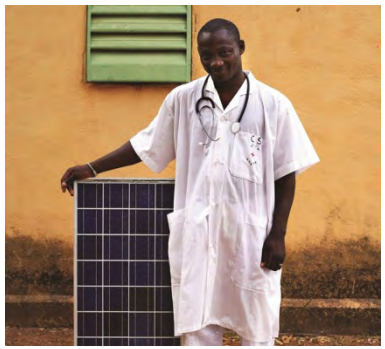
ESMAP
Energy Sector Management Assistance Program

Concentrating photovoltaic (CPV)





Agenda

- CPV TECHNOLOGY
- COMPARISON: CPV, PV AND CSP
- CPV MARKET

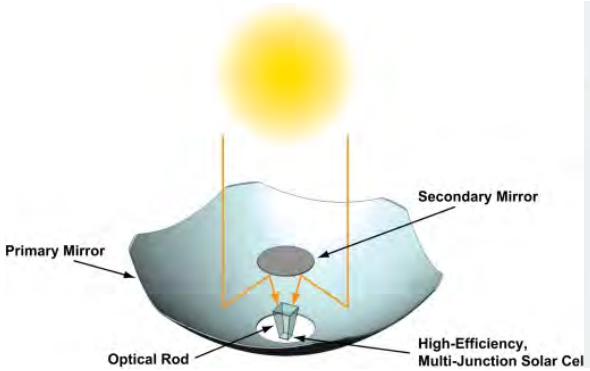
CPV Technology

CPV Technology Features

- Concentrating photovoltaic makes use of the photovoltaic effect but adding lenses and mirror to concentrate the sunlight.
- CPV technology started about 10-15 years ago when the cost of Silicon was high and there was a need to reduce the area of cell material.
- It works with DNI instead of GHI.
- Potential for solar cell efficiencies greater than 40%
- Concentration ratio can reach over 400X
- Small cell area of around 1cm2
- Accurate Solar System Tracker (~0.01º) and ventilation are required

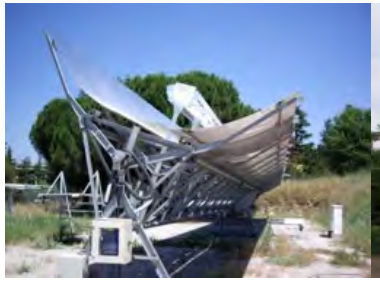
Optical designs:

Reflective Mirror



Refractive Lens

Tracking Systems:



Euclides (~40X)

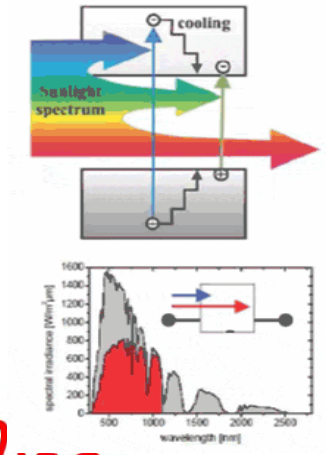
Two-axis tracker (>400X)

CPV Technology

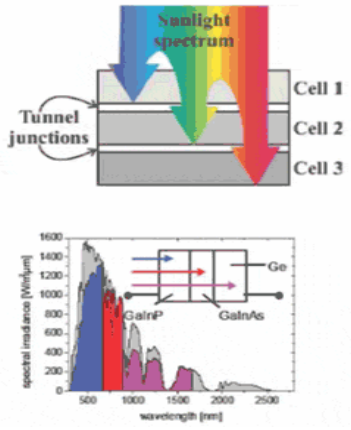
Description of Cell Classes of CPV as a function of Concentrated Ratio

Class of CPV	Concentration Ratio	Type of Cell
High-Concentration MultiJunction cells (HCPV)	>400X	Multijunction - Multiple Photoelectric Effect + Optical concentration
Medium-Concentration (MCPV)	~3X-100X	Silicon or other cells – Optical concentration
Enhanced concentration modules (LCPV)	<3X	Silicon modules -Optical concentration

Silicon

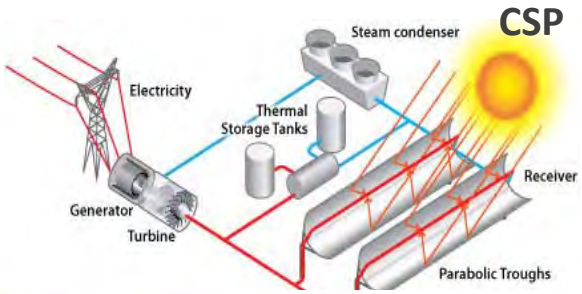


Multijunction

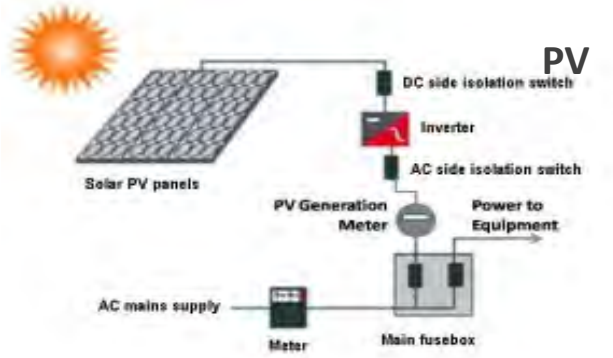


The high concentration (>400X) and efficiencies (>35%) reached in Multijunction System allows to Reduce the cell size to 1cm^2 or even 1mm^2

Technical Comparison



- **Solar to Thermal** -> Thermal to Electricity conversion
- Use the Direct Normal Radiation (DNI)
- Size: Power plant range from 1MWe to 200MWe



- Direct Solar to Electricity conversion (Photoelectric Effect)
- Tracked systems use Global Normal Radiation (GNI)
- Fixed System use Global Horizontal Irradiance (GHI) increased by a factor to account the inclined surface

- Direct Solar to Electricity conversion (Multiple Photoelectric Effect)
- Use the Direct Normal Radiation (DNI)
- Size: Modular, solar fields between 100kW-100MW

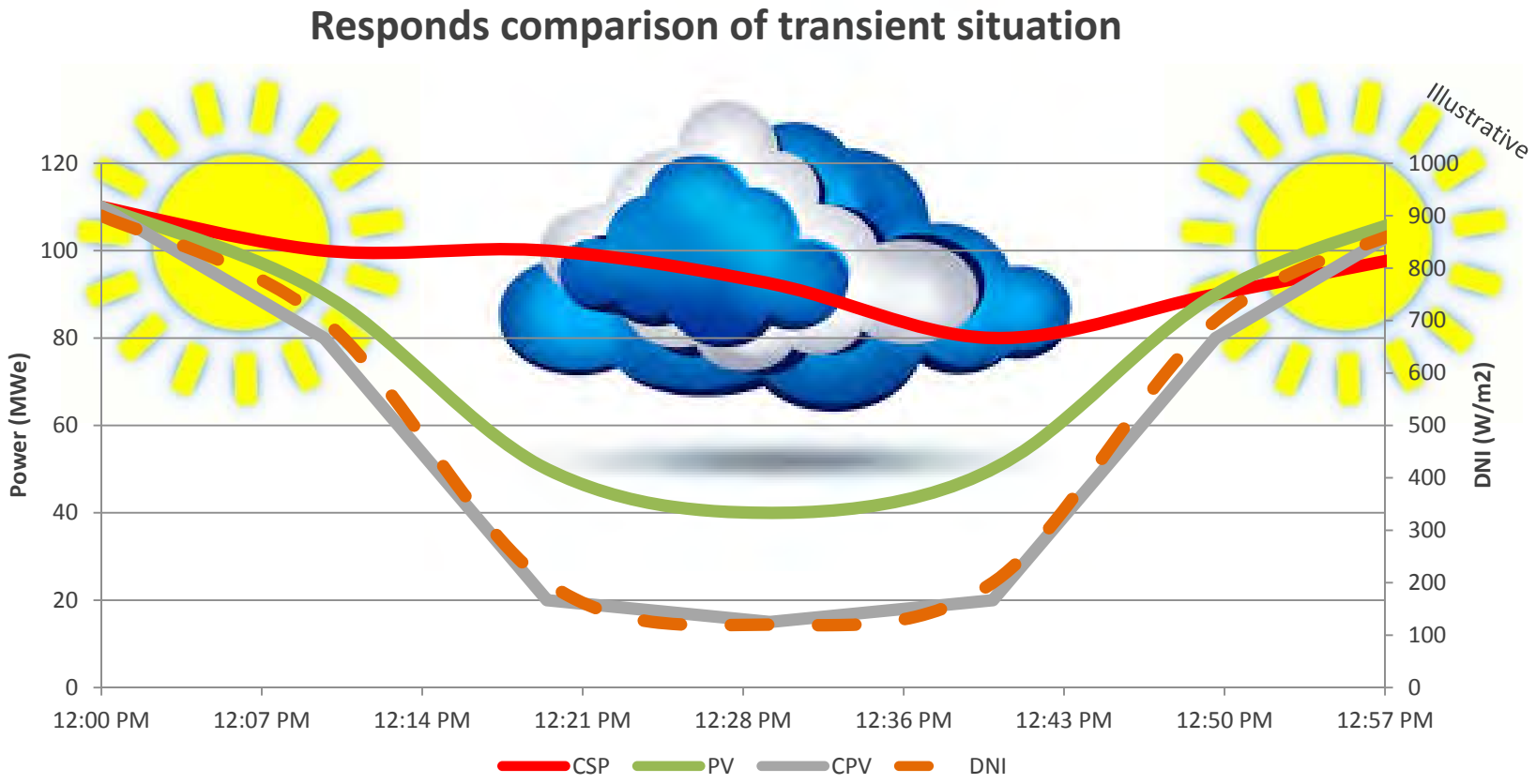
Technical Comparison

Estimation of CAPEX, OPEX and LEC for the three different technologies

	CSP	CPV	PV
Maturity	30 years of proven technology (depending on the technology)	Under development, or first commercial stages	More than 30 years of proven technology
LCOE estimate 2013 ($c/kWh)	17-29	13-24	10-20
Installed capacity (end 2013)	~3500 MW	~300 MW	~100 GW
Annual Solar-Electricity conversion efficiency	16-19%	19-22% (24-35% peak)	15-17%
Dispatchability	Yes	No	No
Water use	Medium-High (dry or wet cooling)	Very Low	Very Low

Source: adapted from S2m, Protermosolar, CPV Consortium, GTM Research, IHS

Technical Comparison



➢ As CPV systems do not have inertia nor can take advantage of diffuse irradiation they respond in a quite negative way to transient situations

Source: S2m

CPV Market

Eight to six years ago, there was more than 20 companies in the CPV industry. Nowadays, few companies are competing for the CPV market worldwide.

Industry is now dominated by three system manufacturers: Soitec, Amonix and Suncore-Emcore

Most important system manufacturers in CPV with real projects by the end of 2012

Company	Capacity(MW) in 2012*	Manufacturing Capacity (MW/year)	Type of System
AMONIX	40	100	Lens, pedestal
Soitec	10	70 MW in Freiburg; 140 MW in San Diego	Lens, pedestal
SolFocus	6	50	Secondary mirror, pedestal
suncore 日芯光伏科技有限公司 Suncore Photovoltaic Technology Co.,Ltd.	53	200	Lens, pedestal
TOTAL	**~110**	**~600**	

*Installed

Source [NREL]

Conclusions

- CPV system price is still the double than PV system price but they have the highest efficiency of all solar power systems (>25%) .
- Reduced CPV market competition by strong ongoing consolidation.
- CPV is not dispatchable and grid integration on large scale can be more complicated than for PV.
- CPV has a steep cost reduction path ahead, and last year the pipeline of projects
- According to a report HIS (2013), the global market for CPV systems is “on the verge of explosive growth, with worldwide installations set to skyrocket 750% between 2013 and 2020”.

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Thank You.

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