



**EU SOLARIS**  
The European Research Infrastructure  
for Concentrated Solar Power


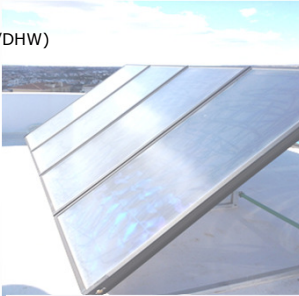





## Concentrating solar thermal systems: Perspectives for Greece

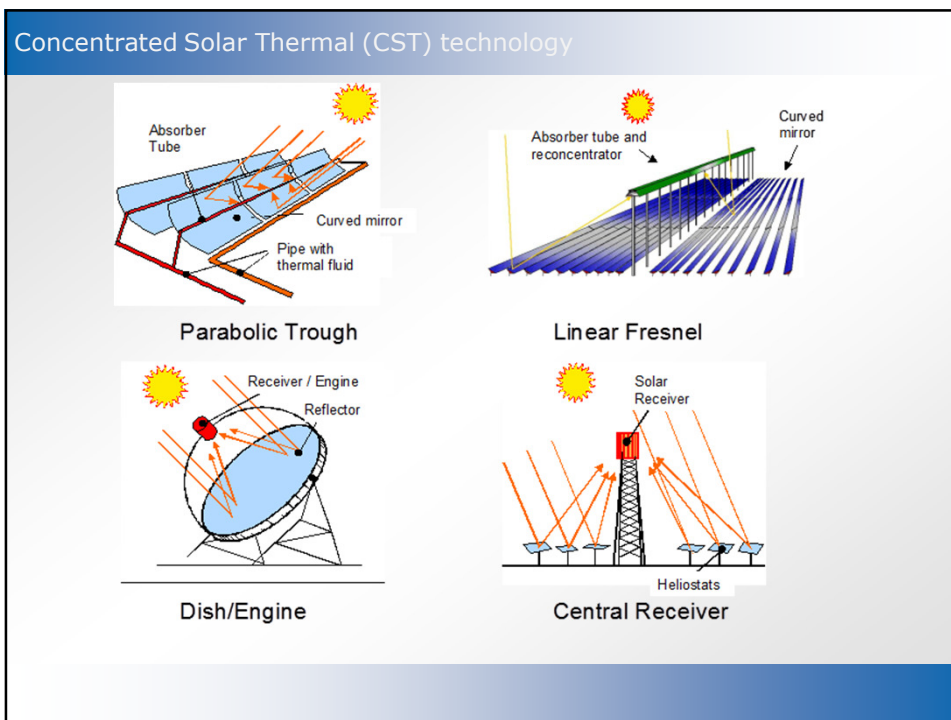
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### Solar thermal systems applications' overview

	<b>Household use</b>	<ul style="list-style-type: none"> <li>- Sanitary / Domestic hot water (SHW/DHW)</li> <li>- Space heating</li> <li>- Solar cooling</li> </ul>	 
	<b>Industrial use</b>	<ul style="list-style-type: none"> <li>- Hot water preparation / pre-heating</li> <li>- Solar cooling</li> <li>- Steam production</li> </ul>	
	<b>Desalination</b>	<ul style="list-style-type: none"> <li>- Thermal method (evaporation)</li> </ul>	
	<b>Power sector</b>	<ul style="list-style-type: none"> <li>- Electricity production</li> </ul>	
	<b>Cogeneration</b>	<ul style="list-style-type: none"> <li>- Electricity production</li> <li>- Heat production</li> </ul>	

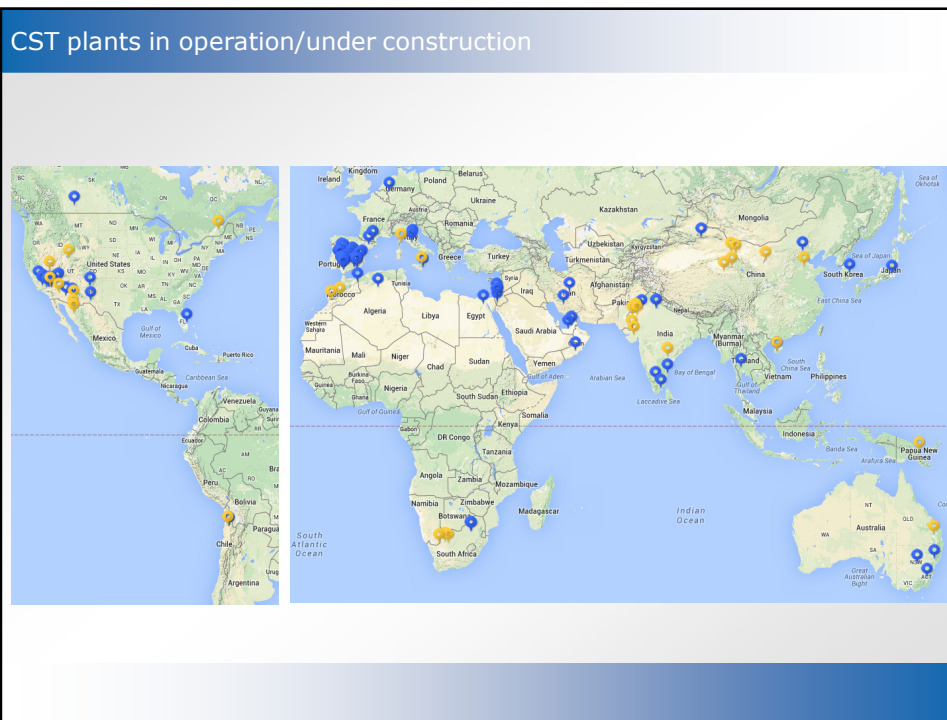


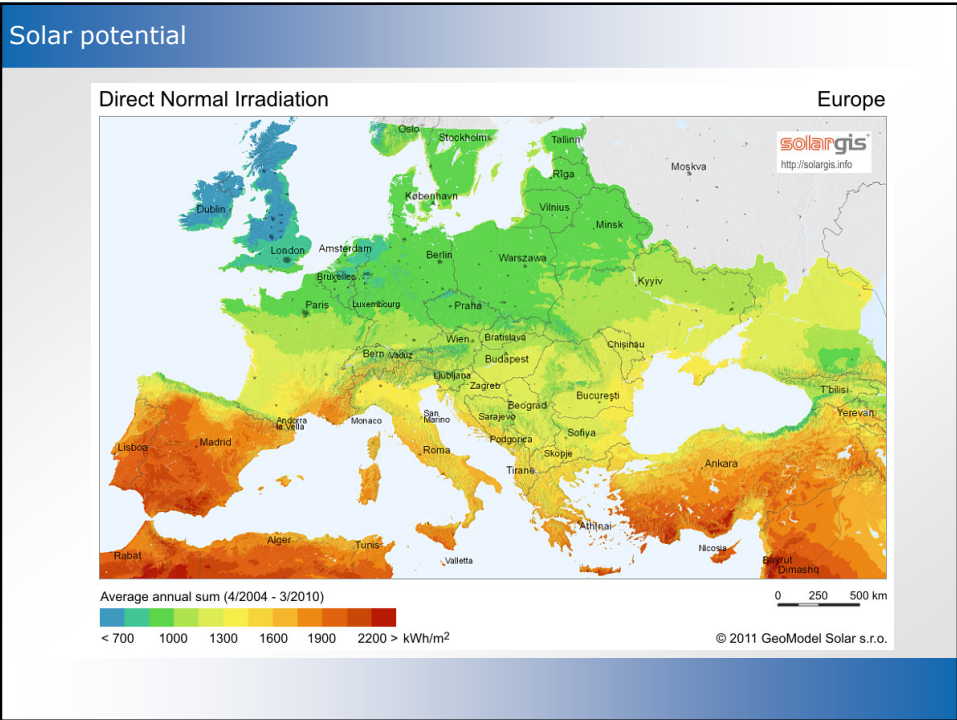
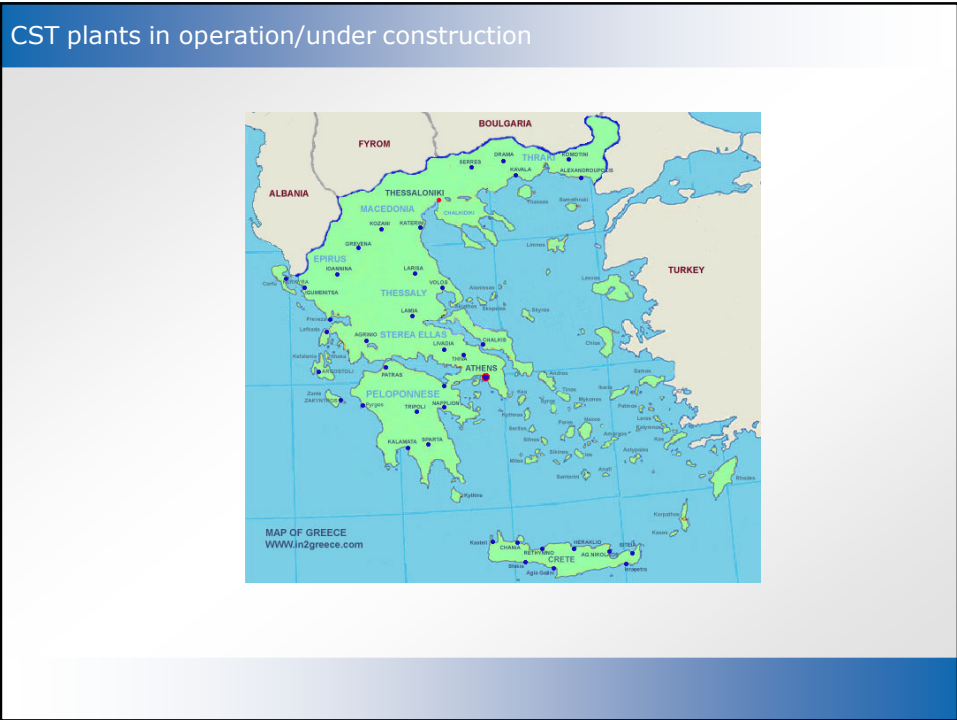
### CST systems

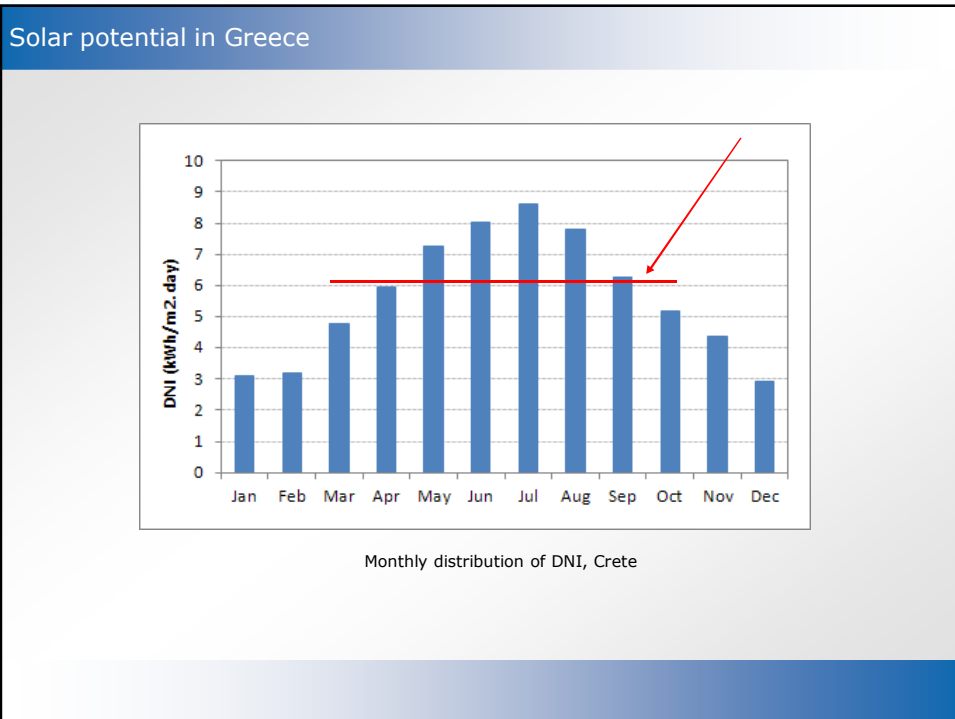
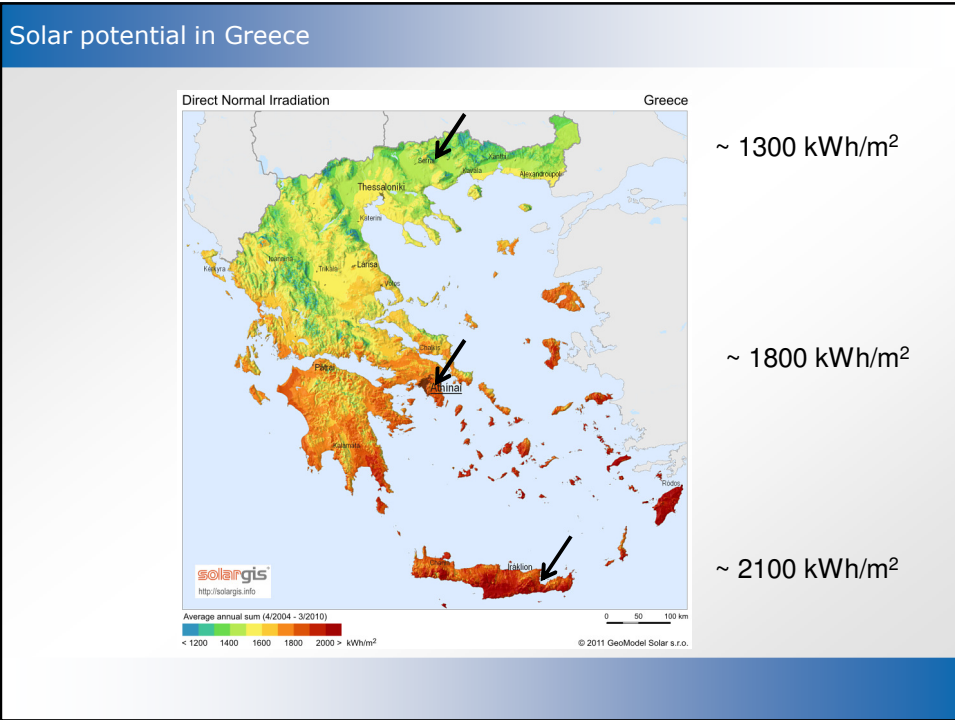
<p style="text-align: center;"><b>Parabolic Dish</b></p> <ul style="list-style-type: none"> <li>• Point focus concentration</li> <li>• Reflective plate with Stirling engine</li> <li>• No heating storage</li> <li>• Solar to electricity efficiency 30%</li> <li>• Temperature range 1000 °C</li> </ul>	<p style="text-align: center;"><b>Central receiver</b></p> <ul style="list-style-type: none"> <li>• Point focus concentration</li> <li>• Solar to electricity efficiency 16%</li> <li>• Temperature range 550 °C</li> </ul>	<p style="text-align: center;"><b>Parabolic trough</b></p> <ul style="list-style-type: none"> <li>• Linear concentration</li> <li>• Solar to electricity efficiency 15%.</li> <li>• Industrial applications</li> <li>• Temperature range 400 °C</li> </ul>	<p style="text-align: center;"><b>Linear Fresnel</b></p> <ul style="list-style-type: none"> <li>• Linear concentration</li> <li>• Solar to electricity efficiency 16%.</li> <li>• Industrial applications</li> <li>• Temperature range 300 °C</li> </ul>

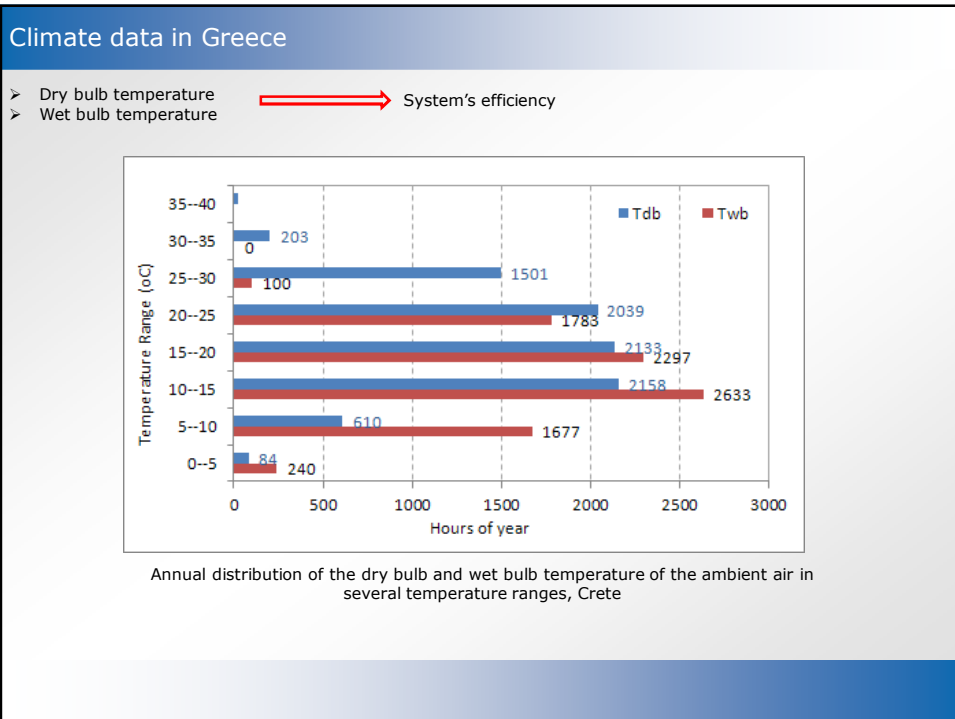
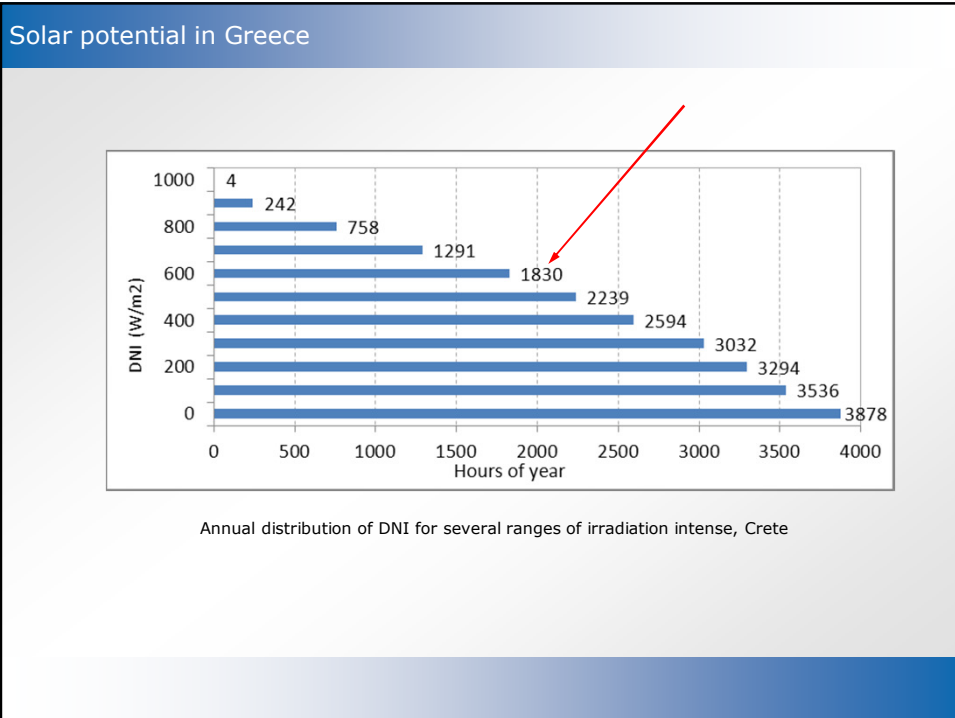
### CST main characteristics

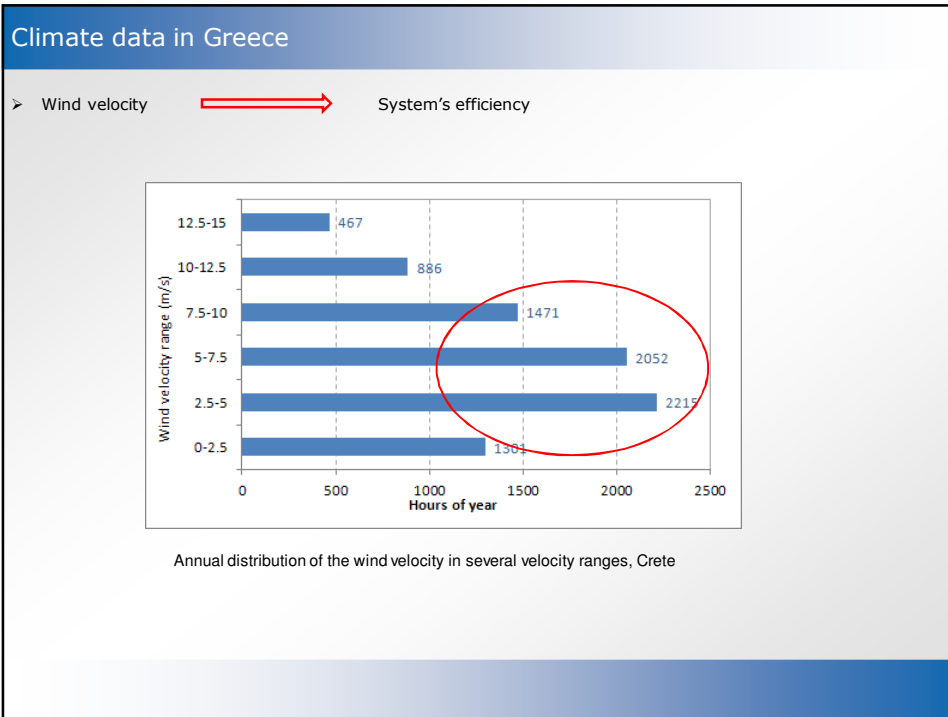
CST Technology	Parabolic Trough	Linear Fresnel	Solar Tower	Parabolic Dish
<b>Focus</b>	Linear	Linear	Point	Point
<b>Tracking</b>	1 axis	1 axis	2 axis	2 axis
<b>Mirrors shape</b>	Curved	Flat, curved	Flat	Curved
<b>Receiver</b>	Moving pipe with/without vacuum	Fixed pipe(s) with/without vacuum	Fixed external surface	Circular area of the stirling engine
<b>Working fluid</b>	Thermal oil, molten salt, pressurized water, 2 phase water			Hydrogen, helium
<b>Minimum system collector surface</b>	150 m <sup>2</sup>	150 m <sup>2</sup>	1,000m <sup>2</sup>	100 m <sup>2</sup>
<b>Steam / industrial use</b>	✓	✓	×	×
<b>Solar cooling</b>	✓	✓	×	×
<b>Desalination</b>	✓	✓	✓	×
<b>Power plant</b>	✓	✓	✓	✓
<b>Power cycle</b>	Rankine	Rankine	Rankine	Stirling
<b>Storage (thermal)</b>	✓	✓	✓	×
<b>Grid stability</b>	✓	✓	✓	×
<b>Hybridization</b>	✓	✓	✓	✓












### Other technological factors

**CST design and site selection**

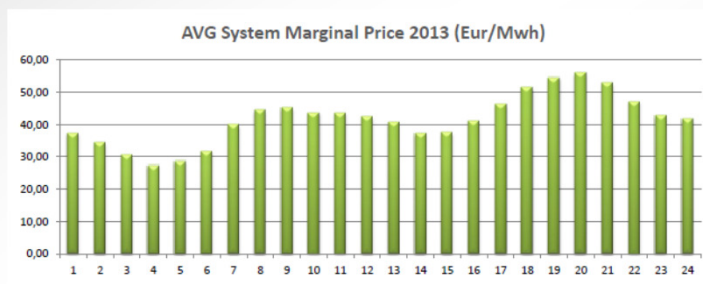
- Land parameters (**cost**, topography, inclination, leveling, protected areas, vicinity to airports / built areas e.t.c.)
- Water availability
- Accessibility
- Electricity grid
- Cleanliness of the atmosphere



## Market perspectives

### Electricity sector

- Law 3851/2010 RES
- Directive 2009/28/EC targets by 2020
  - 40% RES for electricity production
  - 20% RES gross energy consumption for heating / cooling
  - 10% RES in transport sector
- The system's marginal price is rather low compared to the levelized CST generation cost



## Market perspectives

### Electricity sector

- Favorable FITs for wind and PVs (~2.100MW wind and 2.900 PVs already installed)
- NOT favorable FITs for CSPs (285-265 €/MWh), based on :

CSP	CAPEX	OPEX	CF
<b>NO Storage</b>	3800	2,0%	20,0%
<b>WITH Storage</b>	4800	2,0%	30,0%

#### A potentially feasible scenario:

Technology	CSP											
	Storage 0-3h /24h				Storage 3-7h /24h				Storage ≥7h /24h			
	≤2MW	2-20 MW	20-50 MW	≥50MW	≤2MW	2-20 MW	20-50 MW	≥50MW	≤2MW	2-20 MW	20-50 MW	≥50MW
CAPEX €/kW	6500	5200	4800	4200	7800	6200	5200	4800	9100	7300	6500	6000
OPEX	3%	3%	2,5-3%	2,5%	3%	3%	2,5-3%	2,5%	3%	3%	2,5-3%	2,5%
CF	≤20%	≤20%	≤20%	≤20%	20-40%	20-40%	20-40%	20-40%	≥40%	≥40%	≥40%	≥40%



### Market perspectives

**Industrial sector**

- Food industry (dairy products, cold cut and process meat factories, pastry and cake confectioneries, olive oil refineries, tinned goods, slaughterhouses).
- Agro-industries (solar drying, horticulture–nursery greenhouses, slaughterhouses, meat processing, livestock landings).
- Textiles (tanneries, leather treatment, cloth, refineries, textile treatment workshops).
- Chemical industry (cosmetics, detergents, pharmaceuticals, wax, distilleries, breweries).
- Beverage industry (wineries, liquor and wine distilleries, breweries, soft drinks).

Industrial Sector	Process	Temperature Level [°C]
Food and Beverages	Drying	30 - 90
	Washing	40 - 80
	Pasteurizing	80 - 110
	Boiling	95 - 105
	Sterilizing	140 - 150
Textile Industry	Washing	40 - 80
	Bleaching	60 - 100
	Dyeing	100 - 160
	Heat Treatment	40 - 60
Chemical Industry	Boiling	95 - 105
	Distilling	110 - 300
	Various chem. Processes	120 - 180
All Sectors	Pre-heating of Boiler Feed-water	30 - 100
	Heating of Factory Buildings	30 - 80

### Market perspectives

**Industrial sector**

- ✓ **Direct steam generation**
- ✓ Air conditioning for the industrial buildings
- ✓ (Hot water production)

### Market perspectives

**Industrial sector – a case study**

- Steam need characteristics 170 °C / 7 bar / 700 kg/hr / yearly consumption 1.555 MWh
- Total solar field net aperture area 1.056m<sup>2</sup> (Fresnel )
- No storage

Simulation results for a typical operating year

Parameter	Value
Produced energy from solar collectors field (MWh / year)	746
Energy produced by collector (kWh / m <sup>2</sup> )	777
Percentage of solar coverage (%)	46

### Market perspectives

**Solar cooling sector**

- Cooling load is coincident with the availability of solar energy
- Cooling requirements of a building coincide with high solar radiation
- The use of linear focus concentrating solar collectors would enable the integration of two-stage solar thermal chillers in solar cooling systems (inlet temperatures >100°C)

"Closed circuit" solar cooling system

Typical buildings' cooling consumption throughout the year, 1.2MW<sub>cool</sub> load

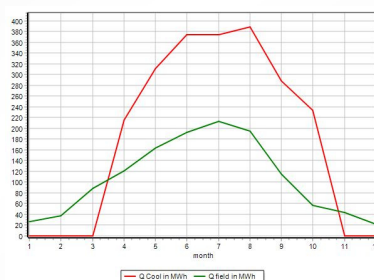
## Market perspectives

### Solar cooling sector – a case study

- Cooling load 1,2MW<sub>cool load</sub>
- Total solar field net aperture area 1.716m<sup>2</sup> ( parabolic trough)
- Two-stage steam solar chiller with nominal cooling capacity of 1.163kW

Simulation results for a typical operating year

Parameter	Value
Heat energy at the output of the solar collectors field (MWh / year)	1.296,8
Maximum output cooling energy (MWh / year)	2.185,9
Percentage of solar coverage (%)	49



## Conclusions

- Greece constitutes an extraordinary option for CST technology implementation given the **climate** conditions
- Industry, solar air-conditioning, desalination and power generation are possible applications.
- Essential requirements for feasible CPS plants are the climate conditions, especially the **DNI** of the location, the availability and **cost** of land, the availability of water and the social acceptance of the projects.
- Effective supporting mechanisms are required, either by means of FITs or by initial cost subsidies, to ensure the **financial viability** of the project.
- An effective **legal and regulatory framework** is needed, which will support this technology in its take-off stage, in a way similar to that of wind- or PV-technology.
- CST are investments that call for a multifaceted decision-making procedure, as they are still very capital intensive.



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