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

Heliostat Consortium: Update on Resource, Training, and Education Development and Women+ in Concentrating Solar

Lead: Rebecca Mitchell, NREL
Co-lead: Jeremy Sment, SNL

September 27, 2022

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

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Scope of Resource, Training, and Education

Education Institute Involvement

Training Resources

Diversity, Equity, and Inclusion

Online Database

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

HelioCon RTE Objectives

- Develop heliostat training programs
  - Identify training and education needs of labs, industry, and universities
  - Design and test training materials for new workers
- Engage education institutes to develop workforce pipeline
  - Support heliostat Master's/PhD thesis development, technical training programs
  - Create heliostat grant opportunities
  - Provide internships opportunities
- Promote Diversity, Equity, and Inclusion (DEI)
  - Create programs that benefit minority/underserved communities
- Create centralized resource database
  - Compile all RTE materials and information into centralized web-based resource

RTE Top Ranked Gaps

Tier 1 Gaps (Most Important)	
R1	Heliostat technology resources are not accessible in a centralized web-based format • Need for a heliostat reference library that is accessible to newcomers • Lack of documentation and accessibility of current institutional knowledge, including knowledge on industry standards, materials, procedures, and case studies of lessons learned • Need for a centralized database to find information on available software/hardware tools and methods • Need for a centralized database of training/education materials
R2	Lack of heliostat research projects in universities • Small number of university students/faculties performing heliostat-related research • Very few students masters/PhD thesis projects related to heliostats/CSP • Need for CSP/heliostat research funding accessible to minority/underrepresented students
R3	Little public awareness of CSP/heliostat technologies • Awareness of CSP/heliostat technologies is not widespread across students or the public • Lack of informational videos and documents introducing heliostat/solar thermal technologies to a general audience • Lack of CSP/heliostats social media content
R4	Lack of resources and guidance for promoting DEI in CSP workforce • Lack of DEI training resources and guidance for heliostat workforce • Need resources for project leaders to prioritize DEI in project planning • Need for more partnerships with minority-serving institutions

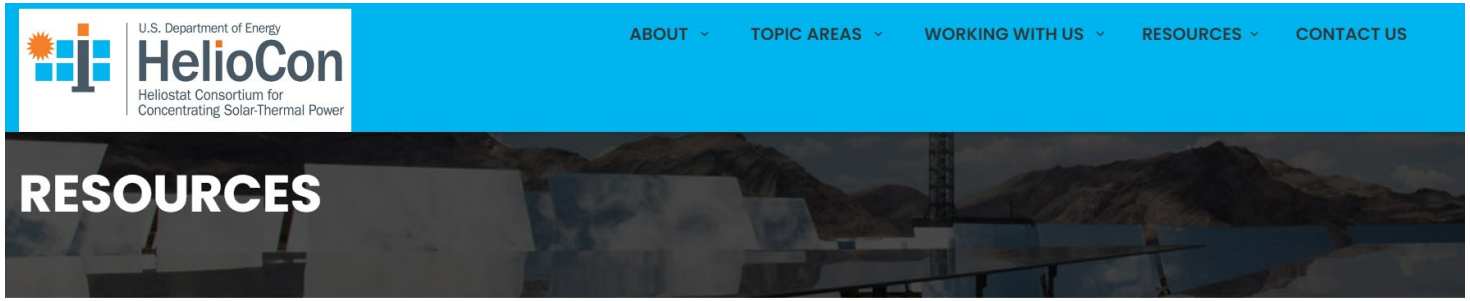
Recommended Pathways

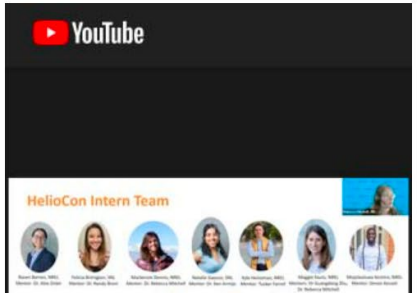
HelioCon scope focuses on the resource database

Gaps	Recommended Pathways
R1: Heliostat technology resources are not accessible in a centralized-web based format	• Compile institutional knowledge, such as manufacturing and plant O&M best practices and lessons learned through interviews and surveys • Compile available resource materials including industry data/knowledge, references, training and educational resources, and available tools • Organize resource materials and data into web database
R2: Lack of heliostat research projects in universities	• Establish connections between students/faculty and researchers/industry leaders through internship opportunities • Identify and support PhD/masters students to purse heliostat-focused thesis projects • Pose industry problems to universities to innovate solutions
R3: Little public awareness of CSP/heliostat technologies	• Create short introductory/informational videos targeted at a general audience • Create social media accounts for CSP/heliostat technologies and enlist researchers and students to generate content • Create public events, such as seminar series or workshops to educate a broad audience of heliostat fundamentals • Partner with universities to create annual fundamental CSP trainings open to the public
R4: Lack of resources and guidance for promoting DEI in CSP workforce	• Consult with DEI staff/experts establish resource and training materials, create diverse project teams • Partner with minority-serving institutions on CSP projects • Identify organizations and contacts to partner with that work with underserved communities

Resource Database - https://heliocon.org/

- Reference library
- Education and training resources
- Lists of heliostat component suppliers and developers, metrology tools, and software tools
- Existing power tower plant database
- List of standards/guidelines
- Summary of best practices and lessons learned
- References to external resources
- Example education modules, homework problems, and projects for heliostat coursework





Resources

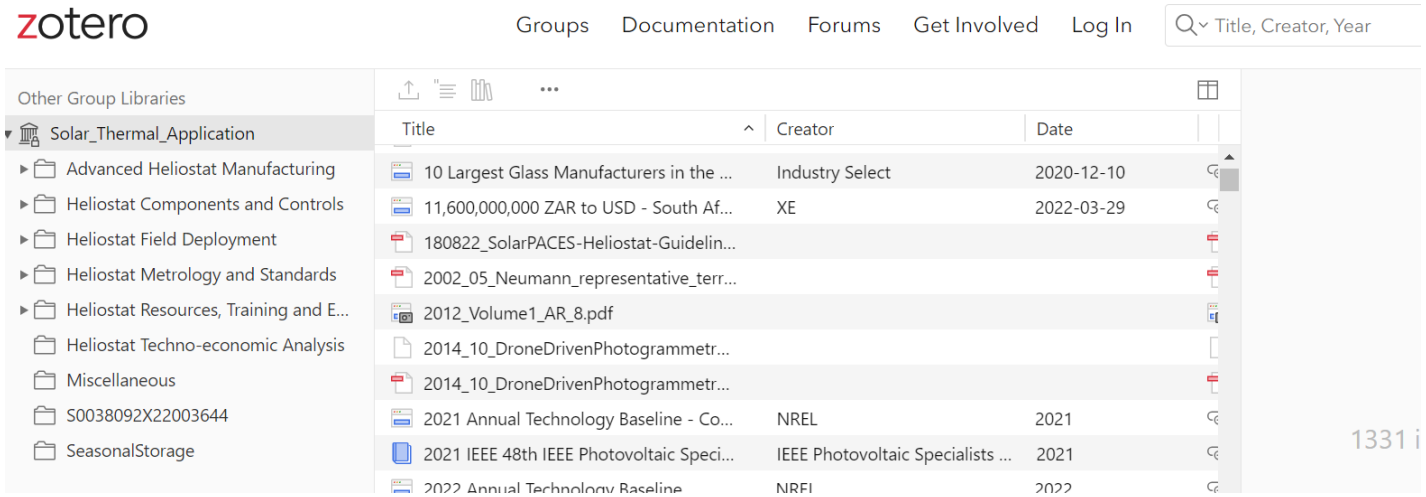
The resources in this section include background on concentrating solar power (CSP), available scientific publications, videos, and additional information on heliostats.

- Background on Concentrating Solar Power
- HelioCon Seminar and Educational Videos
- Zotero References
- HelioCon Publications

Reference Library

https://www.zotero.org/groups/4045055/solar_thermal_application/library

- Created in Zotero
- Scientific publications pertaining to heliostats and power tower solar fields
- Over 300 publicly available sites and articles



Education and Training Resources

https://heliocon.org/resources/heliocon_esev.html
https://heliocon.org/resource_download/An_Overview_of_Heliostats_and_Concentrating_Solar_Power_Tower_Plants.pdf

- Video recordings and slides from over 20 HelioCon Seminars featuring industry and R&D experts within and outside the HelioCon team
- Two-part video tutorial on SolTrace
- Introductory document on CSP power tower plants and heliostats through the design cycle


HelioCon
Heliostat Consortium for Concentrating Solar-Thermal Power
Heliostat Consortium Seminar Series
Brought to you by the Resource, Training, and Education (RTE) topic area

Dr. Guangdong Zhu
Guangdong_Zhu@nrel.gov
303-275-4497

Senior Researcher, National Renewable Energy Laboratory (NREL)

Host: Dr. Rebecca Mitchell

Title: An Undervalued Foundation for Heliostat Technologies: Optical Characterization, Modeling, and Measurement

When: February 16th 1-2 PM MST

Zoom: https://nrel.zoomgov.com/j/1611110823?pwd=Z0NQTlVmZ2NhSXZmbnIwNnhRZWNWQT09

Abstract:

Optical characterization, modeling, and measurement is a fundamental element of heliostat technology development and deployment but has been undervalued in the past. This talk will provide a quick overview on the optical aspects of heliostat technology, which include:

- Sun shape and its beam spread due to various opto-mechanical errors.
- Mirror reflectance and its degradation due to aging and soiling.
- Ray-trace modeling software
- Measurement of opto-mechanical errors.
- Needs of standards in defining a full suite of optical characterization and requirements for metrology development.

The talk will also provide a personal perspective on the metrology development within HelioCon.

Bio:

Dr. Guangdong Zhu has been a senior researcher in the Concentrating Solar Power (CSP) and Geothermal Technology programs at the National Renewable Energy Laboratory (NREL) since 2010. At NREL, he has been leading research efforts related to solar collector optical characterization, linear Fresnel technology, and renewable energy hybridization. He is the executive director of the newly formed 5-year Heliostat Consortium co-led by NREL and Sandia National Labs, partnering with ASTRI. He is the associate editor of the ASME Journal of Energy Resources Technology since 2019. He served as the technical/general program chair for ASME Energy Sustainability international conference from 2017 - 2020. He won NREL's President's award and Outstanding New Partnership Award in 2016. He has published over 40 peer-reviewed journal/conference papers and given numerous invited presentations at various research institutes. Dr. Zhu obtained his Ph.D. from the University of New Mexico in 2006.


HelioCon
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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.


HelioCon
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Heliostat Consortium Seminar Series
Brought to you by the Resource, Training, and Education (RTE) topic area

Dr. Adriana Zurita
Senior Researcher and Project Manager, Tewer Engineering
azurita@tewer.es

Marco Carrascosa
CEO, Tewer Engineering
mcarrascosa@tewer.es

Host: Dr. Rebecca Mitchell, National Renewable Energy Laboratory

Title: Calibration and Characterization Systems in Solar Concentration Plants: Field Expertise, Conclusions, and Lessons Learned.

When: October 18th 9-10 AM MDT

Zoom: https://nrel.zoomgov.com/j/1603628227

Abstract:

To ensure the efficient operation of a concentration solar plant, it is essential that all heliostats are correctly aligned and focused. Calibration and characterization systems ensure that each heliostat is accurately positioned and optimally reflects sunlight, allowing to maximize the energy production, maintaining the solar field efficiency, and enabling precise control and proactive maintenance of the heliostats that make up the solar energy capture system. This seminar provides a comprehensive overview of the importance of calibration and characterization systems in the O&M of solar concentration plants, drawing from the practical knowledge and experiences of Tewer in developing, implementing, and commissioning these systems for heliostats in tower based CSP plants. It will be explored the significance of integrating these systems in terms of comprehending the optical behavior of the heliostats, analyze the current state-of-the-art practices, discuss the pros and cons, and offer insights into Tewer's specialized expertise in this field.

Bios:

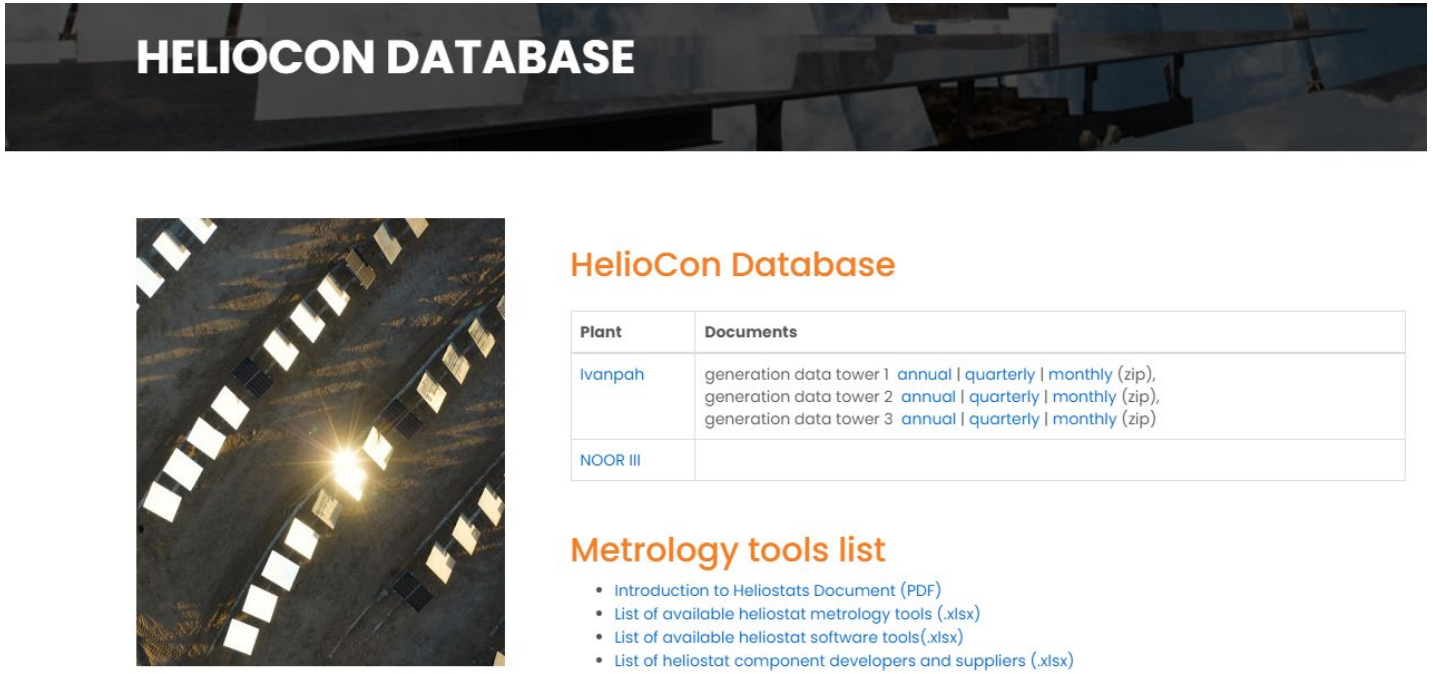
Adriana is Mechanical Engineer (Simón Bolivar University, Venezuela) and holds a PhD in Mechanical Engineering Sciences (Pontificia Universidad Católica of Chile) with more than 7 years of experience in solar energy as Researcher and Project Manager, with advanced knowledge in the modeling of PV, CSP and hybrid plants, energy storage systems, solar resource assessment, energy economics, being involved in conceptual studies, feasibility analyses, and conceptual engineering of solar power plants. Currently she leads R&D and commercial projects in Tewer Engineering, having led the commissioning and development of the Heliostats Calibration System (HCS) at Cerro Dominador's solar thermal power plant (Atacama Chile).

Marco is Mechanical Engineer (Politécnica University of Madrid) and holds an MBA in Business Management by the ESADE Business & Law School. Marco has more than 14 years of experience managing teams and divisions in the field of renewable energy, particularly in Concentrated Solar Power, Automotive and Rail sectors around the world. Marco Antonio was previously TERMOPOWER's CEO and has worked in other many companies as R&D Project Manager and Value Analyst. He has cooperated in various Projects: Tonopah Solar (2012-2014), Planta Termosolar Moron de la Frontera (2011-2012) and HITECO (2009-2010), as he is an expert in concentrated solar technologies including parabolic trough collectors (HCE & Frames), central tower systems (solar field and receiver), stirling dishes, and Fresnel reflectors.

HelioCon Database

https://heliocon.org/plant_information_overview.html

- Components list includes solar field equipment suppliers, thermal energy system providers, and power block equipment suppliers
- Metrology list includes tools to measure specular reflectance, opto-mechanical errors, and heliostat shape
- Software list includes tools for modeling, simulation, and optimization of CSP power systems
- Database containing details on commercial power tower installations



Introduction to Heliostats Document

https://heliocon.org/resources/Background_on_Concentrating_Solar_Power.html

- Document providing an introduction into each heliostat topic area with selected references
- Meant to serve as resource to onboard new hires into CSP

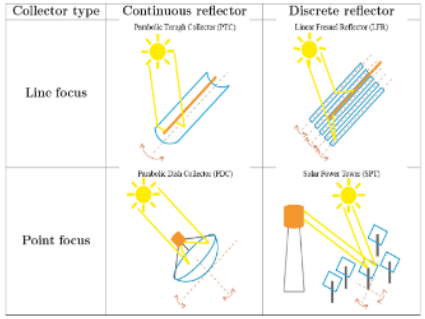


Figure 1: Types of CSP: the basic optics [a]

Background on Concentrating Solar Power

Concentrating solar power (CSP) is a renewable energy technology that uses mirrors to concentrate solar rays onto a receiver. The receiver converts that radiation to thermal energy, which can either be stored in a heat transfer fluid, used to directly generate electricity with a standard steam turbine generator, or used as process heat for industrial processes.

The four main types of CSP are parabolic trough collector, linear Fresnel reflector, parabolic dish collector, and solar power tower, as seen in Figure 1. The parabolic trough design consists of a curved mirror that reflects light onto a tube full of heat transfer fluid running the length of the trough. The linear Fresnel reflector is similar but is made up of a series of non-curved mirrors instead of a curved one. Both designs are linear, meaning they only need to move along one axis of rotation to track the sun. Parabolic dish collectors are made of a large parabolic mirror that focuses the sunlight on to a single point which has a heat transfer fluid where the energy can be stored. The power tower design consists of a large field of multifaceted mirrors (heliostats) that reflect the sunlight on to a central tower receiver that collects the radiation and stored the thermal energy. The power tower design is the most promising in terms of large-scale energy production so it will be the main topic being expanded upon here.

Northeastern's Educational Program

- Awarded through HelioCon's first round Requests for Proposals (RFP)
- Northeastern uses a co-op program to provide professional/practical experiences to students
- Develop educational and practical research experiences with heliostats:
  - Full credit CSP university course for undergraduate and graduate students
  - Senior capstone projects
  - Short industry courses offered to the public

LVX VERITAS VIRTVS

Northeastern University

In the first 3 months:

Guided LSAMP students in conducting research experiments evaluating heliostat cleaning methods

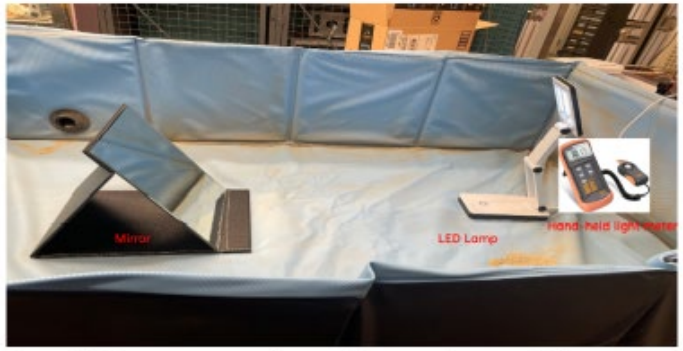
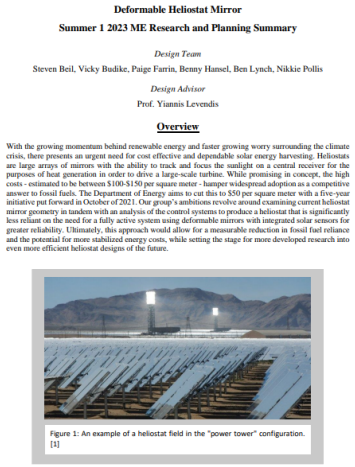


Figure 1.1 Experiment set-up showing the mirror, lamp, and light meter used.

Designed 3 heliostat/CSP focused capstone projects



Deformable Heliostat Mirror

Summer 1 2023 ME Research and Planning Summary

Design Team

Steven Beil, Vicky Budike, Paige Farrin, Benny Hansel, Ben Lynch, Nikkie Pollis

Design Advisor

Prof. Yiannis Levendis

Overview

With the growing momentum behind renewable energy and faster growing worry surrounding the climate crisis, there presents an urgent need for cost effective and dependable solar energy harvesting. Heliostats are large arrays of mirrors with the ability to track and focus the sunlight on a central receiver for the purposes of heat generation in order to drive a large-scale turbine. While promising in concept, the high costs - estimated to be between $100-$150 per square meter - hamper widespread adoption as a competitive answer to fossil fuels. The Department of Energy aims to cut this to $50 per square meter with a five-year initiative put forward in October of 2021. Our group's ambitions revolve around examining current heliostat mirror geometry in tandem with an analysis of the control systems to produce a heliostat that is significantly less reliant on the need for a fully active system using deformable mirrors with integrated solar sensors for greater reliability. Ultimately, this approach would allow for a measurable reduction in fossil fuel reliance and the potential for more stabilized energy costs, while setting the stage for more developed research into even more efficient heliostat designs of the future.

Figure 1: An example of a heliostat field in the "power tower" configuration. [1]

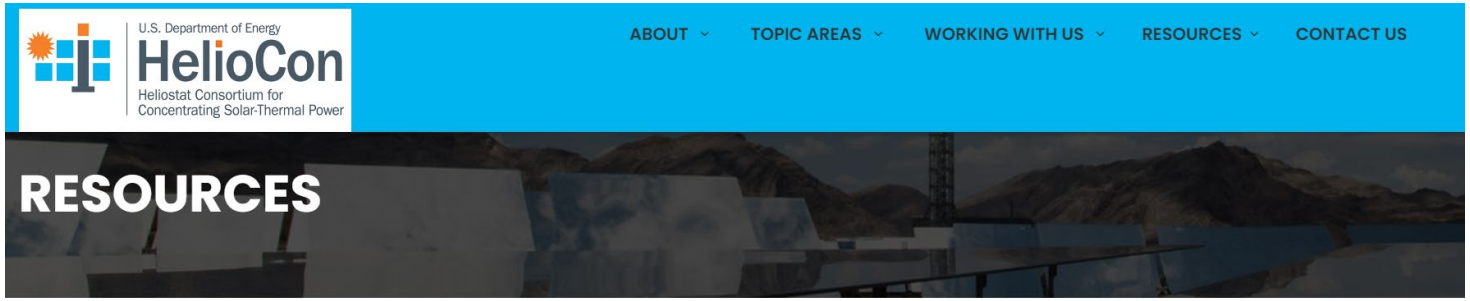
conceptual design • components • integration • mass production • heliostat field

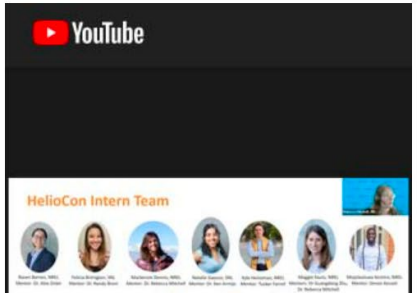
Next Steps for the Resource Database

- Reference library
- Education and training resources
- Lists of heliostat component suppliers and developers, metrology tools, and software tools
- Existing power tower plant database

Expand

- List of standards/guidelines
- Summary of best practices and lessons learned
- References to external resources
- Example education modules, homework problems, and projects for heliostat coursework





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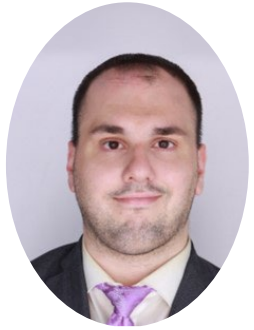
- Zotero References
- HelioCon Publications

HelioCon Intern Team

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

Watch the HelioCon intern seminar: https://www.youtube.com/watch?v=qvuS-l4AOFg&ab_channel=NRELLearning

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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