Innovative Energy Concepts for Buildings in Tropical Climates

Case Studies: Office buildings | Residential buildings | New & Retrofits

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Buildings & Energy

Buildings are like a leaky bucket with lots of unnecessary wastages.

ENERGY SUPPLY
(renewable) energy

ENERGY WASTAGE

ENERGY STORAGE
electric cars/batteries/thermal

ENERGY DEMAND

Let’s plug the holes!
50% Energy Savings in Danish Building Stock

MEASURED ENERGY CONSUMPTION
50% reduction in heating per square meter for entire building stock

Let’s do the same in Asia!
Energy Efficient Buildings with Good Payback time
Case studies from the South East Asian countries

Energy Consumption of Green Office Buildings

Measured data for New and Retrofitted Buildings by IEN Consultants

“Energy Efficient Buildings”
Malaysian stamp series

All buildings by IEN Consultants

GEO building
DIAMOND building

Where?
Both located about 25 km south of the capital, Kuala Lumpur, in Bangi and Putrajaya, respectively
Climate Data of Malaysia: Hot & Humid

MONTHLY DIURNAL AVERAGES
ASHRAE Standard 55

LOCATION: KUALA LUMPUR, -, MYS
Latitude/Longitude: 3.12° North, 101.55° East. Time Zone from Greenwich 8
Data Source: IWE Data 486470 WMO Station Number, Elevation 22 m

LEGEND

HOURLY AVERAGES

TEMPERATURE: (degrees C)
- DRY BULB MEAN
- WET BULB MEAN
- DRY BULB (all hours)

COMFORT ZONE
- SUMMER
- WINTER
(At 50% Relative Humidity)

RADIATION: (Wh/sq.m)
- GLOBAL HORIZ
- DIRECT NORMAL
- DIFFUSE

Temperature Range:
- 10 to 40 °C
- Fit to Data

Display Dry Bulb Temp (all hours)
Case study no. 1

Energy Efficient Office case study in Bangi:

GEO BUILDING
(MALAYSIA, 2007)
GEO Building (formerly ZEO) in Malaysia

**Key data:**
- Gross Floor Area: 4,000 m²
- Energy Index: 64 kWh/m²/year (excl. PV)
- Energy Index: 30 kWh/m²/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

![Bar chart showing electricity production and consumption for normal office building, planned GEO building, and actual GEO building.](image)

- **Normal office building**: High electricity consumption with slight production.
- **Planned GEO building**: Moderate production and consumption.
- **Actual GEO building**: Balanced production and consumption, close to zero energy building concept.

Electricity production and consumption are measured in kWh/m²/year.
GEO building: Latest energy measurements

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

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 kWp)

Total area = 766 sq.m
Cost ~ RM 3 million (yr 2005 contract value)

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

TABS (19°C)
PCM tank
PCM flat ice-10
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

- Embedded water pipes
- Cool Floor Slab
- 22°C
- AHU
- 18°C
- Small AHU with heat pipe
- High COP
- Phase Change Material (PCM) Tank
- 10°C
- Chiller
- 21°C
- Cool Dry air 17 – 19 °C
Rainwater Collection and River Roof
(alternate cooling tower)

Sky Radiant Temperature
10 – 20 °C at night

~ 25 °C
~ 95% RH

Radiation
Convection
Evaporation

PV Roof

~ 35 °C

Chiller
Pump
Drain
Rainwater Tank
Toilets, Irrigation

Chiller Condenser (heat rejection)

Gutter
The River Roof of GEO Building
to be operated at night only

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

**Video 2:**
Manifold splashing water onto PV roof

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

Video link:
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
GEO building: Floor Slab Cooling
GEO building: Floor Slab Cooling
Radiant Cooling allows Higher Air Temperature

Predicted Percentage of Dissatisfied (PPD)

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
Thermal Comfort for Concrete Floor Slab Cooling

Slab cooling 10 pm – 8 am

Computer wattage: 30 W (normal)

Thermal comfort zone 22.5 – 25.5 °C

Temperature [°C]

Weekend  Monday - Friday  Weekend

0:00 12:00 0:00 12:00 0:00 12:00 0:00 12:00 0:00 12:00 0:00 12:00

room air temperature  operative room temperature  ceiling surface temperature  floor surface temperature
Efficient High Temperature Cooling

- 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
Almost 100% Daylit Building

Block direct sunlight  |  Reflect diffuse daylight onto ceiling  |  Glare protection

South facade
Almost 100% Daylit Building

Blind encapsulated in double glazing, no maintenance needed. Looks as good as new after seven years and counting....!

Semi-specular tannenbaum reflector in the ceiling. Maintains inward light reflection without causing glare to the occupants. Translucent cubicle walls parallel to the façade ensures daylight passage to table top.
Daylight Measurements

1. Occupants prefer working in daylight

2. Electrical lighting consumption is 25 times lower than the code requirement

Measured lighting consumption during office hours is only 0.56 W/m²
Daylight factor in atrium about 1 – 1.5%

Nice light pattern through PV atrium roof
Green Office case study in Putrajaya:

DIAMOND BUILDING
(MALAYSIA, 2010)
Winner of 2012 ASEAN Energy Award
(ST Diamond Building, Putrajaya, Malaysia)

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
Self-shading facades

DIAMOND BUILDING similar design with vernacular buildings

Result of many SIMULATIONS

Result of many GENERATIONS

Book available free online:
http://um.dk/da/~/media/Malaysia/Documents/Other/Book%20Finalist%20LR.ashx
1/3 Energy Consumption

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

AWARDS:
- 2012 ASEAN energy award Winner
- 2013 ASHRAE Technology Award (2nd place)
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.
Façade daylighting

ST DIAMOND COOLING SYSTEMS

INTERNAL COOLING SYSTEM

1. FLOORSLAB COOLING
2. MECHANICAL VENTILATION

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. Some people worked down to 33 lux without switching on the lighting.
Day-Lighting- Office

- Mirror lightshelf
- Fixed blinds for glare control
- Daylight reflected onto ceiling
Daylight Skylight through Roof
Take in diffuse light only
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

![Thermographic image of floor slab cooling in ST Diamond](image_url)

![Diagram showing kW cooling](diagram_url)
ST Diamond Building: Floor slab cooling measurements

1 month of measured data

Source: Greening Asia – Emerging Principles for Sustainable Architecture.

Copyright: Nirmal Kishnani. 2012. Publisher: FuturArc
3-minute video

Sustainable Features of ST Diamond Building. Available at YouTube:
http://www.youtube.com/watch?v=3H_sXCTDayc
Case study no. 3

Energy Efficient Retrofit case study

EECCHI OFFICE RETROFIT
(JAKARTA, 2011)
53% Measured Energy Savings

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<th>BEFORE</th>
<th>Energy</th>
<th>AFTER</th>
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<td>45 dB</td>
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<table>
<thead>
<tr>
<th>Daylight</th>
<th>View out</th>
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<tbody>
<tr>
<td>No</td>
<td>Yes</td>
</tr>
</tbody>
</table>

**BEFORE**

- Image of a cluttered office with a man working at a desk.

**AFTER**

- Image of a tidy office with people working at desks with better lighting and ventilation.
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

Temperature in Office (°C)

*小时 of the day*
Case study no. 4

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 daylit, even when the blinds are fully engaged.
Case study no. 5

ZERO Energy Bungalow

EARTH BERM HOUSE

(KUALA LUMPUR, 2016)
INNOVATION: Night Sky Cooling

Bungalow 100% natural cooling, no air-conditioning

The roof at night!

What is the coolest place of the building?

To be completed next month!

Similar design by Design Unit Sdn. Bhd.
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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Appendix slides
**Gregers REIMANN**  
Roles: Energy Efficiency Consultant

Gregers is the managing director of IEN Consultants, the pioneering green building consultancy in Malaysia, with offices in Singapore as well as China. He specialises in building designs that have good daylighting, are highly energy efficient and have excellent thermal and visual comfort.

Key project references during his 10 years of working in Asia include the Setia City Mall (first green certified shopping mall in Malaysia), the new IKEA in Kuala Lumpur (ongoing), ST Diamond Building (2012 ASEAN Energy Award winner) and the GEO Building designed to be a zero energy office building. Other green projects include the KLIA2 airport terminal, the KL Eco City, the Pertamina Energy Tower – the first skyscraper designed to be ZERO energy – and energy efficiency building retrofit works incl. daylight retrofitting of the Asian Development Bank in Manila.

Gregers has also been a technical reviewer for the EU Energy-Efficiency Buildings project and is newly appointed Chairman of the “Energy Efficient Buildings” committee under the EU-Malaysian Chambers of Commerce and Industries (EUMCCI).

Gregers regularly contributes to green building articles and frequently guest lectures at universities internationally. He has a keen interest to pursue innovative and integrated design solutions bridging the gap between architects and engineers. Gregers is also ‘walking the talk’ with respect to green living habits, which includes commuting to work by a foldable electric bicycle that combines easily with public transport.
IEN Consultants

3.2 million square meters of green building space

Gregers (MD)  Poul (Founder)
We are a diverse group of individuals

5 different degrees
6 different nationalities
4 LEED AP
8 GBI Facilitators