

CSP tower

Apr 10 2023



10+ Years of
Innovation

35+ Years of
Mature prior
Innovation



CSP tower site selection;

- “better rich and healthy than poor and sick” –true for all CSP, select superior solar condition; high DNI, no dust, no high wind, preferably low environment obstacles (rare species and plants (*))
 - Additionally for CSP tower;
 - Huge advantage of tower over trough is that no grading and leveling needed, terrain can remain untouched, extremely important with environmental concern (**)
 - low attenuation (clear visibility)
- South CA, New Mexico as perfect examples

(*) Ivanpah 400MW handling turtles and rare plants reached \$100 million costs

(**) still \$10's of millions were committed for future expenses to return the site to its original.

CSP tower market implementation;

- Recommended approach as per commercialization and R&D – maximize standard industrial products and suppliers; examples:
 - Power block including heat exchangers (HX), including: Receiver, if steam, Boiler and HX suppliers, if Molten Salt (MS), same or similar
 - *Bad prior examples, Barstow SANDIA Solar 1 and Tonopa-SolarReserve (Boing) rocket science supplying the receiver*
 - *Good examples, Ansaldo, Babcock, ABB, Bechtel EPC,.... Heliostat drive system (see specifically below)...*
 - The only exception is when not existing in the market (example last century 80's HCE, Heat Collection Element, for trough coating sputtering machine, now standard)

CSP tower performance model;

- Yearly hourly performance model;
 - Recommended from the initial beginning, serving for the design, including;
 - Obtaining TMY, Typical Meteorological Year, more particularly DNI (Direct Normal Insolation), high wind, or local special characteristics (sand storms etc.)
 - Install as early, weather station at the site with DNI measurement (*), which after 1-2 years will serve to tune satellite or other data.
(*) requires site visit, monthly or so, *better no measurements than not reliable*
 - What not recommended;
 - No design point(s), defined day(s), hour(s) (equinox, 10 am, as bad examples)
 - Minutes model, even not 10 minutes – too much data, with no valuable basis, particularly TMY
 - Hourly recommendation, means that the model serves for performance evaluation, and commitments, with accordingly statistical approach; also meaning:
 - Not intended for operational modeling, only for design and following purposes

Solar Field (SF) (1);

- Large SF and tower versus multiple small towers
 - Recommending single tower, potentially 2, second for storage pending storage media
 - Multiple towers, yet to be proven;
 - Starting with perfect good example – CPV tower, would make lot of sense
 - For others HTF (Heat Transfer Fluid) and storage media, clearly problematic
- Land utilization;
 - Trough land utilization is about 1:3 reflecting surface versus land,
 - Tower currently obtains 1:4 to 1:5, tall tower reduces it potentially below trough (*)
 - Currently Dubai tallest reaching tower, 266.44 m' including the receiver atop – *at the time (Last century 1970's-1980's – then tower was dominant CSP (R&D only) - and selected to be 800 m' and above)*
 - Multi towers have relatively high land utilization, in addition to above issues, NOTE that the “superior” North SF efficiency, when facing the advantage of circumferential receiver, flux uniformity, requires more south SF Heliostats (**).

(*) no comparison with no concentration solar

(**) Last century very good papers on tower, nevertheless, were wrong in respect to the tower in layout, localized to the South, should be to the North



Solar Field (SF) (2);

- SF Layout;

- *Highly recommended tip– obtain permit or else to use BrightSource tool for the layout*
- Assuming no grading, after making 3D surface map. Accounting, not only for Blocking and Shadowing (B&S), but;
 - Necessary driveways and accesses inside SF (increasing adjacent distance)
 - Rare plants, drainage paths and other obstacles and its impact on B&S
 - Potentially allowing “high” density, near to the tower, by controlling heliostat position to not crash adjacent

Solar Field (SF) Heliostats (1);

- Note: as per last section, and based on the only commercial experience of large SF and tower;
- Challenging requirement of high optical precision (single milliradian optical tools level) and sustaining high wind, in protection mode, and reasonably high for operation (*recall site selection*)
- Past \$75/ m² goal for installed costs, has been achieved (excluding external additional site costs), NREL targeting challenging \$50/m²
- Those costs meet below 1cent/kWh conventional fuel – even at site with below 2500 Wh/m² DNI, like Spain, middle east, China, with realistic 40% solar to ~thermal efficiency.
- Large surface heliostat versus small
 - Commercial CSP tower have both 25 m² as well as above 100 m² heliostat. Reason for large surface;
 - Single milliradian high precision drive, conventionally costly (*aviation standard – resolved by introducing mechanical conventional suppliers*)
 - Trenching for power and control cables (*– resolved by wireless control and local PV with small electrical storage*)



Solar Field (SF) Heliostats (2);

- Glass mirror versus others reflecting surfaces
 - Unbeatable conventional many centuries glass mirrors (*)
 - Others metal like aluminum with reduce reflectivity
 - Composite material foils, will reduce reflectivity and worse specularly – less important for other CSP technologies but crucial for tower. In addition short durability.
 - (*) provided, keeping experienced silver layer coating protection – see PS10 saint Gobin mirrors replaced after a couple of years
(lead free copper free ect. – redundant since well preserved inside the structure, even upon CA disposal standard)
- Heliostat types options
 - Encouraging mechanical engineers for novelties, but as of now, 2 concepts prevails;
 - LUZ (mech. eng. shuki mor) Torgue tube with mirror support or truss
 - Schlaich bergermann circular rays with cables, stretch membrane, Stellio pentagon
 - Pylon; for both introduced to the ground , meeting opening note challenges as per optical accuracy and wind sustainability
- Drive power – local PV and small electrical storage (battery, super capacitor.. , preventing trenching
- Control – wireless, preventing trenching

Tower

- Height;
 - *(Last century 70's-80's – then tower was the dominant CSP (R&D only) and selected to be 800 m' and above)*
- As of now the 200 m' + receiver height is common (Dubai, the tallest 262.44 m')
- Steel frame for Ivanpah 130 m', concrete for above (100 m' height considered to be the height to switch)
- *Bechtel information evaluated possible 1350 feet (400 mw) see above, land utilization consequence*
- The receiver elevated by crane at Ivanpah, by hydraulic pull up inside the concrete tower at Ashalim and Dubai
- Environmental aspects;
 - Wind experience probably true for CSP tower, with no noise consequences
 - Hopefully others concern like for birds have been ruled out
 - ~~*BUT BUT, bad advocate since true environmentalist, likes technology including the pyramid (also CA concrete junctions as well as Centre Pompidou). The hypocrite doesn't.*~~

Receiver

- Steam receiver
 - *On one hand, the only well proven tower technology (after trough), on the other, since storage is a must, steam storage (PS10, PS20 and SA Khi) is limited both by size and costs.*
 - Currently 585°C as per conventional power supplier
 - Super Critical steam hasn't been followed, same as per conventional power industry (600°C-620°C even when applied, not above)
- MS, Molten Salt, receiver;
 - CSP tower current approaches MS as HTF as well as storage media
 - *(as opposed to well proven MS storage for trough 400C, not yet for the 560°C of tower – preferably not to mention bad reputation cases)*
- Air receiver
 - Excellent pilots for references, both for:
 - Open loop atmospheric air, even with pretention that 80% recycling is obtainable (60% was realized)
 - Closed loops behind quartz “windows” with potentially different gases as HTF.
 - Excellent cope with ceramic storage media, *storage costs remaining an issue (*) see next Storage slide*
 - Excellent industrial suppliers, with proven shelf products – *in other words, could be committed and supply with industrial backup.*
- Other media (relevant to next slide storage media)
 - Super critical CO₂ – the selection of NREL, following study of alternatives (*with reservations*)
 - Sodium which should have been perfect (as in Nuclear power industry) and probably due to Spain PSA failure, didn't follow
 - Others – questionable (*at the time, a well professional chemist, recommended, re. MS, to stop looking for better and cheaper – “there are no”*), Certainly not liquid glass etc.

Storage

Background: crucial in solar, and furthermore for CSP, while PV rely on electrical storage (wishful \$150/kWhe), thermal CSP obtains \$100/kWhe (***) not really comparable since requires the power block (***)

- “Solar salt” name given to NaNO_3 - KNO_3 60%/40%, 400C proven industrially as well as in trough CSP (Spain, Arizona...), 560C potential not yet ~mature
- Other salts – main issue is costs – Solar Salt low price (<1000\$/ton, pending market), probably due to agriculture use, unbeatable. True even for small additive to improve, reduce molten point, etc.
- Ceramic material – most desirable but necessitating gas as HTF , Heat Transfer Fluid, with its receiver issues:
 - (*) costs issue:
 - Ceramic saddle from pallets are well industrially proven, used for chemical reactors
 - “Dream” for simpler; Sand (fluidized bed), gravel stones, local granite rocks... not yet obtained
- Steam – as mentioned, proven but expensive and size limited
 - Phase change – relevant and attractive for steam, which has been ~dropped and not just because:
 - Challenging HX (Heat Exchanger), container, and pumps
- Exotic material: Sodium which should have been perfect (as in Nuclear power) and probably due to Spain PSA failure didn’t follow, molten glass (? as mentioned)...