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Renewable Energy

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Selected Indicators	2004		2005
Investment in new renewable capacity (annual)	$30	➧	$38 billion
Renewables power capacity (existing, excl. large hydro)	160	➧	182 GW
Renewables power capacity (existing, incl. large hydro)	895	➧	930 GW
Wind power capacity (existing)	48	➧	59 GW
Grid-connected solar PV capacity (existing)	2.0	➧	3.1 GW
Solar PV production (annual)	1150	➧	1700 MW
Solar hot water capacity (existing)	77	➧	88 GWth
Ethanol production (annual)	30.5	➧	33 billion liters
Biodiesel production (annual)	2.1	➧	3.9 billion liters
Countries with policy targets	45	➧	49
States/provinces/countries with feed-in policies	37	➧	41
States/provinces/countries with RPS policies	38	➧	38
States/provinces/countries with biofuels mandates	22	➧	38

Figure 2-10 Renewables data 2004-2005 (REN21)

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– **Figure 2-13 Renewables electricity capacity**

Technology	World Total	Developing Countries	EU-25	China	Germany	U.S.	Spain	India	Japan
Small hydropower	66	44	12	38.5	1.6	3.0	1.7	1.7	3.5
Wind power	59	6.3	40.5	1.3	18.4	9.2	10.0	4.4	1.2
Biomass power	44	24	8	2.0	1.7	7.2	0.5	0.9	> 0.1
Geothermal power	9.3	4.7	0.8	~ 0	0	2.8	0	0	0.5
Solar photovoltaic-grid	3.1	~ 0	1.7	~ 0	1.5	0.2	< 0.1	~ 0	1.2
Solar thermal electric	0.4	0	~ 0	0	0	0.4	~ 0	0	0
Ocean (tidal) power	0.3	0	0.3	0	0	0	0	0	0
Total renewable power capacity (excluding large hydro)	182	79	63	42	23	23	12	7	6
For comparison:									
Large hydropower	750	340	115	80	7	95	17	n/a	45
Total electric power capacity	4,100	1,500	710	510	130	1,060	78	n/a	280

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Thermo Solar Power Plant

Theory

CSP: Concentrating Solar Power

CSP is
- ideal for multi-megawatt central power stations
- dispatch able power for peaking and intermediate loads through hybridization and/or thermal storage
- distributed power for grid support and remote applications
- rapidly deployed because it uses conventional items such as glass, steel, gears, turbines, etc.
- Water requirements similar to coal-fired plant.

Dish Stirling

Solar Tower

Parabolic Trough

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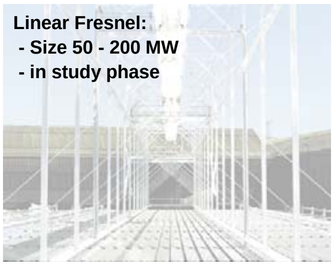
CSP Technology provides sustainable, clean and reliable power from 10 kW to 200 MW



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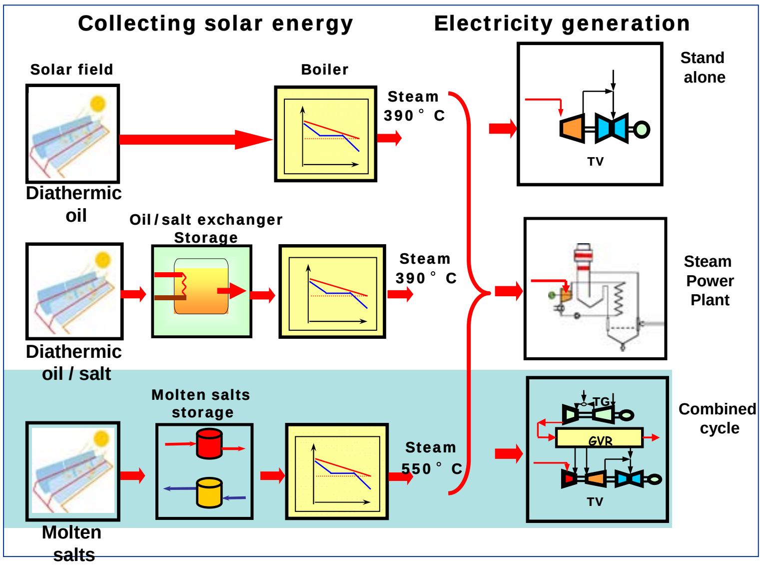
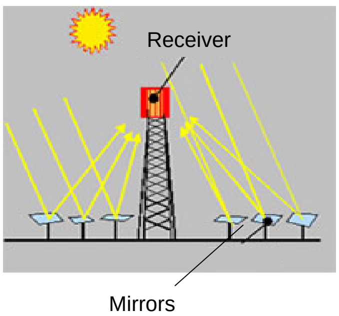
Key point: integration

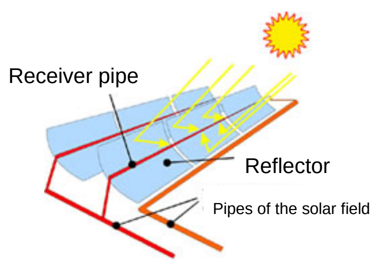


Two systems

Linear parabolic collectors

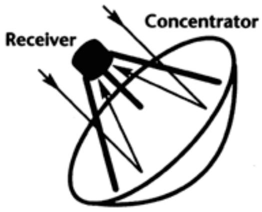
Systems with tower





Stirling EuroDISH

Functional diagram of a parabolic dish with Stirling motor at the focus



A dish/Stirling system consists of a wide-diameter parabolic mirror with a Stirling-type external combustion motor installed in its focal area.

The parabolic dish-mirror continuously tracks the sun, so that the sun's rays are reflected onto its focal plane, obtaining a Gaussian shape concentrated solar energy map and several tens of kW.

The Stirling motor is an external combustion motor that employs the thermodynamic cycle of the same name and that has two advantages that make it appropriate for this application:

- Combustion is external, that is, the energy contribution may from sunlight collected by the parabolic dish and concentrated on its focal zone.
- It is a high-performance thermodynamic cycle.

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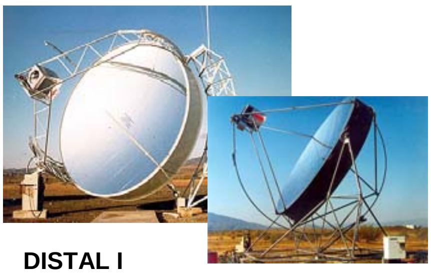
Plataforma Solar de Almería



DISTAL I

In operation since 1992, this installation initially consisted of 3 7.5 m diameter parabolic dish units capable of collecting up to 40 kW_t energy with a SOLO V160 9 kW_e Stirling motor located in its focal zone

EuroDISH

The second and latest attempt to make this technology economical is the Spanish-German EUROdish project.

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CesiRicerca

EuroDISH with Stirling motor SOLO V161

Milano, CesiRicerca laboratory

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World Development

Nevada Solar One acciona

Thermosolar plant in Puertollano IBERDROLA

"Archimede" Project ENEA

Nevada Solar One

Location: Boulder City, NV
Excellent Solar resource
Moderate wind speed

Near major grid substations
Water available

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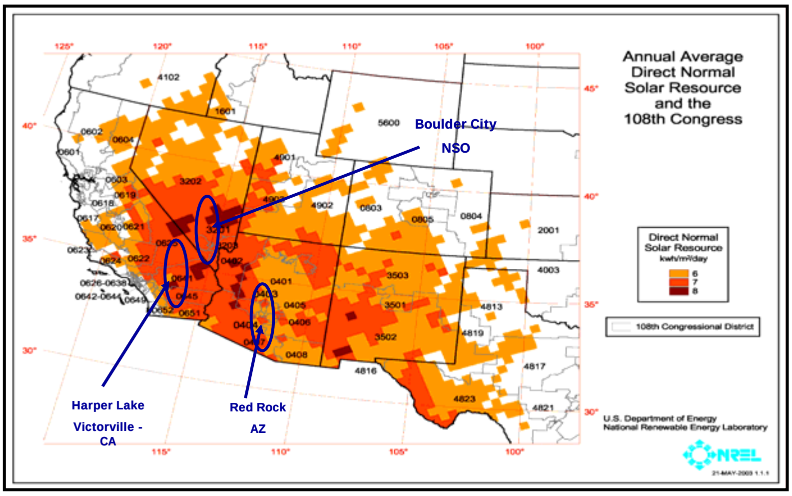
NSO – DIRECT NORMAL RADIATION = 7.141 KWh/m²/day – 2606 KWh/m²/year



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PROJECT OVERVIEW: NSO Characteristics

SOLAR FIELD	
Solar Collector Assemblies	760
Aperture Area (m/ft)	5/16
Aperture Area (m^2/sq. ft.)	470/5059
Length (m/ft.)	100/328
Concentration Ratio	71
Optical Efficiency	0.77
# of Mirror Segments	182,400
# of Receiver Tubes	18,240
Field Aperture (m^2)	357,200
Site Area (Km^2/acres)	1.62/400
Field Inlet Temperature (°C/°F)	300/573
Field Outlet Temperature (°C/°F)	390/735

POWER BLOCK	
Turbine Generator Gross Output	75 MWe
Net Output to Utility	72 MWe
Solar Steam Inlet Pressure	86.1 bars/1248.8 psi
Solar Steam Reheat Pressure	19.5 bars/282.8 psi
Solar Steam Inlet Temperature	371°C / 700°F

- Generating Capacity 64 MW (Nominal)
- 72 MW Net Output Steam turbine
- 357,200 m2 of Solar Field
- Annual Production > 130,000 MWh
- Construction in Less than 18 months
- 1,600.000 men hours
- Excellent safety record
- *Capital investment : ≈ 250 Millions USD*

Solar Field

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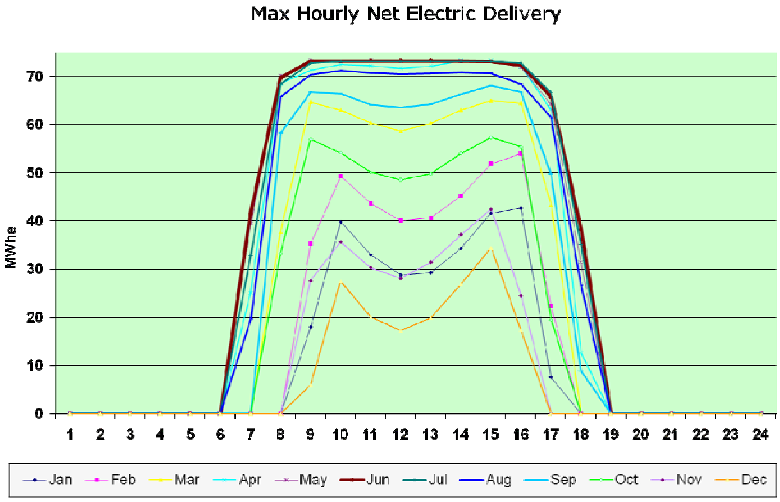

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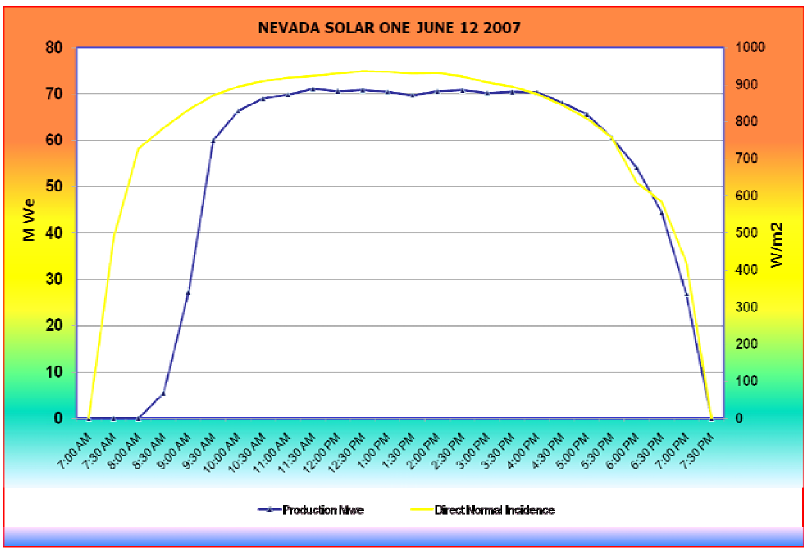
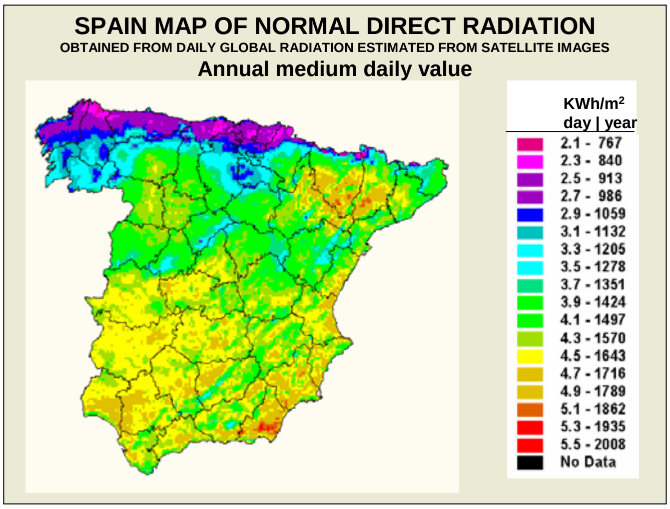


Iberdrola Energías Renovables
Thermosolar Power Plant in Puertollano

Direct Solar Radiation: estimation made from Satellite data



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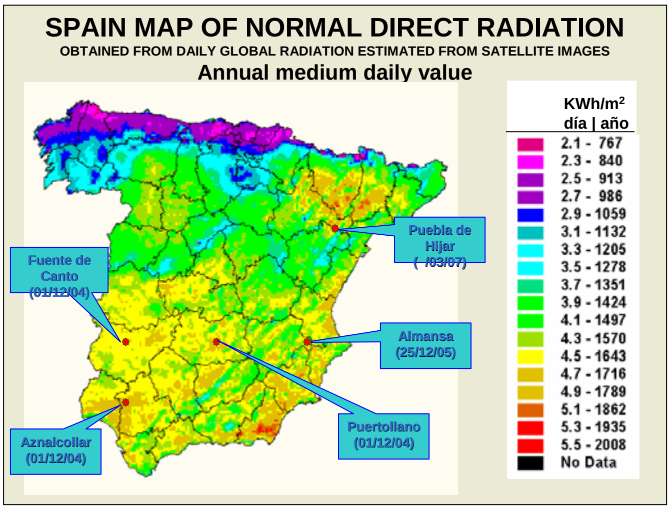
Meteo measure stations



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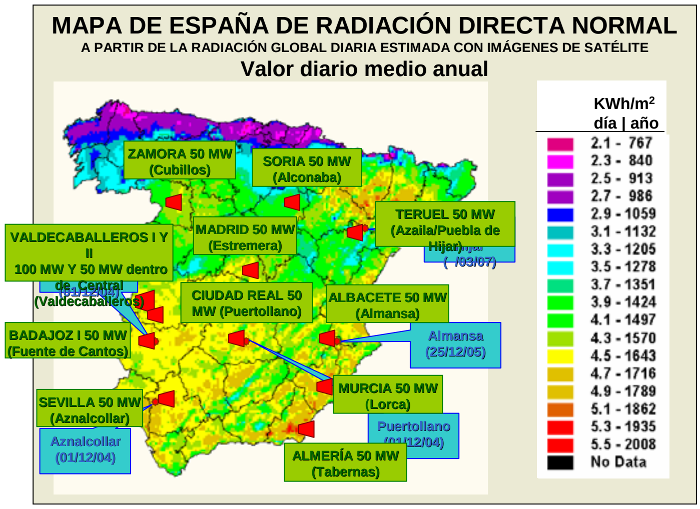
Thermosolar power plants under Promotion



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Puertollano Project Data

Design Data

Power output:	50MWe
Production:	114,2GWh/year
Auxiliary electrical consumption:	11,08 GWh/year
Gas hybridation:	15%
Equivalent working hours:	2062 h/year
Water consumption:	570.000 m3/year
Gas Consumption:	59.275.727 kWh/year

Period of construction:

Beginning of the works:	19-03-07
Plant in operation:	End of 2008

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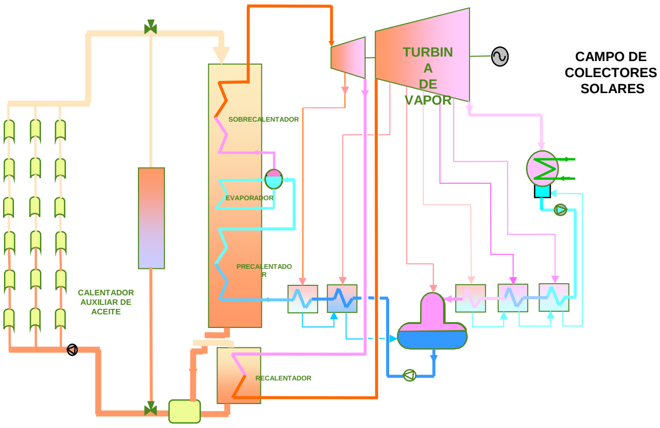
Puertollano Process Diagram

CCP's technology (Cilinder Parabolic trough collectors)



Basic principle of working

- A heat tranfer fluid (oil) is heated by the Solar Field
- Steam is produced from the oil
- Electricity is generated from the steam

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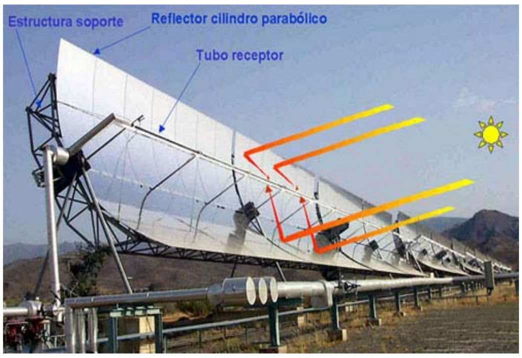
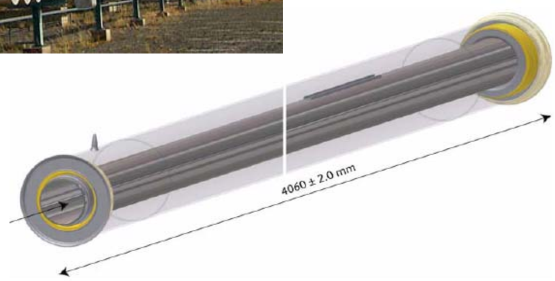
CCP - Cylinder Parabolic trough collector



Absorber tube



CCP - Cylinder Parabolic trough collector

Number of loops (600 m)	88
Number of collectors (150 m)	352
Total area of captation	287.760 m^2
Volume of thermal oil	1.000 m3
Oil limit temperature	12 – 400 ºC
Number of absorber tubes (4 m)	12.672
Number of mirrors	118.272

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Puertollano Panoramic Photo

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Plants in Operation

SEGS Plants (Solar Electric Generation System)

Nine plants in total (354 MWe)
SEGS I, 14 MW.
SEGS II to VII, 30 MW (photo).
SEGS VIII y IX, 80 MW.
Start up of the first Plant in 1984
Energy produced more than 10.000.000 MWh.
More than 25.000 hours in operation.
Installed in the dessert of Mojave (California, EEUU)
30% of direct hybridation with Gas.

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Focus on Archimede Project

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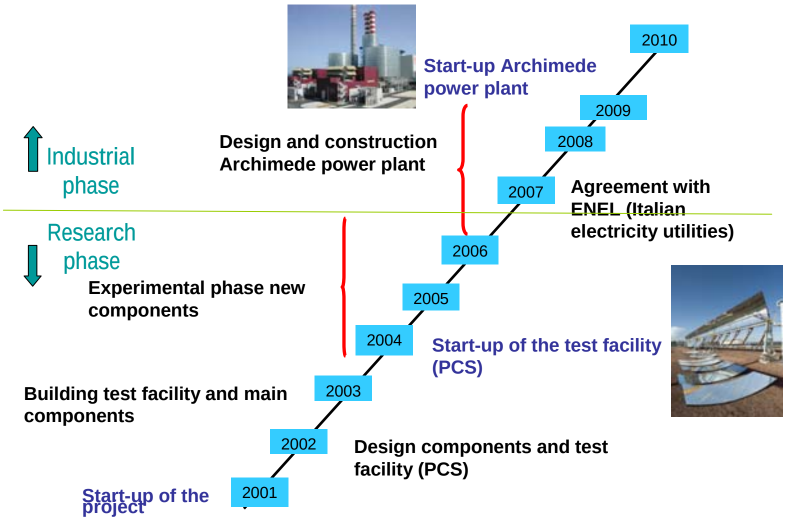
CSP ROADMAP



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R&D Activities

ENEA design introduces relevant improvements to the current technology:

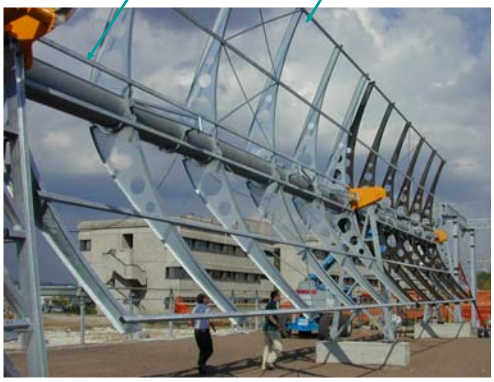
- **New solar collector design**
- **Innovative receiving tube**
- **New heat transfer fluid**
- **Energy storage**

New solar parabolic collector design

- Supporting structure
- Reflective panels
- Tracking system
- Limited number of assembling parts
- Simple installation and on field regulation
- Reduced manufacture and installation costs

Supporting arms (parabolic shape)

Main beam (single tube)



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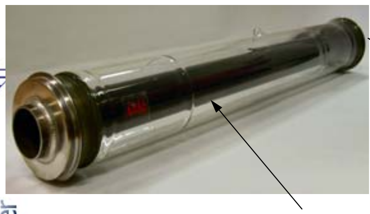
New receiver tube

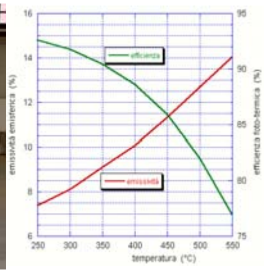


New bellow

New coating

- Stable up to 600°C
- Solar absorbance >= 94%
- Thermal emittance
  ~ 10% at 400°C
  < 14% at 550°C

Sputtering machine



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New heat transfer fluid

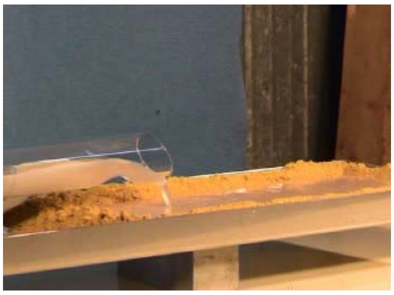
Molten salt (60% $NaNO_3$ 40% KNO_3)

Advantages:

- **High working temperature** (stable in air up to 600°C, low vapor pressure)
- **High thermal capacity**
- **Low cost and environmental impact**
- **Suitable for thermal storage** (atmospheric pressure)

Disadvantages:

- **High freezing temperature** (238°C)
- **Auxiliary electric heating system**



Archimede energy conversion cascade

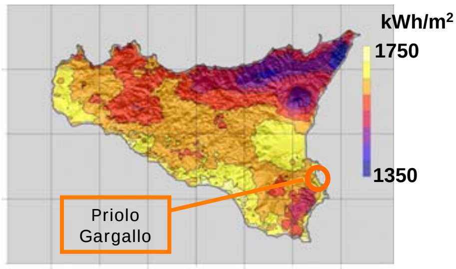
Mean yearly conversion factors

Collectors (65,3 %)

	One axis tracking	Shades, Extremity losses	Optic efficency	Thermal efficency	Storage	Electric generation	
DNI	88 %	91,9 %	81 %	80,7 %	82,2 %	41 %	
W/m^2 199	175,1	160,9	130,3	105,1	86,4	35,4	

Overall efficency = 17,8 %

Site selection



Global insolation in Sicily

- The site has been selected due to:
- Combined Cycle Power Plant with steam integrability chance
- High Global Insulation: 4,7 - 4,8 KWh/(m^2 day) (max Italian value)
- Constant and predictable climate
- Not windy
- Space available for solar field (100ha)
- Flat site with 360° free horizon
- Good auxiliary structures

Demonstration plant: “Archimede” project

The plant will be located in Sicily at Priolo Gargallo near Siracusa and will be integrated in an ENEL Plant

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Design parameters and expected performances

Parameter	U.M.	Value
Direct Normal Irradiation	kWh/(m^2 y)	1.936
Collectors' area	m^2	40780
Hot tank temperature	°C	550
Cold tank temperature	°C	290
Thermal storage capacity	MWh	130
Maximum SG thermal power	MWt	15
Nominal electric power	MWe	5,9
Gross electric energy produced	MWh/y	12300
Primary energy saving	TOE/y	2.571
Avoided CO_2 emissions	t/y	8.028

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Demonstration plant: “Archimede” project

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Timing

	Activities	2007	2008	2009	2010	2011
1	Preliminary Design					
2	Executive Design & Procurement					
3	Plant Erection					
4	Commissioning					
5	Experimental Operation					

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Energy Price

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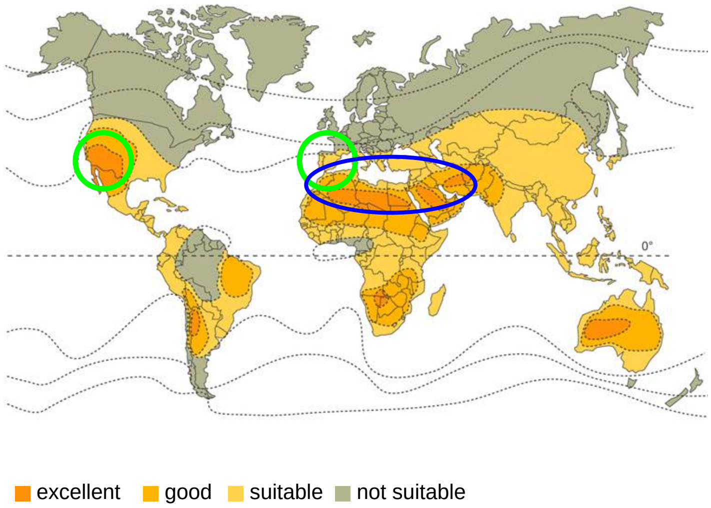
Promising Markets for CSP



Source: Solar Millennium AG, Erlangen

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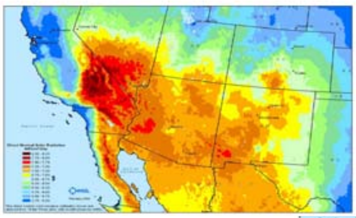
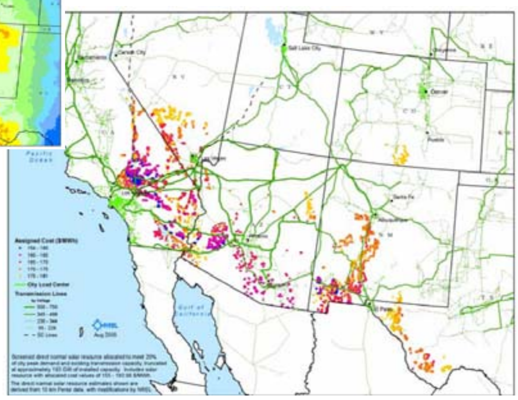
High Potential for CSP in the South West of USA

Huge power demand meets excellent solar resource





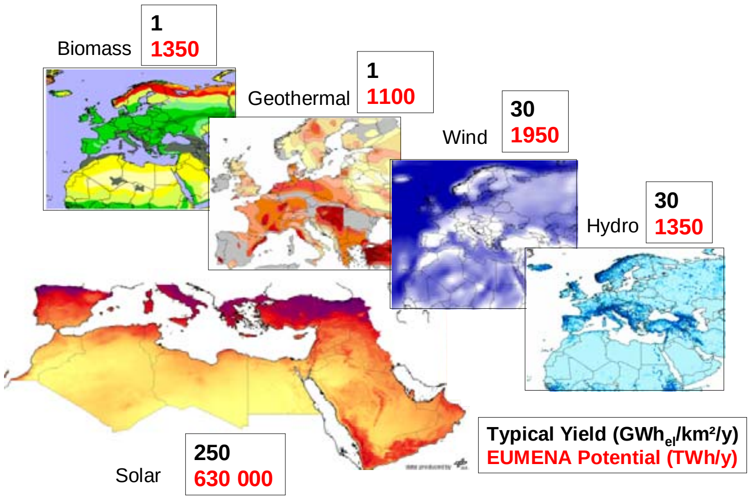
Potential of identified areas:

- 200 GW generation capacity
- 470 TWh electricity per year (≈ 17% of total U.S. consumption)

(Source: NREL)

Long-Term Economic Electricity Potentials in EUMENA

Every 10 km² in MENA yield 15 million barrels of fuel oil per year in form of solar energy



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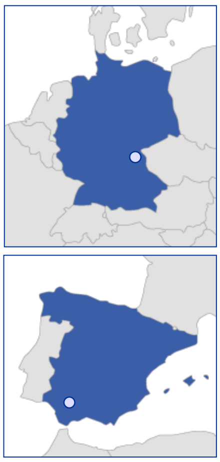
Production Line for Receivers in Germany and Spain

- ➔ Production Line in Mitterteich, Germany, operating since August 2006
- ➔ Production Line near Seville, Spain, operating in March 08
- ➔ annual capacity about 110 -160 MW per line
- ➔ total Investment : 37 Mio Euro



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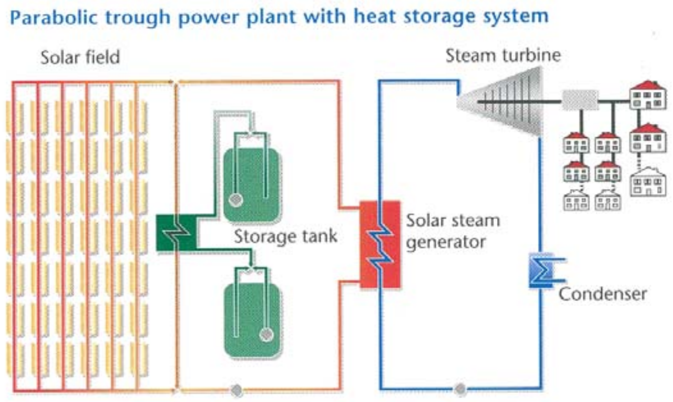
Parabolic Trough Power Plant

- Utility scale plant with conventional power block
- 2000 - 7000 full load hours via hybrid mode or using thermal storage
- firm, dispatchable peak power w/o need of back-up capacity in the electric system
- LECs today: 13 - 20 ct/kWh, future: 5 - 10 ct/kWh



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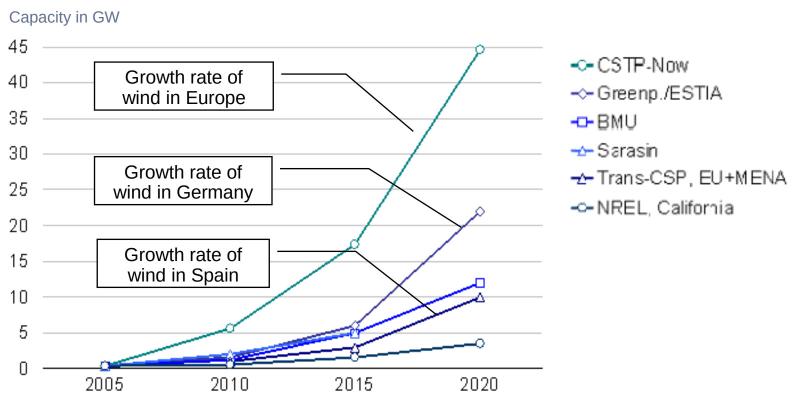
How fast will the CSP-Market grow?

- Forecasts for next 15 years between 4 and 45 GW (cum.)
- in which forecast should we trust ?



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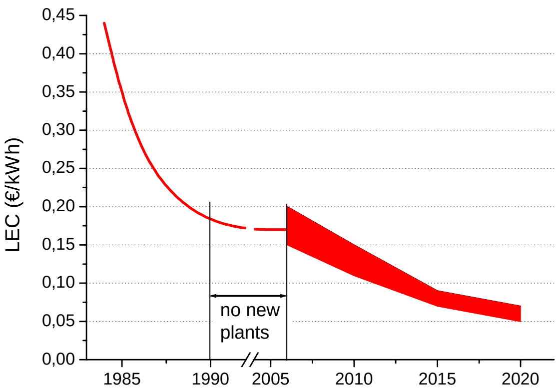
Roadmap for Parabolic Trough Plants

What brings the cost down?

- ➔ innovations in components and system, improved production technology
- ➔ improving the overall efficiency
- ➔ increasing the full load hours by using thermal storage
- ➔ bigger power blocks (economy of scale)
- ➔ reducing the O&M costs



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Key Success Factors for a Strong Market Growth

- ➔ Technical and economical success of the first projects
- ➔ stable green pricing or subsidies to bridge the initial gap in LECs
- ➔ Successful LEC-reduction strong R&D to leverage the potential of technical improvement. Major challenges:
  - higher temperatures (coatings, HTF)
  - thermal storage
  - component and system optimization
- ➔ New markets and market opportunities (Power from North Africa to Europe)
- ➔ strong CSP industry and strong political commitment

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The Role of the EU and the Member States
Push technology, pull demand, push generation

Market development and penetration:

- ➔ Install demand pull instruments, promote feed-in-laws as most powerful instrument to push generation
- ➔ open the European transmission grid for solar power from North Africa and secure this power import by implementing demand pull instruments

Technology:

- ➔ R&D-funding for material, component and system development (e.g. coatings, storage, direct steam/molten salt systems)
- ➔ Fund demonstration plants to push new technologies (only proven technology is bankable)

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PS10 construction (March 2006)

PS10 Project

PS10 project was oriented to the construction of 11MW concentrating solar thermal plant using the technology of tower and heliostats field, for commercial exploitation in the frame of the R.D.436/2004 and later regulatory dispositions, that allow to this class of plants to access to a solar electricity tariff about 0,21€/kWh, (premium about 0,18€/kWh + pool about 0,03€/kWh)

- PS10 plant is promoted by Sanlúcar Solar S.A., company belonging entirely to Abengoa
- PS10 is financed by Banc Sabadell as Project Finance
- PS10 will achieve economical feasibility through the annual generation of 23GWh of electricity

PS10 Plant Cost: 35.000.000 €

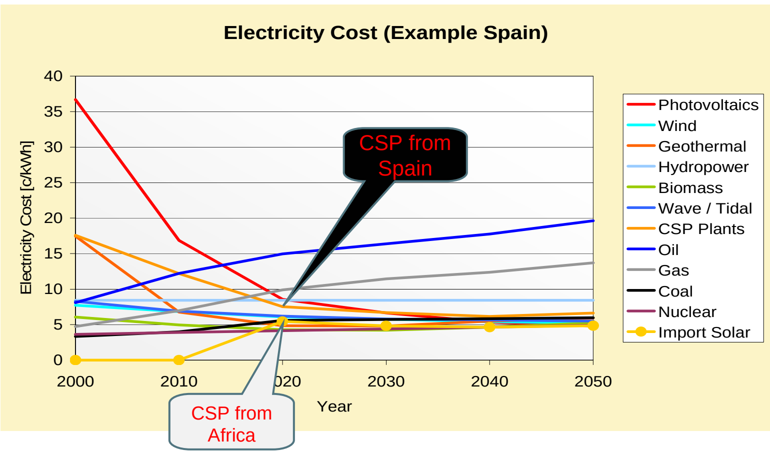
European Commission contribution to the Project PS10: 5.000.000 €

Autonomic Government Junta de Andalucía contribution to the project PS10: 1.200.000 €

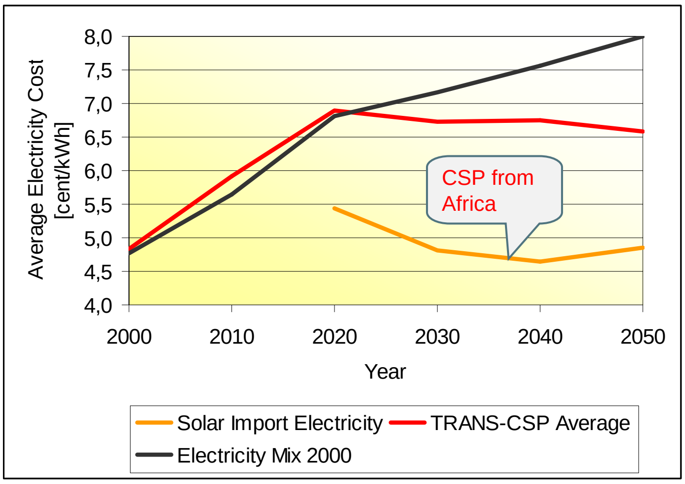
CSP: plant in Spain or in Africa ?

import from Africa cheaper than Spanish production:

going south: Solar gain stronger than transmission loss

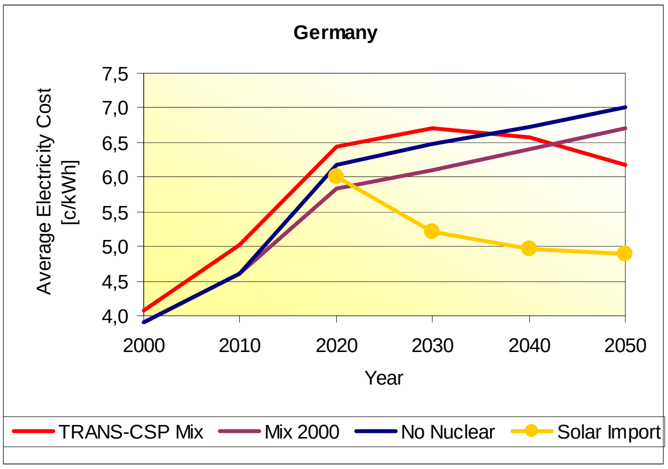


Power generation cost from new plants, in Spain



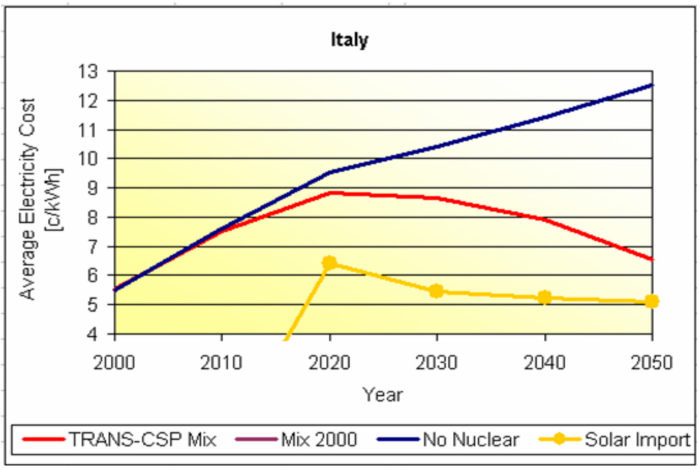
Cost of Electricity Mix

(Only New Plants, No Import)



TRANS-CSP Mix: Energy Mix as described here incl. RUE, RES and CCS
Mix 2000: Maintaining exactly the Power Mix like in the Year 2000 with CCS
No Nuclear: Mix like in the Year 2000, but substituting Nuclear by Coal & CCS

Power generation cost from new plants in Italy



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