BIPV – From Add-On PV to Real Integration

Challenges and Options

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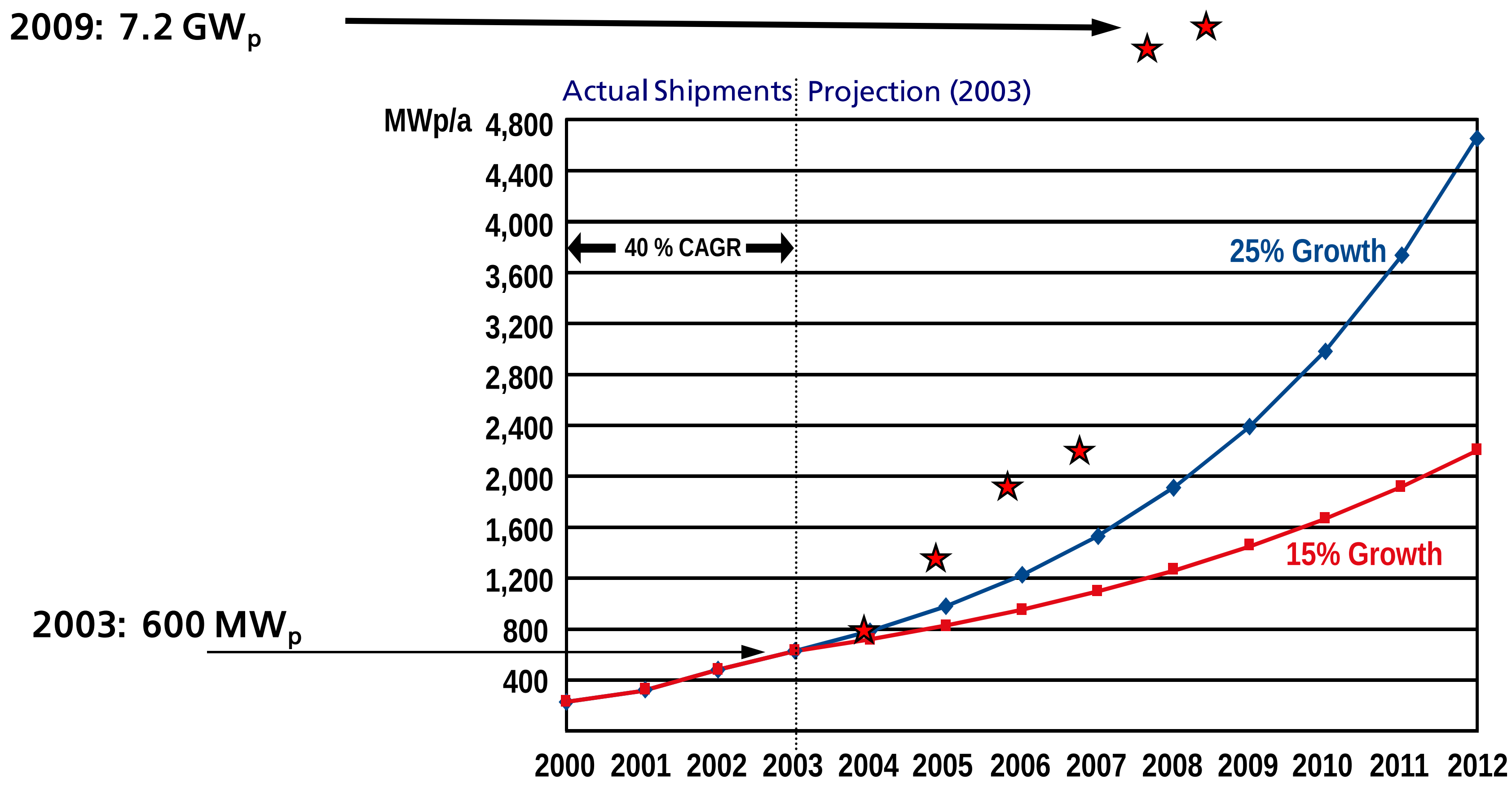
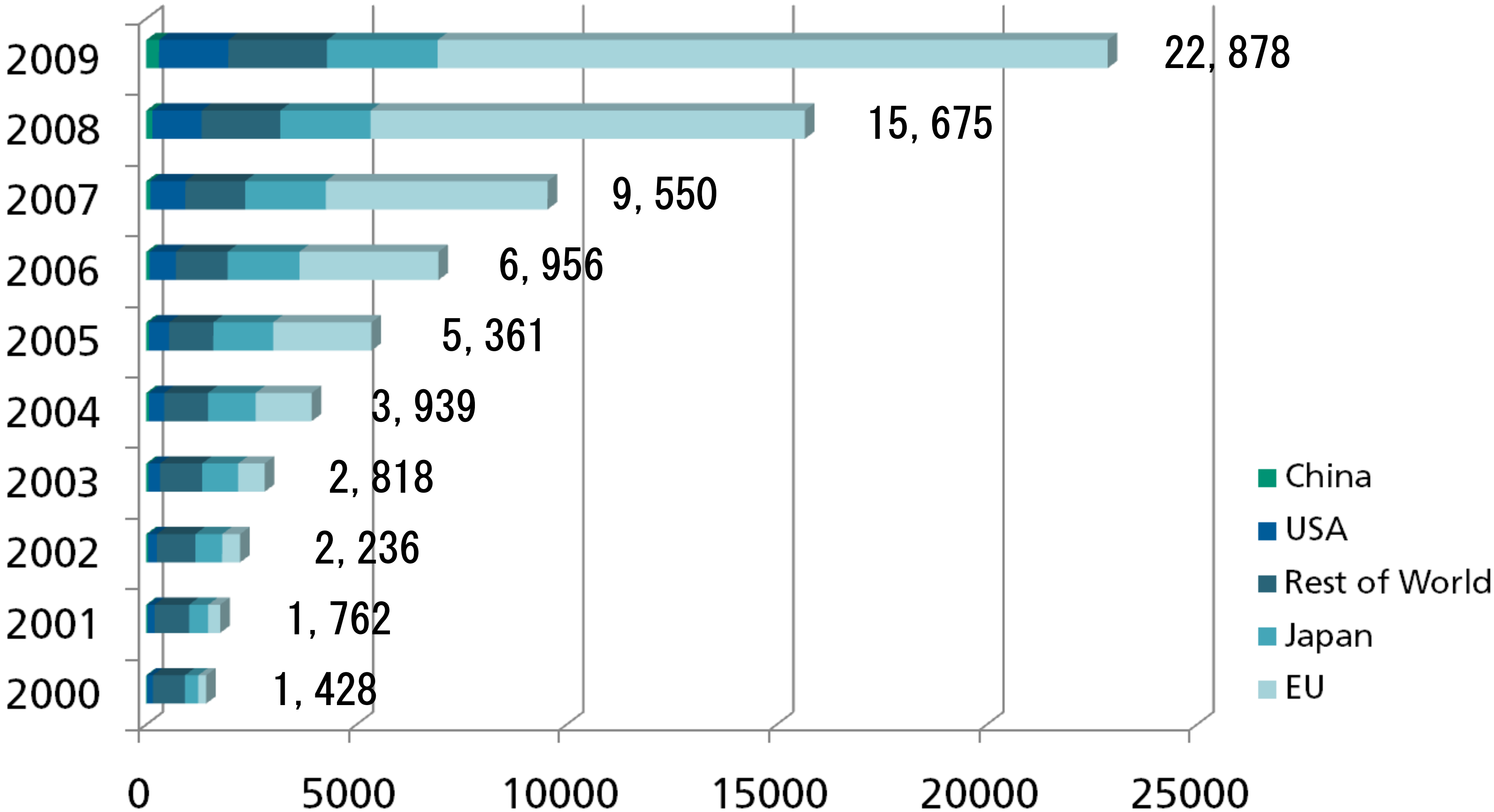
The PV Industry | Global PV Module Install Base



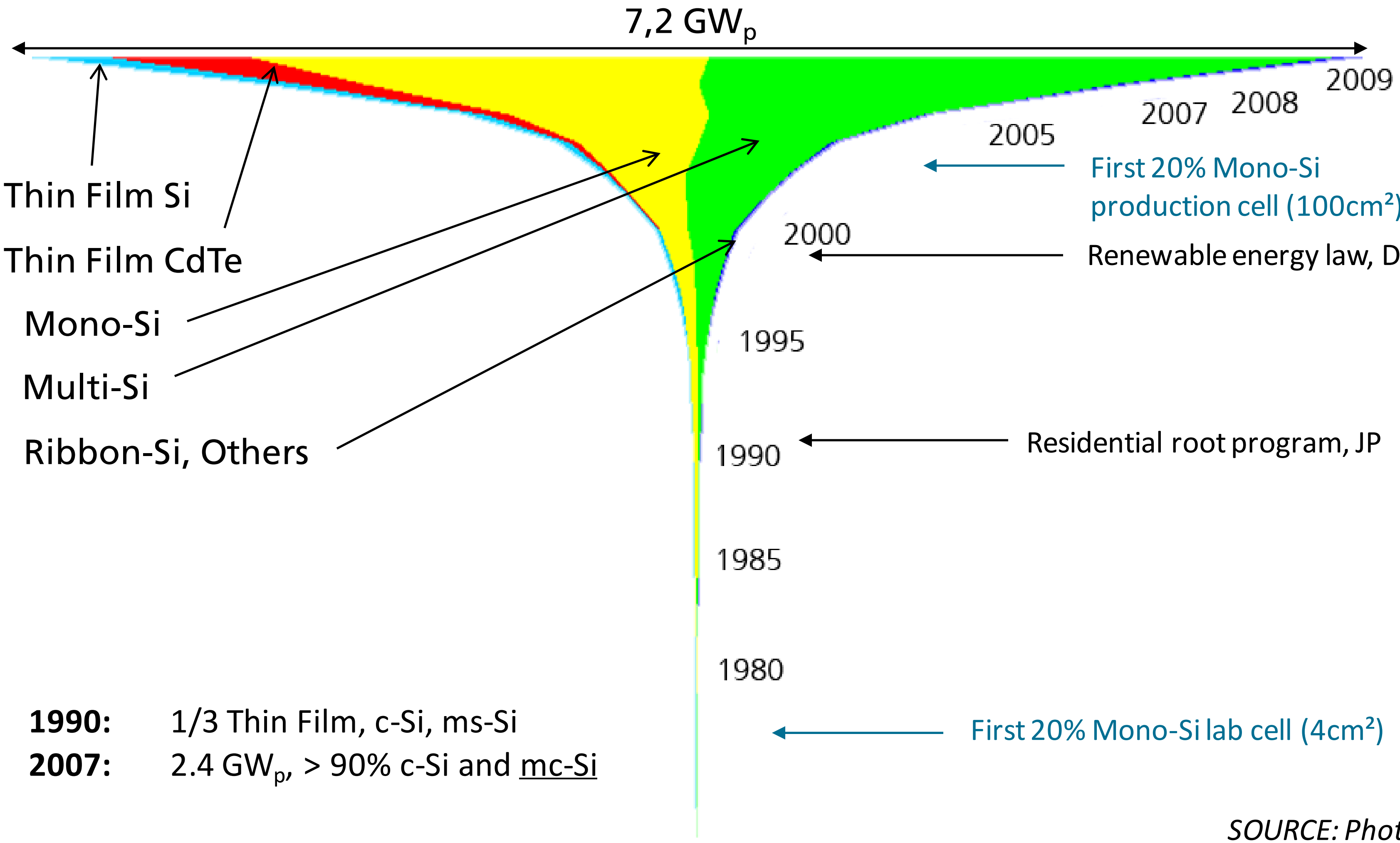
SOURCES: 2000 – 03 – Strategies Unlimited; '06 – EPIA "Solar Generation; '07 – LBBW Report; '10 – Solar Buzz

The PV Industry | Cumulative PV Power (2000 – 2009)



SOURCE: EPIA

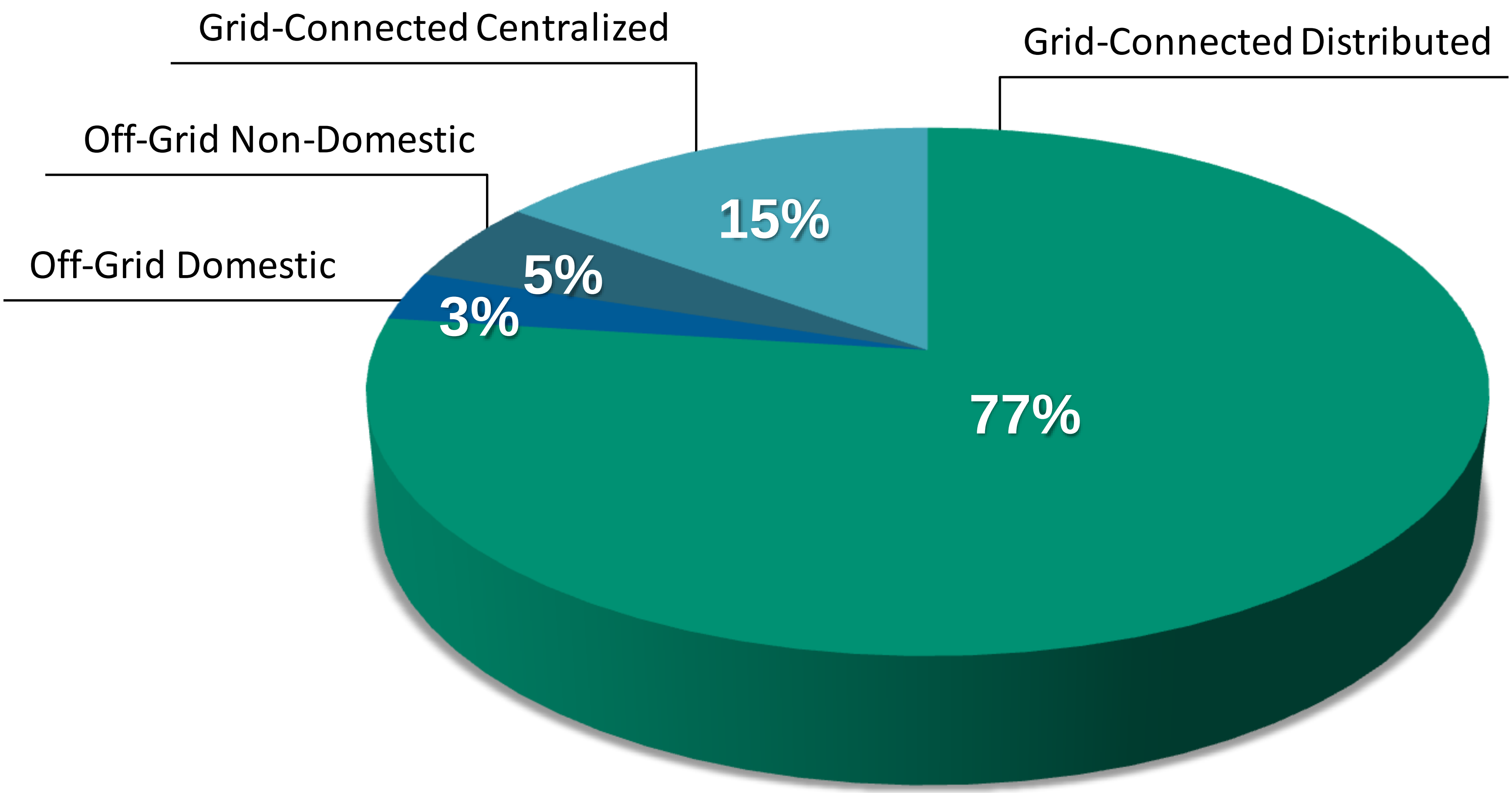
The PV Industry | Development of the Worldwide PV Market



1990: 1/3 Thin Film, c-Si, ms-Si
2007: 2.4 GW_p, > 90% c-Si and <u>mc-Si</u>

SOURCE: Photon

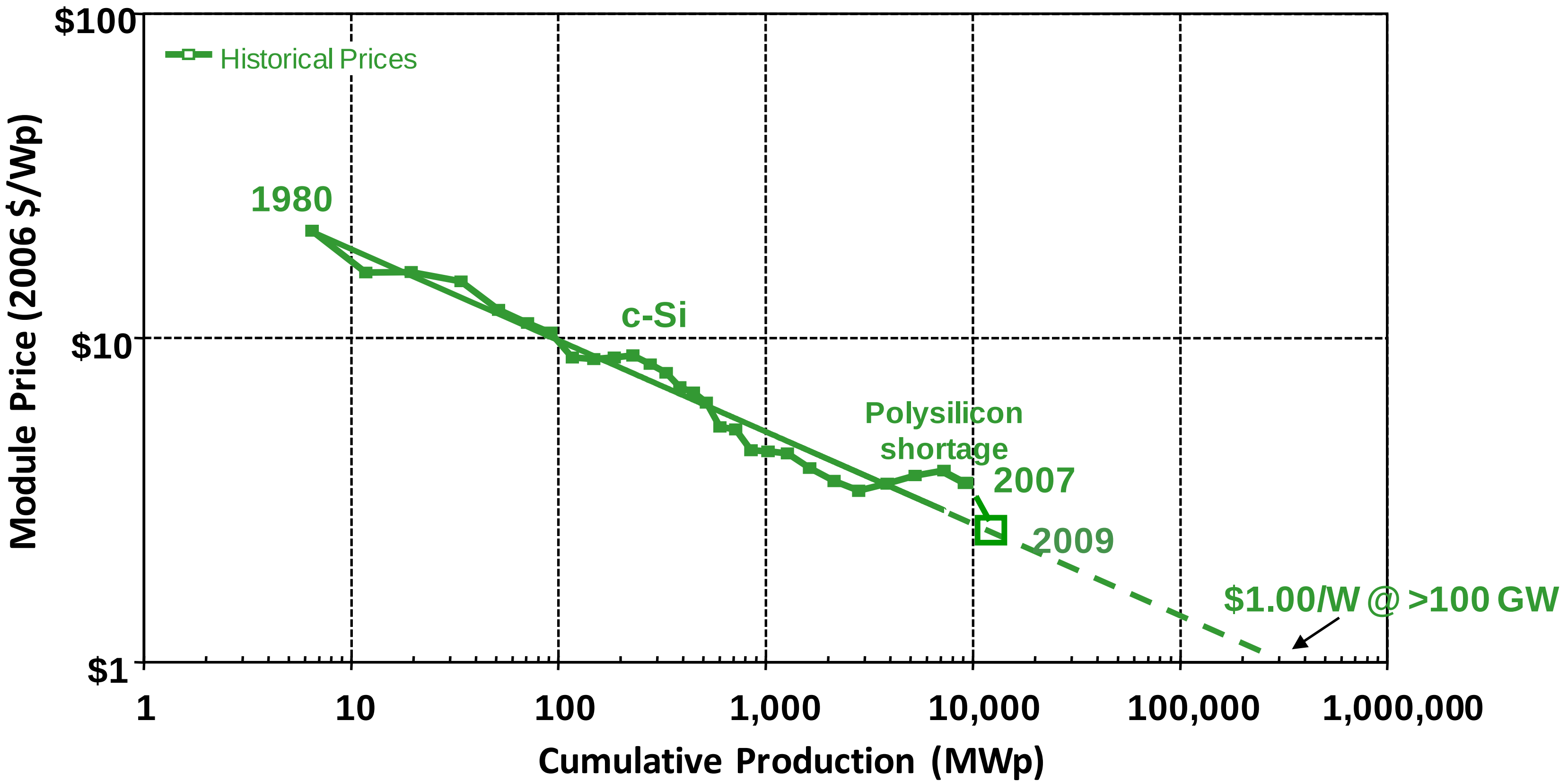
The PV Industry | Installed Capacity / Key Applications



SOURCE: Frost & Sullivan, EPIA

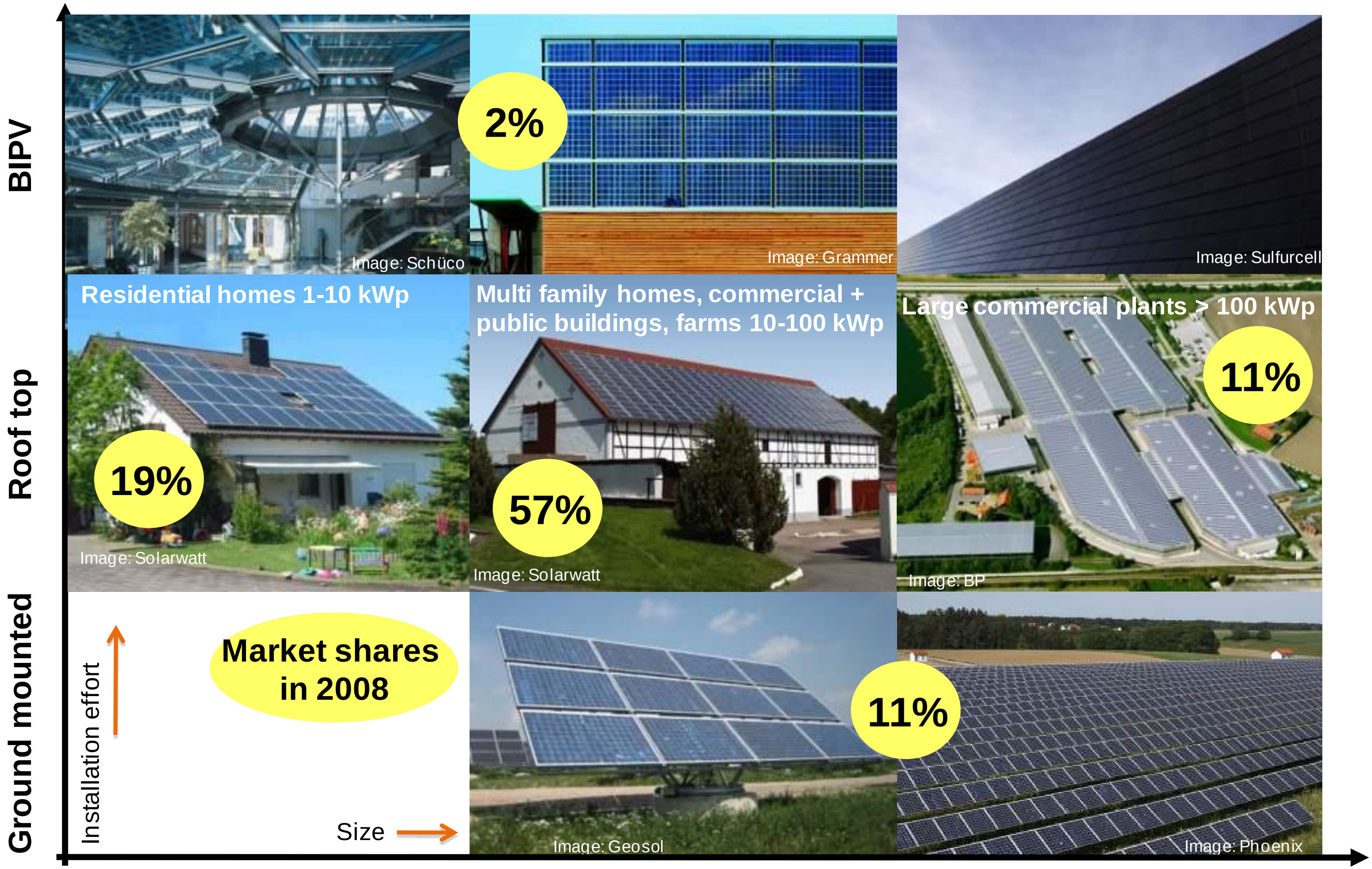
The PV Industry | Module Price Development in $/W

Mass Production and Technological Progress



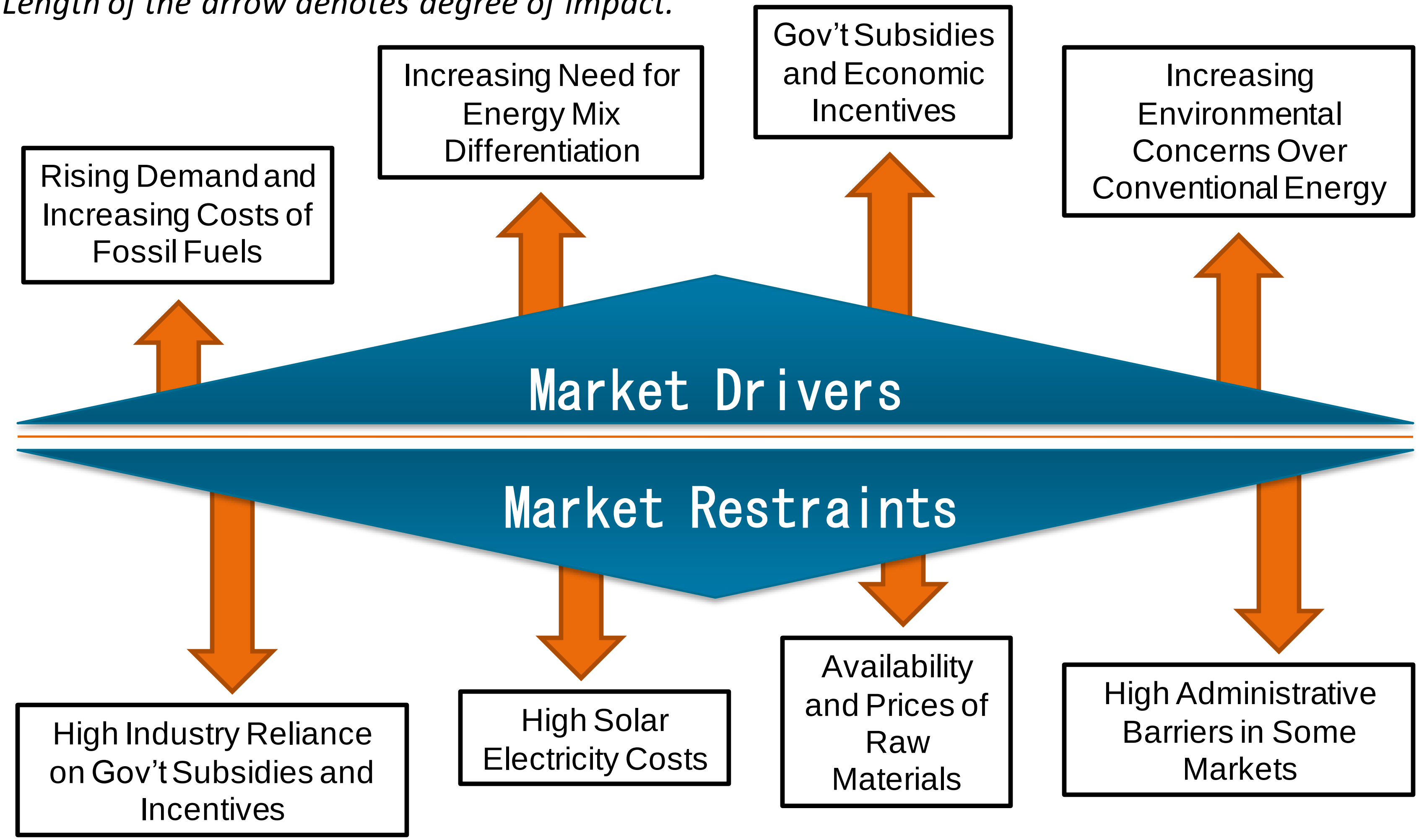
SOURCE: EPIA

Photovoltaic market segments in Germany



The PV Industry | Force Field Analysis (World, 2010)

Length of the arrow denotes degree of impact.



SOURCE: Frost & Sullivan

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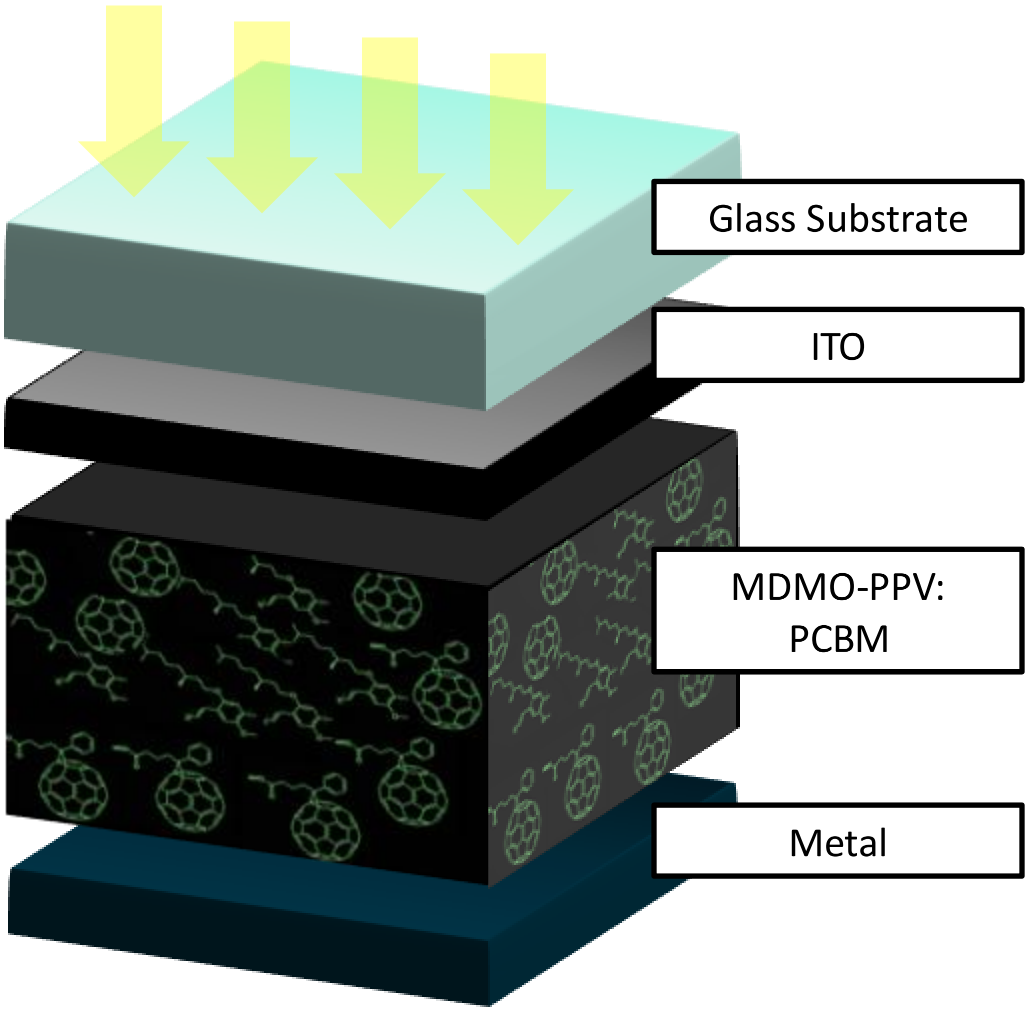
PV Technologies | Segmentation of Efficiencies

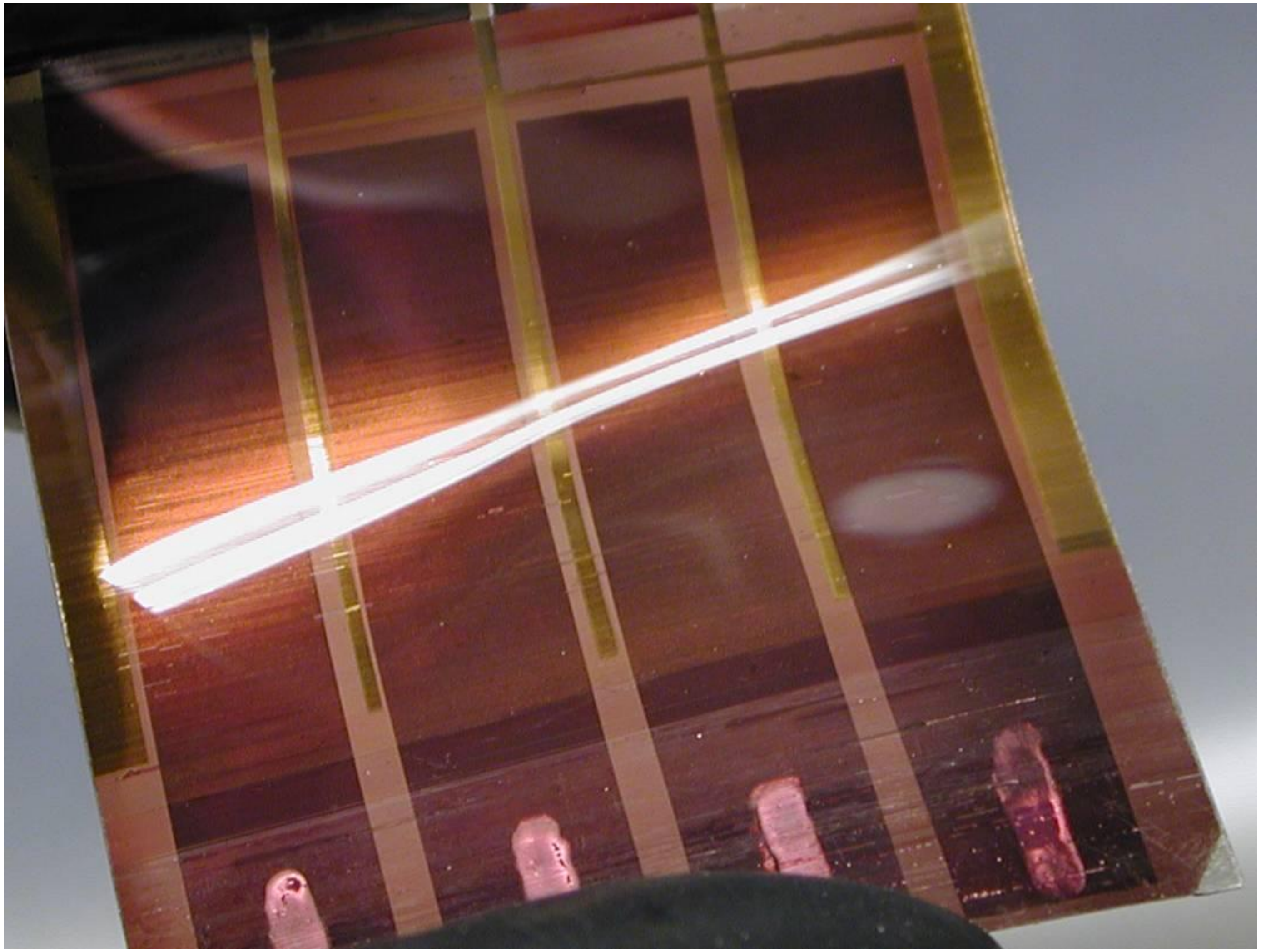
Major PV technologies and their typical conversion efficiencies.

TECHNOLOGY	CONVERSION EFFICIENCY
Organic, Dye, Nanostructure Cells	**1 - 5%**
Thin Film Cells (a-Si, Microcryst.-Si, CIS, CIGS, CdTe)	**6 - 11%**
mc-Si, umg-Si, Simple c-Si Cells	**14 - 18%**
High-Efficiency, Mainly c-Si Cells	**20 - 24%**
High-Efficiency III/V Tandem Cells for Concentrators With 25 - 30% Module Efficiency	**36 - 41.1%**

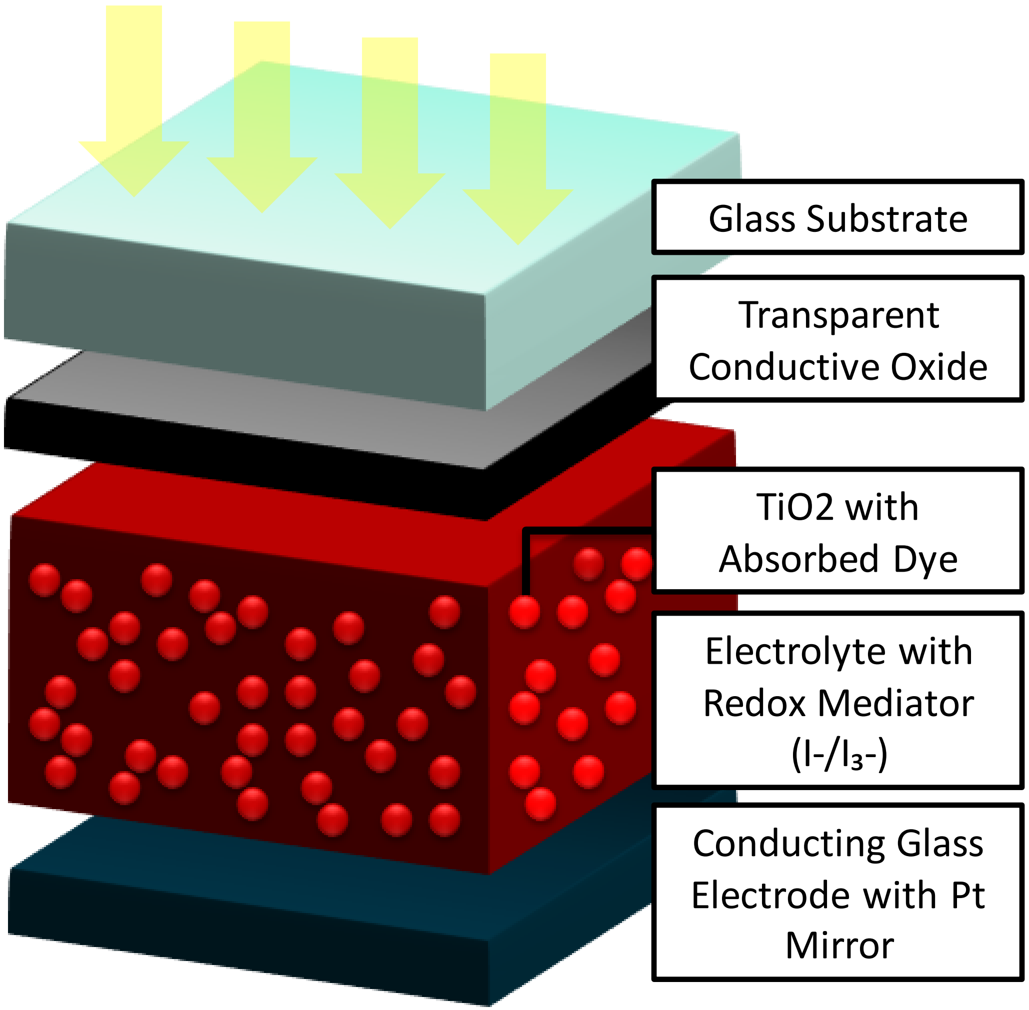
PV Technologies | Organic Solar Cells



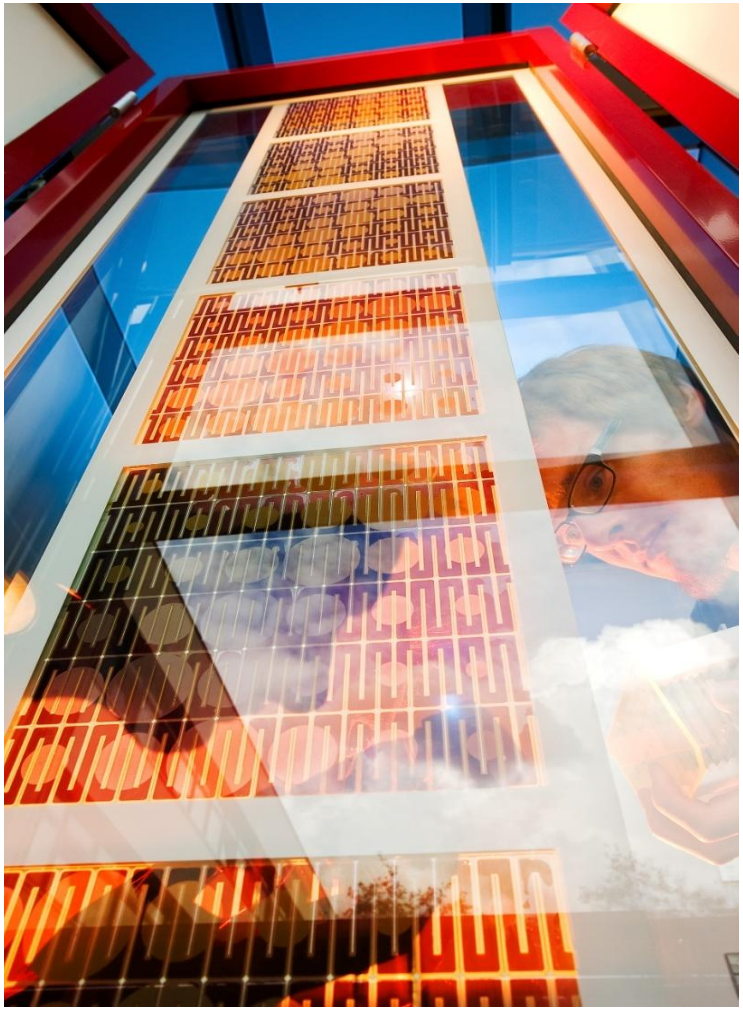
PV Technologies | Organic Solar Cells

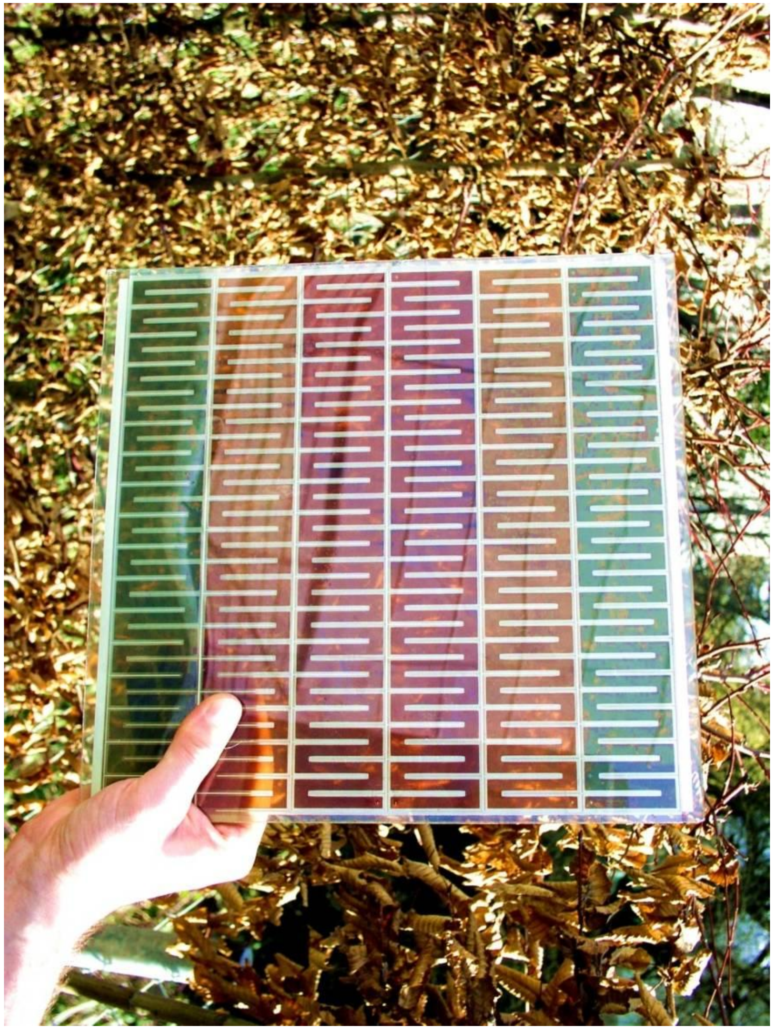


PV Technologies | Dye-Sensitized Solar Cells

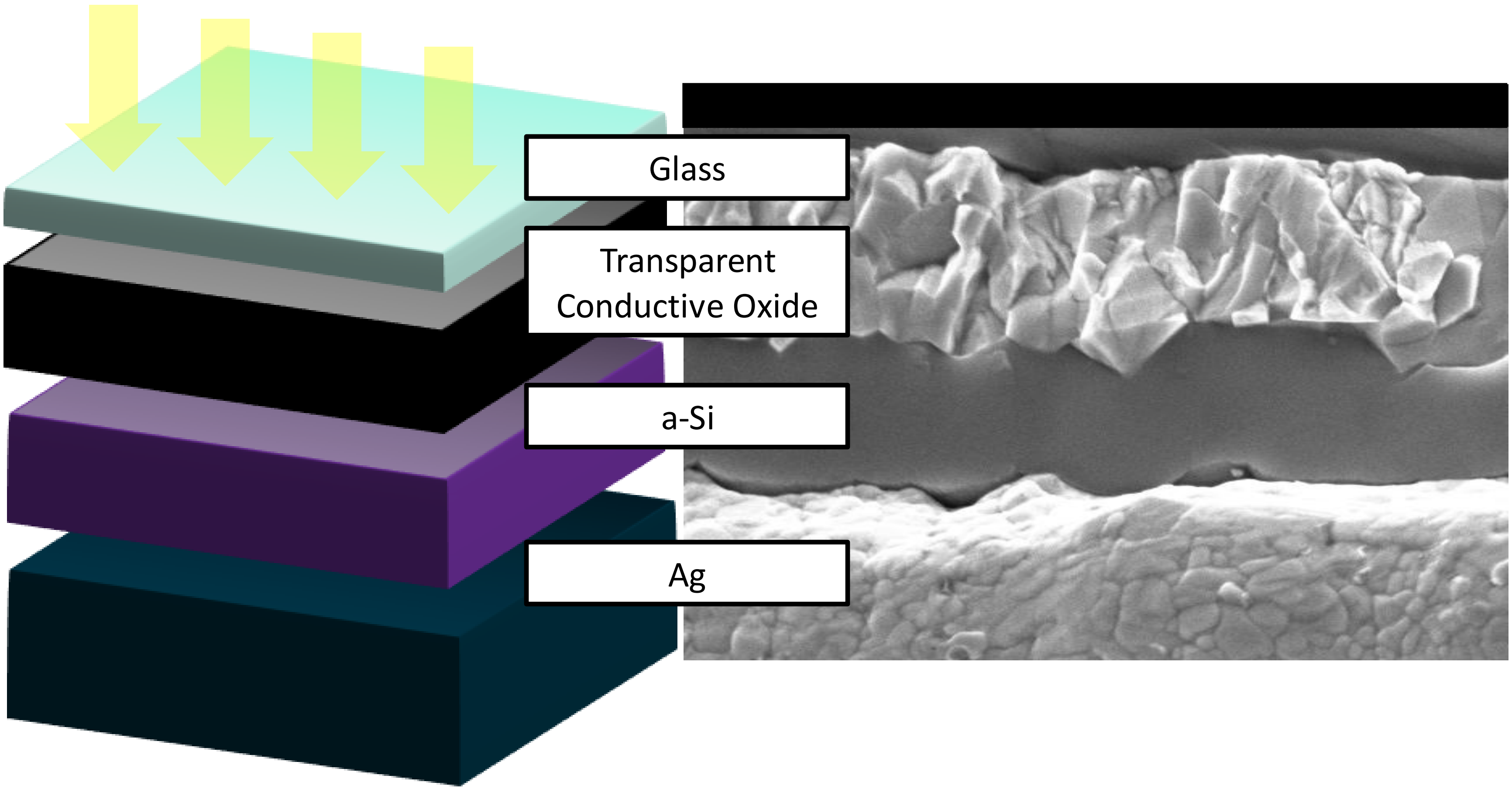


PV Technologies | Dye-Sensitized Solar Cells

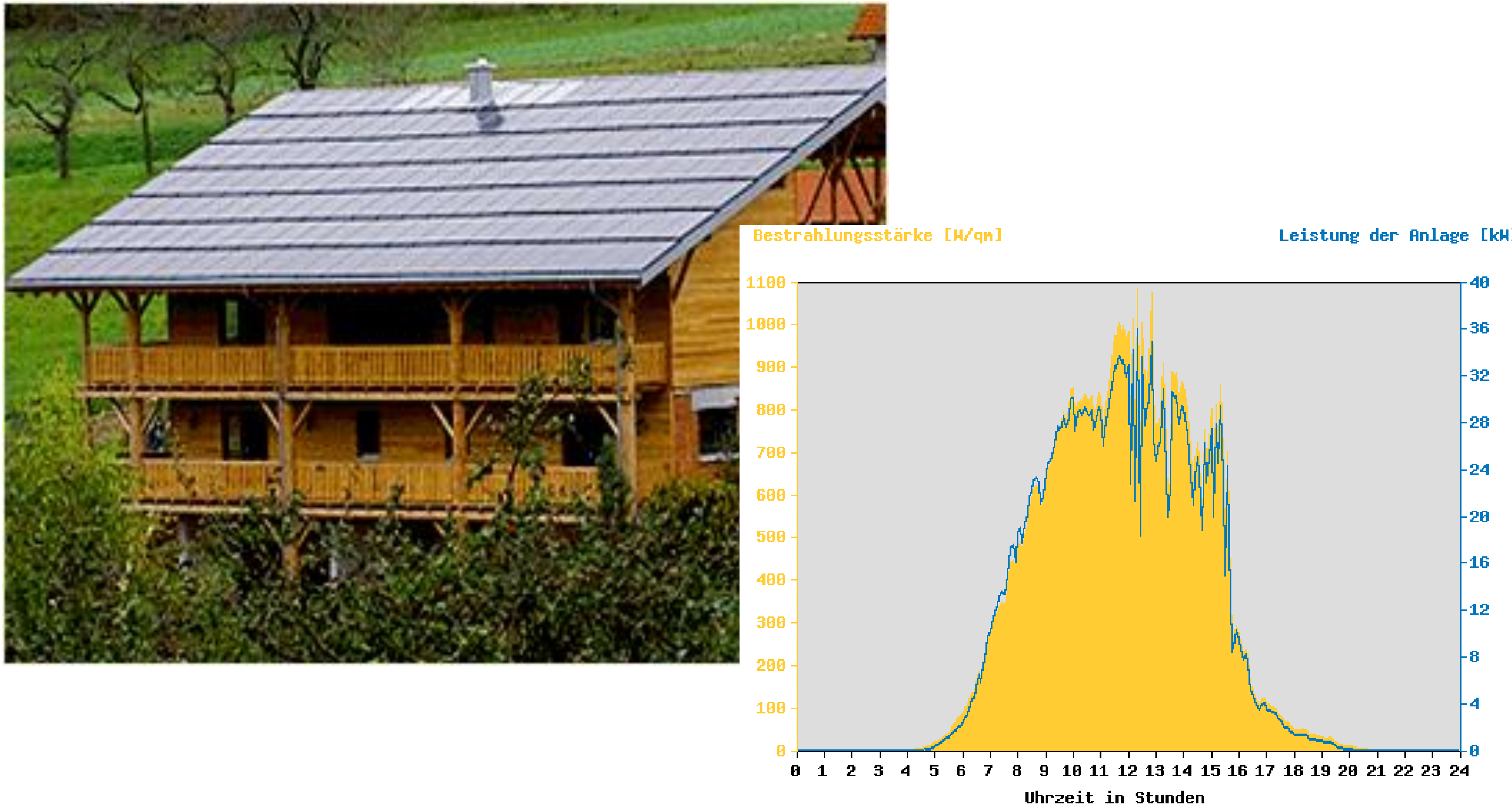




PV Technologies | Amorphous Silicon Solar Cells

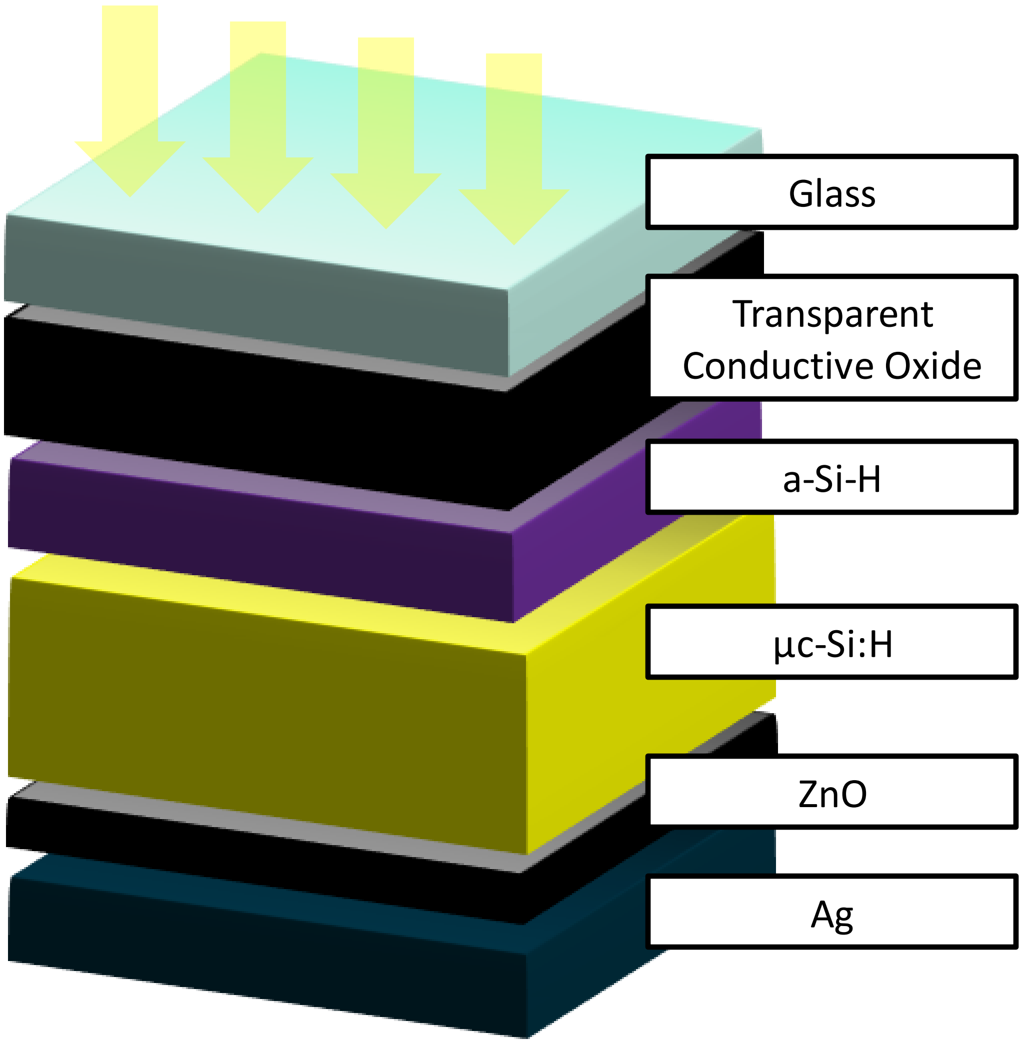


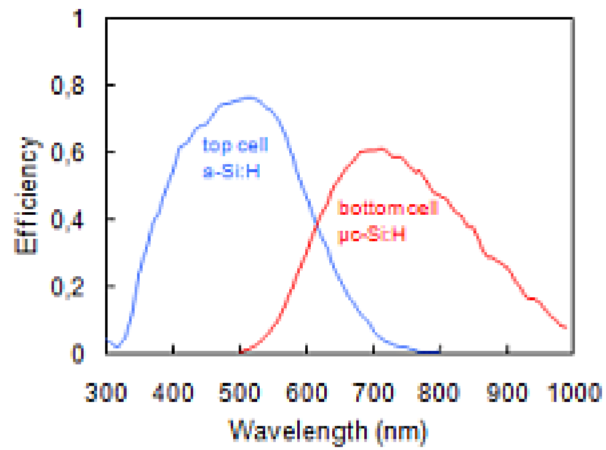
PV Technologies | Amorphous Silicon Solar Cells



SOURCE: Schott Solar

PV Technologies | Amorphous + Microcrystalline Silicon

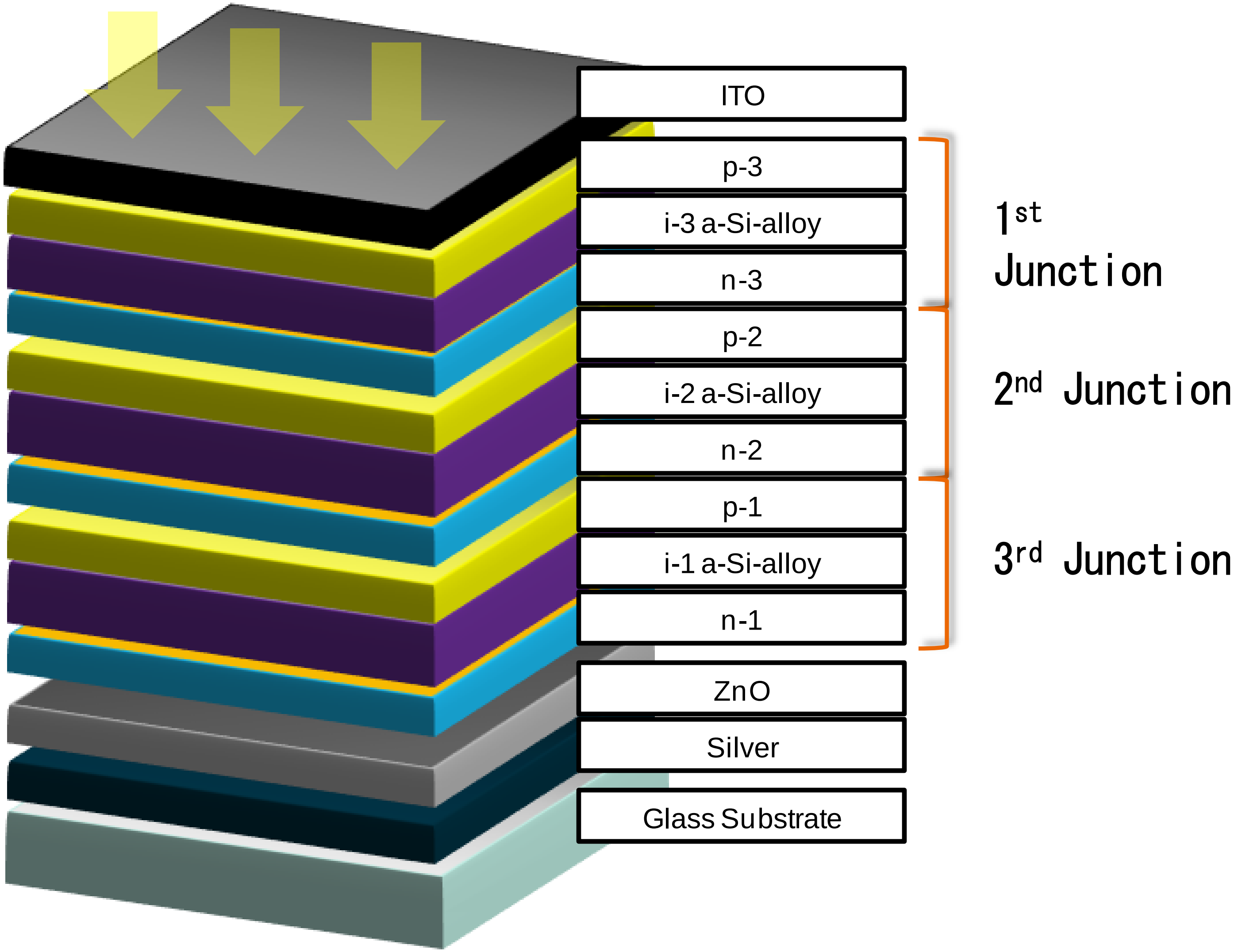




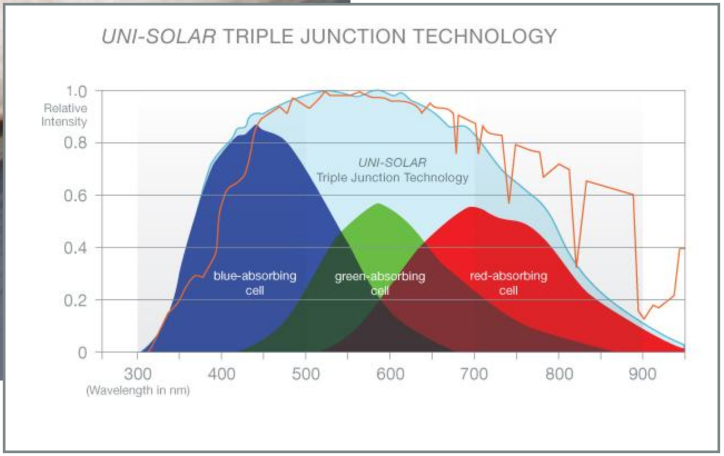
PV Technologies | Amorphous + Microcrystalline Silicon

SOURCE: AstroEnergy

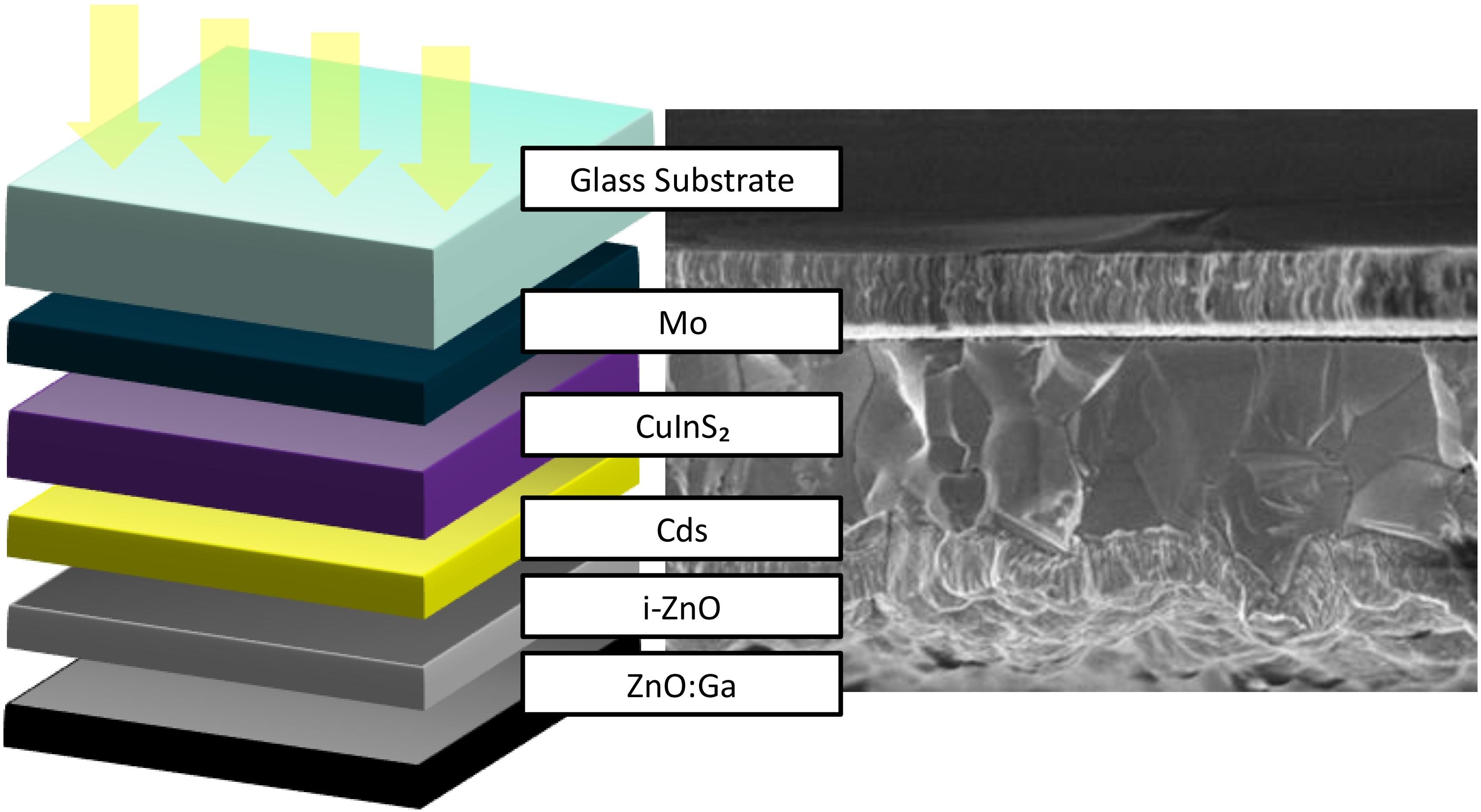
PV Technologies | Thin Film Multi-Junction Solar Cells



PV Technologies | Thin Film Multi-Junction Solar Cells

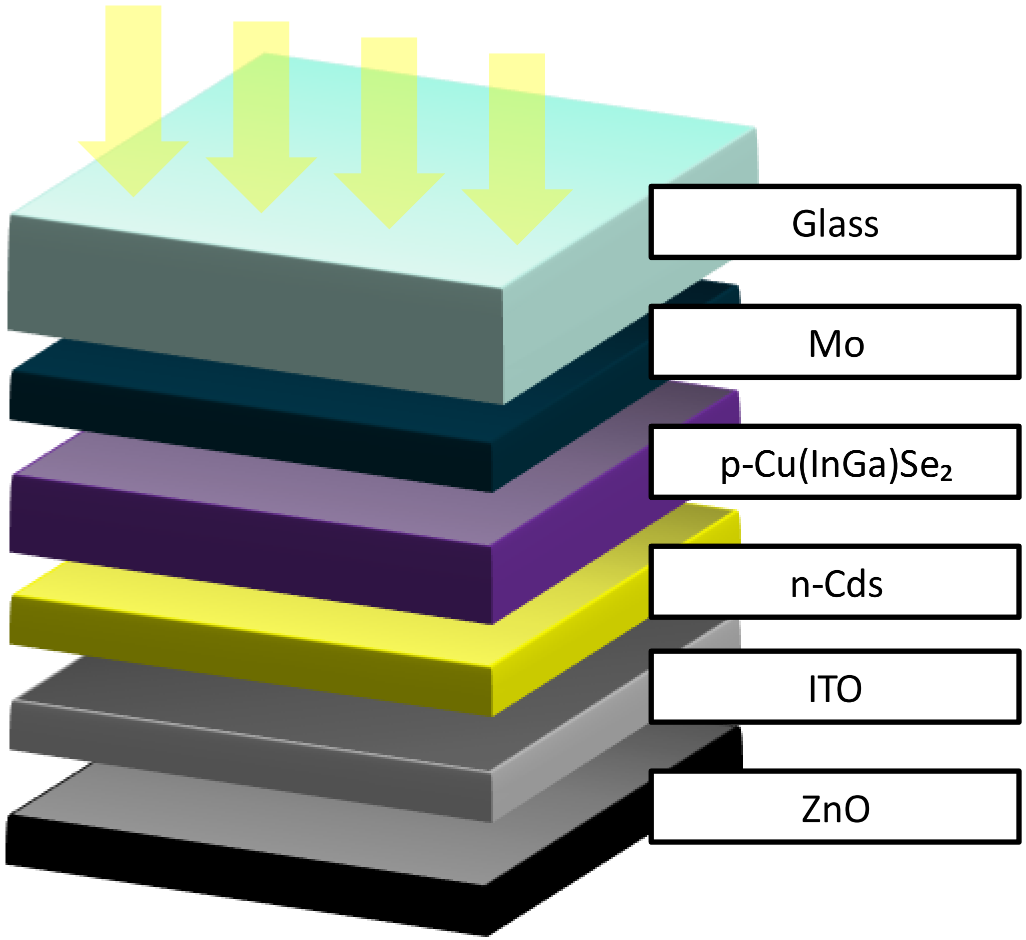


PV Technologies | CIS Solar Cells



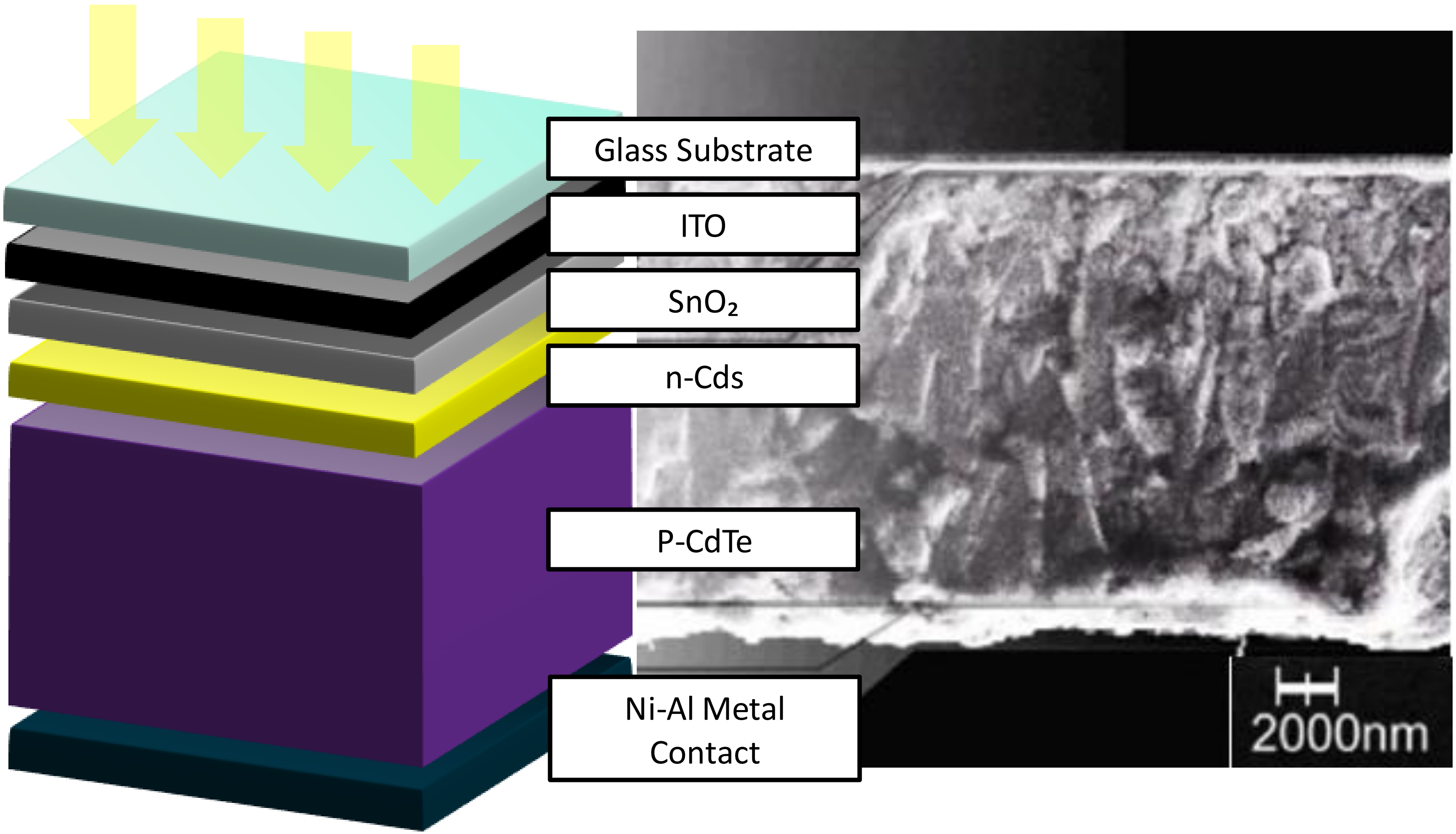
PV Technologies | CIS Solar Cells

PV Technologies | CIGS Solar Cells



PV Technologies | CIGS Solar Cells

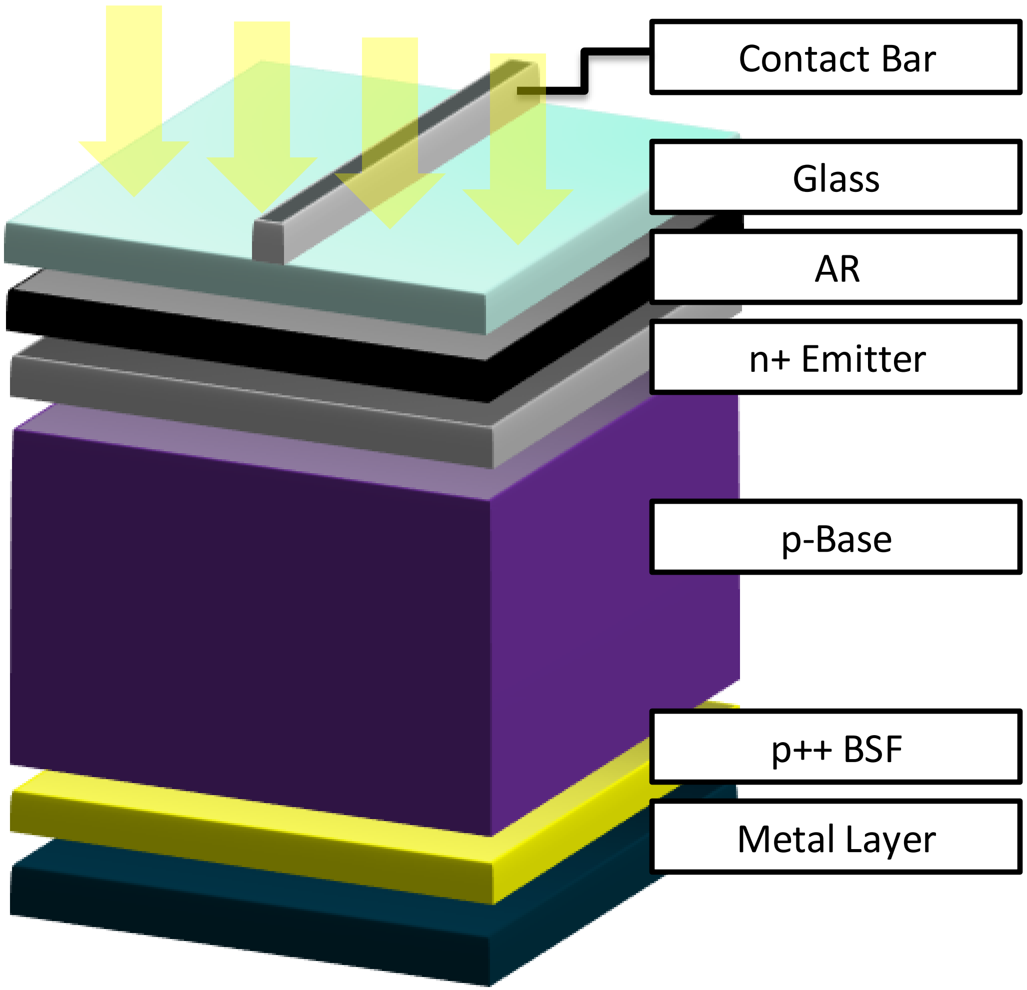
PV Technologies | CdTe Solar Cells



PV Technologies | CdTe Solar Cells

SOURCE: First Solar

PV Technologies | Mono- and Multicrystalline Silicon

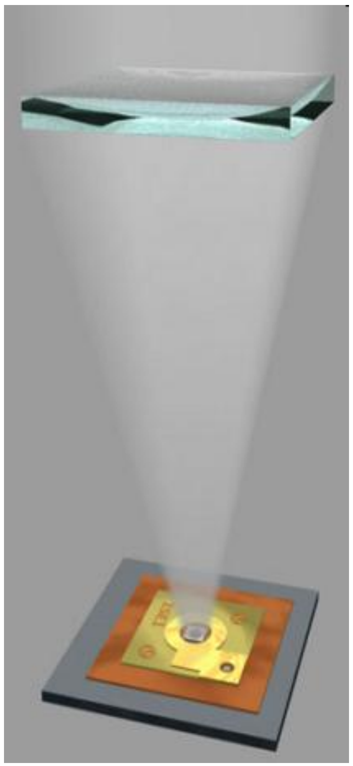


PV Technologies | Mono- and Multicrystalline Silicon

PV Technologies | Multi-Junction Solar Cells

Examples of multi-junction solar cells in concentrating systems.

CELL EFFICIENCY



Up to 41.1%

MODULE EFFICIENCY

28.5%

AC SYSTEM EFFICIENCY

23%

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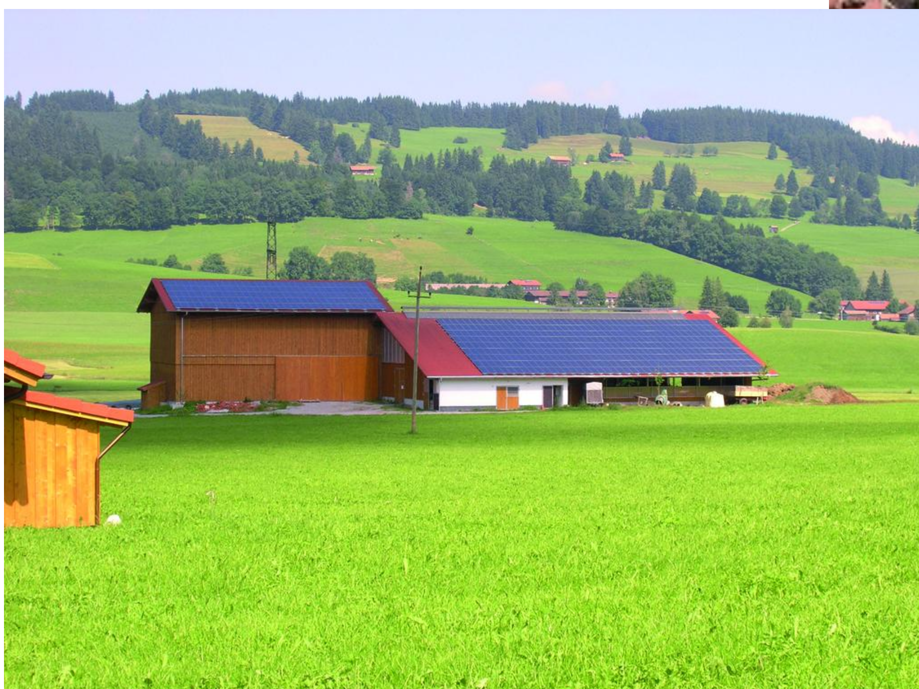
PV in Building Environments | Residential Rooftops



50% of residential rooftops with PV are found in agricultural areas.

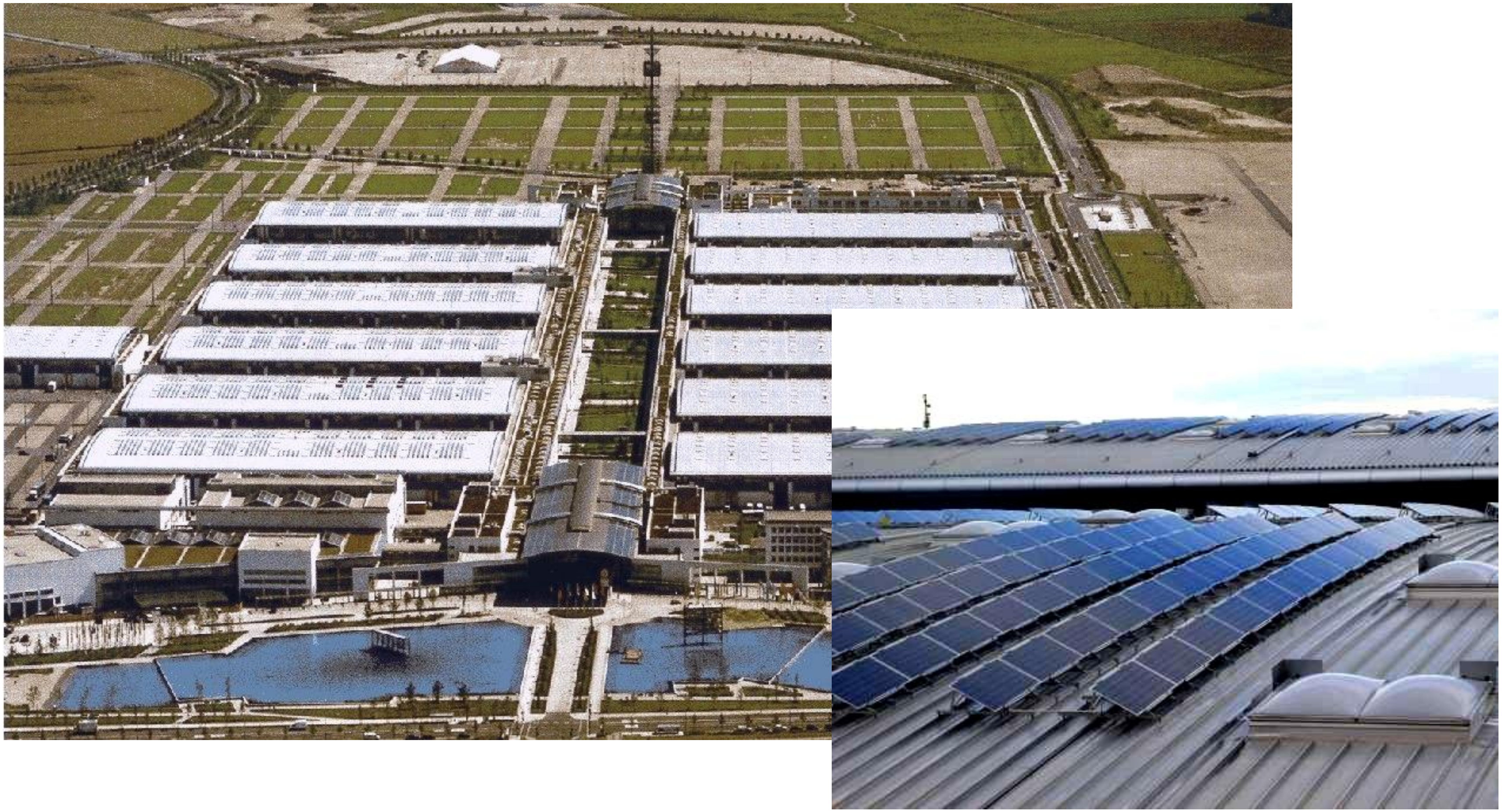
PV in Building Environments | Bundeskanzleramt | Berlin | D

SOURCE: BSW

PV in Building Environments | The Vatican | Vatican City

SOURCE: Reuters Images

PV in Building Environments | New Munich Trade Fair Center



SOURCE: IBF Ingenieure, energytech.at

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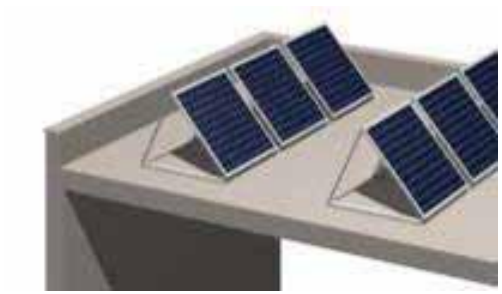
PV in the Building Envelope | Integration of Renewables

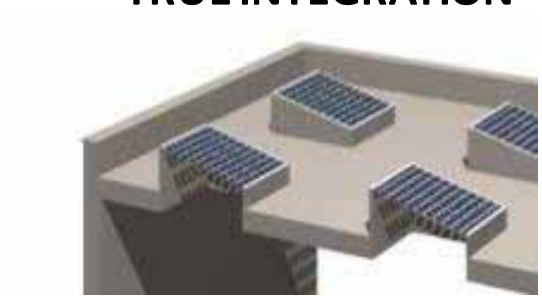
- Current use of renewables dominated by application in single-family houses: solar domestic hot water and PV systems
- Limited penetration in new non-residential buildings
- Almost no penetration in existing non-residential building stock
- Integration in façades especially necessary for high-rise buildings with small roof area

PV in the Building Envelope | Integration of Renewables

SIMPLE ADDITION



TRUE INTEGRATION



- Completely different requirements for "true integration" and "simple addition"
- True integration of renewables leads to multifunctional energy-gaining building envelopes
- At least one additional function required for "truly" integrated components
- "Integration" has strong aesthetic implications

SOURCE: ECN & BEAR Architects

PV in the Building Envelope | BIPV

BIPV is a multifunctional building component:

- Electricity generation
- Shading systems
- Weather protection
- Noise protection
- Heat insulation
- Sunlight modification

PV in the Building Envelope | BIPV | Examples

In this example, windows have been replaced with transparent a-Si-based thin film modules.

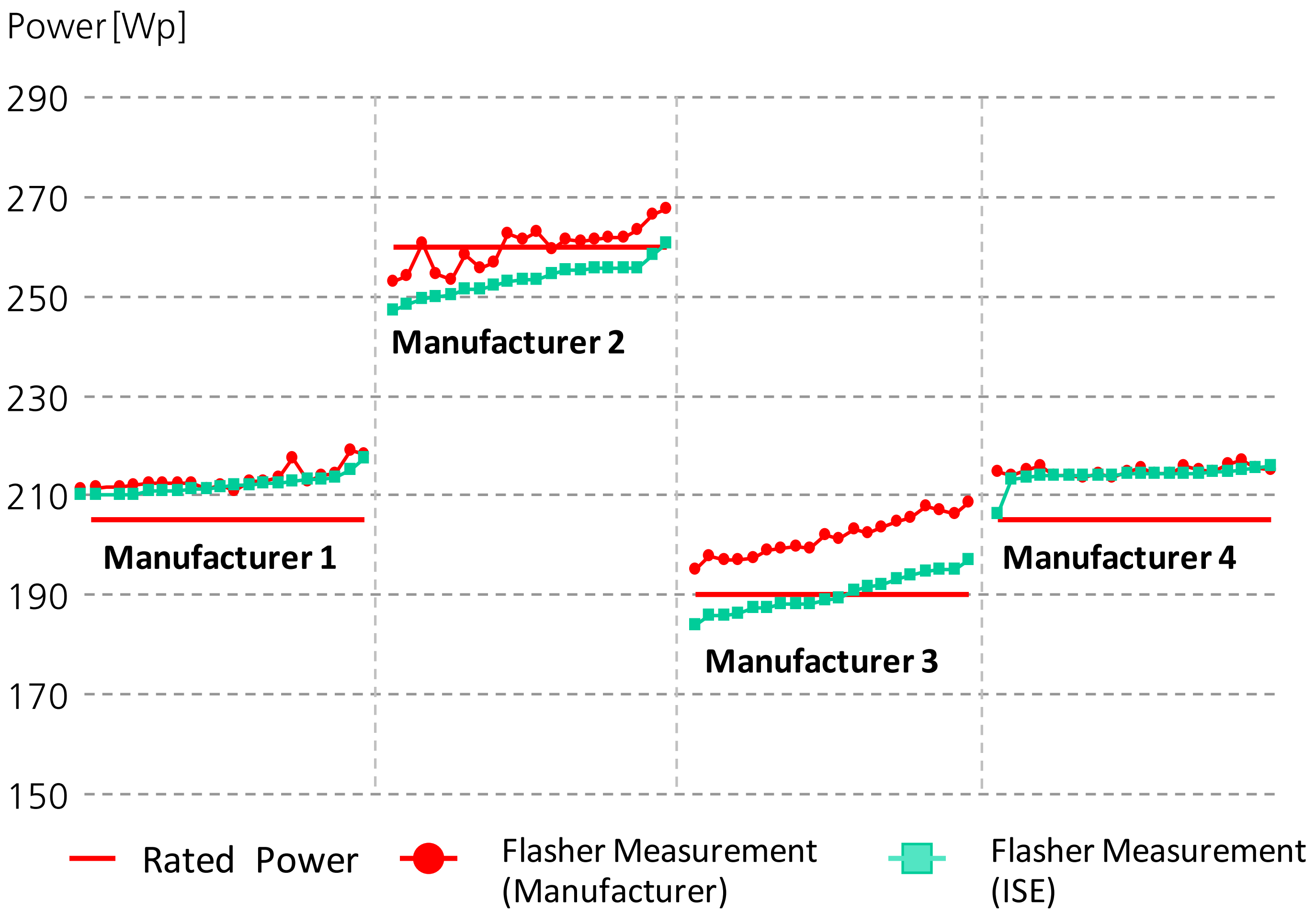
SOURCE: Schott Solar

PV in the Building Envelope | BIPV | Examples

PV in the Building Envelope | BIPV | Examples

PV in the Building Envelope | Performance Issues

Pmpp values of 4 different modules produced by 4 different manufacturers.



PV in the Building Envelope | Performance Issues

Sources of performance losses in solar modules.

ESG = Solar irradiation in kWh

η_{STC} = Solar generator‘s conversion efficiency

EPV_{USE} = Energy made available by inverter in kWh

$E_{SG} * \eta_{STC} = E_{NOMINAL}$	100%
Irradiation < 1000 W/m²	-3 to -5%
Module Temperature > 25°C	-2 to -6%
Inverter Losses	-5%
Other System Losses	-7%
EPV_{USE}	**82 to 77%**

PV in the Building Envelope | Performance Issues

An overview of module temperatures in building-integrated photovoltaic systems.

Ventilation	PV Module Temperature (°C)	
	Maximum Value*	Average Value
Unventilated	80 - 90	45 - 50
Minimal to Modest	60 - 75	35 - 40
Extensive	50 - 65	30 - 35

** Assumes a maximum room temperature of 40 C.*

SOURCE: "Die Performance Gebaudeintegrierter Photovoltaik (BIPV), Final Report", 6. EU Rahmenprogramm 2009

PV in the Building Envelope | Performance Issues

The larger the number of module interconnects, the higher the risk of corrosion-related system failure.

SOURCE: Solé Power

PV in the Building Envelope | Performance Issues

Counteracting the output loss created by seasonal shading requires specialised module designs such as these.

PV in the Building Envelope | The Good News

- Statistical data from Germany's Thousand Roof Program (1985 – 86)
- Modules show less than 2% performance degradation after 20 years
- No evidence of continuous degradation in crystalline silicon PV modules

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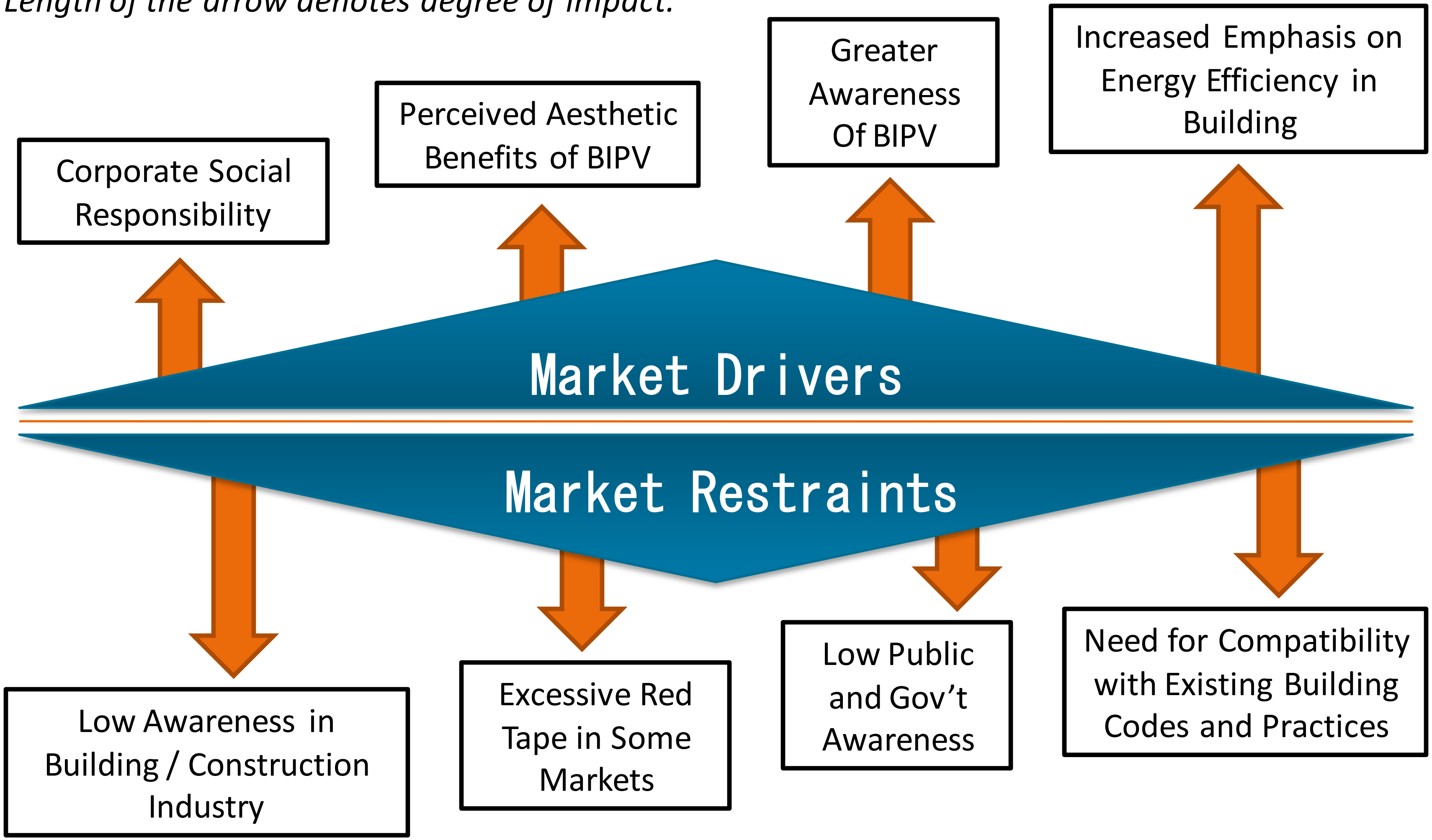
BIPV Markets | Drivers and Restraints Specific to BIPV Markets

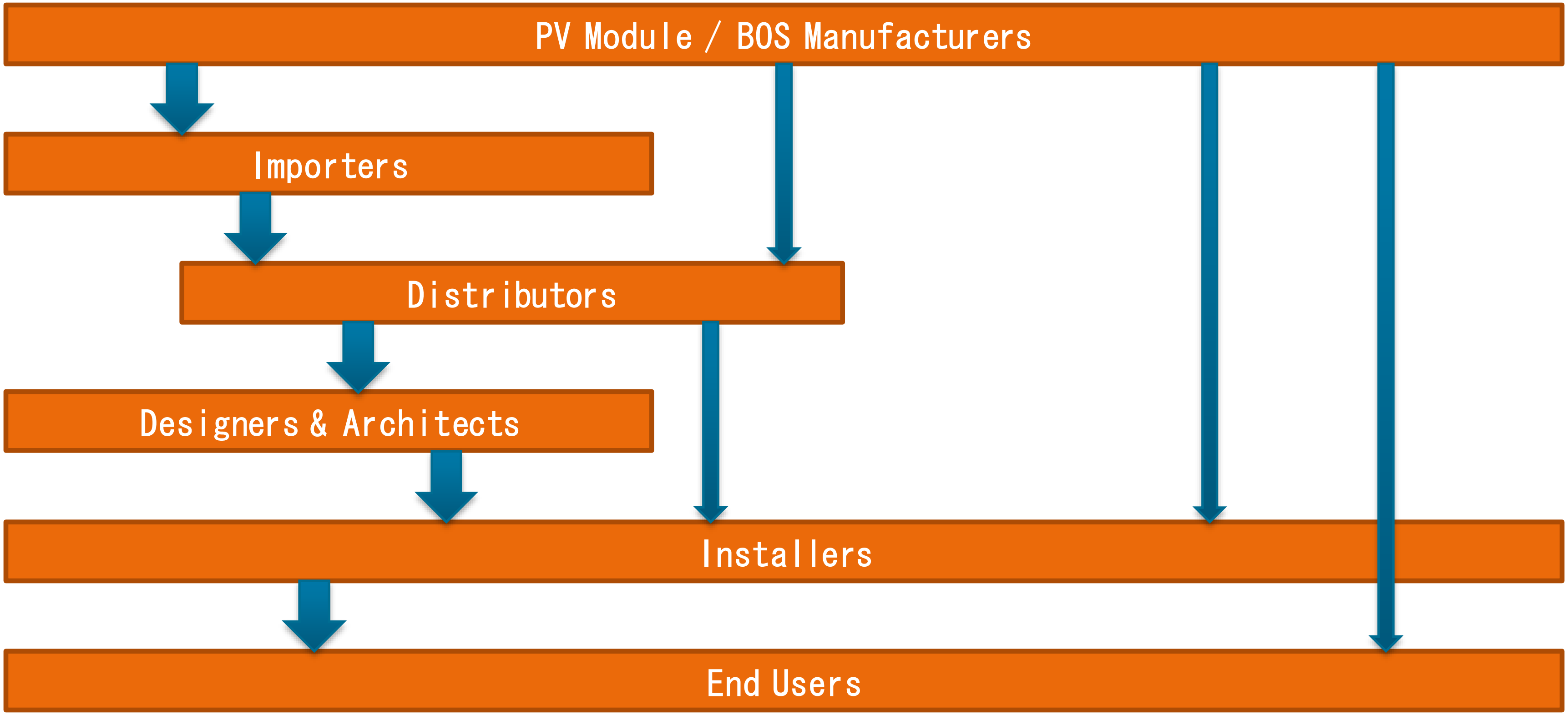
Length of the arrow denotes degree of impact.



SOURCE: Frost & Sullivan

BIPV Markets | Drivers and Restraints Specific to BIPV Markets

The BIPV value chain. Width of the arrow denotes importance of channel.



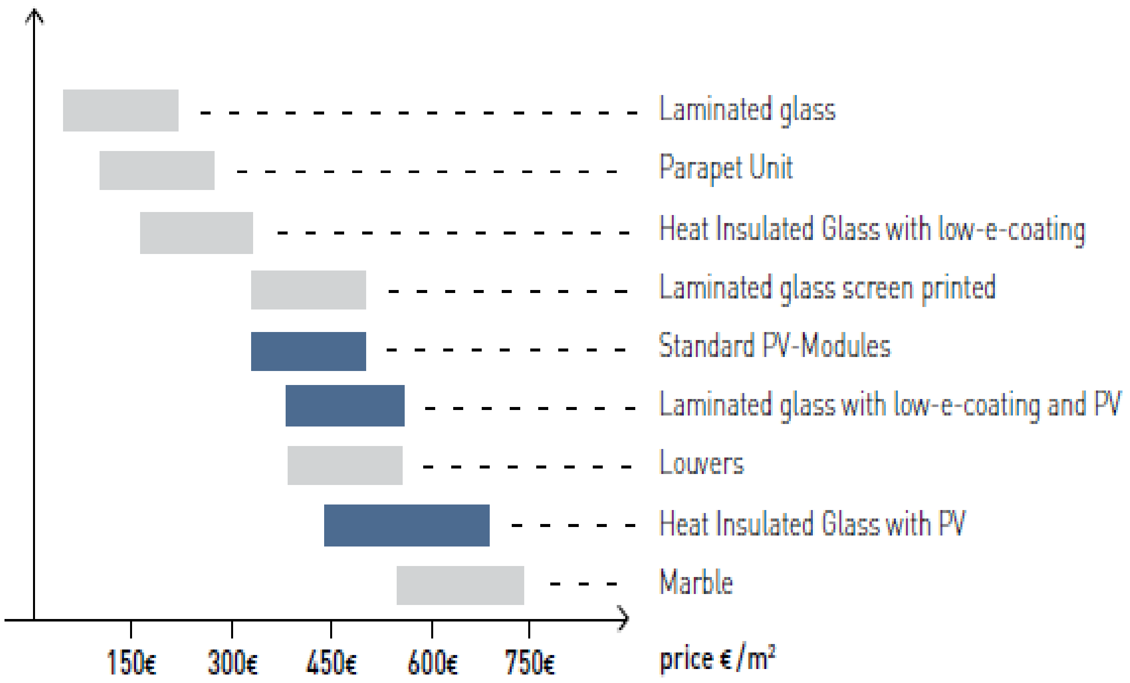
The BIPV market involves more participants from other industries than standard PV – deployment is slower as a result.

SOURCE: Frost & Sullivan

BIPV Markets | Drivers and Restraints Specific to BIPV Markets

- Building industry is primary customer for BIPV
- Components have to follow the characteristics of the building market as much as possible
- Planning and installation is a considerable cost factor for integrated components
- Costs have to be taken into consideration when developing new technologies
- True building integration is “high tech”

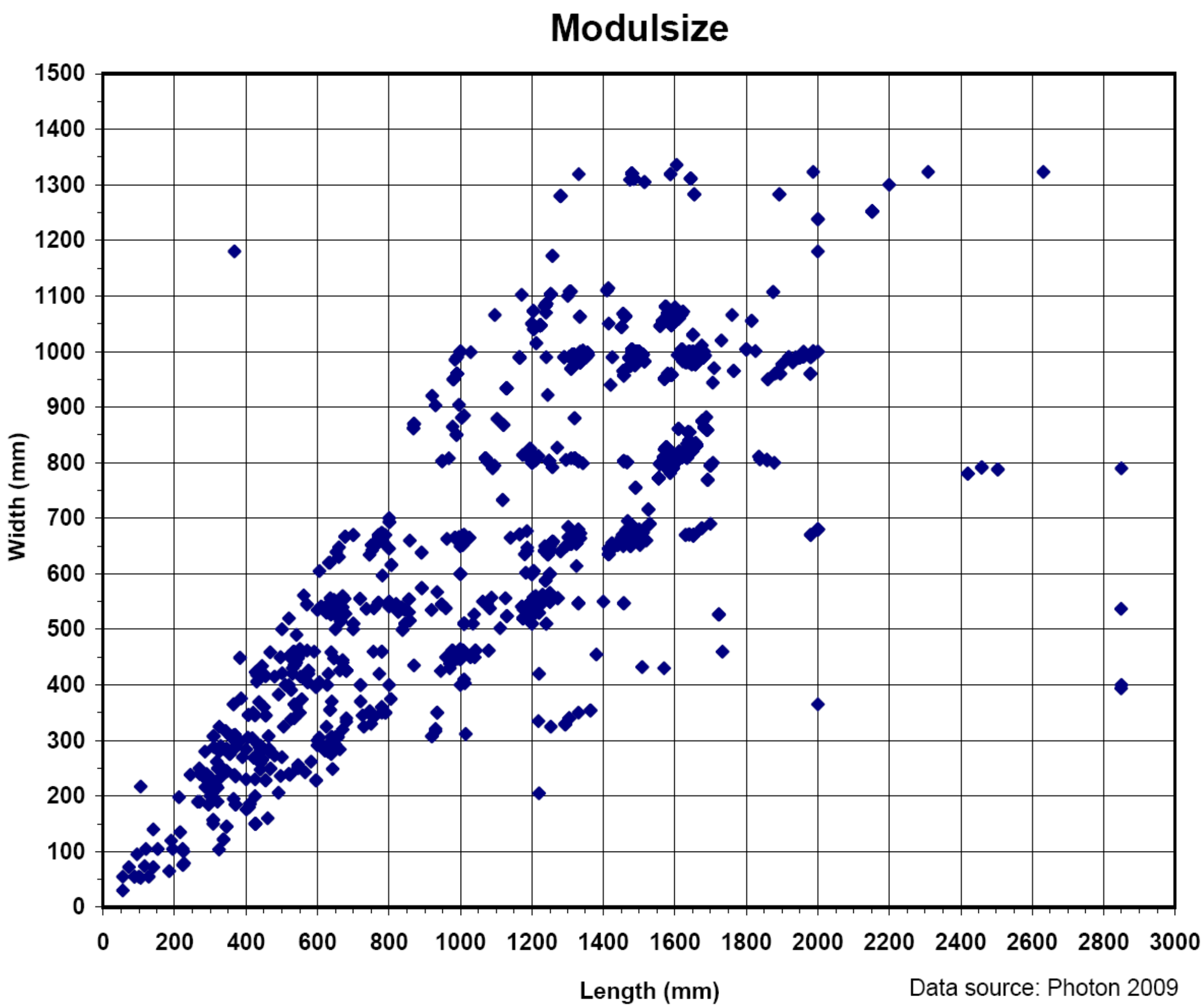
BIPV Markets | Drivers and Restraints Specific to BIPV Markets



- BIPV is still too expensive for mass-market adoption
- The added value of BIPV as a multifunctional building component is still unknown
- Solar modules are priced in $ / Wp; pricing in $ / m² is more useful to architects

BIPV Markets | Drivers and Restraints Specific to BIPV Markets

The figure below demonstrates the lack of uniform size and standards in PV modules.



BIPV Markets | Drivers and Restraints Specific to BIPV Markets

Examples of perception barriers in BIPV markets.

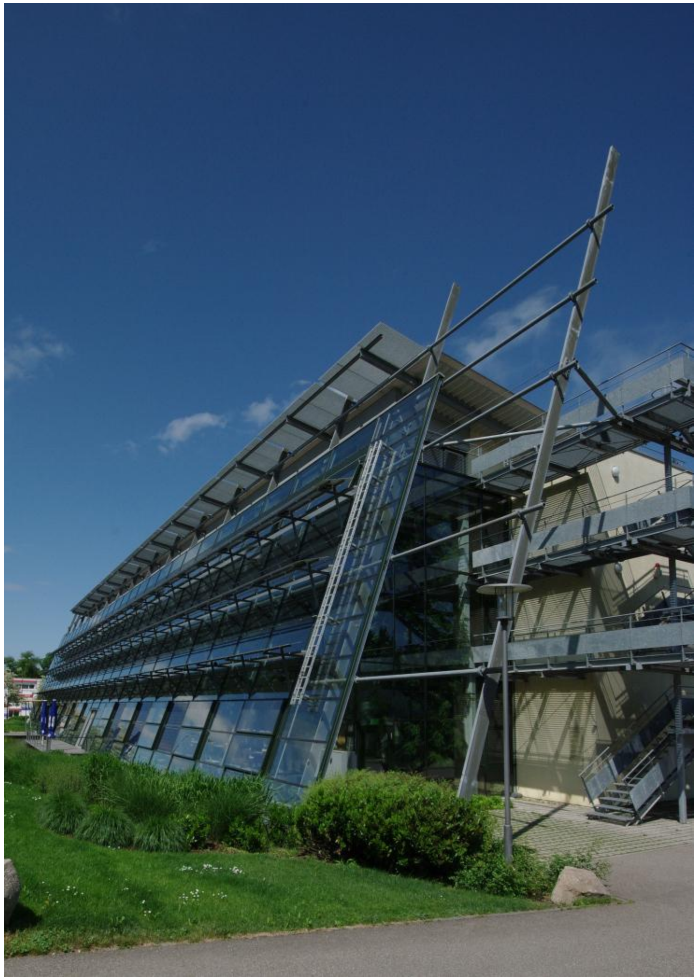
Lack of **awareness** of the increasing role electricity consumption plays in determining the value of buildings

Lack of **clear information** regarding the advantages of building-integrated PV among both architects and clients

Some architects feel that BIPV lacks **aesthetic value** and could negatively impact a building’s market worth

BIPV Markets | Drivers and Restraints Specific to BIPV Markets

Picture: Solar Fabrik, Freiburg, Germany



- Building codes have to be harmonised (e.g., requirements on snow loads)
- Lower price efficiency of façade installations has to be balanced by other economic benefits
- Training of architects, craftsmen, and planners is particularly important

BIPV Markets | Social and Cultural Differences

The tradeoff between cost and durability.

TILED ROOF

LIFETIME	80 YEARS
Costs	35 – 50 €/m²
LIFETIME COST	**35 – 50 €/m²**

TAR PAPER ROOFING

LIFETIME	20 YEARS
Costs - Tar	10 – 15 €/m²
Costs - Sheathing	10 – 15 €/m²
LIFETIME COST	**50 – 75 €/m²**

BIPV Markets | Case Studies | Japan

What are the factors behind Japan's success?

- Strong government policy and support (Kyoto Protocol)
- Japan aims to cover nearly 50% of its residential power load from BIPV systems by 2030
- High cost of grid electricity
- Due to the scarcity of open tracts of land in the country, no installation of PV systems possible (indirect benefit for BIPV in urban areas)
- Large-scale commercialization of BIPV Systems in Japan means reduced costs
- Excellent rapport between local manufacturers, real estate project developers and architects (no information, education or training necessary)

BIPV Markets | Case Studies | Japan

- Nearly 13 major manufactures in Japan who focus on BIPV
- Robust R&D programs to study BIPV’s feasibility and applications
- Other Asian countries still import BIPV systems
- Japan dominates global production of PV systems – accounts for over 40% of worldwide production

BIPV Markets | Case Studies | Japan

Example: Sekisui Chemical

- One of Japan's largest prefabricated house vendors
- Provides PV systems and heat pumps as standard (cost advantage through large-scale production = more equipment for the houses, not cheaper prices)
- Financing offer: higher-performance PV systems mean lower interest rates on credit (together with Sumitomo Bank, Japan)
- **BIPV sales would be much lower if prefabricated house vendors in Japan did not use these strategies**

BIPV Markets | Case Studies | South Korea and Malaysia

- Offer immediate promise for BIPV
- Demand for BIPV systems in South Korea is driven by government-mandated targets, solar subsidy programs and favorable availability of sunlight
- South Korean law: 5% of the aggregate cost of public buildings with more than 9840ft^2 (3000m^2) must be spent on renewable energies
- The Malaysia Energy Centre (Pusat Tenaga Malaysia) has promoted BIPV aggressively since 2005 (ZEO Building – Zero Energy Office)
- In 2004, the Global Environment Facility, together with the United Nations Development Program, had approved a grant of nearly $4.7 million to support BIPV development in Malaysia
- Total installed BIPV capacity as of 2007 has been valued at 596.3 kW

BIPV Markets | Case Studies | France

- BIPV-specific feed-in tariffs introduced in 2006
- France's BIPV market second-largest in Europe as of the end of 2007
- Supportive laws prepare French BIPV sector for further expansion:
  - Thermal code (RT2005) calling for minimum energetic performance
  - RT2012: New buildings' consumption must be reduced by 50 kW/year/m² as of 2012
- By 2020, all new buildings in France will be plus energy buildings

BIPV Markets | EU Regulations

- Buildings produce 40% of all CO_2 emissions in EU25
- Decision in Europe (taken end of 2010): all new buildings after 2020 have to be net-zero
- Use of renewables has to be increased, especially in large non-residential buildings
- Small roof area means roof cannot be the only source of energy – façade must also be used
- Façades will be truely building i integrated
- BIPV driver

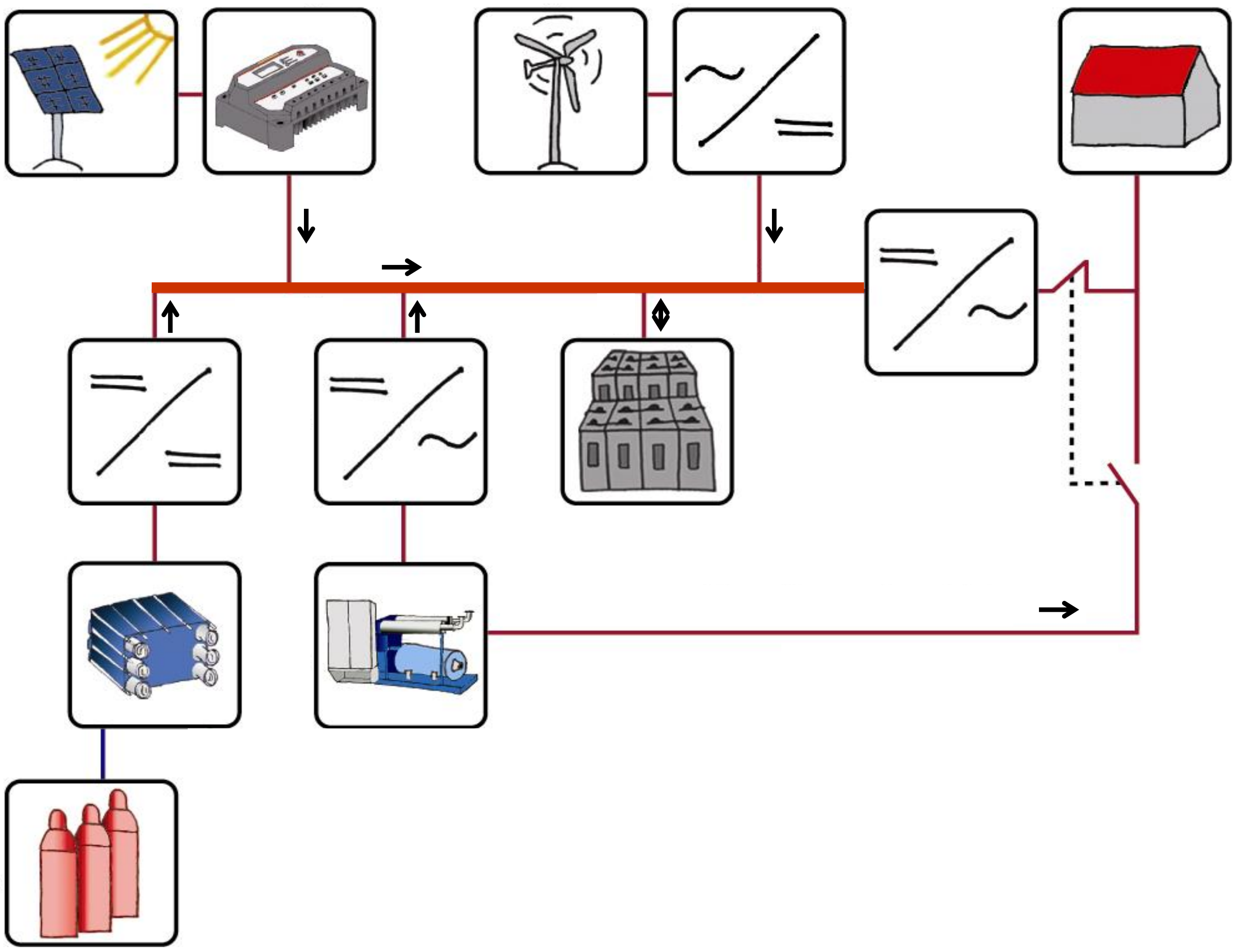
SOURCE: Sonnenkraft, fabi architekten, Hochschule Regensburg, Fraunhofer ISE

BIPV Markets | Rappenecker Hof | Black Forest | D

- Earliest BIPV system in Germany
  (off-grid system)
- House constructed in 1662
- Renovated in 1987
- Modules still in spec as of 2010

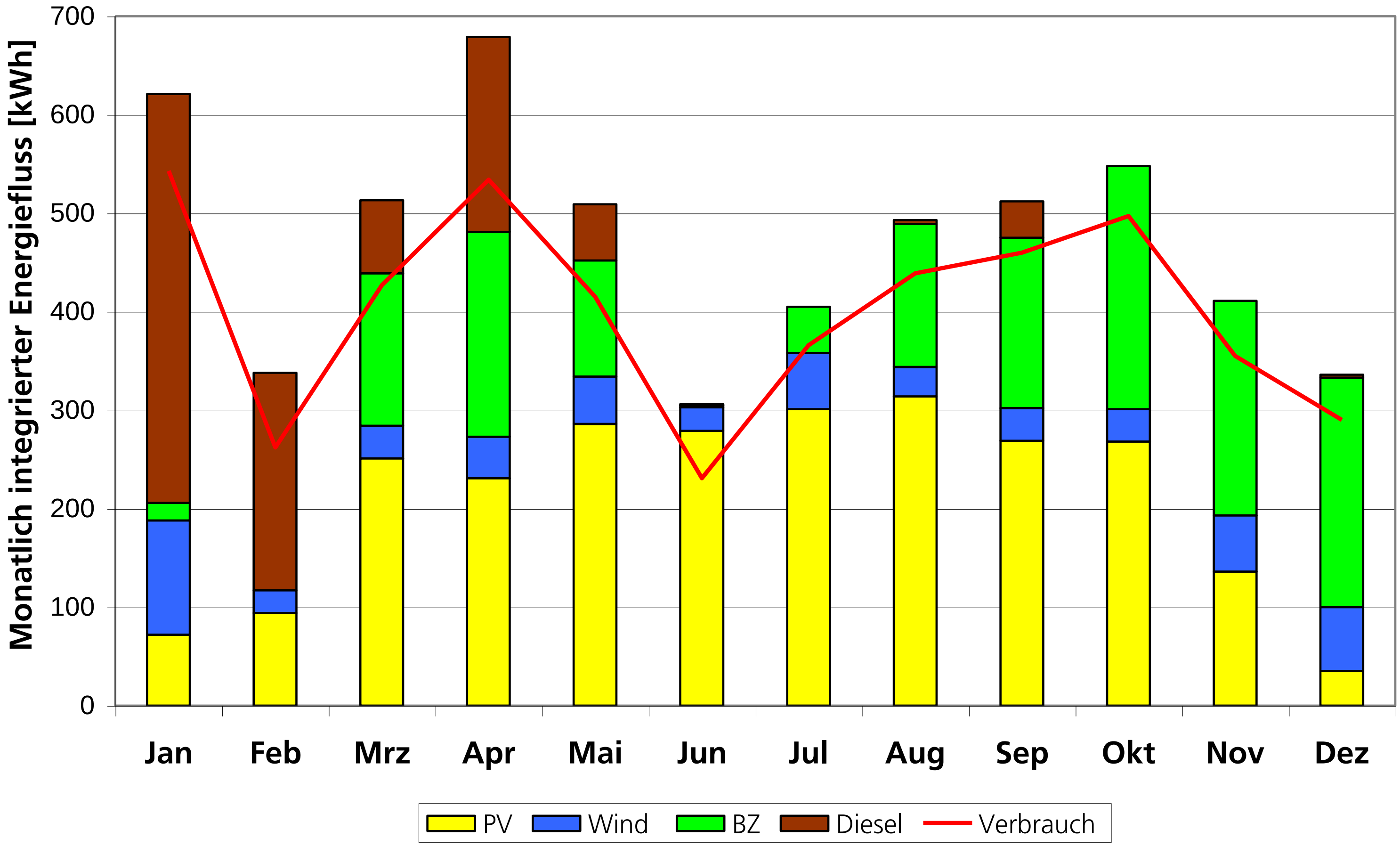
BIPV Markets | Rappenecker Hof | Black Forest | D

An overview of power generation systems at Rappenecker Hof.



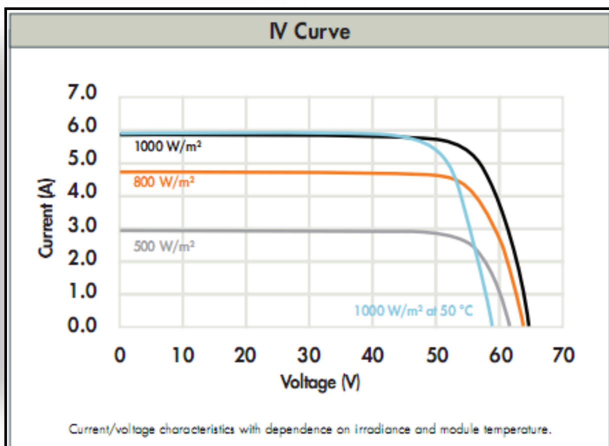
BIPV Markets | Rappenecker Hof | Black Forest | D

Energy production and consumption at Rappenecker Hof in 2005.



BIPV Markets | Solar Decathlon 2009: Team Germany

BIPV Markets | Solar Decathlon 2009: Team Germany



Roof: Sunpower 300 Solar Panel

- Cell: Monocrystalline
- Efficiency: 18.4%
- Peak Power (Panel): 300 Wp
- 1560 x 105 mm
- Module Price: $4.26/W

Façade: Wuerth Solar WSG00xx

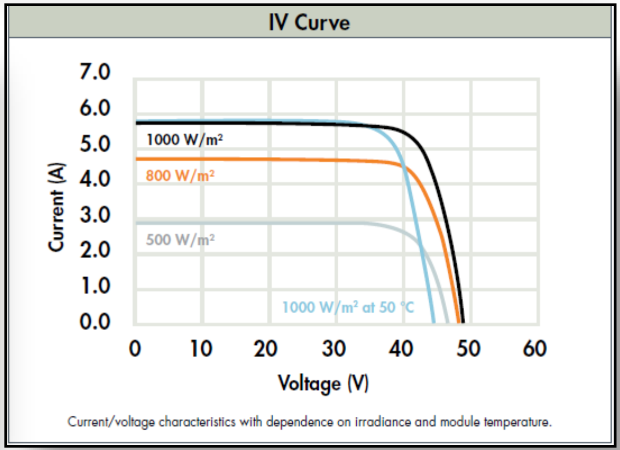
- Cell: CIS (good for diffuse light)
- Efficiency: ~10%
- Peak Power (Panel): 35 Wp
- 300x1200 mm
- Module Price: $5.55/Wp

Features

- Entire envelope is BIPV
- Solar louvers (shade & power) adjust automatically to face the sun

BIPV Markets | Solar Decathlon 2009: University of Illinois

BIPV Markets | Solar Decathlon 2009: University of Illinois



Roof

- Cell: Monocrystalline
- Sunpower 225 Solar Panel
- 18.1% Efficiency
- Peak Power (Panel): 225Wp
- 20 panels (4.5 kWp) installed
- 1560x800mm

Solar Electricity Production

- 11-12,000 kWh/yr

Features

- Uniform appearance: all black cells + back contact, fully covers roof
- High efficiency

BIPV Markets | Solar Decathlon 2009: Team Spain

BIPV Markets | Solar Decathlon 2009: Team Spain


Roof: Sunpower 220 Panels

- Cell: Monocrystalline
- Efficiency: 17.7%
- Peak Power (Panel): 220 Wp
- 1560 x 800 mm
- 50 Panels (11 kWp)
- Roof is also a dual-axis tracking system

Façade: SILIKEN

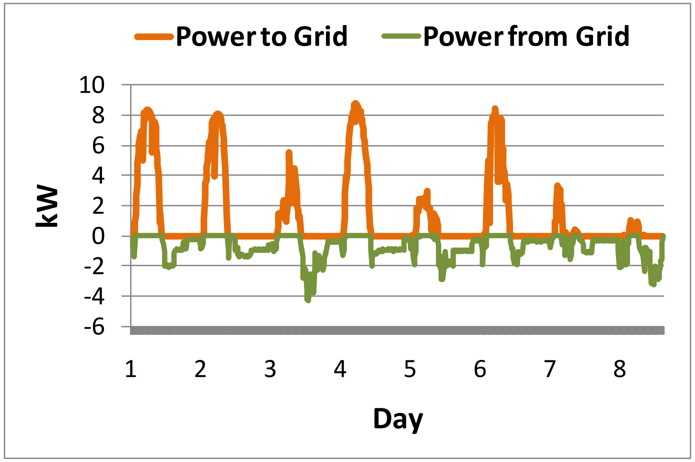
- Cell: Polycrystalline
- Peak Power (Panel): 90 W
- 50 Modules in Façade (4.3 kW)

Features

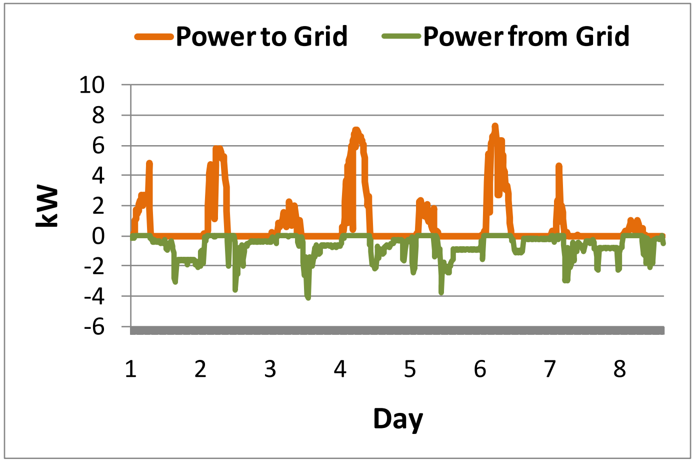
- PV laminated in glass and integrated within vertical glass façade elements
- Unusual architecture

BIPV Markets | Solar Decathlon 2009: BiPV Power Production

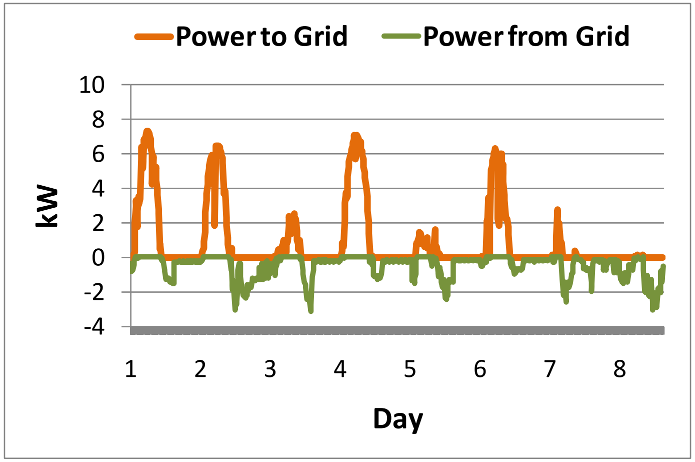
GERMANY

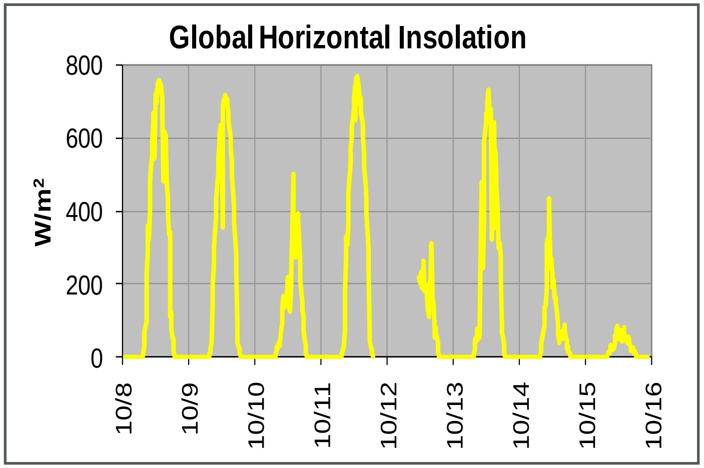


SPAIN



UNIVERSITY OF ILLINOIS





BIPV Markets | Solar Decathlon 2009: BiPV Power Production

- Event took place during one week in October
- Moderate/poor conditions for solar energy production - overcast, rainy, $< 800\ W/m^2$
- **Despite this, two buildings produced enough electricity to power two efficient homes**

Team	Power	
	Used	Produced
Germany	120	**235**
University of Illinois	90	**170**
Spain	116	**143**

BIPV Markets | Solarmarkt | Freiburg | D

SOURCE: Solarmarkt (Kindly provided by Gerhard Stryi-Hipp)

BIPV | Bielefelder Alm | Bielefeld | D

SOURCE: BSW

BIPV Markets | Ferdinand-Braun-Institut | Berlin | D | 2007

BIPV Markets | Lehrter Bahnhof | Berlin | D

SOURCE: BSW

BIPV Markets | SMA | Kassel | D

SOURCE: BSW | SMA

BIPV Markets | Monte Rosa Hütte | Wallis | CH | 2009

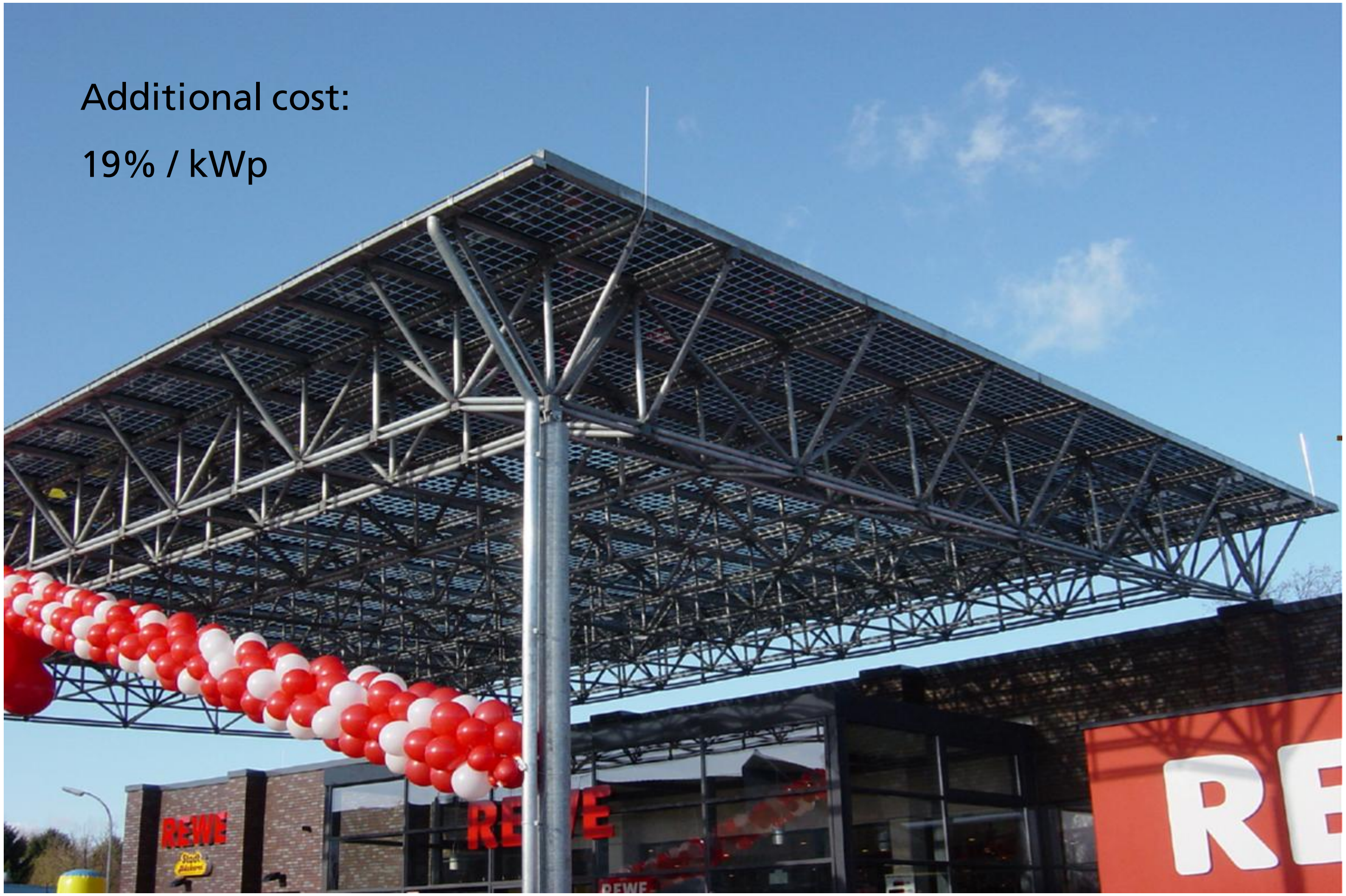
BIPV Markets | Suntech | China

SOURCE: solarfassade.info

BIPV Markets | Shopping Center | Gelsenkirchen | D

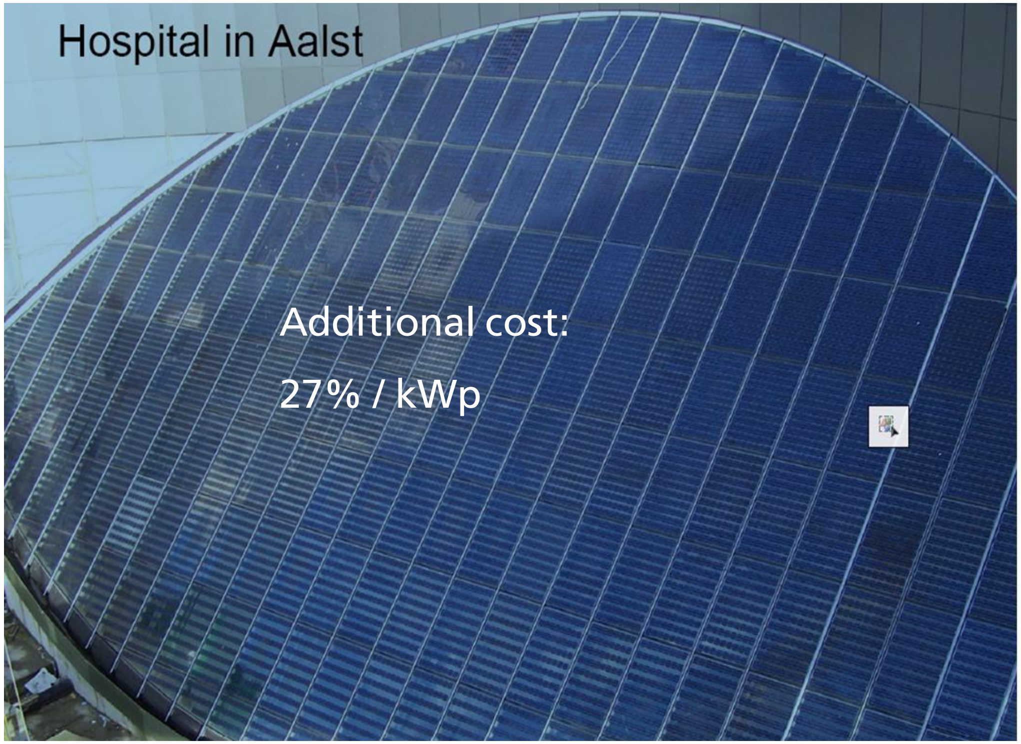
Additional cost:

19% / kWp



SOURCE: Scheuten Solar GmBH

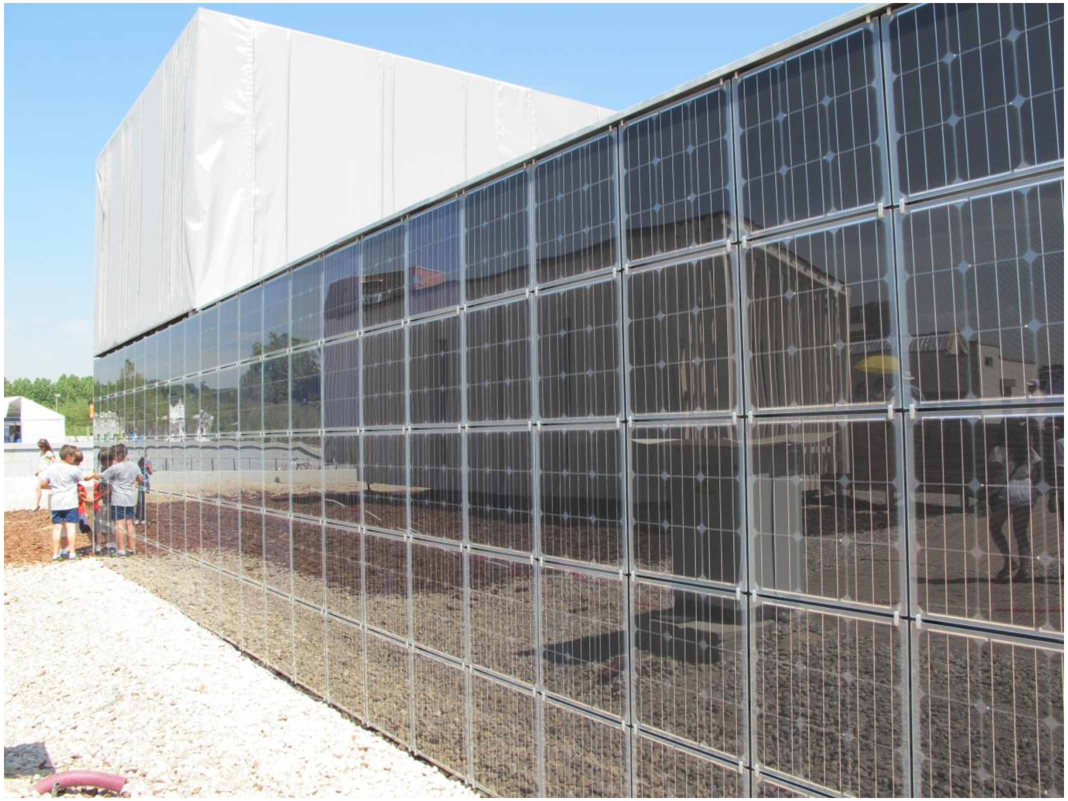
BIPV Markets | OLV Hospital | Aalst | Belgium



Photos: Scheuten Solar Germany GmbH

BIPV Markets | Solar Decathlon EU, Team Uni Herrera

BIPV Markets | Solar Decathlon EU, Team Wuppertal



BIPV Markets | Solar Decathlon EU, Team Fh Berlin

CONCLUSION

- Future buildings: more (only) electricity dependent
- EU legislation supporting large deployment of RES and moving towards energy-efficient buildings with RES
- Unlimited potential for BIPV in both space and demand
- PV very close to competitiveness with retail electricity prices

Thank you for your kind attention!