Solar Thermal Power Plants
On the verge of commercialization (in Spain,...)

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Speeches 1 & 2 of 4:

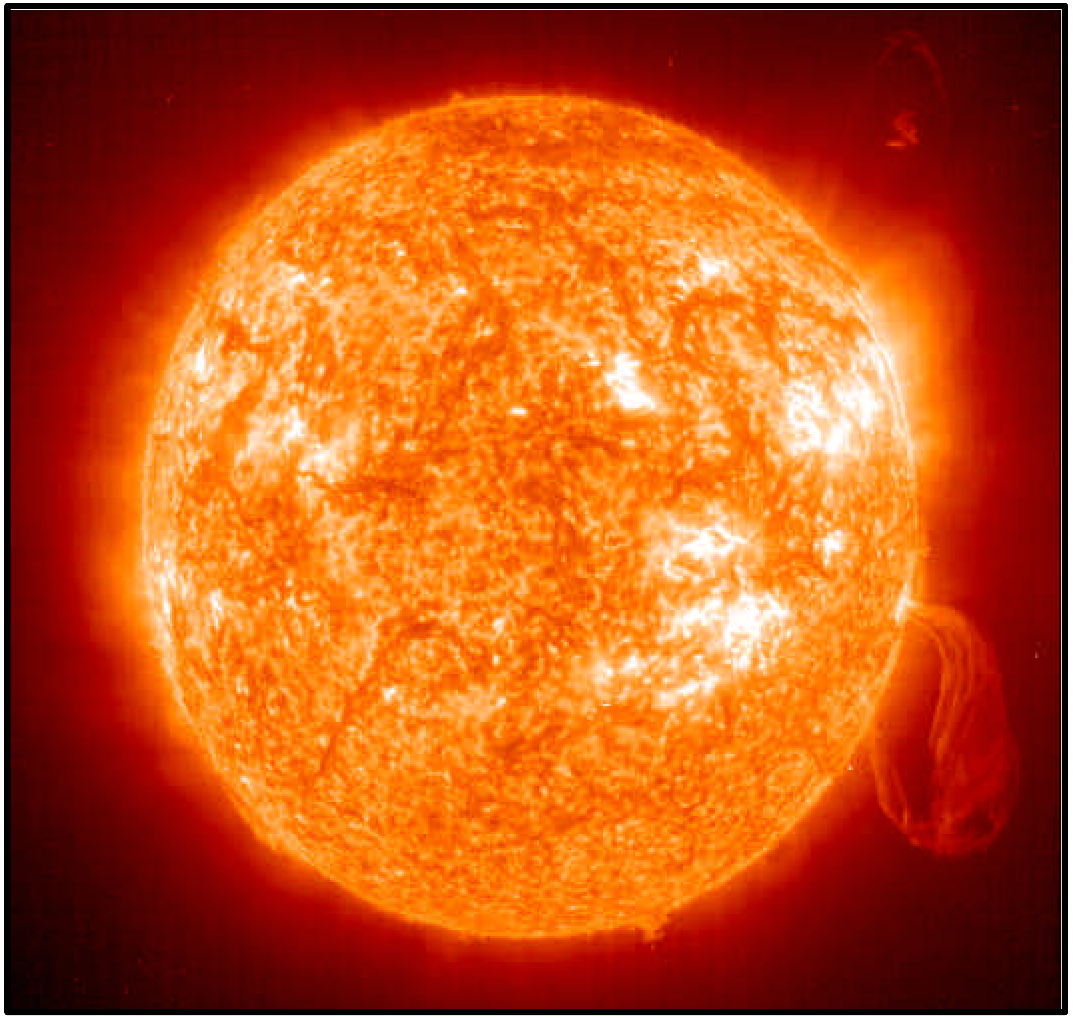
1) Solar thermal Power Plants. On the verge to Commercialization

(To introduce the technology, the survey the context, the potential, the glabal and Mediterranean market, oportunities, ...)

2) Concentrating Solar Power Technologies and Innovations

(To introduce the technological options, the status of the technologies, projects and innovations, …)

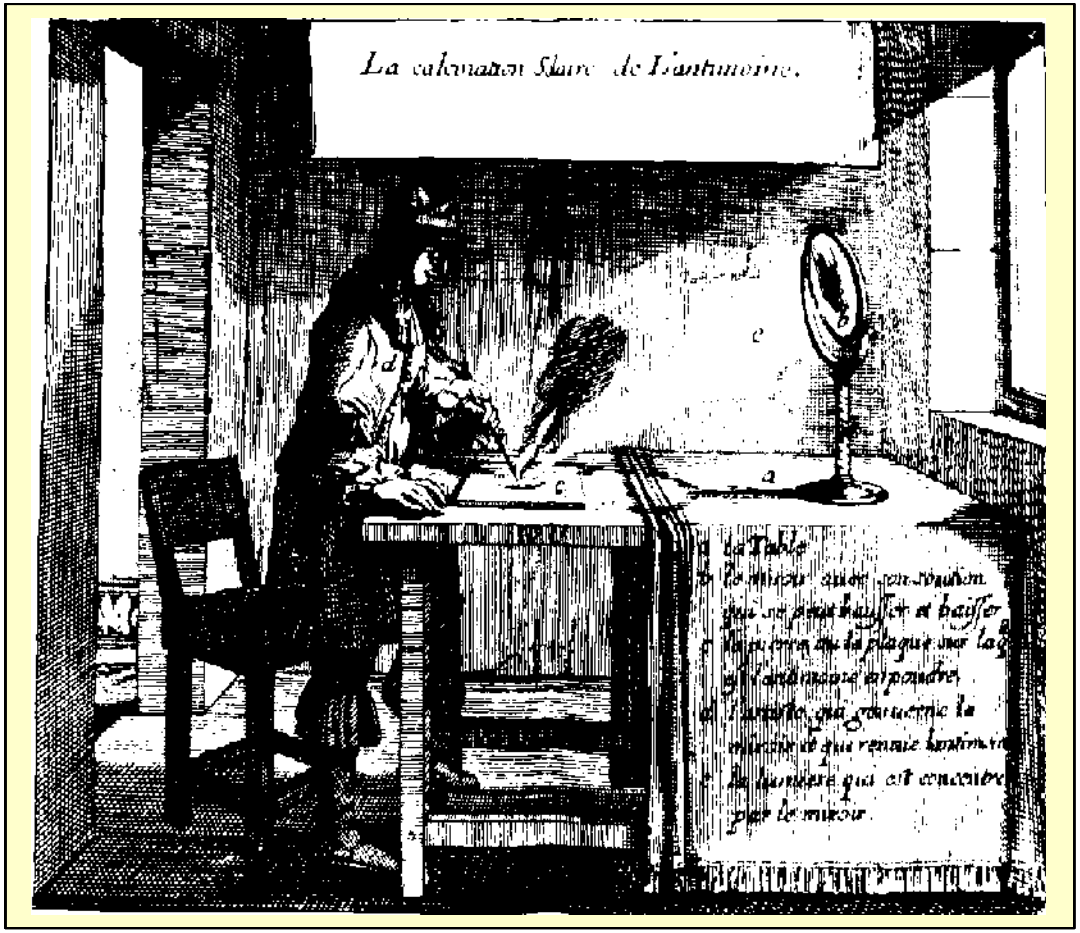
A little of history on solar energy use



- Since 4.500 millons of years the solar radiation “powers” the Earth.
- 700 years (B.C.): Glass used to concentrate solar radiation to produce fire.
- 300 years (BC): Grieeks and Romans use mirros as weapons.
- 30 tears (BC): Vitruvio describes in his 10 books the Solar Architecture.
- Year 20: A Chinese document describes the use of mirrors to light troches in religious ceremonies.

A little of history on solar energy use

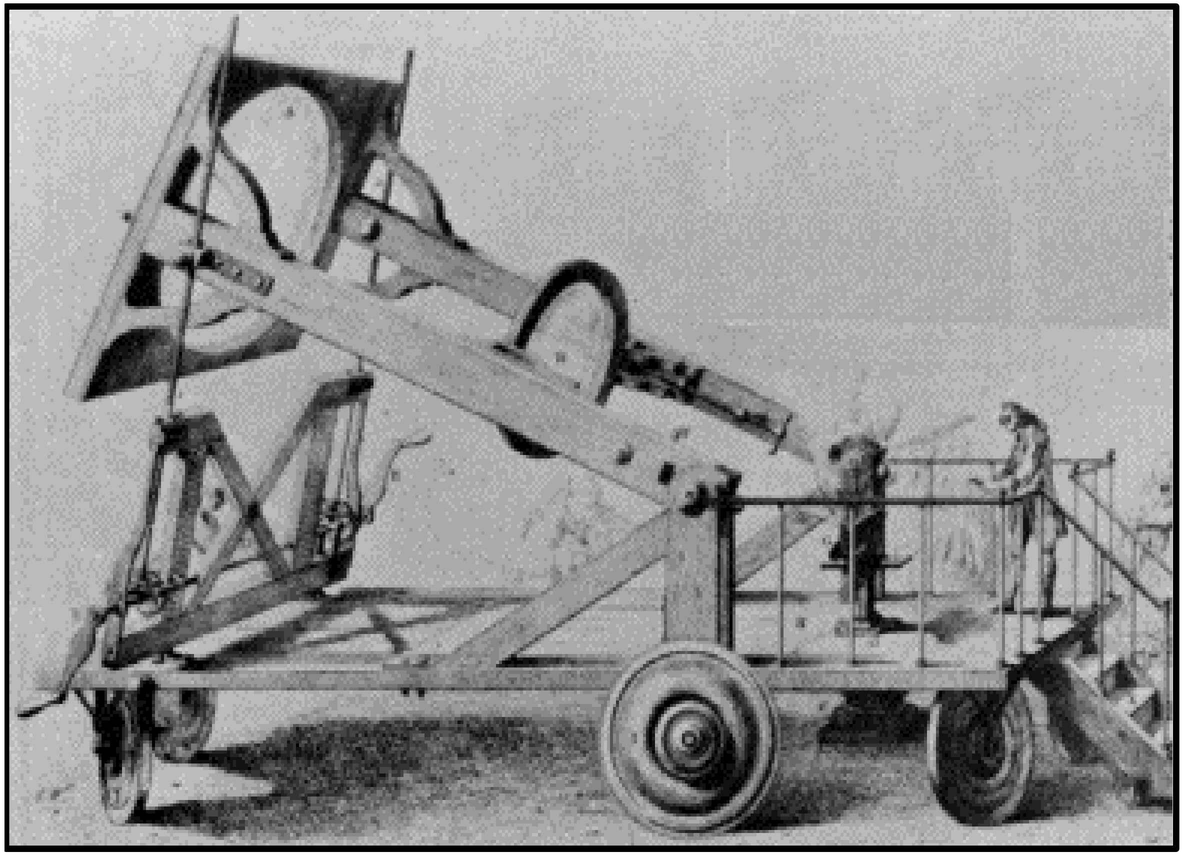
Utilization of concentrated solar energy to melt antimony (French picture of XVII century)



- 100: The Italian historian Plinio the Young built a solarized house using glas to increase the solar gains.
- 1-500: Roman baths built with large windows oriented to South and solar water heating.
- 600: The Justiniano's Code regulates the protection of rooms oriented to Sun in public buildings and houses to guaranty the "right to sun access"
- 1643-1715: French Luis XIV reign "The Sun king", was a time for solar experiments.
- 1695: French Georges Buffon used mirrors for solar concentration and to light wood and to melt lead.

A little of history on solar energy use

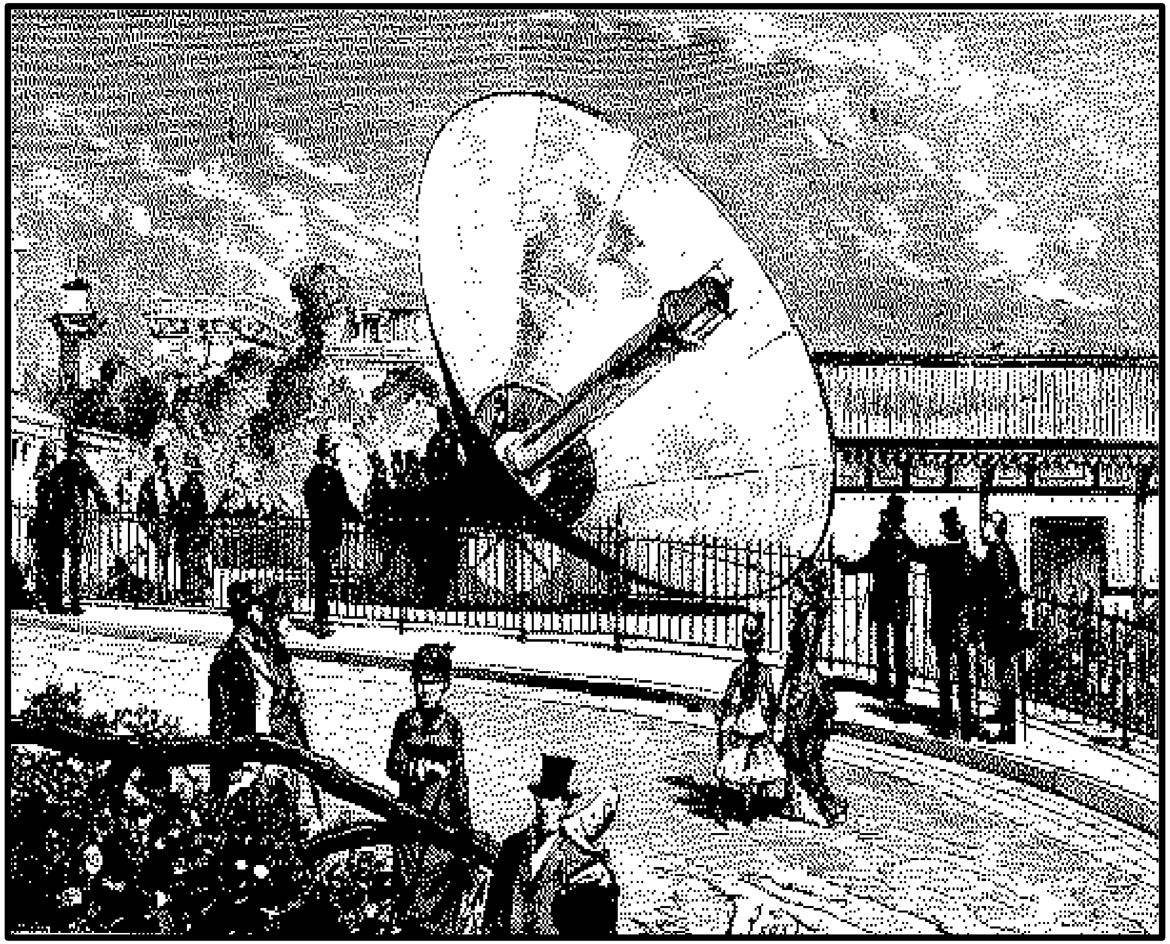
Solar furnance of Antoine Lavoisier (Picture of XVIII century)



- 1700s: Antoine Lavoisier built a solar furnace to melt Platinum.
- 1700s: Great Britain and Nederland leads the development of greenhouses with glass walls and South orientation/tilt.
- 1767: The French scientific Horace du Saussure invented the first solar hot box to heat water
- 1800: In France it is demonstrated the capability of the solar energy to produce vapour and electricity.
- 1830s: The Astronomous Sir used a solar stove during his expedition in South Africa.

A little of history on solar energy use

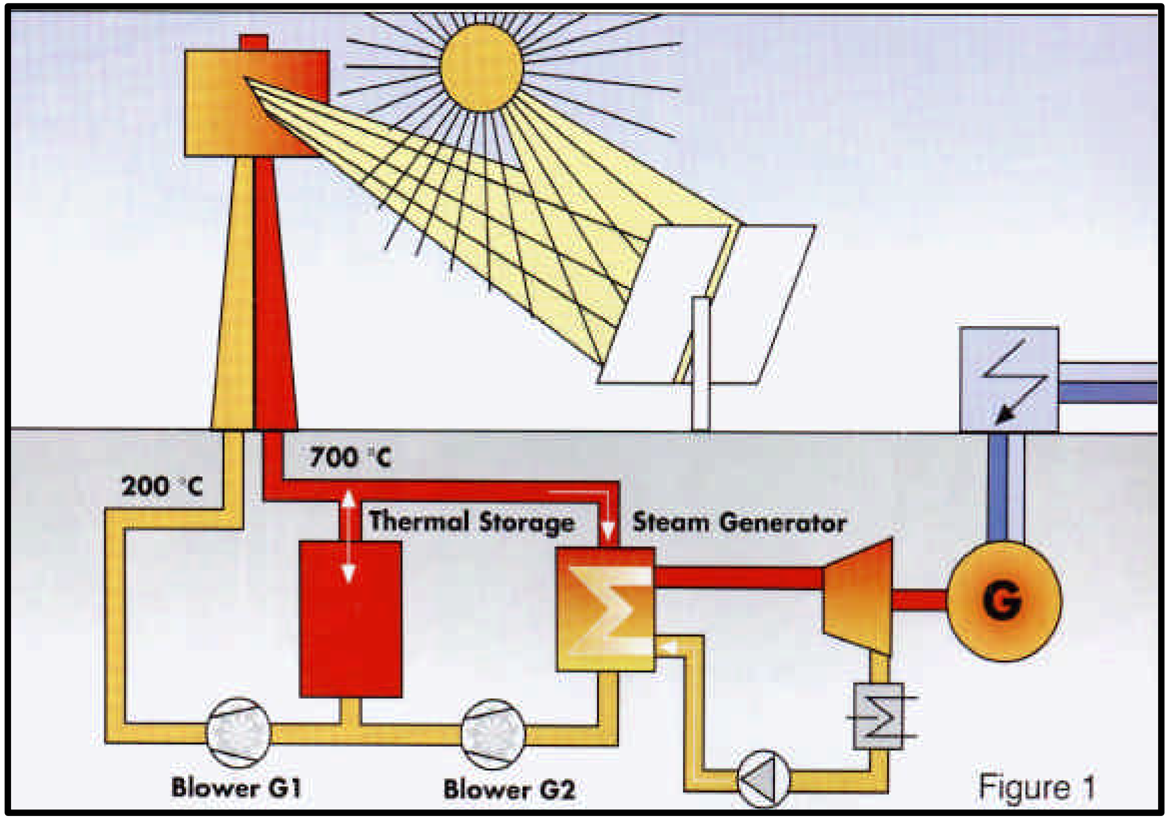
Solar Engine of Augustin Mouchot during the World exhibition of 1861 in Paris

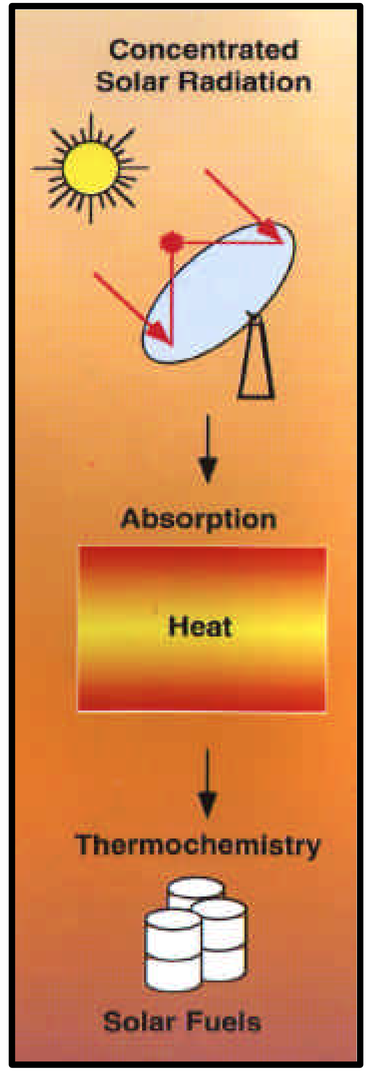


- 1839: Scientific Edmund Becquerel observes the photovoltaic effect.
- 1861: French mathematician Augustin Mouchot patents a solar engine.
- Late 1800s – Early 1900s: wide use of solar energy devices
- 1954: Beginning of Photovoltaic cells
- 1973: First oil crisis
- 1981: AIE - Plataforma Solar de Almería starts its activities
- 80's: Other experimental facilities for Concentrated solar worldwide (USA,FR,JP,IL,...)

Main Objectives of the Solar Concentration Technologies

- Short term to midterm → **Electricity production**
- Midterm to longterm → **Solar Chemistry**

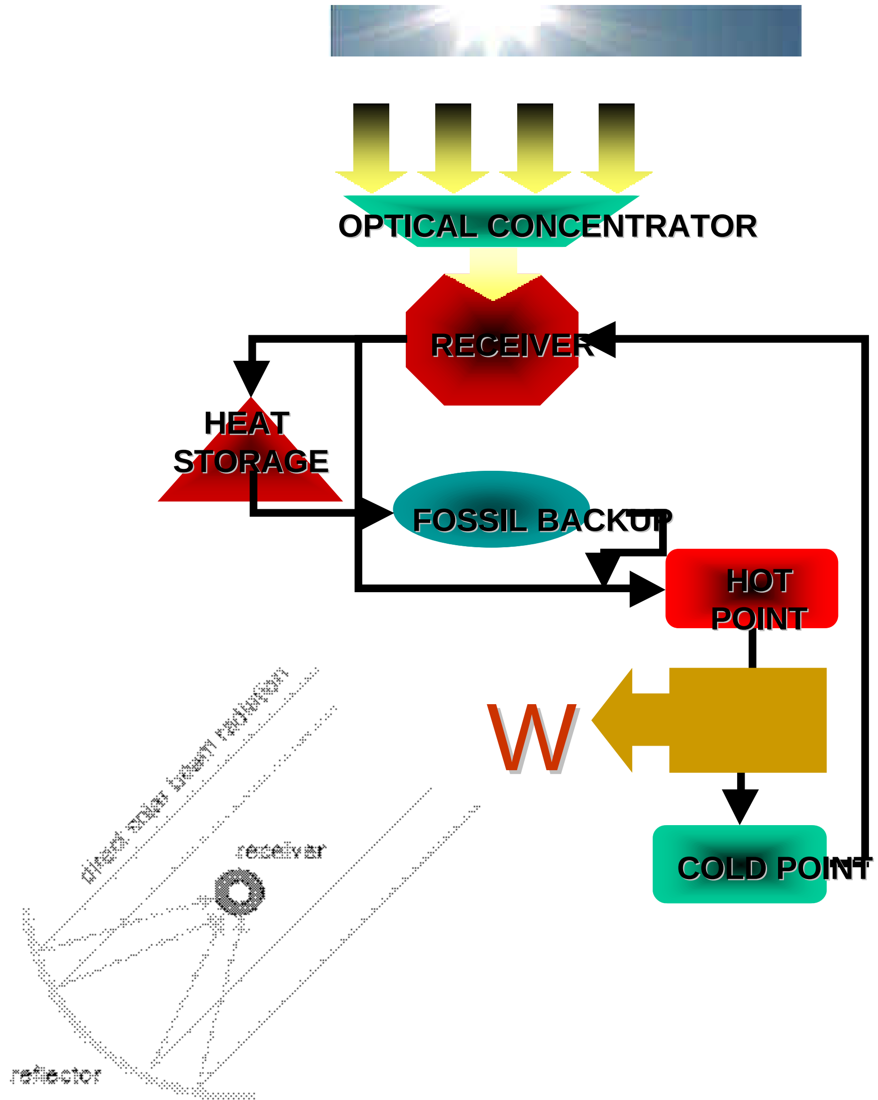




Final Objective: Production of "solar" fuels

What is Solar Thermal Power?

- One of the quasi-direct ways to obtain power from the sun.
- Four main elements are required: a concentrator, a receiver, some form of transport media or storage, and power conversion.
- The concentrated sunlight (DNI) is absorbed on a receiver that is specially designed to reduce heat losses.
- A fluid flowing through the receiver takes the heat away towards the power cycle,
- Air, water, oil and molten salt are used as heat transfer fluids.



STP-Technology Overview

- Many different types of systems are possible, including combinations with other renewable and non-renewable technologies, but
- the three most promising solar thermal technologies are:

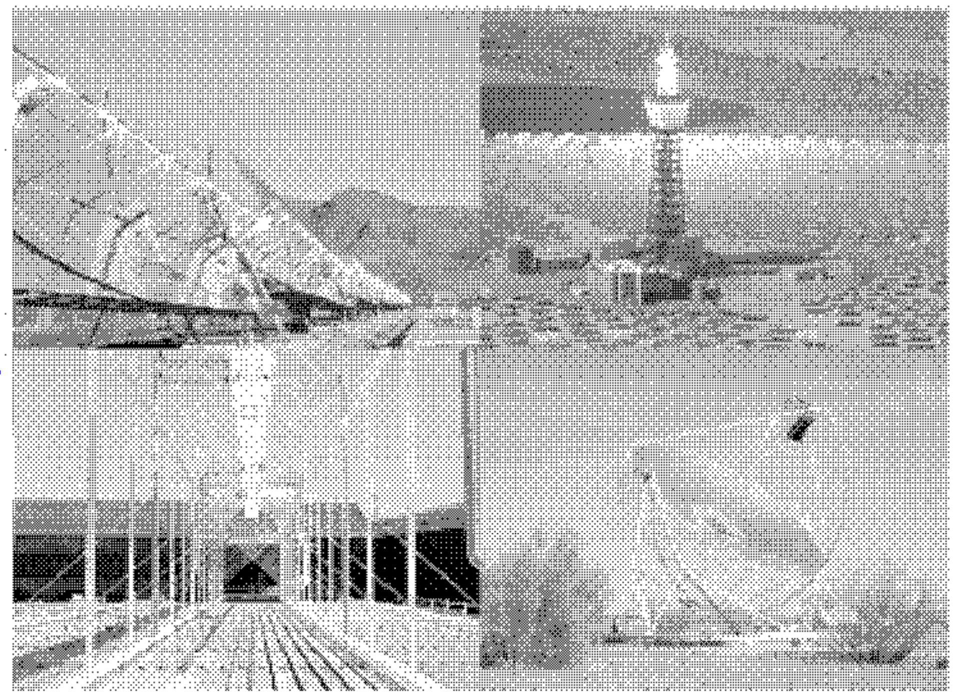
(Linear absorber:)

- 1A) Parabolic trough
- 1B) Linear Fresnel

("~Punctual" absorber)

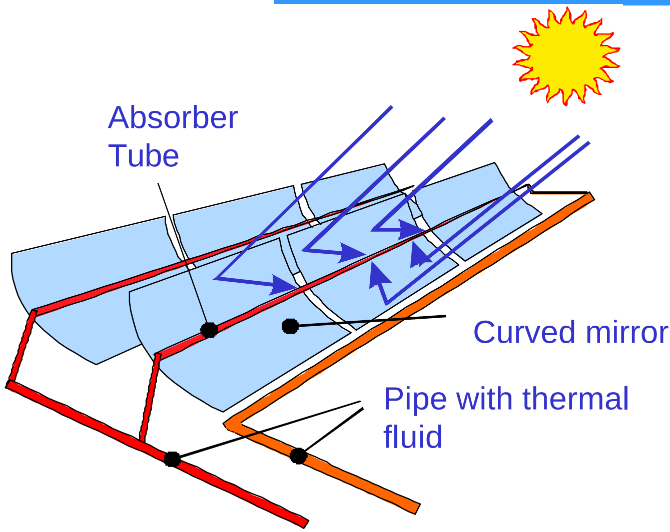
- 2) Central receiver solar tower
- 3) Parabolic dish

parabolic trough (PSA) solar tower (SNL)

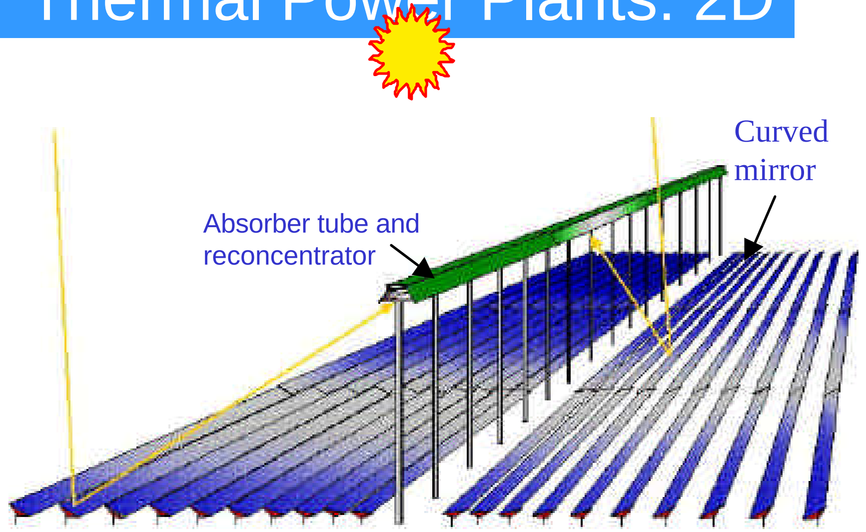


linear Fresnel (Solarmundo) parabolic dish (SBP)

CSP Technologies in competence: Solar Thermal Power Plants: 2D

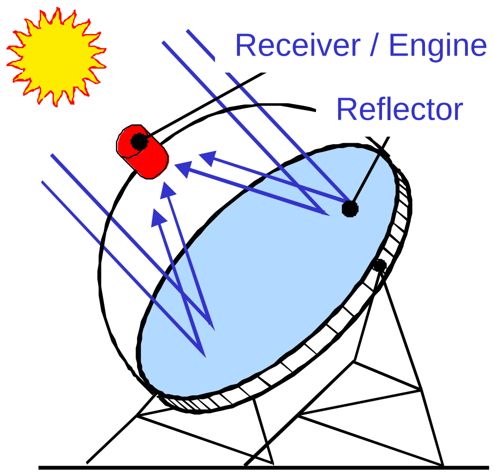


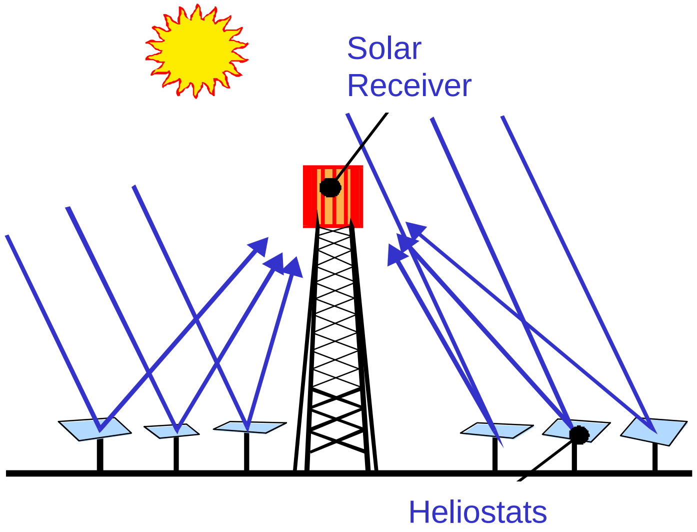
Parabolic troughs



Linear Fresnel reflector

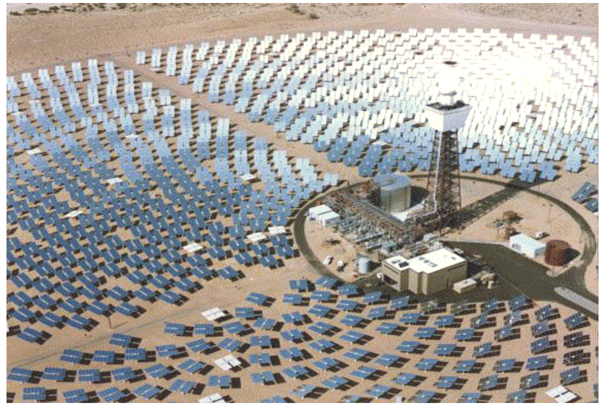
Solar Thermal Power Plants: 3D





Parabolic dishes

Central Receiver

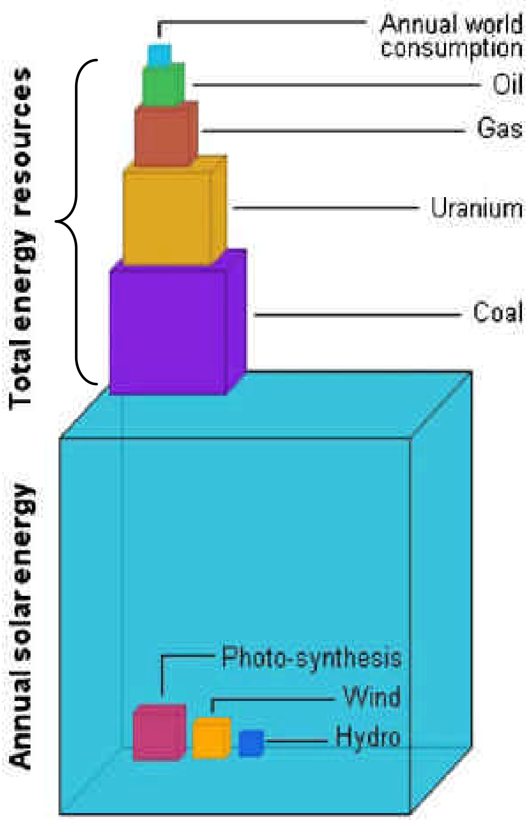


Technology comparison

	Parabolic troughs	Central Receiver	Dish-Stirling
Power	30-320 MW	10-200 MW	5-25 kW
Operation temperature	390-500 ºC	565-800 ºC	750 ºC
Annual capacity factor	23-50 %	20-77 %	25 %
Peak efficiency	20 %	18-23 %	29.4 %
Net annual efficiency	11- 16 %	15- 20 %	12 - 25 %
Commercial status	Commercial	Construction	Prototypes demonstration
Technical risk	Low	Low/Medium	High
Storage availability	Limited	Yes	Batteries
Hybrid designs	Yes	Yes	Yes
Cost kW installed EURO/kW	2 300 - 2 500	2 500 - 2 900	5 000 - 8 000
Concentration Ratio	**~75 suns**	**~200-1000 suns**	**~1000-3000 suns**

Potential of STPP

Only to give an order of magnitude



Source: World Energy Council

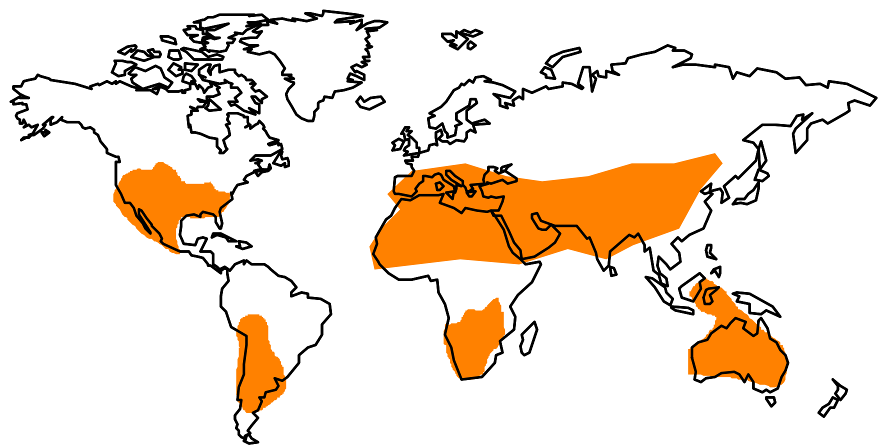
STPP Electricity:

1. Global solar radiation on earth	(TWh/year)	$240 * 10^6$
2. Dessertic areas (7% of earth surface)	(TWh/year)	$16 * 10^6$
3. Solar fraction of DNI available (70%)	(TWh/year)	$11{,}2 * 10^6$
4. Efficiency of CSP plants (15%)	(TWh/year)	$1{,}68 * 10^6$
5. Percentage of area with good infrastructures (1% of dessert areas)	(TWh/year)	$16{,}8 * 10^3$
6. World electricity demand year 2000	(TWh/year)	$15 * 10^3$

1% of arid and semi-arid areas are enough to supply annual World demand of **electricity**

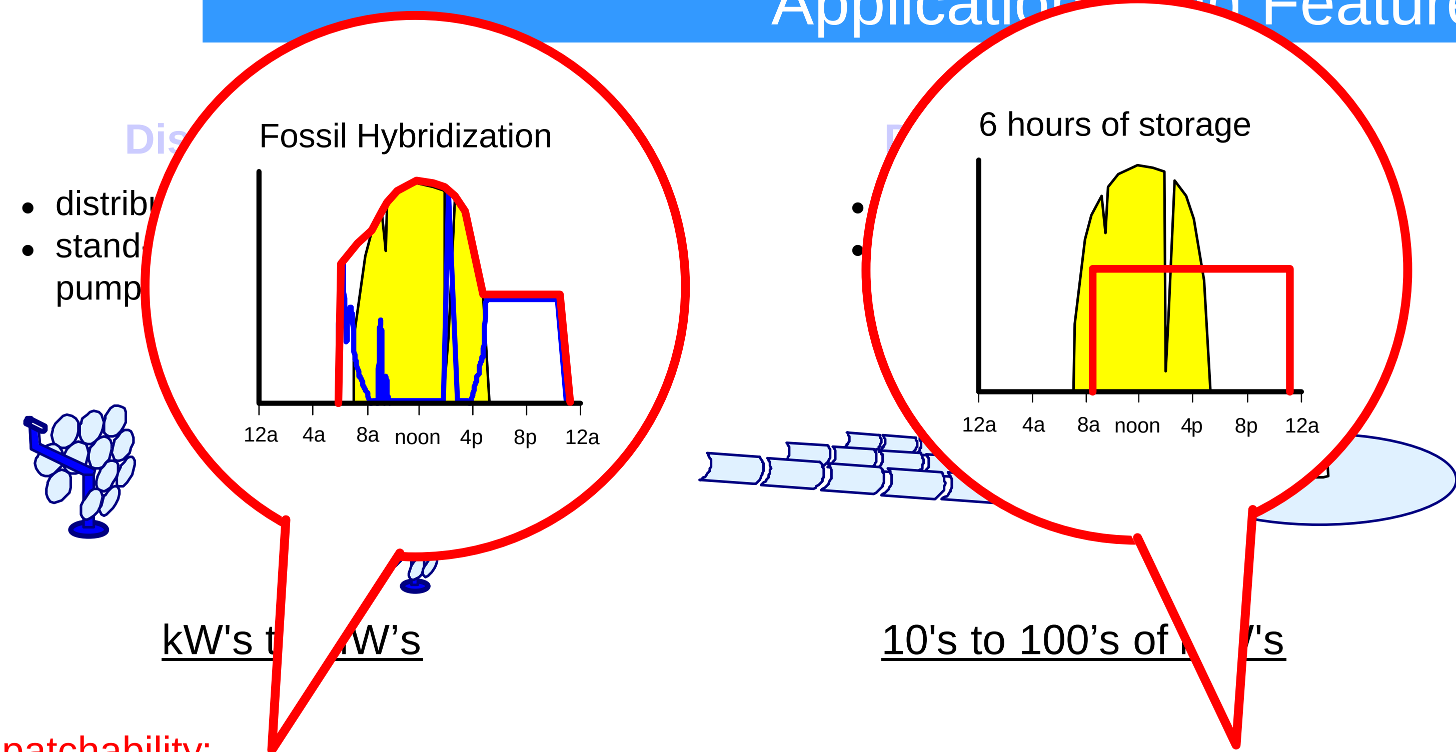
STPP, What can it do?

- "There are no technical, economic or resource barriers to **supplying 5% of the world's electricity needs** from solar thermal power **by 2040"**
- "The STPP industry is capable of becoming a dynamic, innovative **€16.4 billion annual business** within 20 years",



- Solar thermal power **is capable of supplying electricity to more than 100 million people** living in the sunniest parts of the world, within two decades.

STPP or Concentrating Solar Power: Applications and Features



Dispatchability:

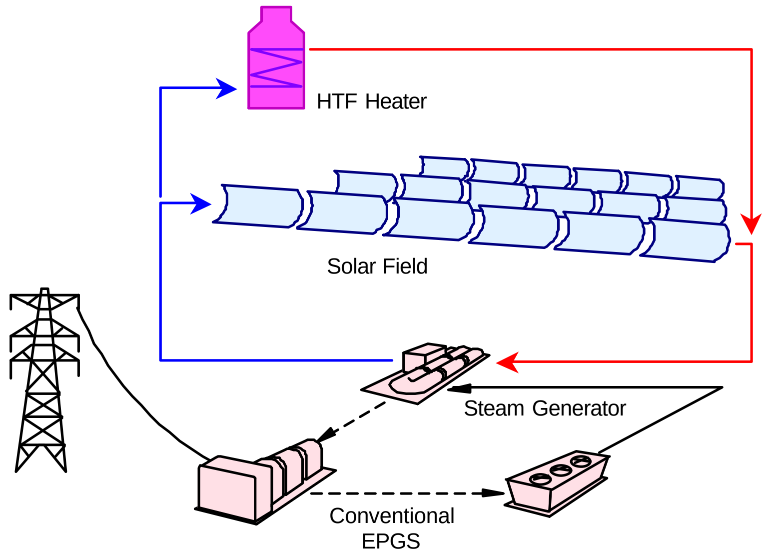
- hybridization with gas or liquid fuels for extended Stirling or Brayton engine operation
- hybrid gas combined cycle
- coal, fuel oil, or gas steam cycle
- thermal storage for peaking, load following, or extended operation

Manufacturing:

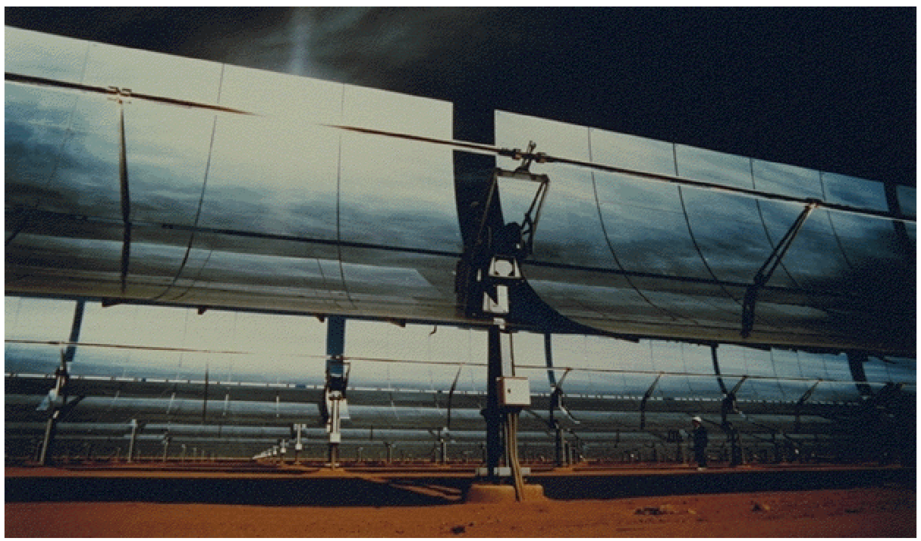
- Relatively conventional technology (glass, steel, gears, heat engines, etc.) allows rapid manufacturing scale-up, low risk, conventional maintenance

Dispatchable Power:
Parabolic Troughs

- LUZ demonstrated that large-scale solar thermal systems can meet users' needs.
- 9 SEGS plants (354 MW) continue to add to more than 100 plant-years experience.



KJC



Technology Features:
- 30-200MW plants
- Demonstrated technology
- Easily hybridized
- Storage options limited

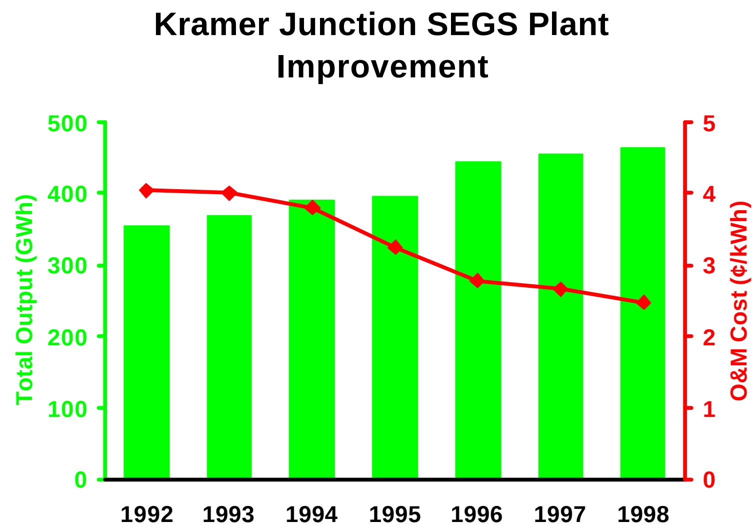
Dispatchable Power:

Commercial Parabolic Troughs

Table 1. Characteristics of SEGS I through IX [1]

SEGS Plant	First Year of Operation	Net Output (MW_e)	Solar Field Outlet Temperature (°C)	Solar Field Area (m^2)	Solar/Fossil Turbine Efficiency (%)	Annual Output (MWh)	Dispatchability Provided by
I	1985	13.8	307	82,960	31.5/ NA	30.100	3 hours-thermal storage Gas-fired superheater
II	1986	30	316	190,338	29.4/37.3	80,500	Gas-fired boiler
III/IV	1987	30	349	230,300	30.6/37.4	92.780	Gas-fired boiler
V	1988	30	349	250,500	30.6/37.4	91.820	Gas-fired boiler
VI	1989	30	390	188,000	37.5/39.5	90.850	Gas-fired boiler
VII	1989	30	390	194,280	37.5/39.5	92.646	Gas-fired boiler
VIII	1990	80	390	464,340	37.6/37.6	252,750	Gas-fired HTF heater
IX	1991	80	390	483,960	37.6/37.6	256,125	Gas-fired HTF heater
Total:		354		$2{,}3 \cdot 10^6$		1 TWh	

- SEGS systems continue to set records for improved solar performance
- O&M costs have decreased 30% with 10 years of experience and development
  - Results are applicable to other solar thermal systems.



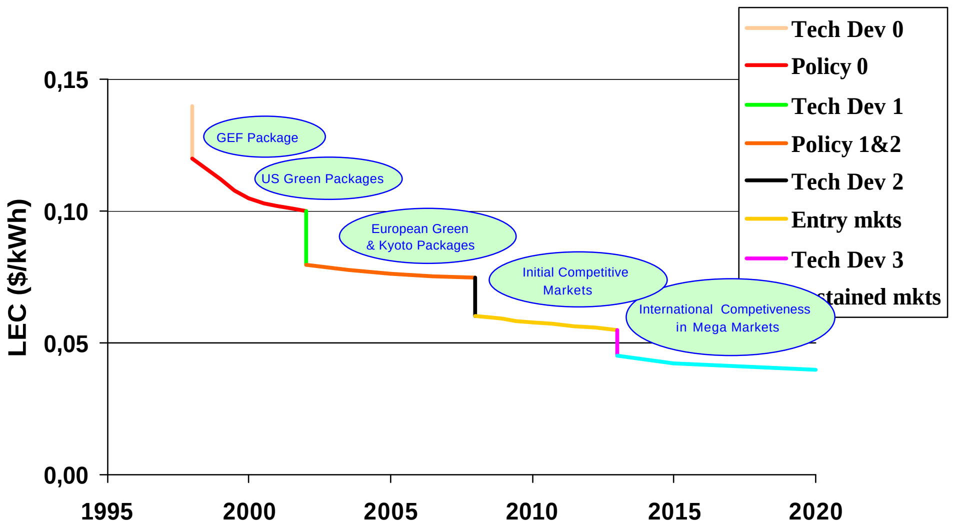
KJC

DISS/PSA

Direct-steam production and other technology enhancements are being developed to reduce costs

Technology Roadmapping has identified market and technology paths forward

- Green Markets
- Advanced collectors
- Integration with combined-cycle plants



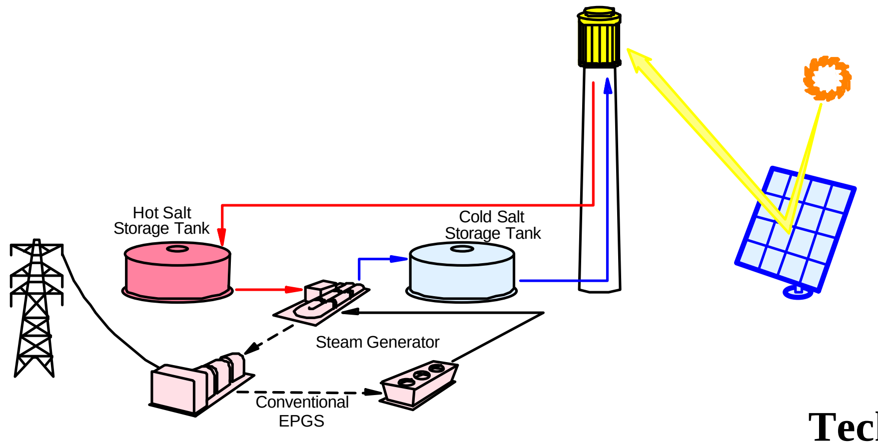

Harper Lake SEGS

International project development is underway in Egypt, Mexico, Morocco, Crete, and elsewhere

Although there are no current system suppliers, major consortia have formed to bid on next plant opportunities

Power Towers

- Numerous systems, including extensive testing of Solar One and the PSA, have demonstrated the potential of power towers
- Solar Two (10MW) and TSA (1MW) testing have demonstrated the improved performance of advanced systems



PSA

Solar Two

Technology Features:

50-200MW (and larger) plants for peaking and bulk power

Low-cost molten salt storage offers load following and capacity factors >60%

Hybridization, especially of air systems, is straight-forward

Dispatchable Power:
Experimental Power Towers in the Wold

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**

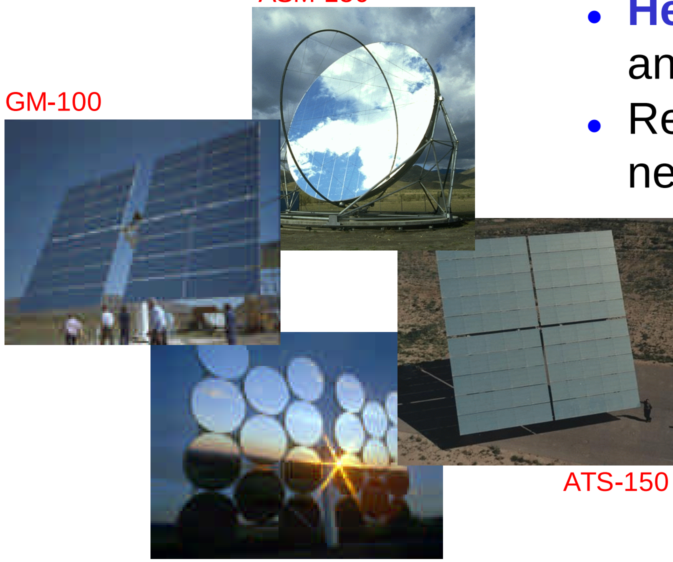
* Projects under development.
** Thermal

•••

Power Towers: Status

ASM-150

GM-100



ATS-150

SAIC-170

- **Heliostat** performance is excellent and well-established
- Reducing costs of early builds is needed

Solar Two

TSA

- **Receiver** performance and operability have been demonstrated
- Lifetime and reliability data are needed
- Advanced systems will enhance **hybridization**, especially with combined cycle plants

- Solar Two and PHOEBUS-type systems have both been successfully demonstrated at a size that could allow direct scale-up to commercial systems (>50MW)

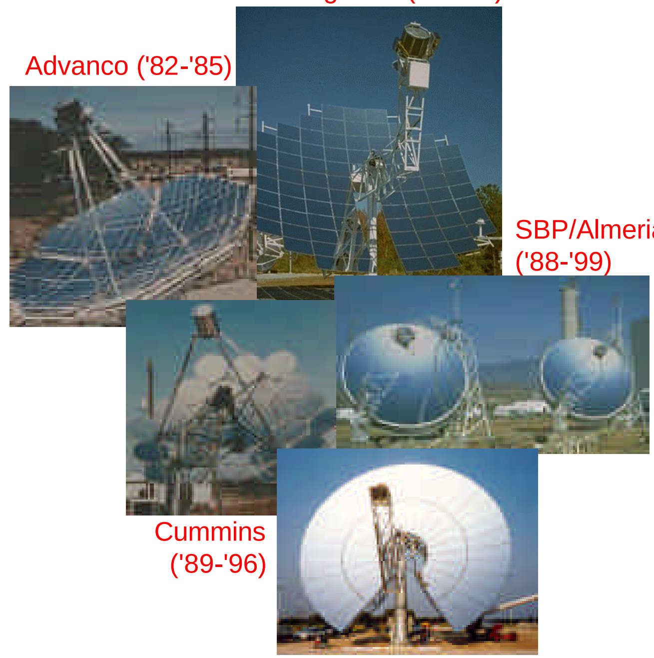
PS10; ...(PS-20), AZNALCOLLAR-20

Solar Two

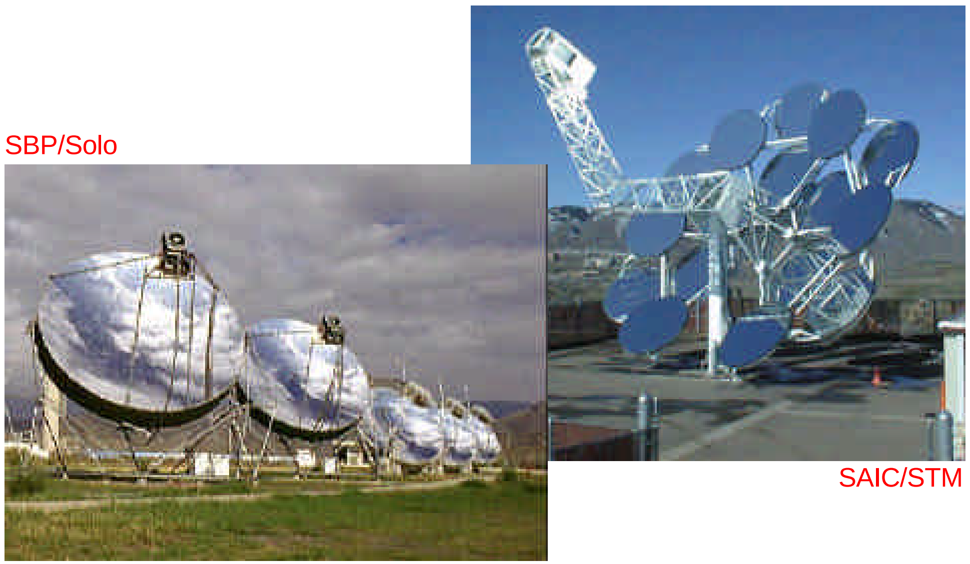
Dish/Engine Systems

- A number of dish, receiver, and engine designs have demonstrated the high performance needed for commercial systems

MDAC ('83-'88)
Boeing/SES ('98-'99)
Advanco ('82-'85)
SBP/Almeria ('88-'99)
Cummins ('89-'96)



SBP/Solo
SAIC/STM



- Technology Features:
  - High efficiency
  - Modularity (10-25kW)
  - Hybrid capabilities

Dish/Engine Systems:
Status

Boeing

SAIC/STM

SBP/Solo

- A number of dish and receiver designs have demonstrated the high performance needed for commercial systems
- Receiver lifetimes still need improvement
- Dish cost reduction in early production is critical

Solo

STM

- Advanced Stirling engines are demonstrating both high efficiency and extended life

Dish/Engine Systems:
The Future

European and U. S. industry are currently developing early commercial systems

Engine costs will decrease dramatically as engine production for co-generation and automotive markets expands

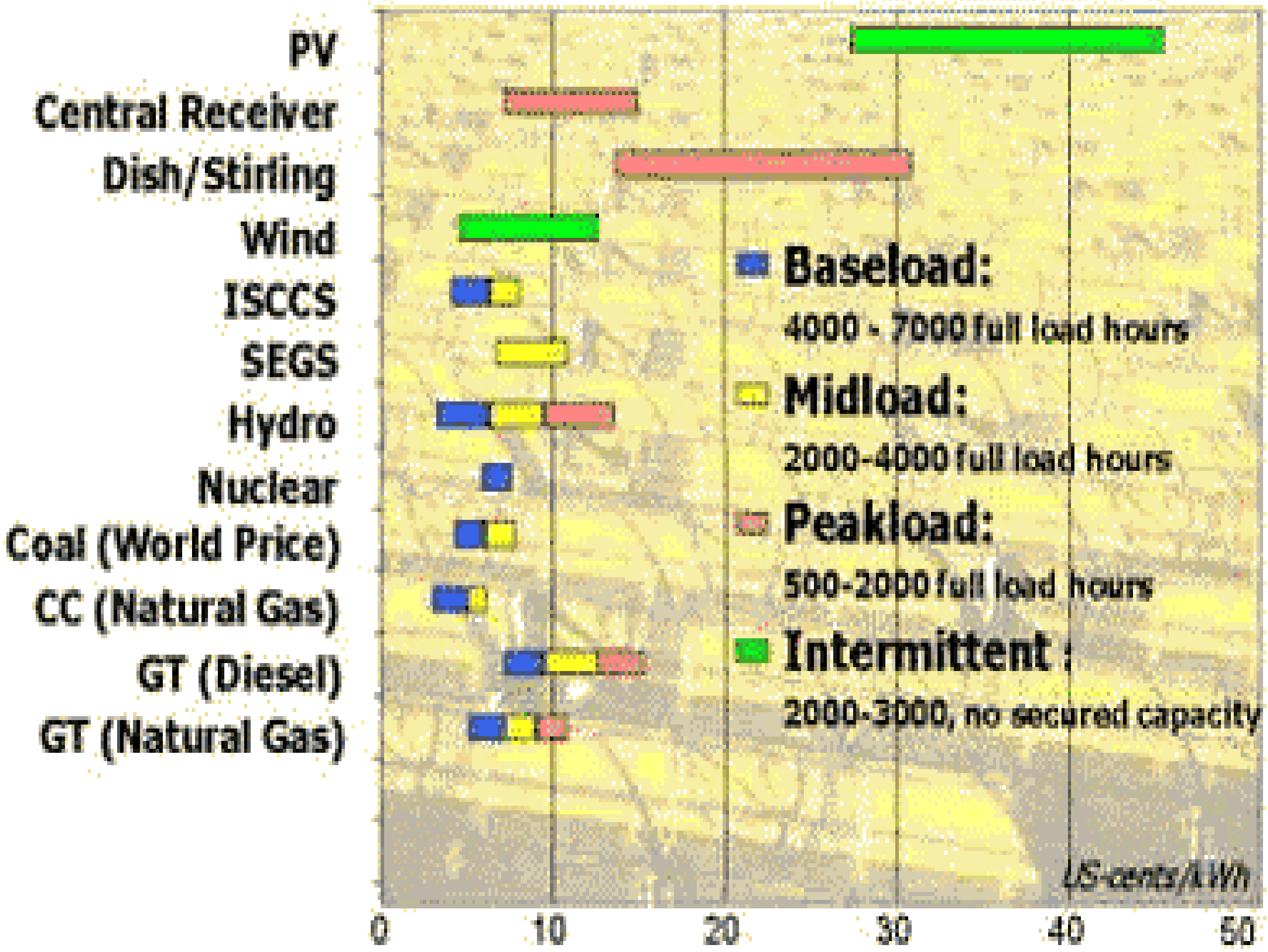
SES/Boeing

SAIC/STM

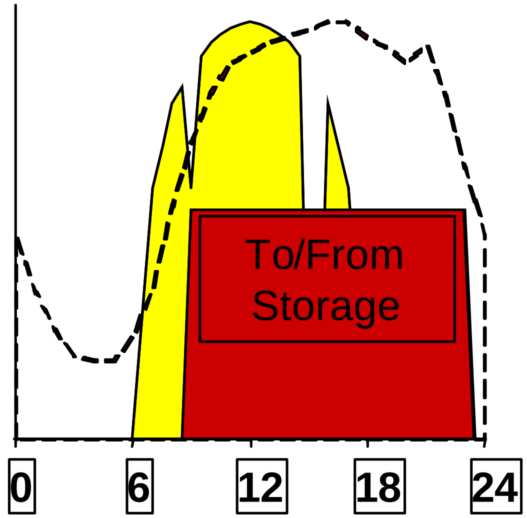
SBP/Solo

Green market opportunities continue to develop in the U.S. and internationally

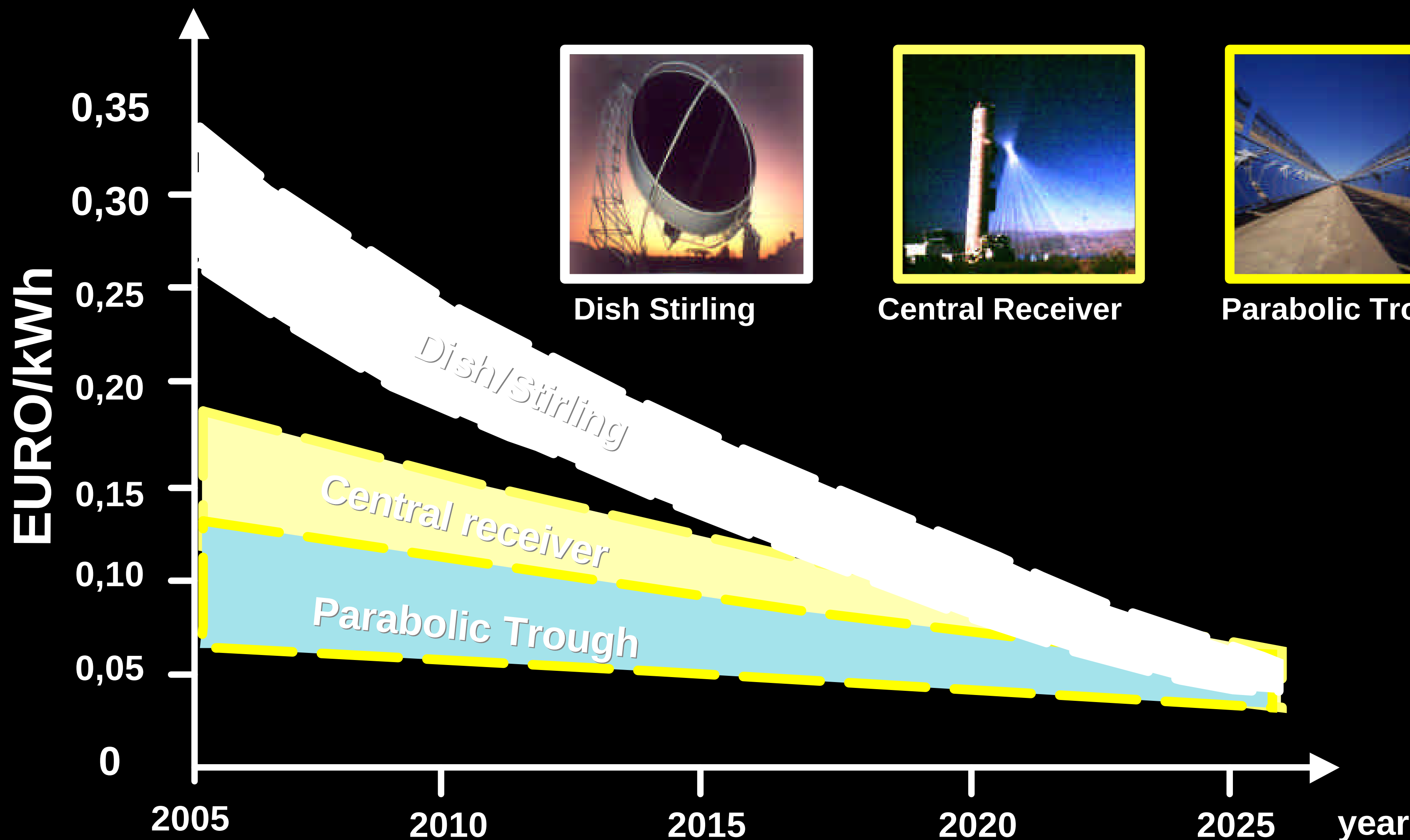
STPP Costs in comparison



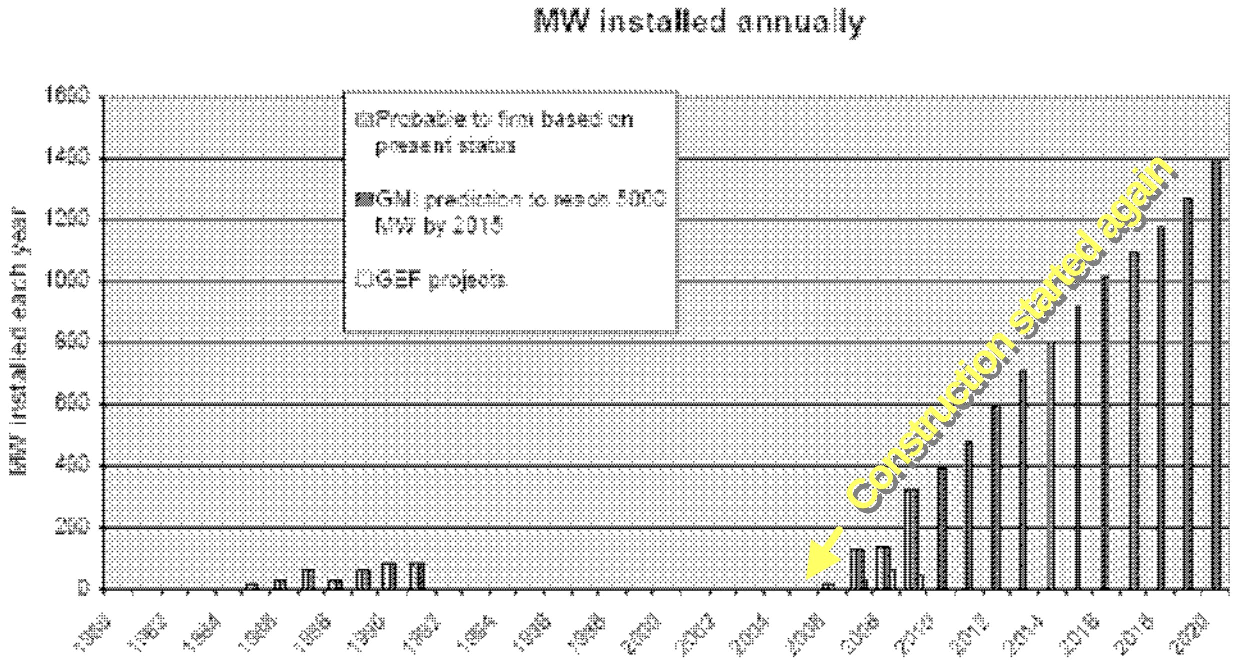
Source: International Energy Agency (2000)
http://www.solarpaces.org/economics.html

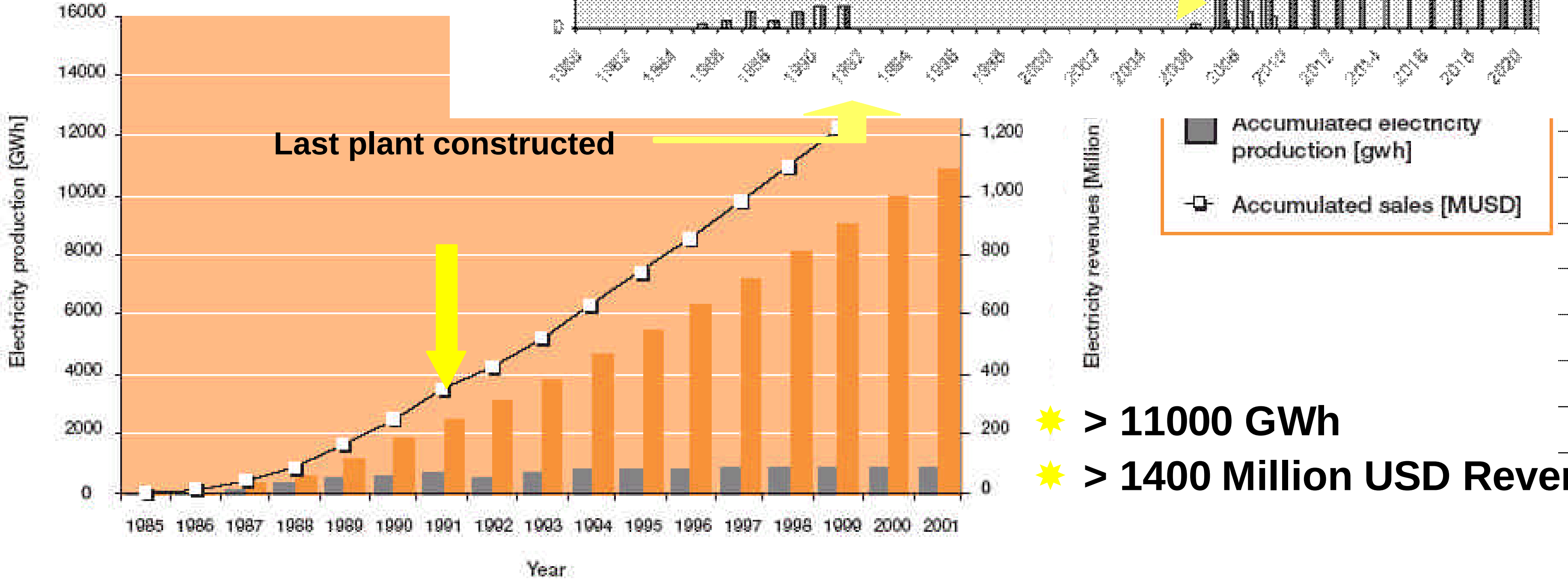


Cost Objectives for the STPP



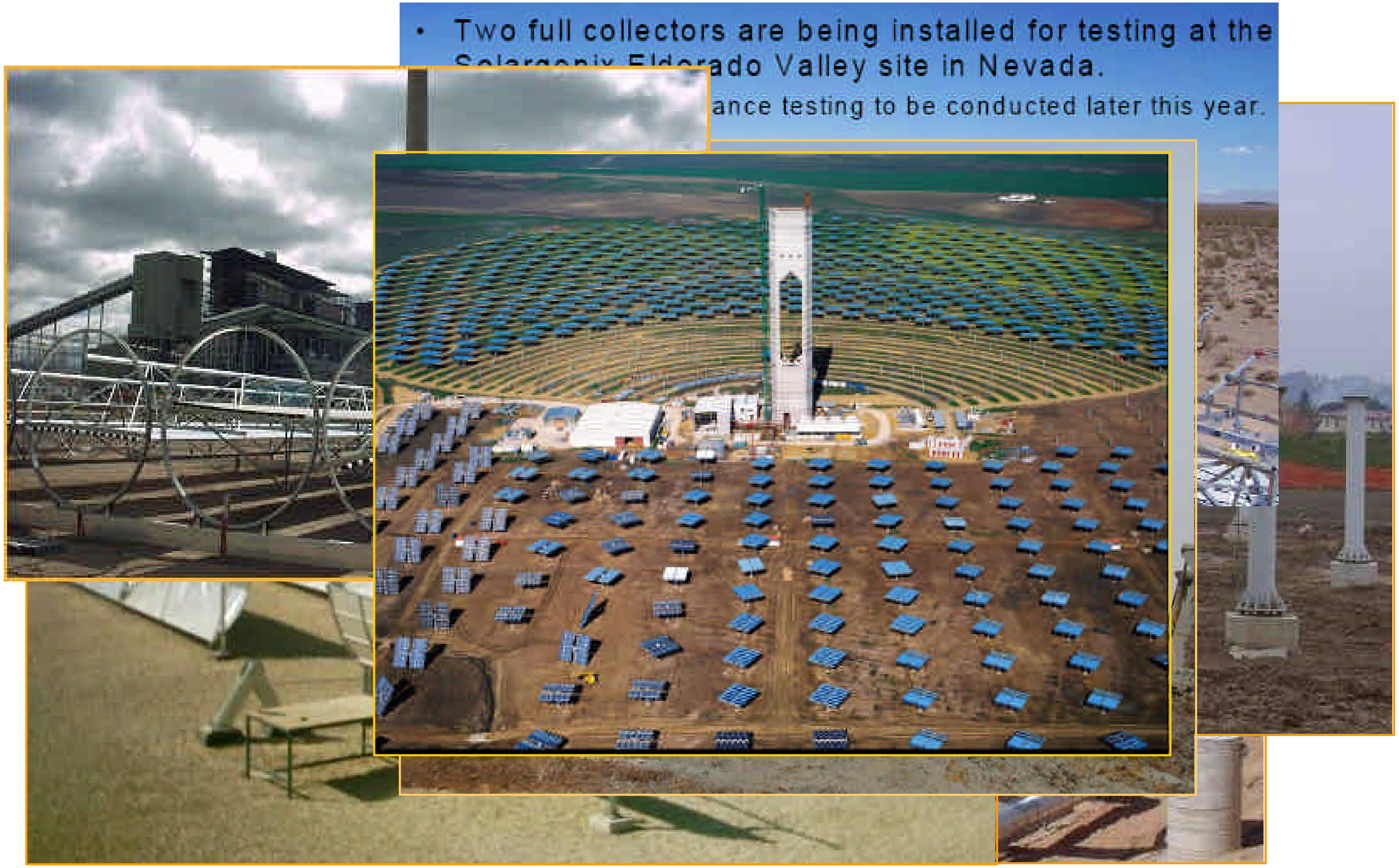
The SEGS Experience i





- > 11000 GWh
- > 1400 Million USD Reven

Construction of plants started again



Large companies are planing more than 600 MW until 2010 in Spain

OCUPARÁ 250 HECTÁREAS Y CUANDO ESTÉ EN OPERACIÓN EMPLEARÁ A 40 PERSONAS

Iberdrola invertirá 250 millones de euros en una central solar de 50 Mw

En Alcázar la empresa Eyra, del grupo ACS, proyecta una instalación similar, informó el director general de In...

Las centrales necesitan agua abundante, mucha superficie, gas natural y evacuación eléctrica

CincoDías

ACS construirá la mayor central termosolar del mundo en Granada

■ El proyecto, cifrado en 500 millones, integra a la alemana Solar Millenium ■ La planta se ubicará en Guadix y generará cien megavatios

La banca logra más flexibilidad contable con su cartera industrial

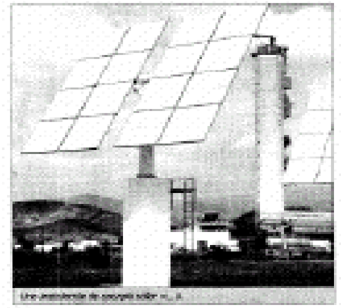
El FMI rebaja una décima el PIB previsto por Solbes

GUADIX

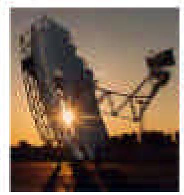
La mayor planta termosolar del mundo obtiene la licencia

El proyecto sólo necesita el permiso del Ministerio de Industria tras obtener la declaración de impacto ambiental

La planta termosolar prevista en la comarca de Guadix ha conseguido la declaración de impacto medioambiental favorable por parte de la Delegación de Medio Ambiente. La central será la mayor de todo el mundo.



Utility Plans 500-Megawatt Solar Thermal Project in California



Edison International subsidiary Southern California Edison (SCE), the nation's leading purchaser of renewable energy, and Stirling Energy Systems announced an agreement that could result in construction of a massive, 4,500-acre solar generating station in Southern California. When completed, the proposed power station would be the world's largest solar facility, capable of producing more electricity than all other U.S. solar projects combined.

The 20-year power purchase agreement signed today, which is subject to California Public Utilities Commission approval, calls for development of a 500-megawatt (MW) solar project 70 miles northeast of Los Angeles using innovative Stirling dish technology. The agreement includes an option to expand the project to 850 MW. Initially, Stirling would build a one-MW test facility using 40 of the company's 37-foot-diameter dish assemblies. Subsequently, a 20,000-dish array would be constructed near Victorville, Calif., during a four-year period.

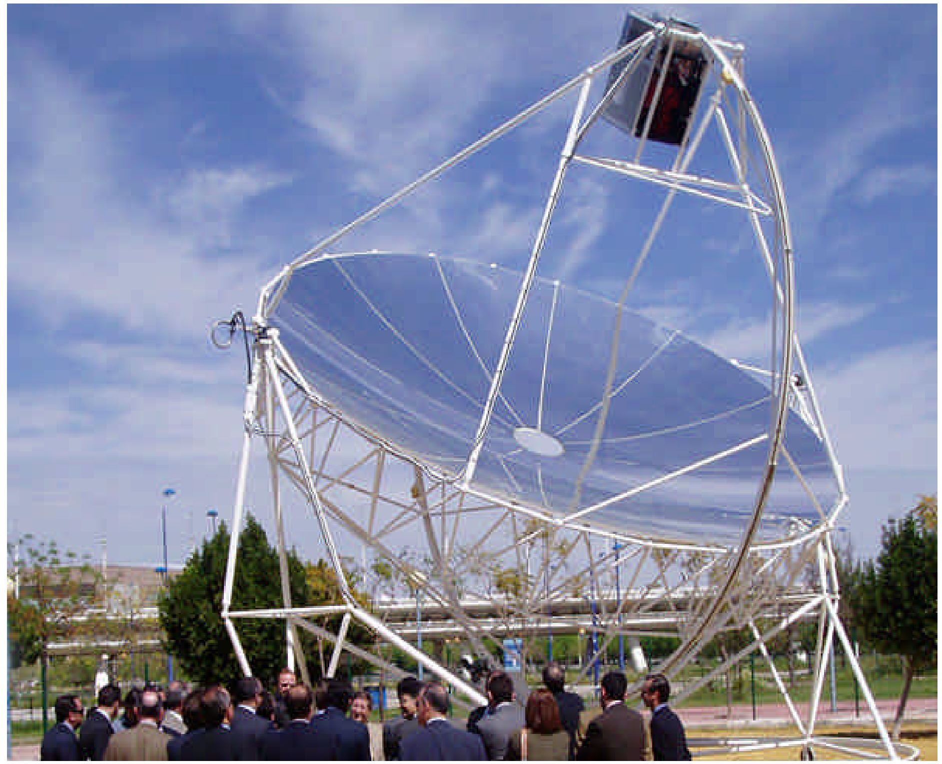
- Buyers Guide
- Archived articles
- Job Center
- Events Calendar
- Store: E-Books, Reference Books & More

Starting of commercialization: First STPP grid-connected!!

•EuroDish system in Seville (Spain).

•Signature of power purchase contract between CENTER and ENDESA in March 2004.

•~10 kWe_peak



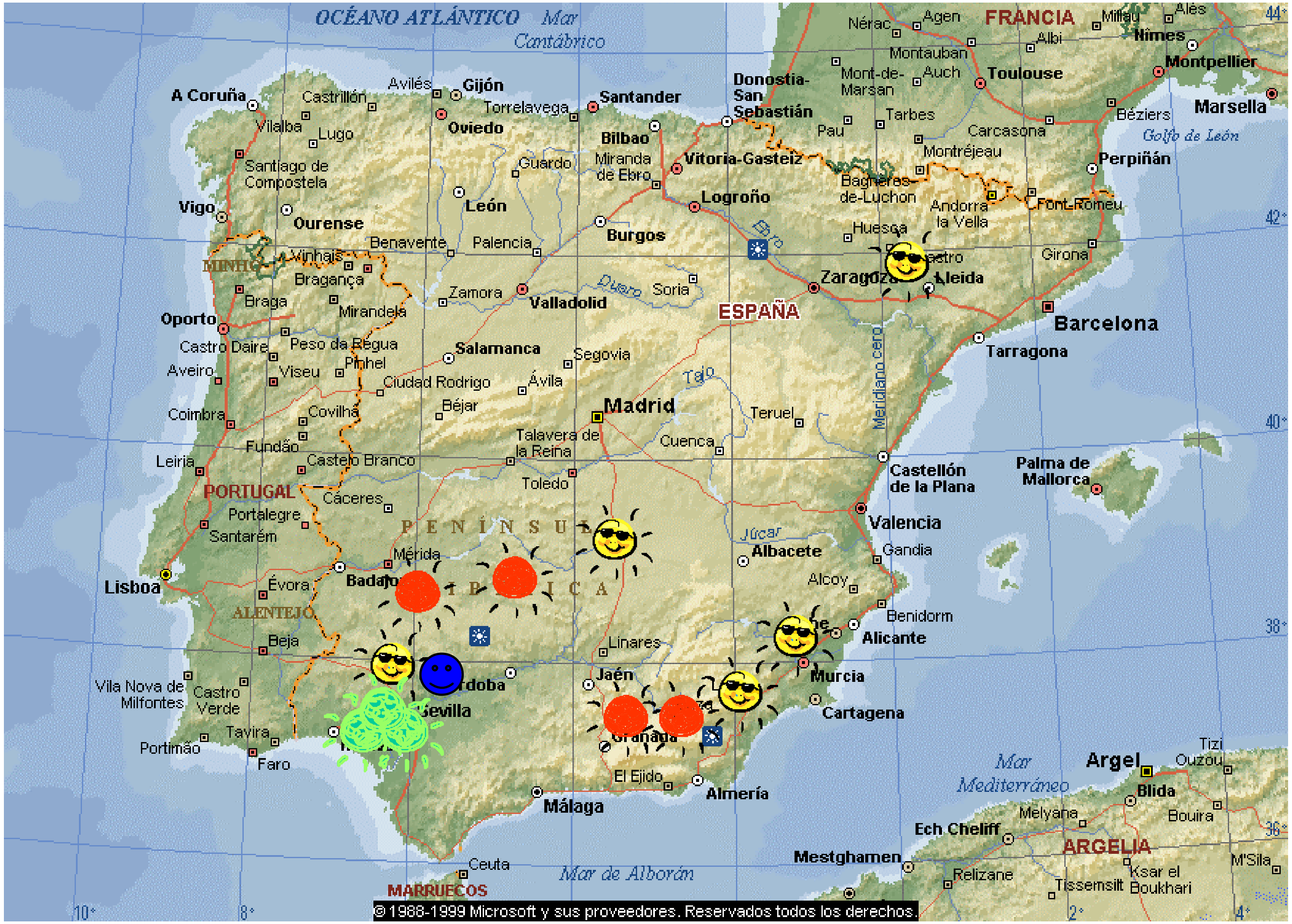
STPP initiatives for Spain
(updated information as of October 2004)

Iberdrola

ACS/SM

Abengoa

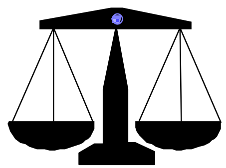
Sener



>500 MW

Why in Spain? ...

SPECIAL REGIME. - PREMIUM AND MARKET PRICES



Electricity Premium

R&D portion Investment Subsidies

Tax Deductions

Directive 96/92/EC on the Common Rules for the Internal Market in Electricity

Directive 2001/77/EC on the promotion of electricity produced from RES

The incentive scheme in Spain

a) Regulated Tariff (Art. 22.1.a):

- Selling electricity to distributor. Selling price is a percentage of ART. Tariff is unique for all market program periods.
- It is compulsory to supply production predictions.

Payment: % ART + Reactive (between +8% and –4%) + Deviations

Advantages:

- Well known Prices Scheme
- Less volatile premiums

Disadvantages:

- Higher deviation costs than the market option (10% ART)
- Less profitability than market option

The incentive scheme in Spain

b) Going to the electricity stock market:

- ❑ Operating as a market agent and joining the market.

Payment: Pool market price + Power guarantee + Premium + Incentive + Reactive (between + 8% and –4%) + Deviations

Advantages:

- ❑ Higher profatibility from premium
- ❑ Less deviation cost (10% Pool price)

Disadvantages:

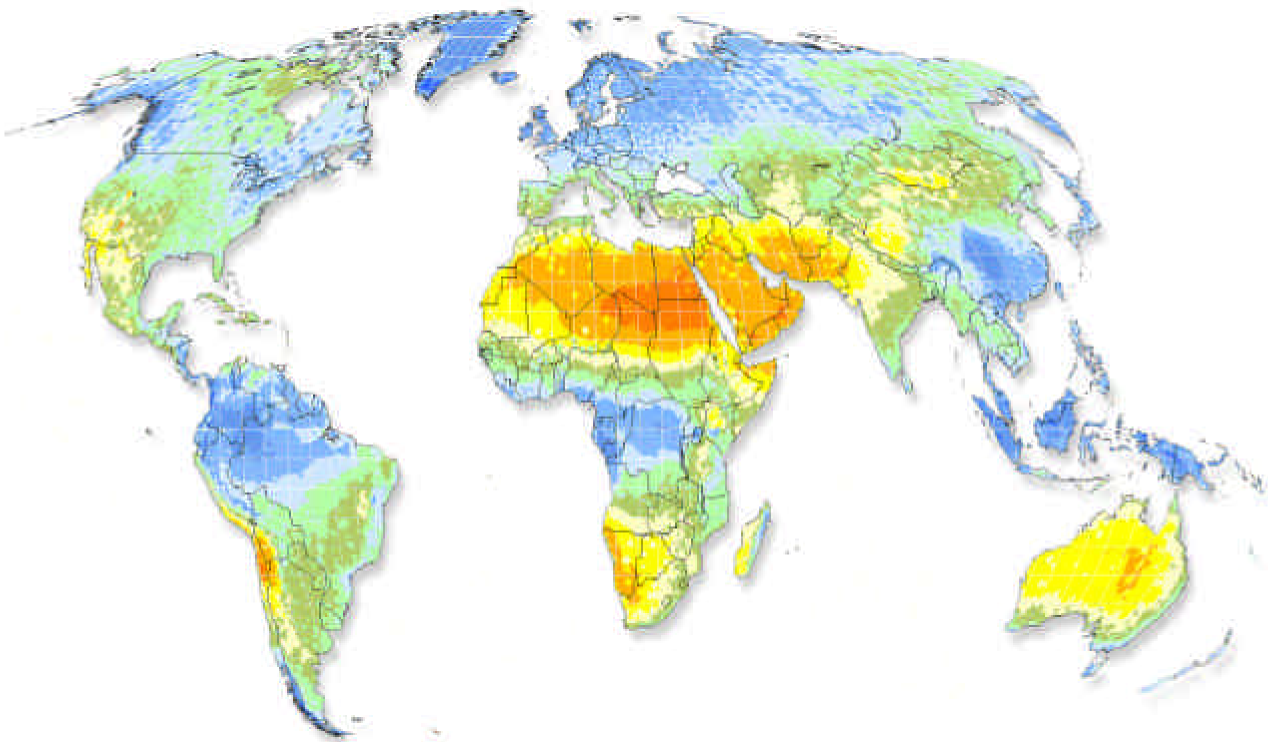
- ❑ Adapt to market agent capabilities.
- ❑ Higher risk:
  - Lower deviation tolerance
  - Variations of pool price (hydropower fluctuations, weather influence, fuel prices,...)

The incentive scheme in Spain

- **Regulated tariff:**
  - ✓300 % of ART (First 25 years) – 240% (from 26th year)
- **Electricity stock market:**
  - ✓Premium: 250 % of ART (First 25 years) – 200% (from 26th year)
  - ✓Incentive: 10% of ART

ART: 7.2072 c€/kWh for 2004

Zones of interest for deployment of STPP



Source: SunLab

- **Desserts of North and South Africa,**
- **Mediterranean region**
- **Arabian Peninsula and Near East,**
- Different areas of India,
- Northwest and central part of Australia,
- High plains of Andean Countries,
- North-East of Brazil,
- North of Mexico, and
- Southwest of USA.

Potential in Europe+ North Africa + Middle East

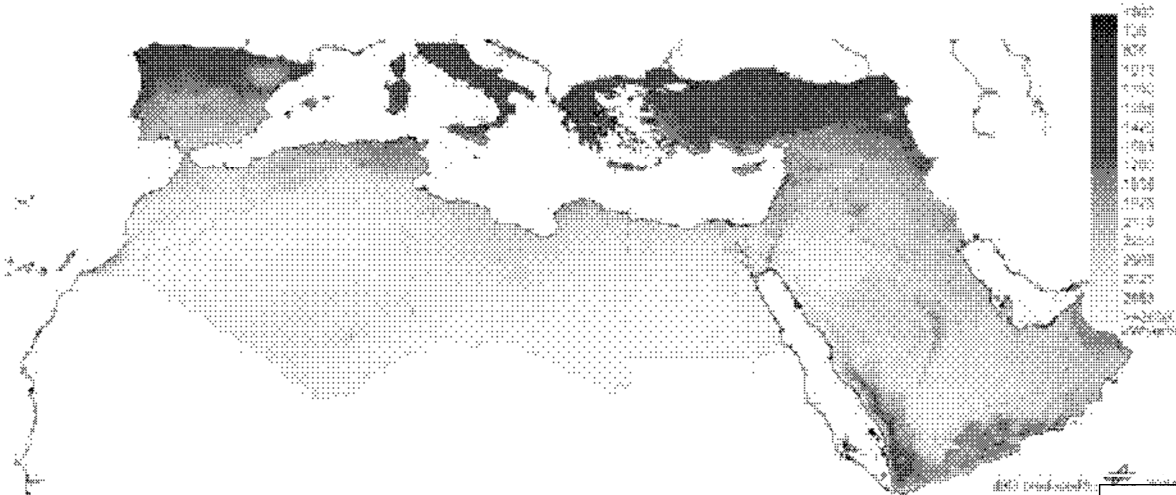
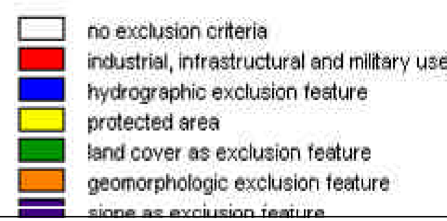
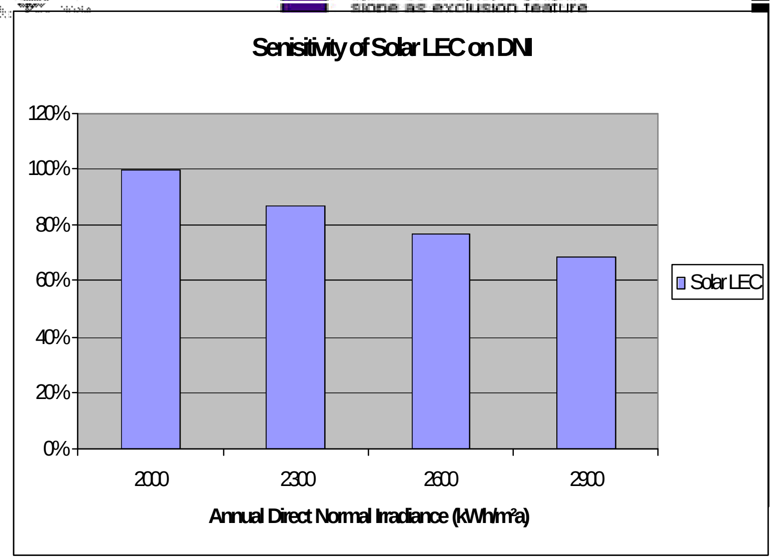


Figure 4: Annual Direct Solar Irradiance in the southern EU-MENA Region. The primary energy received by each square meter of land equals 1 – 2 barrels of oil per year.



Potential in Europe
= 2500 TWh
Potential in North Africa + Middle East
allmost infinite !



The Idea of Med-CSP and EU-MENA

From founding document of TREC (TransMediterranean Renewable Energies Cooperation), 2003:

Key factors for development in the 21st century are

- ***energy***
- ***water***
- ***climate stability***
- ***peace***

MED-CSP: Strategic partnership between European Union (EU) and Middle East (ME) and North Africa (NA):

- MENA has vast (solar) resources as valuable “export product” for its economic growth
- EU can provide Technologies and finance to “activate those potentials” and to cope with its national and international responsibility for climate protection

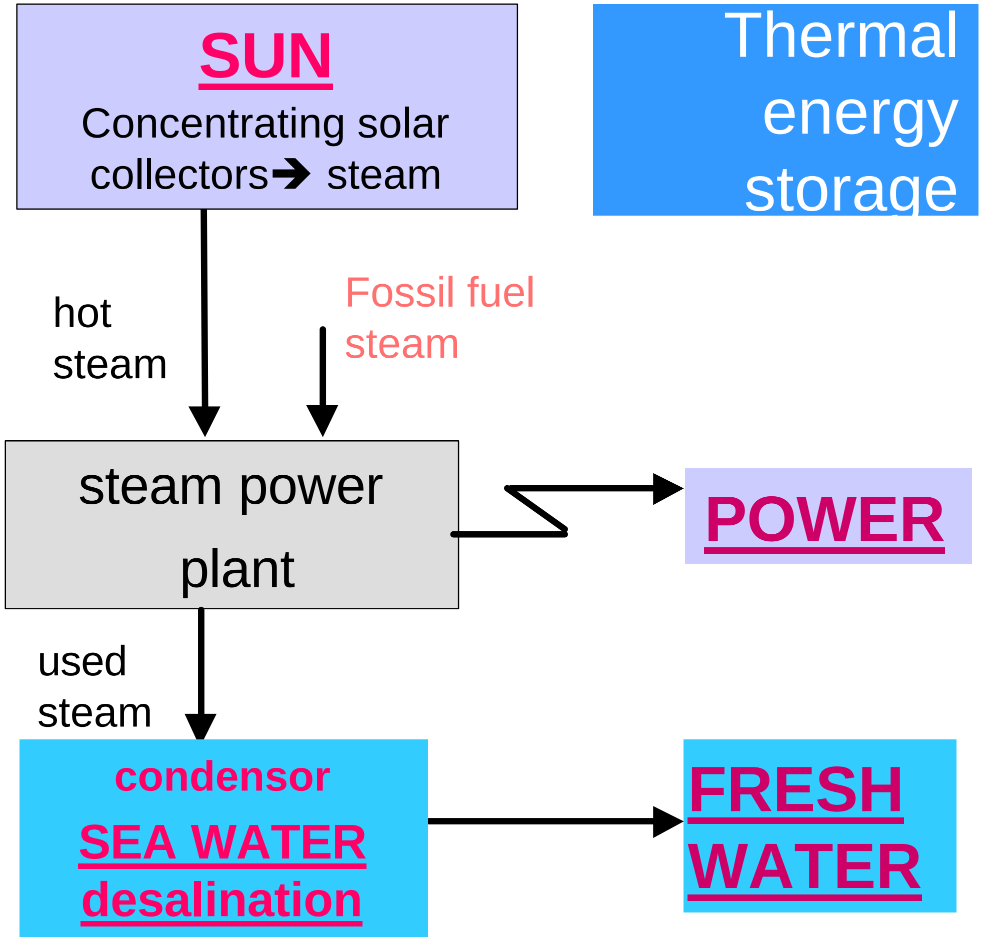
- Solar technology competence build-up
- Solar technology cost reduction
- Large-scale solar energy utilization

Common goals – joint efforts/projects:

Co-operative actions to open these gateways for sustainable prosperity in the sun-belt

STPP may be used for co-generation of electricity and process heat.

for example: **SUN + SEAWATER → POWER + FRESH WATER**



- Solar electricity
  - Integrated reserve capacity,
  - power accord. to demand
  - assured operation

up to 24 h/d solar

1 kWh elecricity → 40 liter H_2O

TREC, founding document 2003

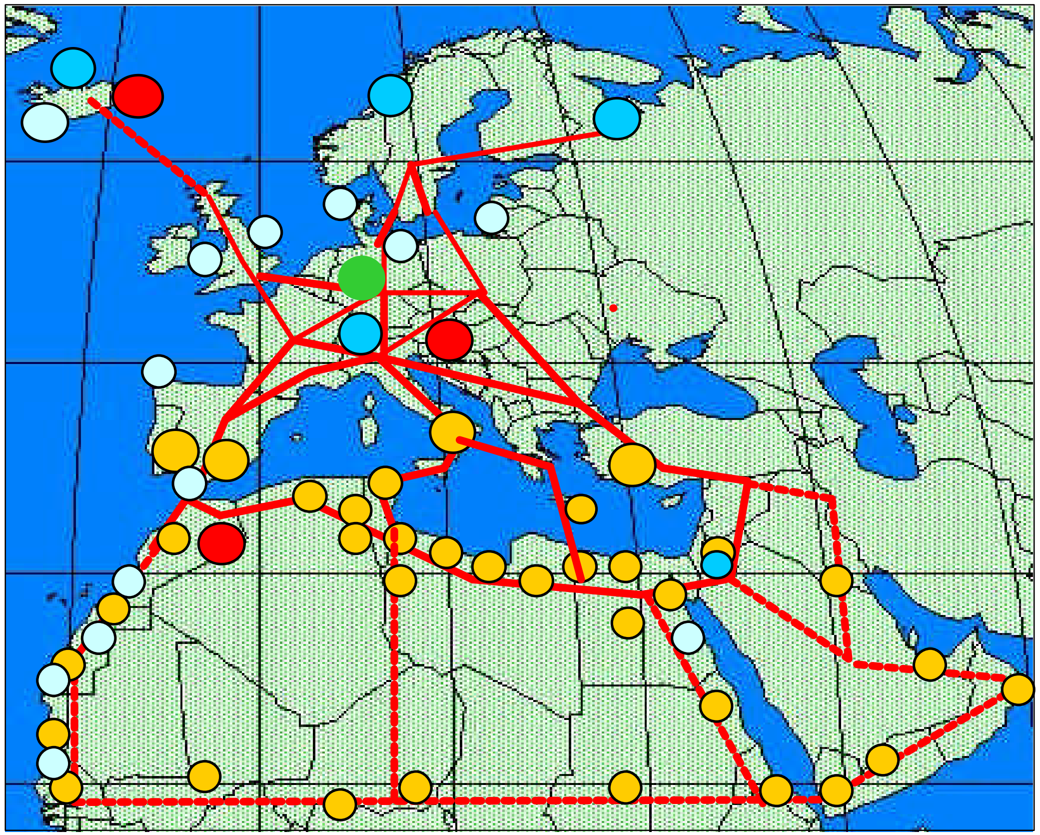
Then these regions would be able to

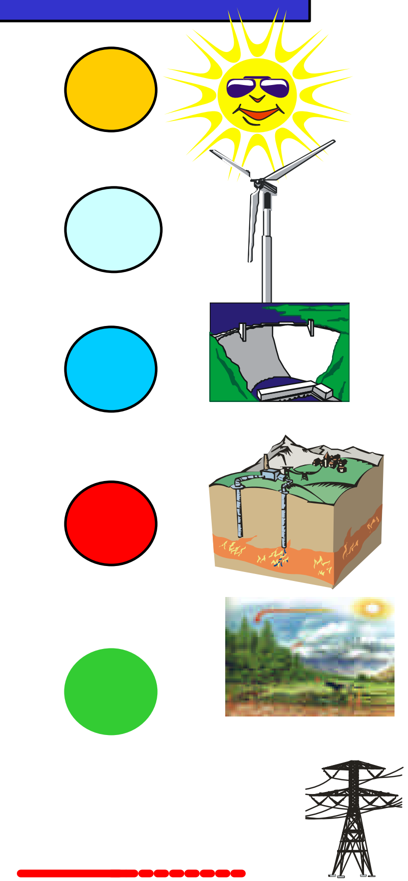
1. *produce sufficient energy for the growing power and desalination needs in MENA,*
2. *produce enough clean power, for Europe to comply with its climate stabilization obligations,*
3. *reduce costs for solar energy to below fossil fuel prices,*
4. *terminate their dependence on expiring fossil energy resources,*
5. *reduce conflicts for limited fossil resources*
6. *preserve fossil fuel reserves for high-value product rather than burning it.*

Lesson learned from European integration:

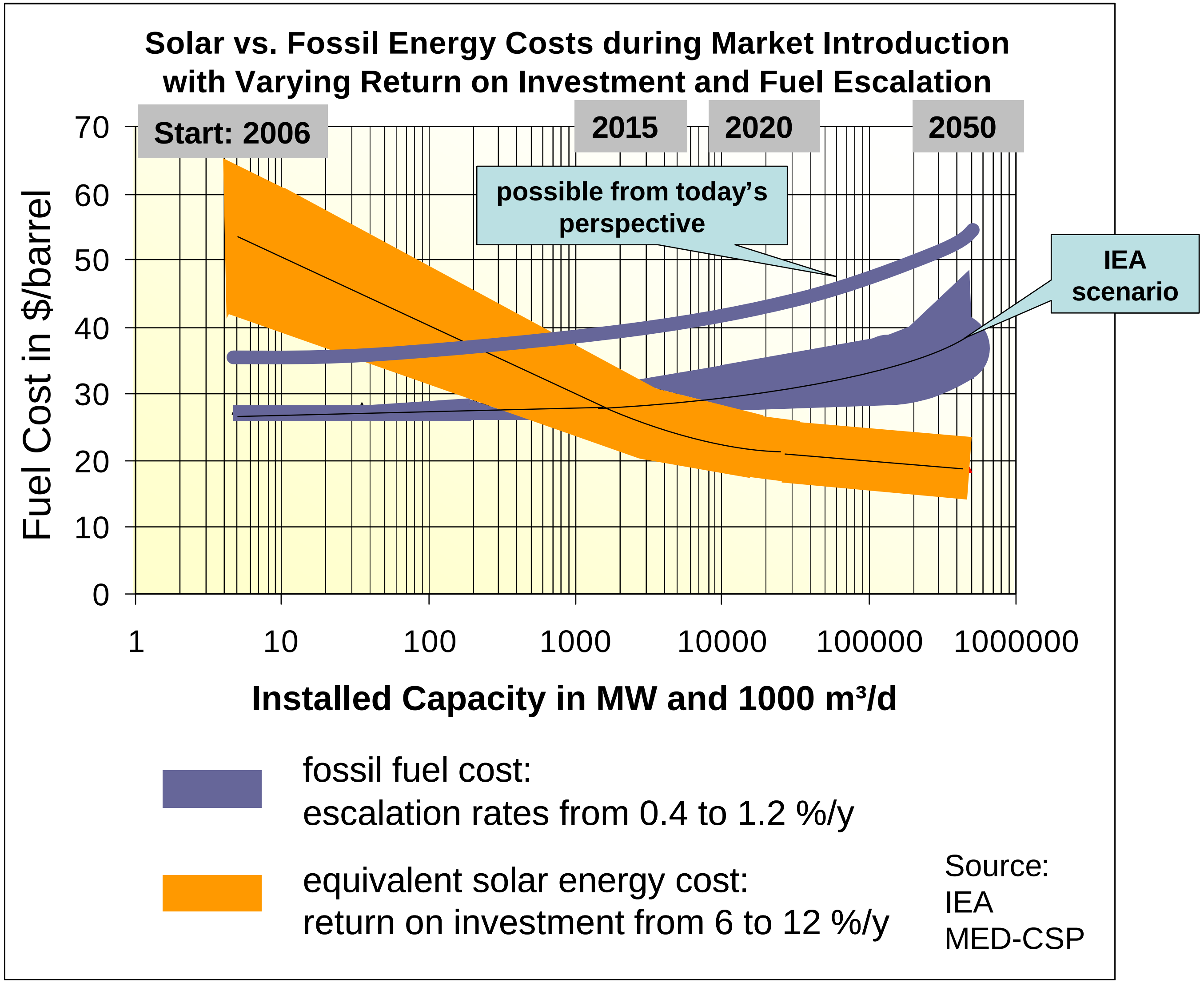
The more national economies are interweaved,
the higher are stability and prosperity of that region -
since economically positive interconnections are made.


TREC
Trans- Mediterranean Renewable Energy Cooperation



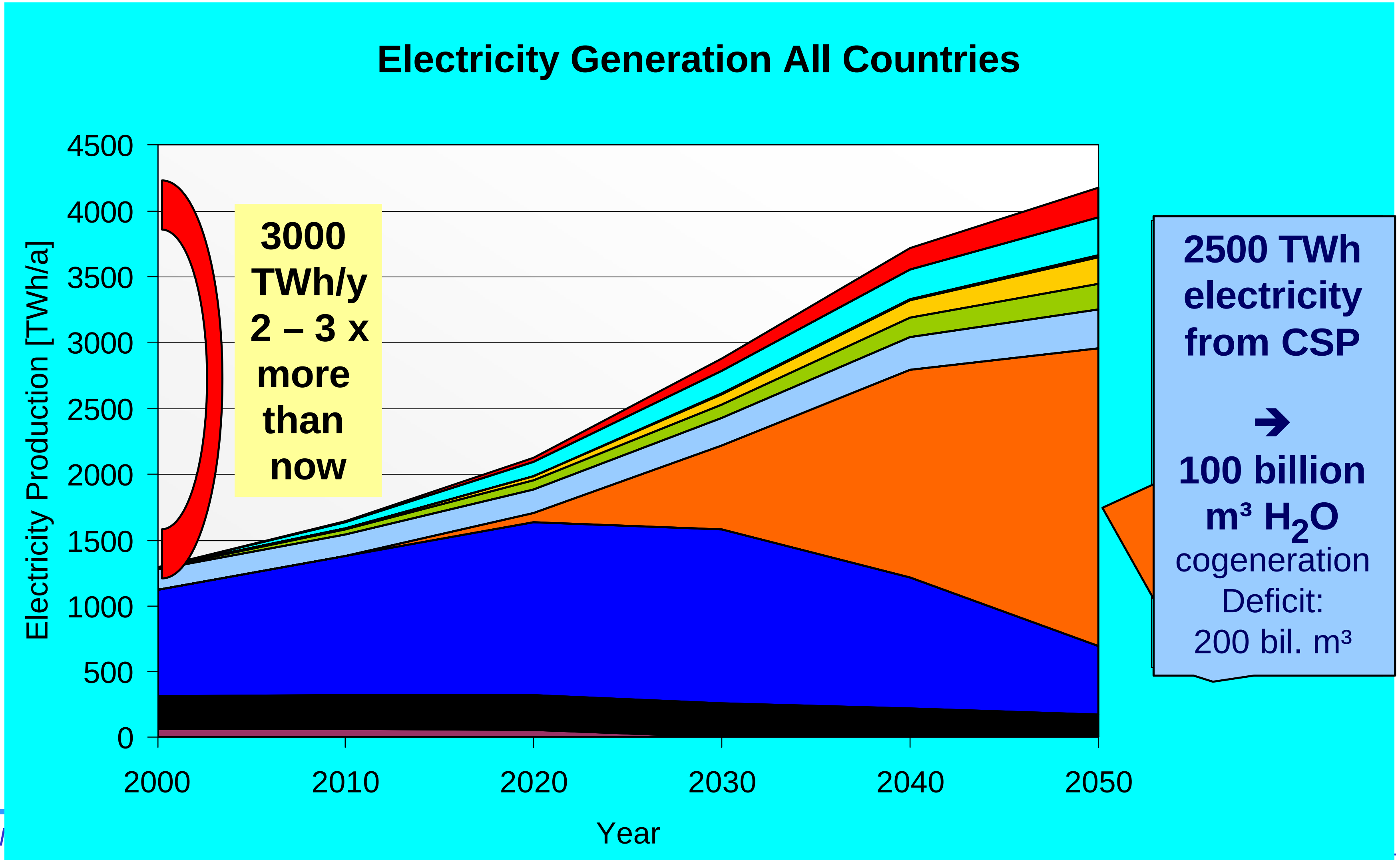


Cost Objectives for the STPP

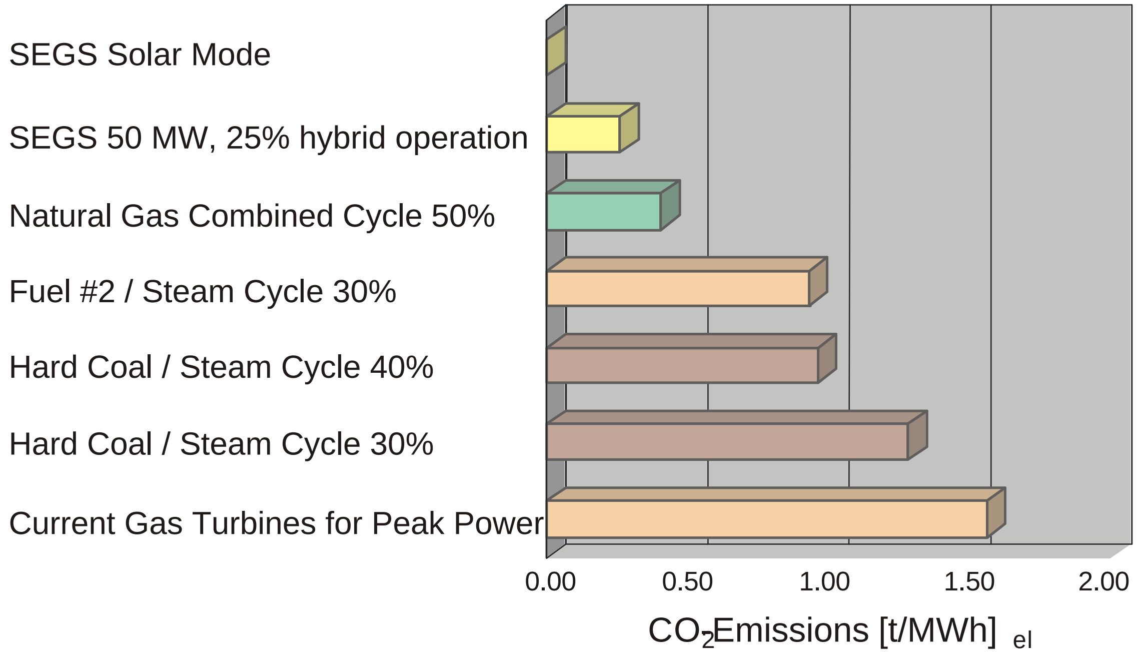


Explosion of electricity demand by growth of population and economy

study DLR: www.dlr.de/tt/med-csp



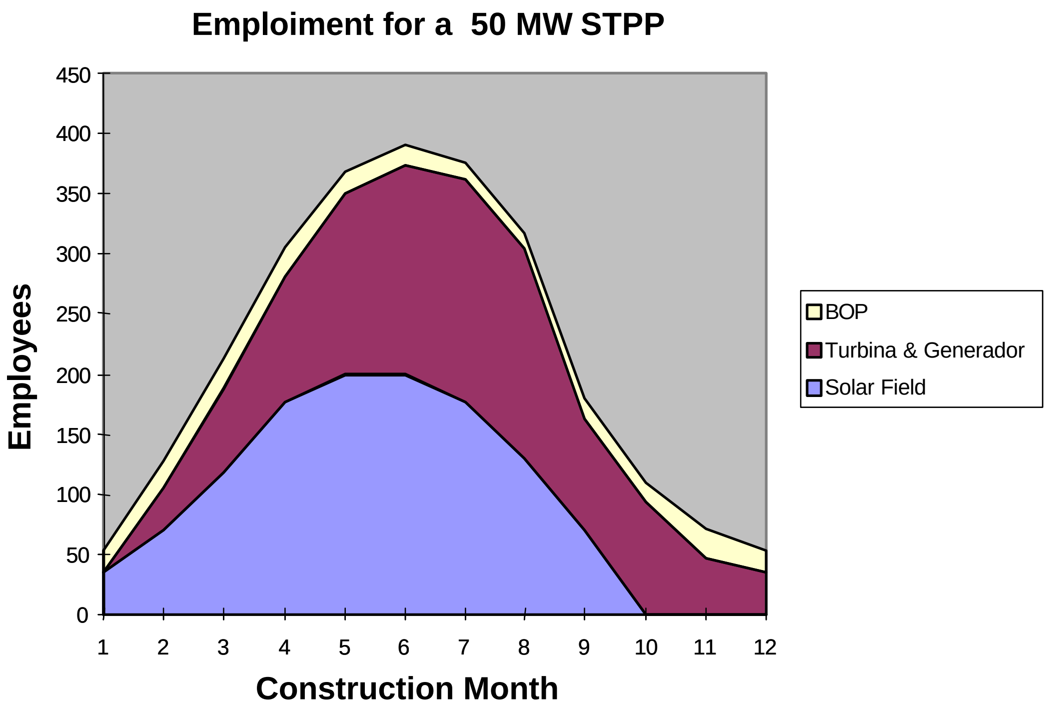
Other advenges / implications of the STPP
CO2 mitigation by STPP



A 50 MW STPP would avoid:

- The consumption of 35.920 t coal/year
  - 897.990 t of coal in 25 years of the plant life.
- This would mitigate 89.314 tons of CO_2 per year
  - 2,23 millions of tons CO_2 during the plant life.
- Values of NOx mitigation are 291 tons/year and 7.280 tons in 25 years.

Other advenges / implications of the STPP Emploiment



- More than half of equipments and services come from local or national suppliers
- During the about 15 months of construction (STPP of 50 Mwe) the required manpower is about 400 employees.
- After construction, about one permanent employee is required per each MW

100MW CSP:

50-100 O&M Jobs

500-1000 Construction Jobs

200-400 Manufacturing Jobs

40.000t Steel

50.000t Concrete

11.000t Glass

THANKS FOR YOUR ATTENTION !

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Survey reports