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CSP TECHNOLOGIES: STATE OF THE ART , THE PROSPECTS FOR THE FUTURE AND POSSIBLE APPLICATIONS / TECHNOLOGY TRANSFERS FOR WEST AFRICA

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CS(T)P Technologies: State of the art , the prospects for the future and possible applications / technology transfers for West Africa

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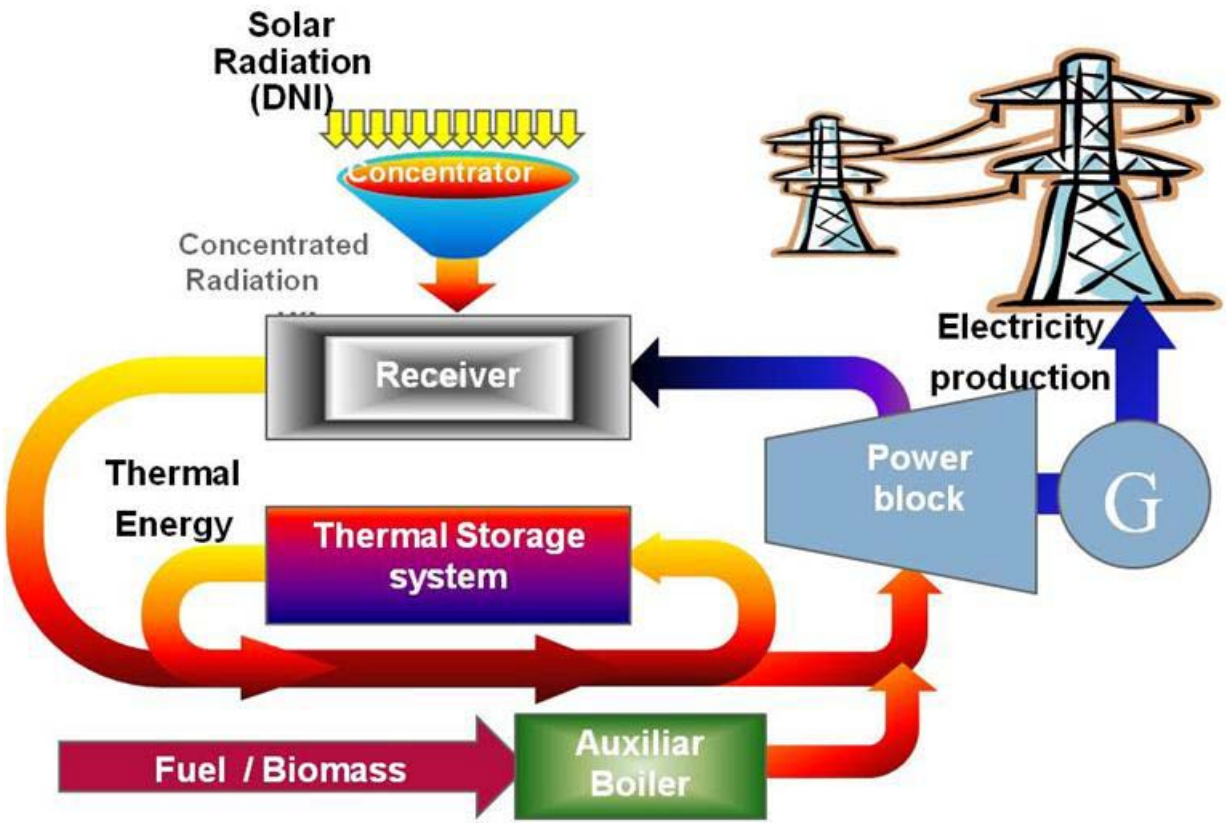
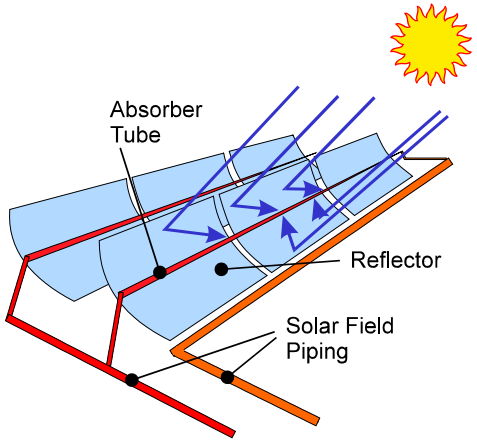
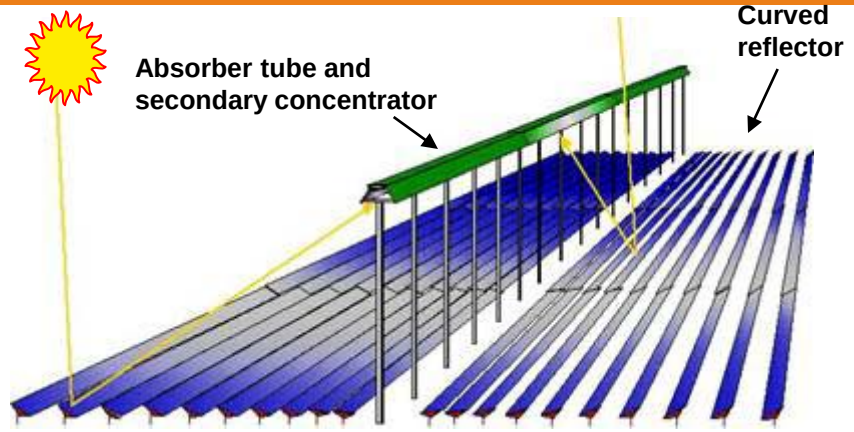
What is Concentrating Solar Power (CSP)?, How it works?



2D Concentration systems

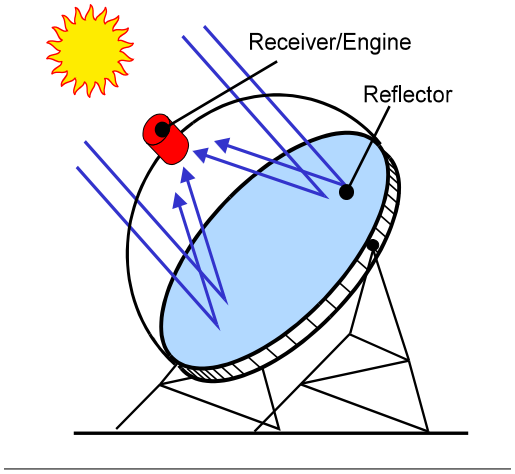


Parabolic Trough

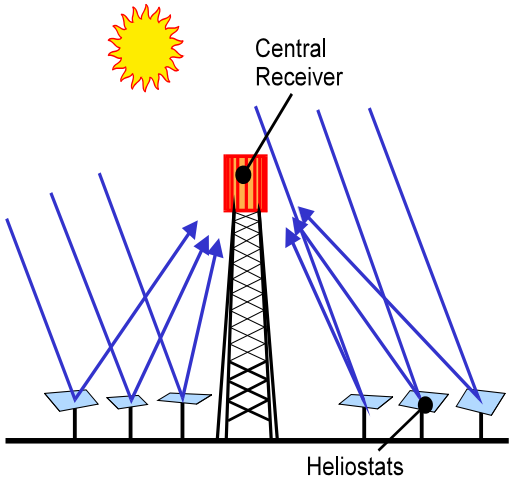


Linear Fresnel

3D Concentration systems

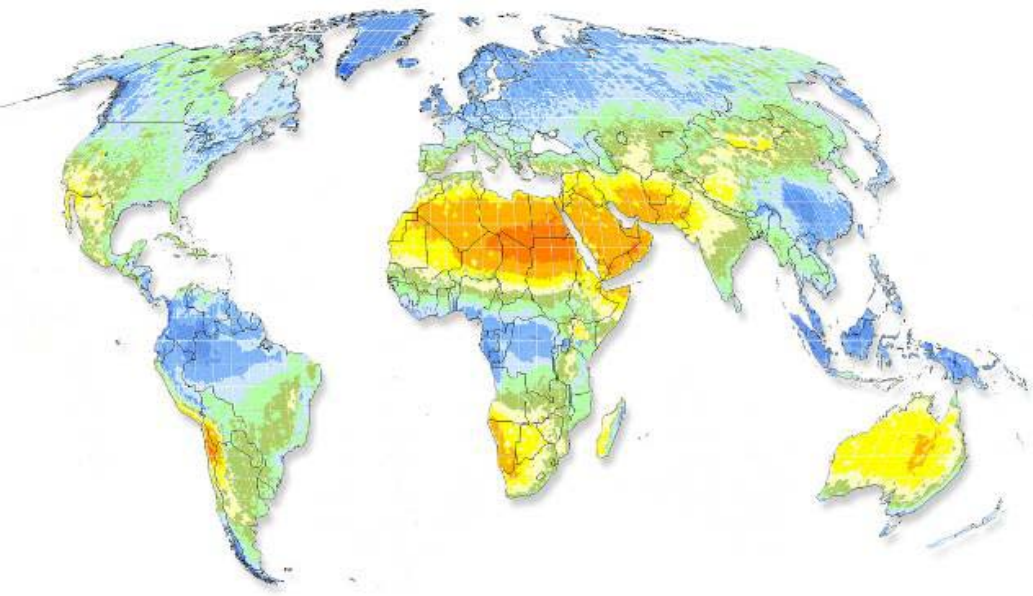


Parabolic Dishes



Central Receiver

Zones of interest for deployment of CSP and CSP land needs to cover electricity demand

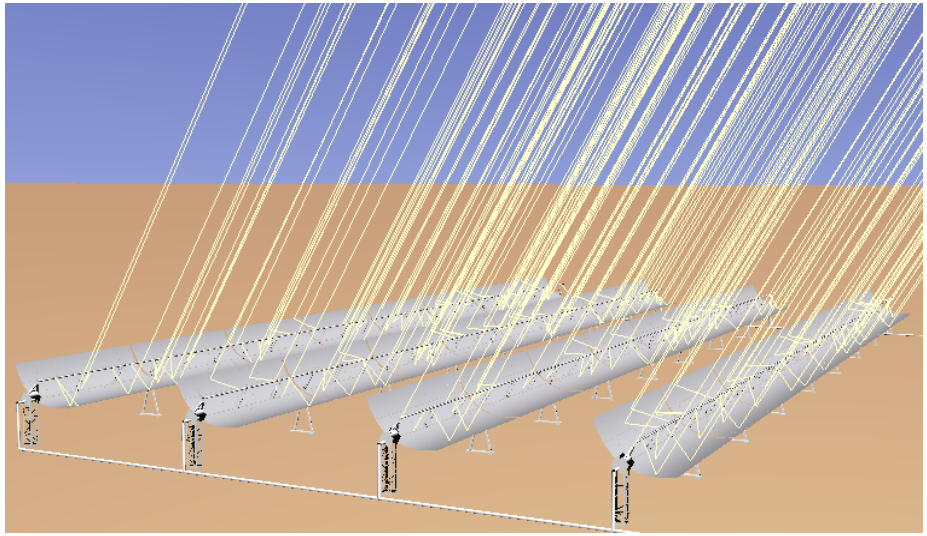


Source: SunLab

The “sun belt” (+/-40º lat):

- Deserts of 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.

STATE OF THE ART OF THE TECHNOLOGIES:
Parabolic Trough (PT)



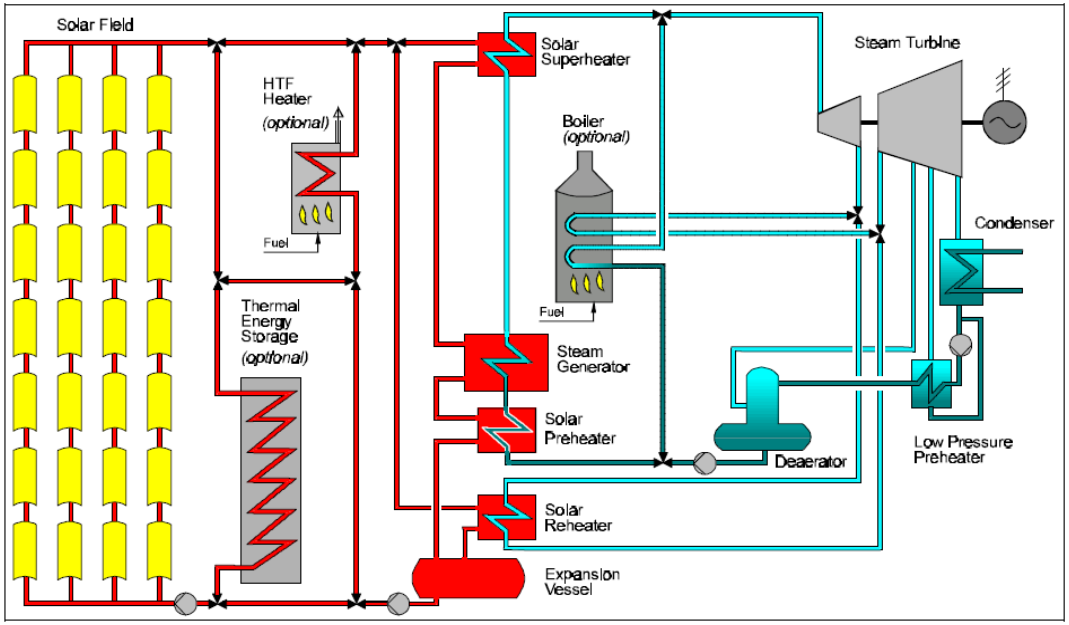
Solar field:

- modular quantity of PT solar collectors placed along parallel rows,
- oriented by a sun-tracking system along a single axis,
- optimal capacity for current technology: about 150-200 MWe.

Collector:

- parabolic-shaped mirror,
- concentrates the solar radiation onto a linear receiver, located at its focal length,
- vacuum tube receivers with selective coating.

PT – Power plant scheme



Steam generation:

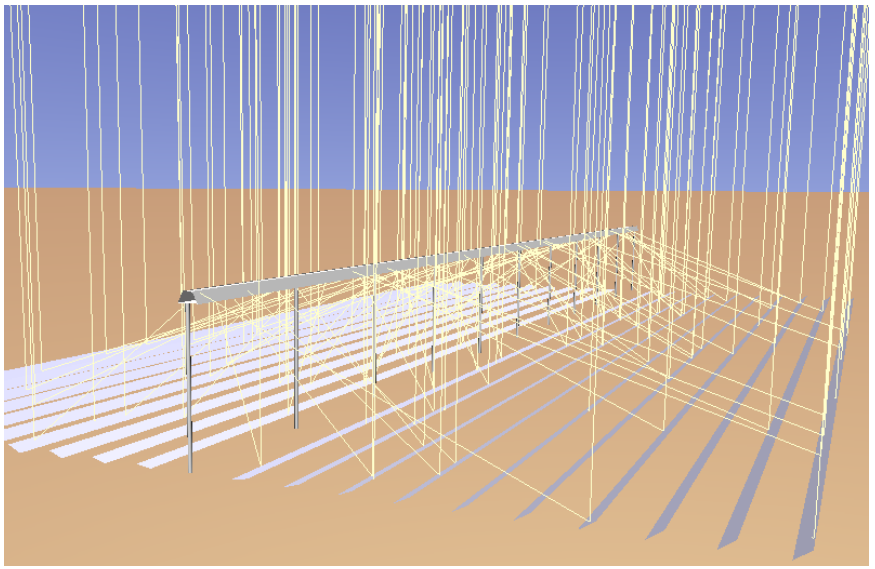
- Usually indirect steam generation with synthetic oil as HTF heated up to 400 ºC
- Direct Steam Generation (DSG) and Molten Salts as HTF and Organic Rankine Cycle (ORC) successfully tested in experimental facilities.

Optional subsystems to increase the capacity factor:

- Thermal Energy Storage (TES)
- Back-up boiler

STATE OF THE ART OF THE TECHNOLOGIES:
Linear Fresnel Reflectors (LF)

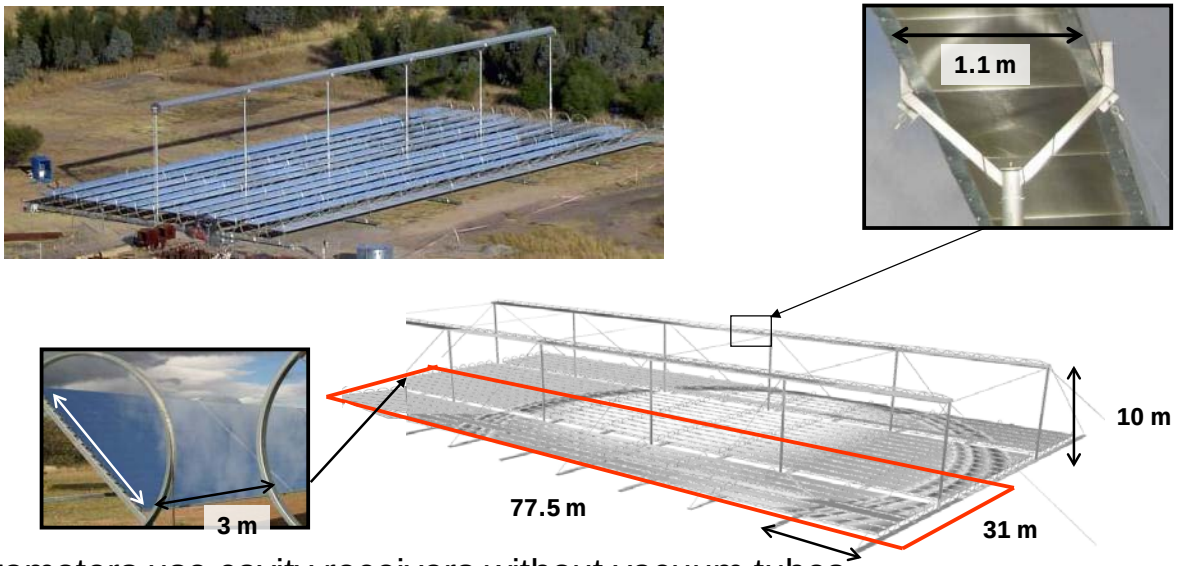
- Rotating flat or slightly curved mirrors focusing sun rays onto a linear receiver.
- Low temperature water/steam (250 - 400˚C) directly coupled to a steam turbine.



- Low cost and robust
- Metallic support structure easily assembled without specialized work
- High land use

- Low field efficiencies
- No commercially available storage
- Lack of operational record over long periods of time.

LF – Component design

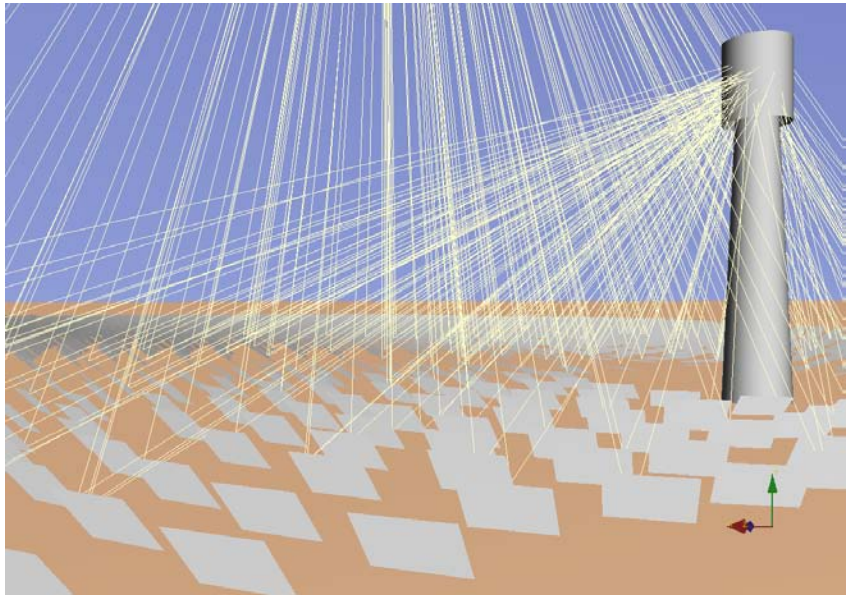


Most technology promoters use cavity receivers without vacuum tubes.

- **2 different solar field** designs for electricity generation:
  - classical LF from Novatec and SPG: single-pipe receiver with secondary reflector,
  - compact LF (CLFR) from Areva: multiple pipe receiver with no secondary reflector.
- **Steam generation**:
  - mostly Direct Steam Generation (DSG),(Low temperature saturated steam)
  - solar preheating, ISCC and other low temperature applications such as solar air conditioning.

STATE OF THE ART OF THE TECHNOLOGIES:
Central Receiver (CR)

- Mirrors called heliostats with two-axis sun-tracking focus concentrated solar radiation on a receiver at the top of a tower.
- Receiver transforms the concentrated radiation into thermal energy
- Solar field layouts: “north field”, “surround field”, multi tower concept.

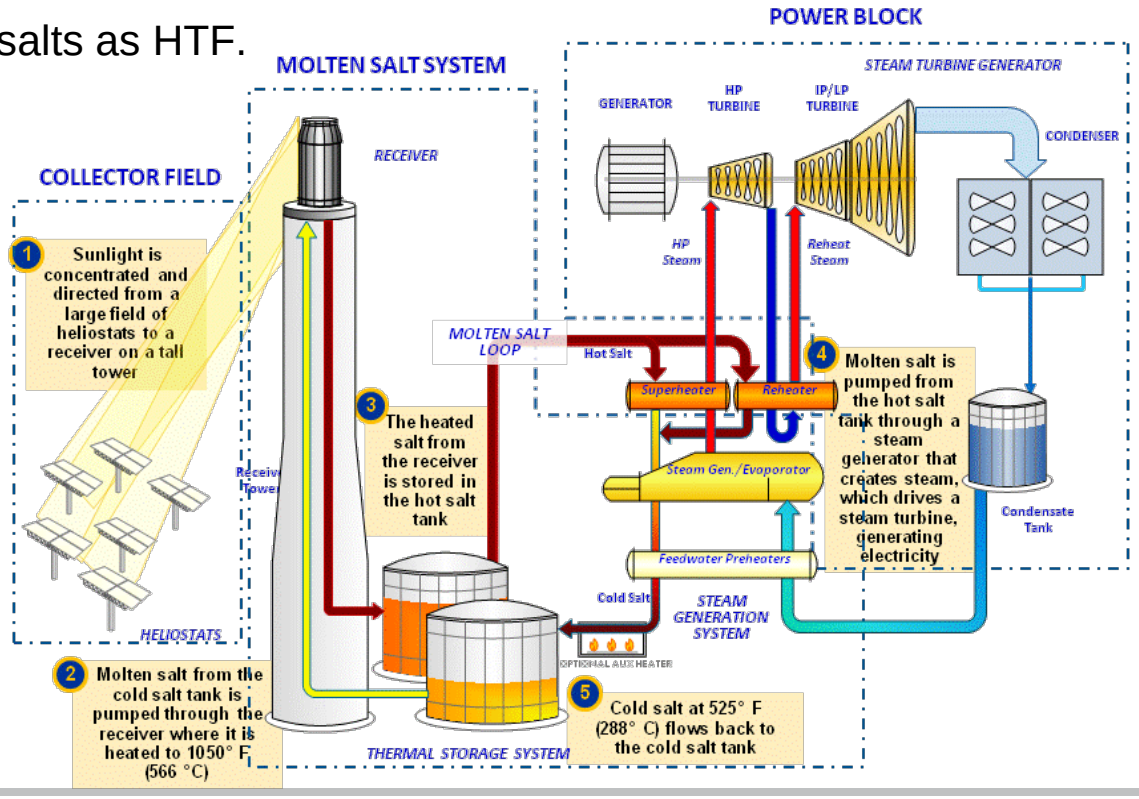


- Piping not required throughout the solar field
- Very high temperatures (300 to 1200ºC) without significant thermal losses
- Hybridization and thermal storage relatively easy and low cost.

- High material stress

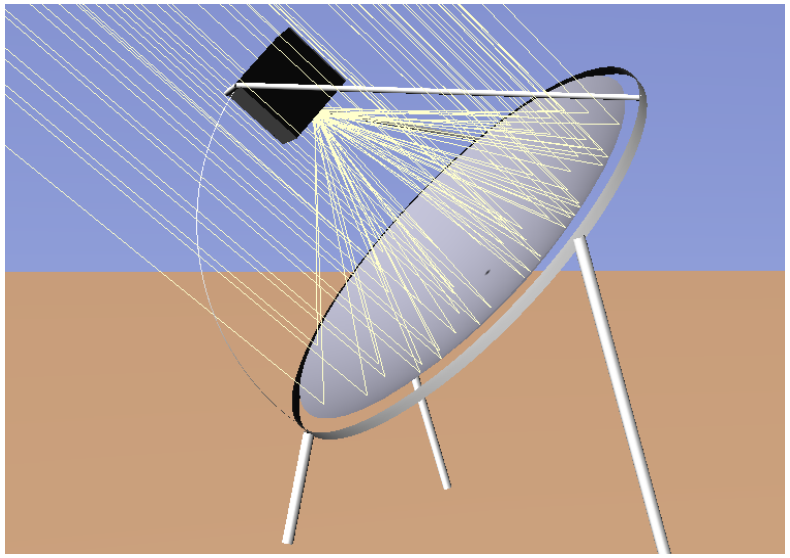
CR – Power plant scheme

- Currently two configurations are used in commercial CR projects:
  - Water/Steam as HTF,
  - Molten salts as HTF.



STATE OF THE ART OF TECHNOLOGIES:
Parabolic Dish (PD)

- Parabolic shaped mirrored surface mounted on a two-axial tracking system
- Concentrates sunlight onto a receiver mounted at the focal point.
- Cavity receiver coupled to a high-efficiency Stirling engine placed at the focal point of the dish:
- Individual units from 10 to 25 kW



- high temperatures (up to 800 ºC)
- high efficiency
- no cooling water requirement
- off-grid, centralized or decentralized operation.

- high thermal gradients and stress.
- no concept for thermal storage
- high investment costs

Installed capacity worldwide by technology

PLANT	LOCATION	PROMOTER	CAPACITY (Mwe)
SEGS (9 plants)	California (USA)	Luz	354
Saguaro* (ORC)	Saguaro (AZ, USA)	Acciona	1
Nevada Solar One	Boulder (NV, USA)	Acciona	72
Andasol 1	Guadix (Spain)	ACS - Solar Millenium	50
Andasol 2	Guadix (Spain)	ACS - Solar Millenium	50
Ibersol	Puertollano (Spain)	Iberdrola	50
La Risca	Alvarado (Spain)	Acciona	50
Extresol 1	Torre de M. Sesmero (Spain)	ACS - Cobra	50
Solnova 1	Sanlucar (Spain)	Abengoa	50
Solnova 3	Sanlucar (Spain)	Abengoa	50
La Florida	Badajoz (Spain)	Renovables SAMCA	50
TOTAL CAPACITY FOR PARABOLIC TROUGH TECHNOLOGY			827

PLANT	LOCATION	PROMOTER	CAPACITY (Mwe)
John Marcheff Solar Project	Liddell, (Australia)	Areva	4
Kimberlina	Bakersfield, (CA, USA)	Areva	5
Puerto Errado 1	Calasparra, (Spain)	Novatec	1,40
TOTAL CAPACITY FOR LINEAR FRESNEL TECHNOLOGY			10,4

PLANT	LOCATION	PROMOTER	CAPACITY (Mwe)
PS10 (water/steam)	Sanlucar la Mayor (Spain)	Abengoa	11
PS20 (water/steam)	Sanlucar la Mayor (Spain)	Abengoa	20
SEDC* (superh. steam)	Rotem (Israel)	BrightSource	5
Sierra SunTower (water/steam)	Lancaster (CA, USA)	eSolar	5
Jülich* (air)	Germany	DLR**	1,5
TOTAL CAPACITY FOR CENTRAL RECEIVER TECHNOLOGY			42,5

PLANT	LOCATION	PROMOTER	CAPACITY (Mwe)
Villarobledo	Albacete (Spain)	Renovalia Energy, Infinia	1
Maricopa Solar	Peoria (AZ, USA)	SES, Tessera	1.5
TOTAL CAPACITY FOR PARABOLIC DISH TECHNOLOGY			2,5

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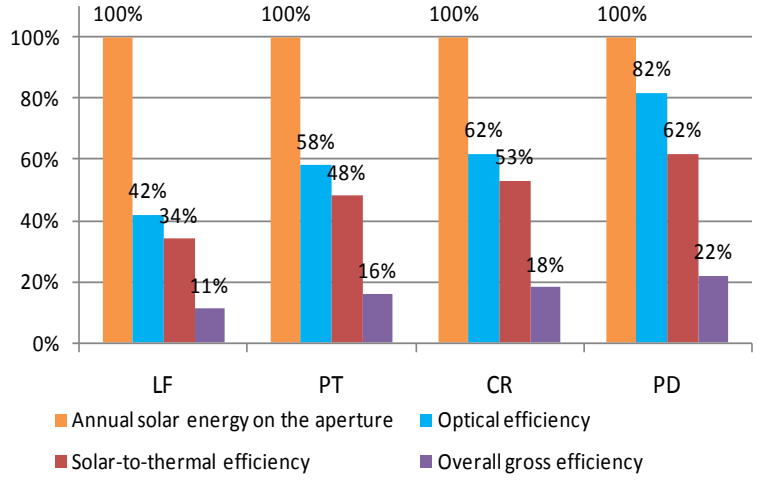
Expected trends and evolution on CSP:

Awaited breakthroughs:

- Fluids
  - High Temperature Working Fluids. DSG or molten salts generation (PT), gases (CR), room-temperature ionic liquids and lithium salts, nanotechnology additives in advanced HTF
- Heat collection element (PT)
  - Increased dimensions, different characteristics in zones working at different temperatures …. High temperature durable selective coatings…etc
- Mirror assembly
  - Spectrally selective mirrors or lenses, new reflective materials (polymers or composite), thin-film protection layers for reflectors, dust-repellent mirrors,…
- Thermal Storage
  - PCM, thermo chemical storage/release cycles, thermo cline storage tank,…
- Power block
  - Heat engines specifically designed for integration in a CSTP system, “solarized” gas turbines or combined cycles,…

System efficiency

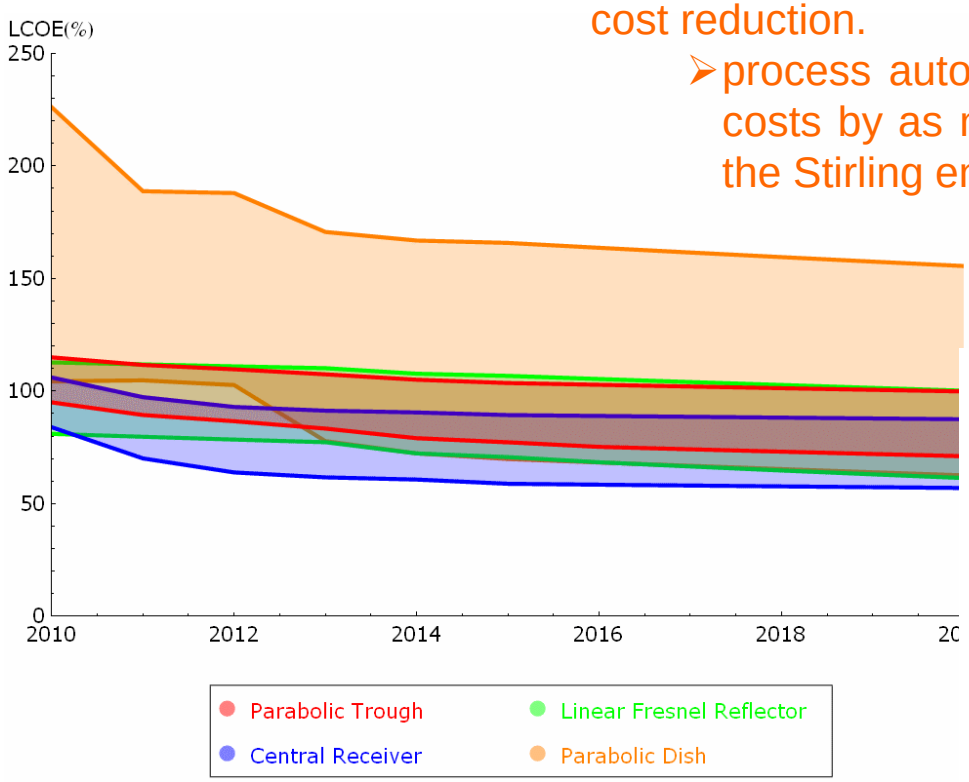
LF	PT	CR	PD
System efficiency 2010			
Efficiency increase 2015			
3-5%	7-9%	4-6%	0.5-6%
Efficiency increase 2020			
13-20%	10-14%	6-8%	10-15%



Levelized Cost of Electricity

PD are most expensive now, but have the best potential for cost reduction.

- process automation and mass production may reduce costs by as much as 40% for the mirrors and 55% for the Stirling engines.



PT are now competitive with other renewable alternatives.

- About 0.17 y 0.18 €/kWh in Spain and as low as 0.10 €/kWh in sites with higher direct radiation,
- Expected to compete with conventional thermal power plants by 2020.

The case of West Africa

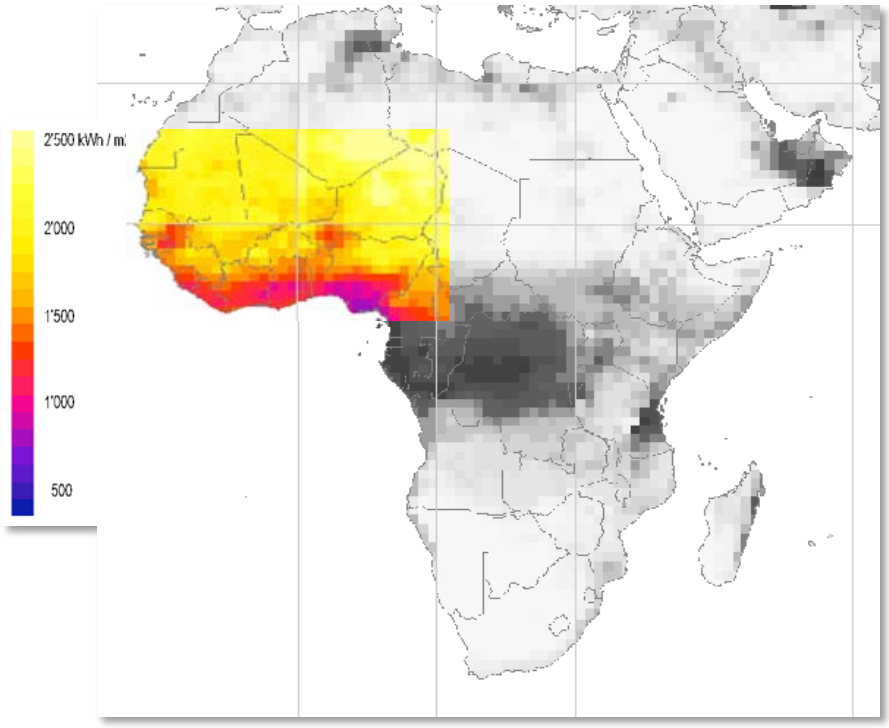
Satellite & ground measurements

derived irradiation data

Yearly sum of direct normal irradiation

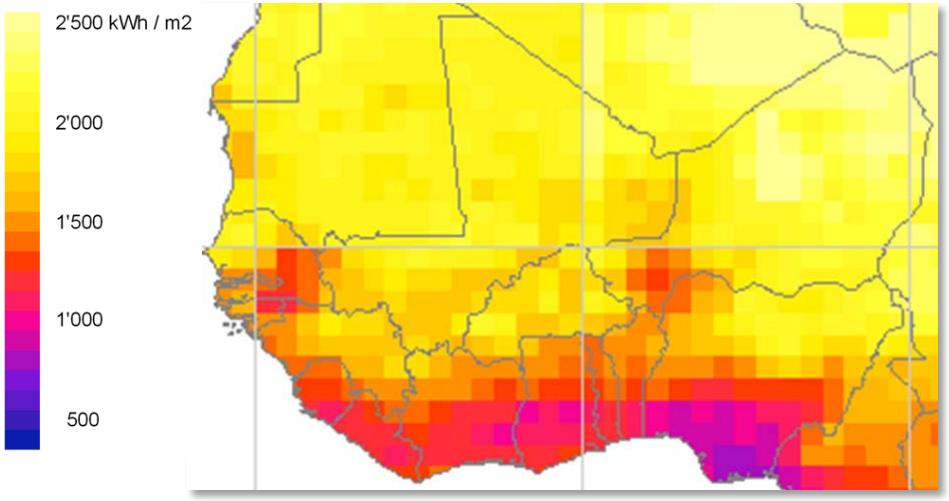
Grid resolution: 1 º

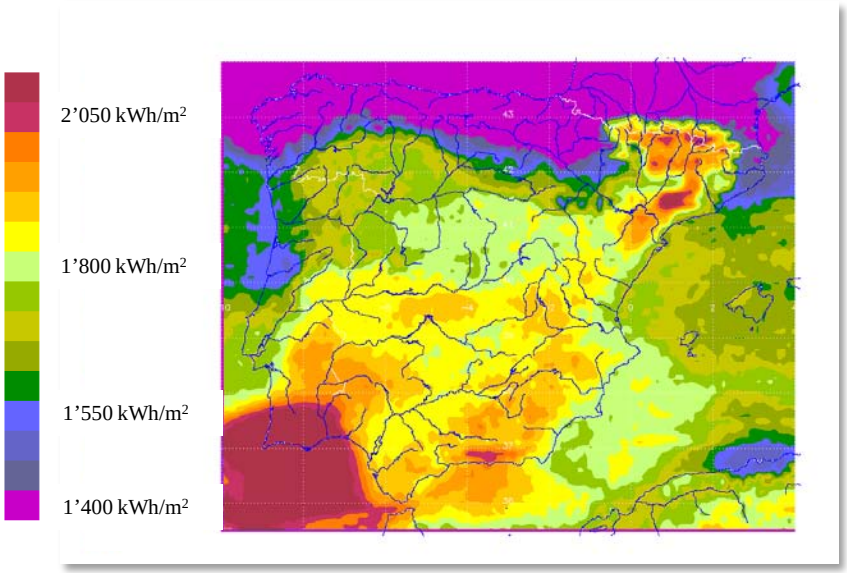
Period: 1981-2000



Meteotest; database Meteonorm (www.meteonorm.com)

Solar irradiation maps





Meteotest; database Meteonorm (www.meteonorm.com)

Comparison Western Africa vs. Southen Spain

Annual simulations with SimulCET

Site	Southern Spain	Dakar, Senegal	
Latitude	37.38º N	14.72º N	
DNI	2049 kWh/m^2	2039 kWh/m^2	**-0.49%**
Optical losses	454765 MWh	404049 MWh	**-11.15%**
Gross power production	172801 MWh	183406 MWh	**6.14%**
Net power production	152016 MWh	159789 MWh	**5.11%**

Reference plant: Parabolic Trough, 154 loops, EuroTrough collectors, 6h TES. Hourly simulations.

Conclusions

- Several CSP technologies are today commercially available at different stage of maturity
- Although during commercialization process of CSP (2005-2010) cost reduction has been achieved in some key components (mirrors, structures). Additional significant cost reduction and efficiency improvements are expected in the near future (2010-2020)
- High CSP potential in west Africa mainly based in two facts
  - ➢ High level of solar radiation available
  - ➢ Better solar resource utilization due to the lower latitude.
- CSP development and deployment for west Africa …..to think ….and discuss….
  - ➢ CSP Plants are modular, able to be used as decentralized energy systems and/or centralized energy systems .
  - ➢ Many plant sizes and technological options are available.
  - ➢ Which is the best approach for applying CSP to west Africa?

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