

Is a resurgence of the CSP market in the US possible, when and why?



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What a CSP Market Needs

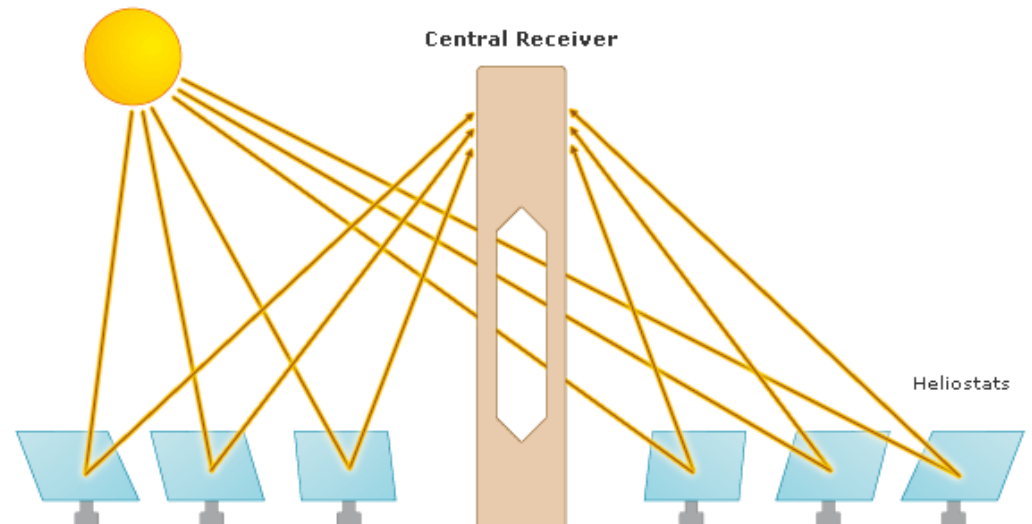
- Good DNI, plus
- Market demand, and
- Favorable policies.

Given this, CSP plants must be cost competitive and meet the performance needs of the market as defined by the demand curve and grid reliability.

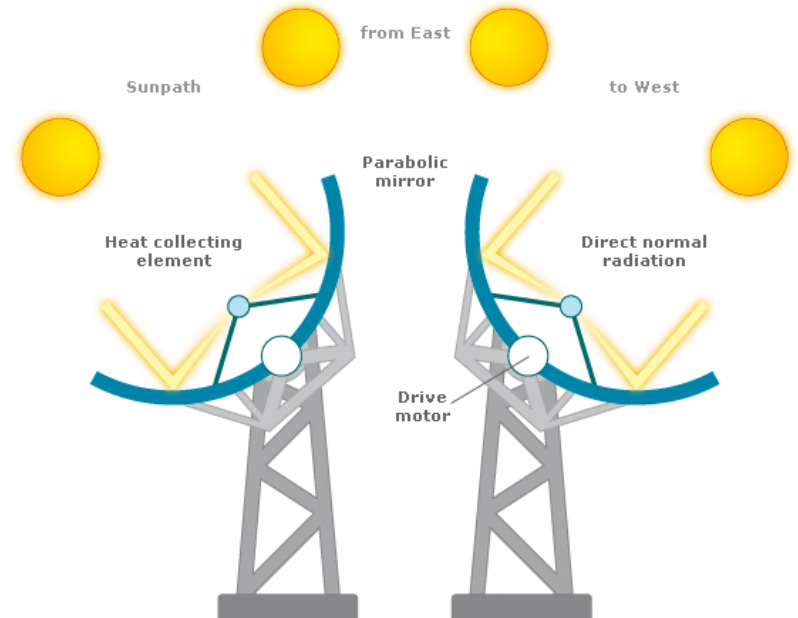
My answer

- Yes, a resurgence of CSP in the SW US is possible and likely
- Why?
 - DNI is excellent
 - Market opportunities are emerging due to growing amounts of wind and PV on the grid and the retiring of more fossil plants
 - CSP is flexible, dispatchable and carbon-free and provides many of the essential grid services needed for a reliable grid and can be designed to meet off-taker needs
 - Costs are decreasing rapidly and are expected to decrease further and are becoming competitive with natural gas plants

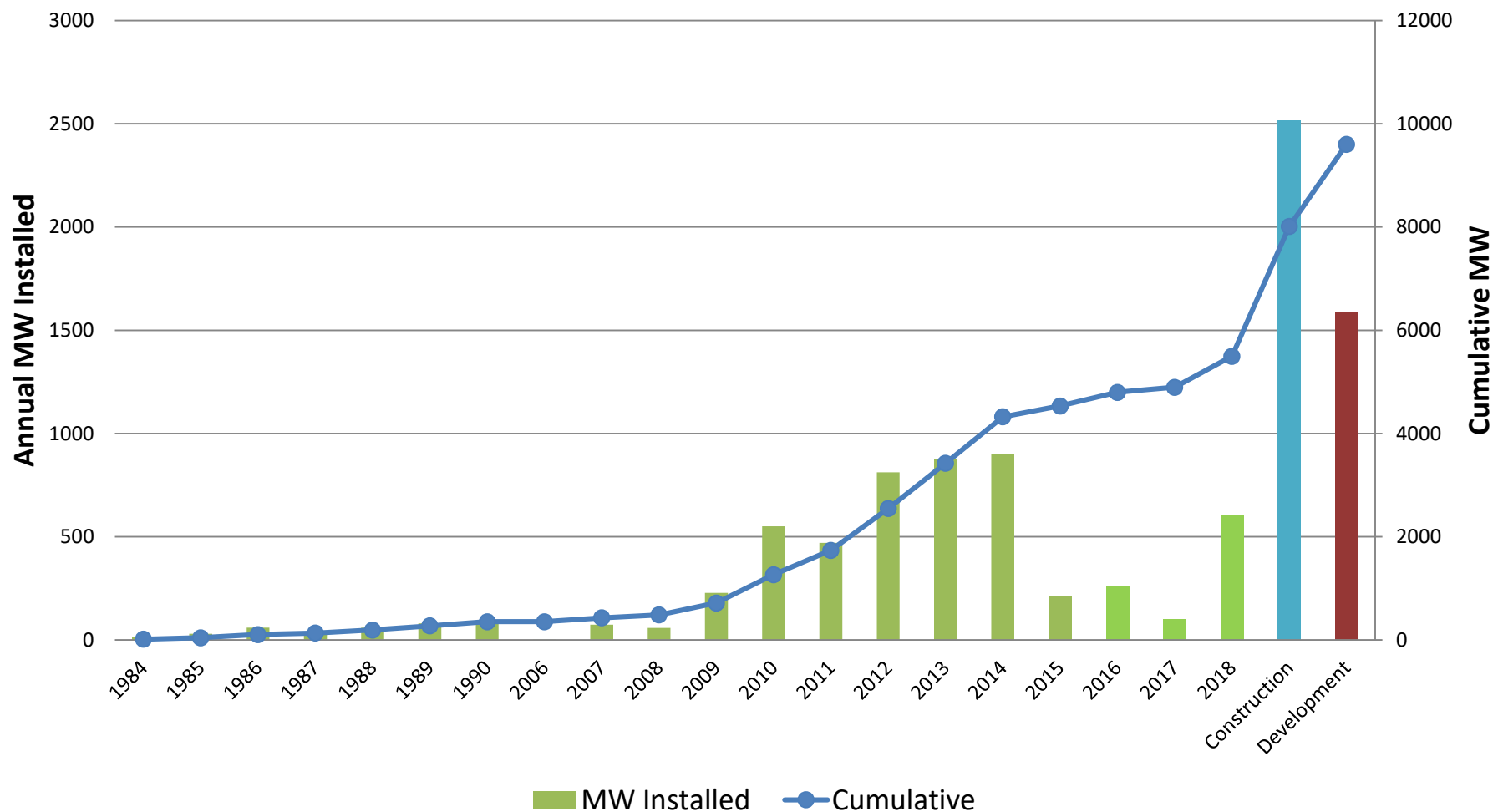
Power tower



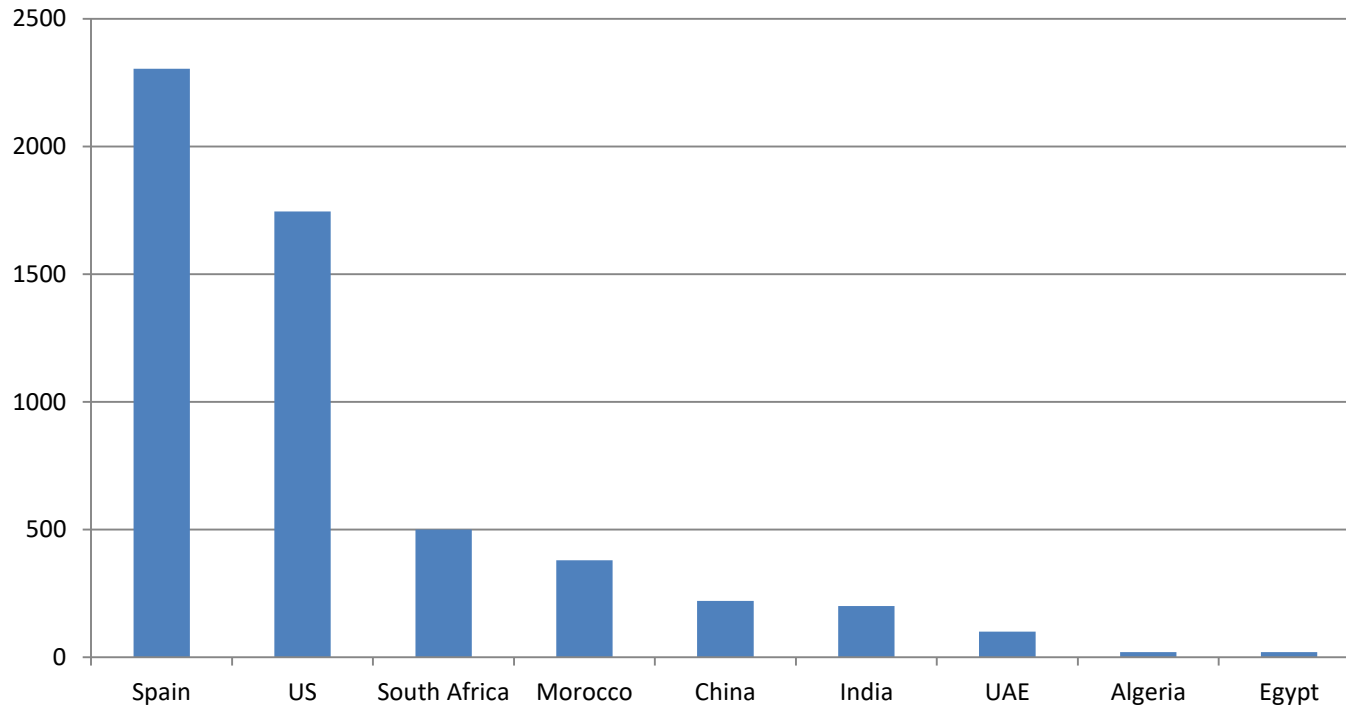
Parabolic trough



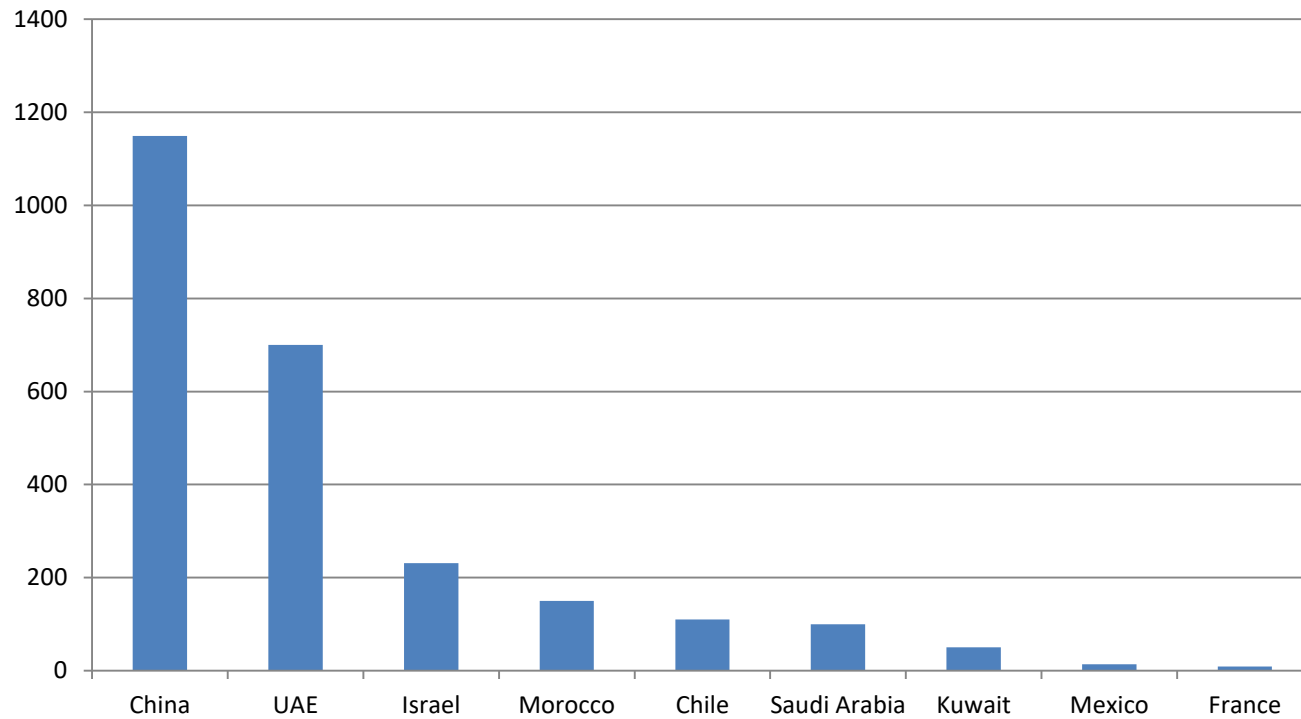
CSP Installed Capacity (MW)



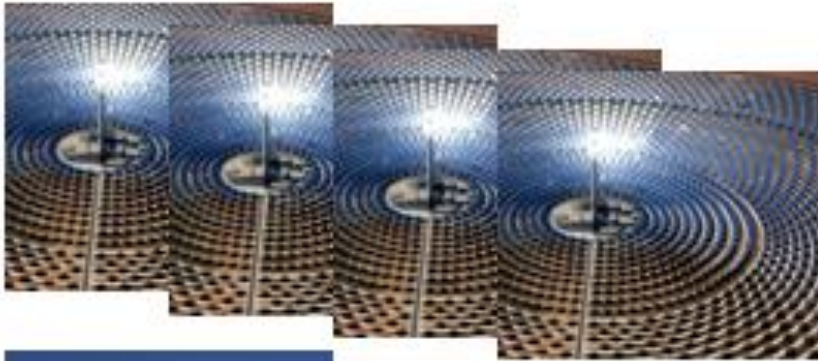
Where are the operating CSP plants ?



Where are CSP plants under construction?



CSP cost is coming down



↓ 50%



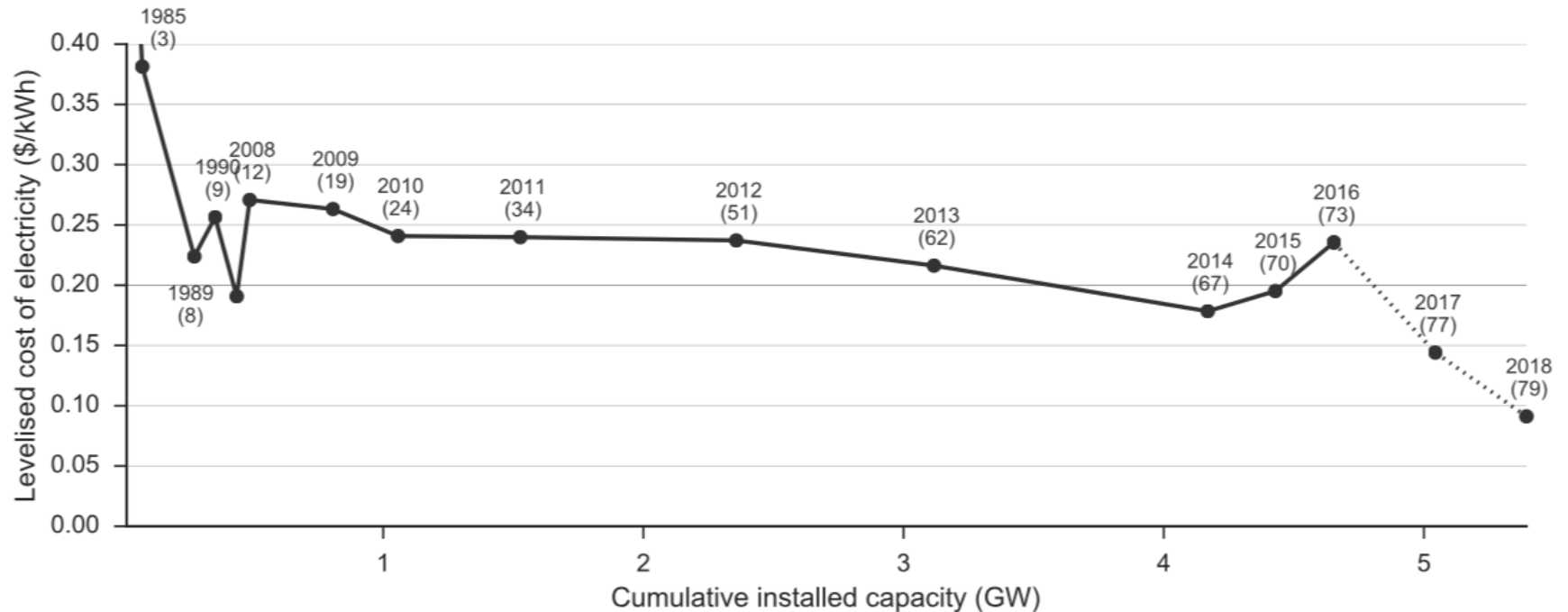
↓ 43%



↓ 40%

CSP Learning Curve

Lillestam, Labordena, Patt and Pfenninger, Nature Energy, 2017



DEWA Solar Project

- Large project – 950 MW
- Located in Dubai, UAE
- DNI around 2000 kWh/m²year
- 100 MW MS Tower + 200 MW x 3 Trough with 11-15 hrs molten salt storage + 250 MW PV
- CSP plant is designed to meet off-taker's requirements to operate from 4 pm until 10 am
- Construction started Dec 2018
- COD Dec 2020
- **Blended tariff 7.3 c/kWh**

Competitiveness = Price

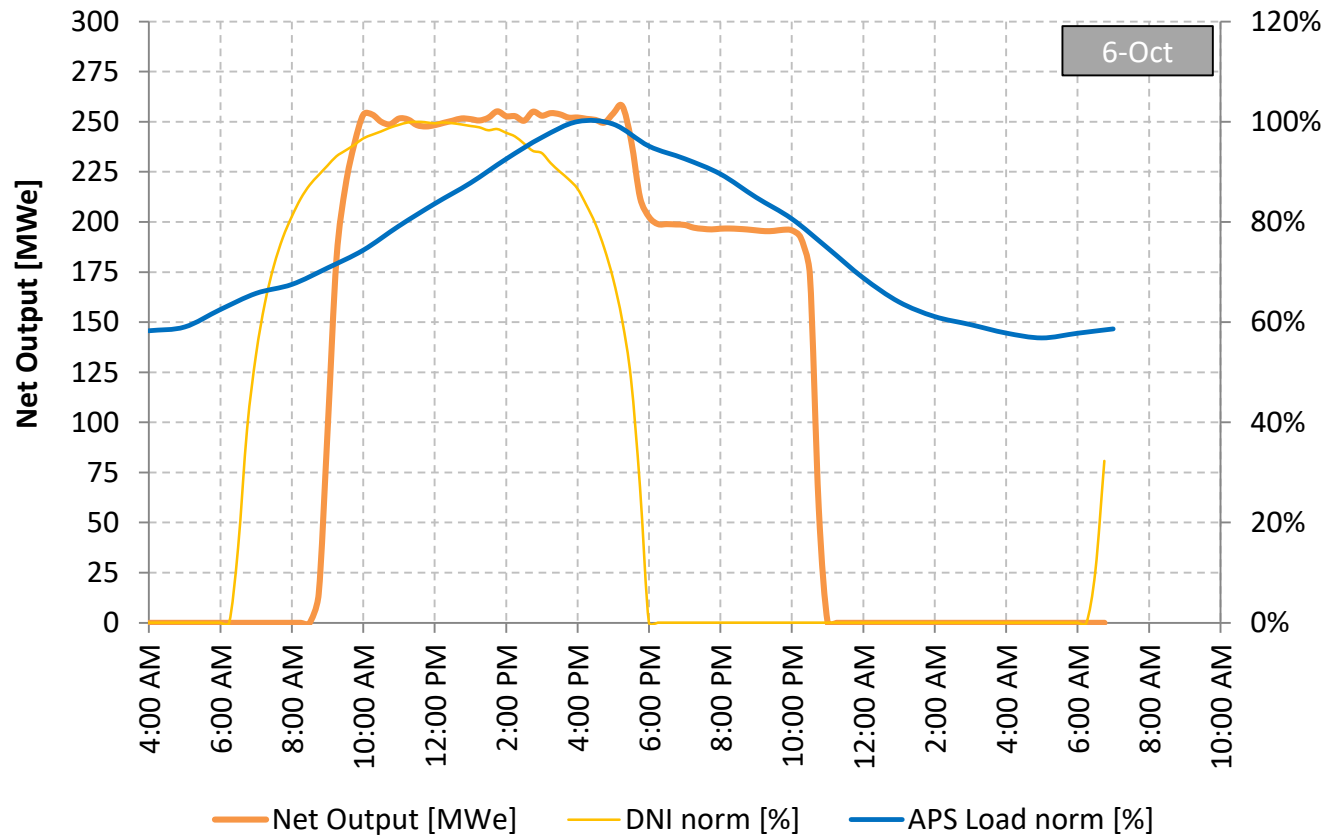
- Cost of CSP today? Perhaps use DEWA project as an example – 7.3 c/kWh for a large hybrid project in an area with not so high DNI
- What might that cost be in the US SW where the DNI is 25% higher but with everything the same? Perhaps 20% lower, around 6 c/kWh
- As more CSP plants are built, the cost will continue to decline

Solana – Abengoa - Arizona



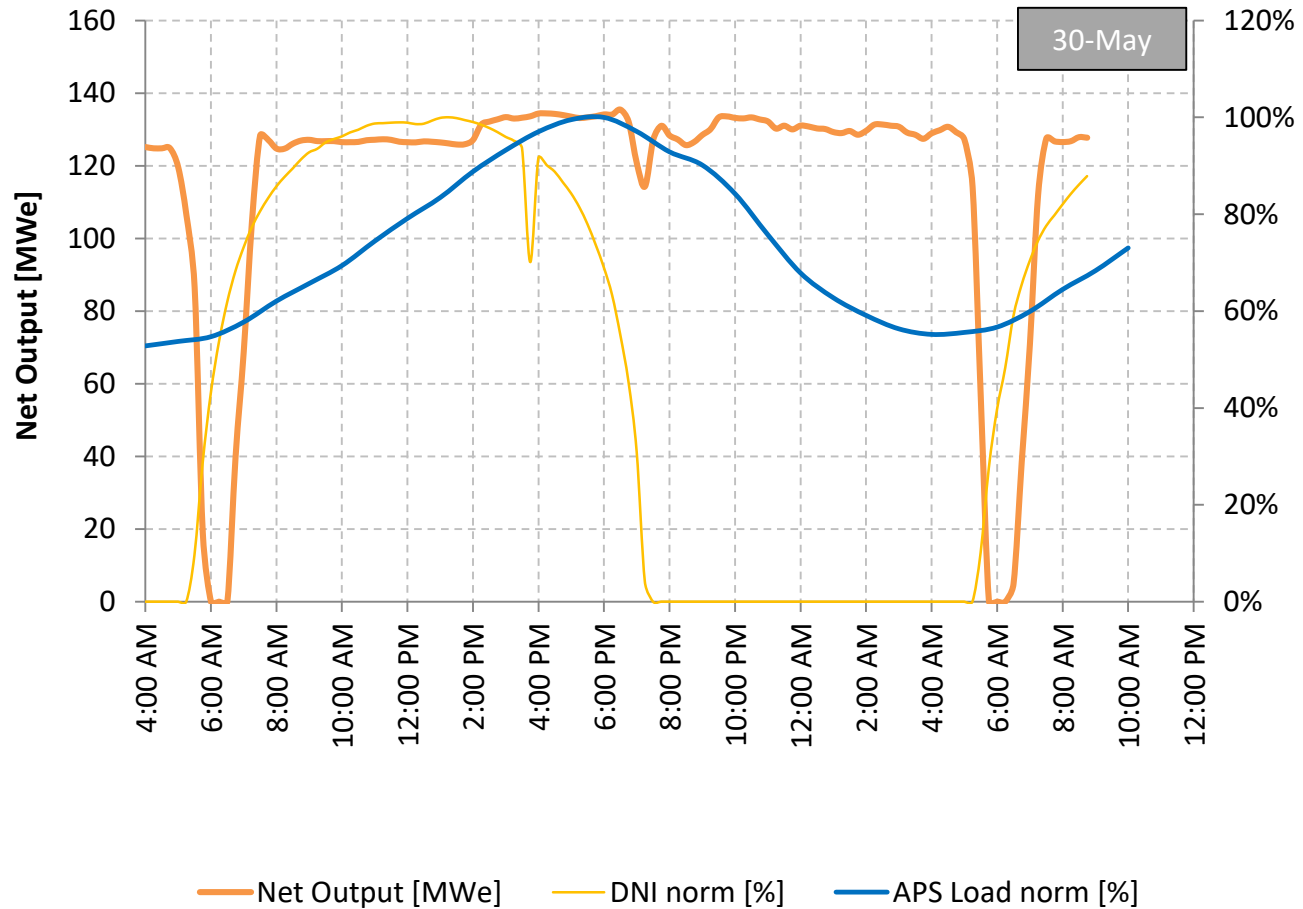
Solana Generating Station

Clear Day, 2 Turbines, Summer APS Profile



Solana Generating Station

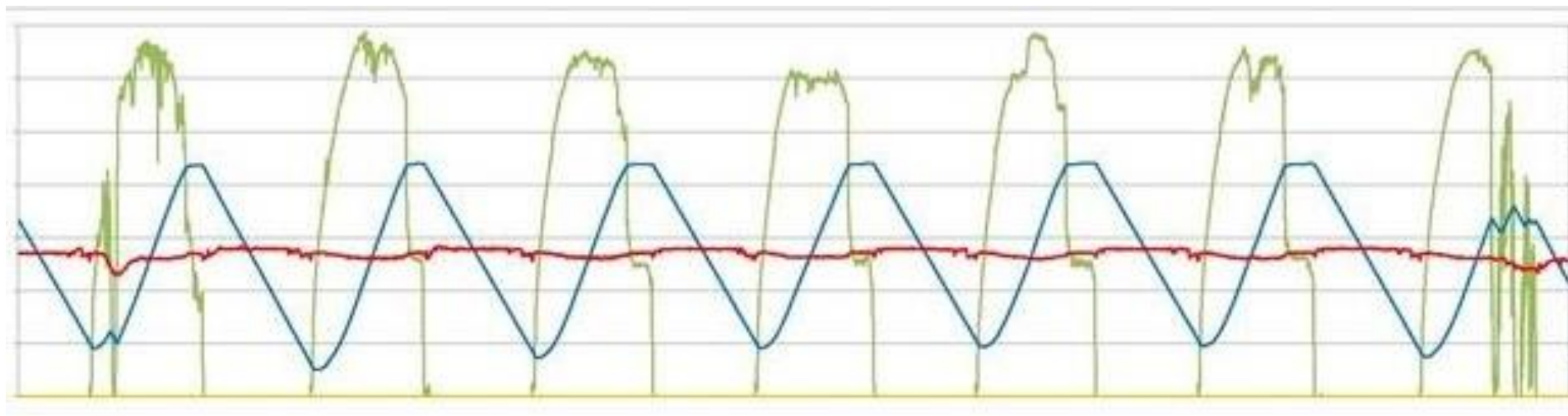
Clear Day, 24 / 7 Op., Summer APS Profile



CENTRAL TOWER PLANTS with MOLTEN SALT STORAGE



Gemasolar: Summer Operation



Turbine operates continuously day and night

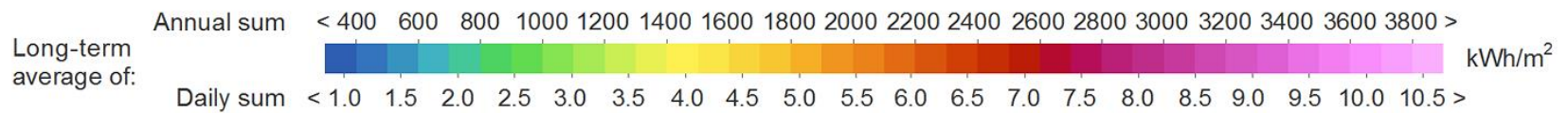
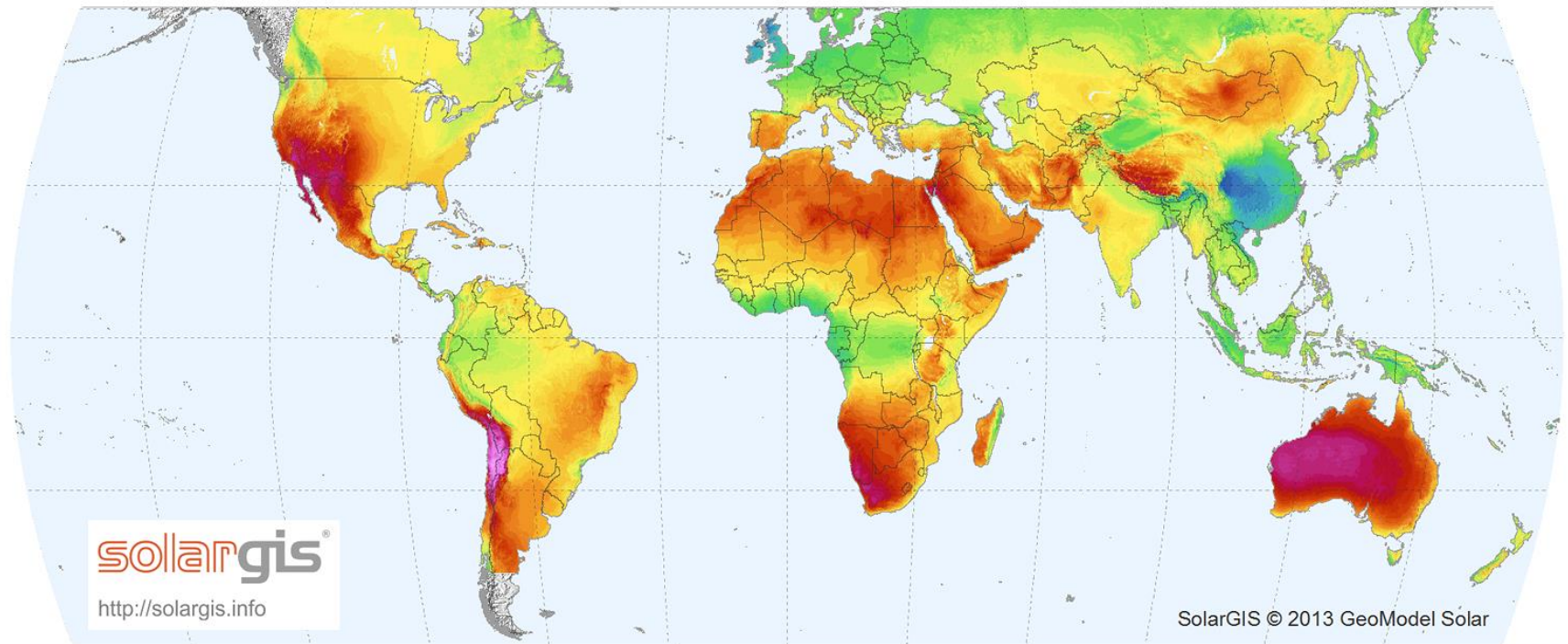
What a CSP Market Needs

- Good DNI, plus
- Market demand, and
- Favorable policies.

Best places for CSP

WORLD MAP OF DIRECT NORMAL IRRADIATION

GeoModel
SOLAR



Market Opportunities

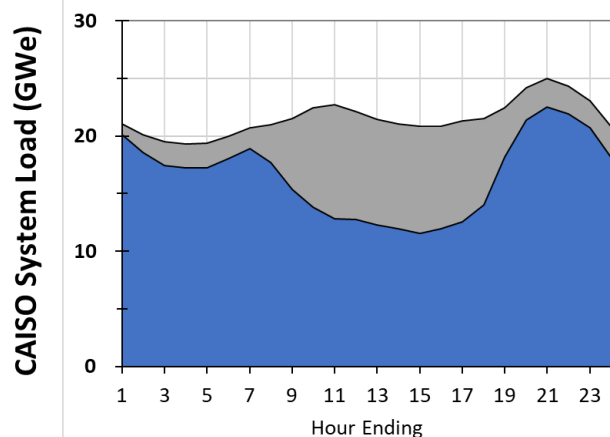
- In **California**, there are lots of moving parts.
 - Recent legislation (SB 100) has a goal of zero carbon by 2045.
 - Studying how to get NG off their system and how to expand the grid into the west or connect CAISO and LADWP grids.
 - Plan to close the last nuclear power plant in the state in 2025.
 - Duck curve is getting worse as more wind and PV are added to the grid
 - The IRP process should result in RFOs (thus the market demand)
- In **Arizona**, intense pressure for 50% renewable generation by 2030 failed but APS claimed it would need 5,400 MW of new NG plants to provide the needed flexibility to manage the grid.
- In **Nevada**, the 50% renewable generation by 2030 passed.

CAISO Spring System Load

9 April 2017 - Actual CAISO System Load

Spring/Fall

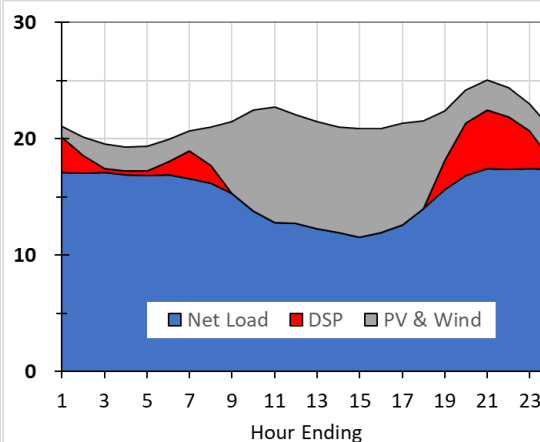
Actual Wind & PV Generation



Existing:

- Wind 3,373 MW
- Solar 7,438 MW

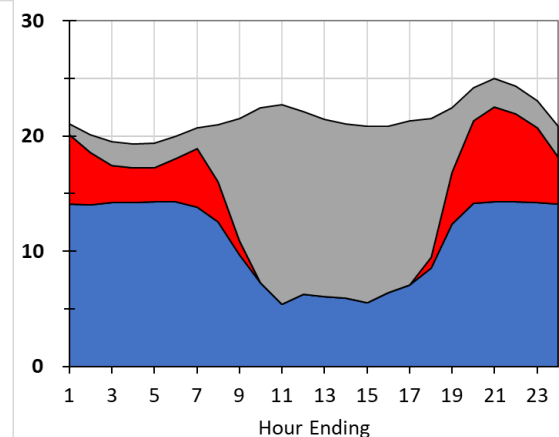
Adding 5 GW DSP



Existing:

- Wind 3,373 MW
- Solar 7,438 MW

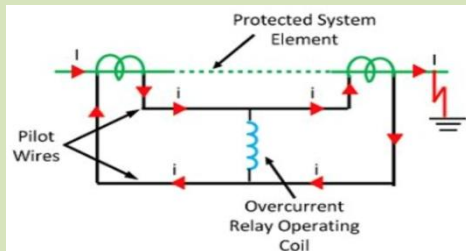
Actual Wind + 2 x PV + 10 GW DSP



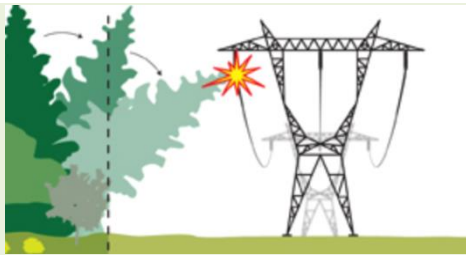
Assumed:

- Wind 3,373 MW
- Solar 14,876 MW

Dispatchable CSP Provides Grid Strength



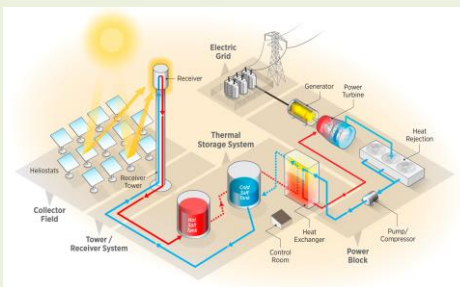
Transmission and distribution lines are protected from system disturbances by a network of relays and disconnect devices called Protective Relay Schemes.



When a fault occurs on a power line, the energized conductors become grounded. Line voltage plummets toward zero, causing the current to spike to very high levels.



Protective relay schemes are designed to “trip” in response to high levels of short circuit current, to open and isolate faults.



High levels of short circuit current can only be supplied by synchronous generation such as dispatchable CSP.

Dispatchable CSP enables greater penetration of inverter-based generation.

Favorable policies

- For now, the DOE Loan Guarantee is still available (long term low interest debt).
- The ITC is also available, based on the year that construction is started: if by 2019, 30%; if by 2020, 26%; if by 2021, 22% and after 2021, 10%.
- State sales and property tax incentives also exist.

My answer (again)

- Yes, a resurgence of CSP in the SW US is possible and likely
- Why?
 - DNI is excellent
 - Market opportunities are emerging due to the movement towards carbon-free grid
 - CSP provides many of the essential grid services needed for a reliable grid and to meet off-taker needs
 - The 7.3 c/kWhr price is a critical benchmark. Costs are expected to decrease further and are becoming competitive with natural gas plants

Conclusion

I believe that once the decision makers understand where CSP is today in cost and grid-related performance, and the flexibility that CSP offers, the US market in the SW US will once again open for CSP.

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