Heliostat Consortium: Gaps Analysis on Heliostat Soiling for Achieving a Fully Competitive Heliostat Industry

Michael E. Cholette[1]*, Giovanni Picotti[2], Tucker Farrel[3], Rebecca Schaller[4], Matthew Muller[5], Alexander Zolan[6], Randolph Brost[7], Guangdong Zhu[8]

[1] Associate Professor, Queensland University of Technology, Brisbane, QLD, Australia, michael.cholette@qut.edu.au

[2] Research Associate, Queensland University of Technology, Brisbane, QLD, Australia, g.picotti@qut.edu.au

[3] Research Engineer, National Renewable Energy Laboratory, Golden, CO, USA, tucker.farrell@nrel.gov

[4]Researcher, Sandia National Laboratories, Albuquerque, NM, USA, rschall@sandia.gov

[5] Researcher, National Renewable Energy Laboratory, Golden, CO, USA, matthew.muller@nrel.gov

[6] Researcher, National Renewable Energy Laboratory, Golden, CO, USA, alexander.zolan@nrel.gov

[7] Principal Researcher, Sandia National Laboratories, Albuquerque, NM, USA, rcbrost@sandia.gov

[8] Senior Researcher & Group Manager, National Renewable Energy Laboratory, Golden, CO, USA, guangdong.zhu@nrel.gov

*Corresponding Author

1. Introduction

The National Renewable Energy Laboratory (NREL), partnering with Sandia National Laboratories (Sandia) and the Australian Solar Thermal Research Institute (ASTRI), proposes to develop and manage a national laboratory-led U.S. consortium to support research, development, validation, commercialization, and deployment of low-cost and high-performance heliostats with optimized operation and maintenance (OM) for concentrating solar power (CSP) and concentrating solar thermal (CST) applications. This heliostat consortium (HelioCon) will work closely with the U.S. Department of Energy (DOE) and a board of advisors composed of CSP developers, component suppliers, utilities, and international experts to achieve DOE SunShot objectives for U.S.-manufactured heliostat cost, performance, and reliability. To further advance U.S. heliostat technologies, HelioCon will engage subject-matter experts and general stakeholders for direct, project-level collaboration, external consulting, and mission-specific panels or workshops.

In Year 1 of HelioCon, a roadmap study report will be developed to identify the high-priority gaps in advancing heliostat technologies. The paper here will present our initial findings on the topic of heliostats soiling.

2. Scope of the topic

Maintaining high optical efficiency of a solar field is of paramount importance for the economics of a solar tower power plant. One of the key degradation modes is the loss of reflectance due to the accumulation of dust on the surface of the heliostats. Reports have indicated that these soiling losses can vary significantly from site to site — from a few tenths of a percentage point to a few percentage points per day, depending on the site characteristics [1,2]. These losses have led CSP operators to periodically clean heliostats using a number of different cleaning apparatus [3], but these operations can be expensive and have been identified as a key opportunity to reduce costs [4]. Moreover, the disparity in soiling rates across different sites has made the planning of soiling mitigation measures (e.g. cleaning resources, schedules) difficult, particularly at the time of site selection. The heliostat soiling topic is concerned with the development of procedures for advanced measurements of soiling and local environmental characteristic, soiling predictive models, and soling mitigation techniques for both existing and planned CSP plants. This includes three main areas:

- Measurements:

- Assessment of deposited and airborne dust characteristics (e.g. amount, size distribution, composition, concentration) and their variation across different CSP-relevant sites;
- Development of standard methodologies to assess and report reflectance losses of soiled heliostats;
- Establishment of strategies and technologies for monitoring soiling losses of large solar fields;

- Modelling and Characterizing Soiling Processes:
  - Deepen understanding of the key mechanisms within each of the soiling processes;
  - Develop and validate models that describe the key mechanisms;
  - Improvement and development of new techniques for predicting soiling losses;
- Mitigation:
  - Development of methodologies for optimizing mirror washing resources and deployment;
  - Assessment and development of both new active (e.g. automated trucks) and passive (e.g. coatings) mitigation techniques.

For each area, a thorough analysis is performed to establish the current state of the art and identify the main gaps, which are then listed and organized in tiers, and assigned to the heliostat development stage to which they: conceptual design; components; integrated heliostat; mass production; deployed field..

3. Gaps analysis

The identified gaps are ranked and analyzed to assign priority Tiers, with those categorized as "Tier 1" being the most important. There are 4 preliminary "Tier 1" gaps in the heliostat soiling section, namely: 1) the lack of tools to perform soiling evaluation during site selection, 2) the under exploration of design and automation of new cleaning systems, 3) the lack of standards or data to assess anti-soiling coating durability/performance, and 4) the poor understanding of trade-offs between soiling losses, cleaning regime, design choices (e.g. site selection, solar multiple), and heliostat reliability. Since the report is still under development

A summary is then provided to state required functionality of the addressing solutions, the justification and benefits by addressing the given gap, and the proposed addressing strategies for the 4 Tier-1 gaps. Among these gaps, 1) and 4) are paramount for enhancing the performance of CSP plants and reduce the risk for investors, whereas 2) and 3) offers great opportunity for reducing cleaning and soiling costs while requiring extensive research for thorough performance assessment and improvements.

Eventually, an evaluation of the impact of the top-ranked gaps is provided. To give an example, for what concern gap 1), using average soiling rates between values available in literature (0.3%/day to 0.03%/day) the corresponding LCOH variation is ~0.15 cents/kWh, or ~8% of the expected LCOH. Moreover, a deeper analysis conducted on the high soiling scenario confirms that a better planning of cleaning resources could reduce the LCOH impact of a high soiling rate but can only offset about half of the LCOH increase. Hence, soiling assessment at site selection phase could be a crucial factor for the performance and feasibility of the plant. Similar analyses are performed on the other top-ranked gaps.

References

[1] A. Alami Merrouni, R. Conceição, A. Mouaky, H.G. Silva, and A. Ghennioui, Renewable Energy 162, 1777 (2020).
[2] A.A. Hachicha, I. Al-Sawafta, and D. Ben Hamadou, Renewable Energy 143, 263 (2019).
[3] S. Bouaddi, A. Fernández-García, C. Sansom, J. Sarasua, F. Wolfertstetter, H. Bouzekri, F. Sutter, and I. Azpitarte, Sustainability 10, 3937 (2018).
[4] T. Mancini, J. Gary, G. Kolb, and C. Ho, Power Tower Technology Roadmap and Cost Reduction Plan. (2011), pp. SAND2011-2419, 1011644.