Philippine solar resource characterization, challenges and implications for the sector

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Presentation Overview

- Mott MacDonald introduction as technical advisor
- Context and challenges for appropriate government incentive definition
- Overview: Solar Resource Characterization
- Overview: Capacity Utilization Factor (CUF)
- Case Study: Mott MacDonald study results: Independent Solar Energy Yield Assessment in the Philippines (for PSPA)
- Conclusions and recommendations
Mott MacDonald Introduction

14k staff

We work in 140 countries

£1bn turnover

Employee owned
Definition of appropriate tariff support mechanisms are instrumental to meet national renewable energy targets.

Tariff calculations driven by cost and revenue potential, with the latest driven by variable renewable resource production.

Optimal characterization of resource and estimation of system energy production are instrumental to confirm adequate tariff structure and to justify individual project viability.

**Challenges**

- Limited measurement data for resource characterization.
- Using consistent metrics for plant technical assumptions and capacity factor ratio estimations for tariff calculations.
Solar Resource Characterization
Solar Irradiance – Definitions

- “Global” solar radiation comprises direct, diffuse and Albedo
Solar Irradiance – Definitions

- **Average over time to understand “input energy” / “fuel”**
  - **Typical range is 1,600 – 2,000 kWh/m²/year**
Regional Solar Irradiance Profile
**Gathering Data**

- Terrestrial versus satellite data sources – fundamentals
- Available data sources in region (e.g. MeteoNorm, SolarGIS, 3Tier, National Meteorological Agency, etc)
- Availability of ground measurement stations in region
- Site meteorological station for accurate long term prediction (pyrometers, reference cell)

**Data Analysis**

- Correlation/verification of two independent sources of Irradiance data e.g.
  - National Meteorological Agency, SolarGIS, etc
- Independent Energy Yield Analysis, using:
  - In-house modelling
  - off-the-shelf software (PVSYST)
Solar Irradiation Selection Considerations

- Available irradiation data accuracy varies significantly across the region
  - Countries with more complex topography subject to higher variations in irradiance conditions
  - Long-term, quality-controlled pyranometer measurements close to the site (e.g. within 20 km) the best possible irradiance data source
- Satellite-derived irradiation data an essential tool, but only subject to suitable validation
  - Validation must be for ground measured data in a similar climate to the Project site, and ideally located close by
Irradiation Data Sources – Philippines

- PAGASA - Solar Irradiation ground data:
  - Davao from 2012-2014
  - El Salvador, Cagayan De Oro from 2011-2014
  - ISU, Isabela from 2011-2014
  - Quezon City from 2011-2014

- Solar PV Plant Generation data:
  - CEPALCO 1 MWp DC (Gross capacity), from 2004
  - SACASOL 22 MWp DC (Gross capacity) from August 2014

- Other – Commercial satellite data providers
  - SolarGIS, 3Tier, Vortex, (MeteoNorm)
Metrics for Capacity Utilization Factor (CUF)
Calculating CUF For a Solar Plant

- Maximum possible power that can be produced by a 1MW plant over 1 year:
  \[ 1\text{MW} \times 365 \text{ Days} \times 24 \text{ hours} = 8,760 \text{ MWH} \]

- A 1 MW power plant that produces 8,760 MWH over 1 year has a CUF of 100%.

- CUF = Generation / (Plant Size * 8760)

- Plant Size = Solar plant size in MWp (DC)
Solar vs. Other Power Plants

- CUF 10-40% (solar and wind) vs 80% + (thermal and hydro)
- Solar PV plants have significant internal losses between the sunlight striking the modules to generate DC electricity and the inverters converting to AC electricity, to supply to the grid
- Solar PV is the only power technology where there is a significant difference between DC (Gross) capacity and AC (Net) capacity – DC (Gross) capacity is typically from 1.1 to 1.4 times the AC (net) capacity
- CUP needs to be clearly defined (e.g. AC or DC?) and plant assumptions for energy estimation representative of latest industry trends
Case Study: Mott MacDonald study results for Independent Solar Energy Yield Assessment in the Philippines (for Philippine Solar Power Alliance)
Philippine Irradiation Data Selection: Key Questions to Address

- PAGASA data is short-term
  - Representative of long-term?
  - Consistent with other data sources?
- SolarGIS “iMaps” satellite-mapping shows irradiance at any location in the Philippines
  - Modelling accuracy?
  - How to validate?
## Philippine Irradiation Data Selection: Six candidate solar PV plant sites

<table>
<thead>
<tr>
<th>Title</th>
<th>City/Town</th>
<th>Coordinates</th>
<th>Horizontal Global Irradiation (kWh/m²yr)</th>
<th>Summary Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Luzon 1</td>
<td>Santiago City, Isabela</td>
<td>16.700° 121.667°</td>
<td>1,764</td>
<td>Mid-range irradiation for Luzon</td>
</tr>
<tr>
<td>Luzon 2</td>
<td>Bayambang, Pangasinan</td>
<td>15.837° 120.440°</td>
<td>1,987</td>
<td>High irradiation for Luzon</td>
</tr>
<tr>
<td>Visayas 1</td>
<td>Iloilo, Panay</td>
<td>11.051° 122.812°</td>
<td>1,873</td>
<td>High irradiation for Visayas</td>
</tr>
<tr>
<td>Visayas 2</td>
<td>Jaro, Leyte</td>
<td>11.160° 124.763°</td>
<td>1,644</td>
<td>Low irradiation for Visayas</td>
</tr>
<tr>
<td>Mindanao 1</td>
<td>El Salvador City, Miṣamis Oriental</td>
<td>8.533° 124.550°</td>
<td>1,974</td>
<td>High irradiation for Mindanao</td>
</tr>
<tr>
<td>Mindanao 2</td>
<td>Kidapawan City, Cotabato</td>
<td>7.041° 125.046°</td>
<td>1,851</td>
<td>Mid-range irradiation for Mindanao</td>
</tr>
</tbody>
</table>
**DC Capacity Factor Results, 1 MWp PV plant**

<table>
<thead>
<tr>
<th>Areas</th>
<th>Annual Average Irradiance (kWh/m²)</th>
<th>Initial PR (%)</th>
<th>Plant Energy Yield (MWh/year) Year 1</th>
<th>Average DC Capacity Factor, Years 1-20</th>
<th>Average AC Capacity Factor, Years 1-20</th>
</tr>
</thead>
<tbody>
<tr>
<td>Luzon 1</td>
<td>1,799.3</td>
<td>79.9%</td>
<td>1,433</td>
<td>15.4%</td>
<td>17.8%</td>
</tr>
<tr>
<td>Luzon 2</td>
<td>2,066.5</td>
<td>79.3%</td>
<td>1,634</td>
<td>17.6%</td>
<td>20.4%</td>
</tr>
<tr>
<td>Visayas 1</td>
<td>1,899.2</td>
<td>79.1%</td>
<td>1,498</td>
<td>16.1%</td>
<td>18.7%</td>
</tr>
<tr>
<td>Visayas 2</td>
<td>1,655.5</td>
<td>79.6%</td>
<td>1,314</td>
<td>14.1%</td>
<td>16.4%</td>
</tr>
<tr>
<td>Mindanao 1</td>
<td>1,991.8</td>
<td>79.0%</td>
<td>1,569</td>
<td>16.9%</td>
<td>19.5%</td>
</tr>
<tr>
<td>Mindanao 2</td>
<td>1,862.1</td>
<td>79.5%</td>
<td>1,476</td>
<td>15.9%</td>
<td>18.4%</td>
</tr>
<tr>
<td><strong>Average</strong></td>
<td><strong>16.0%</strong></td>
<td><strong>18.5%</strong></td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>
Study Results – Capacity Factor

- Average P50 lifetime capacity factor:
  - DC basis: 14.1-17.6%
  - AC basis: 16.4-20.4% (can raise with plant design)

- Operating plant DC capacity factors:
  - 15.0-16.5% during the first operating years, per range of 15.0-18.7% estimated by this study

- For P90 case typically used for debt financing, lifetime: DC capacity factor of 12.9-16.0%
Conclusions and Recommendations
To justify tariff structure, the Philippine ERC released a paper in 2012 in which a 22% capacity factor was proposed for solar PV projects in the Philippines, by reference to international PV plant operating experience.

Our independent study identified capacity factors in the range 14.1-20.4%, depending on definition and design.

The case study illustrates how poor resource data and large variations in country-wide resource can lead to both inappropriate policy and misdirected project siting.

- Undermines the ability to meet national targets
- Discusses mitigation actions that can be taken
Recommendations

- Derive CUF from optimized resource characterization at national/regional level using a combination of satellite-derived simulation (e.g. mapping) and available measurement data.
- Increase ground resource mapping and validation of simulated resource data to reduce typical spatial variability due to topographical and climate regional characteristics.
- Consistent capacity factor definitions are adopted for calculations of tariff structure.
Thank you for your attention
<table>
<thead>
<tr>
<th>Loss Type</th>
<th>Typical Losses</th>
<th>Typical Annual Average Losses in % (in SEA)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Capture Losses</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Spectral</td>
<td>0.5% loss to 0.5% gain</td>
<td></td>
</tr>
<tr>
<td>Shading</td>
<td>1 - 5% loss</td>
<td></td>
</tr>
<tr>
<td>Soiling</td>
<td>1 - 2% loss</td>
<td></td>
</tr>
<tr>
<td>Angular</td>
<td>1 - 3.5% loss</td>
<td></td>
</tr>
<tr>
<td>Low irradiance performance</td>
<td>3.5% loss to 2% gain</td>
<td></td>
</tr>
<tr>
<td>Temperature losses</td>
<td>4 – 12 % loss</td>
<td></td>
</tr>
<tr>
<td>Power tolerance</td>
<td>3% loss to 2% gain</td>
<td></td>
</tr>
<tr>
<td>Light-induced degradation (LID)</td>
<td>0 – 2 % loss</td>
<td></td>
</tr>
<tr>
<td>MPP tracking losses</td>
<td>0 - 1% loss</td>
<td></td>
</tr>
<tr>
<td>Mismatch</td>
<td>0.5 – 1% loss</td>
<td></td>
</tr>
<tr>
<td>DC and AC cabling losses</td>
<td>1 - 4% loss</td>
<td></td>
</tr>
<tr>
<td>Inverter curtailment</td>
<td>0 - 4% loss</td>
<td></td>
</tr>
<tr>
<td>AC/DC Inverter conversion</td>
<td>1 - 4% loss</td>
<td></td>
</tr>
<tr>
<td>Transformer</td>
<td>1 - 2% loss</td>
<td></td>
</tr>
<tr>
<td>Auxiliary</td>
<td>0 – 2% loss</td>
<td></td>
</tr>
<tr>
<td>Unavailability</td>
<td>0 - 2% loss</td>
<td></td>
</tr>
<tr>
<td><strong>System Losses</strong></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Mott MacDonald Validation Analysis

- In-field Operating Data
- Plant Design
- PV module
- Laboratory Test Result

Validation Analysis

PV Plant Performance Modelling

Calculated Power Output

Modelling Error

Actual Power Output

- Less than 1% difference compared to actual energy output
- High correlation coefficient on a one minute basis (more than 99%)

Good agreement between Mott MacDonald’s in-house modelling and actual plant performance under the observed environmental conditions for both plants
References


• “Gaining confidence in PV module performance through laboratory testing, factory audit and analysis of in-field data”, POWER-GEN Asia, Bangkok, October 2012. Napier-Moore, PA; Verojporn, S.