



SUNBORNE ENERGY DISCUSSION

WITH

Forum of Electricity Regulators

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Aseem Sharma

Chief Operating Officer

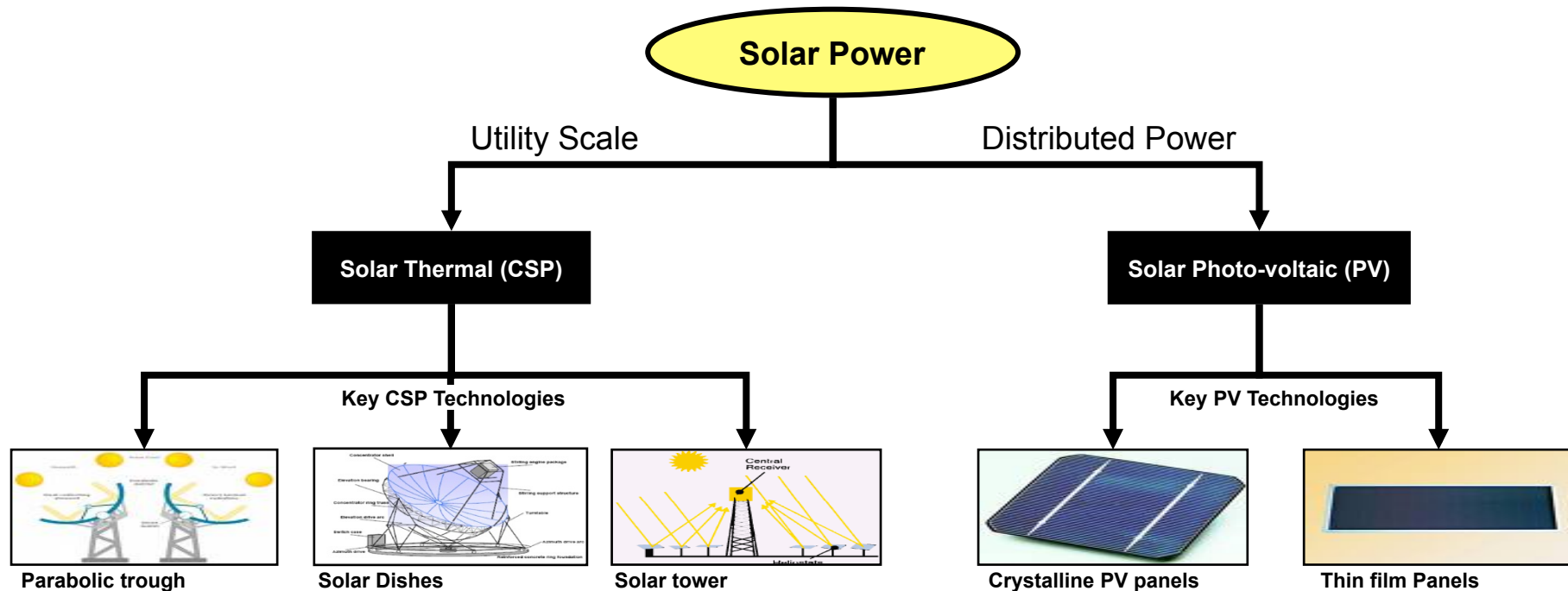


Agenda

- ☀ Understanding CSP Plant Economics
- ☀ CSP Costs
- ☀ CSP Plant Efficiency / Capacity Factors
- ☀ Weather Data
- ☀ Radiation and Electric Output comparison US/India
- ☀ Recommendations



Different Solar Technologies



Solar Thermal Technology

PROS

- Better suited to Utility scale power generation
- Leverages components already in use for thermal plants
- Storage allows for peak period generation
- Hybridization allows for better economics and base load power

CONS

- O&M costs higher
- Monsoons impact PLF

Solar PV Technology

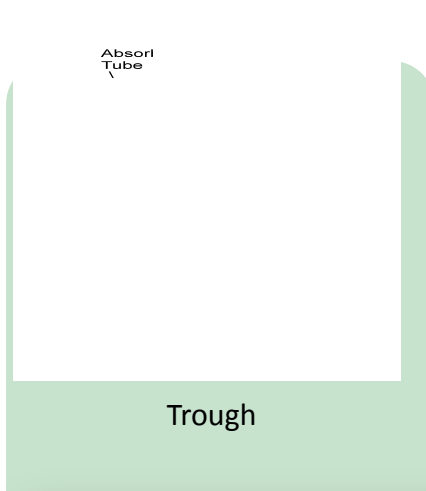
PROS

- Good for distributed power generation
- Scales down to KW-scale deployments
- Can be put on roof-tops
- Minimal O&M

CONS

- Higher installed Cap Ex
- No storage capability
- Variability in output

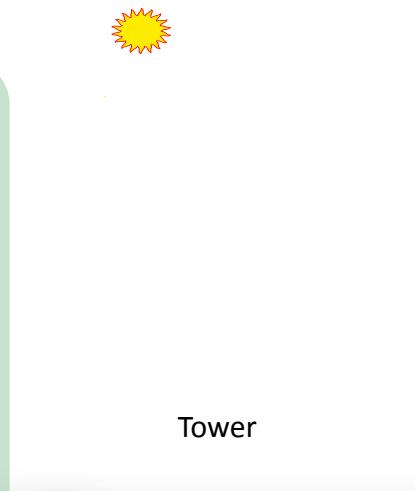
Various types of CSP



Trough



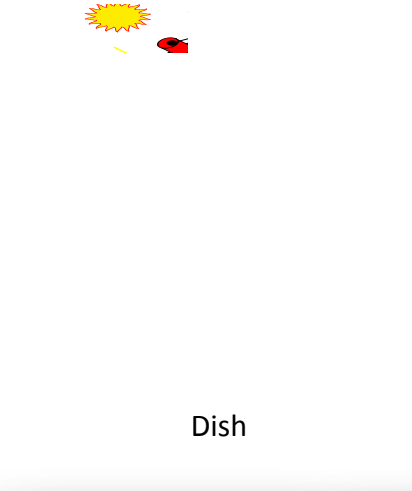
- 20 + years of operational experience worldwide
- 500+MW installed
- Established global supply chain
- Molten salt, or hot oil storage
- Indirect steam generation



Tower



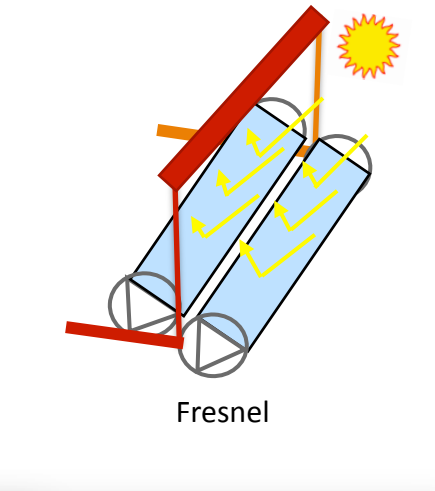
- Array of individually tracking mirrors
- Less land requirement
- Small scale demo plants operating
- Molten salt storage capability
- Higher operating temp



Dish



- Distributed systems possible
- Higher temperature
- Higher cost
- Not proven at scale
- Limited storage capability
- Suitable for off-grid generation

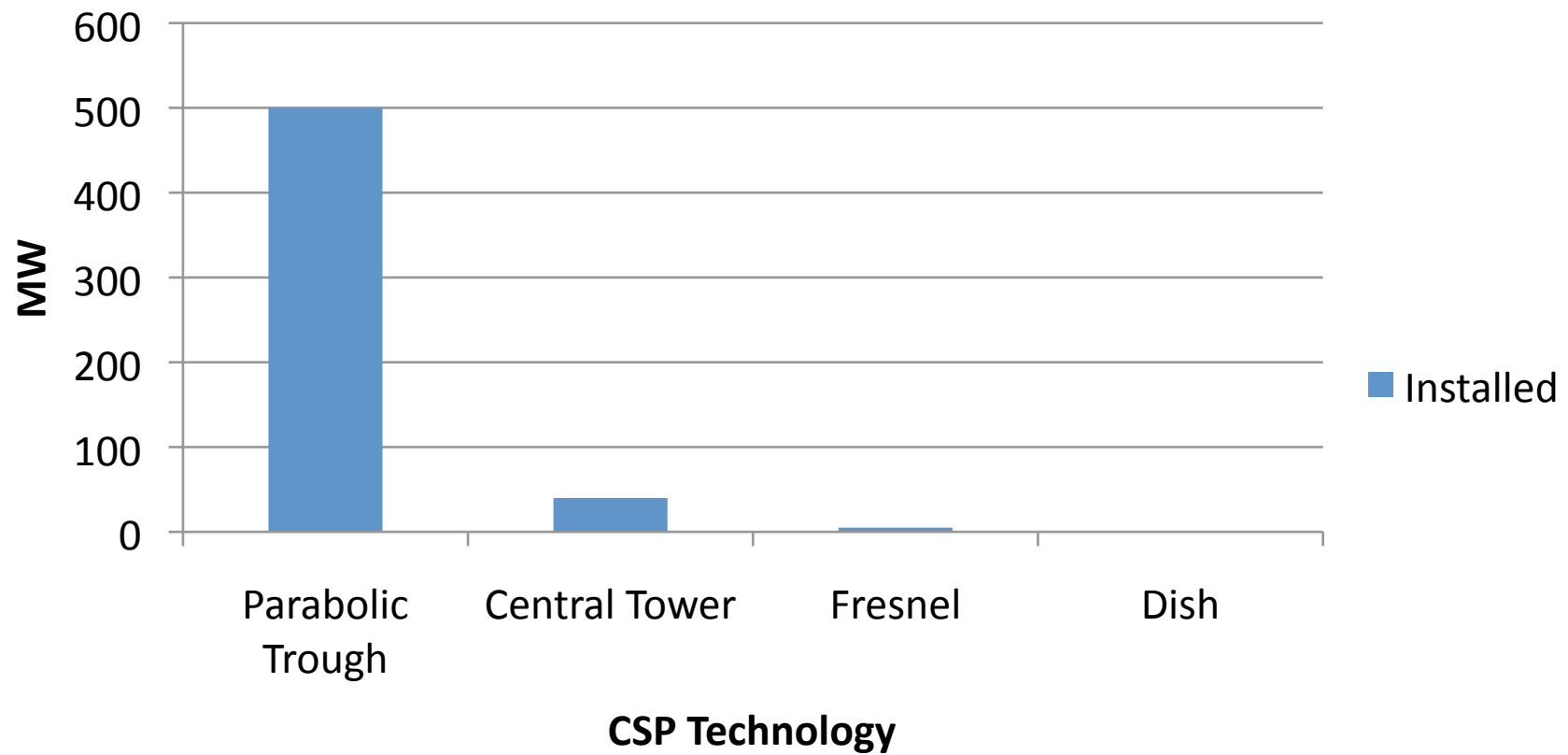


Fresnel



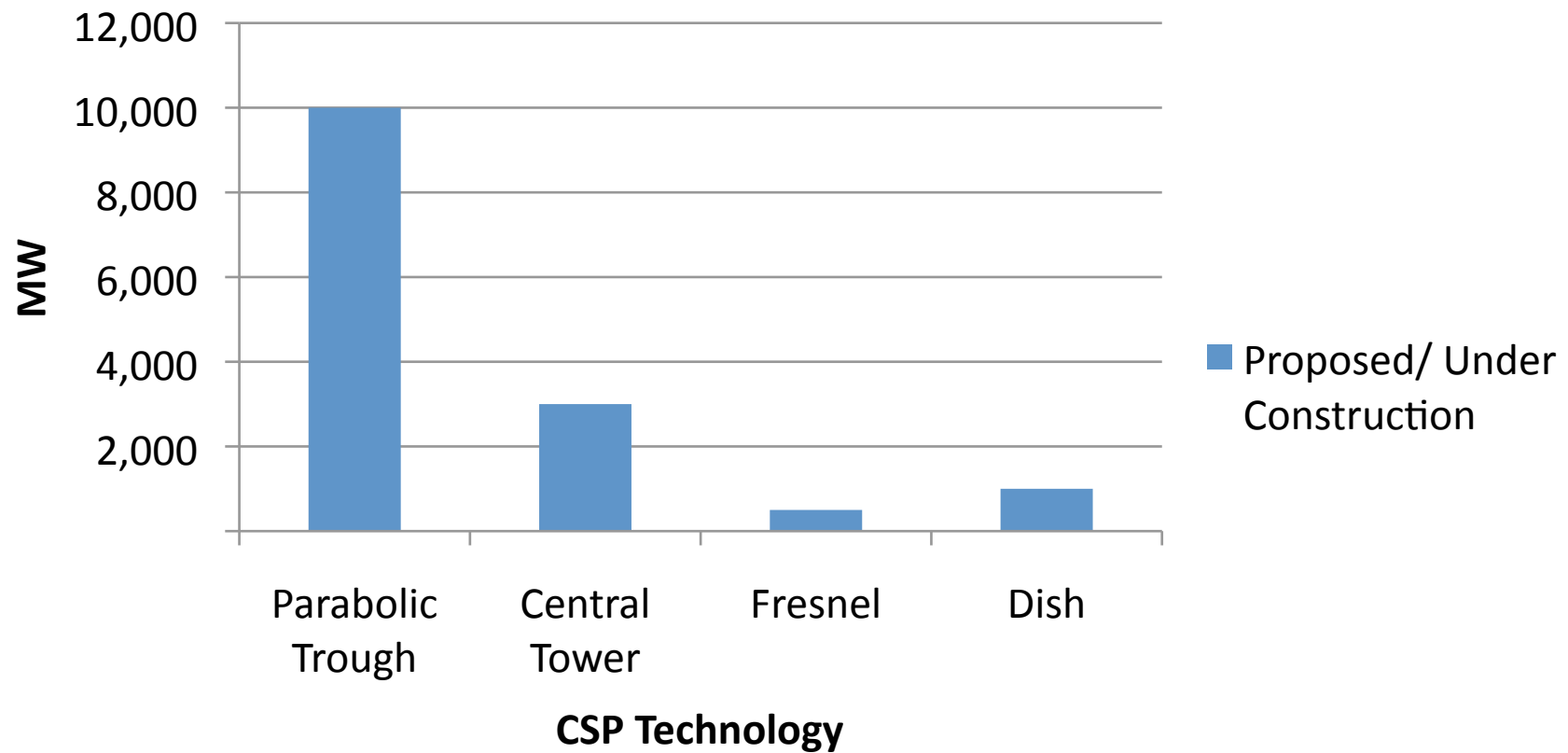
- Lower efficiency
- Lower cost
- Unproven tech

CSP Deployment by Technology Installed



CSP Deployment by Technology

Proposed/ Under Construction



Understanding CSP Plant Economics

Economics are largely driven by

Capital Costs/MW

- Design
- Equipment costs
- Localization
- Import Duties
- Land, Engineering & Construction costs

Operating Costs/MW of energy generated

- Raw Material Costs – Minimal
- Labor, Maintenance, Services

Understanding CSP plant economics

- ☀ Plant Efficiency
 - Latitude/Location
 - Design/Technology
- ☀ Plant Capacity Factor
 - Latitude/Location
 - Climatic Conditions
 - Solar Radiation
 - Quantity – Yearly average
 - Quality – Normal Direct vs. Total
- ☀ Plant Financing
 - Debt Ratio
 - Debt Rate
 - Debt Term

CSP Capital Costs – Historical

- ☀ Cost/MW installed
- ☀ Reliable Historical Data
 - Nevada Solar One
 - \$266MM for a 64MW Plant = \$4.15MM/MW
 - \$266MM assuming 72MW Nominal Capacity = \$3.69MM/MW
 - Acciona Plants In Spain
 - Under construction - 1st to be commissioned in Aug 09
 - \$4MM/MW
 - Andasol 1, 2 – included 7.5 hours of storage
 - Euro 300MM each = \$420MM/50MW = \$8.4MM/MW
 - MASDAR – SHAMS 1 - \$4MM/MW
- ☀ SunBorne Target for 1st India Plant = \$3.5MM/MW ~ 17Cr
 - Assuming all import duties are removed
 - Driven by using local EPC
 - Aggressive local procurement

Current Global Cap Ex norms are near \$4MM/MW

SunBorne estimates \$3.5MM/MW for India

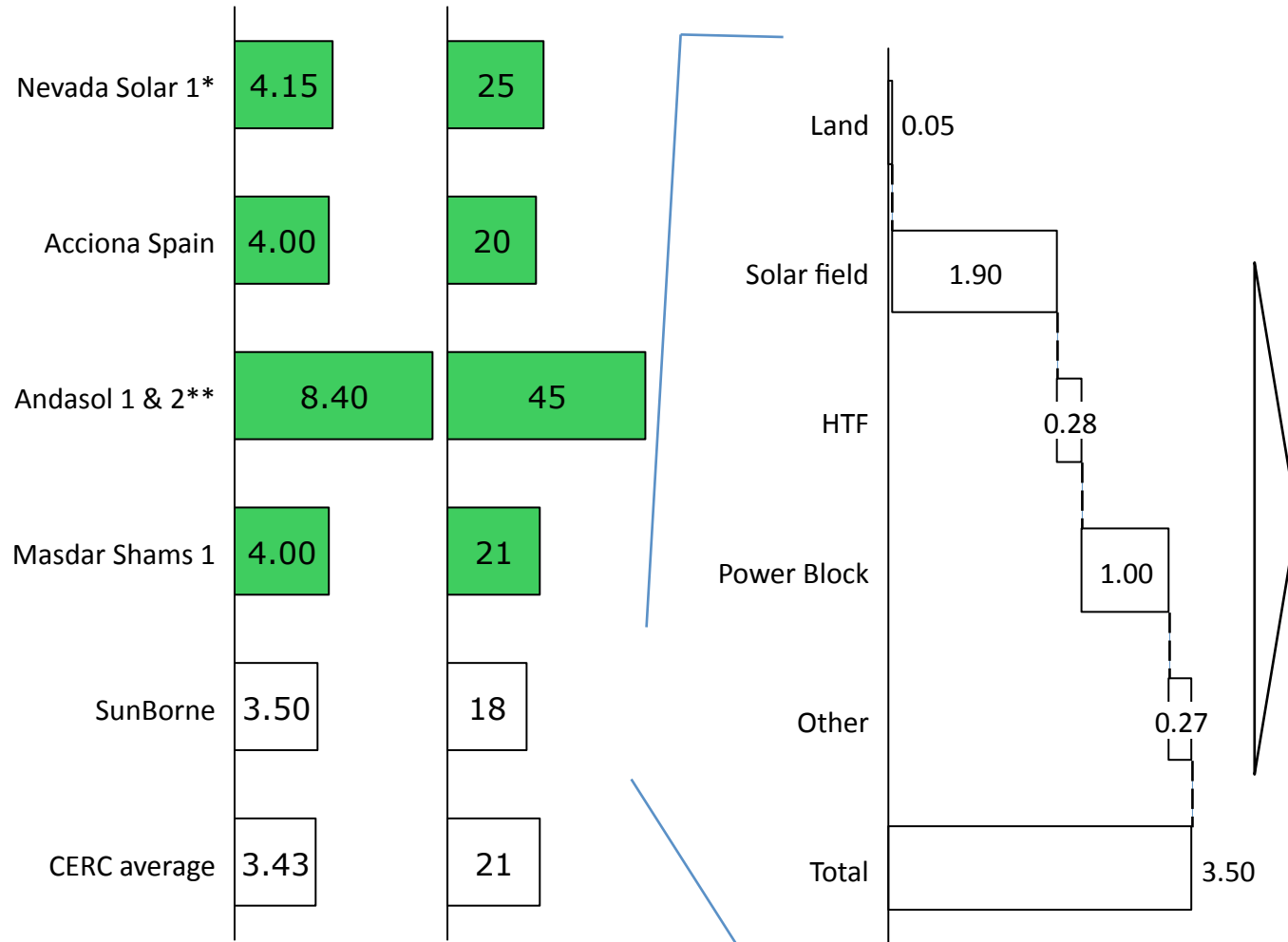


Recent plant CAPEX for CSP trough
MW

Capacity factor
%

CAPEX break up
\$/W

■ Under construction
 Proposed



Implications

- Average CAPEX estimated for CSP is primarily dependent on proposed CSP plants
- Most of the critical high value components will be imported for the first plant

* Actual cost as suggested by Nevada solar 1 team

** Includes 7.5 hours of storage

Source: Industry sources, CERC solar tariff guideline, SunBorne estimates

CSP Operating Costs

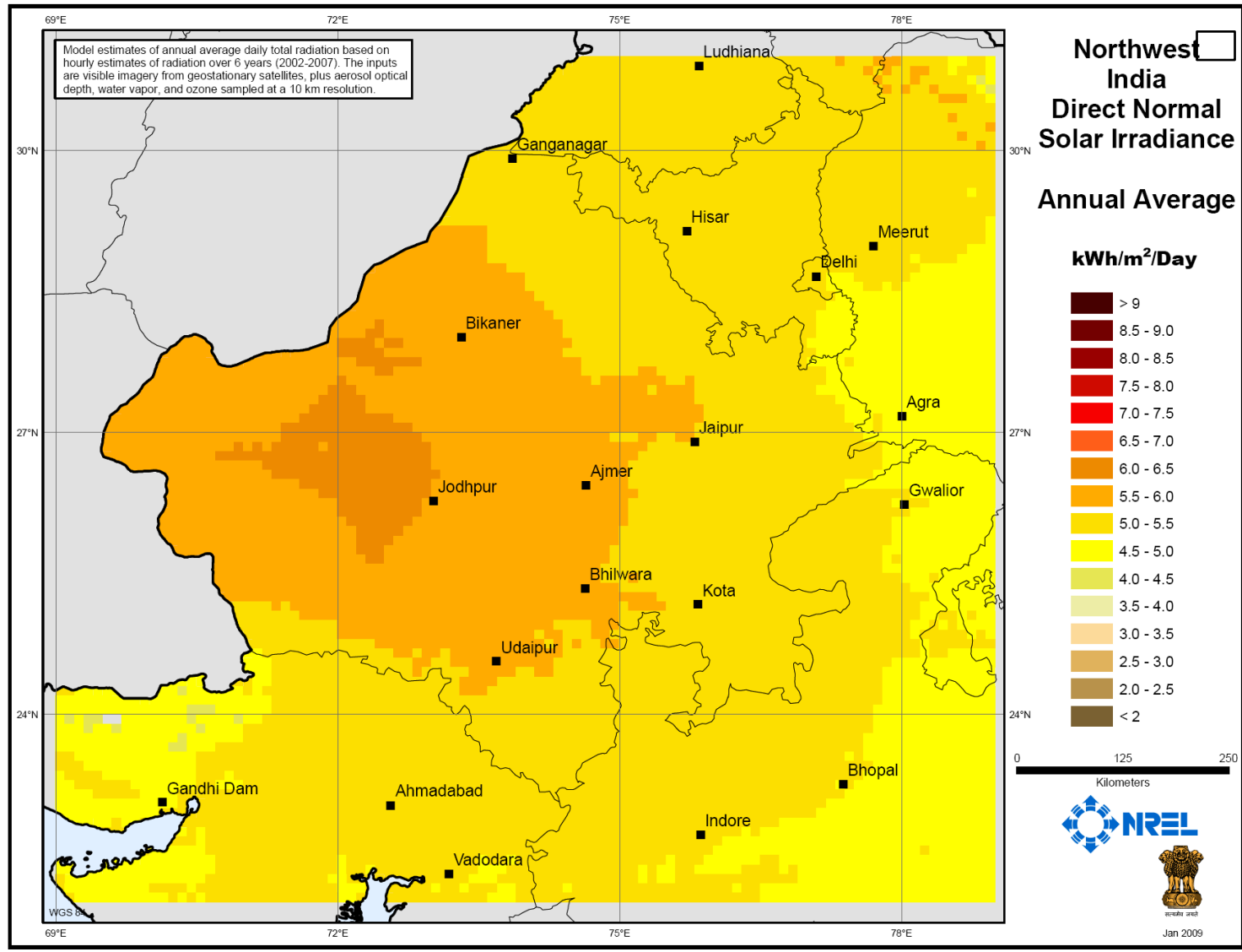
- ☀ Source of energy is free
- ☀ Labor rates will be better in India
- ☀ Maintenance is largely consumables (breakage, wear & tear)
- ☀ Pay for water, gas (if hybrid or partial)
- ☀ NREL estimates \$25/MWhr
- ☀ SunBorne Estimate \$20-25/MWhr for India(matches CERC estimates of Rs 960/MW)

Plant efficiency / Capacity Factor

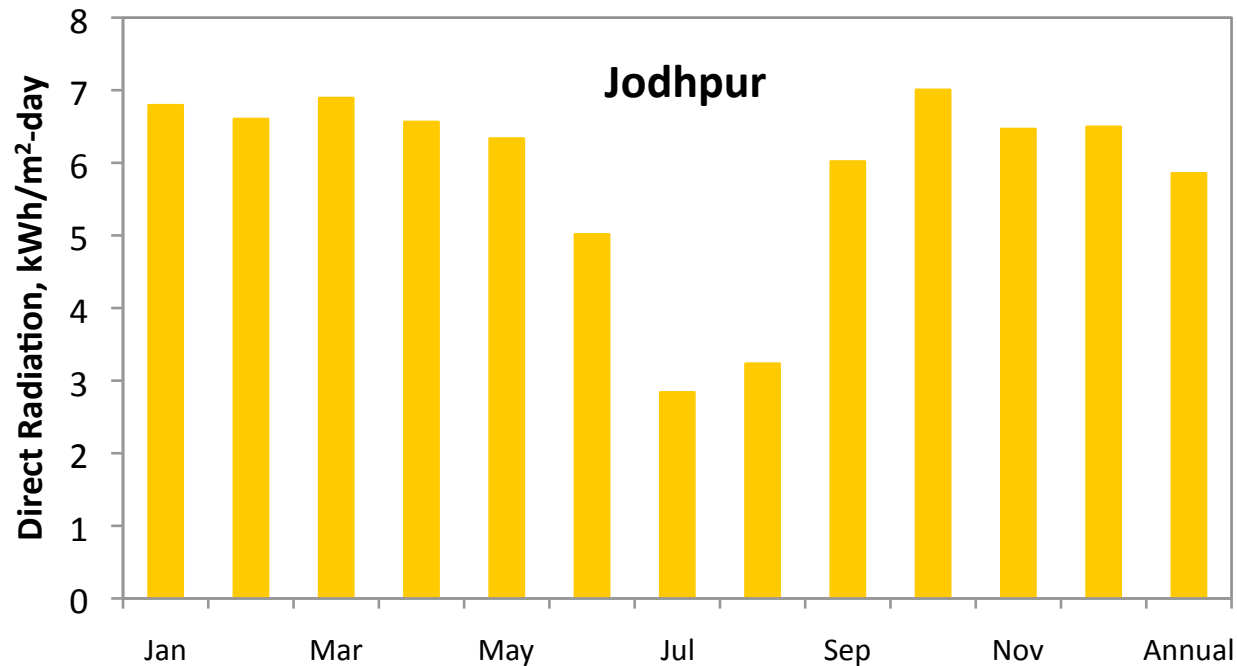


- ☀️ CSP Plant will operate at ~ 14% efficiency in locations we have evaluated in Gujarat/Rajasthan
- ☀️ Plant Capacity Factor = 17-20% for West India locations
 - Latitude/Location – Favorable compared to US/Spain
 - Lower latitudes will have better sun incident angle and hence better performance
 - Climatic Conditions – Favorable compared to US/Spain
 - Temperatures and wind speed are more favorable in India
 - Solar Radiation
 - Quantity – Yearly average
 - Comparable to Spain but below best US locations
 - Monsoons play a significant role over much of India including Gujarat
 - Quality – Normal Direct vs. Total

Solar Resource India Map – IMD

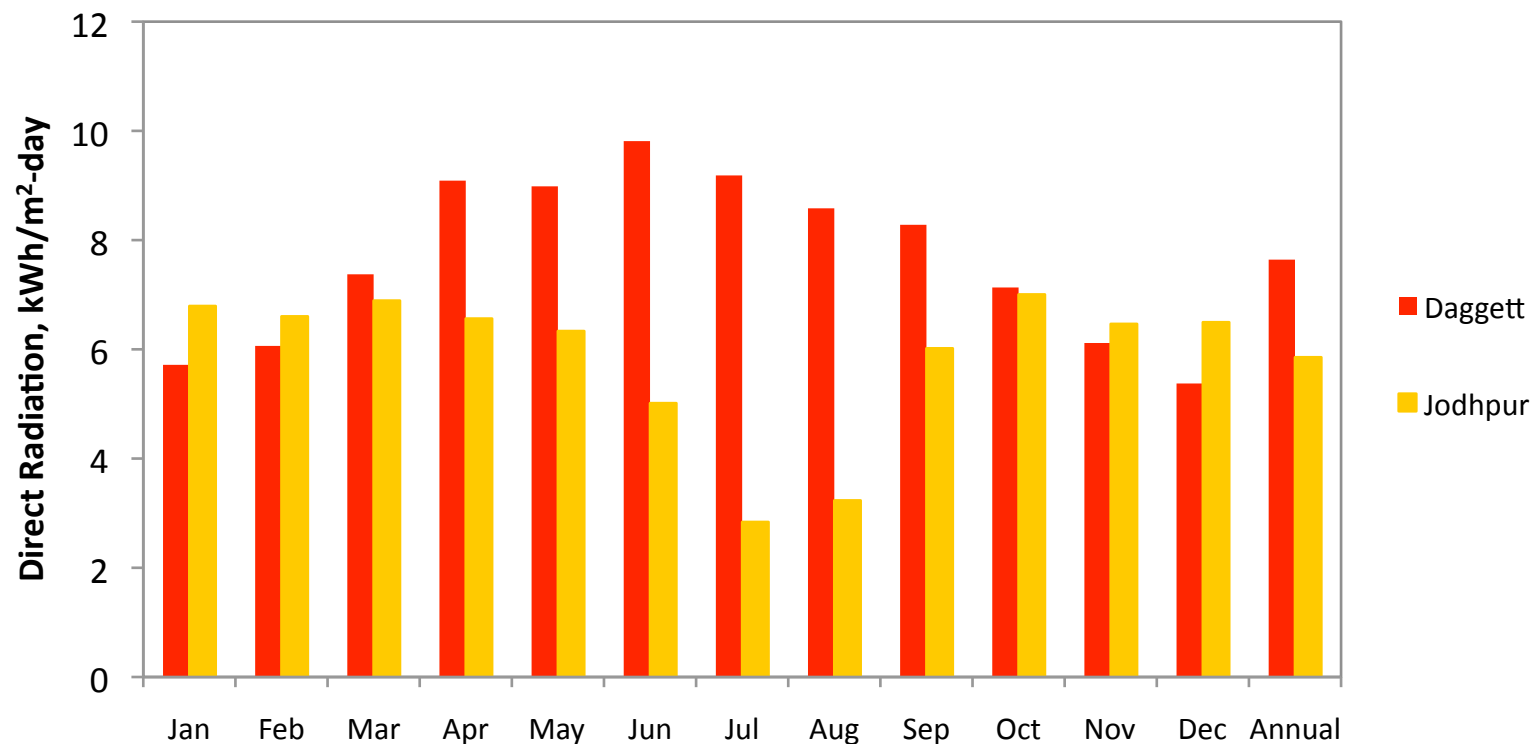


Monsoon impact on Direct Solar Radiation at Jodhpur



- Monsoons have a significant impact on Indian radiation
- Capacity Factor will be ~ 20%
- However CSP can address this issue through
 - Hybridization
 - Storage

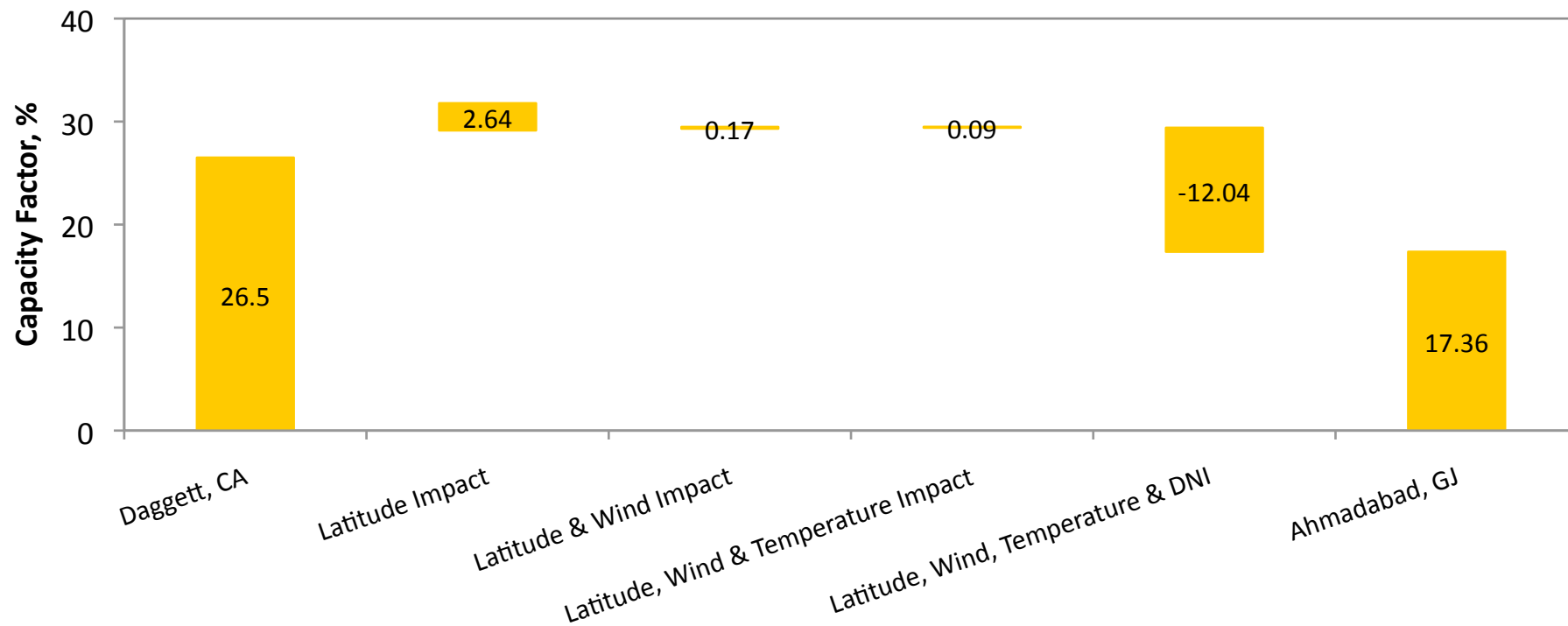
Direct Solar Radiation Comparison Jodhpur vs. USA



Best Solar Radiation in US is better than Jodhpur
Cannot translate US Capacity Factors for India locations

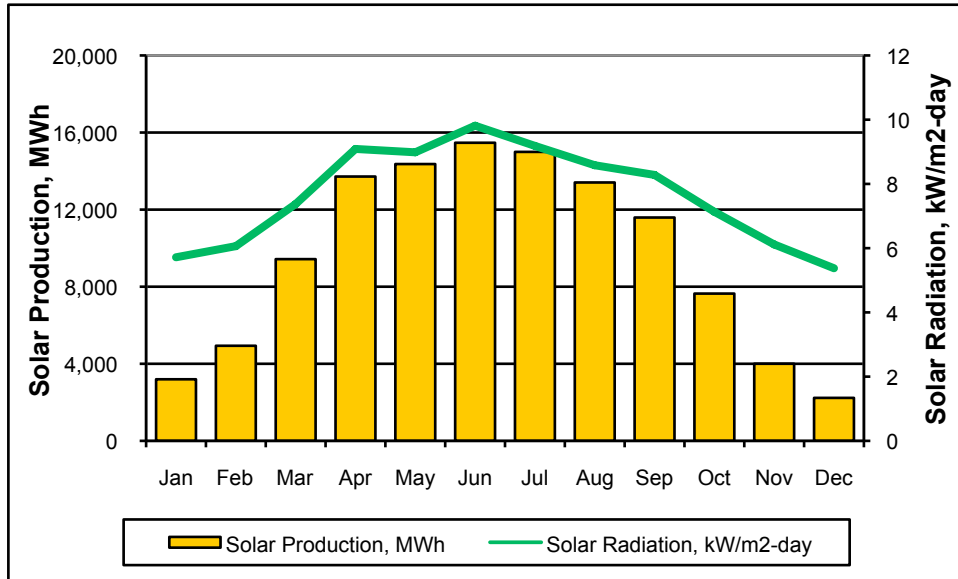
Capacity Factor Comparison between Daggett, USA and Ahmadabad

☀️ Analysis is done using NREL's SAM model

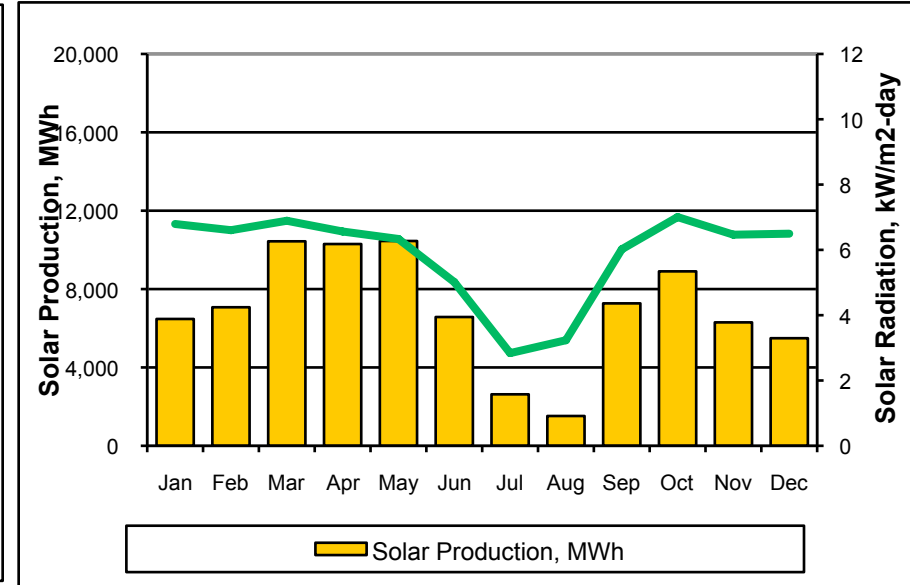


DNI impact because of monsoons is significant

Monthly Electrical Output USA vs. Jodhpur



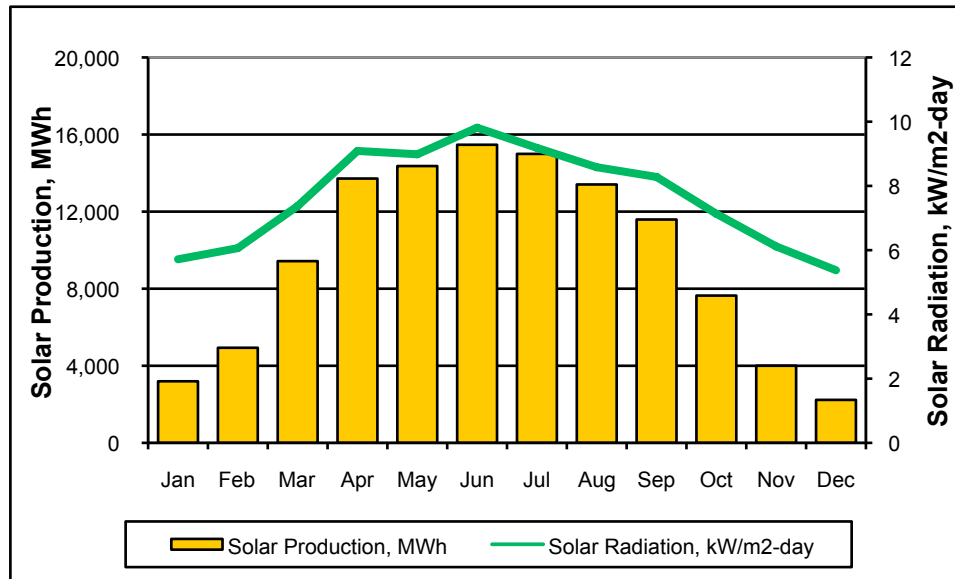
Daggett, CA



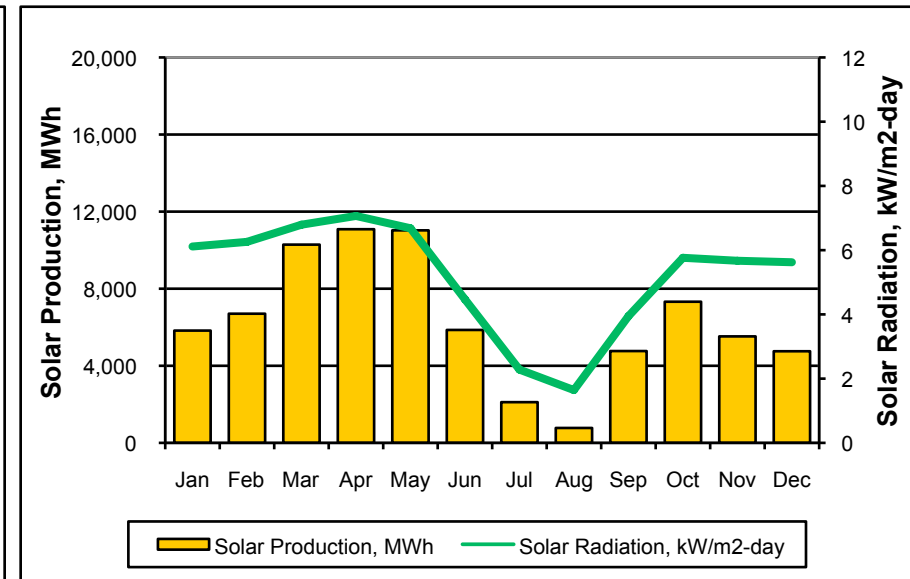
Jodhpur, RJ

- Monsoon has a significant impact on CSP plant performance in India
- Capacity Factors for Jodhpur will be 20% compared to 25% for SEGS Plants in California
- Hybridization and Storage can increase the Capacity Factor to 25% or more

Monthly Electrical Output USA vs. Ahmadabad



Daggett, CA



Ahmadabad, GJ

Monsoon has a significant impact on CSP plant performance in India
Capacity Factor for Ahmadabad will be 17-18%

Hybridization and Storage Significantly Improve Economics

- ☀ SunBorne recommendation is to allow up to 25% hybridization
- ☀ This will raise Capacity Factor from 18% to 25%
- ☀ Hybridization smoothes out output
- ☀ It will reduce startup losses
- ☀ It will lower LCOE
- ☀ Every hour of storage increases Capacity Factor by 4%
 - How much will be driven by tariff and costs



Summary

- ☀ Expected Capital Expense for initial CSP Plants in India will be ~17cr/MW (over time the costs will drop)
- ☀ Capacity Factors expected with monsoon impact will be 17-20%
- ☀ Tariffs should be technology neutral
- ☀ Only CSP can take advantage of Hybridization and Storage to boost Capacity Factors and provide power to meet peak load
- ☀ Ideal Hybridization will be up to 25%
- ☀ Ideal storage will be company specific and will depend on tariff
- ☀ Storage will allow generators to match peak loads