SOLAR ENERGY
TECHNOLOGIES OFFICE
U.S. Department Of Energy

Solar Resource and Technical Potential Modeling

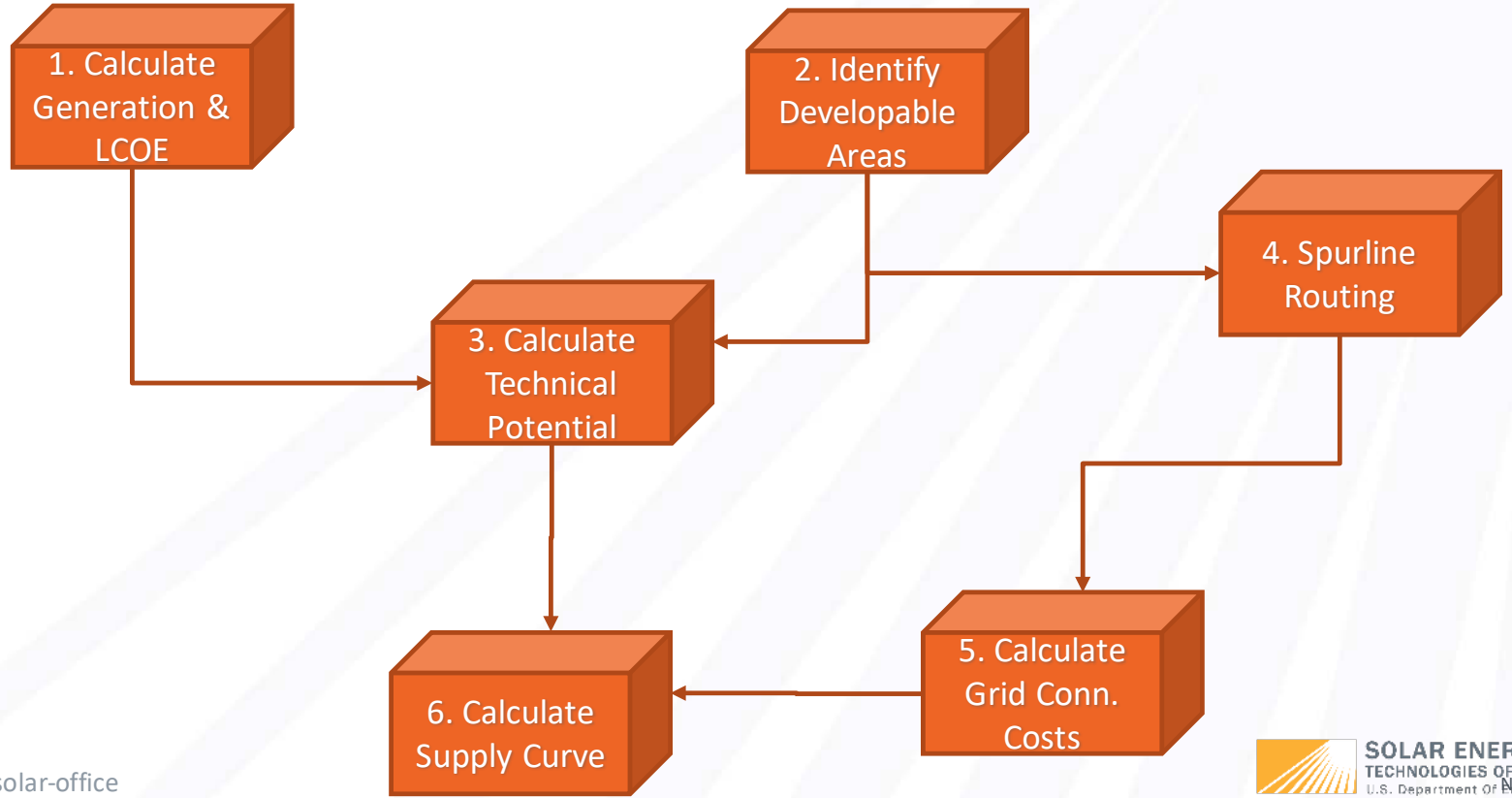
Nick Grue

Solar Technical Potential and Infrastructure, Transmission, and Operating Resilience Analysis Webinar
November 15, 2019

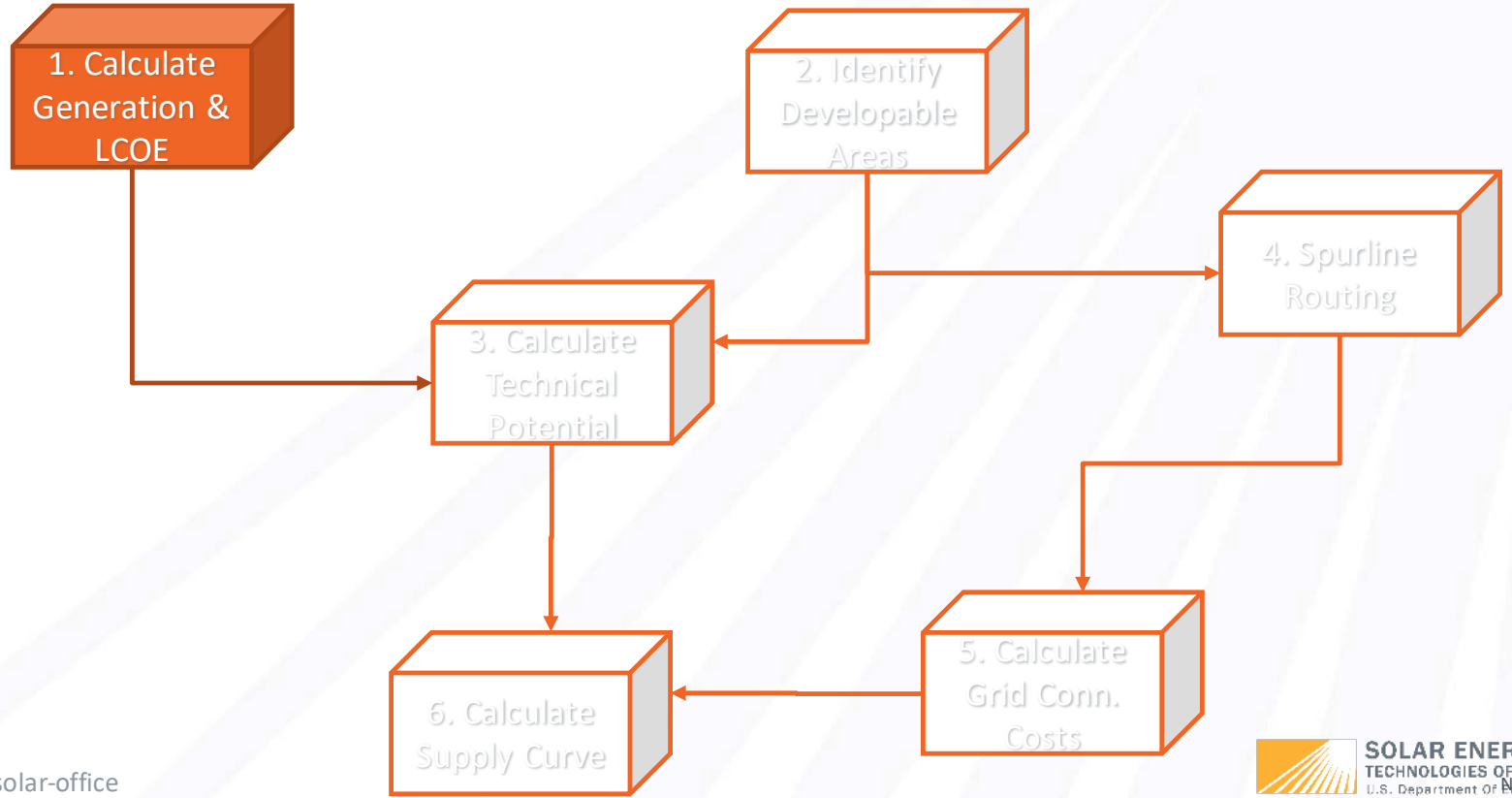
Purpose

- To identify potentially developable area for new photovoltaic systems.
- Quantity cost of development and interconnection.
- Provide some guidance on locations to further investigate for new development.

Technical Potential & Supply Curve Modeling

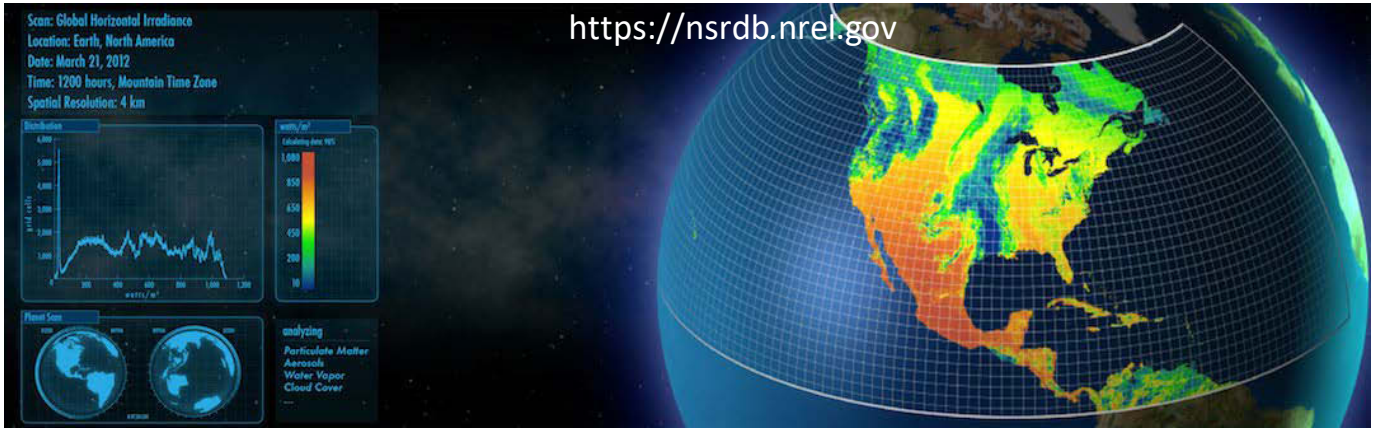


Technical Potential & Supply Curve Modeling



National Solar Radiation Database

- The NSRDB seeks to advance our knowledge of solar radiation and its applications for renewable energy and beyond.
- The NSRDB provides a serially complete database of solar irradiance and meteorological information across the United States and in a growing number of international locations.
- The NSRDB provides 20 years (+ Typical Meteorological Year) of half-hourly data at a 4x4-km spatial resolution.
- The NSRDB uses the Physical Solar Model **(PSM)** to compute solar radiation from satellite observations.



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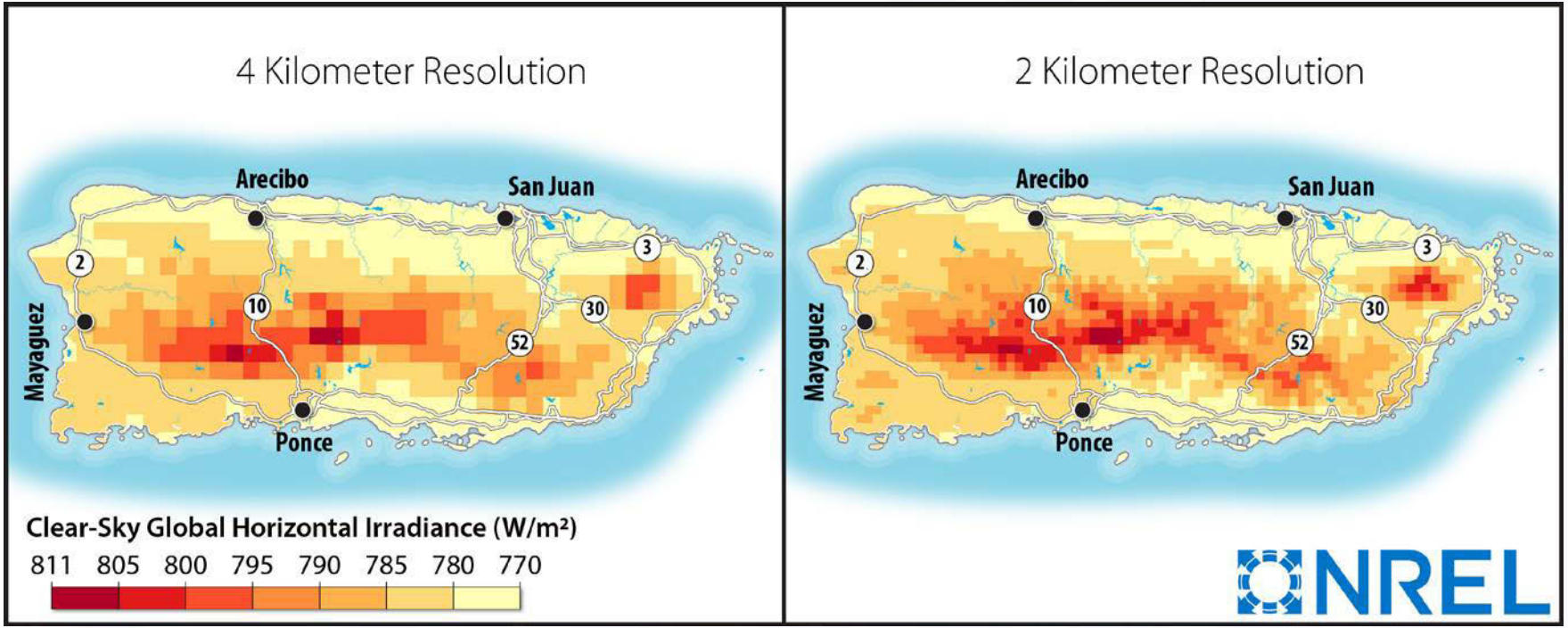
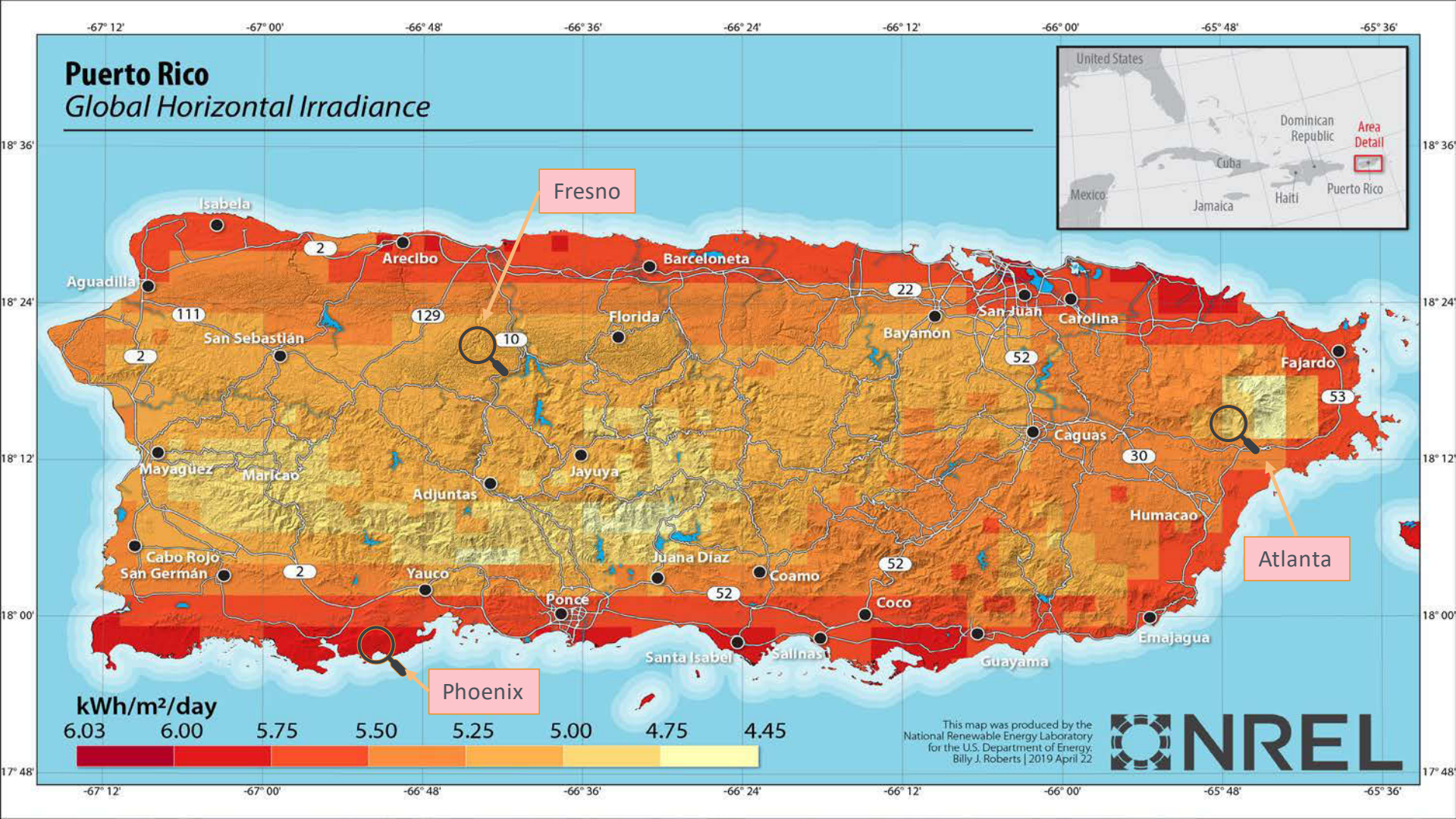
Methodology – Spatial Downscaling

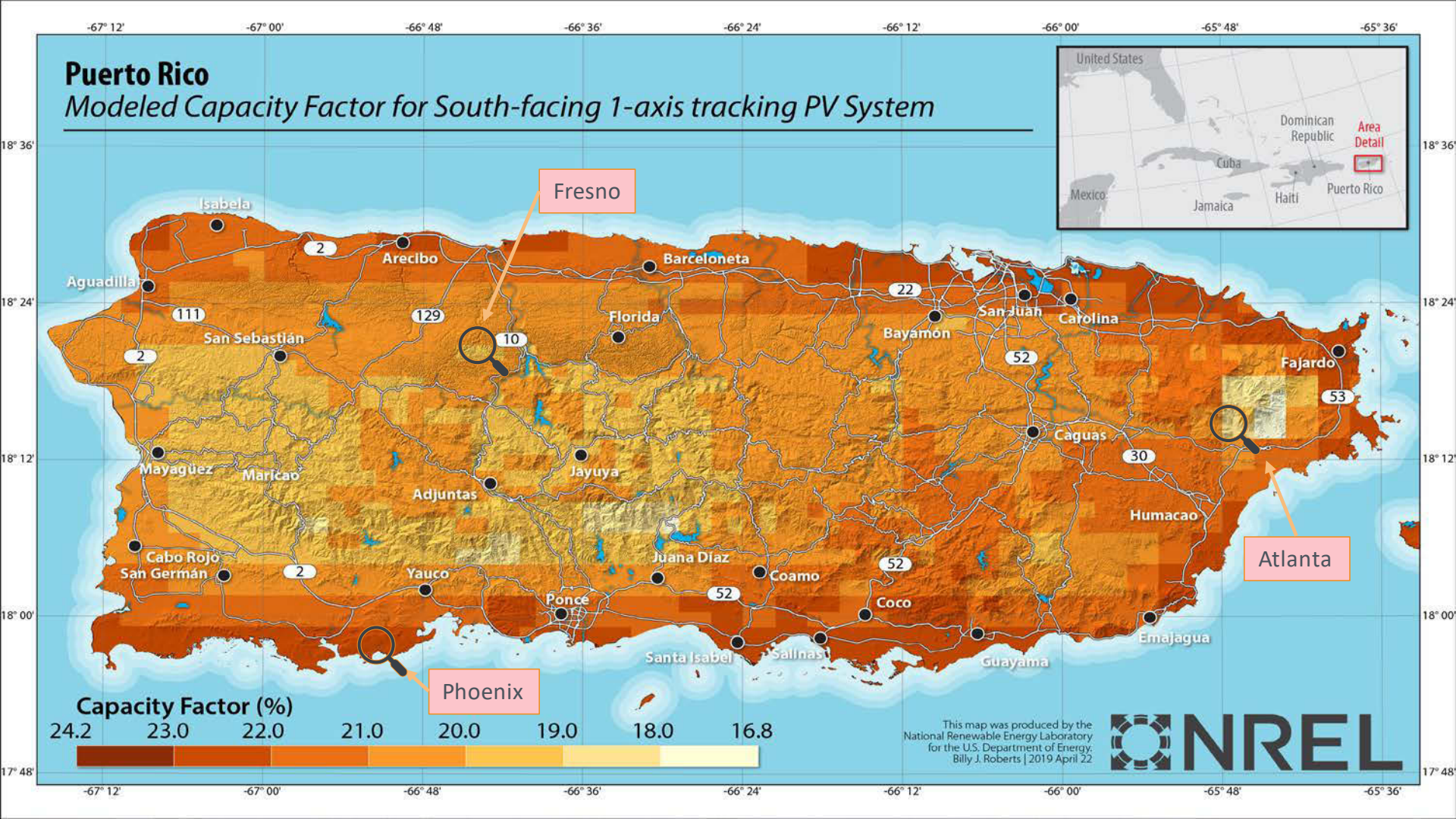
- This clear-sky irradiance map illustrates the spatial downscaling:



PV System Configuration

Parameter	Setting
Type	1 Axis Tracking
Losses	14.07 %
Tilt	0 Degrees
Panel Type	Standard
Inverter Efficiency	96 %
Ground Cover Ratio	0.4
DC / AC Ratio	1.3
Power Density	~33 MW/km^2


Puerto Rico
Global Horizontal Irradiance
United States
Dominican Republic
Area Detail
Cuba
Mexico
Jamaica
Haiti
Puerto Rico
Fresno
Atlanta
Phoenix
Isabela
Arecibo
Barceloneta
Aguadilla
San Sebastián
Florida
Bayamón
San Juan
Carolina
Fajardo
Caguas
Mayagüez
Maricao
Adjuntas
Jayuya
Humacao
Cabo Rojo
San Germán
Yauco
Juana Díaz
Coamo
Ponce
Coco
Emajagua
Santa Isabel
Salinas
Guayama
kWh/m²/day
6.03
6.00
5.75
5.50
5.25
5.00
4.75
4.45
This map was produced by the National Renewable Energy Laboratory for the U.S. Department of Energy.
Billy J. Roberts | 2019 April 22
NREL
-67° 12'
-67° 00'
-66° 48'
-66° 36'
-66° 24'
-66° 12'
-66° 00'
-65° 48'
-65° 36'
18° 36'
18° 24'
18° 12'
18° 00'
17° 48'


Puerto Rico
Modeled Capacity Factor for South-facing 1-axis tracking PV System
United States
Dominican Republic
Area Detail
Cuba
Mexico
Jamaica
Haiti
Puerto Rico
Fresno
Atlanta
Phoenix
Isabela
Aguadilla
Arecibo
Barceloneta
Florida
San Sebastián
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Jayuya
Humacao
Cabo Rojo
San Germán
Yauco
Juana Díaz
Coamo
Ponce
Coco
Santa Isabel
Salinas
Guayama
Emajagua
Capacity Factor (%)
24.2
23.0
22.0
21.0
20.0
19.0
18.0
16.8
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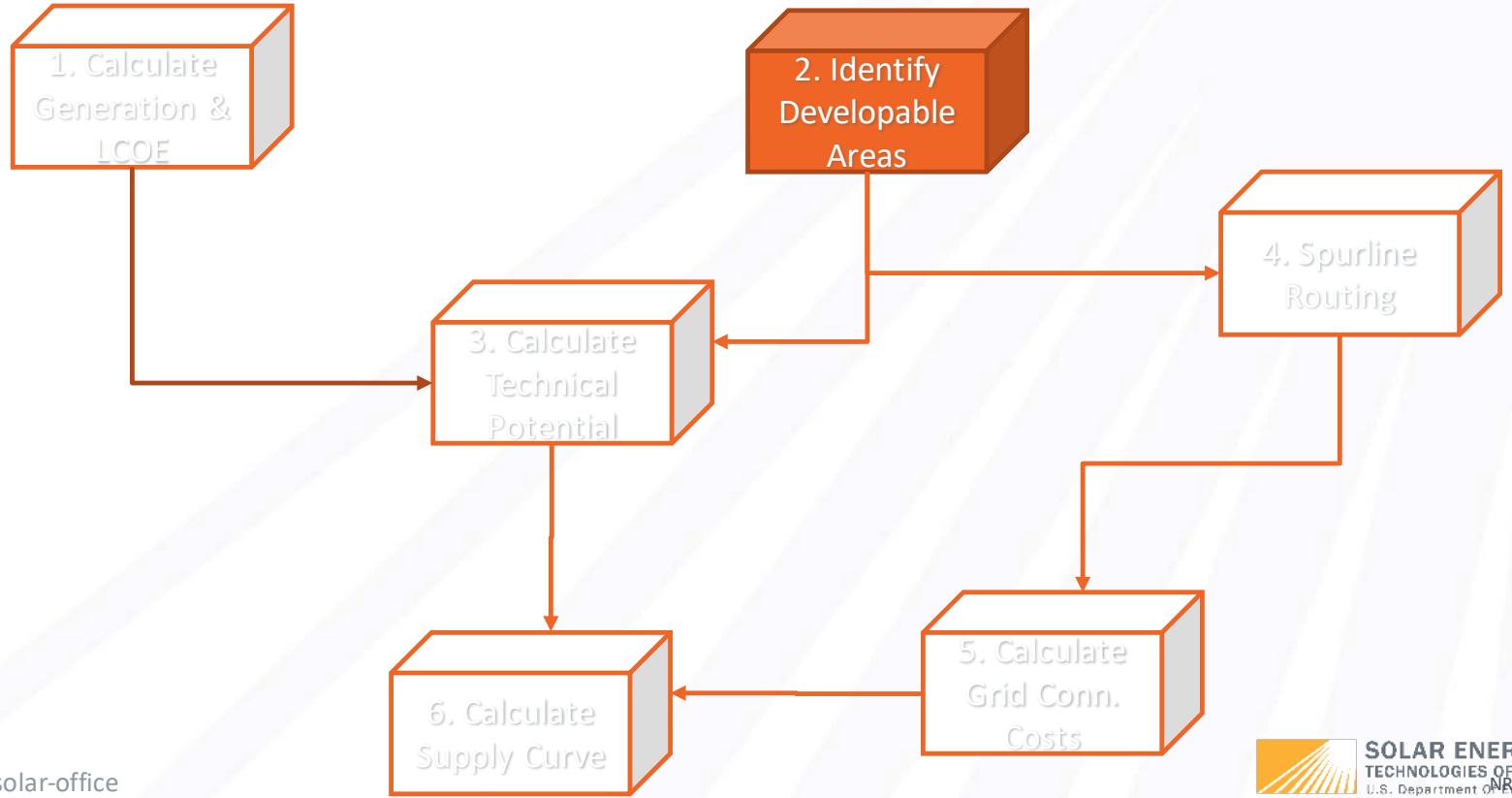
-65° 36'
18° 36'
18° 24'
18° 12'
18° 00'
17° 48'

Site Levelized Cost of Energy Calculations

Assumption	Value	Fixed or Variable
Capital Cost	$1.6 Million / MW	Variable
Fixed O&M	$11,850 / MW-yr	Variable
Fixed Charge Rate	0.0669	Fixed

Still need to calculate interconnection costs

Technical Potential & Supply Curve Modeling



Identify Developable Areas

- Where are potential land areas that are available for new development?

Geographic Exclusions

Category	Source	Exclusion Arguments
Slope	U.S. Forest Service	> 5% slope
Man-made structures	Humanitarian OpenStreetMap Team	Presence of man-made structures
Protected Areas	U.S. Forest Service	Presence of protected areas
Land Cover	MRLC National Land Cover Dataset (2001)	Waterbodies; Wetlands; Developed Land
Contiguous Area Filter*	n/a	< 0.2 km^2


Puerto Rico
Photovoltaic Development Potential
Utility Scale
United States
Dominican Republic
Area Detail
Cuba
Mexico
Jamaica
Haiti
Puerto Rico
-67° 12'
-67° 00'
-66° 48'
-66° 36'
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Humacao
Cabo Rojo
San Germán
Yauco
Juana Díaz
Coamo
Ponce
Coco
Santa Isabel
Salinas
Guayama
Emajagua
2
111
129
10
22
52
53
30
PV Developable Area
This map was produced by the National Renewable Energy Laboratory for the U.S. Department of Energy.
Billy J. Roberts | 2019 April 22
NREL

Large swaths of land are procedurally disaggregated

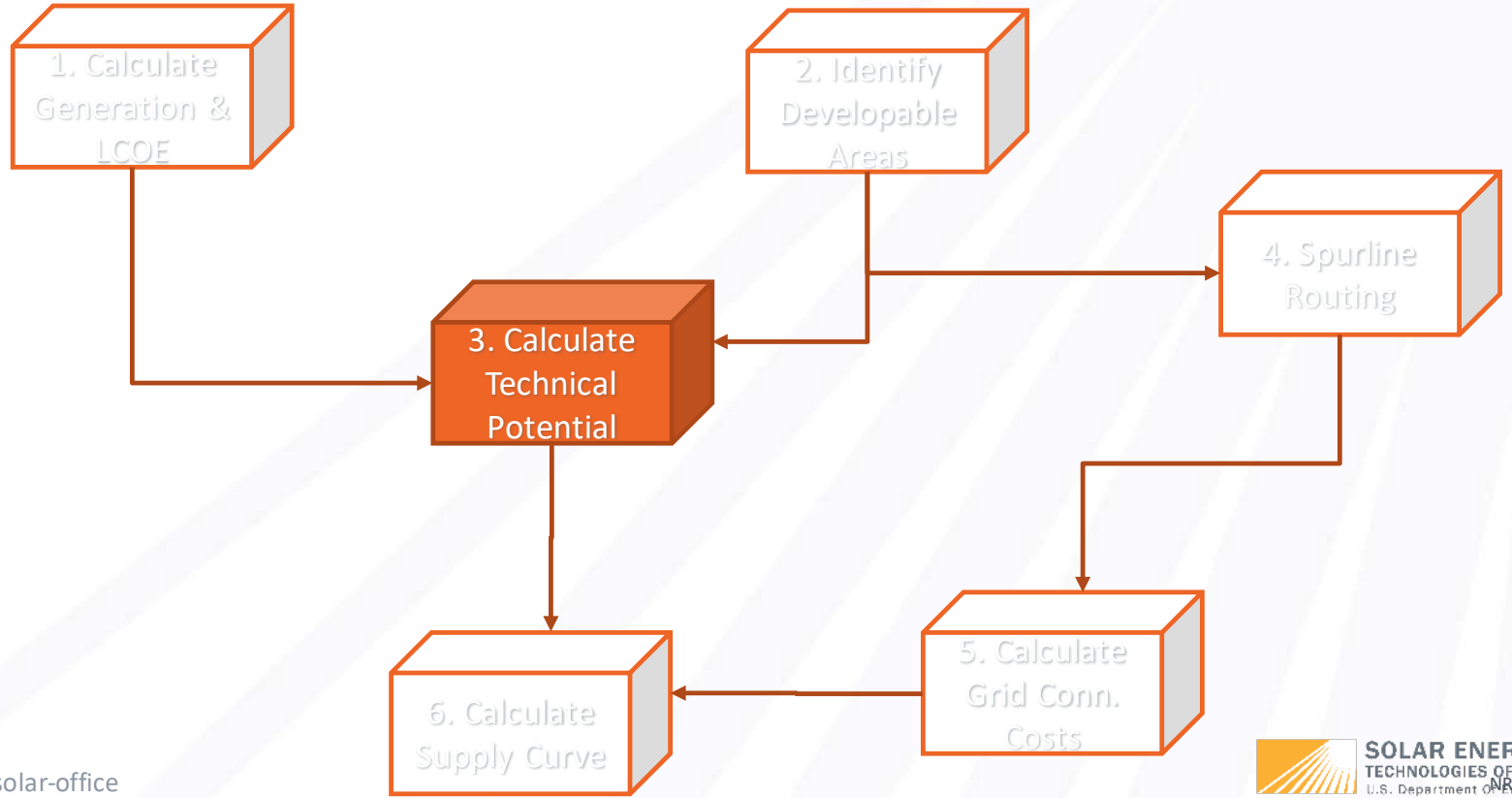
The purpose is to represent a more reasonable PV plant shape

Any locations that can accommodate more than 100 MW of nameplate capacity is further disaggregated

Available Areas

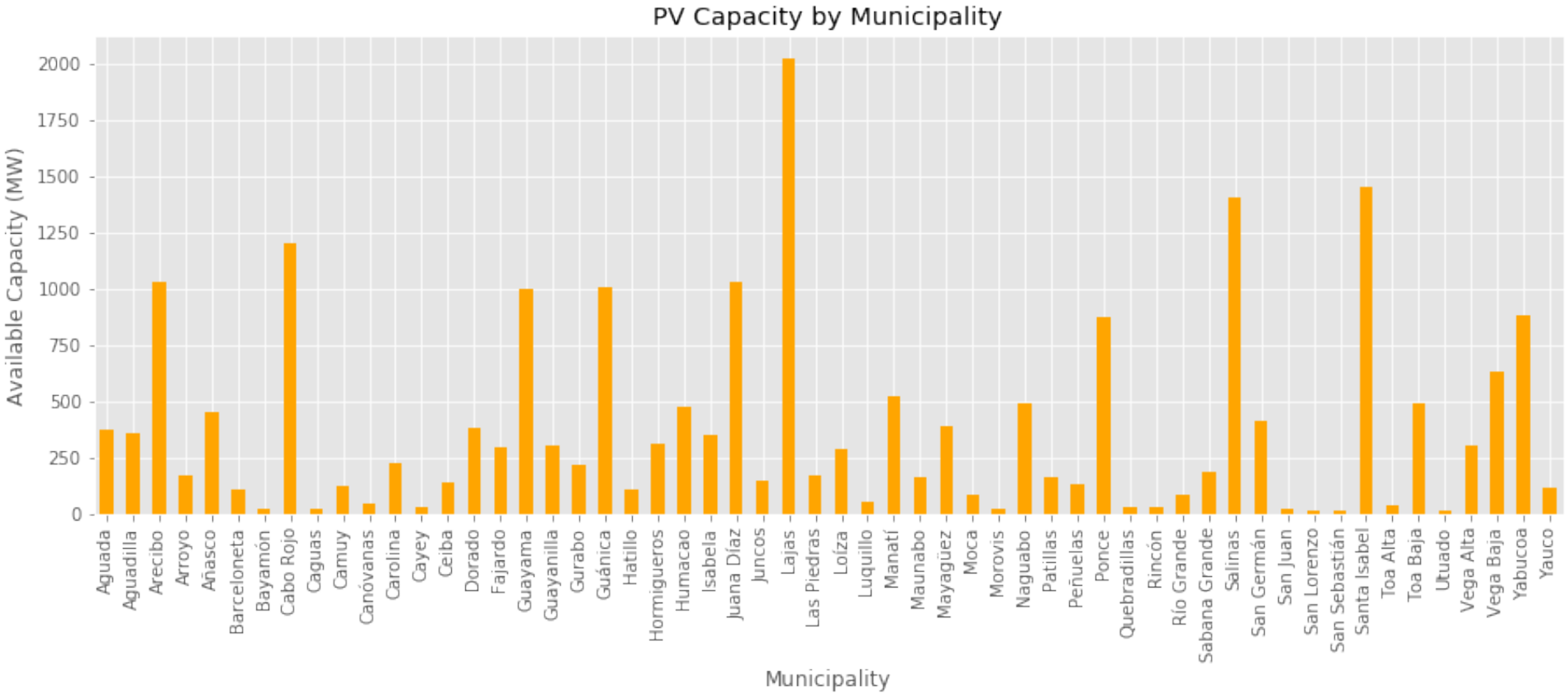
- ~ 650 sq.km. available area based on used assumptions.
- Majority of available land in the South.
- Some available land near load centers in the North.
- Slope was the most impactful exclusion due to highly mountainous regions central to the island.

Technical Potential & Supply Curve Modeling

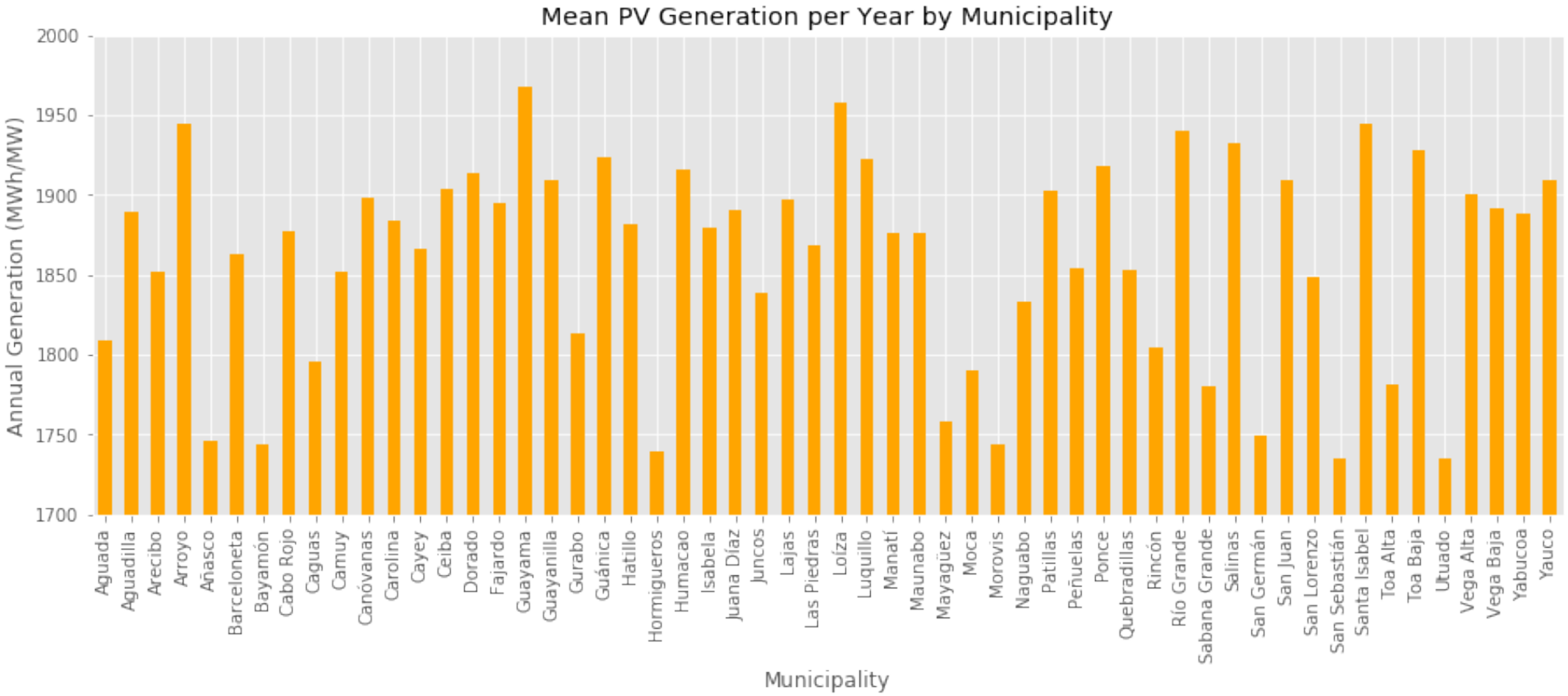


Technical Potential

1. Calculate capacity based on assumed land exclusion restrictions
2. Using solar resource data, calculate potential annual generation



*Municipalities without any capacity (using assumed exclusions) are not present.



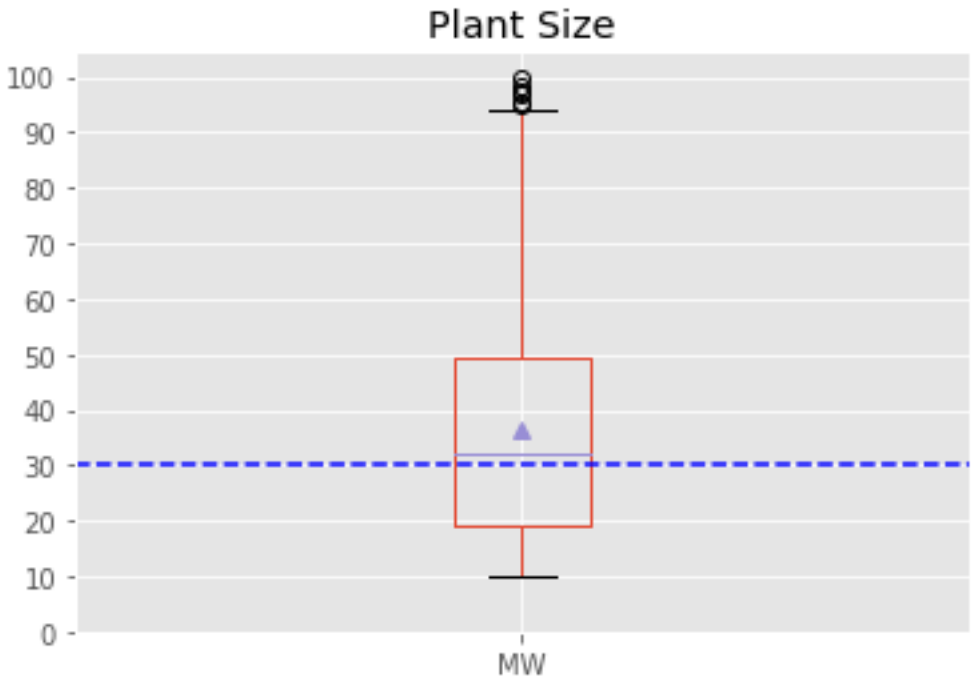
*Municipalities without any capacity (using assumed exclusions) are not present.

PV System Characteristics

- The PV system that SIEMENS modeled is static compared to NREL's analysis
- Though based on the SIEMENS modeled PV system, the dynamic nature of the analysis for Task 1 shows greater variance in system capacity, performance, and costs

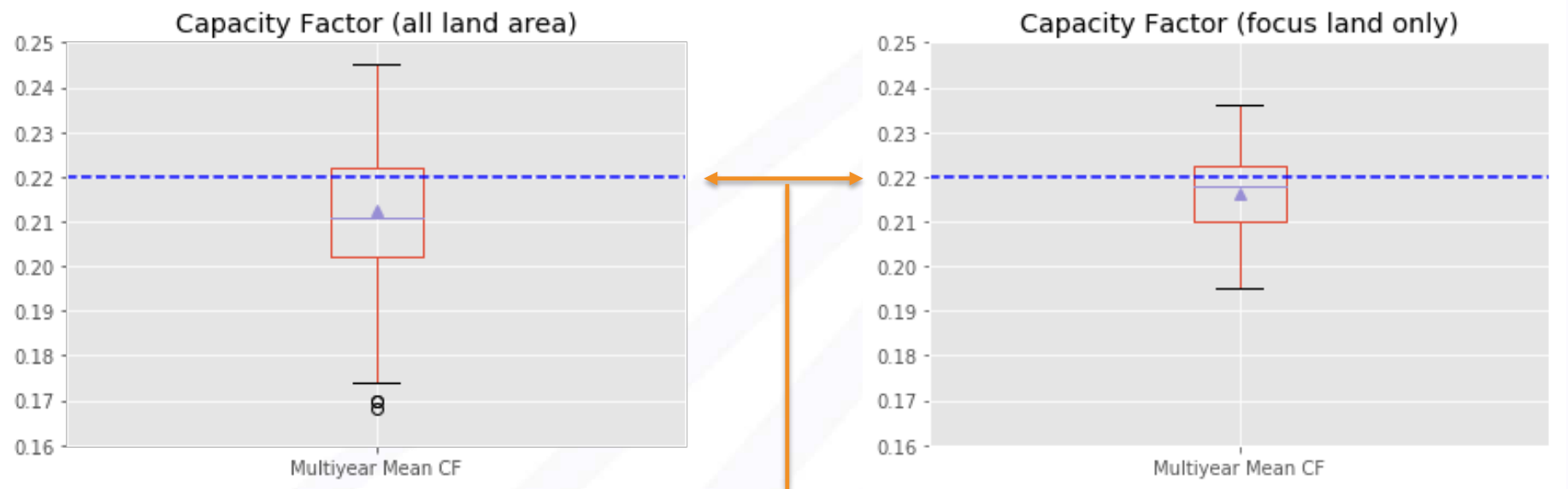
	SIEMENS	NREL
PV System Size (MW)	30	10 <= Size <= 100
Capacity Factor (%)	22	16.8 <= CF <= 24.5
Dist. To Interconnection (mi)	1	~0 <= Dist <= 11

PV System Size



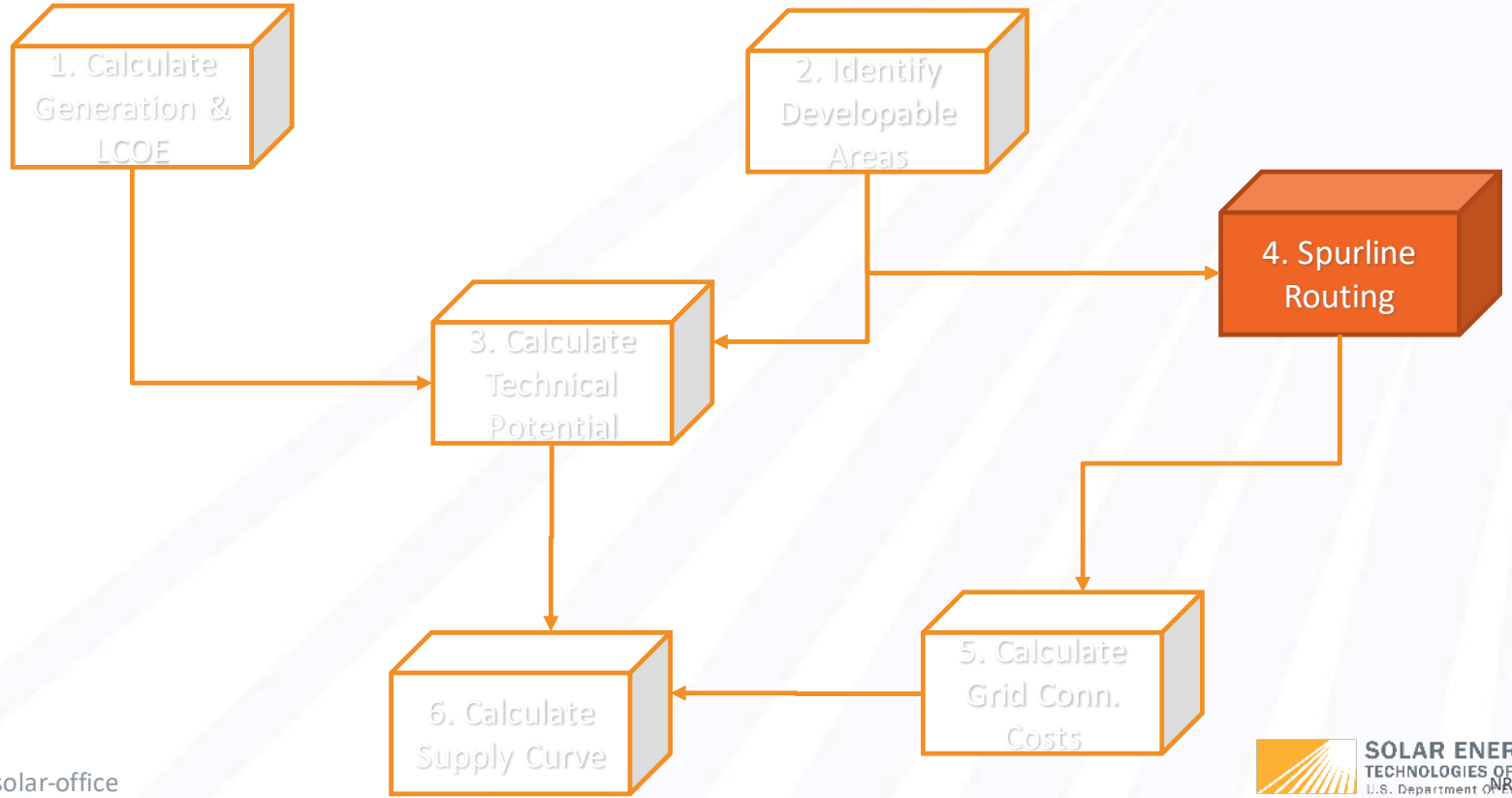
SIEMENS capacity assumption

Capacity Factor



SIEMENS capacity factor assumption

Technical Potential & Supply Curve Modeling



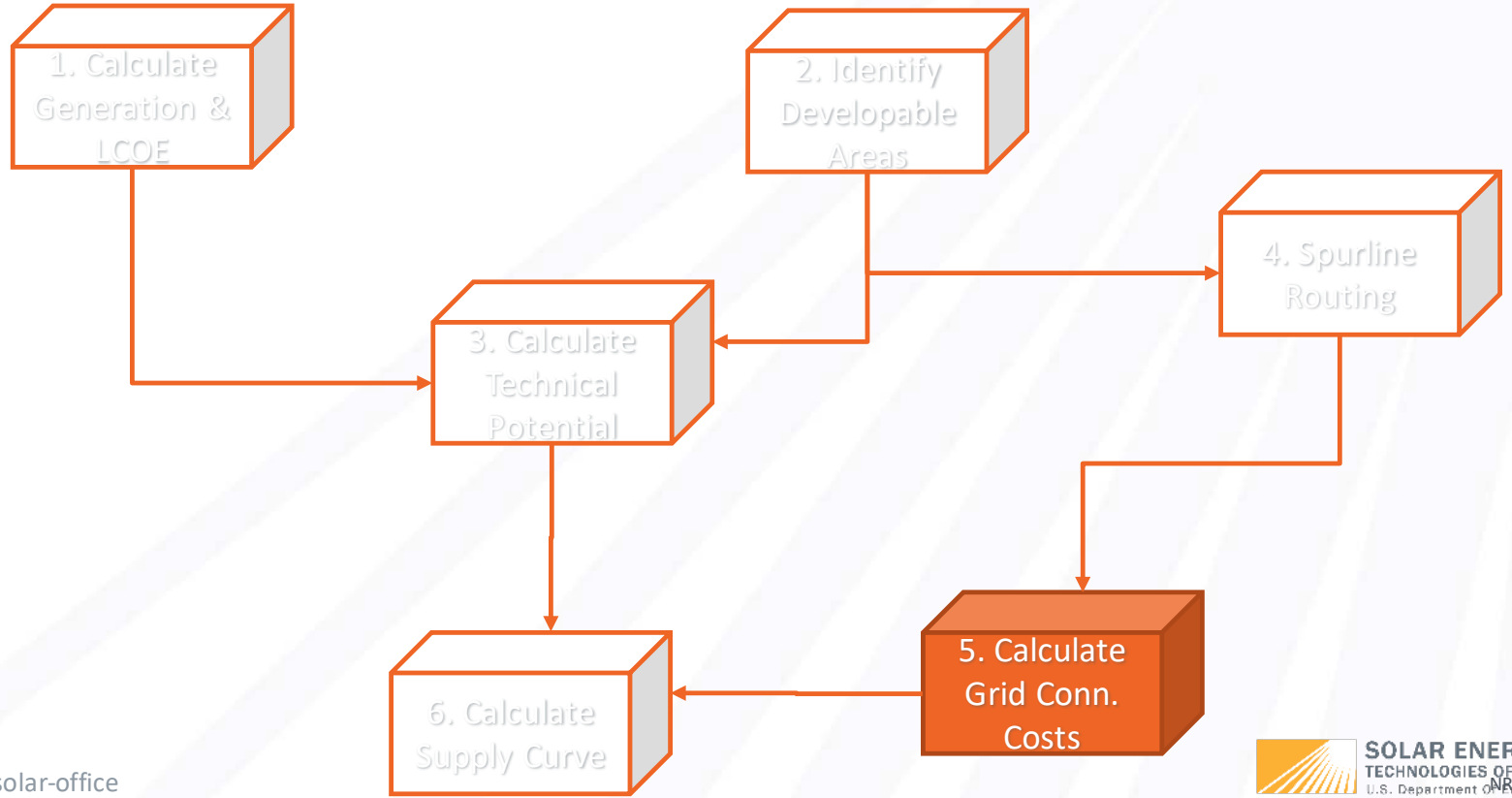
Spurline Routing

- What are potential routes for connecting new PV plants to existing transmission substations?

Spurline Routing Logic

- Spurlines link solar plant to the nearest substation, preferring the cheapest route possible.
- Spurlines will avoid the following in descending order of priority:
  - Waterbodies / Ocean
  - Protected Areas
  - Urban Areas
- Spurlines prefer to reach previously existing corridors as quickly as possible, then following the corridor to a nearby substation.

Technical Potential & Supply Curve Modeling



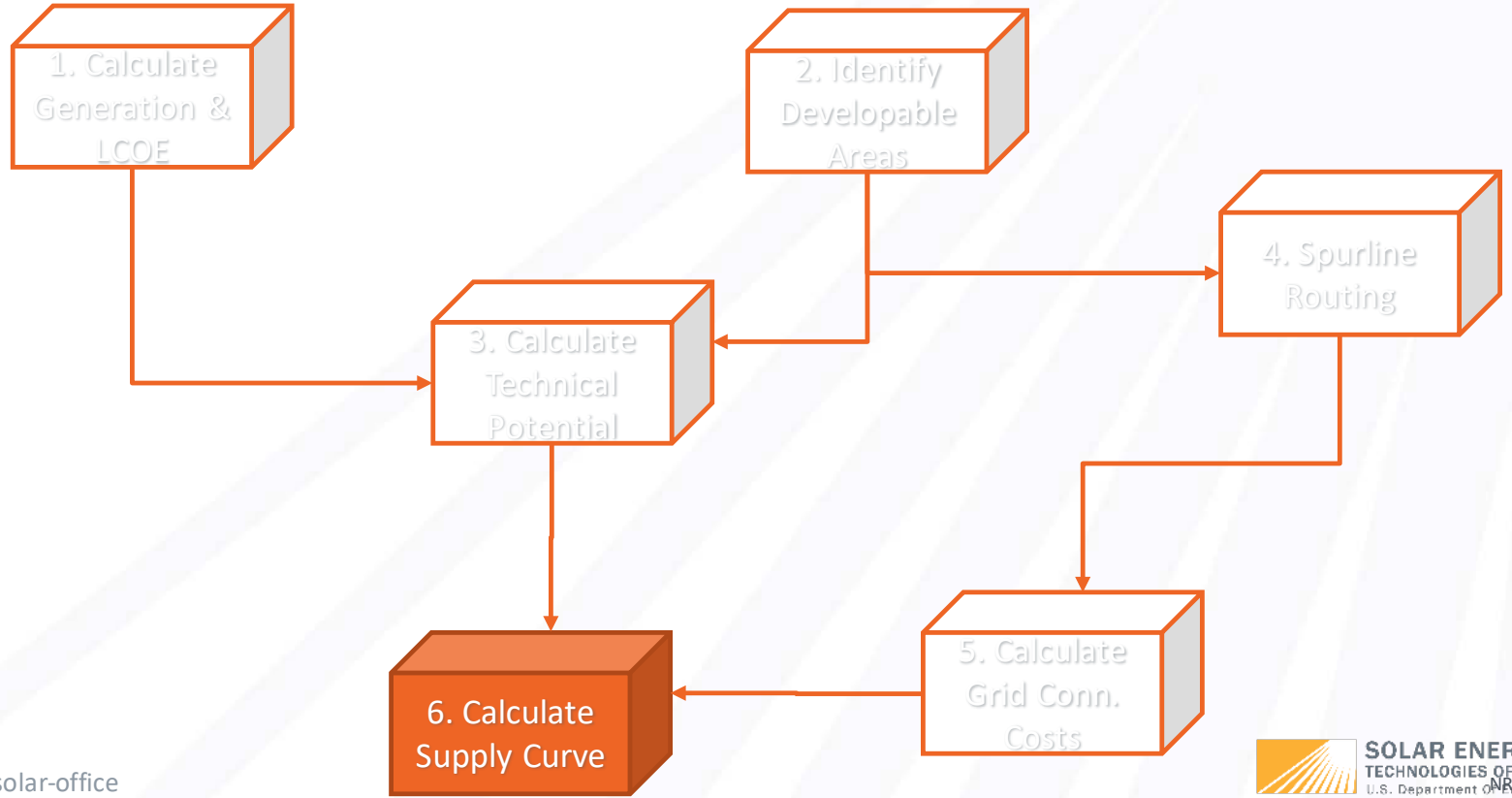
Calculate Grid Connection Costs

- With our modeled spurlines, how expensive is interconnection?

Interconnection Cost Assumptions

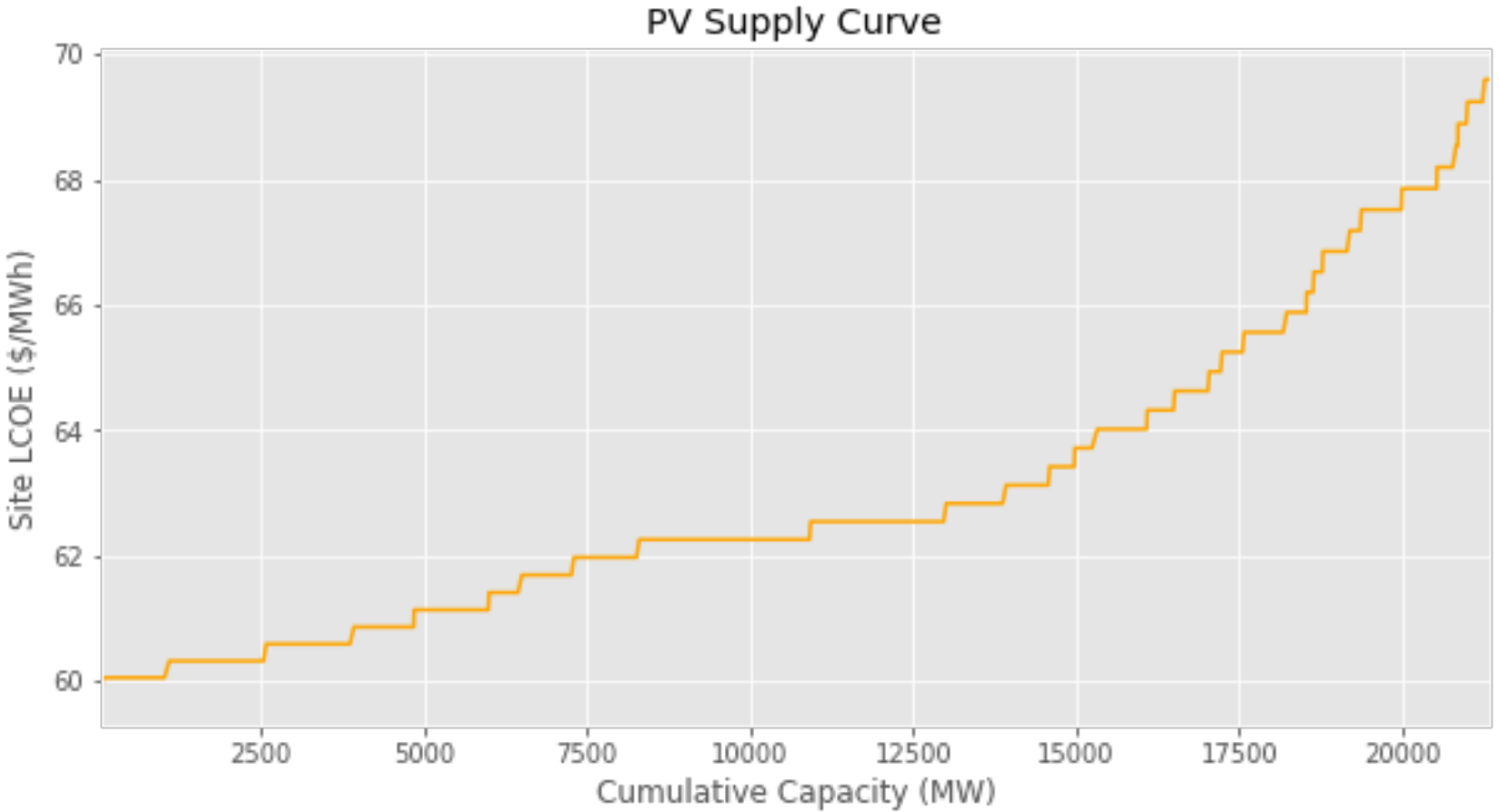
Assumption	Value	Fixed or Variable
Interconnecting Line (Gen-Tie)	$1.5 Million / Mile	Variable
Right of Way Costs (115 kV, 50 ft. wide) / Land Cost	$3 / m^2	Variable
New Bay for Interconnection	$2.4 Million	Fixed
Control House Extension	$300 Thousand	Fixed

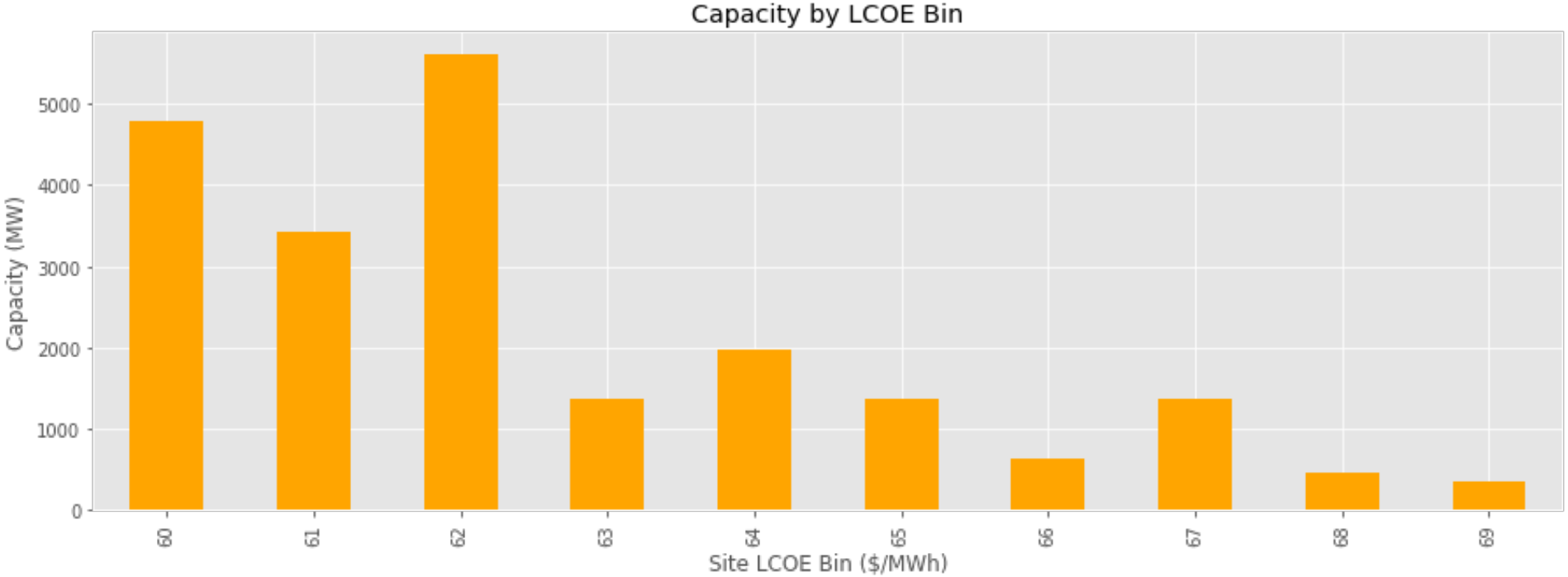
Technical Potential & Supply Curve Modeling

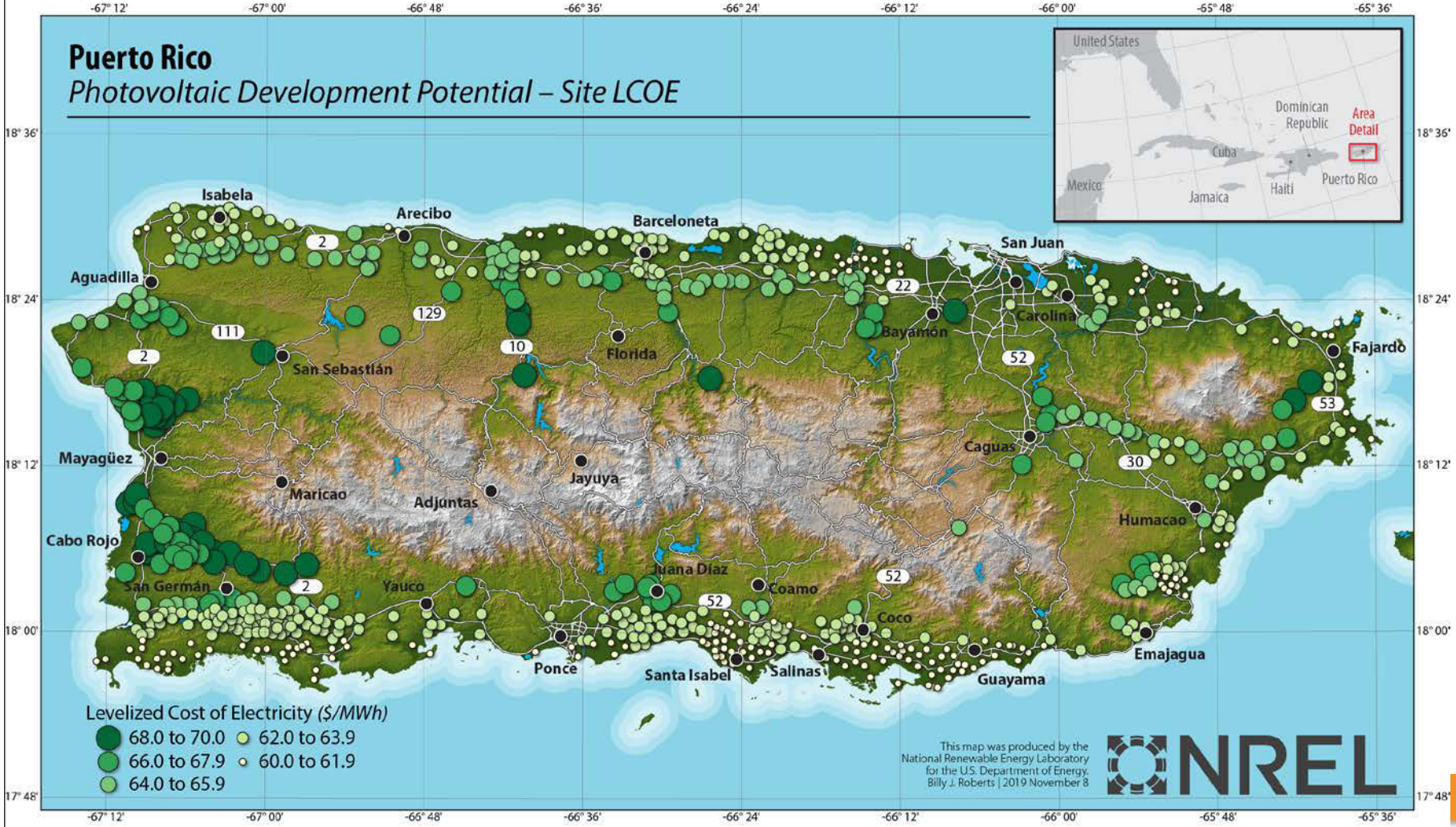


Supply Curve

1. Combine system and interconnection costs
    1. Levelized Cost of Energy (LCOE)
    2. Levelized Cost of Transmission (LCOT)
2. Rank sites based on lowest total cost


PV Supply Curve
Site LCOE ($/MWh)
70
68
66
64
62
60
2500
5000
7500
10000
12500
15000
17500
20000
Cumulative Capacity (MW)


Capacity by LCOE Bin
Capacity (MW)
0
1000
2000
3000
4000
5000
60
61
62
63
64
65
66
67
68
69
Site LCOE Bin ($/MWh)


Puerto Rico
Photovoltaic Development Potential – Site LCOE
United States
Dominican Republic
Area Detail
Cuba
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-67° 12'
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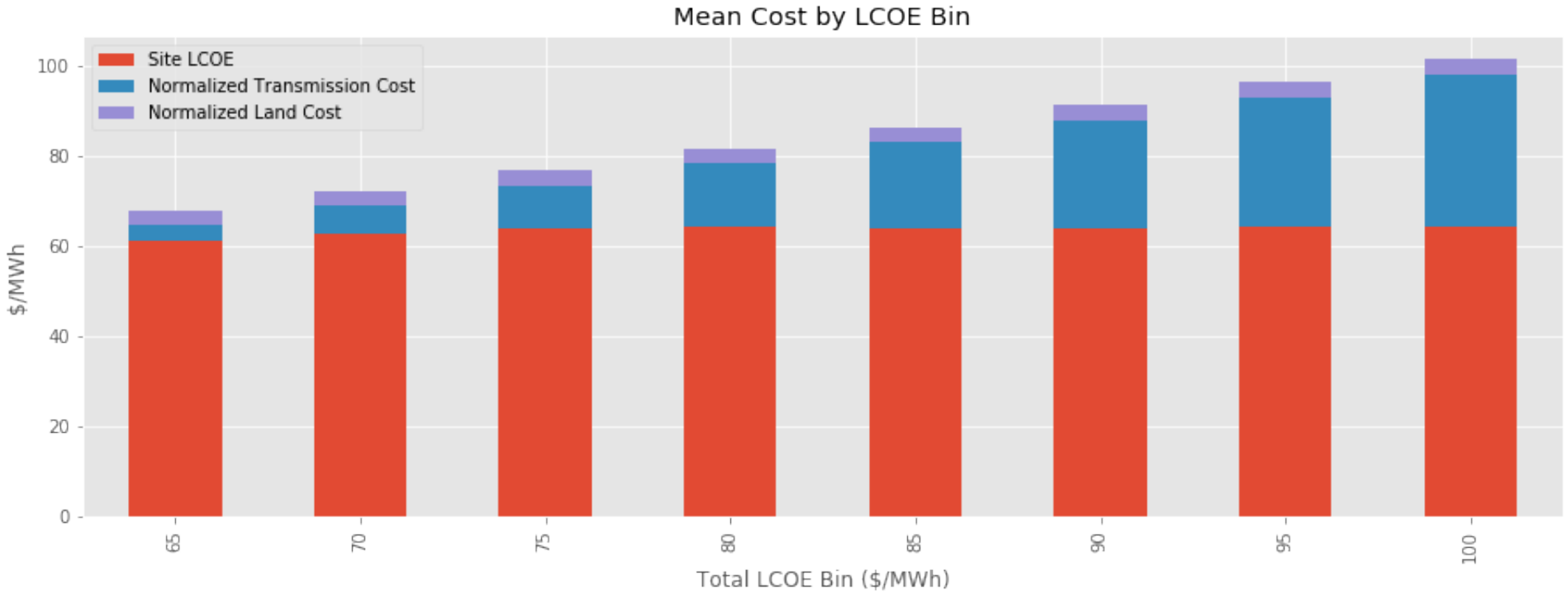
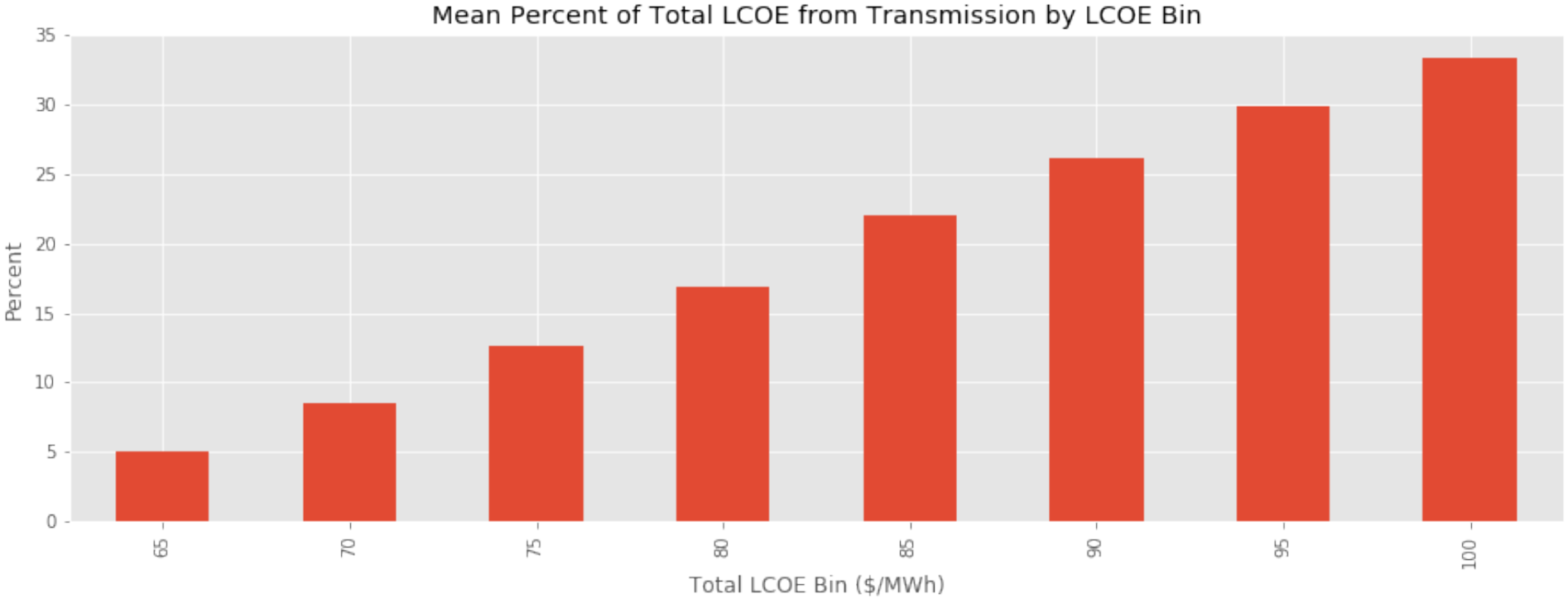
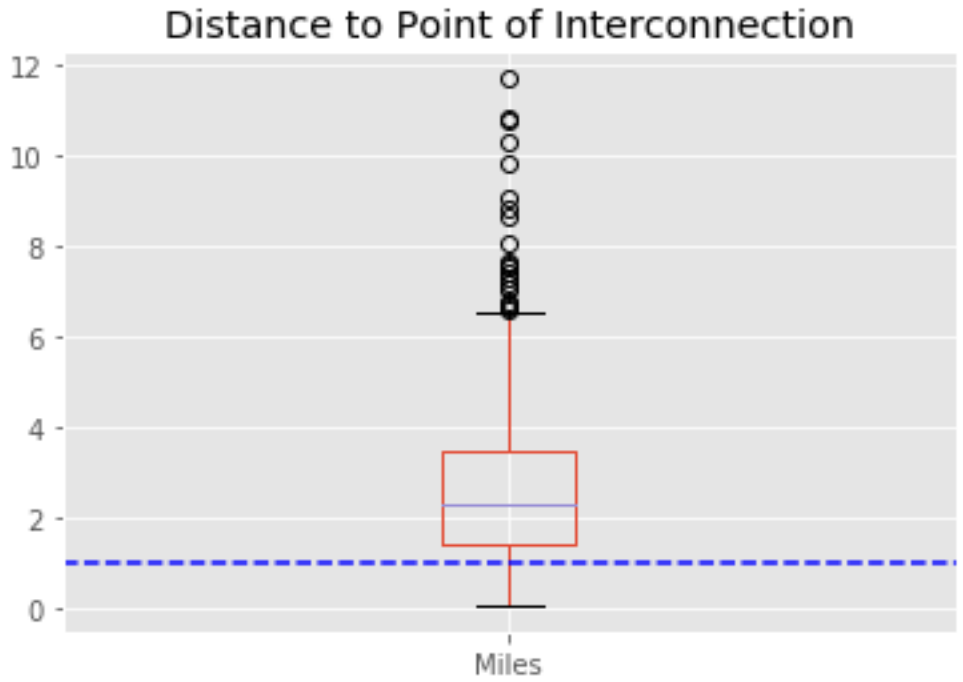
San Germán
Yauco
Coco
Emajagua
Ponce
Santa Isabel
Salinas
Guayama
2
111
129
10
22
52
53
30
Levelized Cost of Electricity ($/MWh)
68.0 to 70.0
66.0 to 67.9
64.0 to 65.9
62.0 to 63.9
60.0 to 61.9
This map was produced by the National Renewable Energy Laboratory for the U.S. Department of Energy.
Billy J. Roberts | 2019 November 8
NREL



Site LCOE (which is primarily affected by resource quality) generally doesn't change the overall cost. The greater transmission costs generally drive higher LCOE costs.


Mean Percent of Total LCOE from Transmission by LCOE Bin
Percent
0
5
10
15
20
25
30
35
65
70
75
80
85
90
95
100
Total LCOE Bin ($/MWh)

Interconnection



SIEMENS distance to point of interconnection assumption

Supply Curve Analysis Considerations

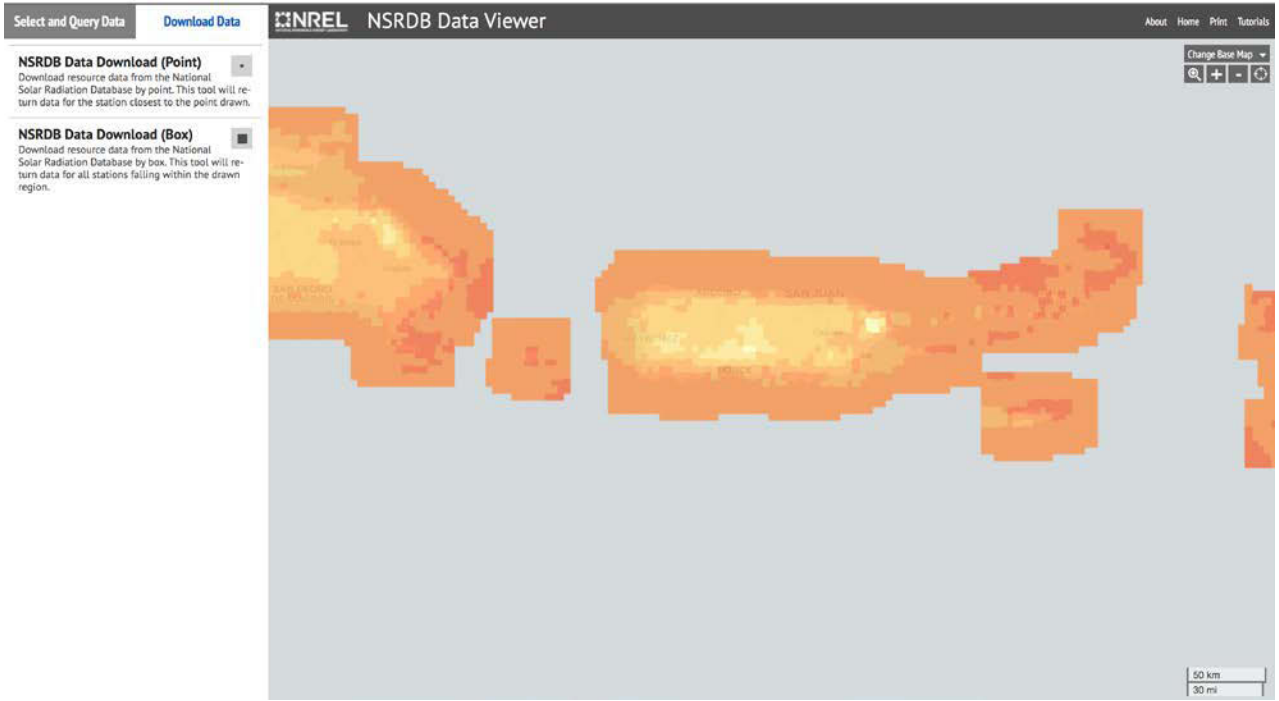
- An abundance of area is available for new PV development using our applied assumptions, though may not be near large load centers.
- Our assumptions may not consider socially-valuable land or other land usage that would prohibit development.
- The cheapest locations are not always available for development.
- The supply curve results should be used as guidance for further on-the-ground investigation.

Resource Data

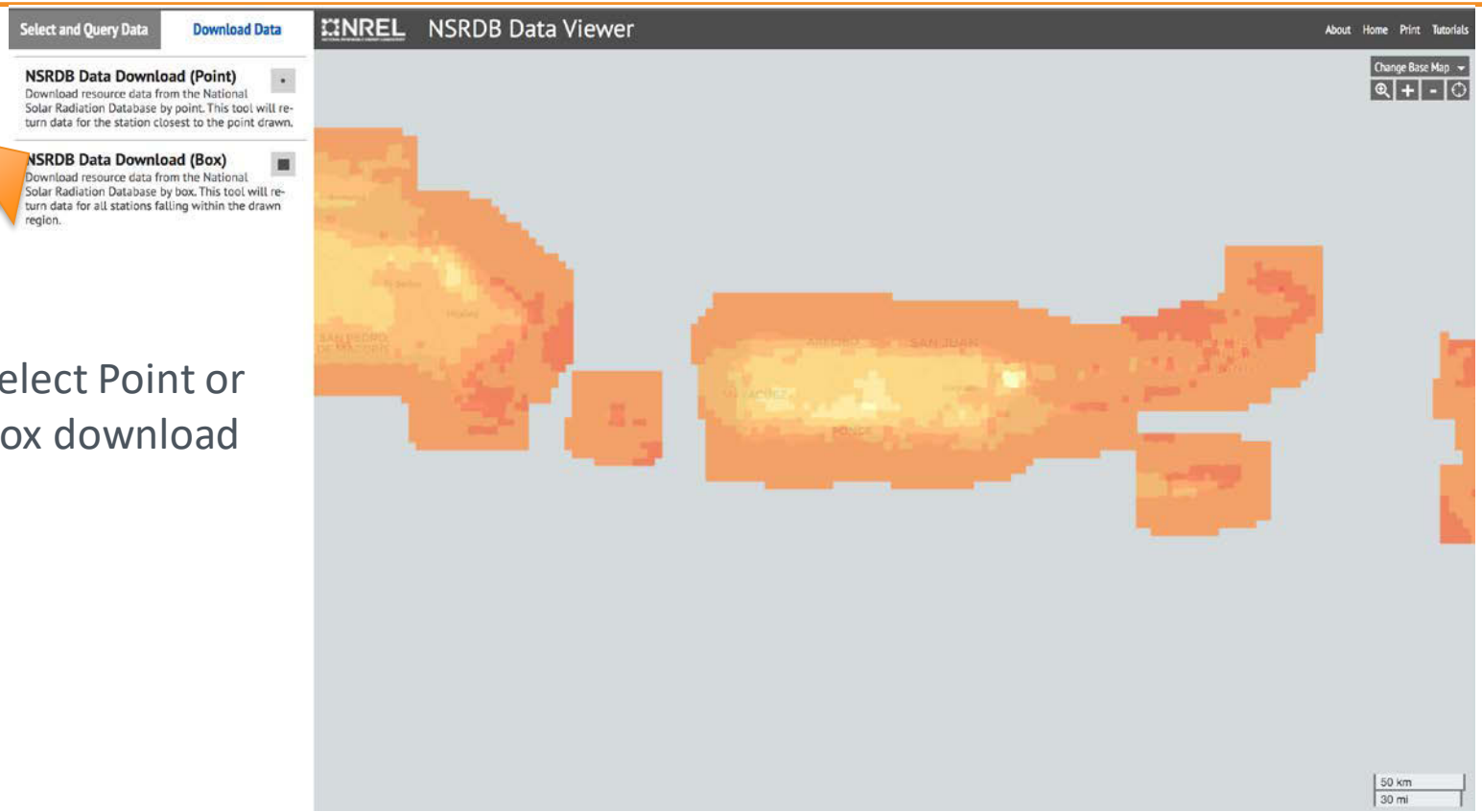
- NSRDB Simulated High Resolution Solar Resource Data is available for public download.

Downloadable Simulated High Resolution Solar Resource Data

maps.nrel.gov/nsrdb-viewer



Downloadable Simulated High-Resolution Solar Resource Data

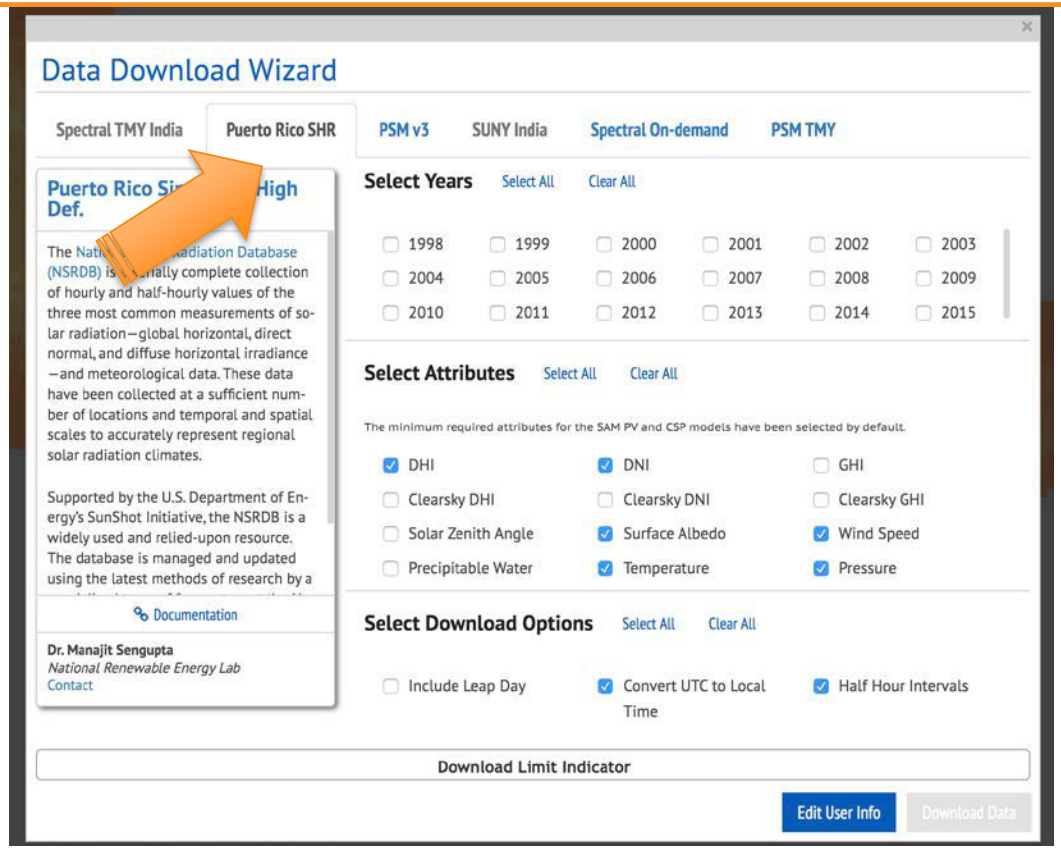


Select Point or Box download

maps.nrel.gov/nsrdb-viewer

Downloadable Simulated High-Resolution Solar Resource Data

Select “Puerto Rico SHR” to see data years, variables, and other download options



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Thank You!

Nick Grue

nick.grue@nrel.gov

NREL/PR-6A20-75548

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