POSITIVE ENERGY LOW-RISE, ZERO ENERGY MID-RISE & SUPER LOW ENERGY HIGH-RISE BUILDINGS FOR THE TROPICS

Dr Gao Chun Ping
Building & Construction Authority
Singapore
<table>
<thead>
<tr>
<th></th>
<th>1960</th>
<th>2016</th>
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</thead>
<tbody>
<tr>
<td>People</td>
<td>1.64 mil</td>
<td>5.61 mil</td>
</tr>
<tr>
<td>Land</td>
<td>580 sq.km</td>
<td>720 sq.km</td>
</tr>
<tr>
<td>GDP per capita</td>
<td>US$ 428</td>
<td>US$ 52,962</td>
</tr>
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BUILDINGS IN HOT AND HUMID CLIMATE

- High solar irradiation (50% more than temperate countries)
- High solar angle (all sides shading)
- High air temperature: 25-32°C
- Small diurnal air temperature range: less than 10°C
- High humidity: >50% and very high at night
- Light winds: 0.5-3 m/s
- Cloudy sky with high diffused light components
- Heavy rainfall (>2000 mm)

source: UTM
Figure 3-5. Diffuse Solar Radiation as Percent of Total for Vertical Surfaces (0800-1800 hours)
Building Energy Consumption for Commercial Buildings

Energy Consumption for Residential Buildings

Source: BCA, HDB, NEA, NUS
GREEN BUILDING MOVEMENT

Target: greening 80% of the building stock by 2030

5 Key Assessment Criteria
1. Energy Efficiency
2. Water Efficiency
3. Environmental Protection
4. Indoor Env. Quality
5. Other Green Features

Public Sector Taking The Lead
Spurring The Private Sector
Developing Green Building Technology

Building Industry Capabilities Through Training
Legislating Minimum Standards
International Profiling & Raising Awareness

New Buildings
Existing Buildings
Building Occupants
Target: greening 80% of the building stock by 2030

>33% of total GFA greened

>3,000 Green Building Projects

>89 Mil m² of total GFA greened
CURRENT ENERGY TRENDS IN SINGAPORE

**Lower energy consumption**

- **Solar PV Energy Factor (kWh/m².yr)**
  - **Base case**
  - **Accelerated Scenario**

- **National projection of PV installation**
  - Cumulative SolarNova PV installation (GWp)

- **Projection of Solar PV energy factor**
  - **Cumulative SolarNova PV installation (GWp)**
  - **2017**, **2020**, **2030**
ZEB@BCA Academy

- More than 30 technologies
- 8 years of Net Zero Energy
- 66% Energy Savings

Source: NUS, NTU
ZEB@BCAA Inspires More ZEB Developments

- BCAA Campus Devt
  - ZEB Plus (Low-rise)
  - ZEB 2.0 (Mid-rise)
  - SLEB (High-rise)

- MOE Schools

- NUS Net Zero Building

- HeartQuarter GUI

- SLA St John Island

- SIT New Campus @ Punggol

- SAS Zero Net Energy Campus

Our Aspiration

Urban ZEB
- High-rise high density
- Singapore is renewable energy disadvantage country
- Solar is more promising but constraint by roof space

Tropical ZEB
- High energy to cool buildings
- High humidity
- Design of natural ventilation in commercial buildings is not a norm
- Lifestyle
PE-ZE-SLEB Technology Roadmap

Feasibility study
- International scan
- Data analysis of >1,200 buildings
- 2 separate modelling exercises
- Validation with measurements

Industry consultation
- 4 industry engagement sessions/workshops
- > 10 interviews with stakeholders
- Surveyed 124 stakeholders

PE-ZE-SLEB Roadmap
- Technologies identified and prioritized
- Recommendation for RD&D
- Recommendation for implementation & adoption

Jul 2016 – Sep 2017
PE-ZE-SLEB Technologies for Tropical Urban Cities

I. Passive Strategies
II. Active Strategies
III. Energy Management
IV. Renewable Energy

Building Automation
- Fault detection and diagnostics (FDD)
- Energy Management System
- Occupancy sensing & demand control
- Weather sensing & system resetting

Smart Control
- Model predictive control
- Machine learning
- IOT integration with BMS
- Personalised control of lighting/ACMV

Plug Load Management
- Smart plug
- Load monitoring and tracking
- Sleep mode optimisation

Roof & Site Optimisation
- Maximising roof and façade spaces
- Site planning for solar utilization

PV Technologies
- Highly efficient module
- Anti-shading design
- Anti-degradation system
- High performance BIPV
- PV integration with greenery
- PV energy management

Positive Energy
Low-rise buildings

Zero Energy
Medium-rise buildings

Super Low Energy
High-rise buildings

I. Passive Strategies
II. Active Strategies
III. Energy Management
IV. Renewable Energy
Desiccant / Membrane / Evaporative Cooling Based ACMV System

- A hybrid system comprising composite desiccant and nano-woven membrane and indirect evaporative cooler (IEC)
- No compressor
- Improved air dehumidification efficiency up to 85%
- 40% energy savings for air-con system
- Prototyped and patented

Source: NUS
Testbed: BCA SkyLab – World’s First High-rise Rotatable Lab for the Tropics

PLUG & PLAY 
fully configurable

+ 

ROTATABLE 
in any orientation

Optimise building designs in

REAL-WORLD TROPICAL CONDITIONS
- Savings in floor to floor height due to reduced air duct size
- Decouple latent & sensible cooling
- Decentralised ventilation
- Low lift chiller

**Latent Cooling**
Dedicated Outdoor Air System (DOAS)

**Sensible Cooling**
Passive chilled beams

**Fresh Air**
Underfloor Air Distribution Network

Gypsum/plaster conduits hide M&E fittings

Design completed on 3for2 implementation at UWCSEA

Source: SEC-FCL
Median value, at benchmarked buildings: 176 kWh/m²/year

90% of buildings above this value: 112 kWh/m²/year

82 kWh/m²/year

Lighting and electrical appliances
Fans and pumps for DVUs and PCBs
Chilled water for DVUs and PCBs

40% more energy efficient than Platinum office Buildings

71 kWh/m²/year

Targeted EUI by end of project
Case Study for Schools

In collaboration with

Stocktaking

Survey & workshop

Data analysis

Measurements

Solar modeling

Energy modeling

AC Energy 122.17 MWh (22%)
Plug Load 216.74 MWh (38%)
Security, External lighting 27.81 MWh (5%)
Space lights 145.47 MWh (26%)
Corridor lighting 16.95 MWh (3%)

Plug Load (MWh)
Space Lights energy (MWh)
Corridor Lighting(MWh)
Common Area Lighting

[Graph showing energy distribution and usage]

[Image of a meeting with three people discussing]

[Diagram of a building with labels Primary School and Secondary School]
Positive energy school status is possible with current available technologies

60% of schools have potential of achieving PES/ZES with cost effective energy efficient measures
MID & HIGH-RISE OFFICE BUILDINGS - 2017

Total Energy Consumption Breakdown

7-Storey Office Building

- BASELINE
- NV CORRIDOR
- HORIZONTAL SHADE
- DCV
- EFFICIENT LIGHTING
- PLUG LOAD MANAGEMENT
- PASSIVE CHILLED BEAM + VAV (28 deg SetPoint)
- HYBRID COOLING (28 deg SetPoint)
- HYBRID COOLING with DCV & Plug load reduction to 5 W/m²

EEI = 45 kWh/m²/yr

20-Storey Office Building

- 2005 BASELINE
- CURRENT DISLOYAL
- HORIZONTAL SHADE
- DCV
- EFFICIENT LIGHTING
- PLUG LOAD MANAGEMENT
- PASSIVE CHILLED BEAM + VAV (28 deg SetPoint)
- PASSIVE CHILLED BEAM + VAV (28 deg SetPoint+Reduced vent regimes)
- PASSIVE CHILLED BEAM + VAV (28 deg SetPoint+Plugs load reduction to 3 W/m²)
- PASSIVE CHILLED BEAM + VAV (28 deg SetPoint+Plugs load reduction to 5 W/m²)
- PASSIVE CHILLED BEAM + VAV (28 deg SetPoint+Plugs load reduction to 5 W/m²)
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- PASSIVE CHILLER...
With technological advancement and cost reduction, PE-ZE-SLEB would be technologically and economically viable for mainstream adoption by 2030.
PE-ZE-SLEB DEFINITION

### Positive Energy
- **Key Characteristics**
  - Highest Energy Efficiency
  - Consumption Includes Plug Load
  - On-site Renewable Energy Preferred

- **Applicability**
  - Low Rise (1-3 storey)
  - School, Camp, IHL
  - RE > EC

- **Energy Efficiency & Renewable Energy**
  - RE : Renewable energy
  - EC : Energy consumption

### Zero Energy
- **Key Characteristics**
  - EEI: < 100 kWh/m².yr
  - EC = RE

- **Applicability**
  - Mid Rise (4-7 storey)
  - School, IHL, Office
  - EEI: < 100 kWh/m².yr

### Super Low Energy
- **Key Characteristics**
  - EEI is 60% less than 2005 building code level (244 kWh/m²/yr)

- **Applicability**
  - High Rise (>=8 storey)
  - Office, Retail, Hotel
  - EEI: < 100 kWh/m².yr

**EEI** is 60% less than 2005 building code level (244 kWh/m²/yr)
POSITIVE RESPONSES FROM THE INDUSTRY

82% of respondents view PE-ZE-SLEB policy is important for national carbon reduction targets

74% of respondents support or strongly support PE-ZE-SLEB policy
Infeasibility of PE/ZE/SLEBs in the tropics and urban setting

Potential conflict with other aspects of building codes & other regulations

Lack of knowledge, awareness and training of the application of technologies

Lack of demonstration and test-bedding opportunities

Lack of cost-effective cutting edge technologies in the market

High perceived cost for PE/ZE/SLEB

Lack of policies/incentives schemes

BUT THERE ARE CHALLENGES TO BE ADDRESSED...

<table>
<thead>
<tr>
<th>Challenge</th>
<th>Percentage</th>
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<tbody>
<tr>
<td>High perceived cost for PE/ZE/SLEB</td>
<td>[VALUE]</td>
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<td>Lack of policies/incentives schemes</td>
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<tr>
<td>Lack of demonstration and test-bedding opportunities</td>
<td>3.65</td>
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<tr>
<td>Lack of cost-effective cutting edge technologies in the market</td>
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<td>Potential conflict with other aspects of building codes &amp; other regulations</td>
<td>3.48</td>
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<td>Infeasibility of PE/ZE/SLEBs in the tropics and urban setting</td>
<td>3.31</td>
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PE-ZE-SLEB: FROM R&D TO ADOPTION

- PE-ZE-SLEB definition
- Technology feasibility & roadmapping
- Research & development plan
- Testbedding & demonstration

- Creating value
- Public sector taking lead
- Incentivising private sector
- Developing industry capability
FROM R&D TO ADOPTION

Research, Development & Demonstration
- PE Possible for schools with today’s technologies
- Achievable for new commercial buildings by 2030
- More RD&D for
  - High temp/hybrid cooling with innovative dehumidification
  - Plug load management, system integration, etc.
- More demonstration and piloting

Deployment & Adoption
- To develop an eco-system to spur adoption
- Starting from schools and low rise office buildings
- Driving PE-ZE-SLEB through Green Building Certification
- Cost-benefit studies for strong business case
- To tackle information & regulatory barriers
GREEN BUILDINGS INNOVATION CLUSTER

- A one-stop integrated RD&D hub to **experiment, exhibit**, and **exchange** knowledge of promising building energy efficient solutions
- **Accelerate adoption** of promising building energy efficient technologies and solutions

$ 52 Mil
FY15-FY20

BCA-Keppel Land Joint Challenge Call

To achieve overall energy savings of at least **20%** better than the best-in-class Green Mark Platinum buildings
Build Green - The Future is Now

Thank you