1.2.2.604/35979 – Value of Flow Forecast to Power System Analytics

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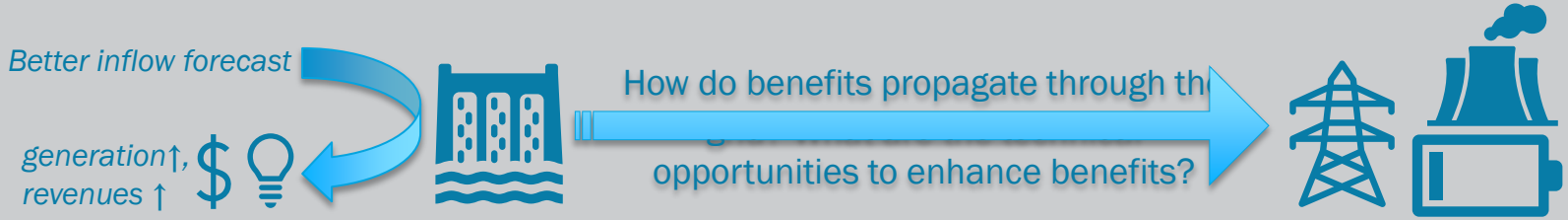
Project Overview

Project Summary

- Value of flow forecast for hydropower generation is typically assessed at individual power plants or cascading plants in one river basin. With this approach, only benefits in generation and revenues are quantified. It is unclear if flow forecasts and hydro-meteorological forecast in general can provide services to the power grid as a system.
- We cascaded flow forecasts at 85 locations across the Western US into power grid operations to expose how forecasts are presently integrated and how this integration influences the value proposition of flow forecast to the power grid.



Intended Outcomes

- A baseline understanding of the value of flow forecasts all the way to power grid operations.
- Novel guidance to inflow forecast developers on the wider impact and use of their products
- Technical gap analysis of the hydropower scheduling tool chain to enhance hydropower opportunities
- Transfer lesson-learn to industry and academia via publications and new projects

Project Information

Principal Investigator(s)

- Nathalie Voisin (PNNL), Thomas Mosier (INL)

Project Partners/Subs

- Jordan Kern (North Carolina State University)
- Andy Wood (National Corporation for Atmospheric Research)
- Hongxiang Yang, Kostas Oikonomou, Sean Turner (PNNL)

Project Status

Completed – Extended in a new phase

Project Duration

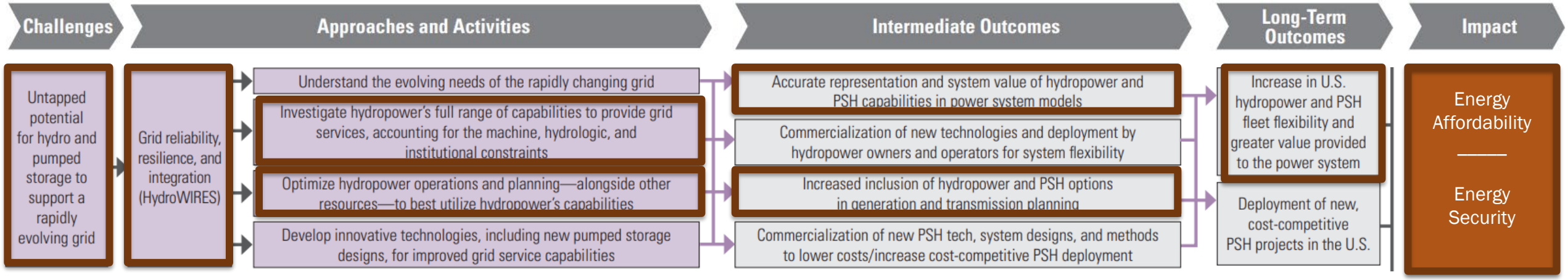
- October 2019
- April 2021

Total Costed (FY20–FY21)

$288k

Project Objectives: Relevance

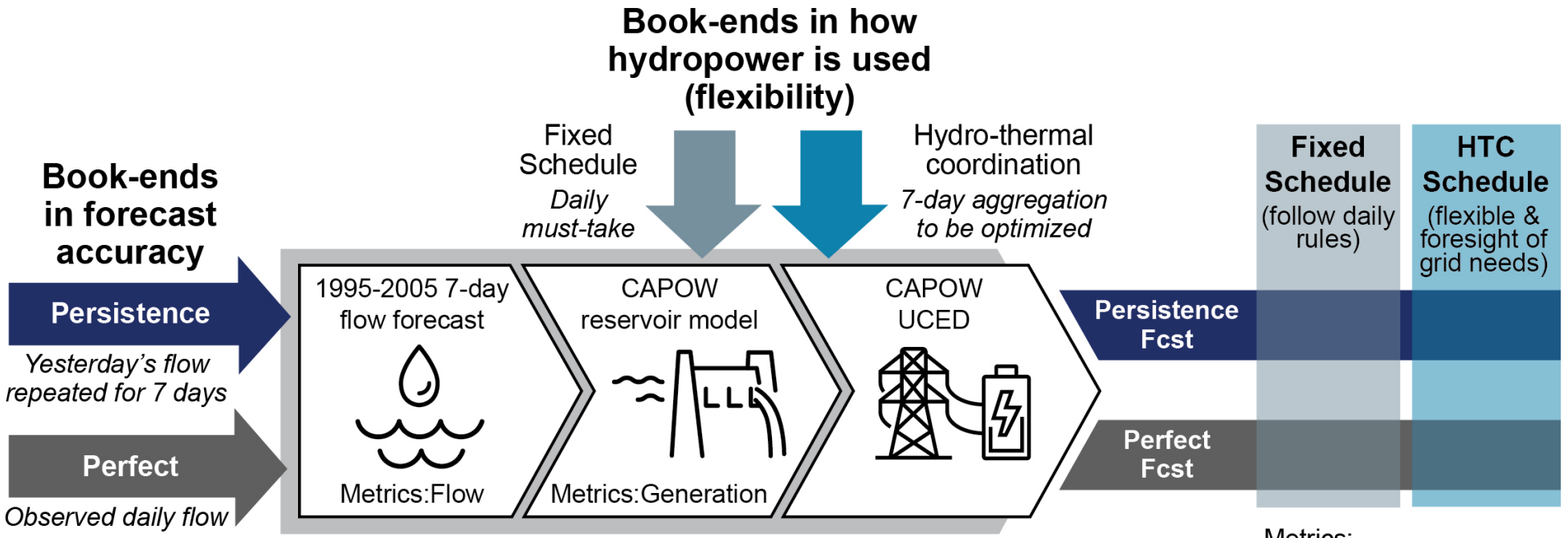
Relevance to Program Goals:

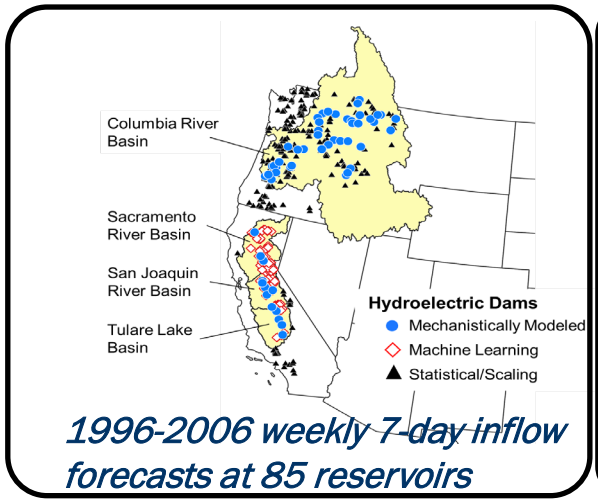


By exposing the value of inflow forecast all the way to the power grid, the project also contributes to the basin-scale water-energy tradeoff dialog with insight on regional power grid reliability and energy cost i.e. beyond asset-scale revenues

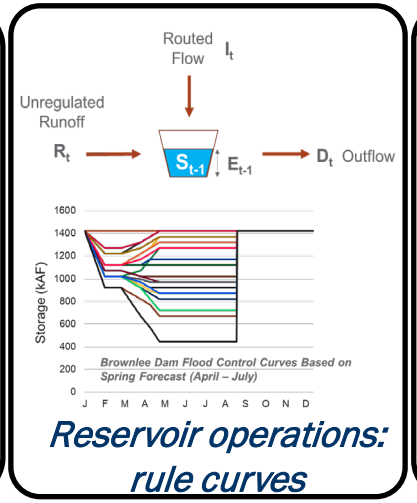
Project Objectives: Approach

First cascading of medium range flow forecast over multiple river basins through a reservoir operations and power system models

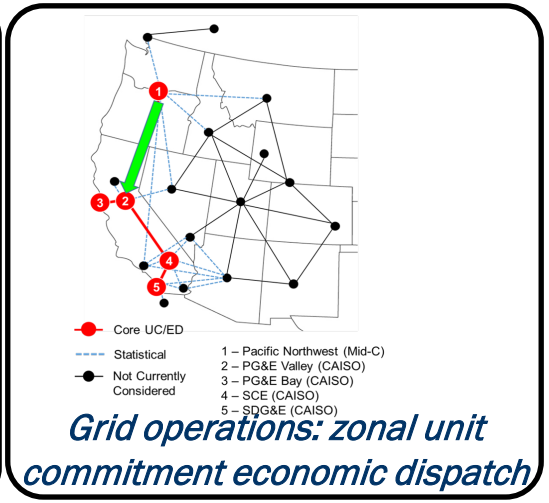




1996-2006 weekly 7-day inflow forecasts at 85 reservoirs



Reservoir operations: rule curves



Grid operations: zonal unit commitment economic dispatch

Metrics:
- Regional System Cost
- Regional Electricity Prices

Zonal representation restricts the perspective to system operators but allows >10^3 simulations in forecast mode.

Project Objectives: Expected Outputs and Intended Outcomes

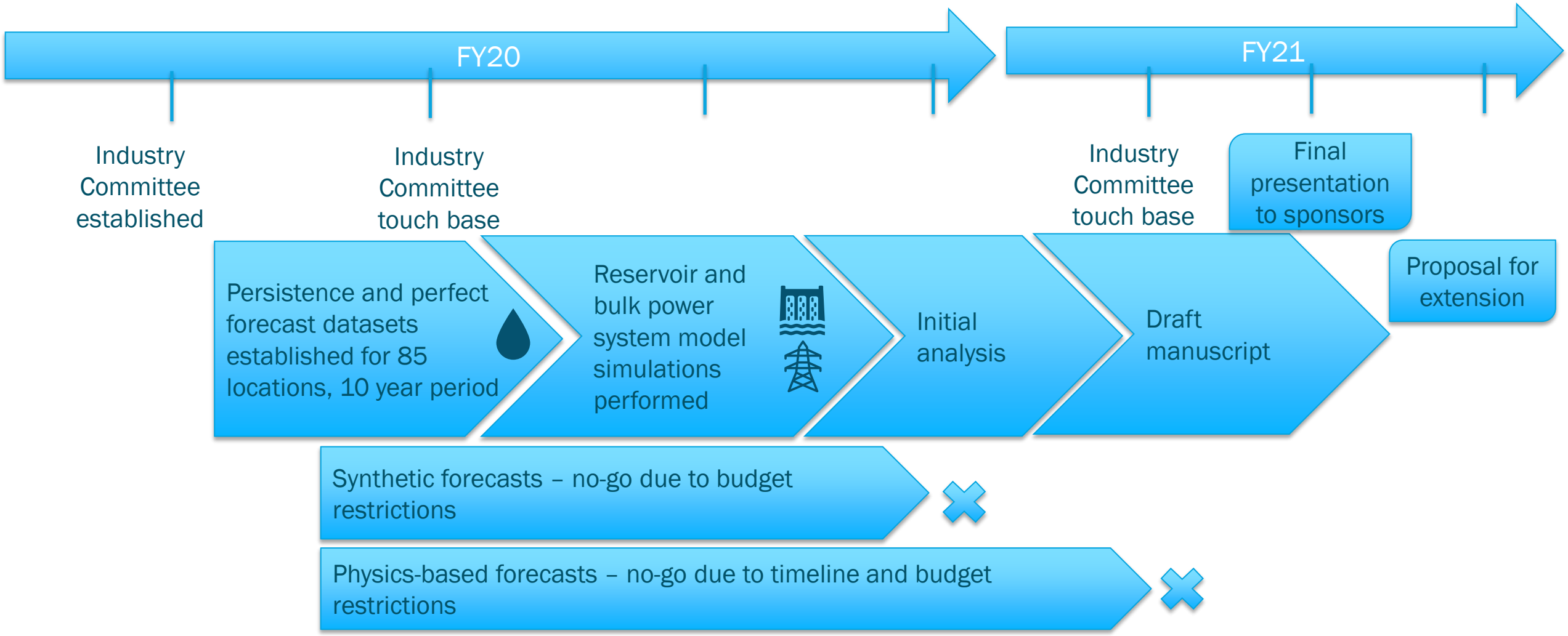
Outputs:

- New applied research workflow on hydropower scheduling
- Datasets of western coastal power grid electricity prices and key performance metrics such as loss of load and greenhouse gas emissions
- 2 Publications
- 5 presentations at international conferences and industry consortiums

Outcomes:

- Challenge reported by the hydropower industry on the non-monetized hydropower services finally quantified
- Technical gap analysis on hydropower representation in bulk power system models to address the quantified conflicting expectations between system operators and hydropower operators
- Awareness of commercial software developers for innovation on hydropower scheduling

Project Timeline



Project Budget

FY20	FY21	Total Actual Costs FY19–FY21	FY22
Costed	Costed	Total Costed	Costed
$225K	$63K	$288K	$12k (publication)

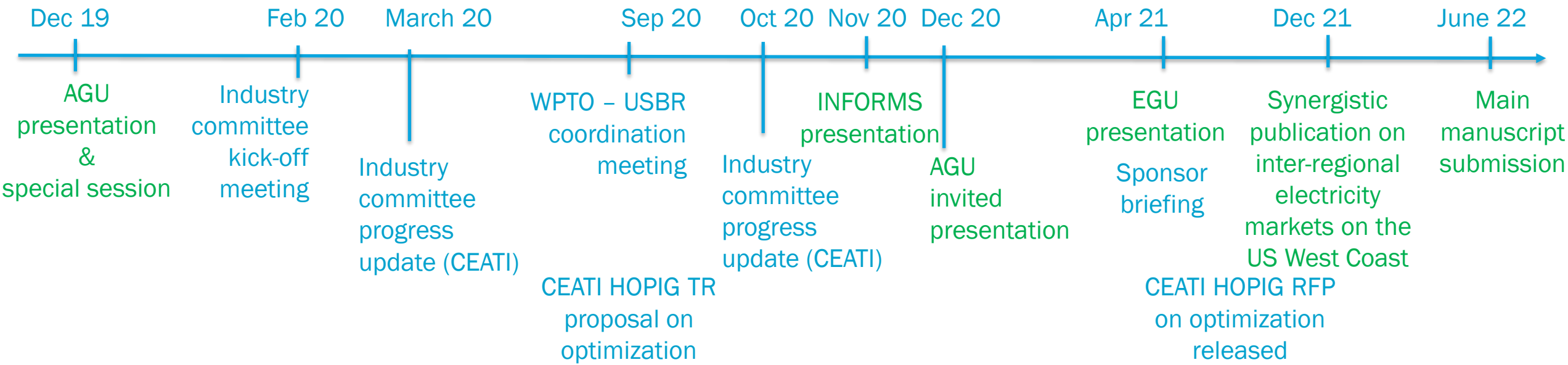
- No discrepancy in budget
- Delay in execution associated with contracts and availability of forecast datasets at reservoir locations
- GNG stage gate used for the development of synthetic flow forecasts expected to provide preliminary results prior to using physics-based inflow forecasts.
- GNG stage gate on the use of physics-based inflow forecast – evaluation of the forecast was not performed and not included in the project due to budget and timeline

End-User Engagement and Dissemination

Combination of industry engagement:

- Industry committee (USBR, Brookfield Renewables, TVA, OPG)
- Presentations at industry consortiums (CEATI HOPIG, WPTO-USBR coordination webinars),
- Co-led proposition of technical project with CEATI HOPIG on hydropower scheduling optimization with an emphasis on toolchains – the project was voted, moved into request for proposal, awarded and started in Fall 2021

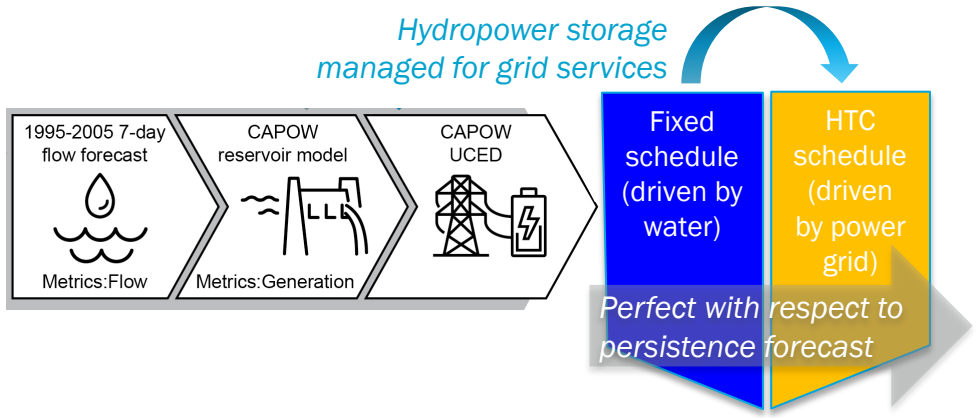
and academic engagement with presentations at national and international conferences and peer-reviewed scientific publications

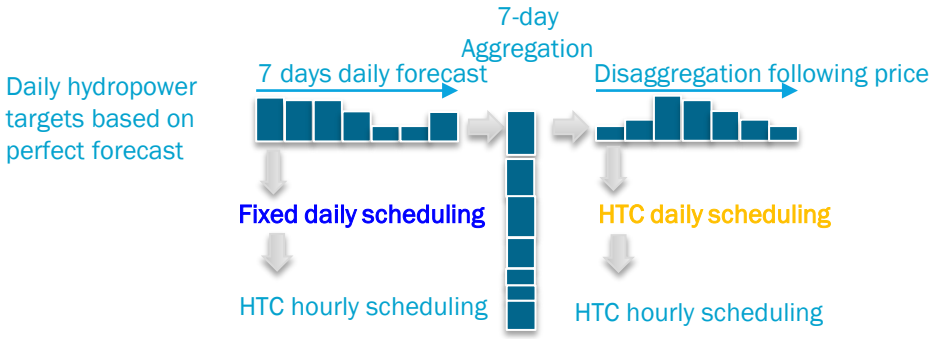


Performance: Accomplishments and Progress

We quantified the impact of medium range flow forecasts accuracy to western US power grid day-ahead operations:

APPROACH

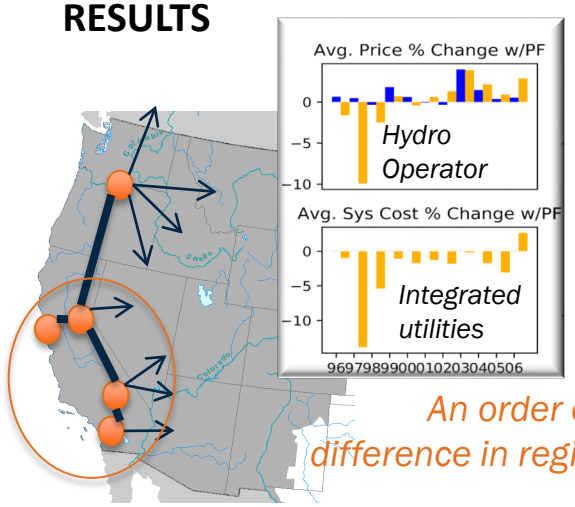




Modeling chain used for scheduling hydropower is key in determining flow forecast services and exploring incentives

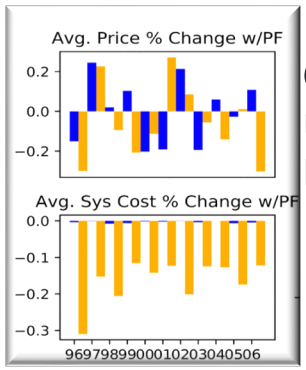
Voisin, N., J. Kern, K. Oikonomou, H. Yang, S. Turner, T. Mosier, A. Wood "Regional variations in medium range flow forecast value to the power grid: a western US Case Study". Applied Energy (submitted).

RESULTS



Pacific Northwest, substantial sensitivity of both prices and system cost, enhanced under an HTC scheduling.

An order of magnitude difference in regional impacts



California, marginal influence on price and system cost

Results indicate the value of increased forecast accuracy (perfect minus persistence)

HIGHLIGHTS

- Accurate hydropower storage forecasting that enables hydropower operators to alter schedule within a week benefits customers by reducing price volatility and power system cost
- More accurate inflow forecasts combined with a scheduling approach tuned for power grid needs can reduce the regional system cost and price by 2 and 1% respectively in California
- The potential is more substantial in the Pacific Northwest with potential reductions of the regional system cost and price by 10 and 7% respectively
- We clarify the nuances in hydropower scheduling toolchains needed to explore climate services for power grid opportunities (customers) and for hydropower operators

Performance: Accomplishments and Progress (cont.)

Cross pollination across projects, technical assistance to industry and new modeling methods for academia

Phase 1

Perfect Load Forecast & Fuel Prices

Grid Perspective – Prices

Storage – perfect initial conditions

7-day perfect/persistence flow forecast

Reservoir Operating Rules – Perfect Foresight

Grid Operations Hydro Dispatch (HTC)

Voisin et al. "Regional variations in flow forecast value to the power grid: a western US Case Study". ERL (in prep).

Coordination on power grid modeling

Hydropower Representation in Production Cost Model (HydroWIRES B1) FY20-21

Transfer to industry already in progress

Lesson Learnt to Academia already in progress

Industry support to help enhance value of forecast and hydropower operational services

SBIR – Valuation of AI/ML inflow forecast FY21-23

CEATI HOPIG Flow Forecast Optimization Project FY22-23

WPTO Technical Assistance – Great River Hydro FY22-23

Operations to Research – clarification of modeling chains and new research models

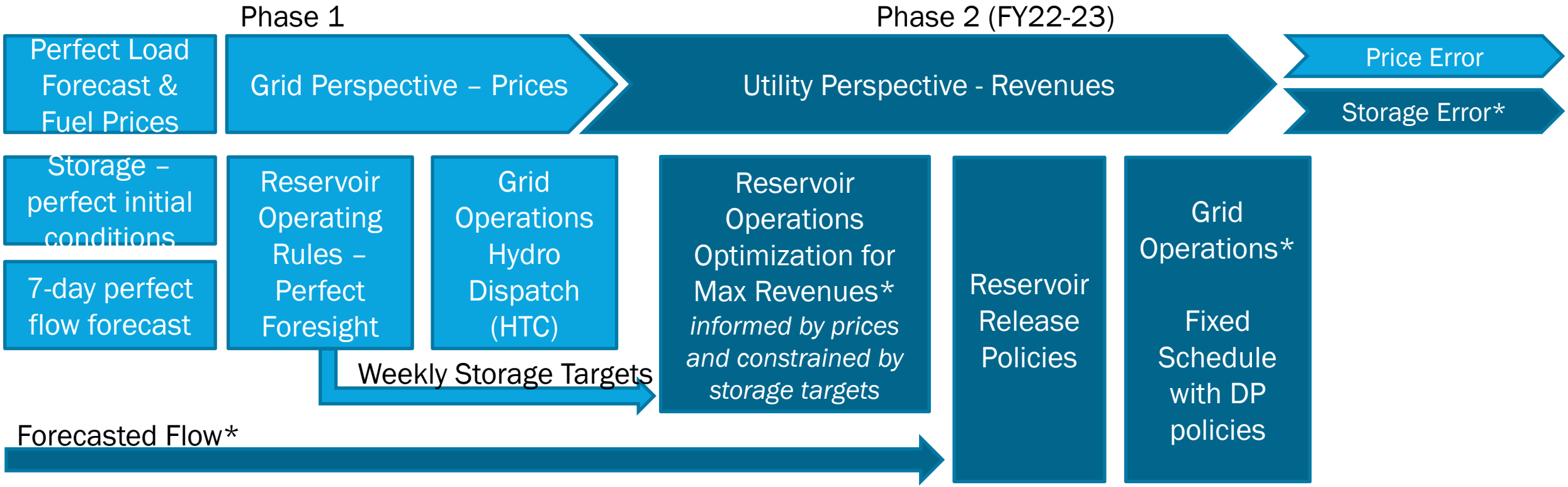
Oikonomou et al. 2022. Core process representation in power system operational models: Gaps, challenges, and opportunities for multisector dynamics research. Energy. 2022;238:122049.

Office of Science – Integrated Multi Scale Multi Sector Modeling – development of a new power grid model and hydropower scheduling toolchain

Future Work

Phase 2 - PNNL: $300k, (incl. $200k subcontracts)

- North Carolina State University (Kern): extended power grid modeling – 300 forecast locations
- Cornell University (Steinschneider): synthetic forecasts
- Extended workflow representative of hydropower scheduling operations for both bulk system operators and hydropower utilities



Q&A