IDEAS LUNCH LAST LIPID

INTEGRATED DESIGN, ARCHITECTURE AND SUSTAINABILITY

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

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Thesis Director:

Prof. Emmanuel REY

ÉCOLE 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)

Sustainable urban development
(renovation of building stock)

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)

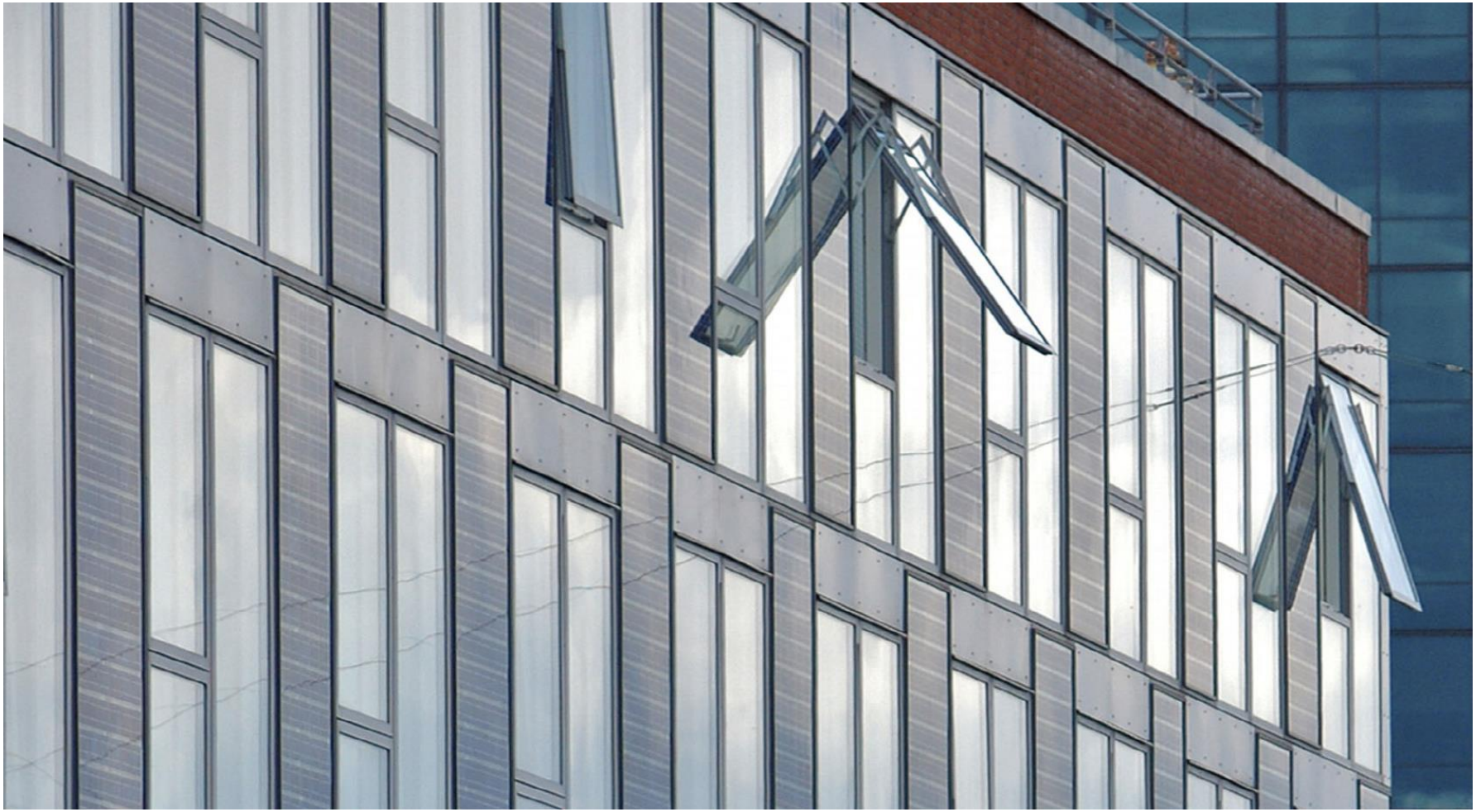
CURRENT PRACTICE | Design barriers

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

View from Microcity building roof | Neuchâtel

2.Hypothesis and Research Question

Hypothesis

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

Hypothesis

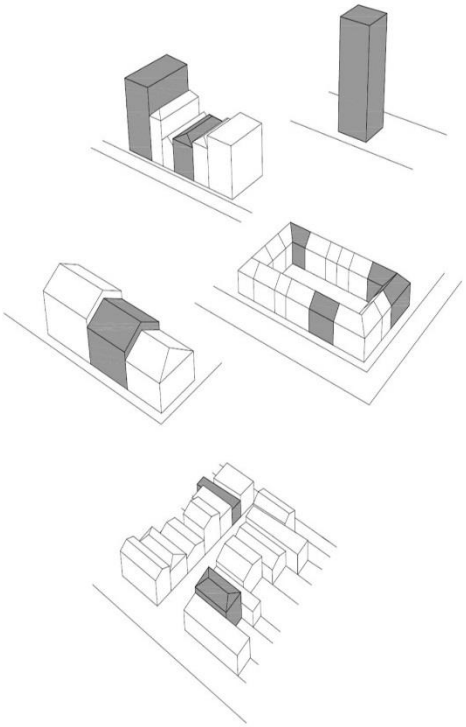
« BIPV is an "architectural material" that could help stimulate sustainable urban renewal processes »

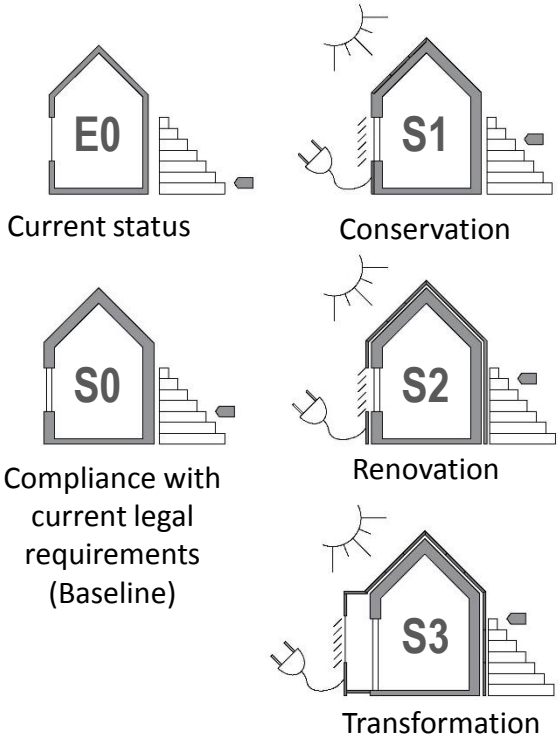
Research question

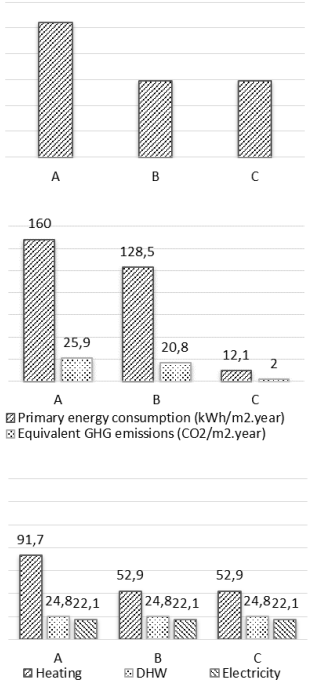
« How can BIPV be made part of common practice in renewal projects in the urban context ? »

3.Methodology

Three-step methodology







(PHASE 1)
IDENTIFICATION OF ARCHETYPAL SITUATIONS

>

(PHASE 2)
DESIGN SCENARIOS WITH BIPV SOLUTIONS

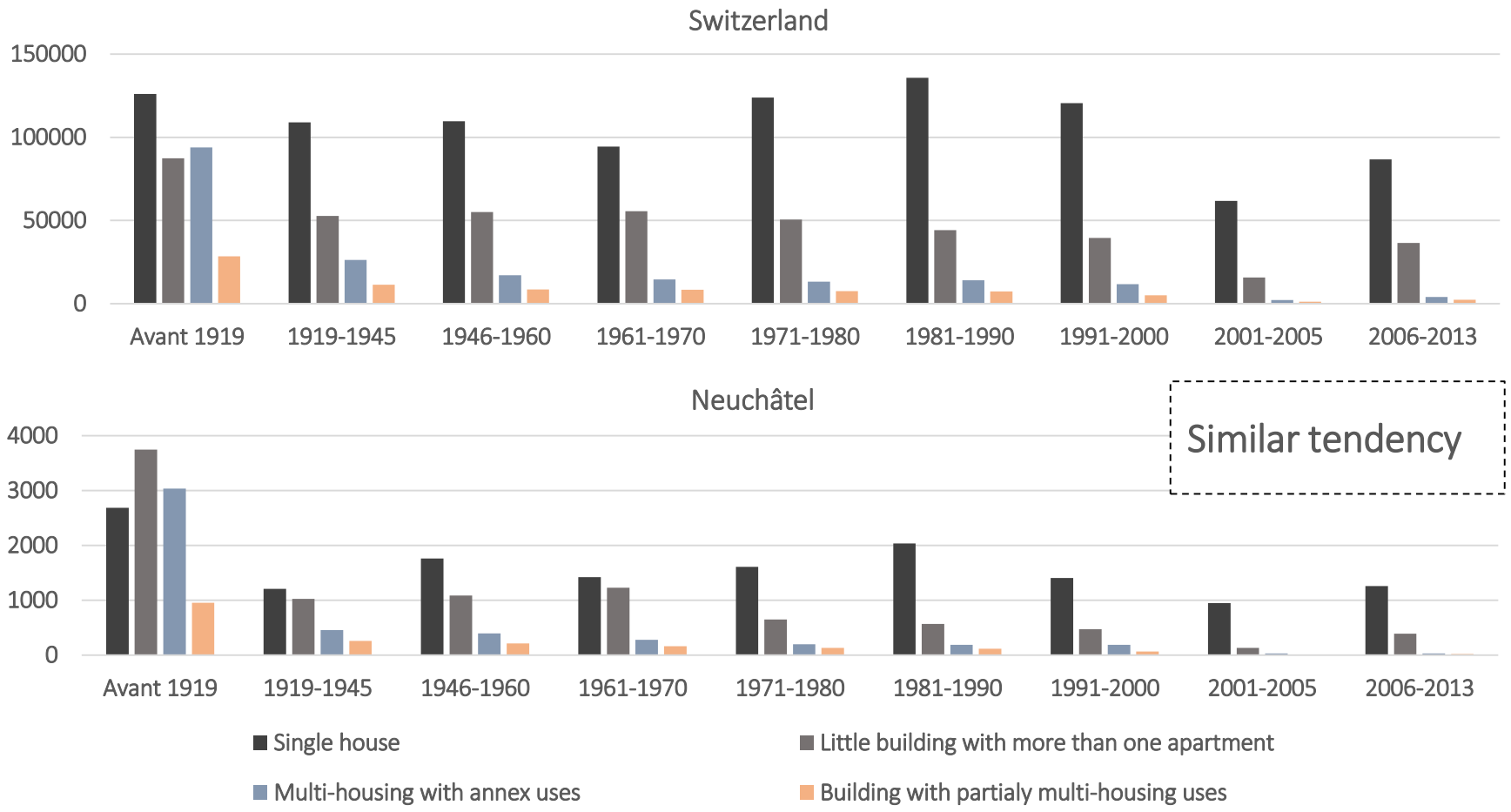
>

(PHASE 3)
MULTI-CRITERIA ASSESSMENT

Methodology
PHASE 1 – Archetypal situations

PHASE 1 – IDENTIFICATION OF ARCHETYPAL SITUATIONS

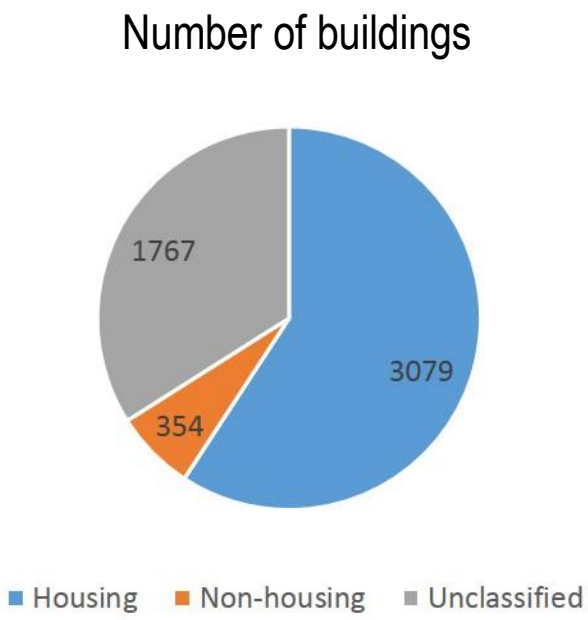
1) Neuchâtel as a representative city in Switzerland

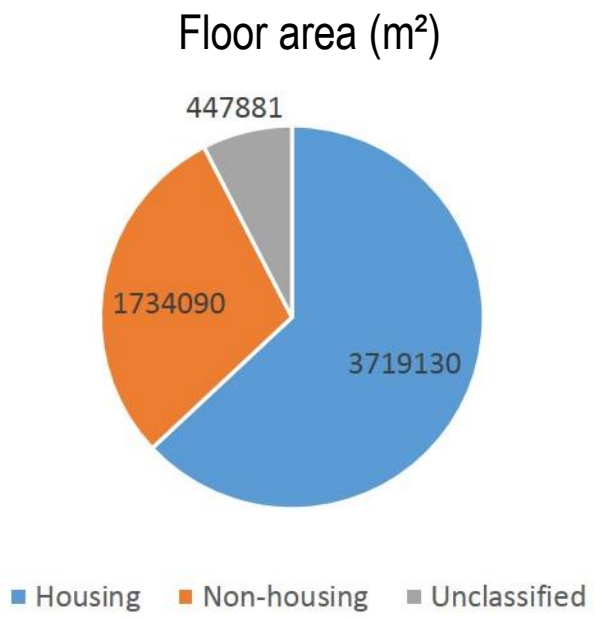


Référence: Office Fédérale de Statistique (OFS), 2014

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)

A - Construction period

before 1919 | 1919-1945 | 1946-1970 | 1971-1985 | 1986-1995 | 1996-2005

B - Urban context

Isolated building

Adjacent building

C – Roof potential

Flat roof

Sloped roof

D – Facade potential

1-4 floors

5-7 floors

>7 floors

E - Architectural quality
Level of protection

Interesting
I

Common
II

Unattractive
III

F - Type of owner

Co-ownership
(PPE)

Small owner
(<3 properties)

Large owner
(≥3 properties)

PHASE 1 – IDENTIFICATION OF ARCHETYPAL SITUATIONS

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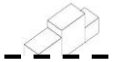


C – Roof potential

D – Façade potential

In order to extrapolate the results, we do not take into account:
Highly protected or special buildings

E - Architectural quality
Level of protection

~~Interesting~~ I | Common II | Unattractive III

F - Type of owner


Co-ownership (PPE)

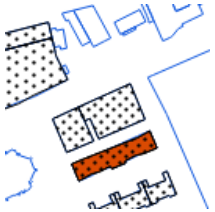
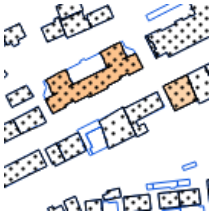

Small owner (<3 properties)


Large owner (≥3 properties)

PHASE 1 – IDENTIFICATION OF ARCHETYPAL SITUATIONS – Urban data analysis

Main parameter

A - Construction period

	1	2	3	4	5	6
	Before 1919	1919-1945	1946-1970	1971-1985	1986-1995	1996-2005
						
						
Number of buildings	1234	315	631	464	76	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

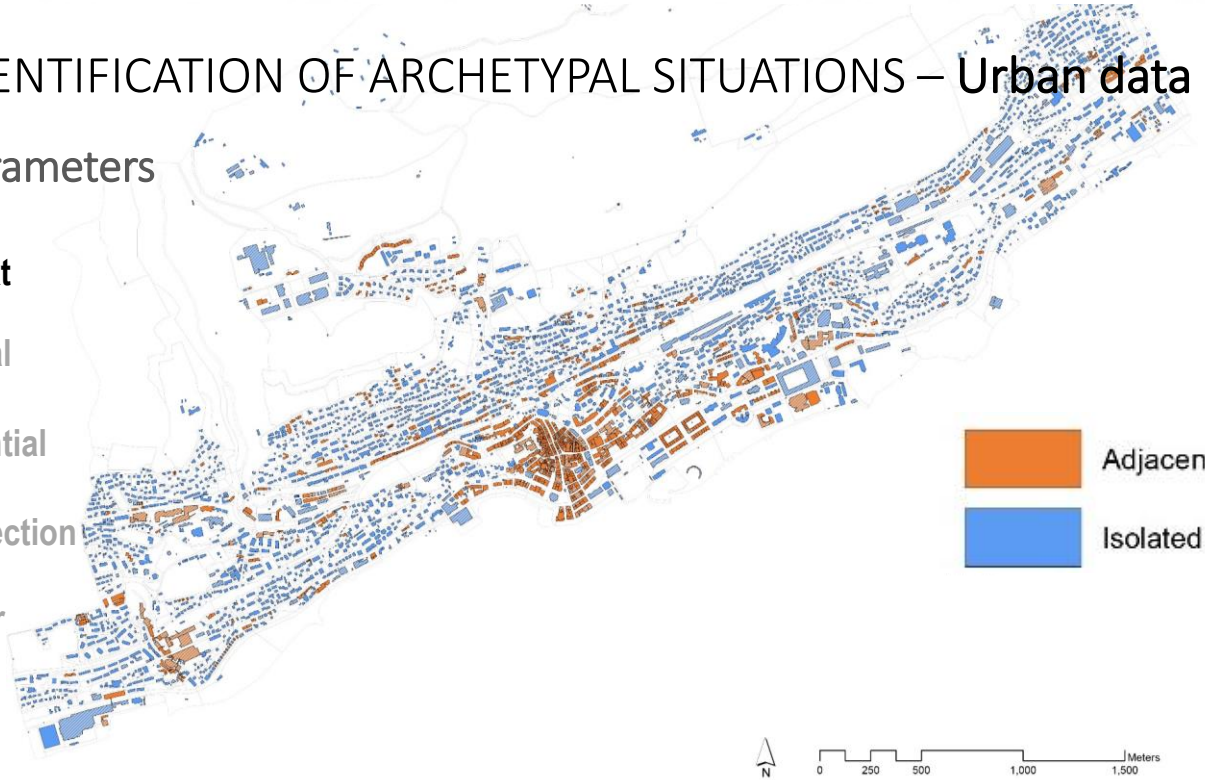
B – Urban context

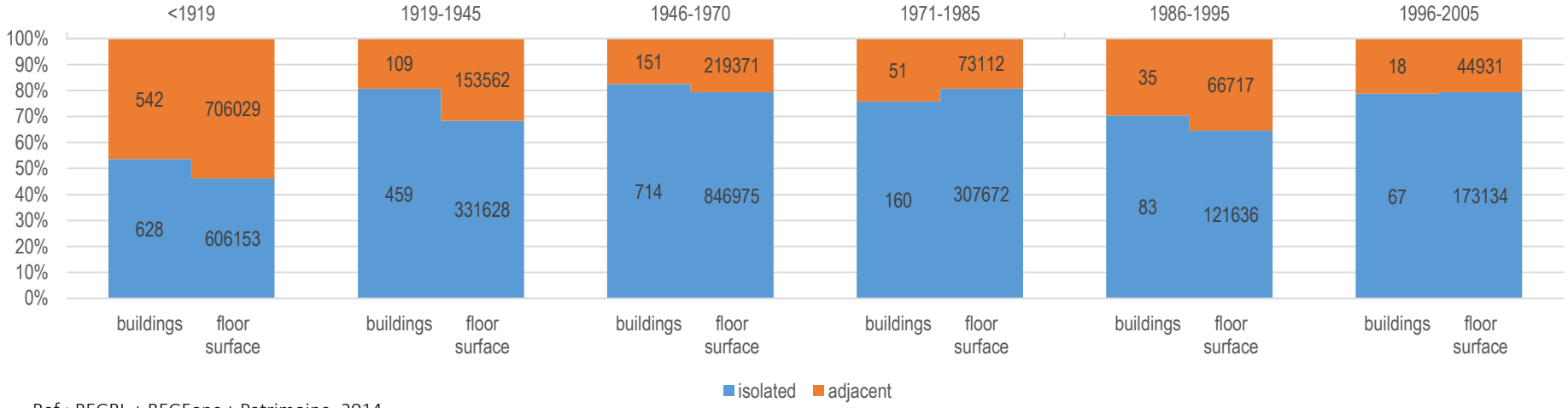
C – Roof potential

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

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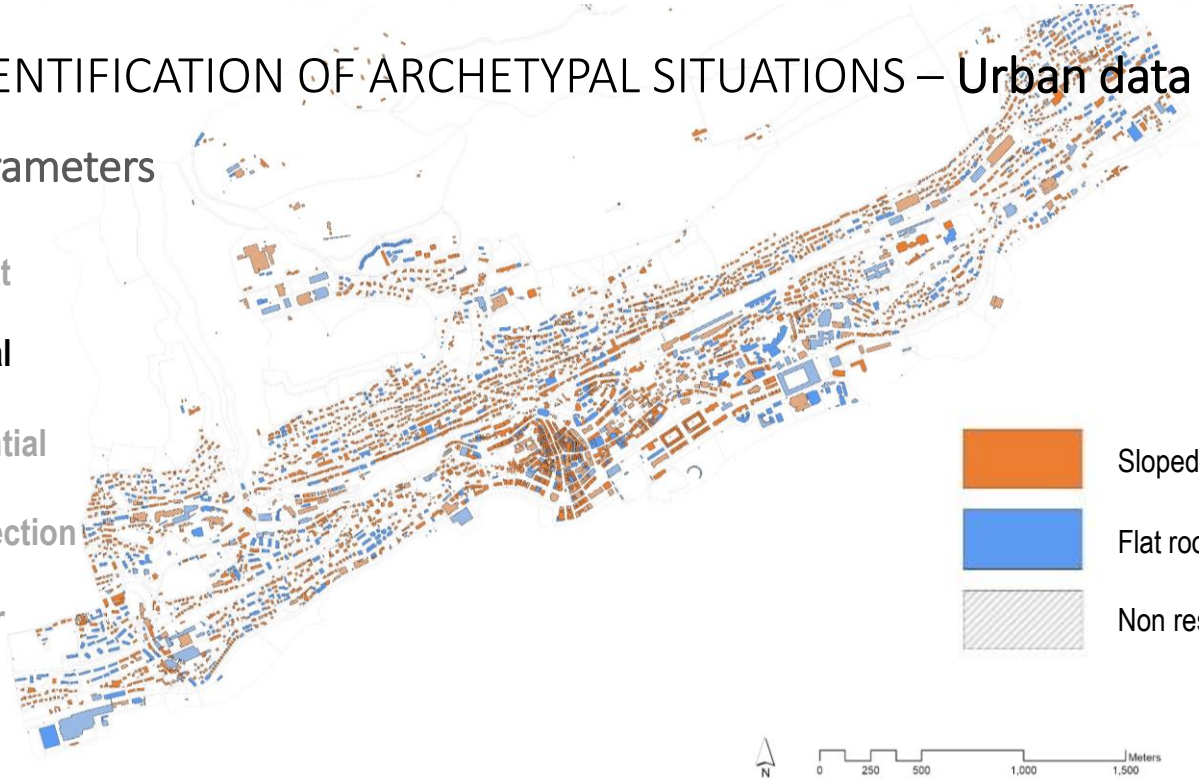
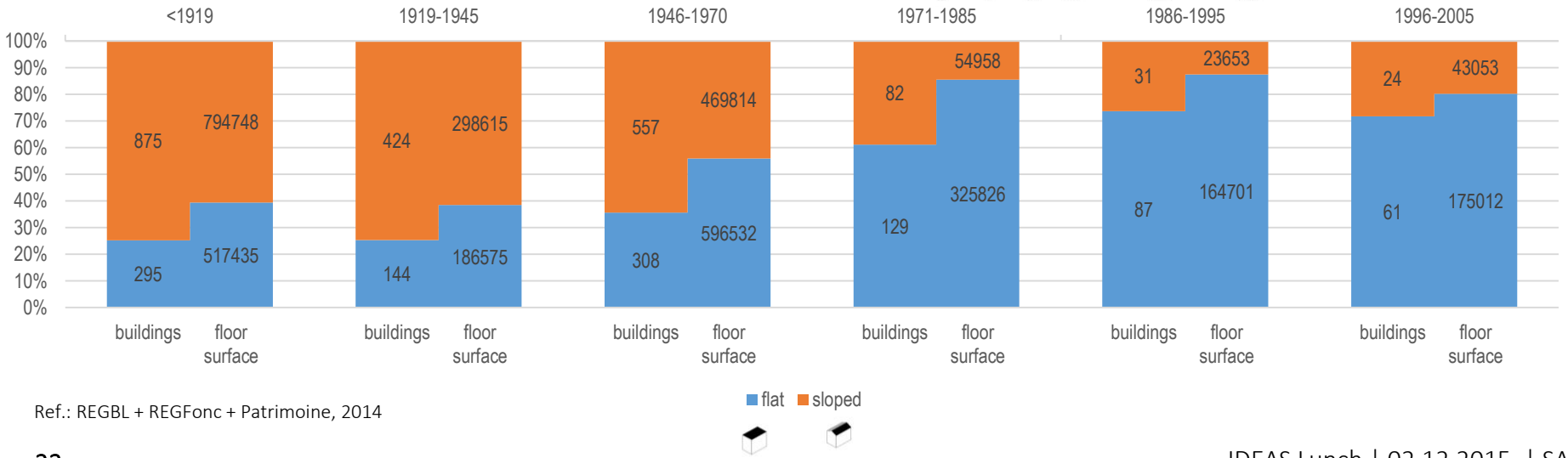
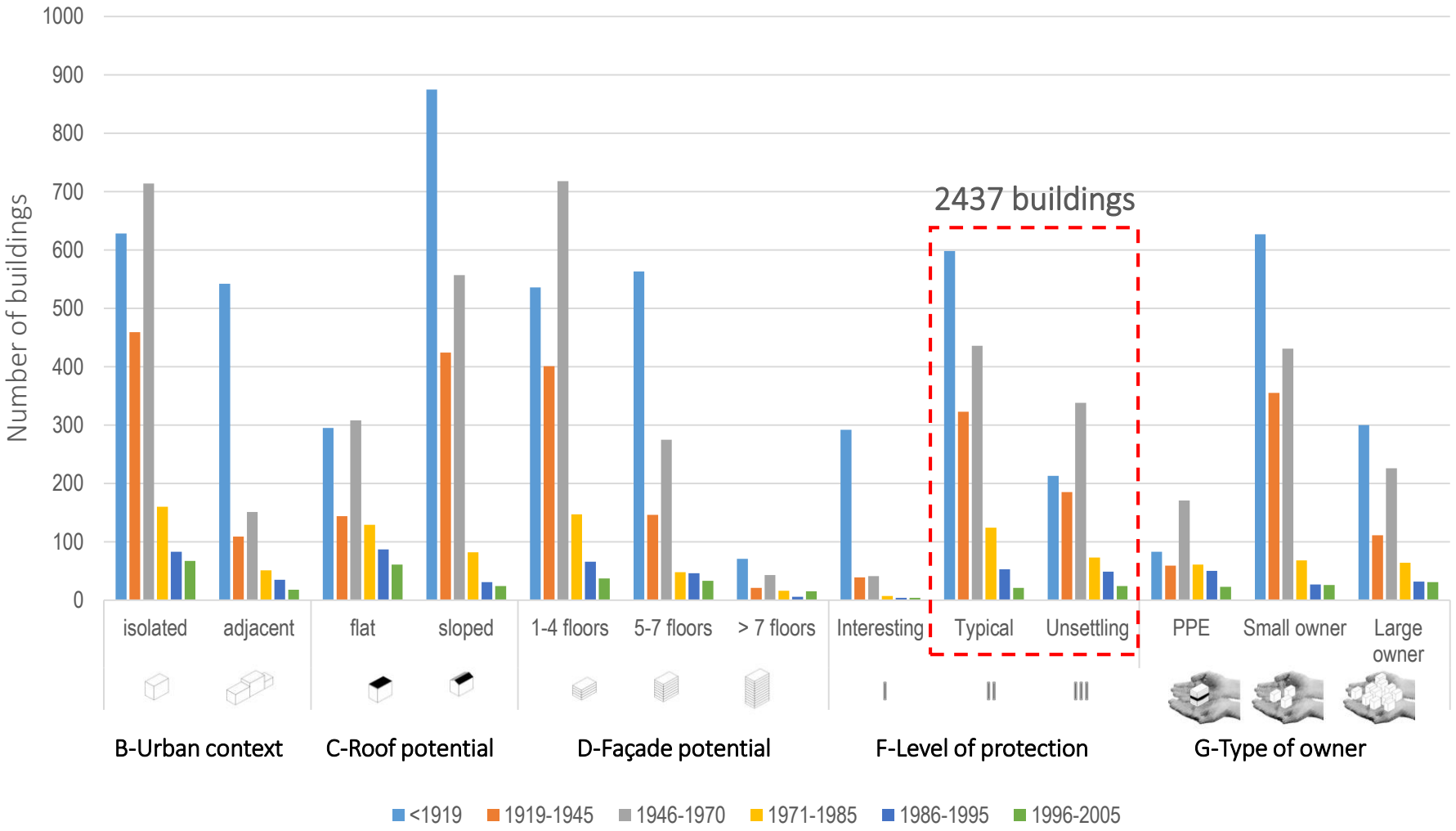




Ref.: REGBL + REGFonc + Patrimoine, 2014

PHASE 1 – IDENTIFICATION OF ARCHETYPAL SITUATIONS – Urban data analysis

Overview of all parameters (Neuchâtel)



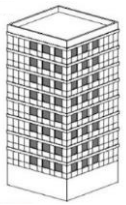
Ref.: REGBL + REGFonc + Patrimoine, 2014

PHASE 1 – IDENTIFICATION OF ARCHETYPAL SITUATIONS – Residential archetypes

Example of parameter combination - Residential archetype n° 4

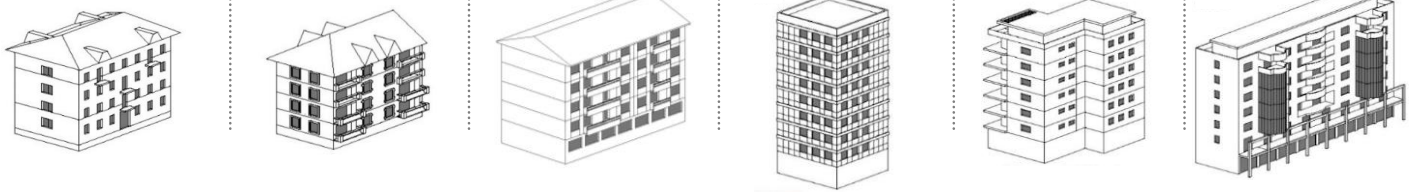
A - Construction period	before 1919	1919-1945	1946-1970	1971-1985	1986-1995	1996-2005
B - Urban context		Isolated building		Adjacent building		
C – Roof potential		Flat roof		Sloped roof		
D – Façade potential		1-4 floors	5-7 floors	>7 floors		
E - Architectural quality Level of protection		Interesting I	Common II	Unattractive III		
F - Type of owner		Co-ownership (PPE)	Small owner (<3 properties)	Large owner (≥3 properties)		

Arch. 4



PHASE 1 – IDENTIFICATION OF ARCHETYPAL SITUATIONS – Residential archetypes

A - Construction period	before 1919	1919-1945	1946-1970	1971-1985	1986-1995	1996-2005
B - Urban context	Adjacent building	Isolated building	Isolated building	Isolated building	Isolated building	Isolated building
C – Roof potential	Sloped roof	Sloped roof	Sloped roof	Flat roof	Flat roof	Flat roof
D – Façade potential	1-4 floors	1-4 floors	1-4 floors	>7 floors	5-7 floors	5-7 floors
E - Architectural quality Level of protection	Common II	Common II	Common II	Common II	Common / Unattractive II i / III	Common / Unattractive II i / III
F - Type of owner	Small owner (<3 properties)	Small owner (<3 properties)	Small owner (<3 properties)	Large owner (≥3 properties)	Co-ownership (PPE)	Large owner (≥3 properties)
	Arch. 1	Arch. 2	Arch. 3	Arch. 4	Arch. 5	Arch. 6



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

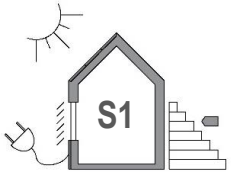
Methodology
PHASE 2 – Design scenarios

PHASE 2 – DESIGN SCENARIOS WITH BIPV SOLUTIONS

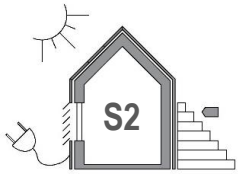
1) Definition of design renewal scenarios

Current status (detailed analysis of the case study)

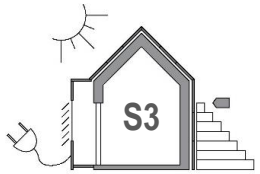
Baseline: Compliance with current legal requirements (current practices)



Conservation: **Maintaining the expression** of the building while improving the energy performance of the building (at least current legal requirements)



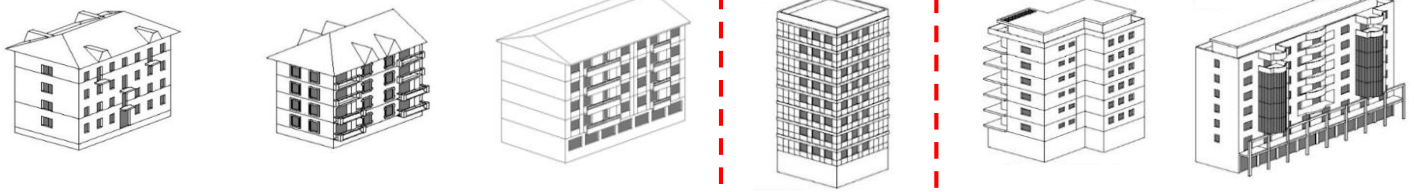
Renovation: **Maintaining the general expressive lines** of the building while reaching high energy performance (at least Minergie standard)



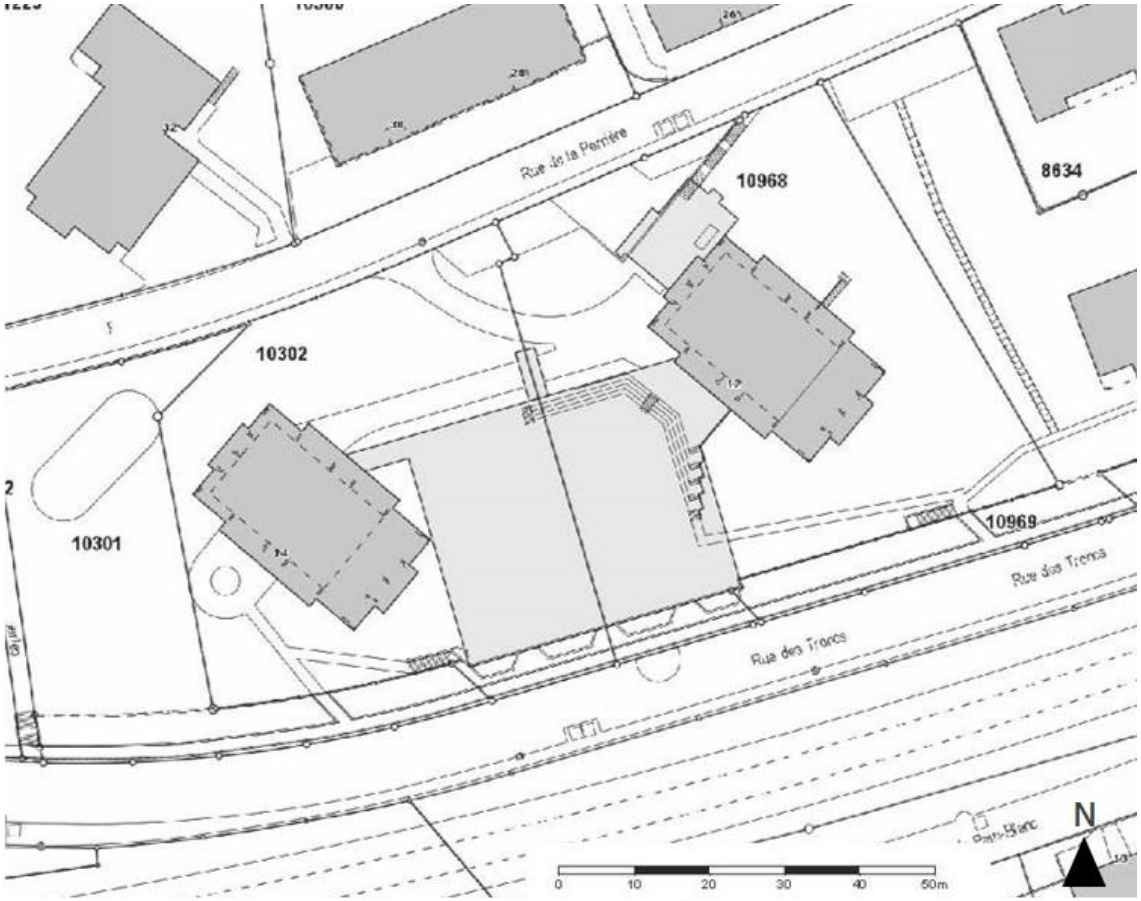
Transformation: **Best energy performance** and **maximum electricity production** possible with aesthetic and formal coherence over the whole building (at least 2000 Watt Society | Energy strategy 2050)

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

	Arch. 1	Arch. 2	Arch. 3	Arch. 4	Arch. 5	Arch. 6
A - Construction period	before 1919	1919-1945	1946-1970	1971-1985	1986-1995	1996-2005
B - Urban context	Adjacent building	Isolated building	Isolated building	Isolated building	Isolated building	Isolated building
C – Roof potential	Sloped roof	Sloped roof	Sloped roof	Flat roof	Flat roof	Flat roof
D – Façade potential	1-4 floors	1-4 floors	1-4 floors	>7 floors	5-7 floors	5-7 floors
E - Architectural quality Level of protection	Common II	Common II	Common II	Common II	Common / Unattractive II / III	Common / Unattractive II / III
F - Type of owner	Small owner (<3 proprieties)	Small owner (<3 proprieties)	Small owner (<3 proprieties)	Large owner (≥3 proprieties)	Co-ownership (PPE)	Large owner (≥3 proprieties)



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



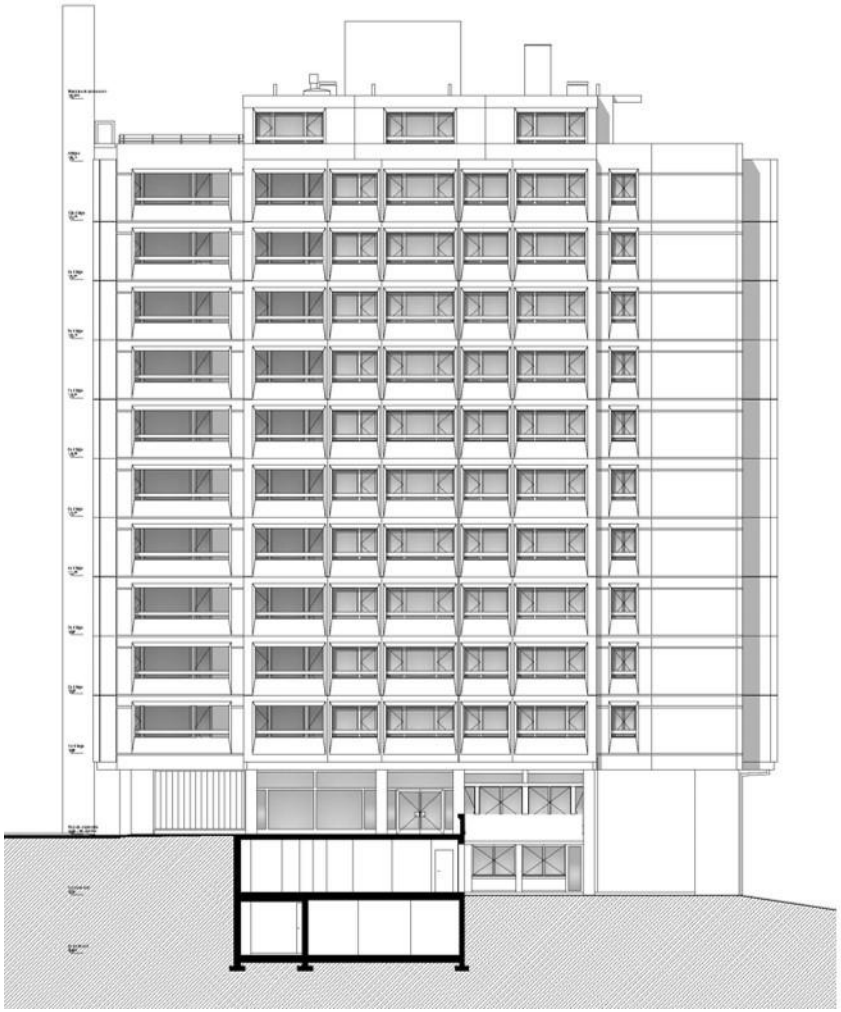
- Neighborhood of Serrières
- Residential buildings (apartments between 2 and 4.5 rooms)
- 10 stories + 1 attic (apartment 6.5 rooms)
- Level of protection II (common / typical)
- Heating system: central heating (for 5 buildings)

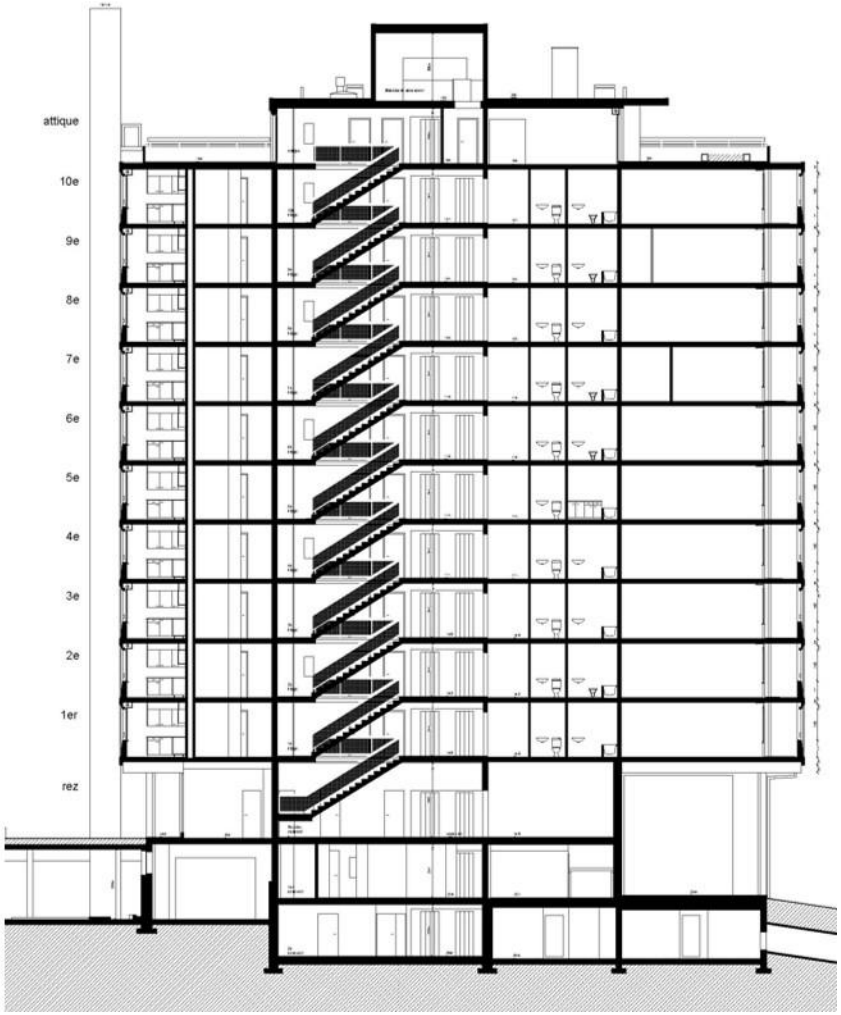
Rue Troncs 12 and 14 (Neuchâtel)

Period of construction: 1972-1973

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

E0 | Current status





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

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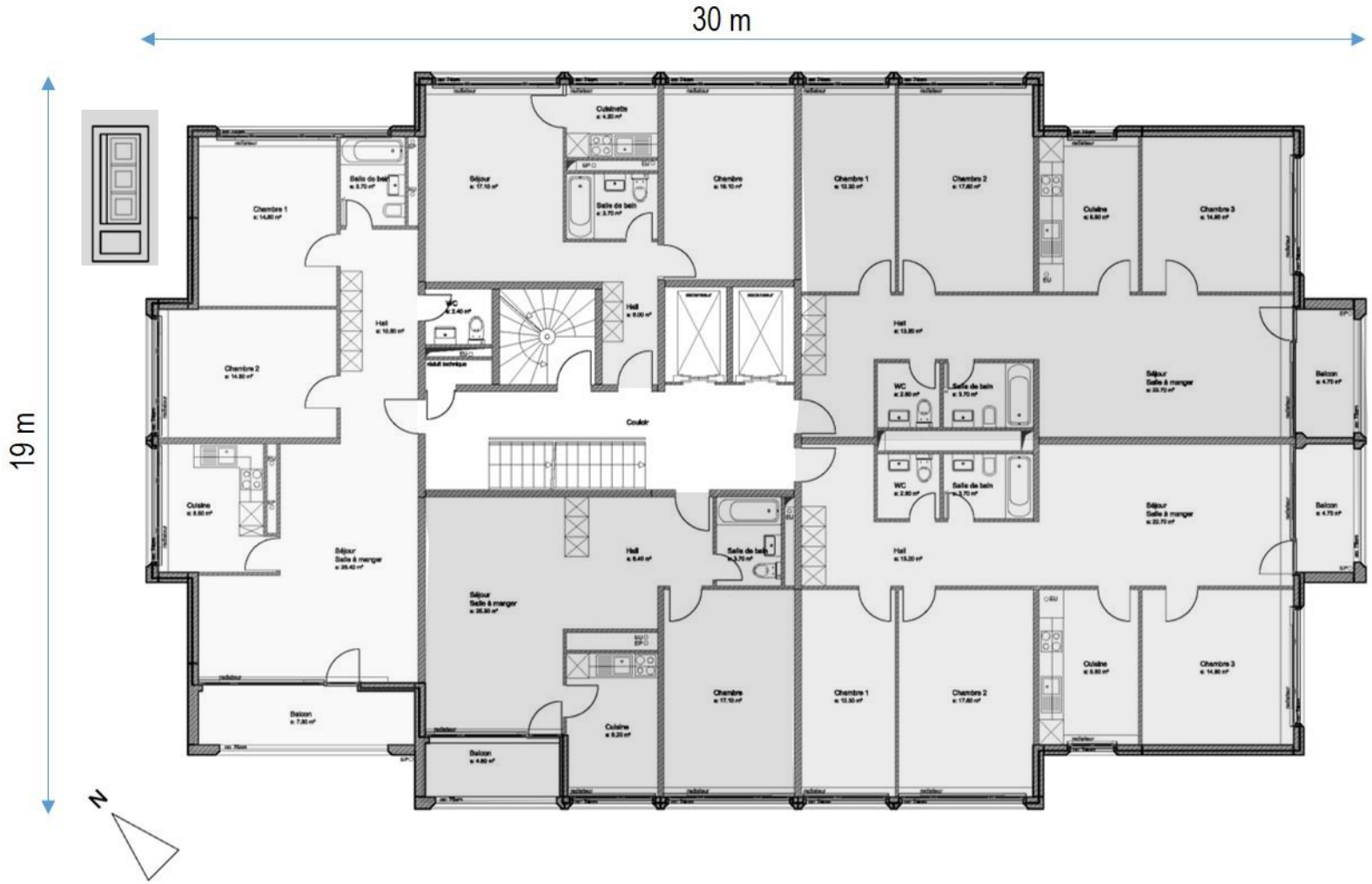

PHASE 2 – DESIGN SCENARIOS WITH BIPV SOLUTIONS – FIRST CASE STUDY

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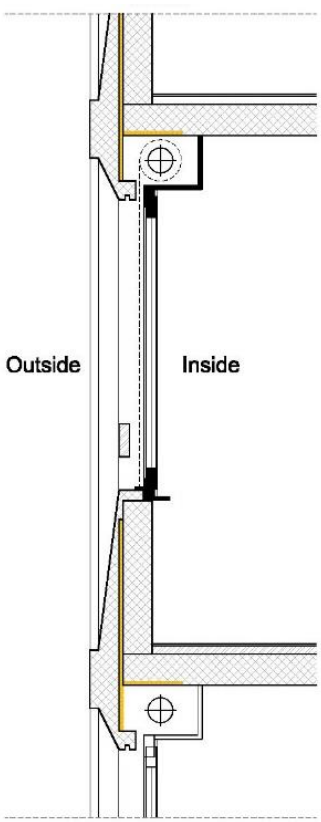
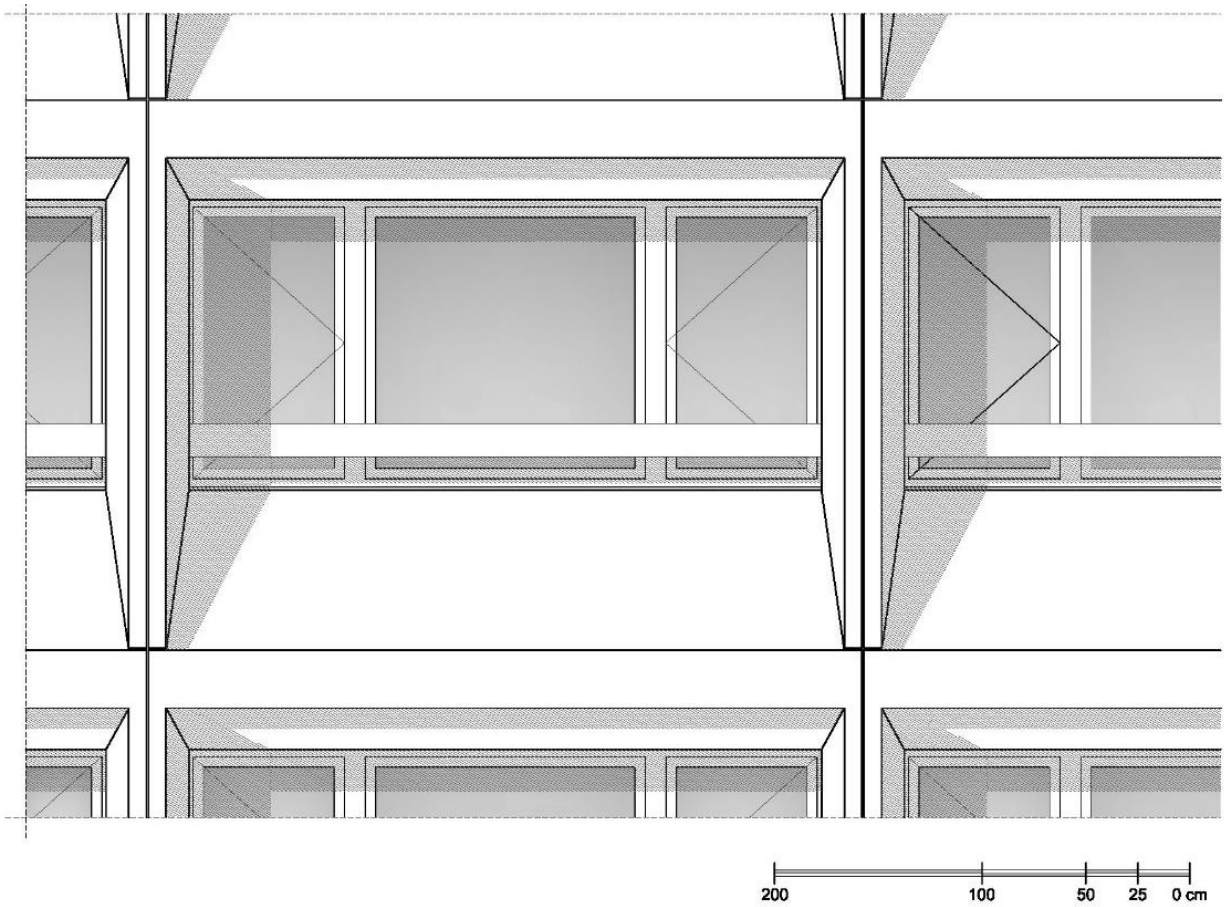
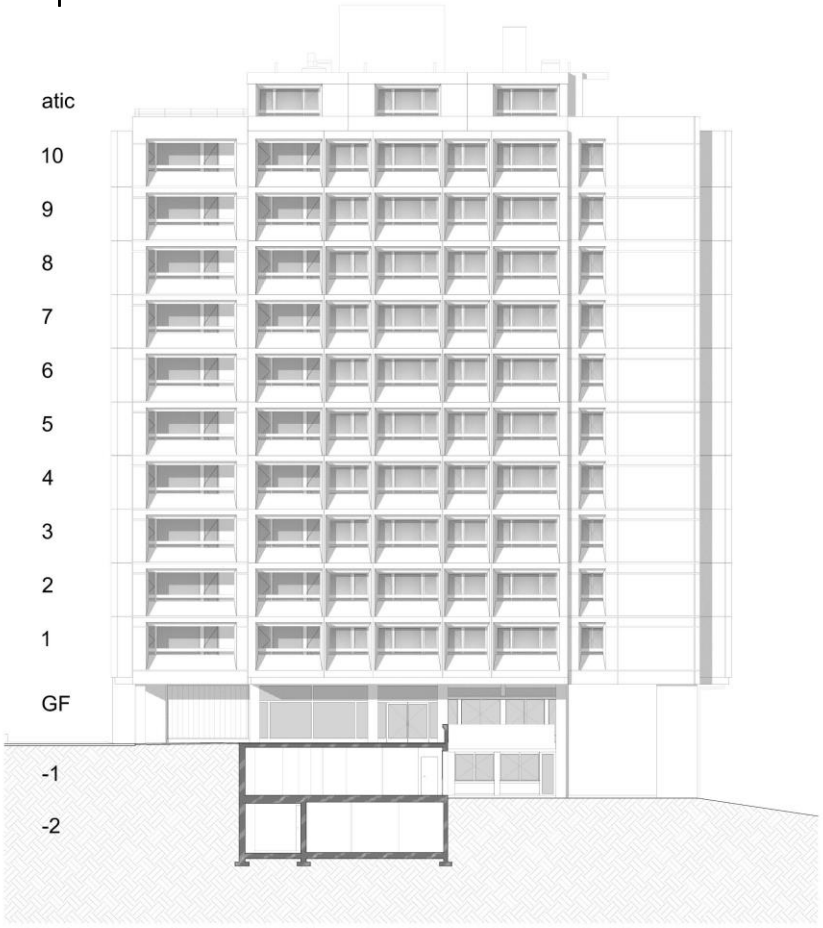
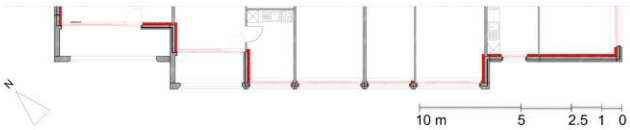


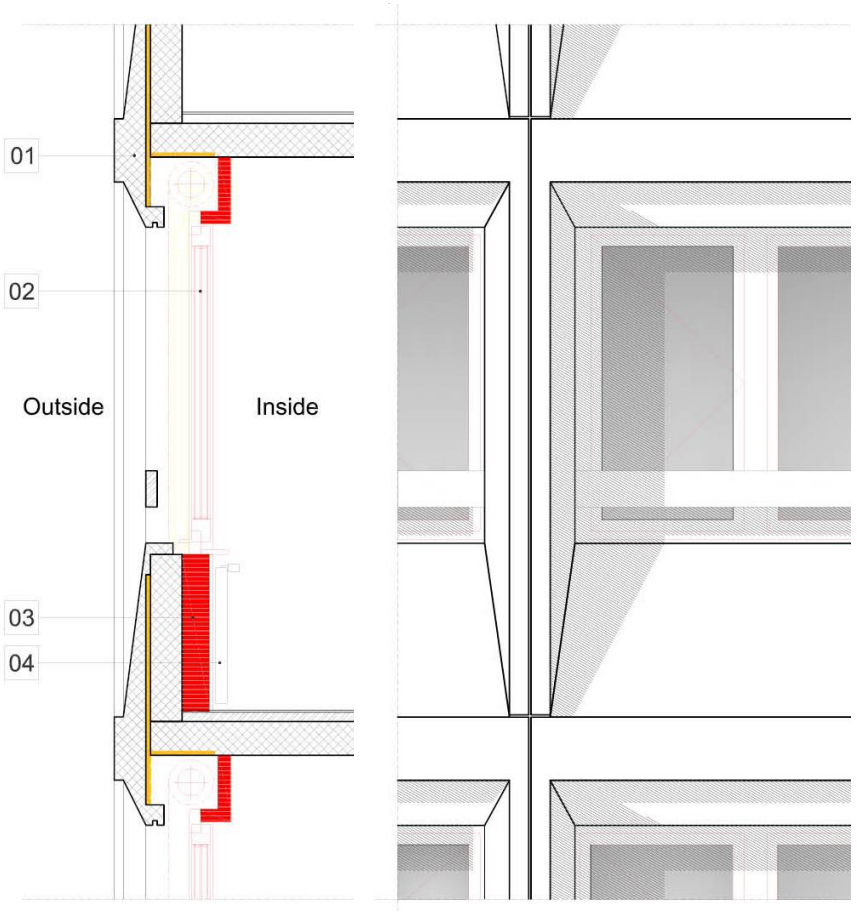


PHASE 2 – DESIGN SCENARIOS WITH BIPV SOLUTIONS – FIRST CASE STUDY

S0 | Baseline

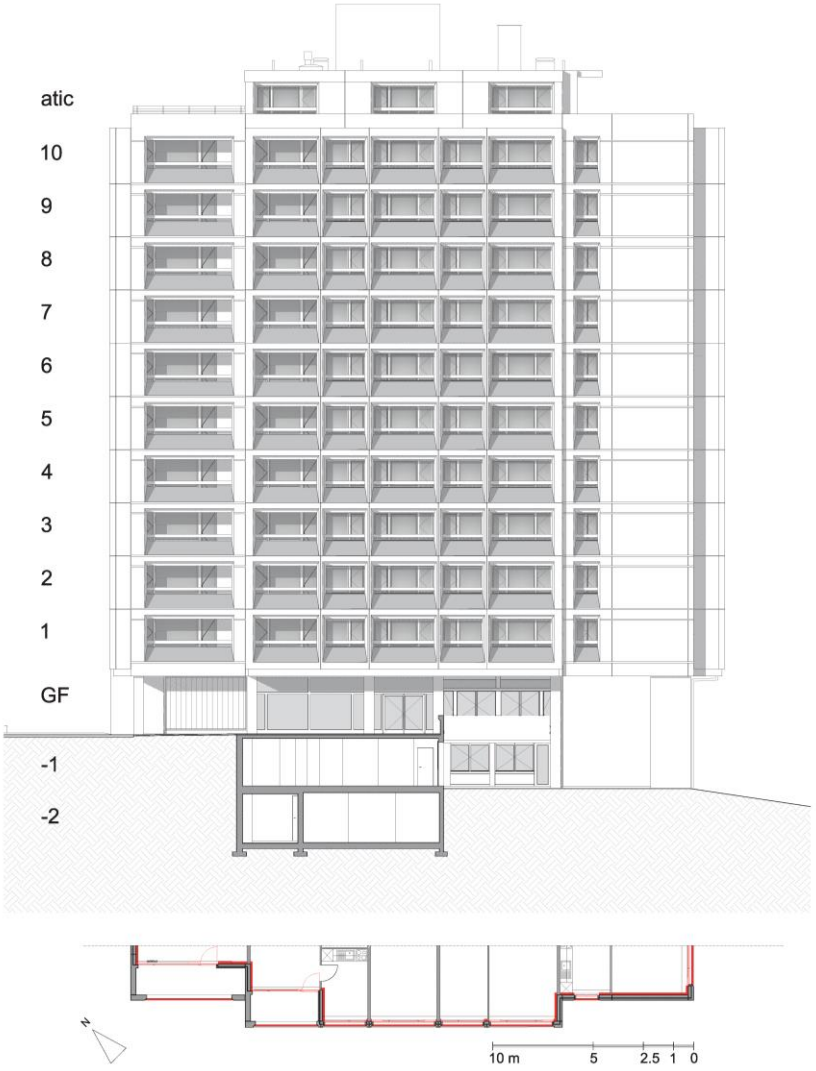


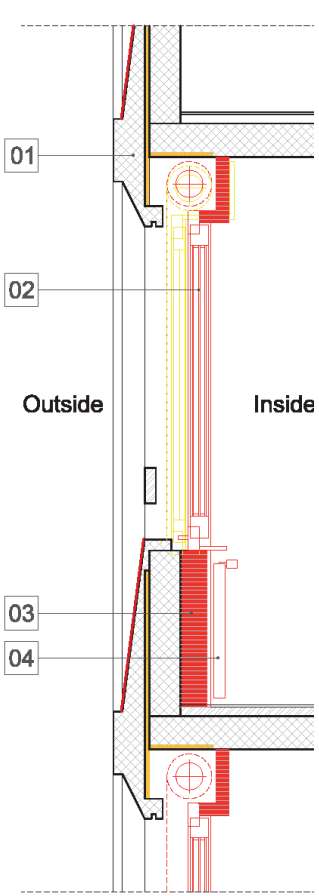


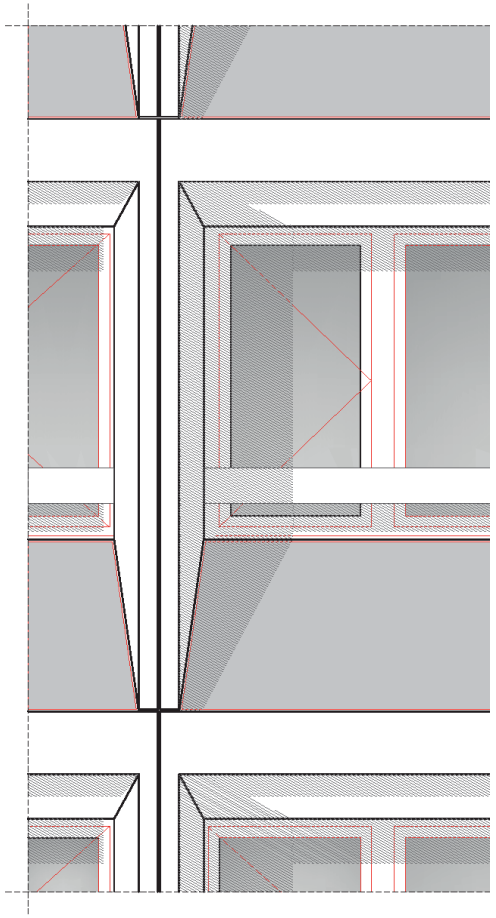


PHASE 2 – DESIGN SCENARIOS WITH BIPV SOLUTIONS – FIRST CASE STUDY

S1 | Conservation

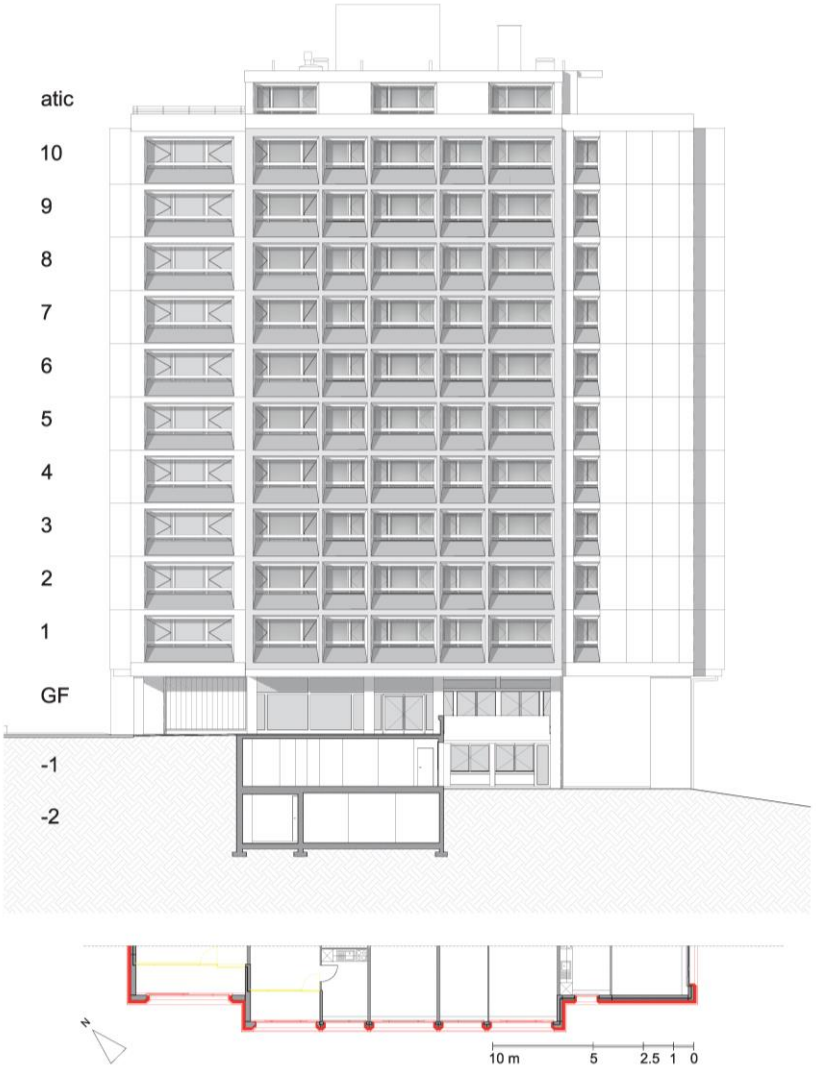


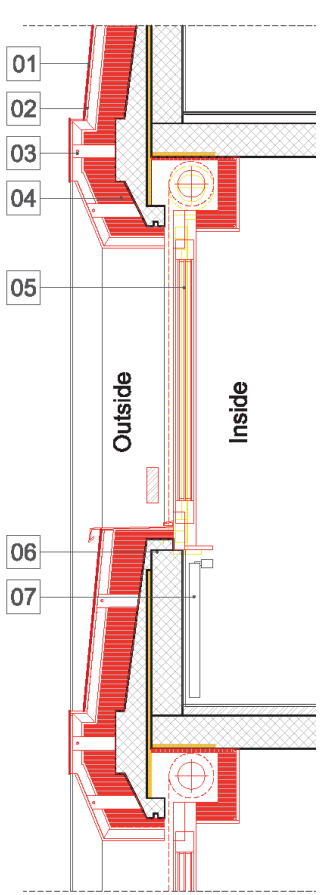


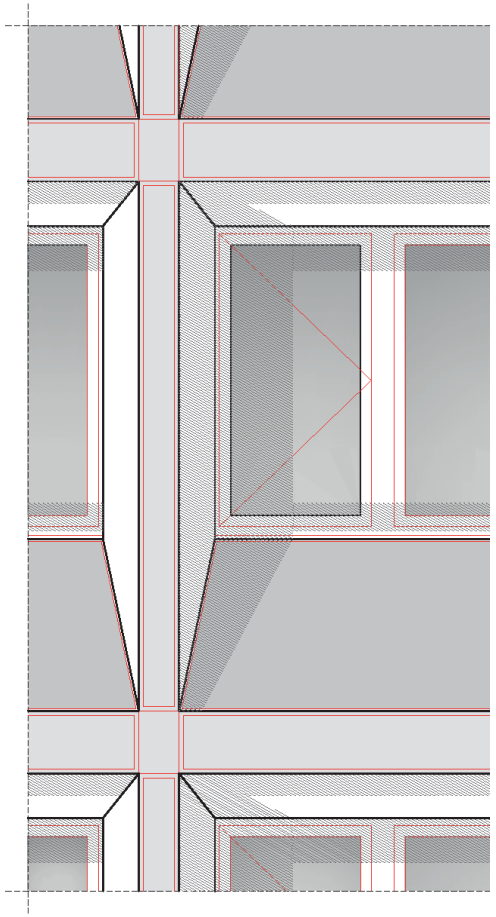


PHASE 2 – DESIGN SCENARIOS WITH BIPV SOLUTIONS – FIRST CASE STUDY

S2 | Renovation

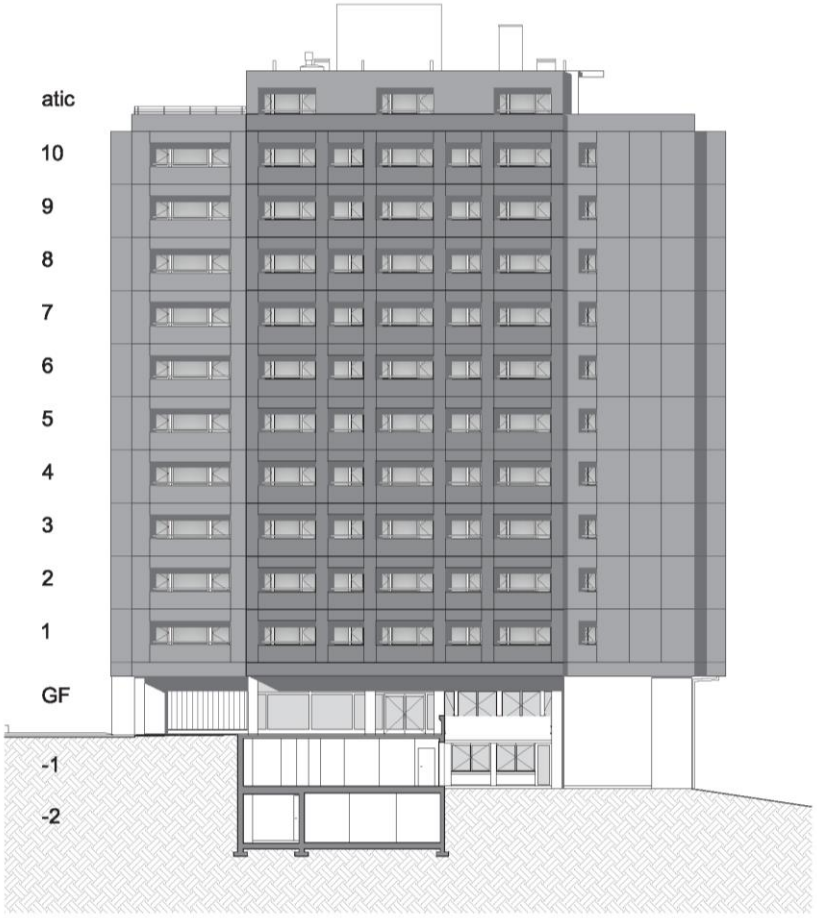


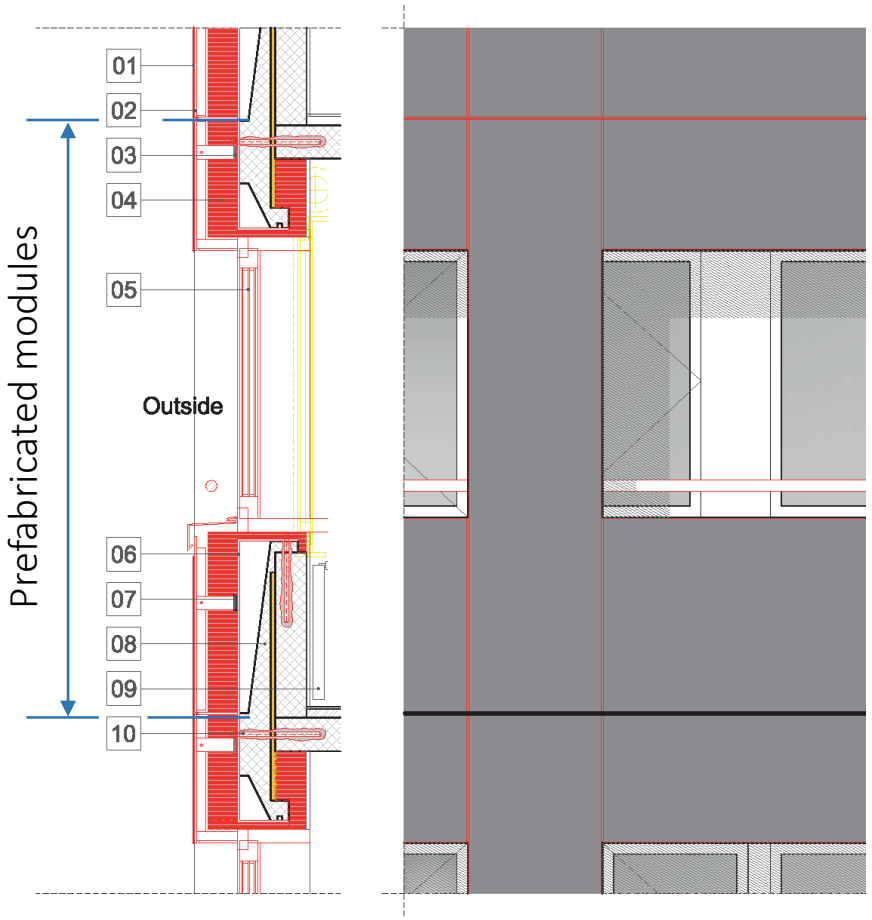




PHASE 2 – DESIGN SCENARIOS WITH BIPV SOLUTIONS – FIRST CASE STUDY

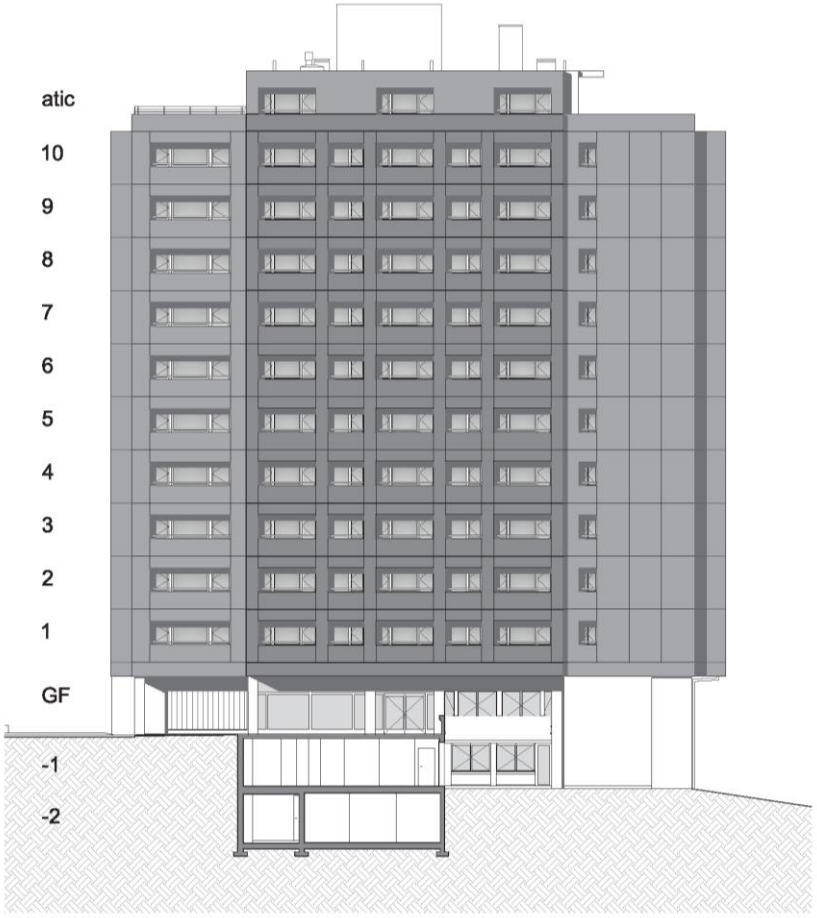
S3 | Transformation





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

S3 | Transformation

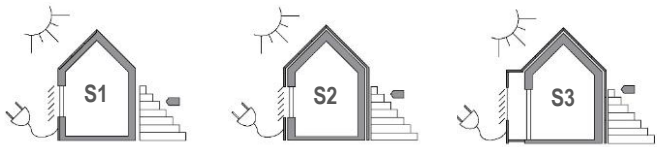


Reference: Caisse de pension COOP building. Morges (CH)

Methodology
PHASE 3 - Multi-criteria assessment

PHASE 3 – MULTI-CRITERIA ASSESSMENT

1) Definition of acceptability evaluation process



PHASE2: Design renovation scenarios

Final design

Active Interfaces collaboration

Technology, Constructive aspects, ……

Iterative process

Workshop
Group of experts
Group of non-experts

Urban planning commission

Design proposition

PHASE 3: Pre-assessment (energy)

Final quantitative assessment

To ensure the acceptability of each scenario project (qualitative)

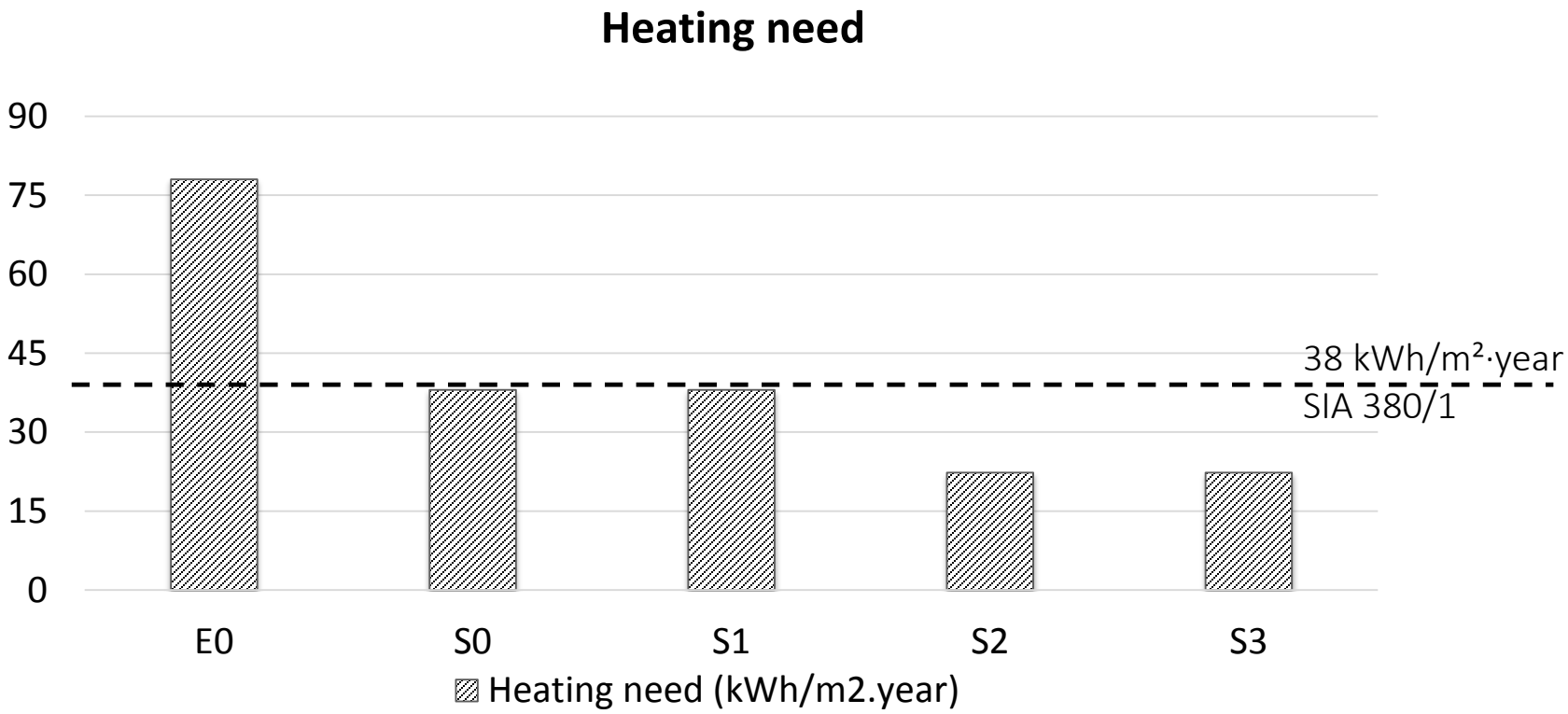
PHASE 3 – MULTI-CRITERIA ASSESSMENT

2) Definition of final assessment indicators

Assessment indicator	*Unit*	*Method / tool used*	*3D modelling LoD*
1. Energy and emissions			
- Primary energy consumption	$kWh_{PE}/m^2.year$	Energy Plus	LOD3
- Equivalent GHG emissions	$CO_{2EQ}/m^2.year$	Energy Plus	LOD3
2. Indoor comfort			
- Daylight autonomy (DA) – 300 lux	% of time	Radiance / Daysim	LOD4
- Overheating	hours per year	Energy Plus	LOD3
3. Photovoltaic installation			
- Annual production	$kWh_{FE}/m^2.year$	Energy Plus	LOD3
- Self-consumption potential (electricity covered ratio)	%	-	-
4. Global cost-effectiveness			
- Global cost	CHF/m2	EPIQR + INSPIRE-Tool	-
- Impact on rent	CHF/ m^2.year	-	-
- NPV (Net Present Value)	CHF	-	-
- Payback	years	-	-
5. LCA - Life Cycle Analysis			
- Embodied energy balance	MJ	ecoinvent + KBOB	-
- Embodied energy payback	years	-	-

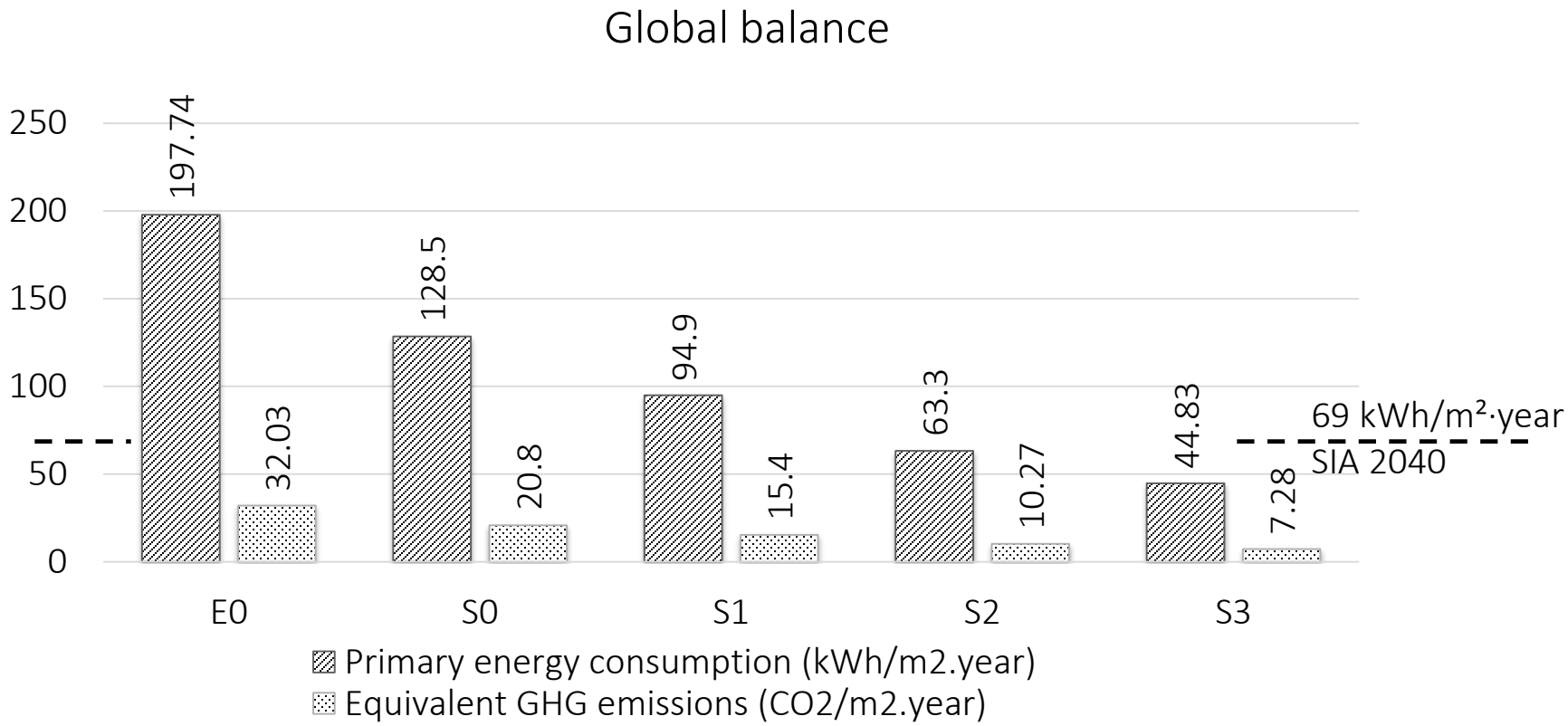
PHASE 3 – MULTI-CRITERIA ASSESSMENT – FIRST CASE STUDY

1. Energy and emissions



PHASE 3 – MULTI-CRITERIA ASSESSMENT – FIRST CASE STUDY

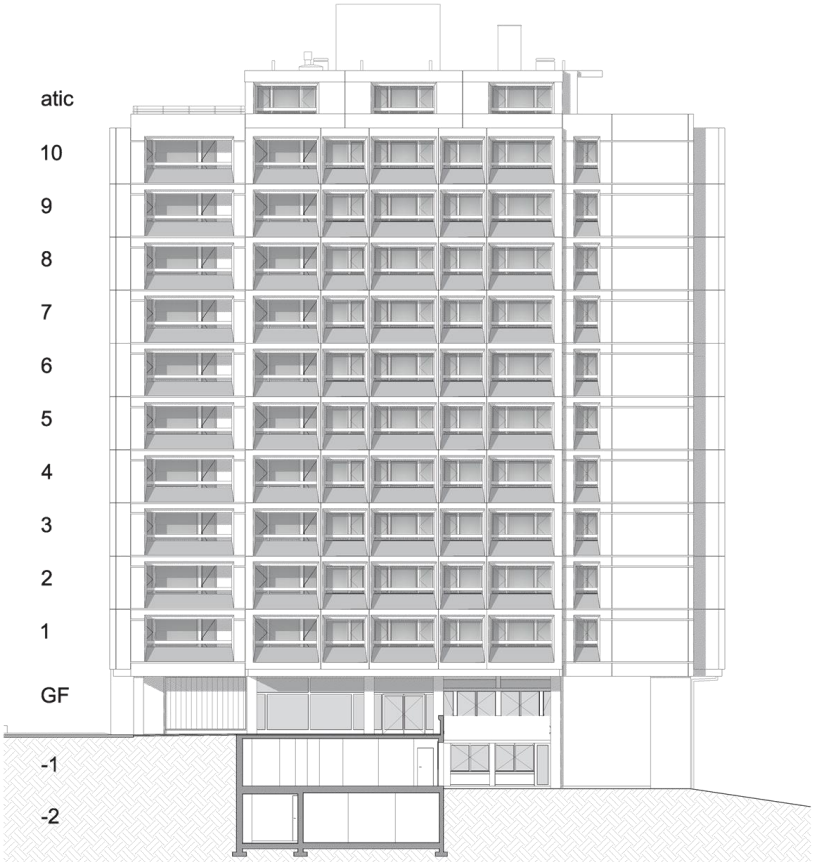
1. Energy and emissions



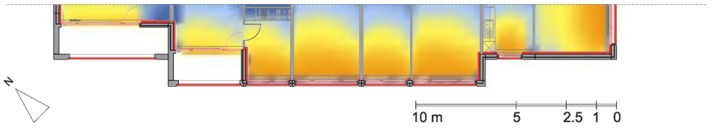
PHASE 3 – MULTI-CRITERIA ASSESSMENT – FIRST CASE STUDY

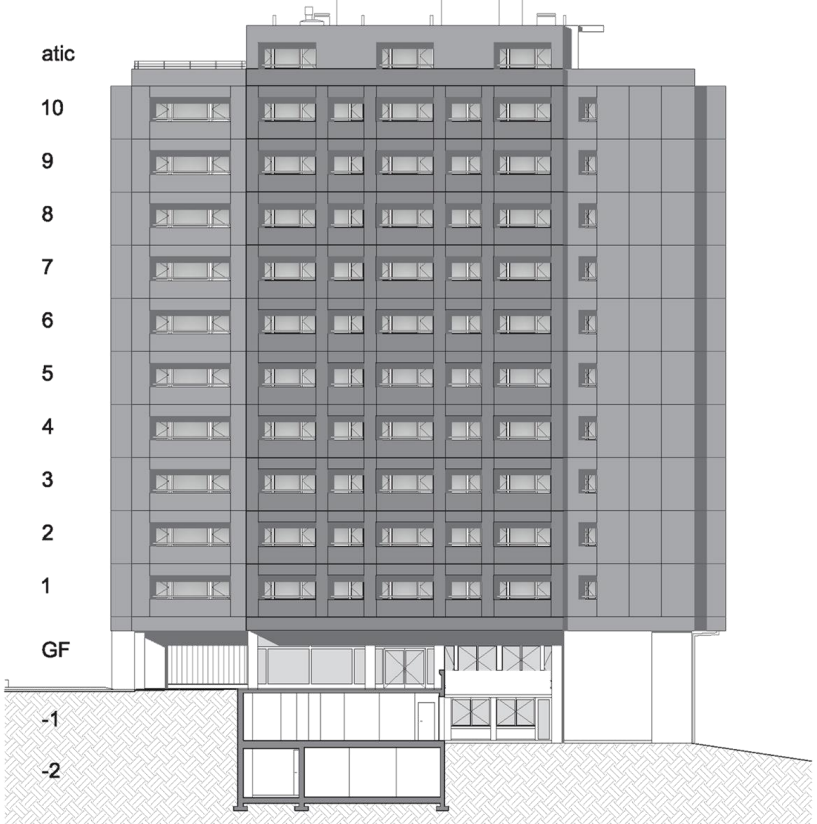
2. Indoor comfort

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

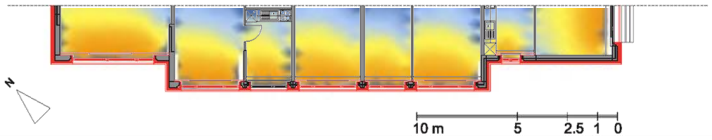


S1 | Conservation



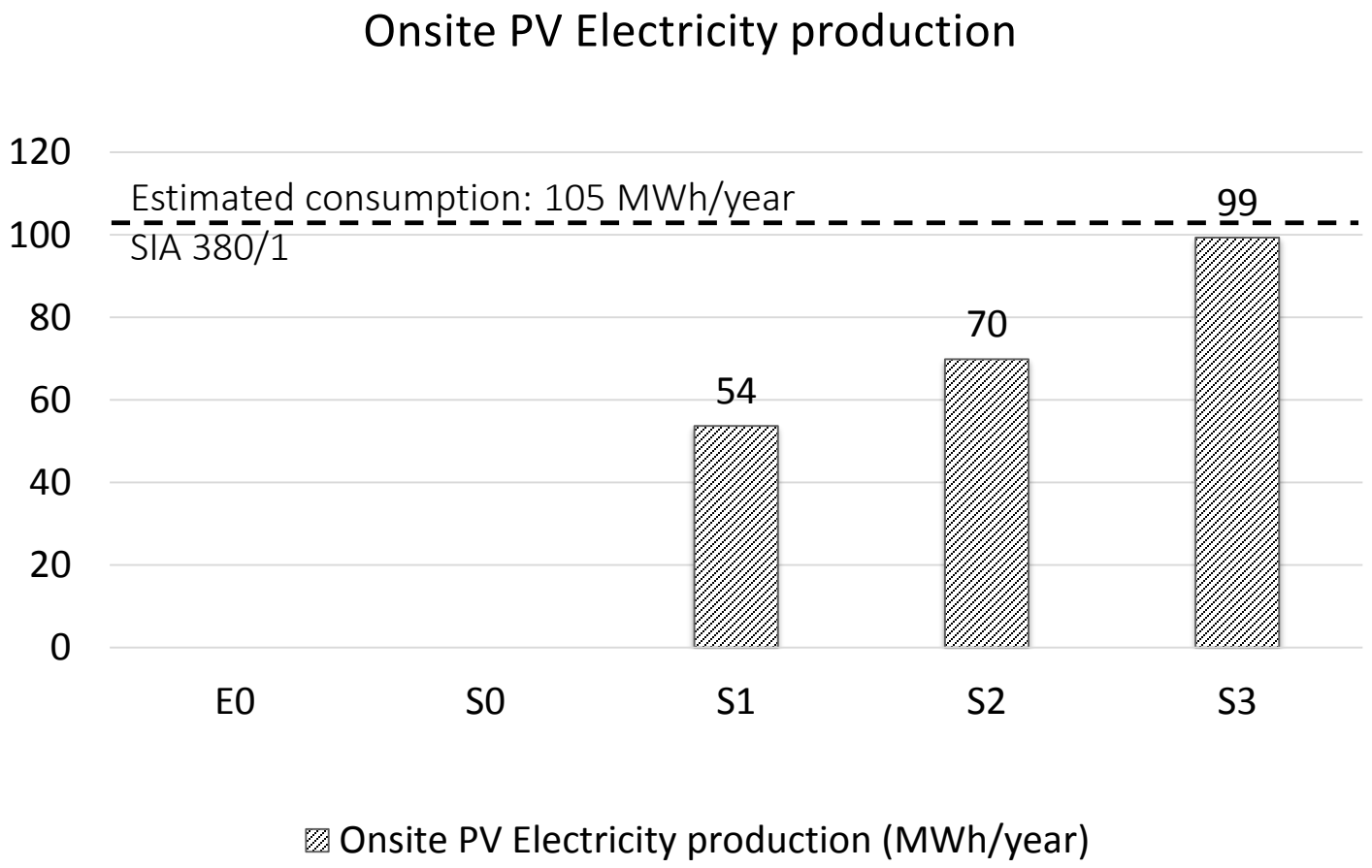


S3 | Transformation



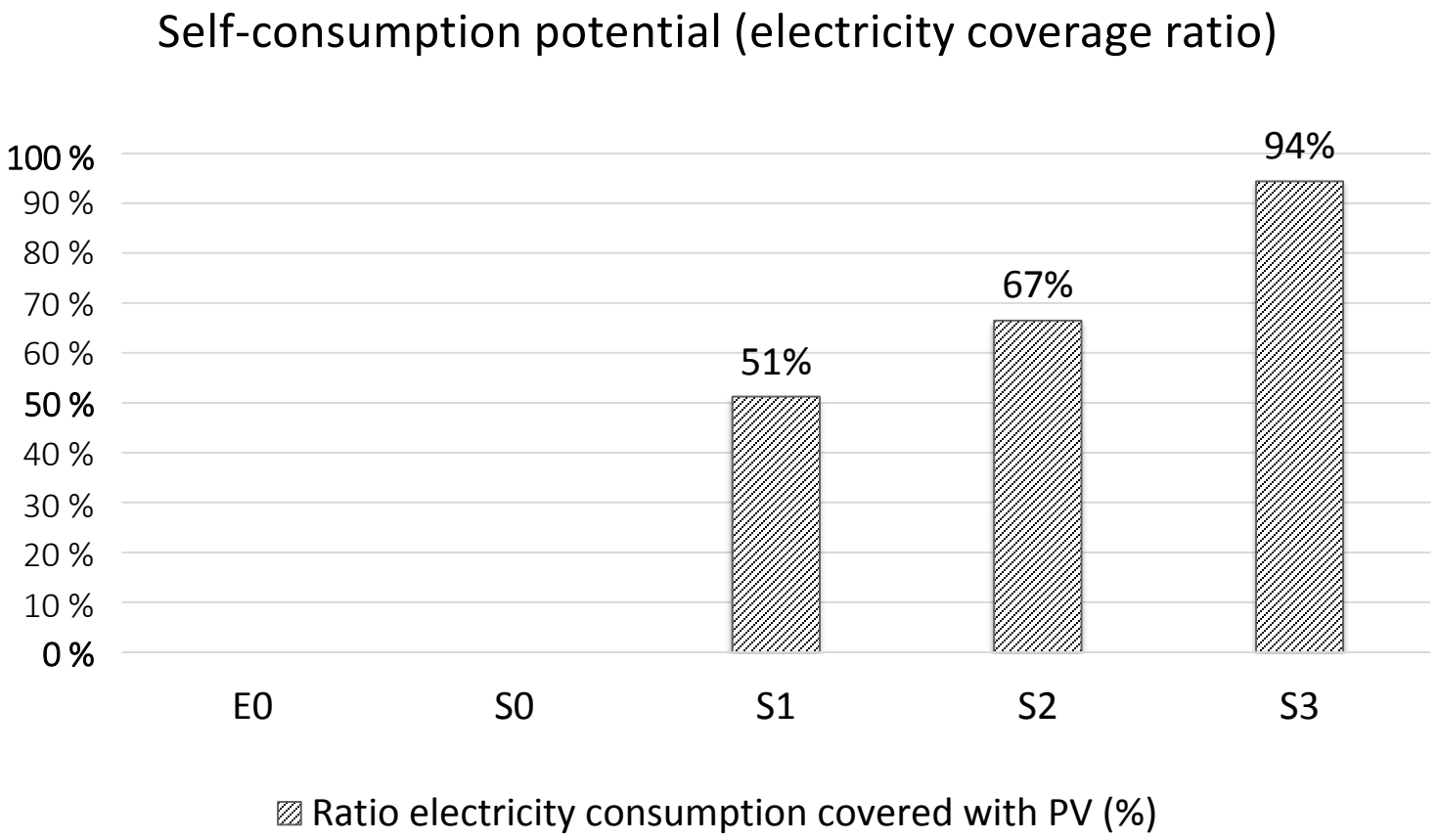
PHASE 3 – MULTI-CRITERIA ASSESSMENT – FIRST CASE STUDY

3. Photovoltaic installation



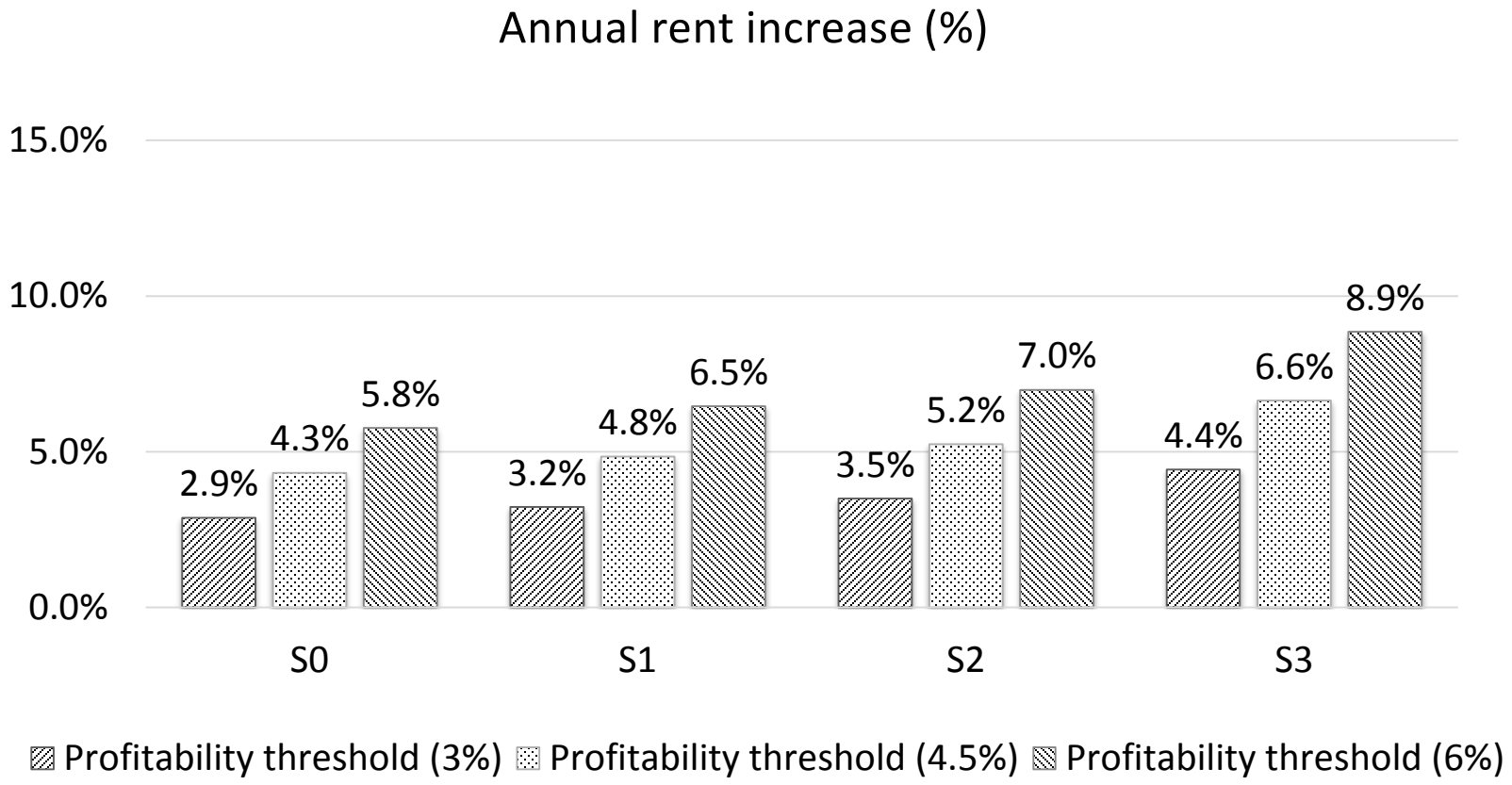
PHASE 3 – MULTI-CRITERIA ASSESSMENT – FIRST CASE STUDY

3. Photovoltaic installation



PHASE 3 – MULTI-CRITERIA ASSESSMENT – FIRST CASE STUDY

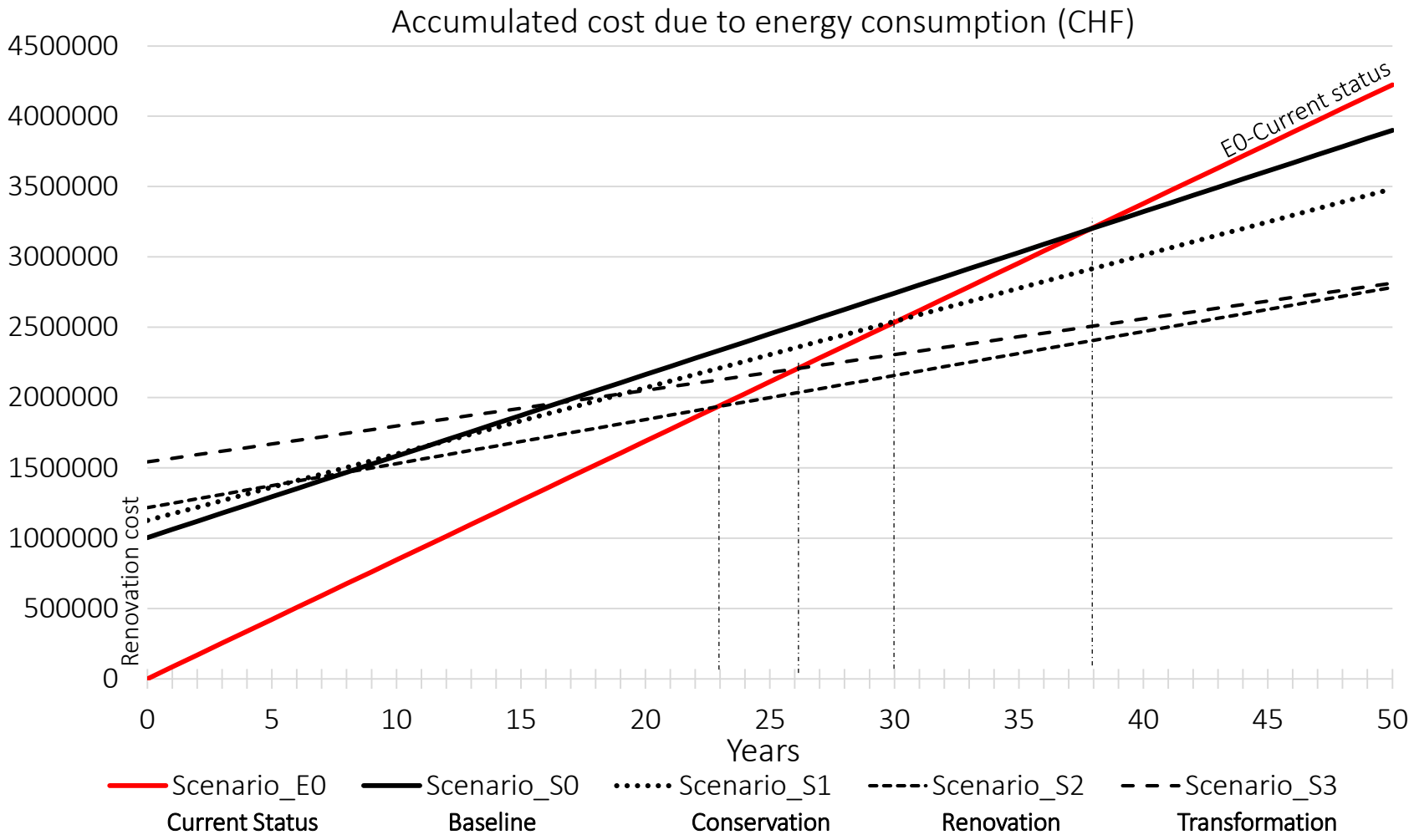
4. Global cost-effectiveness



Mean rent level in Neuchatel: **220 CHF/m2 per year**

PHASE 3 – MULTI-CRITERIA ASSESSMENT – FIRST CASE STUDY

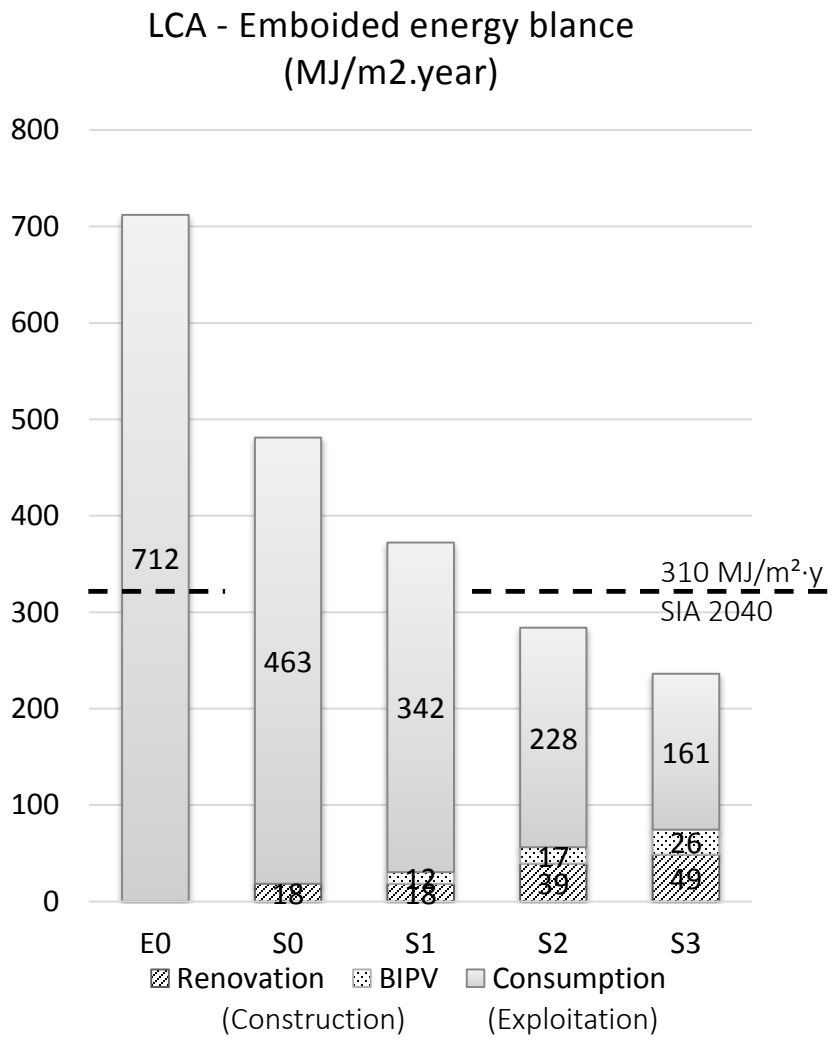
4. Global cost-effectiveness

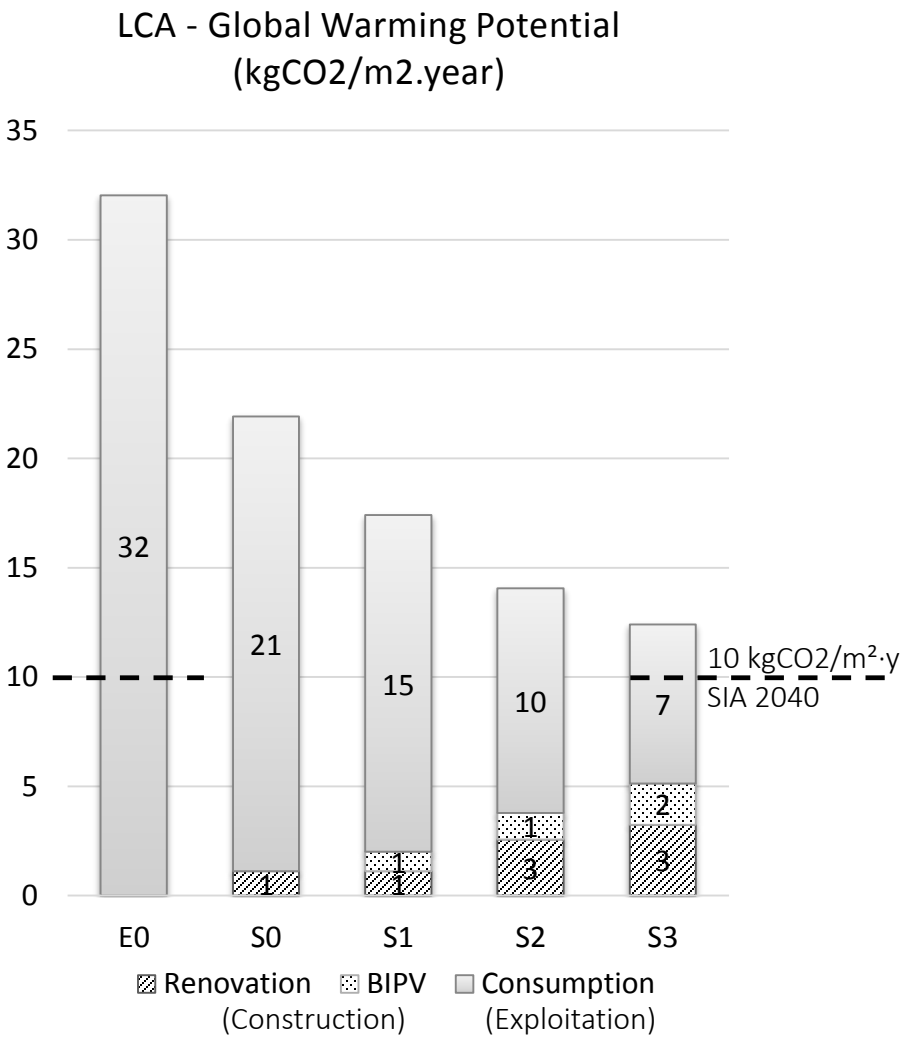


PHASE 3 – MULTI-CRITERIA ASSESSMENT – FIRST CASE STUDY

eco-bat
Eco Balance Assessment Tool

5. Life cycle analysis





4. Next steps

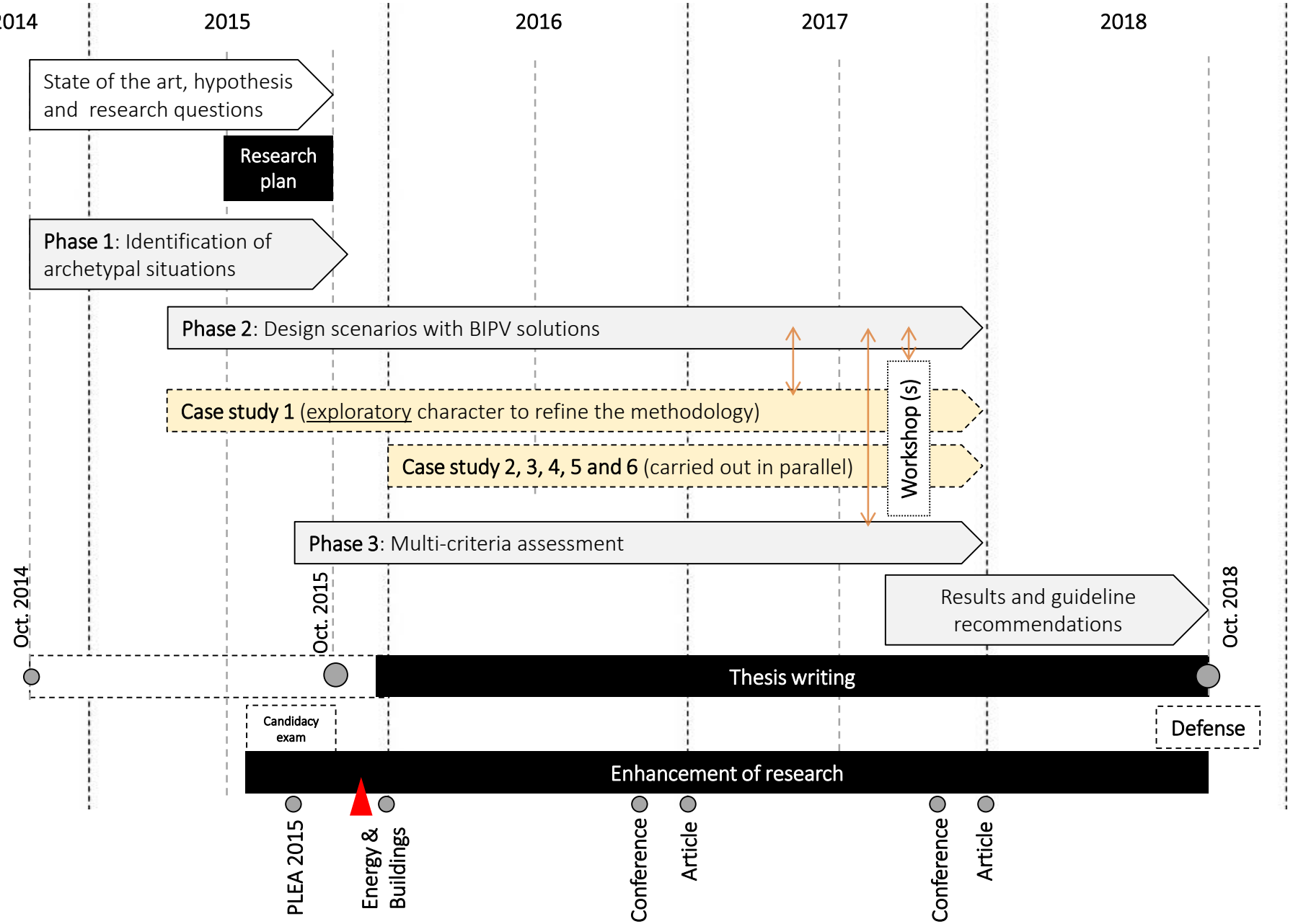
NEXT STEPS

- **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

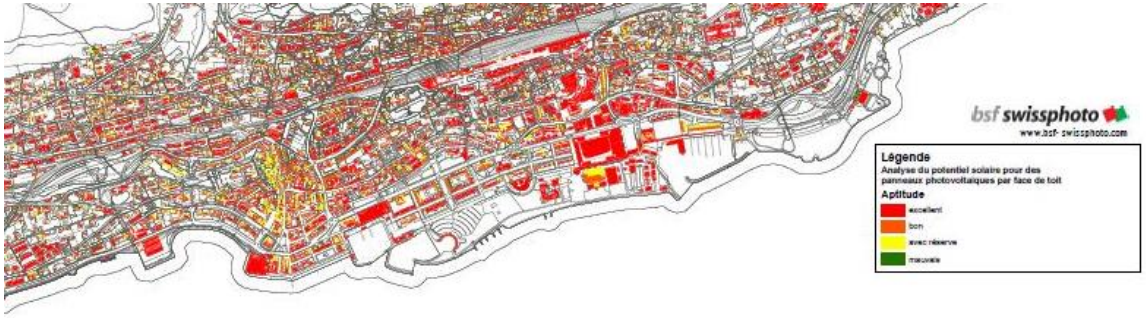

2014
2015
2016
2017
2018
State of the art, hypothesis and research questions
Research plan
Phase 1: Identification of archetypal situations
Phase 2: Design scenarios with BIPV solutions
Case study 1 (exploratory character to refine the methodology)
Case study 2, 3, 4, 5 and 6 (carried out in parallel)
Workshop (s)
Phase 3: Multi-criteria assessment
Oct. 2014
Oct. 2015
Results and guideline recommendations
Oct. 2018
Thesis writing
Candidacy exam
Defense
Enhancement of research
PLEA 2015
Energy & Buildings
Conference
Article
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**



Ville de Neuchâtel **Potentiel de production d'électricité photovoltaïque**

PHASE 1 – IDENTIFICATION OF ARCHETYPAL SITUATIONS

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

Two types of existing studies

based on…

… urban data

Potential energy savings (for future scenarios)

Global strategic decisions (public institutions)

… single building projects

Specific application of materials and products

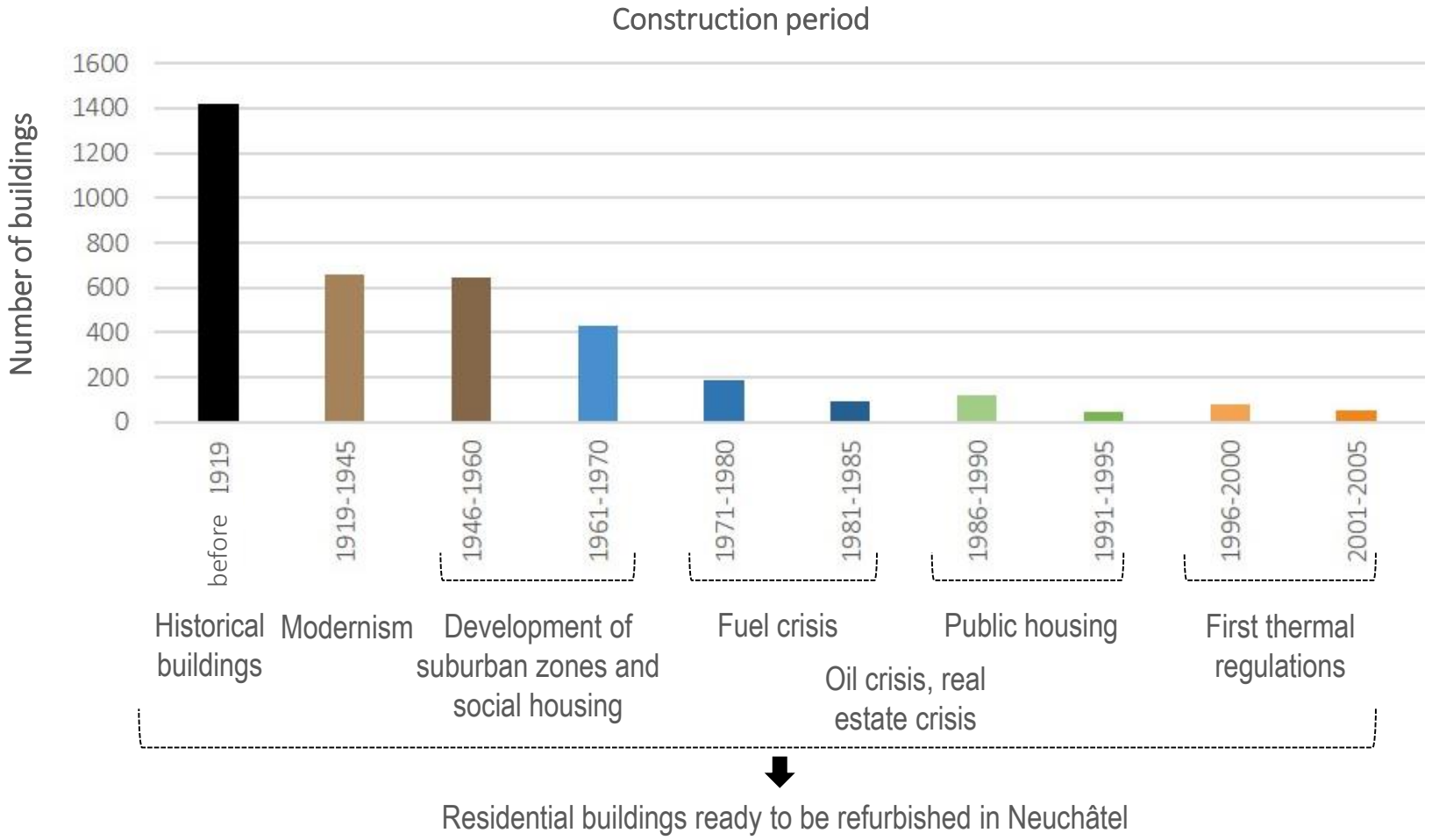
Reference in architectural practices (designers)

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

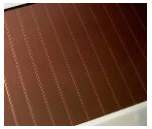
3) Definition of the residential archetypes (set of parameters)



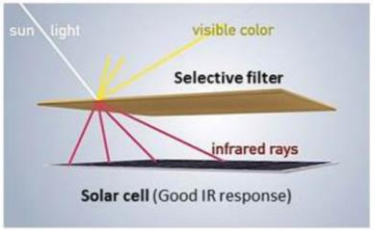
Référence: Office Fédérale de Statistique (OFS), 2014

PHASE 2 – DESIGN SCENARIOS WITH BIPV SOLUTIONS

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

	Common used			In development	
Available technologies	Monocrystalline silicon (sc-Si)	Polycrystalline silicon (mc-Si)	Amorphous silicon (a-Si)	Cadmium telluride	Copper indium gallium selenide / sulphide
					
	Crystalline silicon cells (100x100 mm)		Thin-film cell	Nanotechnology based solar cells	
Efficiency	17-22%	11-17%	4-8%	4-10%	
Used (ratio)	85%		14%	1%	

Reference: IEA SHC Task 41 Solar energy systems in architecture (2012)



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

We propose…

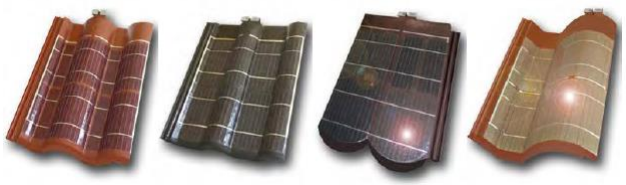
A technology selection based on the architectural design response that we want to obtain, **evaluating their effect** on the whole renovation process.

PHASE 2 – DESIGN SCENARIOS WITH BIPV SOLUTIONS

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

	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.
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.		

Reference: IEA SHC Task 41 Solar energy systems in architecture (2012)



We propose…

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

PHASE 2 – DESIGN SCENARIOS WITH BIPV SOLUTIONS

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

Renovation examples

Chiasso (CH), 2012

Romanshorn (CH), 2013

New constructions examples

Laax (CH), 2012

Ijsselstein (NL), 2002

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

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

(*) 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

Used by public authorities to create our recommendations

… visual sensitivity

Aim to hide the installations in order to maintain the architectural quality

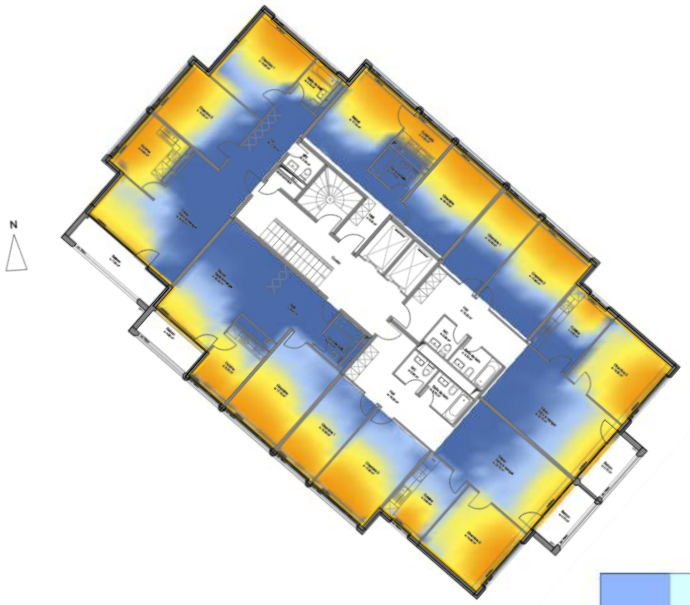
We propose…

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**).

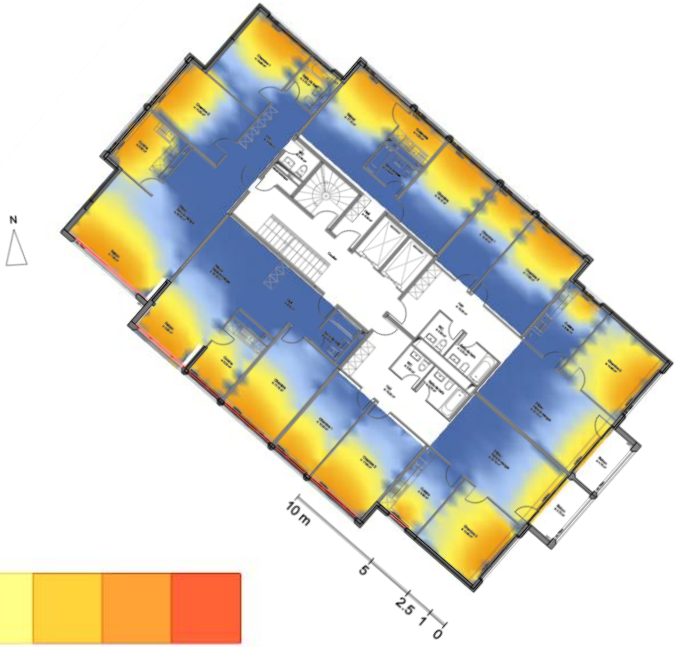
PHASE 3 – MULTI-CRITERIA ASSESSMENT – FIRST CASE STUDY

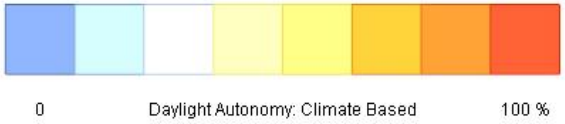
Daylight Autonomy | 300 lux | Occupation 8 am – 10 pm | Time ratio with more than 300 Lux

S1



S2





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

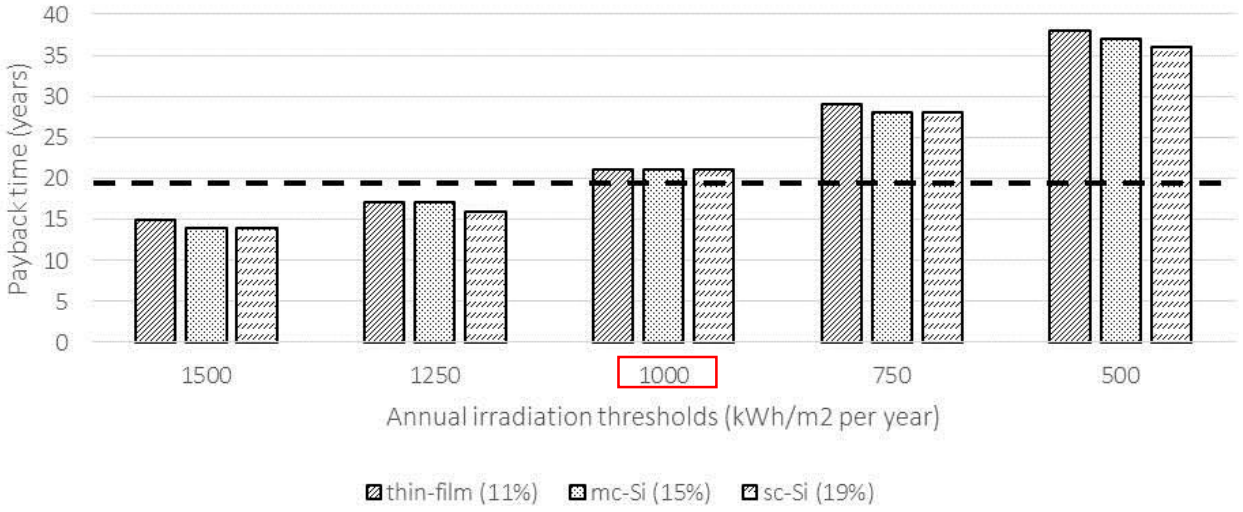
S1: **29.67 %**

S2: **28.23 %**

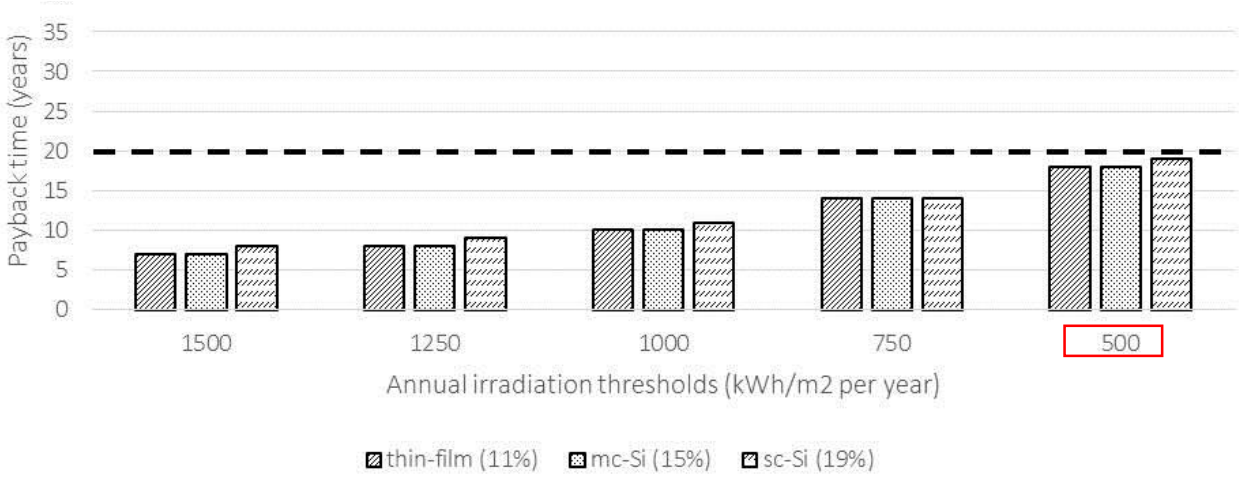
PHASE 3 – MULTI-CRITERIA ASSESSMENT – FIRST CASE STUDY

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

Current prices

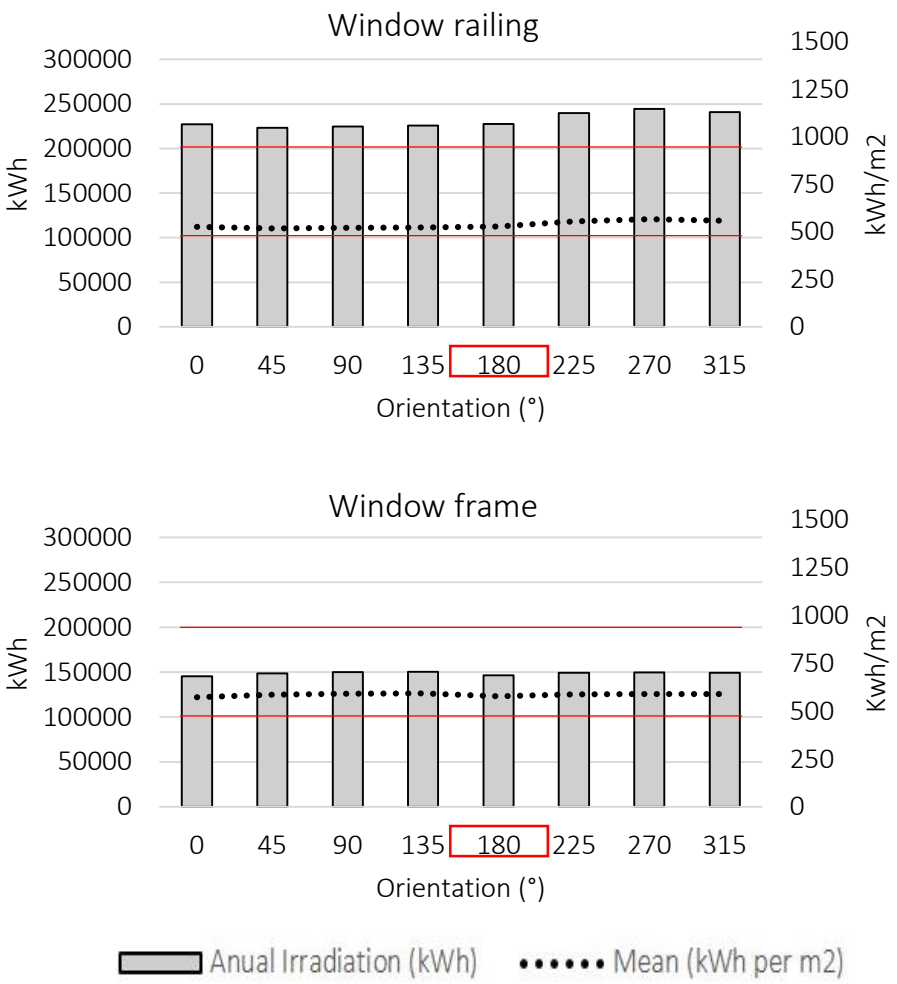


2020 prices



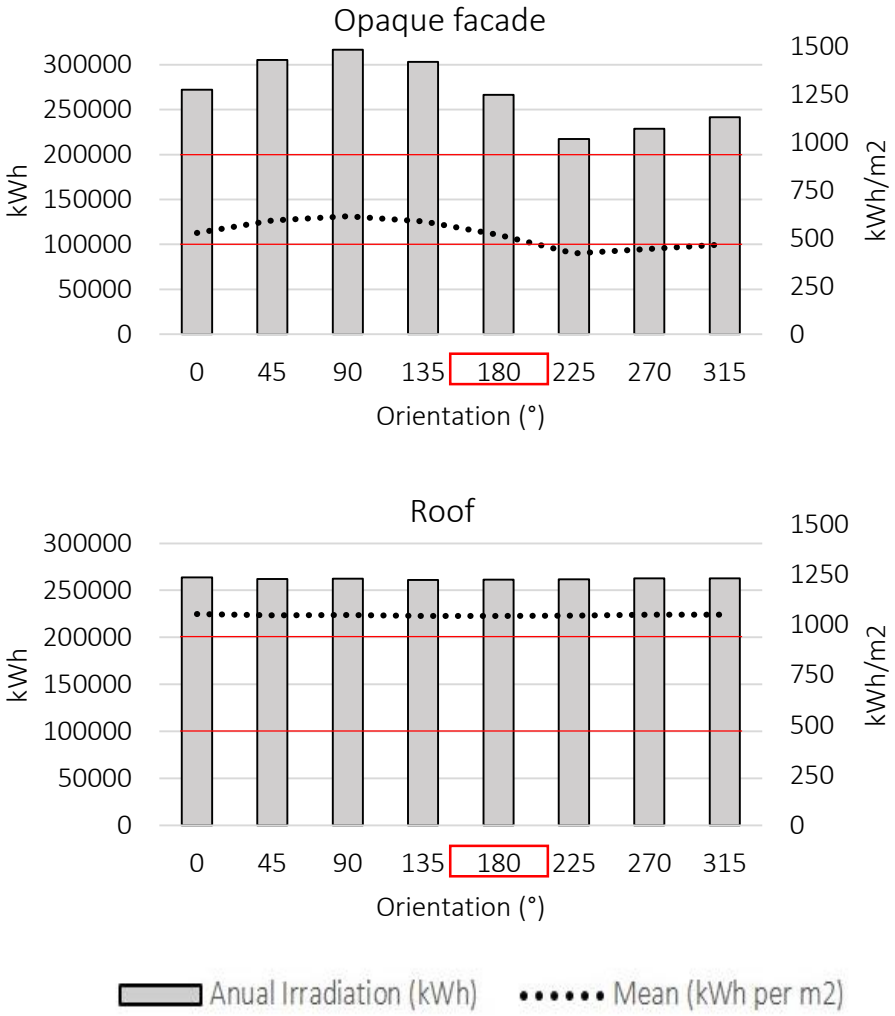
PHASE 3 – MULTI-CRITERIA ASSESSMENT – FIRST CASE STUDY

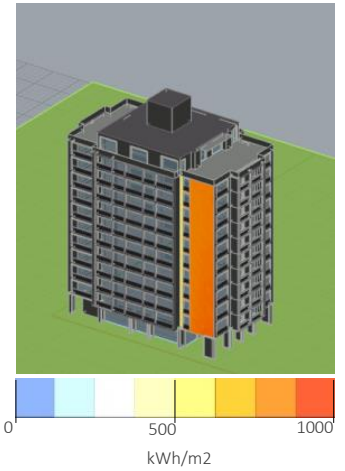
Solar exposure study | Orientation sensitivity study

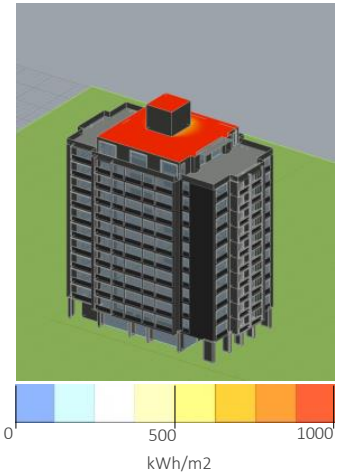


PHASE 3 – MULTI-CRITERIA ASSESSMENT – FIRST CASE STUDY

Solar exposure study | Orientation sensitivity study







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)