Scuola universitaria professionale della Svizzera italiana
Dipartimento ambiente costruzioni e design
Istituto sostenibilità applicata all'ambiente costruito

SUPSI

Perspective of qualities applied to **BIPV sector**

Pierluigi Bonomo,
Francesco Frontini
Swiss BiPV Competence Centre

9 ottobre 2017


Z3 building, Züblin Headquarter, Stuttgart (source: Construct PV)

BIPV at SUPSI, since 2004

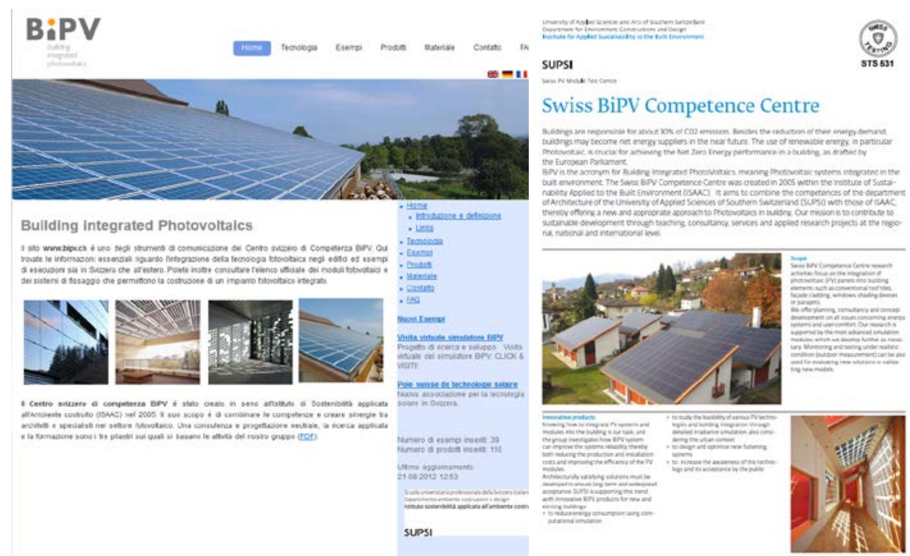
2004: LEEE-TISO projects on BIPV

With a workshop, specialists of photovoltaics, Architects, Industry and the Public sector began the dialog on obstacles, promising potentials and direction of research on BIPV.

Swiss BIPV Competence Centre

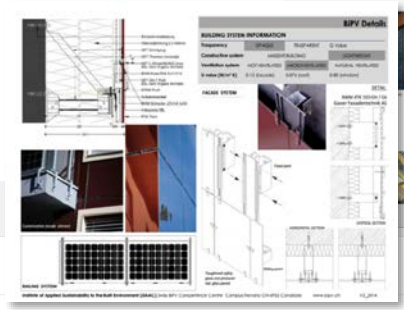
Our first project :

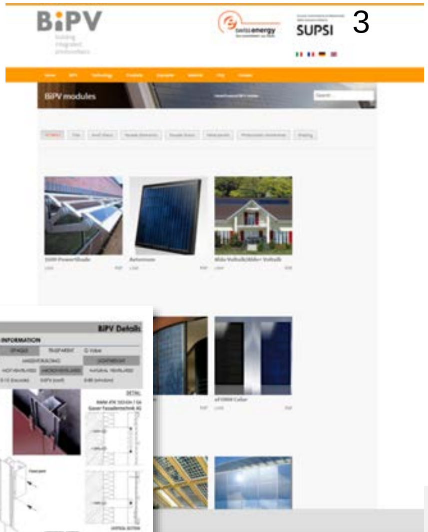
«Swiss PV test centre – TISO and BiPV project 2003-2006»



(source: Swiss BIPV Competence Centre)

BIPV…our platform!





Google bipv

Tutti Immagini Notizie Video Shopping Altro Strumenti di ricerca

Circa 472.000 risultati (0,40 secondi)

BiPV
www.bipv.ch/index.php/it/
Il Centro svizzero di competenza BiPV é stato creato in seno all'Istituto di Sostenibilità applicata all'Ambiente costruito (ISAAC) nel 2005. Il suo scopo é di ...

www.bipv.ch

Immagini relative a bipv — Segnala immagini non appropriate

Altre immagini per bipv

Fotovoltaico architettonicamente integrato - Wikipedia
https://it.wikipedia.org/wiki/Fotovoltaico_architettonicamente_integrato
FAI è l'acronimo di fotovoltaico architettonicamente integrato, corrispondente in lingua italiana all'acronimo inglese BIPV che significa Building Integrated Photo ...

Building-integrated photovoltaics - Wikipedia, the free encyclopedia
https://en.wikipedia.org/wiki/Building-integrated_photovoltaics - Traduci questa pagina
Building-integrated photovoltaics (BIPV) are photovoltaic materials that are used to replace conventional building materials in parts of the building envelope ...

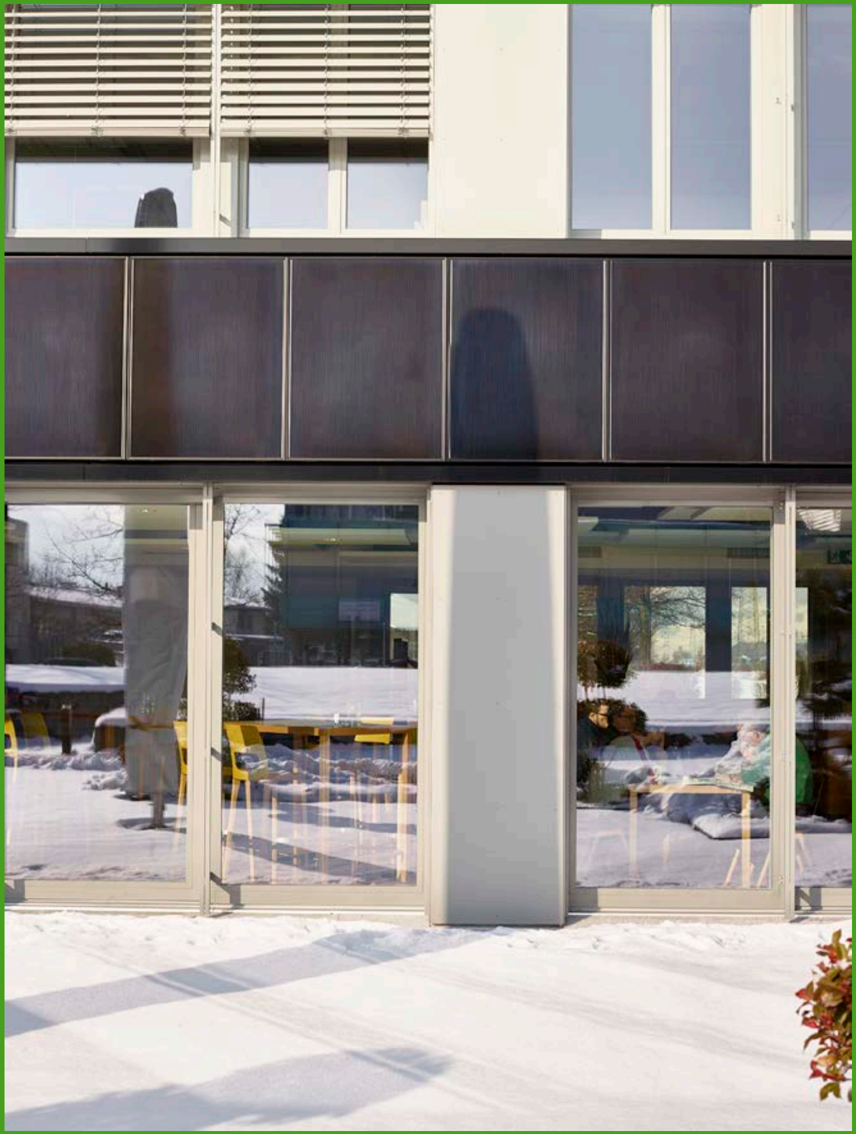
Onyx Solar® - Integrazione Fotovoltaica Per L´Edificio (BIPV ...
www.onyxsolar.com/it/
In collaborazione con Enel Green Power, Onyx Solar® offre al mercato italiano le sue innovatrici soluzioni per integrazione fotovoltaica (BIPV). ENEL, il maggior ...

BIPV - Building Integrated Photovoltaics Guide - PolySolar
www.polysolar.co.uk/BIPV.../building-integrated-photovoltaics... - Traduci questa pagina
BIPV - Building-integrated photovoltaics. The photovoltaic panel is integrated into the building fabric rather than a 'tack-on' addition replacing conventional ...

Building Integrated Photovoltaics (BIPV) | Whole Building Design Guide
https://www.wbdg.org/resources/bipv.php - Traduci questa pagina
di S Strong - Citato da 20 - Articoli correlati
27 dic 2011 - A Building Integrated Photovoltaics (BIPV) system consists of integrating photovoltaics

Summary

- **BIPV… just 1%?**
- **Real operating conditions for BIPV**
- **Characterization of customizable BIPV**
- **BIPV requirements**



Flumroc Headquarter in Zurich, Viridén + Partner AG PIcture: SUPSI-EnergieSchweiz

BIPV …just 1%?

Energy consumed in the buildings sector consists of residential and commercial end users and accounts for 20.1% of the total delivered energy consumed worldwide (~40% EU).

INTERNATIONAL ENERGY OUTLOOK 2016
Release Date: May 11, 2016 (US Energy Information Administration)

The global building sector consumed nearly 122 exajoules (EJ) (equivalent to 34 x 10^6 GWh) in 2014, over 30% of total final energy consumption. It contributes for nearly ¼ of GHG worldwide.

GLOBAL STATUS REPORT 2016
Global Alliance for Buildings and Construction –COP 22, Paris

The global building sector has enormous potential to reduce energy related GHG emissions, especially through energy efficiency measures (55 EJ in 2050…)...

GLOBAL STATUS REPORT 2016
Global Alliance for Buildings and Construction –COP 22, Paris

BIPV …just 1%? Which perspective?

BIPV?

5%

PEB

BUILDING
2DS 2050
ENERGY DEMAND
(105-120 EJ)

At the end of 2016 PV covered 1,8 % of the world's total electricity consumption
(3,5 -7% in Europe)

Snapshot of Global Photovoltaic Markets 2017". report. International Energy Agency. 19 April 2017.

Energy efficiency is the first goal
«Conserving energy is the best way»

ENERGY CONSUMPTION

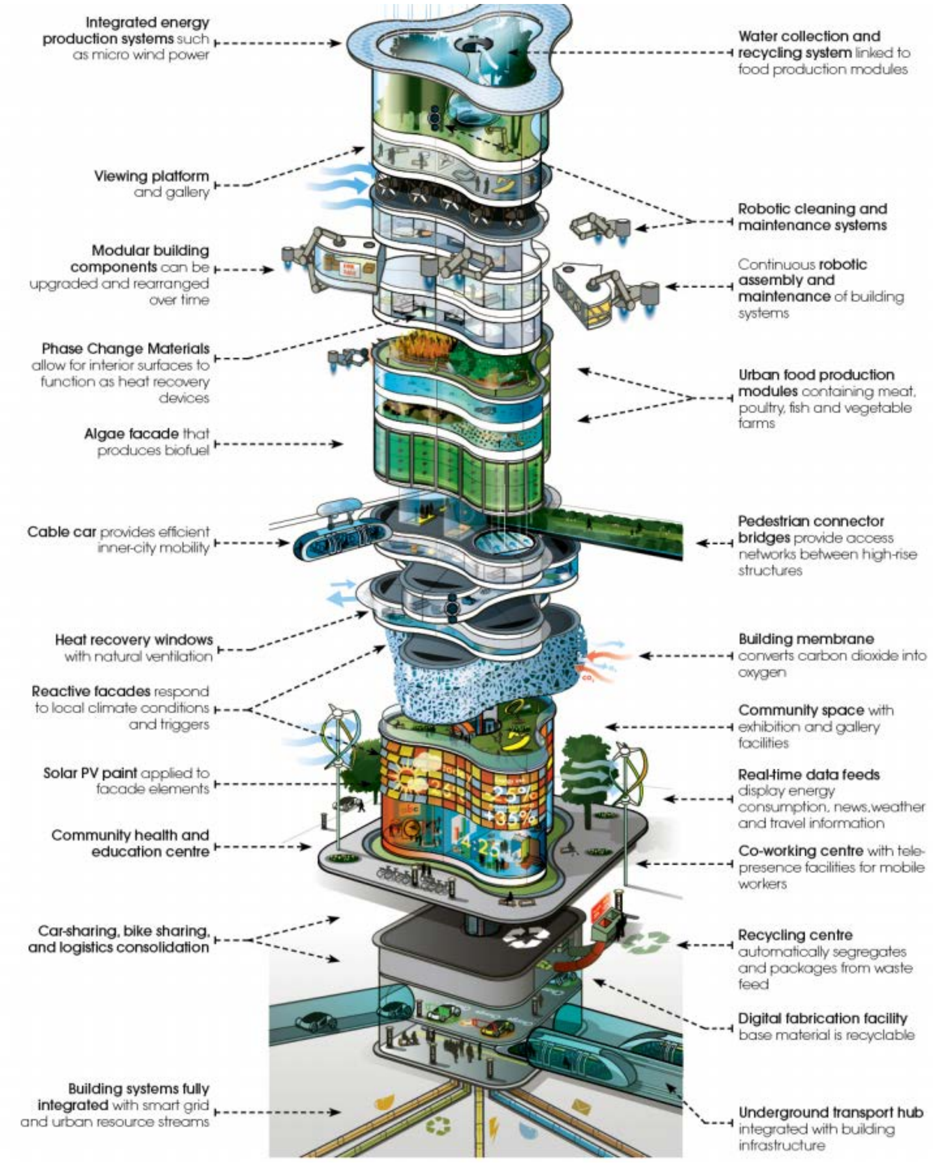
Which PV % will be BIPV?

Buildings can be plus-energy

IEA, Transition to Sustainable Buildings Strategies and Opportunities to 2050, Report 2013
GLOBAL STATUS REPORT 2016 Global Alliance for Buildings and Construction –COP 22, Paris

BIPV is not a niche PV market…

..it is as part of the (future) building vision



“…part of an urban ecosystem producing food and energy, providing clean air and water… buildings evolve from being passive shells, into adaptive and responsive organisms - living and breathing structures supporting the cities of tomorrow”

(J. Hargrave, ARUP)

(Source: http://www.arup.com/homepage_imagining_buildings_of_the_future.aspx)

BIPV …an adventure started with architecture


Housing Development in Munich (D), Thomas Herzog with Fraunhofer ISE , 1979-82
(source: Herzog+Partner Archive)

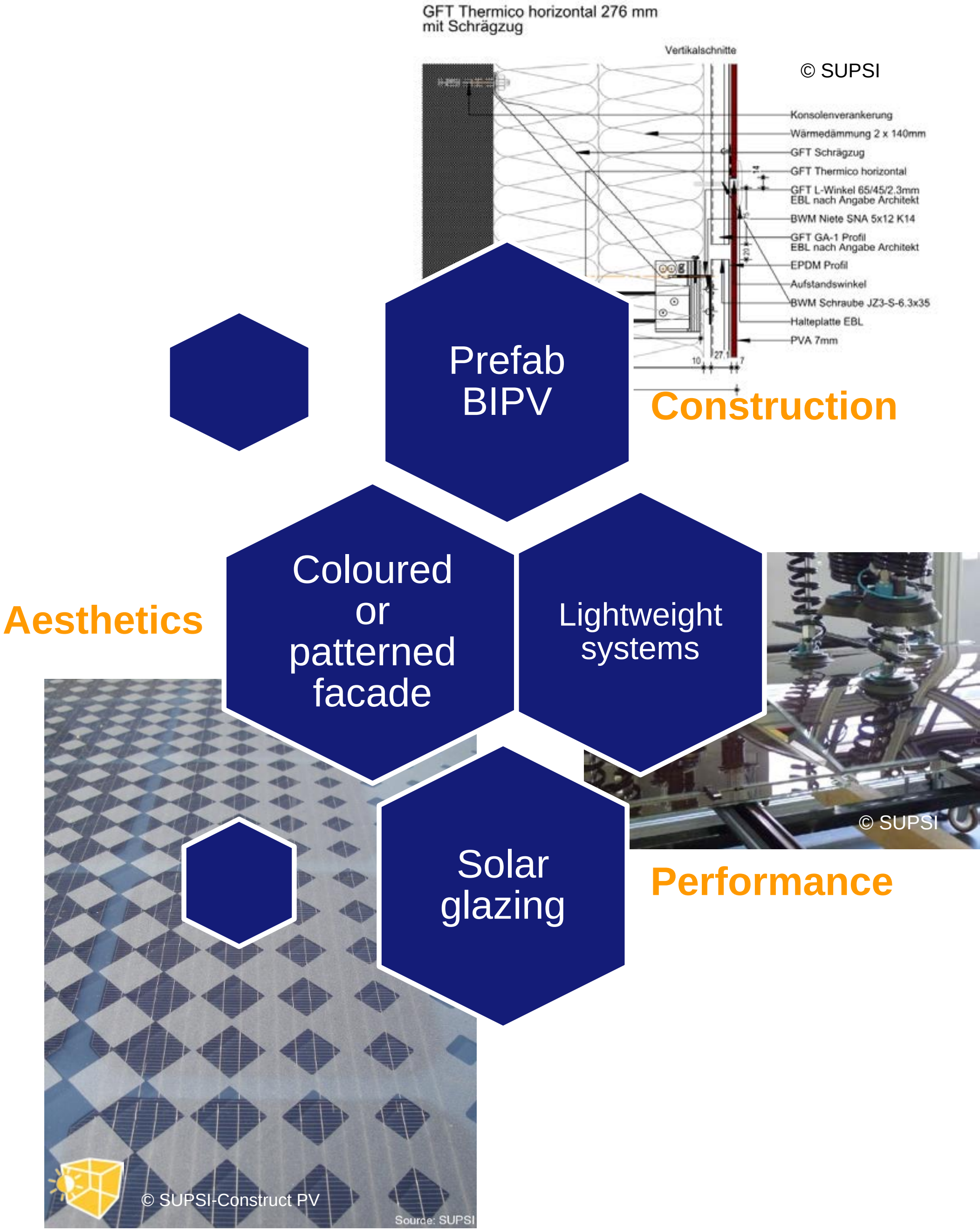
Photovoltaics and materials

A new architecture, a new opportunity

Z2 Building, Züblin, Stuttgart (Construct PV ®)

BIPV innovative trends

- The process of photovoltaic transfer in building ranges between *new* and *tradition*
- The slow process of innovation is linked to new conceptual models: architectural image, technology, energy, construction, process…
- We describe some main trends that we believe will have the chance to emerge within the next 5 years



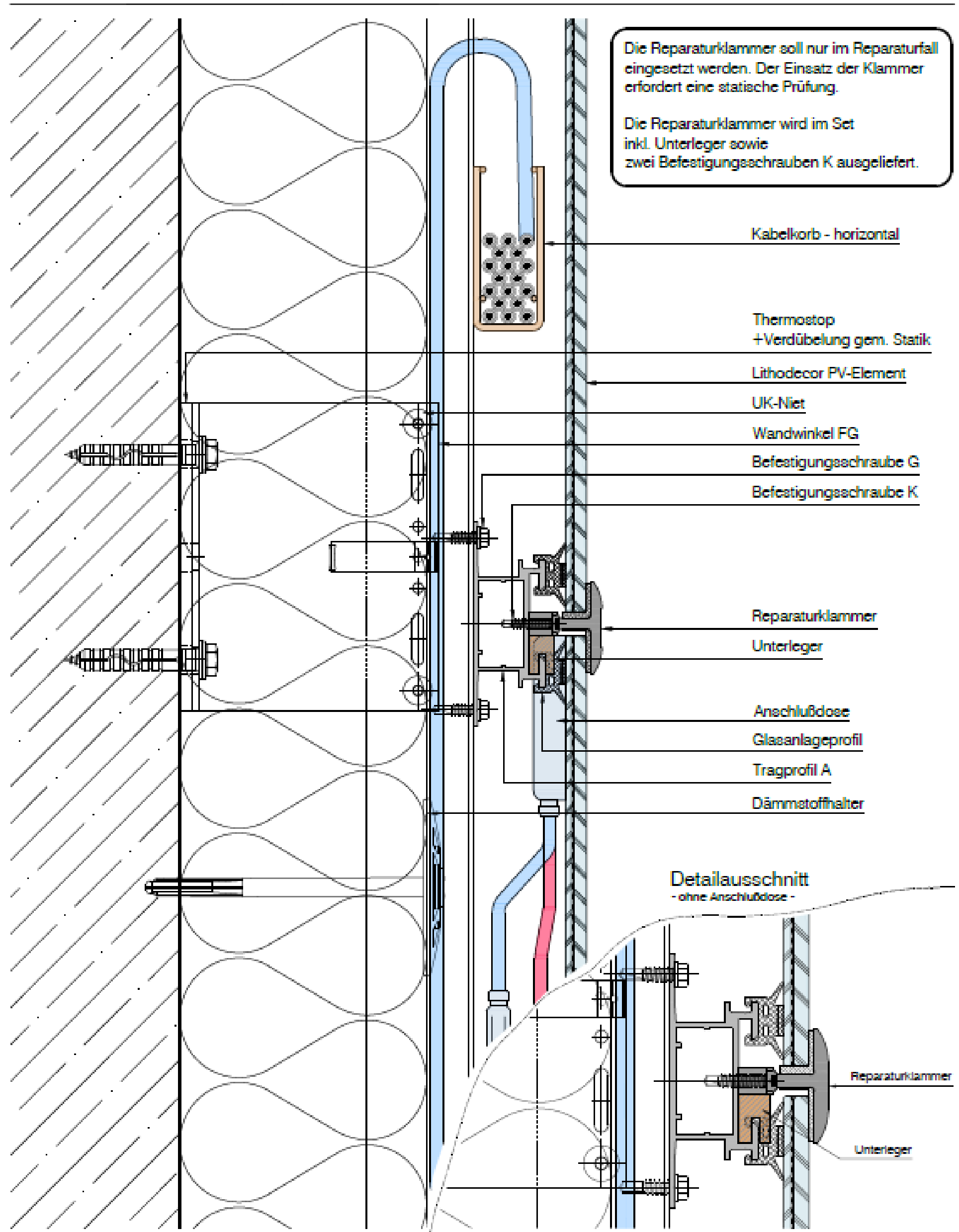
BIPV… quality?

BIPV and…**multifunctionality**

The acronym **BiPV** is referred to systems in which the photovoltaic element (PV), along with the role to produce energy, becomes a building component, integrated part of architecture and building skin

A lot of definitions: Task 7 IEA, Task 41 IEA, EN 50583, Task 15 IEA, etc…

We don’t have a definition fo integrated wood, steel…



© Lithodecor

BIPV as…**part of the building skin**

Which level?

- **Basis constructive element**
  Material, cell….module, basic element (e.g. tile, cladding panel, etc.)

- **Functional constructive element**
  System satisfying a part of the performance demand for the building skin (e.g. roof tiling system, cladding system)

- **Modular-unitized BIPV construction system**
  optimally combining BIPV modules with building/electrical sub-constructions (prefabrication, plug & play, etc.)

CSEM

MEYER Burger Megaslate

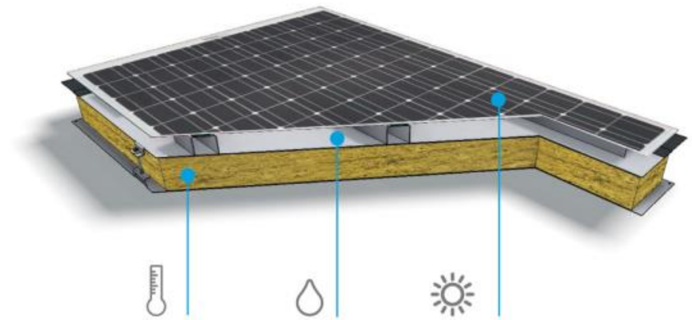

Solaire Face Intec

BIPV as…**construction component**

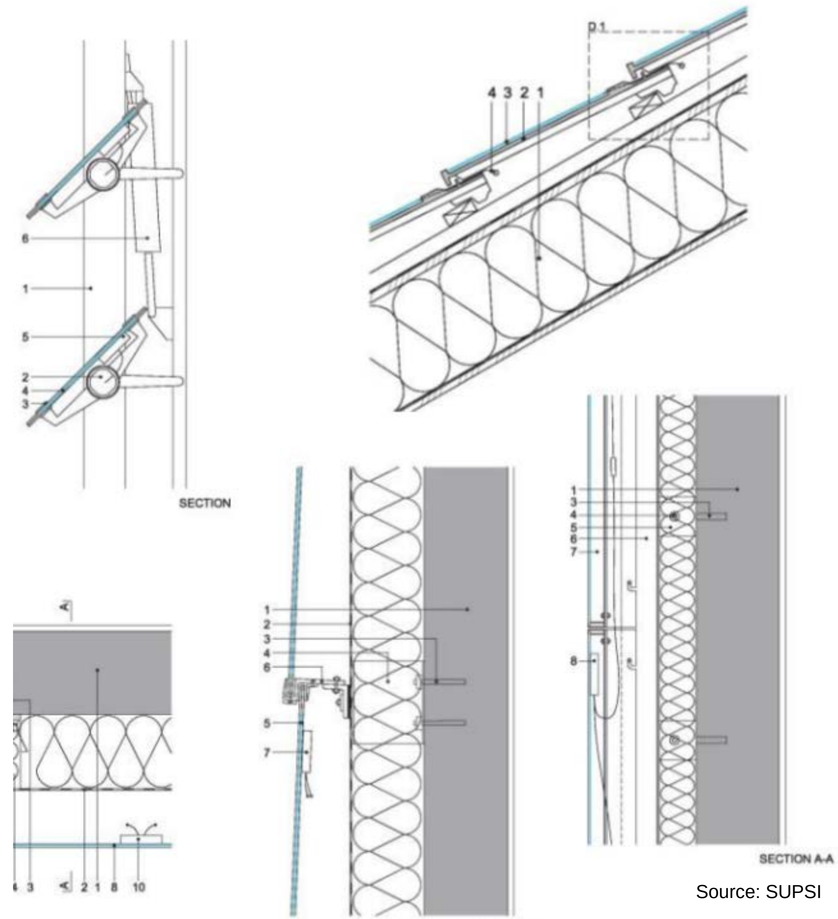
- **Building envelope engineering**
  Building skin detailed engineering, performance-based design approach, culture of construction detail

- **Building standard compliance**
  Qualification as a building product (CPR 305/2011-CE Marking , building codes and design approaches, EN 50583)

- **Technological innovation (of the building skin)**
  Modularity, lightweight, easy mounting, adaptability/flexibility, durability



Source: Designergy



Source: SUPSI

Reference: P. Bonomo et al., *Overview and analysis of current BIPV products: new criteria for supporting the technological transfer in the building sector*, VITRUVIO - International Journal of Architectural Technology and Sustainability,

BIPV qualification…Standards and norms

Electrical

EN 50583:2016

Photovoltaics in buildings.

BIPV products and systems

Building

PV Module

- IEC 61646: *Thin-film terrestrial photovoltaic (PV) modules, Design qualification and type approval*
- IEC 61215: *Crystalline silicon terrestrial photovoltaic (PV) modules, Design qualification and type approval*
- IEC 61730: *Photovoltaic module safety qualification*
- Low Voltage Directive (LVD) 2006/95/CE

(CE-marking of electrical devices)

- Electromagnetic Compatibility Directive (EMCD)
- Module System and Safety Test (Ageing, Mechanical performance of System,...)

Building product

- Construction Products Regulation (CPR)
    - Basic requirements for building products (Annex I)
    - General principles for CE-mark (DoP, hENs, ETA, …)
    - Harmonized Standards (hENs) and European technical Assessment (ETA)

CE –Mark for Building products

Energy Performance of Buildings Directive (EPBD)

BIPV… operating conditions

European Project – Construct PV

Call identifier: FP7-ENERGY.2011.2.1–4

“Develop and demonstrate customizable, efficient and low cost BIPV for opaque surfaces of buildings”

- *Collaborative project*

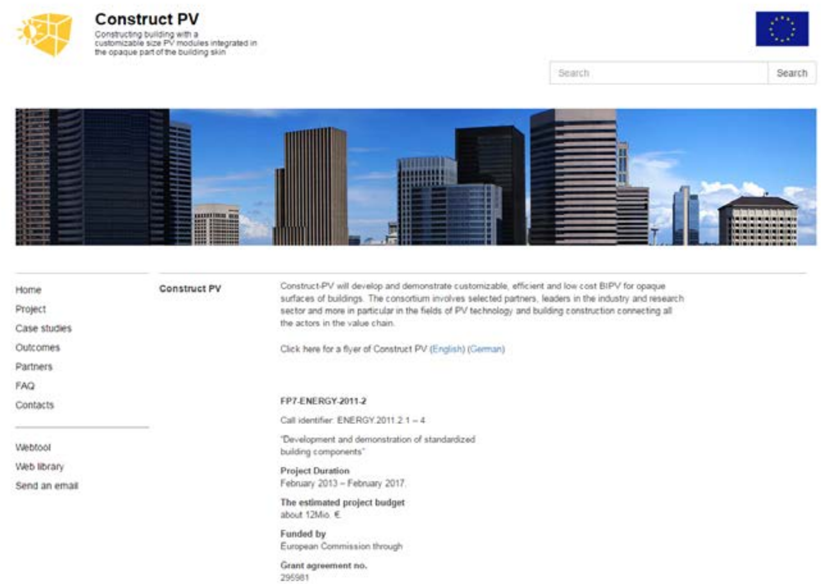
(large consortium, different stakeholders)

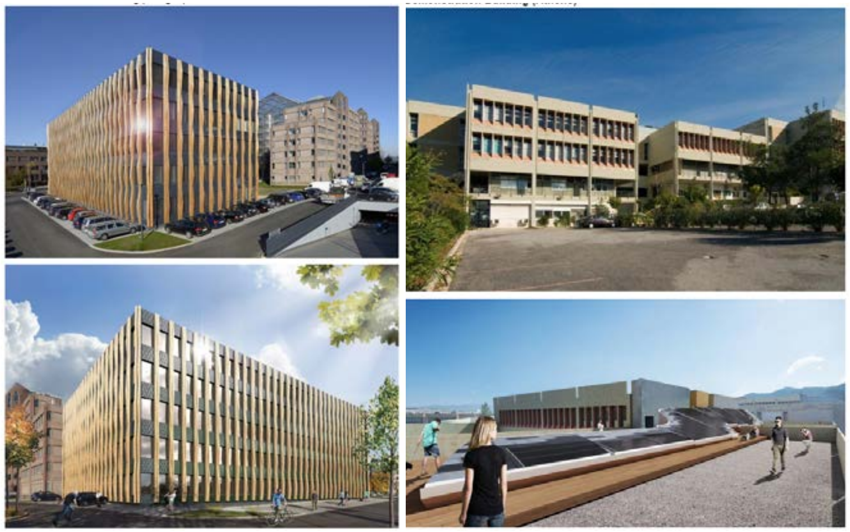
- *Demonstration project (TRL 7)*

(involvement of large industries, strong business plan, large investment from industrial partners)

Duration: 2011 (Proposal + Kick-off)
February 2013 – February 2017

Estimated project budget: 12Mio. €.

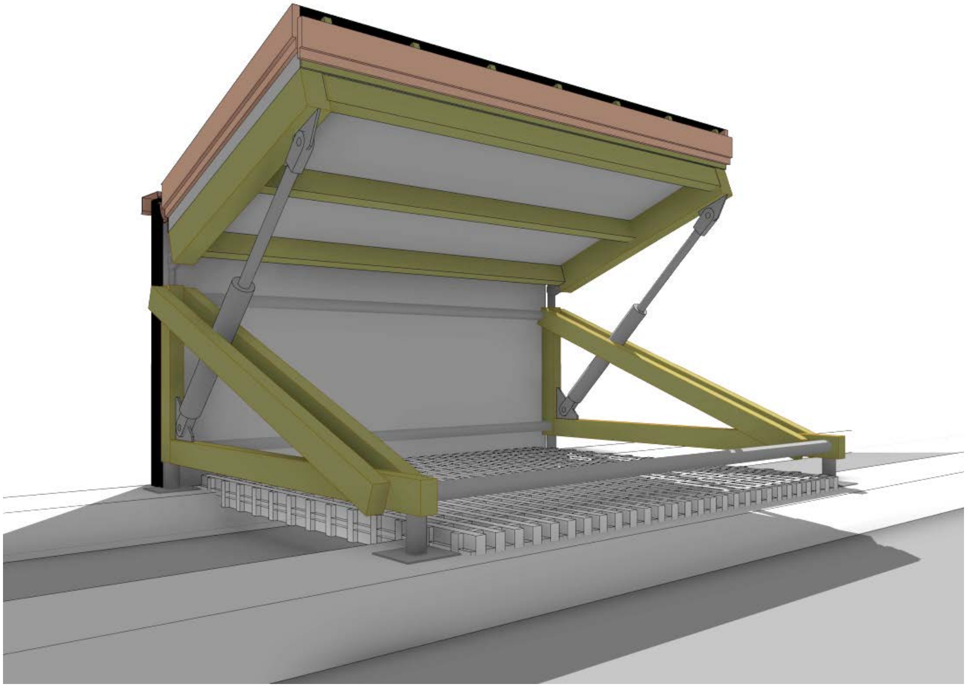


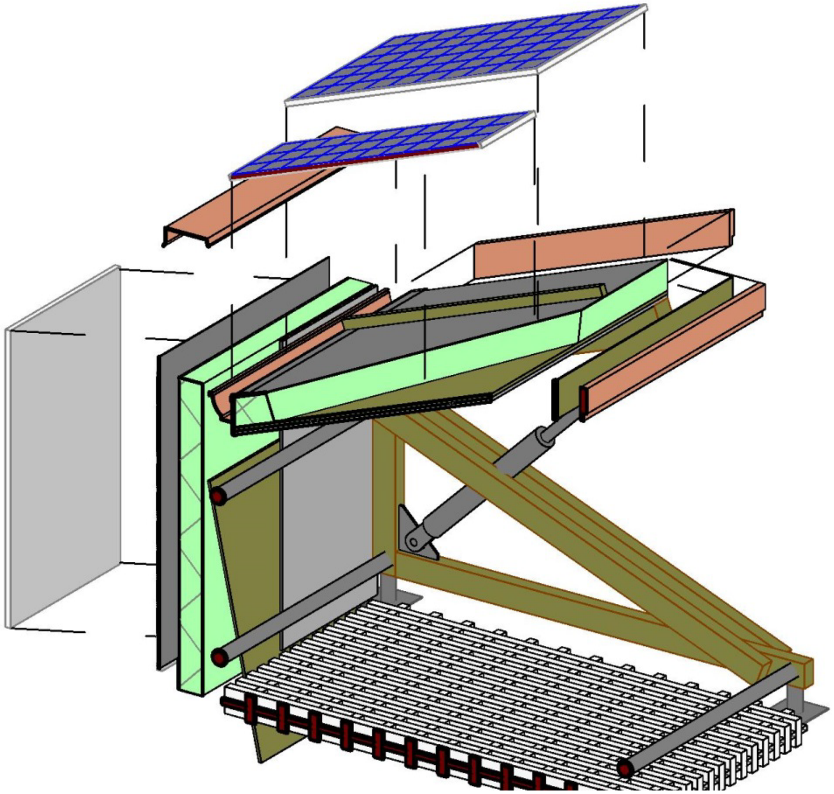


ZÜBLIN
ADVANCED MANAGEMENT SOLUTIONS
Fraunhofer ISE
MEYER BURGER
TEGOLA CANADESE innovation in building
TECHNISCHE UNIVERSITÄT DRESDEN
D'APPOLONIA
ENEA
UNStudio
NTUA
Scuola universitaria professionale della Svizzera italiana SUPSI
SMA

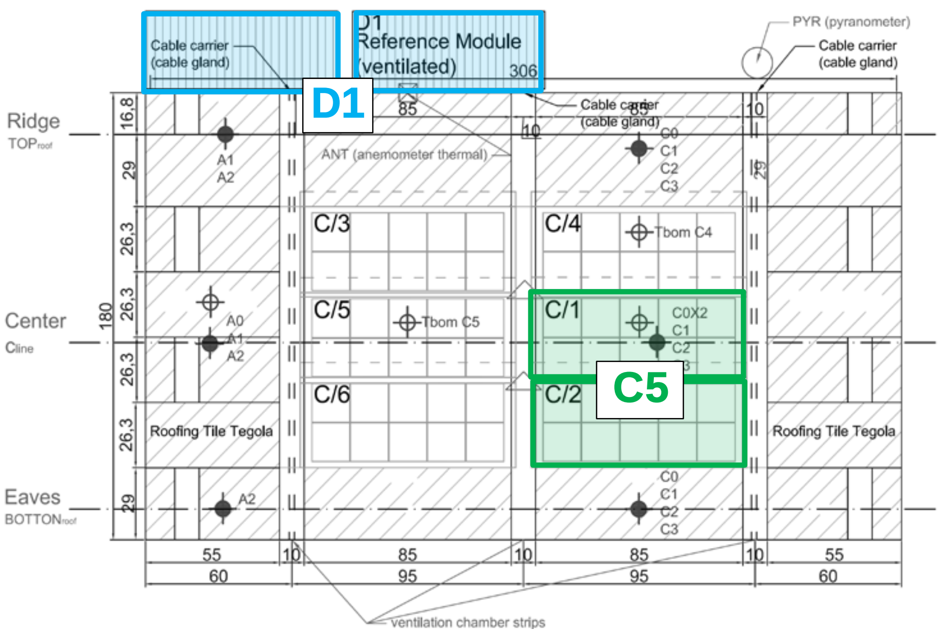

CONSTRUCT PV
SUPSI
CONSTRUCT PV

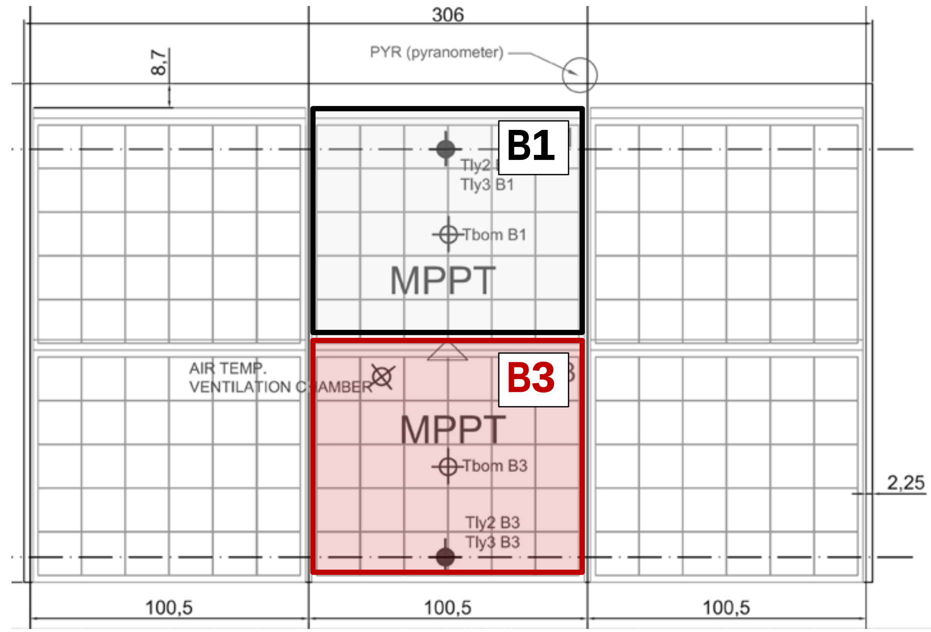
Construct PV. Demo activity at SUPSI



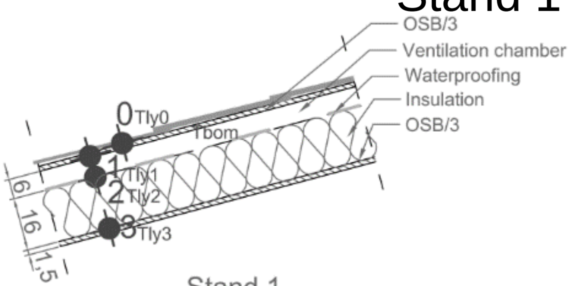


Construct PV. Demo activity with test facilities at SUPSI





Stand 1



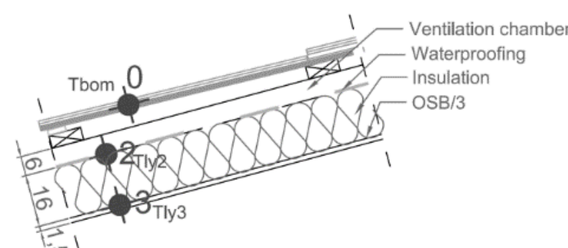
Stand 1
(ConstructPV_Tegola)

SUPSI Campus (Lugano, CH)

Comparison between modules:

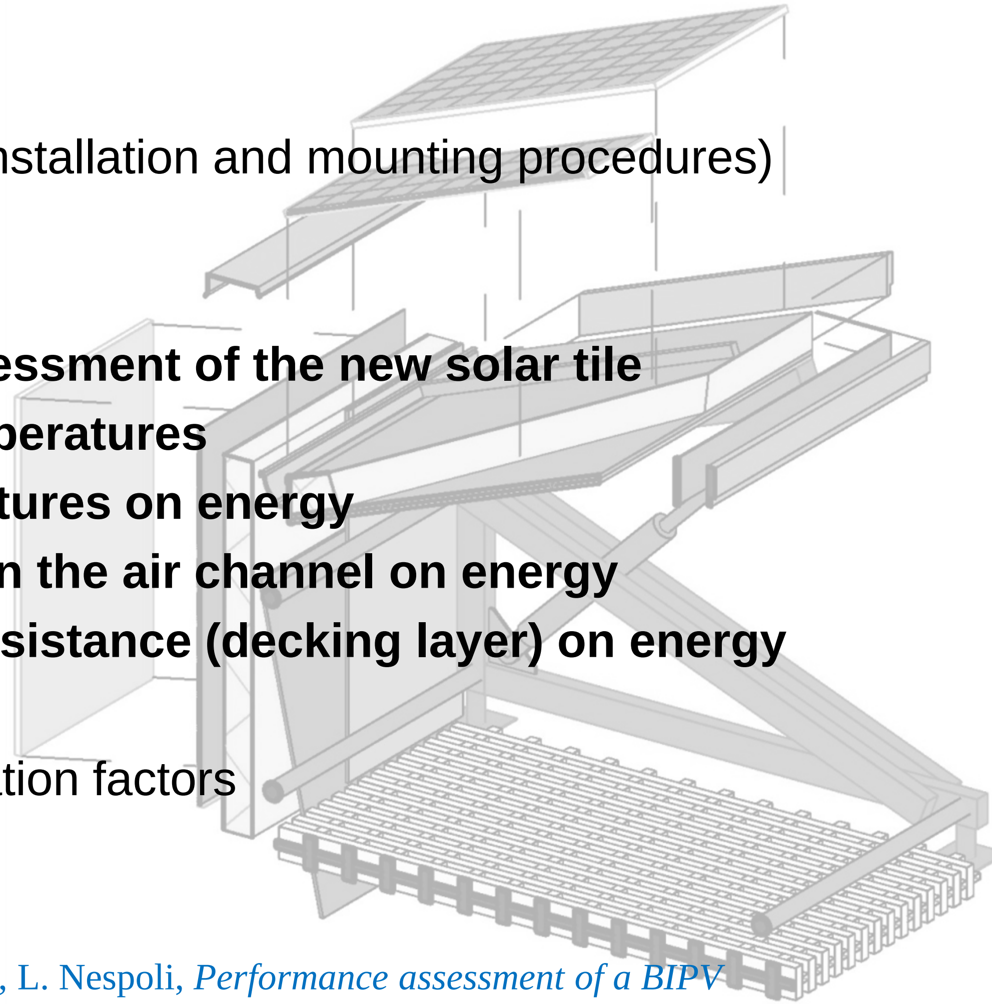
- *C5 Tegola prototype full-roof integrated*
- *D1 (Tegola ventilated)*
- *B3 Meyer Burger Megaslate full-roof*

Stand 2



Stand 2
(MB_Megaslate)

Test facilities, which goals?



- Demonstrate the technology (installation and mounting procedures)
- Dissemination and training

- **Energy yield monitoring/assessment of the new solar tile**
- **Analysis of In-layer roof temperatures**
- **Effects of operating temperatures on energy**
- **Effects of ventilation speed in the air channel on energy**
- **Effects of the roof thermal resistance (decking layer) on energy**

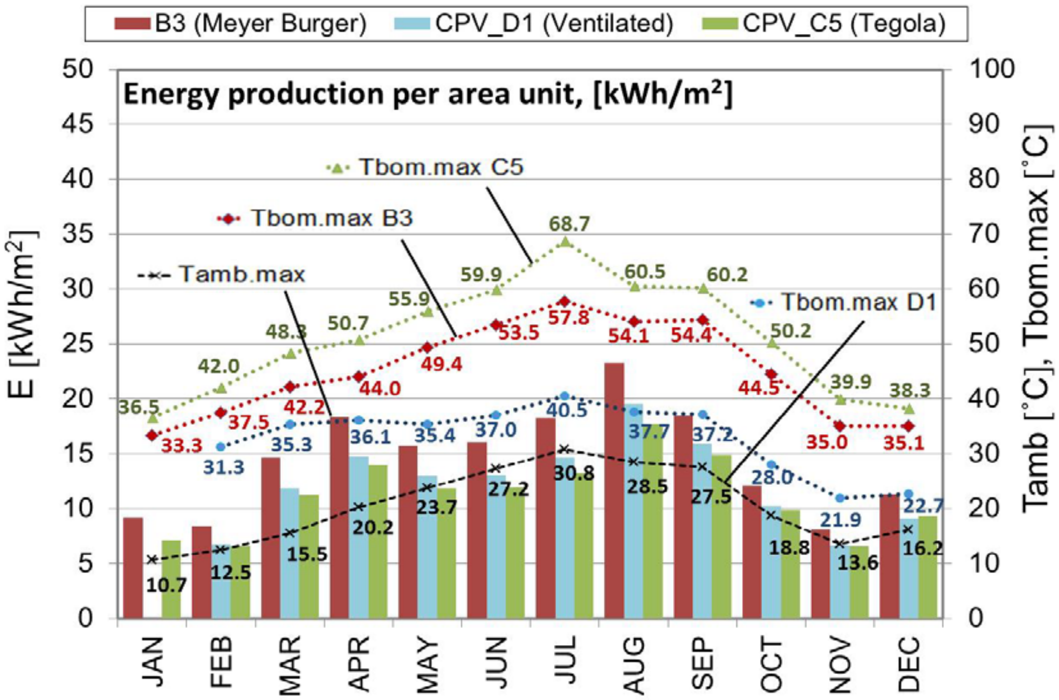
- Evaluation of possible optimization factors

Reference:

C. S. Polo López, P. Bonomo, Francesco, F., V. Medici, L. Nespoli, *Performance assessment of a BIPV Roofing Tile in outdoor testing* , IEEE-PVSC 44, Washington DC, 2017

Energy yield assessment

- Energy Production per square meter (kWh/m2), reported to the average outdoor temperature (*Tamb*) and to *Tbom*
- The energy output of the solar tile (C5) is generally lower than the other full-roof system (B3), mainly due to higher operating temperatures
- Differences in Final Yield (kWh/kWp):
  - C5-B3 is 14% July, 2% December
  - C5-D1 is **9%** July, 3% December

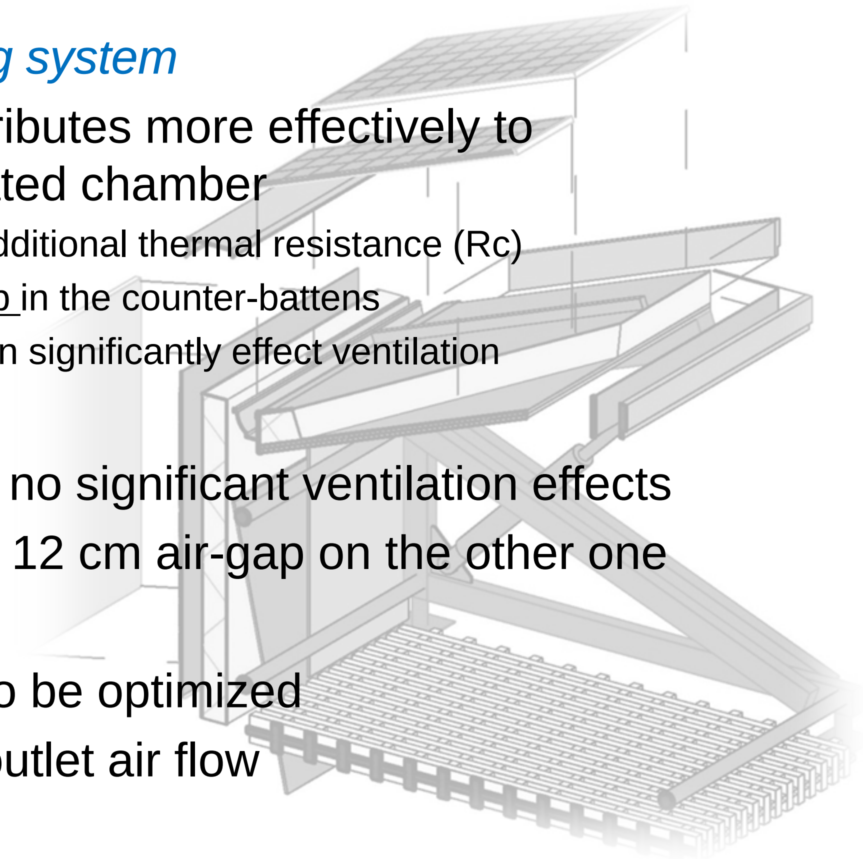


Questions:

Effects or module solution?

Effect of roof construction?
Ventilation technique/thermal resistance

Which factors affected the solar tile behavior?



Ventilation strategy related to roof mounting system

- A counter-batten system generally contributes more effectively to reducing Tbom than a roof with a ventilated chamber
  - Due to the absence of decking board and its additional thermal resistance (Rc)
  - Due to the usual higher thickness of the air-gap in the counter-battens
  - Possible micro-ventilation of tile's joints that can significantly effect ventilation

Length of the roof/thickness of air gap

- Test-stands with short pitch (1,8 m) and no significant ventilation effects
- Solar tile roof stand with 6cm air-gap vs 12 cm air-gap on the other one

Further aspects

- Possible self-shading in some periods to be optimized
- Ridge construction detail with a worse outlet air flow

Building skin construction technique has a crucial role for thermal behavior, building comfort and PV yield

BIPV and customization…
Aesthetics vs performance?

Reference:
E. Saretta, P. Bonomo, F. Frontini, *Active BIPV Glass Facades: Current Trends of Innovation*, Glass Performance Days, Tampere, Finland, 2017

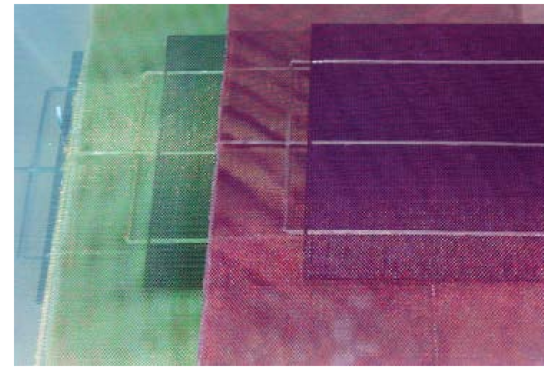
BIPV…flagship projects


Mehrfamilienhaus Brütten (Photo: René Schmid Architekten)


RothStrasse Zurich, Refurbishment (Photo: Viriden+Partners)

European Project – SMART-Flex

Demonstration of the ***flexible manufacturing*** of ***multifunctional and customizable BIPV glass elements*** at the ***industrial scale*** and for "***ordinary***" buildings



- Industrial Partner

GLASSBEL
Via Solis SOLAR SYSTEM SUPPLIER
MONDRAGON ASSEMBLY
PI
CREATIVE AMADEO
sunbeam

- Coordinator

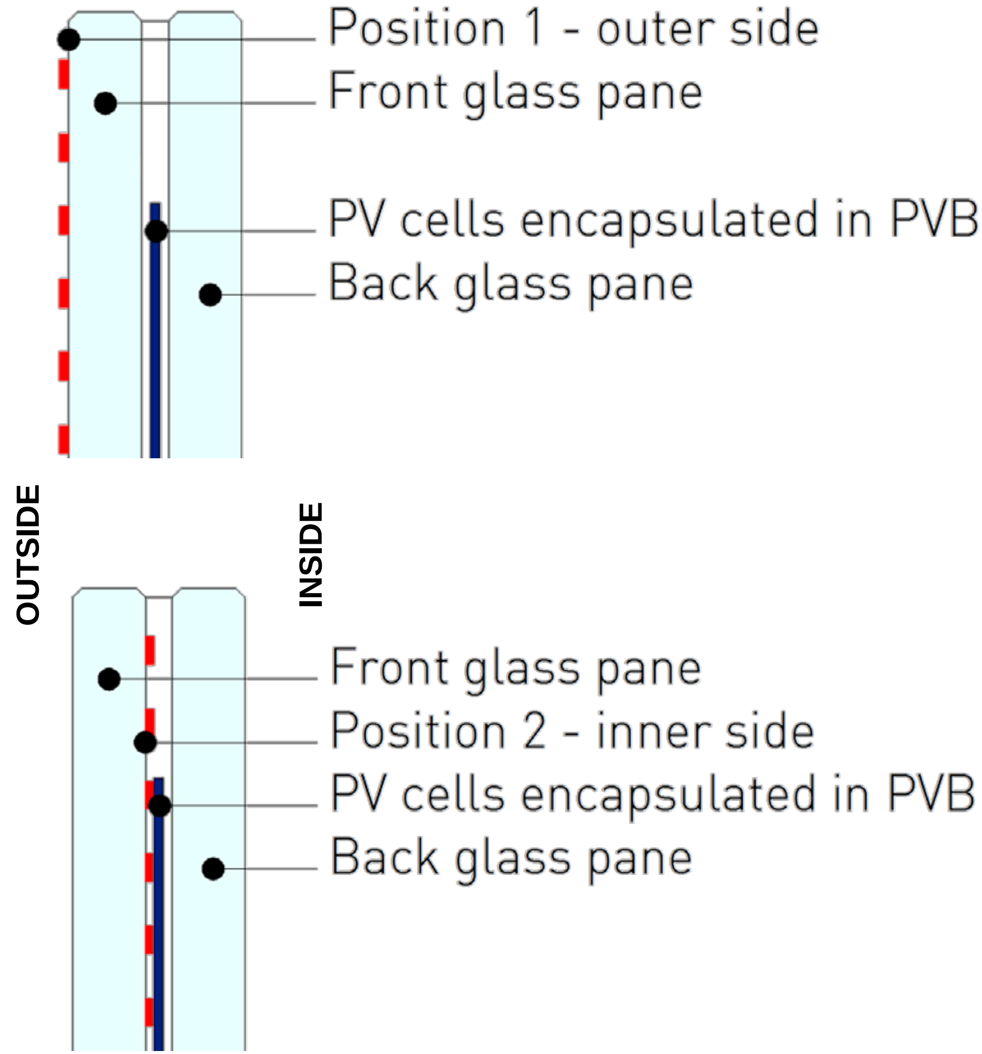
pro tech

SmartFlex Solarfacades

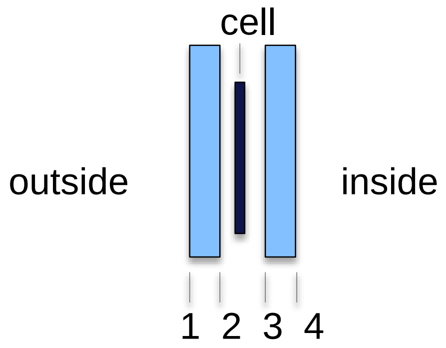
www.smartflex-solarfacades.eu

Coloured BIPV modules

- Ceramic digital printed glass

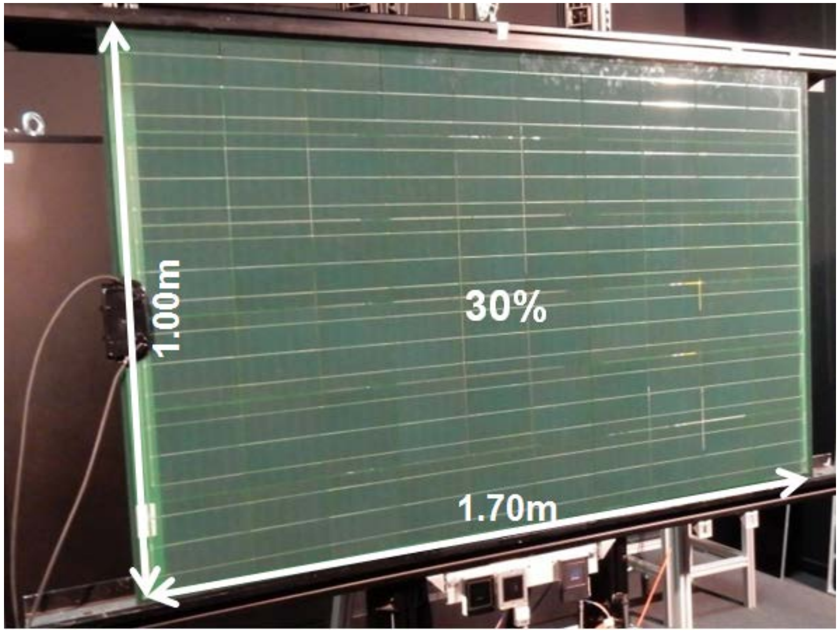


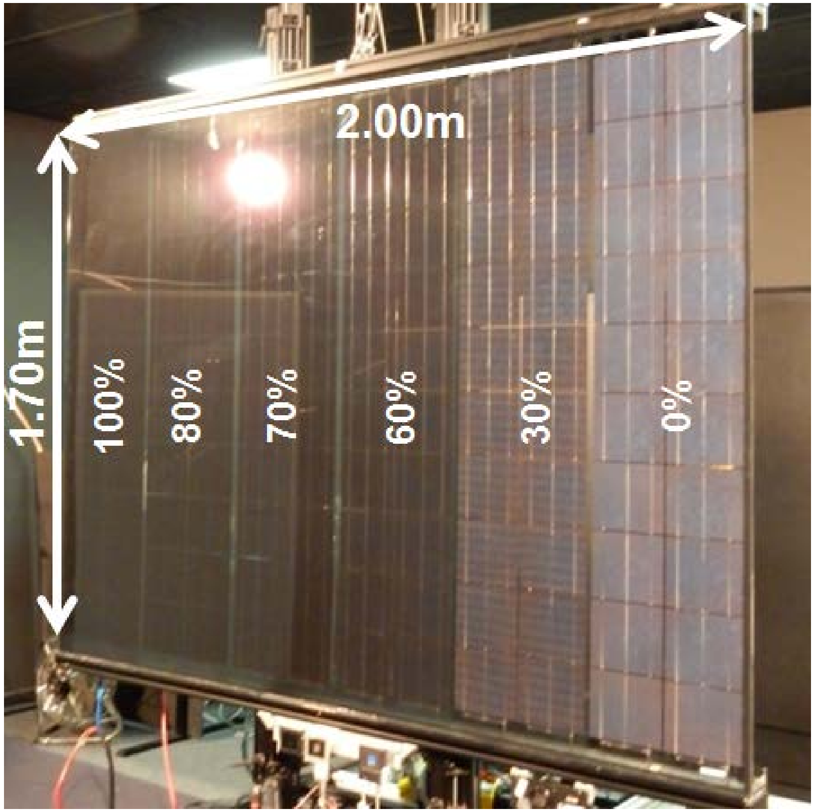
Power measurement at STC

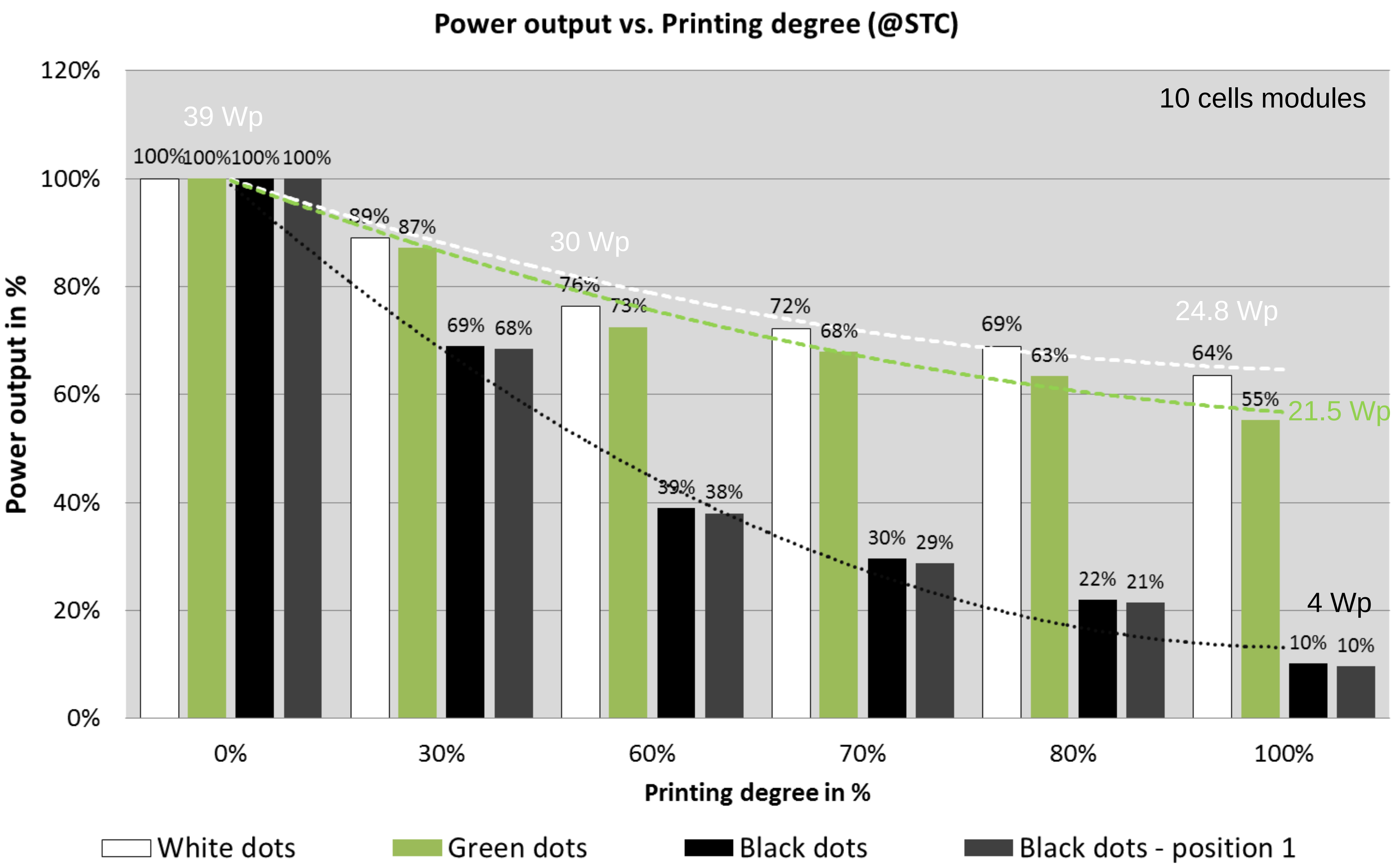


- Full colored modules (white, green, black, transparent)

- Large module with different color degrees
  - Color in Pos 1 or Pos 2

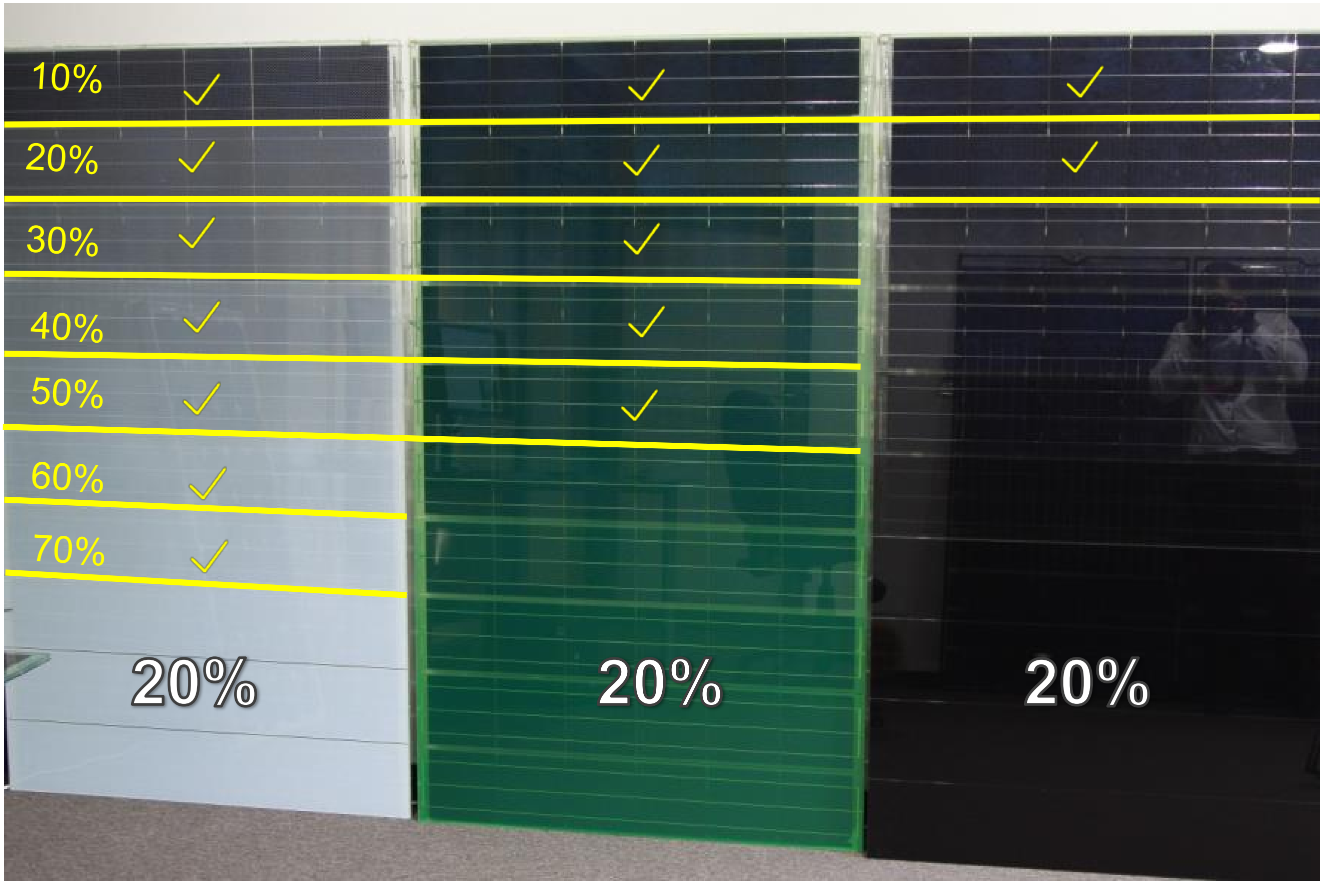





Power output vs. Printing degree (@STC)
10 cells modules
39 Wp
30 Wp
24.8 Wp
21.5 Wp
4 Wp
Power output in %
120%
100%
80%
60%
40%
20%
0%
100% 100% 100% 100%
89% 87% 69% 68%
76% 73% 39% 38%
72% 68% 30% 29%
69% 63% 22% 21%
64% 55% 10% 10%
0%
30%
60%
70%
80%
100%
Printing degree in %
White dots
Green dots
Black dots
Black dots - position 1

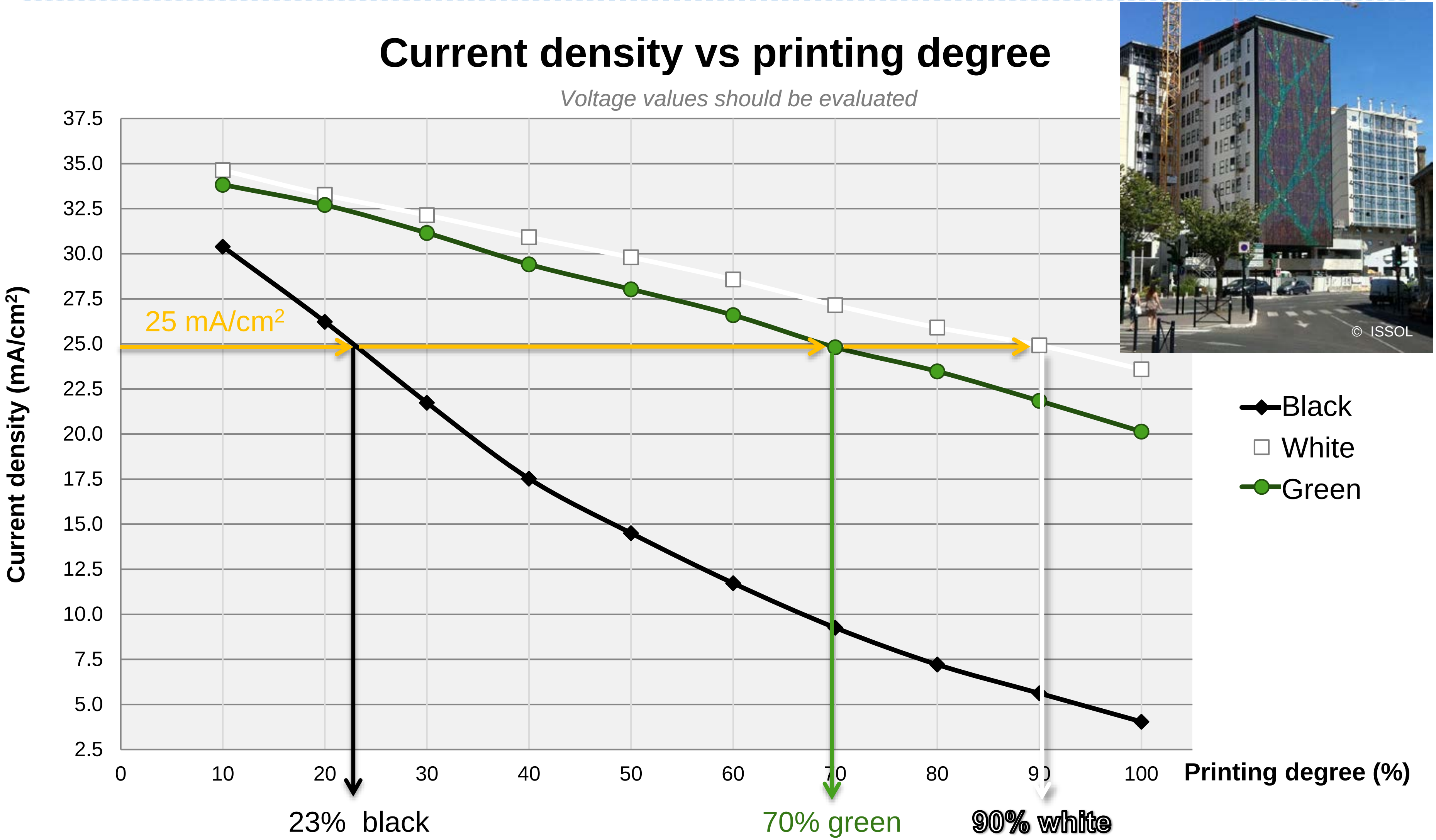
Coloured BIPV modules: power vs design?

Suitable printing degrees for limiting the power losses to

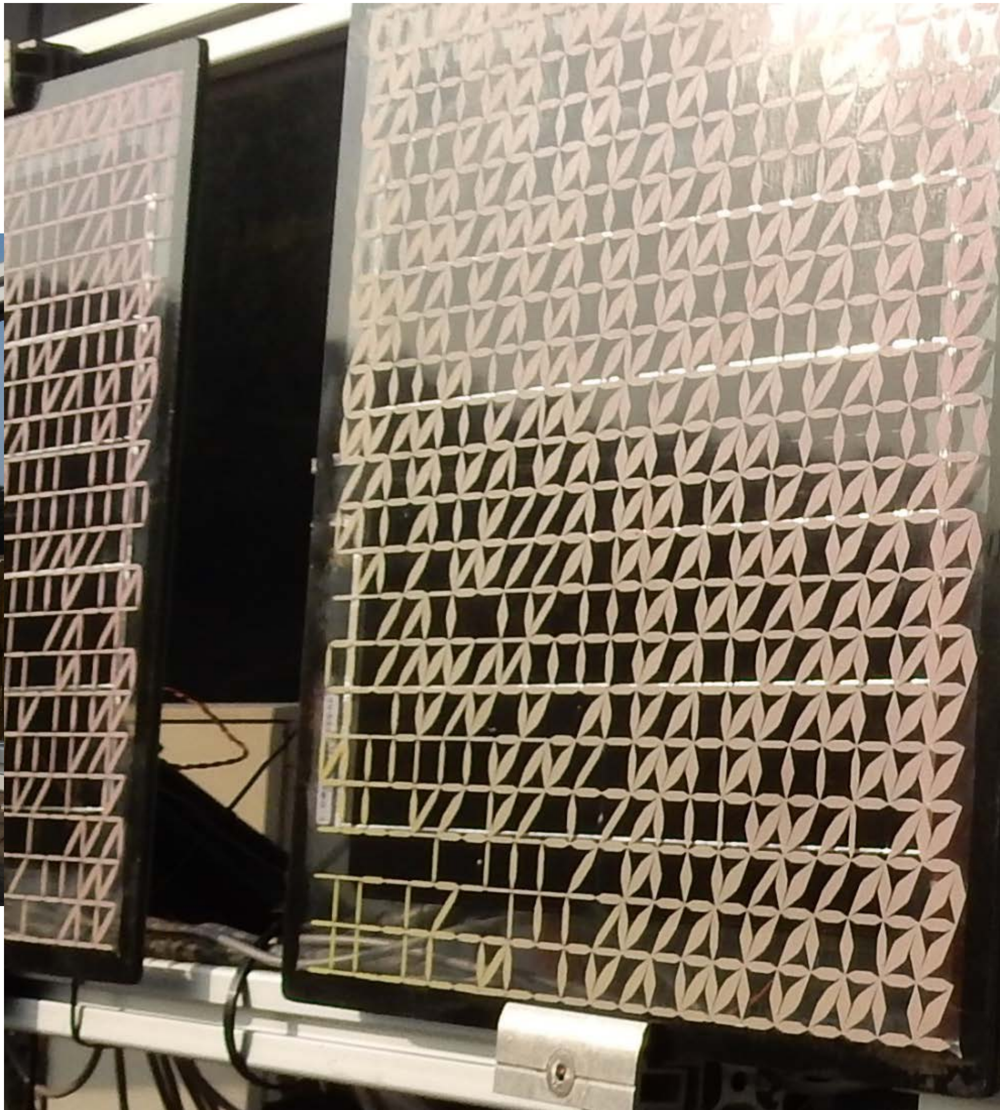


Saretta, Erika and Frontini, Francesco and Bonomo, Pierluigi and Weber, Thomas and Berghold, Juliane (2016) *Indoor and outdoor characterization of innovative colored BIPV modules for facade application*, EUPVSEC 2016

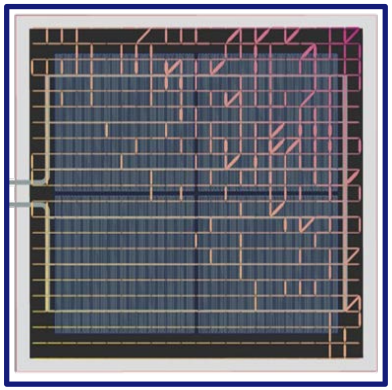
Coloured BIPV modules: electrical optimization



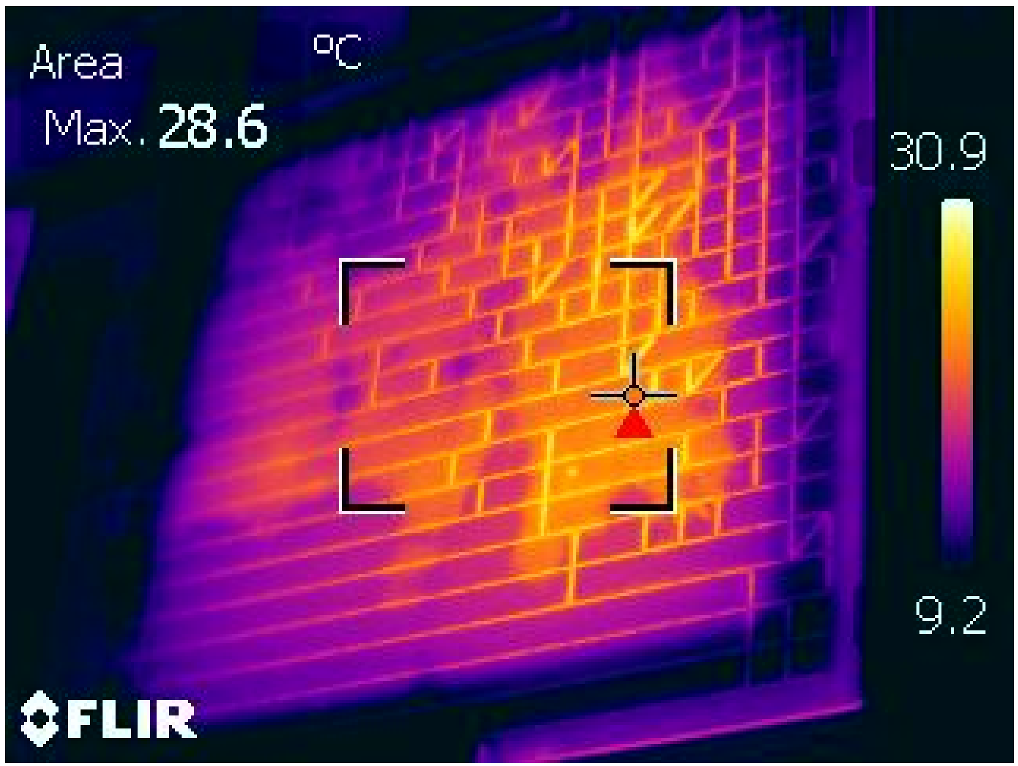
Outdoor behavior of special designed prototypes



Outdoor behavior of special designed prototypes



T1 – 10%



$I_{density}$:34.43 mA/cm^2

Pm = 14.84 W

$\Delta T_{(MAX;MIN)}$

≈ 10-15°

Further aspects need to be investigated to ensure reliability and durability of these product!

BIPV …
and performance?

Reference requirements

- EN 50583-1 & 2: 2016 Photovoltaics in Buildings

Needs? (CPR 305/2011)

Mechanical resistance and stability

Safety in case of fire

Hygiene, health and the environment

Safety and accessibility in use

Protection against noise

Energy economy and heat retention

Sustainable use of natural resources

…and others

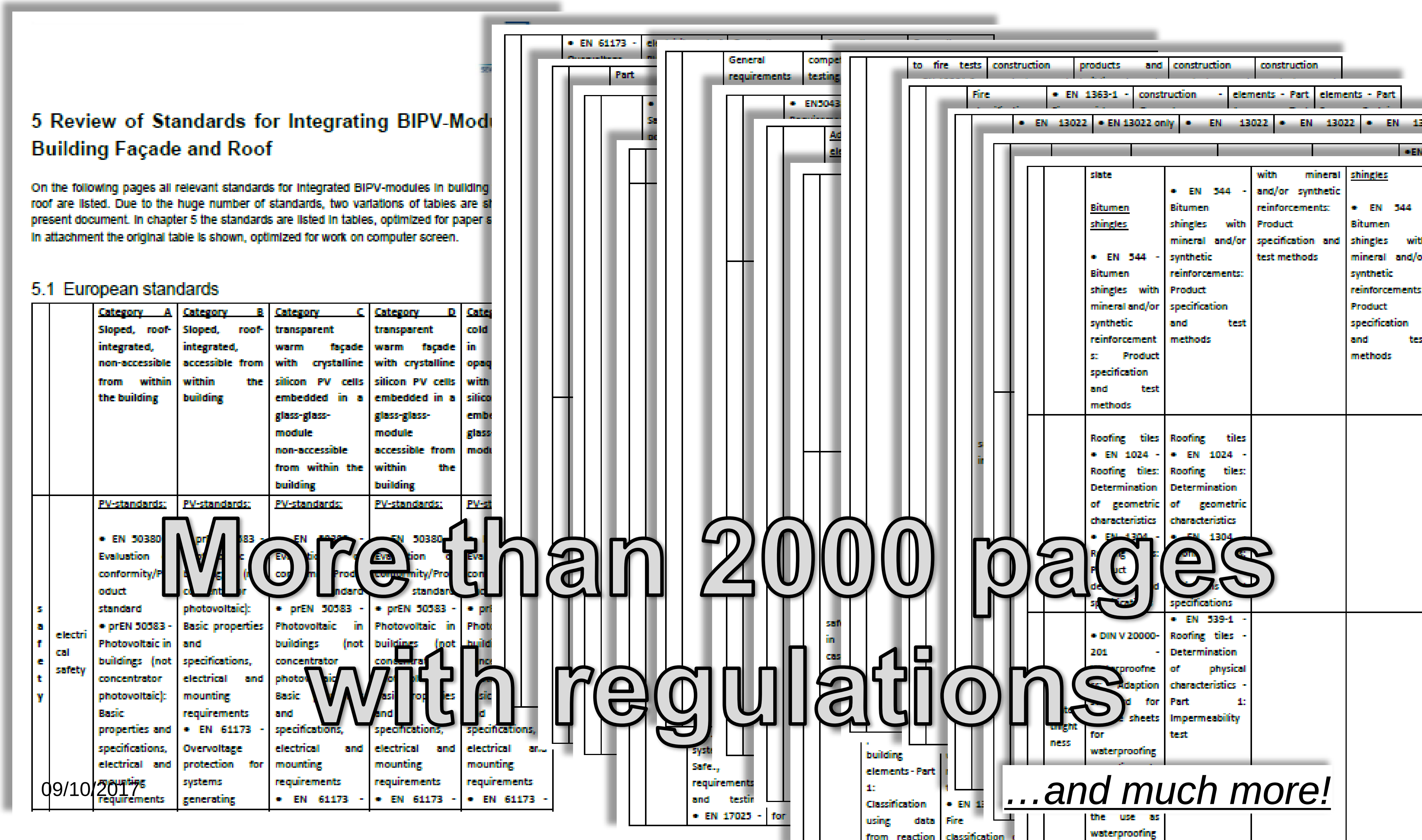
Electricity for consumption by user

PV self-sufficiency

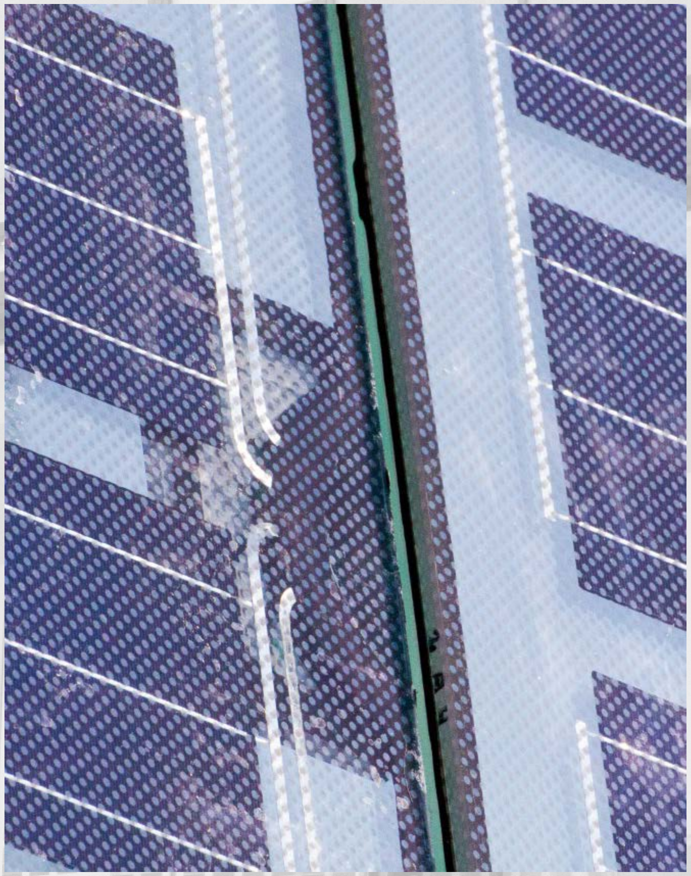
Aesthetically pleasing building appearance

Ease of maintenance/ durability and reliability

BIPV issues: building, architecture, electrical perf., safty



An example: double skin BIPV façade



1. Mechanlical safety

Glazing requirements

e.g. EN 14449, EN 12543, EN 12600, ...

Construction system standards

e.g. EN 13830 for Curtain walling, ETAG 002 for SSG, ...

Building standards

relevant national building regulation and standards (e.g. Eurocode EN 1990-1...-9)

EUROPEAN STANDARD
NORME EUROPÉENNE
EUROPÄISCHE NORM

EN ISO 12543-2

August 2011

ICS 81.040.20

Supersedes EN ISO 12543-2:1998

English Version

Glass in building - Laminated glass and laminated safety glass - Part 2: Laminated safety glass (ISO 12543-2:2011)

Verre dans la construction - Verre feuilleté et verre feuilleté de sécurité - Partie 2: Verre feuilleté de sécurité (ISO 12543-2:2011)

EOTA

European Organisation for Technical Approvals
Europäische Organisation für Technische Zulassungen
Organisation Européenne pour l'Agrément Technique

ETAG 002

Edition November 1999

1st amendment: October 2001

2nd amendment: November 2005

3rd amendment: May 2012

GUIDELINE FOR EUROPEAN TECHNICAL APPROVAL FOR

STRUCTURAL SEALANT GLAZING KITS (SSGK)

Part 1: SUPPORTED AND UNSUPPORTED SYSTEMS

EUROPEAN STANDARD
NORME EUROPÉENNE
EUROPÄISCHE NORM

EN 13830

April 2015

ICS 91.060.10

Supersedes EN 1383

English Version

Curtain walling - Product standard

Norme de produit

Vorhangfassaden - Produktnorm

EUROPEAN STANDARD
NORME EUROPÉENNE
EUROPÄISCHENORM

EN 12600

November 2002

ICS 81.040.20; 91.100.99

English version

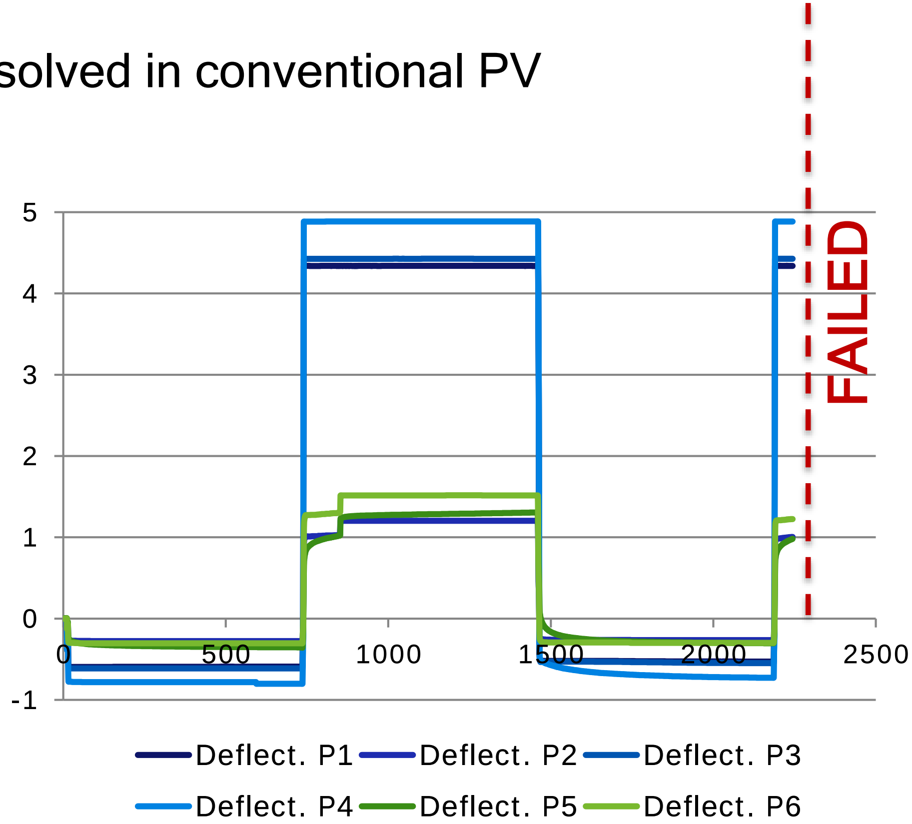
Glass in building-Pendulum test-Impact test method and classification for flat glass

Verre dans la construction-Essai au pendule-Méthode d'essai d'impact et classification du verre plat

Glas im Bauwesen-Pendelschlagversuch-Verfahren für die Stoßprüfung und die Klassifizierung von Flachglas

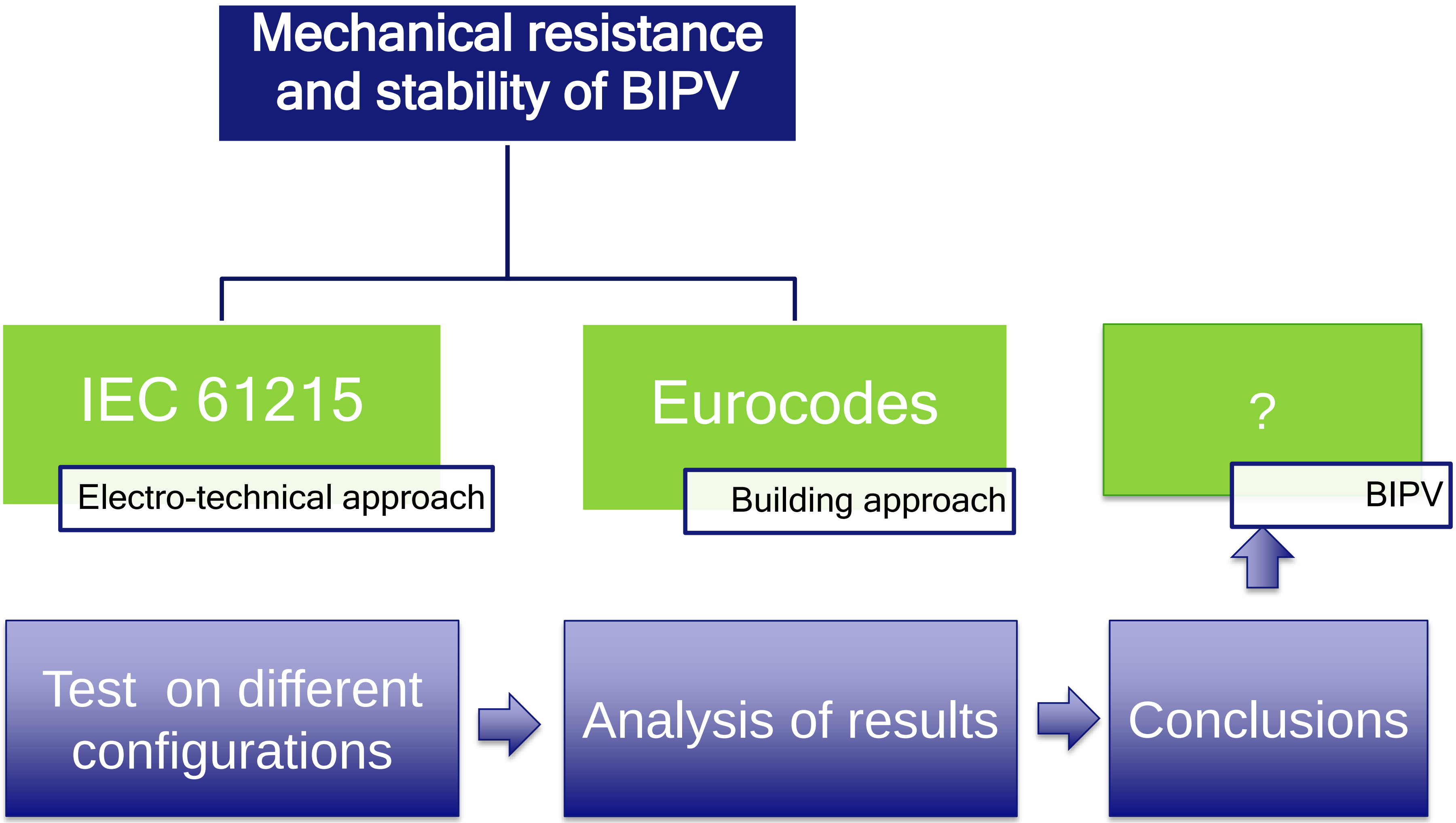
IEC Static mechanical load test

- Type B failed (clamps on the short sides)
- Direction of load (wind, snow…)…interaction with substructures
- Interaction is not studied, is not properly solved in conventional PV



simply changing the fixing system..

...beyond the conventional approach?

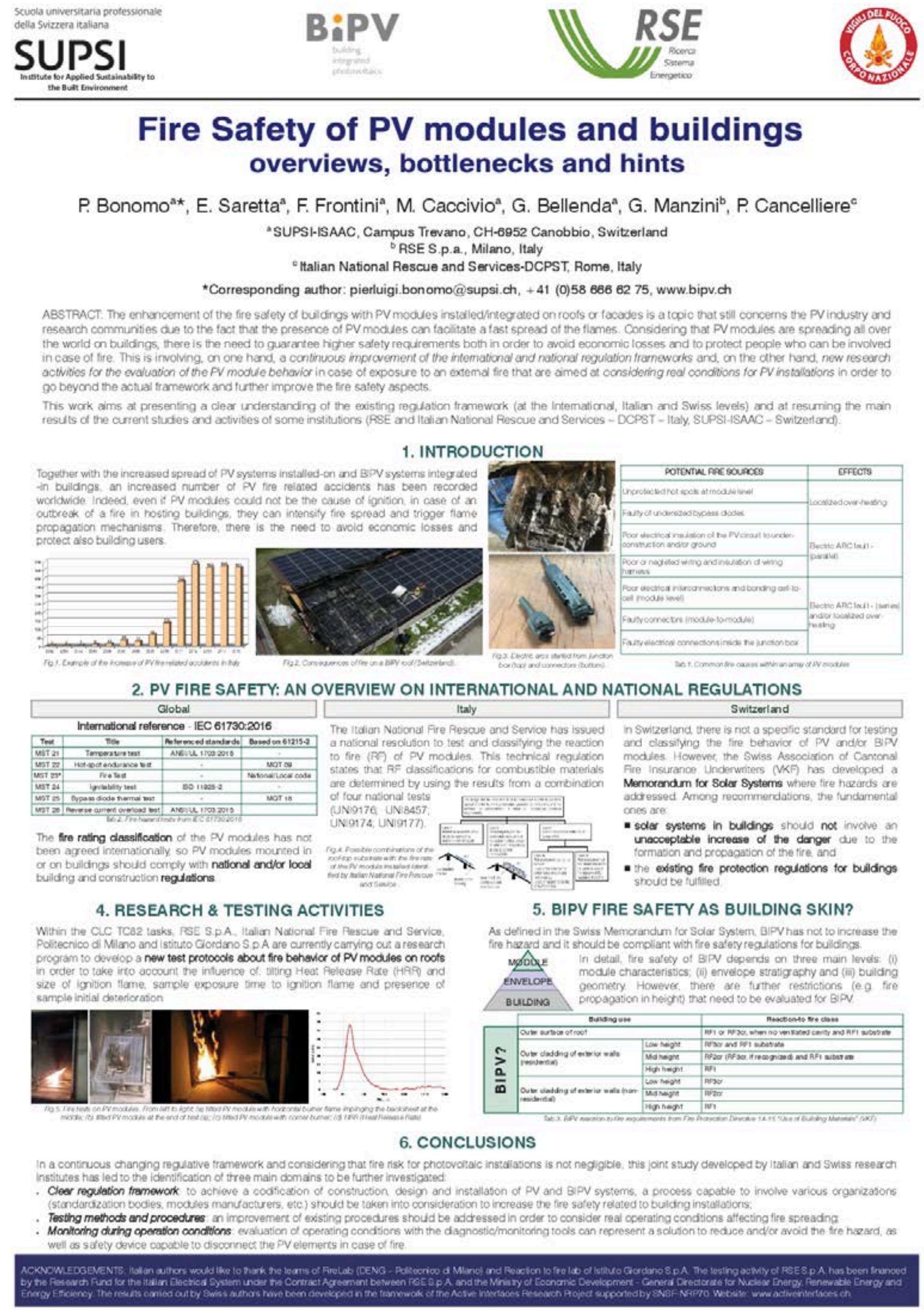


2. Fire Safety

Analysis of fire risk has led to the arising of three main domains to be further improved:

- **Clear regulation framework**
- **Testing methods and procedures**
- **Monitoring during operating conditions**

P. Bonomo, E. Saretta, F. Frontini, M. Caccivio, G. Bellenda, G. Manzini, P. Cancelliere, *FIRE SAFETY OF PV MODULES AND BUILDINGS: OVERVIEWS, BOTTLENECKS AND HINTS*, EU PVSEC 2017, Amsterdam



Conclusions

There is no „standard“ facade but many types

BIPV…quality

BIPV=Building skin system
(project/local-based approach)

- *Key-Topics*:
  - **Aesthetics**: research on optimizing design and energy/reliability
  - **Construction**: Developments on the regulatory framework and research on performance for various requirements
  - **Process/real transfer**: pilot projects, communication, how to solve real barriers


Source: FaceActive *Batineg*

How much does BIPV cost?

Cost of complete BIPV roof tiling

including mounting, transportation and other costs

- a significant price range bust quite standardized for categories
- BIPV roof system extra-costs are about 200 €/m2 (>200-600%)

Cost of façade cladding

Not including mounting, transportation and other costs (apart from the curtain wall)

- a significant price range project-dependent, cannot be generalized
- BIPV facades can be cheaper than conventional materials!
- BIPV façade system extra-cost are 20-40%

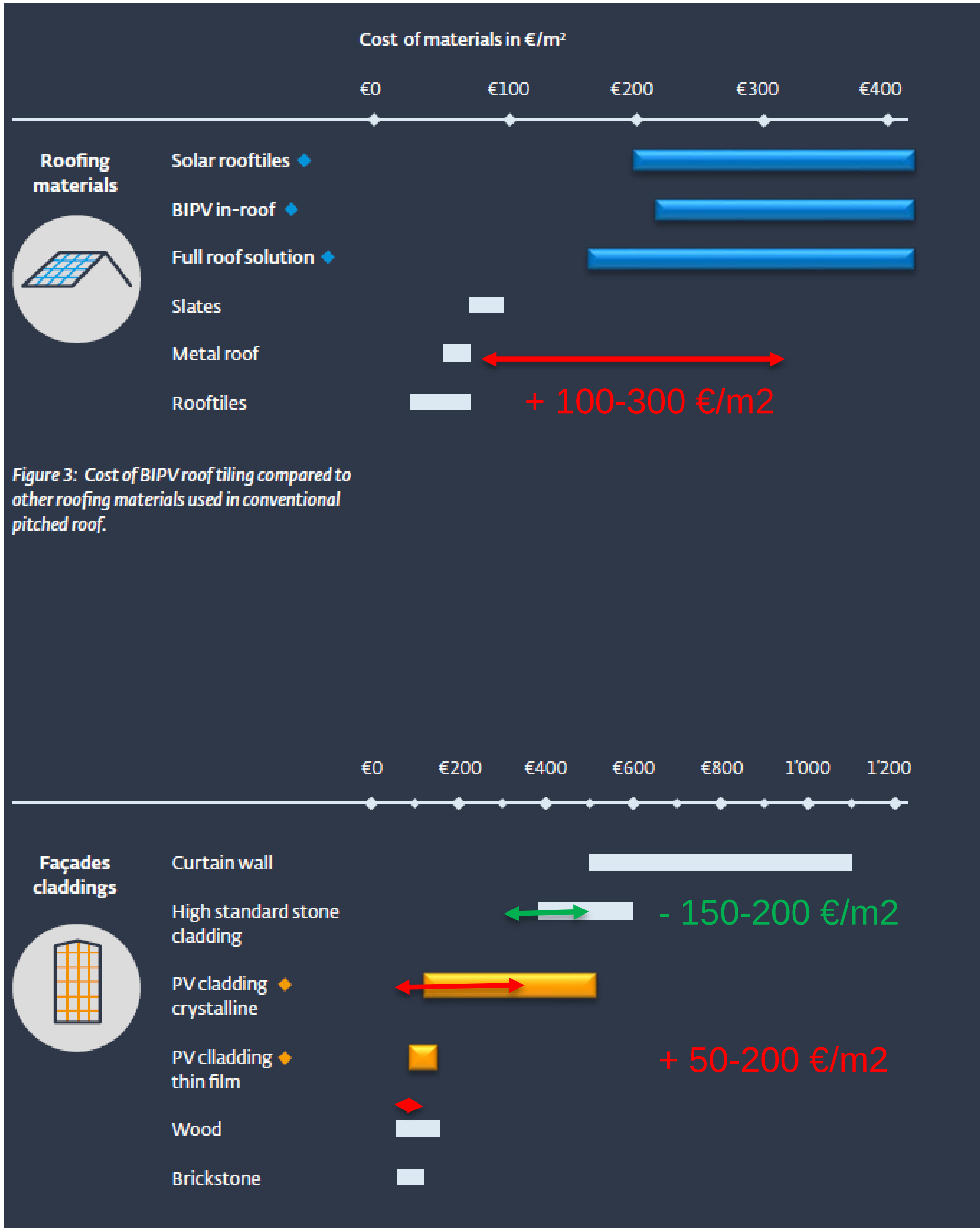


Figure 3: Cost of BIPV roof tiling compared to other roofing materials used in conventional pitched roof.

Source: BIPV Status Report 2017 (SUPSI-SEAC) www.bipv.ch

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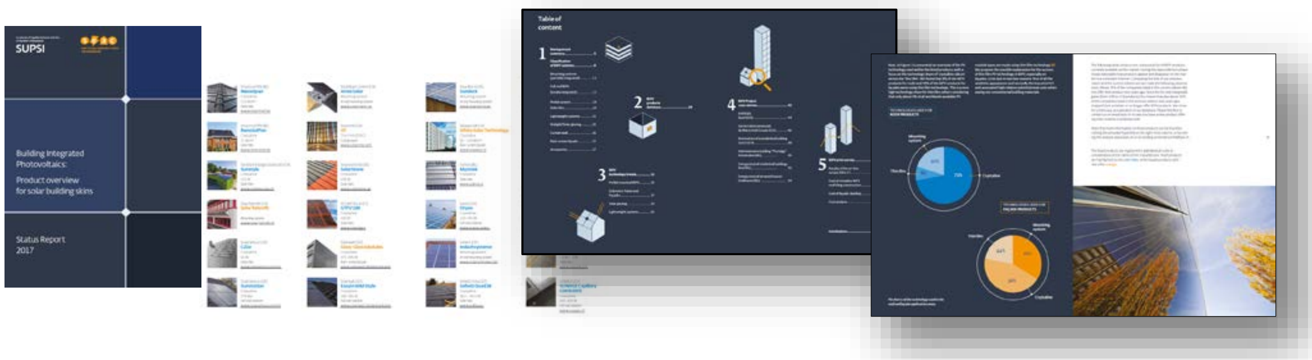

have a look to our report!

www.bipv.ch

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