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## Effect of soiling on photovoltaic modules in Norway

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### Abstract

Accumulation of sediments, i.e. dust or dirt-particles may significantly reduce the output of a PV system. In Norway, the first significant installations in grid-connected PV appeared in 2014, and hence there is a growing interest in the performance of PV under Norwegian climate and insolation conditions. In this paper we study losses due to soiling of PV modules in an inland climate in Norway and assess the cleaning effect of rain in this environment. We also show that the effect of soiling can be accurately determined by a combination of optical measurements and high precision balance measurements, where the accumulated dust density is assessed by measuring the weight-changes of cloths used to clean glass samples. Initial optical and physical analysis of the dust at the field site must be performed in order to correlate the dust density to the reduction in transmittance for the soil present at the given site. After this correlation is established direct and quantitative measurements of transmission reduction due to soiling can be obtained for field locations without laboratory access. The weight measurements can hence supplement the classical method of applying a cleaned cell for reference to improve the accuracy of soiling studies performed for field deployed solar modules. This is of value for estimating power losses due to soiling for PV plants in remote areas, such as Kalkbult in South Africa.

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## 1. Introduction

A substantial amount of research time and money has been invested to bring solar cells to their current STC efficiencies, while far less time and money have been invested in addressing externalities which prevents the solar cells from reaching similar conversion efficiencies when actually deployed in the field [1]. Accumulation of sediments, i.e. dust or dirt-particles, is one such external effect, which may significantly reduce the output of a PV system. Literature shows annual soiling losses ranging from between 1-7 % in regions such as Spain [2], [3], to more than 10% in dry locations such as Cyprus [4] and Kuwait [5]. Typically, areas with long periods without rain suffer more than areas with more regular rain events. The effect of soiling on field deployed PV modules is difficult to quantify because there are a very wide range of parameters, which affect the output of the solar cells. Both accurate prediction of power production and optimal cleaning solutions may depend on precise measurements of the production losses due to soiling. Accurate measurements are also needed to relate the amount of soiling on the PV panels to factors in the environment, and thereby get a better understanding of soiling losses and improve our capability of predicting them. The most widespread method used to assess the effect of dust on solar panels is to compare modules that are cleaned at regular intervals with otherwise identical modules that receive no cleaning [6], [7]. Some studies also use the solar irradiation as measured by a regularly cleaned pyranometer or determined from satellite data and compensate for the effect of temperature [4], [8]. These approaches give an estimate of the power lost due to soiling, but do not provide quantitative information about the amount of soiling responsible for this loss. A more fundamental understanding of power losses due to dust is provided through characterization of the optical, chemical and physical properties of the soil and the exposed glass samples [9]–[12]. These studies are usually performed using exposed glass pieces rather than full size framed modules, and at test sites in the immediate approximation of research laboratories. However, it would be beneficial to be able to carry out quantitative dust analysis also on modules in more remote field locations representative of many of the utility scale solar power plants. In this paper we describe quantitative measurements of dust and transmission losses at a test site in Norway, and how the approach used can supplement traditional soiling measurements and improve the accuracy of soiling studies performed at remote locations.

## 2. Experimental

### 2.1. Test site and laboratory in Norway

The test site in Norway is located in immediate proximity of an indoor optical laboratory. To study the natural accumulation of soil at the site, sixteen glass samples of standard low-iron 2 mm glass used in PV manufacturing are placed on the rooftop at a tilt angle of 45°. The glass has no microstructure, but eight of the glass samples had a commercial anti-soiling coating applied. The glass samples were mounted on a rack as an extension of an existing PV system using angle brackets for easy removal and remounting. The amount of soiling accumulated on the exposed glass samples is studied by use of a high precision balance with an accuracy of 0.0001 gram. The optical properties of the exposed glass are characterized using a dedicated setup for measuring angularly and spectrally dependent reflection and transmission measurements. Finally, the structure of the soiling material itself is characterized using Scanning Electron Microscopy (SEM).

### 2.2. Field test site in Kalkbult, South Africa

The field test site in SA is constructed within the fences of Scatec Solar's 75 MW solar plant in Kalkbult. The area is semi-arid land with an annual rainfall of approximately 38 cm. There have been uncertainties related to the effect of soiling on PV modules in this type of climate. The modules deployed at the field test station are sixteen mc-Si modules from ReneSola and eight CdTe modules from FirstSolar. At the Kalkbult plant, Scatec Solar has 312 000 polycrystalline silicon modules from BYD. Data from the plant will allow for direct comparison of the energy output and reduce uncertainties. Each module at the field test station is connected to an active load to measure module temperature and full IV curves. The test site also includes dust traps and a weather station measuring direct and global irradiation, ambient temperature, wind, humidity, barometric pressure and rain.

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