Zero Energy Buildings: Colombian perspective

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Institutions: Universidad Nacional de Colombia sede Manizales.
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II. Theoretical aspects: ZEB

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I. Introduction

Climate change

Zero Buildings (ZEB)

Energy

Passive Designs
- Ventilation.
- Thermal envelope.
- Solar gains.
- Energy efficient appliances.

Active Designs
- Renewable energy.
- HVAC systems (Heating, Ventilation and Air Conditioning).
- Smart grid (BMS, BAS, IoT).

Reduce energy consumption
II. Theoretical aspects: ZEB

Further development in ZEB:

- **Definitions and methodologies**
- **Different conditions**

- PEB (>100%)
  - NZEB (100%)
  - nZEB (60%-75%)
  - LEB (50%)

- **NZEB +** surplus power supply to the local power grid.
  - Renewable energies supply the total demand
  - They can have: storage and smart grids.
  - BMS – BAS.

- **nZEB +**

- **LEB +**
  - Renewable energy
  - Air conditioning systems much more efficient
  - Climate adaptation
  - Passive Design Techniques
  - Energy efficiency in construction
  - Comfort in indoor environment (air conditioning system)

Active cooperation of users and Energy management systems (EMS)

Fig. 1: ZEB classification according to Chinese energy reduction standards in 2016. Adapted from
III. Colombian perspective

- Law 1715 of 2014.
- Resolution 549 of 2015 - Energy and Water Saving Guide

<table>
<thead>
<tr>
<th>Design measure</th>
<th>Action area</th>
<th>Recommended measures</th>
</tr>
</thead>
<tbody>
<tr>
<td>Passive</td>
<td>From the architecture of the building</td>
<td>• Window / Wall ratio</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Solar protection</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Natural ventilation</td>
</tr>
<tr>
<td>Active</td>
<td>illumination</td>
<td>• Daylight and daylight control</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Efficient emergency lighting</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Air economizers</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Coefficient of performance (COP)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Exterior lighting control</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Controls:       occupancy</td>
</tr>
</tbody>
</table>

Table 1: Measures for educational institutions - Energy and Water Saving Guide.
III. Colombian perspective

- Average base consumption:

\[
40 \frac{kWh}{m^2 \times \text{year}}
\]

- Energy-saving percentage: 45%

- LEB base consumption:

\[
Base \ consumption \ - \ energy \ saving \ percentage = 40 - (40 \times 45\%) = 22 \frac{kWh}{m^2 \times \text{year}}
\]
IV. Case study: University Campus ZEB Characteristics:

- National University of Colombia headquarters Manizales Campus la Nubia (cold climate).
- 14 buildings with different uses of energy and different degrees of antiquity.
- 6 academic buildings (new and intermediate).

<table>
<thead>
<tr>
<th>Building</th>
<th>Features</th>
<th>Load</th>
<th>fp = 0.95</th>
</tr>
</thead>
</table>
| L        | • Interior comfort - bioclimatic design.  
           • Energy efficiency in architecture and electrical networks. Opened in 2013. | 161.5 kW |  |
| P        | • Current architectural and electrical designs, but with deficits. Opened in 2003. | 78.85 kW |  |
| Q        | • Current architectural and electrical designs, but with deficits. Opened in 2003. | 109.3 kW |  |
| S1       | • Internal comfort - bioclimatic design.  
           • Energy efficiency in architecture and electrical networks. Opening in 2019. | 57 kW |  |
| S2       | • Internal comfort - bioclimatic design.  
           • Energy efficiency in architecture and electrical networks. Opening in 2019. | 114 kW |  |
| W        | • Internal comfort - bioclimatic design.  
           • Energy efficiency in architecture and electrical networks, 10kVA photovoltaic solar systems, rainwater storage system for sanitation | 95 kW |  |

Table 2: Current status of the La Nubia campus academic buildings.
IV. Case study: University campus ZEB

A. LEB level Campus la Nubia:

- New buildings comply with the water and energy saving guide.
- Application of annual and hourly correction factors.
- Application of active and passive measures described in the guide for intermediate buildings.

<table>
<thead>
<tr>
<th>Buildings</th>
<th>L</th>
<th>P</th>
<th>Q</th>
<th>S1</th>
<th>S2</th>
<th>W</th>
<th>Total (kWh)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Area m²</td>
<td>7226</td>
<td>3555</td>
<td>3700</td>
<td>2452</td>
<td>5000</td>
<td>5200</td>
<td></td>
</tr>
<tr>
<td>Load (kWh)</td>
<td>162</td>
<td>79</td>
<td>109</td>
<td>57</td>
<td>114</td>
<td>95</td>
<td></td>
</tr>
<tr>
<td>Building base consumption kWh/(m² year)</td>
<td>49,6</td>
<td>49,2</td>
<td>65,5</td>
<td>51,6</td>
<td>50,6</td>
<td>40,5</td>
<td>306,9</td>
</tr>
<tr>
<td>Total per Building kWh/(m² year)</td>
<td>27,3</td>
<td>49,2</td>
<td>65,5</td>
<td>28,4</td>
<td>27,8</td>
<td>22,3</td>
<td>220,4</td>
</tr>
</tbody>
</table>

Table 2: Base consumption by buildings of the La Nubia campus.

Fig. 2: Base consumption of each building compared to average base consumption and LEB base consumption.

Source: Own elaboration.
IV. Case study: University campus ZEB

B. nZEB level Campus La Nubia:

- Reductions of 60% to 75% in energy consumption with renewable energies.

<table>
<thead>
<tr>
<th>Building</th>
<th>L</th>
<th>P</th>
<th>Q</th>
<th>S1</th>
<th>S2</th>
<th>W</th>
<th>TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Area (m²)</td>
<td>7226</td>
<td>3555</td>
<td>3700</td>
<td>2452</td>
<td>5000</td>
<td>5200</td>
<td>27133</td>
</tr>
<tr>
<td>Base consumption</td>
<td>49,6</td>
<td>49,2</td>
<td>65,5</td>
<td>51,6</td>
<td>50,6</td>
<td>40,5</td>
<td>306,9</td>
</tr>
<tr>
<td>(kWh/ m²*year)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LEB consumption -</td>
<td>27,3</td>
<td>24,6</td>
<td>32,7</td>
<td>28,4</td>
<td>27,8</td>
<td>22,3</td>
<td>163,1</td>
</tr>
<tr>
<td>50% (kWh/ m²*year)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>75% of base consumption</td>
<td>37,2</td>
<td>36,9</td>
<td>49,1</td>
<td>38,7</td>
<td>37,9</td>
<td>30,4</td>
<td>230,2</td>
</tr>
<tr>
<td>(kWh/m²*year)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Consume to be a nZEB</td>
<td>12,4</td>
<td>12,3</td>
<td>16,4</td>
<td>12,9</td>
<td>12,6</td>
<td>10,1</td>
<td>76,7</td>
</tr>
<tr>
<td>(kWh/ m²*year)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PV power (kWh/ m²*year)</td>
<td>14,9</td>
<td>12,3</td>
<td>16,4</td>
<td>15,5</td>
<td>15,2</td>
<td>12,2</td>
<td>86,3</td>
</tr>
<tr>
<td>PV generation (MWh/</td>
<td>107,5</td>
<td>43,7</td>
<td>60,6</td>
<td>37,9</td>
<td>75,9</td>
<td>63,2</td>
<td>388,8</td>
</tr>
<tr>
<td>year)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PV power (kWh)</td>
<td>65,4</td>
<td>26,6</td>
<td>36,9</td>
<td>23,1</td>
<td>46,2</td>
<td>38,5</td>
<td>236,7</td>
</tr>
<tr>
<td>4,5 day</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 4: Consumption and power PV per building to be nZEB.

<table>
<thead>
<tr>
<th>Buildings</th>
<th>Power PV (kWh)</th>
<th>Panel Quantity</th>
<th>m²² Required on deck</th>
<th>m²² Available in blocks</th>
</tr>
</thead>
<tbody>
<tr>
<td>L</td>
<td>65,4</td>
<td>198</td>
<td>495,6</td>
<td>3300</td>
</tr>
<tr>
<td>P</td>
<td>26,6</td>
<td>81</td>
<td>201,7</td>
<td>1000</td>
</tr>
<tr>
<td>Q</td>
<td>36,9</td>
<td>112</td>
<td>279,4</td>
<td>1200</td>
</tr>
<tr>
<td>S1</td>
<td>23,1</td>
<td>70</td>
<td>174,9</td>
<td>0</td>
</tr>
<tr>
<td>S2</td>
<td>46,2</td>
<td>140</td>
<td>349,9</td>
<td>2000</td>
</tr>
<tr>
<td>W</td>
<td>28,5</td>
<td>86</td>
<td>215,8</td>
<td>1000</td>
</tr>
<tr>
<td>TOTAL</td>
<td>226,7</td>
<td>687</td>
<td>1717,3</td>
<td>8500</td>
</tr>
</tbody>
</table>

Table 5: PV capacity required to be nZEB.
IV. Case study: University campus ZEB

C. NZEB - PEB levels Campus La nubia:

Reductions of 100% in energy consumption with the photovoltaic solar system, energy storage systems and smart grids.

- Building Management Systems (BMS) and Building Automation Systems (BAS).
- Laboratory in active demand management – GESDELEC.

Equipment:

(3) KING PIGEON GATEWAY S373
(1) KING PIGEON RTU S272
(1) Network analyzer
(2) Portable computing equipment.
(4) Humidity and temperature sensors
(1) 4G LoRa Gateway S281 King Pigeon
IV. Case study: University campus ZEB

C. NZEB – PEB

1) BMS development on buildings La Nubia Campus:

- Option I: Gateway S373

Fig. 3: Communication architectures for the BMS system using Gateway S373 proposed. Source: Own elaboration.
IV. Case study: University campus ZEB

C. NZEB - PEB

1) BMS development on buildings La Nubia Campus:

- Option I: Gateway S373
IV. Case study: University campus ZEB

C. NZEB – PEB

1) BMS development on buildings La Nubia Campus:

- Option II: Gateway LoRa S281

Fig. 5: BMS for some buildings using on Campus La Nubia S281 proposed. Source: Own elaboration.
II. Case study: University campus ZEB

C. NZEB – PEB

2) BAS development (control and automation) on La Nubia:

Gateway S272

Fig. 6: BAS with automation and control on Campus La Nubia proposed. Source: Own elaboration.
V. Conclusions

- Competitive electricity markets through smart grids and distributed (renewable) energy resources.

- Integration of prosumers in distribution networks.

- There must be local adaptation for ZEBs (Latin America And Colombia).

- PEB as the last step of the ZEB (use of active and passive technologies at a maximum level).
VI. Questions