Solar World Congress 2025

Real-Time Estimation of Urban Solar Rooftop Potential: A Case Study

Summary

Accurate on-the-fly estimation of solar rooftop potential is a valuable tool for optimizing solar energy harvesting in urban photovoltaic (PV) system design. In densely populated areas, precise determination of available rooftop or façade space is challenging due to the complex geometry of buildings, shading by surrounding structures etc. While several tools exist in the market such as Mapdwell, Google Project Sunroof, Cadastre Solaire Luxembourg, they typically rely mostly on static, annual estimates and often simplify or avoid complex geometries of the buildings and atmospheric data.

In this paper, we present a case study showcasing the dynamic, real-time estimation of solar rooftop potential using in-situ measurements from ground-based sensors combined with high resolution building geometry. We validate our results using plane-of-array irradiance that we collected via pyranometers at two distinct tilt angles. The proposed approach can be replicated for higher resolution city-wide solar potential analysis and supports informed decision-making for policymakers, urban planners, and individual stakeholders looking to invest in rooftop solar installations.

Keywords: Dynamic Solar Cadaster, Rooftop Solar Potential, Urban Photovoltaics

1. Introduction

Urban areas are witnessing rapid growth with a significant increase in energy demand, prompting a global push toward sustainable and decentralized energy solutions. Among these, rooftop solar photovoltaic (PV) systems offer a highly promising pathway for clean energy generation, particularly in densely populated cities where establishing large-scale power generators or PV farms are often unfeasible, due to limited land availability. Additionally, unlocking the full potential of rooftop solar energy in urban environments hinges on the ability to accurately assess, in high resolution, the solar potential of available building surfaces for both rooftops and façades.

Traditional approaches to solar potential assessment often rely on annual average irradiance data and generalized assumptions about rooftop availability. Tools such as Google Project Sunroof (2015), Mapdwell (2014), and Cadastre Solaire Luxembourg (2019), provide valuable insights but are typically based on precomputed static datasets and simplified models. These tools often tend to overlook complex building geometries, real-time atmospheric conditions such as clear or cloudy sky etc., leading to potentially significant inaccuracies in solar energy estimation.

To address these limitations, we performed a case study to estimate rooftop solar potential using real-time site-specific irradiance measurements and a high-resolution digital surface model (DSM) of a building. The DSM was generated from lidar data provided by the local municipality. Minute-by-minute measurements of solar radiation components i.e. Direct Normal Irradiance (DNI), Diffuse Horizontal Irradiance (DHI), Global Horizontal Irradiance (GHI), extraterrestrial beam irradiance, ground albedo, 25° and 51° plane-of-array measurements were collected. We estimated the direct, diffuse and reflected solar radiation on the building surface and two PV panels. For diffuse radiation , the simplified Perez model, known for its accuracy (García et al., 2021; Li and Cheung, 2002; Demain et al., 2013, G Notton et al., 2006) was used. Unlike static tools, this method supports dynamic analysis that can adapt to specific conditions and building orientations, thereby providing more granular and accurate estimations.

To validate our framework, we use in-situ measurements configured at two tilt angles representative of typical rooftop panel installations. These measurements serve as a ground truth to evaluate the performance of our model under real-world conditions.

2. Methodology

The irradiance data used in this case study is based on measurements taken from 22 to 24 July, 2022 (3 days). The DSM consisted of 232673 faces and was prepared from lidar point cloud data using the triangulated irregular network (TIN) method, shown in Fig 1 (left). Additionally, two surfaces mimicking the two pyranometers at tilt angles of 25° and 51°, with the azimuth of 180° were positioned to obtain simulated total solar irradiance on both surfaces. The simulator is designed to calculate the direct, diffuse and reflected solar radiation components of each individual building face (equations provided in final version). We also perform rooftop potential analysis on the three building in the DSM as shown in Fig 3 (left).

The results mentioned here do not include shading of the DSM faces (like walls, rooftop surface or ground) by other faces, which shall be included in the final version.

3. Priliminary Results and Discussion

For a single timestamp of (minute-by-minute) data, the total solar irradiance was obtained in ≈ 7 seconds on a laptop running on 2.4 GHz 8-core Intel core i9, with 4GB VRAM and 16 GB RAM on the DSM with 232673 individual faces. This imples that computation on more DSM faces can be performed without loosing the benefit of real-time processing, which should be under 1 minute for given data.

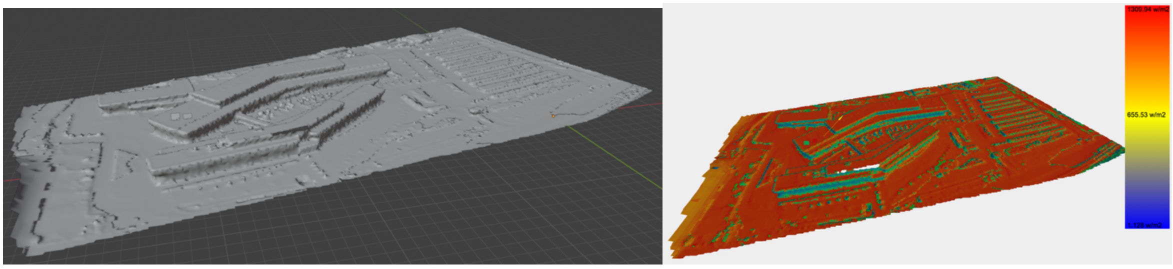

Fig 1 (left) DSM with 232673 faces used in the study (right) Snapshot of the total solar irradiation profile on the DSM for the timestamp of 2022-07-22 at 5:38 UTC

The two surfaces mimicking the pyranometers with the tilt angles of 25° and 51°, and azimuth of 180° were utilized for obtaining simulated total irradiance. The results are provided in Figure 2 (left) for 25° tilt angle and (right) for 51° tilt angle.

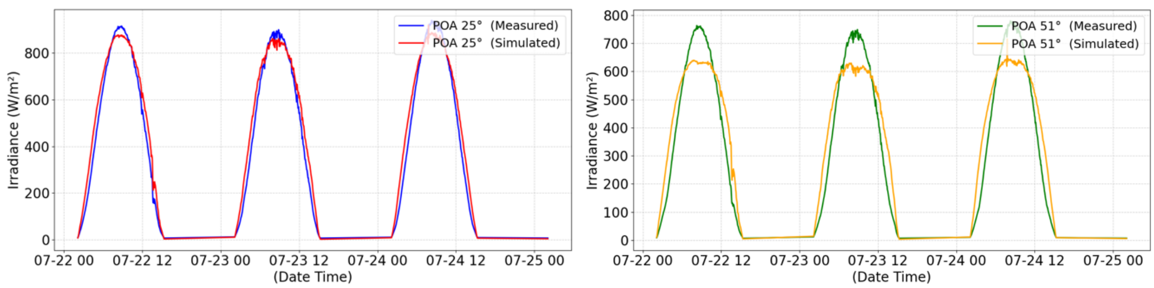

Fig 2 Measured vs simulated plane-of-array irradiation for 25° tilt angle (left) and 51° tilt angle (right)

From the results, we conclude that the total solar irradiation profiles for the both the surfaces with tilt angles are relatively closer to what was measured by the ground station. We also additionally observe that the results were closer for the surface with 25° tilt angle compared with 51° tilt angle. This is subjected to further analysis in our final version.

After the validation of our results on the two surface, we estimate the total rooftop solar potential on our DSM, assuming the PV perform at 22 % efficiency (Sreenath et al., 2024).

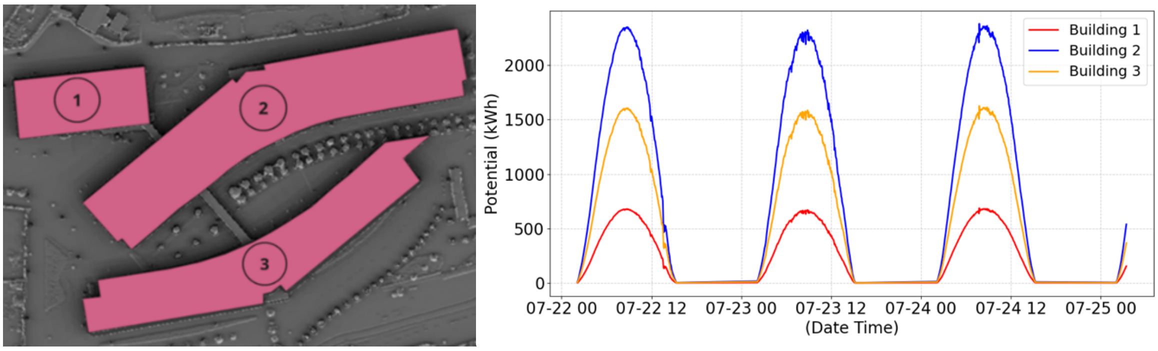

Fig 3 (left) Building layout with numerical identifier (right) Total rooftop solar PV potential on minute-by-minute resolution for all the buildings

The results are provided in Figure 3 (right), from the figure we notice that the rooftop surfaces behave in correlated manner, with Building 2 providing the highest yield. (further analysis on the shading and occulisions as a function of time shall be provided in the final version)

4. References

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