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## **Sustainable Building Envelopes (Ecobuildings, Retrofit, Performance Gap)**

# **Solar Energy in retrofitting building: 10 case studies of integration in the residential heritage of the 20<sup>th</sup> century in Western Switzerland**

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### **Abstract**

The main purpose of the research is to suggest qualitative and efficient integrated solutions of solar energy into existing buildings in a delicate balance between energy production and respect of the building quality and its context. Solar capture is integrated into the building envelope according to harmonious composition respecting the global architectural logic. Calculations show that existing buildings have significant potential for solar integration on both roofs and facades. The research raises many questions about the way we apply solar panels on the different parts of a building and encourages developments of products as photovoltaic and thermal panels towards sustainable buildings.

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## **1. Findings and Goals for future**

The research starts from three fundamentals findings. First, the interest developed for the solar power and his necessity toward a sustainable energy production. Secondly, the growing of the number of aging buildings. Thirdly, existing buildings retrofit is a non-usual practice.

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### 1.1 Solar energy needs

The energy retrofit of the existing buildings and the construction of new energy-efficient buildings are challenges to reach the goals of energy strategy 2050 in Switzerland. Solar energy is essential to tackle sustainable changes. Increase of decentralized electricity production sites and thus the development of a renewable energy systems as well as the development of global energy management are large projects to develop [1]. Nowadays, solar energy production is not yet widespread despite its huge potential. It represents only 2% of the total electricity supply in Switzerland [2].

### 1.2. Modern heritage and new constructions

An important part (24-34 %) of buildings with more than 3 levels were built before 1920 in cantons of Fribourg, Vaud and Geneva. Then, a second period of quantitative construction which corresponds to urban sprawl mechanism started in the 1960s. Nowadays, a lot of residential buildings are getting old. This set of buildings is less energy efficient than new constructions and consumes up to seven times more energy [2].

### 1.3. Retrofitting existing buildings

Introduction of renewable energies in new buildings or extended spaces such as attics is mandatory in the requests for building permits. The requirement of renewable energy production varies depending on the canton. Nowadays, only 0.9% of real estate is retrofitted. A proposition is to consider the building envelop, the building technologies and at the same time, the introduction of renewable energies like solar energy in energy retrofit. The research lies in a global process which takes into account various stages of renovation. The goal is to encourage the owners and the planners to consider this process as long-term costs savings and ensure a full and synergic use of necessary facilities during the retrofit period (installation of scaffolds for attaching the peripheral insulation also used for installing solar panels).

## 2. Ten case studies



Fig.1. The 10 studied buildings (a) Avenue de carouge,48 Genève ; (b) Avenue d'Edouard dapples19, Lausanne ; (c) Rue de Borde1, Lausanne ; (d) Chemin du Levant 137, Lausanne ; (e) Avenue du Bois de la chapelle 69, Genève ; (f) Route de Morges 24, Cossonay ; (g) Impasse de la forêt 20, Fribourg ; (h) Avenue du bois de la chapelle 89, Genève ; (i) Rue de Zurich 17, Genève (j) Avenue de Roseraie 34, Genève.

The research is based on typologies of residential buildings of the 20th century that have been selected as part of eREN research project developed at the institute TRANSFORM, SLL and published in June 2016. Ten studied buildings are scattered across 3 cantons of Western Switzerland (Fribourg, Vaud and Geneva). They have more than 3 dwellings and represent 17- 35% of real estate depending on the canton but a significant portion of dwellings; 72% to 89% [3]. Collective housings retained show several periods of construction (from 1901 to 1988) and are presented following the date of construction [4]. See Fig. 1. They are located in different contexts sometimes in a dense and sensible urban context that influence the strategy of solar panels integration.

### 3. Method of solar energy integration and calculations

Finding solutions and scenarios to integrate solar capture elements on existing buildings needed knowledge in historical, architectural, energetic, technical and economical fields. The challenge is to find the right balance in each case. Thus, based on the actual practices and the available products, we defined a scenario balance and a scenario maximum. The balanced one is based on the actual uses and offers a possible response to solar integration for today. In the majority of cases, the roof and handrails are favorable surfaces for integration of photovoltaics and thermal panels. In the scenario maximum, we propose a possible answer for tomorrow through a global intervention on the entire building envelope.

Depending on the type of the building, two different strategies of solar panels integration have been developed. The first one is the symbiotic approach: active surfaces are placed by copying architectural existing organization. For example, strategies of integration in cases (c), (d), (e), (f) and (g) are similar. While helping aesthetes, handrails or roofs are identified as suitable surfaces for solar integration in balance scenarios. The scenario maximum for cases (d), (f) and (g) suggest a solar integration in the entire facade. The second strategy, by creating a new personal identity of the building, is at odds with the existing language of the context. For cases studies (a), (h) and (e), we propose a new expression of the building through solar integration by keeping the rhythm and structure of the facade. Potential surfaces for solar panels integration in cases (b) and (j) are too cramped and have non-orthogonal dimensions. Thus, the integration of solar panels is not addressed.

#### 3.1 Toward 100% productive envelope

This problematic invites to search a good use of solar panels on facades. Nowadays, solar panels are installed on the new or retrofit building roofs. The law on the spatial planning specify to “*orient urban development into built environment*”. The concept of densification is coupled with construction of new buildings and retrofitting existing buildings in order to be denser and more energy efficient. So, more productive surfaces such as facades of collective housings need to be use for producing energy. For example, external insulation application could be linked with solar panels integration or the extension of a current building is the opportunity to introduce solar facade on the roof.

Finally, the aim is to achieve maximized productive envelopes for new and retrofitted buildings. Envelopes could be composed by vegetation modules, active modules or passive modules. That is the reason why integration of solar panels on facade is an actual and central issue in this research.

#### 3.2 Energy production calculations

The energy production calculations have been performed on both roofs and facades for the 10 building cases and the corresponding energy coverage ratio for electrical and thermal production of the building have been obtained.

Solar panel types have been selected from the current market with available Swiss or European products with different photovoltaic and thermal technologies. Also, standard size panels have been selected. The aim of the calculations is to provide quantitative information on the energy yield (kWh/m<sup>2</sup>). Calculations were provided by PVSyst software for monthly and yearly production.

#### 4. Case study 01: Avenue de Carouge 48, Geneva

##### 4.1. Architectural logic

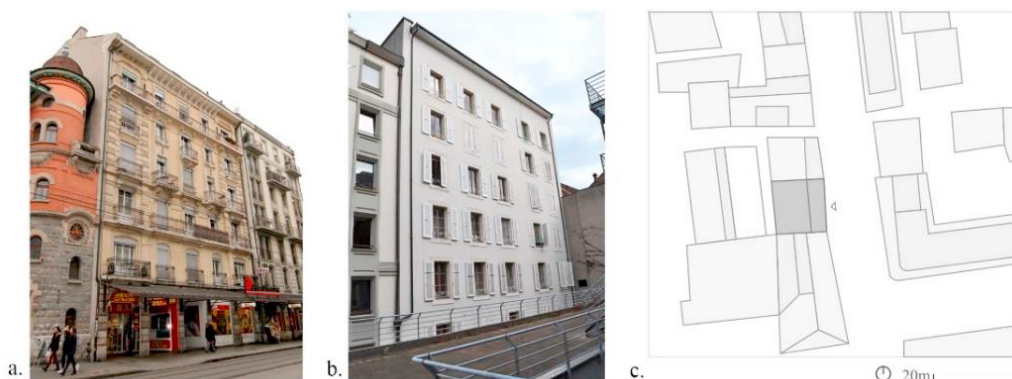


Fig. 2. (a) East facade; (b) West facade; (c) Situation plan

The building was constructed in Geneva in 1901. It is included in a dense urban island organized around a courtyard. The building is contiguous in the North with a residential building and in the South with a theater that, even if it is not classified as a protected building, has architectural qualities. The roof is asymmetric and neighboring buildings are closely spaced.

It is a characteristic example of 1900's buildings: The East facade on the street side is well decorated while the West facade on the courtyard side is rather plain. The West façade that is not visible from the street and the roof are key surfaces of the intervention. We ordered available productive surfaces for solar panels integration. Light grey color show non advised potential productive surfaces while dark grey color show adequate productive surfaces. See Fig. 3.



Fig. 3. (a) Schematic section with intervention surfaces; (b) Hierarchy of potential productive surfaces: West facade; (c) Hierarchy of potential productive surfaces: East facade; (d) Hierarchy of potential productive surfaces: Roof

#### 4.2. Choice of solar panels and integration

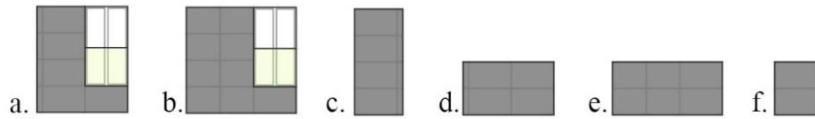


Fig. 4. (a) Example of Meyer Burger solar panels integration; (b) Texture, color and seals of Meyer burger thermal panels;

Thermal and photovoltaic panels supplier is Meyer Burger company. The production of solar panels is located in Thun, Switzerland. The color of solar panels is homogeneous and seals of solar panels are fine and regular. See Fig.4

In order to ensure the best use of the West facade, the main idea is to redesign the whole surface by giving it a new identity. The lower part of the facade is less sunny however it is studied as the rest of the surface. Based on the fact that the building retrofit is planned, the integration of solar panels needs to occur at the same time. Windows, railing and external insulation are thinking with the integration of solar panels. Windows are extended to the floor slab. The rhythm of openings is regular.

The proposition is to create hybrid module composed by photovoltaic panels, an efficient window, a transparent railing and external insulation. Window, railing and insulation are regular components. See Fig. 5. In this case study, six different hybrid modules form the facade. Elements should be assembled on a fix metal structure before being installed on the existing facade. Openings and glass railings (yellow) balance dark color of solar panels (dark grey) and create a new look for the retrofitted facade. The renovated West roof pitch is entirely covered by photovoltaics, thermal solar panels and dummies. The intervention on the roof could be the balance scenario. The new West facade with hybrid solar modules could be the maximum scenario.

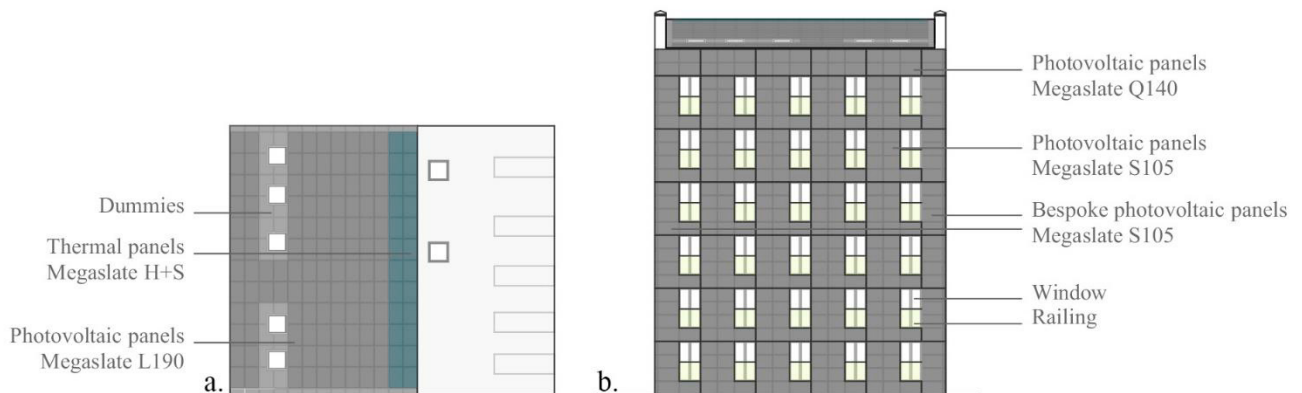


Fig. 5. Different types of hybrid modules (a) hybrid module includes 5 solar panels and regular components; (b) hybrid module includes 9 solar panels and regular components; (c) hybrid module includes 4 solar panels; (d) hybrid module includes 4 solar panels; (e) hybrid module includes 6 solar panels; (f) hybrid module includes 2 solar panels.

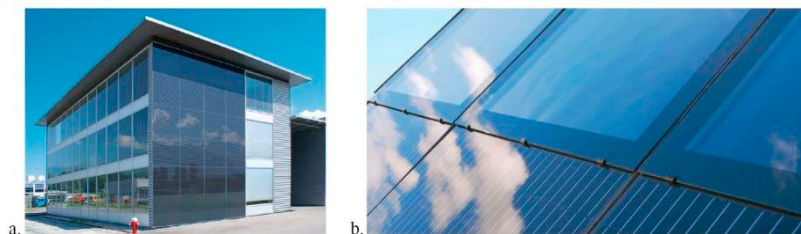


Fig. 6. (a) Retrofitted energy productive roof; (b). West façade composed with hybrid modules.



### 4.3. Calculations and conclusions

According to a previous research eREN, the heat needs before renovation are 285 MJ/m<sup>2</sup>. The heat needs after renovation which include peripheral insulation, windows replacing and complete roof renovation are 108 MJ/m<sup>2</sup>, which is smaller than the SIA 380/1 target value of 112.8 MJ/m<sup>2</sup>. With energy reference area about 2072 m<sup>2</sup>, the annual power needs for heating are 62'160 kWh/year and 222'344 kWh/year after and before renovation, respectively. For electrical needs, 18 households live in the building and a consumption of 3'500 kWh/year for each family has been considered.

112 photovoltaic panels are installed on West pitch roof 15°, 84° azimuth, and produce 22'450 kWh on average over the year. They produce about 36% of total electricity needs. No shading from other buildings is taking into account.

300 photovoltaic panels are installed on West façade 90°, 84° azimuth, and produce 24'137 kWh on average over the year. The building opposite shadow is estimated about 30% of the final production. So, the estimated electricity production on façade is 16'895 kWh on average over the year. It represents 27% of the electricity needs. Based on a first approach with PVsyst calculations and panel cost, the cost of the PV system including integrated Megaslate panels on the roof is 46 cts/kWh, to be compared with 34 cts/kWh with standard panels. The cost of integrated photovoltaics panels on façade is 72 cts/kWh without shadowing consideration.

Table 1. Electricity production breakdown per month (without shadow)

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
Roof Power production (kWh)	593	985	1840	2399	2928	3220	3280	2800	2025	1239	675	467
Façade Power production (kWh)	761	1188	2090	2548	2962	3201	3295	2943	2259	1439	844	607

With an SIA 384/1 target value of 75 MJ/m<sup>2</sup>, the Domestic hot water needs are about 43'167 kWh/year, which is comparable with heat needs after renovation. 24 solar panels are installed on the upper part of the West pitch roof 15°, 84° azimuth. Assuming an efficiency of solar thermal panels of 60%, the annual production is 13'854 kWh/year, which represents a coverage rate of 32% over the year.

Table 2. Hot water production breakdown per month

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
Coverage rate of hot water needs per month (%)	10	17	31	41	51	56	57	48	35	21	11	8

To conclude, this example of solar panels integration on façade is a high impact intervention which reinforced the existing duality of the building: the renovated new West facade contrasts with the East facade on the street side. The implementation of solar panels and global renovation through the preassembled hybrid modules seems to allow easier and faster energy facade retrofit. For cost consideration, the two scenarios of solar integration on both roof and façade make sense if they are linked with building retrofit especially for the scenario maximum. Furthermore, a holistic approach in building energy retrofit including the integration of renewable energy is therefore necessary.

Finally, the studied scenarios have made it possible to assess solar integration potential and have provided a basis for calculations. The next step is to develop architectural projects which include construction details of panels integration for each case study.

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