The Los Angeles 100% Renewable Energy Study

Chapter 5. Utility Options for Local Solar and Storage

FINAL REPORT: LA100—The Los Angeles 100% Renewable Energy Study

March 2021

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Los Angeles Department of Water & Power

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Chapter 5. Utility Options for Local Solar and Storage

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Lead Author of Chapter 5: Meghan Mooney[1]

GIS Techno-Economic Analysis Modeling: Meghan Mooney,[1] Ben Sigrin,[1] Jane Lockshin,[1] Brady Cowiestoll,[1] Paul Denholm[1]

Distribution Modeling: Bryan Palmintier,[1] Kelsey Horowitz,[1] Sherin Abraham,[1] Tarek Elgindy,[1] Kwami Sedzro[1]

[1] National Renewable Energy Laboratory

Suggested Citation—Entire Report

Cochran, Jaquelin, and Paul Denholm, eds. 2021. *The Los Angeles 100% Renewable Energy Study*. Golden, CO: National Renewable Energy Laboratory. NREL/TP-6A20-79444. https://maps.nrel.gov/la100/.

Suggested Citation—Chapter 5

Mooney, Meghan, Bryan Palmintier, Ben Sigrin, Jane Lockshin, Brady Cowiestoll, Paul Denholm, Kelsey Horowitz, Sherin Abraham, Tarek Elgindy, and Kwami Sedzro. 2021. "Chapter 5: Utility Options for Local Solar and Storage." In *The Los Angeles 100% Renewable Energy Study*, edited by Jaquelin Cochran and Paul Denholm. Golden, CO: National Renewable Energy Laboratory. NREL/TP-6A20-79444-5. https://www.nrel.gov/docs/fy21osti/79444-5.pdf.

The Los Angeles 100% Renewable Energy Study

Produced under direction of the Los Angeles Department of Water and Power by the National Renewable Energy Laboratory (NREL) under ACT Agreement 18-39, LADWP Ref: 47481.

Los Angeles Department of Water & Power

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Context

The Los Angeles 100% Renewable Energy Study (LA100) is presented as a collection of 12 chapters and an executive summary, each of which is available as an individual download.

- The **Executive Summary** describes the study and scenarios, explores the high-level findings that span the study, and summarizes key findings from each chapter.
- **Chapter 1: Introduction** introduces the study and acknowledges those who contributed to it.
- **Chapter 2: Study Approach** describes the study approach, including the modeling framework and scenarios.
- **Chapter 3: Electricity Demand Projections** explores how electricity is consumed by customers now, how that might change through 2045, and potential opportunities to better align electricity demand and supply.
- **Chapter 4: Customer-Adopted Rooftop Solar and Storage** explores the technical and economic potential for rooftop solar in LA, and how much solar and storage might be adopted by customers.
- **Chapter 5: Utility Options for Local Solar and Storage** (this chapter) identifies and ranks locations for utility-scale solar (ground-mount, parking canopy, and floating) and storage, and associated costs for integrating these assets into the distribution system.
- **Chapter 6: Renewable Energy Investments and Operations** explores pathways to 100% renewable electricity, describing the types of generation resources added, their costs, and how the systems maintain sufficient resources to serve customer demand, including resource adequacy and transmission reliability.
- **Chapter 7: Distribution System Analysis** summarizes the growth in distribution-connected energy resources and provides a detailed review of impacts to the distribution grid of growth in customer electricity demand, solar, and storage, as well as required distribution grid upgrades and associated costs.
- **Chapter 8: Greenhouse Gas Emissions** summarizes greenhouse gas emissions from power, buildings, and transportation sectors, along with the potential costs of those emissions.
- **Chapter 9: Air Quality and Public Health** summarizes changes to air quality (fine particulate matter and ozone) and public health (premature mortality, emergency room visits due to asthma, and hospital admissions due to cardiovascular diseases), and the potential economic value of public health benefits.
- **Chapter 10: Environmental Justice** explores implications for environmental justice, including procedural and distributional justice, with an in-depth review of how projections for customer rooftop solar and health benefits vary by census tract.
- **Chapter 11: Economic Impacts and Jobs** reviews economic impacts, including local net economic impacts and gross workforce impacts.
- **Chapter 12: Synthesis** reviews high-level findings, costs, benefits, and lessons learned from integrating this diverse suite of models and conducting a high-fidelity 100% renewable energy study.

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Key Findings

Reaching 100% decarbonization of the LADWP power system will include renewable energy resources sited within the city limits of Los Angeles. In addition to customer-adopted rooftop solar (see Chapter 4), there is rich opportunity for locally sited, but non-customer-owned resources in LADWP territory. These options include ground-mount solar and storage, parking canopy solar, and floating solar—none of which is assumed to directly offset customer electricity consumption. This chapter explores the technical and economic viability of non-customer rooftop local solar and storage resources and the corresponding cost of integrating these technologies to the subtransmission portion (34.5kV) of the distribution grid.

- 5,700 MW_{PV} and 1,599 $MW_{Battery}$ of non-rooftop local solar technical potential exists within the LADWP in-basin service territory, i.e., for ground-mount (solar-only and solar-plus-storage), parking canopy, or floating solar projects.
  - Of this total, 850 MW of capacity exists for projects >10 MW, 2,100 MW for projects >1 MW, and the remainder for projects <1 MW.
  - Significant opportunity for local solar in LA exists in the city's parking lots. Parking canopy solar makes up the majority (58% or about 3,900 MW) of the city's local solar potential.
  - Though LA is urban, ground-mount solar makes up a considerable portion (40%, or about 2,200 MW) of the city's local solar opportunity.
- A site development cost ranking analysis of this potential (Figure 1) indicates that about 4,400 MW or about 80% of the non-rooftop local solar potential can be built at or below $100/MWh based on 2019 capital costs. These estimates do not include any existing or future federal or state incentives.
  - Single-axis tracking and floating solar sites are most highly ranked, but the largest potential overall for lands <$100/MWh is parking canopies (61%).
  - Land acquisition costs are assumed to be zero for parking canopy and floating solar sites, making many of them competitively ranked compared to ground-mount installations on non-government-owned lands.
  - Both land acquisition costs and distance to 34.5kV distribution interconnection lines play an important role in determining cost-optimal locations for siting PV in LA.

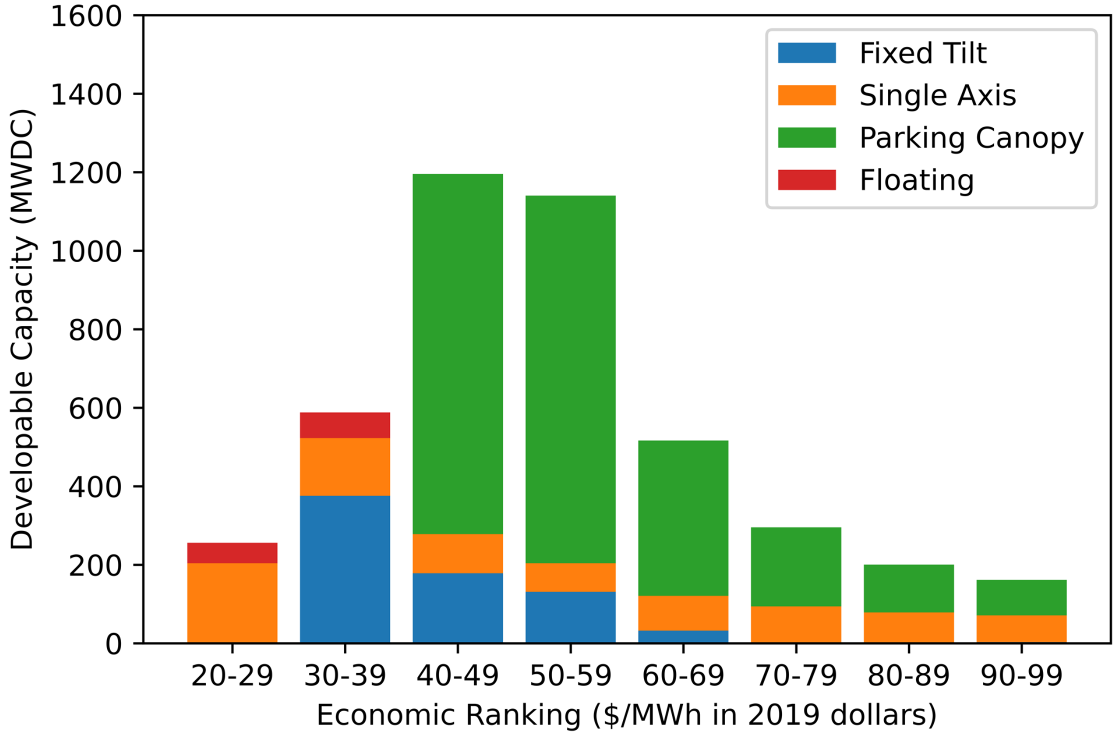


Figure 1. PV-only site cost ranking of non-rooftop solar sites with 2019 economic ranking <$100/MWh

- The additional distribution grid upgrade costs for integrating this non-rooftop local solar and storage (beyond the changes already required for load and customer rooftop solar) are generally low enough to not limit non-rooftop deployment.
  - If sited based on distribution system integration costs, approximately one-third (31%–37% depending on scenario) of the technical capacity could be integrated with zero additional distribution upgrade cost.
  - In some instances, the addition of non-rooftop local solar could slightly reduce (typically by less than 2%) the required distribution system upgrade costs compared to the cost of upgrades needed for load and non-rooftop solar.
  - Even with large quantities of non-rooftop solar, nearly all potential buildouts have <$20/kW average upgrade costs. This represents a small fraction of the estimated capital cost of non-rooftop solar (estimated at $1,065/kW in 2045).

1 Introduction

Many capacity expansion plans only consider the bulk power system (i.e., large generators and the high-voltage transmission network). However, reaching 100% decarbonization of the LADWP power system will include a combination of renewable energy resources sited within and outside the city limits of Los Angeles. In addition to customer-adopted rooftop solar (see Chapter 4), there is rich opportunity for locally sited, but non-customer-owned resources in LADWP territory. These options include ground-mounted solar and storage, parking canopy solar, and floating solar—none of which is assumed to directly offset customer electricity consumption. This chapter explores the technical and economic viability of non-customer rooftop local solar and storage resources and the corresponding cost of impacts on the subtransmission portion (34.5kV) of the distribution grid. Table 1 provides a taxonomy of terms used to describe these different solar and solar-plus-storage related technologies within the LA100 study.

The work in this chapter reflects the techno-economic analysis used to rank and site the available capacity for non-rooftop solar and corresponding storage as well as corresponding upgrade costs for the distribution system. The magnitude of local solar and storage potential and associated distribution-grid-integration costs are then used as inputs to the capacity expansion modeling (Chapter 6). The capacity expansion analysis in turn identifies investments in non-rooftop solar and storage within the city, but aggregated to each receiving station. The LA100 study then physically situates these resources to specific locations within the city based on the geospatial analysis described in this chapter. The distribution impact and cost analysis (Chapter 7) considers the impact of these resources as part of the suite of upgrades that would be required to manage all changes, including from changes to customer electricity demand, on the distribution grid.

Table 1. Solar and Solar-Plus-Storage Project Taxonomy in the LA100 Study

<table>
<tr><th>Project Location</th><th colspan="2">Technology Type</th><th>Definition</th><th>Deployment Method</th><th>Report Chapter</th><th>Project Costs in 2019 (2019$)</th></tr>
<tr><td>Out-of-basin solar</td><td colspan="2">Ground mount, single-axis tracking
(some with storage)</td><td>Megawatt-scale, transmission-connected, unspecified ownership. May also include coupled storage.</td><td>The quantity (MW) deployed and the spatial location is determined by the capacity expansion model (RPM).</td><td>Ch. 6</td><td>$\$1,579/\text{kW}_{AC}$</td></tr>
<tr><td rowspan="4">In-basin “local solar”</td><td colspan="2">Rooftop solar, fixed-tilt
(some with storage)</td><td>Distribution-connected systems adopted by consumers.</td><td>The quantity deployed and the spatial location is determined by the customer solar adoption model (dGen).</td><td>Ch. 4 (adoption)
Ch. 7 (distribution analysis)</td><td>$\$1,653/\text{kW}_{DC}$ (commercial)
$\$2,592/\text{kW}_{DC}$ (residential)</td></tr>
<tr><td rowspan="3">Non-Rooftop</td><td>Ground-mount, fixed-tilt and single-axis tracking
(some with storage)</td><td>Distribution-connected systems with unspecified ownership. May also include coupled or decoupled storage.</td><td rowspan="3">The quantity deployed is determined by the RPM model, and the spatial location is determined by the GIS site-ranking analysis.</td><td rowspan="3">Ch. 5 (technical and economic potential, distribution cost curves)
Ch. 7 (distribution analysis)</td><td rowspan="3">Cost imputed between utility-scale and commercial-scale based on project size, plus any identified distribution upgrades needed per project.</td></tr>
<tr><td>Parking canopy
(some with storage)</td><td>Distribution-connected systems with unspecified ownership and built on a parking lot canopy using fixed-tilt. May also include coupled or decoupled storage.</td></tr>
<tr><td>Floating solar</td><td>Distribution-connected systems deployed on water bodies using fixed-tilt.</td></tr>
</table>

Project costs are based on the NREL ATB (2019) and are in 2019$.

Goals for in-basin local solar deployment are explicitly defined within the Mayor's Los Angeles Green New Deal (pLAn 2019). These goals reflect a concern that the benefits of local solar are equitably shared among all LADWP ratepayers. Specifically, the pLAn describes the following local solar goals:

- Increase cumulative capacity of local solar to 1,950 MW[1] by 2045
- Create a standard plan that requires all new parking lot structures to have solar
- Provide community solar programs that expand access to solar savings for low-income and renter households via solar rooftops and shared solar programs.

As outlined in Table 1, the LA100 study interprets the pLAn local solar definition to include customer-adopted rooftop solar (as simulated by the dGen model and discussed in Chapter 4) and the non-rooftop local solar options explored in this chapter, such as ground-mount PV, floating solar, and parking canopy solar. Identifying non-rooftop solar options can facilitate siting decisions for community solar programs.

Deployments for non-rooftop local solar are determined by the Resource Planning Model (RPM, discussed in Chapter 6). However, from RPM alone, it is not obvious which urban sites are suitable for solar. Moreover, a consideration of the opportunity cost of land use is key—simply because a deployment *could* occur does not mean that it should. This component of LA100 helps define pathways to feasibly achieve the above goals at least cost to the ratepayer. This component of LA100 answers the questions: (1) What is the technical potential for non-rooftop local solar projects within the LADWP service territory? (2) What are the associated costs and locations of optimal project sites?

To answer these questions, we specifically considered:

1. The overall system needs for building in-basin solar and storage at projected price points that consider the local cost of land and labor in LA, as well as other local factors
2. The availability of suitable space for siting these resources, considering the potential for these sites to be ground-mounted solar plus storage, solar installed on a canopy structure in parking lots, and floating solar
3. The impact of the deployment of these resources on the distribution grid and associated upgrade costs at different penetration levels.

In this chapter, we review our methods, assumptions, and results in these three areas.

Context within LA100

This chapter is part of the Los Angeles 100% Renewable Energy Study (LA100), a first-of-its-kind power systems analysis to determine what investments could be made to achieve LA's 100% renewable energy goals. Figure 2 provides a high-level view of how the analysis presented here relates to other components of the study. See Chapter 1 for additional background on LA100, and Chapter 1, Section 1.9, for more detail on the report structure.

[1] For reference, in 2020 there was approximately 380 MW of rooftop solar, 25 MW of local utility-built solar, and 65 MW of local solar developed through the LADWP feed-in tariff program.

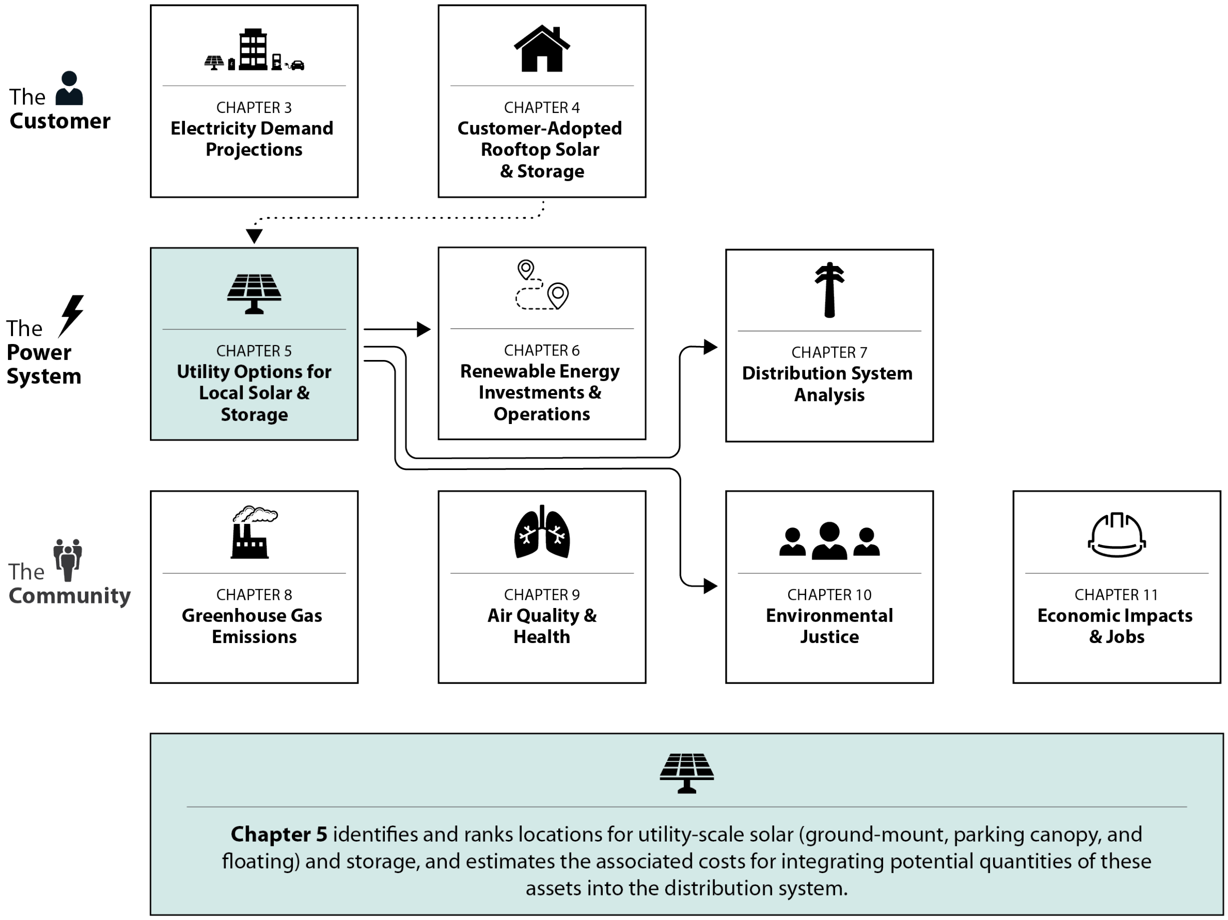


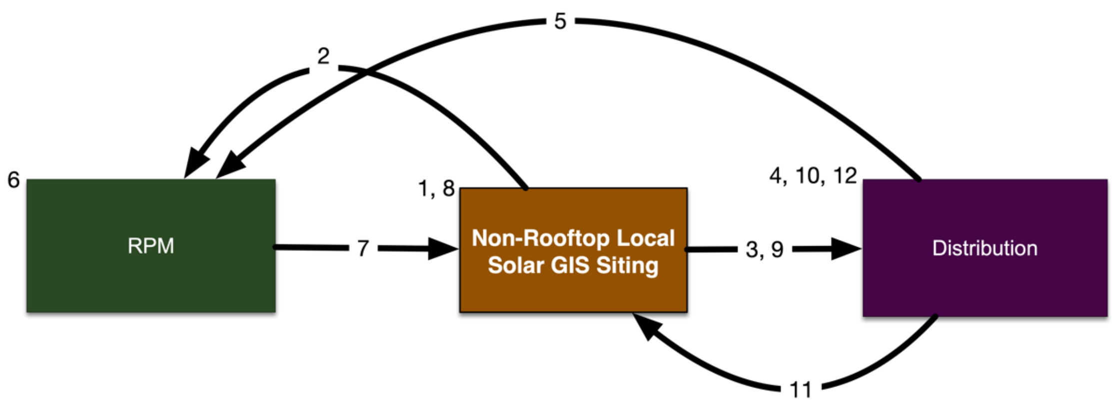
Figure 2. Overview of how this chapter, Chapter 5, relates to other components of LA100

Chapter 4 (Customer-Adopted Rooftop Solar and Storage) provides data on customer solar development connected to the subtransmission system, which serves as inputs to the hosting capacity analysis in this chapter. The results from this chapter provide inputs to the power system analyses in Chapters 6 and 7 and the environmental justice analysis in Chapter 10.

In particular, this chapter presents analysis for possible locations and associated distribution-grid-integration costs. The analysis that determines how much additional solar and storage would be of value for each scenario is addressed through systemwide planning, covered in Chapter 6. Chapter 7 evaluates the combined impacts of these installations, along with changes to customer electricity demand and rooftop solar to assess upgrades needed for the distribution grid.

2 Summary of Model Interactions

The link among the non-rooftop local solar GIS siting and distribution analyses and capacity expansion model is summarized in Figure 3. The capacity expansion model, RPM, operates at coarser geographic resolution than distribution analysis and lacks the spatial precision required to identify exactly where within the city to build, so GIS analysis was used to determine specific sites that could be economically developed. The GIS technical potential and site development cost ranking assessment are used both as inputs to RPM as well as an output siting method to place RPM nodal solar deployments on the grid. The distribution analysis requires the higher spatial resolution provided by the GIS analysis in order to accurately assess distribution impacts of the non-rooftop local solar in combination with load changes and customer-adopted solar and storage, which are estimated using the dGen model (see Chapter 4). The distribution upgrade cost curves, which describe how non-rooftop local solar integration costs vary with penetration level, served as inputs to RPM to understand if the costs were significant enough to potentially affect the nodes at which the capacity expansion model built non-rooftop local solar. However, based on 2045 built capacity, we found that the distribution costs were not high enough to influence the outcome of the capacity expansion modeling, so the distribution and bulk models were not mathematically linked.



1. Non-Rooftop Local Solar creates GIS siting evaluation and techno-economic ranking (Ch. 5).
2. Non-Rooftop Local Solar passes nodal capacity limits to RPM (Ch. 5).
3. Non-Rooftop Local Solar passes ranked sites to distribution.
4. Distribution creates cost curves (Ch. 5).
5. Distribution passes curves to RPM (Ch. 5).
6. RPM determines mix of generation investments required to reach 100% RE (Ch. 6).
7. RPM passes nodal local solar deployments for GIS siting (Ch. 7).
8. Non-Rooftop Local Solar sites RPM nodal solar deployments at optimal locations using GIS techno-economic ranking (Ch. 7).
9. Non-Rooftop Local Solar passes information on new non-rooftop solar and storage capacity to Distribution (Ch. 5).
10. Non-Rooftop Local Solar passes information on new non-rooftop solar and storage capacity to Distribution (Ch. 5).
11. f needed, iterate between GIS analysis and Distribution cost curves to adjust sites to reduce upgrade costs (Ch. 5).
12. Compute actual distribution integration costs (Ch. 7).

Figure 3. LA100 model interactions with the non-rooftop local solar siting analysis

3 Methodology and Assumptions

3.1 Siting Non-Rooftop Local Solar and Storage

As mentioned above, although the optimal non-rooftop local solar deployment capacities are determined by RPM based on a least-cost optimization that ensures reliability (discussed in Chapter 6), RPM lacks the spatial granularity to vet specific sites within the city. To resolve this constraint, we conduct a GIS-based siting analysis to screen and rank potential sites for solar and storage projects for each suitable parcel within LADWP's in-basin service territory. This GIS analysis considers whether a solar system could be sited within the parcel, then ranks its suitability based on a least-cost algorithm that considers project size, cost of land acquisition, land ownership, distance to 34.5kV grid interconnection, and current land use. The end result is a ranked list of potential solar sites that informs both (1) pathways toward achieving LADWP's local solar deployment goals and (2) interactions with capacity expansion (Chapter 6) and distribution grid integration efforts (Chapter 7) in the LA100 study.

3.1.1 Identifying Potential Non-Rooftop Local Solar Sites

The basic geographic units of analysis are the NREL-defined "land IDs," which colloquially are public and private parcels of land or distinct areas within LADWP's in-basin territory. Characteristics of the land IDs, or parcels, are assembled from multiple sources (covered in the appendix). Parcels with occupied and vacant buildings are sourced from the City of Los Angeles Tax Assessor Dataset (Los Angeles County 2017b). We also include specific floating solar sites that were provided by LADWP (Table 2). Potential parking canopy sites are identified using a layer of existing parking lots in Los Angeles (Los Angeles County 2014). After assembling each of these potential sites, we then apply technology-specific site exclusions to further refine potential sites for non-rooftop local solar development.

Table 2. Floating Solar Projects Considered in the GIS Siting Analysis

Project	Capacity (MW)
Lower Stone Lake Canyon Reservoir	28
Encino Reservoir	24
LA Reservoir	20
Silver Lake	17
Hollywood Reservoir	16
Upper Stone Canyon Reservoir	11
Upper Hollywood Reservoir	1
Green Verdugo Reservoir	0.5

3.1.2 Siting Exclusions for Non-Rooftop Local Solar Sites

To calculate the technical potential for non-rooftop local solar, we first exclude land in LADWP that is unsuitable for local solar development. Criteria for the majority of exclusions used in this study were based on a common core of exclusions described in Lopez et al. (2012). These are complemented by additional exclusions based on conversations with LADWP subject-matter experts. The following exclusions were applied, by technology type:

Ground Mount Exclusions

- Existing developments (buildings, streets, bike paths, airport runways)
- Land cover (water, wetlands, forests, shrubland, farmland)
- Parks and recreational sites
- Steep terrain (slope greater than 10%[2])
- Landmarks (schools, cemeteries, stadiums, etc.)
- Excessively shaded areas[3]
- Existing parking lots

Carport Exclusions

- Non-parking lot lands
- Residential parking lots[4]

The parking canopy analysis exclusively considers existing nonresidential parking lots. Additional siting parameters are described in Table 3.

Table 3. Additional Local Solar and Storage Siting Parameters

Component	Variable	Value	Source
Power Densities	Parking canopy solar PV module power density	183 W/m^2	NREL Cost Model (Unpublished)[a]
	Fixed-tilt power density	38.6 MW/km^2	Ong et al. (2013)
	Single-axis tracking power density	35.3 MW/km^2	Ong et al. (2013)
	Storage[b]	< 1 MW: 17 MW/acre 1–10 MW: 32 MW/acre 10–50 MW: 44 MW/acre 50–100 MW: 49 MW/acre	Engineering estimate[c]

[2] Based on LADWP feedback, the traditional >5% slope exclusion used in national analyses was relaxed to a 10% threshold to allow for steeper terrain currently being developed in Los Angeles.
[3] We used a metric called topographic position index (TPI) to exclude shaded areas. TPI is a calculation of the difference in elevation of a given raster cell to cells in its immediate neighborhood; that is, TPI creates a proxy for shading from building shadows for a given parcel relative to its neighboring buildings. Areas with negative TPI values were excluded as being excessively shaded. The TPI was calculated using LiDAR-derived building footprint data with building height information (Los Angeles County, 2017a). The TPI does not account for shading from trees because we assume trees will be excavated for canopy or ground-mount PV development.
[4] Residential parking lots are excluded due to data availability.

Component	Variable	Value	Source
		>100 MW: 51 MW/acre	
Land Use Area Requirements	Ground-mount contiguous land area	Land with area for at least 50-kW projects	N/A
	Parking lot contiguous canopy area	Parking canopies with area for at least 5 kW projects	LADWP[d]
	Parking canopy setbacks	1 meter	NREL[e]
	Storage to PV capacity ratio	4-hr: 0.71 8-hr: 1.0	Engineering Estimate

[a] NREL assumes a 183 W/m^2 panel power density based on a stated panel efficiency of 17.4% for poly-crystalline modules in 2018 from the California Net Energy Metering Database with a packing density of 95%.

[b] For siting solar-plus-storage, we give preference to ground-mount sites (i.e., single-axis and fixed-tilt); however, in practice, we allow solar-plus-storage to be sited on some carport sites if demanded by the capacity expansion model.

[c] The storage power density estimate assumes an average 53 MW/acre and 20-foot setback for 4-hour storage.

[d] Based on LADWP feedback, 5 kW was determined to be the minimum project size that LADWP would consider for parking canopy PV deployment.

[e] NREL assumes a 1-meter setback from the road for canopy construction. NREL also assumes that parking canopies are built with heights tall enough to accommodate fire trucks.

3.1.3 Calculating the Economic Ranking of Sites

After excluding sites based on technical unsuitability, all remaining sites are ranked by their development cost in $/MWh in 2019 dollars. Our economic ranking is a modified version of levelized cost of energy (LCOE). LCOE is a metric that evaluates the time-discounted cost of energy over the system lifetime and is appropriate for comparing the cost of energy for competing project sites. An alternative interpretation of LCOE is that it is the minimum amount of compensation per MWh generated that would be needed to recover project costs, including profit margin. The economic ranking metric is distinct from the standard LCOE formula in that it includes a unitless favorability scalar and that land lease costs are included in variable operation and maintenance costs. Thus, while economic ranking is interpretable in $/MWh terms, it should not be literally interpreted as a levelized cost of energy.

The following elements to our modified LCOE calculation are considered: overnight capital cost ($/kW); fixed operation and maintenance costs ($/kW-year); project weighted cost of capital (WACC); cost of private land purchase ($/ft^2) or public land lease ($/site-year); cost of grid interconnection ($/ft); cost differences for union vs. non-union labor (%); and project cost scalars for favorable or unfavorable sites (%) (Table 4). The economic ranking does not include any federal or state incentives (e.g., Federal Investment Tax Credit).

The formula for economic ranking (1) is:

$$Economic\ Ranking\ = FS * \frac{(\ FCR\ *\ CAPEX\ +\ FOM\ ) + 1000}{(CF * 8760)} +\ VOM\ (1)$$

Where FS is the favorability scalar (unitless), FCR is the fixed charge rate (%, amount of revenue per dollar of investment required that must be recovered annually to pay the carrying charges on that investment), CAPEX is the overnight turn-key capital cost ($), FOM is the fixed annual operation and maintenance cost ($), CF is the annual system capacity factor (%), and VOM is the variable operation and maintenance cost ($/kWh).

Furthermore, the formula for CAPEX (2) is:

$$CAPEX = Overnight\ capital\ cost + Cost\ to\ interconnect + Land\ acquisition \quad (2)$$

Overnight capital cost is calculated based on the 2019 NREL Annual Technology Baseline (ATB) (NREL 2019) cost for solar PV systems based on their size (kW). Overnight capital costs (in 2019$) are capacity based as determined by an exponential interpolation between the capital cost of utility-scale projects (23 MW at $1,094/kW) and commercial-scale projects (0.3 MW at $1,653/kW). To avoid double-counting the cost of land acquisition, we subtract $0.03/W from the ATB capital costs—which is the generic NREL assumption for land acquisition costs—as we can more accurately calculate site costs based on their assessed land value. Capital costs are escalated by 13% for projects sited on government-owned lands, which we presume would be LADWP built, to account for LADWP union labor costs as compared to a private developer. Finally, the LCOE is adjusted to include other considerations provided by LADWP, including the prioritization of vacant land, brownfield sites, and Ports of Long Beach and Los Angeles parking canopy solar, as well as the de-prioritization of industrial refiners, land within 500 feet of public transit, and ground-mount sites near airports and the Ports. Prioritization of sites was done through a -2.5% scalar to the economic ranking while de-prioritization of sites was done through a +2.5% increase. Further details of the economic ranking parameters are listed in Table 4.

Table 4. Parameters Affecting Non-Rooftop Local Solar Economic Ranking Calculation (2019$)

Component	Variable Category	Variable	Value	Source
Fixed charge rate (FCR)		All technologies[a]	0.052	NREL 2019 Annual Technology Baseline Data – PV Utility
Capital costs (CAPEX)	Overnight capital cost	Utility-scale project, benchmarked at 23 MW	$1,094/kW$_{DC}$	NREL 2019 Annual Technology Baseline Data – PV Utility
		Commercial-scale project, benchmarked at 0.3 MW	$1,653/kW$_{DC}$	NREL 2019 Annual Technology Baseline Data – PV Commercial
	Cost to Interconnect[b]	Underground lines	$812.46/ft	LADWP
		Overhead lines	$100/ft	LADWP

Component	Variable Category	Variable	Value	Source
	Land Acquisition	Private land cost based on assessed value (excludes parking canopies and floating solar)	Variable, $/ft²	LA County Tax Assessor's Database (2017)
		LADWP-owned land	$0/year/site	LADWP
		Public land, non-LADWP owned	$10,000/year/site	LADWP
Fixed operation and maintenance costs (FOM)		Utility-scale project (fixed-tilt and 1-axis tracking)	$13.4/kW$_{DC}$-year	NREL 2019 Annual Technology Baseline Data – PV Utility
		Commercial-scale project (parking canopy and floating solar)	$16.5/kW$_{DC}$-year	NREL 2019 Annual Technology Baseline Data – PV Commercial
Variable operation and maintenance costs (VOM)		All technologies	$0/kWh	NREL 2019 Annual Technology Baseline
Other costs		Union labor costs for government-owned land	+13% TCC cost increase	LADWP
		High-priority sites for development: Vacant parcels Brownfield sites Port of Long Beach (parking canopy solar)[c]	0.975 (i.e., reduces economic ranking by 2.5%)	LADWP
		Low-priority sites for development: Refineries Port of Long Beach (ground-mounted) Residential land within 500 ft of public transit	1.025 (i.e., increases economic ranking by 2.5%)	LADWP

[a] An economic life of 20 years is assumed for all technologies.

[b] This captures the cost of running additional 34.5kV electric distribution lines to the nearest existing 34.5kV lines. Transformer costs are already included in equipment capital cost estimates, and additional upgrades required on the distribution system to accommodate the new sites are treated separately as described in the next section (Section 3.2).

[c] Based on LADWP feedback and current discussions of building parking canopy PV at the Port of Long Beach, we have applied a -2.5% FCR cost reduction in effort to prioritize parking canopy PV decisions at the Port.

Summary of Assumptions— Non-Rooftop Local Solar and Storage

- This GIS analysis screens and ranks potential sites for non-rooftop solar projects for each suitable parcel within the city of LA. The analysis considers whether a solar system could be sited within the parcel, then ranks its suitability based on a least-cost algorithm that considers project size, cost of land acquisition, land ownership, distance to 34.5kV grid interconnection, and current land use.
- Customer-sited rooftop solar is treated separately (see Chapter 4).
- Four solar configurations were considered: fixed-tilt and single-axis tracking ground-mount solar, fixed-axis floating PV, and fixed-tilt parking canopy PV. Additionally, two solar-plus-storage configurations were considered: fixed-tilt plus storage and single-axis tracking ground-mount solar plus storage.
- Non-rooftop local solar sites are first excluded based on technical unsuitability. Remaining sites are then ranked by their site economic ranking in \$/MWh in 2019\$.
- Technical suitability:
    - Exclusion criteria for ground-mount systems include existing developments (i.e., buildings, streets, bike paths, airport runways), certain land covers (i.e., water, wetlands, forests, shrubland, farmland), parks and recreational sites, steep terrain (slopes > 10%), landmarks (i.e., schools, cemeteries, stadiums, etc.), excessively shaded areas, and existing parking lots. Exclusion criteria for parking canopy solar include non-parking lot lands and residential parking lots. For floating solar, we exclude all lands except eight reservoir sites provided by LADWP.
    - For ground-mount systems, we require suitable lands to be large enough to at least fit a 50-kW project. For parking canopies, we require parking lots large enough to fit a 5-kW system with a 1-meter setback.
    - For fixed-tilt ground-mount and fixed-tilt floating solar we assume a power density of 38.6 MW/km^2. For single-axis tracking ground-mount solar we assume a power density of 35.3 MW/km^2. For parking canopy solar, we assume a power density of 183 MW/km^2. When siting solar plus storage, we take into consideration the power density of batteries, which we assume is a function of capacity, with an average of 53 MW/acre and assuming a 12-foot setback.
- Site development cost ranking analysis:
    - The following elements for the economic ranking calculation are considered: overnight capital cost (\$/kW); fixed operation and maintenance costs (\$/kW-year); project weighted cost of capital (WACC); cost of private land purchase (\$/ft^2) or public land lease (\$/site-year); cost of grid interconnection (\$/ft); cost differences of union vs non-union labor (%); and project cost scalars for favorable or unfavorable sites (%).
    - Based on LADWP feedback, we prioritized vacant parcels, brownfield sites, and the Ports (for parking canopy solar), while we deprioritized refineries, ground-mount solar at the Ports, and residential lands within 500 ft of public transit. Prioritization of sites was done through a -2.5% scalar while de-prioritization of sites as done through a +2.5% scalar.
    - Capital costs are escalated by 13% for projects sited on government-owned lands, which we presume would be LADWP-built, to account for LADWP union labor costs as compared to a private developer.
- Interactions with other models:

- This GIS non-rooftop local solar siting analysis links the distribution and capacity expansion models in the LA100 modeling framework. The capacity expansion model, RPM, operates at coarser geographic resolution; however, it lacks the spatial precision required to identify exactly where within the city to build. The non-rooftop local solar GIS siting feasibility and site development cost ranking analysis provide inputs to the systemwide expansion planning effort (Chapter 6) by providing a transmission node-level aggregate of the best technically feasible site and a site cost ranking of cost-optimal parcels of land to build solar on the distribution system (Chapter 7). The local solar GIS siting analysis also interacts with the dGen and distribution models to ensure that planned sites do not result in distribution violations. Each of these models are iterated to ensure convergence.
- Per-node technical potential capacities from the GIS suitability analysis are capped at $82.6/MWh and then fed to RPM to provide their nodal technical potential baseline.
- Total rooftop (Chapter 4) and non-rooftop local solar deployments (Chapter 7) are compared to the LA Mayor's pLAn local solar goals to ensure capacity compliance in 2030 and 2045.

3.2 Determining the Distribution Upgrade Costs for Integrating Non-Rooftop In-Basin Solar

After creating a ranked list of potential sites for possible deployment of non-rooftop solar and storage as described above, we sought to understand the potential costs of integrating installations of these resources onto the distribution grid while keeping the grid within acceptable operating ranges. This analysis utilized the same distribution analysis tools and techniques described in detail in Chapter 7. A summary of the non-rooftop solar and storage evaluation is included here for reference, summarized in four steps:

1. Develop and validate electric distribution models: This study created electrical models for the majority of the circuits on the distribution system. Such models did not previously exist. These models were created using LADWP's GIS database, other data sources from LADWP, and extensive discussion with and review by LADWP's distribution subject-matter experts.
2. Use automated distribution upgrades to estimate the cost of upgrading from today's distribution grid to 2045 without any non-rooftop solar. Load changes and rooftop solar are included.
3. Use the same automated distribution upgrade approach to estimate the costs of increasing amounts of non-rooftop solar. The different non-rooftop solar quantities were derived based on the ranked list of solar sites from the analysis described in above (from lowest to highest cost). The first deployment corresponds to installing only the highest-ranked (lowest-cost) group of sites, the second to installing the #1 and #2 ranked sites, the third to installing the #1, #2, and #3 ranked sites, and so on. A total of 36 levels of non-rooftop solar for each of the 19 subtransmission (receiving station, or RS) regions were evaluated.
4. Compare the costs for each deployment to the corresponding case without non-rooftop solar to compute the additional cost (or savings) for the non-rooftop solar integration. This creates a cost curve for the integration of non-rooftop solar as function of installed solar and storage.

In all cases, upgrade cost analysis is conducted using a NREL-developed automated upgrade algorithm (described in more detail in Chapter 7), which was required due to the large number of circuits under study. The set of possible upgrades include a range of traditional utility upgrades (e.g., new voltage regulators, adjusting regulator set points, reconductoring). We do not consider building new circuits in this analysis or emerging solutions (e.g., the use of distributed energy management or advanced distribution management systems), although both solutions could play a role in practice. Upgrades assume advanced inverter controls (autonomous volt-var plus volt-watt control) are used on all solar and storage.

Summary of Assumptions— Estimate Cost Curve for Integrating Non-Rooftop Local Solar Connected Solar and Storage

- Cost curves for integrating non-rooftop local solar were only calculated for 2045.
- Non-rooftop local solar was sited solely based on the economic and land use ranking, which includes costs to extend distribution lines to sites for interconnection, but without optimizing locations for further distribution grid value, such as to reduce distribution upgrade costs.
- Upgrade costs are based on cost data from LADWP and supplemented where necessary with other California costs from the NREL Distribution Unit Cost Database (Horowitz 2019) that were reviewed by LADWP experts.
- Simulations were conducted for 11 timepoints in the year, corresponding to both system and local peaks, max solar to load ratio, and other key design points as described in Chapter 7.
- Upgrades were used to correct line and transformer overloads and over and under voltages.
- Results from over 84% of the 34.5kV system (13 of 19 RS stations and associated 34.5kV circuits) were used in developing cost curves. The missing regions encountered modeling, numeric or computational errors so were excluded. In some cases, missing scenario results from the 13 regions used were estimated from similar scenarios on the same region. Of these 10 regions successfully examined all suitable sites identified in the technical potential analysis above. Of the other three regions, an average across scenarios of 77%–99% of the maximum technical capacity was able to be included.
- Additional assumptions are included in Chapter 7.

4 Results

4.1 How Much Local Non-Rooftop Solar Is Theoretically Developable and How Much Might It Cost?

LADWP has 5,666 MW_{PV} and 1,599 $MW_{Battery}$ of non-rooftop local solar technical potential within its service territory. Table 5 provides a total accounting of LADWP in-basin technical potential for all types of non-rooftop local solar, including solar-plus-storage. Of the total available potential, parking canopy solar makes up 58%, or 3,295 MW, while ground-mount solar makes up 40%, or 2,252 MW. The majority of ground-mount and parking canopy solar is located in non-LADWP owned lands, though the majority of potential on LADWP-owned lands is made up of ground-mount (64%) or floating solar (32%) types. Of the total non-rooftop local solar technical potential, 852 MW of capacity exists for projects >10 MW, 2,136 MW for projects >1 MW, and the remainder for projects <1 MW. Of the 5,666 MW of technical potential for non-rooftop local solar, we estimate 4,354 MW (77%) could be deployed at a modified levelized cost of energy (LCOE) of < $100/MWh based on 2019 capital costs.

Table 5. Technical Potential for All Types of Non-Rooftop Local Solar and Storage (Ground Mount, Parking Lot Canopy, and Floating Solar)

	Developable PV Capacity (MW_{DC})	Developable Storage Capacity (MW_{DC})	Developable Land Area (km^2)	Developable LADWP-Owned Area (km^2)	Total Developable Sites
Ground Mount	2,252[a]	1,599[b]	62.23	5.40	11,765
Parking Lot Canopy	3,296	0	18.01	0.30	19,036
Floating	118	0	2.69	2.69	8
Total Non-Rooftop	**5,666**	**1,599**	**82.93**	**8.39**	**30,809**

[a] Because urban land is scarce, potential for ground-mount solar varies if there is on-site storage.

[b] This assumes 4-hr batteries. Depending on battery type (i.e., 4-hr or 8-hr), the storage technical potential of solar-plus-storage installations will vary, and it will affect the associated PV capacity.

Potential project sites differ substantially by costs and how well they meet LADWP preferences. Figure 4 shows the ranking of the developable non-rooftop local solar sites stratified by the four technology configurations. As a reminder, our economic ranking, or modified LCOE, is calculated using the value of land, distance to interconnection, economies of scale, and the standard NREL siting exclusions. Additionally, we include land use considerations provided by LADWP, including the prioritization of vacant land, brownfield sites, and Ports of Long Beach and Los Angeles parking canopy solar, as well as the de-prioritization of industrial refineries, land within 500 feet of public transit, and ground-mount sites near airports and the Ports. In this ranking, as depicted in Figure 4, single-axis tracking and floating solar sites are most highly ranked, but the largest potential overall for lands <$100/MWh is parking canopies (61%). Land acquisition costs are assumed to be zero for parking canopy and floating solar sites, making many of them competitively ranked compared to ground-mount installations on non-government-owned lands.

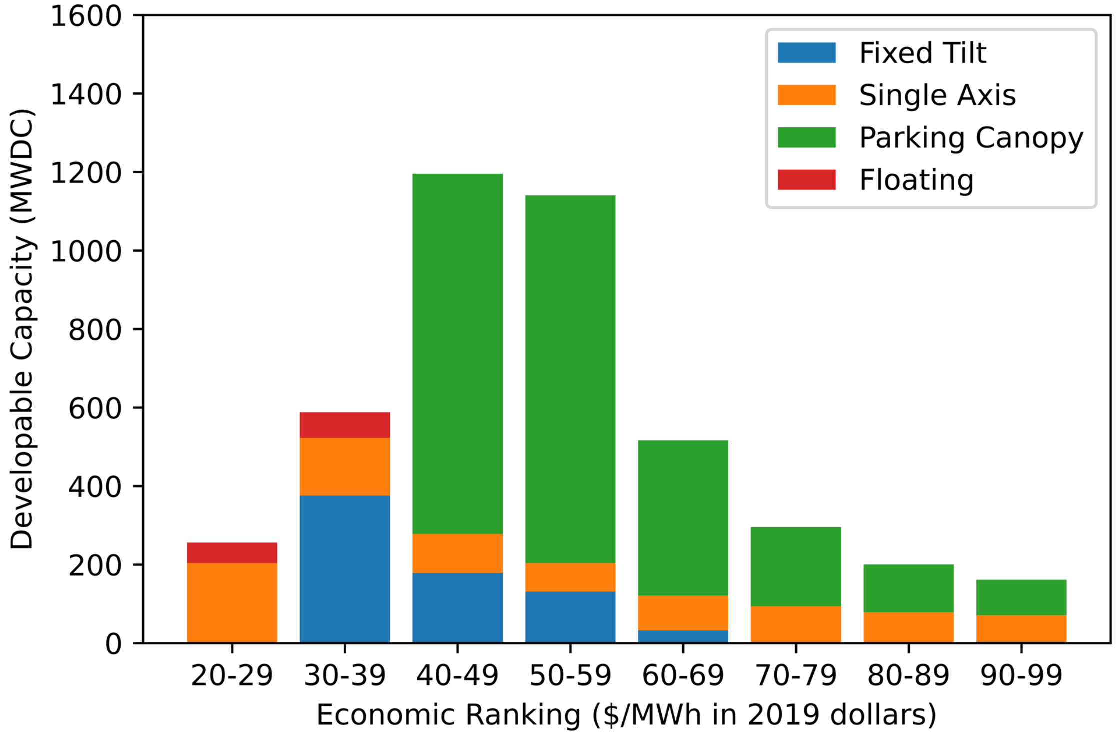


Figure 4. PV-only site cost ranking of non-rooftop local solar sites using LADWP's preference ranking with 2019 economic ranking < $100/MWh

4.1.1 Which Areas of LADWP Have the Most Potential Sites for Non-Rooftop Local Solar Development?

The left side of Figure 5 shows the amount of non-rooftop local solar technical potential (in MW) by census tract, which serves as proxies for neighborhoods. Several tracts have technical potential greater than 100 MW, but the Port of Long Beach, Los Angeles International Airport (LAX), and northwest Los Angeles are particularly noteworthy. The right side of Figure 5 shows the modeled average economic ranking by tract, grouping all sites that have technical potential. As shaded, darker-green tracts represent those associated with more expensive solar projects. From this map, we can see that the cheapest lands for non-rooftop local solar (i.e., lighter green shades) exist in areas with larger concentrations of LADWP- or other government-owned lands while the most expensive tracts tend to be further away from 34.5kV distribution interconnection lines or have higher land values. Due to the zero land acquisition costs associated with parking canopies, much of the city's tracts have reasonably lower average economic rankings in 2019. Comparing the two maps, much non-rooftop local solar potential exists across the city at reasonably low costs for in-basin resources.

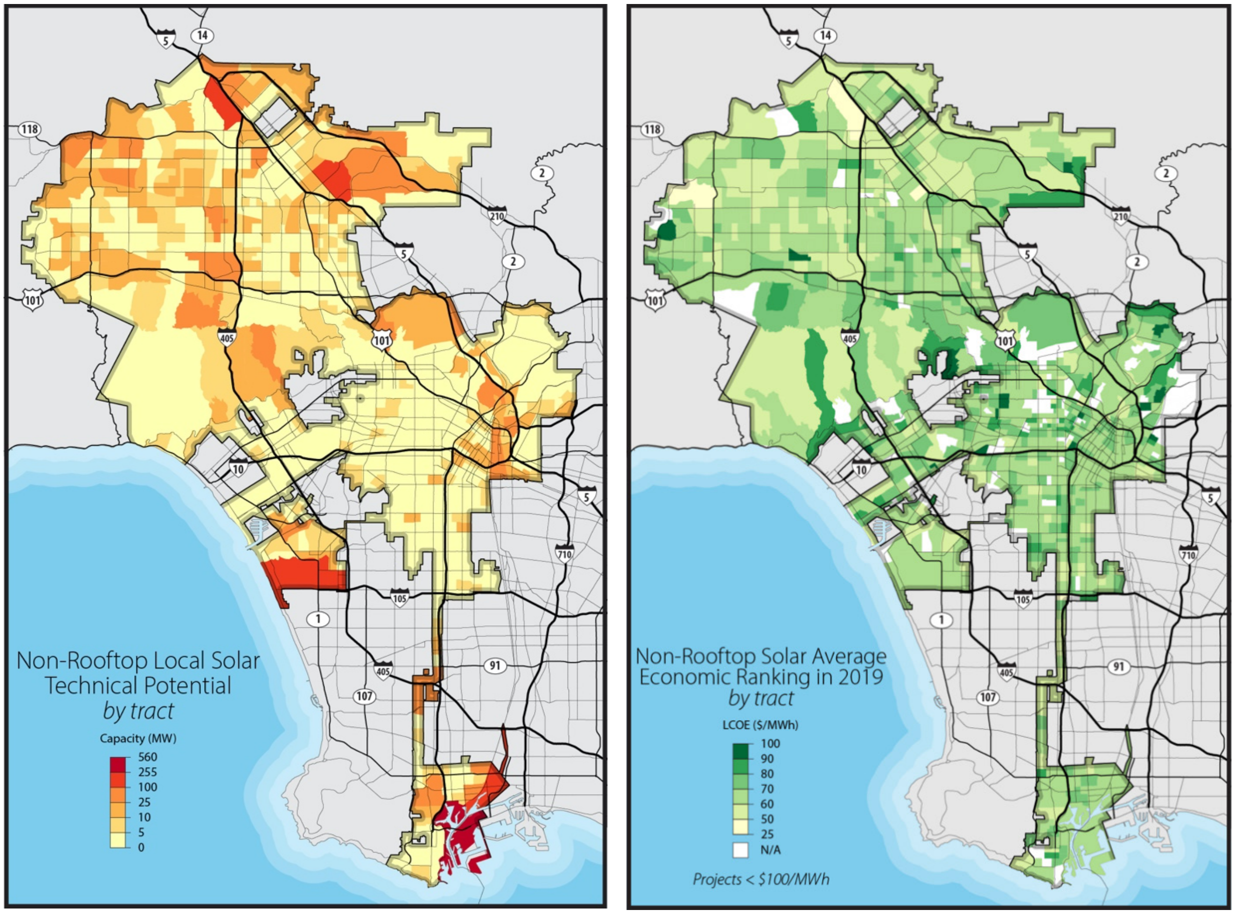


Figure 5. Non-rooftop local solar (PV-only) by tract: technical potential (left) and average economic ranking (right) in 2019 for projects <$100/MWh

4.1.2 How Sensitive Are the Non-Rooftop Local Solar Siting Results to Different Key Factors?

Figure 6 and Figure 7 demonstrate sensitivity of the ranking algorithm to three factors. Figure 6 shows the amount of technical potential by cost of land acquisition. The majority of <$100/MWh sites correspond to zero- or low-cost land (i.e., parking canopy, floating solar, or on LADWP land); however, there are still feasible sites at higher land costs.

Figure 7 shows the amount of technical potential by cost of interconnection. Costs are primarily based on distance to a 34.5kV interconnection point using either underground or overhead lines. The most frequent grid interconnection cost was zero, which occurs when a 34.5kV line intersects the site itself. Note that the interconnection cost is primarily based on line extension costs and not based on project size; larger-capacity projects might require modifications to the distribution system, the costs are which are not included in this figure.

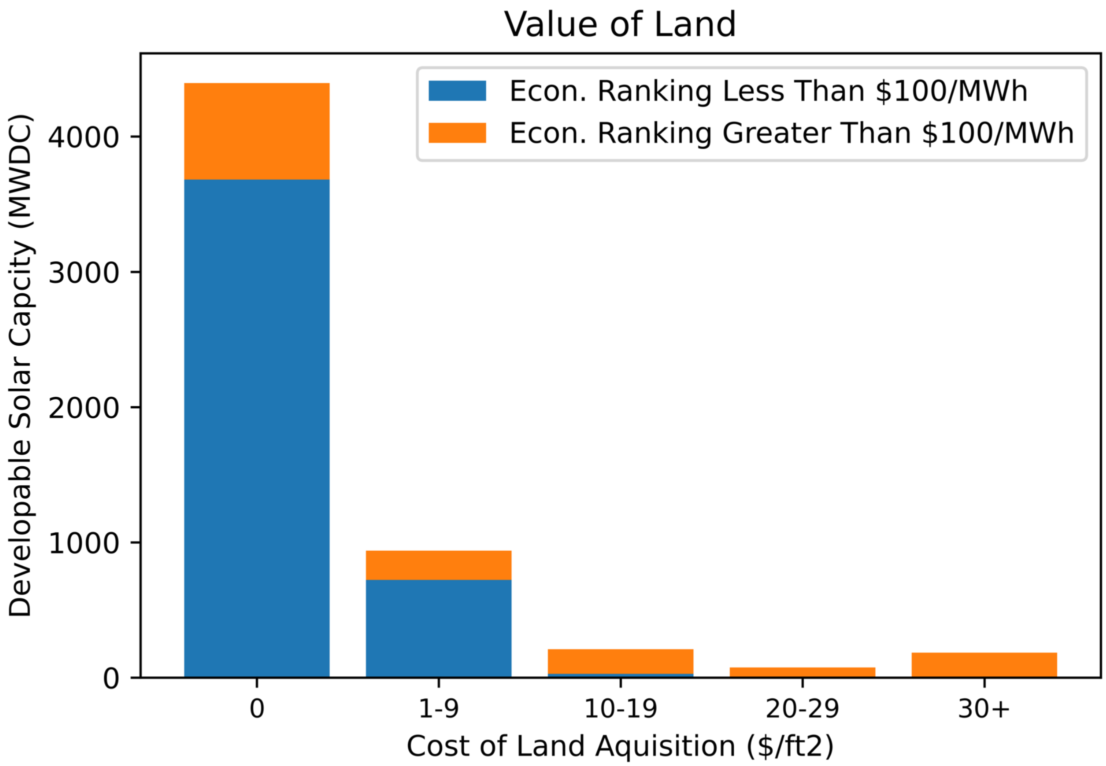


Figure 6. Distribution of developable local solar PV capacity by land acquisition cost and economic ranking

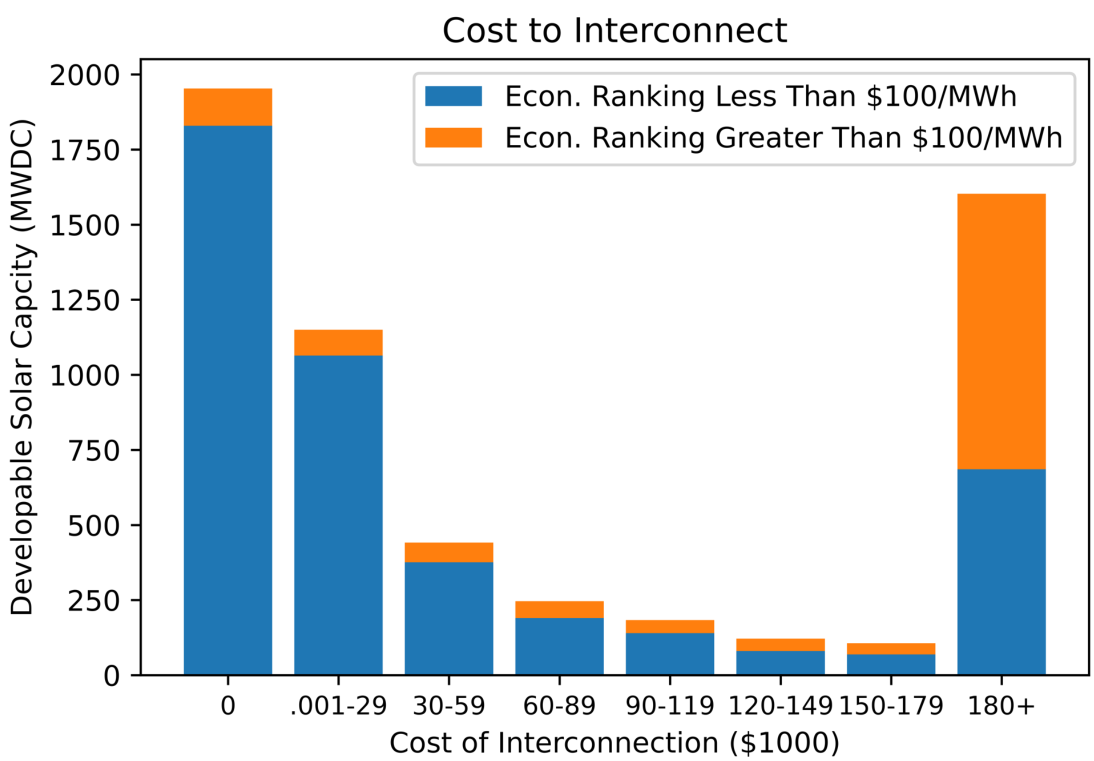


Figure 7. Distribution of developable local solar PV capacity by grid interconnection cost and economic ranking

4.2 How Do Distribution Grid Upgrade Costs Vary with the Quantity of Non-Rooftop Local Solar Deployed?

Figure 8 shows the quantity of non-rooftop solar that can be installed across the LADWP in-basin service territory for various costs per kW for all scenarios. In total, there is some deferral value (costs <$0/kW) for all scenarios for appropriately sited penetration levels of at least 250 MW. The greatest amount of local solar can be deployed with "negative costs" in the SB100 – Stress scenario because the local solar is able to defer some of the upgrades that would otherwise be needed to accommodate the very high loads associated with that case.

Figure 8 also shows that in all scenarios, significant amounts (1.8–2.2 GW, depending on scenario) of appropriately sited non-rooftop solar could be installed without increasing distribution upgrade costs beyond those already needed for load and rooftop solar alone (shown as <=$0/kW), and an additional 1 GW can be installed for ≤$5/kW. This is the case even with the solar deployed according to the rankings developed based on the GIS analysis described above, rather than by optimizing solar placement to minimize distribution grid integration costs and/or maximize deferral benefits. This cost is also based on utilizing only traditional solutions for grid integration, rather than leveraging any existing or emerging new technologies and approaches.

For reference, the installed 2045 capital cost used for non-rooftop local solar before grid upgrades was $1,065/kW, so even the higher categories of distribution upgrade costs (e.g., $20/kW) represent just a few percent of the project cost.

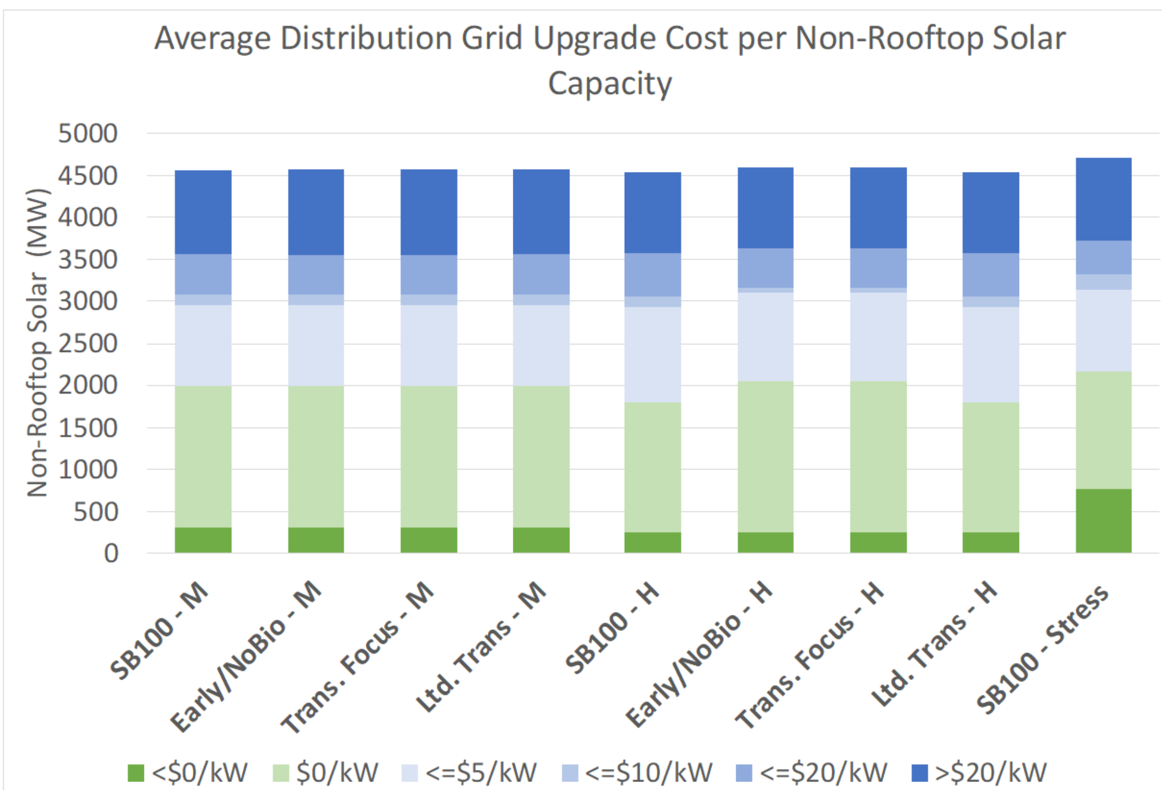


Figure 8. Distribution grid upgrade cost per systemwide non-rooftop solar capacity (2045)

These results include results from only about 84% of the 34.5kV system, so additional capacity would likely be available in each of the cost groupings if these regions were added.

4.2.1 Looking Deeper: Non-Linear Patterns of Grid Upgrade Costs for Non-Rooftop Distribution-Connected Solar

At the regional (RS) level, the function of upgrade costs for increasing amounts of non-rooftop solar can vary widely due to local grid conditions and loading patterns. Figure 9 shows an example region where up to about 125 MW of solar can be added without requiring any additional upgrade cost beyond that already required for load and rooftop solar. A range of capacities that can be built without requiring upgrades is found in 88%–93% of modeled regions, depending on the scenario. A series of discrete upgrades enables ever-larger amounts of solar to be added. After each upgrade, there is another plateau at which some additional solar can be added before the next upgrade is required.

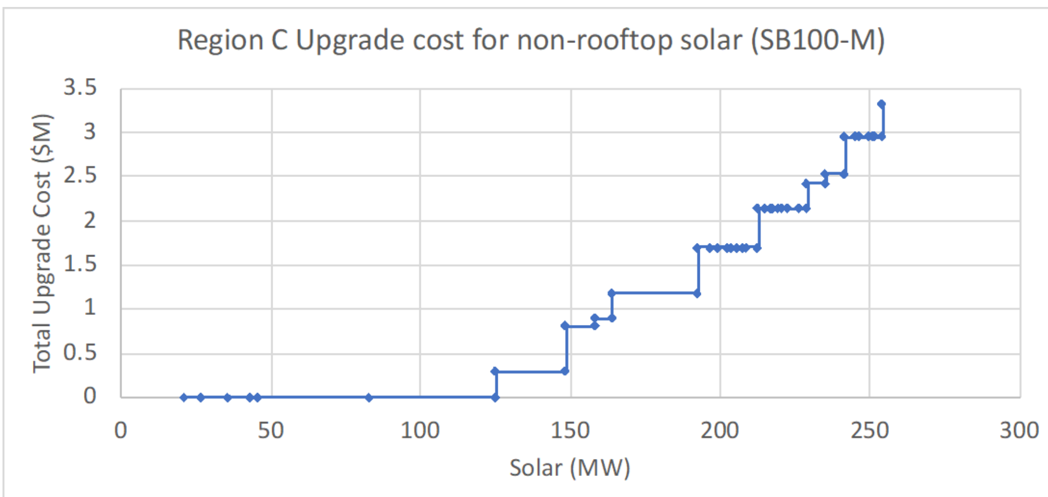


Figure 9. Distribution upgrade costs for non-rooftop solar showing zero integration cost up to about 125 MW, followed by a series of upgrades being required as the quantity of solar increases

After each upgrade, some additional solar can be added without requiring additional upgrades

As seen in Figure 10, in other regions, such as region S in the SB100 – Moderate scenario, all identified solar sites can be integrated without requiring any upgrades.

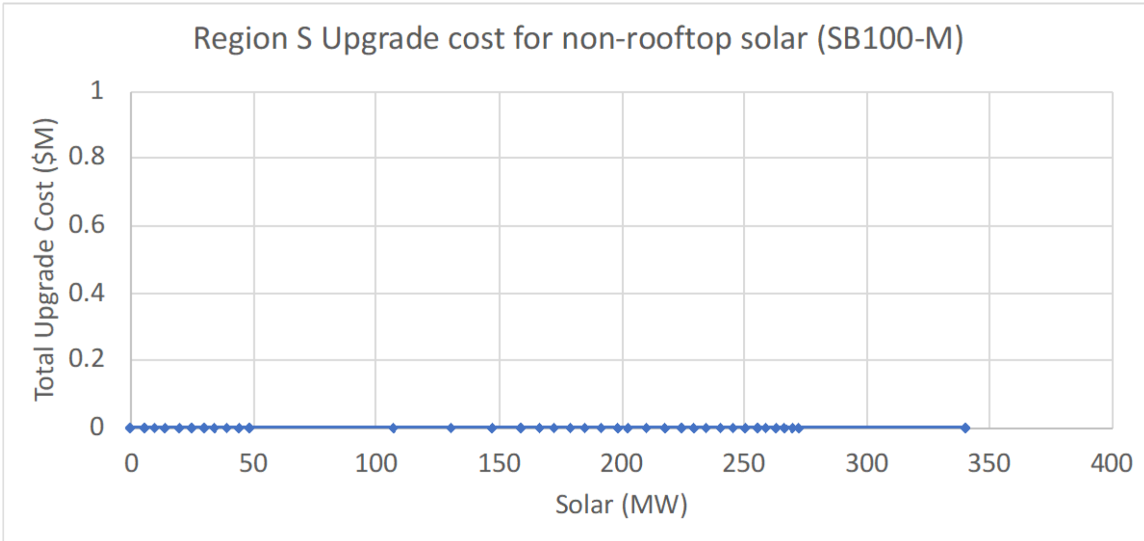


Figure 10. Non-rooftop solar integration cost curve showing zero upgrade cost up to the maximum capacity of identified sites

In other regions, after the first upgrade, there is a region of relatively low upgrade costs up until a considerably higher point after which additional upgrades are required more frequently as the total costs climb more steeply (see Figure 11). In this same figure, Region M in the SB100 – Moderate scenario shows how an increase in total solar may not always drive an increase in relative upgrade costs. Here, the costs (beyond those needed for load and rooftop solar) increase and then decrease again (as shown by the “ripples” in the cost curve). This could be due to a certain quantity of solar (e.g., ~110 MW in Figure 11), requires some form of upgrade, causing a non-zero cost. While when additional sites are added—based on the ranking described in Section 3.1—they defer the need to upgrade some piece of equipment to support load or rooftop solar, which decreases the relative total upgrade cost (e.g., at ~175 MW in Figure 11). Yet more non-rooftop solar may then require additional upgrades, bringing the cost up and so forth causing the ripples. However, as shown in Figure 11, at some point the quantity of non-rooftop solar can eventually be high enough to cause a monotonic increase in cost with penetration.

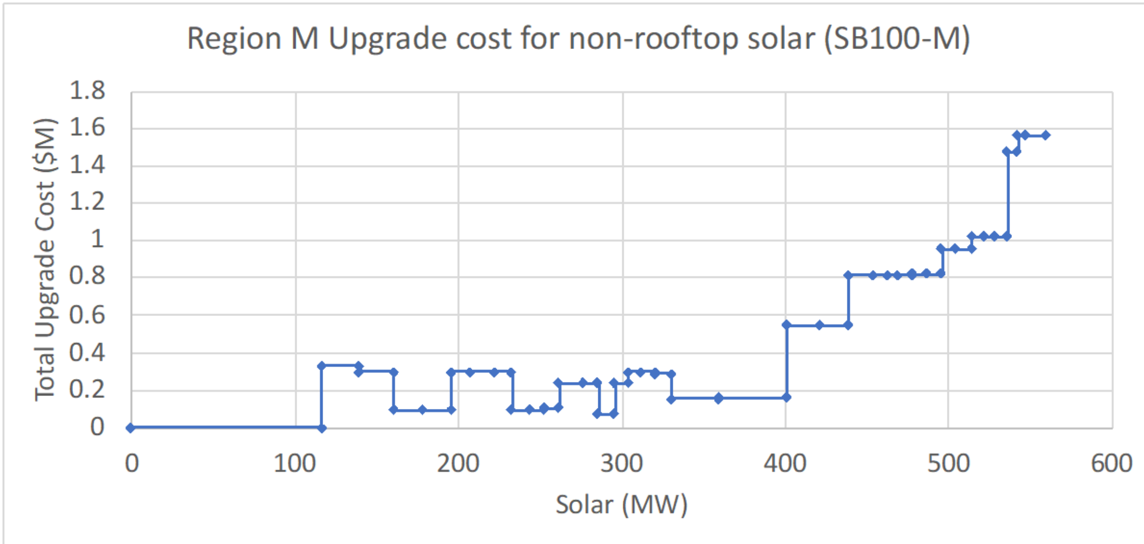


Figure 11. Cost curve for non-rooftop solar upgrade costs showing a capacity range of zero upgrade cost, followed by a range of rather modest and up and down costs (see text), and finally a region of more steady cost increases

For 19%–38% of the regions (depending on the scenario), we also see some penetration levels with integration costs <$0/kW, indicating that the addition of non-rooftop local solar was able to effectively defer distribution upgrades that would have otherwise been required to address load growth and customer-adopted rooftop solar. Figure 12 shows one such case where after a small amount of non-rooftop solar is installed, the integration cost drops below zero, indicating that adding between about 20 and 80 MW of non-rooftop solar actually helps to defer about $1 million in distribution upgrades.

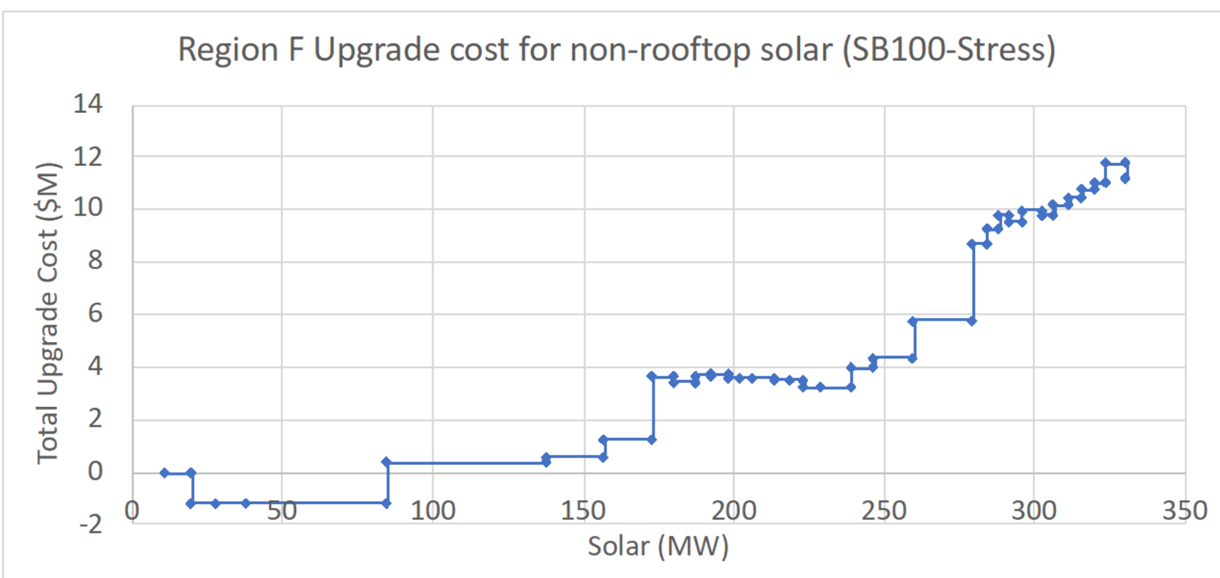


Figure 12. Cost curve for non-rooftop solar illustrating a region of negative upgrade costs that indicates the addition of non-rooftop solar in the range of about 20–80 MW was able to defer some upgrades that would be otherwise required for load and rooftop solar

So far, we have explored *total* upgrade costs, but the information passed to the capacity expansion planning effort (and also that shown in Figure 8) is normalized to the corresponding installed solar capacity to produce the *average* distribution upgrade cost per kW of solar capacity. Figure 13 shows how even a simple total upgrade cost curve can result in a potentially counterintuitive result: increasing solar capacity results in decreasing average upgrade costs. This is because the single upgrade required at around 7 MW of non-rooftop solar is sufficient to support up to the maximum identified solar capacity. As a result, if only 7 MW of capacity is installed, it must cover the entire upgrade cost of around $100K, resulting in an average upgrade cost of over $15/kW. But as additional solar capacity is installed, the same upgrade cost can be spread across a larger capacity of solar, reducing the average cost an order of magnitude to <$1.2/kW with the maximum capacity installed around 88 MW.

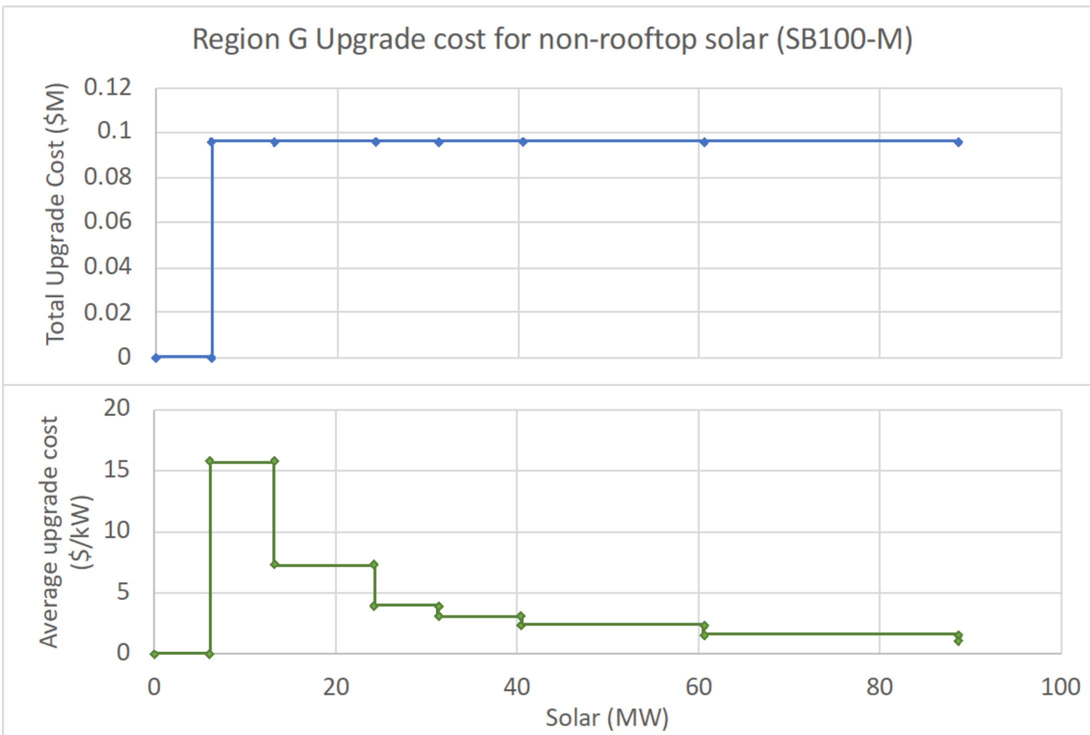


Figure 13. Comparison of total and average cost curves showing how a single upgrade results in a single step and then flat total upgrade costs but creates a steadily decreasing average cost

This effect is most pronounced for upgrades that are required at relatively low installed solar capacity. As seen in Figure 14, the more common cost curve where considerable solar capacity can be installed without requiring any upgrades, and then a series of upgrades is needed, produces a stairstep of total costs. Here we still see a decreasing average cost after an upgrade, but the effect is much less pronounced because the upgrades could be covered by a larger amount of non-rooftop local solar capacity.

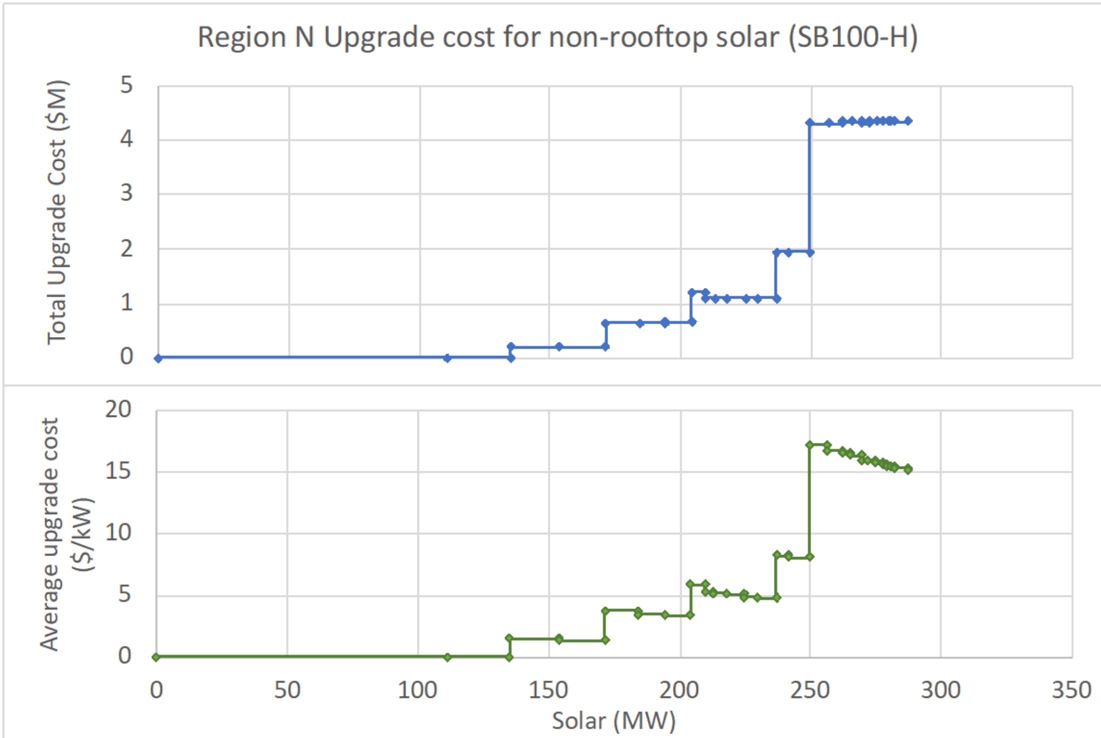


Figure 14. Comparison of total and average costs for a more complex total cost curve, showing how the decline in average cost is less pronounced when it starts at higher capacities

4.2.2 Looking Deeper: Spatial Patterns for Upgrade Costs of Non-Rooftop Distribution-Connected Solar

The amount of non-rooftop solar that can be integrated at various average costs, varies by RS region as a result of differences in the grid, loads, other distributed energy resources, and size of the region. These results are summarized by region for ≤\$0/kW and ≤\$10/kW in Table 6 and Table 7, respectively. The results for the SB100 – Moderate scenario are shown geographically in Figure 15. These levels assume the site buildout based on the prioritization order described above. Geographic results for other scenarios are generally similar. Note that results were not available for regions E, J, and HAL.

Table 6. Maximum Capacity of Non-Rooftop Local Solar (MW) per RS Region That Can Be Installed with ≤$0/kW of Distribution Grid Upgrade Costs

RS Region	SB100 - M	Early/ NoBio - M	Trans. Focus - M	Ltd. Trans - M	SB100 - H	Early/ NoBio - H	Trans. Focus - H	Ltd. Trans - H	SB100 - S	Average
A	14	14	14	14	14	14	14	14	14	14
B	305	305	305	305	305	305	305	305	305	305
C	46	46	46	46	46	46	46	254	254	92
D	193	193	193	193	193	193	193	193	193	193
F	38	38	38	38	38	38	38	38	38	38
G	—	—	—	—	220	—	—	—	—	24
H	95	95	95	95	95	95	95	95	95	95
K	200	200	97	97	200	200	200	97	97	154
M	—	—	—	—	—	—	—	—	—	0
N	154	154	111	111	154	154	154	111	111	135
P	62	62	11	11	—	62	62	62	62	44
Q	18	18	24	24	24	18	18	24	24	21
RIN	158	158	158	158	139	158	158	158	158	156
S	340	340	340	340	340	340	340	340	340	340
T	209	209	209	209	273	209	209	209	209	216
U	161	161	161	161	127	161	161	161	161	158
Total	**1,993**	**1,993**	**1,802**	**1,802**	**2,168**	**1,993**	**1,993**	**2,062**	**2,062**	**1,985**

Table 7. Maximum Capacity of Non-Rooftop Local Solar (MW) per RS Region That Can Be Installed with ≤$10/kW of Distribution Grid Upgrade Costs

RS Region	SB100 - M	Early/ NoBio - M	Trans. Focus - M	Ltd. Trans - M	SB100 - H	Early/ NoBio - H	Trans. Focus - H	Ltd. Trans - H	SB100 - S	Average
A	14	14	14	14	14	14	14	14	14	14
B	305	305	305	305	305	305	305	305	305	305
C	226	226	223	223	223	226	226	254	254	231
D	193	193	193	193	193	193	193	193	193	193
F	38	38	38	38	157	38	38	38	38	52
G	89	89	269	269	269	89	89	269	269	189
H	95	95	95	95	95	95	95	95	95	95
K	234	234	97	97	234	234	234	97	97	173
M	560	560	548	548	548	560	560	560	560	556
N	241	241	241	241	230	241	241	249	249	242
P	62	62	11	11	62	62	62	62	62	51
Q	18	18	24	24	24	18	18	24	24	21
RIN	236	236	221	221	229	236	236	221	221	228
S	340	340	340	340	340	340	340	340	340	340
T	273	273	273	273	273	273	273	273	273	273
U	161	161	161	161	127	161	161	161	161	158
Total	**3,086**	**3,086**	**3,053**	**3,053**	**3,323**	**3,086**	**3,086**	**3,156**	**3,156**	**3,120**

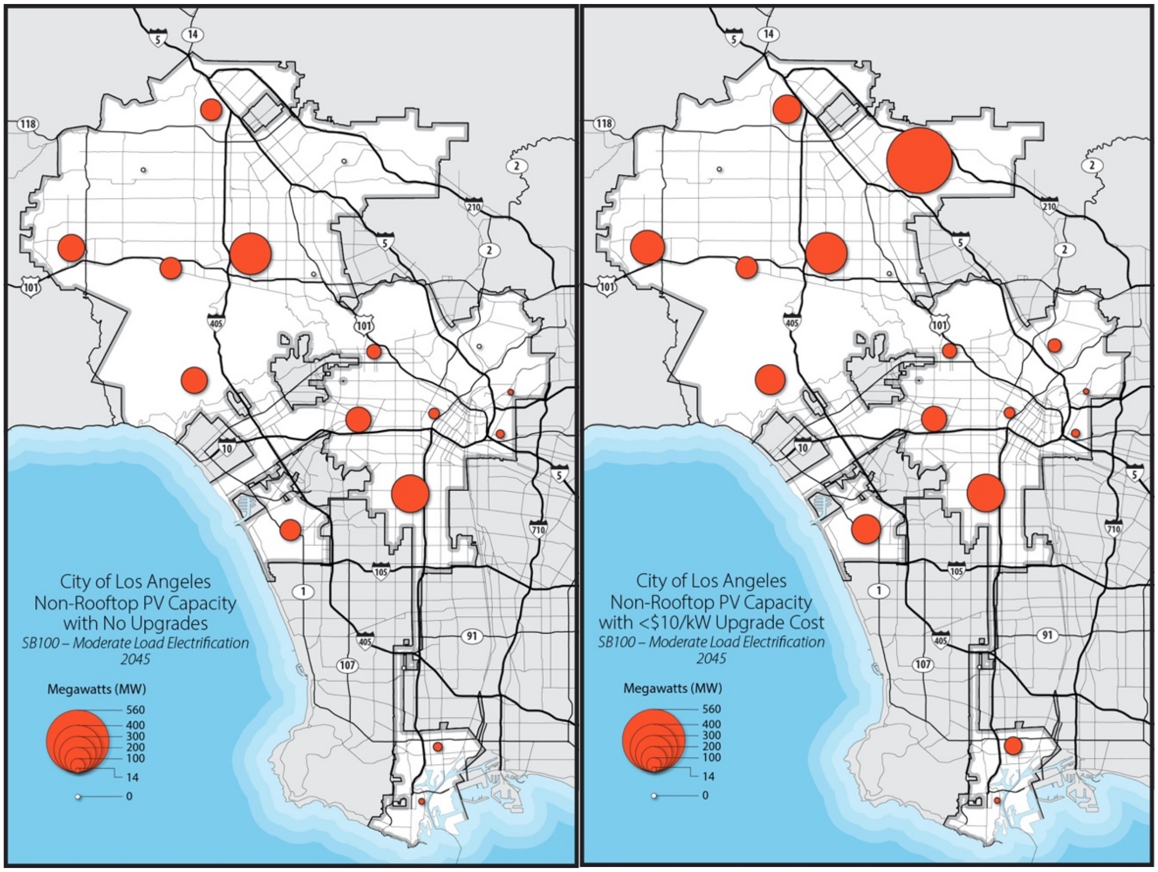


Figure 15. Map showing total capacity of non-rooftop solar that can be installed by region for no additional upgrade cost (left) and for ≤$10/kW (right) relative to the upgrade costs required for load and rooftop solar

These results are for the SB100 – Moderate scenario.

5 Summary of Non-Rooftop Local Solar

Our analysis indicates that over 5,666 MW of non-rooftop local solar technical potential exists across ground-mount, parking canopy, and floating solar projects. Of the 5,666 MW, most (80%) has a modified LCOE less than \$100/MWh. However, actual project costs could differ from the modeled project costs herein, as these represent our estimates with the caveats described in the following section.

Our ranking algorithm is primarily based on cost, favoring the larger projects that are sited on land with zero and low acquisition costs and near receiving stations. However, other ranking criteria are considered based on LADWP feedback, including prioritizing vacant land, brownfield sites, and parking canopy solar at the Ports of LA and Long Beach, as well as de-prioritizing industrial refineries, land within 500 feet of public transit, and ground-mount sites near airports and the Ports. Because the technical potential of urban solar exceeds the optimal deployment quantity (as determined by the capacity expansion model, i.e., RPM, discussed in Chapter 6), it is possible for LADWP to eliminate unfavorable sites and retain the most promising ones.

Final capacity expansion results (discussed in Chapter 6) indicate a range of 313–1,046 MW of non-rooftop local solar might be built in an optimal resource portfolio for LADWP. At lower amounts built, most of the non-rooftop local solar would be single-axis tracking or floating solar, though at larger buildouts, parking canopies dominate. Chapter 7 unpacks the geographic assignments of RPM non-rooftop local solar deployments and their impacts on the distribution grid.

Depending on the quantity of non-rooftop solar, its location on the LADWP system, and other scenario-driven factors like load, the addition of non-rooftop solar may or may not require additional upgrades beyond those required for load and rooftop solar alone. In fact, at least 2,000 MW of non-rooftop solar could be installed without requiring additional upgrades beyond load and rooftop solar; however, this capacity is only achievable at zero upgrade cost if sited using the ranking from Section 3.1 and limited to each region's zero upgrade cost capacity (Table 6).

In this chapter, we have seen how even with large quantities of non-rooftop solar installed, the relative upgrade costs remain low, accounting for only a few percent or less of the total capital costs for the corresponding solar. In Chapter 7, we examine the marginal upgrade costs for the installed non-rooftop solar for the LA100 scenarios.

Finally, Chapter 7 explores all distribution-connected local solar resources deployed.

6 Caveats and Opportunities for Cost Reduction

Consistent with rest of the LA100 study, the GIS analysis uses capital costs as represented in the NREL 2019 ATB. Solar capital costs are generally expected to decrease over time, which affects how much local solar would be built by RPM annually and also affects inter-project rankings. These declining costs are used in the capacity expansion modeling (as detailed in Chapter 6), but we do not update the economic rank screening for non-rooftop solar sites. As this modified LCOE is only used for non-rooftop site ranking, it is expected that even under lower future costs, the rank order would remain very similar.

The ranking of sites is also affected by an assumption of economies of scale in building larger non-rooftop local solar projects. These costs are based on an exponential interpolation between commercial- and utility-scale overnight capital costs. LA100 does not explicitly consider business models or ownership structures that would be conducive to developing local solar, though there are substantive financial differences between, say, utility- vs. developer-built non-rooftop local solar. LA100 also does not consider policy or regulations that could affect incentives to develop non-rooftop local solar.

In addition, the GIS analysis does not consider the full range of land use and zoning challenges that can influence the feasibility of developing a solar project. For instance, the analysis was unable to consider the influence of conditional use permits (e.g., prior solar projects on land zoned as agricultural have had challenges getting permitting approval). NREL's recommendation is to consider this analysis to be a first step in vetting potential non-rooftop local solar sites; the next step is for a human expert to begin inspecting the sites individually for further consideration.

Finally, the assumed locations for non-rooftop solar are prioritized without directly considering the distribution grid upgrade costs. These costs nevertheless remain low; however, there may be additional opportunity for cost savings and/or distribution upgrade deferral if the locations of non-rooftop solar were optimized based on grid needs.

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Appendix. Data Sources for Non-Rooftop Technical Potential and Economic Ranking

Table 8. Data Sources for Non-Rooftop Technical Potential and Economic Ranking

Data Set	Source
Slope	SRTM 30-meters
Rivers and Waterbodies	Los Angeles County (2011)
Streets	Used parcel data with 50 ft buffer
Forest and Shrubland Cover	2016 National Land Cover Database (MRLC 2016)
Parks	City: City of Los Angeles (2016)
	County: Los Angeles County (2016)
	State: ArcGIS Map Services (2014)
Farmland and Recreational Areas	2017 LA County Tax Assessor's Database (Los Angeles County 2017a)
Land Value	2017 LA County Tax Assessor's Database (Los Angeles County 2017a)
LADWP-Owned Parcels	LADWP
Government-Owned Parcels	LADWP
Easements	LADWP
Distribution Lines (34.5 and 4.8 kV)	LADWP's FRAMME database (PGES)
Parking Lots	Los Angeles County (2014)
Shading	NREL derived Topographic Position Index of building shading, derived from LARIAC 2014 (Los Angeles County 2017a)
Landmarks	UCLA (2015)
Buildings	Los Angeles County (2017a)
Bike Paths	SCAG (2019)
Zoning	City of Los Angeles (2019)

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March 2021

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

Los Angeles Department of Water & Power

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