

Value of flow forecast for power system analytics

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Abstract

Most hydropower utilities rely on flow forecasts to manage the water resources of their reservoir systems and to help marketers and schedulers make efficient use of power generating resources. Flow forecast providers and dam operators typically assess the value of flow forecasts by assessing the skill of the forecasts in a verification exercise. Although there are many flow forecasting approaches available—from physics-based approaches associated with statistical pre and post processors and data assimilation, to emerging machine-learning based approaches—there is little consensus on how to choose the best forecast product. Nor are there established methods for translating forecast skill—a summary statistic amalgamating multiple types of errors—to forecast value (benefits or avoided cost) as perceived by a marketer or scheduler. In this work we develop such an approach by combining a water resources management model with a power grid model. Flow forecasts are developed at 85 locations for a varying range of skills, from perfect, to persistent and in-between. Using reservoir and power grid simulations over the Western U.S., we propagate flow forecasts through the power grid model, mapping flow forecast skill to regional hydropower revenues, production costs and carbon emissions. We develop a deeper understanding of the influence of regional and seasonal differences in markets and hydrologic dynamics on forecast value. We discuss future research directions to integrate hydrologic forecasts into decision-making at the utility and wider system scale.



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N. Voisin*, J. Kern, T. Mosier, K. Oikonomou,
S. Turner, A. Wood, H. Yan

NCAR

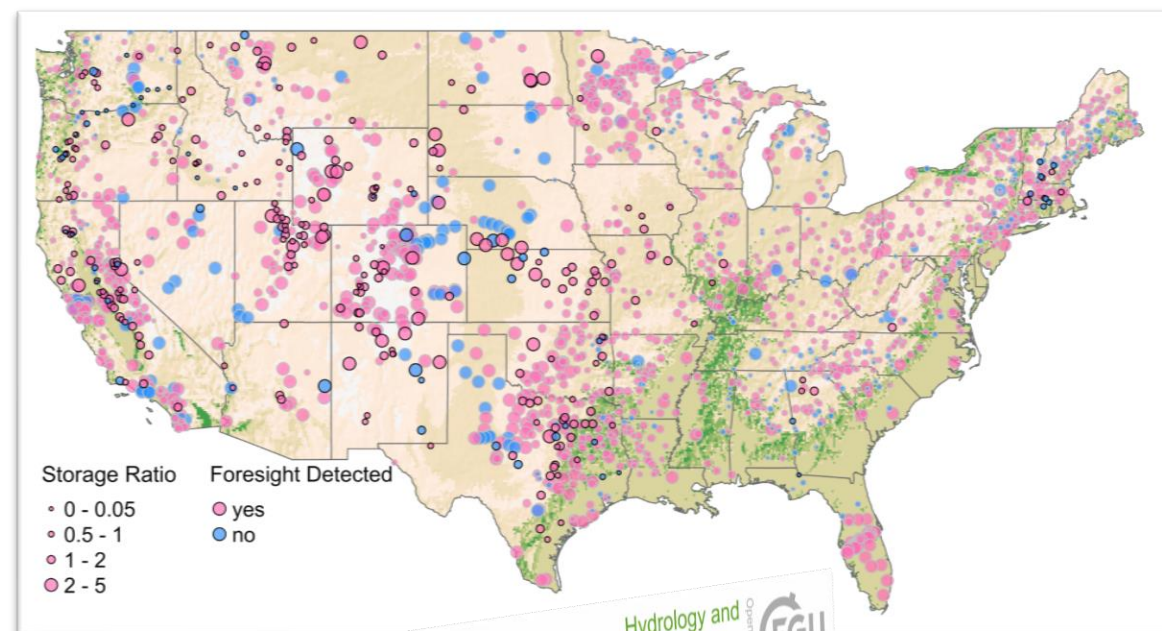
NC STATE
UNIVERSITY



AGU FALL
MEETING



Flow forecast value for water management has been demonstrated



Releases from a large majority of reservoirs are modified based on inflow forecasts.

Turner, S. W. D., Xu, W., & Voisin, N. (2020). Inferred inflow forecast horizons guiding reservoir release decisions across the United States. *Hydrol. Earth Syst. Sci.*, 24(3), 1275-1291. doi:10.5194/hess-24-1275-2020

Hydrol. Earth Syst. Sci., 23, 2735-2750, 2019
https://doi.org/10.5194/hess-23-2735-2019
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Analysis of the effects of biases in ensemble streamflow prediction (ESP) forecasts on electricity production in hydropower reservoir management

Richard Arsenault^{1,2} and Pascal Côté²
¹Department of construction engineering, École de technologie supérieure
²Quebec Power Operations, Rio Tinto, Jonquière, G7S 4R5, Canada

Role of hydrologic information in stochastic dynamic programming: a case study of the Kemano hydropower system in British Columbia

Authors: Quentin Desreumaux, Pascal Côté, and Robert Leconte
Publication: Canadian Journal of Civil Engineering • 26 August 2014 • DOI: 10.1139/cjce-2014-0000

Water Resources Research

RESEARCH ARTICLE
10.1029/2019WR026604

Key Points:
• Ensemble Forecast Operations for Lake Mendocino is a new probabilistic decision support system for reservoir flood control operations.

Forecast Informed Reservoir Operations Using Ensemble Streamflow Predictions for a Multipurpose Reservoir in Northern California

Chris J. Delaney¹, Robert K. Hartman², John Mendoza¹, Michael Dettinger³, Luca Delle Monache³, Jay Jasperse¹, F. Martin Ralph³, Cary Talbot⁴, James Brown⁵, David Reynolds⁶, and Simone Evett⁷

Advances in Water Resources
Volume 71, September 2014, Pages 200-208

Short-term optimal operation of water systems using ensemble forecasts

L. Raso^{a, b, c, d}, D. Schwanenberg^{c, d}, N.C. van de Giesen^a, P.J. van Overloop^a

Advances in Water Resources
Volume 103, May 2017, Pages 51-63

Informing the operations of water reservoirs over multiple temporal scales by direct use of hydro-meteorological data

Simona Denaro^a, Daniela Anghileri^b, Matteo Giuliani^a, Andrea Castelletti^{a, b, c}

Published: 30 May 2007

Climate, stream flow prediction and water management in northeast Brazil: societal trends and forecast value

Kenneth Broad^a, Alexander Pfaff^a, Renzo Taddei^a, A. Sankarasubramanian, Upmanu Lall & Francisco de Assis
Climatic Change 84, 217-239(2007) | Cite this article
33 Citations | 5 Altmetric | Metrics

The valuation of flow forecasts is however limited to enhanced river services within a watershed

Flow Forecast

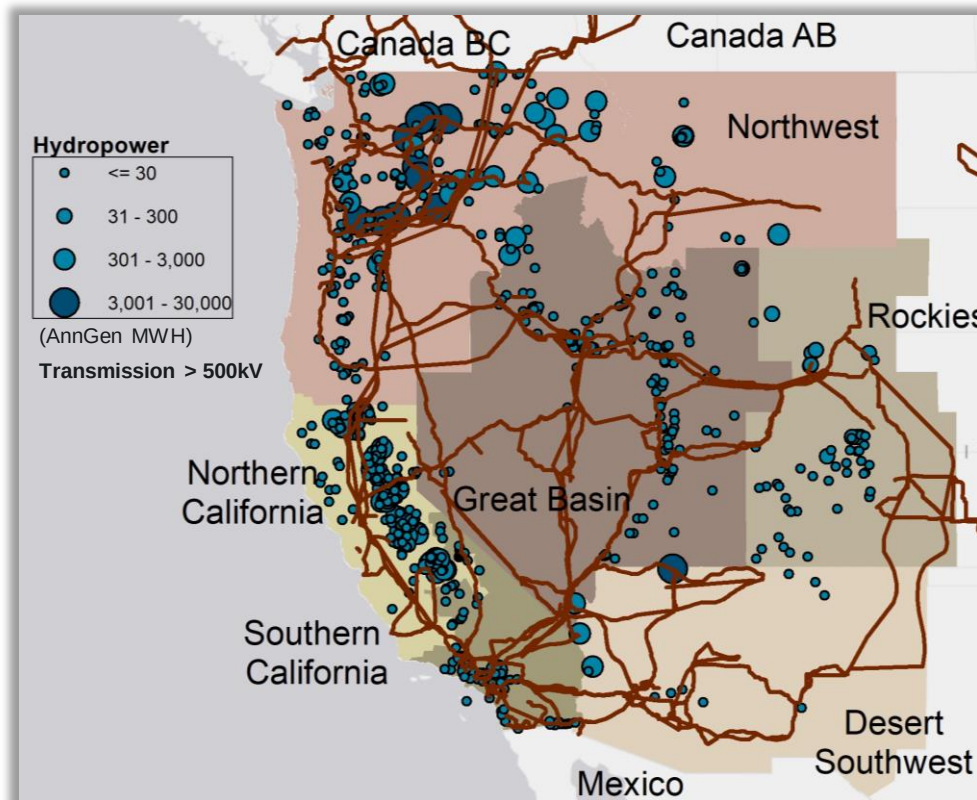
- Accuracy
- Reliability

Water Management / Decision Support System

- Reliability of river services
- Value of river services

Valuation mostly based on enhanced river services

- Hydropower generation & revenues
- Agriculture yield & revenues



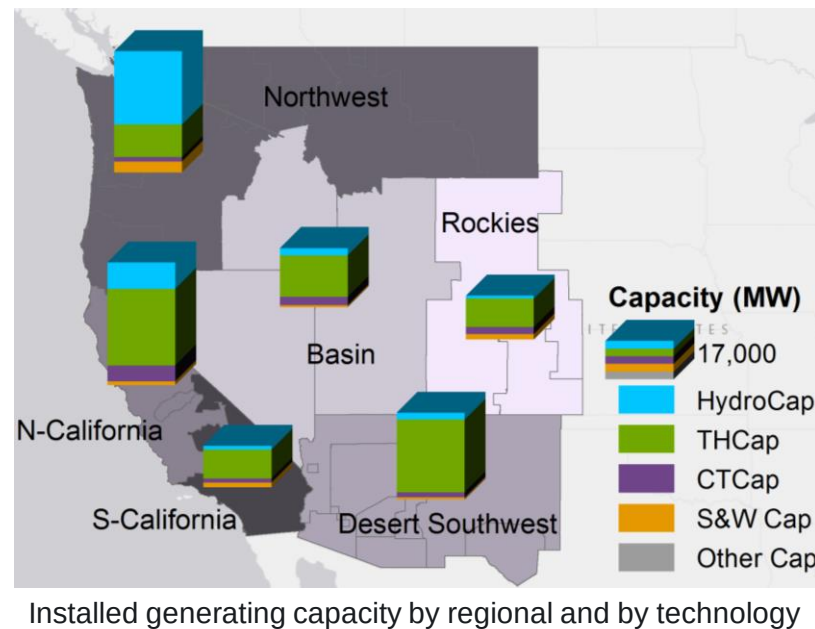
Hydropower rarely serves local load. Hydropower provides cost effective flexible operations (reserve, regulation, ramping, etc). What is the value of flow forecast for grid services?

Science questions

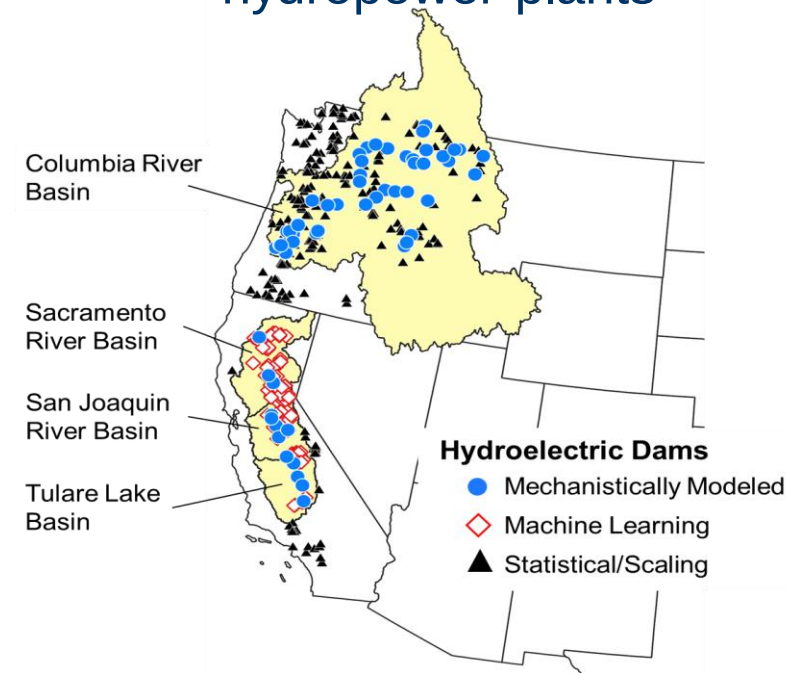
- What is the value of flow forecast for the power grid?
- What have we learned about how flow forecasts influence power systems models to:
 - ✓ Guide the development of flow forecast products specific to grid services
 - ✓ Advance science in hydropower and grid operations under forecast uncertainty?

A Western U.S. Case Study & the CAPOW model

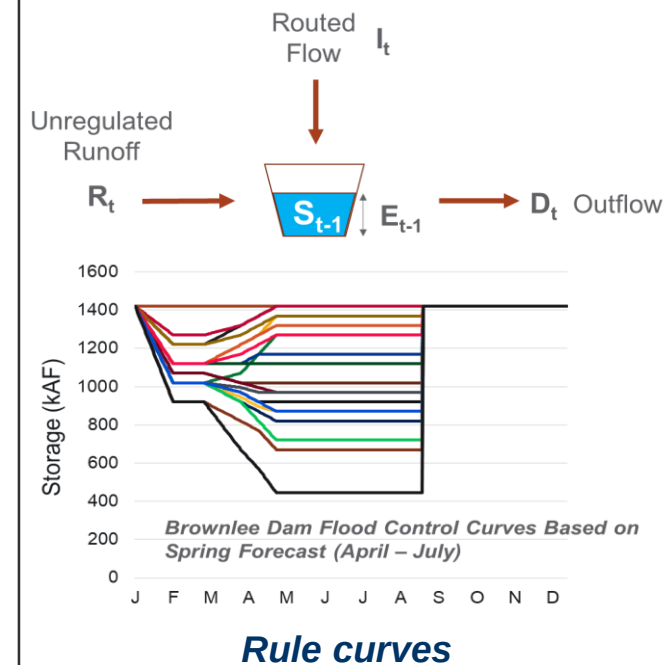
Contribution of hydropower to grid services might be regional



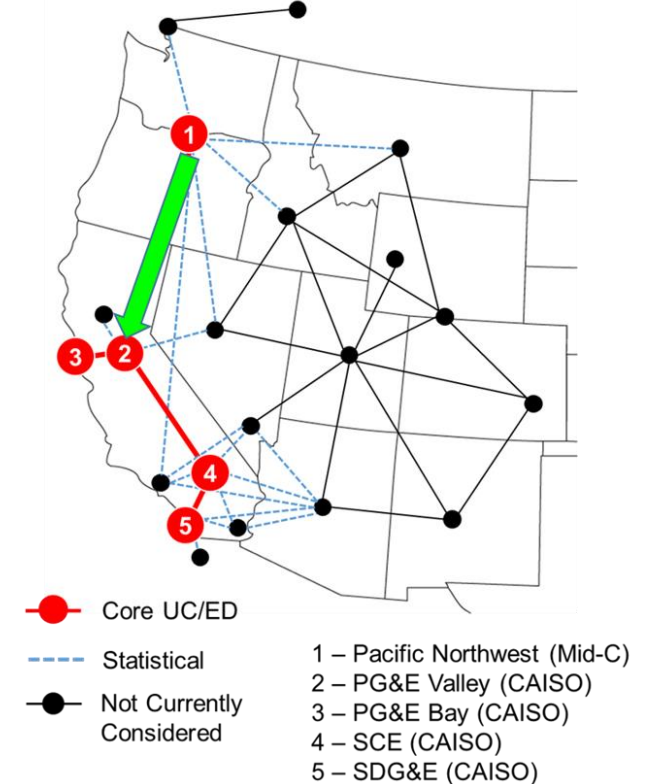
85 represented hydropower plants



CAPOW
Explicit representation of reservoir operations



CAPOW
Zonal unit commitment economic dispatch



Experimental approach

2 book-ends in how
hydropower is used
(flexibility)

2 book-ends
in forecast
accuracy

1995-2005
7-day daily
flow forecast

Fixed
Schedule
Daily must-
take

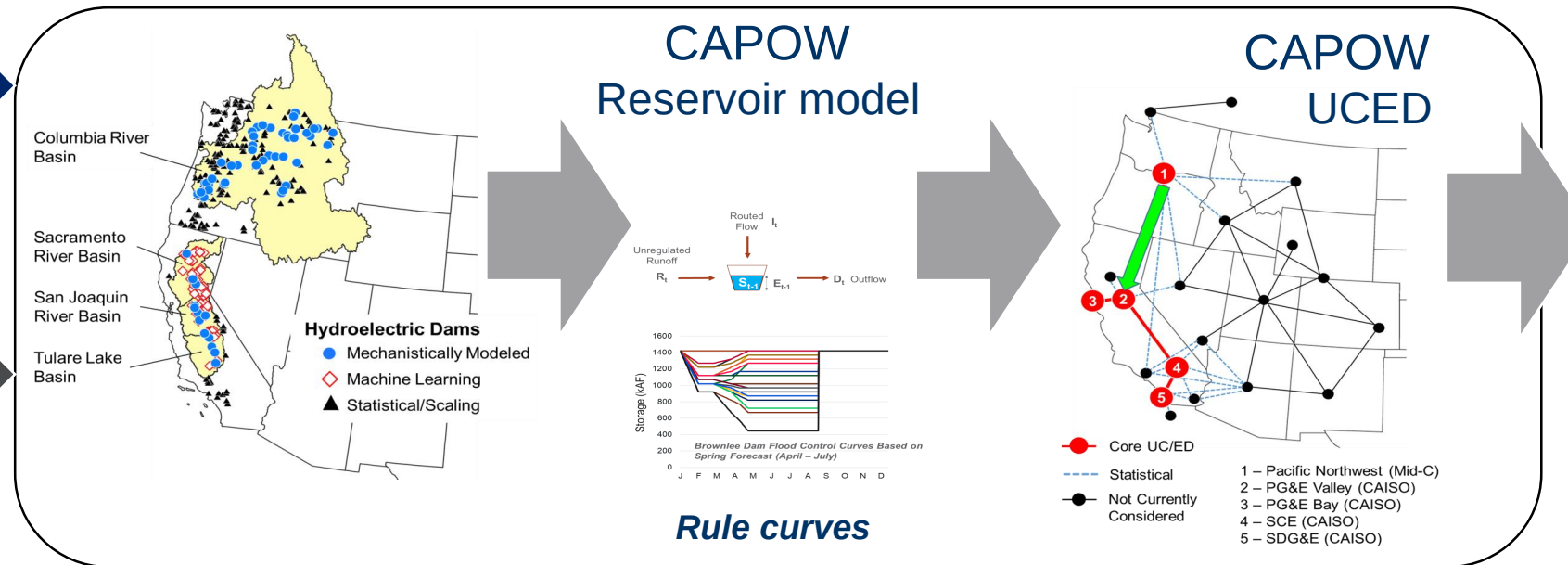
Hydro-thermal
coordination
7-day aggregation
to be optimized

Persistence

Yesterday flow
repeated for 7 days

Perfect

Observed daily
flow



Metrics: Flow

Metrics: Generation

Fixed
Schedule
(follow daily
rules)

HTC
Schedule
(flexible &
foresight
of grid needs)

Persistence
Fcst

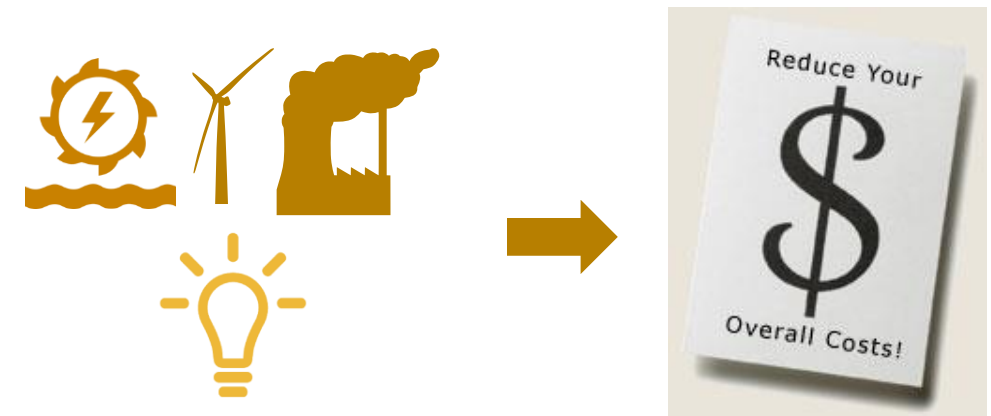
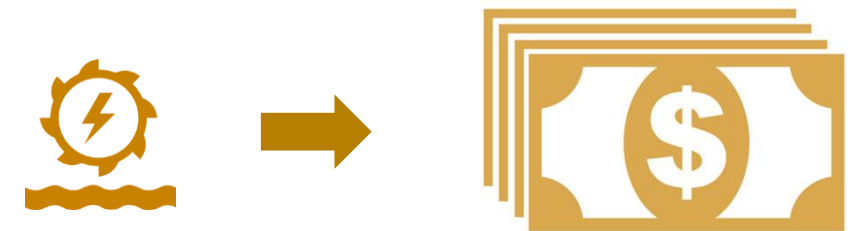
Perfect
Fcst

Metrics:

- Regional System Cost
- Regional Electricity Prices

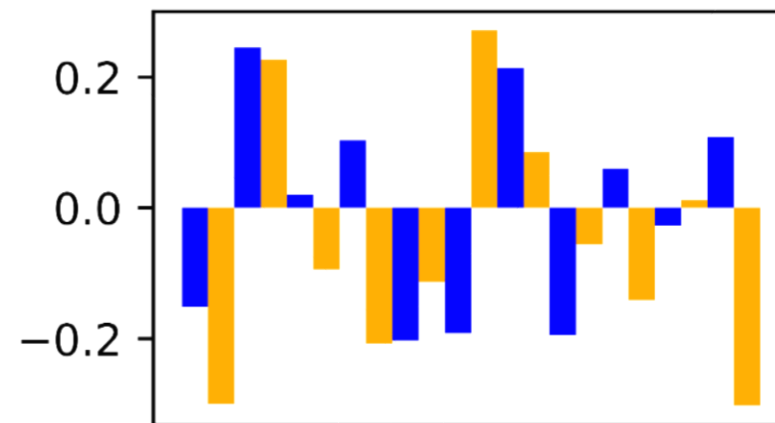
Metrics

- Change in electricity prices
 - ~ changes in revenues
 - map with traditional flow forecast valuation approach for hydropower
 - capture any complex interactions between forecast skill and price variations
- Changes in system cost
 - ~ avoided cost
 - value to utilities with mixed generation portfolio and system operators

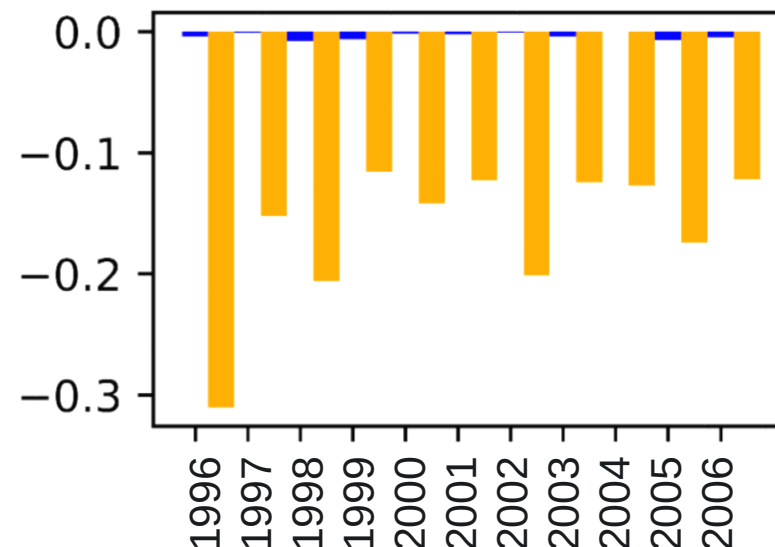


In California, the value of flow forecast propagates mostly into changes in revenue.

Avg. Price - % Change w/ Persist. Fcst



Avg. Syst. Cost - % Change w/ Persist. Fcst



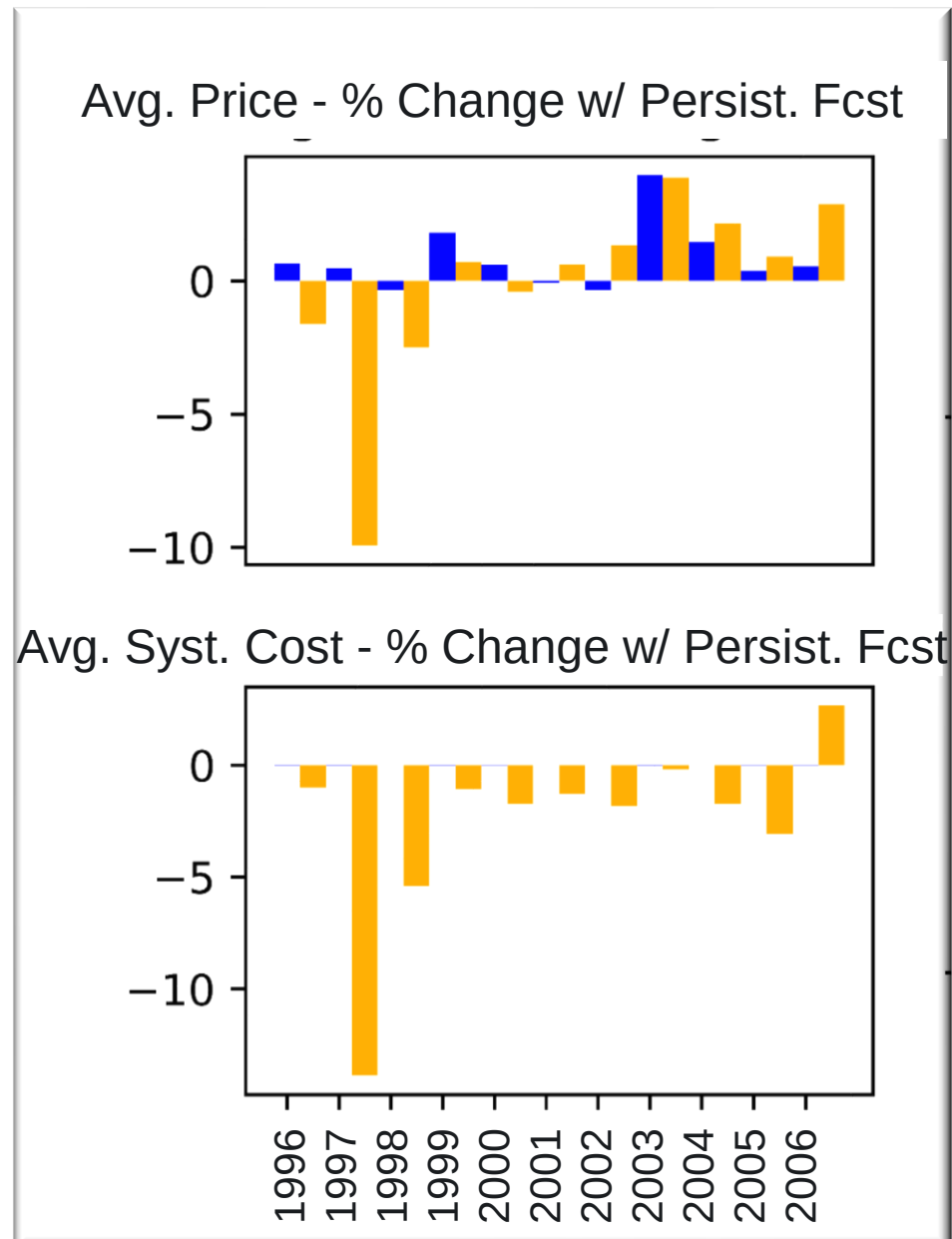
Large Regional Impact: direct relationship between changes in generation and revenues.

Low system-wide impact: HTC enhances value of forecast by further decreasing the system cost (0.3%)

 Fixed schedule, Perfect wrt Persistence
 HTC scheduling, Perfect wrt Persistence

In the Northwest, the value of flow forecast propagates mostly into changes in avoided cost.

And the type of unit commitment for hydropower plays a large role in this valuation process!



Conflicting regional impact: prices are impacted by the forecast. An HTC scheduling enhances price fluctuations and potentially decrease revenues.

High system-wide impact: Combined with HTC, forecast reduce price volatility, system cost and CO2 emission significantly.

■ Fixed schedule, Perfect wrt Persistence
■ HTC scheduling, Perfect wrt Persistence

Conclusions

- The valuation of flow forecast for power systems requires a production cost model in some regions
 - Over California, the value of flow forecasts remains mostly regional measured in generation and revenues.
 - Over the Pacific Northwest, flow forecasts influence both regional and system-wide dynamics (revenues, prices, system-cost).
- For regions with system-wide impact, dual / coordinated optimization schemes can balance regional and system-wide benefits.
- The cost of errors remains a challenge to assess with existing tools.

Thank you
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