

AURORA Workshop



April 22, 2021

Agenda

- General Terms
- Overview
- Zonal Simulation (Portfolio Costing)
- Long Term Capacity Expansion (LTCE)



IRPAC Reminder

- **Please provide feedback during IRPAC meetings**
- **IRPAC meetings review/develop Input Assumptions**
- Feedback helps with:
 - IRPAC discussions
 - Collaboration
 - New ideas
 - Developing the best IRP

Commonly Used Terms



- Area – Geographic, market, balancing area
- ATC – Available Transmission Capability
- aMW – Average Megawatt (average energy over a time period)
- Link – Transmission line
- LT – Long-Term
- LTCE – Long-Term Capacity Expansion
- Marginal Resource – Last Resource dispatched for the Zone
- MW – Megawatt, (1,000 kilowatts or 1,000,000 watts)
- Nameplate – Rated Resource Capacity
- PPA – Power Purchase Agreement
- PURPA – Public Utility Regulatory Policies Act
- WECC – Western Electricity Coordinating Council
- Zone – One or more Areas

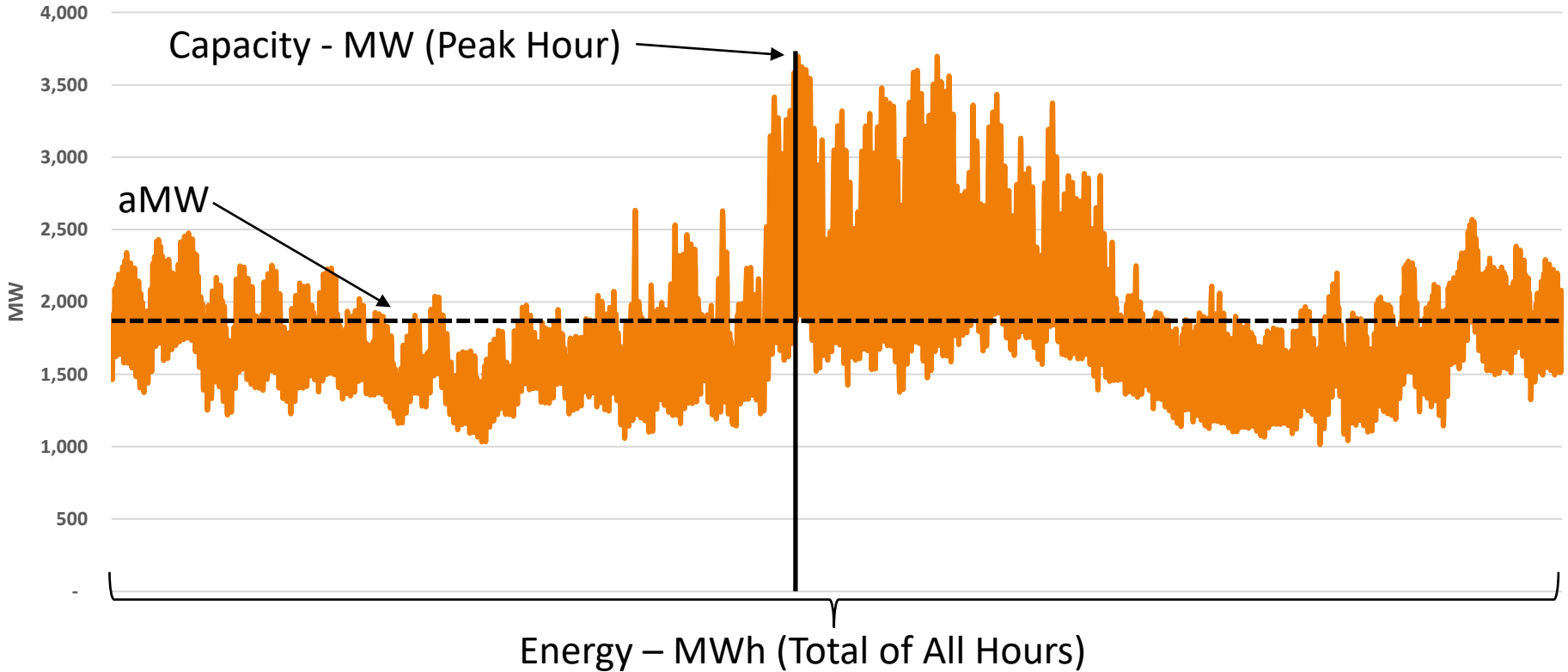
Capacity Versus Energy



- Capacity (MW) = highest demand for energy during a time period
 - PEAK HOUR
 - July 22, 2019 = 3,242 MW
 - All Time System Peak – July 7, 2017 = 3,422 MW
- Energy (MWh) = total energy used during a time period
 - ALL HOURS
 - 2019 Total Annual Sales = 17,387,636 MWh
 - aMW = 1,985 MW (17,387,636 MWh/8,760 hours)

Capacity Versus Energy

(Continued)



Capacity Versus Energy

(Continued)

Resource Size = 100 MW

Resource Availability = 93%

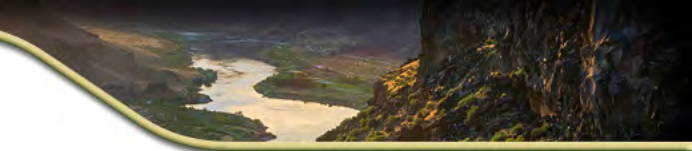
Resource Peak Hour Contribution = 100 MW

Resource Annual Energy = 814,680 MWh

Average Annual Residential Usage = 11,209 kWh

Average Residential Customer Demand at System Peak = ~2.2 kW

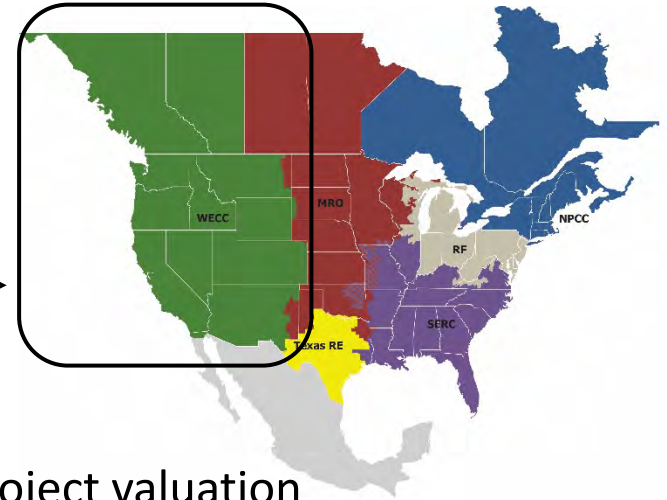
	Average Residential Homes Served
Capacity MW (System Peak Hour Demand)	45,739
Energy MWh (Total of all Hours)	72,681



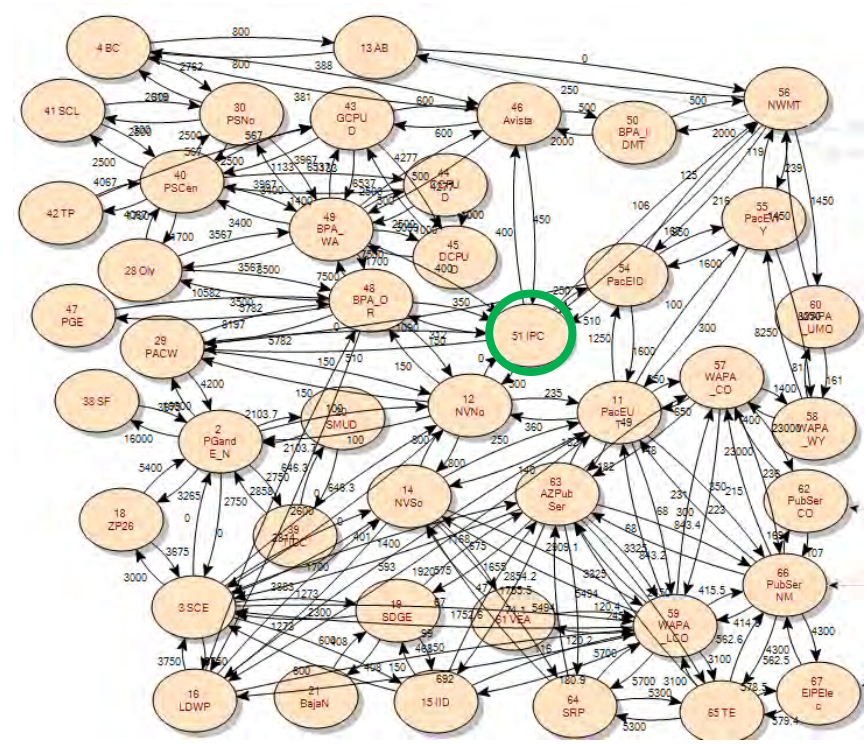
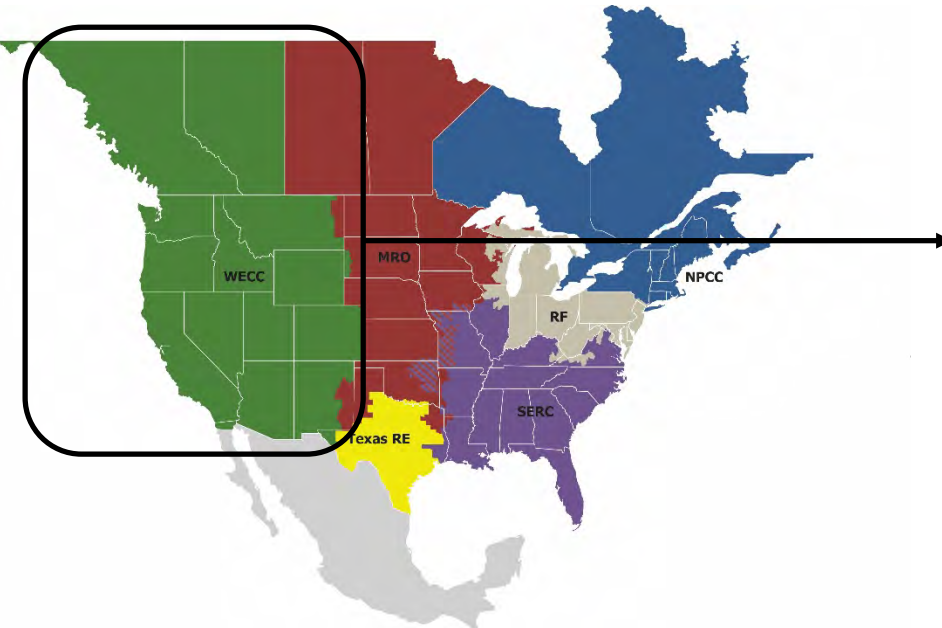
Aurora Overview

Aurora

- Developed by EPIS, Inc. in 1997
- Merged with Energy Exemplar in 2018
 - [energyexemplar.com](https://www.energyexemplar.com)
- Energy Exemplar Models
 - Aurora, Plexos
- Electric Market Price Forecasting Tool
 - Hourly time step used for IRP
 - Simulates Entire WECC
- Used by multiple entities worldwide
- Used in various areas within Idaho Power
 - IRP, Regulatory, coal analyses, PURPA pricing, project valuation
- Used in multiple IRP cycles



System Topology



System Topology

(Continued)

- Resources and demand are located within each Area.
- Area description
 - Areas are assigned by geographic region.
 - One Area can occupy a zone.
 - Multiple Areas can occupy a zone.
 - Areas are connected by transmission links.

Modeling Logic



- Basic concept – supply/demand
- Resources supply demand
 - Generation units are dispatched based on economics and constraints.
 - Electricity flows based on economics and constraints.
 - Resource stacks are calculated every hour.
 - Marginal generation units set the zonal price.

Resource Stack Example



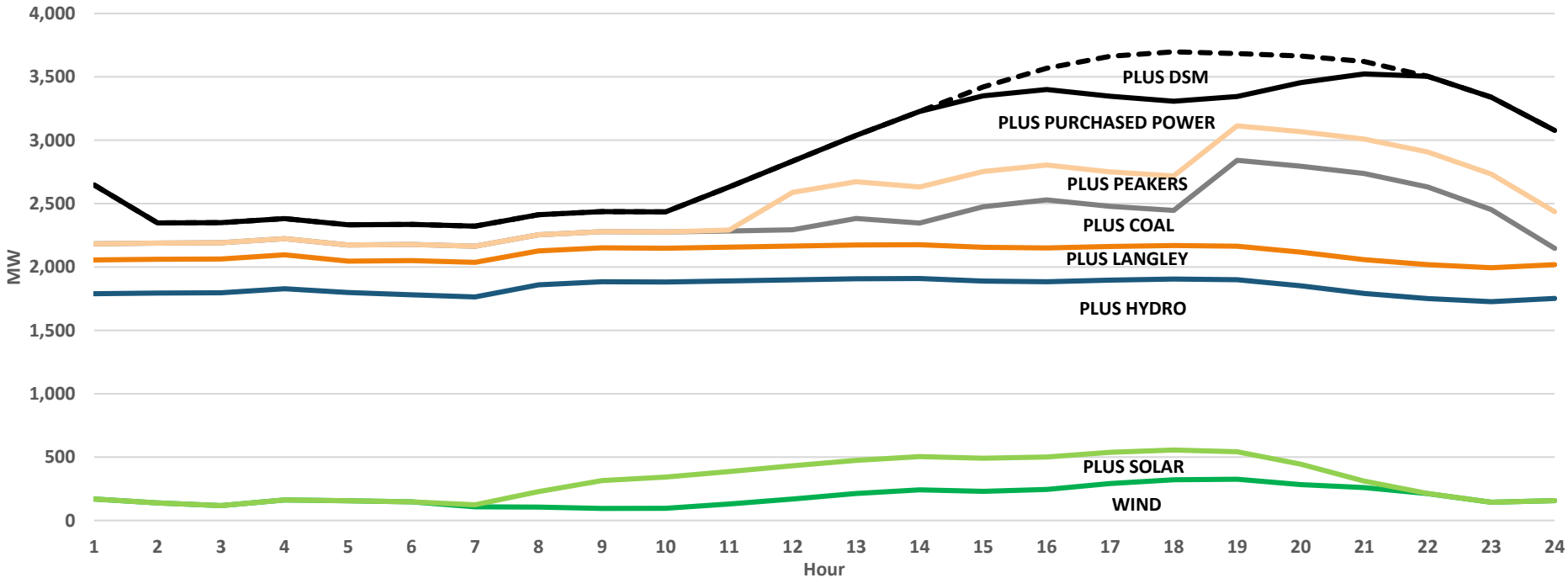
Resource	MW
System Demand	1,200
Coal	300
Natural Gas (Base)	150
Hydro Generation	600
Must Run Resources	150

Resource	MW
System Demand	3,400
Demand Response	300
Market Purchases	230
Natural Gas (Peaker)	350
Coal	800
Natural Gas (Base)	270
Hydro Generation	1,100
Must-run Resources	350

Note: Resource types and resource units are grouped together for this example.

Resource Stack Example

(Aurora Peak Hour - Sample Output)



Aurora Database



- Aurora provides a default WECC database.
- Many competing models don't provide a database.
- Database captures what's happening around us.
 - Important to model entire WECC during sensitivity analyses.
 - Examples – high carbon cost future, high gas cost future, etc.
 - As futures change – **MARKET PRICES CHANGE**
 - Never a good idea to plan in a bubble.

Example Data Sources



Resource Information

- NERC Electric Supply & Demand Database
 - nerc.com/pa/RAPA/ESD/Pages/default.aspx
- EIA-860
 - eia.gov/electricity/data/eia860/
- EIA Form-411
 - eia.gov/electricity/data/eia411/
- California Energy Commission, StatCanada, USDOE, Energy Exemplar, NREL, EPA, FERC

Example Data Sources

(continued)

Transmission Information

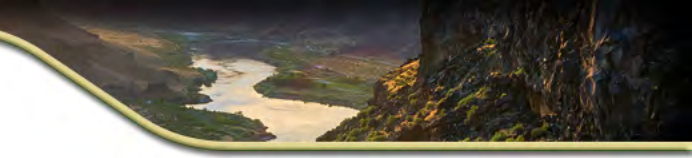
- WECC Power Supply Assessment
 - wecc.biz/SystemAdequacyPlanning/Pages/Default.aspx
- WECC Path Ratings Catalog
 - [wecc.biz/Pages/results.aspx?k=ALL\(Path+Rating+Catalog\)](http://wecc.biz/Pages/results.aspx?k=ALL(Path+Rating+Catalog))
- BC Hydro actual transmission flows
- Approximations from published maps

Example Data Sources

(continued)

Fuel Information

- Natural Gas
 - EIA
 - eia.gov/naturalgas/
 - NYMEX
 - cmegroup.com/company/nymex.html
 - Proprietary subscriptions
- Coal
 - EIA



Aurora Database Refinement



- IRP Process
 - IRPAC recommendations
- Default database is a good starting point
- Additional reasons for refinements:
 - Newer price forecasts are available
 - Standard industry practice
 - Proprietary information
 - Sensitivity analyses



Zonal Simulation

Zonal Simulation

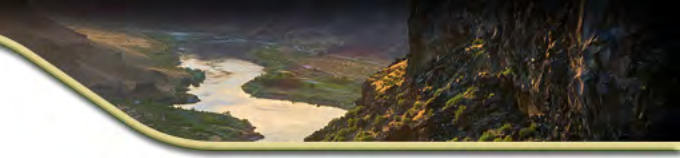


- Hourly simulation for entire WECC is performed
 - Existing and New Resources
- Portfolio simulation for Idaho Power (portfolio costing)
- Resources are dispatched to serve demand
- Energy flows based on demand/economics

Zonal Simulation

(Continued)

- Hourly dispatch considerations:
 - Economics
 - Ramp rates
 - Regulation services
 - Examples: RegUp, RegDown
 - Min Up/Min Down
 - Maintenance schedules
 - Transmission ratings
 - Must-run resources



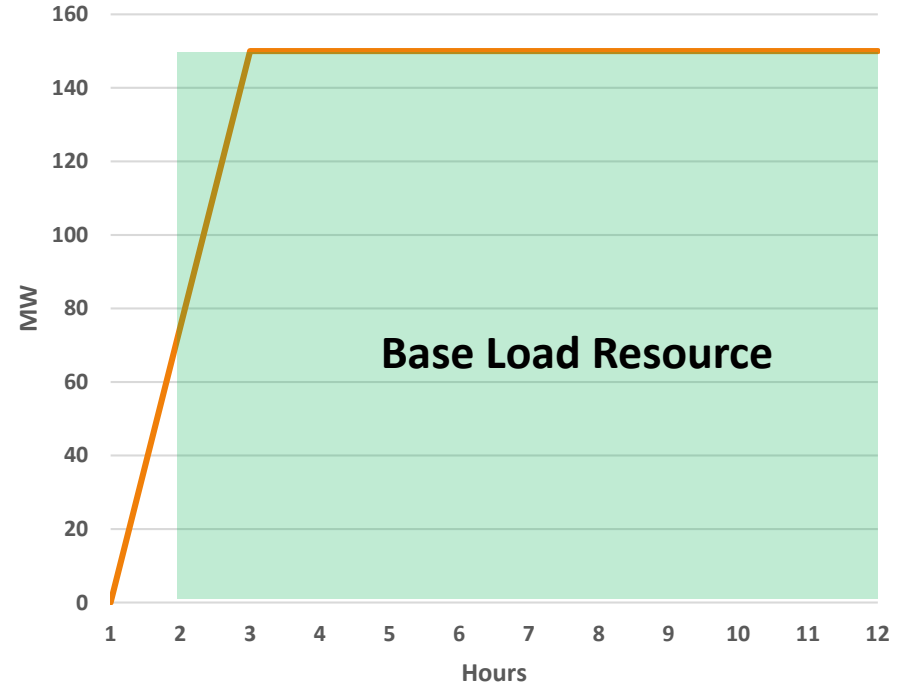
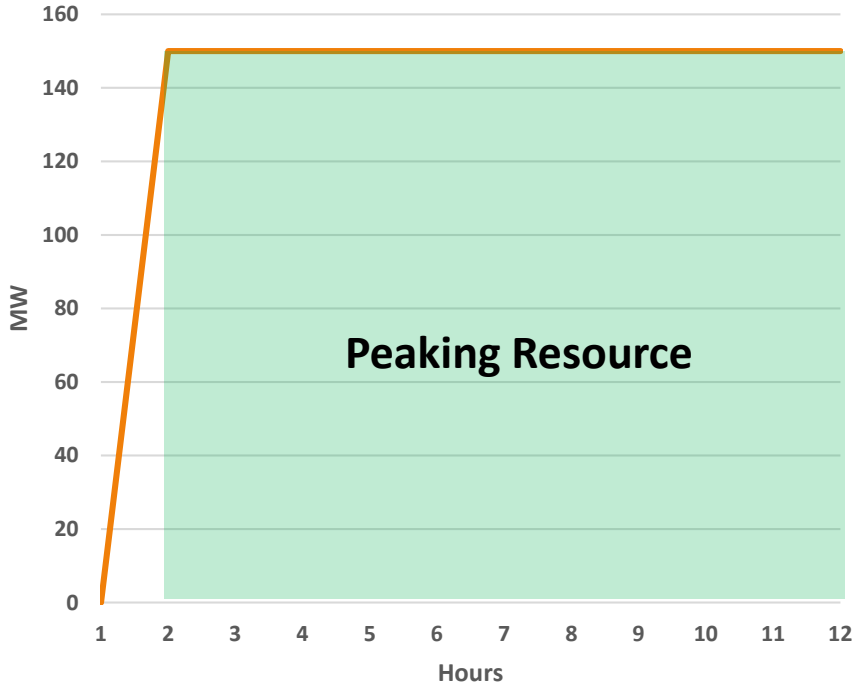
Ramp Rate Examples



- Amount a resource can increase generation within the next hour.
- Peaking resource – 100% ramp rate
 - Used for limited hours to meet high-load hours
 - 150 MW nameplate, 100% Ramp Rate
 - Hour 1 = off; hour 2 = 150 MW (full output)
- Baseload resource – 50% ramp rate
 - Used for all hours to meet all load hours
 - 150 MW nameplate, 50% ramp rate
 - Hour 1 = off; hour 2 = 75 MW; hour 3 = 150 MW (full output)

Ramp Rate Examples

(Continued)



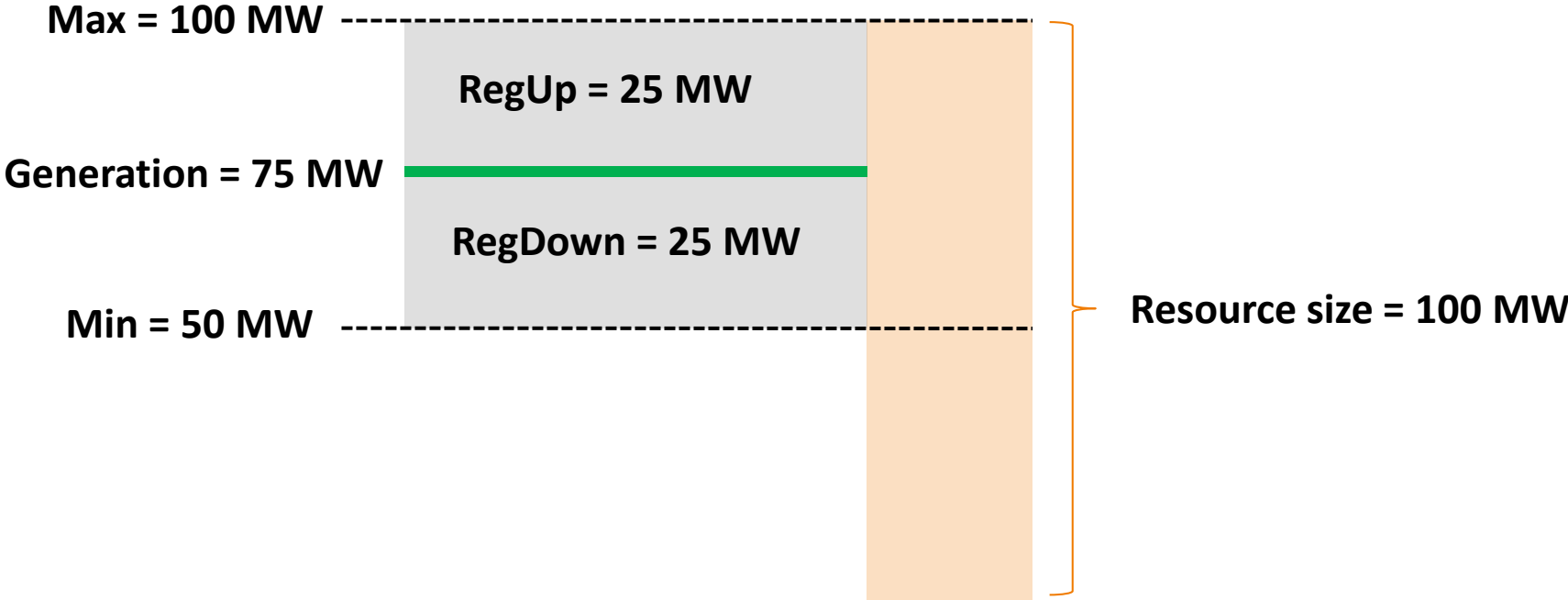
Regulation Services Example



- Reg Up = under supply
 - Example: Variable resource generation decreases; flexible resource needs to increase generation.
- Reg Down = over supply
 - Example: Variable resource generation increases; flexible resource needs to decrease generation.

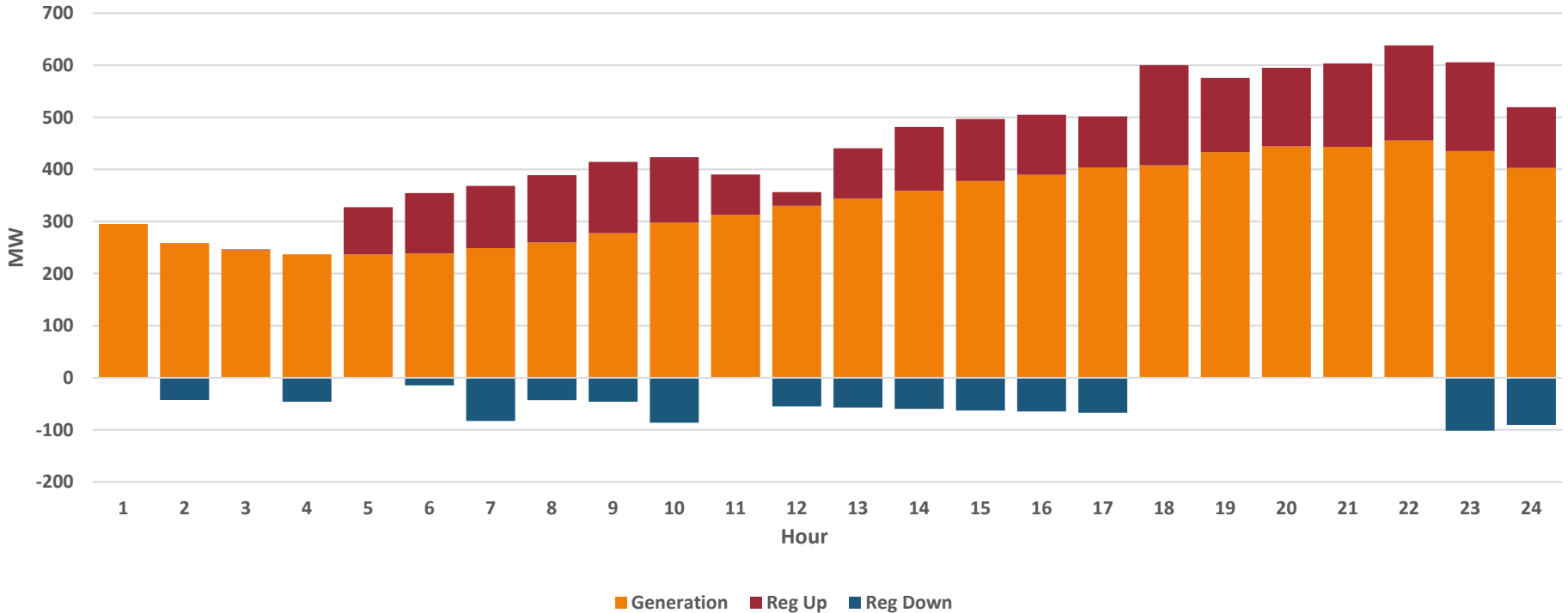
Regulation Services Example

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Regulation Services Example - Hydro

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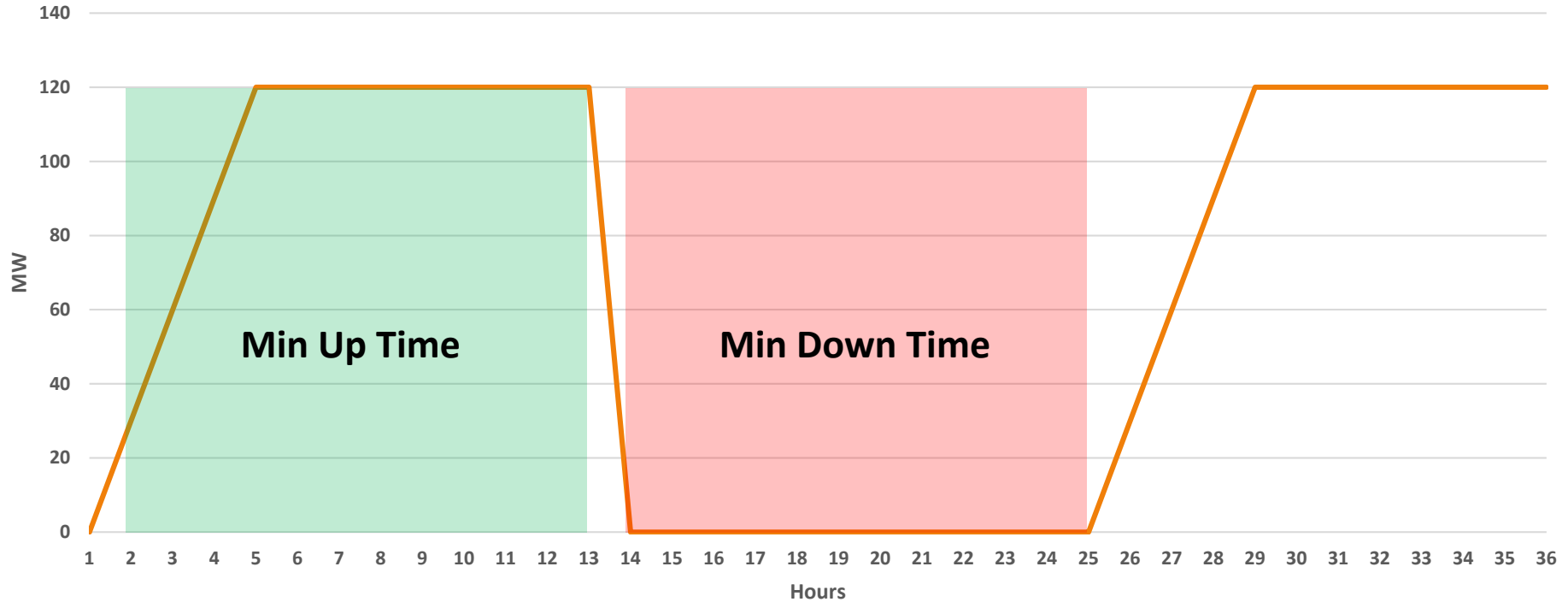
Min Up/Down Example



- Operational constraints often require resources to remain on or off for designated time periods.
- Min Up = 12 Hours
- Min Down = 12 Hours
- Once a resource starts up, it must remain operational for 12 hours.
- Once a resource shuts down, it must remain off for 12 hours.

Min Up/Down Example

(Continue)



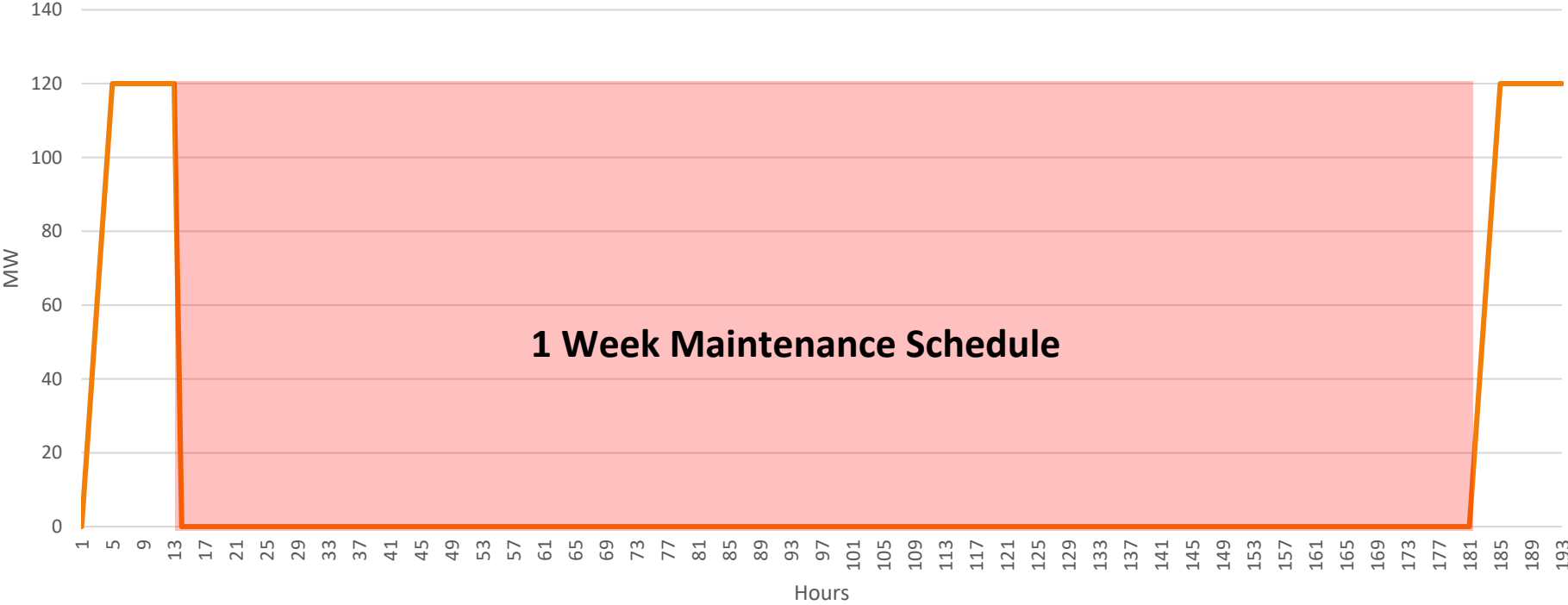
Maintenance Schedule Example



- Designated maintenance schedules for planned maintenance
- Turbine overhaul
- Bearing replacements
- Generator rebuilds
- Etc.

Maintenance Schedule Example

(Continued)



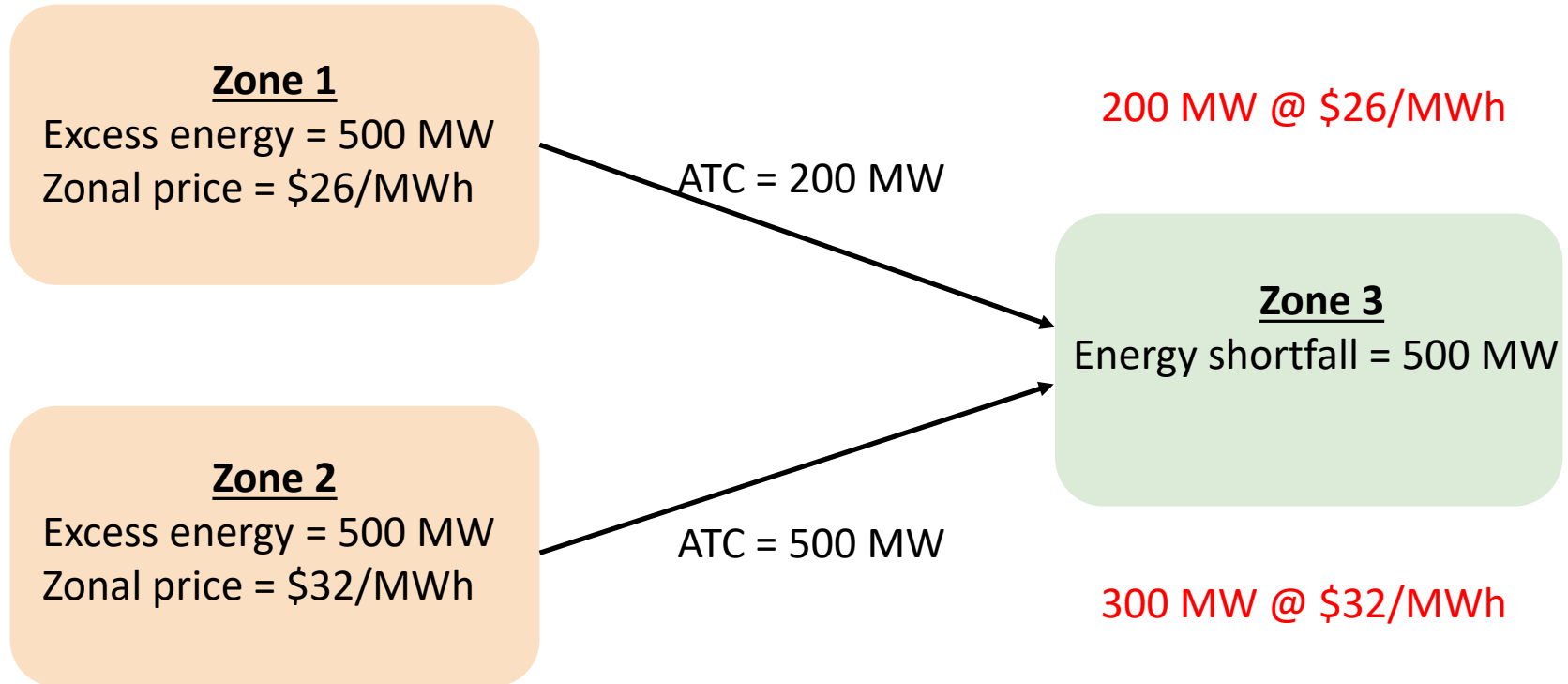
Transmission Rating Example



- Transmission line ratings can limit the amount of energy flow.
- Energy might be cheaper in one zone, but if the line doesn't have sufficient capacity, energy can't flow.

Transmission Rating Example

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Must Run Resources Example

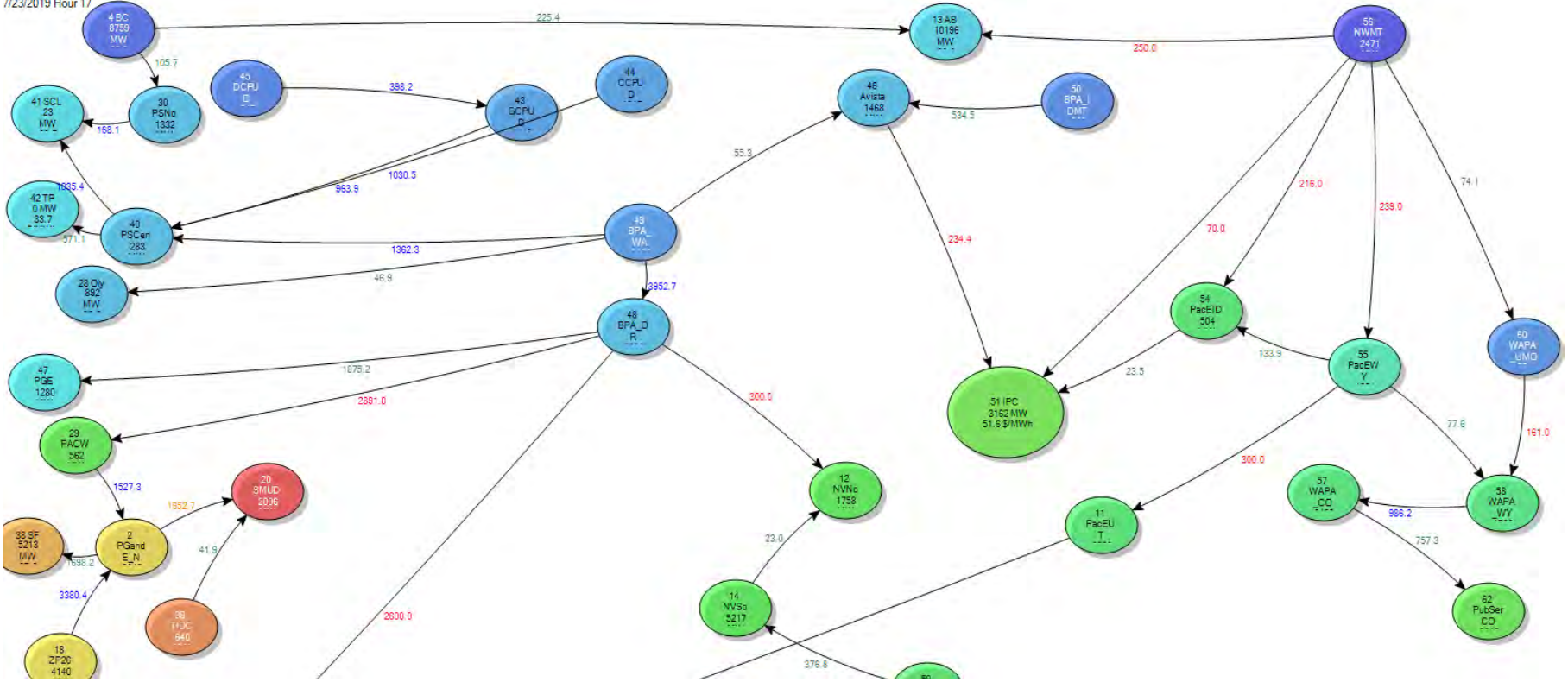


- PURPA/PPA
- Forecasted generation is input into Aurora.
- Must-run resources always run at 100% of forecasted generation.

Heavy Load Hour – Example

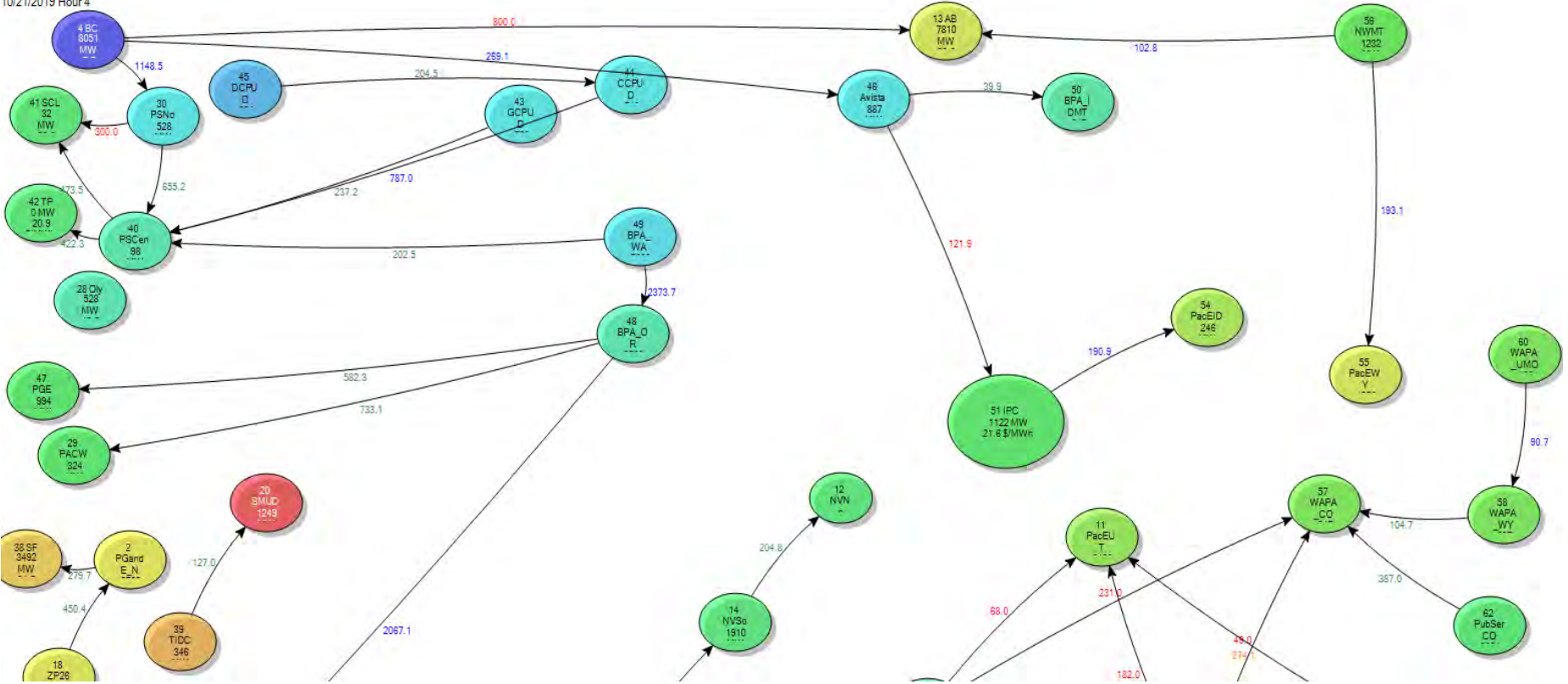


7/23/2019 Hour 17



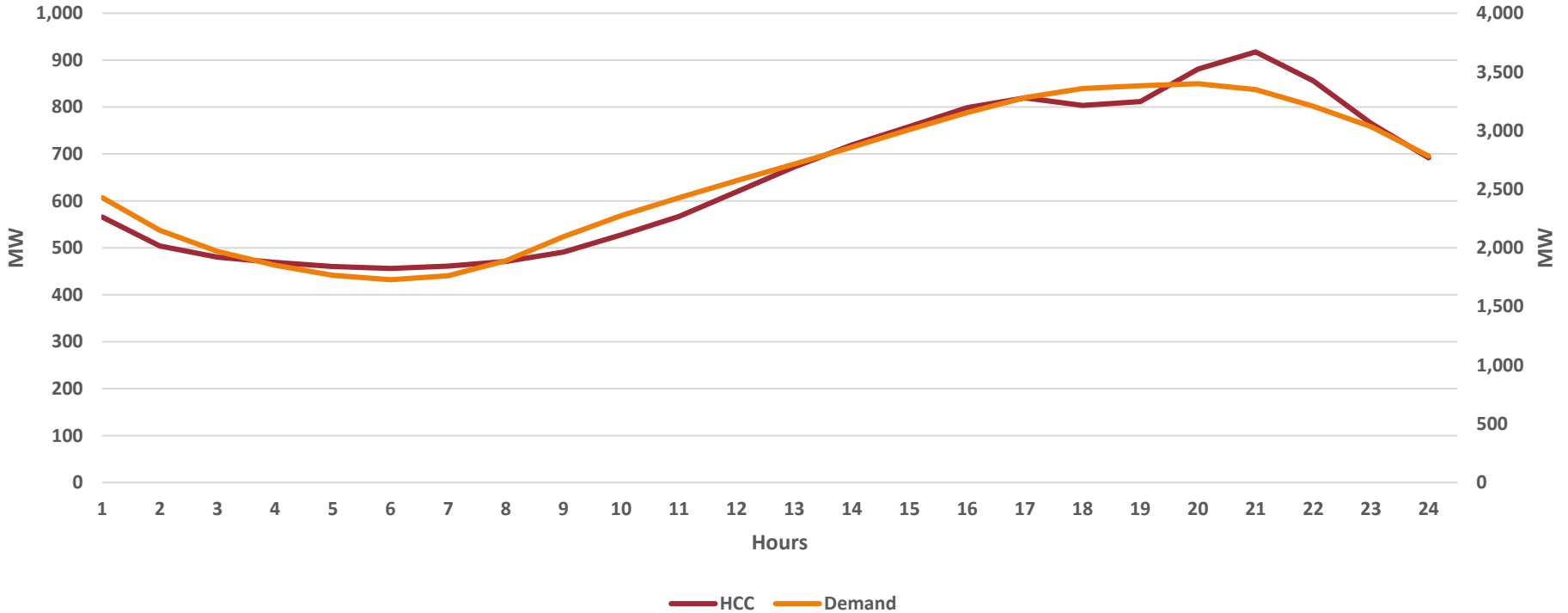
Light Load Hour - Example

10/21/2019 Hour 4



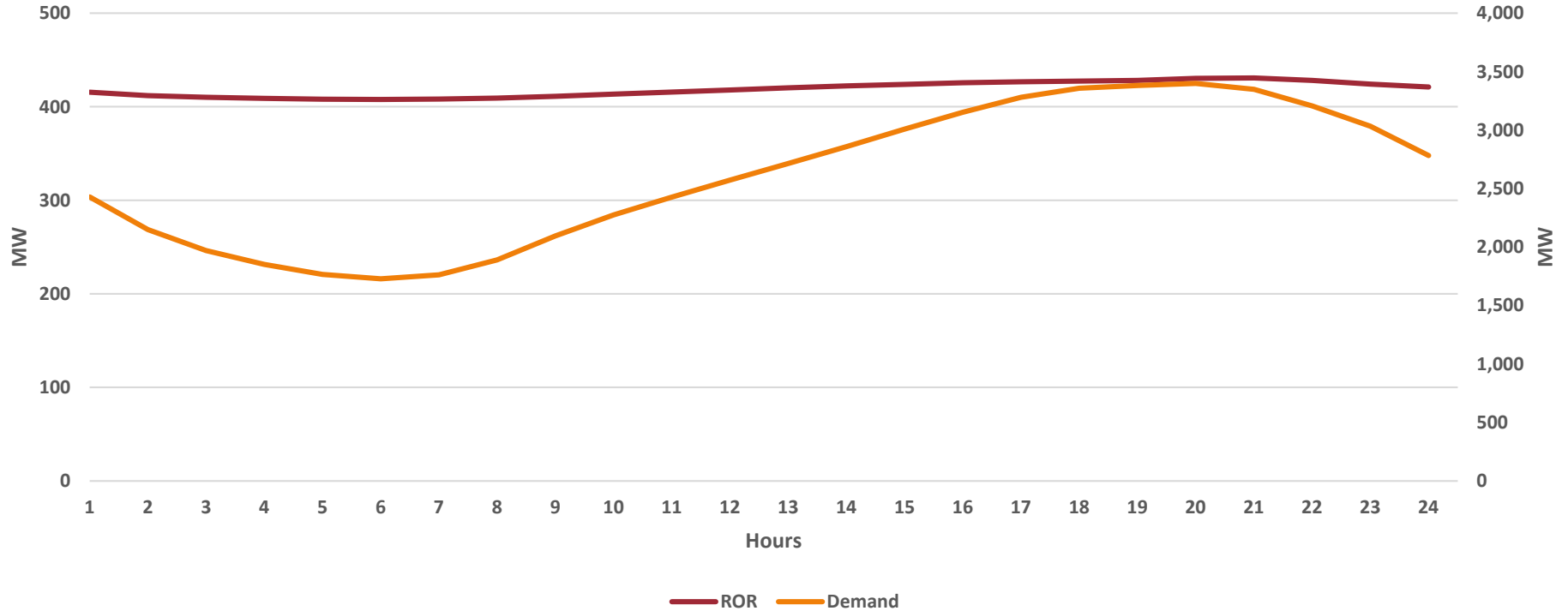
Aurora Dispatch Example

(Hells Canyon Complex)



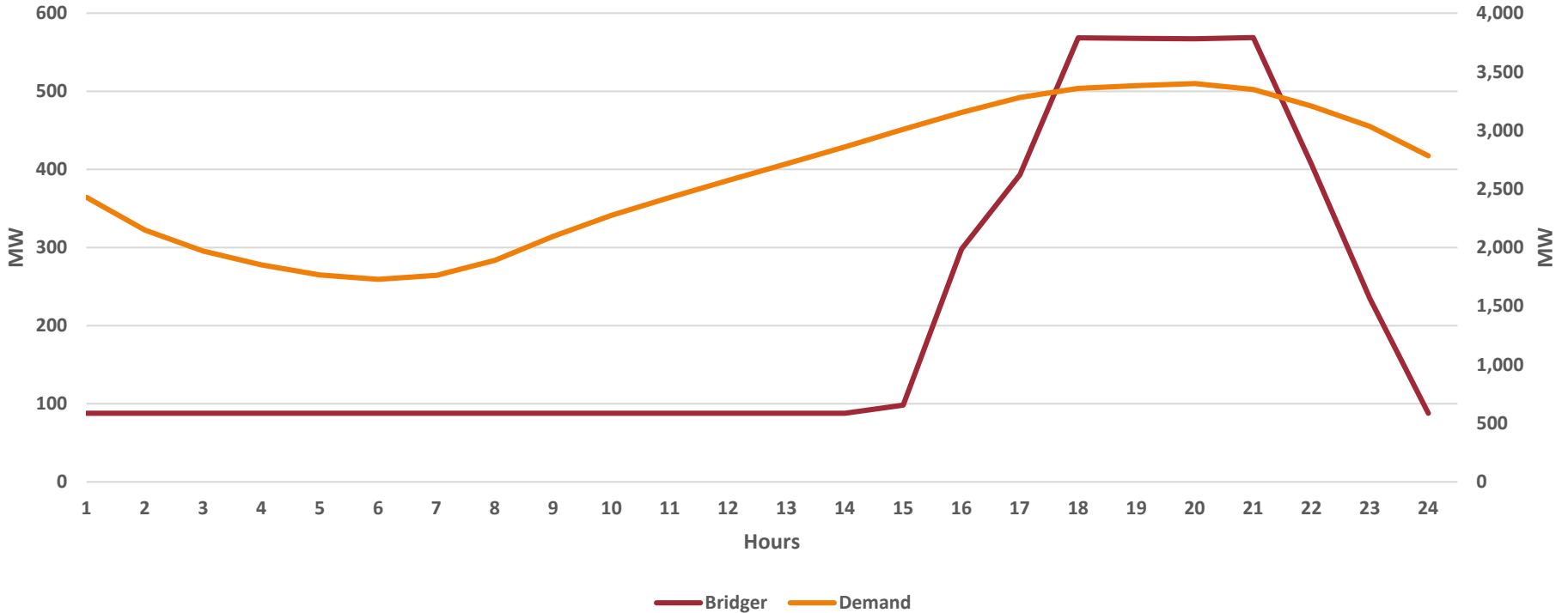
Aurora Dispatch Example

(Run of River)



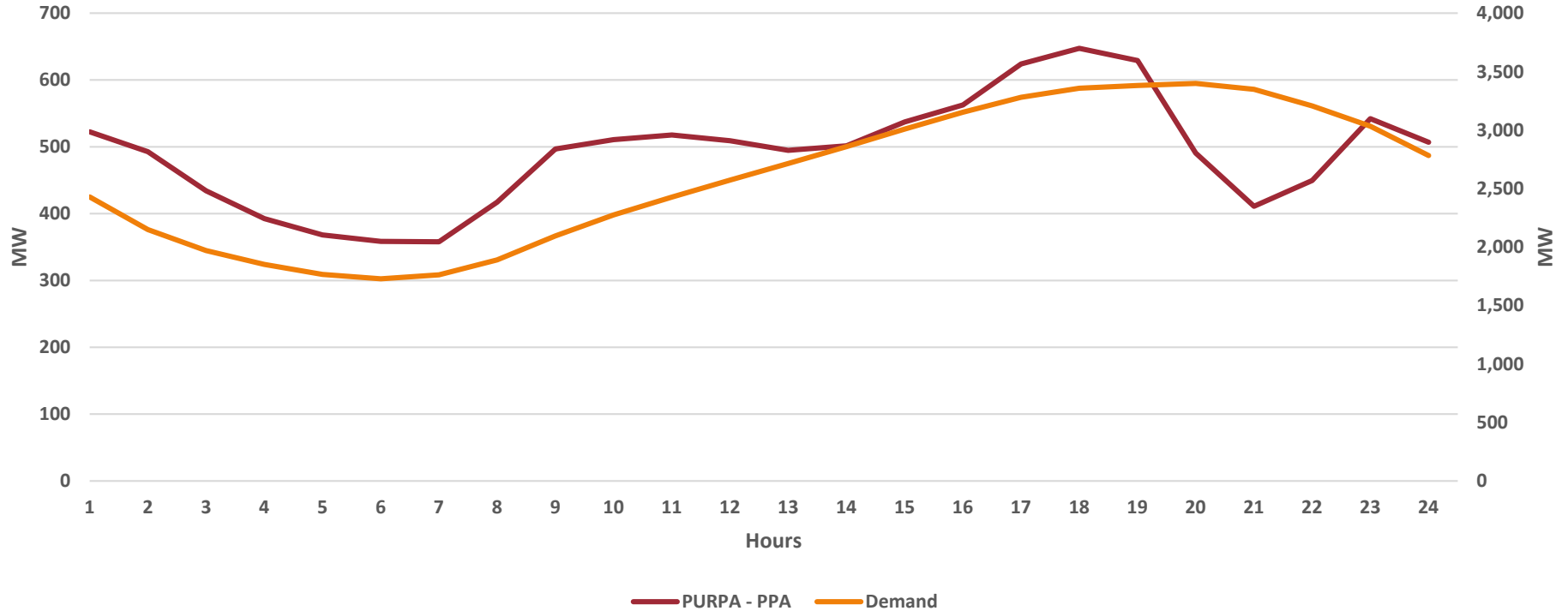
Aurora Dispatch Example

(Jim Bridger)



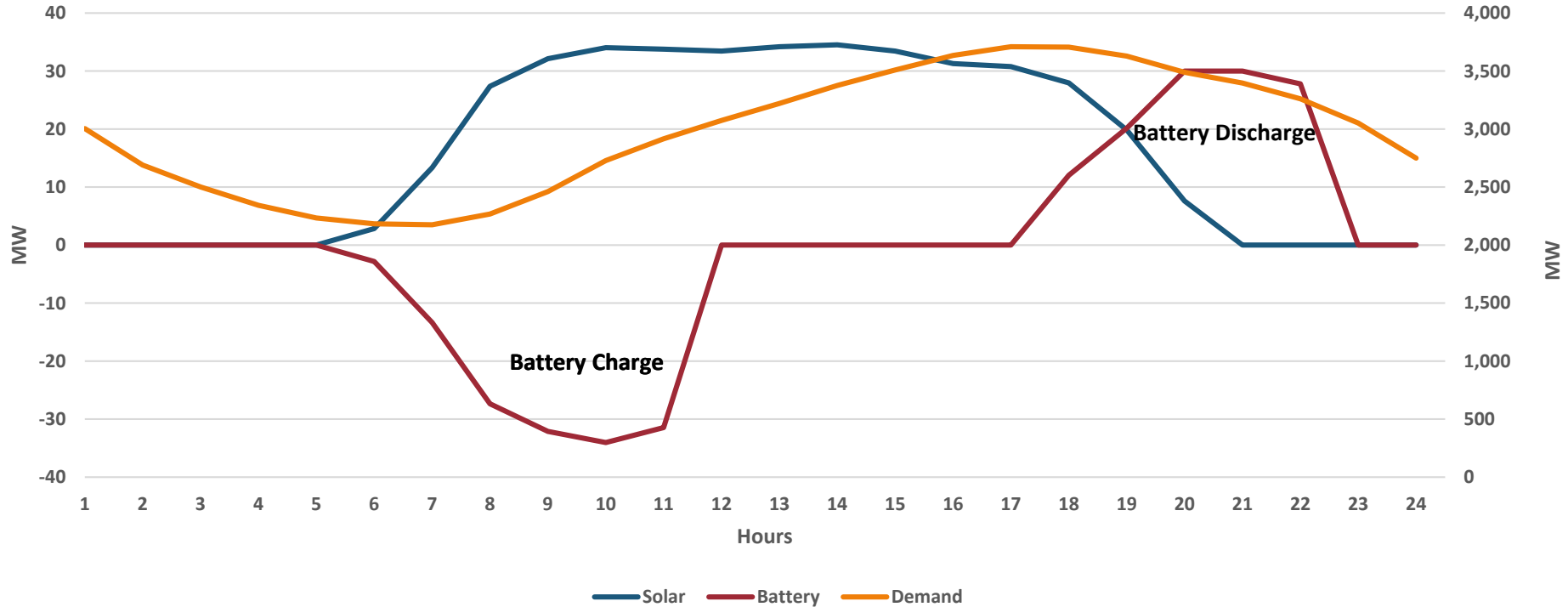
Aurora Dispatch Example

(PURPA – PPA)



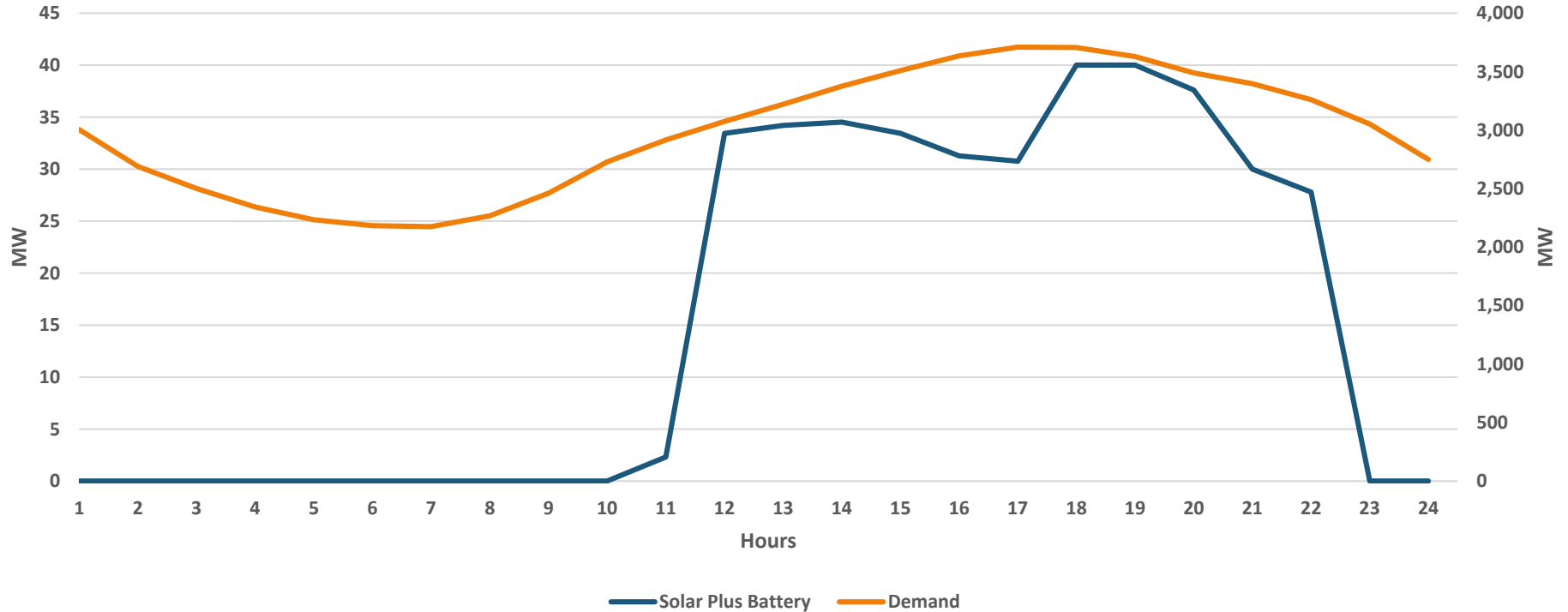
Aurora Dispatch Example

(Solar – Battery)



Aurora Dispatch Example

(Solar – Battery Combined)



Model Verification-Validation



- Flow-through inputs are checked for accuracy.
- Examples of flow-through inputs:
 - Load forecast
 - Hydro generation
 - Natural gas prices
 - Coal prices
 - PURPA/PPA
 - New resource assumptions
- **Inputs must equal outputs**

Model Verification-Validation Example

(Load Forecast)

Aurora Output					0
Time_Period	Report_Year	Item	Energy	Input	Differences
2021_01_01 Hr 01		2021 Total	1,591	1,591	(0.00)
2021_01_01 Hr 02		2021 Total	1,591	1,591	0.00
2021_01_01 Hr 03		2021 Total	1,487	1,487	(0.00)
2021_01_01 Hr 04		2021 Total	1,474	1,474	(0.00)
2021_01_01 Hr 05		2021 Total	1,464	1,464	0.00
2021_01_01 Hr 06		2021 Total	1,511	1,511	(0.00)
2021_01_01 Hr 07		2021 Total	1,579	1,579	(0.00)
2021_01_01 Hr 08		2021 Total	1,696	1,696	(0.00)
2021_01_01 Hr 09		2021 Total	1,798	1,798	0.00
2021_01_01 Hr 10		2021 Total	1,875	1,875	0.00
2021_01_01 Hr 11		2021 Total	1,916	1,916	(0.00)
2021_01_01 Hr 12		2021 Total	1,912	1,912	(0.00)



Long-Term Capacity Expansion (LTCE)

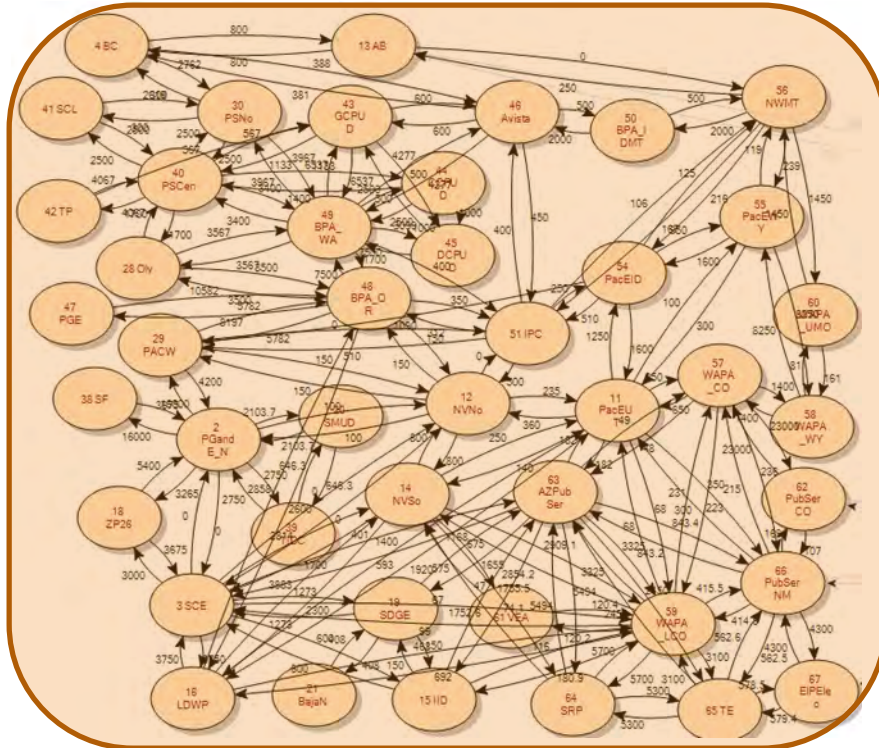
LTCE Description



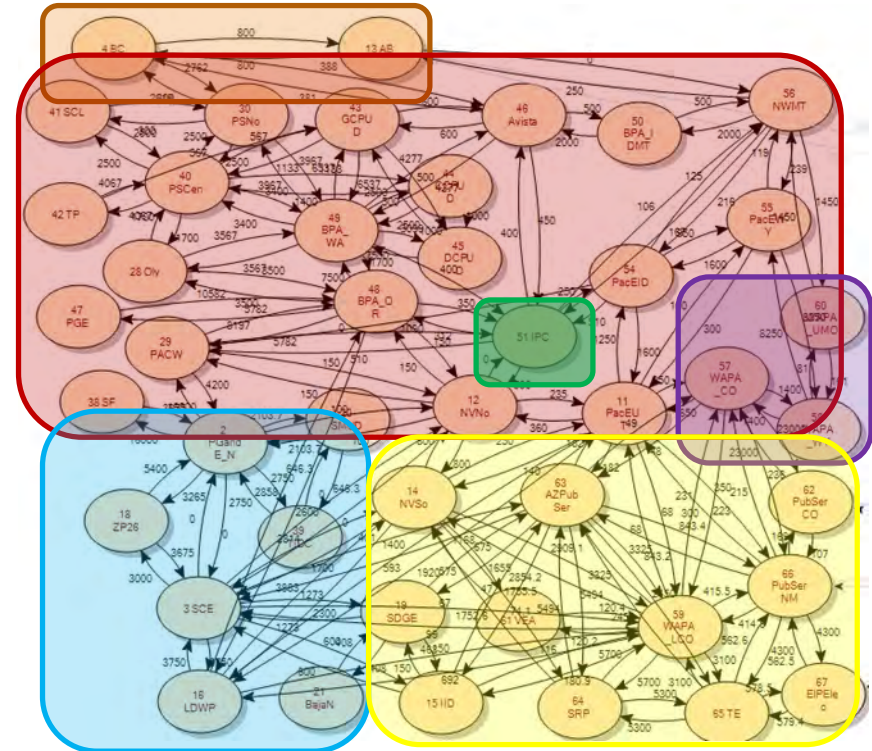
- Resources are built or retired based on the following:
 - Load and resource balance analysis
 - Planning margin requirements
 - Economics
 - Future/existing resource costs
 - Constraints
 - RPS requirements
 - Regulation requirements
 - Etc.

LTCE Differences

2019 IRP



2021 IRP



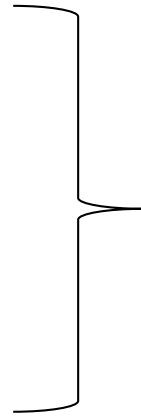
Load and Resource Balance Analysis



+ Supply

- Demand

= Surplus / (Deficiency)



+ Existing and future resources

+ Existing and future transmission capacity

- Load forecast

= Surplus / (Deficiency)

Load and Resource Balance Analysis Adjusted for Planning Margin

+ Supply

- Demand

= Surplus / (Deficiency)

Demand = Demand * Planning Margin

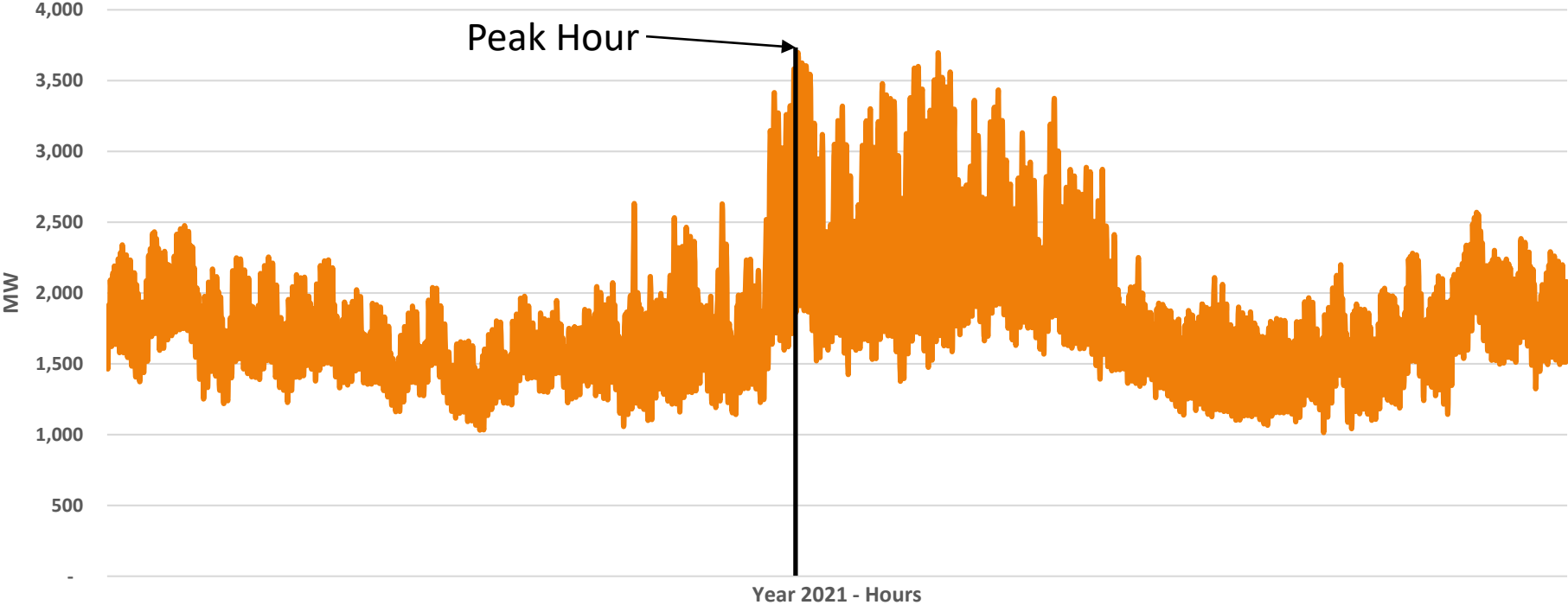
Example

Demand = 3,500 MW

Planning margin = 15%

Planning margin requirement = **4,025 MW**

Demand - Year 2021



Economics/Constraints



- Need determined from load and resource balance
 - New and existing resources are ranked on cost.
 - Resources are added or retired based on cost and resource attributes.
 - Constraints can alter resource selections.
 - RPS requirements
 - Emission constraints

LTCE Simulation



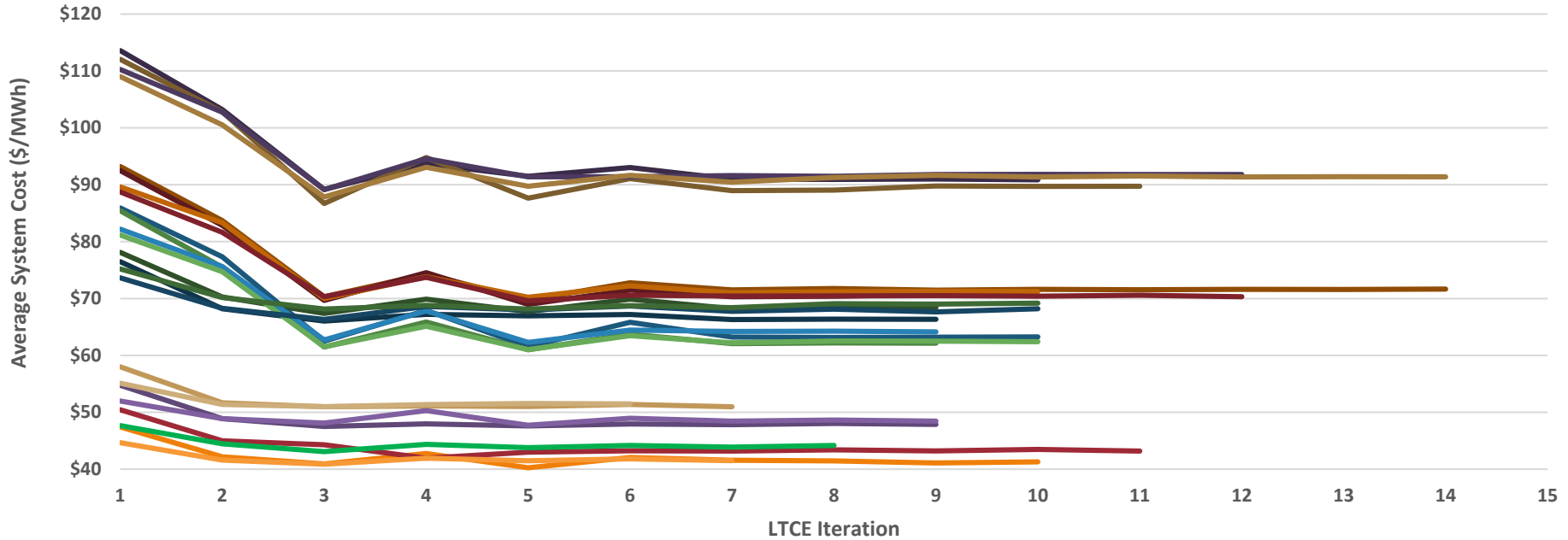
- Step 1 – Load and resource balance analysis performed
- Step 2 – New/existing resource valuation created
- Step 3 – New/existing resources added/removed for first LTCE
- Step 4 – First LTCE iteration starts
 - Zonal simulation sampling is used for Average System Cost calculations.
 - All hours, one week per month, 20 years
- Step 5 – Repeat steps 3 and 4 (using different resource combinations) until a minimum of five iterations are performed.
- Final step – convergence

Convergence



- Convergence requirements:
 - Average System Cost between iterations must be within study precision level.
 - Resource additions or retirements between iterations must be similar.
 - If large changes are occurring, model convergence doesn't occur, even if the precision level is met.

2019 IRP System Convergence



- P1
- P2
- P3
- P4
- P5
- P6
- P7
- P8
- P9
- P10
- P11
- P12
- P13
- P14
- P15
- P16
- P17
- P18
- P19
- P20
- P21
- P22
- P23
- P24

System Convergence



- Final LT iteration creates a Resource Modifier Table (RMT) within Aurora.
- RMT is used to adjust the default WECC database.
 - New resource additions
 - Existing resource retirements
- Every LTCE creates an RMT.

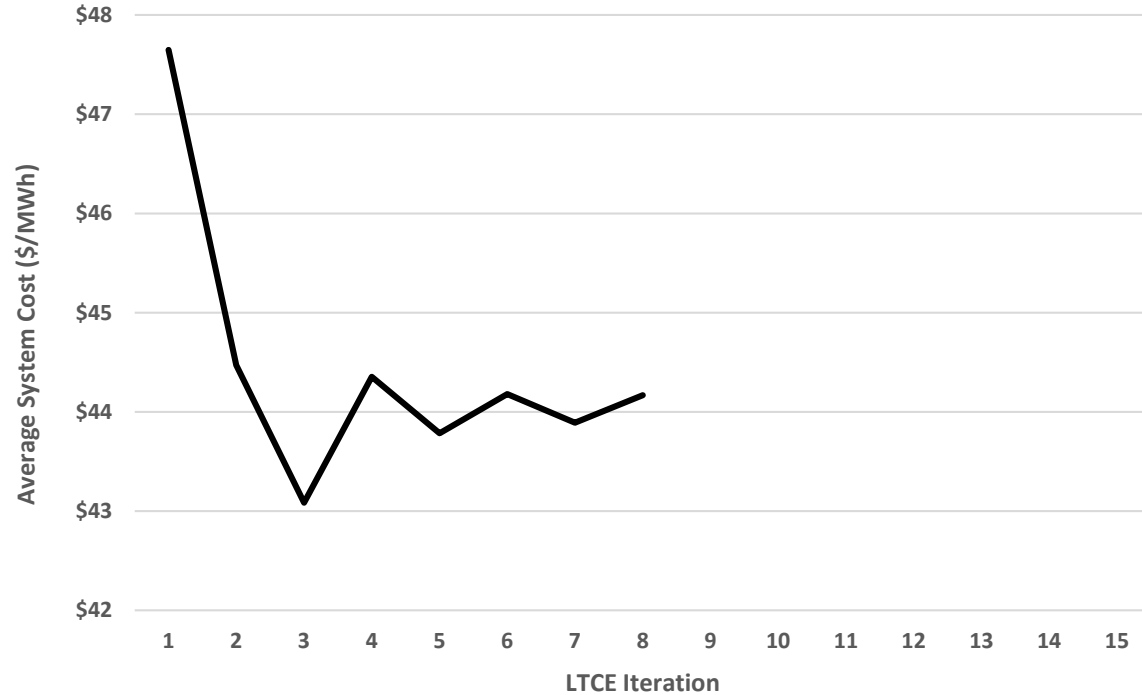


2019 IRP Results

LTCE WECC Portfolio 14 ("Planning Gas – Planning Carbon")

Convergence

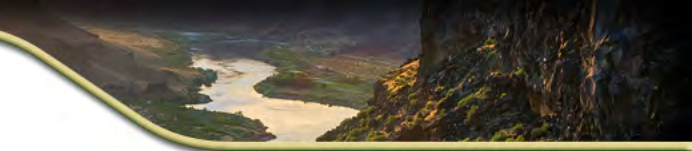
LTCE WECC Portfolio 14



<u>LT Iteration</u>	<u>Average System Cost</u>	<u>Change</u>
1	\$47.65	
2	\$44.47	-6.67%
3	\$43.09	-3.12%
4	\$44.35	2.94%
5	\$43.79	-1.28%
6	\$44.18	0.90%
7	\$43.89	-0.65%
8	\$44.17	0.63%

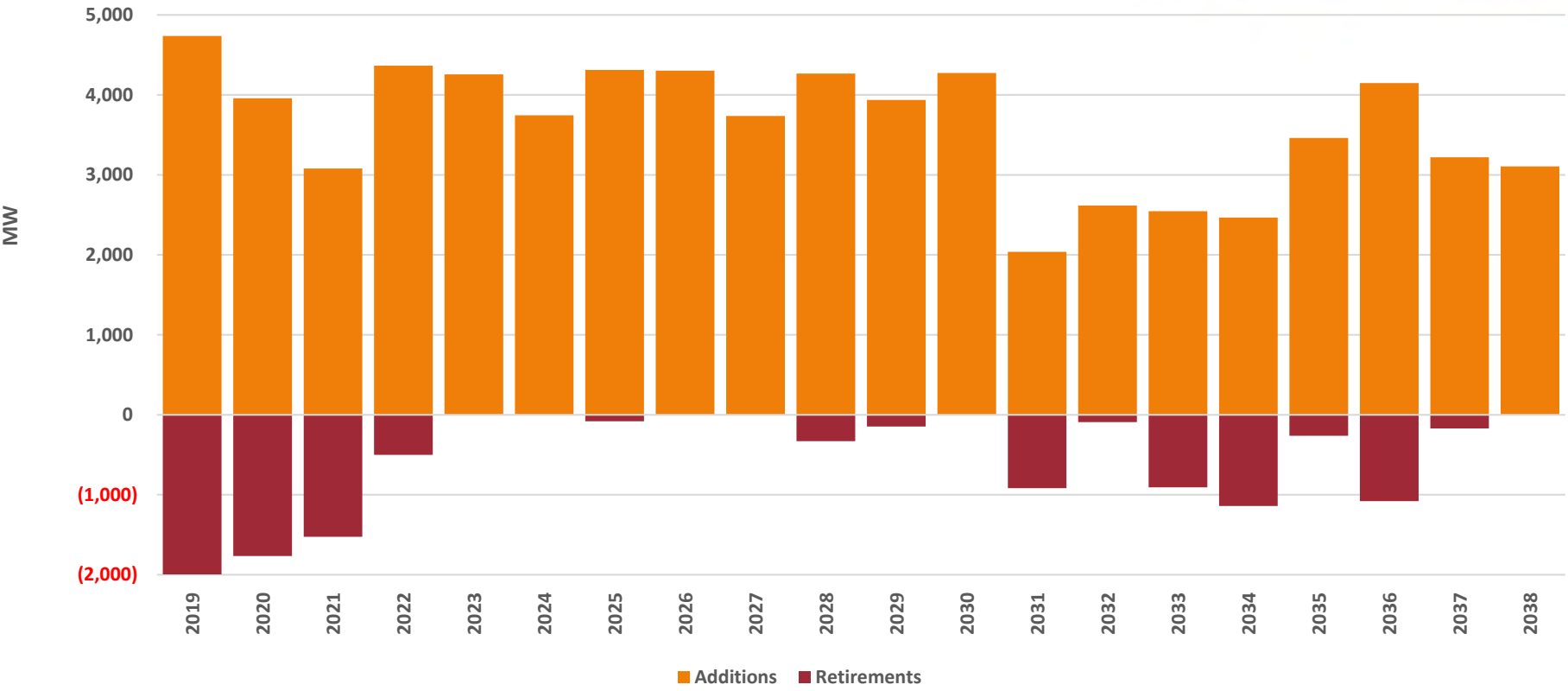
Resource Selection

LTCE WECC Portfolio 14



(MW) Iteration	Gas		Solar		Battery		DR		Bridger	
	Add	UnAdd	Add	UnAdd	Add	UnAdd	Add	UnAdd	Retire	Change
1	411	0	535	0	80	0	35	0	0	0
2									177	0
3	111	111	240	335			10	0	0	177
4										
5										
6	300	111	0	120						
7										
8										
Total	600		320		80		45		177	

WECC Buildout – LTCE WECC P14



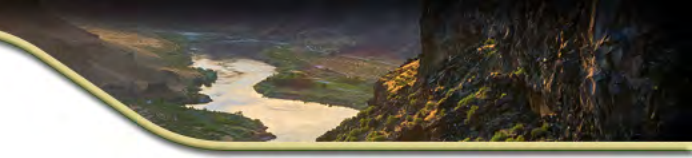
WECC Buildout – LTCE WECC P14



WECC Buildout Summary

LTCE WECC Portfolio 14

- Total additions = 72,505 MW
 - Renewables = 38,125 MW
 - Non-renewables = 34,380 MW
- Total retirements = (11,443 MW)
 - Renewables = (2 MW)
 - Non-renewables = (11,441 MW)
- **Net position – 61,062 MW**



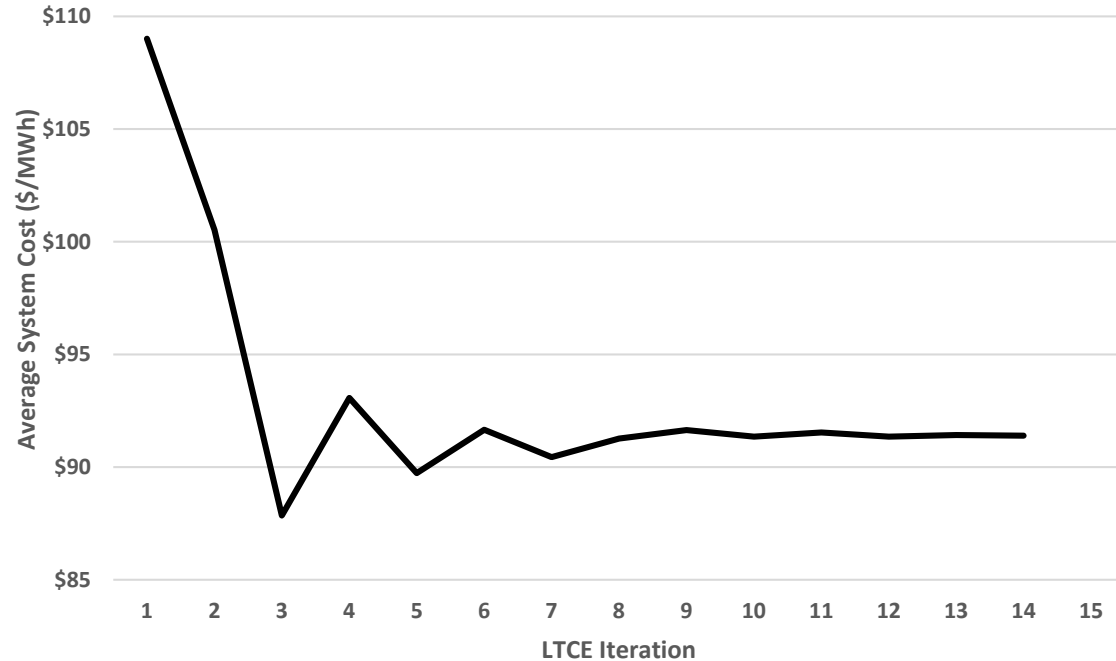


2019 IRP Results

LTCE WECC Portfolio 24
 (“High Gas – High Carbon”)

Convergence

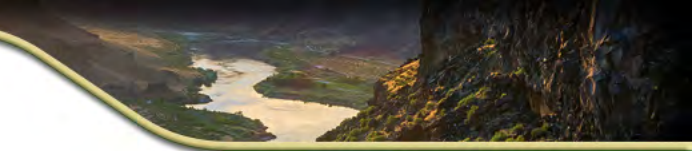
LTCE WECC Portfolio 24



<u>LT Iteration</u>	<u>Average System Cost</u>	<u>Change</u>
1	\$109.01	
2	\$100.53	-7.78%
3	\$87.85	-12.61%
4	\$93.07	5.94%
5	\$89.73	-3.59%
6	\$91.66	2.15%
7	\$90.44	-1.33%
8	\$91.27	0.91%
9	\$91.64	0.41%
10	\$91.35	-0.32%
11	\$91.54	0.20%
12	\$91.35	-0.20%
13	\$91.42	0.07%
14	\$91.39	-0.03%

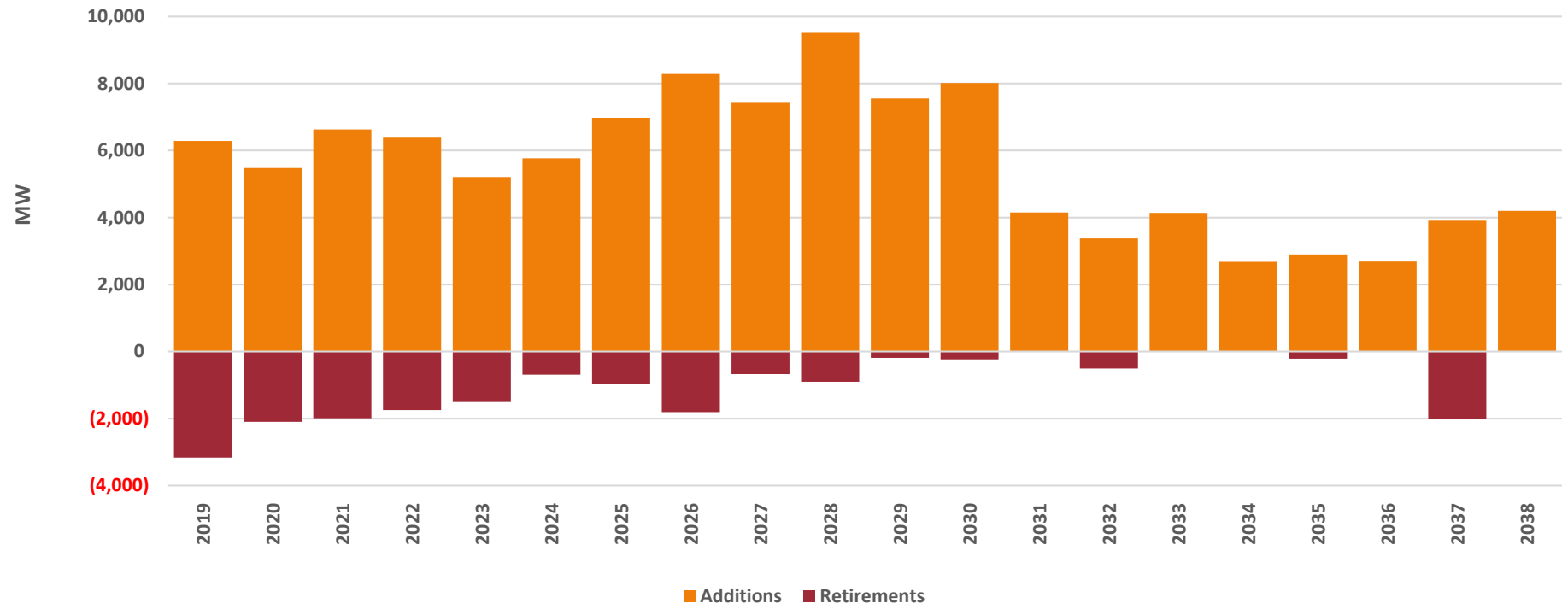
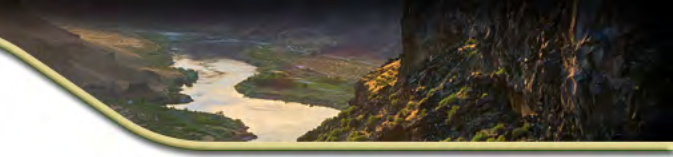
Resource Selection

LTCE WECC Portfolio 24

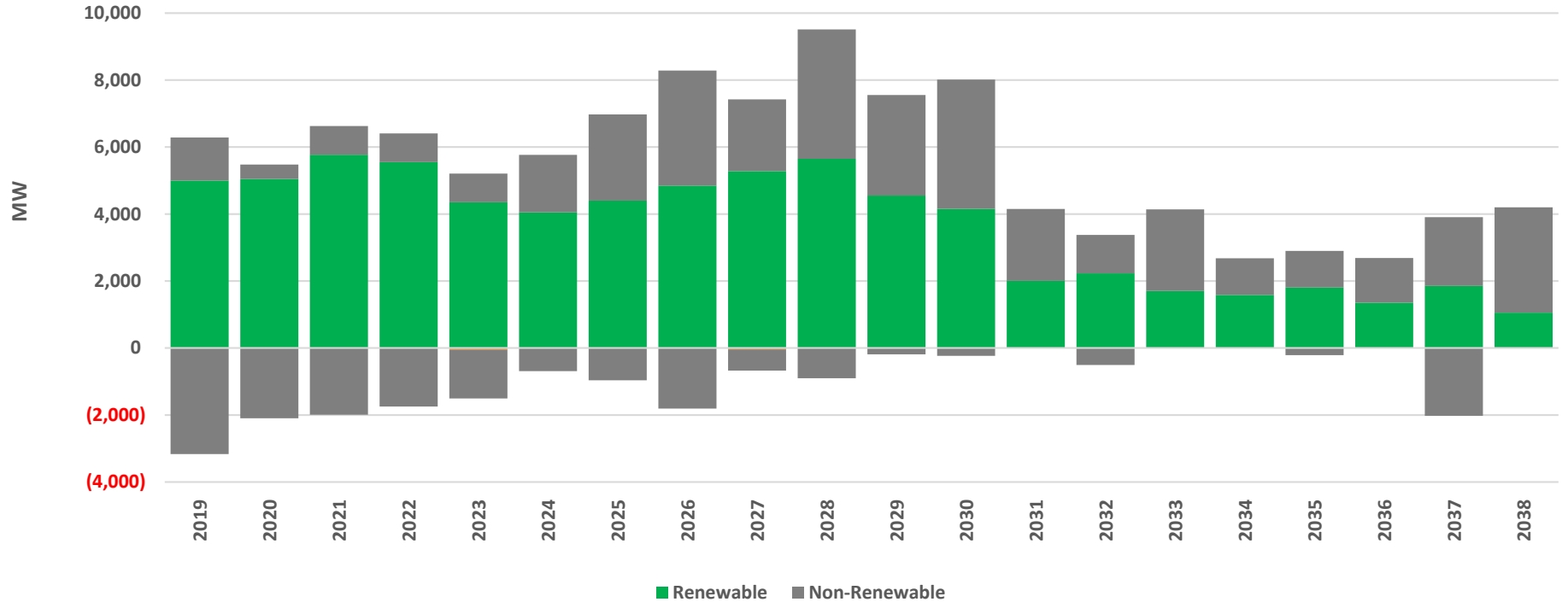


(MW) Iteration	Gas		Solar		Wind		Battery		Biomass		DR		Nuclear		Pumped Storage		Bridger	
	Add	UnAdd	Add	UnAdd	Add	UnAdd	Add	UnAdd	Add	UnAdd	Add	UnAdd	Add	UnAdd	Add	UnAdd	Retire	Change
1			495	0			30	0	60	0	30	0	420	0				
2	300	0	850	455	1100	0	0	30	180	30	15	0	0	240			528	0
3			925	770	0	900	100	0	0	210	0	45	0	180	500	0	180	177
4	0	300	40	80	100	0	0	20			20	0						
5																		
6			40	0	300	0			120	0	0	5					0	177
7					500	0												
8					0	200			0	30	0	15						
9																		
10																		
11																		
12					200	0			30	60								
13					100	0			0	30								
Total	0		1045		1200		80		30		0		0		500		708	

WECC Buildout – LTCE WECC P24



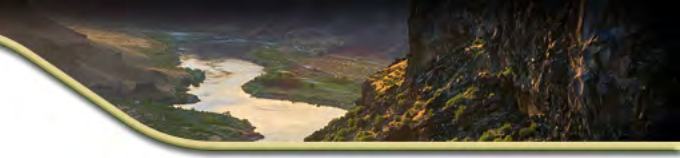
WECC Buildout – LTCE WECC P24



WECC Buildout Summary

LTCE WECC Portfolio 24

- Total additions = 111,579 MW
 - Renewables = 72,250 MW
 - Non-renewables = 39,329 MW
- Total retirements = (18,720 MW)
 - Renewables = (102 MW)
 - Non-renewables = (18,619 MW)
- **Net position – 92,859 MW**



WECC Buildout Comparison



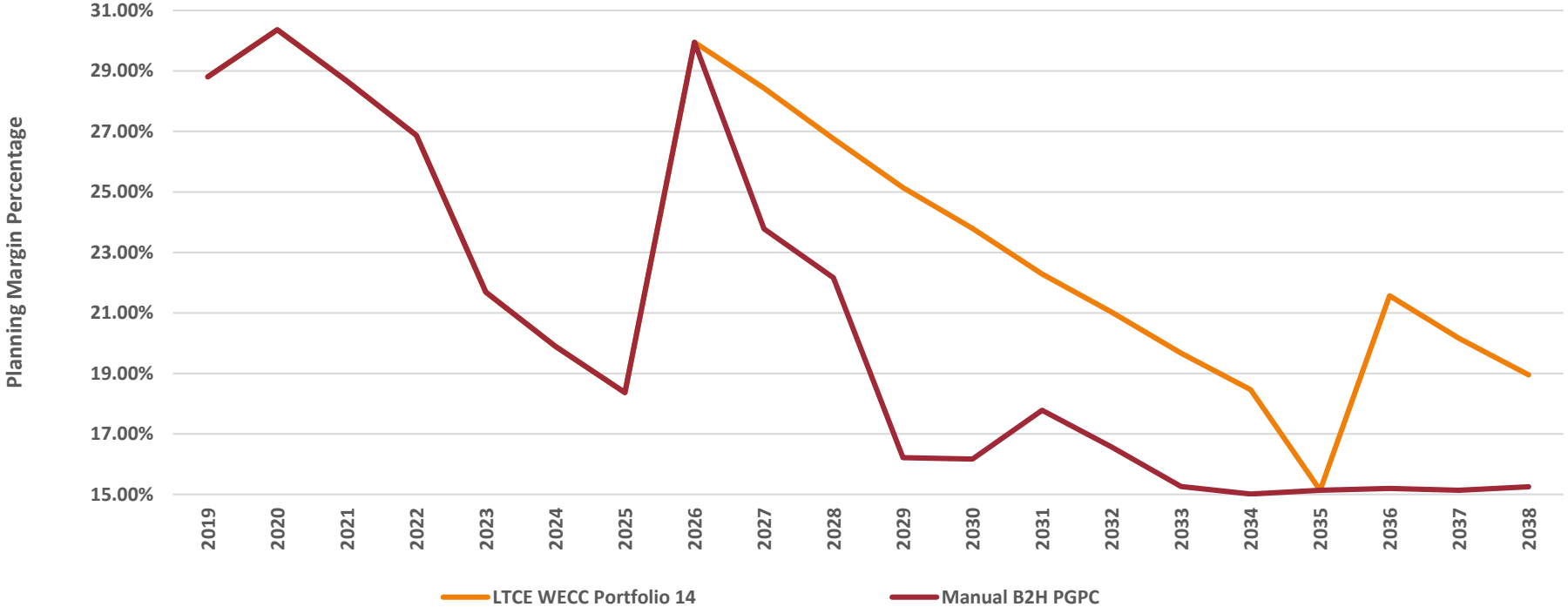
(MW)	LTCE WECC Portfolio 14	LTCE WECC Portfolio 24	Differences
Total Additions	72,505	111,579	39,074
Renewables	38,125	72,250	34,125
Non-Renewables	34,380	39,329	4,949
Total Retirements	(11,443)	(18,720)	(7,277)
Renewables	(2)	(102)	(100)
Non-Renewables	(11,441)	(18,619)	(7,178)
Net Position	61,062	92,859	31,797

LTCE vs Manual Process

Reserve Margin: 15%				LTCE WECC Portfolio 14		Manual B2H PGPC	
Time_Period	Peak Demand	Resource Peak	Import Capacity	Surplus /	Planning Margin	Surplus /	Planning Margin
	MW	Capacity	with B2H	Deficiency		Deficiency	
	MW	MW	MW	MW	MW	MW	MW
2019	3,479	3,847	634	480	28.81%	480	28.81%
2020	3,528	3,736	863	542	30.36%	542	30.36%
2021	3,576	3,678	923	489	28.67%	489	28.67%
2022	3,627	3,678	923	430	26.87%	430	26.87%
2023	3,677	3,678	923	246	21.69%	246	21.69%
2024	3,732	3,678	923	183	19.89%	183	19.89%
2025	3,780	3,678	923	127	18.37%	127	18.37%
2026	3,825	3,543	1,554	572	29.95%	572	29.95%
2027	3,871	3,543	1,554	520	28.43%	340	23.78%
2028	3,918	3,538	1,554	461	26.76%	281	22.16%
2029	3,966	3,536	1,554	402	25.14%	48	16.22%
2030	4,012	3,534	1,554	353	23.79%	47	16.17%
2031	4,058	3,525	1,554	296	22.29%	113	17.78%
2032	4,103	3,523	1,554	247	21.03%	64	16.57%
2033	4,146	3,515	1,554	194	19.67%	11	15.26%
2034	4,193	3,515	1,554	145	18.46%	0	15.01%
2035	4,242	2,807	1,554	6	15.14%	6	15.14%
2036	4,291	2,807	1,554	282	21.57%	8	15.20%
2037	4,340	2,800	1,554	224	20.16%	6	15.13%
2038	4,389	2,800	1,554	173	18.95%	11	15.25%

LTCE vs Manual Process

(continued)



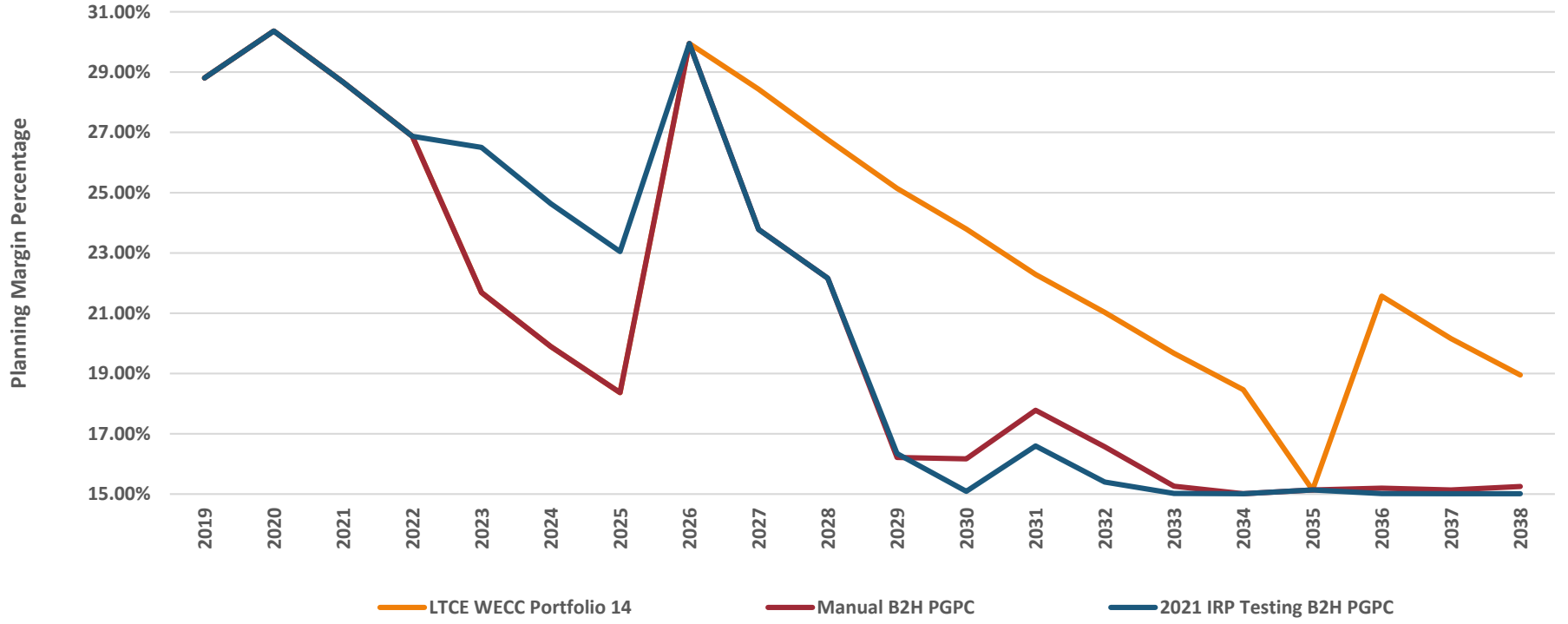
2021 IRP LTCE Testing

Reserve Margin: 15%				LTCE WECC Portfolio 14		Manual B2H PGPC		2021 IRP Testing B2H PGPC *	
Time_Period	Peak Demand MW	Resource Peak Capacity MW	Import Capacity with B2H MW	Surplus / Deficiency MW	Planning Margin MW	Surplus / Deficiency MW	Planning Margin MW	Surplus / Deficiency MW	Planning Margin MW
2019	3,479	3,847	634	480	28.81%	480	28.81%	480	28.81%
2020	3,528	3,736	863	542	30.36%	542	30.36%	542	30.36%
2021	3,576	3,678	923	489	28.67%	489	28.67%	489	28.67%
2022	3,627	3,678	923	430	26.87%	430	26.87%	430	26.87%
2023	3,677	3,678	923	246	21.69%	246	21.69%	423	26.50%
2024	3,732	3,678	923	183	19.89%	183	19.89%	360	24.64%
2025	3,780	3,678	923	127	18.37%	127	18.37%	304	23.05%
2026	3,825	3,543	1,554	572	29.95%	572	29.95%	572	29.95%
2027	3,871	3,543	1,554	520	28.43%	340	23.78%	340	23.78%
2028	3,918	3,538	1,554	461	26.76%	281	22.16%	281	22.16%
2029	3,966	3,536	1,554	402	25.14%	48	16.22%	53	16.34%
2030	4,012	3,534	1,554	353	23.79%	47	16.17%	4	15.09%
2031	4,058	3,525	1,554	296	22.29%	113	17.78%	65	16.60%
2032	4,103	3,523	1,554	247	21.03%	64	16.57%	16	15.40%
2033	4,146	3,515	1,554	194	19.67%	11	15.26%	1	15.02%
2034	4,193	3,515	1,554	145	18.46%	0	15.01%	0	15.01%
2035	4,242	2,807	1,554	6	15.14%	6	15.14%	6	15.14%
2036	4,291	2,807	1,554	282	21.57%	8	15.20%	1	15.02%
2037	4,340	2,800	1,554	224	20.16%	6	15.13%	0	15.01%
2038	4,389	2,800	1,554	173	18.95%	11	15.25%	1	15.01%

Note: Initial Testing for 2021 IRP using 2019 IRP Inputs with the newest Aurora version.

2021 IRP LTCE Testing

(continued)





The End...