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Solar Market Impact on the Glass Industry

Guardian Industries

Jim West

Scott Thomsen

Solar Market Impact

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- Global Solar Market Growth
- Solar Industry Economics
- Need For Low Iron Glass
- Primary Glass Manufacturer Infrastructure Impact
- Glass Requirements For Solar Applications
- Questions

The Emerging Solar Market

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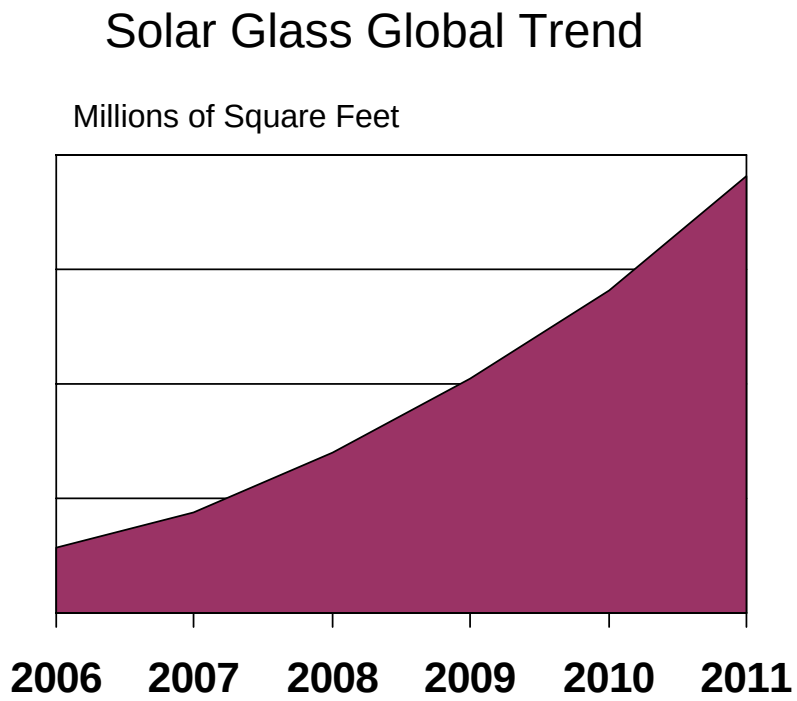
- Many solar industry experts feel the primary glass manufacturers have been slow in response to solar industry glass demand
- The reality is the total solar market has been a very small percentage of the installed float and pattern glass capacity
- In 2004 the total solar glass consumption worldwide was less than 0.1% of the total glass produced globally
- Industry experts point to 30-40% CAGR as the primary indicator of the market
- But primary glass manufacturers commonly focus on tonnage and square meters to drive investments

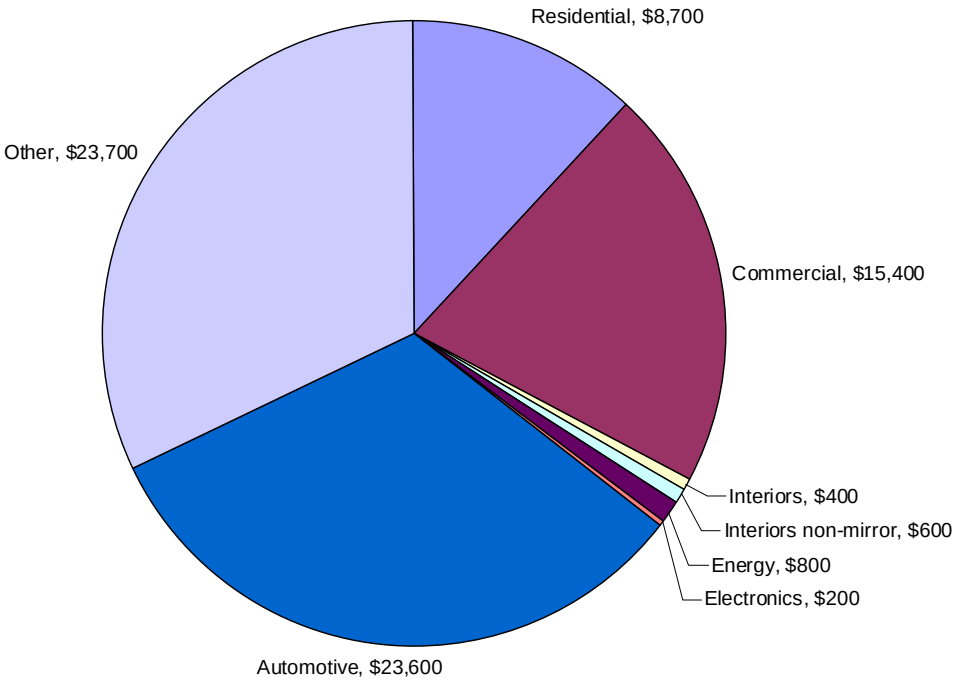
Solar Glass Market Growth

- Global market CAGR continues at 30-40% pace
- Largest growth area has been low iron pattern glass in the past 5 years for c-Si technology
- Government incentives are driving growth
- Current demand driven by Photovoltaics (PV) but concentrating solar power (CSP) is emerging
- USA growth is expected to accelerate in next 4 years

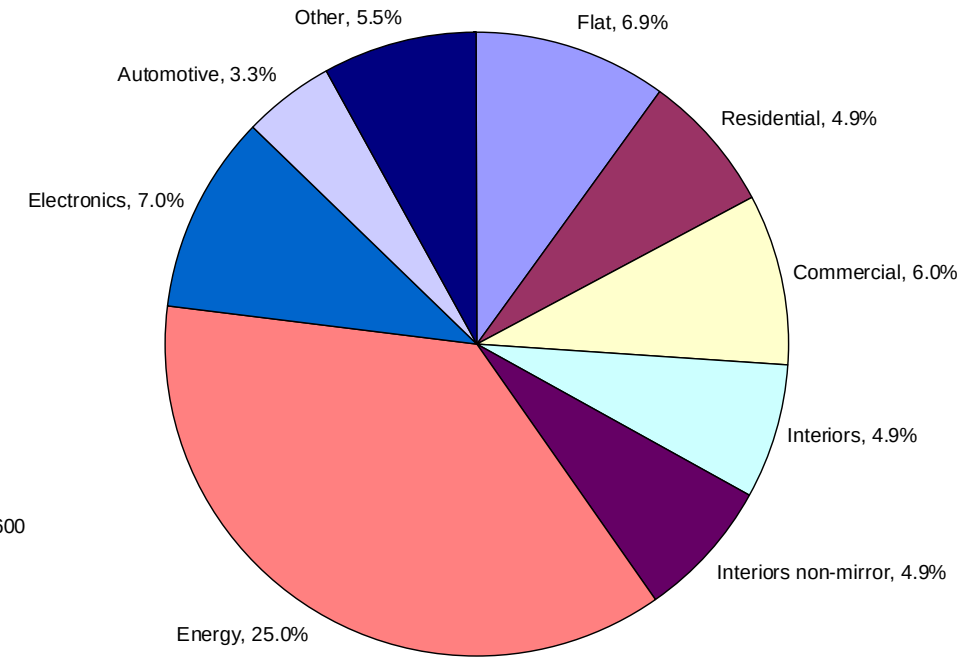


2012 Global Glass Markets

Total 2012 Global Available Market ($ mil)



Total 2012 Global Available Market - Annual Growth



Global energy glass consumption in 2012 will be 1.1% of total market

Source: Freedonia 2008

Economics will drive demand

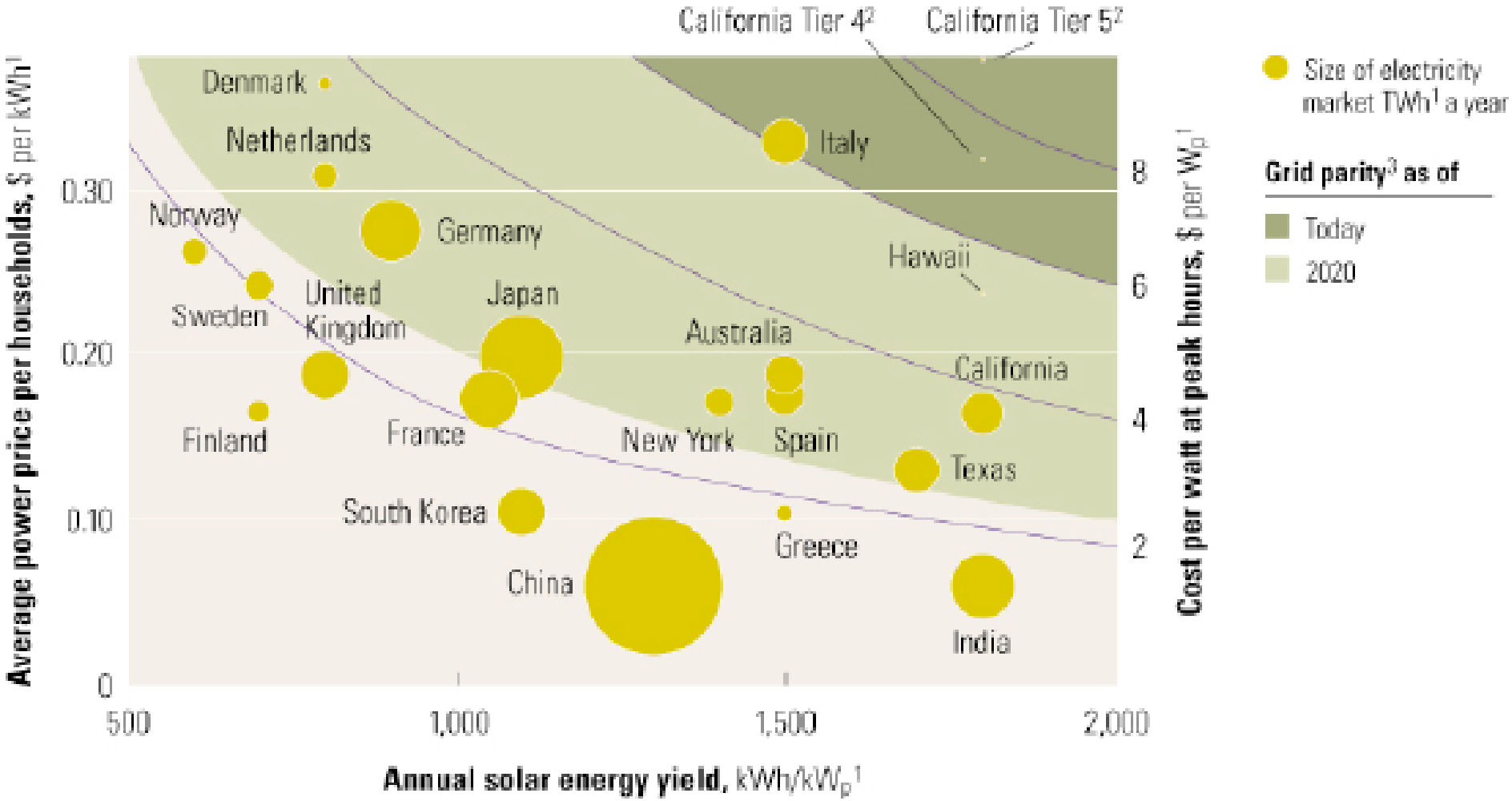
- Economics will drive solar glass production output not hype

- Several market segments have been decimated because they responded to market hype on growth rates as opposed to true, sustainable business demand
  - 90's .com boom to bust
  - 00's telecom boom to bust

- There is not doubt that the solar market growth will be high but several key factors are driving demand…
  - Government subsidies
  - Green building trends
  - National security concerns for energy generation

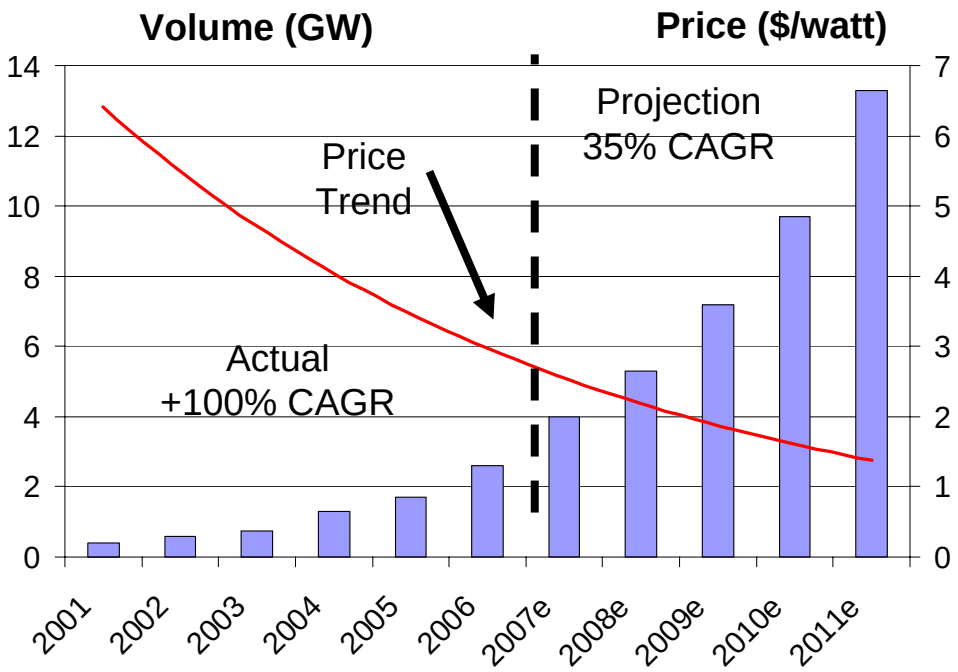
- The industry needs to drive cost down to grid parity in order for solar to become a long term viable business

Grid Parity Key To Business Growth



Economics of Solar Business

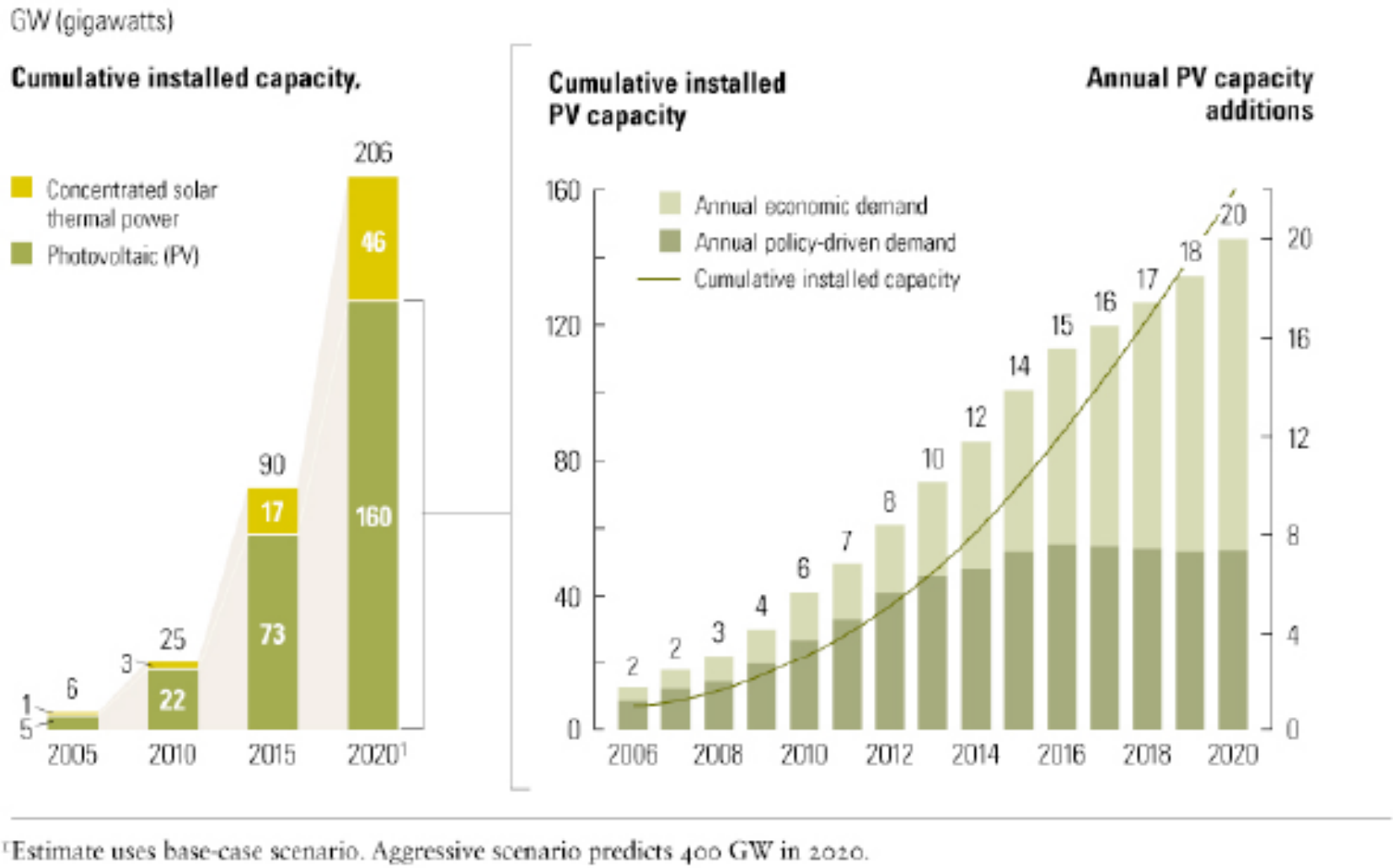
PV Module Growth vs. Price



- 2007 Global market module revenues ~$12 Billion
- Module pricing expected to continue to drop as volumes increase
- Price reductions driven by:
  - Phase out of incentives
  - Improvements in technology
  - Economies of scale

$$\$ \text{ Production / Watt} = \frac{\text{Cost / m}^2}{\text{Watt / m}^2}$$

2020 Global Solar PV Capacity



[1]Estimate uses base-case scenario. Aggressive scenario predicts 400 GW in 2020.

Will global demand equal capacity growth in the next decade?

The Need For Low Iron Glass

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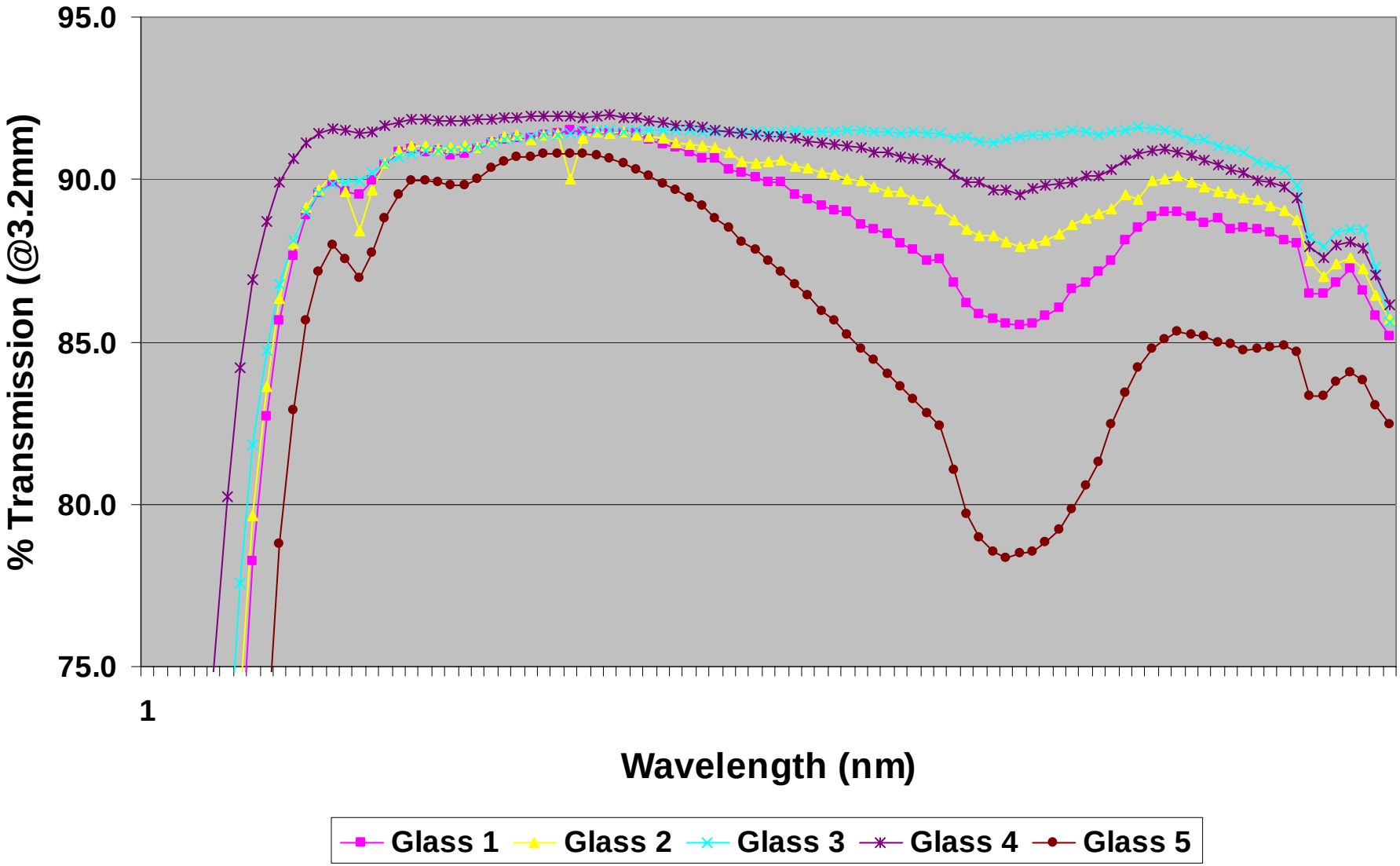
- Economics is driving the solar industry ($/watt)
- The higher the solar efficiency the higher the revenue for all members of the supply chain
- Selection of low iron glass is based on economics and not marketing pull
- The level of iron content in the glass varies depending on the efficiency and total cost of the solar application
- The key thing to remember is not all low iron glass is low iron solar glass; optimizing for the visible spectrum does not return the necessary value to justify the increased price

Low Iron Glass Spectral Comparison



Low Iron Glass

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- General rule of thumb is the higher the solar efficiency a higher solar transmission glass can be used based on economics
- The solar transmission requirements vary based on the application

CSP:	Tsolar > 90.7% on 4-mm Float
c-Si PV:	Tsolar > 91.0% on 3-mm Pattern
a-Si Single Junction:	Tsolar > 89.0% on 3-mm Float
CIS TF PV:	Tsolar > 90.0% on 3-mm Float
CdTe TF PV:	Tsolar > 90.0% on 3-mm Float

PGM Infrastructure

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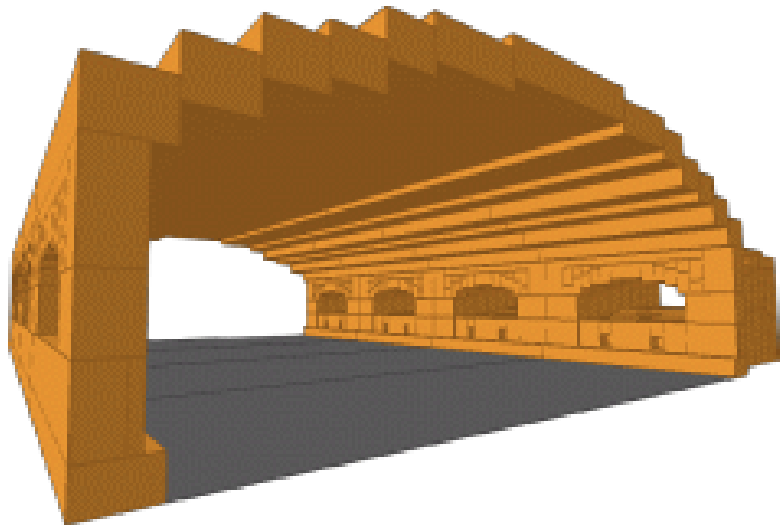
- The solar market impact to the glass industry has been minimal too date
  - > 90% of production has been low iron pattern solar glass
  - Typical pattern line is 120 mtons versus 700 mtons for float
  - Cost to transition lower on pattern than float lines
  - Pattern line sizes optimized for solar market as opposed to jumbos
- Glass companies could convert architectural pattern lines to solar and/or build green field facilities for solar due to limited tonnage requirements
- The growth of the thin film PV industry increases the global demand for low iron solar float glass
  - Historically required transitions due to low volume requirements
  - TF PV approaching limits of dedicated solar float lines

Glass Production Infrastructure

- Low iron solar glass production impact on float and pattern lines is significant

- Furnaces must be designed to handle higher melting and refining temperatures
  - Higher grade refractories
  - Deeper tank depths (1.5-m to 2.0-m)
  - Thicker and higher quality bottom pavers
  - Improved flow and thermal controls



- Even with improved design and materials furnace life will be reduced for low iron solar glass

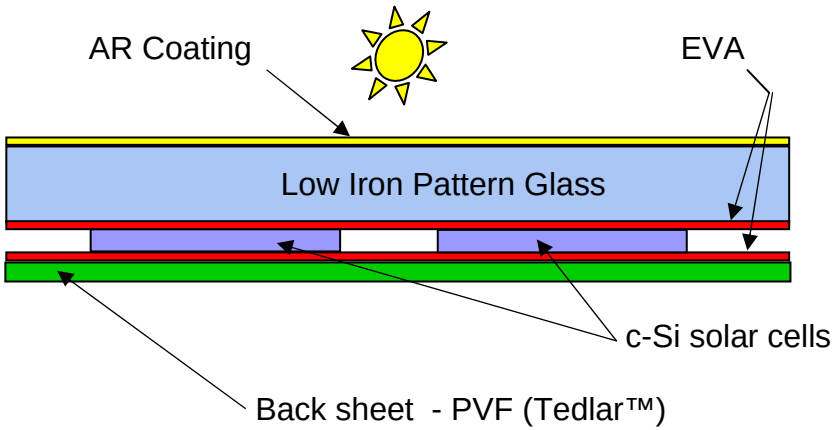
Glass Production Infrastructure

- Low iron containing materials are essential for solar glass production

- Single largest challenge for low iron solar pattern and float production is sourcing of the raw materials
  - Low iron sand
  - Low iron dolomite (may be removed)
  - Low iron limestone
  - Low iron glass cullet

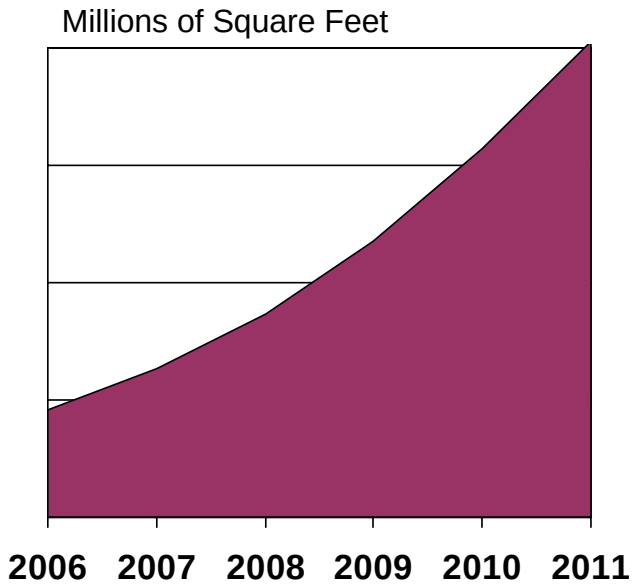
- Low iron containing materials drives up the cost to produce due to purchase price and freight costs from mines

C-Si PV Glass



Module Efficiency (%)	13-19
Wavelength range (nm)	400-1150

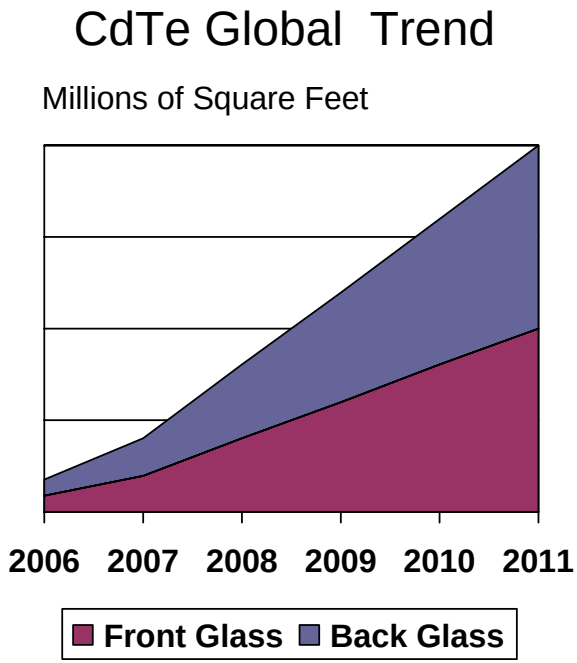
Silicon Global Module Trend



- Market dominated by solar pattern glass: Tsolar > 91.4%
- Market is migrating to AR coated solar pattern glass: Tsolar > 94%

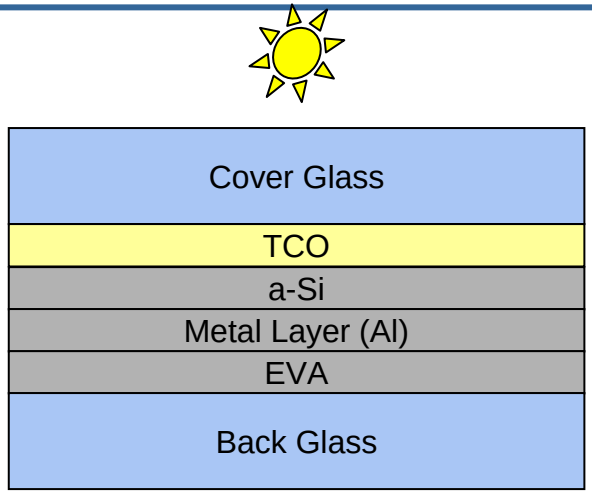
Thin Film CdTe PV Glass

Module Efficiency (%)	9-11
Wavelength range (nm)	400-900

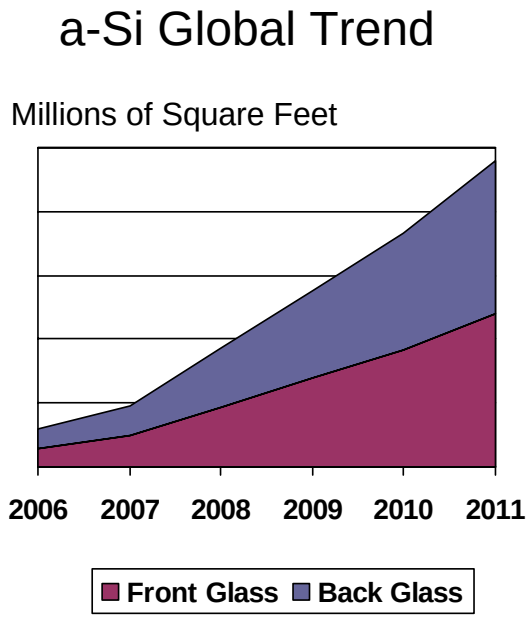


- CdTe benefits most from a low iron float glass: T_{solar} > 90%
- Module transmission heavily impacted by TCO coating
- Back glass is standard clear float glass

Thin Film a-Si PV Glass

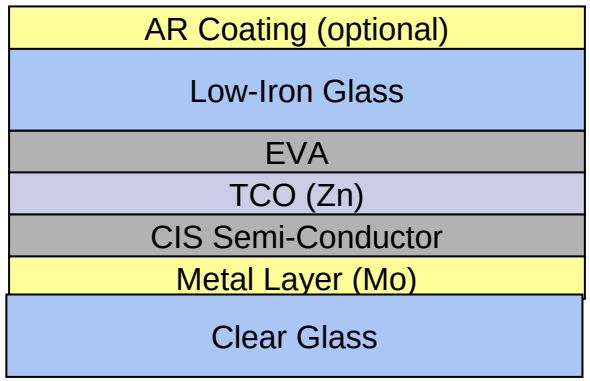


	Single	Tandem
Module Efficiency (%)	6-7	8-10
Wavelength range (nm)	400-750	400-1000



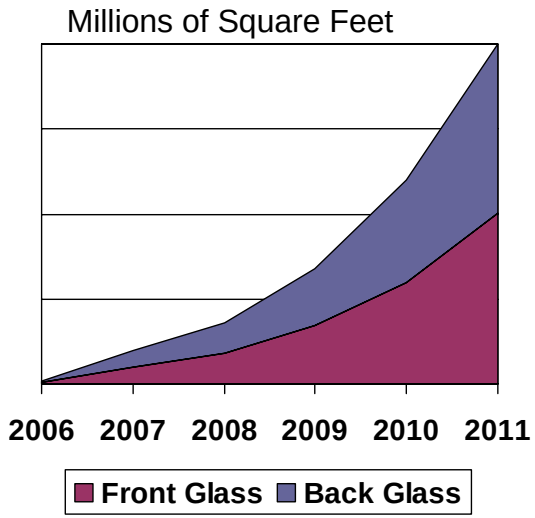
- a-Si single junction value analysis optimized for Tsolar > 89% float glass
- a-Si tandem junction benefits most from a Tsolar > 90% float glass
- Module performance heavily influenced by the TCO coating
- Back glass using standard clear glass

Thin Film CIS PV Glass



Module Efficiency (%)	10-12
Wavelength range (nm)	400-1150

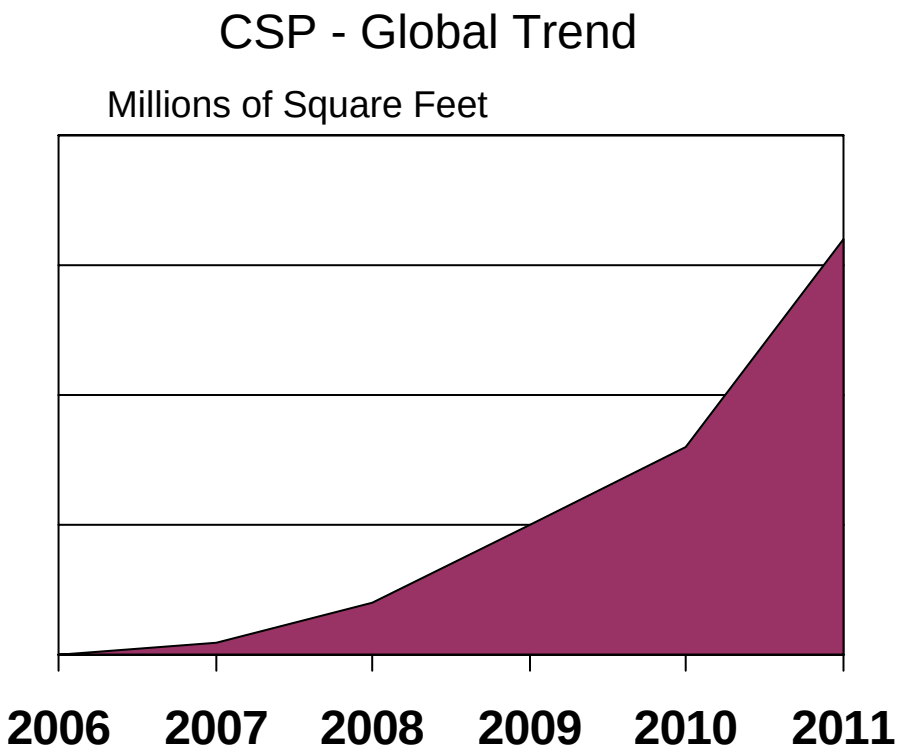
CIS/CIGS Global Trend



- Value analysis demonstrated with glass having Tsolar > 90%
- CIS can utilize a low iron pattern or float glass with AR coating for front glass
- Clear glass with a Mo coating is used for the back glass

CSP Glass

- Emerging but proven technology
  - 1st Parabolic trough field installed in early 1980's
- Historically a low volume market
  - 1980-1990: 30M ft2
  - 2005-2007: 5 M ft2
- Market requires very high solar transmission due to second surface mirror requirements
- Float glass required with Tsolar > 90.7% on 4-mm glass
- Glass needs vary from 0.95-mm to 4.00-mm



The Emerging Solar Market

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- The solar market is growing at a rapid pace but will still need another 4-5 years to become a major glass market segment
- Glass production for solar has been dominated by low iron pattern glass for c-Si PV
- Thin film PV and CSP technologies will drive the demand and capacity increases in float assets; until volume is sizable it is difficult to dedicate float lines to the solar industry
- Based on current projections solar will be a viable market segment equal to residential, commercial, automotive, etc. in 2015
- The key sustaining the growth is the reduction in $ per watt

Questions?

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Photovoltaics

Concentrating Solar Power

Thermal – Hot Water