Photography: Lightyear one (Lightyear 2019)

Urban solar potential assessment for onboard solar in electric vehicles

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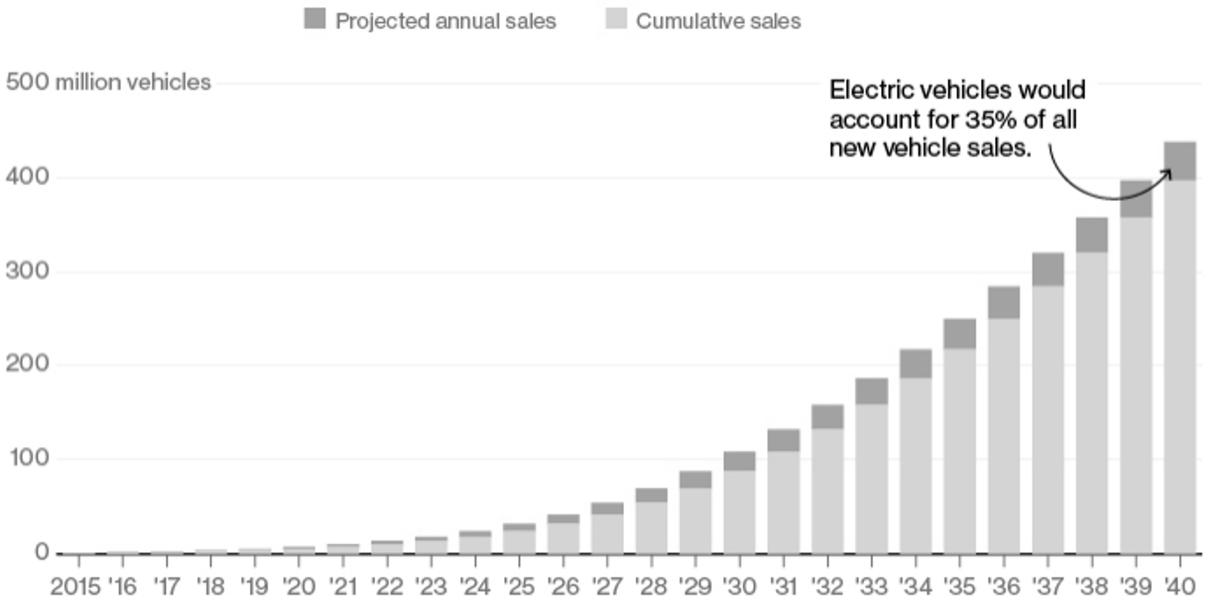
#1 Motivation for EV: Decarbonizing the Transport Sector



Source: Bloomberg

Transport sector ≥ 23% of CO_{2eq} emissions.

The fast growing of e-mobility market:

Will highly contribute to the acceleration of global electricity demand;

By 2025 is expected 180TWh/year (400GW installed power capacity);

80 million chargers.

Source: IEA ”Global EV Outlook”, 2020

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Vehicle integrated photovoltaics – ViPV


Lightyear one (Lightyear 2019)

Onboard PV is cheaper and lighter (thus more efficient) than adding more battery capacity – increased range;

Reducing ‘fast’ charging from grid increases convenience and battery lifetime;

Reduces peak demand from the electrical grid.

It is worth? How far can we drive with onboard solar power?

Assumptions

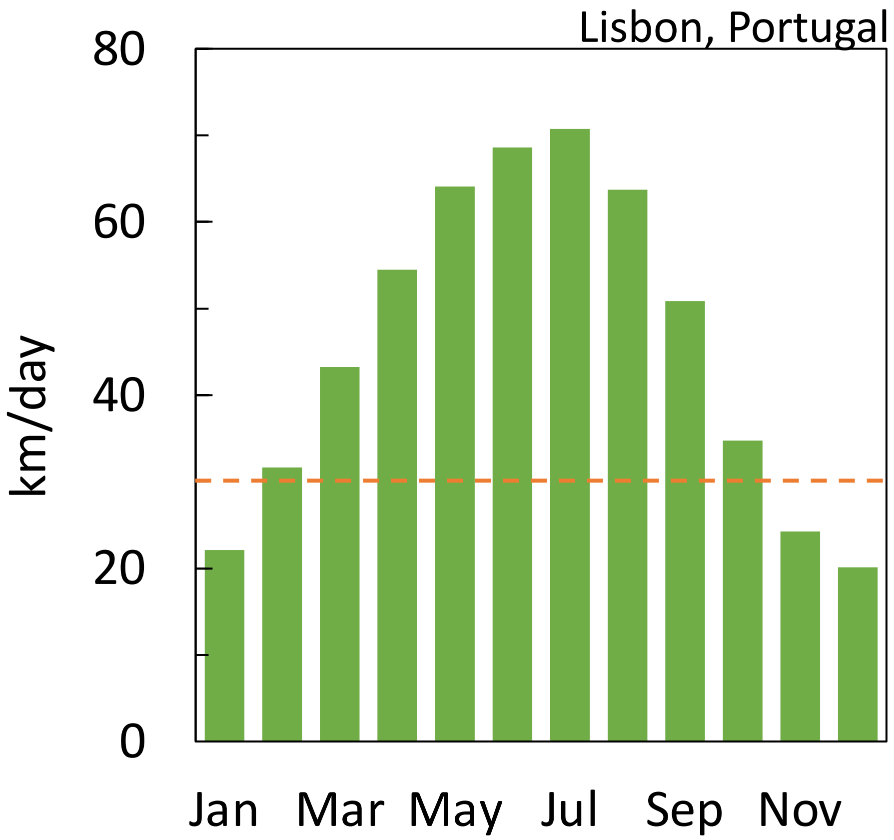
- Consumption 12.5 km/kWh

Daily average irradiation

- 3.66 kWh/kWp/day

Daily extended driving range

- 45.7 km/kWp/day



For 30 km/day vehicle kilometer travelled (VKT)

- Autonomy 9 months/year

Solar provides 93% annual charge

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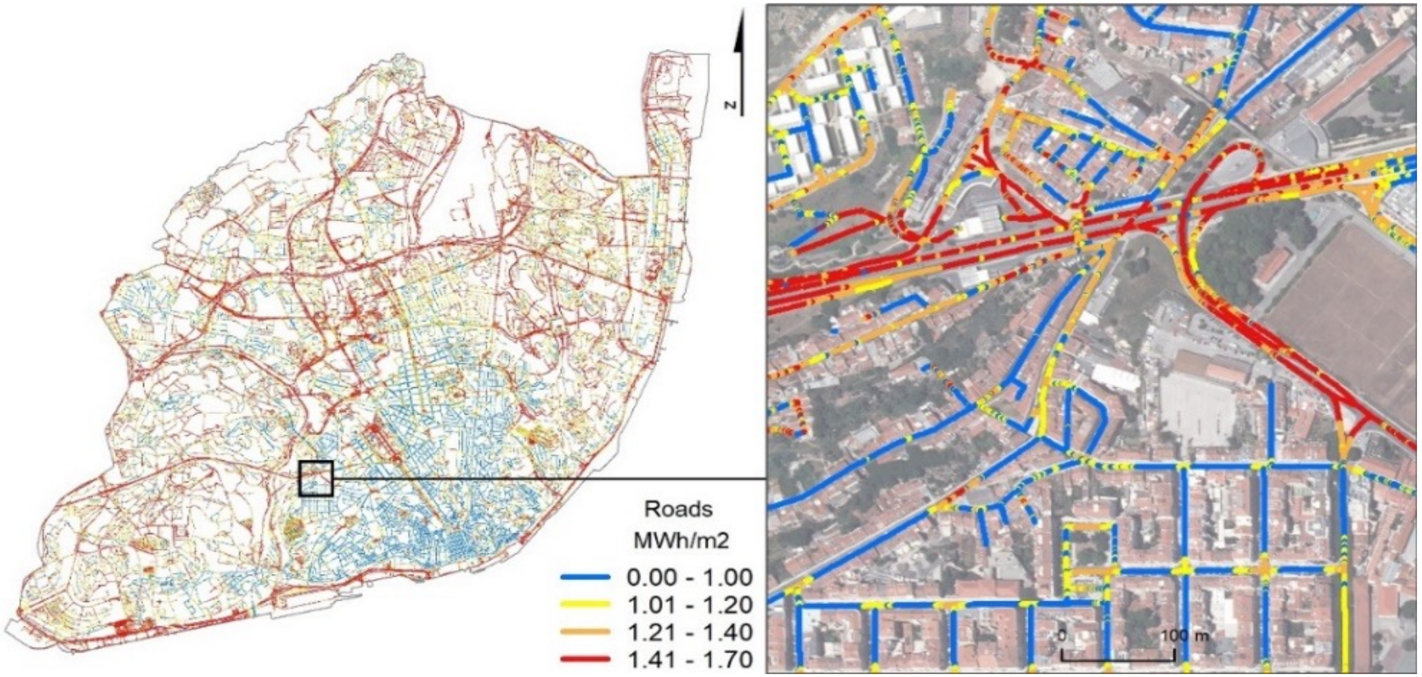
How far can we really drive with solar power?

- How much irradiation for solar vehicles is lost due to shadowing in the urban environment?
- How does that impact the economics and usefulness of solar powered vehicles in the city?

Simulating one year of irradiation onto roads of Lisbon



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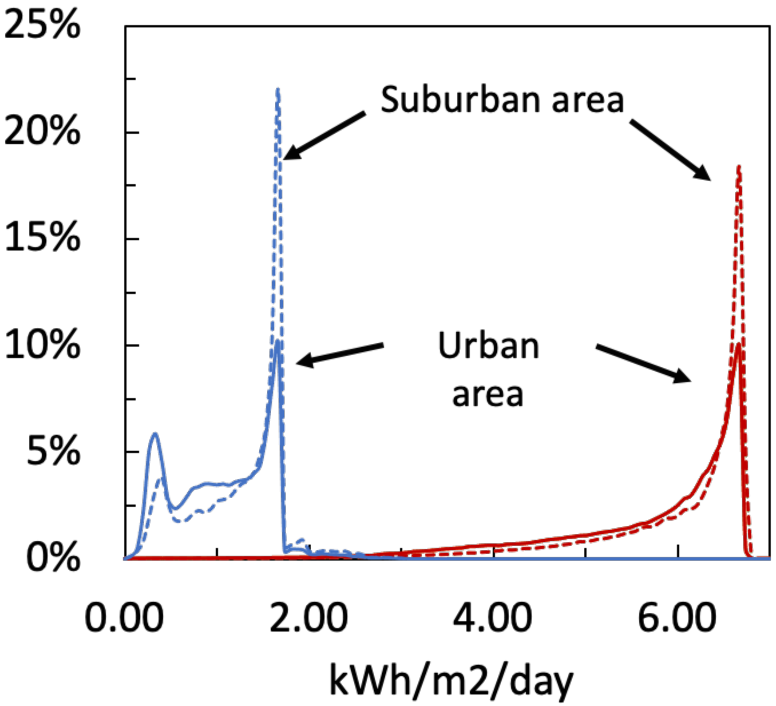
Simulating one year of irradiation onto roads of Lisbon
Building density affects shadowing

- Higher irradiation in summer
- More shadowing in winter
- Higher density leads to more shadowing, more relevant in winter



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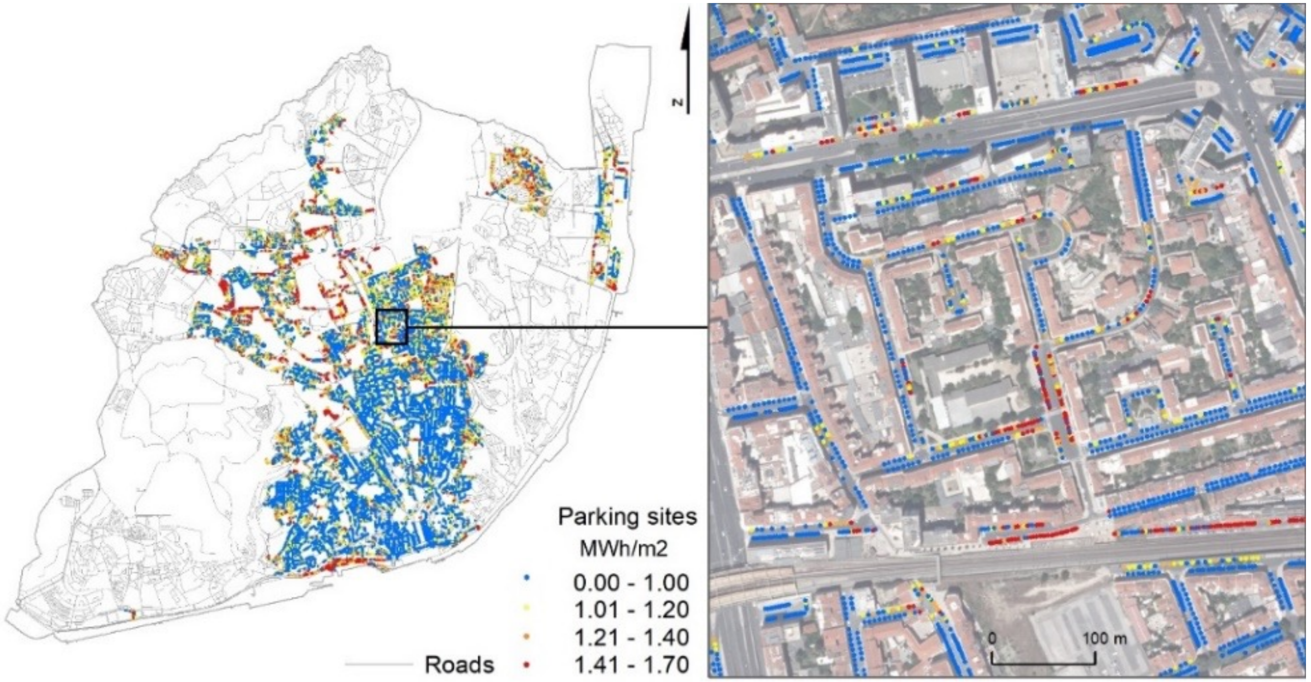
Simulating one year of irradiation onto roads of Lisbon

Parking spaces 'suffer' more shadows



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Simulating one year of irradiation onto roads of Lisbon

- Effect of **shadowing** should be considered when discussing solar extended range in urban areas: **25% loss for roads, 40% for parking**
- Most interesting markets for the introduction of onboard solar are **public transport** and **service vehicles**, including car-sharing, ride-hailing or taxiing services

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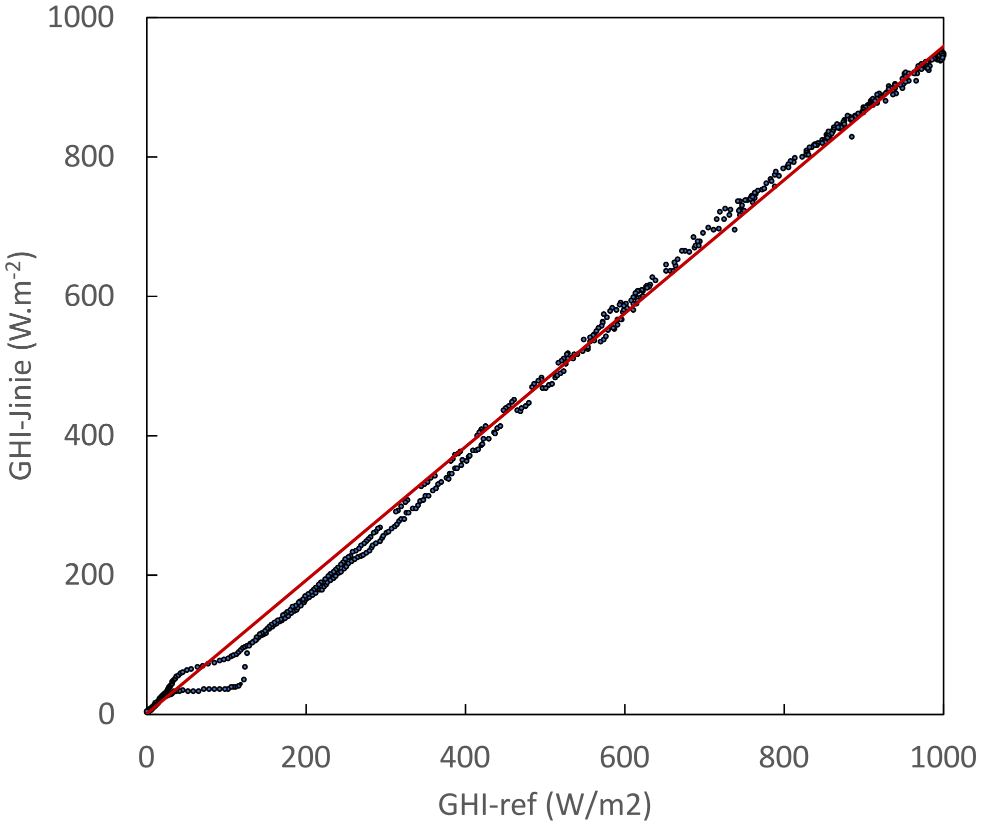
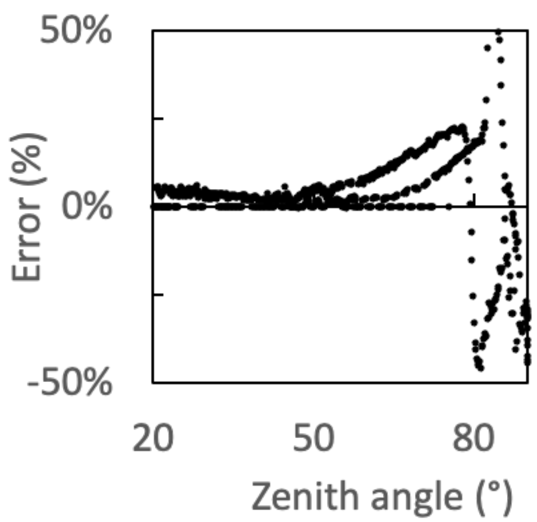
Experimental assessment – using urban buses as probes

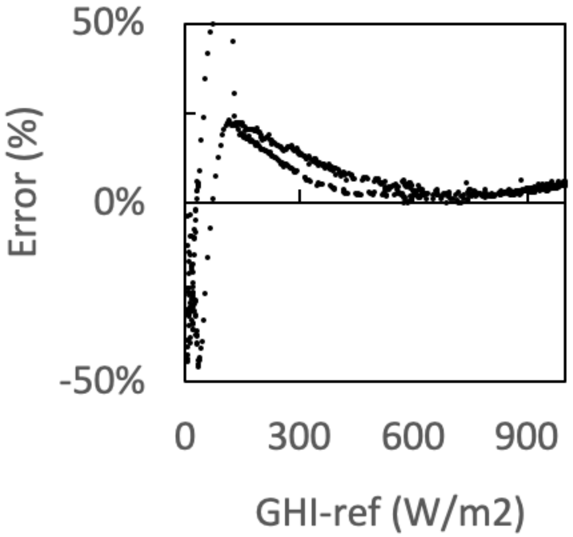
Silicon sensor

Experimental assessment - sensor calibration



Good fit to calibrated irradiance measurements





Larger errors for high angle of incidence (zenith above >75°) not very relevant for PV estimation for the urban environment

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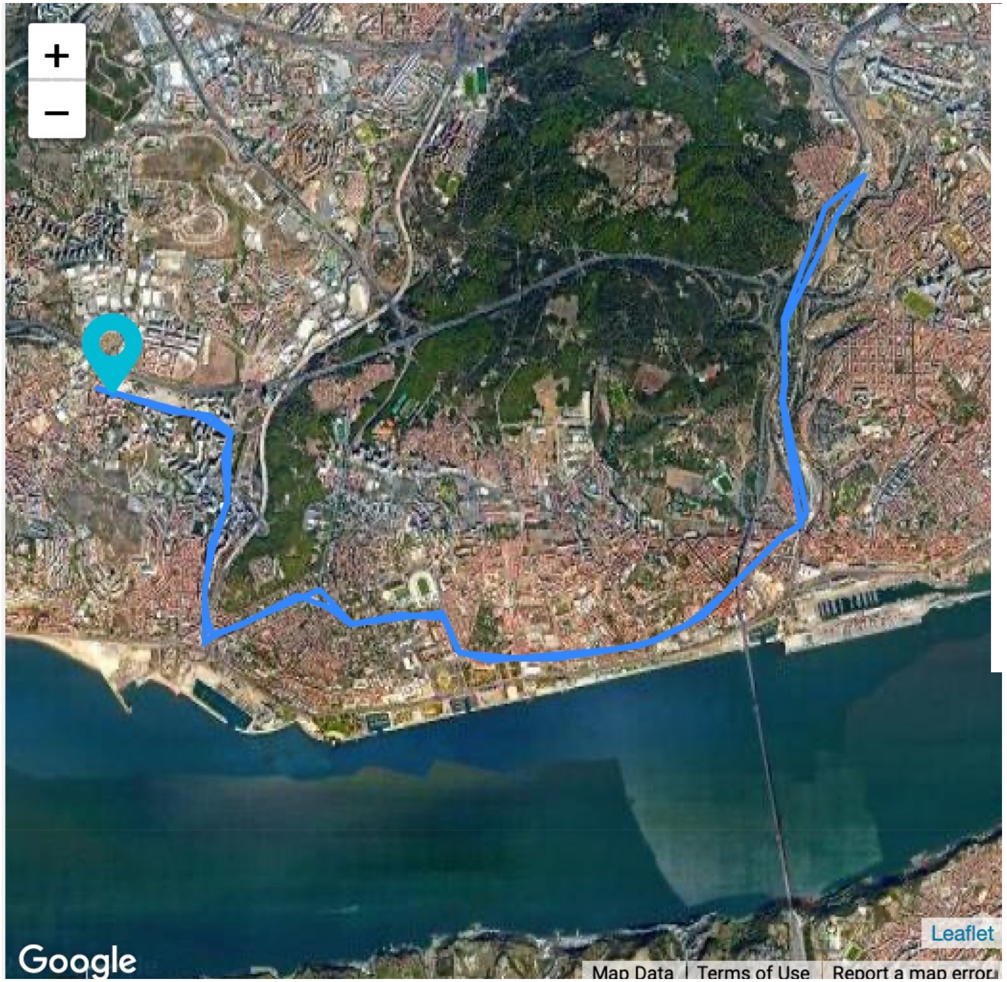
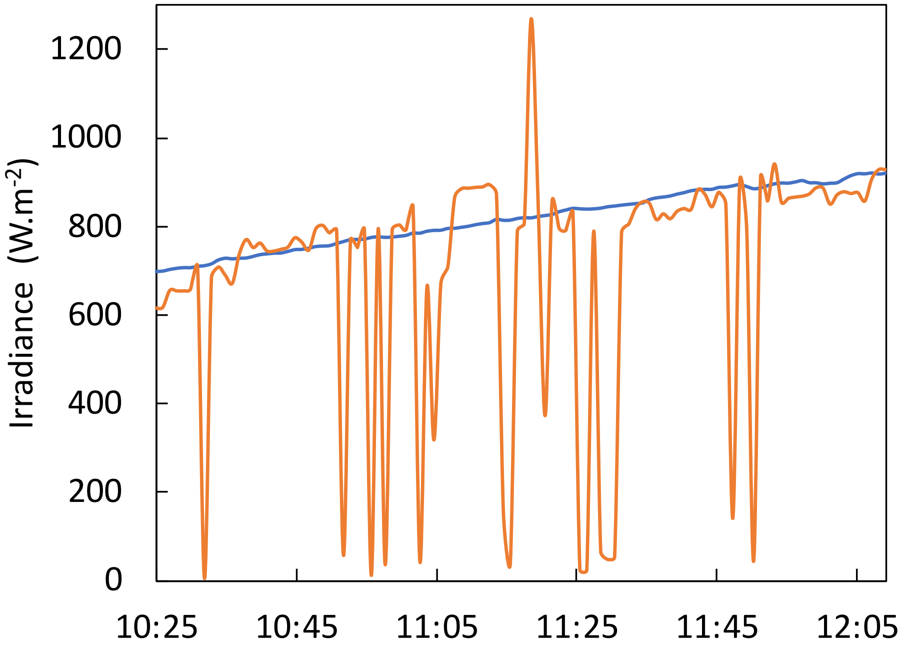
Experimental assessment - measurements





Short term (strong) shadowing events.

Comparison to **GHI** allows identification clouds

Higher irradiance on bus associated to:

- road/bus inclination
- fortuitous reflected irradiance

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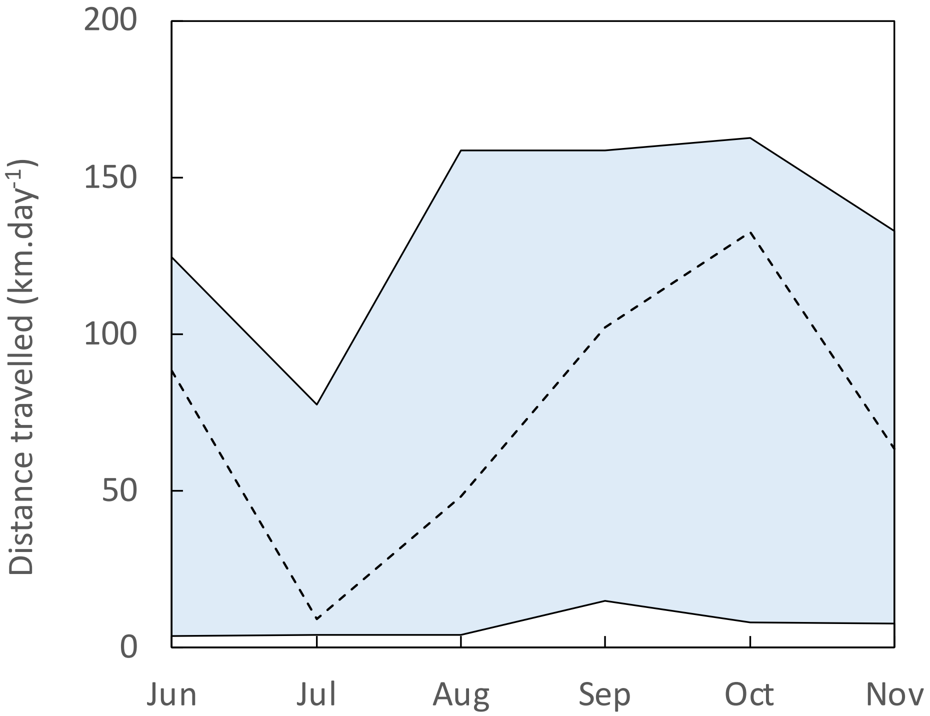
Experimental assessment - measurements

Bus included in the normal routes planning;

Routes include all metropolitan area: city centre, residential area, river side, etc >> all have different shadowing patterns.

Onboard Jinie measurements compared with synchronous GHI at **Faculty of Sciences of the University of Lisbon**.

Results - Distance travelled



25th/50th/75th percentile for daily distance travelled

- 1/3 of the days bus hardly moves (only within central bus station);
- Wide monthly variation, sensitive to route planning.

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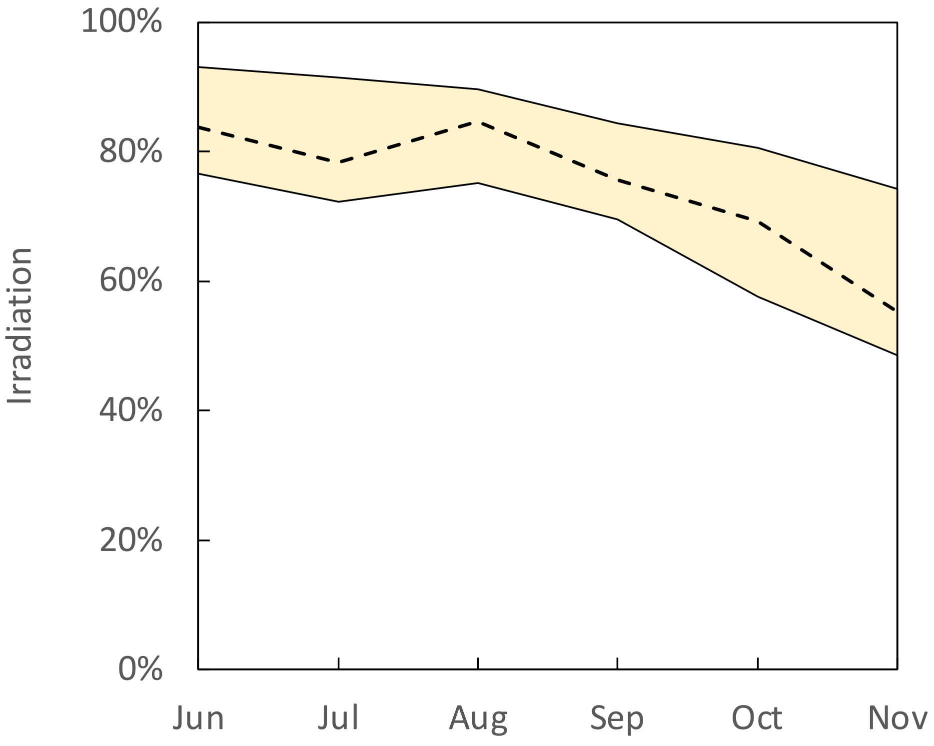
Results - Effect of shadwoing



$25^{th}/50^{th}/75^{th}$ percentile for monthly irradiation loss due to shadowing only. [comparison to stationary measured GHI]

- In summer lower impact from shadowing (due to higher solar elevation during the day);
- Median losses sensitive to specific routes for each month.

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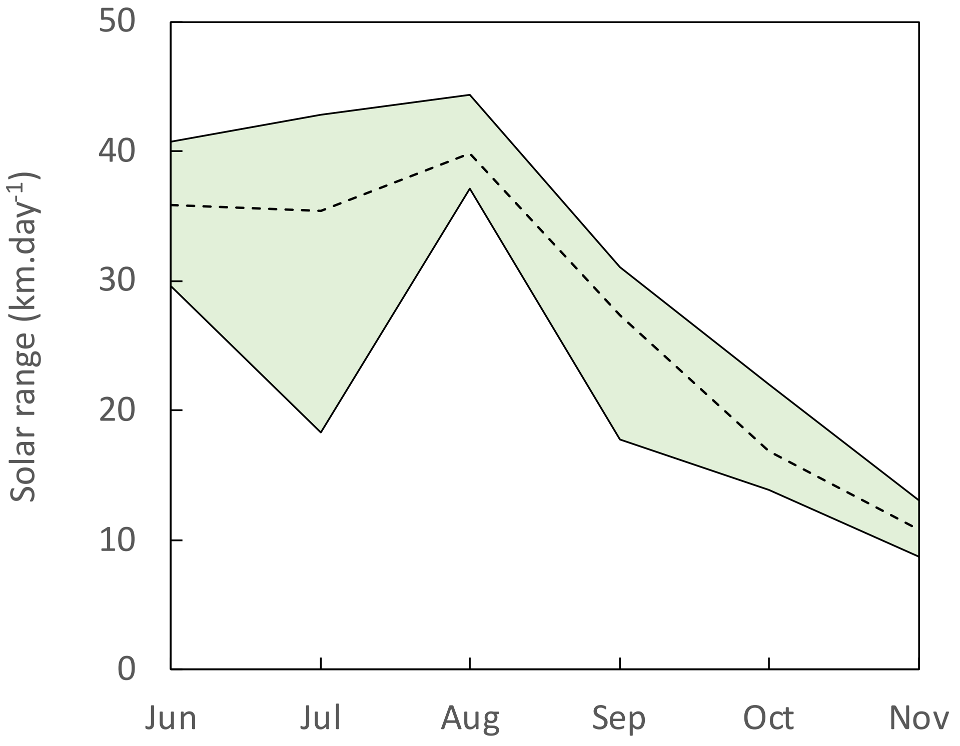
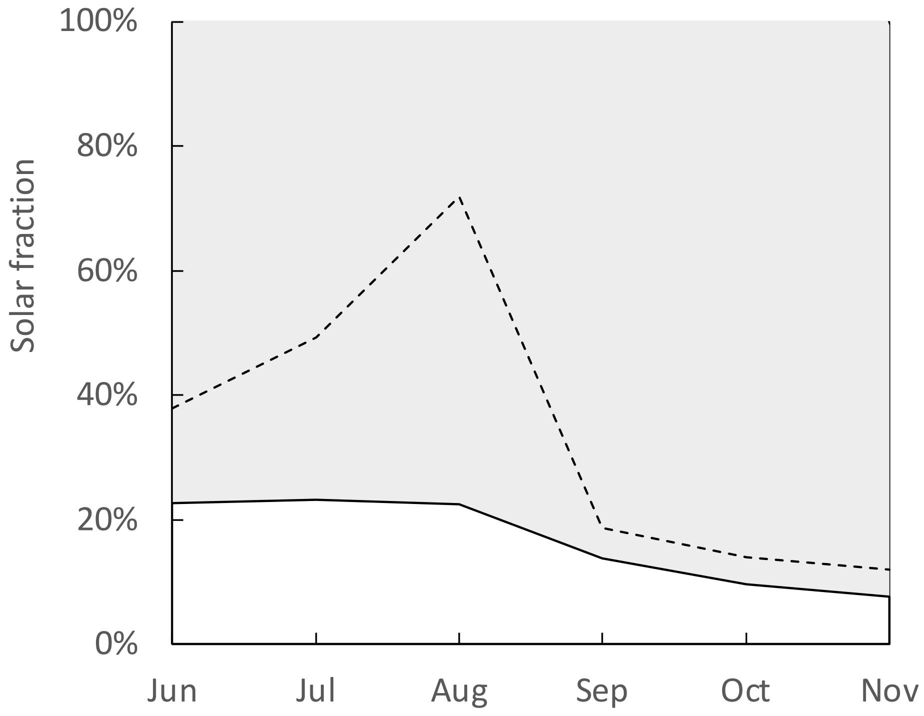
Results - Solar Range



25th/50th/75th percentile for solar range assuming **10 kWp and 150 kWh/100km**

- In summer, higher irradiation and lower effect from shadows;
- Daily solar range sensitive to specific routes for each month.

Results - Solar fraction



$25^{th}/50^{th}/75^{th}$ percentile for solar fraction

- Top quartile always exceeds 100% (bus is mostly parked during the day)
- Median **very sensitive to route planning;**
- Bottom quartile **about 20%, sensitive to season.**

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Conclusions

- Ongoing assessment of solar potential using urban buses;

- Modelling results indicate about 25% loss due to shadowing from buildings;

- Annual average solar fraction is 20%-40%;

- Solar potential of VIPV for buses (and other vehicles) critical depends:
    - on route planning
    - outdoor parking facilities

Thank you for your attention!

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