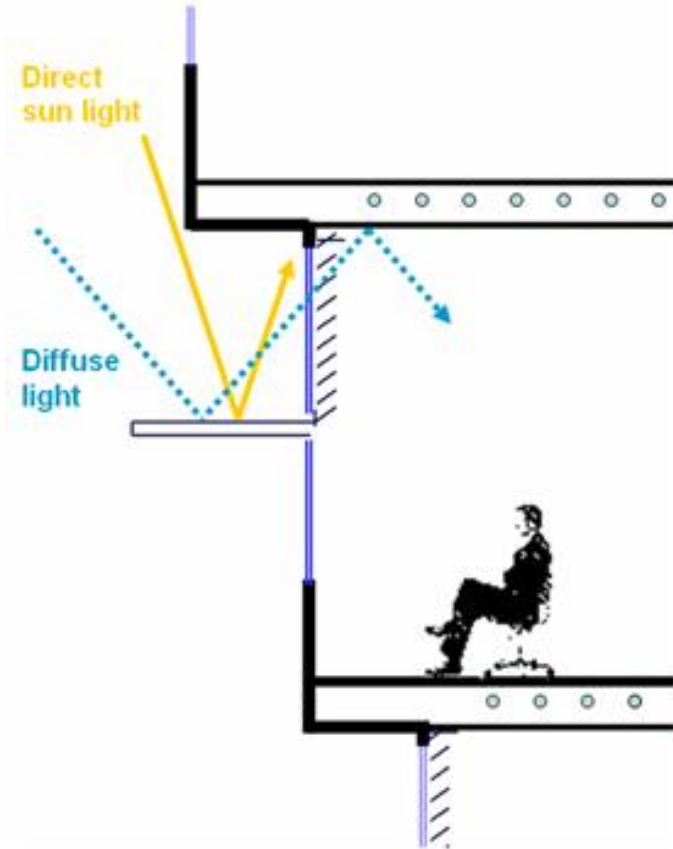
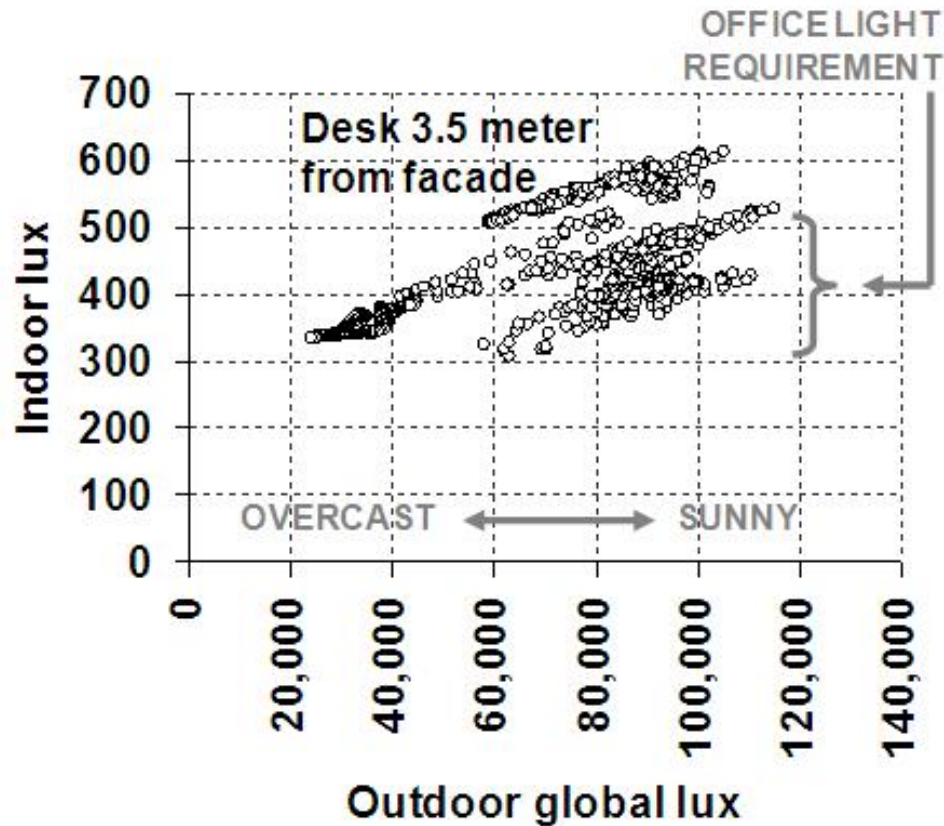


Figure 14: Dew point measured in each work station from 1 – 10 March 2008

# Split Window Design



# Daylight Measurements



- Lighting consumption:  $0.56 \text{ W/m}^2$
- Code requirement:  $15 \text{ W/m}^2$

25 times more efficient

## Transparent PV atrium roof

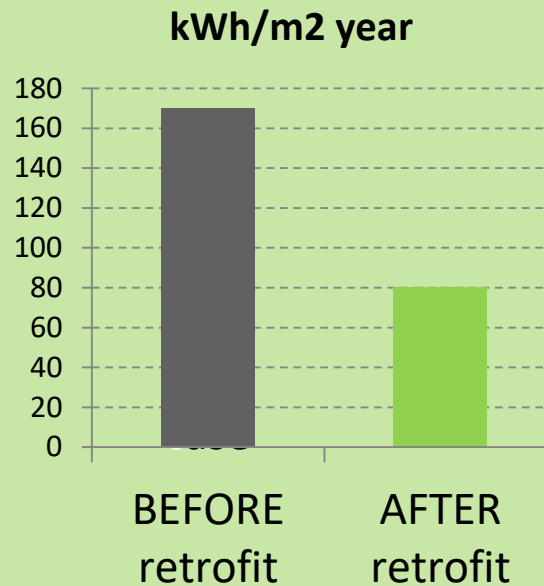


- ♦ PV sandwiched in low-e glass
- ♦ 13% transparent area

**Daylight factor  
in atrium about  
1 – 1.5%**

**Nice light  
pattern through  
PV atrium roof**

# Case study

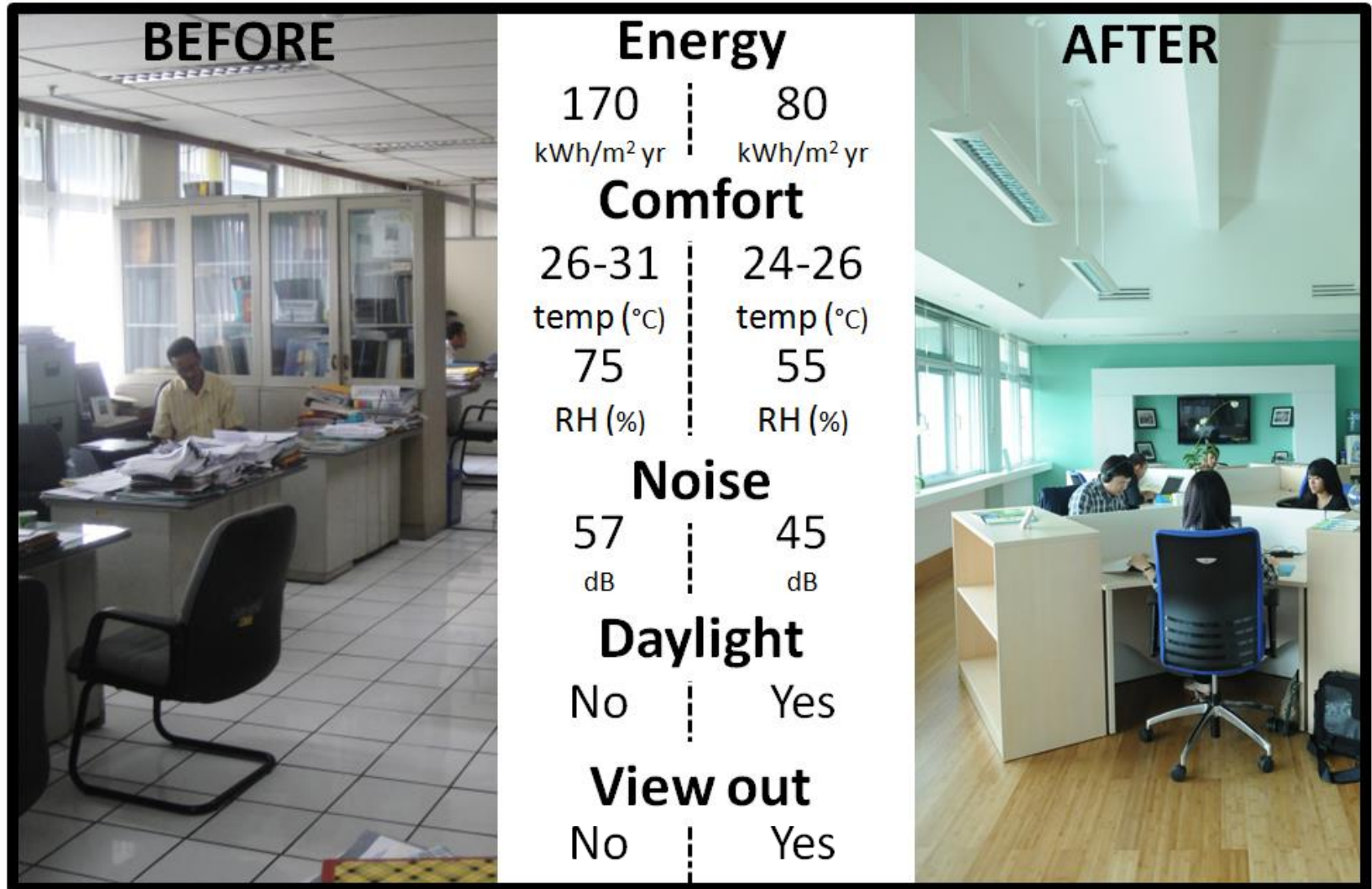


Energy Efficient Retrofit case study

## EECCHI OFFICE RETROFIT (JAKARTA, 2011)

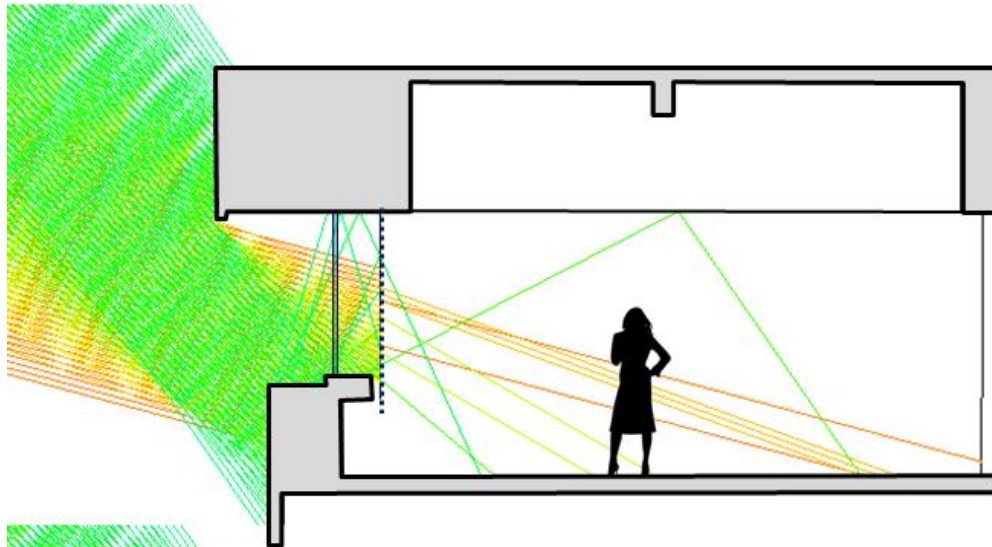


# 53% Measured Energy Savings



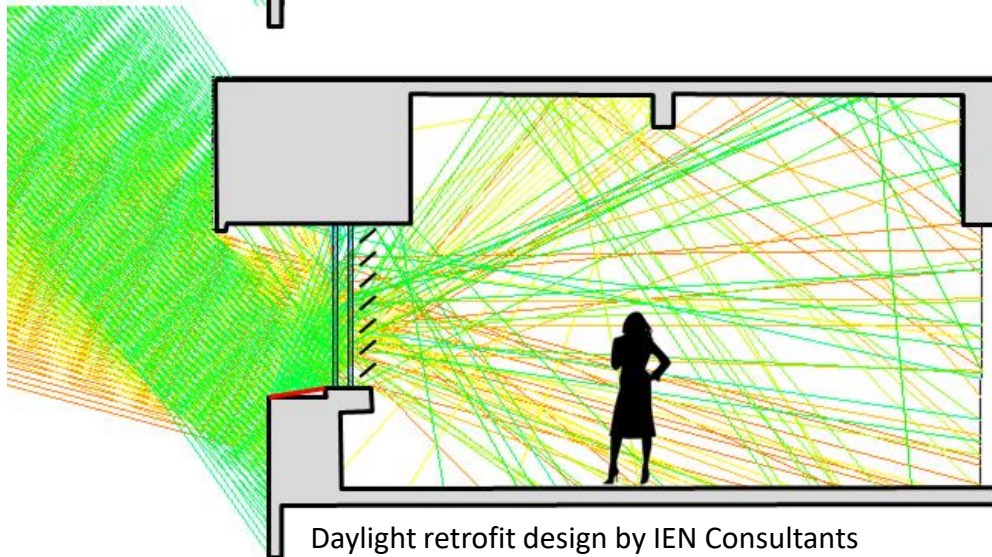


# Retrofit & Improved Thermal Comfort



## BEFORE RETROFIT

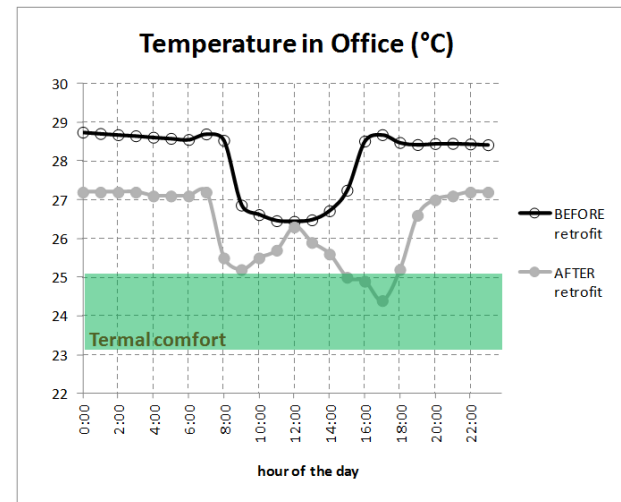
- Vertical blinds blocking most of the daylight
- Suspended ceiling



## AFTER RETROFIT

- Mirror lightshelf on external ledge reflecting diffuse daylight onto the high ceiling (suspended ceiling removed)
- Perforate venetian blinds
- Extra window pane

Daylight retrofit design by IEN Consultants



# Extra Window Pane after Retrofit



## Case study



Innovative daylighting facade for highrise building

# **MMK OFFICE TOWER**

**(KUALA LUMPUR, 2015)**



# Innovative façade daylighting

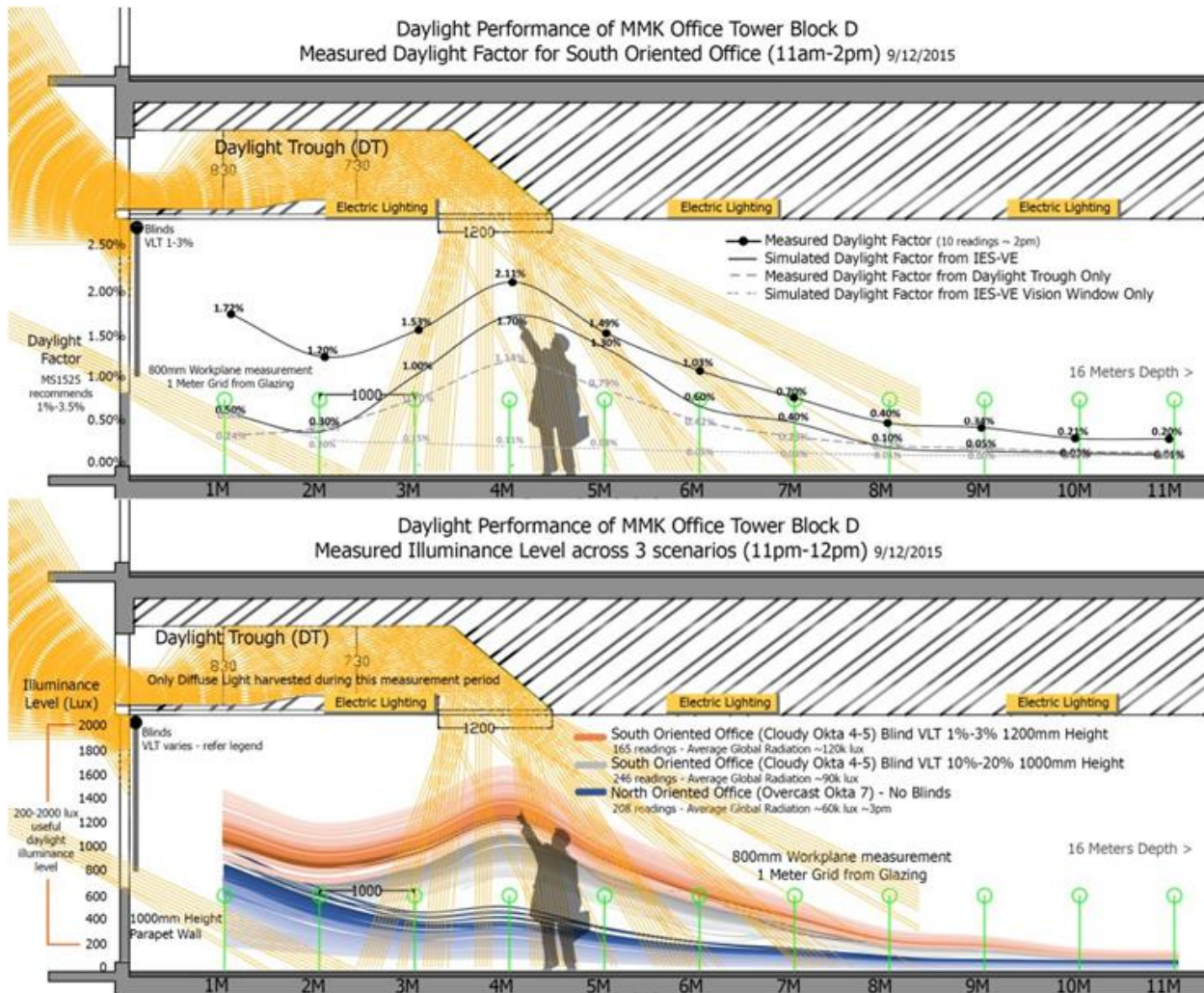
The MMK high rise office tower @ Damansara Perdana, Malaysia

Innovative daylight duct  
from facade

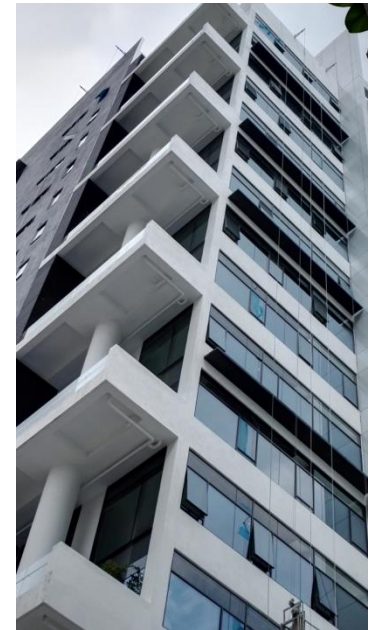


Daylight design by IEN Consultants

# 7 meters daylight with blinds down



Measured daylight show that the first **7 meters** can be daylight, even when the blinds are fully engaged



Daylight design by IEN Consultants

# CONCLUSION

”Expensive **not** to go green”

**Buildings are  
Like a Leaky Bucket**



**with lots of  
unnecessary wastages**

Plug the holes, and you are  
well on the way to a green  
energy efficient  
inexpensive building

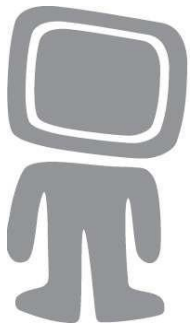




Thank you



How I commute in Kuala Lumpur  
(video [link](#))



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Singapore | Malaysia | China

# Appendix slides



Office case study in Bangi, Malaysia:

## **GEO BUILDING**



# Winner of 2012 ASEAN Energy Award

(ST Diamond Building, Putrajaya, Malaysia)





# ASHRAE Technology Award 2013 (2<sup>nd</sup> place)

(ST Diamond Building, Putrajaya, Malaysia)





# ST Diamond juxtaposed with Sarawak Longhouse

## (in the book “The Cooperation”, 2012)

Malaysia and Denmark's commitment to the field of

### Green Energy in Architecture

as well as in cooperation and capacity building within the field, can be illustrated by the mutually beneficial involvement of IEN Consultants with the development of this field in Malaysia over the years. IEN Consultants was originally a proprietorship established by a Danish Chief Technical Advisor involved in the identification of energy projects in Malaysia. When the company took on the LEO Building projects it gained recognition in Malaysia and IEN Consultants managed to build up a team of consultants, most of them Malaysian, who with their experience on the LEO Building, became known further afield. This helped gain further commissions on such projects as the Green Tech Building and what has become known as The Diamond Building in Putrajaya.

“Green Buildings” are perceived to be expensive, both because of the costs of employing the expertise necessary to develop and refine the building and system designs, and because of the relatively high capital costs of green technology items. It takes time for reduced operating costs, which come with reduced energy usage, to counterbalance the increased capital investment and this has been a significant brake on development worldwide. However, given that approximately 40% of worldwide carbon emissions come from buildings, it is clear that there is a need for the “greening” of buildings to

make a significant contribution to carbon reductions.

As a result much effort has gone into the dissemination of green ideas to the Malaysian building industry, including the idea that the advantages of reduction of whole life costs of buildings as opposed to just capital costs are worthwhile. The fact that some “green” input to building design in Malaysia has moved from a subsidised base, using for example Danish funding for the LEO Building and European Union funding for the Green Tech Office Building, to a fully Malaysia funded base in the case of the so-called “Diamond Building” indicates some success in changing attitudes to operating costs vs capital costs ascribed to “Green Buildings”.

Improved energy efficiency is already recognised by the Malaysian government to be more important than being certification under the Green Building Index (GBI) scheme. That scheme therefore carries tax and stamp duty benefits to encourage the real application of green ideas in the design and operation of buildings.

Beyond this, IEN Consultants is now involved with a UNDP funded project, with the Ministry of Works, to promote low carbon buildings in Malaysia. It is hoped, amongst other things that it will lead to a building code by 2015 specifying much lower carbon footprints even than the LEO Building or the Diamond Building.



Modern sunshade  
Diamond Building in festive season lighting



Traditional sunshade  
Rungus Longhouse, Sabah

Another major area of involvement was in

### Capacity Building for Malaysian Industry and Academia in EE Building design.

The objective of the scheme, which was implemented by the Ministry of Energy, Communications and Multimedia (now Ministry of Energy, Green Technology and Water), was to develop capacity in the optimisation of energy efficient building design. This was done through training sessions, seminars, specific analysis of existing buildings and design development of new buildings. A key partner in this endeavour was the Public Works Department (JKR) and there was close cooperation with Schools Division and Healthcare Division, so the lessons learned were comprehensive, and the dissemination of the results widespread.

The project produced reports outlining design strategies for new buildings, making lessons learned from the LEO Building described above available to practitioners and academics across Malaysia. The project also produced reports on “Energy Efficiency Promotion: Lessons Learned and Future Activities”, and undertook an evaluation of JKR design standards.

The project certainly raised awareness and improved the country's knowledge base regarding energy efficiency in buildings and made recommendations to Ministry of Energy, Green Technology and Water and JKR to set up demonstration offices, a very successful example of which was in Wisma Damansara.

Book available free online:  
<http://um.dk/da/~media/Malaysia/Documents/Other/Book%20Finalist%20LR.ashx>



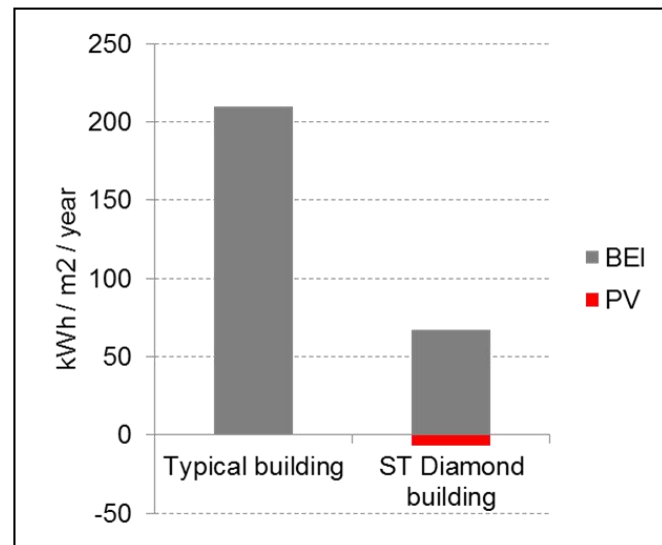
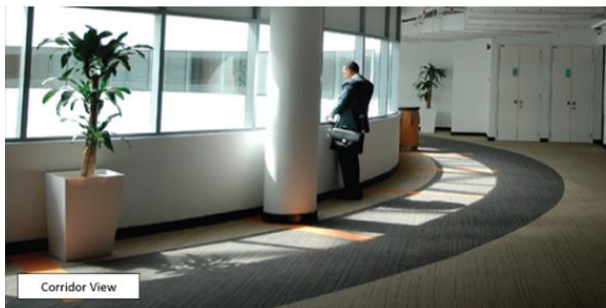


# 1/3 Energy Consumption (ST Diamond Building)



## Key Data

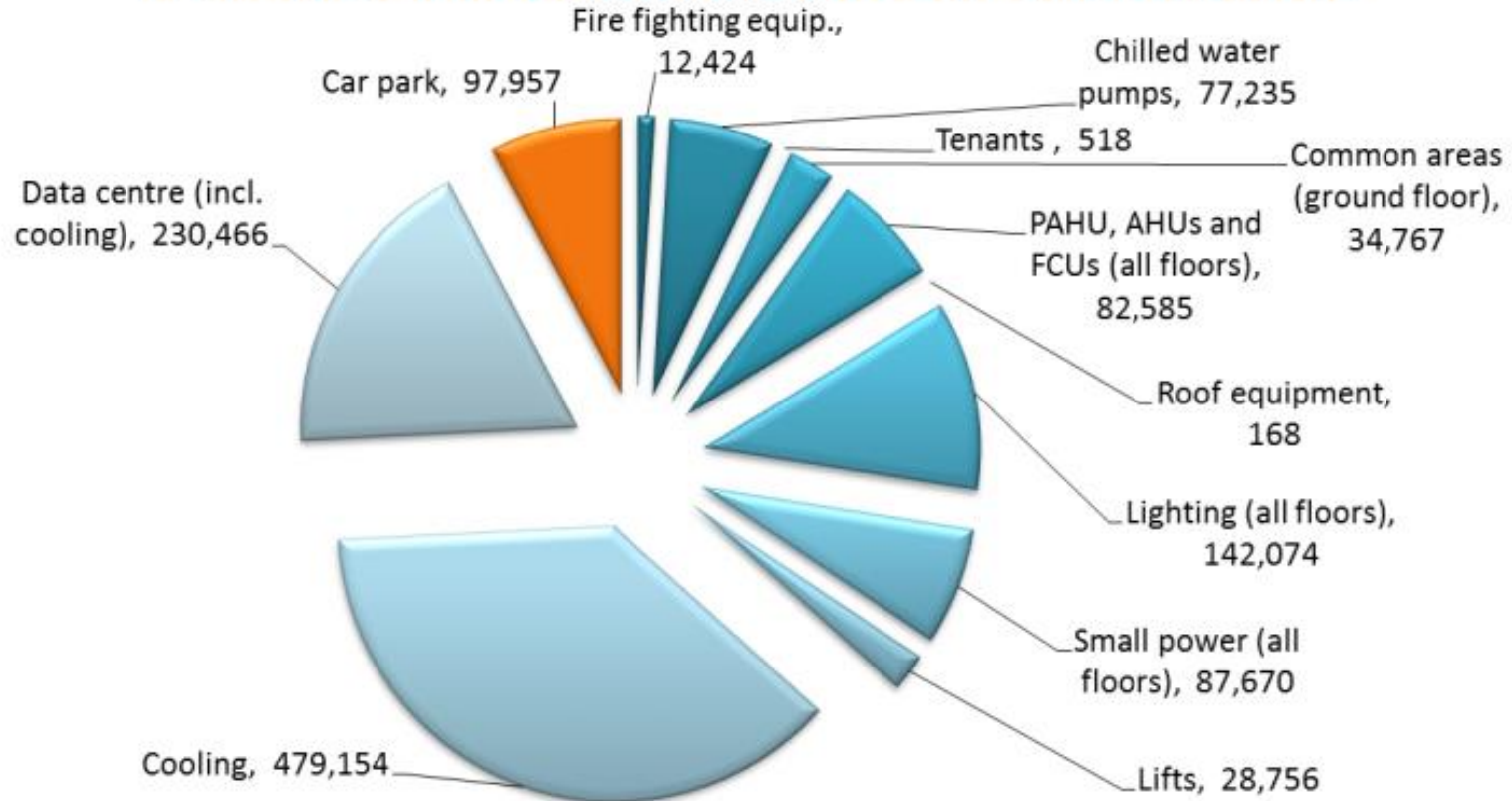
Gross Floor Are: 14,000sqm  
Year of Completion: 2010  
Building Energy Intensity: 69kWh/m<sup>2</sup>\*year  
Total Construction Cost: RM60mil  
Additional EE Cost: 3.2%  
Payback Period: < 3years  
IRR: 34% (based on 7year Lease Term)



# Measured Energy Break-down

## ST Diamond Building. Measured Energy Consumptions for year 2011 (kWh/year)

Data marked with orange always excluded from EEI calculation



### Note:

- District cooling has been converted to electricity using SCOP of 3.8



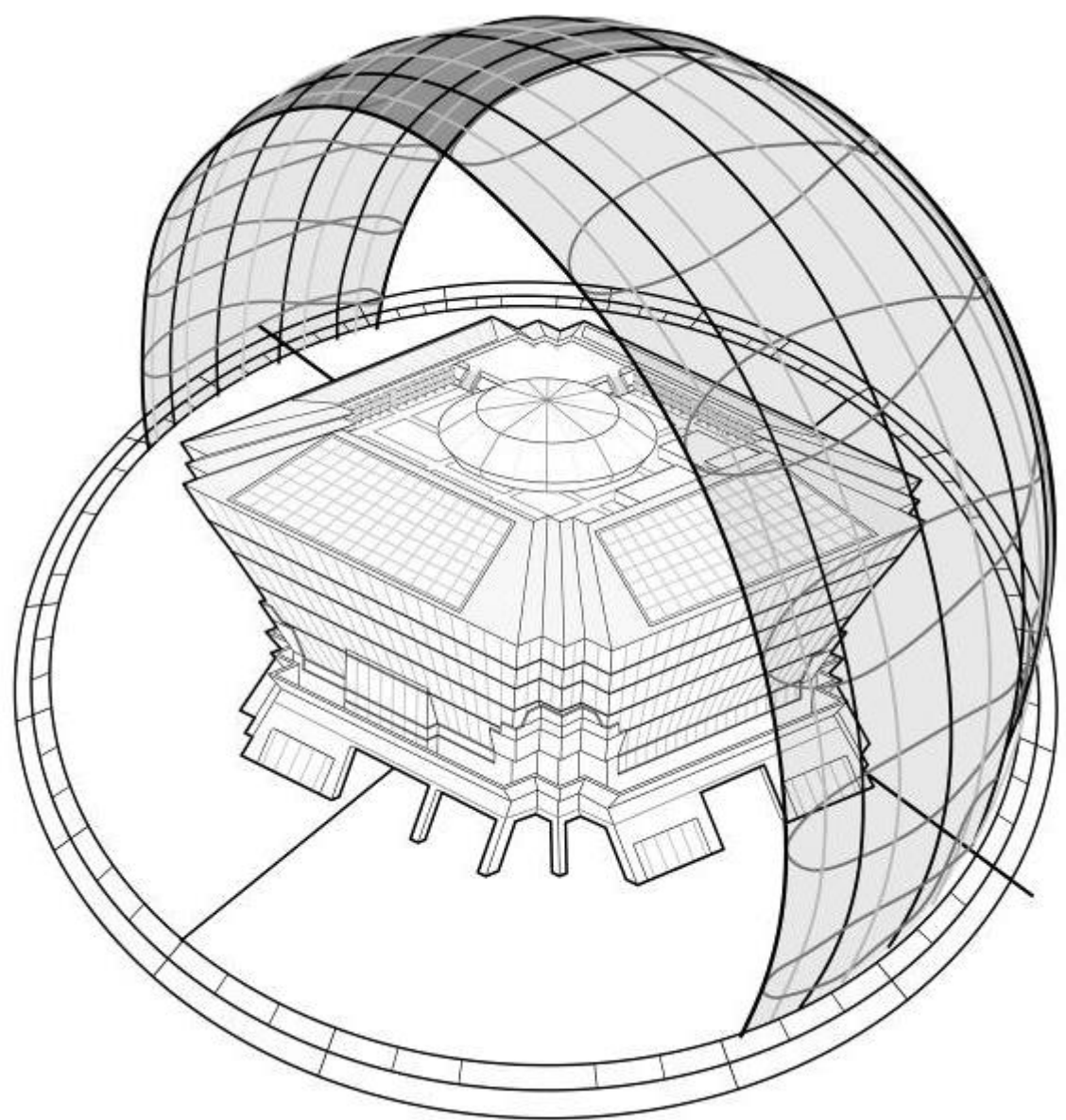
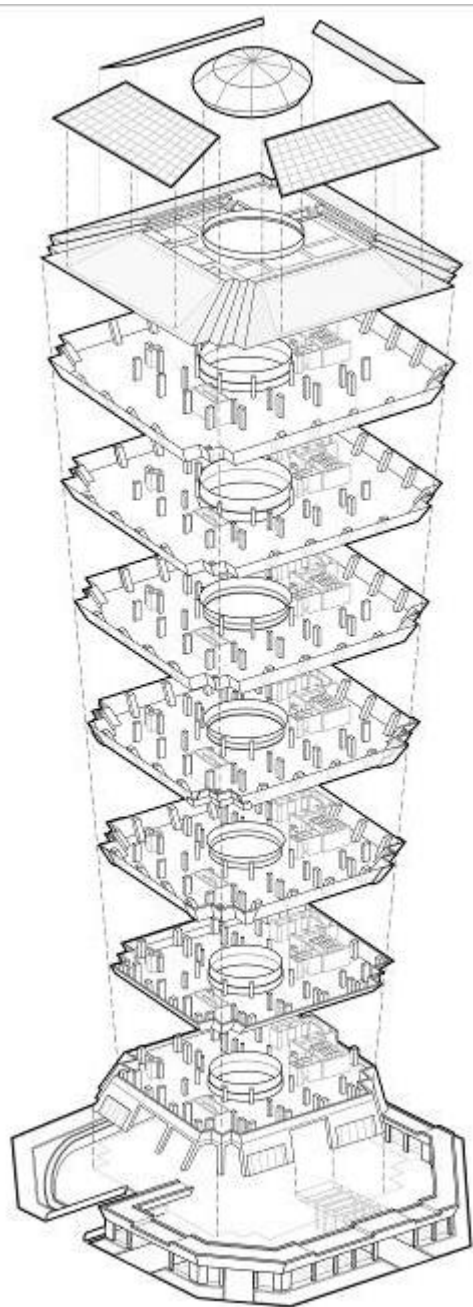
# 3-minute video



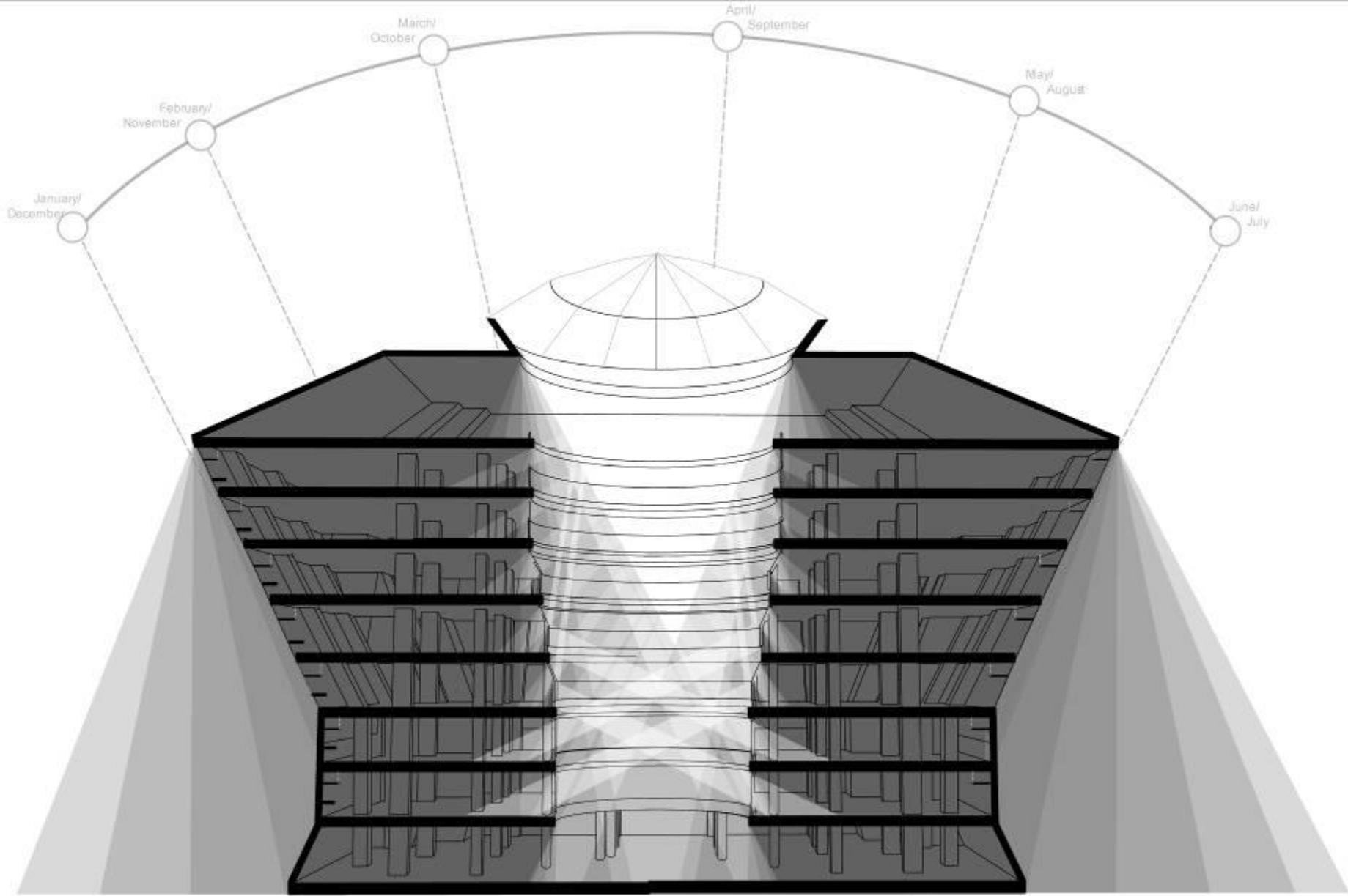
Sustainable Features of ST Diamond Building.

Available at YouTube:

[http://www.youtube.com/watch?v=3H\\_sXCtDayc](http://www.youtube.com/watch?v=3H_sXCtDayc)



Self-shading facades

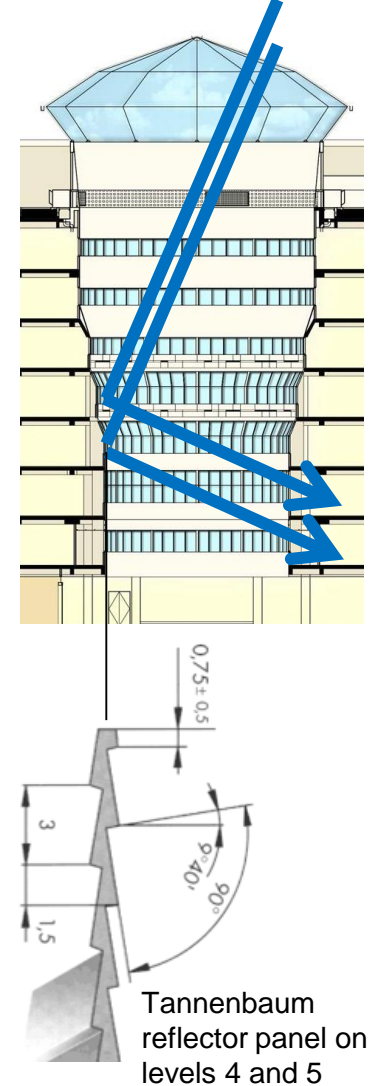
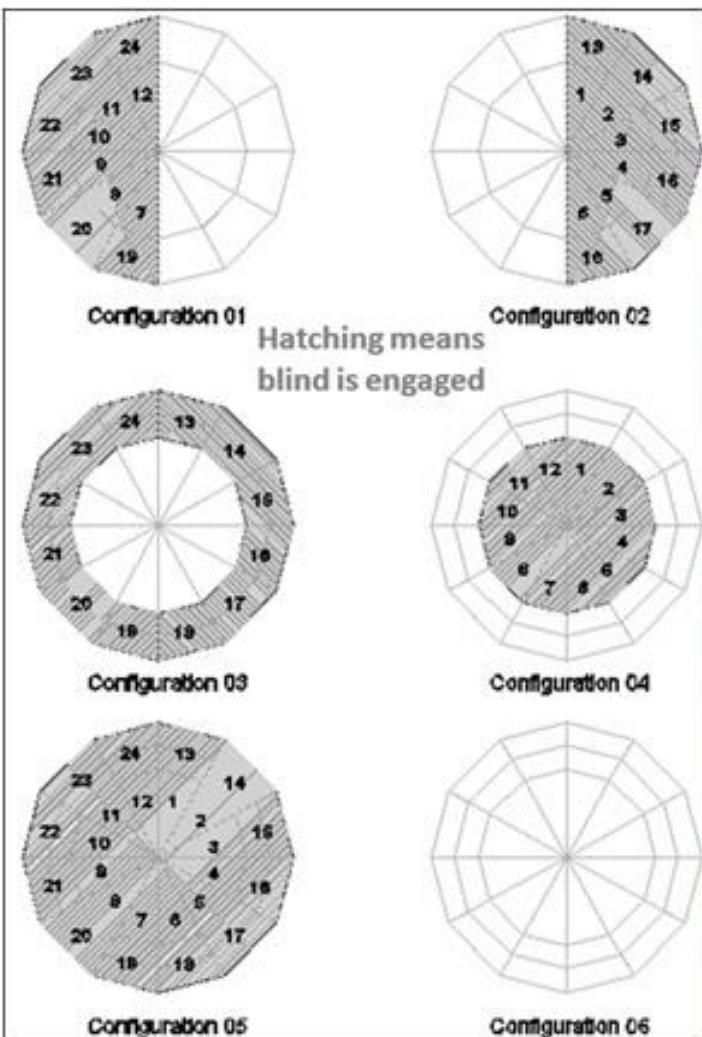


Atrium daylighting

PERSPECTIVE  
SECTIONAL CUT  
ANNUAL LIGHT-RAY TRACING



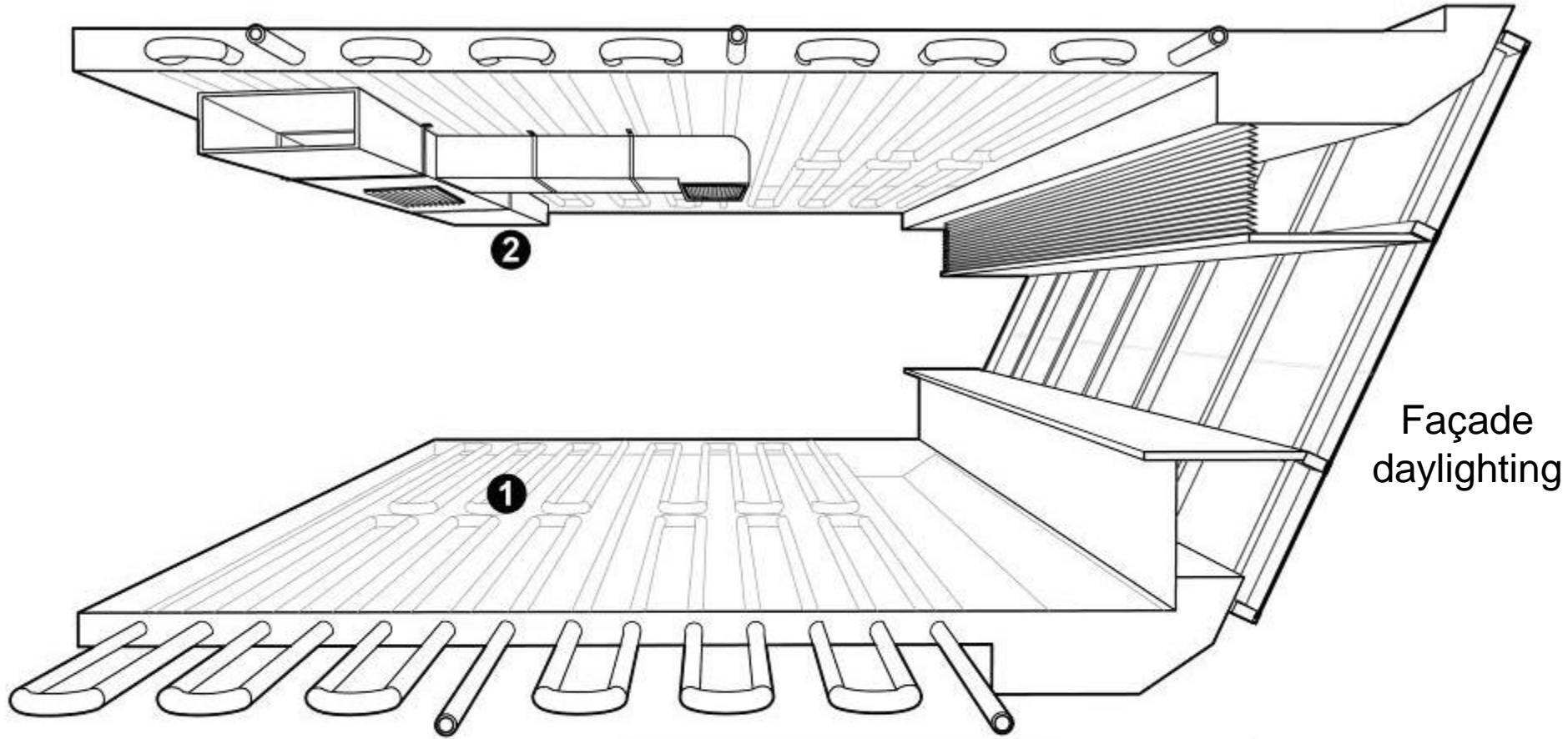




## Atrium Daylight Design

The atrium has been carefully designed optimize daylight utilization for each floor employing the combination of the following three strategies:

1. Automated blind with six different configuration to maintain the appropriate daylighting levels at all times. The blinds with 30% light transmittance are adjusted every 15 minutes and follow a three different control strategies for morning, mid-day and evening
2. The windows size becomes larger deeper into the atrium to cater for lower daylight levels
3. A band of Tannenbaum reflector panels are applied to 4<sup>th</sup> and 5<sup>th</sup> floor to deflect daylight across the atrium to 1<sup>st</sup> and 2<sup>nd</sup> floor where daylight levels are the lowest. The 'christmas tree' profile reflectors have an inclination of 10° and reflect about 85% of the light in semi-diffuse manner, hence, avoiding visual glare issues for the building occupants.



ST DIAMOND  
COOLING SYSTEMS

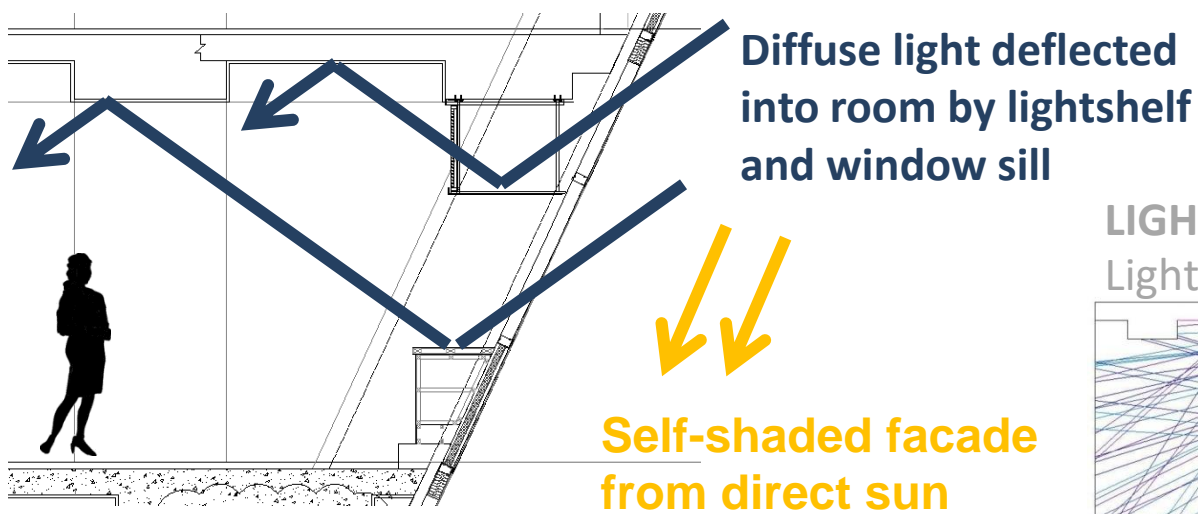


**INTERNAL COOLING SYSTEM**

FLOORSLAB COOLING **1**

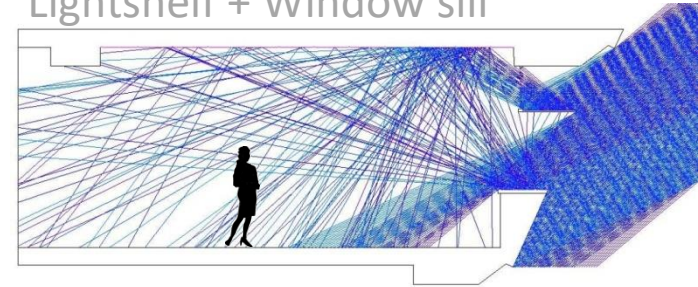
MECHANICAL VENTILATION **2**



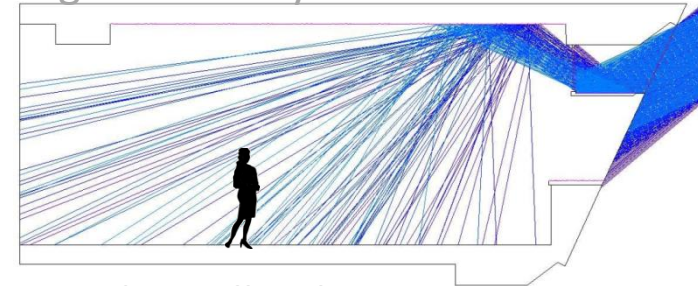


# FACADE

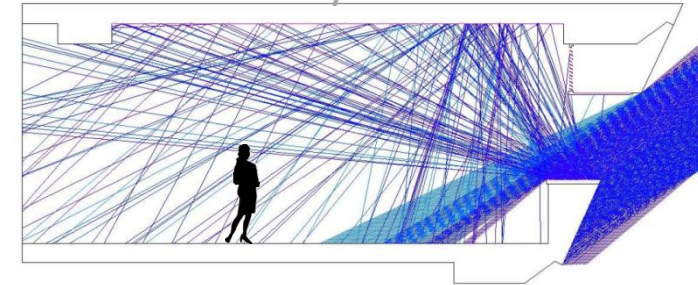
**LIGHT REFLECTIONS FROM:**  
Lightshelf + Window sill



Lightshelf only



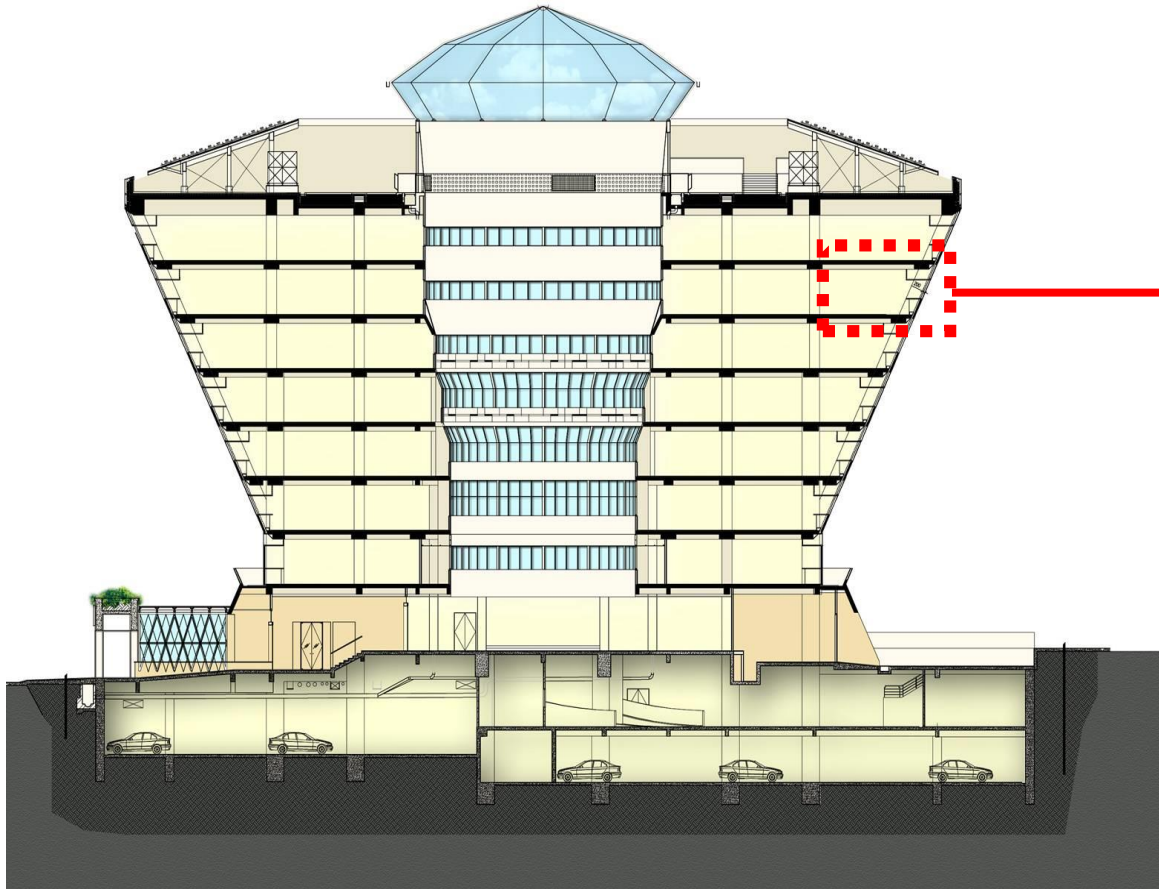
Window sill only



## Façade Daylight Design

The building is 50% daylight. The façade daylighting system consists of a mirror lightshelf and a white painted window sill. Both deflect daylight onto the white ceiling for improved daylight distribution until 5 meters from the façade + 2 additional meters of corridor space. Installed office lighting is 8.4 W/m<sup>2</sup>, but 1-year measurements show consumption of only 0.9 W/m<sup>2</sup> showing high reliance on daylighting

# Day-Lighting- Office



Mirror  
lightshelf



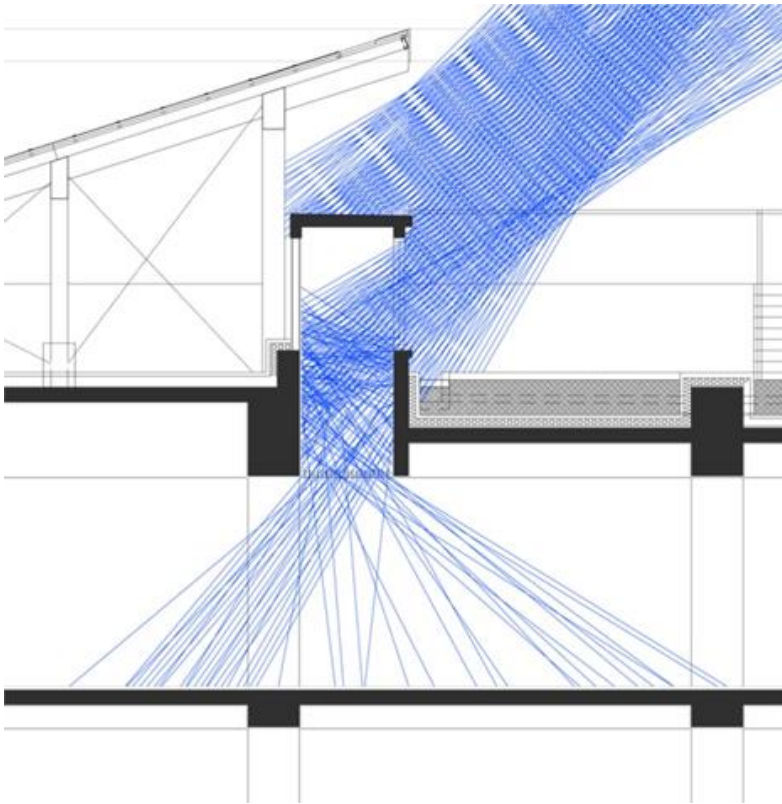
Fixed  
blinds for  
glare  
control



Daylight  
reflected  
onto  
ceiling

# Daylight Skylight through Roof

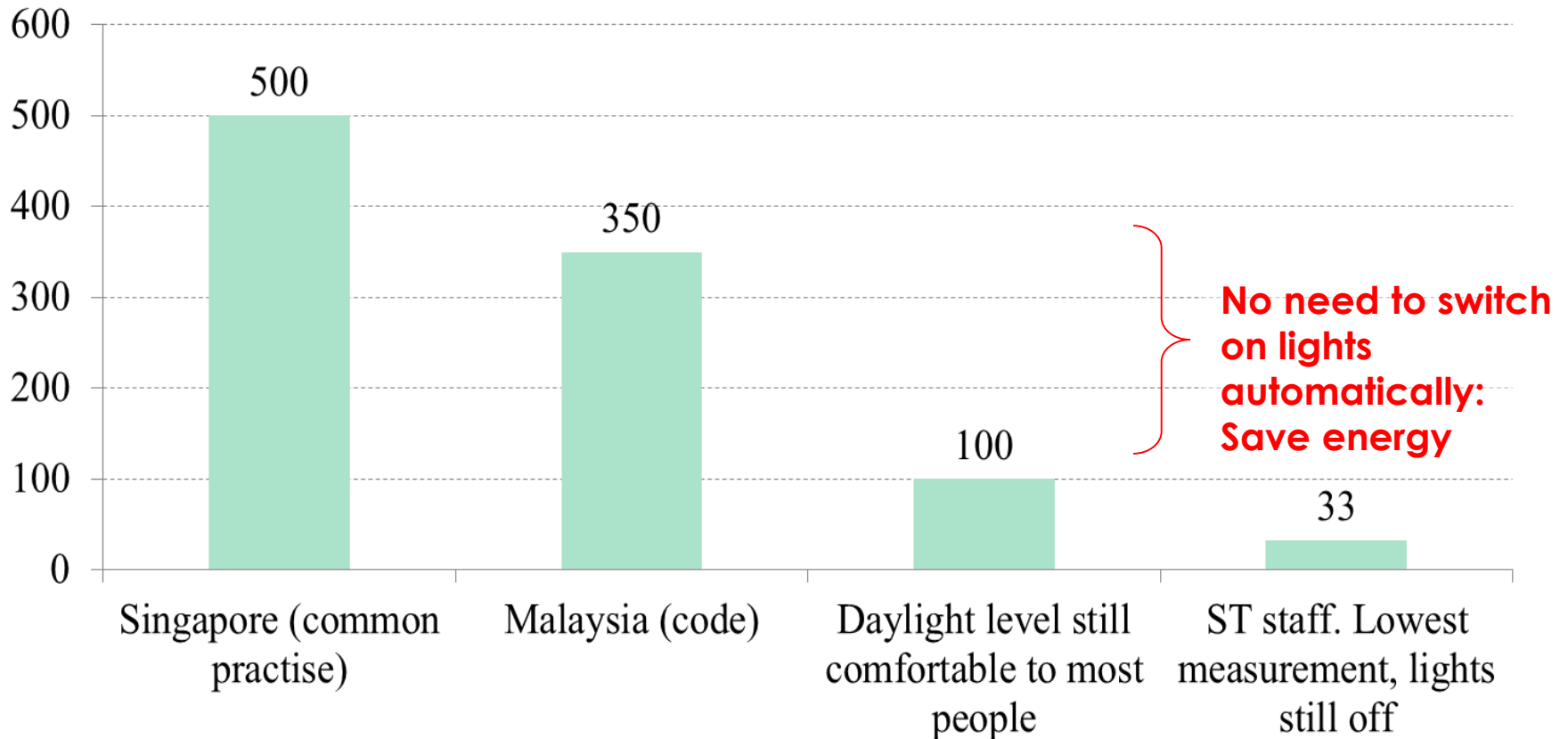
Take in diffuse light only





# Lighting Levels

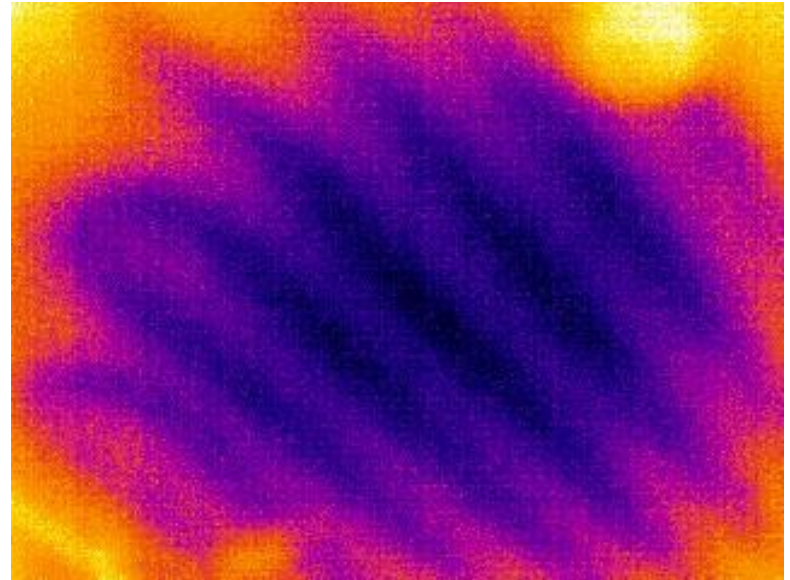
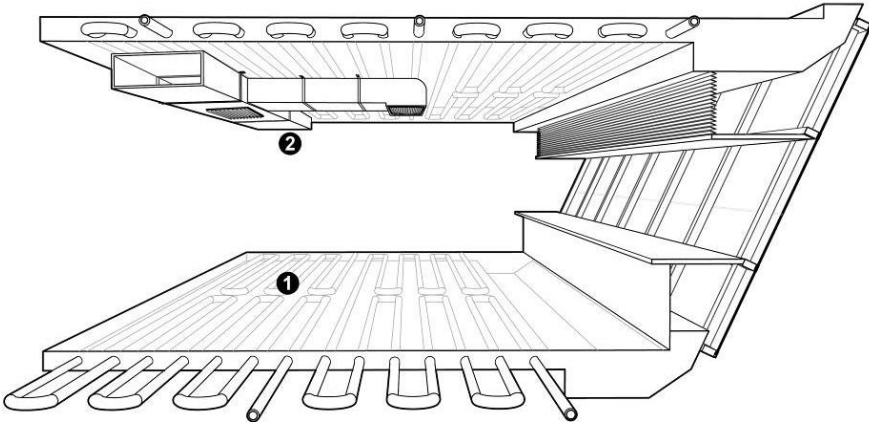
Office (lux)





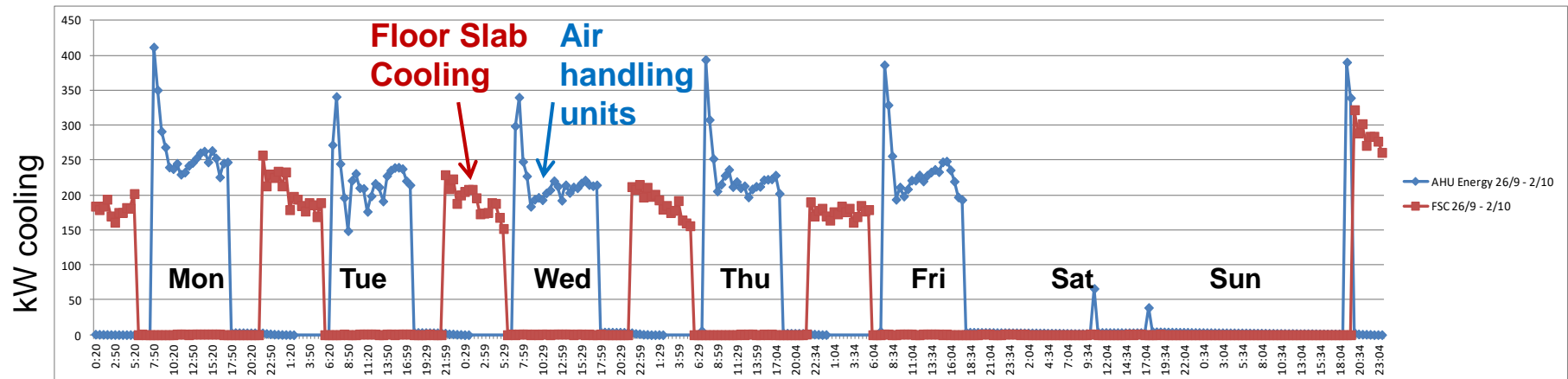
# Floor Slab Cooling in ST Diamond Building

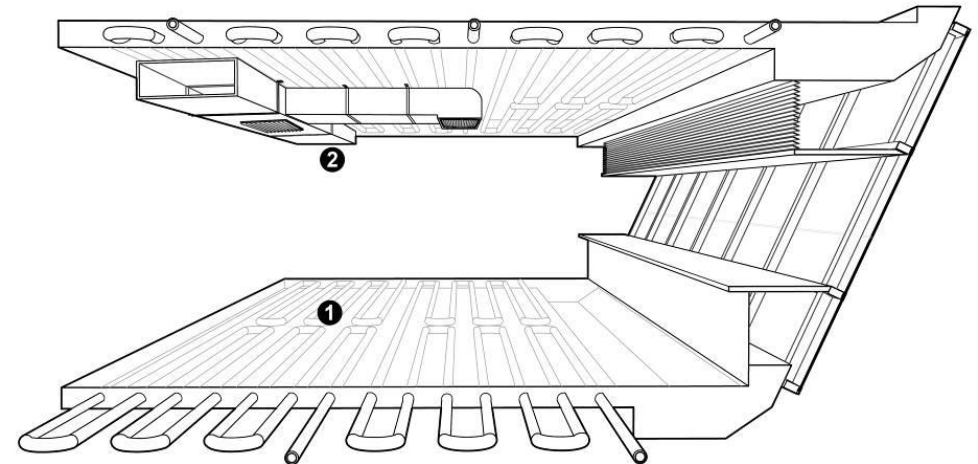
Floor slab cooling system embedded in RC slab



Thermographic image of floor slab cooling in ST Diamond  
Picture courtesy of: PS Soong, Pureaire

Illustration courtesy of:  
Greening Asia – Emerging Principles for Sustainable Architecture.  
Copyright: Nirmal Kishnani, 2012. Publisher: FuturArc



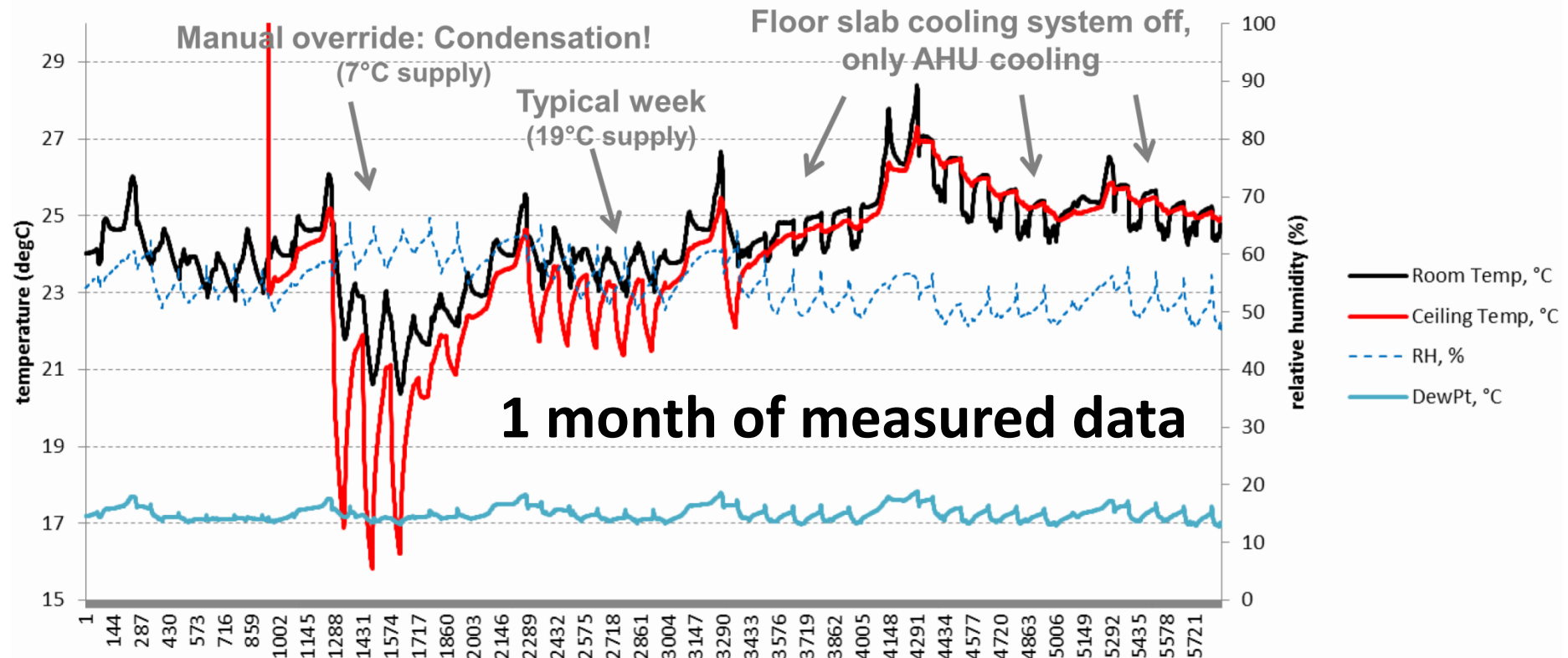


Source: Greening Asia – Emerging Principles for Sustainable Architecture.

Copyright: Nirmal Kishnani. 2012. Publisher: FuturArc

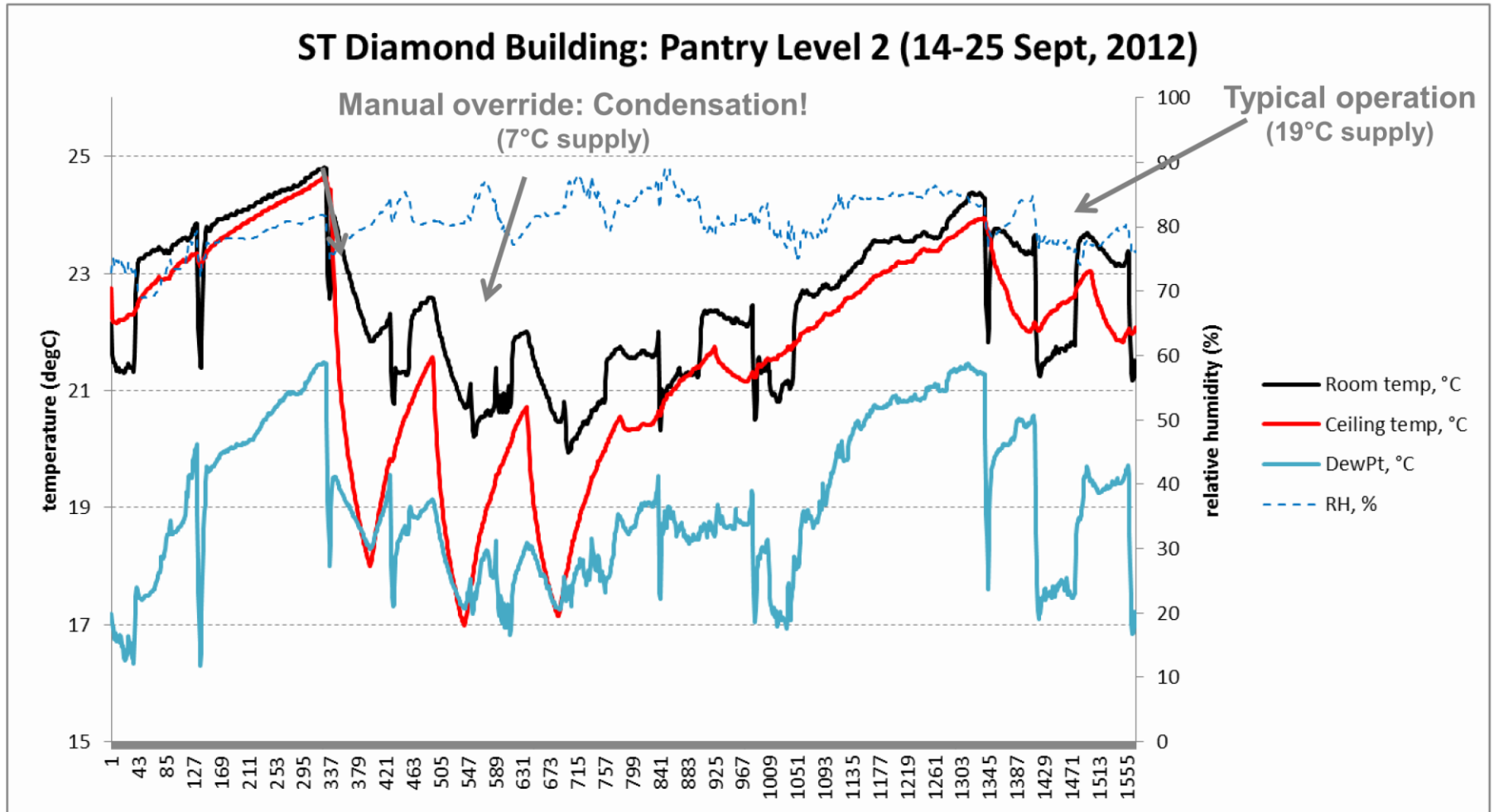
## ST Diamond Building: Floor slab cooling measurements

### ST Diamond Building: Level 6, West, Hamidah room (8 Sept - 18 Oct, 2012)



# Floor Slab Cooling: Condensation accident!

Due to manual override of supply temperature to floor slabs



# Floor Slab Cooling: Measured Correlation

Clear correlation between ceiling surface temperature and Cooling energy

## Ceiling Surface Temperature Change vs Cooling Energy

