AB INITIO SIMULATION of the PV ENERGY PRODUCTION DEPENDENCE on MODULE MATERIALS and LAYERING

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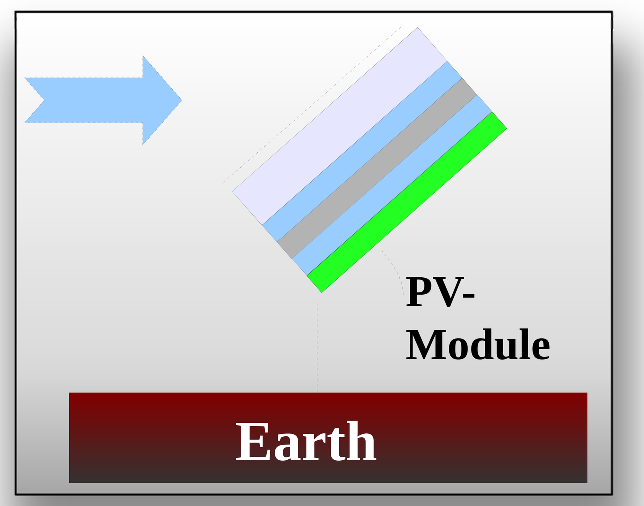
Abstract

The thermal equilibrium in the PV module is calculated by solving a 1D equation system originating from 2D air flow simulations. This exposes the influence of material, geometric and external parameters on the electric production of PV-modules

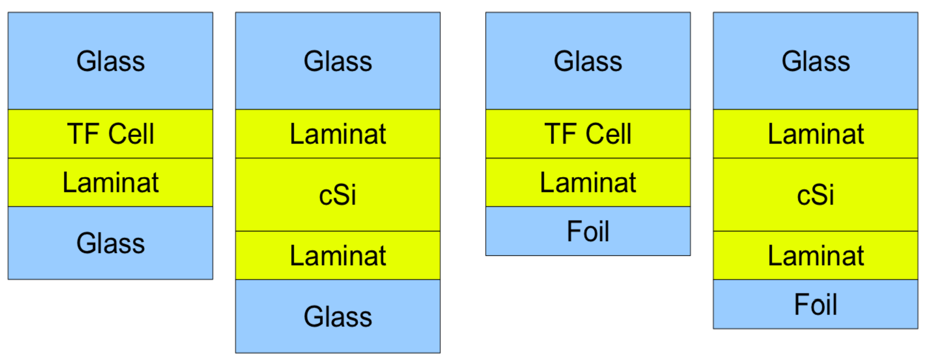
Physical Model

Free standings are defined by free parameters e.g. their tilt angle, the distance to earth, and the material layering and parameters. The 1D thermal transfer through the layers together with the 2D>1D air cooling and radiative heat exchange to the sky and the ground deliver the layers' temperatures and the electric output. The heat source due to unconverted light is temperature-coupled.

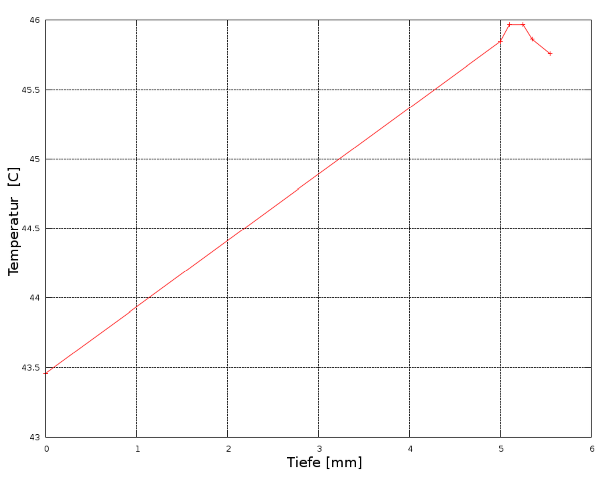


By assuming standard modules of a given kind (i.e. cSi, CdTe, Cis), individual parameters can varied, to find possible levers for material and module optimizations.

Standard module: 3mm front glass, front+back EVA laminate 0.3 mm, 3mm glass or 0.3 mm backsheet, glass thermal emissivity: 0.85, 1300 W/m^2, Modul 0.5 m over ground, 40°tilt, 1m height.



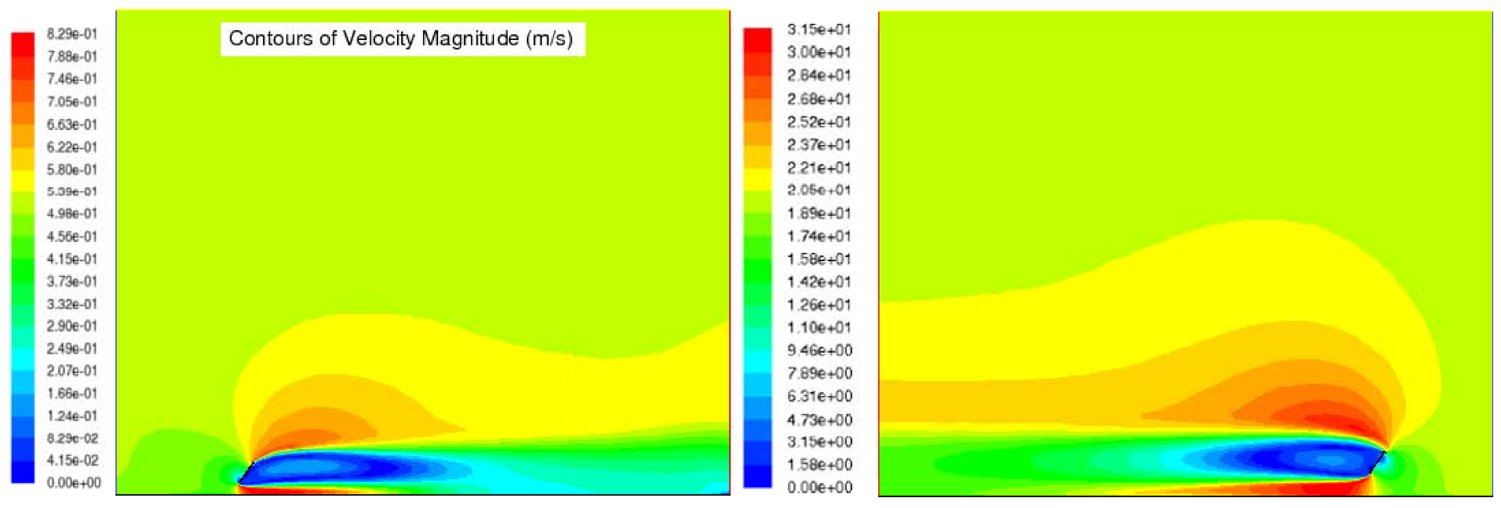
Module Layering



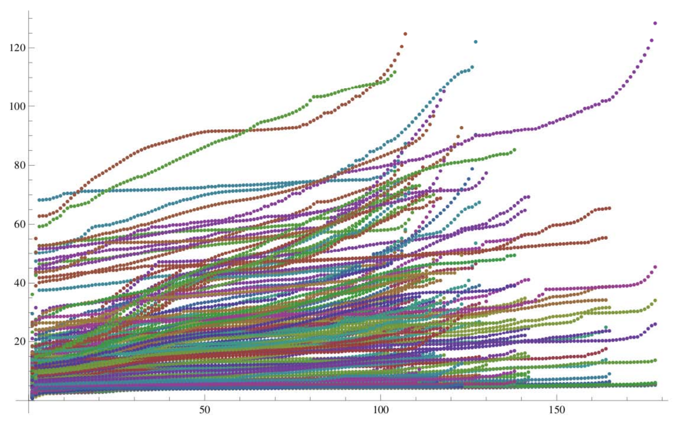
Depth-Temperarture Profile

Air Cooling Model (2D to 1D):

2D Fluid Dynamics



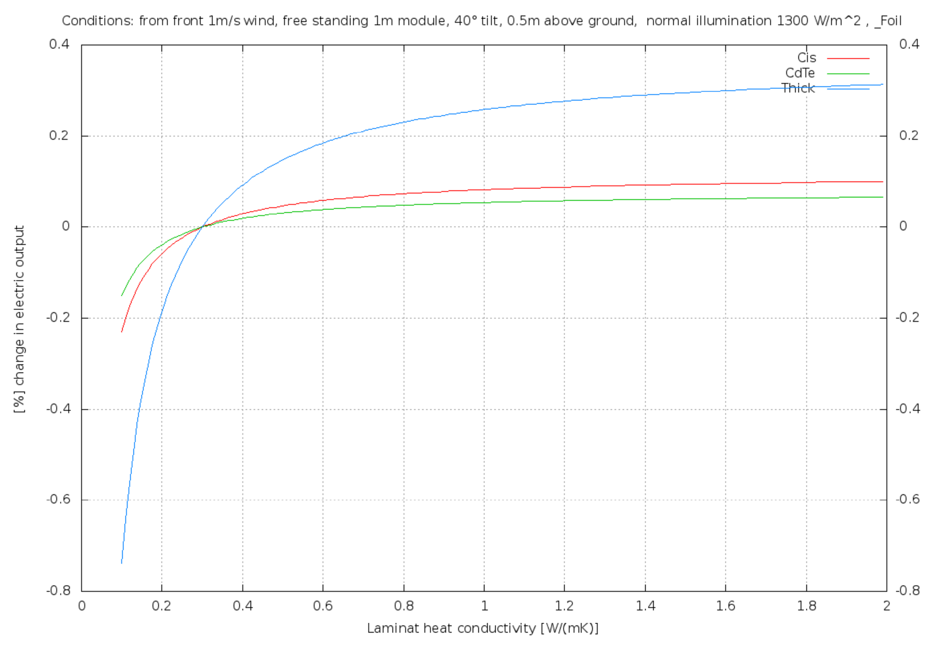
$$h_t = p_0 + p_1 H + p_2\alpha + p_3 h + p_4 v + p_5 P + 6p_6 H^2 + p_7\alpha^2 + p_8 h^2 + p_9 v^2 + p_{10} P^2 + p_{11} H\alpha + p_{12} Hh + \ldots + p_{16} H^3 + \ldots .$$

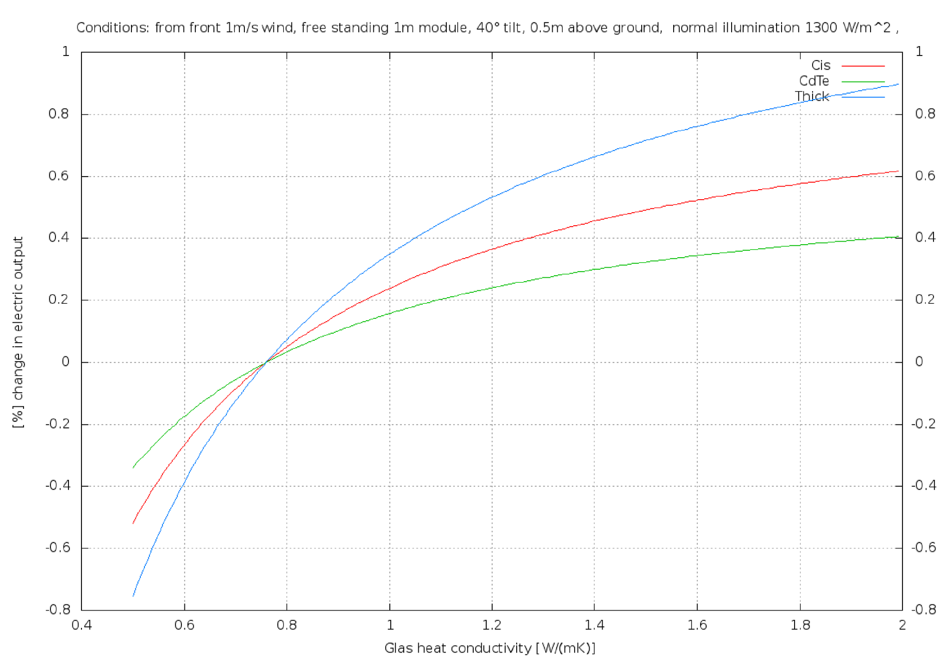


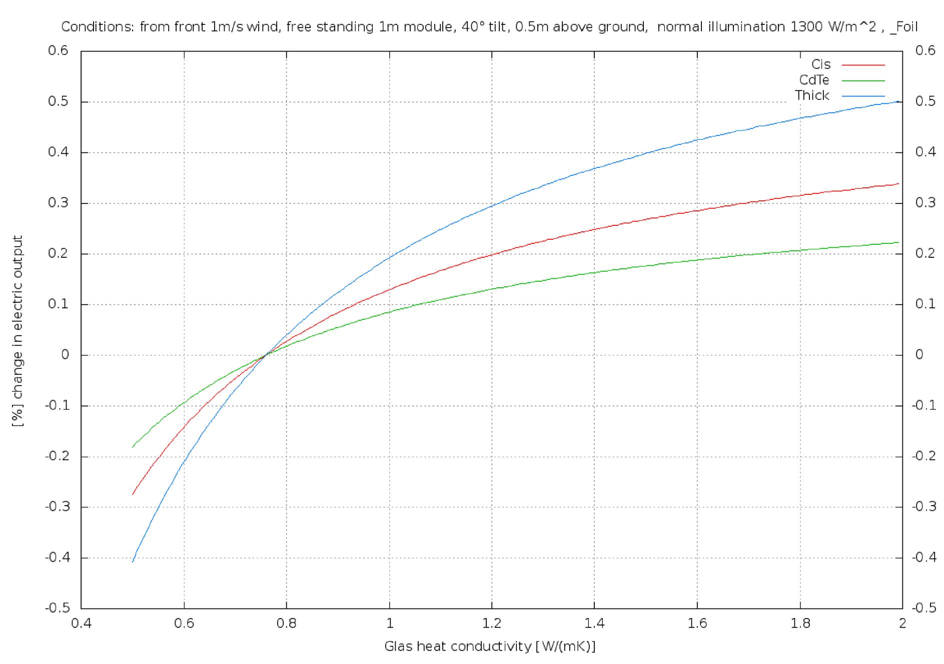
From parameterized 2D CFD simulations, the cooling parameters on the module surfaces are calculated for 1800 different geometric and wind parameter sets. The open parameters of a general series expansion are fitted to obtain a 1D-parameterized air cooling model.

Results:

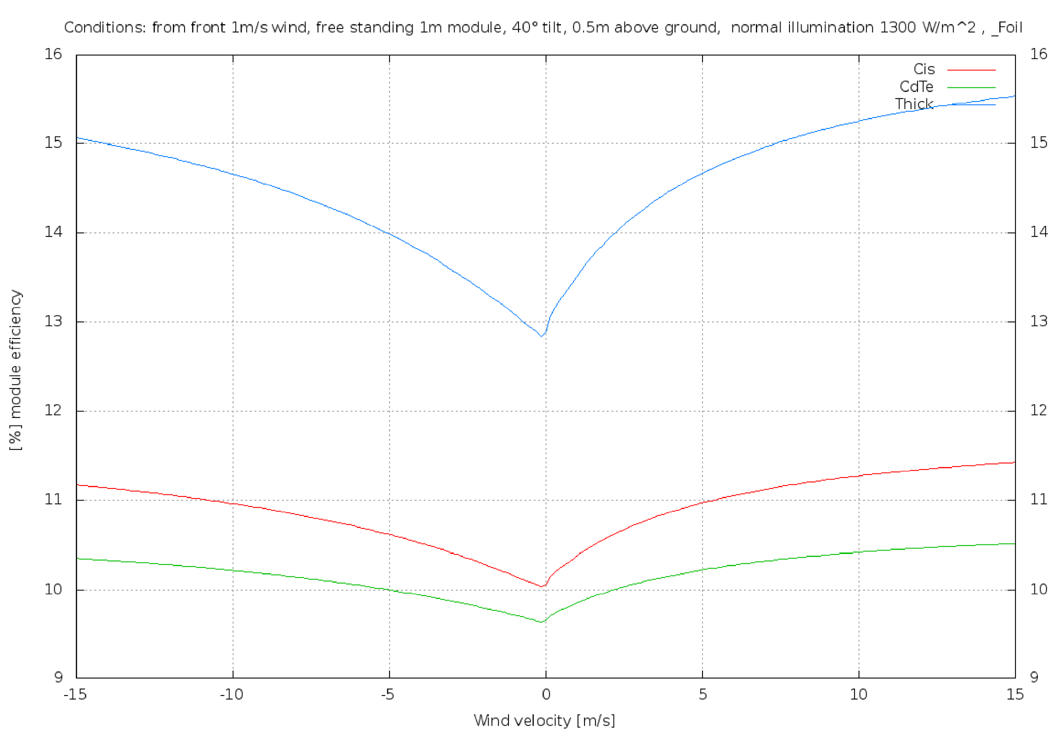
The results show, that apart from known air cooling optimizations, also 1 to 2 % plus in electrical output can be gained by improving the infrared thermal emissivity of the glass.

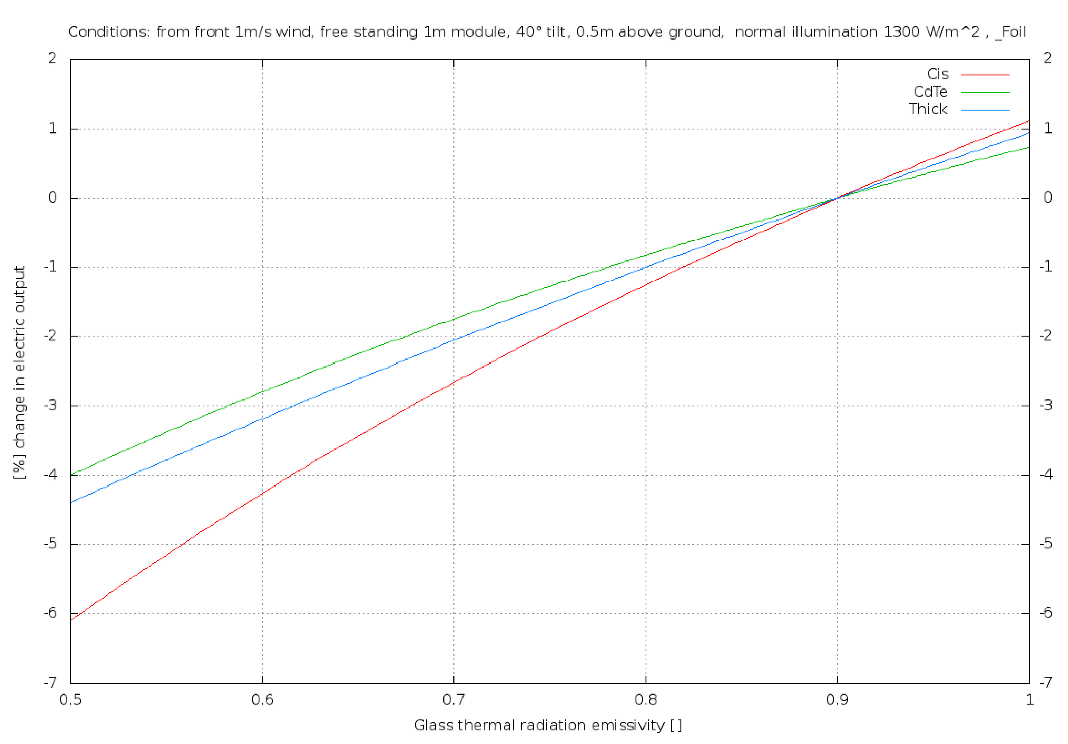


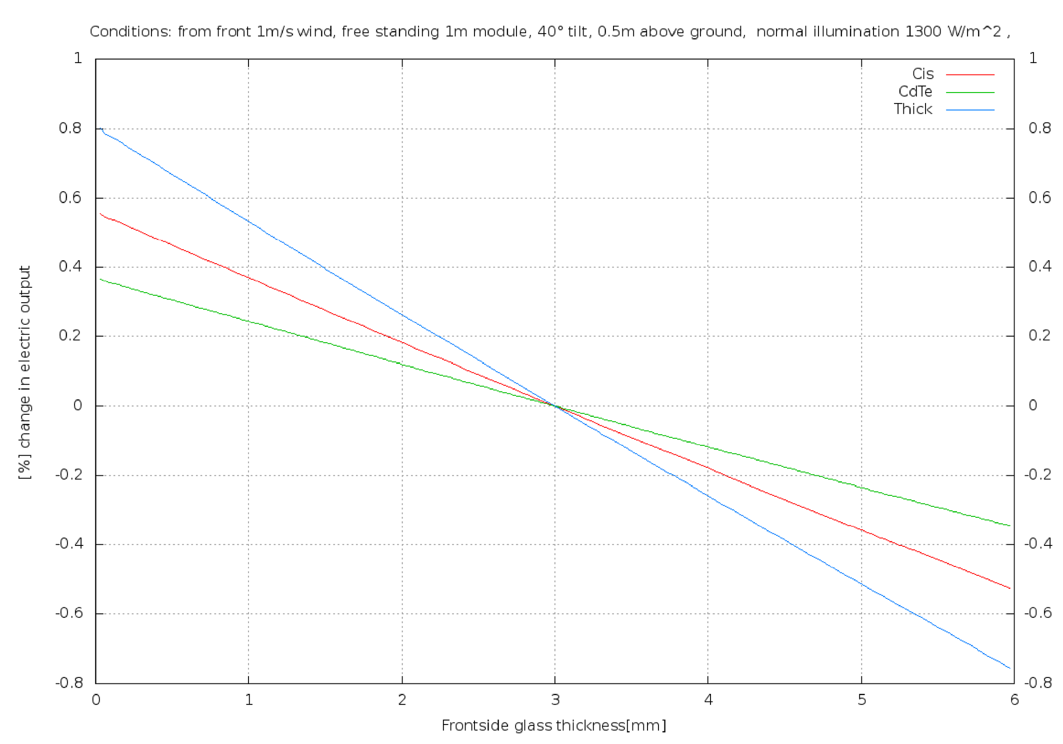




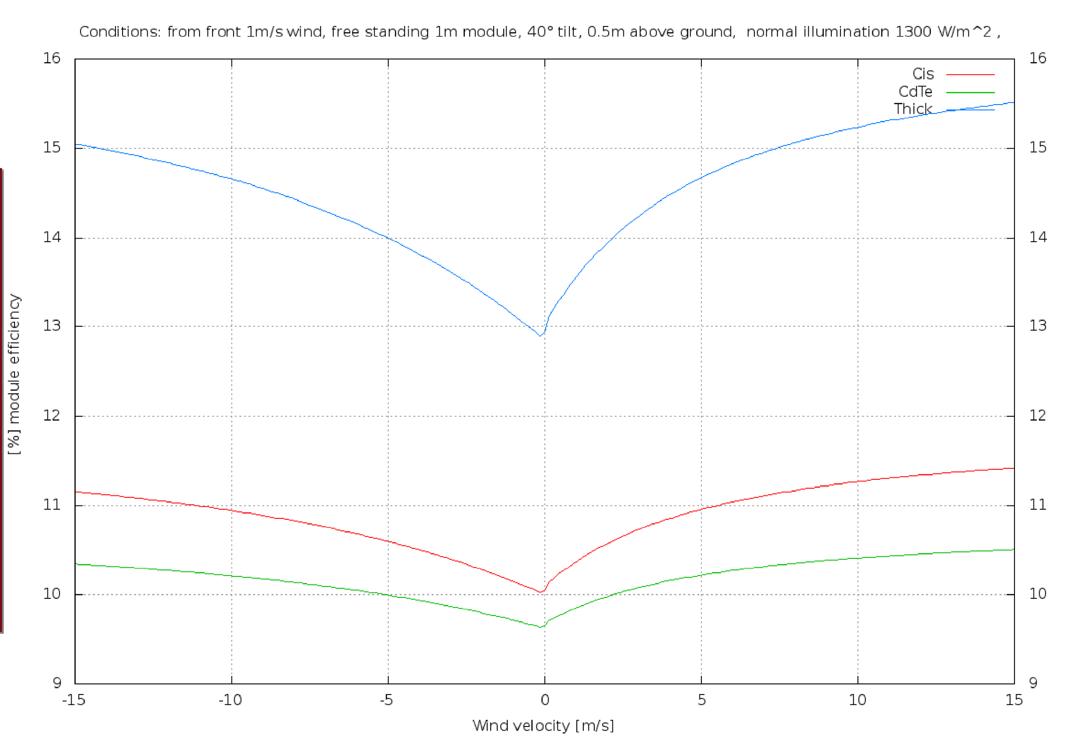
Glass+Backsheet

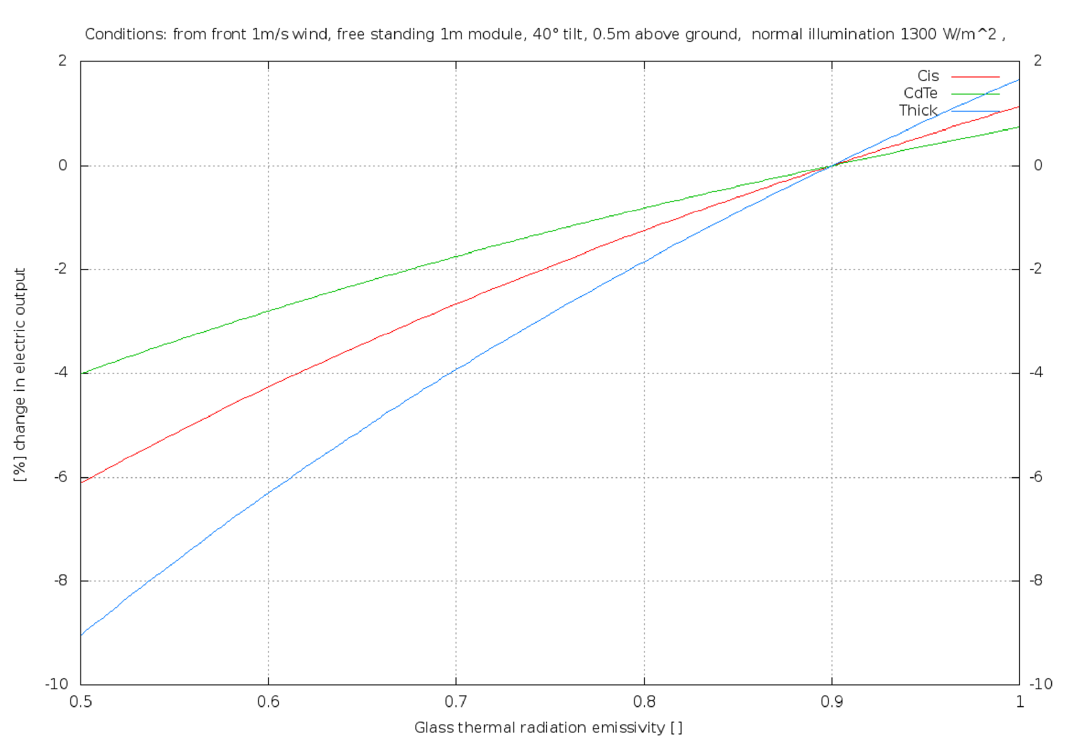


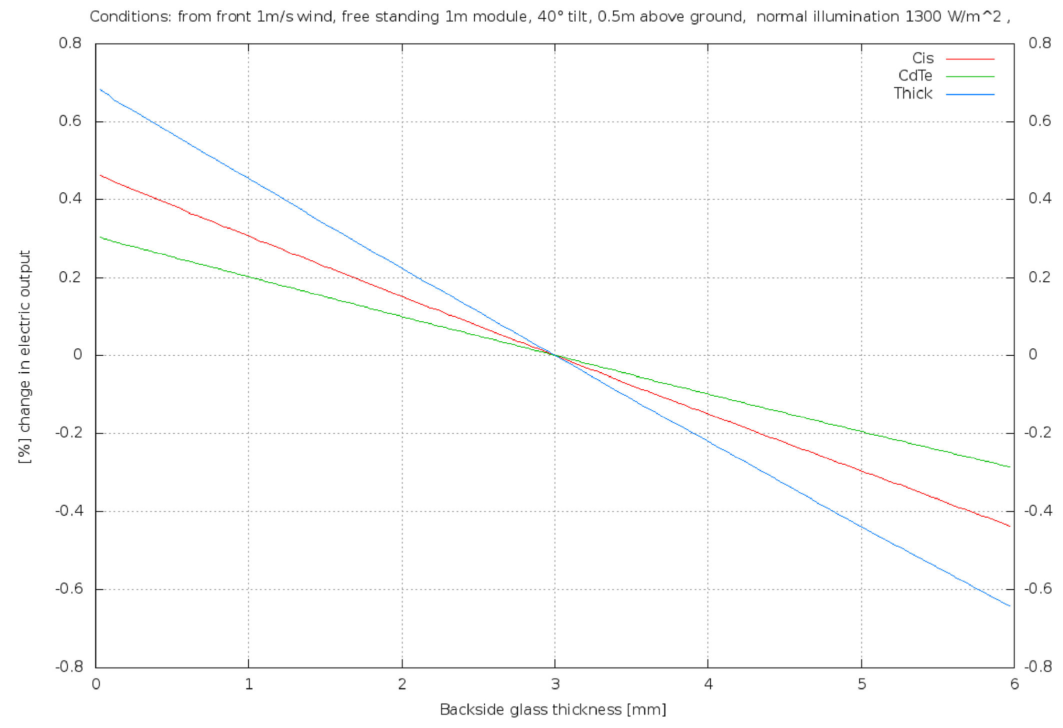




Glass+Glass







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[1] B. Kubicek, K.A. Berger, Ab Initio Simulation von Photovoltaik-Modulen, 26. Symposium Photovoltaische Solarenergien, E8, 2011.
[2] B. Kubicek, R. Ebner, S. Novalin, Ab Initio Simulations of The Superstrate TF-Module Performance Depending On The Back Foil Properties, Third International Conference on Thin-Film Photovoltaics, Munich, 2011.

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