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

UC Santa Barbara, October 2018

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.
Go 100% Renewable Energy Project
Shows how and where 100% Renewable Energy is happening now.

Mapped so far: 12+ Countries, 67 Cities, 62 Regions/States representing more than 256.7 million people (and counting...) who have shifted or are committed to shifting within the next few decades to 100% renewable energy in at least one sector.
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 trillion
- Solar: $2.8 trillion
- Nuclear: $1.4 trillion
- Hydro: $1.1 trillion
- Gas: $0.8 trillion
- Coal: $0.7 trillion

Source: Bloomberg New Energy Finance, NEO 2017

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

13 February 2017
SPP
52% wind

19 February 2018 CAISO
77% wind & solar

November 2017
ERCOT
45% wind

25 December 2016
Scotland
153% wind

9 April 2017
UK 56%
wind & solar

March 2018
Portugal
100% wind & solar

9 July 2015
Denmark
140% wind

May 2016
Germany
67% wind & solar

26 December 2014
South Australia
61% wind & solar

Source: Bloomberg New Energy Finance, various
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>38,000GW (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: -776 TWh/yr
- Gas: +483 TWh/yr
- Renewables: +256 TWh/yr
- Power demand: -78 TWh/yr

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

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

- **Energy Efficiency**
  - Zero Net Energy Residential Buildings Goal: 63,000 GWh/year

- **2015-2050 Timeline**
  - 2015-2016: 33% RPS Goal
  - 2020: 12 GW DG Goal, 8 GW Utility-Scale Goal
  - 2025: 50% Renewables Goal
  - 2030: Reduce GHG Emissions 80% below 1990 levels
  - 2050: Reduce GHG Emissions to 1990 Level (AB 32) – Represents 30% Reduction from Projected GHG Emissions

- **Renewable Energy**
  - 2016: 50% Renewables Goal
  - Over 1.5 million ZEVs on California Roadways Goal

- **Transportation Energy**
  - 10% Light-Duty State Vehicles be ZEV
  - 25% of Light-Duty State Vehicles be ZEV

- **GHG**
  - Reduce GHG Emissions by 40% below 1990
  - 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>Solar</td>
<td>85 MW</td>
<td>9,952 MW PV</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1,237 MW Thermal</td>
</tr>
<tr>
<td></td>
<td></td>
<td>6,569 MW BTM¹</td>
</tr>
<tr>
<td>Wind</td>
<td>3,309 MW</td>
<td>6,295 MW</td>
</tr>
</tbody>
</table>

¹ See GoSolarCalifonia.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 and 3-hour ramps are about four years ahead of the CAISO’s original estimate.
NOT the Duck: ISO gross load curve is changing
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.

### Monthly CO₂

![Graph showing monthly CO₂ emissions from 2014 to 2017](Image)

*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 [ISO](Link). For official emissions data and CARA.*
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.

[Graph showing current CO₂ per resource and a trend line showing today’s CO₂ emissions.]

Page 18
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

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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

Pumped Hydro 96%
• 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 w/in 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

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Governance change necessary
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>18,165 miles of transmission lines</td>
<td>142,000 circuit miles of distribution lines</td>
</tr>
<tr>
<td>~2,800 subst. transformers</td>
<td>~1MM dist. line transformers</td>
</tr>
<tr>
<td>173 unplanned t-line outages</td>
<td>28k unplanned dist. outages</td>
</tr>
<tr>
<td>24 planned t-line outages</td>
<td>19k 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
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)</td>
<td>69,999</td>
<td>266,866</td>
<td>281%</td>
</tr>
<tr>
<td>Plug-in Electric Vehicle (registrations)</td>
<td></td>
<td></td>
<td></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>

Solar PV BTM Ownership 2015-2018

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

Residential
Commercial
Educational
Industrial
Other Govt
Non-Profit
Military

Market Driven New PV Products will Enter the Market

solar art
source: Verein Sonnensegel Münsingen

glazing
source: Atlantis

BIPV Hongkong
source: 3S Photovoltaics
BIPV Products will become competitive
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
Lots of DR, storage and export - or curtailment
No more “baseload”

Source: CAISO OASIS; CEC proposed IRP; LM Power; CESA; Bloomberg New Energy Finance
A suite of solutions are necessary

<table>
<thead>
<tr>
<th>Storage</th>
<th>Western EIM expansion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Increase the effective participation by energy storage resources.</td>
<td>Expand the western Energy Imbalance Market.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Demand response</th>
<th>Regional coordination</th>
</tr>
</thead>
<tbody>
<tr>
<td>Enable adjustments in consumer demand, both up and down, when warranted by grid conditions.</td>
<td>Offers more diversified set of clean energy resources through a cost effective and reliable regional market.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Time-of-use rates</th>
<th>Electric vehicles</th>
</tr>
</thead>
<tbody>
<tr>
<td>Implement time-of-use rates that match consumption with efficient use of clean energy supplies.</td>
<td>Incorporate electric vehicle charging systems that are responsive to changing grid conditions.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Renewable portfolio diversity</th>
<th>Flexible resources</th>
</tr>
</thead>
<tbody>
<tr>
<td>Explore procurement strategies to achieve a more diverse renewable portfolio.</td>
<td>Invest in fast-responding resources that can follow sudden increases and decreases in demand.</td>
</tr>
</tbody>
</table>
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

- Europe (EU-28): $1.03 billion
- China: $1.02 billion
- California: $5.69 billion

Source: Next 10 California 2014 Green Innovation Index
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
A new “Low Carbon Circle” The future is: Decentralized, diversified, decarbonized and digitized

= Opportunity for Storage/resiliency
And 100% Renewables in all Sectors
Thank you

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