BPA’s 2024 Resource Program

Planning and Development

Public Workshop

June 1, 2023

Agenda

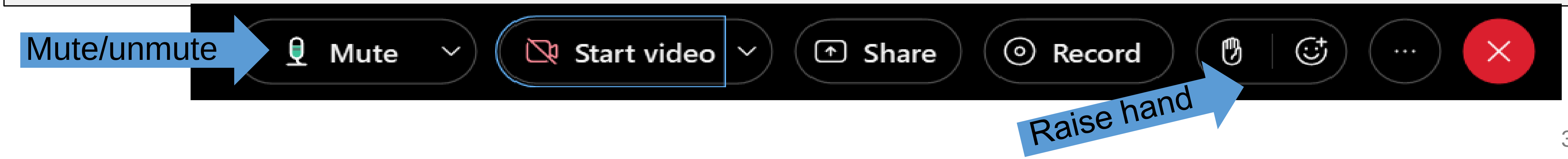
Time Start	Time End	Topic	Presenter(s)
9 a.m.	9:05 a.m.	Intro and Expectations	Brian Dombeck
9:05 a.m.	9:30 a.m.	Power Planning at BPA	Ryan Egerdahl
9:30 a.m.	10:00 a.m.	Mechanics of Identifying Resource Solutions	Eric Graessley
10:00 a.m.	10:15 a.m.	B R E A K	
10:15 a.m.	11:10 a.m.	RP24 Scenarios and Sensitivities	Adela Arguello Eric Graessley Hanna Lee Erin Riley
11:00 a.m.	11:15 a.m.	B R E A K	
11:15 a.m.	11:55 a.m.	Public Discussion and Q&A	All
11:55 a.m.	12 p.m.	Wrap Up	Brian Dombeck

Format

- Presenters will take pauses for questions.
- Questions will be addressed in the order received.
- Please state your name and organization.
- If a question/opportunity for feedback arises during a presentation, please:
  - Webex: Write it in the Webex Q&A or raise your Webex hand; when called on, mute/unmute yourself.

Note: The "Chat" feature in Webex has been disabled for this meeting. Please type Questions in the "Q&A" box or raise your hand to be recognized.

Webex:



Workshop Roles & Expectations

Bonneville: Provide open and inclusive opportunities for feedback.

Participants: Provide feedback and share perspectives.

All: Respect one another and assume good intentions.

Bring a constructive mentality.

BPA Power Planning Overview

Power Planning at BPA

- Each year, BPA publishes the Pacific Northwest Loads and Resources Study – often referred to as the **White Book** - which analyzes BPA's projections of retail loads, contract obligations, contract purchases, and resource capabilities over a 10-year study horizon and describes expected energy and capacity deficits under varying water conditions.

- On a biennial basis, long-term power planners in BPA Power services conduct an IRP-like assessment collectively referred to as the **Resource Program** which examines uncertainty in loads, water supply, natural gas prices, and electricity market prices to develop a least-cost portfolio of resources that meet BPA's obligations.

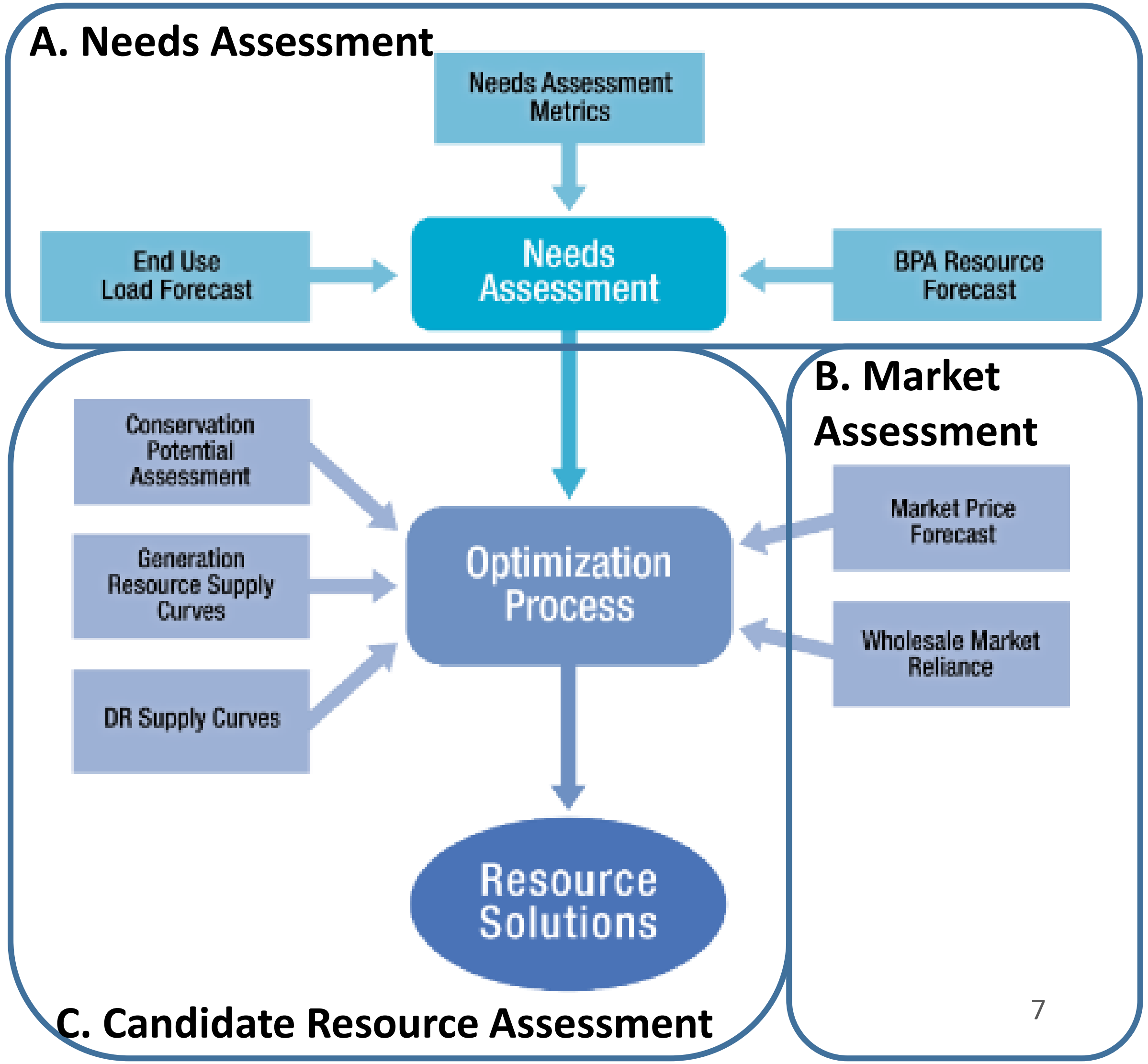
- These processes are voluntarily undertaken to inform acquisition strategies and provide valuable insight into how Bonneville can meet its obligations and strategic objectives cost-effectively. <u>They are neither decision documents nor a process required by any external entity.</u>

BPA Resource Program Process Map

A. The **Needs Assessment** measures the federal system's expected generating resource capabilities to meet projected load obligations and produces a set of metrics which characterize the expected surplus/deficit of the existing system over the study period.

B. The **Market Assessment** simulates the evolution of power markets in the Western Interconnect to generate a long-term forecast of Mid-Columbia prices and market availability under a variety of generation, load, and economic conditions

C. The **Candidate Resource Assessment** explores how the varying costs, performance, and availability of candidate demand-and-supply-side resources (including conservation, demand response, market purchases, and generating resources) can be used to provide a least-cost resource strategy for meeting identified needs



Key Findings of the 2022 Resource Program

- The **Needs Assessment** found that over the 10-year study period of FY24-33 the federal system was projected to have HLH energy deficits, most notably in the winter and late summer, and to have surpluses under the Super-Peak and the 18-Hour Capacity metrics with the P10 HLH metric deficits representing the most constrained periods and conditions for BPA to meet its obligations.

- The **Market Assessment** found that prices were expected to exhibit significant volatility over time, including relatively tight market conditions in key summer/winter months and a high-likelihood of negative average prices in the spring

- Least-cost resource strategies identified in the **Candidate Resource Assessment** relied primarily on conservation, demand response, and market purchases to fill expected system needs, with renewables showing up in costlier, volatility-reducing portfolios
  - **Conservation Potential Assessment** (CPA) and **Demand Response Potential Assessment** (DRPA) produced by external consultants and relied on supply curves developed and used by the Northwest Power and Conservation Council (NWPCC) in its 2021 Power Plan
  - Cost and performance characteristics of candidate supply-side resources developed from external information in conjunction with SME judgment
  - Market expected to have adequate availability to fill needs over most of study horizon, with notable exceptions emerging in October months later in the study.

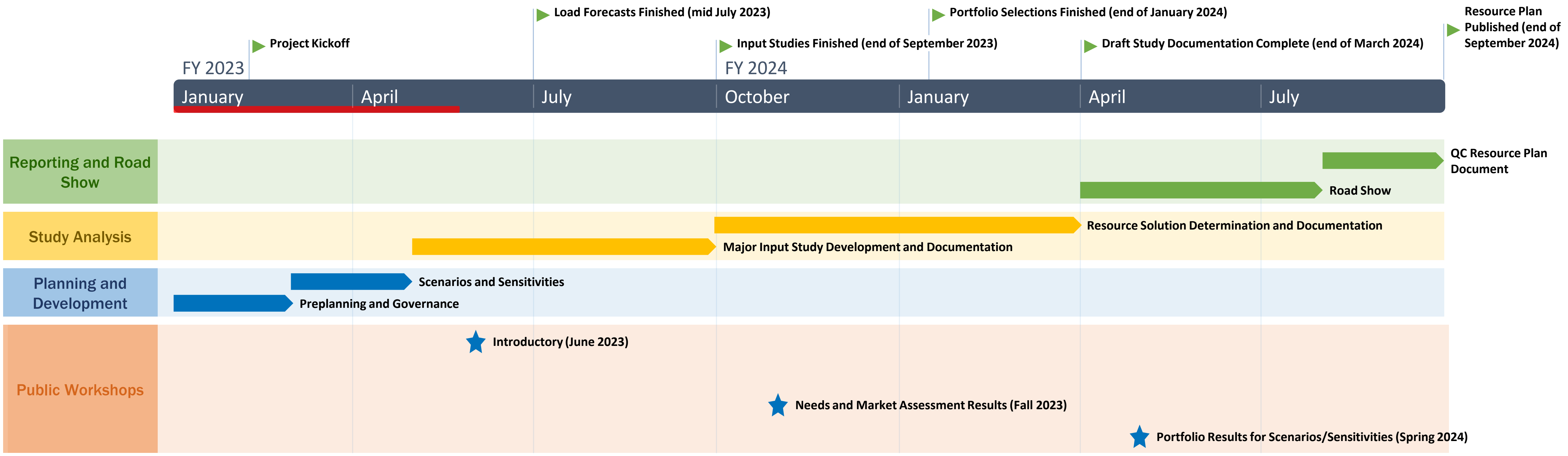
For RP24, a Complex Planning Environment

- New long-term power contracts (2028)
- Regional and national clean energy policies
- Supply chain challenges
- Emergent technologies, markets, and programs

Planning Approach to 2024 Resource Program

- Maintain emphasis on examining how various uncertainties influence identified least-cost resource solutions
- Expand analysis to include limited topological considerations to further align BPA power planning with the Western Power Pool's (WPP) Western Resource Adequacy Program (WRAP)
- Replace Aurora portfolio optimization methodology with new solver developed by BPA specifically for the Resource Program in determining least-cost resource strategy for meeting identified needs
- Two scenarios:
  - Base case
  - Accelerated clean energy transition (Fast Transition)
- Sensitivity Analyses (more details later in presentation)
  - Stress system loads and generating resources
  - Costs and availability of candidate resources
  - Prices and ability to rely on wholesale power market

2024 Resource Program Timeline



*For illustrative purposes only. All dates tentative and subject to change

Resource Program Connection to Provider of Choice

To help inform BPA customer contract elections:

- Provides valuable insight into potential BPA resource portfolio sizes, costs, and compositions;

- Evaluates the implied fuel mix and carbon content of BPA system;

Resource Program Connection to NWPCC Planning

- Council’s Power Plan

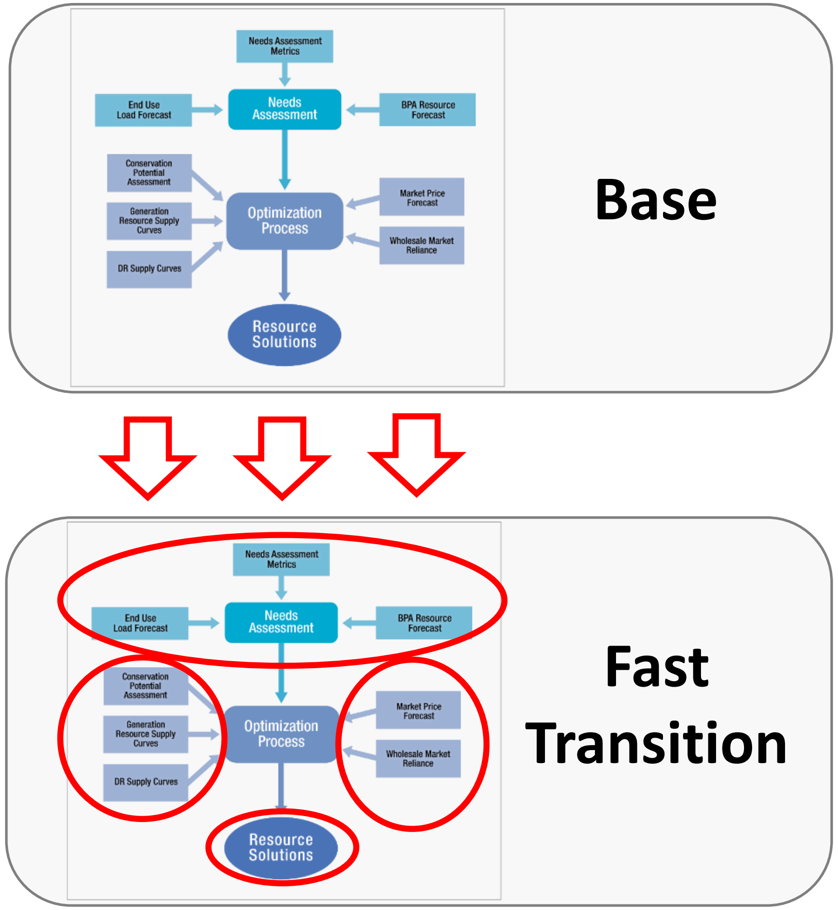
- Conservation and 6(b) of the 1980 Northwest Power Act (NWPA)
  - BPA Energy Efficiency Action Plan (EEAP)

- “Major resources” and 6(c) of the 1980 NWPA
  - Planned capability greater than 50 aMW acquired for period of more than 5 years

RP24 Planning Framework

Scenarios

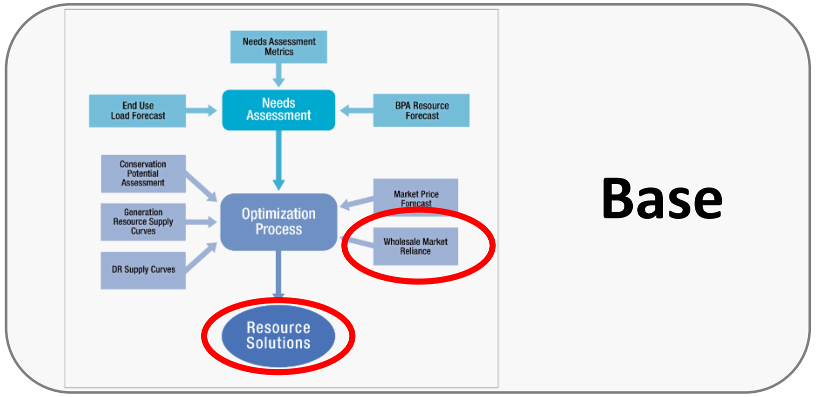
Scenarios are comprised of a set of inputs that are consistently developed for a future outlook.



Sensitivities

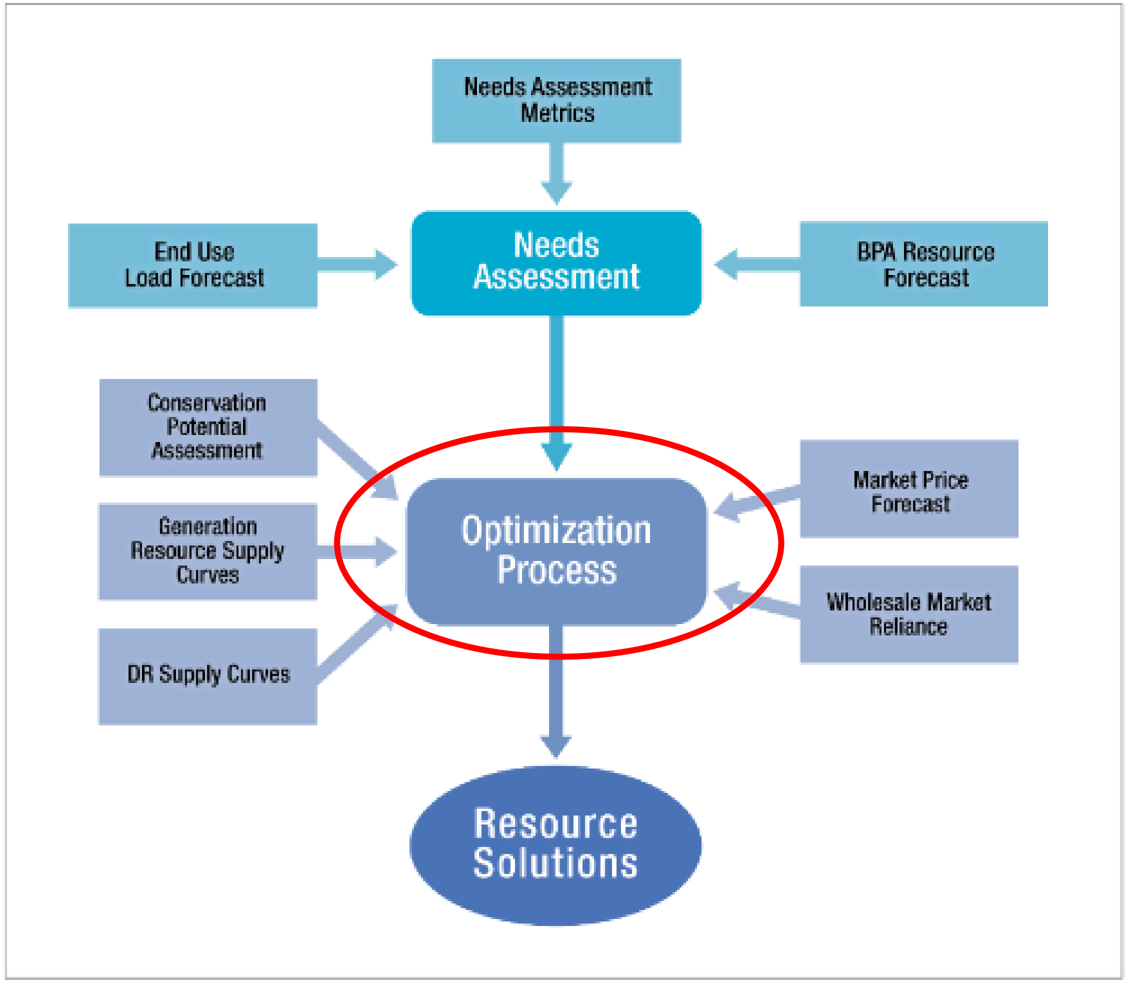
Changes to individual input assumptions (or smaller subsets of input assumptions) within a given scenario.

- Provide BPA decision-makers with additional options to address key strategic interests (PoC / Carbon Vision, etc).
- Evaluate solution sensitivity to specific assumptions
- Assess solution robustness.



Resource Selection Methodology

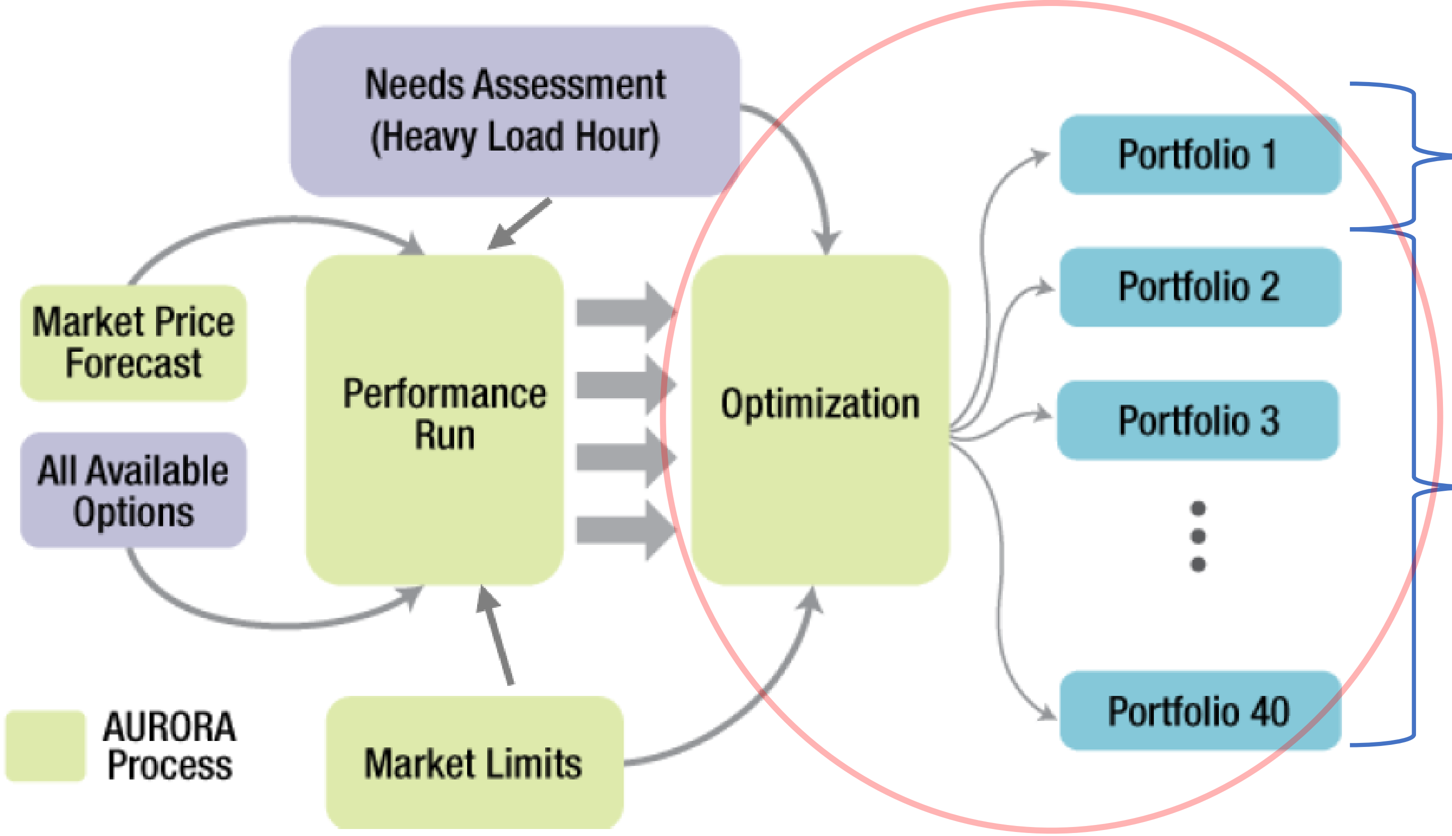
The Solver (Optimization Process)



Outline

- Aurora's Portfolio Optimization (old process)
  - Quick review
  - Issues and limitations
- New Solver
  - Main benefits
  - Focus on addressing uncertainty through scenarios + sensitivities

Aurora Portfolio Optimization Review



Aurora solves for:

1) **The least-cost solution** (portfolio)* that satisfies monthly p10 HLH energy needs over the planning horizon

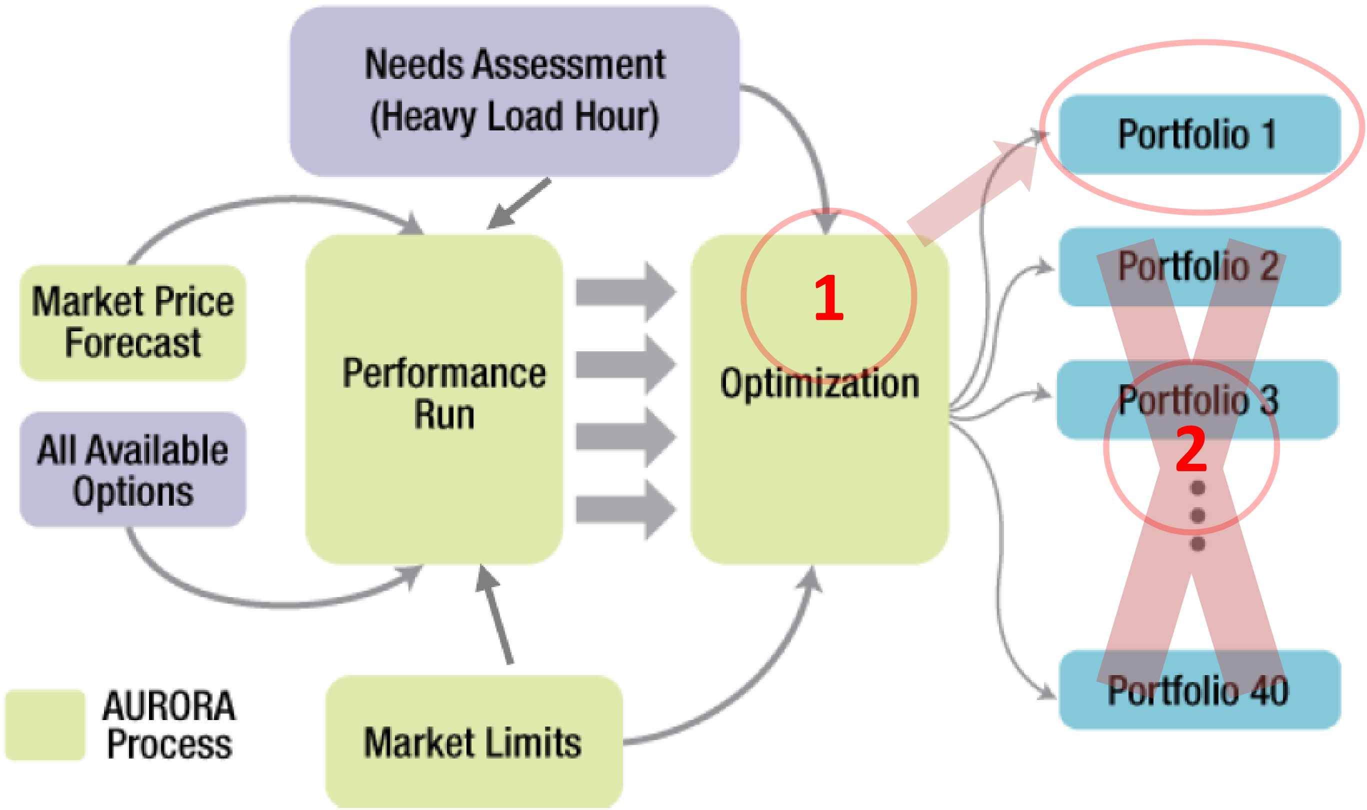
2) **39 additional portfolios** that minimize *variation* of total costs—reducing the overall range of potential financial outcomes under different possible future conditions, given the selected resources and market reliance

*A solution, or portfolio, is a combination of selected resources and market reliance that meet needs over the planning horizon

Aurora Portfolio Optimization Issues and Limitations

- **Very poor fit for BPA needs**
  - The portfolio optimization is designed for more traditional utility planning (meet annual planning reserve margins and low variability energy needs)
  - Extensive modifications / customizations are required to capture BPA’s stochastic energy needs and 18-hour capacity metric
  - Limited developer appetite to support changes that impact only one user of the model
- **~12-24 hours of runtime to solve for one case / scenario**
  - Vast majority related to inefficient data management
- **Highly time consuming to modify once working**
  - Evaluating key drivers of resource selection decisions required significant time and effort
  - Very limited ability to accommodate exploratory analysis
- **39 variance reducing portfolios have arbitrary budget limits, limited comparative value across cases, and often largely fail to reduce risk**
  - The model would increase spending by $50-100+ million to reduce risks by $10 million (roughly analogous to paying $50,000 to insure a $25,000 car)
  - Does not explicitly address tail risks (adverse outcomes were becoming more likely and had higher costs)

New Solver

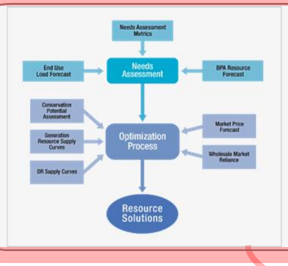


1. Replaces Aurora, finds the least cost solution to all needs with optimization using well established algorithms and solvers widely available in statistical programming tools (R/Python)
2. Eliminates variance reduction portfolios
3. Provides numerous additional benefits (next slide)

New Solver Benefits

- **Can model all existing BPA needs**
  - Separately or any combination of monthly p10 energy for HLH/LLH/super-peak/graveyard/flat
  - 18-hour summer and winter capacity metric
  - Readily accommodate WRAP metrics separately or in combination with other BPA needs
- **High flexibility enables us to focus on addressing risk and uncertainty through scenarios + sensitivities**
  - **Gives us the ability to tie different resource selections to specific risks**
  - Evaluate key drivers of resource selection decisions to better understand results
  - More readily accommodates evolving agency priorities and uncertain policy environment
- **Estimated 10 minute solve time per case**
  - For comparison, Aurora typically solves for about 150 **billion** variables when producing the rate case price forecast with ~ 1 week of solve time. For a single hour of a single iteration of that study, Aurora is solving for about 6,200 variables with tens of thousands of constraints in a fraction of a second. The new solver will only need to evaluate about 200 variables with 1,000-2,000 constraints.

Making Sense of Results

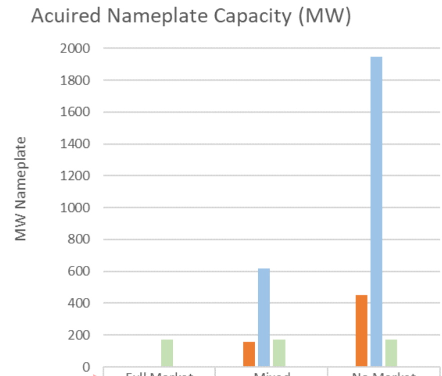


Base

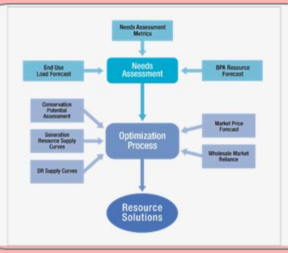
- Base Sensitivity 1
- Base Sensitivity 2
- ⋮
- Base Sensitivity N

Help inform internal evaluations / support customer requests

Select results shared externally in resource program document



	Full Market	Mixed	No Market
Solar	0	0	0
Solar plus 4hr Storage	0	156	451
Wind	0	618	1945
CGS uprate	170	170	170
6hr Storage	0	0	0
SMR	0	0	0



Fast Transition

- FT Sensitivity 1
- FT Sensitivity 2
- ⋮
- FT Sensitivity N

Scenarios and Sensitivities

RP24 Planning Framework

Scenarios

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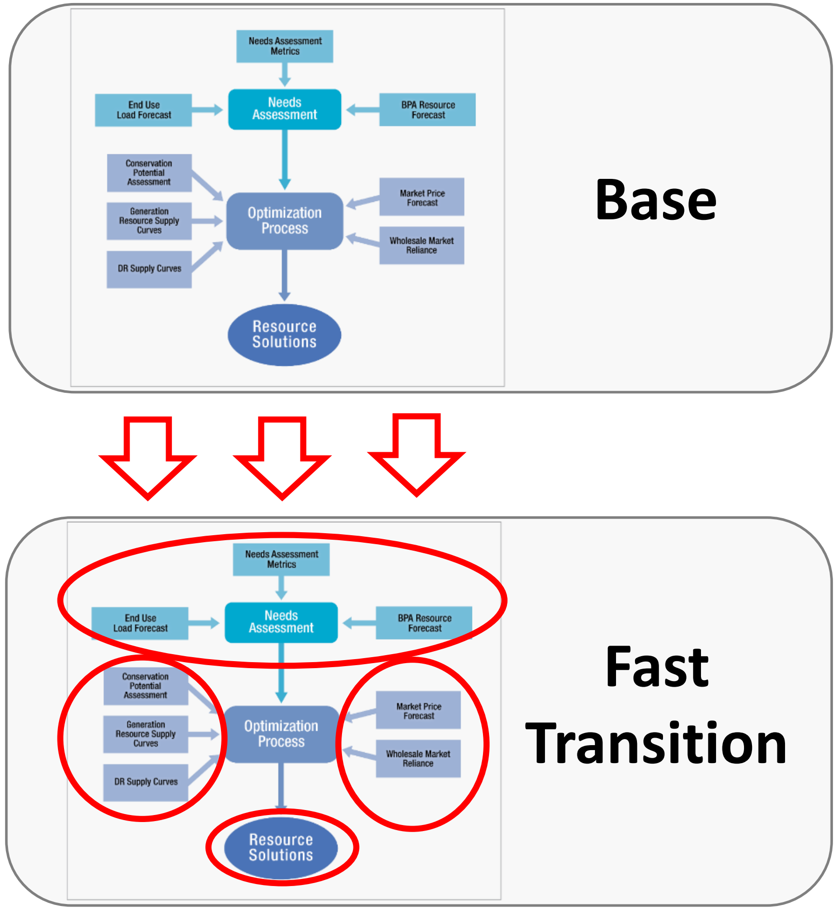

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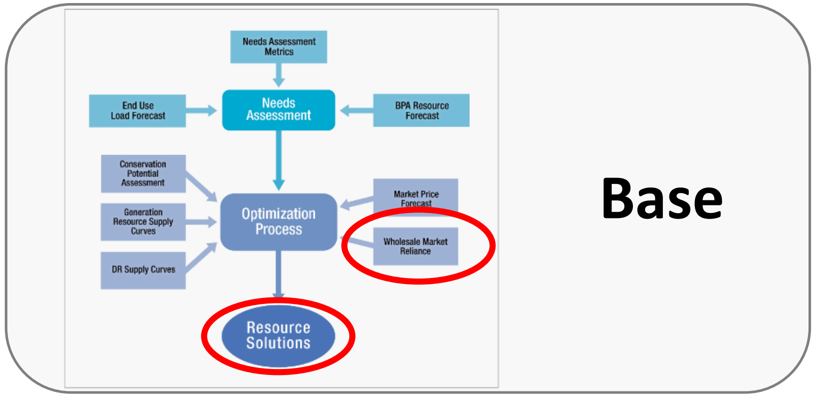


Two Scenarios: Base and Fast Transition

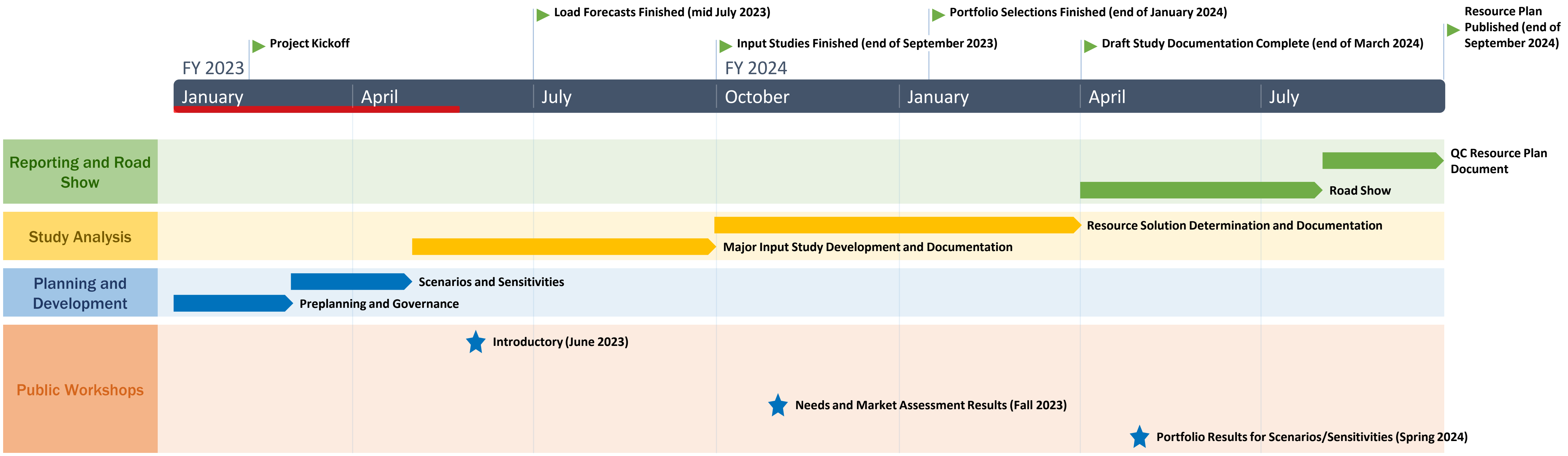
Category	Base	Fast Transition (relative to base)
BPA Loads	• Expected, mid-range load growth with average economic activity • Electrification / behind-the-meter (BTM) solar PV consistent with current policy • Two zones (primary and BPA-SE) • Expected conservation removed ("Frozen efficiency") • Current customer elections • Climate change impacts on technology saturation and temperature adjustments	• Moderately higher load growth, slightly elevated economic activity • Higher electrification/ BTM solar PV, and speculative loads
BPA Resources	• Federal hydro under 2020 EIS selected alternative & AOP24 treaty • Planned FCRPS upgrades (increased capacity at some plants during study period) • Current CGS (no uprate) • Climate change impacts on hydro generation from RMJOC-II, 2035 and beyond.	***Same as Base scenario***
Energy Efficiency and Demand Response	• Refresh Conservation Potential Assessment (CPA) based on new industry trends and updated study years • Include frequently deployable energy shifting products in the Demand Response Potential Assessment (DRPA) and update study years • Incorporate zonal considerations and updated climate change assumptions	• Adjust potential based on load
Market Landscape	• Mid-range values for all fundamental assumptions (expected case WECC-wide loads, gas prices, resource costs, carbon prices, etc.) • All current Federal/state policies • High likelihood resource additions/retirements over next rate period • **Climate change not explicitly accounted for in WECC loads/resources**	• Higher electrification and moderately higher load growth • WECC-wide carbon allowance pricing • Accelerated decarbonization targets and/or additional ZEM targets in areas currently lacking explicit policies
Candidate Generating Resources	• High likelihood emerging tech (SMRs), solar, wind, and storage. • Cost and performance characteristics developed from best available estimates using BPA specific assumptions	***Same as Base scenario***
Solver	• Twenty year study horizon (FY26-FY45) • Mixed-integer programming (MIP) approach solves for single portfolio which meets BPA needs at lowest total system cost (NPV)	***Same as Base scenario***

Potential Sensitivities

Sensitivity	Details
BPA Loads – Traditional Load Growth	• Higher T2 elections of existing customer base (AHWM load growth is served by BPA), customers serve less of their own load growth with non-federal resources • Load characteristics set by scenarios (Base, FT) • Adjust EE/DR potential (if applicable)
BPA Loads – Block Adder	• Capture impact from additional flat block obligations placed on BPA e.g. 5(b) contracts from IOUs or NLSL from existing customers
Transmission – Possible B2H Delay	• Capture impact from hypothetical delay to energization of B2H and transfer service capability from Mid-C to BPA-SE
Market - Prices	• Positional shifts in price distribution reflecting sustained changes in energy prices (higher/lower) • Changes to shape of price distribution to reflect increased tail risk from additional extreme events or significant renewables buildouts
Market – Availability	• Changes to BPA ability to meet needs by relying on market purchases
Candidate Resources – Costs/Availability	• Costs and availability of candidate supply-side resources • Cost/benefits of EE/DR from UCT perspective
Evaluate Incremental Need Impacts	• Run solver with no needs, only HLH energy, and only capacity to better understand contributors to resource selection
Study Horizon	• Consider shorter time horizon (e.g. ten instead of twenty years) to see how near term resource selections are influenced by long term assumptions

Discussion

Next Steps



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Get in Touch

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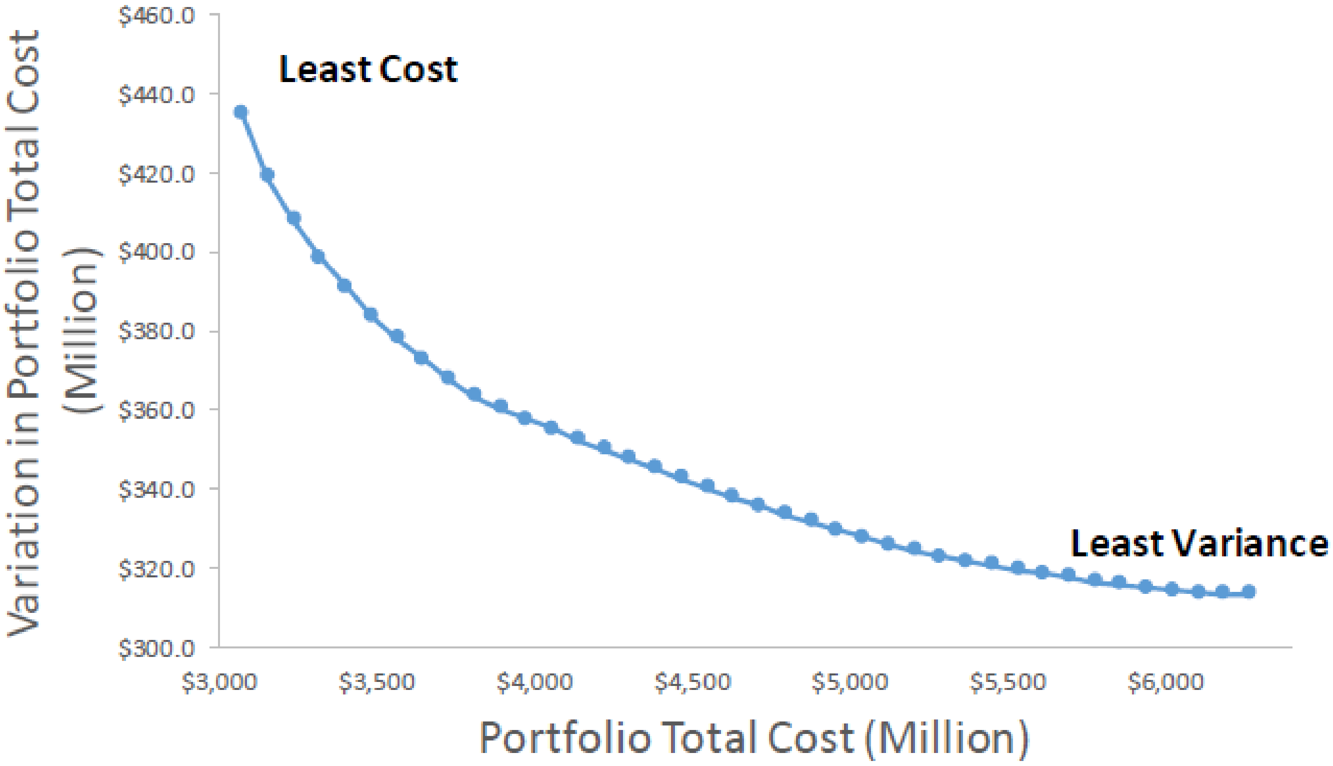
HYDRO POWER FLOWS HERE

Appendix: Solver

Aurora Portfolio Optimization Variance Reduction

- BPA selected 40 portfolios to calculate the trade-offs between minimizing total cost against the variation of portfolio costs.
- After developing the two end points (least cost / least variance), the range of average total portfolio cost was then split up across the 40 portfolios
- For each point along this range, the model solved for a result that minimizes total portfolio variation without exceeding that particular total cost level.



Constrained Optimization Refresher

- Objective function (min / max)
- Linear constraints
- Restrictions on decision variables

Linear program / other solvers* evaluate these systems of equations to find values for all decision variables that satisfy all constraints and produce the highest / lowest result of the objective function

*For more, Gurobi has a great summary of how they solve mixed integer problems

Standard Form of LPP

$$\text{Max } z = c_1x_1 + c_2x_2 + \dots + c_nx_n + 0s_1 + 0s_2 + \dots + 0s_m \quad \text{——(1)}$$

Subject to the constraints

$$\left\{\begin{array}{lcl} a_{11}x_1 + a_{12}x_2 + \dots + a_{1n}x_n + s_1 & = & b_1 \\ a_{21}x_1 + a_{22}x_2 + \dots + a_{2n}x_n + s_2 & = & b_2 \\ & \vdots & \\ a_{m1}x_1 + a_{m2}x_2 + \dots + a_{mn}x_n + s_m & = & b_m \end{array}\right. \quad \text{——(2)}$$

where,

$$x_1, x_2, \dots, x_n, s_1, s_2, \dots, s_m \geq 0 \quad \text{——(3)}$$

LPP in Matrix Form

Objective function:

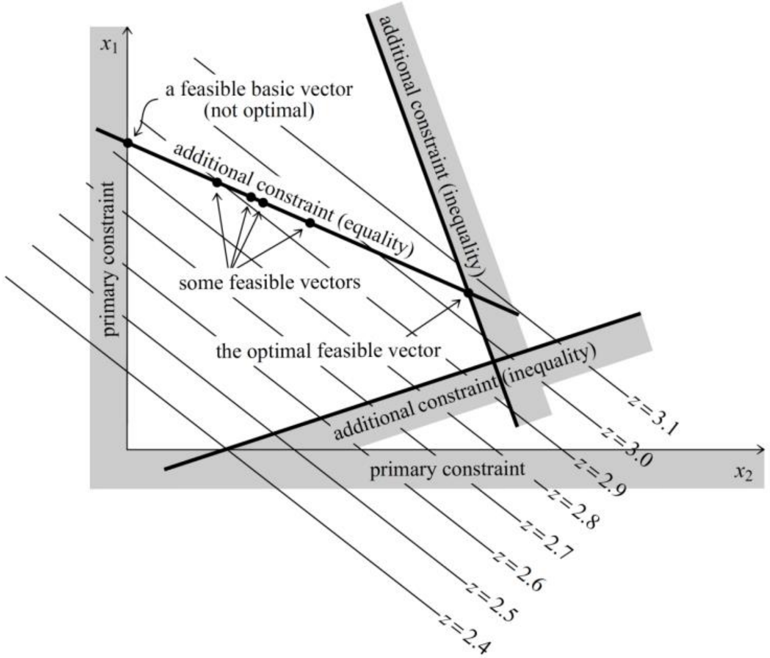
Maximize $z = \mathbf{c}\mathbf{X}^T$

Constraint Equations:

Subject to $\mathbf{AX} = \mathbf{b}$, $\mathbf{b} \geq \mathbf{0}$

Non-negative Restriction:

$\mathbf{X} \geq \mathbf{0}$



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Subject to the constraints

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Illustrative case

Filler values representing:

- 3 resource options
- 6 months of energy needs
- One year summer and winter capacity needs
- One year resource net costs (levelized fixed costs + variable costs – Energy benefits)

		Solar	Wind	SMR	MR_jan	MR_feb	MR_mar	MR_apr	MR_may	MR_jun	Total Portfolio Cost ($M)
Decision Variables		**0.00**	**0.00**	**0.34**	**0.50**	**0.45**	**0.42**	**0.37**	**0.37**	**0.36**	
	ResourceCost ($M)	311.9	329.3	386.3	29.4	27.2	22.1	15.9	14.0	13.2	
Objective Function	**Portfolio Cost ($M)**	**0.0**	**0.0**	**132.1**	**14.7**	**12.2**	**9.2**	**5.8**	**5.1**	**4.7**	**183.9**

		Month	Solar	Wind	SMR	MR_jan	MR_feb	MR_mar	MR_apr	MR_may	MR_jun	Needs	Acquired
Constraints	**Energy (aMW)**	Jan	**791**	**1541**	**950**	**649**	**0**	**0**	**0**	**0**	**0**	**649**	649
		Feb	**1054**	**1194**	**950**	**0**	**590**	**0**	**0**	**0**	**0**	**590**	590
		Mar	**1414**	**1655**	**950**	**0**	**0**	**557**	**0**	**0**	**0**	**557**	557
		Apr	**1433**	**1620**	**950**	**0**	**0**	**0**	**506**	**0**	**0**	**506**	506
		May	**1753**	**1473**	**950**	**0**	**0**	**0**	**0**	**512**	**0**	**512**	512
		Jun	**1929**	**1762**	**950**	**0**	**0**	**0**	**0**	**0**	**506**	**506**	506
	Capacity	Summer	**250**	**500**	**950**	**0**	**0**	**0**	**0**	**0**	**0**	**325**	325
		Winter	**750**	**750**	**950**	**0**	**0**	**0**	**0**	**0**	**0**	**275**	325
	WRAP	*Summer*	***250***	***500***	***950***	***0***	***0***	***0***	***0***	***0***	***0***	***162.5***	*325*
		Winter	***750***	***750***	***950***	***0***	***0***	***0***	***0***	***0***	***0***	***137.5***	*325*

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Subject to the constraints

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where,

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LPP in Matrix Form

Objective function:

Maximize $z = cX^T$

Constraint Equations:

Subject to $AX = b$,
$b \geq 0$

Non-negative Restriction:

$X \geq 0$

Objective function

Solve for decision variables (amounts of resources to acquire) that minimize total portfolio costs

		Solar	Wind	SMR	MR_jan	MR_feb	MR_mar	MR_apr	MR_may	MR_jun	Total Portfolio Cost ($M)
Decision Variables		0.00	0.00	0.34	0.50	0.45	0.42	0.37	0.37	0.36	
	ResourceCost ($M)	311.9	329.3	386.3	29.4	27.2	22.1	15.9	14.0	13.2	
Objective Function	Portfolio Cost ($M)	0.0	0.0	132.1	14.7	12.2	9.2	5.8	5.1	4.7	183.9

		Month	Solar	Wind	SMR	MR_jan	MR_feb	MR_mar	MR_apr	MR_may	MR_jun	Needs	Acquired
Constraints	Energy (aMW)	Jan	791	1541	950	649	0	0	0	0	0	649	649
		Feb	1054	1194	950	0	590	0	0	0	0	590	590
		Mar	1414	1655	950	0	0	557	0	0	0	557	557
		Apr	1433	1620	950	0	0	0	506	0	0	506	506
		May	1753	1473	950	0	0	0	0	512	0	512	512
		Jun	1929	1762	950	0	0	0	0	0	506	506	506
	Capacity	Summer	250	500	950	0	0	0	0	0	0	325	325
		Winter	750	750	950	0	0	0	0	0	0	275	325
	WRAP	*Summer*	*250*	*500*	*950*	*0*	*0*	*0*	*0*	*0*	*0*	*162.5*	*325*
		Winter	*750*	*750*	*950*	*0*	*0*	*0*	*0*	*0*	*0*	*137.5*	*325*

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Constraints

Use January to show how constraints are represented

			Solar	Wind	SMR	MR_jan	MR_feb	MR_mar	MR_apr	MR_may	MR_jun		
Decision Variables			0.00	0.00	0.34	0.50	0.45	0.42	0.37	0.37	0.36	Total Portfolio Cost ($M)	
	ResourceCost ($M)		311.9	329.3	386.3	29.4	27.2	22.1	15.9	14.0	13.2		
Objective Function	Portfolio Cost ($M)		0.0	0.0	132.1	14.7	12.2	9.2	5.8	5.1	4.7	183.9	
		Month	**Solar**	**Wind**	**SMR**	**MR_jan**	**MR_feb**	**MR_mar**	**MR_apr**	**MR_may**	**MR_jun**	**Needs**	**Acquired**
Constraints	Energy (aMW)	Jan	791	1541	950	649	0	0	0	0	0	649	649
		Feb	1054	1194	950	0	590	0	0	0	0	590	590
		Mar	1414	1655	950	0	0	557	0	0	0	557	557
		Apr	1433	1620	950	0	0	0	506	0	0	506	506
		May	1753	1473	950	0	0	0	0	512	0	512	512
		Jun	1929	1762	950	0	0	0	0	0	506	506	506
	Capacity	Summer	250	500	950	0	0	0	0	0	0	325	325
		Winter	750	750	950	0	0	0	0	0	0	275	325
	WRAP	*Summer*	*250*	*500*	*950*	*0*	*0*	*0*	*0*	*0*	*0*	*162.5*	*325*
		Winter	*750*	*750*	*950*	*0*	*0*	*0*	*0*	*0*	*0*	*137.5*	*325*

Standard Form of LPP

$$\text{Max } z = c_1x_1 + c_2x_2 + \dots + c_nx_n + 0s_1 + 0s_2 + \dots + 0s_m \quad \text{——(1)}$$

Subject to the constraints

$$\begin{cases} a_{11}x_1 + a_{12}x_2 + \dots + a_{1n}x_n + s_1 = b_1 \\ a_{21}x_1 + a_{22}x_2 + \dots + a_{2n}x_n + s_2 = b_2 \\ \vdots \\ a_{m1}x_1 + a_{m2}x_2 + \dots + a_{mn}x_n + s_m = b_m \end{cases} \quad \text{——(2)}$$

where,

$$x_1, x_2, \dots, x_n, s_1, s_2, \dots, s_m \geq 0 \quad \text{——(3)}$$

LPP in Matrix Form

Objective function:

Maximize $z = cX^T$

Constraint Equations:

Subject to $AX = b$, $b \geq 0$

Non-negative Restriction:

$X \geq 0$

$$\textit{Jan Energy Constraint } 791 * X_1 + 1541 * X_2 + 950 * X_3 + 649 * X_4 \geq 649$$

		Solar	Wind	SMR	MR_jan	MR_feb	MR_mar	MR_apr	MR_may	MR_jun	
Decision Variables		**0.00**	**0.00**	**0.34**	**0.50**	**0.45**	**0.42**	**0.37**	**0.37**	**0.36**	**Total Portfolio Cost ($M)**
	ResourceCost ($M)	311.9	329.3	386.3	29.4	27.2	22.1	15.9	14.0	13.2	
Objective Function	**Portfolio Cost ($M)**	**0.0**	**0.0**	**132.1**	**14.7**	**12.2**	**9.2**	**5.8**	**5.1**	**4.7**	**183.9**

		Month	Solar	Wind	SMR	MR_jan	MR_feb	MR_mar	MR_apr	MR_may	MR_jun	Needs	Acquired
Constraints	**Energy (aMW)**	Jan	**791**	**1541**	**950**	**649**	**0**	**0**	**0**	**0**	**0**	**649**	649
		Feb	**1054**	**1194**	**950**	**0**	**590**	**0**	**0**	**0**	**0**	**590**	590
		Mar	**1414**	**1655**	**950**	**0**	**0**	**557**	**0**	**0**	**0**	**557**	557
		Apr	**1433**	**1620**	**950**	**0**	**0**	**0**	**506**	**0**	**0**	**506**	506
		May	**1753**	**1473**	**950**	**0**	**0**	**0**	**0**	**512**	**0**	**512**	512
		Jun	**1929**	**1762**	**950**	**0**	**0**	**0**	**0**	**0**	**506**	**506**	506
	Capacity	Summer	**250**	**500**	**950**	**0**	**0**	**0**	**0**	**0**	**0**	**325**	325
		Winter	**750**	**750**	**950**	**0**	**0**	**0**	**0**	**0**	**0**	**275**	325
	WRAP	*Summer*	***250***	***500***	***950***	***0***	***0***	***0***	***0***	***0***	***0***	***162.5***	*325*
		Winter	***750***	***750***	***950***	***0***	***0***	***0***	***0***	***0***	***0***	***137.5***	*325*

Standard Form of LPP

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Subject to the constraints

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where,

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Solutions!

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	ResourceCost ($M)	311.9	329.3	386.3	29.4	27.2	22.1	15.9	14.0	13.2	
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	Capacity	Summer	250	500	950	0	0	0	0	0	0	325	325
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	WRAP	*Summer*	*250*	*500*	*950*	*0*	*0*	*0*	*0*	*0*	*0*	*162.5*	*325*
		Winter	*750*	*750*	*950*	*0*	*0*	*0*	*0*	*0*	*0*	*137.5*	*325*