EU-SOLARIS – Internal Project Proposal

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2. Name of sponsoring General Assembly Member(s)

Professor Julian Blanco Galvez

3. Title of proposal

FLARES - Fast Laser Assessment for near Real-time Evaluation of Soiling

4. Researchers involved in the proposal and their affiliations

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5. Abstract

Maximization of concentrated solar thermal (CST) technology performance and minimization of operational expenditures (OPEX) require considering not only the solar resource, but also other effects such as soiling. Dust accumulation modifies the optical properties of solar collectors and mirror surfaces leading to a significative reduction of the useful solar energy [1], [2]. Current research points out that soiling can decrease specular reflectance by about 10% per month in low-soiling regime regions and higher than 40% in locations with high atmospheric aerosol loads, such as deserts [3]. Thus, soiling stands out as one of the most impactful factors to be considered when assessing CST performance and corresponding OPEX. Nonetheless, soiling assessment is still performed in CST manually by operators using portable reflectometers, which is a time-consuming task. Besides, automatic instruments, such as the Tracking Cleanliness Sensor (TraCS) [4] or the AVUS Instrument [5], only do spatial punctual measurements, which means that for bigger solar fields and for a precise soiling assessment, multiple ones have to be installed, increasing the capital expenditures (CAPEX). Additionally, there is no current instrumentation to measure soiling effect in Fresnel secondary optics or Stirling dishes, due to their height and size.

Therefore, the development of new techniques is needed to automatize and generalize soiling assessment for all CST technologies, while simultaneously making it faster and able to measure a greater number of units. In this project, a novel technique using a 3D laser scanner will be developed and tested at real solar fields, such as the one at IMDEA Energy (IMDEA), Spain, and at the Cyprus Institute (CYI), Cyprus. Measurements will be compared with reflectometer data aiming to establish a model with an absolute reflectance error lower than 2%. Some preliminary tests have been already performed at IMDEA, see Figure 1, showing promising results.

6. Background, deemed importance and relevance

Terrestrial laser scanning with LiDAR scanners has been applied in concentrating solar power during the last years (e.g., by [6], [7]). The possibility of a very fast acquisition of dense 3D point clouds containing several million data points has mainly been used for shape assessment, but also for a preliminary assessment of the cleanliness of mirrors [8].

The possibility to address soiling/cleanliness, shape measurements (for repairs/improvements to individual heliostats), and tracking calibrations simultaneously and with a single measurement device holds great potential for commercial operators of large solar fields. Additionally, for the research at the solar fields of IMDEA, CYI, and others around the globe, the benefits of applying the laser scanning method (once or even more regularly after definition of an appropriate work flow) would most likely offer a better and faster way of generating a more detailed understanding of the details of operation of the solar fields and enhance their efficiency. Applying the laser scanner method to two different installations is of key importance for enhancing and generalizing the application of the laser scanning in different setups, since the type of soiling is different according to the site, as well as the heliostats' geometry. To achieve this, modelling of the bidirectional reflectance of naturally soiled samples for each site will be performed to understand the effect of the incidence angle on the backscatter power. Moreover, there is a gap in soiling assessment for secondary receivers, due to their small size and high curvature, such as it happens in Fresnel systems. Not only this, but assessing soiling on Stirling dishes is also not developed, since reaching the center of the dish is quite difficult and the height of the structure is also another obstacle. Thus, it is also intended to do a novel employment of this technique on the soiling assessment at secondary optics, in this case in the Fresnel loop installed at CYI, as well as in the Stirling dish. A successful development means that it will be possible to measure soiling effect for CST technologies, including primary and secondary optics, which is of key importance for operation, maintenance and efficiency of any technology.

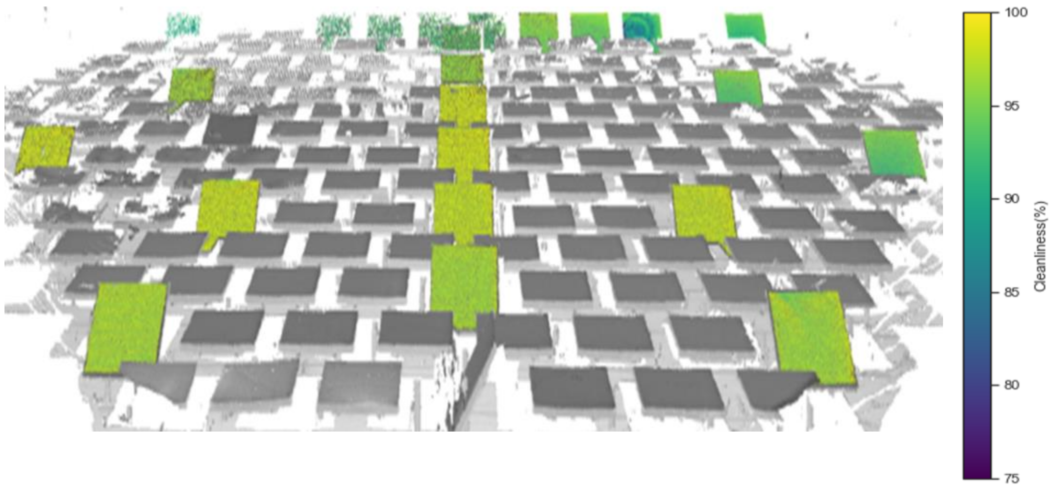

Figure 1. LIDAR based cleanliness measurement of the IMDEA Energy solar field [8].

7. Work plan, duration and milestones

Six measurement campaigns are planned in the project:

1. One month of outdoor exposure of small mirror samples at IMDEA.
2. One month of outdoor exposure of small mirror samples at CYI.
3. Two weeks at FISE for set-up and calibration of the method. Lab testing with naturally soiled samples, and microscopy, particle counter and photogoniometer measurements with the samples from IMDEA and CYI for BRDF modelling.
4. Two weeks at IMDEA solar field, application of the method and test.
5. Three weeks at CYI solar field, Fresnel loop and Stirling dish, application of the method and test.

It is planned that at least one to two scientists from each institution will take part in the experimental campaigns, which means that experimentation 3, 4 and 5 will require the travel and lodging expenses of two to four people. The duration is scheduled for 18 months starting in November 2023.

WP 1 Naturally soiled samples and BRDF calibration

Task 1.1. Calibration and modelling

- Measurement campaign of small mirror samples naturally soiled.
- Microscope and particle counter measurements to analyze the coverage and particle size distribution of the samples from Mostóles, Spain, and Pentakomo, Cyprus.
- Photogoniometer measurements and BRDF modelling of the samples.
- Distance and incident angle calibration measurements with the laser scanner for artificially soiled samples and with the naturally soiled ones.

WP 2 Measurement campaigns and evaluation

Task 2.1. Solar fields laser measurement campaign

- Laser scanner measurements at IMDEA and CYI solar field and comparison with hand-held reflectometer.
- Processing of laser scanner data, and cleanliness, shape and tracking assessment.
- Comparison against different methods, such as camera-based soiling measurements developed or being developed at IMDEA or CYI regarding the heliostat field.

Task 2.2. Stirling dish laser measurement campaign

- Laser measurements of the Stirling dish at CYI, and comparison with hand-held reflectometer where it is possible to perform (because it can hardly be reached with a handheld reflectometer).

Task 2.3. Fresnel primary and secondary optics laser measurement campaign

- Laser measurements of the Fresnel Primary at CYI and comparison with hand-held reflectometer, as well as laser measurements of its secondary optics.

WP 3 Dissemination

Task 3.1. Attendance of SolarPACES 2024 conference

- Dissemination of the results regarding soiling assessment in different technologies.
- Networking for future access to bigger operating facilities to further test the distance limitation of the method for accurate results.

Task 3.2 Publication of at least one to two Q1-journal paper

- One publication regarding the fast novel near-real time soiling laser scanning technique including the shape and tracking assessment.
- Another publication concerning the application and generalization of the technique to both Stirling dish and Fresnel, but most importantly, to its secondary, since there is no technique, method or instrumentation to assess soiling effect.

8. List of deliverables

Two reports will be delivered. A first mid-term report, which will include a deliverable containing WP1 and possibly results from Task 2.1 from WP2. A final report, including another deliverable containing all the results regarding Task 2.2 and 2.3 from WP2.

9. Expected short term and long-term outcomes

It is expected that with the combined experience of Fraunhofer ISE, IMDEA Energy, and the Cyprus Institute in laser scanning, soiling measurements and heliostat field O&M, a common and "globally" applicable approach to the use of the LiDAR measurement method during solar field operation can be developed. One of the targets of the proposed project is to generate measurements which allow a direct comparison of the existing facilities of the research infrastructures. Additionally, it is expected that in the short term, the collected results would already allow improvements of the solar field infrastructure such as a fast and robust measure to assess soiling several CST technologies, as well as identification of shape and tracking errors. As a long-term result, the development and implementation of the simple, universal, fast, and precise measurement method in these institutes will have a lasting positive impact on the operation and maintenance of the solar field facilities and therefore improve the quality of the services offered to the users of CST RIs and eventually reduce the OPEX.

For RIs:
- Predictability, better and fast soiling assessment
- Transfer of soiling models: better interoperability
- Shape and tracking error detection
- Faster maintenance / problem detection / cost reduction
- Facilities efficiency enhancement

1-2 Journal papers
1-2 Conference contributions

10. Budget breakdown between partners

The total budget of 45 000 € is divided between partners according to the following table:

11. Explanation of the cost structure

Cost category	Item	IMDEA	FISE	CYI
Travel of R&D members	Transport (2 measurement campaigns, 2 to 4 persons) + SolarPACES 2024	4000 €	4000 €	4000 €
	Meal and lodging expenses (2×2 weeks + 2*3 weeks, 2 to 4 persons)	5000 €	5000 €	4000 €
Consumables	Lambertian reference samples for LiDAR	-	1000 €	-
	Mirror samples + holder supports + reflectometer servicing	3000 €	-	4000 €
Minor pieces of equipment	DLRS camera	3000 €	-	-
Publishing journal fees	e.g. Solar Energy (1 or 2 publications)		5000 €	-
Congress fees	SolarPACES 2024	1000 €	1000 €	1000 €
Sub-total		16 000 €	16 000 €	13 000 €
Total		45 000 €		

References

[1] R. Conceição, J. González-Aguilar, A. A. Merrouni, and M. Romero, "Soiling effect in solar energy conversion systems: A review," *Renew. Sustain. Energy Rev.*, vol. 162, no. April, 2022, doi: 10.1016/j.rser.2022.112434.

[2] A. A. Merrouni, F. Wolfertstetter, A. Mezrhab, S. Wilbert, and R. Pitz-Paal, "Investigation of Soiling Effect on Different Solar Mirror Materials under Moroccan Climate," *Energy Procedia*, vol. 69, pp. 1948–1957, 2015, doi: 10.1016/j.egypro.2015.03.194.

[3] A. Azouzoute, A. A. Merrouni, M. Garoum, and E. G. Bennouna, "Soiling loss of solar glass and mirror samples in the region with arid climate," *Energy Reports*, vol. 6, pp. 693–698, 2020, doi: 10.1016/j.egyr.2019.09.051.

[4] F. Wolfertstetter *et al.*, "Monitoring of mirror and sensor soiling with TraCS for improved quality of ground based irradiance measurements," *Energy Procedia*, vol. 49, pp. 2422–2432, 2014, doi: 10.1016/j.egypro.2014.03.257.

[5] A. Heimsath *et al.*, "Automated Monitoring of Soiling with AVUS Instrument for Improved Solar Site Assessment," in *SolarPACES 2017*, 2017, vol. 190008–1.

[6] A. M. Bonanos, M. Faka, D. Abate, S. Hermon, and M. J. Blanco, "Heliostat surface shape characterization for accurate flux prediction," *Renew. Energy*, vol. 142, pp. 30–40, 2019, doi: 10.1016/j.renene.2019.04.051.

[7] C. Q. Little, D. E. Small, and J. Yellowhair, "LIDAR for heliostat optical error assessment," *AIP Conf. Proc.*, vol. 2445, 2022, doi: 10.1063/5.0087691.

[8] M. F. Eceiza, M. Bitterling, T. Schmidt, T. Boehret, D. Wohlfeld, and G. Bern, "Terrestrial Laser Scanning for Fast Spatially Resolved Cleanliness Assessment of Heliostat Fields," SolarPACES, 2022.