projeto HC-PV

WORKSHOP ON CONCENTRATOR PHOTOVOLTAIC AND THERMAL SOLAR GENERATION

August 25 2011

Solar Thermal Power

Technological options, Current Deployment and Future Challenges

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Solar Thermal Power (STP) in a Global Energy Context. ~ Sustainability

In a global context with:

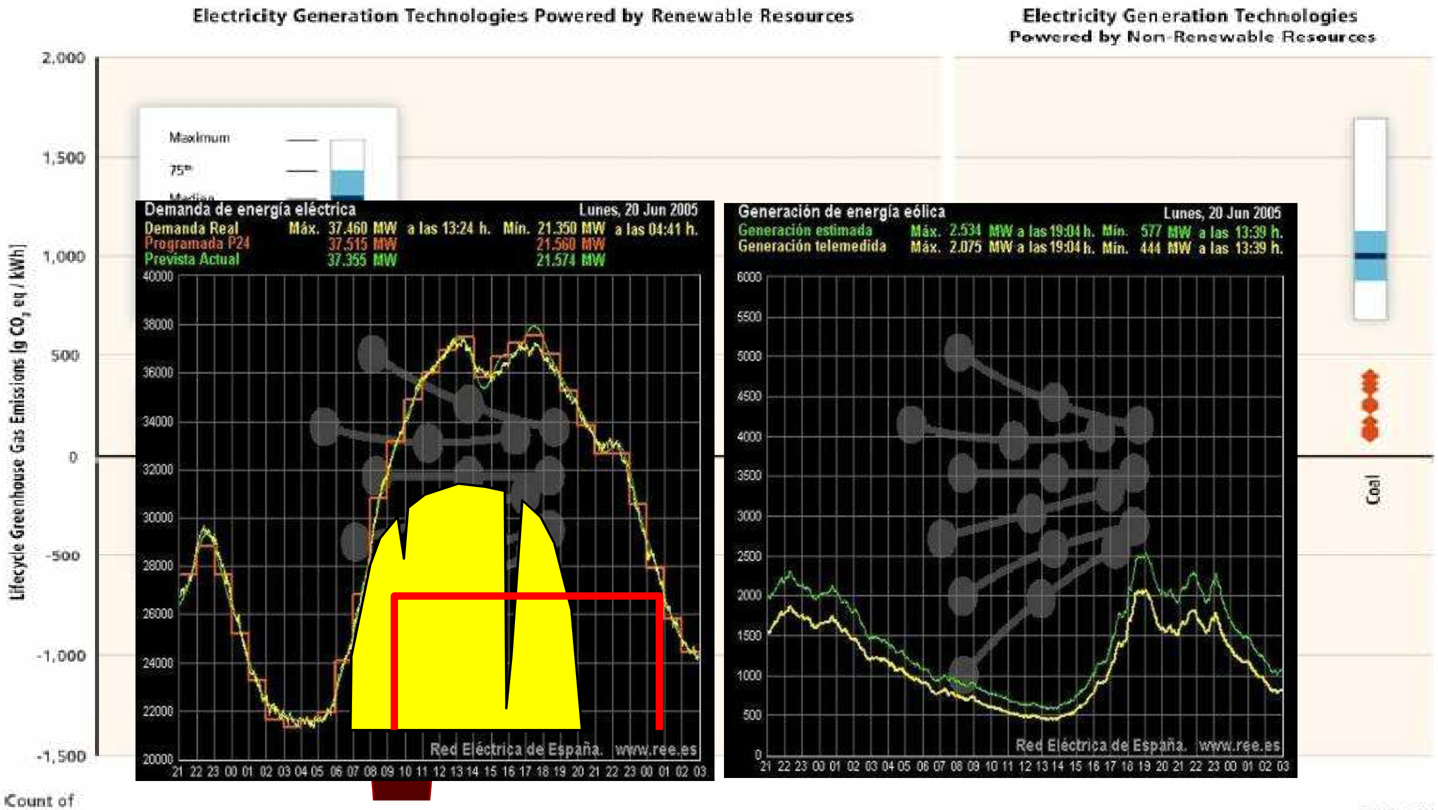
- Population growth (associated with the consumption of energy; where of the 7000M that we are now, 1400M of people does not have access to electricity)
- Economic development is closely linked (correlated) to consumption of energy in general (and of electricity in particular)
- Perception that fossil fuels have begun its decline
- A renewed concern about the environmental anthropogenic impact and the potential catastrophes associated with some energy sources,

➢ It seems inescapable the growing and significant deployment of renewable energy (~ sustainability)

- Eg: The recent study by the Intergovernmental Panel on Climate Change (IPCC), proposed scenarios to reach between 17% and 43% of renewable primary energy in 2030 (and between 27% and 77% by 2050), with a maximum investment associated with this development somewhat less than 1% of annual world gross product.

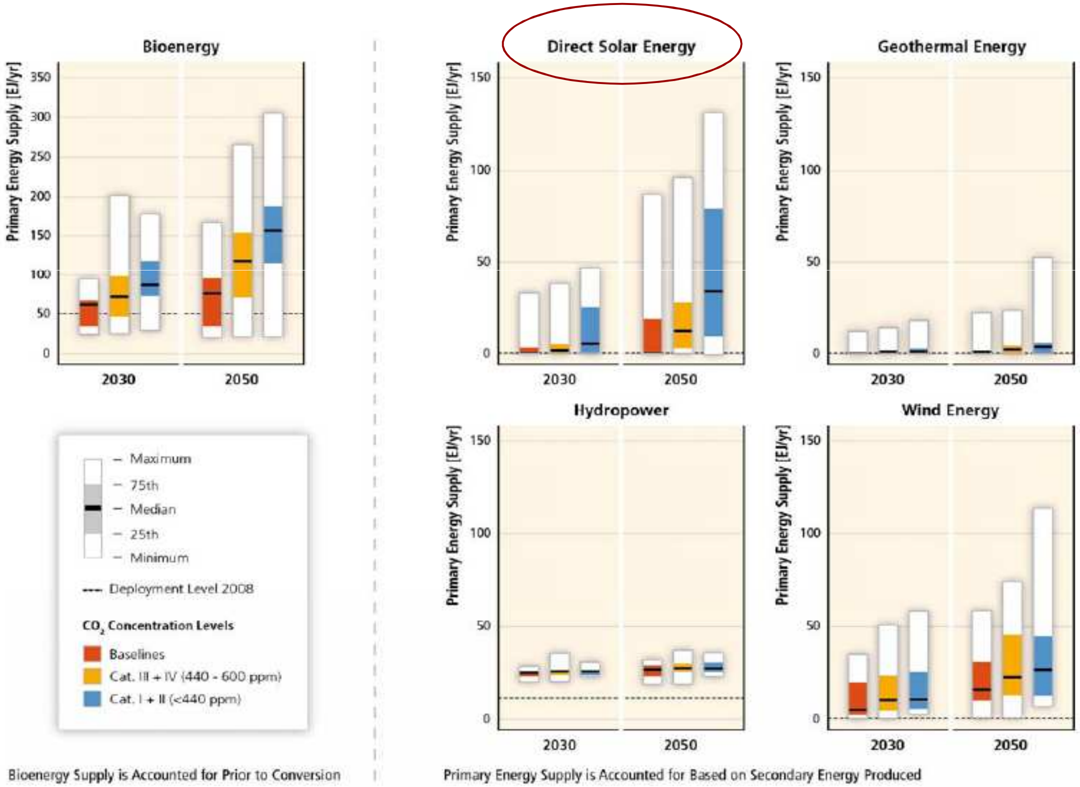
- In this context, the Solar Thermal Power (STP) may play a

CO2 emissions per kWh for different options energáticas (IPCC source)



- The Solar Power can provide electricity at peak hours in summer, when hydropower and wind power are scarce.

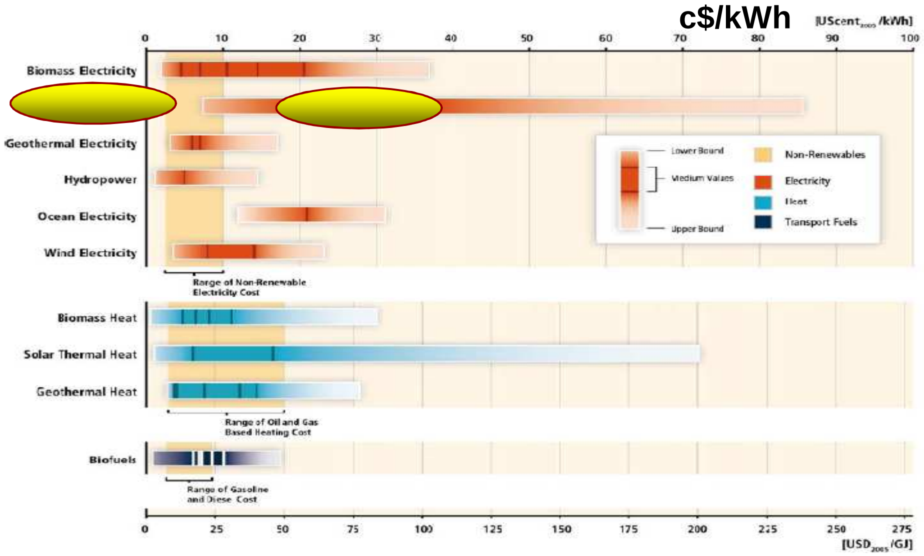
- During 2008-2009, 140 of 300 GWe newly installed globally (IPCC data) were Renewables and more than half of these were installed in developing countries
- The IPCC offers a variety of scenarios in which the STP plays a relevant role



- Players which enter soon in the market can play with an advantage in technology supply

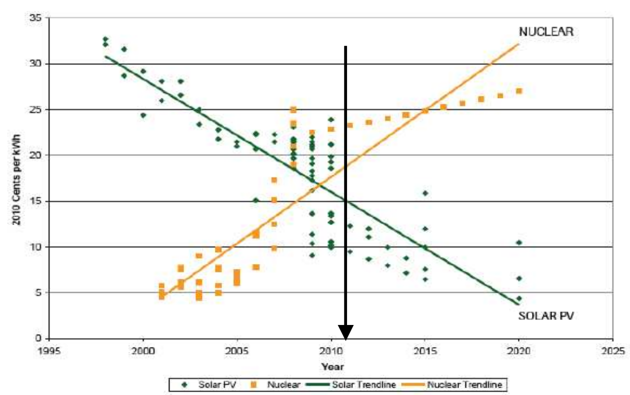
The STE in a Global Context.
Competitiveness in cost as Challenge

- The cost of STP electricity is higher than conventional, although in some scenarios it is almost economically competitive.
- The costs depend on several factors, such as:
  - Technical aspects: (Characteristics of technology)
  - Regional variations in costs and resources
  - Economics (interest rates, etc.).
- **The relative competitiveness is distorted** because the market does not include externalities in the costs of the conventional electricity (as impacts on health, environment, etc.).
- The cost competitiveness has references variables (eg: Nuclear vs FV)



Fuente:IPCC-Special Report on Renewable Energy Sources (2011)

Figure 12. Solar and Nuclear Costs: The Historic Crossover

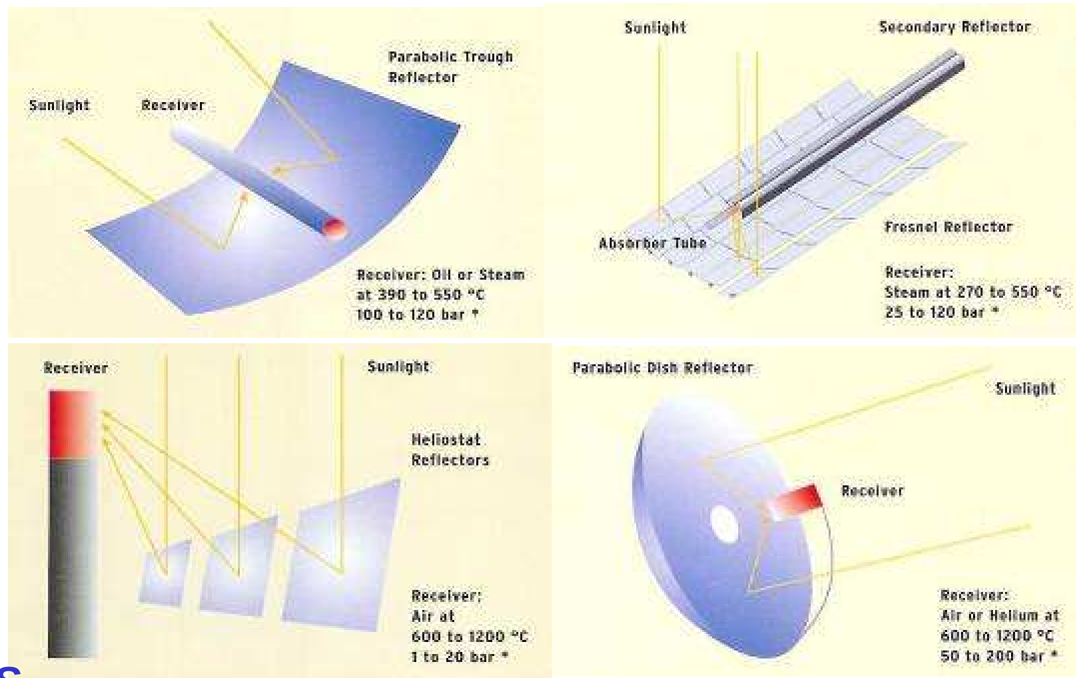


Fuente: WorldWatch Inst."Nuclear Status Report, 2011

Solar Thermal Power.

Technology Options

- Solar Thermal Power (**STP**) or Concentrating Solar Power (**CSP**) includes a range of different technologies characterized by concentrating solar radiation and a Photo-Thermal conversion.
- **Concentrating** solar radiation, CS, enables higher temperatures and / or energy fluxes, reducing the costs of conversion (eg. In electricity) and increasing the thermal and thermodynamic efficiencies.
- Many different types of systems are possible, including combinations with other renewable and non-renewable technologies, but the most deployed solar thermal power technologies are distinguished by the shape of its concentrator and receiver:



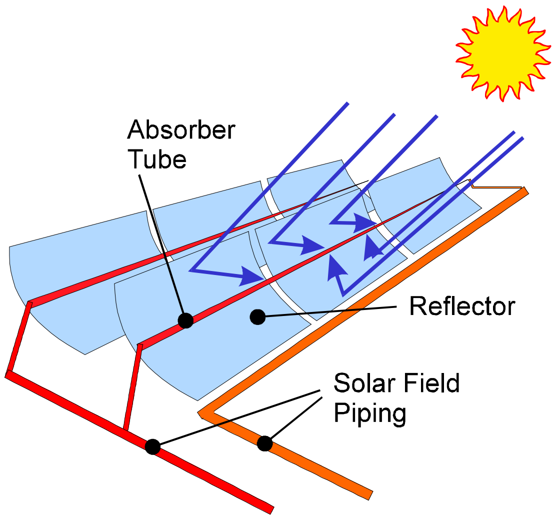
Linear absorber or line-focus:

- Parabolic trough, **PT**
- Linear Fresnel, **LF**

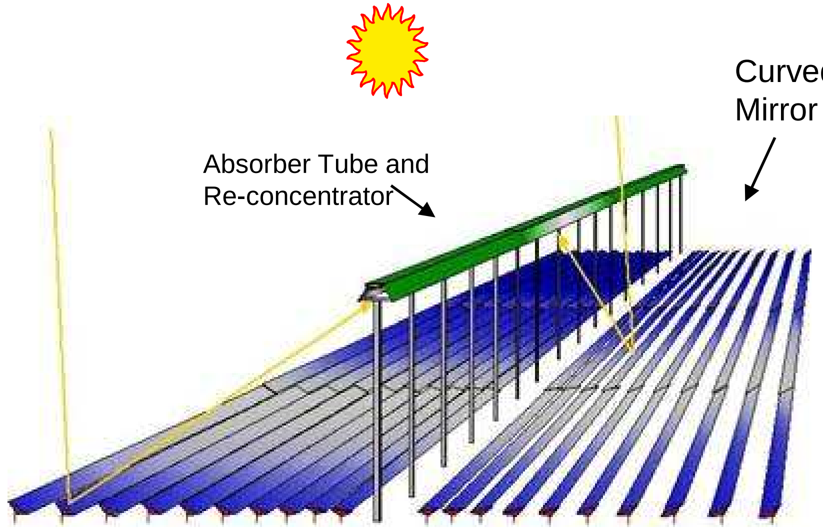
“~Punctual” absorber or **Point Focus** (=> **High Concentration**)

- Central Receiver solar tower, **CR**
- Parabolic Dish or Dish-Stirling, **DS**

STP – Line Focus

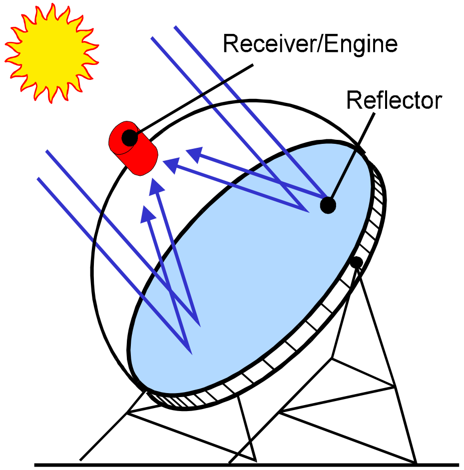


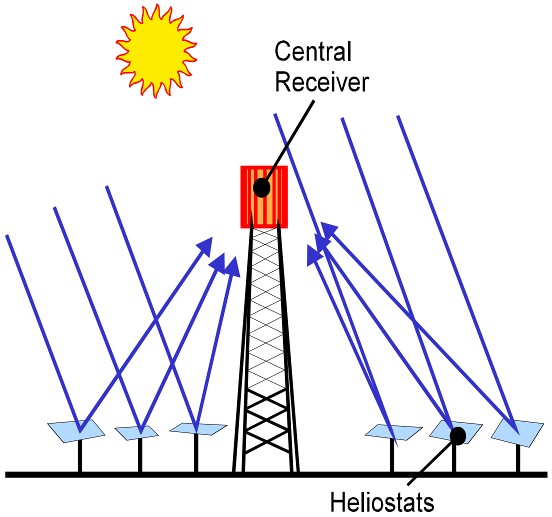
Parabolic Trough



Linear Fresnel

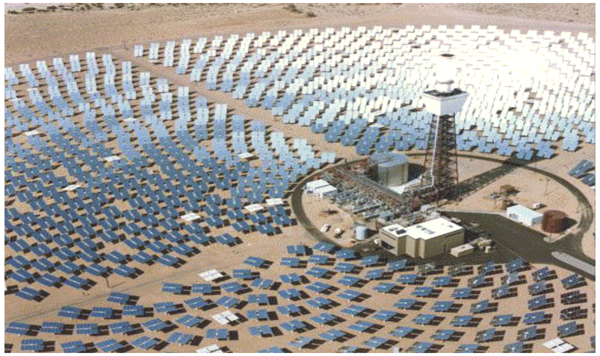
STP – "Point" Focus





Parabolic Dishes

Central Receiver

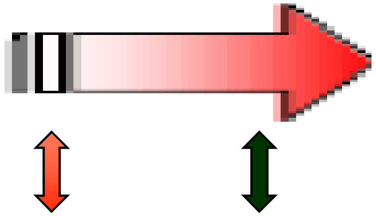


Principle of Solar Thermal Power Plants (STP)

STP use concentrated solar energy to raise the temperature of a heat transfer fluid, and, optionally co-firing with other fuels (as NG) or storage, to drive steam turbines, gas turbines or piston engines, to deliver electricity or combined heat and power.

Concentrating solar collectors

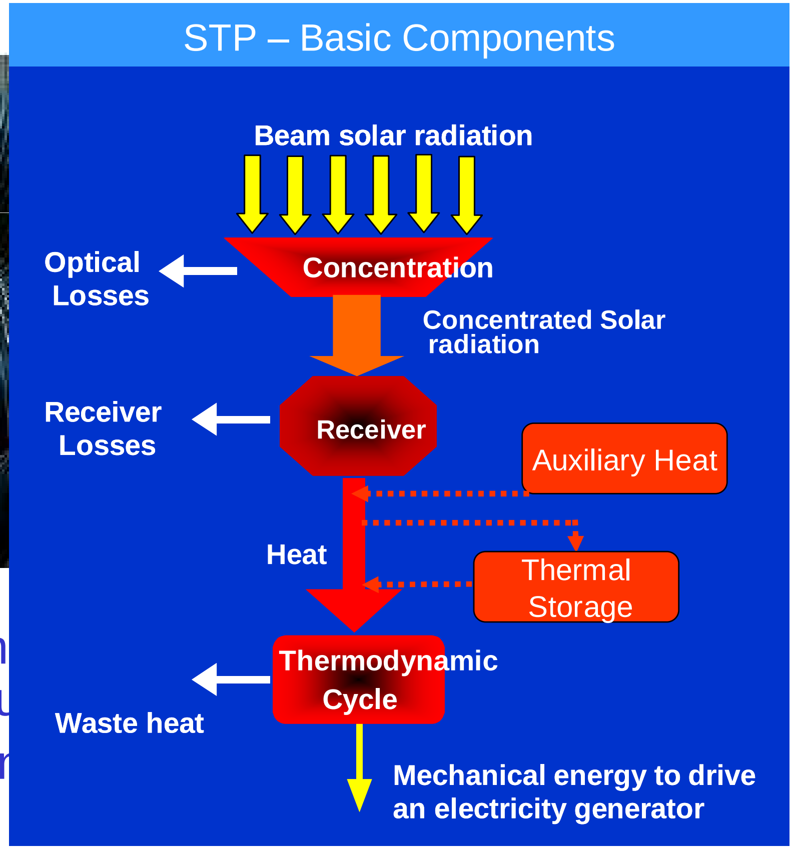
Steam or Gas



(Optional) **Heat Storage**

(Optional) **Auxiliary Heat**

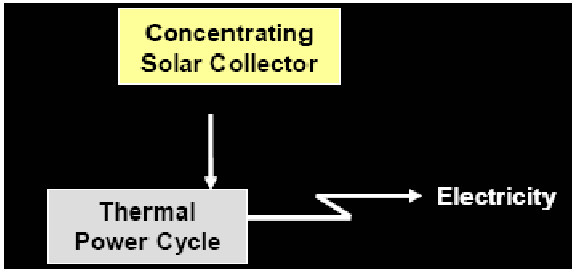
Steam tu
& Gen



The Solar Thermal Power enables multiple schemes of implementation

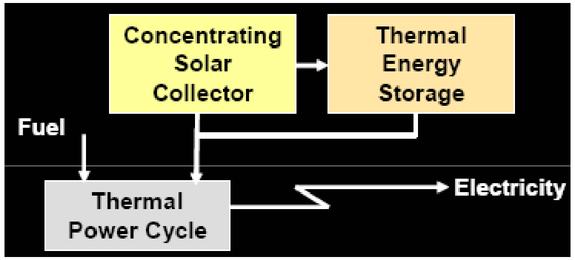
OPTION 1: Electricity Generation
Solar Only in flowing mode

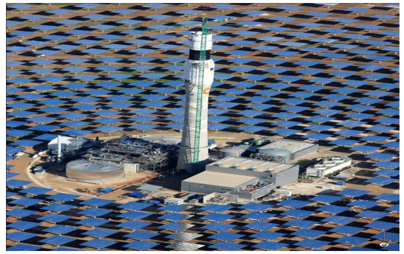
(electricity is produced only when there is DNI))



OPTION 2: Electricity Generation
Solar Only with thermal storage

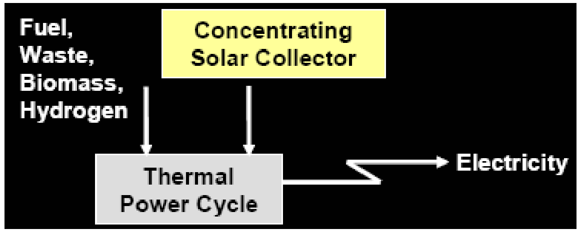
(Heat storage allows to manage transients by clouds and demand fitting)





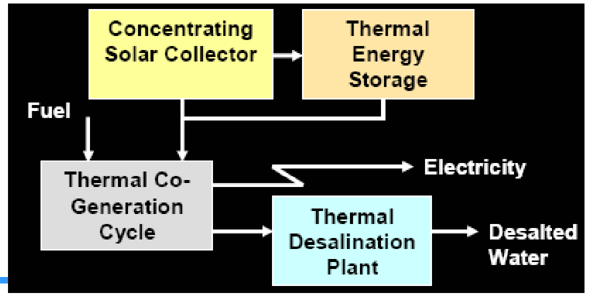
OPTION 3: Electricity Generation with hybridization

(Hibridization allows to manage transient clouds and demand fitting)



OPTION 4: CO-generation of power and heat (f.i. for desalinated water) with hibridization

(Addressing two needs: electricity and water as in many coastal and desert regions of MENA)



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Potential placements

Which placements are feasible for STP?

Enough solar resource

1. **Start using maps of Direct Normal Irradiation (Usualy estimated from satellite)**
2. **To elliminate sites with “typical” DNI < 1825 kWh/m2/year (or 5 KWh/m2/day)**
3. **Exclussion of protected zones, water and urban zones**
4. **To elliminate zones with terrains tilted > 3%**
5. **To elliminate zones with sizes < 5 km2.**
6. **Then, apply 2nd order criteria (land costs, potential suport from administrations in the zone, water access, electrical gaz network access, roads access, etc.**

Feasibility of potential placement

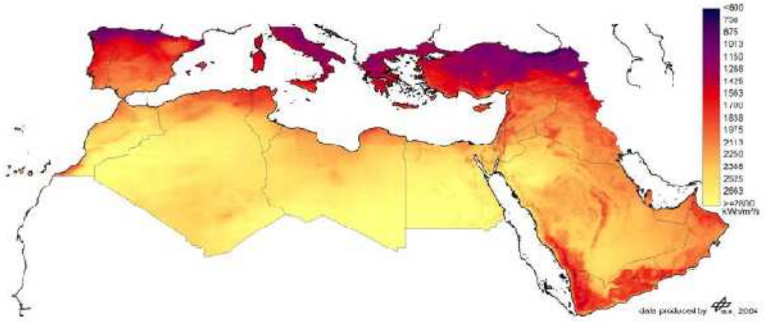
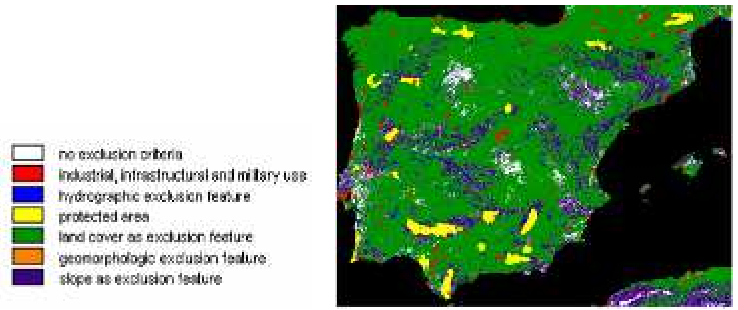


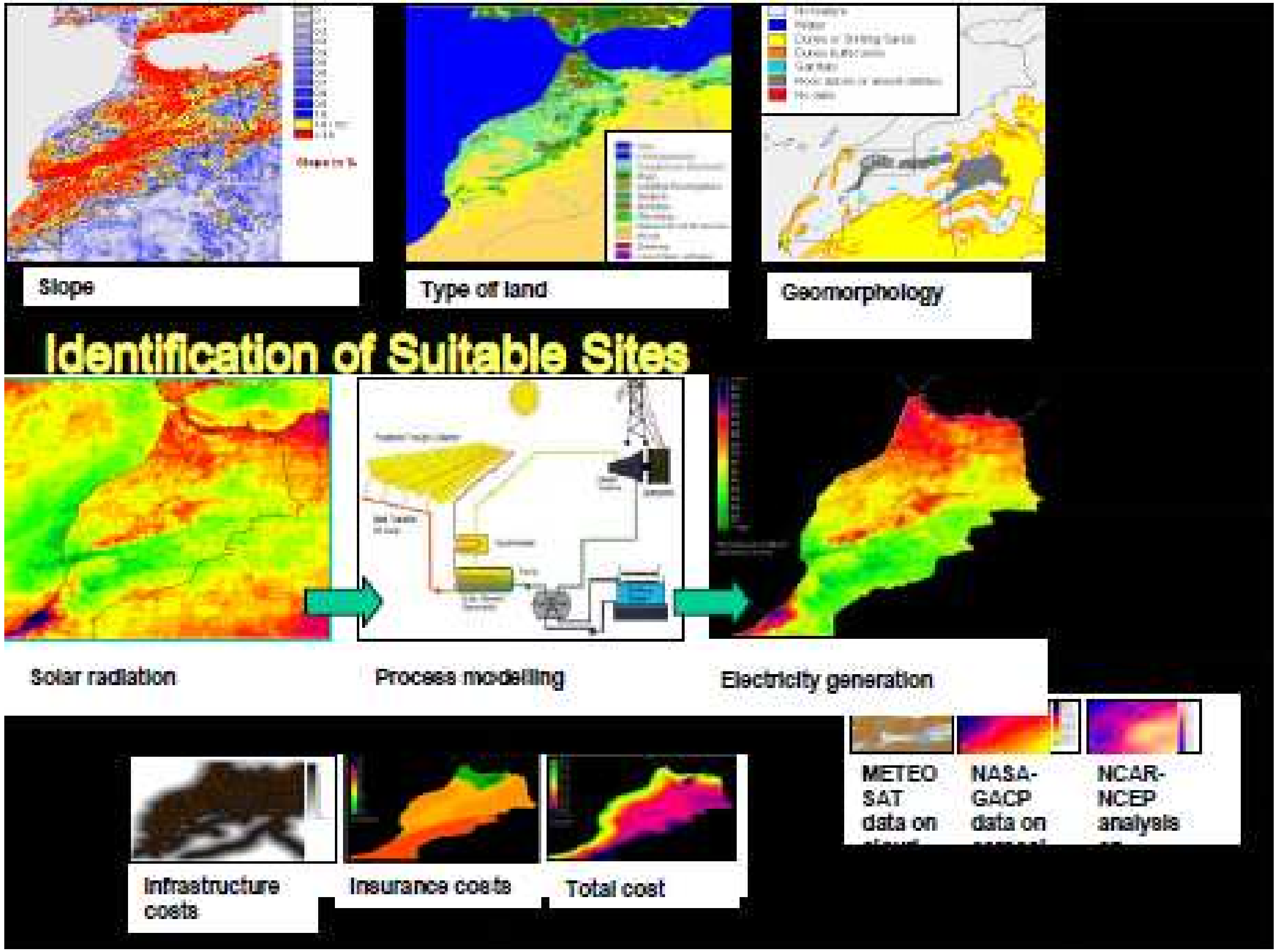
Figure 4: Annual Direct Solar Irradiance in the southern EU-MENA Region. The primary energy received by each square meter of land equals 1 – 2 barrels of oil per year.

- Potential in **Europa** = 2500 TWh
- Potential in **North Africa** almost infinite **(~“solar mine“!)**



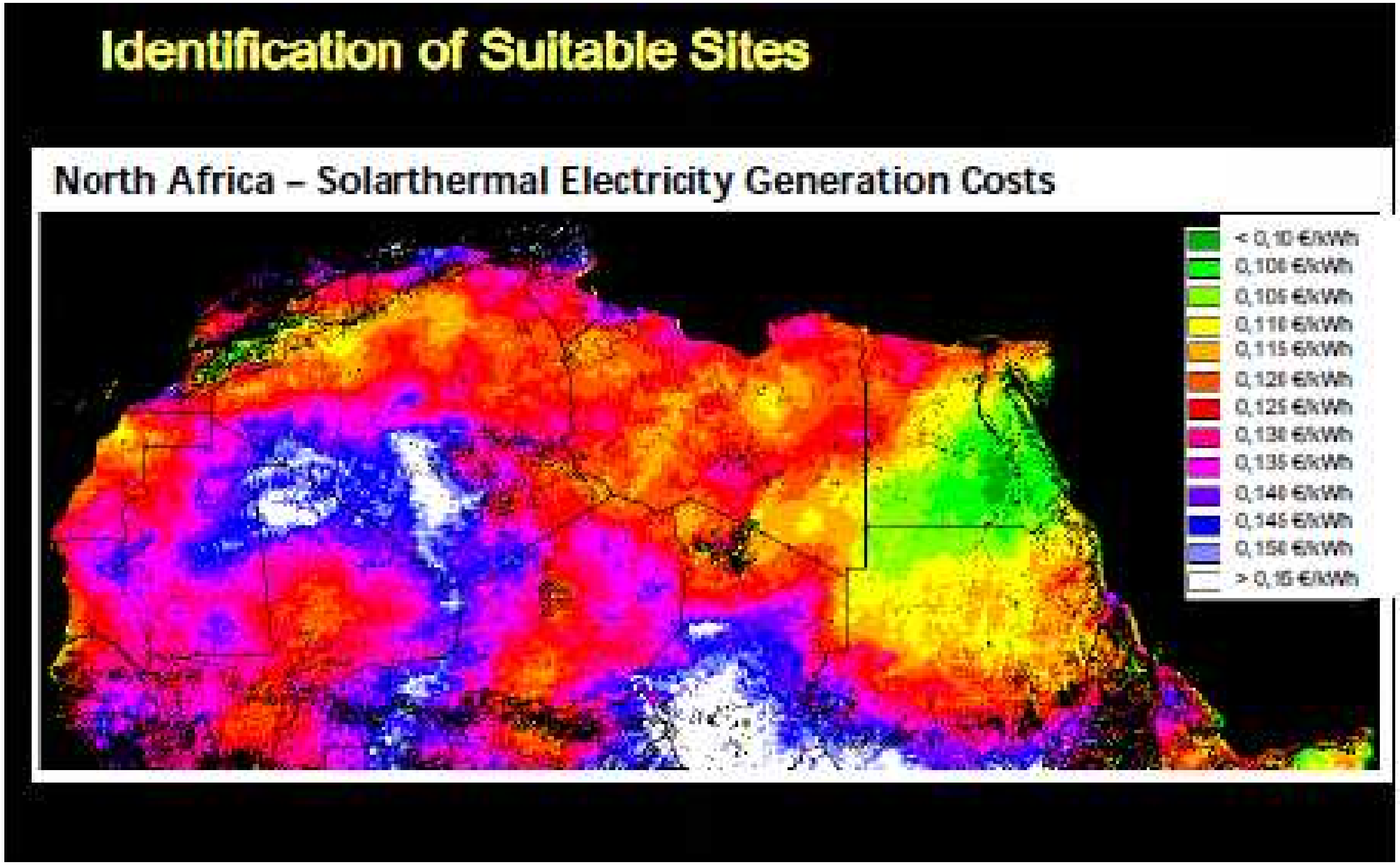
Which placements are feasible for STP?

Pre-selection by combination of GIS (Geographical Information Systems), Satellite data for DNI assessment, technology data, …



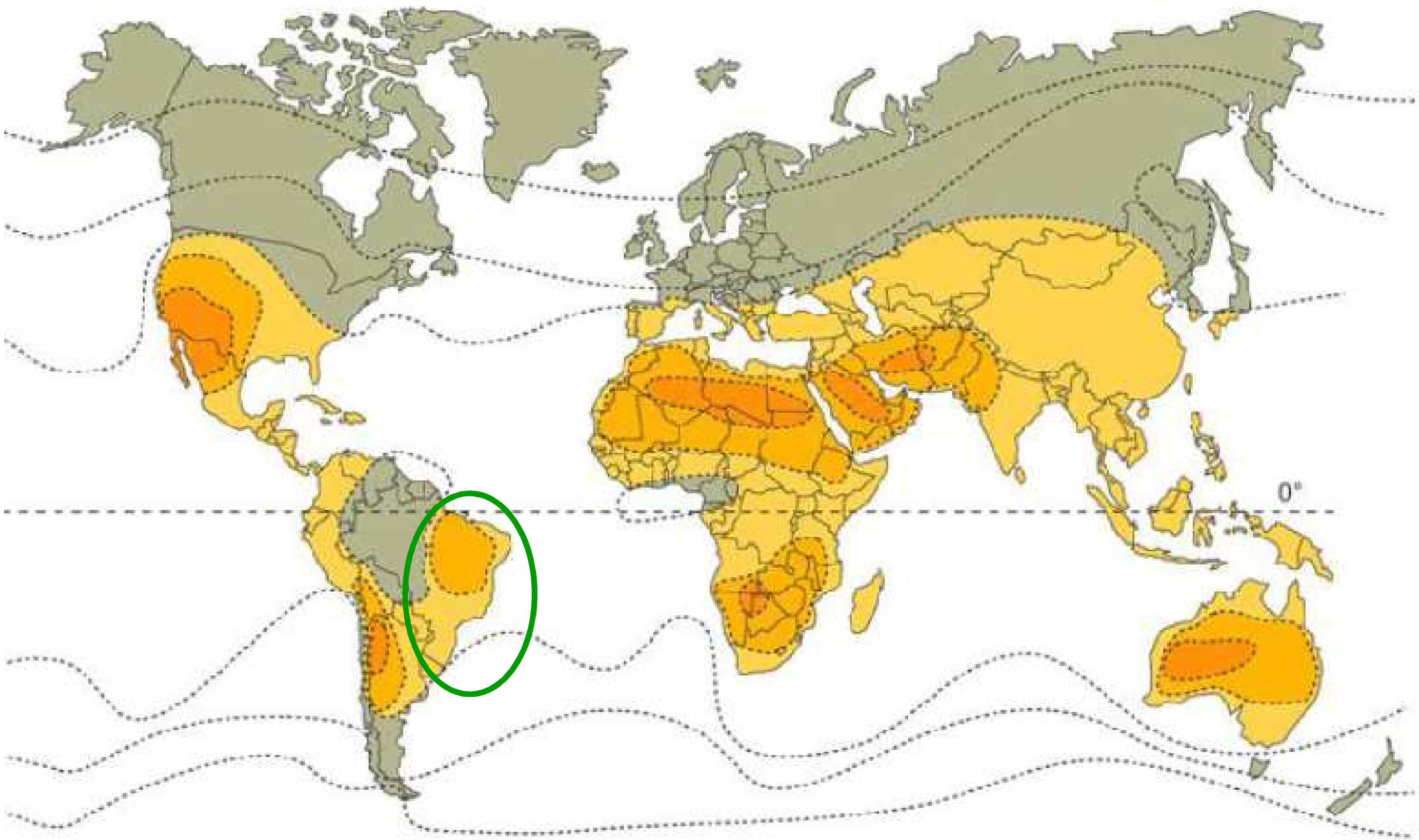
(Source: DLR)

Which placements are feasible for STP?



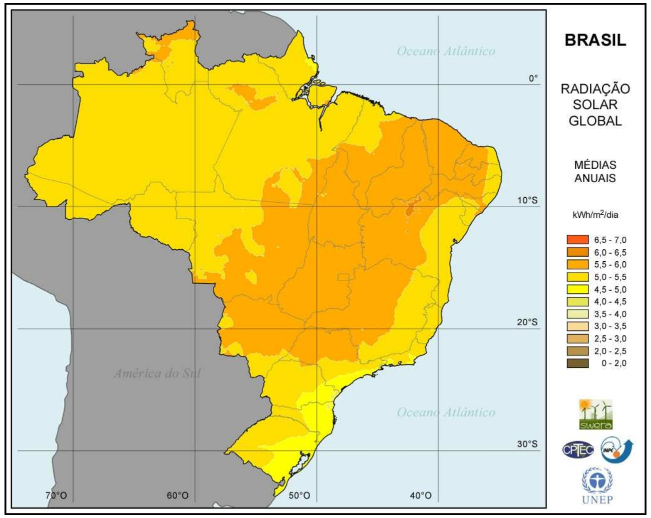
(Source: DLR)

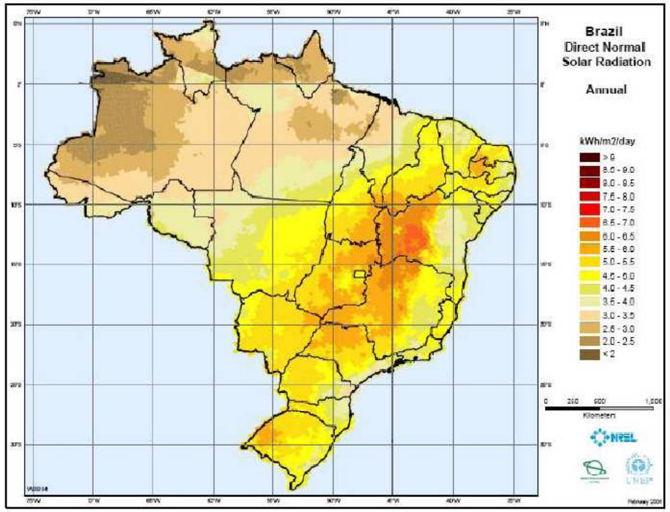
Classification of regions by the Annual Direct Normal Irradiation (DNI)



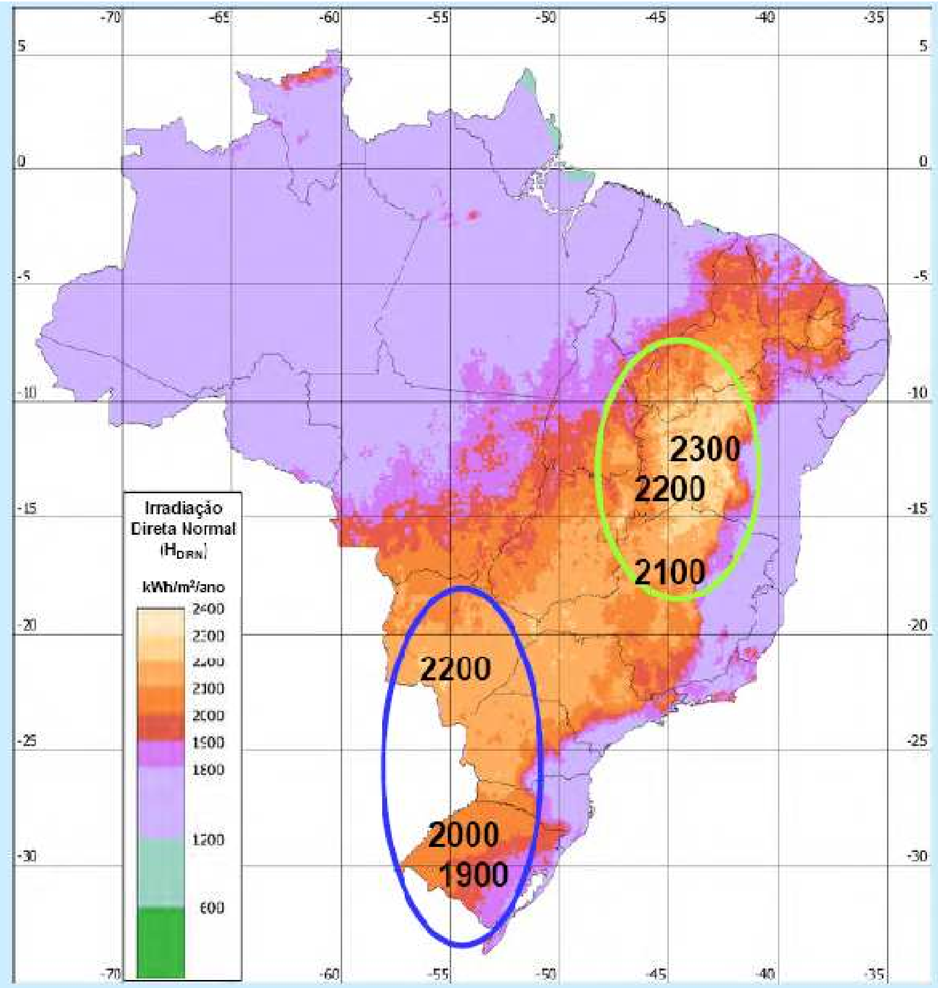
- Excellent (>2200 kWh/m²·a)
- Good (>2000 kWh/m²·a)
- Acceptable (>1800 kWh/m²·a)
- Low (<1600 kWh/m²·a)

The Potential of Brazil: Large areas of Brazil with Solar Rad. Good to Excellent





SWERA / NREL – jul 2006



Irradiação Direta Normal (H_{DIRN})

- Mapa kWh/m²/ano
- Escala
- Áreas com altos níveis de irradiação (PI, BA, GO, MG, SP, PR, MT, MS)
- **Áreas com valores altos Oeste de SP, PR, SC e RS.**

Annual Direct Normal Irradiation on Surfaces Tracking continuously the Sun in kWh/m²/year

Source: T.Viana (CEFET-RJ), Rüther (UFSC), F. Ramos (INPE)

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The Potential (to deploy S
in the START Missio

International Energy Agency (IEA)
Solar Power and Chemical Energy Systems

SolarPACES
START Report 2/98

START Mission to Brazil

CEPEL ELETROBRÁS SYSTEM
Weizmann Institute of Science | Ciemat | DLR | Sun•Lab
DRAFT 12/14/2004

Mission Summary

Conclusions

ENERGÍAS RENOVABLES
amERica
El periodismo de las energía limpias

Lunes, 22 agosto 2011

Inicio | Panorama | Eólica | Solar | Bioenergía | Otras fuentes | Ahorro
Agenda | Empresas | Empleo | Consejo asesor | Quienes somos | Suscríbete

térmica

BRASIL

Solar más biomasa con polémica

Miércoles, 10 agosto 2011

André Ramalho

La empresa brasileña Braxenergy quiere competir en la próxima subasta de energía nueva, prevista para el 17 y 18 de agosto, con dos plantas de energía solar pioneras en el país. Los proyectos, localizados en el estado de Paraíba, región Nordeste, prevén el uso de la energía solar durante el día para calentar la caldera de las plantas Corema I (30 MW) y Corema II (20 MW). En momentos en que no hay sol, la idea es utilizar el bagazo de la caña de azúcar y la biomasa de coco directamente al fuego de la caldera para la generación de energía.

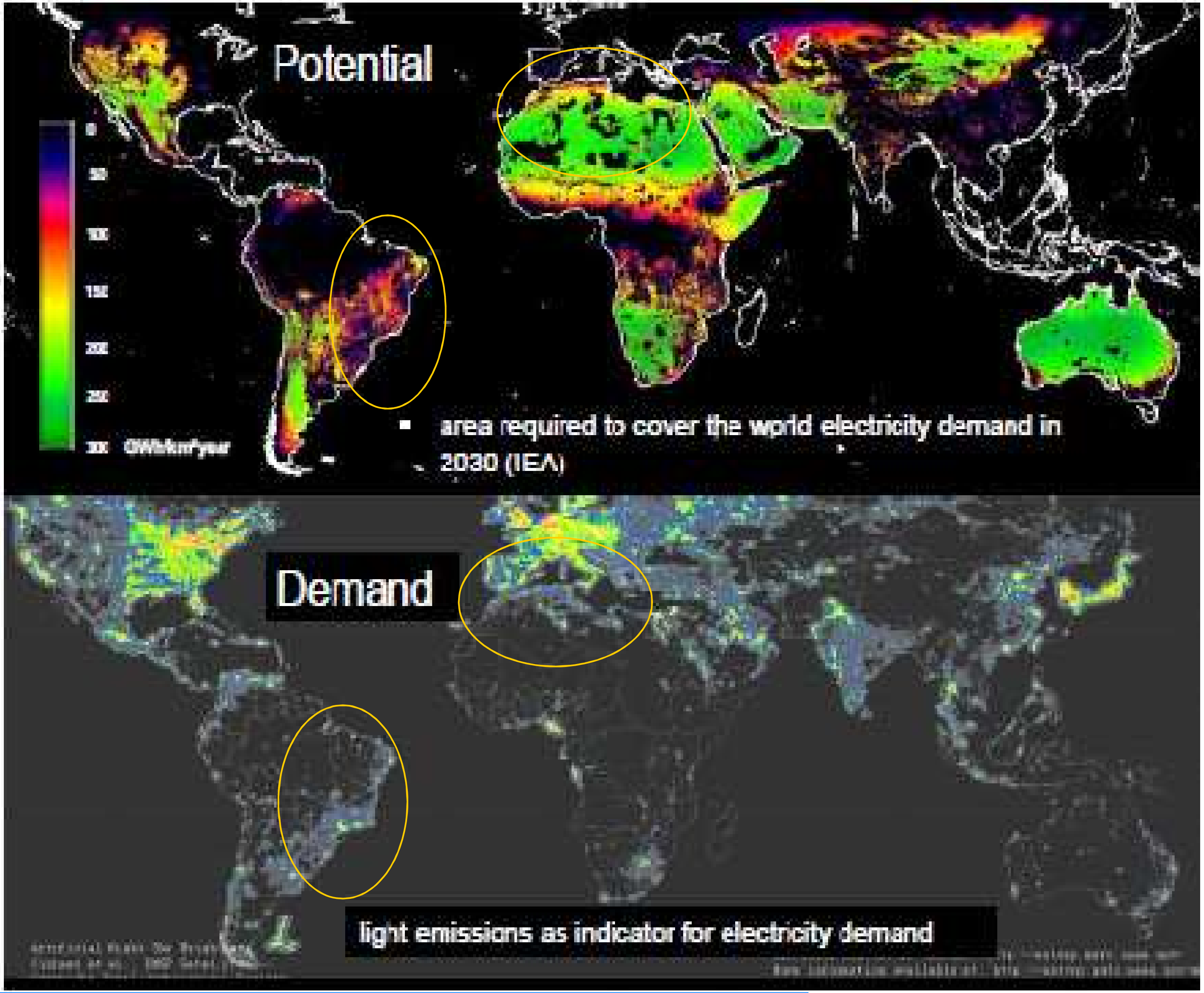
Sin embargo, el avance del proyecto puede pagar por su originalidad. Su participación en la subasta depende de un acuerdo con la Empresa de Investigación Energética (EPE), que vetó la participación del proyecto en el concurso.

EPE argumenta que las reglas de la subasta no prevén la participación de las plantas solares, ya que, sostiene, limita la contratación de los parques eólicos, biomasa, pequeñas centrales hidroeléctricas y termoeléctricas a gas natural.

Por su parte, Braxenergy arguye que la Agencia Nacional de Energía Eléctrica (Aneel) ha clasificado el proyecto como biomasa, y que éste debe ser el marco que debe considerar EPE. La empresa apeló la decisión en el entendimiento de que su negocio es una central térmica. La apelación está pendiente de la decisión final.

technologies.

There is a Complementarity among STP Potential and Power Demand

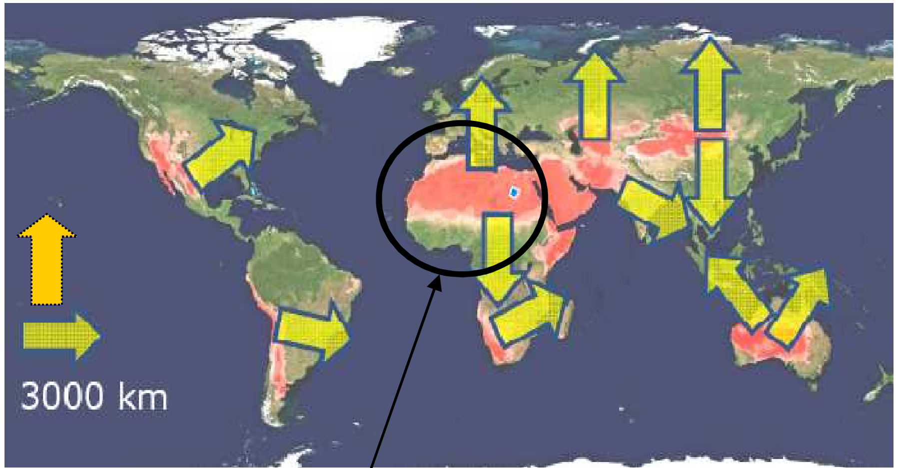


This complamantarity could be an opportunity either for local development using solar technologies or/and by “to export” solar electricity …

Potential of the Solar Thermal Power

Some curious Figures

- ✓ **The 90% of the electricity consumption** in the World could by supplied with Solar Thermal Power Plants occupying an area of **300x300 km2** in desert zones
- ✓ Electricity Transportation at distances of **3000 km** by D.C. high Voltage only implies **10% of losses**



- ✓ F.i.: Electricity demand in whole Europe could be covered by STPP installed in the North of Africa (where there are > 20% higher solar resource) with only this 10% of transmission losses by a 800 kV D.C. and connection through the Mediterranean Sea. (= proposal of the Roma Club, TRMED y CSPMED)…

- ✓ The Power Consumption in the EU, in 2005 was 3300 TWh, and the Technical Potential of STPP in Argelia with DNI>1800kWh/m2·a) is about 169.440 TWh/año (~50 times the EU Power demand)

Potential of Solar power plants
Desertec Idea

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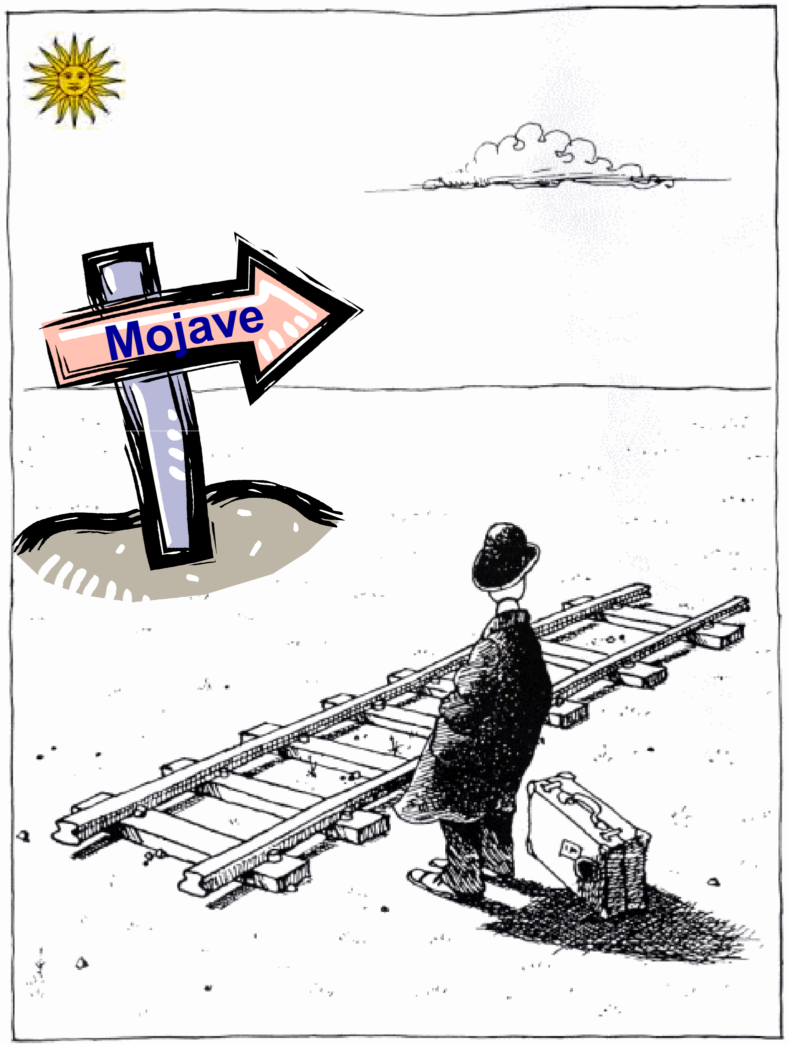
Current Deployment.

Nowadays (2007-...) we are living a second chance for commercial deployment of STP

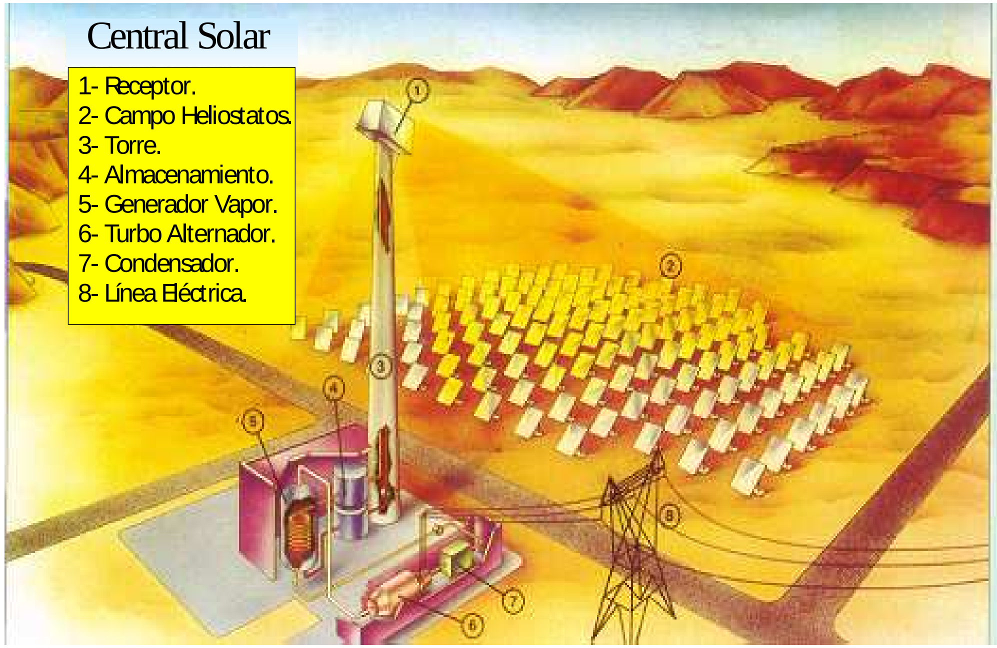
A LITTLE HISTORY

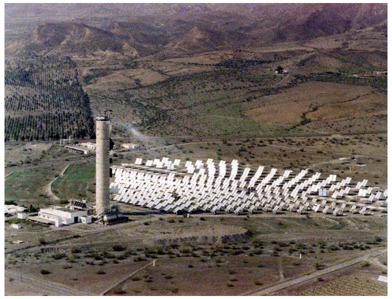


In the 80s we lost the train of demonstration projects on a large scale

… We are now at a crossroads with a large volume of plants under construction but many doubts in the present and future

The 1974 oil crisis prompted the development of a variety of CSP facilities for testing and evaluation of components and demonstration of plant schemes





CESA 1, PSA, Almería, Spain

CRS, PSA, Almería, Spain

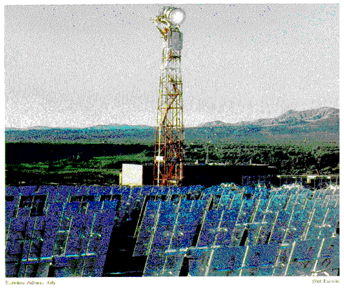
SOLAR 1, Barstow, California, USA

SOLAR 2, Barstow, California, USA

NSTTF,Albuquerque, N.M., USA

WEIZMAN, Rehovot, Israel

THEMIS, Targassone, France



EURELIOS, Adriano, Italy

SUNSHINE, Nio, Japón

Seven Years Ago CSP and SolarPACES (IEA task) were almost Declared Dead

Today STP makes Headlines on National Newspaper Cover Pages

(Associated investments to the projects in the actual deployment represent

about 4000 M€/year)

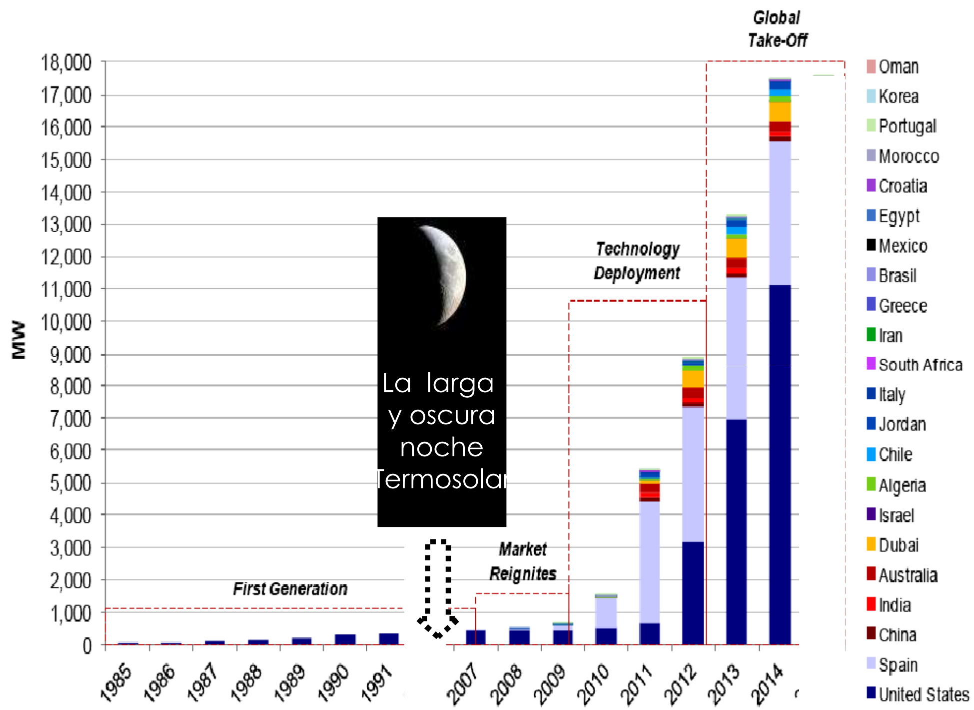
2007: STP commercialization started and grows quickly **in Spain**, Why in Spain?

In Spain we have specially favorable conditions, for <u>several reasons</u>:

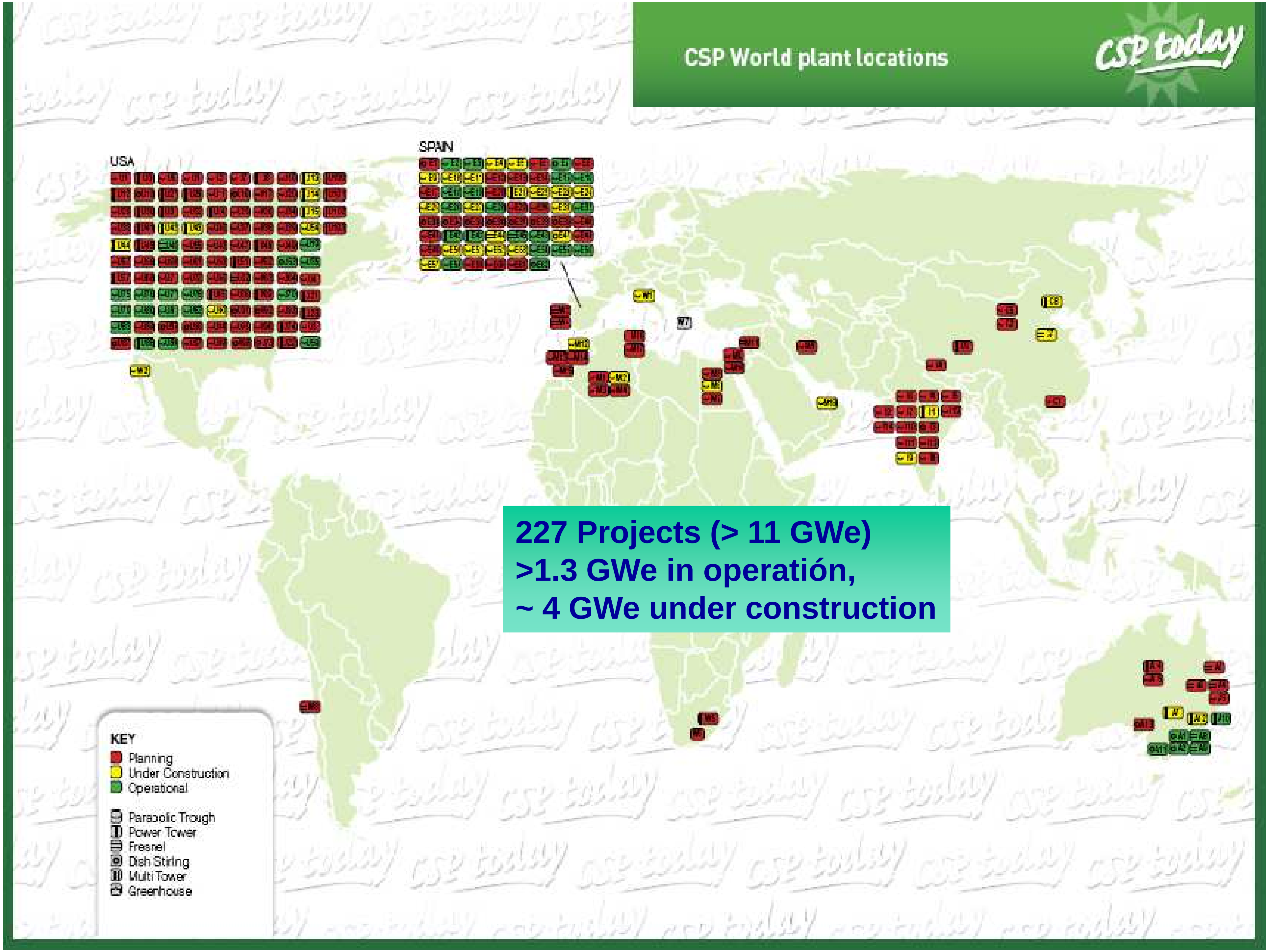
- **Administration support (**RD 436/ 2004 **feed in tariff** -> ~0.23 €/kWh,.. **RD 661/2007** ~0.27 €/kWh,.. + European&regional incentives, etc.)
- An rather complete and open **international facility for R&D&D projects** in Concentrating solar Technologies (**Plataforma Solar de Almería**)
- Probably the highest **solar resource** in European side of the Mediterranean.
- The existence of **a industrial sector** interested in this developments (ABENGOA, ACS, SENER, IBERDROLA, ...ACCIONA,…)
- ...All this reasons together make **Feasible** the **construction of the 2500 MWe** projected in the Spanish Plan de Energías Renovables (2005-2010)

Besides, .. There is a Reactivation of international interest on STP

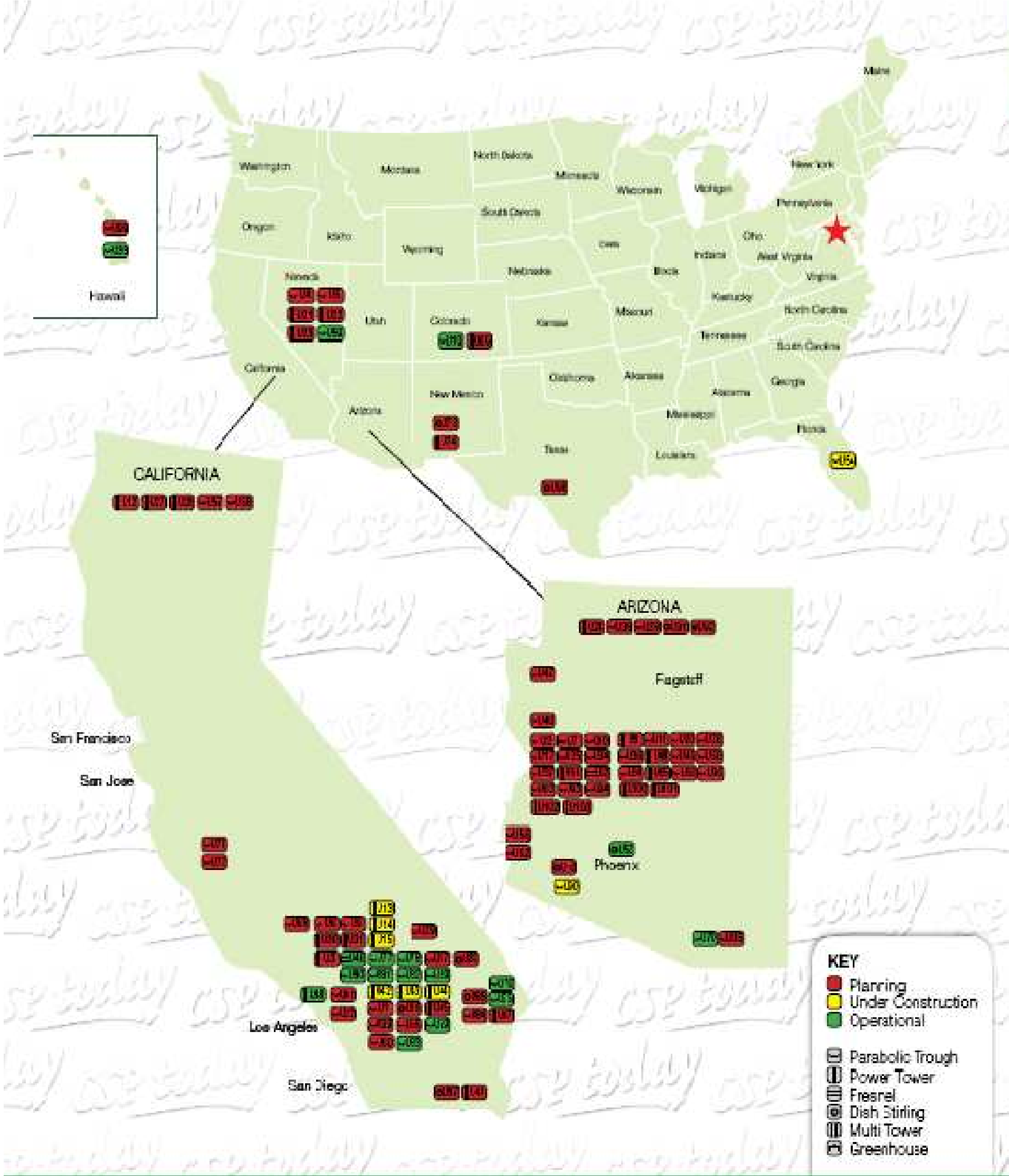
- The industrial reactivation of STP **added another 1000 MW in 2007-2010 to 354 in the late 80's.**
- At Medium-term the deployment of **20 GWe by 2020 is seen as realistic.** (The investment associated with this deployment would be around 80.000 M €)
- By technology (of ~ 11 GWe with different development in **late 2010**) prevail **PT** with **5.6 GWe**, followed by **CR** systems projects total ~ **3.5 GWe** and **Dish-Stirling** with **1.6 GWe**. The **0.1 GWe** of **Fresnel** channels are merely testimonials
- In the **U.S**. Deployment is being reactivated with projects supported by the U.S. Department of Interior amounting (end 2010) upto **4.5 GWe**.
- The STE is attracting interest in **other regions such as MENA, China, India, Australia, South Africa, ...**



SOURCE: "Global Concentrated Solar Power Markets and Strategies: 2010-2025," IHS Emerging Energy Research, April 2010



227 Projects (> 11 GWe)
>1.3 GWe in operatión,
~ 4 GWe under construction

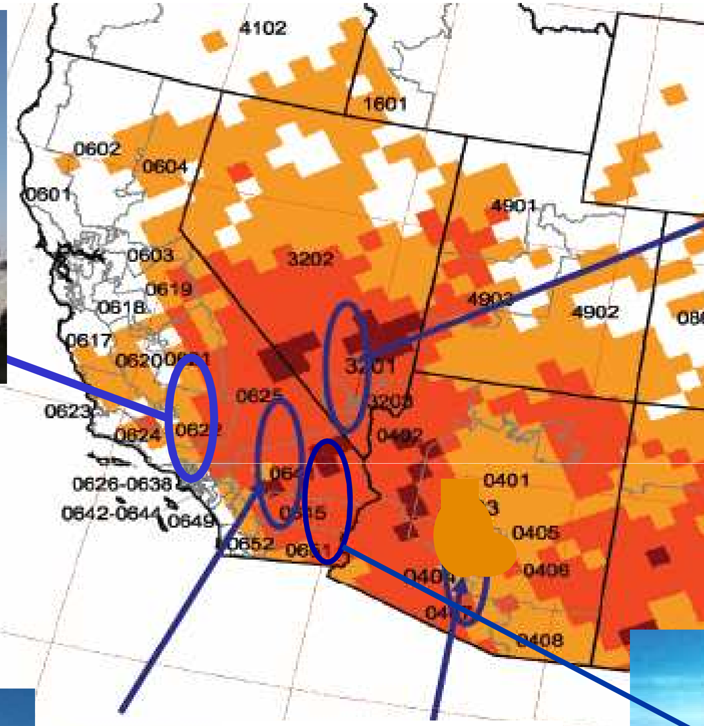


CSP USA plant locations

- U 1. Abengoa Mojave Solar Project
- U 2. Agua Caliente
- U 3. Alpine Power Tower Project
- U 4. Amargosa Farm Road Solar Energy Project 1
- U 5. Amargosa Farm Road Solar Energy Project 2
- U 6. Beacon
- U 7. Big Horn
- U 8. Black Rock Hill
- U 9. Blythe
- U 10. Boulevard's Aguila
- U 11. Bouse
- U 12. Brightsource SCE
- U 13. Brightsource PG&E 5
- U 14. Brightsource PG&E 6
- U 15. Brightsource PG&E 7
- U 16. Buckeye Landfill Project
- U 17. Burnt Mountain
- U 18. Calico Solar Energy Project
- U 19. Cameo Coal-Fired Hybrid Demonstration Project
- U 20. Centennial
- U 21. Coyote Springs 1
- U 22. Coyote Springs 2
- U 23. Crescent Dunes Tonopah)
- U 24. Crossroads
- U 25. Dendera Valley
- U 26. Eagletail
- U 27. eSolar 1
- U 28. eSolar 2
- U 29. Ft Irwin Solar Power Project
- U 30. Gaskell Sun Power Tower I
- U 31. Gaskell Sun Power Tower II
- U 32. Genesis Solar Energy Project
- U 33. Harper Lake Solar Plant
- U 34. Harquahala
- U 35. Holaniku, Keyhole Point
- U 36. Horizon
- U 37. Horizon Aguila
- U 38. Hualapai Valley Solar Project
- U 39. Hualapai Valley Solar Project
- U 40. Hyder Valley Solar Energy
- U 41. Imperial Valley Solar Project
- U 42. Ivanpah PG& E 2
- U 43. Ivanpah PG&E 1
- U 44. Ivanpah SCE
- U 45. Ivanpah Solar Electric Generating
- U 46. Kimberlina + Linear Fresnel
- U 47. Kingman Project
- U 48. La Paz Solar Tower
- U 49. La Posa Solar Therma
- U 50. Little Horn
- U 51. LSR Jackrabbit
- U 52. LSR Palo Verde
- U 53. Maricopa Solar Project
- U 54. Martin Next Generation Solar Energy Center
- U 55. Mojave Solar Park
- U 56. Mountain Spring
- U 57. Mt. Signal Solar
- U 58. Mt. Signal Solar
- U 59. Nevada Solar One
- U 60. Palen
- U 61. Palmdale Hybrid Gas-Solar Plant
- U 62. Palo Verde
- U 63. Palomas
- U 64. Quartzsite
- U 65. Quartzsite
- U 66. Ranegras
- U 67. Rice Solar Power Project
- U 68. Ridgecrest
- U 69. Saguache Solar
- U 70. Saguaro Power Plant
- U 71. San Joaquin Solar 1
- U 72. San Joaquin Solar 2
- U 73. San Luis Valley
- U 74. Santa Teresa New Mexico Sun Power Tower
- U 75. SEGS I
- U 76. SEGS II
- U 77. SEGS III
- U 78. SEGS IV
- U 79. SEGS IX
- U 80. SEGS V
- U 81. SEGS VI
- U 82. SEGS VII
- U 83. SEGS VIII
- U 84. Senator
- U 85. SES I
- U 86. SES Solar One
- U 87. SES- Solar 2
- U 88. Sierra SunTower
- U 89. Sky Trough Demonstration
- U 90. Solana
- U 91. SolarCAT Pilot Plant
- U 92. SolarCAT Pilot Plant
- U 93. Sonoran Solar Project
- U 94. Sonoran Solar Energy Project
- U 95. UA Tech Park Thermal Storage Demonstration Project
- U 96. Vicksburg
- U 97. Victorville Hybrid Gas-Solar Plant
- U 98. Western Ranch
- U 99. Westside Solar Project
- U 100. Wildcat Harquvar South
- U 101. Wildcat Harquvar South
- U 102. Wildcat Quartzsite
- U 103. Wildcat Quartzsite

OPERATIONAL PLANTS IN USA

Kimberlina 5 MW
Bakersfild, California



Nevada Solar One 64 MW
Boulder City, Nevada

Sierra Sun Tower 5 MW
Lancaster, California

Red Rock 1 MW
Arizona

SEGS Plants (Total 354 MW)
Kramer Junction / Harper Lake, California

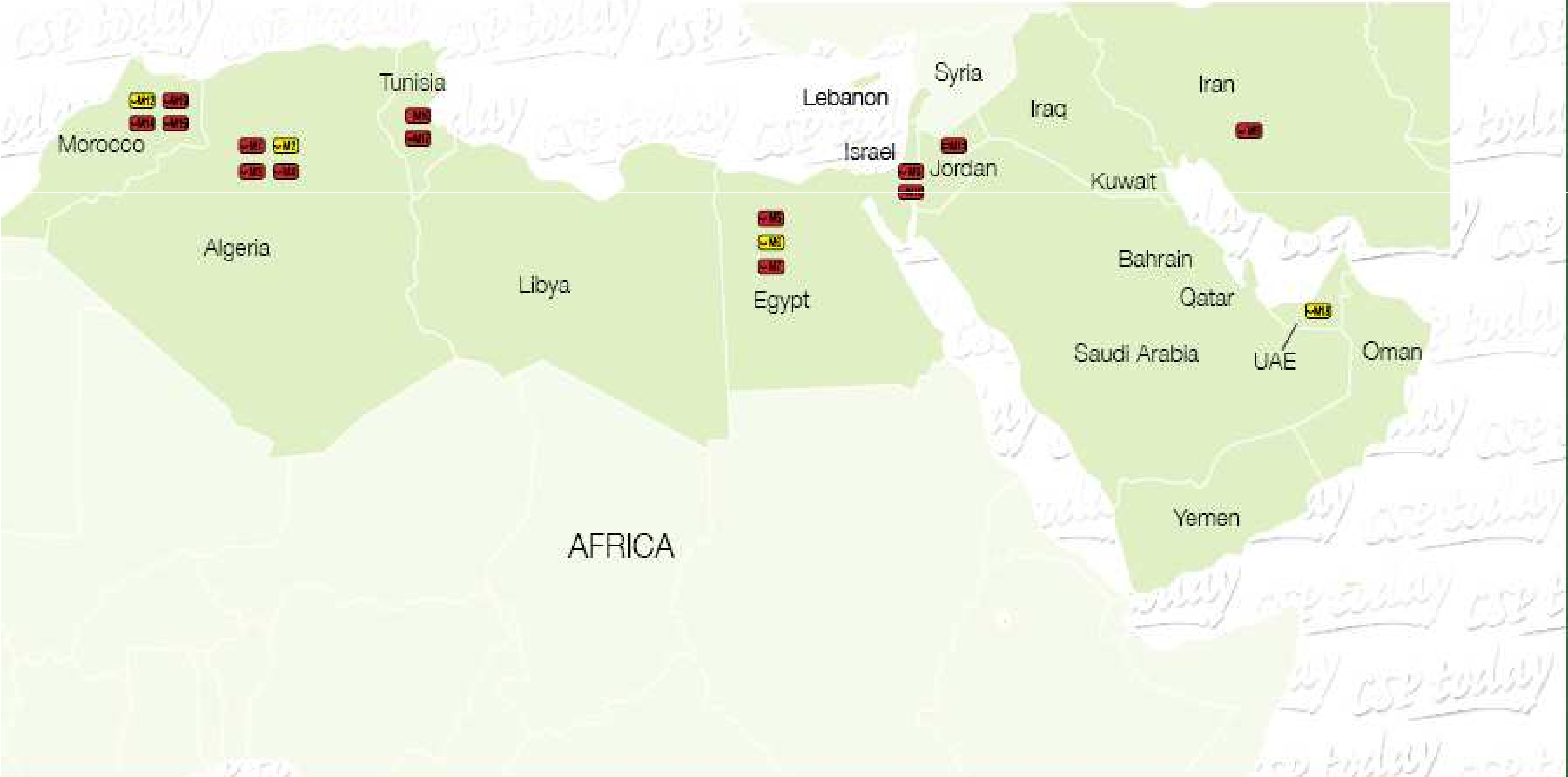
CSP MENA plant locations

KEY

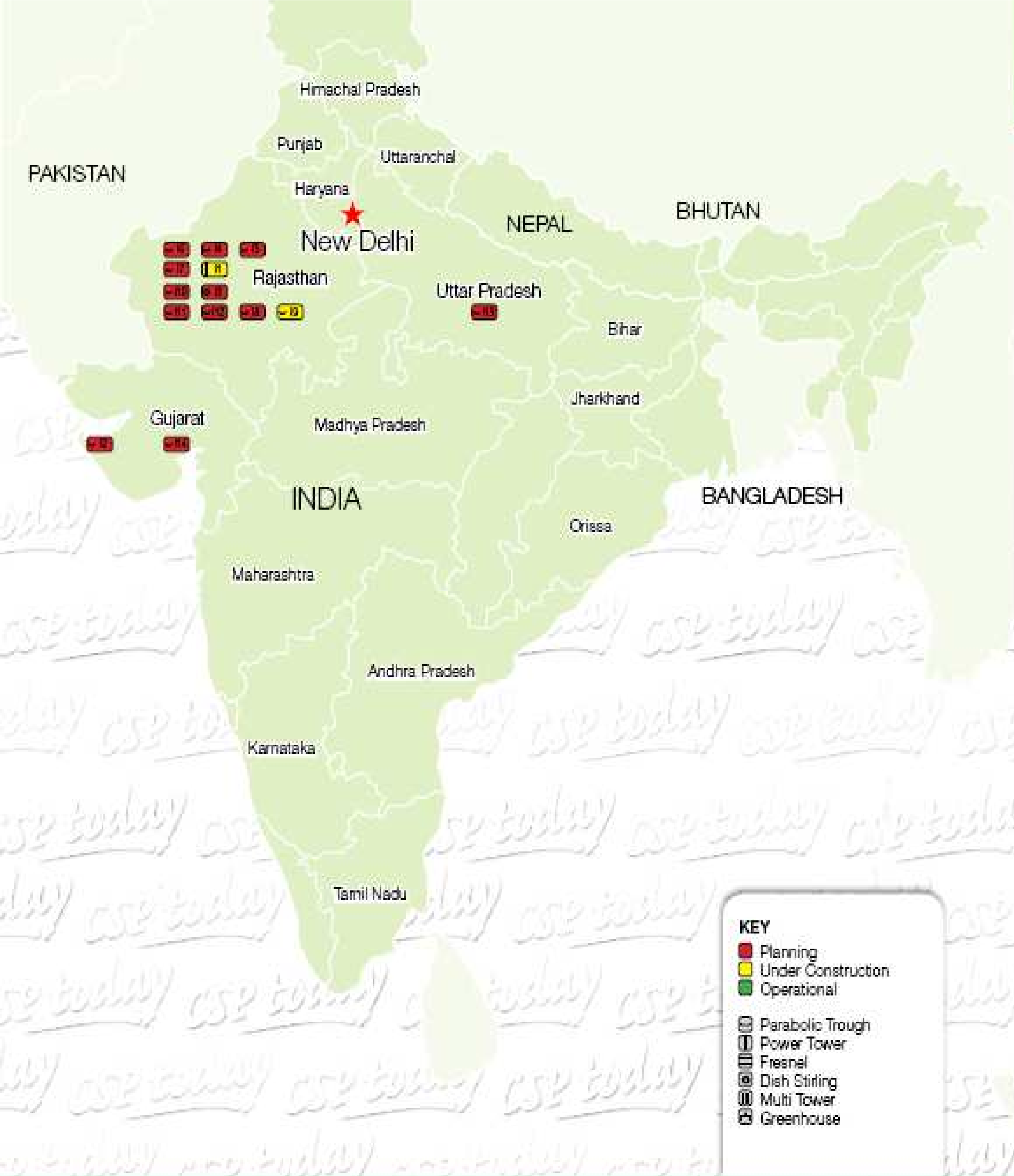
- Planning
- Under Construction
- Operational

- Parabolic Trough
- Power Tower
- Fresnel
- Dish Stirling
- Multi Tower
- Greenhouse

M 1. Algeria, Hassi-R'mel II
M 2. Algeria, Hassi-R'mel ISCC
M 3. Algeria, Meghaier
M 4. Algeria, Naâma
M 5. Egypt, Kom Ombo Project
M 6. Egypt, Kuraymat ISCC
M 7. Egypt, Marsa Alam
M 8. Iran, Yazd ISCC
M 9. Israel, Ashalim
M 10. Israel, Solar Energy Development Center (SEDC)
M 11. Jordan, Joan1
M 12. Morocco, Ain-Ben-Mathar ISCC
M 13. Morocco, Ain-Ben-Mathar ISCC 2
M 14. Morocco, Ouarzazate Project
M 15. Morocco, Tan Tan CSP-Desal Project
M 16. Tunisia, Elmed CSP – Project
M 17. Tunisia, IPP-CSP Project
M 18. UAE, Shams 1



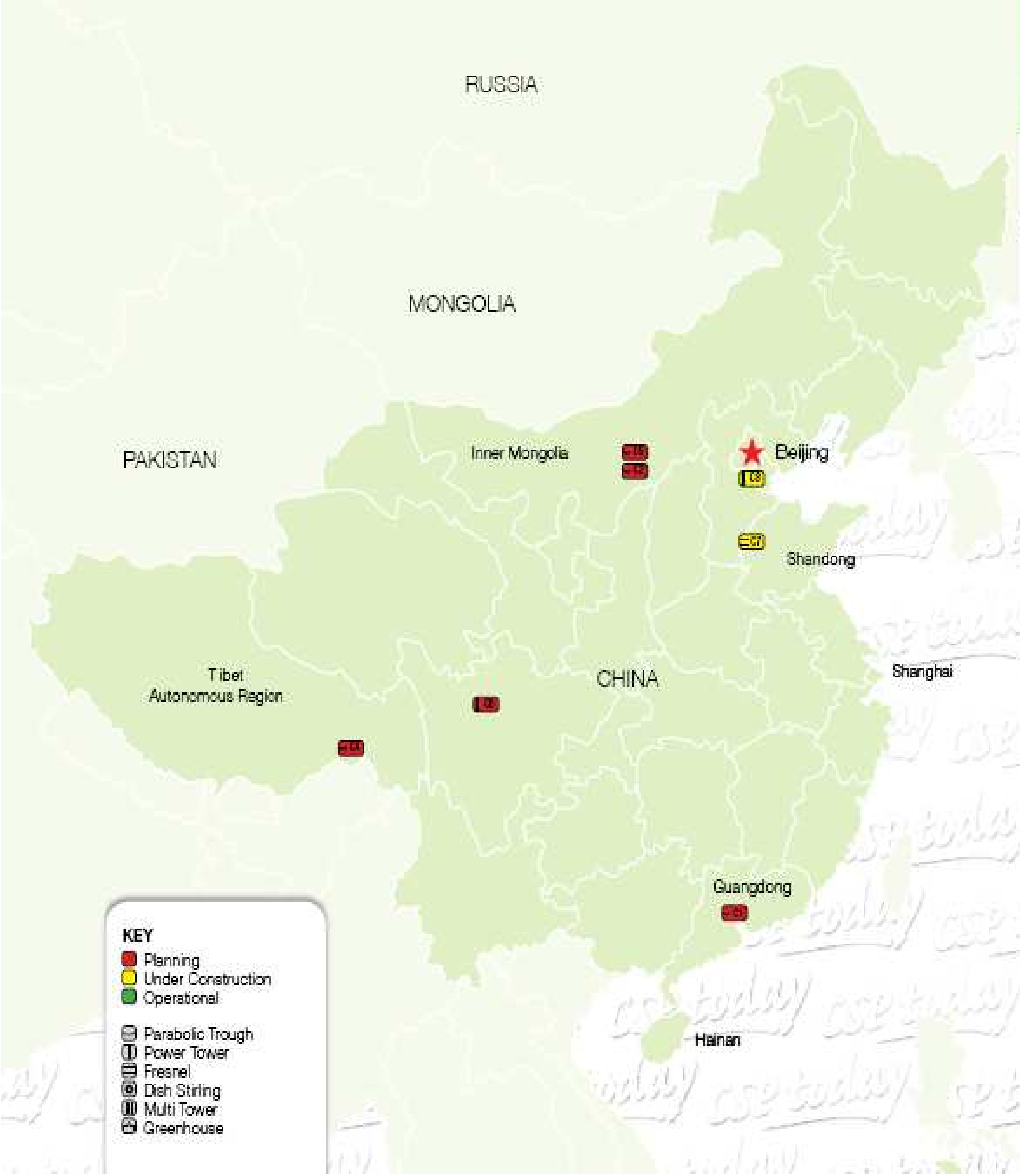
CSP India plant locations



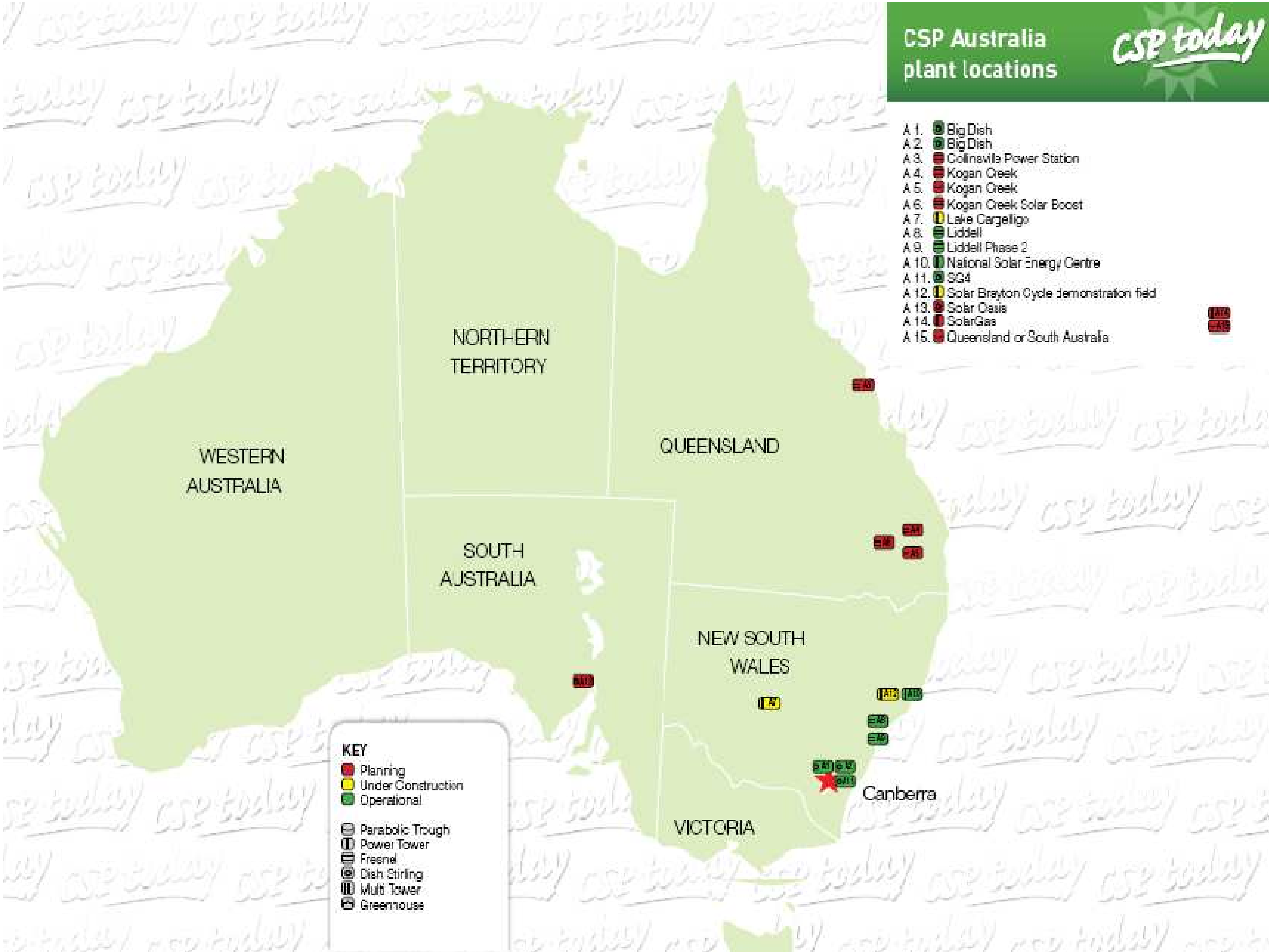
I 1. Acme Rajasthan Solar Power
I 2. Aurum Renewable Energy Private
I 3. Bap Project
I 4. Corporate Ispat Alloys Limited
I 5. Godwari Power and Ispat Limited
I 6. KVK Energy Ventures Private Limited
I 7. Lanco Infratech Limited
I 8. Megha Engineering and Infrastructures LTD
I 9. Rajasthan Solar One
I 10. Rajasthan Sun Technique Energy Private Limited
I 11. Rajasthan
I 12. Rajasthan
I 13. Uttar Pradesh
I 14. Gujarat

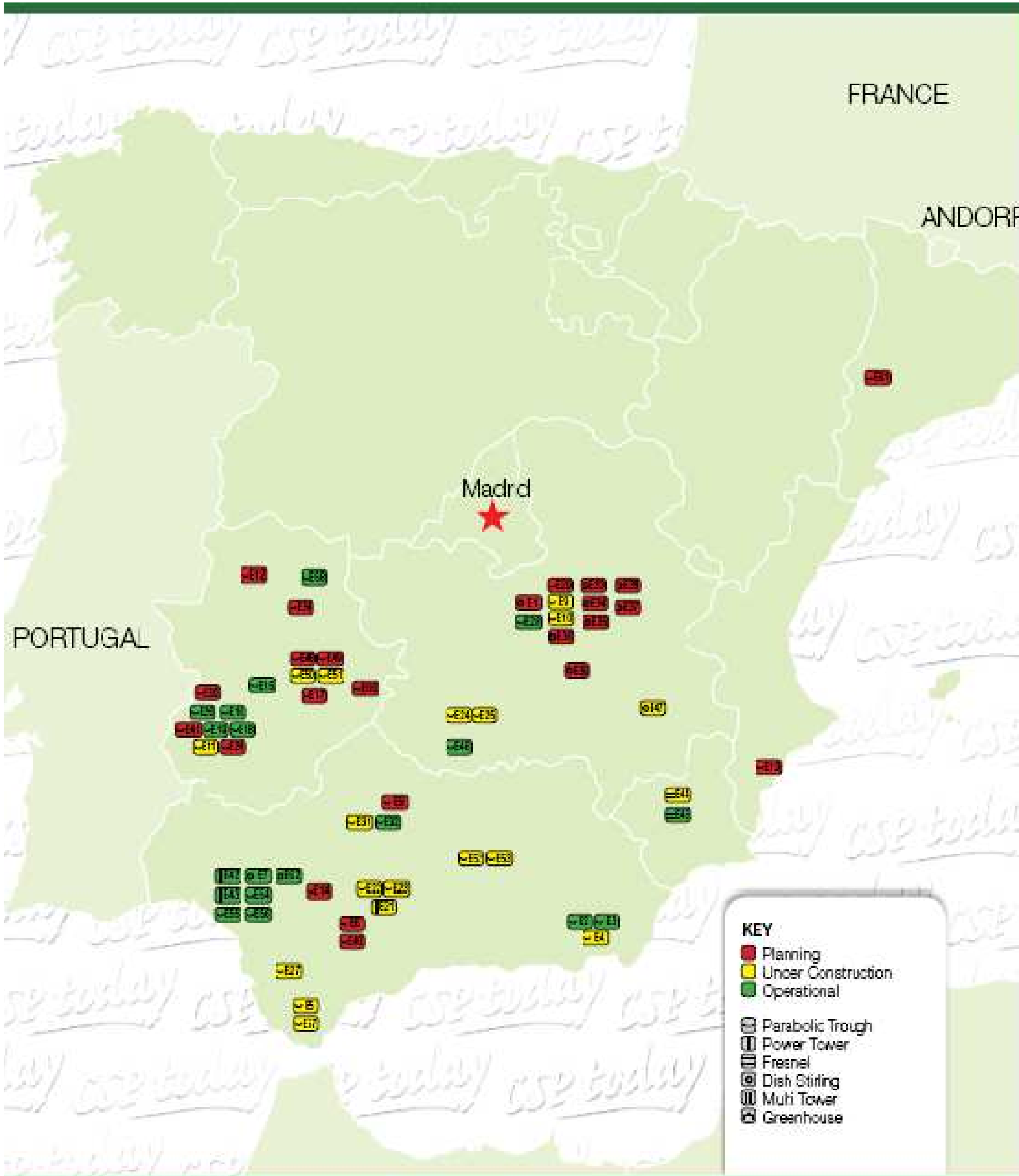
CSP China plant locations

csp today



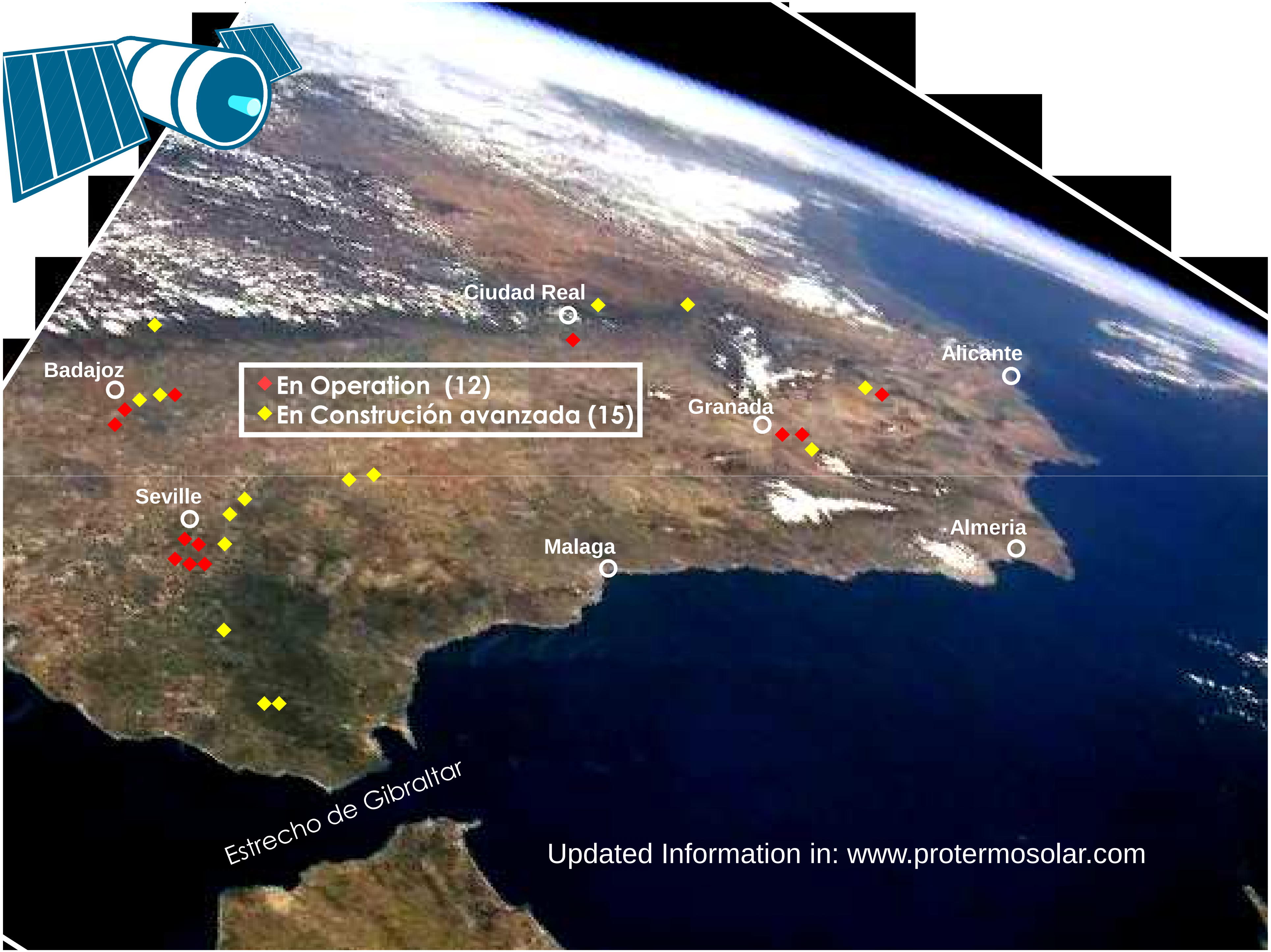
C 1. China, Guangdong
C 2. China, Ordos, Inner Mongolia
C 3. China
C 4. China, Inner Mongolia, Xin Jiang, Tibet
C 5. China, Bejing Control Technology Development
C 6. China, GD Energy
C 7. China, Himin Solar
C 8. China, IEECAS


CSP Australia
plant locations
csp today
A 1. Big Dish
A 2. Big Dish
A 3. Collinsville Power Station
A 4. Kogan Creek
A 5. Kogan Creek
A 6. Kogan Creek Solar Boost
A 7. Lake Cargelligo
A 8. Liddell
A 9. Liddell Phase 2
A 10. National Solar Energy Centre
A 11. SG4
A 12. Solar Brayton Cycle demonstration field
A 13. Solar Oasis
A 14. SolarGas
A 15. Queensland or South Australia
NORTHERN TERRITORY
WESTERN AUSTRALIA
QUEENSLAND
SOUTH AUSTRALIA
NEW SOUTH WALES
VICTORIA
Canberra
KEY
Planning
Under Construction
Operational
Parabolic Trough
Power Tower
Fresnel
Dish Stirling
Multi Tower
Greenhouse



CSP Spain plant locations

E 1. PL. Termosolar 8MW Puertollano
E 2. Andasol 1
E 3. Andasol 2
E 4. Andasol 3
E 5. Arcosol 50 (Vale 1)
E 6. Arenales PS
E 7. Aznalcollar TH
E 8. C. Termosolar "La Africana"
E 9. C.Solar Termoelectrica "AST 1A"
E 10. C.Solar Termoelectrica "AST 1B"
E 11. C.Solar Termoelectrica "Astexol-2"
E 12. C.Solar Termoelectrica Caceres
E 13. C.Solar Termoelectrica Enerstar Villena
E 14. Casablanca
E 15. Central Solar Termoelectrica La Dehesa
E 16. Central Solar Termoelectrica La Florida
E 17. Extremasol 1
E 18. Extresol 1
E 19. Extresol 2
E 20. Extresol 3
E 21. Gemasolar (CTS Solar Tres)
E 22. HelioEnergy 1
E 23. HelioEnergy 2
E 24. Helios 1
E 25. Helios 2
E 26. La Risca (Alvarado 1)
E 27. Lebrija 1
E 28. Manchasol 1
E 29. Manchasol 2
E 30. Pl. Termoelectrica de Consol Orellana
E 31. PL. Termoelectrica de Palma del Rio I
E 32. PL. Termoelectrica de Palma del Rio II
E 33. PL. Termosolar 10MW Puertollano
E 34. PL. Termosolar 10MW Puertollano
E 35. PL. Termosolar 10MW Puertollano
E 36. PL. Termosolar 10MW Puertollano
E 37. PL. Termosolar 10MW Puertollano
E 38. PL. Termosolar 14MW Puertollano
E 39. PL. Termosolar 990KW Casas de los Pinos
E 40. PL. Termosolar de Morón
E 41. PL. Termosolar de Clivenza I
E 42. PS10
E 43. PS20
E 44. Puerto Errado 2
E 45. Puerto Errado I
E 46. Puertollano Ibersol
E 47. Renovalia
E 48. Solacor 6
E 49. Solaben I
E 50. Solaben II
E 51. Solaben III
E 52. Solacor 1
E 53. Solacor 2
E 54. Solnova 1
E 55. Solnova 3
E 56. Solnova 4
E 57. Termesol 50 (Valle 2)
E 58. Termoelectrica de Majadas
E 59. Termosol 1
E 60. Termosol 2
E 61. Termosolar Borges S.L.
E 62. Envirodish


Ciudad Real
Badajoz
En Operation (12)
En Construción avanzada (15)
Alicante
Granada
Seville
Almeria
Malaga
Estrecho de Gibraltar
Updated Information in: www.protermosolar.com

	Nombre de la Central Solar Termoeléctrica	Localidad	Potencia MW	Fase	Provincia	Tecnología
OPERATIVAS	PS10	Sanlúcar la Mayor	11	Fase	Sevilla	Receptor central
	ANDASOL 1	Aldeire	50	Fase	Granada	Canales parabólicos
	PS20	Sanlúcar la Mayor	20	Fase	Sevilla	Receptor central
	PUERTOLLANO IBERSOL	Puertollano	50	Fase 1	Ciudad Real	Canales parabólicos
	PUERTO ERRADO 1	Calasparra	1,4	Fase 1	Murcia	Fresnel
	LA RISCA	Alvarado	50	Fase 1	Badajoz	Canales parabólicos
	ANDASOL 2	Aldeire	50	Fase 1	Granada	Canales parabólicos
	EXTRESOL 1	Torre de Miguel Sesmero	50	Fase 1	Badajoz	Canales parabólicos
	SOLNOVA 1	Sanlúcar la Mayor	50	Fase 1	Sevilla	Canales parabólicos
	SOLNOVA 3	Sanlúcar la Mayor	50	Fase 1	Sevilla	Canales parabólicos
	SOLNOVA 4	Sanlúcar la Mayor	50	Fase 2	Sevilla	Canales parabólicos
	LA FLORIDA	Alvarado	50	Fase 1	Badajoz	Canales parabólicos
	MAJADAS	Majadas	50	Fase 1	Cáceres	Canales parabólicos
	LA DEHESA	La Garrovilla	50	Fase 1	Badajoz	Canales parabólicos
	PALMA DEL RÍO II	Palma del Río	50	Fase 1	Córdoba	Canales parabólicos
	EXTRESOL-2	Torre de Miguel Sesmero	50	Fase 2	Badajoz	Canales parabólicos
	MANCHASOL-1	Alcázar de San Juan	50	Fase 2	Ciudad Real	Canales parabólicos
	GEMASOLAR	Fuentes de Andalucía	17	Fase 2	Sevilla	Receptor central
CONSTRUCCIÓN AVANZADA	CASA DEL ÁNGEL	Casas de los Pinos	1	Fase 3	Cuenca	Discos parabólicos
	PUERTO ERRADO 2	Puerto Errado	30	Fase 1	Murcia	Fresnel
	ANDASOL - 3	Aldeire	50	Fase 1	Granada	Canales parabólicos
	PALMA DEL RÍO I	Palma del Río	50	Fase 1	Córdoba	Canales parabólicos
	HELIOENERGY 1	Écija	50	Fase 2	Sevilla	Canales parabólicos
	HELIOENERGY 2	Écija	50	Fase 2	Sevilla	Canales parabólicos
	LEBRIJA 1	Lebrija	50	Fase 2	Sevilla	Canales parabólicos
	TERMOSOL-50	San José del Valle	50	Fase 3	Cádiz	Canales parabólicos
	ARCOSOL-50	San José del Valle	50	Fase 3	Cádiz	Canales parabólicos
	ARIES Solar Termoeléctrica Extremadura-2	Badajoz	50	Fase 3	Badajoz	Canales parabólicos
	ARIES Solar Termoeléctrica-1A	Alcázar de San Juan	50	Fase 2	Ciudad Real	Canales parabólicos
	ARIES Solar Termoeléctrica-1B	Alcázar de San Juan	50	Fase 2	Ciudad Real	Canales parabólicos
	SOL GUZMAN	Palma del Río	50	Fase 1	Córdoba	Canales parabólicos
	HELIOS I	Puerto Lápice	50	Fase 1	Ciudad Real	Canales parabólicos
	HELIOS II	Puerto Lápice	50	Fase 1	Ciudad Real	Canales parabólicos
	SOLACOR I	El Carpio	50	Fase 2	Córdoba	Canales parabólicos
	SOLACOR 2	El Carpio	50	Fase 2	Córdoba	Canales parabólicos
	SOLABEN 2	Logrosán	50	Fase 3	Cáceres	Canales parabólicos
	SOLABEN 3	Logrosán	50	Fase 3	Cáceres	Canales parabólicos
PREASIGNADAS	LA AFRICANA	Fuente Palmera	50	Fase 1	Córdoba	Canales parabólicos
	CONSOL ORELLANA	Orellana	50	Fase 1	Badajoz	Canales parabólicos
	MORÓN	Morón de la Frontera	50	Fase 2	Sevilla	Canales parabólicos
	MANCHASOL-2	Alcázar	50	Fase 3	Ciudad Real	Canales parabólicos
	OLIVENZA 1	Olivenza	50	Fase 3	Badajoz	Canales parabólicos
	EXTRESOL-3	Torre de Miguel Sesmero	50	Fase 3	Badajoz	Canales parabólicos
	SOLABEN 1	Logrosán	50	Fase 3	Cáceres	Canales parabólicos
	TERMOSOL 1	Navalvillar de Pela	50	Fase 4	Badajoz	Canales parabólicos
	TERMOSOL 2	Navalvillar de Pela	50	Fase 4	Badajoz	Canales parabólicos
	BORGES	Borges Blanques	22	Fase 4	Lérida	Canales parabólicos
	EXTREMASOL 1	Villanueva de la Serena	50	Fase 4	Badajoz	Canales parabólicos
	SOLABEN 6	Logrosán	50	Fase 4	Cáceres	Canales parabólicos
	CÁCERES	Galisteo	50	Fase 4	Cáceres	Canales parabólicos
	CASABLANCA	Talarubias	50	Fase 4	Badajoz	Canales parabólicos
	ENERSTAR VILLENA	Alicante	50	Fase 4	Alicante	Canales parabólicos
	8MW PUERTOLLANO	Puertollano	8	Fase 4	Ciudad Real	Discos parabólicos
	10MW PUERTOLLANO	Puertollano	10	Fase 4	Ciudad Real	Discos parabólicos
	10MW PUERTOLLANO	Puertollano	10	Fase 4	Ciudad Real	Discos parabólicos
	10MW PUERTOLLANO	Puertollano	10	Fase 4	Ciudad Real	Discos parabólicos
	10MW PUERTOLLANO	Puertollano	10	Fase 4	Ciudad Real	Discos parabólicos
	10MW PUERTOLLANO	Puertollano	10	Fase 4	Ciudad Real	Discos parabólicos
	14 MW PUERTOLLANO	Puertollano	12	Fase 4	Ciudad Real	Discos parabólicos
	ARENALES	Morón de la Frontera	50	Fase 4	Sevilla	Canales parabólicos

Total 60

LOCALIZACIÓN DE CENTRALES SOLARES TERMOÉLECTRICAS EN ESPAÑA

PROTERMO SOLAR

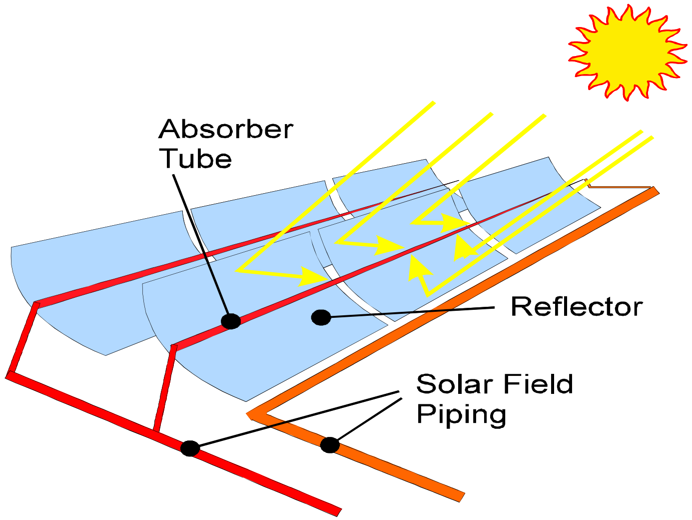
Mayo, 2011 (STE-España):

- **750 MWe operativos**
- **881 MWe en construcción avanzada**
- **842 MWe Preasignados**

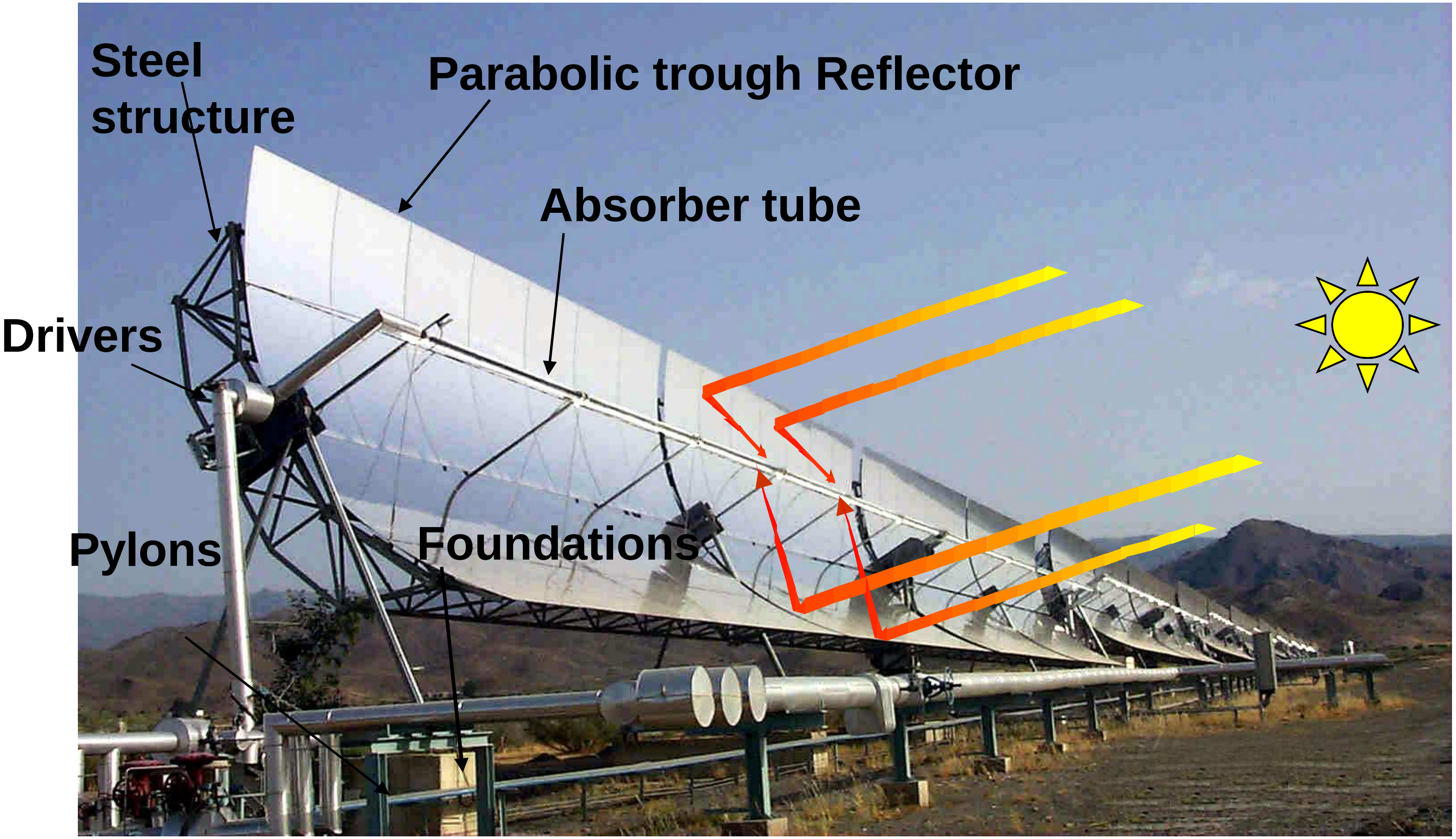
STP with Parabolic Trough (PT)

Parabolic Trough Solar Power Plant.

COMMON VIEW



Parabolic Trough Collectors



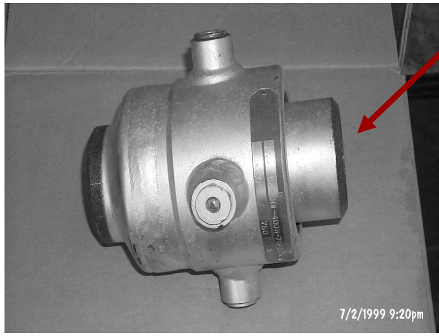
Different Drives

a) Electric

b) hydraulic

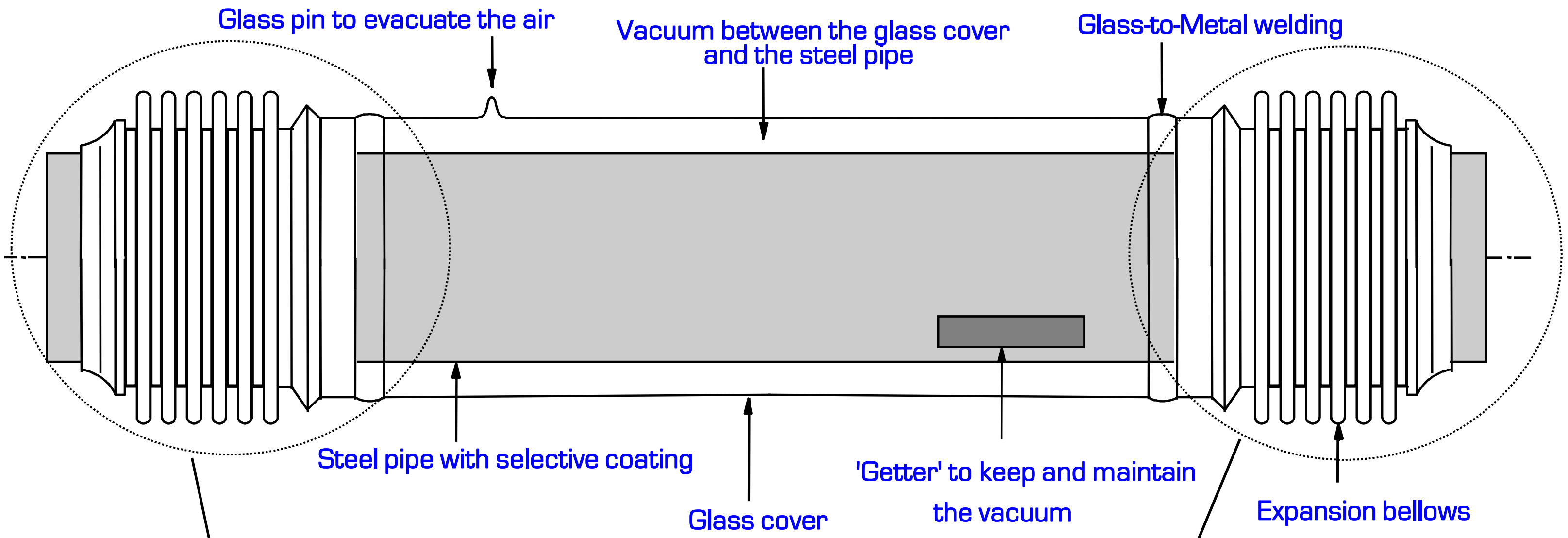
Inter connections

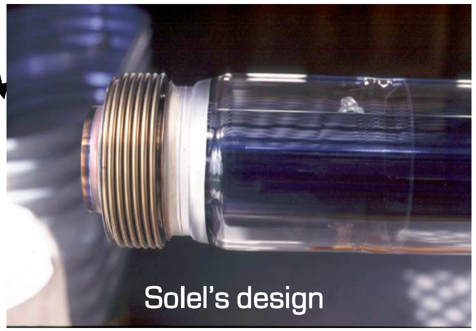
a) Flexible hoses

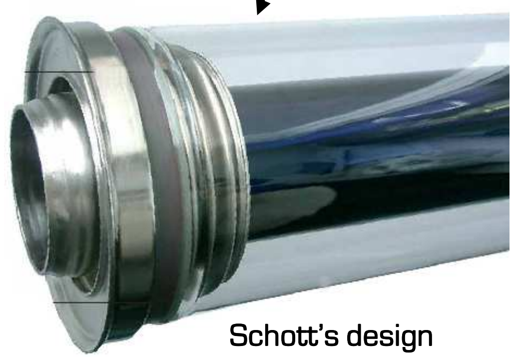


b) ball joints

Absorber Tubes for PTCs

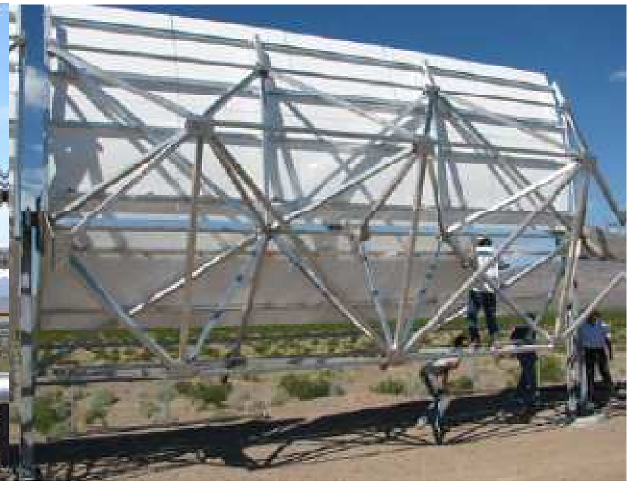






SKAL-ET 150 Flagsol

SENER



Acciona SGX SENER

ALBIASA SOLAR

LS-3

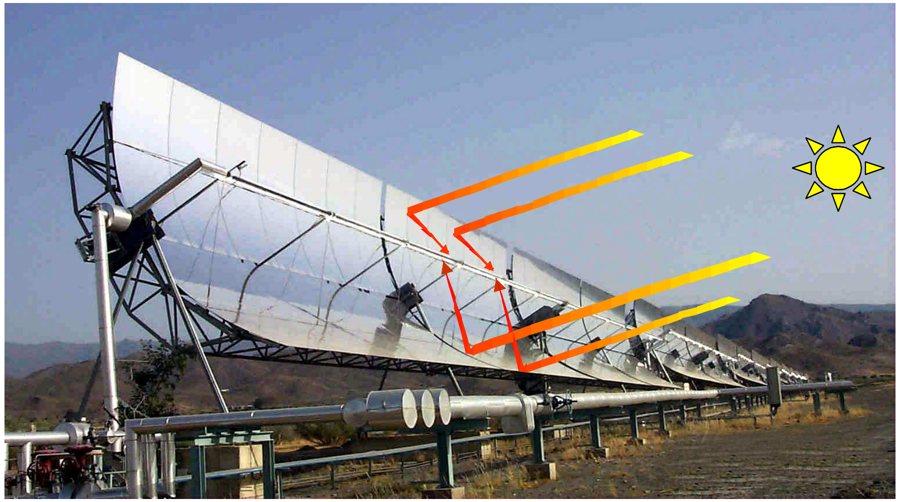
EuroTrough

Solargenix

…and many others…

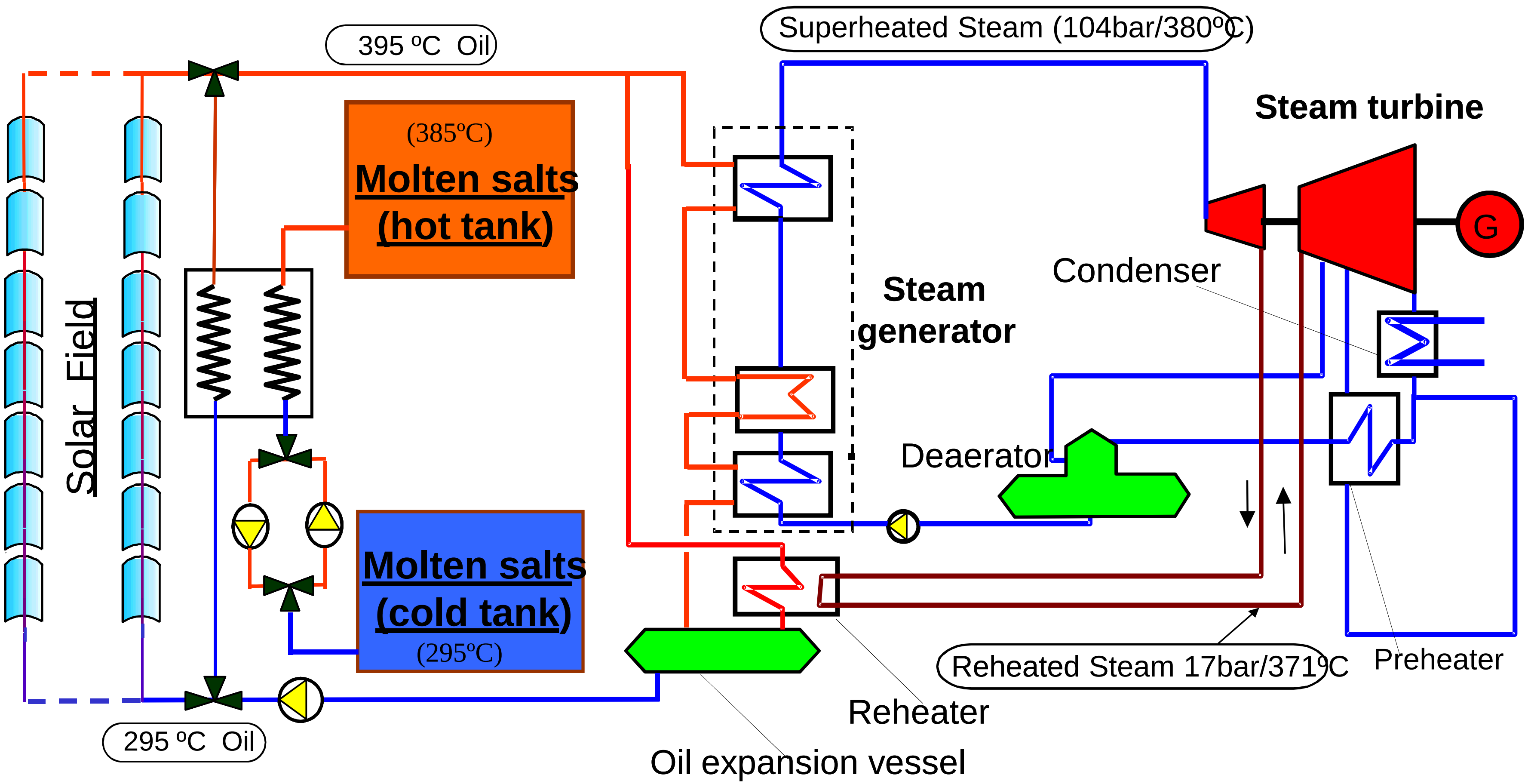
Some basic characteristics of the STP-PT

- Receiver **line focus**. 1-axis tracking, limited to ~ 500 °C. Solar Fluxes of 20-80 kW/m2.
- ~ **1km of receiver and PT per MWe** (for MS = 1 and width of 6 m).
- Conventional **Rankine steam cycle.**
- **Efficiency** (annual) solar-electricity conversion ~ 13-15% (annual average)
- **Capacity factor** of ~ 20-50%
- **PT is the most "mature"** [~ 70% of projects: 354 MW operating in California since 1989 ... + 1MWe in Arizona (2006) + 64 MWe in Nevada (2007) + 700 MWe in Spain in April, 2011 + 70 MWe in MENA + ...]
- ~ **5000 MWe for 2014-15**

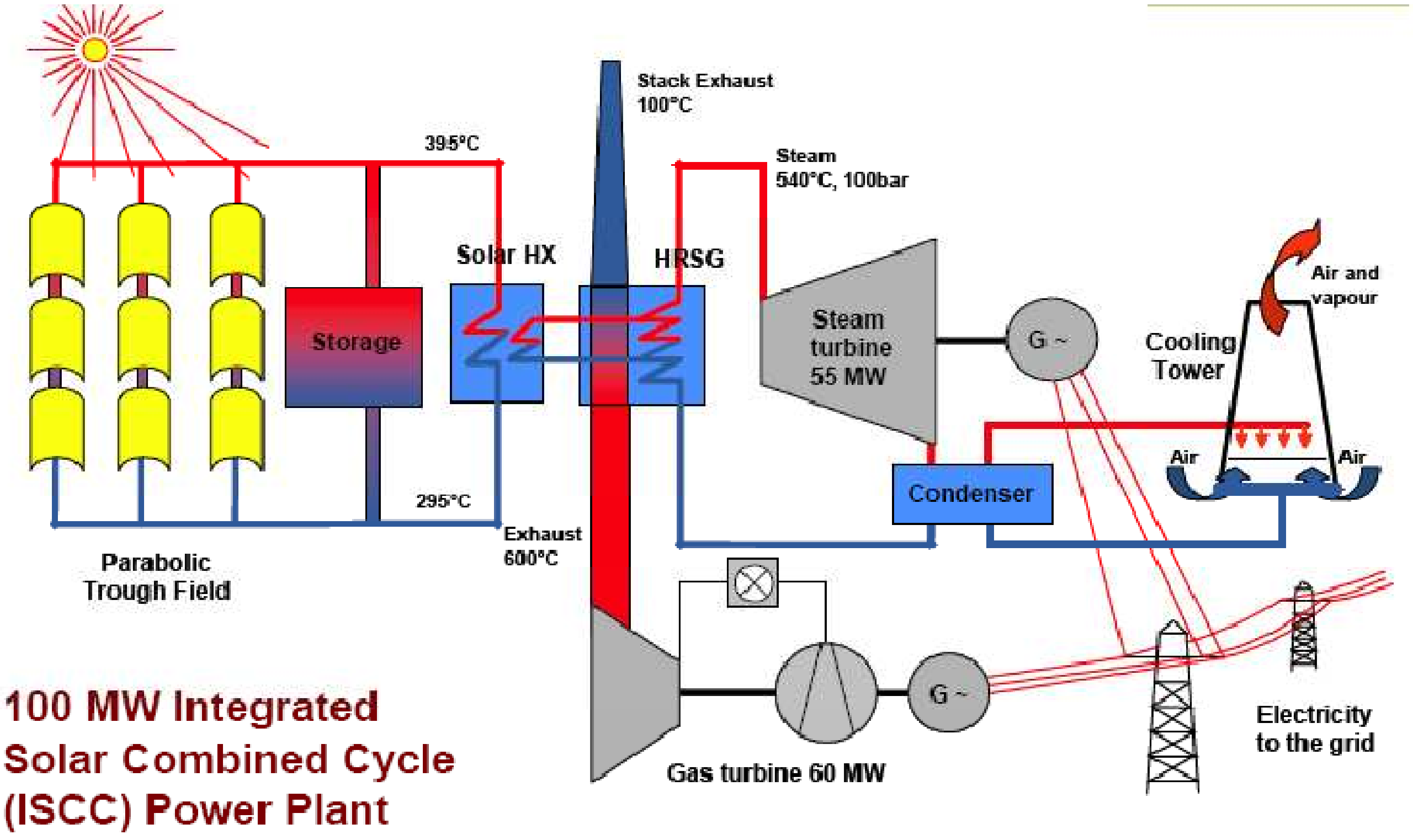


PT - "Solar" Steam Power Plant

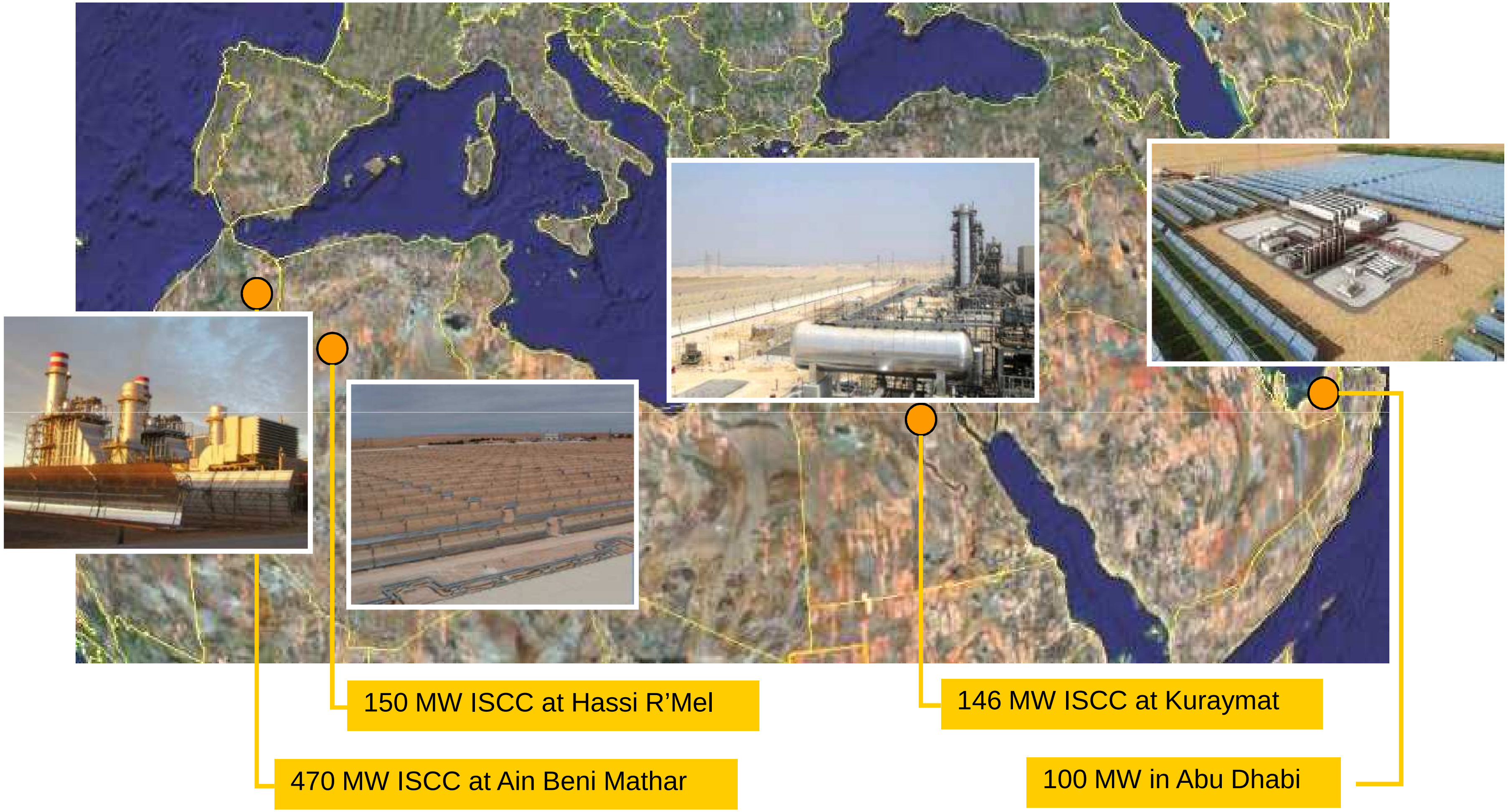
Simplified scheme of current solar power plants with PTCs (Parabolic Troughs Collectors)



Variation ISCC (Integrated Solar Combined Cycle) plant = CSP scheme with World Bank support

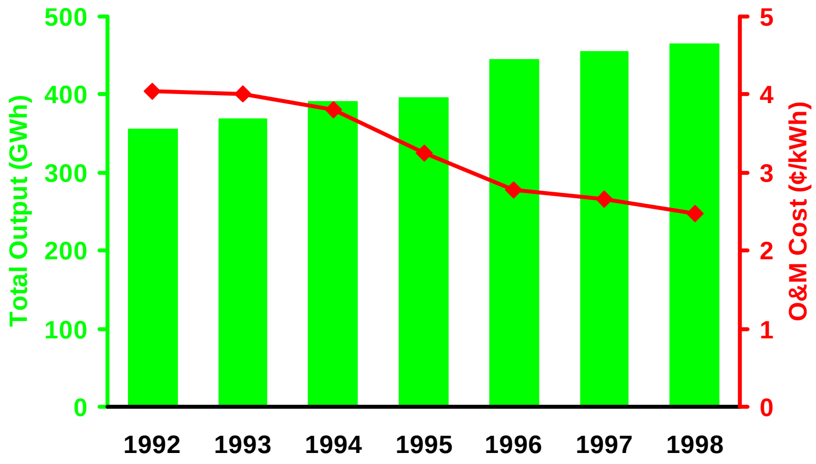


First Projects in the MENA Region



- Learning Curve reactivated from the SEGS plants, with improvements in:
  - Decreased costs of O & M> 30% from the first SEGS
  - Reduced installation time and commissioning,
  - First impact by Economies of Scale

Kramer Junction SEGS Plant Mejoras



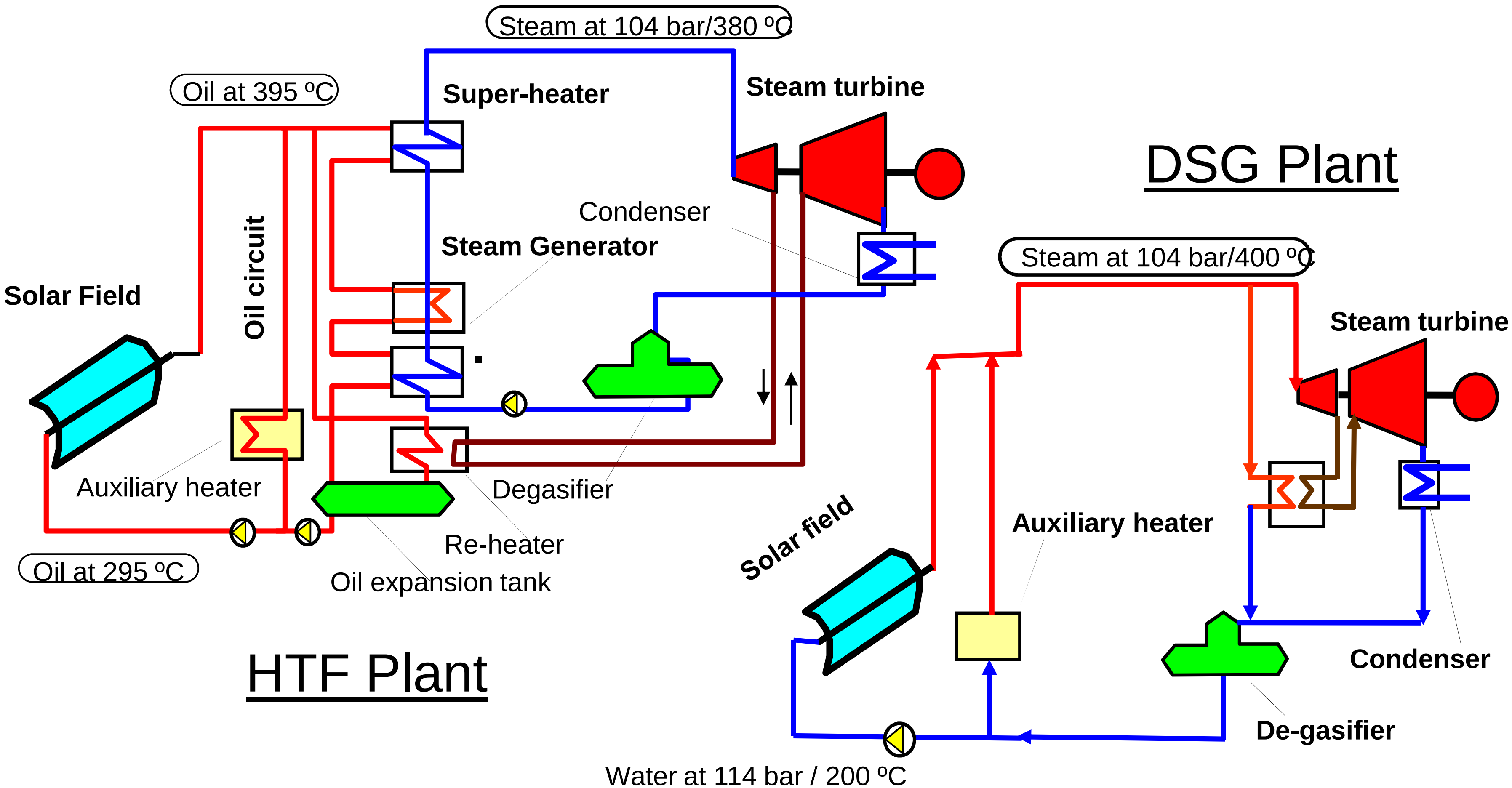
KJC

DISS/PSA

Several ways to reduce the electricity cost :

- New concepts of plant (as direct steam generation, ..)
- New components
- More competence in the supplies (mainly in the receiver, …)

✓ Direct Steam Generation (DSG) in the solar collectors to achieve higher efficiencies and simplicity



Other lines of R & D for Cost Reduction in PT

Feasibility of new working fluids that have less maintenance than oil currently used in thermal parabolic trough

Experimental Plant of PT with Gas as HTF , at PSA

Overview of the plant

PT with gas test loop in operation

Feasibility of new working fluids that have less maintenance than oil currently used in thermal parabolic trough

Pilot plant at ENEA Casaccia (Italy) with molten salt as HTF

Overview of the solar field

Eg. PT Plants CCP in operation

Eg. PT Plants CCP in operation

Eg. PT Plants CCP in operation

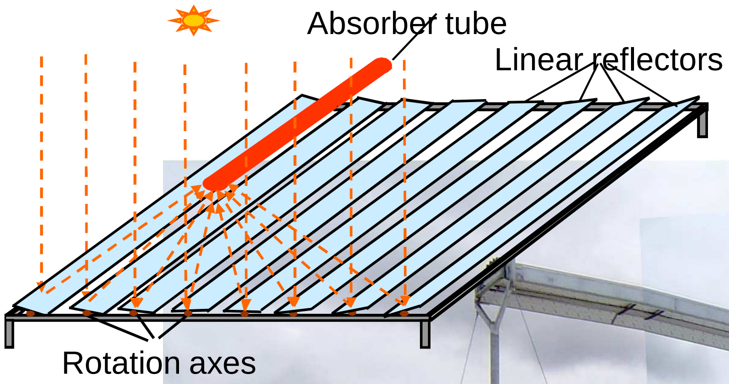
Eg. PT Plants CCP in operation

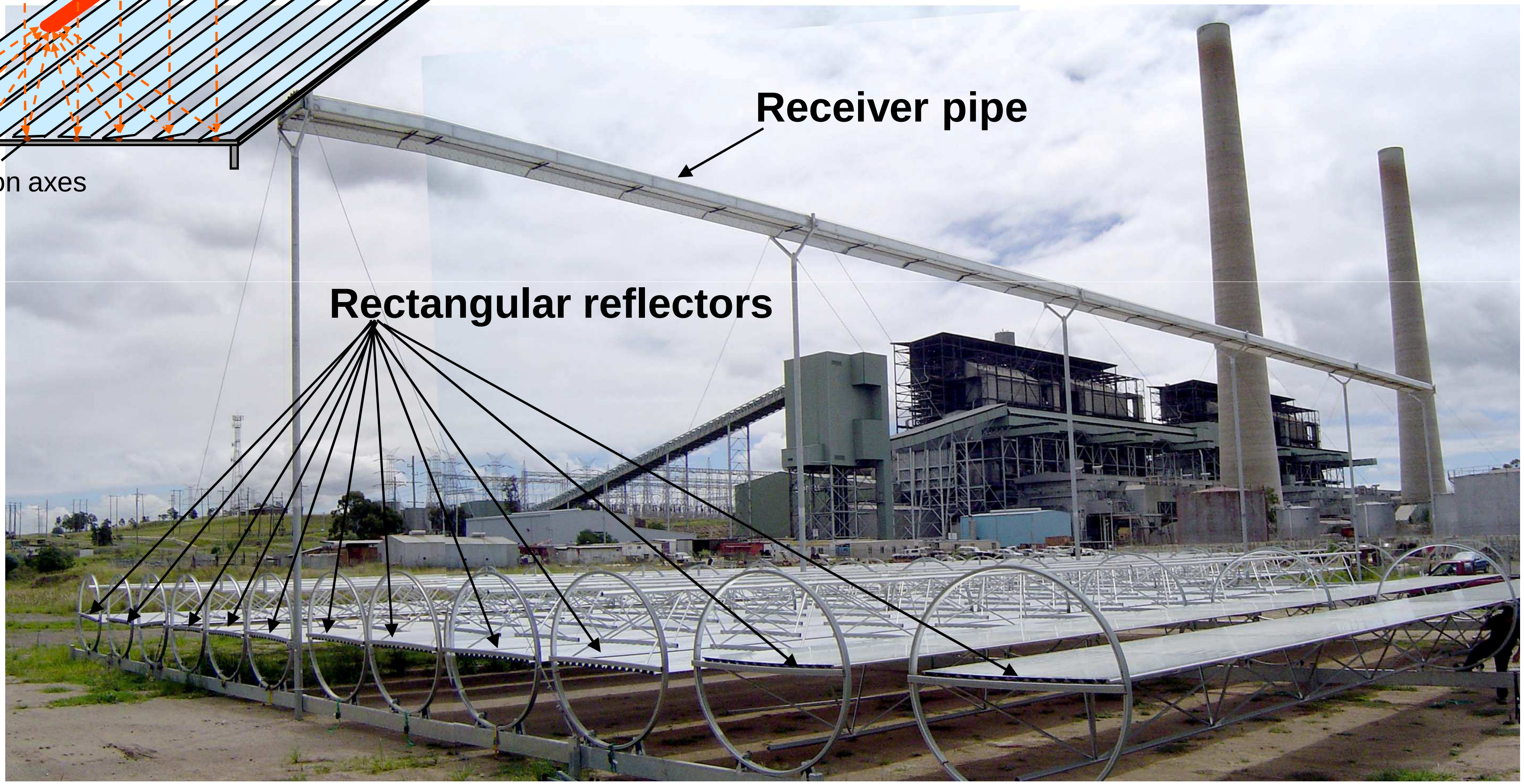
Eg. PT Plants CCP in operation

Eg. PT Plants CCP in operation

STP with Linear Fresnel Collectors

Linear Fresnel Concentrator
(Innovation for PTs ?)





- **Line focus** receiver. **1-axis tracking**, limited to **~ 350 °C** . Solar Fluxes of 10-40 kW/m2.
- Conventional **Rankine** steam **cycle**.
- **Efficiency (annual)** solar-electricity conversion ~ **9-12%** (annual average)
- **Capacity factor** ~ 20-30%
- Best occupation of land and cheaper than PT but lower concentrator optical efficiency.
- 2 MWe in Spain (Aug, 2011) + 5 MWe in USA + projects for 70 MWe in the pipeline + ...
  ~ 100 MWe for 2014-15

Ej.: 1 MW-thermal CLFR Demonstration, Australia

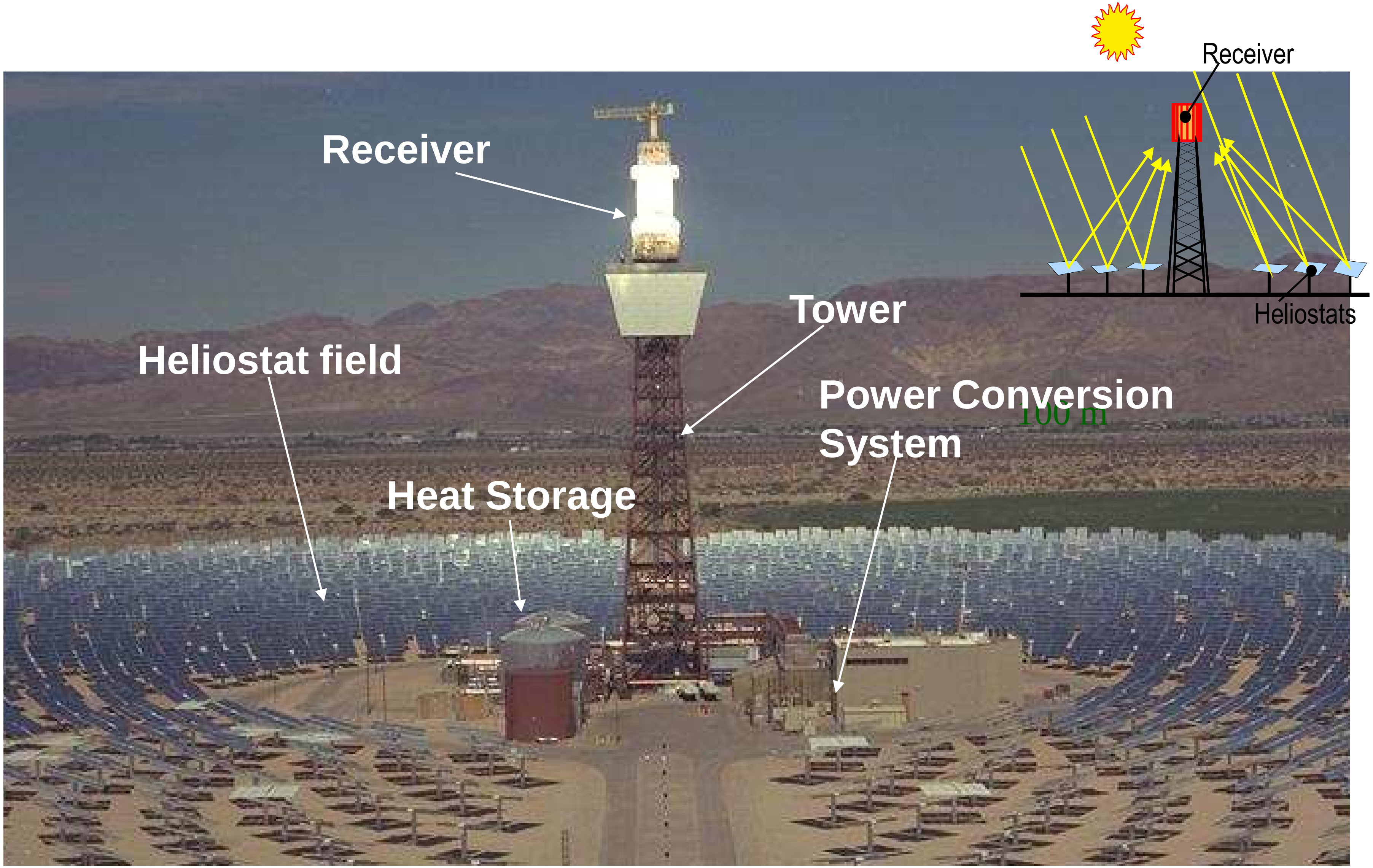
Source: Solar Heat and Power

- 1.2 megawatt of (peak) thermal power.
- Construction of additional 12 segments for 15 MW-th completed by end of 2006.
- Will be connected to steam turbine of 2,000 MW coal-fired power plant.

Eg. Puerto Errado (Spain): 2 MWe in Operation (+ …70MWe under construction)

STP with Central Receiver

Central Receiver Solar Power Plant, CR



- **Two axes tracking** is required. HTF Temperatures between **250ºC- 1100 ºC**. Solar Fluxes of **300-1000 kW/m2**
- **First Commercial Power Plant** (in the world) inaugurated in March **2007**, in Seville (Solucar-**PS10**),
- **Cycles Rankine, Brayton and Combined**
- **Numerous systems**, including extensive testing of Solar One and the PSA, have **demonstrated** the potential of power towers.
- **Mean Annual efficiencies** (solar to electricity): **13-16%**
- **Capacity factors up to ~70%** (in Spain and upto 85 % with highest DNI)
- Ongoing projects of plants:
  - ~**300 MW in Spain (50 MWe in operation**: PS10, PS20, Gemasolar**)**
  - …**2,500 MWe in USA**. (eSolar, Brightsource, Rocketdine, Solar Reserve) (5 MWe en operación)
  - 100 MWe in Sudáfrica ¿?
  - 50 MWe in MENA ¿?

COST AND PERFORMANCE FORECASTS, SL-5641 2003.

- **Learning Curve reactivated** with PS10, PS20, eSolar, Gemasolar, …
- Although the maturity is considered lower than in PT, the **greater potential in efficiency and cost reduction** of CR plants tends to balance the deployment of CR and PT plants.
- **Three preferred technology options**: Water-Steam (saturated, superheated, ...), Molten Salts and air (atmospheric or presurized).

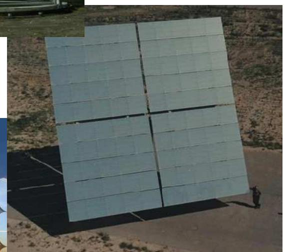
Project	Country	Power (MW $_e$)	Heat Transfer Fluid	Storage media	Beginning operation
SSPS	Spain	0.5	Liquid Sodium	Sodium	1981
EURELIOS	Italy	1	Steam	Nitrate Salt/Water	1981
SUNSHINE	Japan	1	Steam	Nitrate Salt/Water	1981
Solar One	U.S.A.	10	Steam	Oil/Rock	1982
CESA-1	Spain	1	Steam	Nitrate Salt	1982
MSEE/Cat B	U.S.A.	1	Nitrate Salt	Nitrate Salt	1983
THEMIS	France	2.5	Hitech Salt	Hitech Salt	1984
SPP-5	Russia	5	Steam	Water/Steam	1986
TSA	Spain	1	Air	Ceramic	1993
Solar Two	U.S.A.	10	Nitrate Salt	Nitrate Salt	1996
Consolar	Israel	0.5**	Pressurized Air	Fossil Hybrid	2001
Solgate*	Spain	0.3	Pressurized air	Fossil Hybrid	2002
PS10*	Spain	10	~~Air~~ **Steam**	Ceramic	~~2003~~ **Sept 2006**
Solar Tres*	Spain	15	Nitrate Salt	Nitrate Salt	~~2004~~ **2008**
PS-20*	Spain	**20**	~~Air~~ **Steam**	Ceramic	**2008**

* Projects under development.
** Thermal

…

ASM-150

GM-100



SAIC-170

ATS-150

- **Heliostat** performance is excellent and well-established
- Actual reference:
  - Sizes ~ 120 m2
  - Specific Cost: ~200 €/m2
- Reducing costs is a priority for the profitability.

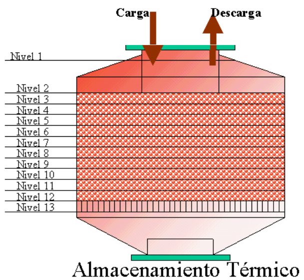
Solar Two

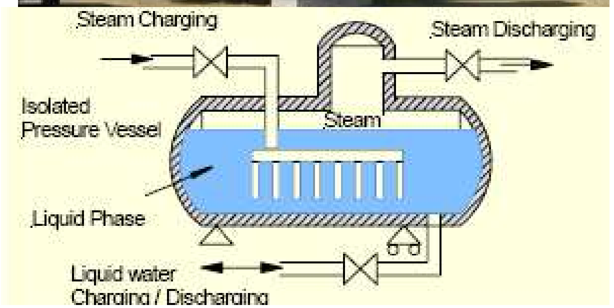
- **Receiver** pe
  demonstrated
- Lifetime and
- Advanced sy
  temperature
  (superheated
  salts: **500-60**

Pilot Plant and Small Heliostat (7.3 m2) of Bright Source&LUZ 2

CR Power Towers: Status

- **Heat Storage** found a **good solution** when **molten salts** are used; **reasonable solution** when using **air** and is **pending for improvements when using water steam** as HTF.
- Costs reduction should achieve values < ~20 €/kWh.

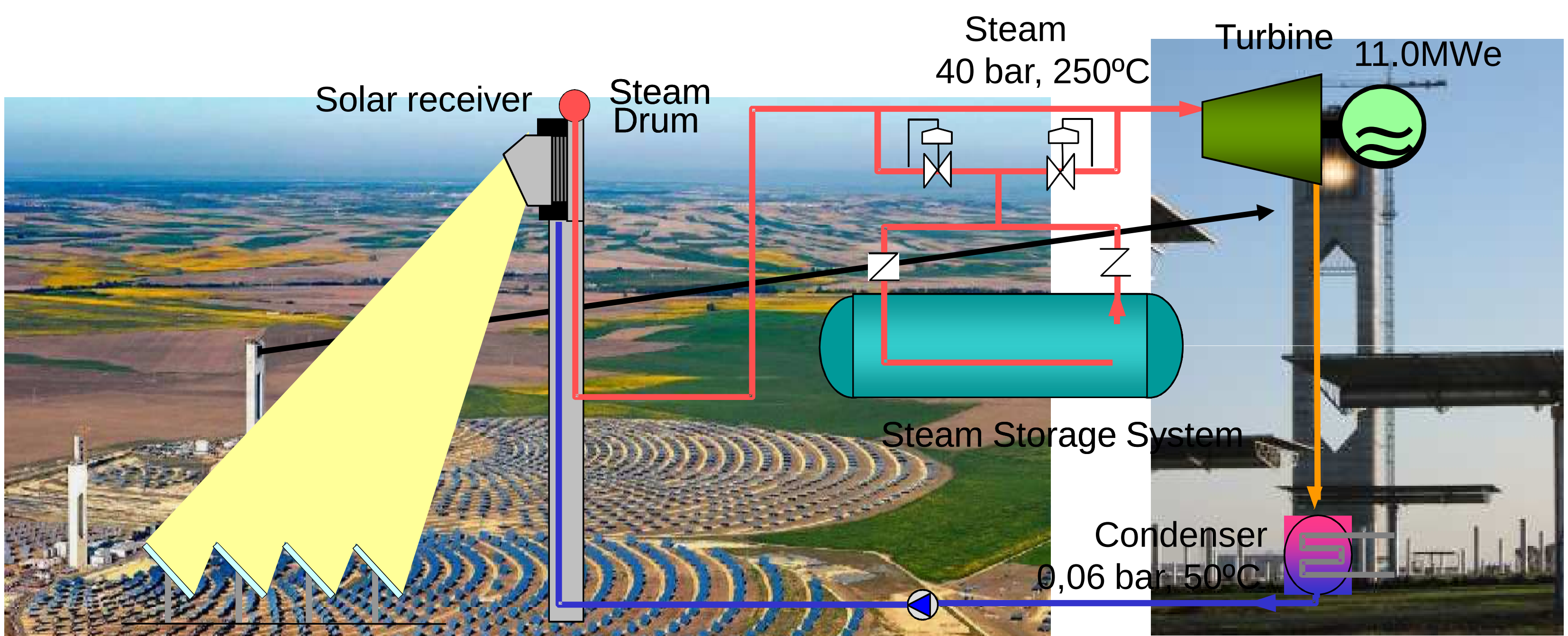




TSA

CR: First Commercial Power Plants.
PS 10 and PS 20

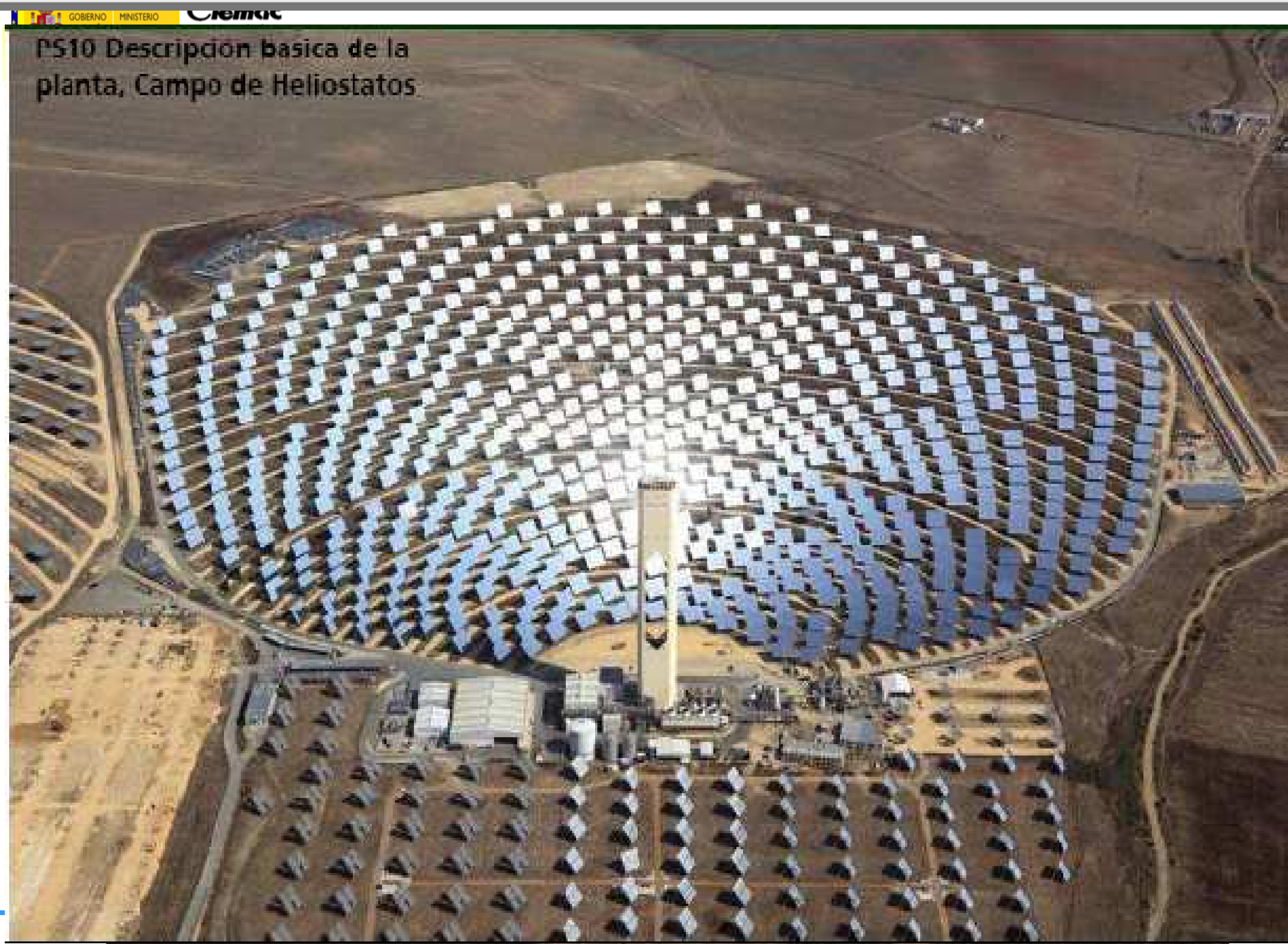
SOLUCAR PS10 Sanlucar Solar Project



General Description	
Emplacement	Sanlúcar M. (Sevilla), Lat 37.4º, Lon 6.23º
Nominal Power	11.02MWe
Tower Height	100m
Receiver Technology	Saturated Steam
Receiver Geometry	Cavity180º, 4 Pannels 5m x 12m
Heliostats	624 @ 121m2
Thermal Storage Technology	Water/Steam
Thermal Storage Capacity	15MWh, 50min @ 50% Rate
Steam Cycle	40bar 250ºC, 2 Pressures
Electric Generation	6.3kV, 50Hz -> 66kV, 50Hz
Land	60Has
Annual Electricity Production	23.0GWh

Vista aérea de las Plantas PS-

PS10 Y PS20 en Sanlucar la Mayor, Sevilla


GOBIERNO
MINISTERIO
PS10 Descripcion basica de la
planta, Campo de Heliostatos

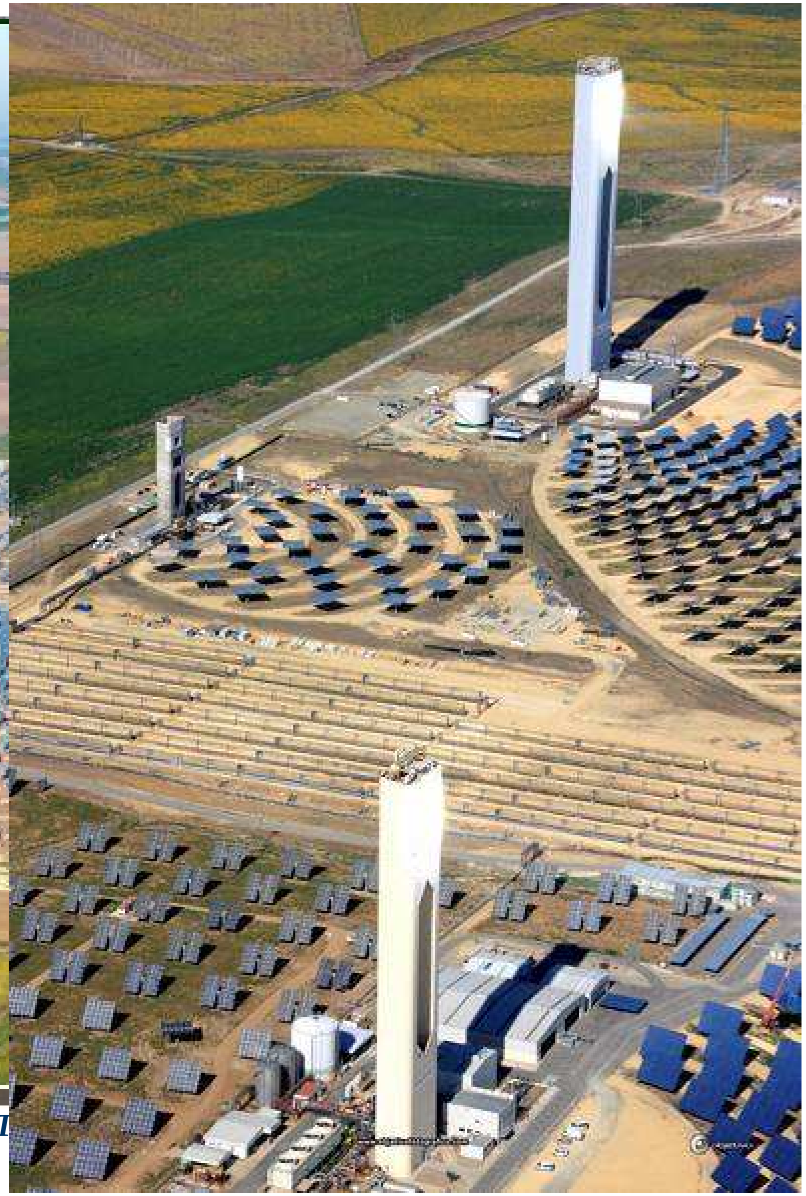
Heliostats Aiming Tests

GOBIERNO DE ESPAÑA MINISTERIO DE CIENCIA

Ciemat Centro de Investigaciones

Concentrated Solar Flux

PS20. Already in Commercial application



Alpine Sun Tower: Planta de 92 MWe de eSolar en California

National Renewable Energy Laboratory
Concentrating Solar Power: Projects

Alpine SunTower

This page provides information on Alpine SunTower, a concentrating solar power (CSP) project, with data organized by background, participants, and power plant configuration. Pacific Gas and Electric Company has entered into an agreement with Alpine SunTower, LLC, a subsidiary of NRG Energy, for 92 megawatts of renewable, solar thermal power. The Alpine SunTower project features eSolar's modular, scalable solar thermal technology and is scheduled for completion in 2012.

Project Overview

Project Name:	Alpine SunTower
Country:	United States
Location:	Lancaster, California (Antelope Valley)
Owner(s):	
Technology:	Power tower
Turbine Capacity:	Net: 92.0 MW
Status:	Under development
Start Year:	2012

Do you have more information, corrections, or comments?

Status Date:	November 6, 2009

Background

Technology:	Power tower
Status:	Under development
Country:	United States
City:	Lancaster
State:	California
Region:	Antelope Valley
Electricity Generation:	192,000 MWh/yr
Start Production:	2012
PPA/Tariff Date:	June 25, 2009

Participants

Developer(s):	NRG Energy
Generation Offtaker(s):	Pacific Gas & Electric (PG&E)

Plant Configuration

Solar Field

Heliostat Manufacturer:	eSolar

Power Block

Turbine Capacity (Net):	92.0 MW

Ivanpah: 440 MWe (de Brightsource ~Luz2) en California

National Renewable Energy Laboratory
Concentrating Solar Power: Projects

Ivanpah Solar Electric Generating Station

This page provides information on Ivanpah Solar Electric Generating Station , a concentrating solar power (CSP) project, with data organized by background, participants, and power plant configuration.

Project Overview

Project Name:	Ivanpah Solar Electric Generating Station (Ivanpah)
Country:	United States
Location:	Primm, NV, California
Owner(s):	
Technology:	Power tower
Turbine Capacity:	Net: 440.0 MW Gross: 468.0 MW
Status:	Under development
Start Year:	2013

Do you have more information, corrections, or comments?

Status Date:	December 17, 2009

Background

Technology:	Power tower
Status:	Under development
Country:	United States
City:	Primm, NV
State:	California
County:	San Bernardino, CA
Lat/Long Location:	35°33' 8.5? North, 115°27' 30.97? West
Land Area:	4,073 acres
Solar Resource:	2,717 kWh/m ²/yr
Source of Solar Resource:	NREL Solar Power Prospector
Electricity Generation:	1,079,232 MWh/yr (Expected/Planned)
Contact(s):	Andy Taylor
Company:	BrightSource Energy
Break Ground:	January 2010
Start Production:	October 2013
Construction Job-Years:	1896
Annual O&M Jobs:	90
Tariff Period:	20 to 25 years
Project Type:	Commercial Plant

Participants

Developer(s):	BrightSource Energy
EPC Contractor:	Bechtel Engineering
Generation Offtaker(s):	Pacific Gas & Electric; Southern California Edison

Plant Configuration

Solar Field

Heliostat Solar-Field Aperture Area:	2,295,960 m ²
# of Heliostats:	214,000
Heliostat Aperture Area:	14.08 m ²
Tower Height:	459 ft

Receiver Manufacturer:	Riley Power
Receiver Type:	Solar receiver steam generator
Heat-Transfer Fluid Type:	Water
Receiver Inlet Temp:	480°F
Receiver Outlet Temp:	1050°F
Receiver Temp. Difference:	570°F

Power Block

Turbine Capacity (Gross):	468.0 MW
Turbine Capacity (Net):	440.0 MW
Turbine Description:	Gross is 117 MW per unit; net is 110 MW per unit
Output Type:	Rankine
Cooling Method:	Dry cooling
Annual Solar-to-Electricity Efficiency (Gross):	28.72%
Fossil Backup Type:	Natural gas

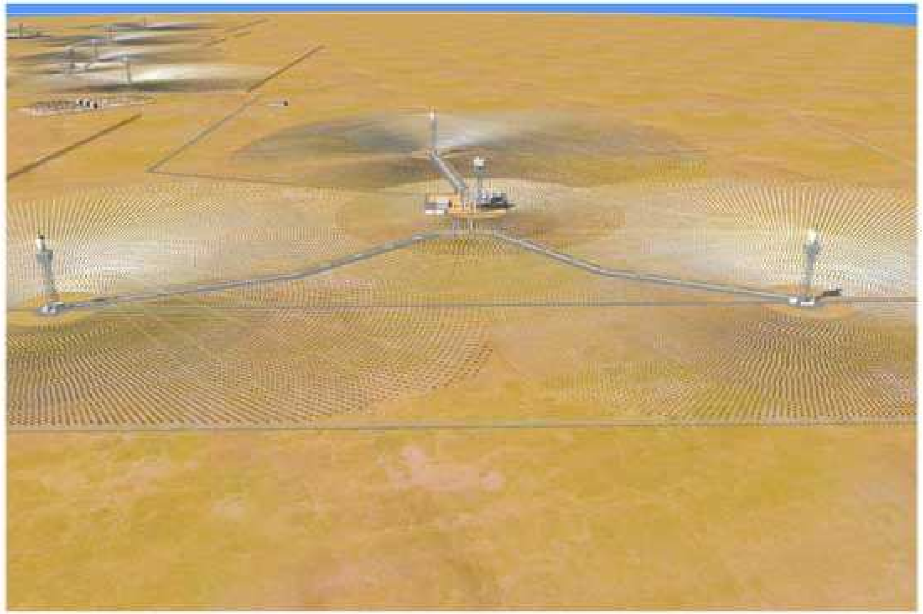
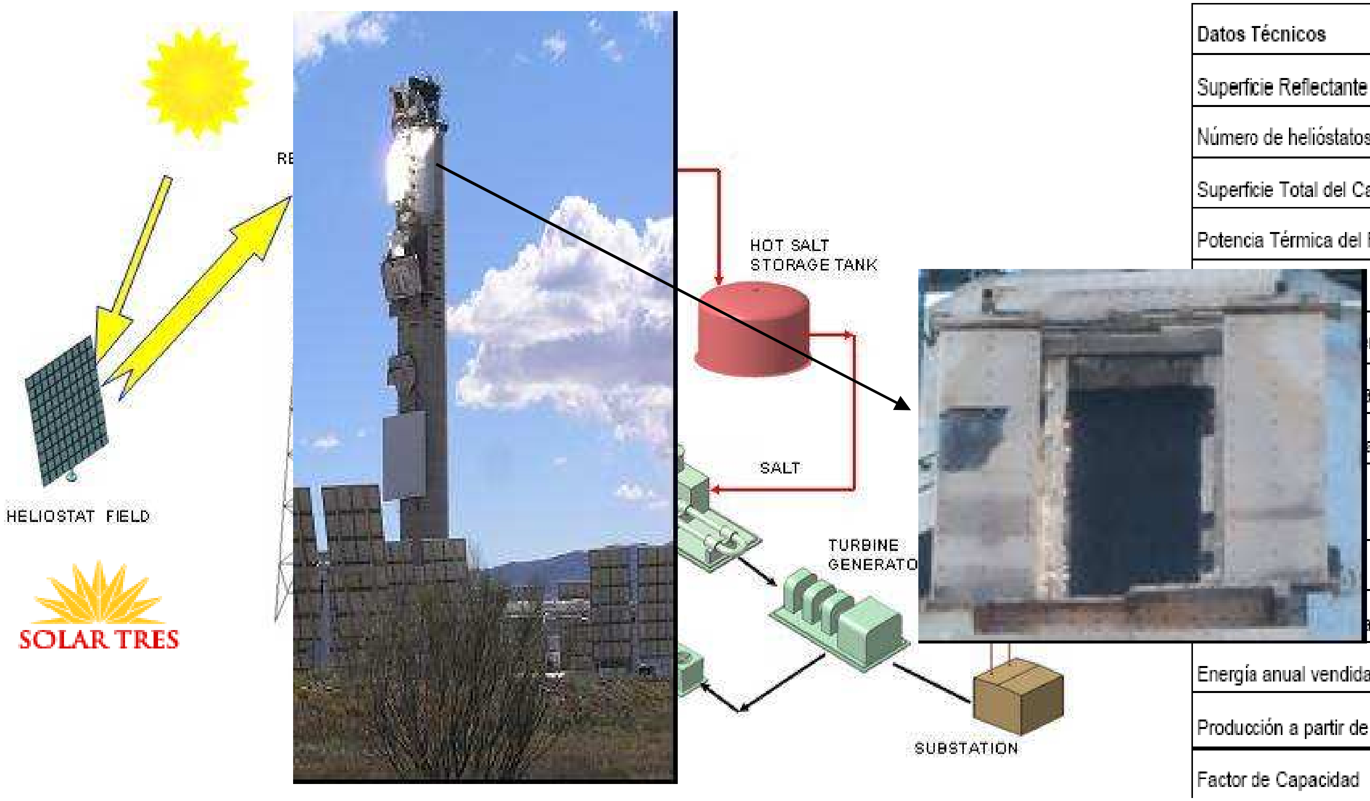


FIGURE 1.3-4
CLOSE-UP OF IVANPAH 1
IVANPAH SOLAR ELECTRIC GENERATING SYSTEM
CH2MHILL

Solar Tres / GEMASOLAR



Datos Técnicos	
Superficie Reflectante del Campo de Helióstatos	264825 m^2
Número de helióstatos	2750
Superficie Total del Campo de Helióstatos	142.31 Ha
Potencia Térmica del Receptor	120 MWt
	120 m
...namiento Térmico	15 horas
...a	17 MWe
...a de GN	16 MWt
...l directa anual sobre Helióstatos	2062 kWh/m^2
Energía anual vendida	105566 MWhe
Producción a partir de GN	15%
Factor de Capacidad	71%

- **Solar Tres** Project partially financed by the **European Commission** (with 5 M€; Contract No. NNE5/2001/369; with a consortium **SENER, CIEMAT, ALSTOM-SIEMENS, SAINT GOBAIN y GHERSA.**
- Sener & Ciemat (with a budget of 6 M€) **validated the receiver Technology**
- **TORRESOL** promotes the **GEMASOLAR** Power plant (budget ~240 M€)

6. Construcción y puesta en marcha de GEMASOLAR

Construcción Abril 2009

GOBIERNO DE ESPAÑA MINISTERIO DE CIENCIA E INNOVACIÓN
Ciemat Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas

Torresol Energy reinventing solar power

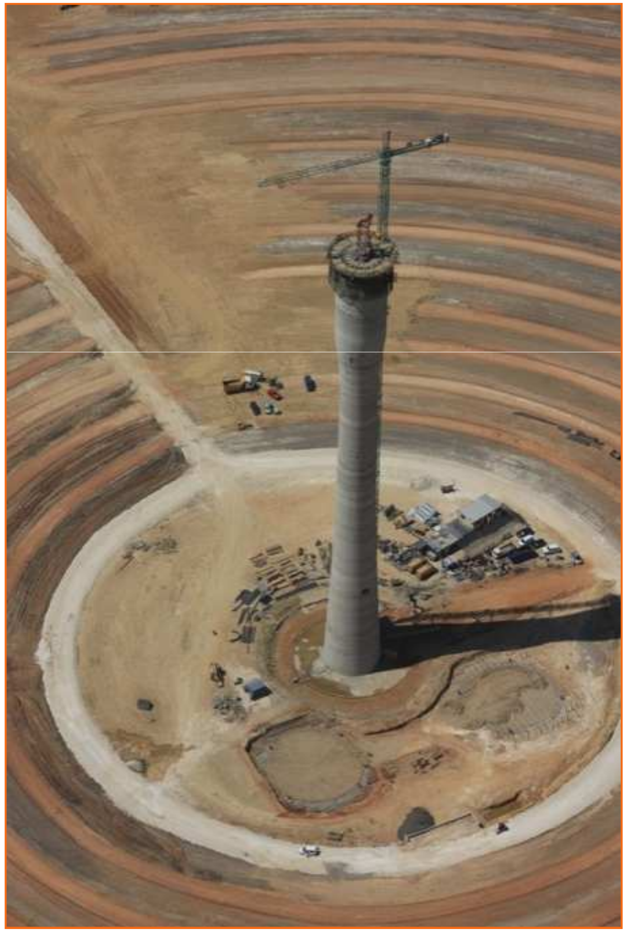
6. Construcción y puesta en marcha de GEMASOLAR

Construcción Mayo 2009

2 días más tarde →

6. Construcción y puesta en marcha de GEMASOLAR

Construcción Junio 2009



6. Construcción y puesta en marcha de GEMASOLAR

Construcción Octubre 2009

6. Construcción y puesta en marcha de GEMASOLAR

Construcción Mayo 2010

6. Construcción y puesta en marcha de GEMASOLAR

Mecanismos de heliostatos

6. Construcción y puesta en marcha de GEMASOLAR

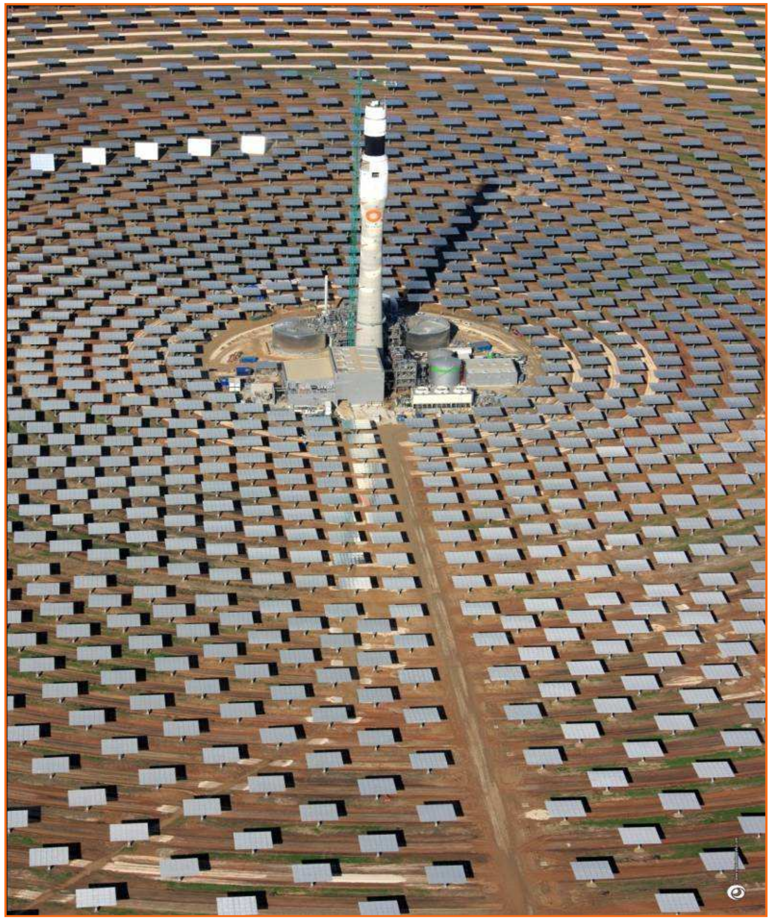
Construcción Mayo 2010

6. Construcción y puesta en marcha de GEMASOLAR

Construcción Octubre 2010

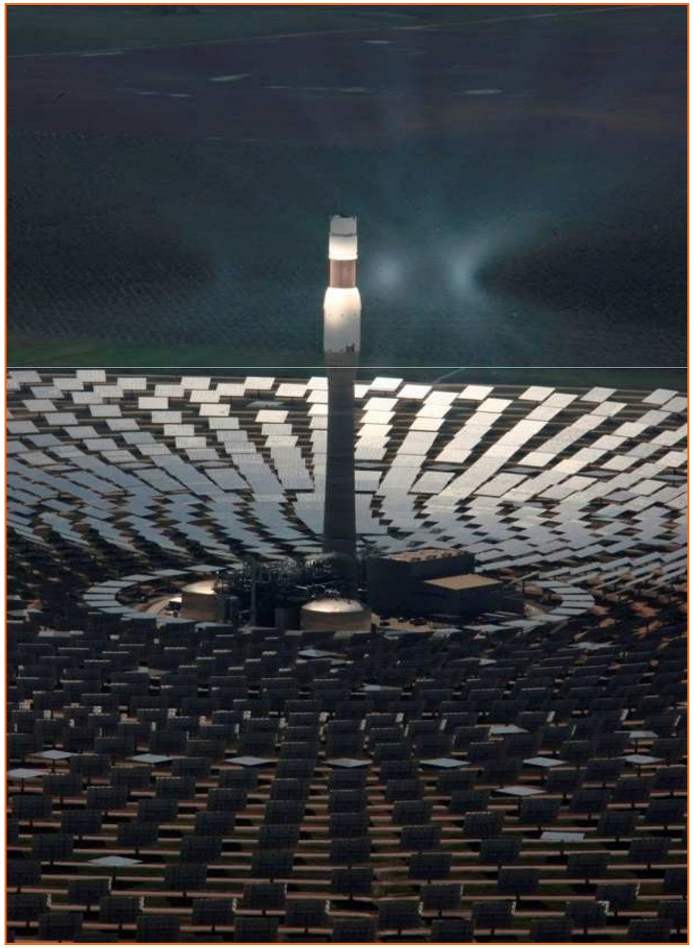
6. Construcción y puesta en marcha de GEMASOLAR

Finalización de la construcción Diciembre 2010



6. Construcción y puesta en marcha de GEMASOLAR

Puesta en Marcha 2011



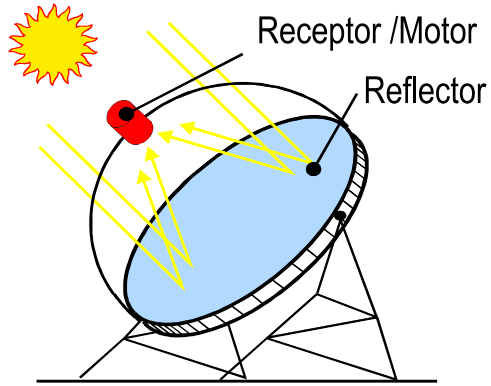
6. Construcción y puesta en marcha de GEMASOLAR

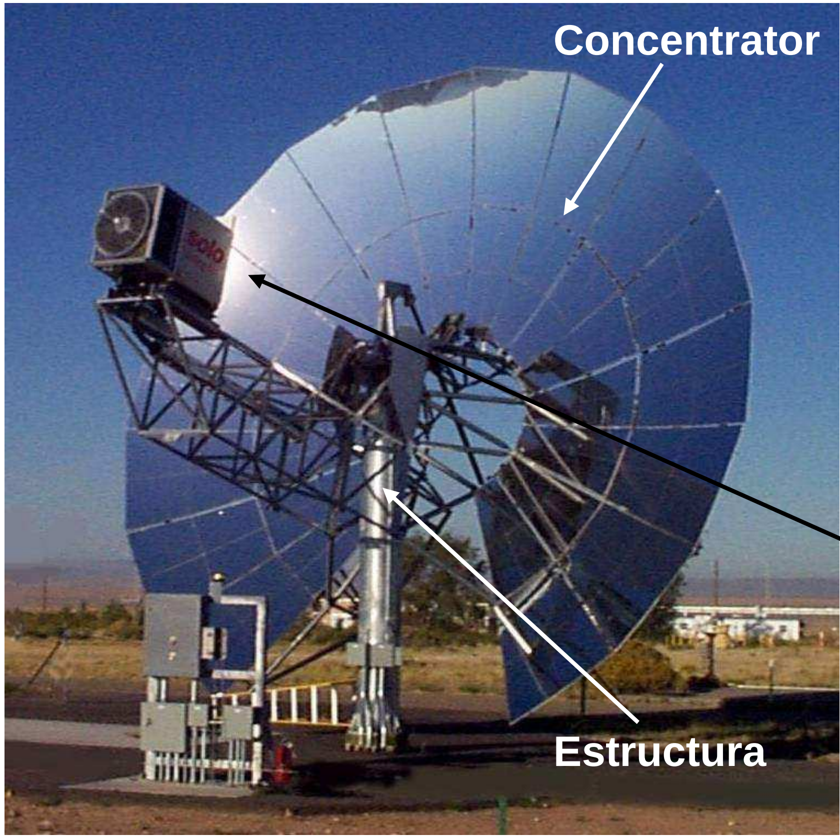
Puesta en Marcha 2011

CR with Atmospheric Air Technology:

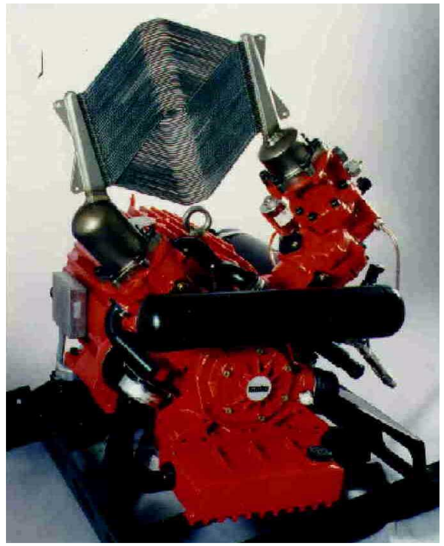
Dish -Stirling

Stirling Parabolic Dishes





Typical Dish-Stirling System (e.g.: WG Associates,10-kWe)



Solarized Stirling engine

DS, Technology Status and Challenges

- The variety of designs dish-concentrator (continuous or faceted paraboloid + support structure, ..) and receiver-engines have demonstrated high efficiency (29.5% record solar-electricity)
- **The durability of the engine-receiver requires improvements**

Boeing

SAIC/STM

SBP/Solo

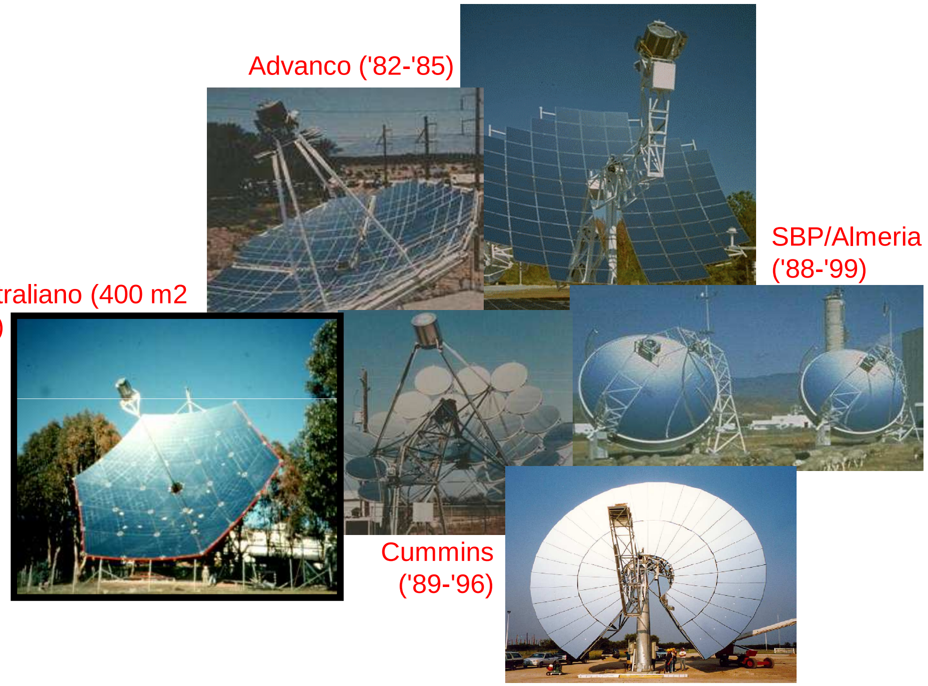
- **The high installation costs (~11000 €/kWe) and the lack of feasible (heat / electricity) storage makes DS compete in an scenario favorable to PV and CPF**

Solo

STM

Stirling Parabolic Dishes
Basic Characteristics

- Two axes tracking. Parabolic mirror Dish as concentrator. Temps. Of 600 ºC -800 ºC. Solar Fluxes: 500-3000 kW/m2.
- Stirling Cycle is the standard but Brayton cycles are feasible for the future
- Large variety of concentrator designs; High efficiency demonstrated (up-to 30 % peak and 20-22% annual average)
- A Commercial plant under construction in Spain (~1 MW)
- It allows Distributed Power Generation, with units of 3-25 Kwe
- **Projects in pipeline:**
  - Spain: **~0.1 +1 MWe**
  - EEUU: **800 MW** (SCE - 20,000 Dishes) **+ 300 MW** con SDG&E – 12,000 dishes)??



Infinia Corp., EEUU

- 3 kWe
- Free piston
- Low maintenance (10 years?)
- Just few prototypes in operation
- Starting the fabrication
- High spectation about the costs


1 MWe Villarrobledo

New Developments on DS

New Dish Stirling of 25 kW (EEUU)

Dish Stirling of 3 kWe (EEUU)

Cost of Solar Thermal Electricity?

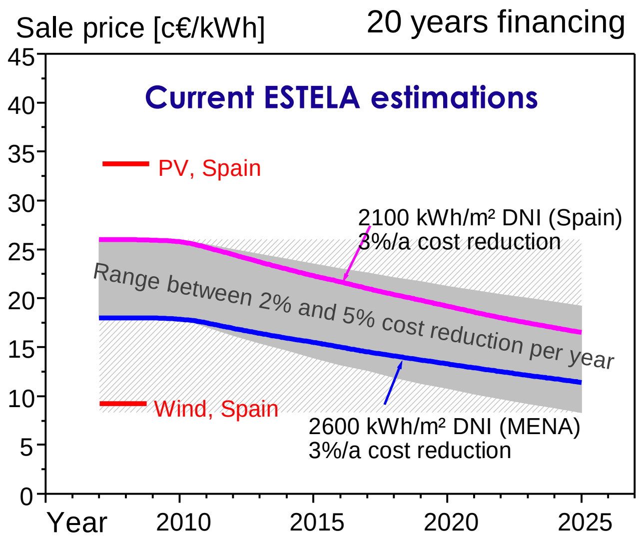
COST REDUCTION IS THE MAIN ISSUE

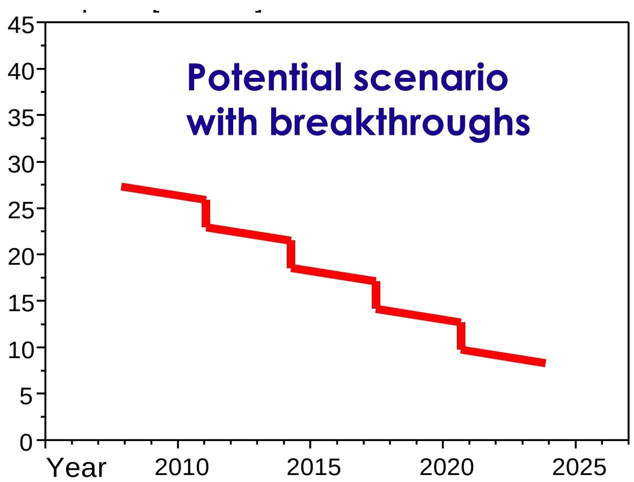
What brings the cost down?

- Innovation in systems and components
- Improving production technology
- Increasing the overall efficiency
- Enlarging the number of operation hours
- Bigger power blocks
- Reducing the O & M costs
- Learning curve in construction
- Economies of scale

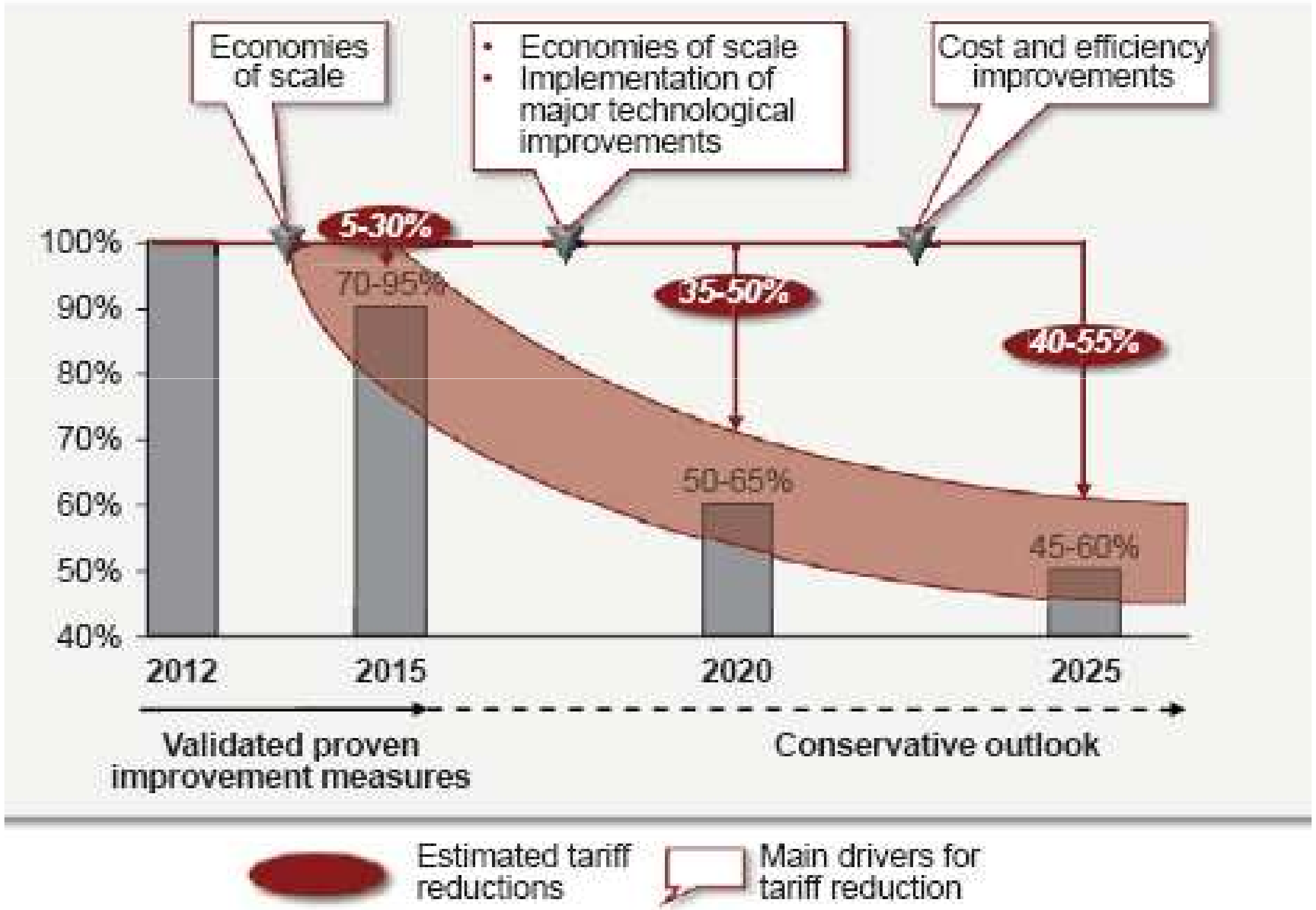
<u>Current Investment costs in Spain for a 50 MW plant:</u>

•4.000 €/kW without storage / 2000 h/year
•6.000 €/kW with 7 hours storage / 3600 h/ year

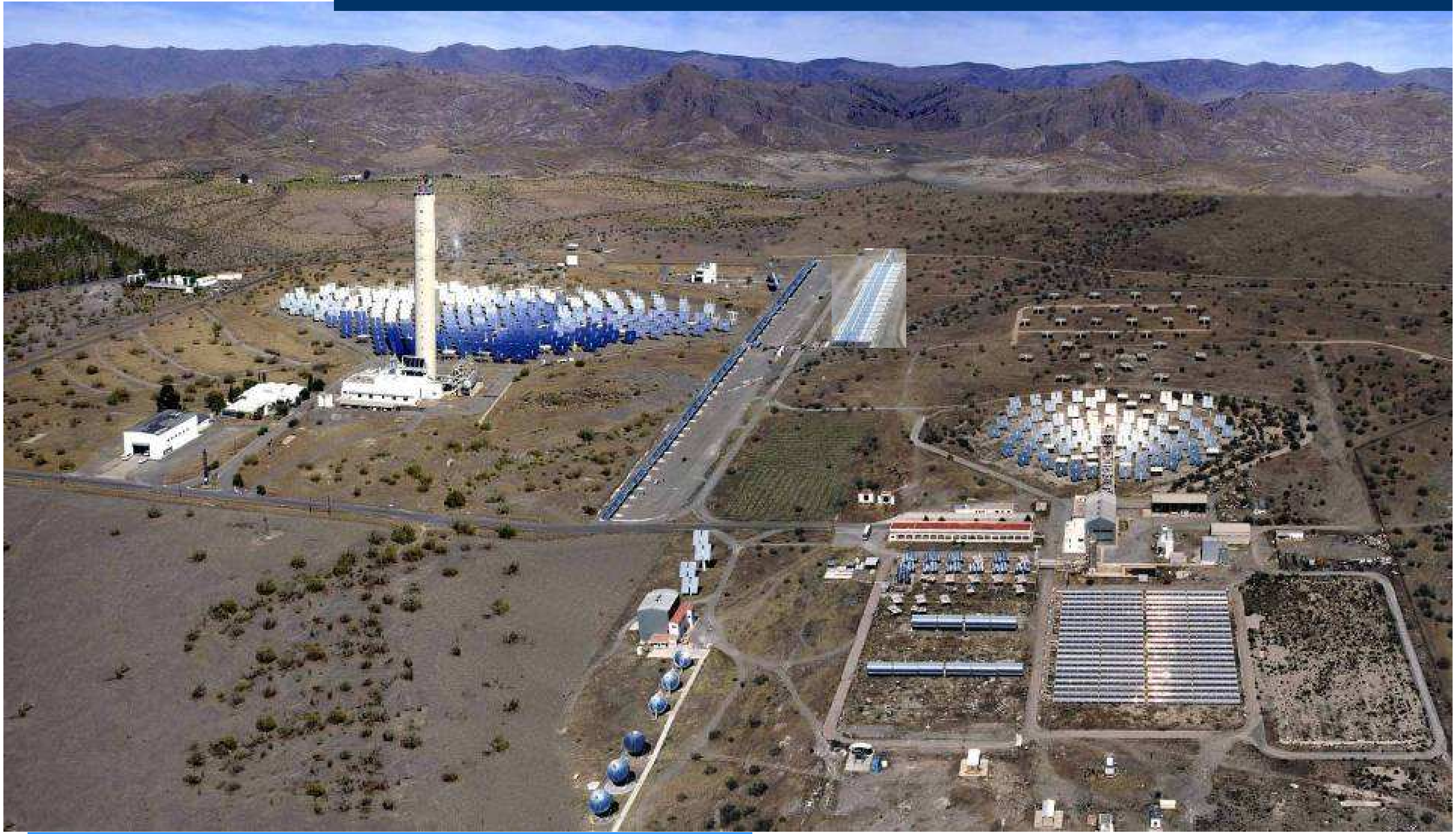




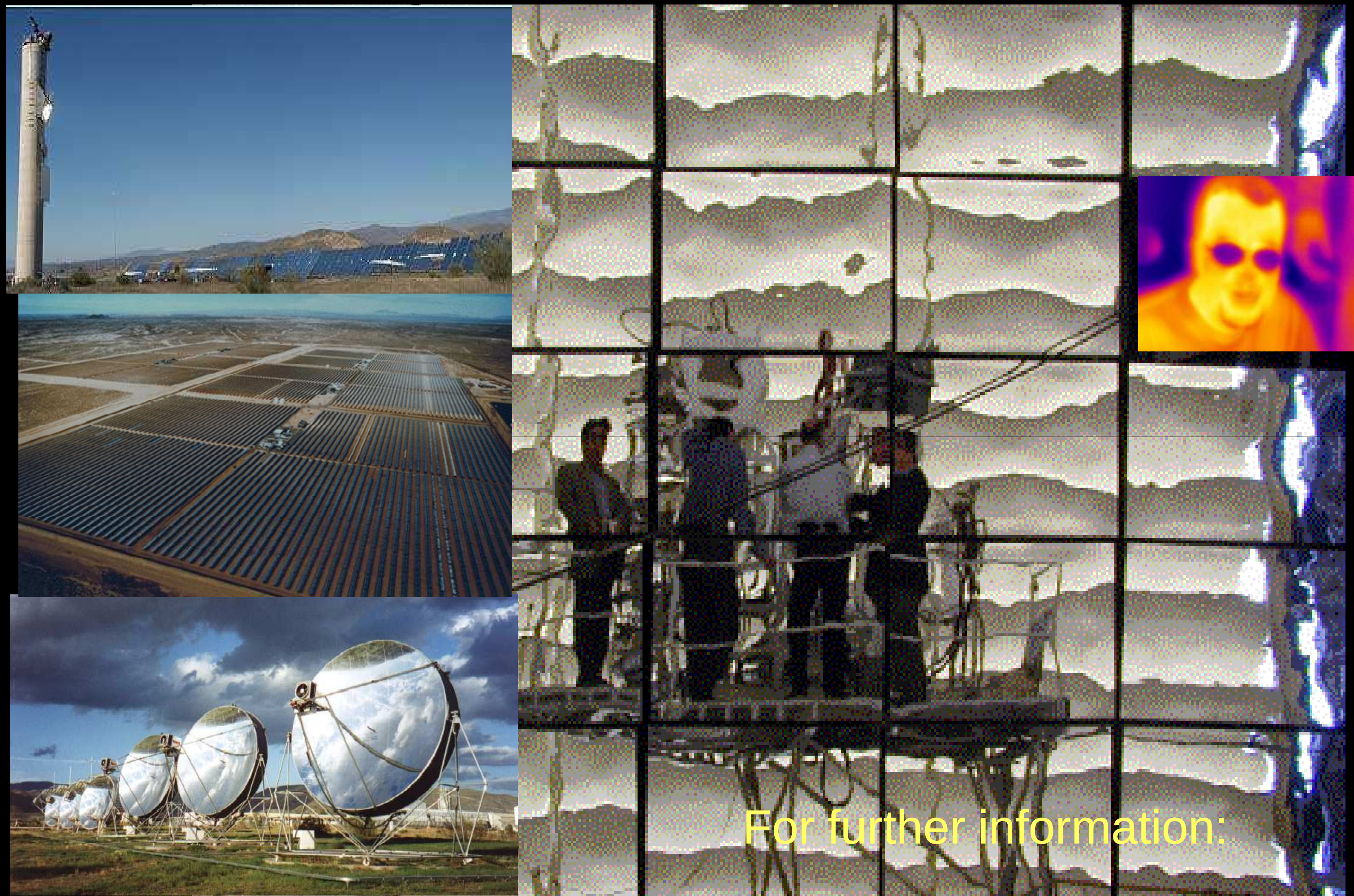
What brings the cost down?



…From the Plataforma Solar de Almería (PSA), we will continue trying to contribute to sustainability by "R&D in potential industrial applications of concentrating solar thermal energy and solar photochemistry"



THANKS FOR YOUR ATTENTION !



www.psa.es

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