IDEAS LUNCH LAST LIPID

INTEGRATED DESIGN, ARCHITECTURE AND SUSTAINABILITY

Life-cycle analysis of renovation projects with Building-Integrated Photovoltaics: Influence of energy use scenarios

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ÉCOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE | active interfaces | 70 NRP Energy Turnaround National Research Programme

CONTEXT | Switzerland

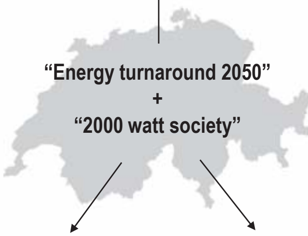
Importance of **urban renewal** for the evolution of the built environment towards sustainability

[**1,500,000** existing residential buildings to be renovated]

[OFS, 2014]

Annual objectives	2005	2100
Primary non-renewable energy, Mean power per person [W]	5800	2000
GHG emission [tCO_2]	8.6	1.0

[SIA 2040, 2011]



- Leave nuclear electricity production
- Reduce the use of fossil energy and CO_2 emissions

	2020	2035	2050
Evolution of global energy consumption per person	-16%	-43%	-54%
Evolution of electric energy consumption per person	-3%	-13%	-18%

[SFOE, 2015]

Promotion of photovoltaics (PV)

[**30%** coverage of electricity demand]

[IEA, 2002]

Integrated design strategies with BIPV

[Synergies to **increase acceptance** of projects for a massive penetration of PV in Switzerland]

[MoPEC, 2014], [ModEnHA, 2015], [Programme Bâtiment, 2016] and [Minergie, 2017]

AGENDA

CONTEXT | Switzerland

Current practices and existing regulations* are **far from Swiss objectives**

⬇

Architectural design could accelerate the process of **linking BIPV** with **renovation of residential building stock**

* [SIA 380/1, 2016]

View from Microcity building roof | Neuchâtel

OBJECTIVES | Expected research outcomes

- Development of **convincing reference design examples** of renovation projects with BIPV using real buildings
- Detailed multi-criteria **assessment** of proposed BIPV solutions :
  - **quantitative** (energy, environment, thermal and visual comfort, global costs, LCA)
  - **qualitative** (acceptance) – workshop with experts and non-experts

View from Ch. de Belleroche | *Neuchâtel*

CASE STUDIES | Current status

Archetype 1 – built in 1919

Rue du Beauregard 1 (Neuchâtel)

- 4 stories (8 apartments)
- Level of protection: II - common
- Heating system: central heating (Oil boiler)
- Energy reference surface: 788 m²

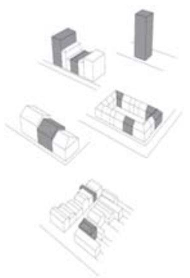
Archetype 4 – built in 1972-73

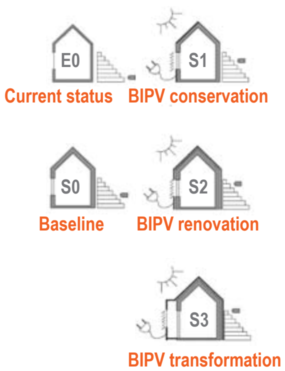
Rue Troncs 12 and 14 (Neuchâtel)

- 10 stories + 1 attic (52 apartments)
- Level of protection: II - common
- Heating system: central heating (Oil boiler)
- Energy reference surface: 5'263 m²

METHODOLOGY | Four main phases

Phase 1 Identification of archetypes (residential buildings) > **Phase 2** Case study selection > **Phase 3** Design scenarios with BIPV solutions > **Phase 4** Multi-criteria assessment





Energy and emissions

Life Cycle Analysis

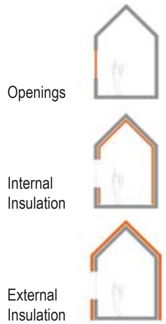
Photovoltaic installation

Indoor comfort

Cost-effectiveness

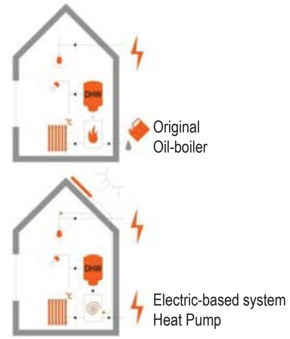
DESIGN SCENARIOS IMPLEMENTATION | Renovation strategies

Passive strategies



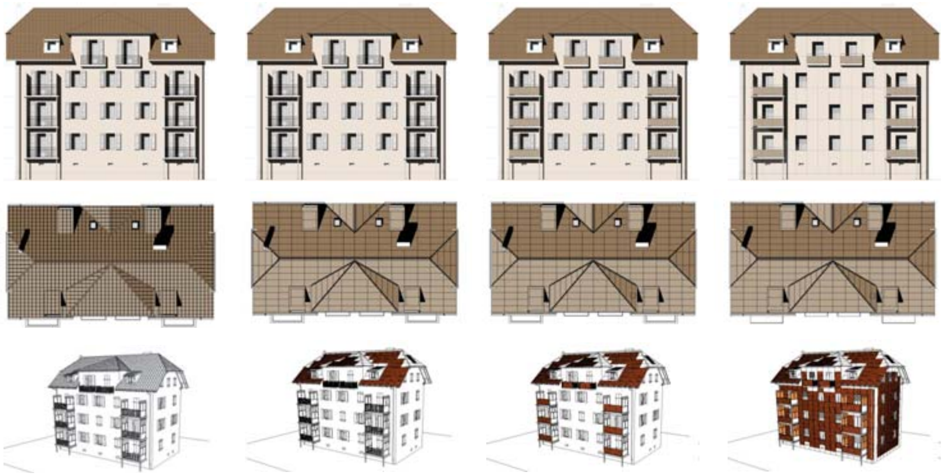
Swiss targets: 2000 Watt Society
[SIA 2040, 2011]

Active strategies



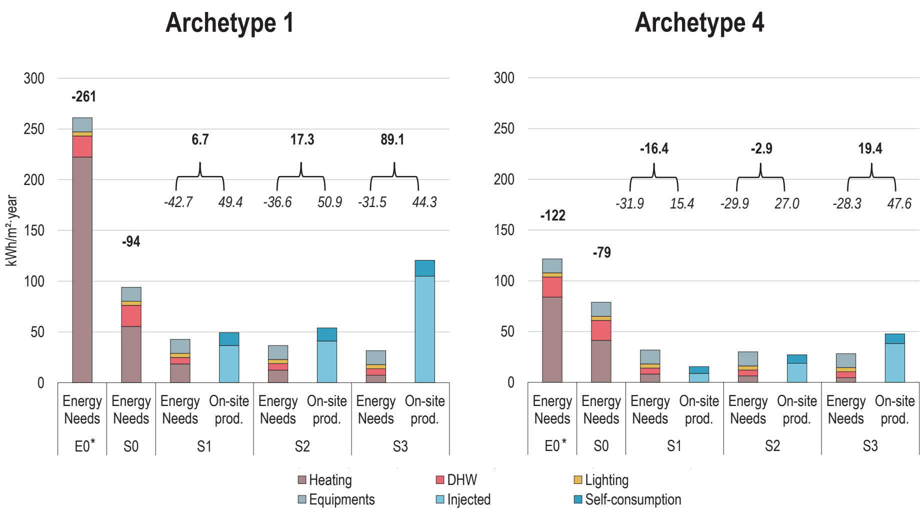
DESIGN SCENARIOS IMPLEMENTATION | Archetype 1

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



S. Aguacil Moreno, S. Lufkin and E. Rey. ACTIVE INTERFACES. Holistic design strategies for renovation projects with building-integrated photovoltaics (BIPV): case study from the 1900s in Neuchâtel (Switzerland).15. Nationale Photovoltaik-Tagung 2017, Lausanne, Switzerland, 2017.

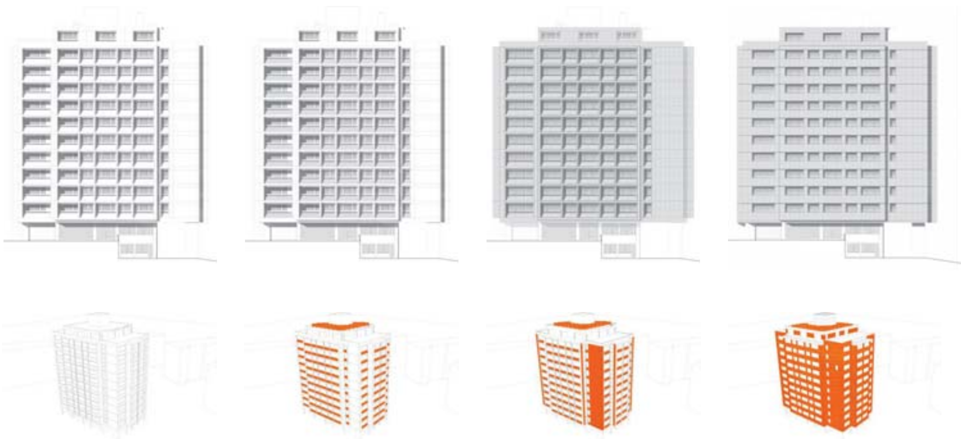
DESIGN SCENARIOS IMPLEMENTATION | Checking the energy performance



* Calibrating the energy model using real consumption

DESIGN SCENARIOS IMPLEMENTATION | Archetype 4

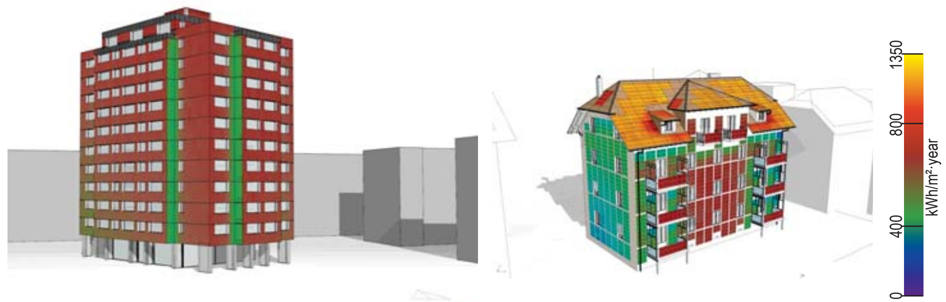
S0-Baseline | **S1-Conservation** | **S2-Renovation** | **S3-Transformation**



S. Aguacil Moreno, S. Lufkin and E. Rey. Towards integrated design strategies for implementing BIPV systems into urban renewal processes: first case study in Neuchâtel (Switzerland). Sustainable Built Environment (SBE) regional conference, Zurich, Switzerland, 2016.

ACTIVE SURFACES POTENTIAL | Energy balance

From the **design phase**, we have identified all possible active surfaces using standard and custom-size PV panels.



ACTIVE SURFACES POTENTIAL | Energy balance

From the **design phase**, we have identified all possible active surfaces using standard and custom-size PV panels.

➡ Does the energy assessment have to take into account **100% of identified active surfaces** for renovation projects ?

BIPV APPROACH | Renovation of existing buildings in urban areas

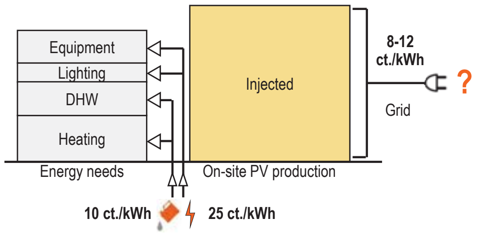
- Linking **the BIPV installation to the needs of the building**, as a **symbiosis** relationship:
  - Building offers a support to the active elements
  - BIPV panels offers protection (façade element) and electricity produced on-site
- Based on **life-cycle analysis** and **cost**, taking into account **whole renovation process**, starting from design phase to **ensure the architectural quality**
- Comparing results with **2000 Watt society targets**

a) 100% active surfaces considered

b) Selection of active surfaces

c) Integration of batteries

BAPV APPROACH | Exclusively feed-in-tariff approach with non-integrated PV



Sizing criteria:

- **Independent** from the building demand
- PV installation **as big as possible to maximise injection using BAPV** (building-attached photovoltaics) instead of BIPV
- Best orientation of PV panels **using building as a support**
- Based on **financial aspects** (fast return on investment – energy service company)

SEAT Manufacture in Martorell (Barcelone)

BIPV APPROACH | Definitions

Annual electricity coverage ratio: Ratio between total production of PV electricity and total electricity needs.

(1) $$\textbf{Anual electricity coverage ratio}\ [\%] = \frac{\text{Total PV production}}{\text{Total anual electricity needs}} \times 100$$

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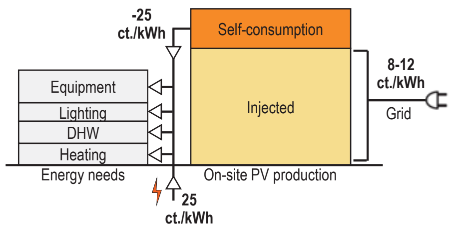
Self-consumption (SC) ratio: Percentage of electricity produced by the BIPV system that is consumed directly by the building. Shows the level of utilization of the PV installation.

(2) $$\textbf{Self-consumption ratio } [\%] = \frac{\sum_0^{8760} \text{Hourly PV electricity consumption on-site}}{\text{Total PV production}} \times 100$$

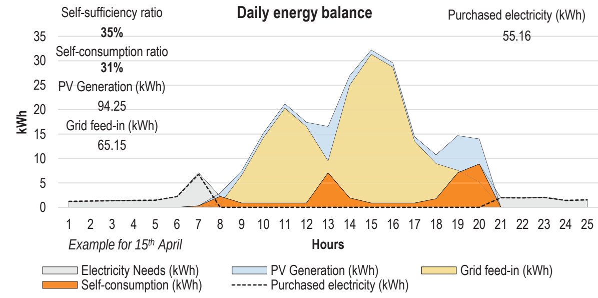
BIPV APPROACH | Scenario with 100% active surfaces injecting the overproduction



Strategies:

Taking into account **100% of potential active surfaces.**
Replacing existing **HVAC by electricity-based** system with heat-pump to increase SC.

100% active surfaces considered



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(2) $$\textbf{Self-consumption ratio } [\%] = \frac{\sum_0^{8760} \text{Hourly PV electricity consumption on-site}}{\text{Total PV production}} \times 100$$

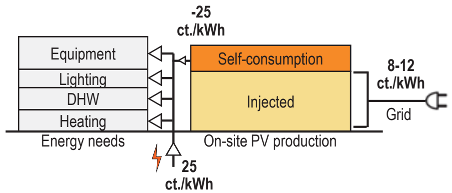
Self-sufficiency (SS) ratio: Ratio between the PV electricity consumed on-site and the total electricity needs. Shows the real coverage of the demand for electricity on the basis of self-consumption, equivalent to the level of energy independence of the building.

(3) $$\textbf{Self-sufficiency ratio } [\%] = \frac{\sum_0^{8760} \text{Hourly PV electricity consumption on-site}}{\text{Total electricity needs}} \times 100$$

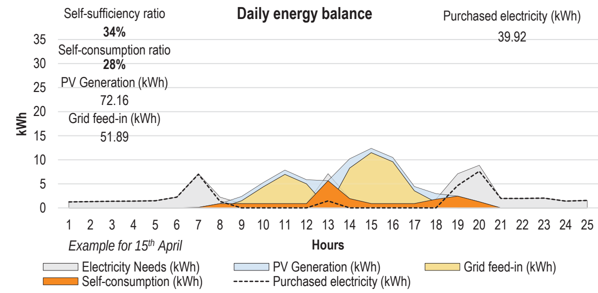
BIPV APPROACH | Scenario selecting active surfaces regarding SC and SS

Strategies:

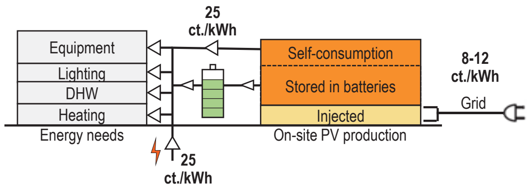
Selection of active surfaces to **maximise self-consumption and self-sufficiency**, **minimizing the overproduction** (avoiding excessive electricity injection into the grid).



Selecting active surfaces



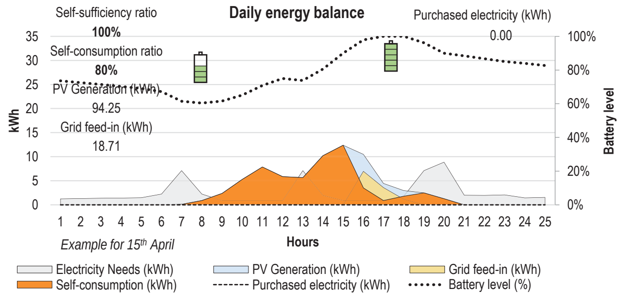
BIPV APPROACH | Scenario using batteries to increase self-consumption



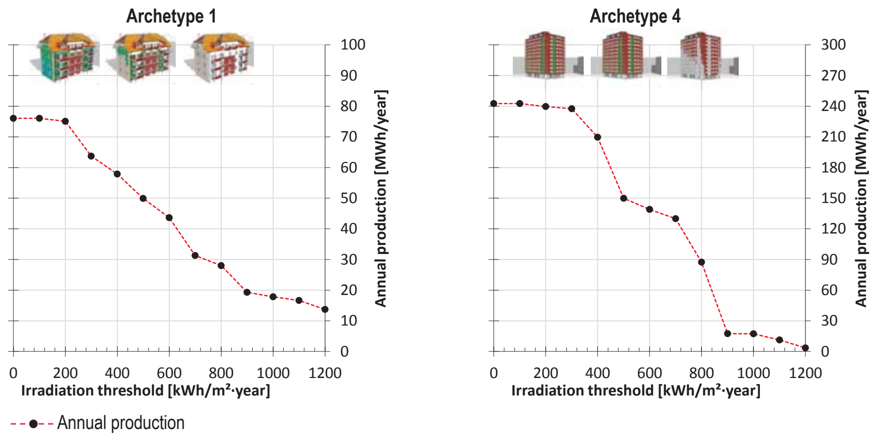
Strategies:

Introducing batteries to store overproduction, sizing it to cover mean daily demand.

Integrating batteries



BIPV APPROACH | Selection of active surfaces



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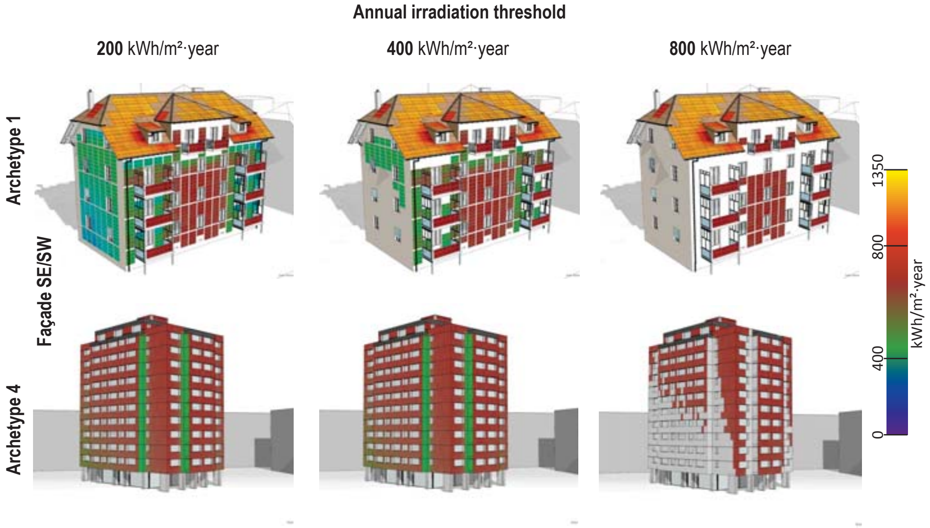

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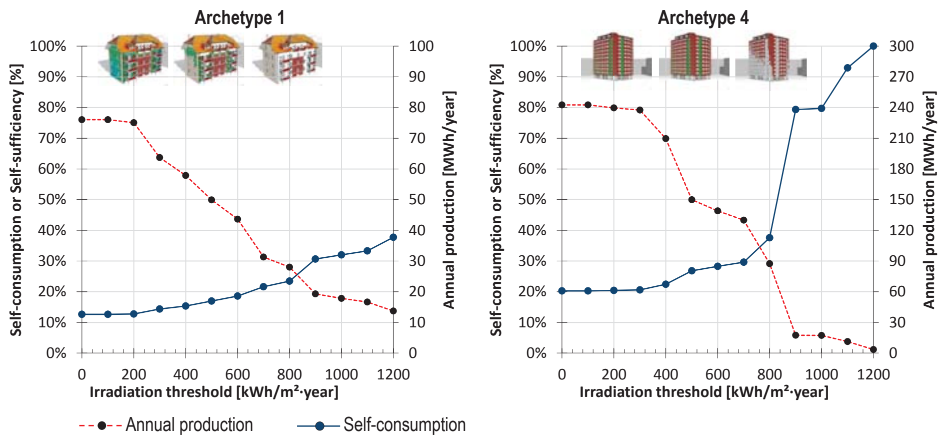

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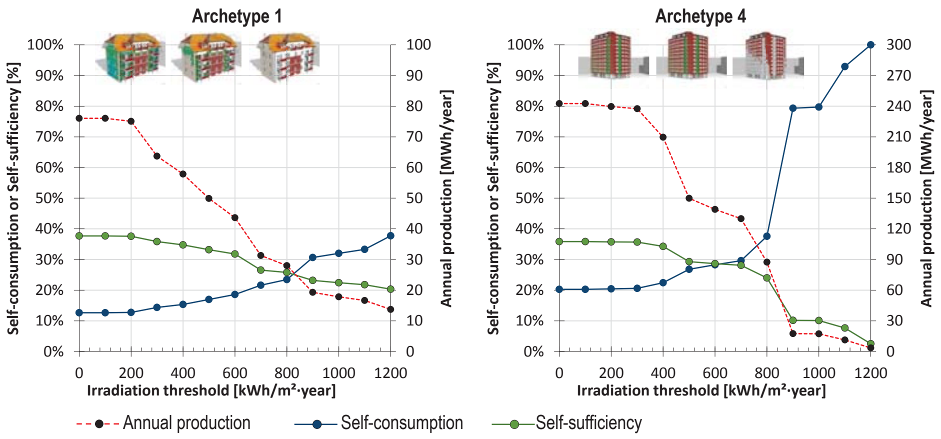

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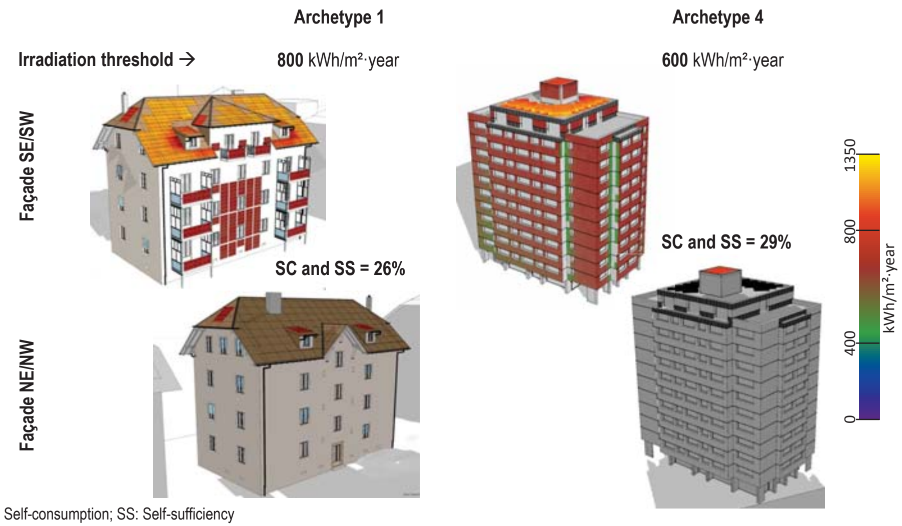

SC: Self-consumption; SS: Self-sufficiency

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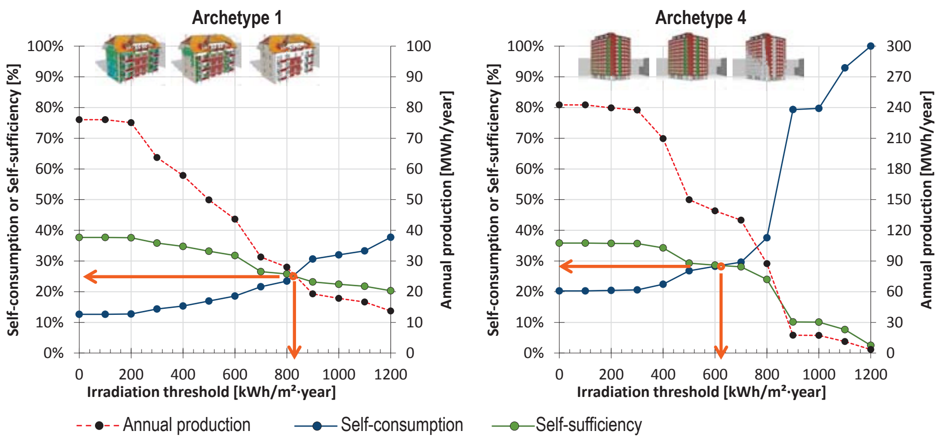

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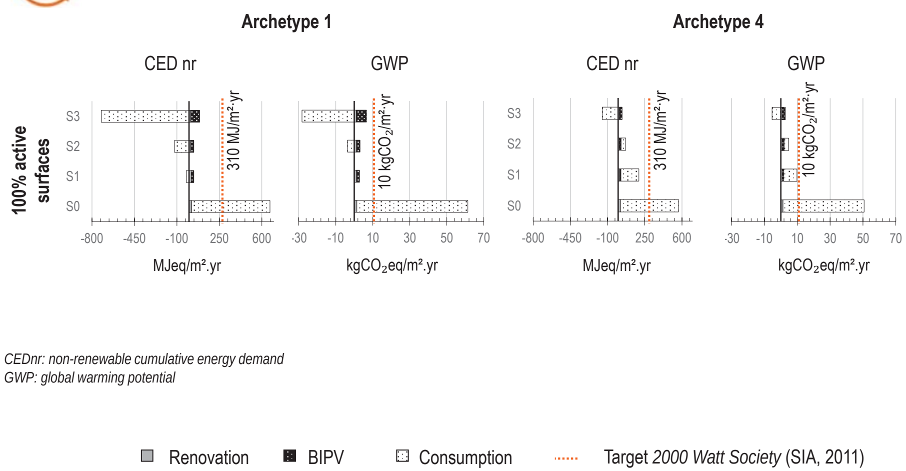
COMPARISON | archetypes and energy use scenarios

LCA - Life Cycle Analysis



CEDnr: non-renewable cumulative energy demand
GWP: global warming potential

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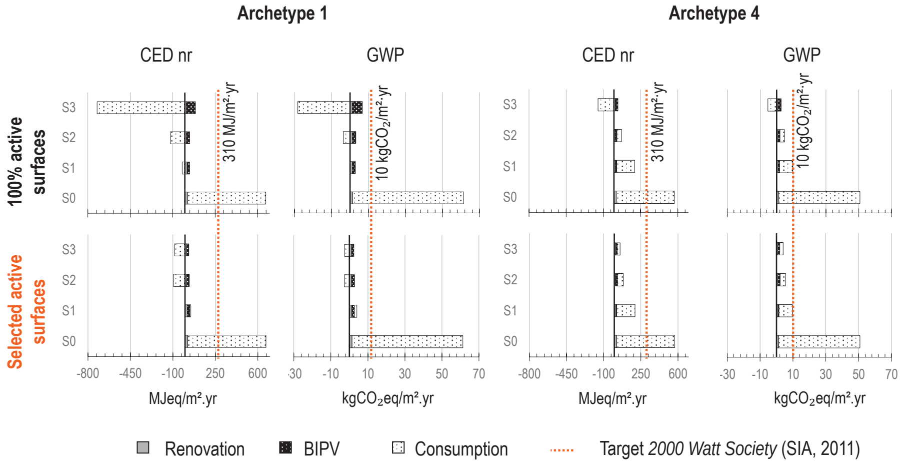

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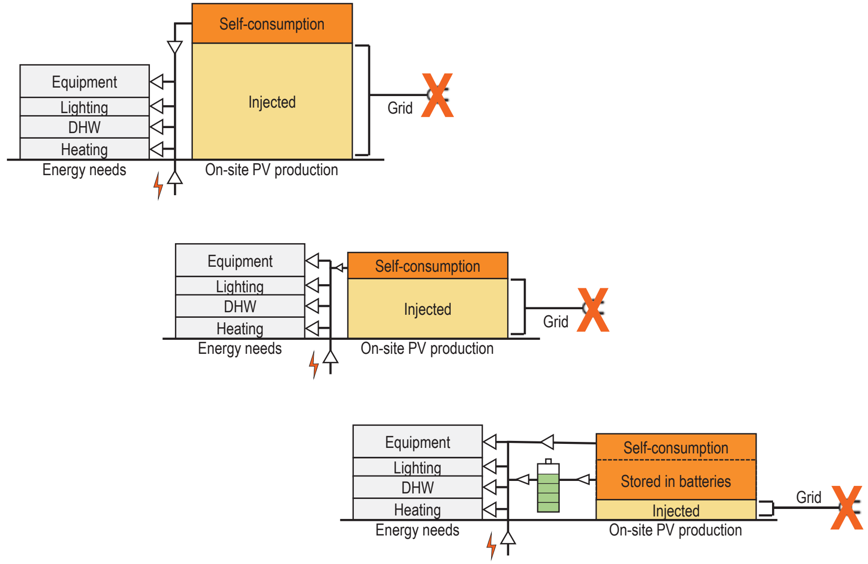

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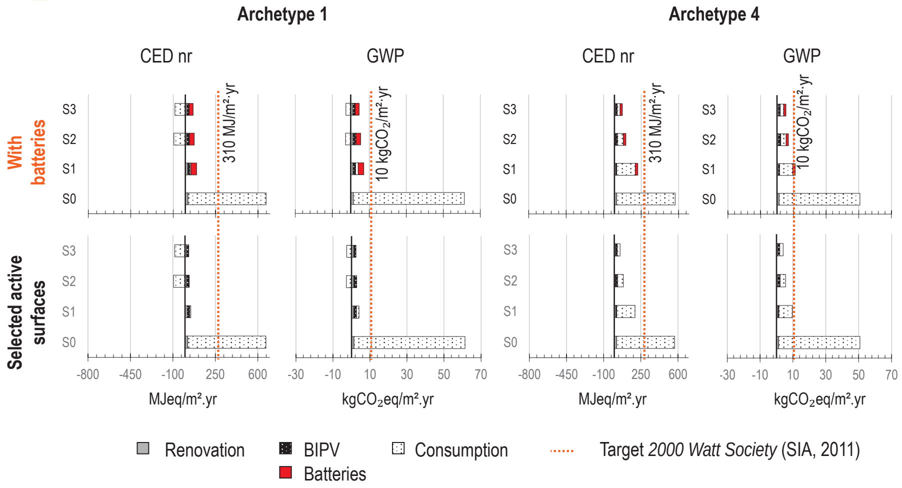

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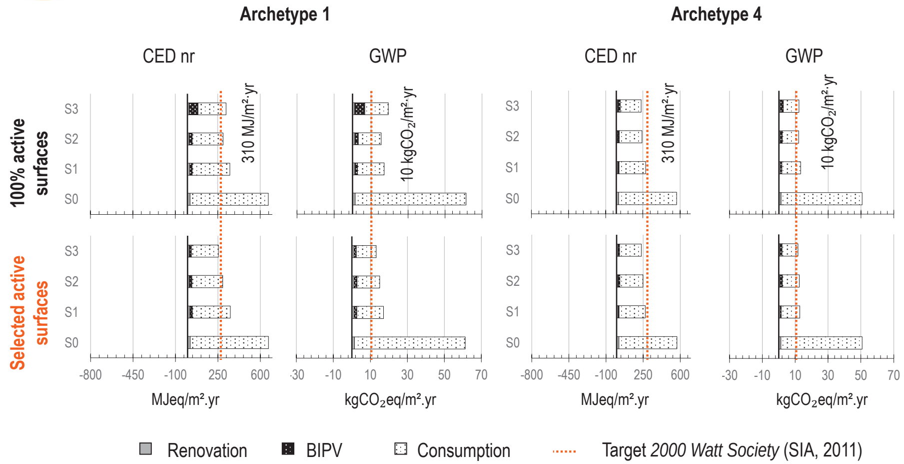
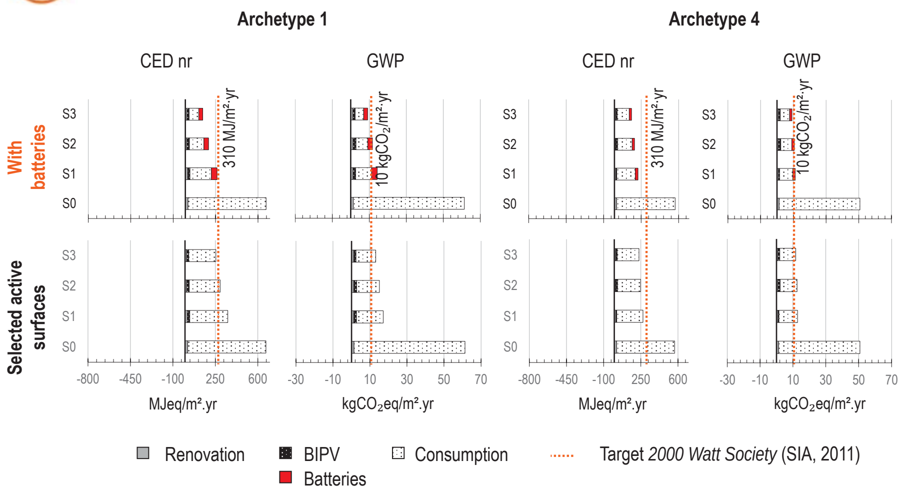
COMPARISON | archetypes and energy use scenarios

LCA - Life Cycle Analysis – without injection



COMPARISON | archetypes and energy use scenarios

LCA - Life Cycle Analysis – without injection

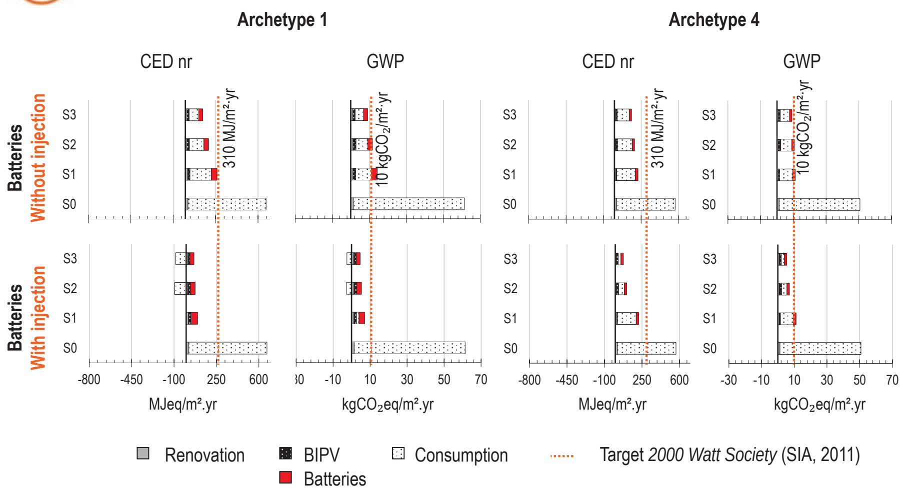


SPECIAL HIGHLIGHTS | Preliminary findings

- Energy renovation projects without PV integration are **no longer an option** if we want to achieve **long-term carbon and energy targets**.
- Results of the two case studies highlight the **importance of selecting the active surfaces** to achieve carbon neutrality.
- These elements allow us to achieve the performance objectives **in a more rational way by sizing the PV installation to minimize the grid-injected energy**. This in turn allows avoiding the intrinsic problem linked to **decreasing prices of injected electricity and the incompatibilities with the existing grid.**
- **Batteries could have a key role** to achieve the Swiss targets if the injection into the grid is not possible.

COMPARISON | archetypes and energy use scenarios

LCA - Life Cycle Analysis – the role of batteries



WORK IN PROGRESS | Next steps and milestones

- **Finalization of the two first case studies**
  - Realization of expressive 3D visualizations
- **Three other case studies (activities conducted in parallel)**
  - Detailed design scenarios for each case study
  - Optimization and detailed assessment of design scenarios
  - Realization of expressive 3D visualizations
- **In-depth comparative analysis of financial parameters**
- **Cross comparison of modeling scenarios (e.g. weather, vegetation)**
- **Workshop with experts / workshop with non-experts** (qualitative assessment of the level of acceptance of the design propositions)