E3 Overview and Preliminary APS IRP

APS IRP Stakeholder Workshop
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Outline

- Introduction to E3
- Key takeaways from regional planning studies
- Modeling to support APS’ preliminary IRP development
Introduction to E3
+ Founded in 1989, E3 is a leading energy consultancy with a unique 360-degree view of the industry
+ E3 operates at the nexus of energy, environment, and economics
+ Our team employs a unique combination of economic analysis, modeling acumen, and deep strategic insight to solve complex problems for a diverse client base
E3’s project scope and breadth is unmatched for a firm of its size

- We complete over 250 projects a year across the energy sector and across the globe
- This focus allows for constant innovation and development of best-in-class tools and analysis that leads to strategic insights, answers, and recommendations

**E3 Practice Areas**

**Asset Valuation & Strategy**
- Determines asset values and strategies from multiple perspectives
- Uses proprietary in-house models and in-depth knowledge of public policy, regulation and market institutions

**DERs & Rates**
- Analyzes distributed energy resources, emphasizing their costs and benefits now and in the future
- Supports rate design and distribution system planning

**Planning**
- Develops and deploys proprietary tools to aid resource planners
- Informs longer-term system planning and forecasting

**Clean Energy Policy**
- Provides market and policy analysis on clean energy technologies and climate change issues
- Includes comprehensive and long-term GHG analysis

**Market Analysis**
- Models wholesale energy markets both in isolation and as part of broader, more regional markets
- Key insights to inform system operators and market participants
Key Findings from Regional Planning Studies
Key E3 resource planning studies

- E3’s resource planning studies focus on questions of how to meet aggressive carbon reduction and clean energy goals in the electric sector while maintaining reliability and managing costs

- **2016 Power Supply Improvement Plan** (HECO, 2016)
- **Pacific Northwest Low Carbon Scenario Analysis** (PGP, 2017)
- **Ongoing IRP Support** (CPUC, 2016-’19)
- **2018 IRP Support** (SMUD, 2018)
- **Deep Decarbonization in a High Renewables Future** (CEC, 2018)
- **Upper Midwest 2019 IRP Support** (Xcel, 2018-’19)
- **Resource Adequacy under Deep Decarbonization** (Calpine, 2019)
Key findings common across E3 studies

1. Meeting deep economy-wide carbon reduction goals will require multiple transformations that directly impact the electricity sector, including (1) decarbonization of power supply and (2) electrification of transportation and key building end uses.

2. Achieving a low-carbon grid is technically feasible and can be affordable, but eliminating carbon from the electricity sector entirely appears challenging and cost-prohibitive.

3. A technology-neutral policy focused on carbon reductions will enable utilities to meet clean energy goals more affordably than policies that establish goals for specific technologies.

4. Even in a deeply decarbonized grid, natural gas resources will continue to play a crucial role in meeting reliability needs as “firm” resources, dispatchable on demand but rarely called upon.
Four “pillars” of decarbonization to meet long-term goals

1. Low carbon electricity
2. Electrification
3. Energy efficiency & conservation
4. Low carbon fuels

Four foundational elements are consistently identified in studies of strategies to meet deep decarbonization goals.

Across most decarbonization studies, electric sector plays a central role in meeting goals:

- Through direct carbon reductions
- Through electrification of loads to reduce emissions in other sectors
In spite of aggressive levels of energy efficiency, 2050 loads increase in deep decarbonization scenarios by as much as 50%.

SMUD Demand Forecast Under “80x50” Carbon Reduction Scenario

- Newly electrified end uses drive an increase in load
- High levels of energy efficiency keep load growth relatively low
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Historical Solar PPA Price Trends

Cost trends for emerging technologies have transformed the economics of decarbonization of electricity

- Availability of solar and wind at low PPA prices ($15-35/MWh) offers a competitive source of energy supply to displace fossil resources
- Anticipated trends in costs of battery storage may offer a low cost solution to balancing & integration challenges

Planning challenge for utilities seeking to decarbonize is balancing integration of renewables with maintaining a reliable system

Figure Source: Utility Scale Solar, 2018 Edition (LBNL)

Historical Wind PPA Price Trends

Figure Source: 2017 Wind Technologies Market Report (LBNL)
SMUD examined two bookend scenarios in its 2018 IRP process:

1. **SD9 Goal**, which is on a straightline path to meet the SMUD’s goal of 90% carbon reductions by 2050; and

2. **Absolute Zero**, which requires SMUD divest of its gas resources and serve all loads with carbon-free resources

Meeting SD9 goal appears affordable, but exponential cost increase to achieve “Absolute Zero” target is driven by reliability challenges without dispatchable resource capacity

### Total Installed Capacity (MW)

<table>
<thead>
<tr>
<th>Capacity Type</th>
<th>Today</th>
<th>2040</th>
</tr>
</thead>
<tbody>
<tr>
<td>SMUD Existing Dispatchable Gen</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SMUD Renewable Gen</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Additional Reliability Resources</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Unspecified Capacity</td>
<td></td>
<td></td>
</tr>
</tbody>
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### Revenue Requirement (2016 $B/yr)

<table>
<thead>
<tr>
<th>Year</th>
<th>Total</th>
</tr>
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<tbody>
<tr>
<td>Today</td>
<td>$1.36</td>
</tr>
<tr>
<td>2040</td>
<td>$2.04</td>
</tr>
<tr>
<td></td>
<td>$5.13</td>
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</tbody>
</table>

### Average Retail Rate (2016 cents/kWh)

<table>
<thead>
<tr>
<th>Year</th>
<th>Rate</th>
</tr>
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<tbody>
<tr>
<td>Today</td>
<td>12.8</td>
</tr>
<tr>
<td>SD9</td>
<td>13.6</td>
</tr>
<tr>
<td>Absolute Zero</td>
<td>34.4</td>
</tr>
</tbody>
</table>
Scenario analysis in the Northwest highlights low-cost opportunities to achieve significant carbon reductions with investment in renewables & coal shutdown.
1. Meeting deep economy-wide carbon reduction goals will require multiple transformations that directly impact the electricity sector, including (1) decarbonization of power supply and (2) electrification of transportation and key building end uses.

2. Achieving a low-carbon grid is technically feasible and can be affordable, but eliminating carbon from the electricity sector entirely appears challenging and cost-prohibitive.

3. A technology-neutral policy focused on carbon reductions will enable utilities to meet clean energy goals more affordably than policies that establish goals for specific technologies.

4. Even in a deeply decarbonized grid, natural gas resources will continue to play a crucial role in meeting reliability needs as “firm” resources, dispatchable on demand but rarely called upon.
A technology-neutral approach to establishing future goals will provide optionality as opportunities for carbon reductions evolve, enabling utilities to choose the most affordable “building blocks”.

<table>
<thead>
<tr>
<th>Building Block</th>
<th>Description</th>
</tr>
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<tbody>
<tr>
<td>Nuclear</td>
<td>Maintain existing carbon-free generation</td>
</tr>
<tr>
<td>Renewables</td>
<td>Increase and diversify carbon-free generation</td>
</tr>
<tr>
<td>Fuel switching</td>
<td>Conversion from coal to gas (or other) generation</td>
</tr>
<tr>
<td>Clean imports</td>
<td>Utilize excess low-carbon electricity</td>
</tr>
<tr>
<td>Electrification</td>
<td>Electrify transportation sector and select building end uses</td>
</tr>
<tr>
<td>Energy storage</td>
<td>Load shifting/absorbing excess solar via energy storage</td>
</tr>
<tr>
<td>Demand management</td>
<td>Energy efficiency and other demand-side measures</td>
</tr>
</tbody>
</table>
Establishing policies, targets, and goals using carbon as the “currency” provides opportunities for least-cost emissions reductions

- RPS-style production quotas lead to higher costs and lower carbon reductions due to renewable integration challenges
- Targets on carbon enables utilities to identify least-cost approach to meet clean energy goal using a combination of building blocks

Under all deep carbon reduction scenarios examined, expansion of renewable development is crucial to meeting targets
Northwest decarbonization study examined value of existing hydro & nuclear plants under a range of policy options:

- In the Reference Case, lost capacity and energy is replaced with natural gas generation.
- In the 80% GHG Reduction Case, lost energy is replaced with renewables; lost capacity is replaced with gas generation.
- In the 50% RPS Case, lost energy & capacity is replaced with natural gas generation.

Higher value in a carbon constrained world reflects the significant increase in cost to meet GHG policy goals should existing low carbon resources retire.

Value of Existing Hydro & Nuclear

<table>
<thead>
<tr>
<th>Policy Case</th>
<th>Market Value of Carbon-Free Resources ($/MWh)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reference</td>
<td>$61</td>
</tr>
<tr>
<td>80% Reduction</td>
<td>$91</td>
</tr>
<tr>
<td>50% RPS</td>
<td>$38</td>
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</tbody>
</table>

Value of carbon-free attribute of hydro and nuclear is captured in market value under GHG policy. High RPS policy erodes value of other carbon-free resources and could lead to retirement.
1. Meeting deep economy-wide carbon reduction goals will require multiple transformations that directly impact the electricity sector, including (1) decarbonization of power supply and (2) electrification of transportation and key building end uses.

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Evolving paradigms in planning for system reliability

Traditional Planning Paradigm

- Resource adequacy focused on ensuring enough dispatchable resources to meet peak demand
  - A system planned to meet peak demand would implicitly be capable of meeting lower demands throughout the year as well

New Planning Paradigm

- New types of resources add complexity to reliability planning
  - Variable resources & storage may not dispatch at full capacity when needed
  - Due to interactive effects, most challenging period for reliability may not be peak demand
Wind and solar ELCC curves decline due to lack of coincidence of production with a shifting net peak.

Storage and DR ELCC curves decline as net peak flattens out and outlasts the duration of the resource.
+ In the absence of dispatchable gas and coal resources, significant new investment in renewables and storage are needed for reliability
  - 20 GW of wind and solar
  - 5 GW of 17-hr storage
  - +$2.9 billion/yr in incremental fixed costs

+ Meeting reliability needs results in significant “overbuild” of renewables
  - Renewables + nuclear capable of meeting 160% of Xcel annual energy needs—but large quantities must be curtailed

+ Scale of investments results in exponential cost increase to achieve final 5% GHG reductions
On a system that relies predominantly on variable resources & storage to meet reliability needs, reliability events result from sustained energy shortages—not peak needs.

Reliability challenges could alternatively be solved by resources that can dispatch on demand across extended periods but are rarely used.

Nine-Day Snapshot* of Resource Availability, 100% GHG Reduction Scenario

* Nine-day snapshot chosen from simulation of loads and resources on >23,000 operating days.
1. Meeting deep economy-wide carbon reduction goals will require multiple transformations that directly impact the electricity sector, including (1) decarbonization of power supply and (2) electrification of transportation and key building end uses.

2. Achieving a low-carbon grid is technically feasible and can be affordable, but eliminating carbon from the electricity sector entirely appears challenging and cost-prohibitive.
   - Cost breakthroughs in renewables & storage coupled with sustained low gas prices provide significant opportunities for low carbon energy resources.
   - “Hockey-stick” cost curves indicate very high marginal costs to fully decarbonize electricity.

3. A technology-neutral policy focused on carbon reductions will enable utilities to meet clean energy goals more affordably than policies that establish goals for specific technologies.
   - Least-cost opportunities for carbon reductions will vary depending on the utility and may change over time as technologies mature & markets evolve.
   - Providing utilities with flexibility to meet clean energy goals allows more efficient pathway to policy objectives.
   - Preserving existing sources of carbon-free generation helps mitigate costs to achieve carbon reductions within electricity sector, but long-term viability of existing resources depends on policy choices & design.

4. Even in a deeply decarbonized grid, natural gas resources will continue to play a crucial role in meeting reliability needs as “firm” resources, dispatchable on demand but rarely called upon.
   - Capacity value of renewable and storage resources decline with increasing penetration.
   - Maintaining significant quantities of gas generation resources that run infrequently to meet resource adequacy needs is likely part of the least-cost strategy to achieve deep carbon reductions in electricity.
E3’s Modeling for Preliminary IRP
Four groups of scenarios

Scenarios modeled generally fall into four broad categories based on the driving type of policy that determines the investments needed in each:

1. **Carbon**: portfolios designed to meet a specific carbon goal (MMT)

2. **Renewable Portfolio Standard (RPS)**: portfolios designed to meet a kWh production quota for renewables, determined as a percent of retail sales

3. **Clean**: portfolios designed to meet a kWh production quota for carbon-free resources, determined as a percent of retail sales
   - Includes nuclear & clean imports

4. **Commission Policy Proposals**: portfolios designed to test limits investment in new natural gas infrastructure as well as various RPS levels
Thank You

Questions?