

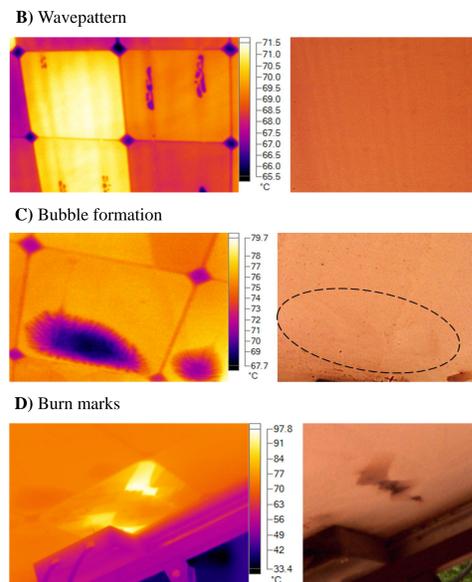
## Introduction

- Current study is based on panels commissioned as part of a BIPV for 8 years, and currently stacked on site as spares. This study could reveal annual degradation in panels that are stacked on site, exposed to ambient conditions, but not in operation.
- These panels were also studied for the impact of soiling on operating cell-temperatures and other defects.
- Thirty-three 9-year-old monocrystalline Photovoltaic (PV) panels were inspected for degradations and simultaneous PV performance using thermal imager and I-V curve tracers respectively.
- Picture (A) shows the setup for degradation inspection and I-V curve measurement of PV panels. The setup is located at Centre for Sustainable Technologies, Indian Institute of Science campus, Bangalore.

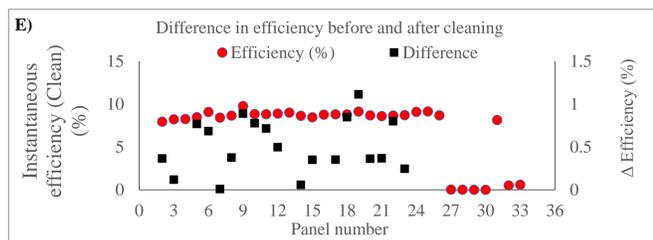


## Results

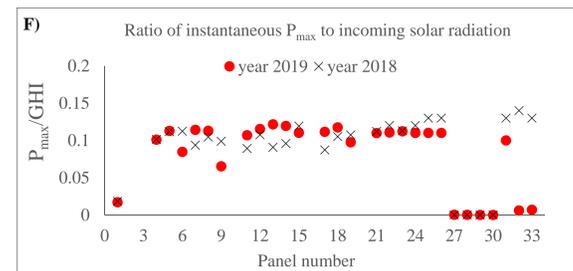
- Typical defects observed through thermal imagery were hot spots, hot cells, cell cracks, wavelattern, bubble formation, burn marks. Thermal images of few typical defects and their corresponding visible spectrum image are shown below (B - D)



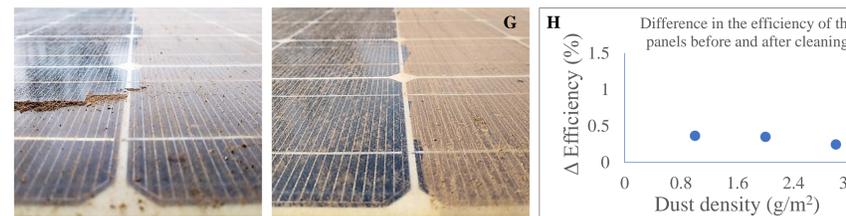
- I-V curves and simultaneous radiation measurement were made using AMPROBE solar-600 Solar Analyzer and AMPROBE Solar-4000 sensor respectively, before and after cleaning the panels. Following, efficiency calculations are shown below (E).



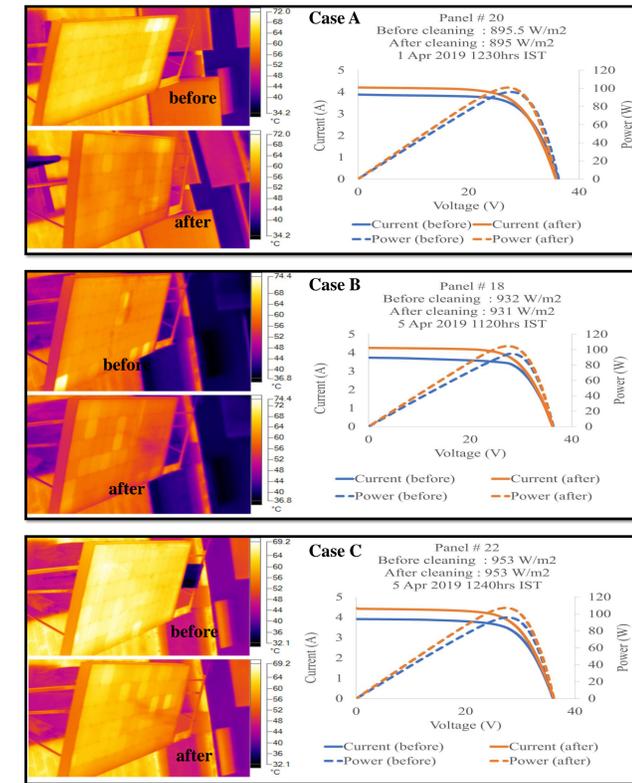
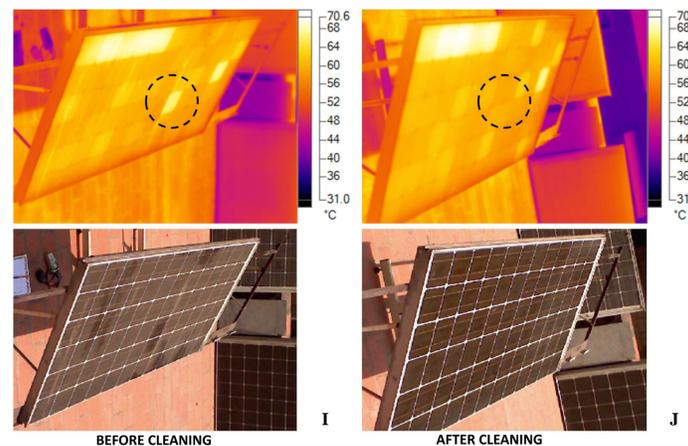
- The current year's performance was compared with the same of previous year [1]. Plot shown below (F) indicated a weak consistency in change in performance between the year 2018 and 2019.



- The dust measurement were made row wise (panel has 72 cells, 12 rows and 6 columns). The row numbering starts from the junction box side, which is on the right hand side during our measurements. Picture (G) below shows the dust collection in progress.



- The scatter plot of dust density and difference in efficiency is shown above (H) for three panels. Higher dust settlement at the edges of the panel was seen, possibly due to the influence of wind and rain/dew collection (pooling) along the frame edges over time.
- The common phenomenon observed in most of our panels were the absence of heated cells post cleaning. In the following picture (I-J), indicated by the dotted circles, the heated cells underlying soiling region disappear after cleaning. This phenomenon was observed in [2] as well. According to the [3], possible reasons for the hot cells are cell mismatch, cell internal defect and defective front contact. Our observation suggests the possibility of dust and soiling to also cause heated cells.



- In **Case A**, heated cells are significant, and they disappear after cleaning. In **case B** and **C**, the heated cells are noticeable after cleaning too. But, the differences in the three I-V curves of panels are similar and hence in our observations, presence of heated cells show no unique change in performance of panels. In [3], there was a noticeable power loss, while in [4], no performance decrease was observed. The current study observed 2-10 heated cells in panels with 72 cells, and found no significant on panel performance.

## Conclusions

- The current performance was compared with previous year's performance and no consistent reduction was found.
- Thermal anomalies were observed, notably, single and multiple heated cells were observed in the presence of dust and found to disappear after cleaning. Our future work is to investigate the extent of the role of dust in aggravating or alleviating the heated cells.
- The study reveals that for less than 15% of heated cells no significant impact on performance was observed.

## REFERENCES

- [1] Rao, R.R., & Mani, M. "Case study on degradation of 8-year-old BiPV modules in Bangalore, India". 2018 IEEE 7th WCPEC (A Joint Conference of 45th IEEE PVSC, 28th PVSEC & 34th EU PVSEC), 0758- 0761.
- [2] Bharadwaj, Pallavi & Karnataka, Kaustubh & John, Vinod." Formation of Hotspots on Healthy PV Modules and Their Effect on Output Performance", 2018, 0676-0680. 10.1109/PVSC.2018.8548126.
- [3] C. Vodermayr, M. Mayer, M. Mayer, T. Muller, M. Niess, G. Wotruba, G. Becker, M. Zehner, and J. Schumacher, "First results—correlation between IR images and electrical behavior and energy yield of PV modules," in Proceedings of the 23rd European photovoltaic solar energy conference and exhibition (EU PVSEC). Valencia, Spain, 2008.
- [4] Elias Roumpakias, Fotis Bouroutzikas, Anastassios Stamatelos. On-site Inspection of PV Panels, Aided by Infrared Thermography. Advances in Applied Sciences. Vol. 1, No. 3, 2016, pp. 53-62.