Solar Resource and Technical Potential Modeling

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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.
1. Calculate Generation & LCOE
2. Identify Developable Areas
3. Calculate Technical Potential
4. Spurline Routing
5. Calculate Grid Conn. Costs
6. Calculate Supply Curve
1. Calculate Generation & LCOE
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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.
Methodology – Spatial Downscaling

- This clear-sky irradiance map illustrates the spatial downscaling:
## PV System Configuration

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Setting</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type</td>
<td>1 Axis Tracking</td>
</tr>
<tr>
<td>Losses</td>
<td>14.07 %</td>
</tr>
<tr>
<td>Tilt</td>
<td>0 Degrees</td>
</tr>
<tr>
<td>Panel Type</td>
<td>Standard</td>
</tr>
<tr>
<td>Inverter Efficiency</td>
<td>96 %</td>
</tr>
<tr>
<td>Ground Cover Ratio</td>
<td>0.4</td>
</tr>
<tr>
<td>DC / AC Ratio</td>
<td>1.3</td>
</tr>
<tr>
<td>Power Density</td>
<td>~33 MW/km²</td>
</tr>
</tbody>
</table>
Puerto Rico
Modeled Capacity Factor for South-facing 1-axis tracking PV System

Capacity Factor (%)

24.2  23.0  22.0  21.0  20.0  19.0  18.0  16.8

This map was produced by the National Renewable Energy Laboratory for the U.S. Department of Energy.
## Site Levelized Cost of Energy Calculations

<table>
<thead>
<tr>
<th>Assumption</th>
<th>Value</th>
<th>Fixed or Variable</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capital Cost</td>
<td>$1.6 Million / MW</td>
<td>Variable</td>
</tr>
<tr>
<td>Fixed O&amp;M</td>
<td>$11,850 / MW-yr</td>
<td>Variable</td>
</tr>
<tr>
<td>Fixed Charge Rate</td>
<td>0.0669</td>
<td>Fixed</td>
</tr>
</tbody>
</table>

Still need to calculate interconnection costs
1. Calculate Generation & LCOE
2. Identify Developable Areas
3. Calculate Technical Potential
4. Spurline Routing
5. Calculate Grid Conn. Costs
6. Calculate Supply Curve
Identify Developable Areas

• Where are potential land areas that are available for new development?
## Geographic Exclusions

<table>
<thead>
<tr>
<th>Category</th>
<th>Source</th>
<th>Exclusion Arguments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Slope</td>
<td>U.S. Forest Service</td>
<td>&gt; 5% slope</td>
</tr>
<tr>
<td>Man-made structures</td>
<td>Humanitarian OpenStreetMap Team</td>
<td>Presence of man-made structures</td>
</tr>
<tr>
<td>Protected Areas</td>
<td>U.S. Forest Service</td>
<td>Presence of protected areas</td>
</tr>
<tr>
<td>Land Cover</td>
<td>MRLC National Land Cover Dataset (2001)</td>
<td>Waterbodies; Wetlands; Developed Land</td>
</tr>
<tr>
<td>Contiguous Area Filter*</td>
<td>n/a</td>
<td>&lt; 0.2 km²</td>
</tr>
</tbody>
</table>
Puerto Rico
Photovoltaic Development Potential

Utility Scale

Identified Developable Areas for PV
Identified locations available for development according to geographic exclusion assumptions

2. Identify Developable Areas
Utility Scale
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

1. Calculate Generation & LCOE
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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.
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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

<table>
<thead>
<tr>
<th></th>
<th>SIEMENS</th>
<th>NREL</th>
</tr>
</thead>
<tbody>
<tr>
<td>PV System Size (MW)</td>
<td>30</td>
<td>10 &lt;= Size &lt;= 100</td>
</tr>
<tr>
<td>Capacity Factor (%)</td>
<td>22</td>
<td>16.8 &lt;= CF &lt;= 24.5</td>
</tr>
<tr>
<td>Dist. To Interconnection (mi)</td>
<td>1</td>
<td>~0 &lt;= Dist &lt;= 11</td>
</tr>
</tbody>
</table>
PV System Size

Plant Size

SIEMENS capacity assumption
Capacity Factor

SIEMENS capacity factor assumption
Technical Potential & Supply Curve Modeling

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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.
1. Calculate Generation & LCOE
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Calculate Grid Connection Costs

• With our modeled spurlines, how expensive is interconnection?
## Interconnection Cost Assumptions

<table>
<thead>
<tr>
<th>Assumption</th>
<th>Value</th>
<th>Fixed or Variable</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interconnecting Line (Gen-Tie)</td>
<td>$1.5 Million / Mile</td>
<td>Variable</td>
</tr>
<tr>
<td>Right of Way Costs (115 kV, 50 ft. wide) / Land Cost</td>
<td>$3 / m²</td>
<td>Variable</td>
</tr>
<tr>
<td>New Bay for Interconnection</td>
<td>$2.4 Million</td>
<td>Fixed</td>
</tr>
<tr>
<td>Control House Extension</td>
<td>$300 Thousand</td>
<td>Fixed</td>
</tr>
</tbody>
</table>
Technical Potential & Supply Curve Modeling

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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)

Cumulative Capacity (MW)

energy.gov/solar-office
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.
Interconnection

Distance to Point of 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

maps.nrel.gov/nsrdb-viewer
Thank You!

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