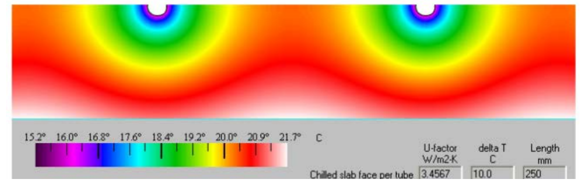
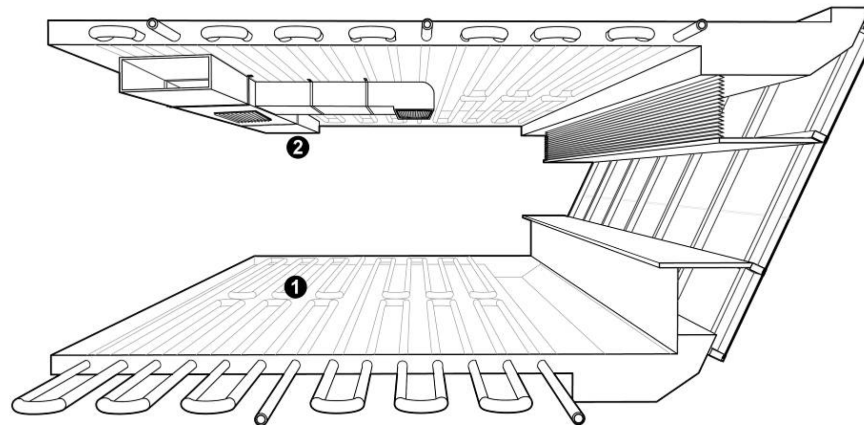
Innovative Solutions
for Energy Efficient Buildings





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Buildings & Energy

Buildings are like a leaky bucket with lots of unnecessary wastages

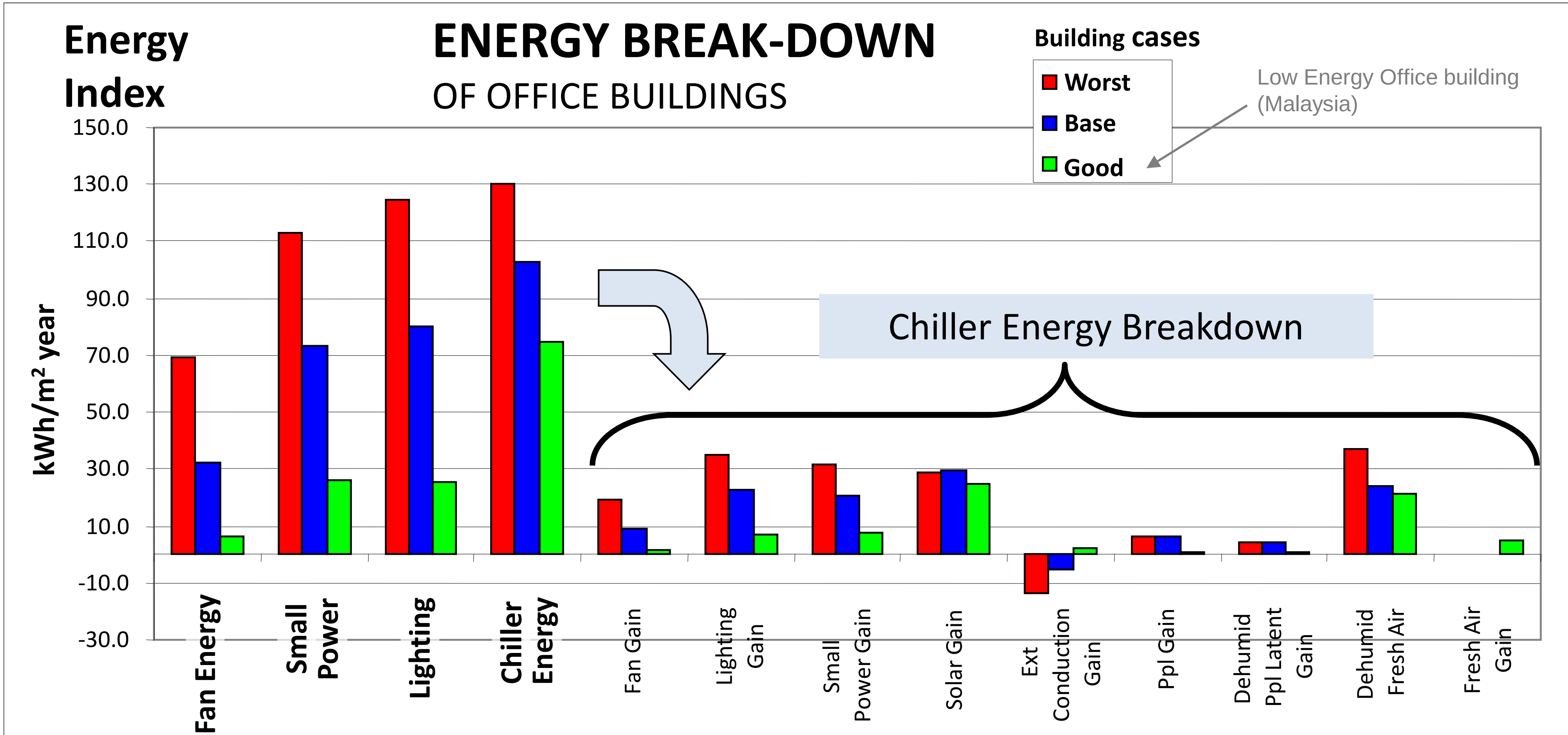
ENERGY SUPPLY
(renewable) energy

ENERGY STORAGE
electric cars/batteries/thermal

ENERGY DEMAND

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?”**

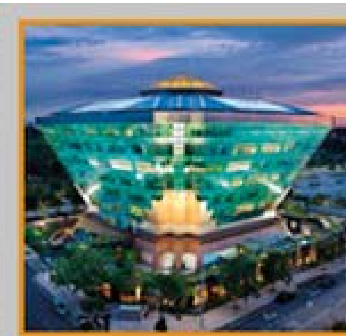


Energy Efficient Buildings with Good Payback time

Case studies from the South East Asian countries

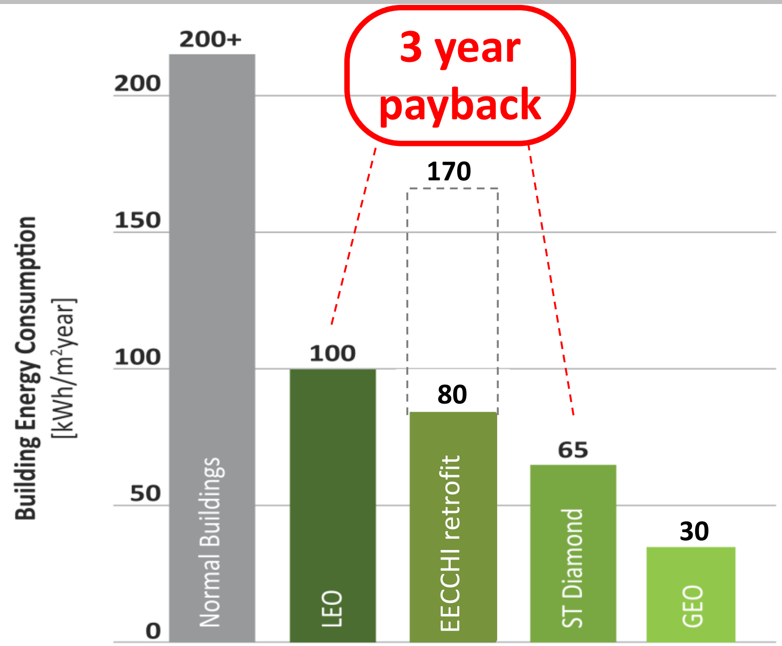
LEO Building

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

IEN CONSULTANTS

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^2
- Energy Index: 64 $kWh/m^2/year$ (excl. PV)
- Energy Index: 30 $kWh/m^2/year$ (incl. PV)
- Additional construction cost: 18% (excl. PV)
- Additional construction cost: 33% (incl. PV)

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

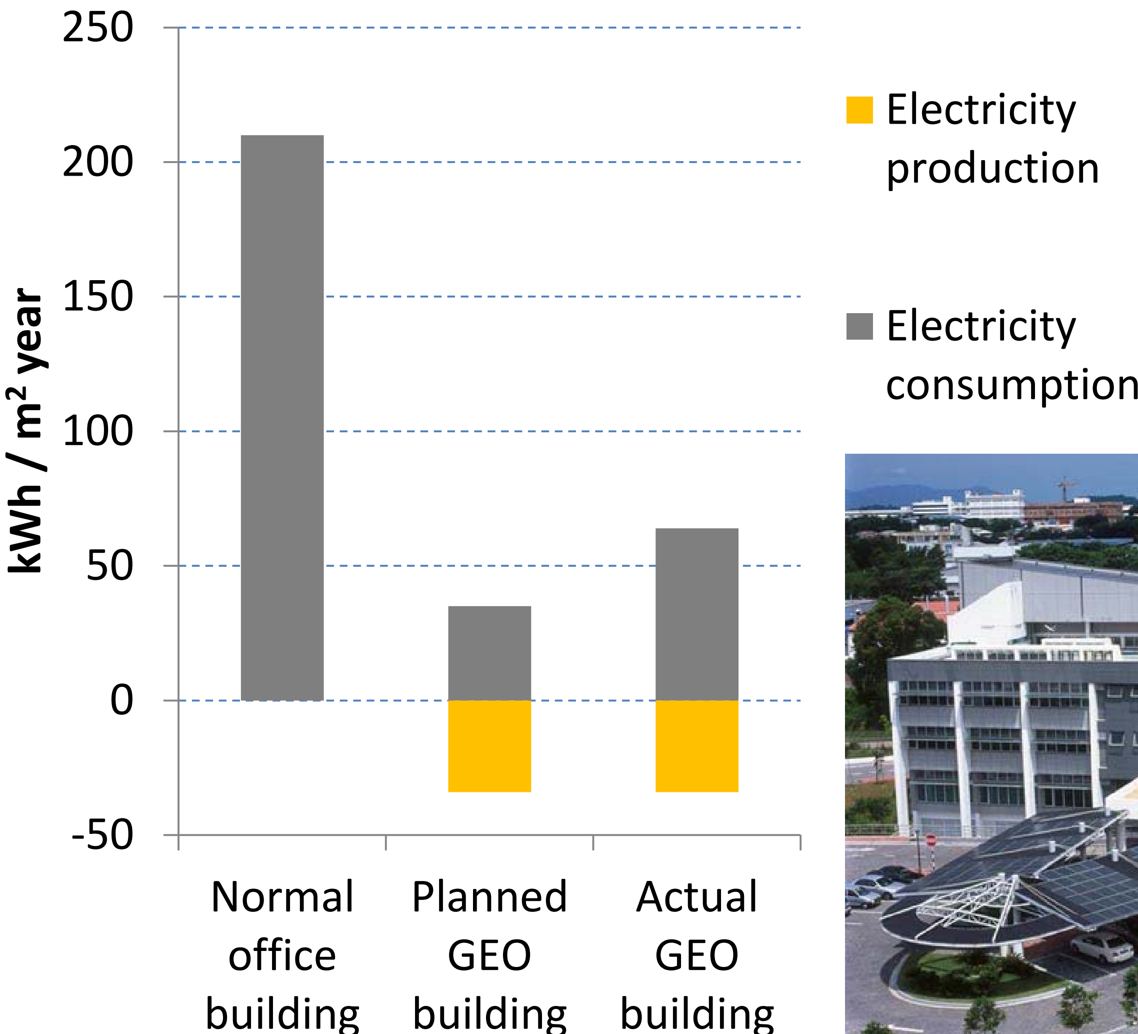
Greentech Malaysia office, Bangi, Malaysia (Occupation Oct 2007)

Energy Design Concepts
of GEO Building

Concept no. 1
Zero Energy Building

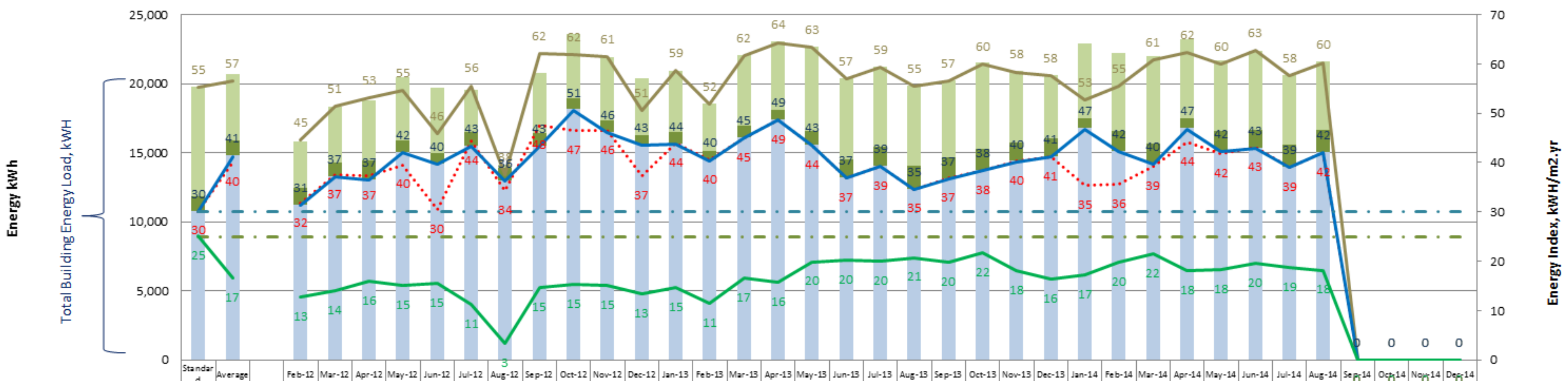
Concept no. 2
Shift load to the night, hence, reducing peak demand for power utilities

Concept no. 1: Zero Energy Building



GEO building: Energy measurements

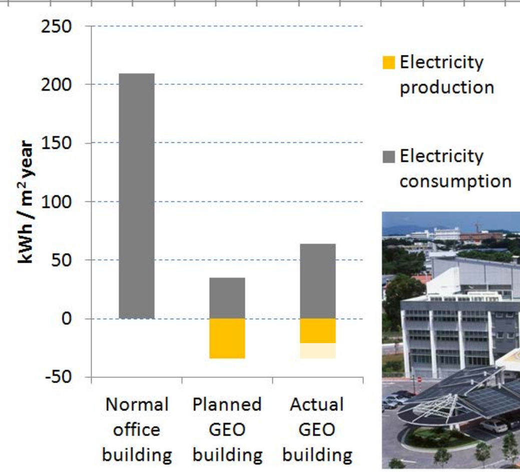
Graph 1 : GEO Building Energy Usage & Generation Performance , 2012-2014(Aug)



	Standard	Average		Feb-12	Mar-12	Apr-12	May-12	Jun-12	Jul-12
kWhPV used	7,949	4,811		3,389	3,994	4,385	4,573	4,752	3,092
kWhRec	1,051	1,114		1,179	1,034	1,319	826	780	945
kWh Total (net)	10,800	14,788		11,241	13,278	13,098	15,039	14,203	15,541
TNB BEI [kWh/m2.yr]	55	57		45	51	53	55	46	56
TNB NET BEI [kWh/m2.yr]	30	40		32	37	37	40	30	44
BEMS NET BEI [kWh/m2.yr]	30	41		31	37	37	42	40	43
Net BEI 30 Line	30	30	30	30	30	30	30	30	30
PVI 25 Line	25	25	25	25	25	25	25	25	25
meter PVI [kWh/m2.yr]	25	17		13	14	16	15	15	11

	Aug-12	Sep-12	Oct-12	Nov-12	Dec-12	Jan-13	Feb-13	Mar-13	Apr-13	May-13	Jun-13	Jul-13
kWhPV used	250	4,360	4,663	4,564	4,105	4,466	3,412	5,129	4,957	6,106	5,941	5,800
kWhRec	927	875	816	812	674	807	674	841	677	1,026	1,279	1,336
kWh Total (net)	12,979	15,514	18,145	16,502	15,581	15,682	14,481	16,093	17,396	15,565	13,196	14,063
TNB BEI [kWh/m2.yr]	38	62	62	61	51	59	52	62	64	63	57	59
TNB NET BEI [kWh/m2.yr]												
BEMS NET BEI [kWh/m2.yr]												
Net BEI 30 Line												
PVI 25 Line												
meter PVI [kWh/m2.yr]												

	Aug-13	Sep-13	Oct-13	Nov-13	Dec-13	Jan-14	Feb-14	Mar-14	Apr-14	May-14	Jun-14	Jul-14	Aug-14	Sep-14	Oct-14	Nov-14	Dec-14
kWhPV used	5,753	5,583	6,225	5,153	4,569	5,437	5,640	6,303	5,741	5,091	5,703	5,024	4,973	0	0	0	0
kWhRec	1,683	1,509	1,528	1,333	1,303	726	1,472	1,432	726	1,472	1,328	1,657	1,546				
kWh Total (net)	12,389	13,165	13,745	14,400	14,735	16,777	15,124	14,248	16,777	15,124	15,341	13,952	15,068	0	0	0	0
TNB BEI [kWh/m2.yr]	55	57	60	58	58	53	55	61	62	60	63	58	60	0	0	0	0
TNB NET BEI [kWh/m2.yr]							36	39	44	42	43	39	42	0	0	0	0
BEMS NET BEI [kWh/m2.yr]							42	40	47	42	43	39	42	0	0	0	0
Net BEI 30 Line							30	30	30	30	30	30	30	30	30	30	30
PVI 25 Line							25	25	25	25	25	25	25	25	25	25	25
meter PVI [kWh/m2.yr]							20	22	18	18	20	19	18	0	0	0	0



2014 (Aug)

40% drop
(inverter problem)

No change

Concept no. 2: Shift load to the night

Electricity demand curve

Malaysia (2012)

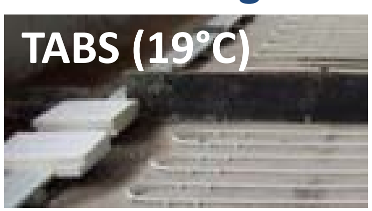
BUY electricity from the grid

SELL electricity to the grid

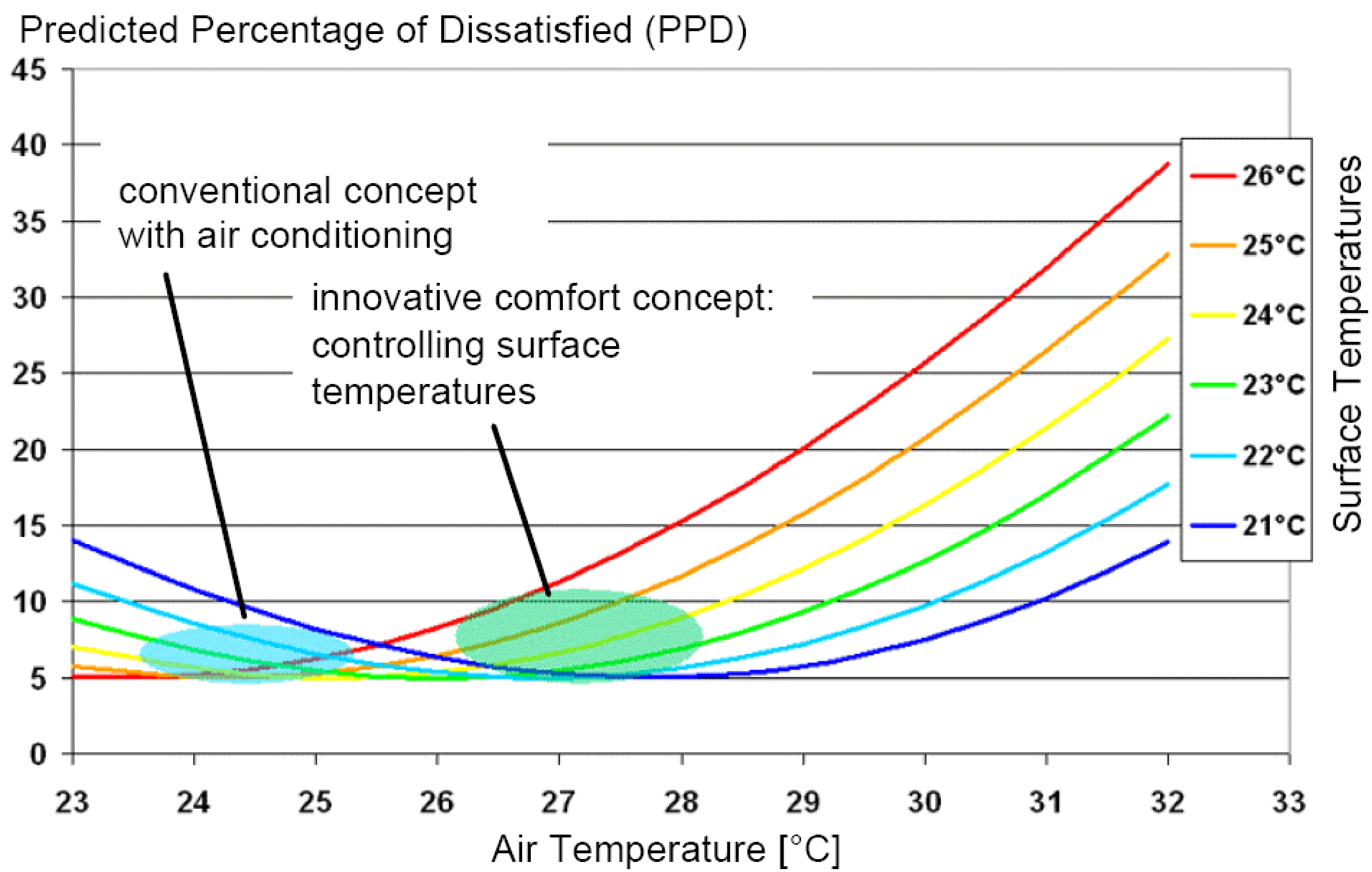
How?	Thermal storage	Solar PV

Building integrated photovoltaic (91 kW_p)

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



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

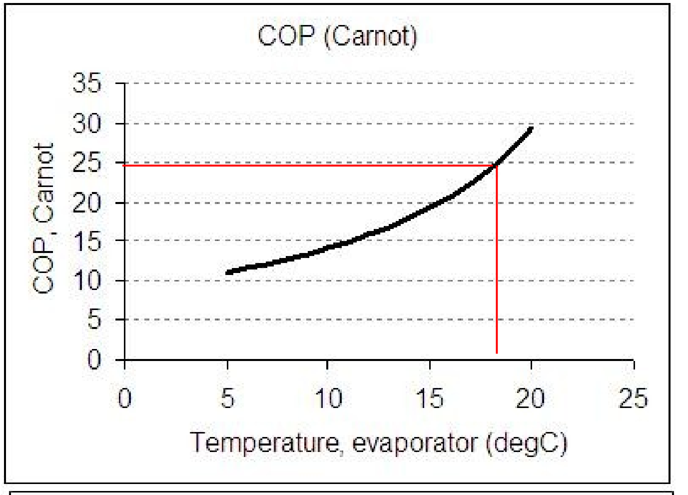
Efficient High Temperature Cooling

$$COP_{refrigerator} = \frac{T_c}{T_H - T_C}$$

- 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**)

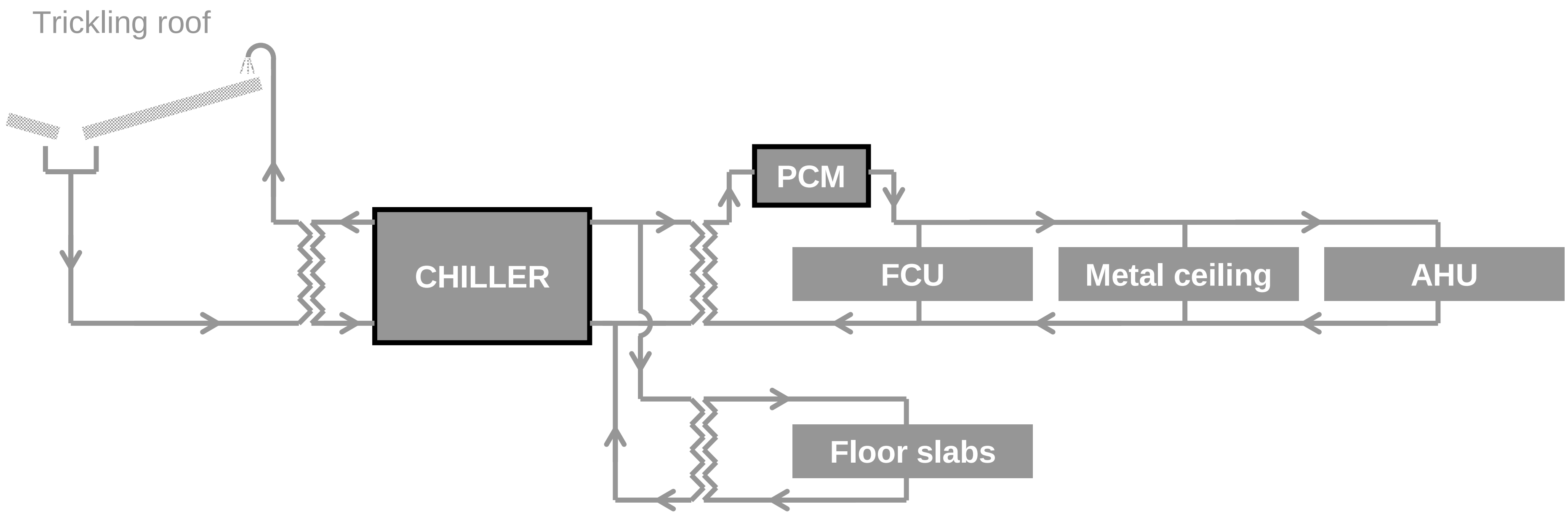
- Chillers only supply cooling to thermal storages, hence, **maximum COP** for chiller operation can be ensured at all times. NB. Maximum COP is at part load (~75% load)



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

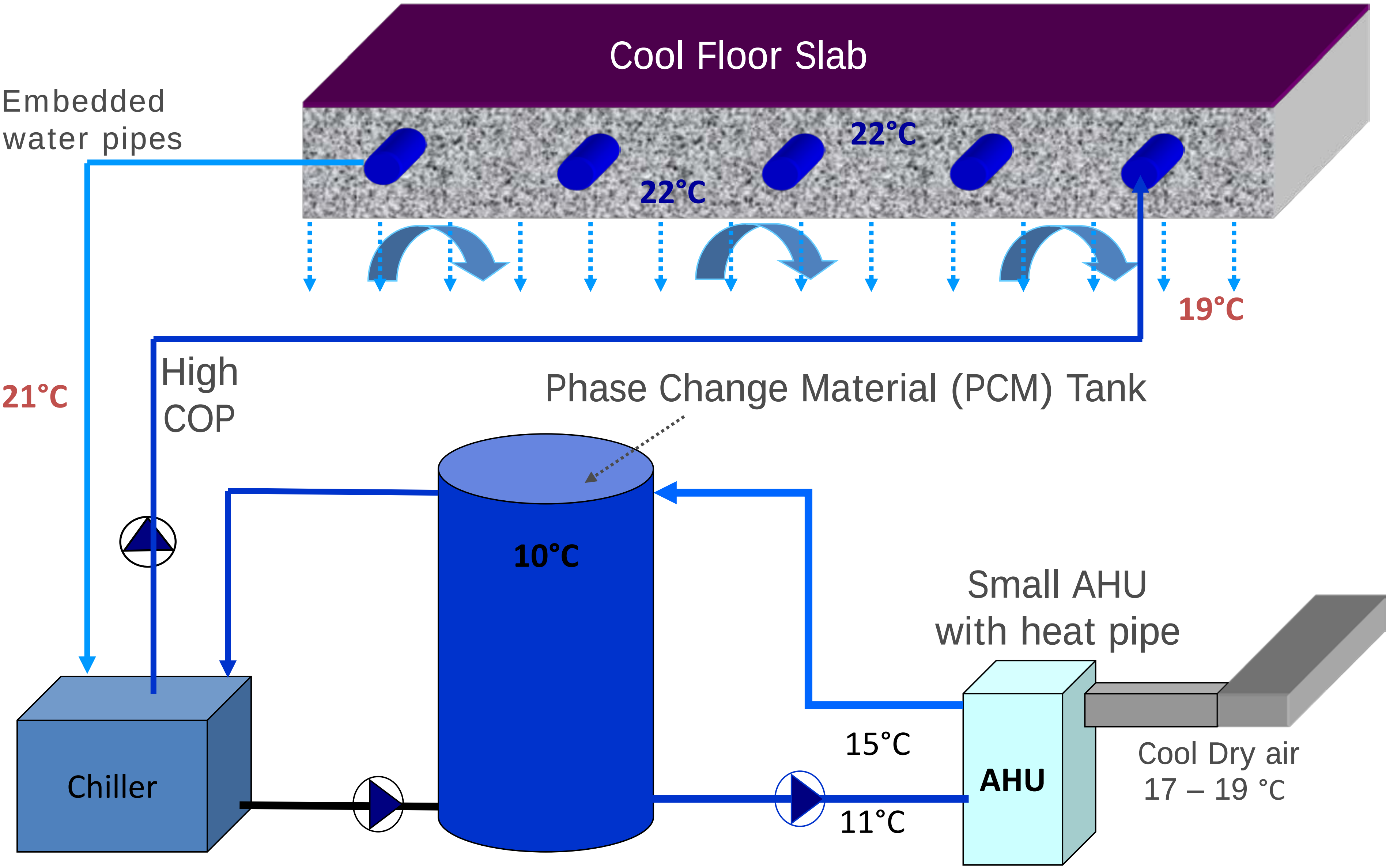
Schematic Design of Cooling System

GEO building



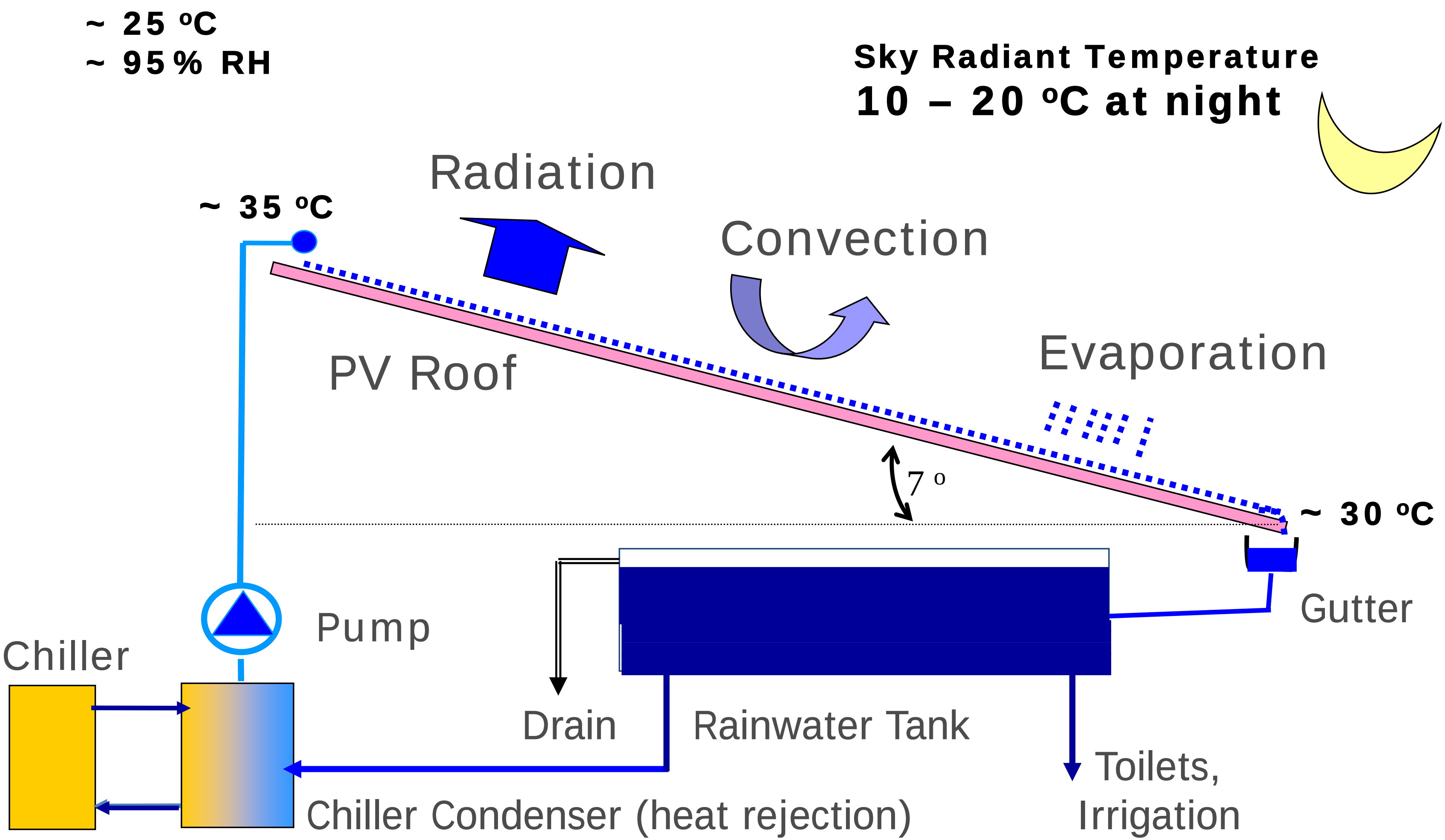
PCM:	Phase Change Material (thermal storage tank with "10°C ice")
FCU:	Fan Coil Units
Metal ceiling:	Radiant cooling metal ceiling
AHU:	Air handling unit
Floor slabs:	Concrete floor and ceiling slab cooling (TABS, thermally activate building structure)
Trickling roof:	7° tilt flat roof flooded with condenser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



The River Roof of GEO Building

to be operated at night only

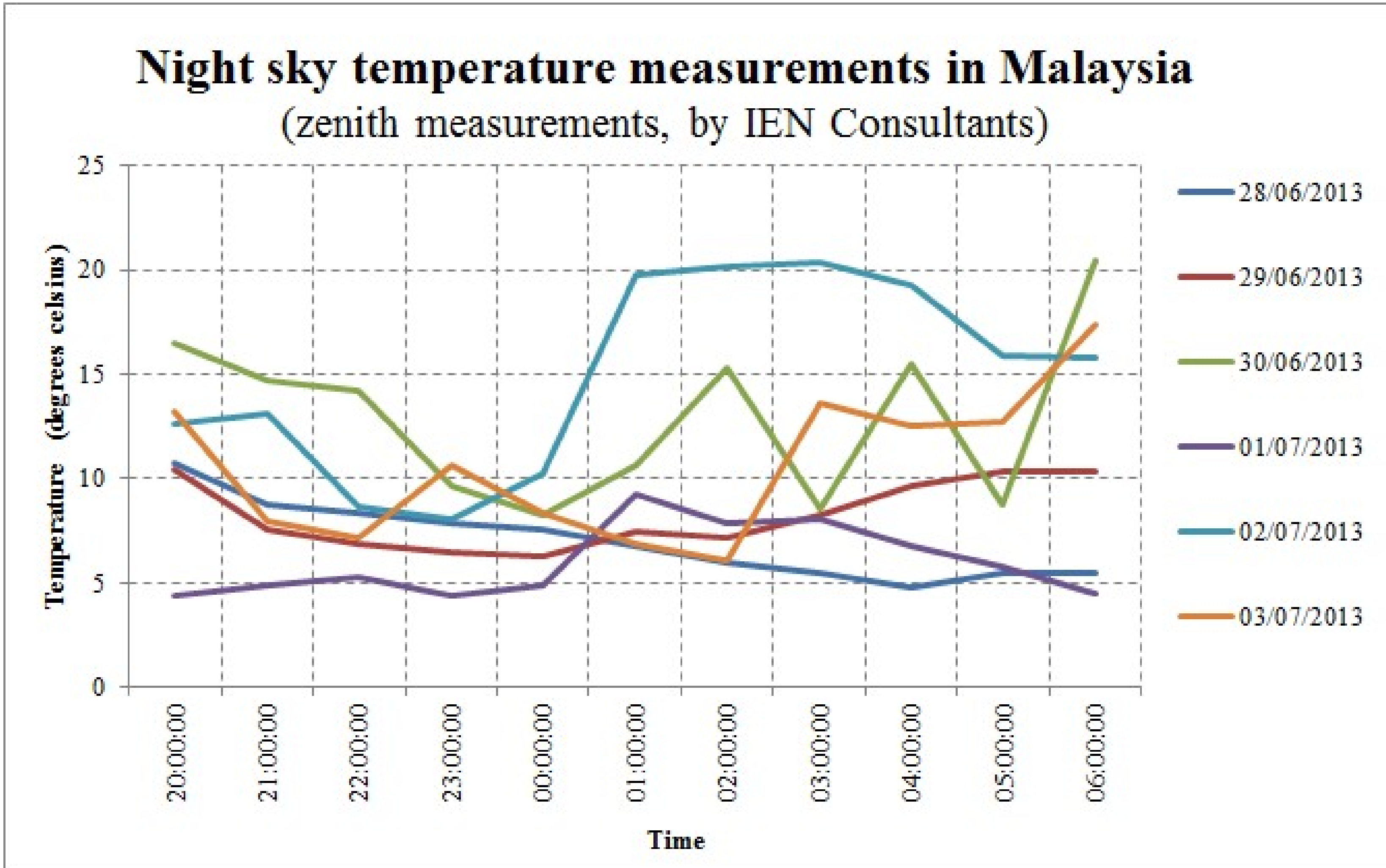
Video 1:
Gutter for ‘cooling tower’ water & rainwater

Video link:
https://www.youtube.com/watch?v=h8gC4dlB330

Video 2:
Manifold splashing water onto PV roof

Video link:
https://www.youtube.com/watch?v=nb_JntSXoiA

River roof cooling primarily through sky radiation



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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

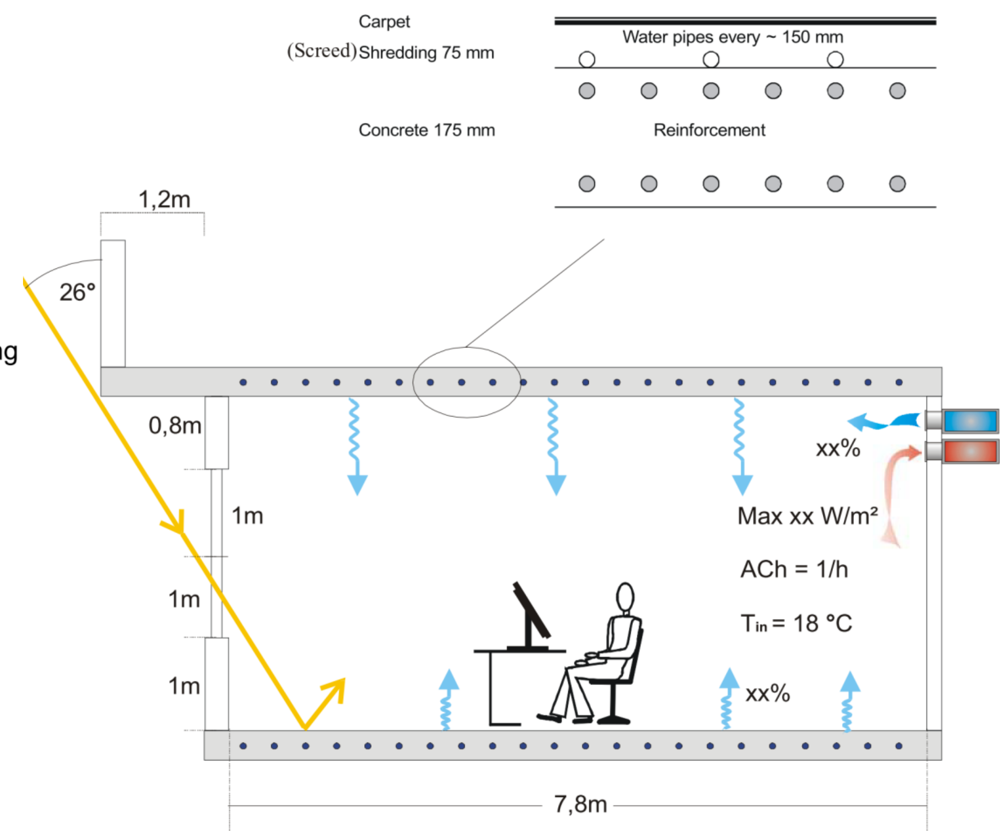
GEO Building

Computer modeling of GEO Building

by Transsolar using TRNSYS

boundary conditions

floor area and volume	95 m² / 356 m³
length facade:	12.2 m
depth:	7.8 m
height:	3.75 m without suspended ceiling
facade:	
50 % opake	20 cm leightweight concrete
50 % glazings with frames	sun protection glazings 50 % light transmission 25 % SHGC Ug-value = 1.1 W/m²/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

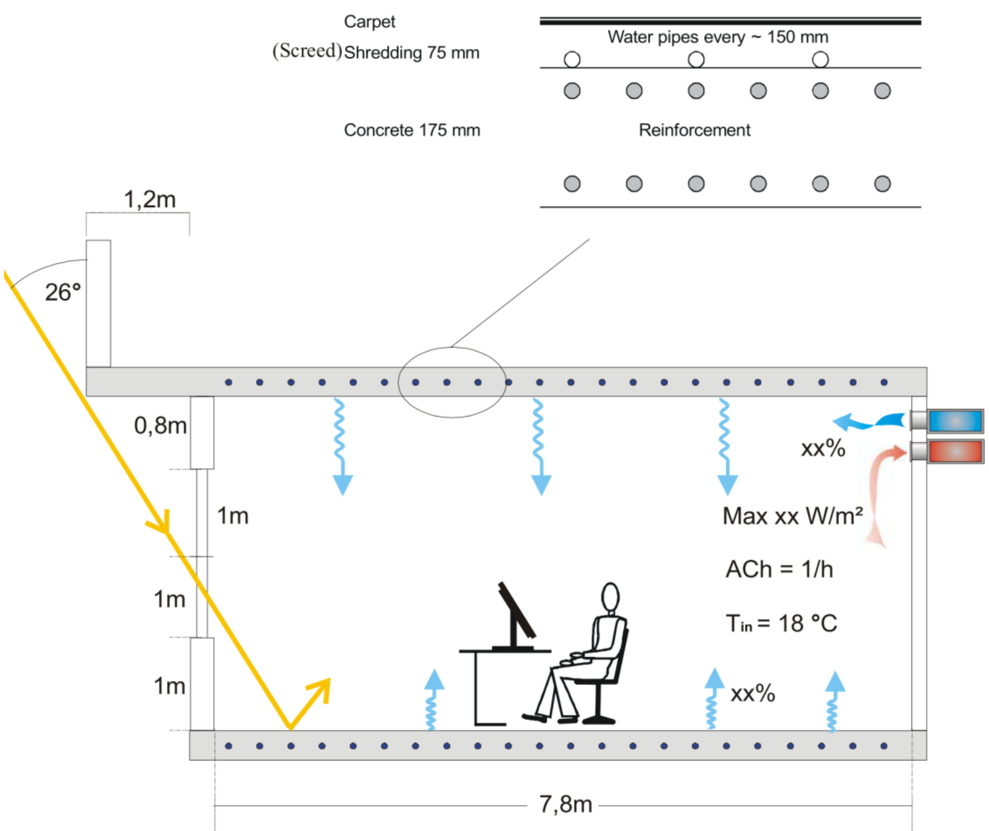
Persons	10 with 75 W sensible heat gain from 8 am to 5 pm
PC	10 with 31 W, variant: 10 with 100 W

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

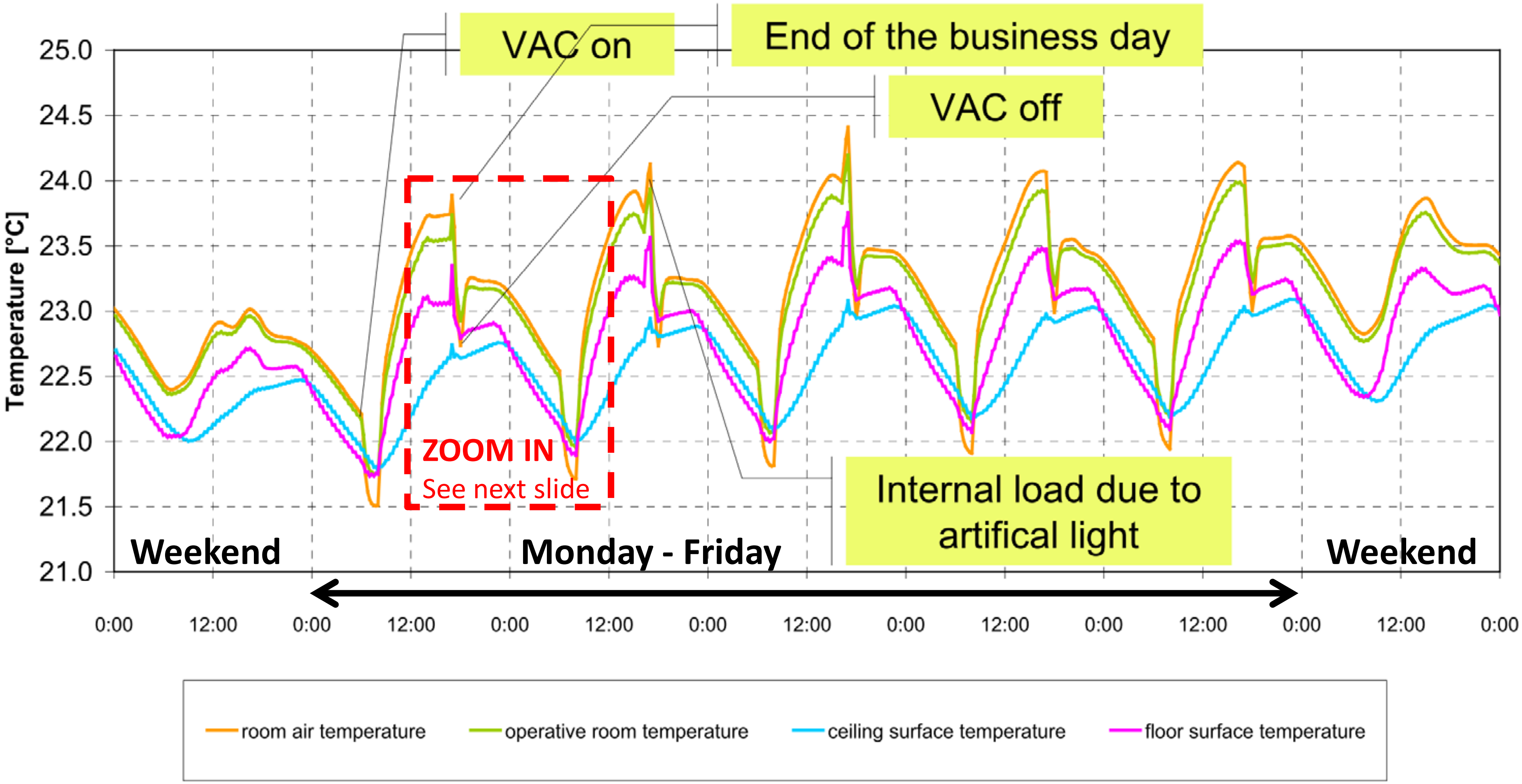
Slab cooling

Operation time	10 pm to 8 am
Inlet fluid temperature	20 °C
Mass flow	12 kg/m²/h
Pipe dimension	20x2 mm, distance: 15 cm
active area	80 %



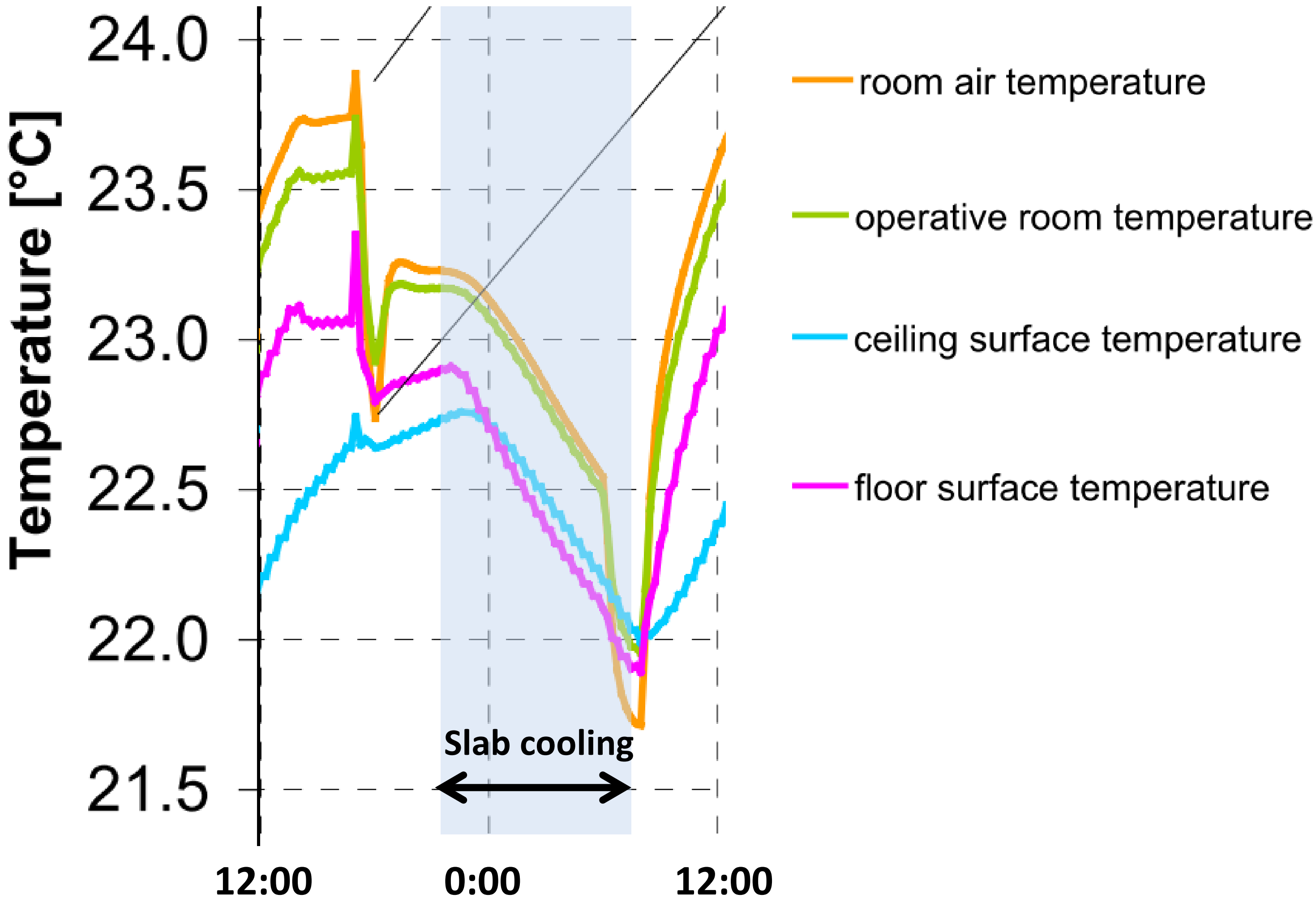
Energy Model for Concrete Floor Slab Cooling

Slab cooling 10 pm – 8 am



Energy Model for Concrete Floor Slab Cooling

Slab cooling 10 pm – 8 am



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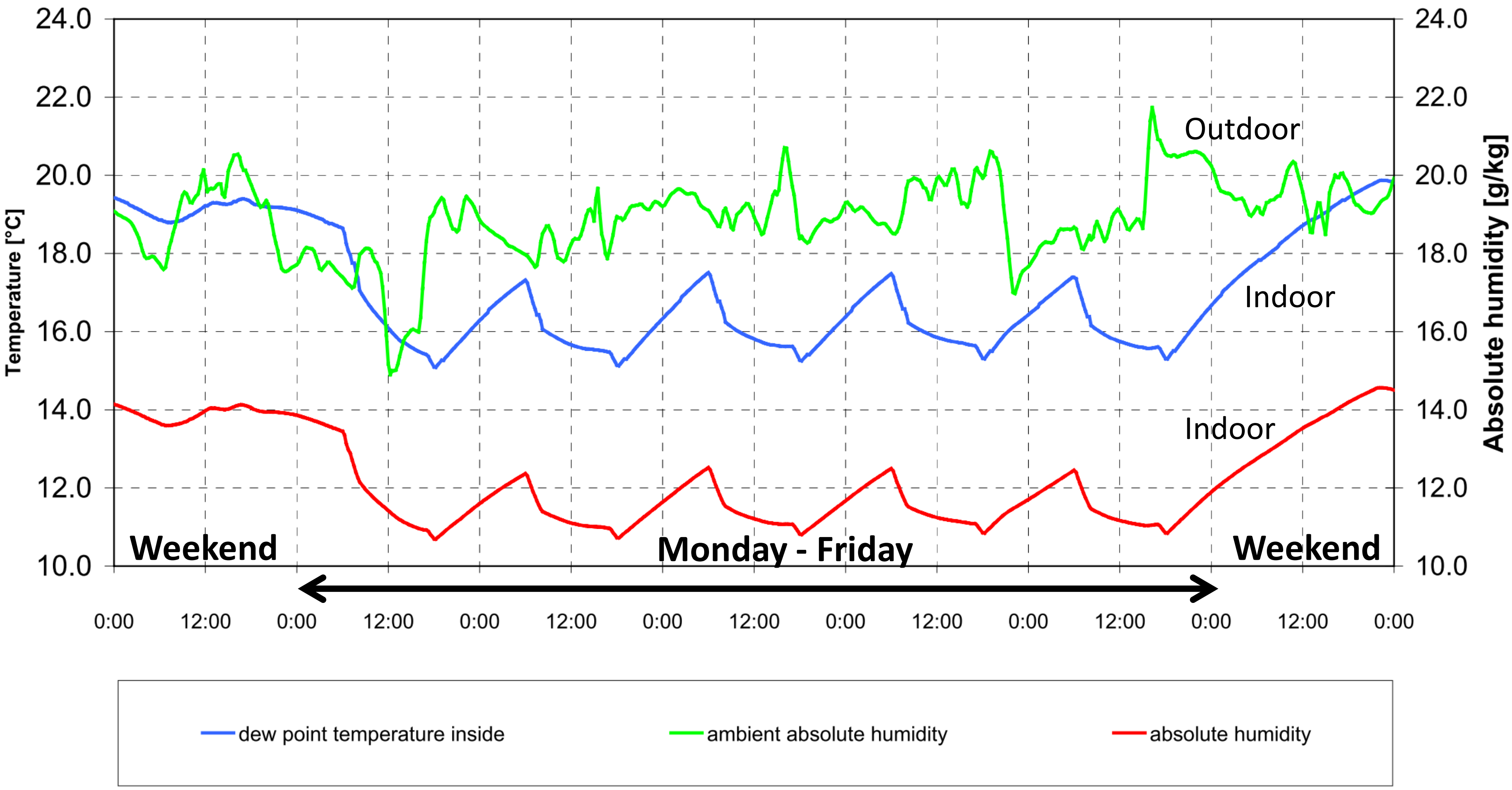
TRANS SOLAR

Energy Model for Concrete Floor Slab Cooling

Slab cooling 10 pm – 8 am



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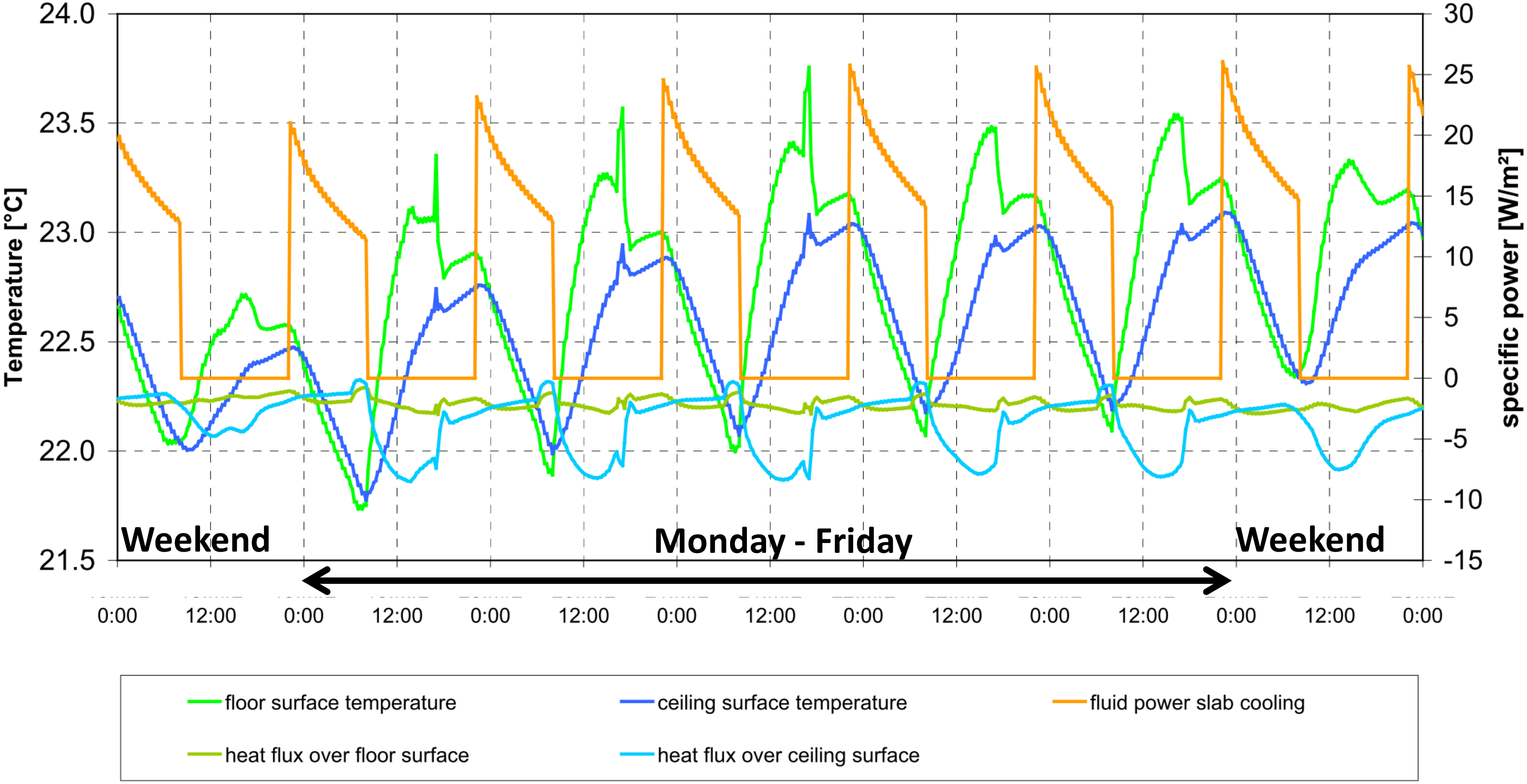
TRANS SOLAR

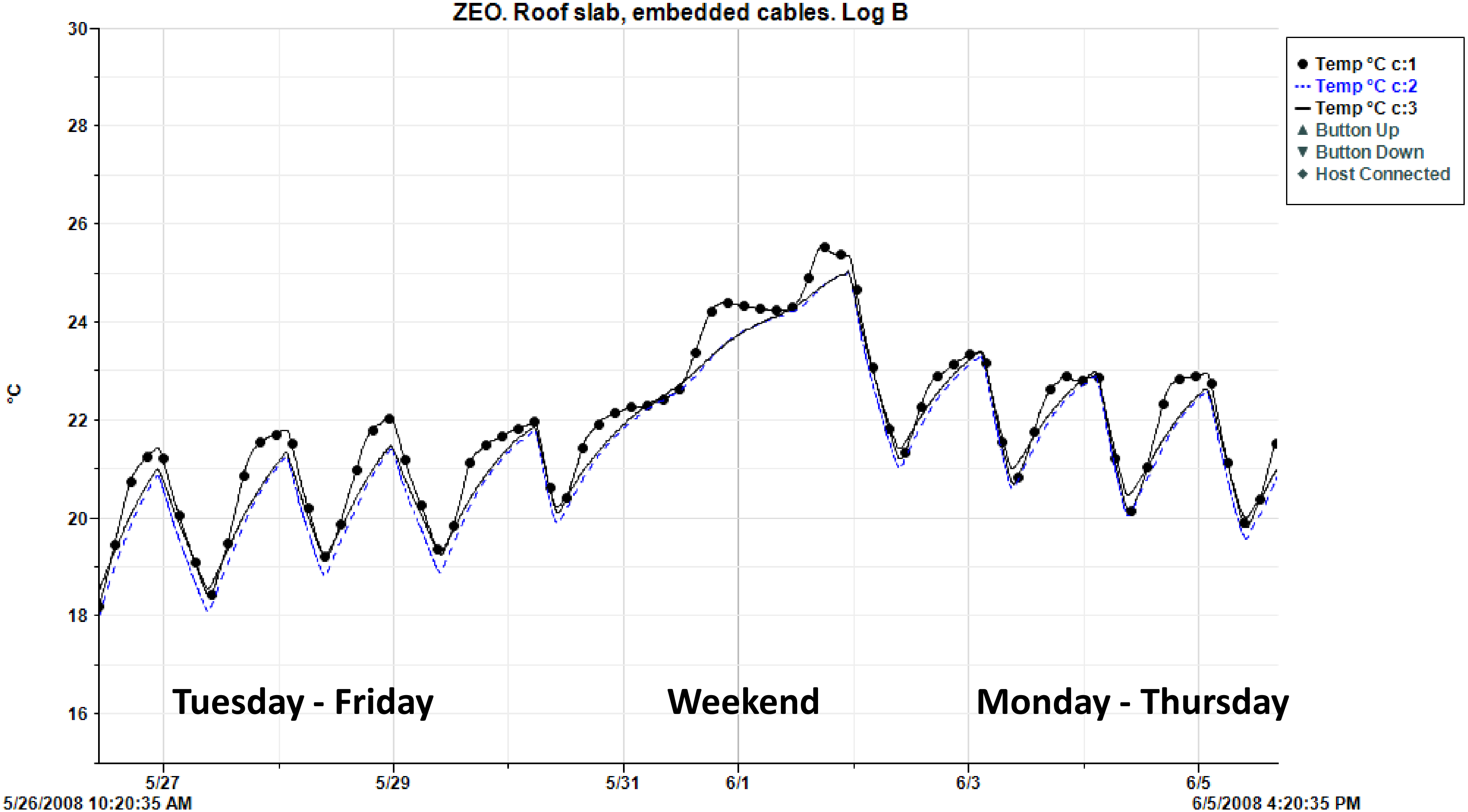
Energy Model for Concrete Floor Slab Cooling

Slab cooling 10 pm – 8 am



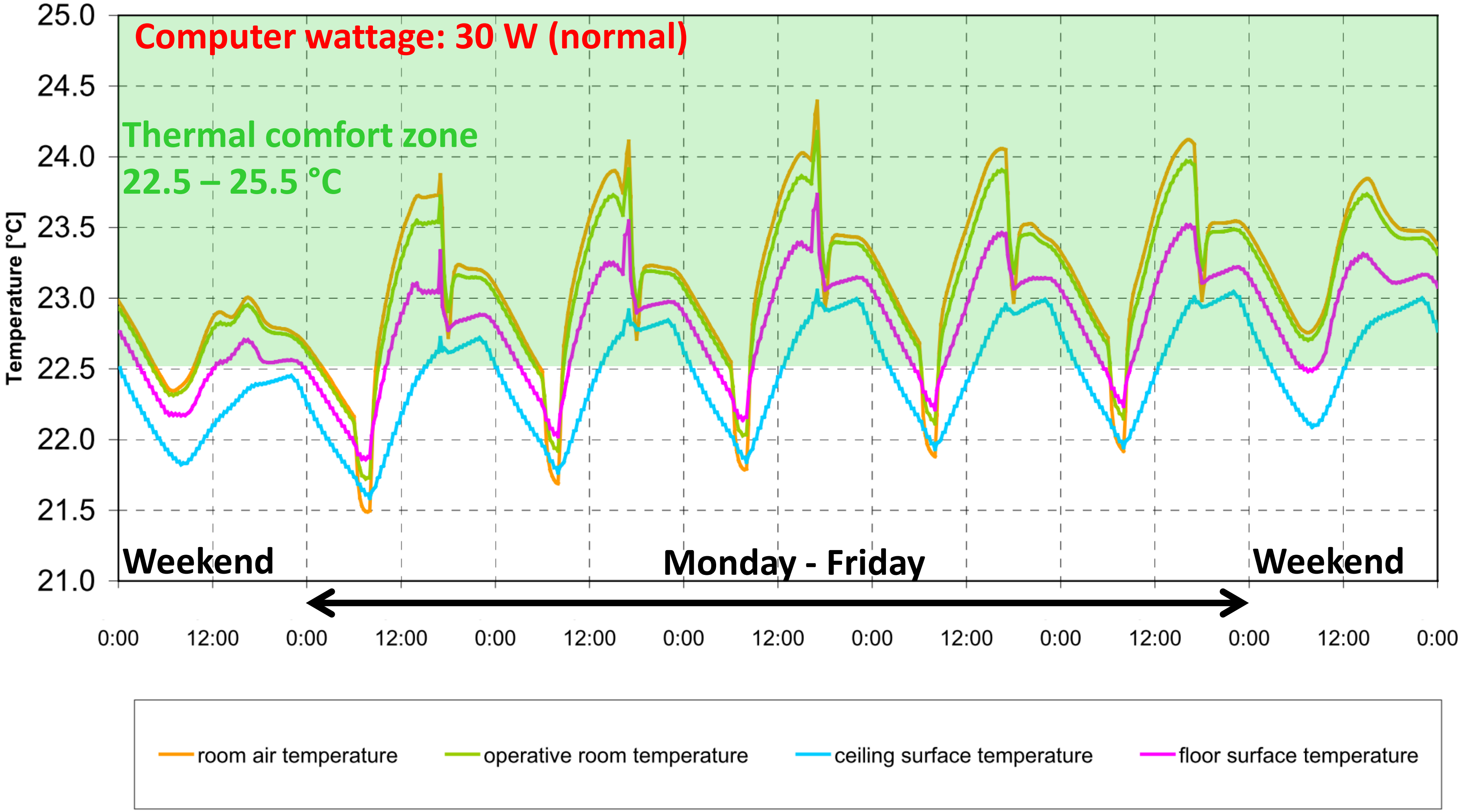
Measured Concrete Slab Core Temperature

Roof slab of GEO Building



Thermal Comfort for Concrete Floor Slab Cooling

Slab cooling 10 pm – 8 am



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TRANS SOLAR

Measured Temperature for Open Plan Office

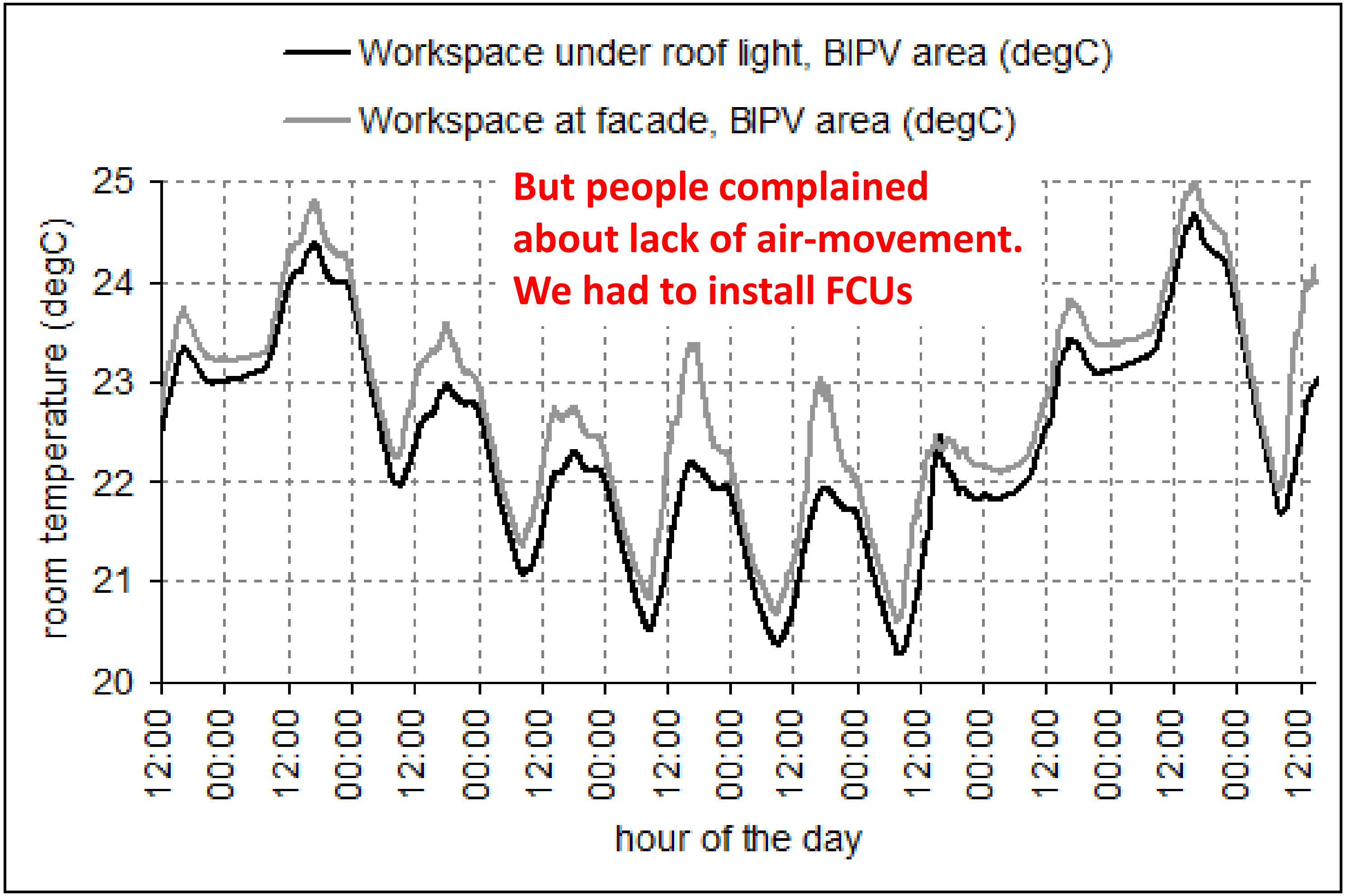


Figure 13: Temperature measured in each workstation from 1 – 10 March 2008

Measured Dew Point Temperature for Open Plan Office

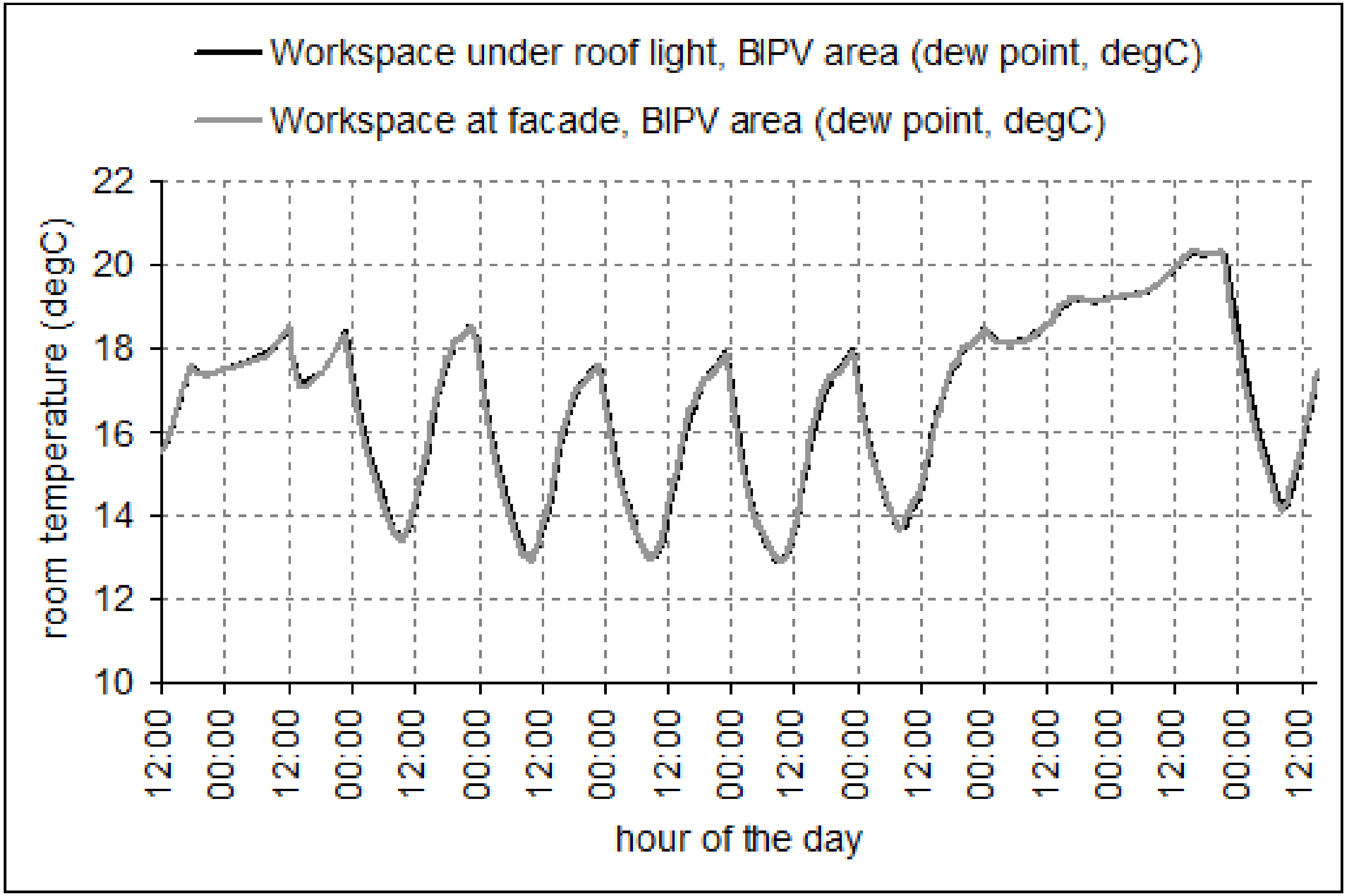
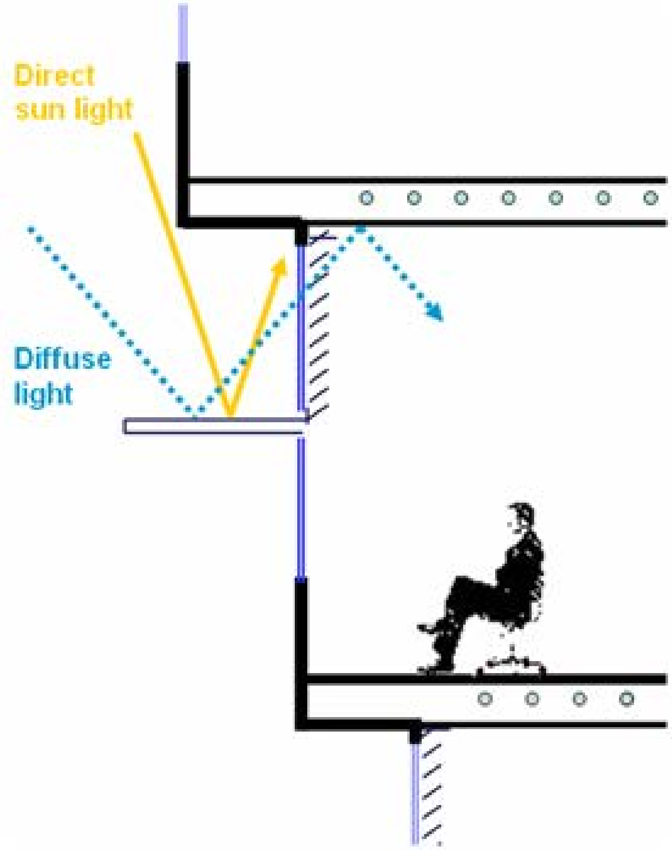
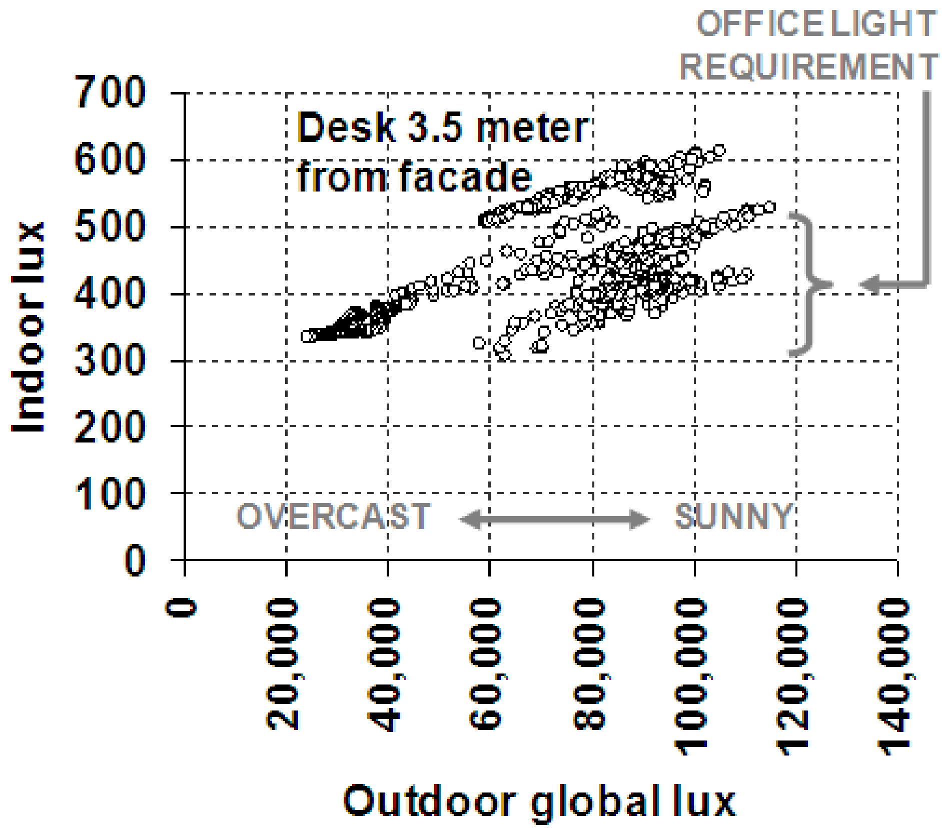


Figure 14: Dew point measured in each work station from 1 – 10 March 2008

Split Window Design



Daylight Measurements



- Lighting consumption: 0.56 W/m²
- Code requirement: 15 W/m²

25 times more efficient

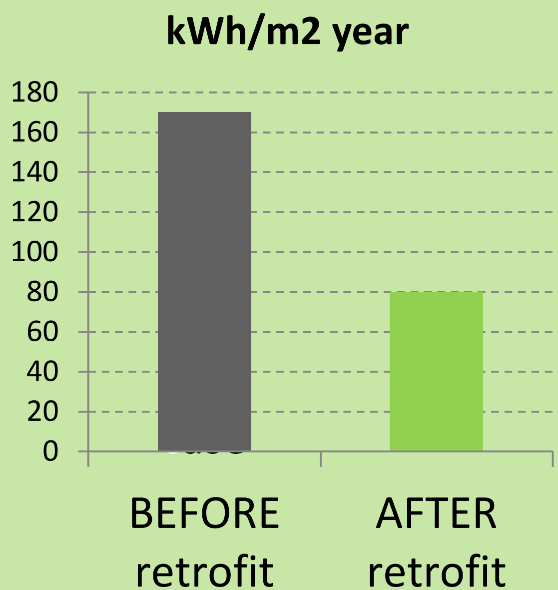
Transparent PV atrium roof

- 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

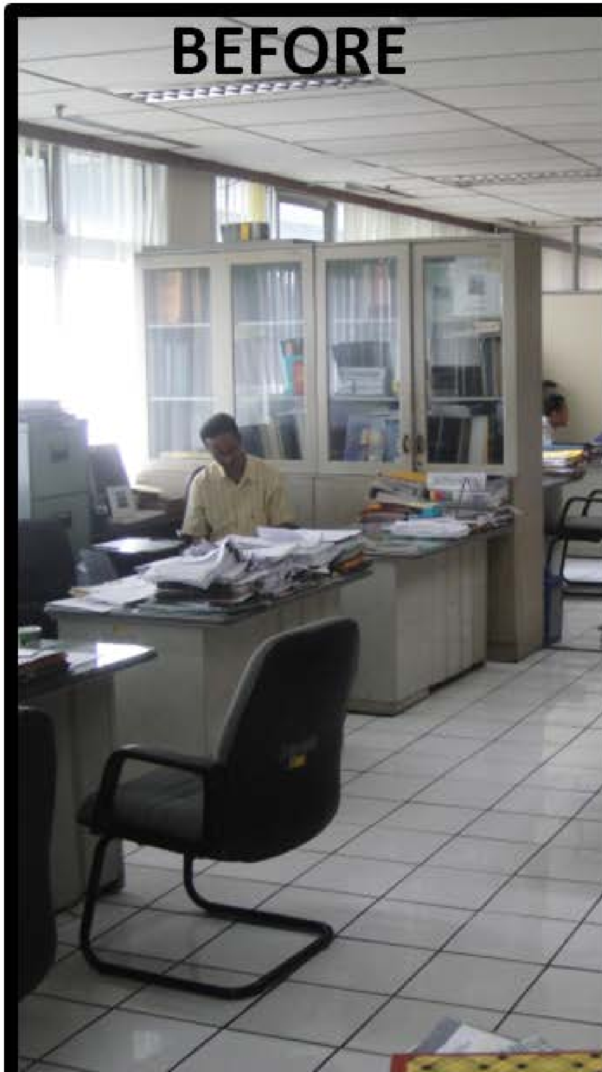


Energy Efficient Retrofit case study

EECCHI OFFICE RETROFIT

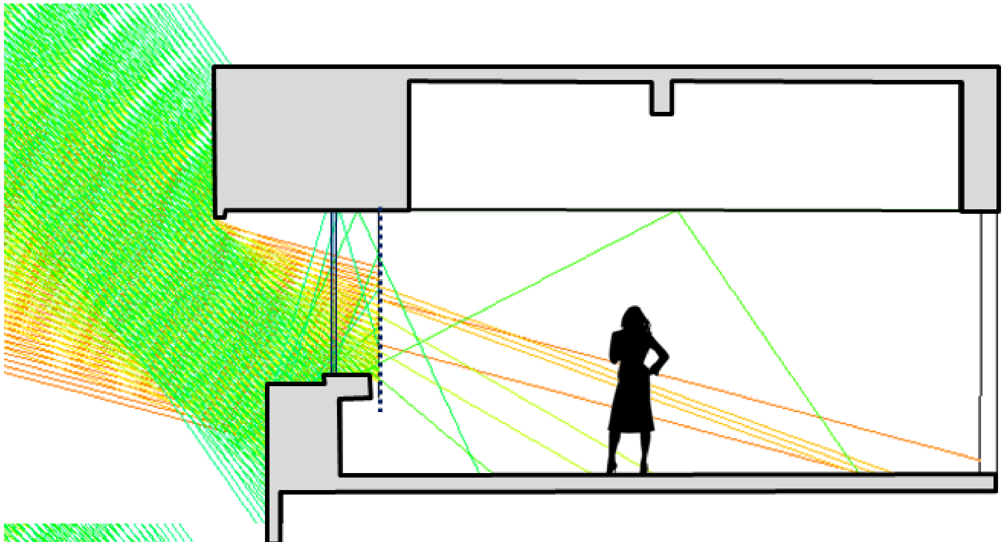
(JAKARTA, 2011)

53% Measured Energy Savings



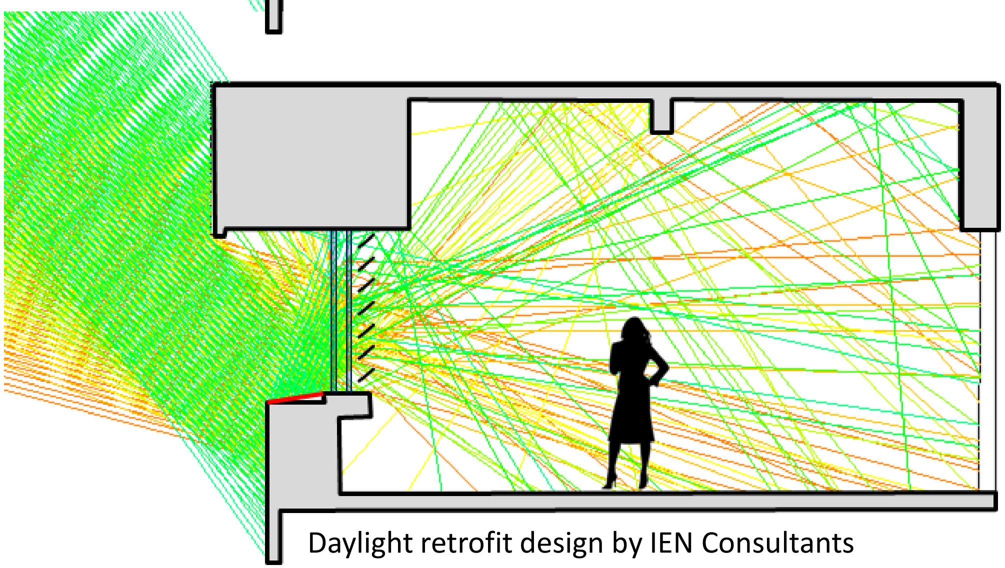
	Before	After
Energy	170 kWh/m² yr	80 kWh/m² yr
Comfort	26-31 temp (°C)	24-26 temp (°C)
	75 RH (%)	55 RH (%)
Noise	57 dB	45 dB
Daylight	No	Yes
View out		

Retrofit & Improved Thermal Comfort



BEFORE RETROFIT

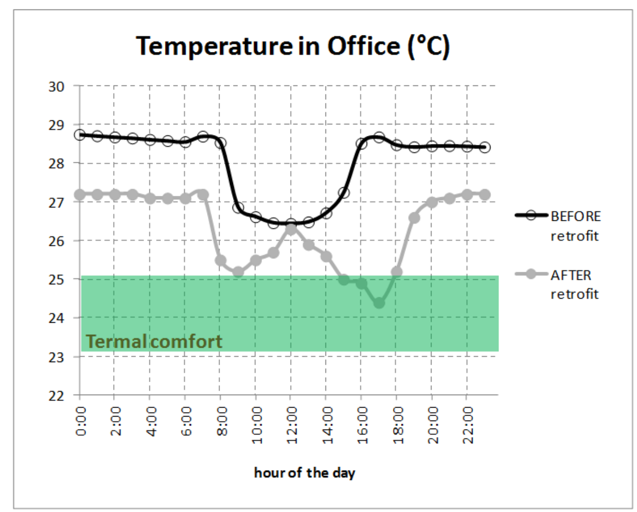
- Vertical blinds blocking most of the daylight
- Suspended ceiling



Daylight retrofit design by IEN Consultants

AFTER RETROFIT

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



Case study

Innovative daylighting facade for highrise building

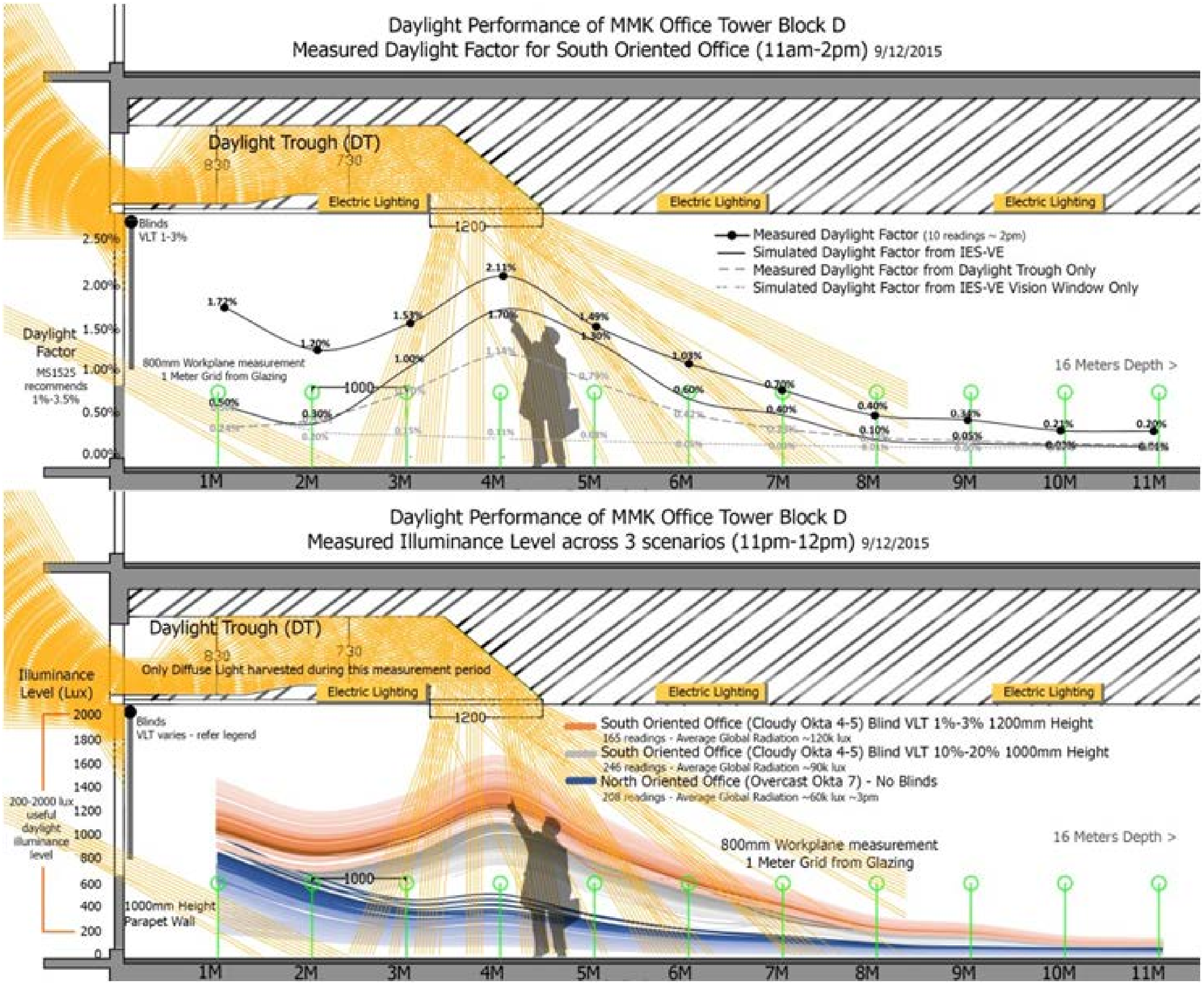
MMK OFFICE TOWER

(KUALA LUMPUR, 2015)

Innovative façade daylighting

The MMK high rise office tower @ Damansara Perdana, Malaysia

7 meters daylight with blinds down



Daylight design by IEN Consultants

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

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)

I E N CONSULTANTS

Architects: Soontorn Boonyatikarn (Thailand) and NR Architect (Malaysia)
Energy efficiency and sustainability: IEN Consultants

Mechanical & Electrical: Primetech Engineers
Contractor: Putra Perdana Construction
Client: Malaysian Energy Commission

ASHRAE Technology Award 2013 (2nd place)

(ST Diamond Building, Putrajaya, Malaysia)

I E N CONSULTANTS

Architects: Soontorn Boonyatikarn (Thailand) and NR Architect (Malaysia)
Energy efficiency and sustainability: IEN Consultants

Mechanical & Electrical: Primetech Engineers
Contractor: Putra Perdana Construction
Client: Malaysian Energy Commission

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 the 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 mere 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.

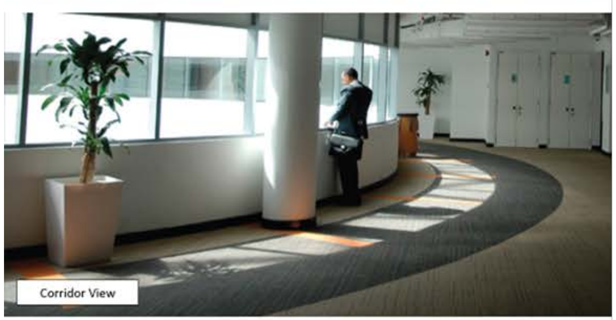
The objective of the scheme, which was implemented by the Ministry of Energy, Communications and Multimedia (now Ministry of Energy, Green Technology and Water), was to develop capacity in the optimisation of energy efficient building design. This was done through training sessions, seminars, specific 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)

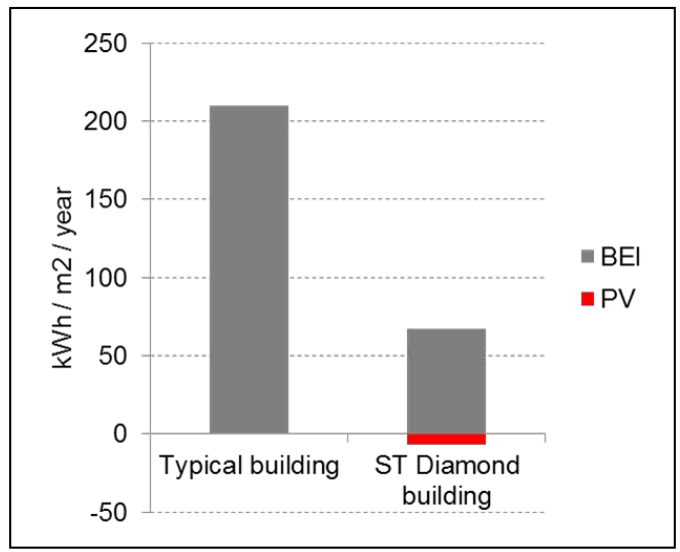


Key Data
Gross Floor Are: 14,000sqm
Year of Completion: 2010
Building Energy Intensity: 69kWh/m2*year
Total Construction Cost: RM60mil
Additional EE Cost: 3.2%
Payback Period: **< 3years**
IRR: 34% (based on 7year Lease Term)

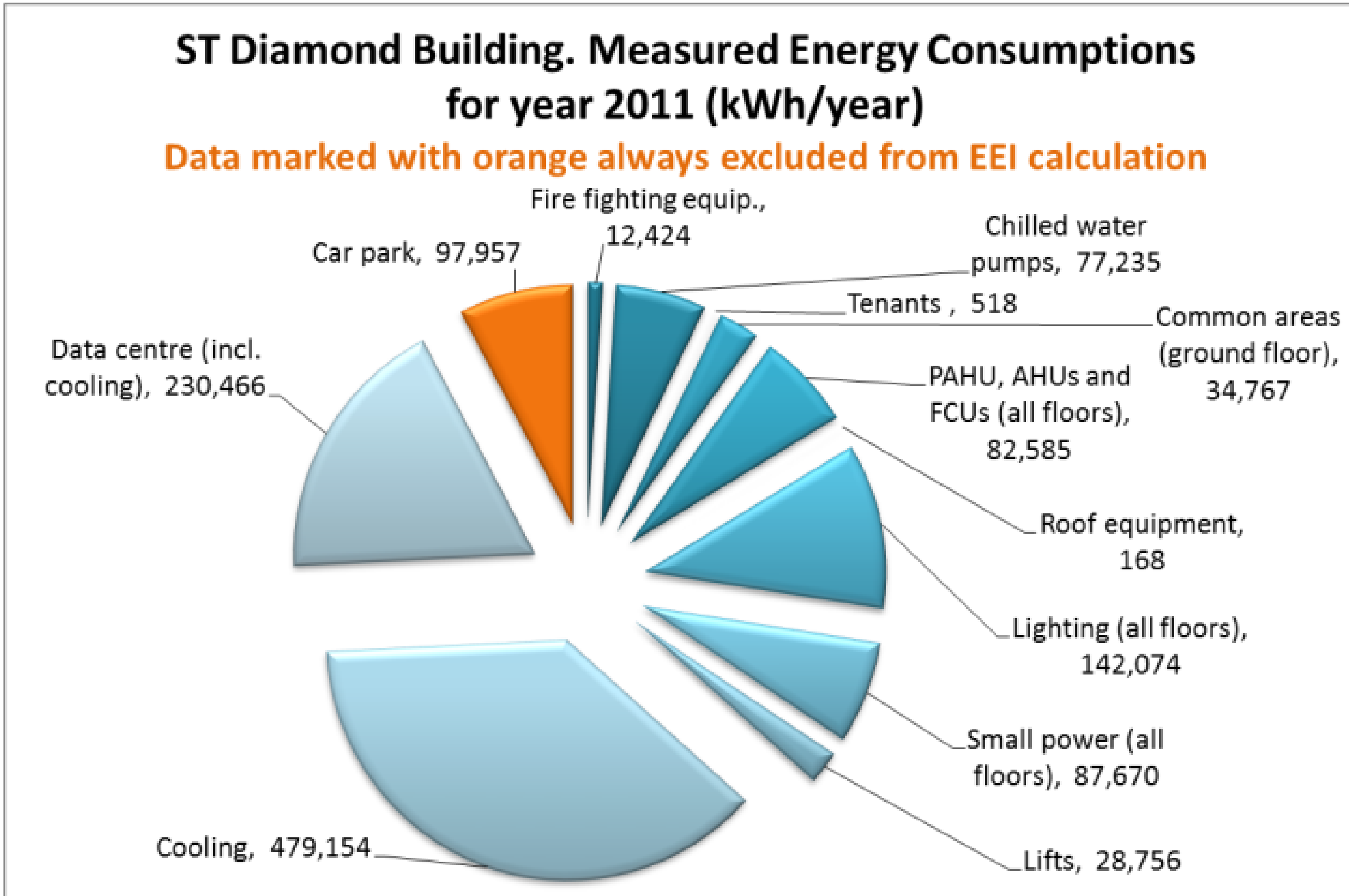
green building index
GBI **Platinum**

BCA GREEN MARK
Green Mark **Platinum**

2012 ASEAN energy award **Winner**



Measured Energy Break-down



Note:
o District cooling has been converted to electricity using SCOP of 3.8

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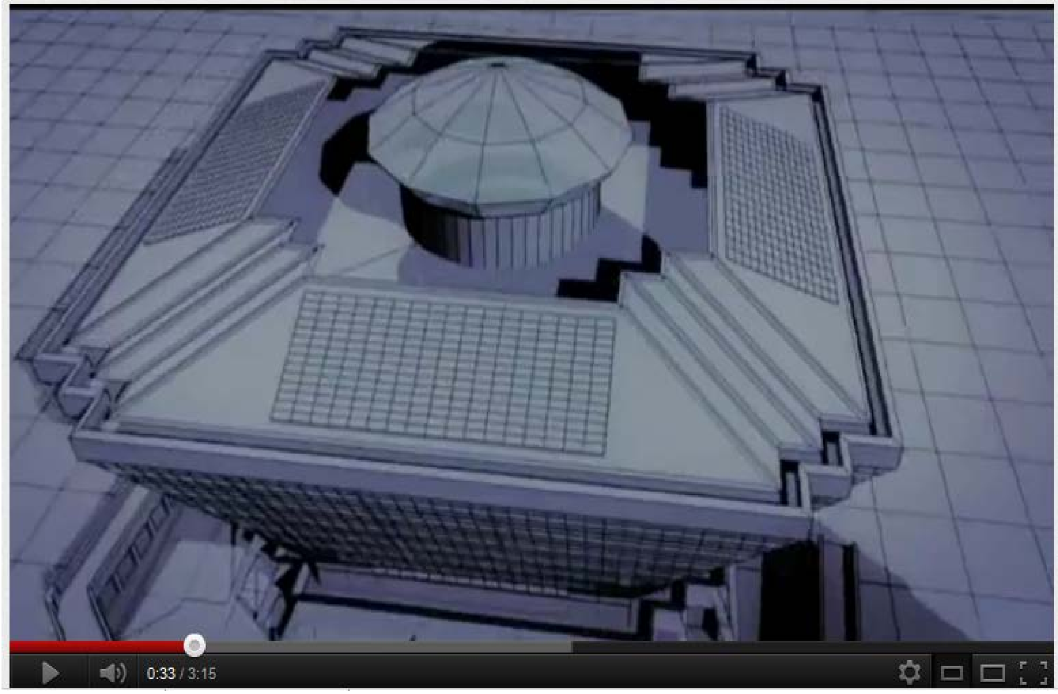
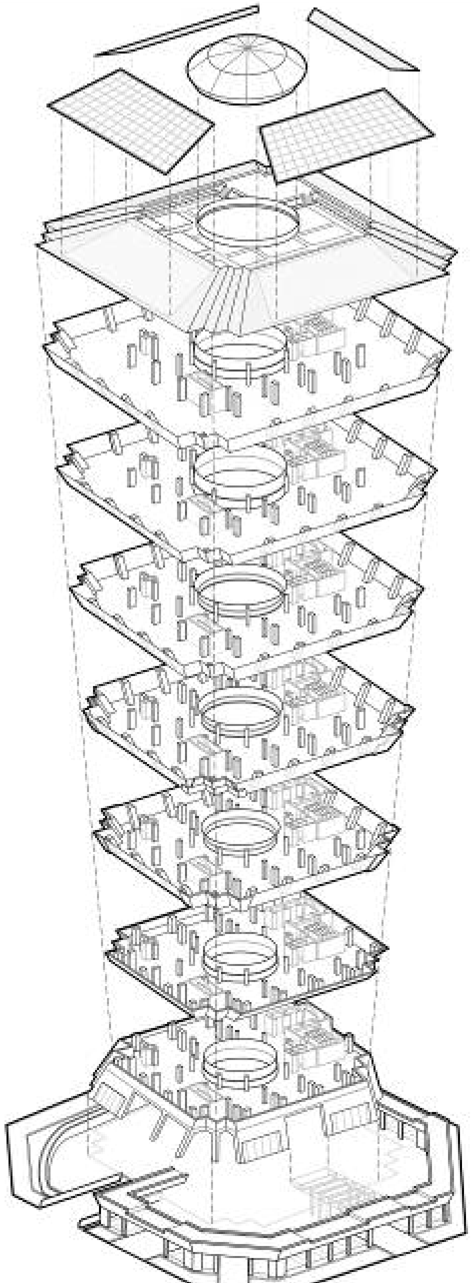
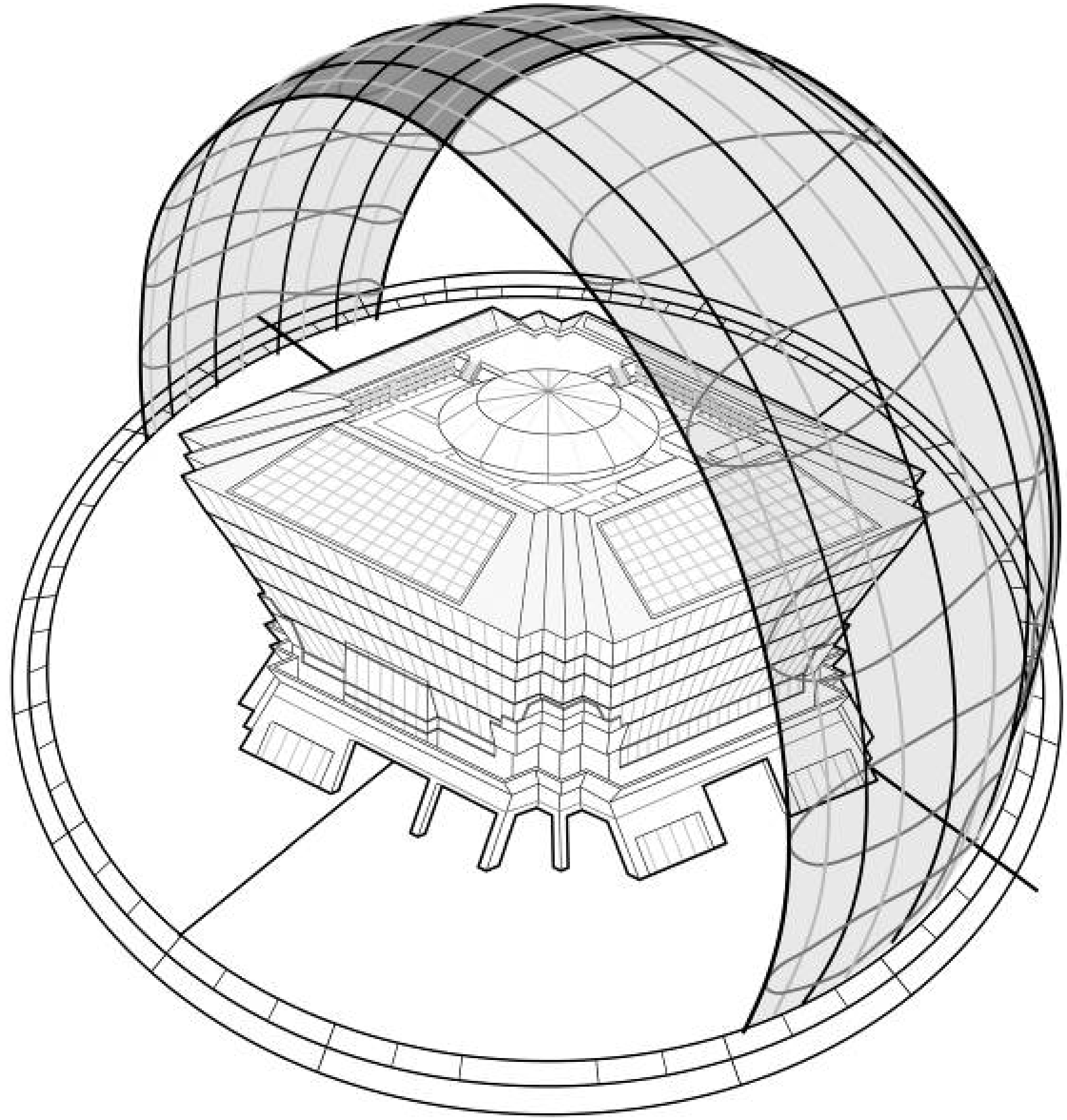
3-minute video



Sustainable Features of ST Diamond Building.
Available at YouTube:
http://www.youtube.com/watch?v=3H_sXCtDayc





Self-shading facades

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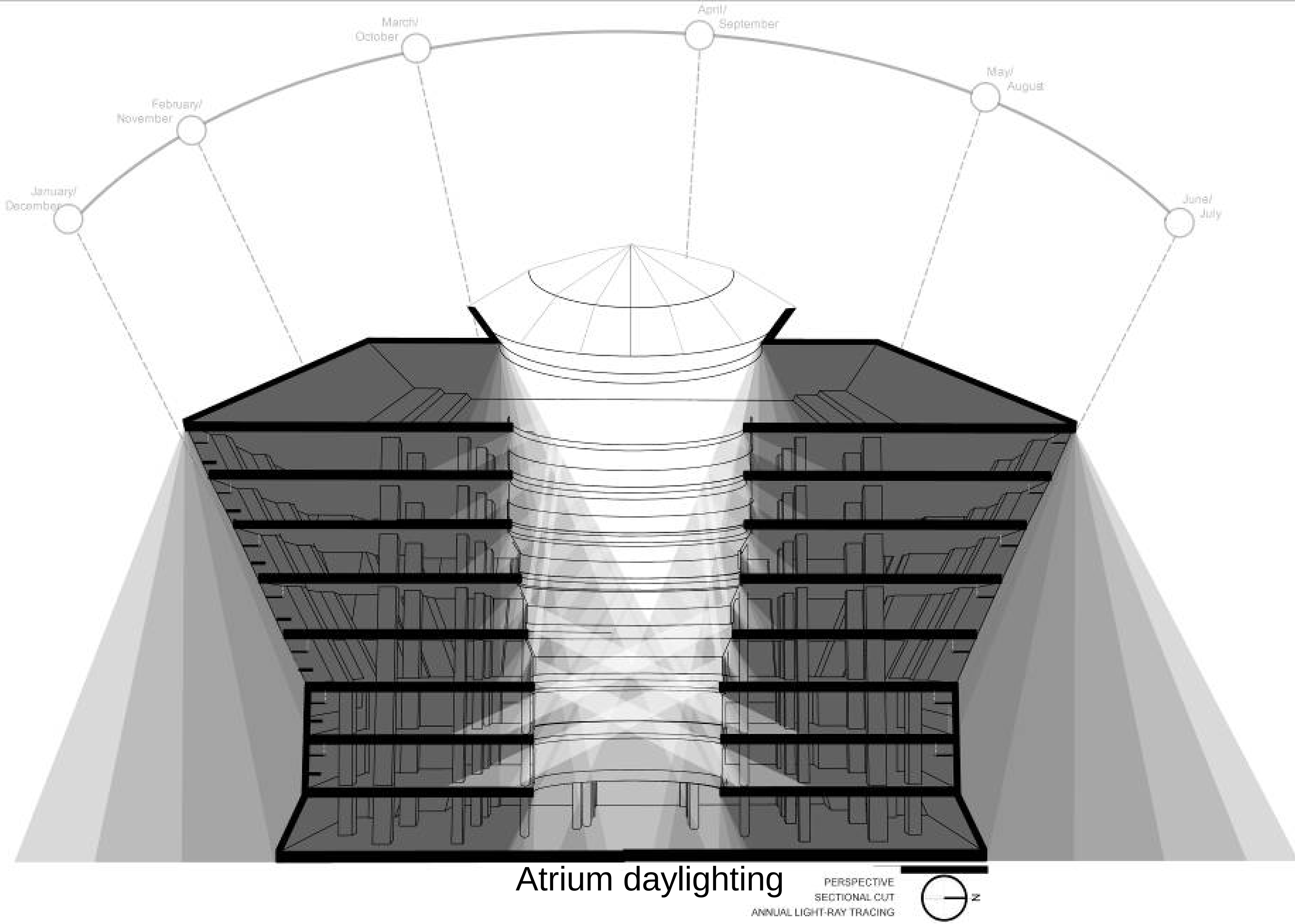
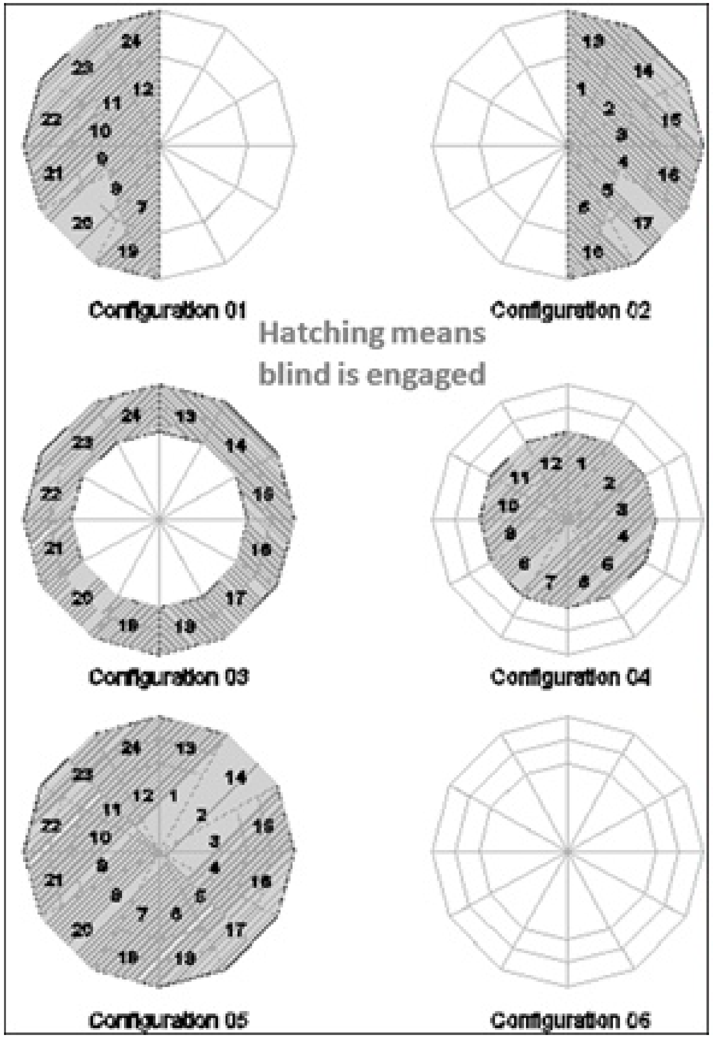
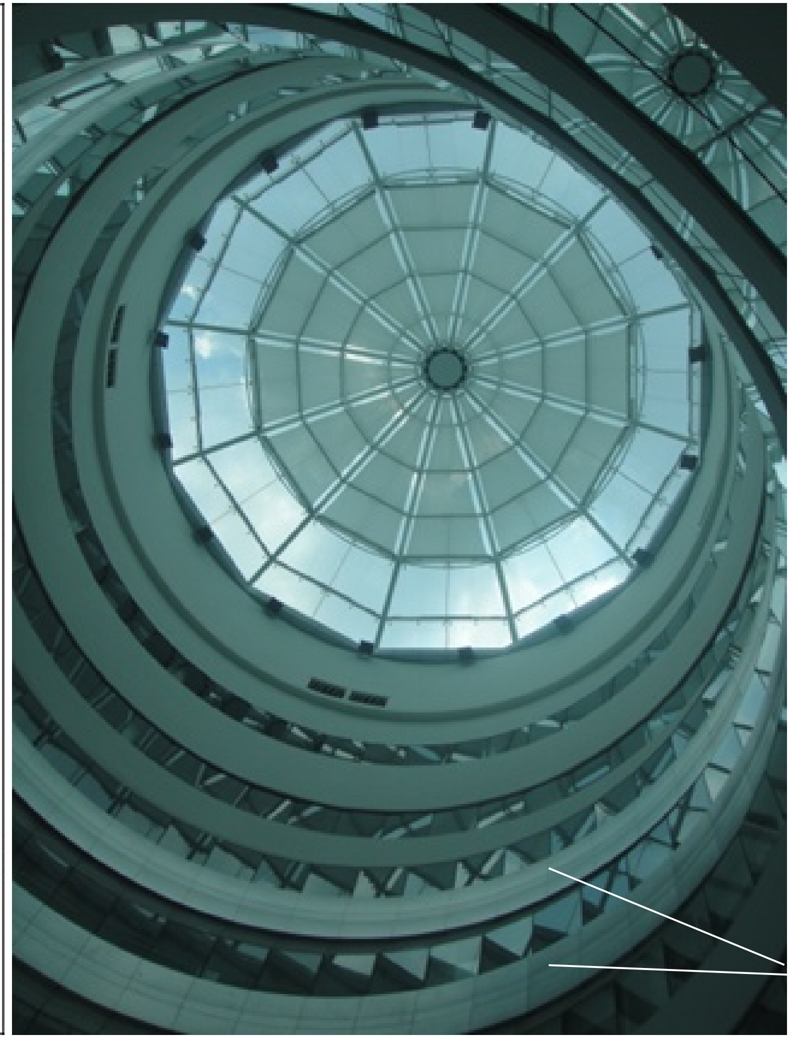
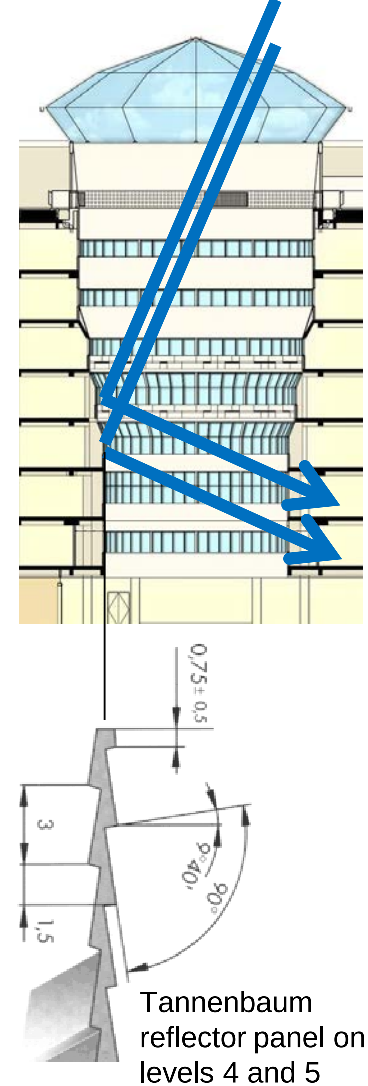


Atrium daylighting



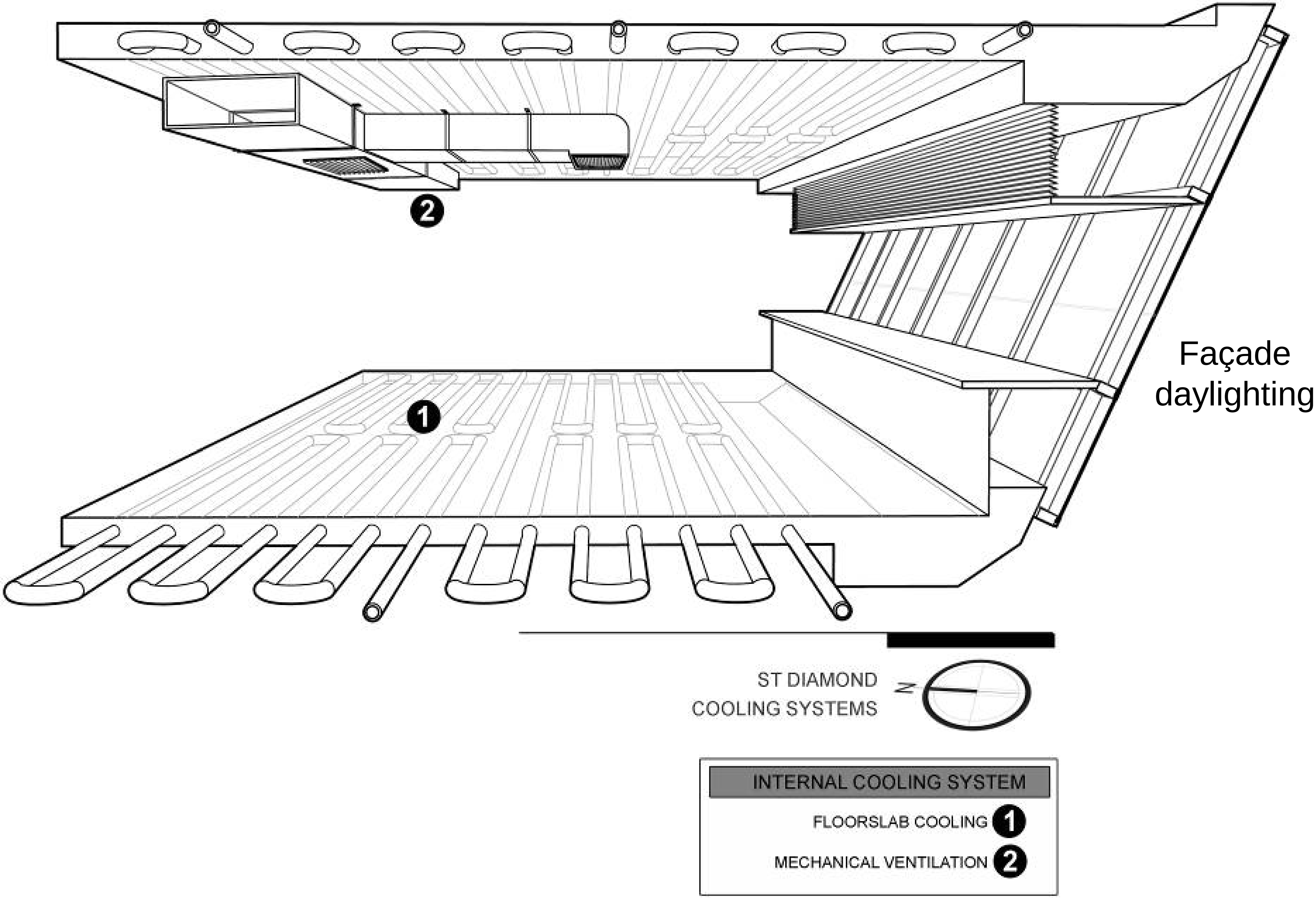




Atrium Daylight Design

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 4th and 5th floor to deflect daylight across the atrium to 1st and 2nd 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.



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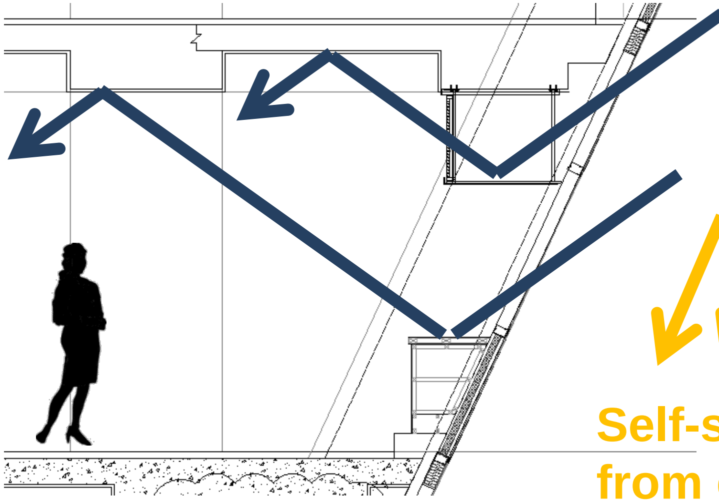
Source: Greening Asia – Emerging Principles for Sustainable Architecture.

FACADE

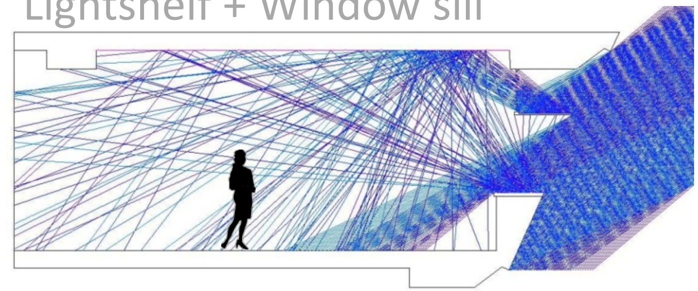


Diffuse light deflected into room by lightshelf and window sill

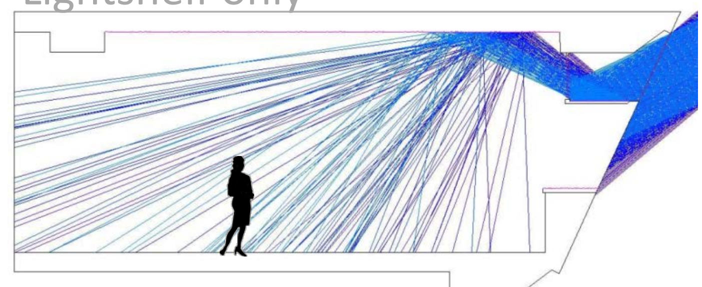
Self-shaded facade from direct sun

LIGHT REFLECTIONS FROM:

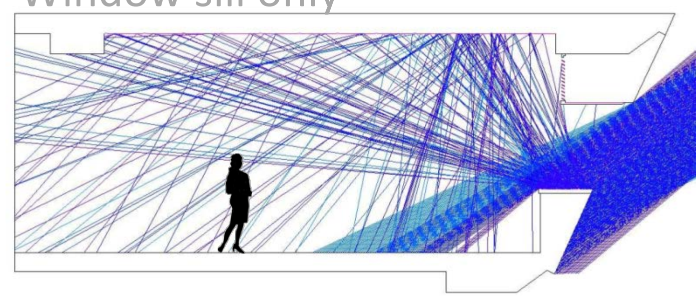
Lightshelf + Window sill



Lightshelf only



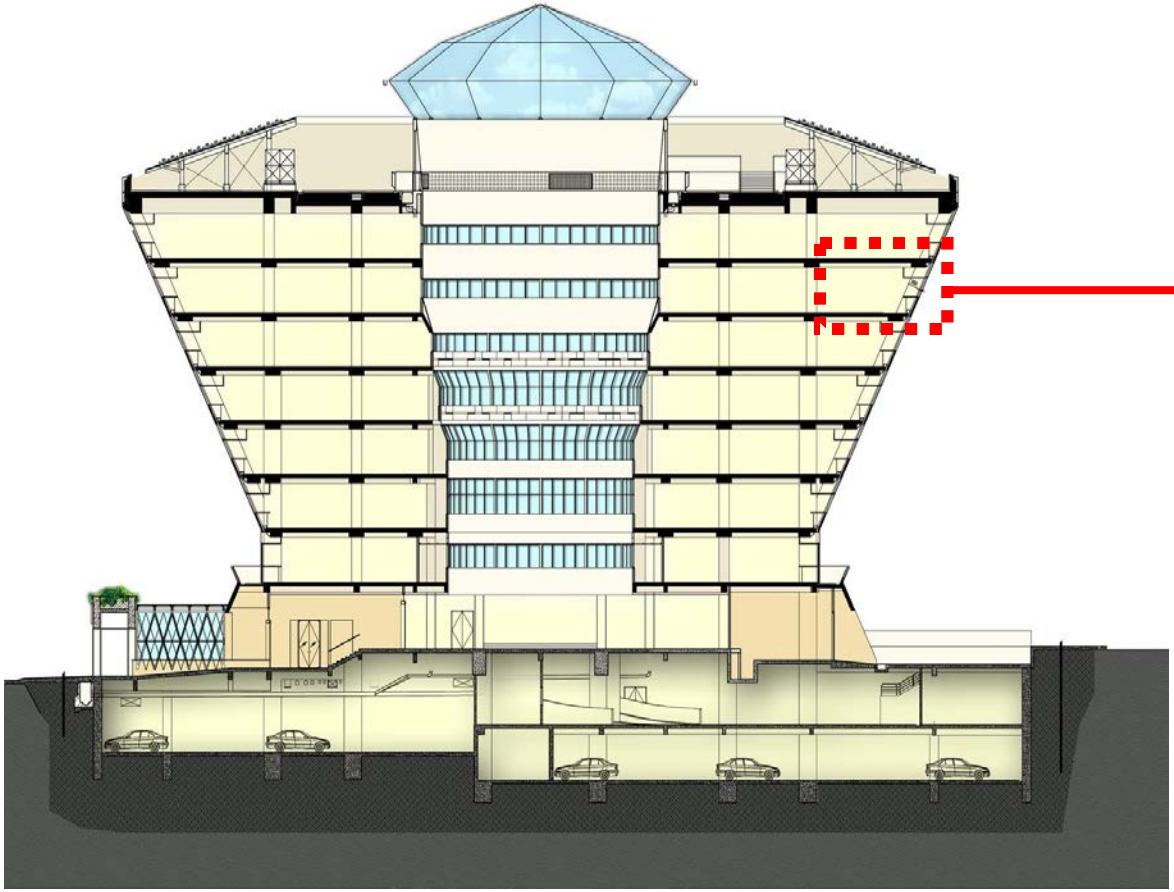
Window sill only



Façade Daylight Design

The building is 50% daylit. 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/m2, but 1-year measurements show consumption of only 0.9 W/m2 showing high reliance on daylighting

Day-Lighting- Office



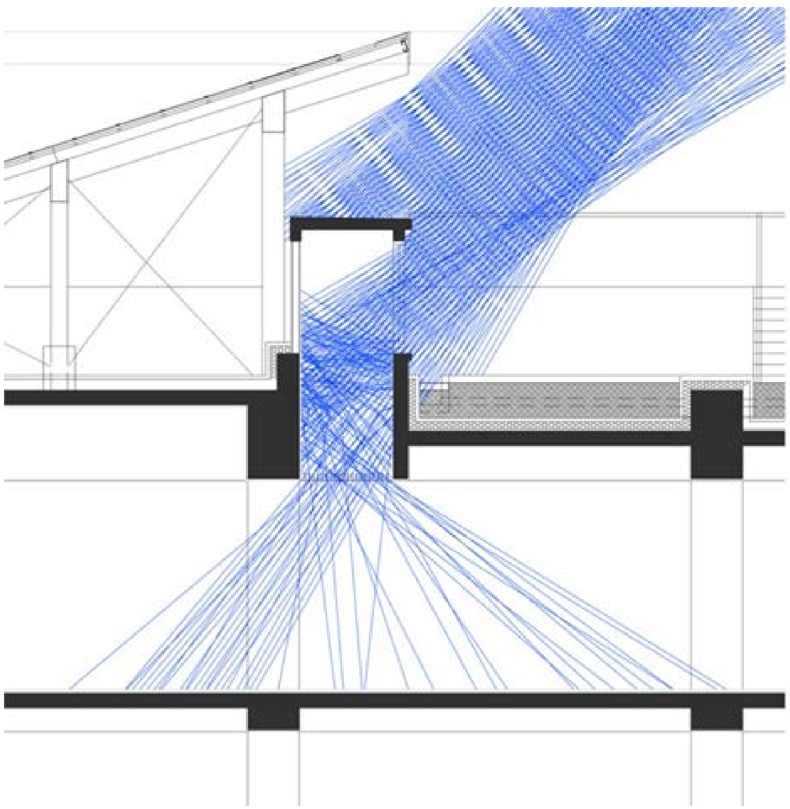
Mirror lightshelf

Fixed blinds for glare control

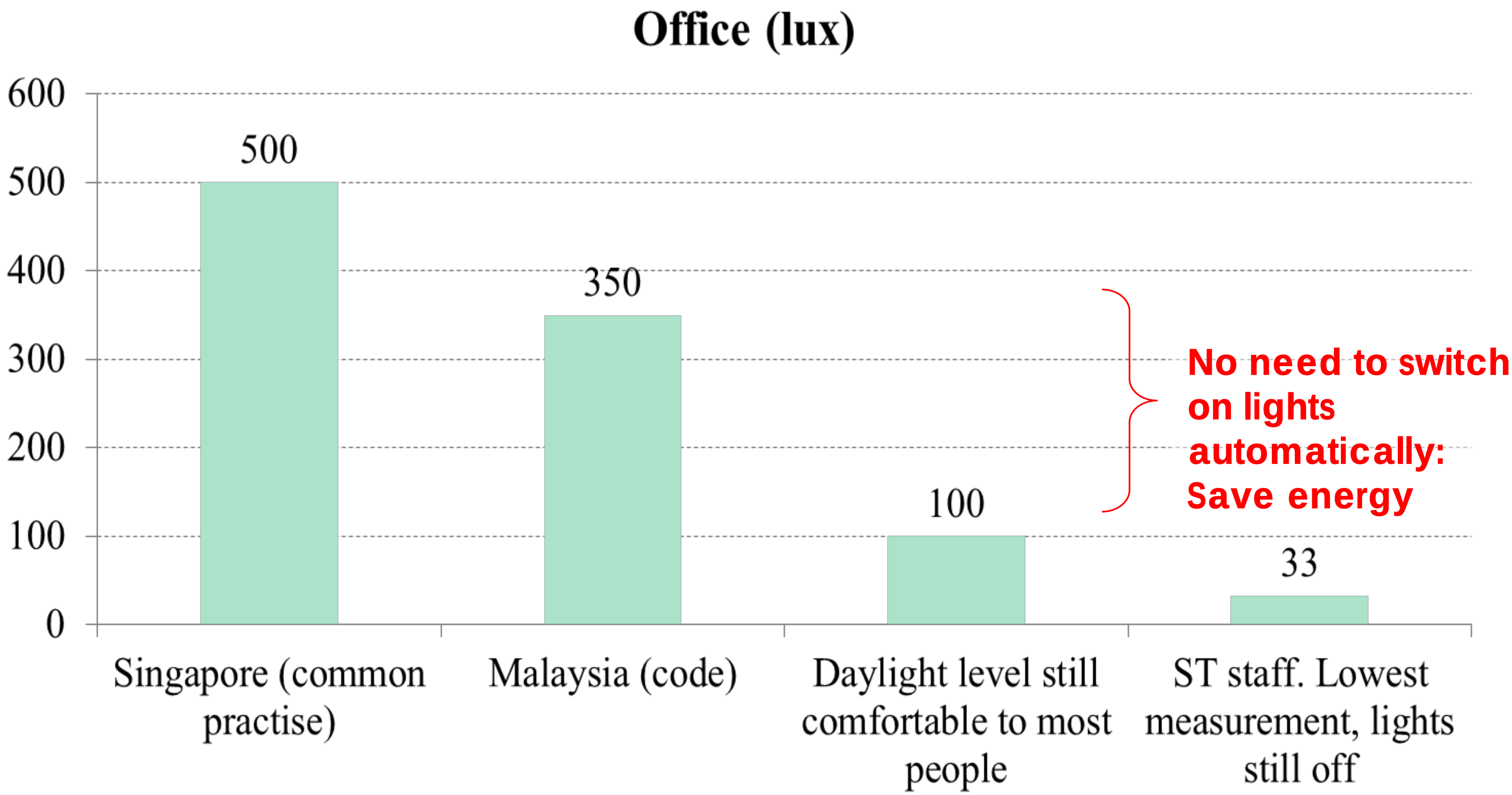
Daylight reflected onto ceiling

Daylight Skylight through Roof

Take in diffuse light only



Lighting Levels



Floor Slab Cooling in ST Diamond Building

Floor slab cooling system embedded in RC slab

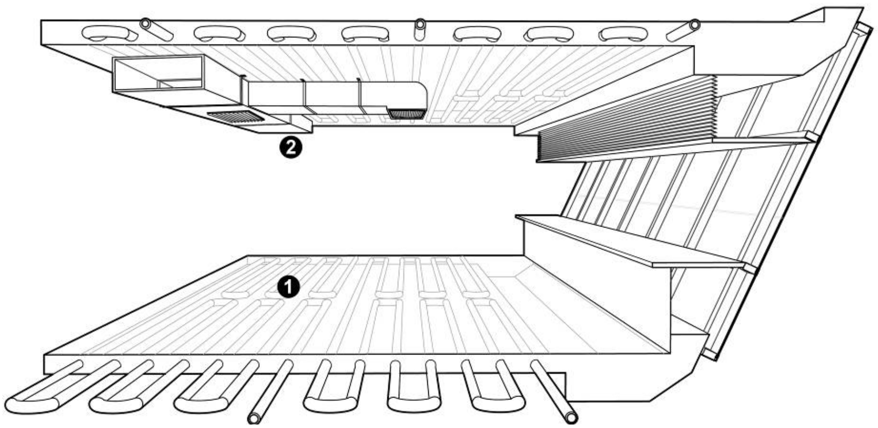


Illustration courtesy of:
Greening Asia – Emerging Principles for Sustainable Architecture.
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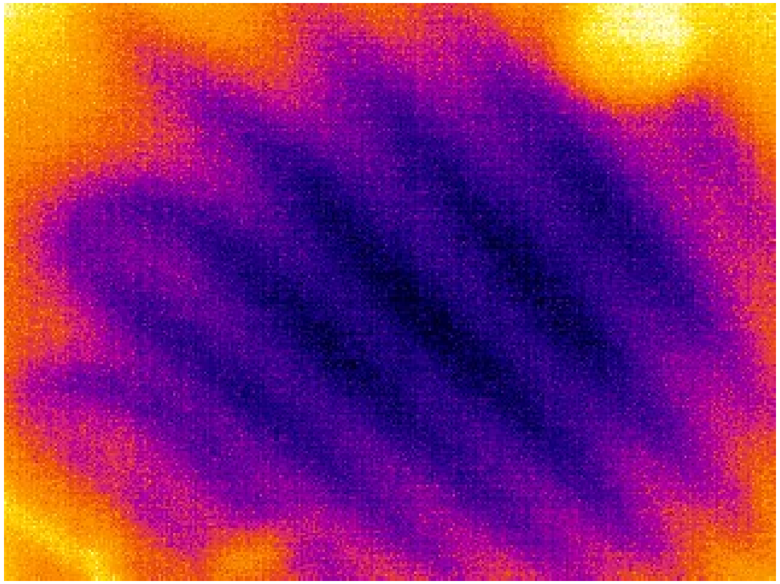
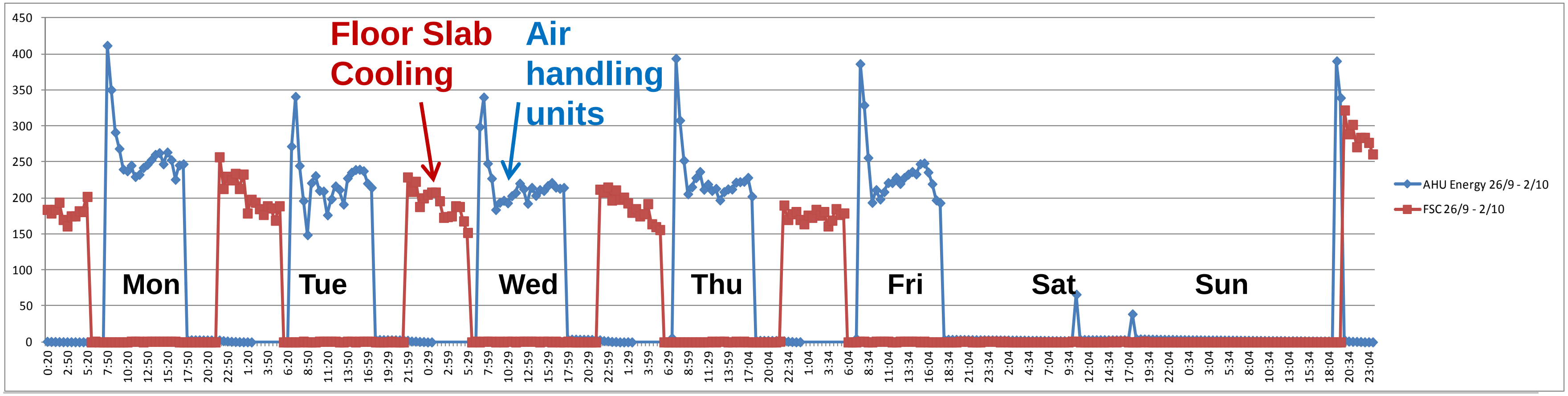


Thermographic image of floor slab cooling in ST Diamond
Picture courtesy of: PS Soong, Pureaire



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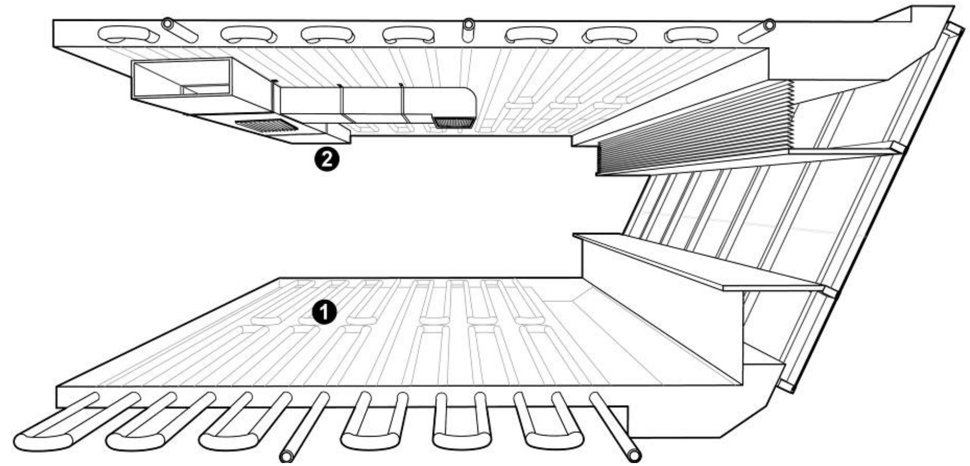
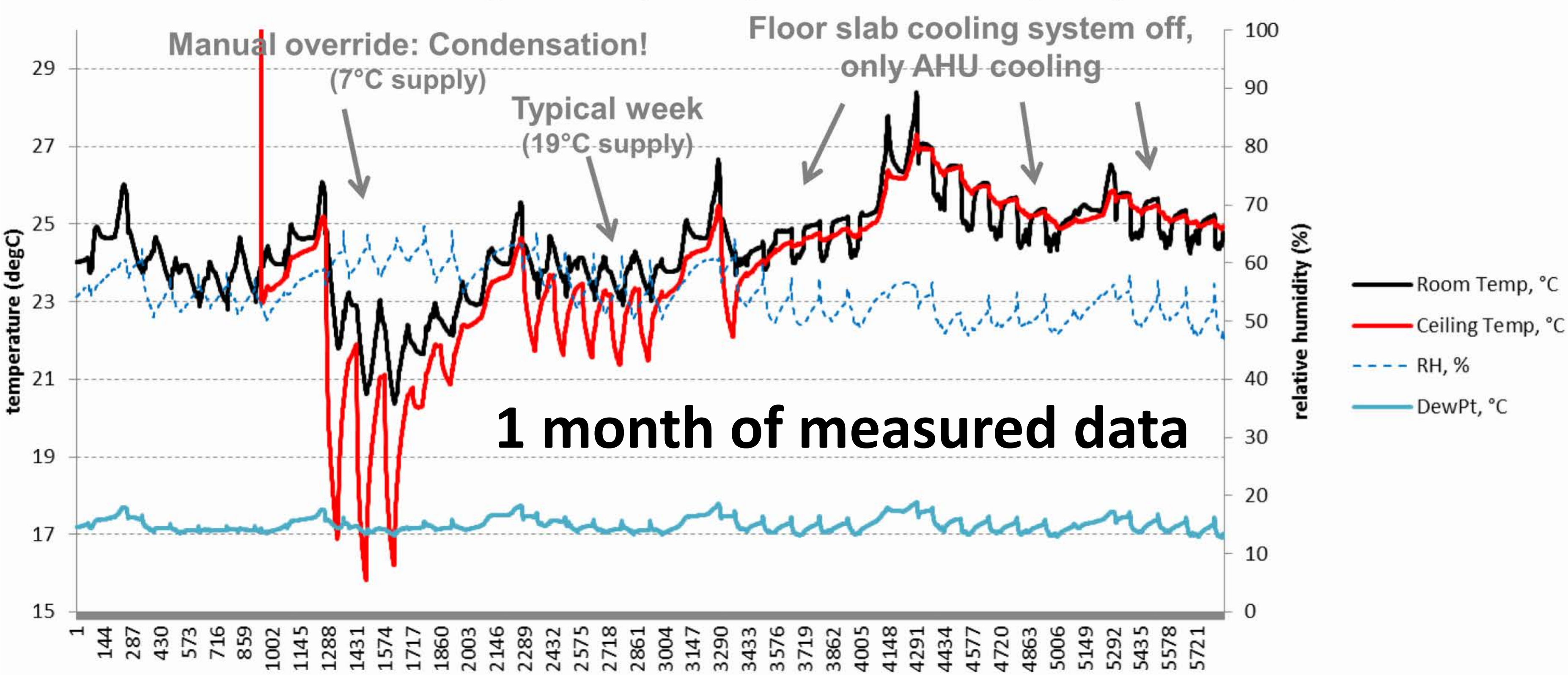
ST Diamond Building: Floor slab cooling measurements



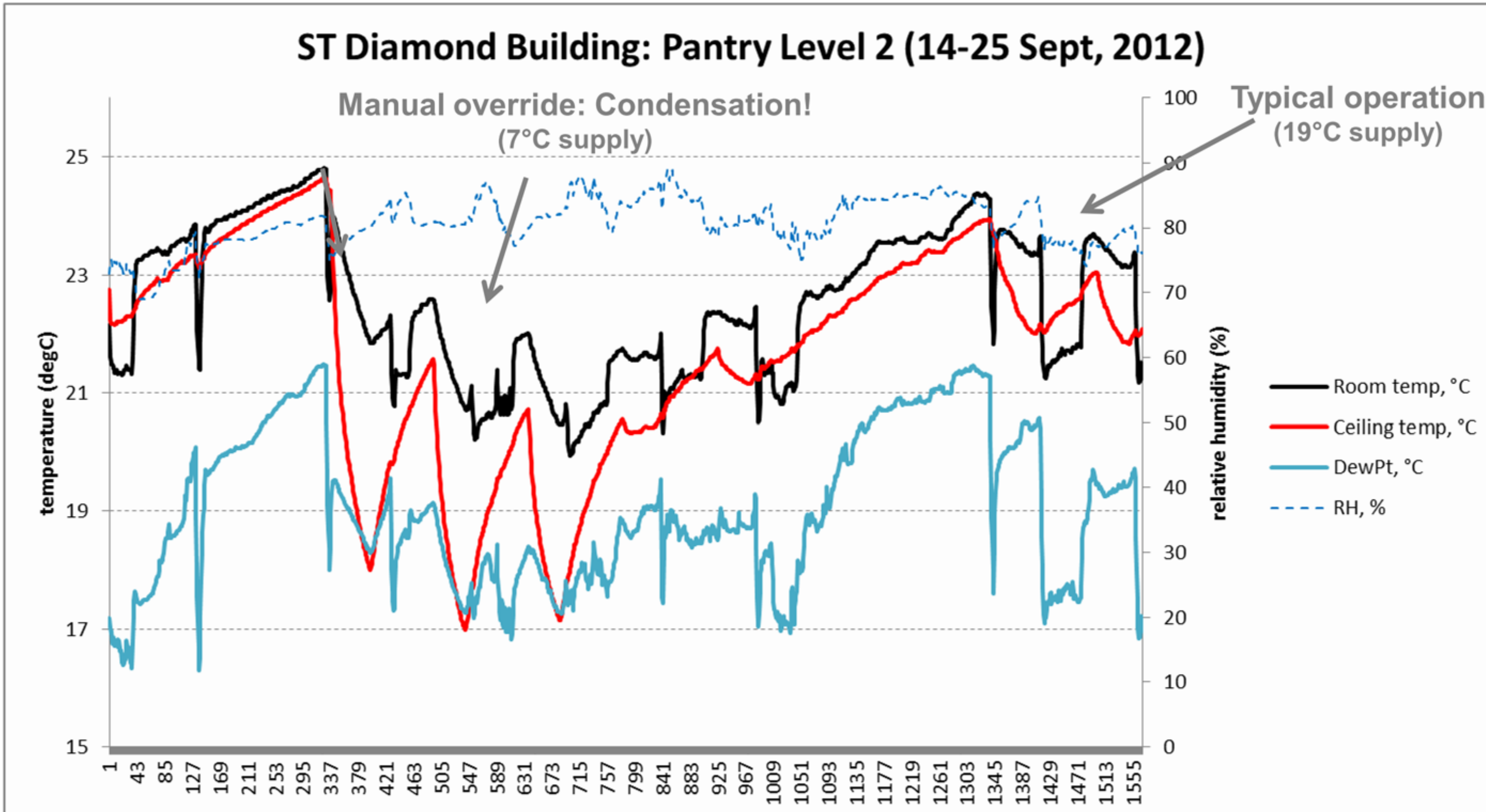
Source: Greening Asia – Emerging Principles for Sustainable Architecture.

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



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Floor Slab Cooling: Measured Correlation

Clear correlation between ceiling surface temperature and Cooling energy