FICHTNER SOLAR GmbH
a company of the Fichtner group

KEARNEY and Associates

KfW

UNEP

GEF

The Federal Ministry for the Environment, Nature Conservation and Nuclear Safety

International Executive Conference on Expanding the Market for Concentrating Solar Power (CSP) - Moving Opportunities into Projects

19 - 20 June 2002
Berlin, Germany

The Status and Prospects of CSP Technologies

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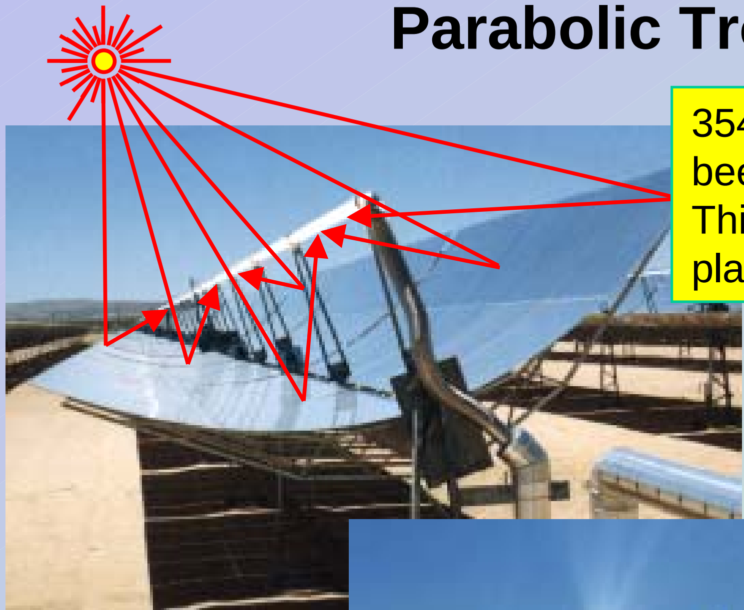
President of Kearney and Associates

Parabolic Troughs, Towers, Dish / Stirling

354 MWe of the **Parabolic Trough Technology** have successfully been operated in California for about fifteen years.
This technology is proven and suitable for grid connected power plants of 30 to 200 MWe unit size.



The **Tower Technology** uses higher concentrations. Thereby higher temperatures and higher conversion efficiencies can be obtained.
In the medium term this technology can be applied for grid connected power plants of 30 to 200 MWe unit size.

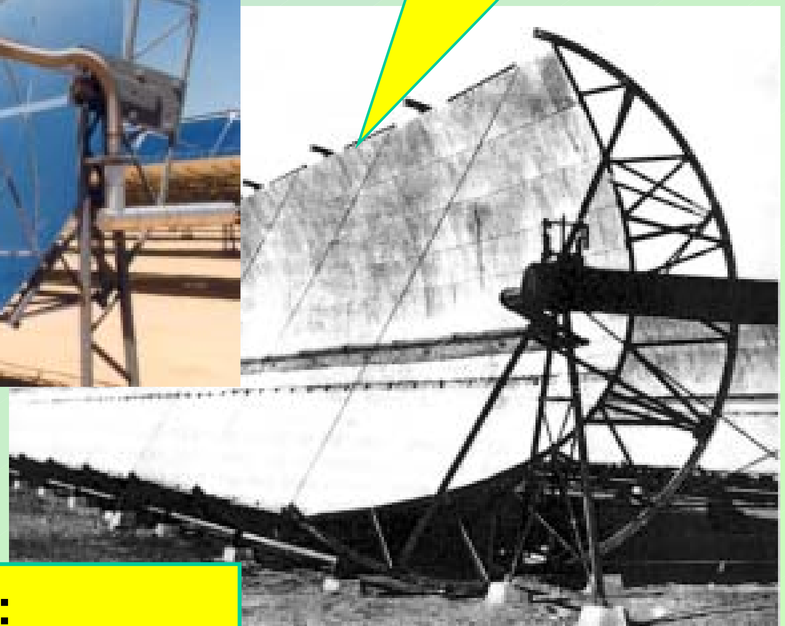
The **Dish / Stirling Technology** is suitable for smaller grid independent applications of 10 kW to 1 MW.
The generation cost is much less than the one of photovoltaic installations.

Development of Parabolic Trough Collector

2002: Eurotrough

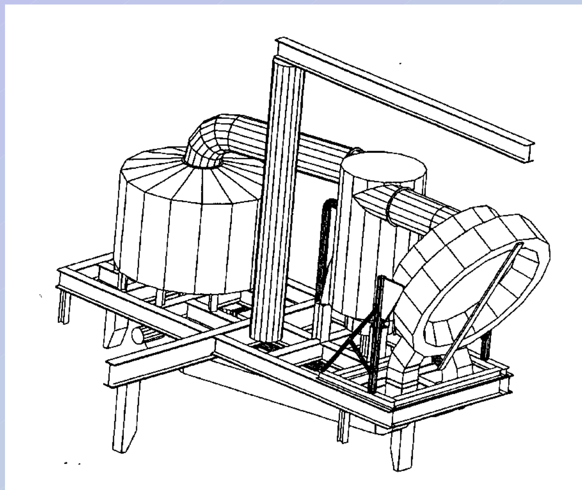
1990: Luz LS3

1912: Shuman



Improved performance and reduced cost due to:
- **Lighter weight and higher stiffness of structure**
- **Better values of reflectivity, absorbtivity and emissivity**

Tower Technology (Receivers and Heliostats)



Volumetric Air Receiver

Tube Receiver

100 m² Heliostat
(DLR - PSA)

150 m² Heliostat
(Advanced Thermal Systems)

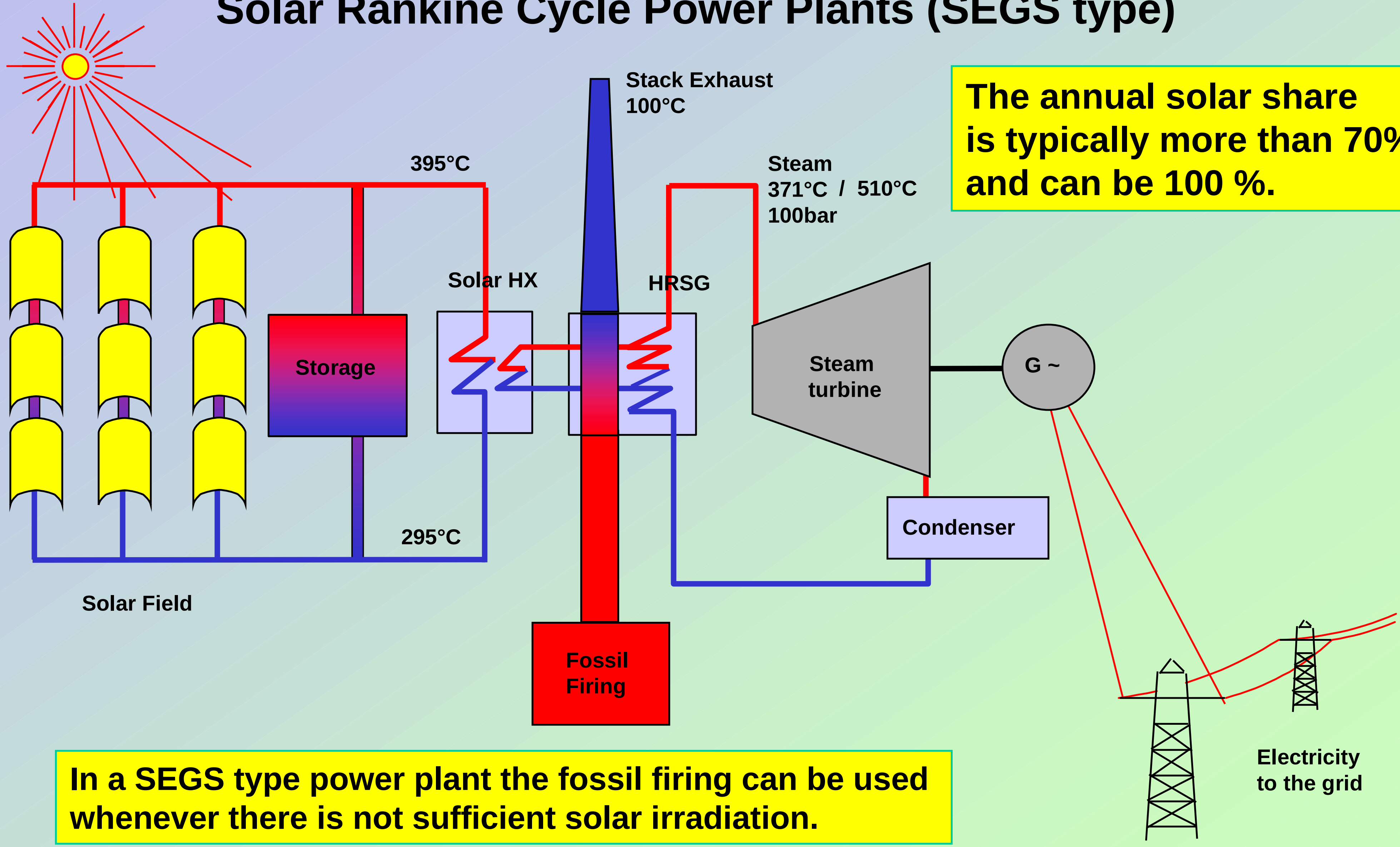
150 m² Heliostat
(Steinmüller)

Solar Tower Facilities

Facility, location and state of development [1)]	First Year of Operation	Net Output [MW_e]	Heat Transfer Fluid (HTF)	Thermal Energy Storage HTF
Eurelios, Adrano, Italy (d)	1981	1.0	water/ steam	eutectic salt storage
Themis, Targasonne, France (d)	1982	2.3	salt	salt storage
Sunshine, Nio, Japan (d)	1981	1.0	water/ saturated steam	steam storage
IEA-SSPS, Almeria, Spain (d)	1981	0.5	sodium from 1987: air	sodium storage
CESA 1, Almería, Spain (d)	1983	1.0	water/ steam from 1989: air	salt storage
Solar I, Barstow, USA (p)	1982	10.0	water/ steam	oil storage
Crimea, USSR (d)	1988	5.0	water/ steam	
Solar II, Barstow, USA (p)	1995	10.0	salt	salt storage
TSA, Almeria, Spain (d)	1995	2,5 MW_t	air, water/ steam	salt storage
GAST-20 study, Germany plus Spain (c)			air	
PHOEBUS, Jordan (c)			air, water/steam	salt storage
COLON SOLAR, Spain (c)		10	water/steam	no storage
PS10, Spain (c)		10	air, water/steam	ceramic storage
SOLAR TRES, Spain (c)		15	molten salt, water/steam	salt storage

(e) = experimental; (d) = demonstration; (p) = pilot; (c) = concept

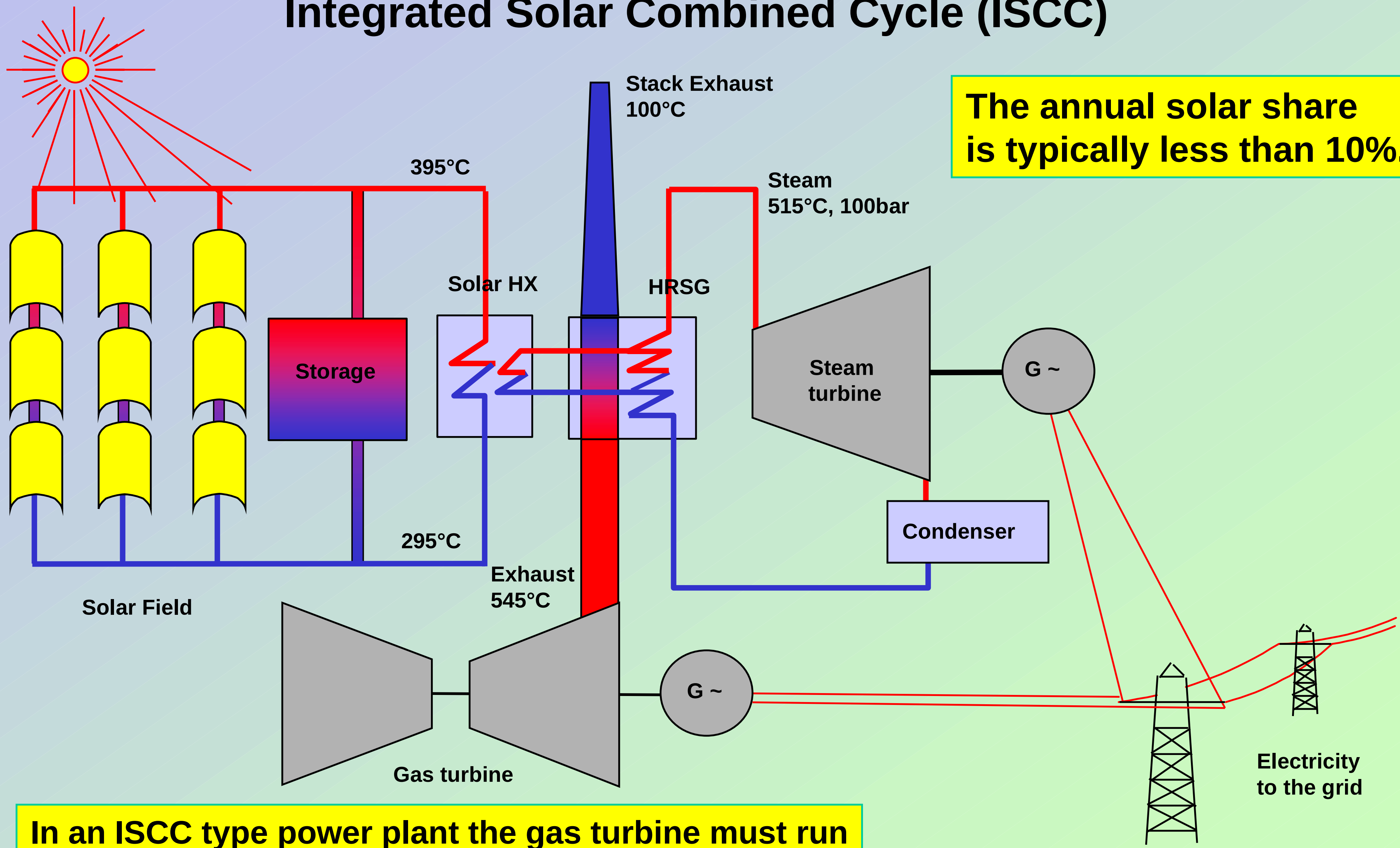
Solar Rankine Cycle Power Plants (SEGS type)



The annual solar share is typically more than 70% and can be 100 %.

In a SEGS type power plant the fossil firing can be used whenever there is not sufficient solar irradiation.

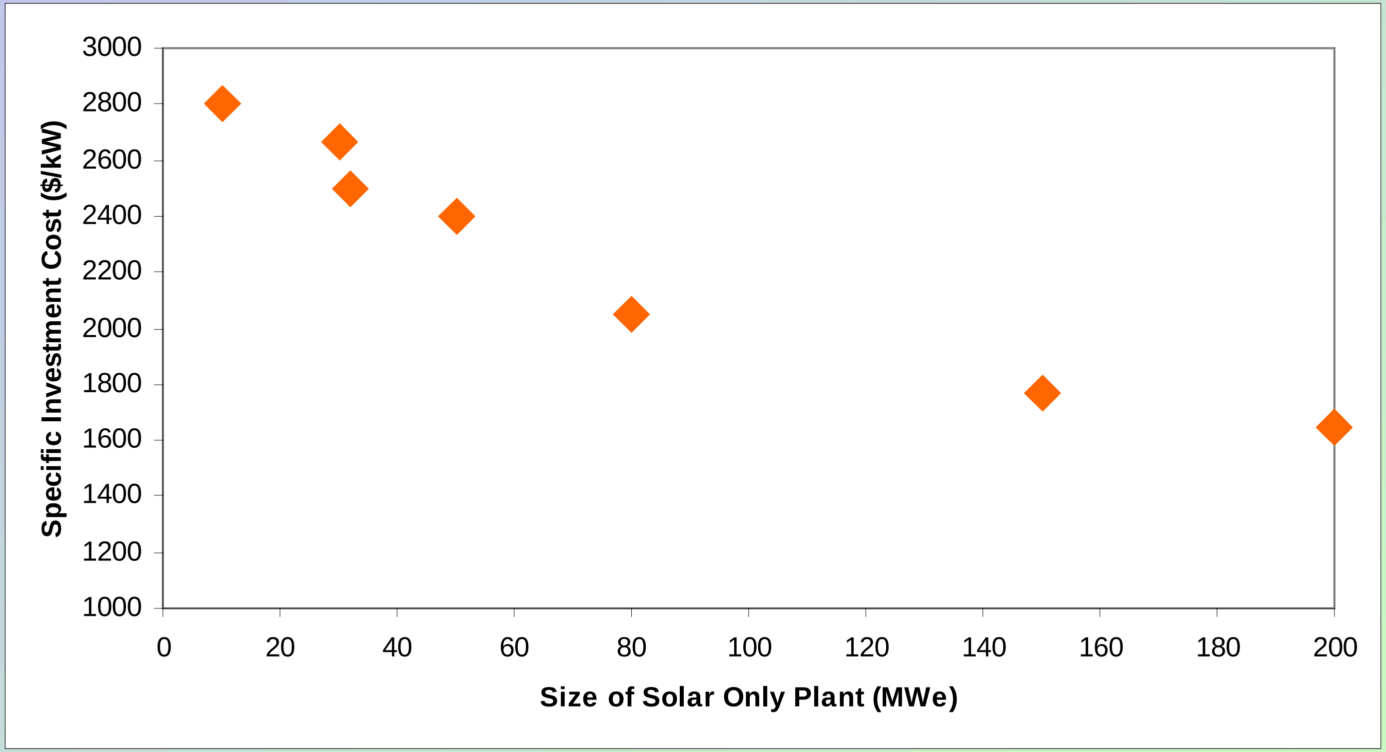
Integrated Solar Combined Cycle (ISCC)



The annual solar share is typically less than 10%.

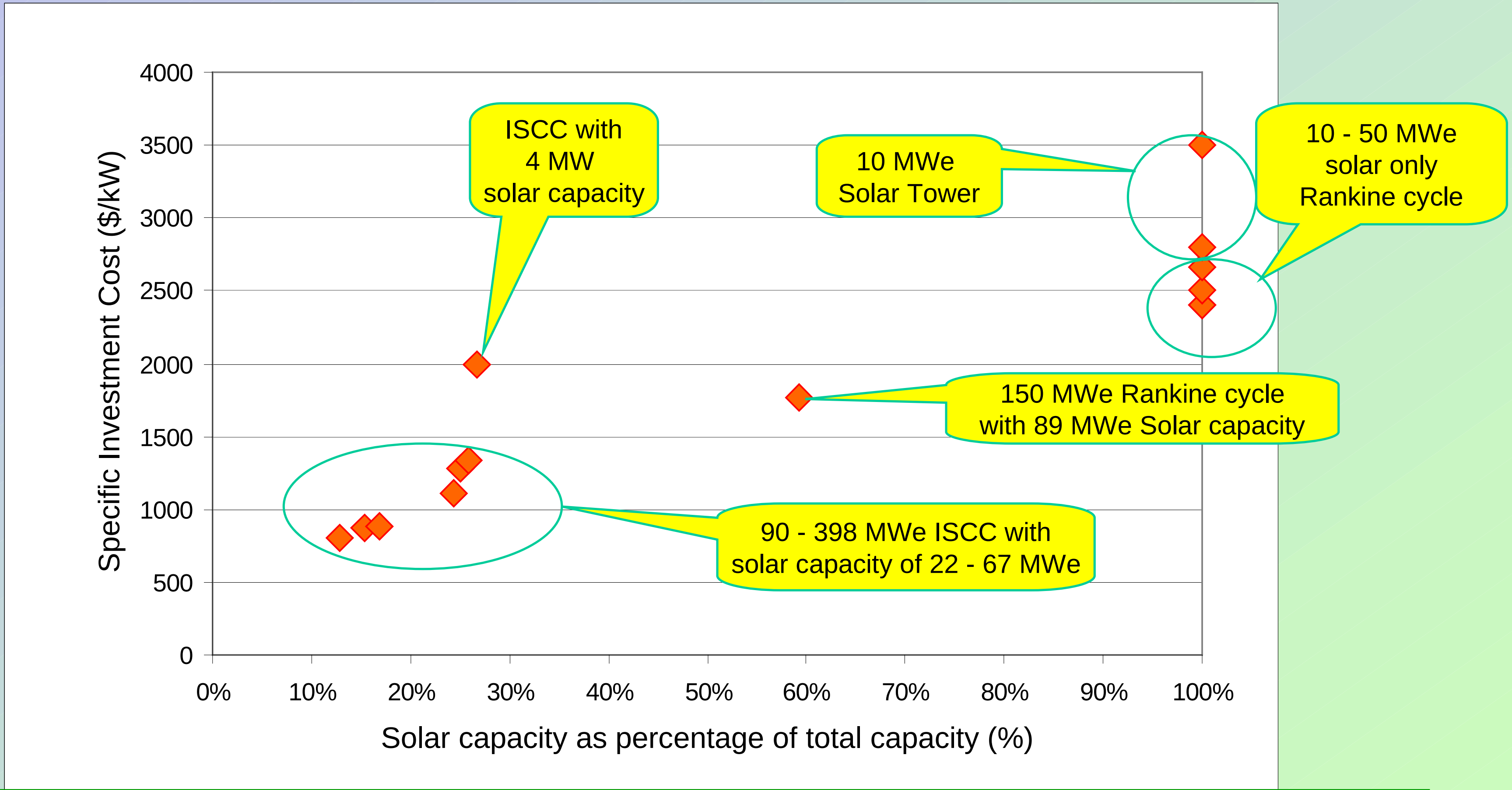
In an ISCC type power plant the gas turbine must run in order to use the solar heat.

Typical specific investment cost of parabolic trough solar only plants (2001)



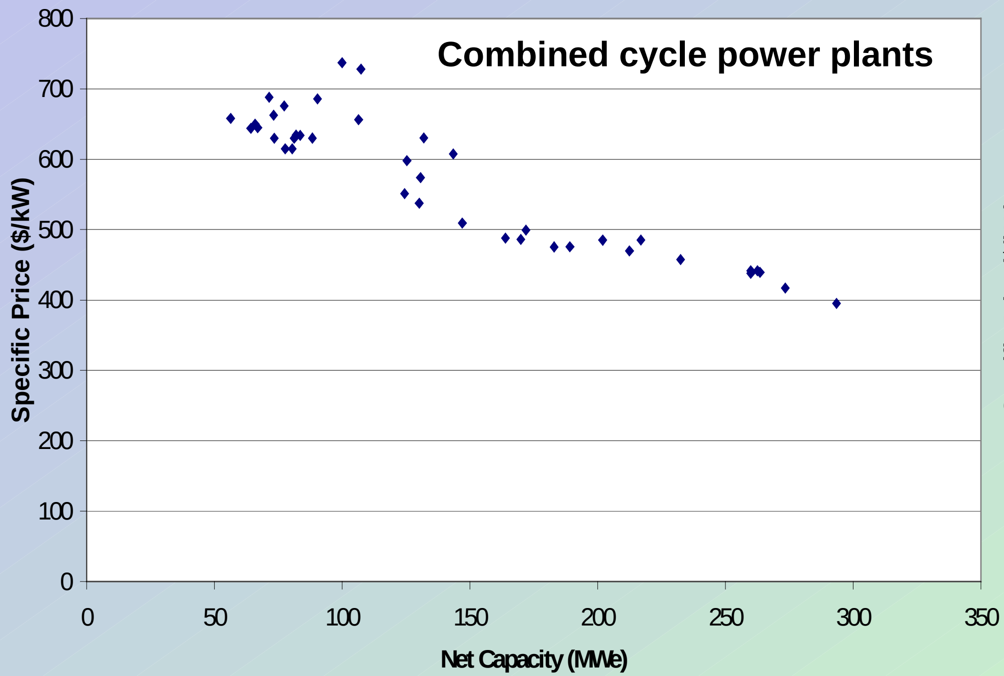
The specific investment cost of solar thermal power plants decrease with size and vary depending on local conditions and requirements, sourcing of components and careful design.

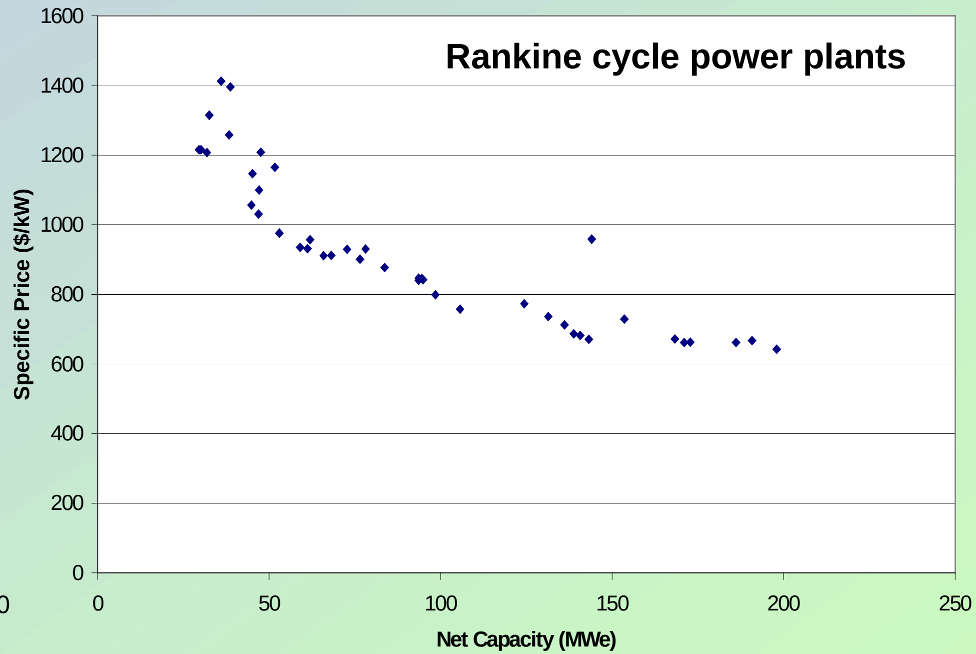
Specific investment cost of solar thermal power plants (2001)



The specific investment cost of solar thermal power plants decrease with size and increase with solar share.
It varies depending on local conditions and requirements, sourcing of components and careful design.

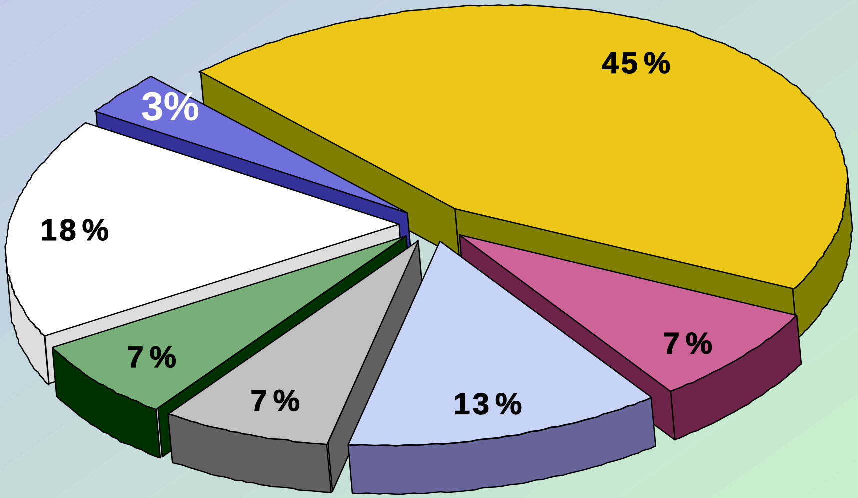
Typical specific investment cost of fossil power plants (2001)





The specific investment cost of fossil power plants decrease with size and vary depending on local conditions and requirements, sourcing of components and careful design.

Typical Breakup of Investment Cost of Solar Rankine Cycle Plants

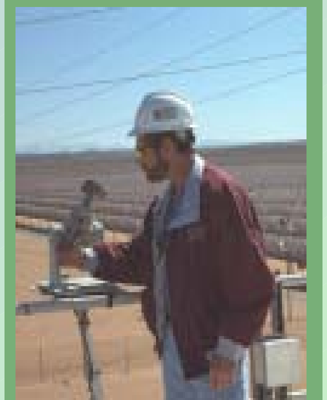


Site Work and Infrastructure 3 %

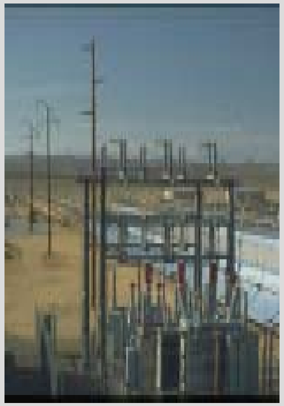
Solar Field 45 %

Other 18 %

Services 7 %



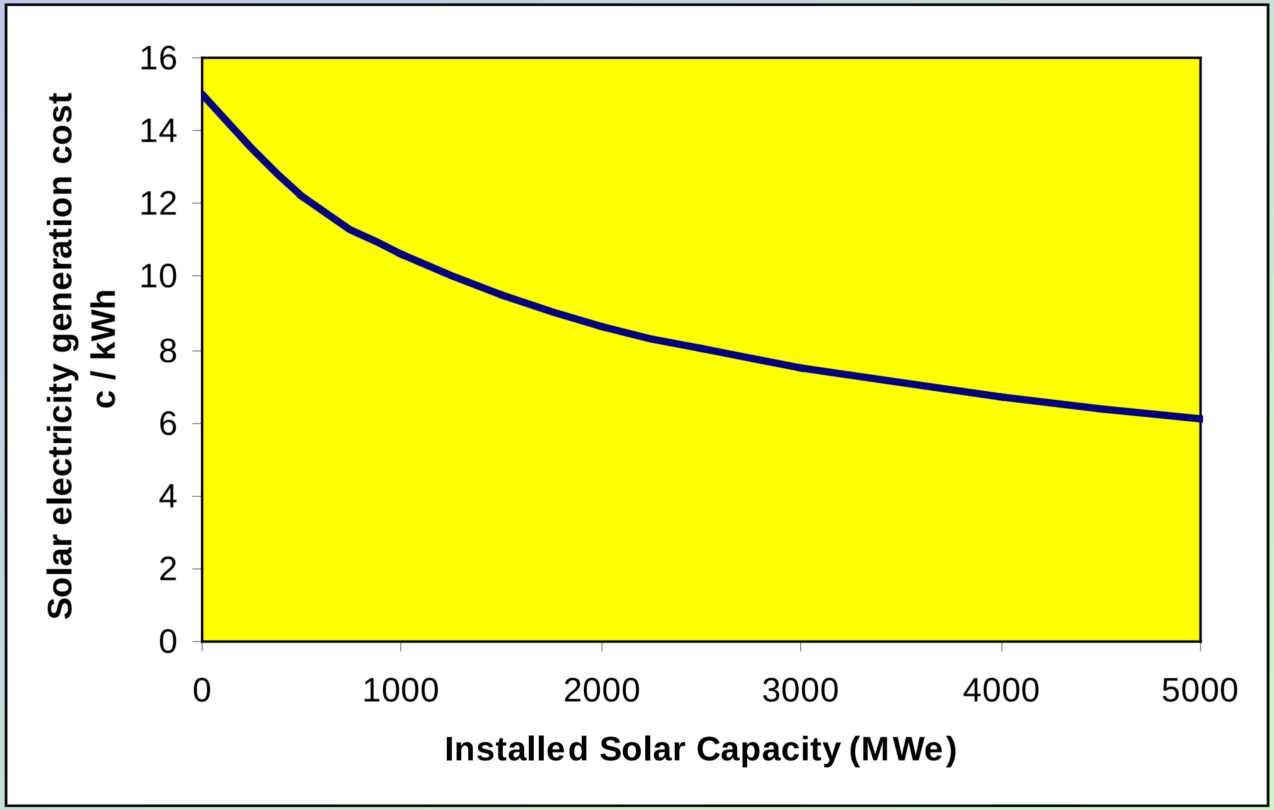
BoP 7 %



Power Block 13 %

HTF System 7 %

Volume will decrease generation cost

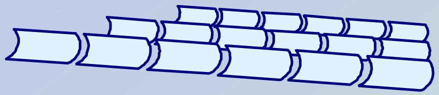


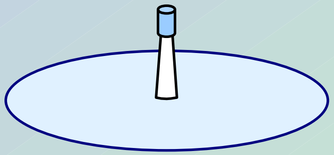
The CSP industry anticipates reducing solar power generation costs in the midterm (2010) by about 20 %, assuming an order volume of more than 100 MWe of solar capacity per year.
In the longer term the CSP industry has set a goal of solar generation cost of 6 c/kWh after reaching approximately 5000 MWe of installed solar capacity.

Commercial Applications and Features

Dispatchable Power

- utility peak and intermediate
- high-value, green markets

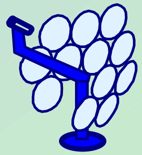


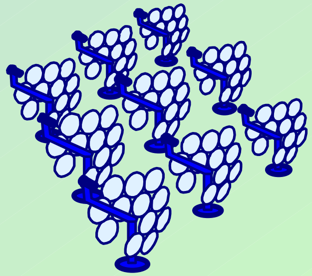


10's to 100’s of MW's

Distributed Power

- distributed, on-grid (e.g., line support)
- stand-alone, off-grid (e.g., water pumping, village electrification)

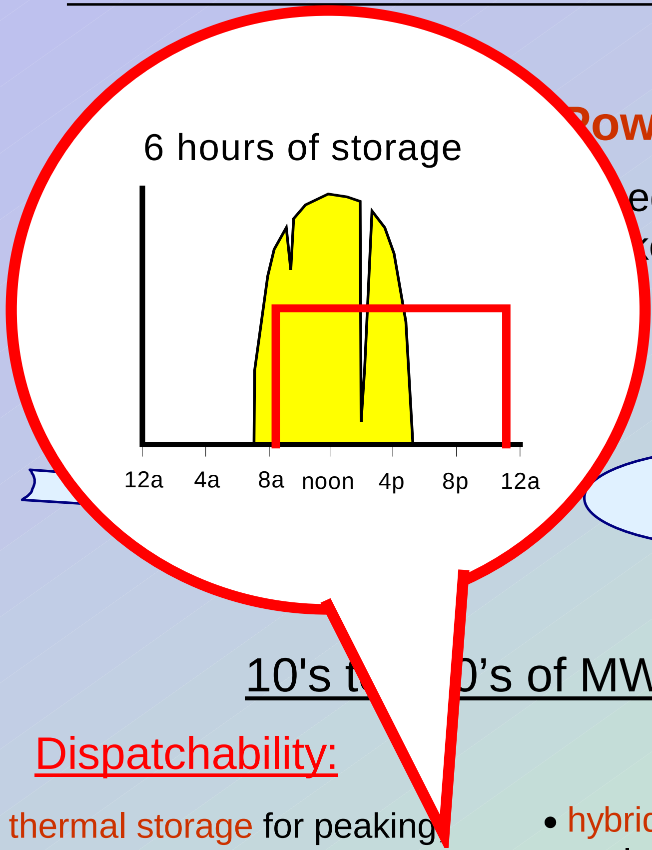




kW's to MW’s

Manufacturing:

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



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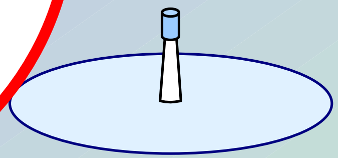

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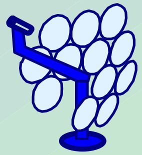
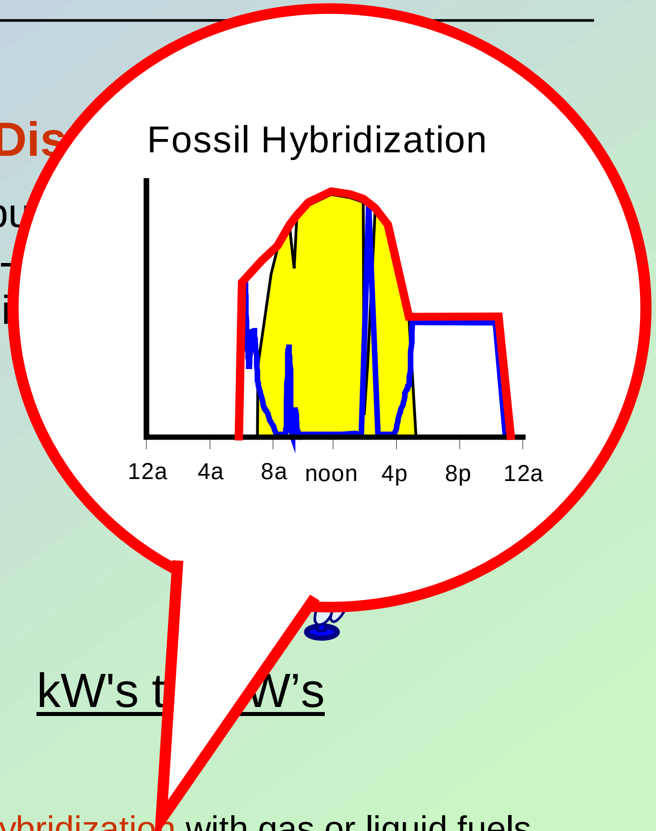




10's t 0's of MW's

kW's t W's

Dispatchability:

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

Manufacturing:

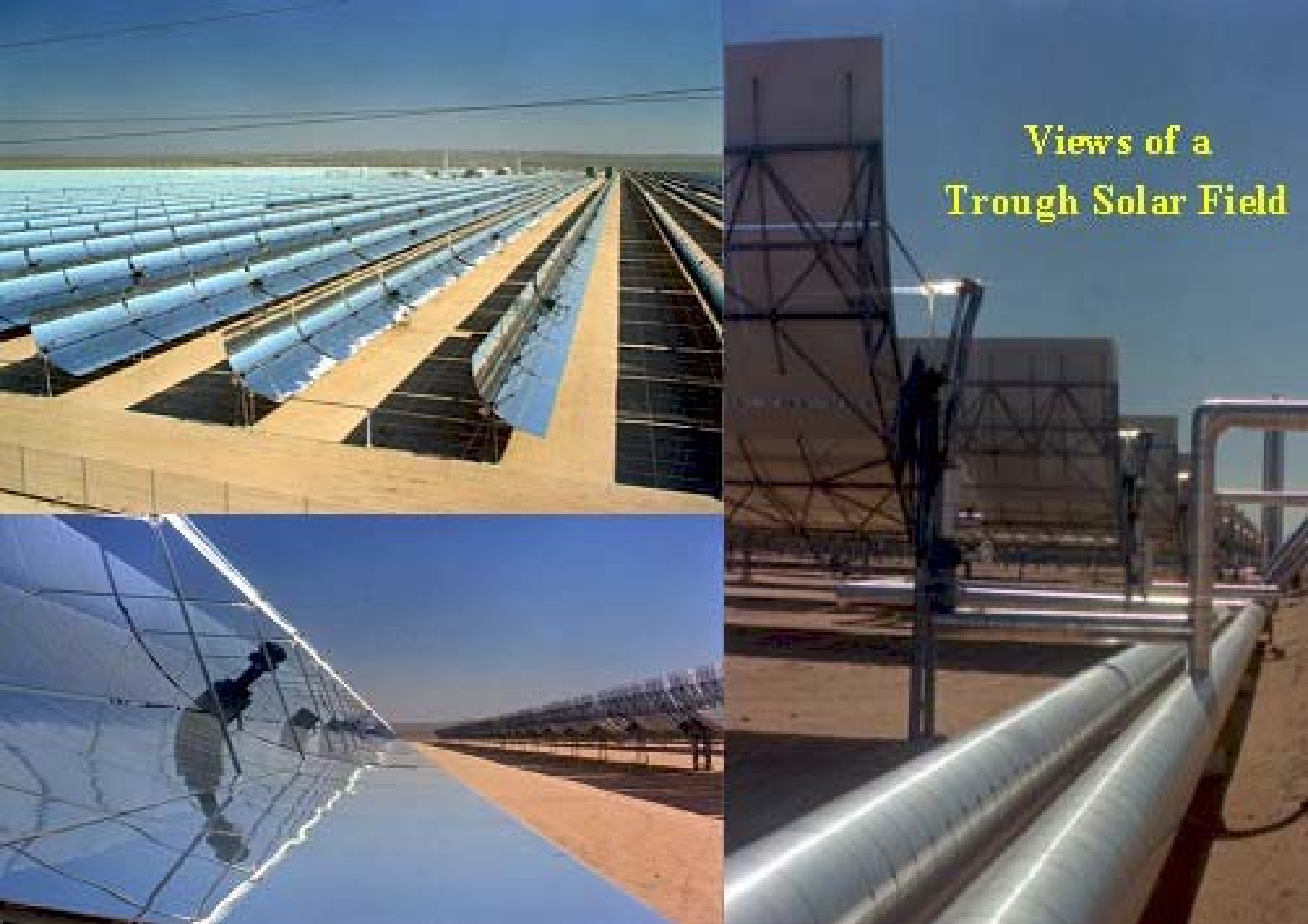
- Relatively conventional technology (glass, steel, gears, heat engines, etc.) allows rapid manufacturing scale-up, low risk, conventional maintenance

Operating SEGS Plants – 354 MWe in Mojave Desert, California, USA

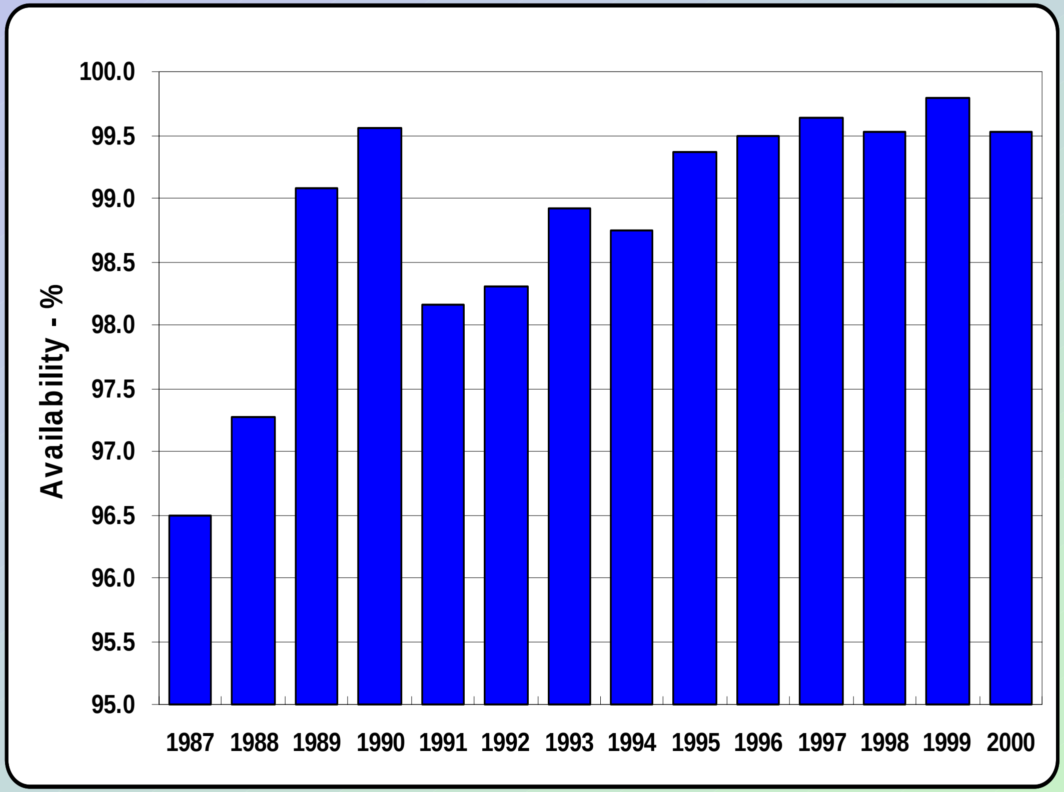
SEGS Plant	1st Year of Operation	Net Output (MW_e)	Solar Field Outlet Temp. (°C/°F)	Solar Field Area (m^2)	Solar Turbine Eff. (%)	Fossil Turbine Eff. (%)	Annual Output (MWh)
I	1985	13.8	307/585	82,960	31.5	-	30,100
II	1986	30	316/601	190,338	29.4	37.3	80,500
III & IV	1987	30	349/660	230,300	30.6	37.4	92,780
V	1988	30	349/660	250,500	30.6	37.4	91,820
VI	1989	30	390/734	188,000	37.5	39.5	90,850
VII	1989	30	390/734	194,280	37.5	39.5	92,646
VIII	1990	80	390/734	464,340	37.6	37.6	252,750
IX	1991	80	390/734	483,960	37.6	37.6	256,125

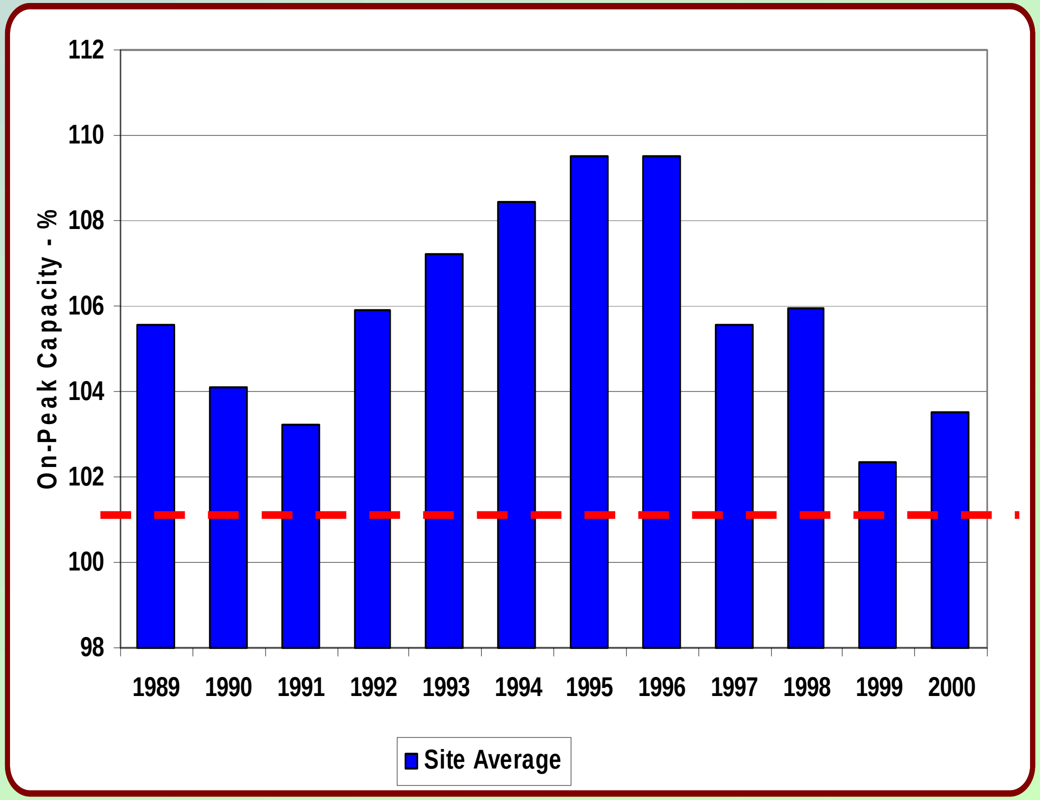
Kramer Junction, Calif.
Five 30-MWe Trough Plants

- Reliable and high performing parabolic trough plants in the Mojave Desert
- 150 MW at this site … a unique view of large scale renewable energy
- 14+ years operating experience


Views of a
Trough Solar Field

Kramer Junction SEGS
Collector Availability & Peak Capacity



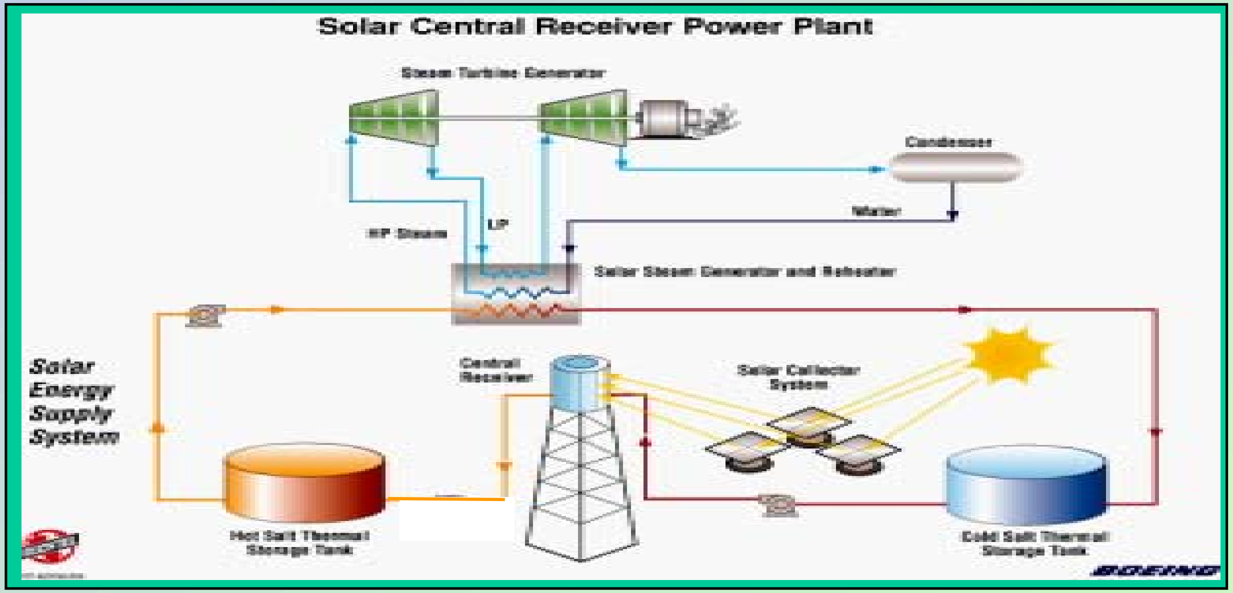


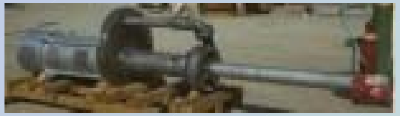
Trough Solar System O&M

- Collector maintenance for large modular solar field
- Periodic mirror washing
- Control system integrated into plant DCS -- requires limited operator action and monitoring
- Fluid system routine except for freeze protection
- Additional cost of solar field O&M about <0.5-1cent/kWh
- O&M methods continuously improving

Solar Power Tower Plant – 10 MWe + Retrofit

- Solar Energy Collection and Storage System
  - * Uses molten salt system for capturing and storing thermal energy
- Steam Turbine Power Generation System
  - * Conventional off-the-shelf system





Molten Salt Pump

Steam Turbine

Storage Tanks

Power Tower

Heliostat

10 MW Solar Power Tower Background and Experience

Solar One*

- 1982-1988
- Barstow, CA
- 10MWe
- Experimental
- 1st U.S. power tower
- Water / Steam
- No Storage
- 25% capacity factor
- Gov't incentives
  - * DOE program
- Proved towers are effective, reliable and practical for utility scale power
- Limitation: no thermal storage caused power interruptions

Solar Two*

- 1994-1999
- Barstow, CA
- 10MWe
- Experimental
- Retrofit of Solar One
- Molten Salt / Steam
- Thermal Storage
- 35% capacity factor
- Gov't incentives
  - * DOE / Consortium
- Mitigated technical risks
- Proved thermal storage operation and value to economics of solar plant
- Stimulated commercial interest - Spain

Solar Tres (planned)

- *2001 - Present*
- *Southern Spain*
- *15MWe turbine*
- *Commercial - Ready*
- *Improved design*
- *Molten Salt / Steam*
- *Thermal Storage*
- *65% capacity factor*
- *Gov't incentives*
  - ** Grants, loans and electricity premium*
- *Precursor to 50MWe and larger plants*
- *Operational in 2004*

* Source: Sandia National Laboratories, "An Evaluation of Molten-Salt Power Towers Including Results of the Solar Two Project", Nov 2001

Modular Technology – 1 MWe, Las Vegas, Nevada, USA

- 1 MWe installation underway and planned for completion in 2004
- Highest efficiency solar technology demonstrated (30% solar-electric)
- Modular 25 kWe units
- Can burn fossil fuel for night time operation
- Applications: grid-connected; remote village electrification, water pumping, remote grid
- Developmental stage - proven reliability a key goal

Trough Plant Experience Curve Projection

(Based on next plant = 100 MWe with Thermal Storage)