PV SYSTEMS
Building Integrated Photovoltaics

Building integrated PV

- BIPV issues
  - Inclination
  - Orientation
  - Shading
  - Temperature
  - Design
- PV & architecture
- Categories of BIPV
- PV integrated in public spaces

Building integrated PV

- Optimal inclination for maximizing energy yield but aesthetically it may not make sense
- Optimal orientation usually south (north) but not always (e.g. in a region prone to early morning fog, optimal may be slightly to the west)

Building integrated PV

- Importance of shading – crucial during system & building design (micro-inverters make PV system more tolerant to shading mistakes)

Building integrated PV

- Importance of shading – crucial during system & building design (micro-inverters make PV system more tolerant to shading mistakes)
- Notice that high surrounding buildings may also alter (i.e. usually block!) diffusive light

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Building integrated PV

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Building integrated PV

- Importance of temperature: (ventilated) air gap behind module to keep 'low' module temperature (extra: insulating function!)
- Design!
  - 'High-tech' or 'Green' look
  - Replacement for other facade materials (e.g. office building)

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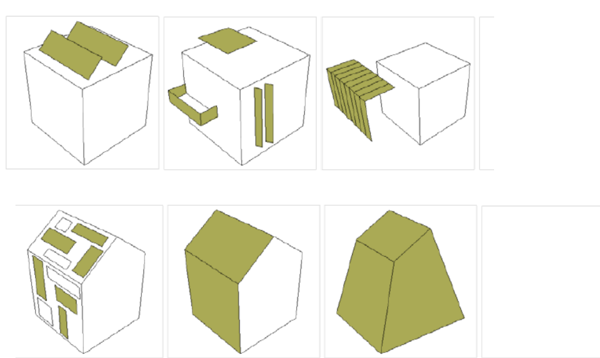
HOW CAN PV BE INCORPORATED INTO THE BUILDING DESIGN?

1. added technical element
2. added elements with double function
3. free standing structure
4. part of surface composition
5. complete façade/roof surface
6. form optimized for solar energy



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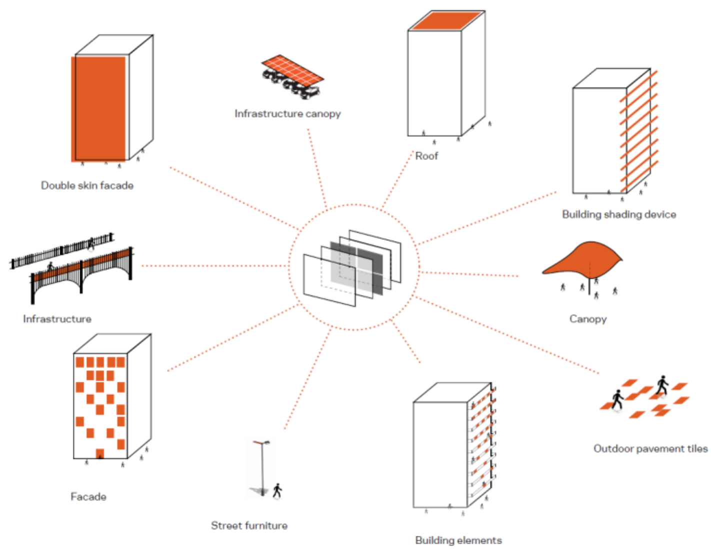
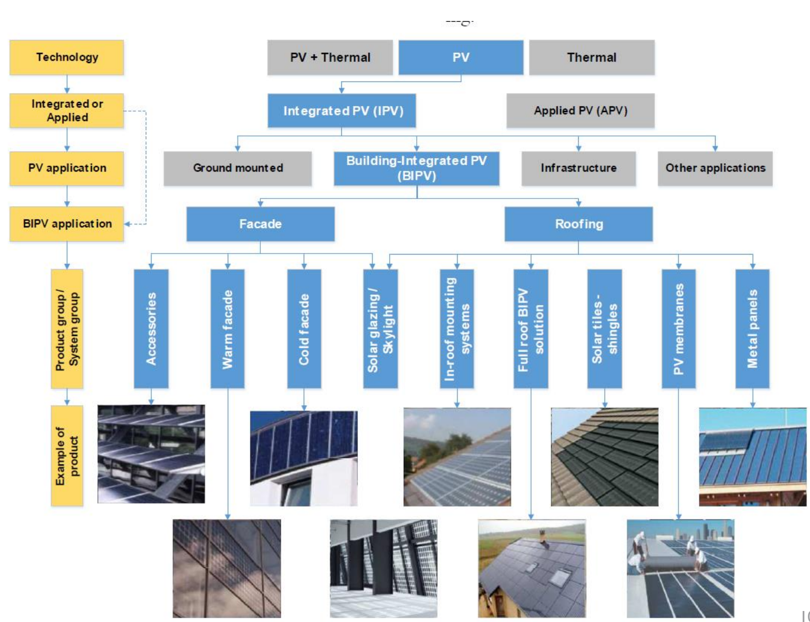
HOW CAN PV BE INCORPORATED INTO THE BUILDING DESIGN?



MANY DIFFERENT CLASSIFICATION SCHEMES



SOLAR ROOF TILES

LARGE SIZED TILES (SOURCES: WWW.NEWROOF-HYBRID.COM)

SMALL SIZED TILES (SOURCES: PANOTRON, FORNACE FONTI)

Solar tiles: Joint QREN project coordinated by Revigres, Innovation Award in "Energy Live Expo" 2012.

SOLAR ROOF TILES

SCX SOLOROOF AS BIPV FULL ROOF SOLUTION (TILBURG, THE NETHERLANDS), 75 TERRACED DWELLINGS

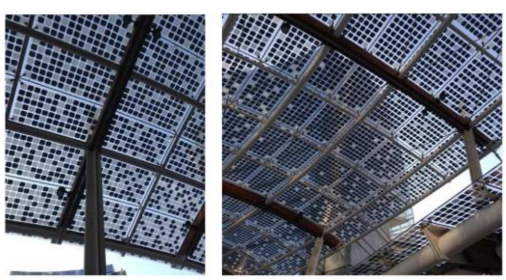
STAFIER STANDAARD AS AN IN-ROOF MOUNTING SYSTEM (MAARN, THE NETHERLANDS), 29 TERRACED DWELLINGS

SOLAR ROOF TILES

METAL PV PANELS (SOURCE: KALZIP, TEGOLA CANADESE)

. PV MEMBRANES EMBEDDED IN A FLAT ROOF COVER (SOURCE: WEKA DAKSYSTEMEN).

SOLAR GLAZING



PORTA NUOVA MILANO - PIAZZA AULENTI (SOURCE: ENERGY GLASS)

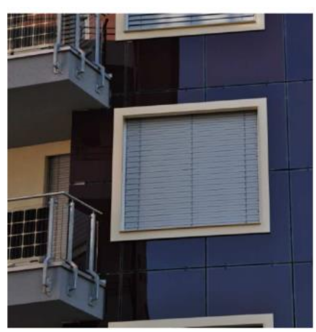
THE "HERON TOWER" IN LONDON WITH THE SEMI-TRANSPARENT DOBLE SKIN -BIPV FAÇADE (PICTURE: P. BONOMO).

SOLAR FACADES

WARM FAÇADE BIPV SOLUTION, MONTE ROSA HUT (ZERMATT, SWITZERLAND) (ARCHITECT: ETH STUDIO MONTE ROSA)

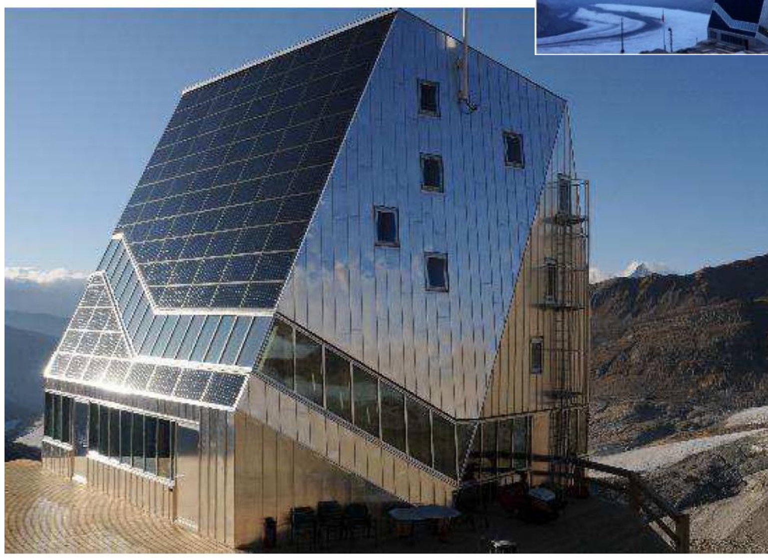
Fig. 3.B.24: warm façade solution. Zara Fashion Store, Cologne, Germany, Architekturbüro Angela und Georg Feinhals: opaque monocrystalline cells combined with transparent glazing in post-beam curtain wall structure, © Solon.

SOLAR FACADES



WARM FAÇADE BIPV SOLUTION, PALAZZO POSITIVO (CHIASSO, SWITZERLAND)
(ARCHITECT: TOUR BAUMANAGEMENT AG, BAD RAGAZ, PICTURES: F. FRONTINI, SUPSI)

SOLAR FACADES



WARM FAÇADE BIPV SOLUTION, MONTE ROSA HUT (ZERMATT, SWITZERLAND) (ARCHITECT: *ETH STUDIO MONTE ROSA)*

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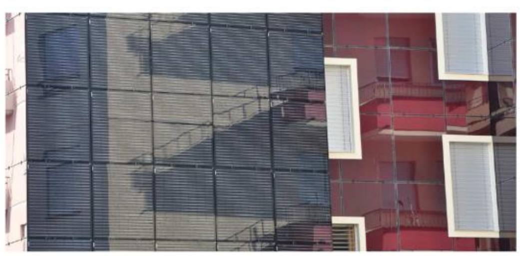
SOLAR FACADES



Cold facades have an air gap for ventilation

PALAZZO POSITIVO IN CHIASSO (SWITZERLAND), REFURBISHMENT WITH A BIPV COLD FACADE (SOURCE: F. FRONTINI, SUPSI)

COLD FAÇADE BIPV SOLUTION, FRODEPARKEN (UPPSALA, SWEDEN) (ARCHITECT: *WHITE ARCHITECTS)*

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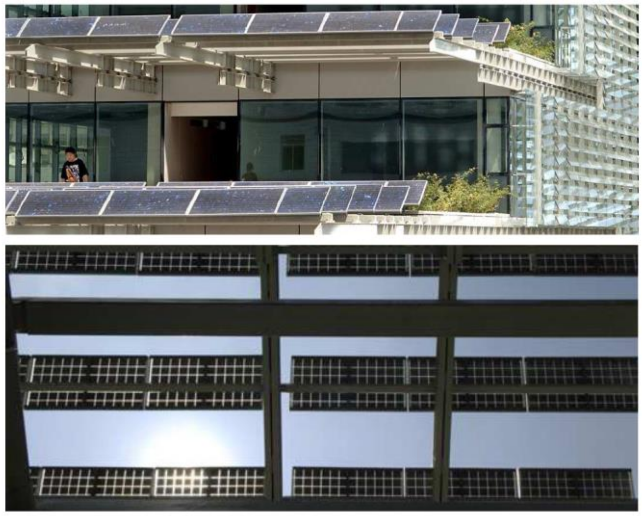
SOLAR ACCESSORIES

Fig. 3.B.28: solar shading solution: Left: Colt Ellisse PV sliding shades at Company HQ, Bitterfeld-Wolfen, Germany, © Colt, Right: Keuringsdienst, Eindhoven, The Netherlands, Yanovshtchinsky Architekten: using Colt Shadovoltaic as shading device, © Colt.

Fig. 3.B.29 SBL Offices Linz, Austria, Helmut Schimek, shading louvres with integrated photovoltaics and suntracking system, © Colt

SOLAR ACCESSORIES



PV SHADINGS IN THE SIEEB BUILDING, BEJING, MARIO CUCINELLA ARCHITECTS (SOURCE: WWW.SINOITAENVIRONMENT.ORG/)

SOLAR ACCESSORIES

Fig. 3.B.30: spandrels and parapet solutions. Left: Housing Estate, Ekovikki, Finland, Oy Reijo Jallinoja: semi-transparent PV modules with two-paned glazing in parapet areas, Resource: PV NORD. Right: Kollektivhuset, Copenhagen, Denmark, Domus Arkitekter: PV cells were laminated to a single glass, heat transmitted from the cells was used in an innovative way to create thermal comfort during spring and autumn, during summer they are ventilated with an optimized shaft behind the cells and a coloured shutter through airgaps in the bottom and top of the glazing of the balcony, Resource: PV NORD.

12 kW | Server de Vouga, 2012

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SOLAR ACCESSORIES

TEXTILE PV ARCHITECTURE, SOFT HOUSE, IBA HAMBURGKENNEDY & VIOLICH ARCHITECTURE (SOURCE: WWW.IBA-HAMBURG.DE/)

17 Innovative materials for new BIPV solutions - EU PVTP Conference, London 8 July 2015

BELECTRIC®
Belectric OPV GmbH

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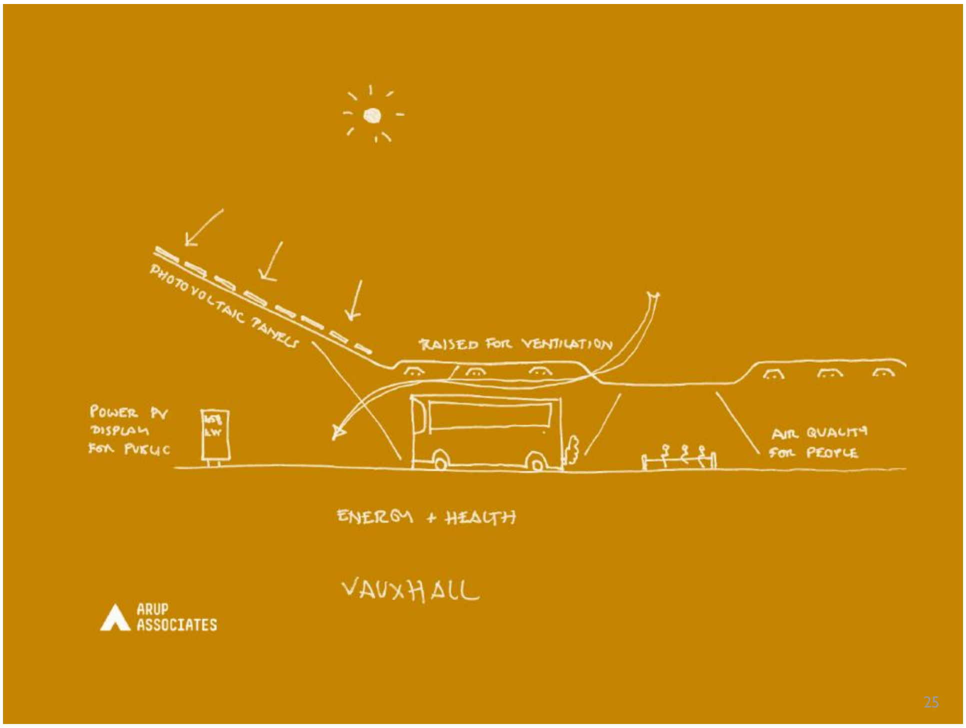
PHOTOVOLTAIC PANELS
RAISED FOR VENTILATION
POWER PV DISPLAY FOR PUBLIC
AIR QUALITY FOR PEOPLE
ENERGY + HEALTH
VAUXHALL
ARUP ASSOCIATES
25


ARUP ASSOCIATES
Did you know?
1500
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BIPV IS DIFFERENT FROM STANDARD PV

Performance

- As much **energy** as possible
- At the **lowest cost** of investment

Integration

- As **functional** as possible
- At the **highest added value**

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BIPV IS DIFFERENT FROM STANDARD PV

Performance

No or positive temperature dependence

High efficiency & stability

Efficiencies independent of light intensity & type

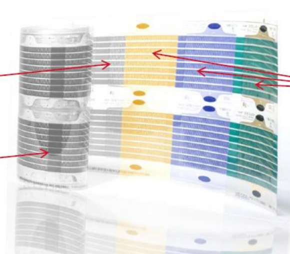
Low costs & capex light production

Efficient off-axis light collection

Semi-transparency and grey-scales

Flexible and light-weight

Thin - minimal material usage



Ability for different colors

Integration

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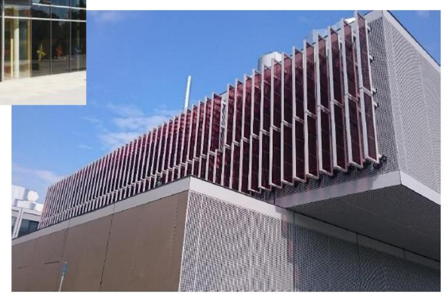
BIPV IS DIFFERENT FROM STANDARD PV

With courtesy from Colt international GmbH

Passive system
- Sun shading
- Design

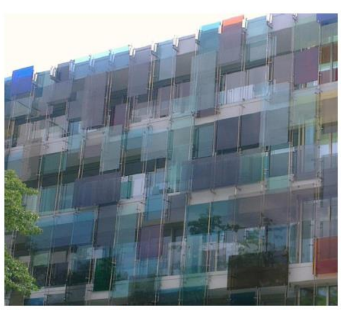
Active system
- Sun shading
- Design
- Electricity generation



Merck – modular innovation center - Darmstadt

BIPV IS DIFFERENT FROM STANDARD PV

Colored windows in architecture (no PV function):



Diener & Diener / Norvatis Campus / Basel, Suisse

Merck's portfolio of darker colors (example OPV):

Examples of colors feasible with Merck's OPV solutions

BIPV IS DIFFERENT FROM STANDARD PV

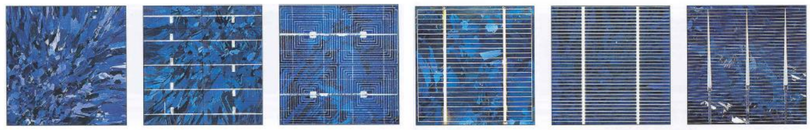


Fig. 3.B.36. different variations of the pattern of metallic grid on multicrystalline cells, © IEA - PVPS Task 7

Fig. 3.B.35. multicrystalline silicon wafers; first the blue antireflective standard colour with the best efficiency, the second is the original wafer without reflective layer, then cells with other colours that have different anti-reflective layers, © Sunways

BIPV IS DIFFERENT FROM STANDARD PV

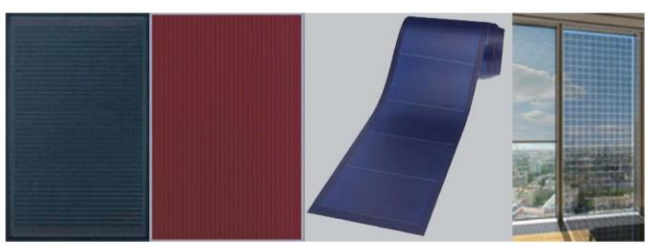
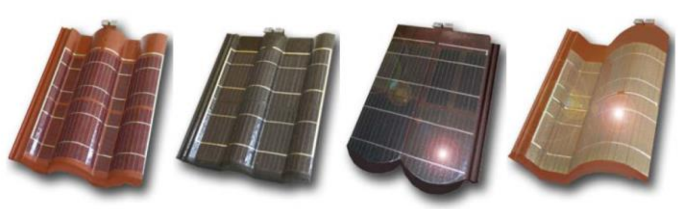


Fig. 3.B.38: black thin film module © Sharp, magenta thin film module © Rixin, solar laminate, © Unisolar, translucent thin film mosule, © Schüco



Variations of shape of the tile, © IdeaS Solar

BIPV IS DIFFERENT FROM STANDARD PV

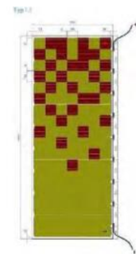
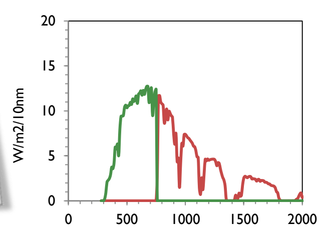


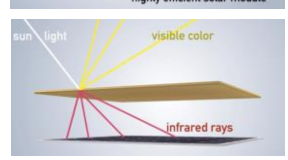
Fig 3.6: home + pavilion for Solar Decathlon, photo of façade and technical drawing of a façade module, ©Prof. Dr. Jan Cremers

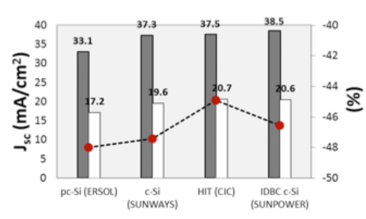
FIGURE 19: A COMPLEX BIPV FACADE IN THE SOLAR DECATHLON "PARA ECO HOUSE" (SOURCE: C. POLO, SUPSI)

BIPV IS DIFFERENT FROM STANDARD PV

SOLAXESS
white solar technology







BIPV IS DIFFERENT FROM STANDARD PV

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BIPV IS DIFFERENT FROM STANDARD PV

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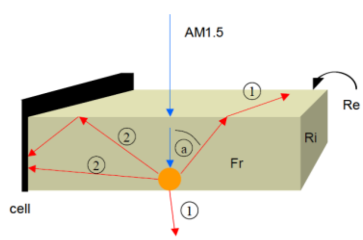
BIPV IS DIFFERENT FROM STANDARD PV

37

BIPV IS DIFFERENT FROM STANDARD PV



Totally transparent (to the visible light).
Natural sunlight for indoor lighting but only making use of about ½ of the available energy.

Luminescent material absorbs IR radiation and re-emits it with a different 'colour', the photon flux going to the solar cell on the window edge as if in an optical fiber.

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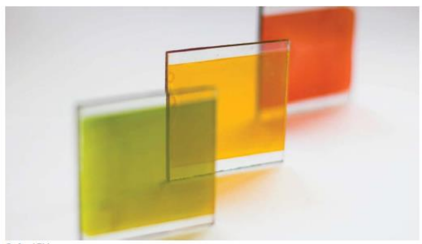
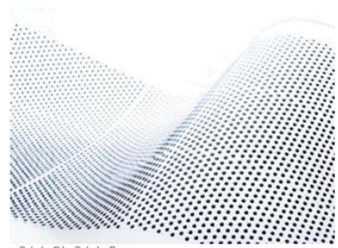
BIPV IS DIFFERENT FROM STANDARD PV

Onyx Solar Photovoltaics Transparent Glass installed into San Anton Market, Madrid (Spain)

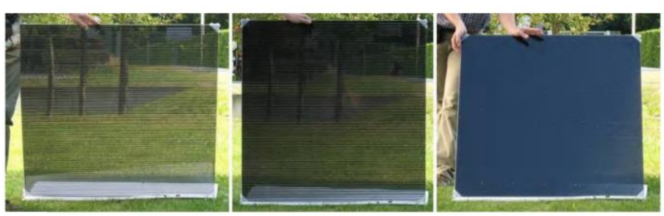


Oxford PV

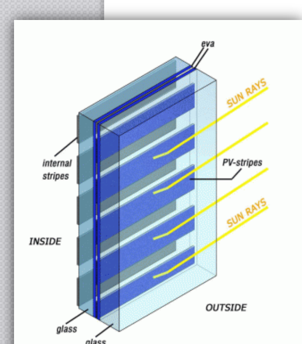


Sphelar® by Sphelar Power
Based on crystalline silicon balls, ® module

BIPV IS DIFFERENT FROM STANDARD PV

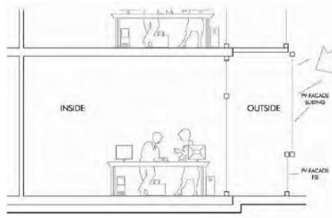


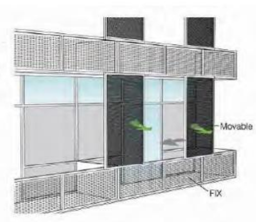
First prototype of the new angle selective façade (without PV functionality).

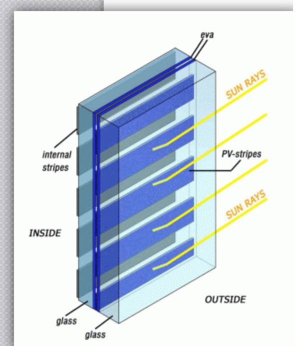


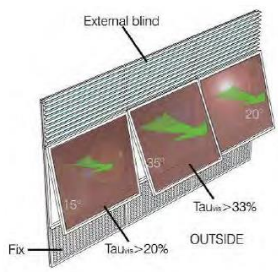
The alignment of the two sets of strips leads to very sensitive obstruction to light as function of the incidence angle.

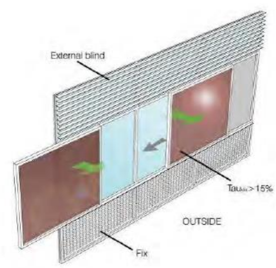
BIPV IS DIFFERENT FROM STANDARD PV











The pictures present an idea of the integration of the new façade as an external shading device.

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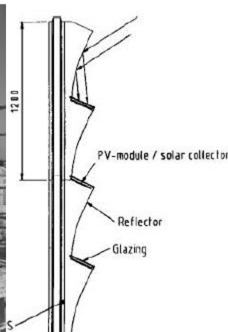
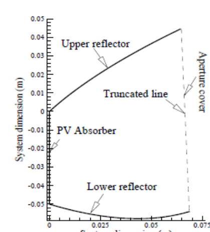
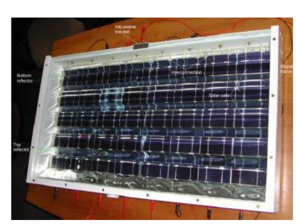
BIPV IS DIFFERENT FROM STANDARD PV







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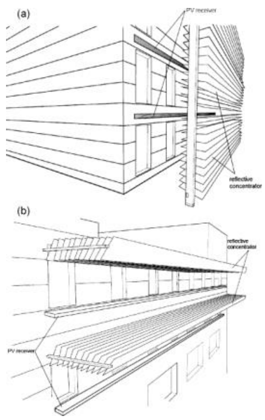
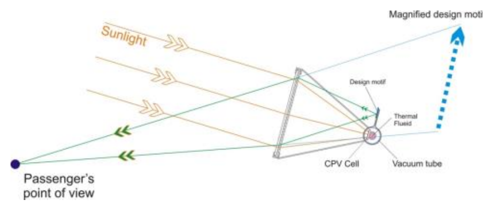
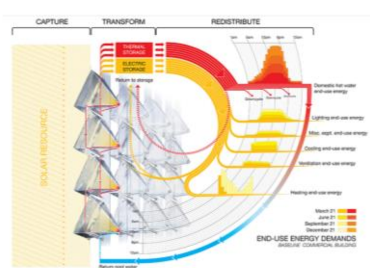
BIPV IS DIFFERENT FROM STANDARD PV





BIPV IS DIFFERENT FROM STANDARD PV

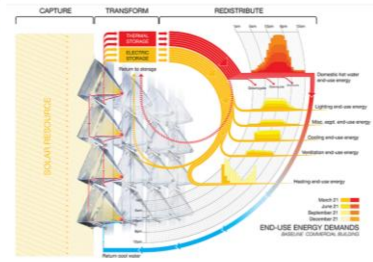


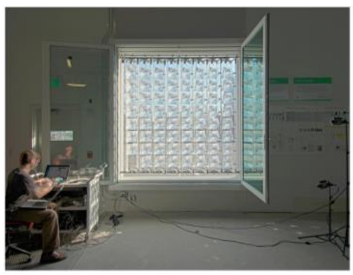
Kinetic solar facade

Moving concentrating glass prisms for beam solar irradiation

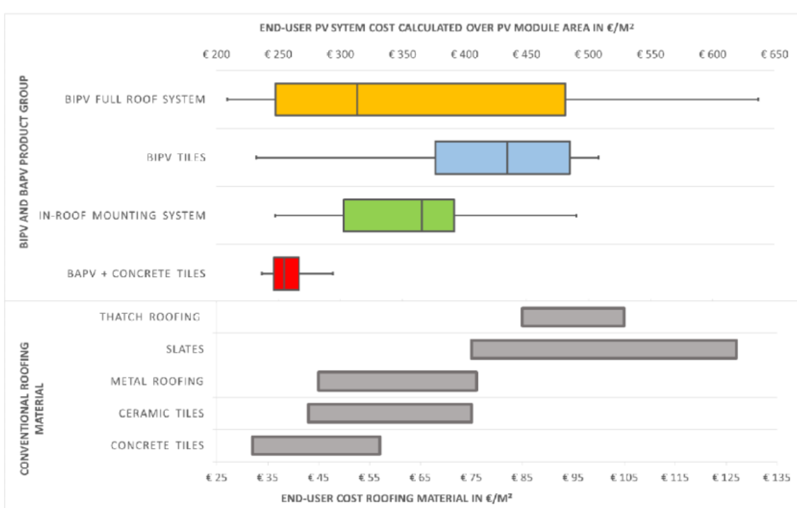
- ❑ Diffuse radiation gets through for indoor lighting
- ❑ Heat is collected and may be used for heating/cooling of the building

BIPV IS DIFFERENT FROM STANDARD PV



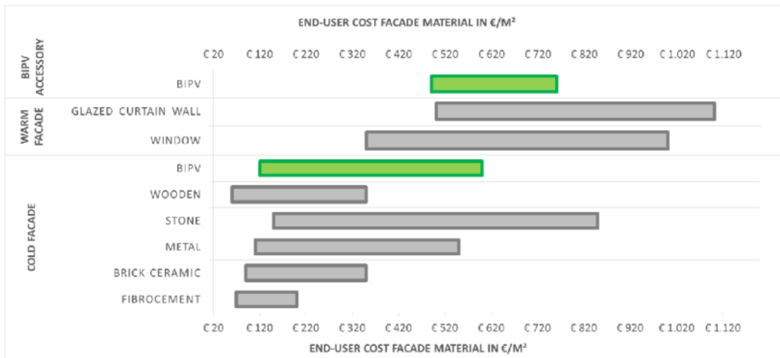


THE COST OF BIPV



G. Verberne et al., *BIPV Products for Façades and Roofs: A Market Analysis*, 29th EU-PVSEC 2014

THE COST OF BIPV



G. Verberne et al., *BIPV Products for Façades and Roofs: A Market Analysis*, 29th EU-PVSEC 2014

THE COST OF BIPV

Comments

- ❑Roof BIPV market more developed than facades
- ❑Average end-user price is about 300 €/m^2, in spite of large range of prices
- ❑Assuming 15% efficiency (150W/m^2) one gets 2€/W so there is a +200% premium for BIPV [compare with 0.60 €/W for factory gate module]
- ❑But we're avoiding using other roof/facade materials with similar costs (but less 'function') so one can argue that **BIPV is free**.

BIPV in public spaces

- Increase locally produced renewable electricity
- Bring PV closer to the people
- Promote sustainability (usually more visible than when in/on buildings)
- Examples:
  - Urban street equipment
  - Shelters, barriers, shading structures
  - Urban art

BIPV in public spaces

Main design issues

- Solar resource (shadings more likely)
- Visual appearance (key issue)
- Vandalism and theft
- Easy maintenance
- Cost

BIPV in public spaces

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BIPV in public spaces

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BIPV in public spaces

BIPV in public spaces

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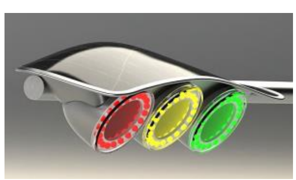
BIPV in public spaces



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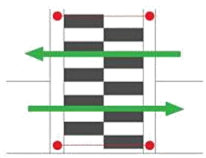
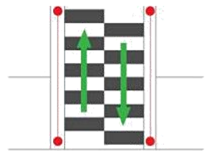
BIPV in public spaces



A driver drive on

A pedestrian stop at a crosswalk



A driver stop a car at a crosswalk

A pedestrian cross the street at a crosswalk

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BIPV in public spaces

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BIPV in public spaces

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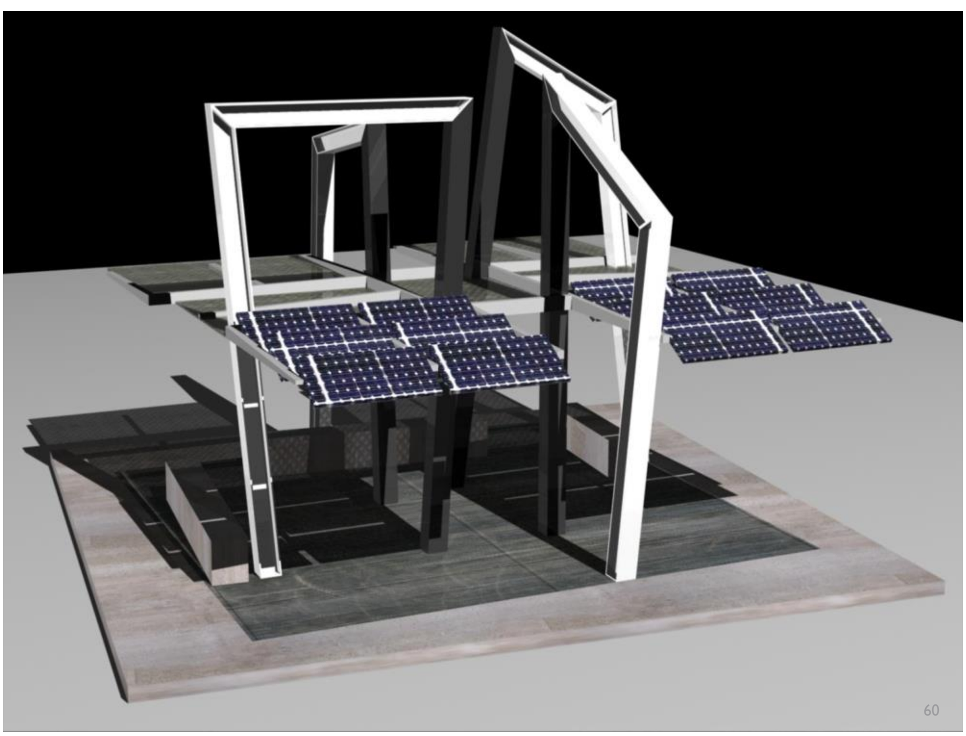

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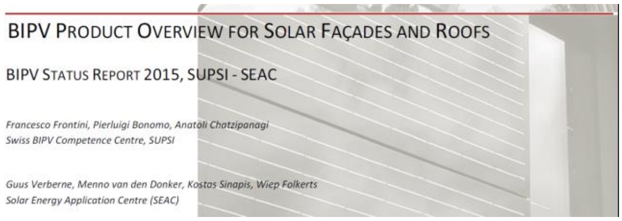
SONIC BLOOM @SEATTLE FESTIVAL 2015

sensors located in each flower are triggered by people's movement, setting off a chorus of interactive harmonic tones

mounted on the top of each painted flower head are 46 locally made photo voltaic cells that collect the energy from the sun and feed it back into the electrical grid. this sustainable feature completely offsets the energy-efficient LED lighting and speaker electrical consumption for the project.

Further reading


BIPV PRODUCT OVERVIEW FOR SOLAR FAÇADES AND ROOFS

BIPV STATUS REPORT 2015, SUPSI - SEAC

Francesco Frontini, Pierluigi Bonomo, Anatoli Chatzipanagi
Swiss BIPV Competence Centre, SUPSI

Guus Verberne, Menno van den Donker, Kostas Sinapis, Wiep Folkerts
Solar Energy Application Centre (SEAC)

T.41.A.2 I Task 41 - Solar energy & Architecture SHC International Energy Agency - Solar Heating and Cooling Programme

SOLAR ENERGY SYSTEMS IN ARCHITECTURE

integration criteria and guidelines

DESIGNING PHOTOVOLTAIC SYSTEMS FOR ARCHITECTURAL INTEGRATION

criteria and guidelines for product and system developers

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