General Capacity Investigation
Oregon PUC

Phase I Workshop: What is Capacity

June 14, 2019

John Fazio
NW Power and Conservation Council

Outline

- Energy, Capacity and Flexibility
- Hydroelectric sustained-peaking capability
- Associated System Capacity Contribution (ASCC)
- Adequacy Reserve Margin (ARM)
- Validation of ARMs and ASCCs
- Optional:
  Why solar ASCC is so much higher than its standalone capacity value for the PNW power supply

General Definitions

- Energy = Quantity
  Measured in megawatt-hours or
  average megawatts (1 aMW = 8,760 MW-hrs)

- Capacity = Rate of producing energy
  Measured in megawatts

- Flexibility = Ramping capability
  The ability of the power system to continuously match generation to system demands

THE 2021 NORTHWEST POWER PLAN

Another way to think about it

- **Energy** equates to fuel
  Must have sufficient fuel to meet the highest expected annual average energy demand

- **Capacity** equates to machines
  Must have sufficient machine capability to meet the highest expected hourly demand

- **Flexibility** = equates to ramping
  Must have sufficient machine flexibility to increase or decrease generation moment by moment to balance within-hour scheduling mismatches

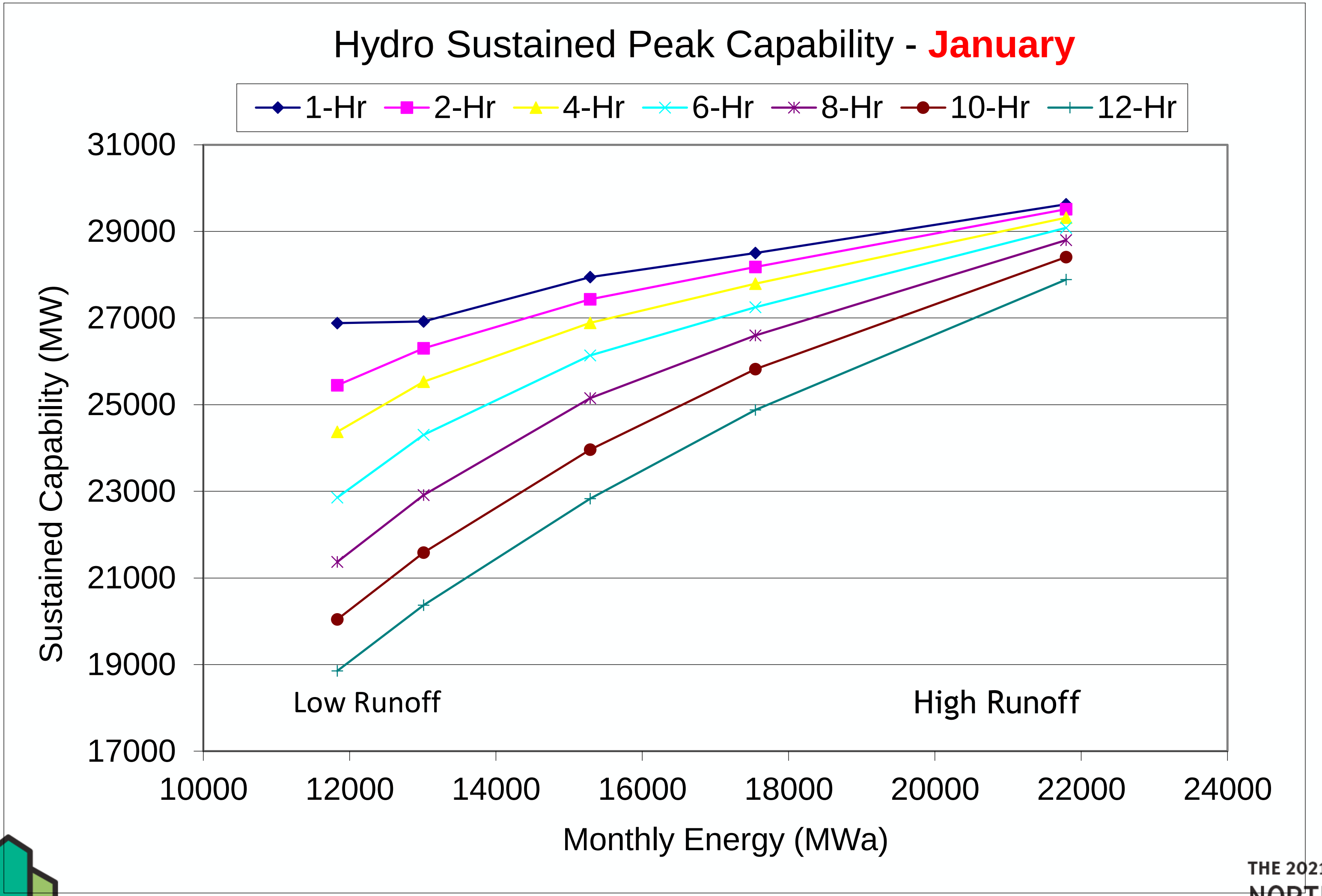
Capacity of Hydroelectric Systems
(with limited storage)

- Single-Hour Capacity
  - Maximum power capability during peak-demand hour
  - Single-hour hydro capacity = 34,222 MW
  - Cannot be sustained over a cold snap or heat wave

- Sustained-Peak Capacity
  - Maximum average power capability during a limited number of peak-demand hours
  - Sustained-peak hydro capability ~ 23,000 MW[1]
  - Can be sustained over a cold snap

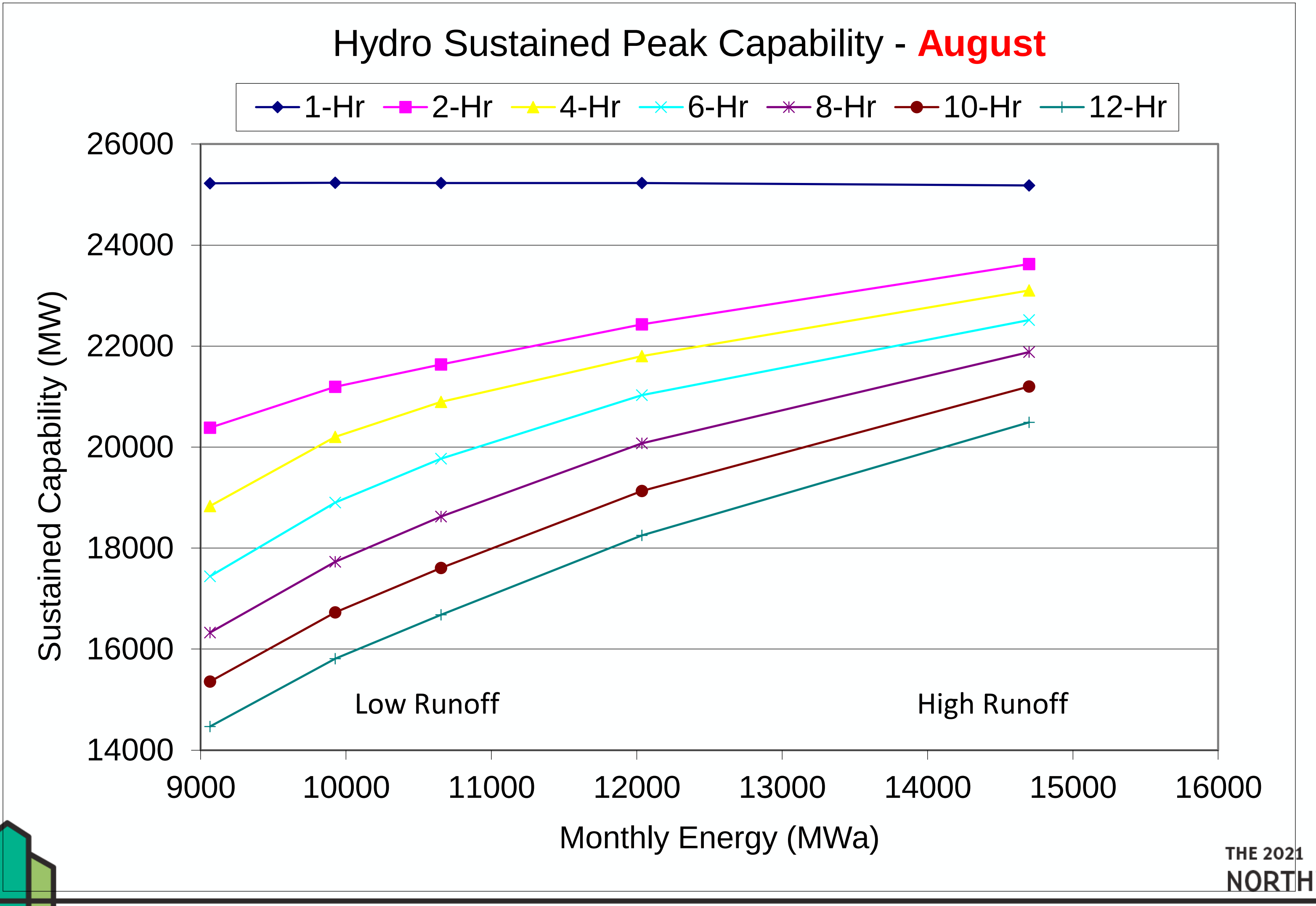
[1]For 6 peak hours/day in January during the lowest runoff water year

Sustained-Peak Capacity varies by Month, Water Condition and Duration of Peak



THE 2021 NORTHWEST POWER PLAN

Sustained-Peak Capacity varies by Month, Water Condition and Duration of Peak



THE 2021 NORTHWEST POWER PLAN

Standalone Capacity vs. Net System Capacity

- Standalone capacity is the percentage of nameplate capacity that can be counted on with no interaction with available storage (i.e. hydroelectric system)

- Net system capacity is the percentage of nameplate capacity that can be counted on when allowed to interact with storage facilities (i.e. hydroelectric system)

Power Plan Adequacy Requirements
(ARM and ASCC)

- The Adequacy Reserve Margin (ARM) is the amount of surplus capacity (or energy) needed, over the expected weather-normalized peak load (or average load), to ensure adequacy, in units of percent of expected load.
- The ARM is used in the Regional Portfolio Model as the adequacy test for resource buildouts.

- The Associated System Capacity Contribution (ASCC) is the net firm capacity gained when a resource is added to a power supply with storage, in units of percent of nameplate capacity.
- ASCC values are used to calculate ARMs and to assess if a power supply meets the ARM standard.

Associated System Capacity Contribution

- ASCC is the net firm capacity gained when a resource is added to a power supply with storage (e.g. hydroelectric system).

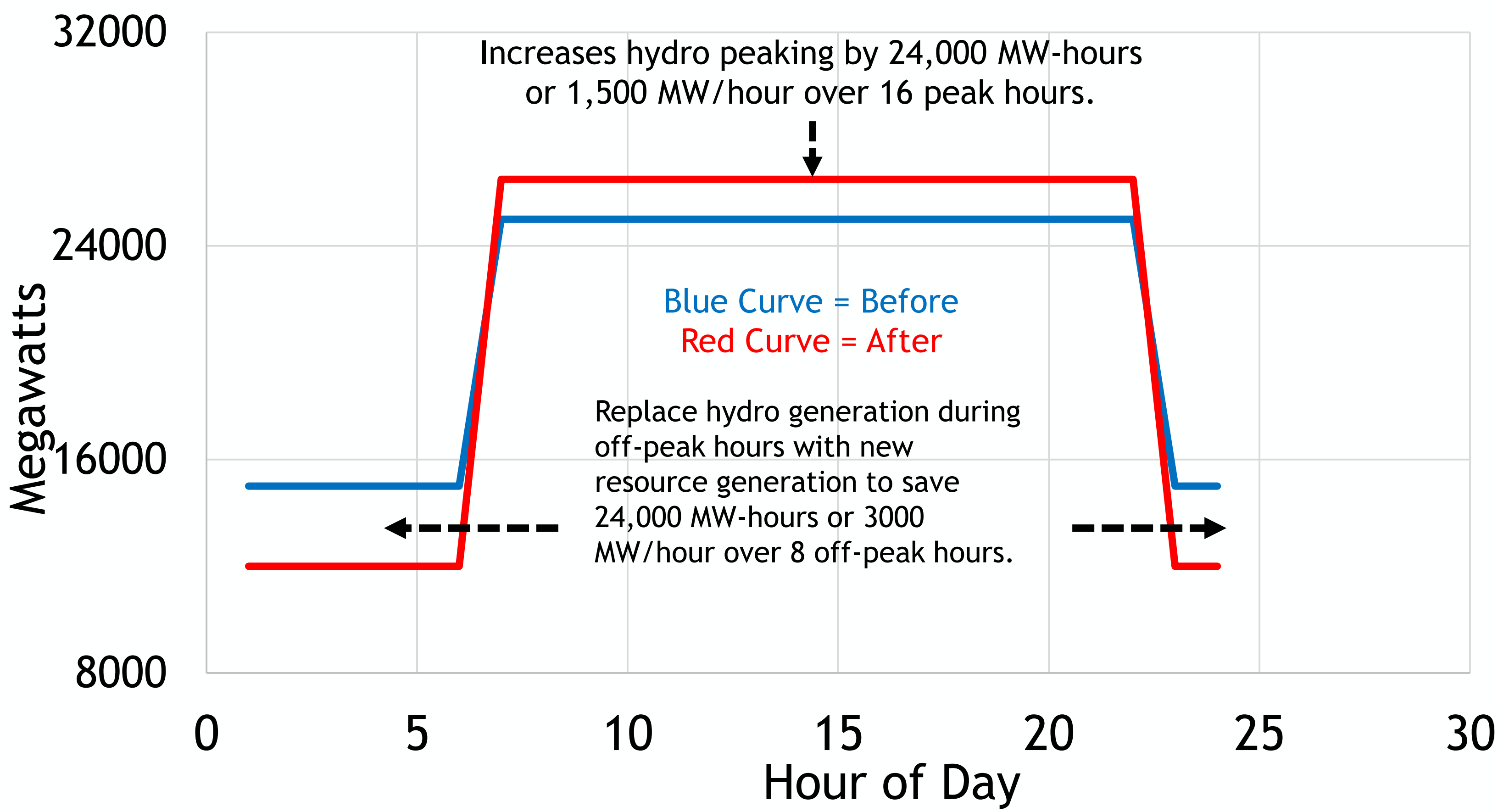
- During off-peak hours (conditions allowing), the added resource can be operated to replace hydro generation, which saves water

- Saved water translates into added hydro capacity

- ASCC = Resource's stand-alone capacity + Added hydro capacity

Hydro Capacity Gained with New Resource

Using Hydro Storage to Increase Capacity



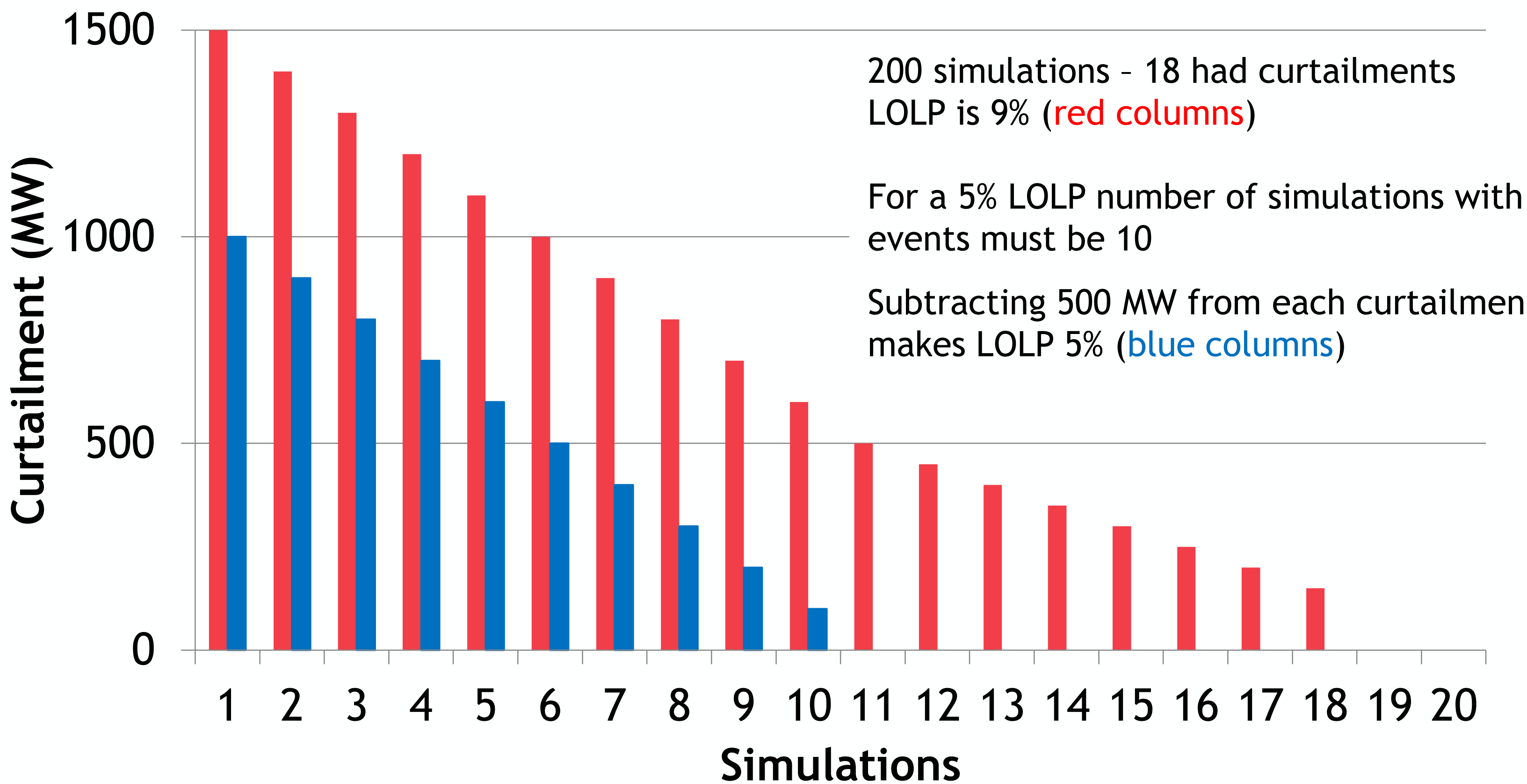
THE 2021 NORTHWEST POWER PLAN

Calculating ASCC

1. Base case:
   Begin with an inadequate supply (i.e. LOLP >> 5%)
2. Determine how much "perfect" capacity is needed to reduce LOLP to 5% (cap-need-base)
3. Study case:
   Add a new resource (with nameplate-capacity)
4. Determine how much "perfect" capacity is needed to reduce LOLP to 5% (cap-need-study)
5. $$\text{ASCC} = \frac{\text{cap-need-base} - \text{cap-need-study}}{\text{nameplate-capacity}}$$

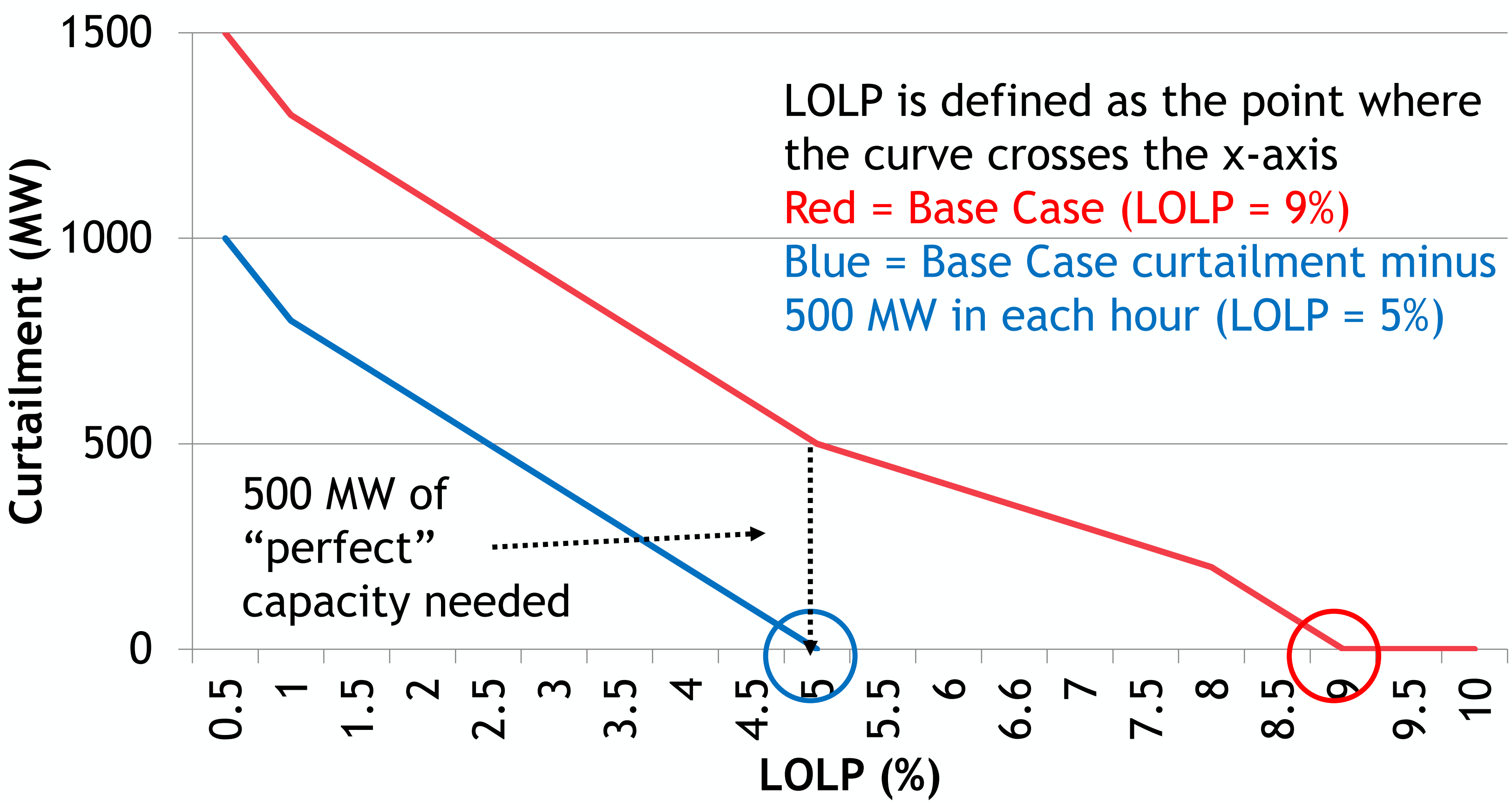
Peak-Hour Curtailment Duration Curve

(Largest hour curtailment per game, sorted highest to lowest)



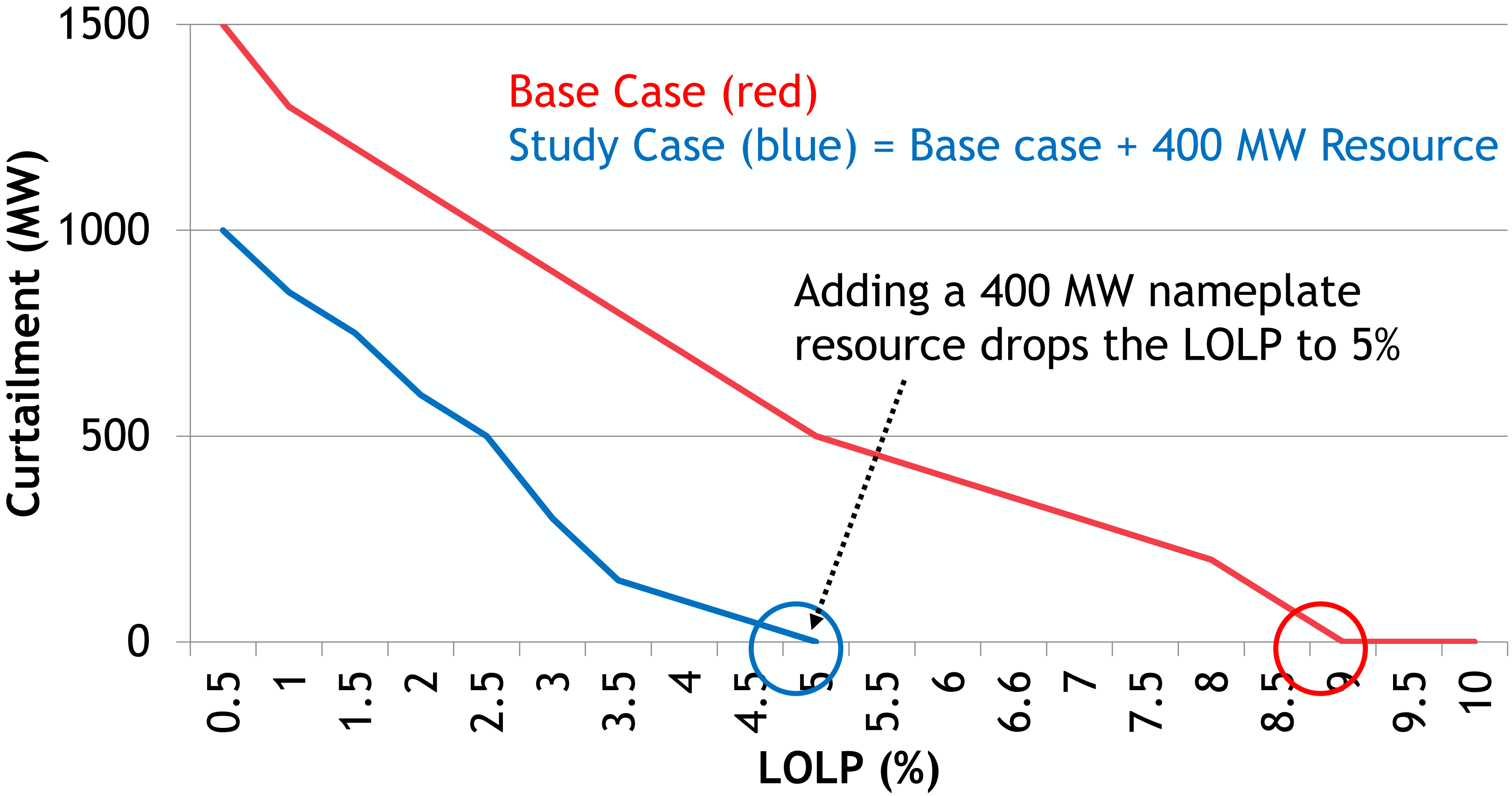
Peak-Hour Curtailment Duration Curve

(Same as before but LOLP on x-axis)



Peak-Hour Curtailment Duration Curve

(Same as before but LOLP on x-axis)



Adding a 400 MW resource is equivalent to adding 500 MW of "perfect" capacity to the curtailment curve, thus
ASCC = 500/400 = 125%

THE 2021 NORTHWEST POWER PLAN

ASCC Values (%) from the 7th PLan[1,2]

Resource	Fall	Winer	Spring	Summer
Solar PV	26	81	81	42
Energy Efficiency	124	101	114	116
Wind	3	11	11	8
Gas-Fired Turbine	128	100	102	120
Geothermal	128	100	102	120

[1]The net gain in peaking capability should be attributed to the hydro system.
[2]Incremental capacity gains diminish as more resource is added.

ASCC vs. ELCC

- The ASCC is essentially the same as the Effective Load Carrying Capability (ELCC)
- The Council chose to use a different name because of the way in which it calculates ASCC
- ELCC is more typically calculated using Expected Unserved Energy (EUE) instead of using the curtailment duration curve
- ELCC is more precise because it accounts for all shortfall hours but it takes longer to assess (more iterations)
- ASCC is faster and is sufficient for the analytical tools used to develop the power plan

Calculating ELCC using EUE

- Begin with an adequate power supply (however it is defined)
- Record the EUE
- Add an increment of load and record the increase in peak hour load
- The resulting EUE is larger because the new system (with higher load) becomes less adequate
- Add increments of new resource until the EUE matches the original EUE (for an adequate supply)
- The ELCC (in units of percent) tells us how much peak load each unit of new resource can serve without affecting adequacy
- <u>Example</u>: If ELCC is 10% then 100 MW of resource can serve 10 MW of peak load adequately

- $\text{ELCC} = 100 \times \dfrac{\text{increase in peak load}}{\text{added nameplate capacity}}$

Adequacy Reserve Margin

- The Adequacy Reserve Margin (ARM) is the amount of surplus capacity (or energy) needed, over the expected weather-normalized peak load (or average load), to ensure adequacy.
- The Council's 5% Loss-of-Load-Probability (LOLP) standard is translated into an Adequacy Reserve Margin (ARM).
- Seasonal (quarterly) ARM's are used in the Council's Regional Portfolio Model to ensure that resulting resource strategies yield adequate future power supplies.

Calculating ARMs

- The capacity ARM is calculated by subtracting the expected peak load from the aggregate capacity of a system whose LOLP is exactly 5%, divided by the load.
- The energy ARM is calculated by subtracting the expected average load from the aggregate average generating capability of a system whose LOLP is 5%, divided by the load.

- Aggregate capacity takes ASCC values into account, which include forced outage rates and maintenance.
- Expected peak and average loads are weather-normalized

- ARM_E (energy) = (average capability – average load)/average load
- ARM_C (capacity) = (peaking capacity – peak load)/peak load

ARM_C (Capacity)

(Based on a power supply just at a 5% LOLP)

Resource Type	Adequacy Reserve Calc	Value (MW)
Thermal	Nameplate	15,000
Wind	ASCC value of 5%	250
Hydro	Lowest 10-hr sustained peak	20,625
Solar	ASCC value of 25%	125
Imports	Max per hour	2,500
Total Resource		**38,500**
Load	Peak-hour Load	35,000
ARM Capacity	**(Resource - Load)/Load**	**10%**

Example of How the ARM_C Works

For a Future Operating Year	
Peaking capability	41,000 MW
Peak load	39,000 MW
Implied adequacy reserve	(41,000 – 39,000)/39,000 = 5%
ARM Capacity Requirement	10%
Assessment:	System is inadequate
Action:	More resource needed
Resource need = (ARM * Load) + Load	(0.1 * 39,000) + 39,000 = 42,900 MW
Incremental resource need = Resource need – peaking capability	42,900 – 41,000 = 1,900 MW

For this example, to meet the 10% ARM requirement, an additional 1900 MW of capacity must be added to the system.

THE 2021 NORTHWEST POWER PLAN

Validating ASCC and ARMs

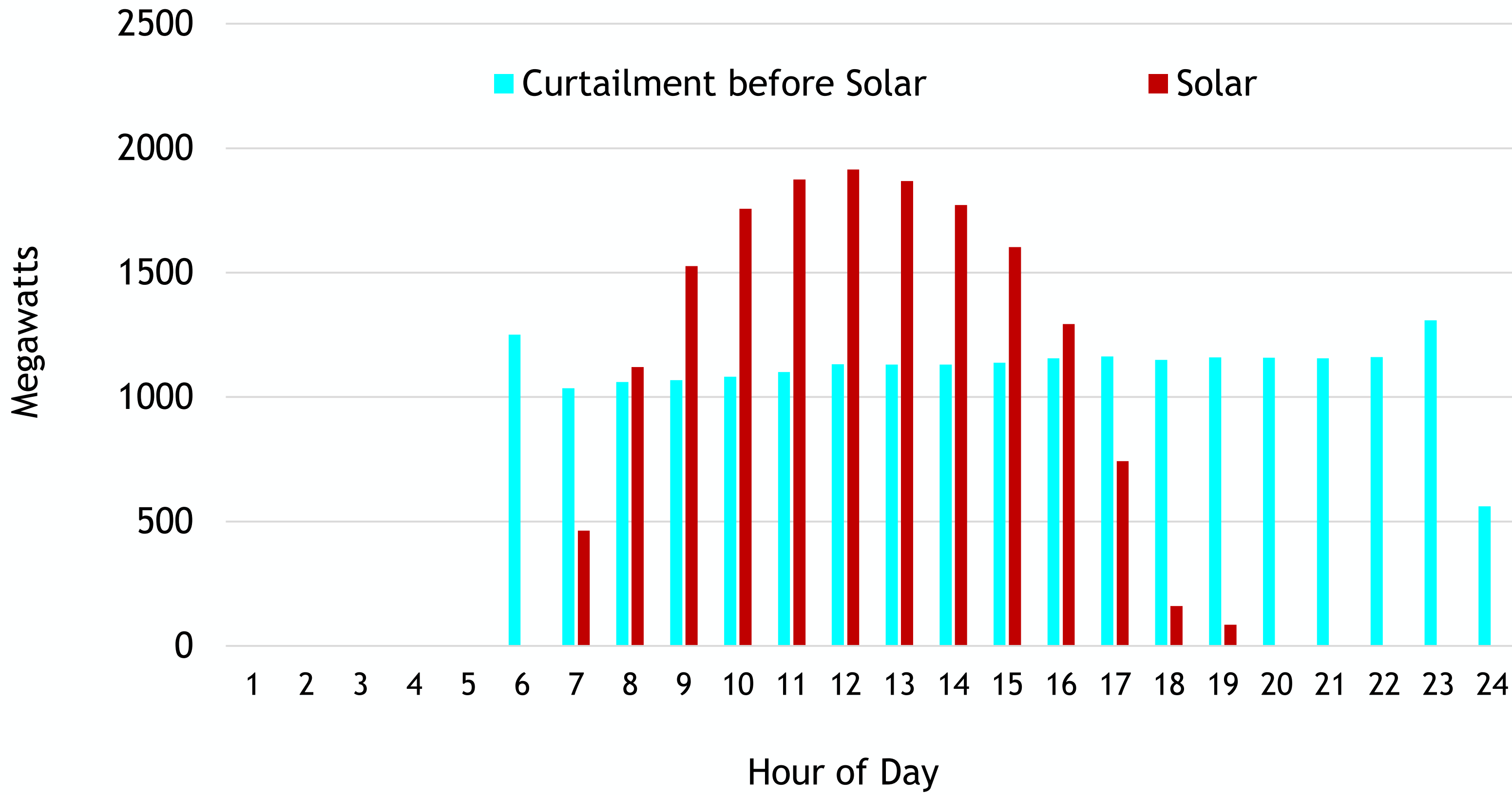
- From the 7th power plan, several future year resource buildouts were selected to test for adequacy
- Goal: LOLP should be between about 2% and 5% (i.e. to ensure an adequate but not overbuilt supply)
- For all tested years from the 7th plan output, the LOLP fell within the desired range.
- Without using the ASCC values, future resource mixes were always overbuilt (i.e. LOLP = 0%)

Optional

Why Solar Integrated Capacity is so much higher than its Standalone Capacity

- Simulated curtailment events range from one hour to over 24 hours
- About 1/3 of all curtailment events are 18 hours in duration (because the hydro system is used to flatten out anticipated peak hours shortfalls)
- Since solar only provides generation roughly between 7am and 7pm, not all of the 18-hour shortfall events will be satisfied
- However, when coupled with hydro storage, the combined effect can satisfy many more longer-duration curtailment events
- Example is provided in the following slides…

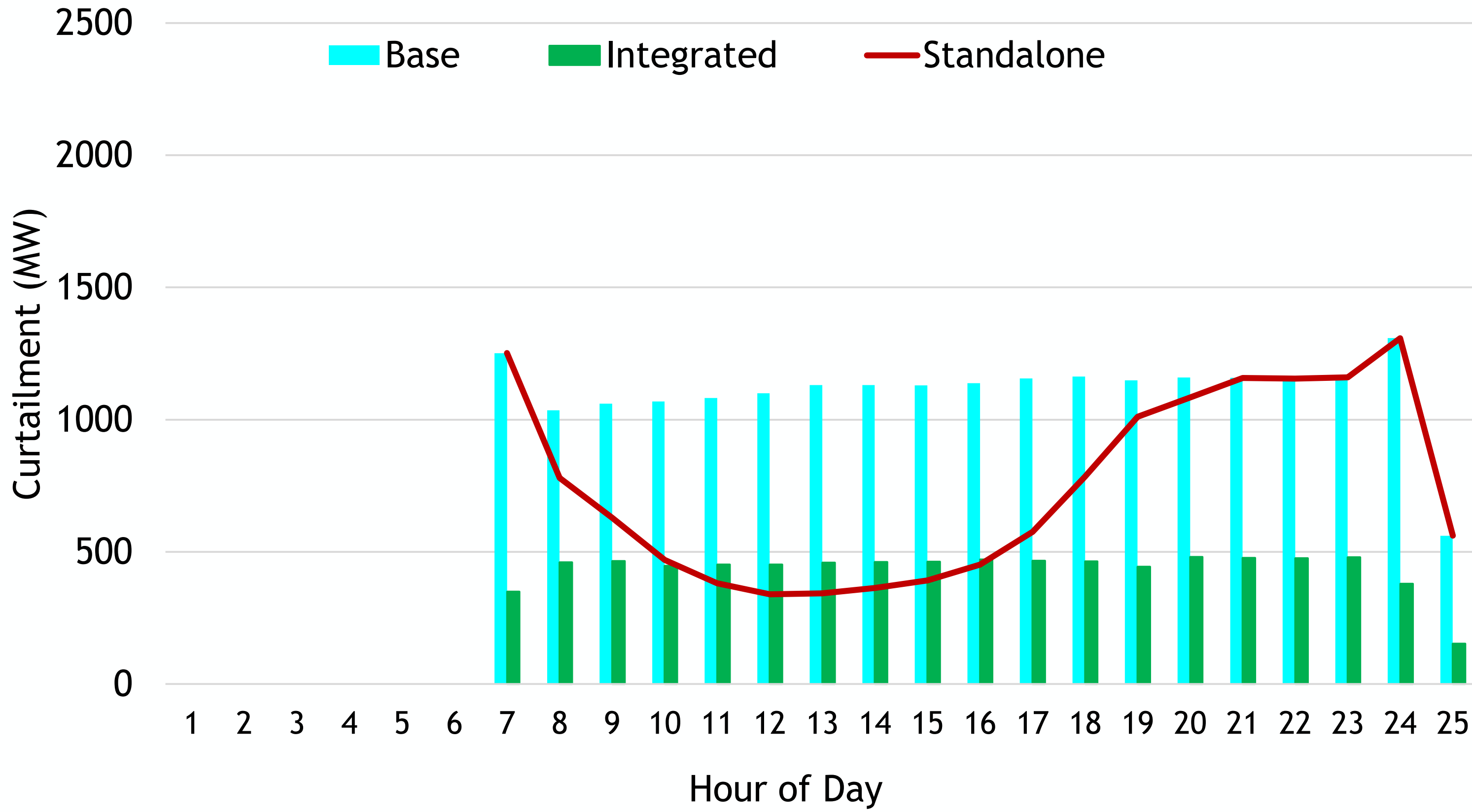
Typical Shortfall Event and Solar Generation



- Some curtailments occur when solar is not generating
- As a standalone resource, surplus solar generation cannot be shifted into other hours

THE 2021 NORTHWEST POWER PLAN

Curtailment with Standalone and Integrated Solar



THE 2021 NORTHWEST POWER PLAN

Integrating Solar affects Hydro & Thermal Resources