Architectural design strategies for Building-Integrated Photovoltaics (BIPV) in urban renewal processes

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Thesis Director:
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IDEAS LUNCH | LAST LIPID
INTEGRATED DESIGN, ARCHITECTURE AND SUSTAINABILITY

EPFL
Ecole Polytechnique Fédérale de Lausanne

active interfaces

Energy Turnaround
National Research Programme NRP 70
1. Research framework
Importance of **urban renewal** for the evolution of the built environment towards sustainability (1,500,000 existing residential buildings to be renovated)

“Energy turnaround 2050”
+ “2000 watt society”

Importance of **photovoltaics (PV)** for the Energy turnaround (30% coverage of Swiss roofs/façade)

Integrated design strategies with BIPV: searching synergies to increase acceptance of projects (to achieve a massive penetration of PV in CH)
What are the barriers that explain the limited motivation of architects?

BIPV-promoting initiatives (energy, normative and economics)

BIPV from an architectural point of view
CURRENT PRACTICE | Technological-Economical barriers

Large cost difference between standard and custom-made products (SEAT Manufacture in Martorell | Solar Decathlon House of Cardenal Herrera University)
CURRENT PRACTICE | Design barriers

Aesthetics and economic issues of building renovations with non-integrated PV elements
CURRENT PRACTICE | Socio-cultural acceptance barriers

Absence of clear regulations | Absence of good BIPV examples | Tendency to reject renovation projects with PV panels (by authorities, by society)
CURRENT PRACTICE | Assessment barriers

*Necessity of properly evaluated examples by a multi-criteria assessment to motivate designers to use BIPV (Student Housing Denmark)*
Current practices and existing regulations are far from Swiss objectives

“Energy turnaround 2050”
+ “2000 watt society”

Architects and BIPV have an important role in achieving Swiss objectives

Necessity of architectural design criteria for BIPV in renovation projects
Urban and architectural design could

Accelerate the process of linking BIPV with renewal of building stock
2. Hypothesis and Research Question
Hypothesis

« BIPV is an “architectural material” that could help stimulate sustainable urban renewal processes »
2. Hypothesis and research question

Hypothesis

« BIPV is an “architectural material” that could help stimulate sustainable urban renewal processes »

Research question

« How can BIPV be made part of common practice in renewal projects in the urban context? »
3. Methodology
Three-step methodology

(PHASE 1) IDENTIFICATION OF ARCHETYPAL SITUATIONS

(PHASE 2) DESIGN SCENARIOS WITH BIPV SOLUTIONS

(PHASE 3) MULTI-CRITERIA ASSESSMENT
Methodology

PHASE 1 – Archetypal situations
1) Neuchâtel as a representative city in Switzerland

**PHASE 1 – IDENTIFICATION OF ARCHETYPAL SITUATIONS**

Référence: Office Fédérale de Statistique (OFS), 2014
PHASE 1 – IDENTIFICATION OF ARCHETYPAL SITUATIONS

2) Why focus only on residential buildings?

Référence: Ville de Neuchâtel - Office Fédérale de Statistique (OFS), 2014
PHASE 1 – IDENTIFICATION OF ARCHETYPAL SITUATIONS

3) Definition of the residential archetypes (set of parameters)

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<td>&gt;7 floors</td>
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<td>E - Architectural quality</td>
<td>Interesting</td>
<td>Common</td>
<td>Unattractive</td>
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<tr>
<td>Level of protection</td>
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<td>II</td>
<td>III</td>
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<tr>
<td>F - Type of owner</td>
<td>Co-ownership (PPE)</td>
<td>Small owner (&lt;3 properties)</td>
<td>Large owner (≥3 properties)</td>
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</table>
PHASE 1 – IDENTIFICATION OF ARCHETYPAL SITUATIONS

3) Definition of the residential archetypes (set of parameters)

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In order to extrapolate the results, we do not take into account:
Highly protected or special buildings
PHASE 1 – IDENTIFICATION OF ARCHETYPAL SITUATIONS – Urban data analysis

Main parameter

A - Construction period

1. Before 1919
2. 1919-1945
3. 1946-1970
4. 1971-1985
5. 1986-1995
6. 1996-2005

Number of buildings:
- 1: 1234
- 2: 315
- 3: 631
- 4: 464
- 5: 76
- 6: 52

5200 residential buildings in total → We have the complete data for 2772 buildings

Ref.: REGBL + REGFoncier + Patrimoine
PHASE 1 – IDENTIFICATION OF ARCHETYPAL SITUATIONS – Urban data analysis

Crossing of parameters

B – Urban context

C – Roof potential

D – Facade potential

E – Level of protection

F – Type of owner

Ref.: REGBL + REGFonc + Patrimoine, 2014
PHASE 1 – IDENTIFICATION OF ARCHETYPAL SITUATIONS – Urban data analysis

Crossing of parameters

B – Urban context
C – Roof potential
D – Facade potential
E – Level of protection
F – Type of owner

Ref.: REGBL + REGFonc + Patrimoine, 2014
PHASE 1 – IDENTIFICATION OF ARCHETYPAL SITUATIONS – Urban data analysis

Overview of all parameters (Neuchâtel)

Number of buildings

- B-Urban context
  - isolated
  - adjacent
  - flat
  - sloped
- C-Roof potential
- D-Façade potential
- E-Level of protection
  - Interesting
  - Typical
  - Unsettling
- F-POP
- G-Type of owner
  - PPE
  - Small owner
  - Large owner

2437 buildings

Ref.: REGBL + REGFonc + Patrimoine, 2014
**PHASE 1 – IDENTIFICATION OF ARCHETYPAL SITUATIONS – Residential archetypes**

Example of parameter combination - Residential archetype n° 4

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Arch. 4
PHASE 1 – IDENTIFICATION OF ARCHETYPAL SITUATIONS – Residential archetypes

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For each one of them we will choose a case study in Neuchâtel (real buildings)
Methodology

PHASE 2 – Design scenarios
PHASE 2 – DESIGN SCENARIOS WITH BIPV SOLUTIONS

1) Definition of design renewal scenarios

- **Current status**: (detailed analysis of the case study)
- **Baseline**: Compliance with current legal requirements (current practices)
- **Conservation**: Maintaining the expression of the building while improving the energy performance of the building (at least current legal requirements)
- **Renovation**: Maintaining the general expressive lines of the building while reaching high energy performance (at least Minergie standard)
- **Transformation**: Best energy performance and maximum electricity production possible with aesthetic and formal coherence over the whole building (at least 2000 Watt Society | Energy strategy 2050)
### PHASE 2 – DESIGN SCENARIOS WITH BIPV SOLUTIONS – FIRST CASE STUDY

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<tr>
<td>Level of protection</td>
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<td><img src="image2" alt="Arch. 2" /></td>
<td><img src="image3" alt="Arch. 3" /></td>
<td><img src="image4" alt="Arch. 4" /></td>
<td><img src="image5" alt="Arch. 5" /></td>
<td><img src="image6" alt="Arch. 6" /></td>
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<td>Co-ownership (PPE)</td>
<td>Large owner (≥3 proprieties)</td>
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</tbody>
</table>
• Neighborhood of Serrières
• Residential buildings (apartments between 2 and 4.5 rooms)
• 10 stories + 1 attic (apartment 6.5 rooms)
• Level of protection II (common / typical)
• Heating system: central heating (for 5 buildings)
PHASE 2 – DESIGN SCENARIOS WITH BIPV SOLUTIONS – FIRST CASE STUDY

E0 | Current status
PHASE 2 – DESIGN SCENARIOS WITH BIPV SOLUTIONS – FIRST CASE STUDY

E0 | Current status
PHASE 2 – DESIGN SCENARIOS WITH BIPV SOLUTIONS – FIRST CASE STUDY

E0 | Current status
PHASE 2 – DESIGN SCENARIOS WITH BIPV SOLUTIONS – FIRST CASE STUDY

S0 | Baseline
PHASE 2 – DESIGN SCENARIOS WITH BIPV SOLUTIONS – FIRST CASE STUDY

S1 | Conservation
PHASE 2 – DESIGN SCENARIOS WITH BIPV SOLUTIONS – FIRST CASE STUDY

S2 | Renovation
PHASE 2 – DESIGN SCENARIOS WITH BIPV SOLUTIONS – FIRST CASE STUDY

S3 | Transformation

1. Research framework
2. Hypothesis and research question
3. Methodology – First case study
4. Next steps
5. Timeline

Prefabricated modules
PHASE 2 – DESIGN SCENARIOS WITH BIPV SOLUTIONS – FIRST CASE STUDY

S3 | Transformation

Reference: Caisse de pension COOP building. Morges (CH)
Methodology

PHASE 3 - Multi-criteria assessment
PHASE 3 – MULTI-CRITERIA ASSESSMENT

1) Definition of acceptability evaluation process

PHASE 2: Design renovation scenarios

Active Interfaces collaboration
Technology, Constructive aspects, ......

PHASE 3: Pre-assessment (energy)

To ensure the acceptability of each scenario project (qualitative)

Final design

Final quantitative assessment

Design proposition

S1

S2

S3

Workshop
Group of experts
Group of non-experts

Urban planning commission

Iterative process

First case study

Next steps

Methodology

Research framework

Hypothesis and research question
## PHASE 3 – MULTI-CRITERIA ASSESSMENT

### 2) Definition of final assessment indicators

<table>
<thead>
<tr>
<th>Assessment indicator</th>
<th>Unit</th>
<th>Method / tool used</th>
<th>3D modelling LoD</th>
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<tbody>
<tr>
<td><strong>1. Energy and emissions</strong></td>
<td></td>
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<tr>
<td>Primary energy consumption</td>
<td>kWh&lt;sub&gt;PE&lt;/sub&gt;/m².year</td>
<td>Energy Plus</td>
<td>LOD3</td>
</tr>
<tr>
<td>Equivalent GHG emissions</td>
<td>CO₂EQ/m².year</td>
<td>Energy Plus</td>
<td>LOD3</td>
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<tr>
<td><strong>2. Indoor comfort</strong></td>
<td></td>
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<tr>
<td>Daylight autonomy (DA) – 300 lux</td>
<td>% of time</td>
<td>Radiance / Daysim</td>
<td>LOD4</td>
</tr>
<tr>
<td>Overheating</td>
<td>hours per year</td>
<td>Energy Plus</td>
<td>LOD3</td>
</tr>
<tr>
<td><strong>3. Photovoltaic installation</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Annual production</td>
<td>kWh&lt;sub&gt;FE&lt;/sub&gt;/m².year</td>
<td>Energy Plus</td>
<td>LOD3</td>
</tr>
<tr>
<td>Self-consumption potential</td>
<td>%</td>
<td>-</td>
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<tr>
<td>(electricity covered ratio)</td>
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<td><strong>4. Global cost-effectiveness</strong></td>
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<tr>
<td>Global cost</td>
<td>CHF/m²</td>
<td>EPIQR + INSPIRE-Tool</td>
<td>-</td>
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<tr>
<td>Impact on rent</td>
<td>CHF/ m².year</td>
<td>-</td>
<td>-</td>
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<td>NPV (Net Present Value)</td>
<td>CHF</td>
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<td>-</td>
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<tr>
<td>Payback</td>
<td>years</td>
<td>-</td>
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<td><strong>5. LCA - Life Cycle Analysis</strong></td>
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<tr>
<td>Embodied energy balance</td>
<td>MJ</td>
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<tr>
<td>Embodied energy payback</td>
<td>years</td>
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PHASE 3 – MULTI-CRITERIA ASSESSMENT – FIRST CASE STUDY

1. Energy and emissions

Heating need

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<tr>
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<th>Heating need (kWh/m²·year)</th>
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<tbody>
<tr>
<td>E0</td>
<td>75</td>
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<tr>
<td>S0</td>
<td>30</td>
</tr>
<tr>
<td>S1</td>
<td>15</td>
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<tr>
<td>S2</td>
<td>15</td>
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<tr>
<td>S3</td>
<td>15</td>
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38 kWh/m²·year
SIA 380/1
PHASE 3 – MULTI-CRITERIA ASSESSMENT – FIRST CASE STUDY

1. Energy and emissions

Global balance

- Primary energy consumption (kWh/m²·year)
- Equivalent GHG emissions (CO2/m²·year)

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<thead>
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<th></th>
<th>E0</th>
<th>S0</th>
<th>S1</th>
<th>S2</th>
<th>S3</th>
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<tbody>
<tr>
<td>Value</td>
<td>197.74</td>
<td>128.5</td>
<td>94.9</td>
<td>63.3</td>
<td>44.83</td>
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</table>

69 kWh/m²·year
SIA 2040
PHASE 3 – MULTI-CRITERIA ASSESSMENT – FIRST CASE STUDY

2. Indoor comfort

Daylight Autonomy | 300 lux | Occupation 8 am – 10 pm | Time ratio with more than 300-Lux

S1 | Conservation

S3 | Transformation

PHASE 3 – MULTI-CRITERIA ASSESSMENT – FIRST CASE STUDY

2. Indoor comfort

Daylight Autonomy | 300 lux | Occupation 8 am – 10 pm | Time ratio with more than 300-Lux

S1 | Conservation

S3 | Transformation
PHASE 3 – MULTI-CRITERIA ASSESSMENT – FIRST CASE STUDY

3. Photovoltaic installation

Onsite PV Electricity production

Estimated consumption: 105 MWh/year

SIA 380/1

Onsite PV Electricity production (MWh/year)
PHASE 3 – MULTI-CRITERIA ASSESSMENT – FIRST CASE STUDY

3. Photovoltaic installation

Self-consumption potential (electricity coverage ratio)

### Ratio electricity consumption covered with PV (%)

- **E0**: 0%
- **S0**: 0%
- **S1**: 51%
- **S2**: 67%
- **S3**: 94%
4. Global cost-effectiveness

Mean rent level in Neuchatel: **220 CHF/m² per year**
PHASE 3 – MULTI-CRITERIA ASSESSMENT – FIRST CASE STUDY

4. Global cost-effectiveness

Accumulated cost due to energy consumption (CHF)

- Scenario_E0 (Current Status)
- Scenario_S0 (Baseline)
- Scenario_S1 (Conservation)
- Scenario_S2 (Renovation)
- Scenario_S3 (Transformation)

Years

0 5 10 15 20 25 30 35 40 45 50

0 500000 1000000 1500000 2000000 2500000 3000000 3500000 4000000 4500000

Renovation cost

IDEAS Lunch | 02.12.2015 | SA
PHASE 3 – MULTI-CRITERIA ASSESSMENT – FIRST CASE STUDY

5. Life cycle analysis

LCA - Embodied energy balance (MJ/m².year)

- E0 Renovation (Construction): 712
- S0: 463
- S1: 342
- S2: 228
- S3: 161

LCA - Global Warming Potential (kgCO2/m².year)

- E0 Renovation (Construction): 310 MJ/m²·y
- S0: 32
- S1: 21
- S2: 15
- S3: 10

- SIA 2040

R & D

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4. Next steps
NEXT STEPS

• Finalization of the first exploratory case study
  - Develop a list of requirements for new technological solutions
  - Consolidate the detailed assessment of the design scenarios
  - Realization of expressive 3D visualizations

• Five other case studies (activities conducted in parallel)
  - Selection of five representative buildings
  - Detailed design scenarios for each case study
  - Detailed assessment of the design scenarios
  - Realization of expressive 3D visualizations

• Coordination / extrapolation with urban design analyses
5. Timeline
Research plan:

Phase 1: Identification of archetypal situations

Phase 2: Design scenarios with BIPV solutions
- Case study 1 (exploratory character to refine the methodology)
- Case study 2, 3, 4, 5 and 6 (carried out in parallel)

Phase 3: Multi-criteria assessment

Workshop(s)

Results and guideline recommendations

Timeline:
- Oct. 2014: State of the art, hypothesis and research questions
- Oct. 2015: enhancement of research
- Oct. 2015: Candidacy exam
- Oct. 2015: Thesis writing
- Oct. 2018: Defense

Events:
- PLEA 2015
- Energy & Buildings
- Conference
- Article
Extra Slides
PHASE 1 – IDENTIFICATION OF ARCHETYPAL SITUATIONS

1) Neuchâtel as a representative city in Switzerland

- **Representative** of the urban areas in the Swiss plateau
- City facing the development of a **new masterplan** (current masterplan from 1994)
- Strong interest for **energy efficiency** and **renewable energy** issues (Energy City Label, European Energy Award GOLD, member of the European HOLISTIC Consortium)
- **Availability of data** (such as the solar cadaster and aerial thermography)
- Presence of the **Swiss Solar Connect**

![Neuchâtel map with potential for photovoltaic electricity production](image)
PHASE 1 – IDENTIFICATION OF ARCHETYPAL SITUATIONS

0) State of the art of building renewal process in Switzerland

Two types of existing studies

... urban data

Potential energy savings (for future scenarios)

Global strategic decisions (public institutions)

... single building projects

Specific application of materials and products

Reference in architectural practices (designers)

We propose...

To link both scales through the design of renovation strategies at building scale on residential archetypal situations, to extrapolate the results to the urban scale.
**PHASE 1 – IDENTIFICATION OF ARCHETYPAL SITUATIONS**

3) Definition of the residential archetypes (set of parameters)

![Graph showing construction period of residential buildings](image)

- Historical buildings
- Modernism
- Development of suburban zones and social housing
- Fuel crisis
- Oil crisis, real estate crisis
- Public housing
- First thermal regulations

Residential buildings ready to be refurbished in Neuchâtel

Référence: Office Fédérale de Statistique (OFS), 2014
PHASE 2 – DESIGN SCENARIOS WITH BIPV SOLUTIONS

0) State of the art of BIPV in renovation projects | Technology

We propose...

A technology selection based on the architectural design response that we want to obtain, evaluating their effect on the whole renovation process.

Available technologies

- Monocrystalline silicon (sc-Si)
- Polycrystalline silicon (mc-Si)
- Amorphous silicon (a-Si)
- Crystalline silicon cells (100x100 mm)
- Thin-film cell

Efficiency

- 17-22%
- 11-17%
- 4-8%
- 4-10%

Used (ratio)

- 85%
- 14%
- 1%

Available technologies

- Cadmium telluride
- Copper indium gallium selenide / sulphide
- Nanotechnology based solar cells

Reference: CSEM filter technology to make white solar modules (www.CSEM.ch)

Reference: IEA SHC Task 41 Solar energy systems in architecture (2012)
PHASE 2 – DESIGN SCENARIOS WITH BIPV SOLUTIONS

0) State of the art of BIPV in renovation projects | BIPV products

We propose...

Show real applications in renovation projects and possibilities of adaptation to different architectural situations, through construction details in real renovation projects.

Available Formats / tech.
- Flat (with PV cells)
- Flexible (Laminates)

Flexibility / can be designed
- Size and appearance
- Size, flexibility, shape and appearance

Compatibility / construction
- Compatible with the most commons constructions materials (glass or metal) in opaque or semi-transparent surfaces.

PV Features / exigencies / limitations
- Architects must to know capabilities, potential, specific applications, strengths an weakness of photovoltaics products in buildings.

Architectural design process

For architects and planners:

Available product specially designed by industry to be integrated in buildings offers the possibility to use PV as a “material” or building component in the design process.

Reference: IEA SHC Task 41 Solar energy systems in architecture (2012)
PHASE 2 – DESIGN SCENARIOS WITH BIPV SOLUTIONS

0) State of the art of BIPV in renovation projects | Best practice

We propose...

Make a catalog of renovation examples with BIPV, developed and assessed in detail to make a reference tool for architects.
PHASE 3 – MULTI-CRITERIA ASSESSMENT

0) State of the art of assessment methods and tools for BIPV | Quantitative aspects

<table>
<thead>
<tr>
<th>Method/tool</th>
<th>Renovation scenarios</th>
<th>Economy</th>
<th>Energy</th>
<th>Level of performance</th>
<th>LCA</th>
<th>PV</th>
<th>Comparison with the energy objectives</th>
<th>Objective</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heliodon</td>
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<td></td>
<td></td>
<td>(*)</td>
<td></td>
<td></td>
<td></td>
<td>Support tool for solar design in architecture</td>
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<tr>
<td>CECB</td>
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<td>*</td>
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<td>Cantonal energy certificate for buildings</td>
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<tr>
<td>PV-Syst</td>
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<td>Energy and economic assessment of photovoltaic installations</td>
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<tr>
<td>EpiQr+</td>
<td>*</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td>Diagnosis and cost calculation of renovation</td>
</tr>
<tr>
<td>INSPIRE Tool</td>
<td>*</td>
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<td>*</td>
<td>*</td>
<td>(*)</td>
<td></td>
<td></td>
<td>Tool for making strategic decisions during the early design phase (about 30% error)</td>
</tr>
<tr>
<td>LESOSAI</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>(*)</td>
<td>(*)</td>
<td></td>
<td>Justification for the energy label (regulation)</td>
</tr>
</tbody>
</table>

(*) Studied at a low level of detail  (**) SIA or Minergie, not Swiss Objectives

We propose...

Analysis (workflow) with different tools, using a holistic approach to show the influence of BIPV on the renovation process and a comparison to Swiss objectives.
PHASE 3 – MULTI-CRITERIA ASSESSMENT

0) State of the art of assessment methods and tools for BIPV | Qualitative aspects

Guidelines based on visual impact

- two approaches ...
  - ... geometrical recommendations
  - ... visual sensitivity

Used by public authorities to create our recommendations
Aim to hide the installations in order to maintain the architectural quality

We propose...

Using BIPV to develop a new architectural language and do the assessments through a group of stakeholders involved in the renovation process (experts and non-experts).
**PHASE 3 – MULTI-CRITERIA ASSESSMENT – FIRST CASE STUDY**

**Daylight Autonomy** | 300 lux | Occupation 8 am – 10 pm | Time ratio with more than 300 Lux

**Spatial Daylight Autonomy** | 300 lux | Surface ratio with > 50% of time with more than 300 lux

S1: **29.67 %**   
S2: **28.23 %**
PHASE 3 – MULTI-CRITERIA ASSESSMENT – FIRST CASE STUDY

Solar exposure study | Irradiation thresholds of cost-effectiveness for each technology

Current prices

![Current prices graph showing payback time for different annual irradiation thresholds (kWh/m² per year).]

2020 prices

![2020 prices graph showing payback time for different annual irradiation thresholds (kWh/m² per year).]
PHASE 3 – MULTI-CRITERIA ASSESSMENT – FIRST CASE STUDY

Solar exposure study | Orientation sensitivity study

![Graph showing kWh/m² based on window railing orientation]

![Graph showing kWh/m² based on window frame orientation]

- **Window railing**
  - Orientation (°): 0, 45, 90, 135, 180, 225, 270, 315
  - kWh/m² range:
    - 0 to 1500 kWh/m²
  - Graph illustrates the kWh/m² for different orientations.

- **Window frame**
  - Orientation (°): 0, 45, 90, 135, 180, 225, 270, 315
  - kWh/m² range:
    - 0 to 1500 kWh/m²
  - Graph illustrates the kWh/m² for different orientations.

Legend:
- **Anual Irradiation (kWh)**
- **Mean (kWh per m²)**
PHASE 3 – MULTI-CRITERIA ASSESSMENT – FIRST CASE STUDY

Solar exposure study | Orientation sensitivity study

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**Opaque facade**

- | kWh/m² | Orientation (°) |
---|---|---|
0 | 50000 | 0 |
50 | 100000 | 45 |
100 | 150000 | 90 |
150 | 200000 | 135 |
200 | 250000 | 180 |
250 | 300000 | 225 |
300 | 350000 | 270 |
350 | 400000 | 315 |

**Roof**

- | kWh/m² | Orientation (°) |
---|---|---|
0 | 50000 | 0 |
50 | 100000 | 45 |
100 | 150000 | 90 |
150 | 200000 | 135 |
200 | 250000 | 180 |
250 | 300000 | 225 |
300 | 350000 | 270 |
350 | 400000 | 315 |

Legend:
- Anual Irradiation (kWh)
- Mean (kWh per m²)
0. Active Interfaces project

www.activeinterfaces.ch
MAIN GOALS OF ACTIVE INTERFACES PROJECT

- Identification of the *operational barriers* for massive penetration of PV in renovation projects in Switzerland

- Development of *alternative and novel strategic approaches* for BIPV in urban renewal processes - from industrial R & D to implementation by end users

- Concrete *experimentation on real case studies* of urban renewal processes

- Establishment of *concrete recommendations* to achieve a breakthrough in the current practice in Switzerland
SUBPROJECTS

• Project 01 – Technology
• Project 02 – Design
• Project 03 – Socio-economy
• Project 04 – Assessment
• Project 05 – Dissemination
SUBPROJECTS

- Project 01 – Technology
- Project 02 – Design
- Project 03 – Socio-economy
- Project 04 – Assessment
- Project 05 – Dissemination
OBJECTIVES | Urban design

- Estimate **real BIPV production** at urban-scale.
- Integrate solar energy considerations into **regulations** and **masterplans**
- Support decision-makers planning the building integration of photovoltaics to respond to the **need for renewable energy** while **preserving the quality of the urban environment**
OBJECTIVES | Architectural design

- Catalogue of best practices and report on design obstacles
- Development of a residential typology based on the archetypal situations
- Development of urban renewal scenarios for each archetypal situation: architectural design of bioclimatic and active building envelopes
- Detailed multi-criteria assessment of proposed BIPV solutions:
  - quantitative (energy, environment, thermal and visual comfort, global costs, LCA)
  - qualitative (acceptance)