



Assessing the Solar Photovoltaic Potential in Puerto Rican Brownfields and Reservoirs: Analysis and Modeling

Angela Ortega Pastor, Grant Ellwood, Maya Fein-Cole, Jal Desai, Larson Lovdal, Evan Rosenlieb, Marie Rivers, Ben Rakov, and Gail Mosey

June 2024

Contents

1 Introduction and Overview

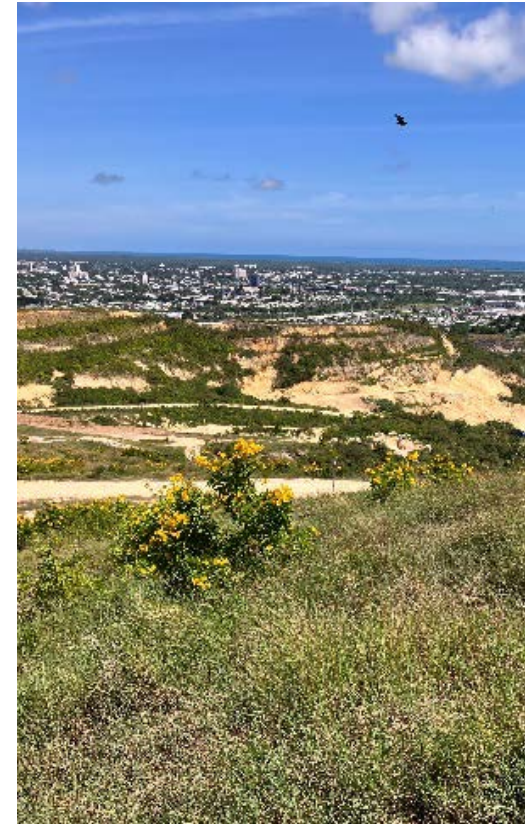
2 Techno-Economic Analysis:

- [Overview](#)
 - [Superfund and Other Contaminated Sites](#)
 - [Landfills](#)
 - [Power Plant Footprints](#)
 - [Transmission Lines Rights-of-Way](#)
 - [Reservoirs](#)
-

3 Project Development

- [Cycle and Strategy](#)
 - [Site Selection](#)
 - [Best Practices and Considerations](#)
 - [Ownership Models](#)
-

4 Resources



Ponce Landfill. Photo by Maya Fein-Cole, NREL 89458

Acknowledgements

The authors would like to express our gratitude to the following organizations for their invaluable contributions and feedback: the Department of Energy Grid Deployment Office, the Environmental Protection Agency – Region 2 Caribbean Office, the United States Department of Agriculture Puerto Rico Office, the Energy Affairs Secretariat Office of the Governor of Puerto Rico, the Puerto Rico Department of Natural Resources, the Puerto Rico Office of Management and Budget, AES Puerto Rico, GeneraPR, and other key stakeholders.

We are also deeply thankful to the municipalities of Barceloneta, Cayey, Cidra, Fajardo, Guayama, Jayuya, Juncos, Mayaguez, Peñuelas, Ponce, San Juan, and Toa Alta, as well as EC Waste, ConWaste, and AES, for welcoming us to visit their sites. Without their support, our study would not be nearly as comprehensive.

This work was authored by the National Renewable Energy Laboratory, operated by Alliance for Sustainable Energy, LLC, for the U.S. Department of Energy (DOE) under Contract No. DE-AC36-08GO28308. Support for the work was also provided by the Federal Emergency Management Agency under Interagency Agreement HSFE02-23-IRWA-0003, Year 1. The views expressed in the article do not necessarily represent the views of the DOE or the U.S. Government. The U.S. Government retains and the publisher, by accepting the article for publication, acknowledges that the U.S. Government retains a nonexclusive, paid-up, irrevocable, worldwide license to publish or reproduce the published form of this work, or allow others to do so, for U.S. Government purposes.

Introduction and Overview

Puerto Rico's Commitment To Achieving 100% Clean Energy by 2050 Will Require Identification of Suitable Sites for New Generation Projects



Photo by Joe DeNero, NREL 84662

Benefits of redeveloping **brownfields**—lands previously used for **industrial and commercial purposes that may be contaminated**—include

- Expands energy infrastructure without compromising limited land resources
- Contributes to the remediation and productive reuse of previously marginalized areas.

Benefits of adding **floating solar photovoltaics (PV) to reservoirs** include

- Supports water resource management, including quality and conservation
- Enhances energy production and supply based on proximity to hydroelectric plants and water treatment and pumping stations
- Provides incremental scaling without disruption.

Analysis and Modeling to Assess Solar PV Potential on Puerto Rican Brownfields and Reservoirs

In this study, the National Renewable Energy Laboratory (NREL) evaluated the theoretical solar PV potential on:

- Brownfields
 - Superfund and other contaminated sites
 - Landfills
 - Power plant footprints
 - Transmission lines rights-of-way
- Reservoirs.

NREL then performed a detailed techno-economic analysis on select locations.

This report summarizes the results of this study and provides a series of technical, regulatory, and economic considerations.

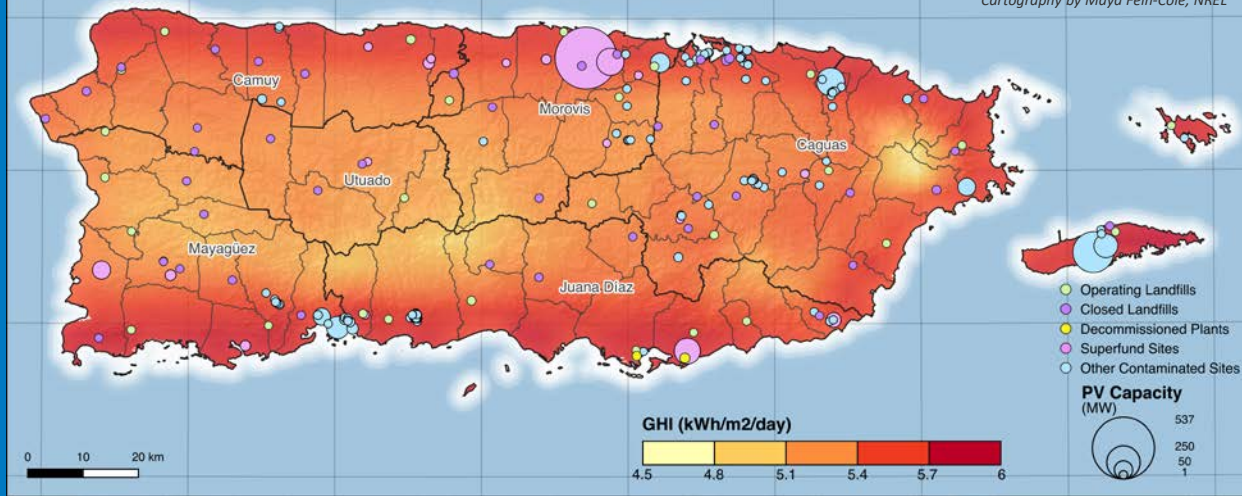
[Technical annexes](#) provide additional details.



Cayey Landfill. Photo by Maya Fein-Cole, NREL 89452

Estimated Theoretical Solar PV Potential: Up to 3.3 Gigawatts (GW) Across Puerto Rico Brownfields and Reservoirs

For this study, brownfields include Superfund and other contaminated sites, landfills, power plant footprints, and transmission lines rights-of-way.



213 MW of estimated solar PV capacity on **41 closed landfills**

1–2.5 GW of estimated capacity across **160 contaminated sites**

78 MW of estimated capacity at **two power plant footprints**

21–50 MW of estimated capacity on one studied **transmission line right-of-way**

636 MW of estimated FPV capacity on **55 waterbodies**

All analyzed sites are within 1 mile or less of existing transmission lines operating at 38kV, 115kV, or 230kV. The team did not conduct a hosting capacity study.

Redeveloping Brownfield vs. Greenfield Sites Presents Distinct Costs and Challenges

EPA's Brownfields and Superfund Programs and USDA REAP loans and grants can help make sites "shovel ready" for renewable energy project development



Photo by Angela Ortega Pastor, NREL/29454

Brownfield redevelopment:

- Often incurs higher upfront costs because of the need for site assessment, decontamination, and potential remediation of pollutants, which can delay project initiation and increase financial risk.
- However, it can offer benefits such as access to existing infrastructure and community support for revitalizing unused industrial lands.

In contrast, greenfield development:

- Typically involves lower initial environmental management costs and fewer legal complexities.
- May face greater public and regulatory resistance because of land use changes and potential ecological impacts, influencing project location and viability decisions.

Using Brownfields for Energy Projects Offers Potential Benefits

Benefits of using brownfields may include the following:

- **Economic and Community Advancement:** Generates local jobs, increases tax revenues, and creates new revenue streams through energy cost savings and lease revenue for governments
- **Environmental Improvement and Land-Use Efficiency:** Reduces pressure on development of natural habitats, reduces cleanup costs, and addresses environmental justice in underserved communities
- **Infrastructure and Energy Resilience:** Leverages existing infrastructure for cost-effective development and enhances energy reliability—especially near critical infrastructure—supporting essential services during outages
- **Environmental Justice:** Addresses longstanding environmental and social neglect in traditionally underserved or marginalized areas, where brownfields are typically located, by reducing energy costs, creating local jobs and opportunities for skill development programs, and enhancing local energy resilience.

Closed landfills mandate the use of nonpenetrative, ballasted ground-mount solar PV systems, which rely on weights and have a fixed tilt for stability (fixed-tilt systems are common because of their lower maintenance costs). In other brownfields, pole ground-mounted systems may be appropriate and can be more economical than ballasted systems.



Mayaguez Landfill. Photo by Angela Ortega Pastor, NREL 89451

Using Floating PV (FPV) on Reservoirs Offers Potential Benefits

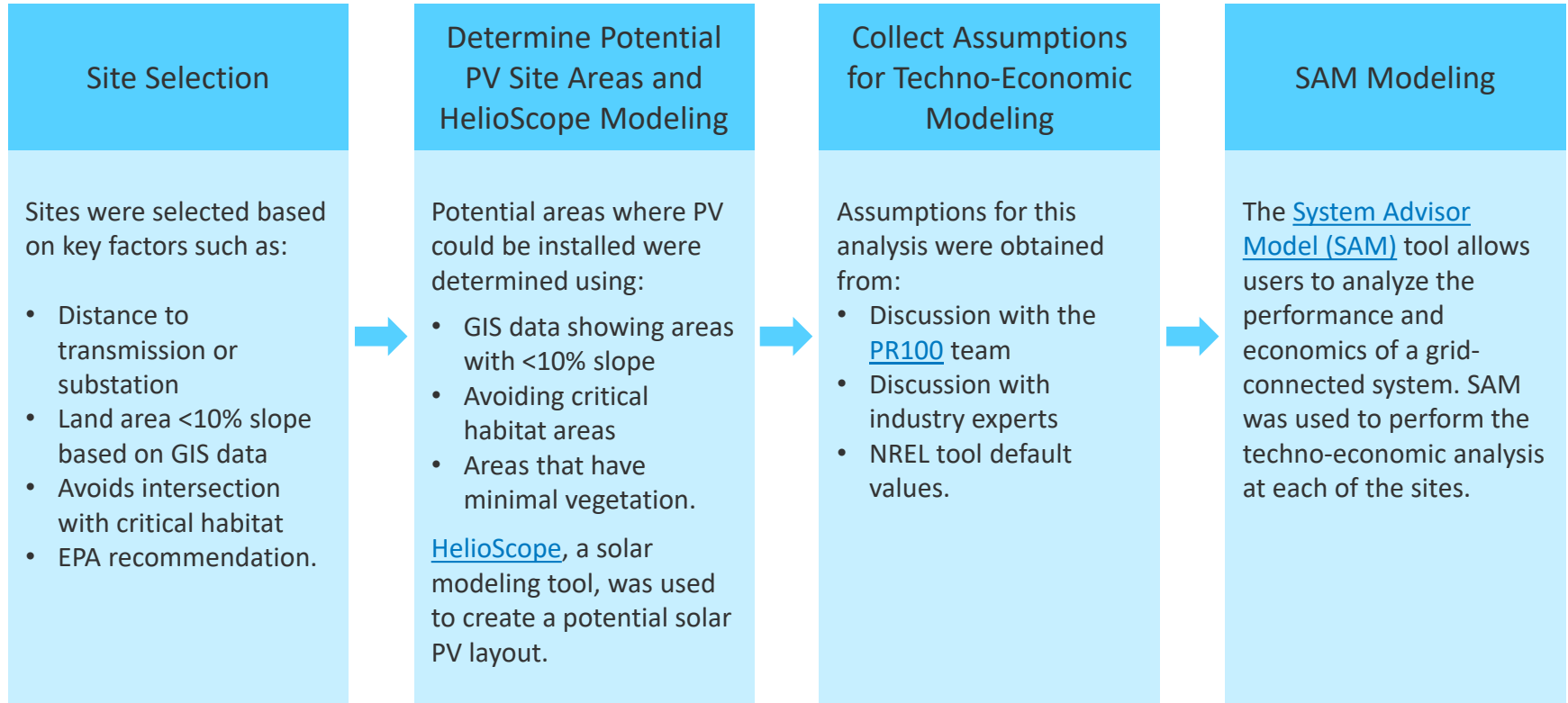
- **Water Resource Management:** Solar panels act as a barrier, reducing water exposure to sunlight and wind and *reducing evaporation rates for improved water conservation.*
- **Water Quality:** Solar panels can act as a physical barrier, intercepting pollutants from adjacent lands and reducing runoff. Shading limits sunlight and keeps temperatures lower, making *water less conducive to algae growth.*
- **Synergy With Hydroelectric Plants:** Combining FPV with hydroelectric facilities enhances energy production (water flow synchronized to meet varying demand).
- **Dynamic Scaling:** FPV allows incremental capacity expansion, adapting to changing energy needs without significant disruptions.
- **Closer Energy Source:** FPV can supply energy to water treatment and pumping stations based on close proximity.
- **Solar PV Module Cooling:** Water beneath the panels dissipates heat, preventing overheating and maintaining optimal operating temperatures for solar modules.



Photo by Dennis Schroeder, NREL 53264

Techno-Economic Analysis (TEA): Overview

Brownfields: Analysis Overview



NREL Conducted Analyses on Solar PV for Brownfields and Reservoirs in Puerto Rico

	Superfund and Other Contaminated Sites	Landfills	Power Plant Footprints	Transmission Lines Rights-of-Way (ROWS)	Reservoirs
Analysis overview	<ul style="list-style-type: none"> • 18 superfund and 142 contaminated sites were evaluated for PV feasibility at a high level • An in-depth techno-economic analysis of 6 superfund sites assessed how much grant money is needed to meet economic targets under municipality (Muni)-owned and third-party-owned models 	<ul style="list-style-type: none"> • In-depth techno-economic analysis for 9 landfills • Two ownership models (Muni and third-party owned) analyzed to determine how much grant money is required to meet economic targets 	<ul style="list-style-type: none"> • In-depth techno-economic analysis of 2 power plant footprints. • A parametric analysis was conducted to determine the sensitivity of different parameters 	<ul style="list-style-type: none"> • Case study: High-level analysis of the capacity potential of solar PV development along the ROW of the Mayagüez to Arecibo transmission line 	<ul style="list-style-type: none"> • 55 waterbodies were assessed to determine the suitability of adding FPV and how much capacity could be added
Key assumptions	<ul style="list-style-type: none"> • PV system type: ballasted and pole-mount PV system • Land lease cost: \$2,400/acre • Assumed 4 acres/megawatt DC (MWdc) for PV area capacity 	<ul style="list-style-type: none"> • PV system type: ballasted PV system • Land lease cost: \$2,400/acre • HelioScope was used to determine PV area and capacity 	<ul style="list-style-type: none"> • PV system type: pole-mounted PV system • Land lease cost: \$1,200/acre (Chevron Phillips Superfund Site) • HelioScope was used to determine PV area and capacity 	<ul style="list-style-type: none"> • Assumed a PV capacity range of 3 to 6.9 acres/MWdc 	<ul style="list-style-type: none"> • Assumed roughly 2.5 acres/MWdc for PV area capacity

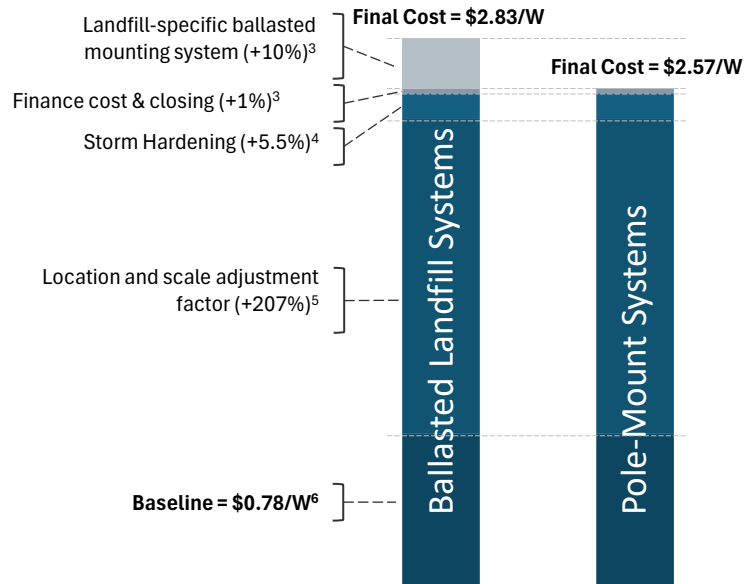
Economic Considerations for Clean Energy Development on Brownfields

- **High upfront costs and strict interconnection standards**, which limits medium-scale projects. These standards create difficult economics for projects above 250 kW that aren't large enough to amortize additional utility scale interconnection costs¹.
- To cover development expenses, for projects less than 5 MW, it is estimated that **PPA prices must range between \$120 and \$140 per megawatt-hour (MWh), compared to a baseline of \$108 per MWh²**. Given that brownfields do not require a large amount of power, the potential savings from self-consumption of generated power are limited.
- **Projects owned by entities based in Puerto Rico are generally not eligible for the Investment Tax Credit (ITC)** but can benefit from the Production Tax Credit (PTC), including direct payment options.

¹ We assume that all additional key commercial costs (i.e., supplemental insurance, interconnection requirements) were represented in the Tranche 1 PPA data and therefore are accounted for in our capital costs via the PR100 adjustment factors.

² The capacity-weighted average contract price in the Tranche 1 PPA data [filed with PREB](#). Note: Operation and maintenance (O&M) costs were calculated by subtracting the 13% land lease component from the Annual Technology Baseline (ATB) value (because land costs are explicitly included separately in the model) and then applying the same adjustments as capital costs.

Capital Cost Stack for Solar PV in Brownfields



³ Industry Benchmark

⁴ [RMI – Solar Under Storm](#)

⁵ For systems <5 MW. Puerto Rico Grid Resilience and Transitions to 100% Renewable Energy Study (PR100), 2024

⁶ Assumed 2023 technology moderate case baseline from NREL's ATB

Tax Incentives Available for Clean Energy Development in Puerto Rico

Federal Incentives:

- Depending on ownership, Projects built in Puerto Rico are eligible for the Investment Tax Credit (ITC) and Production Tax Credit (PTC), as well as stackable bonuses.¹
- U.S. tax liable entities may qualify for the full suite of clean energy tax credits and bonuses. Eligible credits will depend on project location, system size, wage rates, and employment of apprentices from registered apprenticeships.² Visit the [Federal Solar Tax Credits for Businesses](#) webpage for an overview of the ITC, PTC, and bonuses.
- Territory-based government and tax-exempt entities can now benefit from certain clean energy investment and production credits using new options enabled by the Inflation Reduction Act of 2022. Visit the [Clean Energy Tax Credits in the U.S. Territories Using Elective Pay](#) webpage for more information on how territory-based entities can access clean energy tax credits.

Local Incentives:

- The [Green Energy Incentives Act of Puerto Rico](#) provides a 100% exemption from state excise tax and sales and use taxes for raw materials and machinery used in the production of green energy.

¹ Projects *owned* by Puerto Rico–based entities are generally not ITC eligible but can use the PTC, including direct pay.

² System upgrades/interconnection costs are ITC eligible for projects less than 5 MW. To be eligible for the full rate, projects must be less than 1 MW or meet prevailing wage/apprenticeship labor requirements.

Note: To account for the cost of transferring tax credits, a 10% reduction to the total tax credit has been applied (e.g., 40% ITC was reduced to 36%). PTC values remain unchanged.

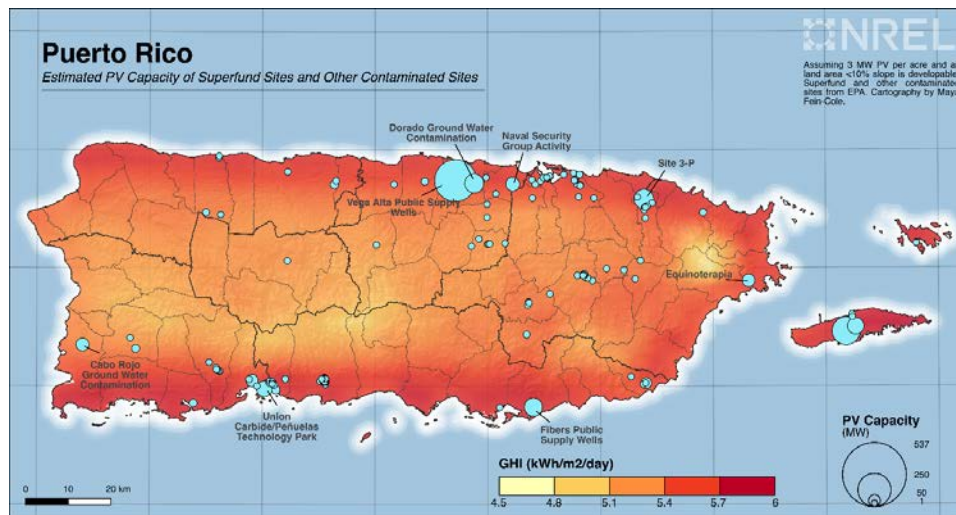
			2023 to 2033
ITC	Full rate (if project meets labor requirements ^b)	Base Credit	30%
		Domestic Content Bonus	10%
		Energy Community Bonus	10%
	Low-income bonus (1.8 GW/yr cap)	<5 MW projects in LMI communities or Indian land	10%
Qualified low-income residential building project / Qualified low-income economic benefit project		20%	
PTC for 10 years (\$2022)	Full rate (if project meets labor requirements ^b)	Base Credit	2.75 ¢
		Domestic Content Bonus	0.3 ¢
		Energy Community Bonus	0.3 ¢

Photo from [Federal Solar Tax Credits for Businesses](#), DOE

Techno-Economic Analysis: Superfund and Other Contaminated Sites

Brownfields: 160 Superfund and Contaminated Sites Offer Estimated 1–2.5 GW Solar PV Capacity

Type of Site	Number Evaluated	≥10 developable acres Potential 1-3 MW of solar PV generation each	≥25 developable acres Potential 3-8 MW of solar PV generation each	Total Capacity
Superfunds	18	13	9	0.56-1.28 GW
Other Contaminated Sites	142	20	14	0.52-1.19 GW
	160	33	23	1–2.5 GW



GE Palmer site. Photo by Angela Ortega Pastor, NREL 89449

Across 160 Contaminated Sites, Sites >10 Acres Show Significant—Up to 2.5 GW—Solar PV Potential

Site Name	Program	City	Area <= 10% (acres)	PV Potential (MW), Assuming 6.9 acres per MW	PV Potential (MW) Assuming 3 acres per MW
Vega Alta Public Supply Wells	Superfund	Vega Alta	1,611	233	537
Abandoned Industrial Property	Brownfields	Vieques	977	141	325
House Used as Dumpsite (Site 3-P)	Brownfields	Canóvanas	596	86	199
Dorado Ground Water Contamination	Superfund	Dorado	571	82	190
Fibers Public Supply Wells	Superfund	Jobos	534	77	178
Polideportivo	Brownfields	Vieques	463	67	155
Haz107-Union Carbide (Peuelas Technology Park)	Brownfields	Peñuelas	424	61	141
Naval Security Group Activity	Brownfields	Toa Baja	337	48	112
Cabo Rojo Ground Water Contamination	Superfund	Cabo Rojo	299	43	100
Equinoterapia	Brownfields	Naguabo	285	41	95
Haz105-Ppg Industries + Ppg Canal	Brownfields	Guayanilla	263	38	88
Maunabo Area Ground Water Contamination	Superfund	Maunabo	198	28	66
Pet029 Ponce Salts Industries	Brownfields	Peñuelas	99	14	33
Upjohn Facility	Superfund	Barceloneta	93	13	31
San German Ground Water Contamination	Superfund	San Germán	78	11	26
Ochoa Fertilizer Co.	Superfund	Guanica	58	8	20
Vega Baja Solid Waste Disposal	Superfund	Río Abajo Ward	50	7	17
Pet007-Hercor (Ippe/Upe)	Brownfields	Peñuelas	44	6	15
Pet009 -PR Olefins	Brownfields	Peñuelas	36	5	12
GE Palmer	Brownfields	Río Grande	29	4	10
Soller Sugar Company	Brownfields	Camuy	29	4	10
Antiguo Hospital Menonita	Brownfields	Cayey	27	3	9
Pet006 - Gulf Chemicals	Brownfields	Peñuelas	25	3	8
PRIDCO Facility T-12440-79	Brownfields	Yauco	24	3	8
La Playita	Brownfields	San Juan	20	3	7
Haz106-Rico Chemicals Corporation	Brownfields	Guayanilla	19	3	6
Proteco	Superfund	Peñuelas	17	2	6
Jassen Inc.	Superfund	Gurabo	16	2	5
The Battery Recycling Company	Superfund	Arecibo	15	2	5
Pesticide Warehouse I	Superfund	Arecibo	14	2	5
Millipore Cidra Inc	Brownfields	Cidra	11	2	4
Pridco Old Wastewater Treatment Plant	Brownfields	Caguas	10	1	3
Gulf Gas Station	Brownfields	Cataño	10	1	3

Seven Superfund Sites Selected for Detailed Analysis

NREL evaluated **18 Superfund sites** and **142 contaminated sites** at a high level (sites provided by EPA).

NREL conducted an **in-depth techno-economic analysis for 7 sites** chosen based on:

- Area with slopes less than 10%
- Existing vegetation cover
- Existing structures and development
- Proximity to substation and transmission
- Community and local government engagement
- Preliminary assessment by Puerto Rico Industrial Development Company (PRIDCO)¹
- Feedback from EPA.

Two Superfund sites—**Barceloneta and Juncos**—are also classified as landfills.

Juncos

Barceloneta

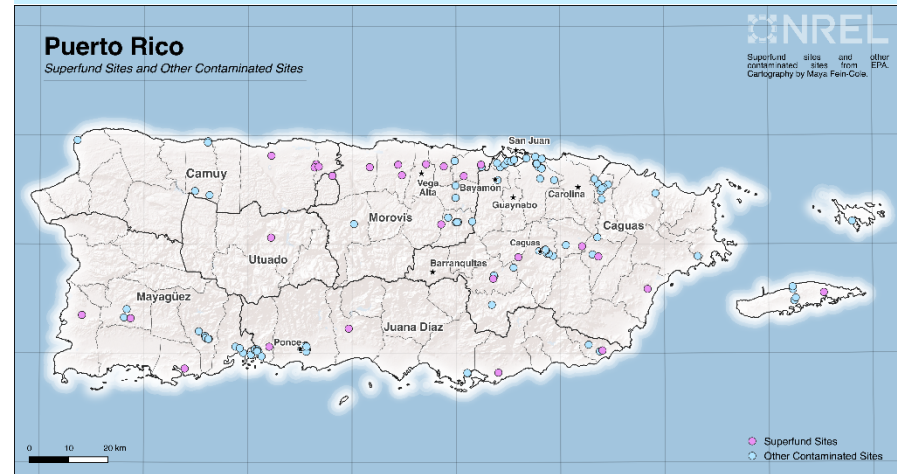
GE Palmer

Millipore Cidra

The Battery Recycling Company

Penuelas Technology Park

Haz105-Ppg Industries + Ppg Canal



¹ Preliminary assessment by PRIDCO identified 46 sites based on generation potential, mitigation/corrective action status, and/or proximity to transmission lines.

Superfund Sites: Redevelopment Is Economically Viable

Approximately 190 MW of solar PV can be added on 756 acres of land across 7 Superfund sites.

Superfund/Contaminated Site Location	Land Area (acres) ¹	PV Capacity (MW)	Year 1 Generation and Uncertainty (GWh)	Year 1 O&M Costs (\$M)	Total Capital Costs (\$M)	Stand-Alone Internal Rate of Return (IRR) Under Muni-Owned Ownership Structure	IRR Under Third-Party Ownership Structure
Juncos	10	3	5 (P70)	0.1	9	0.4%	3.4%
Barceloneta – 5 MW ²	11	3	4 (P67)	0.1	9	-0.1%	2.3%
GE Palmer – 5 MW ²	20	5	8 (P61)	0.2	13	2.4%	7%
Millipore Cidra	11	3	4 (P69)	0.1	7	1.2%	4.6%
The Battery Recycling Company	16	4	6 (P66)	0.2	10	1.9%	5.9%
Penuelas Technology Park	424	106	170 (P72)	3	203	11%	20.6%
Haz105-Ppg Industries + Ppg Canal	264	66	107 (P64)	2	133	8.8%	15.5%

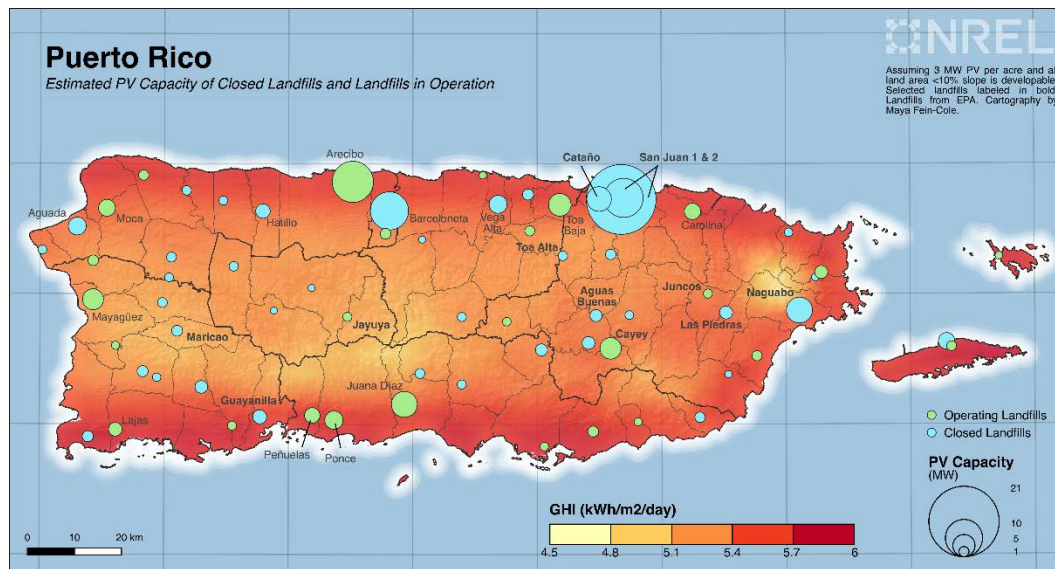
¹ The 10% ballasted system capital cost adder, which was applied to landfill sites, is removed because there is assumed to be no land capping on the decommissioned sites; therefore, standard pole-mounted PV is viable rather than ballasted installation.

² Under third-party ownership models, the PV capacity at GE Palmer was reduced to 5 MW to take advantage of the low-income ITC bonus, which is available **only** for projects that are <5 MW.

Techno-Economic Analysis: Landfills

Brownfields: 41 Closed Landfills Represent Estimated 213 MW Solar PV Capacity

Solar PV installation on closed landfills—which are typically near high loads—avoids disturbing the landfill cap and can alleviate pressure of installing on greenfields.



View from San Juan Landfill. Photo by Gail Mosey, NREL 89455

Landfills: Strategic Investments Needed To Realize Potential

Approximately 27 MW of solar PV can be added on 75 acres of land across 9 landfills.

Landfill Location	Land Area (acres) ¹	PV Capacity (MW)	Year 1 Generation and Uncertainty (GWh)	Year 1 O&M Costs (\$M)	Total Capital Costs (\$M)	Stand-Alone IRR Under Muni-Owned Ownership Structure	Stand-Alone IRR Under Third-Party Ownership Structure
Aguas Buenas	6	2	3.3 (P60)	0.1	6.0	0.4%	3.3%
Cataño – 5 MW ²	14	5	8.2 (P56)	0.2	14.3	1.3%	5.0%
Cayey	11	4	5.6 (P69)	0.1	10.1	0.7%	3.8%
Guayanilla	5	2	2.8 (P67)	0.1	4.9	1.1%	4.7%
Las Piedras	6	2	3.2 (P70)	0.1	5.8	0.5%	3.6%
Maricao	3	1	1.5 (P60)	0.1	3.0	-1.0%	1.0%
Naguabo – 5 MW ²	14	5	7.8 (P71)	0.2	14.3	0.4%	3.4%
San Juan 1 – 5 MW ²	14	5	8.1 (P58)	0.2	14.3	1.1%	4.7%
Toa Alta	2	1	1.0 (P69)	0.1	2.0	-0.3%	2.1%

¹ Land area is adjusted to include a (+10%) buffer to the total land area that could house PV alone.

² Under third-party ownership models, the solar PV capacity at Cataño, Naguabo, and San Juan 1 sites was reduced to 5 MW to take advantage of the low-income ITC bonus, which is available **only** for projects that are <5 MW.

Active Landfills: Potential

According to EPA regulations, landfill cells are typically closed with a 3:1 slope (33.5%) with a small low-slope area on top of cell. Slopes <10% are most suitable to PV development, so highly sloped closed landfills will have limited capacity.

Landfill	Currently Available		Potentially Available After Full or Partial Closure		Notes
	Area (acres)	Estimated PV Capacity ¹	Area (acres)	Estimated PV Capacity	
Fajardo	4	0.6–1.3 MW	8	1.2–2.7 MW	<ul style="list-style-type: none"> • One closed cell with ~4 low-slope acres on top • Second cell to be closed soon; ~8 low-slope acres on top depending on how cell is closed • Third, smaller cell to be opened
Guayama	0	0 MW	5	0.7–1.7 MW	<ul style="list-style-type: none"> • Planning to increase height by ~20 meters (m) and close 17 acres • Currently ~5 low-slope acres on top of cell
Mayagüez	0	0 MW	3.4	0.5–1.1 MW	<ul style="list-style-type: none"> • Planning to increase active cell height by ~15–20 m and close • Currently ~3.4 low-slope acres on top of active cell • Planning to open new cells
Peñuelas Valley	0	0 MW	N/A	N/A	<ul style="list-style-type: none"> • 170 total acres; ~39 acres currently in use • Land available now is sloped and north-facing • Minimal low-slope area expected after closure
Ponce	0	0 MW	3.2	0.5–1.1 MW	<ul style="list-style-type: none"> • 146 total acres; no final cover anywhere • Minimal low-slope area expected with closure, ~3.2 flat acres on top of largest active cell

¹ Capacity estimated assuming 3–6.9 acres per MW.

Landfills: Financial Considerations for Project Development

- The analysis stresses the necessity for **strategic investments to ensure economic viability**. Municipal-owned projects are anticipated to need about 16% of the total capital costs to be funded through incentives or subsidies. Meanwhile, projects owned by third parties are likely to require around 11% of the total capital costs to be met through financial support mechanisms.
- Projects such as Cataño, Guayanilla, and San Juan 1¹ show strong economic potential, achieving internal rates of return (IRRs) of 6%–7% under a third-party ownership model.
- This analysis also showcased sites with higher initial debt leverage could benefit from reduced capital costs, enhancing their attractiveness. Third-party ownership models, because of the ITC and incentives, also present appealing opportunities for development.
- **Challenges to project viability under both models include high installation costs, low PPA pricing, and tax credit eligibility.**

¹ Because **only** projects <5 MW are eligible for the 10% low-income ITC bonus, if San Juan 1 is reduced to 5 MW of PV instead of the full capacity of 8.88 MW, it shows stronger economic potential.



San Juan Landfill. Photo by Gail Mosey, NREL 89450

Landfills: Site Selection Methodology

Q: Is the distance to transmission or a substation 1 mile or less?

YES

NO

Site not considered

Q: How much area is conducive for PV development (i.e., areas <10% slope and with minimal vegetation)?

SIGNIFICANT AREA

MINIMAL DEVELOPABLE AREA

Site not considered

Q: Does the site intersect critical habitat?

NO

YES

Site not considered

Considered site for other factors (could be more than one):

A. 2011 study:
Cataño
San Juan

B. Site visited:
Cayey
Toa Alta

C. EPA
recommended:
Las Piedras
Maricao
Naguabo

D. Remaining sites based on
good developable PV areas:
Aguas Buenas
Guayanilla
Juncos*

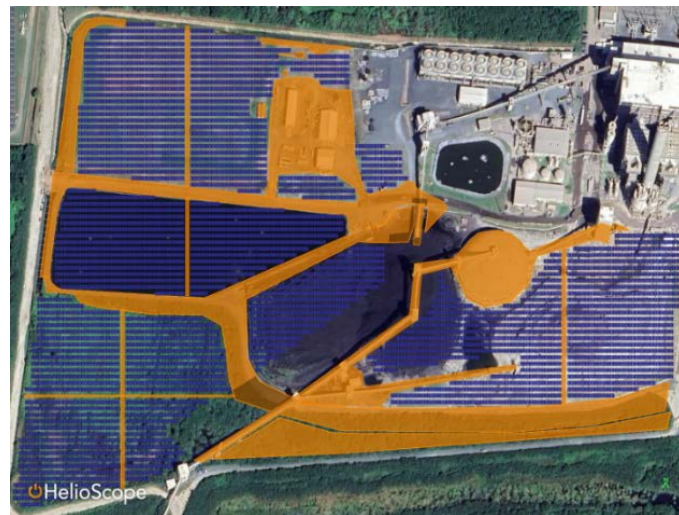
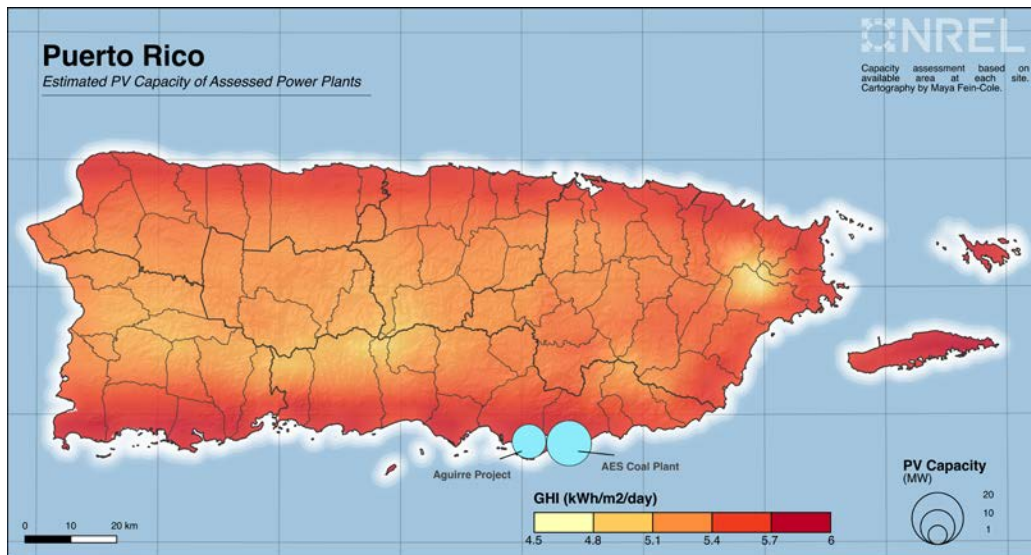
* Also, a Superfund site.

Techno-Economic Analysis: Power Plant Footprints

Brownfields: Two Examined Power Plant Footprints Represent Estimated 78 MW Solar PV Capacity

Power plant footprints offer large amounts of land, which allows economies of scale and takes advantage of using pole-mount solar PV to reduce capital costs and improve project feasibility.

Solar PV potential was evaluated on the **Aguirre Power Plant** and **Guayama Coal Plant**. While these plants are currently in operation, they serve to illustrate the opportunities to repurpose the site for solar PV development.



Coal Plant in Guayama. Photo from GIS

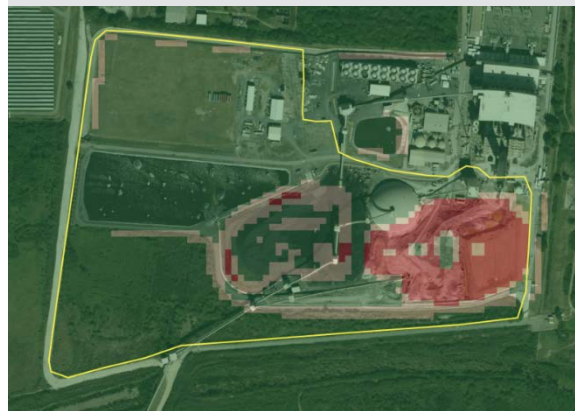
Power Plant Footprints: Assessed Available Areas and Techno-Economic Potential for Adding Solar PV

Four case studies were analyzed: (1) Aguirre combined areas 1, 2, and 3, (2) Aguirre area 3, (3) Guayama Coal Plant¹, and (4) Chevron Phillips² areas.

Aguirre



Guayama Coal Plant



*Chevron Phillips
Superfund Site*



¹ The coal plant in Guayama is slated for closure in 2027, as such the footprint will not be available for redevelopment until 2028.

² The Chevron Phillips Superfund site, adjacent to the Guayama Coal Plant, was considered for possible expansion to the redevelopment of the Guayama Coal Plant.

Photos from GIS

Power Plant Footprints: Redevelopment Is Economically Viable

Power plant footprints offer economically favorable projects because they benefit from economies of scale and reduced capital cost of pole-mount systems.¹

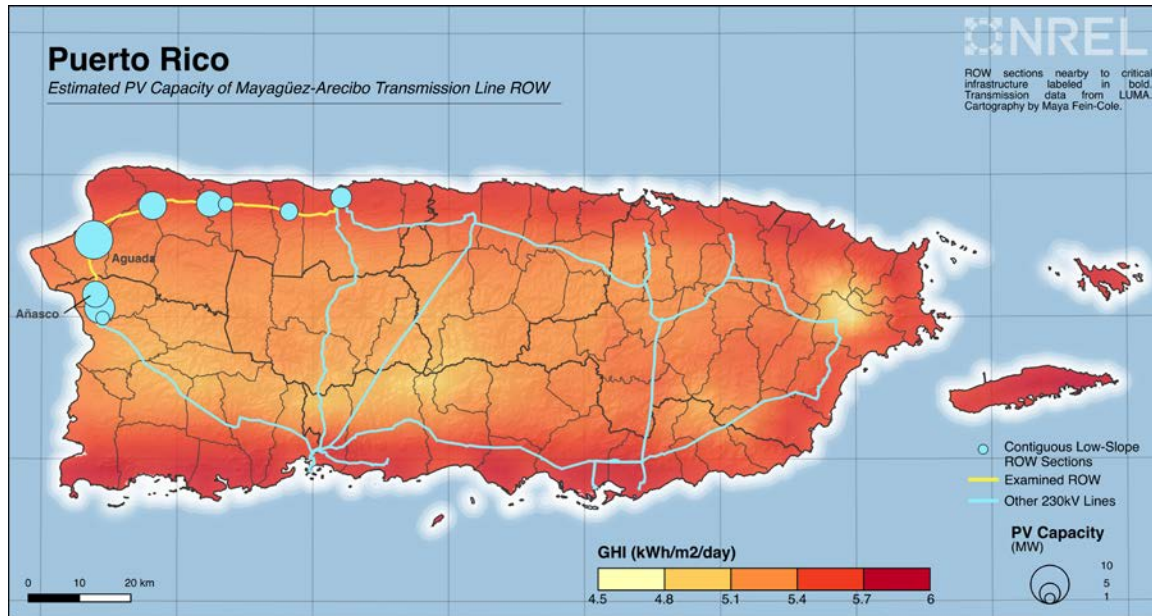
Location	Inputs Varied								Outputs		
	Generation Uncertainty	Land Area	PV Capacity	Capital Cost	Nominal Discount Rate	PPA Price	Annual Interest Rate	Land Lease Cost	Net Capital Cost	IRR at End of Analysis	Net Present Value
<i>Units</i>	<i>%</i>	<i>acres</i>	<i>MW</i>	<i>\$/W_{dc}</i>	<i>%/year</i>	<i>\$/kWh</i>	<i>%</i>	<i>\$/acre</i>	<i>\$</i>	<i>%</i>	<i>\$</i>
Aguirre 1, 2, 3	P67	33	9.7	2.45	8%	0.108	7%	\$0	24,144,000	8.9%	330,694
Aguirre 3	P67	5	0.7	2.57	8%	0.108	7%	\$0	1,710,260	11.8%	88,583
Guayama Coal Plant	P67	65	14.9	2.33	8%	0.108	7%	\$0	35,168,700	12.3%	2,083,360
Chevron Phillips	P67	175	53.5	2.06	8%	0.108	7%	\$1,200	112,237,000	22%	15,714,300

¹ The 10% ballasted system capital cost adder, which was applied to landfill sites, was removed because there is assumed to be **no land capping** on the decommissioned sites; therefore, standard pole-mounted PV is viable rather than ballasted installation.

Techno-Economic Analysis: Transmission Line Rights-of-Way

Brownfields: Examined Transmission Line ROW Estimated 21–50 MW Solar PV Capacity

Installing solar PV on right-of-way (ROW) land under 230-kilovolt (kV) transmission lines offers a strategic opportunity to use otherwise underused spaces for energy generation—with important consideration for technical and safety standards, shading, and vegetation management.



Fiber Wells Supply Project. Photo by Angela Ortega Pastor, NREL 89448

Considerations for Transmission Line Rights-of-Way (ROW) Development

- **Comply with regulations regarding minimum clearances** (may vary depending on the voltage class) between solar panels and transmission infrastructure to prevent electrical hazards.
- **Evaluate and mitigate electromagnetic interference** from solar PV components to maintain transmission line functionality.
- **Design access routes** to ensure transmission line maintenance and emergency repairs can be conducted without obstruction. **Coordinate maintenance schedules** for the solar PV installation and transmission infrastructure to avoid disruptions.
- Prevent new structures or modifications in solar installations from compromising the **stability of existing transmission infrastructure**.
- **Implement comprehensive grounding and protection** strategies for both solar and transmission systems to manage electrical faults and lightning strikes.
- **Consider the shading effects** of transmission towers and cables on solar insolation in the design of the solar array.
- **Adjust regular vegetation management practices** under transmission lines as necessary to support solar PV operations.
- **Engage with local communities** and perform **environmental assessments** to address land use changes, particularly in ecologically sensitive areas.

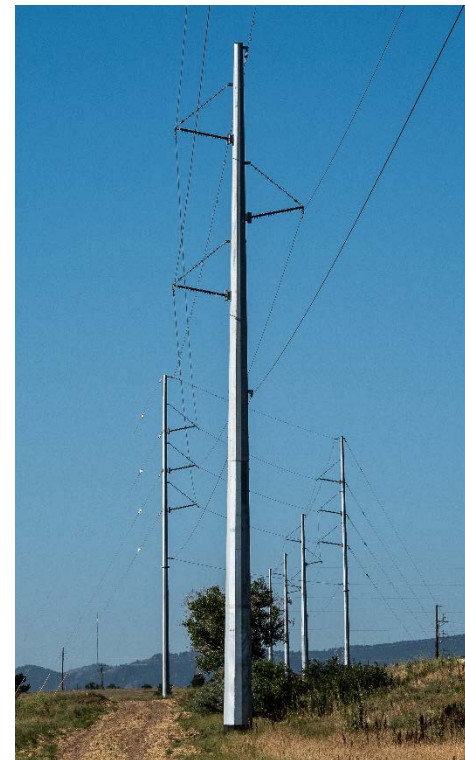


Photo by Dennis Schroeder, NREL 62201

ROW: Mayagüez to Arecibo Transmission Line Evaluated for Potential Solar PV Development

- Land between 50 – 200 feet of a high-voltage transmission line was considered transmission line ROW.
- **1,671 acres** of ROW along the Mayagüez to Arecibo transmission line were evaluated for solar PV development.
- **87%** of this land is classified as specially protected rustic land, urban land or roads¹, and is undevelopable for PV under current land use plan.



¹ Land use data and protections from the 2015 Puerto Rico Land Use Plan (Puerto Rico Planning Board).

ROW: Nine Sections Remain Potentially Developable for Solar PV After Spatial Exclusions

Spatial exclusions from ROW siting:

- Slopes >10%¹
- Protected areas²
- Critical habitat³
- Substations⁴
- Road network⁵
- Urban Land⁵
- All specifically protected rustic land types except for agricultural⁵
- Minimum contiguous area of 1 acre
- Existing vegetation cover and structures shown in satellite imagery.

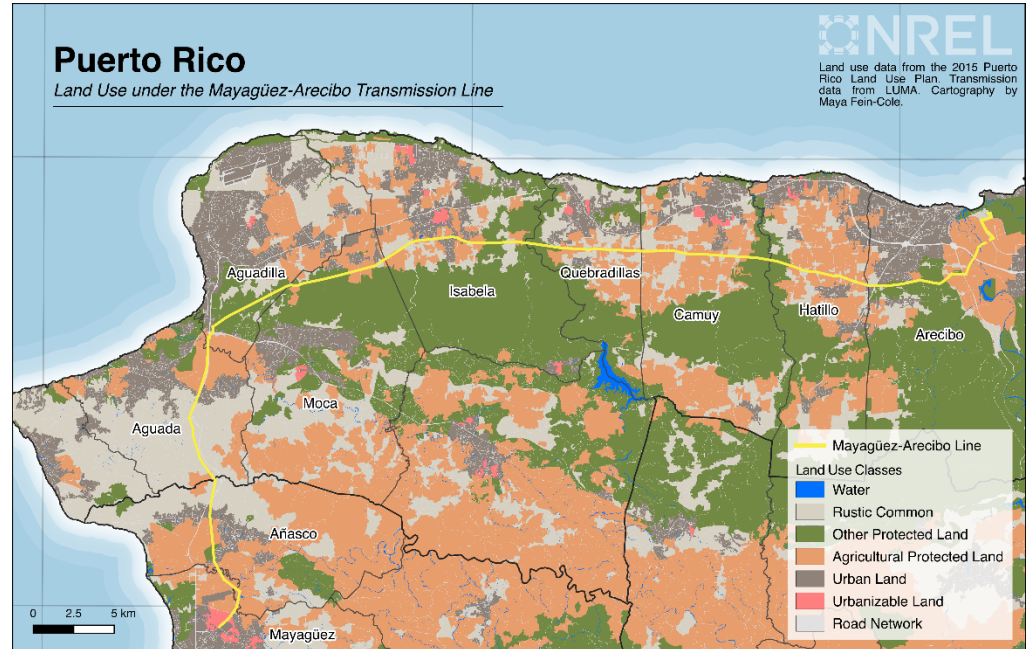
Two sections in **Aguada** and **Añasco** were proximal to substations and critical infrastructures.



¹ USGS, ² WDPA, ³ USFWS, ⁴ LUMA, ⁵ PR Planning Board

ROW: Competing Land-Use Concerns

- All nine selected ROW sections are fully or partially within agricultural protected land designated by the 2015 Puerto Rico Land-Use Plan.
- Shifts in land-use priorities over time can change land protections and availability for development.
- Given limited land availability in ROWs following the siting exclusions, agricultural protected land was considered potentially developable with the caveat it would require changes in land-use planning and a comprehensive stakeholder and community engagement process.

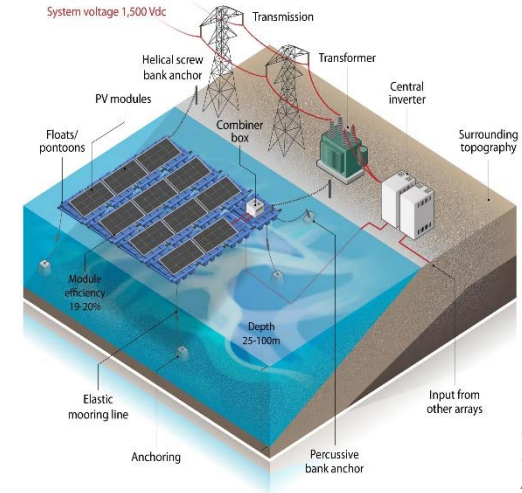
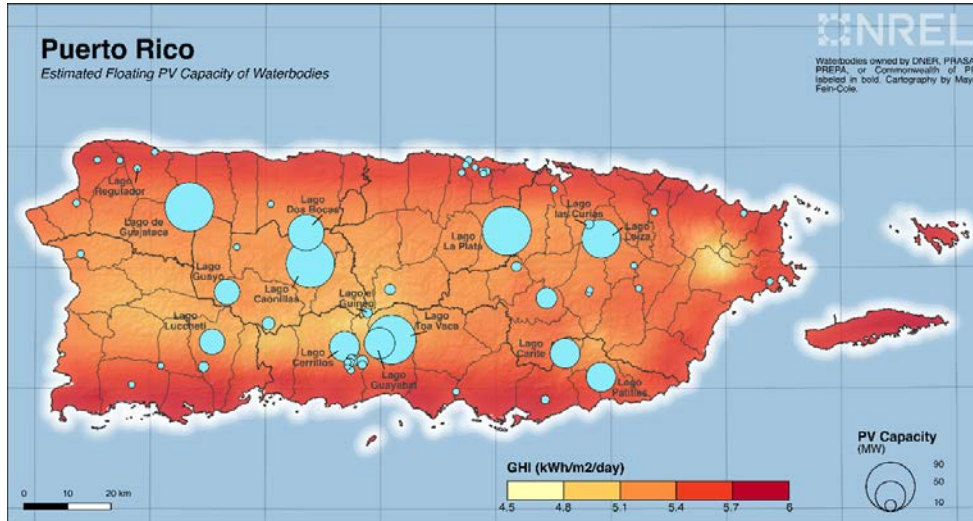


Only rustic common (light gray) and urbanizable land (pink) are developable under current land-use plan.

Techno-Economic Analysis: Floating PV in Reservoirs

FPV: 55 Examined Waterbodies Represent Estimated 636 MW Solar PV Capacity

Puerto Rican reservoirs offer favorable conditions for FPV development due to the absence of snow, ice, and extreme water level variations, the lack of inland freight shipping reducing ship wake concerns, and fewer inlet-induced water current issues from smaller rivers.



Representative configuration of stand-alone FPV. *Illustration by Alfred Hicks, NREL 65944*

Using the NREL reV model and assuming 70% ground cover ratio; 11 degrees panel tilt; 1-MW/hectare panel density; 25% suitable waterbody area; 1.03 multiplier to incorporate evaporative cooling benefit.

Reservoirs: Abundant Developable Area

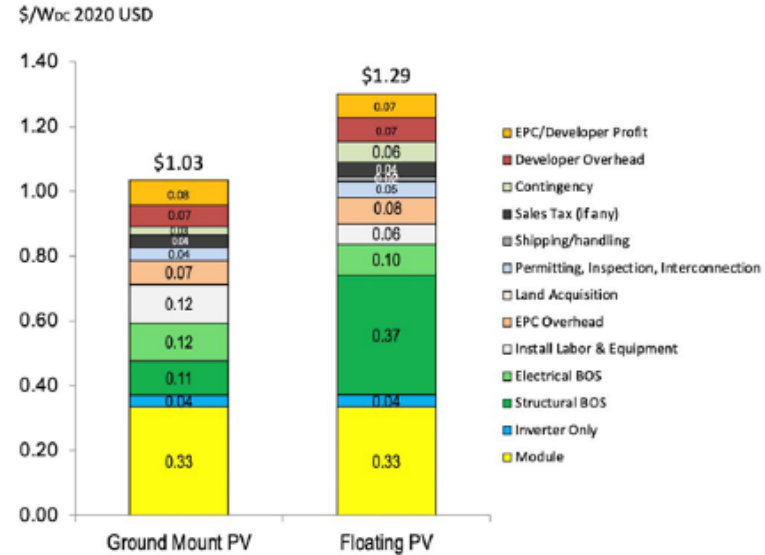
Waterbodies were assessed for FPV suitability, assuming a conservative 25% usage area similar to U.S. norms and focusing on reservoirs with Puerto Rico Electric Power Authority (PREPA) or Puerto Rico Aqueduct and Sewer Authority (PRASA) dams. Bathymetry data were used to gauge depth and slope for potential FPV sites → likely representing 75% of Puerto Rico's FPV capacity.

- **Abundant Developable Area:** The estimated developable area across all six examined reservoirs exceeds the initial assumption of 25%. In five of these reservoirs, the estimated area is significantly more than double this assumed value.
- **Diverse Development Opportunities:** Most reservoirs offer multiple attractive sites for FPV development, each with varying potential impacts. These options range from larger systems located centrally to smaller systems nestled in inlets.
- **Moderate Water Level Variation:** In general, these reservoirs experience moderate water level variations, especially compared to larger reservoirs in drier regions of the continental United States, which exhibit larger seasonal precipitation fluctuations.
- **Accessible Transmission Infrastructure:** The distance to transmission infrastructure, at least within this subset of reservoirs, does not appear to be a major hindrance to development.

Number of Waterbodies	Average Capacity Factor	Total Suitable Area (acres)	Total Capacity (MW)	Total Generation (GWh/year)
55	17.6%	1,572	636	1,010

Economic Considerations for FPV Development

- A 2021 cost model released by the National Renewable Energy Laboratory (NREL) shows capital expenditures (**CapEx**) for FPV to be **~25% higher than ground-mount PV** for median environmental conditions (average water depth, average depth variation, and so on).
- Holding other variables the same, the capital costs **increase ~15% when designed for the maximum windspeed**—higher than 5.5% needed for storm hardening ground-mount systems, but similar to the capital cost increase of storm hardening plus the ballasted mounting needed for solar on landfills.
- The full life-cycle operations and maintenance costs of utility-scale FPV farms are not yet fully characterized. However, in the near- to mid-term, **utility-scale FPV costs appear to be similar to those of ground-mount systems** and are not expected to be a significant driver in relative affordability of FPV compared to the CapEx differences.



U.S. installed costs of 10-MWDC base-scenario FPV system and ground-mounted PV system (Ramasamy and Margolis 2021)

Reservoirs: 15 Waterbodies Assessed for Solar PV Suitability

Waterbody Name	Dam Name	National Inventory of Dams ID	Dam Owner	Area (acres)	FPV Potential (GWh/year)
Lago Regulador	Lago Regulador	PR00076	Puerto Rico Aqueduct and Sewer Authority	13.3	2.2
Lago las Curias	Las Curias Dam	PR00022	Puerto Rico Aqueduct and Sewer Authority	42.7	6.6
Lago El Guineo	Guineo Dam	PR00012	Puerto Rico Electric Power Authority	45.6	6.8
Lago Guayo	Guayo Dam	PR00005	Puerto Rico Electric Power Authority	258.4	40.4
Lago Lucchetti	Lucchetti Dam	PR00003	Puerto Rico Electric Power Authority	265.5	40.5
Lago Patillas	Patillas Dam	PR00023	Puerto Rico Electric Power Authority	297.2	49.2
Lago Carite	Carite Dam	PR00021	Puerto Rico Electric Power Authority	309.2	49.8
Lago Cerrillos	Cerillos Dam	PR82201	Natural Resources and Environmental Dept.	334.5	50.0
Lago Guayabal	Guayabal Dam	PR00013	Puerto Rico Electric Power Authority	347.1	51.7
Lago Dos Bocas	Dos Bocas Dam	PR00009	Puerto Rico Electric Power Authority	412.8	63.0
Lago Loiza	Loiza Dam	PR00024	Puerto Rico Aqueduct and Sewer Authority	437.0	68.3
Lago Caonillas	Caonillas Dam	PR00011	Puerto Rico Electric Power Authority	579.1	89.0
Lago Toa Vaca	Toa Vaca Dam	PR00014	Puerto Rico Aqueduct and Sewer Authority	585.8	91.0
Lago La Plata	La Plata Dam	PR00017	Puerto Rico Aqueduct and Sewer Authority	633.9	97.4
Lago de Guajataca	Guajataca Dam	PR00001	Puerto Rico Electric Power Authority	860.2	136.0

Blue: More in-depth analysis performed on highlighted reservoirs because of available bathymetry data.

Reservoirs: Six Waterbodies With Bathymetry Data Allow for Explicit Estimates of Available Area

For an area to be considered available for development, it must be:

- **More than 100 m from dams** to allow for dam maintenance and limit the effect of currents caused by outflow
- Filled with water at **low fill volumes** or be in a location where the underlying floor is flat (under the **2% slope** threshold)
- **At least a meter deep at maximum fill** (5th percentile of typical operating level based on available U.S. Geological Survey [USGS] gauge data).

Areas that fit these criteria but do not form a contiguous area large enough to allow for utility-scale FPV (~1 MW) are excluded.

Waterbody Name	Dam Owner	Developable %	FPV Potential, Calculated Coverage (GWh/year)	FPV Potential, Assumed 25% Coverage (GWh/year)
Lago Lucchetti	PREPA	27%	44	40.5
Lago Patillas	PREPA	81%	159	49.2
Lago Carite	PREPA	83%	165	49.8
Lago Guayabal	PREPA	76%	157	51.7
Lago Caonillas	PREPA	48%	299	89.0
Lago La Plata	PRASA	66%	257	97.4



Lago Caonillas, Carite, Guayabal, La Plata, Lucchetti, and Patillas. Photo from GIS

Technical Considerations for FPV on Reservoirs

- Designing systems for **water currents** and **water-level variation**¹ primarily affects the anchoring/mooring and cables such as the load rating and number of anchoring/mooring lines required. These are common engineering considerations for any FPV system and not unique to Puerto Rico.
- Engineering for Class V **hurricane-level winds** has been done (because FPV has been developed in other locations subject to hurricanes or typhoons, such as Florida and in southern Japan and Southeast Asia). However, **systems in Puerto Rico may require more than has typically been seen** in these areas.
 - Wind loading affects the stress on anchoring/mooring systems and float-to-float connections in addition to considerations relevant to the panels and racks of ground-mount solar.
 - Impacts on the load rating and number of anchoring/mooring lines are most important; however, less common float geometries/designs and float-to-float connections will also likely be required.
 - Triangular FPV floats may be more resilient to wind and wave loads.

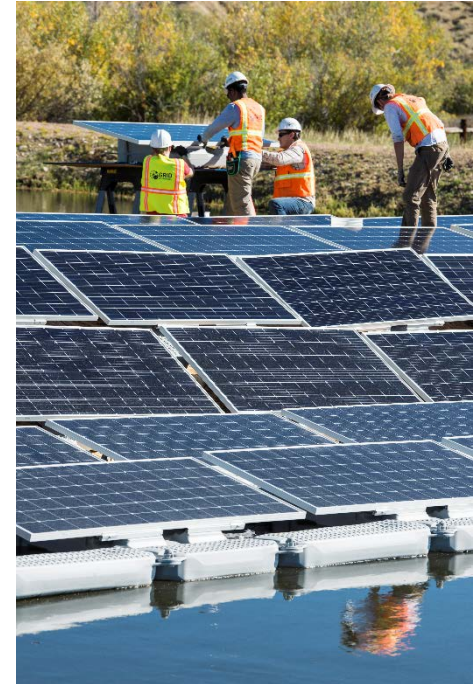
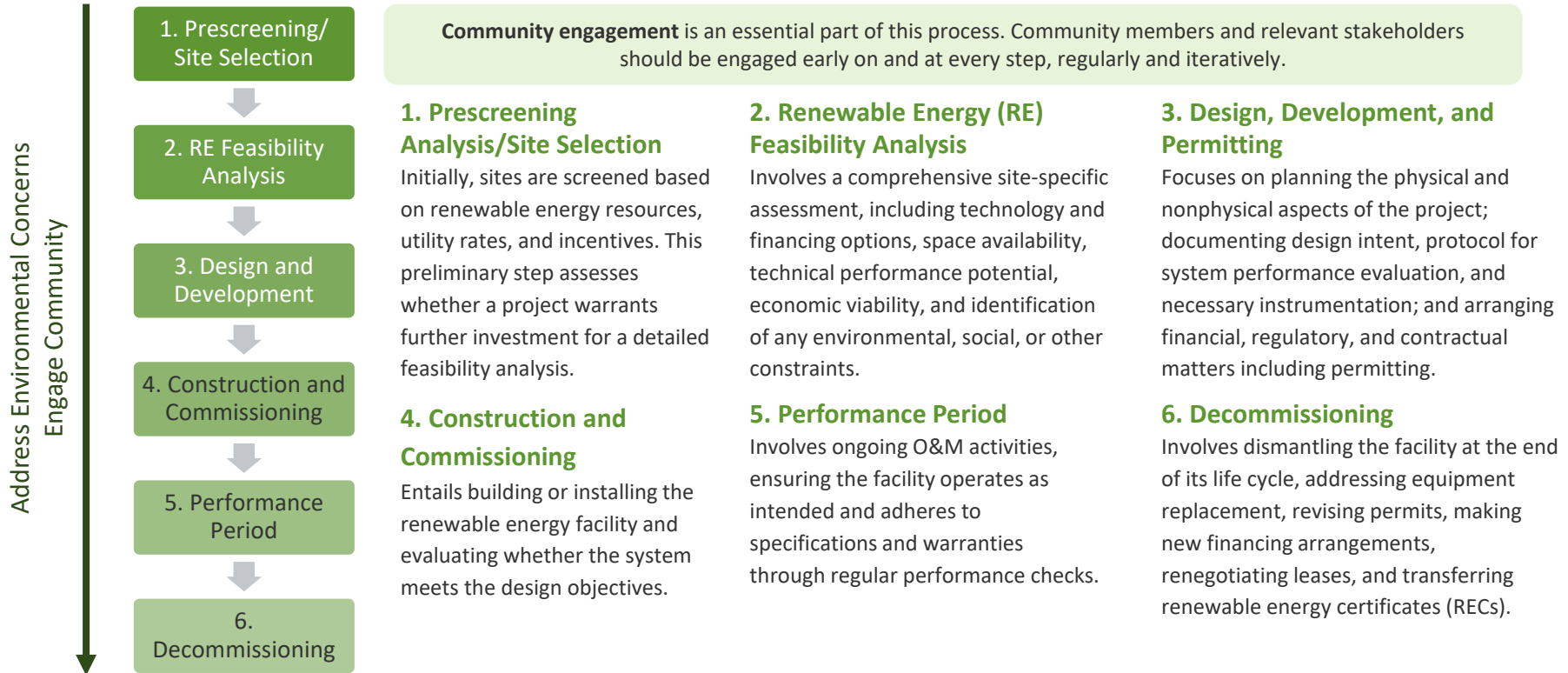


Photo by Dennis Schroeder, NREL 53254

¹ Absent of snow and ice loads and large vessel wakes

Project Development: Cycle and Strategy

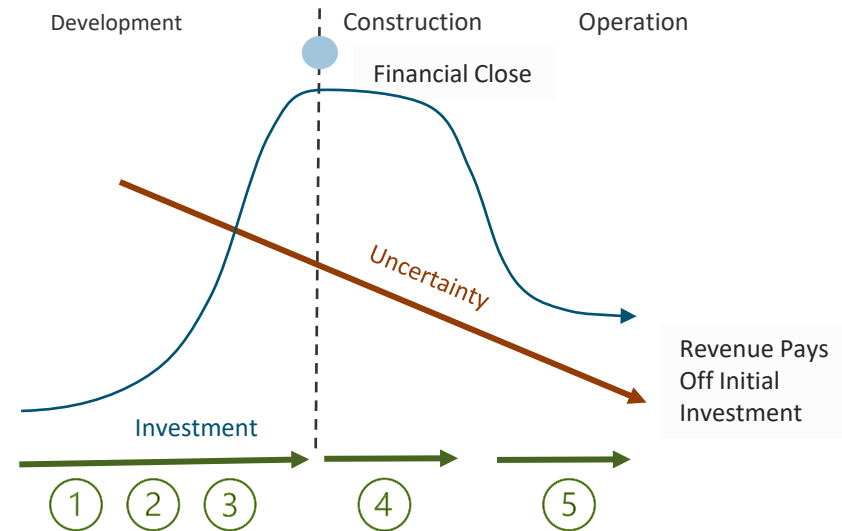
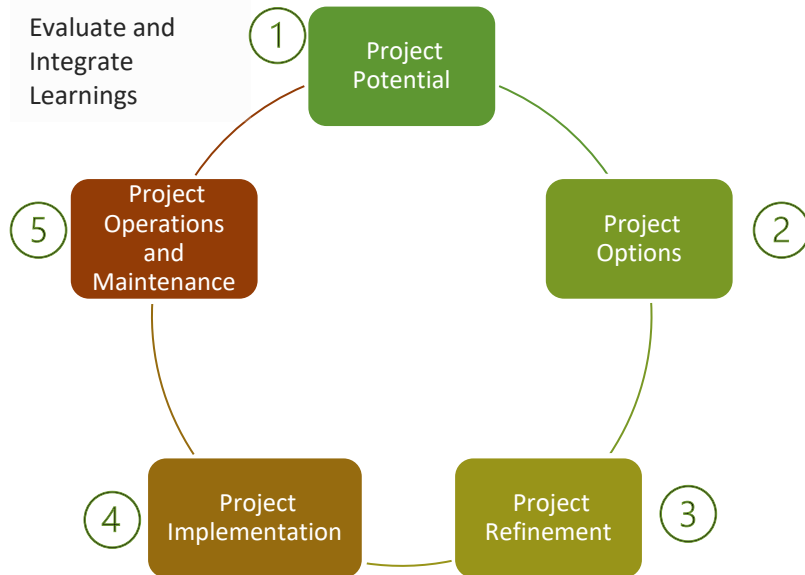
Typical Clean Energy Project Development Cycle



Developing a Project and Financing Strategy

Project development is an iterative process that enhances success by focusing on crucial investment decision points, optimizing resource allocation, and improving decision making. A structured process aids in identifying and implementing the most feasible techno-economic solutions to meet specific project requirements.

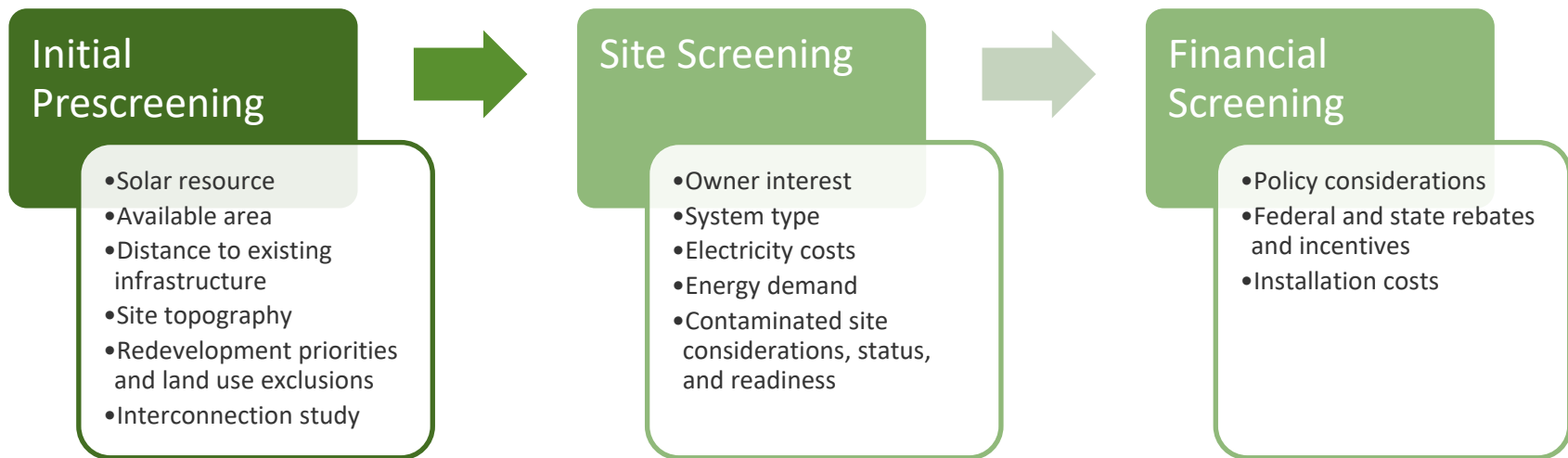
By adopting an incremental investment strategy, one can mitigate risks early in the life cycle.
Key throughout the process is to address and reduce risks along the way.



Project Development: Site Selection

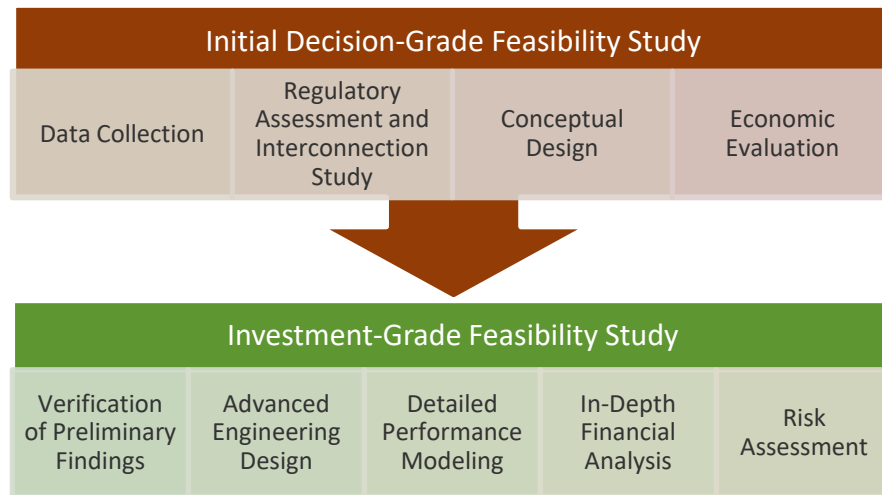
Selecting Sites: Many Sites Have Potential for Solar PV, But Not All Are Equally Suitable

Initial screenings help determine whether a detailed feasibility analysis is warranted.



Selecting Sites: Initial Decision-Grade Feasibility Study, Then a Detailed Investment-Grade Study

- 1. Decision-Grade Feasibility Study:** Involves gathering basic information about the site, brownfield characteristics, PV technologies, and regulatory requirements. This phase aims to decide whether to proceed with a more detailed analysis.
- 2. Investment-Grade Feasibility Study:** Conducted for promising sites to confirm decision-grade study assumptions, collect more data, and develop a preliminary engineering design. This study includes detailed performance modeling and financial analysis, often leading to project financing.



Assessing a brownfield for solar project feasibility involves **understanding its functional requirements**, such as waste management, water infiltration prevention, and stormwater management. The feasibility assessment must consider the integration of the PV system with these existing brownfield systems.

Feasibility studies should consider the general physical setting, brownfield technical siting considerations, PV technology options, and community support.

Project Development: Best Practices and Considerations

Development of Clean Energy Projects Can Often Begin Before or Concurrently With Cleanup

Many sites that are possibly contaminated must first undergo an environmental evaluation. Some sites may need little to no cleanup whereas others might require minimal to significant remediation before they can be repurposed.

1. Integration With Cleanup Plans

Coordinate closely with environmental agencies and cleanup teams to ensure the solar project aligns with ongoing remediation efforts. Adjust solar project planning to accommodate cleanup schedules and activities.

2. Safety and Environmental Protections

Implement stringent safety protocols for construction and operation in areas undergoing remediation. Use protective measures to prevent interference with cleanup processes and to safeguard workers and equipment.

3. Flexible Design and Phasing

Design the solar installation in phases, allowing for flexible deployment as different areas of the site become available post-cleanup. Use modular and movable solar infrastructure where feasible to adapt to changing site conditions.

4. Monitoring and Communication

Establish continuous monitoring and communication channels between the solar project team and the cleanup crew. This ensures timely responses to any emerging issues and aligns both efforts toward site safety and regulatory compliance.

The [Handbook on Siting Renewable Energy Projects While Addressing Environmental Issues](#) introduces typical cleanup and reuse processes and the renewable energy project development process, including the unique siting opportunities and potential benefits associated with this reuse.



Barceloneta Superfund site. Photo by Maya Fein-Cole, NREL 89457

Best Practices* for Siting Solar PV on Brownfields

Geosynthetic Cover Management

Geosynthetic covers can reduce mowing requirements and provide a setting with less dust and potential damage to solar PV panels.

Lightning Protection and Grounding

Protect from electrical surges and lightning strikes through proper grounding complying with safety standards.

Flexible Rack Systems

Cast-in-place systems can result in cost savings and are suitable for brownfield installation because of the ability to adapt to uneven terrain and ground penetration requirements.

Cover Management

Consider impact of PV arrays on plant growth because of shading and moisture availability and maintain compatibility with vegetative cover for erosion control.

Brownfield Gas-System Compatibility

Design compatibly with existing gas collection, monitoring, generation; allow dual-space functionality: solar PV potentially powers gas management equipment and offers cost savings and sustainability.

Stormwater Management

Ensure compliance with National Pollutant Discharge Elimination System (NPDES) and other stormwater management regulations; accommodate changes in runoff patterns because of solar PV system installation.

Site Security

Implement security measures such as perimeter fencing, security cameras, and possibly motion sensors to protect against theft, vandalism, and unauthorized access.

Operations and Maintenance Considerations

Adhere to brownfield post-closure plans and workforce safety protocols, manage panel washing and water, and ensure routine maintenance of stormwater systems and vegetative cover.

System Monitoring and Troubleshooting

Use remote monitoring systems to identify system performance anomalies and conduct troubleshooting.

*Not all practices will be suitable or appropriate for every site, and each location should be assessed on a case-by-case basis to determine the most effective approach.

Adapted from [Best Practices For Siting Solar Photovoltaics On Municipal Solid Waste Landfills](#).

What To Consider When Siting Solar PV on Brownfields

Stable Ground

For landfills in particular, the subsurface and cap of the landfill should be stable. Landfill solar developers generally avoid projects on landfills that have been capped for <2–3 years because of potential for high settlement rates.

Post-Closure Period

Renewable energy can be installed on brownfields, ensuring it does not compromise cleanup measures—such as landfill caps or restrictive covenants—and poses no health or environmental risks.

Solar Resource

The site should have optimal solar insolation with minimal shading from nearby structures or trees.

Site Accessibility and Proximity to Infrastructure and Interconnection

Assess accessibility for construction and maintenance; ensure connectivity to transmission lines and substations for easier and cost-effective grid connection.

Land Area With Adequate Slope

Sufficient continuous space to accommodate desired solar capacity, considering spacing between solar panels and other infrastructure. Ideal sloping between 0% and 10%, but systems can be installed up to 20%.

Environmental Impact

The site should have minimal environmental risks and manageable contamination levels that do not hinder installation or operation. Clean energy setups are feasible on brownfields with groundwater treatment if they do not disrupt treatment or monitoring processes.

Community Support

Engage local communities to address concerns and highlight project benefits such as job creation and environmental improvements.

Regulatory Compliance

Consider sites where the necessary permits for PV installation can be easily obtained and where there are no major regulatory hurdles—including whether the permitted post-closure use included solar PV system installation and operation.

What To Consider When Siting FPV

Water Depth, Stability, and Slope of Bottom

Ideally, waterbodies have consistent and moderate depths, neither too shallow nor too deep, to ensure the stability and safety of the floating structures.

Water Fluctuations

Sites with minimal seasonal water level fluctuations are more suitable because large variations might affect the system's anchoring and electrical connections.

Solar Resource

Look for optimal solar insolation with minimal shading from nearby structures or trees.

Waves and Wind, Currents, and Anchoring and Mooring

Seek protected or calm areas so strong waves or winds don't affect stability of floating structures. Consider suitable conditions for securely anchoring or mooring FPV panels without damaging the waterbody floor.

Water Quality

Sites with less organic material can reduce potential degradation or damage to the FPV structures.

Environmental Impact

Seek sites that pose minimal environmental risks when transformed into FPV site, with minimal disruption to local ecosystems, aquatic life, and water quality. Monitor potential temperature changes in the water underneath.

Site Accessibility and Proximity to Infrastructure

Assess accessibility for construction and maintenance; ensure connectivity to transmission lines and substations for easier and cost-effective grid connection.

Regulatory Compliance and Water Use Compatibility

Consider sites with easily obtainable permits for FPV installation and no major regulatory hurdles. Also consider compatibility with other waterbody uses such as recreation or fishing.

Best Practices for Building Community Support

Be transparent.

- **Host public meetings** and workshops to share project details with stakeholders. Share contracts and agreements and ensure they are easy to understand.
- **Share benefits to the community**, including how revenues generated from projects will support, e.g., local programs or community initiatives.
- **Ensure partner accountability for meeting community needs** by establishing oversight mechanisms and reporting requirements, e.g., performance guarantees.

Engage stakeholders early.

Solicit input, address concerns, and incorporate feedback into project plans. Consider **establishing community advisory committees or task forces** to ensure community voices are heard in planning and decision making.

- Involve community members in project **prioritization** and **partner-selection** processes.
- Collaborate with **local media** outlets to share information about the project and its potential benefits.

Demonstrate success

and showcase successful projects from other similar municipalities. Share success stories through local media.

Build local partnerships

and seek endorsements and support from local business associations, chambers of commerce, and community organizations; identify local champions.

Proactively mitigate visual impacts.

For **solar PV**, use **practical measures**, e.g., nonintrusive fencing and motion-activated lights, and conceal structures with earthen berms or strategically planted trees. Visualization models can **demonstrate project appearance to stakeholders**; share in public forums and materials.

FPV systems are typically less obstructive because of their low profile and location in depressions; however, visual impacts cannot be masked with landscaping. **Use visualization tools to site FPV farms in inconspicuous locations**, such as secluded inlets.

Regulatory Considerations for Clean Energy Development on Brownfields and Reservoirs

- **Interconnection processes** have a critical effect on energy project scale and technology.
 - All analyzed sites are within 1 mile or less of existing transmission lines operating at 38kV, 115kV, or 230kV.
 - Policy limits systems to 500 kW before additional technical screening is required, and to 1 MW overall for distribution-level voltages. Systems larger than 1 MW will require additional monitoring systems and will need to be connected to transmission-level voltages.¹
 - Complex technical and regulatory criteria can be costly (~10% of project costs) and complicated, particularly for large-scale projects needing grid upgrades.
 - Limited grid hosting capacity can hinder new projects.
 - Extensive approval process can delay projects and inflate budgets.
- **Low power purchase agreement (PPA) pricing** can directly influence the economic feasibility and scale of energy projects because it determines the revenue generated over the project's lifetime—affecting investment decisions, profitability, and financial viability.
- **Environmental permitting and National Environmental Policy Act (NEPA) review** dictate the regulatory compliance required to minimize environmental impacts.
 - Projects that involve federal funding, permits, or land located in/near sensitive environments or of public concern, among others, may trigger NEPA review.
 - Projects qualifying for NEPA exclusions can bypass extensive environmental reviews, significantly reducing development timelines and costs.

Transmission-level interconnection offers **wider market access** but incurs **higher costs and complexity**.

Distribution-level interconnection is **quicker and cheaper** but **limits project size** and faces **capacity constraints**, impacting project scale and economics.

¹ [Motion Submitting Complete Version of Technical Interconnection Requirements Document](#) (2022)

Co-Siting and Mixed-Use Options To Consider in Brownfield Redevelopment

Brownfield sites may have rooftop solar PV potential.

- Rooftop areas tend to be small, but sites are often located in built-up areas where energy demand is higher.
- There is potential for co-siting PV with other development based on landowner priorities.
- Developments that could be accompanied by PV include parking lots, emergency response centers, recycling plants, cement plants, and other industrial areas.

Various Brownfields, Cataño (left) and Ponce (center, right)



Existing rooftop PV observed on Fox Former Delicias Theater/Mall (Brownfields), Ponce



Municipal Land Parcel (Brownfields), Cataño



Gulf Gas Station (Brownfields), Cataño



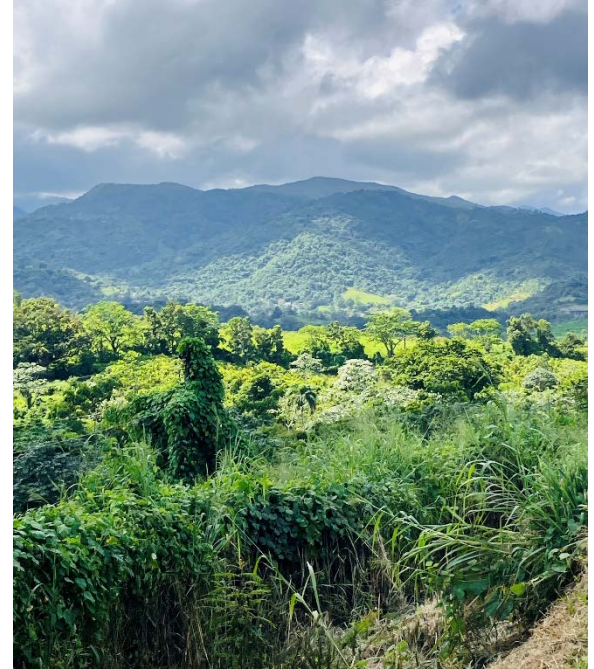
Photos from GIS

Project Development: Ownership Models

Ownership Models: Consider Goals, Engagement, Financials, Expertise, Risk, and More

Site owners seeking to redevelop brownfields should ask:

- What are our clean energy goals, and how do they align with our community's values?
- What are our financial resources and the availability of external funding?
- Do we have the technical expertise to manage clean energy systems, or should we seek partnerships?
- How do we prioritize risk management and long-term financial stability?
- What is our timeline for clean energy implementation, and how will we scale our efforts?
- How can we engage our community effectively and ensure their support?
- What level of control and flexibility do we need over clean energy projects?
- What funding opportunities and legal/regulatory considerations are relevant to our jurisdiction?
- Are we prepared for long-term commitments and potential changes in ownership models?



View from Fajardo Landfill. Photo by Angela Ortega Pastor, NREL 89453

Typical Ownership Models: Advantages and Potential Challenges

Model	Overview and Advantages	Possible Challenges
Municipality Owned	The municipality finances the project with tax-exempt bonds, owns it, and sells the generated power to a utility for distribution. This approach offers direct control, cost savings, revenue opportunities, and local employment.	High upfront costs, limited technical expertise, regulatory and administrative hurdles, risk and uncertainty, limited scalability, and funding constraints. Municipalities must be able to access capital markets to issue bonds.
Utility Owned	The utility invests in the project under strict regulations, hosting or partnering with a site host. Benefits include stable investment, grid integration, expert access, economies of scale, and long-term predictability.	Long-term commitment involves potential cost increases, dependency on agreements, limited local control, transition challenges, tax and ownership implications, risk aversion, and the risk of overlooking smaller community-based projects because of investment priorities.
Third-Party Owned	An external investor finances and owns the project, earning returns through incentives and subscriptions with the site host. This approach eliminates upfront costs, lowers risk, provides access to expertise, and ensures long-term predictability.	



Guayama Landfill. Photo by Maya Fein-Cole, NREL 89456

Typical Ownership Models: Costs, Maintenance, and Exit Strategies

Model	Life-Cycle Costs and Maintenance	Exit Strategies
Municipality Owned	The municipality covers all life-cycle costs, from initial capital expenditures to maintenance and decommissioning, and controls maintenance to meet local standards and sustainability goals. However, lacking economies of scale and specialized expertise could increase these costs.	The municipality retains complete control, enabling decisions on asset sales or leases if goals or financial needs change. It should evaluate its capacity for long-term commitments and consider leasing if direct management is unsustainable.
Utility Owned	The utility covers significant life-cycle costs, using its scale and expertise for cost efficiency, and handles maintenance with established procedures and economies of scale. However, its long-term costs can be affected by financial stability and regulatory changes.	The municipality should assess the utility's long-term plans and stability because strategic shifts could disrupt project continuity. It needs to evaluate risks from regulatory changes that could affect the utility's long-term support and understand the conditions and implications of a potential project transfer to align with its energy and financial objectives.
Third-Party Owned	The investor covers most life-cycle costs and maintenance, reducing the municipality's financial risk with fixed or predictable costs under the agreement. However, project cost control and durability depend on the investor's commitment to maintenance and contract compliance.	The municipality should understand the investor's investment horizon and exit plans, including potential stake sales or refinancing. It is crucial to clarify end-of-investment procedures, such as the possibility of municipal takeover or sale to others, ensuring alignment with community energy goals and infrastructure needs.

Other Ownership Models

Model	Overview
Community Shared Renewables	The subscription represents a portion of the generation from the community solar project and often translates to savings on the participant's electric bill.
On-Site Behind-the-Meter	An electricity customer installs and owns a renewable project on the customer side of the meter to supply on-site power and displace power purchased from the utility.
Cooperative Local Ownership	Local landowners and investors pool their resources into an LLC to own and operate the project while selling output to the local utility to incorporate into its grid mix to serve all customers.
Flip Structure	Investors without tax liability bring in a tax-motivated corporate equity partner to own most of the project for the period of tax credits (6–10 years) and then “flip” project ownership to the local investor thereafter.



Photo by Werner Slocum, NREL 81423

Resources

RE-Powering America's Land



What Is RE-Powering?

- [What is RE-Powering?](#)
- [What are the Benefits of These Projects?](#)
- [What if Cleanup Activities are Ongoing?](#)

How To Identify Sites

- [Looking for a Renewable Energy Site? Find Sites in the RE-Powering Mapper.](#)
- [Is a Solar or Wind Project Feasible at My Site? Use the RE-Powering Decision Tree.](#)
- [Review Sites with Feasibility Studies.](#)

How To Develop Sites

- [Does the Site have Sufficient Resource?](#)
- [How can I Finance a Project?](#)
- [Are Incentives and Policies Available?](#)
- [Inflation Reduction Act Information.](#)
- [How Can I Get Protection from Cleanup Liability if I Buy or Lease a Property?](#)
- [How do you Develop Solar on Landfills? Read this Best Practice.](#)
- [Does the Site Need Interconnection?](#)
- [Read these Success Stories.](#)

Learn More

- [Where Can You Find RE-Powering Sites? Check out the Tracking Matrix.](#)
- [What are Some Benefits of Actual RE-Powering Sites?](#)
- [What is Community Solar?](#)
- [Review the Critical Infrastructure Study.](#)
- [Superfund Program.](#)

RE-Powering America's Land: Siting Renewable Energy on Potentially Contaminated Land, Landfills, and Mine Sites

The RE-Powering Electronic Decision Tree tool guides users through a site screening for suitability for solar PV or wind installations. The tool addresses the following types of sites:

- Potentially contaminated sites (Superfund, brownfield, Resource Conservation and Recovery Act [RCRA], mine site)
- Landfill (municipal solid waste; construction and demolition or similar unit)
- Underused (abandoned parcels, parking lots, buffer zones)
- Rooftop (solar PV only; commercial/industrial roofs).

It provides:

- A step-by-step walk through of key considerations for RE development at the site
- Suggested resources to help you answer screening questions to gauge the site's potential
- Reports summarizing your answers to the screening questions, initial findings regarding suitability, and other comments about the site.

See [documentation](#).

Screening Sites for Wind Energy Potential
Emphasis on Redevelopment of Potentially Contaminated Lands or Underutilized Sites

RE-Powering America's Land Initiative: Wind Energy Decision Tree

Through ongoing collaboration, the Environmental Protection Agency (EPA) and Department of Energy's National Renewable Energy Laboratory (NREL) created a decision tree to guide state and local governments and other stakeholders through a process for screening sites for their suitability for future redevelopment with wind energy.

Targeted sites include brownfields, Superfund sites, RCRA sites, abandoned parcels, landfills, and mining sites. EPA encourages the development of these targeted sites, instead of green space.

This decision tree can be used to screen individual sites for wind energy potential or for a community-scale evaluation of multiple sites. The process is also applicable for a range of sites, from single turbine installations to large wind farms.

It is not intended to replace or substitute the need for a detailed site-specific assessment that would follow an initial screening based on the decision tree. Tips on how to obtain information relevant to various parameters in the decision tree are provided.

Through the RE-Powering America's Land initiative, the EPA encourages renewable energy development on potentially contaminated land when aligned with the community's vision for the site. This tool outlines considerations specific to the redevelopment of potentially contaminated sites. Potentially contaminated land includes sites where contamination is suspected but has not been confirmed and sites where contamination has been identified.

The EPA also promotes redevelopment of urban sites to achieve "Smart Growth" objectives. Community vision for the site, as well as the site's key attributes, should shape the redevelopment plan.

Many additional resources can be found on the following EPA and NREL websites:
www.epa.gov/renewableenergy.html
www.nrel.gov/learning/ov_wind.html

Process Overview

- I. Pre-Screening**
 - Wind Resource
 - Available Area
 - Distance to Existing Infrastructure
 - Site Topography
 - Redevelopment Priorities & Land Use Exclusions
- II. Site Screening**
 - Owner Interest
 - System Type
 - Contaminated Site Considerations, Status, and Readiness
 - Electricity Costs
 - Energy Demand
- III. Financial Screening**
 - Policy Considerations
 - Federal and State rebates and incentives
 - Installation costs

Key Audiences & Document Purpose

Stakeholder	Purpose
State and Local Governments	To help states and municipalities screen and prioritize existing sites for their suitability for wind installations. Targeted sites include brownfields, Superfund sites, RCRA sites, publicly owned facilities, abandoned parcels, landfills, and mining sites.
Clean-up Project Managers	To aid clean-up project managers to screen their potentially contaminated sites for wind development potential.
Renewable Energy Developers	To introduce renewable energy developers to considerations unique to redevelopment of potentially contaminated sites and provide a common framework for discussions with state and local governments on the potential development of sites for wind installation. This content is primarily oriented to those of all the screening process.
Site Owners	To help site owners evaluate a given

More Info

- 1. More Info: Overview
- 2. More Info: Characteristics & Requirements
 - Information on Solar Resources
 - Unutilized Solar Resources
 - Unutilized Acreage
 - Unutilized Available Areas
 - Unutilized Available Sites
 - Unutilized Available Sites
 - Transmission Lines
 - Unutilized Access to Energy

Site Characteristics and Redevelopment

Information on Solar Resources

Sites tracked within EPA's **EE: Potential "Hotspot"** tool contain solar resource information.

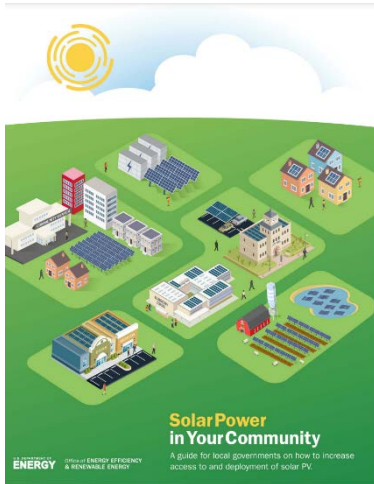
In addition, the U.S. Department of Energy's National Renewable Energy Laboratory (NREL) and its SunShot program provide resources to explore solar resource:

NREL's **Renewable Energy Resource Data** provide information at a regional level, while **PVWatts Viewer** provides resource based on site address, zip code, or latitude and longitude. The EPA's **SolarScore**

NREL Solar Resource Map

Photo from EPA

Solar Development and Financing



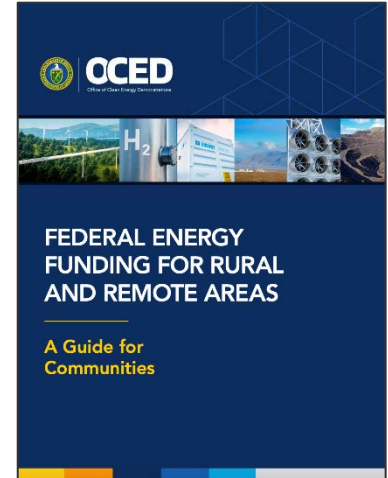
[Solar Development Guide for Local Governments](#)



[U.S. Department of Energy \(DOE\) Large-Scale Solar Siting Information](#)

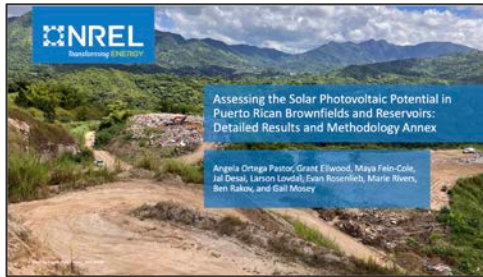


[Financing Renewable Energy Projects on Contaminated Lands Fact Sheet](#)

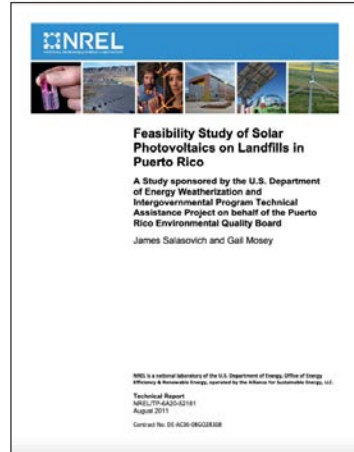


[Federal Energy Funding for Communities Guidebook](#)

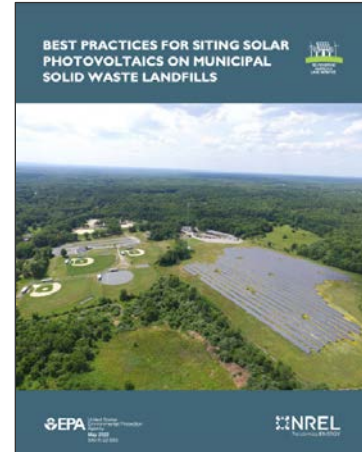
Solar PV in Brownfields



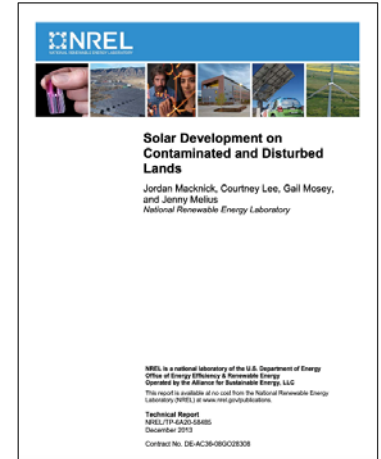
[Assessing the Solar Photovoltaic Potential in Puerto Rican Brownfields and Reservoirs: Detailed Analysis and Annexes](#)



[2011 NREL Feasibility Study on Puerto Rico Landfills](#)



[Best Practices for Siting Solar PV on Municipal Solid Waste Landfills](#)



[Solar Development on Contaminated and Disturbed Lands](#)



www.nrel.gov

NREL/PR-7A40-89876

This work was authored by the National Renewable Energy Laboratory, operated by Alliance for Sustainable Energy, LLC, for the U.S. Department of Energy (DOE) under Contract No. DE-AC36-08GO28308. Support for the work was also provided by the Federal Emergency Management Agency under Interagency Agreement HSFE02-23-IRWA-0003, Year 1. The views expressed in the article do not necessarily represent the views of the DOE or the U.S. Government. The U.S. Government retains and the publisher, by accepting the article for publication, acknowledges that the U.S. Government retains a nonexclusive, paid-up, irrevocable, worldwide license to publish or reproduce the published form of this work, or allow others to do so, for U.S. Government purposes.

Photo from iStock-627281636

