GRAFFITI ON SOLAR NOISE BARRIERS
A CASE STUDY

Chris Tzikas[1], Minne de Jong[1], Lenneke Slooff[2], Michael Debije[3], Stijn Verkuilen[4], Wiep Folkerts[1]

[1]SEAC (Solar Energy Application Centre), Eindhoven, The Netherlands
[2]ECN (Energy research Centre of the Netherlands), Petten, The Netherlands
[3]TU/e Eindhoven University of Technology, Eindhoven, The Netherlands
[4]Heijmans, Rosmalen, The Netherlands

ABSTRACT: Infrastructure Integrated PhotoVoltaics (I2PV) is the next big step for large scale energy production. PV cells can be integrated in a wide range of infrastructure applications without requiring any additional space. In this way the infrastructure can have the additional functionality of producing electricity from sunlight. One of the promising I2PV applications are the PhotoVoltaic Noise Barriers (PVNBs). In this context the Solar Noise Barriers (SONOB) project was developed with the goal of studying the performance of PVNBs. In this case study, we study the effects of a common form of street pollution -graffiti- on PVNBs.
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1 INTRODUCTION

The aim of the SONOB project was the development of a breakthrough modular solar noise barrier concept. For this purpose, two PVNBs were constructed in the Living Lab, located at the Randweg in the South-West of ‘s Hertogenbosch, the Netherlands. The two barriers were placed in an orthogonal orientation to each other. One barrier faced South and North, the other faced East and West. The barriers inclined 15° away from the road: to the North and to the East, respectively. The Living Lab was officially opened on June 18th 2015, attracting national and international attention.

The design of the barrier was based on the Modulair GeluidsScherm (MGS) design directives of Rijkswaterstaat. It consisted of 4 cassettes of 5 x 1 m^2 equipped with, from bottom to top, monofacial polycrystalline c-Si, bifacial monocrystalline c-Si, an orange luminescent solar concentrator (LSC) and a Red LSC plate (see Figure 1) [1][2][3].

Figure 1: Depiction of the Living Lab prototype PVNB.

In this case study, we aim to investigate the effect that a common kind of street pollution -graffiti- has on the performance of a PVNB [4]. In this paper, the results comparing the effects of surface artwork on the monofacial and bifacial c-Si panels of the East/West oriented PVNB will be presented. Each panel was divided into two separate sub-panels consisting of 48 c-Si cells each (see Figure 2).

Prior to integration of the panels into the noise barrier prototype, all panels were flashed, showing an average rated power of 178 Wp for the monofacial panels, 207 Wp for the front side of the bifacial panels and 195 Wp for the rear side (bifaciality factor of ~94%). For the manufacture of the PVNB, both the monofacial and the bifacial c-Si cells were laminated between thick glass plates.

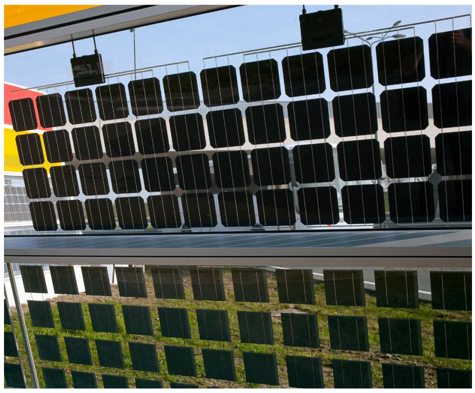

Figure 2: Closer depiction of the monofacial (bottom) and bifacial (top) c-Si cells of the PVNB.

To evaluate and analyse the electrical output of the PVNB, the Living Lab was equipped with measurement equipment for monitoring PV output (using IV tracers), solar irradiation, cell temperature and general weather data. The IV-tracer was controlled by a laptop computer and recorded measurements every 2 minutes for each of the panels, providing characteristic current *vs* voltage curves in order to study the effect of shading imposed by the graffiti. Every 24 hours, a summary of the measured data, consisting of irradiance data, V_{oc}, I_{sc}, V_{mpp}, I_{mpp}, cell temperatures and weather, data was automatically compiled and sent to the central SEAC server. In this way we were able to analyze the data remotely.

2 APPLICATION OF THE GRAFFITI

Graffiti is a potential risk for solar noise barriers, as it imposes a permanent, direct form of shading, blocking the incident light from reaching the PV cells and affecting the output of the PVNB. In the Living Lab we studied this effect in detail. Furthermore, we have treated a part of the barrier with anti-graffiti coating to study its effectiveness.

Figure 3: Artistic graffiti by Gart Smits on the East/West PVNB applied for research purposes.

Prior to the application of the street art, roughly half of the surface of the barrier was coated with a commercial anti-graffiti coating. The anti-graffiti coating was applied on the right half of the East/West PVNB while the left side remained uncoated for comparison reasons. The graffiti artwork represents a portrait of Nikola Tesla, a pioneer in electricity and the designer of our modern day electricity grid (see Figure 3). The portrait was produced by graffiti artist Gart Smits over a period of eight hours using commercial spray paints.

This experiment took place on the East/West PVNB while the South/North facing one remained undisturbed and acted as a reference for comparison purposes. The image effectively blocked incident sunlight from the West in the covered areas.

The purpose of the anti-graffiti coating application was to investigate the ease with which graffiti can be removed from a PVNB and the affect on panel performance after the removal of the artwork. A secondary analysis was performed to investigate the effect that this coating may have on the reflectance properties of the panel surface and thus to the energy production of the noise barrier.

3 PERFORMANCE RESULTS

The anti-graffiti coating application took place a few weeks before the application of the graffiti in order for its effect to be studied. In Figure 4 a single, clear day is chosen as representative for comparison between the coated and uncoated parts of the same panel.

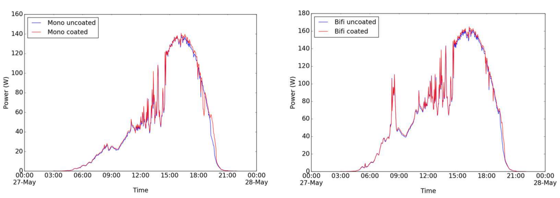

Figure 4: Power of the coated and uncoated mono-facial (left) and bi-facial (right) parts of the same panel of the East/West PVNB.

As shown in Figure 4, there is almost no negative effect on the power production of the anti-graffiti coated side of the panel which produces exactly the same power as the uncoated side. This result was consistent for the other days measured.

The graffiti remained on the PVNB surface for an entire summer month (June 2016) and its effect was studied using the DC Performance Ratio (PR) quality factor. The reason for selecting this factor was the fact that it is largely independent of the orientation, location, incident solar irradiation and conversion efficiency of a PV system [2]. It is a factor that describes the relationship between the actual and theoretical energy outputs of a PV system and gives an indication of how efficient a PV system is.

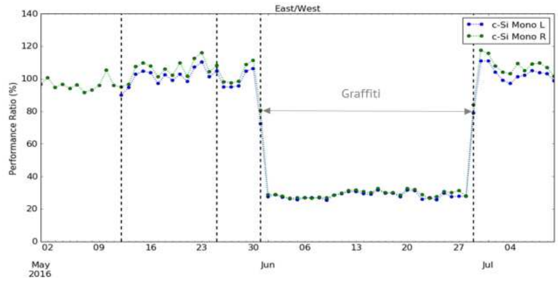

Figure 5: DC Performance Ratio of the monofacial panel as a function of time.

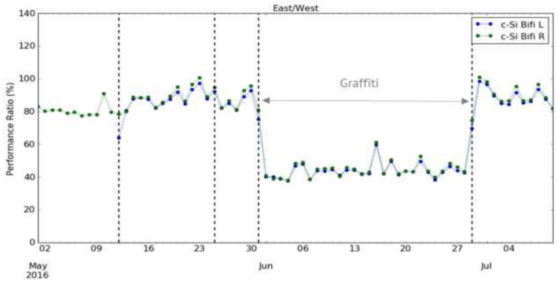

Figure 6: DC Performance Ratio of the bifacial panel as a function of time.

After the application of the graffiti the performance ratio of both the monofacial and bifacial modules dropped dramatically, as expected [5][6]. As can be seen in Figure 5 and Figure 6, the performance ratio of the monofacial panel dropped to below 30% and remained almost stable during all the days of the experiment, as both the direct and the diffuse light were blocked.

For the bifacial panel, the performance ratio was slightly higher as it dropped to just above 40%. This is primarily due to the fact that the rear side of the panel remained unaffected by the graffiti receiving light and slightly boosting the overall performance, although the coverage on this panel by the artwork was also somewhgat more restricted, which would also influence the PR.

4 REMOVAL OF THE GRAFFITI

One of the primary goals of the anti-graffiti coating application was to investigate the ease with which graffiti can be removed from a glass surface and whether the PV performance is recovered. For the removal of the graffiti, high-pressure warm water was used for the anti-graffiti coated part of the noise barrier, while application of a solvent was also needed for the uncoated part. The graffiti from the orange LSC plate was intentionally not removed.

After the removal of the graffiti the performance ratios of both panels were fully restored and appeared to be as high as before its application (see Figure 5 and Figure 6).

Following the completion a full year of field testing and the graffiti case study for the PVNB, the test field was dismantled according to the project plan in July 2016 and the different plates were transported for further studies.

Figure 7: Depiction of the PVNB after the removal of the graffiti.

5 CONCLUSIONS

After the application of the graffiti the DC performance ratio (PR) of both the monofacial and bifacial panels dropped dramatically, as expected. In the case of the bifacial panel, the PR was measured to be about 40% higher than the monofacial panel. This is partially due to the fact that the rear side of the panel remained unaffected by the graffiti, receiving light and slightly boosting the overall performance. After the removal of the graffiti the performance ratios of both panels were fully restored and measured to be as high as before its application.

An anti-graffiti coating was applied in the right half of the noise barrier. The performance comparison showed no negative effect in the coated area of the barrier in comparison with the uncoated one. For the removal of the graffiti, high-pressure warm water was used for the anti-graffiti coated part while also the application of a solvent was needed for the uncoated part. This was a very useful outcome for developers of commercial PVNBs as it constitutes an inexpensive solution that has the potential to significantly reduce the Operation & Maintenance costs of such an application.

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