Two EVALUATION MODELS for POSSIBLE GLARING EFFECTS of FLAT PLATE PV-GENERATORS

AUSTRIAN INSTITUTE OF TECHNOLOGY

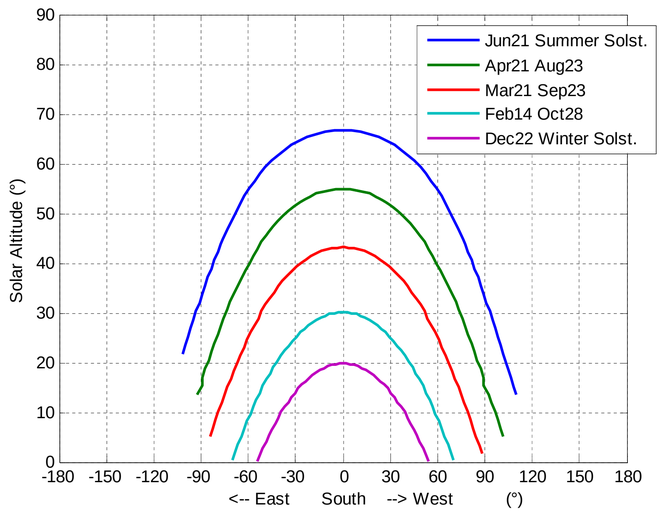
Karl A. Berger, Bernhard Kubicek, Energy Department, Giefinggasse 2, A-1210 Wien

Abstract

To evaluate the possible glaring of a agricultural roof-mounted PV assembly onto cars driving on a street, two evaluation methods were used: A volumetric stochastic pathtracing and an analytic model.
With both, it was shown that there is hardly any risk for drivers. However, the calculation methods could be useful for large scale building integrated PV setups.

Physical Model

Due to geographical location of the building, and the date, the sun path can be calculated, together with its intensity according to the atmospheric absorption:



A glaring surface usually exhibits a mixture of diffuse and direct reflection. Generally, there exists a reflection intensity depending of incidence angle and output angle. For glass surfaces, direct reflection is dominant, and the intensity is defined by the Fresnel equations.

$$R_\mathrm{s} = \left(\frac{n_1\cos\theta_\mathrm{i} - n_2\cos\theta_\mathrm{t}}{n_1\cos\theta_\mathrm{i} + n_2\cos\theta_\mathrm{t}}\right)^2 = \left[\frac{n_1\cos\theta_\mathrm{i} - n_2\sqrt{1-\left(\frac{n_1}{n_2}\sin\theta_\mathrm{i}\right)^2}}{n_1\cos\theta_\mathrm{i} + n_2\sqrt{1-\left(\frac{n_1}{n_2}\sin\theta_\mathrm{i}\right)^2}}\right]^2$$

$$R_\mathrm{p} = \left(\frac{n_1\cos\theta_\mathrm{t} - n_2\cos\theta_\mathrm{i}}{n_1\cos\theta_\mathrm{t} + n_2\cos\theta_\mathrm{i}}\right)^2 = \left[\frac{n_1\sqrt{1-\left(\frac{n_1}{n_2}\sin\theta_\mathrm{i}\right)^2} - n_2\cos\theta_\mathrm{i}}{n_1\sqrt{1-\left(\frac{n_1}{n_2}\sin\theta_\mathrm{i}\right)^2} + n_2\cos\theta_\mathrm{i}}\right]^2$$

Vdara Hotel “death ray”:

The Vdara Hotel in Las Vegas is often quoted as an example of glaring problems that could equally occur with building integrated PV.
Due to the south orientation, and the parabolic shape of the façade, the sun causes a moving focus. There were news reports of tourists claiming singed hair and melted plastic bags [1].

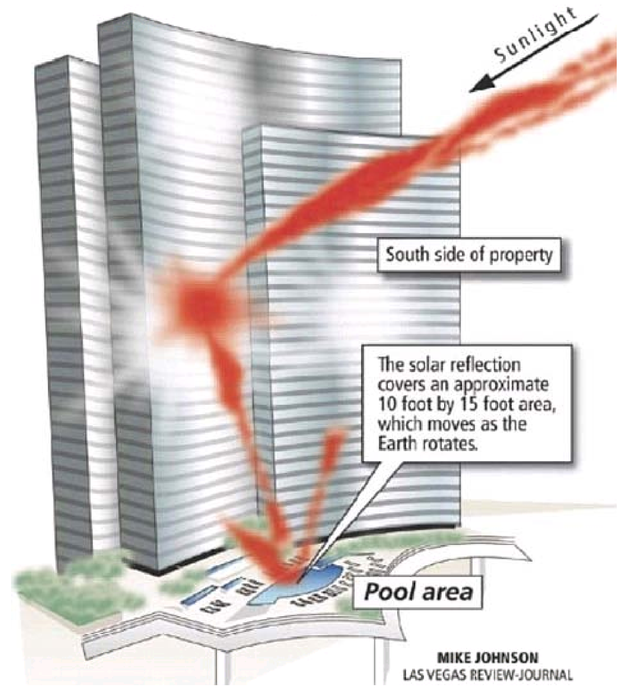
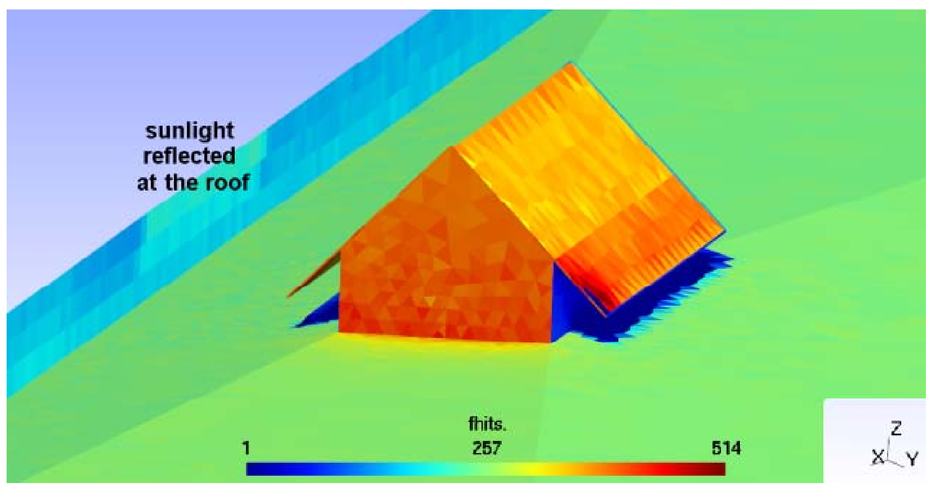


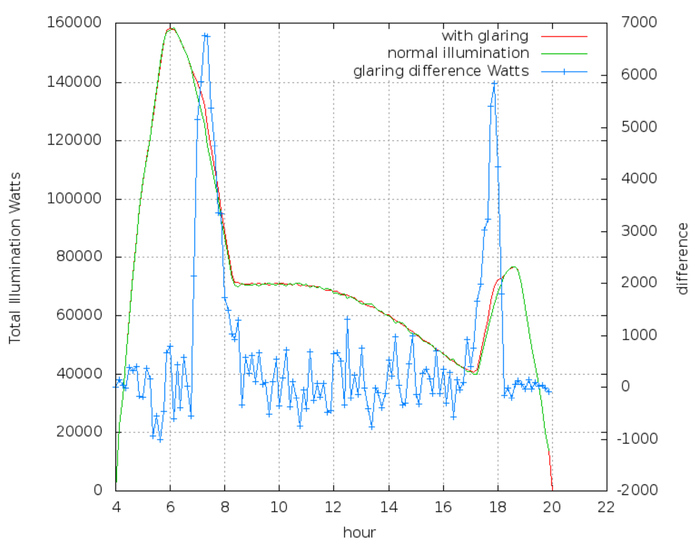
Image cited for scientific purpose from the Las Vegas Review Journal

Example case:

The reflection of the roof integrated PV setup is assumed critical, if it illuminates a strip by the height of a lorry over the center line of the road. City officials wanted to have an estimate on when and how intense the glaring affects the traffic.

Volumetric forward Raytracing

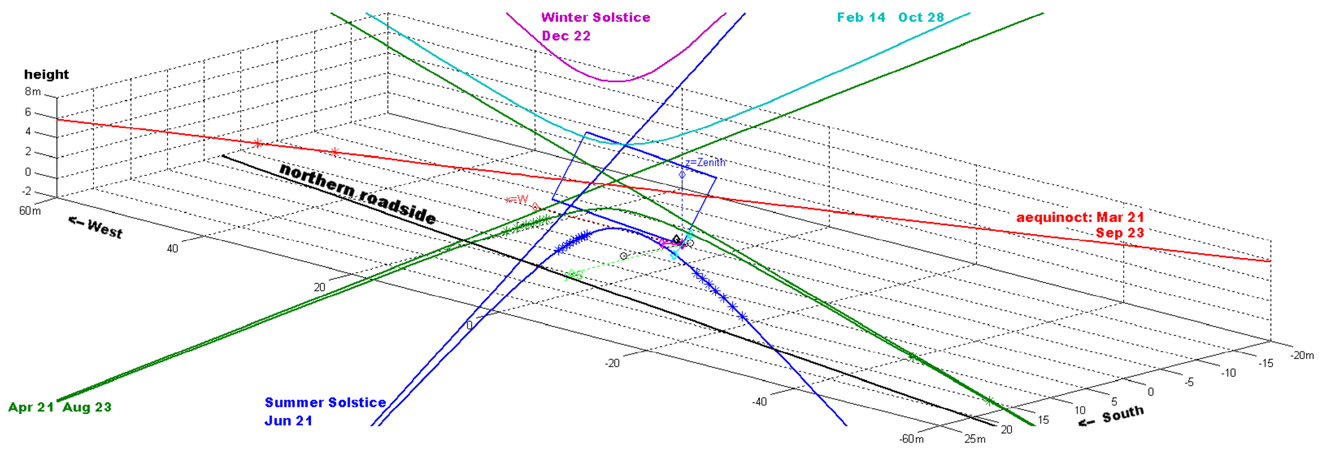




By casting random rays from a sky surface on the model geometry, the actual shape of the reflection can be calculated on the critical strip above the road.
By taking the strip’s difference between a reflecting root, and a non-reflecting roof, the intensity can be used as indicator.

However, due to stochastic calculation of each simulation, the difference exhibits noise that can only be suppressed by time intensive computations.

Single-Point Analytic Model



By simplifying the whole roof as a small source when viewed from the street, the reflected light path can be analytically calculated and intersected with the ground surface and the plane above road’s center line.
The calculations is highly performant, but not able to predict the extension of the glaring light cone, especially for curved roofs

REFERENCES

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[3] B. Semlitsch, Advanced Raytracing Techniques for Simulation of Thermal Radiation in Fluids, Diploma thesis Technical university Vienna, 2010