Ascend Analytics

Better models. Better decisions.

Low CO_2 Study

Presentation for NPPD Board Retreat

March 10th, 2021

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

Proven and Broadly Adopted

Differentiated Value for Enhanced Decision Analysis

PowerSimm OPS
OPERATIONAL STRATEGY

- Optimal short-term dispatch
- Determine operating strategies from position and financial exposure
- Track realized customer revenue and costs to settled day ahead and real time price
- Optimize financial exposure between day ahead and real time prices

PowerSimm Portfolio Manager
PORTFOLIO MANAGEMENT

- Portfolio management
- Generation asset management
- Hydro and renewable asset modeling
- Retail management & pricing
- Energy purchases and sales
- CFaR, GMaR, EaR

PowerSimm Planner
VALUATION & PLANNING

- Asset valuation
- Resource Planning
- Capacity Expansion Planning
- Reliability Analysis
- Renewable Integration
- Long-term Price Forecasting

BatterySimm Operations
STORAGE OPTIMIZATION

- Optimal offers to ISO
- Continuous adjust ISO offers
- Forecast probabilities of price spikes
- Renewables plus storage

BatterySimm Valuation
STORAGE VALUATION

- Optimal siting and sizing
- Captures realistic revenues given imperfect foresight
- Battery cycle analysis

CurveDeveloper

- Complete set of forward curves and forecast curves for 30 years
- ISO settlement data
- 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.**

Major Conclusions Continued

- 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 CO_2 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 Forecasting Framework

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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*

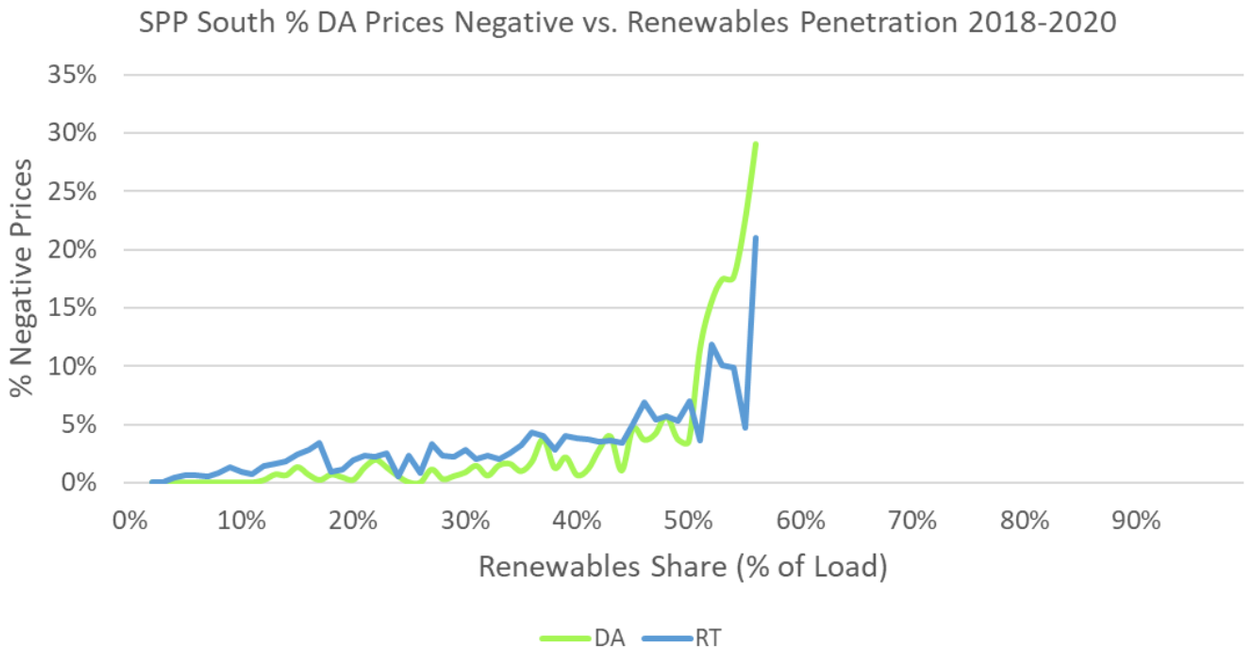
Outputs

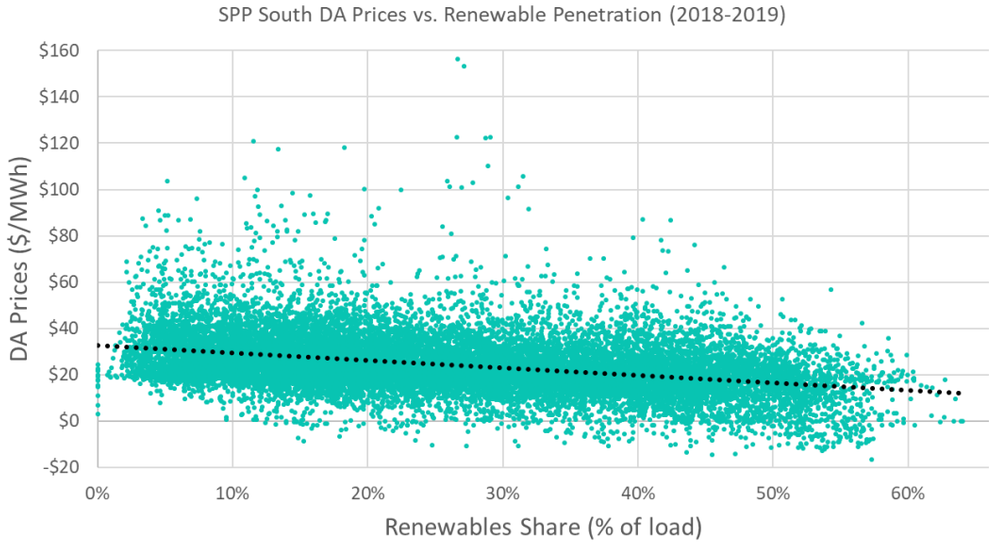
- Long-run on/off-peak forwards
- Volatility
- Price Shapes
- RT Price Spikes
- Capacity Prices
- Ancillary Prices

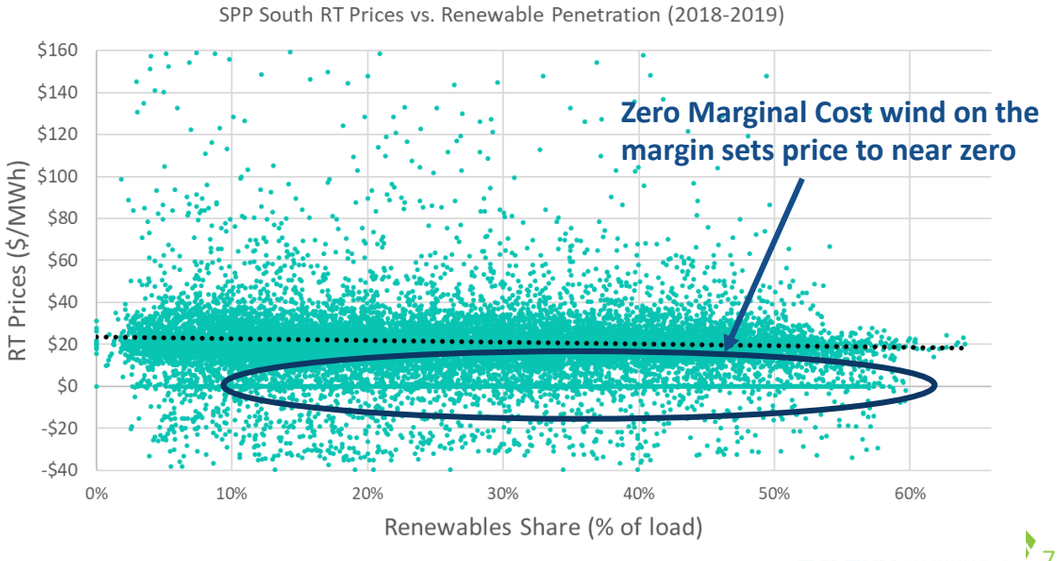
Fundamental Anchors

- Alignment with Markets
- Long-run equilibrium
- Barriers to Entry
- Stakeholder Demand
- Meaningful Uncertainty

Price Depression as Renewable Penetrations Rise







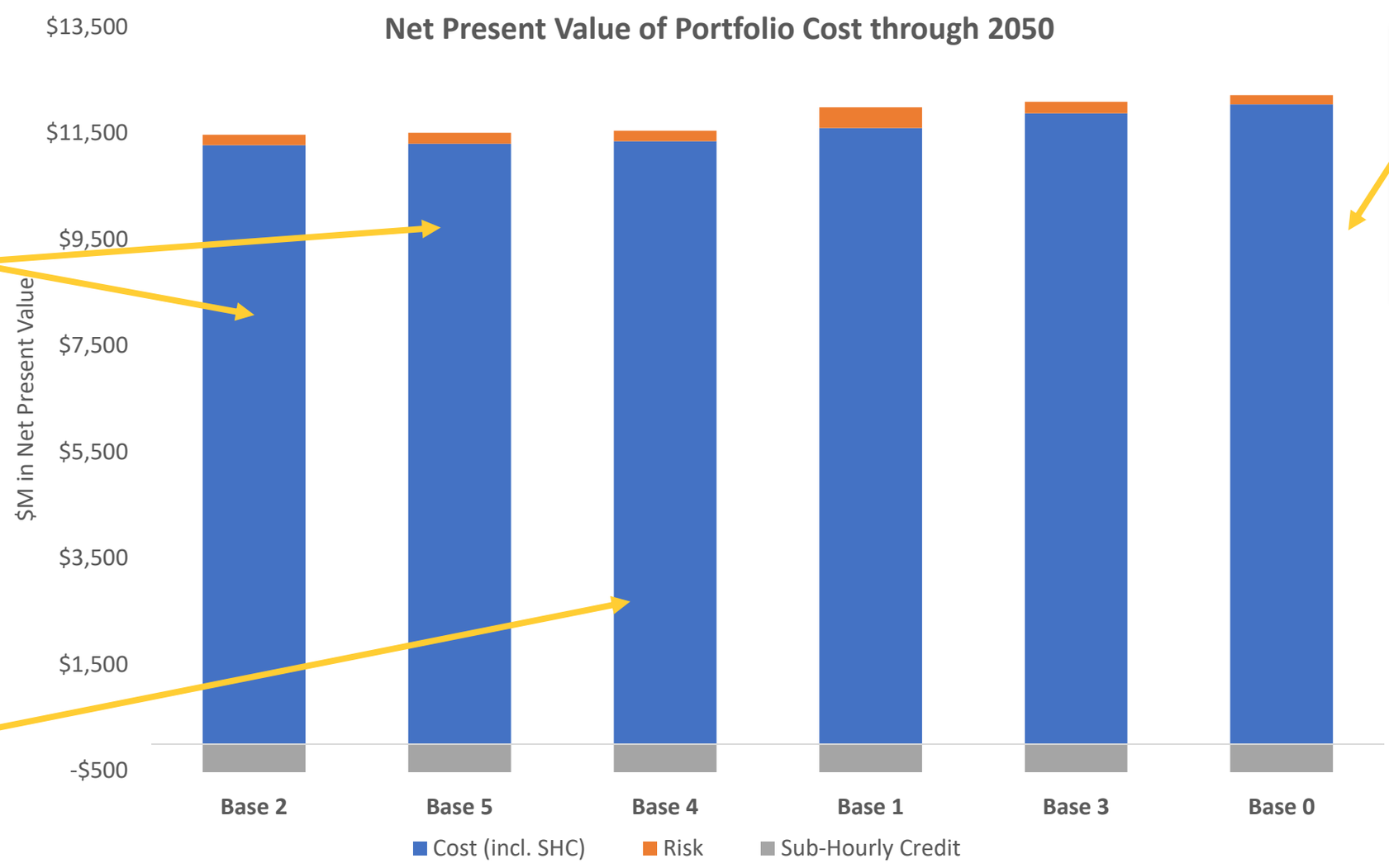
- Price depression at high renewables penetration appears in both real-time and day-ahead markets
- Negative prices and renewable curtailment accelerate as renewables shares climb above ~25%, then rapidly accelerate at penetrations above 50%
- With large quantities of renewables in the queue, prices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

Description of Cases

Case	Description	SPP 2030/2050 GHG emissions rates in lbs/MWh	What would indicate that we are living in this Scenario?
Base	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.	800/600	Not expected to be a plausible forecast, as it assumes no advancement in clean energy technology or additional policy to drive emissions reductions
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.



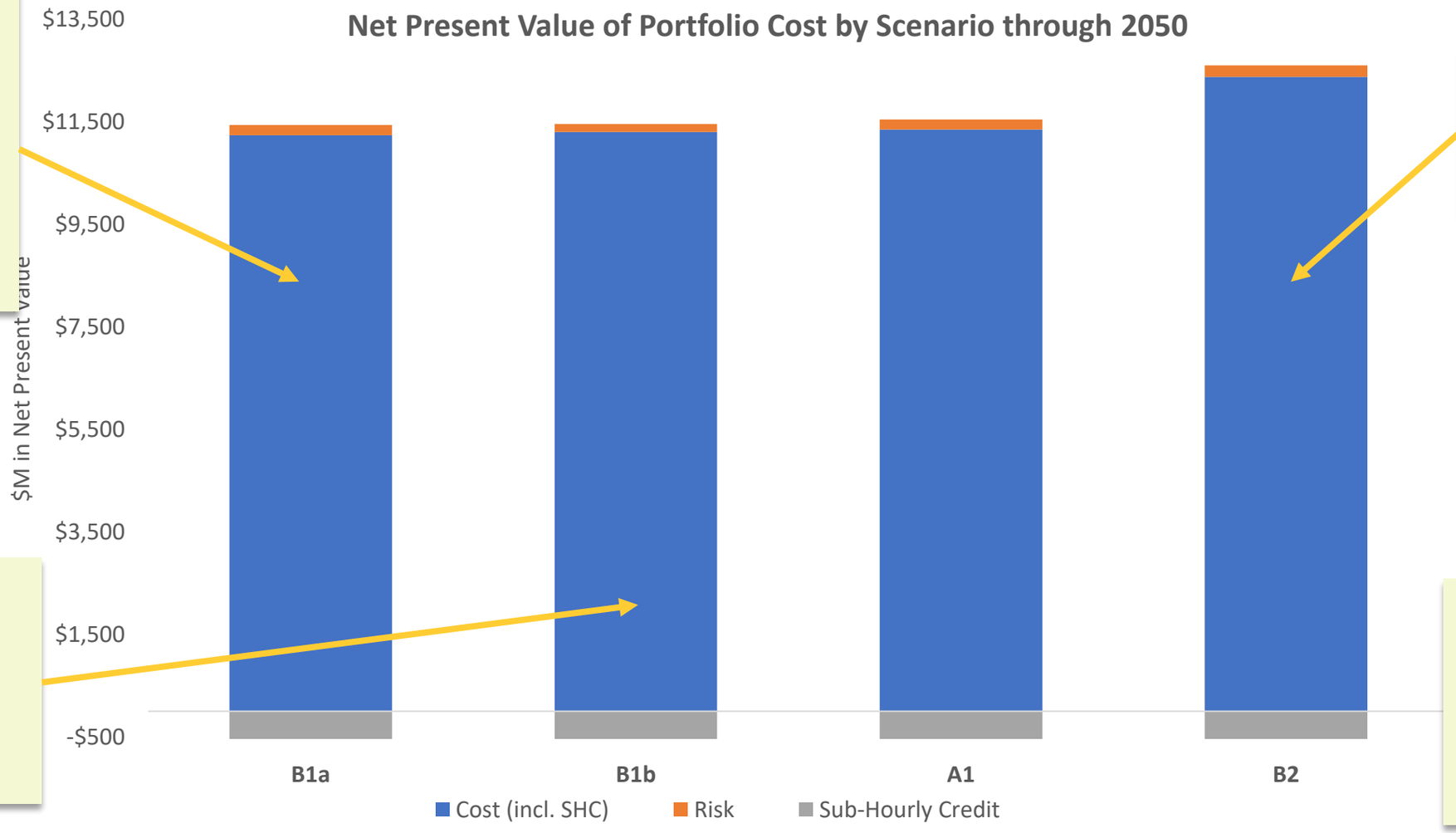
Base 0: Keeping GGS through 2035 and and Cooper through the end of its operating license is the highest cost portfolio

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

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

A & B Case Results – Bar Chart

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

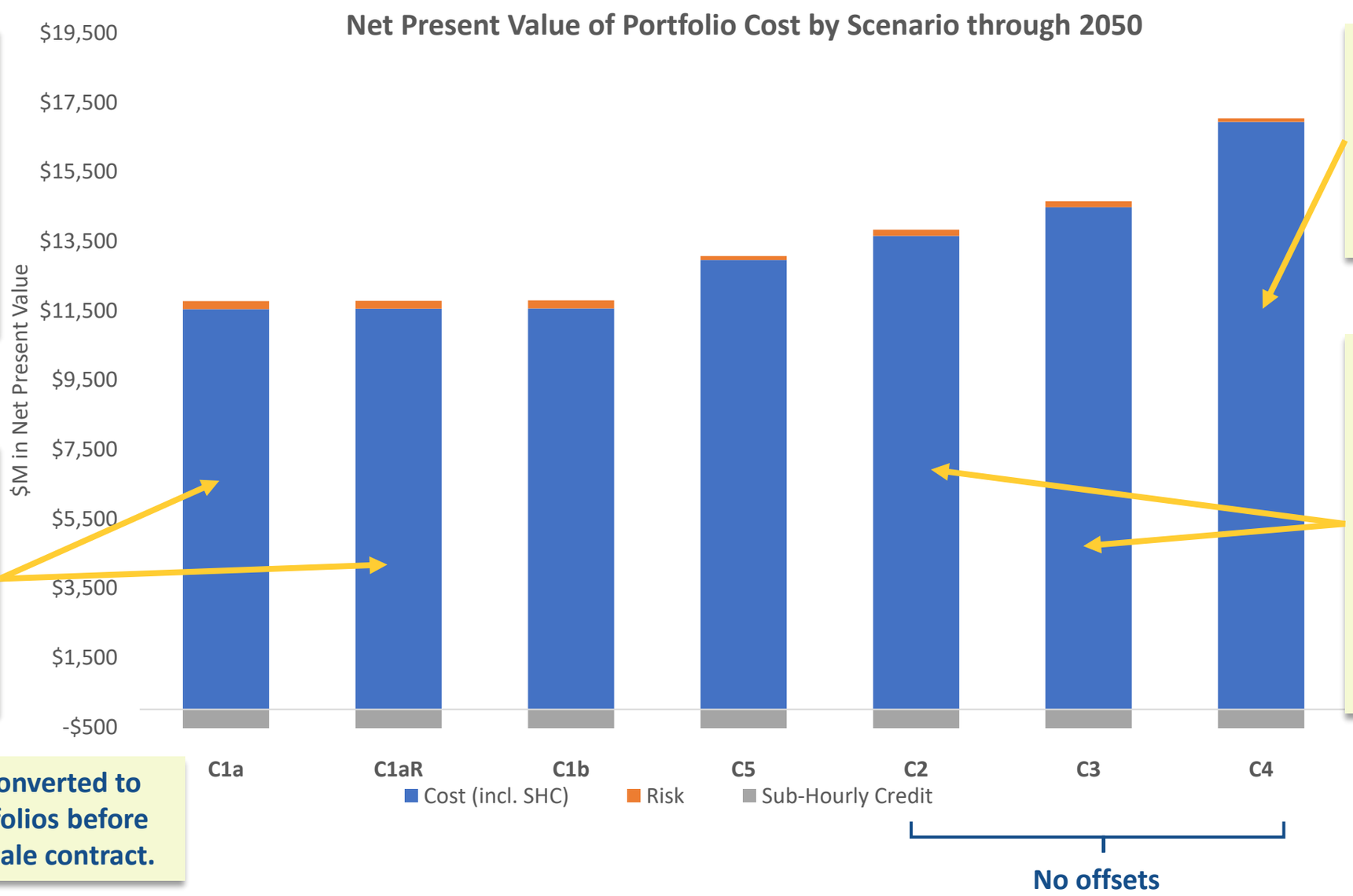
Sheldon retires or is converted to natural gas in all portfolios before the end of the wholesale contract.

C Case Results – Bar Chart

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.

Sheldon retires 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

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.

CO2 Case	Description	NPV ($billion) 2021 – 2050	New Resources in 2035 (Nameplate MW)			
			Solar	Wind	4-hr Battery	Flex Gas
Base	No carbon constraints	$11.5 – 12.2	1,600 - 1,900	200	0 - 1,700	0 – 1,700
Case A & B	Case A - Approx. same as projections based on EIA Case B - 50% Carbon Reduction by 2030 and 80% reduction by 2050.	$11.4 – 12.6	1,500 – 3,000	200	900 - 1,900	0 - 200
Case C	Path to 100% carbon free 0% Offsets	$13.8 – 17.1	2,600	200	1,500 – 2,500	200 - 460
Case C	Path to 100% carbon free using lower cost offsets	$11.8 – 13.1	1,600 – 2,200	200	100 – 2,400	200 – 1,900

Carbon Dioxide Emissions (lbs/MWh)

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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

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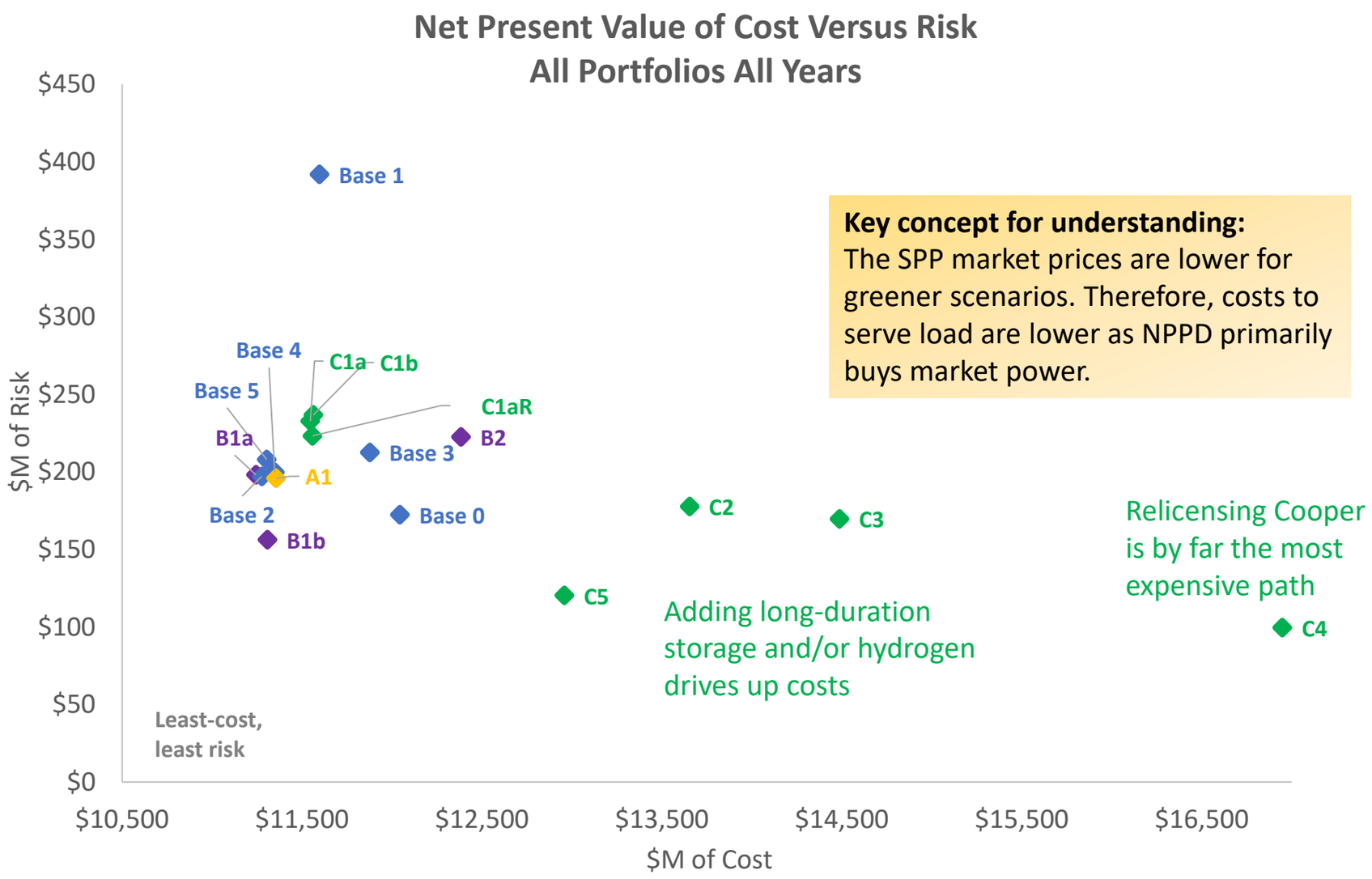
Key Take-Aways

- NPPD typically becomes a net annual purchaser of energy when our existing baseload generation retires.
  - NPPD is typically buying the maximum amount allowable by the model.
  - 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



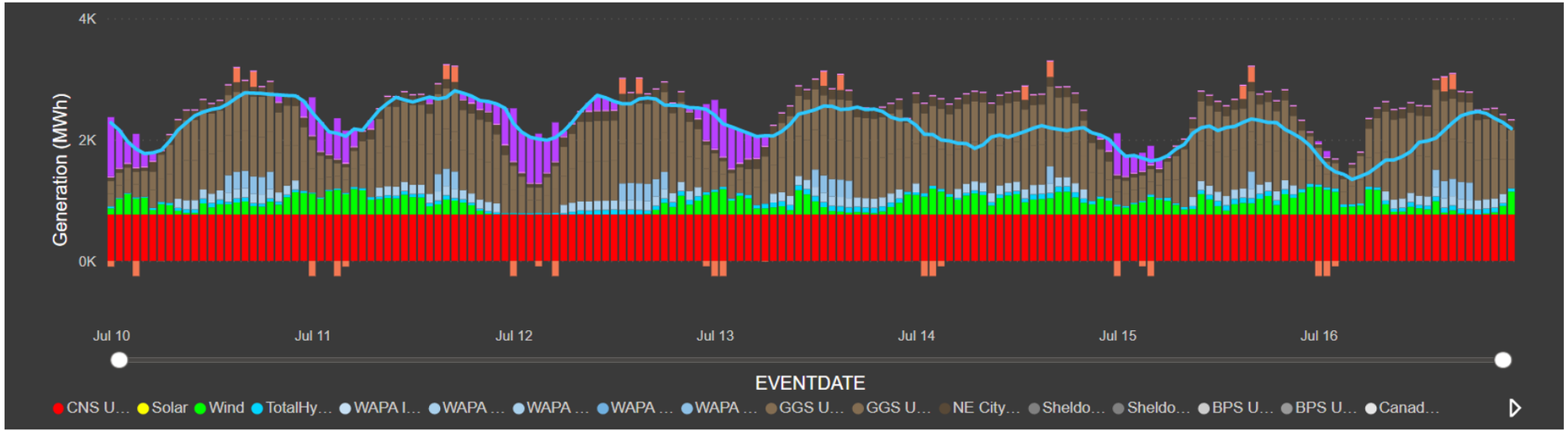
Key concept for understanding:
The SPP market prices are lower for greener scenarios. Therefore, costs to serve load are lower as NPPD primarily buys market power.

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.**

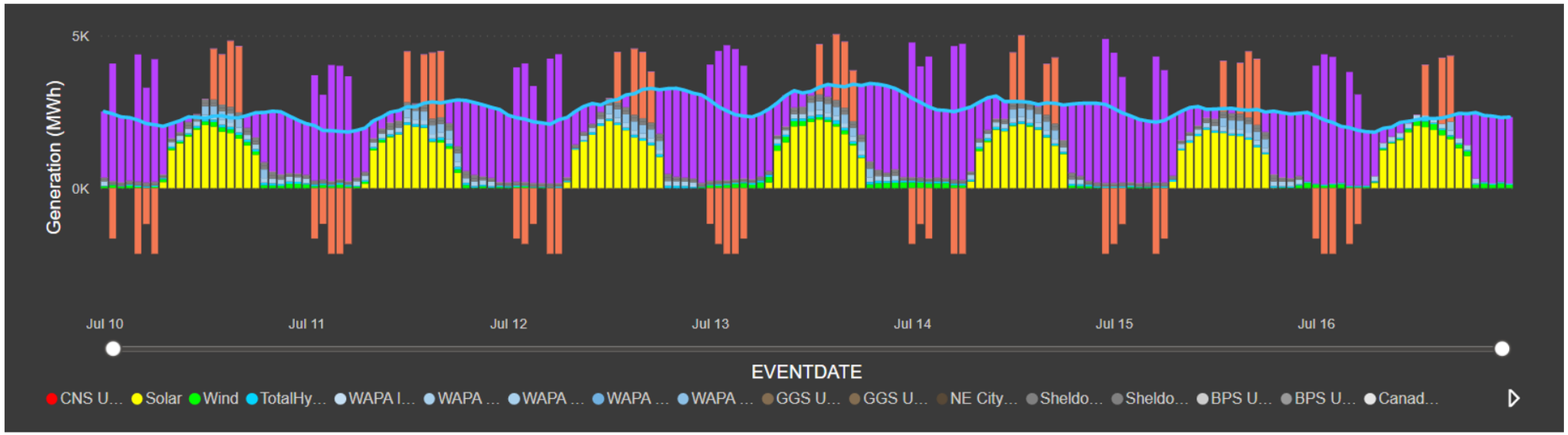
Understanding Changes in Dispatch: Base 0, July 10 - 16

2030



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

2050



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

Portfolio	Metric Score	Reason
Base 0	Yellow	Exceeds metric in 2032
Base 1	Green	Does not exceed metric
Base 2	Green	Does not exceed metric
Base 3	Yellow	Nearly exceeds metric
Base 4	Green	Does not exceed metric
Base 5	Green	Does not exceed metric

A & B Cases

Portfolio	Metric Score	Reason
A1	Green	Does not exceed metric
B1a	Green	Does not exceed metric
B1b	Green	Does not exceed metric
B2	Yellow	Nearly exceeds metric

45th CFC metric comparisons – Carbon Case C

Portfolio	Metric Score	Reason
C1a/r	Green	Does not exceed metric
C1b	Green	Does not exceed metric
C2	Red	Exceeds metric
C3	Red	Exceeds metric
C4	Red	Exceeds metric
C5	Yellow	Nearly exceeds metric

- 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.

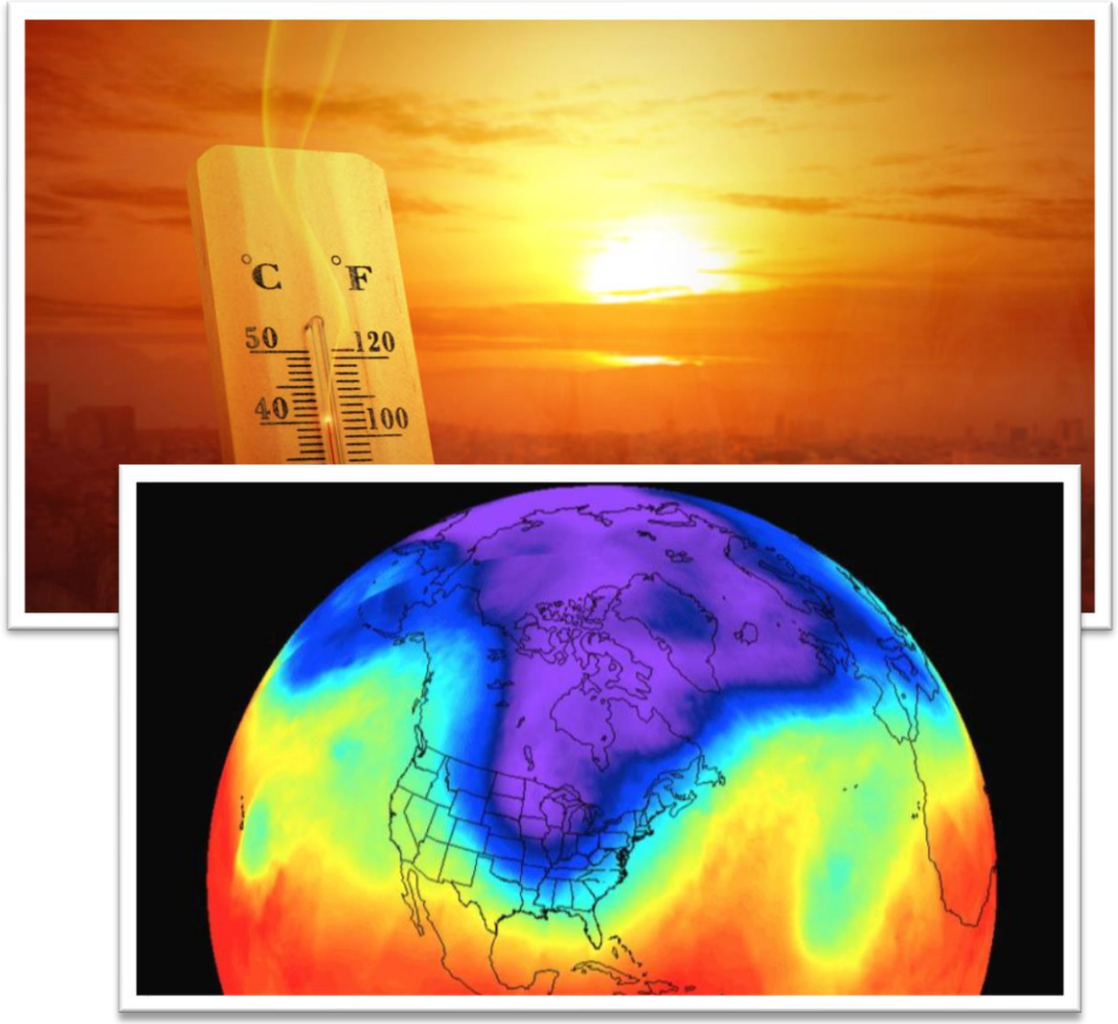
Ensuring ongoing reliability

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

- 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 <u>most</u> 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

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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 CO_2 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.

Signpost Summary

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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