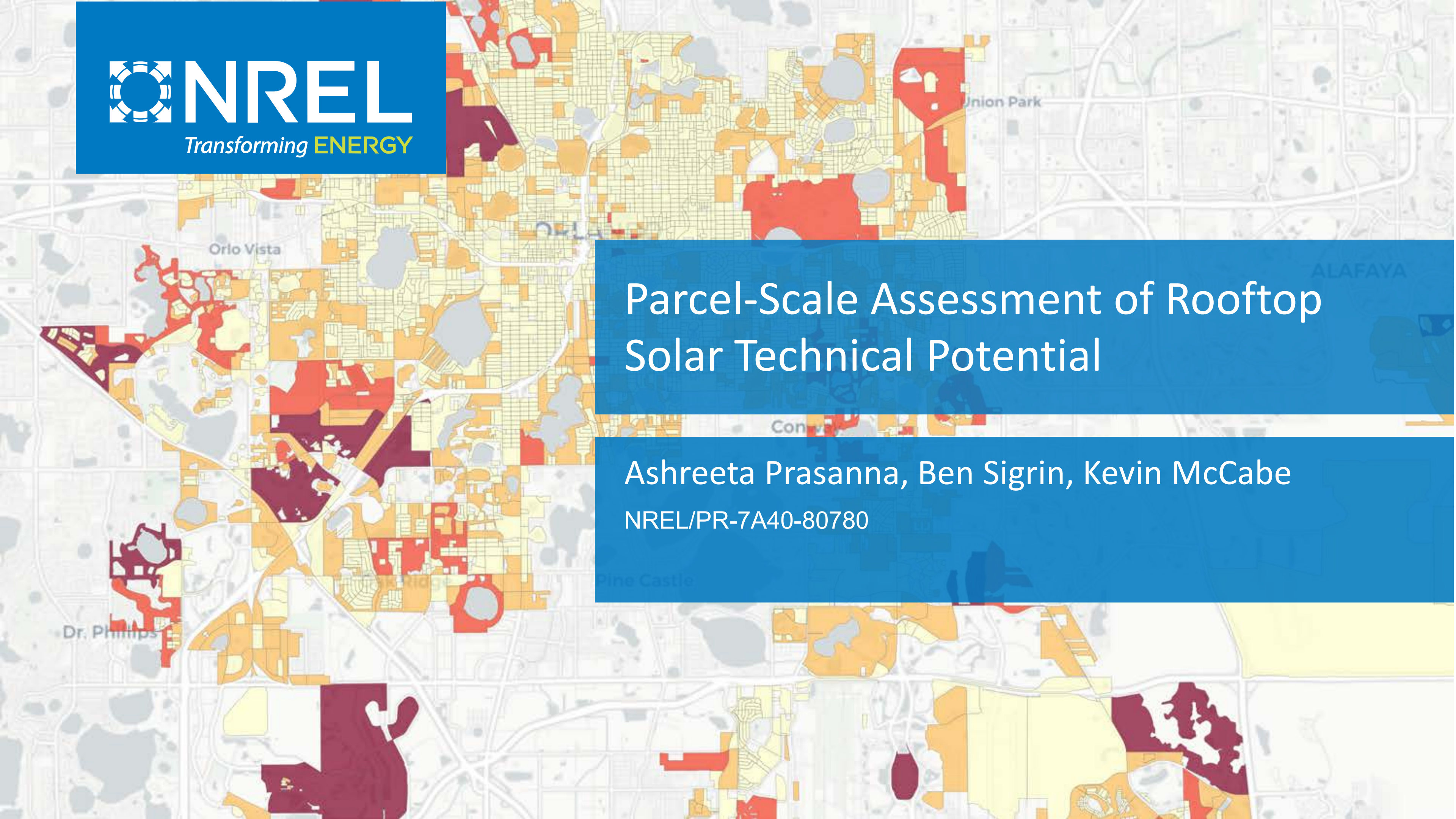

Parcel-Scale Assessment of Rooftop Solar Technical Potential

Ashreeta Prasanna, Ben Sigrin, Kevin McCabe

NREL/PR-7A40-80780

Executive Summary

Understanding the potential for rooftop solar and other distributed energy resources (DERs) to contribute to power system planning is increasingly relevant for cities, utilities, and other planning entities. Such planning efforts typically require an estimate of *technical potential*, or the feasible technology potential independent of economic considerations.

Currently, best-in-class rooftop solar technical potential methods use Light Detection and Ranging (LiDAR) data which can identify each roof plane tilt, azimuth, and unshaded area. However, LiDAR data is not universally available and, even when available, obtaining and processing this data can be expensive. In contrast, parcel-level data is easy to use and widely available as it is generated by jurisdictions to levy property taxes. Such data universely reports building footprint area, which is highly correlated with roof area suitable (developable) for rooftop solar. Moreover, parcel data identifies building end-use, tenure, and other building characteristics not provided by LiDAR.

To explore the feasibility of using parcel data to assess technical potential more broadly, we compare estimates using parcel data in Orlando, Florida (HIFLD 2020) to those generated using LiDAR data (Koebrich et al. 2021). We find that the parcel-based method results in accurate technical potential estimates at a block and city-scale, though only after accounting for shading and other factors that derate developable roof area. The results of this study demonstrate a scalable, low-effort approach to assess rooftop solar technical potential for every city and community in the U.S.

Key Results

- The distribution of rooftop solar technical potential for Orlando at block and city scale, as well as by building use type and by tenure of occupants.
    - As part of this analysis an interactive map for Orlando is developed which presents the rooftop technical potential for each block.
- A derating factor was calculated based on comparison of the LiDAR and parcel-scale datasets to account for shading and other factors affecting developable area. This derating factor should be applied to the building footprint area to improve the estimated rooftop solar technical potential in future analysis.
- After applying the derating factor, the mean absolute error (MAE) over the 71,021 parcels analyzed is 60 kW (4095 sqft. of developable roof area). The MAE over the 3255 census blocks analyzed is 1347 kW (4322 sqft. of developable roof area). The total technical potential for Orlando over 288,000 parcels after applying the derating factor is 5.57 GW.

Datasets

- The main dataset used in this analysis is a national parcel dataset (HIFLD 2020) which contains descriptive data and geometries for 1.3 million parcels in the U.S. This dataset contains information on the building occupancy classification, number of stories, building area, built year , valuation, etc. for 288,000 parcels in Orlando.
- The LiDAR data used for calibration is obtained from the Orlando Utilities Commission (OUC) (Koebrich et al. 2021). This dataset contains information for 122,000 parcels in Orlando.
- Geospatial information at parcel and block scale was used to combine these datasets for calibration at parcel scale, based on a spatial merge using geometry and crosschecking with the address information which is part of both datasets. The combined dataset contains information for 71,021 parcels and 3,255 census blocks* in the city of Orlando.

*Outliers, i.e., extreme high or low values, including null values are removed after creating the combined dataset and the numbers reported exclude outliers.

Methodology

1. Initial value of the total roof area equivalent to the building footprint area reported for the parcel.
2. Random assignment of roof azimuth and tilt values for each parcel based on the empirical probability distributions provided in Gagnon et al. 2016.
3. Run the Renewable Energy Potential (ReV) model (Maclaurin et al. 2019 and Rossol et al. 2021) and obtain the average capacity factor (based on 8760 profiles) for each parcel per unit area.
4. Calculate the technical potential for each parcel (in terms of kW and net area available for development) and well as annual generation for each parcel using the total roof area and capacity factor.
5. Compare the rooftop solar technical potential at city and block scale with data from a LiDAR analysis of Orlando. Calculate a derating factor based on the comparison of developable roof area in both datasets.
6. Update technical potential using a derate factor that accounts for translation from building footprint area to net solar-suitable rooftop area based on the comparison in #5.

Calibration of Developable Roof Area

Definitionally, building footprint area will overestimate a building's rooftop developable area for solar panels. First, the roof area differs from the building footprint based on the number of planes and their tilt. Additionally, the roof "developable" area for solar is reduced by the portions that are overly shaded, excessively tilted, and are north-facing. Suitable area is also influenced by roof structural suitability, whether the roof materials are unsuitable for solar, and other factors.

Thus, building footprint area should be derated to generate an unbiased developable area estimate. Here, we estimate the derating factor using building-level developable area estimates using LiDAR data for Orlando Utilities Commission (OUC) (Koebrich et al. 2021).

Calibration of Developable Roof Area

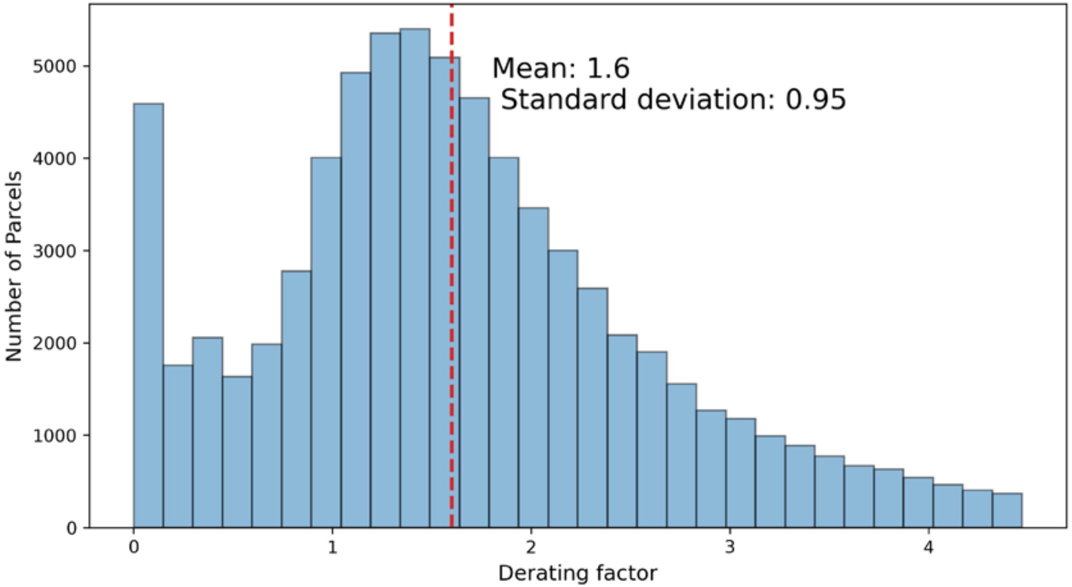

*Figure 1: Histogram of the derating factor for 71,021 parcels.**

A derating factor is calculated using building-level developable area estimates using LiDAR data for Orlando Utilities Commission (OUC) (Koebrich et al. 2021) and the building footprint area from the parcel dataset.

$$\text{Derating Factor} = \frac{Developable\ Roof\ Sqft\ (from\ Parcel\ dataset)}{Developable\ Roof\ Sqft\ (from\ OUC\ LiDAR\ dataset)}$$

*Outliers, i.e., extreme high or low values, including null values are removed in the above figure.

Results

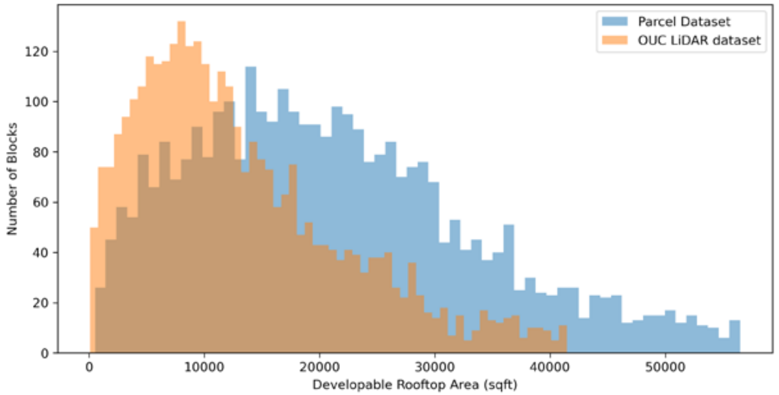

Figure 2: Histogram of developable roof area by census block.

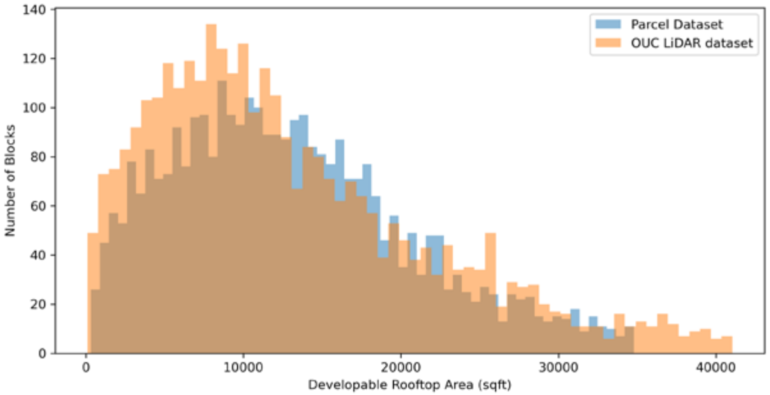

Figure 3: Histogram of developable roof area by census block after applying the derating factor.

Comparison of Technical Potential

Technical potential in terms of developable roof area from the LiDAR dataset is lower than that from the Parcel dataset because it accounts for shading and roof geometry. The derating factor corrects for these factors.

*Outliers, i.e., extreme high or low values, including null values are removed in the above figures.

Comparison of Technical Potential

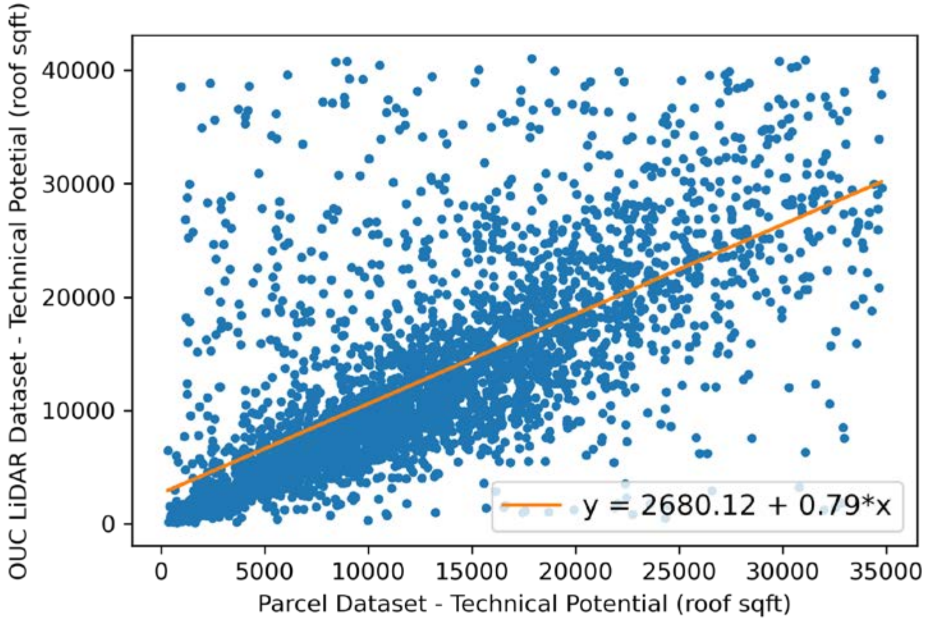

Figure 4: Correlation between the rooftop solar technical potential from the parcel dataset and rooftop solar technical potential from the LiDAR dataset after applying the derating factor.

After applying the derating factor, the mean absolute error (MAE) over the 71,021 parcels analyzed is 60 kW (4095 sqft. of developable roof area).

The MAE over the 3255 census blocks analyzed is 1347 kW (4322 sqft. of developable roof area).

Rooftop PV Technical Potential by Census Block

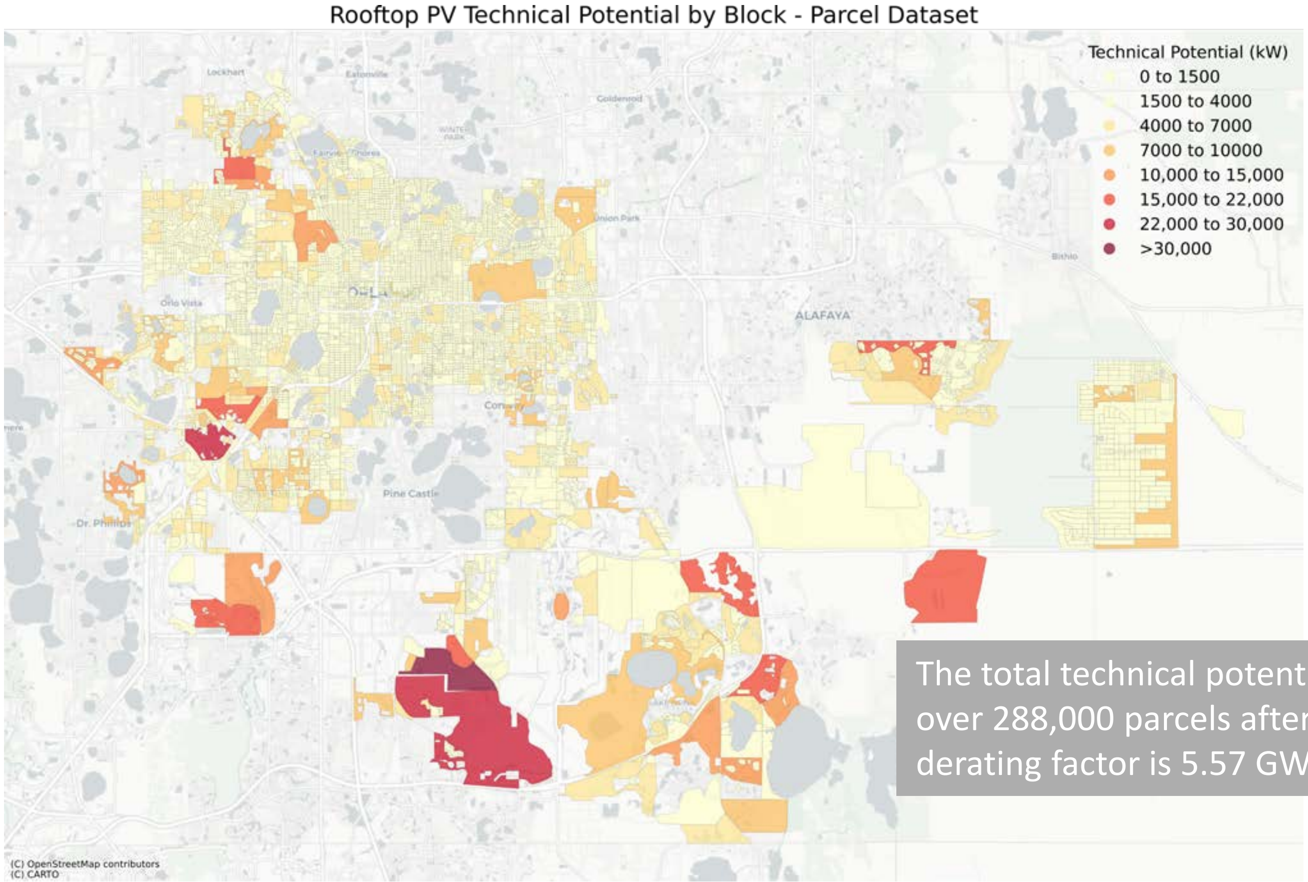

Figure 5: Estimated rooftop solar technical potential by Census block

The total technical potential for Orlando over 288,000 parcels after applying the derating factor is 5.57 GW.

Technical potential by building use

Building use type	Capacity (MW)*
Single-Family	3000
Multi-Family	700
Commercial	700
Industrial	700
Government & Recreational	200
Total	5300

Single-family buildings have the highest rooftop solar technical potential, followed by multi-family and commercial buildings.

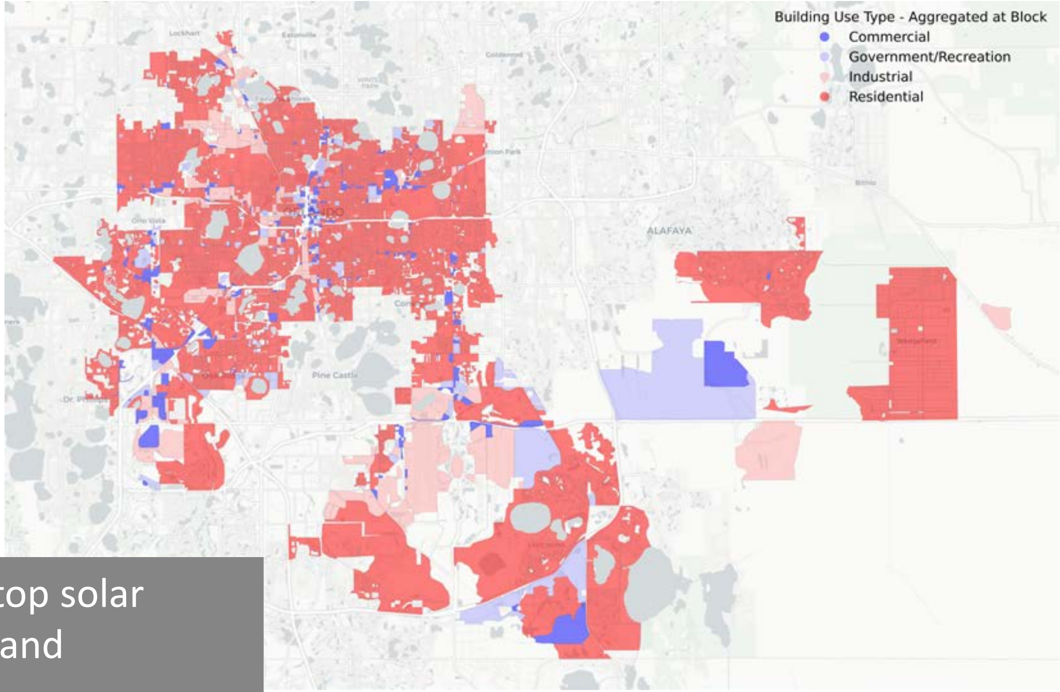

Figure 6: Modal land-use type by Census block

*Values have been rounded to nearest 100 MW.

Technical potential by occupant tenure

Occupant Tenure	Capacity (MW)
Owner Occupied	2930
Renter Occupied	2630

Rooftop solar technical potential is equally distributed across owner occupied and renter occupied parcels.

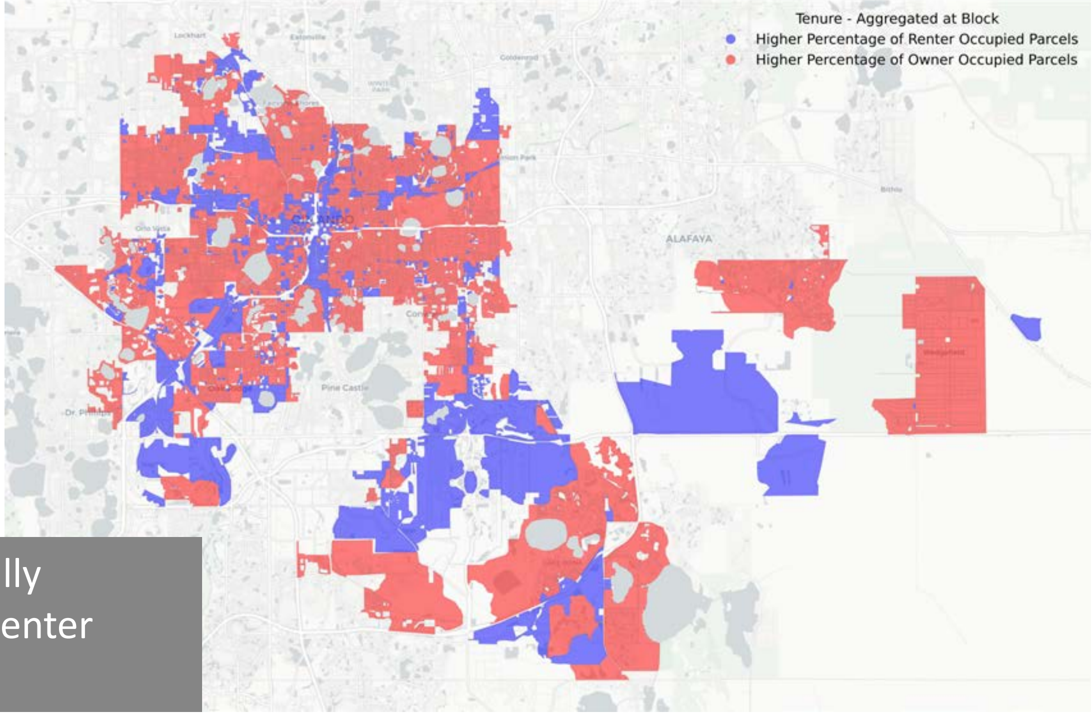

Figure 7: Modal building tenure (owner- or renter-occupied) by Census block

Conclusions and Future Work

Conclusions

In this analysis we present a scalable approach to assess rooftop solar technical potential for every city and community in the U.S. While LiDAR data is growing in popularity, it is still technically complex to process and not available in all geometries. In contrast, most jurisdictions make parcel data publicly available and publish building footprint area in order levy property taxes.

The city of Orlando is selected to demonstrate the proof-of-concept and to show specific results. Although the accuracy of the parcel-level approach is enhanced using LiDAR observations, accuracy when reporting results at the block, tract, or city-level are high. Practitioners can weigh the best method for their analytical needs.

The results of this analysis include the distribution of rooftop solar technical potential geographically, by building use type and by tenure for the city of Orlando.

Using the comparison with processed LiDAR data for the city of Orlando, we calculate a derating factor which can improve accuracy of the estimated rooftop solar technical potential in future analysis.

Future work

- Application of methodology to additional cities to improve robustness of the derating parameter estimate
- Machine learning applied to extend LiDAR data for all cities across the U.S. to derive regional assumptions for azimuth, tilt and roof area.
- Assessment of solar technical potential for ground mount solar using information from the parcel dataset.
- Assessment of community solar and battery storage using the parcel dataset.
- Hosting capacity analysis for cities/utilities using the parcel dataset.

References

Gagnon, Pieter, Robert Margolis, Jennifer Melius, Caleb Phillips, and Ryan Elmore. 2016. Rooftop Solar Photovoltaic Technical Potential in the United States: A Detailed Assessment. NREL/TP-6A20-65298. https://www.nrel.gov/docs/fy16osti/65298.pdf

Homeland Infrastructure Foundation-Level Data (HIFLD) (2020). *Parcel Data - Lightbox*. https://gii.dhs.gov/hifld/content/hifld-data-catalog

Koebrich, Sam, Ben Sigrin, Robert Spencer, Paul Schwabe, Scott Haase, Sam Choi and Justin Kramer. 2021. Distributed Solar Adoption in Orlando: A Household-Level Model for Distribution Resource Planning. NREL PR-6A20-77308. https://www.nrel.gov/docs/fy21osti/77308.pdf

Maclaurin, Galen J., Nicholas W. Grue, Anthony J. Lopez, and Donna M. Heimiller. 2019. "The Renewable Energy Potential (reV) Model: A Geospatial Platform for Technical Potential and Supply Curve Modeling." Golden, Colorado, United States: National Renewable Energy Laboratory. NREL/TP-6A20-73067. https://doi.org/10.2172/1563140.

Michael Rossol, Grant Buster, Mike Bannister, Robert Spencer, and Travis Williams. The Renewable Energy Potential Model (reV). https://github.com/NREL/reV (version v0.5.0), 2021. https://doi.org/10.5281/zenodo.4711470.

This work was authored by the National Renewable Energy Laboratory, operated by Alliance for Sustainable Energy, LLC, for the U.S. Department of Energy (DOE) under Contract No. DE-AC36-08GO28308. Funding provided by the U.S. Department of Energy Office of Energy Efficiency and Renewable Energy Solar Energy Technologies Office. The views expressed in the article do not necessarily represent the views of the DOE or the U.S. Government. The U.S. Government retains and the publisher, by accepting the article for publication, acknowledges that the U.S. Government retains a nonexclusive, paid-up, irrevocable, worldwide license to publish or reproduce the published form of this work, or allow others to do so, for U.S. Government purposes.

Definition of data fields

Developable Roof Area (m^2): Calculated using the total building area and number of stories for each parcel provided in the parcel-scale dataset.

$$\text{Developable Roof Area } (m^2) = \frac{\text{Total Building Area } (m^2)}{\text{Number of Stories}}$$

Tilt Angle (degrees): Generated through random sample generation based on the probability distributions provided in the NREL technical report NREL/TP-6A20-65298 by Gagnon et al.

Azimuth Angle (degrees): Generated through random sample generation based on the probability distributions provided in the NREL technical report NREL/TP-6A20-65298 by Gagnon et al.

Panel efficiency: 160 W/m2, same as the value used in the technical report NREL PR-6A20-77308 by Koebrich et al. 2021.

Generation and Capacity by Parcel: Simulated using the Renewable Energy Potential (ReV) Model by Maclaurin et al. and Rossol et al. using the 2012 weather file for each location.

Generation and Capacity by Block: Spatial join of parcel and block geometries. Aggregation of individual parcel scale generation and capacity to block scale.