Definition and Methodology for Implementing of Net Zero Energy Building in Japan

Hideharu Niwa

NIKKEN SEKKEI Research Institute
Background on NZEB in Japan

1. NZEB (Net Zero Energy Building) has become recognized to be important for energy conservation and global warming prevention.

2. In Japan, after the East Japan Great Disaster, the need of self-sufficiency of energy has been recognized from the viewpoint of energy security.

3. Definition and Evaluation method of NZEB is not so clear that design method of NZEB is not yet established.

#1 Methodology for realization of NZEB in Japan
#2 Case study of NZEB for a model office building in Tokyo
#1 Methodology for realization of Net Zero Energy Buildings in Japan
Design Methods of Traditional Japanese Architecture

Design Methods for Saving Energy and Resource
1. Enjoying the Fluctuation of Indoor Environment
2. Strict Load Control
3. Use of Natural Energy
4. Use of Natural Materials

Traditional Japanese Architecture “京町屋”
Examples of Natural Energy Using of Modern Architecture

A big atrium inside to encourage natural ventilation by chimney effect

Natural Lighting

Deep shelf to intake natural sunlight

Natural Ventilation

in 1960's

in 1980's
For comfortable summer

**Shading of Sunlight**

深い庇とカーテンにより、外部から侵入する日射や熱を遮る。また、貯留した雨水を屋根に散布し、蒸発潜熱を利用して日射のあたる屋根面を冷やす。

**Purging of Inner Heat**

屋根にたまった熱は、エアフロー屋根により速やかに排出し、屋根面を冷やし室内への流入を防ぐ。

**Natural Ventilation**

比較的気温の低い日や夜間は、開口部を開放することによって、結露湿や木立をぬけてきた清風を室内にとりこみ、自然通風やナイトバージによって良好な環境が得られる。

**Radiation Cooling**

床下空間に清風を通すことで、床面が冷却され、床面からの輻射によって涼感を得る。

**Well Water Cooling**

室内に供給される空気は、まず「風の道」を通る間に地中熱で冷やされ、さらに地下水によって冷やされてから各室に送られる。

Completed in 1995

**Fig. Example of Passive Design for Eco-logical Building**
Design Methods of Sustainable Buildings in Japan

Passive and Active Design Methods are combined

1. Natural ventilation
2. Day lighting
3. Use of underground heat
4. Photovoltaic power
5. Solar heat collector
6. Wind power

Completed in 2002

Fig. Example of Passive and Active Design for Typical Sustainable Building
Typical Sustainable Buildings designed by NIKKEN SEKKEI

Urban Type
左上：日建設計東京ビル（2003年竣工）
右上：東北電力本店ビル（2002年竣工）
下：関電ビルディング（2004年竣工）

Suburb Type
上：地球環境戦略研究機関IGES（2002年竣工）
下：トヨタ自動車本館（2005年竣工）
CO₂ Emission of Sustainable Buildings Designed by NS

Average of Office Building in Tokyo 105

Average 64
reduced almost 40%

Fig. CO₂ Emission of Typical Sustainable Buildings designed by NS
Forward to Net Zero Energy Building from Sustainable Building

CO2 Emission of Building in Tokyo (2005)

Fig. Relationship between Floor Area and CO2 Emission of Building in Tokyo
A Policy on Realization of Zero Energy Buildings in Japan

Ministry of Economy, Trade and Industry

Workshop on Realization and Popularization of ZEB (2009)

Fig. Primary energy saving for each technology to realize ZEB
Definition of Net Zero Energy Buildings discussed in Japan

Net Zero Energy Building is defined as A=D or B=C

Note: Renewable energy is on-site generation from on-site renewable

Fig. Primary Energy Flow of Net Zero Energy Building
Approach to Net Zero Energy Buildings

Fig. Approach to Net Zero Energy Building
Energy Consumption of Buildings is Calculated as below

**Demand side**

- **A**
  - Low Energy Buildings

**Supply side**

- **B**
  - Low Energy Infrastructure

\[
\begin{align*}
A \times B &= 1.0 \times 1.0 = 1.0 & \text{Reference Building} \\
A \times B &= 0.7 \times 0.7 = 0.49 & 50\% \text{ Energy Saving Building} \\
A \times B &= 0.5 \times 0.5 = 0.25 & 75\% \text{ Energy Saving Building}
\end{align*}
\]

Fig. Energy Saving by the method of Demand Side and Supply Side
Energy Saving by the method of Demand and Supply Side

Fig. Relationship between Supply Side Energy and Demand Side Energy

Supply Side Energy Ratio (%) vs. Demand Side Energy Ratio (%)

- Reference Building
- Low Energy Buildings
- Low Energy Building
- net Zero Energy Building
- Low Energy Infrastructure

Energy Consumption

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Design Methods of Net Zero Energy Buildings

#1 Passive Design Methods for Low Energy Building

- Optimization of Outside Environment
- Optimization of Indoor Environment
- Load Reduction
- Use of Natural Energy
- Use of Unutilized Energy

#2 Active Design Methods for Low Energy Infra

- High Efficiency System
- Use of Renewable Energy
- Energy Management

#3 Energy Management Method

Fig. Design Methods of Net Zero Energy Building
An Image of Net Zero Energy Building

1. **Optimization of Outside Environment**
   1.1 Location of Building Ventilation, Location of Building
   1.2 Outside Environment Planning Green and water, Surface Material

2. **Optimization Indoor Environment**
   2.1 Thermal Environment Temperature, Humidity, Radiation
   2.2 Lighting Environment Optimization of Illumination
   2.3 Air Quality Outside Air Volume

3. **Load Reduction**
   3.1 Shading of Sunlight Tree, Building Shape
   3.2 Insulation of Envelope Window Surface, Pair Glass Double Skin, Roof Greening
   3.3 Reduction of Inner heat Waiting Power, Clouding

4. **Use of Natural Energy**
   4.1 Natural Lighting Top light, Light shelf, Light Duct
   4.2 Natural Ventilation
   4.3 Earth heat Using Earth Tube, Geo-HP
   4.4 Solar Heat Using Passive and Active

5. **Use of Unutilized Energy**
   5.1 Temperature Difference Ground Water

6. **High Efficiency System**
   6.1 Lighting LED, Natural Lighting Task & Ambient Lighting
   6.2 HVAC High Efficiency Equipment
   6.3 Heat Source High Efficiency System
   6.4 Electricity High Efficiency Trans
   6.5 Others HW Supply system
   6.6 Control Blind Control Task & Ambient Control

7. **Resource and Material**
   7.1 Resource
   7.2 Materials
   7.3 Waste

8. **Use of Renewable Energy**
   8.1 PV
   8.2 Wind Power
   8.3 Biomass

9. **Energy Management**
   9.1 BEMS
   9.2 LCEM
   9.3 Visualization

**Fig Image of net Zero Energy Building**
#2 Case Study of NZEB for a Model Building in Tokyo
Building Models for Case Study

A Reference Building  B Low Energy Building  C net Zero Energy Building

Fig. Building Models for Case Study  3F Office  Floor Area 4800 m² in Tokyo
## Calculation Conditions of each Building

<table>
<thead>
<tr>
<th>Case</th>
<th>Reference Building</th>
<th>Low Energy Building</th>
<th>net Zero Energy Building</th>
</tr>
</thead>
<tbody>
<tr>
<td>Location</td>
<td>Tokyo</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Usage</td>
<td>Office</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Scale</td>
<td>3 stories above ground; 4,800 m² in total floor area; 3,200 m² in air-conditioned floor space</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Indoor temperature and humidity</td>
<td>Summer (Jun to Sep) at 26°C/50%; Winter (Dec to Feb) at 22°C/40%</td>
<td>Intermediate seasons (others) at 24°C/50%</td>
<td></td>
</tr>
<tr>
<td>Air-conditioner operation time</td>
<td>8:00 to 20:00 hours (Sunday, Saturday and legal holidays at halt)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Outer walls</td>
<td>Concrete 150 mm thick Air layer Foamed styrene 25 mm thick Plaster board 12 mm thick</td>
<td>Sheet metal 1.2 mm + air layer Concrete 150 mm Foamed styrene 50 mm + air layer Plaster board 9+12 mm</td>
<td>Sheet metal 1.2 mm + air layer Concrete 150 mm Foamed styrene 50 mm + air layer Plaster board 9+12 mm</td>
</tr>
<tr>
<td></td>
<td>heat insulating K=0.9 W/m²·K</td>
<td>heat insulating K=0.5 W/m²·K</td>
<td>heat insulating K=0.5 W/m²·K</td>
</tr>
<tr>
<td>Window</td>
<td>Window ratio at 47% (window height 1.8 m)</td>
<td>Window ratio at 42% (window height 1.6 m)</td>
<td>Window ratio at 82% (window height 3.0 m)</td>
</tr>
<tr>
<td></td>
<td>Single pane glass 6 mm K=4.8 W/m²·K Shade factor: 0.66 when rolling blind closed and 1.0 when open</td>
<td>Single pane glass 6 mm K=4.8 W/m²·K Shade factor: 0.66 when rolling blind closed and 1.0 when open</td>
<td>AF+Low-e glass K=1.8 W/m²·K Shade factor: 0.12 when rolling blind closed and 0.3 when open</td>
</tr>
<tr>
<td>Eaves</td>
<td>None</td>
<td>1.25m</td>
<td>1.25m+Light Shelf</td>
</tr>
<tr>
<td>Louvers</td>
<td>None</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td>Lighting</td>
<td>14.1 W/m² 750 lx (HF)</td>
<td>5.8 W/m² 500 lx (HF)</td>
<td>1.6 W/m² 350 lx (LED+TAL)</td>
</tr>
<tr>
<td>Equip. heat</td>
<td>20 W/m² (Load factor 50% in daytime, 12.5% in night waiting)</td>
<td>15 W/m² (Load factor 50% in daytime, 12.5% in night waiting)</td>
<td>10 W/m² (Load factor 50% in daytime, 12.5% in night waiting)</td>
</tr>
<tr>
<td>Personnel density</td>
<td>10 m²/person, sensible heat 65 W/person, latent heat 55 W/person</td>
<td>Effective</td>
<td></td>
</tr>
<tr>
<td>Natural Ventilation</td>
<td>None</td>
<td>None</td>
<td>Effective</td>
</tr>
</tbody>
</table>
**Calculation Conditions of each HVAC System**

<table>
<thead>
<tr>
<th>Case</th>
<th>Reference Building</th>
<th>Low Energy Building</th>
<th>nearly Zero Energy Building</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Outdoor air-conditioner</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rated operations</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Outdoor equip.’s</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>performance coefficient</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cooling</td>
<td>3.0</td>
<td>5.0</td>
<td>7.0</td>
</tr>
<tr>
<td>Heating</td>
<td>3.5</td>
<td>5.5</td>
<td>7.5</td>
</tr>
</tbody>
</table>

Input rate characteristic against load factor during partial loading operation (in cooling)

<table>
<thead>
<tr>
<th>Case</th>
<th>Reference Building</th>
<th>Low Energy Building</th>
<th>nearly Zero Energy Building</th>
</tr>
</thead>
<tbody>
<tr>
<td>Refrigerant control</td>
<td>Constant evaporation temp.</td>
<td>Constant evaporation temp.</td>
<td>Variable evaporation temp.</td>
</tr>
<tr>
<td>Fan control</td>
<td>Not existing</td>
<td>Same as left</td>
<td>Same as left</td>
</tr>
<tr>
<td>Fan consumption power ratio</td>
<td>1.0</td>
<td>0.8</td>
<td>0.6</td>
</tr>
<tr>
<td>Fan at halt when thermostat is off</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Outdoor air treatment</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>System</td>
<td>Total heat exchanger</td>
<td>Same as left</td>
<td>Total heat exchanger + Outdoor air treatment air-conditioner</td>
</tr>
<tr>
<td>heat exchanger efficiency</td>
<td>60%</td>
<td>70%</td>
<td>80%</td>
</tr>
</tbody>
</table>

**Diagram**: Graphs showing input ratio against load factor for Reference Building, Low Energy Building, and nearly Zero Energy Building.
Sectional Shapes of each Building

Reference Building

No eaves

Low Energy Building

eaves

net Zero Energy Building

eaves

Light shelf

Fig. Sectional Shapes of each Building
Calculated Results - Indoor Illumination distribution

Reference Building

Low Energy Building

net Zero Energy Building

the entire office space is day-lighted

Fig. Indoor Illumination Distribution of each Building
Calculated Results - Daylight use ratio

Reference Building (manual blind on 500 lx)

Average ratio 40%

Average ratio 75%

net Zero Energy Building (automatic blind on 500 lx)

Fig. Daylight use ratio of Reference Building and ZEB
Calculated Results - Electric Power for Lighting

Fig. Electric Power Consumption for Lighting of each Building

Energy Consumption of ZEB decreases more than 80% as compared with Reference Building
Fig. Annual Cooling and Heating Load of each Building

In case of ZEB, annual heating load increases, because inner heat gain decreases, and heat loss through window increases as compared with reference building or low energy building.
Calculated Results - Renewable Energy Generation

In case of ZEB photovoltaic power panel is provided on the rooftop (800 m² in area, 0.165 in electricity conversion efficiency)

Annual Power Generation (MWh)

Design Point

南面（東京） 800㎡

年度発電量 [MWh/年]

Fig. Annual Photovoltaic Power Generation as Angle of Panel
Calculated Results - Primary Energy Consumption

**Annual Primary Energy Consumption (MJ/m²·a)**

<table>
<thead>
<tr>
<th>Generation</th>
<th>Consumption※</th>
</tr>
</thead>
<tbody>
<tr>
<td>600</td>
<td>0</td>
</tr>
<tr>
<td>400</td>
<td>200</td>
</tr>
<tr>
<td>200</td>
<td>400</td>
</tr>
<tr>
<td>0</td>
<td>600</td>
</tr>
<tr>
<td>200</td>
<td>800</td>
</tr>
<tr>
<td>400</td>
<td>1,000</td>
</tr>
<tr>
<td>600</td>
<td>1,200</td>
</tr>
<tr>
<td>800</td>
<td>1,400</td>
</tr>
<tr>
<td>1,000</td>
<td>1,600</td>
</tr>
</tbody>
</table>

### Reference Building
- Generation: 263
- Consumption: 408, 439

### Low Energy Building
- Generation: 189, 181, 237
- Consumption: 607
- Renewable Energy: 385
- 45% reduction

### Zero Energy Building
- Generation: 369, 131, 178, 176
- Consumption: 65% reduction

**Fig. Annual Primary Energy Consumption and Generation**

Energy Consumption of ZEB decreases by 65% as compared with the Reference Building.

Energy Consumption of ZEB is roughly balanced with renewable energy generation.
Examples of nearly ZEBs in the world

Malaysia ST Diamond Building

Korea National Environmental Research

France Elithis Tower

Finland Environmental Center
Examples of ZEB oriented Buildings in Japan

Public Building

Commercial Building (urban)

Commercial Building (Suburb)

(寒冷地)
Mapping of nearly ZEBs in the World

Fig. Mapping of nearly ZEBs in the World
Road to ZEB from Reference Building in Japan
Thanks for your attention