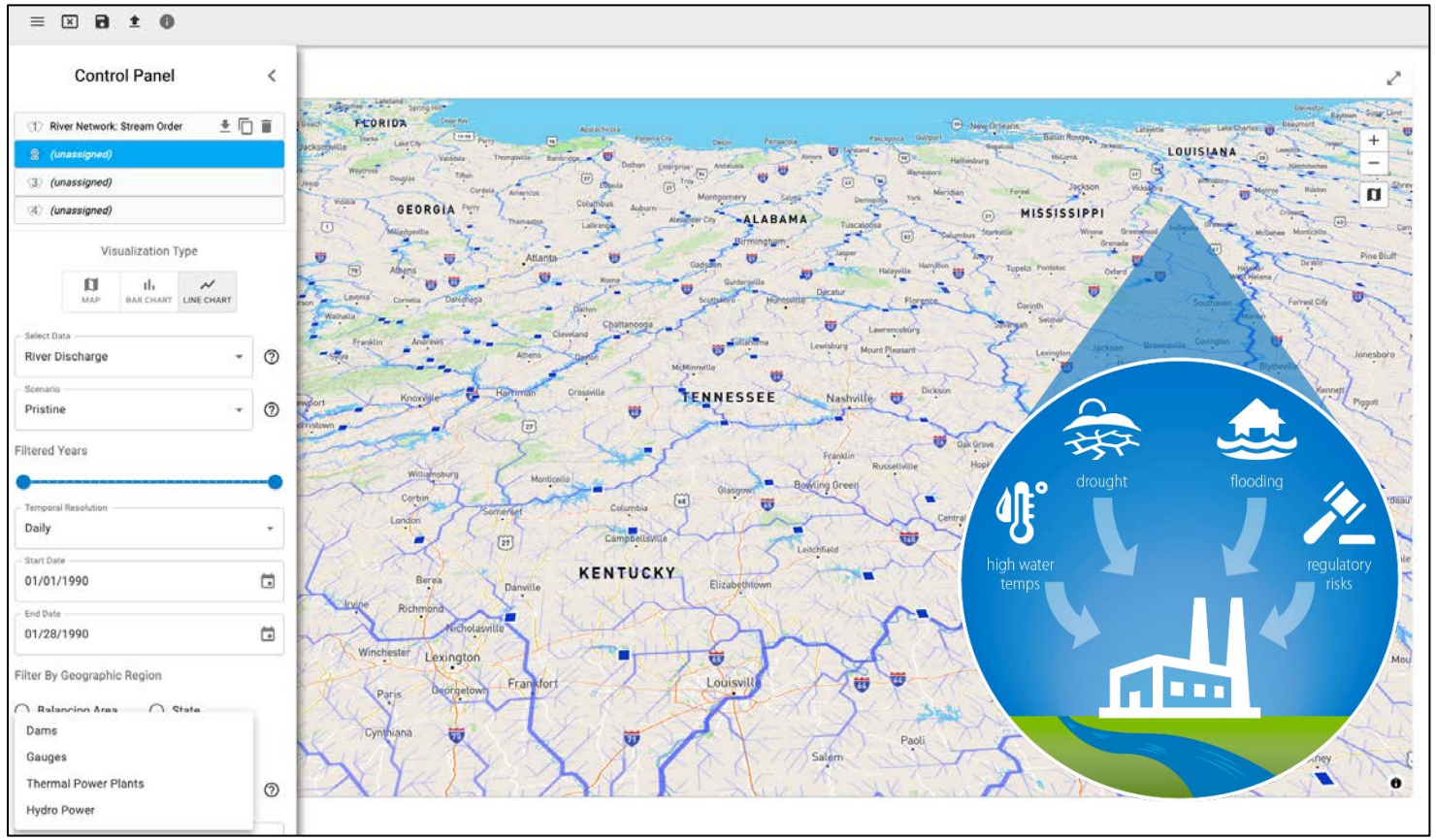
# 1.4.2.402 – *Water Risk for the Bulk Power System: Asset to Grid Impacts*




Ariel Miara, Ph.D.
National Renewable Energy Laboratory

ariel.miara@nrel.gov
July 27, 2022

NREL/PR-6A20-83363

This work was authored in part by the National Renewable Energy Laboratory, operated by Alliance for Sustainable Energy, LLC, for the U.S. Department of Energy (DOE) under Contract No. DE-AC36-08GO28308. Funding provided by the U.S. Department of Energy Office of Energy Efficiency and Renewable Energy Water Power Technologies Office. The views expressed in the article do not necessarily represent the views of the DOE or the U.S. Government. The U.S. Government retains and the publisher, by accepting the article for publication, acknowledges that the U.S. Government retains a nonexclusive, paid-up, irrevocable, worldwide license to publish or reproduce the published form of this work, or allow others to do so, for U.S. Government purposes.

# Project Overview

## Project Summary

Utilities and stakeholders need a standardized mechanism for evaluating how future climate and hydrologic conditions translate to water-related risks for power grid assets and systems to support planning decisions. Yet, no such mechanism exists. To address this need, our goals are to:

(1) Develop and execute a state-of-the-art multi-model framework to assess future climate-water impacts and risks to the grid, including sensitivities to varying hydrologic drivers and infrastructure scenarios.

(2) Create a standardized interactive visualization platform, using data from the climate-water risk assessments, that enables stakeholders to evaluate climate-water impacts, risks, and adaptation measures for power systems.

## Intended Outcomes: Key Deliverables and Products

- High-resolution climate-water risk modeling framework and assessments to support regional grid planning under stakeholder-informed climate-water-energy scenarios
- National visualization tool and data sets, informed by stakeholders, to support industry (ISOs, RTOs, utilities), DOE, academia, and public understanding of climate impacts and water risk to power system planning and operations.

## Project Information

### Principal Investigator(s)

- Ariel Miara (NREL), Henriette Jager (ORNL), Nicole Jackson (SNL), Erik Shuster (NETL)

### Project Partners/Subs

- CUNY Advanced Science Research Center (Charles Vorosmarty, Fabio Corsi)
- EPRI (Nalini Rao)

### Project Status

Ongoing

### Project Duration

- Start date: June 2020
- End date: September 2023

### Total Costed, All Labs (FY19–FY21)

$628K

# Project Objectives: Relevance to Program Goals

| Challenges | Intermediate Outcomes | Long-Term Outcomes |
|---|---|---|
| Untapped potential for hydro and pumped storage hydropower (PSH) to support a rapidly evolving grid | Accurate representation and system value of hydropower in power system models<br>Increased inclusion of hydropower and PSH options in generation and transmission planning | Increase in U.S. hydropower and PSH fleet flexibility and greater value provided to the power system |
| Addressing environmental impacts and hydrologic uncertainties | Incorporation of mitigation/adaptation strategies/modified infrastructure to reduce impacts of hydrologic variations or extreme events on hydro | Increased resilience of aquatic ecosystems from improved science on environmental impacts of hydropower |
| Lack of access to information to support decision making | Improvements in river/water data availability, accessibility, and management<br>Commercialization and use of new analytical tools to weigh multi-objective trade-offs at basin scales | Improved decision-making processes and basin-wide management of river resources for multiple objectives |

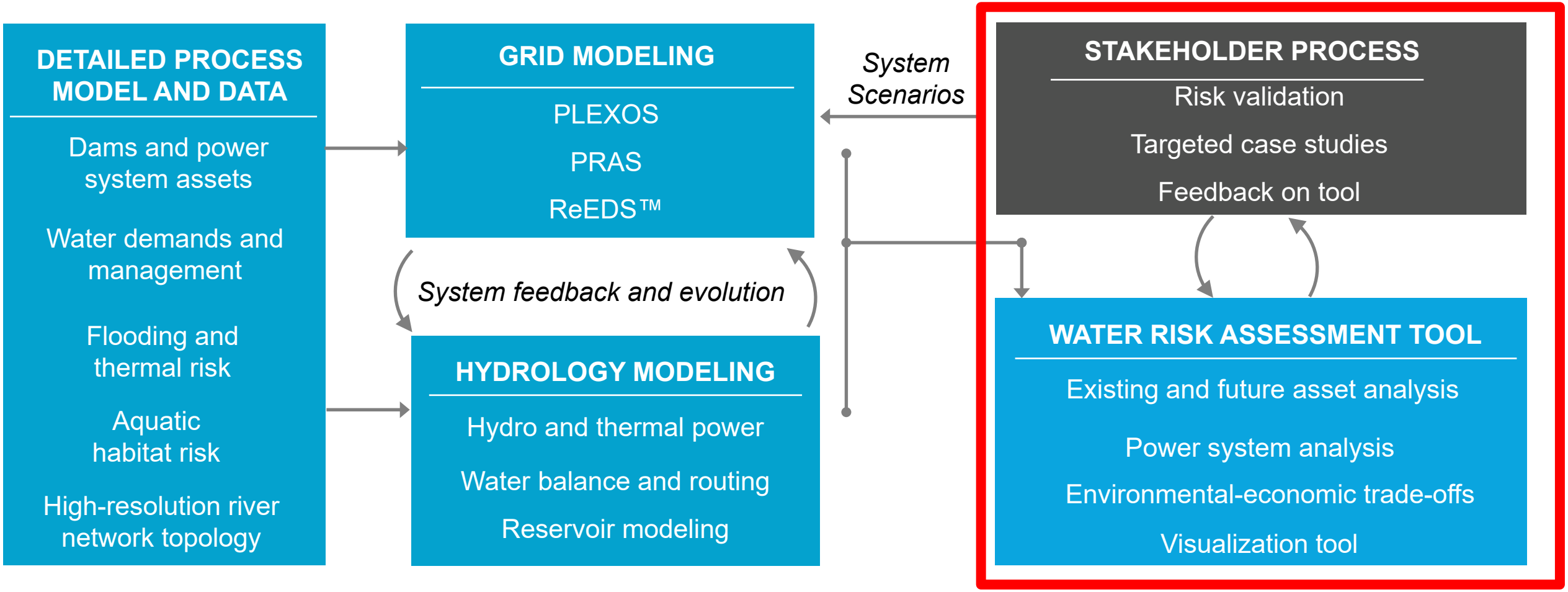
**<u>Direct Answer to Program Activity 4 Goal:</u>**

*"Release a nationwide analysis and visualization platform that enables utilities and system operators to evaluate potential long-term water availability and climate change-related risks to existing and new hydropower assets at meaningful local or regional scales."*

# Approach

**Water risk analysis of grid assets and operations using high-resolution water-energy modeling**

Advancing an existing model framework by (1) incorporating hydropower and reservoir operations, (2) further improving spatial resolution, (3) conducting sensitivity analyses through ensemble modeling, and (4) assessing the risk to the power grid through a series of industry-relevant indicators.



# Project Objectives: Expected Outputs and Intended Outcomes

## Expected Outputs

**Climate-water impact and risk assessments**

- Trade-offs in power system operations when considering climate and water constraints/risks
- Flooding and thermal risks
- Hydro and thermal power under climate change
- Climate impacts and adaption for power systems
- Regional analyses.

**A nationwide analysis and visualization platform that is interactive, seamless, and hosts a large range of data sets and model results from the novel modeling framework and assessments**

## Intended Outcomes

Improve methods of capturing thermal plant and dam (powered/non-powered) impacts on riverine ecosystems.

Improve the representation of hydropower in power system models.

Establish a transparent framework that evaluates how future climate and hydrologic conditions translate to water-related risks for power grid assets and systems.

Enable quantitative insights to support near-term operations and/or long-term planning decisions.

Enhance knowledge base for climate impact and adaptation planning for utilities and system operators.

Enhance WPTO's understanding of hydropower's role and potential under future climate-water-energy scenarios.

# Project Timeline

## FY 2021

- Integrate high-resolution data sets and powered/non-powered dam representation to modeling framework.
- Develop visualization and analysis Prototype.
- Stakeholder engagement kickoff workshop for climate-energy scenario design

## FY 2022

- Visualization tool development go/no-go
- Finalize methods for full suite of energy-water models and risk analyses
- Contemporary climate modeling analysis showcasing methods and improved representation of hydropower in power system models
- Stakeholder feedback on preliminary results and visualization tool

## FY 2023

- Visualization tool release and long-term support proposal
- Publication of series of energy-water assessments
- Region-specific stakeholder discussions and analysis

# End-User Engagement and Dissemination

**Feedback on research approach and results**

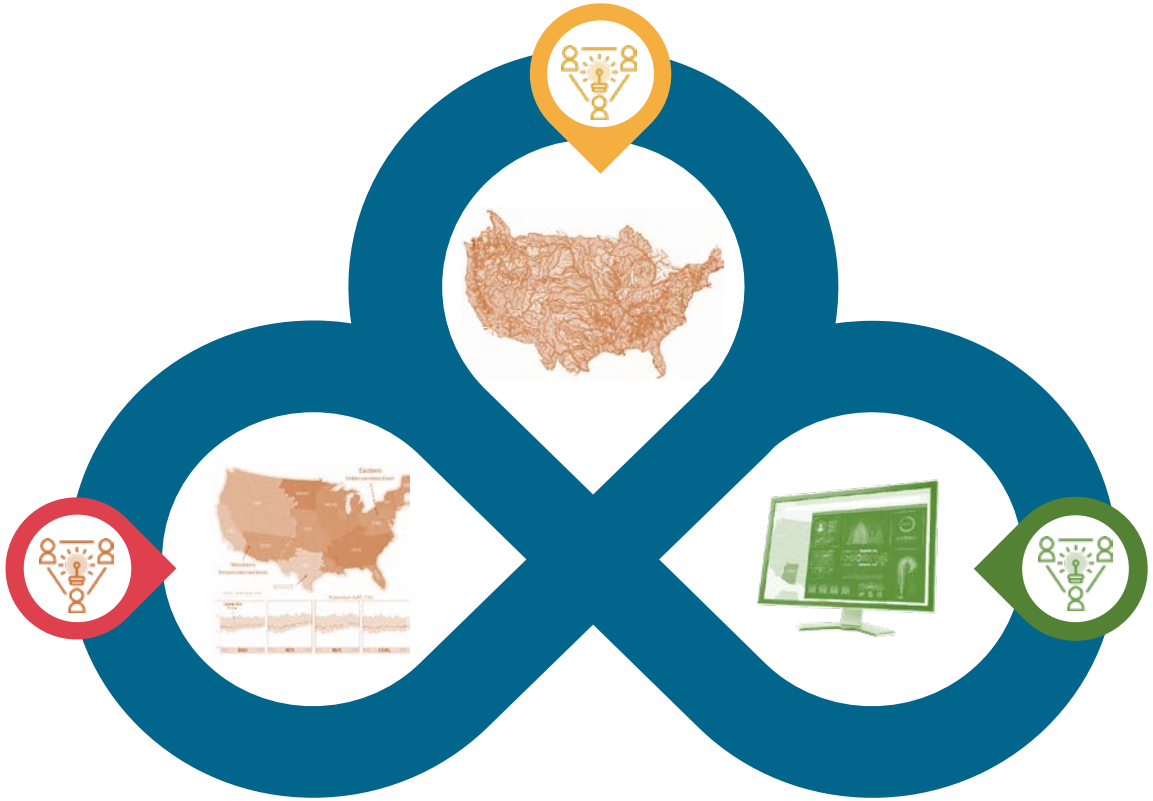
**Our goal**: Ensure results are meaningful and relevant

**Stakeholder opportunity**: Learn and share input throughout the course of research

**Codeveloping energy-water scenarios**

**Our goal**:
Consider stakeholder interests

**Stakeholder opportunity**:
1-1 meetings with team to inform the design of scenarios relevant to service territory and grid assets



**Feedback and testing of visualization tool**

**Our goal:**
Ease of use for efficient data access and interactive analysis

**Stakeholder opportunity:**
Access to data and results relevant for climate planning and scenarios

**Dissemination**

1. Provide useful data and information through the visualization platform for stakeholders, including Independent system operators (ISOs), regional transmission operators (RTOs), utilities, and water resource planners, the public, and academia.
2. Publications of a series of energy-water modeling assessments + presentations at webinars, workshops, and conferences.

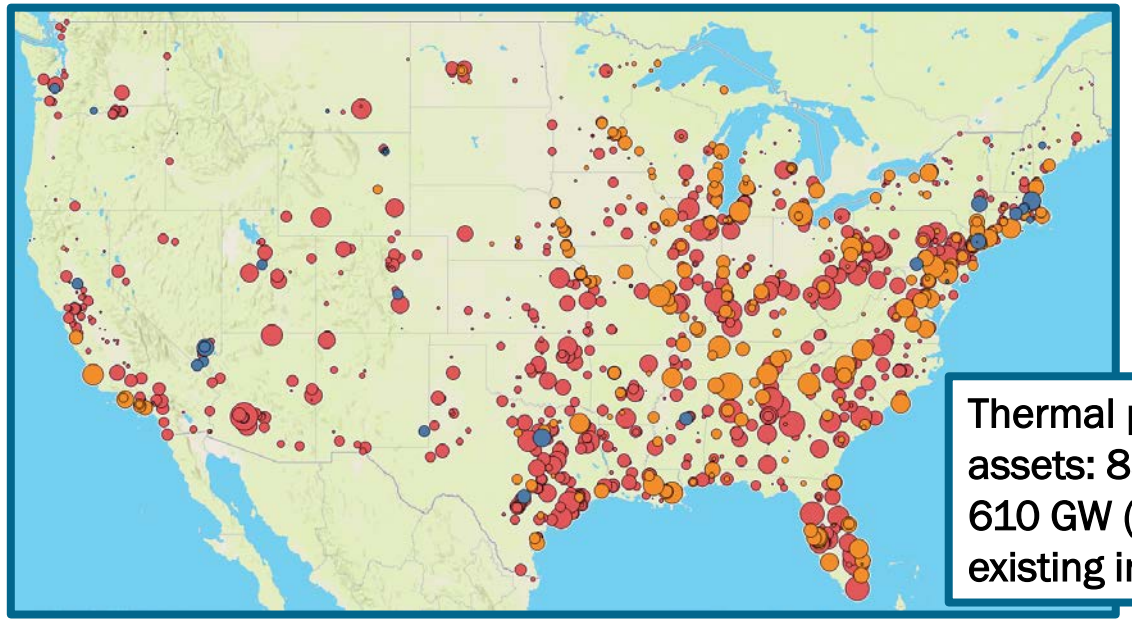
# Performance, Accomplishments, and Progress: Energy-Water Modeling Assessments

## Accomplishments

- High-spatial-resolution (1-minute, 2x2 km) hydrologic modeling
- Infrastructure data sets assembled:
  - Dams (powered/non-powered), thermal plants.
- Established methods and tested model framework under historic climate conditions
- Integrated weekly hydropower constraints, from hydrologic models to grid dispatch modeling.

## Progress

- Thermal and flood risk analyses
- Demonstrating trade-offs between thermal and hydro asset operations when including climate-water constraints, which also cascade to grid-level impacts
- Other infrastructure and water demands: generating stations, large non-power dams, reservoir water demands.

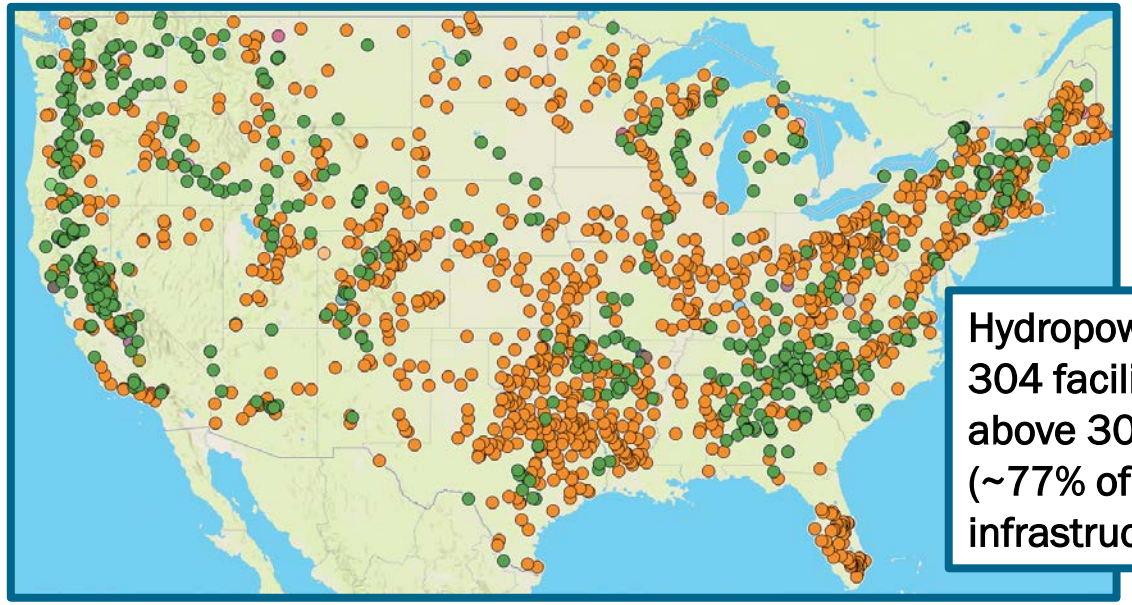


Once through

Recirculating

Dry cooling

Thermal power assets: 839 facilities, 610 GW (~80%) of existing infrastructure



Powered dam

Non-powered dam

Hydropower assets: 304 facilities (all above 30 MW), 61.5 (~77% of existing infrastructure)

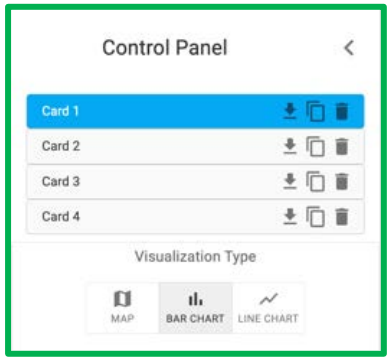
# Performance, Accomplishments, and Progress: Visualization Tool

## Accomplishments

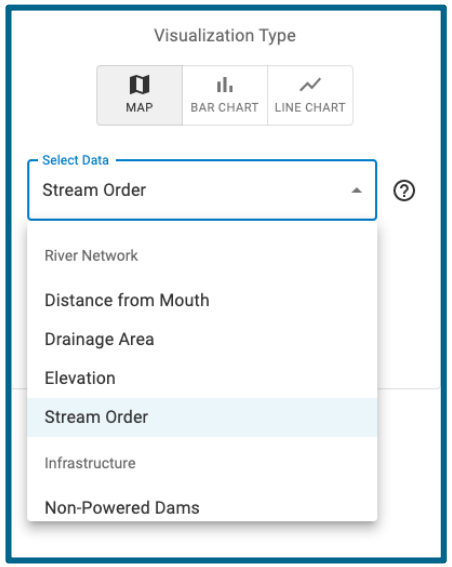
- The tool has demonstrated stability and efficient performance with a subset of data sets designed to meet the project outcomes:
  - Publicly available analysis platform with nationwide conterminous scope
  - Considers multiple power asset and system-level climate-water-energy attributes at the same time.
- Identified approaches to reduce risks associated with large data sets and a range of queries.

## Progress

- Connecting the data sets across models
- Continue adding data and results from all models in the modeling framework.
- Enhancing API/visualization so users can successfully interrogate the data sets.
- Stakeholder feedback (ongoing).

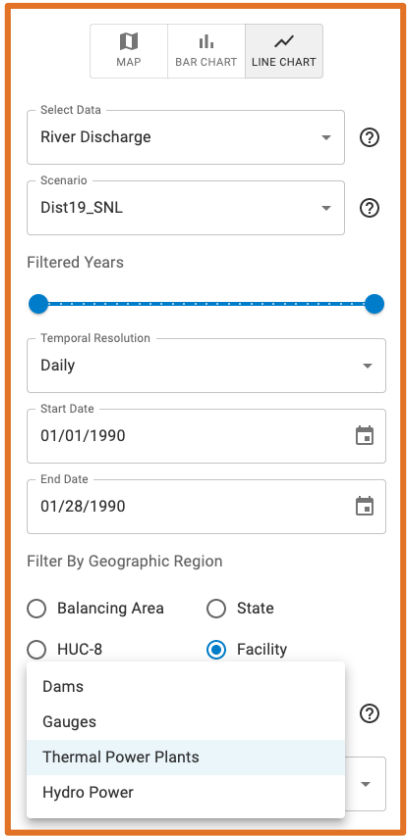


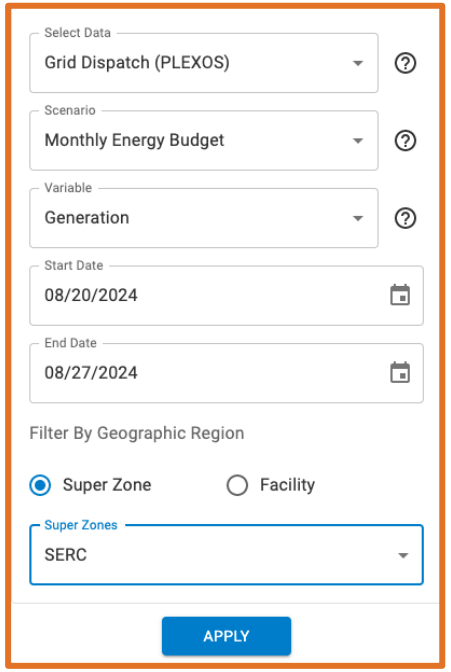

*Consolidated area for all controls and placing all data in an organized workflow*




*Explore river network topology*

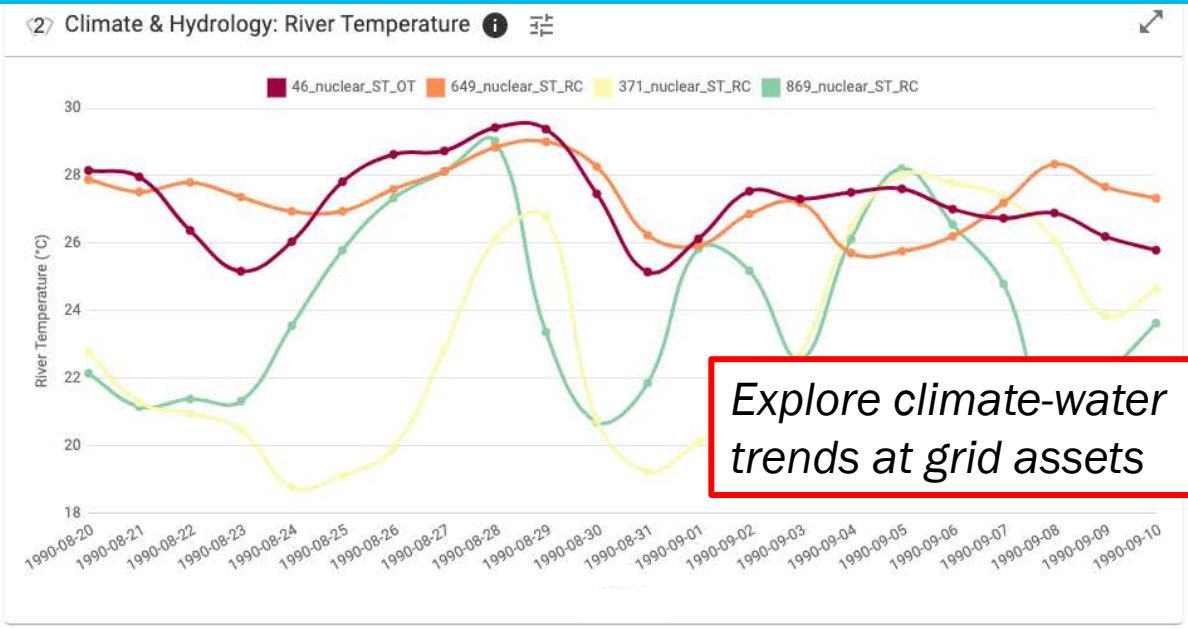
*Evaluate climate-water trends at grid assets and impacts on available capacity and grid operations*



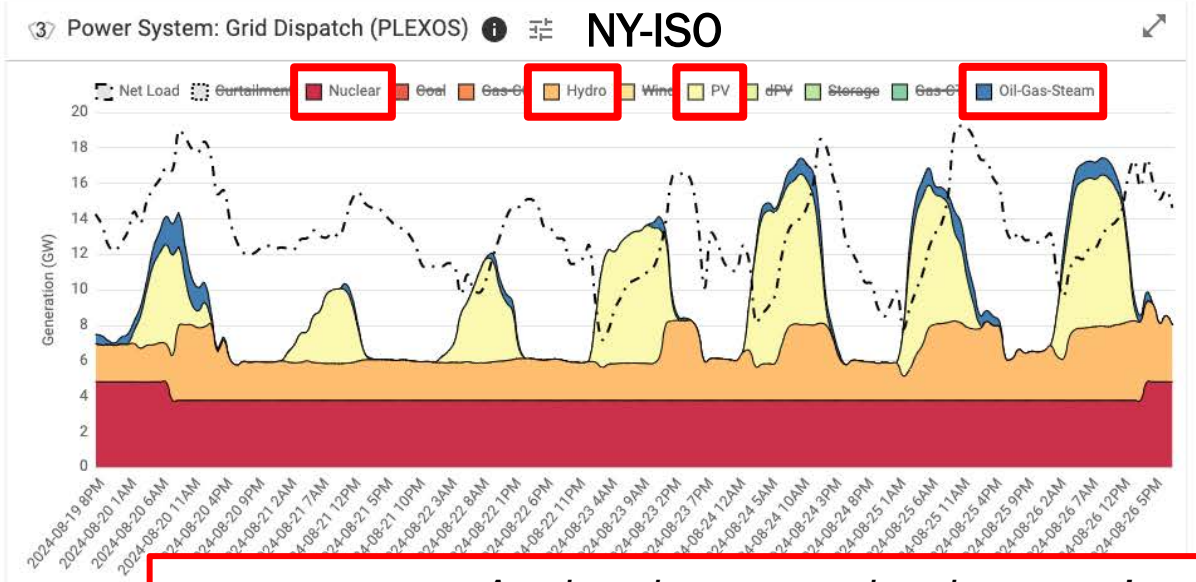



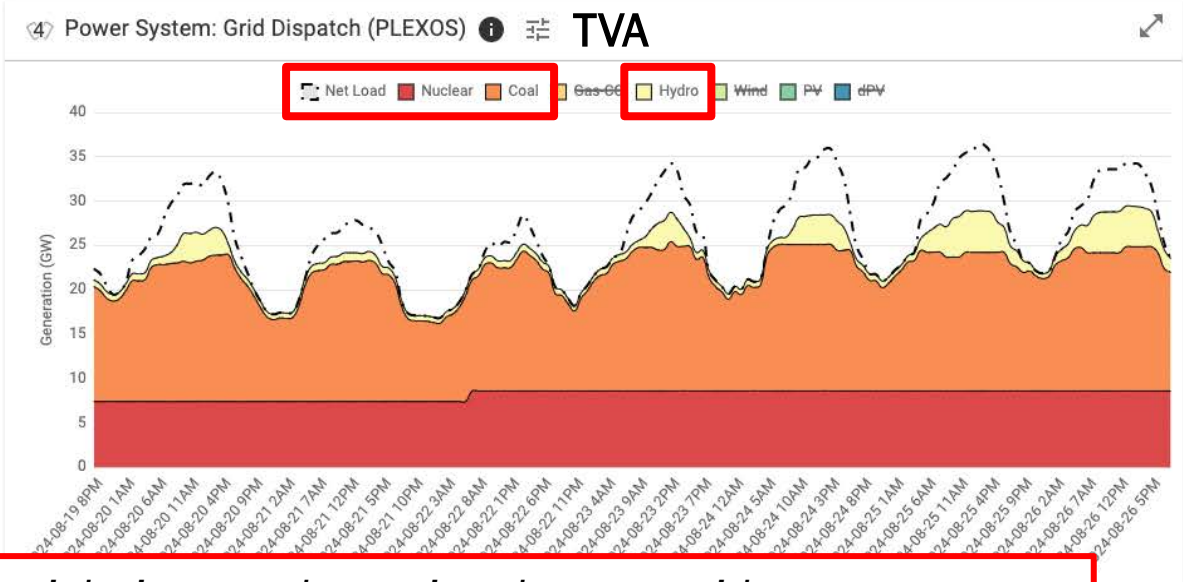
# Performance, Accomplishments, and Progress: Visualization Tool


*Explore infrastructure and river network topology in a grid region or watershed of interest*




*Explore climate-water trends at grid assets*




*Analyze how asset-level constraints might impact the regional power grid:*
*Regional or scenario comparison + trade-offs across technologies*

# Future Work

- Finalize energy-water model runs and series of analyses on water risk topics including:
  - Trade-offs in power system operations in reliability when considering water risk to hydro and thermal assets
  - Climate-water impacts and adaptation for long-term power system planning
  - Future climate-water impacts on hydro and thermal assets, including available capacity
  - Thermal and ecological risk
  - Flood risk.
- Demonstrate an updated version of the water risk visualization tool in a webinar with DOE and industry stakeholders that includes a larger set of modeling results (Target date: Early Q1, FY 2023)
- Continue stakeholder engagement on water metrics, analyses, and the visualization tool:
  - Solicit feedback from a group of test users (across DOE labs and industry) throughout Q1 and Q2 of FY 2023.
  - Feedback will inform potential tool development (beyond FY 2023) and help prioritize final development and analysis.
- Perform regional case study analyses: Implement the multi-model framework under region-specific scenarios or using region-specific models and data, in coordination with regional stakeholders.

# Project Budget

| Lab | FY 2019 Costs | FY 2020 Costs | FY 2021 Costs | Total Actual Costs FY 2019–FY 2021 |
|---|---|---|---|---|
| NREL | NA | NA | $161K | $161K |
| NREL (sub to CUNY) | NA | NA | $120K | $120K |
| NREL (sub to EPRI) | NA | NA | $100K | $100K |
| ORNL | NA | NA | $148K | $148K |
| SNL | NA | NA | $99K | $99K |
| SNL | NA | NA | $0K | $0K |
| **Total** | NA | NA | $628K | $628K |

- Minor overall difference from FY 2021 planned costs ($617K), no change in scope required
  - $124K (20%) of in-kind cost-share from CUNY, EPRI, and stakeholders for FY 2021.