

SUPSI

Perspective of qualities applied to **BIPV** sector

Pierluigi Bonomo,
Francesco Frontini
Swiss BiPV Competence Centre

9 ottobre 2017

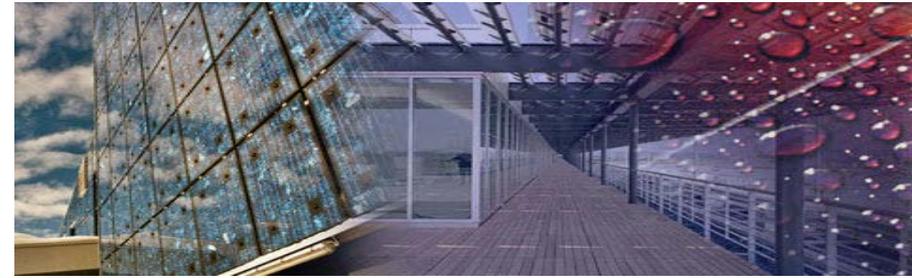


BIPV at SUPSI, since 2004

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»



BiPV
 Building Integrated Photovoltaics

Home Tecnologia Esempi Prodotti Rubriche Contatti FA

University of Applied Sciences and Arts of Southern Switzerland
 Department for Environment, Construction and Design
 Institute for Applied Sustainable Buildings in the Built Environment

SUPSI
 Swiss PV Module Test Centre

Swiss BIPV Competence Centre

Buildings are responsible for about 30% of CO2 emissions. Besides the reduction of their energy demand, buildings may become net energy suppliers in the near future. The use of renewable energy, in particular Photovoltaic, is crucial for achieving the Net Zero Energy performance in a building, as drafted by the European Parliament.

BiPV is the acronym for Building Integrated Photovoltaics, meaning Photovoltaic systems integrated in the built environment. The Swiss BiPV Competence Centre was created in 2005 within the Institute of Sustainability Applied to the Built Environment (ISAAC). It aims to combine the competences of the department of Architecture of the University of Applied Sciences of Southern Switzerland (SUPSI) with those of ISAAC, thereby offering a new and appropriate approach for Photovoltaics in building. Our mission is to contribute to a sustainable development through teaching, consultancy services and applied research projects at the regional, national and international level.

News
 Swiss BIPV Competence Centre research activities focus on the integration of photovoltaic (PV) panels into building envelopes, such as conventional roof tiles, facade cladding, sustainability and energy development (all of them concerning energy systems and applications). Our research is supported by the most advanced simulation methods, which we develop further as necessary. Monitoring and testing under realistic conditions (qualitative measurement) can be used for validating new solutions or existing ones.

Innovative products
 Working close to integrators, PV systems and modules into the building's roof, walls and facade are developed. The main goal is to improve the system reliability, thereby reducing the production and installation costs and increasing the efficiency of the PV modules.

Architecturally and building solutions must be developed around long-term and environmental appearance. SUPSI is supporting this trend with innovative BIPV products for new and existing buildings.

- To study the feasibility of various PV technologies and building integration through detailed simulation and analysis during the initial project.
- To design and optimize new building systems.
- To increase the awareness of this technology and its application by the public.

Numero di esempi (moduli): 30
 Numero di moduli (moduli): 110

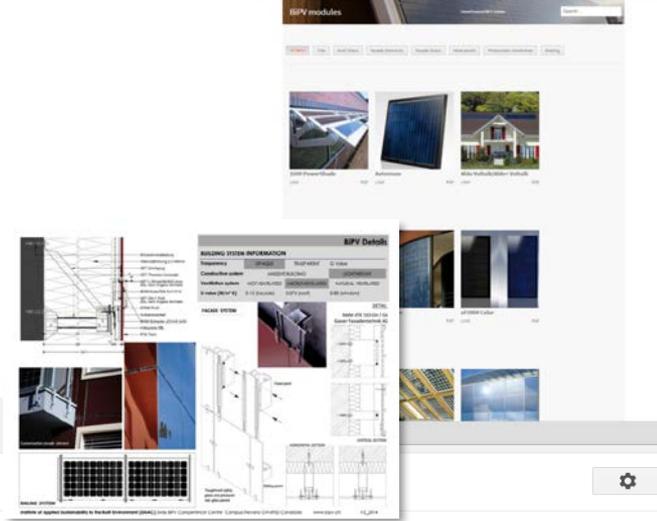
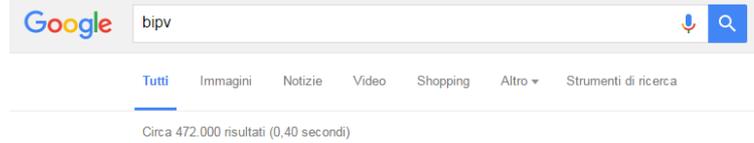
Ultimo aggiornamento: 21.08.2012, 12:53

Scienze ambientali e ingegneria della Svizzera italiana
 Dipartimento Ambiente, Costruzione e Design
 Istituto Sostenibilità Applicata all'ambiente edico

• To reduce energy consumption using computational simulation

SUPSI

BIPV...our platform!



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 innovativi 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**



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 34×10^6 GWh) in 2014, over 30% of total final energy consumption. It contributes for nearly $\frac{1}{4}$ 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?

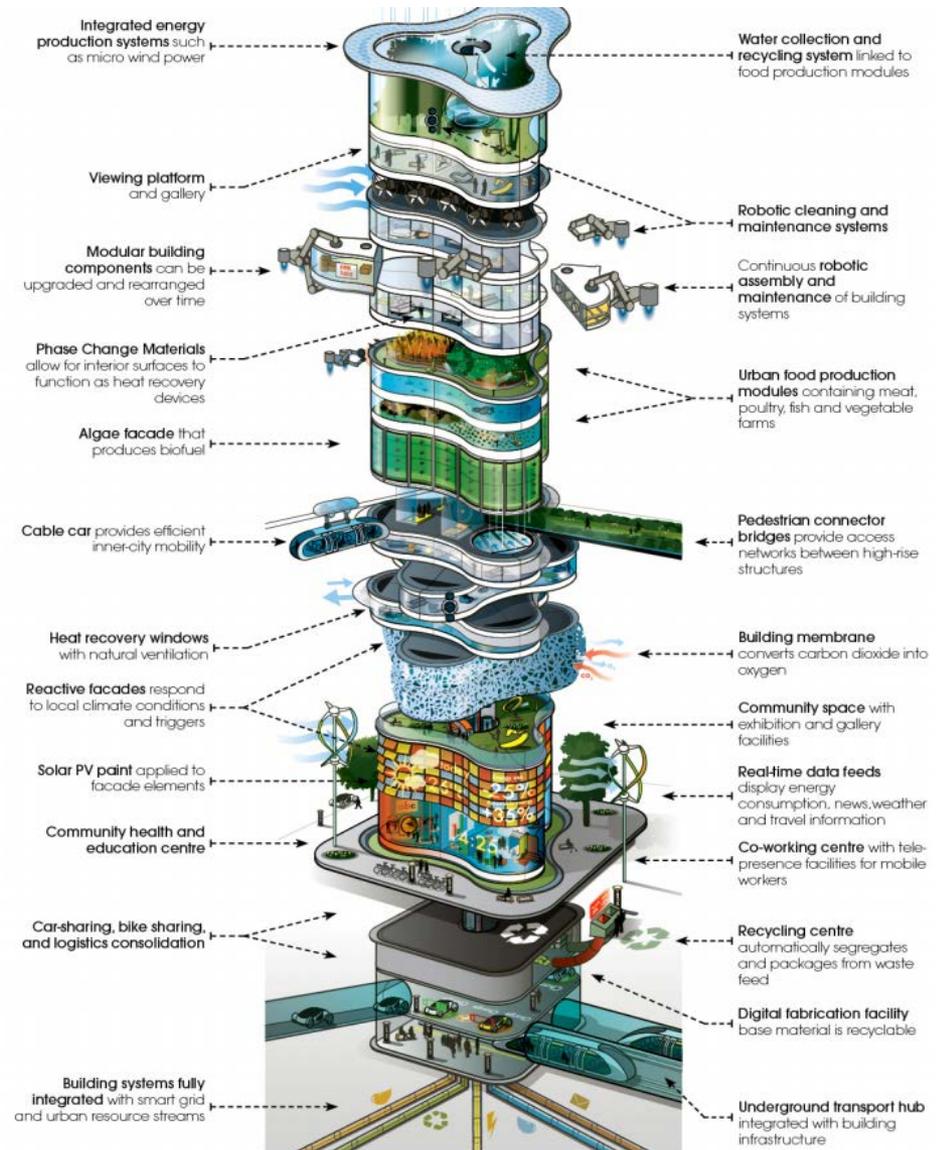
Buildings can be plus-energy

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)



BIPV ...an adventure started with architecture



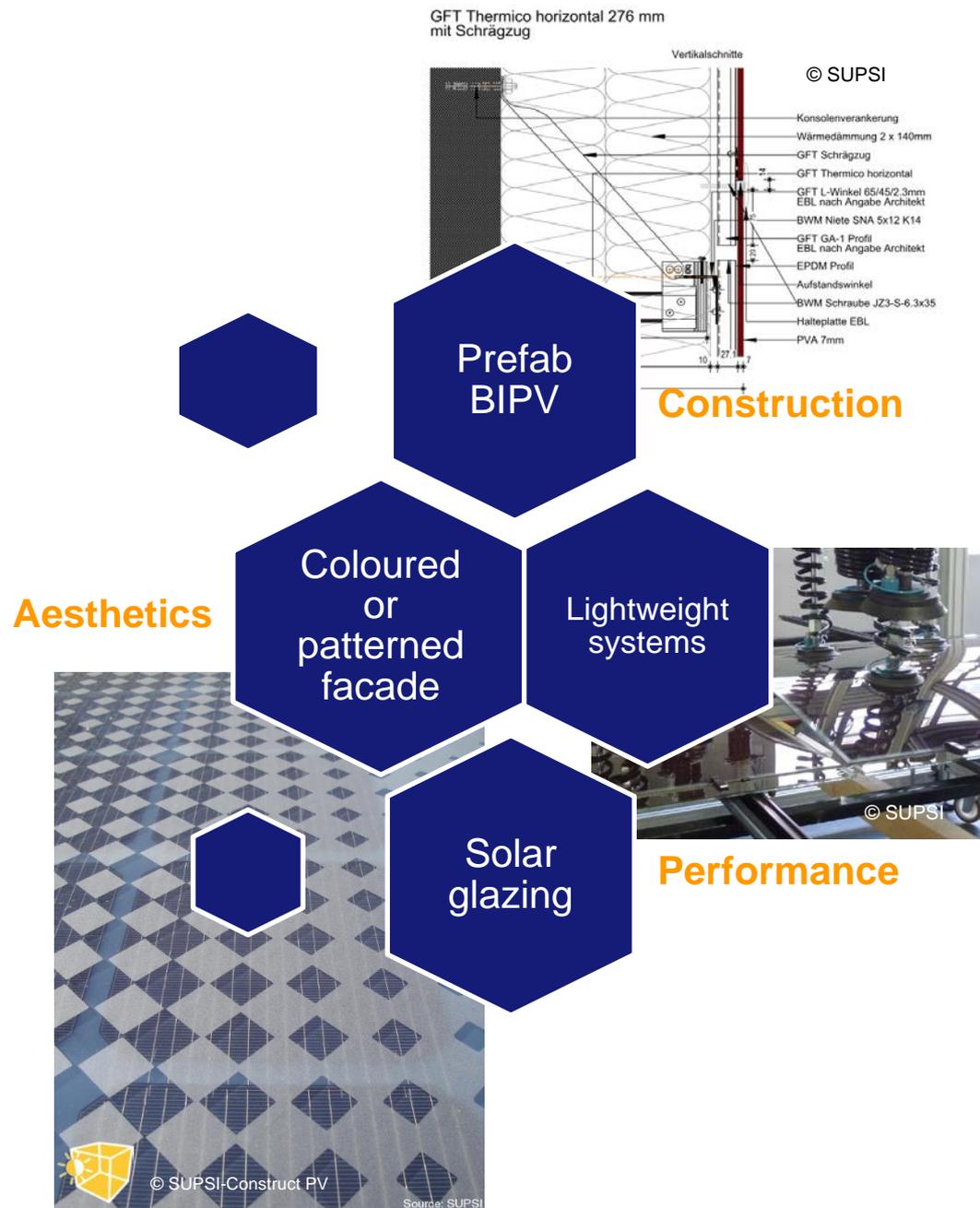
Photovoltaics and materials

A new architecture, a new opportunity



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



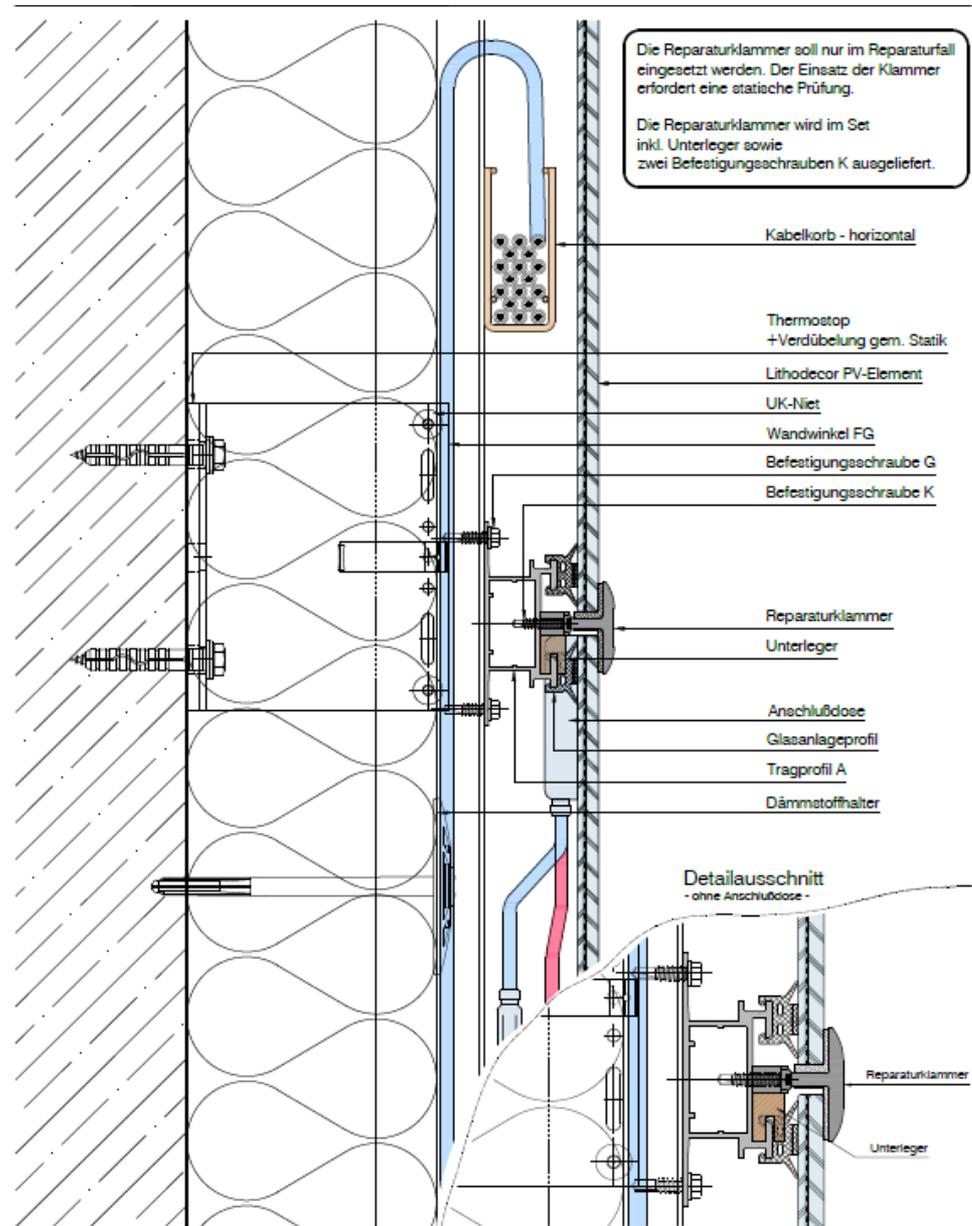
BIPV... quality?

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 for integrated wood, steel...



BIPV as...part of the building skin

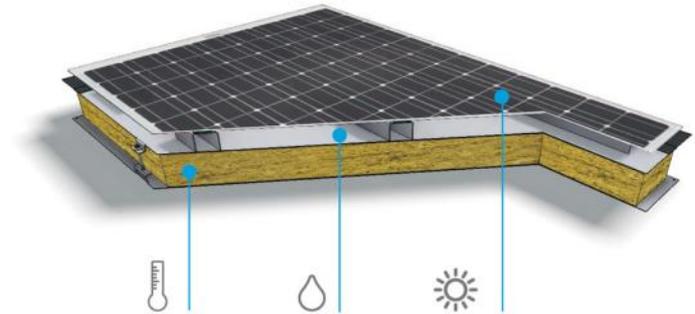
Which level?

- **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.)

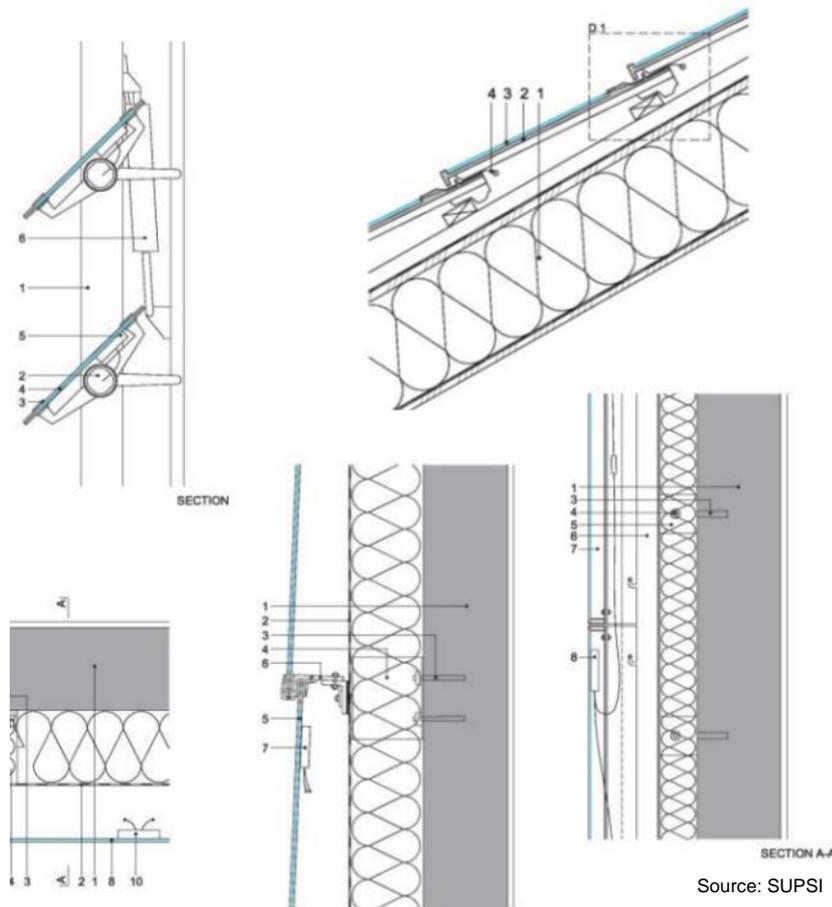


BIPV as...construction component

- 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



EN 50583:2016

Photovoltaics in buildings. BIPV products and systems



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



| | |
|--|--|
| <p>Home</p> <p>Project</p> <p>Case studies</p> <p>Outcomes</p> <p>Partners</p> <p>FAQ</p> <p>Contacts</p> <hr/> <p>Webfoot</p> <p>Web library</p> <p>Send an email</p> | <p>Construct PV</p> <p>Construct PV will develop and demonstrate customizable, efficient and low cost BIPV for opaque surfaces of buildings. The consortium involves selected partners, leaders in the industry and research sector and more in particular in the fields of PV technology and building construction connecting all the actors in the value chain.</p> <p>Click here for a flyer of Construct PV (English) (German)</p> <p>FP7-ENERGY-2011-2</p> <p>Call identifier: ENERGY.2011.2.1 – 4</p> <p>"Development and demonstration of standardized building components"</p> <p>Project Duration February 2013 – February 2017.</p> <p>The estimated project budget about 12Mio. €.</p> <p>Funded by European Commission through</p> <p>Grant agreement no. 295581</p> |
|--|--|

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

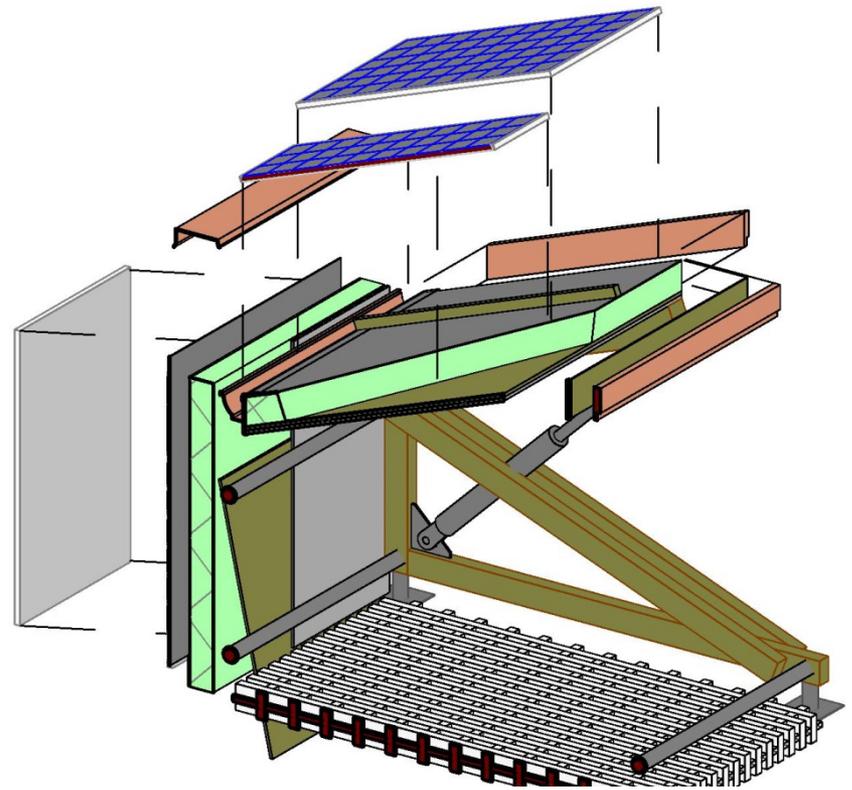
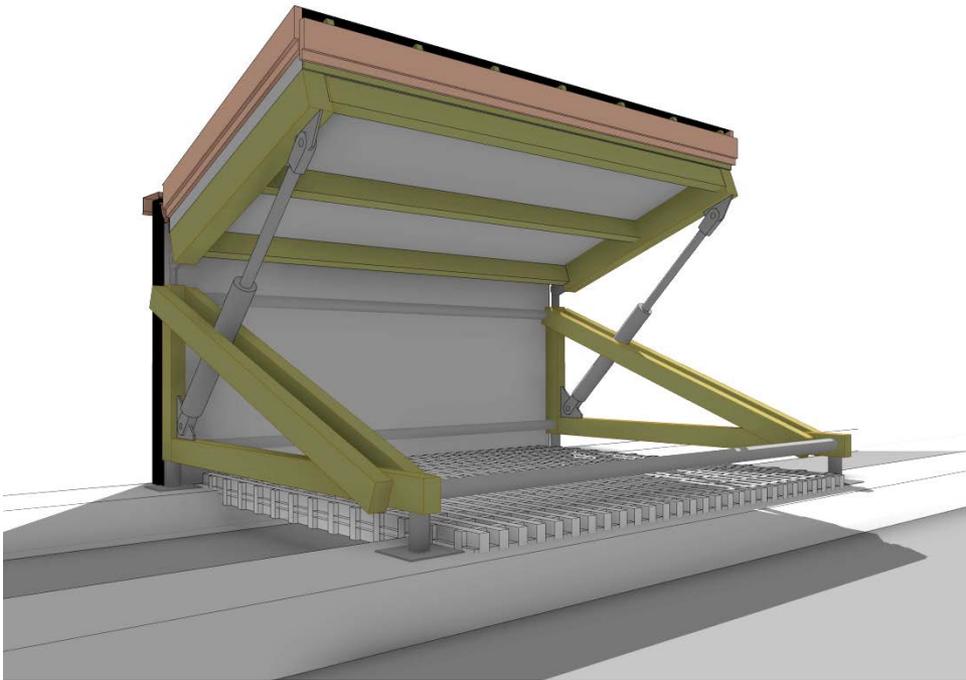
Estimated project budget: 12Mio. €



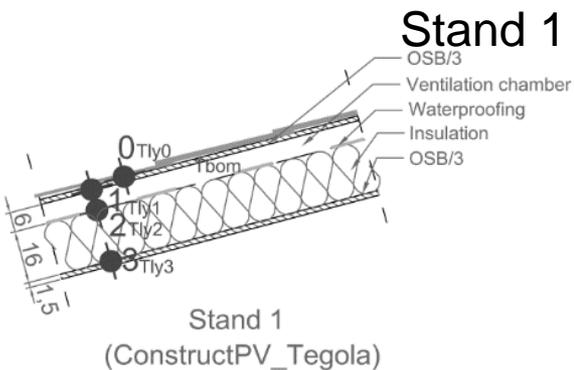
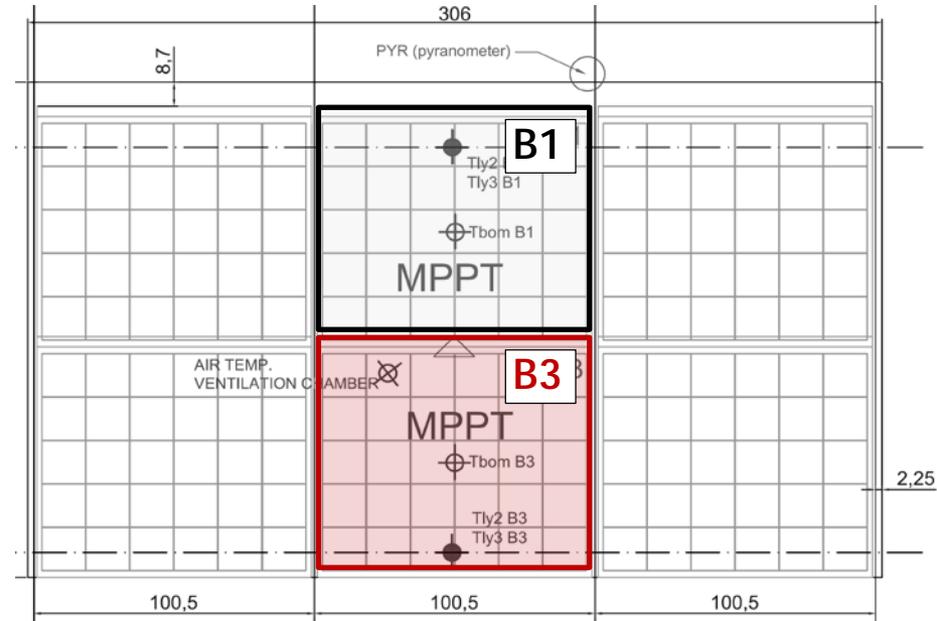
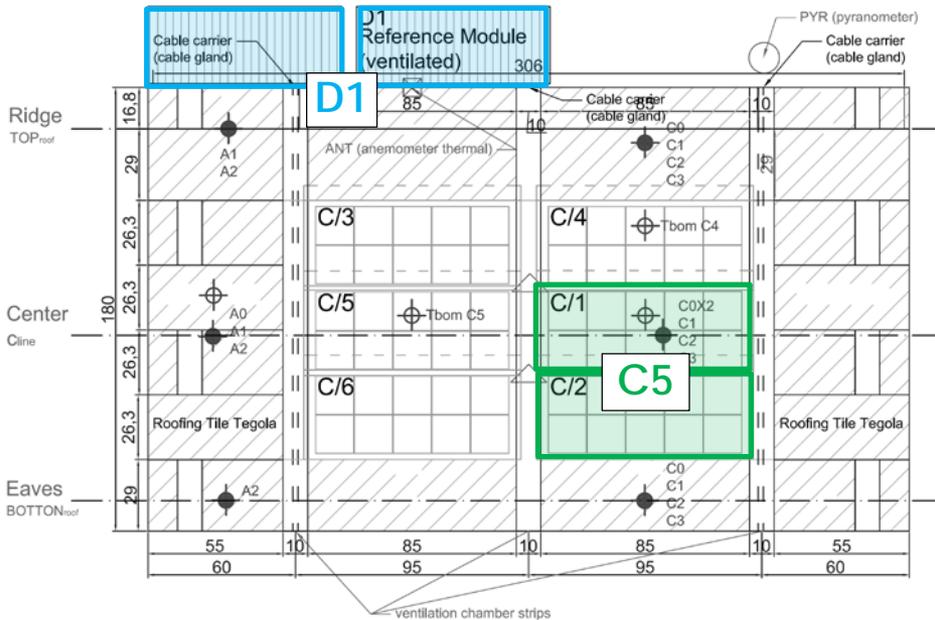


University of Applied Sciences and Arts
of Western Switzerland
SUPSI
CONSTRUCT
PV

Construct PV. Demo activity at SUPSI



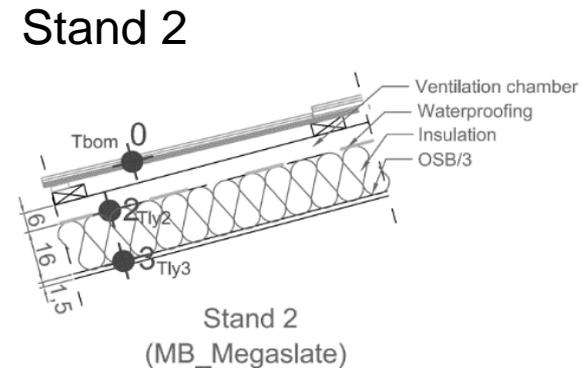
Construct PV. Demo activity with test facilities at SUPSI



SUPSI Campus (Lugano, CH)

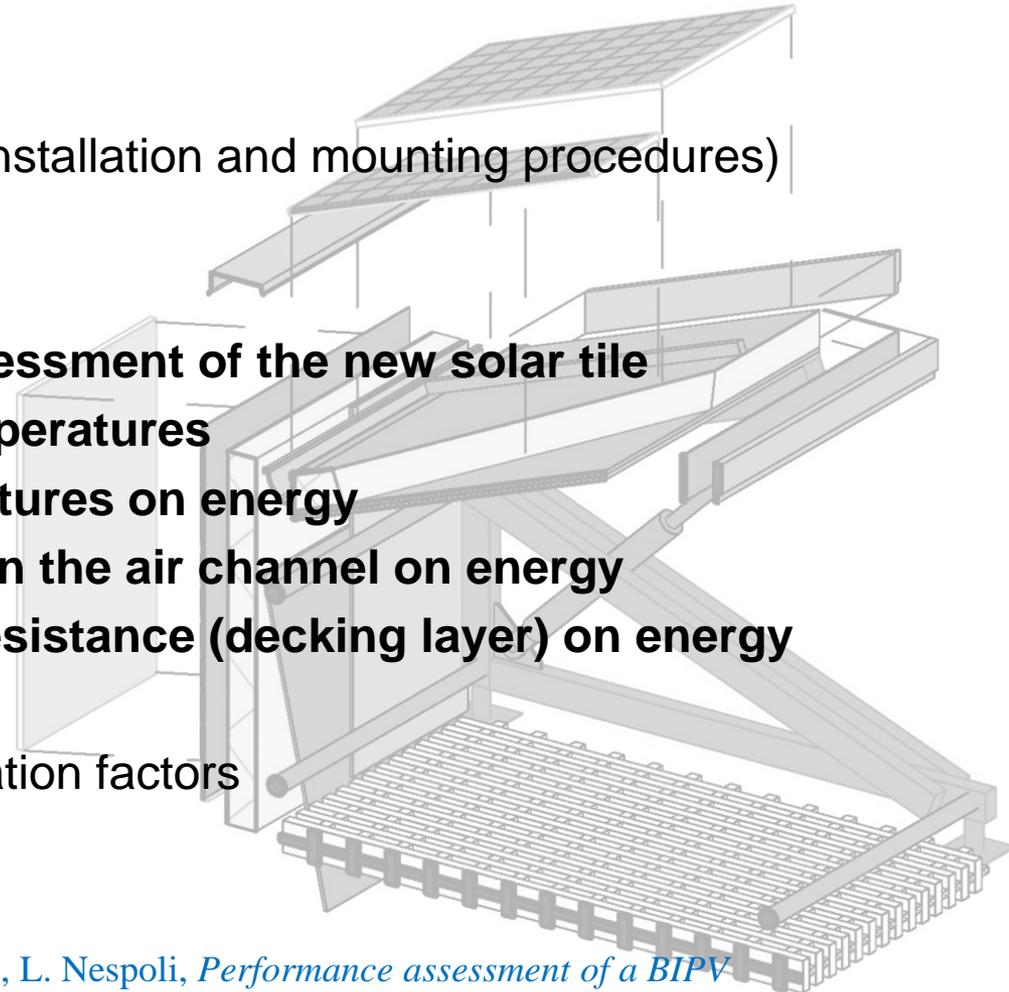
Comparison between modules:

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



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

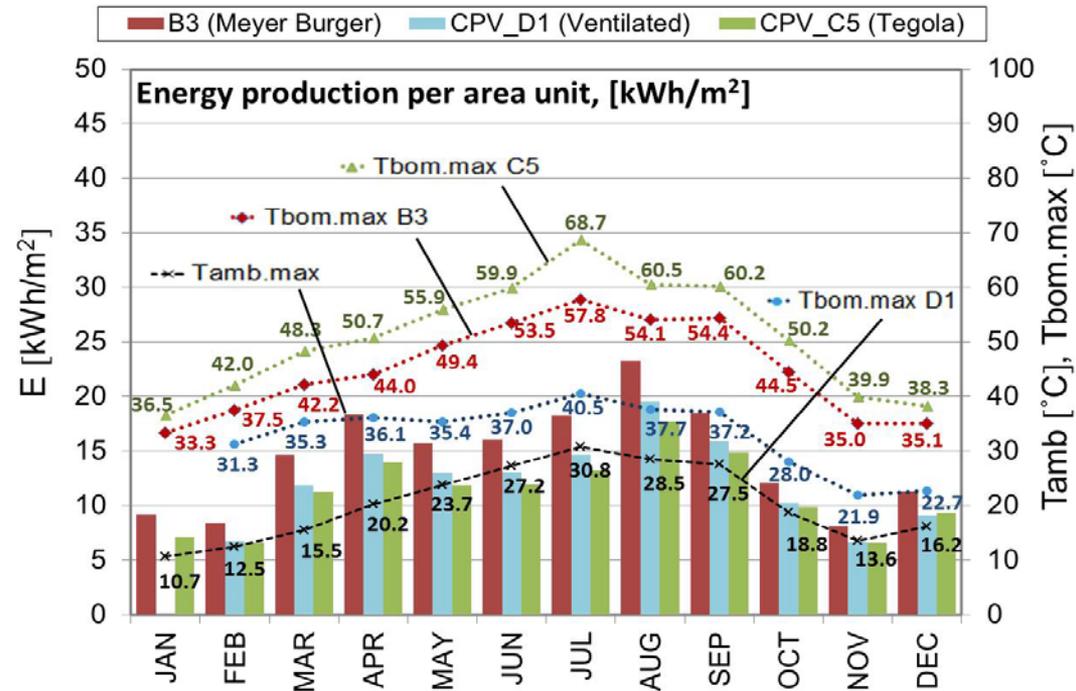


Reference:

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

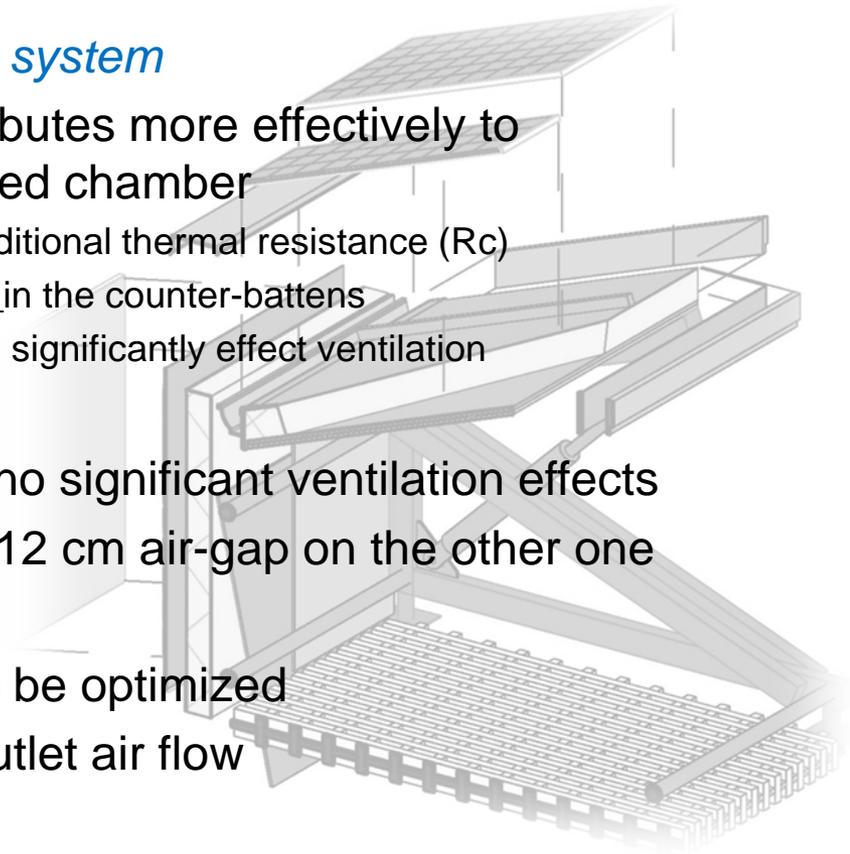
- A counter-batten system generally contributes more effectively to reducing T_{bom} than a roof with a ventilated chamber
 - Due to the absence of decking board and its additional thermal resistance (R_c)
 - Due to the usual higher thickness of the air-gap in the counter-battens
 - Possible micro-ventilation 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



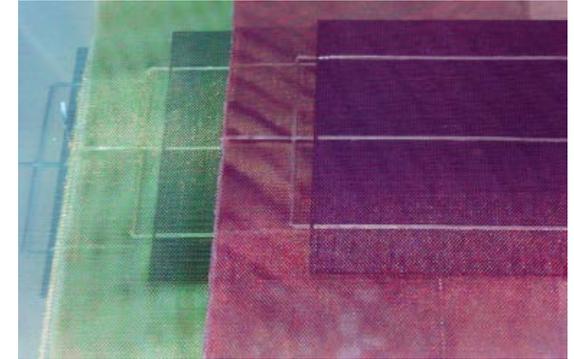
Mehrfamilienhaus Brütten (Photo: René Schmid Architekten)



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



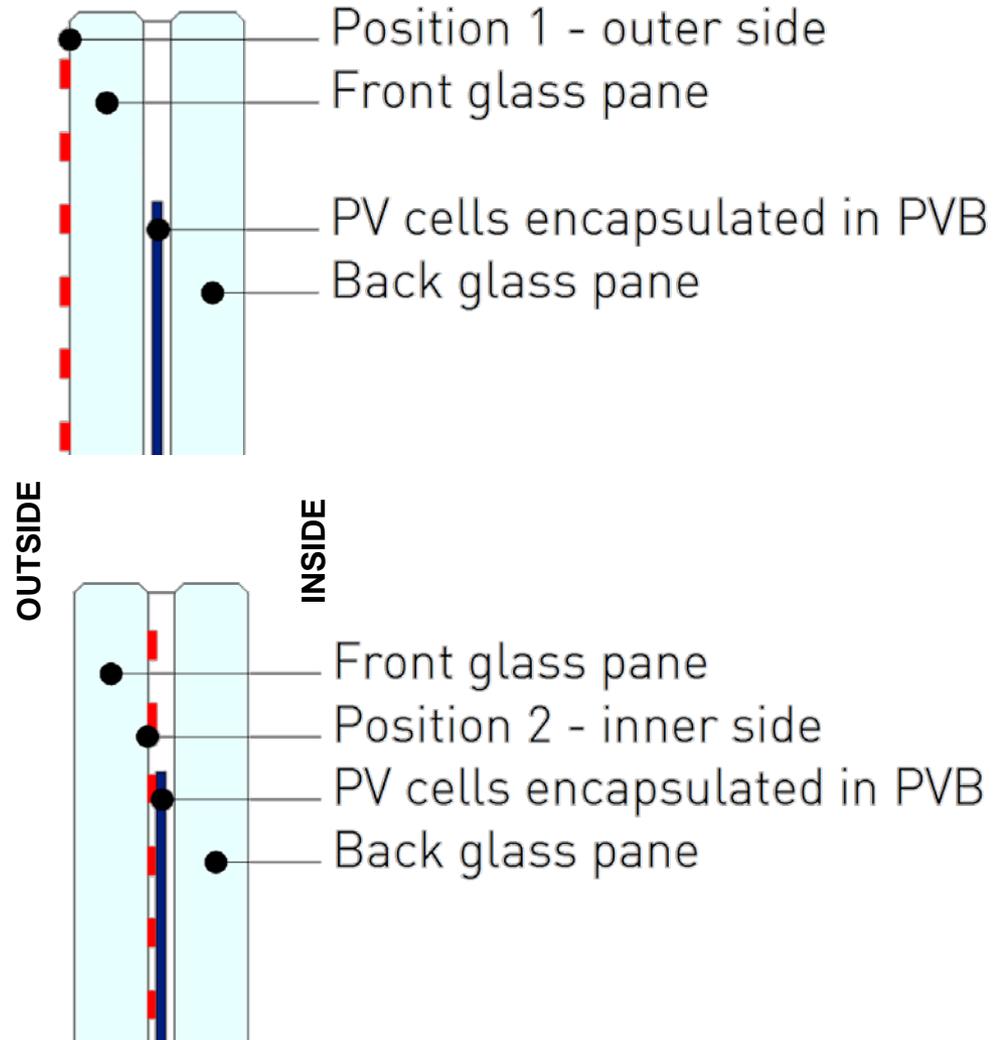
- Coordinator



Coloured BIPV modules

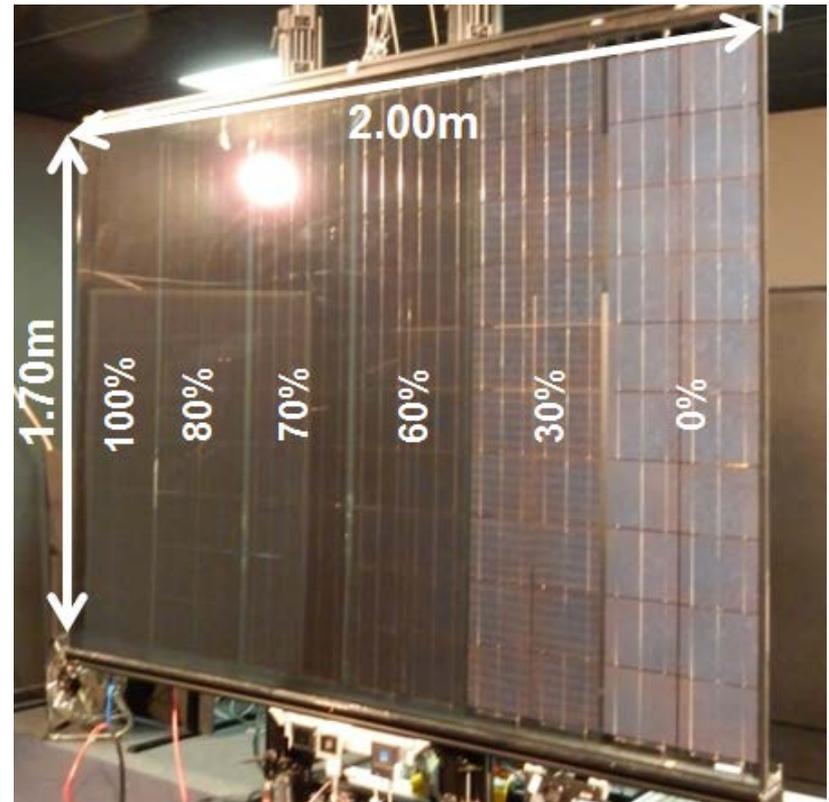
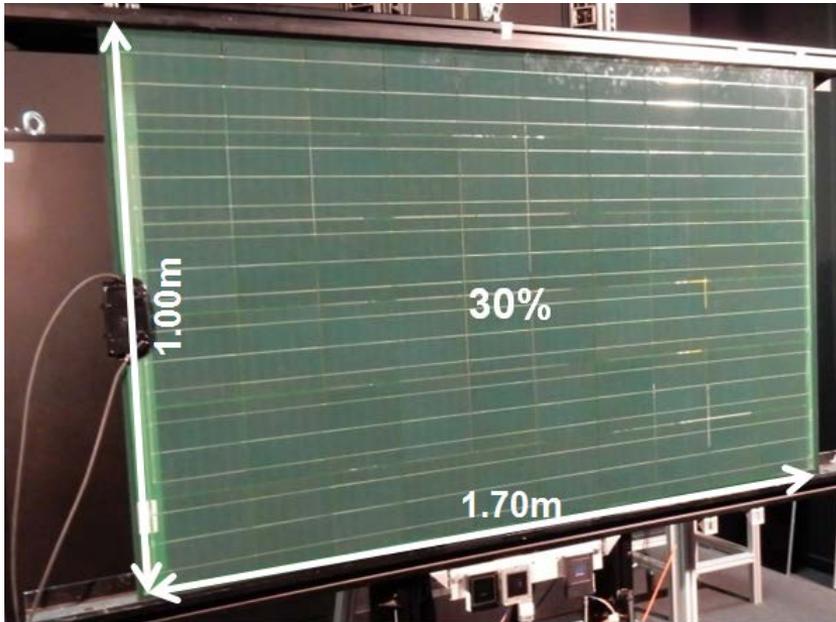
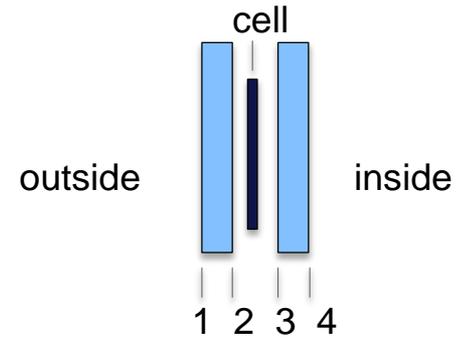


- Ceramic digital printed glass

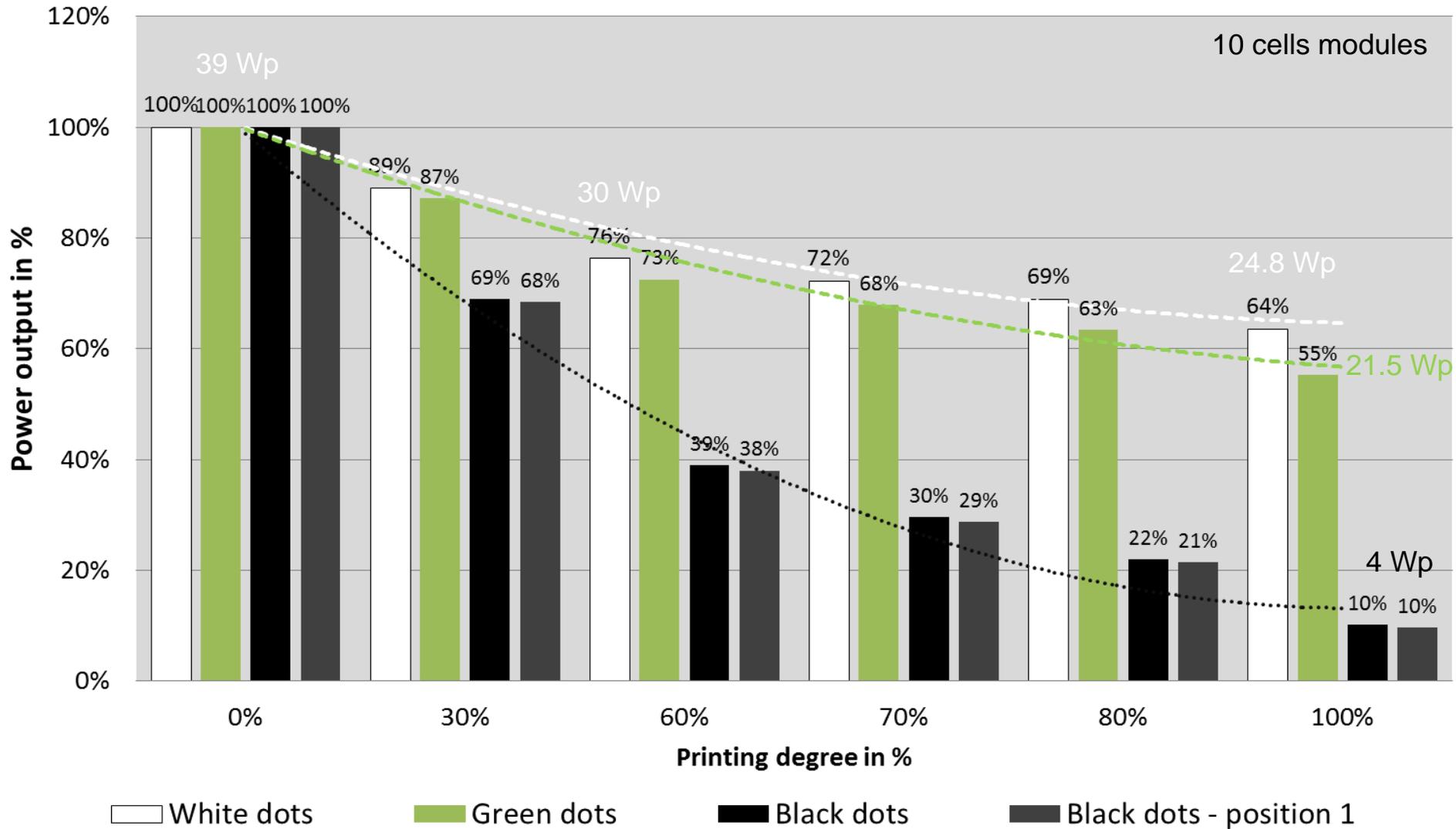


Power measurement at STC

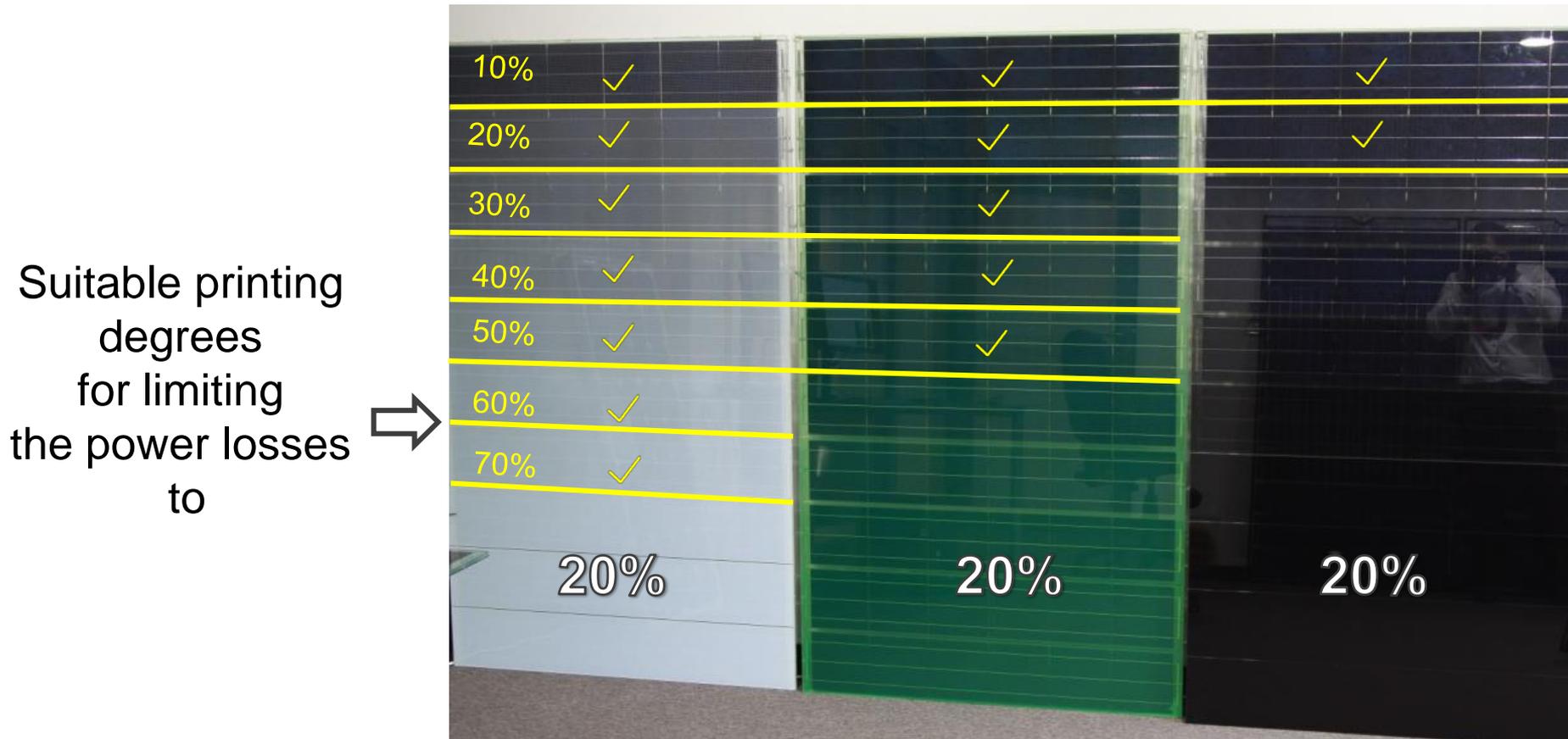
- Full colored modules (white, green, black, transparent)
- Large module with different color degrees
 - Color in Pos 1 or Pos 2



Power output vs. Printing degree (@STC)



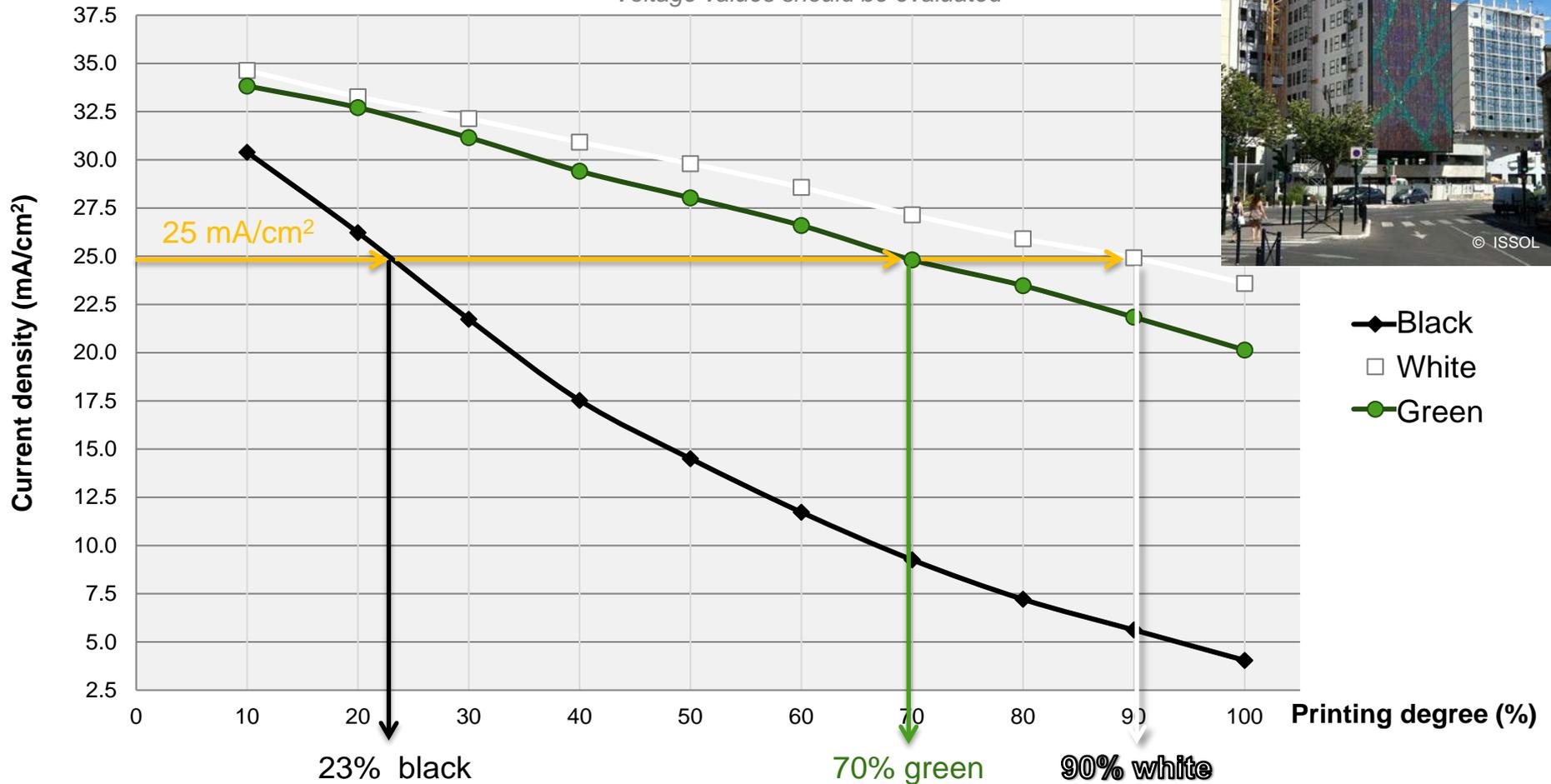
Coloured BIPV modules: power vs design?



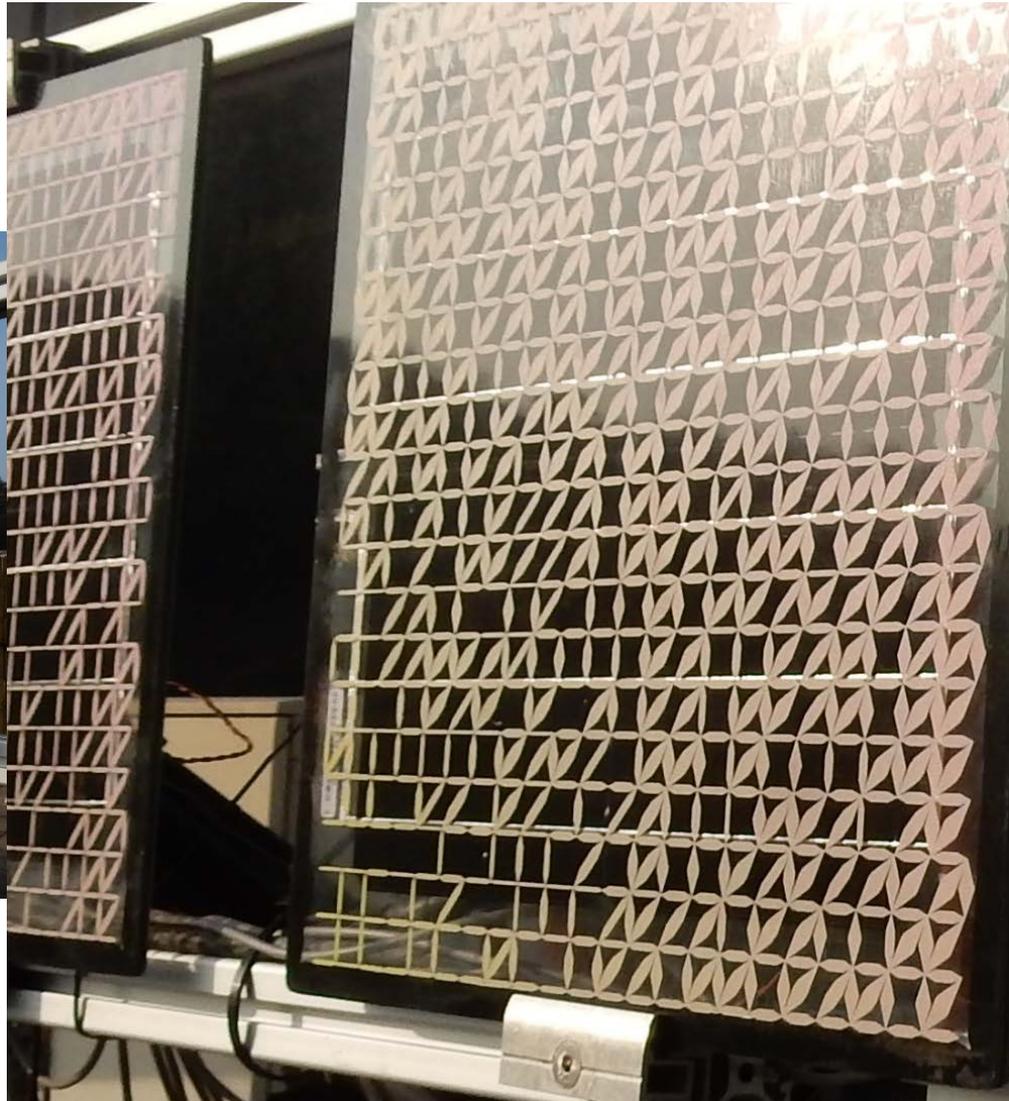
Coloured BIPV modules: electrical optimization

Current density vs printing degree

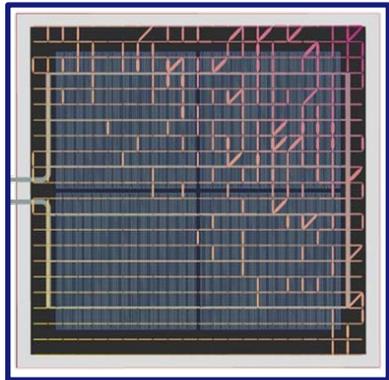
Voltage values should be evaluated



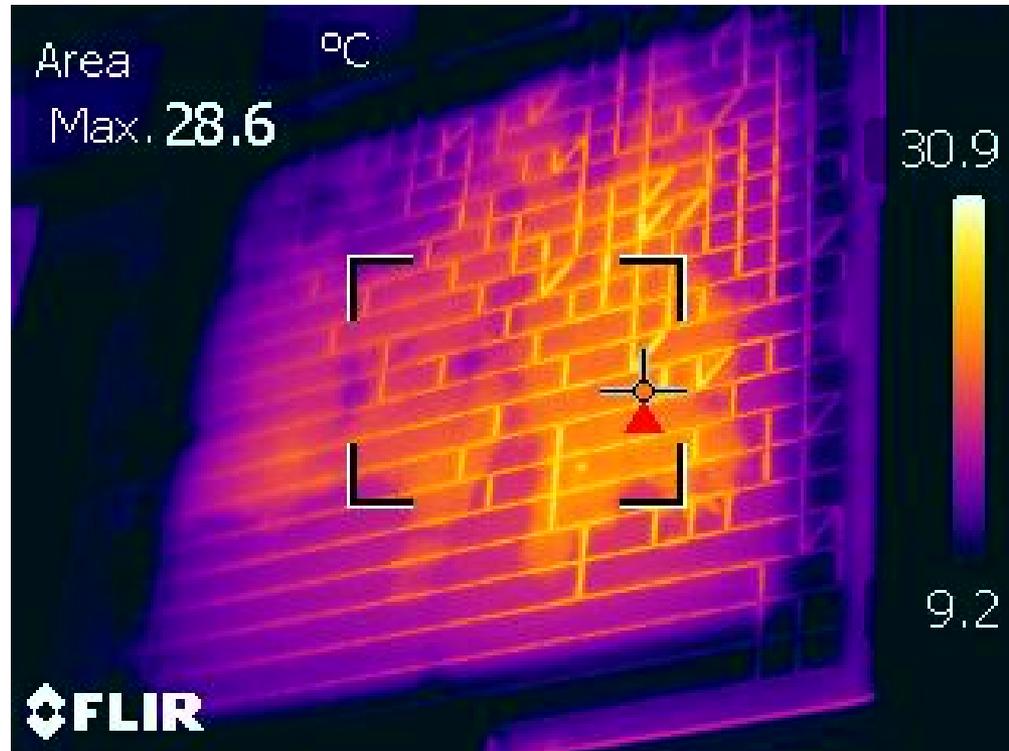
Outdoor behavior of special designed prototypes



Outdoor behavior of special designed prototypes



T1 – 10%



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

$P_m = 14.84 \text{ W}$

$\Delta T_{(\text{MAX;MIN})}$
 $\approx 10\text{-}15^\circ$

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

5 Review of Standards for Integrating BIPV-Module Building Façade and Roof

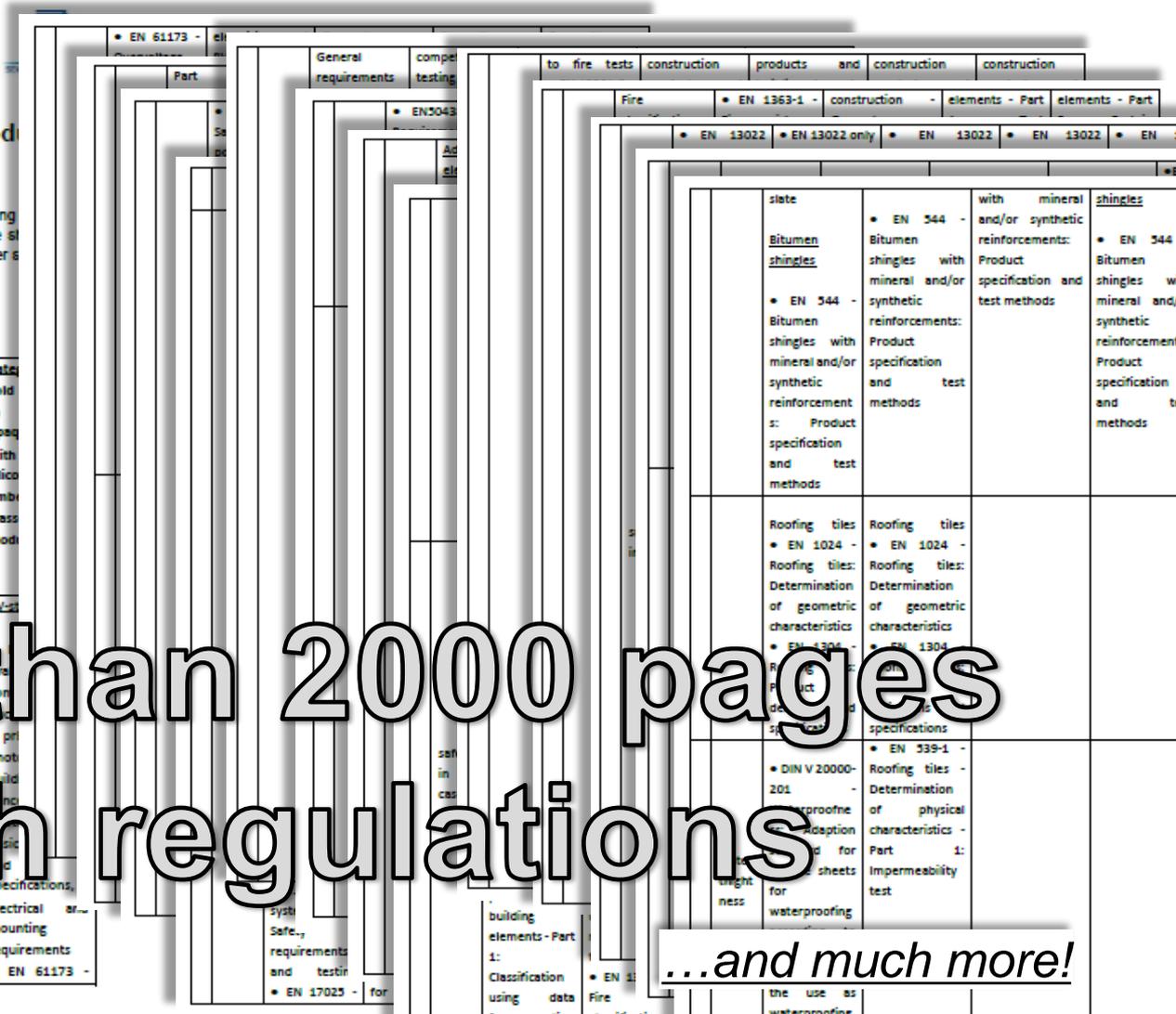
On the following pages all relevant standards for Integrated BIPV-modules in building roof are listed. Due to the huge number of standards, two variations of tables are shown in this present document. In chapter 5 the standards are listed in tables, optimized for paper use. In attachment the original table is shown, optimized for work on computer screen.

5.1 European standards

| | Category A | Category B | Category C | Category D | Category E |
|-------------------|--|--|--|--|--|
| | Sloped, roof-integrated, non-accessible from within the building | Sloped, roof-integrated, accessible from within the building | transparent warm façade with crystalline silicon PV cells embedded in a glass-glass-module non-accessible from within the building | transparent warm façade with crystalline silicon PV cells embedded in a glass-glass-module accessible from within the building | cold in opaque silicon embedded glass-module |
| | PV-standards: | PV-standards: | PV-standards: | PV-standards: | PV-standards: |
| electrical safety | <ul style="list-style-type: none"> EN 50380 - Evaluation conformity/Product standard prEN 50383 - Photovoltaic in buildings (not concentrator photovoltaic): Basic properties and specifications, electrical and mounting requirements EN 61173 - Overvoltage protection for systems generating | <ul style="list-style-type: none"> EN 50380 - Evaluation conformity/Product standard prEN 50383 - Photovoltaic in buildings (not concentrator photovoltaic): Basic properties and specifications, electrical and mounting requirements EN 61173 - Overvoltage protection for systems generating | <ul style="list-style-type: none"> EN 50380 - Evaluation conformity/Product standard prEN 50383 - Photovoltaic in buildings (not concentrator photovoltaic): Basic properties and specifications, electrical and mounting requirements EN 61173 - Overvoltage protection for systems generating | <ul style="list-style-type: none"> EN 50380 - Evaluation conformity/Product standard prEN 50383 - Photovoltaic in buildings (not concentrator photovoltaic): Basic properties and specifications, electrical and mounting requirements EN 61173 - Overvoltage protection for systems generating | <ul style="list-style-type: none"> EN 50380 - Evaluation conformity/Product standard prEN 50383 - Photovoltaic in buildings (not concentrator photovoltaic): Basic properties and specifications, electrical and mounting requirements EN 61173 - Overvoltage protection for systems generating |

More than 2000 pages with regulations

...and much more!



An example: double skin BIPV façade



© Tomas Lenkimas; Glassbe (courtesy: SmartFlex Project)

1. Mechanical 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 **EN ISO 12543-2**
 NORME EUROPÉENNE
 EUROPÄISCHE NORM
 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 -
 Sécurité - Partie 2: Verre feuilleté de sécurité (ISO 12543-2:2011)

ETA
 European Organisation for Technical Approvals
 Europäische Organisation für Technische Zulassungen
 Organisation Européenne pour l'Agrement 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)**

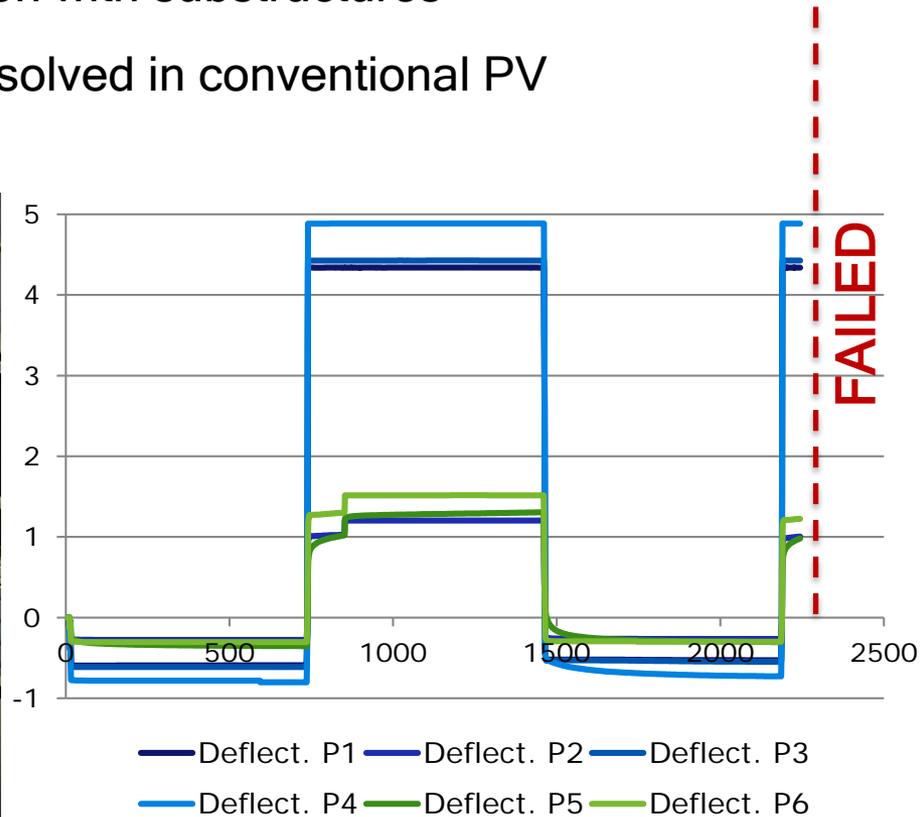
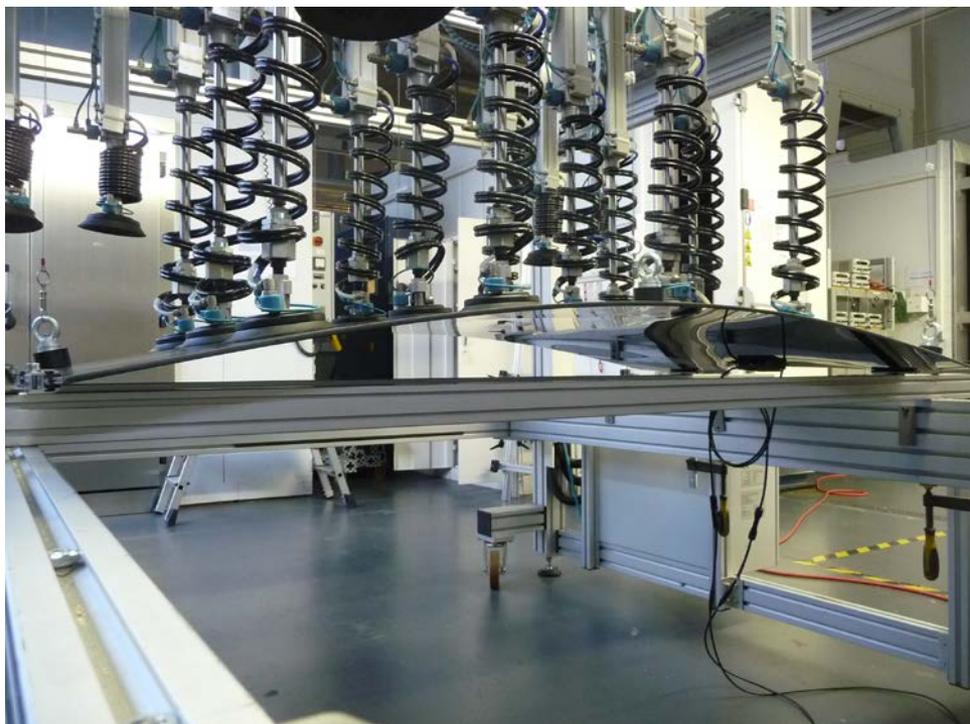
Part 1: SUPPORTED AND UNSUPPORTED SYSTEMS

EUROPEAN STANDARD **EN 13830**
 NORME EUROPÉENNE
 EUROPÄISCHE NORM
 April 2015
 ICS 91.060.10 Supersedes EN 13830
 English Version
 Curtain walling - Product standard
 Norme de produit
 Vorhangfassaden - Produktnorm

EUROPEAN STANDARD **EN 12600**
 NORME EUROPÉENNE
 EUROPÄISCHE NORM
 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

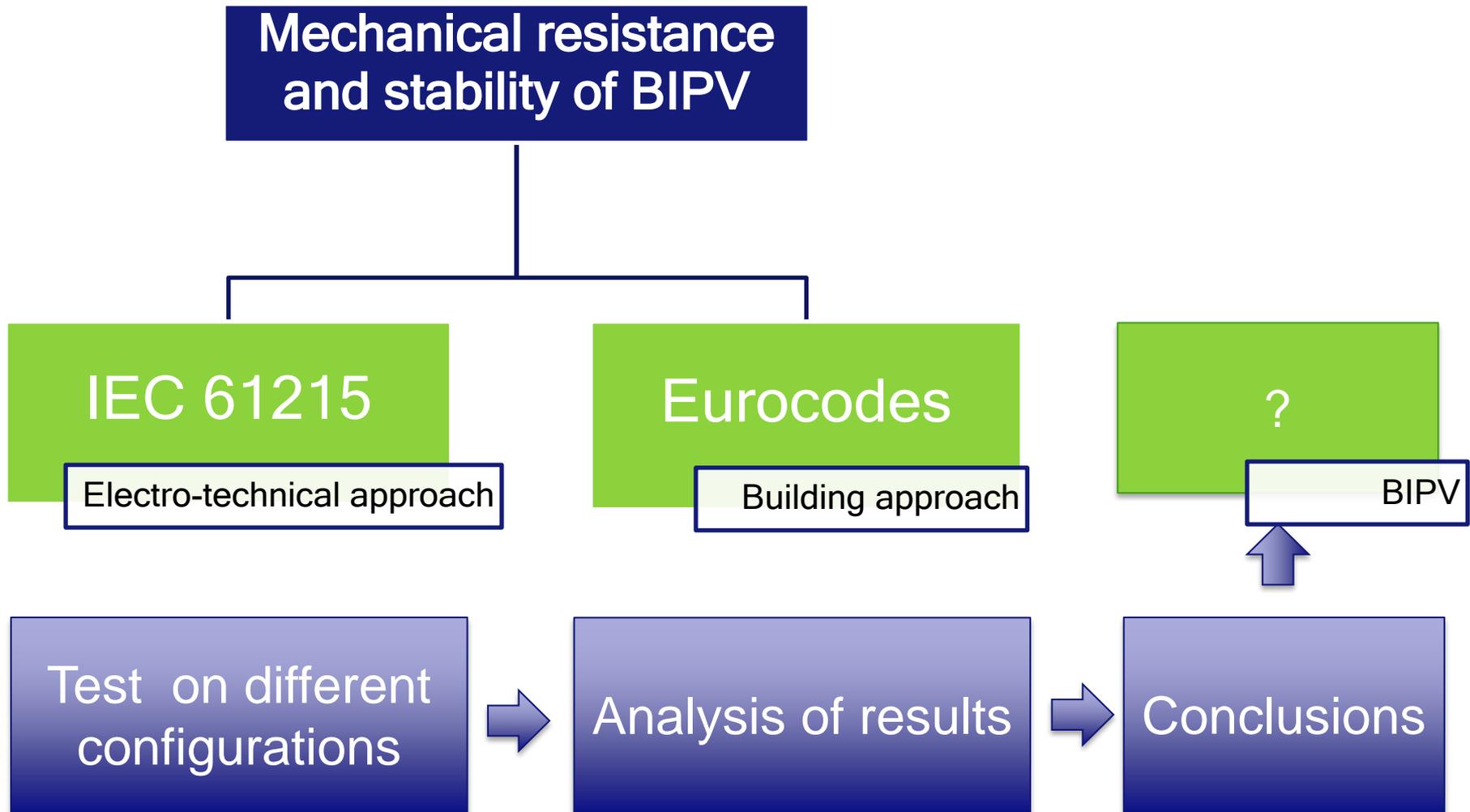
- Type B failed (clamps on the short sides)
- Direction of load (wind, snow...)...interaction with substructures
- Interaction is not studied, is not properly solved in conventional PV



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

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Fire Safety of PV modules and buildings overviews, bottlenecks and hints

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ABSTRACT. The enhancement of the fire safety of buildings with PV modules installed/integrated on roofs or facades is a topic that still concerns the PV industry and research communities due to the fact that the presence of PV modules can facilitate a fast spread of the flames. Considering that PV modules are spreading all over the world on buildings, there is the need to guarantee higher safety requirements both in order to avoid economic losses and to protect people who can be involved in case of fire. This is involving, on one hand, a continuous improvement of the international and national regulation frameworks and, on the other hand, new research activities for the evaluation of the PV module behavior in case of exposure to an external fire that are aimed at considering real conditions for PV installations in order to go beyond the actual framework and further improve the fire safety aspects.

This work aims at presenting a clear understanding of the existing regulation framework (at the international, Italian and Swiss levels) and at returning the main results of the current studies and activities of some institutions (RSE and Italian National Rescue and Services – DCPST – Italy, SUPSI-ISAAC – Switzerland).

1. INTRODUCTION

Together with the increased spread of PV systems installed on and BIPV systems integrated in buildings, an increased number of PV fire related accidents has been recorded worldwide. Indeed, even if PV modules could not be the cause of ignition, in case of an outbreak of a fire in hosting buildings, they can intensify fire spread and trigger flame propagation mechanisms. Therefore, there is the need to avoid economic losses and protect also building users.

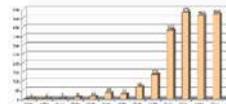


Fig. 1. Example of the increase of PV fire-related accidents in Italy



Fig. 2. Consequences of fire on a BIPV roof (Switzerland)



Fig. 3. Electric arcs started from junction box (left) and connector (bottom)

| POTENTIAL FIRE SOURCES | EFFECTS |
|---|--|
| Unprotected hot spots at module level | Localized over-heating |
| Faulty of undereized bypass diodes | |
| Poor electrical insulation of the PV circuit (under-construction and/or ground) | Electro-ARC fault (parallel) |
| Poor or neglected wiring and insulation of wiring harness | |
| Poor electrical interconnections and bonding off-to-cell (module level) | Electro-ARC fault (series) and/or localized over-heating |
| Faulty connectors (module-to-module) | |
| Faulty electrical connections inside the junction box | |

Tab. 1. Common fire causes within any of PV modules

2. PV FIRE SAFETY: AN OVERVIEW ON INTERNATIONAL AND NATIONAL REGULATIONS

| Global | Italy | Switzerland | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|-------------------------------|---------------------|---------------------|------------------|--------|------------------|-------------------|---|--------|---------------------------|---|--------|---------|-----------|---|---------------------|--------|-------------------|-------------|---|--------|---------------------------|---|--------|--------|-------------------------------|-------------------|---|--|--|
| <p>International reference - IEC 61730:2016</p> <table border="1"> <thead> <tr> <th>Test</th> <th>Title</th> <th>Reference standards</th> <th>Based on 61215-2</th> </tr> </thead> <tbody> <tr> <td>MST 21</td> <td>Temperature test</td> <td>ANSI/UL 1703-2015</td> <td>-</td> </tr> <tr> <td>MST 22</td> <td>Hot-spot and/or soot test</td> <td>-</td> <td>MST 29</td> </tr> <tr> <td>MST 23*</td> <td>Fire test</td> <td>-</td> <td>National/Local code</td> </tr> <tr> <td>MST 24</td> <td>Ignitability test</td> <td>ISO 11093-2</td> <td>-</td> </tr> <tr> <td>MST 25</td> <td>Bypass diode thermal test</td> <td>-</td> <td>MST 16</td> </tr> <tr> <td>MST 26</td> <td>Reverse current overload test</td> <td>ANSI/UL 1703-2015</td> <td>-</td> </tr> </tbody> </table> <p>for a PV fire hazard classification (IEC 61730:2016)</p> | Test | Title | Reference standards | Based on 61215-2 | MST 21 | Temperature test | ANSI/UL 1703-2015 | - | MST 22 | Hot-spot and/or soot test | - | MST 29 | MST 23* | Fire test | - | National/Local code | MST 24 | Ignitability test | ISO 11093-2 | - | MST 25 | Bypass diode thermal test | - | MST 16 | MST 26 | Reverse current overload test | ANSI/UL 1703-2015 | - | <p>The Italian National Fire Rescue and Service has issued a national resolution to test and classifying the reaction to fire (RF) of PV modules. This technical regulation states that RF classifications for combustible materials are determined by using the results from a combination of four national tests (UNI 9176, UNI 9457, UNI 9174, UNI 9177).</p> | <p>In Switzerland, there is not a specific standard for testing and classifying the fire behavior of PV and/or BIPV modules. However, the Swiss Association of Cantonal Fire Insurance Underwriters (VKF) has developed a Memorandum for Solar Systems where fire hazards are addressed. Among recommendations, the fundamental ones are:</p> <ul style="list-style-type: none"> ■ solar systems in buildings should not involve an unacceptable increase of the danger due to the formation and propagation of the fire, and ■ the existing fire protection regulations for buildings should be fulfilled. |
| Test | Title | Reference standards | Based on 61215-2 | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| MST 21 | Temperature test | ANSI/UL 1703-2015 | - | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| MST 22 | Hot-spot and/or soot test | - | MST 29 | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| MST 23* | Fire test | - | National/Local code | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| MST 24 | Ignitability test | ISO 11093-2 | - | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| MST 25 | Bypass diode thermal test | - | MST 16 | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| MST 26 | Reverse current overload test | ANSI/UL 1703-2015 | - | | | | | | | | | | | | | | | | | | | | | | | | | | | |

The fire rating classification of the PV modules has not been agreed internationally, so PV modules mounted in or on buildings should comply with national and/or local building and construction regulations.



4. RESEARCH & TESTING ACTIVITIES

Within the CLC TCB2 tasks, RSE S.p.A., Italian National Fire Rescue and Service, Politecnico di Milano and Istituto Giordano S.p.A are currently carrying out a research program to develop a new test protocols about fire behavior of PV modules on roofs in order to take into account the influence of: wiring heat, Release Rate (RRR) and size of ignition flame, sample exposure time to ignition flame and presence of sample initial deterioration.



Fig. 5. Fire tests on PV modules. From left to right: the tested PV module with horizontal burner flame impinging the backsheet of the module; the tested PV module with horizontal burner flame impinging the backsheet of the module; the tested PV module with horizontal burner flame impinging the backsheet of the module.

5. BIPV FIRE SAFETY AS BUILDING SKIN?

As defined in the Swiss Memorandum for Solar System, BIPV has not to increase the fire hazard and it should be compliant with fire safety regulations for buildings.

In detail, fire safety of BIPV depends on three main levels: (i) module characteristics, (ii) envelope stratigraphy and (iii) building geometry. However, there are further restrictions (e.g. fire propagation in height) that need to be evaluated for BIPV.

| BIPV? | Building use | Reaction to fire class | |
|-------------|--|------------------------|---|
| | | EN 13501-1 | EN 13501-2 |
| BIPV? | Outer surface of roof (residential) | Low height | RF1 or RF2a, when not ventilated cavity and RFI substrate |
| | Outer cladding of exterior walls (residential) | Low height | RF2a or RFI substrate |
| | | Mid height | RF2a or RF2a if re-igniters and RFI substrate |
| | | High height | RF1 |
| | Outer cladding of exterior walls (non-residential) | Low height | RF2a |
| | | Mid height | RF2a |
| High height | | RF1 | |

Tab. 3. BIPV reaction to fire requirements from Fire Protection Directive 14.11.13 (Use of Building Materials) (ENF)

6. CONCLUSIONS

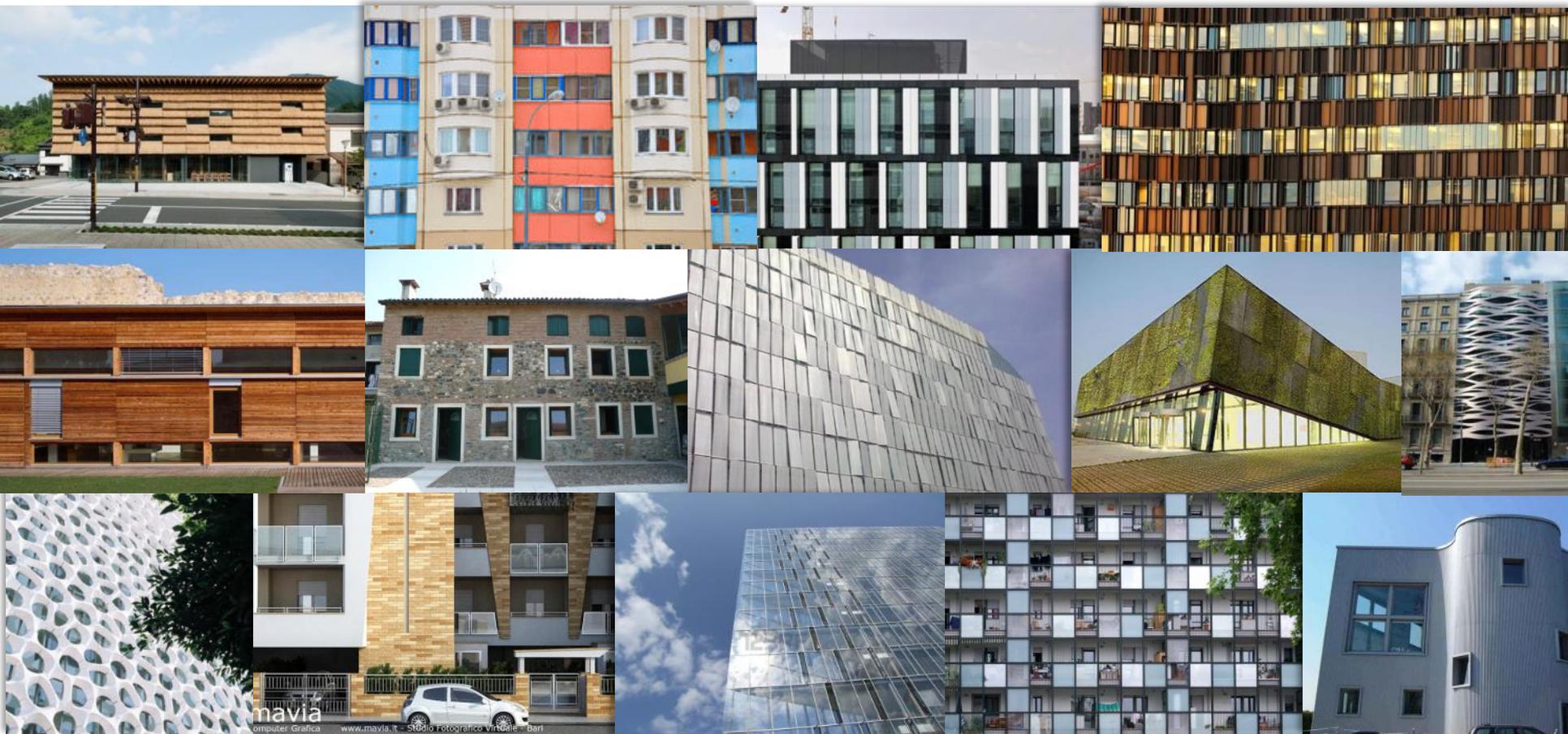
In a continuous changing regulative framework and considering that fire risk for photovoltaic installations is not negligible, this joint study developed by Italian and Swiss research institutes has led to the identification of three main domains to be further investigated:

- **Clear regulation framework:** to achieve a codification of construction, design and installation of PV and BIPV systems, a process capable to involve various organizations (standardization bodies, modules manufacturers, etc.) should be taken into consideration to increase the fire safety related to building installations;
- **Testing methods and procedures:** an improvement of existing procedures should be addressed in order to consider real operating conditions affecting fire spreading;
- **Monitoring during operation conditions:** evaluation of operating conditions with the diagnostic/monitoring tools can represent a solution to reduce and/or avoid the fire hazard, as well as a safety device capable to disconnect the PV elements in case of fire.

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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



How much does BIPV cost?

Cost of complete BIPV roof tiling

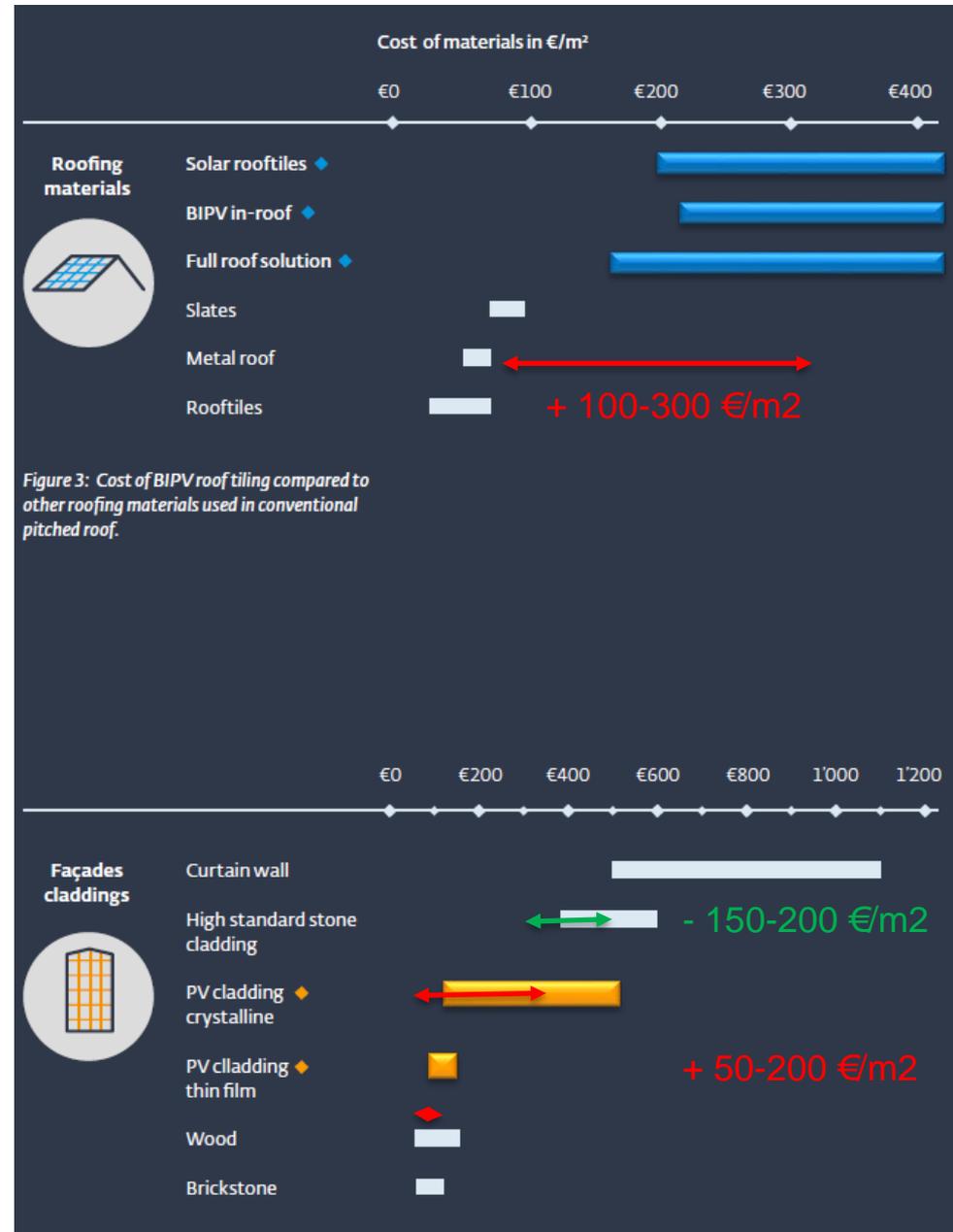
including mounting, transportation and other costs

- a significant price range but 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 façades can be cheaper than conventional materials!
- BIPV façade system extra-cost are 20-40%

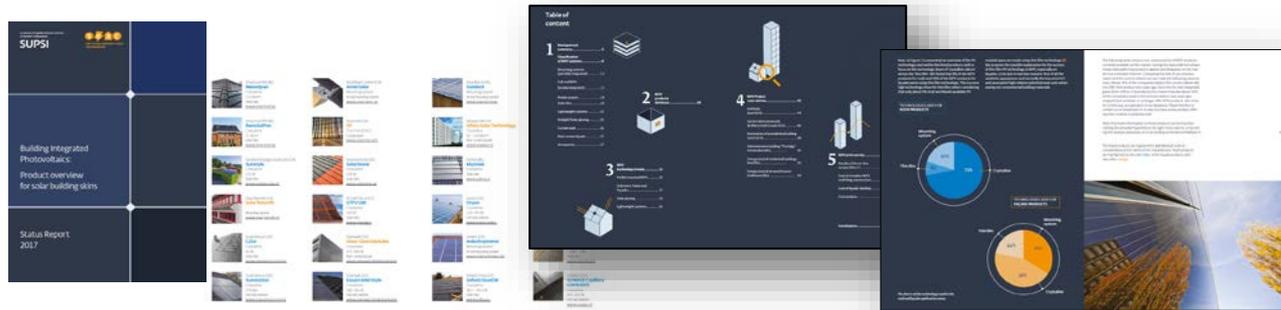


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Thank you for your attention!



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//// active
interfaces

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