Renewables Integration Study
Update

Mark Rothleder
Executive Director, Market Analysis and Development

February 10, 2012
Agenda

1. Process Update: Summary of where we have been, where we are now, and where we are going

2. Detailed reports on work group activities
   1. Study Group 3 – PRM Analysis Deep Dive analysis of PRM
   2. Study Group 1 – Stochastic Simulation
   3. Study Group 2 – Step 1 Sensitivity
   4. Study Group 4 – 5 minute simulation
   5. Study Group 5 – Reserve and BAA Coordination

3. Next steps discussion

Note: Study work is in progress, results are not final and are subject to change
Process Update
Where We Have Been

• CAISO has been using PLEXOS to estimate need for new resources to integrate renewables
  – Develop detailed data inputs for hourly production simulation
    • Loads, renewable profiles, etc.
    • Regulation and Load Following Requirements (Step 1)
    • Import capabilities
  – Run PLEXOS to simulate hourly production
  – Log “violation” when resource stack is insufficient to meet load, reserve, regulation and LFU requirements
  – Add resources until no more violations

Note: Study work is in progress, results are not final and are subject to change
What We Have Learned

• “Deep-dive” analysis showed us that PLEXOS results were being influenced by factors not strictly related to renewable integration needs:
  – Load levels
  – Import availability
  – Hydro production
  – Renewable production during critical hours

• These factors have traditionally been analyzed using techniques other than production simulation
  – Reliability analysis focused on loss of load

Note: Study work is in progress, results are not final and are subject to change
“Deep-Dive” Analysis of All-Gas Case

- Previous analysis showed need in All-Gas Case, despite seemingly high reserve margins
- Deep-dive analysis revealed two key factors:
  1. Reserve margin was overstated -- effective PRM for the All-Gas Case is 21%, not 41%
     - Key differences are operating limits on imports, simulated hydro production vs. NQC values
  2. Need in All-Gas Case driven largely by Regulation Up and Load Following Up requirements
     - Accounts for remaining 4% increase above the 17% PRM

Note: Study work is in progress, results are not final and are subject to change
Where We Are Now

- CAISO is now proposing to supplement our modeling with a different type of analysis to address those factors unrelated to integration need, as a new step in the process
  - Reliability modeling that calculates Loss of Load Probability (LOLP) and Loss of Load Expectation (LOLE)
  - PG&E and E3 have been developing models to conduct this analysis
  - CAISO has also developed a stochastic analysis approach that to test simultaneous ramping capability
  - CAISO has not yet decided which model to use in this case

Note: Study work is in progress, results are not final and are subject to change
CAISO Proposed New Approach

**Previous Methodology**

- Loads, gen. profiles, imports, etc.
  - Step 1: Calculate hourly flexibility reserve requirement
  - Step 2: Test for violations in PLEXOS

**Current Proposal**

- Loads, gen. profiles, imports, etc.
  - Step 1: Calculate hourly flexibility reserve requirement
  - Step 2: Develop base system need using LOLP
  - Step 3: Test for flexibility within base portfolio

Note: Study work is in progress, results are not final and are subject to change
Potential Idea to Limit Scope of Current Analysis

- CAISO and some stakeholders continue to disagree about CAISO finding of need in All-Gas Case under 21% PRM
  - Some stakeholders believe Reg. and LFU requirements attributable to *load* are already accounted for in 17% PRM
  - CAISO continues to be concerned that the PRM does not account for these needs
- CAISO is considering whether to defer this question to a future PRM proceeding
  - This would limit the scope of our current analysis to incremental Reg. and LFU requirements associated with renewables

Note: Study work is in progress, results are not final and are subject to change.
Step 1 of Proposed New Approach

- Calculate Regulation and Load Following Requirements associated with variability and uncertainty of load, wind and solar for each resource portfolio
- Unchanged from previous approach

Note: Study work is in progress, results are not final and are subject to change
Step 2 of Proposed New Approach

• Conduct LOLP modeling to determine need for new capacity to meet a reliability standard of 1-day-in-10-years
  – Calibrate model to reflect 17% PRM under All-Gas Case
  – For each portfolio, calculate change to PRM needed to achieve same reliability as All-Gas Case
    • Expected renewable production will be different from NQC
    • Incremental increase in Reg. and LFU requirements due to renewable penetration
  – Add resources as needed to meet the updated PRM to reflect changes from All-Gas case

Note: Study work is in progress, results are not final and are subject to change
Step 3 of Proposed New Approach

• Test for flexibility within portfolio that comes from Step 2
  – Includes any resources added to meet reliability standard
• Need for ramping capability is not the same thing as need for new resources
  – Conversion of existing resources to something more flexible could solve a ramping problem without changing the PRM
• Stochastic component estimates the probability of having a ramping capacity shortage based on distribution of hourly ramps
  – Within-hour ramps also assessed through incorporation of Step 1 results
• PLEXOS runs to test operability of portfolio that comes from Step 3

Note: Study work is in progress, results are not final and are subject to change
Study Group 3: 15-17% Planning Reserve Margin (PRM) Case Analysis

• Review of “All-Gas” indicates actual planning reserve margin is 21%
• Results are sensitive to load, imports, hydro and outages
• A portion of needs above traditional PRM attributable to load following requirements
Update to the Deep-Dive Analysis – E3

Arne Olson, Partner
Nick Schlag, Consultant
CAISO Deep Dive Analysis

Shucheng Liu
Comparison of California Load and Resource Balance (July 22, 2020)

Note: Study work is in progress, results are not final and are subject to change.
# Environment Constrained Case California Load and Resource Balance (July 22, 2020)

<table>
<thead>
<tr>
<th></th>
<th>H13</th>
<th>H14</th>
<th>H15</th>
<th>H16</th>
<th>H17</th>
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<tr>
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<td></td>
<td></td>
<td></td>
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<td>Load</td>
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<td>4,555</td>
<td>4,489</td>
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<td>LFU</td>
<td>2,155</td>
<td>1,993</td>
<td>2,101</td>
<td>2,012</td>
<td>1,929</td>
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<tr>
<td><strong>Total</strong></td>
<td>67,008</td>
<td>69,396</td>
<td>70,412</td>
<td>69,987</td>
<td>67,991</td>
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<tr>
<td><strong>Supply (MW)</strong></td>
<td></td>
<td></td>
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<tr>
<td>Import</td>
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<td>10,614</td>
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<td>4,489</td>
<td>4,479</td>
</tr>
<tr>
<td>LFU</td>
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<td>1,993</td>
<td>2,101</td>
<td>2,012</td>
<td>1,929</td>
</tr>
<tr>
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<td>67,008</td>
<td>69,396</td>
<td>70,412</td>
<td>69,987</td>
<td>67,991</td>
</tr>
<tr>
<td><strong>Shortage (MW)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LFU</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Outage (MW)</td>
<td>4,820</td>
<td>4,500</td>
<td>5,093</td>
<td>4,906</td>
<td>4,641</td>
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</tbody>
</table>

Note: Study work is in progress, results are not final and are subject to change.
<table>
<thead>
<tr>
<th></th>
<th>H13</th>
<th>H14</th>
<th>H15</th>
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<tr>
<td><strong>Demand (MW)</strong></td>
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<td></td>
<td></td>
<td></td>
<td></td>
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<td>Load</td>
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<td><strong>Total</strong></td>
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<td>69,911</td>
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<td>67,937</td>
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<tr>
<td>Import</td>
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<td>14,886</td>
<td>14,886</td>
<td>14,886</td>
<td>14,886</td>
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<td>Generation</td>
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<td>47,858</td>
<td>48,703</td>
<td>48,435</td>
<td>46,536</td>
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<tr>
<td>Upward AS</td>
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<td>4,463</td>
<td>4,442</td>
<td>4,562</td>
<td>4,414</td>
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<td>LFU</td>
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<td>838</td>
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<td>68,031</td>
<td>68,848</td>
<td>68,721</td>
<td>67,650</td>
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<td><strong>Shortage (MW)</strong></td>
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<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>LFU</td>
<td>0</td>
<td>1,311</td>
<td>1,063</td>
<td>961</td>
<td>287</td>
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<tr>
<td>Outage (MW)</td>
<td>4,820</td>
<td>4,500</td>
<td>5,093</td>
<td>4,906</td>
<td>4,641</td>
</tr>
</tbody>
</table>

Note: Study work is in progress, results are not final and are subject to change.
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Study Group 1: Stochastic Simulation

• **Purpose**
  – To incorporate uncertainties in key input assumptions in determining need for capacity

• **Scope**
  – May apply to all cases
  – May be used together with Plexos simulation

• **Study Approach**
  – Probabilistic simulation
  – Loss of Load Probability (LOLP)

Note: Study work is in progress, results are not final and are subject to change
E3- LOLP Analysis Work

California ISO Working Group

February 10, 2012

Arne Olson
Andrew DeBenedictis
Ryan Jones
PG&E Using GE-MARS to estimate resource need for 33% RPS scenarios

January 2012
A Stochastic Model for Analyzing Ramping Capacity Sufficiency

Shucheng Liu, Ph.D.
Principal, Market Development

January 5, 2012
A stochastic model is needed to assess the probability of upward ramping capacity sufficiency.

- A deterministic production simulation case adopts only one of the many possible combinations of input assumptions.
- A stochastic model can evaluate various input combinations based on probability distributions and correlations among the stochastic input variables.
- Monte Carlo simulation determines the probability of having a ramping capacity shortage.
- It complements the deterministic production simulation.

Note: Study work is in progress, results are not final and are subject to change.
Available ramping capacity depends on the balance of supply and demand.

Supply curve is constructed based on variable cost of each generation unit.

Note: Study work is in progress, results are not final and are subject to change.
Uncertainties in supply and demand affect availability of ramping capacity.

Note: Study work is in progress, results are not final and are subject to change.
Available ramping capacity of each generation unit is determined based on the following factors:

- Maximum and minimum capacity
- Unit availability (due to forced and maintenance outages)
- Dispatch level
- Ramp rate
- Ramp time allowed (10 or 20 minutes)

Note: Study work is in progress, results are not final and are subject to change
Ramping capacity shortage may occur due to variations in both availability and requirement.

Note: Study work is in progress, results are not final and are subject to change.
This CA-wide stochastic model considers uncertainties in some of the key inputs, including:

- California load forecast
- Requirements for regulation-up service and load following-up
- Generation by wind, solar, and hydro resources
- California total import capability
- Availability of generation units

Note: Study work is in progress, results are not final and are subject to change.
The model is developed for a time period in which all hours have similar conditions.

- It is not a unit commitment model
- The model does not have chronologic constraint (such as min run time and min down time, etc.)
- All hours within the period are assumed to be independent from each other and have identical probability distribution functions
- Monte Carlo simulation determines the probability of having ramping capacity shortage for each hour
- Probability of ramping capacity shortage in the whole year is calculated using Binomial distribution

Note: Study work is in progress, results are not final and are subject to change
Probability distributions are fitted based on data from the Plexos production simulation model.

- Hourly California load forecast
- Hourly regulation and load following-up requirement
- Hourly wind, solar, and hydro generation
- California total import limit and hourly import and export results

Note: Study work is in progress, results are not final and are subject to change.
The probability distribution functions for the High-Load case in “Super-Peak” period are as follows:

Net Import distribution function is not used in the cases presented in this document. The CA total import limit is used instead.

Note: Study work is in progress, results are not final and are subject to change.
Probability distribution functions for the High-Load case in “Super-Peak” period. (cont.)

Note: Study work is in progress, results are not final and are subject to change.
Probability distribution functions for the High-Load case in “Super-Peak” period.(cont.)

Note: Study work is in progress, results are not final and are subject to change
Probability distribution functions for the High-Load case in “Super-Peak” period.(cont.)

Note: Study work is in progress, results are not final and are subject to change
Correlations among the stochastic variables are enforced.

<table>
<thead>
<tr>
<th></th>
<th>Load</th>
<th>Net Import</th>
<th>Wind</th>
<th>Solar</th>
<th>Hydro</th>
<th>RegU</th>
<th>LFU</th>
</tr>
</thead>
<tbody>
<tr>
<td>Load</td>
<td>1</td>
<td>0.8092</td>
<td>-0.0947</td>
<td>-0.1997</td>
<td>0.4302</td>
<td>0.3801</td>
<td>0.0722</td>
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<tr>
<td>Net Import</td>
<td>0.8092</td>
<td>1</td>
<td>-0.2814</td>
<td>-0.3772</td>
<td>0.0040</td>
<td>0.2449</td>
<td>0.2203</td>
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<tr>
<td>Wind</td>
<td>-0.0947</td>
<td>-0.2814</td>
<td>1</td>
<td>-0.1618</td>
<td>0.2855</td>
<td>-0.0108</td>
<td>0.0609</td>
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<tr>
<td>Solar</td>
<td>-0.1997</td>
<td>-0.3772</td>
<td>-0.1618</td>
<td>1</td>
<td>0.0254</td>
<td>-0.1101</td>
<td>-0.5064</td>
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<tr>
<td>Hydro</td>
<td>0.4302</td>
<td>0.0040</td>
<td>0.2855</td>
<td>0.0254</td>
<td>1</td>
<td>0.3094</td>
<td>-0.1283</td>
</tr>
<tr>
<td>RegU</td>
<td>0.3801</td>
<td>0.2449</td>
<td>-0.0108</td>
<td>-0.1101</td>
<td>0.3094</td>
<td>1</td>
<td>0.1415</td>
</tr>
<tr>
<td>LFU</td>
<td>0.0722</td>
<td>0.2203</td>
<td>0.0609</td>
<td>-0.5064</td>
<td>-0.1283</td>
<td>0.1415</td>
<td>1</td>
</tr>
</tbody>
</table>

This is the correlation matrix of the High-Load case in “Super-Peak” period

Note: Study work is in progress, results are not final and are subject to change.
Generation units in the stochastic model have the following characteristics same as in the Plexos model.

- **From input data**
  - Maximum and minimum capacity
  - Ramp rate
  - Forced outage and maintenance outage rates

- **From Plexos simulation results**
  - Average generation cost

Note: Study work is in progress, results are not final and are subject to change.
Generation unit availability is stochastically determined.

- Forced and maintenance outages are determined independently for each generation unit.
- Each of the outages is determined based on the unit’s outage rate and a draw using a uniform distribution function.
- A maintenance outage allocation factor is applied to represent the seasonal pattern of maintenance.
- The unit is unavailable when any one of the outages occurs.

Note: Study work is in progress, results are not final and are subject to change.
Contributions by each generation unit to meet energy, AS, and load following requirements are subject to:

- 10-min upward ramping capacity constraint
  \[ AS_i \leq \min(10 \times \text{RampRate}_i, \text{MaxCap}_i - \text{MinCap}_i) \]

- 20-min upward ramping capacity constraint
  \[ AS_i + LFU_i \leq \min(20 \times \text{RampRate}_i, \text{MaxCap}_i - \text{MinCap}_i) \]

- Maximum capacity constraint
  \[ E_i + AS_i + LFU_i \leq \text{MaxCap}_i \]

Note: Study work is in progress, results are not final and are subject to change.
The model seeks a least-cost solution to meet energy, AS and load following requirements.

- Generation units are dispatched economically to meet load first
- Remaining qualified ramping capacity is used to meet upward ancillary service and load following requirements
- Dispatch and ramping capacity are co-optimized when there is a ramping capacity shortage initially

Note: Study work is in progress, results are not final and are subject to change
Monte Carlo simulation produces probabilistic results.

- Monte Carlo simulation is conducted using this stochastic model
- The simulation results are presented in a probability distribution format
- The key results are the probability to have ramping capacity shortage each hour and the probabilistic distribution of the volume of the shortages

Note: Study work is in progress, results are not final and are subject to change
Three cases of the 33% renewable integration study were simulated using the stochastic model.

• The High-Load case for year 2020

• High-Load case with 4,600 MW additional generic resources (the capacity need identified in Need-Run of Plexos simulation)

• The Trajectory case for year 2020

Note: Study work is in progress, results are not final and are subject to change
The High-Load case has a 0.8% probability to have 20-min ramping capacity shortage each hour in the Super-Peak period.

Note: Study work is in progress, results are not final and are subject to change
The highest 20-min ramping capacity shortage is 4,661 MW.

Note: Study work is in progress, results are not final and are subject to change.
The probability to have 10-min ramping capacity shortage each hour is 0.1% in the Super-Peak period.

20-min ramping capacity shortage includes 10-min shortage based on the definition of 20-min ramping capacity constraint and additive requirement for AS and load following.

Note: Study work is in progress, results are not final and are subject to change.
Probabilities of ramping capacity shortage decreased after 4,600 MW generic resources were added.

4,600 MW is the capacity need identified in Need-Run of Plexos simulation for the High-Load case.

Note: Study work is in progress, results are not final and are subject to change.
The Trajectory case also has a small probability of ramping capacity shortage in the Super-Peak period.

Note: Study work is in progress, results are not final and are subject to change.
The Monte Carlo simulation results are summarized as follows:

<table>
<thead>
<tr>
<th># of Hours in the Period</th>
<th>Probability of Shortage</th>
<th>Max Shortage (MW)</th>
<th>Trajectory Case</th>
</tr>
</thead>
<tbody>
<tr>
<td>Super-Peak 10-min</td>
<td>630</td>
<td>2,180</td>
<td>630</td>
</tr>
<tr>
<td>Super-Peak 20-min</td>
<td>630</td>
<td>4,661</td>
<td>630</td>
</tr>
<tr>
<td>Summer Off-Peak 10-min</td>
<td>2298</td>
<td>1,420</td>
<td>630</td>
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<tr>
<td>Summer Off-Peak 20-min</td>
<td>2298</td>
<td>3,855</td>
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<td>Super-Peak 10-min</td>
<td>630</td>
<td>0</td>
<td>630</td>
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<tr>
<td>Super-Peak 20-min</td>
<td>630</td>
<td>760</td>
<td>630</td>
</tr>
<tr>
<td>Super-Peak 10-min</td>
<td>630</td>
<td>206</td>
<td>630</td>
</tr>
<tr>
<td>Super-Peak 20-min</td>
<td>630</td>
<td>1,456</td>
<td>630</td>
</tr>
</tbody>
</table>

- Super-Peak: June-September, Monday-Saturday, H12-H17
- Summer Off-Peak: non-Super-Peak hours in June-September
- Periods not listed in the table do not have ramping capacity shortage

Note: Study work is in progress, results are not final and are subject to change
The cumulative probabilities of ramping capacity shortage are calculated using Binomial distribution.

<table>
<thead>
<tr>
<th></th>
<th>High-Load Case</th>
<th>High-Load Case with 4,600 MW Generic Resources</th>
<th>Trajectory Case</th>
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<td>10-min</td>
<td>20-min</td>
<td>10-min</td>
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<td>1</td>
<td>81.3%</td>
<td>100.0%</td>
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<td>2</td>
<td>49.9%</td>
<td>99.8%</td>
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<tr>
<td>3</td>
<td>23.6%</td>
<td>99.1%</td>
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<td>4</td>
<td>8.9%</td>
<td>97.2%</td>
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<td>5</td>
<td>2.8%</td>
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<tr>
<td>6</td>
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<td>10</td>
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<td>14</td>
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<td>15</td>
<td>0.0%</td>
<td>2.9%</td>
<td>0.0%</td>
</tr>
<tr>
<td>16</td>
<td>0.0%</td>
<td>1.5%</td>
<td>0.0%</td>
</tr>
<tr>
<td>17</td>
<td>0.0%</td>
<td>0.7%</td>
<td>0.0%</td>
</tr>
<tr>
<td>18</td>
<td>0.0%</td>
<td>0.3%</td>
<td>0.0%</td>
</tr>
<tr>
<td>19</td>
<td>0.0%</td>
<td>0.1%</td>
<td>0.0%</td>
</tr>
<tr>
<td>20</td>
<td>0.0%</td>
<td>0.1%</td>
<td>0.0%</td>
</tr>
<tr>
<td>21</td>
<td>0.0%</td>
<td>0.0%</td>
<td>0.0%</td>
</tr>
<tr>
<td>22</td>
<td>0.0%</td>
<td>0.0%</td>
<td>0.0%</td>
</tr>
</tbody>
</table>

It is the probability to have at least $i$ hours with ramping capacity shortage in year 2020.

Note: Study work is in progress, results are not final and are subject to change.
Expected number of hours with ramping capacity shortage in 2020 are calculated based on the probabilities.

<table>
<thead>
<tr>
<th></th>
<th>High-Load Case</th>
<th>High-Load Case with 4,600 MW Generic Resources</th>
<th>Trajectory Case</th>
</tr>
</thead>
<tbody>
<tr>
<td>10-min</td>
<td>1.68</td>
<td>0.00</td>
<td>0.25</td>
</tr>
<tr>
<td>20-min</td>
<td>8.59</td>
<td>0.38</td>
<td>0.25</td>
</tr>
</tbody>
</table>

The expected hours with ramping capacity shortage can be compared with the “1-in-10” LOLP criteria (1 event in 10 years or 0.1 hours per year)

Note: Study work is in progress, results are not final and are subject to change.
Co-optimization re-dispatches resources to free up more ramping capacity when needed.

- In each iteration generation units are first dispatched based on capacity stacked up by cost
- Ramping capacity from remaining units is used to meet upward ancillary service and load following requirements
- Dispatch and ramping capacity are co-optimized when there is a ramping capacity shortage initially
- Co-optimization finds a least-cost solution to meet requirements for energy, ancillary service, and load following
- Shortage occurs in ramping capacity when supply is insufficient

Note: Study work is in progress, results are not final and are subject to change
Probability of ramping capacity shortage is much lower with co-optimization in the Monte Carlo simulation.

Note: Study work is in progress, results are not final and are subject to change.
Commercial software is used to develop the model and conduct Monte Carlo simulations.

Palisade Decision Tools Suite
http://www.palisade.com/

Frontline Risk Solver Platform for Excel
http://solver.com/platform/risk-solver-platform.htm

Note: Study work is in progress, results are not final and are subject to change
Study Group 2: Step 1 Sensitivity

• Purpose:
  – Review and improve representation of variability and forecast error parameters for load/wind/solar being used in the study

• Scope:
  – To estimate Step 1 requirements for sue in Plexos simulations or stochastic simulations

• Study Approach:
  – Bracket range of forecast errors for wind and solar (PV and CST) based on past forecast experience and reasonable achievable forecast improvements
  – Where there is little or no forecast experience (PV and CST) use a range based on other studies or industry knowledge of forecast errors
  – Develop a range of forecast errors and corresponding Step 1 inputs to use in Plexos and in stochastic simulations
  – Refinement of forecast error for solar thermal should be incorporated

Note: Study work is in progress, results are not final and are subject to change
The Step 1 team is tasked with addressing concerns surrounding Step 1 results and conduct sensitivity analysis to better inform the larger workgroup

Proposed Agenda

• Task Force request that we calculate the following:
  – Calculate T-30 minutes for PIRP
  – Calculate T-30 minutes for Trajectory

• Wind Errors
  – Upper bound
  – Lower bound

• Solar Errors
  – Upper bound
  – Lower bound

• Load Forecast Errors (2010 or 2011)

• Monthly or hourly load-following values for needs run?

Note: Study work is in progress, results are not final and are subject to change
What wind forecast errors should we use in our studies?

<table>
<thead>
<tr>
<th>Wind</th>
<th>Persistent</th>
<th>Hours</th>
<th>Spring</th>
<th>Summer</th>
<th>Fall</th>
<th>Winter</th>
</tr>
</thead>
<tbody>
<tr>
<td>Current Errors used in Studies</td>
<td>T-1</td>
<td>All</td>
<td>4.0%</td>
<td>3.8%</td>
<td>3.2%</td>
<td>3.1%</td>
</tr>
<tr>
<td>2010 PIRP HA Forecast Errors</td>
<td>PIRP</td>
<td>All</td>
<td>10.5%</td>
<td>8.9%</td>
<td>8.4%</td>
<td>6.7%</td>
</tr>
<tr>
<td><strong>Future Studies</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Upper Limit Persistent (T-1)</td>
<td>PIRP</td>
<td>All</td>
<td>8.4%</td>
<td>7.1%</td>
<td>5.3%</td>
<td>3.9%</td>
</tr>
<tr>
<td>Lower Limit Persistent (T-30)</td>
<td>PIRP</td>
<td>All</td>
<td>2.9%</td>
<td>2.3%</td>
<td>1.8%</td>
<td>1.4%</td>
</tr>
</tbody>
</table>

- T-1 for the Trajectory case would be used for the Step 1 analysis
- PIRP T-1 and T-30 forecast errors would be used as the upper and lower bounds to bookend load-following and regulation requirements

Note: Study work is in progress, results are not final and are subject to change
Current solar HA forecast errors used in Step 1 studies

<table>
<thead>
<tr>
<th>Technology</th>
<th>Persistent</th>
<th>Hours</th>
<th>0&lt;=CL&lt;0.2</th>
<th>.2&lt;=CL&lt;0.5</th>
<th>.5&lt;=CL&lt;0.8</th>
<th>.8&lt;=CL&lt;1.0</th>
</tr>
</thead>
<tbody>
<tr>
<td>Large PV</td>
<td>T-1</td>
<td>Hours 12-16</td>
<td>3.5%</td>
<td>6.9%</td>
<td>5.6%</td>
<td>2.3%</td>
</tr>
<tr>
<td>Large solar Thermal</td>
<td>T-1</td>
<td>Hours 12-16</td>
<td>6.0%</td>
<td>10.9%</td>
<td>10.8%</td>
<td>3.0%</td>
</tr>
<tr>
<td>Distributed PV</td>
<td>T-1</td>
<td>Hours 12-16</td>
<td>2.2%</td>
<td>4.7%</td>
<td>3.9%</td>
<td>1.8%</td>
</tr>
<tr>
<td>Customer Side PV</td>
<td>T-1</td>
<td>Hours 12-16</td>
<td>1.6%</td>
<td>3.3%</td>
<td>3.1%</td>
<td>1.6%</td>
</tr>
</tbody>
</table>

Note: Study work is in progress, results are not final and are subject to change.
Proposed solar HA forecast errors upper and lower bounds by technology for Step 1 studies

<table>
<thead>
<tr>
<th>Technology</th>
<th>Persistent</th>
<th>Hours</th>
<th>0&lt;=CI&lt;0.2</th>
<th>0.2&lt;=CI&lt;0.5</th>
<th>0.5&lt;=CI&lt;0.8</th>
<th>0.8&lt;=CI&lt;=1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Large PV (PV) Upper Limit</td>
<td>(T-1) + 20%</td>
<td>12-16</td>
<td>4.20%</td>
<td>8.28%</td>
<td>6.72%</td>
<td>2.76%</td>
</tr>
<tr>
<td>Large PV (PV) Lower Limit</td>
<td>(T-1) - 20%</td>
<td>12-16</td>
<td>2.80%</td>
<td>5.52%</td>
<td>4.48%</td>
<td>1.84%</td>
</tr>
<tr>
<td>Large Solar Thermal (ST) Upper Limit</td>
<td>(T-1) + 20%</td>
<td>12-16</td>
<td>7.20%</td>
<td>13.08%</td>
<td>12.96%</td>
<td>3.60%</td>
</tr>
<tr>
<td>Large Solar Thermal (ST) Lower Limit</td>
<td>(T-1) - 20%</td>
<td>12-16</td>
<td>4.80%</td>
<td>8.72%</td>
<td>8.64%</td>
<td>2.40%</td>
</tr>
<tr>
<td>Distribute PV (DG) Upper Limit</td>
<td>(T-1) + 20%</td>
<td>12-16</td>
<td>2.64%</td>
<td>5.64%</td>
<td>4.68%</td>
<td>2.16%</td>
</tr>
<tr>
<td>Distribute PV (DG) Lower Limit</td>
<td>(T-1) - 20%</td>
<td>12-16</td>
<td>1.76%</td>
<td>3.76%</td>
<td>3.12%</td>
<td>1.44%</td>
</tr>
<tr>
<td>Customer Side PV (CPV) Upper Limit</td>
<td>(T-1) + 20%</td>
<td>12-16</td>
<td>1.92%</td>
<td>3.96%</td>
<td>3.72%</td>
<td>1.92%</td>
</tr>
<tr>
<td>Customer Side PV (CPV) Lower Limit</td>
<td>(T-1) - 20%</td>
<td>12-16</td>
<td>1.28%</td>
<td>2.64%</td>
<td>2.48%</td>
<td>1.28%</td>
</tr>
</tbody>
</table>
Current and proposed Load HA forecast errors for Step 1 studies

<table>
<thead>
<tr>
<th>Load</th>
<th>Hours</th>
<th>Spring MW</th>
<th>Summer MW</th>
<th>Fall MW</th>
<th>Winter MW</th>
</tr>
</thead>
<tbody>
<tr>
<td>Current HA Forecast Errors used in Studies (2010 Actual)</td>
<td>All</td>
<td>545</td>
<td>636</td>
<td>540</td>
<td>682</td>
</tr>
<tr>
<td>RT Forecast Errors (2010 Actual)</td>
<td>All</td>
<td>216</td>
<td>288</td>
<td>277</td>
<td>231</td>
</tr>
<tr>
<td>High Load Forecast Errors</td>
<td>All</td>
<td>611</td>
<td>700</td>
<td>602</td>
<td>764</td>
</tr>
<tr>
<td>Current HA Forecast Errors used in Studies (2011)</td>
<td>All</td>
<td>517</td>
<td>1002</td>
<td>662</td>
<td>622</td>
</tr>
<tr>
<td>RT Forecast Errors (2011)</td>
<td>All</td>
<td>243</td>
<td>264</td>
<td>290</td>
<td>255</td>
</tr>
</tbody>
</table>

- 2010 HA and RT forecast errors used for all scenarios
- High Load HA Forecast Errors used for the High Load Case

Note: Study work is in progress, results are not final and are subject to change
Hourly load following up requirement for the Trajectory scenario

Hourly Load Following Up Requirements
Summer 2020 - 33% Trajectory

- Trajectory (High Errors):
  - 1: 3,229
  - 2: 3,209
  - 3: 3,236
  - 4: 3,252
  - 5: 3,180
  - 6: 3,798
  - 7: 3,827
  - 8: 3,029
  - 9: 3,091
  - 10: 3,627
  - 11: 3,275
  - 12: 4,183
  - 13: 3,927
  - 14: 3,707
  - 15: 3,163
  - 16: 3,243
  - 17: 3,509
  - 18: 3,128
  - 19: 3,229

- Trajectory (Low Errors):
  - 1: 2,288
  - 2: 2,264
  - 3: 2,189
  - 4: 2,354
  - 5: 2,409
  - 6: 2,521
  - 7: 2,728
  - 8: 2,573
  - 9: 2,342
  - 10: 2,394
  - 11: 2,710
  - 12: 2,428
  - 13: 2,831
  - 14: 2,579
  - 15: 2,538
  - 16: 2,556
  - 17: 2,643
  - 18: 2,495
  - 19: 2,903
  - 20: 3,043
  - 21: 2,762
  - 22: 2,581

- Difference:
  - 1: 941
  - 2: 944
  - 3: 745
  - 4: 559
  - 5: 1,021
  - 6: 842
  - 7: 659
  - 8: 1,071
  - 9: 1,254
  - 10: 687
  - 11: 521
  - 12: 696
  - 13: 917
  - 14: 847
  - 15: 1,352
  - 16: 1,348
  - 17: 1,169
  - 18: 1,205
  - 19: 520
  - 20: 748
  - 21: 606
  - 22: 503
  - 23: 366
  - 24: 648
Hourly load following up requirement comparison for the High Load scenario

Hourly Load Following Up Requirements
Summer 2020 - 33% High Load
Hourly load following up requirement for the Trajectory scenario -- high and low forecast errors and T-1 errors

Hourly Load Following Up Requirements
Summer 2020 - 33% Trajectory
Hourly load following up requirement for the High Load scenario - high and low forecast errors and T-1 errors
Load-following difference between monthly maximum and hourly values for July 20

Note: Study work is in progress, results are not final and are subject to change
What data should be passed from Step 1 to Step 2

Average hourly load values are used in production simulation for all 8760 hours including the peak hour (Preferred)

- **Regulation values passed to Step 2**
  - Pass on the maximum (95 percentile) hourly values as is currently done for all hours

- **Load Following values passed to Step 2**
  - **Needs Requirement**
    - Pass on *hourly* load-following values (95 percentile) from Step 1 for all hours
  - **Cost Requirements**
    - Pass on hourly load-following values (95 percentile) from Step 1 for all hours

The 95 percentile values are truncated from the seasonal values because of the larger sample size

Note: Study work is in progress, results are not final and are subject to change
Study Group 4: 5-minute Production Simulation

• Purpose
  – To validate findings from hourly production simulations

• Scope
  – Based on 2020 High-Load case
  – Selected days with upward ramping capacity shortage

• Schedule
  – Complete simulation in November, 2011

Note: Study work is in progress, results are not final and are subject to change
Study Group 4: 5-minute Production Simulation - Ramping Constraints

• 10-min upward AS constraint

\[ AS_i \leq 10 \times \text{RampRate}_i \]

• 20-min upward AS and LF constraint

\[ AS_i + LFU_i \leq 20 \times \text{RampRate}_i \]

• Total ramping capacity constraint

\[ 12 \times E_i + AS_i + LFU_i \leq 60 \times \text{RampRate}_i \]

Note: Study work is in progress, results are not final and are subject to change
Study Group 4: 5-minute Production Simulation – Comparison of Load Profiles

Comparison of California Total Load

Note: Study work is in progress, results are not final and are subject to change
Study Group 4: 5-minute Production Simulation - Comparison of Load Following-Up Requirements

![Graph showing comparison of California load following-up requirements]

Note: Study work is in progress, results are not final and are subject to change.
Study Group 4: 5-minute Production Simulation - Comparison of 20-min Ramping Capacity Shortages

Comparison of California 20-min Ramping Capacity Shortage

Note: Study work is in progress, results are not final and are subject to change
Study Group 4: 5-minute Production Simulation – Summary of Results

• Load profiles
  – There is a small difference between the 5-min load profile and hourly load profile as the two came from different sources.

• Load following-up requirements
  – 5-min requirement is lower than hourly as it considers forecast errors only

• 20-min ramping capacity shortage
  – 20-min ramping capacity shortage exists in all 5-min intervals in the three hours simulated
  – Interval 8 of HE 16 has highest shortage in 5-min simulation due to large increase in load following-up requirement and ramping constraints

Note: Study work is in progress, results are not final and are subject to change
Study Group 5: Reserves with BAA Coordination

• Purpose

The renewable integrations studies to date have assumed existing interbalancing authority area operations:

– Intertie scheduling is predominantly hourly schedules
  • 40% of renewable imports
– Dynamic transfer will accommodate some transfers:
  • Existing dynamic scheduled resources
  • 15% of renewable imports
– Intra-hour schedule (15 minute scheduling)
  • 15% of renewable imports
– Ancillary services provided by existing resources specific system imports.

The renewable integrations studies to date have also assumed:

– Outside of CA, BAAs have no contingency, regulation, or load following requirements

Note: Study work is in progress, results are not final and are subject to change
Study Group 5: Reserves with BAA Coordination

• Proposed Sensitivities:
  – Part A: Suggestions to refine representation of neighboring BAs commitment/dispatch
  – Part B: Evaluate impact of increase in intra-hour scheduling and dynamic scheduling
  – Part C: Evaluate impact of CA’s use of excess flexibility from neighboring BAs

• Status
  – Complete simulation in January, 2012

Note: Study work is in progress, results are not final and are subject to change
Study Group 5: WECC reserve requirements modeled

• Modeled reserve requirement in the WECC
  – spinning reserve requirement = 3% of regional load
  – non-spinning reserve requirements = 3% of regional load
  – regulation = 1% of regional load
  – Load following will be based on EIM study assumption

• Defined resources in WECC to provide reserves
  – CCs, CTs and dispatchable (above minimum) hydro; exclude baseload
  – Coal

• Represented Large Coal as more flexible
  – Jointly owned resources: Pmin = 70% of Pmax
  – Other large coal: Pmin=50% of Pmax

Note: Study work is in progress, results are not final and are subject to change
Study Group 5: CO2 Adder representation

- **CA**
  - CO2 adder in CA remained $36.60/Ston

- **WECC (except CA and BPA)**
  - Replace adder with hurdle rate
  - Hurdle rate = 0.435 MTons/Mwh * 36.3 $/STon * 1.102 (Ston/Mton) = $17.4 /Mwh

- **BPA**
  - 20% x $17.4/Mwh = $3.48/Mwh
  - Refer to ARB rules

Note: Study work is in progress, results are not final and are subject to change
Study Group 5: Changes to GHG and coal flexibility modeling observed increase capacity factor of external Coal resources.

Note: Study work is in progress, results are not final and are subject to change.
Study Group 5: Changes to GHG and coal flexibility modeling observed increase capacity factor of external Coal resources.

Note: Study work is in progress, results are not final and are subject to change.
Next Steps:

• Incorporate local capacity resources
• Assess alternatives for meeting residual needs
• Test underlying assumptions regarding

Note: Study work is in progress, results are not final and are subject to change
Next Steps: Incorporate LCR Study results

• Purpose:
  – Consider resources capacity needed to meet local reliability needs as a result of retirement of OTC
  – Determine residual flexibility needs

• Scope
  – Big Creek/Ventura – 430 MW
  – LA Basin – 2,370 MW
  – San Diego – 531 MW

• Plan
  – Cases are prepared with LCR resource capacity
  – February apply study process with LCR resources

Note: Study work is in progress, results are not final and are subject to change
Next Steps: Test operational robustness of underlying assumptions

• Perform additional analysis testing robustness of assumptions
  – Demand Response
  – Energy Efficiency
  – Load forecast
  – Outage / Maintenance rates
  – Import / Export limitations
  – Renewable online schedule

Note: Study work is in progress, results are not final and are subject to change
Next Steps: Develop method for studying alternative to meeting needs

• Purpose:
  – After consideration of local resources, if residual shortage needs are identified test different solutions for meeting residual needs:
    • Storage
    • Curtailment / dispatchable renewable
    • Reserve sharing
    • Different combinations of conventional resources
    • Dynamic transfers
    • Additional demand response
  – Assess feasibility of alternative solutions
  – Leverage EPRI/NREL work to the extent possible

Note: Study work is in progress, results are not final and are subject to change