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Integrated Design 2.1

Are there good examples of BIPV architecture?

Recent developments in photovoltaic technologies enable stimulating architectural integration into building facades and rooftops. Although scarce, good examples of renovation projects already exist in Switzerland.

Thanks to the novel generation of products [cf. sheet 1.2] which enable interesting and architecturally coherent variations in proportion, surface, color and texture, BIPV is becoming a true building material with all the traditional characteristics of construction and expression. Recent projects in Switzerland illustrate how available products can be implemented.

Keywords: BIPV architectural integration; Renovation project; Active façade.
Target audience: Regulation makers; Owners & other decision makers; Architects & engineers; Suppliers & companies; Broader public.

Fig. 1 Renovation in Zurich, Viriden+Partner (©O.Wavre).

Fig. 2 Renovation of a residential building in Romanshorn (©Viriden + Partner).

We here present successful examples of renovated buildings with BIPV in Switzerland, in order to demonstrate the possibilities from an architectural perspective. The literature review shows that most BIPV studies and applications focus on commercial and office buildings [1,2], mainly because such buildings present less barriers to BIPV implementation due to (in general) the existence of an owner-occupant. There is in fact an insufficient number of aesthetically convincing exemplary buildings of residential renovation projects with BIPV. The few examples found are focused on singular or historical buildings (with a high level of heritage protection), such as churches or monuments [3]. Further examples can be found in [2,4], a large census of new construction projects, as well as in [1] for the most recent flagship projects.

Example 1 (Fig. 1): Multi-family residential building renovated in 2016 and located in Zurich. The project consists of a two-floor extension and a completely renovated building envelope. Apart from the replacement of the windows, an external insulation was added using a ventilated façade system with BIPV elements, totalling to 1'535 m^2 of silicon mono-Si cells modules, custom-sized and visually modified to obtain a grey mat appearance (148 kWp of installed power in standard test conditions (STC)).

Fig. 3 Farmhouse in Ecuvillens (©O.Wavre).

Fig. 4 Hôtel des associations des Rochettes, Neuchâtel (©P. Heinstein).

In addition, a non-integrated PV installation of 165 m^2 of standard mono-Si PV modules is placed on the roof. This example allows architects to see that it is possible to maintain or improve architectural quality using available products based on mature technology (mono-Si cells) [5,6].

Example 2 (Fig. 2): Solar Prix in 2013. This residential building renovation by Viriden + Partner arch. was one of the first buildings in Switzerland to integrate photovoltaics on facades [5].

Example 3 (Fig. 3): Farmhouse located in a heritage protected area in Ecuvillens, representing a good example of a complete roof renovation using large terra cotta tiles based on mono-Si cells in response to the prohibition against using standard PV panels. The efficiency of these visually-customized BIPV panels is about 20% lower than standard PV panels. This installation of 230 m^2 produces around 28 MWh/year [7].

Example 4 (Fig. 4): Roof renovation of the “Hôtel des associations des Rochettes”, an administrative building built in 1880. Shows a fully integrated BIPV installation using black mono-Si cells and completed with specially sized dummy modules (non-active) [8].

These examples show that a new field is opening up for architectural design. It is now possible and realistic to design renovation projects with a high level of acceptance by employing existing BIPV elements as a new construction material for facades and roofs that actively participates in both defining the visual character of the building and improving its energy performance, environmental impact [cf. sheets 3.2 and 3.3] and cost-effectiveness [cf. sheet 4.4].

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Integrated Design 2.2

Are BIPV compatible with buildings from different construction periods?

Renovation projects with BIPV are an efficient way to achieve the Energy Strategy 2050 targets [cf. sheet 3.1]. Here, we illustrate how BIPV renovation strategies are compatible with buildings from different construction periods and typologies.

The construction period mainly defines the actual status of a building, i.e., its current energy performances and improvements needed. Based on this, the BIPV strategy will range from lightest to heaviest [cf. sheet 2.3]. We conclude that BIPV renovation projects are relevant not just for a specific construction period or type, but for a wide palette of buildings in the Swiss context.

Keywords: BIPV architectural integration; Renovation project; Construction period.
Target audience: Regulation makers; Owners & other decision makers; Architects & engineers; Suppliers & companies.

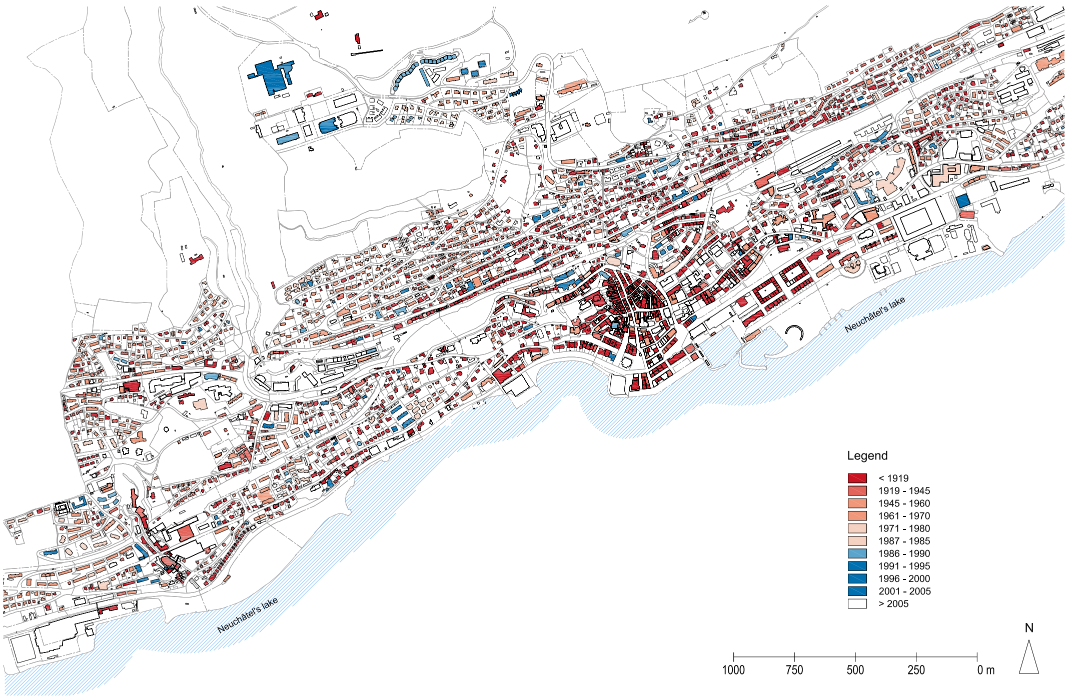

Fig. 1 Geo-data on the spatial disposition based on construction period for the city of Neuchâtel, data from 2015 [1] (©EPFL-LAST).

The project demonstrates that renovation strategies with BIPV are a lever to activate urban renewal processes for a whole series of buildings from varying periods of construction, and not just for a specific type of building or construction period. Therefore, the approach begins by identifying five residential archetypes within the building stock of the City of Neuchâtel, which is representative of the Swiss residential building stock [1].

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Fig. 1 shows geo-data on the spatial disposition for the construction period for residential buildings built before 1919 until 2005 [2]. The number of residential buildings built until 2005 and their equivalent floor area led to a total of 3,017 buildings with 3,650,921 m^2 of floor area.

	Arch. 1	Arch. 2	Arch. 3	Arch. 4	Arch. 5
A - Construction period	before 1919	1919-1945	1946-1970	1971-1985	1986-2005
B - Urban context	Isolated	Isolated	Isolated	Isolated	Isolated
C – Roof potential	Sloped	Sloped	Flat	Flat	Flat
D – Façade potential	5-7 floors	1-4 floors	5-7 floors	> 7 floors	5-7 floors
E - Architectural quality (heritage)	Typical II	Typical II	Typical II	Typical II	Unattractive III
					
Address	Rue de Beauregard 1	Rue du Rocher 25	Rue du Chasselas 2-6	Rue des Troncs 12-14	Route de Pierre-à-Bot 34

Fig. 2 Definition of five archetypal situations according to selection criteria A-E [1] (©EPFL-LAST).

The top-down analysis presented in this summary sheet serves to further an understanding of the residential building stock of the city of Neuchâtel and to define representative residential archetypes based on five selection criteria A-E (Fig. 2) [3]. Subsequently, a relevant case study is selected for each archetype. These real case studies are crucial for the development of BIPV renovation strategies [cf. sheet 2.3].

Since buildings considered typical (classified as category II or III according to the Architectural Heritage Service of Neuchâtel) can be found in any Swiss Plateau city, focusing on these buildings ensu-res the potential for application of the research results in other contexts, conditional to considering the particularities of the project in question.

Each archetype, defined by its period of construction, urban context, type of roof, type of facade and level of heritage protection, requires different intervention strategies depending on the design objective from an architectural point of view and considering the sensitivity of the context in which it is located [cf sheet 2.3].

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Integrated Design 2.3

Are BIPV compatible with different renovation strategies?

BIPV can be successfully integrated into renovation projects with various levels of intervention, from lightest to heaviest. Here, we illustrate three possible strategies.

After analysis of the current status of the building in order to detect the improvement potential [cf. sheet 2.2], we can propose three design scenarios for incorporating BIPV: S1-Conservation, S2-Renovation, and S3-Transformation. Each scenario implies a technological approach and defines specific energy performance targets.

Keywords: BIPV architectural integration; Renovation project; Level of intervention.
Target audience: Regulation makers; Owners & other decision makers; Architects & engineers; Suppliers & companies; Broader public.

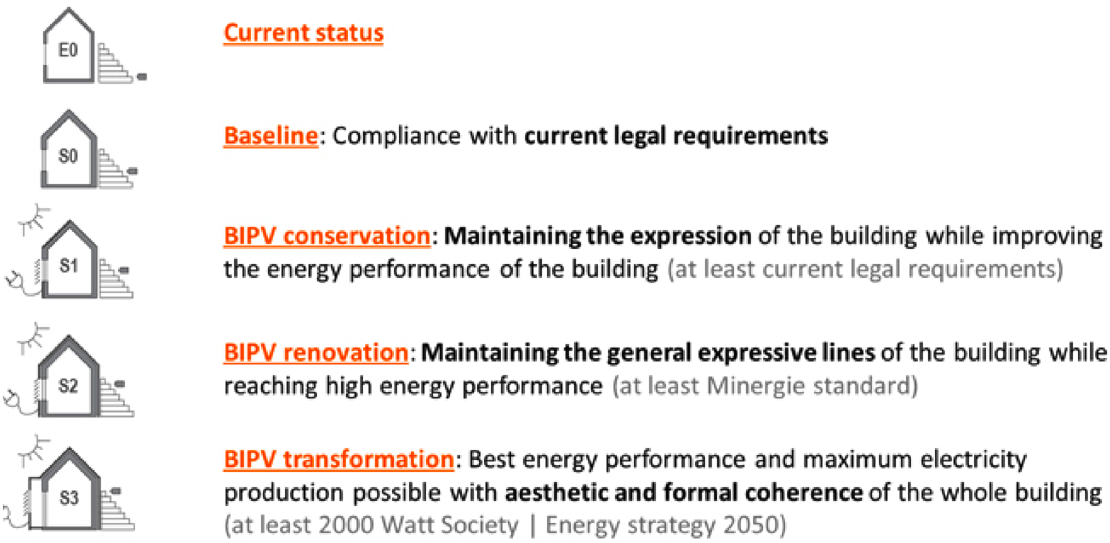

Fig. 1 Proposed renovation design scenarios for BIPV strategy : E0-Current status, S0-Baseline, S1-Conservation, S2-Renovation and S3-Transformation [1] (©EPFL-LAST).

One of the main issues faced when requesting a construction permit for a BIPV renovation project relates to the visual impact on the final aspect of the building. We propose three different approaches from an architectural design standpoint to try to address this matter.

Before choosing a scenario for BIPV strategy – S1-Conservation, S2-Renovation or S3-Transformation (Fig. 1) – it is necessary to study each building in detail to obtain a picture of the actual situation. Thus, the first reference scenario is the current status (E0), where all the necessary information to define renewal strategies, technical feasibility and economic feasibility is compiled. This study is also used to detect all BIPV integration opportunities in the building's thermal envelope. The subsequent scenarios, defined in terms of architectural objectives, will try to respond to the demands of the built environment in each archetypal situation.

E0-Current Status | S1-Conservation | S2-Renovation | S3-Transformation

Fig. 2 Example of BIPV renovation scenarios proposed according to design and energy performance objectives [1] (©EPFL-LAST).

S1-Conservation: This scenario aims to maintain the substance or expression of the building when possible (considering current practices) while improving its energy performance, by replacing defective elements with better performing ones: for instance, by changing windows, internal wall insulation and roof insulation. The highest performance is not necessarily achieved, because we want to respect the existing appearance of the building, but current legal requirements [2] should at least be achieved. In addition, unlike the baseline (S0, current practice), in this scenario (S1) we propose to respect the targets needed to obtain a subsidy of 60 CHF/m^2 from the "programme bâtiment" [3] which promotes energy renovation of existing building envelopes.

S2-Renovation: This scenario aims to maintain the general expressive lines of the building while reaching high energy performance and high electricity production (as reference, at least Swiss Minergie® standard label [4] for renovation projects), placing photovoltaic elements wherever possible.

S3-Transformation: This scenario involves a global strategy corresponding to the best energy performance and maximum electricity production possible (at least 2,000-Watt Society [5], according to Energy strategy 2050 [6]) with aesthetic and formal coherence of the whole building, but allowing the image of the building to be changed radically. The results of this scenario should show the energy performance improvement potential for each type of building and the feasibility of achieving the 2,000-Watt Society concept targets.

Fig. 2 shows an example of implementation of the different BIPV renovation scenarios for the Archetype 4, built in the 70s as detailed in [sheet 2.2]. For S1, the window railings are used and an internal insulation is proposed. For S2, a ventilated facade renders almost all opaque surfaces active. Finally, for S3 we propose a prefabricated facade using low-carbon materials modulated using standard-size PV elements.

The multi-criteria scenario assessment, which integrates both qualitative and quantitative aspects, is described in [1] and [sheets 3.2 and 3.3]. Through an iterative process between the assessment and design phases, the scenarios are refined in an integrated process to ensure the architectural quality of the propositions.

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Integrated Design 2.4

How can BIPV be integrated in architectural design?

To overcome the various obstacles that prevent the implementation of Building-integrated photovoltaics (BIPV) in renovation projects, early integration in the design process is key. Here, we provide recommendations on how to proceed.

Due to the interaction between BIPV and several building concepts, working with Building-integrated photovoltaics (BIPV) must be anticipated from the very beginning of the project. The complexity of implementation means collaboration between various professionals is required. Although difficulties in this process remain, a calculated investment during the planning phase and the support of a professional informed about BIPV issues could greatly facilitate implementation.

Keywords: Architectural design process, Architectural integration, Design phase.
Target audience: Owners & other decision makers; Architects & engineers; Suppliers & companies.

Unlike Building-added photovoltaics (BAPV), which act as an addition to an existing building, Building-integrated photovoltaics (BIPV) form an integral component of the building. In addition to producing energy, BIPV have one or more other essential structure functions, such as, for example, protection against falls (guardrails) or protection against bad weather (facade cladding).

Due to its multifunctional nature, the integration of BIPV into the building is challenging for the following reasons:

- It is a component that interacts with the energy concept of the building through its energy producing function and its possible involvement in the layers of the building envelope; and
- It is a component that interacts with the architectural concept through one or another of its other functions, whether in terms of aesthetics, safety for people, etc.

Integrate BIPV from the project genesis

Thus, to guarantee implementation, it is necessary to think about BIPV in parallel to the other building issues from the genesis of the project onward. Opportunities to integrate BIPV into the work are increased by ensuring that it is an integral part of energy and architectural concepts. Building design and construction involves many successive tasks, which are described by the SIA in its various standards [1]. Some of them can influence the implementation of BIPV to the extent that important decisions concerning it are taken there. These tasks can be described as "critical moments" for BIPV [2].

As soon as the objectives are defined (see SIA phase 1: Definition of objectives), decision makers can promote or hinder the implementation of BIPV. For example, "the share of renewable energy planned" to meet the building's energy needs. SIA phase 2: Preliminary studies contains the task of a specialized engineer "Development of a provisional program of installations and equipment" this may impact directly on the implementation of BIPV. These two examples show the importance of thinking about BIPV upstream, failing which, it might not be considered.

A joint integration

Designers must have the resources, knowledge and skills to integrate BIPV into planning from the start. However, although it is up to the project manager - often, the architect - to integrate BIPV, this person is not necessarily in a

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position to do so, because BIPV generates complexity due to its interactions with the building concepts [3]. Therefore, a healthy collaboration between the various stakeholders is necessary to ensure its implementation.

However, several limiting factors have to be overcome in order for collaboration to take place from the onset of the project. While SIA standards [4] include tasks for specialized engineers and architects from phase 1, these are optional. In practice, only a few owners mandate these preliminary study phases [2], which are essential to the development of energy and architectural concepts in general, and to the implementation of BIPV in particular. Even with reference to the current practice of commissioning as early as phase 3 (during which, according to SIA, standard tasks are no longer optional), there is no requirement for them to be carried out jointly by the architect and the specialized engineer.

An iterative approach

The development of building concept by integrating all the different components, including BIPV, is done through the project action generally led by the architect. It is an iterative and cumulative approach : the project is refined over time, and it goes through successive stages, from deciding on the major orientations, to integrating more detailed elements.

If the architect develops the project continuously, the engineers are mobilized as needed, without necessarily sharing an overall vision of the stakes of the building. These distinct postures (due to the current process model and professional cultures) prevent the close collaboration necessary for complex integration of BIPV. Greater involvement of engineers in project work should therefore be considered from the earliest design stage. However, owners should be aware that the implementation of BIPV in this context lengthens the planning phase and increases its costs. On the other hand, this benefits the project in general and the BIPV in particular, in the sense that its implementation is favored, its integration into the installation concept is more coherent, its relevance in relation to other building concepts is ensured and therefore its cost justified. Note that the implementation of BIPV can only be possible with the support of a convinced and informed project owner.

Stakeholders to be included

Companies from the construction sector, who could play a central role in the implementation of BIPV thanks to their product knowledge, enter the process late (SIA phase 4: Call for tenders). This reduces the possibility of knowledge transfer to designers and their participation in the project development. To address this deficit, the creation of an advisory role led by a professional with knowledge of planning methods, technical and physical challenges of buildings and BIPV products and technology should be considered. Suppliers would find in this specialist a vector of diffusion for their products in an emerging market. It remains to be defined which professional circle could propose this hybrid profile, located between disciplines.

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