High Temperature Solar Thermal Power Plant with Particle Receiver and Direct Thermal Storage

Positioning of CSP in Future Electricity Networks

Frédéric Siros, EDF

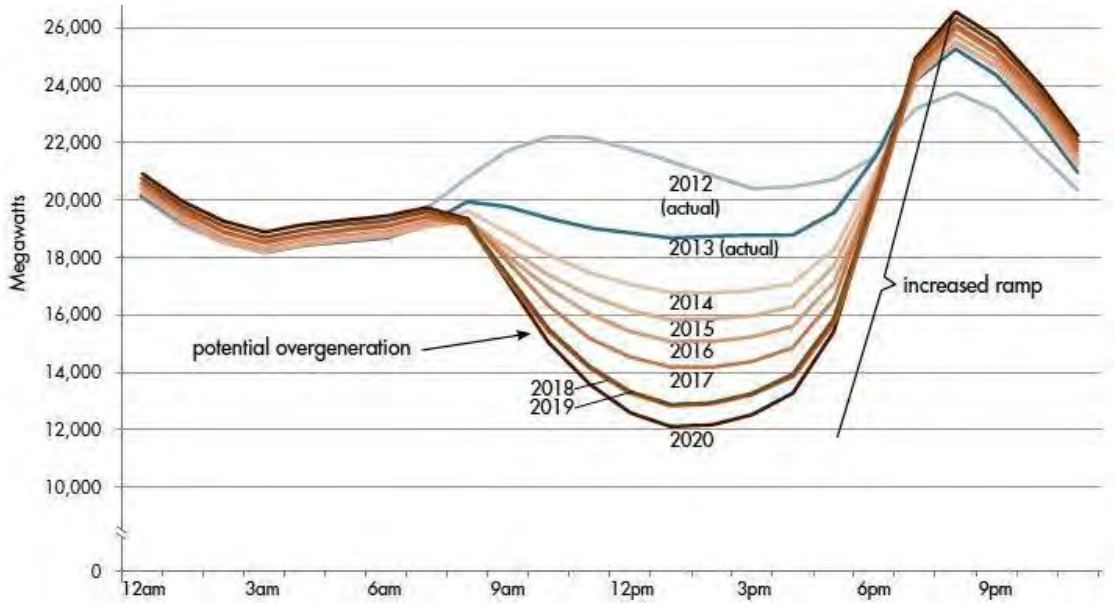
Next-CSP Infoday
Online – Thursday, July 8, 2021

This project has received funding from the EU Horizon 2020 Framework Programme for Research and Innovation under grant agreement no 727762

Value of CSP Generation

Cost is important, but value is crucial – Flexibility means value

- Flexible renewables including CSP are enablers, not competitors, of intermittent renewables such as Photovoltaic.
- The major stakeholders of the renewable generation sector eventually became aware of that a few years ago (about 10 years late)
- The growing share of variable Wind and PV increases the variability of the net demand
- Flexible renewable generation and/or massive storage are needed to reach a renewable share higher than approx. 40%



Potential Alternatives to CSP…

…for Flexible and Renewable Power Generation

Potential Alternatives to CSP for Flexible Renewable Power Generation

Network limitations → Flexible renewable generation or utility-scale storage is needed everywhere

- Including in desert areas. What technologies can compete with CSP in these areas? Obviously not hydro or biomass (lack of water)
- No area is suited to both geothermal and CSP (to the best of our knowledge)
- No significant deployment of CAES is forecasted
- Heat pumping: round-trip efficiency ~40%. Converting coal plants into such units can be interesting but has limited deployment potential

PV farm + batteries? Yes

- The LCOEs to be compared are those for **shifted** power generation

PV + Batteries: Cost of Shifted Electricity

LCOS of 4-hour Li-ion battery and LCOE of stored PV generation released in 4 nighttime hours

All estimated values are in US$/MWh

Scenario for cost decrease	2020		2030		2040	
	LCOS	LCOE	LCOS	LCOE	LCOS	LCOE
High	161	221	135	165	126	150
Medium	148	208	92.7	125	81.5	105
Low	133	193	55.5	88.2	44.8	68.3

Sources:

- Cole W., Frazier A.W. *Cost Projections for Utility-Scale Battery Storage*. Golden, NREL, June 2019
- US Energy Information Administration, *Capital Cost and Performance Characteristic Estimates for Utility Scale Electric Power Generating Technologies*, February 2020
- International Renewable Energy Agency (IRENA), *Renewable Power Generation Costs in 2019*

PV + Batteries: Cost of Shifted Electricity

LCOS of 4-hour Li-ion battery and LCOE of stored PV generation released in 4 nighttime hours

Again: the LCOEs correspond to solar energy collected during daytime, then fully shifted as power generation during nighttime only

Scenario for cost decrease	2020		2030		2040	
	LCOS	LCOE	LCOS	LCOE	LCOS	LCOE
High	161	221	135	165	126	150
Medium	148	208	92.7	125	81.5	105
Low	133	193	55.5	88.2	44.8	68.3

CSP is cheaper in 2020 and should be cheaper in 2030 and 2040 (whatever the scenario that will prevail)… But not by a huge margin

Therefore, novel CSP concepts such as that developed in Next-CSP are welcome to maintain this lead

CSP Plants Must Be Peakers…

…Here is Why

Policies and Subsidies do Matter

The pricing of electricity must reflect the grid's needs

Typical example of wrong subsidy: flat feed-in tariff.

Resulting plant designs: plants that generate power during daytime

- Parabolic trough plants: extended generation after sunset
- Solar towers (allowing for higher storage capacities): round-the-clock power generation (base load). Not much better than the above

Example of a clever pricing of the electricity: South Africa

- Tariff from 16:30 to 21:30 = Day tariff x 2.7
- Tariff during the night (22:30 → 05:00) = 0

Assigning a Price to Flexible Power Generation According to TOD

Spot market value = marginal cost of displaced power plant

- During daytime: ~0 (marginal PV or Wind; PV works wherever CSP works)
- During nighttime: fuel + variable O&M costs of last fossil-fueled plant called by the network (according to the merit order)

Pricing mechanisms try to alleviate this extreme contrast

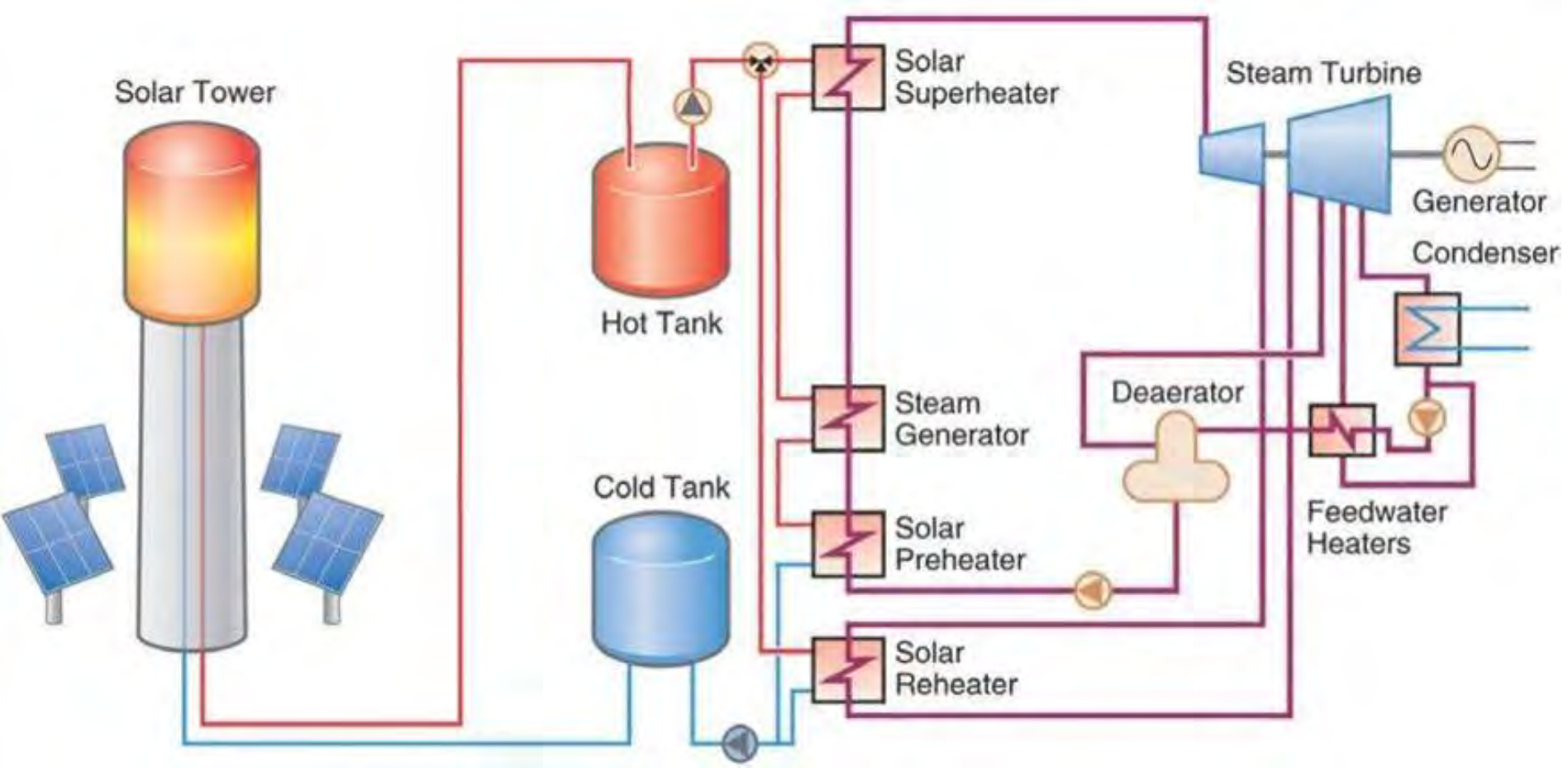
- Long-term PPAs are difficult to devise but drive generation prices down because the financing of the plant is safer, hence cheaper
- Market price plus premium is a powerful tool that exposes the power plant to market needs

Relative Sizing of the Main Islands of a CSP Plant

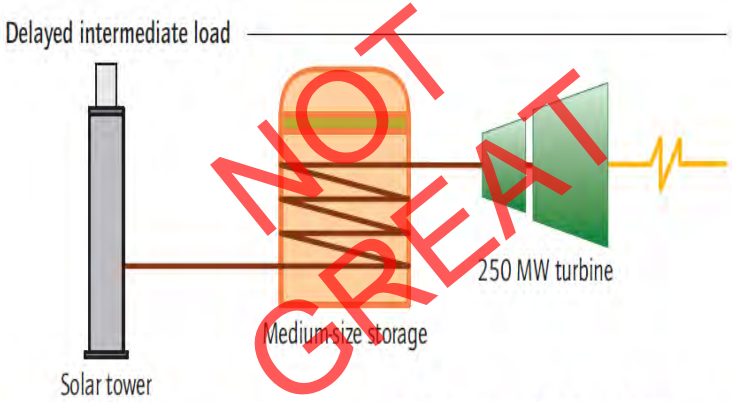
Solar Island

Storage

Power Block



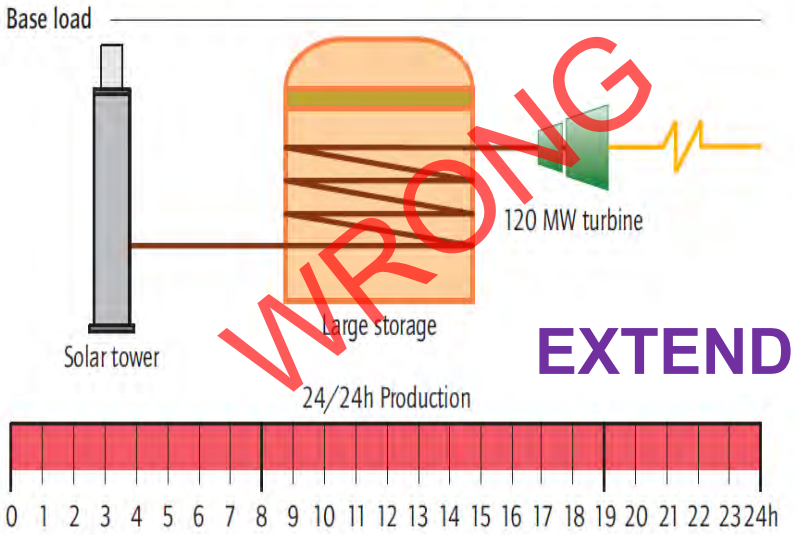
Relative Sizing of Solar Island, Storage, and Power Cycle



NOT GREAT

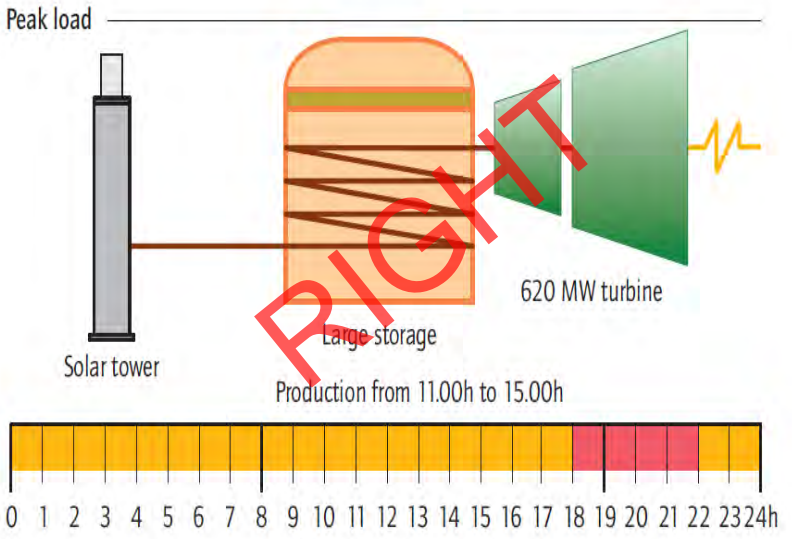
Source : CSP Roadmap 2010, AIE

SHIFT



WRONG

EXTEND



RIGHT

CONCENTRATE

Example: Arizona (USA)

TOD Schedule and PPA Coefficients for the 2017 RFP in Arizona

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
00-01	1	1	1	1	1	1	1	1	1	1	1	1
01-02	1	1	1	1	1	1	1	1	1	1	1	1
02-03	1	1	1	1	1	1	1	1	1	1	1	1
03-04	1	1	1	1	1	1	1	1	1	1	1	1
04-05	1	1	1	1	1	1	1	1	1	1	1	1
05-06	1	1	1	1	1	1	1	1	1	1	1	1
06-07	1	1	1	1	1	1	1	1	1	1	1	1
07-08	2	2	2	1	1	1	1	1	1	1	1	2
08-09	2	2	2	1	1	1	1	1	1	1	1	2
09-10	1	1	1	1	1	1	1	1	1	1	1	1
10-11	1	1	1	1	1	1	1	1	1	1	1	1
11-12	1	1	1	1	1	1	1	1	1	1	1	1
12-13	1	1	1	1	1	1	1	1	1	1	1	1
13-14	1	1	1	1	1	1	2	2	1	1	1	1
14-15	1	1	1	1	1	2	2	2	2	1	1	1
15-16	1	1	1	1	1	4	4	4	4	1	1	1
16-17	1	1	1	2	2	4	4	4	4	2	2	1
17-18	1	1	1	2	2	4	4	4	4	2	2	1
18-19	3	3	3	3	3	4	4	4	4	3	3	3
19-20	3	3	3	3	3	4	4	4	4	3	3	3
20-21	2	2	2	3	3	4	4	4	4	3	3	2
21-22	2	2	2	2	2	2	2	2	2	2	2	2
22-23	1	1	1	1	1	1	1	1	1	1	1	1
23-24	1	1	1	1	1	1	1	1	1	1	1	1

Source: H. Price, *Dispatchable Power Plant*, 2017

TOD PPA coefficients

4	5
3	3
2	1
1	0

“Best fit” CSP Plant (Molten Salt Tower)

Weighted average coefficient on price of electricity = 5,60

Versus coefficient = 1,73 for a plant operating with a 63% capacity factor

→ 3,23 x more value!

	Unit	Comment	
Turbine gross output	MW_e		230
Solar field thermal power	MW_{th}		400
Annual capacity factor	-		17,4%
C.F. most preferred hours	-	Value x 9 (red)	94%
C.F. preferred hours	-	Value x 3 (yellow)	84%
C.F. less preferred hours	-	Value x 1 (green)	19%
C.F. no must take hours	-	Value = 0 (purple)	0,0%
Levelized Cost of Electricity	US$/MW.h		185

Comparison between "best fit" peaker and base load plants

Base load, "Gemasolar-like" plant

- Capacity factor ~63%
- Weighted average coefficient on price = 1.73

Our peaker plant

- Capacity factor = 17.4%
- LCOE = $LCOE_{BaseLoadPlant}$ **x 1,46**, due to 3.6x bigger power cycle (cost: approx. 3x) and somewhat bigger storage and costlier BOP)
- Capex of power cycle = 42.5% of total
- Weighted average coefficient on price = 5.60 = **3.23 x more!**

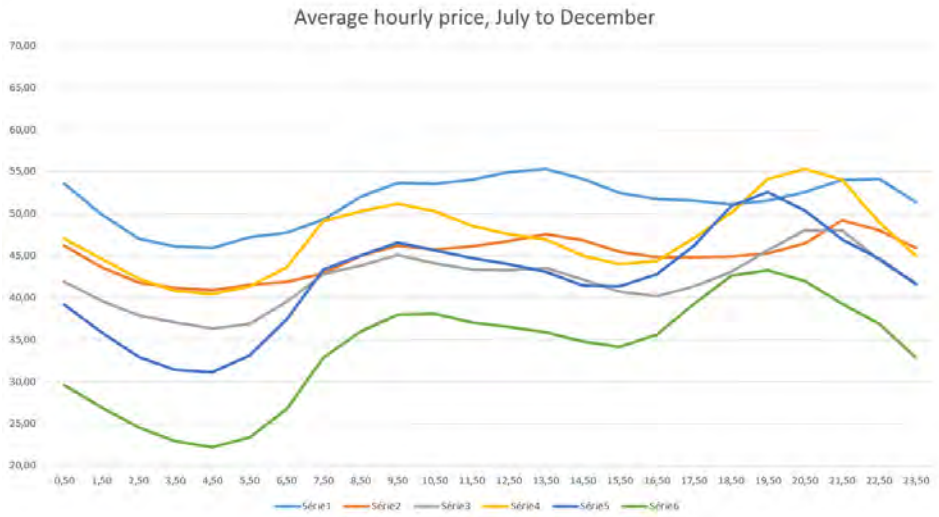
What about Europe?

2019 Day-Ahead Prices in Spain

Source: ENTSO-E's website (open access)

Price levels and variability are too low

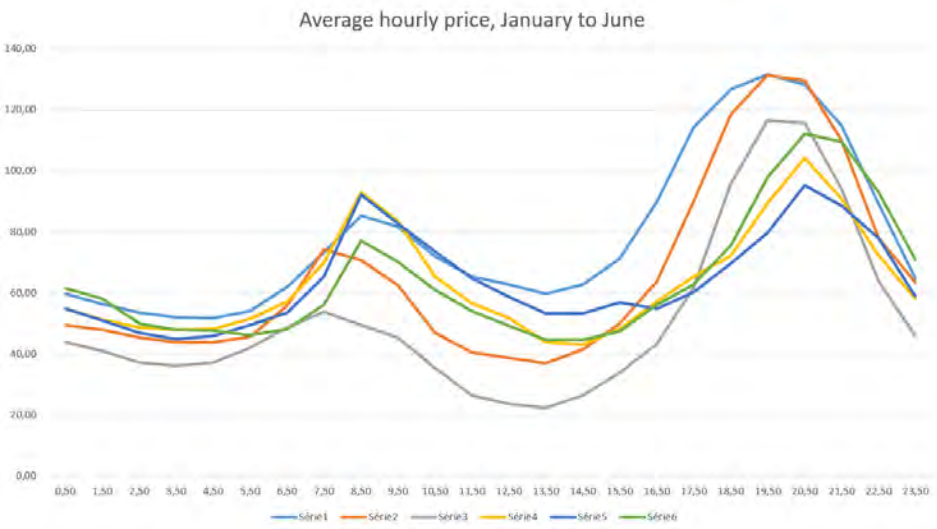
- Prices always < 70 €/MWh, and almost always < 55 €/MWh except in January and February (when CSP works poorly in Spain)



2019 Day-Ahead Prices in Sicily

Variability and average prices are much higher than in Spain

- A CSP plant installed in Sicily could sell electricity 5 hours a day in the evening and sell it at an average price of 108 €/MWh
- BUT the DNI is not great: e.g. 1936 kWh/m^2.year in Priolo Gargallo



Questions?

Frédéric Siros
frederic.siros@edf.fr