

MEASURING LOSSES IN POWER PRODUCTION DUE TO SOILING OF SOLAR PANELS

Ajay Singh (asingh@campbellsci.com) and Matthew Perry (mperry@campbellsci.com)
Campbell Scientific, Inc. Logan, UT USA

INTRODUCTION

As photovoltaic arrays have increasingly generated more electrical energy in the past decade, they have established themselves as viable sources of renewable energy. At present, the efficiency of solar panels is at best 15-23%, meaning only 15-23% of incident energy in the form of light get converted into electrical energy. There are further performance losses in the life time of a solar array. Loss due to dust accumulation on power generation is becoming increasingly important as the total installed size increases. System owners have to find a way to assess losses in energy production due to various factors. Incidentally, there are large PV installations in dry desert regions where natural rain events are scarce and loss in energy production is encountered due to dust accumulations on the solar panels resulting in soiling losses. The decision to clean these panels can be costly and the owners need a monitoring system to make this decision in a cost effective manner.

Several studies have been made in the past to quantify these losses. Ryan et al.¹ compared output of a clean panel versus an identical test panel accumulating dust naturally. Several other researchers^{2, 3} estimated the loss in energy production from the plant performance data.

This paper describes a field deployable soiling loss monitoring system that is based on the method adopted by Ryan et al.¹ and is easy to install. It provides a daily averaged soiling loss index (SLI) that can be used to make cleaning decisions. The SLI is calculated from effective irradiance reaching the cells calculated from the short circuit current of the panels. This method is simple and avoids the complication and cost of a full I-V curve tracer. We also present some results from testing at our site in Logan, UT.

KEY DEFINITIONS

We begin by a definition of the soiling loss index in terms of quantities that can be measured directly from a PV module. We define Soiling Loss Index (SLI) as loss in the irradiance reaching the solar cells. If all other factors are same then this loss is primarily due to the loss in transmission properties of the glass as a result of the soil accumulation. The irradiance is calculated from short circuit current⁵ as

$$G_{eff} = I_{SC} \frac{[1 - \alpha(T - T_0)]}{I_{SC,STC}}$$

Where, G_{eff} : Effective irradiance reaching the solar cells
 I_{SC} : measured short circuit current of the module
 $I_{SC,STC}$: short circuit current at STC
 T : back of module temperature
 T_0 : back of module temperature at STC, typically 25° C
 α : Temperature coefficient of short circuit current.

The soiling loss index (SLI) uses the effective irradiances of a clean reference panel and a dirty test panel, and is defined as:

$$SLI = \left(1 - \frac{G_{eff,Ref}}{G_{eff,Test}} \right) \times 100\%$$

Where, $G_{eff,Ref}$ is the effective irradiance calculated from the clean reference panel and $G_{eff,Test}$ is the same quantity calculated from the test panel.

REFERENCES

1. C. P. Ryan, F. Vignola, and D. K. McDaniels, "Solar Cell Arrays: Degradation Due to Dirt," in *Proceedings of the American Section of the International Solar Energy Society*, Denver, CO, 1989, pp. 234-237.
2. A. Kimber, L. Mitchell, S. Nogradi, and H. Wenger, "The Effect of Soiling on Large Grid-Connected Photovoltaic Systems in California and the Southwest Region of the United States," in *Conference Record of the 2006 IEEE 4th World Conference on Photovoltaic Energy Conversion*, Waikoloa, HI, 2006.
3. S. Canada, "Quality Assurance: Impacts of Soiling on Utility-Scale PV System Performance," *SolarPro Magazine*, no. 6.3, pp. 14-20, May-2013.
4. K. Emery, "Radiometry in photovoltaics: calibration of reference solar cells and evaluation of reference values". In *Handbook of Photovoltaic Science and Engineering*, 1st ed., Wiley, 2003, pp. 701-752.
5. IEC 60904-1, Photovoltaic devices – Part 1: Measurement of photovoltaic current-voltage characteristics, second edition, 2006-9
6. IEC 60904-10, Photovoltaic devices – Photovoltaic devices –Part 10: Methods of linearity measurement, second edition, 2009.

EXPERIMENTAL PROCEDURE

Two identical full size PV panels are mounted side by side. The short circuit current is measured on both panels with a precision current sensing shunt. Back-of-module temperatures are also measured using a thermistor. Measurements are performed during sunset and sunrise. The two modules are short-circuited using a solid state relay for about 5 second every 30 seconds. The short-circuit current is measured using a current shunt. Back-of-module temperatures on both modules are also monitored.

An effective irradiance reaching the cells is calculated in accordance with the IEC 609045, according to the equation 2 above. An initial offset between the two panels is estimated in the beginning and periodically afterwards each time both panels are cleaned. This offset is applied to the subsequent measurements.

In accordance with IEC 60904, we limit the SLI calculation within one hour of local solar noon and for effective irradiance > 800 W/m². This avoids any differences in soiling loss due to zenith angle of sun, module current dependence on irradiance level or spectral differences. We also use a filtering scheme to filter out any unstable data due to clouds etc. The stability criteria adopted is based on the recommendations made in IEC 60904.

RESULTS

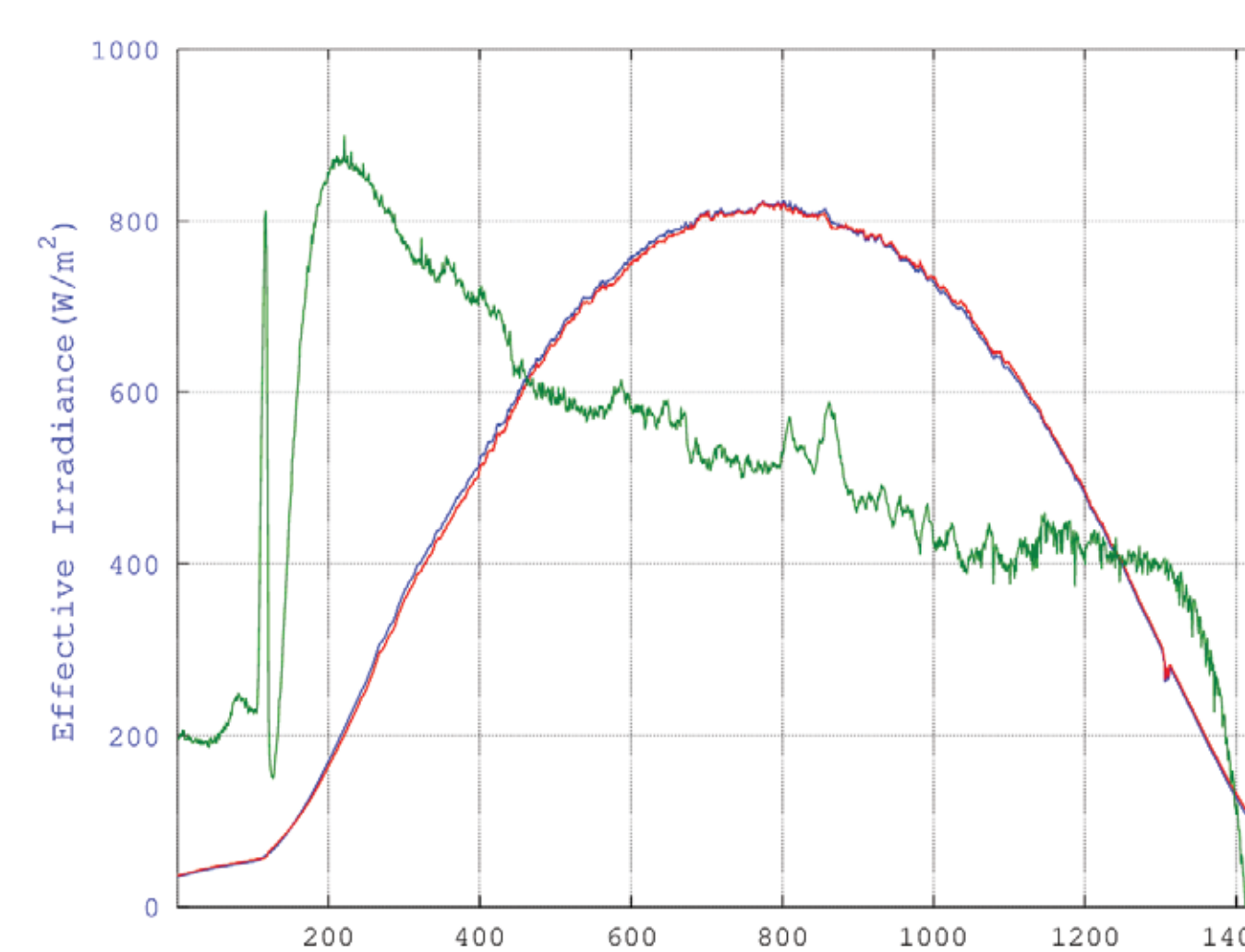


Figure 1: Effective Irradiance as calculated from short circuit current of the PV modules on a clear sky day. The green curve shows the soiling index. The SLI depends on the time of the day.

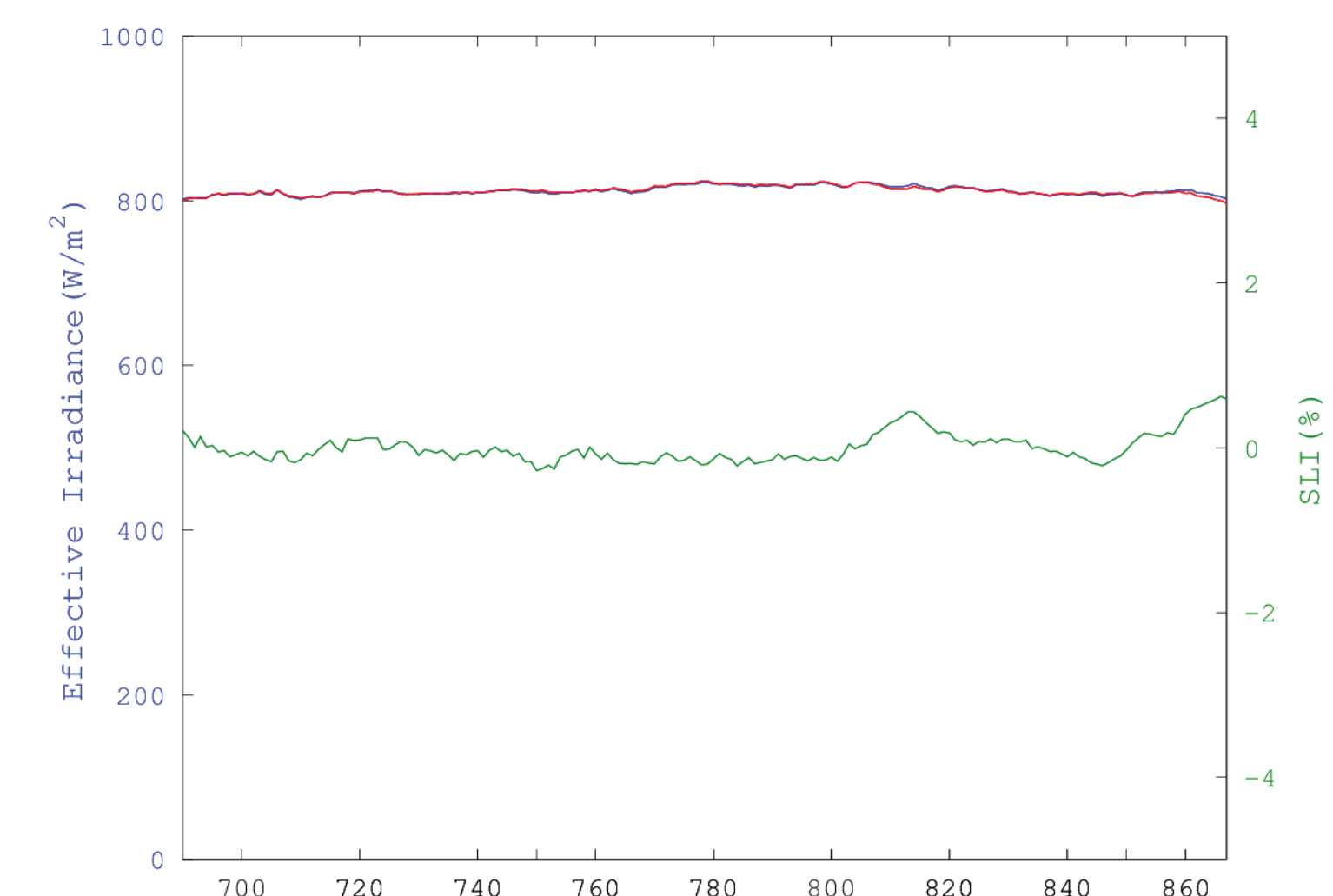


Figure 2: Effective irradiance and SLI during ±1 hour of solar noon and $G_{eff} > 800 \text{ W/m}^2$. The time of the day dependence is absent during this time.

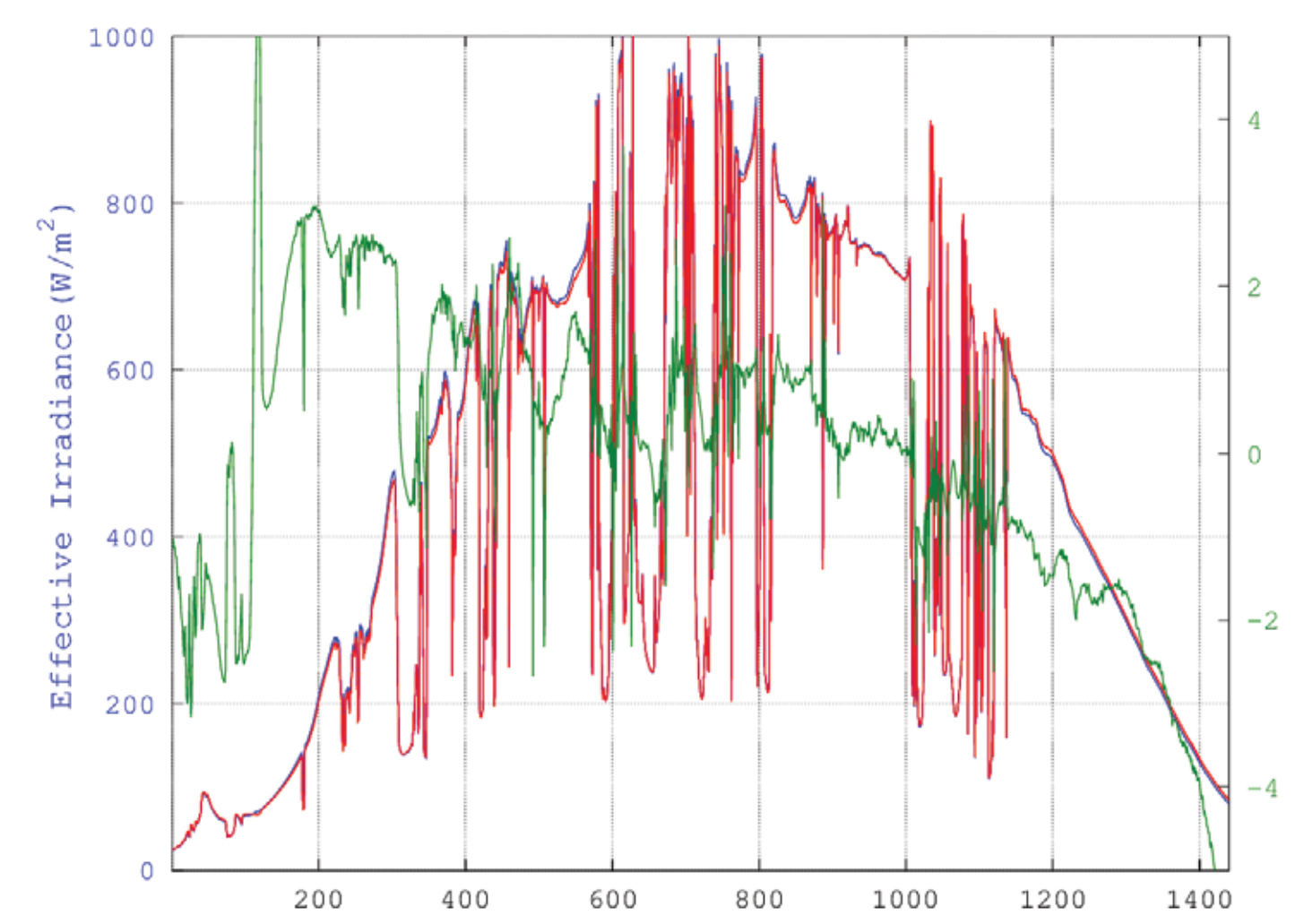


Figure 3: Effective Irradiance and SLI on a cloudy day.

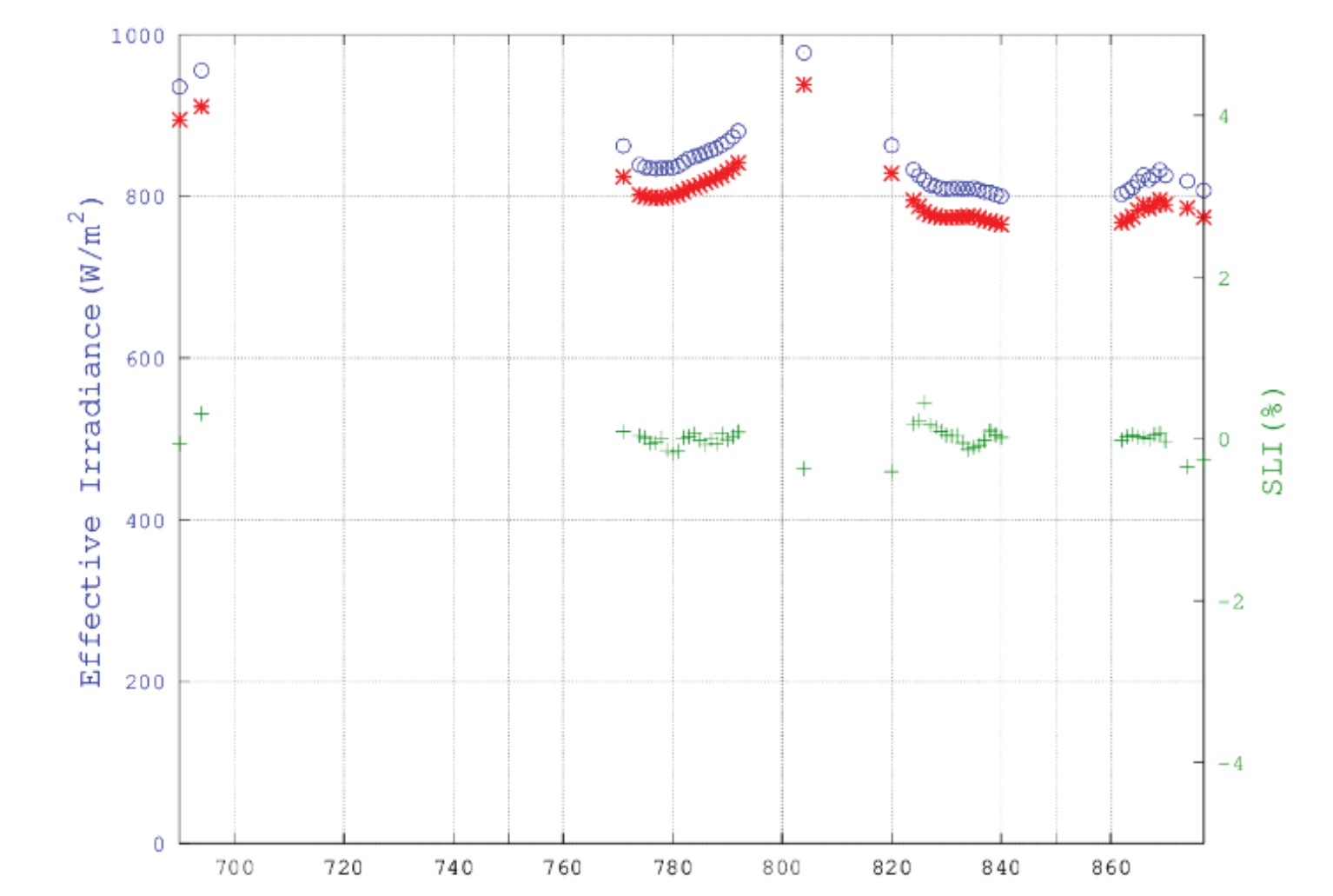


Figure 4: G_{eff} and SLI taken during a cloudy day with $G_{eff} > 800 \text{ W/m}^2$ during ±1 hour of solar noon.

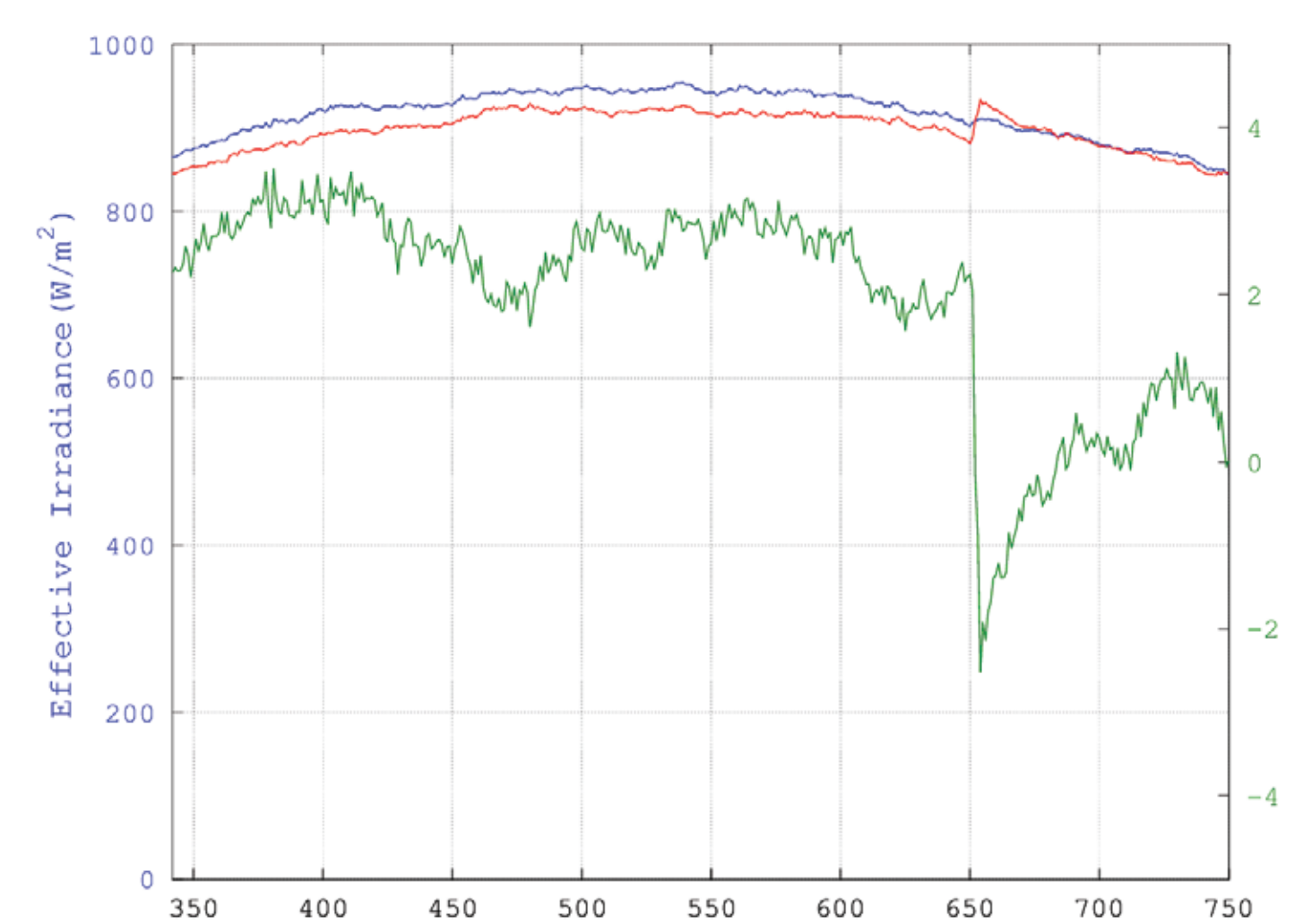


Figure 5: Change in SLI after a cleaning event. Both modules were cleaned at a time corresponding to the record number 650. The cleaning affects the temperature of the modules and it takes some time to recover from this temperature changes. The SLI settles back near zero after some time. Higher SLI before record number 650 is the indication of dirty modules with loss in effective irradiance ~ 2%



Image 1: Photo of soiling test site at Campbell Scientific, Inc., Headquarters, Logan, UT, USA.

For more information on the CRSI2 Soiling Index Datalogger, please visit:
<https://www.campbellsci.com/crsi2>



28 August—1 September 2016