PHOTOVOLTAICS from a VC Perspective

NSF Workshop on Innovation in PV Manufacturing

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Golden, CO

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Outline

- Novus introduction
- What is PV to a customer/investor?
- Where does PV stand today?
- Where to go from here?
- Conclusions

60MW Olmedilla Photovoltaic Park in Olmedilla de Alarcón, Spain

Novus Energy Partners

- Transatlantic cleantech fund with USA/European focus
- Venture Capital – growth stage
- Active ownership
- Target Solar, Wind and the Electrification of Transport
- Fund size: $150M

Why PV?

Opportunity

- 11 000 TWhr of new generation needed by 2030 driven by population and economic growth (IEA 450)
- Traditional alternatives are more expensive than ever
- Environmental concerns
- Energy security
- 89 PW of free and distributed PV power

Status

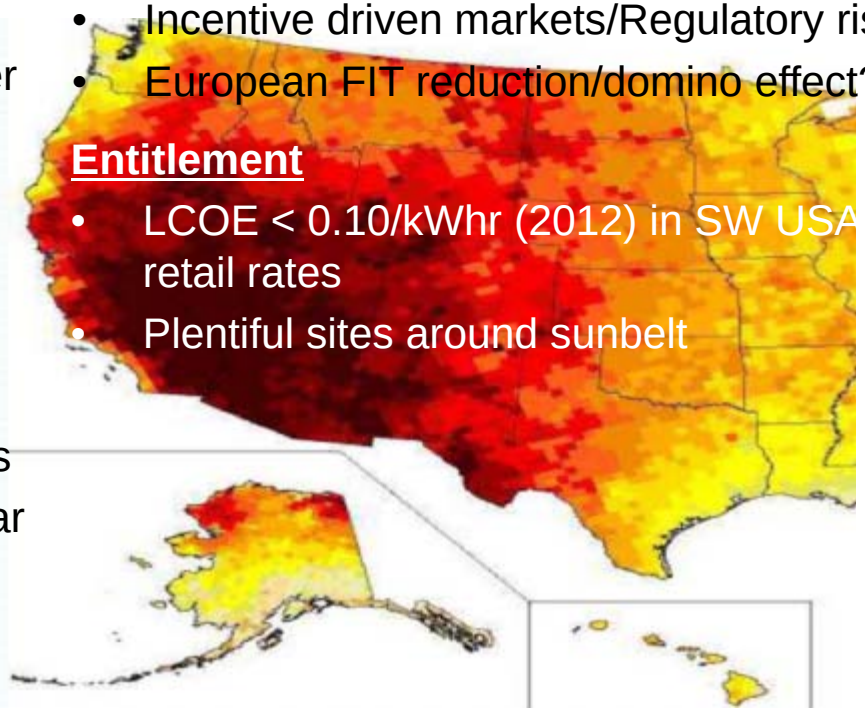
- 7.9 GW PV market w/ 45% CAGR
- >95% grid connected customers
- Germany only GW market and 53% of WW market
- Ongoing shake out and volatile markets
- LCOE <$0.15/kWhr in SW USA – on par with peak power rates

Challenges

- Relative immature technology
  - System cost $3-4/Wp and 20% capacity factor
  - System eff in low teens (%) – LCOE>$0.15/kWhr
  - Economies of scale at 8GW/yr
- Financial environment:
  - Project financing and capacity expansion
- Storage, distribution and grid integration
- Incentive driven markets/Regulatory risk
- European FIT reduction/domino effect?

Entitlement

- LCOE < 0.10/kWhr (2012) in SW USA retail rates
- Plentiful sites around sunbelt



What is PV to the customer/investor?

A grid connected customer is looking for a cost competitive source of electricity

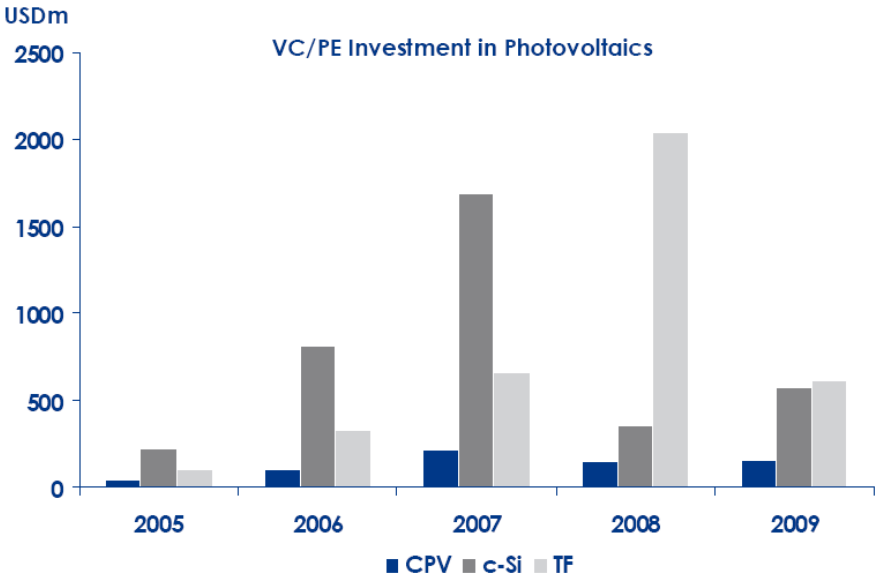
- Nice to have clean alibi, but limited opportunity to differentiate – no ”Intel inside”

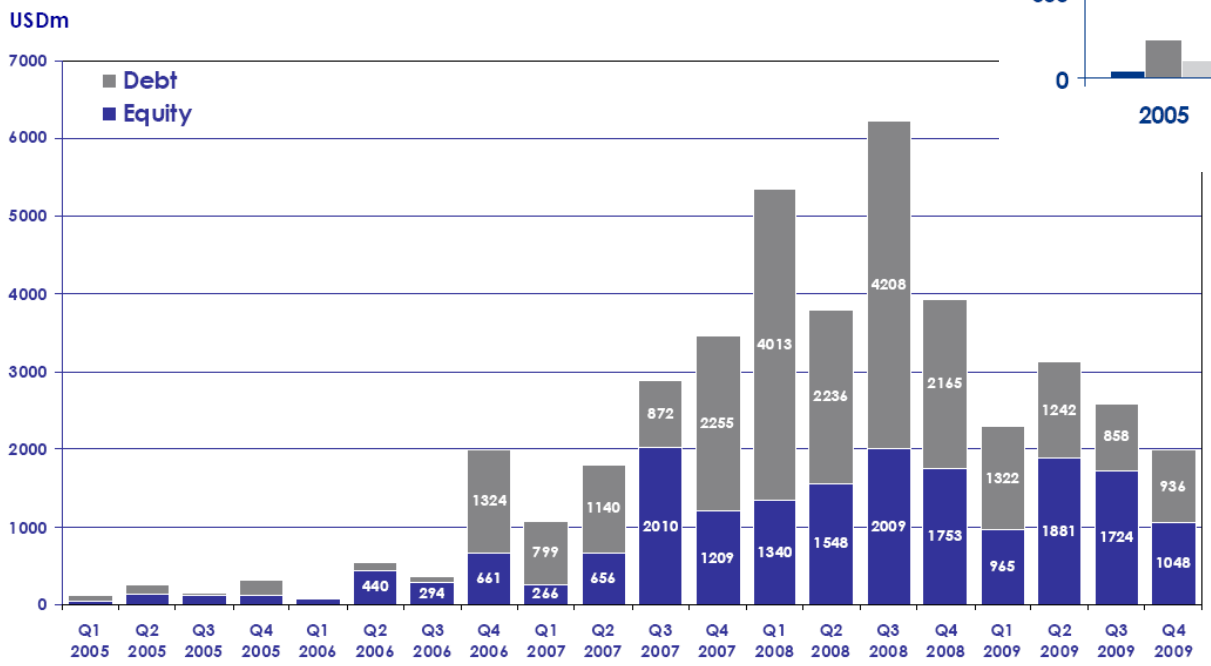
An investor is seeking a stable generation source yielding predictable returns over given time – a bond

- PV technology must have predictable output over > 25 yr lifetime

What happened in 2008/2009?

- Initial incentive driven growth with high margins and heavy investment – gold rush
- Collapse of Spanish market
- Chinese dominate of middle part of value chain
- Financial crises dries up project financing
- **Still - 38% growth from 2009-2010**

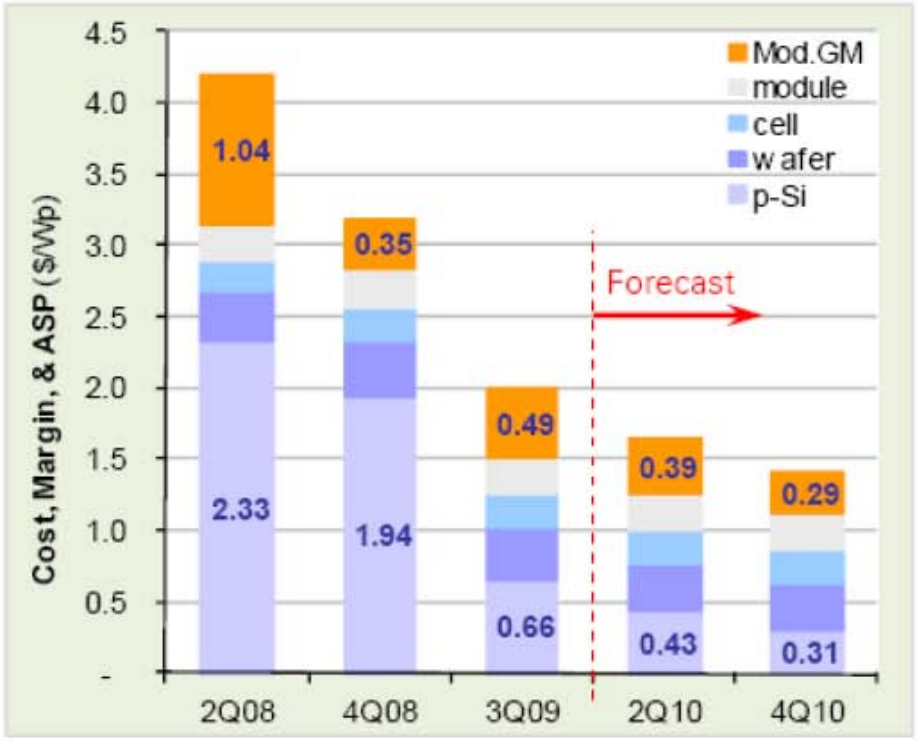




Source: New Energy Focus

Module prices rapidly decline

Figure 8: c-Si solar PV module cost breakdown (p-Si cost evolution)



Source: Deutsche Bank estimates

2Q08: p-Si spot pricing reached >$400/kg in 2Q08, and blended p-Si cost eclipsed $260/kg for some companies. Using a silicon usage efficiency of 8gm/Wp, we estimate p-Si cost ~$2.33/Wp, and processing costs were <$1.00/Wp at full utilization.

3Q09: p-Si spot pricing had declined to below $60/kg by 3Q09, but legacy p-Si drove blended p-Si costs of >$100/kg for many comapnies. Using 6.5gm/Wp, the cost of p-Si was ~$0.66/Wp.

2Q10: we are projecting p-Si prices to average somewhat over $50/kg in 2010, and legacy p-Si to be largely depleted. Using ~$65/kg which may be low for some companies and 6.5gm/Wp we estimate a p-Si cost of ~$0.43/Wp in 1H10.

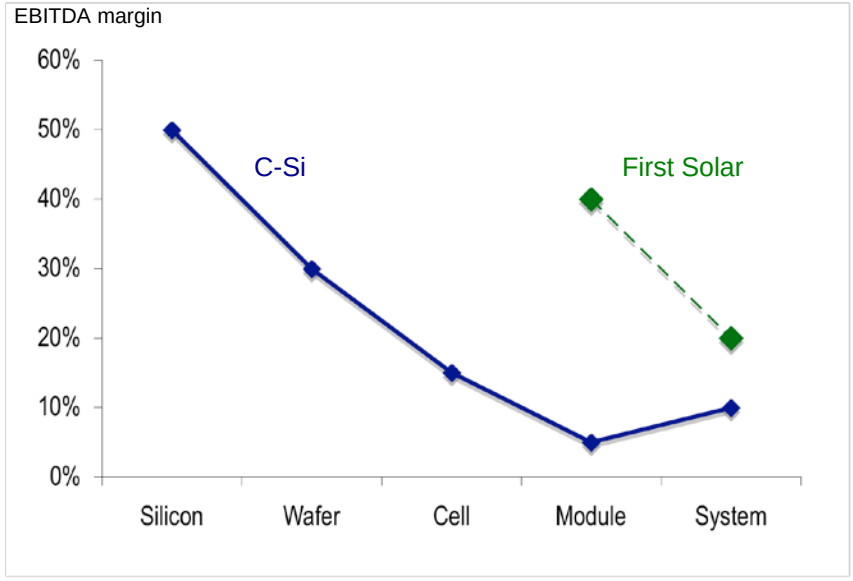
4Q10: we estimate p-Si prices will be <$50/kg by end-2010. Using $47/kg and 6.5gm/Wp we estimate a p-Si cost of $0.31/Wp. With a ~20% gross margin, cost could enable module ASP to approach ~$1.41/Wp by end-2010.

Source: Deutsche Bank

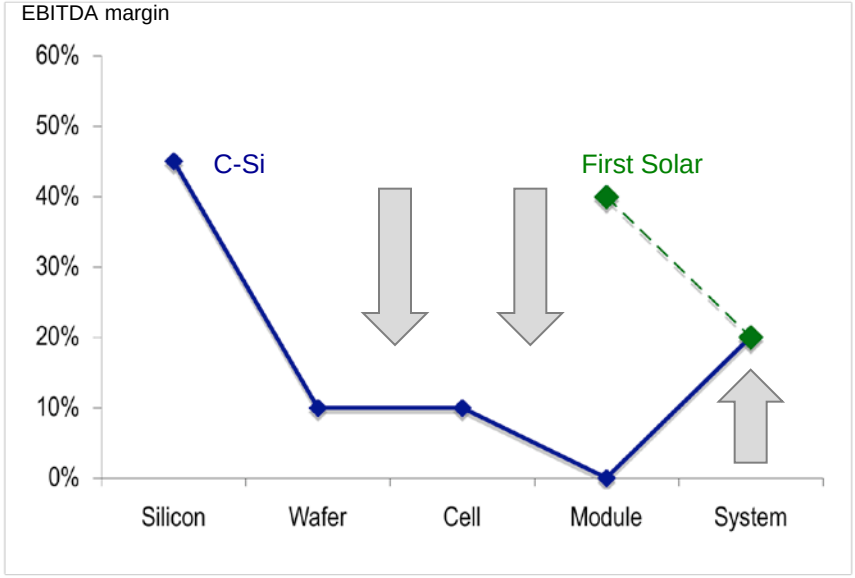
Marigin compression

Estimated EBITDA margins throughout the PV value chain

September 2008

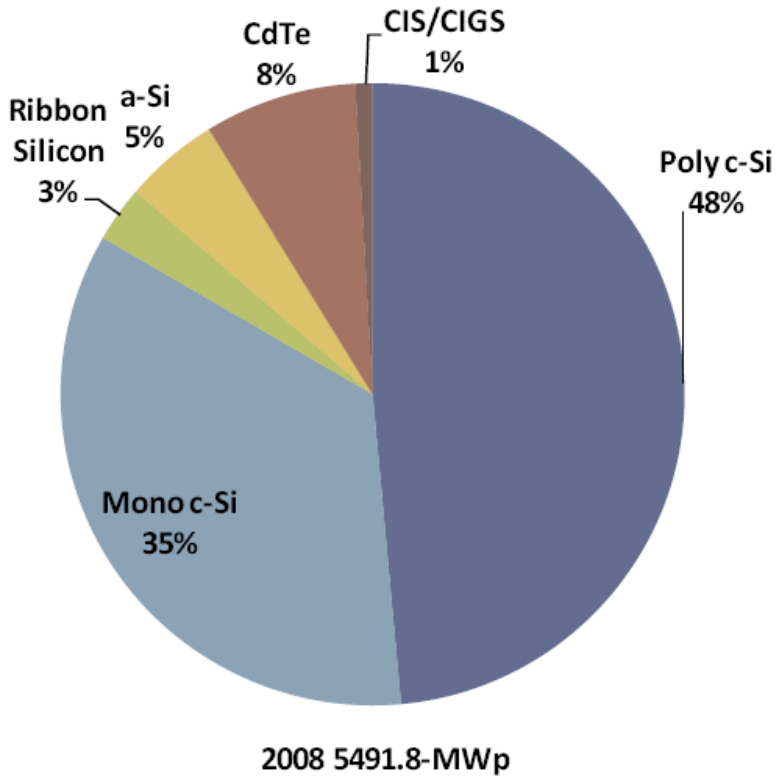


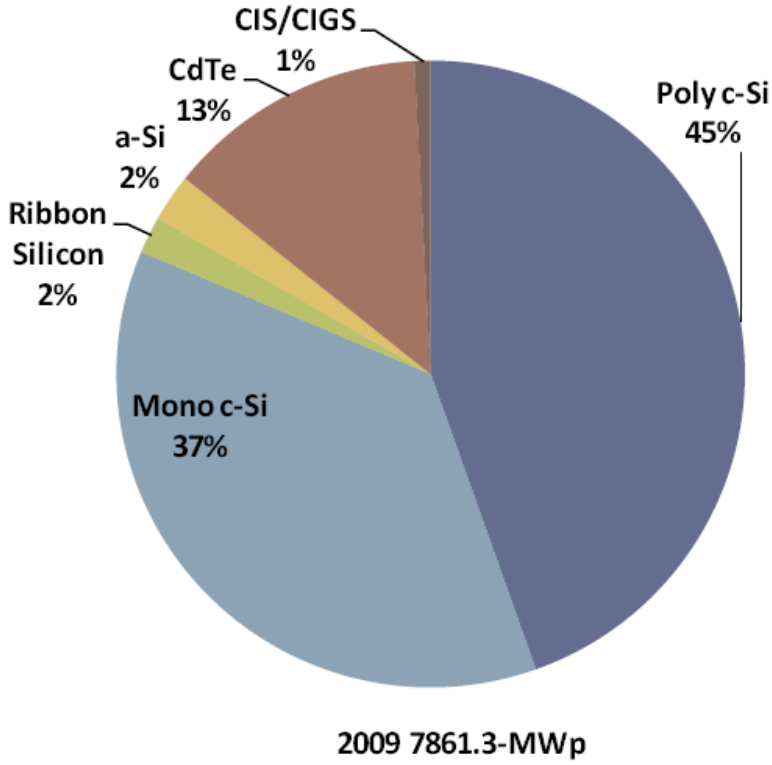
March 2009



Source: Company reports, Novus estimates

World wide PV market growth





Source: Navgant Consulting, April 2010

The NewCo challenge

NewCo must have competitive technology (η, $/Wp, $/kWhr, CapEx), but also financing, bankable product, plan for warranties, economies of scale.

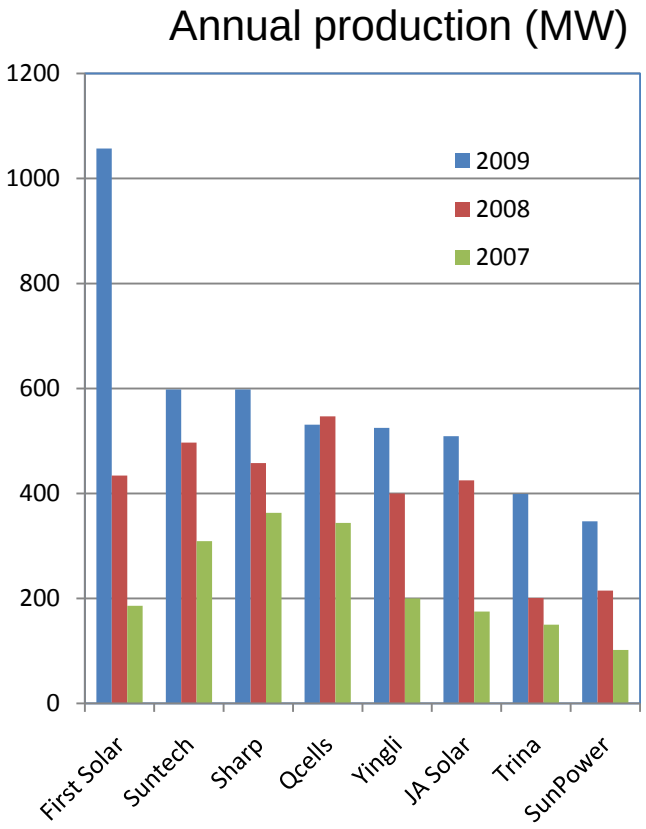
Formidable competition
- See contour of 6-8 companies post shake out with 500MW capacity and BS to compete
- 12/31/2009: FSLR (cash-debt) $661M, STP(-$230M), YGE (-$38M), JASO($191M), TSL($51M), SPWR(-$38M)

Baseline PV company
- FSLR: Rev: $2.1B, EBITA: $661M, R&D: $78M; Prod: 1054 MW
- NewCo must hit market with 200MW+ capacity – $400M
- RD will require external matching – $20-30M
- Warranties, first project financing - $10M

Si panel ASP WILL decrease further: $1.4/Wp (2010) and $1/Wp (2012)

Manufacturing risk – building factories with new technology takes time

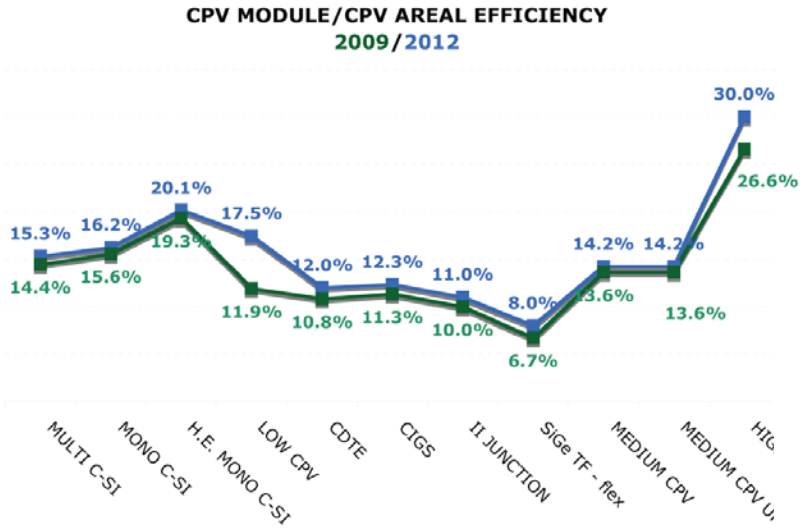
Lots of companies in the middle – need to differentiate
- SPWR back contact, Sanyo HIT, Suntech Pluto
- FSLR – CdTe, CIGS, MJ x-Si, combinations,
- Other: CPV, DSSC, Organic, Flexible, …

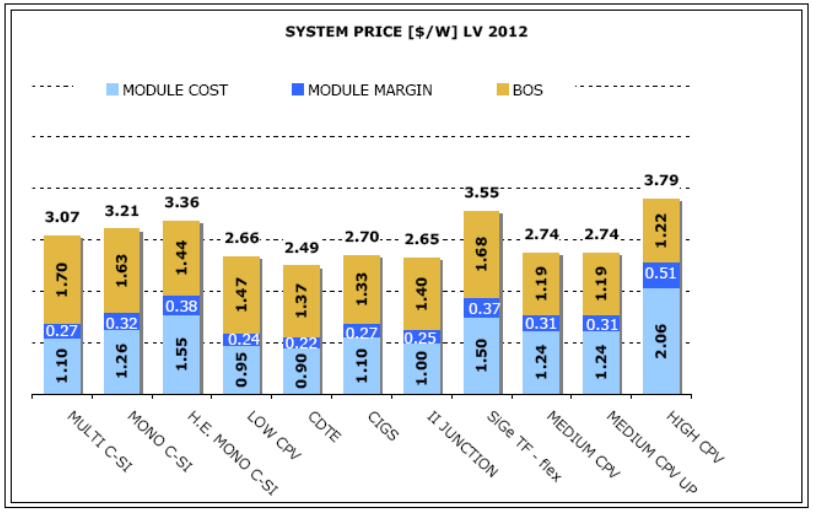


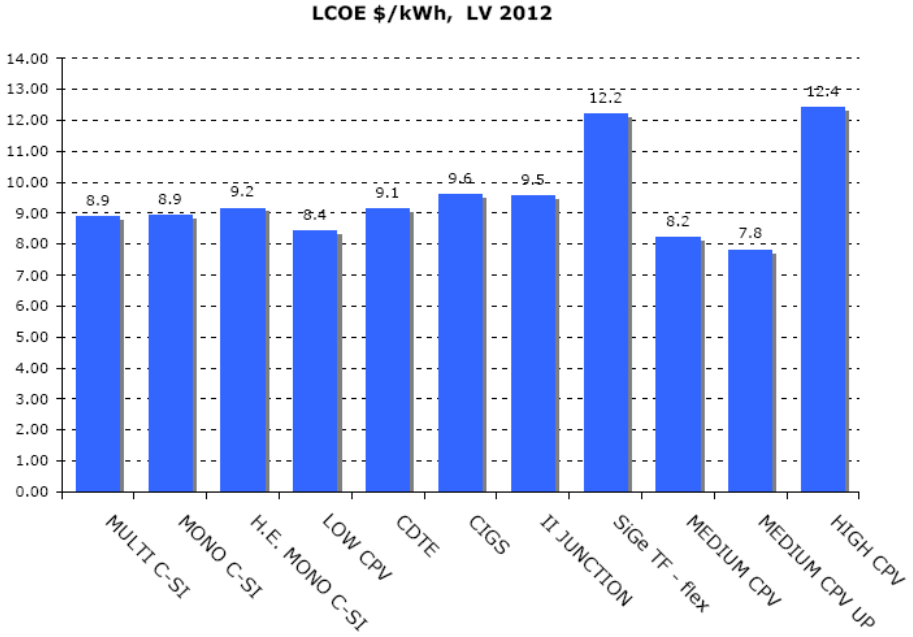
Source: Annual reports,Navigant Consulting

LCOE

$$LCOE = \frac{\text{Initital equity investment} + \sum_{n=1}^{30} \frac{(\text{Annual Costs})^n}{(1+\text{Discount Rate})^n} \cdot (1-\text{Tax Rate}) - \sum_{n=1}^{30} \frac{(\text{Depreciation})^n}{(1+\text{Discount Rate})^n} \cdot (\text{Tax Rate}) - \frac{(\text{Residual Value})}{(1+\text{Discount Rate})^N}}{\sum_{n=1}^{30} \frac{\text{Initial Energy Yield} \left[\frac{\text{kWh}}{\text{kWp}}\right] \cdot (1-\text{Degradation Rate})^n}{(1+\text{Discount Rate})^n}}$$

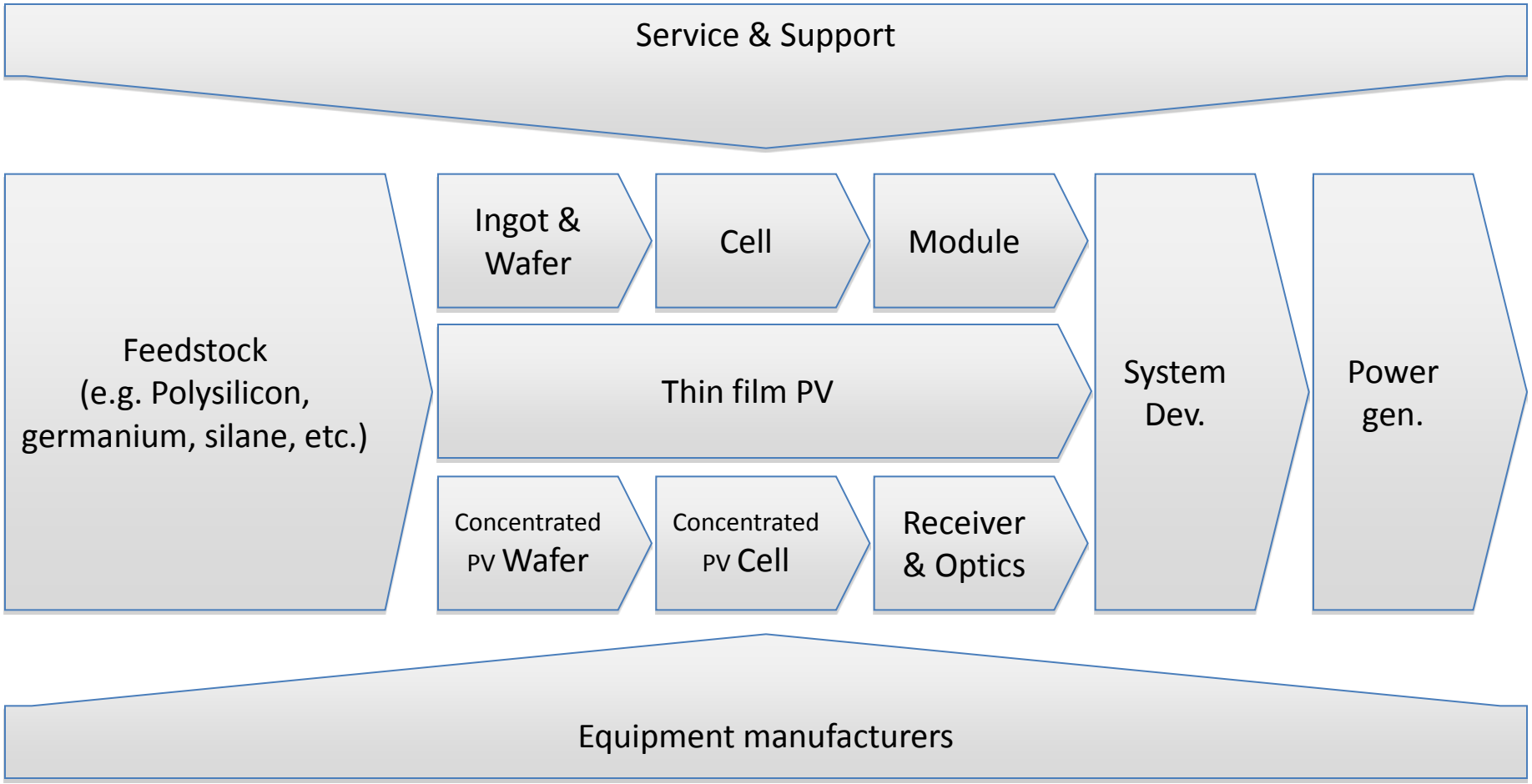






Source: Are Torvik, SEDICO, Inc.

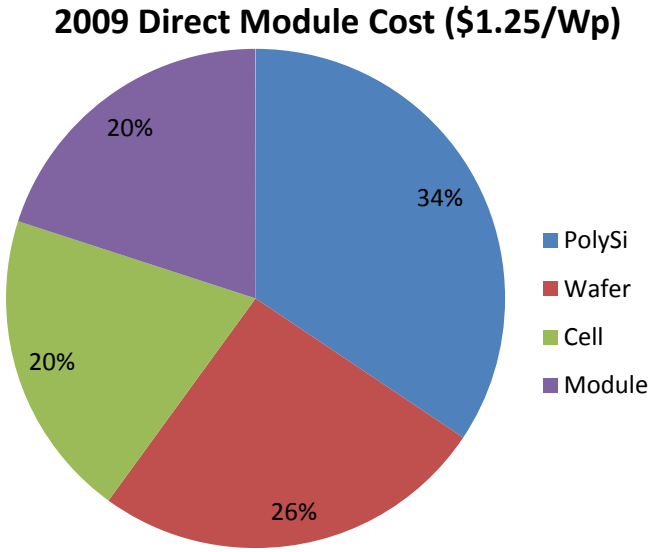
Investment opportunities across the value chain



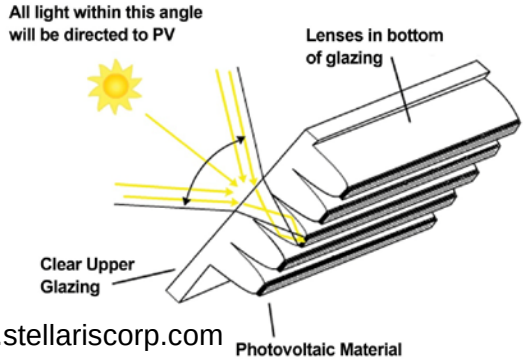
Wafer-based Si

Status
- 85% of WW PV market in 2009
- Size matters: tough to challenge existing value chain and big BS

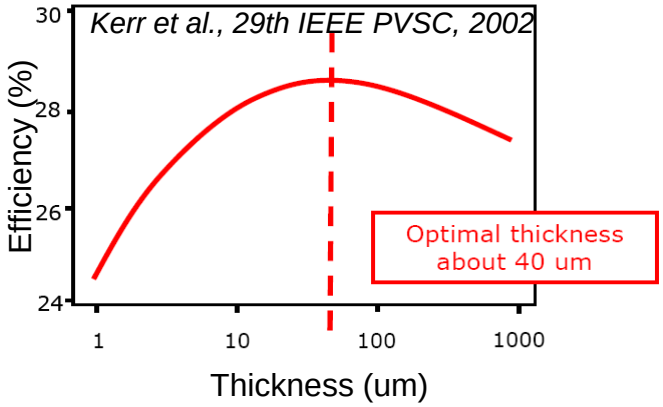
Opportunity: Reduce cost and improve efficiency
- PolySi: Siemens $25-35/kg, FBR: $15-20/kg,…
- Ingot/wafer: t=180 um, 30% Si utilization, 50% Kerf waste, …
- Cell design/process: Novel cell design, passivation, low cost printing, shading, pastes, selective emitter, …
- Module: Optical techniques, concentration, weight, …
- Professionalize services



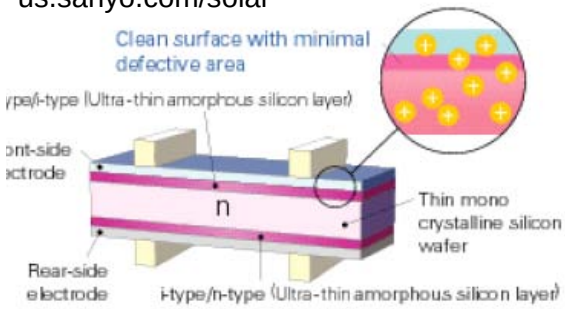
Improving Si utilization is key

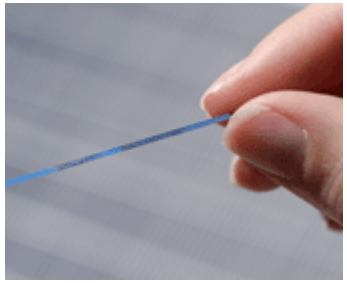


www.stellariscorp.com



us.sanyo.com/solar





www.originenergy.com.au/

Thin Film PV

Status

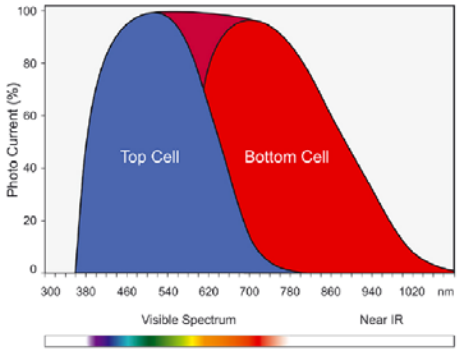
- One true commercial success so far (FSLR 13% WW market)
- Low cost entitlement, efficient materials use, monolithic integration, integrated cell/module manufacturing, …

Challenges

- Efficiency, lifetime, CapEx, equipment vendors, bankability, …

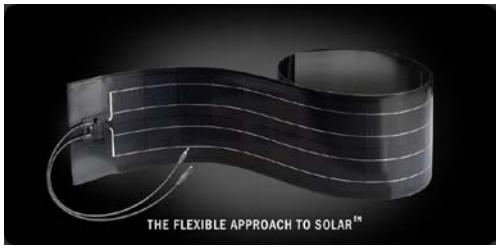
Opportunity: Reduce cost and improve efficiency

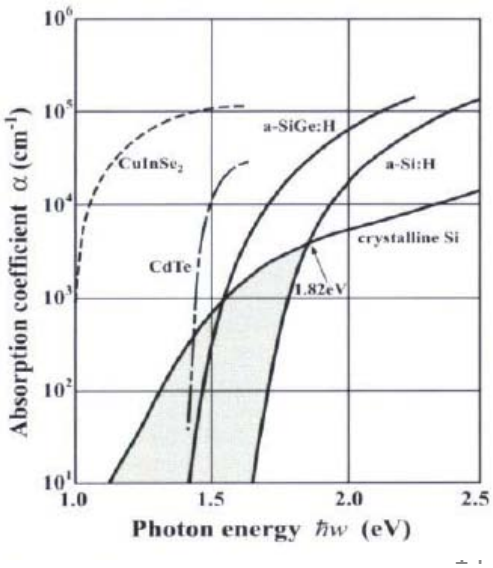
- Improve materials quality
- Increase materials utilization, gas recycling, specialty gases, deposition rates, low temperature deposition, new substrates, non vacuum manufacturing, R2R, …



Tandem Cell Spectral Absorption

a-Si/µc-Si Micromorph





Concentrated PV (CPV)

Status

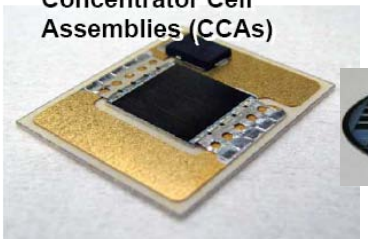
- Low cost entitlement in high DNI, efficient materials use, high power density, upgradability.

Challenge

- Need to demonstrate performance, cost, system efficiency, and verify reliability, O&M costs
- Bankability, must likely finance first projects.

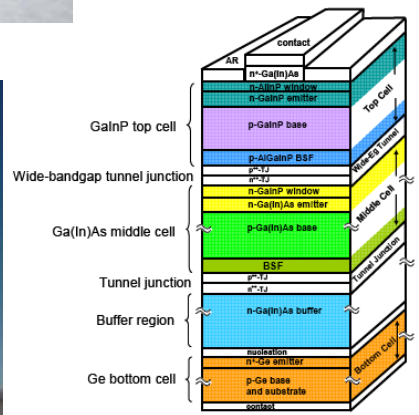
Opportunity:

- Feedstock/substrates: III-V on Si, specialty gases, deposition rates, large area III-V deposition (CVD), …
- Cells: high efficiency Si (30%) and III-V cells (>45%)
- Tracker: reliable, accurate, ease of installation, …
- Receiver: thermal management, reliability, …
- Optics: reflectivity, modularity, assembly, reliability, …
- System: Rapid deployment, O&M, land prep,…



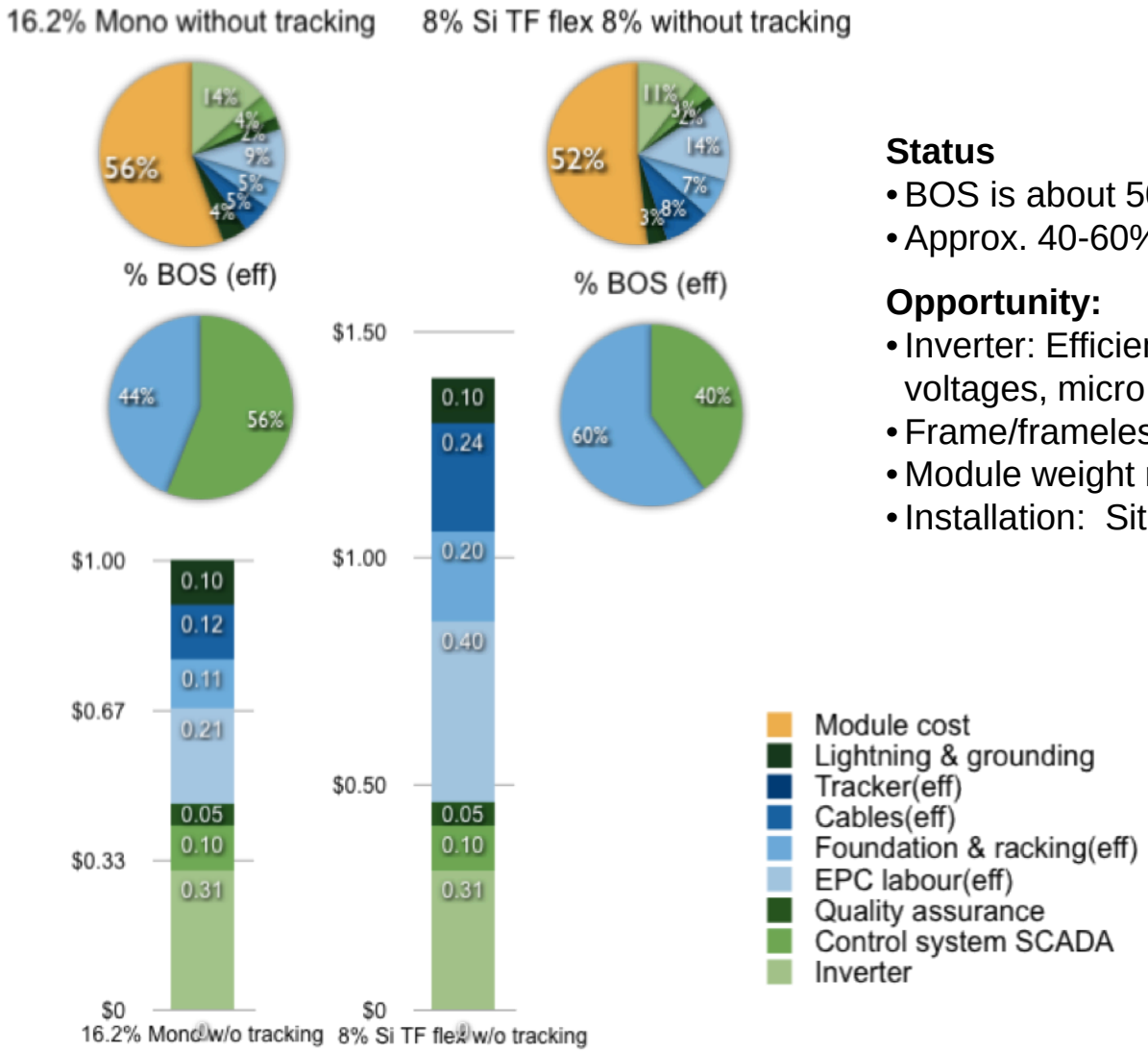
www.spectrolab.com

www.megawattsolar.com



Lattice-Matched (LM)

Balance of System (BOS) Las Vegas ‘12



Status

- BOS is about 50% of total systems cost
- Approx. 40-60% of BOS scales with module efficiency

Opportunity:

- Inverter: Efficiency/SiC power switches, higher voltages, micro inverters, grounding, …
- Frame/frameless/plastic modules
- Module weight reduction and load requirements
- Installation: Site work, deployment rate, …

Source, Are Torvik, SEDICO, Inc.

Conclusions

Mass markets are cost driven

No silver bullet regarding technology
- Various technologies have natural target markets

Cost reduction – 2X in the cards for c-Si?
- Materials utilization and consumption key

Efficiency improvements are central to reduce LCOE
- Materials development
- Novel device design and light trapping

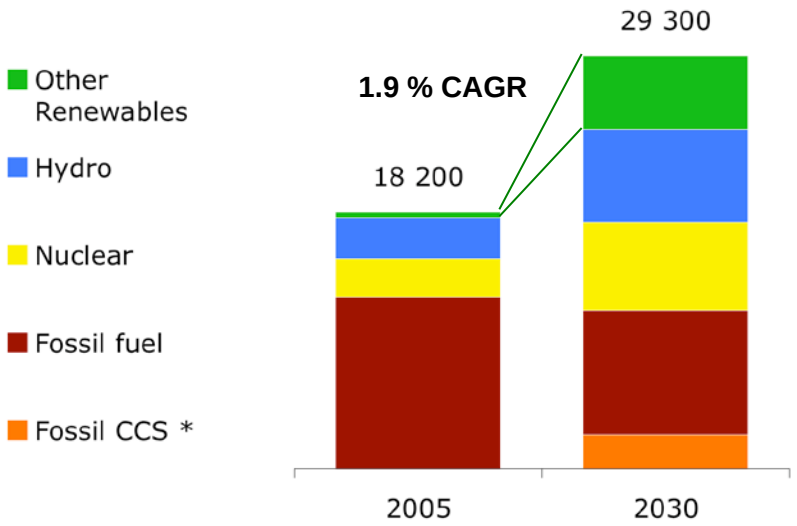
Low-cost manufacturing
- Non vacuum processing improving yield and throughput
- Manufacturing platforms: CapEx, yield, uptime, throughput
- Leverage other fields such as TFT/LCD, Semi, Optics, …

Financing / Bankability / Permitting are additional challenges

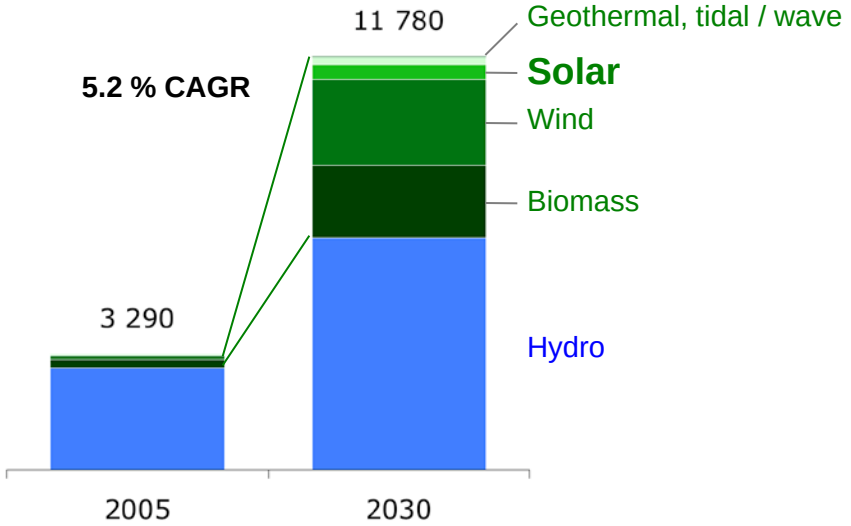
Renewable Energy in the big picture

World electricity generation in TWh 2005 vs. 2030 – IEA 450 Stabilisation Case

Total generation



Renewable generation

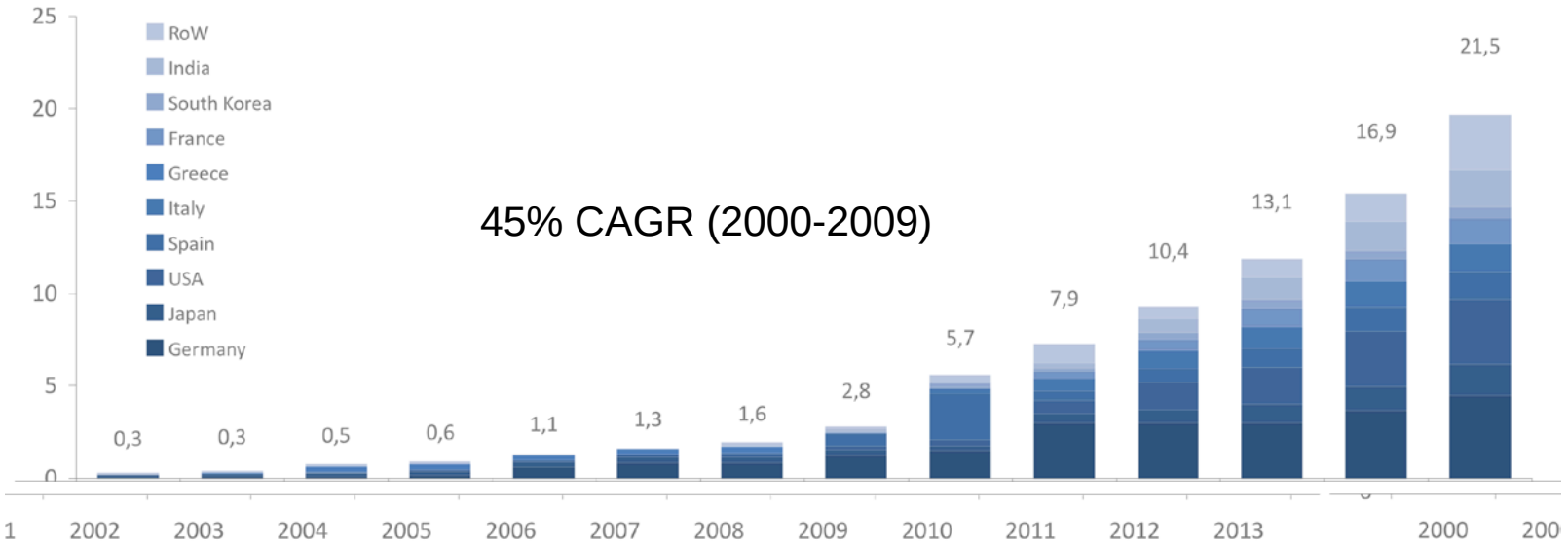


- In **2005**, **Solar Energy** represented **0,02%** of world electricity generation
- IEA estimates solar to grow by a **CAGR of 22%** from 2005 to 2030
- In **2030**, solar is estimated to represent only **1,4%** of world electricity generation

Source: IEA World Energy Outlook 2007

The history of PV

Historical and forecasted PV installations in GW, 2000-2013



- Japan the PV pioneer through the “70,000 roofs program” established in 1994
- Germany positioned in 1998 with the “100,000 roofs program” (fulfilled 2003) and the 1999 PV feed-in tariff, currently at 0,38 €/kWh for ground mounted systems
- California, Spain, Italy, France, Greece, South Korea, ++ follows with similar subsidies

PAST
- Subsidies
- Few GW markets
- High initial growth

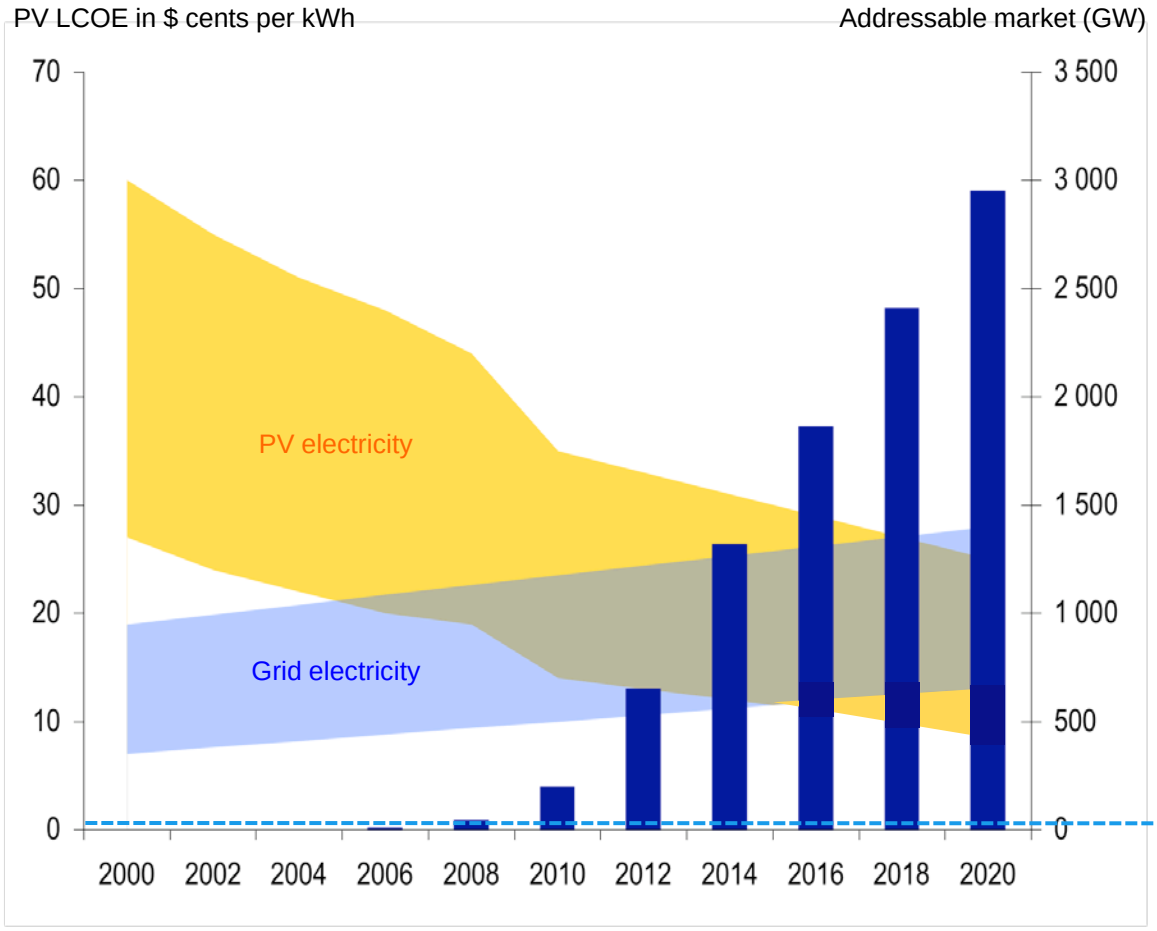
PRESENT
- Financial crisis…but growth
- Extreme volatility
- Shake-out

FUTURE
- Transition to grid parity
- Multiple GW markets
- Maturing PV sector

Source: Analyst reports, Novus estimates

PV price reduction opens new markets

Addressable markets vs. levelized cost of energy (LCOE)



2010-2020: "The PV Transition Phase"

- Current installed base of PV is ~30 GW
- At the current pace of cost reduction, new and huge addressable markets will open every year, according to Photon Consulting
- US and China have stated goals of 20GW each by 2020

Current installations: ~30 GW

PV IS CURRENTLY A VERY SMALL POWER RESOURCE, COMPARED WITH ITS´ MEDIUM TERM POTENTIAL

Source: Photon Consulting, BP Solar, Novus estimates