CSP PROJECTS FROM THE SPANISH INDUSTRY

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Director Energy Cluster of Extremadura
WHAT IS ENERGY CLUSTER OF EXTREMADURA?

- Non-profit bussiness association.
- Mission: To boost cooperation, comercial and technological.
- Development of the energy sector in Extremadura region.
- We pursue competitiveness increase, new business opportunities in strategic markets and launching of innovative R&D projects.
◊ WIDE GEOGRAPHIC AREA FOR INVESTMENT IN ENERGY

◊ LARGE HYDRAULIC CAPACITY

◊ HIGH LEVEL OF SOLAR RADIATION
NUCLEAR POWER: 16,089 GW / H = 25% NUCLEAR ENERGY IN SPAIN

HYDRAULICS: 2210 MW INSTALLED CAPACITY

CSP: 19 PROJECTS AND 950 MW RATED CAPACITY

PHOTOVOLTAIC: 300 MW INSTALLED AND 320 PROJECTS

WIND: 23 PROJECTS OF WIND FARMS AND 501 MW RATED CAPACITY

BIOMASS: 11 PROJECTS AND 150 MW RATED CAPACITY

BIOFUEL: 7 PROJECTS: 605,000 TONNES OF BIODIESEL AND 250,000 TONNES OF BIOETHANOL
Solar Thermal Electric Technology in Spain: A success story of public support to R&TD

ELEMENTS:

- Continuous support to R&TD since late 70’s
- Specialized and highly qualified education in several Spanish Universities
- Active role of Research Centers
- International collaboration
- Feed in tariff system
- Dynamism of the companies

RESULT: INTERNACIONAL LEADERSHIP
### Types of STE Technologies

<table>
<thead>
<tr>
<th>Parabolic trough</th>
<th>Solar tower</th>
<th>Dish Stirling</th>
<th>Linear Fresnel</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1" alt="Parabolic trough" /></td>
<td><img src="image2" alt="Solar tower" /></td>
<td><img src="image3" alt="Dish Stirling" /></td>
<td><img src="image4" alt="Linear Fresnel" /></td>
</tr>
<tr>
<td>Uses parabolic mirrors to concentrate solar radiation on linear tube receiver.</td>
<td>Concentrates solar radiation on a point receiver at the top of a tower.</td>
<td>Uses parabolic dish to concentrate solar radiation on a Stirling engine.</td>
<td>Uses flat mirror design to concentrate sun, enabling simpler production and installation.</td>
</tr>
<tr>
<td>Provides heat storage capabilities.</td>
<td>Enables operation at high temperature level and provides heat storage capabilities.</td>
<td>Has high net solar to electrical efficiency with low water consumption.</td>
<td>Enables other industrial uses such as steam processing.</td>
</tr>
<tr>
<td>Is a long-term, commercially proven technology.</td>
<td>Has high net solar to electrical efficiency and is a commercially proven technology.</td>
<td>Is highly modular and suitable for both small stand-alone, decentralized off-grid power systems and large grid-connected power systems.</td>
<td>Has high land-to-electricity ratio due to linear design and the usability of space below support structure.</td>
</tr>
<tr>
<td>Has high maturity level, operational experience, modularity and large number of providers.</td>
<td>Enables other industrial uses such as steam processing.</td>
<td>Provides heat storage capabilities.</td>
<td>Provides heat storage capabilities.</td>
</tr>
<tr>
<td>Nombre</td>
<td>Localidad</td>
<td>Capacidad</td>
<td>Técnica</td>
</tr>
<tr>
<td>----------------</td>
<td>-----------------</td>
<td>-----------</td>
<td>-------------</td>
</tr>
<tr>
<td>CENTRAL 1</td>
<td>Málaga</td>
<td>10</td>
<td>Térmica</td>
</tr>
<tr>
<td>CENTRAL 2</td>
<td>Seville</td>
<td>15</td>
<td>Térmica</td>
</tr>
<tr>
<td>CENTRAL 3</td>
<td>Valencia</td>
<td>20</td>
<td>Térmica</td>
</tr>
</tbody>
</table>

*Técnica: Térmica, Conexión a red, etc.*

**Localización de centrales termosolares en España**

![Mapa de España con localización de centrales termosolares](image-url)

- **Operativas**
- **Construcción avanzada**
- **Presasignadas**

Total de plantas: 60
SOLNOVA 1, 3 and 4 & PS 10 and PS 20
CTS Puertollano
LA FLORIDA, Alvarado
GEMASOLAR, Fuentes de Andalucía
Breakdown of the operative, under construction and registered plants in Spain

Total: 2423 MW (In operation by the end of 2013)

- 94% Parabolic trough
- 38% With Storage
- 62% Without Storage
- 3% Stirling
- 2% Tower
- 1% Fresnel

Relative to power installed

Source: PROTERMOSOLAR
Forecast for STE plants in Spain

Source: PROTERMOSOLAR
Forecast in European countries by 2020 (NAP’s)

- Spain 5079 MW
- France 540 MW
- Portugal 500 MW
- Italy 600 MW
- Greece 250 MW
- Cyprus 75 MW

Source: PROTERMOSOLAR
FORECAST BY COUNTRIES 2009-2015

The long and dark solar thermal electric night

Source: PROTERMOSOLAR
Economic sectors

1. Promotion (22-36 months, 3-5 mill / €)

1.1. Land and Administrative treatment
   » Resource study, measurements. (2-3 years)
   » Agriculture (Sale or rental of land, 200-300 Ha / project)
   » Environmental studies and reports.
   » Engineering (water supply, access, stream diversions, discharges, discharge lines, plant setup ...)
   » Archaeological studies.
   » Environmental Impact Study (countervailing measures).
   » Attorneys (agreements, contracts, agreements ...) and Notaries
   » Electric Company

1.2. Municipalities (Finance, Tax)

1.3. Conventions (I + D + i)
   » University.
   » Research Centers.
   » Municipality and autonomous region
Economic sectors

2. Financing

» Banks
» Investors (investment funds, institutional investors ...)
» Legal advisor
» Technical Advisor
» Insurance Consultant
» Insurance Companies
Economic sectors

3. Construction (24-30 months, 70-450 workers)

3.1. Directly on the ground

» Earthmoving.
» Civil works.
» Assembly of the metal structures.
» Engineering.
» Machinery (exchangers, boilers, turbines, pipe receivers ...).
» Water, salt and hot oil.
» Electrical (lines, substations ...)
» Isolates.
» Transportation.
» Insurance.

3.2. Indirectly on the ground

» Services (cleaning, catering, hotel ...)
» Transportation.
» Surveillance.
Economic sectors

4. Exploitation (40-50 workers, 20-30 indirect)

4.1. Directly on the ground

» Operation & maintenance.
» Forecasting resource.
» R + D + i.
» Supply.
» Parts.
» Partial maintenance contracts.
» Office and administration.
» Relationship institutions.
» Energy marketing agent
» Network Operator
» Electric Company
The investment required depends on site characteristics and technology.

The investment for a plant tower receiver system with molten salt storage:

- Annual insolation (RDN): 2,700 kWh / m² - 2,000 kWh / m²
- Power: 50 - 60 Mwe
- Storage: 10 - 18 hours
- Net Production: 180 to 220 GWh / year
- INVESTMENT: 300 - 350 M €
  - solar field 45%
  - Receiving system 15%
  - Storage System 9%
  - Steam generation system 7%
  - Power generation system 24%

Source: Torresol Energy
Investment and electricity generation for parabolic trough collectors system with molten salt storage:

- Annual insolation (RDN): 2,700 kWh / m² - 2,000 kWh / m²
- Power: 49.9 Mwe
- Storage: 7 - 8 hours (1,000 MWh)
- Net Production: 160 GWh / year
- INVESTMENT: 300 M €
- CONSTRUCTION 2 YEARS

Source: SOLAR MILLENIUM
Solar field: 30%

- 220 ha, 230,000 mirrors (550,000m²), corresponds to nominal thermal output 300MWh.
- 25,000 absorber tubes (100 km), 2.8 million litres of thermal fluid (298°C-393°C).
- 2 expansion tanks and an overflow tank of thermal fluid, 3 pumps (2+1 back-up) 70,500 l/min.
- 3 natural gas auxiliary boilers 15 MW, solar field instrumentation and control.

Power block: 30%

- Steam generation system and feedwater preheater (2 lines 60.4 kg/s of steam at 380°C, 105bar)
- The Rankine cycle steam turbine 50MW (3 phases, 15 kV, 50Hz)
- Condenser cooled by water from the cooling tower in an open circuit (84,000KW, 140 t/h)
Storage System: 20%

- 2 steel tanks of 38.5 m in diameter and 14 m in height.
- 30,000 t of salt provide a storage capacity of 1.000 MWh of thermal energy.
- Each tank 3 vertical pumps for the transfer of salt (550 m³/h), 3 heat exchangers (292°-386°)

Auxiliary Facilities: 20%

- Water treatment system of providing water for all the systems at the plant (325 m³/h)
- Auxiliary steam system (1,000 kg/h, 10 bar, 255°C)
- Electrical Equipment to transmission of electrical energy from the generator to the main transformer (current 3,500°, isolation voltage of 17.5 kV)
- Control system (Solar field, Steam turbine and the elements that make up the Power block)

Source: SOLAR MILENIOU
# Economical development through job creation

<table>
<thead>
<tr>
<th></th>
<th>Local content</th>
<th>Foreign share</th>
<th>Local manpower demand</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Project development</strong></td>
<td>0-10%</td>
<td>90-100%</td>
<td>6-20 MY</td>
</tr>
<tr>
<td><strong>Engineering planning</strong></td>
<td>30-50%</td>
<td>50-70%</td>
<td>75-95 MY</td>
</tr>
<tr>
<td><strong>Technology (procurement)</strong></td>
<td>30-60%</td>
<td>40-70%</td>
<td>145-220 MY</td>
</tr>
<tr>
<td><strong>Construction and site</strong></td>
<td>100%</td>
<td>0%</td>
<td>320 MY</td>
</tr>
<tr>
<td><strong>Operations and maintenance</strong></td>
<td>90-100%</td>
<td>0-10%</td>
<td>40-45 FTE</td>
</tr>
</tbody>
</table>

Notes: 1 MY (man year) equals 1760 man hours; FTE estándar for full-time equivalent, the reference a 100-MW plant installation.
MODULAR CSP PLANT 100Kwe, 170 Kwt

**Modular operation** in 100kW units.
**It does not need water** (except the one necessary for cleaning).
**Hybrid working**: biogas, biomass, fuel, etc.
**Usage of the surplus thermal power** in a variety processes.

Source: [www.aorasolar.es](http://www.aorasolar.es)
The turbine’s inner process is the following:

• The air is compressed and partially heated in the turbine. Then, the pre-heated compressed air is circulated through the solar receiver where it is reheated to very high temperatures thanks to the concentrated solar radiation from the heliostats field.

• The air is finally used by the hybrid turbine to produce electrical energy (100 kW) and thermal energy (170 kW).

• When there is not enough sun radiation, the turbine will work with any fuel such as gas, biogas, biodiesel and ordinary fuel.

Source: www.aorasolar.es
<table>
<thead>
<tr>
<th>COMPONENT</th>
<th>COST</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solar Field</td>
<td></td>
</tr>
<tr>
<td>Tower</td>
<td></td>
</tr>
<tr>
<td>Solar Receiver</td>
<td></td>
</tr>
<tr>
<td>Hybrid Solar-fuel Turbine</td>
<td></td>
</tr>
<tr>
<td>Solar Field</td>
<td></td>
</tr>
<tr>
<td>Construction: Two month</td>
<td></td>
</tr>
</tbody>
</table>

**100 kW MODULAR UNIT COST**

(*) Installation cost in Spain

Source: [www.aorasolar.es](http://www.aorasolar.es)
Thank you for your attention!

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