OMV Gas & Power

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Concentrated Solar Power (CSP) - facts and opportunities

Günter Maier
Head of Renewable Power
OMV Power International GmbH

Move & More.

CSP business – summary

1. Technology and implementation: CSP parabolic trough is the most mature and bankable technology. Solar Tower Systems and Linear Fresnel Systems are not yet mature enough to allow trouble-free operation (not bankable). However, especially Solar Towers could be a promising alternative for parabolic trough in the near- to mid-term.
2. Market outlook: Market participants expect strong growth in CSP installations of 40% p.a. on average until 2015. Growth will be highest in US and Spain which will remain the biggest market in the next years, and will be driven by both strong political support in terms of subsidy schemes (tax credits or feed-in-tariffs) and state investment such as the American Recovery and Reinvestment Act (ARRA), but infrastructural and land use constraints, and permitting procedures need to be eased. 1 GW Kick-off program by the World Bank could trigger strong growth in MENA region.
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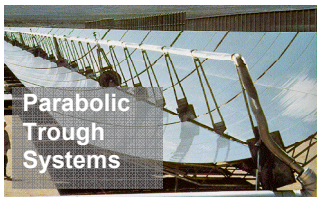
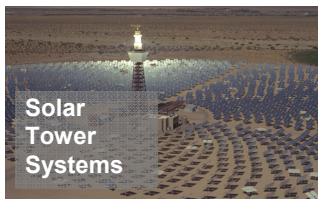
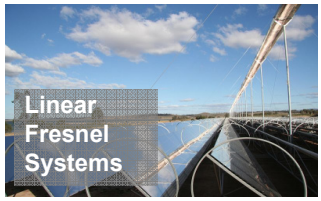
4. Cost competitiveness: Among solar power technologies, CSP is currently the most competitive large scale technology. By increasing the size of plants (e.g. to 120-200 MW) costs will decrease by as much as 40% and increased supply chains to standard components will drive costs down by further 20% in the near-term. Therefore, 100 EUR/MWh seem realistic in the mid-term (2015+).

CSP Plant Technologies







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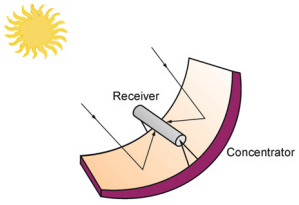
Parabolic Trough Systems



Trough System

- Large parabolic mirrors concentrate the solar irradiation in a focus-line
- Absorber tubes in the focus-line heat up a heat transfer fluid to almost 400°C
- The heat transfer fluid is pumped to a heat exchanger, where it produces steam from water
- The steam is used to produce electricity in a steam turbine
- Space requirement: ~1 km² for 50 MW (without storage)

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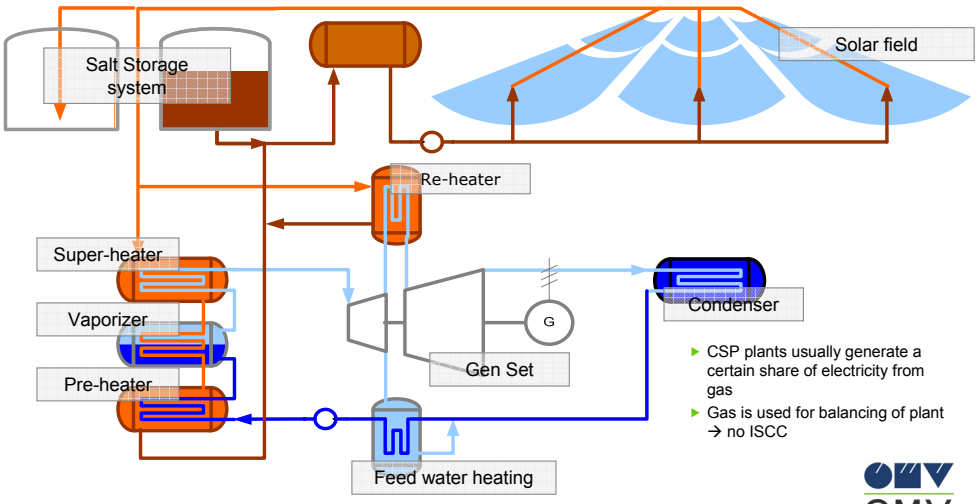
Parabolic Trough Plant Concept (Solar Power only)



- CSP plants usually generate a certain share of electricity from gas
- Gas is used for balancing of plant → no ISCC

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Overview CSP project implementation

	4-6 months	1-2 years	4-8 months	1-2 years	20-25 years
	Project Development			Construction	Operation and Maintenance
	Pre-Feasibility Study	Feasibility Study (incl. FEED)	Final Design / Tender	EPC*	O&M
			Final Investment Decision	Sign construction contracts	
		Obtain permits and authorizations		Cold commissioning → Preliminary acceptance test	Hot commissioning → Final Acceptance
	▸Solar resource assessment ▸Policy and legal framework ▸Technology assessment ▸Financial assessment ▸Implementation strategy ▸Short list of sites	▸Selection and evaluation of appropriate sites ▸Secure promising sites ▸Solar measurements at short listed sites ▸Definition of project technical characteristics ▸Plant design & assembly ▸Project finance	▸Selection of suppliers (mirrors, power block, civil engineering, etc.) ▸Negotiation of the construction contract	▸Earthworks ▸Foundations ▸Solar Field ▸Power Block ▸Thermal storage Confirm plant meets perform-ance commit-ments	▸Operators take delivery of the CSP plant by signing a memorandum of acceptance. Operation can begin ▸Terms & conditions on which electric power is sold vary strongly by country and may or may not be secured by longer-term contracts
Critical success factor	Relationship with Authorities to secure economically feasible conditions	Evaluation of solar data, relationship with land owners	Timely response and high consenting success rate	Access to plant com-ponents at right price	Build in time and budget	Early identifi-cation of perfor-mance issues	High plant availability

* Engineering, Procurement and Construction
** Performance Control

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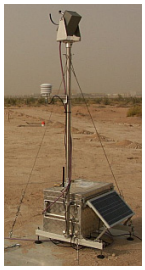
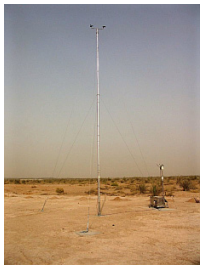
Solar Irradiation Measurements

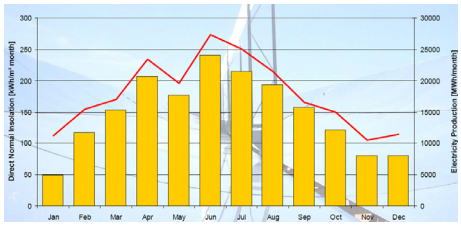




Solar Irradiation Measurement:

- Minimum 1 year measurement of Direct Normal Irradiance (DNI), the major input parameter for a solar thermal power plant
- Measurement with well calibrated instruments (pyranometer)
- Regular cleaning and inspection
- Data logging without losses of data
- Additional sensors:
  - Temperature and Humidity
  - Rain gauge
  - Anemometer and wind vane
  - 10 m wind mast

Solar measurement results:



Modelling of annual energy production of the CSP plant in MWh/a

Source: Lahmeyer International, Flabeg

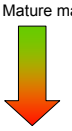
Engineering, Procurement and Construction

- **Selection of suppliers (solar field, power block, civil engineering, etc.)**
  - Access to plant components at right price essential

- **Negotiation of EPC* contract and subcontracts for the following services:**
  - Survey of area
  - Detailed Engineering, Management and Supervision during the construction phase
  - Concept and negotiation of Insurance policies, Insurance for erection and operation of the plant
  - Earthworks
  - Planning of access road, Call for Tenders and Supervision of adaptation of the access road
  - Civil works and foundations
  - Cranes and transportation of special shipments
  - Construction of the cabling from the switching station at the plant to the transformer station and adaptation of the transformer station
  - Manufacturing delivery
  - Assembling the main equipment (solar field, power block, thermal storage)
  - Pre-commissioning, Commissioning, Functional Tests
  - Start of Commercial Operation (COD)

- **Financial structuring options (depending on debt capital availability)**
  - Non-recourse project financing (20% equity, 80% debt common practice)
  - Recourse project financing and transfer to non-recourse after certain period of operation
  - Equity financing (+loan financing)

Mature markets, low risk

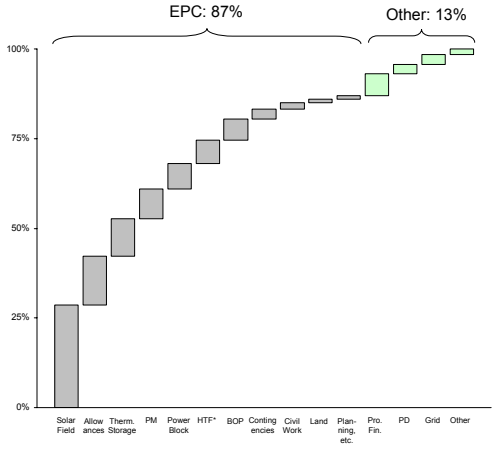


Emerging markets, high risk

* Engineering, Procurement and Construction

Cost build up of a CSP power plant

Based on 50 MW parabolic trough plant with 7.5 h thermal storage



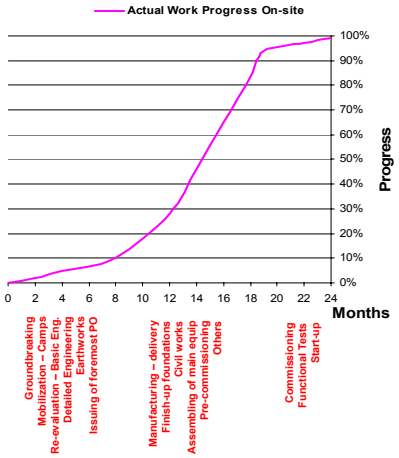
Example Projects:

- **Alvarado I, Spain (Acciona)**
  - 50 MW (without TES*)
  - Total cost: 236 mn EUR
  - Specific cost: 4.72 EUR/W
- **Nevada Solar One, US (Acciona)**
  - 64 MW (without TES*)
  - Total cost: 167 mn EUR
  - Specific cost: 2.60 EUR/W

* Thermal Energy Storage

Source: OMV analysis, Lahmeyer International, MAN Ferrostaal

Construction (I)



Source: Lahmeyer International

Construction (II)

- Absorber tubes and mirror delivery
- Assembly hall erection
- Part of Solar Field erected

- Site preparations for solar field:
  - Top soil stripping and/or clearing of obstacles
  - Removal of dump
  - Grading, compacting, dirt roads
  - Rain water drainage, dust control

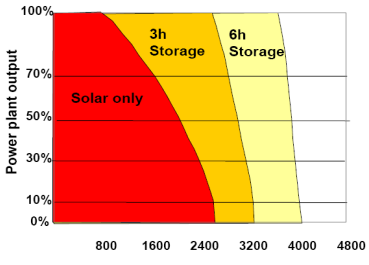
- Foundations
  - Excavation, concrete formwork, reinforcement, backfill

- Range for total cost for site preparation for 2 km²: 10 – 30 Mio.€

Source: Lahmeyer International

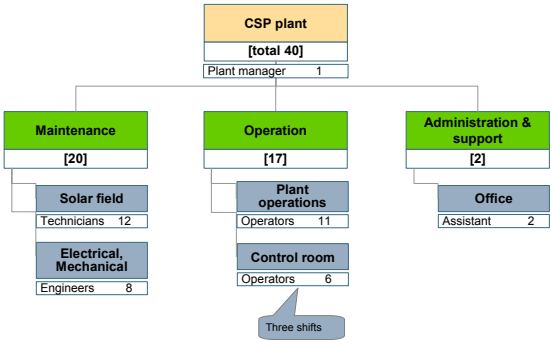
Thermal Energy Storage – TES

- Thermal Energy Storage can enhance CSP output, as operation with stored thermal energy is possible after sunset
- State-of-the-art are molten salt storages with about 28,000 tons of molten salt
- Full load hours: 2,000 hours without storage, 3,400 hours with 7h thermal storage (Andasol 1)

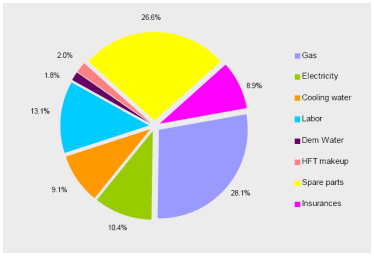


Source: DLR

Operation and Maintenance (I)



OPEX by Cost Item
(base case using water cooling)



- O&M costs dominated by electricity, labour, insurances, and gas.
- Significant staff required for the solar field
- OPEX costs have comparatively little impact on the project's IRR (as compared to feed-in-tariff, CAPEX, gas fraction, and power generation)
- OPEX contribute to about 2% of EPC price and 20% of LEC.
- Once the investment is amortized, projects generate electricity for about 3 to 4 ct€/kWh.

Source: Pöyry, Lahmeyer

Operation and Maintenance (II)

Activities to maintain the Solar Field efficiency

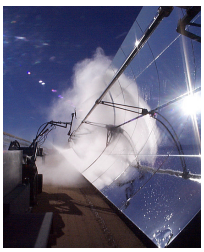
- Collector's reflector washing
- Measurement of reflectivity
- Inspection of HCE* and, if necessary, its replacement
- Replacement of damaged reflectors
- In case of power loss: inspection of individual loops
- Drives and solar sensor maintenance

Activities related to reliability of solar field flow loop hardware

- Detection of HTF** leaks and repair
- Inspection of the pipes insulation and repair, if necessary
- Inspection and maintenance of the valves in the field
- Maintenance and seal replacement of the HTF** pumps

Activities related to monitoring, control and operation planning

- Maintenance, testing and calibration of instruments and wiring in the solar field
- Weather station supervision and maintenance
- Control and monitoring of all the different plant parameters (e.g. flow, temperature, reflectivity of collectors, pressure)
- Suppressing of vegetation in the solar field



* Heat Collector Element ** Heat Transfer Fluid

Source: Lahmeyer

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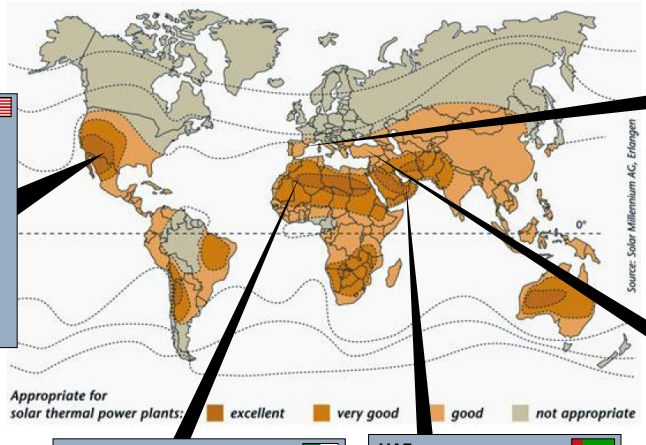
Market outlook

CSP Markets, Irradiation condition, and incentives



US:
- Excellent solar resource in the southwest
- California, Nevada, and New Mexico have required RES shares
- 30% Investment Tax Credit (ITC) was extended to 2017
- Difficult permission process (nature protection, water consumption)

Spain:
- Good solar irradiation
- Leading country in CSP development (81 MW in operation, 839 MW in construction)
- Fixed FIT* (27 ct€/kWh) for 25 years
- Annual 500 MW cap of installed capacity
- Pre-registration of 4000 MW CSP projects
- New Royal Decree to be issued

Turkey:
- Good solar irradiation
- Current legislation not attractive for solar power (FIT=5.2 ct€/kWh for 10 years)
- Draft law currently under discussion with reasonably good FIT*

Algeria:
- Very good to excellent solar resource
- Goal to provide 10% of energy from RES by 2025
- FIT* introduced in 2004
- One CSP plant under construction, two more are planned

UAE:
- Excellent solar resource
- In particular Abu Dhabi promotes solar energy (MASDAR initiative)
- Several solar energy projects launched, among them a 100 MW CSP plant (currently under construction)

* Feed in tariff

Source: SolarPACES, CSP today, Solar Millennium

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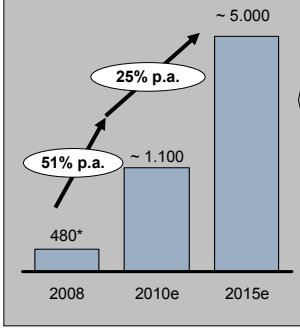
Market outlook

Until 2015 a growth of installed capacity of 4 GW is expected. Currently 540 MW under construction and 7 GW CSP projects in the pipeline.

Installed CSP capacity
in MW



Current CSP plants under construction

Anlage	Land	Start of Operation	Capacity in MW
Martin Next Generation Solar Energy Center		2010	75
Andasol 2		2009	50
Andasol 3		2011	50
Extresol 1		n.d.	50
Solnova 1		2009	50
Solnova 3		2009	50
Puertollano		2009	50
La Risca 1		n.d..	50
Kuraymat		2010	25
Hassi R'mel		2010	20
Ain Beni Mathar		2010	20
PS 20		2009	20
Solar Tres		n.d.	19
Esolar Demonstrator		2009	5
Kimberlina		2009	5
Keahole Solar Power		n.d.	1

Σ = 540 MW

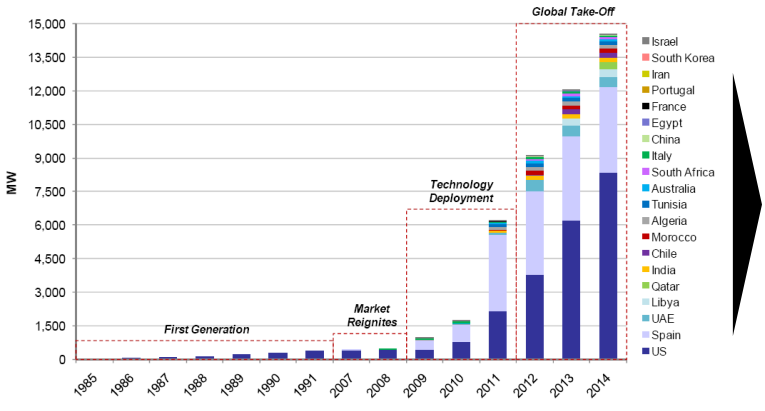
*thereof 469 MW parabolic trough

Source: NREL, DLR, SolarPACES

Market outlook

Current worldwide CSP project pipeline

Forecasted market development 2010-2014
New installed MW per year

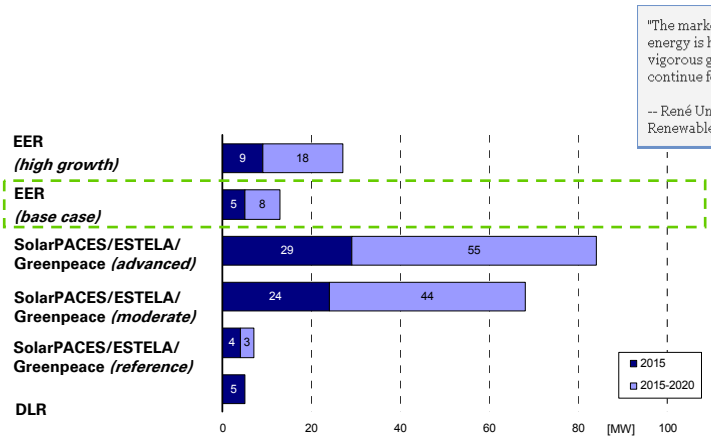


- **Development in Spain (130 projects, 5.7 GW pipeline) key to industry success**
- **US may become largest CSP market by 2013: CSP can strongly benefit from American Recovery and Reinvestment Act (ARRA) if infrastructural and land use constraints, and permitting procedures can be eased.**

Source: EER (2009), Solar Millennium

Projected worldwide installed CSP capacity (GW) in 2015 and additional capacity 2016 - 2020

Market outlook



- Worldwide installed CSP capacity 2008: 480 MW
- More optimistic views from SolarPACES/ESTELA
- Less optimistic view from EER
- IEA only provides long term estimates until 2050

Source:DLR, SolarPACES/ESTELA/Greenpeace, EER

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Industry overview

Technology Providers - Parabolic Trough

Mounting Structures	Mirror Providers	Receiver Providers	HTF Providers	Molten Salt Providers	Turbine Providers
Abengoa*	*3M****	*Archimede Solar Energy srl. – for molten salt receiver***	**Dow Chemicals***	BASF**	Bharat Heavy Electrical Ltd. - India
Flagsol*	**Flabeg Hold. GmbH***	*HIMIN – no reference****	*Lanxess – unknown so far*	**Bertrams HEATEC AG***	**GE Oil & Gas***
Grupo Sener*	*Glasstech Inc.** - USA*	**Schott AG***	**Solutia***	**Durferrit***	Ormat Tech. Inc.** - USA
*Sky Fuel Inc. – in USA and with reflective foil****	*Guardian Ind.**- USA*	**Solel* (Siemens#)**		**Haifa Chemicals***	Pratt & Witney Rocketdyne** (PWR) - USA
Solargenix – in USA, but o.k.	*HERO-Glas****			Pratt & Witney Rocketdyne (PWR) - USA	**Solel* (Siemens#)**
Solel* (Siemens#)	*Naugatuck Glass**- USA*			**SQM* - producer of salt**	MAN Turbo**
	Rioglass Solar (Abengoa only)**				
	*Saint-Gobain****				

*: with experience and reference in CSP
**: probably o.k. if company can provide
***: technology not yet proven

Siemens acquired 100% of Solel for US$418 million in October 2009

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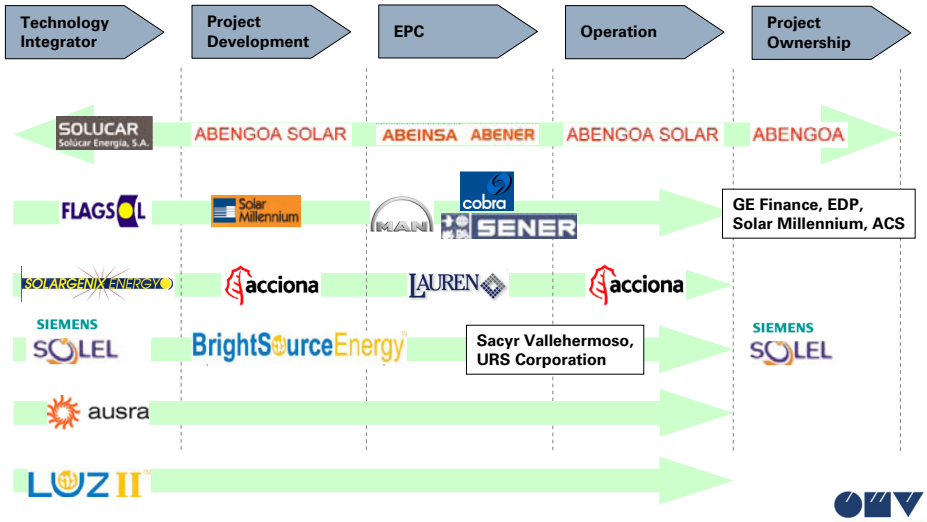
Industry overview

CSP Project Value Chain



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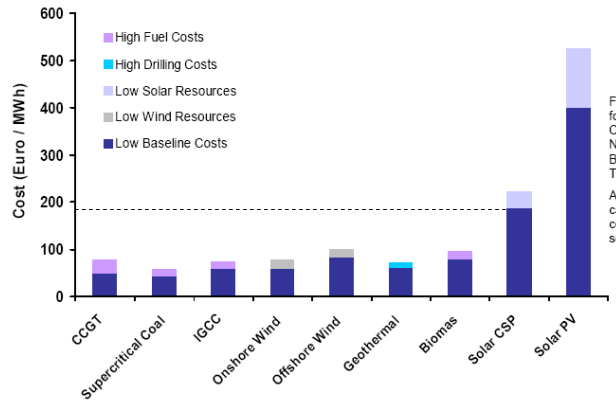
Electricity Generation Cost Comparison of CSP to CCGT and other Renewables (€/MWh)

Cost competitiveness



Source: EER, 2007

ASSUMPTIONS

Fuel cost range assumptions are as follows:
Coal: €30-70 / Tonne
Natural Gas: €5-9 / MMBtu
Biomass (Wood waste): €20-40 / Tonne

Assumes average operating and capital costs, which have been kept constant across low and high scenarios

- **17-year old SEGS* in California produce electricity at approx. 170 €/MWh**
- **In Spain, LEC** is about 230 €/MWh**
- **Increasing the size of plants, costs will decrease by as much as 40%**
- **Increased supply chains to standard components will drive costs down by further 20% in the near term**
- **Therefore, 100 €/MWh seem realistic in the mid-term**

* Solar Electricity Generation System
** Levelized Electricity Cost

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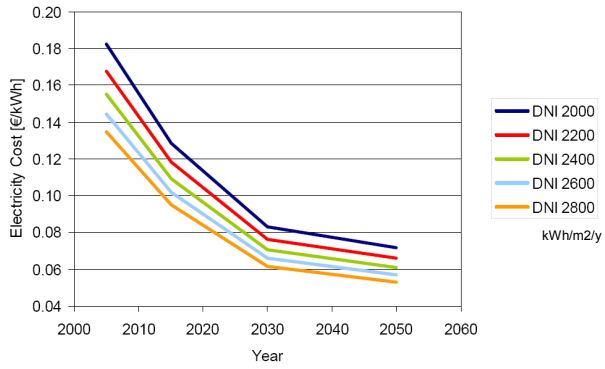
Cost competitiveness

CSP Learning Curves for Several Levels of Solar Irradiation



* Source: Characterisation of Solar Electricity Import Corridors from MENA to Europe Potential, Infrastructure and Cost (DLR, 2009)

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Companies and Profiles – Part I

Logo	Company/Institution	Profile	Potential Task of Interest	Contact Person	Contact Details
OMV	OMV Power International GmbH	Asset backed power wholesale & trading company; development, realisation and operation of gas-fired and renewable power plants (Hydro, Solar, Wind)	Task I	Robert Höller Project Manager Solar Power	OMV Power International GmbH Trabrennstraße 6-8 1020 Wien / Vienna Tel +43 1 40440-22502 Fax+43 1 40440-22510 E-mail: robert.hoeller1@omv.com
Verbund	Verbund Aktiengesellschaft	Utility	Task I	Jan Cupal	Email: jan.cupal@verbund.at
Blue Sky	BLUE SKY Wetteranalysen	Engeneering Bureau for Meteorology; specified in the fields of Energy Meteorology; Solar Irradiation Forecast for PP, cities and buildings; Precipitation and Wind Forecasts for Power Plants; Temperature and Humidity Forecasts for cities and buildings	Task 5	Wolfgang Traunmüller Meteorologist	BLUE SKY Wetteranalysen Steinhüblstraße 1 4800 Attnang-Puchheim Tel +43 7674 206 60 Fax+43 7674 206 61 E-mail: wolfgang.traunmueller@blueskywetter.at

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Companies and Profiles – Part II

Logo	Company/Institution	Profile	Potential Task of Interest	Contact Person	Contact Details
ASiC	ASiC - Austria Solar Innovation Center	Research & development in the field of renewable energy, focus on solar technology.	Task V (IV, VI)	Gerald Steinmaurer Managing director	ASiC - Austria Solar Innovation Center Roseggerstraße 12 A-4600 Wels Tel: +43 7242 9396 5560 Fax: +43 7242 9396 49 5566 E-mail: steinmaurer.gerald@asic.at
Fachhochschule Technikum Wien	University of Applied Sciences Technikum Wien	Master and Bacc. Program "Renewable urban Energy Systems"; Institute of Renewable energy - Various research projects and studies in the field of renewable Energy, Austrian Coordination of IEA ENARD and IEA PVPS activities.	Task 1	Hubert Fechner, Head of Institute, Program Director of the MSc. Course,	Giefinggasse 6 A-1210 Wien Tel.: +43-333-40-77-572 E-mail: fechner@technikum-wien.at
TU Vienna	Vienna University of Technology Institute of Thermodynamics and Energy Conversion	Research & development in the field of Concentrating Solar Power, Solar Chemistry and Renewable Energy Systems		Markus Haider Director	Institute of Thermodynamics and Energy Conversion Technical University of Vienna Getreidemarkt 9/E302 1060 Wien, Austria Tel +43 1 5880130208 E-mail: markus.haider@tuwien.ac.at

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