Will Solar-Generated Electricity Fulfill Its Promise?

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Solar Marketplace

Technology Overview

Crystalline Silicon

- Converts direct or indirect sunlight into electricity using silicon-based cell conversion technology
- Dominant and most proven PV technology with modest cell efficiency improvements in last few years
- Major players with growing cell and module production capacity
  - Q-Cells
  - Suntech
  - Sharp
  - SunPower
  - Motech
  - Kyocera
  - Sanyo
- Module efficiency >20%, suitable for rooftops, small power plants

Solar Marketplace

Technology Overview

Thin Film

- Converts direct or indirect sunlight into electricity using semiconductor material evaporated or deposited on a thin, flexible metal or plastic substrate
- Attracting numerous players with promise of low-cost manufacturing and building integration
  - Systems: First Solar, Sharp, United Solar
  - Fabrication Equipment: Applied Material, Roth & Rau, Centrotherm, Oerlikon
  - VC-backed start-ups: NanoSolar; Solyndra, Konarka, Miasole
- Module efficiency >10% – suitable for 'industrial' rooftops

PV Marketplace

Technology Overview

Concentrating PV (CPV)

- Low concentration PV (LCPV) concentrates sun's energy ~20-100 times onto silicon or multijunction PV cells to create electricity
- High concentration PV (HCPV) concentrates sun's energy 300-1000 times onto multijunction PV cells to create electricity
- Industry is in its infancy; technology has potential for highest cell conversion efficiencies and lowest $/kWh/m^2 costs
- Key players
  - Emcore
  - Concentrix
  - SpectroLab (Boeing)
  - Sharp (developing)
- HCPV module efficiency: >25% possible using dual axis tracking under direct sunlight

PV Marketplace

Technology Overview

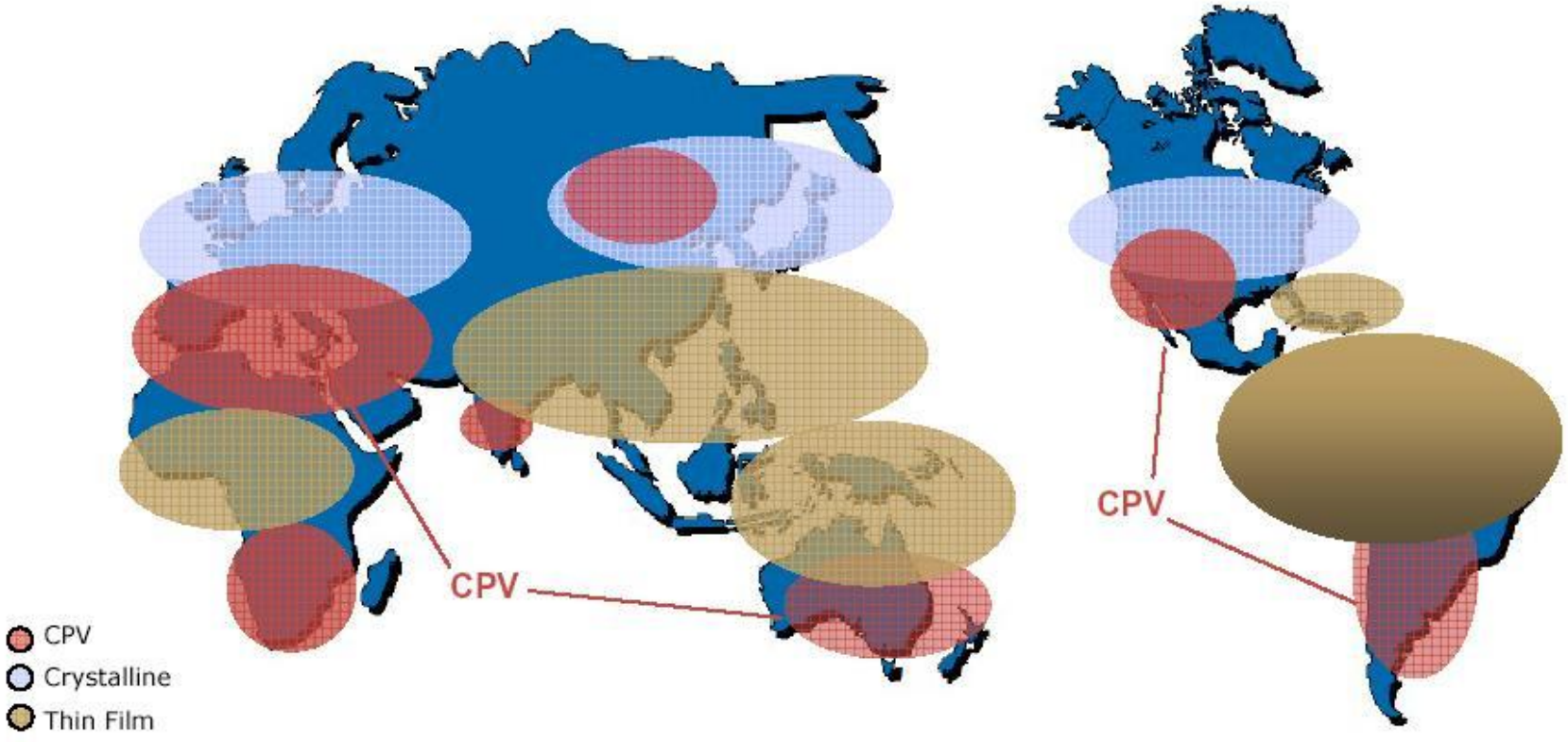
Concentrating Solar Thermal (CST)

- Concentrates the sun's energy to temperatures typically between 400 and 1000°C, heats thermal conductor to drive engine or turbine for generation of 50 MW to 500 MW of power
- Small scale deployments underway; large projects on drawing board
- Key players:
  - Solar Millenium
  - BrightSource
  - Schott
  - Abengoa
  - Solel
- Efficiency of >25% possible depending on concentration technique and power generation technology utilized

PV Technology Comparison

	Advantages	Disadvantages
Silicon PV **Module efficiency typically <20%**	• Indirect sunlight acceptable • Operates with or without tracking • Mature, robust technology	• Limited efficiency improvements possible without adding tracking • Significant efficiency loss at high ambient temperatures
Thin Film PV **Module efficiency typically <10%**	• Indirect sunlight acceptable • Potential for lowest cost/kWh • Can be integrated into building materials	• Low efficiency, long term reliability unproven • Requires significant surface area and large support structure • Efficiency loss at high ambient temperatures • Utilizes scarce, environmentally-challenging materials
High Concentrating Photovoltaics (HCPV) **Module efficiency typically >25%**	• Potential for highest module and system efficiency • Good performance in hot climates • Potential for lowest $/kWh/m^2 • Significant efficiency improvement still possible • Highest power delivery during peak loads	• Requires direct sunlight, complex optics and tracking • Optical and tracking losses degrade system efficiency • Generally not cost effective below 100 kW • Long term reliability unproven
Concentrating Solar Thermal (CST) **Efficiency is configuration-dependent, but could exceed 25%**	• Efficient in large, utility-type installations • Potential to store energy • Not dependent on cell efficiency improvements	• Requires direct sunlight • Capital intensive installation • Remote locations create permitting, land use and transmission line availability challenges • Generally not amenable to distributed power applications

Geography Influences PV Technology Choice



Source: Sharp Solar and SolFocus Presentations, 2008

- Crystalline PV: Best in diffuse light areas with cooler ambient temperatures
- Thin Film PV: Best in diffuse light areas with hotter ambient temperatures
- CPV: Best in direct sunlight areas with hotter ambient temperatures

Leaders in Solar Electricity Capacity
(PV and CST)

Country	Cumulative Capacity (MW)	Estimated New Capacity in 2008 (MW)
Germany	5308	1500
Spain	2973	2281
Japan	2173	235
United States	1547	342
Italy	440	338
France	175	105

Source: Solar Electricity Industries Association, Photovoltaics International

Future Outlook:

- Reduction in feed-in tariff (FIT) and economic downturn will slow capacity growth in Germany
- Recently implemented FIT cap will significantly discourage new deployments in Spain
- Capacity growth of 10% expected in Japan in 2009 with significant jump in 2010
- Delays in implementation of stimulus bill will slow solar growth in US in 2009, but will boost deployments in 2010
- Italy and France implementing policies to encourage solar which should result in annual capacity growth of >40% and >25%, respectively

Solar Electricity Landscape in CY2009

Positives

- Solar-powered electricity generation now exceeds 15GW worldwide, and has recently been growing at >40% per year
- Silicon shortages that were inhibiting deployments in 2007 and 2008 have been overcome
- Concentrating Solar Thermal (CST) system deployments underway on a small scale
- Average installed cost for US PV commercial installations in 2007 *after incentives* was $0.39/kWh, about one-third less than in 2001

More…

Negatives

- Solar energy still represents only <0.1% of global energy output
- Silicon capacity for 2009 is forecast to be as much as twice demand seriously depressing silicon cell pricing; several cell suppliers will merge or go out of business
- Declining feed-in tariffs in Europe and the worldwide economic slump are expected to slow the growth of solar deployments in 2009
- Boom and bust government incentive programs have inhibited steady growth of the solar industry; long-term predictable incentive policies must be put in place

More…

Sources: SEIA, Navigant Consulting, LBNL, PV World, Doty Energy

Solar Electricity Landscape in CY2009

Positives

- Silicon cell material costs are dropping quickly and now represent about one-third of total installed cost
- If the US government approves a national portfolio standard (mandatory percentages of renewable energy) and/or carbon emissions cap and trade legislation, solar energy could be a major beneficiary

Negatives

- Solar-generated peak period electricity is selling for >$0.40/kWh which is still 2X to 4X the current price for hydrocarbon sources; subsidies are still necessary to make solar-generated power competitive
- The scarcity of project funding worldwide is limiting new solar deployments
- Stimulus funding from the US government in the form of loan guarantees and grants is being awarded more slowly than anticipated

Sources: SEIA, Navigant Consulting, LBNL, PV World, Doty Energy

Solar Economics Forecast for CY2012

Module Type	Thin Film	Silicon	LCPV	HCPV
Cell Efficiency @25°C (%)				
Annual Available Irradiance (kWh/m²)				
Annual Electricity Generated (kWh/m²)				
Module Cell Cost ($/m²)				
Module Material Cost ($/m²)				
Optics Cost ($/m²)				
Total Module Cost ($/m²)				
Array Support Structure ($/m²)				
Installation ($/m²)				
Total Module Area Cost ($/m²)				
Inverter Cost at $0.3/W ($/m²)				
System Cost with Inverter at $0.3/W ($/m²)				
Annual Revenue at $0.1/kWh				
System Payback Period at $0.1/kWh				
Annual Revenue at $0.15/kWh				
System Payback Period at 0.15/kWh				

Data available in RevGen Analysis, "Solar Electricity Outlook"

Email Mort Cohen to purchase the RevGen Solar Electricity Outlook incorporating the CY2012 economic forecast

Summary

Competing solar technologies can all be successful as silicon PV slowly yields market share (in terms of kW capacity) to other solar technologies over the next five years

- Silicon PV will retain ~65% market share as a residential solution with growing market in small industrial power plants
- Thin film PV could capture as much as ~25% market share primarily for industrial and building applications; unproven durability over time is slowing uptake
- Concentrating solar thermal systems are beginning to be deployed, but face challenges from land use, permitting and environmental issues. It could capture ~10% market share in utility-type applications
- Concentrating PV is emerging, but still too early to predict success. It could capture 5% market share for industrial and small power plant applications

More…

Sources: NREL, Prometheus Institute, PV World, Navigant Consulting, Greenpeace, Doty Energy

Summary

Forecasts for total solar-generated power vary widely, but a market share less than 5% of global power output is likely by 2020

- Even at 5% market share, solar power represents a sizable growth industry
- Cumulative solar power capacity in 2020 is projected to be 300 GW to 400 GW which represents a 20X to 30X increase from the 15GW in 2008

Well-conceived subsidy and tax credit policies will be required for at least the next three years to help solar reach grid parity with existing energy sources if they remain at their current kWh pricing

Email Mort Cohen to purchase the RevGen Solar Electricity Outlook for further analyses of the Solar Market

Sources: NREL, Prometheus Institute, PV World, Navigant Consulting, Greenpeace, Doty Energy

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