Northwest **Power** and **Conservation** Council

January 4, 2017

MEMORANDUM

TO: **Council Members**

FROM: **John Ollis, Power System Analyst**

SUBJECT: **Background on AURORAxmp model**

BACKGROUND:

Presenter: John Ollis, Ben Kujala

Summary: This presentation will be a primer on the AURORAxmp model and how it fits into the Council's modeling ecosystem.

Relevance: The AURORAxmp model is used periodically to produce the Council's Wholesale Electricity Price Forecast and to support the Marginal Carbon Emissions Study. In addition, AURORAxmp has been used in the past to support other analyses such as the Balancing and Flexibility study in the 7th Power Plan.

Workplan: N/A

Background: Traditionally, power planning entities have needed to have some idea of the future price of electricity to determine if buying power from the market, or purchasing new resources is a good idea. To create a fundamentals-based, wholesale electricity price forecast that reflects actual power system operation, relationships of supply and demand for, and transmission of electricity must be considered. In addition, underlying a wholesale electricity price forecast in this region would be an

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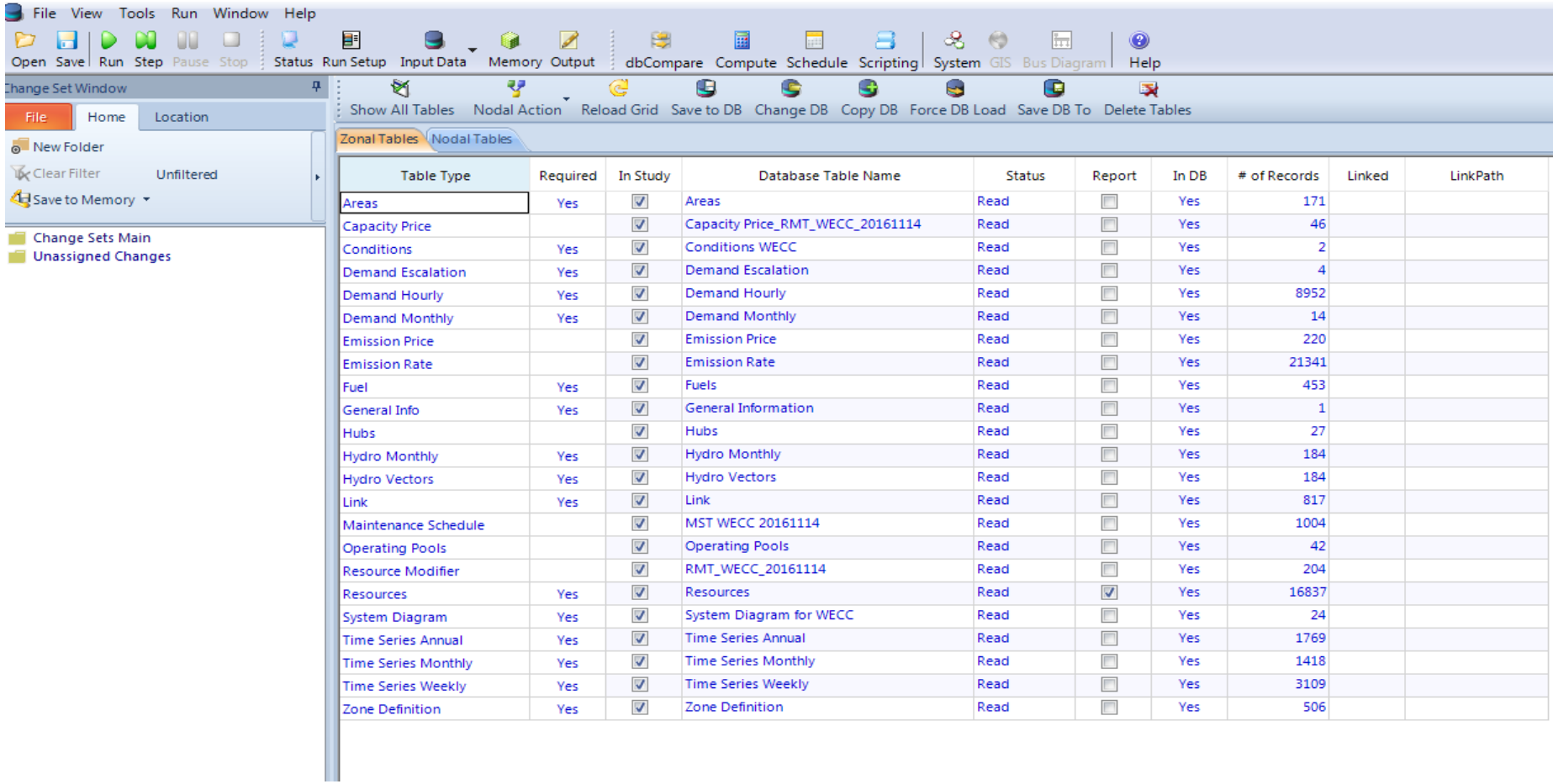
understanding of the operating characteristics of future and existing supply and demand-side resources, as well as unit commitment, ancillary services, fuel prices, hydro, wind and solar conditions.
AURORAxmp captures many of these characteristics of the power system well and has a periodically updated WECC database, and thus, AURORAxmp has been the Council's wholesale market electricity price forecasting model. Since the wholesale electricity price is determined by the variable costs of the most expensive, available supply or demand-side resource necessary to meet the load, the Council can also use AURORAxmp, to determine the average CO2 emissions of marginal unit.

More Info: 2013 Wholesale Electricity Price Forecast:
https://www.nwcouncil.org/media/6829307/wholesaleelectricity.pdf#page=13

2008 Marginal Carbon Emissions Study:
https://www.nwcouncil.org/media/29611/2008_08.pdf

For more information please contact John Ollis.



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Conditions	Yes	☑	Conditions WECC	Read	☐	Yes	2		
Demand Escalation	Yes	☑	Demand Escalation	Read	☐	Yes	4		
Demand Hourly	Yes	☑	Demand Hourly	Read	☐	Yes	8952		
Demand Monthly	Yes	☑	Demand Monthly	Read	☐	Yes	14		
Emission Price		☑	Emission Price	Read	☐	Yes	220		
Emission Rate		☑	Emission Rate	Read	☐	Yes	21341		
Fuel	Yes	☑	Fuels	Read	☐	Yes	453		
General Info	Yes	☑	General Information	Read	☐	Yes	1		
Hubs		☑	Hubs	Read	☐	Yes	27		
Hydro Monthly	Yes	☑	Hydro Monthly	Read	☐	Yes	184		
Hydro Vectors	Yes	☑	Hydro Vectors	Read	☐	Yes	184		
Link	Yes	☑	Link	Read	☐	Yes	817		
Maintenance Schedule		☑	MST WECC 20161114	Read	☐	Yes	1004		
Operating Pools		☑	Operating Pools	Read	☐	Yes	42		
Resource Modifier		☑	RMT_WECC_20161114	Read	☐	Yes	204		
Resources	Yes	☑	Resources	Read	☑	Yes	16837		
System Diagram	Yes	☑	System Diagram for WECC	Read	☐	Yes	24		
Time Series Annual	Yes	☑	Time Series Annual	Read	☐	Yes	1769		
Time Series Monthly	Yes	☑	Time Series Monthly	Read	☐	Yes	1418		
Time Series Weekly	Yes	☑	Time Series Weekly	Read	☐	Yes	3109		
Zone Definition	Yes	☑	Zone Definition	Read	☐	Yes	506		

AURORAxmp: A Primer

Power Committee

January 10, 2017

Northwest **Power** and **Conservation** Council

AURORAxmp: The Product

- Commercial production cost model
  - Licensed by EPIS, LLC since 1997
- Broad user community:
  - Used by 600 users in 95 energy companies, from 43 countries
- Good customer service
  - User community develops and asks for enhancements

History with Council and NW

- Former Council staff (P. Schwartz) and PGE employees some of the early employees of EPIS and developers of AURORAxmp software.

- Many regional utilities use EPIS as an long-term planning support tool.

Council uses for AURORAxmp

Primary model used for two reoccurring reports:

- Marginal Carbon Emissions Study (periodic)
- Wholesale Market Electricity Price Forecast (annual)

Power Plan Inputs:

- Also used to generate data for 7th Plan:
  - Electricity Price Forecast
  - Balancing and Flexibility Study

AURORAxmp: Core Strengths

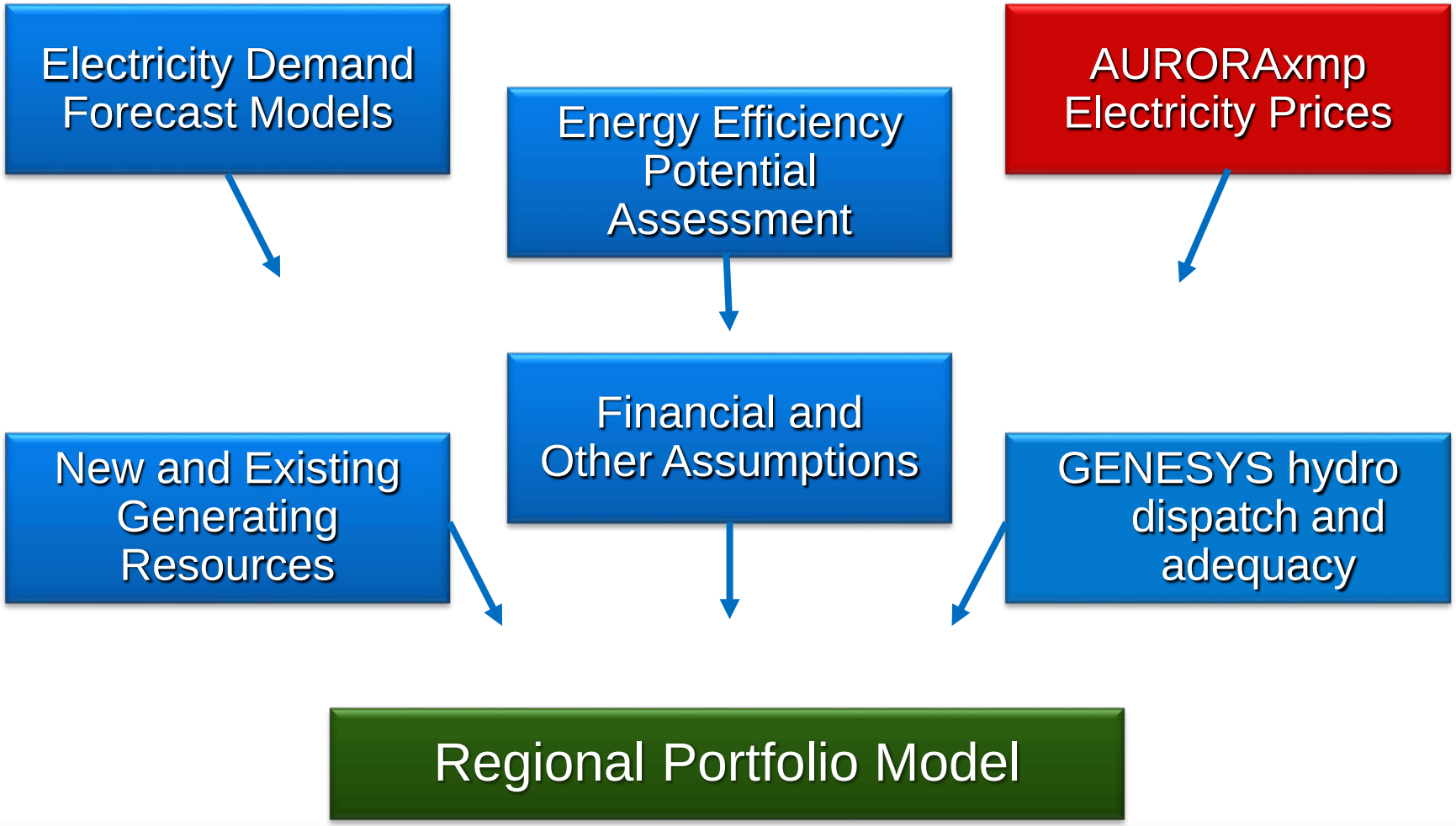
- Electric Market Price Forecasting
  - Used by Council for two reoccurring deliverables:
    - Annual Wholesale Market Price Forecast
    - Periodic Marginal Carbon Emissions Report
- Long-term Capacity Expansion Modeling
- Periodic WECC database updates
- Flexible configuration
- Good Documentation

AURORAxmp: Challenges

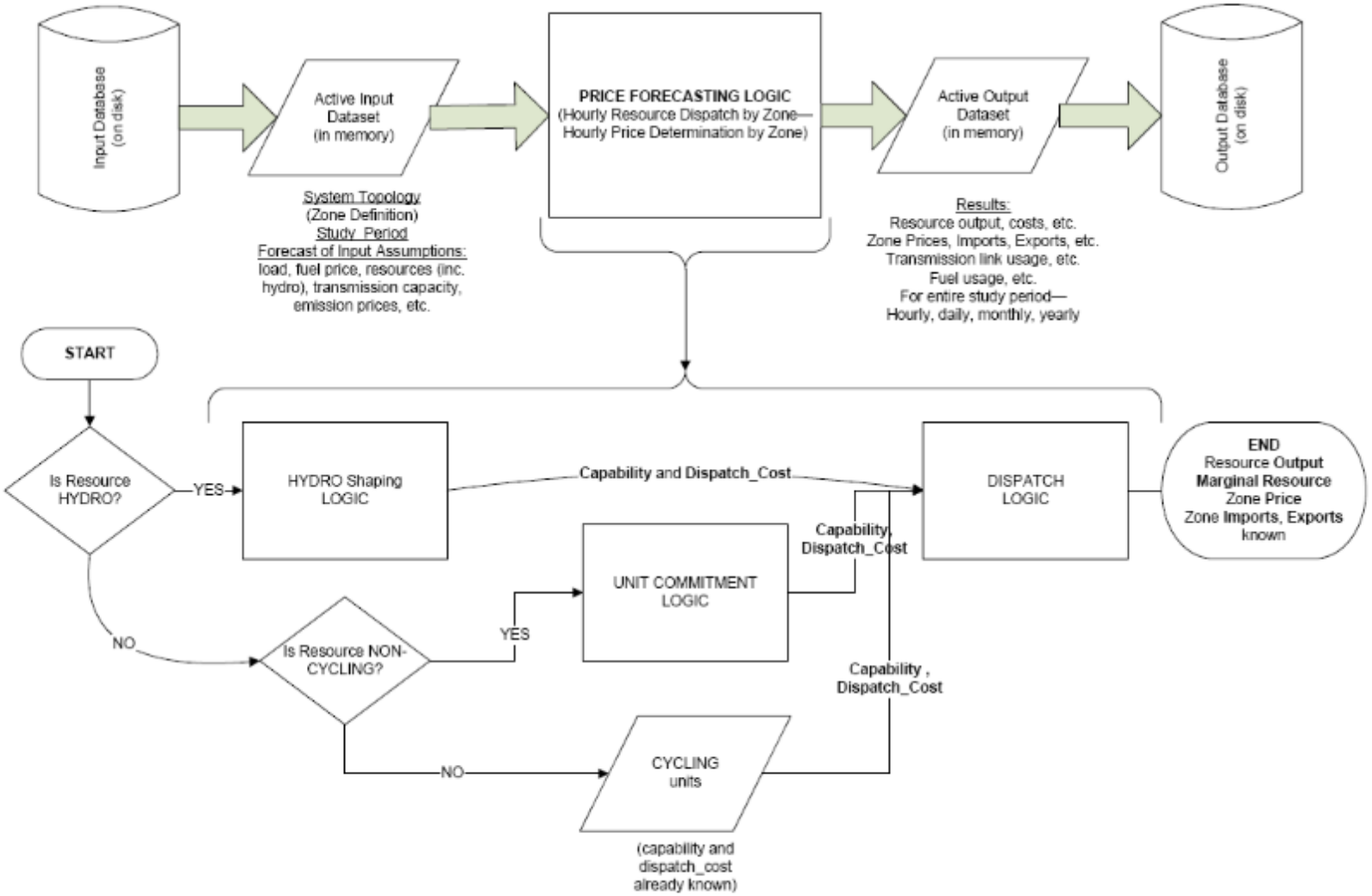
- Hydro modeling
  - Tends to over represent capability (energy and capacity) of cascading hydro systems
- Commitment of resources
  - Early testing on new version, indicates better unit commitment than in previous versions.
- Operating Reserves treatment
  - Previous version of model only accounted for contingency reserves
  - Early testing on new version, indicates major improvements on ancillary services.

Where does AURORAxmp fit?

(Not all links are shown)



AURORAxmp Flow Diagram



Input Data

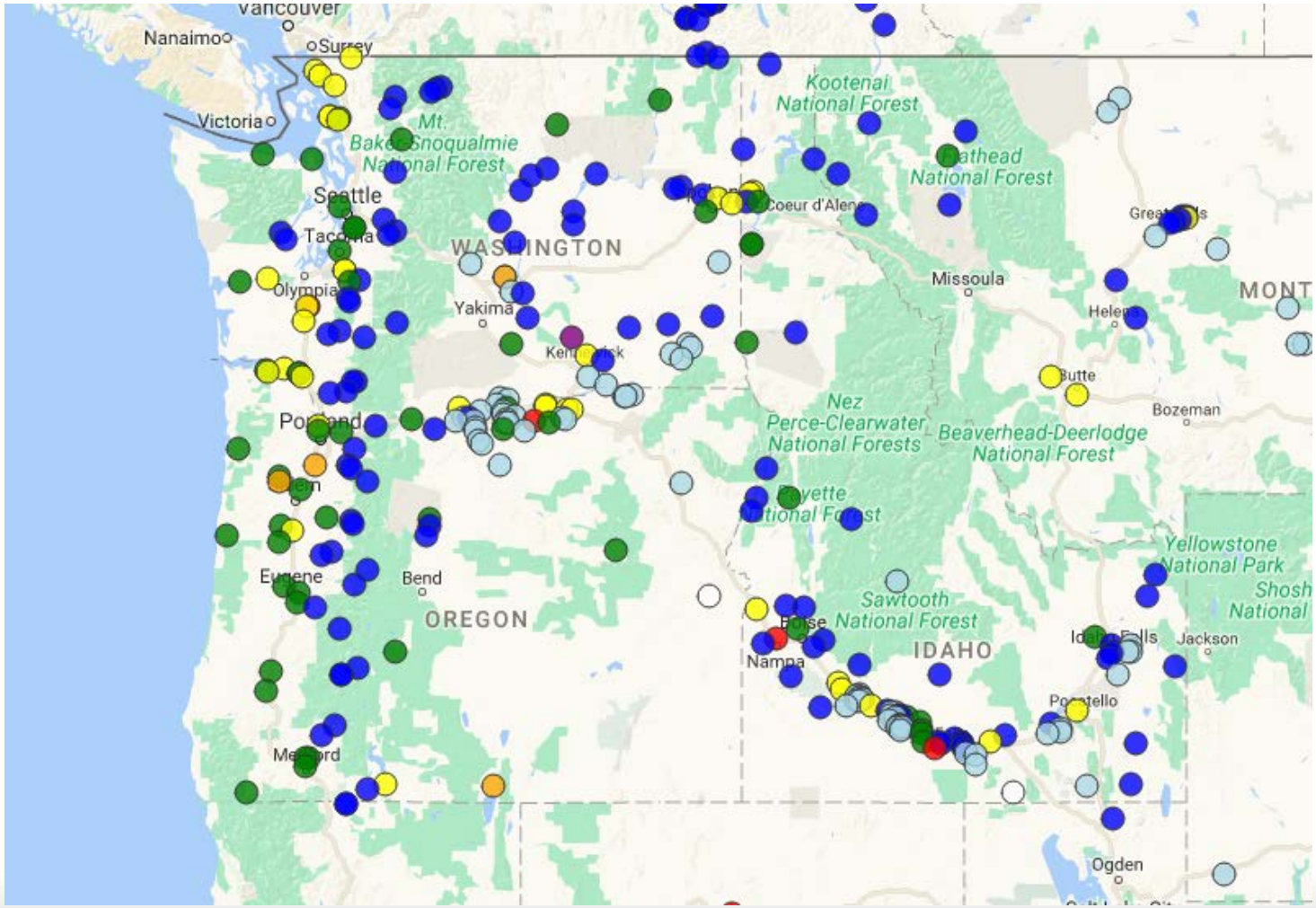
- Generating and demand-side resources
  - Hydro, thermal, storage, DR, EE
  - Physical characteristics of generators
  - Constraints: emissions, ramp limits
  - Location
- Demand by area
  - Shaping by granularity of study
- Detailed transmission between areas

AURORAxmp Topology

- Groups resources into zones based on generation and load location.
  - Resources actually grouped into areas, which are in turn grouped into zones
- The zones are represented as “bubbles”
- Group transmission into zonal links based on main transfer paths
  - Links actually connect areas.
- Links are represented as “sticks”
- The topology is represented in a “stick and bubble” diagram.

Power Generation Map for the Region

https://www.nwcouncil.org/energy/powersupply/map/



Transi
Topo
AURO

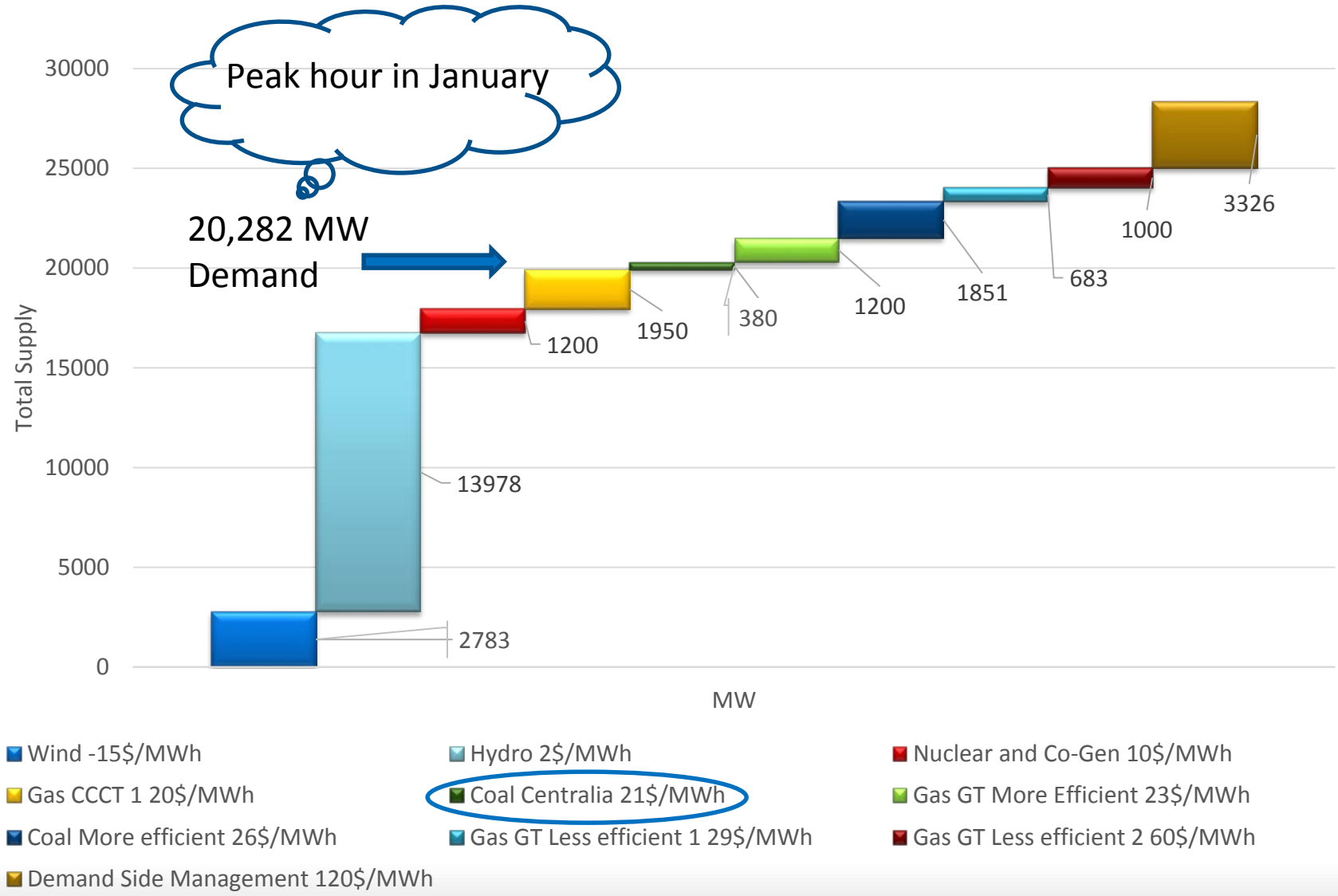
How does Aurora dispatch and unit commit?

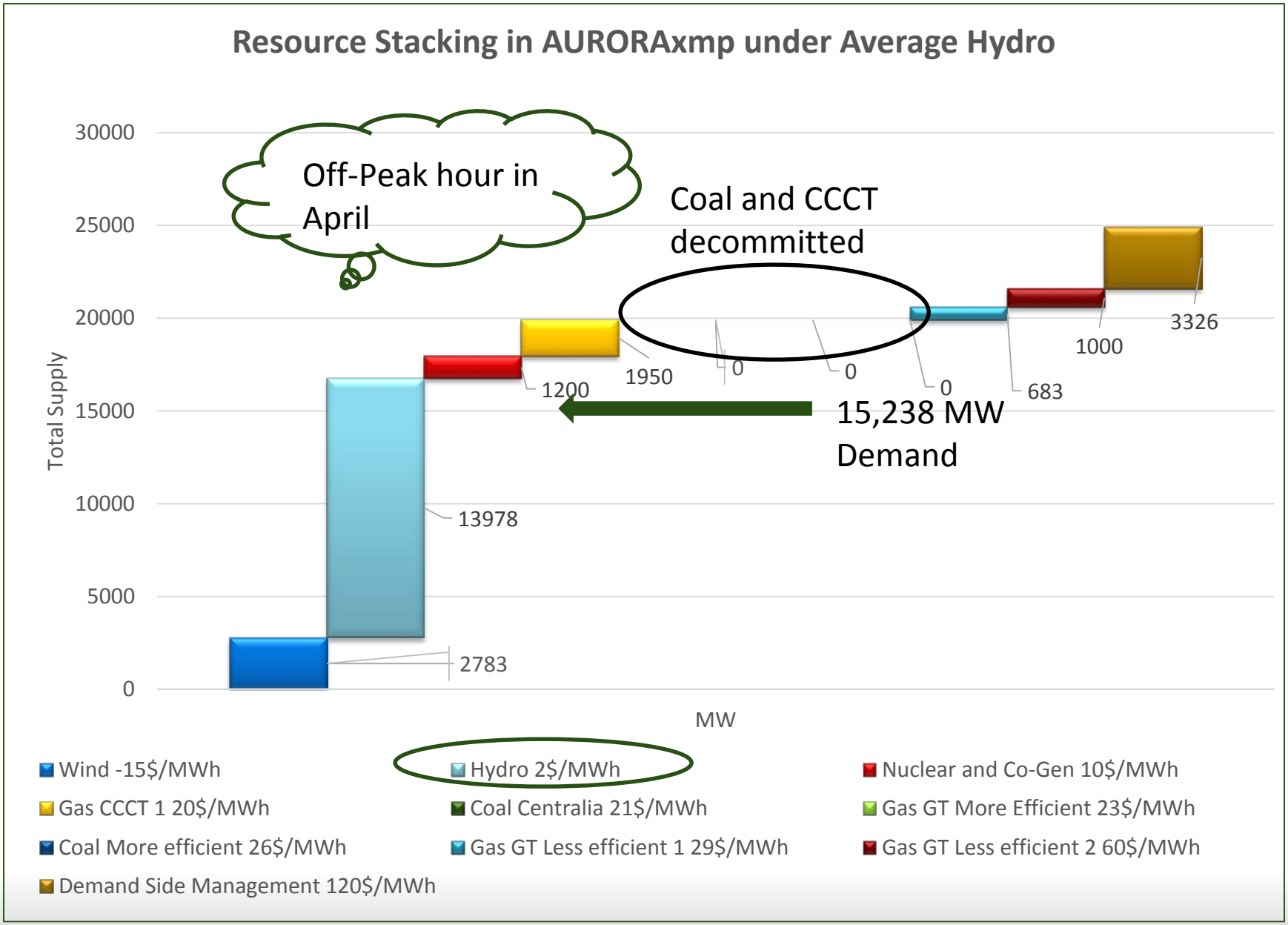
- Unit commitment for simulates operation for non-cycling units
  - Uses 168 hour look-ahead internal forecast of zonal market price
  - If projected revenue minus variable cost >0, then plant assumed to run, if available to commit.
  - If projected revenue minus variable cost <0, then plant assumed to shut-down, if available to de-commit.
- Committed, non-cycling and all cycling units are considered available for dispatch
  - Non-committed non-cycling units are not available for dispatch.

Economic Dispatch Basics

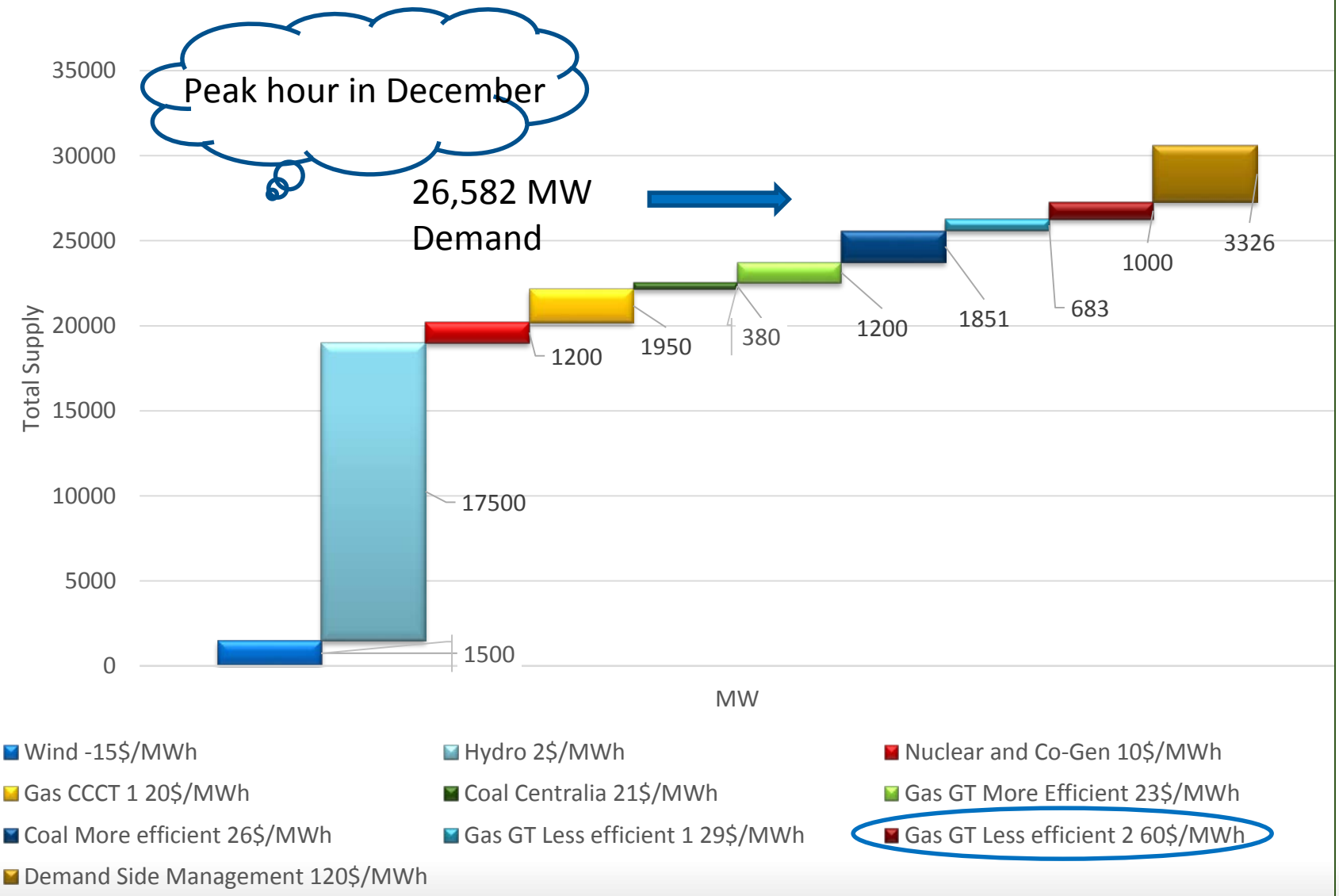
- Resources are “dispatched” according to variable cost, subject to non-cycling and minimum run constraints until hourly demand is met in each area.
- Transmission and generation constraints, losses, wheeling costs and unit start-up costs are considered in the dispatch.
- Available resources are stacked by variable cost

Resource Stacking in AURORAxmp under Average Hydro

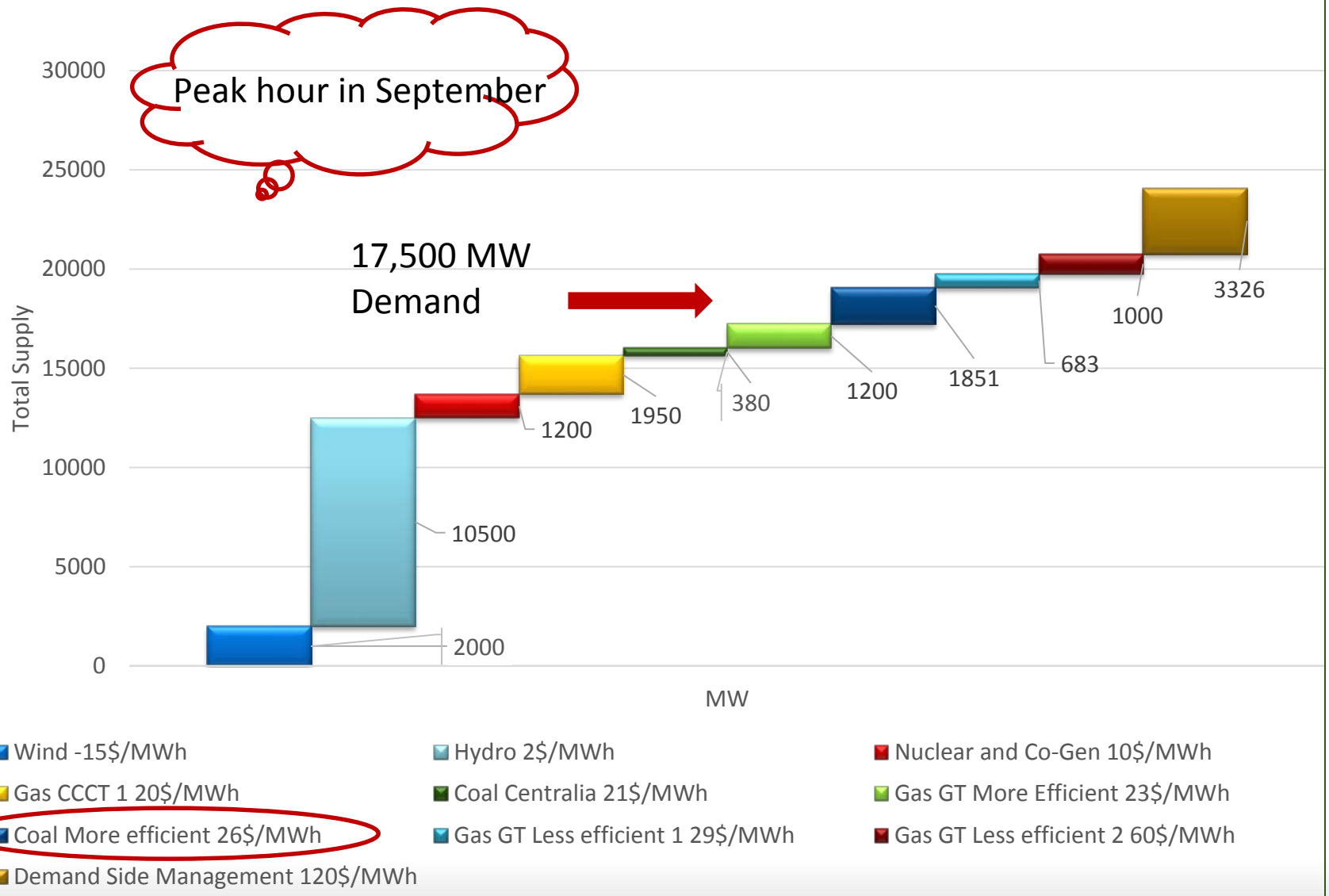



Resource Stacking in AURORAxmp under Average Hydro
Off-Peak hour in April
Coal and CCCT decommitted
15,238 MW Demand
Total Supply
30000
25000
20000
15000
10000
5000
0
13978
2783
1200
1950
0
0
0
683
1000
3326
MW
Wind -15$/MWh
Hydro 2$/MWh
Nuclear and Co-Gen 10$/MWh
Gas CCCT 1 20$/MWh
Coal Centralia 21$/MWh
Gas GT More Efficient 23$/MWh
Coal More efficient 26$/MWh
Gas GT Less efficient 1 29$/MWh
Gas GT Less efficient 2 60$/MWh
Demand Side Management 120$/MWh

Resource Stacking in AURORAxmp under High Load



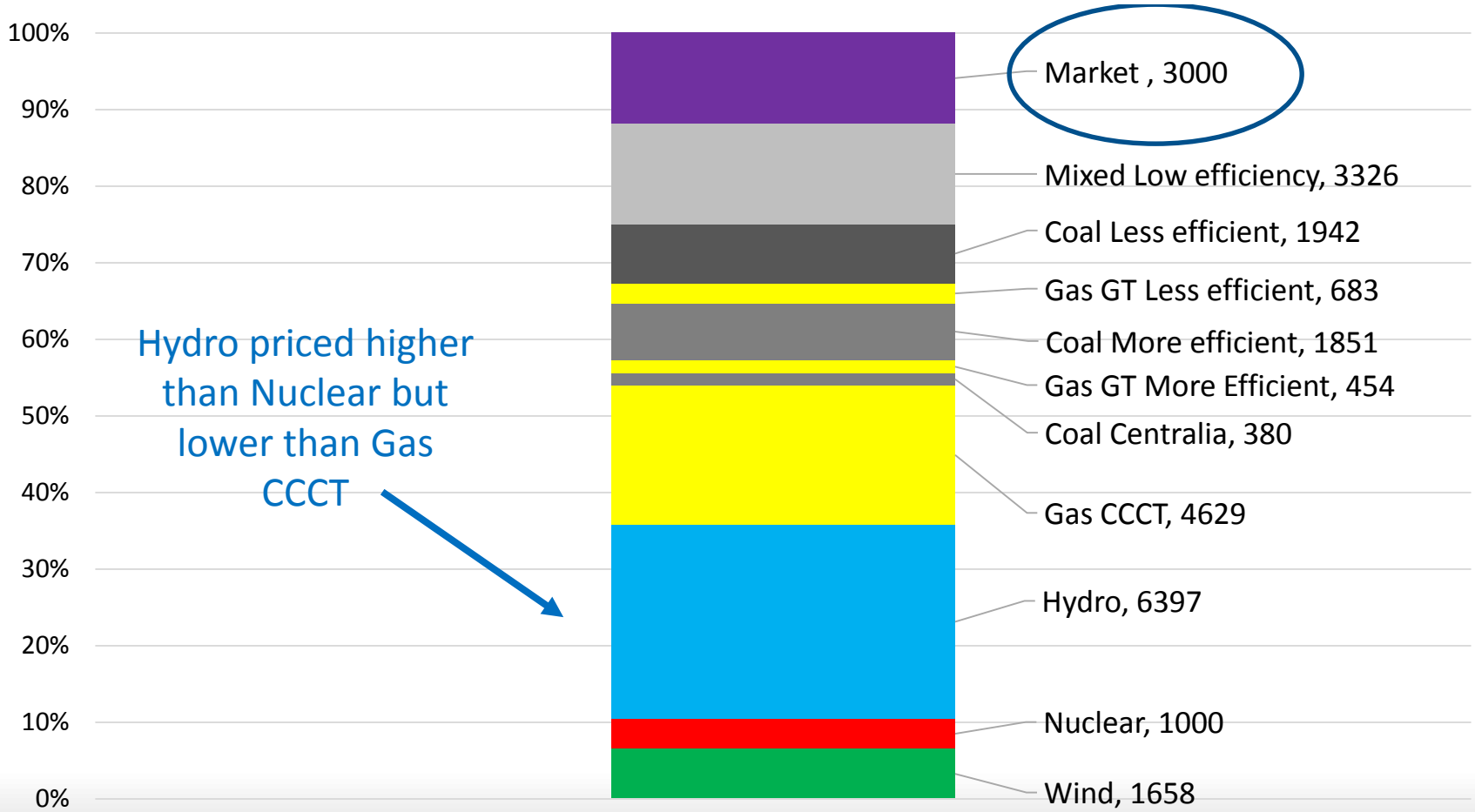
Resource Stacking in AURORAxmp under Low Hydro



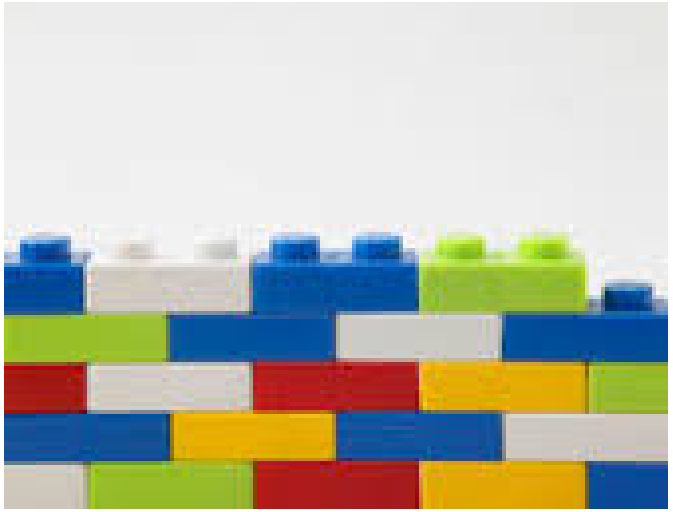
Economic Dispatch Basics

- The market-clearing price is then determined by observing the cost of meeting an incremental increase in demand in each area.
- All operating units in an area receive the hourly market-clearing price for the power they generate.

Sample Resource Stack from GENESYS

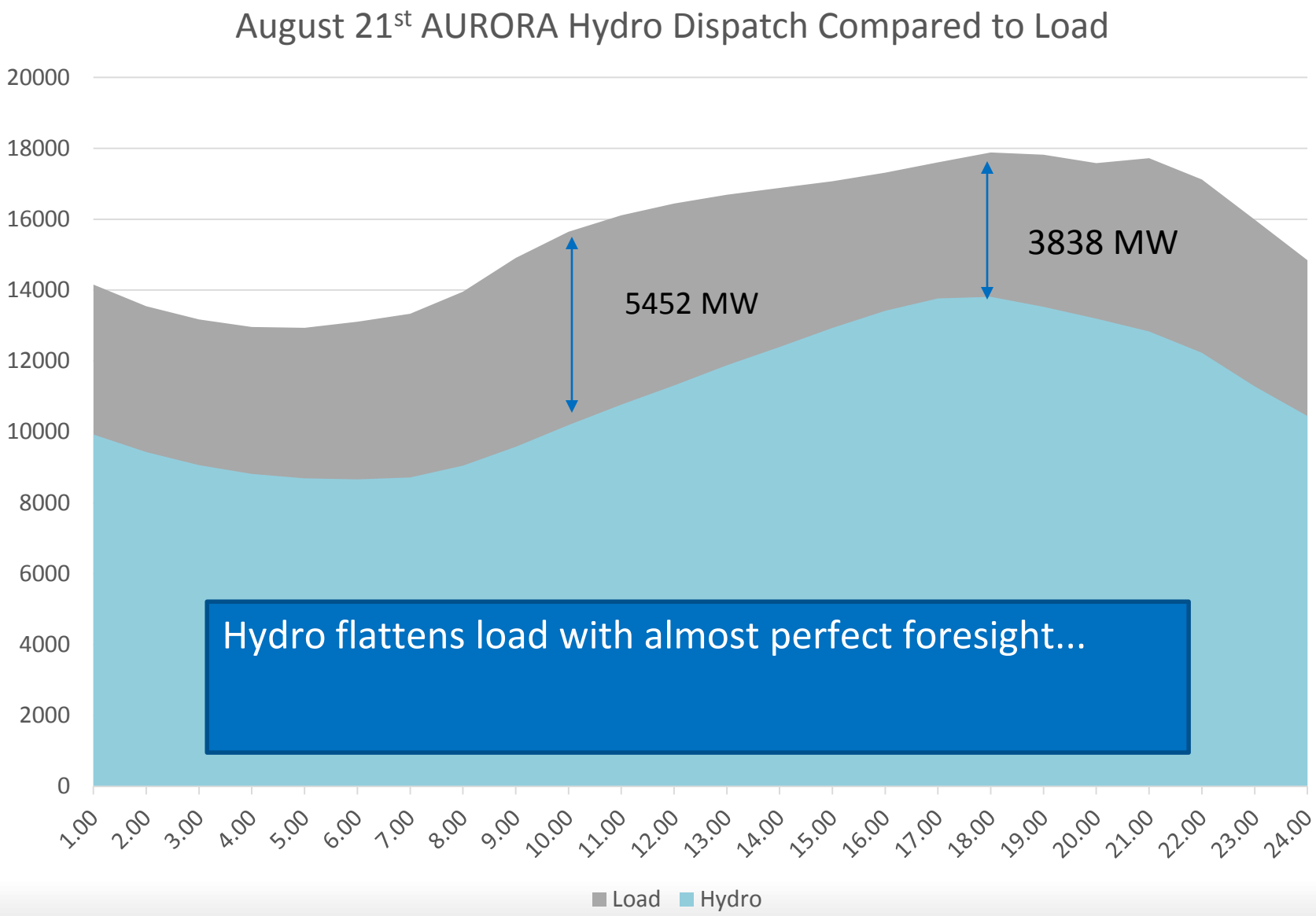


Questions About Resource Stacking?



Treatment of Hydro

- Hydro units are aggregated into sets that all use the same shape.
- A linear smoothing algorithm is used to produce a normalized daily average generation pattern with continuous transitions across month boundaries.
- The Hourly Shape is multiplied by a shaping factor and monthly and annual energy factors to get the basic hourly hydro dispatch.
  - $Hourly\ Shape = \left[\frac{Hourly\ Demand - Average\ Daily\ Demand}{Average\ Daily\ Hydro\ Energy}\right]$
- Checks to ensure sustained maximum, instantaneous max and min limits met


August 21st AURORA Hydro Dispatch Compared to Load
20000
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
5452 MW
3838 MW
Hydro flattens load with almost perfect foresight...
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
9.00
10.00
11.00
12.00
13.00
14.00
15.00
16.00
17.00
18.00
19.00
20.00
21.00
22.00
23.00
24.00
Load
Hydro

Hydro Logic Differences: AURORAxmp and GENESYS

Differences	GENESYS	AURORAxmp
River constraints	Modeled explicitly.	Can be modeled implicitly by well-selected max and min limits.
Daily shape	Meets energy and multiple sustained peaking needs, while maintaining constraints.	Meets energy and some peaking needs, unless constraints violated.
Economics of Hydro	Some concept of different economics of hydro blocks.	Hydro almost entirely shaped by predefined load and shape constraints, not long-term economic considerations.

Treatment of Reserves

- Historically, only contingency reserves could be specified
  - 3% Load and 3% Generation in the WECC
- Now, ancillary services can be defined by ramp speed and timing.
  - Load following and regulation (up and down)
  - Contingency reserves: Spinning and Supplamental

Long-Term Buildout

- Similar to the RPM, AURORAxmp can buildout an economic resource plan from existing and new resources.
- Real, levelized net present value is used to evaluate existing (for retirement) and new resources (for builds).
- Builds to load plus planning reserve margin and contingency reserves

Flexible Configuration and Output

The following can be reported hourly, monthly, and/or annual:

- Resource output
  - Including ancillary service provision
- Simulated transmission flows
- Emissions
- Fuel usage
- Output by scenario

How it gets used in wholesale electricity price forecast?

- Run an hourly study for 20 years.

- Hourly prices are based on the variable cost of the most expensive (in variable terms) generating plant or increment of load curtailment needed to meet load for each hour of the forecast period.

How it gets used in the Marginal Carbon Emissions study?

- Traditionally, run simulations testing 4 or so years in a 20 year period.
- Analyze which unit is marginal in the region in a particular time period.
- Report emissions for those units.
  - While there will be a marginal emission for an hour, there will be a range over a month or year.

Questions About Studies in AURORA

Recent Enhancements

- Commitment Optimization
  - Energy and reserve assigned to resources by total portfolio cost
  - Instead of resource stacking, minimizes an cost objective function.
  - System or pool-wide optimization
- Ancillary Services
  - User defined by ramp rate required
  - Load following, regulation, spinning and supplemental reserve capable
- Longer run times, more intuitive results
  - 2 to 5 minutes for traditional 8760 hour one year run
  - 2 to 7 hours for commitment optimization run

AURORAxmp Flow Diagram