"COUNTING THE SUN" – A DUTCH PUBLIC AWARENESS CAMPAIGN ON PV PERFORMANCE

Wilfried G.J.H.M. van Sark[1,2,*], S. 't Hart[1,3], M.M. de Jong[1], P. de Rijk[1],
P. Moraitis[2], B.B. Kausika[2], and H. van der Velde[2]
[1]Stichting Monitoring Zonnestroom (SMZ), Utrecht, The Netherlands
[2]Copernicus Institute for Sustainable Development, Utrecht University, Heidelberglaan 2, 3584CS Utrecht, the Netherlands, [*]T: +31 30 253 7611, E: w.g.j.h.m.vansark@uu.nl
[3]Holland Solar, Utrecht, The Netherlands

ABSTRACT: As part of the Dutch Solar Days a campaign for the public was organized to raise awareness on the importance of monitoring PV systems. During one week, i.e. between May 12 and May 18, 2014, participants were asked to measure or determine the amount of generated energy by their PV systems. Participants were recruited via social media and a national television show. Over 5000 participants responded, thus making the campaign a huge success. The measurement week started with a few cloudy days, but ended with some clear sky days, being a typical week in May. This resulted in an average energy yield of 33.4 kWh/kWp. Yield differences predominantly could be attributed to irradiation differences over the country: at coastal areas a 25% higher yield was observed. The average performance ratio was 0.74, which showed that most systems are performing well.
Keywords: PV performance, public campaign, citizen science

1 INTRODUCTION

As in many countries, the Netherlands is experiencing a strong market expansion of photovoltaic (PV) technology. The total installed capacity was 722 MWp at the end of 2013, and it is has been doubling for the past two years (see Fig. 1) due to fast decreasing prices [1]. This growth is requiring reliable information on amongst other the performance of PV systems, which is to be shared with the various actors in the market. E.g., accurate PV performance data allows net operators to manage high penetration levels of PV into distribution grids when linked to forecasting and storage options.

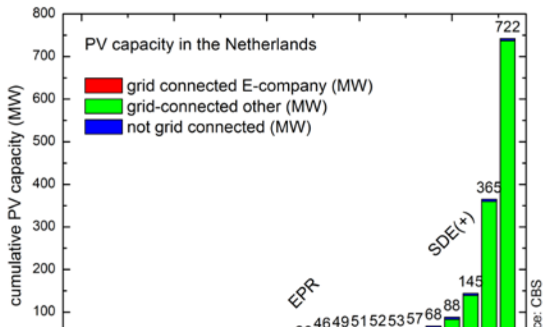

Figure 1. Development of cumulative installed PV capacity in the Netherlands (data source: CBS [2]).

Performance data are not readily available. Installers that have performance data at their disposal tend to be reluctant to share this information. This is particularly true if detailed numbers in question allow for financial insights. Legal contracts that restrict partners to secrecy on financial details often prohibit data sharing, even if they are highly motivated to share data in general terms. Perhaps unintended, PV owners are contributing to 'citizen science' [3], by sharing monitoring data over the Internet. These data can be analyzed by anyone, but the level of detail and the unknown measurement accuracy may prohibit a proper analysis. Statistical principles should be used on large amounts of data for drawing conclusions on performance trends [4].

2 APPROACH

In the Netherlands, the Stichting Monitoring Zonnestroom (Solar power monitoring foundation) and Utrecht University organized a campaign for the public to raise awareness of monitoring their PV system within the framework of the Dutch Solar Days [5]: "Tel de Zon" ("Counting the Sun"). During one week, i.e. between May 12 and May 18, 2014, participants were asked to measure or determine the amount of generated energy by their PV systems.

Supported by social media activity, flyers, and exposure via the national television network consumer show "Kassa" (Figure 2) over 5000 participants were recruited and they have shared their performance as well as information regarding their system: system location (postal code), system capacity (Wp), number of panels, brand and type of panels, inverter capacity, brand and type, orientation, tilt, and year of installation. In addition, remarks were made regarding suspected problems with shading from nearby objects.

Figure 2. Flyer (top) and screenshot of the television show Kassa broadcasted live on Saturday May 24, 2014 (bottom) in which results of the campaign were presented.

Participants were promised that they would receive information on the status of their system, i.e., if their system were performing as expected. For each of these 5000 systems, weekly specific yield and performance ratio was determined. This process was highly automated, using in-house developed *Python* scripts. All participants entered system information as well as the weekly yield on a dedicated web page.

3 ANALYSIS METHOD

3.1 Yield and performance ratio

The time and weather dependent nature of solar power makes it difficult to apply the conventional performance indicators that are used for the regular power plants. In order to compare and evaluate different systems normalized indicators are necessary. The most common indicator is the final system yield, which is the net energy delivered for the specific period divided by the rated power output of the installed array and it has units kWh/kWp [6]. It is a convenient way to compare the energy produced by different PV systems as it normalizes the energy produced according to system size. It has the advantage to be a straightforward indicator as the only measurement that it requires is the actual produced energy. However, it varies widely by climate, by the length of the calculation period and by how the two parameters are defined (e.g., array DC level or inverter AC output). Final system yield is defined as:

$$Y_f = \frac{E}{P_0} \quad (1)$$

with E the generated amount of energy and P_0 the nameplate capacity of the system. The Performance Ratio (PR) is another indicator that is widely used as a measure of the quality of the PV system. It describes the relationship between the actual and theoretical or reference energy output of the PV plant. The actual energy yield is the utilizable AC electricity that is measured at the feed in meter and it is divided by the amount of energy that could be generated if the system operated under Standard Test Conditions. The difference between 100% and the PR value aggregates all the possible energy losses including inverter efficiency, wire losses, panel degradation, mismatch, shades, dust, thermal inefficiencies and system failures [7]. PR is a dimensionless quality indicator and is calculated by dividing final system yield Y_f by reference yield Y_r [7]:

$$PR = \frac{Y_f}{Y_r} \quad (2)$$

First, cumulative solar irradiation from sunrise on May 12 to sunset on May 18 was determined in two ways: 1) adding quarterly global horizontal irradiance (GHI) values from 31 meteorological ground stations in the Netherlands (Royal Netherlands Meteorological Institute, KNMI); 2) determination of hourly irradiance from processing satellite images of 15-min interval and adding these for all hours in the May week. Second, the reference energy yield for each system was calculated using the system information provided by the participants by determination of the irradiance values in the plane of the panels (POA, plane of array), for every quarter (or hour). Third, the measured energy yield was used to calculate the performance ratio.

3.2 Data quality check

Participants were asked to subscribe for the “Tel de Zon” campaign and fill in an online form, providing information for their system and the weekly energy yield during the Solar Week.

The data set went through a thorough quality check to detect errors that occurred during the data entry. A total number of 873 participants did not provide sufficient or correct information on their system or yield and therefore, they were excluded from the analysis. One major issue is meter readings from the smart meter, where net production can be determined from. Especially older systems did not allow for determination of actual production data.

3.3 Plane of array irradiation data

For the determination of PR the total plane of array irradiation is necessary. For that reason the KNMI data was used. The incident global horizontal irradiation can be divided in to three components, the beam component from the direct irradiation on the horizontal surface, the diffuse component and the component from ground reflections. The contribution of the diffuse component to the total value could be from 25% on a sunny day up to 80% on a cloudy day [8]. Also, as the majority of solar panels are tilted towards the sun to maximize the amount of solar radiation on the cell surface, solar radiation incident on an inclined surface has to be calculated by converting the value measured on a horizontal surface to that incident on the tilted surface of interest. A number of models for determining the solar global irradiation on inclined surfaces derived from the global horizontal have been developed and according to studies, the model by Olmo *et al*. was found to have the better match between the predicted and the experimental values [9]. Moreover, it has the advantage to depend only on the clearness index and avoids the separation of the solar beam in to direct and diffuse components. Therefore, in this paper we have used the Olmo model for calculating POA irradiance.

4 RESULTS

Figure 3 shows a map of the Netherlands with all installations that participated in the campaign week. Clearly, the systems are well spread over the country. The total capacity of the systems was 16.2 MWp, with an average installation size of 3.5 kWp. This constitutes 2% of the total amount of PV capacity. Total weekly yield was 531 MWh, and the average weekly yield was 33.4 kWh/kWp.

4.1 Irradiation

The total GHI during the Solar Week on a national level was 41.9 kWh/m^2, however between Monday and Thursday there was cloud cover and rainfalls. The last three days of the Solar Week the sky was clear and the average daily GHI was more than 7 kWh/m^2 (see Fig. 4).

Figure 3. Distribution of participating PV installations over the country.

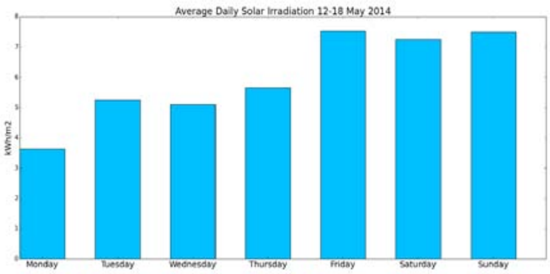

Figure 4. Variation of average daily GHI.

The solar irradiation in the Netherlands differs between the coastal part and the mainland of the country as is shown in Figure 5, which is constructed based on satellite measurements. This clearly affects the yield of systems spread over the country.

4.2 Yield and performance ratio

The average weekly yield was determined to be 33.3 kWh/kWp, the variation is shown in Figure 6. Geographical variation is illustrated in Figure 7, where the average weekly yield per province is shown. The weekly yield is clearly higher in coastal areas, which can be directly related to the geographical variation of irradiation (Fig. 5). The average Performance Ratio is shown in Figure 8 and amounted to 0.74±0.09. Systems that operate with PR values less than 0.60 represent 6.1% of the total sample. Average performance (PR in the range 0.60-0.70) constitutes 18.6% of the sample while good performance (PR in the range 0.70-0.85) has 67.5% of the sample. Only 7.8% of the installations have exceptional performance (PR larger than 0.85).

One of the most important factors that affect the performance of PV systems is shading. The effect of shading is hard to quantify since it depends on the amount of shade that covers the panels but also varies according to the architecture of the whole system. In total, 623 participants reported that their panels have shading issues. The average PR of those systems is 0.71. On the other hand, the average PR for systems of which there was no report for shading was 0.75. However, it is

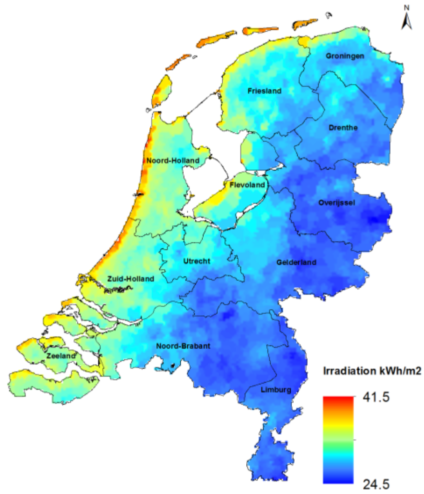

Figure 5. Averaged global horizontal irradiation during the Solar Week.

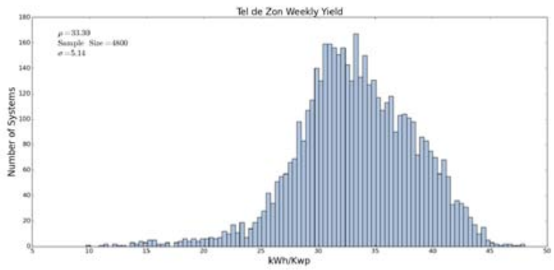

Figure 6. Distribution of weekly annual yield.

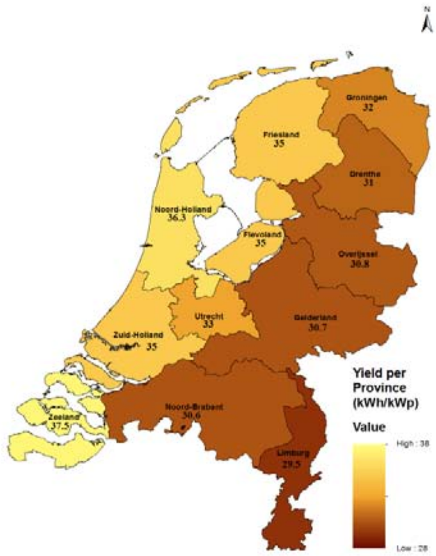

Figure 7. Weekly yield averaged per province.

important to highlight that absence of reporting of a shading problem does not indicate that shading issues do not exist.

The geographical variation of performance ratio is shown in Figure 9. Clearly, the variation is absent, which shows that systems all over the country do perform similarly well.

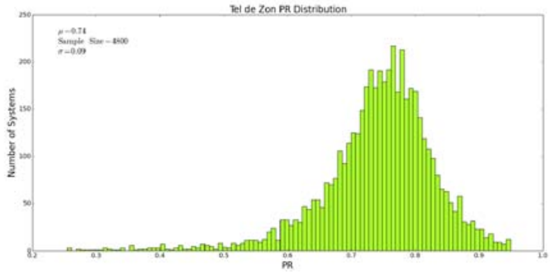

Figure 8. Distribution of performance ratio.

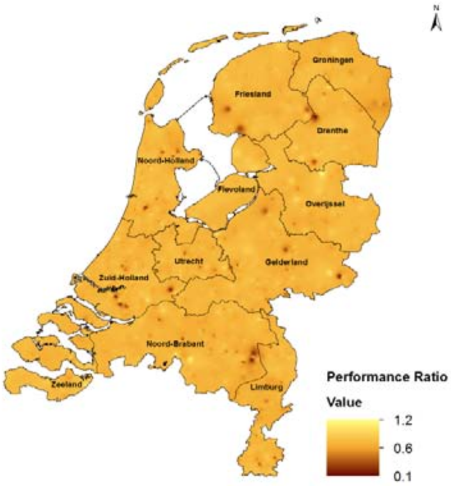

Figure 9. Performance ratio averaged per province.

4.3 System degradation

It is known that the performance of a PV system will decrease over time due to degradation of the panels. Various factors affect the module degradation such as the quality of materials used in manufacturing, the manufacturing process, the quality of assembly and packaging of the cells into the module, as well as maintenance levels employed at the site. In Figure 10 PR value during the Solar Week are presented as a function of installation year of the PV system; the oldest systems were installed in 2000. We observe a slight upward trend, from which we can infer a degradation rate of 1.3% per year, while average degradation from literature for silicon technology is 0.8% per year.

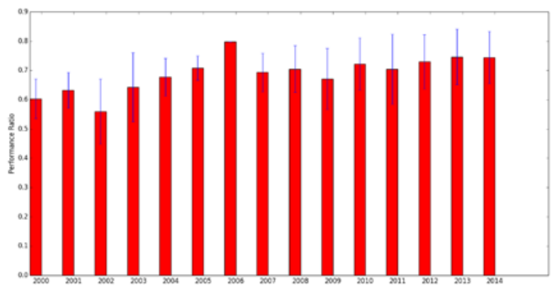

Figure 10. Performance ratio as a function of system installation year.

5 CONCLUSION

A public campaign aiming at raising awareness among PV system owners has been organized as part of the Dutch Solar week in May 2014. With over 5000 participants it has been a great success. Evidently, citizen science has touched base in the PV community.

Results show that PV systems in the Netherlands in general are performing well, with performance ratio values of 0.74±0.09, evenly spread over the country. However, some 10% of the systems suffer most probably from some kind of shadowing. The weekly yield varies over the country, with 25% higher yields at the coast, and this correlates well with irradiation variations over the country in the week.

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7 REFERENCES

[1] W.G.J.H.M. van Sark, P. Muizebelt, J. Cace, A. de Vries, P. de Rijk, *Price Development of Photovoltaic Modules, Inverters, and Systems in the Netherlands in 2012,* Renewable Energy 71 (2014) 18-22.

[2] CBS Statline, http://statline.cbs.nl/statweb/, last access date 25/09/2014.

[3] E. Hand, *Citizen Science: People Power,* Nature 466 (2010), 685-687.

[4] P. Moraitis, W.G.J.H.M. van Sark, *Operational performance of grid-connected PV systems,* Conference Record of the 40th IEEE Photovoltaic Specialists Conference, Denver, CO, USA, 2014, (in press).

[5] www.solardays.nl, last access date 25/09/2014.

[6] IEC 61274, 1998. *Photovoltaics system performance monitoring – Guidelines for measurement, data exchange and analysis*.

[7] N.H. Reich, B. Mueller, A. Armbruster, W.G.J.H.M. van Sark, K. Kiefer, Ch. Reise, *Performance Ratio Revisited: is PR> 90% Realistic?,* Progress in Photovoltaics: Research and Applications 20 (2012) 717-726.

[8] C. Demain, M. Journale, C. c Bertand, *Evaluation of different models to estimate the global solar radiation on inclined surfaces*, Renewable Energy 50 (2013) 710-721.

[9] F.J. Olmo, J.Vida. I. Foyo, Y.Castro-Diez, L. Alados-Arboledas, *Prediction of global irradiance on inclined surfaces*, Energy 24 (1999) 689-704.

[10] D.C. Jordan and S.R. Kurtz, *Photovoltaic Degradation Rates—an Analytical Review.* Progress in Photovoltaics: Research and Applications 21 (2012) 12-29.