

Solar potential in the urban environment

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Assessing solar potential in the urban environment

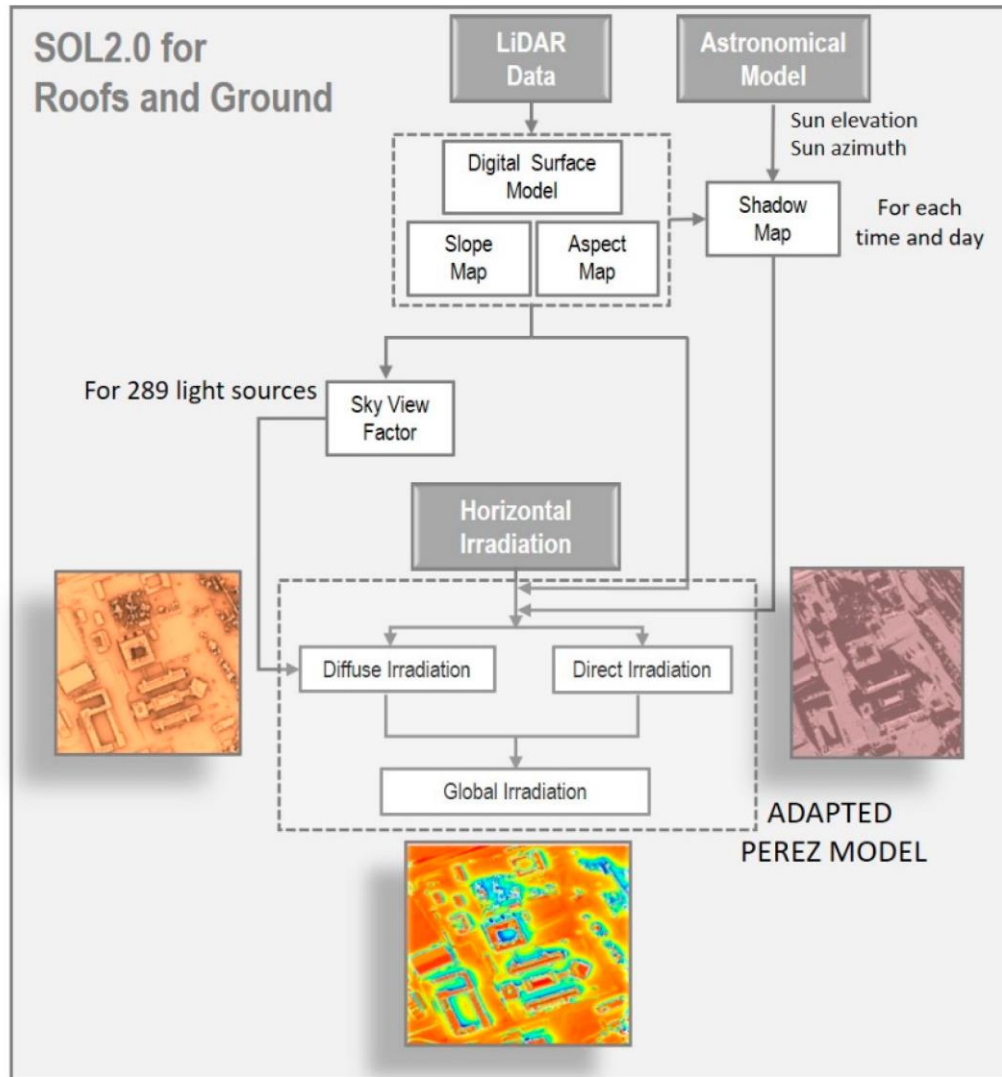
Relevance

- urban design
- public policies
- grid development
- learned individual choices

Requires

- Solar radiation modelling (different levels of sophistication)
- Urban digital representation (DSM)
- Shading calculations (direct irradiance)
- Sky view factor (diffuse irradiance)
- GIS representation

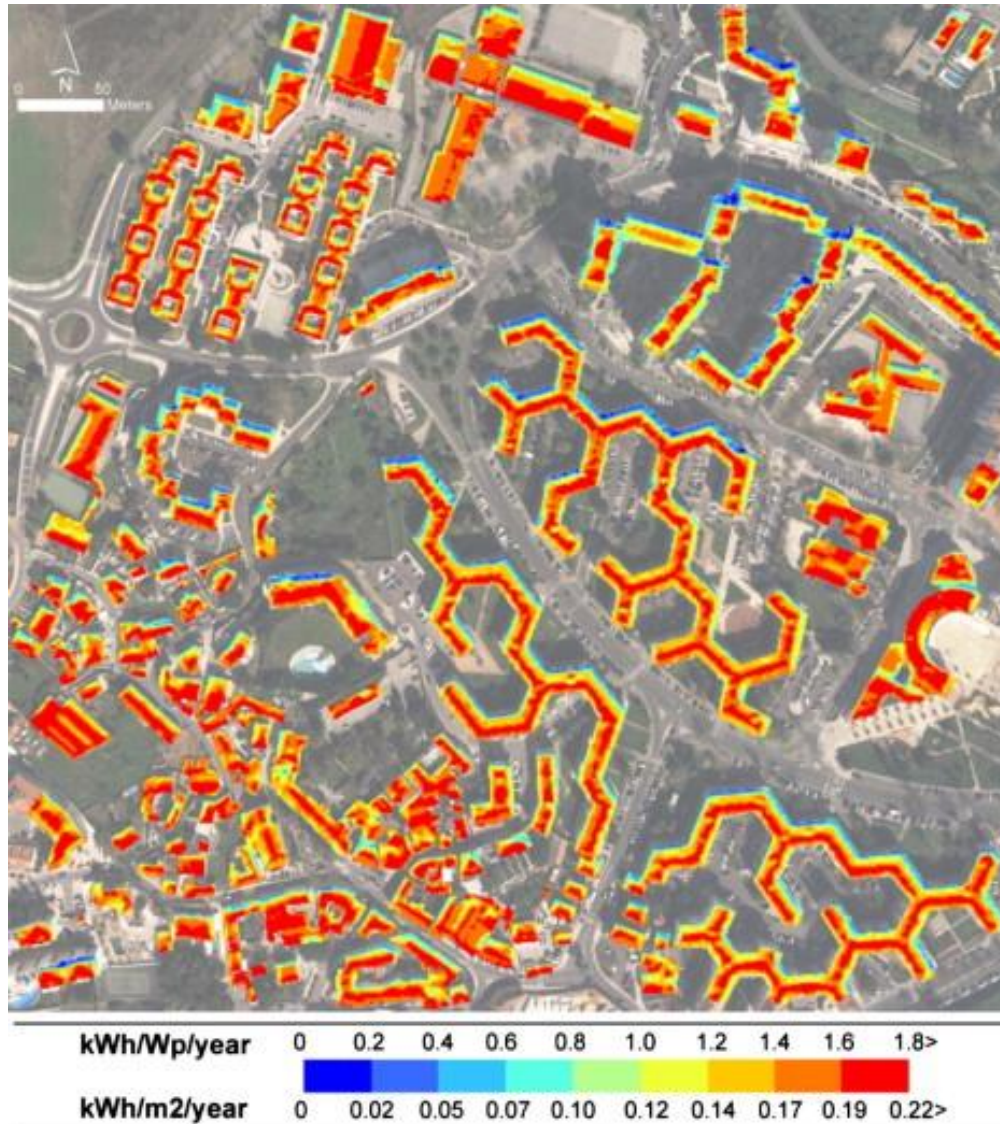
Solar potential rooftops



Modelling

- Irradiance components
- Direct irradiance on an arbitrary surface
- Shading calculation
- Sky view factor calculation from DSM
- Diffuse irradiance from sky view factor
- Reflected irradiance

Solar potential rooftops

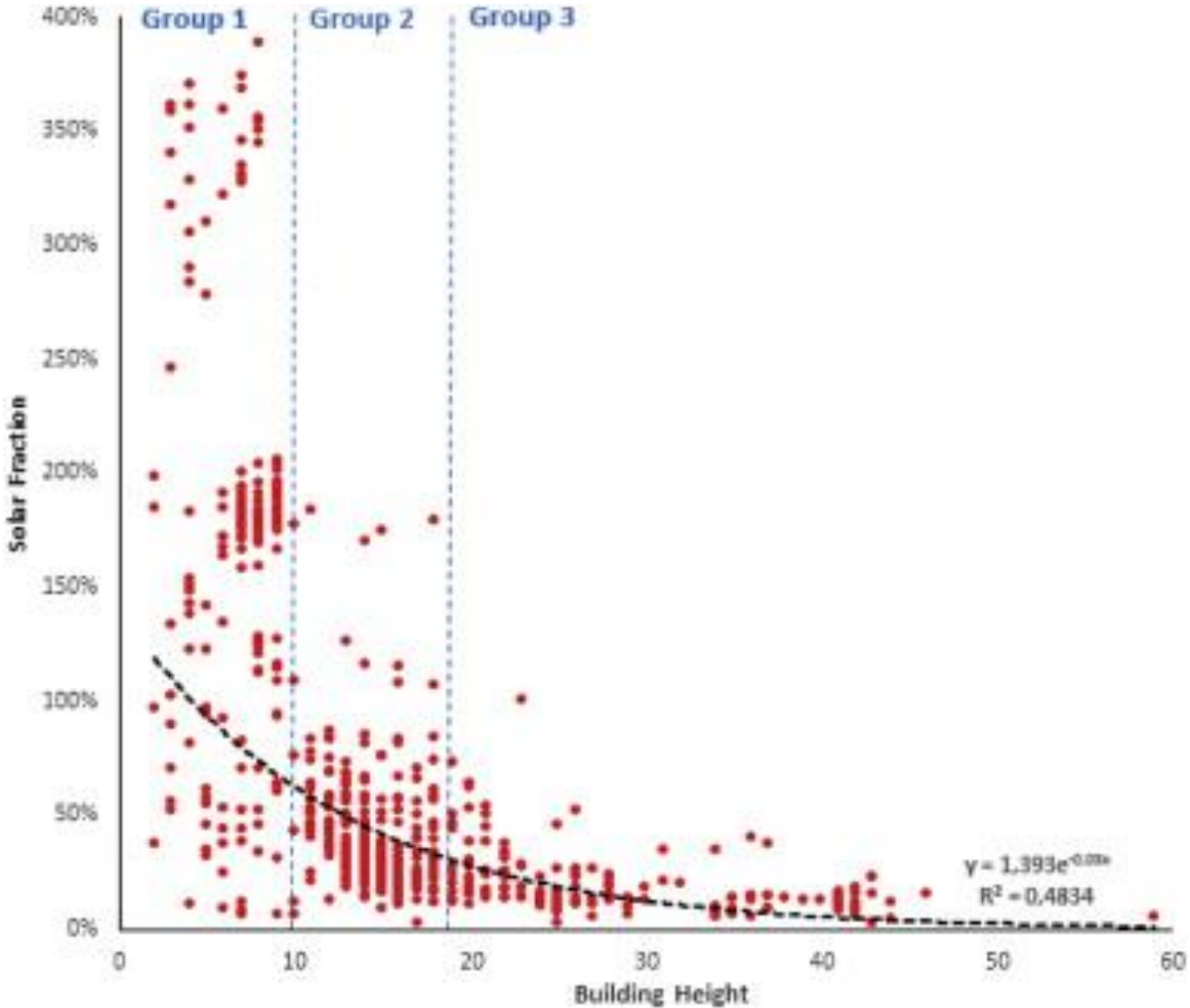
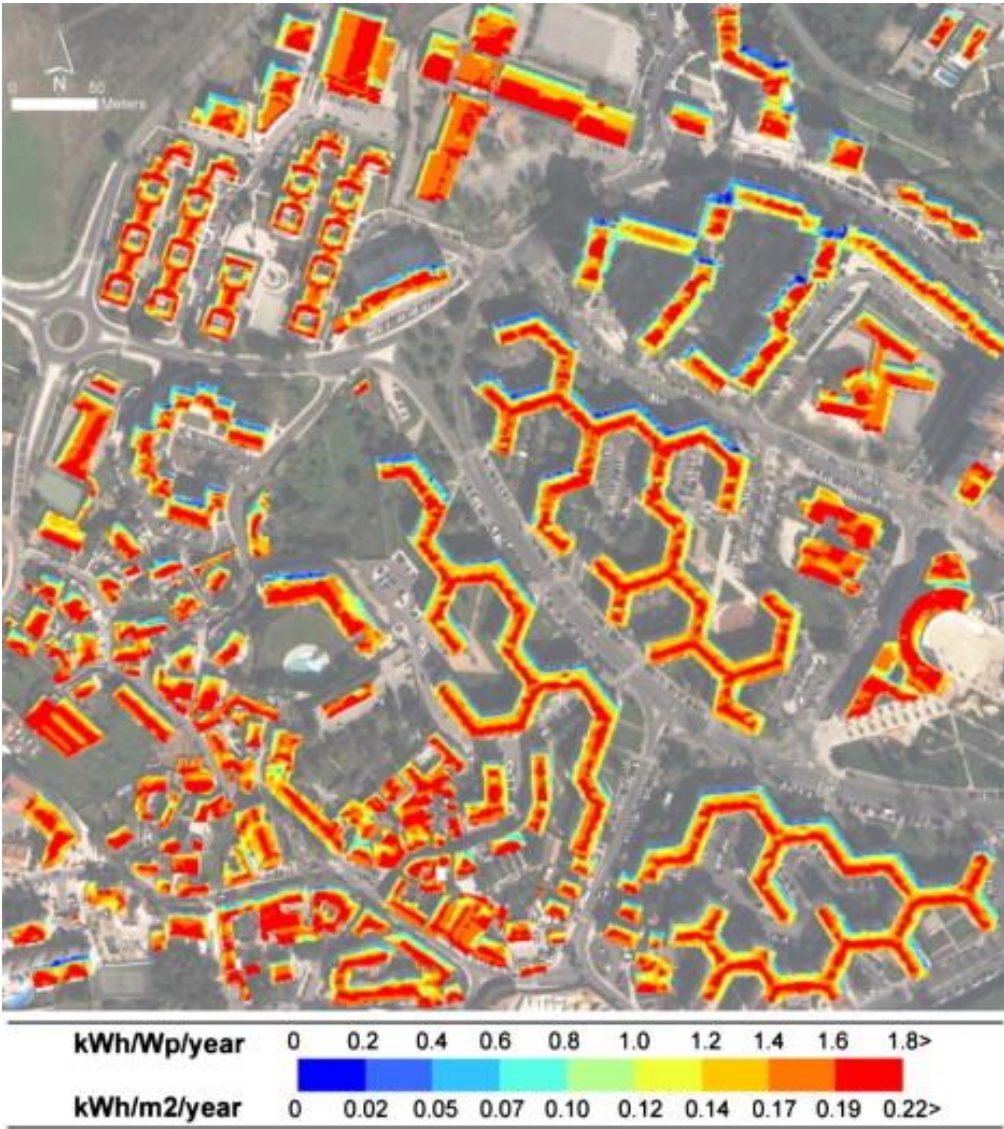


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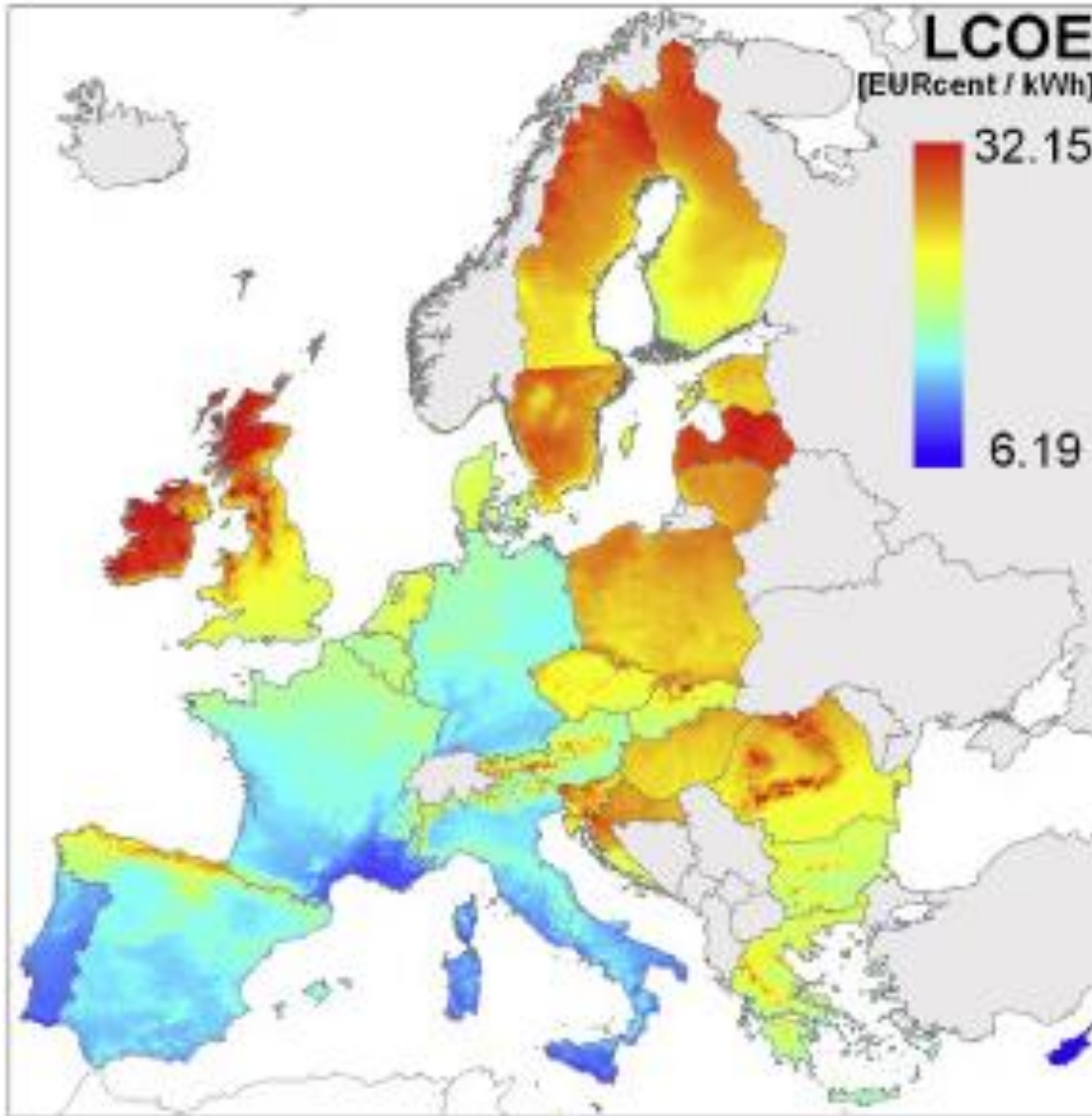
PV potential map: annual average solar electricity yield per nominal installed power and per unit area, assuming efficiency of 12%
[Brito et al 2011, <https://doi.org/10.1016/j.solener.2011.09.031>]

Solar potential rooftops



[Santos et al 2014, <https://doi.org/10.1016/j.apgeog.2014.03.008>]

Solar potential rooftops

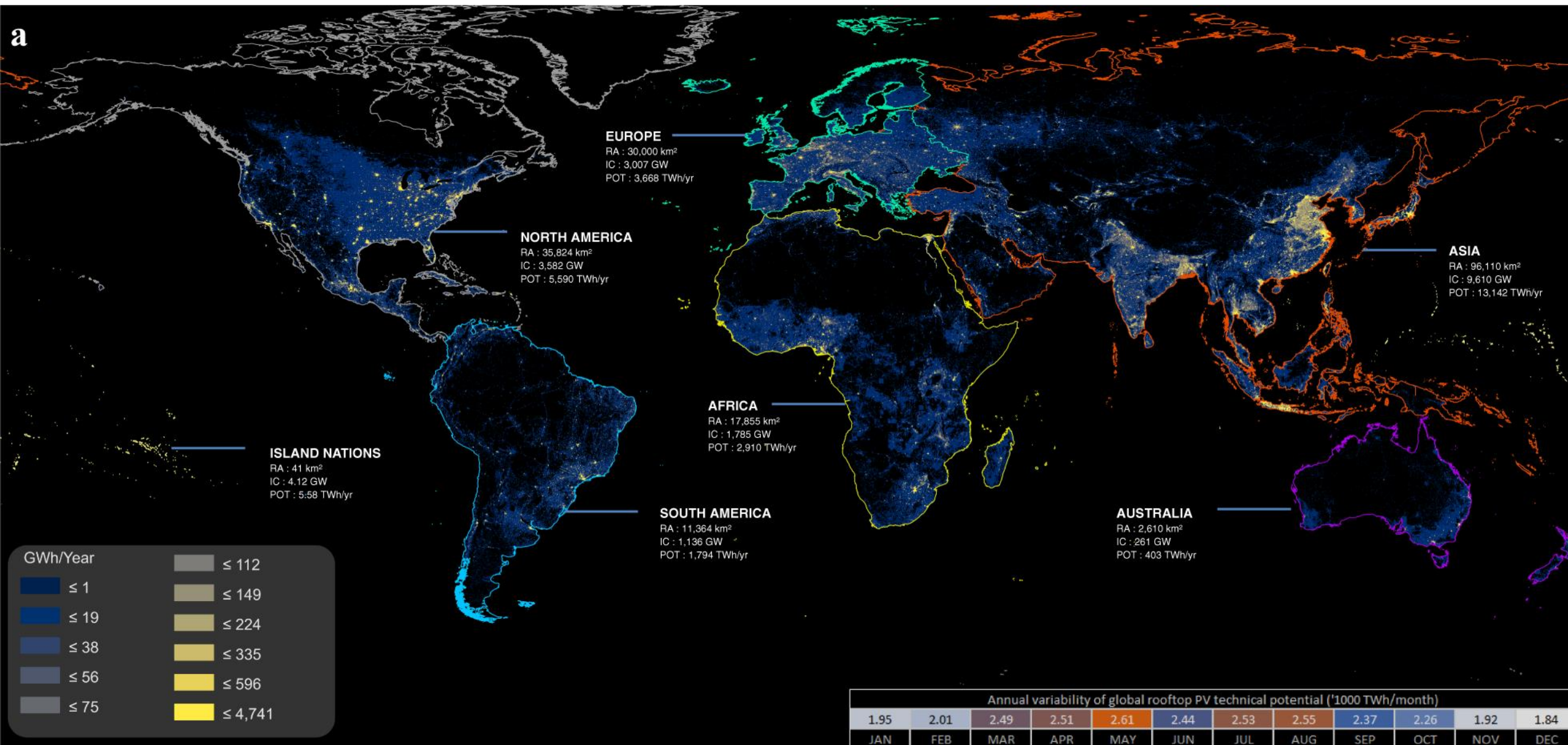


Map of the spatial distribution of the LCOE of rooftop solar PV systems in the EU

[Bodis et al 2019, <https://doi.org/10.1016/j.rser.2019.109309>]

Solar potential rooftops

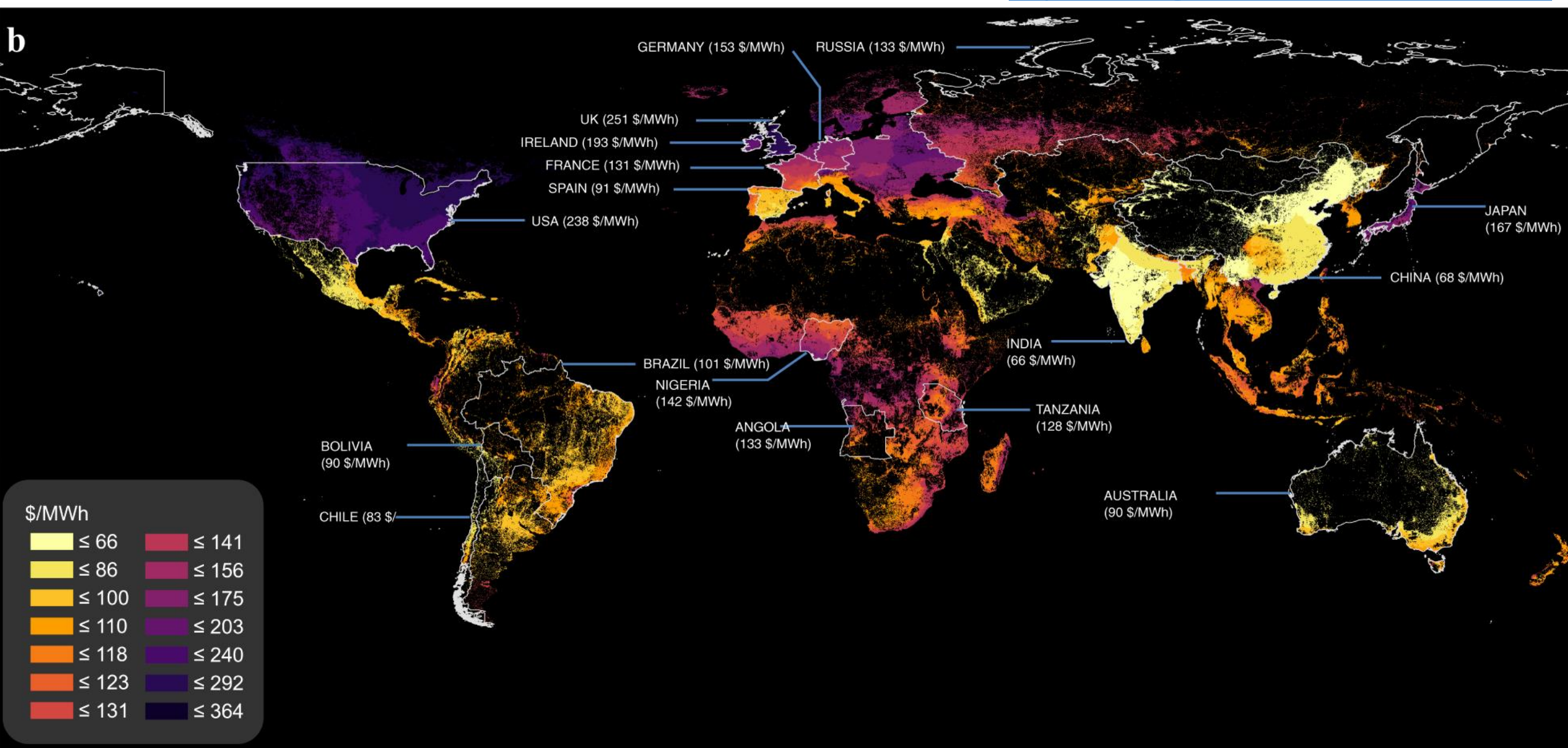
World map of rooftop solar potential technical potential
[Joshi et al 2021, <https://doi.org/10.1038/s41467-021-25720-2>]



Solar potential rooftops

World map of rooftop solar LCOE

[Joshi et al 2021, <https://doi.org/10.1038/s41467-021-25720-2>]



Solar potential facades

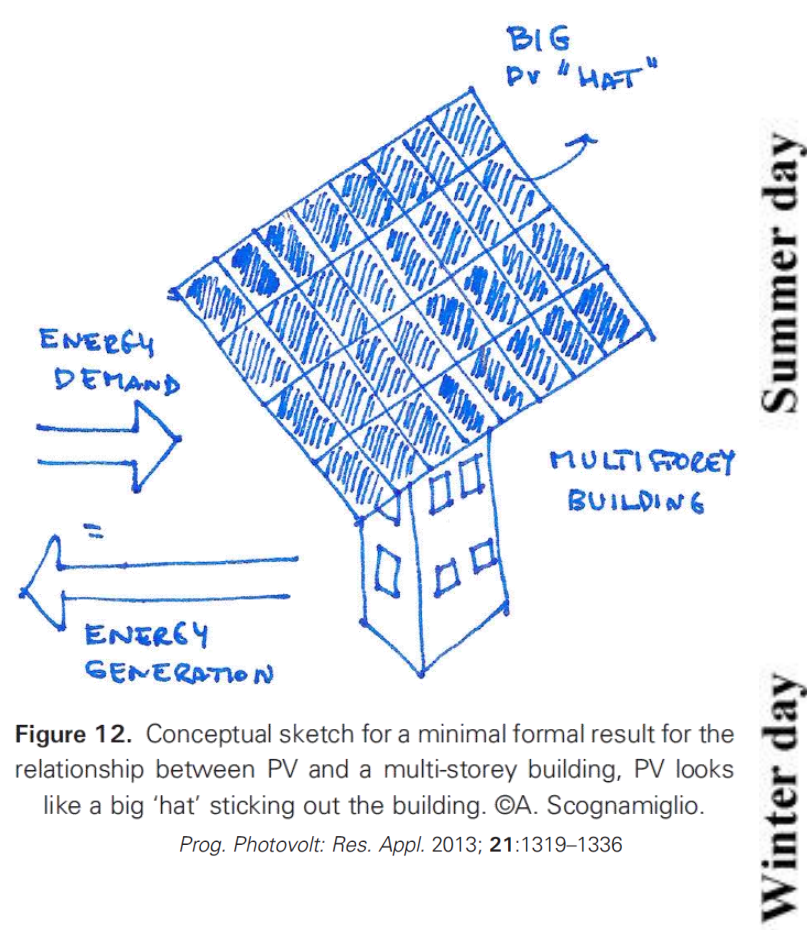
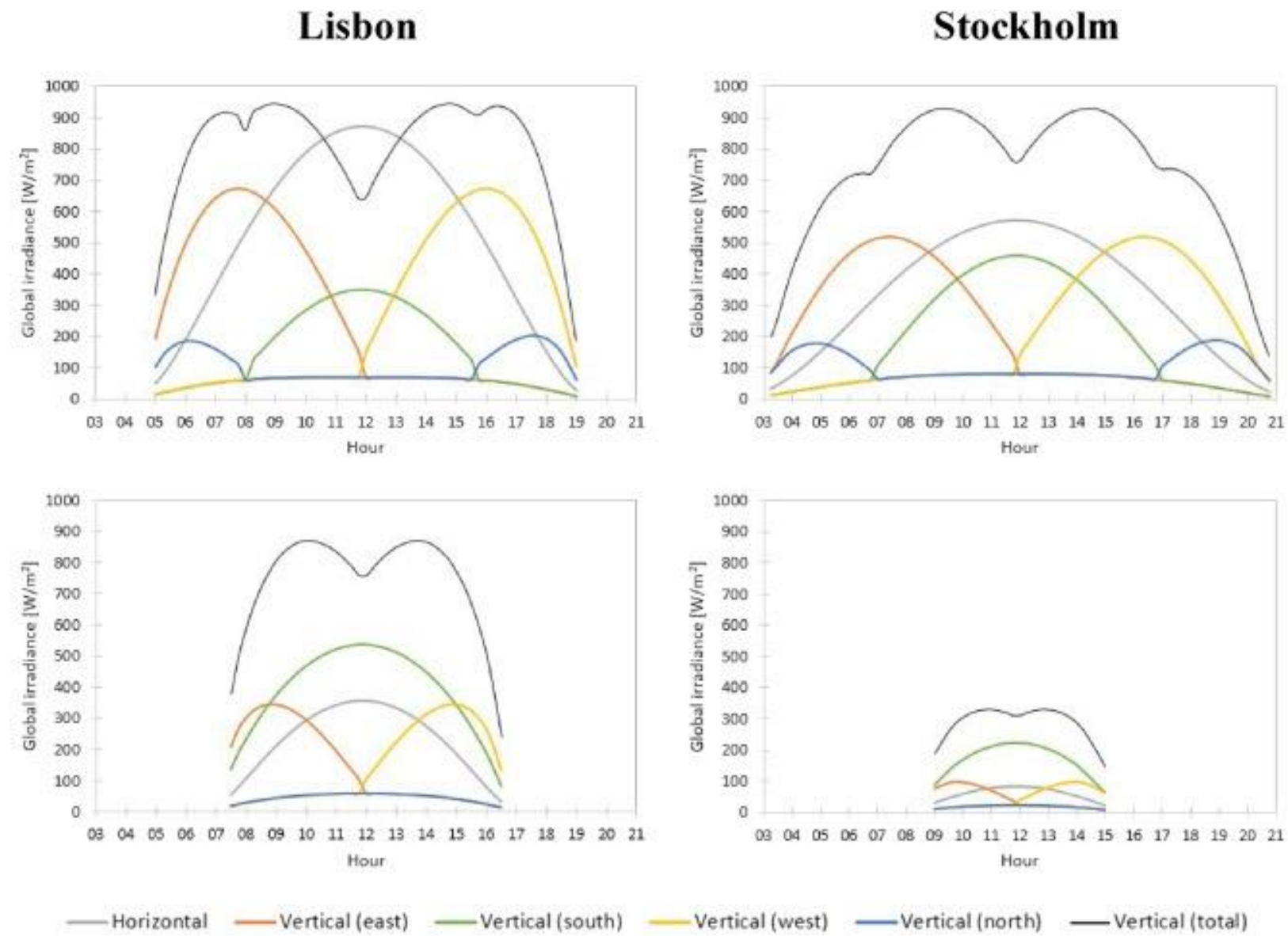
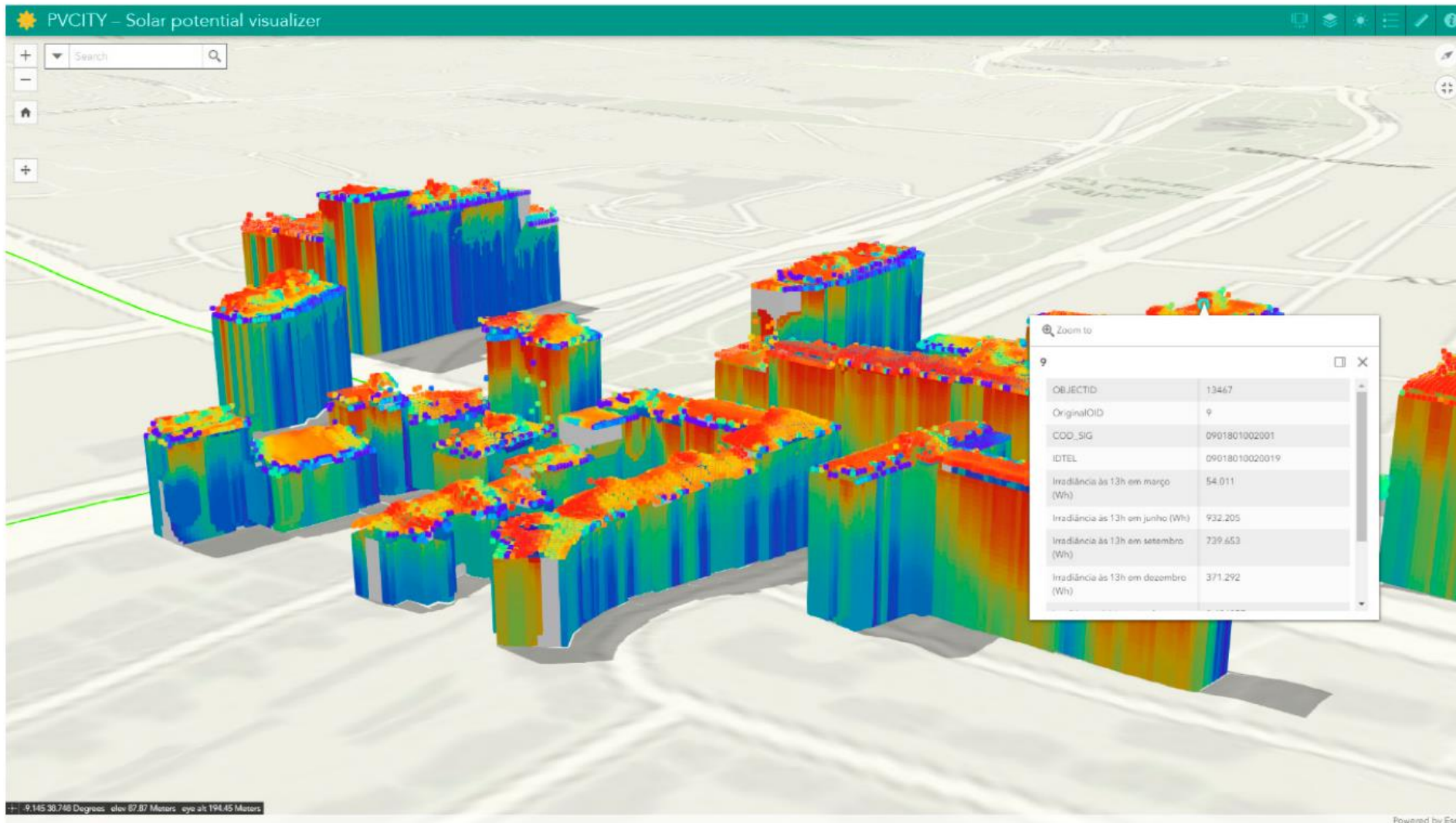


Figure 12. Conceptual sketch for a minimal formal result for the relationship between PV and a multi-storey building, PV looks like a big 'hat' sticking out the building. ©A. Scognamiglio.
Prog. Photovolt: Res. Appl. 2013; **21**:1319–1336



Solar potential facades



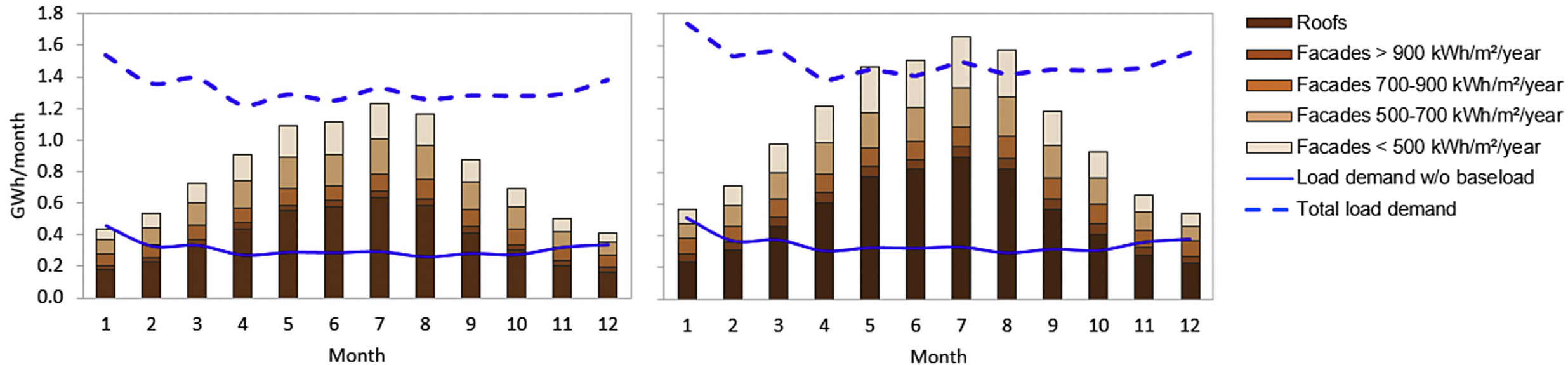
Example of 3D solar potential rendering for a complex urban environment [Brito et al 2021, <https://doi.org/10.3390/en12183457>].

Solar potential facades



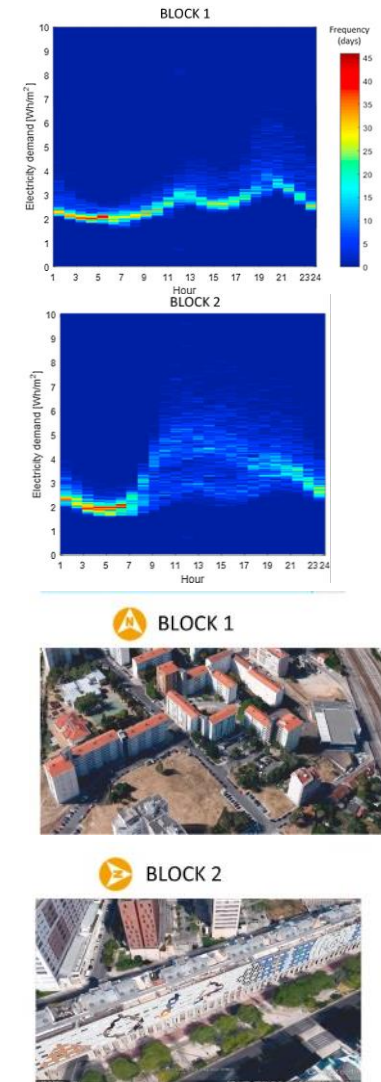
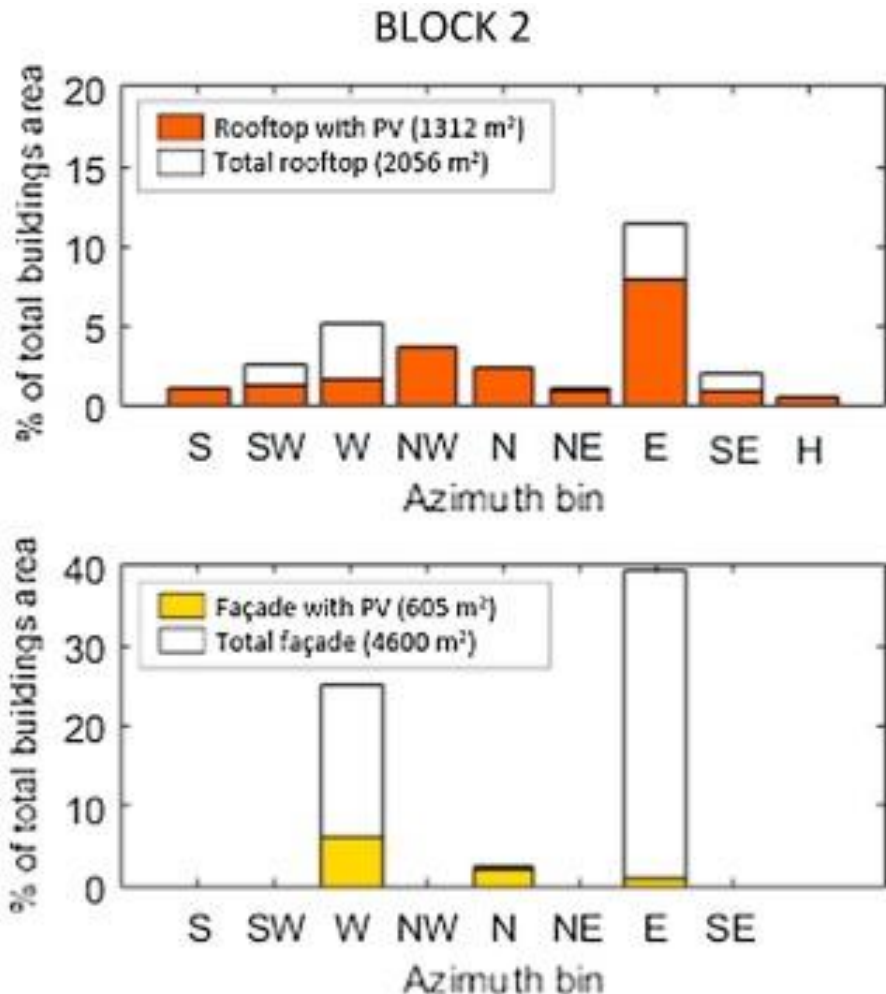
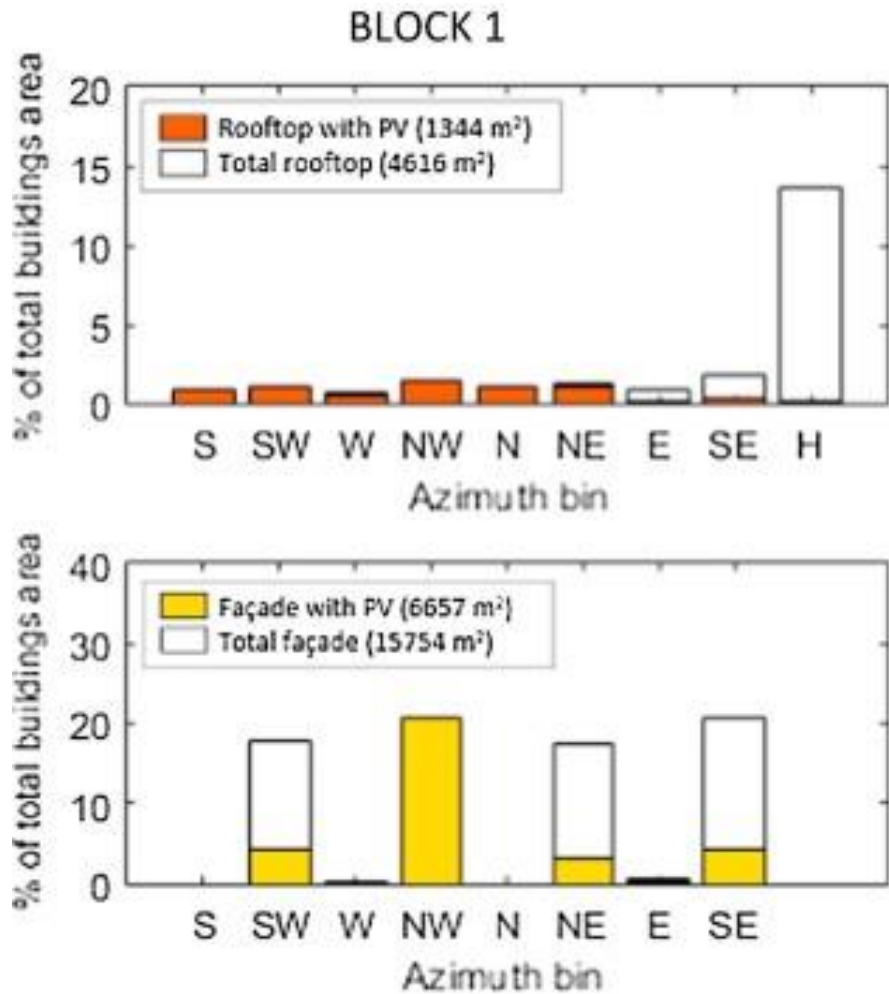
Android application for local 3D solar potential assessment
[Brito et al unpublished].

Solar potential facades



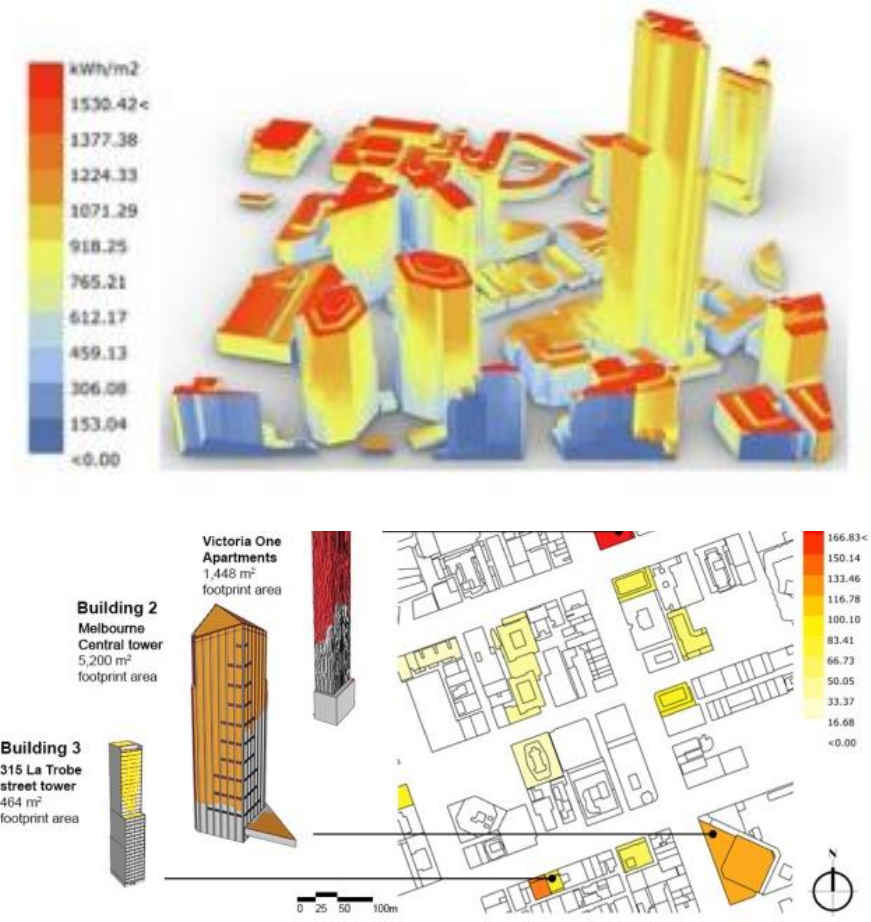
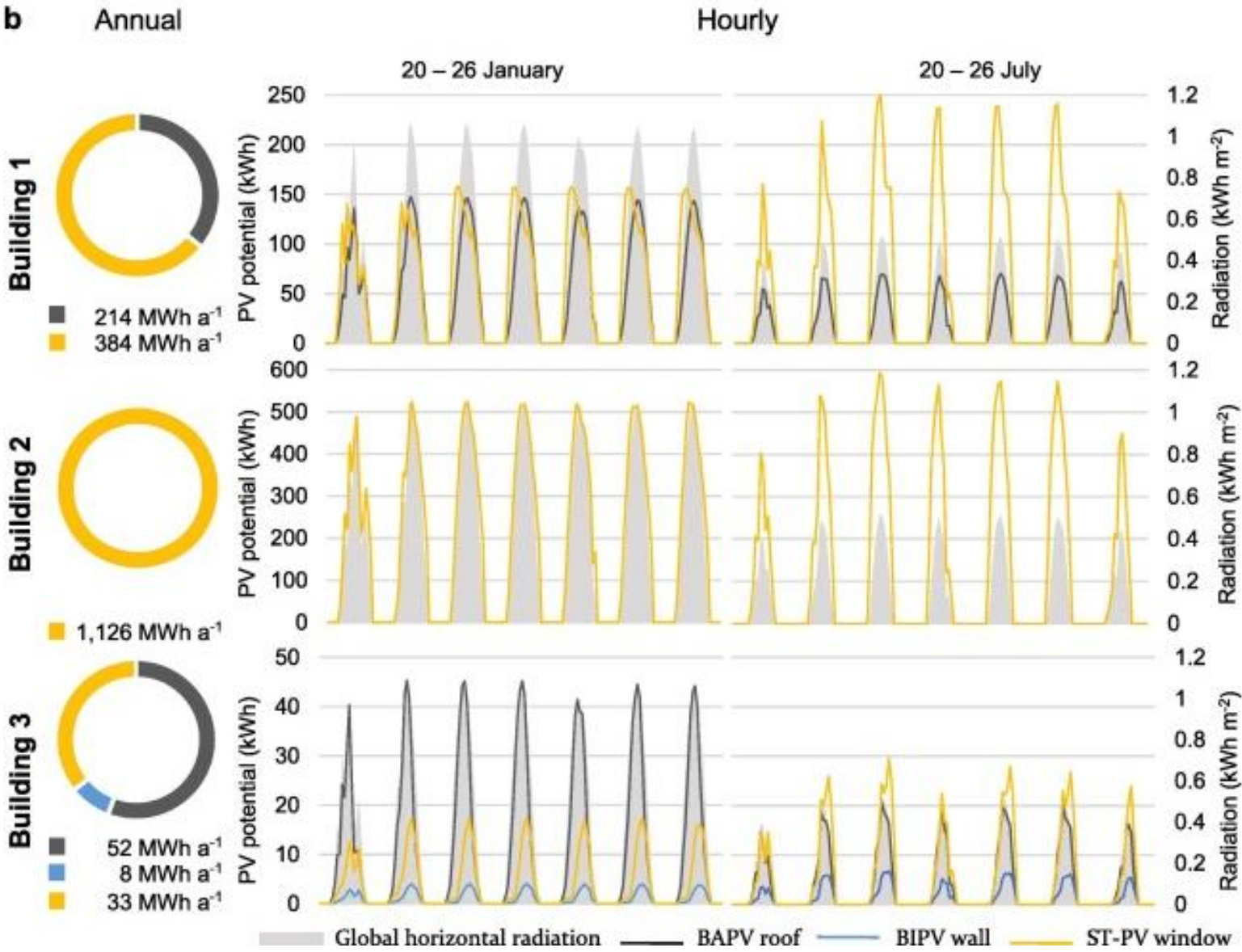
Monthly PV potential and electricity demand (blue solid line: non-baseload monthly electricity demand; blue dashed line: monthly total electricity demand) [Brito et al 2016, <https://doi.org/10.1016/j.renene.2017.03.085>].

Solar potential facades



Optimum distribution of PV area on rooftops and façades Area available (bordered bar) and used for PV, for each orientation. H stands for horizontal rooftop surfaces. [Freitas et al 2018, <https://doi.org/10.1016/j.solener.2017.11.011>].

Solar potential windows

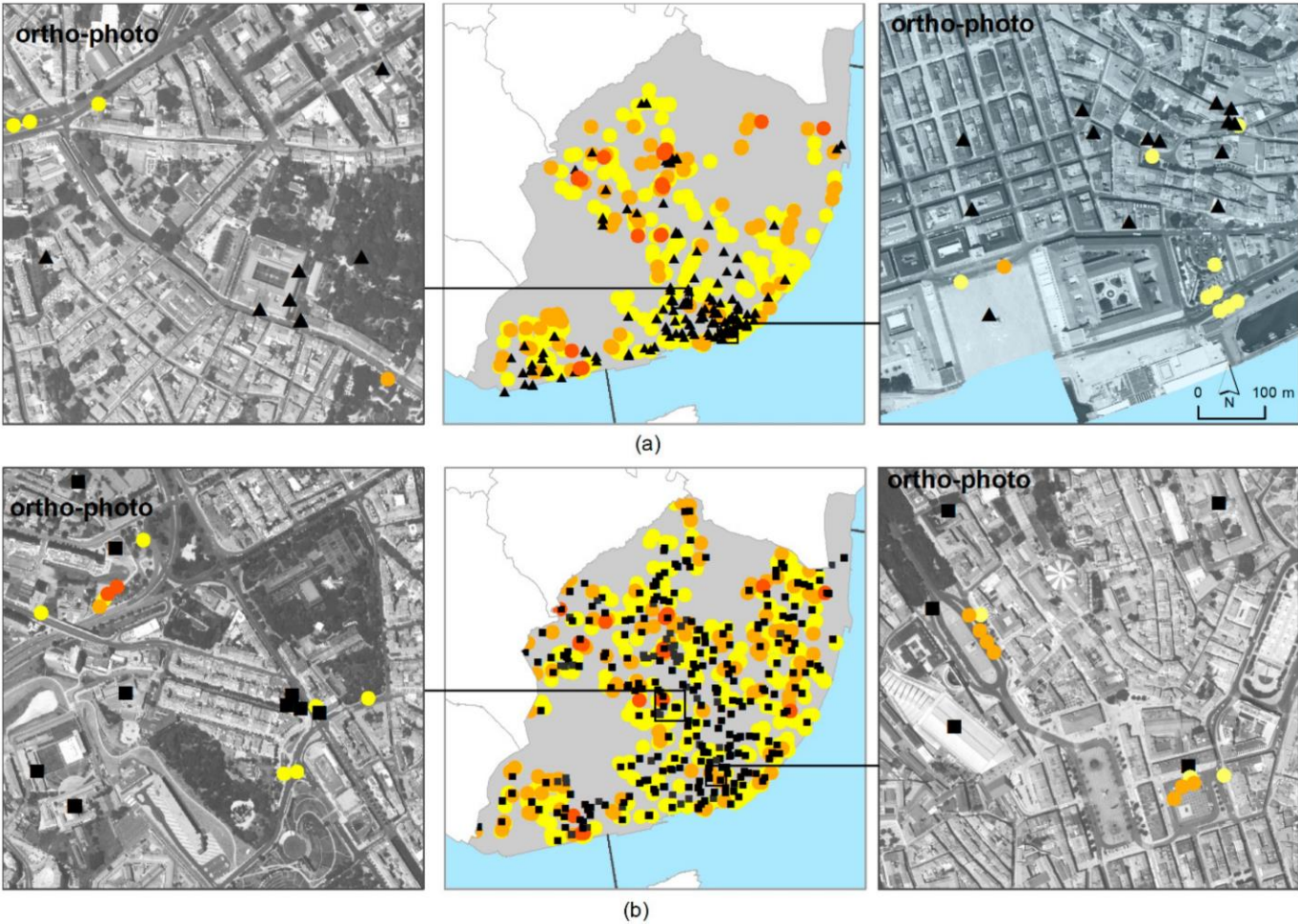
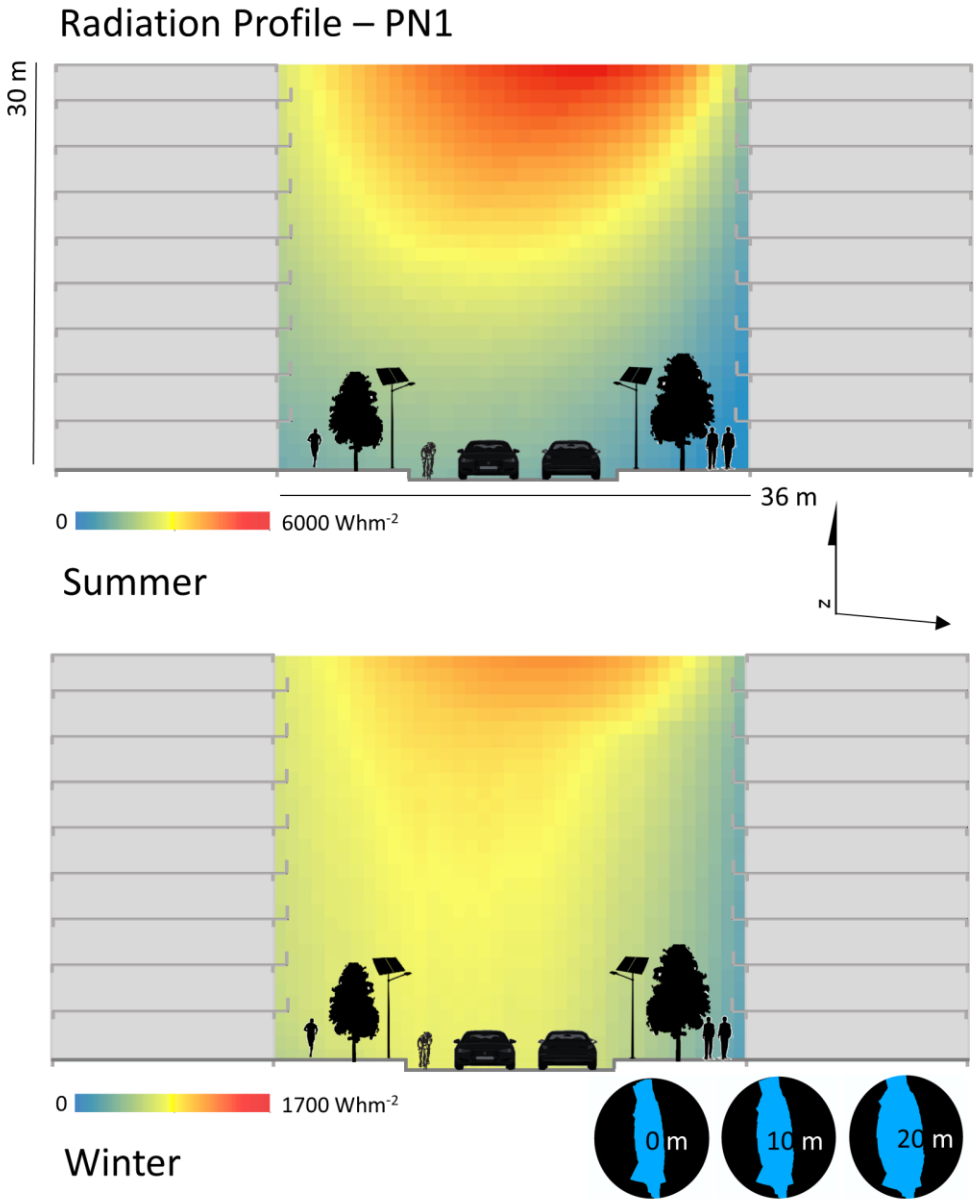


Annual and seasonal PV-window potential of selected buildings, in Melbourne, for typical winter and summer weeks.

[Panagiotidou et al 2021,
<https://doi.org/10.1016/j.solener.2021.10.060>]

Solar potential public spaces

Solar bus shelter locations according to the PV applications and tourist (a) and commuter (b) preferences.
[Santos et al 2021, <https://doi.org/10.3390/app10144801>]

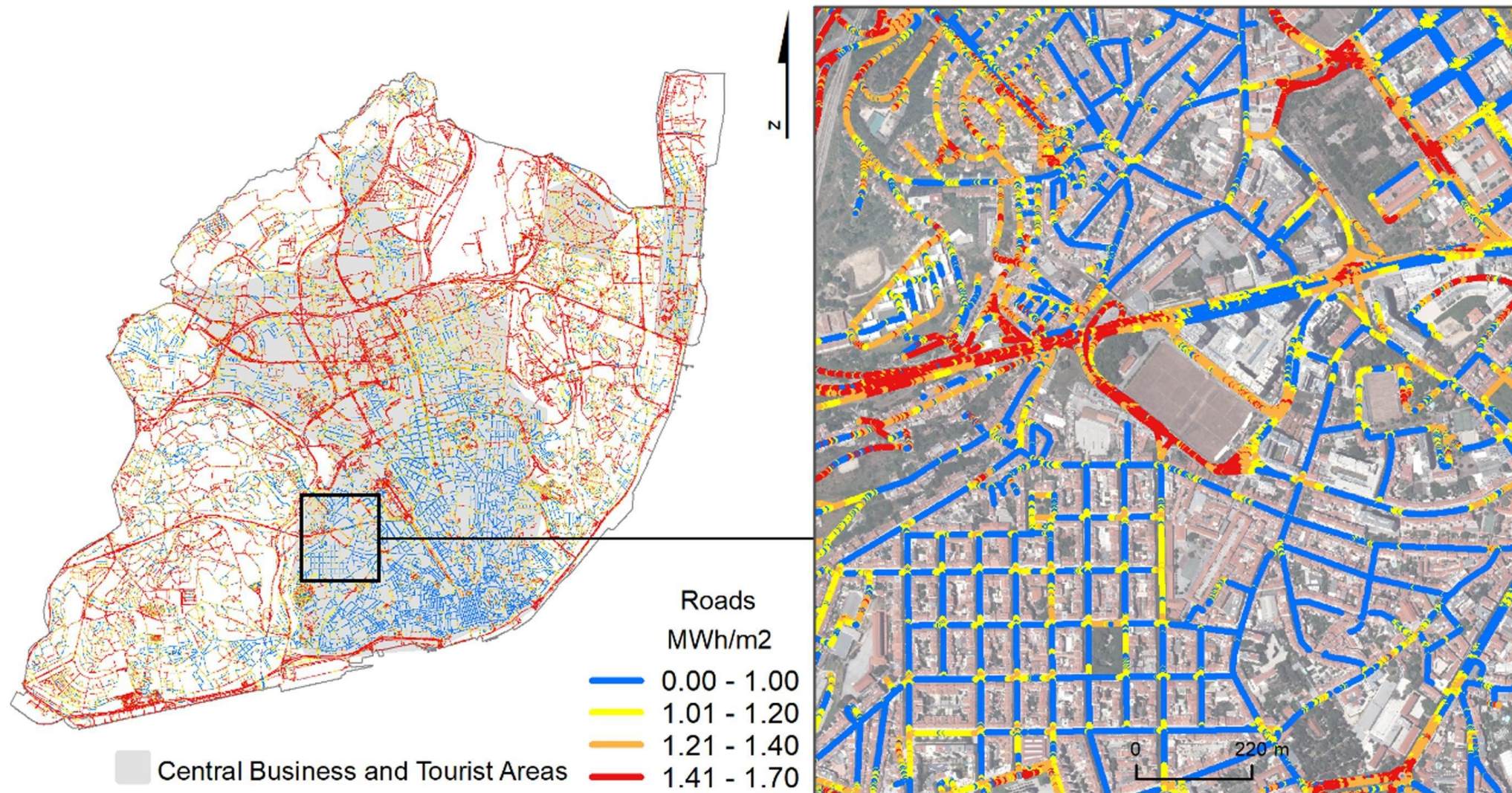


Solar Bus Shelters: PV applications & Users preferences

- Remote small scale sensors & refrigerated vending machine
- Remote small scale sensors & ticket machine
- Remote small scale sensors & small scale info display up to 20"

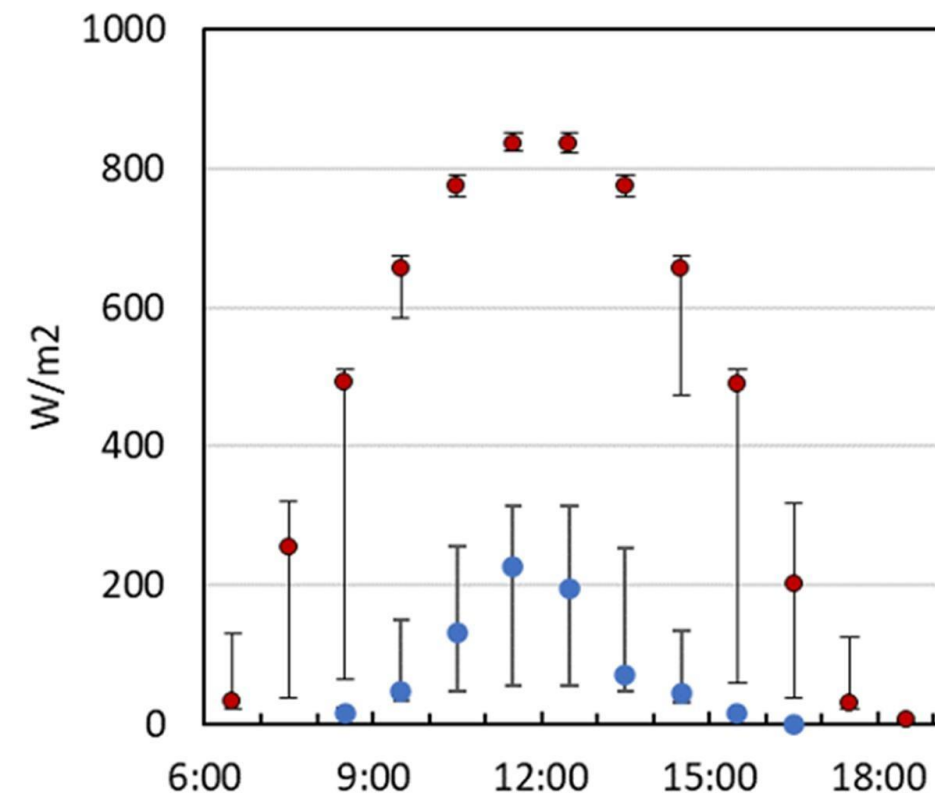
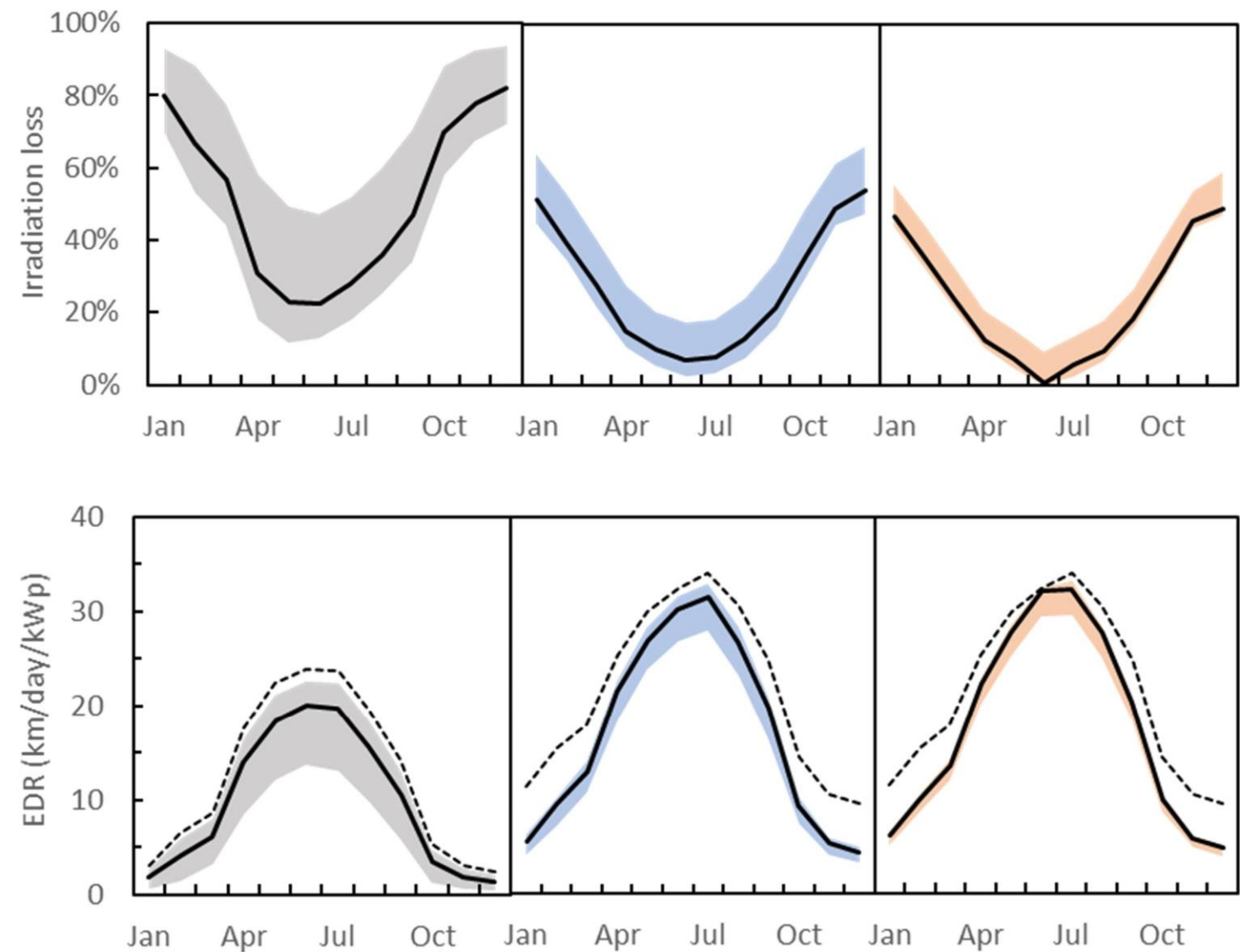
- ▲ Monuments, Museums, Viewpoints
- Health care facilities, Schools, Metro or Train station

Solar potential PV-powered vehicles



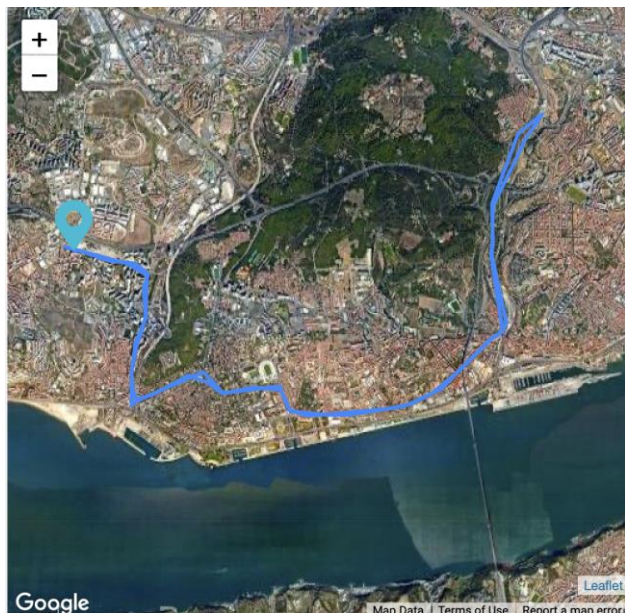
Annual irradiation on urban roads [Brito et al 2021, <https://doi.org/10.1016/j.trd.2021.102810>]

Solar potential PV-powered vehicles

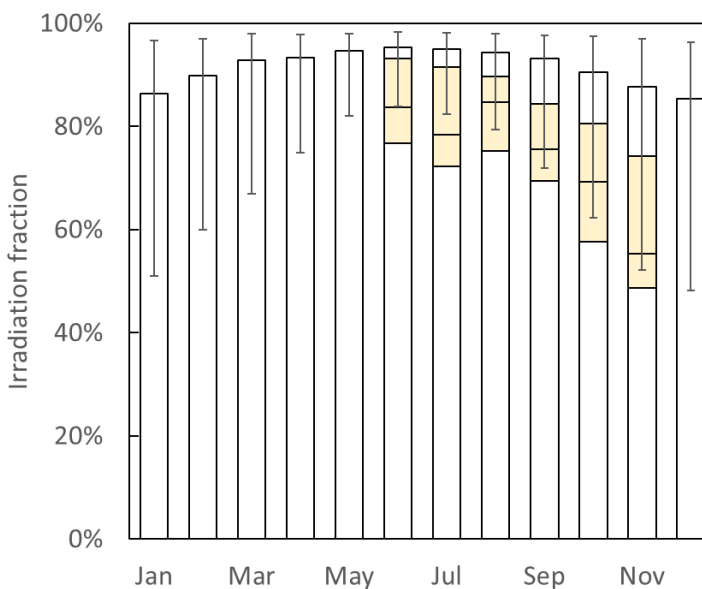
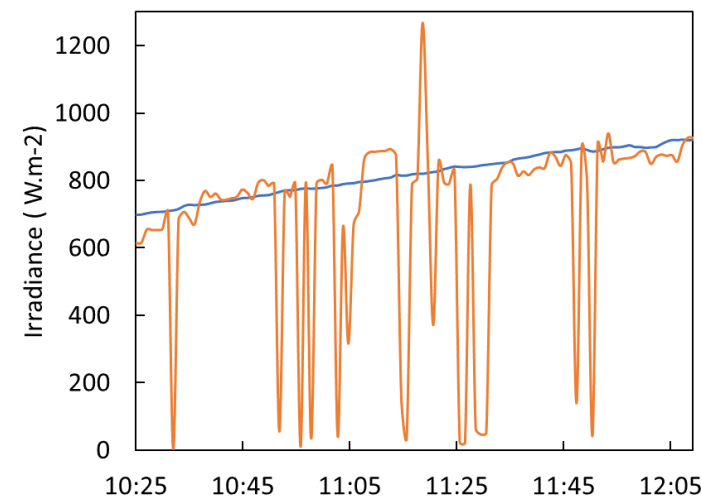


Annual irradiation on urban roads [Brito et al 2021, <https://doi.org/10.1016/j.trd.2021.102810>]

Solar potential PV-powered vehicles



Preliminary model validation



Model accounts for all scheduled routes for each day, not those that were monitored

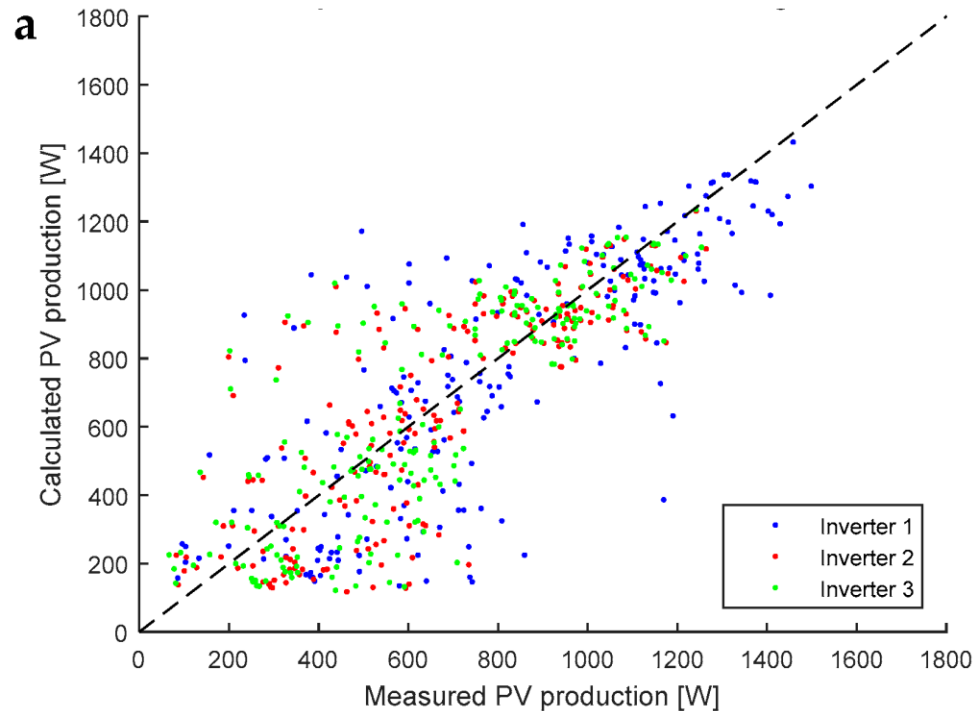
Model expected to overestimate irradiation because assumes middle of the road irradiance

No tree-layer included at this moment

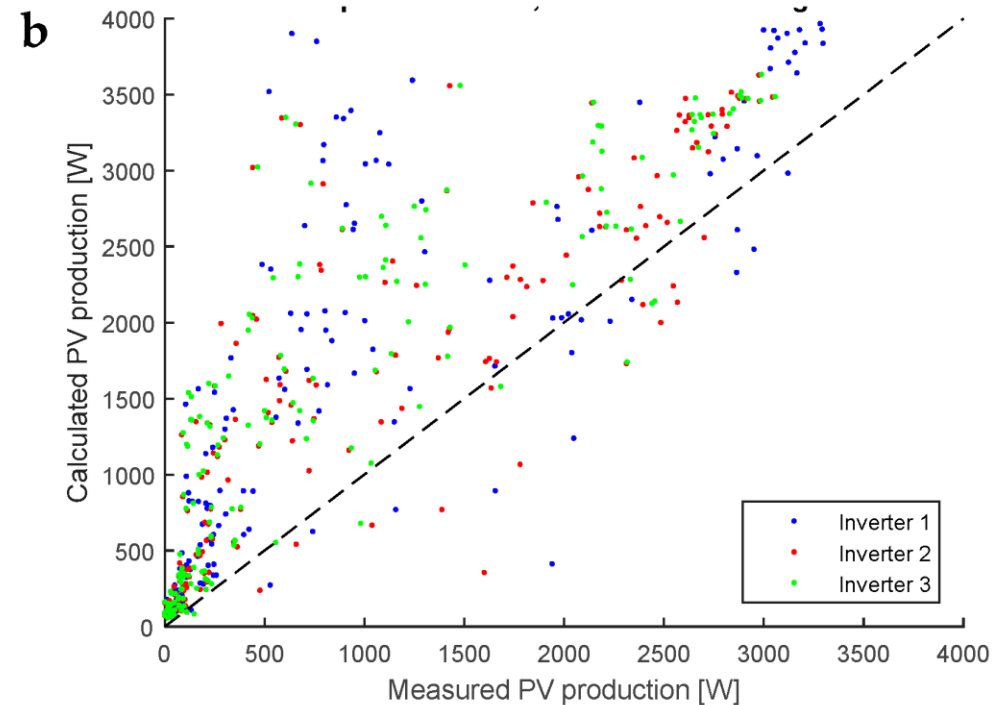
Solar potential model validation



Summer

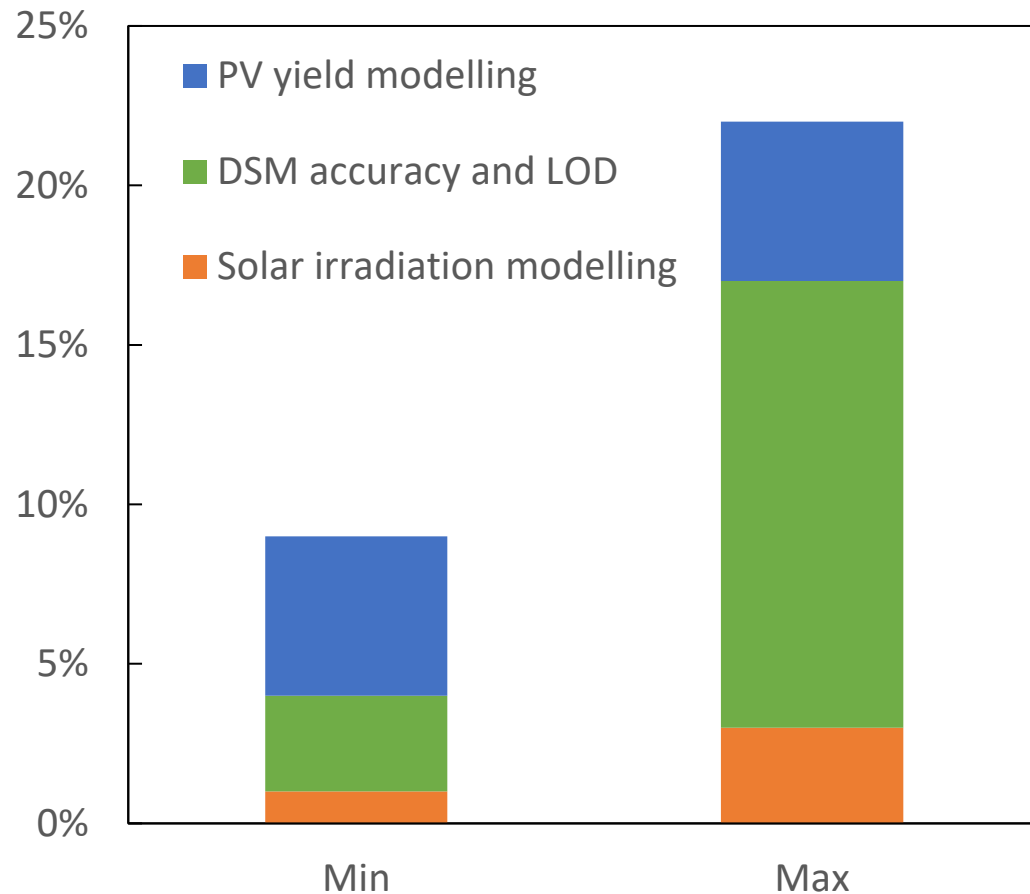


Winter



The level of scattering is lower in summer, due to **fewer cloud cover events**. Overestimation of inverter 3 yields are attributed to poorly modelled **partial shading** in the morning, due to the model low spatial resolution (1 m², much coarser than the solar cell size) and **overgrown trees**. [Brito et al 2021, <https://doi.org/10.3390/en12183457>]

Solar potential model validation



[Brito et al 2021, <https://doi.org/10.1002/ente.202000943>]

Many other assumptions, such as interannual variability, climate change, trees growth, present and future demand profiles and magnitude, etc.

10-25% error in urban solar potential assessment

Sources of uncertainty:

- **Solar irradiation** modelling (transposition)
 - 1% for inclined surfaces
 - 3% for vertical surfaces
(+2% if separating irradiance components)
- **DSM accuracy** and LOD
 - Effect of grid spacing: 1 to 4m leads to +7% error
 - LOD1 to LOD 3 leads to +12% error
 - Neglecting tree shading
 - +10% for rooftops
 - +20% for façades
- **PV yield** modelling
 - 5-6 % due to partial shading losses

Assessing solar potential in the urban environment

Closing remarks

Incredible progress in the last decade, allowing easy one-click estimations of solar potential, return-on-investment, self-consumption of rooftop PV in many geographies.

Challenges

- Big data (for large areas, level of detail, high time and space resolutions)
- Accuracy (DSM, irradiation model simplifications, GHI-to-PV conversion)
- Computing time
- Model validation