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Assessment and Demonstration 5.1

What are the legal requirements for BIPV?

Building-integrated photovoltaic (BIPV) modules/systems have to be compliant with both electro technical standards and existing building codes and practices, since they are both generators of electricity and part of the building envelope.

Standardization of Building-integrated photovoltaic (BIPV) systems is under discussion and progressing at the international level in ongoing research activities and working groups. The BIPV sector, within the legal framework set by the CPR 305/2011, can rely on a solid normative building framework and, for specific requirements, next researches and standardization works are going to contribute in covering gaps and supporting the BIPV market with testing and performance assessments.

Keywords: BIPV quality; Standards; Normative compliance; Testing procedures; Safety.
Target audience: Regulation makers; Owners & other decision makers; Architects & engineers; Suppliers & companies.

According to EN 50583, Parts 1 and 2, "Photovoltaics in buildings" [1], "Photovoltaic modules are considered to be building-integrated, if the photovoltaic modules form a construction product providing a function as defined in the European Construction Product Regulation CPR 305/2011 [2]."

Thus, the Building-integrated photovoltaic (BIPV) module is a prerequisite for the integrity of the building's functionality. If the integrated photovoltaic module is dismounted (in the case of structurally bonded modules, dis-mounting includes the adjacent construction product), the photovoltaic module would have to be replaced by an appropriate construction product".

But beyond definitions, what does this mean? What is the reality for the market?

In most EU countries, as well as in Switzerland, there is a lack of harmonized BIPV standards for building skin technologies (e.g. curtain walls, cold facades, etc..) or official regulations defining special technical requirements and testing/qualification procedures for building envelopes integrating PV. From the electro/technical side, the design qualification and type approval of PV modules is done according to the standard EN 61215 or EN 61646, but these cannot provide a reliable performance assessment for most building requirements. On the other side, from the building perspective, in the current framework a BIPV system is often considered as the conventional equivalent system it is replacing, such as a curtain wall facade or a pitched roof.

Thus, depending on the main mounting categories (roof, facade and external devices) and the main composing material (e.g. glass, membrane, metal, plastic, etc.), the essential BIPV requirements are defined, and the main reference performance are taken from existing standards for construction products.

For example, if, according to the type of installation, PV components can be treated as glazing systems for the building skin, the construction rules of glass building skin must be met. Accordingly, and thanks to the combination of extensive glass know-how with photovoltaic technology, some manufacturers of BIPV glass mark their products according to CE-marking for laminated safety glasses - not developed for PV building integration.

Once the requirements for the BIPV's final intended use in the building skin are identified, the related building performances have to be verified, to assess if the element can be used or not in building envelope (e.g. mechanical safety, fire safety, glass safety, etc. See the basic requirements for construction works are set out in Annex I of CPR 305/2011). Formally, if EN 50583:2016 is applied, it is also necessary to obtain the correct qualification procedure for applying a CE-mark as a construction product according to CPR 305/2011.

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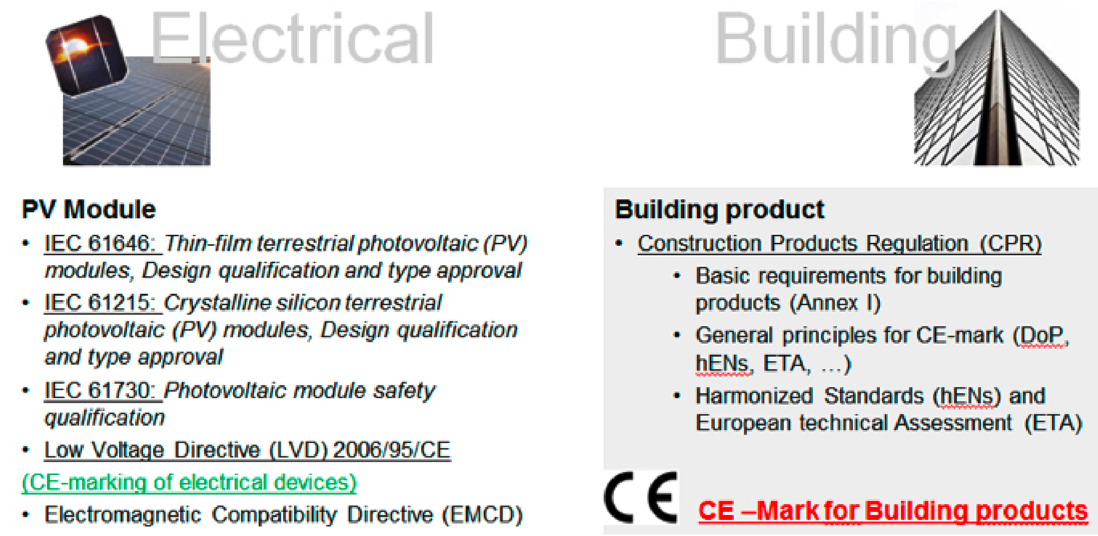

Fig. 1 Overview of electrical and building technical standards (©SUPSI-ISAAC).

In conclusion, we can summarize that:

- BIPV elements, as part of the building construction, are affected by both European directives for construction products and electro-technical standards for PV products;
- Construction products must comply with harmonized standards where available, or the corresponding alternatives allowed by Construction Products Regulation;
- Further requirements for construction products are given by national building codes; and
- In the case of composite material-based construction products such as BIPV, most current standards seem to be not directly applicable/valid for testing some technical requirements (e.g. mechanical, fire safety, etc.).

Performance-based methodology should be applied to each BIPV project, because the required performances can vary depending on the BIPV project location, the building's geometry and typology, the use as well as the envelope system and the specific conventional PV module.

Once the final intended use of the PV element in the building skin is determined, the standards in force (e.g. building codes) can be applied to BIPV elements to verify an adequate performance level for the building use (e.g. this is already adopted in many BIPV glasses for a performance assessment like the safety glass, mechanical resistance, g-value, U-value, etc.). However, in most cases, some missing gaps call for further research, since BIPV requirements cannot be considered the simple sum of building and PV prescriptions in force. The development of new testing procedures for a performance-based approach is still a relevant question for BIPV sector [2-4].

The next challenge in BIPV field will be to identify the missing gaps within the current standardization work and existing normative framework in relation to the most relevant BIPV requirements, performance risks, reliability and potential failure mechanisms to define the main routes for the development of new qualification procedures to support the market.

References

[1] Regulation (EU) No 305/2011. European Construction Product Regulation.
[2] EN 50583:2016 Photovoltaics in Buildings (part 1: BIPV modules and part 2: BIPV system).
[3] P. Bonomo, F. Frontini, E. Saretta, M. Caccivio, G. Bellenda, G. Manzini, P. G. Cappellano. Fire Safety of PV Modules and Buildings: Overviews, Bottlenecks and Hints, EU PVSEC 2017", 2017.
[4] E. Saretta et al. Laminated BIPV glass: approaches for the integration in the building skin. In J.Schneider and B. Weller (Eds.), Engineered Transparency 2016: Glass in Architecture and Structural Engineering (363-372). Ernst&Sohn, 2016.

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Assessment and Demonstration 5.2

How can we define a methodological assessment framework?

This common methodology aims to define terms, to prescribe common assumptions and input values like energy prices, future price developments, assessment periods, impact calculation methods, and system boundaries, and to provide a basis for optimizing possible BIPV solutions.

To achieve as much consistency and comparability as possible among the different projects and work packages within ACTIVE INTERFACES and beyond, a common assessment methodology was developed and outlined. This methodology was the basis for the assessment of energy, greenhouse gas and economic impacts of Building-integrated photovoltaic solutions (BIPV solutions), as well as for comparing BIPV solutions with non-BIPV renovation options.

Keywords: Energy; Greenhouse gas; Cost assessment; Impact analysis; BIPV in building renovation.
Target audience: Architects & engineers; Suppliers & companies.

The impacts of Building-integrated photovoltaic (BIPV) solutions on energy generation and consumption, greenhouse gas emissions (GHG), and costs have to be assessed on the basis of a common methodology, which defines common terms and system boundaries, outlines calculation methods for the impact assessments, and proposes common input values (eg. life spans or energy prices and their future development) [1].

Scope

The impacts of BIPV solutions are assessed for the subsequent impact categories and indicators: Total and non-renewable primary energy use, comprising operational primary energy use (heating, ventilation, air conditioning, domestic hot water and auxiliary energy use), primary energy use for operation and maintenance, and embodied primary energy use for BIPV and renovation measures, including replacements during the assessment period if needed.

Greenhouse gas emissions of energy consumed as well as of embodied energy use (LCA)

Life cycle costs (LCC) during the assessment period comprising costs for interest and amortization during the life cycle or the assessment period and maintenance costs.

System boundaries

The boundary for on-site generation of renewable energy and for the energy consumed by the building (net delivered energy) is the building lot.

Approach for impact assessment of building renovation with BIPV solutions

It is assumed that BIPV solutions are part of a renovation project which might also comprise further energy related and non-energy related measures. To correctly determine the (net) impacts of BIPV solutions assessed on costs, primary energy use and carbon emissions, a common reference renovation option is defined, as it would be carried out if BIPV was not part of the package of renovation measures ("reference renovation" in Fig.1). Net impacts of the renovation solution with BIPV result as the difference between the impacts of the BIPV renovation solution minus the impacts of the renovation option without BIPV. Both solutions will provide a building which is renovated in compliance with existing regulations and which is supposed to be functionally viable for at least the next 20 years.

These factors are determined by LCA and take into account upstream energy use and related emissions for extraction, processing, transportation and distribution of various energy carriers. Primary energy (PE) conversion factors and GHG emission factors of electricity savings due to BIPV depend on the way electricity deliveries from the grid which are replaced by BIPV electricity were generated. We propose to apply the conversion factors of the current national mix of electricity consumed.

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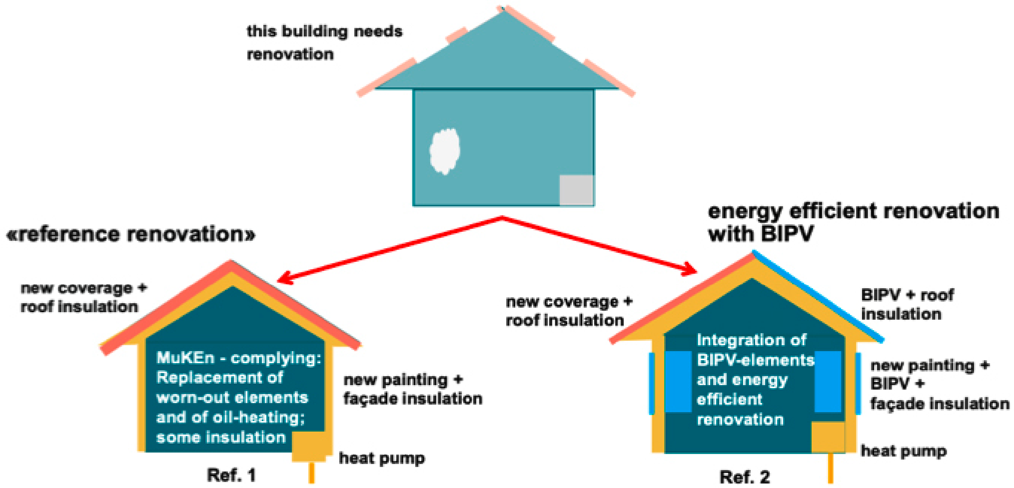

Fig. 1 Definition of a common "reference renovation" versus an energy efficient renovation with BIPV (©econcept).

The conversion factors of energy delivered by district heating and cooling systems depend on the input share of the energy carriers needed to generate district heat or cold, and on the corresponding PE and emission factors.

Cost assessment

The cost assessment is based on a life cycle cost approach, determining global costs: the sum of the present values of the initial investment costs, plus present values of running costs, plus present values of operational, maintenance and replacement costs during the calculation or life cycle period.

Economic valuation of on-site generated BIPV electricity

In the current Swiss situation, determination of the value of BIPV electricity fed into the grid depends on the way BIPV is installed and subsidized: either the feed-in remuneration at cost model (RPC) or the self-consumption model with remuneration for excess electricity fed into the grid. Since RPC remuneration is not available any more, fed-back electricity is valued according to current Swiss energy law, which requires utilities to make market-anchored payments corresponding to the resulting cost savings for the particular utility.

Overall assessment procedure to determine the impacts of BIPV renovation solutions [1]

1. Collection of building data which is needed for the assessment
2. Definition of the necessary reference renovation solution (reference case without BIPV)
3. Definition of the renovation solution with BIPV
4. Determination of system boundaries, general input values (energy prices, interest rates, life spans, assessment period, possible subsidies and remuneration rates for fed-back electricity)
5. Collection/calculation of energy, emission and cost data to determine impacts of the BIPV renovation solution
6. Impact calculation for the reference renovation and for the BIPV renovation case (e.g. with the INSPIRE-tool).
7. Option 1: Further calculations to determine impacts on revenues for the building owner, return on equity, rent increases, etc.
8. Option 2: Sensitivity calculations for different energy prices.

References

[1] W. Ott, M. Lehmann. "Common methodological framework to assess energy, climate and economic impacts of BIPV"; Report 1/3, National Research Programme “Energy Turnaround” (NRP 70) ACTIVE INTERFACES – Holistic strategy to simplify standards, assessments and certification for building integrated photovoltaics. SNF project 153849, 2016.

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Assessment and Demonstration 5.3

How can BIPV be visually assessed?

Visual assessment is necessary to quantify how well photovoltaic modules are visually integrated in a building or environment. Novel methods and tools were developed to assess three main criteria: saliency, reflection and color.

The saliency method is a perception-based assessment of the visual change that a building or environment experiences through a potential BIPV retrofit. This assessment is based on a novel computational simulation method and allows the quantification of the spatio-temporal glare impact of light reflected from BIPV surfaces. The color assessment quantifies how well the perceived color of a PV module matches the desired gamut.

Keywords: Saliency; Reflection; Color.
Target audience: Regulation makers; Owners & other decision makers; Architects & engineers.

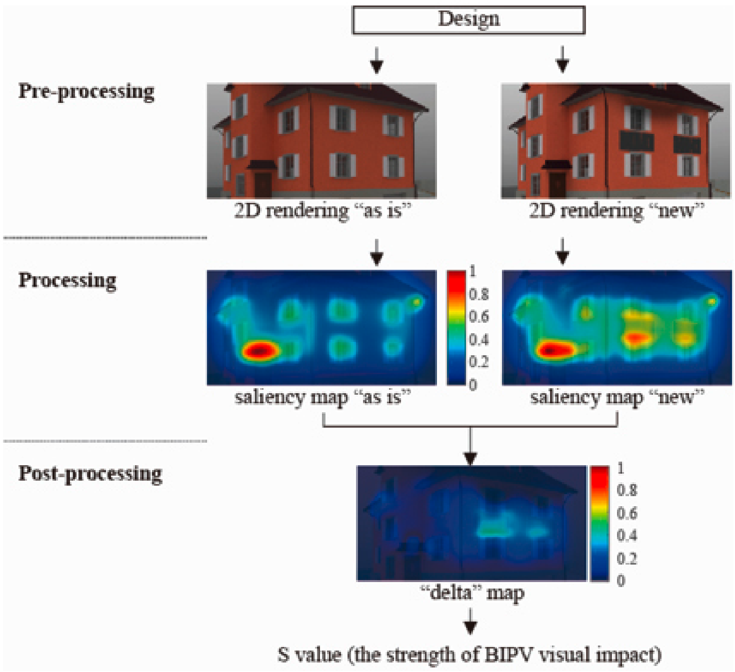

Fig. 1 Simplified workflow of the saliency method (©HSLU-CC-EASE).

Saliency: The **saliency method** is a tool used in computer graphics to prioritize areas of visual attention in 2D images for image compression algorithms or in 3D models for level of detail in modeling. We analyzed several saliency models and transferred the Graph Based Visual Saliency for the first time into the BIPV context, for which several modifications were developed and applied in case studies [1]. The images in Fig. 1 shows a simplified workflow. Based on two images (existing design and proposed new design with BIPV), the modified saliency method computed the visual difference into a delta map, quantifying the visual impact. This visual impact can be related to regulations, e.g. allowing higher impact in industrial areas, and mandating lowest impact for heritage areas [2].

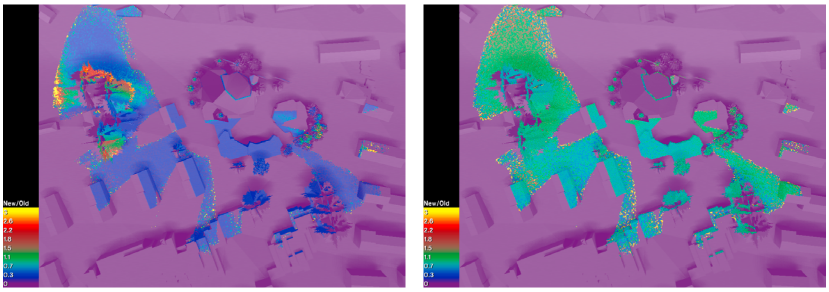

Fig. 2 Left: Standard PV ("new") vs. existing roof ("old"); Right: Satinated PV ("new") vs. existing roof ("old") (©HSLU-CC-EASE).

Reflection: The novel **computational simulation** is based on forward raytracing of sun rays obtained from hourly simulations using weather data, and detailed data obtained from goniophotometric reflection measurements of different BIPV glass properties [3]. Like in the saliency method, the original and proposed state were modeled in 3D as a base for relative comparison. Here the accumulated irradiance "before" and "after" were compared and expressed as false color renderings. The images in Fig. 2, for example, indicate which areas of the site plan are subject to the most increase in irradiance and thus may yield a glare problem (image left). Further simulations using different glass surface properties showed that the glare probability within this area can be reduced to an acceptable level (image right).

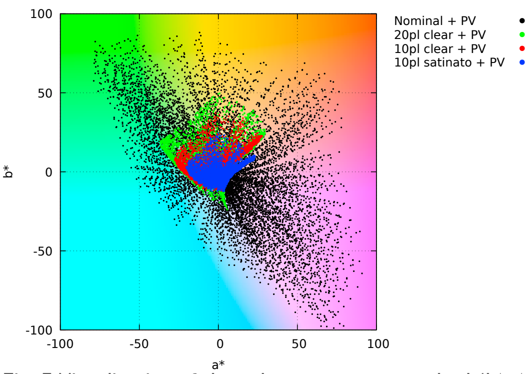

Fig. 3 Visualization of the color assessment method (L*a*b* Effective Gamut) (©HSLU-CC-EASE).

Color: The novel **color assessment method** is again a relative assessment, this time between a specified color and the perceived color, when PV glass is printed digitally with ceramic ink. Two corresponding images were compared and their color differences were computed according to CIE standards. The difference was validated through experiments with humans [4]. In a second step, more than 1,000 colors were specified, printed on glass and assembled as colored PV modules. Using the above method, the color gamut of the specified and perceived colors was compared. The black dots in Fig. 3 show the color coordinates of the specified colors, while the other dots show the corresponding coordinates of the perceived colors when printed on clear and opaque glass with different amount (pl) of ceramic ink, indicating reduced color gamut of digitally-printed colored PV modules [5].

References

[1] R. Xu. Visual Impact assessment of BIPV in building retrofits using saliency methods. PhD Thesis EPFL, 2016.
[2] R. Xu et al. Quantitative Evaluation of BIPV Visual Impact in Building Retrofits using Saliency Models. Energies 10/5, 2017.
[3] Schregle et al. Spatio-Temporal Visualisation of Reflections from Building Integrated Photovoltaics. Buildings 8(8), 2018.
[4] Schregle et al. Computational Colour Matching of Laminated Photovoltaic Modules for Building Envelopes. Buildings, 7(3), 2017.
[5] Schregle, et al. An Image-Based Gamut Analysis of Translucent Digital Ceramic Prints for Coloured Photovoltaic Modules. Buildings, 8(2), 2018.

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Assessment and Demonstration 5.4

How can we improve the knowledge and technology transfer?

BIPV technology suffers from a lack of visibility and knowledge among the broad public, but also among professionals in the construction field [1]. It is therefore important to raise awareness of the existence and feasibility of BIPV solutions, to create synergies between construction and BIPV stakeholders, and to train architects and engineers on the BIPV theme so they can advise their customers on this yet unknown technology.

Several communication vectors have been set up in recent years as part of the ACTIVE INTERFACES project in order to improve knowledge and technology transfer. This knowledge transfer must be done with the stakeholders of the building industry, so they can deal with this new technology, but also so that suppliers can offer them the most adapted solutions.

Keywords: Communication; Education program; Public event; Press release.
Target audience: Regulation makers; Owners & other decision makers; Architects & engineers; Suppliers & companies; Broader public.

Major stakeholders and communication vectors
The knowledge and technology transfer is targeted towards 6 major stakeholder groups:

- Legislation and regulation makers at federal, cantonal and communal level;
- Owners and other decision makers along the value chain;
- Architects, engineering offices;
- Suppliers, integrators, construction companies;
- Scientists and researchers in the concerned fields; and
- The broader public.

In order to optimize communication strategy impact, different types of communication vectors are activated for each group: open access website, public event and written publications (Fig. 1).

Vector	Legislations, regulations makers	Owners and other decision makers	Architects, engineering offices	Suppliers, integrators, companies	Broader public
1. Open access website	⬥	⬥	◆	◆	⬥
2. Public events					
a) Conferences			◆	◆	
b) Knowledge Transfer Platform			◆	◆	
c) Higher and Continuing education			◆	⬥	
3. Written publications					
a) Scientific publications			◆	⬥	
b) Printed version of results	◆	⬥	◆	⬥	
c) Professional press releases	⬥	⬥	◆	◆	
d) Non-specialized press releases	◆	◆	⬥	⬥	◆

Fig. 1 Types of vectors activated for each group ◆ Major target group ⬥ Secondary target group (©EPFL-LAST).

Regional public events & conferences

In the last few years, partners of the ACTIVE INTERFACES project have organized events with the aim of presenting research on new BIPV technologies, but also on BIPV architectural integration strategies and market studies:

- Abend der Wirtschaft 2014 Das solare Gebäude im System, Lucerne (LU), 2014
- Workshop Lifetime and Reliability issues in PV, Manno (TI), 2015
- 3ème Conférence Zéro Carbone, Fribourg (FR), 2015
- 17ème Forum Ecoparc, Neuchâtel (NE), 2017
- Workshop "Community Solar as a Business Opportunity for Municipal Utilities", St. Gallen (SG), 2018.

The progress of research work around BIPV is frequently presented at regional or national conferences, such as : National Photovoltaic Congress, Advanced Building Skin Conference, CISBAT Conference, Bau+Energie Messe and International Sustainable Built Environment (SBE) series Conference.

Working group on BIPV

A working group on the BIPV theme has been set up as part of the activities of the Building Innovation Cluster in Fribourg [2]. This initiative allows professionals in the fields of construction and BIPV to connect, in order to increase participants' visibility with potential customers or partners and create a dialogue between construction stakeholders and BIPV suppliers so that the latter can assess constraints and challenges and propose the most appropriate solutions for the market. These meetings are also an opportunity to introduce participants to some BIPV installations during site visits and thus promote the dissemination of BIPV through examples.

Technology transfer and product development with industry

A collaboration with Glas Trösch, the Swiss leader in glass processing, has led to the development of a new product, called Swisspanel Solar. This is a digital printing glass optimized for PV applications that can be supplied to any PV module manufacturer. Full commercial application has been allowed through the support of the Technology Transfer company ÜserHuus. This product used was publicly launched during SWISSBAU 2018, the largest building fair in Switzerland [3], accompanied by a press release [4]. In parallel, testing for international certification is underway, financially supported by ÜserHuus and following our research partner SUPSI's research findings on compliance with the latest technological standards.

Professional education program

Architects, PV manufacturers and planners who want to learn to create colored PV modules can attend a new professional education course at HSLU [5]. They learn about the meta-c-print method, experiences shared from Swiss research colleagues, product developers, and makers of pilot and demonstration projects, and can manufacture their own PV module at CSEM/EPFL labs. The course is supported by EnergieSchweiz and integrated into the Swissolar/SIA course system.

Summary sheets

The present summary sheets have been written with the aim of synthesizing and structuring the results of the research carried out by all partners in the project. They are intended for different target audiences, depending on their topic and level of detail, and guide the interested reader to more specific content or contact persons.

References

[1] M. Boesiger, J.-P. Bacher, Acceptance of building integrated PV (BIPV) solutions in urban renewal: obstacles and opportunities in Switzerland. Status-Seminar «Forschen für den Bau im Kontext von Energie und Umwelt», Zürich, 2018.

[2] Building Innovation Cluster website: http://energie-batiment.ch/

[3] Swissbau 2018 Glas Trösch Produktvorstellung "SWISSPANEL SOLAR. https://www.youtube.com/watch?v=zFx76b-yaA9M&vl=en

[4] Photovoltaik wird bunt. SWISSPANEL SOLAR: Mehrfarbiger Digitaldruck auf Photovoltaik Glas. https://www.glastroesch.ch/swissbau-2018/pressemitteilungen/pressemitteilung-swisspanel.html

[5] Farbige PV Module. https://www.hslu.ch/de-ch/technik-architektur/weiterbildung/fachkurse/farbige-photovoltaik-module

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Assessment and Demonstration 5.5

How can we raise public awareness?

Pilot or demonstration projects that concern BIPV in general – but not directly residential renovation – were carried out in parallel with the project, in order to test new technologies and their market feasibility.

Their exposure raises public awareness and interest in the profession and paves the way for widespread adoption of innovation. Hence, several P&D projects to test and demonstrate colored PV modules were develope in collaboration with several industry partners. This sheet proposes an overview those activities.

Keywords: Pilot & Demonstration; Energy Challenge; Umweltarena Schweiz; Haus Solaris; NEST@empa.
Target audience: Owners & other decision makers; Architects & engineers; Suppliers & companies; Broader public.

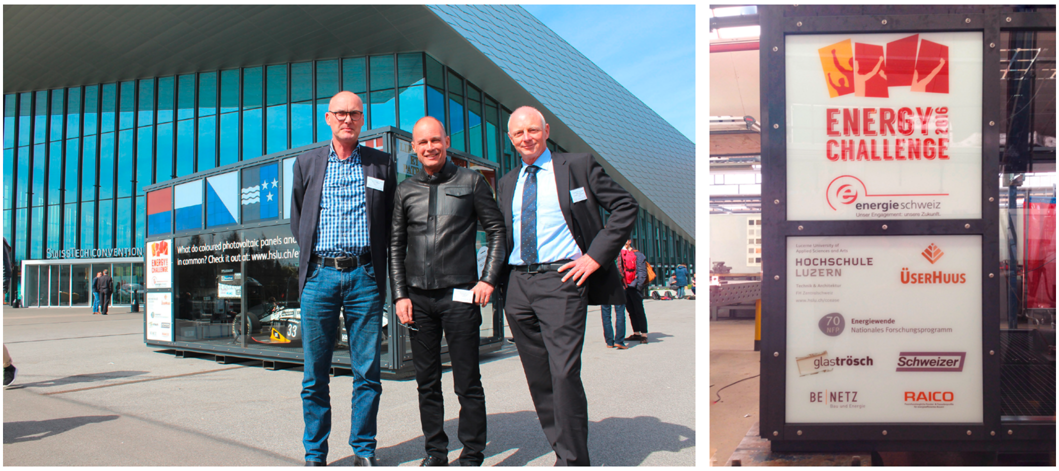

Fig. 1 The HSLU glass box was graced by Swiss Solar Pioneer Bertrand Piccard and Stefan Nowak, national program leaders in PV research, during the 15th National PV Conference at Swisstec Convention Center, Lausanne (©HSLU-CC-EASE).

2016 Energy Challenge: The Energy Challenge is a bi-annual Swiss event to raise public awareness of energy efficiency and renewables through exhibition and experiences, traveling across many cities in Switzerland. We designed and supplied a PV glass box (Fig. 1), featuring our colored PV modules designed as Swiss cantonal flags and serving as shelter and charger of the world's fastest Formula Student e-racing car, build in collaboration between ETH and HSLU. The PV glass box was designed as an off-grid PV system with battery storage and remote energy management system. The electrical system worked failure-free over the course of six months and traveling through eight cities, despite some minor water leakage through the roof. The NRP70 website featured this P&D project in their website's news section [1].

2017 "Swissness" PV facade at Umweltarena Schweiz: The Umweltarena isSwitzerland's national public exhibition centre for applied energy efficiency and renewables, attracting more than 100,000 victors annually. We initiated collaboration with Umweltarena and Technology Transfer company ÜserHuus and designed and built a PV facade on the staircase tower framing the entrance (Fig. 2). The PV facade features all cantonal flags and the national flag as PV modules, and hence underlines Umweltarena's claim of being a point of national interest. Since inauguration in June 2017, all systems work properly, validating the technology readiness [2]. The PV facade's electrical and visual performance is monitored remotely and summarized live on a public display in the visitor's center.

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Fig. 2 Original staircase tower (left) retrofitted with Swissness PV facade (middle) and collaborators Walter Schmid (Umweltarena, 2.f.l) and Jacqueline Schindler (ÜserHuus) during its inauguration on 22.06.2017 (©HSLU-CC-EASE).

House Solaris in Zürich: Architect Adrian Berger commissioned an Austrian PV manufacturer to build a terra cotta colored PV facade with vertically structured glass surfaces creating reflections resembling the dynamic water surfaces of the nearby lake (Fig. 3). HSLU consulted on its meta-c-print specifications for digital ceramic print, which increased electrical efficiency by 30% for the given terra cotta color [3].

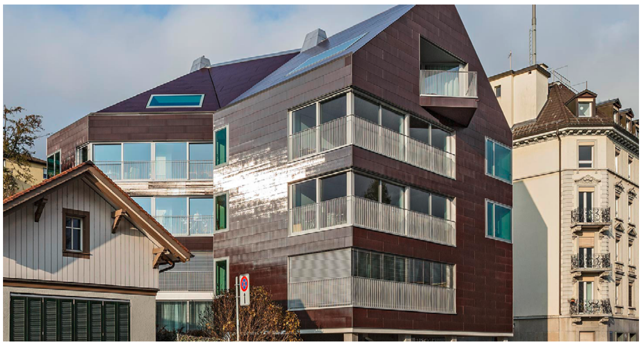
Fig. 3 House Solaris (©HSLU-CC-EASE).


Fig. 4 PV railing at NEST@empa (©HSLU-CC-EASE).

PV railing at NEST@empa: This project [4] features a new generation of our colored PV modules, this time with mono-crystalline PV cells, designed and commissioned by HSLU with support of ÜserHuus (Fig. 4). Three different designs (shutter, ornament and curve) were printed on glass of different finishes and reflection properties (float, silk and satinato). Each PV module is monitored individually so that the visual and electrical impact caused by designs and glass types can be compared. Preliminary results indicate that satinato glass finish provides the best color stability (or rather the least interference of print color with reflected colors), with almost identical electrical performance. This project was jointly developed with the SCCER Future and Energy Efficient Buildings and Districts (FEEBD).

References
[1] From sun to fuel tank – colorful solar panels and electric vehicle. http://www.nfp70.ch/en/News/Pages/04072016_news_nfp70_energy-challenge.aspx
[2] Umweltarena – Photovoltaik-Fassade “Swissness” in der Umwelt Arena Schweiz. http://www.hslu.ch/umweltarena
[3] Haus Solaris by Huggenbergerfries Architects. http://www.hbf.ch/projekte/wohnbauten/wohnhaus-solaris-zuerich/
[4] empa – Farbige PV Brüstung am NEST Gebäude. http://www.hslu.ch/nest-pv

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