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

SUPSI

BIPV needs

SUPSI experience beyond Standard Test Conditions

Mehrzweckhalle Preisegg -Hasle bei Burgdorf (2013) Source: SUPSI-BFE

Dr. Pierluigi Bonomo
ISAAC-Advanced Building Skin Team
Swiss BiPV Competence Centre

6 aprile 2017

BIPV at SUPSI, since 2004

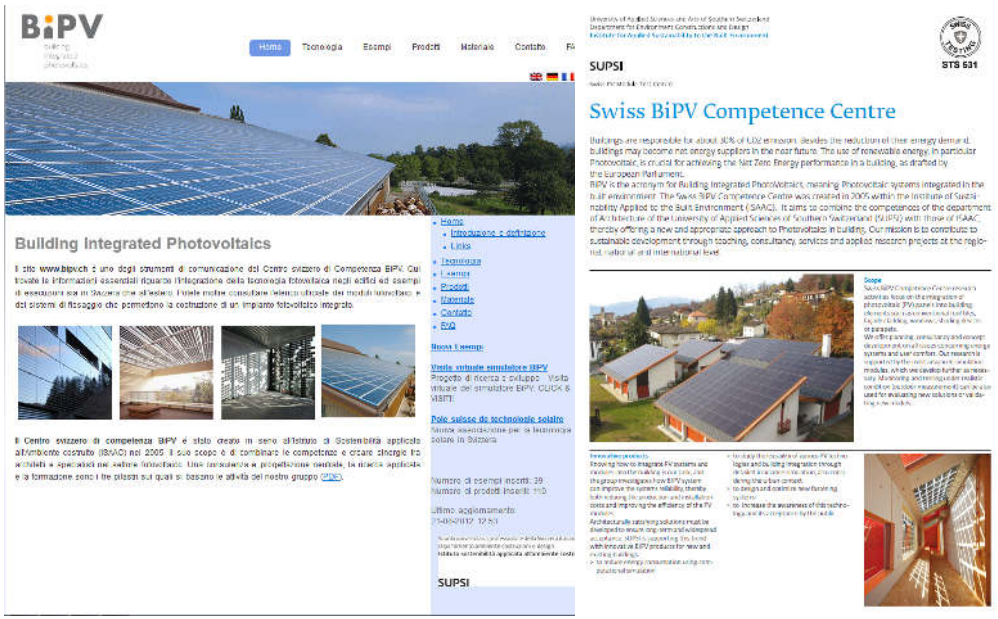
2004: LEEE-TISO projects on BIPV

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

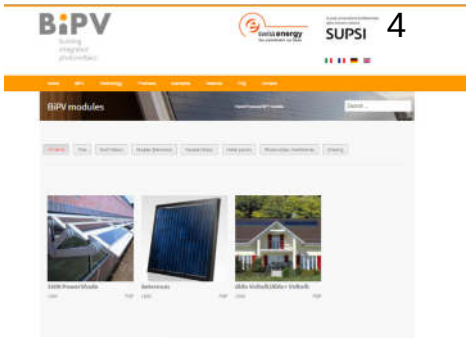
Our first project :

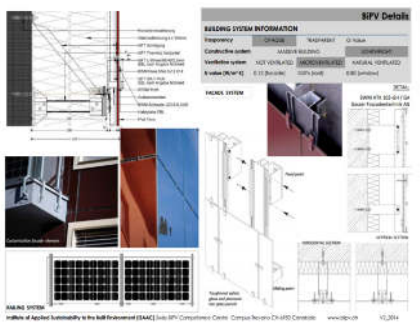
«Swiss PV test centre – TISO and BiPV project 2003-2006»

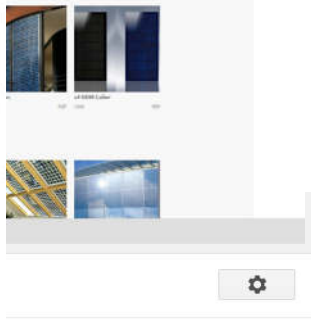


(source: Swiss BIPV Competence Centre)

BIPV…is communication!







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** è stato creato in seno all'Istituto di Sostenibilità applicata all'Ambiente costruito (ISAAC) nel 2005. Il suo scopo è 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 ...

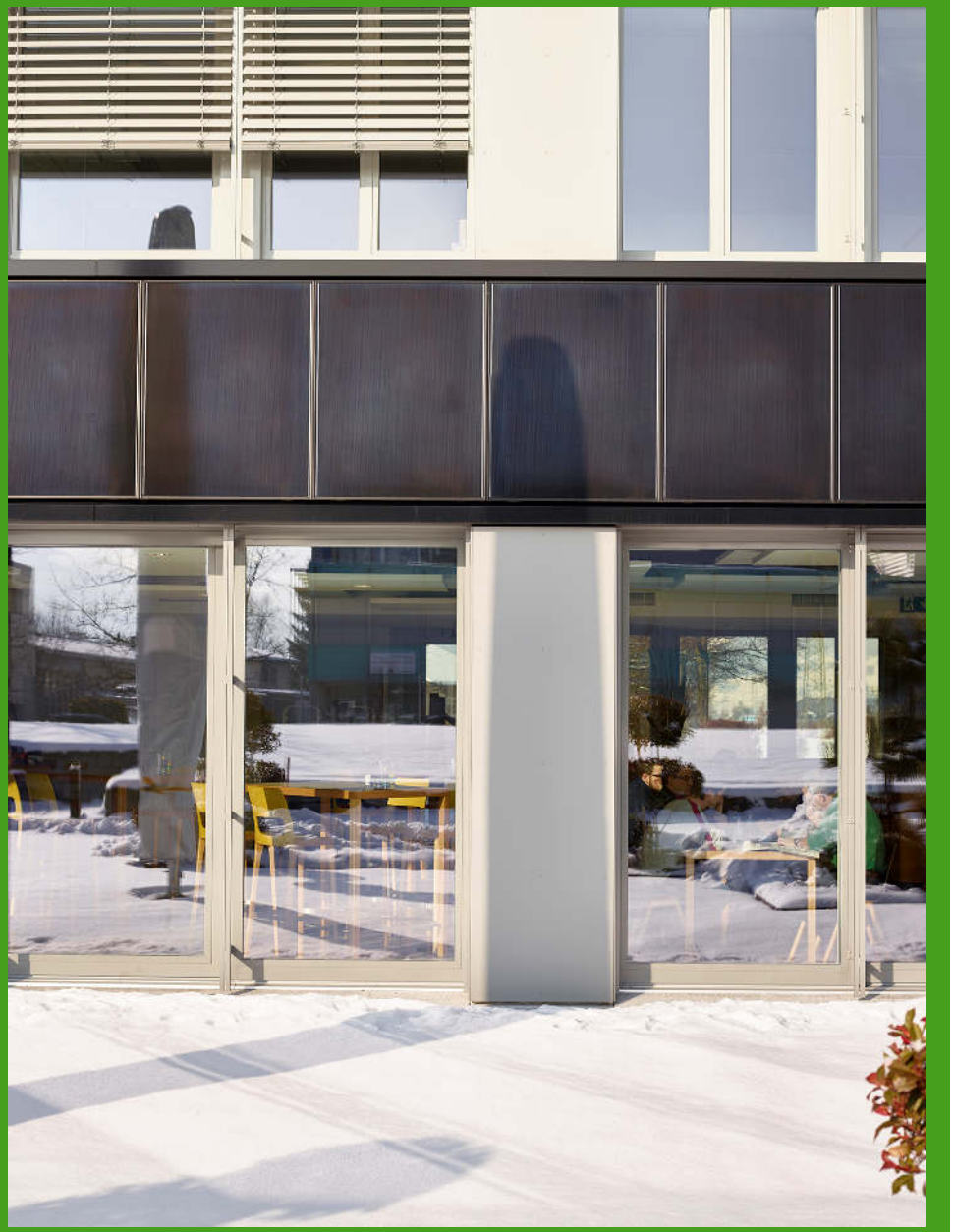
Onyx Solar® - Integrazione Fotovoltaica Per L´Edificio (BIPV ...
www.onyxsolar.com/it/
In collaborazione con Enel Green Power, Onyx Solar® offre al mercato italiano le sue innovatrici soluzioni per integrazione fotovoltaica (**BIPV**). ENEL, il maggior ...

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

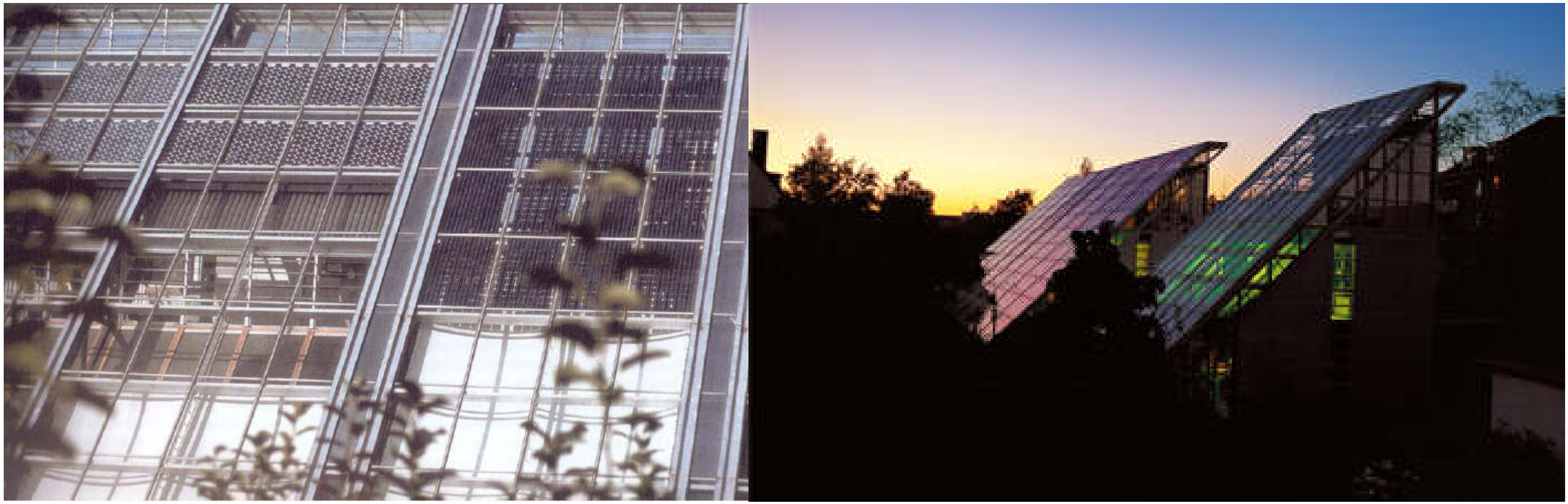
Summary

- **Introduction, research in BIPV**
- **Real operating conditions for BIPV**
- **Characterization of customizable BIPV**
- **…new challenges?**



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

BIPV …an adventure started with architecture



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

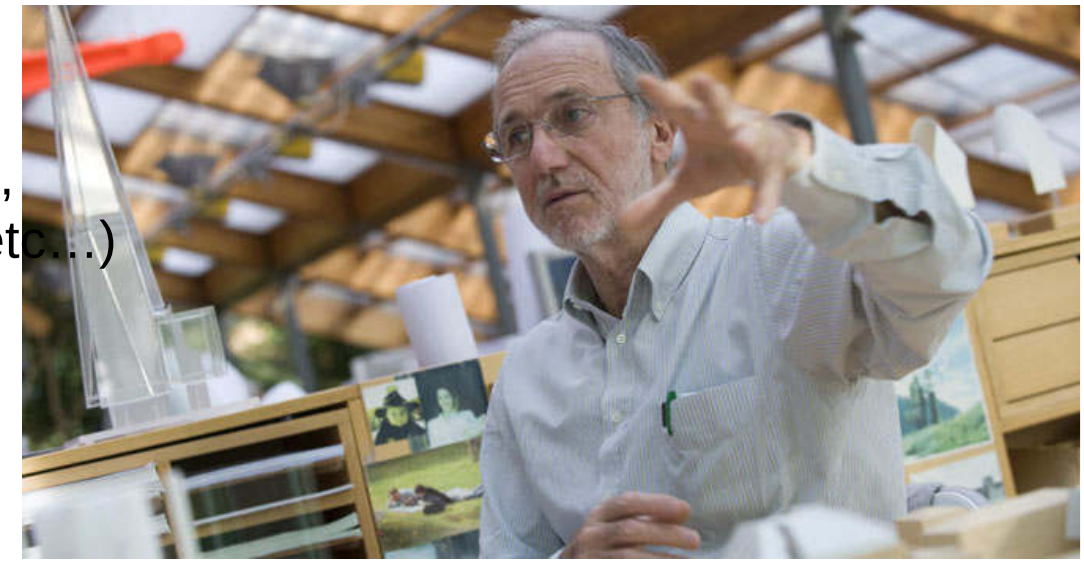
Current issues, current compromises

Asthetics vs performance

(colour, patterns, texture, special pieces, customization, non optimal conditions, etc…)

Aesthetics vs reliability

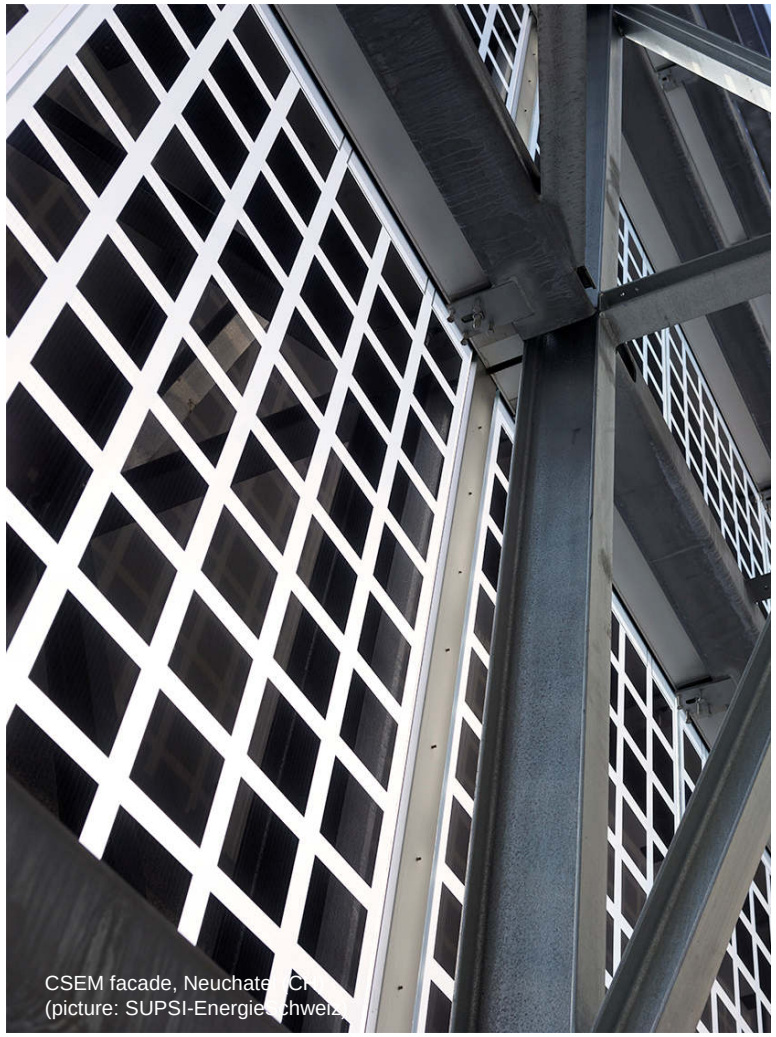
(operating conditions, durability, etc.)



«The architecture is a border art, at borders of disciplines, contaminated. It must, then, be a pirate art, in the sense that inside there is also a lot of robbery… (in a good way). And, again, the art of those who agree to take risks, to be sure also to make mistakes, the extraordinary challenge to explore the expressions of new materials and techniques»

Renzo Piano

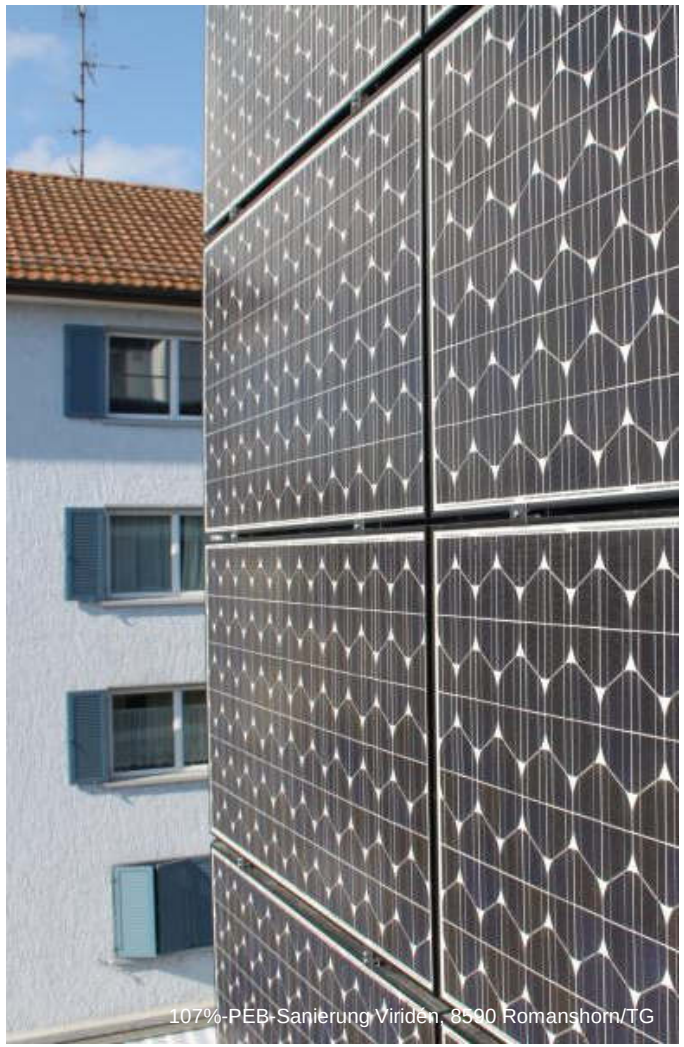
Photovoltaics and materials


CSEM facade, Neuchatel (CH)
(picture: SUPSI-EnergieSchweiz)

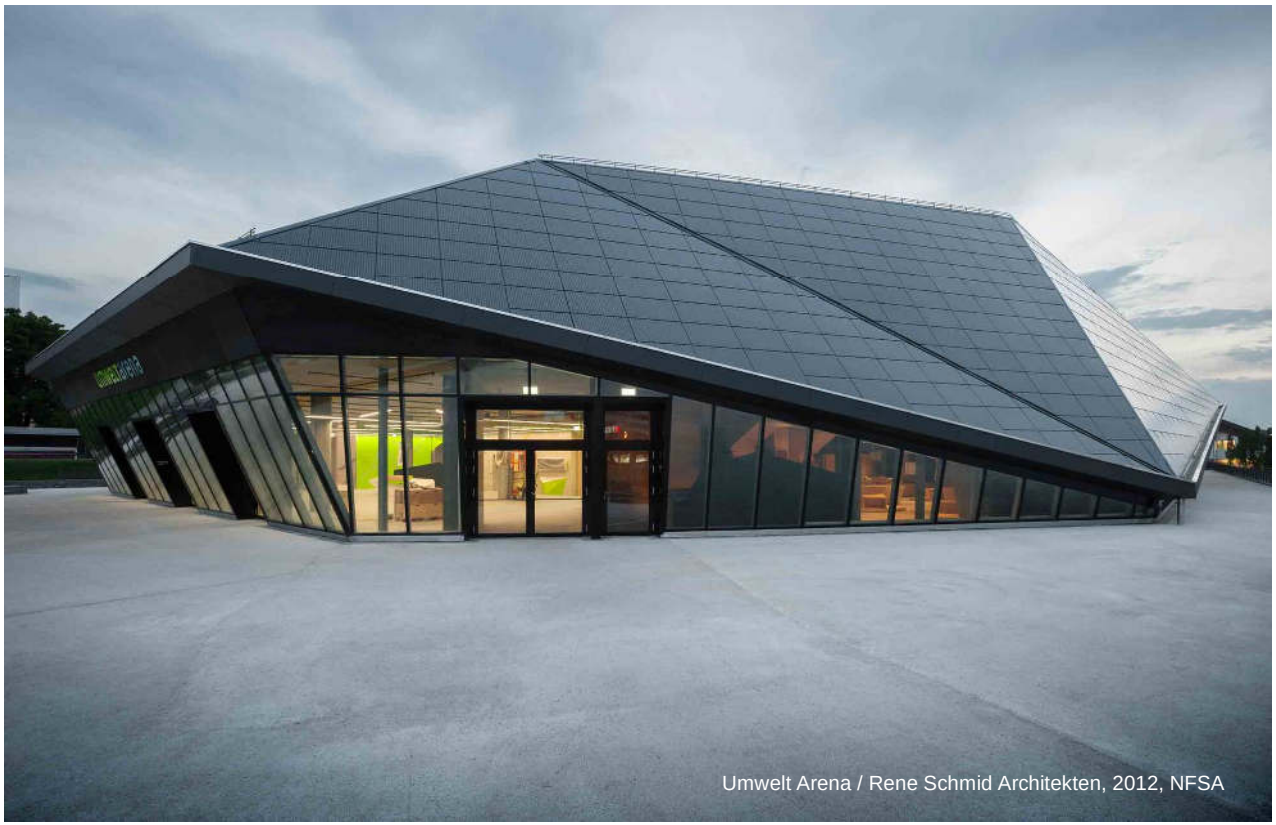
A new dialog, a new semanthics


Casa Solara in Laax (CH), MGT esys
(picture: SUPSI-EnergieSchweiz)

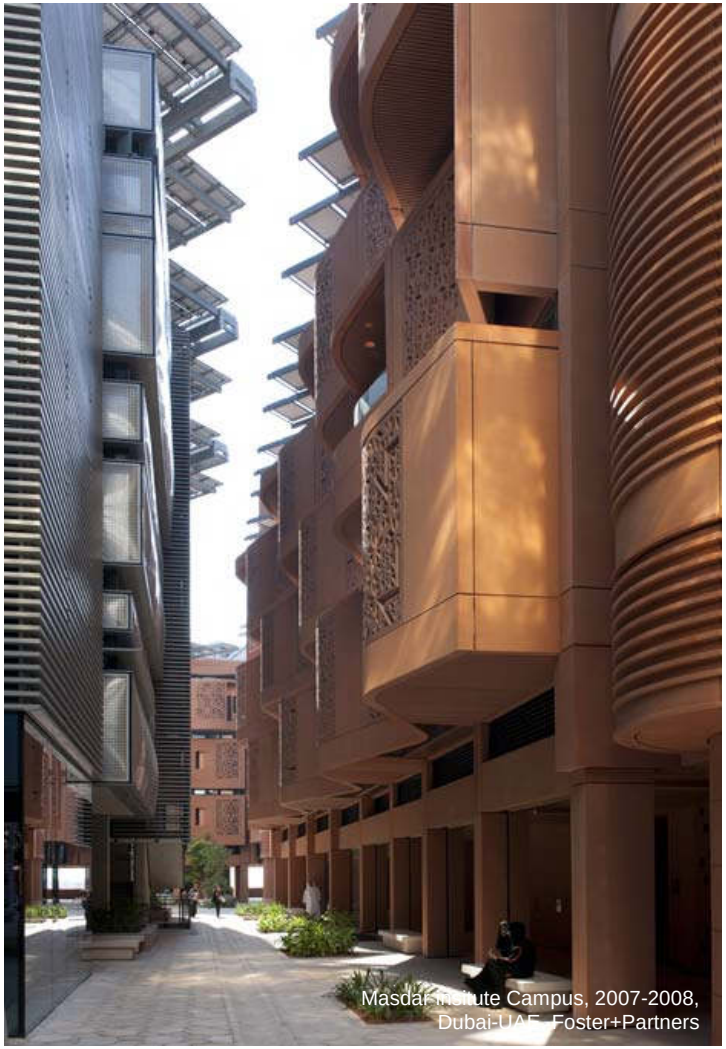
Photovoltaics and architecture


107%-PEB-Sanierung Viriden, 8500 Romanshorn/TG

Integration at building scale


Umwelt Arena / Rene Schmid Architekten, 2012, NFSA

Photovoltaics and city



Masdar Institute Campus, 2007-2008, Dubai-UAE, Foster+Partners

Integration at urban scale

California Academy of Sciences, 2008, San Francisco (USA) Renzo Piano Buinding Workshop

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…

Endesa Pavillion, Barcelona

International BIPV research activities

...and many others

PVsites

SmartFlex Solarfacades

2013-17 Construct PV
Constructing building with a customizable size PV modules integrated in the opaque part of the building skin

PhotoVoltaic TECHNOLOGY PLATFORM

Solar Design

Design 4 Energy

EUR-ACTIVE ROOFer

Sunflower printed organic photovoltaic cells

SOPHIA European Research Infrastructure

2011-2015

Debates, conferences (Europe+US)

NREL U.S. DEPARTMENT OF ENERGY

1990-1996

2004-2007 PV UPSCALE Urban Scale Photovoltaic Systems

2008-2012 Cost-Effective Convert facades into multifunctional, energy gaining components

2012-2016 bfirst fibre-reinforced solar technology

PV ACCEPT 2001-2004

2007-2010 SUNRISE

NEXT buildings

IEA_SHC Task 16 1990-95

SHC SOLAR HEATING & COOLING PROGRAMME INTERNATIONAL ENERGY AGENCY

IEA_PVPS Task 7 1997-2001

IEA_PVPS Task 15 2015-2018

IEA_SHC Task 51 2013-2017

IEA_SHC Task 41 2009-2012

Passive and Hybrid Solar L.E.Buildings
IEA_SHC Task 8 1982-1988

Projects, Platforms

1980 **Architecture** 1990 2000 2010 2020

T. Herzog, Munich, 1979-82

Stadtwerke Aachen, 1991

R. Disch, Solar Siedlung,

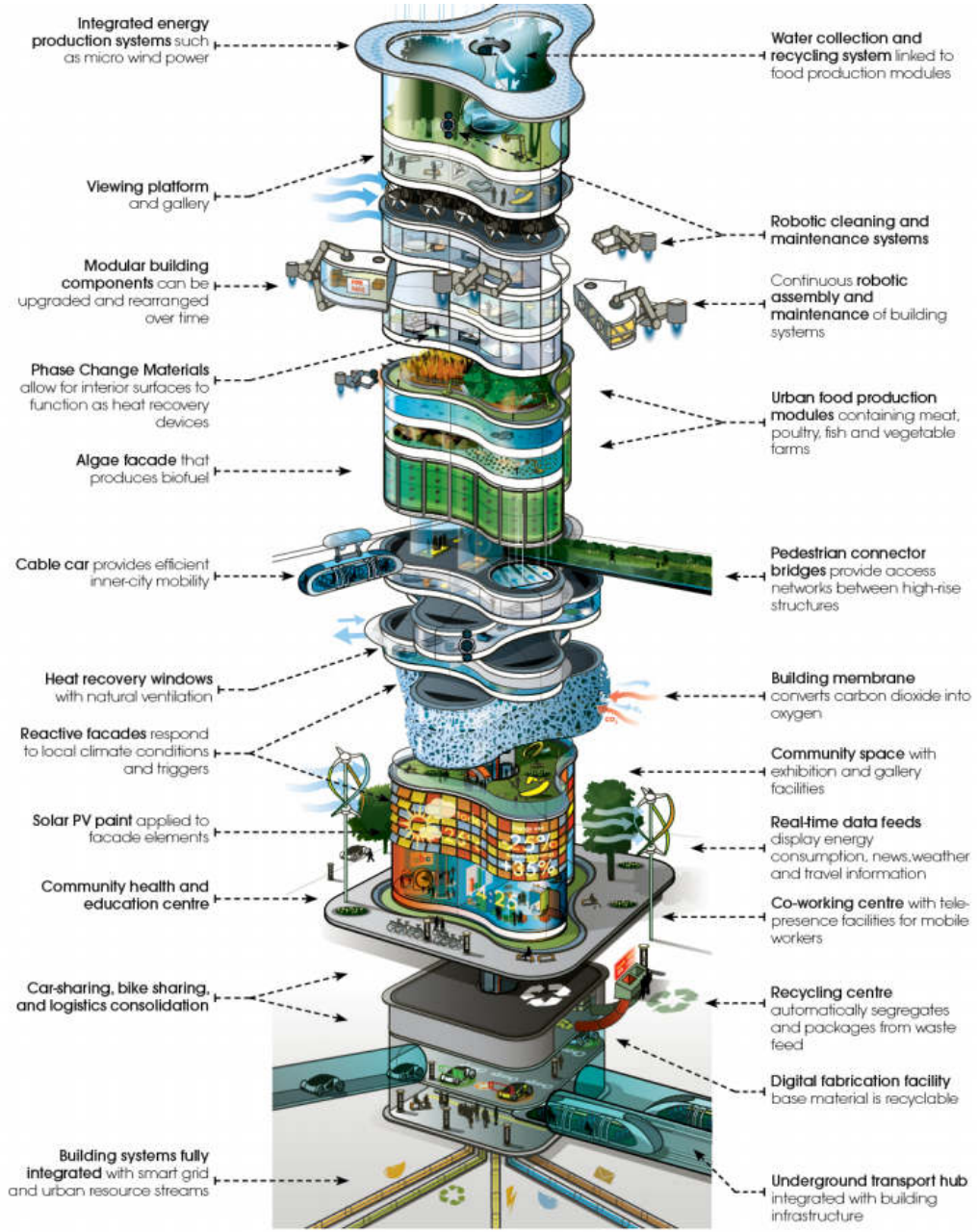
Home+, Solar Decathlon, 2012

ARUP Foresight, Building 2050

BIPV …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 qualification…Standards and norms

EN 50583:2016

Electrical Building

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 **CE –Mark for Building products**

Energy Performance of Buildings Directive (EPBD)

BIPV… operating conditions

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)

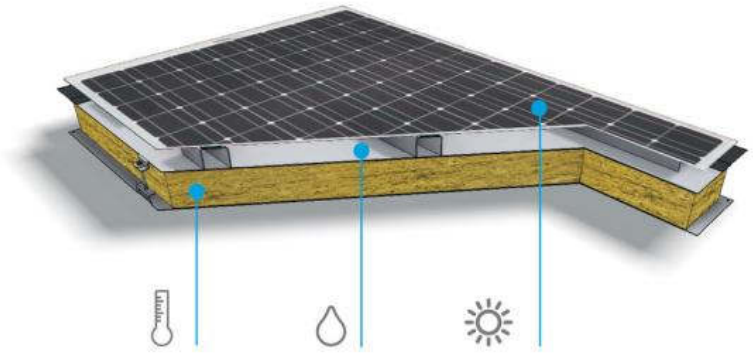
- **Modular-unitized BIPV construction system**
  optimally combining BIPV modules with building/electrical sub-constructions (prefabrication, plug & play, etc.)

CSEM


MEYER Burger Megaslate


Solaire Face Intec

BIPV as…**construction component**

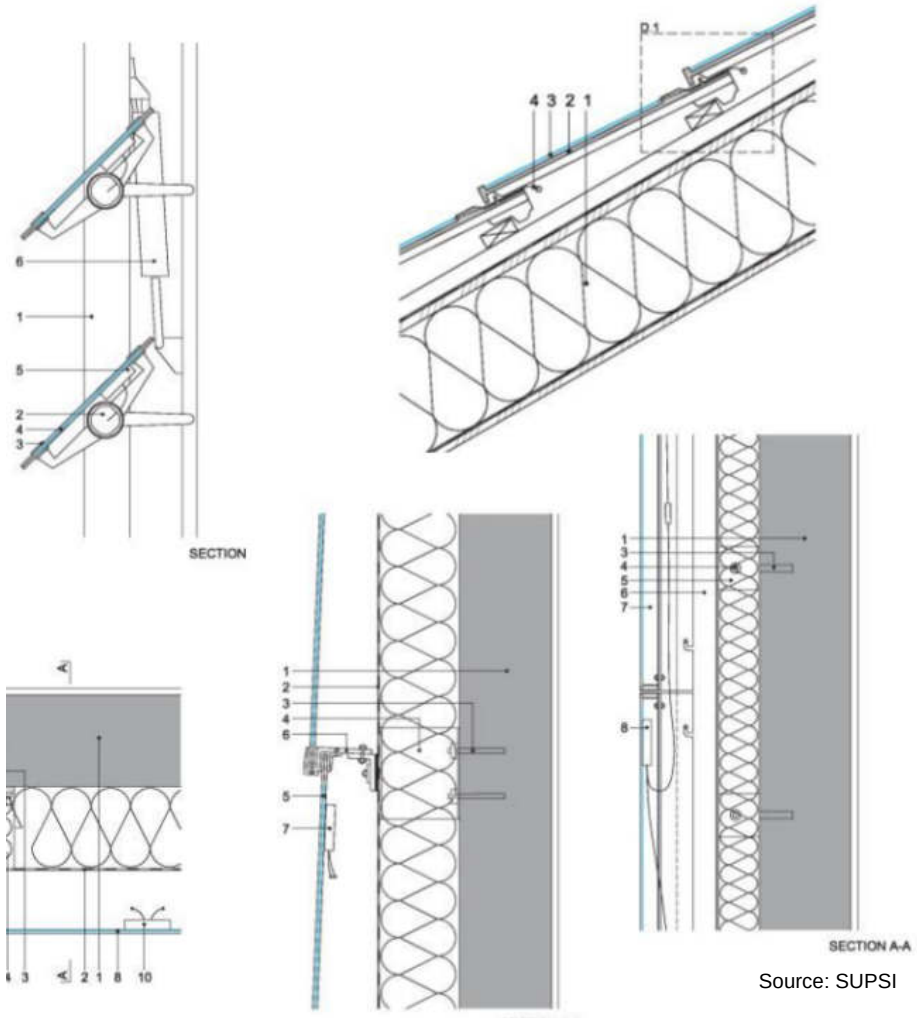


Source: Designergy

- **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: 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,

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*

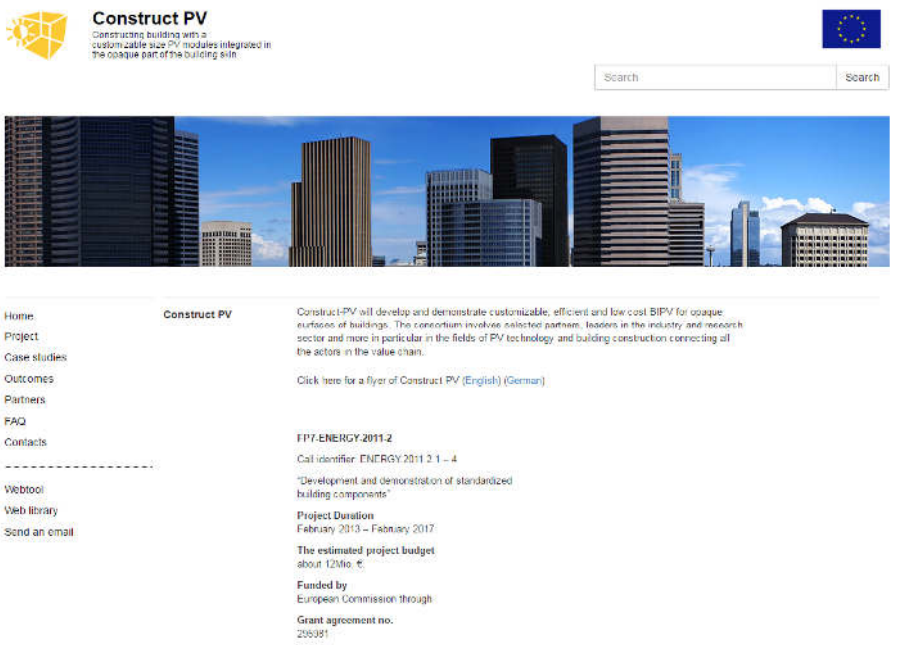
(large consortium, different stakeholders)

- *Demonstration project (TRL 7)*

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

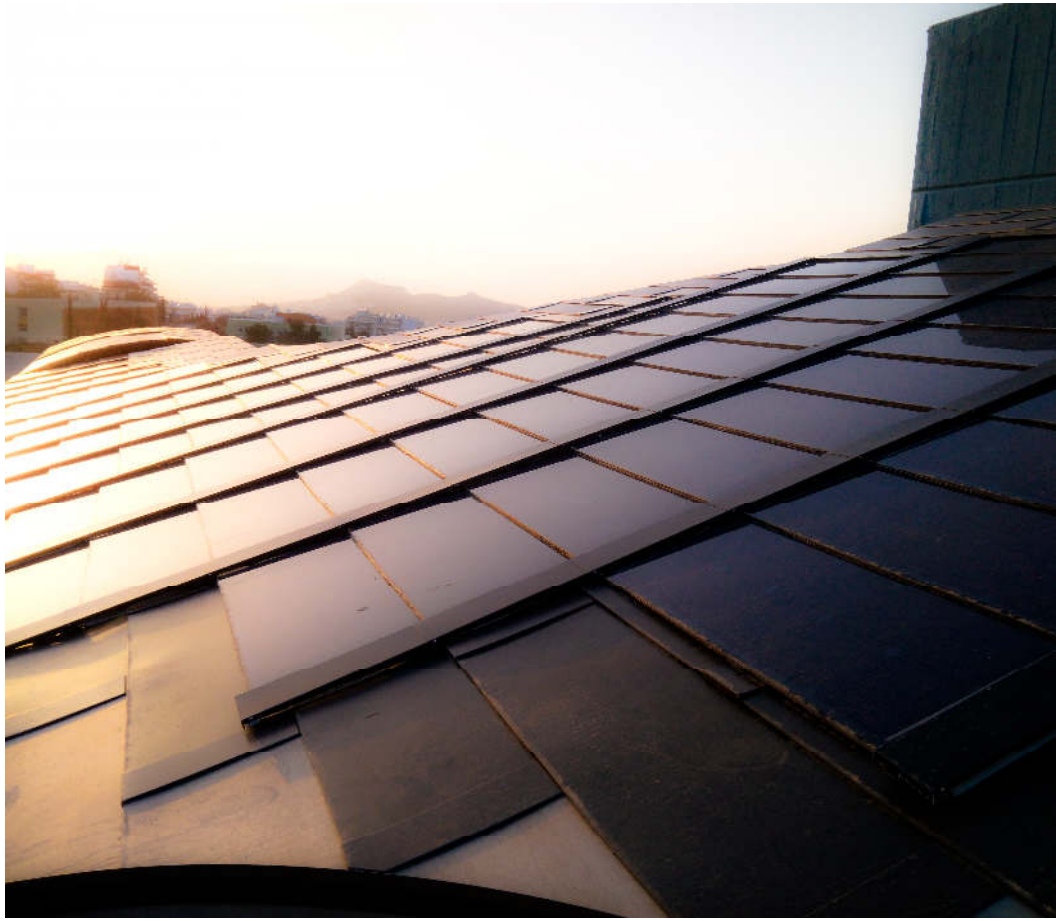
Duration: 2011 (Proposal + Kick-off)
February 2013 – February 2017

Estimated project budget: 12Mio. €.



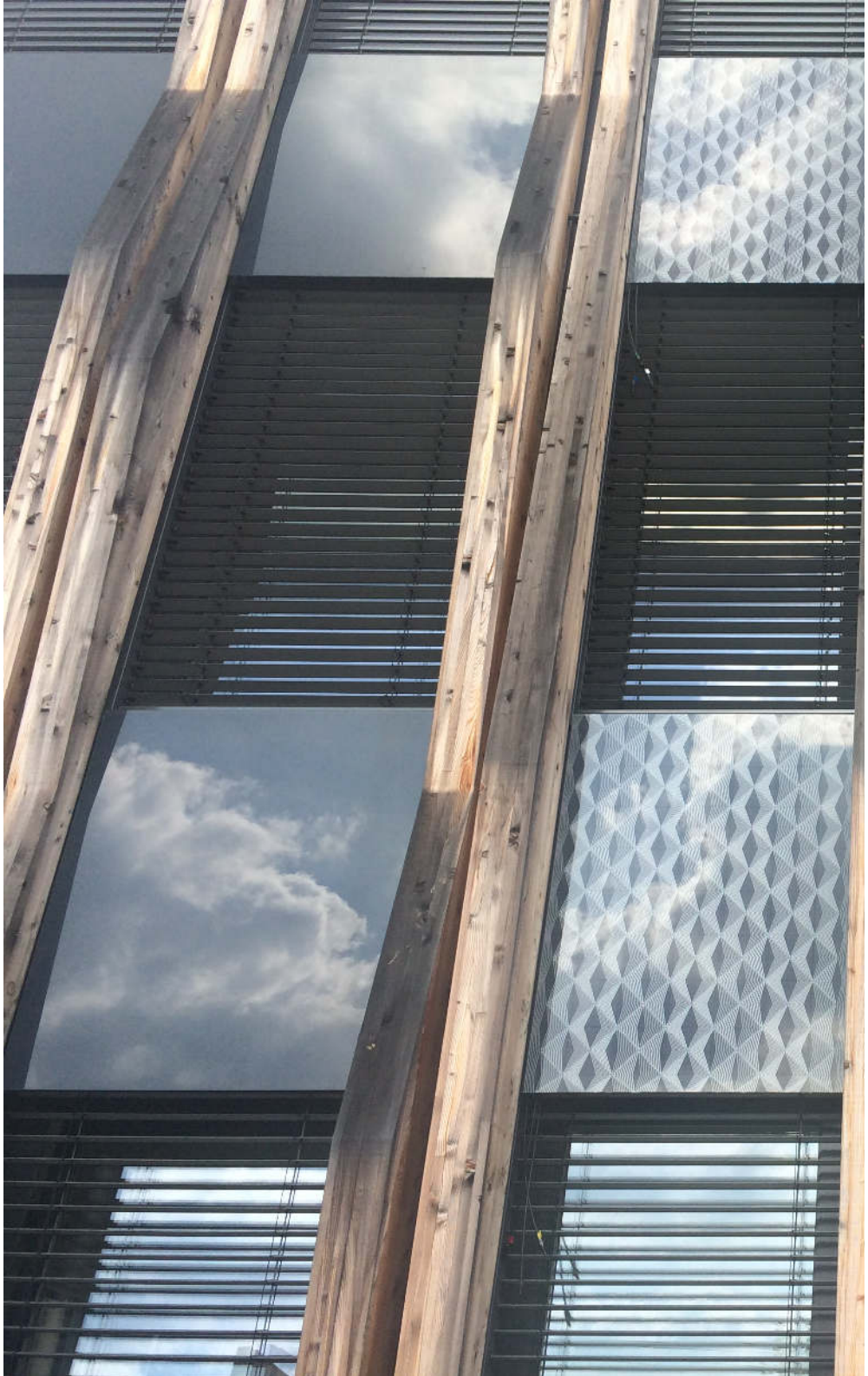
06/04/2017

Construct PV demonstration



NTUA roof, Athens

06/04/2017

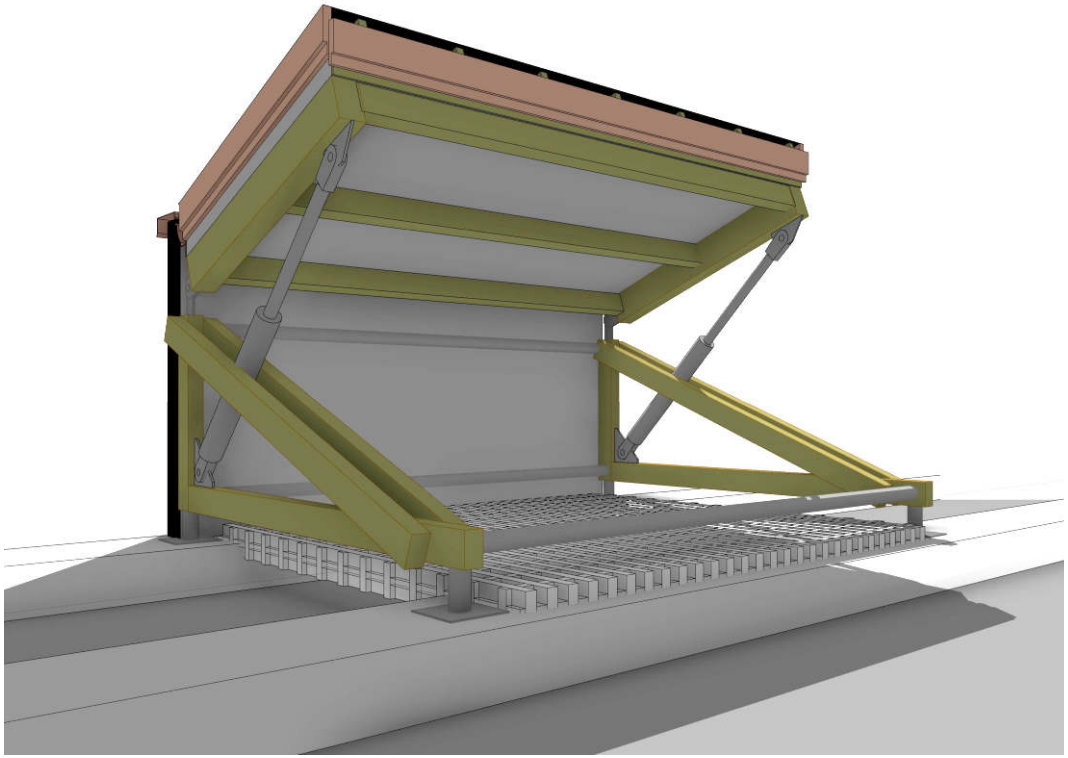


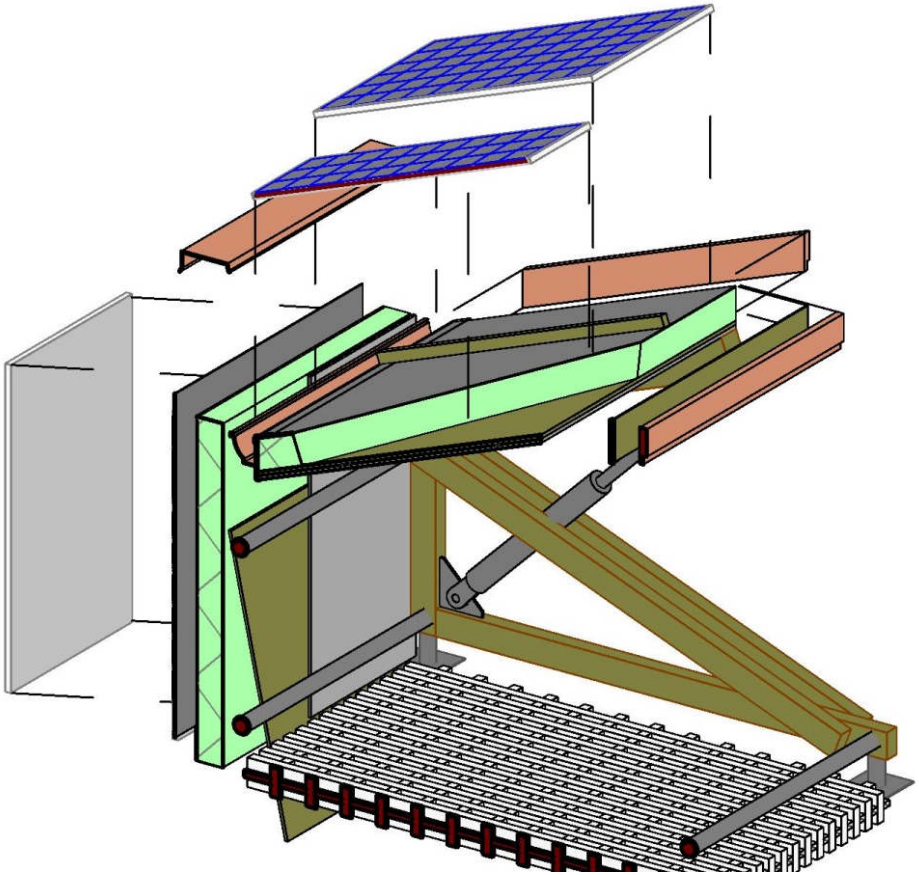
Züblin Facade, Stuttgart


SUPSI
CONSTRUCT PV

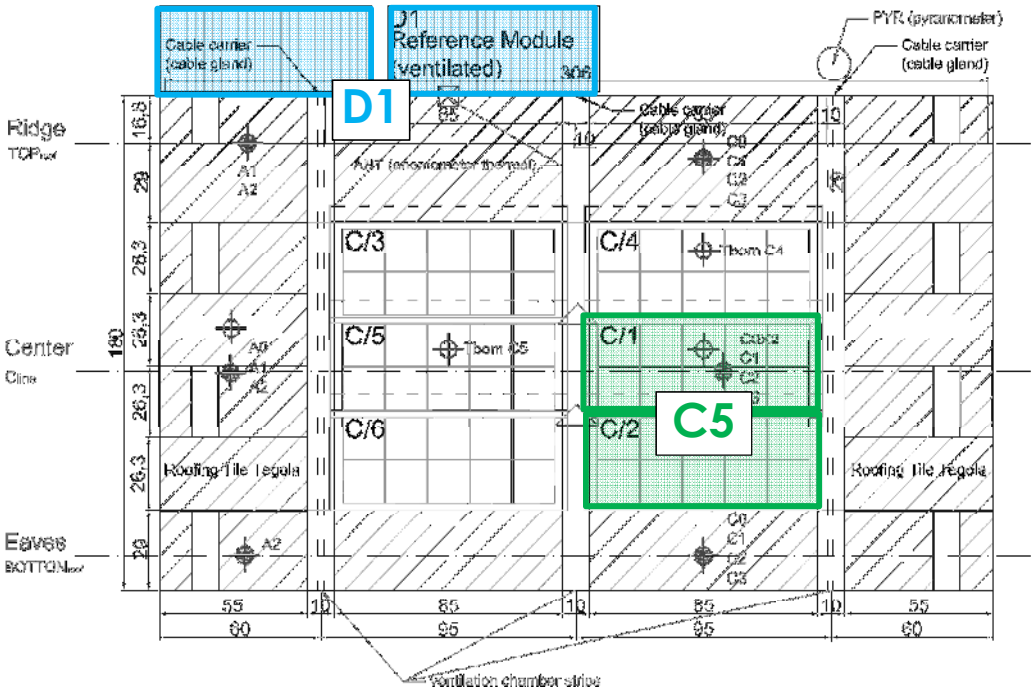
Construct PV

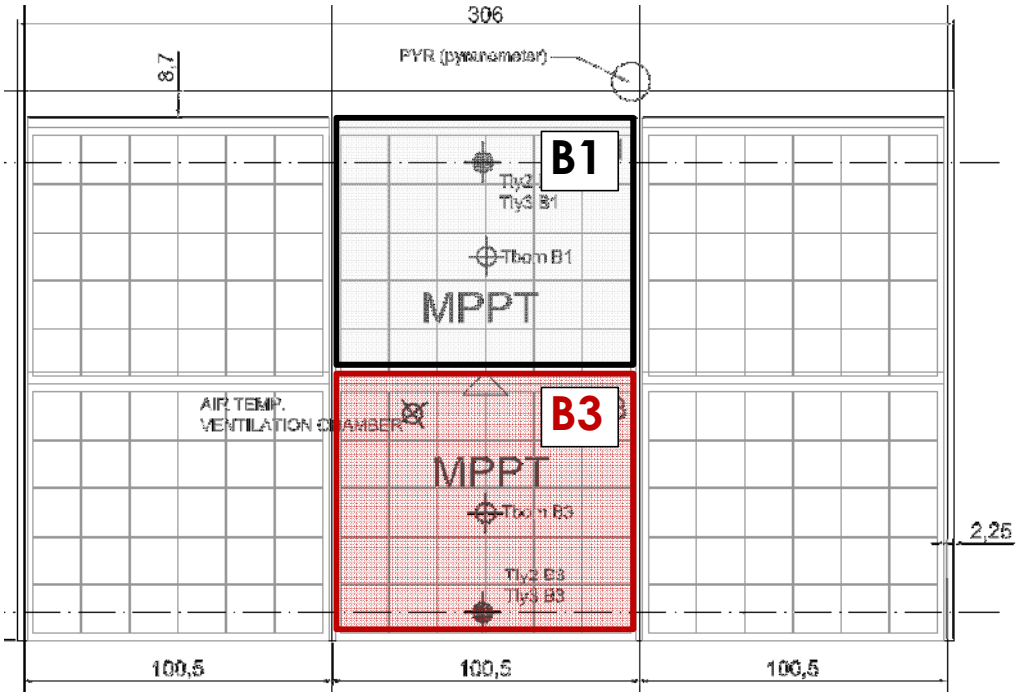
Demo activities: Design of Stand SUPSI



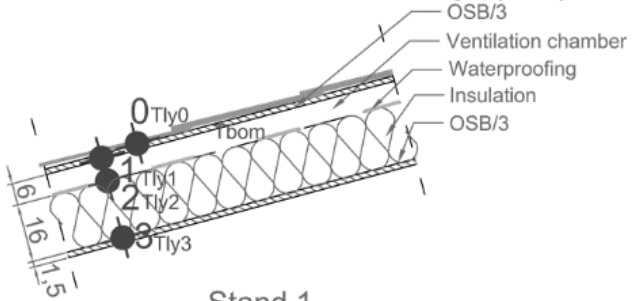


Construct PV
Demo activities: test facility at SUPSI





Stand 1



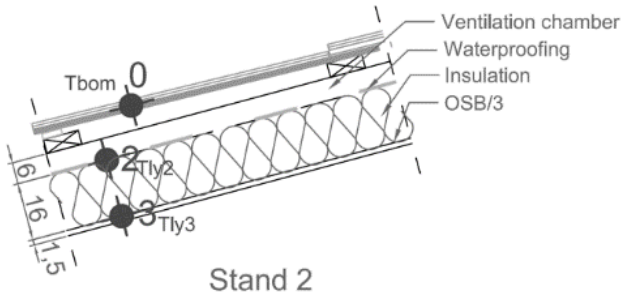
Stand 1
(ConstructPV_Tegola)

SUPSI Campus (Lugano, CH)

Comparison between modules:

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

Stand 2

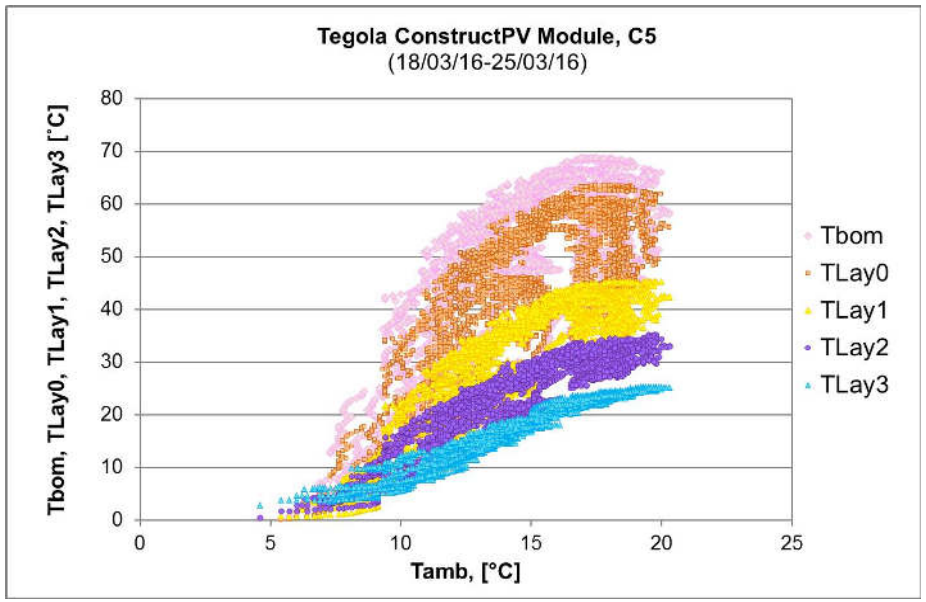


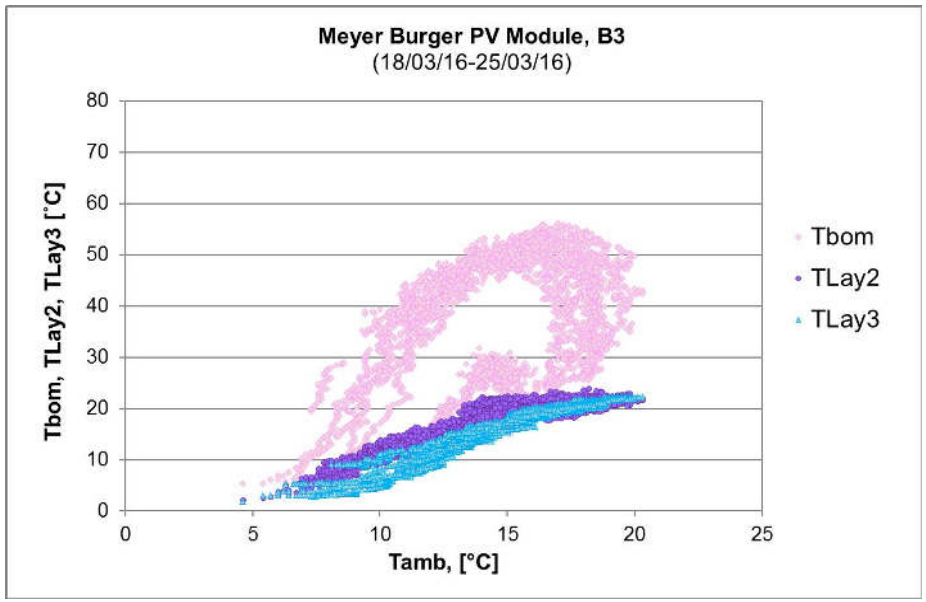
Stand 2
(MB_Megaslate)

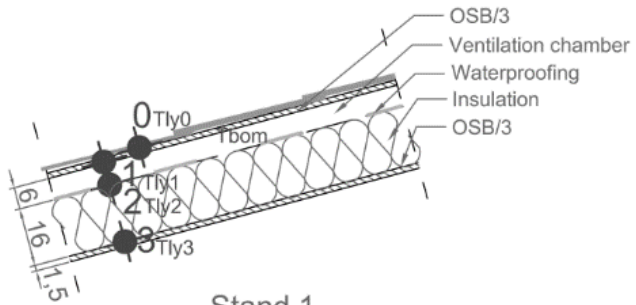
Construct PV

➢ Module temperature, Tbom / Tin-layer

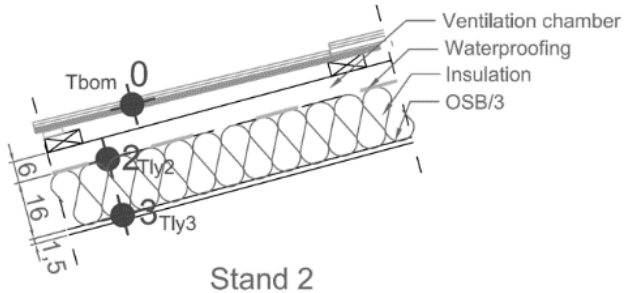
Week period of March (18/03/16-25/03/16) with clear sky conditions





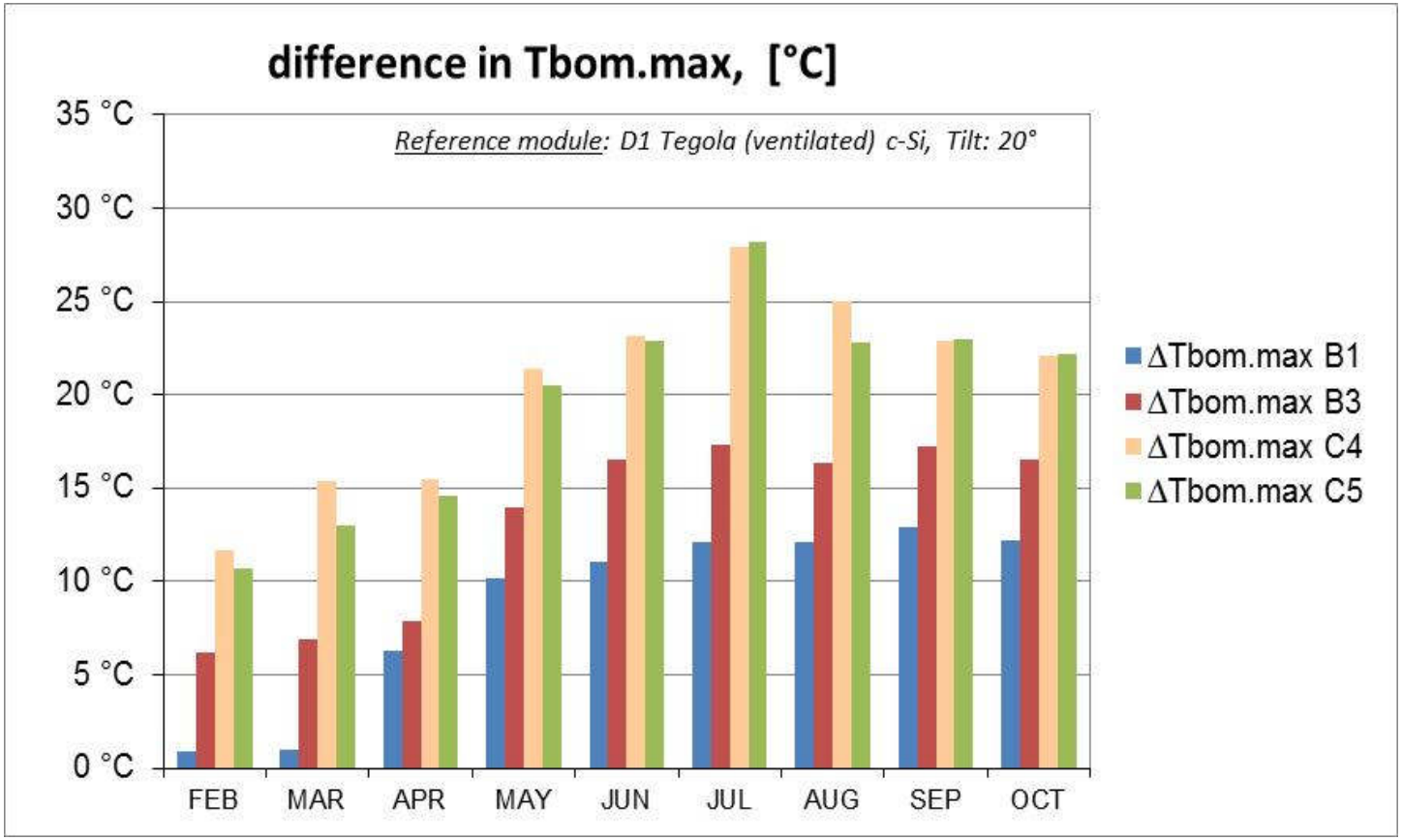


Stand 1
(ConstructPV_Tegola)



Stand 2
(MB_Megaslate)

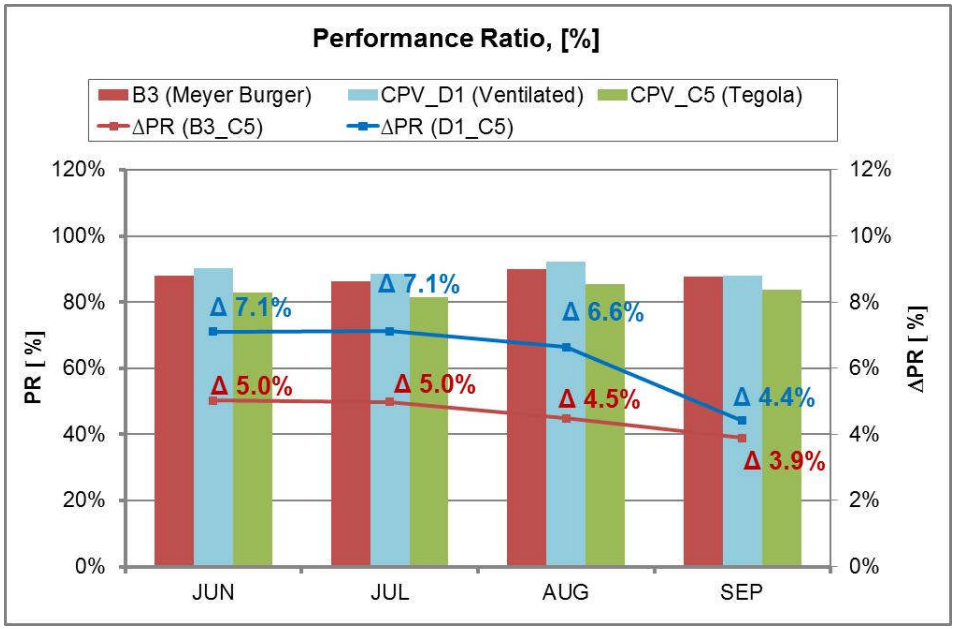
SUPSI Campus (Lugano, CH), differences with the ventilated Tegola module

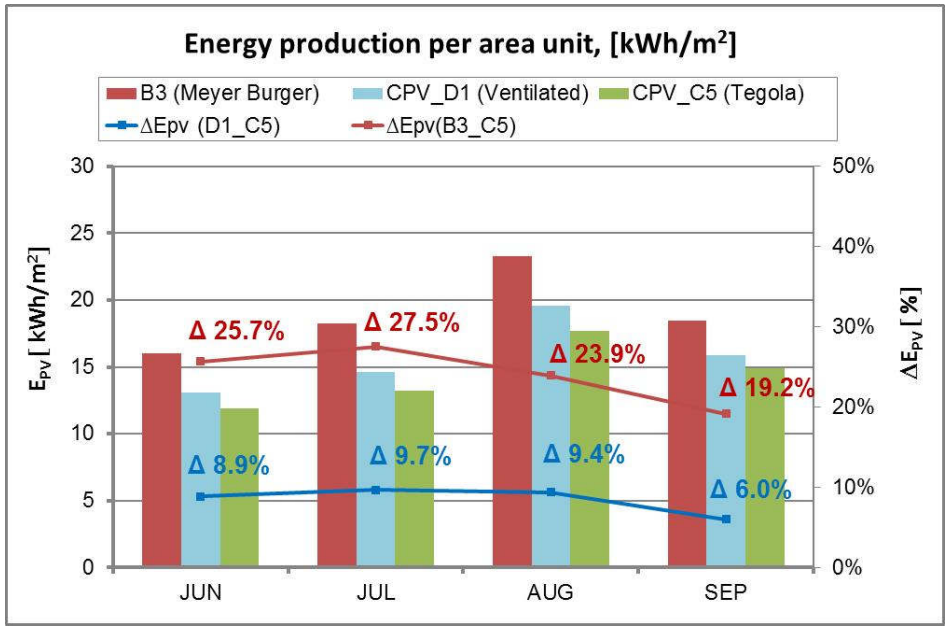


- **Maximum Tbom differences** (D1 full ventilated): **B1: 12.9 ° C** (September)**; B3: 17.3 ° C; C4: 27.9 ° C; C5: 28.2 ° C** (July)
- **Maximum Tbom differences** (between B3 / C5): **10.9 ° C** (July); ~ **6.0 ° C** (from March to October)
- **Next step: to define the correlation between thermal resistance/ventilation with Tbom**

Comparison results (PR and kWh/m2)

Monitoring period: June, July, August and September





SUPSI Campus (Lugano, CH)

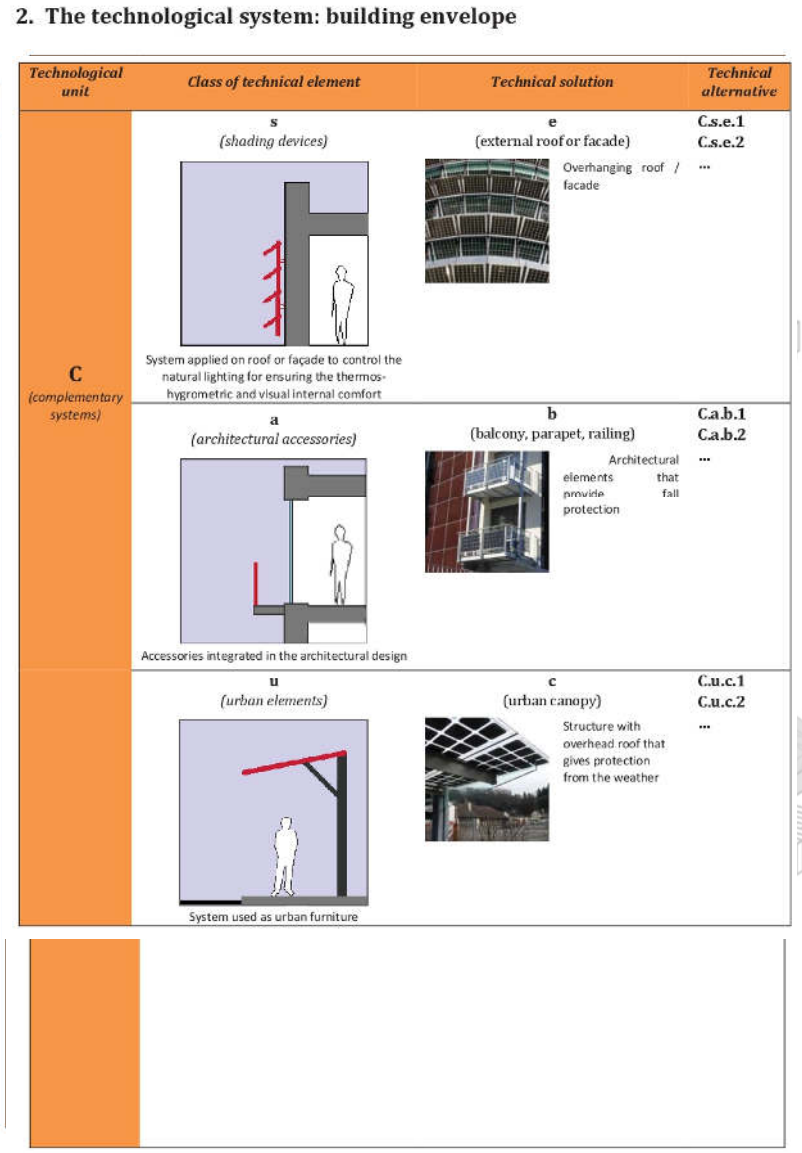
- **Yf [kWh/kWp]:** differences **B3 and C5 → maximum -14.3** (July) - **D1 and C5 → -8.5 % to -5.3%**
- **PR [%]:** differences **B3 and C5 up → -5.0% to -3.9%** - **D1 and C5 → -7.1 % to -4.4%**
- **E_{PV} [kWh/m²]: B3 and C5 → from -25.7% to -19.2%** (maximum 27.5%, July) - **D1 and C5 → -8.9% to -6.0%** (max. -9.7%)

Construct PV
Demo activities: Conclusions and next steps

- Building skin layering has important role for thermal behavior of the cladding and Tbom of PV module (thermal resistance, inertia)
- Roof ventilation technique (chamber, air gap, microventilation) affects the PV cooling
- Building skin strongly affects the final PR, kWh/m2

Further aspects under investigations:

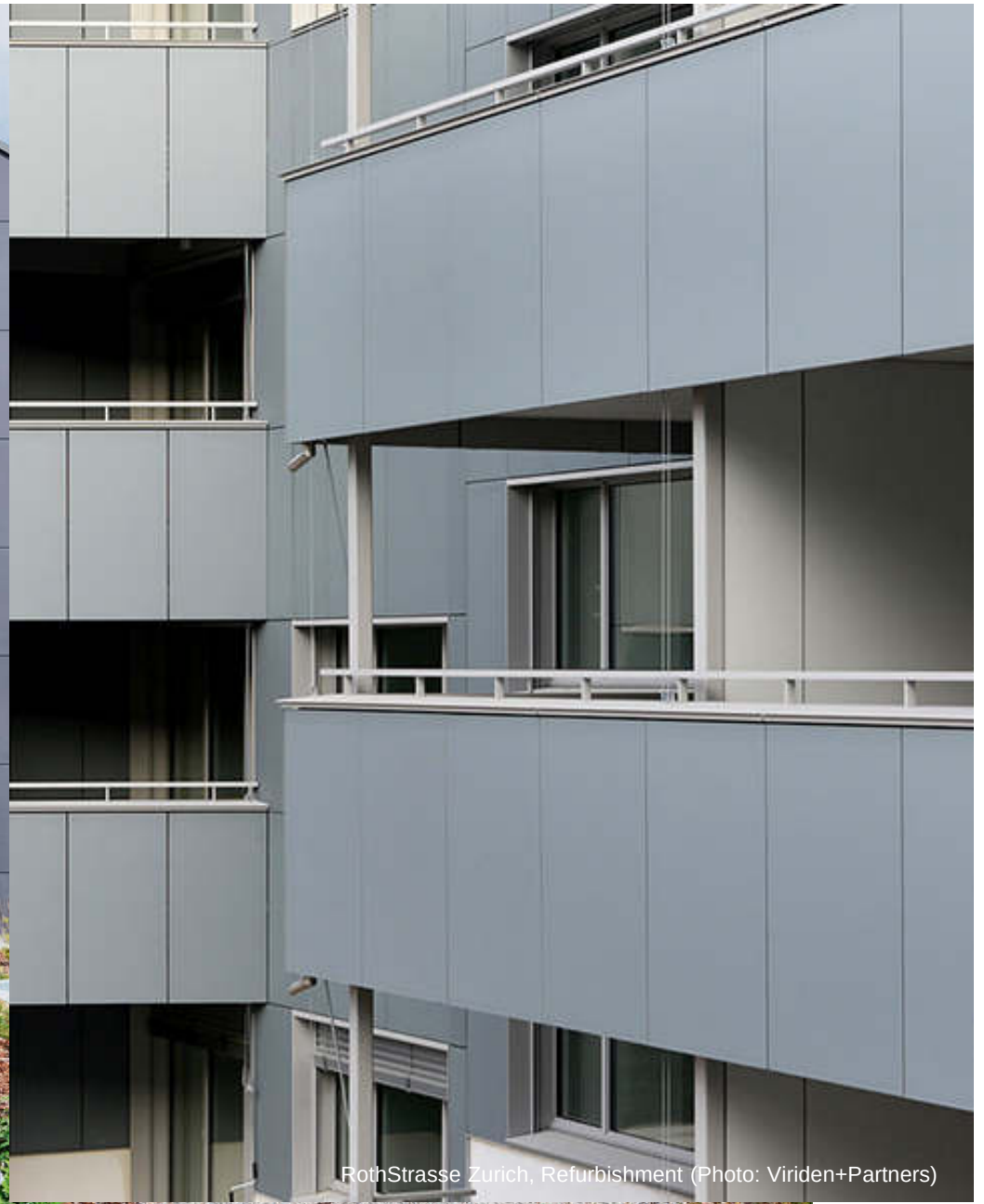
- Data analysis and predictor models
- Evaluation of temperatures and back ventilation effects (tilt, open air gap)
- Optimization of roof layering



BIPV and customization

BIPV…flagship projects

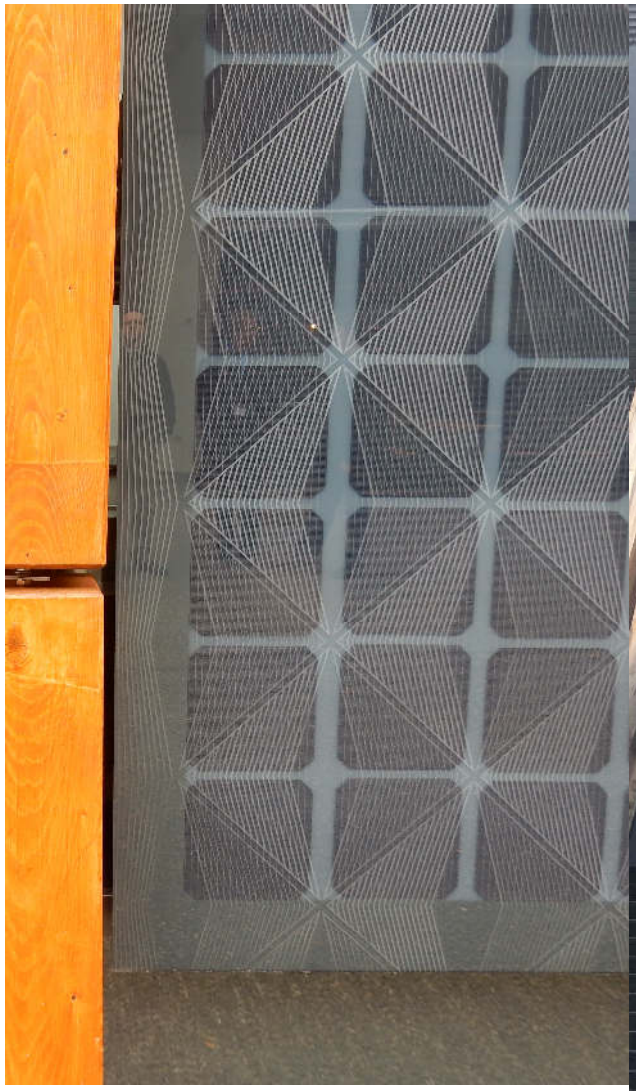
Mehrfamilienhaus Brütten (Photo: René Schmid Architekten)

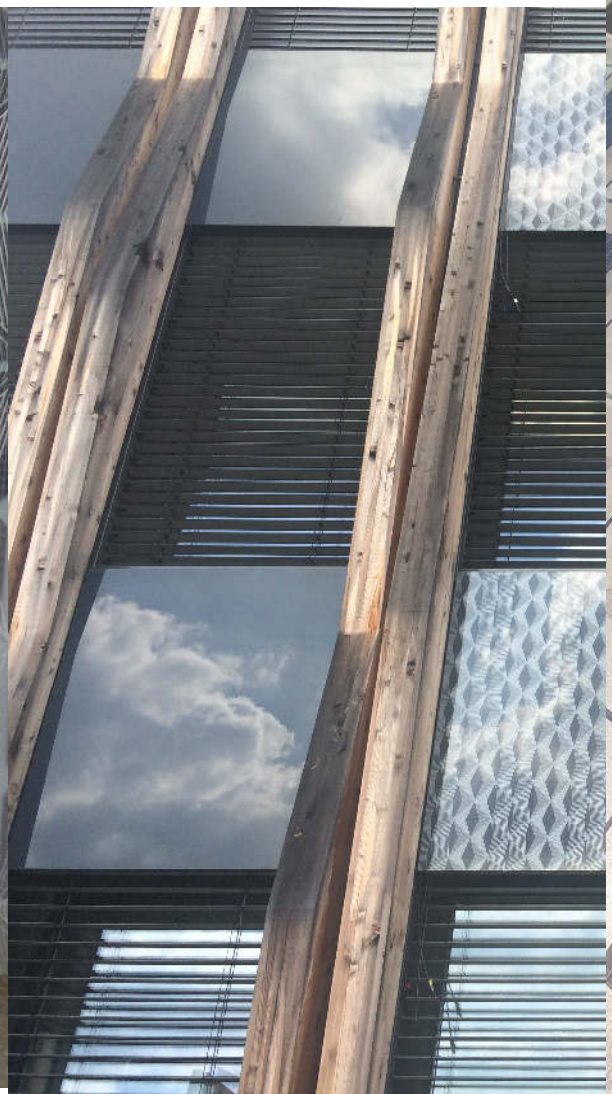


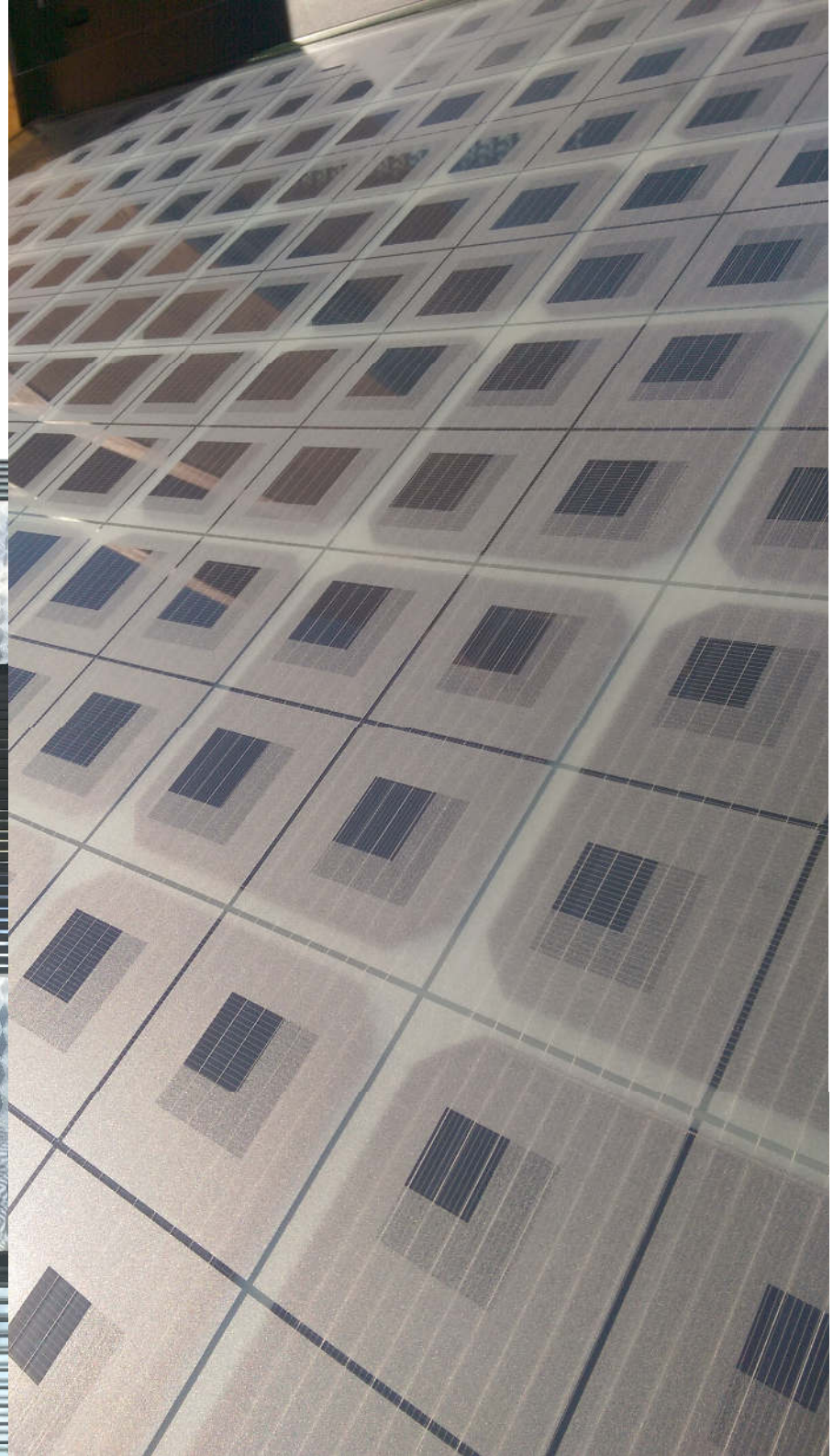
RothStrasse Zurich, Refurbishment (Photo: Viriden+Partners)

Construct PV

Designed solar glass



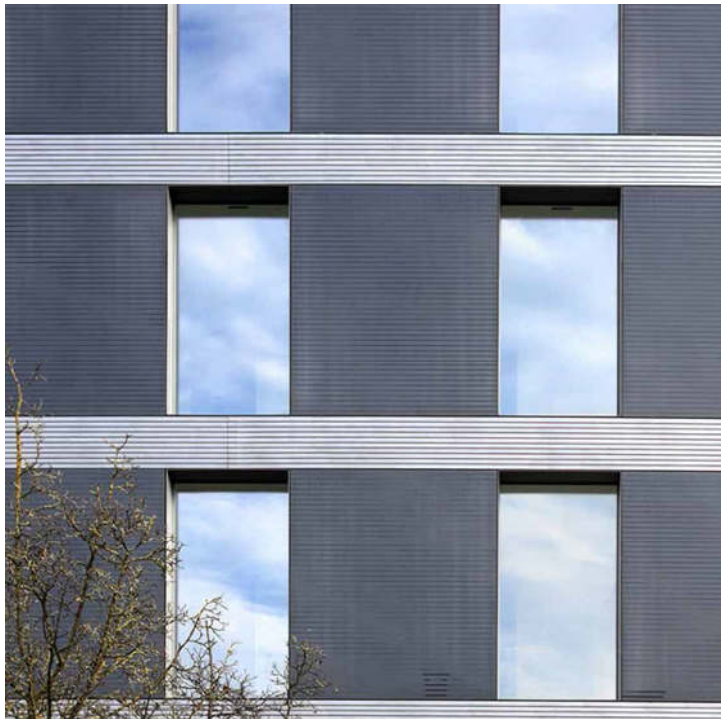




BIPV customization…and Swiss product innovation

(source: CSEM)

(source: HSLU-EASEase)



(source: Schweizer)

Energieautarkes MFH Brütten (sourse: Swiss Solar Prize Norman Foster Solar Award 2016)

BIPV and…**front layer technology**

What is a BIPV module?

- **Is it a PV module with glass in front?**

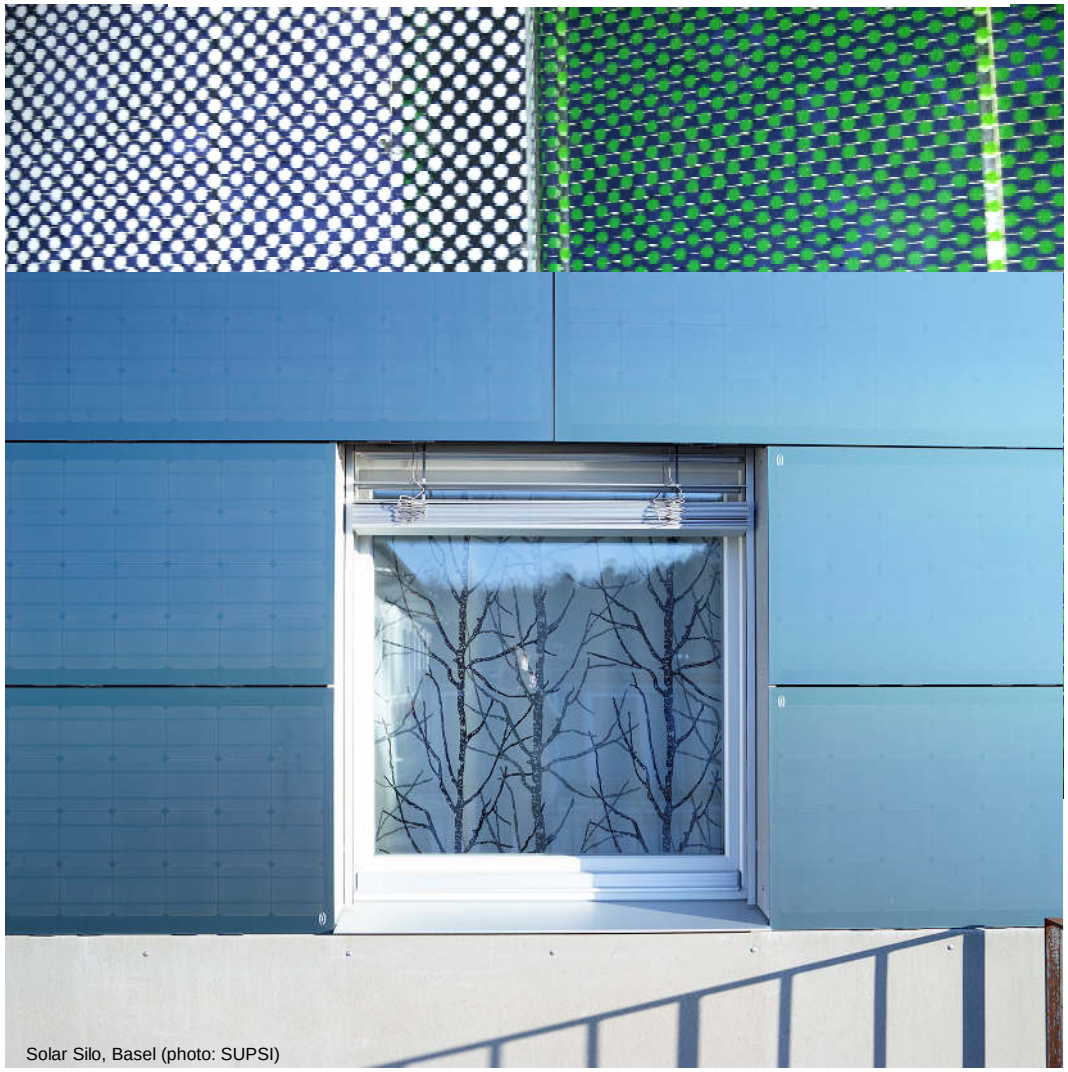
Cells are efficiently exposed to sun

- **Is it an architectural glass with cells behind?**

Cells are visually/energetically filtered

- **Is it a design material producing “also” energy?**

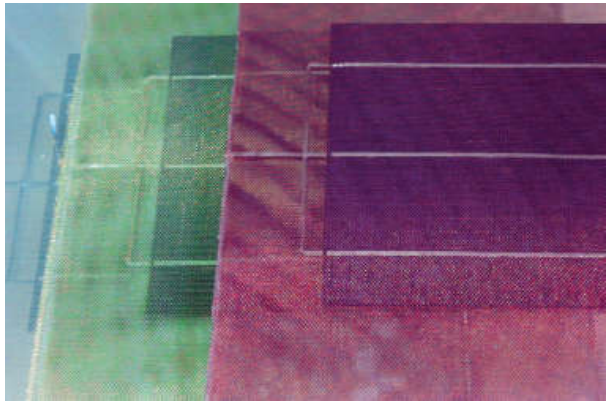
Cells are hidden/submitted to aesthetics



Solar Silo, Basel (photo: SUPSI)

Coloured BIPV modules : performance ?

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 · MONDRAGON ASSEMBLY · PI · CREATIVE AMADEO · sunbeam

- Coordinator

pro tech

SmartFlex Solarfacades

www.smartflex-solarfacades.eu

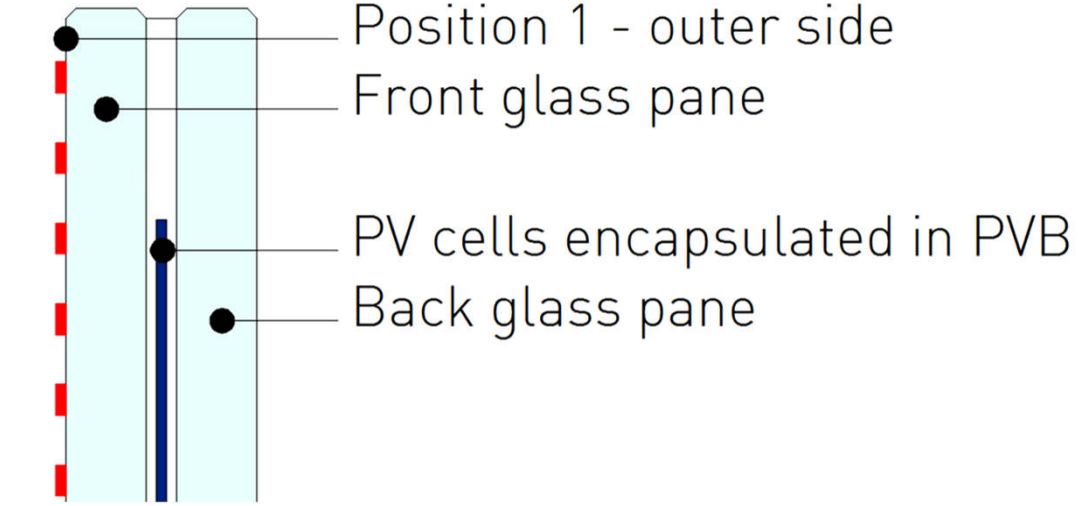
SmartFlex Demonstration of Flexible facade

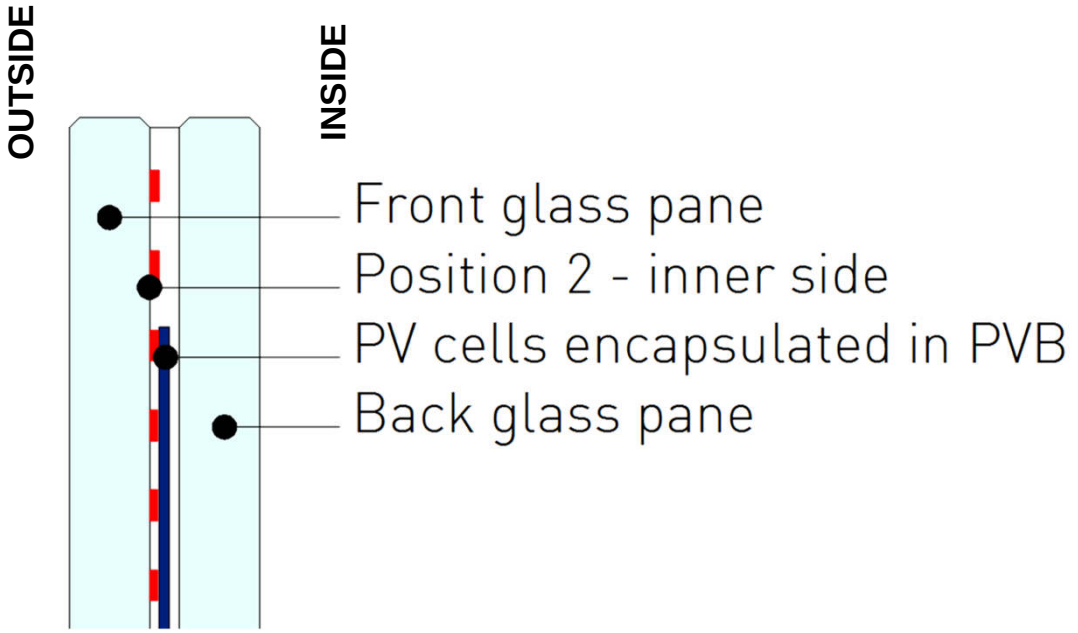
- Large modules (1,5 x 3m) have been used

Glassbel new-facade in Klaipeda

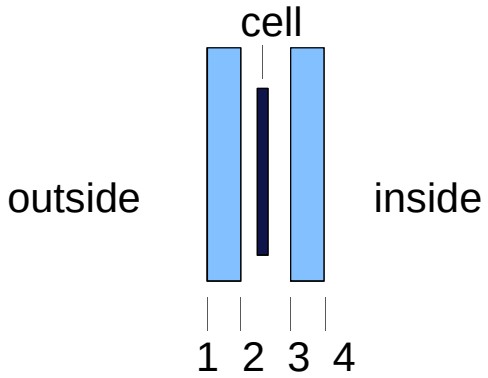
Coloured BIPV modules

- Ceramic digital printed glass



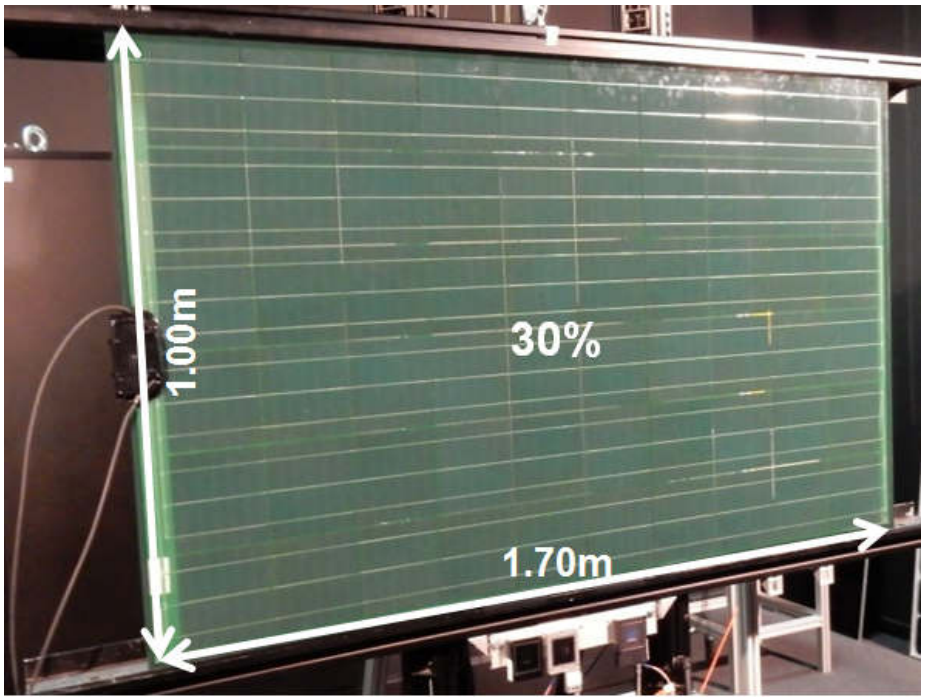


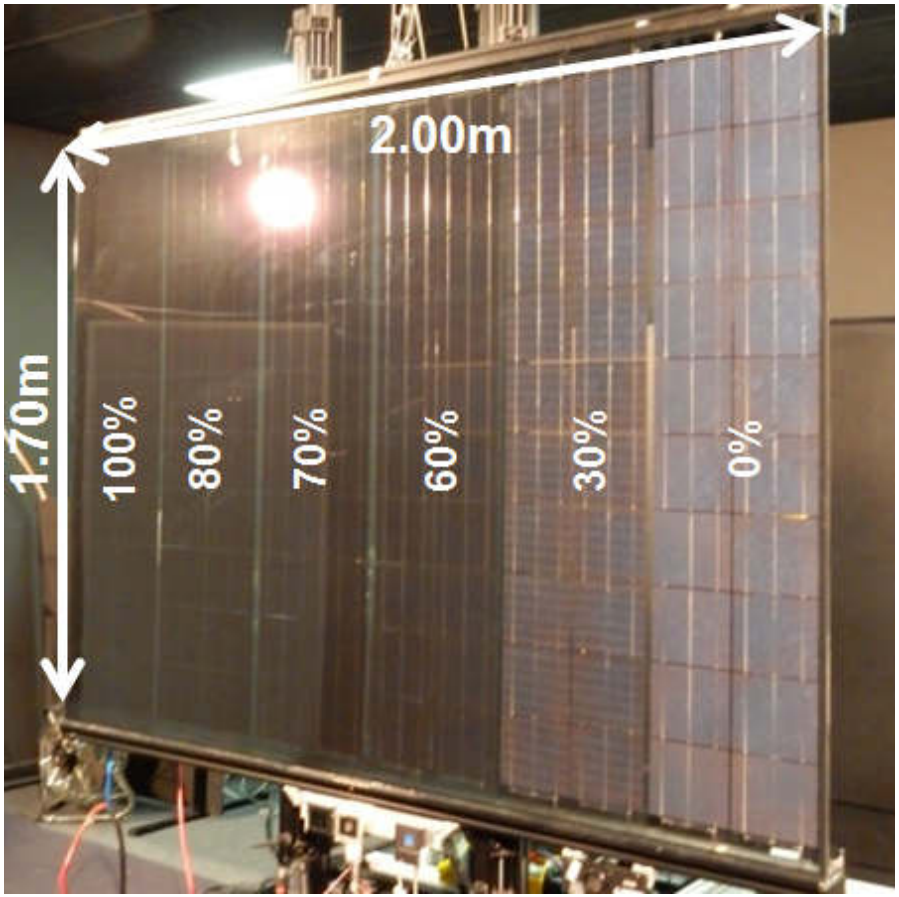
Power measurement at STC



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

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





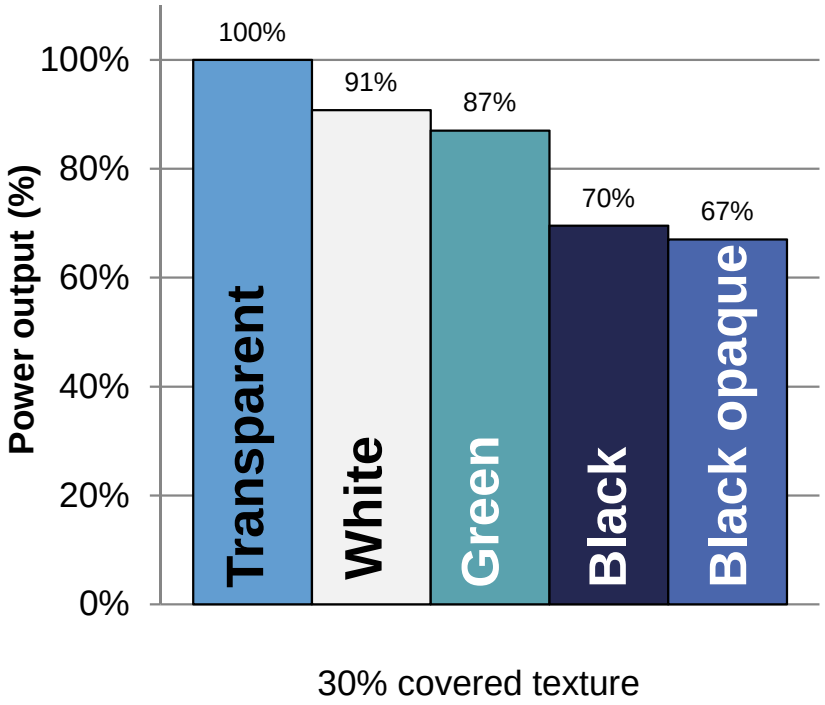
Coloured BIPV modules: performance

Influencing factors

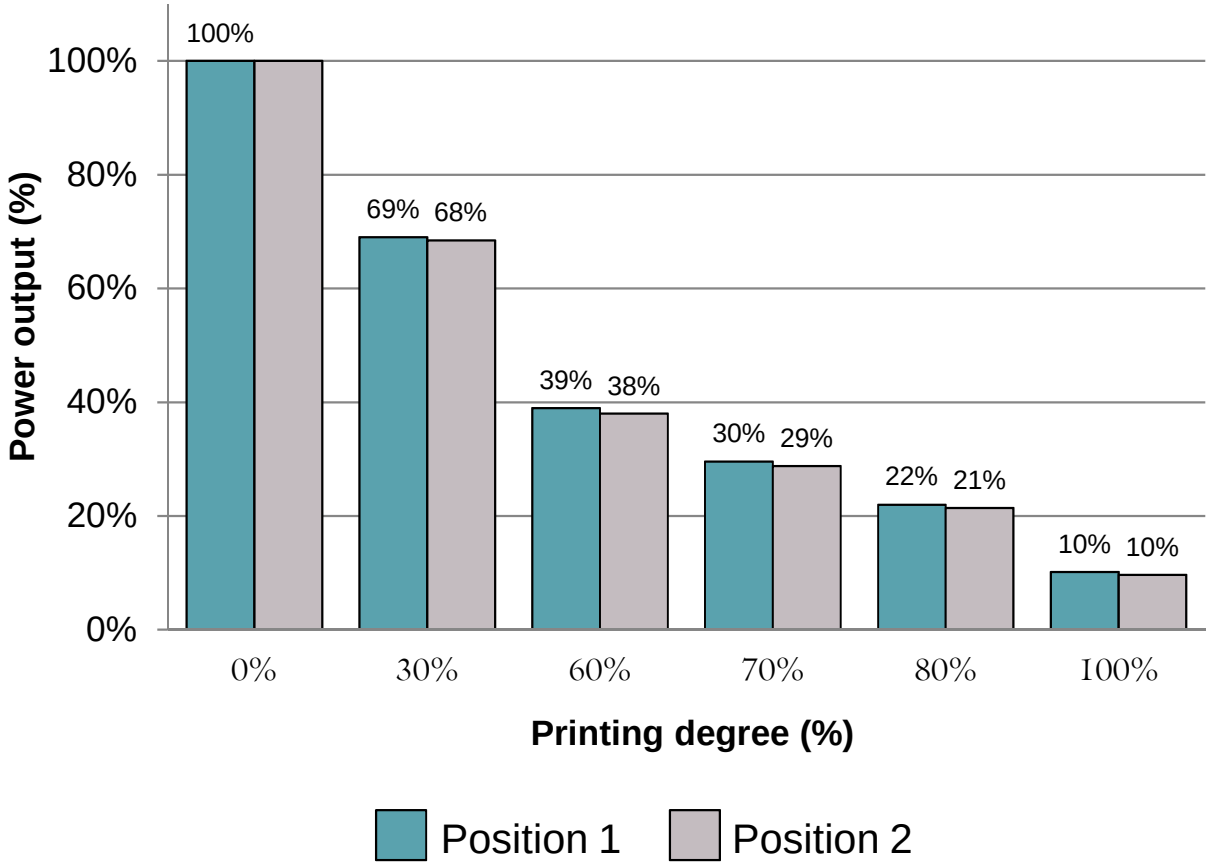
- Colour
- Thickness of the dots
- Printing degree
- Position 1 or 2

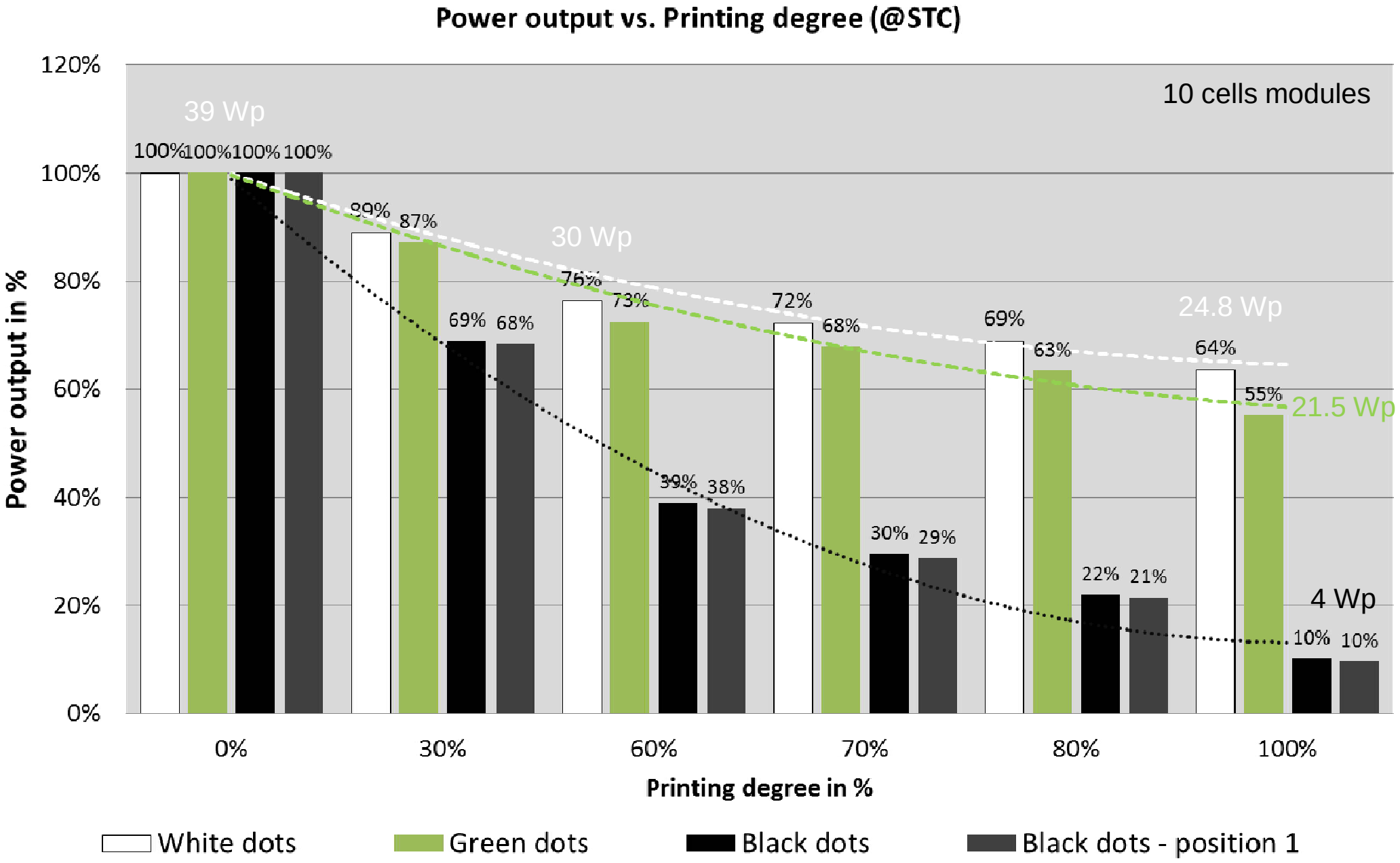
Coloured BIPV modules: performance

Influence of color types



Influence of dot positioning

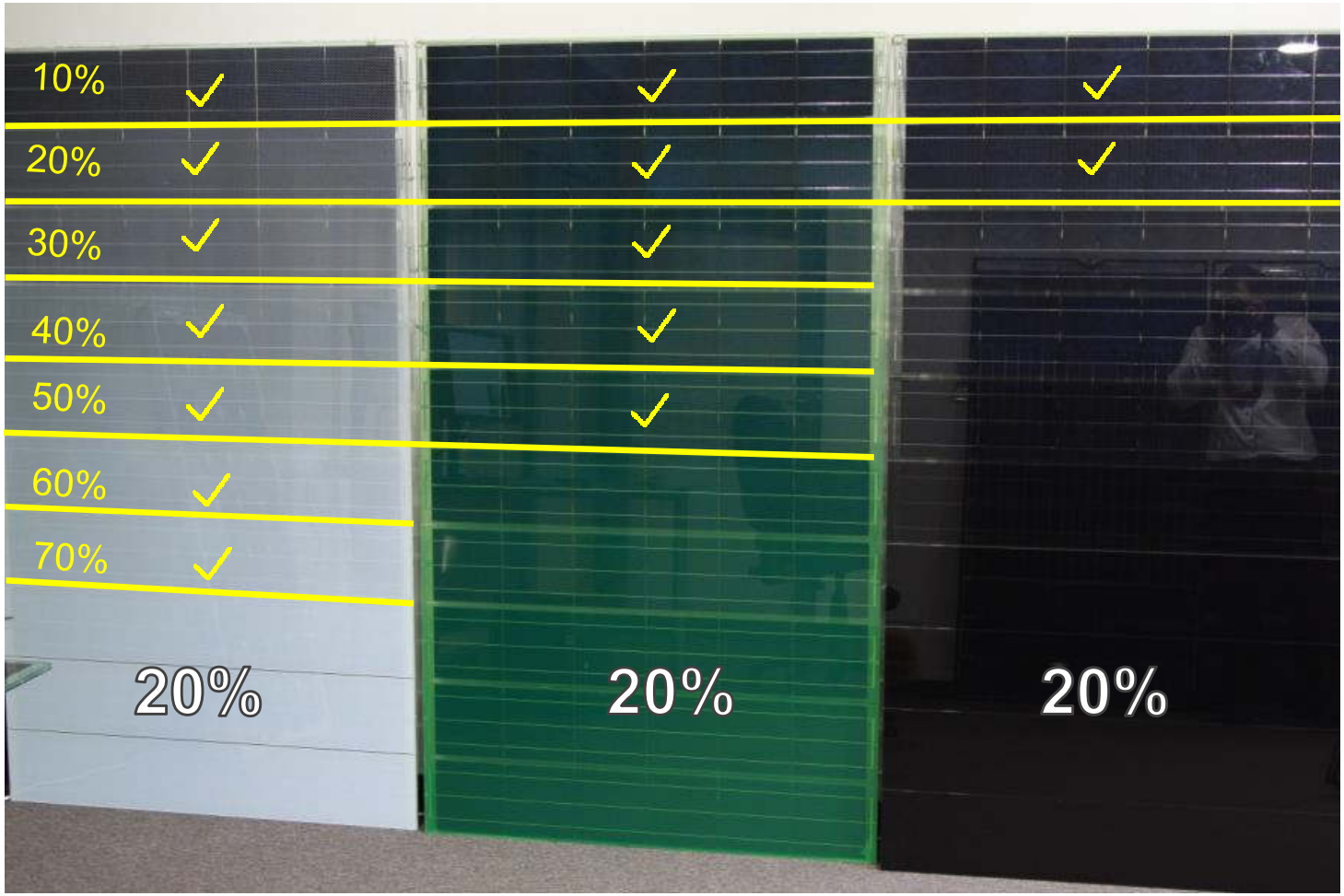



Power output vs. Printing degree (@STC)
10 cells modules
39 Wp
30 Wp
24.8 Wp
21.5 Wp
4 Wp
100% 100% 100% 100%
89% 87%
69% 68%
76% 73%
39% 38%
72% 68%
30% 29%
69% 63%
22% 21%
64% 55%
10% 10%
120%
100%
80%
60%
40%
20%
0%
Power output in %
0%
30%
60%
70%
80%
100%
Printing degree in %
White dots
Green dots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

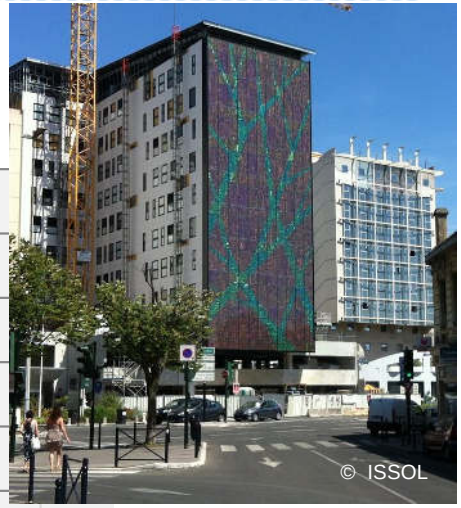
Coloured BIPV modules : optimal design is possible?

Coloured BIPV modules: power vs design

Suitable printing degrees for limiting the power losses to



Coloured BIPV modules: electrical issues



Current density vs printing degree

Voltage values should be evaluated

Current density (mA/cm²)

37.5
35.0
32.5
30.0
27.5
25.0
22.5
20.0
17.5
15.0
12.5
10.0
7.5
5.0
2.5

25 mA/cm²

0 10 20 30 40 50 60 70 80 90 100

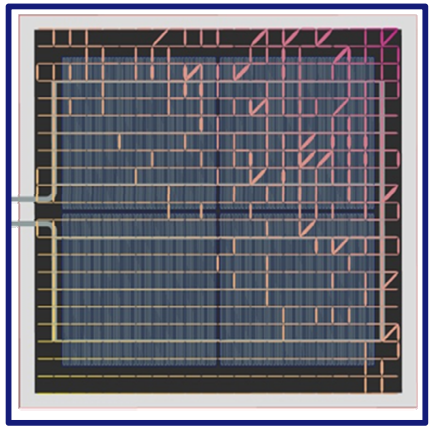
Printing degree (%)

Black
White
Green

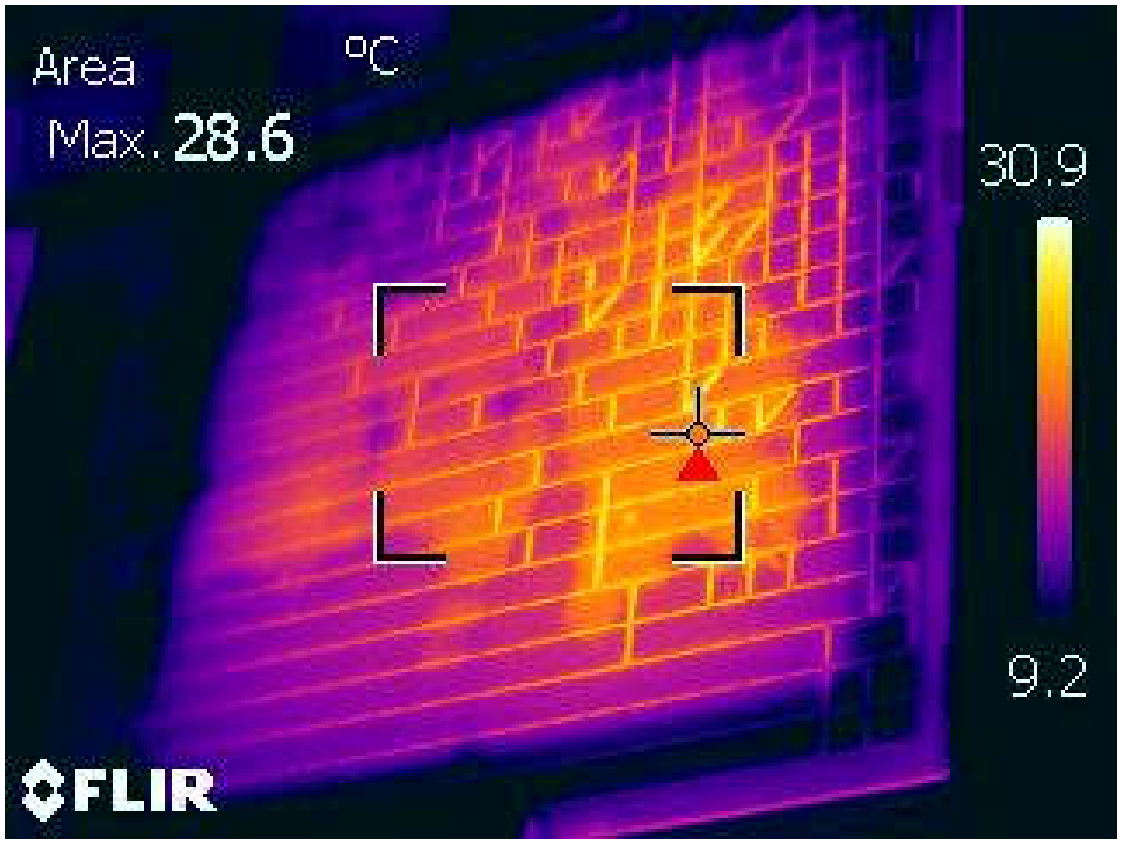
23% black

70% green

90% white



T1 – 10%



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

Pm = 14.84 W

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

≈ 10-15°

Design flexibility of BIPV modules

PRELIMINARY RESULTS

- The current intensity is proportionally dependent on pattern geometrical coverage and colour;
- What about voltage and operating temperaures? thermographic images show the temperature inhomogeneous distribution in some area of the cells
- …the pattern homogeneity/distribution seems to affect the final energy behavior/output

FURTHER INVESTIGATION

- Optical characterization of patterns
- Optimization of pattern design (building…cell level)
- Consequences on operating temperatures, voltage, durability, etc..


HARLEM HOSPITAL CENTER
© Jack Travis

Other aspects

- Shadowing (morphology, urban density, etc.)
- Building typology
- Urban density
- Soiling

- Building skin construction system
- Architectural language

Conclusions

BIPV…beyond STC

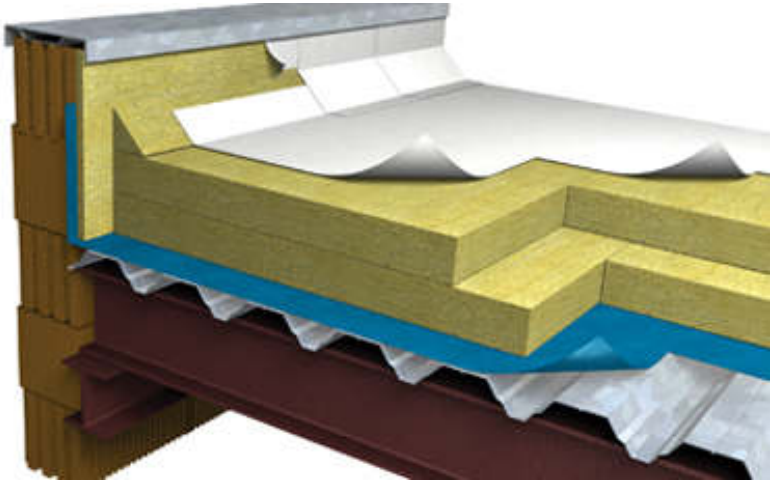
1) External factors of building integration
   - Urban environment: Trees, shadows, soiling
   - Building factors: typological and building features

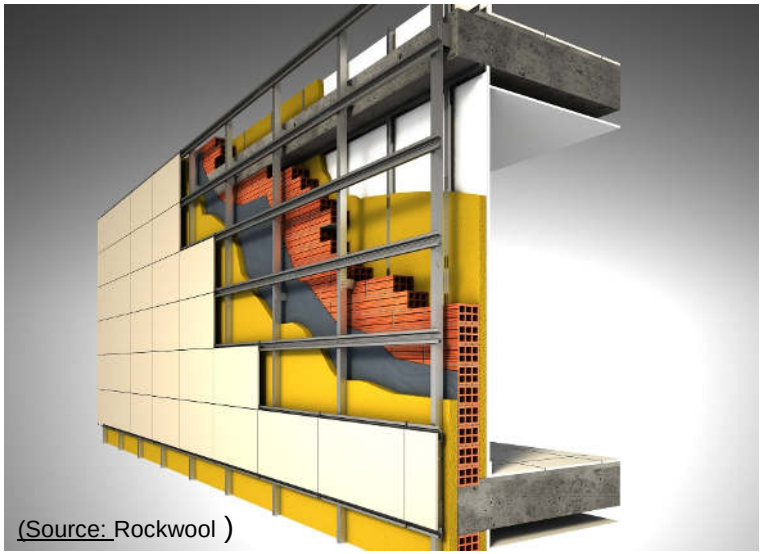
2) Building skin system
   - Ventilation/insulation due to the construction system (operative temperature, stress, durability)

3) BIPV customization
   - Pattern, colours, printing, layering

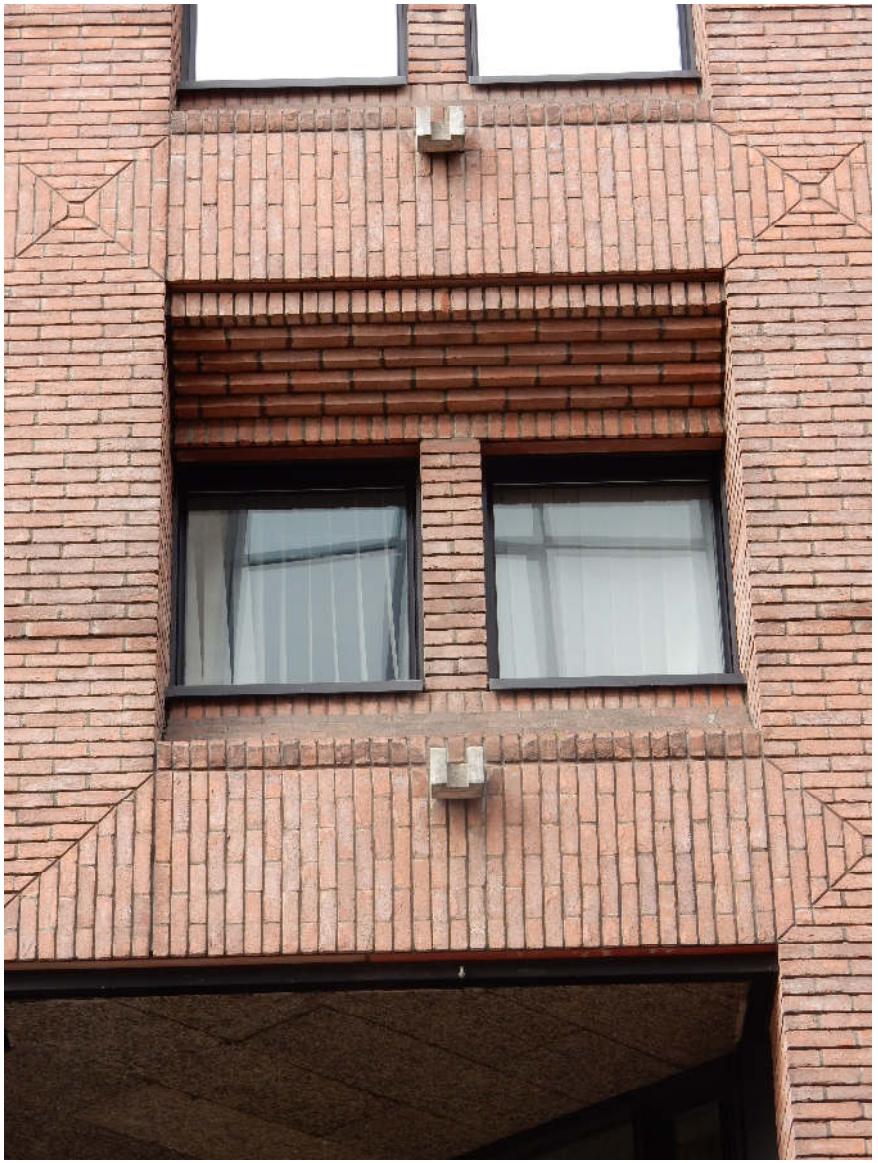
Source: FaceActive *Batineg*

BIPV…it's not a problem of standards… but of information





Architecture use every day standard components



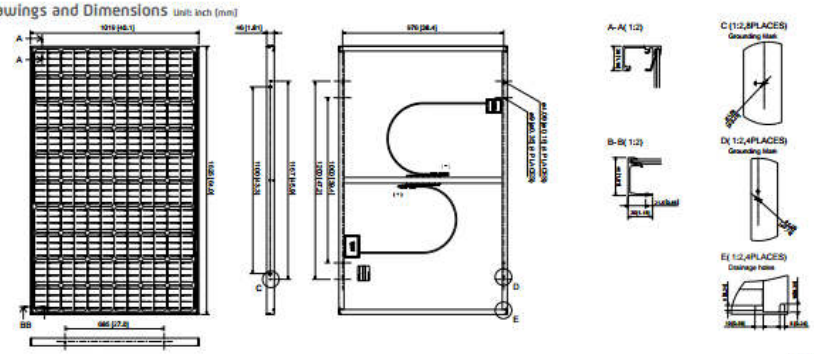
(Detail of a brick facade -building in Lugano, M. Botta, Photo: P. Bonomo)

BIPV …and product information

Specification Sheet

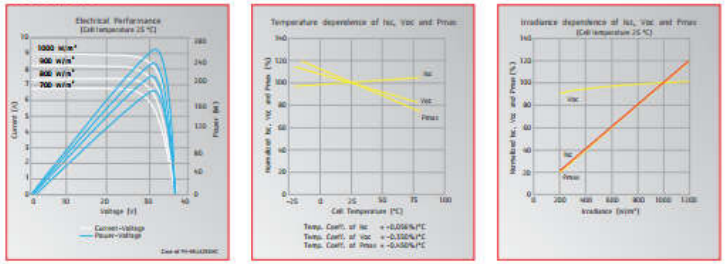
Manufacturer	MITSUBISHI ELECTRIC	
Model name	PV-MLU255HC	PV-MLU250HC
Cell type	Monocrystalline Silicon, 78mm x 156 mm	
Number of cells	120 cells	
Maximum power rating (Pmax)	255Wp	250Wp
Warranted minimum Pmax	247.4Wp	242.5Wp
PV USA test condition rating (PTC)	230.5Wp	225.8Wp
Open circuit voltage (Voc)	37.8V	37.6V
Short circuit current (Isc)	8.89A	8.79A
Maximum power voltage (Vmp)	31.2V	31.0V
Maximum power current (Imp)	8.18A	8.08A
Module efficiency	15.4%	15.1%
Aperture efficiency	16.7%	16.4%
Tolerance of maximum power rating	+3/-3%	
Static load test passed	5,400 Pa	
Number of bus bars per cell	4 Bus bars	
Normal operating cell temperature (NOCT)	45.7°C	
Maximum system voltage	DC 600V	
Fuse rating	15A	
Dimensions	64.0 x 40.1 x 1.81 inch (1625 x 1019 x 46 mm)	
Weight	44 lbs (20kg)	
Number of modules per pallet	20	
Number of modules per container (40 ft. container)	560	
Output terminal	(+) 800mm (-) 1250mm with MC connector (PV-KTB4/6 II-UR, PV-KST4/6 II-UR)	
Certifications	IEC 61215 2nd Edition, UL1703	
Fire rating	Class C	

Drawings and Dimensions Unit: inch (mm)



Unit: mm [inch]

Electrical Characteristics



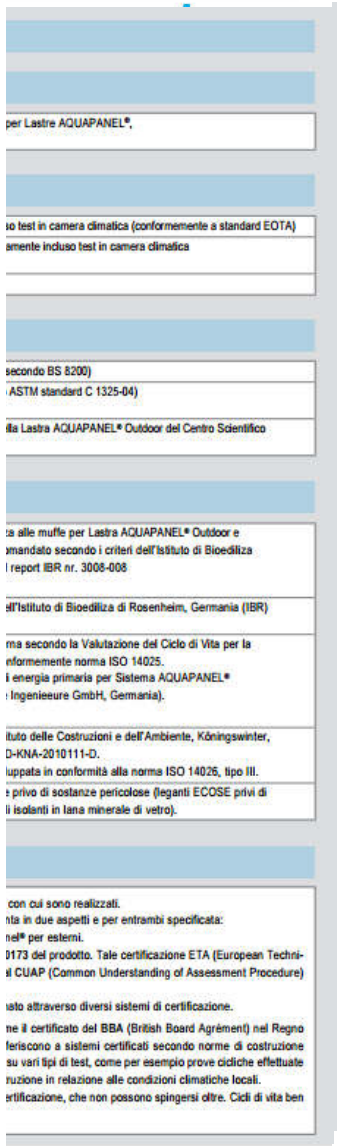
il fissaggio su orditure metalliche con spessori non superiori a 0,7 mm. Per orditure metalliche di maggior spessore usare viti punta Teks.
È necessario iniziare con la vite al centro della lastra e successivamente proseguire verso i bordi. Durante l'installazione assicurarsi che la lastra rimanga aderente alla struttura metallica.

Nella posa delle lastre AQUAPANEL® Outdoor è necessario **lasciare una distanza di 3÷4 mm tra una lastra e l'altra, solamente lungo i bordi longitudinali** (lato lungo).
Questo accorgimento è di fondamentale importanza perché consente allo stucco che verrà applicato sui giunti di penetrare in quantità fino sul retro della superficie e di garantire pertanto l'adeguata resistenza meccanica.
Una applicazione che non tenga conto del distanziamento tra i giunti è da considerare errata e rischia di causare fessurazioni lungo le giunzioni stesse.
Per distanziare correttamente le lastre, prima del fissaggio collocare provvisoriamente una vite (con funzione di distanziatore) tra le due lastre e rimuoverla dopo il fissaggio definitivo, oppure utilizzare comuni distanziatori per piastrelle dello spessore sopra indicato. Per i bordi trasversali (lato corto) non è richiesto questo accorgimento in quanto le lastre devono essere accostate; è invece previsto lo sfalsamento dei giunti pari ad almeno all'interasse dei profili montanti.

Stuccatura dei giunti

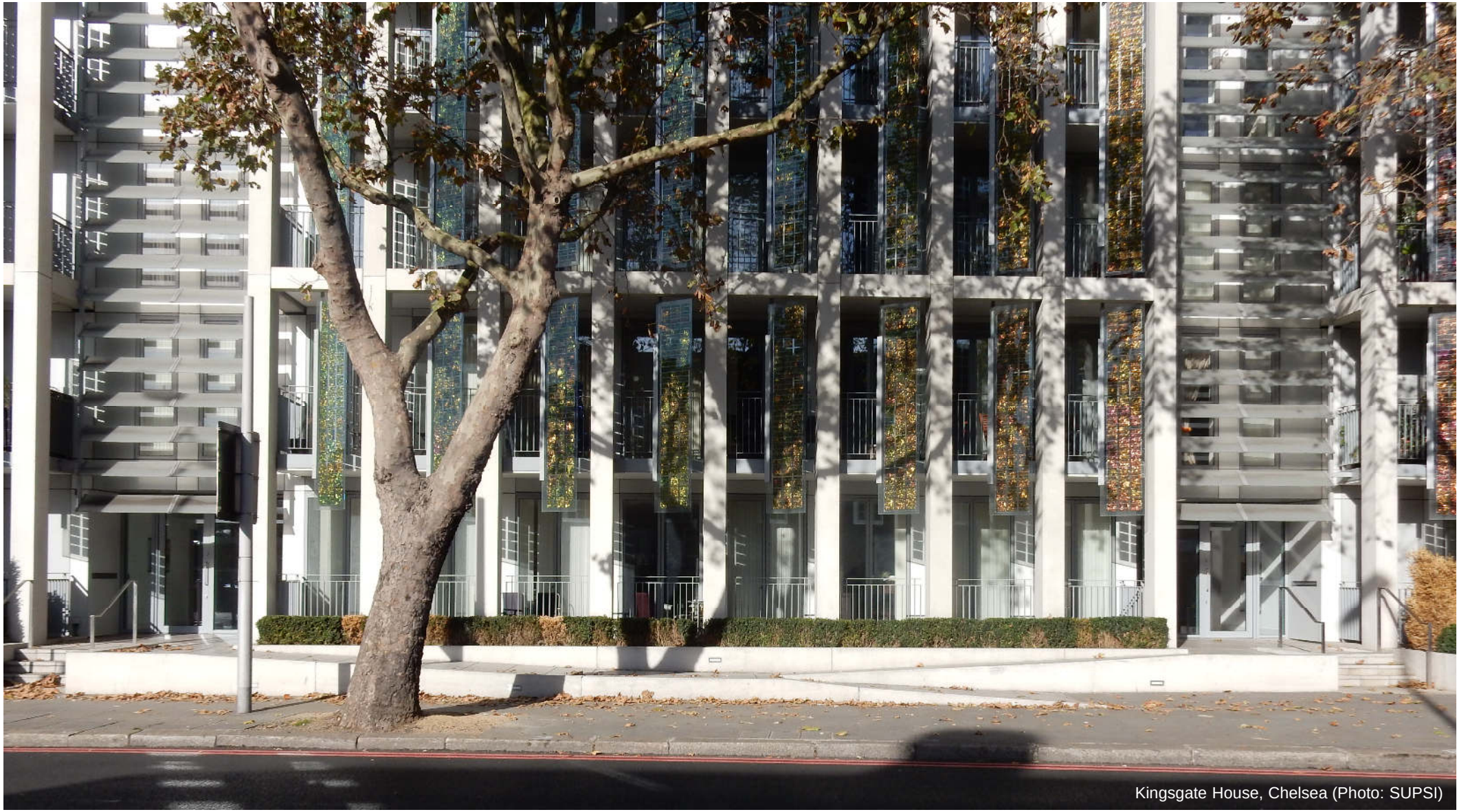
Successivamente al montaggio delle lastre, procedere alla stuccatura dei giunti.

I giunti tra le lastre Aquapanel® Outdoor devono essere stuccati con lo stucco per esterni **Aquapanel® Exterior Basecoat.** La stuccatura si applica in una sola mano, per uno spessore di 2÷3 mm, con



(source: Knauf Aquapanel)

the challenge to explore the expressions of new materials



Kingsgate House, Chelsea (Photo: SUPSI)

Thank you for your attention!

Construct-PV: The research leading to these results received funding from the European Community's Seventh Framework programme (FP7/2007-2013) under grant agreement no 295981 [www.constructpv.eu].

…our path towards a solar built environment