



Innovation Inspired by Nature

Today's talk



- Brief introduction to SolFocus
- Concentrator Photovoltaics (CPV)
 - What are they? (introduction, history)
 - Characteristics
- SolFocus' approach
- The industry's potential



Introduction



- **SolFocus:**
 - Manufacturer of *Photovoltaic Concentrators (CPV)*
 - 3 ½ years old Silicon Valley startup
 - Combination VC, strategic backing (\$100M)
 - Now 130 people
 - Product in test. 4 field sites (Ca, Hi, Az, Spain)
 - Preparing to ramp manufacturing



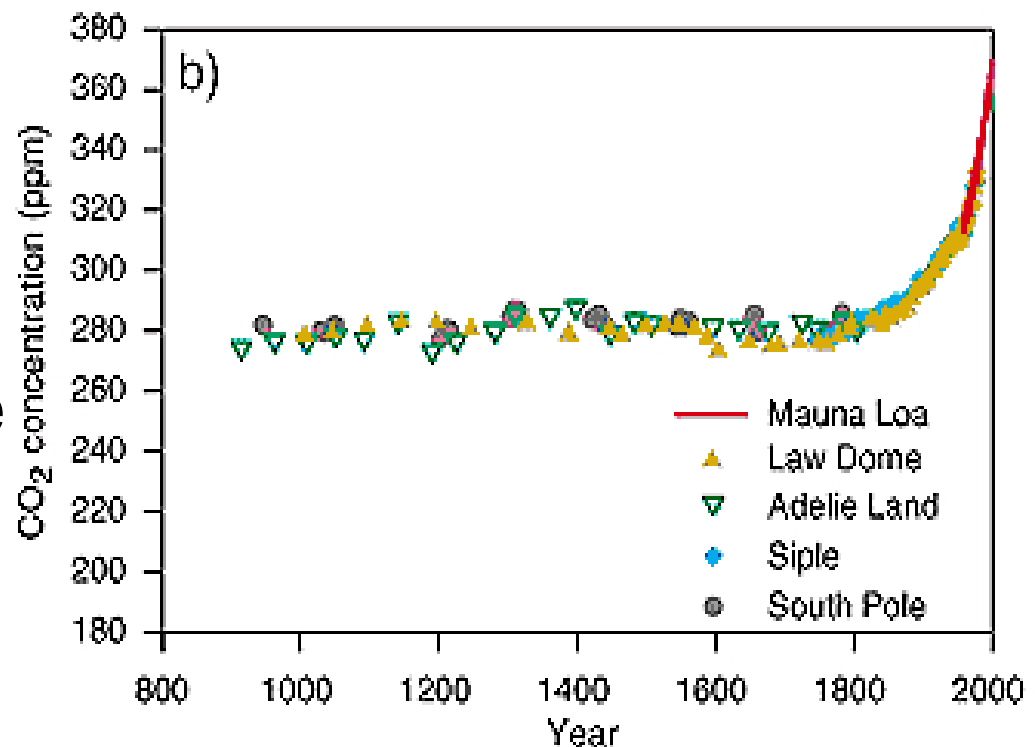
2009/3/10© Sol Focus, Inc.

Motivation:

Unique combination of:



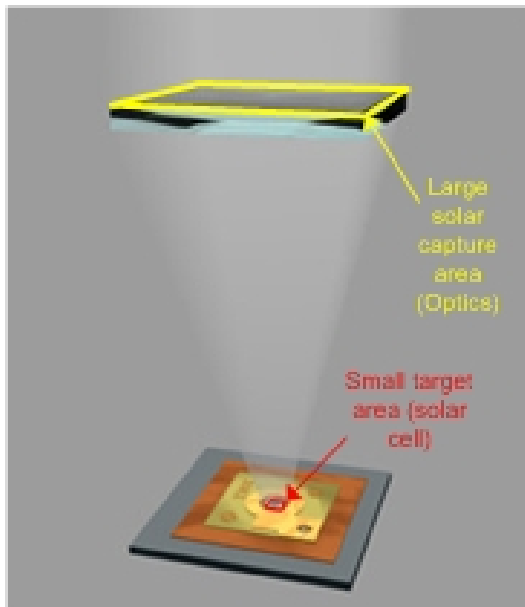
- Unprecedented Climate change issues, awareness
- Favorable economic trends
- Technically feasible solutions



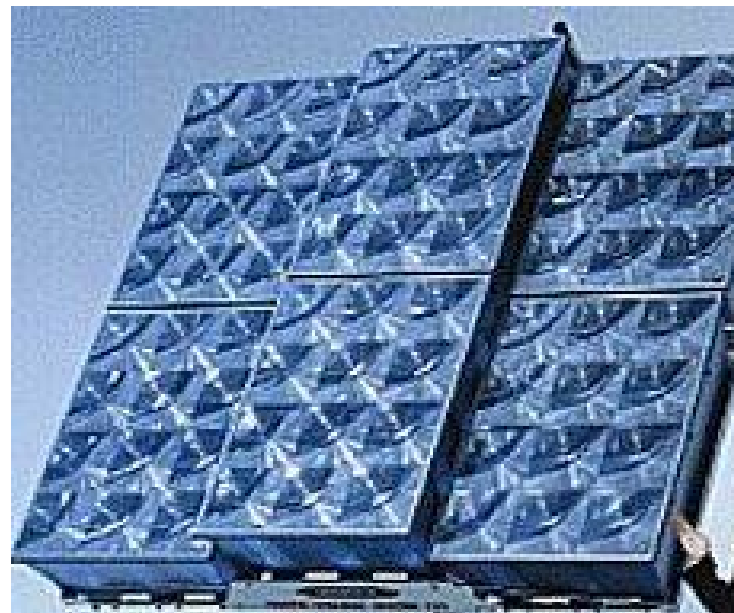
What is CPV?



- Devices using optics to concentrate a LARGE area of sunlight on to a SMALL area of solar cell.
- Typical concentration ratios 150X – 500X – 1200X (some in 10x to 30x range)



■ Image:Reuk Co



■ Image: SunWind Solar

Why CPV?



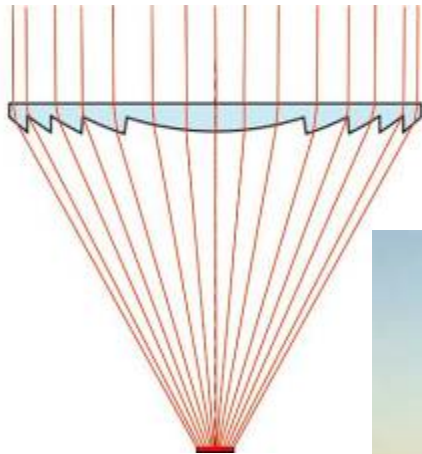
- Most economical technology in areas of ***High Direct Radiation.***
 - Reduces use of expensive photovoltaic material with inexpensive optics
 - Uses established high volume industries for technology & methods (automotive, electronics)



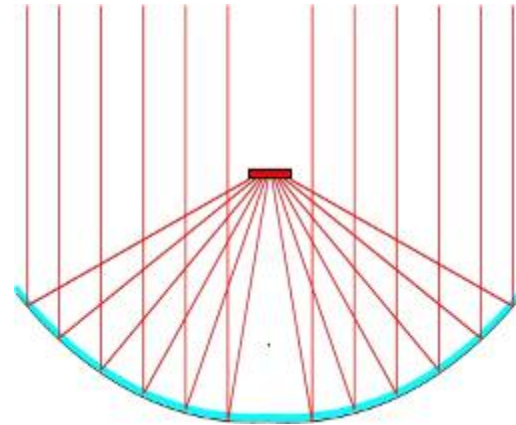
Two fundamental approaches



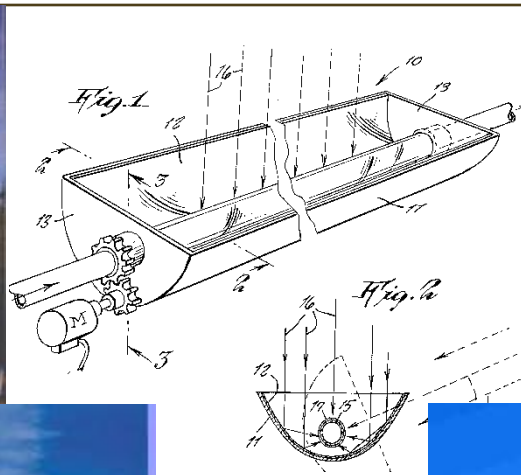
- Refractive: with lenses



- Reflective: with mirrors



Many years under development *but little commercial success*



So why now?



- **They were:**
 - Unreliable
 - Cooling problems
 - Materials problems
 - Not economical
 - Low efficiency cells
 - Expensive tracking requirements
 - Concentrator “tax” – DNI only

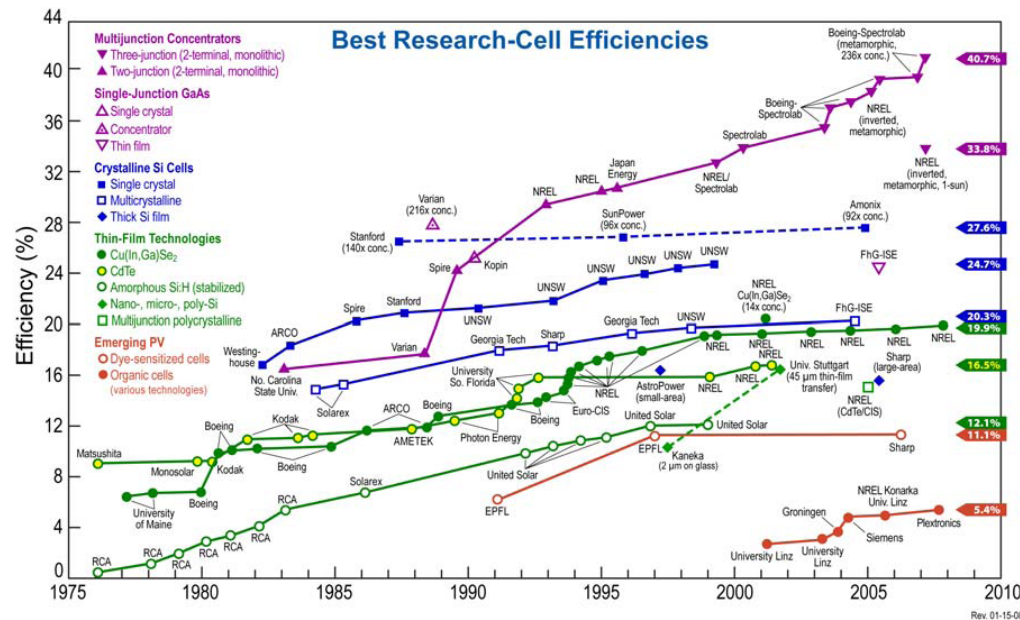
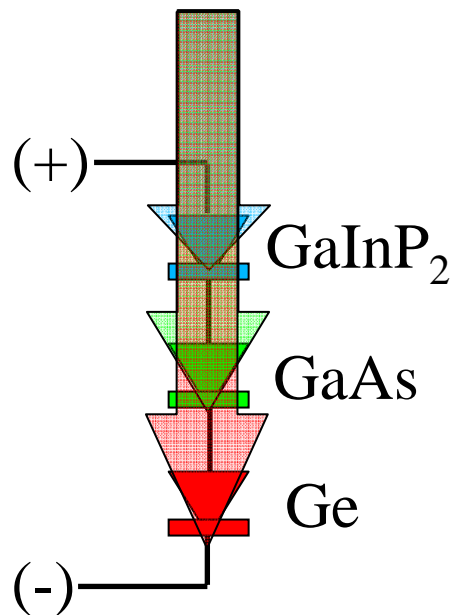
- **Breakthrough:**
 - Triple Junction cells
 - Non Imaging Optics



Triple Junction Cell



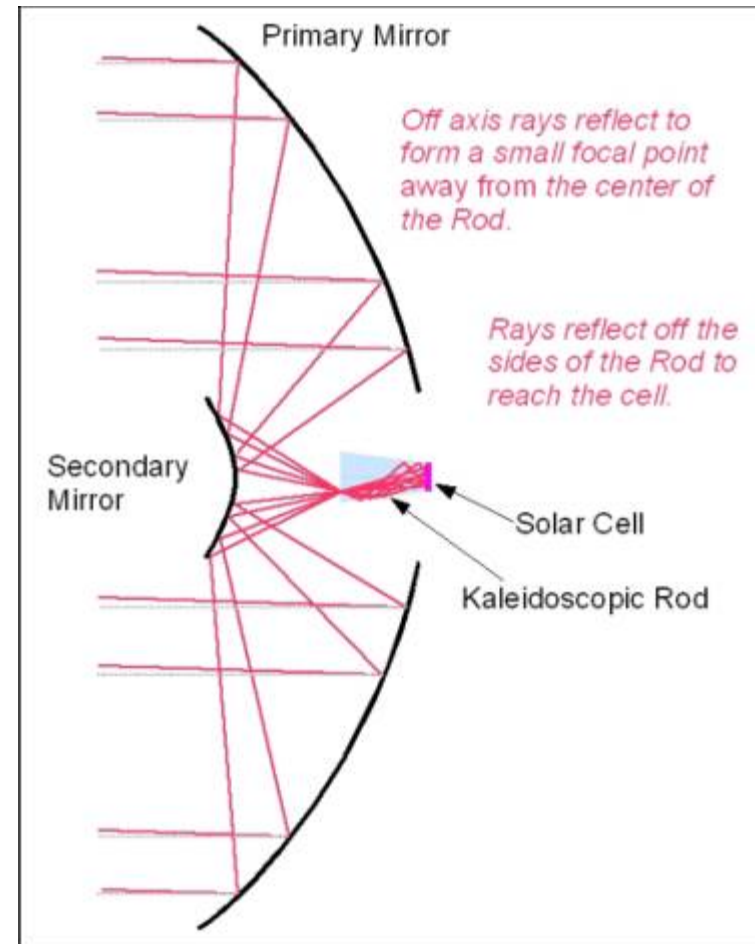
- 3 coupled cells, each tuned to a different part of the solar spectrum – *not Silicon based*
- 40% efficiency demonstrated.
- Theoretical max efficiencies in low 70%



Non Imaging Optics



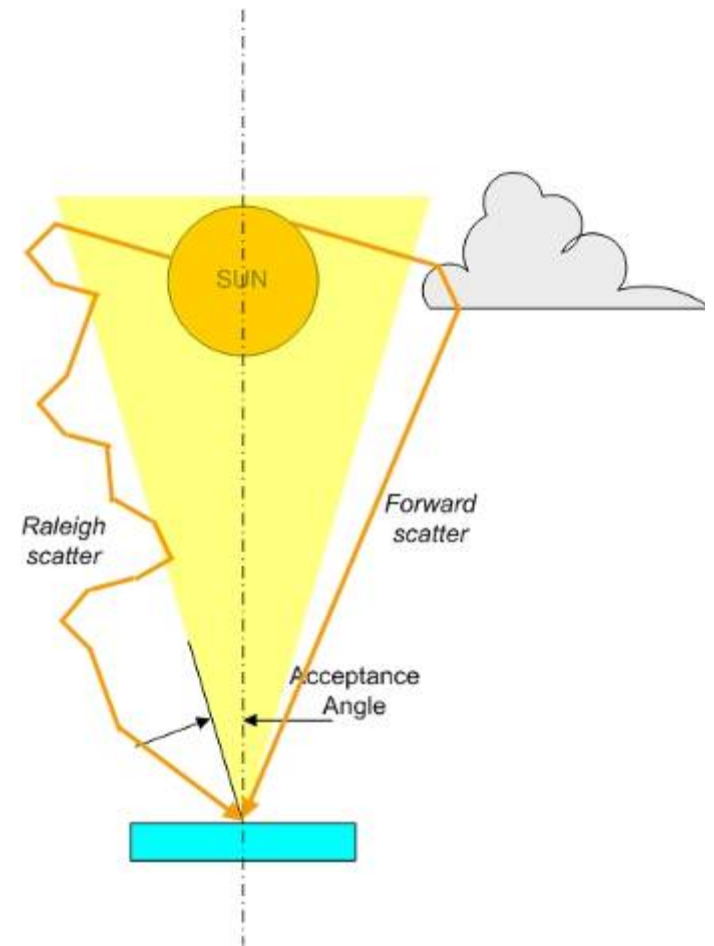
- Science of efficient photon transport.
 - Disregards order of light rays.
 - Allows high concentration
 - Compact, low cost optics
 - Wide acceptance angles.
 - (Kaleidoscope example)



CPV characteristics



- **High power density**
 - Mid 20% efficiency now.
 - Over 33% with new generation cells
- **...but with Narrow Field of View**
- **CPV performs best in areas of high direct radiation, or “DNI”**
 - **Mediterranean climates**
 - close to 40% of the world’s population centers



CPV characteristics



■ Scalable from hundreds of kW to GW

- CSP feasible in large project sizes only
- Thin film: low to moderate sizes
- Silicon: low to medium sizes



SolFocus' CPV product



■ SF-1000



Design constraints



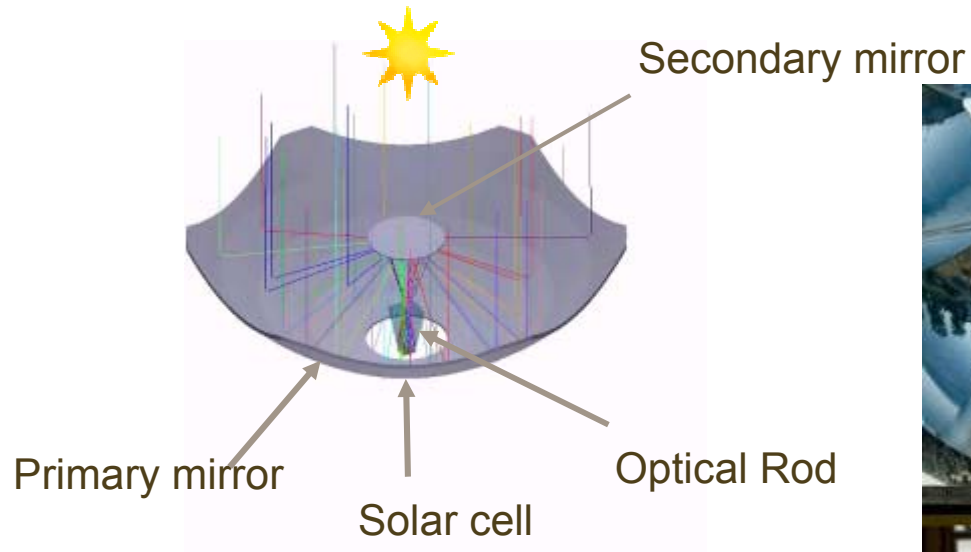
- Hot, arid climates.
 - Must use air cooling only.
 - Short thermal path to minimize cell temperatures
- Long lifetime
 - Passive cooling. No fans, plumbing, chilling, heat exchangers
 - *absolutely* stable cooling. Not conditionally stable.
- Low system level costs
 - Large acceptance angle
 - High volume manufacturing design (repeated assemblies of small concentrators).
 - Very active cost modeling from the start of the project.
- High efficiency
 - High concentration
 - Reflective optics
- Two step development:
 - First make a manufacturable concentrator
 - Second, maximize it's efficiency

Resultant system



Arrays of Cassegranian, reflective concentrators

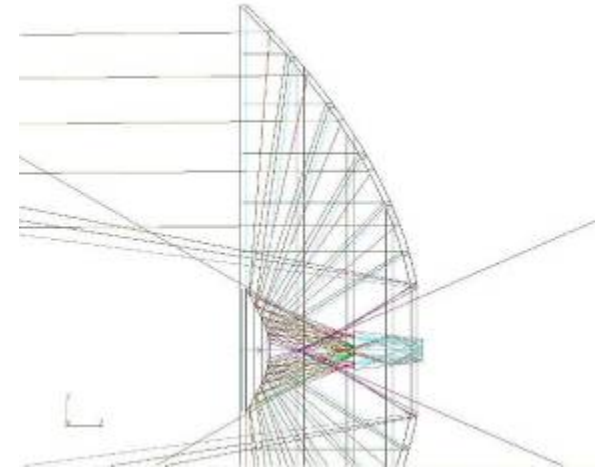
- One cell per mirror
- Simple to manufacture
- Forgiving optics; little alignment needed



Advantages



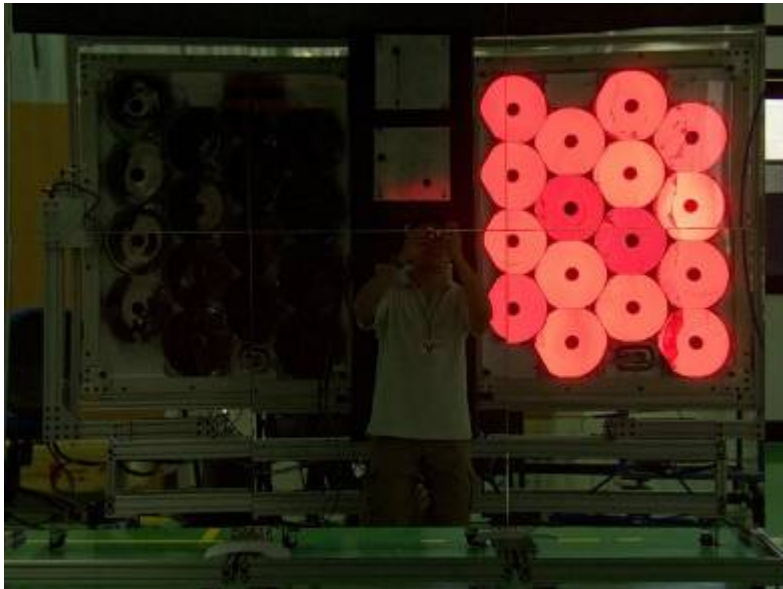
- Mirrors:
 - allow higher efficiencies
 - Approx practical η : Fresnels 83%; Mirrors >88%
 - Mirrors allow higher concentration
 - Easily manufactured at very high volumes



Advantages



- Small modular concentrators
 - allow high volume
 - Low parts count: simpler supply chain
 - Mfg in many places possible
 - Critical manufacturing steps in factory, not field



What else is crucial?



■ Proving Reliability

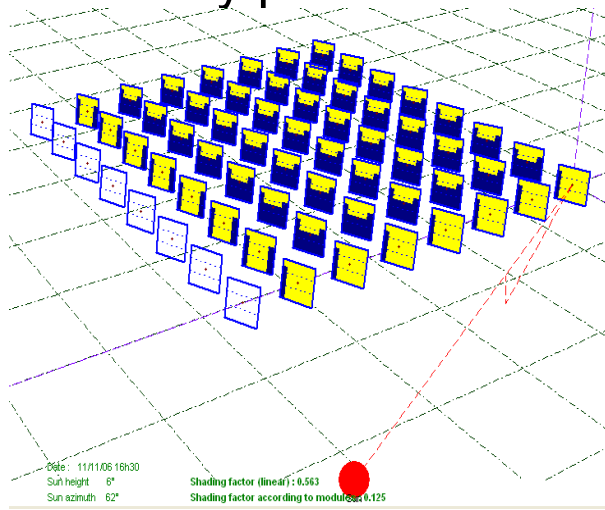
- In-House Reliability Team
- Harsher Reliability Protocols Than Standards

■ Cost control

- Very rich cost model developed early

■ Environmental life cycle analysis

- University partner



Project and System Config Packet		
Project Information	0	0
Project Location	Puertollano	0
Nominal Project Output Power	200	AC KW Peak
Manufacturing Volume	0	MegaWatts
Latitude	40	Degrees
Longitude	4.07	Degrees
Average Insolation	5.4	KW.Hr / m² / day
DNI	850	W/m²
Cell Temperature	45	degrees C
Field Center to Grid Tie In Point	0	meters
Center to Center Tracker Spacing	14	Meters
Land Cost	15000	\$ per Hectare
Land Difficulty Factor	NORMAL	0
System Configuration Inputs		
IF YES then put in transformer power	200	KW
Inverters Top Down or Bottom Up (DOWN, UP)	UP	0
Number of Panels per Tracker	30	Units
IF TOP DN: # Inverters Per Transformer or Group	3	Units

Inverter Power in Watts	500	3000	6000	100,000	200,000	
MFG Volume (MW)						
0.5	\$ 0.70	\$ 0.55	\$ 0.38	\$ 0.36	\$ 0.35	
2	\$ 0.67	\$ 0.52	\$ 0.36	\$ 0.34	\$ 0.33	5%
10	\$ 0.63	\$ 0.50	\$ 0.34	\$ 0.32	\$ 0.32	5%
50	\$ 0.60	\$ 0.47	\$ 0.33	\$ 0.31	\$ 0.30	5%
100	\$ 0.57	\$ 0.45	\$ 0.31	\$ 0.29	\$ 0.29	5%
500	\$ 0.54	\$ 0.43	\$ 0.29	\$ 0.28	\$ 0.27	5%
1000	\$ 0.51	\$ 0.40	\$ 0.28	\$ 0.26	\$ 0.26	5%

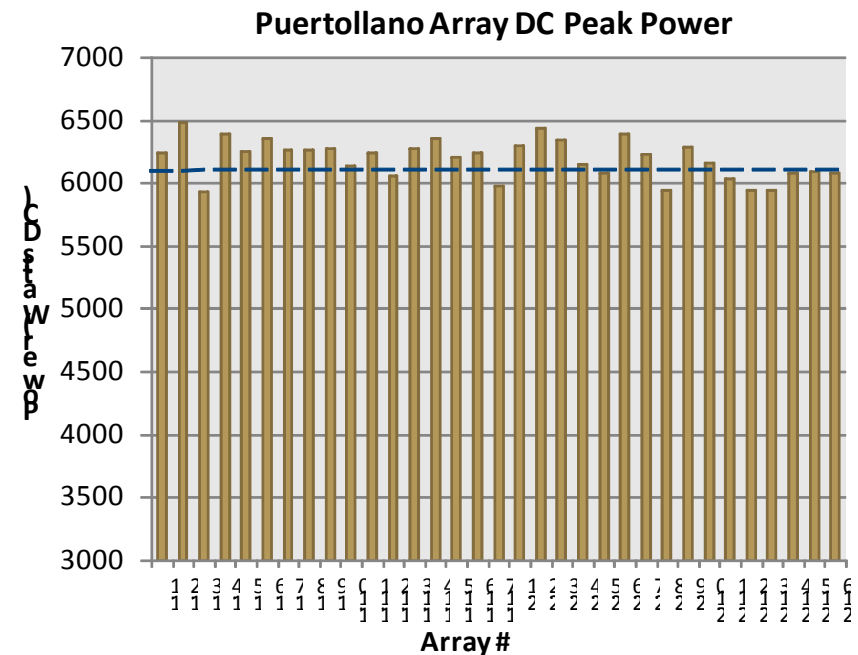
FIELD DEPLOYMENT DETAIL PACKET		
Project Location	Puertollano	
Number of Trackers	42	Units
Number of Panels Per Tracker	30	Units
Number of Panels Per String	10	Units
Area Per Panel	1.55	m²
Number of Panels (assume each Tracker is full)	1260	Units
Ground Cover Ratio	0.238	Fraction
Tracker Spacing	14.00	Meters
Nominal Land Area	0.82	Hectares
DC Peak Pwr per Panel and local DNI and Temperature	178	W Peak DC
Peak Power Out Per Tracker	5343	W Peak DC
Trackers per Inverter	1	Units
Number of Inverters in the Project	42	Units

SF-1000 status



- Meeting or Exceeding Performance Goals
- Three Test Sites Completed
- First Commercial Site at ISFOC – 500 kW
- TUV Certification Complete
- First CPV Panel to Achieve CEC Listing

Ready to start manufacturing ramp



Next steps: Sell, install, learn



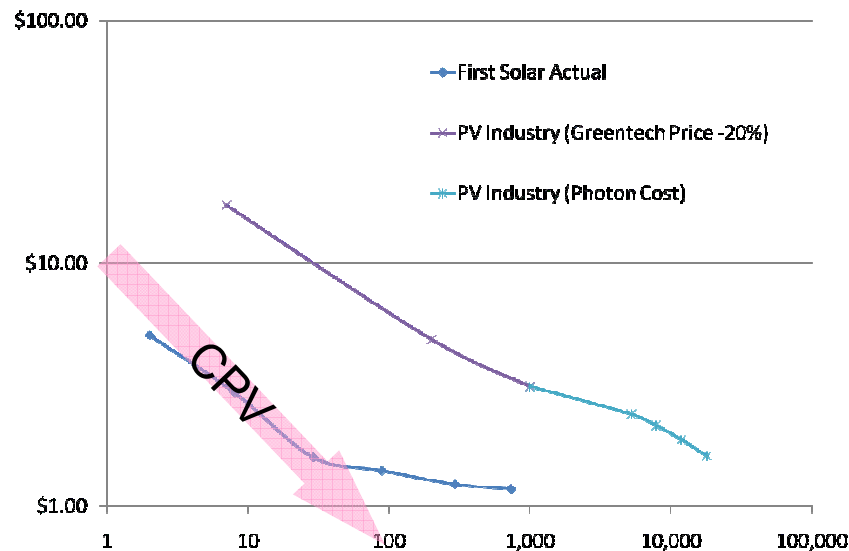
Increased volumes are key to competitiveness



Last: Will this industry be successful?



- Problem:
 - While costs, reliability, ROI look world class, *we're playing catch-up*



Symptoms of growing robustness

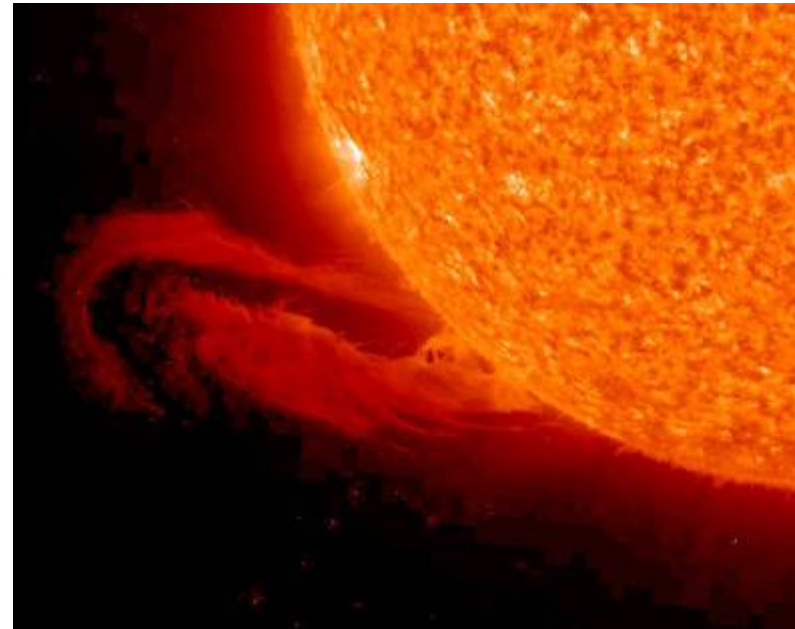


	2004	2008
Approximate number of CPV companies	5	25
Approximate number of high performance cell manufacturers	3	15
Approximate capitalization	\$25M	\$1000M
Installed base	<0.1MW	5MW

Take Home



- CPV no longer in the lab: has been field proven
 - In appropriate areas, will be least cost solution.
 - High volume manufacturing is coming.
-
- ***Let's go build it***



Thank you!

