# Photovoltaic Industry
# and Role of Glass for Reducing Cost of Solar Energy

**Prof. Dr. Şener OKTİK**

**President of Research and Technological Development Group**

**Türkiye Şişe ve Cam Fabrikaları A.Ş.**

*(Chairman of Turkish Solar Energy Industry Association)*

seoktik@sisecam.com

## Disclaimer

**All information has been collected solely for use in this presentation. No warranty undertaking or representation, express or implied, has been made, and no reliance should be placed on the fairness, accuracy, completeness or correctness of the information or opinions contained in the presentation. Prof. Dr. Sener Oktik, and/or SISECAM will not be liable (in negligence or otherwise) for any loss whatsoever arising from any use of information in this presentation.**

- Photovoltaic Power Systems, PVPS
  - Current Status of PVPS
  - Projections for PVPS
  - Reality Ahead

- Photovoltaic Conversion
  - Recent History of Photovoltaic Conversion
  - Future of Harvesting Solar Energy

- Photovoltaic Conversion Systems & Role of Glasses
  - A Current Role of Glasses
  - Future Potentials
    - Technical
    - Economical

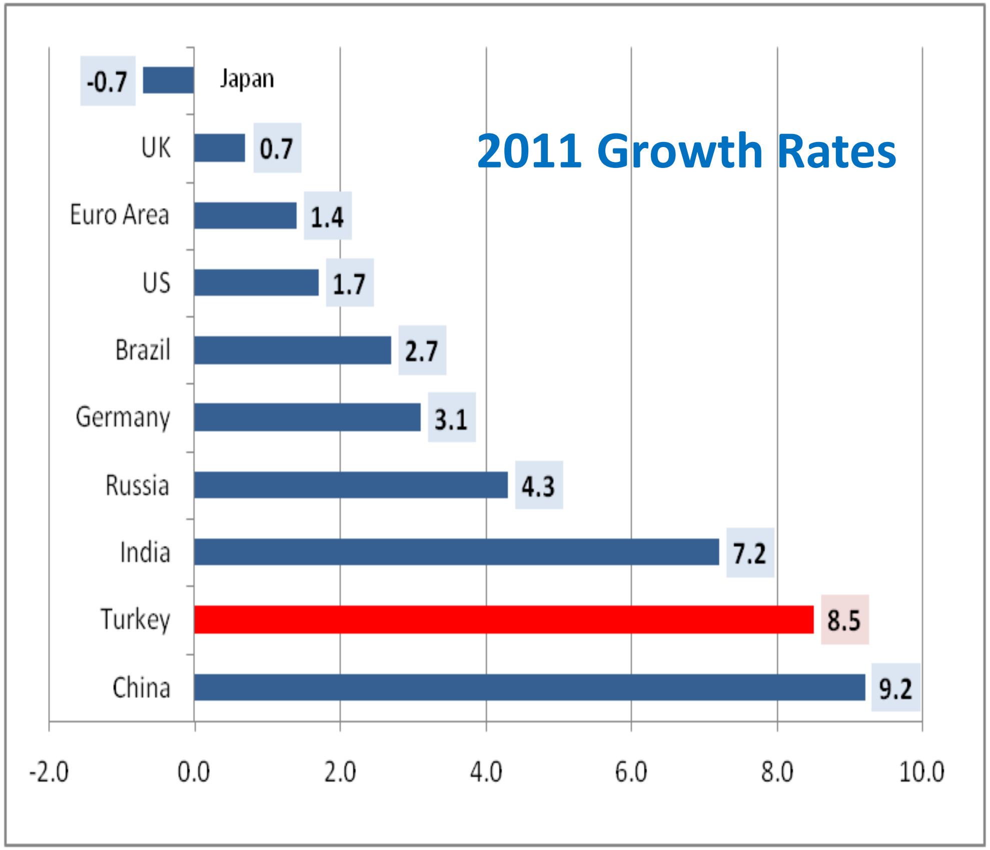
# Turkey at a Glance

| Area | 784 thousand km$^2$ |
|---|---|
| Population | 75 million (2011) |
| Labor Force | 26.7 million (2011) |
| GDP | USD 772 billion (2011) |
| Exports | USD 135 billion (2011) |
| Imports | USD 241 billion (2011) |
| Tourism Revenue | USD 23 billion (2011) |

## 18th Biggest Economy in 2011

## 2002 -2011Mean Annual Growth Rate for Turkey ~6%.

| | | GDP (billion $, 2011) |
|---|---|---|
| 1 | United States | 15.094 |
| 2 | China | 7.298 |
| 3 | Japan | 5.869 |
| 4 | Germany | 3.577 |
| 5 | France | 2.776 |
| 6 | Brazil | 2.493 |
| 7 | United Kingdom | 2.418 |
| 8 | Italy | 2.199 |
| …… | …… | …… |
| 18 | Turkey | 772 |



# Statements by the Energy Market Regulatory Agency, EMRA (October 2011)

✓Turkey ranks sixth in Europe in terms of current power plants capacity and electricity demand *(Germany, France, United Kingdom, Italy, Spain, Turkey)*

✓Turkey is the most rapidly developing electricity market in Europe *(A fully liberalised electricity market in the medium term)*

## Projection to 2030

✓Annual increase of 6.5% in electricity demand

✓Focus is mainly on renewable energy resources *( ~%30 renewable power by 2023)*

✓A total installed power capacity of 140-180GW

✓The third biggest energy market in Europe

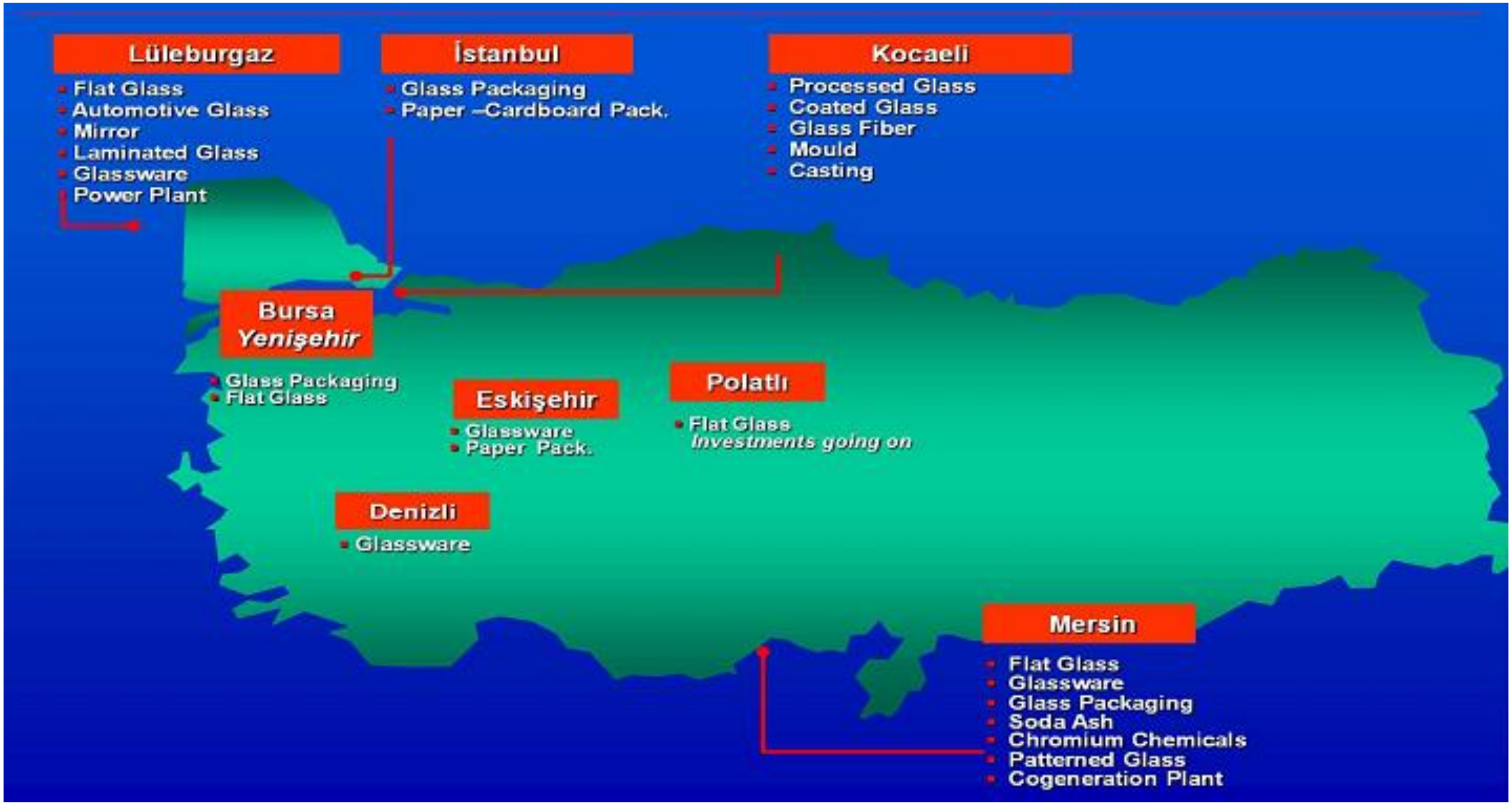
✓Investment in energy is in the range of $225 to $280 billion

## ŞİŞECAM IN BRIEF

- ŞİŞECAM founded in 1935 by İşbank, operates in 4 business segments:
  - -Flat Glass
  - -Glass Packaging
  - -Glassware
  - -Chemicals
- Operations in 8 countries: Turkey, Russia, Bulgaria, Egypt, Georgia, Bosnia Herzegovina, Ukraine and Italy with exports to 140 countries.
- Leading glass manufacturer in Turkey
- Aiming to be in top 3 globally

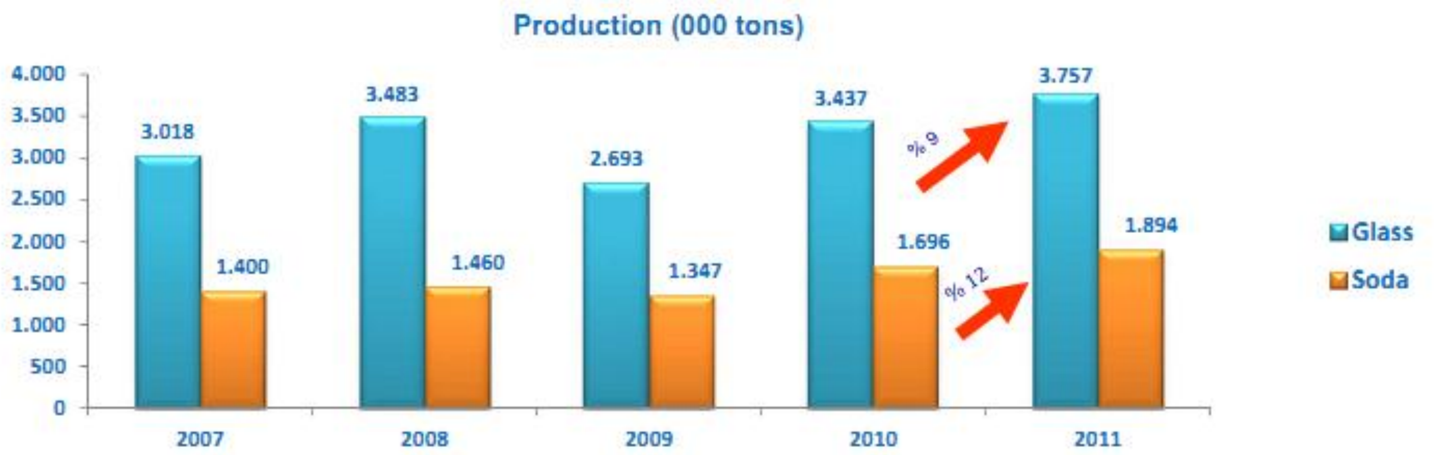
- Annual production of 3.8 million tons of glass and 1.9 million tons of soda ash
- Mcap of US$ 2.2 billion (June 2012), 28% of its shares are listed on ISE (SISE.IS) and 72% held by İşbank
- Net Sales of US$ 3 billion FY 2011
- EBITDA of US$ 758 million FY2011
- Strategic alliances with global players in the region
- 18.000 employees

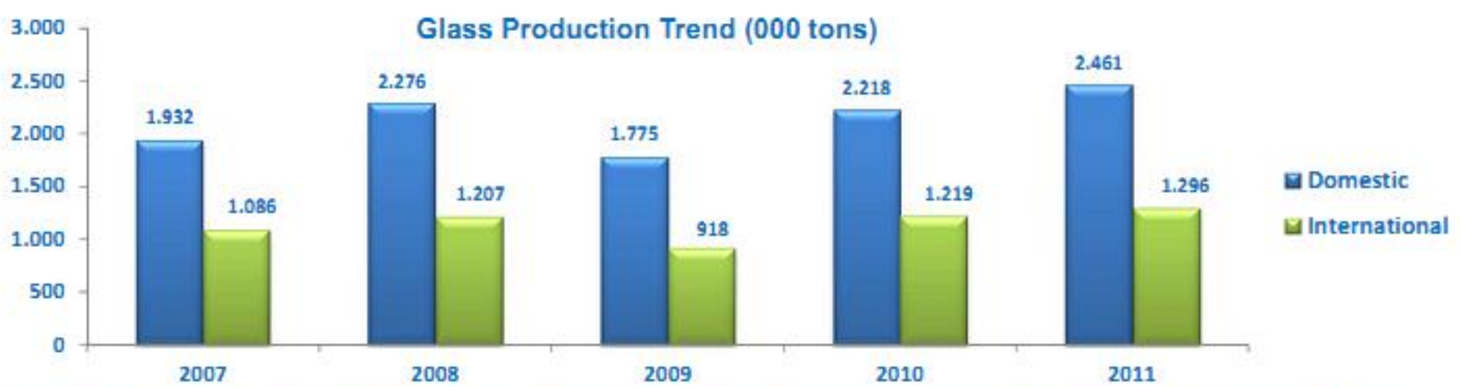
# ŞİŞECAM PRODUCTION SITES IN TURKEY



# ŞİŞECAM PRODUCTION SITES ABROAD

# ŞİŞECAM FACTS & FIGURES




Share of foreign production in total production is in an upward trend as a result of investments made outside Turkey.

# ŞİŞECAM FACTS & FIGURES


- Growth is mainly driven by exports and foreign production as a result of investment strategy in the region.
- As of 2011-end exports reached US$ 880 million.

**Top 10 Exported Countries**

| | |
|---|---|
| Italy | 12% |
| U.K. | 6% |
| Germany | 6% |
| France | 5% |
| Egypt | 5% |
| U.S.A. | 4% |
| China | 4% |
| Russia | 4% |
| Iran | 4% |
| Spain | 3% |

# ŞİŞECAM & GLASS INDUSTRY

## Market Shares (%)*

| | Turkey | Europe | World |
|---|---|---|---|
| Flat Glass | 71 | 13 | 4 |
| Glassware | 58 | 25 | 10 |
| Glass Packaging | 88 | 9 | 4 |
| Soda Ash | 83 | 8 | 4 |

## Şişecam's Position

| (000 tons) | Turkey | Eastern Europe | Russia & Caucasia | MENA |
|---|---|---|---|---|
| Flat Glass | 1 | 1 | 1 | 1 |
| Glassware | World's 3rd Largest Glassware Producer | | | |
| Glass Packaging | 1 | 1 | 1 | 1 |
| Soda Ash | 1 | 1 | 2 | 1 |

## Global Ranking

| | Europe | World |
|---|---|---|
| Flat Glass | 4 | 6 |
| Glassware | 2 | 3 |
| Glass Packaging | 4 | 5 |
| Soda Ash | 4 | 10 |

(*) As of December 2011

## Şişecam vs. Listed Global Players

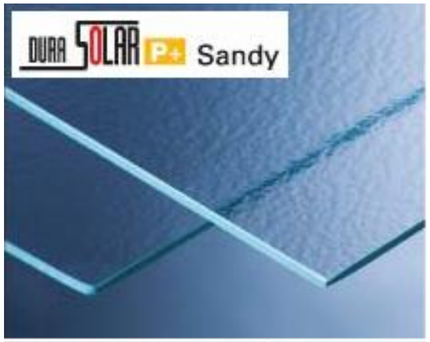
| Rank | Company | Country | Year Founded | Sales (Mil $) | Business Areas ** |
|---|---|---|---|---|---|
| 1 | Saint Gobain | France | 1665 | 54.490 | FG, GP, GF, CE |
| 2 | Asahi | Japan | 1907 | 15.681 | FG,OP |
| 3 | Pilkington | United Kingdom | 1883 | 14.885 | FG,GF,CH |
| 4 | Corning | United States | 1850 | 7.890 | GF |
| 5 | NSG | Japan | 1826 | 7.451 | FG,TG |
| 6 | Owens-Illinois | United States | 1779 | 7.400 | GP |
| 7 | Hoya | Japan | 1941 | 5.336 | GW,OG, EL |
| 8 | Owens Corning | United States | 1938 | 5.300 | GF |
| 9 | Schott | Germany | 1884 | 3.728 | GP, TG, OG |
| 10 | NEG * | Japan | 1949 | 3.419 | GF, TG, EL |
| **11** | **ŞİŞECAM** | **Turkey** | **1935** | **2.980** | **FG, GP, GW, CH** |
| 12 | Gerresheimer | Germany | 1881 | 1.417 | GP |

(*) unaudited 9M-2011

Sales represent 2011-end figures

(**) FG : Flat Glass, GP : Glass Packaging, GW: Glassware,
CH : Chemicals, GF : Glassfiber, CE : Ceramics,
TF : Technical Glass, OG : Optical Glass, EL : Electronics

# ŞİŞECAM & Solar Glass





TRC Durasolar® P+

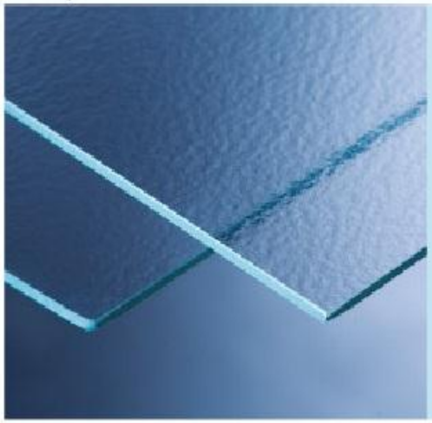
- Tempered High transmission (low iron) patterned solar glasses (Tsol 91,6 %) are produced and processed in Mersin Plant in the south of Turkey.

- Solar glass processing is done on a fully integrated automatic line including an automatic glass packaging and an online quality inspection system.

- The capacity of the new patterned glass furnace will be 8 million sqm and the tempering capacity is 4 million sqm.

# Trakya Cam Solar Glass

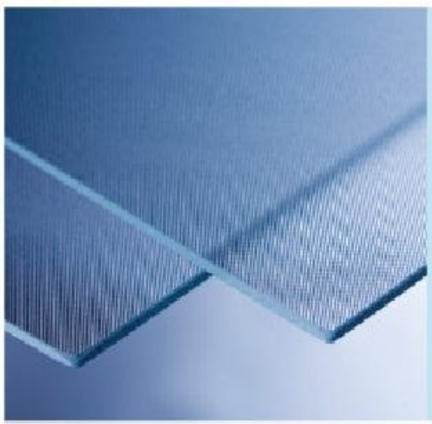
Sandy



| Product | Thickness (mm) | Light Transmittance (D65) $T_{D65}$ | Solar Transmittance (AM 1,5) $T_{sol}$ | SPF Class |
|---|---|---|---|---|
| TRC **Durasolar P+** Sandy | 3,2 | 92,1 % | 91,6 % | U1 |
| TRC **Durasolar P+** Sandy | 4 | 92,0 % | 91,3 % | U1 |

Extra clear, both sides structured tempered patterned glass.

Prism



| Product | Thickness (mm) | Light Transmittance (D65) $T_{D65}$ | Solar Transmittance (AM 1,5) $T_{sol}$ | SPF Class |
|---|---|---|---|---|
| TRC **Durasolar P+** Prism | 3,2 | 91,5 % | 91,3 % | U3 |
| TRC **Durasolar P+** Prism | 4 | 92,0 % | 91,5 % | U2 |

Extra clear, one side prism structured, one side mat tempered patterned glass.

* Both types are available with seamed or grinded edge upon customer request.

# A short History of PVPS Market and Application

- **1970 – 80: powering satellites**
- **1980 – 90: remote applications and first power plant projects**
  *(Clarissa Plains, 6MW, US)*
- **1990 – 00: first support programs for grid integrated applications:**
  *Germany 1,000 roof program , Japan 70,000 roof program*
  *Germany 100,000 roof program*
- **2000 – 10: big boost by Feed-in tariff (EEG) program in Germany,**
  - ✓ *copied by about 50 countries worldwide*
  - ✓ *boom in many and bust in few countries due to overdone support (Spain 08/09, Czech Rep 10/11)*
  - ✓ *… industrialization of the sector, tremendous capacity build across the value chain*
- **2010 – 20: consolidation of the sector, PV competing more and more in**
  *the energy sector with huge growth potential;*
  *… hopefully the advent for off-grid in developing countries!*

Dr. Winfried Hoffmann President EPIA 27th SISECAM Glass Symposium Istanbul, 1st June, 2012

## Current Status of PVPS

# Global Annual Photovoltaic Market & Scenarios upto 2016

**2011**

| | |
|---|---|
| *Total PV Modul Production Capacity* | *45-55GWp/year* |
| *Total PV Modul Production* | *~23 GWp/year* |
| *Toplam PV Power System Installation* | *~20 GWp/year* |


| | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| History/Reduced Incentives | 2.0 | 3.1 | 5.5 | 7.9 | 17.4 | 23.6 | 13.7 | 11.7 | 10.9 | 9.9 | 9.9 |
| Conservative | | | | | | | 19.2 | 19.7 | 20.5 | 21.6 | 22.7 |
| Accelerated | | | | | | | 25.9 | 28.8 | 36.8 | 46.3 | 57.8 |

Source: Paula Mints NAVIGANT Inc. August 2012

## Current Status of PVPS

## 2011

| | |
|---|---|
| *Total PV Modul Production Capacity* | *45-55GWp* |
| *Total PV Modul Production* | *~23 GWp* |
| *Toplam PV Power System Installation* | *~20 GWp* |

| Country | PV Modul Production Capacity (%) (~48 000 MWp) | PV Modul Production Capacity Utilization (%) | PV Modul Production (%) ~23 000 MWp ( ~48% of Capacity) | PV Power System Installation (%) ~20 000 MWp |
|---|---|---|---|---|
| China | 44 | 67 | 44 | 11 |
| Taiwan | 16 | 73 | 18 | < 1 |
| Japan | 11 | 72 | 12 | 6 |
| Europe | 10 | 50 | 7 | 65 |
| USA | 4 | 64 | 3 | 11 |
| ROW | 15 | 73 | 6 | 7 |

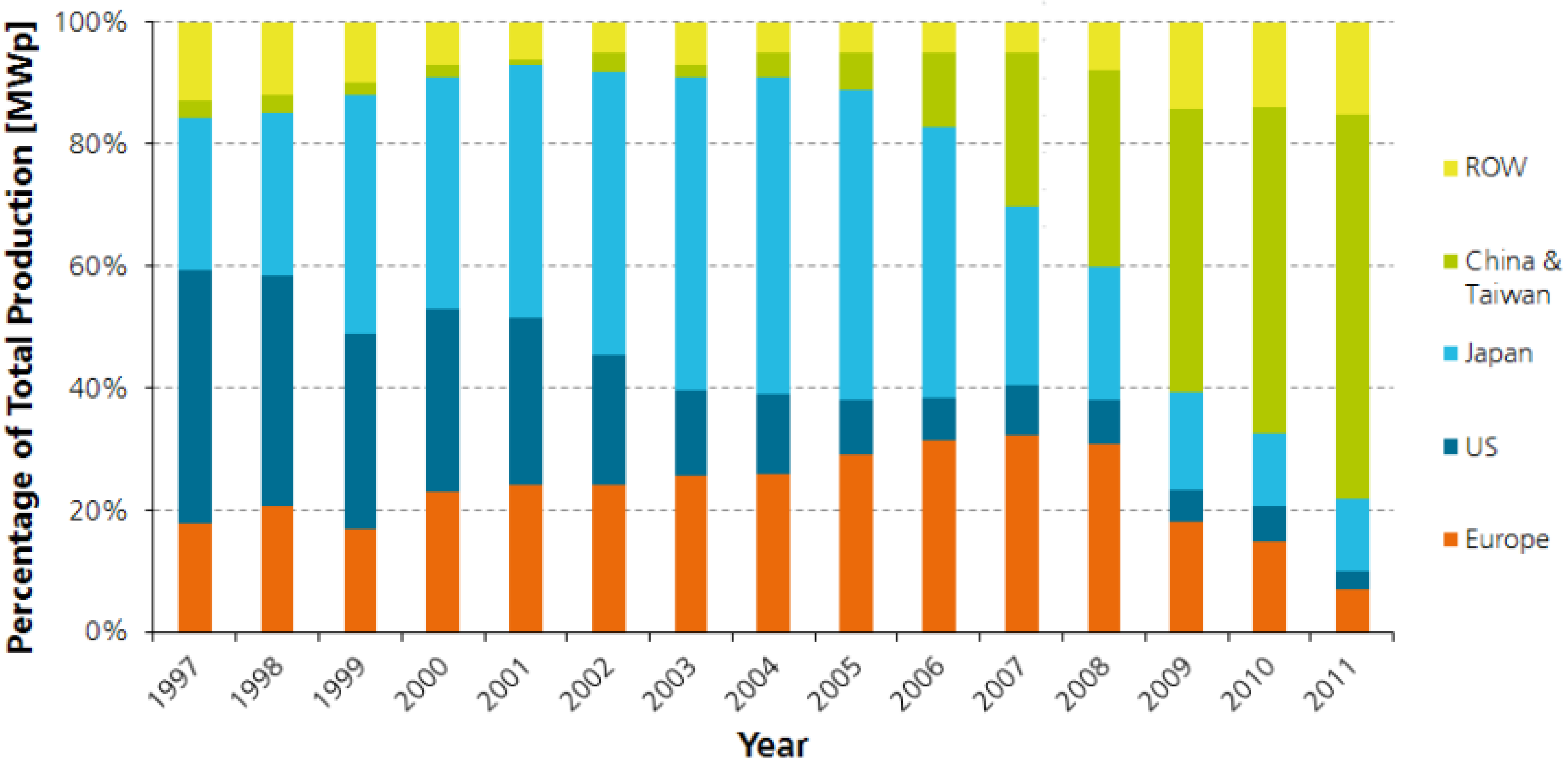
**2011**

**Only ~50 % of the cumulated PV module fabrication capacity used for production**

Source: Paula Mints NAVIGANT Inc. August 2012

## Current Status of PVPS

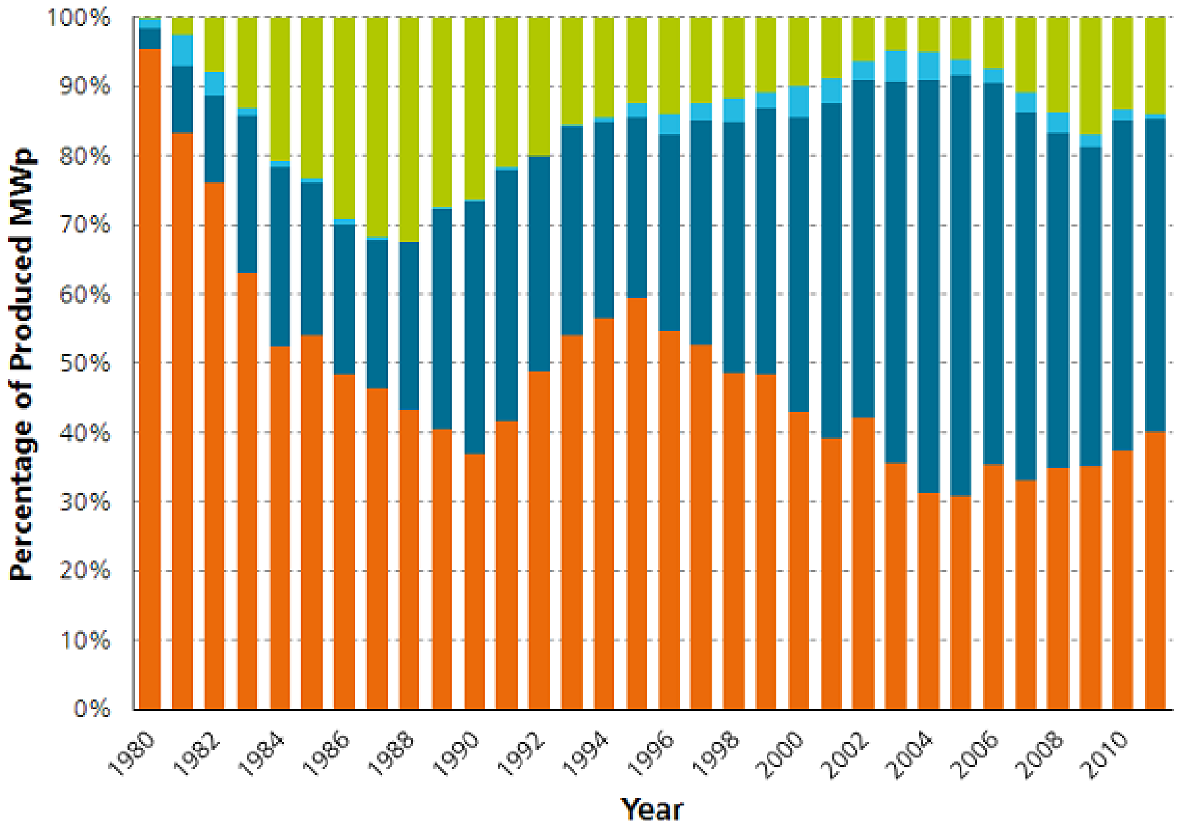
### Historical Development of Worldwide Distribution of Photovoltaic Cell/ Module Production (%)




Data: Navigant Consulting Graph: PSE AG 2012

# Current Status of PVPS

## Photovoltaic Modul Production Development by Technology




Production 2011 (MWp)

| | |
|---|---|
| Thin film | 3,204 |
| Ribbon-Si | 120 |
| Multi-Si | 10,336 |
| Mono-Si | 9,114 |

2011

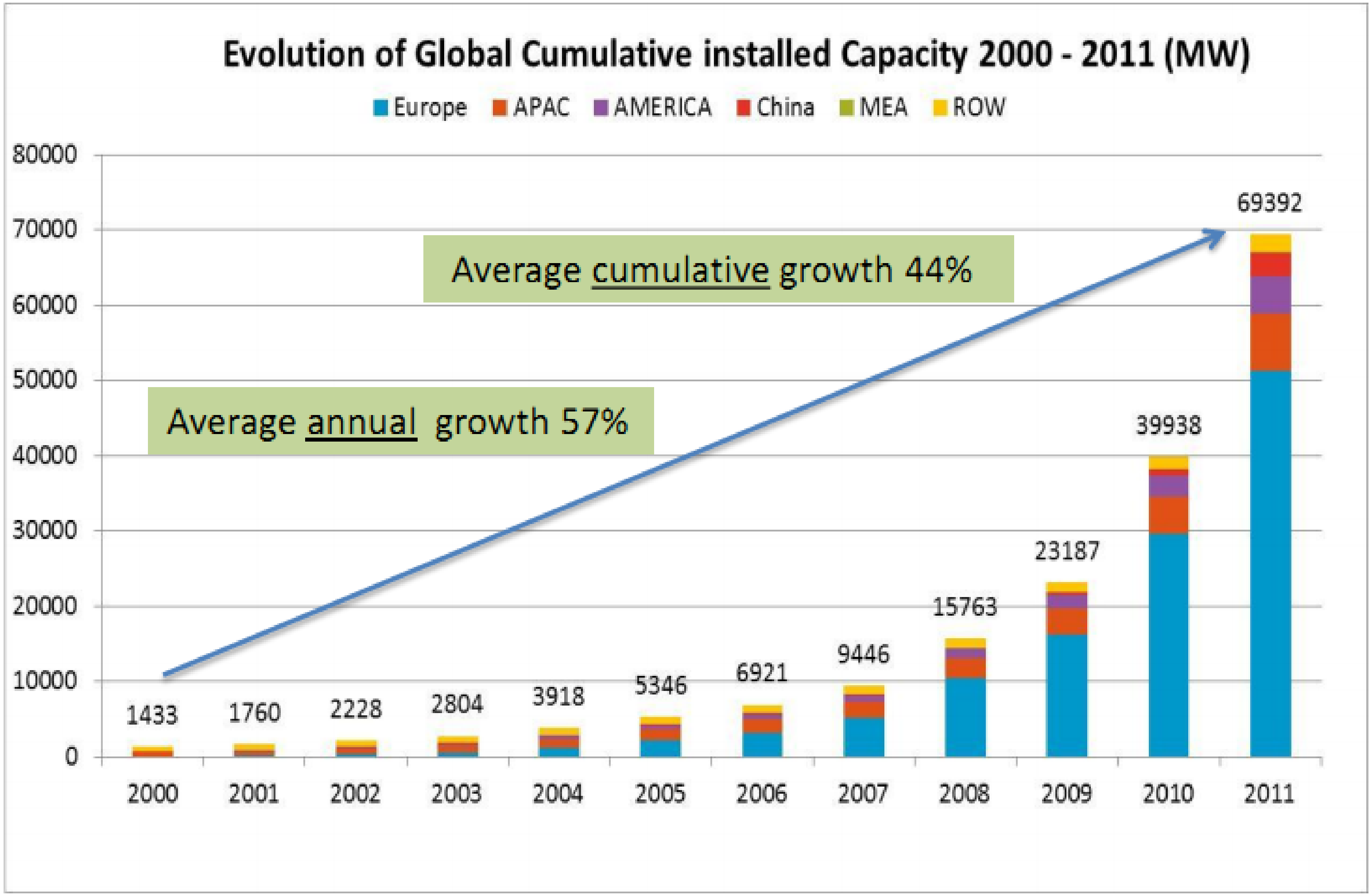
- Bulk Si-wafer based PV technology **86 %**
- Thin Film based PV technology **%14**

Data: Navigant Consulting Graph: PSE AG 2012

## Current Status of PVPS

**PV 2011: ~70 GW (~ 80,000,000 MWh)**

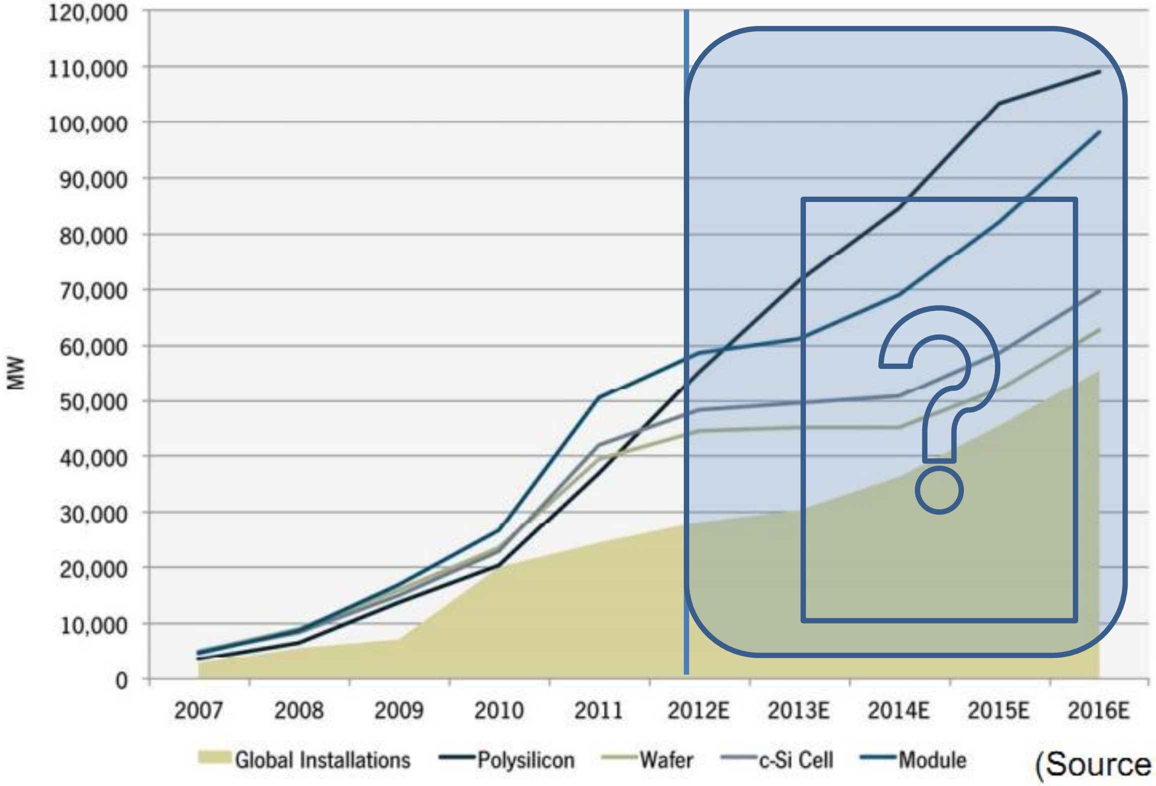
*~the annual output of 9 1300MW Nuclear Reactors*




Source: EPIA Annual Market Workshop 2012

## Current Status of PVPS

# Global Installation and Overcapacities in PV Sector Valuechain




(Source

- chronic overcapacity

**across the value-chain**

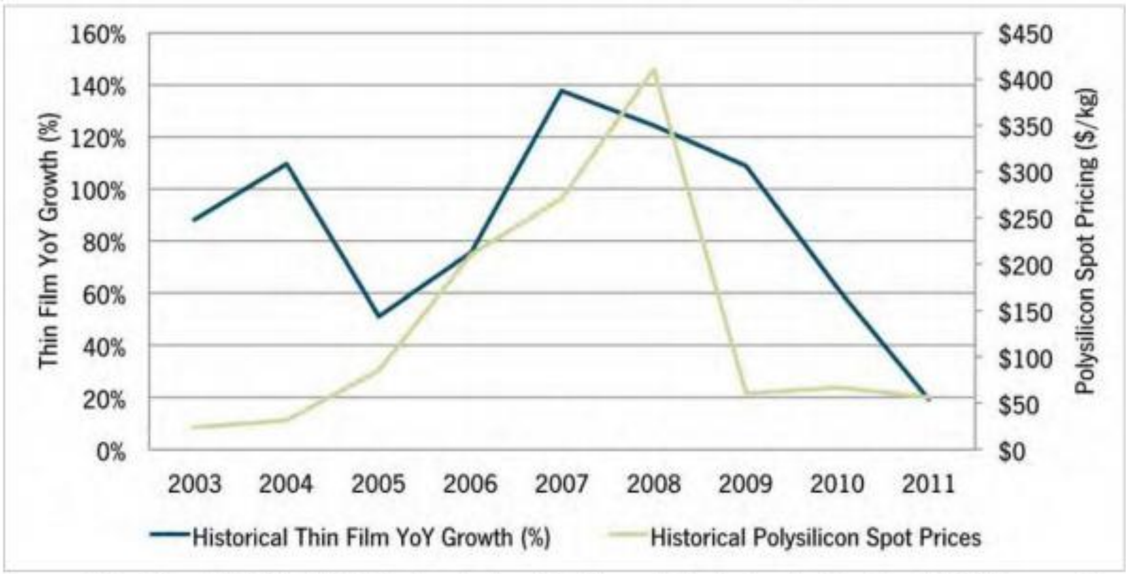
- oversupply
- inventory build-up

**the true nature of the selling environment !**

the solar module market is enormously oversupplied, with nearly twice as much manufacturing capacity as there is demand

*Source:Greentechmedia 2012*

# Polysilicon spot prices and thin film photovoltaic market growth




Source: "Thin Film PV 2012–2016: Technologies, Markets and Strategies for Survival," GTM Research

2003-2007

Polysilicon price fluctuation band 140 <$/kg<400

Thin film PV entered as a substitude exponential increse in annual market growth rate reaching 140% in 2008

2007-2012

Drastic and continious drop in polysilicon prices current price below 20$/kg

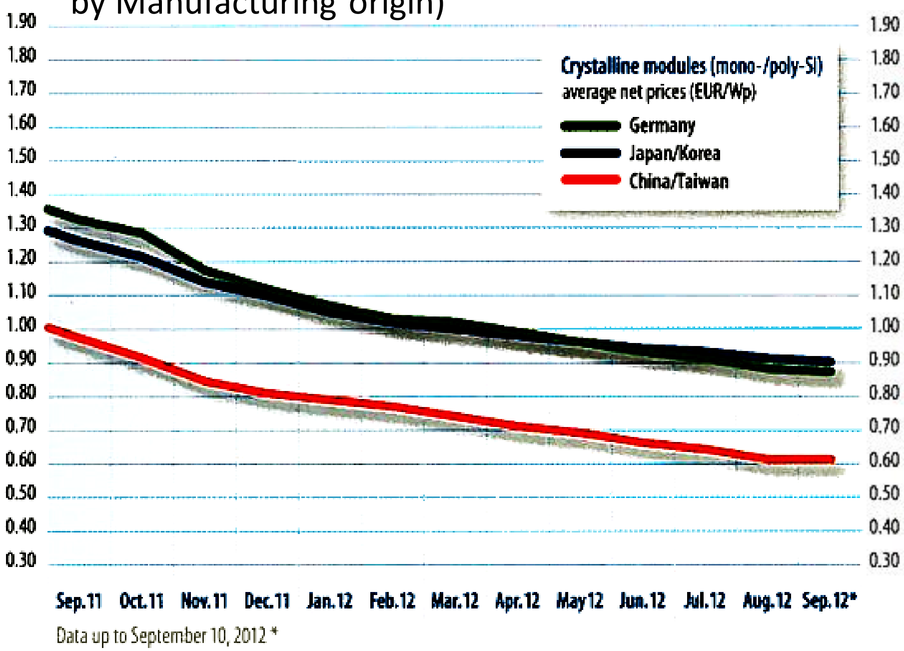
Thin film market growth tumbles down to about 20%

**Current Status of PVPS**

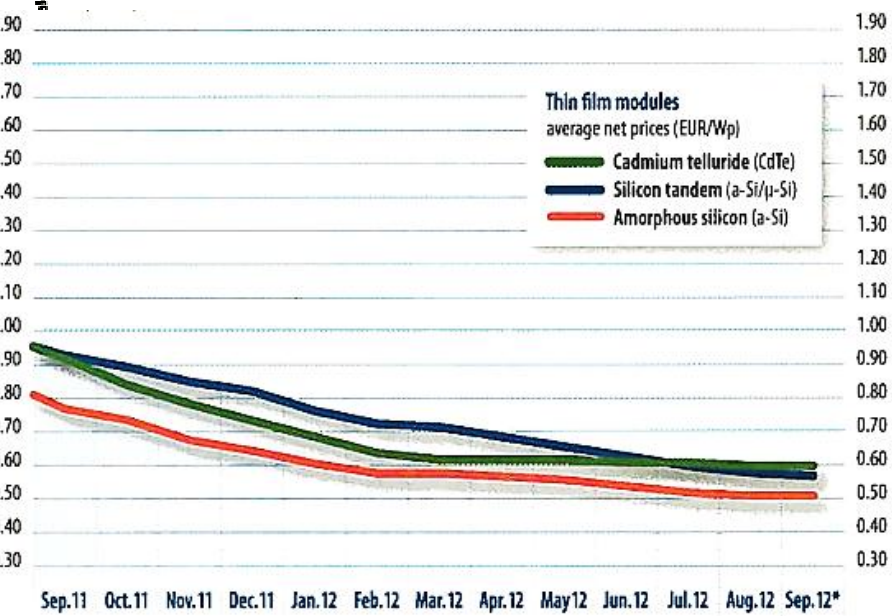
# Photovoltaic Modul Spot Prices, Euro/Wp

*(pvxchange, October 2012)*

Crystalline Modul Spot Prices
by Manufacturing origin)




Thin Film Modul Spot Prices




End of 2012

Crystalline Modul Spot Prices 0.42 – 0.77 Euro/Wp

Thin Film Modul Spot Prices 0.40-0.70 Euro/Wp

http://pvinsights.com/ updated

**IHS REPORT**

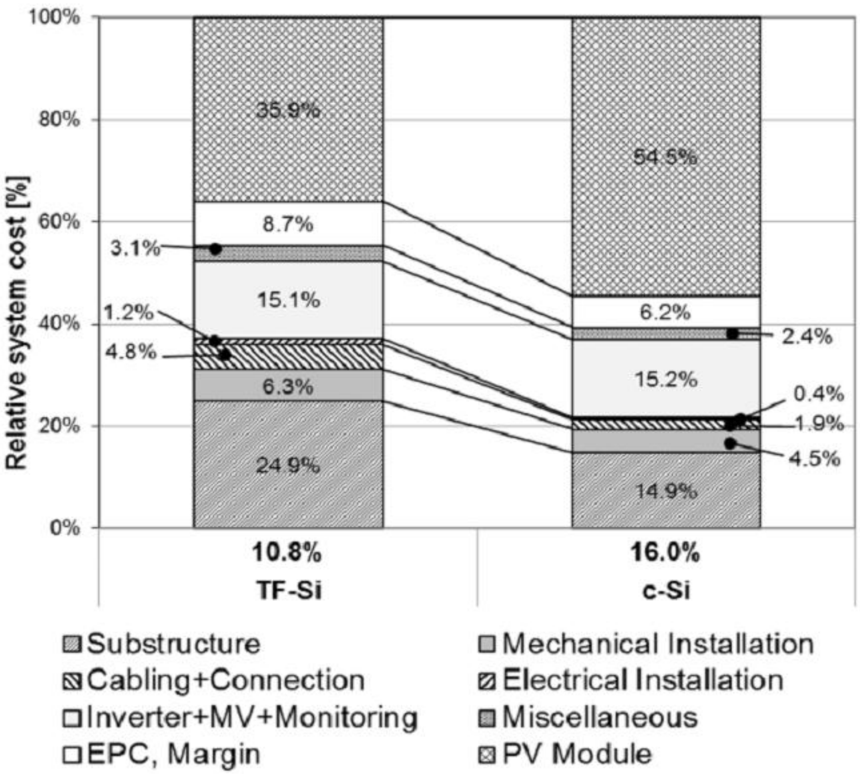
**Chinese c-Si modules price drop**

| | |
|---|---|
| **September 2012** | **-1.9%** |
| **October 2012** | **-3.5%** |
| **November 2012** | **-1.1%** |

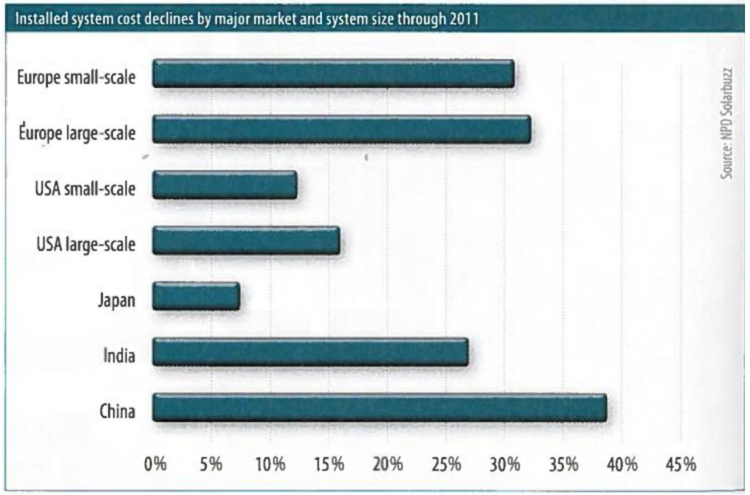
## Current Status of PVPS

# Phoyovoltaic Power Systems

2013 Estimate of a cost Breakdown of PVPS based on Thin Film Silicon and Crtystalline Silicon for 10MWp Ground Mounted System

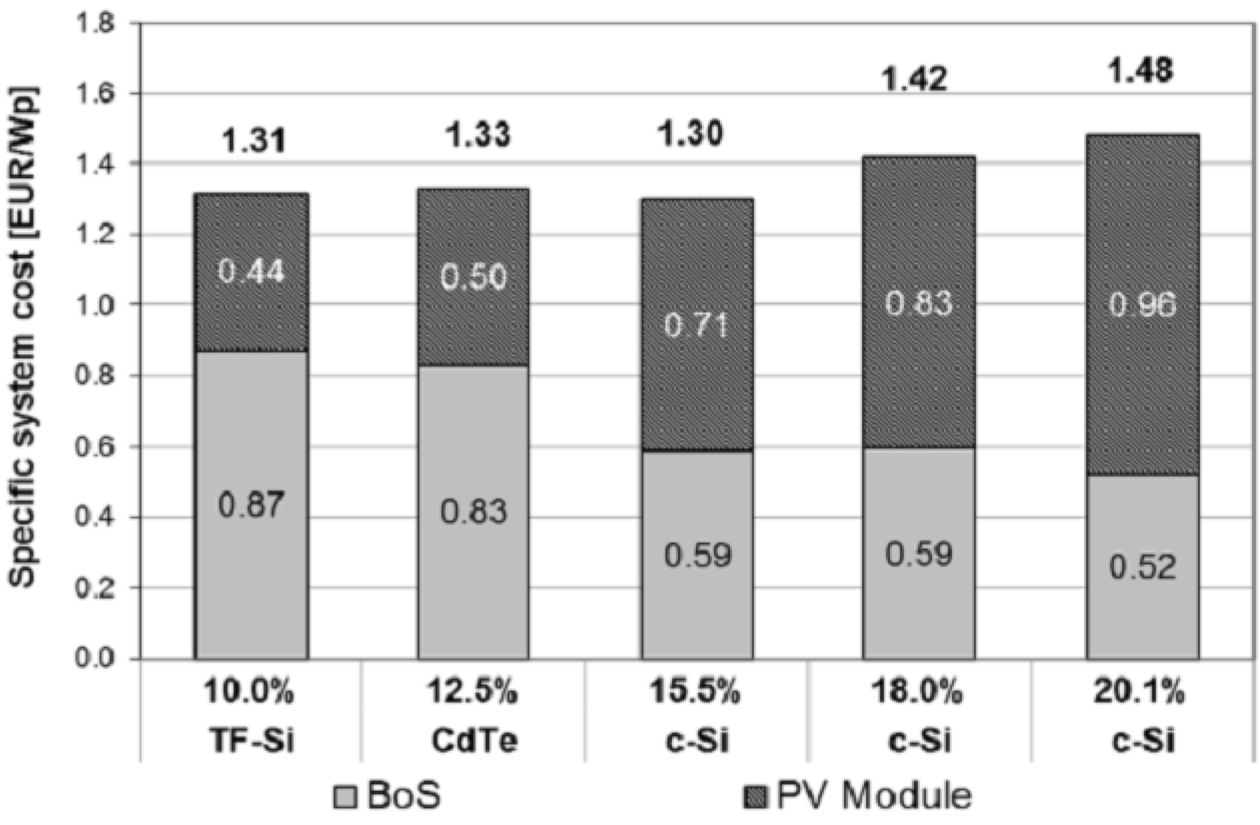



| A Cost Breakdown of PVPS | 2012 (%) | 2020 (%) |
|---|---|---|
| PV Modules | 36-55 | 30-40 |
| PV Inverter +Monitoring | 8-10 | 5-7 |
| Balance of Systems | 13 -17 | 18-25 |
| Installation | 22-26 | 30-40 |

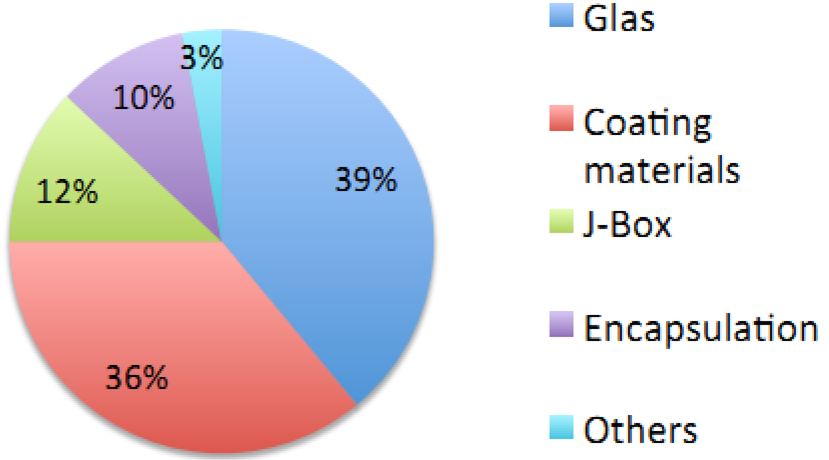


## Current Status of PVPS

2012 PVPS Costs for 10MWp Ground Mounted Systems in Europe

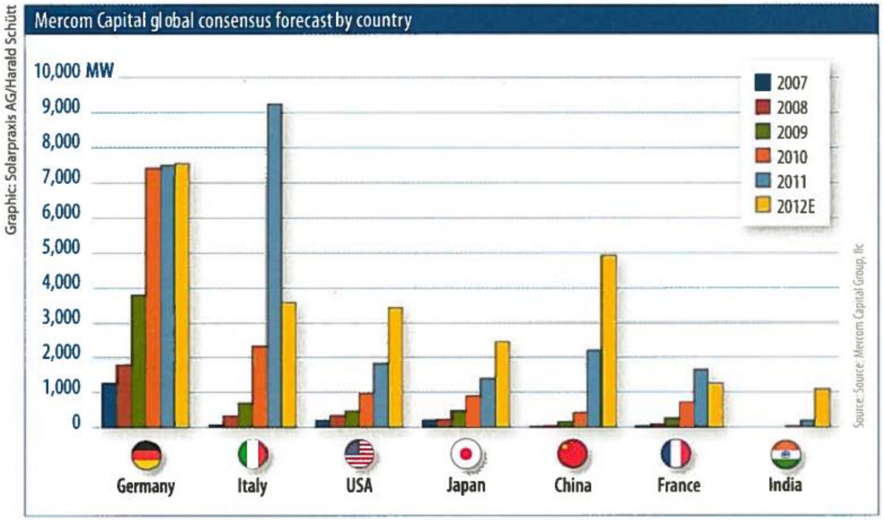


# Breakdown of material cost




- Total material cost of 0.24€/$W_p$ is dominated by glass substrate (0.1€/$W_p$)
- Cell / coating materials around 0.09€/$W_p$

S.Schuller, I Luck and J Berghold (PICON Solar GMBH) , Thin Film Week Berlin 2012

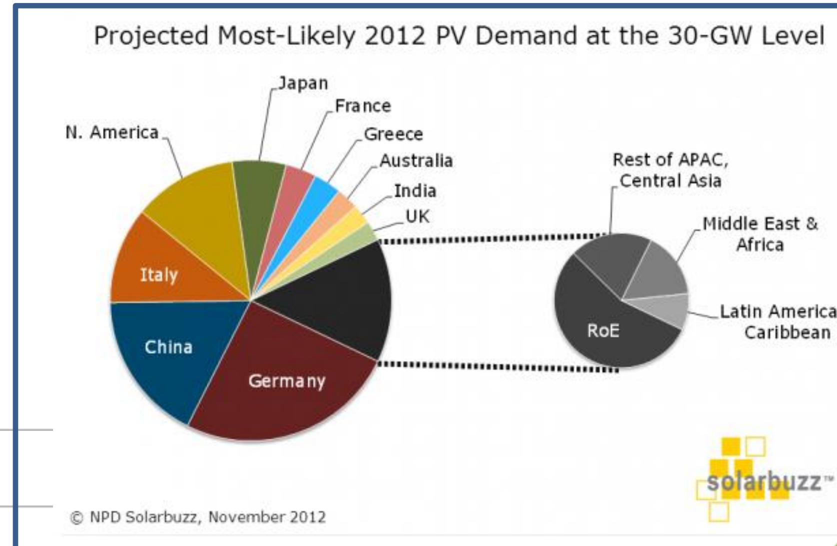


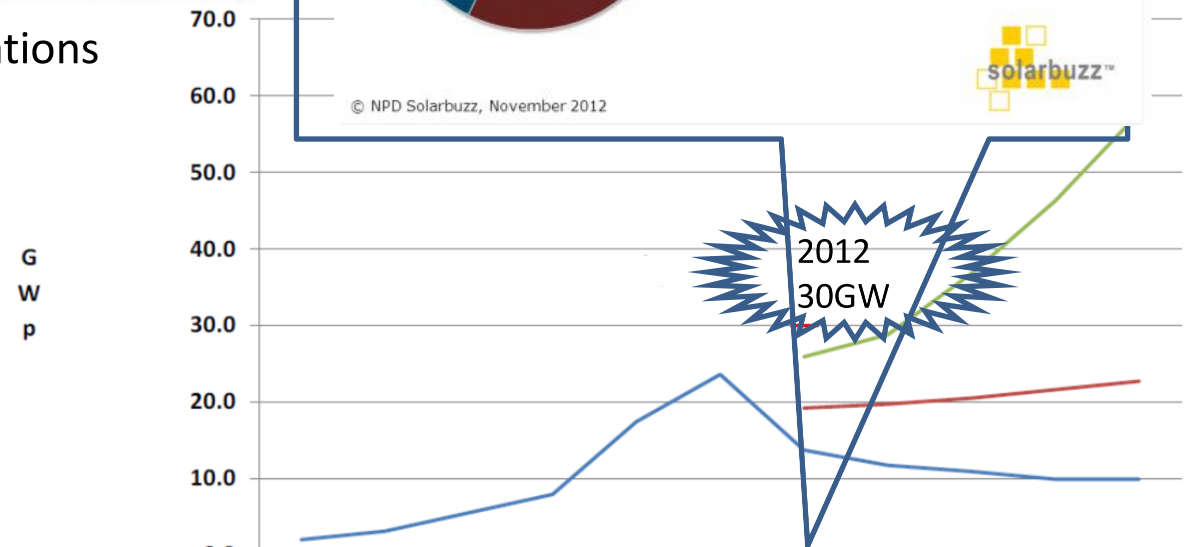

2007-2012 Annual PVPS Installations

## Current Status of PVPS

# «Profitless Prosperity»

**2012**
**30GWp Annual Installment**




| | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| History/Reduced Incentives | 2.0 | 3.1 | 5.5 | 7.9 | 17.4 | 23.6 | 13.7 | 11.7 | 10.9 | 9.9 | 9.9 |
| Conservative | | | | | | | 19.2 | 19.7 | 20.5 | 21.6 | 22.7 |
| Accelerated | | | | | | | 25.9 | 28.8 | 36.8 | 46.3 | 57.8 |

## Current Status of PVPS

**Historicaly «The PV Industry» between different manufacturers across the value-chain used to operate with :**

- ✓ a great ability to adapt
- ✓ 'healthy' competition

**The recent trade disputes in PV Sector ;**

- ✓ Heavily dumped prices by Chinese manufacturers have been continuing
- ✓ PV manufactureres , Jobs and technologies have been destroyed in USA , Europe and ROW as well as China

**Attempts to offset China's anti-competitive trade practices;**

- ✓ *In October, the US Department of Commerce ( DoC ) announced that Chinese producers/exporters sold solar cells in the United States at dumping margins ranging from 18.32% to 249.96%.*
- ✓ *the DoC issued orders to begin collecting duties for five years from Chinese solar cell imports (Effective from 7th December 2012)*
- ✓ *September 2012 The EU Commission initiated an antidumping investigation on solar imports from China (the anti-dumping investigation has to be concluded latest in early June 2012 )*
- ✓ *November 2012 Initiation of an anti-subsidy investigation of industry and market data and inspections of European and Chinese companies by EU Commission officials*

## Current Status of PVPS

# Consolidations , Acquisions & Bancruptcies

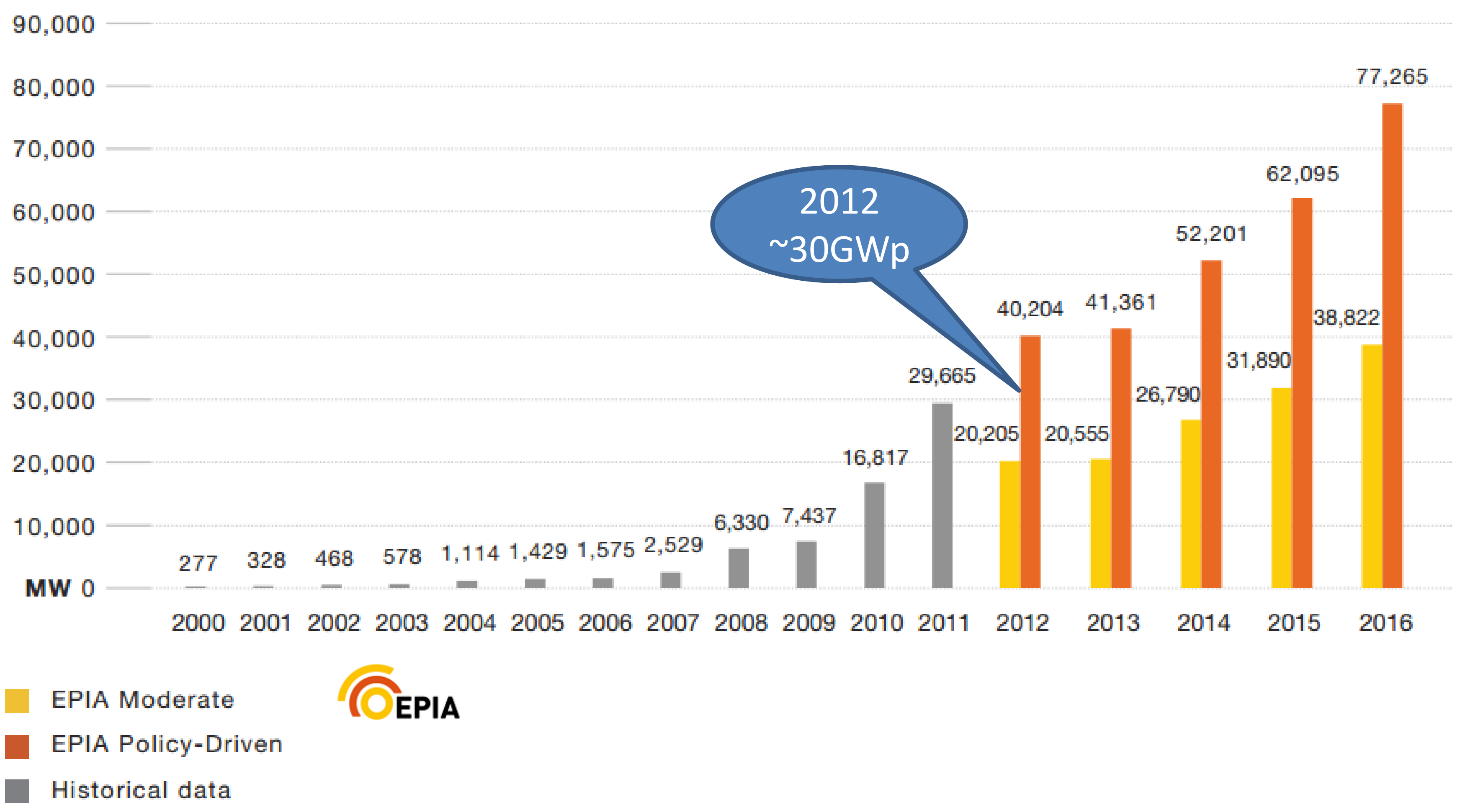
| Year | Company | Country | Product | Technology | Comment |
|---|---|---|---|---|---|
| 2009 | Sontor | DE | Module | a-Si/µ-Si | Production activities sold to Sunfilm (DE) |
| 2009 | Suntech | CN | Module | a-Si | SunFab line not put into operation |
| 2010 | Applied Materials | US | Equipment | a-Si/µ-Si | SunFab turnkey technology sales discontinued |
| 2010 | Sunfilm | DE | Module | a-Si/µ-Si | Bancruptcy and sale of production activities sold to Schueco (DE) |
| 2010 | Sontor | DE | Module | a-Si/µ-Si | Follow-up sale of production activities to Wilms Group (DE) |
| 2010 | Würth Solar | DE | Module | CIGS | Acquisition of production technology license by Manz AG (DE) |
| 2010 | EPV | DE | Module | a-Si | Bancruptcy and sale of production activities sold Sunlogics (US) |
| 2010 | VHF Technologies | DE | Flex laminate | a-Si | Production activities discontinued |
| 2011 | Roth & Rau | DE | Equipment | CdTe | Acquisition of production technology license to investor (CN) |
| 2011 | Solyndra | US | Module | CIGS | Chapter 11 bancruptcy |
| 2012 | Oerlikon | CH | Equipment | a-Si/µ-Si | Production activities sold to Tokyo Electron (JP) |
| 2012 | Würth Solar | DE | Module | CIGS | Production activities sold to Manz AG (DE) |
| 2012 | centrotherm | DE | Equipment | CIGS | Closure of activities in Germany and relocation to ASIA |
| 2012 | Unisolar | US | Flex laminate | a-Si/a-Si/a-Si | Chapter 11 bancruptcy |
| 2012 | Helianthos | NL | Flex laminate | a-Si | Auction to sell production activities |

| China-based PV Company | 2012 2Q Lost |
|---|---|
| LDK crystalline silicon producer | $250 million |
| Yingli | $90 million |
| Trina | $92 million |
| JA Solar | $70 million |

Source: http://www.pv-magazine.com/

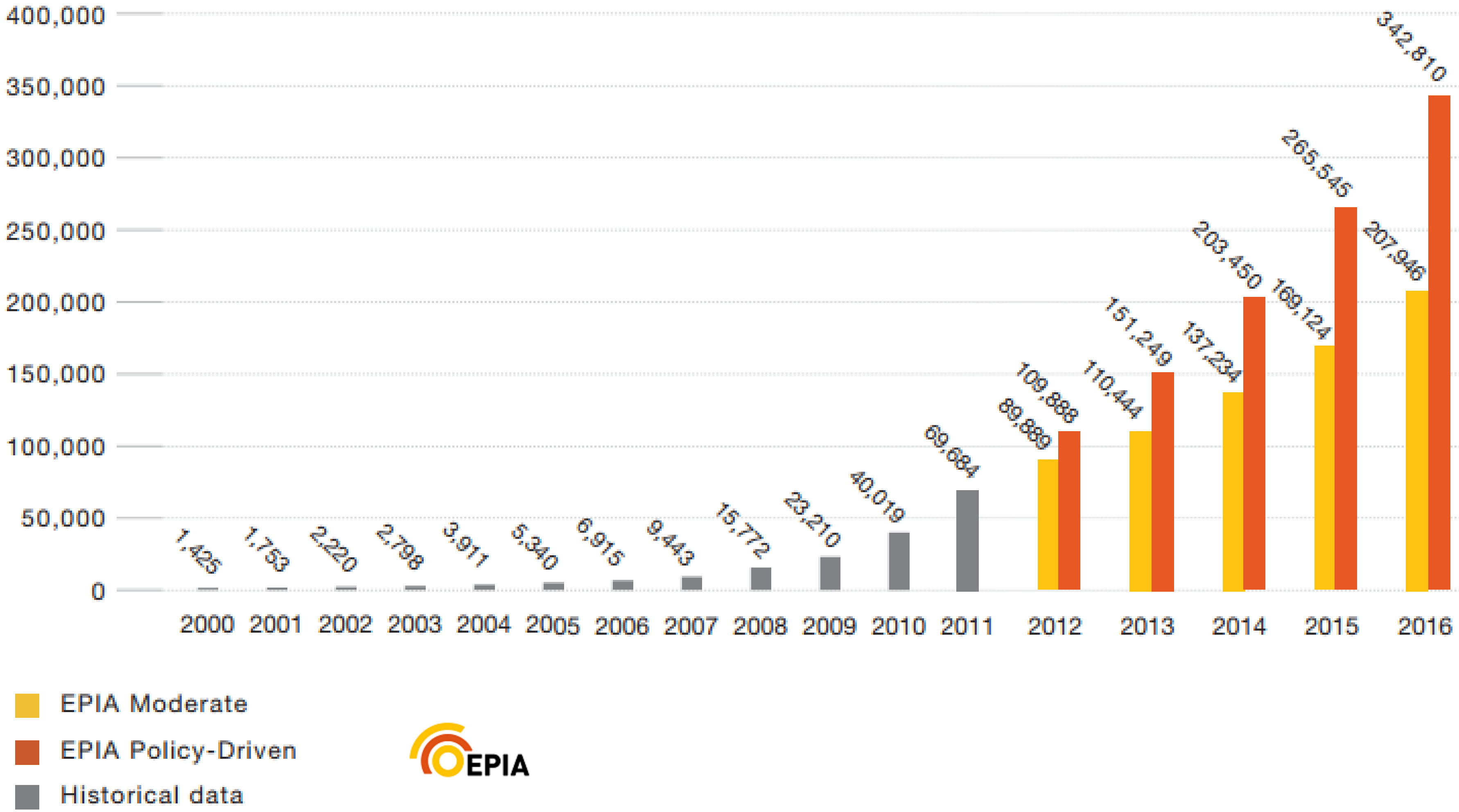
# Projections and Scenarios for PVPS

History of Global PVPS Annual Instalment and Scenarios up to 2016 (MWp)



# Projections and Scenarios for PVPS

History of Global Acumulative PVPS and Scenarios up to 2016 (MWp)



# Projections and Scenarios for PVPS

PVPS Share in Electricity Production for 27 EU Countries+ Sweden + Norway + Turkey

*( 2011 data and Three different Scenarios for 2020 and 2030 )*

EPIA

| Scenarios | 2011 | New 2020 | 2030 |
|---|---|---|---|
| Baseline | 1,75% | 4,00% | 10,00% |
| GW | 51,4 | 122 | 337 |
| TWh | 60,0 | 143 | 404 |
| Accelerated | 1,75% | 8,00% | 15,00% |
| GW | 51,4 | 242 | 505 |
| TWh | 60,0 | 287 | 606 |
| Paradigm Shift | 1,75% | 12,00% | 25,00% |
| GW | 51,4 | 358 | 851 |
| TWh | 60,0 | 430 | 1010 |

# Photovoltaic Sector Value Chain from 2012 to 2013 (I)

( the top 10 predictions for 2013 from the IHS solar research team)

**1. The global PV market will achieve double-digit installation growth in 2013, but market revenue will fall to $75 billion**.

Industry revenues - measured as system prices multiplied by total gigawatts installed - peaked at $94 billion in 2011, but fell sharply to $77 billion in 2012. Revenue is projected to decline once again in 2013 to $75 billion, on the back of lower volume growth and continued system price declines, given that PV component prices continue to fall.

**2. The solar module industry will consolidate further in 2013.**

As 2012 comes to a close, fewer than 150 companies will remain in the photovoltaic upstream value chain, down from more than 750 companies in 2010.Most of the consolidation will involve companies going out of business entirely, IHS says. Many integrated players, particularly those based in China, will fold up shop in 2013. The large expense of building and then operating integrated facilities that are underutilized will be more than many can handle financially.

**3. PV module prices will stabilize in the second half of 2013 as oversupply eases.**

Despite a drastic decline in prices along the silicon supply chain since March 2011, solar prices will stabilize by mid-2013. Changes in market dynamics will help restore the global supply-demand balance.

**4. Solar trade wars will rage on in 2013, yielding few winners.**

As of November 2012, there were six different solar trade cases proceeding involving China, Europe, the United States and India. This cycle of sanction and retaliation will not help solve the fundamental challenge of overcapacity plaguing the global PV industry, according to the report.

**5. South Africa and Romania will emerge as PV markets to watch in 2013.**

The two countries next year will expand from virtually no solar installations to capacity of several hundred megawatts. The PV uptake in both markets is driven by distinct factors: In South Africa, PV additions will mainly stem from the tenders awarded in 2012; in Romania, the growth driver will be a green certificate scheme that will stay in place until 2014.

# Photovoltaic Sector Value Chain from 2012 to 2013 (II)

( the top 10 predictions for 2013 from the IHS solar research team)

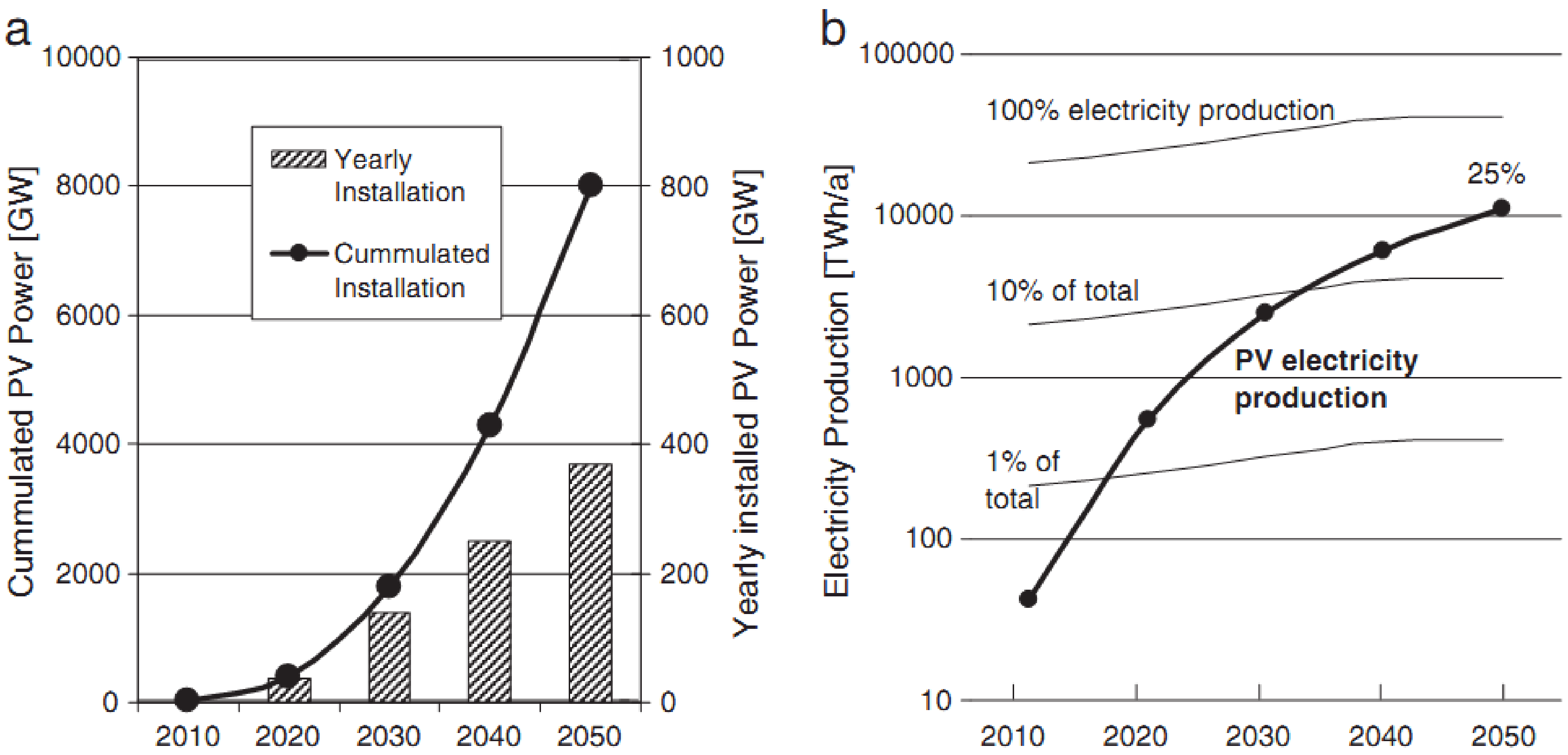
**6. Double-digit returns remain possible for European PV projects in 2013.**
With the subsidy schemes that are currently in place, all EU countries continue to offer attractive conditions for both private and institutional investors. Meanwhile, an evaluation of no-incentive scenarios shows that the most mature market segments are on the cusp of grid parity, allowing healthy returns on investment, IHS says.

**7. Solar will surpass wind in the U.S.**
The year 2013 marks an important milestone, representing the first time that new U.S. solar PV capacity additions will be greater than those made by wind. This is partly a result of the near-term uncertainty over the federal production tax credit for wind, the report explains. However, it is also a reflection of solar PV's increasing competitiveness as a form of renewable power generation in some key U.S. markets.

**8. China will become the world's largest PV market.**
Total PV installations in China next year are predicted to surpass 6 GW, allowing the country to surpass Germany as the No. 1 solar market on the planet.

**9. Energy storage will transform the solar market.**
Batteries increasingly are being seen as an attractive way of retaining PV electricity, letting people use the power later in the day to avoid paying high prices for electricity from the grid. Next year, IHS says, we will see a big jump in the number of residential PV systems installed with batteries attached.

**10. New technology will revive equipment vendors' prospects**.
Finally, improved technologies will help PV manufacturers cut costs, increase margins and, ultimately, distinguish themselves from the competition. Such a focus creates an opportunity for both manufacturers and equipment suppliers to obtain larger revenue streams.



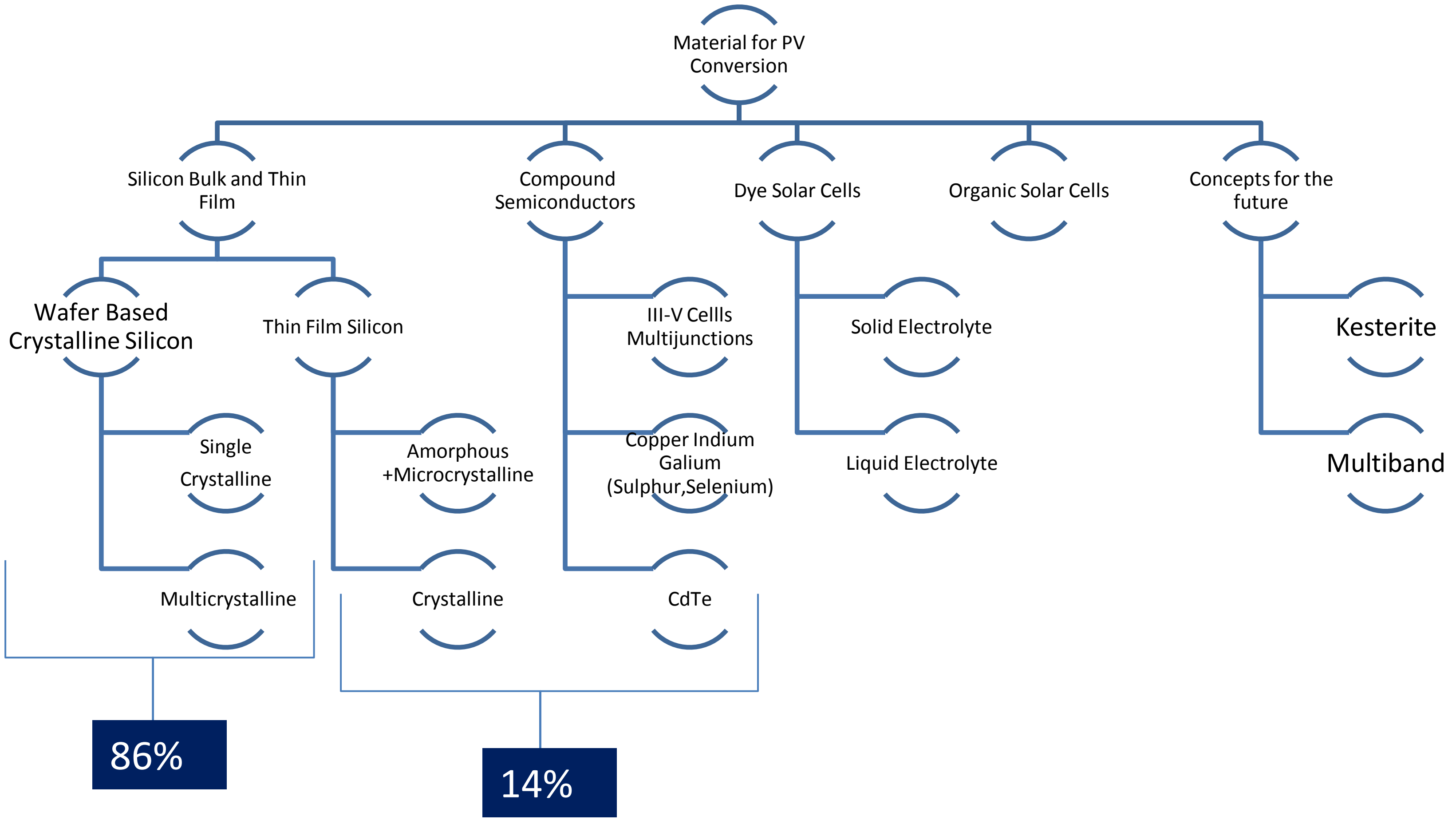

**PVPS growth scenario**

(a) the growth of cumulated respectively yearly installed PV power,

(b) the contribution of solar PV to the worldwide electricity consumption.

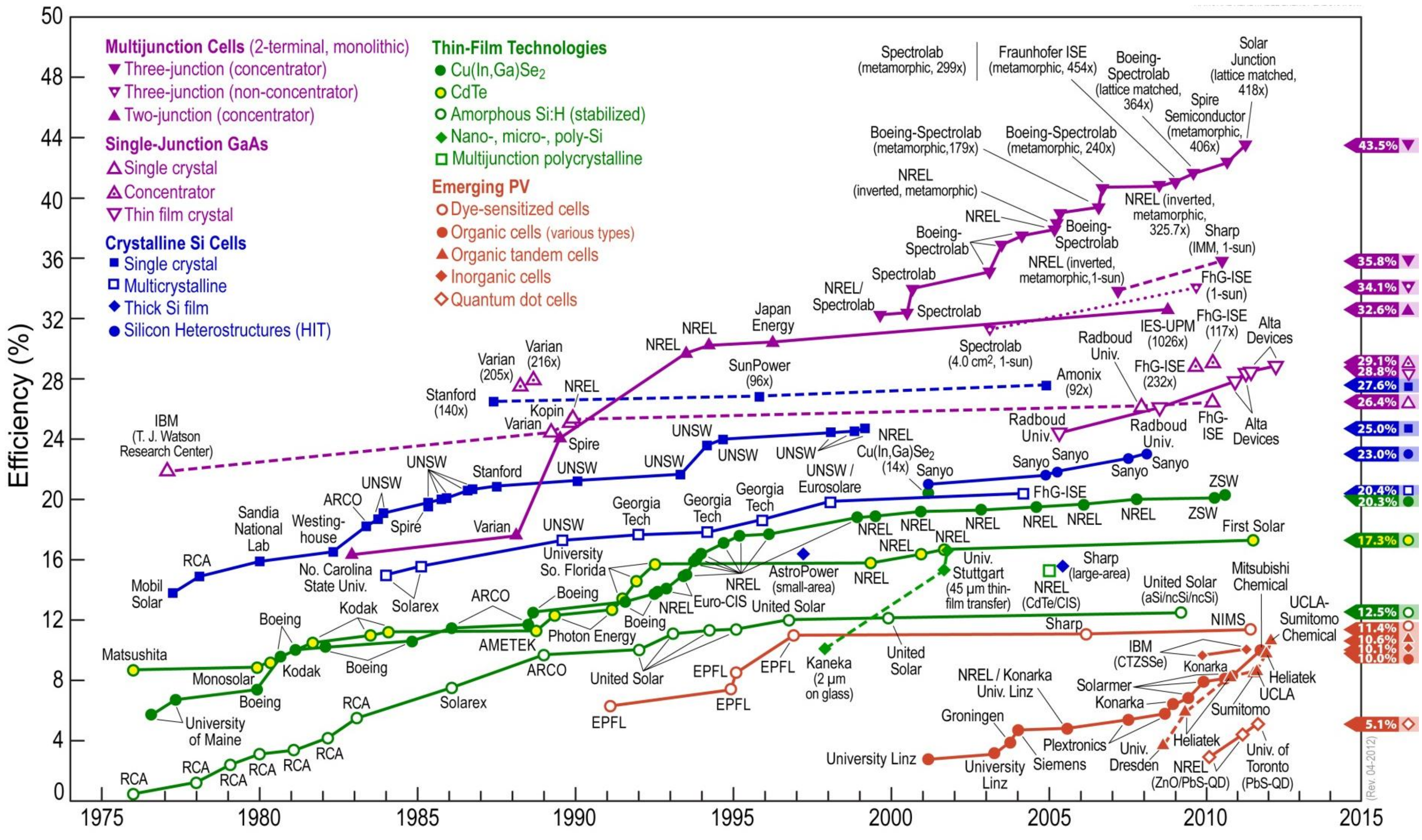
EU Renewable Energy Council (EREC) , RE-thinking 20 50 — A100% Renewable Energy Vision for the European Union, April 2010

# Materials/Technologies for Photovoltaic Conversion

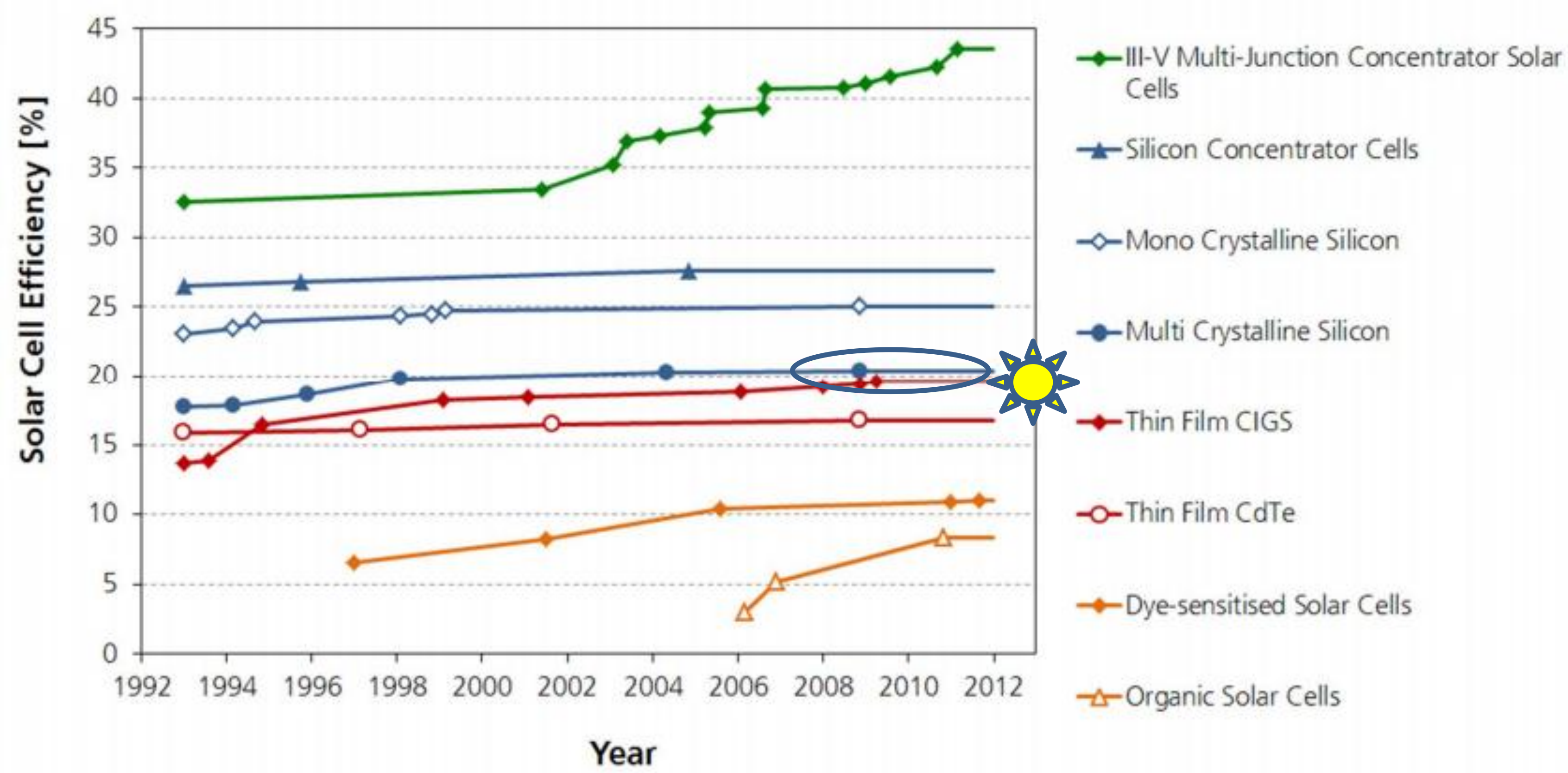


ŞİŞECAM

## Development of conversion efficiency of the best research cells (NREL)

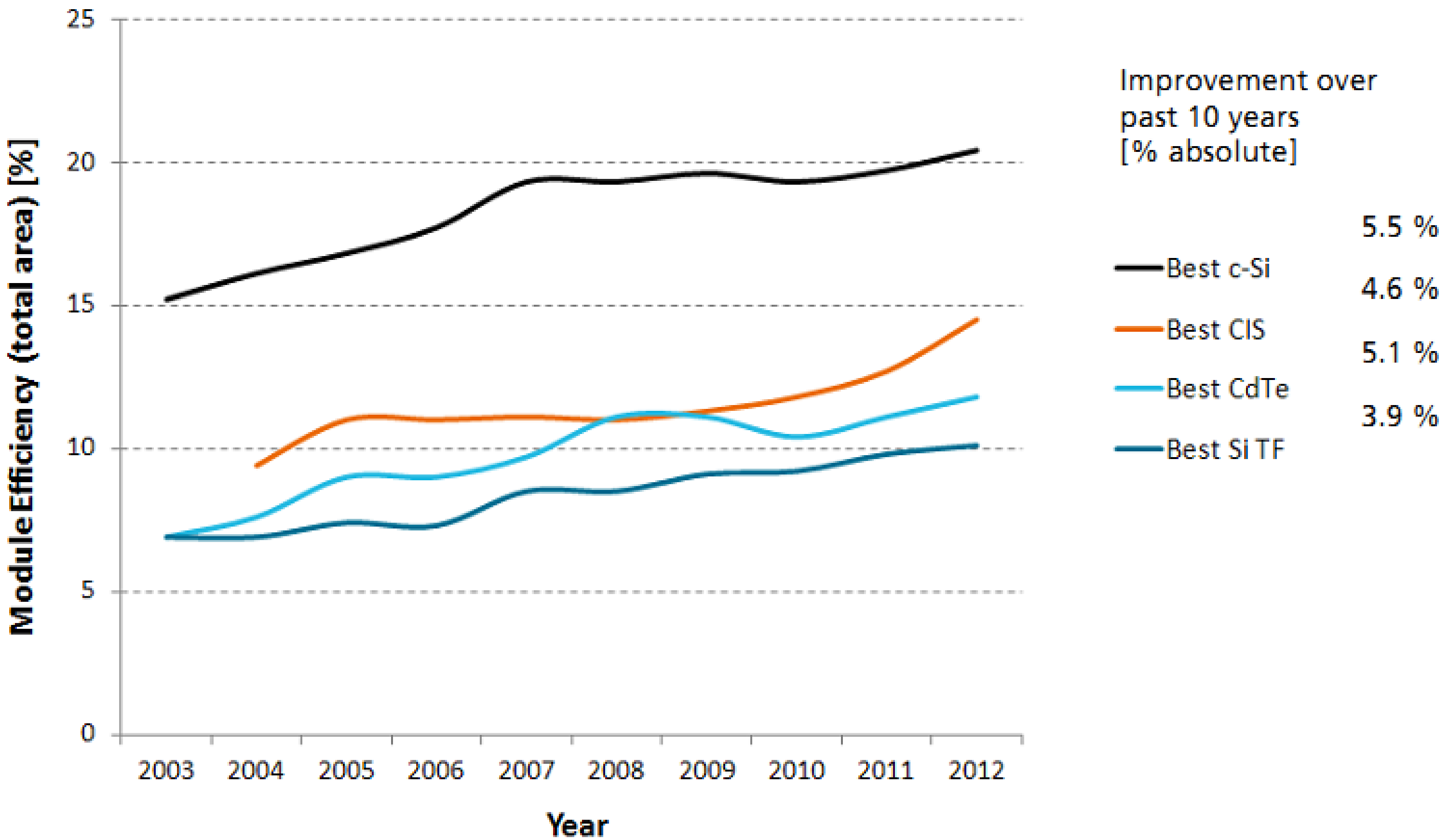


## Development of conversion efficiency of the best research cells



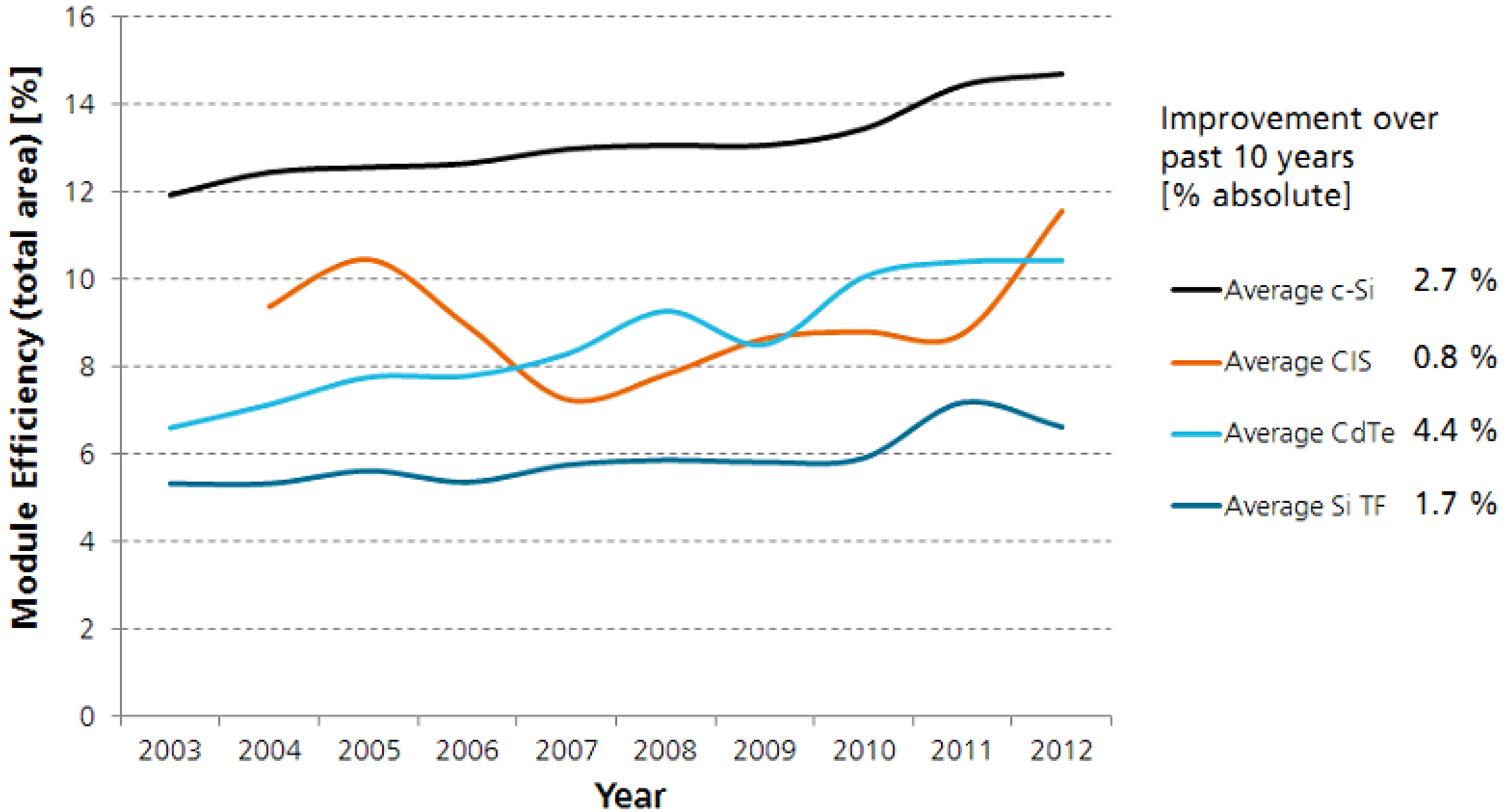

Data: Solar Cell Efficiency Tables (Versions 1-39), Progress in PV: Research and Applications, 1993-2012, Graph: Fraunhofer ISE

# Industrial PV Module Efficiency [%] – Best Modules



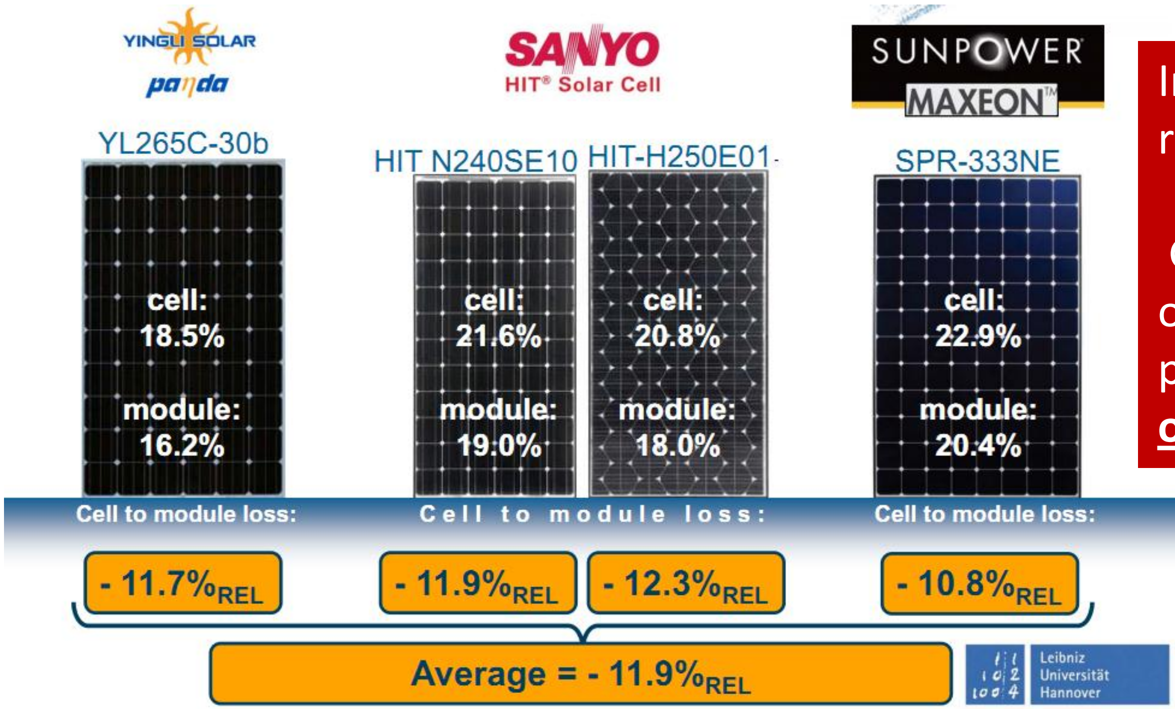

Data: Photon 2/2003-2009, Photon Profi 2/2010-2/2012, Graph: Willeke Fraunhofer ISE 2012

# Industrial PV Module Efficiency [%] – Average Modules




Data: Photon 2/2003-2009, Photon Profi 2/2010-2/2012, Graph: Willeke Fraunhofer ISE 2012

# Cell to Module Loss for Sellected Brands




International PV manufacturing road-maps

Gap between module and cell output power will be closed partly by improving **<u>properties of glass and coating on glass.</u>**

Glasstec Dusseldorf 22-26 October 2012

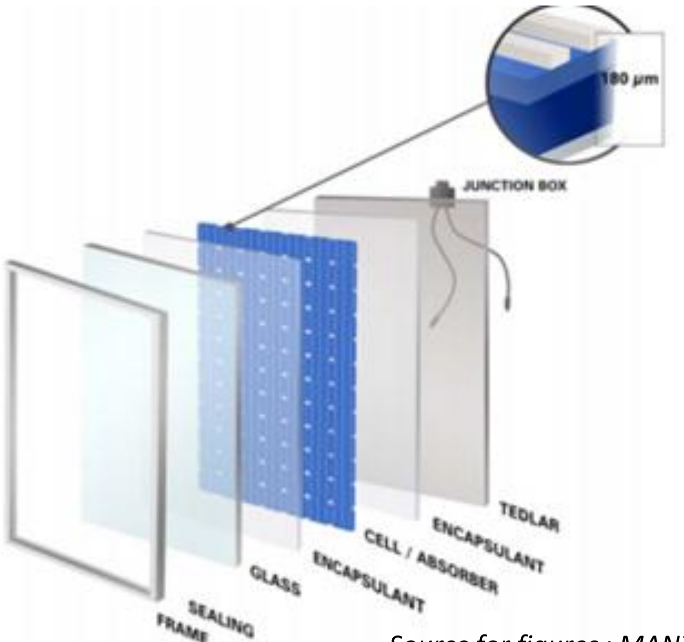
Efficiency, Durability and Cost of Photovoltaic Module directly related to;

- ✓ Mechanical, optical and chemical properties of glass covers and glass substartes/superstrates
- ✓ Coatings on glass covers and glass substrates /superstartes

## Conventional Wafer Based PV Module Encapsulation

**(Total Energy Consumption for Modul Production ~70kWh)**

| Material | Weight (%) | **Energy Balance ($m^2$) | |
|---|---|---|---|
| 3.2mm *Glass | 74 | Production | Tempering |
| | | 20kWh | 2,6kWh |
| Encapsulation (EVA+Tedlar) | ~1 | 14kWh | |
| Silicon | 15 | | |
| Aluminum Frame | 10 | 32.5 kWh (2.5kg Frame for 1m2 module) | |




*Source for figures : MANZ*

## Glass-glass module 2mm Frameless PV Module

**(Total Energy Consumption for Modul Production ~28kWh)**

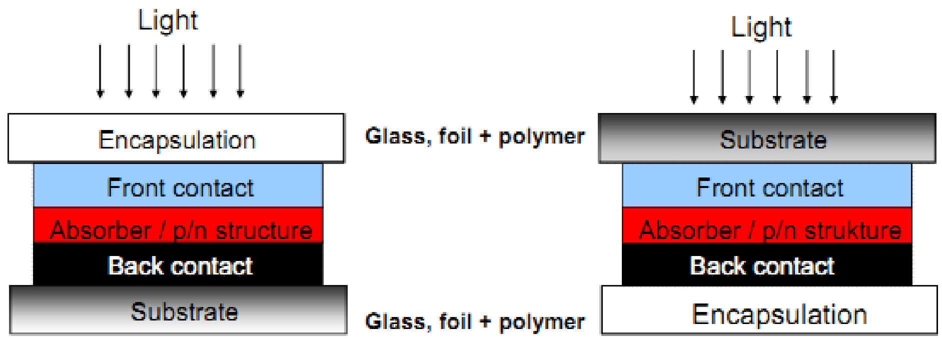
| Material | Weight (%) | ** Energy Balance ($m^2$) | |
|---|---|---|---|
| 2mm Glass | 43 | Production | Tempering |
| | | 12.5kWh | 1.5kWh |
| 2mm Low iron Glass | 42 | 14 kWh | |
| Silicon | 15 | | |

Hermetic Sealing
- ✓ No gas or moisture diffusion
- ✓ Symetric module design avoiding a stress on a cell
- ✓ Avoiding; corrosion, delamination, degredation due to EVA and related sulphuric acid

No need for a frame
Siplified Process

*2.5kg per millimeter per square meter
**J. Weixlberger, Solar Meet Glass at Glasstec 2012 Düseldorf Germany 22 October 2012*

# Thin Film Based Photovoltaic Module Configurations

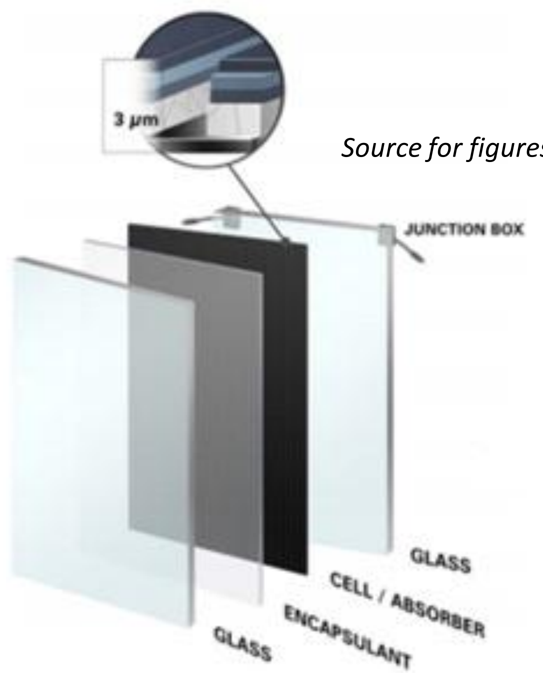



Substrate Configuration

Superstrate Configuration

A weight Breakdown of Thin Film Based Glass to Glass PV Modules

| Material | Thin Film Silicon (%) | CdTe (%) | CIGS/CIGS (%) |
|---|---|---|---|
| Glass | 86 | 95 | 84 |
| Aluminum | 12 | 12 | 12 |
| Other Componets | 14 | 14 | 4 |
| Other Key materilas | Polyol,MDI <1 | EVA <1 | EVA <1 |
| Rare metals | İndium, Germanium | | Indium Galium |




*Source for figures : MANZ*

Source:Securing the supply chain for renewable energy (RE-SUPPLY) – Final Report, E4tech (UK) Ltd & Avalon Consulting November 2012

| Flat Glass Market in 2012 ~ 6.1 x $10^9$ $m^2$ | ( Share in total Market , %) |
|---|---|
| Buldings | 83% |
| Otomotive | %7 |
| Technical Applications | %6 |
| Glass for solar PV | %4 |

# Glass Products for Solar-Energy Conversion

- Solar thermal
  - Flat plate collectors
  - Evacuated tube collectors
- Photovoltaic modules
  - Wafer based
  - Thin film based
- Concentrated Solar Power
  - Mirrors
  - Receivers

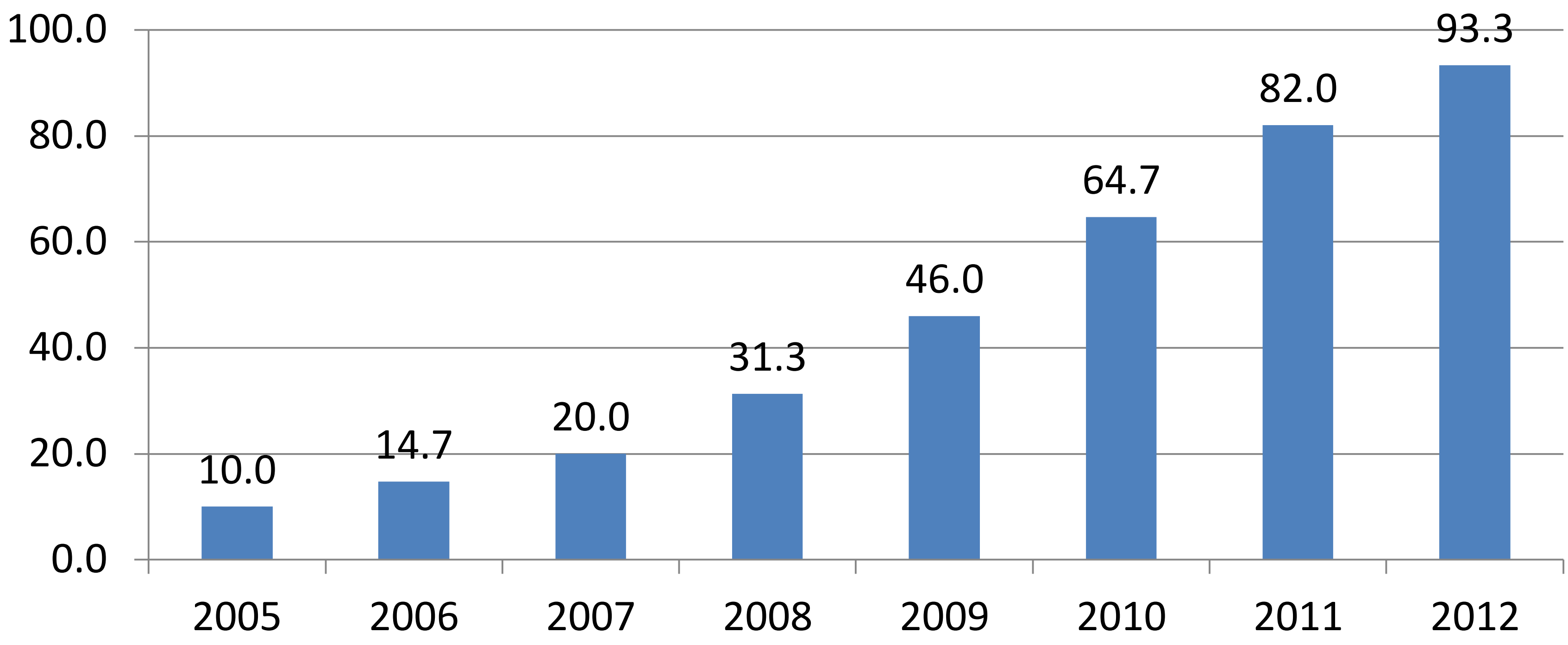
2012 Glass Market for PV ~2.3 x $10^8$ $m^2$

| Country | Share in (%) |
|---|---|
| China | %63 |
| EU | %13 |
| USA | %4 |
| ROW | %20 |

*Source NSG/Pilkinton and DSM Calculation*

# High Transmission Glass Cover Plate for Wafer Based PV Modules (Million m²)

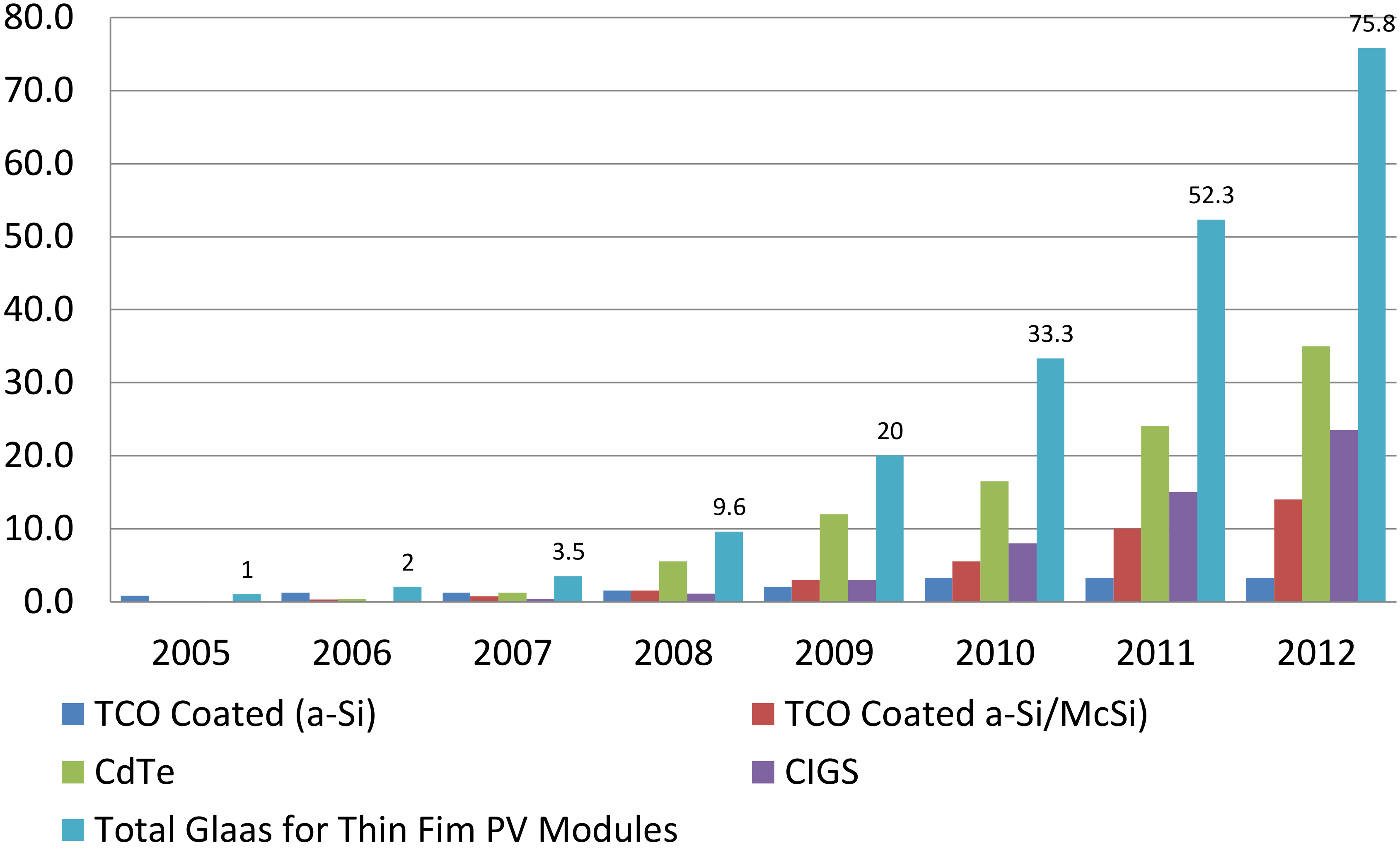
*(Patterned , Antireflective Coating, etc )*




*Data from: Dave Barbieri Stewart Engineers, USA, www.stewartengineers.com*

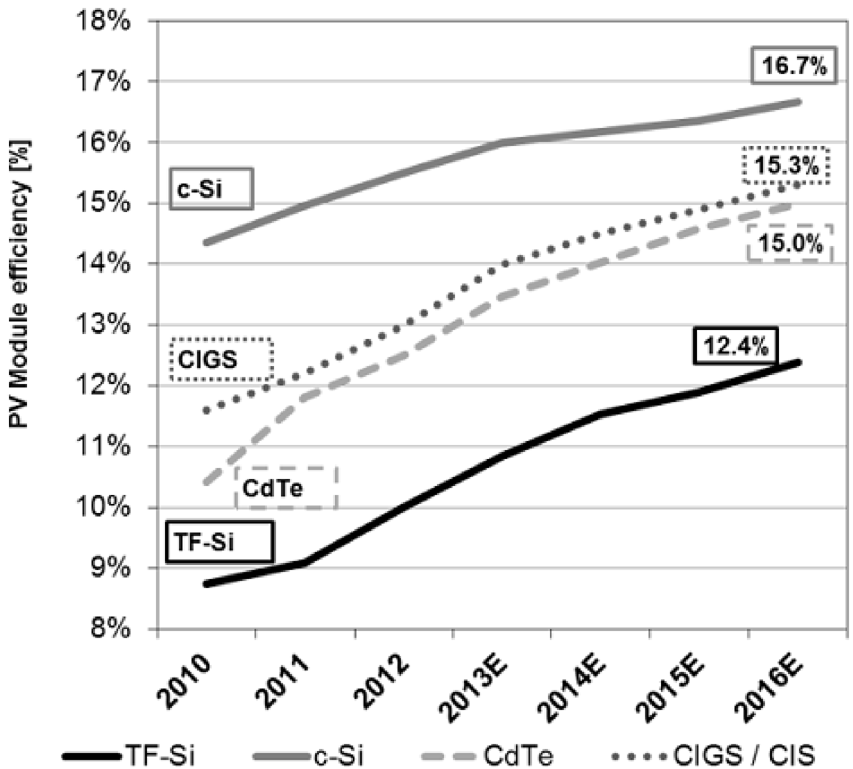
## Glass used For Thin Film Photovoltaic Modules(Million m²)

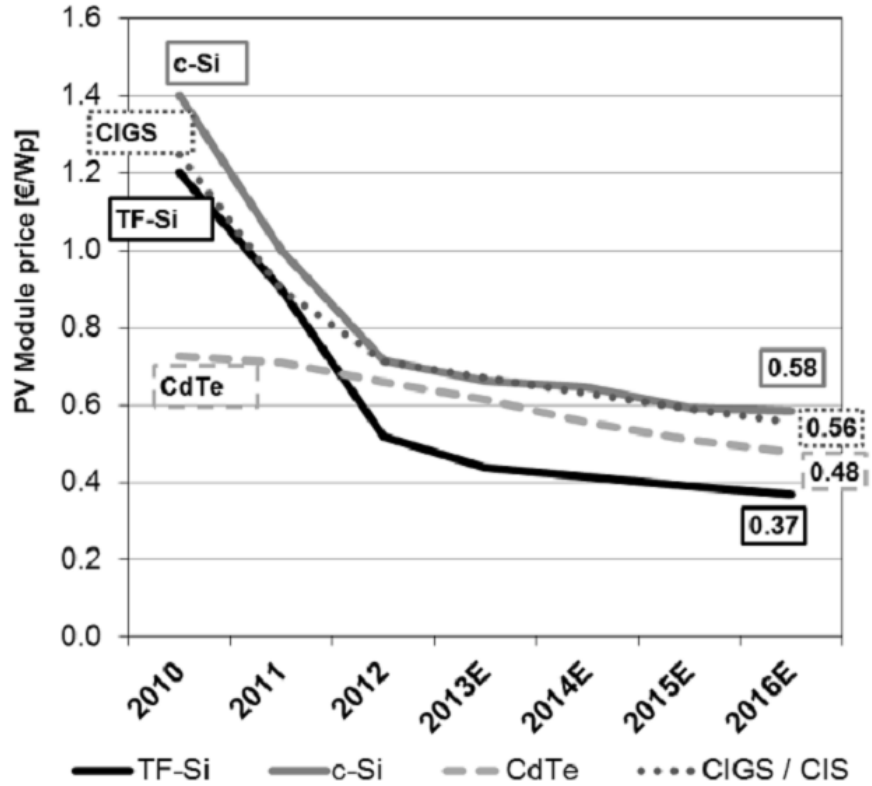
*(Figures do not include equivalent volume of back plate cover glass)*




*Data from: Dave Barbieri Stewart Engineers, USA, www.stewartengineers.com*

# Efficiency & PV Module Efficiency Cost Trends and Forcast upto 2016




Glass covers and glass substartes/superstrates play an important role

Source: BoS costs: Status and optimization to reach industrial grid parity, Stefan Ringbeck, Jürgen Sutterlüti, 27th EU PV Solar Energy Conference and Exhibition , 27 September 2012 Farnkfurt ,Germany

# PV module warranties;

25 years with a maximum allowable degradation rate of 0.8%/year

The International Electrotechnical Commission (IEC) Technical Committee 82, (TC82) has developed and published a number of module and component measurement and qualification standards;

- ✓ IEC 61215 for Crystalline Silicon Modules
- ✓ IEC 61646 for Thin Film Modules
- ✓ IEC 62108 for CPV Modules

- IEC 61646 (Related to Solar Glass)
  - Hail impact 25mm ice ball at 23m/s
  - Wind load 2400 Pa pressure to both sides
  - Heavy snow load 5400Pa pressure

➢ **New: Module Breakage Test (MST32**) Defined new dimensions of the impactor to allow for it to be filled with different material, considered a variety of mounting techniques for the test and defined **<u>the pass criteria for glass breakage based on a 450 mm drop height</u>**

- IEC 62805-1: Measurement of haze of TCO glass
- IEC 62805-2: Measurement of transmittance and reflectance of TCO glass

STANDARDS FOR PV MODULES AND COMPONENTS –RECENT DEVELOPMENTS AND CHALLENGES
John H. Wohlgemuth (NREL) , 27th EUPVSEC 27 Sept 2012, Frankfurt Germany)

## STANDARDS FOR PV MODULES AND COMPONENTS –RECENT DEVELOPMENTS AND CHALLENGES
**John H. Wohlgemuth (NREL) , 27th EUPVSEC 27 Sept 2012, Frankfurt Germany)**

The International PV Module QA Task Force , Working Group has been active in updating its standards as well as developing new standards of interest to the PV industry.

**IEC 61701: 2012 Edition 2 – Salt mist corrosion testing of PV modules**.

The second edition updated the method of test to better match the observed field corrosion of electronic devices.

**IEC 62759: Transportation Testing of PV Modules.**

A draft has been circulating to National Committees with a due date of September 14, 2012. This document defines testing of PV modules in their shipping containers.

**IEC 62782: Dynamic Mechanical Load Testing of PV Modules.**

This has been approved as a New Work Item. In this test the module is mechanically stressed for 1000 cycles to evaluate its susceptibility to broken cells and electrical connectors.

**IEC 62716: Ammonia corrosion testing of PV modules.**

This standard describes test sequences useful to determine the resistance of PV modules to ammonia ($NH_3$) to determine their suitability to be deployed in agricultural locations.

# Solar Industry Expectation from Glass Industry

## Glass as a technical material has only recently gained the attention of the PV industry.

- **Glass Properties:**
  - ✓ **Glass quality** (Compositional control for trace transition metal contents, free from scratches, inclusions and cracks)
  - ✓ **Corrosion resistance** (Improved resistance to 'acid rain' and to corrosive salt environments (surfaces; cleanliness, free of corrosion products, low sodium concentration on the surface and age )
  - ✓ **Maximum transparency over desired UV/vis/IR ranges** ( Nano-composites, glasses with engineered transparencies, low iron glaces etc..))
  - ✓ **No solarization effects**
  - ✓ **High planarity**
  - ✓ **Mechanical strength** (Stronger, 'less brittle' glasses and glasses (thermal/chemical treatments , improved fracture toughness)
  - ✓ **Thermal expansion characteristics of system**
  - ✓ **Thinner glass**

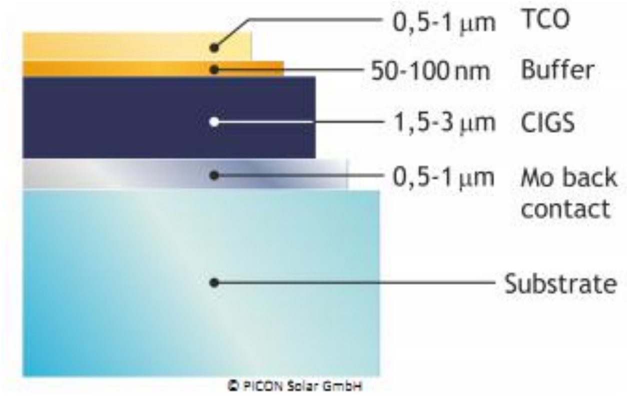
## Solar Industry Expectation from Glass Industry

- ✓ Functional coatings will account for ten to 20 percent of flat glass sales, if not more, by 2015.
- ✓ Functional Coatings/structural surfaces **with acceptable price performance ratio :**

- ✓ Solar Glass with Structured Surfaces
- ✓ Antireflective Coating Surfaces
- ✓ Transparent Conduction Oxides (TC0)
- ✓ Fluorinated Transparent Oxides (FTO)
- ✓ Self Cleaning Coatings
- ✓ Metal Back Contact

# Total Cost of Ownership (TCoO) for Glass/Glass CIGS Modules

- **Process**
  - Glass / glass module production
  - CIGS by co-evaporation
  - Mo back contact, AZO front contact and barrier layer by sputtering
  - Wet chemical CdS buffer including waste treatment
- **Module**
  - 12% module total area efficiency (production average)
  - Monolithically integrated series connection
  - 3.2mm glass/glass module with standard EVA foil, tape edge seal, j-box

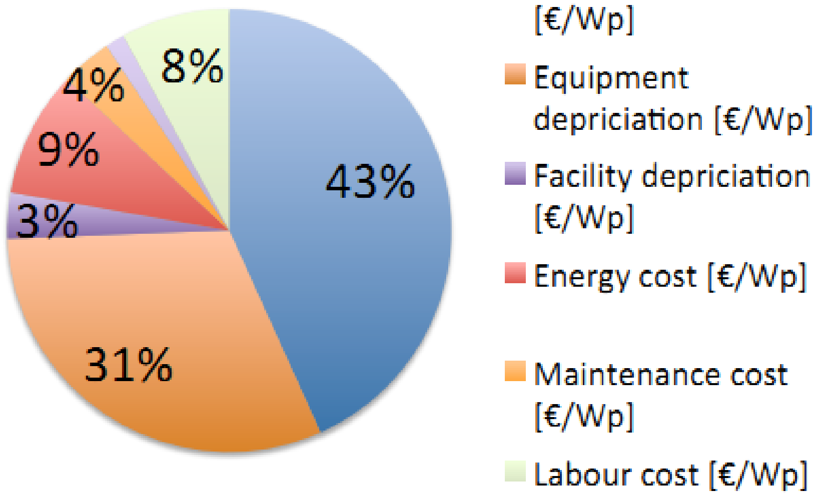



- **Cell design**
  - Glass substrate
  - Na Barrier
  - 0.5µm Mo
  - 1.6µm CIGS
  - 50nm CdS
  - 0.6µm AZO

S.Schuller, I Luck and J Berghold (PICON Solar GMBH) , Thin Film Week Berlin 2012

# Total cost based on assumptions I-III

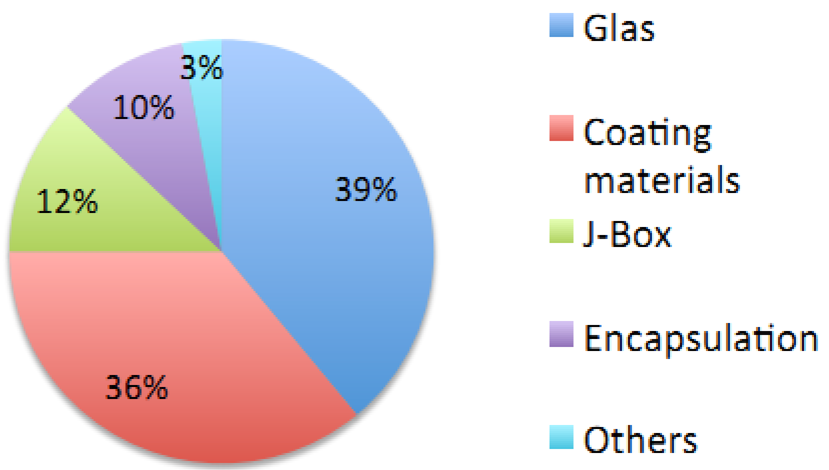
| Cost structure | [€/Wp] |
|---|---|
| Total material cost | 0,244 |
| Equipment depriciation | 0,175 |
| Energy cost | 0,052 |
| Labour cost | 0,045 |
| Maintenance cost | 0,021 |
| Facility depriciation | 0,019 |
| Consumables cost | 0,008 |
| Total cost | 0,563 |




- **Based on ‚state of the art' assumptions, 0.56€/$W_p$ total cost of ownership for CIGS modules is possible**
- Material and equipment cost dominate the cost structure (74%)

S.Schuller, I Luck and J Berghold (PICON Solar GMBH), Thin Film Week Berlin 2012

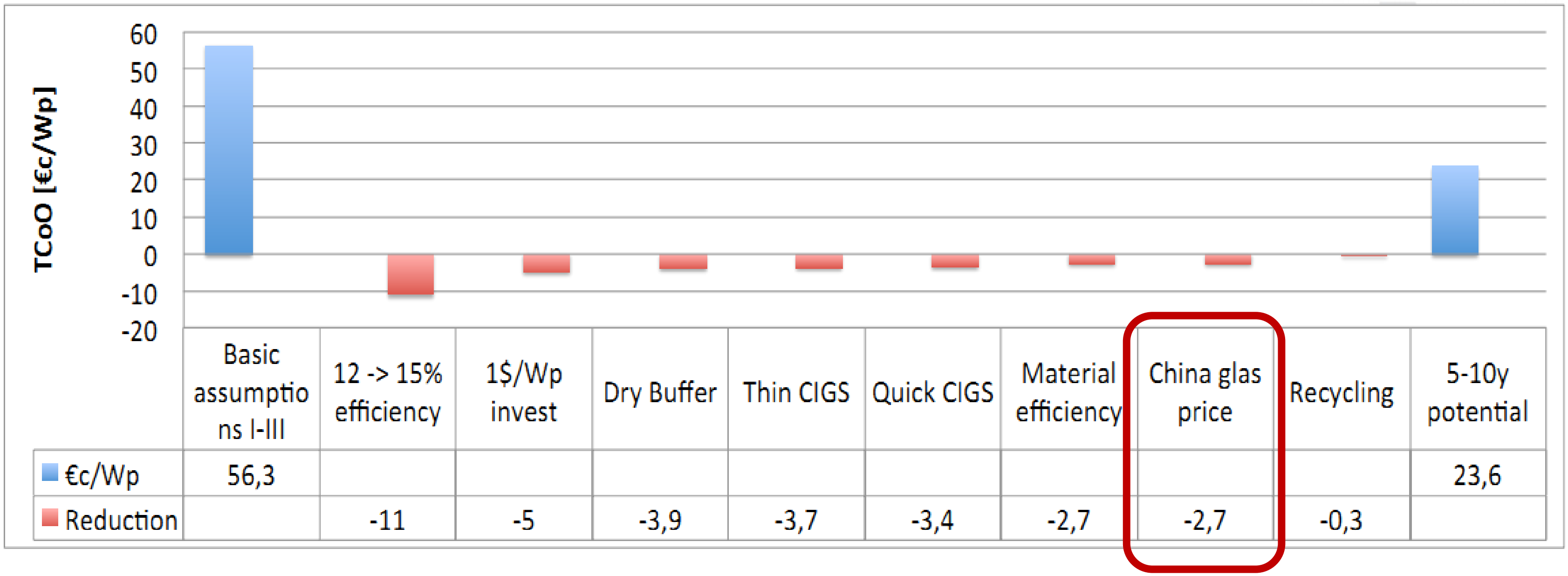
# Breakdown of material cost




- Total material cost of 0.24€/$W_p$ is dominated by glass substrate (0.1€/$W_p$)
- Cell / coating materials around 0.09€/$W_p$

S.Schuller, I Luck and J Berghold (PICON Solar GMBH) , Thin Film Week Berlin 2012

# Price Decrease Potential in Total Cost of Ownership (TCoO) for Glass/Glass CIGS Modules within 5 Years




%30 decrease in cost of solar glass within 5 years !

S.Schuller, I Luck and J Berghold (PICON Solar GMBH) , Thin Film Week Berlin 2012

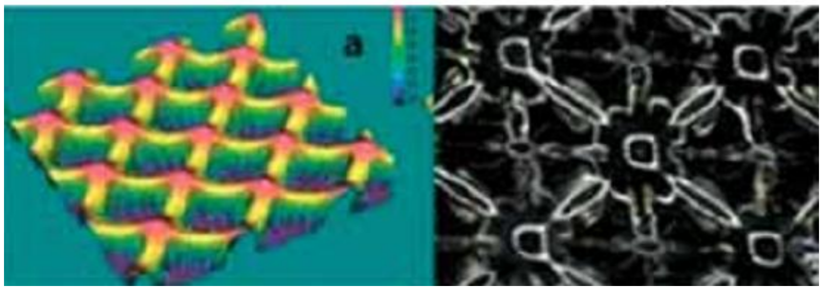
| Photovoltaic Modul Technology | Glass Substrate Specifications | | | |
|---|---|---|---|---|
| | Low iron,high transmission | Antireflective Coating/Surface structuring | Transparant Conducting Oxide with Rough Surface | Transparant Conducting Oxide with Smooth Surface |
| Wafer Based Silicon | Yes | Yes | | |
| Thin Film Silicon (a-Si/μc-Si | Yes | Yes | Yes | |
| CdTe | Yes | Yes | | Yes |
| CIGS | Yes | Yes | | Yes |

| Solar Glass with Structured Surfaces | |
|---|---|
| Macro Structure | Micro Structure |
| Pyramidal Structure | Stochastic Structure |
| Inverted Pyramidal Structure | |
| V Grove Structure | Periodic Structure |
| Ornemental Structure | |
| *Sandy Structure (Şişecam) | |
| With or without antireflective coatings | |

GLASS PERFORMANCE DAYS 2011 Evaluation of the transmittance of solar glassf or PV modulesRaoul Fischer, Michael Köhl1, Karl-Anders Weiß, Markus Heck,

# Anti Reflectivity by Structuring Glass Surfaces

## Macro structured solar glass

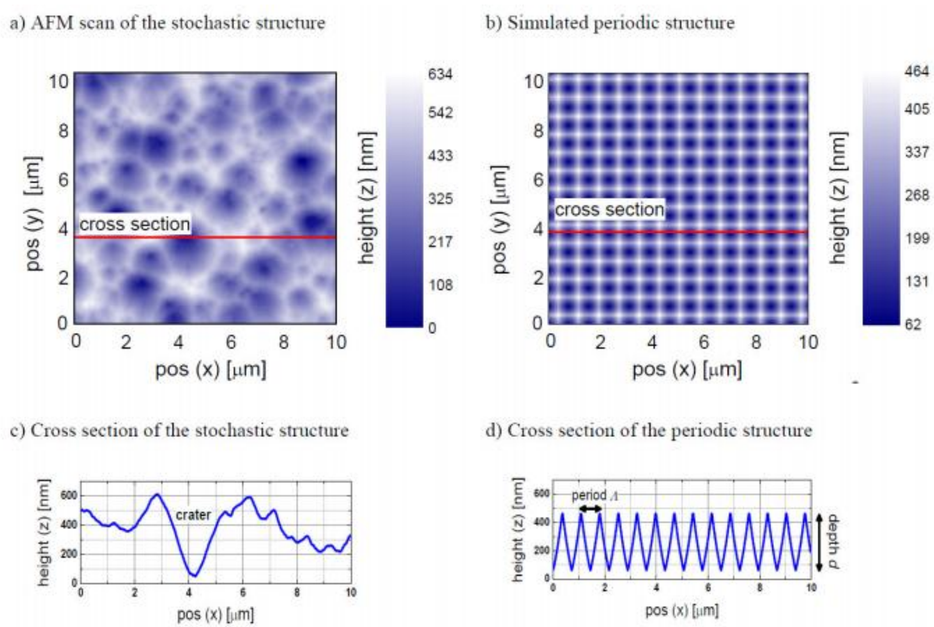



Profi lometric and light micro-scopic images 10x10mm of macro (a) structure (752 µm structural depth)

- ✓ Structure dimensions on the surface of macro structured solar glass exceed the wavelength of solar irradiation.
- ✓ This glass type provides the incoming light more often a surface that is aligned steep relative to the angle of light incidence. Thus, it reduces surface reflection.
- ✓ Additionally such surfaces increase the probability of internal refl ectionas they provide a second chance for the light to reach the PV cell

# Anti Reflectivity by Structuring Glass Surfaces

## Micro structured solar glass (Stochastic and periodical)




- ✓ The micro structured have structure dimensions up to only a few micrometers
- ✓ The dimension of micro-structure are patially in the wavelength range (0.296 – 4.0 µm) of the incoming solar spectrum.
- ✓ Due to this, an effective refractive index gradient results on the surface which reduces reflection

# Anti-Reflective Coating (ARC)

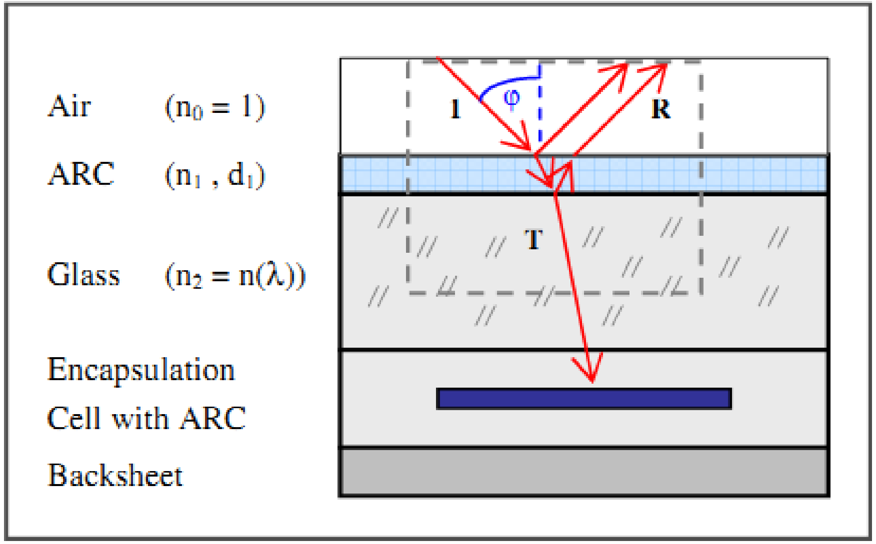
- **AR coatings on front glass of PV modules improve specific energy yield**,

( PVPS systems with non-optimal orientation of modules (horizontal flat roof top vertical facade) energy yield gain of up to 1% ) **( main driver kWh instead of kWp)**

- **important key in module efficiencies and prices**

**(reduce total cost of ownership per kWp)**

- the ARC thickness is tuned for the glass used and controlled to one quarter of the targeted wavelength to optimize anti-reflection capabilities.
- Since sunlight has a broad wavelength, multi-layer coatings are often employed.
- The position of the sun and the incident angle changes throughout the day which affects the light reflected from the surface.
- Thus, an ARC would have to ensure the reduction of reflection and increase in transmission through the day ( rough surface or patterned glass)
- ARC the high durability performance




no = refractive index of air
$n_1$= refractive index of ARC
$n_2$= refractive index of glass
$d_1$= thickness of ARC layer
$\varphi_o$= Angle of incidence for incoming radiation

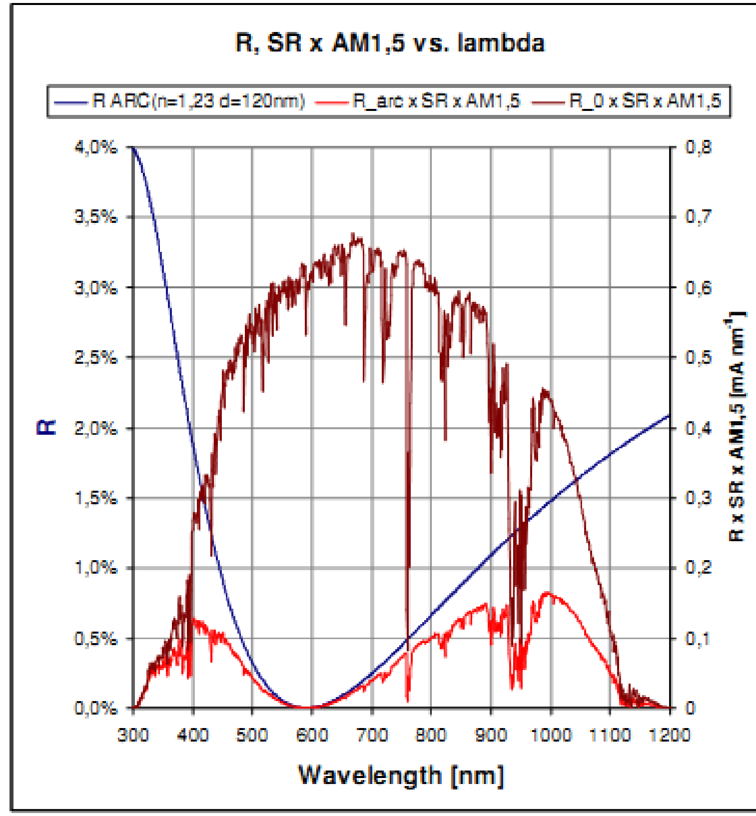
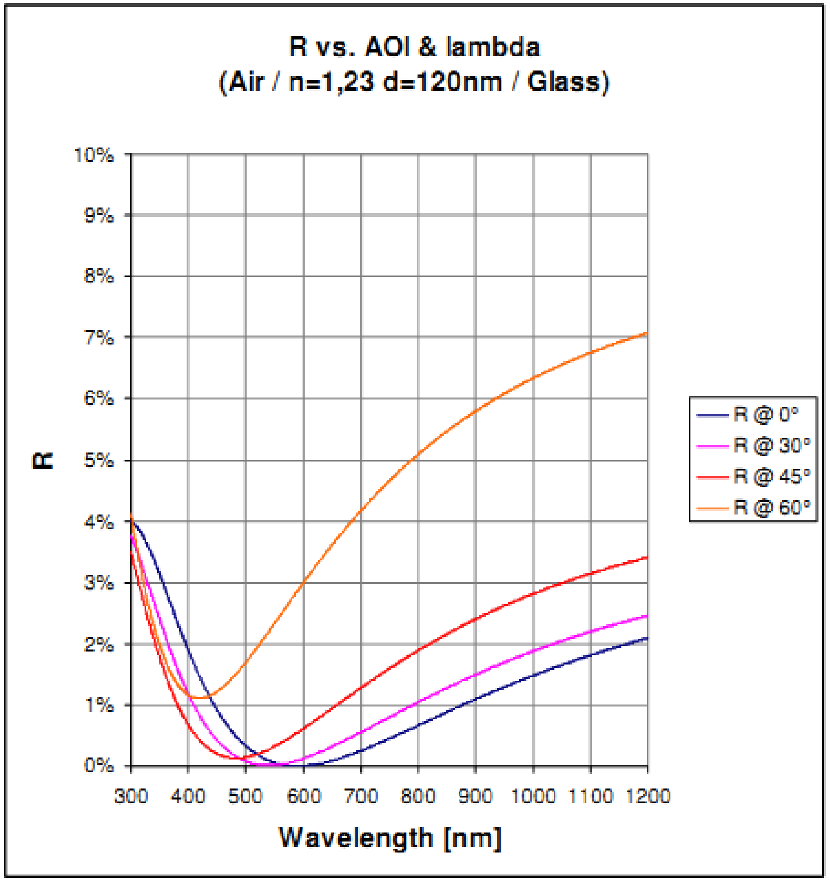



**Fig. 3**: SR x AM1,5 (brown curve), spectral reflectivity R(λ) of a typical AR coating on glass (@ φ = 0, blue curve, see fig. 2) and product of both functions (red curve).

PV MODULES WITH ANTI-REFLECTIVE COATED GLASS: PERFORMANCE SIMULATION AND OUTDOOR MEASUREMENTS OF SPECIFIC ENERGY YIELD GAIN B. Litzenburger, J. Dittrich, 27th EU PVSEC 2012

# Spectral Reflectivity R(λ) of a typical AR coating on glass for different angles of incidence

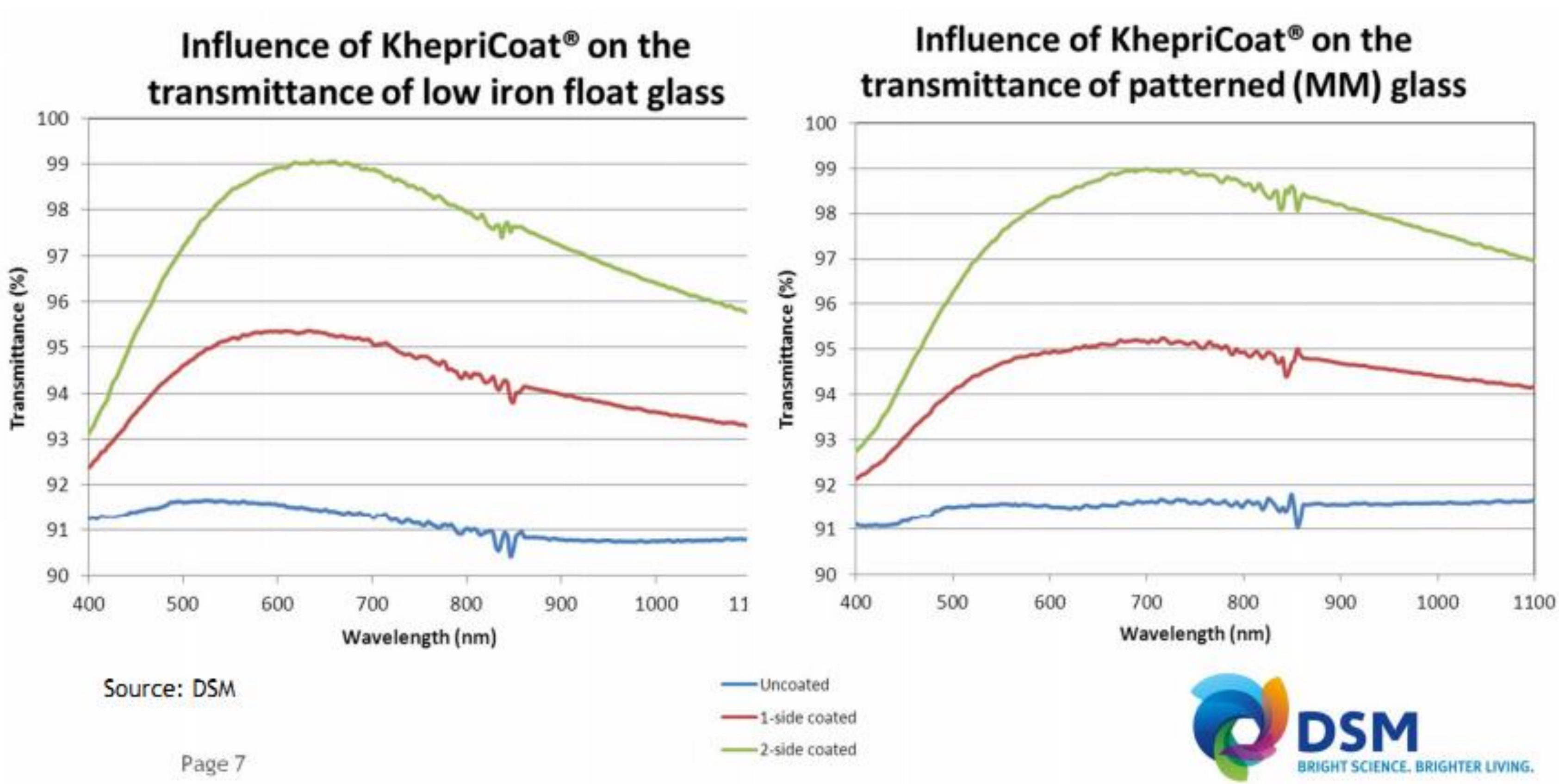



$$R(\lambda,\varphi)=\frac{R_s(\lambda,\varphi)+R_p(\lambda,\varphi)}{2}$$

PV MODULES WITH ANTI-REFLECTIVE COATED GLASS: PERFORMANCE SIMULATION AND OUTDOOR MEASUREMENTS OF SPECIFIC ENERGY YIELD GAIN B. Litzenburger, J. Dittrich, 27th EU PVSEC 2012

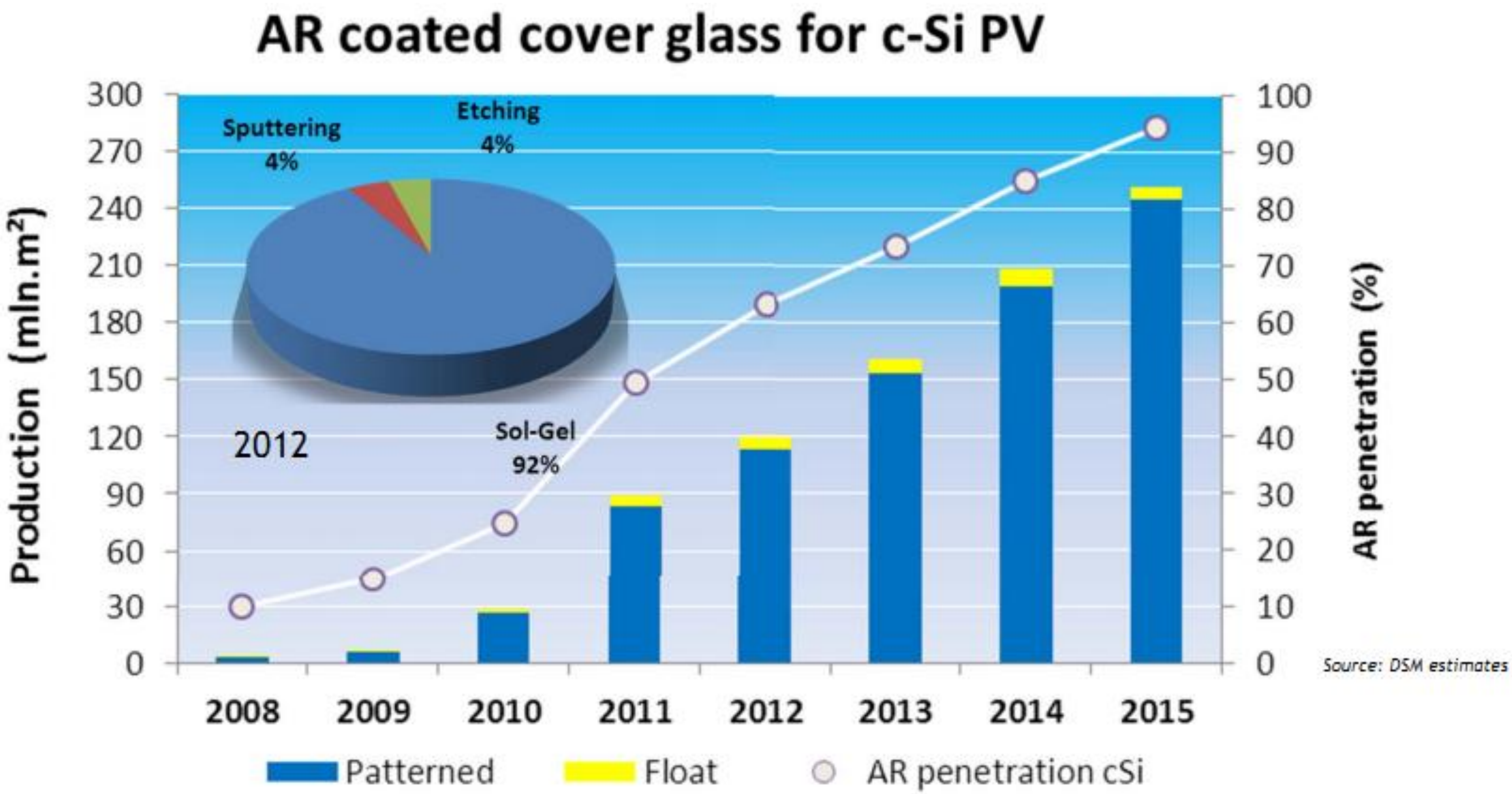
# One Side ARC vs Two Sides ARC on low iron float and patterned glass

*(DSM presentation at Solarpec Glasstech 2012 Düselldorf Germany)*



# Anti-Reflective Coated PV Cover Glass Market Development

(Currently 60% of wafer based PV Modules employe ARC Glass Covers)




*(DSM presentation at Solarpec Glasstech 2012 Düselldorf Germany*)

# Anti-Reflective Coating Technologies

Chemical vapor deposition (CVD):

- Spray through pressure nozzles air (airless) atomizing
  - ✓ overspray,
  - ✓ clogging,
  - ✓ poor deposition control
  - ✓ inconsistent uniformity.
  - ✓ Low cost
  - ✓ On line deposition
- ultrasonic spray head atomizing
  - ✓ minimal overspray
  - ✓ non-clogging performance
  - ✓ uniform coatings
  - ✓ On line deposition

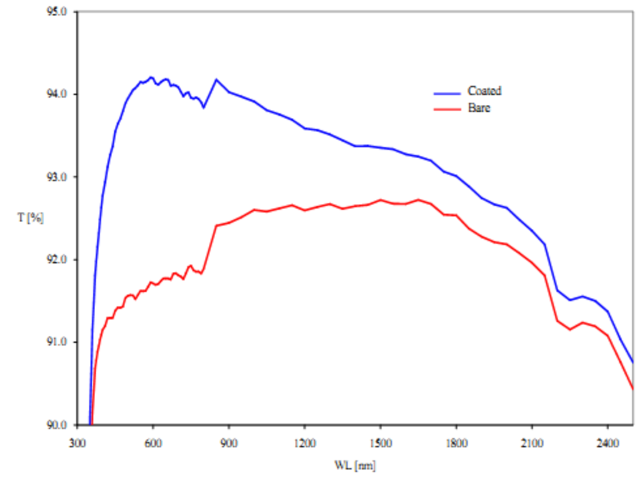
- Physical vapor deposition (PVD): Sputtering
  - ✓ well-developed technology
  - ✓ high deposition rates of up to 150 nm/min.
  - ✓ very uniform coating
  - ✓ high cost
  - ✓ Off-line deposition
- Plasma enhanced CVD (PECVD)
- Atomic Layer Deposition

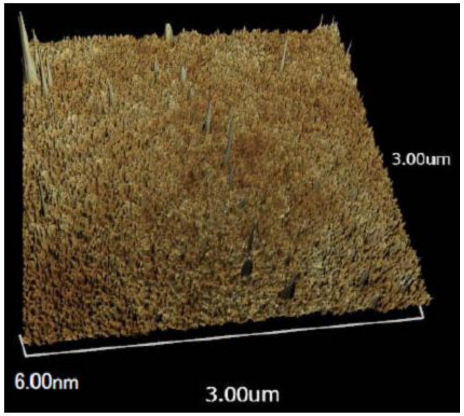
NEW APPROACHES TO ANTI-REFLECTION COATING MATERIALS ON PV GLASS AND COATING PROCESS

*Toru Yoshida, Yasukazu Kishimot and Fan YingYing, 27 EU PVSEC Frankfurt 2012*

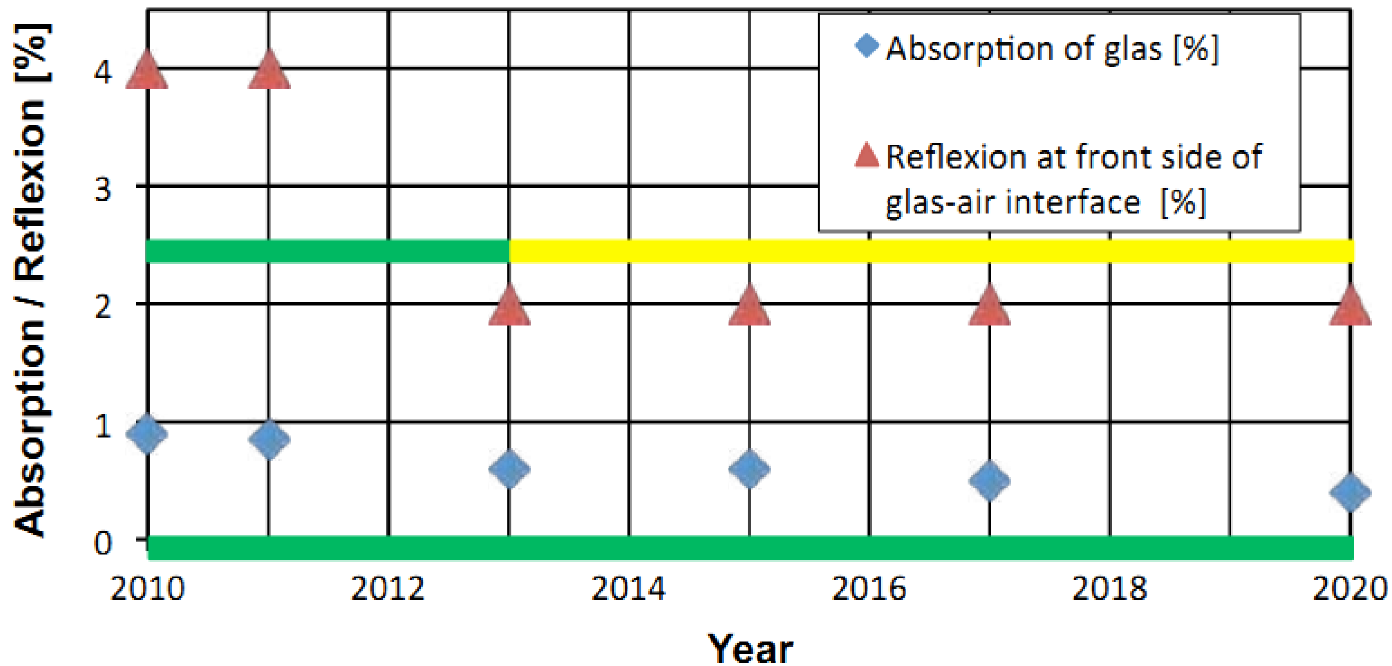
**Next Generation of AR Coating :** Textured AR layers.

- ✓ The texture size does not need to match the λ of light
- ✓ The textured AR can have novel method of minimizing the reflection by re'incidences of the reflected light.
- ✓ The aspect ratio of the texture is an important factor to improve the light efficiency.
- ✓ Using some hybrid'organic composition easily forms the texture structure achieved ( shown AFM picture)
- ✓ The texture'coated glass **improves the light'trapping performance over 3%.**
- ✓ With further optimizations, and **at least 5% of improvement for the light efficiency can be expected theoretically**.
- ✓ The textured AR material has the advantage in comparison with the known AR materials
- ✓ The new AR layer contains **hydrophilic and hydrophobic sites randomly, and rain drops including dirt can be repelled very easily.**
- ✓ The other specs necessary to the AR layer are satisfied



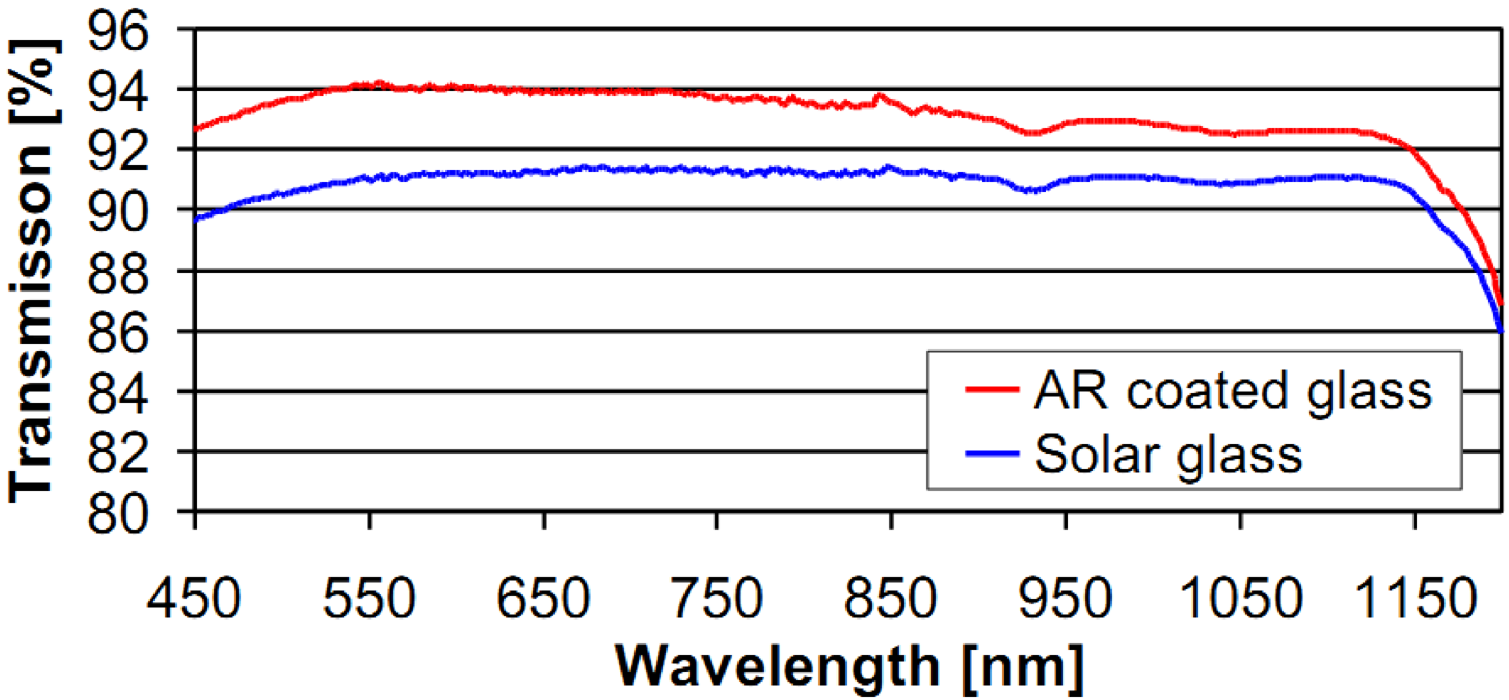



# Projection on the reduction of optical losses e.g. absorption and reflection of front cover glass




SEMI INTERNATIONAL TECHNOLOGY ROADMAP FOR PHOTOVOLTAICS (ITRPV) – CHALLENGES IN C-SI TECHNOLOGY FOR SUPPLIERS AND MANUFACTURERS M. Fischer1, A. Metz2, S. Raithel 27th EU PVSEc 2012

The transmission over the relevant range of the solar spectrum and hence the module performance can be increased by up to 2.5%




SEMI INTERNATIONAL TECHNOLOGY ROADMAP FOR PHOTOVOLTAICS (ITRPV) – CHALLENGES IN C-SI TECHNOLOGY FOR SUPPLIERS AND MANUFACTURERS M. Fischer1, A. Metz2, S. Raithel 27th EU PVSEc 2012

# Transparent Conductive Oxides

- Thin film Photovoltaic Modules require a highly conductive transparent electrode on the glass surface in contact with the active semiconductor layer
- The transparent conductive coating most often used is fluorine doped tin oxide (SnO:F)

  *(similar in composition to the Low-E product produced using the CVD process)*
- Thin film silicon cell production requires microscopically "rough" surface for a transparent conductive layer ( more effectively scatter light into the cell
- CdTe cell production needs a "smooth" transparent conductive electrode to prevent "shorting" of the active layers.
- For thin film PV cell/module production aluminium-zinc oxide (AZO) and indium tin oxide (ITO) are new contenders
- Organic PV cells and Dye PV cells uses a different type of TCO

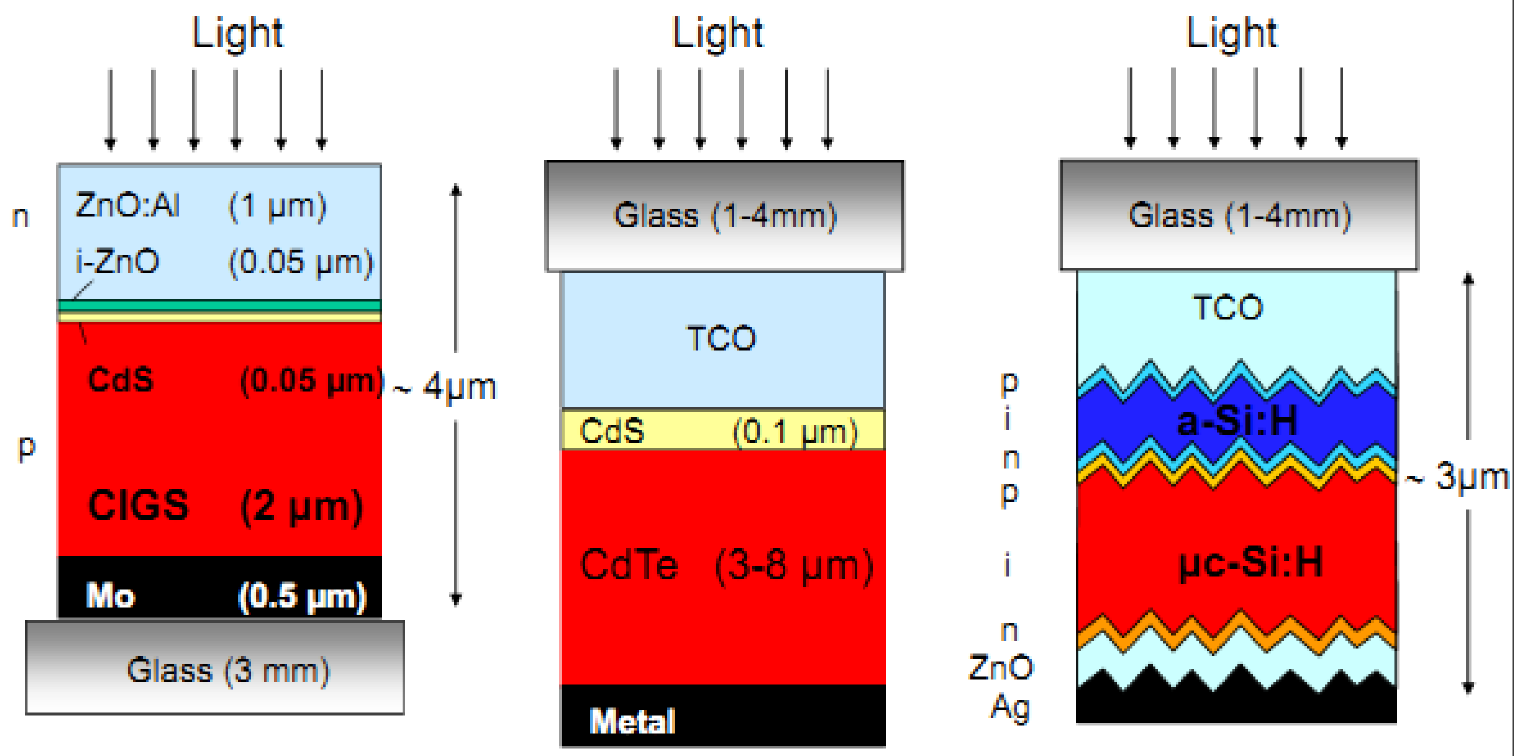
The Glass Industry Approach to Global Megatrends: A Fusion of Macro-, Micro-, and Nano- Technologies for Next Generation Products James J. Finley PPG Glass Technology Center, PPG Industries, Inc.

# Confugurations for thin film modules on the market

**CIGS solar cells:**
$CuIn_{1-x}Ga_xSe_{1-y}S_y$

**CdTe solar cells:**
CdTe

**a-Si/µc-Si tandem cells**
(„Micromorph“)

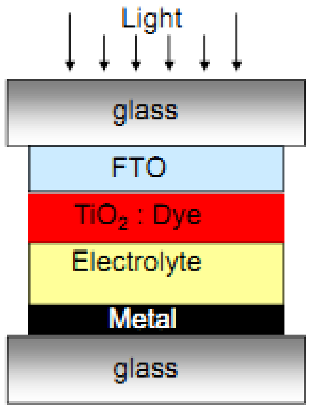



Figures by ZSW

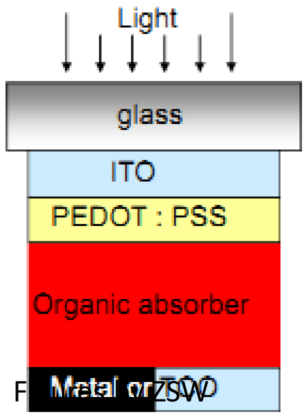
# Configurations for New Tin Film Technologies

Fluorinated tin oxide (**FTO**) **glass** substrates

**Dye-sensitized solar cell**




**Organic solar cell**




**Highly absorbing thin-film gives name to technology**

**Transparent Conductive Oxide (TCO) for front contact**

Transparent, conductive, and ultrathin graphene films, as an alternative to the ubiquitously employed metal oxides window electrodes for solid-state dye-sensitized solar cells, are demonstrated. These graphene films are fabricated from exfoliated graphite oxide, followed by thermal reduction. The obtained films exhibit a high conductivity of 550 S/cm and a transparency of more than 70% over 1000–3000 nm. Furthermore, they show high chemical and thermal stabilities as well as an ultrasmooth surface with tunable wettability.

# Selected Product Criteria

| | Major c-Si | Major a-Si/Tandem Cell | Major CdTe |
|---|---|---|---|
| Coating | None or AR (one Side) | Na Barrier, $SnO_2:F$ | Na Barrier, $SnO_2:F$ |
| Format, mm | 2200 +/- 1 x 2600 mm +/- 1, Untempered | 2200 +/- 1 x 2600 mm +/- 1, Untempered | 600 +/- 0.8 x 1200 mm +/- 0.8 |
| Thickness, mm | 3.2 +/- 0.2<br>4.0 +/- 0.2 | 3.2 +/- 0.2 | 3.2 +/- 0.05 |
| T vis, % | >91% Uncoated[2]<br>>93.5% Coated[2] | 78.5%, 0.7%[1] | 80.5 Min |
| Haze, % | | >10 | 3.5 Max |
| SR, Ohms/Square | | <10 | 9.5 +/-0.8 |
| Reflected Color | | | a* -4.5 to +1.5<br>b* +0.5 to +5.5 |

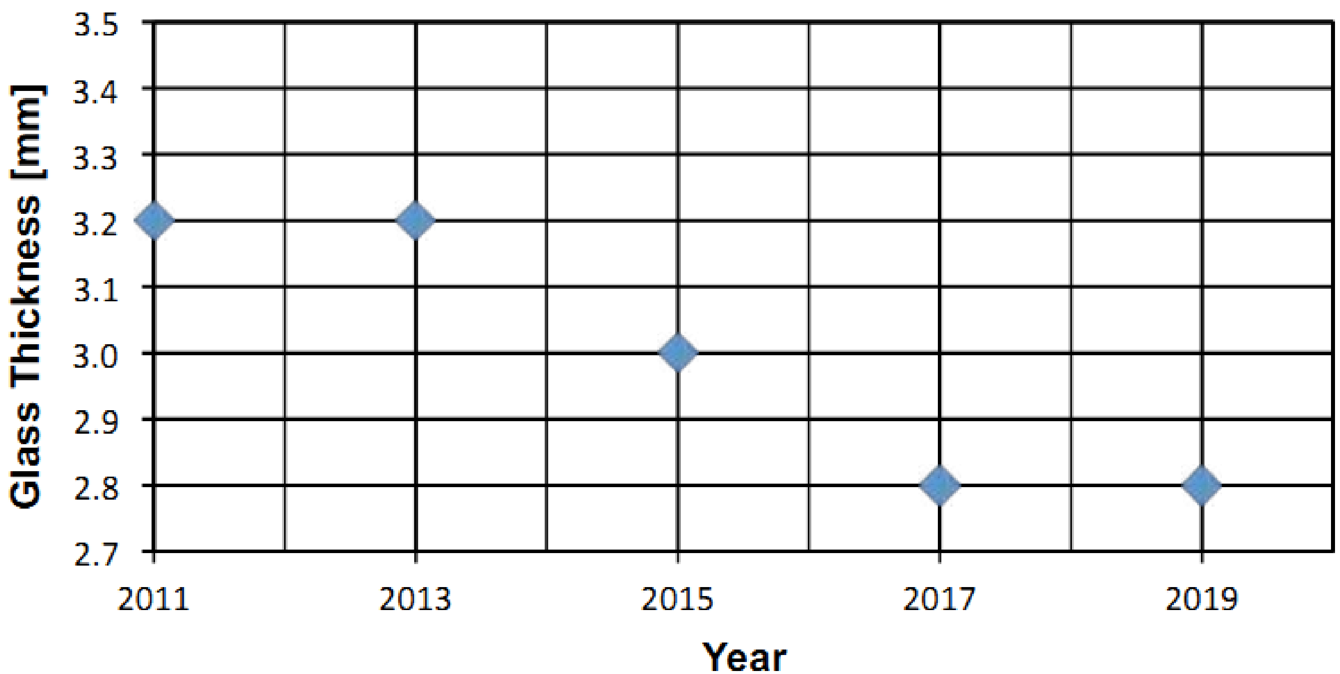
1. Weighted average, uniformity (std. dev/average)
2. Weighted average

# PV-TCO Coating Technology Comparison

| Operation And Product | Sputtered AZO | APCVD SnO:F |
|---|---|---|
| Used Commercially | Not Well Established | Well established |
| Integrated into glass production? | No, separate operation | Yes |
| Capital Cost, $M | 20-50 | 10-25 |
| Variable Cost, $/M2 | 5-7 | 1.5 |
| Application Temperature | Much lower than APCVD | 600-710 C |
| Application Pressure | Vacuum | Atmospheric |
| Coating Precursor Availability | Wide range of targets | Wide range of chemical precursors |
| Requires special handling? | Yes | No, handle like glass |

# Reduction of glass thickness as cost reduction measure

- Solar glass thickness has been reduced from 4.00 mm to 3.2 mm.
- Challenges below 3.0 mm in the glass manufacturing process continuing



## The future of photovoltaic modules

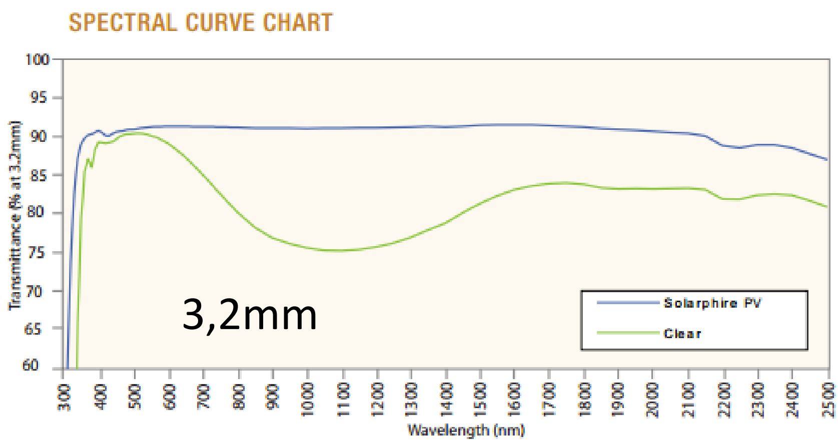
- The modules with thin glass ( 2mm front and 2 mm back sheet glass)
  - ✓ *far more efficient than traditional PV Module*
- Module Productions are being shifted to glass – glass
- Higher yields compared to conventional modules
- Maintaining the same performance and mechanical strength of 4 mm or 3.2mm
- The oprical transmission is also far higher than conventional 3.2 mm low-iron glass for solar glass (with 92.1% against 91.5 )
- 2mm BIPV modules more competitive than thicker modules.

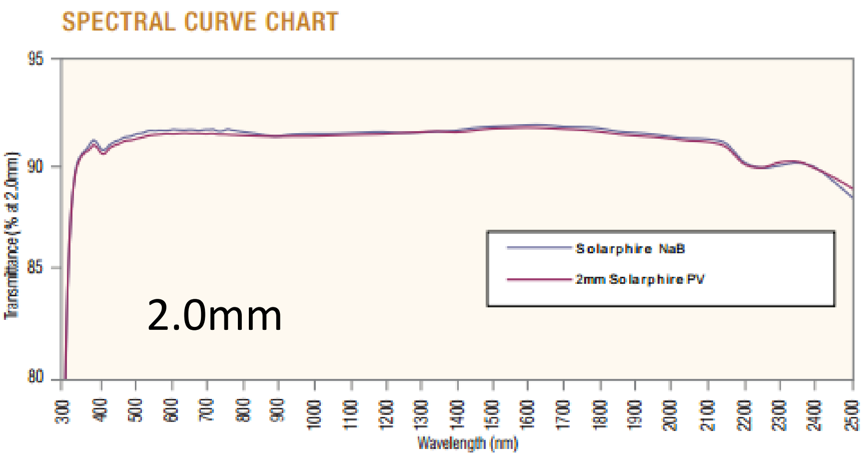
## PPG Industries Flat Glass Business ( March 2012 anouncement)

- Heat-strengthened glass in thicknesses of 2, 2.5 and 2.7mm
- Surface-compression strength that exceeds that of fully tempered glass
- *(greater than 10,000 pounds per square inch)*
- Achieving ASTM C1048 standards for flatness.
- With 2-mm Solarphire glass, solar transmittance improves by 0.3% compared to 3.2mm glass and by 0.5% compared to 4mm glass.
- Heat-strengthened thin glass also gives solar manufacturers the opportunity to cut downstream costs.
- Modul manufacturers may reduce material costs by using glass-on-glass module designs that eliminate the need for, and expense associated with, traditional protective plastic or polyvinyl fluoride (PVF) backing

| *Thicknes s | *Weight per m² | |
|---|---|---|
| 3.2mm | 8kg | |
| 2.5mm | 5.7kg | |
| 2.0 | 5.2 kg | |

*PPG Solarphire NaB



## Standart Back Glass for CIGS

- «window glass» Thickness 2,9 mm weight 7,25 kg/m2 ( widely available ,low cost)
- Strain point 510-515C ,; Annealing point at 550C

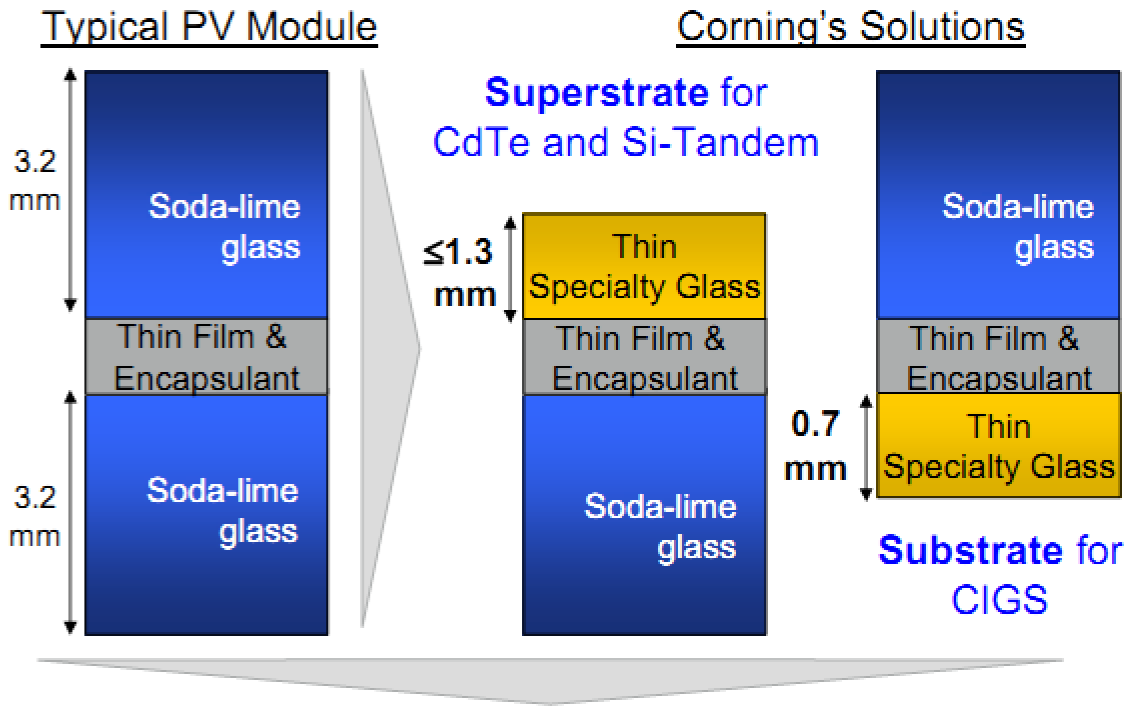
- What is the optimum thickness for CIGS ?

- 2.1mm
- %28 weigt reduction (5.25 kg m2)
- Less material, and less transport cost
- Complex handling higher risk of breakages and processing
- 2mm glass with an intermedidiate strain poin is optimal for CIGS modules

- Below 2mm
- 1.8mm to 0.7mm is possible (automotive industries)
- Cost increase with decreasing thickness

Frank Best, St. Gobain Solar Thin film Week April 19, 2012 Berlin Germany

# One of our latest innovations;
# Thin specialty glass to increase PV conversion efficiency




- Enables increased conversion efficiency
  - Higher transmission
  - Higher processing temperature
  - Enhanced light trapping
- Lowers manufacturing and BOS costs
  - Shorter heating times
  - Shorter cooling times
  - Reduced weight

- Currently wafer based PV modules are using mostly 3.2 mm low-iron patterned glass glass plus various types of backsheets such as EPA or PVB.
- Excluding China there are 38 lines worldwide capable producing patterned glass for solar applications.
- More than 50% of all the patterned glass for solar applications is produced in China.
- The market demand in 2011 for solar patterned glass was about 105 Mio. $m^2$
- The production capacity is at least 30% higher

Prices for 3.2 mm low-iron patterned glass

| | |
|---|---|
| Europe | 5.0 to 5.5 €/$m^2$ |
| China | 4.0 to 4.3 €/$m^2$ |

# Is patterned glass to be substituted by float glass on a long term ?

*(Patterned glass vs Float Glass)*

- Historically toughened patterned glass has been used for cover panels
- A 200t/d patterned glass line can produce at a typical conversion rate of 70% a yearly output of approximately 6.5 Mio m² for 3.2 mm thick glass.
- The expected life time of a furnace is between 5-8 years (due to high temperature operation)
- A typical float glass melting capacity ranges at 600-700 t/day. This results in ~24 Mio m² of 3.2 mm thick glass.

## Solar float glass has been introduced to the market recently

Float Glass: Future Solution for the PV Industry,

- ✓ *Efficient production of large quantities*
- ✓ *Better processability (cutting, grinding and tempering*
- ✓ *Higher transmission*
- ✓ *Mechanical stability*
- ✓ *High degree of flatness and homogeneity*
- ✓ *Cost effectiveness*
- ✓ *Easy application of antireflective coatings and corosion production layers*

# Comparison of general figures of a Patterned Glass line and new Float line

| | Patterned | New Float |
|---|---|---|
| Typical melting capacity [t/a gross] | 87000 | 255000 |
| | | |
| Production yield [%] | 70 | 88 |
| Daily capacity [t/d gross] | 240 | 700 |
| Daily capacity [t/d net] | 168 | 616 |
| Energy consumption [GJ/t gross] | 6,98 | 4,10 |
| Energy consumption [GJ/t netto] | 9,97 | 4,66 |
| | | |
| Energy Costs in [€/t gross] | 131 | 72 |
| Energy Costs in [€/t net] | 187 | 82 |

New Standard In PV Industry: Solar Float Glass With Antireflective Coating, Tobias Plessing; Dr. Hansjoerg Weis (INTERPANE AG), GLASS PERFORMANCE DAYS 2009 | www.gpd.fi

## Patterned glass vs. Float Glass (another view)

2.0 mm patterned solar glass will account for approx. 75% of the global demand in 2020

Compare to float:

- ✓ 1.7% higher transmission (without AR coating) due tothe more dedicated glass chemistry
- ✓ The different glass melting and forming process (in comparison with Float Glass) Structuring capabilities (prismatic and/or matt)
- ✓ Logistical advantages using smaller production units (in comparison with Float Glass) resulting in lower costs per $m^2$
- ✓ Wider range of applications due to Optical & Appearance advantages
- ✓ Today there are just a few production lines worldwide capable to melt and form 2.0 mm patterned solar glass efficiently.
- ✓ Structuring & AR Coating can be combined.

Thanks for your attention

and

for the authors of all refences used