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Rooftop Solar Technical Potential for Low-to-Moderate Income (LMI) Households

Benjamin Sigrin and Meghan Mooney
May 1st, 2018

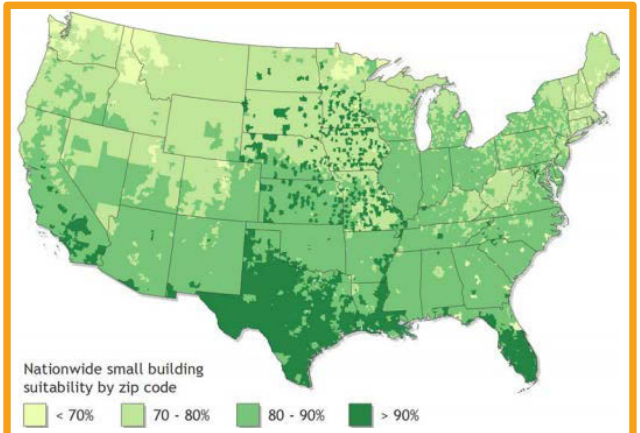
NREL/PR-6A20-71190

SEEDS II Overview

(Solar Energy Evolution and Diffusion Studies)

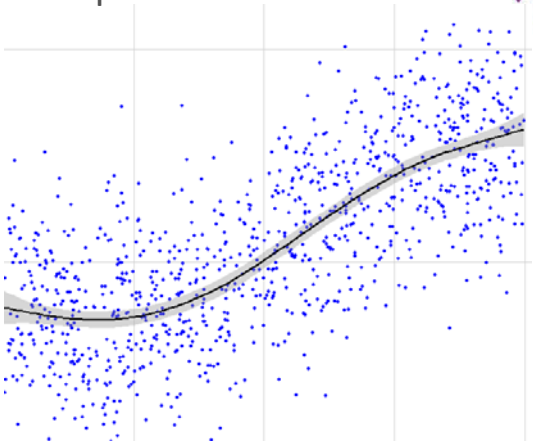
Project Goal:

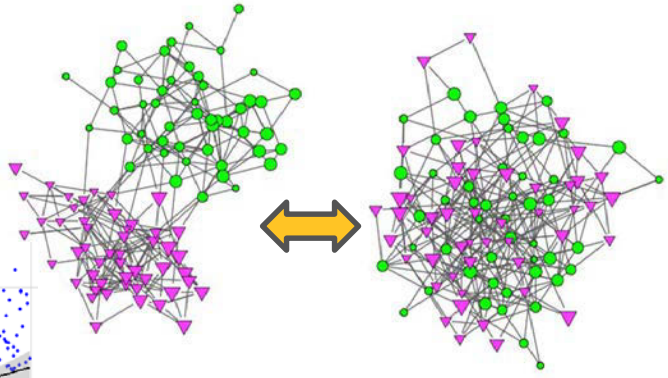
Identify strategies to scale up solar adoption among low-and-moderate income (LMI) communities across the U.S.



Determine technical potential of LMI market and opportunities for new deployment models

Develop predictive models to understand prior adoption successes





Understand role and sources of referrals in LMI communities

Why Does Rooftop Solar Potential for LMI Matter?

- LMI households represent 43% of US population and spend disproportionately more of their income on energy
  - Dollar savings from solar likely more impactful
- Solar has been disproportionately adopted by higher-income households
  - Growing backlash against rooftop solar policies that appear to favor the more affluent
- Increasing interest in policy interventions to include LMI households and create more equitable rooftop solar access
  - However, poor understanding of how much rooftop solar LMI communities can accommodate may lead to ineffective policies

Household Classification	% of Area Median Income
Very Low Income	0-30%
Low Income	30-50%
Moderate Income	50-80%
Middle Income	80-120%
High Income	>120%

Sigrin, Ben, and Mooney, Meghan. 2018. Rooftop Solar Technical Potential for Low-to-Moderate Income Households in the United States. Golden, CO: National Renewable Energy Laboratory. NREL/TP-6A20- 70901. https://www.nrel.gov/docs/fy18osti/70901.pdf.

Key Questions for Technical Potential Analysis

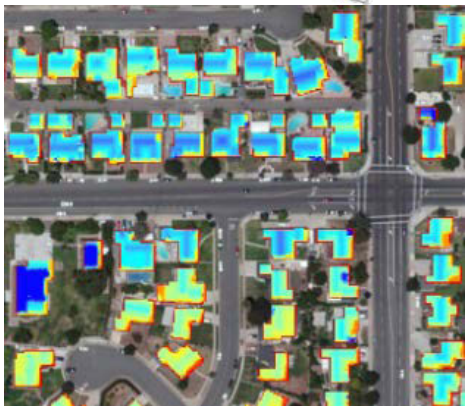
1. How is rooftop solar potential distributed geographically, by income group, building type, and tenure of the building occupants?

2. How much electrical consumption can be offset by rooftop solar?

3. Could non-profit buildings “oversize” systems on their roofs to share solar energy with other LMI households?

Key Activities for Technical Potential Analysis

- Use LiDAR imagery combined with U.S. Census data sets to estimate the total usable rooftop area for LMI households nationally
- Deep analysis of three representative regions (San Bernardino-Riverside, Chicago, and DC), identifying the total rooftop area for other buildings that could host LMI solar (subsidized multi-family housing, churches, schools, etc.)
- Development of data products to inform policymakers, nonprofits, project developers, etc.



Top: Cities with LiDAR data coverage

Bottom: LiDAR assesses premise-level potential for entire building stock

Summary of methodology

- This study uses previously-processed LiDAR scans of U.S. building stock in 128 metro areas (40% of U.S. population)
- LiDAR data is intersected with Census demographics tables of household counts by income, tenure, and building type. LiDAR data does not allow direct observation of the tenant's attributes, thus a disaggregation method is used.
- A statistical model, trained on LiDAR areas, is used to impute building characteristics (area, orientation, shading, etc.)
- Finally, simulate solar generation for each roof using NREL PVWATTS and aggregate at the tract and county level

Definition of solar suitability

Requirement	
Shading	Seasonal requirements: March requires 60% illumination, June requires 70% illumination, September requires 60% illumination, and December requires 50% illumination.
Azimuth	East, Southeast, South, Southwest, or West-facing
Tilt	Average surface tilt <= 60 degree.
Minimum Area	≥ 10 m^2 (~ 1.5 kW)

National Residential PV Solar Rooftop Potential

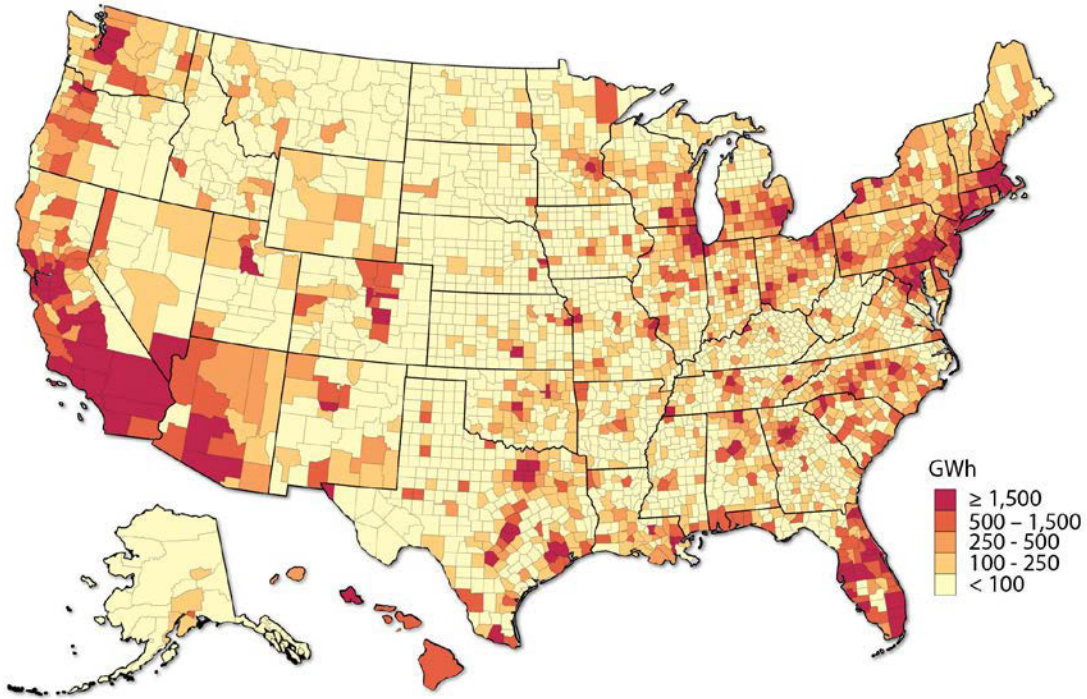
- Annual residential solar potential is ~1000 TWh (roughly 75% of residential electricity consumption)
- LMI opportunity is 415.9 TWh, nearly half (42%) of total annual residential solar potential
- Average household potential is 8,553 kWh nationally
  - Potential is greater for higher incomes but still considerable for even very low income group (8,246 kWh/household)

National residential PV rooftop technical potential by income group

Income Group	Households (millions)	Suitable Buildings (millions)	Suitable Module Area (millions of m^2)	Capacity Potential (GW_{DC})	Annual Generation Potential (TWh/year)
Very Low (0-30% AMI)	19.5	9.4	794.4	127.1	160.8
Low (30-50% AMI)	11.5	5.7	472.8	75.6	95.3
Moderate (50-80% AMI)	18.8	10.4	792.0	126.7	159.8
Middle (80-120% AMI)	21.1	12.3	900.4	144.1	180.8
High (> 120% AMI)	46.0	29.4	2,003.3	320.5	403.1
All LMI Buildings	49.8	25.5	2,059.2	329.4	415.9
All Residential Buildings	116.9	67.2	4,962.9	794.0	999.8

Absolute Residential Solar Potential By County

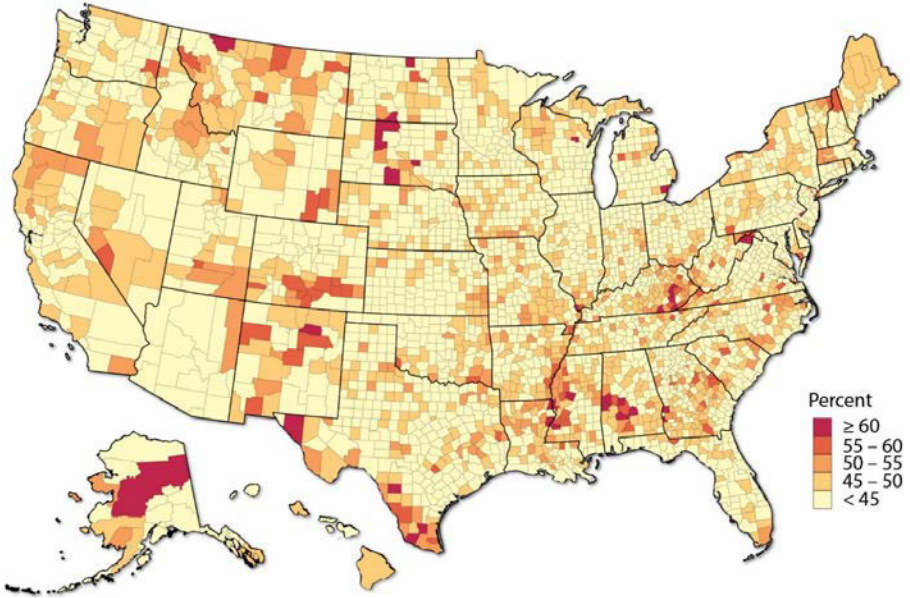
- High potential in densely populated areas with more building stock
- Historical residential solar deployment generally correlates with potential
  - Exceptions: IL, OH, FL, PA, and TX, indicating opportunity for growth



County residential technical potential (GWh)

LMI Solar Potential Relative to Absolute Potential by County

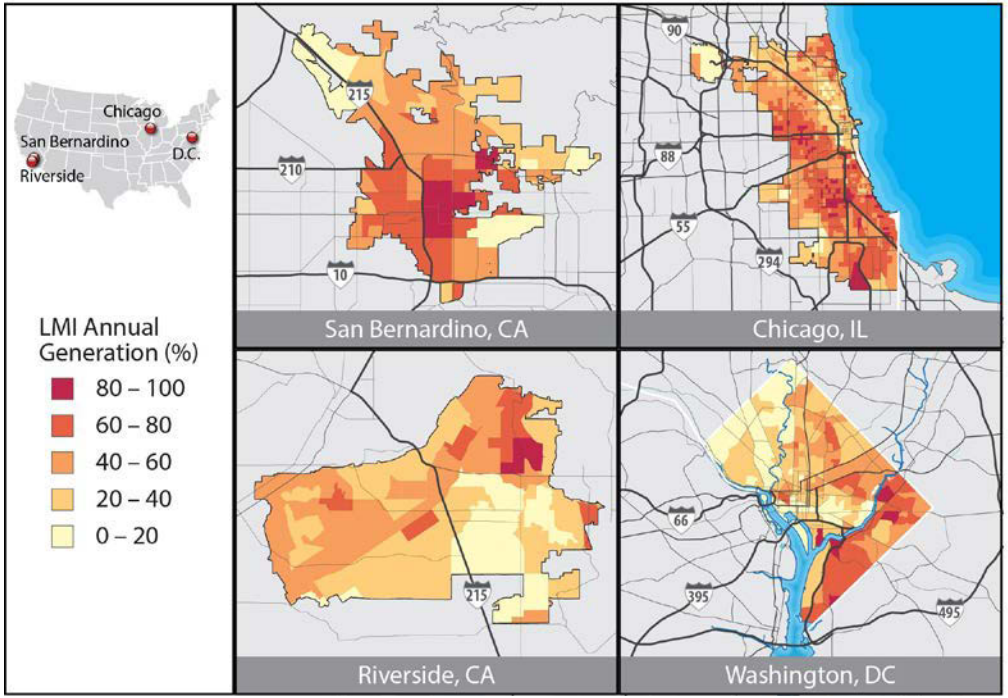
- In 437 counties (14%), LMI solar potential accounts for at least half the county's solar potential
- Unsurprisingly, LMI potential percentages are highest in lower-income counties (mostly rural or semi-rural)
- Areas with relatively high LMI solar percentages include the Southeast (i.e., AL, AR, KY, LA, MS, and WV) and portions of the Midwest and Mountain West



County LMI rooftop technical potential as percent of total potential

Deeper Analysis of Select Cities

- LMI solar potential is strongly correlated with lower-income neighborhoods
- Deploying solar in low-income neighborhoods could substantially increase overall rooftop solar potential in these cities



LMI rooftop technical potential as percent of total potential in select cities

Most LMI Solar Potential Is Not on Single-Family Owner-Occupied Roofs

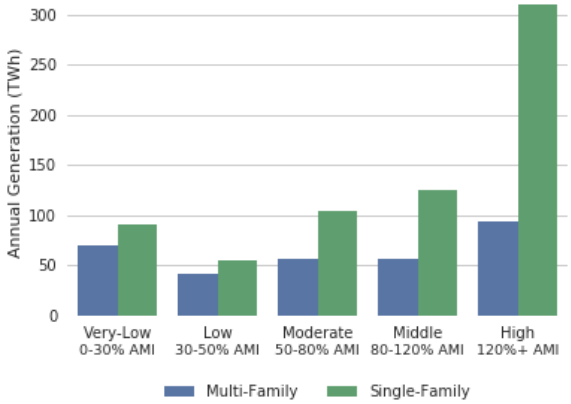
- Deployment of rooftop solar has historically been concentrated on single-family owner-occupied buildings
- Our results indicate that nearly 60% of potential for LMI buildings exists on other underrecognized tenure-type combinations

Tenure-type combinations

SFOO	Single-family owner-occupied
SFRO	Single-family renter-occupied
MFOO	Multi-family owner-occupied
MFRO	Multi-family renter-occupied

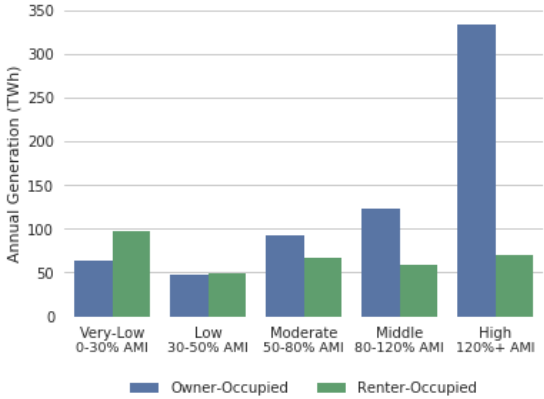
Solar Potential By Income, Building Type and Tenure of Occupants

Generation potential by income group & building type



- Plurality of residential potential is on single-family buildings (683 TWh, 68.4%) vs. multi-family (316 TWh, 31.6%)
- Residential potential of single- and multi-family buildings is more uniform among LMI households

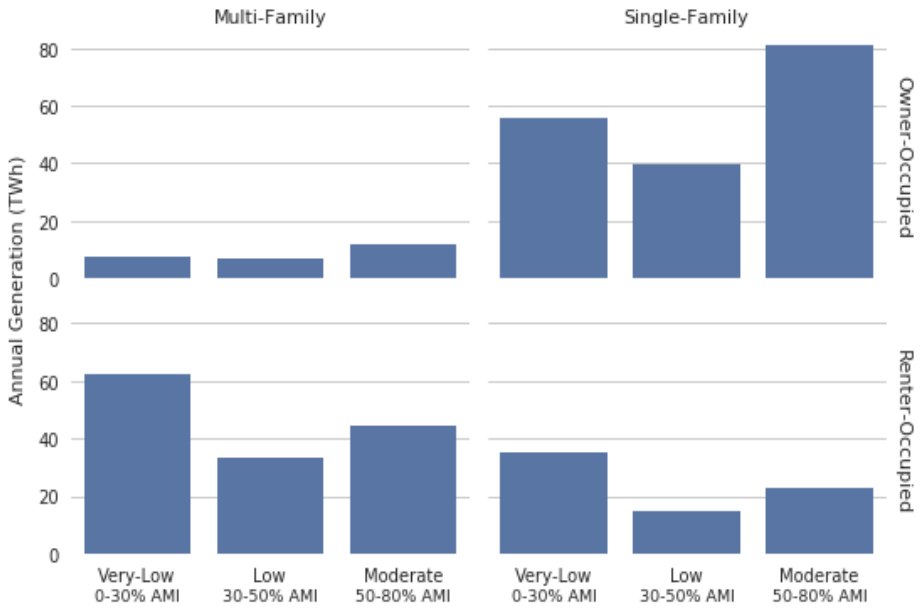
Generation potential by income group & building tenure



- Overall, there is substantially more residential potential (659 TWh , 65.9%) on owner-occupied buildings vs. renter-occupied (341 TWh, 34.1%)
- But for LMI households, potential for renter-occupied (212.7 TWh) slightly exceeds that of owner-occupied buildings (203.3 TWh)

Most LMI Solar Potential Is Unconventional

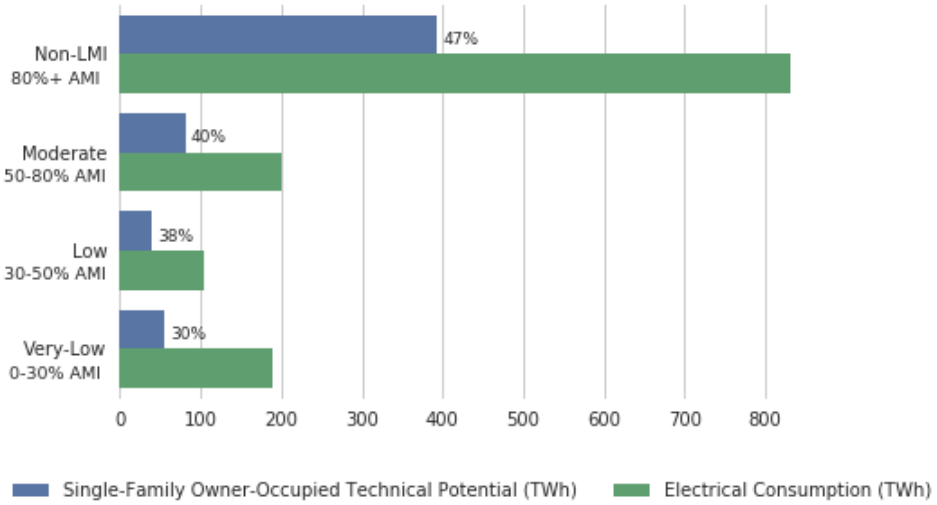
Generation potential (TWh) by building type and tenure



- Solar potential is greatest for SFOO buildings (176.8 TWh) and MFRO buildings (140.1 TWh)
- 60% of LMI residential potential is not on SFOO
  - Improving LMI solar access will likely require non-traditional rooftop solar models (e.g. shared solar)

We Can Offset Some Electricity Consumption With Conventional Rooftop Solar

Percent of electricity consumption solar could offset for SFOO buildings

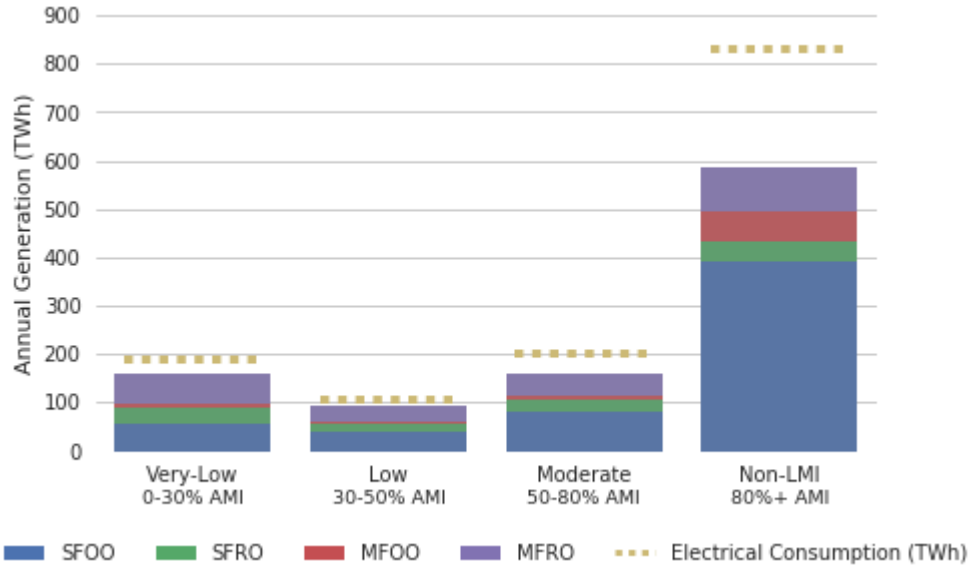


- Conventional rooftop solar can theoretically meet >33% of electrical consumption for all income groups, except very low income
- Non-LMI electrical consumption far exceeds other groups; their conventional rooftop solar potential is also disproportionately greater
  - Partially explains high rates of adoption among non-LMI households

We Can Offset Most Electricity Consumption With All Potential Household Rooftop Solar Sources

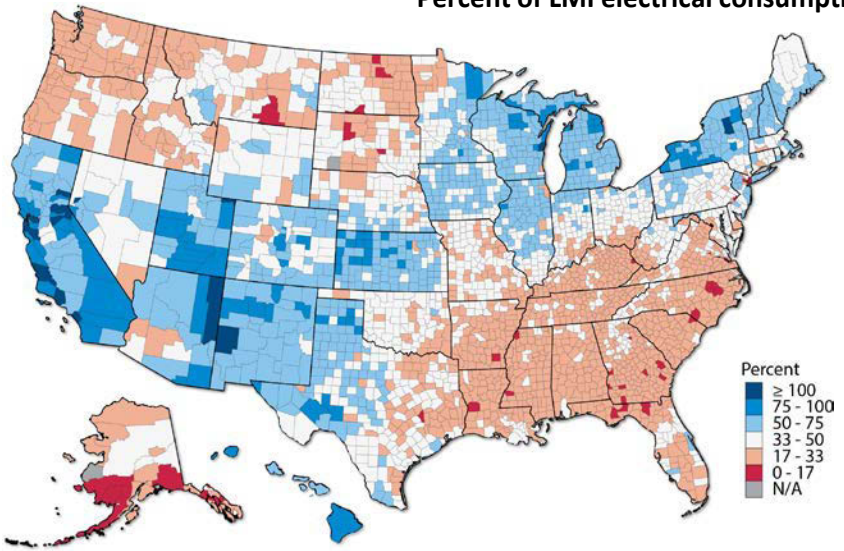
- Solar generation can technically meet most electrical consumption for all income groups if we include renter-occupied (RO), multi-family (MF), and SFOO roof spaces
  - Very Low income group electricity consumption could be offset by 85%
  - Low group consumption could be offset by 91%
  - Moderate group consumption could be offset by 80%
  - Non-LMI consumption could be offset by 70%

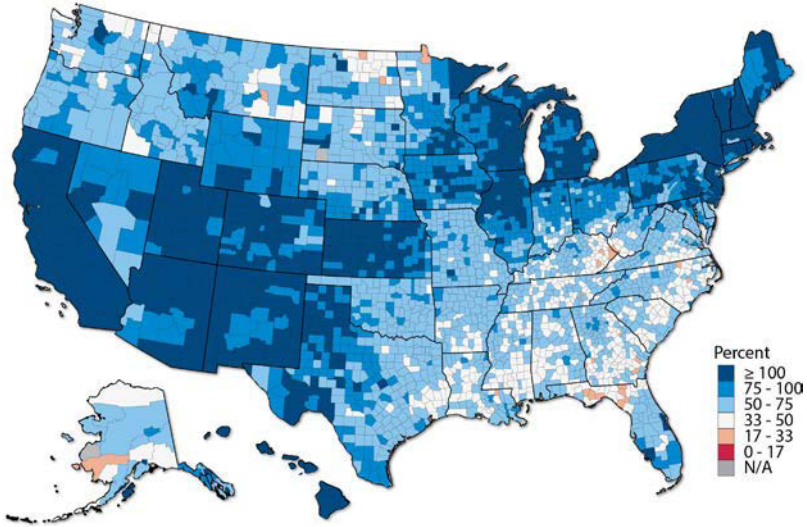
Technical feasibility of matching residential electrical consumption with rooftop solar, by income group



Expanding Roof Stock Dramatically Increases Solar Potential by County

Percent of LMI electrical consumption offsettable by rooftop solar generation





- Using only SFOO roof space, 60% of U.S. counties would have sufficient potential to meet 33% of LMI electricity consumption (left map)
- Using all residential building roof space, 99% of counties would have sufficient potential to meet the 33% threshold (right map)

Technical Potential For Non-Residential Rooftops

Annual generation potential for select third-party buildings in Chicago, Washington D.C., and San Bernardino/Riverside (GWh)

	Chicago	San Bernardino/ Riverside	Washington, D.C.
Public Housing	62.8	16.6	31.0
Public Sites	51.9	24.4[1]	41.1
K-12 Schools	306.4	106.2	73.0
Homeless Shelters	5.3	0.6	5.6
Places of Worship	108.1	7.3	32.8
Total (GWh)	1072.3	311.0	377.1

[1] Due to data limitations, generation potential for San Bernardino public sites was not estimated.

Net excess rooftop potential for each building class, by city

	Chicago	**San Bernardino/ Riverside**	**Washington, D.C.**
Public Housing	0.0	0.0	0.0
Public Sites	0.0	0.0	0.0
K-12 Schools	19.8	19.6	5.5
Homeless Shelters	0.0	0.0	0.0
Places of Worship	31.5	3.2	4.6
Total (GWh)	51.4	22.8	10.1
Total (% of LMI consumption in city)	2.1%	8.7%	1.3%

- Of building types examined, schools unequivocally had most rooftop solar potential
- There is enough generation potential on select building types to meet 9%-29% of LMI consumption in respective cities
- Oversizing systems relative to building load and exporting excess generation can account for 1.3%-8.7% of LMI consumption in respective cities

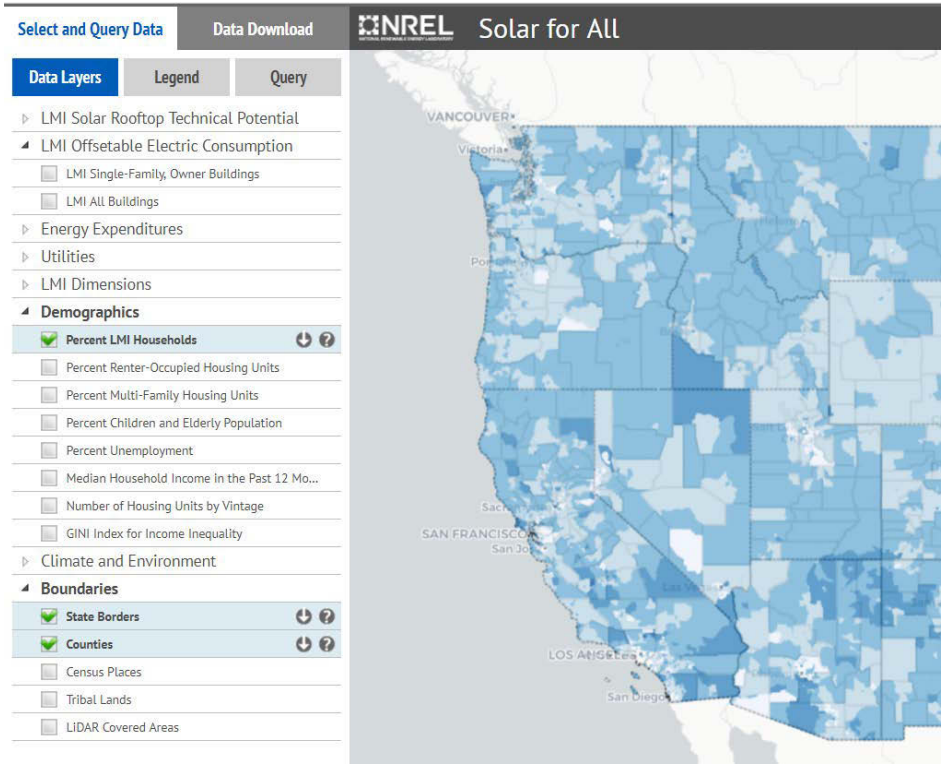
Conclusions

- There is substantial rooftop solar potential on LMI buildings (42% of U.S. total potential)
  - Ignoring LMI communities would significantly limit the rooftop solar potential
- Single-family buildings account for 68% of total U.S. solar potential
  - However, shared and community solar will meaningfully improve access for LMI communities
- Improving LMI access will require innovations to address:
  - Principal-agent problem for renters
  - Access to financing for LMI households
  - Challenges in targeting/educating LMI households with rooftop solar potential
- Possible innovations include:
  - Using public buildings to host solar to serve LMI communities
  - Enabling peer-to-peer sharing of rooftop solar generation within and among groups
  - Redirecting funds for LMI rate subsidization to directly or indirectly incentivize LMI solar deployment

All data used in the study is publicly available

Rooftop Energy Potential of Low Income Communities in America (REPLICA) – Tract-level solar technical potential by income, tenure, and building type, joined with 10 additional datasets to provide socio-demographic and market context (e.g. energy expenditures, demographics, etc.). https://data.nrel.gov/submissions/81

SolarForAll web application - Explore, download, and intersect data in interactive web application https://maps.nrel.gov/solar-for-all/



Screenshot of SolarForAll app

Contact: Benjamin.Sigrin@NREL.gov

Project Website: https://www.nrel.gov/solar/seeds/2017-2019-study.html

Report: https://www.nrel.gov/docs/fy18osti/70901.pdf

Data Set: https://data.nrel.gov/submissions/81

Web App: https://maps.nrel.gov/solar-for-all

Thank you

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TP-6A20-70901