Topic 5.2

3D Solar Potential Modelling and Analysis: A case study for the city of Utrecht

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Summary
The city of Utrecht in the Netherlands has high ambitions in realizing locally produced renewable energy, especially using photovoltaic (PV) solar energy panels. By the year 2030, the Utrecht Central Station district aims to be energy neutral. The present contribution describes two developed methods for the simulation of solar potential. These methods can easily be employed by urban planners to make an optimal decision for designing a smart energy plan for an area or city. The work carried out is part of Smart Sustainable Districts- Deep Dive Utrecht Project, funded by Climate-KIC.

Purpose of Work and Approach
The goal of this work is to analyse the potential for solar PV with regard to the (building) changes in the district. The focus will be on Building Integrated Photo-Voltaics (BIPV). 3D models have been developed to fit two scenarios namely present (2015) and for the year 2030. Implementation of potential analysis helps in coming up with integrated solutions which can provide a significant decrease (grid) in electricity demand of the buildings while at the same time increasing the use of PV and storage solutions by 2030 in the Utrecht CS District, taking into account the existing and planned urban design of the City of Utrecht. In this work, two complementary solutions were used, both set up in a GIS based platform. This helped in exploring and visualizing the data in an efficient way, and allows easy communication to city developers and other stakeholders.

Scientific Innovation and Relevance
The estimated technical PV potentials should be used for comparison against the electricity demand in the area. This would help in providing solutions to make the area energy neutral by maximising solar energy and providing alternatives where and when necessary. Also, a tool to show the suitability of buildings for solar PV installations on a large scale helps planners and developers in decision making in planning energy efficient buildings or neighbourhoods. The results of the solar potential analyses enrich the 3D building models (for each wall and roof surface) and, thus, can be used and queried in further assessments.

Results and Conclusions
The results show what the potential and the capacity of producing electricity by PV power are in different scales. On a higher scale it shows whether a building is suitable for producing sufficient amounts of energy to justify the cost of installing PV modules. On a lower level, it compares different facades or roofs of one building.
Interestingly, the planned developments for the Utrecht district do not seem to affect the solar PV potential to a large extent. It is found that it is not possible to cover the whole electricity demand of the area with only PV power. In order to make the region energy neutral other options like (urban) wind energy, and offsite solar parks or Bio-CHP’s may need to be considered.

3D models of the district have been developed and used to estimate the potential for generation of PV power. The models of the 2030 scenario have been developed on the basis of a trial allotment plan by the municipality. Based on the received irradiation for each wall or roof surface of each building, the buildings in the area have been classified into 4 categories. Two different models have been used for PV potential estimations for rooftop and façades. A constant power density of 150 Wp/m^2 has been used for potential capacity calculations that can be installed on the rooftops and façades of each building (effectively using 15% efficient modules). Both the models have been combined in order to estimate the PV potential for each building for two scenarios; the present (2015) and for the year 2030 with planned changes.

Two main issues addressed are the building roof top and façade potential for solar PV:

1. Current potential
    a. What is the present solar PV potential for the area (roof top/façade)?
    b. Would PV energy supply be enough to fulfil the present electricity demand in the area?
2. Scenario 2030
    a. Would the developments or changes in the buildings influence the potential and to what extent?
    b. Would PV energy supply be enough to fulfil the future electricity demand in the area?

In this work, two complementary solutions were used, both set up in a GIS based platform. This helped in exploring and visualizing the data in an efficient way.

For rooftop analysis the ArcGIS Desktop from ESRI was used. Many layers of information have been created to analyse the data at different resolutions. Elevation data from Actueel Hoogtebestand Nederlands (AHN) was used as a primary input in the model. The Solar Analyst tool of ArcGIS has been used to model solar irradiation values at a spatial resolution of 50 cm allowing studying rooftops with ease. Building footprint and information layer was obtained from Basisregistratie Adressen and Gebouwen (BAG), which is a part of government system for cadastre data in the Netherlands. Slopes and orientations of rooftops have been calculated to distinguish between flat and sloping roofs.

The model has been developed at Copernicus Institute of Sustainable development at Utrecht University and was successfully implemented to classify roof tops into categories [1]. Different power densities for flat and sloping roofs were used to calculate the potential for individual rooftops based on 4 categories. In addition, the criterion that only 35% of the roof area is actually suitable for PV siting (due to presence of dormers, windows, chimney or shading, or potential other use of the roof area such as for water detainment) has been used as a constraint.

To estimate the solar potential for the non-horizontal surfaces particularly facades, another tool was employed. This tool has been developed at Technische Universität München (TUM) in the chair of Geoinformatics. This model calculates the solar potential for both roof and wall surfaces using the OGC standard "CityGML" [2]. However, in this project only the results of wall surfaces were required. For this model the area must be modelled semantically in 3D in order to do the required analysis especially for vertical surfaces such as façades. Figure 1 and Figure 2 show the 3D model of the Utrecht central station area in CityGML LOD2 (Level of Detail).

By this method the solar energy potential (diffuse and direct radiation) for all walls of every single building was calculated. The geographical specific global radiation values are considered as well as shadowing effects [2]. Then, based on the received irradiation for each wall surface of each building, the façades in the study area have been classified into 4 categories, similar to the rooftop categorization to achieve uniformity. Thus, the adjacent walls of each two buildings which receive no irradiation and those with an irradiation of less than 50% (class 0) are omitted. The results are aggregated both per wall surface and per building. Therefore, there is a possibility to visualize which façade is suitable for PV installation.

Figure 1: 3D model with level of detail 2 (LOD2) created in CityGML for 2015. This forms the basis for further solar potential analysis.

Figure 2: 3D model with level of detail 2 (LOD2) created in CityGML for 2030. The planned changes are reflected in the model. Most of the changes will take place in the Jaarbeurs area (Left corner). Planned modifications can be identified from Figure 1 and Figure 2.

The categorization used for both the model is as follows

- **Class 3**: if the building surfaces receive more than 90% of the annual average irradiance of the region. These are optimally best suited surfaces for PV, having maximum efficiency.
- **Class 2**: if the surfaces receive 70-90% of the irradiation of the region.
- **Class 1**: surfaces receiving 50-70% of the irradiance of the region and
- **Class 0**: those areas which receive less than 50%. These areas are termed not suitable.

Results and Conclusions

The results of this simulation can precisely show what the potential and the capacity of producing electricity by PV power are in different scales. On a higher scale, for example, it can show whether a building is suitable for producing sufficient amounts of energy to justify the cost of installing PV modules. On a lower level, it can give a comparison of different facades or roofs of one building. Often the facades on the north sides, for example, are not suitable as shown in Figure 3. A more detailed description would be which part of a façade or roof can produce higher amounts of energy considering shadowing effect of the obstacles in front of the surface.

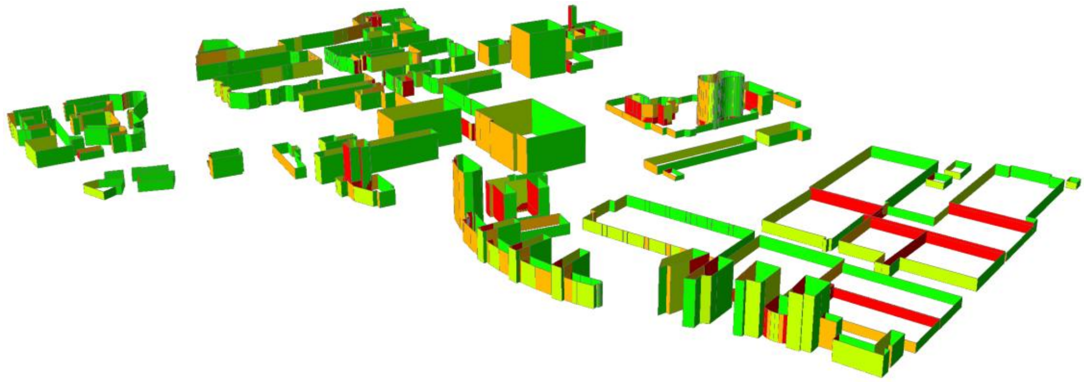

Figure 3: Calculations of PV potential from facades of buildings in the area in 2015 using CityGML models showing four categories. Red wall surfaces are unsuitable surfaces (category 0) and the green surfaces are most suitable (category 3).

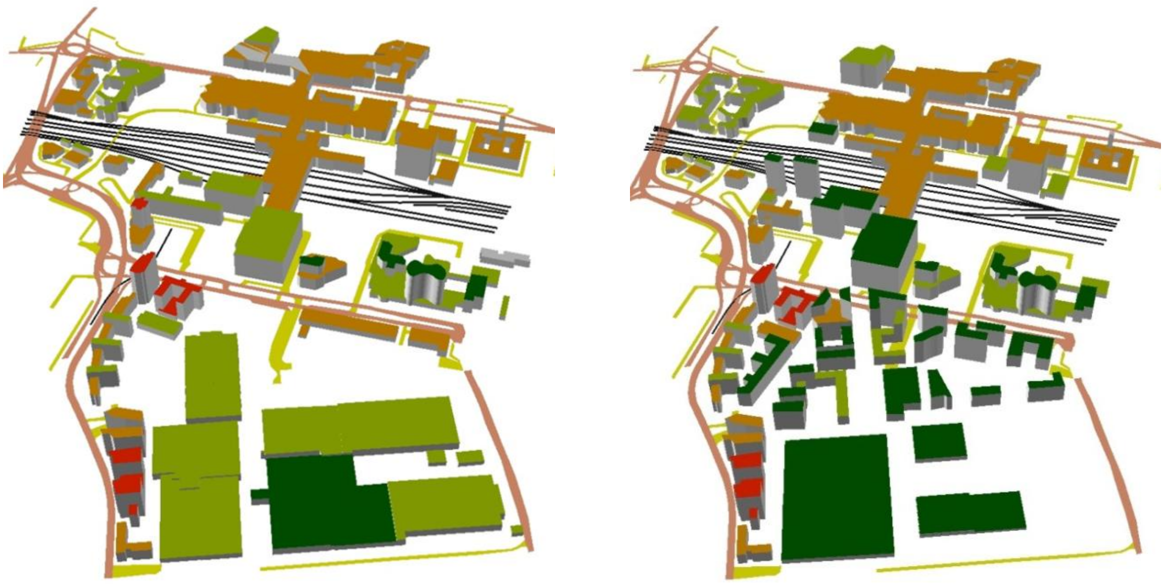

Figure 4: Roof top PV potential for the area in 2015 (left) and 2030 (right). Green roof tops are highly suitable for PV, Red are unsuitable and orange are partially suitable. For 2015 the rooftop potential was calculated at 16MWp and for 2030 the potential was estimated at 14.6 MWp due to the planned changes.

The planned developments for Utrecht city centre do not seem to affect the solar PV potential to a large extent. It is not possible to cover the whole electricity demand of the area with only PV power. The model underestimates the results about 5-10% as some of the assumptions bring down the potential. In order to make the region energy neutral other options like wind energy, and offsite solar parks or Bio-CHP's are to be considered.

References

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