Technical Potential and Meaningful Benefits of Community Solar in the United States

Katy Waechter,[1] Eric O’Shaughnessy,[2] Sudha Kannan,[1]
and Robin Burton[1]

1 National Renewable Energy Laboratory
2 Clean Kilowatts

NREL is a national laboratory of the U.S. Department of Energy
Office of Energy Efficiency & Renewable Energy
Operated by the Alliance for Sustainable Energy, LLC

This report is available at no cost from the National Renewable Energy Laboratory (NREL) at www.nrel.gov/publications.

Contract No. DE-AC36-08GO28308

Technical Report
NREL/TP-6A20-87524
February 2024

Technical Potential and Meaningful Benefits of Community Solar in the United States

Katy Waechter,[1] Eric O'Shaughnessy,[2] Sudha Kannan,[1] and Robin Burton[1]

1 National Renewable Energy Laboratory
2 Clean Kilowatts

Suggested Citation
Waechter, Katy, Eric O'Shaughnessy, Sudha Kannan and Robin Burton. 2024. *Technical Potential and Meaningful Benefits of Community Solar in the United States.* Golden, CO: National Renewable Energy Laboratory. NREL/TP-6A20-87524. https://www.nrel.gov/docs/fy24osti/87524.pdf.

NREL is a national laboratory of the U.S. Department of Energy
Office of Energy Efficiency & Renewable Energy
Operated by the Alliance for Sustainable Energy, LLC

Contract No. DE-AC36-08GO28308

Technical Report
NREL/TP-6A20-87524
February 2024

National Renewable Energy Laboratory
15013 Denver West Parkway
Golden, CO 80401
303-275-3000 • www.nrel.gov

NOTICE

This work was authored in part 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 U.S. Department of Energy Office of Energy Solar Energy Technologies Office. The views expressed herein do not necessarily represent the views of the DOE or the U.S. Government.

Cover Photo by Dennis Schroeder: NREL 60075.

Acronyms

AC	alternating current
ACS	U.S. Census Bureau American Community Survey
AMI	area median income
BTM	behind-the-meter
CBA	community benefit agreement
DC	direct current
DOE	U.S. Department of Energy
EIA	U.S. Energy Information Administration
FCR	fixed charge rate
GW	gigawatt
GWh	gigawatt-hour
IRA	Inflation Reduction Act
JEDI	Jobs and Economic Development Impact
km^2	square kilometer
kW	kilowatt
kWh	kilowatt-hour
LCOE	levelized cost of energy
LEAD	Low-Income Energy Affordability Data
LMI	low- to moderate-income
m^2	square meter
MW	megawatt
MWh	megawatt-hour
NREL	National Renewable Energy Laboratory
NSRDB	National Solar Radiation Database
PV	photovoltaic
reV	Renewable Energy Potential
SAM	System Advisor Model
TWh	terawatt-hour
W	watt

Executive Summary

Community solar is any solar project or purchasing program within a geographic area in which the benefits flow to multiple customers, such as individuals, businesses, nonprofits, and other groups. Community solar customers typically subscribe to or own a portion of the energy generated by a solar array and receive an electric bill credit for electricity generated by their share of the community solar system. Community solar can offer greater household savings for electricity customers, provide access to solar energy for low- to moderate-income (LMI) customers, generate resilience and grid benefits, and boost solar workforce development, among other benefits.[1] The goal of this study was to identify the maximum amount of community solar capacity that is physically feasible for development and the extent of the associated benefits.

The National Renewable Energy Laboratory (NREL) estimated the technical potential for community solar in the United States under two siting regimes (Limited Access and Reference Access). This analysis characterized the variability in local drivers of community solar siting and provided high and low bounds on community solar technical potential. For this analysis, we modified existing siting regimes for ground-mount solar photovoltaics (PV) to reflect community solar siting constraints, including virtual hosting requirements, maximum interconnection distance, and inclusion of rooftop and ground-mount PV array types. This combination of land availability assumptions targeted developable spaces with characteristics reflective of existing community solar installations and that are incompatible with utility-scale renewable energy technology deployments, similar to the methodology in Lopez et al. (2024). This approach prioritizes exclusive siting of community solar. We applied one technology scenario per array type. We used the PV Rooftop model (Gagnon et al. 2016) to estimate PV-developable areas on individual buildings, and we used the Renewable Energy Potential (reV) model (Maclaurin et al. 2019) to estimate developable areas for ground-mount PV and to estimate energy production for both rooftop and ground-mount systems across the United States for our two siting regimes.

At a national level, we estimate that there are 967 gigawatts alternating current (GW_{AC}) of community solar technical potential under the Limited Access regime, amounting to 1,710 terawatt-hours (TWh) of annual energy production. We estimate that there are 2,862 GW_{AC} of community solar technical potential under the Reference Access regime, amounting to 5,921 TWh of annual energy production (Table ES-1). The resource area for rooftop community solar systems (2,776.64 square kilometers [km^2]) is consistent across the Limited Access and Reference Access siting regimes due to its low land conflict potential. The resource area for ground-mount community solar systems ranges from nearly 12,000 to 53,000 km^2. This wide range represents 30% to 126% of the maximum land area for ground-based solar identified for the highest land-use scenario (Decarb+E) in the *Solar Futures Study* (DOE 2021). These resource areas are largely in addition to resource areas considered for utility-scale renewable energy technologies in urban and suburban areas where only smaller systems can be deployed and on not federally owned lands. However, these resource areas are in competition with utility-scale renewable energy technologies in rural areas with larger contiguous developable tracts of land within proximity of substation interconnections, primarily affecting the largest ground-mount PV systems modeled in this study.

---

[1] "Community Solar Basics," DOE, https://www.energy.gov/eere/solar/community-solar-basics

Table ES-1. Technical Potential Estimates by Siting Regime and Array Type

Siting Regime	Array Type	Developable Area (km^2)	Net Capacity Factor (mean)	Capacity (GW$_{AC}$)	Annual Energy Production (TWh)
Limited Access	Rooftop	2,776.64	20.65%	396.99	718.24
	Ground	15,437.60	19.85%	570.51	991.98
Reference Access	Rooftop	2,776.64	20.65%	396.99	718.24
	Ground	53,378.03	20.77%	2,465.14	4,484.77

Our technical potential estimation suggests that community solar could conceivably serve 53.2 million households and 311,750 businesses that cannot access behind-the-meter solar in the United States. In practice, market, economic, and policy constraints mean that the actual number of households and businesses potentially served by community solar is much smaller. Our analysis suggests that community solar could theoretically grow to serve all residential electricity customers who are unable to adopt behind-the-meter solar, including low- to moderate-income (LMI) households. We found that 42% of households and 44% of businesses are unable to access behind-the-meter solar, a decrease from previous estimates that represents a lower overall demand for community solar. Not all community solar capacity is located within the same communities as subscribers, particularly for households renting and multifamily buildings, but it is accessible to subscribers within the same electricity utility service territory.

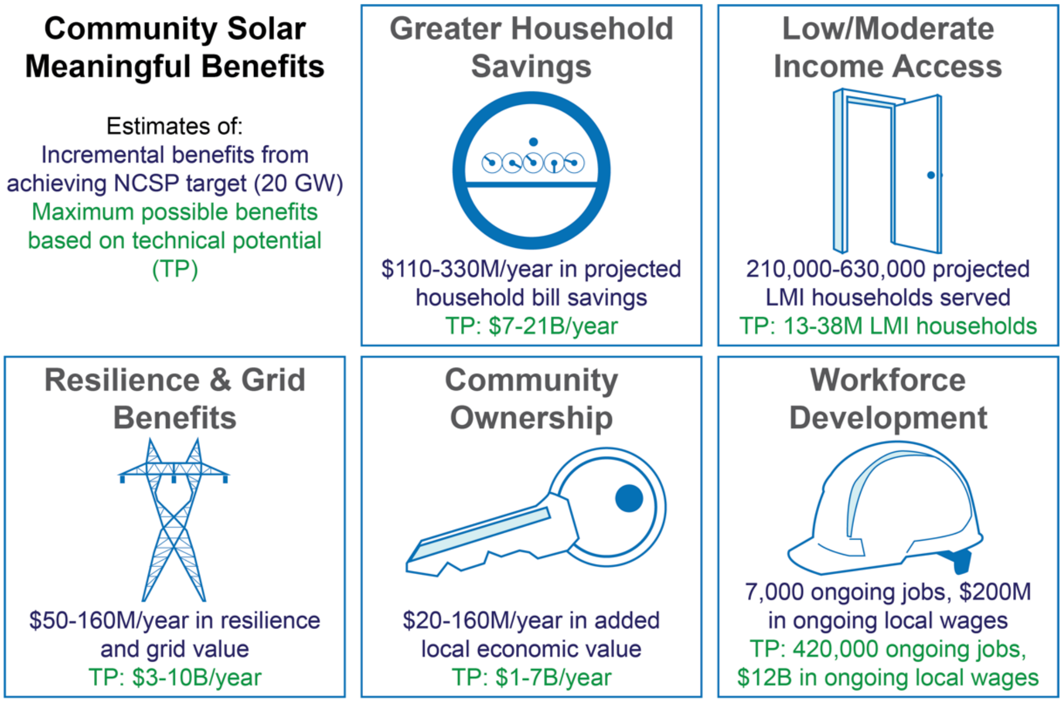


Figure ES-1. Summary of projected meaningful benefits based on near-term community solar deployment

In this report, we also explore the potential gross benefits from the ongoing deployment of community solar, as shown in Figure ES-1. We estimate that, if all technically viable potential community solar is deployed, it could save customers billions of dollars on their electricity bills, serve tens of millions of LMI households, generate billions of dollars in grid resilience and grid service values, drive billions of dollars of economic benefits into host communities, and support hundreds of thousands of jobs. Realistically, the potential accrual of benefits is a fraction of the technical potential estimates. Still, using the 20-GW target set by the U.S. Department of Energy National Community Solar Partnership as a more realistic target for near-term deployment, we estimate that community solar could reduce subscriber electricity costs by around \$110 million–\$330 million per year, serve 210,000–630,000 LMI households, generate \$50 million–\$160 million per year in grid resiliency and service value, drive \$20 million–\$160 million per year in economic benefits into host communities, and support around 7,000 permanent jobs.

Table of Contents

NOTICE ..... **iii**
Acronyms ..... **iv**
Executive Summary ..... **v**
Table of Contents ..... **viii**
1 Introduction **1**
  1.1 Background: Technical Potential 2
  1.2 Background: Meaningful Benefits 3
2 Methodology **5**
  2.1 Estimating Generation 6
  2.2 Siting Constraints and Regimes 7
    2.2.1 Rooftop Siting Constraints 8
    2.2.2 Ground-Mount Siting Constraints 8
    2.2.3 Virtual Hosting Limitations 11
  2.3 Estimating Technical Potential and Offsetable Consumption 12
3 Technical Potential Results **14**
  3.1 Community Solar Capacity and Annual Energy Production 18
    3.1.1 Opportunities for Strategically Siting Community Solar 20
  3.2 Community Solar Technical Potential by Household Income, Tenure, and Building Type 26
4 Meaningful Benefits **28**
  4.1 Greater Household Savings 28
    4.1.1 Household Savings Baseline 28
    4.1.2 Greater Household Savings Estimates 30
  4.2 LMI Household Access 30
    4.2.1 LMI Household Access Baseline 31
    4.2.2 LMI Household Access Estimates 31
  4.3 Resilience and Grid Benefits 31
    4.3.1 Resilience and Grid Benefits Baseline 32
    4.3.2 Resilience and Grid Benefits Estimates 33
  4.4 Community Ownership 34
    4.4.1 Community Ownership Baseline 34
    4.4.2 Estimated Benefits of Community Ownership 34
  4.5 Equitable Workforce Development 35
    4.5.1 Equitable Workforce Development Baseline 36
    4.5.2 Estimated Benefits of Equitable Workforce Development 36
5 Conclusions **38**
  5.1 Future Work 38
References **40**

List of Figures

Figure 1. Community solar technical potential framework (modified from Brown et al. 2016) 3
Figure 2. Size range of solar PV deployments with scaled system size indicator 5
Figure 3. Annual mean global horizontal irradiance from 1998 to 2018 (National Solar Radiation Database for the continental United States, Alaska, and Hawaii) 6
Figure 4. Elevation digital surface model and derived roof area characteristics used by the PV Rooftop model 8
Figure 5. Overview of the method used to determine resource availability after applying solar PV ordinance setbacks (from Lopez et al. 2023) 9
Figure 6. Ground-mount PV technical exclusions adapted from utility-scale solar siting regimes 10
Figure 7. Geographic distribution of potential community solar sites by supply or demand constraint (gray indicates no data) 12
Figure 8. Distribution of households by income with significant barriers for behind-the-meter (BTM) PV compatibility based on tenure, building type, and individual building suitability 14
Figure 9. Modeled community solar capacity for Reference Access siting regime (top) and Limited Access siting regime (bottom) 19
Figure 10. Community solar potential capacity by technology, siting regime, and context 20
Figure 11. Cumulative distribution of modeled ground-mount PV by siting regime 21
Figure 12. Percent of electricity consumption that cannot be met by behind-the-meter PV that can be offset by modeled community solar under the Reference Access siting regime 23
Figure 13. Percent of electricity consumption that cannot be met by behind-the-meter PV that can be offset by modeled community solar under the Limited Access siting regime 23

List of Tables

Table 1. Limited Access Siting Regime Community Solar Technical Potential Results by State 15
Table 2. Reference Siting Regime Community Solar Technical Potential Results by State 16
Table 3. Distribution of Rooftop PV Capacity by Building Occupancy Type 24
Table 4. Percent of Rooftop Area Developable for PV by Building Occupancy Type 25
Table 5. Annual Residential Electricity Consumption by Income, Tenure, and Dwelling Type 27
Table 6. Percent of Modeled Community Solar Supply (Limited Access) Needed To Offset Residential Electricity Consumption by Income, Tenure, and Dwelling Type 27

1 Introduction

The U.S. Department of Energy (DOE) defines community solar as any solar project or purchasing program, within a geographic area, in which the benefits flow to multiple customers, such as individuals, businesses, nonprofits, and other groups.[2] In most cases, customers benefit from energy generated by solar panels at an off-site array. Community solar customers typically subscribe to—or in some cases, own—a portion of the energy generated by a solar array, and receive an electric bill credit for electricity generated by their share of the community solar system. Community solar can be a great option for people who are unable to install solar panels on their roofs because they are renters, can't afford solar, or because their roofs or electrical systems aren't suited to solar.

Community solar is a business model that allows multiple electricity customers to "subscribe" to the output of a shared solar photovoltaic (PV) array. Some definitions of community solar include geographic restrictions, such as requiring that systems serve subscribers in the same utility service territory. Community solar is growing rapidly, with cumulative installed capacity in the United States increasing from around 1 gigawatt (GW_{AC}) in 2018 to more than 7.045 GW_{AC} by the end of 2023 (Xu 2024). The growth of community solar has partly been enabled by state policies that facilitate the subscription business model—namely, policies that allow subscribers to use community solar credits against their utility bill obligations.

Community solar could expand solar access to households and businesses that cannot adopt on-site solar (e.g., rooftop solar). Previous work by the National Renewable Energy Laboratory (NREL) found that community solar could be a viable option for around half of U.S. homes and businesses facing significant barriers to adopting on-site solar due to rooftop constraints, property ownership issues, or other challenges (Feldman et al. 2015). Participation in community solar generally entails no or minimal upfront costs, making community solar adoption a viable option for budget-constrained households. Further, unlike rooftop solar, community solar poses no specific barriers to adoption for households that rent or live in multifamily housing. As a result, community solar expands solar access to populations underserved by conventional on-site solar business models (Heeter et al. 2018; Michaud 2020; Abbott et al. 2022; Hausman 2022). The role of community solar in expanding solar access is further promoted by a growing suite of federal and state policies to promote community solar adoption among low- to moderate-income (LMI) households (Cook and Shah 2018; Heeter et al. 2018; Connelly 2023).

The purpose of this report is twofold: First, we estimate the nationwide technical potential capacity of community solar in the states and the District of Columbia. Other territories were not included due to a lack of accessible data. Second, we explore the implications of our technical potential estimates in terms of the social, economic, and technical benefits of community solar, along with estimated benefits from projects projected to be deployed in the near term. We begin with brief background discussions of both topics.

---

[2] "Community Solar Basics," DOE, https://www.energy.gov/eere/solar/community-solar-basics

1.1 Background: Technical Potential

Technical potential is an estimate of the renewable energy capacity that could physically be deployed without regard to market, economic, or policy constraints. NREL has conducted several studies to estimate technical potential, including a broad study of renewable energy resources (Lopez et al. 2012), a focused study on rooftop solar technical potential (Gagnon et al. 2016), a study on the siting considerations of offshore wind technical potential (Zuckerman et al. 2023), a focused study on floating solar technical potential (Spencer et al. 2019), and a study of the technical potential of clean hydrogen production (Ruth et al. 2020), in addition to per-technology estimates in the Annual Technology Baseline's Standard Scenarios. NREL leveraged data from the previously mentioned rooftop solar technical potential work to assess the feasibility of meeting the electricity consumption of households that rent, live in multifamily buildings, or have low-to-moderate incomes (Mooney and Sigrin 2018). Nonetheless, estimating the technical potential of community solar is distinct. Community solar is unique among renewable energy resources primarily because it is defined by how electricity is consumed rather than how it is generated. Different scales of PV deployment, like utility- or large-scale solar and behind-the-meter solar, are terms typically associated with technical potential discussions. These scales dictate siting based on system sizing and interconnection processes, among other factors: Large-scale solar requires larger tracts of land for deployment and produces more energy than can be used by distribution feeders, whereas behind-the-meter solar requires little to no land and does not require distribution to customers. Solar installations that can provide community solar energy are sized in between large-scale and behind-the-meter solar. Community solar is not defined by a nationally standardized size constraint, although policies at the municipal and state levels can set varying caps on system sizes allowed within their jurisdictions. In addition, community solar can be installed anywhere, including on rooftops and as ground-mounted systems. A defining feature of community solar is that system output is virtually delivered to a specific subset of electricity customers.

Our approach to estimating the technical potential of community solar is informed by the unique aspects of the business model. We estimate the technical potential of community solar through three steps (Figure 1). First, we estimate the technical potential supply of solar systems that could be used for community solar. This step is fundamentally the same as technical potential estimation for other PV energy resources, as described by Gagnon et al. (2016) for rooftop systems and Maclaurin et al. (2019) for ground-mounted systems. The second step expands upon previous PV technical potential analyses by applying localized maximum potential market share thresholds. These thresholds include two primary constraints: (1) a supply constraint that limits modeled ground-mount solar supply sites to those within an economically feasible interconnection distance to substations within a respective electricity service territory, and (2) a demand constraint that limits the capacity of modeled solar supply sites to not exceed local gross electricity consumption. This step identifies how much of the community solar can feasibly be hosted based on potential market share; it is unique to community solar and is a novel contribution of this report. The third step brings the two concepts together: the technical potential of community solar is determined by the overlap of technical potential supply and demand. We explicitly address the ability of community solar technical potential to meet electricity demand from all households and businesses that cannot adopt or face significant barriers to adopting on-site solar. Although there is a wider market for households that prefer community solar over other energy options even when they're able to host on-site solar, this analysis focuses on serving electricity customers without feasible or clear access to on-site solar. We describe our specific methodology for implementing these three steps in Section 2.

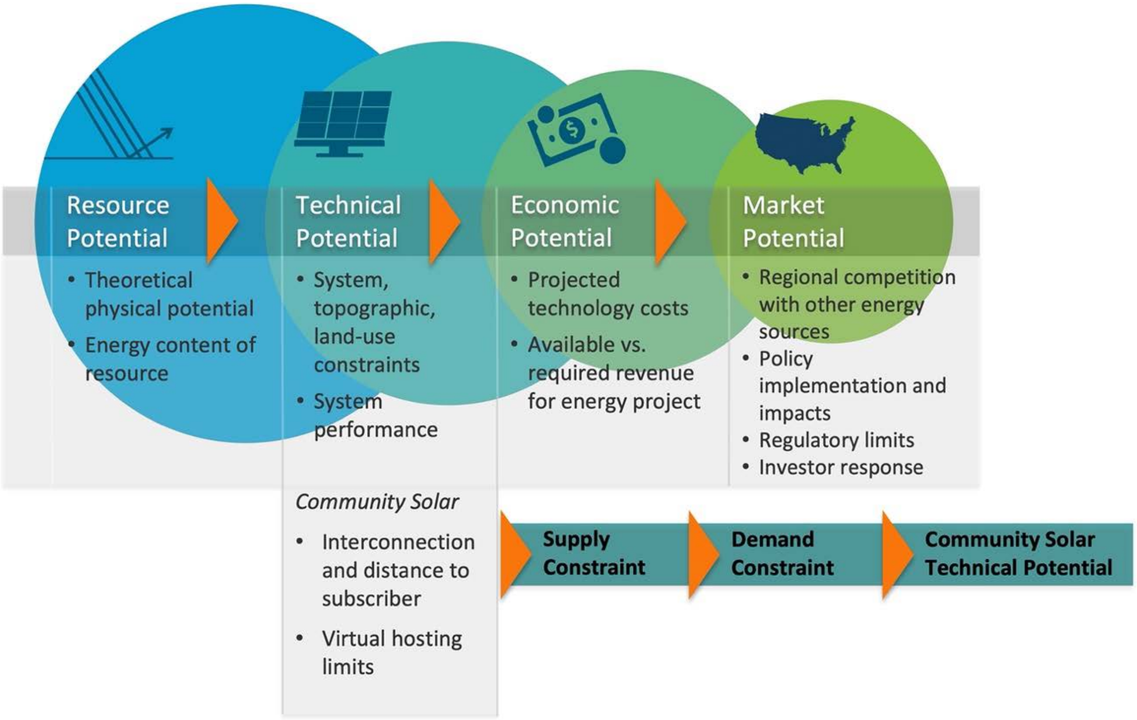


Figure 1. Community solar technical potential framework (modified from Brown et al. 2016)

Our analysis constrains the definition of community solar to require that projects (supply) serve subscribers (demand) within the same utility service territory. As a result, community solar technical potential can be set by supply or demand constraints. In some areas, a lack of developable spaces or high population density mean that supply is the constraining factor that determines community solar technical potential. In other areas, abundant developable spaces or low population density mean that supply exceeds demand, and thus demand is the constraining factor that determines community solar technical potential. We present the results of our technical potential estimation based on these constraints in Section 3.

1.2 Background: Meaningful Benefits

Community solar is also unique among renewable energy resources in terms of its potential benefits. Community solar can provide comparable benefits to rooftop solar by directly serving specific customers, while also expanding solar access to customers not traditionally served by rooftop solar. Community solar can also provide similar benefits as utility-scale solar by leveraging economies of scale and larger project sizes. The unique combination of characteristics that define community solar yield a unique suite of social, economic, and technical benefits.

DOE has identified five meaningful benefits provided by community solar projects.[3] The five meaningful benefit categories are:

- **Greater household savings:** Provide a reduction in electricity bills for residential subscribers.
- **LMI household access:** Include subscribers from LMI households.
- **Resilience and grid benefits:** Include the capability to deliver power to households and/or critical facilities during a grid outage or strengthen grid operations.
- **Community ownership:** Local community members, subscribers, or local community organizations own or have equity in the project, or the project employs other wealth-building strategies.
- **Equitable workforce development:** Support prevailing wages, support pre-apprenticeship programming, and ensure women- and minority-owned businesses have equitable opportunity.

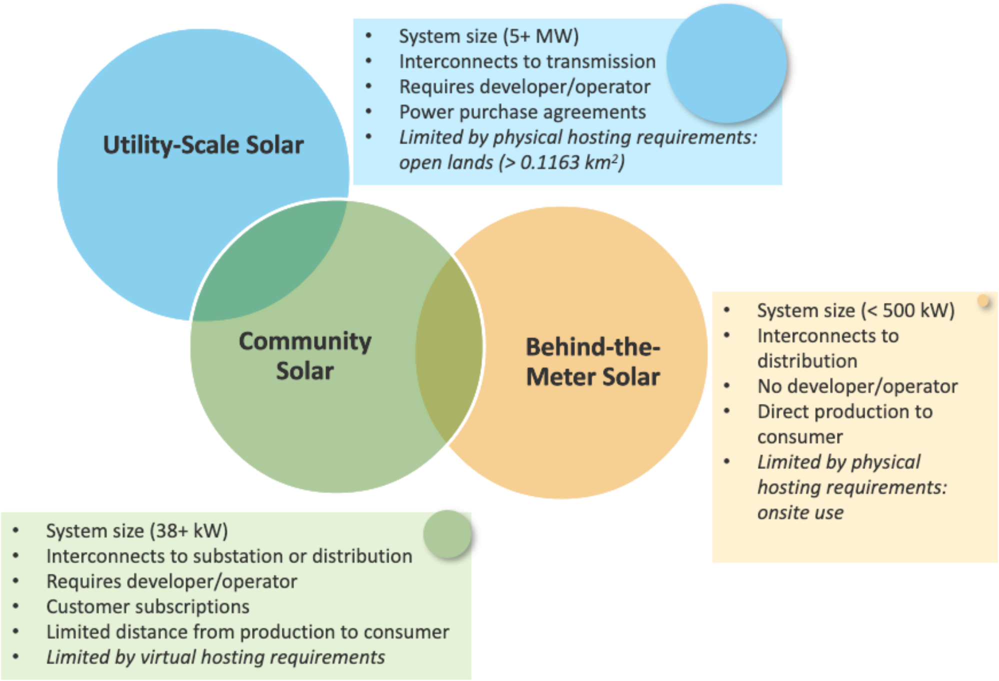
In Section 4, we explore the meaningful benefits in further depth and estimate the potential magnitude of these benefits in the context of our technical potential estimates.

---

[3] "Community Solar Education and Outreach," DOE, https://www.energy.gov/communitysolar/education-and-outreach

2 Methodology

Estimating the technical potential of community solar is a nuanced process that considers installations ranging from individual rooftop solar installations to large-scale utility solar projects. Community solar systems, by definition, operate at flexible scales, including both types of solar energy deployment. In our assessment, we considered rooftop solar and ground-mount solar systems greater than 38 kilowatts alternating current (kW_{AC}) as potential community solar systems. This system size threshold is indicative of PV systems larger than typical single-customer nonresidential systems. Figure 2 compares utility-scale solar, community solar, and behind-the-meter solar deployments and shows to-scale representations of each deployment type's typical system size with accompanying comparative descriptions. This assumption does not take state or utility community solar program caps into account and relies on sample statistics taken from community solar installations through mid-2022 (Chan, Heeter, and Xu 2022).



- System size (5+ MW)
- Interconnects to transmission
- Requires developer/operator
- Power purchase agreements
- *Limited by physical hosting requirements: open lands (> 0.1163 km^2)*

- System size (< 500 kW)
- Interconnects to distribution
- No developer/operator
- Direct production to consumer
- *Limited by physical hosting requirements: onsite use*

- System size (38+ kW)
- Interconnects to substation or distribution
- Requires developer/operator
- Customer subscriptions
- Limited distance from production to consumer
- *Limited by virtual hosting requirements*

Figure 2. Size range of solar PV deployments with scaled system size indicator

To ensure accuracy and relevance in our estimations, we excluded areas otherwise not developable for solar and considered virtual hosting requirements unique to community solar (e.g., maximum interconnection distance, co-location within an electricity service territory, capacity not exceeding within-territory gross electricity consumption). In utility-scale ground-mount PV technical potential analyses, spatial contiguity thresholds of 0.3 square kilometers (km^2) or less are typically applied to exclude potential PV sites smaller than utility-scale size. This filter for utility-scale PV is equivalent to omitting ground-mounted PV sites of 1.2 MW_{AC} or less, assuming the same capacity density used here. The approach used in this study positions the community solar systems modeled in this technical potential assessment as a distinct modeled solar energy deployment type. Ground-mount PV systems modeled can range from 38 kW_{AC} to 67 MW_{AC}, based on modeling parameters discussed further in Section 2.2.2.

This analysis builds on previous work by Lopez et al. (2012), Gagnon et al. (2016), Feldman et al. (2015), and Waechter and Williams (2021). We used both the PV Rooftop model (Gagnon et al. 2016), a legacy software that delineates suitable areas for rooftop PV, and the Renewable Energy Potential (reV) model (Maclaurin et al. 2019), an open-source software used for renewable energy technical potential analysis. reV uses the System Advisor Model (SAM; Blair et al. 2014) within its modeling pipeline to calculate PV system performance and costs for specified technology assumptions. By combining rooftop solar siting results from PV Rooftop and system performance with high-resolution ground-mount solar siting, we estimated community solar technical potential within U.S. Census Bureau (2020) tracts across the United States.

2.1 Estimating Generation

We calculated PV system performance using the reV model and hourly solar irradiance and weather data from the National Solar Radiation Database (NSRDB; Sengupta et al. 2018). We used four resource years (2018–2021) from the Extended CONUS (Continental United States) set from the NSRDB for all states except Alaska. Because the NSRDB is not available above 60° latitude (Figure 3), we used ERA5[4] hourly solar resource data (Copernicus Climate Change Service 2017) covering the same resource years for Alaska. We used the reV model to estimate PV system performance and incorporate siting constraints for community solar installations. We focused on modeling system performance and community solar siting for this technical potential analysis rather than community solar financial models, production and subscriber costs, and interconnection costs.

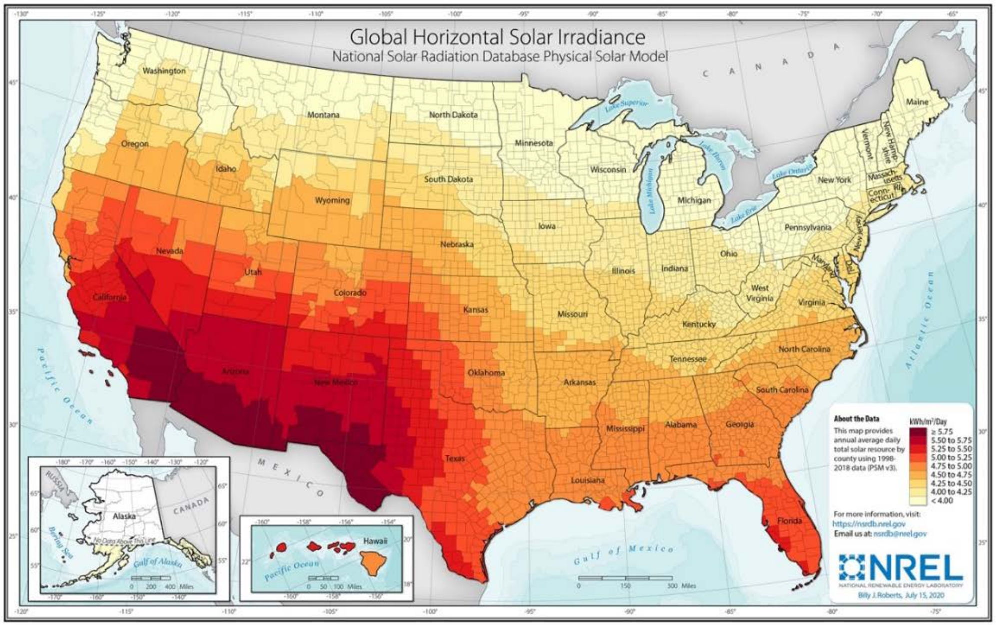


Figure 3. Annual mean global horizontal irradiance from 1998 to 2018 (National Solar Radiation Database for the continental United States, Alaska, and Hawaii)

---

[4] ERA5 is the fifth generation European Centre for Medium-Range Weather Forecasts atmospheric reanalysis of the global climate covering the period from January 1940 to present.

Rooftop system performance in reV was modeled for one system configuration of rooftop PV for 21 unique tilt and azimuth combinations to maintain consistency with previously published rooftop PV siting data (Gagnon et al. 2016, pages 9, 11). Roof areas classified as suitable for PV installation by Gagnon et al. 2016 were used to model and identify buildings with potential to host rooftop community solar systems. For flat roof planes (tilt < 9.5°), the azimuth was assumed to be south and the tilt was assumed to be 15°, with a module area to roof area ratio of .7. For tilted roof planes (tilt > 9.5°), azimuths were assumed to be between 67.5° and 292.5°, and tilts were assumed to be between 9.5° and 60°, with a module area to roof area ratio of .98. We made changes to PV technology based on improvements made since Gagnon et al.'s 2016 publication. In particular, we assumed that the inverter load ratio was 1.22 (Barbose et al. 2022), inverter efficiency was 98%, losses were 8.06%, module efficiency was 20.3% (Ramasamy et al. 2022, pages 22–23), and modules were monocrystalline with a capacity density of 172 watts (W) per square meter.

Ground-mount system performance in reV was modeled for one configuration of ground-mount PV for one tilt and azimuth combination. We assumed an inverter load ratio of 1.34 (Bolinger et al. 2022), inverter efficiency of 98%, losses of 10.4% (NREL 2022), module efficiency of 20.3% (Ramasamy et al. 2022), monocrystalline modules, and one-axis tracking arrays with a capacity density of 48 MW_{DC}/km^2 or 37 MW_{AC}/km^2. These technology assumptions reflect recent reports of trends (Barbose et al. 2023; NREL 2022) in distributed solar and utility-scale solar PV deployment, and they correspond with the calculated capacity density of selected community PV plants' indirect use footprints (EIA 2023b). Multiyear mean capacity factors for each system, described above, were computed across the United States at a four-kilometer resolution with SAM's PVWatts8 under the LCOE Calculator (FCR Method) financial model.

2.2 Siting Constraints and Regimes

As the community solar market has matured in the past decade, generalized community solar siting constraints have emerged. These constraints include closer proximity to subscribers than utility-scale generation sources, interconnection to electricity distribution infrastructure, and co-location with feeders and substations with sufficient available hosting capacity. The latter two constraints are difficult to model, as individual utilities own and maintain both distribution geospatial datasets and hosting capacity information with no complete data proxy available. For this analysis, we assume that rooftop solar interconnects to distribution without limitation, that ground-mount solar interconnects at substations, and that ground-mount solar is in the same electricity service territory as subscribers. Aside from these constraints, local siting drivers of community solar are uncertain, particularly in states without established community solar legislation and programs. We account for some of this uncertainty by presenting two siting regimes for community solar in Section 2.2.2. With community solar's flexible size and form, there are additional benefits for local communities in strategically siting community solar (Gahl and Norris 2022). In a recent study (Heleno et al. 2023), under baseline conditions, community solar projects were found to not require additional distribution grid infrastructure investments and were more likely to defer distribution system upgrades while potentially reducing line losses in primary distribution feeders.

2.2.1 Rooftop Siting Constraints

Siting constraints for rooftop solar are inherited from the PV Rooftop model. The PV Rooftop model uses high-resolution 3D digital surface models that represent the built environment and potential shading obstructions to identify discrete planes that are suitable for rooftop PV development based on plane direction, tilt, massing, and shading (Figure 4). These high-resolution classified data are only available for 128 cities in the continental United States and are limited to 3D representations at the time of data capture (2006–2013), representing up to 23% of the national building stock of the time.

Figure 4. Elevation digital surface model and derived roof area characteristics used by the PV Rooftop model

These classified data were used to train a k-nearest neighbors imputation for PV-developable roof percent across buildings not represented in the PV Rooftop data archive (NREL 2016). The k-nearest neighbors imputation was calculated within a maximum-distance, non-overlapping (Thiessen) polygon basin for each sample city from PV Rooftop's archive. Buildings within each city's basin were imputed based on the PV-developable area characteristics of overlapping training data from PV Rooftop, building occupancy (Lutz et al. 2022), canopy cover (MRLC 2021), and topographic position index. Each building was attributed an occupancy-specific and regionally appropriate distribution of the azimuth, tilt, and developable area of PV-suitable roof planes. In this analysis, rooftop solar followed a singular siting regime based on maximizing per-system capacity. We used USA Structures (ORNL 2023) for building geometries across the United States and the National Structure Inventory (Lutz et al. 2022) for occupancy and building heights.

2.2.2 Ground-Mount Siting Constraints

Ground-mount solar has greater siting variability than rooftop solar. Here, we used methods for assessing siting constraints and regimes for ground-mount solar that were inherited from the reV model and ongoing research by NREL. For this analysis, we used the same solar PV siting regimes as in NREL's Solar Ordinances database (NREL 2022). These regimes with ordinances were found to reduce utility-scale solar PV resources up to 38% (Lopez et al. 2023). reV utilizes a 90-meter grid across the study area and builds locational indices across multiple scales to geospatial datasets pertaining to solar PV exclusion or inclusion. Individual locations are typically identified for each siting regime with a Boolean exclusion or inclusion. This is not the case with solar setbacks. Solar setbacks are often smaller than the standard 90-meter Boolean exclusion or inclusion raster of reV. For setbacks, we calculated the inclusion area as a percentage within a 90-meter raster cell as dictated by the finer-resolution source data, as shown in Figure 5. Figure 5 shows (a) the national solar and transmission infrastructure and (b) a zoomed-in grid cell for PV siting. For each grid cell, setbacks are imposed from features such as roads, structures, and waterways. The remaining area is assumed to be available for PV development. This percent inclusion value was calculated by rasterizing features (e.g., structures, roads, railroads) onto a spatially upscaled Boolean exclusion layer and then totaling the area of the resulting non-excluded sub-90-meter cells normalized by the area of the original 90-meter cell.

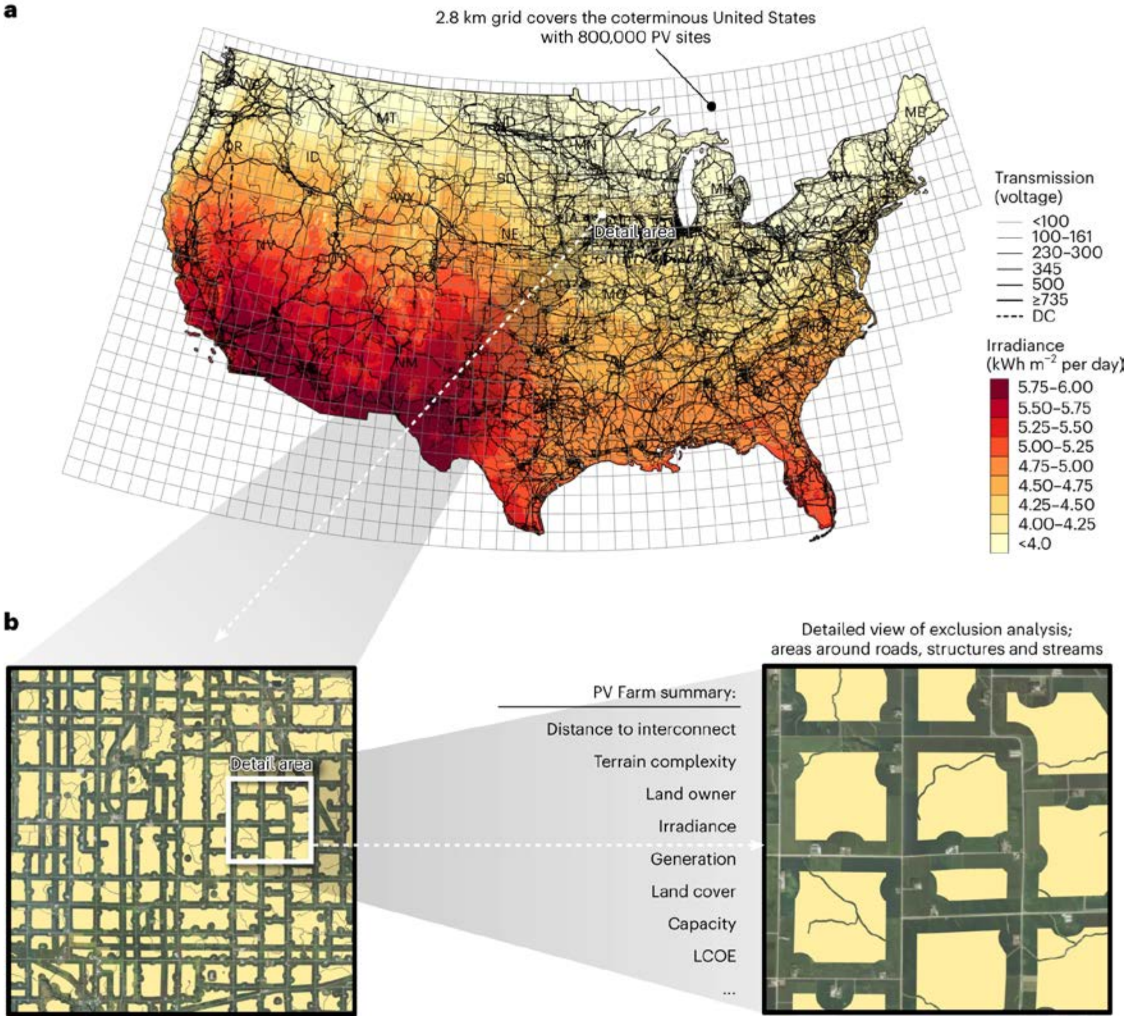


Figure 5. Overview of the method used to determine resource availability after applying solar PV ordinance setbacks (from Lopez et al. 2023)

We utilized two of NREL's three solar PV siting regimes, Reference Access and Limited Access, each of which represents a collection of individual siting constraints, to reflect the plausible differences in solar PV siting restrictions. An overview of these adapted siting regimes is shown in Figure 6, and the two regimes are described as follows:

1. **Reference Access** is a regime that balances siting considerations and is informed by common practices to guide development. For example, a 10% slope restriction is used to prevent complicated racking needs, in addition to other physical restrictions that are assumed under the Open Access scenario. The Reference Access scenario also applies seven documented types of setbacks and restrictions (property line, structures, roads,

water, height, sound, and minimum lot size). For areas without enumerated setback requirements, we apply setbacks scaled to the 50th percentile of enumerated setbacks. Reference Access community solar potential sites are also required to be within two miles of existing substations.

Limited Access is a combination of more stringent siting considerations. Limited Access applies greater setback requirements (90th percentile) from buildings and other infrastructure as well as more comprehensive exclusions. The setback types are consistent with Reference Access. The additional exclusions include additional restrictions of protected areas (categories 3 and 4, PADUS 2023), conservation easements (NCED 2022), stricter slope requirements (0%–5%), and additional incompatible land covers (pasture, gradients of inclusion for low- and moderate-density development). Limited Access community solar potential sites are also required to be within one mile of existing substations.

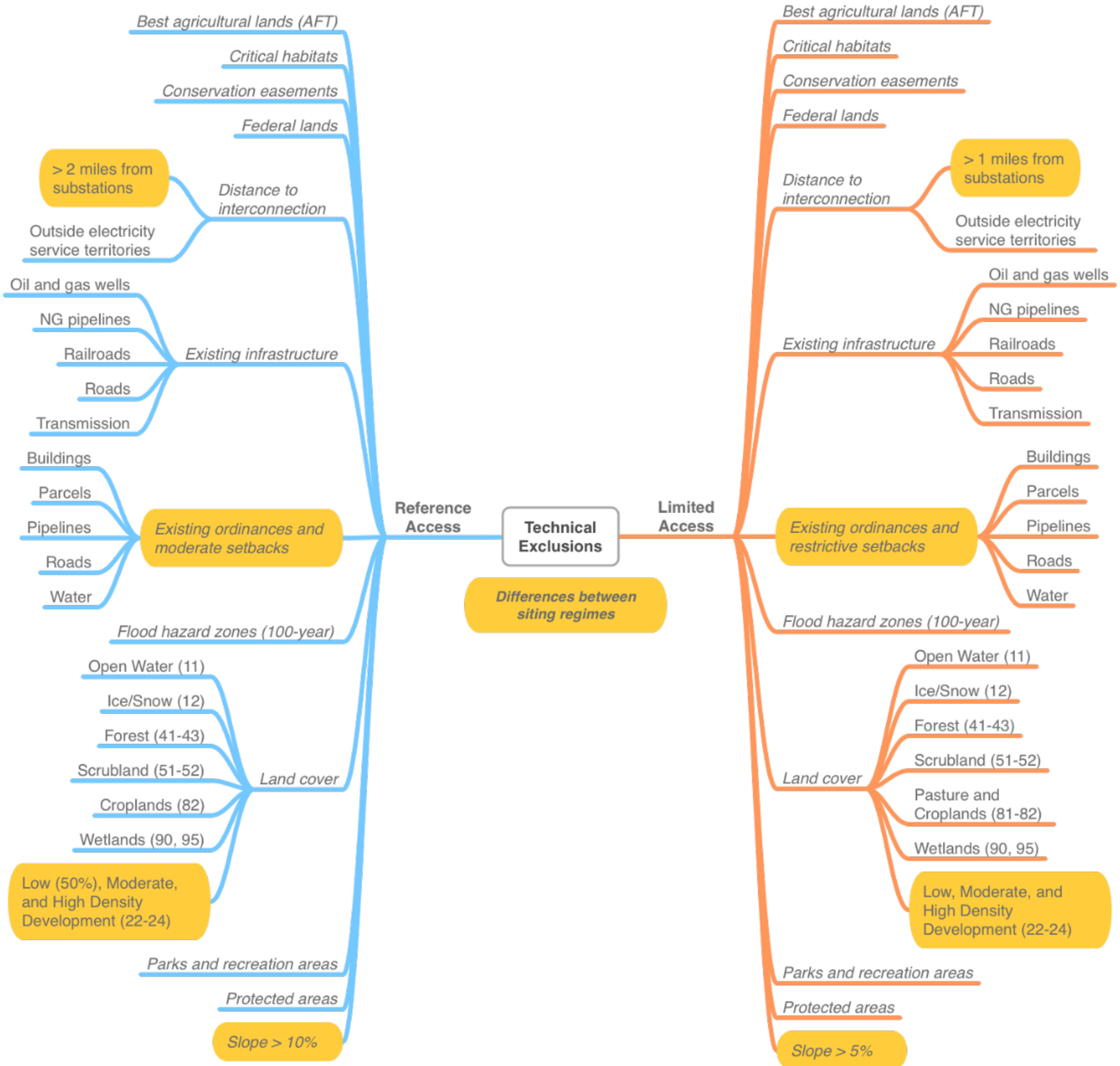


Figure 6. Ground-mount PV technical exclusions adapted from utility-scale solar siting regimes

We did not model the Open Access regime because its purpose is to define a ceiling for a technology's technical potential, something that has been previously established and does not add information to community solar siting. These siting regimes were created to capture a range of deployment barriers, in effect bracketing estimates of solar PV potential along a theoretical gradient of site restrictiveness. We did not analyze the probability of any siting regime, and these siting regimes are not intended to predict future community solar growth. The siting considerations applied within each siting regime are not mutually exclusive. Technical exclusions and setbacks were aggregated at a fixed scale to calculate location-based economics, such as interconnection distance, costs, and interconnection capacity. Community solar installation economics were captured at 1.44 km x 1.44 km^2 (2.07-km^2) resolution, totaling from 650,000 to over 3,000,000 locations across the United States, depending on spatial exclusions. These aggregated community solar supply units include cumulative physically potentially developable spaces for ground-mount community solar PV arrays and range in capacity from 38 $\mathrm{kW_{AC}}$ to 67 $\mathrm{MW_{AC}}$.

2.2.3 Virtual Hosting Limitations

The preceding subsections describe physical hosting for community solar arrays. In addition to limitations to physical hosting, community solar relies on virtual hosting limitations to distinguish it from other forms of solar deployment. We define virtual hosting limitations as constraints applied to solar supply that limit the theoretical maximum amount of solar that can be added in an area. In this analysis, these limitations were applied exclusively to ground-mount PV hosting sites. The first virtual hosting limitation that was applied limited the subscriber pool for community solar to electricity customers within each electric retail service territory (EIA 2023a), a common siting requirement for community solar. Second, we limited the potential ground-mount community solar supply to economically feasible interconnection distances of one mile (Limited Access) and two miles (Reference Access) from substations. In the future, community solar interconnection should be mapped to distribution feeders in addition to substations. Third, we applied a demand constraint to not exceed the serviceable demand within each utility service territory. In service territories where the retail electricity consumption (EIA 2022) exceeded modeled community solar supply, supply was not changed from the direct model outputs. In service territories where the retail electricity consumption was less than the modeled community solar supply, supply was limited within that service territory: We omitted potential community solar sites (1.44 x 1.44 km^2) with the highest site-based levelized cost of energy in the service territory until modeled ground-mount community solar supply fell below annual electricity retail sales. Because retail service territories overlap geographically, tracts were assigned to utility service territories based on majority overlay and weighting by territory area and customer count. Figure 7 shows how potential community solar sites are affected by demand or supply constraints for each siting regime across the continental United States. Areas in brown denote tracts where potential community solar supply falls short of total electricity demand in the Reference siting regime, and areas in red denote the same situation for the Limited Access siting regime. Where Limited Access supply shortages are not shared with the Reference Access scenario, the map shows brown. Areas in yellow denote tracts where potential community solar supply exceeds total electricity demand in the Reference Access siting regime, and areas in orange denote the same situation for the Limited Access siting regime. Where Limited Access supply overages are not shared with the Reference Access scenario, the map shows yellow.

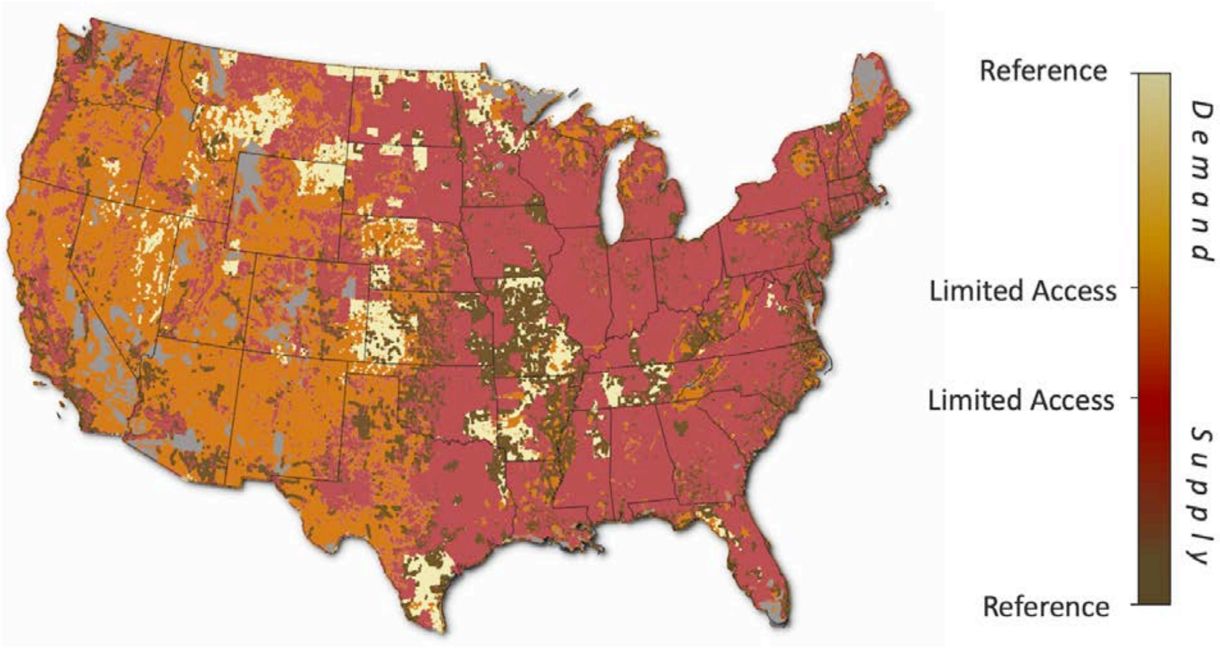


Figure 7. Geographic distribution of potential community solar sites by supply or demand constraint (gray indicates no data)

2.3 Estimating Technical Potential and Offsetable Consumption

For each solar array technology, we calculated capacity (Equation 1) and generation (Equation 2), where developable area includes the roof planes considered suitable for rooftop PV as well as the aggregated ground-mount developable area (1.44 x 1.44 km^2). The capacity density for rooftop PV is 172 W/m^2, and the capacity density for ground-mount PV is 48 MW_{DC}/km^2 or 37 MW_{AC}/km^2. Capacity factors refer to the corresponding multiyear mean capacity factors for each system at 4-km^2 resolution (described in Section 2.1), and time equates to time series length (8,760). For each siting regime, we combined overlapping rooftop and ground-mount system capacities and annual energy production within each tract (Manson et al. 2022) to create tract-level community solar technical potential estimates.

$$Capacity_W = Developable\ Area_{m^2} * Capacity\ Density_{watts/m2}$$

Equation 1: Capacity expressed for solar PV technology

$$Annual\ energy\ production_{MWh} = Capacity_{MW} * Capacity\ Factor_{\%} * Time$$

Equation 2: Technical potential expressed for solar PV technology

We extended the tract-level community solar technical potential estimates by household income, tenure, and building type. Unlike aggregation and Mooney and Sigrin's (2018) methods for normalizing households and buildings for exclusively behind-the-meter rooftop solar modeling, we intersected all community solar suitable building technical potential estimates described in Section 2.2.1 with community solar suitable ground-mount areas within tracts. We then compared that supply to residential and commercial electricity consumption for households and businesses that face significant barriers to adopting on-site solar. Feldman et al. (2015) identified residential demand for solar energy that likely will not be met by behind-the-meter solar as households that rent, are located in buildings with more than three stories (excluding basements), or are located in buildings with roofs that are unsuitable for rooftop solar (e.g., excessive shading, structural or panel issues). Additionally, we considered households that reside in impermanent dwellings (vans, recreational vehicles, boats, mobile homes) to be unsuitable for rooftop solar. Feldman et al. (2015) identified commercial demand for solar energy that likely will not be met by on-site solar as businesses that are located in buildings with more than five establishments, buildings with less than 10,000 square feet with 2–5 establishments, or buildings with less than 10,000 square feet with one establishment and PV-developable roof areas that cannot support at least 20% of the building's overall electricity demand. The ability to meet 20% or more of electricity load was not included in this analysis. Additionally, ground-mount behind-the-meter solar generation was not considered.

Demographic data were disaggregated within tracts based on household income, tenure (own, rent), and building type (single-family, multifamily) (Manson et al. 2022: Tables B19001, B25001, B25003, B25032) using random weighted sampling and proportional allocation methods similar to Mooney and Sigrin (2018). We maintained a consistent definition of previous NREL works focused on LMI households, following the U.S. Department of Housing and Urban Development's 2020 area median income (AMI) limits and binning income limits:

- Very low income: 0%–30% of AMI
- Low income: 30%–50% of AMI
- Moderate income: 50%–80% of AMI
- Middle income: 80%–120% of AMI
- High income: >120% of AMI.

Household income was discretized from the American Community Survey's income bins to $1,000 increments and applied to the U.S. Department of Housing and Urban Development's income breakpoints by household size. Household electricity consumption data from the Low-Income Energy Affordability Data (LEAD) Tool (Ma et al. 2019) was summed across tracts and resampled to match AMI bins, tenure, and building type. Electricity consumption was stratified by income, tenure, and building type and was divided by gross community solar supply within tracts to calculate a per-category percent of electricity demand. Additionally, offsetable electricity consumption for customers unable to access behind-the-meter solar was calculated by dividing that consumption by gross community solar supply within tracts.

3 Technical Potential Results

Overall, we estimate that over 31% (809 TWh) of annual commercial and residential electricity consumption cannot be met by behind-the-meter or on-site solar, including 42% of residential electricity consumption (out of 1,049 TWh total) and 23% of commercial electricity consumption (out of 1,558 TWh total). We found that 42% of households and 44% of businesses are unable to access behind-the-meter solar, which is lower than previous estimates of 49% of households and 48% of businesses (Feldman et al. 2015). This opportunity space for community solar equates to 20% of domestic gross electricity consumption. It is clear from this analysis that access to community solar is highly localized and subject to local supply and demand constraints. The opportunity space for community solar is not uniformly distributed across income levels, tenure, or building types. Figure 8 shows that more than 50% of LMI households likely lack access to on-site solar, and this demonstrates an opportunity space for community solar to benefit LMI customers. Conversely, a majority of middle- and high-income households (>60%) face no discernible physical barriers to accessing behind-the-meter solar.

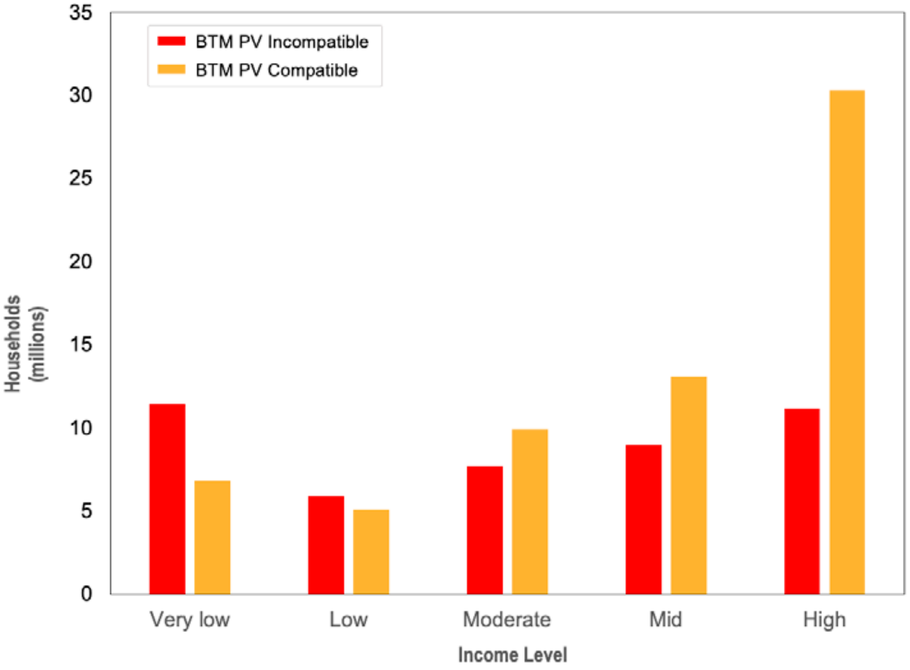


Figure 8. Distribution of households by income with significant barriers for behind-the-meter (BTM) PV compatibility based on tenure, building type, and individual building suitability

Opportunities for community solar and other sources of renewable energy are significant, and the potential community solar supply is significant. We estimate that there is sufficient community solar potential to offset 211% and 643% of electricity consumption for customers unable to access behind-the-meter or on-site solar (Tables 1 and 2) in the Limited Access and Reference Access siting regimes, respectively. This is not uniformly distributed geographically, as shown in Figures 11 and 12. Areas lacking wide access to ground-mount community solar installations are less likely overall to be able to fully offset unmet residential and commercial electricity consumption with community solar.

Table 1. Limited Access Siting Regime Community Solar Technical Potential Results by State

State	ROOFTOP PV			GROUND-MOUNT PV			COMBINED		Percent of Unmet Electricity Consumption Offsetable by Community Solar
	MW_{AC}	GWh	Percent of Capacity	MW_{AC}	GWh	Percent of Capacity	MW_{AC}	GWh	
Alabama	6,902	13,569	50%	6,868	13,718	50%	13,771	27,287	205%
Alaska	913	867	14%	5,721	3,959	86%	6,634	4,827	409%
Arizona	7,260	12,046	33%	14,848	27,487	67%	22,108	39,534	229%
Arkansas	4,751	9,053	51%	4,548	9,634	49%	9,300	18,687	220%
California	36,108	48,482	59%	25,526	48,085	41%	61,635	96,568	135%
Colorado	6,244	12,053	13%	41,931	66,523	87%	48,175	78,577	633%
Connecticut	3,785	7,582	96%	152	1,144	4%	3,937	8,726	90%
Delaware	1,114	2,215	92%	97	614	8%	1,211	2,829	116%
District of Columbia	465	813	100%	0	0	0%	465	813	32%
Florida	19,793	38,700	60%	13,083	23,506	40%	32,876	62,206	104%
Georgia	14,021	27,407	63%	8,319	19,263	37%	22,340	46,671	156%
Hawaii	909	1,917	16%	4,776	7,903	84%	5,686	9,820	425%
Idaho	2,467	4,077	21%	9,209	13,567	79%	11,676	17,645	474%
Illinois	16,059	29,760	78%	4,572	12,337	22%	20,632	42,098	162%
Indiana	11,369	21,486	77%	3,449	11,585	23%	14,819	33,071	250%
Iowa	5,889	11,703	46%	6,992	14,473	54%	12,882	26,176	428%
Kansas	5,756	11,118	19%	23,799	38,496	81%	29,556	49,614	795%
Kentucky	6,423	12,451	45%	7,710	15,057	55%	14,134	27,509	225%
Louisiana	5,454	10,165	71%	2,252	5,339	29%	7,706	15,504	118%
Maine	1,535	3,030	51%	1,501	3,184	49%	3,037	6,214	172%
Maryland	5,832	11,468	87%	851	2,833	13%	6,683	14,301	96%
Massachusetts	5,912	11,716	86%	955	3,228	14%	6,868	14,945	73%
Michigan	13,229	26,017	76%	4,247	11,030	24%	17,476	37,048	193%
Minnesota	8,153	15,947	40%	12,024	20,788	60%	20,178	36,735	354%
Mississippi	4,679	9,434	59%	3,302	8,194	41%	7,981	17,628	206%
Missouri	8,130	15,978	29%	19,722	30,988	71%	27,853	46,967	361%
Montana	2,483	4,497	8%	28,245	37,876	92%	30,728	42,373	1,731%
Nebraska	3,306	6,460	9%	33,834	49,894	91%	37,141	56,355	1,395%
Nevada	3,167	5,162	55%	2,575	5,108	45%	5,742	10,271	131%
New Hampshire	1,461	2,765	87%	221	1,001	13%	1,682	3,766	106%
New Jersey	9,194	18,254	93%	743	3,606	7%	9,937	21,861	84%
New Mexico	2,113	4,113	14%	13,320	23,883	86%	15,434	27,997	532%
New York	17,824	35,651	74%	6,122	13,792	26%	23,946	49,443	69%
North Carolina	13,704	26,994	64%	7,706	19,629	36%	21,410	46,623	154%

State	ROOFTOP PV			GROUND-MOUNT PV			COMBINED		Percent of Unmet Electricity Consumption Offsetable by Community Solar
	MW_{AC}	GWh	Percent of Capacity	MW_{AC}	GWh	Percent of Capacity	MW_{AC}	GWh	
North Dakota	2,909	5,523	11%	22,624	31,147	89%	25,534	36,670	2,049%
Ohio	18,758	36,548	83%	3,769	14,344	17%	22,528	50,893	210%
Oklahoma	4,746	9,110	12%	33,236	51,728	88%	37,982	60,838	568%
Oregon	5,196	7,827	37%	8,866	14,355	63%	14,062	22,183	309%
Pennsylvania	17,215	26,171	87%	2,578	9,314	13%	19,793	35,485	104%
Rhode Island	1,093	2,068	86%	177	467	14%	1,270	2,536	77%
South Carolina	6,756	12,051	51%	6,430	12,731	49%	13,187	24,782	172%
South Dakota	2,450	4,123	7%	30,541	42,170	93%	32,992	46,294	2,409%
Tennessee	8,946	14,987	69%	3,941	8,964	31%	12,887	23,951	131%
Texas	38,206	72,170	29%	93,404	159,795	71%	131,611	231,965	292%
Utah	3,857	7,291	33%	7,824	14,206	67%	11,682	21,498	349%
Vermont	814	1,173	39%	1,270	2,122	61%	2,084	3,295	194%
Virginia	8,907	14,833	57%	6,838	12,533	43%	15,745	27,366	124%
Washington	7,958	11,106	60%	5,251	8,739	40%	13,209	19,845	160%
West Virginia	2,292	3,470	75%	756	2,071	25%	3,049	5,542	116%
Wisconsin	9,422	14,934	69%	4,316	11,101	31%	13,739	26,035	218%
Wyoming	1,035	1,881	5%	19,445	28,453	95%	20,480	30,334	2,293%
Total	396,988	718,241	41%	570,508	991,984	59%	967,49	1,710,226	211%

Table 2. Reference Siting Regime Community Solar Technical Potential Results by State

State	ROOFTOP PV			GROUND-MOUNT PV			COMBINED		Percent of Unmet Electricity Consumption Offsetable by Community Solar
	MW_{AC}	GWh	Percent of Capacity	MW_{AC}	GWh	Percent of Capacity	MW_{AC}	GWh	
Alabama	6,902	13,569	17%	33,213	58,019	83%	40,115	71,589	537%
Alaska	913	867	12%	6,562	5,048	88%	7,476	5,916	502%
Arizona	7,260	12,046	7%	99,617	223,185	93%	106,877	235,232	1,365%
Arkansas	4,751	9,053	17%	23,651	40,524	83%	28,403	49,577	584%
California	36,108	48,482	22%	126,147	261,014	78%	162,25	309,497	432%
Colorado	6,244	12,053	7%	84,761	167,535	93%	91,006	179,589	1,446%
Connecticut	3,785	7,582	54%	3,244	5,055	46%	7,030	12,638	130%
Delaware	1,114	2,215	34%	2,131	3,555	66%	3,245	5,770	237%
District of Columbia	465	813	88%	61	101	12%	527.38	914	36%
Florida	19,793	38,700	32%	42,219	79,807	68%	62,012	118,508	198%

	ROOFTOP PV			GROUND-MOUNT PV			COMBINED		Percent of Unmet Electricity Consumption Offsetable by Community Solar
State	MW$_{AC}$	GWh	Percent of Capacity	MW$_{AC}$	GWh	Percent of Capacity	MW$_{AC}$	GWh	
Georgia	14,021	27,407	23%	48,084	85,723	77%	62,105	113,130	379%
Hawaii	909	1,917	9%	9,575	19,255	91%	10,485	21,172	915%
Idaho	2,467	4,077	5%	43,431	77,741	95%	45,899	81,818	2,200%
Illinois	16,059	29,760	34%	31,188	51,325	66%	47,248	81,085	312%
Indiana	11,369	21,486	23%	37,313	60,194	77%	48,683	81,681	616%
Iowa	5,889	11,703	13%	38,857	63,872	87%	44,746	75,576	1,237%
Kansas	5,756	11,118	8%	65,302	121,734	92%	71,059	132,852	2,130%
Kentucky	6,423	12,451	13%	42,230	68,685	87%	48,654	81,137	664%
Louisiana	5,454	10,165	24%	17,509	31,229	76%	22,963	41,394	315%
Maine	1,535	3,030	18%	7,041	10,640	82%	8,576	13,670	378%
Maryland	5,832	11,468	43%	7,840	12,879	57%	13,673	24,347	163%
Massachusetts	5,912	11,716	43%	7,959	12,411	57%	13,872	24,128	117%
Michigan	13,229	26,017	26%	37,908	58,338	74%	51,137	84,355	440%
Minnesota	8,153	15,947	12%	59,333	93,638	88%	67,487	109,585	1,056%
Mississippi	4,679	9,434	19%	19,784	34,617	81%	24,464	44,051	516%
Missouri	8,130	15,978	9%	87,446	148,193	91%	95,576	164,172	1,262%
Montana	2,483	4,497	2%	105,005	168,873	98%	107,48	173,371	7,084%
Nebraska	3,306	6,460	3%	115,212	205,610	97%	118,51	212,071	5,251%
Nevada	3,167	5,162	14%	18,826	39,483	86%	21,994	44,646	568%
New Hampshire	1,461	2,765	36%	2,639	4,000	64%	4,100	6,766	191%
New Jersey	9,194	18,254	50%	9,063	14,613	50%	18,257	32,868	127%
New Mexico	2,113	4,113	3%	77,693	171,659	97%	79,807	175,773	3,340%
New York	17,824	35,651	36%	31,374	46,275	64%	49,198	81,926	114%
North Carolina	13,704	26,994	25%	41,224	71,894	75%	54,928	98,889	327%
North Dakota	2,909	5,523	3%	82,972	132,545	97%	85,882	138,069	7,716%
Ohio	18,758	36,548	34%	36,095	55,703	66%	54,854	92,252	381%
Oklahoma	4,746	9,110	5%	87,938	165,656	95%	92,684	174,766	1,631%
Oregon	5,196	7,827	11%	40,419	69,027	89%	45,615	76,855	1,070%
Pennsylvania	17,215	26,171	40%	25,583	38,425	60%	42,798	64,596	190%
Rhode Island	1,093	2,068	49%	1,139	1,805	51%	2,232	3,873	118%
South Carolina	6,756	12,051	19%	28,927	51,408	81%	35,684	63,459	440%
South Dakota	2,450	4,123	3%	81,437	138,302	97%	83,888	142,426	7,412%
Tennessee	8,946	14,987	22%	31,109	52,218	78%	40,056	67,206	368%
Texas	38,206	72,170	8%	434,960	860,080	92%	473,166	932,250	1,174%

State	ROOFTOP PV			GROUND-MOUNT PV			COMBINED		Percent of Unmet Electricity Consumption Offsetable by Community Solar
	MW$_{AC}$	GWh	Percent of Capacity	MW$_{AC}$	GWh	Percent of Capacity	MW$_{AC}$	GWh	
Utah	3,857	7,291	7%	48,923	97,114	93%	52,781	104,406	1,693%
Vermont	814	1,173	13%	5,599	8,019	87%	6,413	9,193	5,40%
Virginia	8,907	14,833	21%	33,956	56,290	79%	42,863	71,124	3,22%
Washington	7,958	11,106	21%	29,572	46,854	79%	37,530	57,960	4,66%
West Virginia	2,292	3,470	30%	5,304	8,030	70%	7,597	11,501	2,40%
Wisconsin	9,422	14,934	18%	43,634	69,061	82%	53,057	83,996	705%
Wyoming	1,035	1,881	2%	64,107	117,481	98%	65,143	119,362	9,023%
Total	396,988	718,241	14%	2,465,142	4,484,768	86%	2,862,130	5,203,010	643%

3.1 Community Solar Capacity and Annual Energy Production

The United States has 940 GWAC of community solar capacity under the Limited Access siting regime, amounting to 1,710 TWh of annual energy production (Table 1). Of this, rooftop solar systems comprise 41% of developable capacity, with 2,776 km^2 of developable roof area across commercial, industrial, and residential buildings. Ground-mount solar contributes the remaining 58% of developable capacity, with 15,437 km^2 of developable area. In the Reference Access siting regime, potential community solar capacity increases to 2,862 GWAC, amounting to 5,921 TWh of annual energy production (Table 2). Of this, rooftop solar systems comprise 14% of developable capacity, with 2,776 km^2 of developable roof area across commercial, industrial, and residential buildings. If rooftop solar was limited to public buildings exclusively, only 1.7% of overall community solar technical potential would be available from rooftop arrays. As rooftop community solar projects represent a small minority of community solar projects to date, this is an important consideration for feasibility and future economic and market potential studies. Ground-mount solar contributes the remaining 86% of developable capacity, with 53,378 km^2 of developable area. The Limited Access regime reduces community solar developable area and capacity by 88% from the Reference Access regime, reducing annual energy production by 71%. Figure 9 shows the comparative distribution of ground-mount community solar capacity across the continental United States. Within these estimates, 167 GWAC and 407 TWh/yr of community solar potential is located in disadvantaged communities (DOE 2022a) under the Limited Access siting regime. Community solar sited within disadvantaged communities can offset 91% of those communities' current electricity consumption levels that cannot be met by behind-the-meter solar (441 TWh), as well as providing longer-term community benefits.

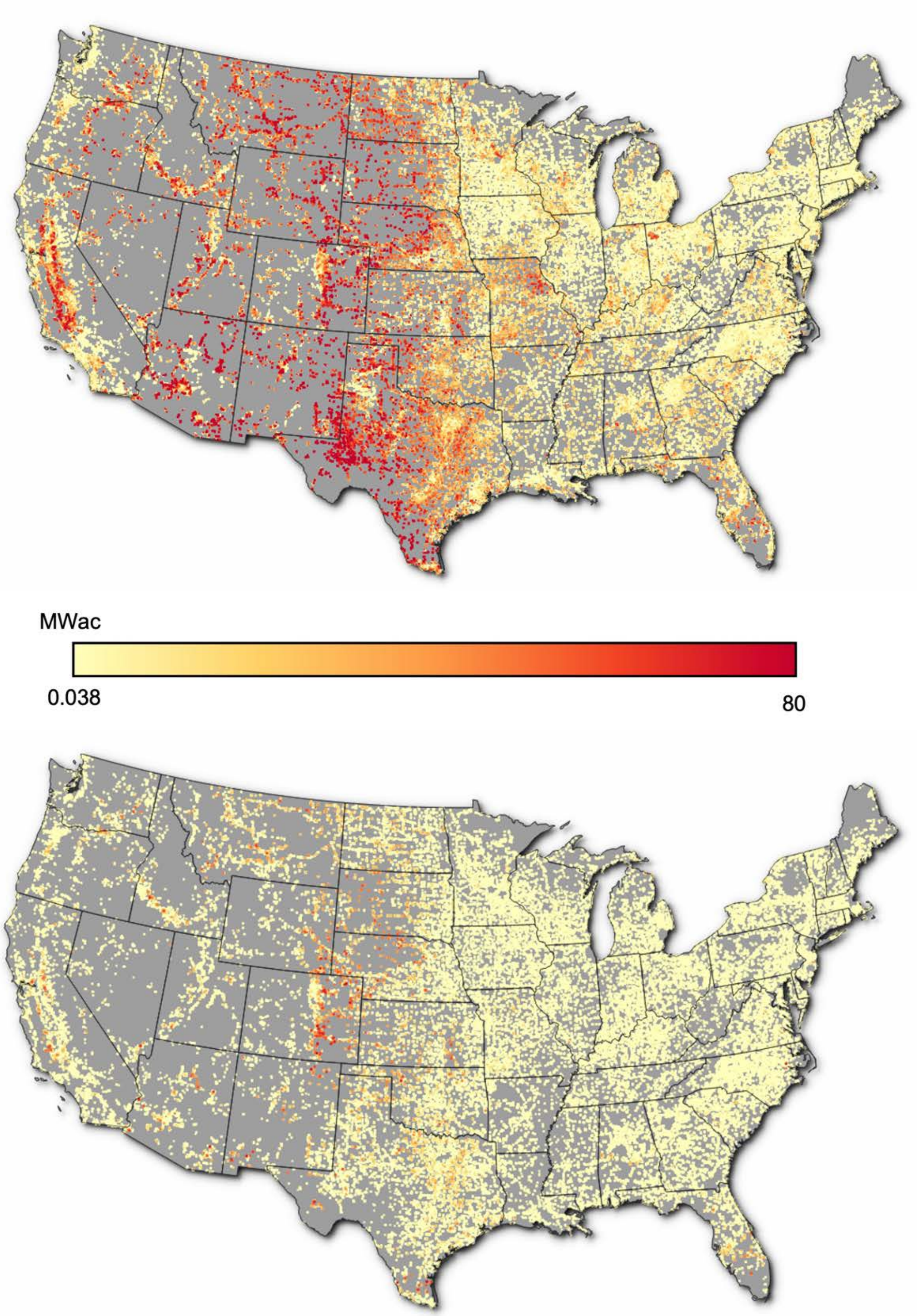


Figure 9. Modeled community solar capacity for Reference Access siting regime (top) and Limited Access siting regime (bottom)

3.1.1 Opportunities for Strategically Siting Community Solar

Overall, rural areas and areas with intensive build-out of grid infrastructure are best suited to host community solar installations, given interconnection assumptions. Dense urban, mountainous, or forested areas, or areas with other preclusions, are least suited to host a cost-competitive, sizeable community solar supply. For ground-mount solar, we found population density, land cover, and ordinances/setbacks to be the most impactful factors in siting community solar supply. Figure 10 shows that 1%–4% of ground-mount PV potential is outside of rural areas[5] and has medium- and low-density development land covers.[6] The majority of community solar potential lies in ground-mount arrays in exurbs and rural contexts, most commonly with open space, grassland, pasture, and barren land covers. Solar ordinances and setbacks within each siting regime decreased gross community solar supply potential by less than 20%. These constraints had a significantly smaller impact on the community solar technical potential estimates than the utility-scale solar estimates, which were found to potentially reduce utility-scale solar capacity by 38% (Lopez et al. 2023). The diminished impact of ordinances and setbacks is due to community solar's unique size—community solar is able to maximize potential deployment by fitting into infill and other areas that large-scale solar cannot. Figure 11 shows that the majority of modeled community solar occurs in aggregations of <10 $\mathrm{MW_{AC}}$ in both siting regimes within the interconnection distance required per regime.

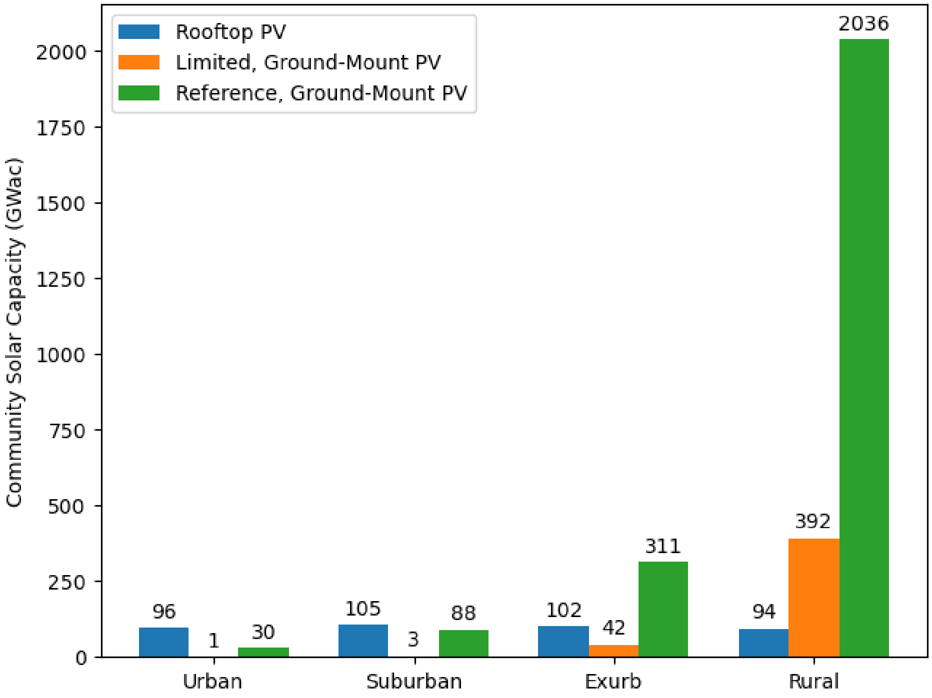


Figure 10. Community solar potential capacity by technology, siting regime, and context

---

[5] Based on spatial overlay of solar power plants (EIA 2023a) between 0.34 and 5 MW and the Global Human Settlement Layer's Degree of Urbanization dataset (Schiavina, Melchiorri, and Pesaresi 2023).

[6] Land cover descriptions are based on overlapping characterization with the National Land Cover Database (https://www.mrlc.gov/data/legends/national-land-cover-database-class-legend-and-description) from the Multi-Resolution Land Characteristics Consortium.

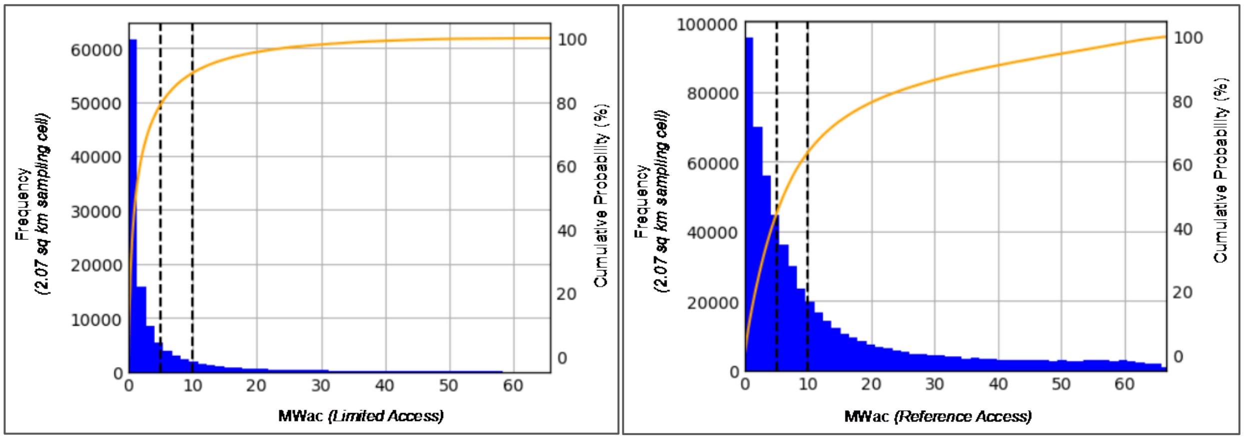


Figure 11. Cumulative distribution of modeled ground-mount PV by siting regime

Although the majority of community solar potential by volume lies in rural and exurb contexts, Figure 10 also shows that rooftop community solar holds significant potential in those areas with higher populations and built-out land covers. The need for community solar likely will not be met by ground-mount PV alone, especially in supply-limited areas and small electricity service territories. In some areas, like the District of Columbia (Table 2), we found no ground-mount PV sites available for community solar that met our siting assumptions, despite the presence of ground-mount community solar in the district (Ellfeldt 2019). Rooftop community solar is most impactful for offsetting unmet local electricity consumption in dense urban and urban contexts where clusters of large (15,000+ square feet) buildings can be found, like commercial or industrial districts. We found that building occupancies including professional/technical services, light industrial, wholesale trade, and K-12 schools offered the highest overall generation potential per building and contributed the highest share of potential capacity among community solar suitable buildings (Table 3). Table 4 lists the distribution of percent rooftop area considered developable for rooftop solar by occupancy type and census region, highlighting regional architecture trends in solar-suitable buildings. Rooftop PV siting is more constrained in regions with an older building stock, regardless of building density. Rooftop arrays on residential buildings have lower capacity per building than industrial and public buildings. Each building was assessed independently and not based on overlaying parcel ownership, potentially understating the impacts of deployment for multiple building complexes.

Community solar is better able to conform to urban and suburban siting constraints than utility-scale solar. However, not enough community solar can be sited within those settings to meet the maximum potential market share for community solar in tracts with large populations or high electricity consumption. Larger ground-mount community solar installations will be most competitive against lower-cost utility-scale solar by focusing on deployment in exurbs and rural areas within demand-constrained service territories. Within urban and suburban areas, municipal lands and repurposed lands[7] (EPA 2023) may serve as potential anchor points for community solar development. Jurisdictions benefitting from utilities with expansive service territories—particularly those encompassing rural areas—demonstrate the greatest opportunity space for community solar. In these areas, it may be necessary to look farther afield, tapping into

---

[7] More information can be found through the U.S. Environmental Protection Agency's RE-Powering initiative (https://www.epa.gov/re-powering).

community solar resources available elsewhere within the utility's service domain. Figures 12 and 13 show the opportunity space for community solar as the percent of electricity consumption that cannot be offset by behind-the-meter on-site solar: Tracts with low offsetable energy levels will likely need to access the community solar supply outside of their own tract and within their service territory, whereas tracts with high offsetable energy levels can host more community solar supply than they can consume, making them hotspots for community solar deployment at larger scales.

Community solar supply was most constrained by the applied virtual hosting limitations and interconnection distance and type requirements. The broader landscape of community solar potential also mirrors regional patterns. These patterns encompass factors like competitive land usage, land valuation metrics, the prevalence of federal lands, and the density of existing grid infrastructure. It is noteworthy that, while this analysis did not factor in agrivoltaic systems, it did account for community solar with conventional inter-row spacing on pastoral lands within the Reference Access siting regime alone.

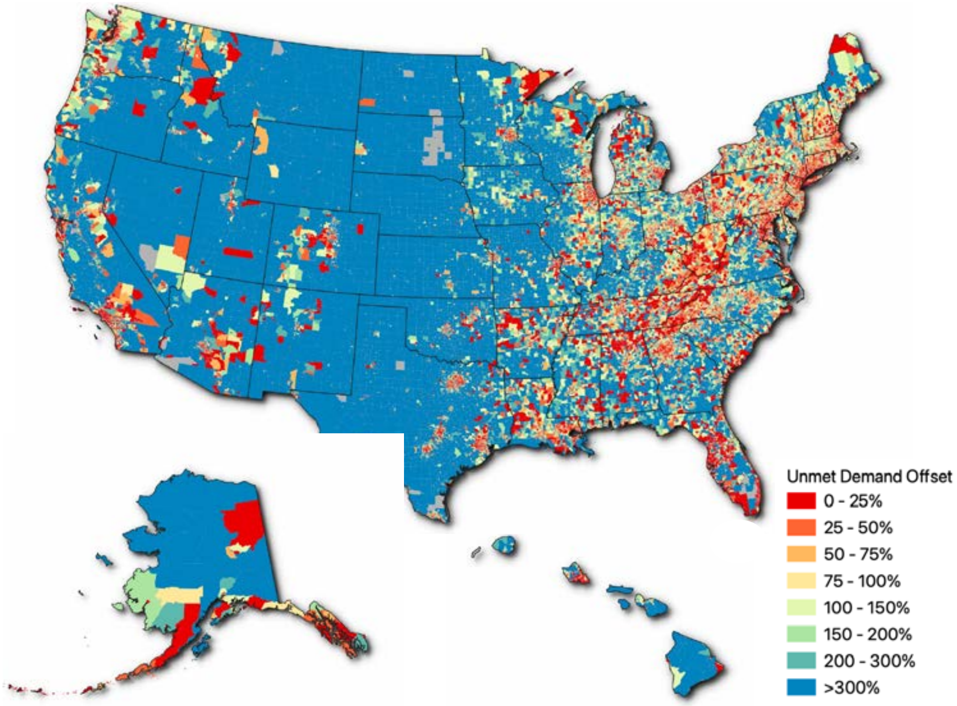


Figure 12. Percent of electricity consumption that cannot be met by behind-the-meter PV that can be offset by modeled community solar under the Reference Access siting regime

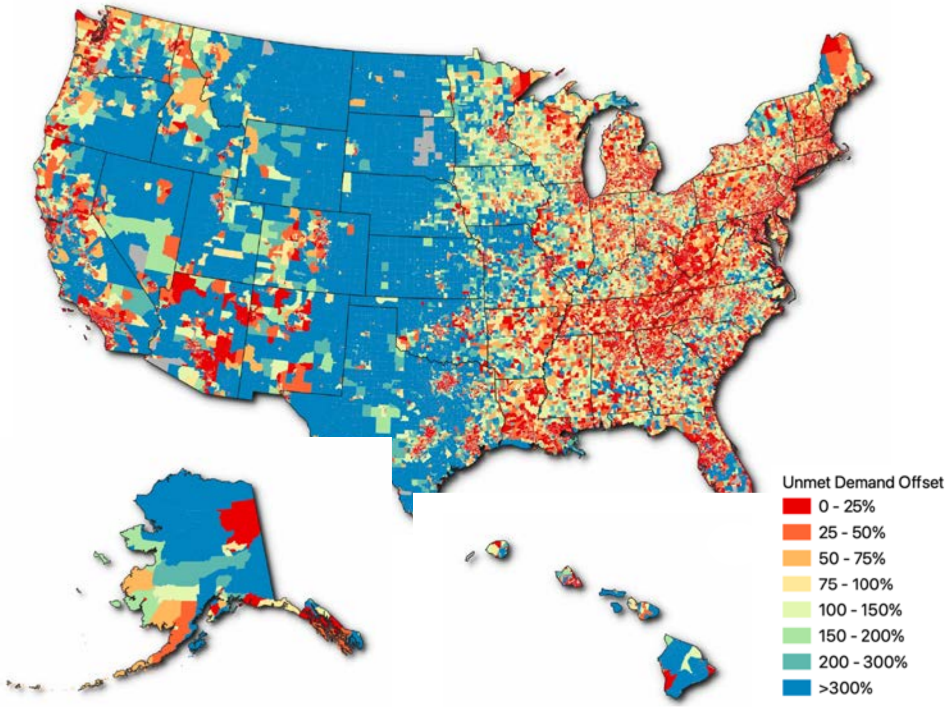


Figure 13. Percent of electricity consumption that cannot be met by behind-the-meter PV that can be offset by modeled community solar under the Limited Access siting regime

Table 3. Distribution of Rooftop PV Capacity by Building Occupancy Type

Sector	Occupancy	Building Count (thousands)	GW_{AC}	Percent of Developable Buildings	Percent of Developable Rooftop Capacity
COMMERCIAL	Banks	29.894	3.0807	0.77%	0.76%
	Entertainment/Recreation	192.435	15.6608	4.94%	3.88%
	Medical Office/Clinic	144.872	11.4305	3.72%	2.83%
	Personal and Repair Services	230.815	18.1668	5.93%	4.50%
	Professional Services	768.993	64.1048	19.74%	15.87%
	Retail	382.722	43.3017	9.83%	10.72%
	Temporary Lodging	66.403	5.6214	1.70%	1.39%
	Theater	7.491	0.9048	0.19%	0.22%
	Wholesale	290.726	43.3146	7.46%	10.72%
INDUSTRIAL	Construction	181.745	11.8024	4.67%	2.92%
	Food/Drug/Chemical	20.903	3.5166	0.54%	0.87%
	Heavy Industrial	90.28	16.9353	2.32%	4.19%
	High Technology	51.158	5.2413	1.31%	1.30%
	Light Industrial	377.466	48.1256	9.69%	11.91%
	Metals/Minerals Processing	20.086	2.9456	0.52%	0.73%
RESIDENTIAL	Single-Family Residential	127.499	10.4291	3.27%	2.58%
	Multifamily Residential (2)	125.268	7.1505	3.22%	1.77%
	Multifamily Residential (3)	37.725	2.2521	0.97%	0.56%
	Multifamily Residential (5)	59.997	3.2425	1.54%	0.80%
	Multifamily Residential (10)	45.605	2.4720	1.17%	0.61%
	Multifamily Residential (20)	40.809	2.6205	1.05%	0.65%
	Multifamily Residential (50)	27.253	2.6839	0.70%	0.66%
OTHER	Church/Nonprofit	172.181	13.6366	4.42%	3.38%
	College/University	10.663	1.9304	0.27%	0.48%
	Emergency Response	17.348	1.6529	0.45%	0.41%
	Government Services	135.88	14.3447	3.49%	3.55%
	Grade School	105.538	23.9871	2.71%	5.94%
	Hospital	22.114	3.3789	0.57%	0.84%
	Institutional Dormitory	45.837	10.7090	1.18%	2.65%
	Nursing Home	47.405	6.5353	1.22%	1.62%
	Parking	17.893	2.8628	0.46%	0.71%

Table 4. Percent of Rooftop Area Developable for PV by Building Occupancy Type

Sector	Building Occupancy	East North Central	East South Central	Middle Atlantic	Mountain	New England	Pacific	South Atlantic	West North Central	West South Central
COMMERCIAL	Banks	63%	65%	54%	51%	50%	58%	60%	58%	64%
	Entertainment and recreation	58%	60%	50%	47%	50%	54%	57%	55%	59%
	Medical office/clinic	60%	59%	50%	44%	49%	55%	56%	56%	63%
	Personal and repair services	62%	62%	53%	48%	49%	57%	58%	56%	64%
	Professional/technical services	57%	58%	49%	44%	44%	53%	52%	51%	60%
	Retail trade	61%	65%	57%	52%	52%	60%	62%	59%	65%
	Temporary lodging	53%	62%	52%	41%	43%	46%	56%	50%	59%
	Theaters	64%	77%	56%	54%	63%	53%	58%	61%	70%
	Wholesale trade	67%	68%	59%	58%	53%	62%	66%	60%	71%
INDUSTRIAL	Construction	58%	60%	50%	43%	45%	54%	52%	51%	61%
	Food/drug/chemicals	73%	62%	63%	57%	55%	61%	65%	64%	69%
	Heavy industry	70%	70%	63%	56%	56%	62%	66%	53%	71%
	High technology	63%	66%	52%	53%	49%	57%	56%	61%	58%
	Light industrial	68%	68%	62%	56%	58%	60%	62%	64%	68%
	Metals/minerals processing	75%	64%	65%	60%	62%	61%	65%	53%	64%
RESIDENTIAL	Single-family dwelling	39%	34%	33%	28%	31%	40%	35%	33%	35%
	Multifamily dwelling (2)	43%	41%	37%	30%	34%	43%	38%	37%	40%
	Multifamily dwelling (3)	45%	43%	38%	31%	35%	44%	40%	37%	45%
	Multifamily dwelling (5)	51%	44%	39%	34%	40%	45%	44%	43%	49%
	Multifamily dwelling (10)	53%	49%	42%	35%	46%	49%	43%	42%	51%
	Multifamily dwelling (20)	50%	60%	47%	32%	48%	50%	43%	47%	42%
	Multifamily dwelling (50)	58%	54%	51%	36%	39%	42%	48%	53%	55%
OTHER	Church/nonprofit	58%	55%	47%	43%	45%	55%	54%	56%	61%
	College/universities	61%	62%	51%	58%	65%	62%	56%	49%	56%
	Emergency response	66%	67%	59%	55%	51%	59%	60%	61%	66%
	General services	64%	62%	50%	52%	46%	57%	61%	58%	67%
	Grade schools	66%	64%	63%	55%	59%	59%	65%	65%	67%
	Hospitals	56%	58%	53%	49%	52%	59%	60%	58%	70%
	Institutional dormitory	54%	60%	47%	43%	48%	48%	54%	49%	64%
	Nursing home	57%	60%	53%	40%	45%	48%	53%	50%	58%
	Parking	57%	67%	52%	52%	48%	52%	55%	61%	65%

3.2 Community Solar Technical Potential by Household Income, Tenure, and Building Type

Our exploration of community solar technical potential reveals its ability to bridge the gap for households without access to behind-the-meter solar. Overall, there is sufficient community solar technical potential to serve all residential income levels, tenures, and building types without significant competition, as shown in Table 6. Even in the Limited Access siting regime, community solar has the technical potential to address the entire annual electricity consumption of these households. The annual energy produced by developing 67% of the community solar technical potential under the Limited Access siting regime would entirely offset current residential electricity consumption in the United States. Table 5 shows the breakdown of community solar supply potential and residential electricity consumption. However, households without behind-the-meter solar access—attributed to factors like housing tenure (such as renters), building types (like multifamily or manufactured homes), or building unsuitability due to shading or structural challenges—consume a cumulative 5% more electricity than their counterparts without physical barriers to on-site solar (53% versus 47%, respectively). To satisfy the electricity needs of these households through community solar alone, 53% (495 GW) of the modeled community solar potential would need to be developed. Regionally, the capacity of states in the Central Plains, Midwest, and Southeast to host community solar supply significantly surpasses the electricity consumption that can't be met by behind-the-meter solar. In contrast, the Mid-Atlantic and West Coast states are more balanced, and the Northeast and select areas of the Southwest are the most challenged, where potential supply trails behind the existing consumption levels that cannot be offset by on-site solar.

Table 5. Annual Residential Electricity Consumption by Income, Tenure, and Dwelling Type

	Very Low *0%–30% AMI*	**Low** *30%–50% AMI*	**Moderate** *50%–80% AMI*	**Mid** *80%–120% AMI*	**High** *120+% AMI*
Owner Occupied, Single-Family	65,350,294	43,536,741	95,785,401	252,458,022	365,500,349
Owner Occupied, Multifamily	932,641	1,364,245	2,499,454	6,401,835	12,061,394
Renter Occupied, Single-Family	44,816,169	17,700,346	29,342,621	84,211,171	28,605,584
Renter Occupied, Multifamily	34,796,418	19,427,293	26,679,484	48,757,529	30,033,638
Mobile Dwelling	2,976,650	5,504,750	19,239,550	59,869,800	38,406,300
Total	**148,872,172**	**87,533,375**	**173,546,510**	**451,698,358**	**474,607,265**

Table 6. Percent of Modeled Community Solar Supply (Limited Access) Needed To Offset Residential Electricity Consumption by Income, Tenure, and Dwelling Type

	Very Low *0%–30% AMI*	**Low** *30%–50% AMI*	**Moderate** *50%–80% AMI*	**Mid** *80%–120% AMI*	**High** *120+% AMI*
Owner Occupied, Single-Family	3.3%	2.2%	4.8%	12.6%	18.2%
Owner Occupied, Multifamily	Less than 1%	Less than 1%	Less than 1%	Less than 1%	Less than 1%
Renter Occupied, Single-Family	2.2%	Less than 1%	1.45%	4.2%	1.4%
Renter Occupied, Multifamily	1.7%	Less than 1%	1.3%	2.4%	1.5%
Mobile Dwelling	Less than 1%	Less than 1%	1.0%	3.0%	1.9%
Total	**7.5%**	**4.4%**	**8.7%**	**22.5%**	**23.7%**

4 Meaningful Benefits

DOE has identified five meaningful benefits that can be provided by community solar projects: greater household savings, LMI household access, resilience and grid benefits, community ownership, and equitable workforce development (DOE 2024). All estimates in this section are based on gross estimated impacts of community solar. Gross estimates do not consider potential interactions between community solar into other domains. For instance, gross estimates of jobs created by community solar do not account for the fact that jobs may be displaced in other industries. In this section, we explore the potential magnitude of these meaningful benefits in the context of our community solar technical potential estimates.

We discuss each meaningful benefit separately in individual sections. In each section, we begin by establishing a baseline of the meaningful benefits provided by existing community solar projects to understand the plausibility of DOE's meaningful benefit targets. We then estimate ranges of the future accrual of meaningful benefits at a national scale. The ranges of meaningful benefits are based on two book-end estimates:

- **Benefits under the National Community Solar Partnership (NCSP) target:** We estimate meaningful benefits at the DOE NCSP deployment target of 20 GW of cumulatively installed community solar. Assuming that at least 6 GW of community solar has been installed as of 2023 (Xu et al. 2023), we estimate the *incremental* benefits that will be achieved if the remaining 14 GW is deployed and provides the associated meaningful benefits.
- **Benefits from technically potential projects:** We estimate the potential accrual of meaningful benefits if DOE targets are achieved and all technically potential community solar is deployed (based on estimates from Section 3). These estimates should be understood as an upper-bound accrual of benefits if all technically potential projects yield feasible levels of benefits, as discussed in each subsection.

4.1 Greater Household Savings

Community solar can reduce household electricity bills. According to DOE, *community solar projects provide meaningful benefits when reducing residential subscriber electricity bills by at least 20%.*

4.1.1 Household Savings Baseline

Subscribers to existing and planned community solar projects generally reduce electricity bills by around 5%–15% (DC DOEE n.d.; Heeter et al. 2021; Mooney 2022; Kennedy 2023).[8] While most typical community solar projects may not currently achieve the 20% meaningful benefit threshold, the target is financially plausible. Ramasamy et al. (2022) estimate that a benchmark, ground-mounted, 500-kW commercial solar system costs around $1,940/kW. Tax credits would

---

[8] Mooney and Kennedy both cite ranges on the order of 5%–15%. Heeter et al. (2021) estimate a nationwide median net value from bill savings of about $24/kW/year for projects that came online in 2021. According to EIA (2023) data, households earning less than $60,000/year use around 9.3 megawatt-hours (MWh)/year, spending around $1,400/year using an average nationwide retail rate of $0.15/kWh. We assume a typical community solar subscription size of 4 kW, consistent with DOE assumptions for NCSP targets (DOE 2022b). That subscription size equates to annual savings of around $96 using the Heeter et al. median estimated savings, or roughly a 7% reduction from current electricity expenditures.

offset at least 30% of those costs, bringing the effective cost down to about $1,360/kW. Assuming the project aims to recoup those costs over 10 years, the project would require annual revenues of about $140/kW. In addition to those installation costs, community solar projects incur ongoing costs to manage subscribers on the order of $30/kW/year (Elevate 2021), increasing minimum revenues to $170/kW/year. For a 4-kW subscription, those costs equate to minimum subscription costs of $680/year. For projects that credit subscribers at the full retail rate, a subscription priced at the minimum cost would yield a roughly 27% electricity bill reduction for a typical household earning less than $60,000/year (see assumptions in Footnote 5). In a more realistic scenario where bill credits are valued at less than the retail rate (e.g., 80%), the bill reduction would be closer to 20%. Clean energy provisions in the federal Inflation Reduction Act (IRA) make the target more plausible (see Text Box 1). Indeed, for certain projects, IRA-based tax credits alone could drive bill savings well above 20%.

Text Box 1. Community solar provisions in the Inflation Reduction Act

The federal Inflation Reduction Act (IRA), passed in 2022, contains several provisions that will support future community solar deployment:

- **Extended and expanded tax credits:** The IRA extends existing tax credits and expands eligibility for tax credits, including by allowing solar projects to choose between upfront investment tax credits and ongoing production-based tax credits.
- **Tax credit transferability and direct payments:** The IRA makes tax credits transferable, meaning that project owners can easily sell the tax credits to other entities. The IRA also allows some entities (e.g., nonprofits) to apply for direct payments of tax credits rather than monetize the value via tax liabilities. See the bottom of this text box for a discussion of how transferability and direct payments affect community solar deployment.
- **Tax credit adders:** The IRA includes several tax credit adders for projects, including a 10-point bonus for projects that meet domestic content standards, a 10-point bonus for projects developed in energy communities (e.g., coal mining communities), a 10-point bonus for projects in or benefitting low-income communities or on tribal lands, and a 10-point bonus for projects sited on low-income housing in low-income communities. These adders can be stacked such that a community solar project could offset as much as 70% of the initial costs through tax credits.
- **Grants:** The IRA includes billions of dollars in grants to be distributed to communities pursuing clean energy investments such as community solar, including funding from the U.S. Environmental Protection Agency’s Solar For All program.

How do tax credit transferability and direct payments affect community solar?

Tax credits can only be monetized by entities with sufficient tax liabilities. As a result, federal tax credits have distorted solar markets by driving project owners to work with tax-equity investors who monetize the tax credits. Tax equity is a complex and costly form of financing, and has created barriers to solar deployment, especially for small projects. The IRA’s transferability and direct payment provisions will reduce financing costs by obviating the need for tax equity or other complex financing structures to monetize tax credits. The reduced barriers could facilitate smaller-scale community solar projects with higher levels of community ownership (see Section 4.4).

4.1.2 Greater Household Savings Estimates

Benefits under NCSP target: $110 million–$330 million/year; $8 million–$24 million/GW	**Benefits from technically potential projects**: $7 billion–$21 billion/year

We estimate potential bill savings as a function of three inputs:

- **Residential share of community solar capacity:** Most projects reserve a large share of capacity for a single "anchor tenant," typically a large commercial or industrial customer. Anchor tenants help improve project financeability by providing a stable, long-term revenue source. Several states restrict anchor tenants to subscribe to no more than 40% of project capacity. In such projects, the remaining 60% of project capacity is split between some mix of residential and nonresidential subscribers. To provide lower- and upper-bound estimates, we assume that residential customers account for 25%–75% of the non-anchor capacity, equating to 15%–45% of total project capacity.
- **Annual project output:** We use annual output estimates from our technical potential analysis for the technical potential estimates and apply a single 20% capacity factor to convert nationwide projected deployment to annual output for the projected potential estimates.
- **Electricity rates:** For the technical potential estimates, we multiply system output aggregated to the zip code level by average zip-code-level residential rates[9] to estimate the total amount that residential customers would pay to buy the equivalent amount of electricity from their electric utilities. For the projected potential estimates, we multiply the projected output by a nationwide average retail electricity rate of $0.15/kWh, given that the projected capacity is at the national level rather than a more geographically granular level.

Estimated bill savings are 20% of the product of the assumed residential share (15%–45%), the annual output, and retail electricity rates. The estimated bill savings from technically potential projects are $7 billion–$21 billion per year. To put those numbers in context, $7 billion is roughly the annual electricity expenditure of all residential customers in Pennsylvania, while $21 billion is roughly the annual residential expenditure in California. The potential bill savings under the NCSP target are $110 million–$330 million per year, or about $8 million–$24 million for each additional GW, a range comparable to the annual residential electricity expenditure of Washington, D.C.

4.2 LMI Household Access

LMI households are underrepresented among PV adopters (Forrester et al. 2023). Community solar could increase LMI household access by addressing several key barriers to LMI PV adoption, such as reducing upfront costs and barriers to adoption for renters (Heeter et al. 2018; Michaud 2020). According to DOE, *community solar projects provide meaningful benefits when at least 40% of subscribers are from LMI households*.

---

[9] Retail rate data are available by utility at the zip code level (Huggins 2022). We first generate zip-code-level residential rates based on residential sales-weighted averages across utilities within zip codes using U.S. Energy Information Administration electricity sales data.

4.2.1 LMI Household Access Baseline

LMI participation in existing community solar projects is far below the meaningful benefit target (Chwastyk et al. 2018). However, state community solar policies are likely to accelerate LMI adoption of community solar. Connelly (2023) projects that about 18% of community solar capacity deployed from 2023–2027 in 15 states will be reserved for LMI customers, largely reflecting state-level LMI community solar policies. The LMI share of subscribers—the criterion in the DOE target—exceeds the LMI share of capacity for two reasons. First, large shares of project capacity are held by anchor tenants, as discussed in Section 4.1. Assuming anchor tenants hold 40% of capacity while smaller subscribers split the remaining 60% of capacity evenly, an 18% LMI share of project capacity equates to a roughly 29% LMI share of subscribers. Second, LMI households tend to use less electricity than more affluent households and may thus subscribe to less capacity on average. Based on U.S. Energy Information Administration (EIA) data, households earning less than $60,000 per year tend use around 10% less electricity per year than more affluent households, implying that the future LMI share of subscribers may be slightly greater than 30%. Hence, while LMI access in existing community solar projects is far below the 40% DOE target, state community solar policies are likely to substantially close that gap in the near future.

4.2.2 LMI Household Access Estimates

Benefits under NCSP target: 210,000–630,000 LMI households served; 15K–45K/GW	**Benefits from technically potential projects:** 13 million–38 million LMI households served

We estimate a technical potential range of LMI households served based on a range of assumptions about the number of residential subscribers per MW of community solar capacity. In Section 4.1, we assumed that residential customers subscribed to 15%–45% of project capacity. Under that assumption, residential households subscribe to 150–450 kW for each MW of community solar capacity. Assuming that households subscribe to 4 kW on average (DOE 2022b), and that LMI households account for 40% of residential subscribers, each MW of community solar capacity would serve around 15–45 LMI subscribers. Under these assumptions, the number of LMI households served by technically potential projects is 13 million–38 million. Applying the same process to incremental NCSP community solar capacity, the nationwide number of LMI households served is about 210,000–630,000, or about 15,000–45,000 per additional GW. To place both numbers in context, data from Forrester et al. (2023) and Davis et al. (2023) suggest that around 860,000 LMI households cumulatively had adopted rooftop solar by the end of 2022.[10]

4.3 Resilience and Grid Benefits

Energy resilience refers to the power system's ability to prevent long-duration electrical outages, mitigate the impacts of outages, and restore power after outages.[11] According to DOE,

---

[10] Data from Forrester et al. (2023) suggest that 22% of rooftop solar adopters through the end of 2022 earned less than 80% of area median income, a typical threshold for identifying LMI households. Davis et al. (2023) estimate that about 3.9 million households had adopted rooftop solar by the end of 2022. The product of the two numbers suggests that around 860,000 LMI households had adopted rooftop solar by the end of 2022.

[11] Resilient Energy Platform defines power sector resilience as "the ability to anticipate, prepare for, and adapt to changing conditions and withstand, respond to, and recover rapidly from disruptions to the power sector through adaptable and holistic planning and technical solutions."

community solar projects provide meaningful resilience and grid benefits by delivering power to households and critical facilities during grid outages and strengthening grid operations through demand response and other actions.

4.3.1 Resilience and Grid Benefits Baseline

While reliable data are lacking, the use of community solar systems to provide resilience and grid benefits is likely rare. Resilience and grid benefits have generally not been prioritized in community solar planning to date (Abbott et al. 2022). Still, anecdotal evidence suggests that a growing number of community solar projects are exploring how to factor resilience into system design (DOE 2023). Theoretically, community solar systems—like all distributed solar systems—can reduce the grid's vulnerability to outages at any one location. Community solar systems that are strategically sited near or on critical facilities can ensure a power source for critical services during broader grid outages. Further, solar systems are not susceptible to short-run supply chain shocks, such as fuel shortages that may arise during natural disasters.

The resilience value of community solar is inherently limited by the intermittent nature of solar output, especially during prolonged storms. As a result, recent research examines solar resiliency in the context of co-located solar plus storage (Anderson et al. 2018; Laws et al. 2018; Abbott et al. 2022). Battery storage enhances the resiliency value of solar by storing and shifting solar output during grid outages. Through battery storage, solar output can more effectively meet critical loads and be shifted to meet nighttime loads. Battery storage can also enhance the grid value of community solar—the second component of DOE's meaningful benefit—strengthening grid operations. Battery storage can effectively convert community solar systems into quasi-dispatchable resources, meaning that solar output can be stored and shifted to provide a broader variety of grid services (e.g., demand response, frequency regulation, capacity reserves).

Battery storage is poised for significant growth (Frazier et al. 2021). Still, significant deployment of battery storage does not imply co-location with community solar. Battery storage is typically more economical when sited at strategic points on the grid rather than co-located with renewable energy projects such as solar (Gorman et al. 2022). The popularity of solar-plus-storage co-location has been enabled in part by incentives created by federal tax credits (Gorman et al. 2022). The IRA removes those distorted incentives by allowing independently sited storage projects to receive tax credits. With the new tax credit structure, the efficiency and value of co-location will need to be evaluated on a case-by-case basis (Gorman et al. 2022). The primary value proposition of co-location moving forward lies in providing grid services (Gorman and Seel 2022). As a result, it is likely that community-solar-plus-storage co-location will only be economically attractive for projects that can effectively monetize the value of grid services provided by batteries.[12] We incorporate these considerations into our estimation of potential benefits in the following section.

---

[12] Some caution is required in evaluating investments in storage solely based on supporting grid resiliency during infrequent grid outages. Such investments add to project costs without increasing project revenues, such that inefficient storage investments would likely deflate subscriber bill savings. Further, most battery storage deployed today uses battery chemistries that rely on supply chains associated with substantial social and environmental risks and damages. The need for battery storage should thus be evaluated carefully on a case-by-case basis.

4.3.2 Resilience and Grid Benefits Estimates

Benefits under NCSP target: $30 million–$100 million/year in avoided outage damages ($2 million–7 million/GW); $20 million–$60 million/year in grid services ($1 million–4 million/GW)	**Benefits from technically potential projects:** $2 billion–$6 billion/year in avoided outage damages; $1.3 billion–$3.8 billion/year in grid services

We estimate potential community solar resilience and grid benefit values as a function of five inputs:

- **Community solar projects co-located with storage:** The future prevalence of community solar co-location with storage remains uncertain. Davis et al. (2023) estimate that 20% of new nonresidential solar projects will be co-located with storage by 2027. To provide a rough technical potential analysis, we assume that 10%–30% of technically potential community solar projects could be co-located with storage. Of those projects, we assume that battery storage capacity equates to 60% of deployed solar capacity, based on typical solar/storage ratios for existing utility-scale solar systems (Bolinger et al. 2022).
- **Reserve capacity for resilience:** For simplicity, we assume that 50% of storage capacity is reserved for backup power (resilience) and 50% is reserved for providing ongoing grid services. Of the battery storage reserved for backup power, we assume that batteries can provide 2 hours of backup power, on average, based on typical storage durations for existing projects (Bolinger et al. 2022). We assume that storage capacity is fully used in a typical outage incident, which lasts around 4 hours on average (EIA 2023d).
- **Value of lost load:** The value of lost load refers to the monetary value of damages caused by blackouts, such as lost economic activity, thermal discomfort, and food spoilage. Most estimates for values of lost load are on the order of $1–$30/kWh, though some estimates range over $100/kWh (Schröder and Kuckshinrich 2015). We assume a value of lost load of $30/kWh.
- **Frequency of outages:** According to EIA (2023) data, the nationwide average number of interruptions from 2013–2021 is 1.3 interruptions per customer, with an average interruption duration of 4.2 hours.
- **Value of grid services:** The value of non-energy grid services (e.g., capacity reserves, ancillary services) has been estimated to be on the order of $10–$100/kW (Balducci et al. 2021). For simplicity, we assume a single value of $50/kW.

We estimate the annual value of backup power as the product of the potential backup gigawatt-hours (GWh), the value of lost load, and the number of outages per year. Under that approach, the estimated value of grid resilience provided by technically potential community solar projects is $2 billion–$6 billion per year, while the estimated value under the NCSP target is $30 million–$100 million per year, or about $2 million–$7 million per each additional GW. To contextualize those numbers, the annual cost of weather-related outages is estimated to be on the order of $18 billion–$33 billion nationally (EOP 2013). Finally, assuming the other half of capacity provides ongoing grid services at an average value of $50/kW, our technical potential grid service value estimate is $1.3 billion–$3.8 billion per year and $20 million–$60 million per year for the estimate under the NCSP target, or about $1 million–$4 million for each additional GW.

4.4 Community Ownership

According to DOE, *community solar projects provide meaningful benefits when community members own or hold equity in project assets*. Community ownership refers to projects where community members have equity ownership rights in community solar projects (Grimley and Chan 2023). In addition to equity ownership, DOE recognizes other community wealth-building strategies such as community benefit agreements (CBAs), meaning contractual agreements to distribute some portion of project benefits into host communities.

4.4.1 Community Ownership Baseline

Community ownership of community solar projects is rare (Bolinger and Paulos 2023). While specific estimates are lacking, community-owned projects account for no more than 5% of installed community solar project capacity.[13] Most community solar projects are owned by for-profit entities not directly tied to host communities (Heeter et al. 2021; Paulos 2022). Financing challenges, regulatory barriers, and lack of expertise impede community ownership (Farrell 2016; McHarg 2016; Paulos 2022; Bolinger and Paulos 2023). Notwithstanding these challenges, the potential benefits of community ownership provide an ongoing incentive for communities to pursue greater ownership of community solar projects (Lantz and Tegen 2009; Kienbaum et al. 2023). Further, communities have a plethora of strategies to achieve community ownership, and tax credit reforms implemented in the IRA have renewed interest in community ownership (Grimley and Chan 2023).

Alternative wealth-building strategies such as CBAs provide practical alternatives to community ownership that still drive economic benefits into host communities. Under a CBA, the project owner contractually agrees to invest in the host community, such as by hiring local labor or contributing to local economic trust funds (DOE 2023). CBAs are an increasingly common model for redistributing the values of large-scale projects that require community acceptance (Wolf-Powers 2011), though the prevalence of CBAs in community solar is unclear.

4.4.2 Estimated Benefits of Community Ownership

Benefits under NCSP target: $20 million–$160 million/year in added local economic value, out of a total of about $550 million/year in economic impacts ($1 million–$11 million/GW)	**Benefits from technically potential projects:** $0.9 billion–$7.2 billion/year in added local economic value, out of a total of about $25 billion/year in economic impacts

We estimate the potential benefits of community ownership as a function of two inputs:

- **Community-owned and CBA shares of capacity.** We were unable to develop literature-based assumptions for the potential future uptake of community ownership and CBAs. To estimate a range of potential benefits, at the low end, we assume that 1% of future community solar capacity is community owned, while the remaining share of capacity is developed with CBAs. At the high end, we assume that 25% of capacity is community owned and the remaining 75% of capacity is developed with CBAs.

---

[13] Customer-owned projects account for a fraction of a percent of installed capacity. According to data collected by the authors as part of NREL's Sharing the Sun project, electric cooperative projects, some of which may meet community ownership criteria, accounted for around 4.7% of capacity as of the end of 2022.

- **Economic benefits of community ownership and CBAs.** Several studies suggest that community ownership roughly doubles the local economic benefits of renewable energy projects relative to absentee ownership models (Lantz and Tegen 2009; Kienbaum et al. 2023). These economic impacts reflect the accrual of project revenues into the community as well as economic "multipliers" that result when those revenues circulate around local businesses. We therefore assume that the local value of community-owned capacity is double the estimated economic impact of typical projects. Research on the quantitative value of CBAs is sparse (Gunton et al. 2023), but Cowell et al. (2011) found that CBAs may redistribute around 5% of annual project earnings to host communities. To explore a plausible range, we assume the economic value of CBAs ranges from 5%–10% of project earnings.

We use NREL's Jobs and Economic Development Impact (JEDI) model to estimate the economic impacts of community solar projects. We then multiply the state-level economic impacts from JEDI by our assumed multipliers as follows:

$$CO\ value = \sum_s CBA\% \left(L\% \times GW_s \times \frac{earnings_s}{GW} \right) + CO\% \left(GW_s \times \frac{impact_s}{GW} \right)$$

Equation 3: Community ownership value based community solar estimated capacity

In Equation 3, $CO\ value$ is the estimated additional local value generated by community ownership or community benefit agreements, $CBA\%$ is the assumed share of project capacity with CBAs (75%–99%), $CO\%$ is the assumed share of project capacity that is community owned (1%–25%), L is the percent of project earnings that are redistributed locally through CBAs (5%–10%), GW_s is the estimated technically potential community solar in state s, and $earnings_s$ and $impacts_s$ are the estimated annual earnings and local economic impacts in state s as estimated by JEDI, respectively. Under that approach, the estimated impact of technically potential projects on *local* economic value from community ownership is \$0.9 billion–\$7.2 billion per year. That is, if all technically potential community solar capacity is developed, and all that capacity includes some form of community ownership, an additional \$0.9 billion–\$7.2 billion of annual economic benefits will accrue to host communities. In terms of the potential under the NCSP target, the JEDI model suggests nationwide average earnings of \$19,000/MW and average economic impacts of \$39,000/MW. Applying those inputs to the process outlined in Equation 3 above, we estimate that community ownership and CBAs could add \$20 million–\$160 million/year in local economic value, or about \$1 million–\$11 million per each additional GW.

It is important to emphasize that these estimates reflect the economic impacts accruing to host communities, not the full economic value of projects. The total economic impact of all technically potential projects using the JEDI model is estimated to be about \$25 billion per year. The total estimated economic impact of incremental capacity under the NCSP target is about \$550 million per year, or about \$40 million per each additional GW.

4.5 Equitable Workforce Development

According to DOE, *community solar projects achieve meaningful benefits by advancing high wages, reducing income disparities across demographic lines, ensuring a workforce that is reflective of the community, and creating a safe working environment.*

4.5.1 Equitable Workforce Development Baseline

The U.S. solar industry actively promotes a more equitable workforce (Gilliland et al. 2022). The U.S. solar industry is more racially diverse than the broader U.S. workforce, though the solar industry exhibits a more significant gender imbalance (Keyser et al. 2023). Solar industry wages are generally competitive, with median industry wages higher than construction industry median wages and slightly higher than the U.S. median wage for all occupations (Gilliland et al. 2022). The solar industry is unionized at comparable levels to the broader U.S. workforce (Keyser et al. 2023).

Further equitable workforce development is compatible with other clean energy and decarbonization objectives. Mayfield and Jenkins (2021) show that efforts to ensure an equitable workforce—such as higher wages, local hiring requirements, and gender and racial equity hiring requirements—have minimal impacts on solar costs and deployment. The reason for these minimal impacts is that labor costs compose a small share of overall project costs—though community solar is more labor-intensive than other forms of solar given the need for ongoing subscriber management. Still, other political and social factors could impede equitable workforce development initiatives, such as political resistance to wage standards or unionization (Mayfield and Jenkins 2021). Further, the U.S. solar industry already faces broad labor shortages. Most surveyed solar companies report hiring difficulties at all levels of the solar supply chain (Gilliland et al. 2022; Keyser et al. 2023). Most solar companies attribute hiring difficulties to the limited supply of job seekers with adequate experience, training, and skills (Gilliland et al. 2022).

4.5.2 Estimated Benefits of Equitable Workforce Development

Benefits under the NCSP target: 290,000 construction positions (20K/GW), 7,000 ongoing jobs (300/GW), $200 million–$230 million in ongoing local wages in host communities ($15 million/GW)	**Benefits from technically potential projects:** 18 million construction positions, 420,000 ongoing jobs, $12 billion–$13 billion in ongoing local wages in host communities

To explore the workforce development impacts of community solar, we estimate the number of jobs associated with new projects and the local wages generated by those projects.

Community solar jobs can be grouped into three categories: construction, operations and maintenance, and subscriber management (e.g., managing subscriber bills, acquiring new subscribers). These solar jobs reflect some combination of local hires (e.g., local hired workers during construction) and positions held outside of host communities (e.g., subscriber management organizations are not typically located in host communities). According to the NREL JEDI model, a typical project supports the equivalent of around 21 full-time construction jobs per MW for one year. After construction, a typical project supports around 0.3 full-time jobs per MW for operations and maintenance. Although similar estimates for subscriber management labor are unavailable, labor requirements estimated by Elevate (2021) suggest that subscriber management typically requires multiple staff on an ongoing basis. For simplicity, we assume that one full-time position is required to manage every 5 MW of community solar capacity.[14]

---

[14] The number of employees per MW may currently be higher, but labor per MW will presumably decline over time as community solar scales and achieves growing economies of scale.

Using those assumptions, nationwide technical potential community solar capacity would support around 18 million construction positions, 250,000 ongoing jobs for operations and maintenance, and 167,000 ongoing jobs for subscriber management. For the NCSP target, incremental deployment would support 290,000 construction positions (about 20,000 per each additional GW), 4,200 ongoing jobs for operations and maintenance (300 per GW), and 2,800 ongoing jobs for subscriber management (200 per GW). For comparison, the entire U.S. solar industry currently employs around 260,000 individuals (IREC 2023).

As already noted, many and possibly most of those jobs would be filled by employees who do not reside in the communities that host community solar projects. To estimate the *local* impacts of wages, we calculate total wages paid for ongoing jobs in operations and maintenance—positions that are presumably held by individuals who live in or near host communities. We assume that average wages could vary from the current industry average for solar photovoltaic installers ($47,970/year) to the industry's 75th percentile wage ($53,700) (BLS 2023). Under those assumptions, local wages accruing to host communities range from $12 billion–$13 billion per year for technically potential capacity and $200 million–$230 million per year for incremental capacity to meet the NCSP target, or about $15 million per each additional GW.

5 Conclusions

This report presents a first-of-its-kind assessment of the technical potential of community solar and provides insight into the distribution of community solar potential by tenure, income, and other building characteristics. This research indicates that a substantial fraction of residential and commercial electricity consumption can be met by community solar across siting regimes intended to represent both balanced, common practices for community solar as well as more restrictive exclusions and setbacks. Our technical potential estimates suggest that the maximum feasible deployment of projects with characteristics typical of community solar projects could generate enough electricity to meet the electricity consumption of 53.2 million households in the United States. In practice, market, economic, and policy constraints mean that the actual number of households potentially served by community solar will be much smaller. Still, our analysis suggests that community solar could conceivably grow to serve a significant portion of those customers who are unable to adopt rooftop or other behind-the-meter solar.

We find that community solar potential can significantly contribute to meeting electricity consumption for households and business that are unable to access on-site solar, such as the many LMI households, renters, and households residing in dwellings not suitable for behind-the-meter solar (e.g., unsuitable roofs for solar, structural problems, code or panel issues, or impermanent or modular housing types).

We also explore the potential benefits of the ongoing deployment of community solar. We estimate that, if all technically potential community solar is deployed, community solar could save customers billions of dollars on their electricity bills, serve tens of millions of LMI households, generate billions of dollars in grid resilience and grid service values, drive billions of dollars of economic benefits into host communities, and support hundreds of thousands of jobs. Realistically, the potential accrual of benefits is a fraction of those high-end estimates based on technical potential capacity. Still, using realistic projections for community solar deployed in the ensuing decade, we estimate that community solar could reduce subscriber electricity costs by around $170 million–$500 million per year, serve 320,000–950,000 LMI households, generate $80 million–$240 million per year in grid resiliency and service value, drive $30 million–$230 million per year in economic benefits into host communities, and support around 10,500 permanent jobs.

5.1 Future Work

We suggest four topics for future work to extend this analysis. First, community solar can be modeled in SAM (Blair et al. 2018) using the community solar financial model with community-solar-specific costs, incentives, and other financial parameters to increase the fidelity of techno-economic potential results. Site-based levelized costs of energy for modeled community solar supply were significantly below (50% less than) reported levelized costs of energy for community solar (Lazard 2023). From this, community solar supply curves could be modeled and could directly compete with other technology supply curves.

Second, community solar interconnection requirements should be expanded to include distribution-level interconnection constraints. Geospatial data representative of national and regional electricity distribution systems are not available, either publicly or as licensed data. Experimental methods exist to classify these data using optical remote sensing and may fit this need if computed on a national scale. As part of distribution interconnection, hosting capacity assessment and power flow analyses can assist project developers and utilities in evaluating site-based community solar feasibility and overall impacts on feeders and downstream customers.

Third, offsetting electricity consumption for households and businesses that cannot access behind-the-meter solar is a first step in assessing community solar potential. A logical next step is furthering this work in developing market potential estimates for community solar, particularly in terms of local policy—including state-level enabling legislation, project size limits, and program and annual limits, among others. Part of developing community solar market potential could include matching electricity consumption and community solar generation time series. Assessing load and supply time series would help establish the degree of paired storage for community solar installations.

Finally, community solar and agrivoltaics are emerging solar PV deployment forms that can provide additional benefits to both communities and habitats beyond utility-scale solar and wind. Community solar and agrivoltaics can occupy the same system size niche, and both can act as a land-saving instance of renewable energy (The Nature Conservancy 2023), capitalizing on incentives and opportunities for programs under both forms. Future agrivoltaic techno-economic potential assessments could include a form of community solar.

References

Abbot, S., M. Tyson, M. Popkin, A. Farthing. 2022. *Community Solar+: How the Next Generation of Community Solar Can Unlock New Value Streams and Help Communities Pursue Holistic Decarbonization*. Boulder, CO: Rocky Mountain Institute.

Anderson, K., N. Laws, S. Marr, L. Lisell, T. Jimenez, T. Case, X. Li, D. Lohmann, D. Cutler. 2018. "Quantifying and Monetizing Renewable Energy Resiliency." *Sustainability* 10:933.

Balducci, P., K. Mongrid, M. Weimar. 2021. "Understanding the Value of Energy Storage for Power System Reliability and Resilience Applications." *Current Sustainable/Renewable Energy Reports* 8: 131–137.

Barbose, G., N. Darghouth, E. O'Shaughnessy, and S. Forrester. 2022. *Tracking the Sun: Pricing and Design Trends for Distributed Photovoltaic Systems in the United States, 2022 Edition.* Berkeley, CA: Lawrence Berkeley National Laboratory. Contract No. DE-AC02-05CH11231. https://emp.lbl.gov/publications/tracking-sun-pricing-and-design-1.

Blair, N., A. Dobos, J. Freeman, T. Neises, M. Wagner, T. Ferguson, P. Gilman, and S. Janzou. 2014. *System Advisor Model, SAM 2014.1.14: General Description*. Golden, CO: National Renewable Energy Laboratory. NREL/TP-6A20-61019. www.nrel.gov/docs/fy14osti/61019.pdf.

BLS. 2023. *Occupational Employment and Wage Statistics, May 2022: 47-2231 Solar Photovoltaic Installers*. Washington, DC: U.S. Bureau of Labor Statistics.

Bolinger, M., J. Seel, C. Warner, and D. Robson. 2022. *Utility-Scale Solar, 2022 Edition: Empirical Trends in Deployment, Technology, Cost, Performance, PPA Pricing, and Value in the United States*. Berkeley, CA: Lawrence Berkeley National Laboratory. Contract No. DE-AC02-05CH11231. https://emp.lbl.gov/publications/utility-scale-solar-2022-edition.

Bolinger, M., B. Paulos. 2023. *Revisiting Community Wind Through the Lens of Community Solar*. Berkeley, CA: Lawrence Berkeley National Laboratory.

Brown, A., P. Beiter, D. Heimiller, C. Davison, P. Denholm, J. Melius, A. Lopez, D. Hettinger, D. Mulcahy, and G. Porro. 2016. *Estimating Renewable Energy Economic Potential in the United States: Methodology and Initial Results*. Golden, CO: National Renewable Energy Laboratory. NREL/TP-6A20-64503. https://www.nrel.gov/docs/fy15osti/64503.pdf.

Chan, G., J. Heeter, and K. Xu. 2022. "Sharing the Sun Community Solar Project Data (June 2022)." NREL Data Catalog. Golden, CO: National Renewable Energy Laboratory. Last updated: December 3, 2022. DOI: 10.7799/1901523.

Chwastyk, D., J. Leader, J. Cramer, M. Rolph. 2018. *Community Solar Program Design Models*. Smart Electric Power Alliance.

Connelly, C. 2023. *Demystifying LMI incentives for community solar projects*. Wood Mackenzie.

Cook, J., M. Shah. 2018. *Focusing the Sun: State Considerations for Designing Community Solar Policy*. Golden, CO: National Renewable Energy Laboratory. NREL/TP-6A20-70663.

Copernicus Climate Change Service. 2017. *ERA5: Fifth generation of European Centre for Medium-Range Weather Forecasts atmospheric reanalyses of the global climate*. Copernicus Climate Change Service Climate Data Store (CDS), 15 June, 2023. https://cds.climate.copernicus.eu/cdsapp#!/dataset/reanalysis-era5-single-levels.

Cowell, R., G. Bristow, M. Munday. 2011. "Acceptance, acceptability and environmental justice: the role of community benefits in wind energy development." *Journal of Environmental Planning and Management* 54(4): 539–557.

Davis, M., S. Leyva Martinez, Z. Gaston, S. Chopra, C. Connelly, M. Sahd, M. Issokson, E. Pierce, C. Seiple, S. Rumery, C. Silver, T. Thompson, J. Baca. 2023. *US Solar Market Insight: 2022 Year in review*. Wood Mackenzie.

DC DOEE. n.d. *Solar Initiatives*. Washington DC Department of Energy and Environment.

DOE. 2021. *Solar Futures Study.* https://www.energy.gov/sites/default/files/2021-09/Solar%20Futures%20Study.pdf.

DOE. 2022a. *J40 DACs Data*. Dataset, accessed 10 May, 2023. https://energyjustice.egs.anl.gov.

DOE. 2022b. *National Community Solar Partnership*. Washington, DC: National Community Solar Partnership.

DOE. 2023. *Building with Benefits: Increased Resilience*. Washington, DC: National Community Solar Partnership.

DOE. 2024. Community Solar Best Practices Guide: Developing Projects with Meaningful Benefits. https://www.energy.gov/communitysolar/community-solar-best-practices-guide-developing-projects-meaningful-benefits.

EIA. 2022. Monthly Form EIA-861M (2020). *Table 10, retail sales of electricity to ultimate customers, annual, by state and utility*. Dataset, accessed 1 May, 2023. https://www.eia.gov/electricity/sales_revenue_price/pdf/table_10.pdf.

EIA. 2023a. *Electric Retail Service Territories*. Dataset, accessed 1 May, 2023. https://atlas.eia.gov/datasets/f4cd55044b924fed9bc8b64022966097/explore.

EIA. 2023b. *Power Plants*. Dataset, accessed 1 May, 2023. https://atlas.eia.gov/datasets/eia::power-plants.

EIA. 2023c. *U.S. Commercial Buildings Energy Consumption Survey.* Washington, DC: U.S. Energy Information Administration.

EIA. 2023d. *U.S. Residential Energy Consumption Survey*. Washington, DC: U.S. Energy Information Administration.

Elevate. 2021. *Community Solar Pro Forma*. Elevate Energy.

Ellfeldt, A. 2019. "Powered By Faith, Religious Groups Emerge As A Conduit For A Just Solar Boom." North Country Public Radio. https://www.northcountrypublicradio.org/news/npr/784483810/powered-by-faith-religious-groups-emerge-as-a-conduit-for-a-just-solar-boom.

EOP. 2013. *Economic Benefits of Increasing Electric Grid Resilience to Weather Outages*. Washington, DC: Executive Office of the President.

EPA. 2023. *RE-Powering Screening Dataset and Geodatabase*. Dataset, accessed 10 October, 2023. https://www.epa.gov/re-powering/how-identify-sites#looking.

Farrell, J. 2016. *Beyond Sharing: How Communities Can Take Ownership of Renewable Power*. Institute for Local Self-Reliance.

Feldman, D., A.M. Brockway, E. Ulrich, and R. Margolis. 2015. *Shared Solar: Current Landscape, Market Potential, and the Impact of Federal Securities Regulation*. Golden, CO: National Renewable Energy Laboratory. NREL/TP-6A20-63892. https://www.nrel.gov/docs/fy15osti/63892.pdf.

Forrester, S., G. Barbose, E. O'Shaughnessy, N. Darghouth, C. Crespo Montañés. 2023. *Residential Solar-Adopter Income and Demographic Trends: 2023 Update*. Berkeley, CA: Lawrence Berkeley National Laboratory.

Frazier, A.W., W. Cole, P. Denholm, S. Machen, N. Gates, N. Blair. 2021. *Storage Futures Study: Economic Potential of Diurnal Storage in the U.S. Power Sector*. Golden, CO: National Renewable Energy Laboratory. NREL/TP-6A20-77449.

Gagnon, P., R. Margolis, J. Melius, C. Phillips, and R. Elmore. 2016. *Rooftop Solar Photovoltaic Technical Potential in the United States: A Detailed Assessment*. Golden, CO: National Renewable Energy Laboratory. NREL/TP-6A20-65298. https://www.nrel.gov/docs/fy16osti/65298.pdf.

Gahl, D. and B. Norris. 2022. *Community Solar Project Siting: A Framework for Producing Zero Carbon Electricity and Serving Ecosystem Enhancement & Conservation*. SEIA Whitepaper. https://www.seia.org/research-resources/community-solar-project-siting.

Gilliland, E., A. Palmer, M. Hernandez. 2022. *National Solar Jobs Census 2021*. International Renewable Energy Council.

Gorman, W., C. Crespo Montañés, A. Mills, J.H. Kim, D. Millstein, R. Wiser. 2022. "Are coupled renewable-battery power plants more valuable than independently sited installations?" *Energy Economics* 107: 105832.

Gorman, W., J. Seel. 2022. *Batteries Included: Top 10 Findings from Berkeley Lab Research on the Growth of Hybrid Power Plants in the United States*. Berkeley, CA: Lawrence Berkeley National Laboratory.

Grimley, M., G. Chan. 2023. *Community Ownership in Community Solar Projects*. University of Minnesota.

Gunton, T., E. Werker, S. Markey. 2021. “Community benefit agreements and natural resource development: Achieving better outcomes.” *Resources Policy* 73: 102155.

Hausman, N. 2022. *How Community Solar Can Benefit Low- and Moderate-Income Customers*. Washington, D.C.: World Resources Institute.

Heeter, J., L. Bird, E. O’Shaughnessy, S. Koebrich. 2018. *Design and Implementation of Community Solar Programs for Low- and Moderate-Income Customers*. Golden, CO: National Renewable Energy Laboratory. NREL/TP-6A20-71652.

Heeter, J., K. Xu, G. Chan. 2021. *Sharing the Sun: Community Solar Deployment, Subscription Savings, and Energy Burden Reduction.* Golden, CO: National Renewable Energy Laboratory. NREL/PR-6A20-80246.

Heeter, J., K. Xu, M. Grimley, G. Chan, and E. Dalecki. 2022. *Status of State Community Solar Program Caps*. Golden, CO: National Renewable Energy Laboratory. NREL/TP-6A20/84077. https://www.nrel.gov/docs/fy23osti/84077.pdf.

Heleno, M., J. P. Carvallo, A. Valenzuela, G. Leventis, C. Miller, and J. Deason. 2023. *Distribution Grid Impacts of Community Solar*. Berkeley, CA: Lawrence Berkeley National Laboratory. Contract No. DE-AC02-05CH11231. https://eta-publications.lbl.gov/sites/default/files/lbl_cs_grid_impacts_final_09.01.23_v2.pdf.

Huggins, J., 2022. *U.S. Electric Utility Companies and Rates: Look-up by Zipcode (2020)*. Golden, CO: National Renewable Energy Laboratory.

IREC. 2023. *National Solar Jobs Census 2022*. Albany, NY: Interstate Renewable Energy Council.

Kennedy, E. 2023. *Community solar saves money with solar energy — without changing your roof*. Kiplinger.

Keyser, D., M. Fiori, B. Jones, H. Ho, S. Jatkar, K. Gordon, G. Coplon-Newfield, C. Frisch, C. Veeder. 2023. *United States Energy & Employment Report 2023*. Washington, D.C.: U.S. Department of Energy.

Kienbaum, J. Farrell, M. Grimley. 2023. *Advantage Local: Why Local Energy Ownership Matters*. Institute for Local Self-Reliance.

Lantz, E., S. Tegen. 2009. *Economic Development Impacts of Community Wind Projects: A Review and Empirical Evaluation*. Golden, CO: National Renewable Energy Laboratory. NREL/CP-500-45555.

Laws, N., K. Anderson, N. DiOrio, X. Li, J. McLaren. 2018. “Impacts of valuing resilience on cost-optimal PV and storage systems for commercial buildings.” *Renewable Energy* 127: 896–909.

Lazard. 2023. Lazard’s LCOE+ (April 2023). https://www.lazard.com/media/2ozoovyg/lazards-lcoeplus-april-2023.pdf.

Lopez, A., W. Cole, B. Sergi, A. Levine, J. Carey, C. Mangan, T. Mai, T. Williams, P. Pinchuk, and J. Gu. 2023. Impact of siting ordinances on land availability for wind and solar development. *Nature Energy*. https://doi.org/10.1038/s41560-023-01319-3.

Lopez, A., P. Pinchuk, M. Gleason, W. Cole, T. Mai, T. Williams, O. Roberts, M. Rivers, M. Bannister, S. Thomson, G. Zuckerman, and B. Sergi. 2024. *Solar Photovoltaics and Land-Based Wind Technical Potential and Supply Curves for the Contiguous United States: 2023 Edition.* Golden, CO: National Renewable Energy Laboratory. NREL/TP-6A20-87843. https://www.nrel.gov/docs/fy24osti/87843.pdf.

Lopez, A., B. Roberts, D. Heimiller, N. Blair, and G. Porro. 2012. *U.S. Renewable Energy Technical Potentials: A GIS-Based Analysis.* Golden, CO: National Renewable Energy Laboratory. NREL/TP-6A20-51946. https://www.nrel.gov/docs/fy12osti/51946.pdf.

Lutz, N., W. Helman, A. Ryan, T. Nguyen, and R. Goss. 2022. *National Structure Inventory.* Dataset, accessed 10 May, 2023. https://github.com/HydrologicEngineeringCenter/NSI.

Ma, O. K. Laymon, M. Day, R. Oliveira, J. Weers, and A. Vimont. 2019. *Low-Income Energy Affordability Data (LEAD) Tool Methodology*. Golden, CO: National Renewable Energy Laboratory. NREL/TP-6A20-74249. https://www.nrel.gov/docs/fy19osti/74249.pdf.

Maclaurin, G.J., N.W. Grue, A.J. Lopez, D.M. Heimiller, M. Rossol, G. Buster, and T. Williams. 2019. *The Renewable Energy Potential (reV) Model: A Geospatial Platform for Technical Potential and Supply Curve Modeling.* Golden, CO: National Renewable Energy Laboratory. NREL/TP-6A20-73067. https://doi.org/10.2172/1563140.

Manson, S., J. Schroeder, D. Van Riper, T. Kugler, and S. Ruggles. 2022. *IPUMS National Historical Geographic Information System: Version 17.0*. Minneapolis, MN: IPUMS. https://doi.org/10.18128/D050.V17.0.

Mayfield, E., J. Jenkins. 2021. “Influence of high road labor policies and practices on renewable energy costs, decarbonization pathways, and labor outcomes.” *Environmental Research Letters* 16: 124012.

McHarg, A. 2016. “Community Benefit through Community Ownership of Renewable Generation in Scotland: Power to the People?” *Sharing the Costs and Benefits of Energy and Resource Activity: Legal Change and Impact on Communities*.

Michaud, G. 2020. “Perspectives on community solar policy adoption across the United States.” *Renewable Energy Focus* 33: 1–15.

Mooney, M. 2022. *How much can you save with community solar?* EnergySage.

MRLC. 2021. *NLCD 2021 Tree Canopy Cover (CONUS)*. Dataset, accessed 12 May, 2023. https://mrlc.gov/data/nlcd-2021-tree-canopy-cover-conus.

NCED. 2022. *National Conservation Easement Database*. Dataset, accessed 12 May, 2023. https://www.conservationeasement.us.

NREL. 2016. "PV Rooftop Database." Dataset, accessed 16 April, 2023. https://dx.doi.org/10.25984/1784725.

NREL. 2022. "2022 Annual Technology Baseline." Golden, CO: National Renewable Energy Laboratory. https://atb.nrel.gov.

ORNL. 2023. *USA Structures*. Dataset, accessed 15 January, 2023. https://disasters.geoplatform.gov/publicdata/Partners/ORNL/USA_Structures/.

PADUS. 2023. *U.S. Geological Survey*. Dataset, accessed 28 October, 2023. https://doi.org/10.5066/P9Q9LQ4B.

Paulos, B. 2022. *Review of Approaches to Energy Sovereignty*. Illinois Power Agency.

Ramasamy, V., J. Zuboy, E. O'Shaughnessy, D. Feldman, J. Desai, M. Woodhouse, P. Basore, R. Margolis. 2022. *U.S. Solar Photovoltaic System and Energy Storage Cost Benchmarks, With Minimum Sustainable Price Analysis: Q1 2022*. Golden, CO: National Renewable Energy Laboratory. NREL/TP-7A40-83586.

Ruth, M.F., P. Jadun, N. Gilroy, E. Connelly, R. Boardman, A.J. Simon, A. Elgowainy, J. Zuboy. 2020. *The Technical and Economic Potential of the H2@Scale Concept within the United States*. Golden, CO: National Renewable Energy Laboratory. NREL/TP-6A20-77610.

Schiavina, M., M. Melchiorri, and M. Pesaresi. 2023. GHS-SMOD R2023A – GHS settlement layers, application of the Degree of Urbanisation methodology (stage I) to GHS-POP R2023A and GHS-BUILT-S R2023A, multitemporal (1975-2030). European Commission, Joint Research Centre (JRC). DOI: 10.2905/A0DF7A6F-49DE-46EA-9BDE-563437A6E2BA.

Schröder, T., W. Kuckshinrichs. 2015. "Value of Lost Load: An Efficient Economic Indicator for Power Supply Security? A Literature Review." *Frontiers in Energy Research* 3: 55.

Sengupta, M., Y. Xie, A. Lopez, A. Habte, G. Maclaurin, and J. Shelby. 2018. "The National Solar Radiation Database (NSRDB)." *Renew. Sustain. Energy Rev.* 89, 51–60. https://doi.org/10.1016/j.rser.2018.03.003.

Sigrin, B. and M. Mooney. 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.

Spencer, R.S., J. Macknick, A. Aznar, A. Warren, M.O. Reese. 2019. "Floating Photovoltaic Systems: Assessing the Technical Potential of Photovoltaic Systems on Man-Made Water Bodies in the Continental United States." *Environ. Sci. Technol.* 53(3): 1680–1689.

The Nature Conservancy. 2023. *Power of Place.* https://www.nature.org/en-us/what-we-do/our-priorities/tackle-climate-change/climate-change-stories/power-of-place/.

Waechter, K. and T. Williams. 2021. *Assessment of Photovoltaic Technical Potential for Community Solar Gardens in Xcel Energy's Service Territory in Northern Colorado*. Golden, CO: National Renewable Energy Laboratory. NREL/TP-6A20-44596.

Wolf-Powers, L. 2011. *Community Benefits Agreements in a Value Capture Context*. In: Value Capture and Land Policies. Lincoln Institute of Land Policy.

Xu, K., J. Sumner, E. Dalecki, R. Burton. 2023. *Expanding Solar Access: State Community Solar Landscape (2022).* Golden, CO: National Renewable Energy Laboratory. NREL/TP-6A20-84247.

Xu, K. 2024. *Sharing the Sun Database, end of 2023 update*. Dataset, unreleased. Accessed January 24, 2024.

Zuckerman, G. R., A. Lopez, T. Williams, R. Green, and G. Buster. 2023. *Impacts of Siting Considerations on Offshore Wind Technical Potential in the United States*. Golden, CO: National Renewable Energy Laboratory. NREL/TP-6120-85088. https://www.nrel.gov/docs/fy23osti/85088.pdf.