GRID FLEXIBLE
SOLAR

Unleashing the Full Potential of Utility-Scale Solar Generation

LEADING THE WORLD’S SUSTAINABLE ENERGY FUTURE
As a least-cost new resource, more solar is added to the power grid every day.

As solar penetration increases, grid operators face new challenges in dispatching the system.

Today, grid operators often rely on fossil-fueled generators to match energy production and consumption, rather than clean resources.

Solar has untapped capabilities that enhance the flexibility of the grid to match supply and demand.

Solar is the future mainstream generation source, capable of delivering energy when and how it is needed.

As a technology leader, First Solar is uniquely positioned to champion market and policy reforms that unleash solar’s full potential.
# Lazard’s Levelized Cost of Energy Analysis, Version 11.0


## Utility-Scale Solar: Cost-Competitive Technology

<table>
<thead>
<tr>
<th>Alternative Energy</th>
<th>Conventional</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solar PV—Roof Top Residential</td>
<td>Diesel Reciprocating Engine</td>
</tr>
<tr>
<td>Solar PV—Roof Top C&amp;I</td>
<td>Natural Gas Reciprocating Engine</td>
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<tr>
<td>Solar PV—Community</td>
<td>Gas Peaking</td>
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<tr>
<td>Solar PV—Crystalline Utility Scale</td>
<td>IGCC</td>
</tr>
<tr>
<td>Solar PV—Thin Film Utility Scale</td>
<td>Nuclear</td>
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<tr>
<td>Solar Thermal Tower with Storage</td>
<td>Coal</td>
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<tr>
<td>Fuel Cell</td>
<td>Gas Combined Cycle</td>
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<td>Microturbine</td>
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<td>Geothermal</td>
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<tr>
<td>Biomass Direct</td>
<td></td>
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<tr>
<td>Wind</td>
<td></td>
</tr>
</tbody>
</table>

Denotes distributed generation technology.

Unsubsidized Levelized Cost of Energy Comparison

<table>
<thead>
<tr>
<th>Technology</th>
<th>Levelized Cost ($/MWh)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solar PV—Thin Film Utility Scale</td>
<td>$0.43</td>
</tr>
<tr>
<td>Solar Thermal Tower with Storage</td>
<td>$0.96</td>
</tr>
<tr>
<td>Fuel Cell</td>
<td>$1.15</td>
</tr>
<tr>
<td>Microturbine</td>
<td>$0.99</td>
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<tr>
<td>Geothermal</td>
<td>$1.17</td>
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<tr>
<td>Biomass Direct</td>
<td>$1.14</td>
</tr>
<tr>
<td>Wind</td>
<td>$1.30</td>
</tr>
<tr>
<td>Diesel Reciprocating Engine</td>
<td>$1.17</td>
</tr>
<tr>
<td>Natural Gas Reciprocating Engine</td>
<td>$1.06</td>
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<tr>
<td>Gas Peaking</td>
<td>$1.15</td>
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<tr>
<td>IGCC</td>
<td>$0.90</td>
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<tr>
<td>Nuclear</td>
<td>$1.12</td>
</tr>
<tr>
<td>Coal</td>
<td>$1.43</td>
</tr>
<tr>
<td>Gas Combined Cycle</td>
<td>$0.42</td>
</tr>
</tbody>
</table>

Curtailment is a low load phenomenon: CAISO high penetration example

High Load Day

Production By Resource Type
Summer Day
Add 10GW New Grid Solar

Low Load Day

Production By Resource Type
Low Load Day
Add 10GW New Grid Solar

Minimum Must Run Generation 8.5 GW
Nuclear, Imports, Thermal & Hydro

Curtailment
### CHARACTERISTICS DRIVING GRID EVOLUTION

#### Grid 1.0

**Grid Characteristics:**
- Utility-scale solar is part of mid-day load, offsetting peak or near-peak demand
- Low adoption of DERs
- Renewables are a must-take resource
- Minimal curtailed energy

**Solar Product Needed:** Energy & Renewable Energy Credits (RECs)

#### Grid 2.0

**Grid Characteristics:**
- Grid operators see evening ramp concerns and need for more flexible asset additions
- Growing adoption of DERs that have limited controllability
- Utility-scale solar transitions to a dispatchable resource

**Solar Product Needed:** Energy, RECs, & Grid Services

#### Grid 3.0

**Grid Characteristics:**
- Utility-scale solar represents significant portion of resource portfolio; curtailments frequent
- Saturated DER market creates excess energy
- Resource Adequacy needs shift
- Storage becomes economic

**Solar Product Needed:** Capacity, Energy, RECs, & Grid Services

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**Net Load = (Load - Solar)**

**Reduced ramp rate by targeted curtailment; available for grid services**
UTILITY-SCALE SOLAR PROVIDES GRID FLEXIBILITY

**GRID 1.0 BASIC SOLAR**
Low solar penetration markets; maximizes energy production

**GRID 2.0 GRID FLEXIBLE SOLAR**
Moderate solar penetration markets; solar controlled to provide flexibility & grid reliability services

**GRID 3.0 FIRM DISPATCHABLE SOLAR**
High solar penetration markets; addition of storage provides firm dispatchable capacity
Dispatchable PV Plant

• CAISO, NREL and First Solar pioneering demonstration of advanced reliability services

• Solar can provide NERC-identified essential services to reliably integrate higher levels of renewable resources, including:
  — Frequency Regulation
  — Voltage Control
  — Ramping capability or flexible capacity

• Automated Generation Control (AGC) regulation accuracy of 24-30% better than fast gas turbines

• Reduces need for services from conventional generation
  — Goes beyond simple PV energy value
  — Enables additional solar
  — Reduces need for expensive storage

GRID SERVICES IN ACTION: FREQUENCY REGULATION

- 30MW headroom
- 4-sec AGC signal provided to Plant Controller
- Tests were conducted for
  - Sunrise
  - Middle of the day
  - Sunset
PV PLANTS OUTPERFORM CONVENTIONAL RESOURCES IN FREQUENCY REGULATION

Regulation accuracy by PV Plant is about 24-30% points better than fast gas turbines.

Blue bars taken from the ISO’s informational submittal to FERC on the performance of resources providing regulation services between January 1, 2015 and March 31, 2016.

CASE STUDY: Hawaiian Electric Leading the Way in PPA Reform

ISSUE

• High penetration of behind-the-meter solar, coupled with an old oil-fired fleet has lead to significant curtailment issues (upwards of 20%)

• Developers have desired “take-or-pay” contracts to mitigate their curtailment risk; however, this shifts the burden to ratepayers

SOLUTION

• New contract structure that balances curtailment risk, creates the opportunity for essential grid services, and results in financeable projects

• Capacity-based payment structure ($/MW-mo)

• In early 2018, HECO formally issued RFPs totaling over 300 MW leveraging the RDG model and new PPA

As solar penetration increases, the energy industry needs to proactively address its impact on grid operation to maintain delivery of safe, reliable and affordable energy.

Large-scale solar power plants are capable of addressing these constraints and increasing flexibility on the grid in a cost effective manner.

Solar is the future mainstream generation source, capable of delivering energy when and how it is needed.
In order to leverage the full benefits of PV, First Solar recommends the following:

• Convene a workshop including grid operators, utilities, generation owners, and industry leaders to examine how best to leverage PV capabilities

• Ensure that any planning, market, or procurement mechanisms recognize and leverage the grid flexibility that solar PV can provide

• Update procurement and market rules that were built around the constraints of conventional thermal generation to instead reflect the needs of grid operators

To learn more, visit www.firstsolar.com/Grid-Evolution
First Solar®

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