Parabolic Trough, Linear Fresnel, Power Tower

A Technology Comparison

Robert Pitz-Paal

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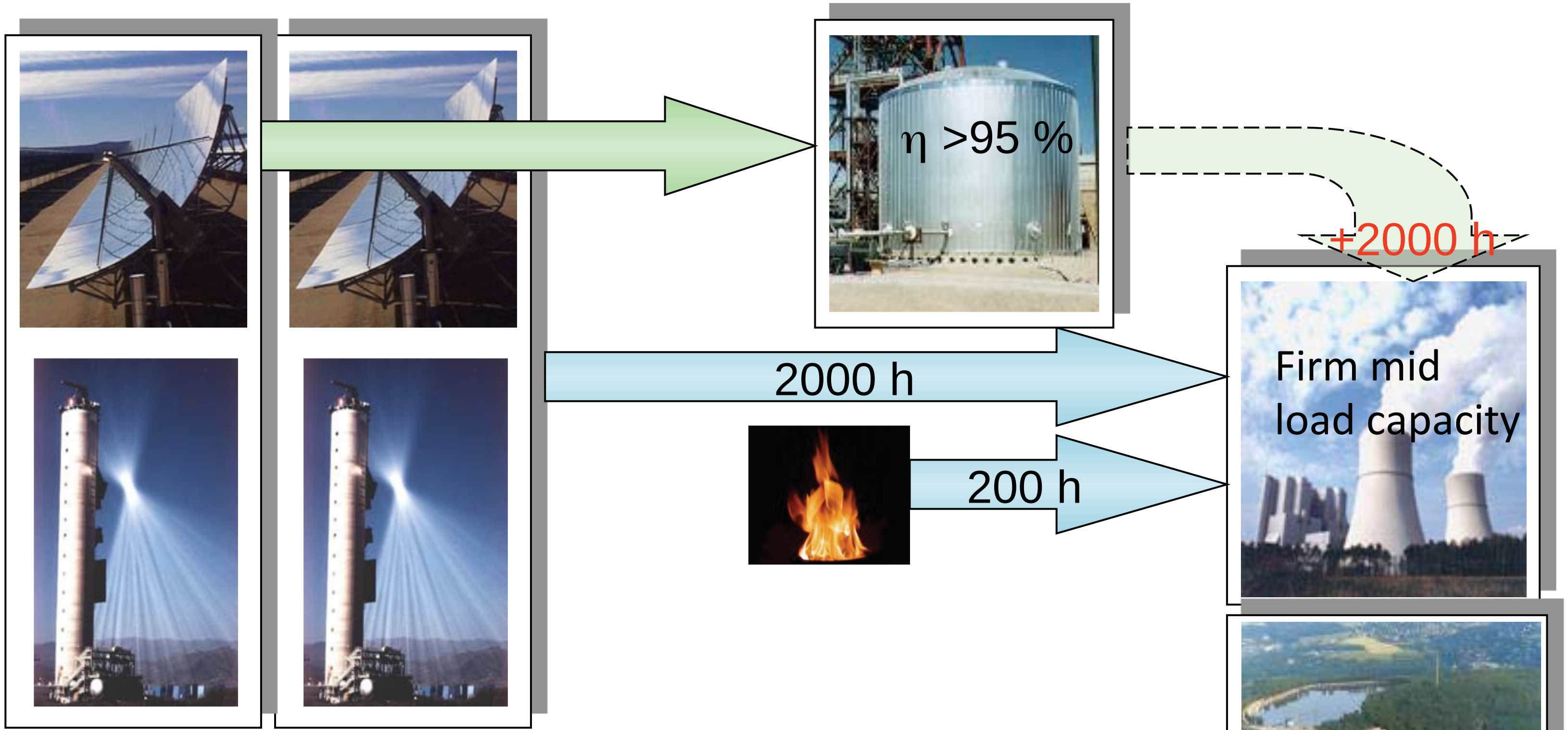
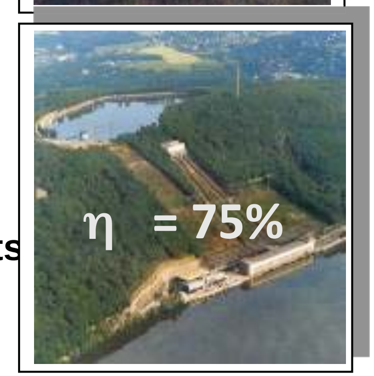
Thermal Storage vs. Electric Storage





CSP with storage and fossil hybridisation can provide all 3 components
Thermal storage economically favorable

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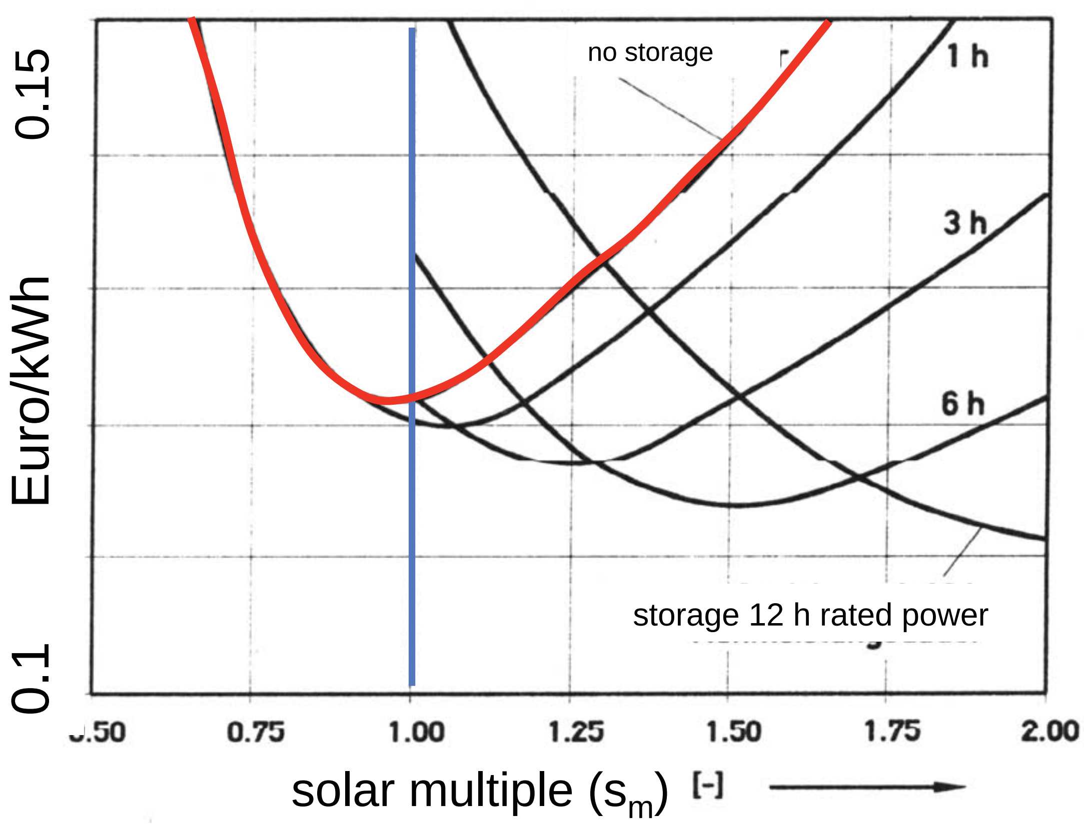
Cost of electricity for CSP system with and without storage

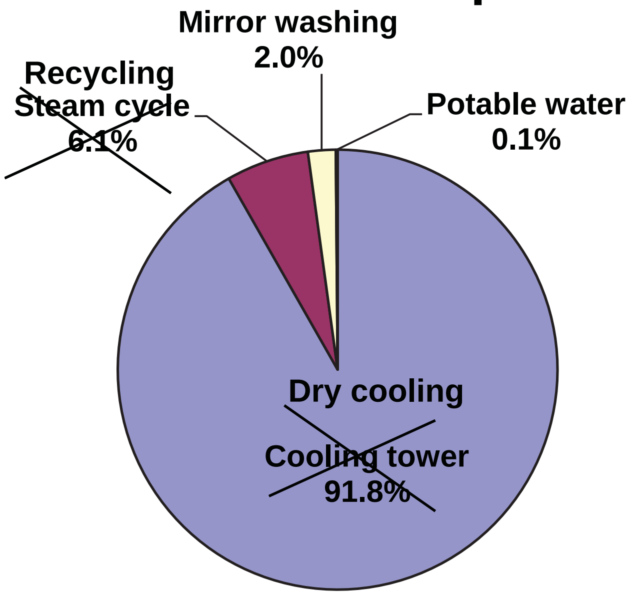


(parabolic trough plant type SEGS VIII,
Pel, = 80 MWel
yearly DNI = 2500 kWh/m²
Sm for 21. March!)

Electricity generation cost as function of solar multiple and storage size

How does CSP react under desert conditions?

Water consumption



Washing (no recycling yet)

75 l / MWh (low soil.)
30 l /m² year (mirror surface)
0,5 l/m² per wasching cycle

Rainfall Cairo = 25 l/m²year

Reflector Degradation?

- Glass mirrors have proven high robustness over >25 years in operation
- DLR has established accelerated aging methods for specific reflector types

Reflector Soiling

- Cleaning of CSP collectors on a weekly basis,
- Soiling depends strongly on site (and seasonal) conditions.
  Variations can be in the order of a factor 2-3
- 5% average soiling leads to revenue losses of 3-6 $/ m²year (depending on electricity price)
- Cleaning need 20 – 40 l/m² year

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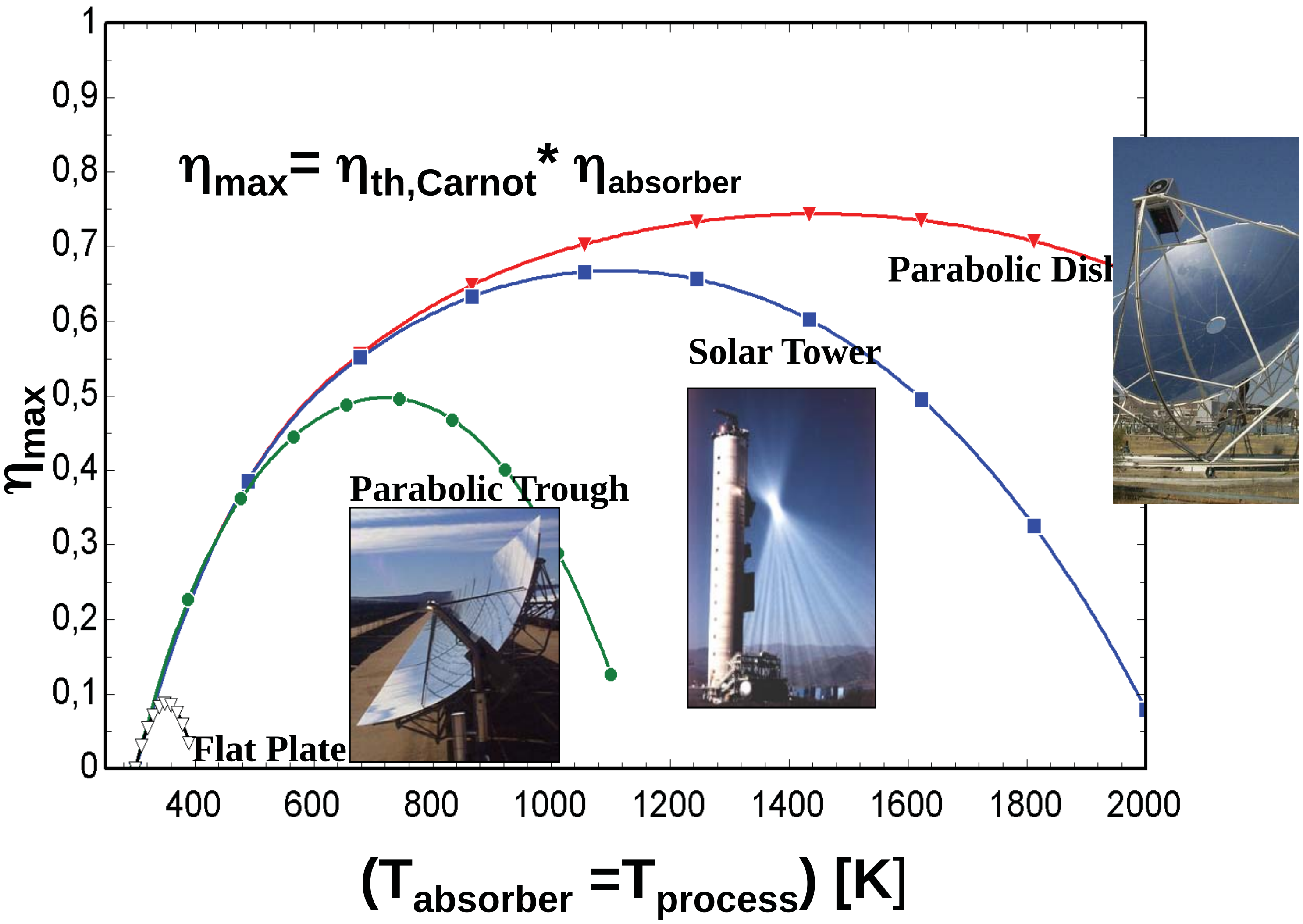
Technology	Peak solar to electricity conversion efficiency	Annual solar-to-electricity efficiency	Water consumption, for wet/dry cooling (m^3/MWh)	Land use (m^2/MWh/a)
Parabolic troughs	23-27%	15-16%	3-4 / 0.2	6-8
Linear Fresnel systems	18-22%	8-10%	3-4 / 0.2	4-6
Towers (central receiver systems)	20-27%	15-17%	3-4 / 0.2	8-12

Efficiency Potential of CSP Systems

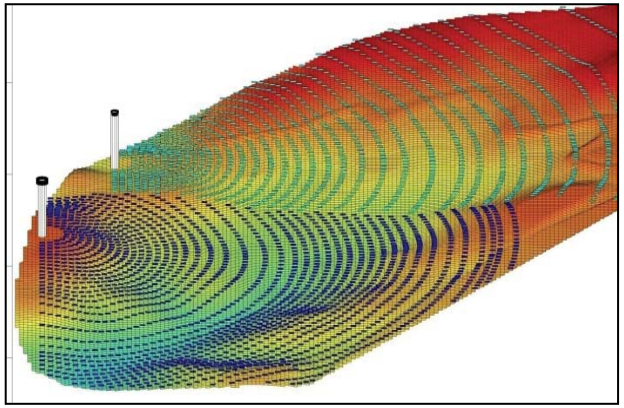


Market Situation

Table 1: CSP Capacity In Operation, Under Construction and Under Development (Q2-2012)

	Parabolic trough (MW)		Solar tower (MW)		Fresnel (MW)	
Operating	1,824	94.3%	67.9	3.5%	40	2.1%
Under Construction	2,433	76.7%	567.7	17.9%	172	5.4%
Under Development	1,280	50.0%	800	31.3%	367	14.3%

Ground Requirements



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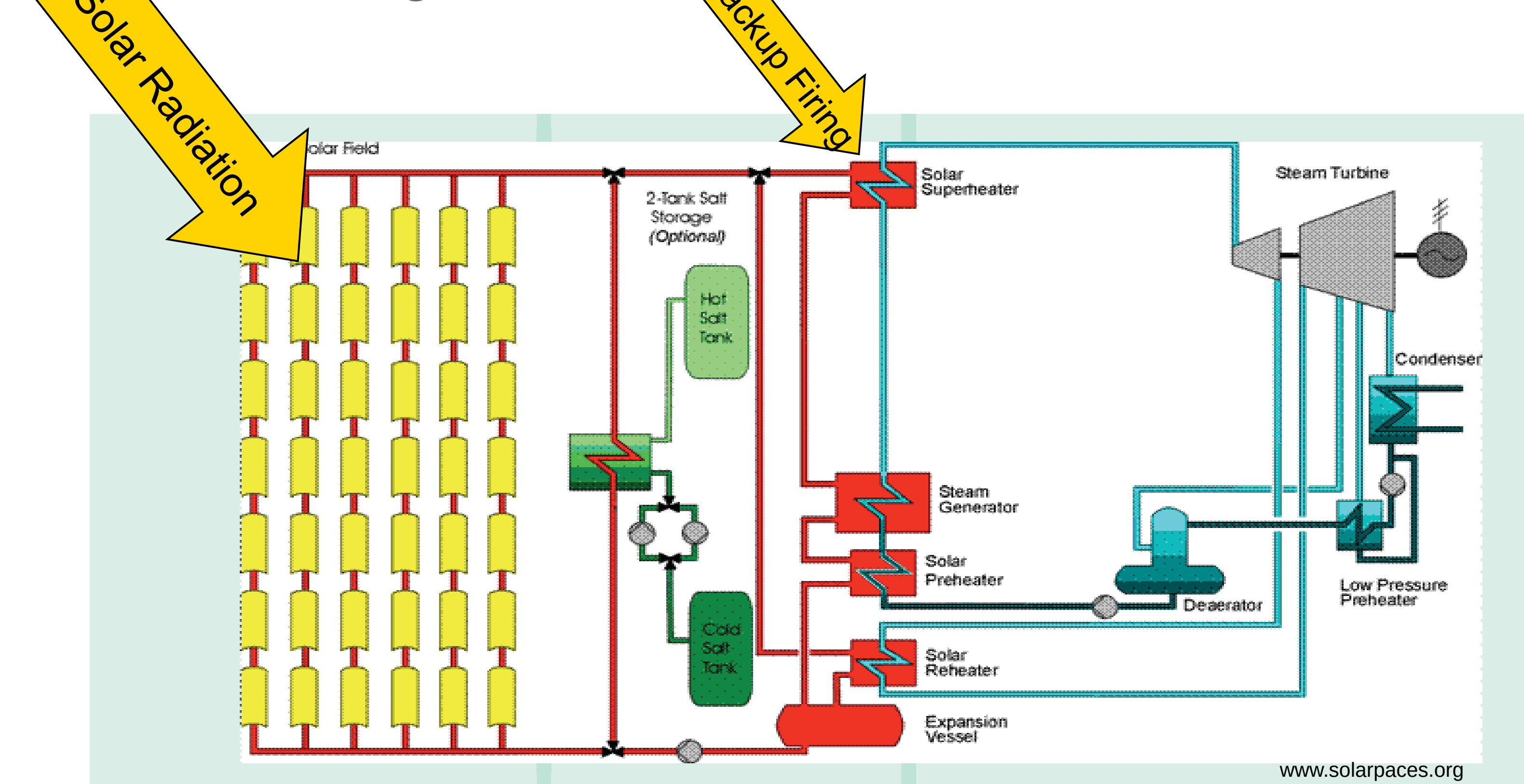
Parabolic Trough Plant Scheme



Solar Field

parabolic trough

collector field

200’000 - 2’200’000 m²

Heat Transfer & Buffer

2-10 hours

capacity

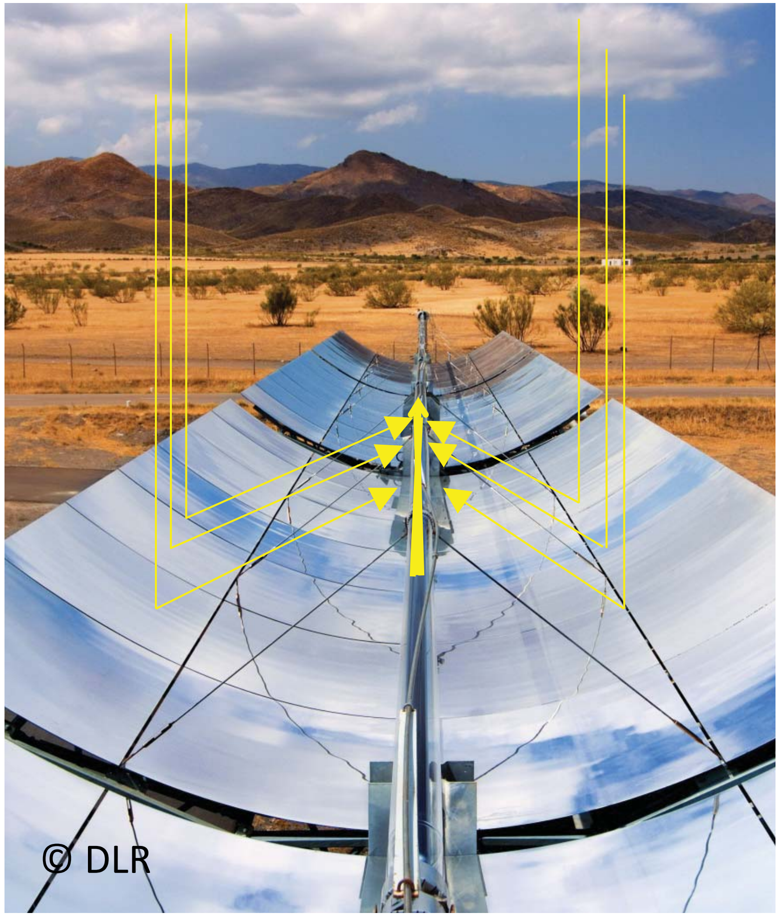
Power Block

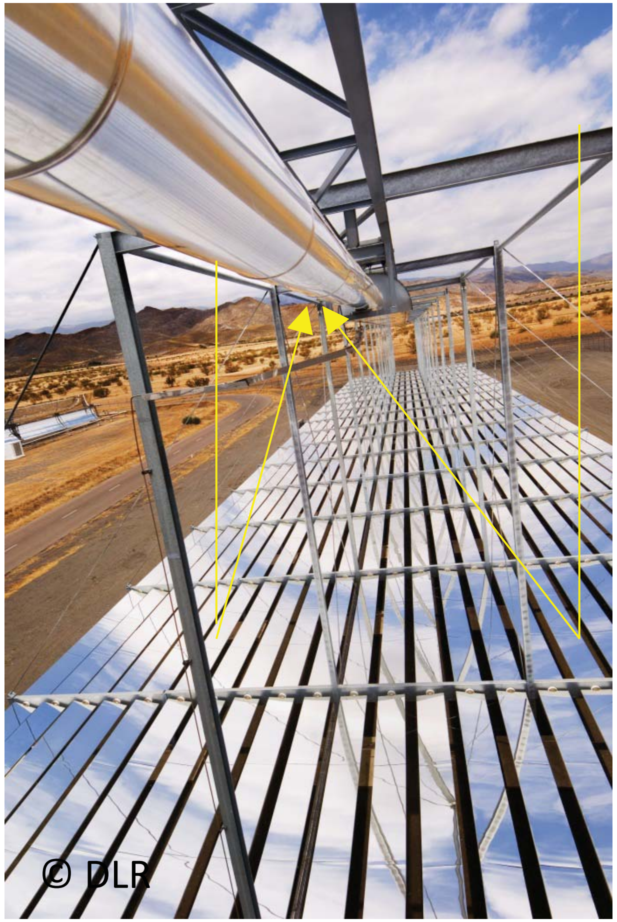
steam cycle

turbine, condenser

30-280 MW

Line Concentrators –how do they work?

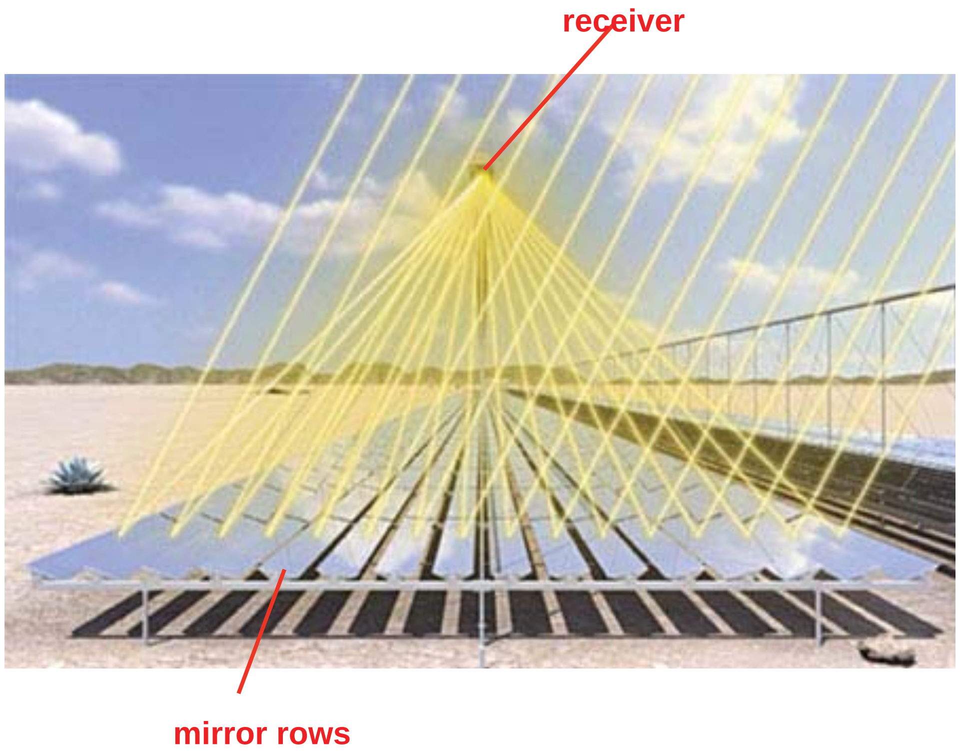


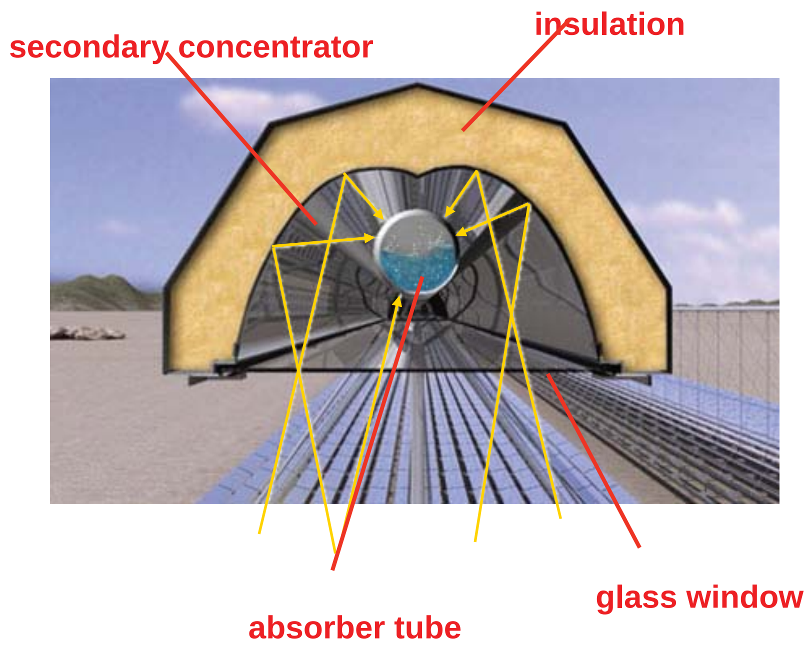


Line Concentrating Collectors

- 1-dimensional curvature of reflector
- short focal distance
- mirror bending required
- receiver length equals collector length
- absorber typically a tube
- heat flux rates 0.01 – 0.1 MW/m²
- absorber temperature limited to 400-600°C
- absorber insulation required (glass)
- parallel rows, only horizontal installation economical
- heat transfer fluids: synthetic oil, water/steam, molten salt, (CO_2)
- hydraulic and thermodynamic design to operating conditions
- heat storage possible
- net solar-to-electric peak efficiency 20-28%
- process heat applications
- performance modeling is state of the art

Linear Fresnel Collector – Working Scheme





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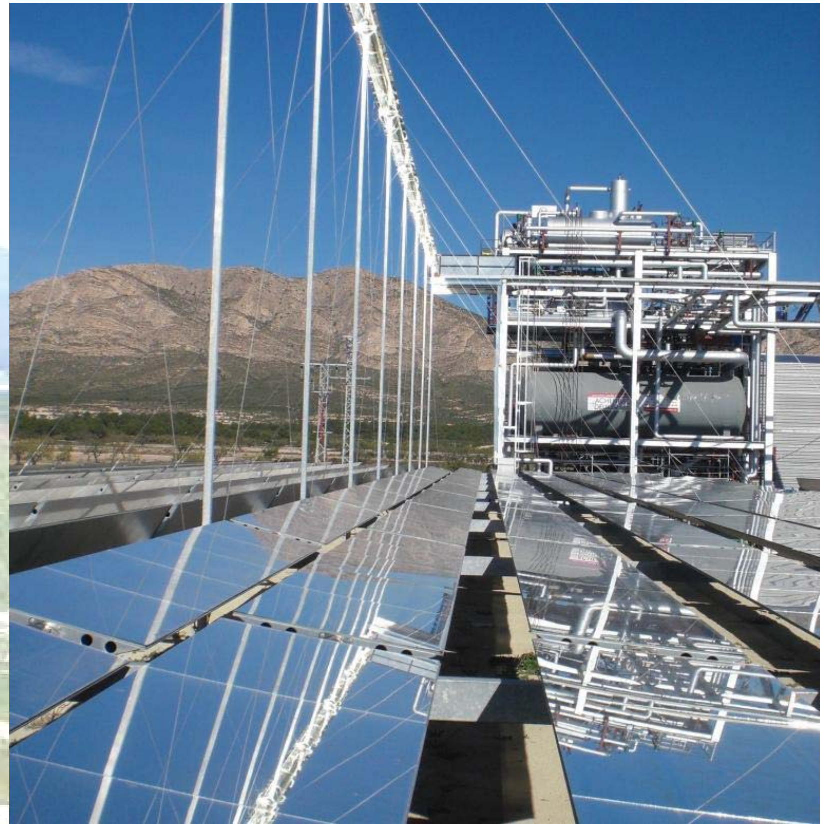
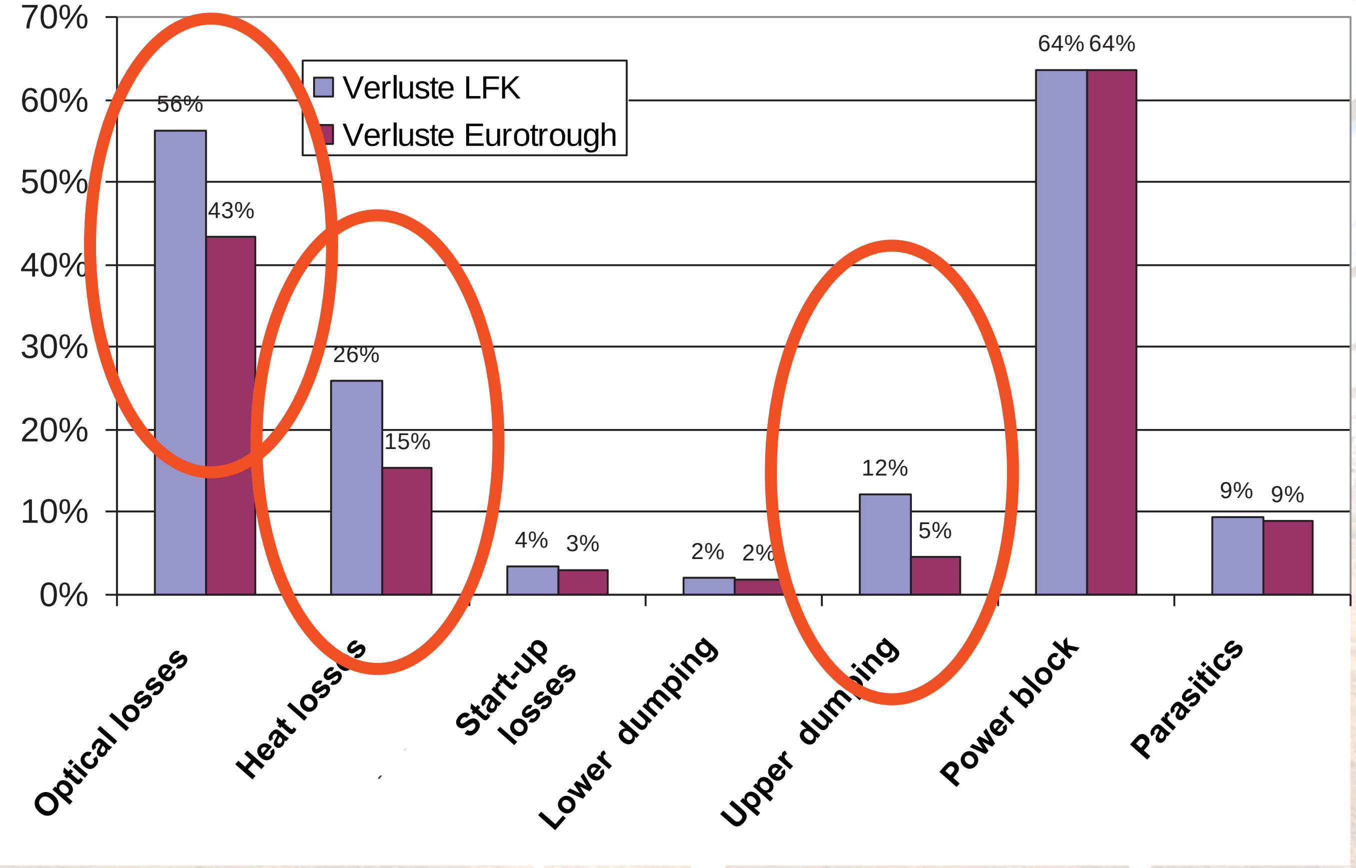
Linear Fresnel Collector - Properties



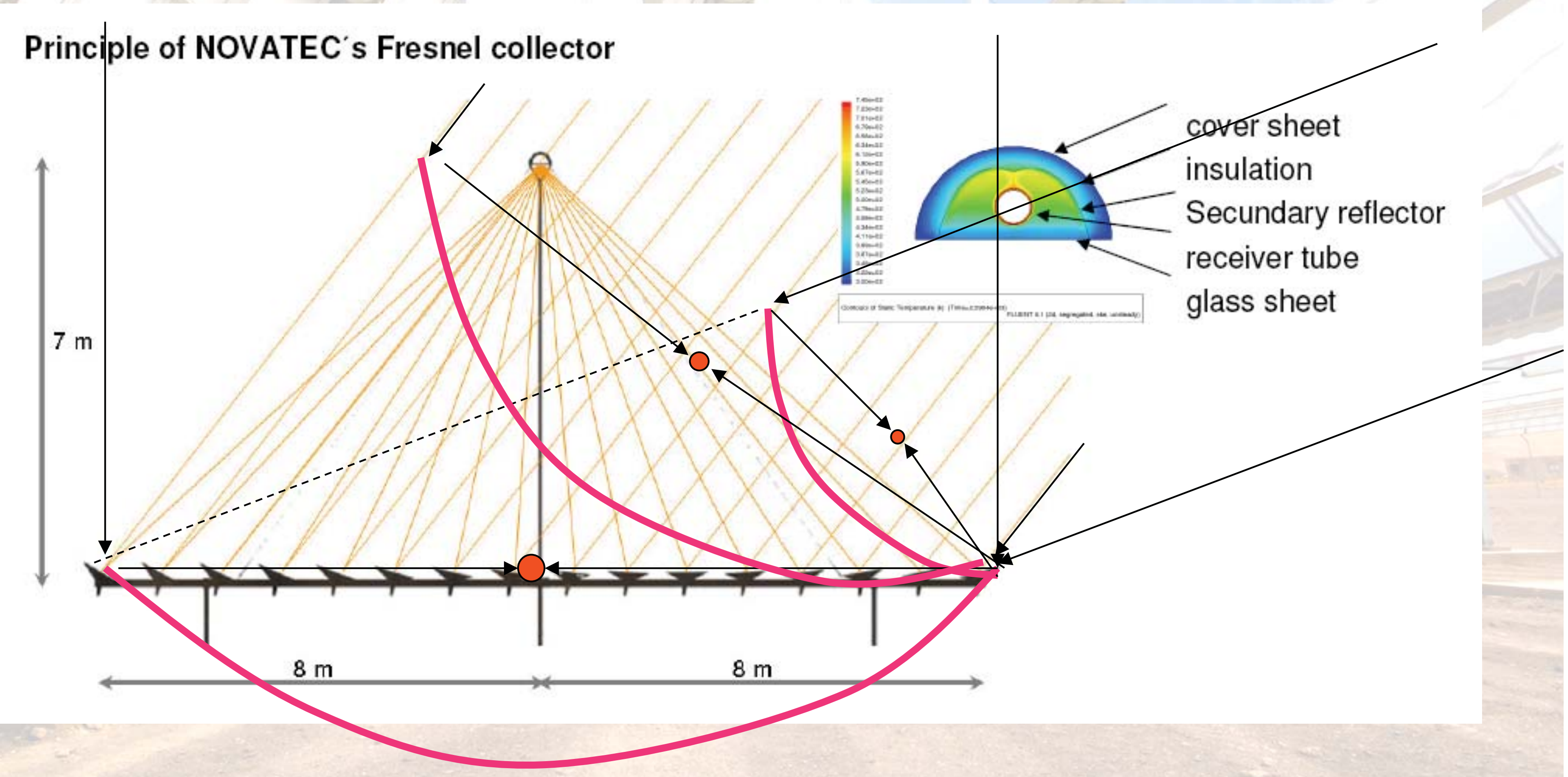
- off-axis, astigmatism
- gaps to reduce shading/blocking
- flat glass, light weight
- less standardized than troughs
- max theoretical concentration and optical efficiency lower than troughs
- collector width up to 20 m
- focal length up to 30 m
- fix receiver
- distance between rows 30-40%
- capture 55-65% of DNI
- two-axis incidence angle impact
- low performance on sun rise/set, high at noon
- low wind forces (low height)
- first commercial plants (Novatec, Areva, …)

What is the difference between Parabolic Trough and Linear Fresnel?

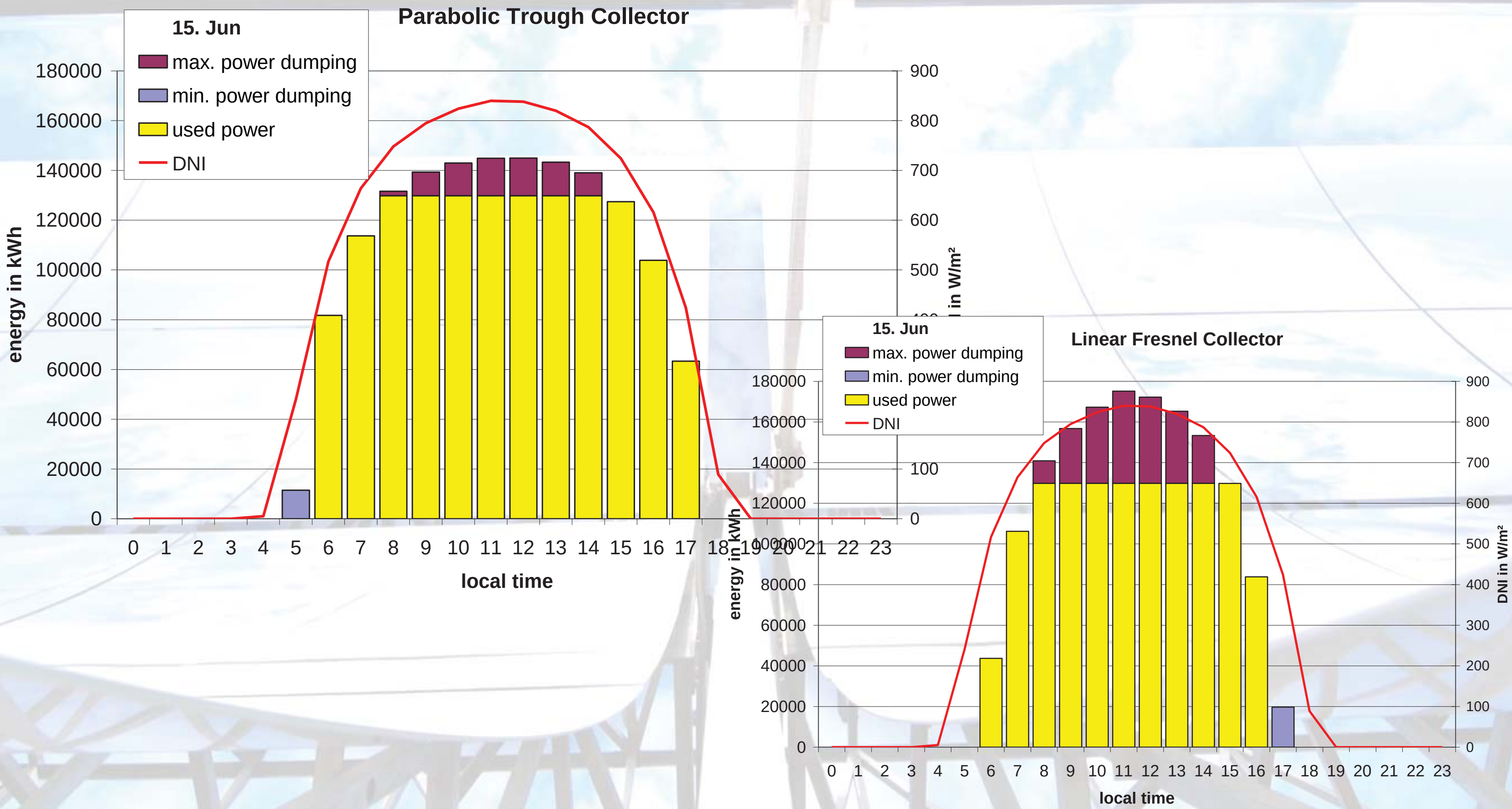


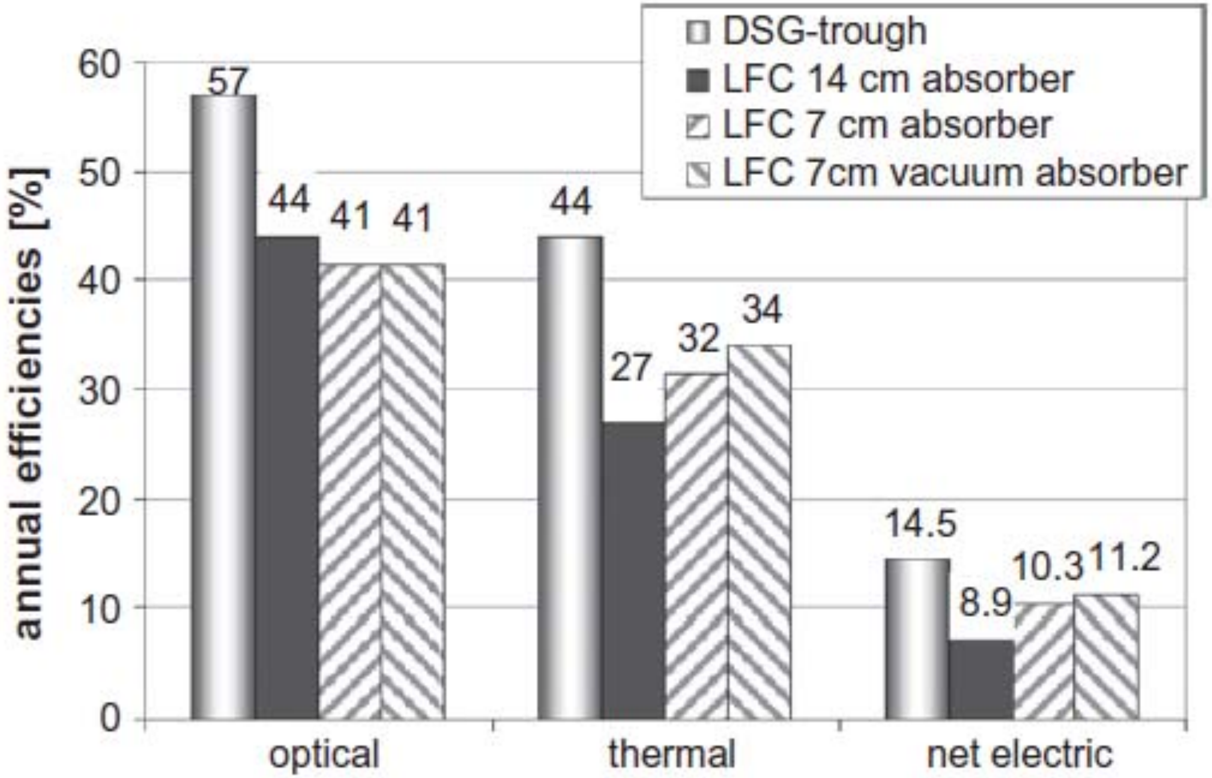
aus Morin et al. Projektbericht Fresnel II, AP 5.2

Why higher optical losses?

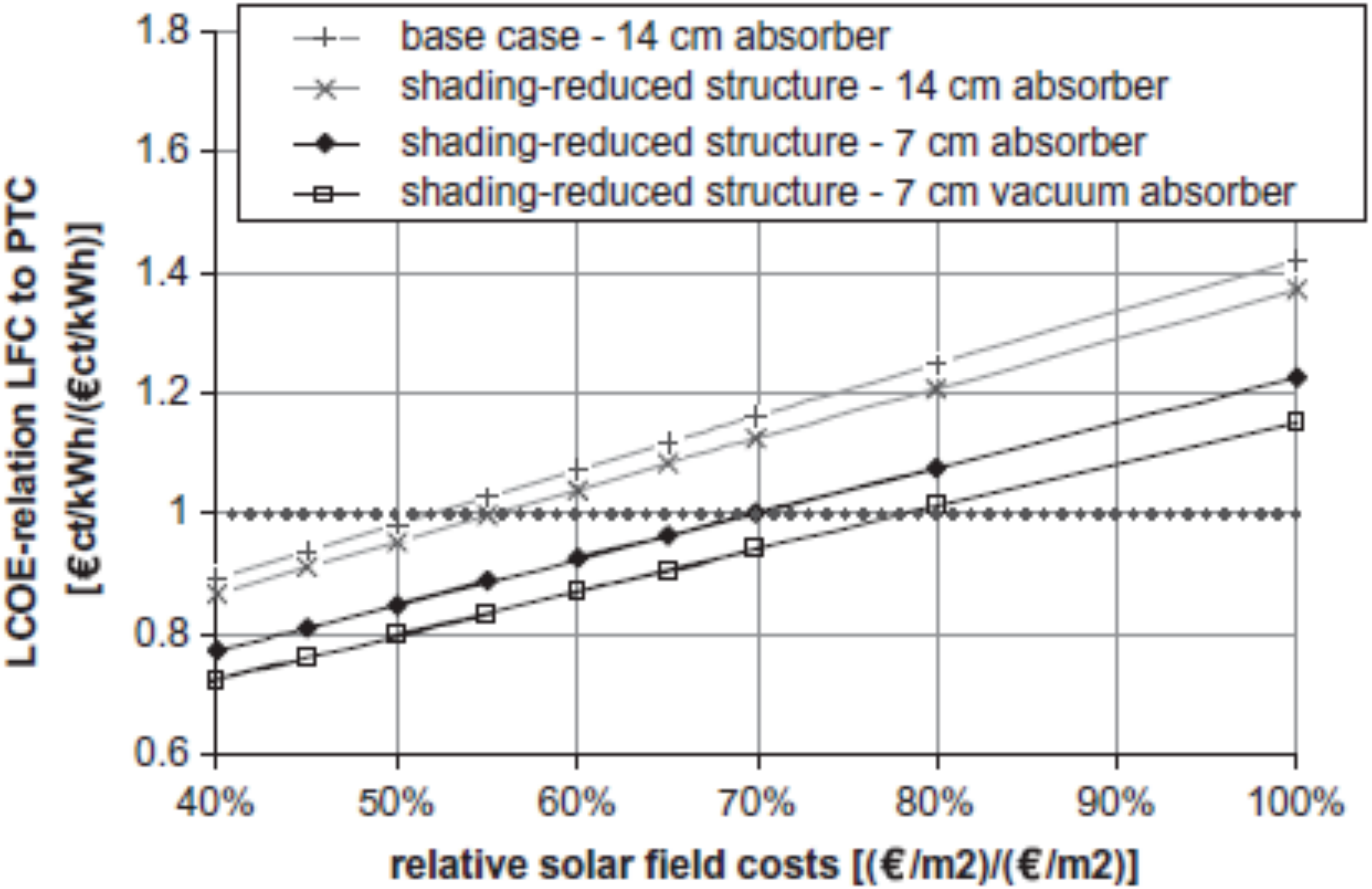


Why more dumping losses?





DSG-trough
LFC 14 cm absorber
LFC 7 cm absorber
LFC 7cm vacuum absorber
annual efficiencies [%]
60
50
40
30
20
10
0
57
44
41
41
44
27
32
34
14.5
8.9
10.3
11.2
optical
thermal
net electric


base case - 14 cm absorber
shading-reduced structure - 14 cm absorber
shading-reduced structure - 7 cm absorber
shading-reduced structure - 7 cm vacuum absorber
LCOE-relation LFC to PTC
[€ct/kWh/(€ct/kWh)]
1.8
1.6
1.4
1.2
1
0.8
0.6
40%
50%
60%
70%
80%
90%
100%
relative solar field costs [(€/m2)/(€/m2)]

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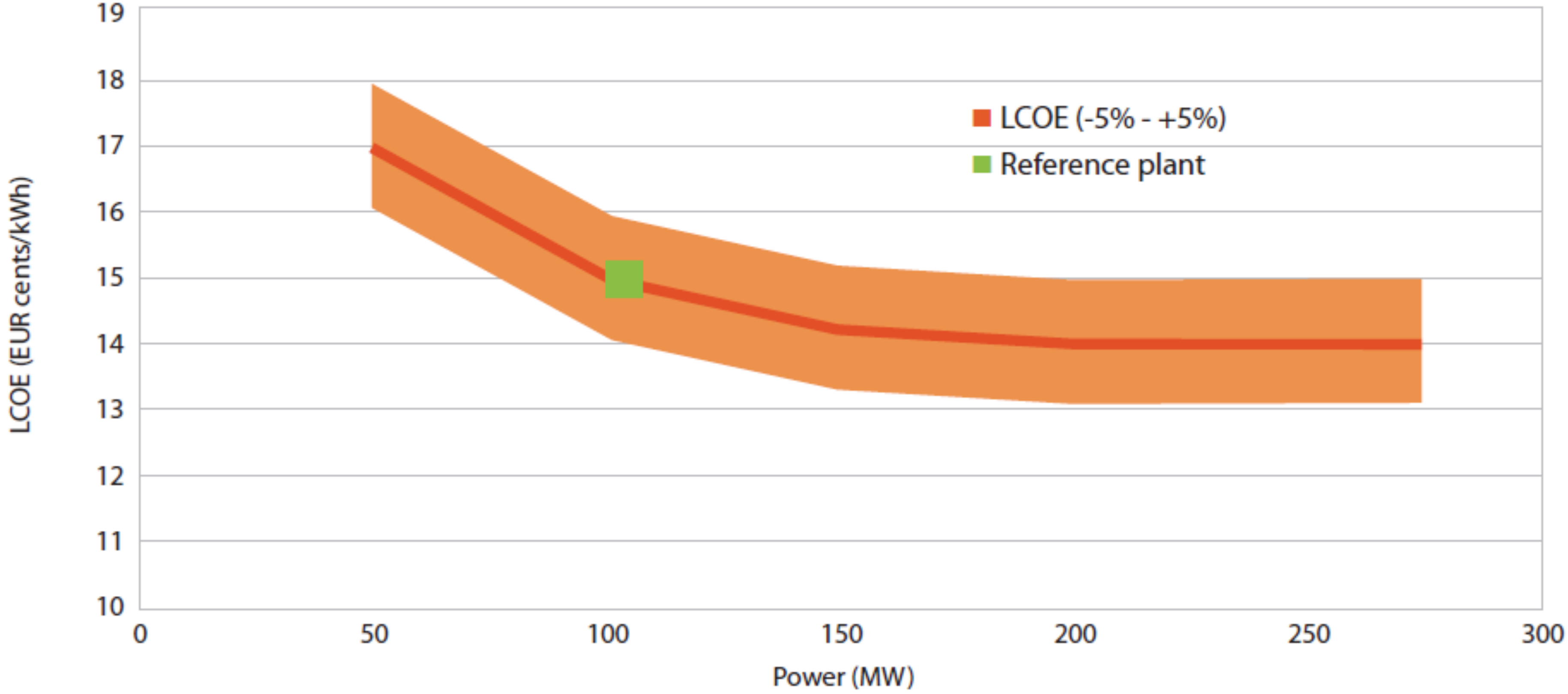
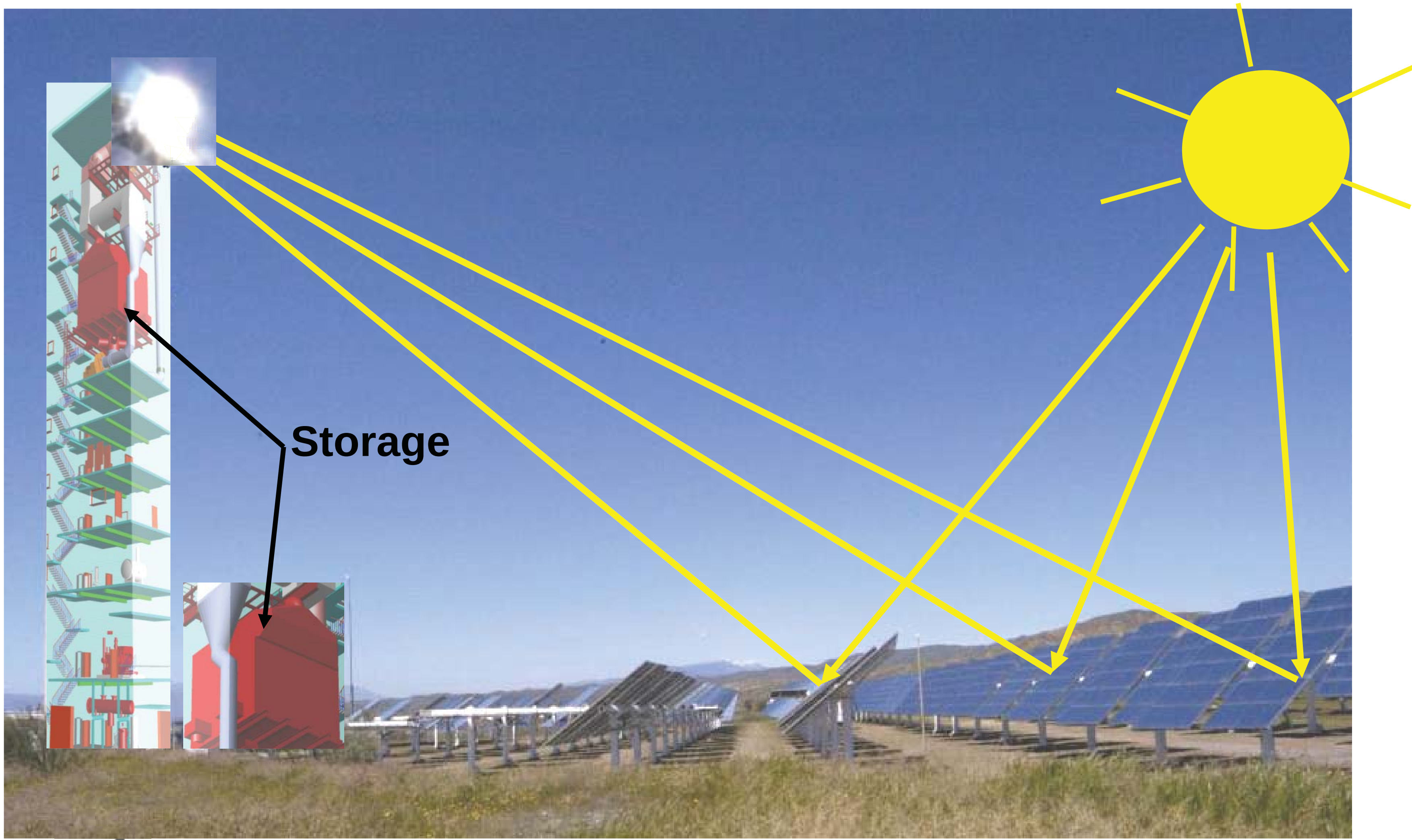
LCOE of Parabolic Trough (Algeria 2400kWh/m²a)



Concept of Tower Technology



Solar Tower

PROS	CONS
Modularity	Complexity
Ability to achieve high temperatures	Limited commercial track record
Wide industrial base for most components	Non–mature technology
Technologically proven	Greater land requirement
Multiple thermal storage options	Longer project development and construction times
Low cost of energy storage	
Output can be dispatched in line with demand	
Great potential for improved efficiency and/or cost reduction	
Greater capacity factor	
Ability to act as base load power plant	

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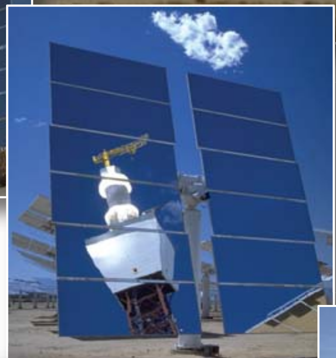
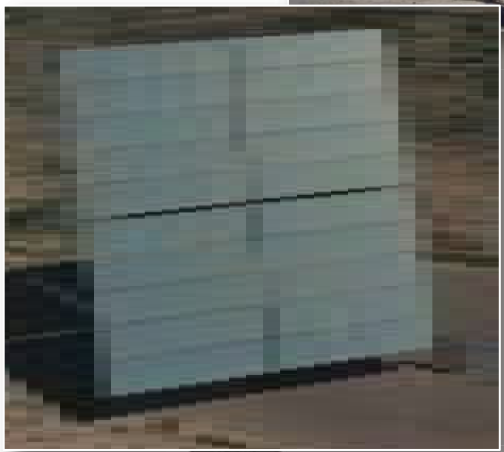
Solar Tower – Steam, Molten Salt

Ivanpah-CA 3x123 MW Brightsource
Tonopah-NV 110 MW SolarReserve
Lancaster-CA 5 / 46 MW eSolar

Heliostats

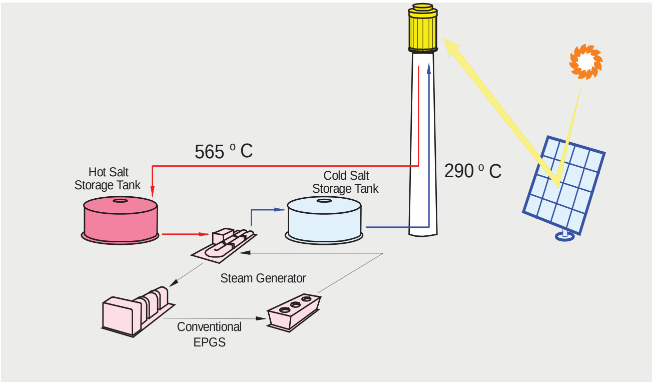




Receiver Concepts

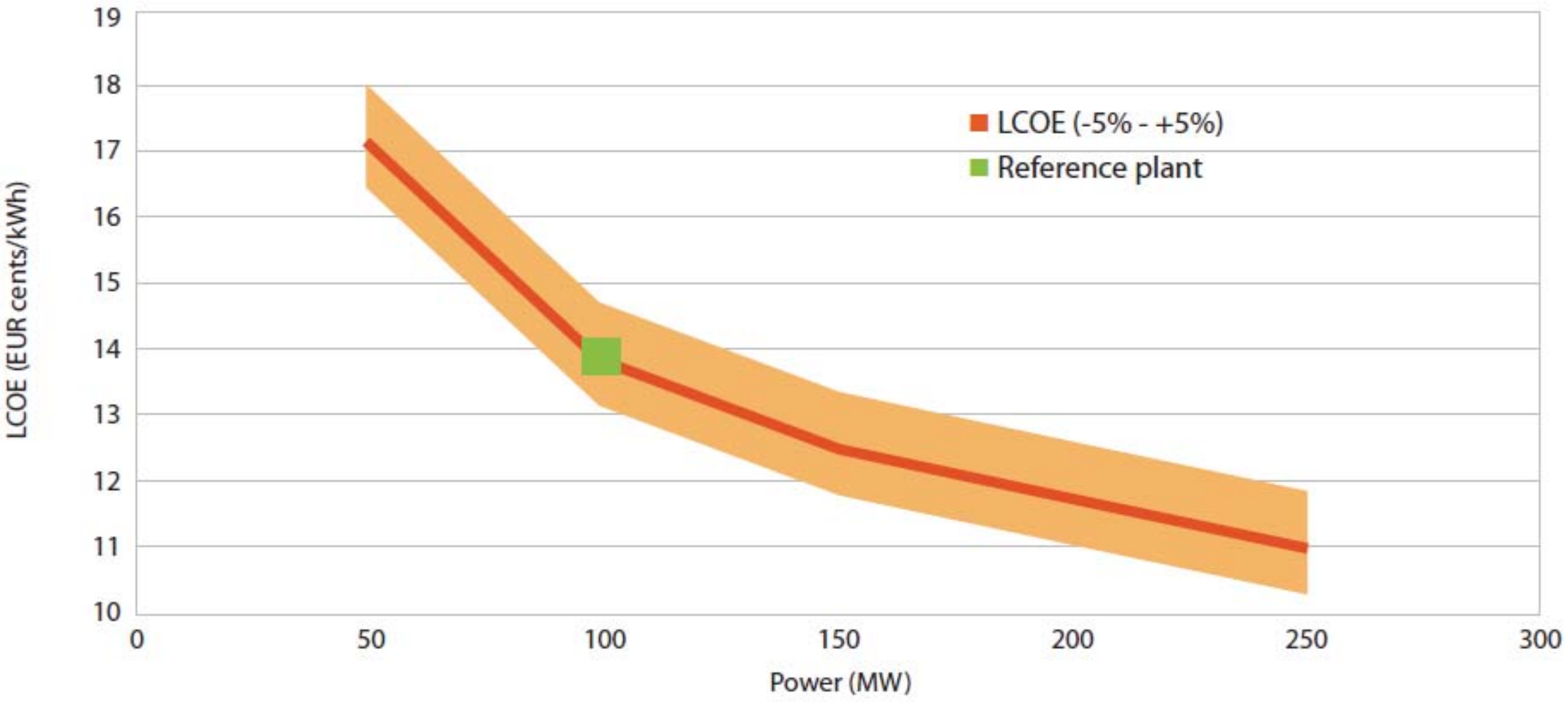


Solar Tower, molten salt – Gemasolar 20 MW Torresol Spain



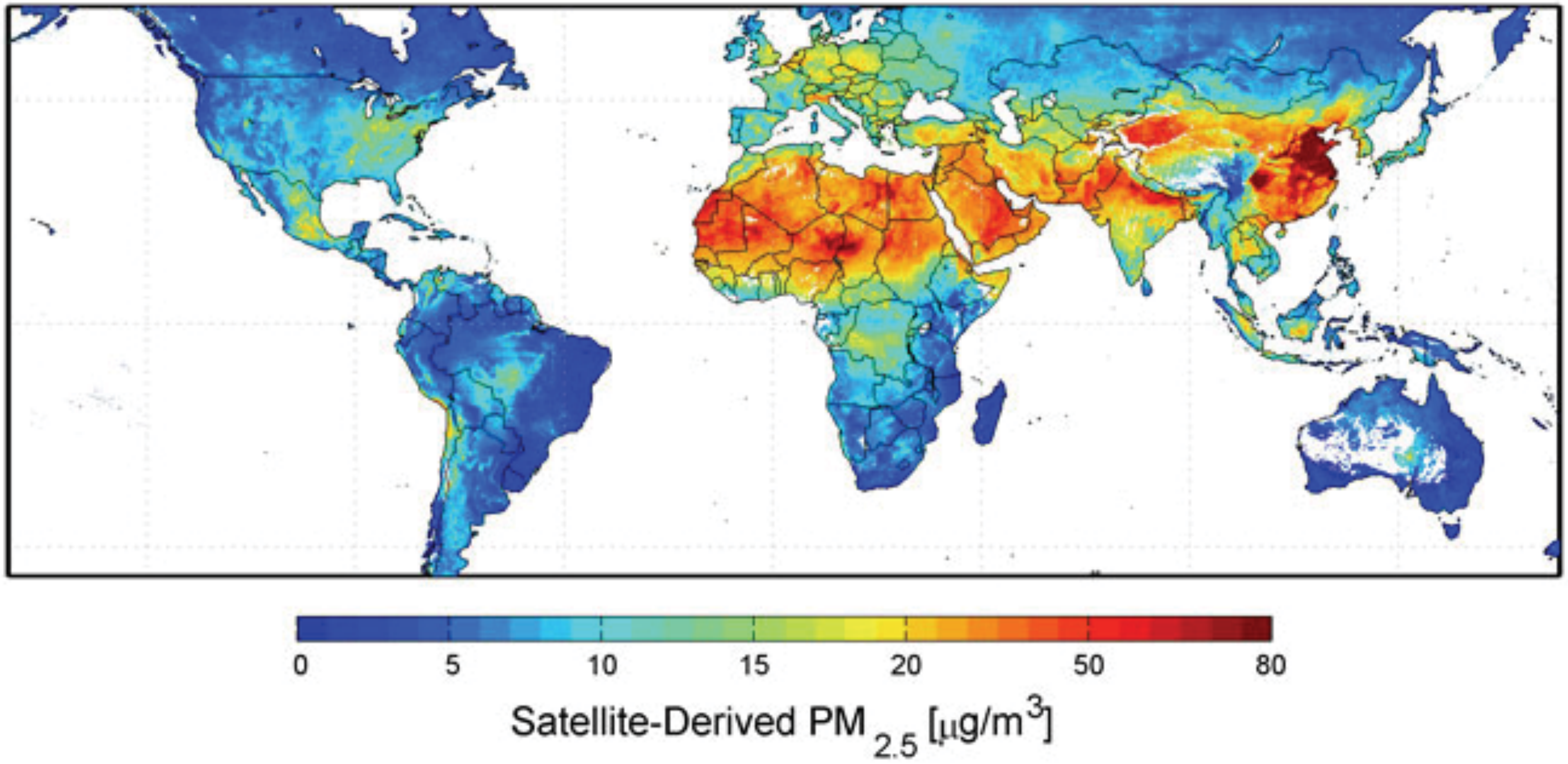
Ivenpah Solarturm Projekt

Example Reference Plant Molten-Salt Tower 100 MW Algeria

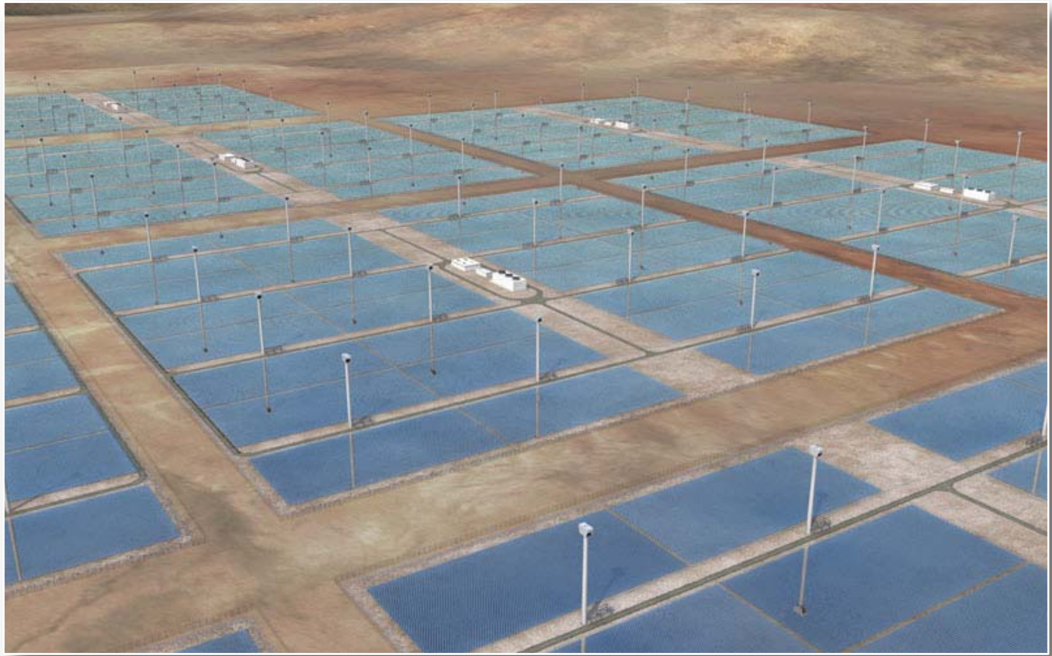


Atmospheric Extinction between Heliostat and Receiver

Aerosol Concentration close to ground surface



Modularity & Scalability



Conclusions

- Trough Tower and Fresnel Systems have very different characteristics and require complex design tools for their layout
- All three technologies have a realistic market potential and can further reduce costs

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Solar Tower Jülich – Solair/HitRec – Air as Heat Transfer Fluid
1.5 MW DLR / KA München