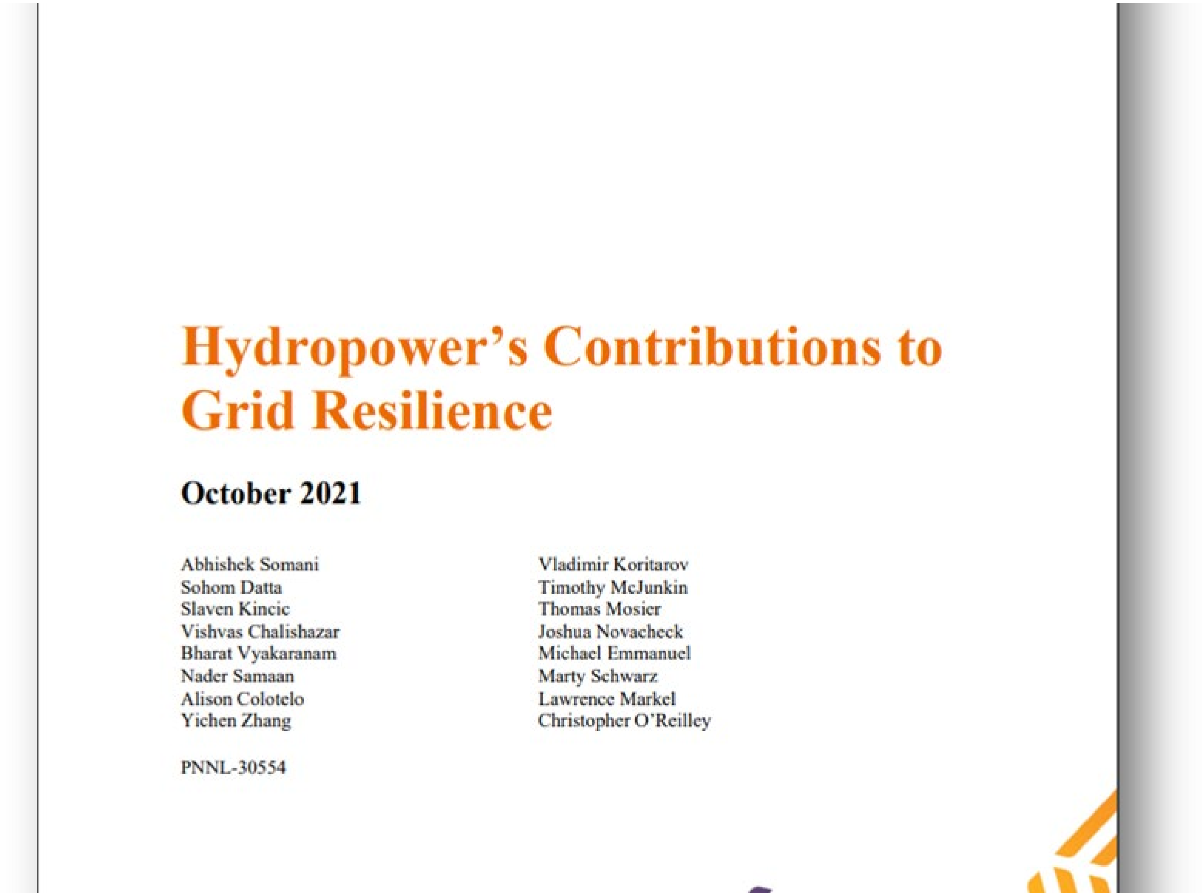
1.2.3.601– Hydropower's Contributions to Grid Resilience



Hydropower's Contributions to Grid Resilience

October 2021

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Project Overview

Project Summary

- Hydropower facilities are often crucial in responding to extreme grid events due to their agility and flexibility. They can quickly change both their real and reactive power outputs to provide voltage support, inertial response, primary frequency response, and operating reserves. However, no standard practices exist to quantify the contributions of hydropower resources, especially for non-market and non-monetized grid services. The project was designed to identify tools, methods, models, and datasets to quantify hydropower's contributions to grid resilience.

Intended Outcomes

- The key outcomes of this project includes a framework to quantify hydropower's contribution to grid resiliency in the Western Interconnection and application for the current generation mix. Models and tools used in this study are accessible to the hydropower community to support decision making for future operations. The longer-term outcome are an improved understanding and quantification of hydropower's value to the power system, and overall improved grid security through utilizing hydropower's flexibility.

Project Information

Principal Investigator(s)

- Abhishek Somani (PI) – PNNL
- Sohom Datta, Vishvas Chalishazar, Nader Samaan, Bharat Vyakaranam, Alison Colotelo – PNNL

Project Partners/Subs

- Thomas Mosier, Timothy McJunkin – INL
- Vladimir Koritarov, Yichen Zhan – ANL
- Josh Novacheck, Mike Emmanuel – NREL
- Larry Markel, Chris O'Reilley – ORNL

Project Status

Completed

Project Duration

- October 2019
- September 2020

Total Costed (FY19–FY21)

$1 M

Project Objectives: Relevance

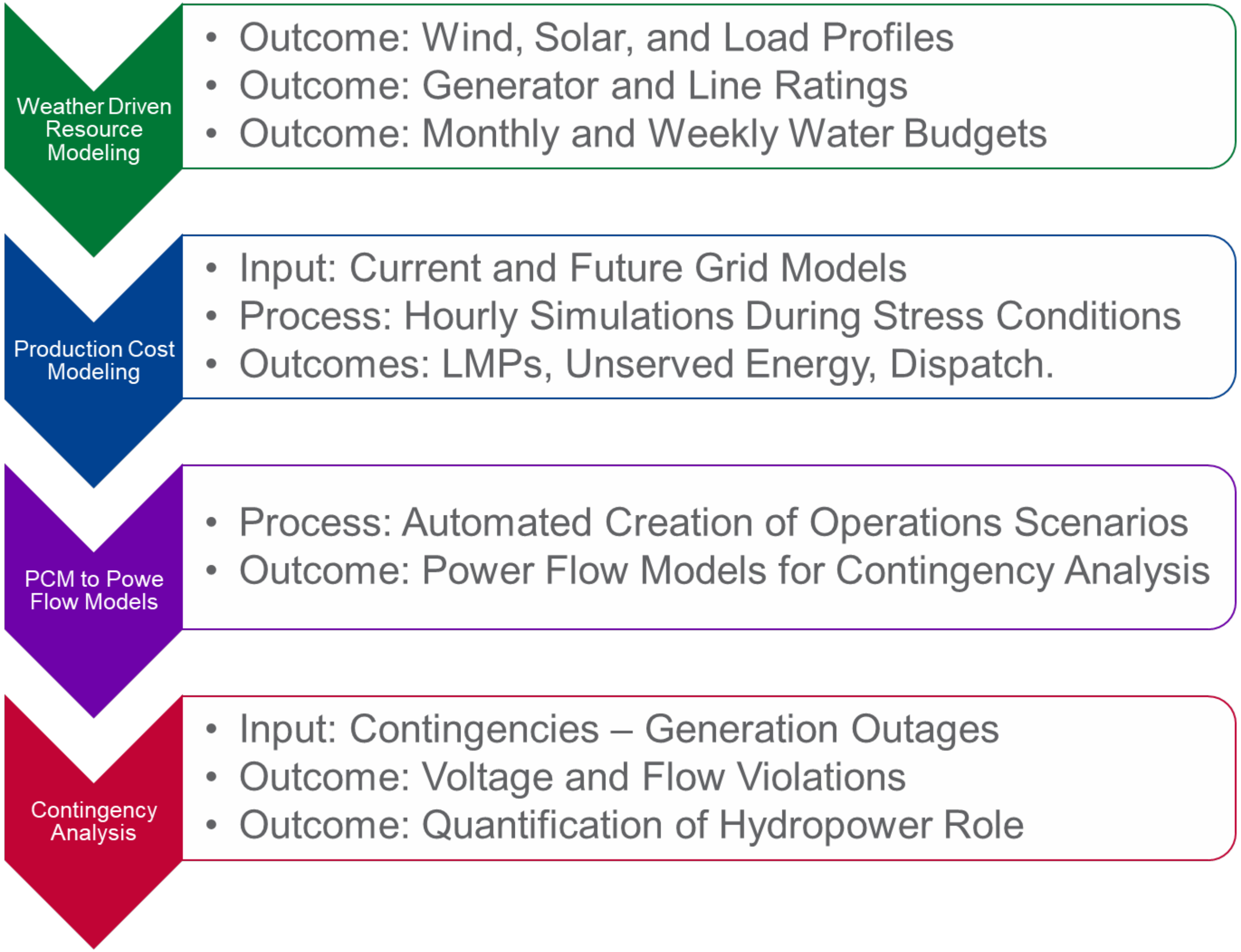
- Challenge:
  - “Untapped potential for hydro and pumped storage to support a rapidly evolving grid” – Grid reliability, resilience, and integration (HydroWIRES)
- Approaches and Activities:
  - Understand the evolving needs of the rapidly changing grid
  - Investigate hydropower’s full range of capabilities to provide grid services, accounting for the machine, hydrologic, and institutional constraints
- Intermediate Outcomes:
  - Accurate representation and system value of hydropower and PSH capabilities in power system models
- Long-term Outcomes:
  - Increase in U.S. hydropower and PSH fleet flexibility and greater value provided to the power system
- Impact:
  - Energy Affordability
  - Energy Security

Project Objectives: Approach

Approach:

Quantified hydropower's response to frequency response using,

1. Historical data: Collected and analyzed PMU data for parts of the WI from past events
2. Simulation tools: Identified and assembled simulation tools to quantify voltage support and frequency response, for
   – Combinations of extreme events
   – Different seasonal loading conditions
   – Variations in water availability
   – Weather-driven wind and solar profiles



Project Objectives: Expected Outputs and Intended Outcomes

Outputs:

- **Identified and assembled different simulation capabilities**, leveraging existing laboratory and commercial tools
- **Identified modeling gaps** that result in inaccurate representation of hydropower's attributes in power system models
  - Led to WPTO-led workshop and follow-on research
- **Published a** report in October 2021, presenting results and modeling framework

Outcomes:

- This study systematically quantified hydropower's contributions to grid resilience.
  - There was anecdotal evidence in the past on the role of hydropower in maintaining grid resilience.
- The study quantified hydropower's contributions in the Western Interconnection:
  - Hydropower constitutes 20-25% of capacity but contributes 30-60% of frequency response. Hydropower is also the largest contributor of voltage support.
- Ability to quantify grid needs and hydropower's contributions will inform grid operators and generation/transmission planners on 1) grid needs in future, and 2) hydropower (and other resources') contributions under a range of extreme events in future.

Project Timeline

FY 2020

The following activities were performed in FY20:

1) Literature review of past extreme events

2) Selected and analyzed scenarios of interest

4) Prepared final report

FY 2021

The following activities were performed in FY21:

1) Finalized report

2) Disseminated results

Project Budget

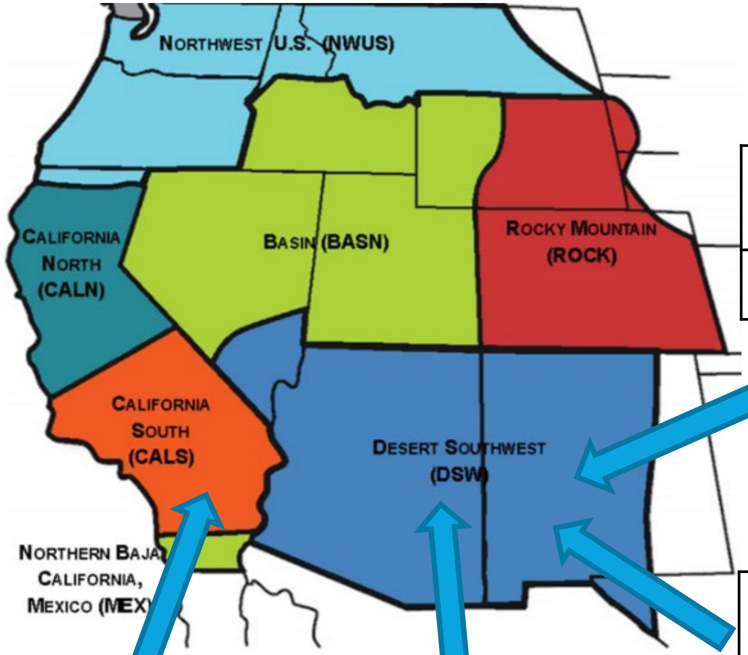
FY19	FY20	FY21	Total Actual Costs FY19–FY21
Costed	**Costed**	**Costed**	**Total Costed**
$0K	$1,000K	$0K	$1,000K

End-User Engagement and Dissemination

- Project team engaged multiple stakeholders (CAISO, WECC, NERC, etc.) through the project to:
  - Identify specific scenarios of interest to the industry
  - Discuss data needs and modeling assumptions
  - Presentation and validation of intermediate results
- Results from the study have been discussed with various stakeholders, including but not limited to:
  - USACE Walla Walla District:
    - In discussions to use framework from report to assess contribution of their dams to grid resiliency
    - Graphics produced from the presentation material being used by USACE's communications team
  - Staffers of US Senators Risch (ID), Crapo (ID), Cantwell (WA), and Murray (WA):
    - Staffers acknowledged the results as first to quantify hydropower's contributions to grid resilience
    - Report cited in a letter to DOE Sec. Granholm w.r.t Lower Snake River dams
  - Western Electricity Coordinating Council (WECC): In discussions with the WECC to augment their studies on the impacts of extreme events on system planning requirements.
- Results have been highlighted in numerous independent web-features: NHA, USCE, Utility Dive
- Publication selected for best paper award at Resilience Week 2020:
  - T. Phillips et al., "A Metric Framework for Evaluating the Resilience Contribution of Hydropower to the Grid," 2020 Resilience Week (RWS), 2020, pp. 78-85, doi: 10.1109/RWS50334.2020.9241249.
- Project team identified gaps in modeling of hydropower in power systems models. The gaps are now being addressed in a separate project, in close coordination with industry

Hydropower has been a major source of frequency response in WI

- In 2018, hydropower constituted ~25% of installed capacity in the WI
- …hydro in the PNW contributed 30-60% of primary frequency response
- Hydropower in the PNW responded to events originating other parts of the Western US
- Results from simulation studies were very similar
  - Simulation tools can be used to assess a variety of new scenarios



Event Timeline	Generation Outage	Northwest Hydropower Contribution
Jul 29, 2017	925 MW	> **30%**

Event Timeline	Generation Outage	Northwest Hydropower Contribution
Mar 3, 2017	680 MW	> **43%**

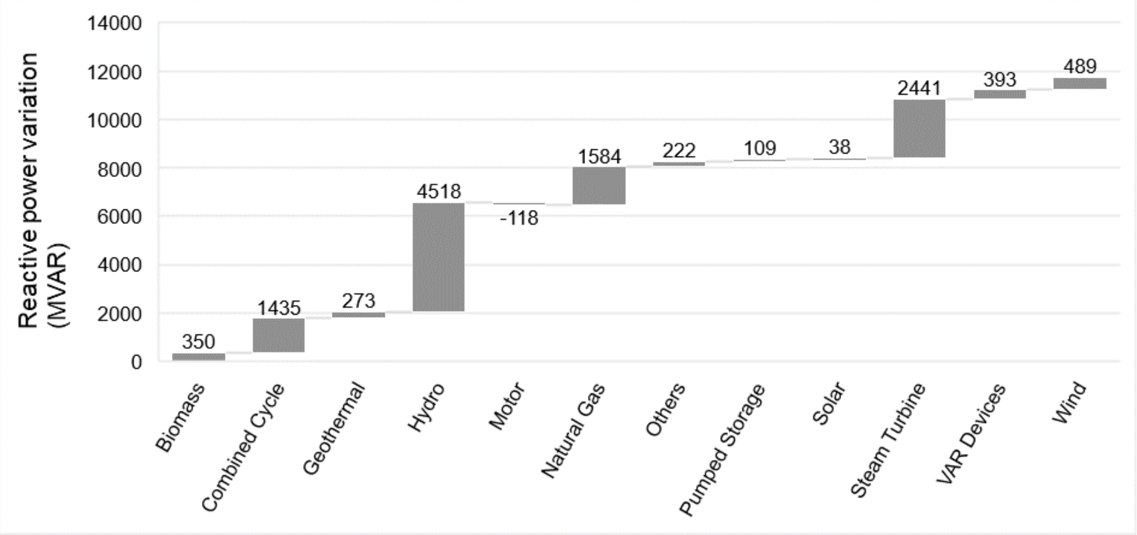
Event Timeline	Generation Outage	Northwest Hydropower Contribution
Apr 20, 2018	700 MW	> **61%**

Event Timeline	Generation Outage	Northwest Hydropower Contribution
Feb 15, 2018	1340 MW	> **39%**

…simulation studies show similar results

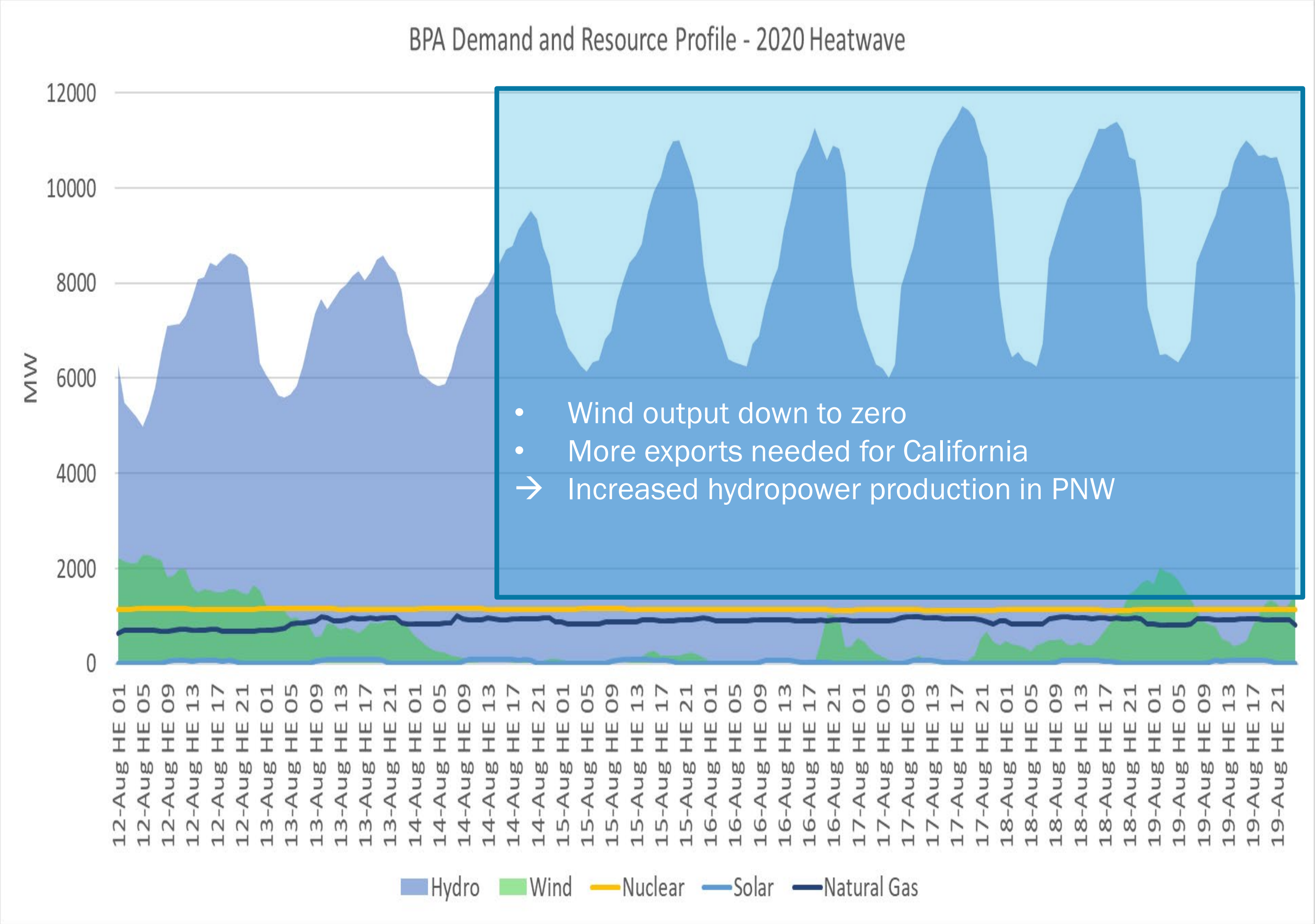
- Simulation studies were carried out to investigate additional scenarios:
  - Scenario 1: Single largest contingency in WI – outage of Palo Verde units in AZ
  - Scenario 2: Outage of multiple natural gas plants following pipeline outage
- Study involved simulation of the entire WI (WECC model), including BC, for the years 2018 and 2028
- Investigated hydropower contributions under different seasons and water availability conditions
- Hydropower is the largest contributor to:
  - Primary frequency response
  - Reactive power (voltage support)

Event Type	Hydropower contribution towards primary frequency
Historical Events in WI	30-61%
(Scenario 1) Largest contingency in WI	47-56%
(Scenario 2) Widespread natural gas plant outages in WI	32-38%



Evolving conditions are changing reliability and resilience needs

- Higher penetration of renewables
- Increased incidences of extreme weather events
  - Heat waves, cold waves
- Increasing common mode failure events
  - Weather impacts resources, infrastructure, and loads simultaneously
- Different set of resource attributes required to deal with these events



Ongoing Activities: Analysis of compounding events

In the follow-up to original work, we are now analyzing the role of hydropower under a compounding set of extreme events. The following set of scenarios are being currently being analyzed, with active engagement from industry stakeholders.

Scenario	Event 1	Event 2	Simulation Plan	Test System
1a	Drought (PCM)	Thermal unit outage and/or transmission outage in power flow and transient stability study	• Event 1: Simulate drought conditions in summer based on historical data. • Event 2: During the drought, perform contingency analysis/reliability studies.	Base case: WECC 2030 Variations: WECC 2030 w/ coal retirement
1b	Drought + Heatwave (PCM)	Thermal unit outage and/or transmission outage in power flow and transient stability study	• Event 1: Simulate drought conditions in summer and simultaneously add a heatwave event for 1-2 week by increasing load based on historical data. • Event 2: During the heatwave, perform contingency analysis/reliability studies	
2a	Heatwave (PCM)	Transmission outage (PCM) - e.g., COI outage due to wildfire	• Event 1: Heatwave event for 1-2 week in summer by increasing load based on historical data. • Event 2: During the heatwave, a compounding transmission outage is modeled that derates COI flow	
2b	Heatwave #1 in July (PCM)	Heatwave #2 in Aug (PCM)	• Even 1: Heatwave event for 1-2 week in summer by increasing load based on historical data. • Event 2: After the first heatwave, a second heatwave is simulated after a month.	

Q&A