Net-Zero Energy Building in the Tropics
School of Design and Environment
SDE 4

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Net Zero Energy Building at the School of Design and Environment
### Opening:
January 2019

### Size:
- 6 Floors
- Gross Floor Area: 8514 m²
- Site Area: 5044 m²
- Site Coverage: 52.6%

### Programme:
- Design Studios
- Hot-Desking Areas
- Research Centres
- Laboratories
- Workshops
- Library
- Seminar Rooms
- NUS-CDL Smart Green Home
- Staff Offices
- Social Plaza and Exhibition Area

*Image: Serie Architects*
SDE4 | Longitudinal Section

Image: Serie Architects
SDE4 | SPACE AND FORM

WELLNESS

EDUCATIONAL MODEL

FLEXIBILITY

COMMUNITY

Wrap around circulation: breakout spaces

Central Study Platform: undergraduate studios

Green terraces

Social plaza

Front garden

Image: Serie Architects
How to achieve a NZEB?

Passive Design: Daylight, Solar Protection, Thermal Mass, Natural ventilation, Building envelope insulation...
Efficient System: HVAC, lighting, Plugload
Comfort: Thermal Comfort, Visual Comfort, Acoustic Comfort, IAQ Comfort
SDE4 | ENERGY REDUCTION STRATEGIES

Image: Transsolar Klimaengineering
2000 MWh/year
100% of reference case

Image: Serie Architects
0. Base Case

The standard architectural form with emphasis on enclosure and architecture as object.

1. Enhancing Natural Ventilation

Loosely stacked planes Occupant controlled glazing Shallow composition depth Optimal North, South opening
Orientation

Design

Simulation
SDE4 | SOLAR LOAD

Frit Glass To Improve Natural Lighting

Wall Facade & Flooring Material To Reduce Glare

Shading Device

Diffused Light

Image: Surbana Jurong + Serie M’Ply
Useful Daylight Illuminance: Floor 6

UDI 300-2000lux

UDI >2000lux

UDI <300lux
1. Over-sailing roof

Uniting the programmatic components is an over-sailing roof. This roof covers the entire plot and shades the whole composition.

2. Solar screens

Massive solar shading panels provide shade in the morning and the evening. These screens also complete the architectural form. The roof accommodates an array of PV cells which generate additional electricity for the building. Minimum East, West facing façade East, West ETTV optimized
SDE4 | ENERGY REDUCTION STRATEGIES

System COP for mechanical ventilation and FCU

<table>
<thead>
<tr>
<th>Reference Building</th>
<th>Option Envelope</th>
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<tbody>
<tr>
<td>209</td>
<td>112</td>
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MWh/a
1947
1602

Plug Loads
Light
Auxiliary
Mechanical Ventilation
FCU
Uncertainty

Image: Transsolar Klimaengineering
1500 MWh/year
75% of reference case

Image: Serie Architects
SDE4 | ENERGY REDUCTION STRATEGIES

Image: Transsolar Klimaengineering
1000 MWh/year of reference case

Image: Serie Architects
SDE4 | THERMAL COMFORT

Air temperature
Mean radiant temperature
Air humidity
Air speed
Clothing factor
Physical activity

PPD – Predicted Percentage of Dissatisfied
PMV – Predicted Mean Vote and 7-point thermal sensation scale

PMV ± 0.5 / PPD ≤ 10 %
high comfort
ASHRAE Standard 55-2013
“...Elevated air speed has long been used in practice as a means to off-setting higher temperatures. Updated in 2013, the ASHRAE Standard 55 includes a procedure for evaluating the cooling effect of elevated air speed using the PMV for elevated air speed (PMVeas).

Rethinking Comfort; A Pathway to Low-energy Buildings
Wolfgang Kessling, Martin Engelhardt and Ina Maia,
Futurarc Magazine, Sept-Oct 2015

Image: TRANSSOLAR KLIMAENGINEERING
**SDE4 | MIXED MODE, HYBRID COOLING**

User Controlled Glazing
Air Conditioning... or not
Spaces can be converted to natural ventilation. AC used only when needed

Hybrid Cooling System
Higher indoor temperature set point
Augmented with elevated wind speed

Accounting for various indoor heat source
Human load, equipment load, lighting, infiltration etc.

Accounting occupant usage pattern
Occupancy & equipment schedule.

Image: Surbana Jurong
510 MWh/year
25%
of reference case
SDE4 | HYBRID SYSTEM | MOCK-UP ROOM
What is your current thermal comfort?

- Very Uncomfortable: 0%
- Uncomfortable: 12%
- Slightly uncomfortable: 8%
- Slightly comfortable: 27%
- Comfortable: 32%
- Very comfortable: 8%

What is your acceptance of current air movement?

- Clearly Unacceptable: 0%
- Just Unacceptable: 6%
- Just Acceptable: 49%
- Clearly Acceptable: 20%

What is your acceptance of current humidity?

- Clearly Unacceptable: 1%
- Just Unacceptable: 5%
- Just Acceptable: 43%
- Clearly Acceptable: 26%
THERMAL SENSATION AND ACCEPTABILITY

Thermal Sensation

Thermal Acceptability

Average Relative Humidity 61.3% (± 1.5%)
SDE4 | HYBRID SYSTEM | SUBJECTIVE SURVEY | STUDENTS N=13(M),13(F)
AIR MOVEMENT PREFERENCE AND ACCEPTABILITY

Air Movement Preference

Air Movement Acceptability

Average Relative Humidity 61.3% (+/- 1.5%)
• 14 Staffs participated
  • 8 females, 6 males
• Session of 3 hours
  • 0-60 minutes: Fixed ceiling fan speed (Speed 3 = 0.6 m/s) and temperature setpoint (27°C)
  • 60-120 minutes: Users can control ceiling fan (increase, decrease speed)
  • 120-180 minutes: Users can control fan and change setpoint
• 6 Surveys to be completed
  • 5 min, 20 min, 60 min, 120 min, 150 min and 180 min
What is your acceptance of current thermal environment?

- **No Control**: 64%
- **Users allowed to control Fan Speed**: 83%
- **Users allowed to control Fan Speed + Thermostat**: 100%

Relative Humidity kept constant at 58% (+/- 3%)
• Higher discomfort during first 15-20 minutes
• Comfort and acceptability reaches 80-85% after 1 hour
• Users satisfaction reach 90% at the end of 2\textsuperscript{nd} hour with control of the Fan Speed. 54\% of users increased the fan speed, the remaining decreased the fan speed or kept it at speed 3
• With temperature control, satisfaction reaches 100\% at the end of the experiments.
• All users decided to reduce room temperature (minimum of 26\textdegree C set-point)
• Average Room temperature at the end of the experiment: 26.4\textdegree C
LED Lighting
- >90% of lighting utilises LED
- > 60% in energy savings
- All Light controllable
  - Scenes
  - Dimming

Receptacle Load Control
- Energy consumption meters for each zone
- KNX control over power supply to each zone

Temp. & Air Quality Control
- Regulation via VAV boxes based on sensor feedback
- Further reducing cooling load

Weather Responsiveness
- Energy savings suggestions communicated to occupants based on weather station data

Daylight Utilisation
- Daylighting sensors
- Dedicated perimeter circuit
- Greater energy savings

Vacancy Detection
- Automatically switches off lighting when area is not in use
Passive Design
- Reducing solar heat gain
- Reducing need for AC

Active Design (Systems)
- Efficient ACMV
- Tapping on centralised cooling
- Hybrid System
- Efficient electrical systems

Reducing Usage (Behavior)
- Equipment selection
- Plug load control

Solar PV Panels
- ~1200 panels
- ~510 MWh/annum of energy generated
- 424 installed kWp

Reference building: typical institution with similar occupancy

Image: Transsolar Klimaengineering
1225 PV Panels, Peak Power : 425 kWp
SDE4 | METERING

- **Net Meter**
- **NUS Power Grid**
- **BTU Meter**
- **NUS Chiller Plant**
- **Energy Production**
- **Energy Consumption**

- **West Facade**
- **East Facade**
- **On-site energy sourcing with rooftop photovoltaic panels**

**Building footprint**

**Site boundary**

**Chiller Water Supply**
SDE4 | DESIGN CHANGES

Before

After

Image: Serie Architects