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<tr>
<td>Author(s)</td>
<td>Hui, SCM</td>
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<tr>
<td>Citation</td>
<td>The Sustainable Building(SB 13) Hong Kong Regional Conference, Hong Kong, China, 12-13 September 2013</td>
</tr>
<tr>
<td>Issued Date</td>
<td>2013</td>
</tr>
<tr>
<td>URL</td>
<td><a href="http://hdl.handle.net/10722/190033">http://hdl.handle.net/10722/190033</a></td>
</tr>
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Assessing carbon footprints of zero carbon buildings

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Introduction

• Low or zero carbon design
  • Achieve sustainability and combat climate change

• Buildings
  • One of the largest sources of carbon dioxide and greenhouse gas (GHG) emissions
  • Building sector presents the most cost effective opportunities for GHG reductions
  • Many countries are developing policies and measures to promote zero or low carbon buildings
Greenhouse gas (GHG) emission trends of Hong Kong 1990-2008

(Source: www.epd.gov.hk)
Greenhouse gas (GHG) emission of Hong Kong 2008

Source: www.epd.gov.hk
Zero Carbon Buildings (ZCB)

- Zero energy building (ZEB) 零能耗建築
  - A building that produces as much energy on-site as it consumes on an annual basis
  - “Net” zero energy building 淨零能耗建築
- In recent years, many researchers and governments investigated the definitions of ZEB and ZCB to develop an internationally agreed and consistent definition
<table>
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<tr>
<th>Terms</th>
<th>Definitions/Meanings</th>
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<tbody>
<tr>
<td>Zero energy building (ZEB) or net zero energy building (NZEB)</td>
<td>A building that produces as much energy on-site as it consumes on an annual basis</td>
</tr>
<tr>
<td>Net zero site energy building (site ZEB)</td>
<td>Amount of energy provided by on-site renewable energy sources is equal to the amount of energy used by the building</td>
</tr>
<tr>
<td>Net off-site zero energy building (off-site ZEB)</td>
<td>Similar to previous one, but consider purchasing of energy off-site from 100% renewable energy sources</td>
</tr>
<tr>
<td>Net zero source/primary energy building (source ZEB)</td>
<td>It produces as much energy as it uses in a year, when accounted for the source. For electricity, only around 35% of the energy used in a fossil fuel power plant is converted to useful electricity and delivered. Site-to-source conversion multipliers are used to calculate a building's total source energy</td>
</tr>
<tr>
<td>Net zero energy cost building (cost ZEB)</td>
<td>The cost of purchasing energy is balanced by income from sales of electricity to the grid of electricity generated on-site</td>
</tr>
<tr>
<td>Net zero energy emissions building, zero carbon building (ZCB), zero emission building</td>
<td>The carbon emissions generated from the on-site or off-site fossil fuel use are balanced by the amount of on-site renewable energy production</td>
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Zero Carbon Buildings (ZCB)

- ZEB is often used in conjunction with ZCB
  - ZEB: reduce the operating energy requirements → zero fossil energy
  - ZCB: use renewable and low-carbon energy sources to offset or balance carbon emissions
- **Balancing** carbon concept for ZCB
  - Two major types of balance:
    - Import/export balance (e.g. for ZCB)
    - Load/generation balance (e.g. for ZEB)
Balancing carbon emissions for zero carbon buildings (ZCB)

**Balancing Carbon**

- Operating energy of building
- Embodied carbon in building materials
- People, “use” and transportation

- On-site renewable and generation
- Off-site renewable, generation and supply
- Other purchased carbon offsets

**Zero “0”**

Balancing carbon emissions for zero carbon buildings (ZCB)
Sources of difference between definitions of ZCB

a. The metric of the balance (e.g. primary energy, final energy, carbon emission)
b. The balancing period (monthly, seasonal, operation year, life cycle)
c. The type of energy use included in the balance (e.g. HVAC, lighting, appliances)
d. The type of energy balance (import/export and load/generation)
e. The accepted renewable energy supply options
f. The connection to the energy infrastructure (grid connected or standalone)
g. Other requirements relating to energy efficiency, the indoor climate and building-grid interaction

(Source: Marszal, et al. (2011))
Zero Carbon Buildings (ZCB)

- Australia has developed a definition for ZCB
  - "A zero carbon building is one that has no net annual Scope 1 and 2 emissions from operation of building incorporated services.
  - Include building envelope, water heater, built-in cooking appliances, fixed lighting, shared infrastructure and installed renewable energy generation
  - ZCB must meet specified standards for energy efficiency and on-site generation
  - Compliance is based on modelling or monitoring of greenhouse gas emissions in kg CO2-e/m²/yr."
Table 2: Variations of ZCB [adapted from ASBEC (2011)]

<table>
<thead>
<tr>
<th>Description</th>
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<tbody>
<tr>
<td>Zero carbon occupied building</td>
<td>Include occupant emissions</td>
</tr>
<tr>
<td>Zero carbon embodied building</td>
<td>Include embodied emissions</td>
</tr>
<tr>
<td>Zero carbon life-cycle building</td>
<td>Include all emission sources in the building life cycle</td>
</tr>
<tr>
<td>Autonomous zero carbon building</td>
<td>No grid connection</td>
</tr>
<tr>
<td>Carbon positive building</td>
<td>Achieves less than zero emissions</td>
</tr>
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</table>
Allowable emission reduction options for zero carbon buildings

1. Energy Efficiency
   - 2a: In building footprint
   - 2b: On land title
   - 2c: Private wire
   - 2d: On-site generation from off-site resources

2. On-site renewable / low carbon energy
   - 3a: Off-site generation
   - 3b: Off-site supply e.g. Green Power

3. Off-site renewable / low carbon energy

- 'Zero carbon' demands a numerical assessment and validation of the building design
- ZCB compliance requires designers to numerically validate the effectiveness of their approaches
Assess Carbon Footprints

- **Carbon** is frequently used as shorthand for either carbon dioxide ($CO_2$) or carbon dioxide equivalents ($CO_2$-e) of greenhouse gases
  - Used as an indicator for environmental impact or sustainability level

- **Carbon footprint**
  - Measure the exclusive direct (on-site, internal), and indirect (off-site, external, embodied, upstream, and downstream) $CO_2$ emissions of an activity, or over the life cycle of a product, measured in kg
Urban cities and their ecological footprints

Human needs and development

Supply  Waste

Supporting ecosystems and resource base
Carbon footprint of a building and its components

- Materials manufacturing
- Materials transport
- Demolition wastes transport
- Demolition wastes treatment
- Building construction
- Building operation
- Building renovation
- De-construction
- Electricity consumption
- On-site fuel consumption
- On-site waste water treatment
- On-site solid wastes treatment
- Industrial processes housed in the building
Assess Carbon Footprints

- International standards for carbon footprint calculation and analysis
  - ISO 14040: Life Cycle Assessment - Principles and Framework
  - BSI: PAS 2050 - Specification for the Assessment of Life-Cycle GHG Emissions of Goods/Services
  - WRI/WBCSD: Greenhouse Gas Protocol
  - IPCC: 2006 Guidelines for National Greenhouse Gas Inventories
Cradle-to-grave is the full Life Cycle Assessment from resource extraction ('cradle') to use phase and disposal phase ('grave').
Assess Carbon Footprints

- HK’s carbon audit guidelines for buildings to report on greenhouse gas emissions focus on:
  - Physical boundaries (site boundaries of building)
  - Operational boundaries (to identify and classify the activities to determine the scope)
    - Scope 1 – direct emissions and removals
    - Scope 2 – energy indirect emissions
    - Scope 3 – other indirect emissions
  - Reporting period (usually one year)
  - Collecting data and information to quantify the greenhouse gas performance
Scope of greenhouse gas (GHG) emissions

(Source: UNEP Sustainable Buildings and Climate Initiative, www.unepsbci.org)
<table>
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<th><strong>Strictly zero carbon</strong></th>
<th>No carbon is emitted within Scopes 1 and 2; neither balancing nor offsets are allowed.</th>
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<tbody>
<tr>
<td><strong>Net zero carbon</strong></td>
<td>All carbon emissions within emissions Scope 1 are eliminated, and emissions within Scope 2 are balanced through export of low or zero carbon goods, internal or external sequestration, or import substitution of Scope 3 emissions.</td>
</tr>
<tr>
<td><strong>Carbon neutral</strong></td>
<td>Any and all emissions for which the building is responsible under Scopes 1 and 2 can be managed through the purchase of offsets from third parties that lie outside the building’s boundaries.</td>
</tr>
<tr>
<td><strong>Low carbon</strong></td>
<td>Emissions under Scopes 1, 2 and 3 are reduced compared to a baseline. The reduction level is often not clearly specified.</td>
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Discussions

- Suitable candidates of ZCB
  - Medium- to high-rise buildings and high operating loads are quite difficult
  - Low-rise residential buildings is more feasible
- Green building sustainability assessments
  - Current assessment schemes (e.g. BEAM Plus, BREEAM and LEED) focus primarily on operational carbon
  - Use carbon footprints to measure sustainability
Discussions

• Carbon footprint is an effective *carbon accounting method* for facilitating GHG trade-offs and optimisation in buildings
  • Implement life cycle thinking into building planning and design
• Composite indicators including environmental, social, and economic footprints can also be developed
Table 4: Design strategies for ZCB

- At the outset, the building project should take into account building energy efficiency and use of renewable energy
- Select the appropriate building site; allow opportunity to apply renewable energy and to reduce transportation and food production needs
- Optimise passive design strategies to protect the natural and comfortable environment in order to reduce energy demand
- Conserve water and reduce the demand for hot water
- Appropriately select materials in order to reduce the environmental impacts
- Reduce energy use in all aspects of the building operation
- Consider building energy efficiency first before introducing renewable energy offsets
Hong Kong Situation

• Urban density
  • The land and space available for housing the population are very limited
  • HK has highly efficient mass transit and public transportation systems

• Comprehensive urban planning and efficient high-performance building design are needed

• Integrate sustainable transportation strategy, urban form and typology
Hong Kong Situation

- Community sustainability
  - High population densities and compact buildings
    - Can provide opportunities for using larger scale community based energy systems and cost-effective energy and utility supply arrangements
    - District cooling system, waste-to-energy recovery approach, centralised solar thermal or other renewable energy systems, and community based greening and water recycling programmes
  - A ‘zero carbon’ community
Conclusions

• ZCB/ZEB will lead the transition into low-carbon societies
• A clear ZCB definition and effective assessment methods are urgently needed
• Use carbon footprints as indicators to measure sustainability and for assessing ZCB
  • More work is needed to develop reliable data and information for footprint or sustainability assessment
THANK YOU

謝謝

我完全自給自足

Zero carbon
Zero energy
Zero waste
Zero-carbon transport
Zero-carbon energy
Zero-carbon home
Zero-carbon city