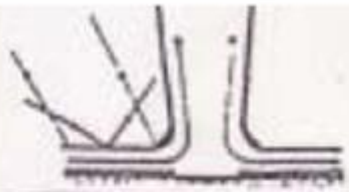
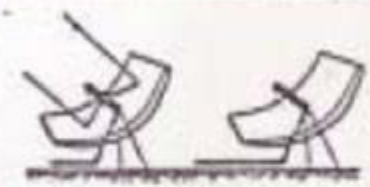
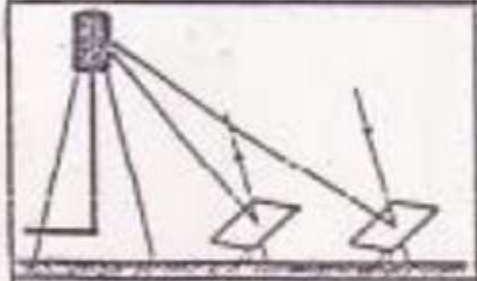
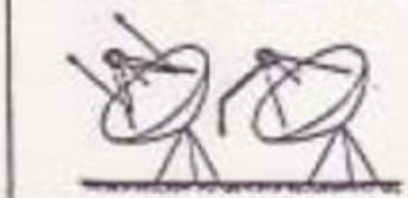
Electrical energy production (thermo-mechanically)

	SOLAR CHIMNEY	C = 1 T<150 °C P<2 MWe
	PARABOLIC TROUGH COLLECTOR	C = 40–80 T<350°C P<50 MWe
	MIRROR FIELD COLLECTOR	C = 200–700 T<1500 °C P<150 MWe
	PARABOLIC DISH COLLECTOR	C = 1000–2500 T<2500°C P<100 kWth/unit

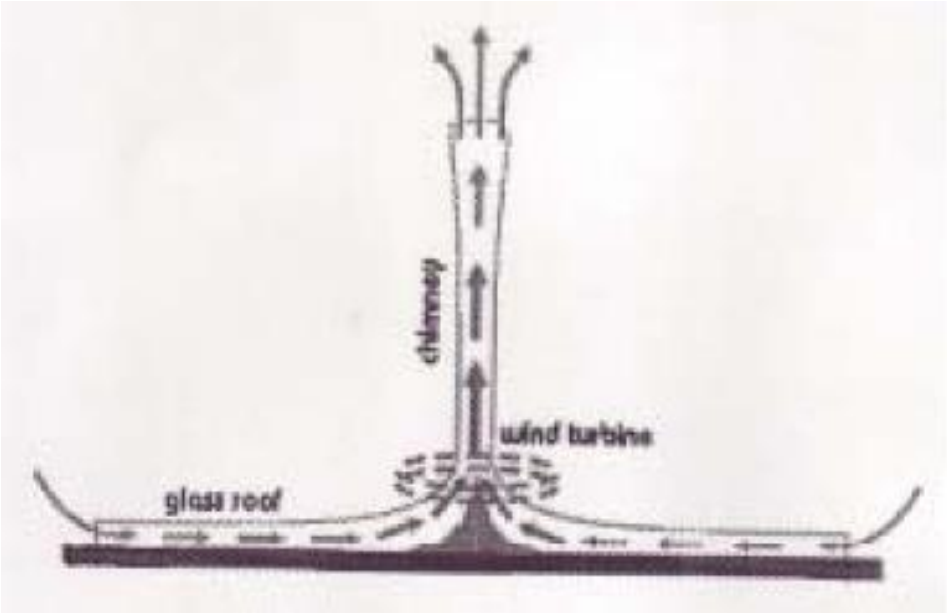
Solar chimney

Parabolic trough

Mirror field

(solar tower)

Parabolic dish



http://www.youtube.com/watch?v=0tWlP0knKQU
http://www.youtube.com/watch?v=pTkmTsKLRq0&NR=1&feature=fvwp
http://www.gizmag.com/enviromission-solar-tower-arizona-clean-energy-renewable/19287/

Efficiency about 3%

The **solar chimney** (the **solar updraft tower)** is a renewable-energy power plant for generating electricity from solar power.

Sunshine falling on a greenhouse-like collector structure around the base of a tall chimney heats the air within it. The resulting convection causes air to rise up the tower by the chimney effect (temperature difference generate the air flow).

This air flow drives wind turbines to produce electricity.

Prototype
Spain, Manzanares 1982
tower 195 m x Ø10 m
area Ø244 m
power 50 kW_e
greenhouse (75%)
The tower failed due to rust and storm winds. The tower blew over and was decommissioned in 1989

Efficiency about 3%

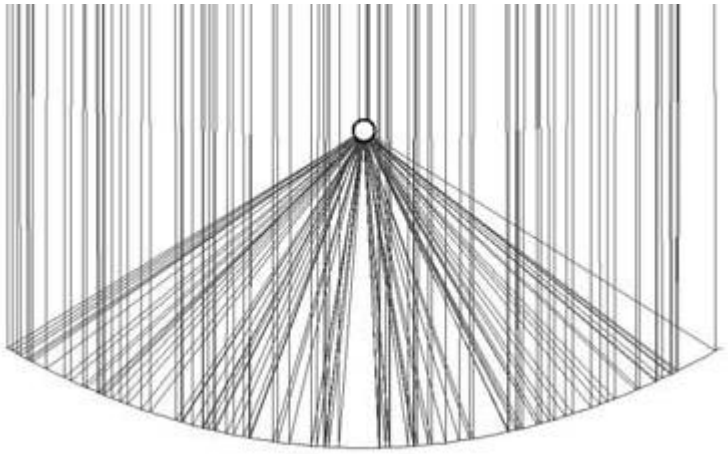
200 MW_e project in Australia (height 1000 m, area Ø7 km)

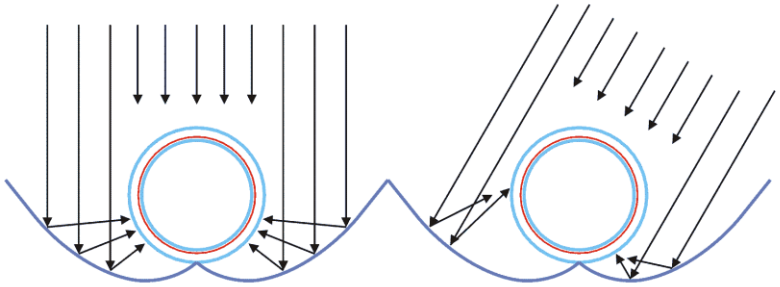
In 2001, EnviroMission proposed to build a solar updraft tower power generating station known as *Solar Tower Buronga* near Buronga, New South Wales.

The company did not complete the project and now plans a similar plant in Arizona.

http://www.enviromission.com.au./

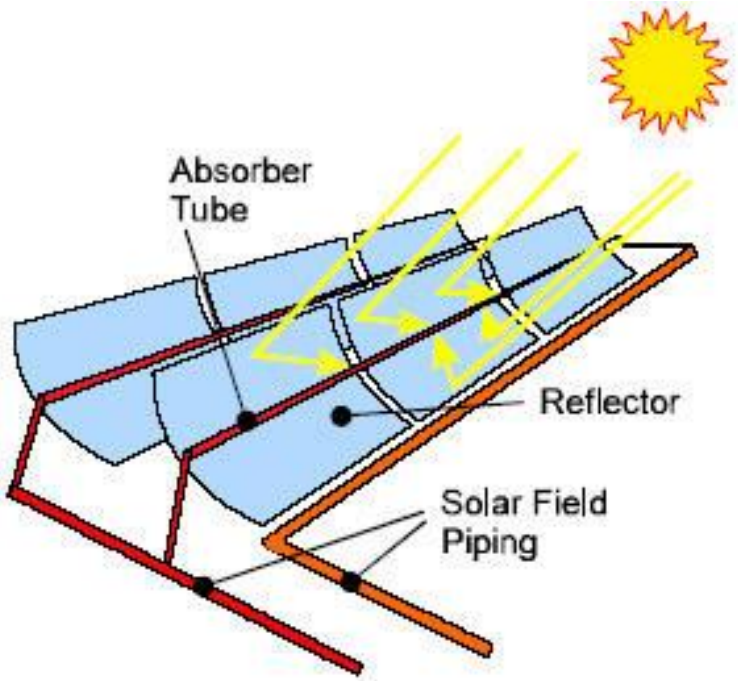
Concentrators

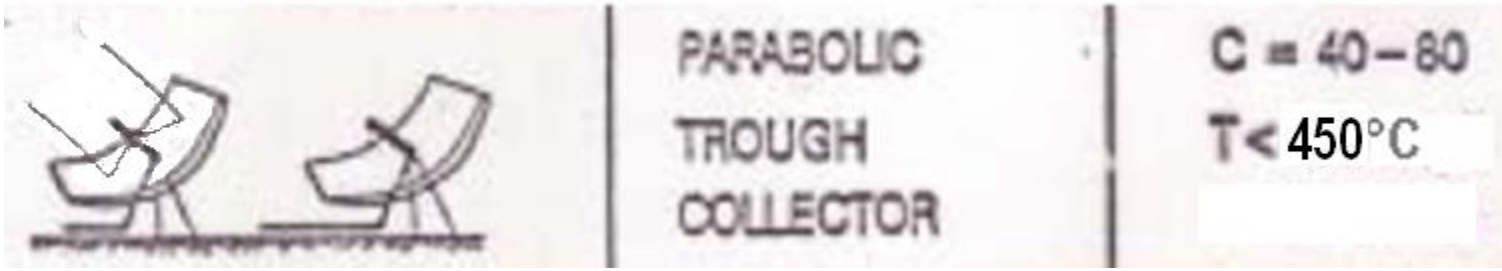


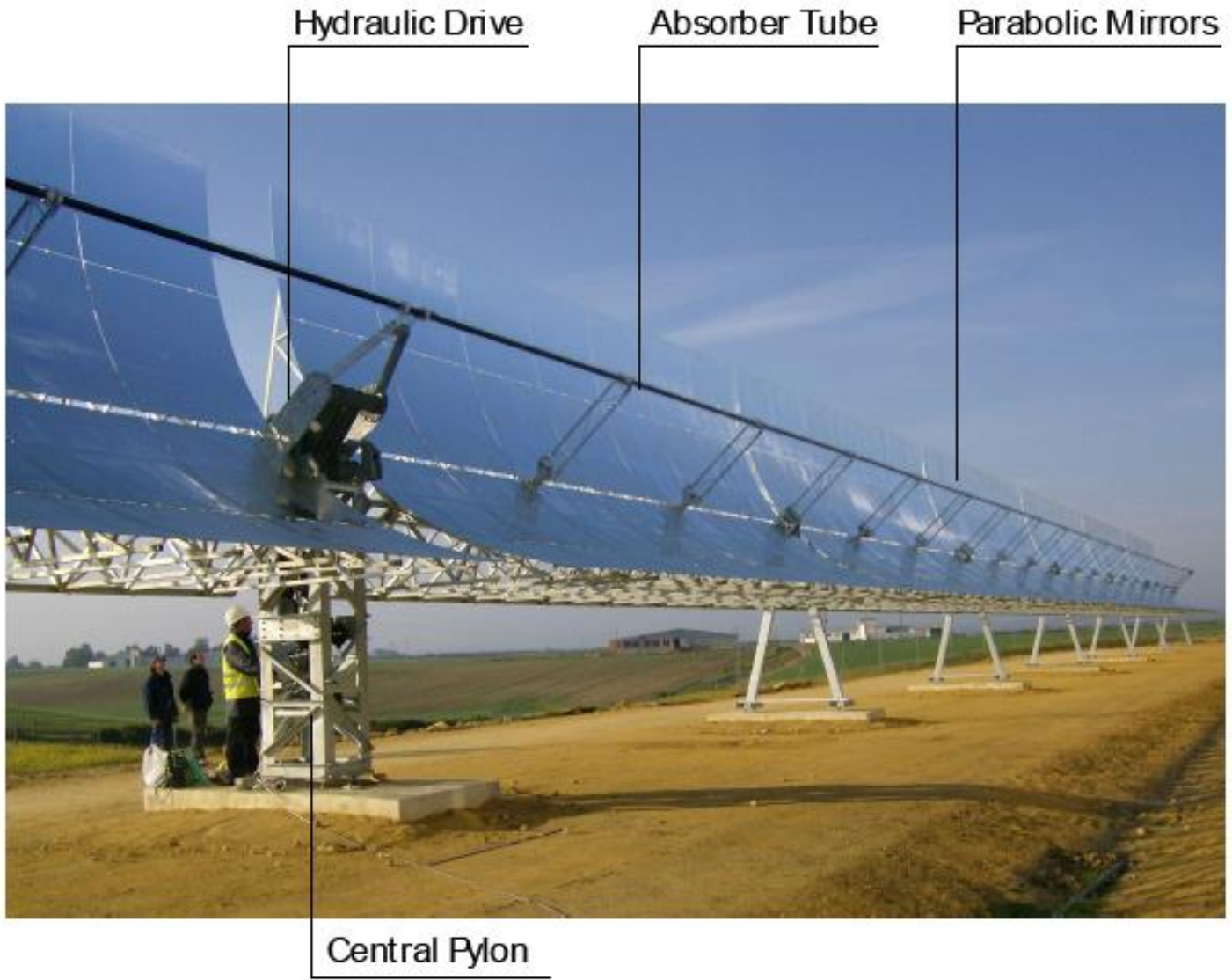


složený parabolický reflektor (CPC)

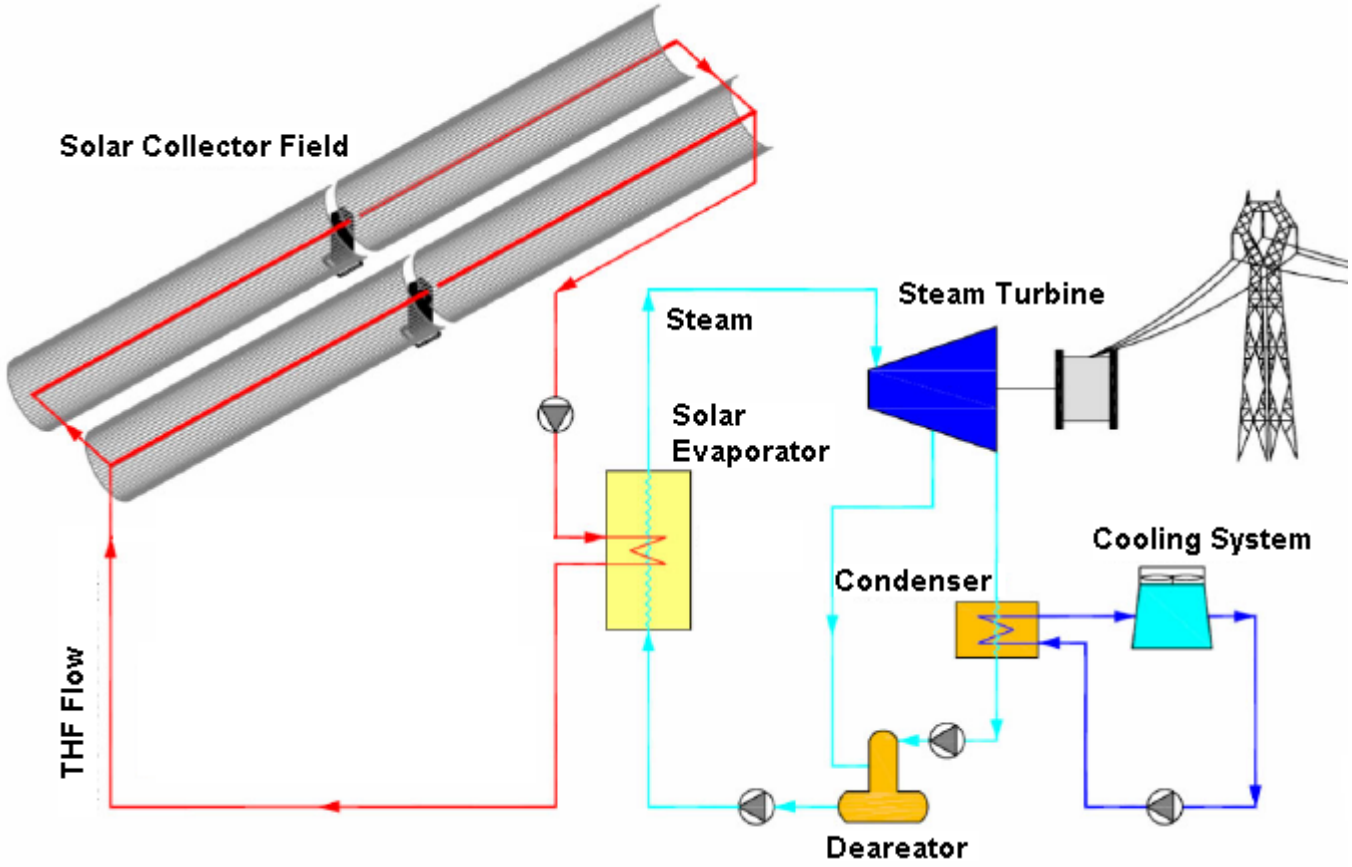
Heating up by a concentrator system




PARABOLIC
TROUGH
COLLECTOR
C = 40 – 80
T < 450°C


Hydraulic Drive
Absorber Tube
Parabolic Mirrors
Central Pylon

Solar parabolic trough power plants



- Hot oil
- 400°C

Combined with natural gas

- 354 MW_e instalation in California (1985)
- 6,5 km^2 (1kW = 18,5 m^2)
- efficiency 5-18%
  (in dependence on season)

354 MW_p Solar PowerStation in „Mojave desert“ in California

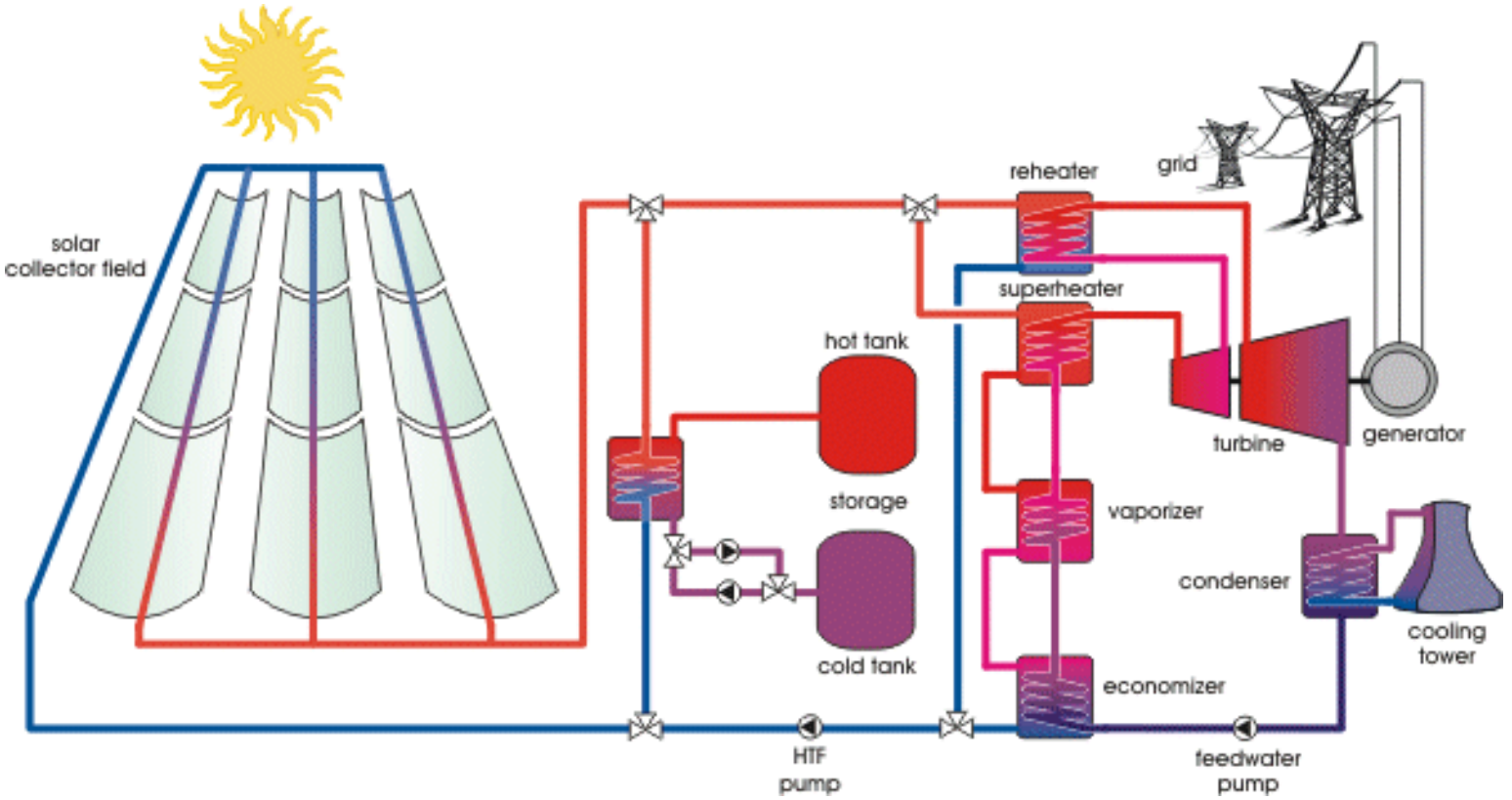
THF is synthetic oil heated to over 400 °C

steam generation without energy storage

at night it can be utilized by burning natural gas

Capacity factor 21%

Solar parabolic through power plants with energy storage



- Hot oil
- 400°C

50 MW plant will have a molten salt thermal storage system containing 28,500 tons of molten salt (60% $NaNO_3$/ 40% KNO_3), capable of storing heat to generate 750 MWh of electricity — enough to operate at full power for 7.5 hours without sunshine

Property	Solar Salt	Hitec	Hitec XL (Calcium Nitrate Salt)	Therminol VP-1
Composition, %				Diphenyl biphenyl oxide
$NaNO_3$	60	7	7	
KNO_3	40	53	45	
$NaNO_2$		40		
$Ca(NO_3)_2$			48	
Freezing Point, C	220	142	120	13
Upper Temperature, C	600	535	500	400
Density @ 300C, kg/m^3	1899	1640	1992	815
Viscosity @ 300C, cp	3.26	3.16	6.37	0.2
Heat capacity @ 300C, J/kg-K	1495	1560	1447	2319

Energy storage

$$W_{th} = mc_{th}\Delta T$$

Effective Storage Fluid Cost

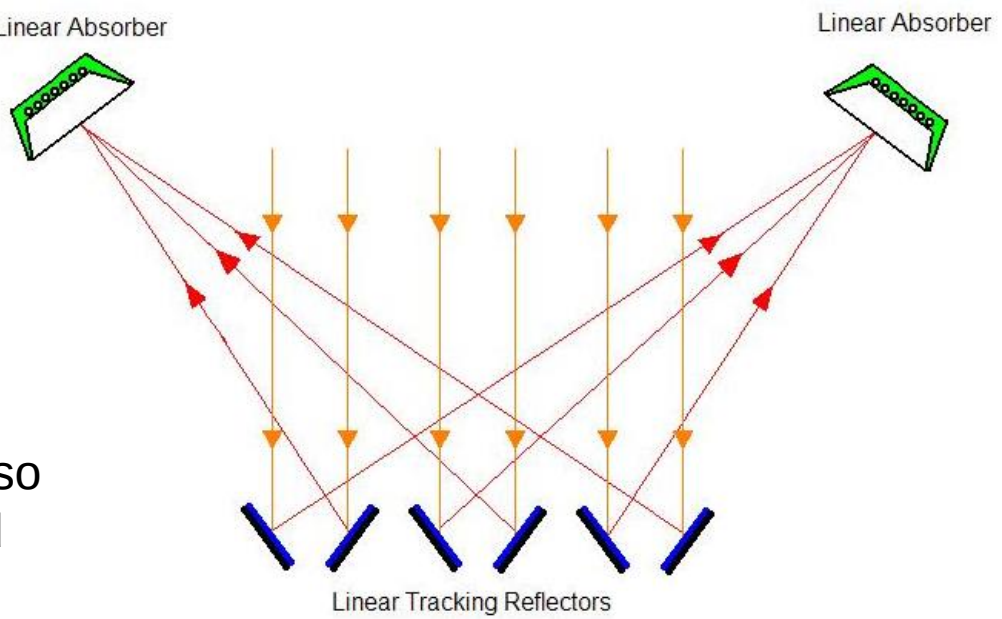
Salt	Temperature Rise	Cost per Kg	Storage Cost
	°C	$/kg	$/kWh$_t$
Hitec (a) [142°C]	200	0.93	10.7
Solar Salt (b) [220°C]	200	0.49	5.8
Calcium Nitrate [HitecXL] (c) [120°C]	200	1.19	15.2
	150	1.19	20.1
	100	1.19	30.0
Therminol VP-1 (d)	100	2.2	57.5

a) 7:53 Na:K Nitrate, 40 Na Nitrite
b) 60:40 Na:K Nitrate
c) 42:15:43 Ca:Na:K Nitrate
d) Diphenyl/biphenyl oxide

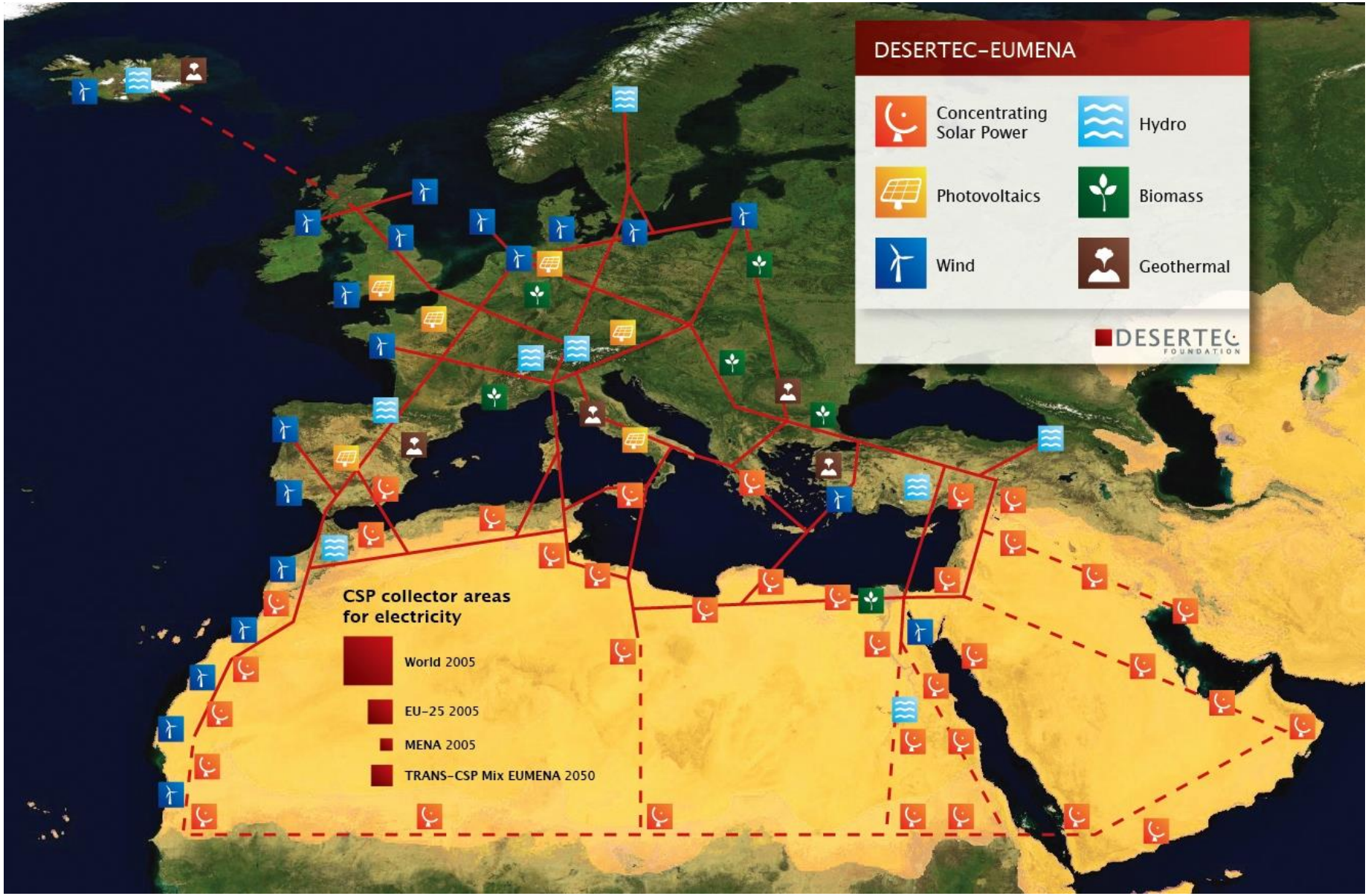
Fresnel reflectors

the simple line-focus geometry with one axis for tracking

The receiver is stationary and so fluid couplings are not required

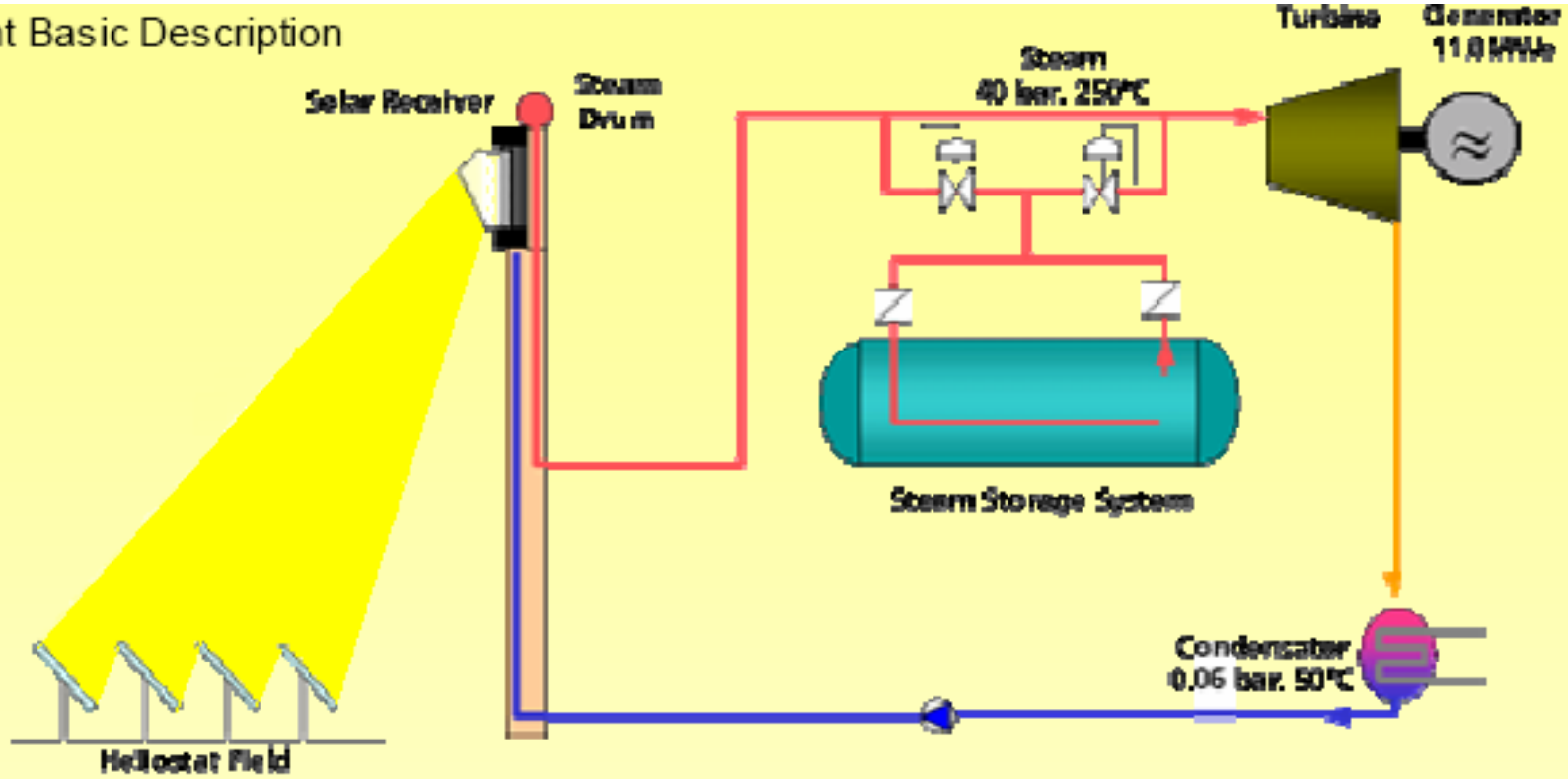


DESERTEC – 400 miliard €

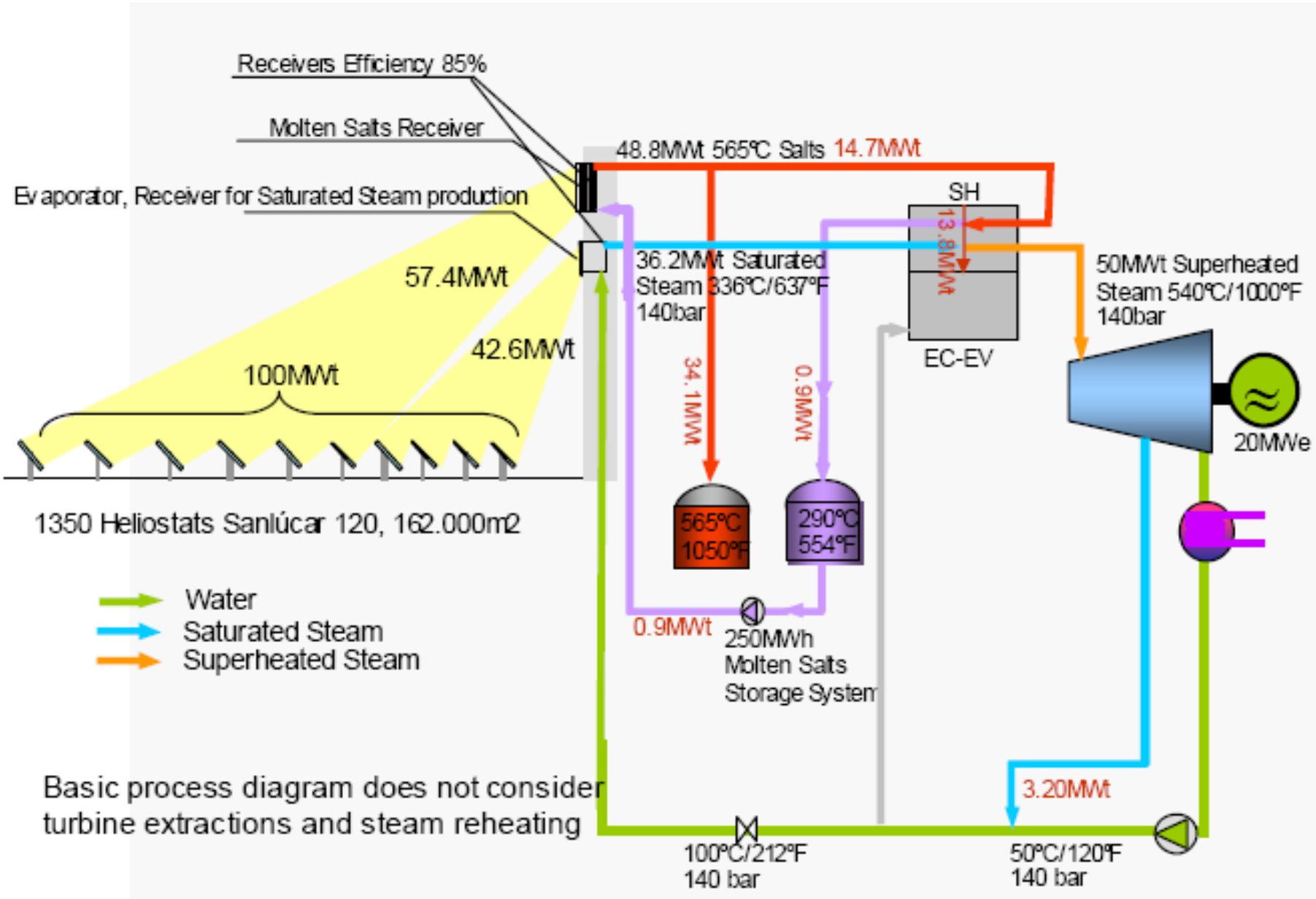


„Solar Tower“

PS10 Plant Basic Description



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, 50 Hz -> 66kV, 50 Hz
Land	60Has
Annual Electricity Production	23.0GWh

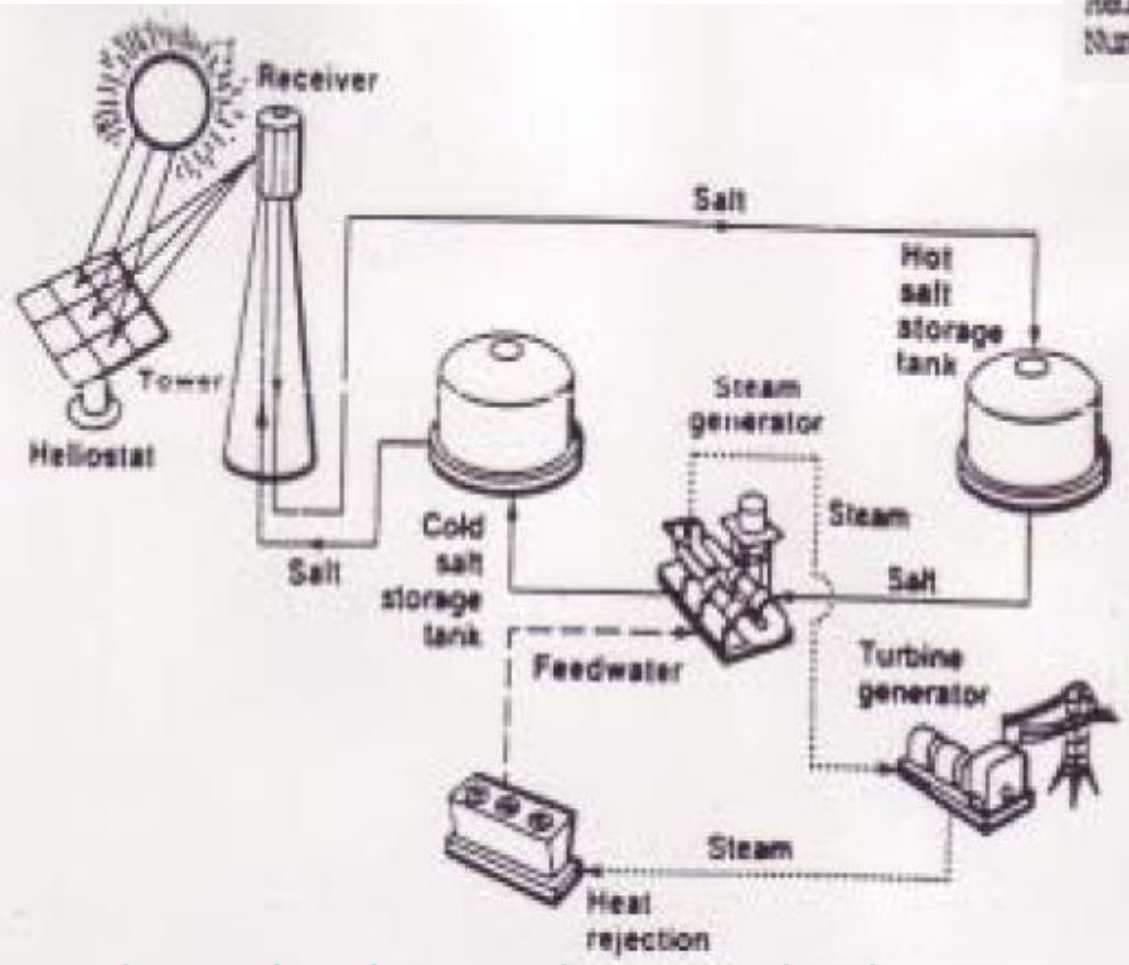

Receivers Efficiency 85%
Molten Salts Receiver
Evaporator, Receiver for Saturated Steam production
57.4MWt
42.6MWt
100MWt
1350 Heliostats Sanlúcar 120, 162.000m2
48.8MWt 565ºC Salts 14.7MWt
36.2MWt Saturated Steam 336ºC/637ºF 140bar
SH
13.8MWt
EC-EV
50MWt Superheated Steam 540ºC/1000ºF 140bar
20MWe
34.1MWt
0.9MWt
565ºC 1050ºF
290ºC 554ºF
0.9MWt
250MWh Molten Salts Storage System
Water
Saturated Steam
Superheated Steam
3.20MWt
100ºC/212ºF 140 bar
50ºC/120ºF 140 bar
Basic process diagram does not consider turbine extractions and steam reheating

Barstow, California (Mojave Desert)

100 MW_e power station project

POWER RANGE	100 MW el.				
OPERATION	Whole year		Summer only		
LOAD	Base	Medium	Peak		
HELIOSTAT FIELD	North	Round			
RECEIVER	Cavity	External			
HEAT TRANSFER MEDIUM	Sodium	Salt	Steam	Gas	Solid
MAXIMUM MEDIUM TEMPERATURE C	500	560	600	800	
STORAGE MEDIUM	Sodium	Salt	Steam	Rock	Solid
DAILY TIME OF OPERATION	8	16	24		
POWER CONVERSION	Ranking Steam	Brayton Gas	Stirling Gas		

Design Point:	Equinox, Noon
Maximum Insolation:	920 W/m²
Net Power:	100 MWel
Storage (11 hrs):	400 MWhth
Solar Multiple:	2.0
Full Power Operating Time:	3500 h/a



The project has not been realized yet

HELIOSTAT FIELD

Area:	$1{,}554 \cdot 10^6 m^2$
Land Use Factor:	0.2
Gross Area:	$7{,}77 \cdot 10^6 m^2$
Field Type:	Surrounding Field
Distance:	110 to 1700 m
Tower Height:	220 m
Heliostat Area:	150 m²
Number of Heliostats:	10,663

RECEIVER

Absorber Area:	1885 m²
Concentration Factor (Average)	480
Max. Flux Intensity:	750 KW/m²
Average Flux Intensity:	415 KW/m²
Absorptivity:	0.95
Max. Thermal Power:	788 MWth
Thermal Heat Losses:	87.9 MW
Inlet Temperature:	360°C
Outlet Temperature:	540°c
Max. Surface Temperature:	609°C
Tube Material:	Incoloy 800H, 20·1.5 mm
Number of Tubes:	3,000
Length of Tubes:	90 m
Lambda (fixed):	20 W/mK

STORAGE

Type:	Cylinder Type
Capacity:	4000 MWh
Molten Salt Mass:	$53{,}4 \cdot 10^6 kg$
Tank Volume:	$28{,}9 \cdot 10^3 m^3$
Diameter:	32.4 m
Height:	35 m

Gemasolar (Fuentes de Andalucía, Spain), operates since 2011

185 ha solar field

2650 heliostats, each 120 m^2

Tower Height: 140 m

HTF: Molten salts

Receiver Inlet Temp:290°C
Receiver Outlet Temp:565°C
Temp. Difference: 275°C

Storage Type:2-tank direct
Storage Capacity:15 hour(s)

Turbine Capacity:19.9 MW

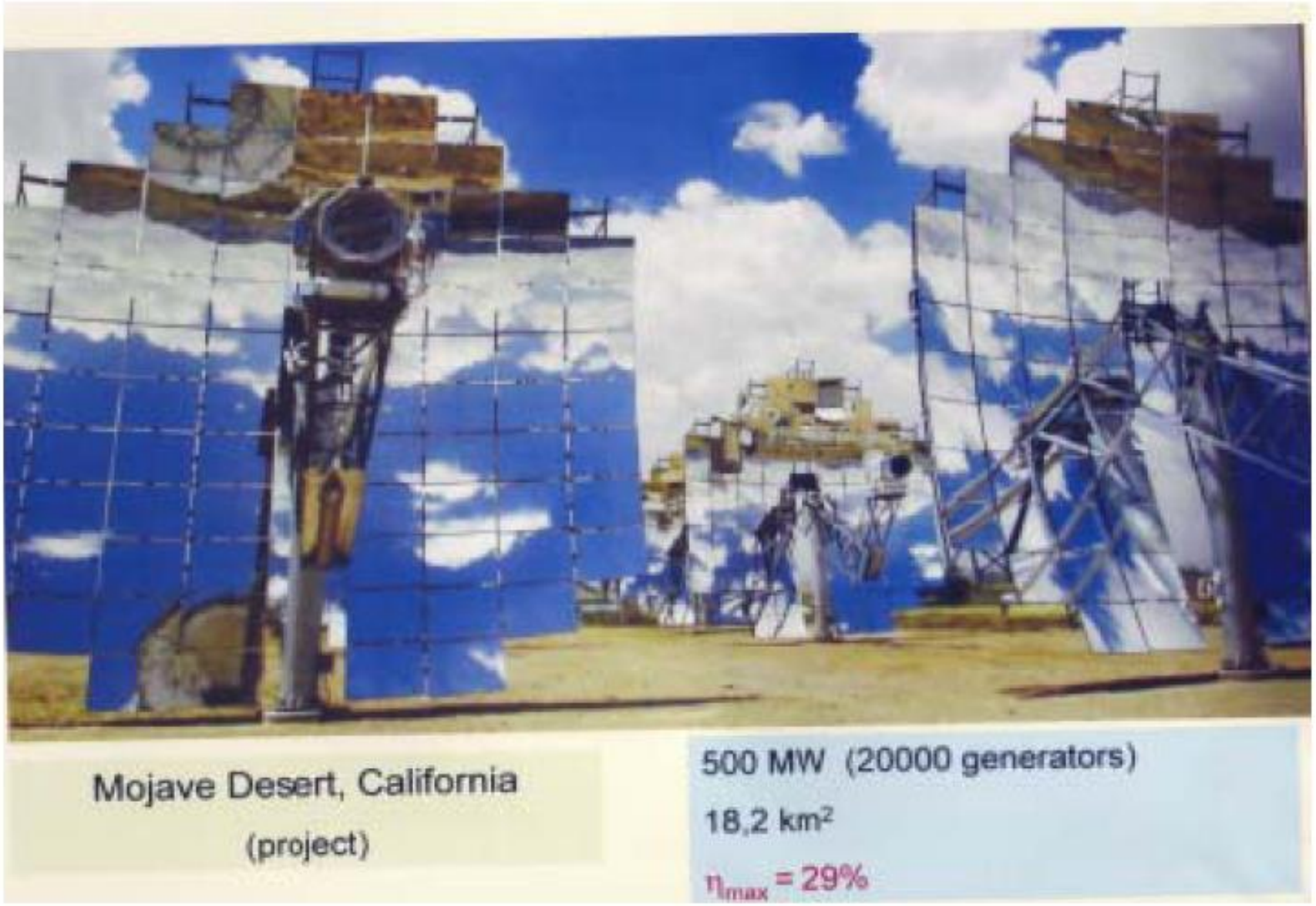
Annual equivalent hours = 6,500.

Fossil Backup Type: Natural gas

Backup Percentage: 15%

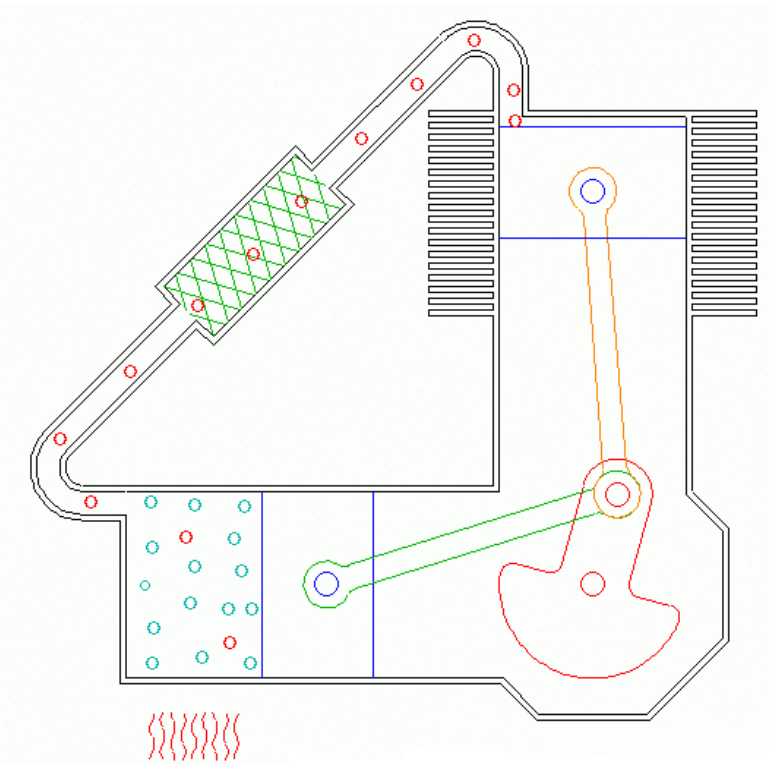
Cost (approx): 230,000,000 Euro

Stirling engines (www.keveney.com/V**stirling**.html)



Realized only 1.5 MW pilot project

Stirling engines (www.keveney.com/V**stirling**.html)



Comparison of system types

Technology	Cylindrical-parabolic	Tower	Parabolic dish
Nominal thermal efficiency	70%	73%	75%
Power of the installation	80–300 MW_{th}	10–100 MW_{th}	1–100 kW_{th}
Working temperature	270–450°C	450–1,000°C	600–1,200°C
Cost of the solar field	210–250 €/m^2 [9]	140–220 €/m^2	~150 €/m^2
Total cost of the investment	2.8–3.5 €/W_e	3–4 €/W_e	10–14 €/W_e

At present, PV systems are cheaper (~ 1.5 EUR/W_p)

Solar Islands

http://www.youtube.com/watch?v=D1XyR3YOVZQ