U.S. Department of Energy
HelioCon
Heliostat Consortium for Concentrating Solar-Thermal Power

Economies of Scale – Field Deployment Considerations to Accommodate Evolving Energy Markets

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conceptual design • components • integration • mass production • heliostat field

Outline

- Approach
- Economies of Scale
- RFP
- Site Selection
- Field Layout
- Supply Chain
- Product Verification
- Capitalization
- Site Preparation
- Assembly and Construction
- Calibration
- Operations and Maintenance
- End of Life Cycle
- Next steps?

Field Deployment Overview

Field Deployment

Site Selection

Field Layout

Supply Chain

Quality Control

Capitalization

Site Preparation

Assembly

Calibration

O&M

End of Life

Field Deployment Cost Strategy

- How could we look at field deployment quantitatively?
- It is impossible to divorce the process from the product

Learning 20%

- Reductions in costs gained from experience, innovation and learning from simply deploying more projects

Heliostat Design 24%

- Heliostat design innovations that reduce costs for deployment

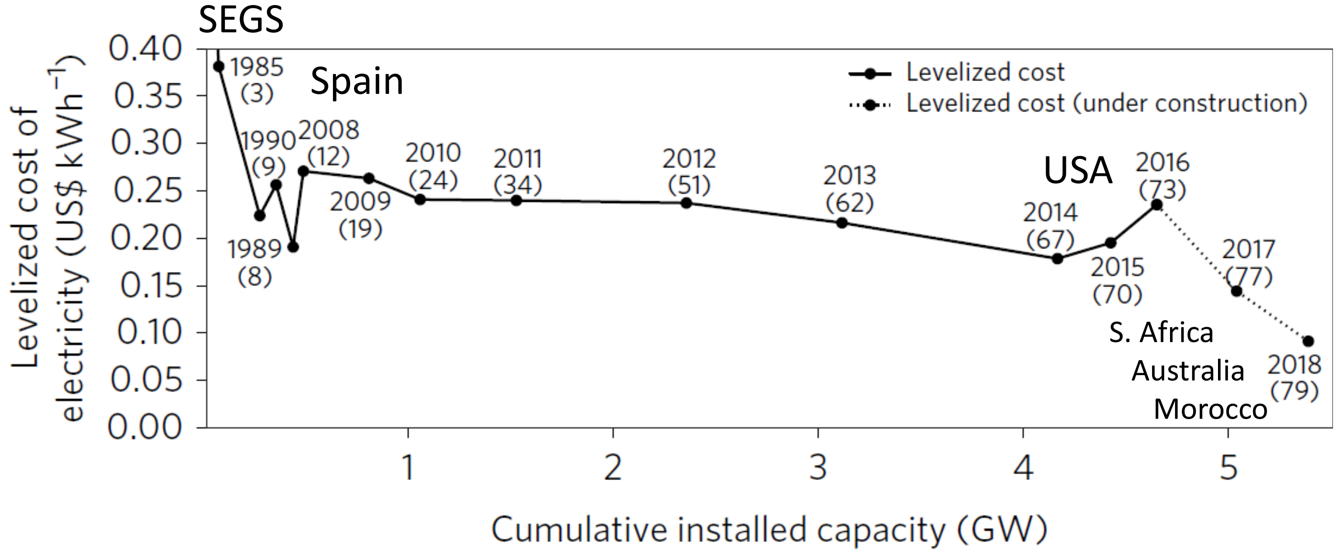
Deployment Innovations 10%

- Process improvements that directly reduce deployment costs

Learning Curves

Learning 20%

- Johan Lilliestam et al.[1] analysis of NREL/SolarPACES data sheet[2]
  - Average PV learning rate is 20% since 1990
  - Trough CSP shows learning rates exceeding 25%
  - CSP's learning curve is reset due to discontinuities in policy and support
  - CSP with heliostats never seems to get enough deployments to meet the following conditions:
    - long periods of stable production and policy support
    - learning curves are more pronounced within a single company/organization
    - cost pressure from competition was present

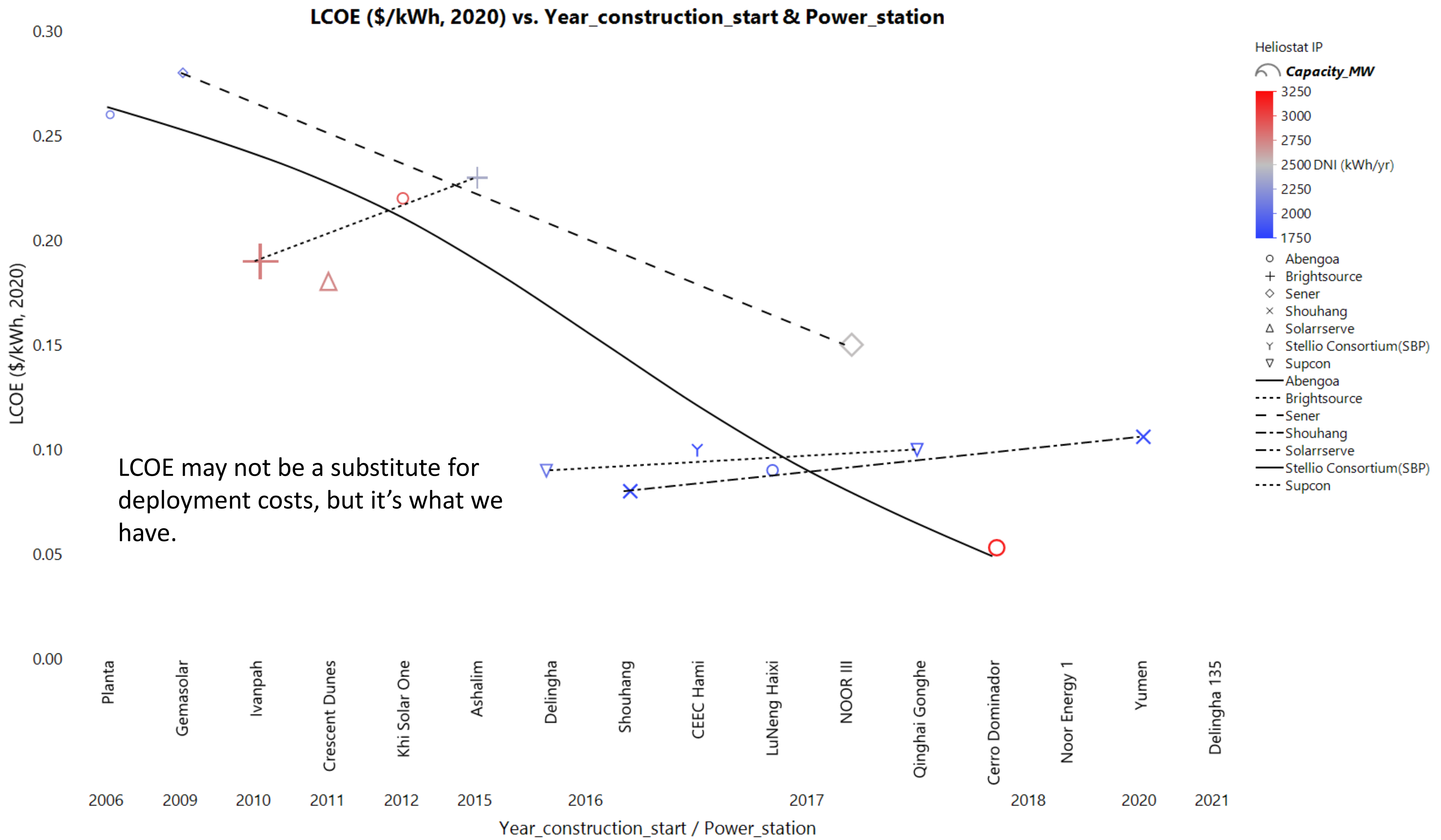


Kurup 2022 Effects of manufacturing a part at increasing scale

[1]Lilliestam, J., Labordena, M., Patt, A., & Pfenninger, S. (2017). Empirically observed learning rates for concentrating solar power and their responses to regime change. *Nature Energy, 2*(7), 17094. doi:10.1038/nenergy.2017.94
[2]NREL. (2020). *Concentrating Solar Power Projects*. https://solarpaces.nrel.gov/download-project-all?_format=csv. Retrieved from: https://solarpaces.nrel.gov/

Learning
20%

Do heliostat developers show learning?



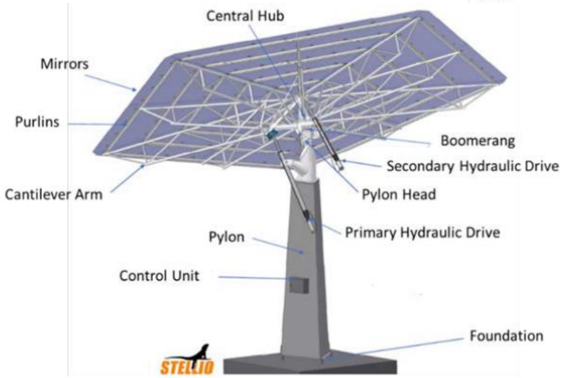
LCOE may not be a substitute for deployment costs, but it's what we have.

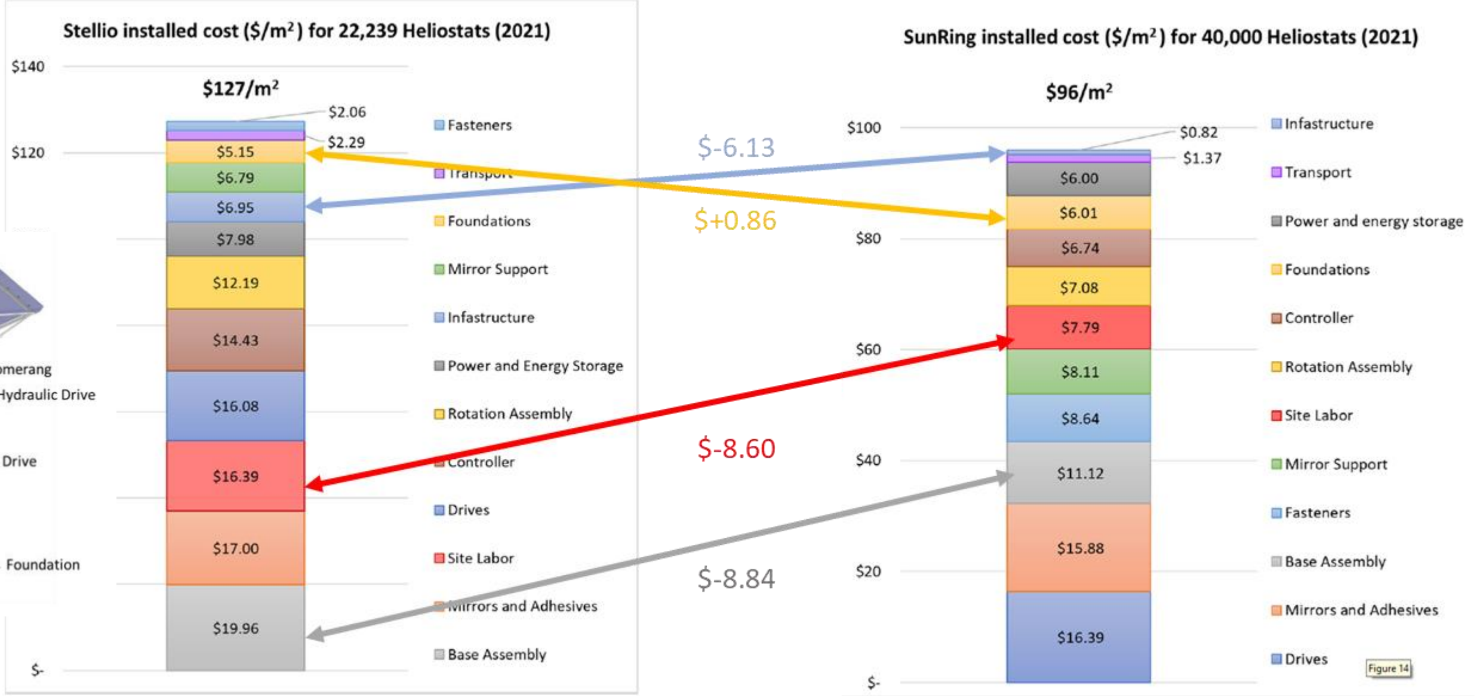
Heliostat Design 24%

Design-Related Cost Reductions to Deployment

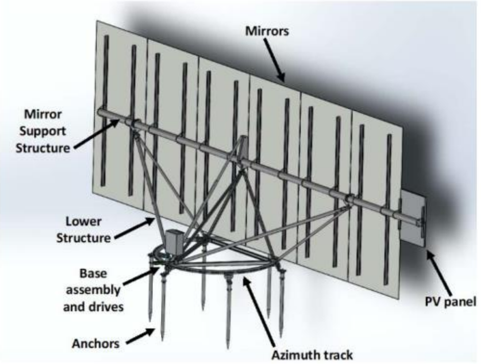
- How much is can heliostat design impact deployment costs
- Kurup et al. present a cost analysis of the Stellio and SunRing heliostat designs
  - Both assume high enough levels of production (>40,000/yr) to achieve economies of scale which is more achievable for small heliostats.
  - SunRing design reveals how heliostat design can make field deployment significantly less costly (~$33/m^2)
  - LCOE studies for Roadmap have shown that heliostat costs savings must be substantial if they reduce optical performance even slightly

Deployment-related costs
$59.87/m^2





Deployment-related costs
$27.11/m^2



Kurup, P., Akar, S., Glynn, S., Augustine, C., & Davenport, P. (2022). *Cost Update: Commercial and Advanced Heliostat Collectors*. Retrieved from United States: https://www.osti.gov/biblio/1847876

Deployment Innovations 10%

Field Deployment Cost Savings

- SAM was used to compare the default settings to the following alternatives.
    - Default (Real) LCOE = 8.62 ₵/kWh
    - Heliostat Cost = 144 $/m^2
- LCOE showed highest sensitivity to service life and solar resource

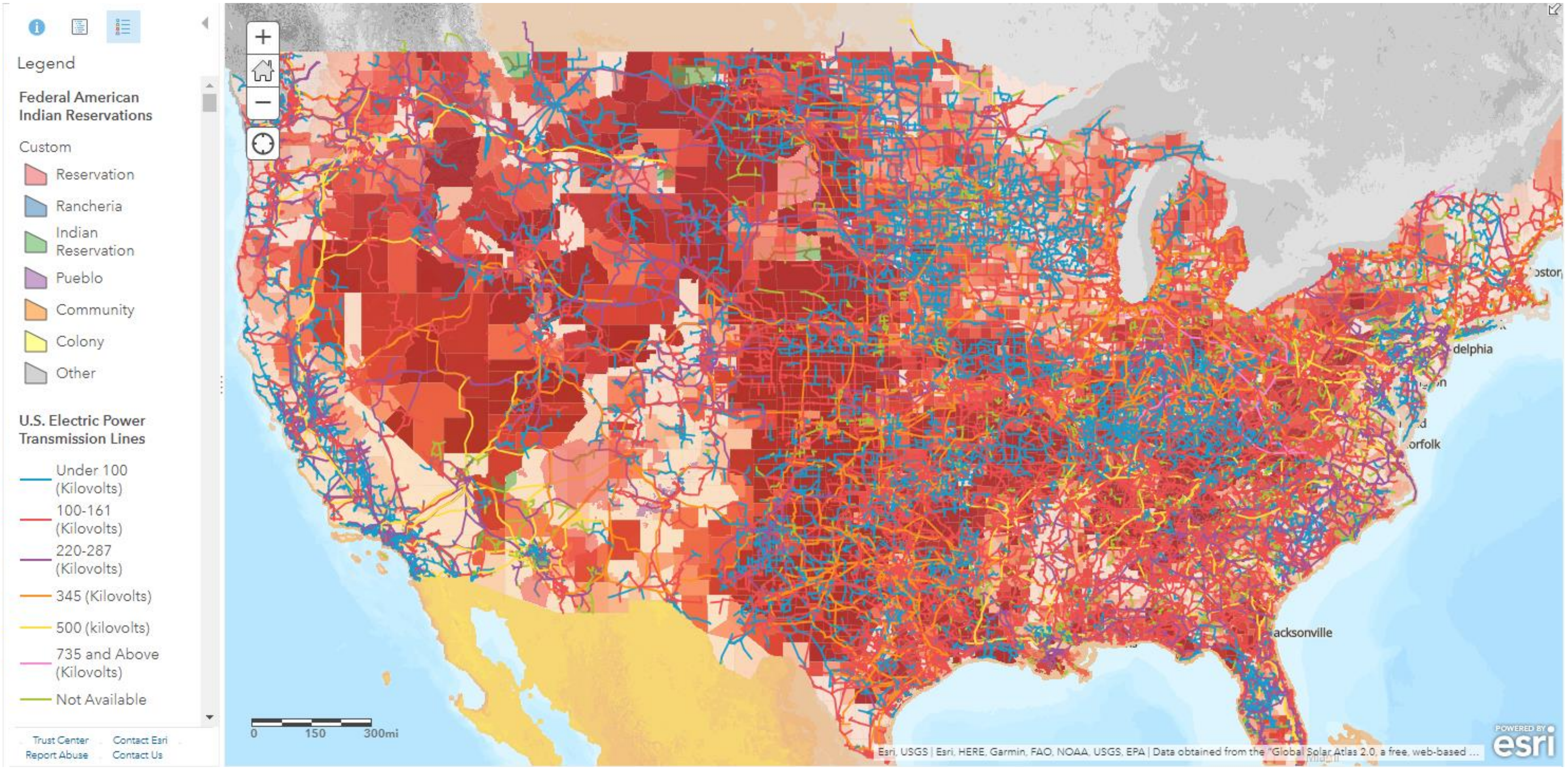
Outcome	LCOE Δ ₵/kWh	LCOE ₵/kWh	Equivalent Heliostat Cost Reduction
Default	0	8.624	0
Extend service life by 10 years at no cost	-0.553	8.071	-$3.31
Increase solar resource by 10% (equivalently, optical performance)	-0.525	8.099	-$3.15
Reducing O&M costs by 20%	-0.240	8.384	-$1.44
Reduce Deployment Time to 6 month	-0.179	8.445	-$1.07
Reduce site preparation to 10 $/m^2	-0.104	8.520	-$0.62
Reduce soiling by 5%	-0.030	8.594	-$0.18
Reduce land costs by 10%	-0.014	8.610	-$0.08
TOTAL	**-1.644**		**-$9.86**

These values are preliminary estimates. A more rigorous analysis will be published as part of the HelioCon Roadmap.

Site Selection

Map Layers

- Solar Resource
- Transmission Lines
- Indigenous communities
    - Several Pueblos, Tribes and the Navajo Nation have recently deployed commercial scale solar energy in the last year.[1,2]
    - Indigenous-led solutions may inform the way CSP could be deployed for these communities.
- Politics?
    - County and town boards oversee land use and are often have political stances that oppose renewable energy.[3]



1. https://www.energy.gov/articles/doe-awards-9-million-tribal-communities-enhance-energy-security-and-resilience

2. https://www.energy.gov/sites/prod/files/2019/01/f58/2.1-Picuris.pdf

3. https://www.reuters.com/world/us/us-solar-expansion-stalled-by-rural-land-use-protests-2022-04-07/

Site Selection

Learning 20%

Deployment innovations 10%

- Solar Resource is possibly the second most critical element
  - because it doesn't matter if you can't get permitted
- Reuters commissioned a study by Wood Mackenzie
  - 1.7 GW of proposed solar capacity was cancelled in 2021 during the permitting stage
  - 103 localities block or restrict renewable deployments
  - Site acquisition is a top threat to growth
  - Sociologists say solar/renewables is the subject of US culture war
    - "For every single large-scale solar project, you're seeing very well-organized opposition on social media."

- Lessons learned from recent past
  - Rice Solar Energy Project –environmental impact study prevented project from capturing tax incentives which dropped from 30% to 10%
  - Rio Mesa 2 – Fossils underlying part of the project area (Modularity?)
  - Red Stone – PPA postponed since 2016 due to energy surplus. While project will continue, learning efficiency was likely reduced (Modularity?)
- Opportunities
  - Engage communities long before proposal to answer concerns and build majority support
  - DEI. Equitable deployments that consult with rural communities to ensure deployments are mutually beneficial.
  - Companies are paying $1000/acre, up from $200
  - PR campaigns that build familiarity of CSP
    - Anchor bias (Global warming is a hoax!) Availability bias (Death rays kill birds!) Bandwagon effect (Save our community!)
  - Policy help at state and federal level (Is this an emergency or not?!)
  - Modular plants with smaller footprints

Request for Proposals (RFP)

RFPs take 2-3 months for a complex project.

- All development must occur in advance
  - Site Research
    - Solar resource
    - Wind data (transient)
    - Community support strategy (must be prior to RFP if possible given the 2-3 month window)
    - Land use and transmission
    - Water and labor source
    - Distance to populous areas
  - Power production
    - Solar uncertainty due to increasing fires, flight paths, type of dust
    - Reliability case
    - LCOE
    - O&M
  - Capitalization plan
  - Deployment time

Request for Proposals (RFP)

Mindset of a utilities:

- "Fleet of old generation plants are going down. 1000s of MW are going off and we need to replace with new capacity. We just need the technology to work."
- Reliability and power production case needs to overwhelm existing skepticism. Too many plants have underperformed.
- "PV+battery is much more competitive than thermal storage. The market has evolved."
- "SCE solicited 4GW of storage over the next 4 years – all batteries. It's tested, modular, proven"
- "Speed is definitely a big deal. Battery supply is tough to get due to a manufacturing bottleneck, so the whole project cycle is 18 months for a battery project. "
- "We do not plan on pursuing another CSP plant at this time. It's not 2010 {incentives, market}
- "Medium term 8 hour storage is interesting but we only need just enough storage during the peak load from 5-9pm."
- "We still need synchronous loading"

Learning 20% | Deployment Innovations 10% | Heliostat Design 24%

Request for Proposals (RFP)

Mindset of Investors:

- “How much money? How much risk? Schedule to ROI”
- “$1 Billion is high risk, by the time you get al.l the institutions lined up the market moves on.”
- “Projects in the $200-300 million range are the sweet spot”
  - “Go small! Get deployable with small modules that can meet any spec.”
  - “10 MW system is best to optimize”
- “Years of zero revenue because technical solutions were difficult to find. Modular layouts will prevent these single points of failure.”
- “Is your EPC properly capitalized to stay long term and will they commit no matter what?”

Request for Proposals (RFP)

Mindset of Developers:

- Optimal heliostat size
  - "There is no consensus on optimal size. We used to think the correct heliostat was the largest thing you could fit on a pile
    - Reduces per-heliostat costs ($10 water-tight connector)
- Optimal field size
  - "Don't get too caught up in the cents {LCOE}! Fields that are more deployable may be more attractive"
- Supply chain
  - It's hard not to get locked into a design too early. People develop trusting relationships with suppliers during development which can make it hard to make needed changes if they sour those relationships.

Request for Proposals (RFP)

Mindset of Developers:

- Quality control
  - “We wrote contracts that had teeth and thought that was good enough. But right now heliostats is a developing technology and we can’t just close our eyes to the technical risks”
  - “Without standards it is hard to know what to measure. Heliostats were received and accepted several months before issues could be discovered after assembly”
- Site Preparation
  - What if there was no preparing field at all?
    - Reduce costs
    - Preserve habitats/environment
    - Vegetation may reduce erosion
    - Vegetation may reduce airborne dust
    - Manual mirror washing may create jobs needed for government incentives and community support
- Assembly and Construction
  - “Maybe the EPC model is wrong when the technology is not yet proven. We need to have these checks and changes, but there is resistance to having the technology creator interacting during construction execution.”

End of Life Cycle

- The default system in SAM was run with a 25-yr life and a 35-yr life
  - LCOE was reduced by 0.55 ₵/kWh which equates to about a $3/m^2$ cost reduction for heliostats
- Life Extension Program
  - Solar One (1982-1986) >>> Solar TWO (1995-1999) gives a blueprint for a successful life extension program
- Postmortem –
  - Beyond Solar Two, the facility was being utilized by researchers outside of the solar energy field. (astronomy, optics, etc.).
  - Eco-tourism
  - Removal and Recycling

Tümer, T., Bhattacharya, D., Mohideen, U., Rieben, R., Souchkov, V., Tom, H., & Zweerink, J. (1999). Solar Two Gamma-Ray Observatory. *Astroparticle Physics, 11*(1), 271-273. doi:https://doi.org/10.1016/S0927-6505(99)00064-X

Path forward

- CSP still has a major role in the REP
  - 24 hr synchronous baseload source
  - long term storage
  - thermal energy and industrial process heat

- Cost targets may be possible with a combination of strategies
  - Increase learning curve by getting more projects
    - Get through the permitting pitfalls by engaging communities early and more flexibility in layout
    - Reduce investor anxiety by removing single-points of failure and price-tag
    - Reduce utility risk by deploying, at least partially, in 6-12 months and match PV reliability
    - Invest in PR to build familiarity and enthusiasm
    - Community-informed solutions working
  - Design heliostats for ease of deployments
    - Minimize foundations
    - Minimize labor
    - Minimize infrastructure
  - Reduce cost of field and O&M
    - Leave ground pristine
      - Minimize prep-costs
      - Reduce airborne dust and cleaning frequency
      - Reduce erosion

More From the HelioCon Seminar Series

- Past seminar presentations now available on the NREL YouTube learning channel: https://www.youtube.com/playlist?list=PLmIn8Hncs7bGAK-hIf4qxuAbHUHK-xgZK
- Subscribe to the seminar series or get in touch: heliostat.consortium@nrel.gov

Next Seminar May 18th!

HelioCon Seminar Series: Heliostat Components and Controls
Speaker: Dr. Ken Armijo, SNL
When: 1-2pm Wednesday May 18th
Zoom:https://nrel.zoomgov.com/j/1610232256?pwd=QlZIYk5mNlRERFFyb3ZhdVA3SGduQT09

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