Basics of High Performance Building Design

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• High-performance green building
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What is high performance building?

High performance building

- High performance buildings (HPB):
  - Are safe, comfortable and efficient
  - Help owners/occupants achieve business missions
  - Operate reliably with minimum unscheduled downtime and fast recovery
  - Enhance organization and occupant performance, retain/increase value
  - Maintain performance within acceptable tolerances throughout their lifespan

(* See also: High Performing Buildings Magazine [http://www.hpbmagazine.org] *)
High performance building

- Many issues are involved; not easy to define
  - A building that integrates and optimizes all major high-performance building attributes, including
    - Energy efficiency,
    - Durability,
    - Life-cycle performance, and
    - Occupant productivity.

(* Source: http://www.nibs.org/?page=hpbc *)
Index of Building (Houses) Performance (Japan)

- **Structure strength**
- **Daylight, ventilation**
- **Fire resistance**
- **Energy efficiency**
- **Sound insulation**
- **Durability**
- **Design for the aged**
High performance building

• Building performance issues
  • Functionality
  • Serviceability
  • Building-occupant comfort

• Trends
  • Use performance as the major criteria for building design (*performance-based*)
  • The need to study, measure, and predict the level of building performance (*to quantify*)
High performance green building

(Image source: http://nems.nih.gov/)
High-perform. green building

- The terms “high performance”, “green”, and “sustainable” are often used interchangeably
  - Focus on ecological, environmental, social, and economic issues of a building
  - Concern over the impacts of built environment on natural environment, economy, health, and productivity
- Encouraged by green building assessment and ratings (e.g. LEED, BREEAM, BEAM Plus)
High-perform. green building

- **Green Building (GB)**
  - A *loosely* defined collection of land-use, building design, and construction strategies that reduces the environmental impacts

- **Sustainable Building [HKGBC]**
  - Provides a quality living amenity for its users and neighbours in terms of social, environmental and economic aspects while minimising negative environmental impact at the local, regional and global levels throughout its full life cycle
High-perform. green building

- It involves a holistic approach to the design and operation of buildings. It considers:
  - 1) Economy and efficiency of resources
  - 2) Life cycle design
  - 3) Human well-being

- Main objectives
  - Be environmentally friendly and responsible
  - Improve the quality of built environment
Resource and material flow in the building ecosystem

**Upstream**
- Bldg. materials
- Energy/fuels
- Fresh water
- Consumer goods
- Solar radiation
- Wind
- Rain

**Downstream**
- Used materials
- Combustion by-product
- Waste water
- Garbage
- Heat
- Polluted air
- Ground water
Cradle-to-grave is the full Life Cycle Assessment from resource extraction ('cradle') to use phase and disposal phase ('grave').

Sustainable design requires life cycle thinking.
Environmental Criteria & Factors

- site selection
- urban design
- landscape planning

- CO₂ emissions
- acid rain
- ozone depletion
- rainforest depletion

- energy performance
- renewable energy
- water conservation

- material selection
- recycling of materials
- waste management
- disposal & reuse

- environmental policy
- transport strategy
- building maintenance

- air quality
- thermal comfort
- lighting & noise
- hazardous materials

- site selection
- urban design
- landscape planning
High-perform. green building

• Green buildings are
  • Energy and resource efficient
  • Non-wasteful and non-polluting
    • Sustainable design that helps minimise broad environmental impacts (e.g. ozone depletion)
  • Highly flexible and adaptable for long-term functionality
  • Easy to operate and maintain (lower running costs)
  • Supportive of the productivity and well-being of the occupants
Potential benefits

Potential benefits

- Green buildings pay
  - Direct benefits (e.g. energy/cost savings)
  - Indirect benefits (e.g. healthier conditions)
  - Wider global benefits (e.g. reduced CO$_2$ emission)
- Life-cycle benefits
  - Total economic and environmental performance
  - Long-term “sustainability”
Potential benefits

- Benefits of green/sustainable buildings:
  - They are designed to be cost effective
  - They boost employee productivity
  - They enhance health and well-being
  - They reduce liability
  - They create value for tenants
  - They increase property value
  - They benefit the community
  - They achieve more predictable results
Potential benefits

- Green building incentives, such as, in Hong Kong, exemptions of gross floor area (GFA) and site coverage (SC)
  - Joint Practice Notes No. 1 & 2: Green and Innovative Buildings
  - Practice Note APP-151, Building Design to Foster a Quality and Sustainable Built Environment
  - Practice Note APP-152, Sustainable Building Design Guidelines
Potential benefits

- What happens when Green becomes code?
- Overseas experience: mandatory codes
Design strategies

- Energy
- Materials
- Water
- Site
- Indoor Air Quality
Building life cycle and sustainable construction

**Energy issues**
- Efficiency
- Renewable

**Water conservation**
- Reduce
- Recycle

**Pre-Building Phase**
- Design

**Designers**

**Contractors**

**Users**

**Construction**

**Operation & maintenance**

**Demolition/Disposal**

**Materials and systems**
- Reduce
- Select

**Waste management**
- Recycle
- Reuse

**Building Phase**

**Post-Building Phase**
Design strategies

• Major aspects:
  • Urban and site design
  • Energy efficiency
  • Renewable energy
  • Building materials
  • Water issues
  • Indoor environment
  • Integrated building design

* See also: http://ibse.hk/GB_design_strategies.pdf
Urban and site design

• Sustainable urban design should consider:
  • Spatial form
  • Movement
  • Design & development
  • Energy
  • Ecology
  • Environmental management

• Goal: to create livable cities
Site analysis and understanding of the environmental factors is important.
Energy efficiency

• For new buildings
  • Designing the building
    • Design strategy
    • Control strategies
    • Commissioning

• For existing buildings
  • Operating and upgrading the building
    • Building management
    • Refurbishment/renovation/retrofitting
    • Maintenance and monitoring
Good design practices

- Integrated & total energy approach
- Efficient systems
- Efficient operation
- User education & awareness
- Good housekeeping
Energy Efficiency

- **High-performance HVAC**
  - HVAC usually accounts for a large portion of building energy use
  - Large energy saving potential
    - Use of high performance HVAC equipment
      - Such as Next Gen chiller & unitary
    - Integrated building design with extended comfort zone
    - Consider and improve part-load performance
    - Proper commissioning and controls (e.g. on humidity)
    - Effective operations and maintenance (O&M)

(* See also: [https://www.wbdg.org/resources/hvac.php](https://www.wbdg.org/resources/hvac.php) )
Renewable energy

- Energy that occurs naturally and repeatedly on earth and can be harnessed for human benefit, e.g. solar, wind and biomass

- Common applications
  - Solar hot water
  - Solar photovoltaic
  - Wind energy
  - Geothermal
  - Small hydros
Renewable energy

- Renewables for buildings
  - Solar energy
    - Passive (low energy architecture)
    - Active (solar thermal)
    - Photovoltaics
  - Other renewables
    - Wind (using buildings to harvest wind energy)
    - Geothermal (e.g. hot springs)
    - Small hydros (e.g. water wheels)
  - Hybrid systems (e.g. PV + wind + diesel)
Integration of solar energy systems in buildings

- Passive solar (e.g. skylight)
- Active solar (solar hot water)
- Photovoltaics
Building materials

• Environmental impact of building materials
  • Through consumption of resources
  • Through production of resources (by-products, wastes, pollution, recyclables)

• Objectives
  • Make informed environmental choices about building materials and systems
  • Careful design & understanding about materials
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<td>Waste Reduction (WR)</td>
<td>Energy Efficiency (EE)</td>
<td>Biodegradable (B)</td>
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<td>Pollution Prevention (P2)</td>
<td>Water Treatment &amp; Conservation (WTC)</td>
<td>Recyclable (R)</td>
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<td>Recycled (RC)</td>
<td>Nontoxic (NT)</td>
<td>Reusable (RU)</td>
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<td>Embodied Energy Reduction (EER)</td>
<td>Renewable Energy Source (RES)</td>
<td>Others (O)</td>
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<tr>
<td>Natural Materials (NM)</td>
<td>Longer Life (LL)</td>
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</tbody>
</table>
Building materials

- Material conservation
  - Adapt existing buildings to new uses
  - Material conserving design & construction
  - Size buildings & systems properly
  - Incorporate reclaimed or recycled materials
  - Use environment-friendly materials & products
  - Design for deconstruction ("close the loop")

- Life cycle assessment (LCA) is often used to evaluate the environmental impact of building materials and products
Water issues

• Design strategy for water efficiency
  • **Reduce** water consumption
    • Low-flush toilets & showerheads
    • Leak detection & prevention
  • Correct use of appliances (e.g. washing machine)
  • **Reuse** and **recycle** water onsite
    • Rainwater collection & recycling
    • Greywater recycling (e.g. for irrigation)
  • No-/Low-water composting toilet
Rainwater recycling system
Water Reclamation Process

- Rainwater Collection System
- Grey-water Collection System
- Sewerage System
- Reclaimed Water Distribution System
- Treated Effluent

To Street Cleansing  To Water Features  To Landscape Irrigation  Other Uses  To Toilet Flushing

- Shower
- Bathtub
- Sink
- Kitchen
- Laundry

Water Reclamation Plant  Sewage Treatment Plant  Greywater Treatment System  Rainwater Treatment System

Indoor environment

- Indoor environmental quality (IEQ)
  - Indoor air quality
    - Ensure health & well-being
  - Visual quality
    - Provide daylight & comfortable conditions
  - Acoustic quality
    - Noise control
  - Controllability
    - Allow occupant control over thermal & visual
Major factors contributing to indoor air quality (IAQ)

Outside air

Construction materials
Building envelope
Furnishings
Equipment
Ventilation systems
Maintenance
Occupants
Electro-magnetic fields

Particulates
Biological contaminants
Volatile organic compounds

Site

Four principles of indoor air quality design

1. Source Control

2. Ventilation Control

3. Occupant Activity Control

4. Building Maintenance

Total Indoor Air Quality

Integrated building design

- Typical integrated design process
  - Preparation
  - Design development
  - Contract documents
  - Construction phase
  - Commissioning
  - Post-occupancy evaluation

- Usually more efforts in preparation and pre-design phases
Elements of Integrated Design

Emphasize the integrated process

Ensure requirements and goals are met (via Building Commissioning, etc.)

Evaluate solutions

Think of the building as a whole

Focus on life cycle design

Develop tailored solutions that yield multiple benefits while meeting requirements & goals

Work together as a team from the beginning

Conduct assessments (e.g., Threat/Vulnerability Assessments & Risk Analysis) to help identify requirements & set goals

(Source: www.wbdg.org)
Integrated building design

- Integrated, multidisciplinary project team
  - Owner's representative
  - Architect
  - Building Services Engineer
  - Civil/Structural Engineer
  - Construction Manager
  - Landscape Architect
  - Specialized Consultants
ASHRAE Standard 189.1
www.ashrae.org/greenstandard

Knowledge is power.
Understanding is power².
ASHRAE Standard 189.1

- It is jointly developed by:
  - ASHRAE (American Society of Heating, Refrigerating and Air-Conditioning Engineers)
  - USGBC (U.S. Green Building Council)
  - IESNA (Illuminating Engineering Society of North America)

- It is also approved by American National Standards Institute (ANSI)
What is Standard 189.1?

- A standard developed in model code language
- Provides minimum requirements for high-performance, green buildings
- Applies to all buildings except low-rise residential buildings (same as ASHRAE Standard 90.1)
- Optional compliance path to the International Green Construction Code (IgCC)
- Not a design guide, not a rating system
Goals for Standard 189.1

- Establish mandatory criteria in all topic areas
  - One “challenge” is existing green building rating systems contain few mandatory provisions
- Provide simple prescriptive compliance options
- Provide flexible performance compliance options
- Complement green building rating programs
  - Standard is not intended to compete with green building rating programs (e.g. LEED)
Standard 189.1 building blocks

(Source: Mr. Kent W. Peterson)
Compliance paths of Standard 189.1

Mandatory + Prescriptive Path
(simple option, very few calculations)

Mandatory + Performance Path
(more options, but more effort)

(Source: Mr. Kent W. Peterson)
ASHRAE Standard 189.1

• Standard 189.1 topic areas:
  - SS Sustainable Sites
  - WE Water Use Efficiency
  - EE Energy Efficiency
  - IEQ Indoor Environmental Quality
  - MR Building’s Impact on the Atmosphere, Materials & Resources
  - CO Construction and Operations Plans
High-Performance Building Design Professional (HBDP)

www.ashrae.org/certification
<table>
<thead>
<tr>
<th>Certification Program</th>
<th>Relevant Experience and Knowledge</th>
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<tbody>
<tr>
<td>Building Energy Assessment Professional (BEAP)</td>
<td>Building energy audit, building energy management, building services systems (design, installation, and/or management)</td>
</tr>
<tr>
<td>Building Energy Modeling Professional (BEMP)</td>
<td>Building energy simulation, energy modeling software, building energy analysis, building services systems (design and/or installation)</td>
</tr>
<tr>
<td>Commissioning Process Management Professional (CPMP)</td>
<td>Building testing and commissioning, facilities operations/management, construction, design, or consulting</td>
</tr>
<tr>
<td>Healthcare Facility Design Professional (HFDP)</td>
<td>Healthcare HVAC&amp;R design, medical equipment &amp; procedures, healthcare facilities operation &amp; maintenance</td>
</tr>
<tr>
<td>High-Performance Building Design Professional (HBDP)</td>
<td>HVAC&amp;R design, sustainability concepts, energy analysis, indoor environment, controls, energy and environmental performance, water conservation, commissioning, building operation &amp; maintenance</td>
</tr>
<tr>
<td>Operations &amp; Performance Management Professional (OPMP)</td>
<td>Facility operations/management, construction, design, or consulting, Facility life cycle, O&amp;M program, building performance management, communications, environmental, health &amp; safety</td>
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</tbody>
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BIM
Building Information Modeling

- Visualization
- Structural analysis
- Cost
- Documentation
- Fabrication/Construction
- Etc...

Building Performance Analysis (BPA)

Whole Building Energy Analysis
- Conceptual Models
- Detailed Models

Energy Analysis Model (EAM)

Other Performance Studies
- Lighting & Daylighting
- Sun & Shadows
- Solar Radiation
- Climate Analysis
- Airflow & Ventilation
- Lifecycle Analysis

(Source: Autodesk http://sustainabilityworkshop.autodesk.com/high-performance-building-design)
Building performance analysis

- **Sustainable Building Projects**
  - Require evaluation of building performance
- **Typical analyses for sustainable buildings:**
  - Climate analysis
  - Solar analysis
  - Building energy analysis
  - Air flow analysis
  - Life cycle analysis
  - Carbon analysis
Building performance analysis

• **Building Information Modeling (BIM)**
  • An approach to design that uses intelligent 3D computer models to create, modify, share, and coordinate information throughout the design process
  • BIM is useful for sustainable design
    • It can help people iteratively test, analyze, and improve the building design
    • It can be used for building performance analysis (BPA)

(See also: [http://en.wikipedia.org/wiki/Building_information_modeling](http://en.wikipedia.org/wiki/Building_information_modeling))
Link with PowerDOE, eQUEST or EnergyPlus
Shading & Peak Load Reduction
Glare & Visual Comfort
Electric Lighting Design & Integration
Computational Fluid Dynamics (CFD)
Life Cycle Cost Analysis (LCCA)
Two Dimensional Heat Flow Modeling
Hygrothermal Modeling
Fenestration Design & Analysis
Assembly Detailing & Specification

EnergyPlus Software

Iterative Whole Building Energy Simulation

Cooling Load Reduction Analysis
HVAC System Optimization
Energy Consumption Optimization
Thermal Comfort Analysis
Passive Systems Integration

(Source: www.synergyefficiency.solutions)
THANK YOU 謝謝 !!

(Further information: http://ibse.hk/cmhui/ )