Method for solar potential mapping of the intra-building over the street unoccupied urban volume

Teresa Santos[a], *Jorge Rocha*[b] *and Killian Lobato*[c*]

[a] *Centro Interdisciplinar de Ciências Sociais (CICS.NOVA), Faculdade de Ciências Sociais e Humanas da Universidade Nova de Lisboa, Colégio Almada Negreiros, Campus de Campolide, Lisboa, Portugal*
[b] *Centre for Geographical Studies, Institute of Geography and Spatial Planning, Edifício IGOT, Universidade de Lisboa, Rua Branca Edmée Marques, Lisbon, Portugal*
[c] *Instituto Dom Luiz (IDL), Faculdade de Ciências da Universidade de Lisboa, Campo Grande, Lisboa, Portugal*
[*]*email klobato@fc.ul.pt*

Introduction

For urban solar energy there is a significant amount of literature on how to evaluate the solar potential of building roof-tops and facades [1]. However, with the advent of the urban street becoming ever more pedestrianised [2] it will subsequently become of higher value for leisure, commerce and services. One can foresee significant occupation of the street with these which will have to be as energy efficient and carbon neutral as possible. As such, their solar potential will require evaluation. Given the significant proportion of the urban landscape that streets occupy, it is therefore pertinent to evaluate the solar potential of streets, or more appropriately, the unoccupied volume above the open street. One interesting recent example is that of solar powered unmanned autonomous flying vehicles requiring to maximise the solar potential of their flight path in a urban environment [3].

A simple and commercially feasible method is demonstrated that permits, at a city scale, the mapping of the solar energy exposure of a surface at any height of the intra-building above street unoccupied volume. This is achieved with recourse to the commercially available Solar Analyst software tool of the ArcGIS platform. This tool is widely used to evaluate the solar potential of roofs in complex urban environments. For the purpose of this paper, the approach is, in essence, to sequentially create at set height intervals virtual surfaces above the street, and then evaluate the insolation on these surfaces whilst still considering the surrounding built environment.

This paper will demonstrate this approach, applied, as an example, to four areas of Lisbon with distinct urban morphologies. For all areas, the daily insolation is calculated for a series heights above street level and for two distinct days. The result is, as a function of height, a series of maps of daily solar insolation.

Results

Figure 1 shows an example of the processed data from these maps to visualise, in cross section, the daily insolation of two streets in one of the examined areas (downtown Lisbon). The streets are similar in terms of width and surrounding building height. However, they differ in orientation. The zones coloured in red are ones where essentially no shading from the built environment occurs. For the street with a mainly N/S orientation, we can see that the west side of the street, has a significant decrease in daily insolation. This decreases with increased height. For the mainly E/W orientated street, there is a marked transition at *ca*. 15m in the intensity of the solar insolation. The south side of the street, as expected for Lisbon's latitude, has a lower degree of insolation. These types of figures can be generated for any section of street of the evaluated city areas.

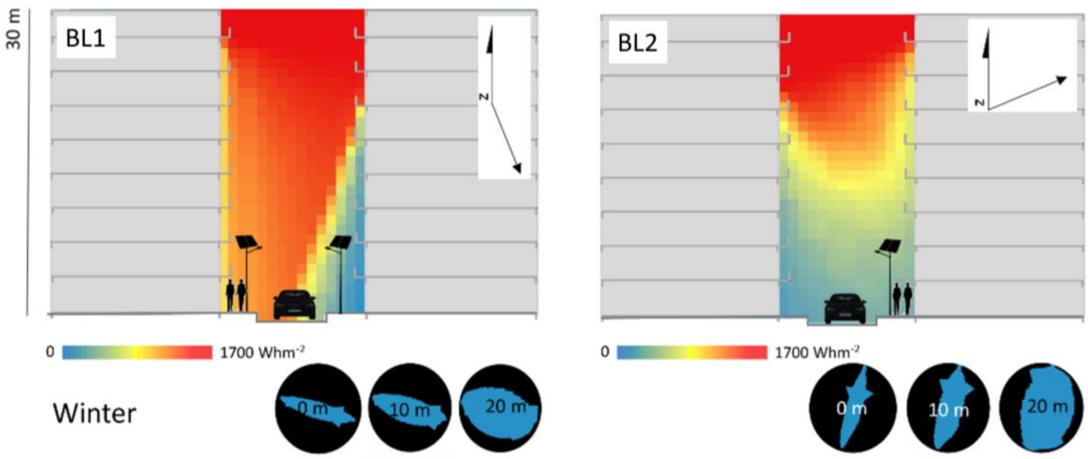

Figure 1 – The two images show section views of the winter solstice daily insolation (global horizontal). Horizontal resolution is 1m, defined by LIDAR data acquisition. Vertical resolution was defined by the set 1m height increment. Here the area of interest is downtown area of Lisbon known as *Baixa de Lisboa* (for the figures this was shortened to BL). Two streets shown have differing orientations, BL1 with an almost direct N/S orientation, whilst BL2 has an almost direct E/W orientation. For the purpose of aiding visual clarity, pedestrians, vehicles and solar powered street lights are depicted. The grey area is that of buildings, with the individual typical flat height depicted as horizontal dark grey lines. For the two streets, the sky view from the centre of the street is shown for 3 different heights above street level.

Conclusions

A simple method, employing a widely sourced commercial software, has been successfully developed to evaluate the solar insolation, at a city scale, of the unoccupied urban volume above the street. The manner in which the data is generated and the nature of data generated can be of substantial importance for city authorities, planners and developers who will always need to determine solar insolation potential. For PV, this can be applied to eg. solar street lighting, e-bike solar power charging stations, solar powered urban furniture and shading, new or temporary kiosks, digital information stands and public transport passenger shelters.

Methods

Figure 2 shows a schematic that described how the height dependent insolation maps were generated. In short, a Digital Surface Map (DSM) derived from Light Detection and Ranging (LIDAR) data of Lisbon was used in conjunction with a building location map to identify buildings and their height. The LIDAR data was not used to determine street height because of the presence objects on the street such as trees, cars or temporary buildings. A Digital Terrain Map (DTM) along with the building height maps were together used to sequentially generate DSMs where the street height was increased whilst maintaining the building height unchanged. The Solar Analyst tool was then run for the DSMs, for the two days of interest. Bi-hourly insolation maps were calculated and then summed to obtain the daily insolation maps for each height above street level.

The Solar Analyst tool has several parameters than can be adjusted which trade calculation time for precision. Some parameters are applicable for direct solar irradiance, whilst others are applicable for diffuse irradiance. Upon reviewing this trade-off, the decision was taken to apply the maximum value for each parameters permissible by the software to maximize calculation precision for direct solar irradiance, whilst the default parameters were sufficient for the diffuse solar irradiance. For the parameters defining the intensity of direct and diffuse irradiance, these were adjusted to ensure that daily insolation, for the respective days, was the same as that reported by the PVGIS for Lisbon [3]. The diffuse radiation model applied was Uniform Sky.

Only horizontal insolation was considered, but any angle and orientation could have been considered, as this is an input option of the Solar Analyst tool. This would result in another series of maps, for each angle and orientation respectively.

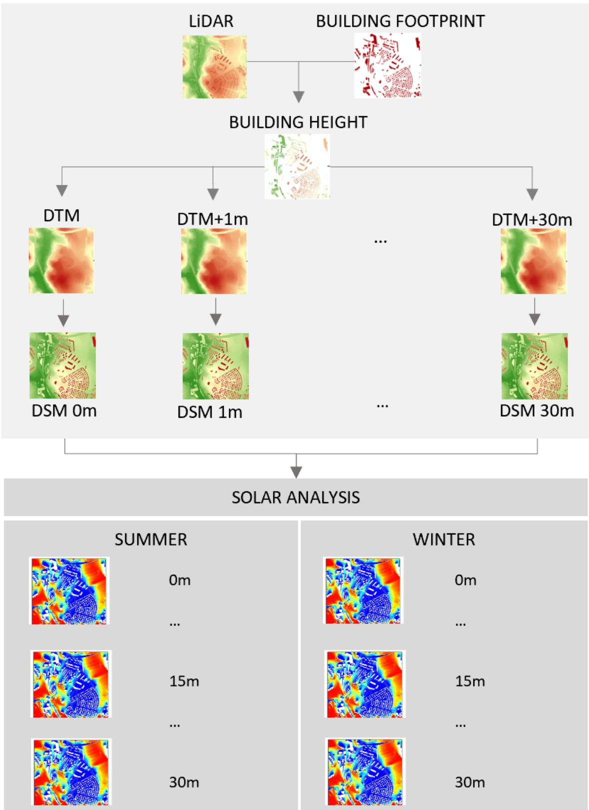

Figure 2 – Schematic representation of the generation of Digital Surface Maps required for the subsequent daily insolation maps calculated for different heights above the street level.

References

[1] International Energy Agency SHC Task 51 - Solar Energy in Urban Planning. Approaches, Methods and Tools for Solar Energy in Urban Planning. (2018).

[2] European Commission - Reclaiming city streets for people: chaos or quality of life? (2004).

[3] Wu *et al*., Neurocomputing 275, 2055–2065 (2018).

[4] Brito *et al*., Sol. Energy 86, 283–288 (2012).

Topic Selection

Topic 5: PV Systems and Storage – Modelling Design, Operation and Performance
Subtopic 5.1: Solar Resource and Forecasting

The topic and subtopic selection is justified because the work presented here discusses a method for determining the solar resource in complex urban environment. This knowledge can be applied to the planning and decision making of how PV systems should be designed and operated in street urban environments to ensure required performance.

Acknowledgements

Teresa Santos wishes to thank FCT project UIDB/04647/2020 - *Centro Interdisciplinar de Ciências Sociais da Universidade Nova de Lisboa* and also FCT *program the Norma Transitória* – DL 57/2016/CP1453/CT0004
Killian Lobato wishes to thank the FCT- project UIDB/50019/2020 – IDL - *Instituto Dom Luiz*