Valuation of NEM Solar: A Wholesale Power Market Perspective

November 21, 2019

Jon Olson, Director
Energy Trading & Contracts
Agenda – NEM solar valuation, a wholesale power market perspective

• Glossary

• Background information - the grid and NEM solar integration

• Operational characteristics of NEM solar

• Factors to consider in wholesale power market valuation:
  - Energy
  - Capacity
  - Financial risk management

• Examples illustrating the factors using SMUD metered data*

• Summary

* Actual metered energy production data from utility scale solar and large scale, NEM solar commercial customers are used to present concepts. Examples are provided to illustrate the valuation of all resources solely from the wholesale power market perspective, and the wholesale power market perspective is just one of several aspects of NEM solar valuation.
Glossary

- **Ancillary services** – Market products that are used to maintain grid stability and reliability
- **Automatic Generation Control (AGC)** – Equipment that automatically adjusts power output of generating units to maintain system reliability
- **Balancing Authority** – The responsible entity that integrates resource plans ahead of time, maintains demand and resource balance within a Balancing Authority Area, and supports interconnection frequency in real time
- **Balancing Authority of Northern California (BANC)** – An entity providing balancing services to 7 organizations
- **California Public Utility Commission (CPUC)** – An entity that regulates privately owned utility companies in California
- **Capacity** – The maximum output an electricity generator, demand-side resources or batteries can deliver to a grid over a specific period of time, measured in megawatts (MW) or kilowatts (kW)
- **Enhanced day ahead market (EDAM)** – A market in development that seeks to maintain reliability, as the penetration of variable energy resources increases
- **Energy Imbalance Market (EIM)** – A real-time bulk power trading market that improves the integration of variable energy resources because of its wide geographic area and its 5 minute real-time dispatch
- **Electricity** – A form of energy
- **Energy** – The amount of electricity produced by a generator, consumed by a customer, or stored by a battery over a specific period of time and measured in megawatt-hours (MWh) and kilowatt-hours (kWh)
- **Federal Energy Regulatory Commission (FERC)** – An agency that regulates the energy industry
- **Financial risk management** – The process of understanding and managing financial risks that a business faces
- **Generator, electricity** – An asset that converts energy into electricity (e.g. hydro-electric generators, wind turbines, solar generators and natural gas generators)
- **NEM** – Net energy metering
- **North American Electric Reliability Corporation (NERC)** – A regulatory body that assures grid reliability and security
- **Power** – The output an electricity generator, demand resources or batteries deliver to a grid, measured in megawatts (MW) or kilowatts (kW)
- **Power Plant** – An asset that provides electricity to the grid
- **Power portfolio** – SMUD owned power plants, transmission lines, contracts and retail electricity consumption obligations managed by SMUD to provide safe, reliable electricity at affordable rates to SMUD customers
- **Resource adequacy capacity** – Capacity requirements set by the CPUC to ensure sufficient capacity to meet peak demand
- **Regulation down** – An ancillary service in which a generator receives an automated signal to decrease output
- **Regulation up** – An ancillary service in which a generator receives an automated signal to increase output
- **System demand** – The amount of power provided by SMUD to meet customer electricity use, including electricity travel losses, over a specific time interval measured in megawatts or kilowatts
- **System supply** – A portfolio of assets available to meet system demand
- **Western Electricity Coordinating Council (WECC)** – An organization that has been delegated to assure grid reliability and security of the Western Interconnection’s Bulk Power System
- **Western Interconnection Bulk Power System** – This system includes more than 35 balancing authorities and spans 14 western states and parts of Mexico and Canada
80 kW installed near SMUD’s electric charging station
What is the grid?
SMUD’s grid is part of the Western Interconnection’s Bulk Power System
To reliably meet system demand, SMUD balances supply and demand every 4 seconds.

Hydro-electric and natural gas power plants have **automatic generation control** (AGC) to automatically maintain supply and demand balance.

Similar to cruise control on a car, the speed is set, and the motor adjusts to maintain the speed.
Operational characteristics of NEM solar

12 kW installed at SMUD’s Customer Service Center
As the sun rises, solar energy increases, power system demand decreases.

When NEM solar produces energy, SMUD’s power system demand decreases.

To meet reliability standards, demand = supply.

To balance the system, SMUD’s power plants reduce energy production.
As the sun sets, solar energy decreases, power system demand increases.

- Power system demand decreases, increasing power system demand.
- To meet reliability standards, demand = supply.
- To balance the system, SMUD’s power plants increase energy production.
Solar energy production is variable, impacting SMUD’s system demand.

To meet reliability standards, demand = supply.

NEM solar energy production decreases with cloud cover, fog and smoke, increasing power system demand.

To balance the system, SMUD’s power plants increase energy production.
My rooftop NEM solar energy production – actual metered data - sunny versus cloudy day

System Production: **86.86 kWh**

System Production: **29.68 kWh**
Like car engines, generators that ramp up and ramp down incur costs.

City driving costs more than highway driving.

<table>
<thead>
<tr>
<th>City Driving</th>
<th>Highway Driving</th>
</tr>
</thead>
<tbody>
<tr>
<td>More starts and stops</td>
<td>Fewer starts and stops</td>
</tr>
<tr>
<td>Speed changes frequently</td>
<td>Speed changes periodically</td>
</tr>
<tr>
<td>Harder on the engine</td>
<td>Easier on the engine</td>
</tr>
<tr>
<td>Requires more gas for each mile</td>
<td>Requires less gas for each mile</td>
</tr>
</tbody>
</table>

It costs more to operate a power grid that has variable energy resources.
Power market valuation of NEM solar
Wholesale power market value of NEM solar

- What is the wholesale power market?
- Energy value of NEM solar
- Capacity value of NEM solar
- NEM solar impact on financial risk management
The wholesale power market is key to managing SMUD’s power portfolio.

SMUD owned assets:
- Hydro-electric
- Natural gas
- Wind
- Solar

Available products:
- Energy
- Capacity
- Ancillary Services (Regulation up/regulation down)

Customer energy demand

NEM
Illustrative: Day-ahead wholesale power market

The day before the operating day, system demand and system supply balance hourly given forecasts.

- **Total consumption**
  - Hourly system demand

**Graph Details:**
- **Axes:**
  - Y-axis: Megawatts (MW)
  - X-axis: Hours (12:00 AM to 11:00 PM)

**Legend:**
- **Renewable and conventional purchases**
- **Hydro-electric**
- **NEM Solar (Small commercial/residential)**
- **Natural Gas**
- **Commercial NEM large solar & utility scale solar**
- **System Load**
- **Total electricity consumption**
During the operating day, conditions vary from the forecast and the portfolio is rebalanced.

<table>
<thead>
<tr>
<th>Factors impacting Demand</th>
<th>Factors impacting Supply</th>
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<tbody>
<tr>
<td>Temperature</td>
<td>Temperature</td>
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<tr>
<td>Clouds</td>
<td>Clouds</td>
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<tr>
<td>Wind</td>
<td>Wind</td>
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<td>Distribution outages</td>
<td>Power plant outages</td>
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<tr>
<td>Smoke</td>
<td>Natural gas prices</td>
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<tr>
<td>Customer behavior</td>
<td>Hydro runoff</td>
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<td>Transmission Limitations</td>
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During the operating day, SMUD participates in the Western Energy Imbalance Market (EIM)

- SMUD began participating in April of 2019
- Entered market to help integrate renewables
- 9 participants (orange in map)
- 5 minute, automated market
- Price incorporates the cost of carbon
- Day ahead market redesign, EDAM, is next major step for integrating more renewables

Take away: SMUD is committed to renewable integration and EIM helps SMUD maximize the value of every dollar SMUD spends
Net wholesale power market energy value

Benefit

Wholesale power market energy value

Cost

NEM energy ongoing integration costs

Net wholesale power market energy value
Illustrative benefit: energy imbalance market valuation of delivered energy given 5 minute prices

10/16/2019 NEM commercial customer energy production
(500 kW installed capacity)
Illustrative cost - ongoing integration costs of solar

Solar energy production varies
Customer electric consumption is flat
SMUD power plants ramp up and ramp down to balance

City driving
versus
highway driving

Energy (kW)


Solar energy consumed by customer
SMUD supplied energy consumed by customer
Solar surplus energy fed back to grid
Illustrative customer electric consumption
Net wholesale power market capacity value

Benefit

Less resource adequacy capacity

Cost

More intra-hour flexible capacity

Net wholesale power market capacity value

Benefit - Cost = Net wholesale power market capacity value
Illustrative benefit: resource adequacy capacity need is less with NEM solar
Illustrative cost: NEM solar increases the need for flexible resource capacity within the hour

<table>
<thead>
<tr>
<th>Time</th>
<th>Energy (kW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>11:00 AM</td>
<td>370 kW</td>
</tr>
<tr>
<td>11:05 AM</td>
<td>370 kW</td>
</tr>
<tr>
<td>11:10 AM</td>
<td>370 kW</td>
</tr>
<tr>
<td>11:15 AM</td>
<td>370 kW</td>
</tr>
<tr>
<td>11:20 AM</td>
<td>370 kW</td>
</tr>
<tr>
<td>11:25 AM</td>
<td>370 kW</td>
</tr>
<tr>
<td>11:30 AM</td>
<td>370 kW</td>
</tr>
<tr>
<td>11:35 AM</td>
<td>370 kW</td>
</tr>
<tr>
<td>11:40 AM</td>
<td>370 kW</td>
</tr>
<tr>
<td>11:45 AM</td>
<td>370 kW</td>
</tr>
<tr>
<td>11:50 AM</td>
<td>370 kW</td>
</tr>
<tr>
<td>11:55 AM</td>
<td>370 kW</td>
</tr>
</tbody>
</table>

- **Solar energy consumed by customer**
- **SMUD supplied energy consumed by customer**
- **Solar surplus energy fed back to grid**
- **Illustrative customer electric consumption = 325 kW**
NEM solar impacts SMUD’s management of financial risk

| Fuel price risk | Energy price volatility & higher cost investment plan |

Risk decreases | Risk increases
Fuel price risk: NEM solar energy reduces SMUD’s financial exposure to fuel prices

More solar energy production = More fuel diversity

Financial risk to the price of natural gas of portfolio #1

Financial risk to the price of natural gas of portfolio #2

- Solar
- Wind
- Hydro
- Natural Gas
Energy risk impact: NEM solar energy increases energy price risk

Solar energy production is variable, increasing price volatility

[Diagram showing supply and demand curves with points 1 and 2, and quantities Q1 and Q2, and prices P1 and P2.]

Demand curve at 5:00 pm
Demand curve at 6:00 pm

Supply curve
Energy risk impact: NEM solar energy increases energy price risk

Energy prices go negative when power plants that are needed to meet system demand later in the day cannot reduce output and are forced to bid lower than their marginal cost.
Illustrative: wholesale energy prices do go negative, May 5, 2019

When prices go negative, SMUD pays twice

Once to produce the energy, and once to sell it into the market
Energy risk impact: Higher cost investment plan since NEM costs more than utility scale solar.

Similar power market benefit for less with utility scale solar.
Examples using metered data from large scale solar to illustrate valuation factors

15 kW installed at SMUD’s Customer Service Center
Examples that illustrate factors that capture the power market value of NEM solar
Illustrative: Large scale solar energy production varies

- October 14, 2019: 1% drop in solar energy production from October 14
- October 15: 41% drop in solar energy production from October 15

Legend:
- Gray: All other supply
- Yellow: Commercial NEM large solar & utility scale solar
- Black: System demand
Illustrative: Other plant adjusts output to counterbalance solar energy variability.

Energy production from a flexible power plant decreases during solar energy production.
Illustrative: NEM integration costs are captured by the change in plant efficiency.

Plant efficiency (MMBtu/MWh)

Plant output from balancing plant (MW)

Flexible power plant

Plant heat rate - the amount of natural gas required for each unit of energy

October 14, 2019  October 15  October 16

Less efficient energy production & higher marginal carbon emissions

More efficient energy production & lower marginal carbon emissions
Illustrative: The efficiency of the balancing plant is lower when solar energy is producing.

Less efficient energy production & higher marginal carbon emissions

More efficient energy production & lower marginal carbon emissions
Lower plant efficiency increases energy production costs and carbon emissions

<table>
<thead>
<tr>
<th></th>
<th>October 14</th>
<th>October 15</th>
<th>October 16</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Plant efficiency</strong></td>
<td>Lower</td>
<td>Higher</td>
<td>Lower</td>
</tr>
<tr>
<td><strong>Energy Cost Increase</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Solar hours</td>
<td>All other</td>
<td>Energy cost is 2.8% higher during solar hours</td>
<td>All other</td>
</tr>
<tr>
<td>Carbon Difference</td>
<td>3% more carbon/MWh during solar hours</td>
<td>1.6% more carbon/MWh during solar hours</td>
<td>0.8% more carbon/MWh during solar hours</td>
</tr>
</tbody>
</table>
NEM solar reduces SMUD’s financial exposure to fuel prices.

Risk Decreases

Fuel price risk
Illustrative: fuel diversity improves with more solar energy production

- Natural gas energy production is 10% less
- Solar is 70% higher
NEM solar increases energy price risk
Illustrative: Solar energy impacts the wholesale energy market price

Energy imbalance market 5 minute prices ($/kWh)

System Demand (MW)

October 14, 2019
October 15
October 16

All other supply
Commercial NEM large solar & utility scale solar
System demand
5 minute energy price
Market prices vary more during hours of solar energy production.
Illustrative: market price volatility is higher during hours of solar energy production

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<th>October 14</th>
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<th>October 16</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>All other hours</td>
<td>All other hours</td>
<td>All other hours</td>
</tr>
<tr>
<td>Mean Price</td>
<td>27</td>
<td>35</td>
<td>34</td>
</tr>
<tr>
<td>Standard Deviation</td>
<td>8 &gt; 6</td>
<td>15 &gt; 5</td>
<td>9 &gt; 4</td>
</tr>
</tbody>
</table>

During solar energy production hours
- Mean price decreases
- Wholesale energy price is lower
- Price volatility increases
- Wholesale energy price is more volatile
Summing it up…
NEM solar valuation -
The power market perspective

**Energy**
- Benefit: Provides energy to grid
- Cost: Incurs ongoing grid integration costs
- Cost: Higher marginal carbon emissions (Valuation discussed further during meeting #4)

**Capacity**
- Benefit: Contributes to resource adequacy capacity needs
- Cost: Increases need for intra-hour flexible capacity

**Financial Risk**
- Benefit: Reduces fuel price risk
- Benefit & Cost: Increases energy price volatility
- Cost: NEM solar costs more than local, utility scale solar