Active Interfaces | Phd Seminar | 29.03.2017

Project 02 - Design
Architectural design strategies for renovation projects with BIPV optimizing self-consumption and self-sufficiency

Sergi Aguadí | Laboratory of Architecture and Sustainable Technologies (EPFL)

2nd PhD Seminar | ACTIVE INTERFACES | Lausanne | 29.03.2017

/// Agenda

• Research methodology
  • Presentation of the case studies - archetype 1 and 4
  • Design scenarios implementation - case studies

• Multi-criteria assessment
  • Indicators
  • Net energy balance
  • Annual irradiation threshold study
  • Optimization process
  • Results comparison

• Next step
  • Integration a PV battery storage system

/// Phase 2 | Case study selection | Residential buildings

Archetype 1
- Built in 1909
- 4 stories
- 8 apartments
- 603 m² floor area

Archetype 4
- Built in 1972
- 11 stories
- 52 apartments
- 5,263 m² floor area

Level of protection: II - common
Heating system: central heating (Oil boiler)
### Phase 3 | Design scenarios implementation | Potentially active surfaces

**Archetype 1 | 1909**

- **S0-Baseline**
- **S1-Conservation**
- **S2-Renovation**
- **S3-Transformation**

### Phase 4 | Multi-criteria assessment | Indicators

<table>
<thead>
<tr>
<th>Assessment indicator</th>
<th>Unit</th>
<th>Method / tool used</th>
<th>3D modeling LoD</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1. Energy and emissions</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Primary energy consumption</td>
<td>kWh/m²·year</td>
<td>Energy Plus</td>
<td>LOD3</td>
</tr>
<tr>
<td>- Equivalent GHG emissions</td>
<td>gCO₂/m²·year</td>
<td>Energy Plus</td>
<td>LOD3</td>
</tr>
<tr>
<td><strong>2. Photovoltaic installation</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- PV Generation</td>
<td>kWh/m²·year</td>
<td>Energy Plus</td>
<td>LOD3</td>
</tr>
<tr>
<td>- Self-consumption</td>
<td>%</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>- Self-sufficiency</td>
<td>%</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td><strong>3. LCA - Life Cycle Analysis</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Embedded energy balance</td>
<td>MJ/m²·year</td>
<td>ecoinvent + KBOB</td>
<td>-</td>
</tr>
<tr>
<td>- Global warming potential</td>
<td>kgCO₂/m²·year</td>
<td>ecoinvent + KBOB</td>
<td>-</td>
</tr>
<tr>
<td><strong>4. Indoor comfort</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Spatial Daylight autonomy (300lux)</td>
<td>% of surface</td>
<td>Radiance / Daysim</td>
<td>LOD4</td>
</tr>
<tr>
<td><strong>5. LCC - Life Cycle Cost</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Accumulated cost</td>
<td>CHF</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>- Payback period</td>
<td>years</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

**Archetype 4 | 1972**

- **S0-Baseline**
- **S1-Conservation**
- **S2-Renovation**
- **S3-Transformation**
### Phase 4 | Optimization | S3 - Transformation

- Self-consumption or Self-sufficiency [%] vs Irradiation threshold [kWh/m²·year]

**Optimum with Heat pump**
- 28 MWh/year
- Prod.PV

**Optimum with Oil-boiler**
- 17 MWh/year
- Prod.PV

### Phase 4 | Annual Irradiation threshold study | S3 - Transformation

- Annual Production potential - S3

- Self-consumption or Self-sufficiency [%] vs Irradiation threshold [kWh/m²·year]

**Archetype 1 | 1909**

- Changing HVAC system (Heat-Pump)

### Phase 4 | Multi-criteria assessment | Net energy balance


**100% Active surfaces kWh/m²·year**

- Optimizing Active surfaces kWh/m²·year

- Archetype 4 | 1972

### Phase 4 | Optimization | S3 - Transformation

- Self-consumption or Self-sufficiency [%] vs Irradiation threshold [kWh/m²·year]

- Archetype 4 | 1972

- Optimize with Heat-pump
### Phase 4 | Multi-criteria assessment

**LCC - Life-cycle cost**

**Archetype 1**

- accumulated cost of energy consumption
- active surfaces
- self-consumption
- conservation

**Archetype 4**

- accumulated cost of energy consumption
- active surfaces
- self-consumption
- conservation

Note: Changing HVAC system (Heat-Pump)

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### Next step | Integration a PV battery storage system

**Annual results**

<table>
<thead>
<tr>
<th>Batteries capacity</th>
<th>Without batteries</th>
<th>With batteries</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average daily demand</td>
<td>83 kWh</td>
<td>Self-consumption 26% → 57%</td>
</tr>
<tr>
<td>Needed capacity</td>
<td>172 kWh</td>
<td>Self-sufficiency 24% → 53%</td>
</tr>
<tr>
<td>Number of batteries*</td>
<td>15</td>
<td>Purchased electricity 5′216 CHF/year 3′214 CHF/year</td>
</tr>
<tr>
<td>Batteries payback</td>
<td>-</td>
<td>5 years</td>
</tr>
</tbody>
</table>

* Battery example: ROLLS 24V 480Ah C100

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### Next step | Integration a PV battery storage system

**Electricity-based HVAC system**

- Without batteries
  - Energy needs
    - Equipment
    - Lighting
    - DHW
    - Heating
  - On-site production
  - Self-consumption
  - Grid

- With batteries
  - Energy needs
  - Equipment
  - Lighting
  - DHW
  - Heating
  - Self-consumption with batteries
  - Grid feed-in

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**Without batteries**

- Self-sufficiency ratio 21%
- Self-consumption ratio 24%
- PV Generation (kWh) 99.86
- Grid feed-in (kWh) 76.38
- Purchased electricity (kWh) 86.23

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**With batteries**

- Self-sufficiency ratio 62%
- Self-consumption ratio 100%
- PV Generation (kWh) 99.86
- Grid feed-in (kWh) 0.00
- Batteries payback 5 years

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* Backup system or grid consumption
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