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PVOPTI-Ray: Optimization of reflecting materials, thermal comfort and photovoltaic yield in an urban context

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Cities are the biggest energy consumers and they are going to be the major victims of climate change. Against this background, the ‚Solar Cities‘ issue is discussed nationally and internationally: cities that are gaining most of their energy need from the sun directly with their own rooftops and facades. At best, black solar modules are used with low reflection and thus a high electricity yield with up to 20%. However, the biggest part of the absorbed solar radiation is transformed into heat. So far no evaluation and simulation tools have not been developed for the urban area, which can estimate the effects of a broad roll-out of photovoltaic (PV) and insolation of facade surfaces in urban districts, especially on the micro-climate in street canyons.

Within this study, the interdependency of irradiation reflections, energy balance and building integrated photovoltaic (BIPV) systems inside complex urban structures was investigated. While research in PV and urban climate modelling is advanced, the interaction of BIPV in cities and urban climate has not yet received the required attention. We want to find an optimum solution regarding the structure of an urban canyon, materials used, optimum façade integrated PV yield and minimum human stress by using combined models for urban climate and photovoltaic yield.

The first step was to assess different, existing models and combine and further develop the best ones in terms of quality and their applicability on the problem. The development was based on the open source urban climate-building model called Solar Long-Wave Environmental Irradiance Geometry (SOLWEIG, Lindberg et al. 2017), which calculates the strongly needed climatologic variables like the mean radiant temperature. The Universal Thermal Climate Index (UTCI) was included in this modelling framework to permit a statement of a possible optimal future thermal comfort scenario. Additionally the wall and ground temperature calculation was improved using the energy transfer models. PV modules were included as optional wall surfaces based on the energy transfer model for BIPV by Lodi et al. 2012. Ground temperatures were improved using the force-restore method regarding different ground conditions and albedo, respectively.

In the second step representative ambient air temperatures, which were fixed originally, had to be calculated to take into account the gradients between the facade and the center of the urban canyons. Therefore, we implemented an urban wind model, published by Roeckle's (1990) PhD thesis. By combining the wind speeds for each grid cell, the surrounding surface temperatures and the calculation method for the canyon air temperature of the Town Energy Balance (TEB) model, the final ambient air temperature is available and can be used to calculate the UTCI.

References:
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Lindberg F, et al.: Urban Multi-scale Environmental Predictor (UMEP) - An integrated tool for city-based climate services. Environmental Modelling and Software (2017)