



# "Projecting VLS-PV power generation costs"

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## Disclaimer



The presented results and discussions on VLS-PV and other technologies cost structure together with application and other aspects are based on interviews, calculations and personal estimates from the author and other contributors, as well as references to public sources.

No liability of any kind is taken for the correctness of the data, results, future projections or used references.







## Overview



- Elements contributing to PV power generation costs
- Trends of PV module and system costs
- Model calculation of generation costs
- Comparison with Concentrated Solar thermal Power ("CSP")
- Summary and conclusions







# Elements contributing to PV power generation cost



## PV system cost

## trends highlighted

- modules
- B.O.S. cost ("balance of system": mounting racks, cables, inverter(s), transformer, ...)
- engineering, permissions, ...

## Financing parameters

#### model parameters assumed

- depreciation period
- equity vs. debt ratio
- conditions of loan
- other parameters (subsidies, tax credits, other support schemes, ...)

### Running cost

- land lease, insurance, maintenance, ...

### Electricity yield

- type of system (stationary, tracked)
- quality of modules, BOS components and system installation (performance ratio)
- site and annual global irradiation

example Germany vs. US

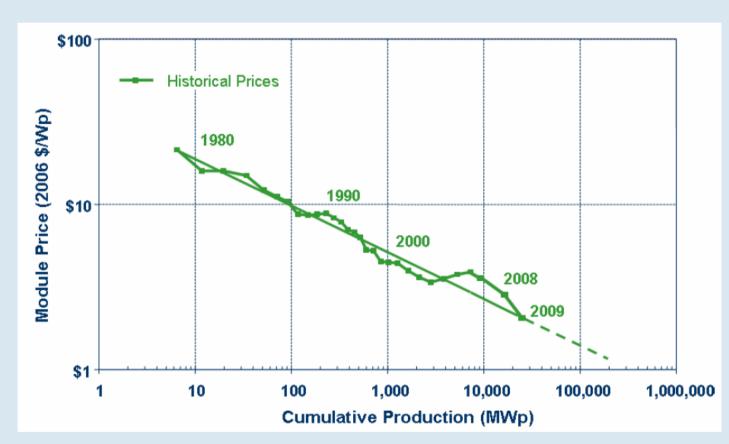






# Degression of PV module price (gross picture)





Source: Adapted from National Renewable Energy Laboratory







# VLS-PV technology and cost trends seen on ~2 year's time scale



Technology	Thin Film				Crystalline wafer based	
	Amorphous	Cadmium	CI(G)S	a-Si/µc-Si	Mono	Multi
	silicon (a-si)	telluride (CdTe)			crystalline	crystalline
Cell Efficiency at STC*					16-19%	14-15%
Module Efficiency	5-7%	8-11%	7-11%	8%	13-15%	12-14%
Area needed per kW** (for modules)	15 m²	11 m²	10 m²	12 m²	app. 7 m²	app. 8 m²
Module Cost (EUR/W)***	~1	<1	~1.2	1-1.2	<1.5	
BOS Cost (EUR/Wp)***	~1.6	~1,1	~1	~1.2	~0.8	
System installed (EUR/Wp)***	~2.6	~2	~2.2	~2.2-2.4	<2.3	

<sup>\*</sup> Standard Testing Conditions: 25°C, light intensity of 1,000W/m², air mass = 1.5

Sources: EPIA/Greenpeace, Solar Generation V (2008); Strategic Research Agenda of the EU PV technology platform; personal estimates – see also latest VLS-PV book; example of large-scale stationary flat-plate systems



<sup>\*\*</sup> kW = kilowatt. Solar PV products and arrays are rated by the power they generate at Standard Testing Conditions

<sup>\*\*\*</sup> expected production costs w/o margins for ~2010-2012



# Intermediate results (VLS-PV on ~2010-2012 time scale)



- Relatively steep degression of PV module costs and prices (-5...10% p.a.)
- Thin film modules at ~1 €Wp; crystalline silicon modules at <~1.5 €Wp (these are in fact lower-end market prices seen already 2009!)</p>
- BOS costs depend distinctly on module efficiency
- ~2 €Wp installed system costs within reach with several technologies







# Model generation cost per kWh for future 2 €/Wp PV system



## Assumptions and parameters

- specific investment (installed system): 2,000 €/kWp

- site / annual global irradiation onto horizontal surface: 1,800 kWh/m².a

- prospected specific electricity yield (stationary system): 1,500 kWh/kWp

- depreciation period: 20 years

- percentage of debt to equity financing: 100% debt

- interest of loan:

Resulting power generation cost:

- O&M (operation and maintenance cost; no land cost) 2 €-ct/kWh

- special parameters (subsidies, tax credits, ...)

15.33 €ct/kWh

5% p.a. flat

none

(similar for tracked PV systems with higher investment / higher yield)

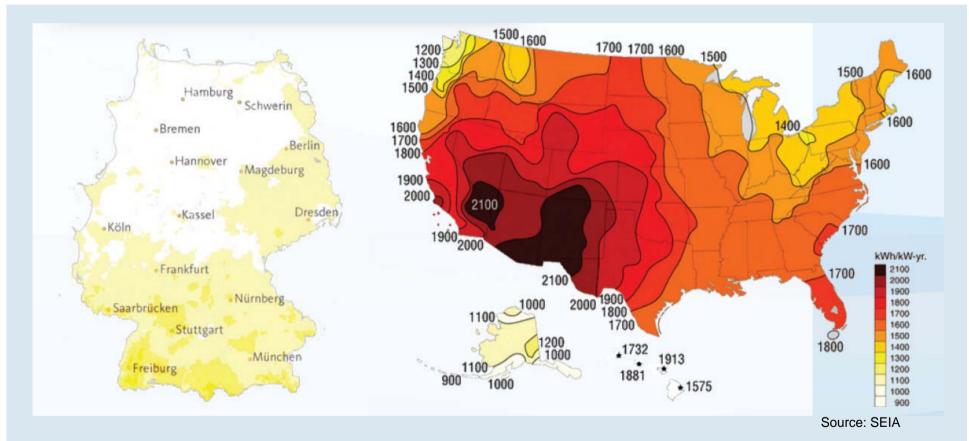
=> 10 ct/kWh within sight for higher-irradiation sites and with support schemes in place !!!





# Solar resources: Germany vs. US





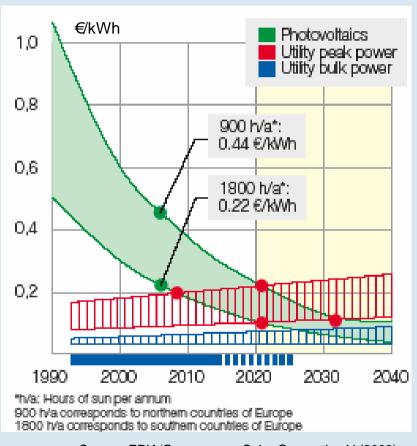
-> globally, numerous desert sites with higher annual irradiation than 1,800 kWh/m².a





# Overall picture for PV

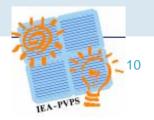




-> PV on track to 15...10 ct/kWh power generation cost at large scale in sunny regions - soon

Source: EPIA/Greenpeace, Solar Generation V (2008)







# Comparison between PV and CSP



# (Concentrated) Solar thermal Power ("CSP")

electricity generation through steam cycle

paraboloc throughs, mirror concentrators



## **Photovoltaics**

direct conversion of sunlight into electricity

solar cells and modules





# Roadmap for CSP plants





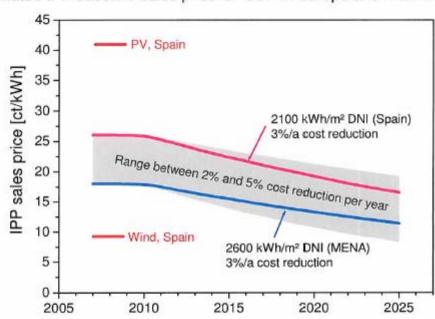
European Solar Thermal Electricity Association

# Roadmap for CSP Plants

Estimated IPP baseline sales price for CSP in Europe and MENA.

#### What makes the costs go down?

- Innovation in systems and components
- Improving production technology
- Increasing the overall efficiency
- Expanding the number of operating hours
- Bigger power blocks
- Reducing the O&M costs



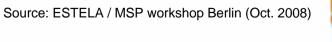
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# Comparative aspects



## **CSP**

### plus

- low-cost storage of heat enables prolonged operation
- -> close to base-load capability
- co-firing of fossil/bio-fuels option

#### minus

- only viable as large unit (>50 MWp)
- concentrating technology
- -> restricted to high direct radiation and low haze geographic regions
- comparatively higher maintenance effort (frequent mirror cleaning)
- water cooling required (or higher cost)
- low starting point but comparatively smaller degression of power generation cost

### PV

### plus

- application flexibility ranging from decentralized small residential system to centralized large plant
- applicable in all geographic regions
- comparatively high cost degression on near-future time scale leads to expectation of favourably low generation costs
- high competition of suppliers
- comparatively easier maintenance

#### minus

 presently not suitable for base load because of missing low-cost electricity storage technology







# Recent public statements confirming PV and CSP power cost perspective and relation



### PG&E: PV prices competitive with solar thermal

Pacific Gas & Electric Co. (PG&E) has ordered more energy from large solar power plants than any other utility in North America. »We are looking at everything, said Roy Kuga, vice president of energy supply for Pacific Gas & Electric (PG&E), at a Pacific Crest Securities clean technology conference in San Francisco on Feb. 27. Over the past year, about 100 different companies have pitched their proposals for large-scale solar power plants to PG&E, whose service territory stretches across some of the best solar energy resources under the Californian sun.

Prompted by a state law requiring that 20 percent of its power portfolio come from renewable resources by 2010 – and a target of 33 percent by 2020 – the San Francisco-based utility has signed contracts for electricity from 955 MW (DC) of PV plants to be completed between 2009 and 2013. This includes the two largest PV plants ever contracted – 688 MW and 250 MW plants, respectively. At the end of February, PG&E also proposed another 500 MW of utility- and third party-owned distributed PV projects up to 20 MW in size that would be installed between 2009 and 2014. The plan is under regulatory review

at the California Public Utilities Commission (CPUC). In addition, the utility has signed contracts for electricity from about 1.7 GW of solar thermal.

»People always ask, 'Which technology is going to prevail?' I hope they all prevail, a said Kuga. Based on PG&E's contracts and Kuga's comments, the utility is spreading its solar bets fairly evenly between solar thermal and PV. Solar thermal \*has a siight advantage\* in land area required, while PV \*has a clear advantage when it comes to water – unless thermal goes to dry cooling.\* While thermal has great potential as \*dispatchable 24/7 power\* when coupled with storage or fossil-fuel generation, in terms of both transmission and price, \*It's a toss-up,\* said Kuga.

A intoss-upin on pricing between largescale solar thermal and PV7 That's news to some – for example, readers of the popular US magazine Scientific American. An article in the magazine's March issue compared PV and solar thermal, citing a price range of 46.9c to 70.5c per kWh for PV and 19.9c to 28.1c for thermal. That completely distorts the reality of current contract prices for large-scale solar in California. For example, PG&E's 25-year contract with solar-thermal parabolic trough developer Solel for power from a 554 MW plant – planned to come on line in 2011 – was approved by the CPUC at a confidential price that »exceeds» 8.6e per kWh, according to public documents. Meanwhile, First Solar's contract with Southern California Edison was approved by the energy regulator »below» a price of 9.7e per kWh for a 20-year deal for power from an up to 21 MW PV plant scheduled to come on line later this year. PG&E's contract with SunPower for power from its 250 MW plant is estimated at approximately 12e per kWh.

Such parity or near-parity deals are the reason Kuga told PHOTON International last August, "These contracts are significant in the industry in that we are finally seeing solar PV where solar thermal and wind are in terms of pricing (see P1 9/2008, p. 50)."

According to Photon International March 2009, p.20:

CSP and PV both at ~10 US\$-ct/kWh in Southern California.\*

Roy Kuga, PG&E: ... in terms of both transmission and price, "It's a toss-up"

\* Note: CA legal framework like tax credits and other conditions need to be taken into account.

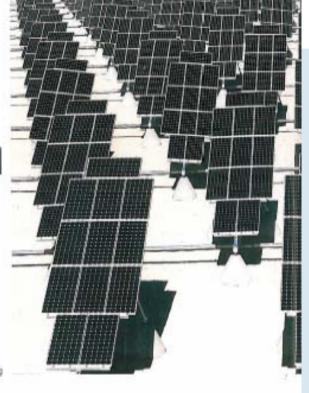








#### markets



Text: Garrett Hering

#### o Highlights

- With acquirement of Opt-Schart property assets, first Solar controls 15 percent of large scott Pic in the paperson in North America — 21 MW
- Augustain accrowd of calify owned
   Junipuled PV would deadle contract
   ad PV to 22 GW
- State of America Cuertan according May deal with Austra Group, while BP Solar and writes win 50 MW in New York

# From pipe dream to pipeline

Progress on 28 GW of PV and 55 GW of solar thermal projects in North America surveyed by PHOTON International

# -> GWp pipeline for both PV and CSP!

Source: Photon International, March 2009







# Summary and conclusions



- PV on track to 15...10 ct/kWh power generation cost at large scale in sunny regions, confirmed by already contracted first VLS-PV systems
- Main differentiator between Concentrated Solar thermal Power (CSP) and PV seen in application aspects, not cost
- VLS-PV an economically attractive, viable future power option in particular for large international initiatives like DESERTEC and MSP (Mediterranean Solar Plan)!







# Thank you for your attention! (and thanks to all who contributed!)





