The Importance of Regional Collaboration and Distributed Solar Resources to Support the Grid

Yucca Valley, California, January 2019

Angelina Galiteva
Founder Renewables 100 Policy Institute,
Vice Chair Board of Governors California
Independent System Operator,
To study and accelerate the global transition to 100% renewable energy in all sectors – electricity transportation, heating cooling, water treatment and fuels.
International Learning & Collaboration, Accelerating Change
Under 2 MOU - Subnational Global Climate Leadership Memorandum of Understanding
Price of renewables continue to decrease
Solar and wind attract 60% of new investment in power generating capacity

Investment, by technology, 2017-2040

($ trillion - 2016 real)

- Wind: $3.3
- Solar: $2.8
- Nuclear: $1.4
- Hydro: $1.1
- Gas: $0.8
- Coal: $0.7

Source: Bloomberg New Energy Finance, NEO 2017
High Levels of Renewable Penetration – the New Normal

- 25 December 2016, Scotland: 153% wind
- 9 July 2015, Denmark: 140% wind
- 9 April 2017, UK: 56% wind & solar
- May 2016, Germany: 67% wind & solar
- March 2018, Portugal: 100% wind & solar
- November 2017, ERCOT: 45% wind
- 13 February 2017, SPP: 52% wind
- 26 December 2014, South Australia: 61% wind & solar
- 19 February 2018, CAISO: 77% wind & solar

Source: Bloomberg New Energy Finance, various
U.S. Renewable Resources

Achieving 100% Renewables include:

- Grid modernization
- Storage options
- Transmission
- Behaviors/education
- Resources
- Cooperation

<table>
<thead>
<tr>
<th>Resource</th>
<th>Solar PV/CSP</th>
<th>Wind</th>
<th>Geothermal</th>
<th>Water Power</th>
<th>Biopower</th>
</tr>
</thead>
<tbody>
<tr>
<td>Theoretical Potential</td>
<td>155,000 GW (PV)</td>
<td>11,000 GW (onshore)</td>
<td>38 GW (conventional)</td>
<td>68 GW</td>
<td>62 GW</td>
</tr>
<tr>
<td></td>
<td>38,000 GW (CSP)</td>
<td>4,200 GW (offshore to 50 nm)</td>
<td>4,000 GW (EGS)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
US power sector fuel mix

- Change in generation 2007-16

- Coal: -776TWh/yr
- Gas: +483TWh/yr
- Renewables: +256TWh/yr
- Power demand: -78TWh/yr

Source: EIA
Electric industry in the midst of unprecedented change - *Driven by fast-growing mix of interrelated issues*

- Existing 50% goal
- Federal Election Impacts
- Gas Storage Challenges
- NEW 100% goal
- Community or Retail Choice
- Grid Modernization
- Regional Collaboration
- Consumer-owned Power
- Transmission & Distribution Systems Interface
- Fossil Plant Retirements
State Energy Policy Drives
Energy RD&D Investments

- Zero Net Energy Residential Buildings Goal
- Zero Net Energy Commercial Buildings Goal
- Double Energy Savings in Existing Buildings Goal

Energy Efficiency

- Reduce GHG Emissions to 1990 Level (AB 32) – Represents 30% Reduction from Projected GHG Emissions
- Reduce GHG Emissions by 40% Below 1990
- Reduce GHG Emissions 80% Below 1990 Levels

Renewable Energy

- 33% RPS Goal
- 12 GW DG Goal
- 8 GW Utility-Scale Goal

Transportation Energy

- 10% Light-Duty State Vehicles be ZEV
- 25% of Light-Duty State Vehicles be ZEV
- Over 1.5 million ZEVs on California Roadways Goal

- Zero Net Energy Residential Buildings Goal
- Zero Net Energy Commercial Buildings Goal
- Double Energy Savings in Existing Buildings Goal

63,000 GWh/Year

2015 2016 2020 2025 2030 2050

Reduce GHG Emissions 80% Below 1990 Levels
### Growth of solar PV and wind on the California ISO system

<table>
<thead>
<tr>
<th></th>
<th>2010</th>
<th>2018</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Solar</strong></td>
<td>85 MW</td>
<td>9,952 MW PV 1,237 MW Thermal</td>
</tr>
<tr>
<td></td>
<td></td>
<td>6,569 MW BTM&lt;sup&gt;1&lt;/sup&gt;</td>
</tr>
<tr>
<td><strong>Wind</strong></td>
<td>3,309 MW</td>
<td>6,295 MW</td>
</tr>
</tbody>
</table>

<sup>1</sup> See GoSolarCalifornia.gov - BTM number includes both investor owned utility and publicly owned utility installations.
Major progress on meeting California's renewable goals

• Currently Installed:
  – 21,000 MW of large-scale renewables
  – 6,000 MW of rooftop solar

• Additional renewables:
  – 3,300 MW for 50% RPS by 2030*
  – 11,400 MW of consumer rooftop solar by 2030**

* 2018 CPUC IRP
**2017 CEC IEPR
The “Duck” turns 10 years old: Actual Net-load & 3-hour Ramps are about Four Years ahead of the CAISO’s Original Estimate.
ISO working on a 50% duck curve

Much steeper ramps

Much deeper belly
Transparency Real-Time Emissions (17:35, January 24, 2018)

Current CO₂ emissions (serving ISO load) AS OF 17:35

- **28,402 MW** Current demand
- **8,828 mTCO₂/h** Current CO₂ emissions
- **0.311 mTCO₂/MWh** Current CO₂ emissions rate
- **24%** Reduction in CO₂ emissions

The California ISO supports the state’s clean air policies by integrating clean, zero carbon resources such as wind and solar. This page shows the success in reducing power plant emissions. CO₂ emissions data is an approximation. View how CO₂ is calculated.

**Historical CO₂ emissions (serving ISO load)**

The addition of zero or very low carbon renewable resources to the grid is reducing CO₂ emissions over time.
Transparency: Real-Time Emissions Source and Daily Outlook

Current CO₂ per resource

CO₂ is produced when a fuel is combusted to turn generator turbines. Wind, solar, batteries, hydro and nuclear operate without emissions.

Today’s CO₂

Emissions typically rise when traditional resources are needed, such as during periods of reduced production of solar and wind resources.
Historical CO₂ emissions (serving ISO load)

The addition of zero or very low carbon renewable resources to the grid is reducing CO₂ emissions over time.

Monthly CO₂

Today’s Outlook is provided for informational purposes ONLY and should not be relied upon by any party for the actual billing values or operational planning. For official data, visit OASIS. For official emissions data, visit CARB.
Solar production complemented the hydro production during the drought years as compared to 2006, which was a high hydro year.
Increasing Trend of Renewable Curtailment Varies with Seasonal and Hydro Conditions
Storage uniquely qualified to help mitigate operational issues

Charge during times of surplus energy

Discharge to mitigate impact of steep ramps
Existing Storage in California

- Pumped Hydro: 4087 MW
- Electro-chemical: 146 MW
- Thermal: 28 MW
- Flywheel: 2 MW
One of nine Grid Operators in the U.S.

- 2/3 of the U.S. is supported by an ISO
- ISO is one of 38 balancing authorities in the western interconnection
The California ISO

• Balance supply and demand…every 4 seconds

• Operate markets for wholesale electricity and reserves

• Manage new resource interconnections

• Plan grid expansions
EIM Efficiencies

Today:
Each BA must balance loads and resources within its borders.

- Limited pool of balancing resources
- Inflexibility
- High levels of reserves
- Economic inefficiencies
- Increased costs to integrate wind/solar

In an EIM:
The market dispatches resources across BAs to balance energy

- Diversity of balancing resources
- Increased flexibility
- Decreased flexible reserves
- More economically efficient
- Decreased integration costs
Regional Collaboration helps to manage surplus power

Energy Imbalance Market

- 5 minute market
- Regionally diverse fleet
- Optimize existing assets
- New governance model
- Completely voluntary
Western Energy Imbalance Market (EIM):

- Savings of $330.52 million since 11/14
- 586,277 MWh curtailment avoided, displacing an estimated 250,845 metric tons of CO2
- Balancing authorities maintain control and reliability responsibilities

Regional Grid Collaboration

- Integration of renewables across a larger geographical area
- Enhances reliability with improved situational awareness
- Reduces costs through automatic economic dispatch
- Comprehensive transmission planning
- More diverse renewables on the system
- Advanced dispatch enables innovation
An integrated regional grid will increase benefits across the West.

**EIM**
- Saved $145 million in 2017
- About 5% of overall energy services

**Extending day-ahead services**
- Creates significantly more benefits than EIM
- Co-optimizes energy and critical grid services increasing EIM benefits
- Improves balancing of supply and demand

**Regional grid** – annual savings could exceed $1.5B
- Captures benefits of EIM and extending day-ahead services
- Enhances reliability across a broader footprint
- Significant savings from coordinated planning & resource sharing
- Reduces overall need for capacity

No change in governance needed

Current governance makes participation highly uncertain

Governance change necessary

No change in governance needed
Risks of California not moving to a regional grid

- Developing clean energy resources becomes more difficult thereby impacting job growth
- Misses opportunity to enhance regional reliability
- Requires continued operation of unnecessary fossil fuel power plants
- Creates risk of not achieving California GHG reduction goals

Other grid operators are vying for control of the western grid. California leaders must act to avoid slowing transition to clean energy
Consumers (Prosumers) as New Energy Supply Participants

Rooftop Solar and storage

Electric Vehicles

Consumer control

Rates and grid signals help them participate
Supporting Evolution of the Electricity Grid

Historical Grid → “Smart” Grid
Potential Transmission Power Flow With High Penetration of DER

- Potential for power to flow bi-directional at the Transmission and Distribution Interface
- The current system is not designed or modeled to accommodate this potential bi-directional power flow which may move the system into unstudied conditions

**LEGEND**

- Power Flow

Potentially hundreds of thousands of injection points from rooftop solar, battery, and other distributed generation resources
Central Fresno Transmission System

Transmission
• Transmit bulk power from generation facilities to distribution substations
• Largely network design
Central Fresno Transmission and Distribution Systems

**Distribution**

- Distributes electric power to end users (customers)
- Radial design
- Requires various levels of granular review
PG&E – System Architecture

There is a significant scale difference between Transmission and Distribution

<table>
<thead>
<tr>
<th>Transmission System</th>
<th>Distribution System</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>18,165</strong> miles of transmission lines</td>
<td><strong>142,000</strong> circuit miles of distribution lines</td>
</tr>
<tr>
<td>~<strong>2,800</strong> subst. transformers</td>
<td>~<strong>1MM</strong> dist. line transformers</td>
</tr>
<tr>
<td><strong>173</strong> unplanned t-line outages</td>
<td><strong>28k</strong> unplanned dist. outages</td>
</tr>
<tr>
<td><strong>24</strong> planned t-line outages</td>
<td><strong>19k</strong> planned dist. outages</td>
</tr>
<tr>
<td>Built not to break -- Resilient</td>
<td>Less resilient</td>
</tr>
<tr>
<td>If it does break -- Contingency</td>
<td>Built for rapid repair response</td>
</tr>
<tr>
<td>Consolidated from 15 control centers to 1 with a hot backup</td>
<td>Consolidated from 16 control centers to 3</td>
</tr>
</tbody>
</table>

While there are challenges, PG&E’s distribution system is well positioned to meet the rapidly growing distributed energy resource model.
Figure 3: Cooperative System between IOUs and CCAs

Existing Programs

- Clean Power SF
- MCE
- Peninsula Clean Energy
- Sonoma Clean Power
- Monterey Bay Community Power
- Valley Clean Energy
- Pioneer Community Energy
- Rancho Mirage Energy Authority
- San Jacinto Power
- Lancaster Choice Energy
- Apple Valley Choice Energy
- Redwood Coast Energy Authority
- Silicon Valley Clean Energy
- Pico Rivera Innovative Municipal Power
- East Bay Clean Energy
- Clean Power Alliance
- King City Community Power
- Solana Energy Alliance
Existing CCE Program Success

- Over 2.5 Million Customer Accounts
- Over $90 Million Estimated Customer Savings in 2018
- Over 940,000 Metric Tons of GHG Avoided as of 2016
Success across California

Source: UCLA Luskin Center, 2017

Source: Clean Power Exchange
Evolving structure of power supply - California

First week of May 2012 (actual)

First week of May 2017 (actual)

First week of May 2030 (modelled)

Huge ramp rates up and down

No more “baseload”

Lots of DR, storage and export - or curtailment

Source: CAISO OASIS; CEC proposed IRP; LM Power; CESA; Bloomberg New Energy Finance
IOUs’ NEM Solar Capacity by Territory and Location (As of March 31, 2018) All DER Technologies are in Play

<table>
<thead>
<tr>
<th>Technology</th>
<th>2013</th>
<th>2016/17</th>
<th>Percent Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy Efficiency (GWh)</td>
<td>1,693</td>
<td>3,197</td>
<td>89%</td>
</tr>
<tr>
<td>Demand Response (MW)</td>
<td>2,187</td>
<td>1,997</td>
<td>-9%</td>
</tr>
<tr>
<td>Behind-the-Meter PV (MW)</td>
<td>2,102</td>
<td>5,900</td>
<td>180%</td>
</tr>
<tr>
<td>Plug-in Electric Vehicle (PEV) (number of registrations)</td>
<td>69,999</td>
<td>266,866</td>
<td>281%</td>
</tr>
<tr>
<td>Distributed Advanced Energy Storage (MW)</td>
<td>54</td>
<td>350</td>
<td>548%</td>
</tr>
<tr>
<td>Microgrids (MW)</td>
<td>122</td>
<td>390</td>
<td>220%</td>
</tr>
</tbody>
</table>

BIPV Products will become competitive
Solar PV BTM Ownership 2015-2018

- Customer Owned
- PPA
- Lease
- Pre-Paid Lease
- Other

Residential
Commercial
Educational
Industrial
Other Govt
Non-Profit
Military

More Californians Work in the Solar Industry Than for All Utilities Combined

Sources:
Solar Foundation, 2015 Solar Jobs Census
U.S. Securities and Exchange Commission, Form 10-K, 2014
http://www.sec.gov/edgar/searchedgar/companysearch.html
Rapid Growth & Clean Energy: Market Cap of General Motors vs. Tesla

107 years for GM to become $50 billion company

12 years for Tesla to become $34 billion company

Based on market value as of 8/5/15
More Cleantech VC Investment into CA than all of Europe and China Combined

Source: Next 10 California 2014 Green Innovation Index
A suite of solutions are necessary

| **Storage** – increase the effective participation by energy storage resources. | **Western EIM expansion** – expand the western Energy Imbalance Market. |
| **Demand response** – enable adjustments in consumer demand, both up and down, when warranted by grid conditions. | **Regional coordination** – offers more diversified set of clean energy resources through a cost effective and reliable regional market. |
| **Time-of-use rates** – implement time-of-use rates that match consumption with efficient use of clean energy supplies. | **Electric vehicles** – incorporate electric vehicle charging systems that are responsive to changing grid conditions. |
| **Renewable portfolio diversity** – explore procurement strategies to achieve a more diverse renewable portfolio. | **Flexible resources** – invest in fast-responding resources that can follow sudden increases and decreases in demand. |
Thank you

Questions?
Angelina Galiteva
+1/310/ 735 3981
a.galiteva@renewables100.org