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

Heliostat Consortium: Updates on Resource, Training, and Education Development for the Concentrating Solar Power Community

Rebecca Mitchell, NREL

ASME Energy Sustainability

July 17, 2024

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

Heliostat Consortium (HelioCon)

US Energy Department has funded 5-year heliostat consortium:

- To advance U.S. heliostat technologies, capabilities and national workforce
- $25M + cost share: 30% of funds allocated to RFPs for engagement of US industries and other stake holders

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

Scope of Resource, Training, and Education

Education Institute Involvement

Training Resources

Diversity, Equity, and Inclusion

Online Database

HelioCon RTE Objectives

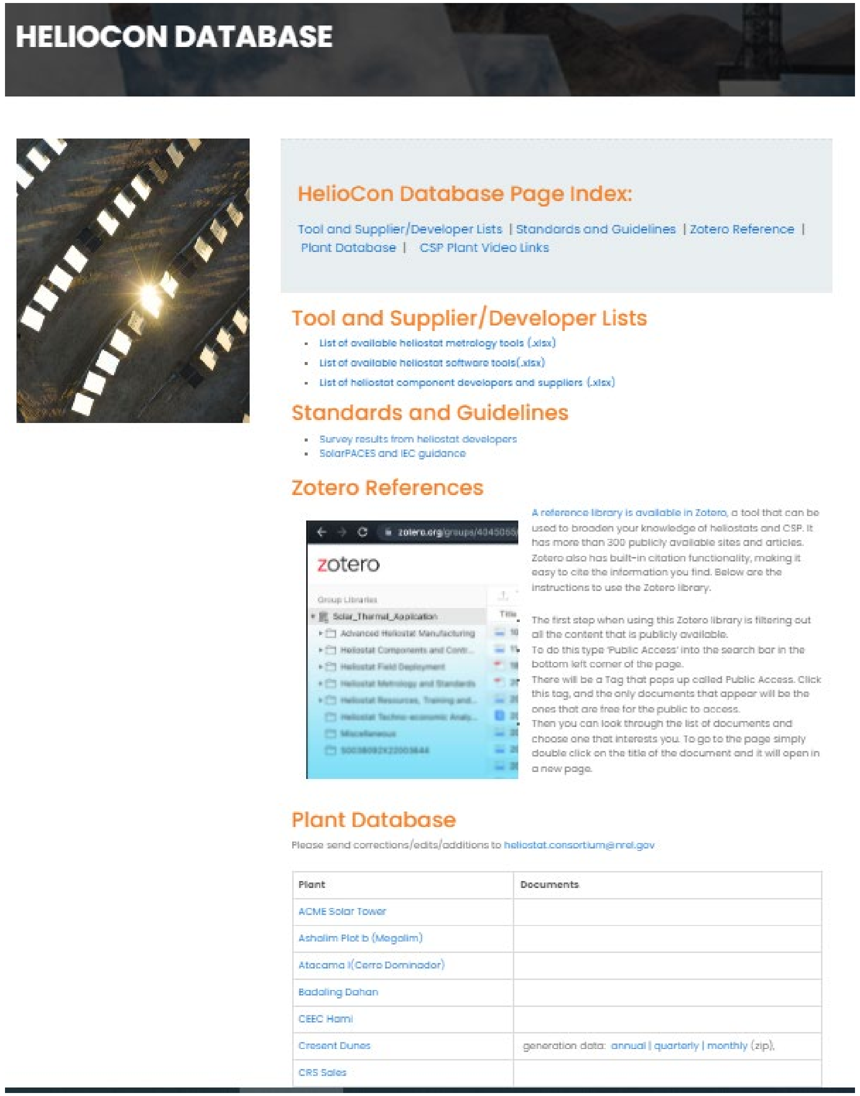
Top Identified Gaps	HelioCon RTE Tasks
Lack of access to CSP knowledge and resources	Create a centralized web resource database
Lack of public awareness of CSP technology	Host an online webinar series featuring experts in the CSP community
Lack of CSP research and education in education institutes	Support education and engage students

Centralized Web Resource Database

HelioCon Database

- Lists of metrology tools, software tools, and supplier contacts
- Information on standards/guidelines
- Zotero Reference library
- Plant Database
- Soon to come: heliostat database

Contributed by Yu Zhou, NREL



Lists of Tools and Suppliers

Heliostat Metrology Tools

Tools and methods to measure:

- Sun shape
- Atmospheric attenuation
- Reflectance
- Optomechanical errors
- Soiling
- Wind loads

Information includes:

- Supplier
- Cost
- Accuracy
- Commercial or under development

Heliostat Software Tools

Software types:

- Optical modeling and ray tracing
- Technoecomonic
- Solar field optimization
- Plant analysis

Information includes:

- Tool developer
- POC
- Download or information link
- Commercial or open source

Component Suppliers

Component types:

- Materials
- Solar field components
- Tower components
- Storage system components
- Power block components

Information includes:

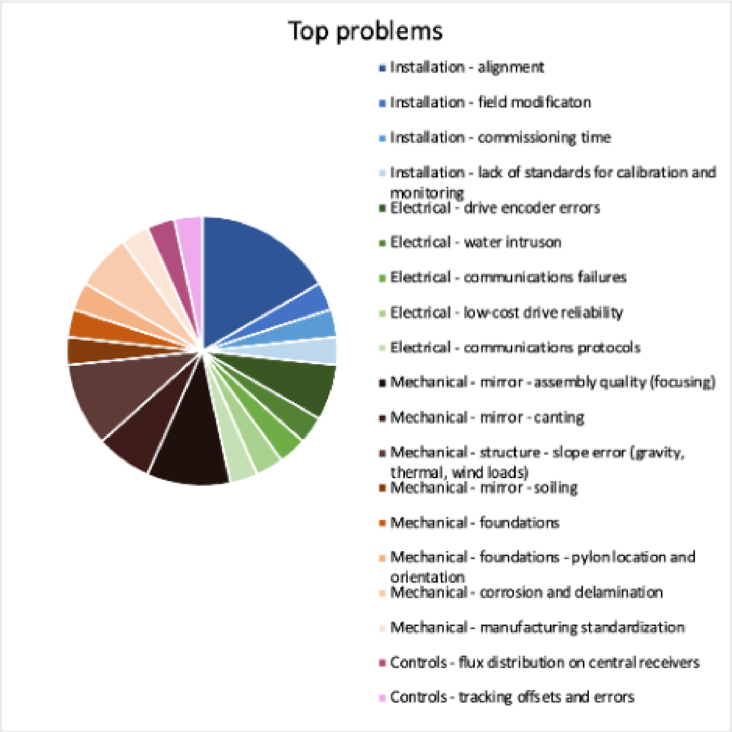
- Supplier company name
- Supplier region/country
- Contact information

Contributed by Yu Zhou and Mike Grabel, NREL

Standards and Guidelines

Heliostat Technology Developer Survey Results

Responses were collected from 14 CSP technology developers on industry trends regarding heliostats and solar fields to inform the development of standards and guidelines.



SolarPACES and IEC guidance

SolarPACES Task III

Task III under the IEA SolarPACES Strategies Plan aims to enhance the technical and economic viability of the emerging technologies through theoretical analyses, simulation codes and experimental work in specialized facilities. The objectives include optimizing the design, evaluation, and use of components and subsystems for concentrating solar thermal energy, with applications in process heat and the development of improved materials. It also includes guidelines for component performance measurement, prioritization of impactful R&D activities, reliability evaluation of solar components and systems, quality assurance tools for concentrator systems, and methodologies for comparing and evaluating storage concepts.

IEC TC 17:

This website is dedicated to preparing international standards for systems of Solar Thermal Electric Plants. The website details standards for various types of Solar Thermal Electric systems such as parabolic troughs, solar towers, linear Fresnel systems, dishes, and thermal storage. It outlines the standards for terminology, design and installation requirements, performance measurement techniques, test methods, safety requirements, and power quality issues. Additionally, the standards address connectivity and interoperability with the power grid, including aspects related to connections, bi-directional communications, centralized control (Smart Grid), and environmental considerations.

Helpful standards related to heliostats:

62862-3-5: Standards for reflectance measurement methods in laboratory for all types of reflector materials, which will be used in concentrating solar technologies.

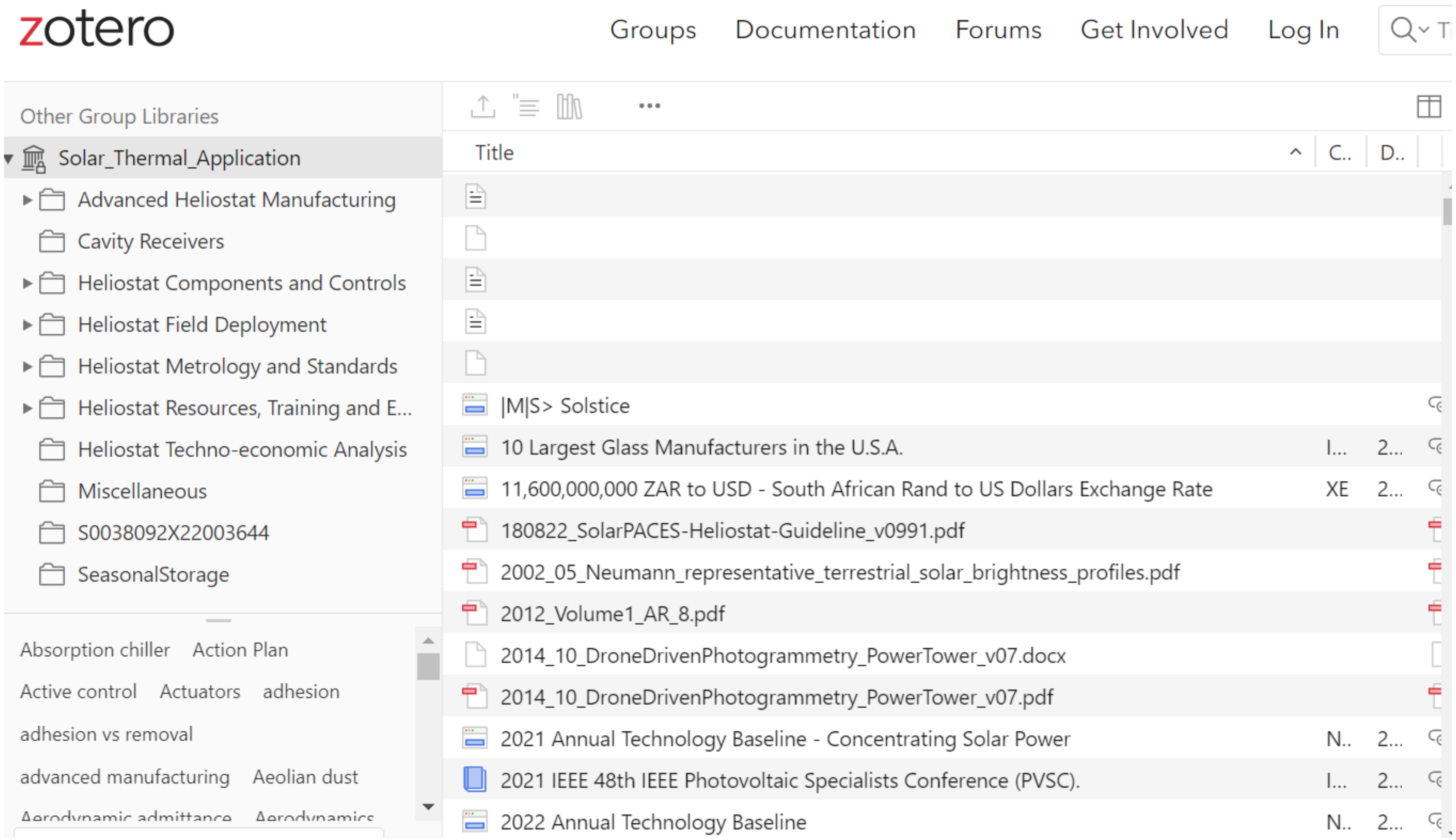
62862-3-6: This standard establishes methods for accelerated aging tests for silvered-glass mirrors used in concentrating solar technologies, and the objective is to effectively qualify these mirrors for outdoor use in various environmental conditions.

62862-4-2: This standard contains technical and test requirements testing rules, packaging, transport, and storage of the heliostat control system of solar power tower plants.

62862-4-3: This standard includes the technical requirements and design qualification of heliostats for solar power tower plants.

Contributed by Daniel Tsvankin and Yu Zhou, NREL

Zotero Reference Library



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Plant Database

Plant Database

Please send corrections/edits/additions to heliostat.consortium@nrel.gov

Plant	Documents
ACME Solar Tower	
Ashalim Plot b (Megalim)	
Atacama I(Cerro Dominador)	
Badaling Dahan	
CEEC Hami	
Cresent Dunes	generation data: annual | quarterly | monthly (zip),
CRS Sales	
CTGR_Qinghai_Golmud_100MW	
CTGR_Qinghai_Quingyu_DC_100MW	
Gemasolar Thermosolar	
Generation 3 Particle Pilot Plant Sandia	
Generation 3 Particle Pilot Plant Saudi	
Greenway CSP Mersin Tower	
Huidong New Energy Akesai 110MW	
Ivanpah	generation data tower 1 annual | quarterly | monthly (zip), generation data tower 2 annual | quarterly | monthly (zip), generation data tower 3 annual | quarterly | monthly (zip)
Jemalong Solar Thermal Station	
Jinta Zhongguang Solar 100MW	
Julich Solar Tower	
Khi Solar One	
Lake Cargelligo	
LuNeng Haixi	
National Solar Thermal Test Facility	
Noor Energy 1 (DEWA IV) - Tower Segment	
NOOR III	
Planta Solar 10	

General Plant Data

- Location: Primm, NV California US
- Owner(s): NRG, Brightsource, Google
- Capacity (MW): 377

Plant Timeline

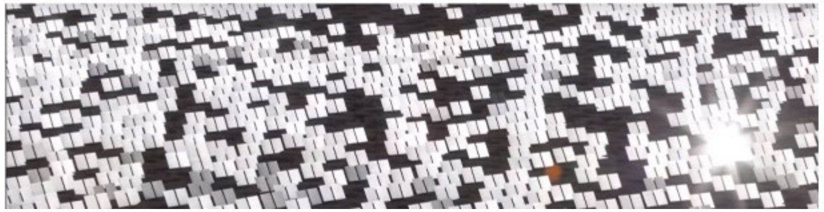
- Generation Start Year: 2014
- Closure Time: May 19- June 8, 2016

Plant Costs

- Construction Cost ($): $2.2 billion
- Specific Cost ($/kW): 6206.6
- LCOE ($/kWh): 0.19

Heliostat Design

- Heliostat Aperture Area (m^2): 14.05
- Heliostat Manufacturer: BrightSource
- Heliostat Model: BrightSource
- Mirror Manufacturer: Guardian USA
- Mirror Model: EcoGuard Solar Boost
- Heliostat Dimension: 4.55m x 3m
- Heliostat Facets (C x R): 2 col x 1 row
- Solar Field Area (m^2): 2.6 million
- Heliostat Cost pm^2 ($): 338.46



Contributed by Yu Zhou and Mike Grabel, NREL

HelioCon Webinar Series

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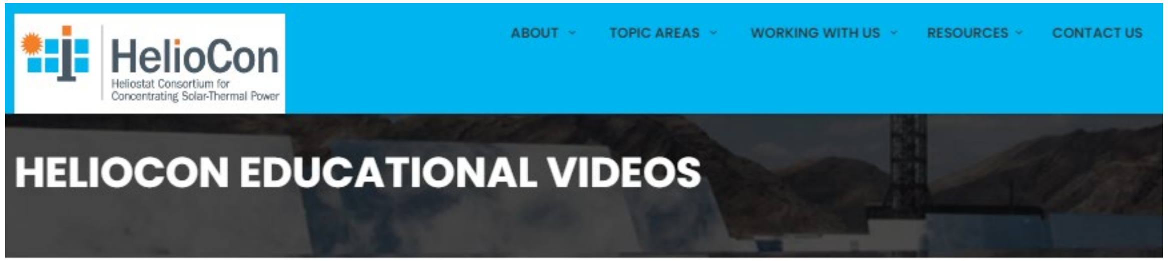
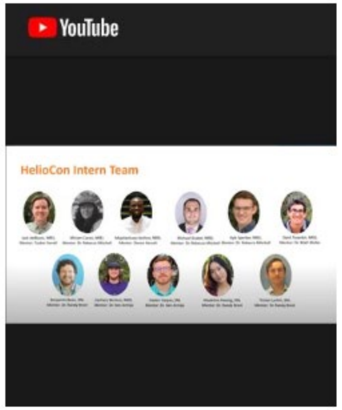
HeliCon Webinar Series

- Almost 30 seminars from the last 3 years
- Can access PDF copies of slides and recorded seminars on Youtube

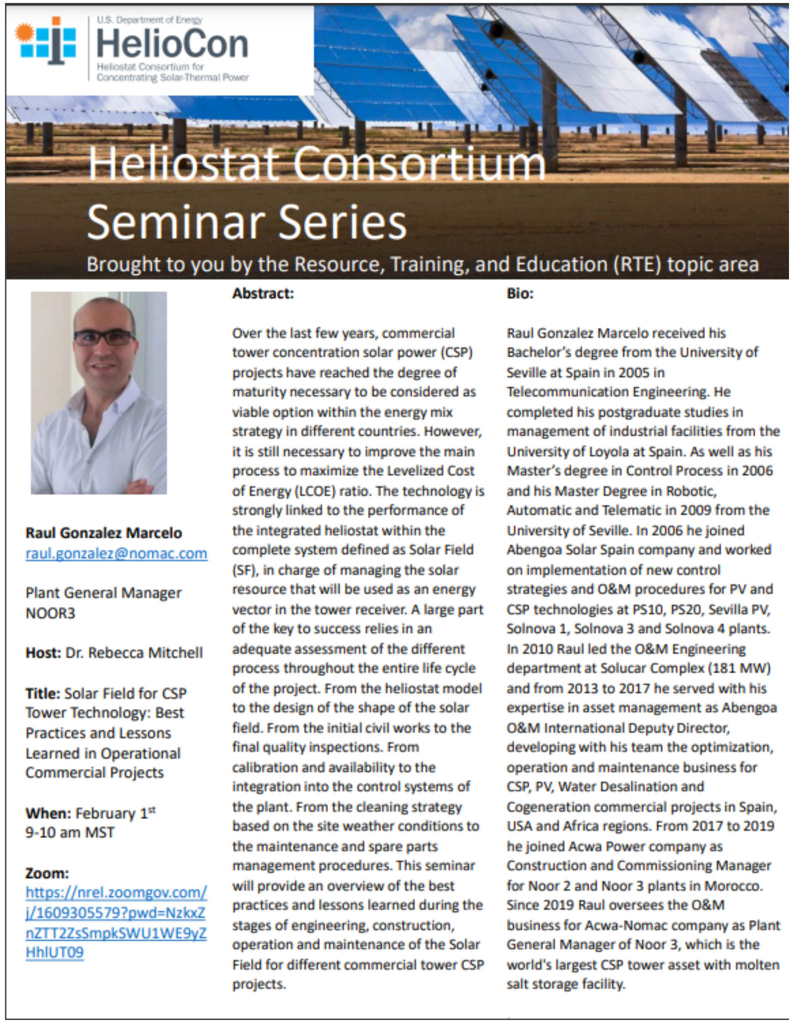




HelioCon Seminar Series

Date	Title	Speaker	Video Link	Training Documents
June 12, 2024	Solar Mirror Reflectance and Standardized Reporting	Tucker Farrell Research Engineer, NREL and Stephanie Meyen Researcher, NREL	video	Slides, Flyer
March 20th, 2024	HELIOCOMM: A Wireless Communications Autonomous System for Concentrated Solar Power Fields	Professor Eirini Tsiropoulou Associate Professor, University of New Mexico	video	Slides, Flyer
February 21, 2024	Digital Twin and Industry 4.0 in Support of Heliostat Technology Advancement	Dr. Michel Izygon Chief Technology Officer, Tietronix Software Inc.	video	Slides, Flyer
January 17, 2024	Fields of Twisting Heliostats for Direct Air Capture and Making Syngas and Cement	Professor Roger Angel Professor of Astronomy and Optical Sciences, University of Arizona	video	Slides, Flyer
November 15, 2023	LSAMP Summer Experience: A Cleaning Mirror Assessment with Reflectance	Engineering Student, Clark Atlanta University and Northeastern University, Courtney Jackson Engineering Student, Clark Atlanta University and Northeastern University	video	Slides, Flyer
October 18, 2023	Calibration and Characterization Systems in Solar Concentration Plants: Field Expertise, Conclusions, and Lessons Learned.	Dr. Adriana Zurita , Marco Carrascosa	video	Slides, Flyer
September 27, 2023	Challenges and Solutions in Heliostat Optical Metrology	Dr. Randy Brost SNL	video	Slides, Flyer

A Glimpse into Plant Management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Heliostat Consortium Seminar Series

Brought to you by the Resource, Training, and Education (RTE) topic area

Raul Gonzalez Marcelo
raul.gonzalez@nomac.com

Plant General Manager
NOOR3

Host: Dr. Rebecca Mitchell

Title: Solar Field for CSP Tower Technology: Best Practices and Lessons Learned in Operational Commercial Projects

When: February 1st
9-10 am MST

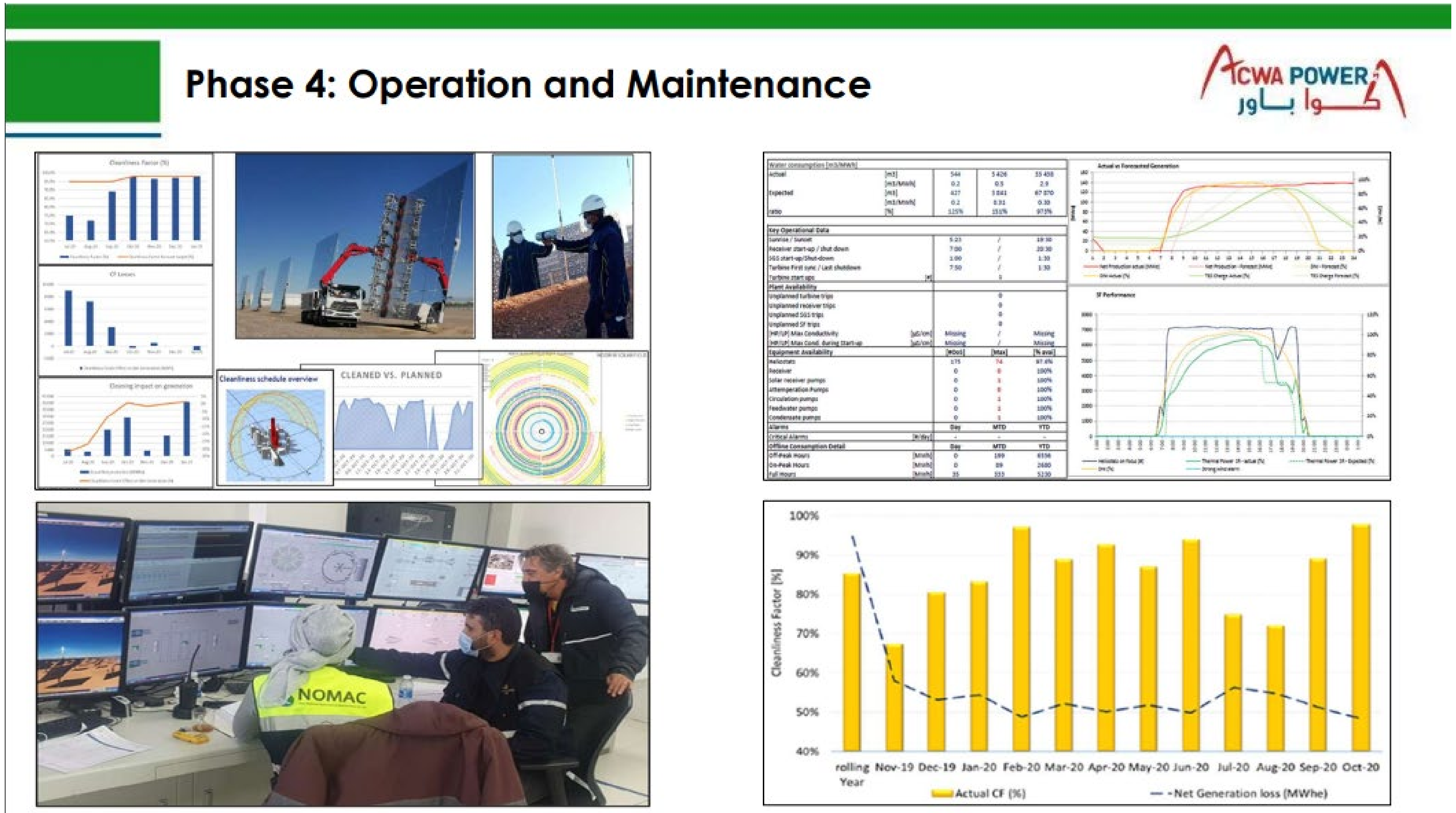
Zoom:
https://nrel.zoomgov.com/j/1609305579?pwd=NzkxZnZTT2ZsSmpkSWU1WE9yZHhlUT09

Abstract:

Over the last few years, commercial tower concentration solar power (CSP) projects have reached the degree of maturity necessary to be considered as viable option within the energy mix strategy in different countries. However, it is still necessary to improve the main process to maximize the Levelized Cost of Energy (LCOE) ratio. The technology is strongly linked to the performance of the integrated heliostat within the complete system defined as Solar Field (SF), in charge of managing the solar resource that will be used as an energy vector in the tower receiver. A large part of the key to success relies in an adequate assessment of the different process throughout the entire life cycle of the project. From the heliostat model to the design of the shape of the solar field. From the initial civil works to the final quality inspections. From calibration and availability to the integration into the control systems of the plant. From the cleaning strategy based on the site weather conditions to the maintenance and spare parts management procedures. This seminar will provide an overview of the best practices and lessons learned during the stages of engineering, construction, operation and maintenance of the Solar Field for different commercial tower CSP projects.

Bio:

Raul Gonzalez Marcelo received his Bachelor's degree from the University of Seville at Spain in 2005 in Telecommunication Engineering. He completed his postgraduate studies in management of industrial facilities from the University of Loyola at Spain. As well as his Master's degree in Control Process in 2006 and his Master Degree in Robotic, Automatic and Telematic in 2009 from the University of Seville. In 2006 he joined Abengoa Solar Spain company and worked on implementation of new control strategies and O&M procedures for PV and CSP technologies at PS10, PS20, Sevilla PV, Solnova 1, Solnova 3 and Solnova 4 plants. In 2010 Raul led the O&M Engineering department at Solucar Complex (181 MW) and from 2013 to 2017 he served with his expertise in asset management as Abengoa O&M International Deputy Director, developing with his team the optimization, operation and maintenance business for CSP, PV, Water Desalination and Cogeneration commercial projects in Spain, USA and Africa regions. From 2017 to 2019 he joined Acwa Power company as Construction and Commissioning Manager for Noor 2 and Noor 3 plants in Morocco. Since 2019 Raul oversees the O&M business for Acwa-Nomac company as Plant General Manager of Noor 3, which is the world's largest CSP tower asset with molten salt storage facility.



A Deep Dive into Heliostat Optical Metrology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Heliostat Consortium Seminar Series

Brought to you by the Resource, Training, and Education (RTE) topic area

Dr. Randy Brost
Technical Staff, Sandia National Laboratories
rcbrost@sandia.gov

Host: Dr. Rebecca Mitchell

Title: Challenges and Solutions in Heliostat Optical Metrology

When: September 27th 1-2 PM MDT

Zoom: https://nrel.zoomgov.com/j/1613394621

Abstract:

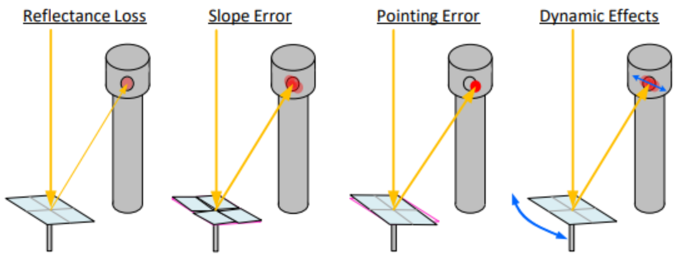
Among the primary concentrating solar collector configurations (trough, dish, linear Fresnel, heliostats), heliostats are unique because they can simultaneously deliver very high temperature and very high power. For example, heliostat solar fields can achieve temperatures over 1000 °C and over 100 MWth power. But these results are only possible if the heliostats have high optical accuracy. Optical errors in heliostat shape, pointing, and control can all contribute to a degradation in overall system performance, with error targets approaching 0.6 mrad (0.04°). These tolerances must be held over enormous sizes. Total heliostat field apertures often exceed 106 m², comprised of many thousands of heliostats with individual apertures sometimes exceeding 150 m². Heliostats appear flat but are curved optics, with very long focal lengths sometimes exceeding 1.5 km, and often including intentional astigmatism. These optical factors, combined with the harsh outdoor desert environment, make effective heliostat metrology a very challenging problem. This presentation will review the fundamentals of heliostat optics and explain how the important heliostat metrology problems are shaped by the heliostat development phase and operating environment. We will review currently available solutions, and then provide a detailed review of systems developed at the Sandia National Laboratories Concentrating Solar Optics Laboratory for measuring heliostat optical performance, both indoors and outdoors. These include high-resolution measurement methods and high-speed airborne methods designed to survey entire heliostat fields. We will conclude with a review of key open problems in heliostat metrology.

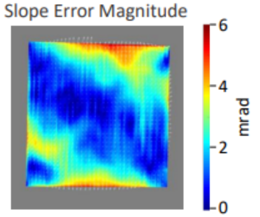
Bio:

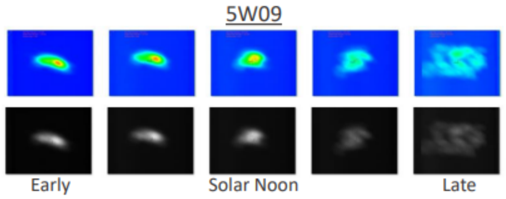
Dr. Randy Brost is a technical staff member at Sandia National Laboratories in the Concentrating Solar Power Technology group. He is currently leading projects related to concentrating solar optics and autonomy. He received his Ph.D. in Computer Science from Carnegie-Mellon University in 1991 and performed robotics research at Sandia National Laboratories until 1997. He then served at Eastman Kodak Company until 2007, implementing a variety of custom software tools supporting advanced manufacturing, metrology, and physics analysis. He then joined SkyFuel, a concentrating solar power company, where he helped develop utility-scale solar collectors, and applied computational methods to optimize new solar collector designs. He returned to Sandia in 2011 and pursued a variety of computer science research topics before joining the Concentrating Solar Technology group in early 2020.

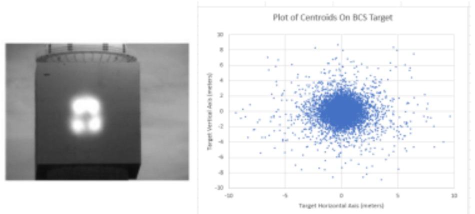
Conclusion

- Heliostat error categories:
  - Reflectance loss
  - Slope error
  - Pointing error
  - Dynamic effects
- Well-established:
  - Material reflectance
  - Indoor high-resolution slope
  - BCS pointing, calibration
- Challenging:
  - Wide-area soiling
  - Optical impact of temperature, tilt, dynamics
  - Distant heliostats
  - Accelerated calibration
  - In-situ optical assessment
  - Ground truth verification
- While seemingly simple, heliostat metrology encounters complex effects and harsh environments.
- Sandia is engaging many of these problems, and seeks to make excellent solutions easily accessible. **OpenCSP@sandia.gov**









Courtesy Crescent Dunes

Note: A lot more great work did not fit!

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Understanding Standardization of Reflectance Measurement

Tucker Farrell
Research Engineer, National Renewable Energy Laboratory
Tucker.Farrell@nrel.gov

Stephanie Meyen
Researcher, National Renewable Energy Laboratory
Stephanie.Meyen@nrel.gov

Host: Dr. Rebecca Mitchell, National Renewable Energy Laboratory

Title: Solar Mirror Reflectance and Standardized Reporting

When: June 12th 9-10 AM MDT

Zoom: https://nrel.zoomgov.com/j/1618791253

Abstract:

About two decades ago, the commercialization of concentrating solar power plants became feasible under the premise, that cost reduction and performance improvements would be achievable to be competitive with other renewable energy technologies. A major factor in ensuring high performance of while implementing efforts in cost reduction is the ability to reliably evaluate said performance. Knowing the solar weighted reflectance of a solar collector or heliostat plus all optical and opto-mechanical errors including the specularity of the mirror, one can model the flux distribution on the receiver, which is the ultimate metric for performance. While an official IEC standard for reflectance characterization is in progress but not yet released, there is a widely accepted measurement guideline and a body of work on reflectance measurement and modeling available. The speakers of this seminar will discuss 1) A definition and explanation of reflectance parameters; 2) The status of standardization efforts and available instrumentation; 3) A description of a best practice measurement procedure and dependencies on application (e.g. material comparison, soiling or degradation analysis); 4) A recommendation to use a generalized, automated data processing and reporting code.

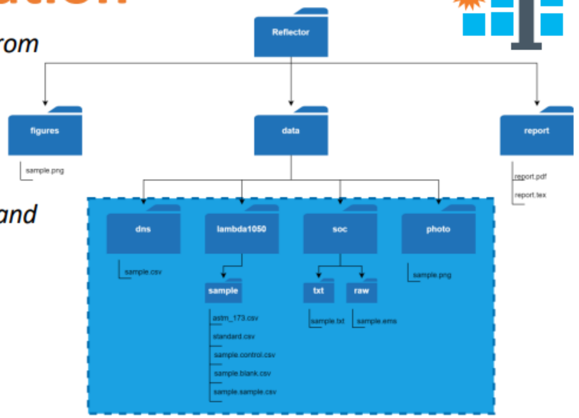
Bios:

Tucker Farrell has been a research engineer at NREL since 2020. He has contributed to the development of optical tools used to assess optical quality and heliostat performance metrics. His work began with flight planning for autonomous UAS and has progressed to include learning and computer vision techniques for image analysis. He also works in optical material characterization, accelerated aging, and life cycle modeling for solar reflectors, absorbers, and lately, particles. Finally, he's one of NREL's 3 operators of our 10-kW solar furnace.

Stephanie Meyen holds a Master's degree in optical engineering and has joined NREL in early 2024 as a researcher focusing on heliostat qualification metrology and standardization. Her previous experience in CSP research spans the time between 2005 to 2014, working at the DLR Solar Research Institute in Germany and at the Plataforma Solar de Almeria in Spain. At the time, Mrs. Meyen was a critical team member during the establishment of two main CSP quality assurance laboratories, the QUARZ-Center and the OPAC laboratory. During the recent decade, Mrs. Meyen explored the US space and astronomy industry working with space-bound LIDAR systems and high precision metrology for giant telescope mirrors. However, the energy crisis prompted her to return to the CSP community.

A tool for standard report generation

- *A Python codebase integrated with LaTex to generate a standard report from a standard set of measurements.*
- *To use:*
  - *User measures each sample in accordance with the procedure*
  - *User saves files in accordance with the template*
  - *Script takes raw data and outputs a standard reflectance report pdf and .tex.*
    - *Hemispherical solar-weighted value*
    - *Specular reflectance value at collected wavelength*
    - *Spectral reflectance*
    - *Measurement uncertainty values*
    - *Photos and sample descriptions*
    - *Means and methods for sample preparation and calculation*
- *Open-source software to be released this year*



User puts data here – that's it

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Come Speak For Our Webinar Series!

Email Heliostat.Consortium@nrel.gov

Support Education and Engage Students

Northeastern Efforts to Create Research and Education Projects

- A full credit CSP course for graduate/undergraduates
- Solar thermal senior capstone projects
- Short industry courses offered to the public **coming this fall**
  - Introduction to CSP
  - Incident solar radiation prediction (ray trace basics, losses, software)
  - Receiver design
  - Energy storage
  - Potential for production processes

LVX VERITAS VIRTVS

Northeastern University

CSP Courses Questionnaire

https://docs.google.com/forms/d/e/1FAIpQLSfgCCDEYJ7N2dJNI5D-4Iu2WWUKpYXEdCWYuHj9C7sbTqZZmA/viewform?usp=sf_link

Spotlighting Student Work in Solar Thermal

HelioCon Intern Seminar

Jack deBloois, NREL
Mentor: Tucker Farrell

Miriam Caron, NREL
Mentor: Dr. Rebecca Mitchell

Mojolaoluwa Keshiro, NREL
Mentor: Devon Kesseli

Michael Grabel, NREL
Mentor: Dr. Rebecca Mitchell

Kyle Sperber, NREL
Mentor: Dr. Rebecca Mitchell

Danil Tsvankin, NREL
Mentor: Dr. Matt Muller

Benjamin Bean, SNL
Mentor: Dr. Randy Brost

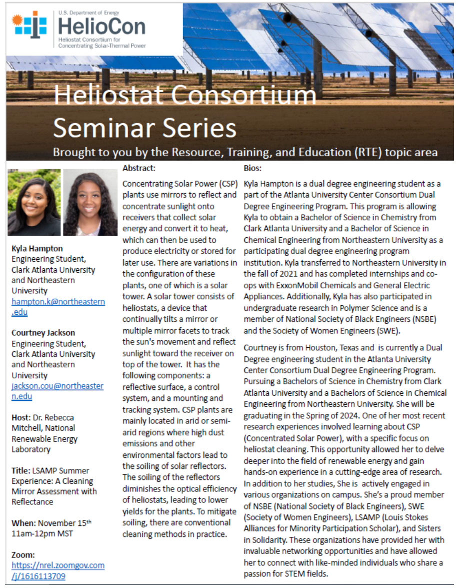
Zachary Berinus, NREL
Mentor: Dr. Ken Armijo

Haden Harper, SNL
Mentor: Dr. Ken Armijo

Madeline Hwang, SNL
Mentor: Dr. Randy Brost

Tristan Larkin, SNL
Mentor: Dr. Randy Brost

NE LSAMP Mirror Washing Study



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Seminar Series
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Kyla Hampton
Engineering Student, Clark Atlanta University and Northeastern University
hampton.k@northeastern.edu

Courtney Jackson
Engineering Student, Clark Atlanta University and Northeastern University
jackson.cou@northeastern.edu

Host: Dr. Rebecca Mitchell, National Renewable Energy Laboratory

Title: LSAMP Summer Experience: A Cleaning Mirror Assessment with Reflectance

When: November 15th
11am-12pm MST

Zoom:
https://nrel.zoomgov.com/j/1616113709

Abstract:

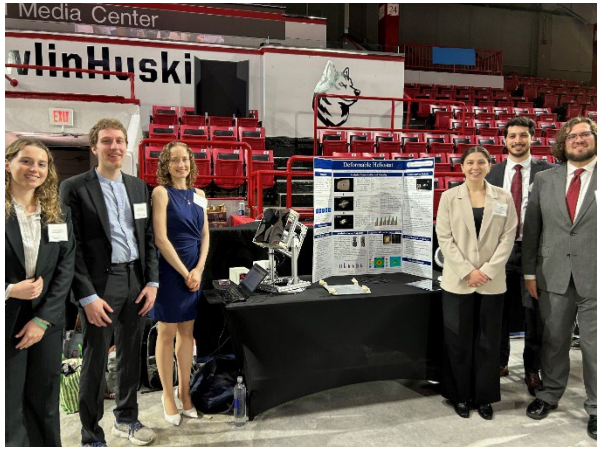
Concentrating Solar Power (CSP) plants use mirrors to reflect and concentrate sunlight onto receivers that collect solar energy and convert it to heat, which can then be used to produce electricity or stored for later use. There are variations in the configuration of these plants, one of which is a solar tower. A solar tower consists of heliostats, a device that continually tilts a mirror or multiple mirror facets to track the sun's movement and reflect sunlight toward the receiver on top of the tower. It has the following components: a reflective surface, a control system, and a mounting and tracking system. CSP plants are mainly located in arid or semi-arid regions where high dust emissions and other environmental factors lead to the soiling of solar reflectors. The soiling of the reflectors diminishes the optical efficiency of heliostats, leading to lower yields for the plants. To mitigate soiling, there are conventional cleaning methods in practice.

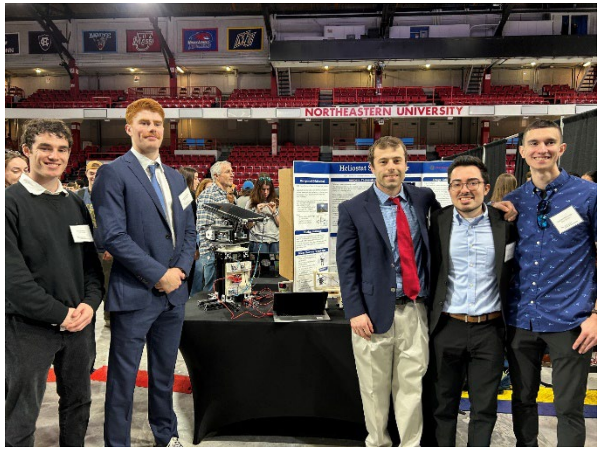
Bios:

Kyla Hampton is a dual degree engineering student as a part of the Atlanta University Center Consortium Dual Degree Engineering Program. This program is allowing Kyla to obtain a Bachelor of Science in Chemistry from Clark Atlanta University and a Bachelor of Science in Chemical Engineering from Northeastern University as a participating dual degree engineering program institution. Kyla transferred to Northeastern University in the fall of 2021 and has completed internships and co-ops with ExxonMobil Chemicals and General Electric Appliances. Additionally, Kyla has also participated in undergraduate research in Polymer Science and is a member of National Society of Black Engineers (NSBE) and the Society of Women Engineers (SWE).

Courtney is from Houston, Texas and is currently a Dual Degree engineering student in the Atlanta University Center Consortium Dual Degree Engineering Program. Pursuing a Bachelors of Science in Chemistry from Clark Atlanta University and a Bachelors of Science in Chemical Engineering from Northeastern University. She will be graduating in the Spring of 2024. One of her most recent research experiences involved learning about CSP (Concentrated Solar Power), with a specific focus on heliostat cleaning. This opportunity allowed her to delve deeper into the field of renewable energy and gain hands-on experience in a cutting-edge area of research. In addition to her studies, She is actively engaged in various organizations on campus. She's a proud member of NSBE (National Society of Black Engineers), SWE (Society of Women Engineers), LSAMP (Louis Stokes Alliances for Minority Participation Scholar), and Sisters in Solidarity. These organizations have provided her with invaluable networking opportunities and have allowed her to connect with like-minded individuals who share a passion for STEM fields.

NE Capstone Projects





https://heliocon.org/NE_universty_highlight.html

Join Women+ in Concentrating Solar

Promoting and supporting underrepresented genders in the solar thermal community

WOMEN+ IN CONCENTRATED SOLAR

https://women.solarpaces.org/

Get in Touch!

- Heliostat.Consortium@nrel.gov – for general HelioCon inquiries
- Rebecca.Mitchell@nrel.gov – for inquires about RTE
    - If you're a student, get in touch with me!
- Provide feedback on our website: https://heliocon.org/contact_us.html
    - We want to hear from you about the resources on our website
- Complete the Short Industry Course Questionnaire

https://docs.google.com/forms/d/e/1FAIpQLSfgCCDEYJ7N2dJNI5D-4Iu2WWUKpYXEdCWYuHj9C7sbTqZZmA/viewform?usp=sf_link