Simulating diffuse, glossy and specular albedo materials for enhanced bifacial solar module output.

An effective way of improving photovoltaic (PV) yield while keeping the costs low is by using bifacial modules. As opposed to conventional monofacial modules, bifacial modules produce electricity by accepting solar irradiance from the front and the rear side. A crucial element in enhancing the bifacial output is the ground reflectance, *i.e.*, albedo. The module output strongly depends on the angle and wavelength of the incident irradiance and many nanophotonic light management strategies are particularly sensitive to these parameters [1, 2, 3, 4, 5]. Thus, understanding the spectral and angular albedo of the ground-reflector becomes important for the accurate understanding of albedo-dependent module output. Various sophisticated models [6, 7, 8, 9] help in calculating the bifacial output due to albedo but often use wavelength and/or angle averaged albedo.

To overcome this, we developed an albedo-centric reverse ray-tracing algorithm that can simulate short-circuit current density of a bifacial module under the influence of albedo materials with complex spectral and angular reflectance. The software can model a wide range of reflectors, *i.e*, diffuse, glossy [10] , specular, and a combination of the three. It can also accommodate custom reflectors like metamaterials or free-space luminescent solar concentrators [11]. The algorithm also accepts any spectral and angular irradiance and tailored PV modules, while accounting for self-shading.

Our study shows that under AM1.5G illumination at 85˚ relative to the horizontal, a diffuse reflector outperforms a specular reflector for any value of module height and tilt. A diffuse reflector also proves to be more robust to the changes in module orientation and consequently, self-shading.

Such an approach can help in the fundamental understanding of the influence surface properties of a reflector on a solar module. It can facilitate in assessing the performance of currently existing natural and artificial reflectors and inspire ideas to devise novel albedo materials for higher bifacial output. Furthermore, when combined with the open-circuit voltage and local spectro-angular irradiance [12] measurements, the above methodology can assist in selecting the best module-albedo pair and their optimal configuration.

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