Ascend Analytics

- Founded in 2002 with 50 employees in Boulder, Oakland and Bozeman
- Seven integrated software products for operations, portfolio analytics, and planning
- Consulting and custom analytical solutions

<table>
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<th>Proven and Broadly Adopted</th>
<th>Differentiated Value for Enhanced Decision Analysis</th>
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<td><strong>PowerSimm OPS</strong></td>
<td><strong>PowerSimm Portfolio Manager</strong></td>
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<tr>
<td>OPERATIONAL STRATEGY</td>
<td>PORTFOLIO MANAGEMENT</td>
</tr>
<tr>
<td>• Optimal short-term dispatch</td>
<td>• Portfolio management</td>
</tr>
<tr>
<td>• Determine operating strategies from position and financial exposure</td>
<td>• Generation asset management</td>
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<tr>
<td>• Track realized customer revenue and costs to settled day ahead and real time price</td>
<td>• Hydro and renewable asset modeling</td>
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<td>• Optimize financial exposure between day ahead and real time prices</td>
<td>• Retail management &amp; pricing</td>
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<td>• CFaR, GMaR, EaR</td>
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<td><strong>BatterySimm Operations</strong></td>
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<tr>
<td>STORAGE OPTIMIZATION</td>
<td>VALUATION &amp; PLANNING</td>
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<tr>
<td>• Optimal offers to ISO</td>
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<td>• Continuous adjust ISO offers</td>
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<td>• Forecast probabilities of price spikes</td>
<td>• Capacity Expansion Planning</td>
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<tr>
<td>• Renewables plus storage</td>
<td>• Reliability Analysis</td>
</tr>
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<td></td>
<td>• Renewable Integration</td>
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<td></td>
<td>• Long-term Price Forecasting</td>
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</table>

| **BatterySimm Valuation**   | **CurveDeveloper**                                |
| STORAGE VALUATION           |                                                   |
| • Optimal siting and sizing | • Complete set of forward curves and forecast curves for 30 years |
| • Captures realistic revenues given imperfect foresight | • ISO settlement data                              |
| • Battery cycle analysis    | • Incorporate broker projections                  |
Major Conclusions of the Study

➢ The model indicates a combination of our existing resources with renewables (for energy) paired with batteries and flexible gas (for integration and capacity) can provide reliable power at costs below the 45th Cooperative Finance Corporation (CFC) to NPPD & its customers.

➢ The blend between batteries and flexible gas depends on the assumptions with respect to the cost of battery storage and the effective load carrying capacity value of storage (i.e., its accredited capacity).

➢ Solar is the most cost-effective renewable resource, although this could change if the Production Tax Credit is extended indefinitely.

➢ The SPP market is changing rapidly with the addition of wind, solar, and soon battery resources combined with the retirement of older baseload resources, particularly coal and older gas units.

➢ These market changes portend declining average prices and lower market heat rates as well as increasing price volatility. These changing market dynamics put economic pressure on less flexible baseload generation to exit the market in favor of renewables and flexible capacity resources.

➢ This study specifically recognizes the “hidden” value of sub-hourly markets. This value is captured by flexible resources like batteries and flexible gas through sub-hourly market interactions. The value is expected to increase as more renewables come online and legacy baseload resources retire.
Ascend performed 12 optimizations according to differing assumptions about carbon limits and the state of the SPP market. In each run, the model favored retiring Cooper and GGS before the end of the existing wholesale contract. Ascend also modeled 5 additional sensitivities with hand-built portfolios.

- Moving GGS to seasonal operation during the summer peak season lengthens the useful life of GGS.
- The least-cost resource plan in all scenarios requires significant procurement of new resources before the end of the wholesale power contract.

NPPD would switch from a net exporter to a net importer from the wholesale market due to significantly declining average power prices in SPP.

The model does not find Carbon Capture, Utilization & Storage (CCUS) & small-modular nuclear reactors or relicensing Cooper to be cost-effective strategies without significant offsets from tax credits, carbon sale, etc.

If Ascend’s forecast of the cost of energy declining more in the low carbon scenarios is correct, then we find that decarbonization to approximately 90% carbon-free can be as cost-effective as the business-as-usual approach.

- Going from 90% to 100% carbon free is not recommended as the costs are significantly higher, equivalent to approximately $200/metric ton of CO₂ abated.
High Level Study Process

Define Assumptions

- Emissions limits
- Candidate resources
- SPP market evolution
- Power Prices
- Capacity value of renewables and batteries

Capacity Expansion Studies

- Allow model to optimize retirements and additions/conversion
- Define constraints (reserve margin, energy provision, GHG emissions, tech limitations)
- Develop sensitivity portfolios to test certain key decision points

Production Cost and Market Analysis

- Run resulting portfolios through economic dispatch
- Calculate annual costs and net present value, plus market price risk
Fundamental Anchors

Long-run equilibrium
Barriers to Entry
Stakeholder Demand
Meaningful Uncertainty

Policy and Macro Assumptions

Climate & RPS Policy
Load Growth
Market Forwards
Electrification
Technology Costs

Can be adjusted based on scenario assumptions

Buildout

Supply Stack
Interconnection Queue
Transmission

Price Formation

Load
Ramps
Power Flows
Renewable Generation
Curtailment
Marginal Unit
Weather

Outputs

Long-run on/off-peak forwards
Volatility
Price Shapes
RT Price Spikes
Capacity Prices
Ancillary Prices

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Price Depression as Renewable Penetrations Rise

- Price depression at high renewables penetration appears in both real-time and day-ahead markets
- Negative prices and renewable curtailment accelerate as renewables shares climb above ~25%, then rapidly accelerate at penetrations above 50%
- With large quantities of renewables in the queue, prices are expected to continue to decline as renewable penetrations rise

Zero Marginal Cost wind on the margin sets price to near zero
## Description of Cases

<table>
<thead>
<tr>
<th>Case</th>
<th>Description</th>
<th>SPP 2030/2050 GHG emissions rates in lbs/MWh</th>
<th>What would indicate that we are living in this Scenario?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Base</td>
<td>Freeze current market conditions, inclusive of known renewable projects in the next few years. This case serves as a benchmark to other cases with stricter carbon reductions.</td>
<td>800/600</td>
<td>Not expected to be a plausible forecast, as it assumes no advancement in clean energy technology or additional policy to drive emissions reductions</td>
</tr>
</tbody>
</table>
| A    | Roughly matches the Energy Information Agency’s projection for SPP in the 2020 Annual Energy Outlook (AEO) | 700/600 | • No new climate/clean energy policies  
• The advancement of renewable and energy storage technology is slow relative to current expectations  
• Slow retirement of existing baseload assets  
• 4-Hour Batteries largely retain capacity value |
| B    | 50% Carbon Reduction by 2030 and 80% reduction by 2050. | 700/300 | • Largely administrative led energy and climate policy by Biden administration. Strong state actions.   
• Renewable and energy storage cost performance meet or slightly exceed current expectations  
• Maintain or accelerate current rate of baseload retirements  
• No major breakthroughs in long-duration storage, small modular nuclear, or green hydrogen required  
• Capacity value of 4-hour batteries declines significantly |
| C    | Path to 100% carbon free | 650/0 | • Stringent climate legislation passed at the Federal and state levels  
• Significant technological advancement in long-duration storage technology and green hydrogen  
• Sharp decline in the capacity value of 4-hour batteries |
Base Case Results – Bar Chart

Replacing GGS with flexible resources and renewables before the end of the wholesale contract is slightly lower than other portfolios.

In base 4, Cooper is retired before the end of the wholesale contract but GGS operates until 2035.

Base 0: Keeping GGS through 2035 and and Cooper through the end of its operating license is the highest cost portfolio.

Sheldon is converted to natural gas in all portfolios before the end of the wholesale contract.
B1a relies mostly on solar, storage, and a small amount of flexible gas to replace GGS and Cooper before the end of the wholesale contract.

Adding CCUS is the most expensive option in A&B cases.

Using GGS seasonally (i.e. in the summer) is a good strategy to maximize its usefulness.

Sheldon retires or is converted to natural gas in all portfolios before the end of the wholesale contract.
The C1 series primarily rely on solar and flexible gas as replacement resources. C1b uses seasonal generation at GGS to extend the lifespan.

C1a and C1aR, which use Combustion Turbines versus RICE units, are functionally equivalent in value.

Sheldonretires or is converted to natural gas in all portfolios before the end of the wholesale contract.

Relicensing Cooper (C4) is far and away the most expensive option to drive towards zero emissions.

Getting the “last mile” to 100% clean without offsets is expensive. Green hydrogen is least cost, followed by adding long-duration storage and then Cooper relicense.
## Results

- Resource plans for CO2 Cases A & B are very close to the same due to the similar market prices assumptions.
- Going to 100% carbon free, with no carbon offsets, is significantly more expensive than using lower cost offsets.

<table>
<thead>
<tr>
<th>CO2 Case</th>
<th>Description</th>
<th>NPV ($billion) 2021 – 2050</th>
<th>New Resources in 2035 (Nameplate MW)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Solar</td>
</tr>
<tr>
<td>Base</td>
<td>No carbon constraints</td>
<td>$11.5 – 12.2</td>
<td>1,600 - 1,900</td>
</tr>
<tr>
<td>Case A &amp; B</td>
<td>Case A - Approx. same as projections based on EIA</td>
<td>$11.4 – 12.6</td>
<td>1,500 – 3,000</td>
</tr>
<tr>
<td>Case B</td>
<td>Case B - 50% Carbon Reduction by 2030 and 80% reduction by 2050.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Case C</td>
<td>Path to 100% carbon free 0% Offsets</td>
<td>$13.8 – 17.1</td>
<td>2,600</td>
</tr>
<tr>
<td>Case C</td>
<td>Path to 100% carbon free using lower cost offsets</td>
<td>$11.8 – 13.1</td>
<td>1,600 – 2,200</td>
</tr>
</tbody>
</table>

**Signpost:** The effective load carrying capacity of batteries Watch how SPP forecasts the ELCC of battery storage. If the ELCC drops like it does in Scenario C, more flexible gas should be added to the portfolio.
Carbon Dioxide Emissions (lbs/MWh)

**Key Take-Aways**

- NPPD Carbon Intensity in 2005 was approximately 1,650 lbs/MWh
- 2017/18 Average carbon intensity was 1,100 lbs/MWh
- All resource portfolios were at or below the carbon intensity limits for each Carbon Case.
- Business as usual carbon intensity for most years was 1,000 – 1100 lbs/MWh
- “A” cases are 600 lbs/MWh by 2030, dropping to 500 lbs/MWh by 2050.
- “B” cases are 600 lbs/MWh by 2030, dropping to 330 lbs/MWh by 2050.
- “C” cases all drive to zero, with some assuming approximately 10% of emissions reductions coming through carbon offsets in other sectors.
Net Energy Position

Key Take-Aways

• NPPD typically becomes a net annual purchaser of energy when our existing baseload generation retires.
  o NPPD is typically buying the maximum amount allowable by the model.
  o The maximum amount is 50% of native load energy

• Market purchases are generally the least-cost energy as renewables flood the SPP system, even in the base case
Mapping all portfolios with cost and risk

Net Present Value of Cost Versus Risk
All Portfolios All Years

Key Take-Aways

• Most portfolios cluster in similar area of total portfolio cost.

• Forcing a 100% clean portfolio drives up costs significantly. However, getting to 93% clean with 7% offsets (C1a and C1b) is competitive with higher emitting portfolios.

• Price risk from fuel and market price volatility are all small relative to expected value (<5%).

• Most portfolios show similar risk characteristics. Base 1 has more exposure to gas price risk.

• This doesn’t encompass all risks. For example, capital cost risk is not included in risk value.

Key concept for understanding:
The SPP market prices are lower for greener scenarios. Therefore, costs to serve load are lower as NPPD primarily buys market power.

Adding long-duration storage and/or hydrogen drives up costs

Relicensing Cooper is by far the most expensive path

Least-cost, least risk

Least-cost, least risk
Understanding Changes in Dispatch: Base 0, July 10 - 16

2030: Long energy and capacity, with CNS and GGS as primary resources

2050: Baseload resources replaced with solar, storage, and gas. Primarily purchasing from market at night. Serving most load with solar during the day. Batteries arbitrage from mid-day to early evening.
## 45th CFC metric comparisons

### Base Case

<table>
<thead>
<tr>
<th>Portfolio</th>
<th>Metric Score</th>
<th>Reason</th>
</tr>
</thead>
<tbody>
<tr>
<td>Base 0</td>
<td>Yellow</td>
<td>Exceeds metric in 2032</td>
</tr>
<tr>
<td>Base 1</td>
<td>Green</td>
<td>Does not exceed metric</td>
</tr>
<tr>
<td>Base 2</td>
<td>Green</td>
<td>Does not exceed metric</td>
</tr>
<tr>
<td>Base 3</td>
<td>Yellow</td>
<td>Nearly exceeds metric</td>
</tr>
<tr>
<td>Base 4</td>
<td>Green</td>
<td>Does not exceed metric</td>
</tr>
<tr>
<td>Base 5</td>
<td>Green</td>
<td>Does not exceed metric</td>
</tr>
</tbody>
</table>

### A & B Cases

<table>
<thead>
<tr>
<th>Portfolio</th>
<th>Metric Score</th>
<th>Reason</th>
</tr>
</thead>
<tbody>
<tr>
<td>A1</td>
<td>Green</td>
<td>Does not exceed metric</td>
</tr>
<tr>
<td>B1a</td>
<td>Green</td>
<td>Does not exceed metric</td>
</tr>
<tr>
<td>B1b</td>
<td>Green</td>
<td>Does not exceed metric</td>
</tr>
<tr>
<td>B2</td>
<td>Yellow</td>
<td>Nearly exceeds metric</td>
</tr>
</tbody>
</table>
45th CFC metric comparisons – Carbon Case C

<table>
<thead>
<tr>
<th>Portfolio</th>
<th>Metric Score</th>
<th>Reason</th>
</tr>
</thead>
<tbody>
<tr>
<td>C1a/r</td>
<td>Green</td>
<td>Does not exceed metric</td>
</tr>
<tr>
<td>C1b</td>
<td>Green</td>
<td>Does not exceed metric</td>
</tr>
<tr>
<td>C2</td>
<td>Red</td>
<td>Exceeds metric</td>
</tr>
<tr>
<td>C3</td>
<td>Red</td>
<td>Exceeds metric</td>
</tr>
<tr>
<td>C4</td>
<td>Red</td>
<td>Exceeds metric</td>
</tr>
<tr>
<td>C5</td>
<td>Yellow</td>
<td>Nearly exceeds metric</td>
</tr>
</tbody>
</table>

- Optimized portfolios that allow up to 7% carbon emissions offsets remain under the CFC metric
- Portfolios that drive to absolute zero emissions exceed the metric.
- Achieving the “last mile” of emissions to get to zero costs about $200/metric ton, about 5 – 10x the cost of equivalent emissions reductions in other sectors such as soil carbon sequestration, high GWP potential gas destruction, transportation electrification, etc.
Ensuring ongoing reliability

<table>
<thead>
<tr>
<th>Portfolio</th>
<th>Percent of ELCC adjusted peak capacity with limited duration</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Base 0</td>
<td>47%</td>
<td>Green</td>
</tr>
<tr>
<td>Base 1</td>
<td>12%</td>
<td>Green</td>
</tr>
<tr>
<td>Base 2</td>
<td>74%</td>
<td>Yellow</td>
</tr>
<tr>
<td>Base 3</td>
<td>74%</td>
<td>Yellow</td>
</tr>
<tr>
<td>Base 4</td>
<td>47%</td>
<td>Green</td>
</tr>
<tr>
<td>Base 5</td>
<td>67%</td>
<td>Yellow</td>
</tr>
<tr>
<td>A1</td>
<td>66%</td>
<td>Yellow</td>
</tr>
<tr>
<td>B1a</td>
<td>67%</td>
<td>Yellow</td>
</tr>
<tr>
<td>B1b</td>
<td>82%</td>
<td>Red</td>
</tr>
<tr>
<td>B2</td>
<td>45%</td>
<td>Green</td>
</tr>
<tr>
<td>C1a</td>
<td>27%</td>
<td>Green</td>
</tr>
<tr>
<td>C1aR</td>
<td>26%</td>
<td>Green</td>
</tr>
<tr>
<td>C1b</td>
<td>15%</td>
<td>Green</td>
</tr>
<tr>
<td>C2</td>
<td>67%</td>
<td>Yellow</td>
</tr>
<tr>
<td>C3</td>
<td>74%</td>
<td>Yellow</td>
</tr>
<tr>
<td>C4</td>
<td>59%</td>
<td>Yellow</td>
</tr>
<tr>
<td>C5</td>
<td>60%</td>
<td>Yellow</td>
</tr>
</tbody>
</table>

- All portfolios meet reserve margin per SPP rules, therefore all portfolios would be considered contributing to SPP’s reliability requirements.
- This metric is scored based on the amount of ELCC adjusted capacity in the portfolio that is duration limited, including batteries, renewables and demand response.
- Less than 50% duration limited is green, less than 75% is yellow, more than 75% is red.
Planning for extreme events

- Understanding the difference between resource adequacy and resiliency
  - Resource adequacy is making sure enough electric generation capacity is available to meet demand most of the time.
    - Having a 100% resource adequate system would be too expensive.
  - Resiliency is making sure power systems are adequately hardened for extreme weather events.
    - Insulation, de-icing procedures, dual-fuel, redundancy in transmission and distribution systems, undergrounding, etc.

- Resource planning should consider extreme “black swan” events but should not necessarily plan to build a system to be able to withstand them. Cost over the long-run must be weighed.
  - Robust power systems have a diversity of resources in a wide footprint.
  - Diversity = both supply side and demand side options, technology diversity, fuel diversity, and geographic diversity.
  - Distributed systems are more resilient than large concentrated systems.
Stranded Debt & Post 2035 Production Obligations

Key Take-Aways

- Most of the existing resources’ debt is retired by 2035
- There is a significant amount of debt and contractual obligations post 2035 for all CO₂ reduction scenarios
  - Debt is either new debt on existing resources or new thermal and battery resources
  - Contractual obligations (power purchase agreements) are solar & wind resource additions
- In the Base case there is $2.8 - $4 billion in debt and obligations remaining after 2035.
  - In Cases A & B, these costs are estimated to be $0.1 - $0.7 billion higher
  - In Case C, these costs are estimated to be $0.8 - $1.1 billion higher

The Bottom line
Given our projections of the future make up of the electric grid, the economics suggest NPPD should make significant new investments in renewable energy and flexible resources for integration and reliability. This transformation requires a long-term commitment from the wholesale customers to be feasible.
Declining Power Prices

Track the average implied heat rates (power price divided by natural gas price) and see if they continue to decline as we expect. This decline should roughly track how much renewable energy is added to the system. As solar is added, a “duck” shape will develop. This indicates larger and less flexible resources will be economically challenged relative to flexible resources.

Increasing price volatility and the “hidden” value of sub-hourly markets

Prices are expected to become more volatile. This shows a market need for more flexible resources such as batteries and flexible gas to capture the value, particularly in the real-time energy market. Sub-hourly value becomes more important as time goes on, a concept which can be tested and tracked, especially if NPPD procures a battery resource.

The capacity value of duration-limited resources such as solar and storage

The understanding of the capacity value of duration limited resources such as renewables and batteries continues to evolve, and the way SPP accredits these resources will change over time. Given what we know today, a system of mostly renewables balanced by storage and a small amount of flexible gas can be reliable.

The cost of storage

Our analysis uses a point forecast for the declining cost of battery storage. Costs above or below our expectation should drive actual procurement decisions in the future.

The Production Tax Credit for wind

The new Stimulus Act includes a 1-year extension of the PTC for wind. While we model a sunset of the PTC, history suggests that the credit will continue to be renewed. If this happens, wind should be more economic relative to solar and the split between solar and wind deployment would be more balanced than what we show.
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