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Sensitivity of power system operations to water availability: insight for designing ensemble hydro-meteorological forecasts

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U.S. DEPARTMENT OF ENERGY

Value of climate services to hydropower plants

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Climate services

1. Probabilistic hydro-meteorological forecast: Provide the most accurate short term and mid term flow forecasts.

Inform short term and mid term optimization

Unit - Operations

2. Reservoir operations optimization scheme.

Inform on multi-objectives/ constraints

Water Management Priorities
- Downstream water supply
- Environmental flows
- Downstream flooding
- Lake levels

3. Value Metrics for hydropower operator
- Maintained operational license
- Increased potential generation
- Reduced operational cost

Challenges: all metrics have different scales and units

Objective: Value of climate services to both hydropower plants and the Western U.S. electric grid

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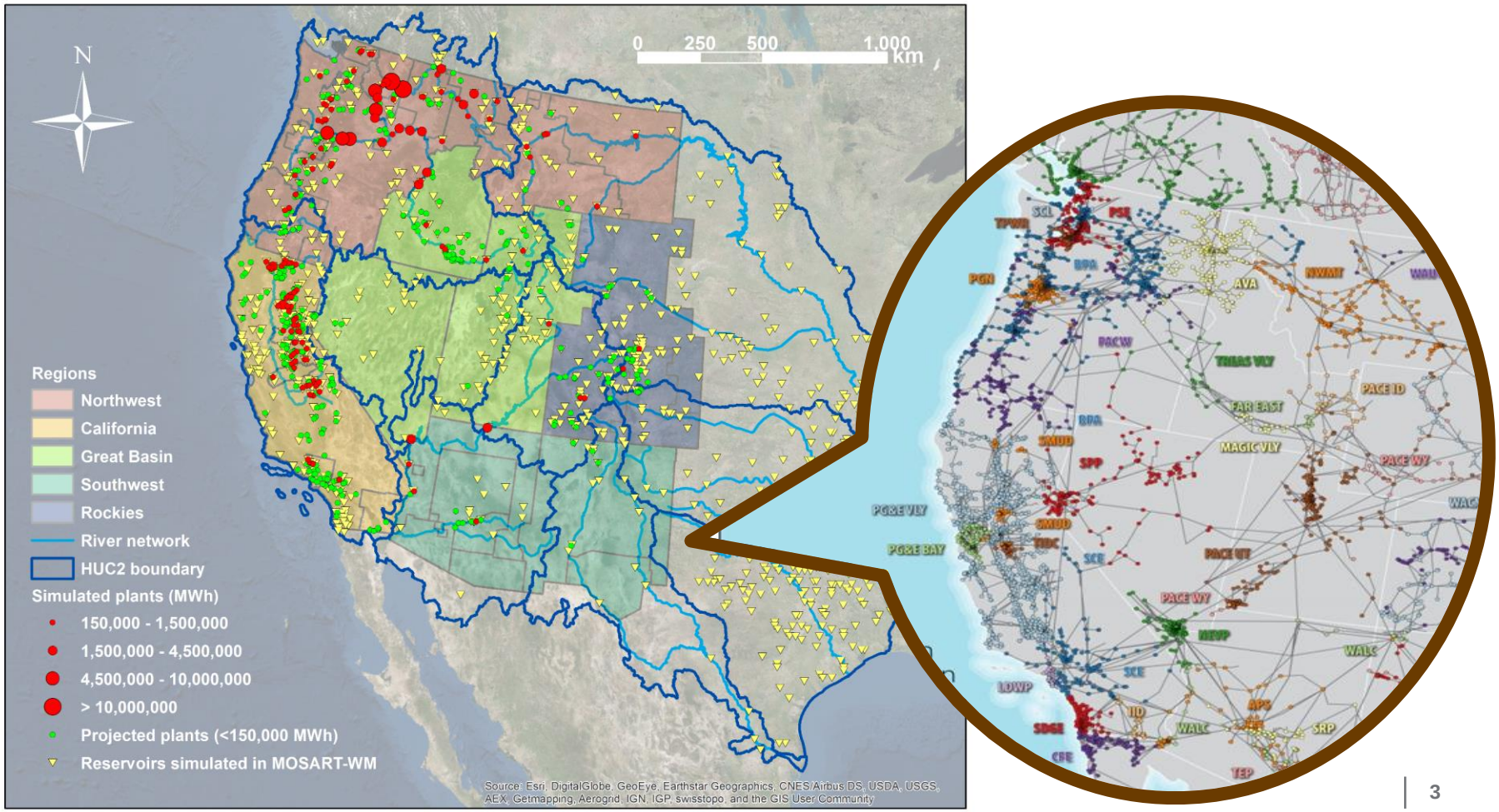
Approach: Transfer flow forecast information at 150 hydropower plants into power system operations, represented by over 15,000 nodes and 1,000 transmission lines



Value of climate services to the Western U.S. electric grid

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1. Quantify the sensitivity of power system operations to water availability
2. Can this sensitivity be predicted, and how well?
3. Convinced? Let's customize a regional flow forecast system.

Quantify the sensitivity of Western U.S. Electric Grid to Hydro-Climate Conditions

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56 years of historical climate

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Hydrological Simulations

↓

Large Scale Water Management

↓

Translate into monthly hydropower potential

Translate into maximum thermo-electric capacity

↓

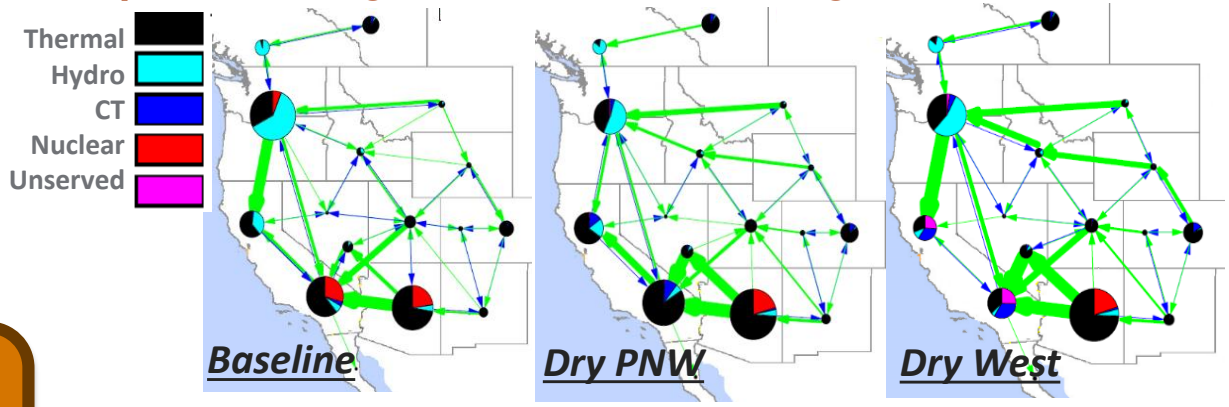
Production Cost Model

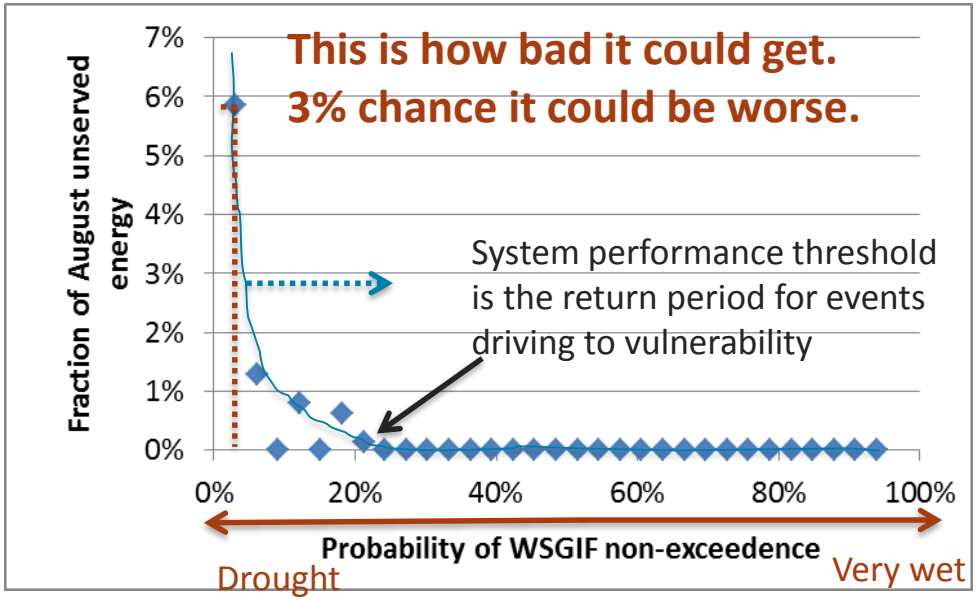
From impact assessment to vulnerability assessment.

Voisin N, M Kintner-Meyer, J Dirks, R Skaggs, D Wu, T Nguyen, Y Xie, M Hejazi. 2016. "Vulnerability of the US Western Electric Grid to Hydro-Climatological Conditions: How Bad Can it Get?" *Energy* **115**: 1-12. DOI: 10.1016/j.energy.2016.08.059

Regional generation portfolio and transmission

Specific drought patterns drive to higher vulnerability





Value of Climate Information for Power System Operations Planning

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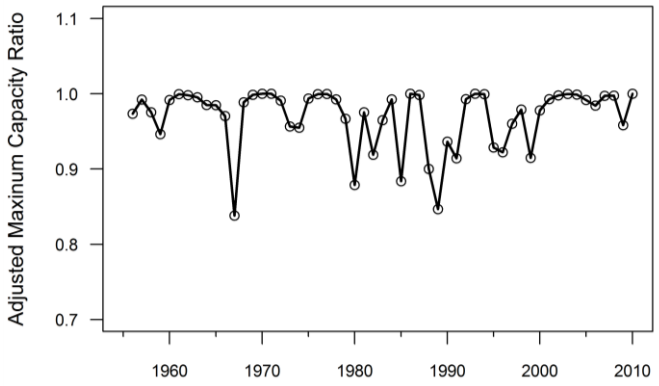
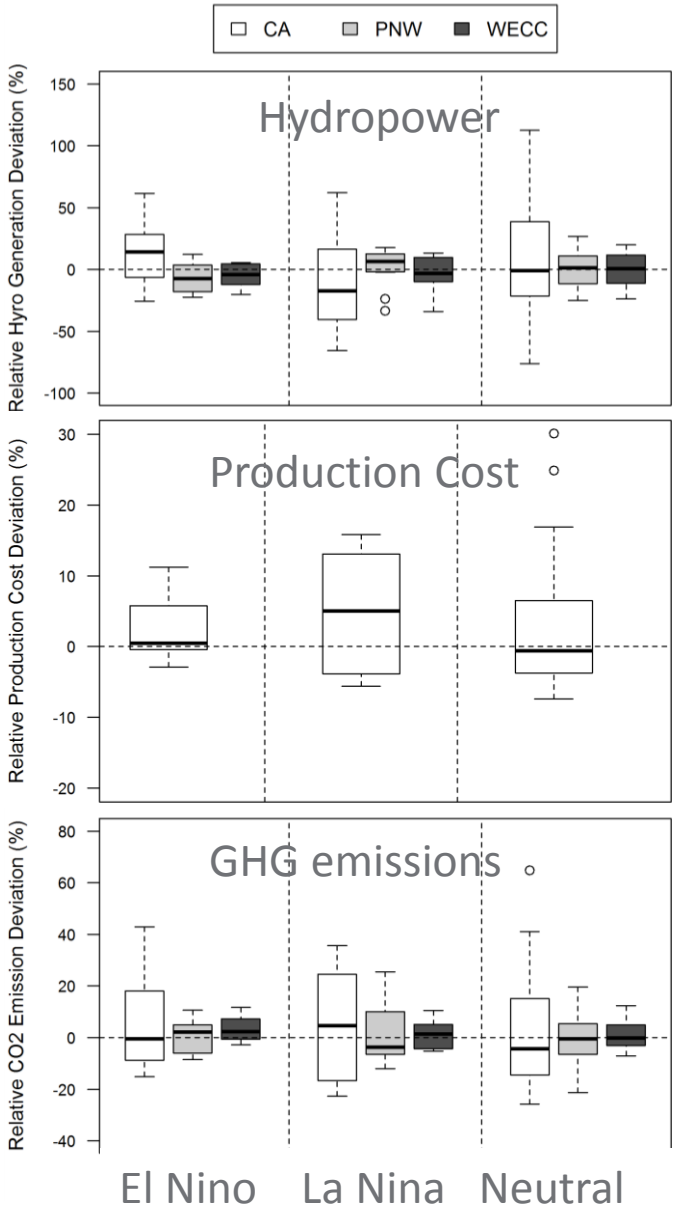
ENSO climate oscillations indices can be used to plan for joint water-electricity management



- El Niño conditions: less prone to brownout and power outages
- Neutral ENSO conditions: more economic power operations (-1%) over the WECC and less carbon emissions (-4%) in California.
- La Niña conditions : least economic operations (+5%) with the highest carbon emission in California (5%) albeit the lowest in the PNW (-4%).



Voisin, N., M. Kintner-Meyer, D. Wu, R. Skaggs, T. Fu, T. Zhou, T. Nguyen, and I. Kraucunas, 2017: Opportunities for joint water-energy management: sensitivity of the 2010 Western U.S. electricity grid operations to climate oscillations. Bull. Am. Meteorol. Soc., BAMS-D-16-0253.1, doi:10.1175/BAMS-D-16-0253.1

Outstanding questions to further integrate hydro-meteorological information into power system operations

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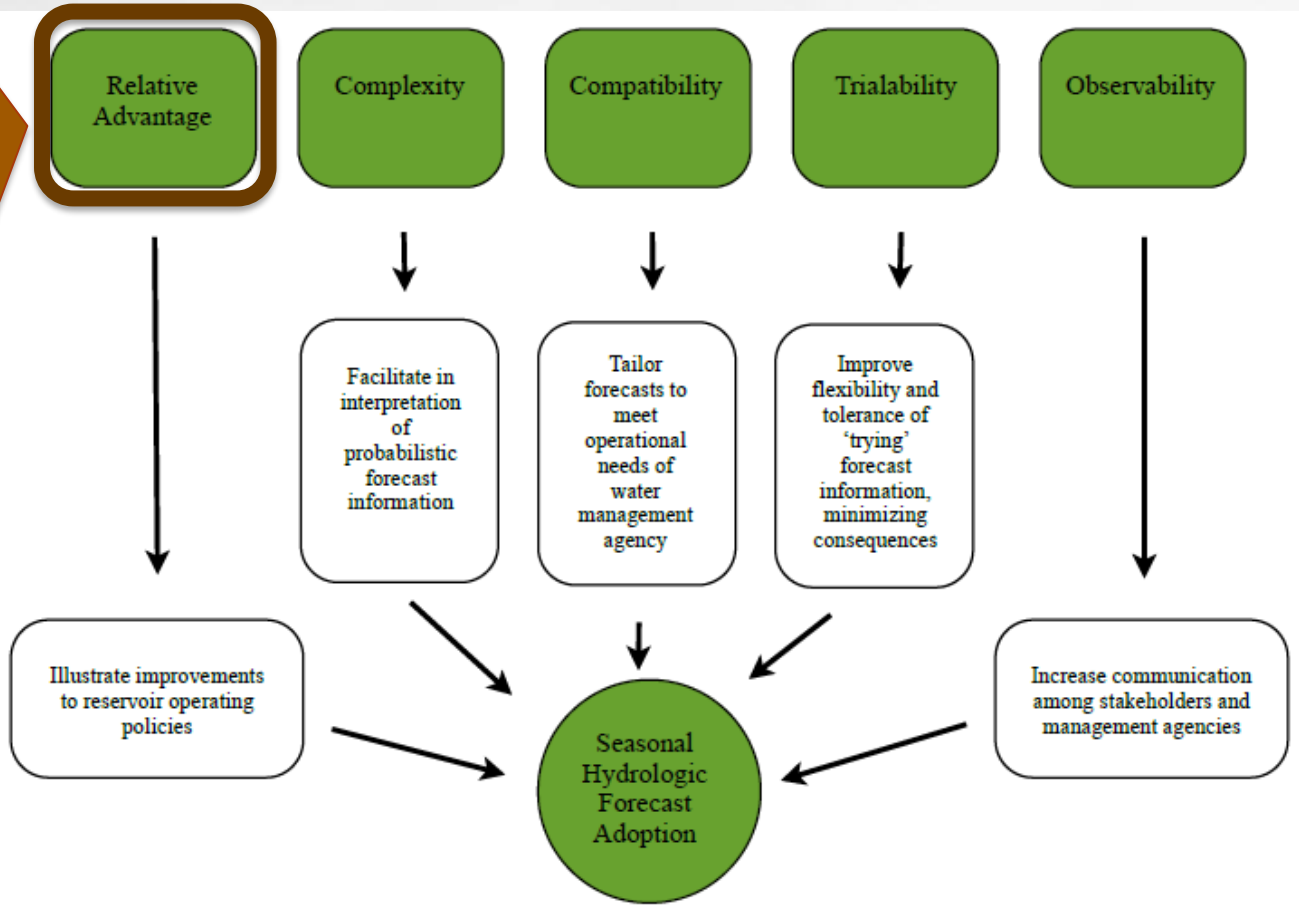
3. Convinced? Let's customize a regional flow forecast system.

Two roadblocks:

1) Who are the potential investors?
2) What are the benefits at the scale of their interest?



Seasonal Hydroclimatic Forecasts as Innovations and the Challenges of Adoption by Water Managers (Whateley, Palmer and Brown, J. Wat. Res. Plan. Mgnt, 2014)

Identify investors and scales of key performance metrics

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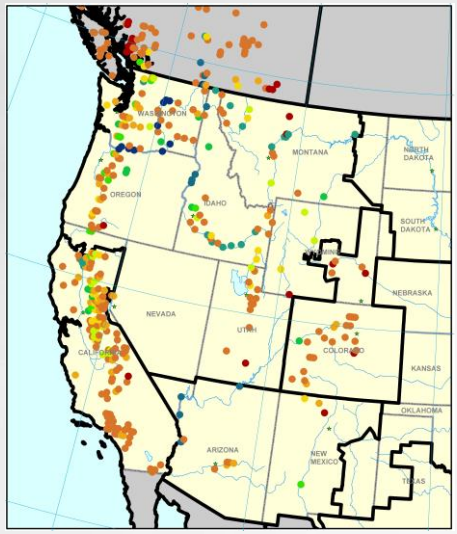
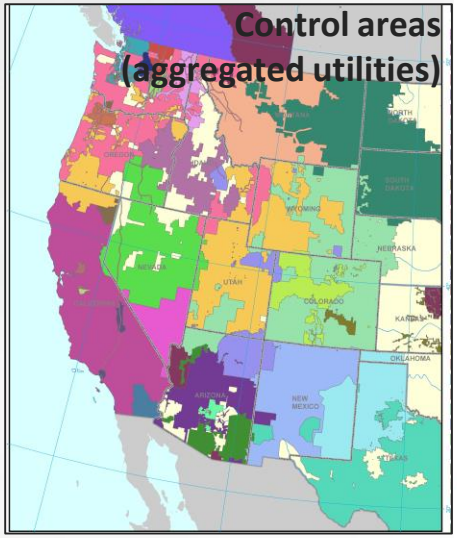
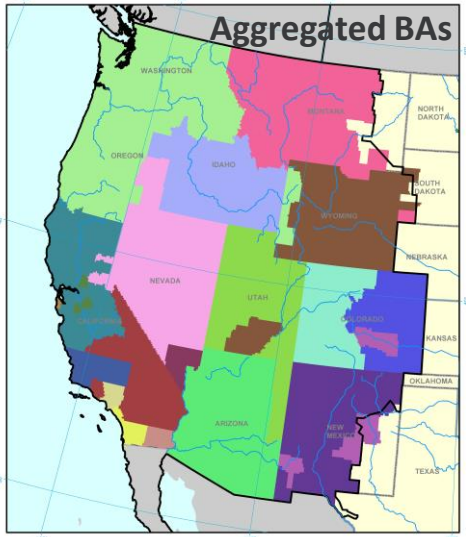
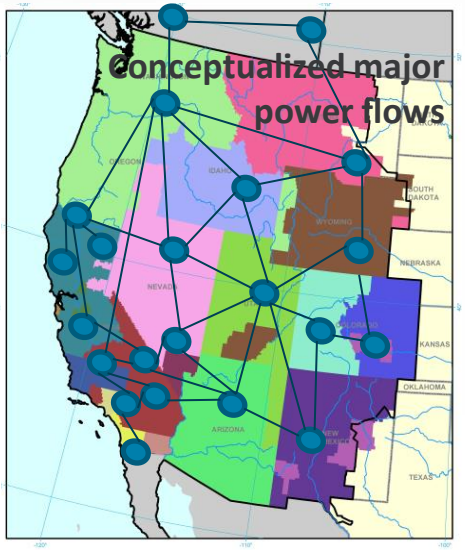
Spatial scales

Hydro power plants	Utility	Balancing authority	Electricity Grid
> 200	> 100	37	1









Objectives: Least cost generation, planned maintenance, infrastructure development, financial benefits

Objectives : Resilience analyses, Integration of renewables, Planning for transmission lines

Hydro-scheduling does not focus only on optimum plant-scale generation

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Market - Energy price for different grid services

Need information from hydropower operator for:

1) bids into the market
2) optimize most economic generation to supply utility's contracts.

Great power comes with great responsibilities

Unit Operations Management

1) Downstream constraints (flood, water rights, water quality)
2) Upstream constraints (lake levels)
3) Constraints in discharge variations
4) *Maintenance cost for start/stop operations*
5) *Maximum head for power production*

Hydropower operator

Hydro-scheduling Optimization for short term horizon

1) Maintain operational license (meet upstream, downstream and variations constraints)
2) Inform marketers for capabilities on day-ahead, 4 hours and hourly for different services (generation, reserve, regulation)
3) Optimize head for power production over multiple horizons

Rather, hydro-scheduling focuses on utility scale performance metrics. What about the scale for valuing climate services?

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Regional fuel prices

Regional availability of hydropower

Observed storage

Inform

Utility - Services bid

Bids

Revenues

Regional Market Prices

Services capabilities?

BA - Priority Grid services

Energy regulation

Inform seasonal maintenance, and contract prices

Climate services

Unit - Operations

Inform short term and mid term optimization

Water Management Priorities (other uses)

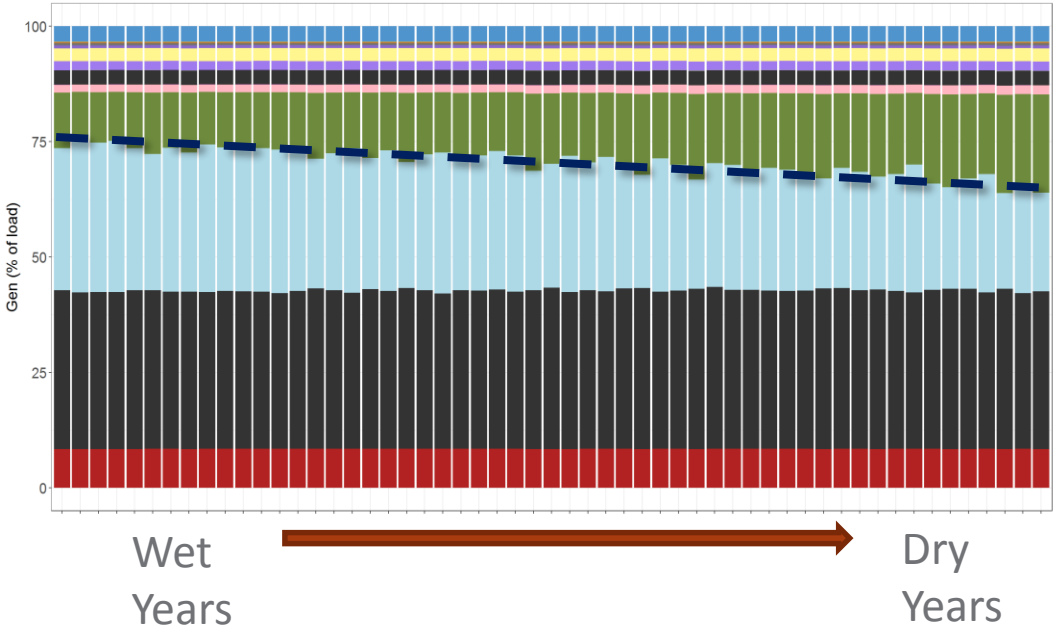
Value Metrics for utility

- Increased benefits
- Reduced operational cost
- Maintained operational licenses

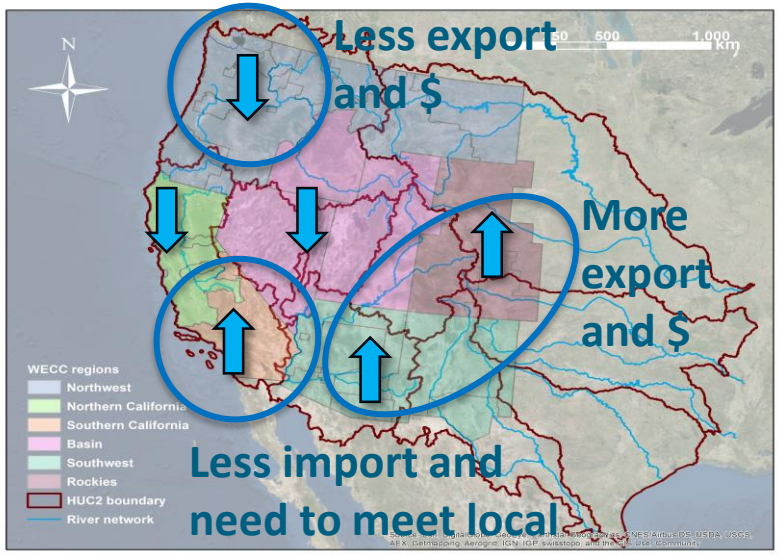
Common unit !

Let's do it again - Sensitivity of power system operations to regional water availability at the utility scale, $ unit

- Power system operations (2010 infrastructure) under 55 years of water availability



Regional variations in changes in total generation.



Information for bids: droughts affect regional import and exports and could inform annual contracts.

Robustness of the value of climate information: Import/export (Value) is function of fuel prices

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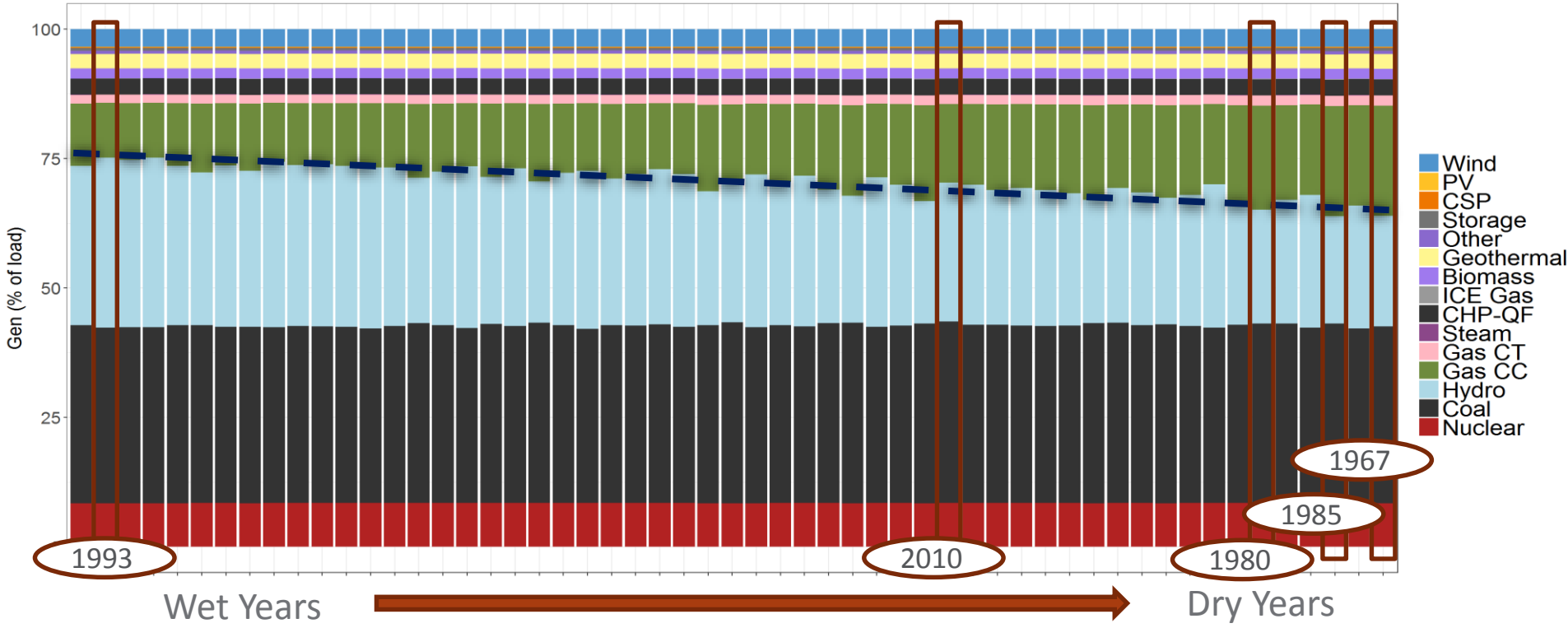

	Low	Low-Medium	High-Medium	High	2010 Baseline
Average Price ($/mmBtu):	2.5	5	7.5	10	4.84

- High gas price is 2040 estimate from EIA 2017 Annual Energy Outlook and NREL 2017 Annual Technology Baseline
- Gas price > coal
- Gas price < oil and other very expensive fuels

Upper value of dry conditions forecast increases as fuel price increases

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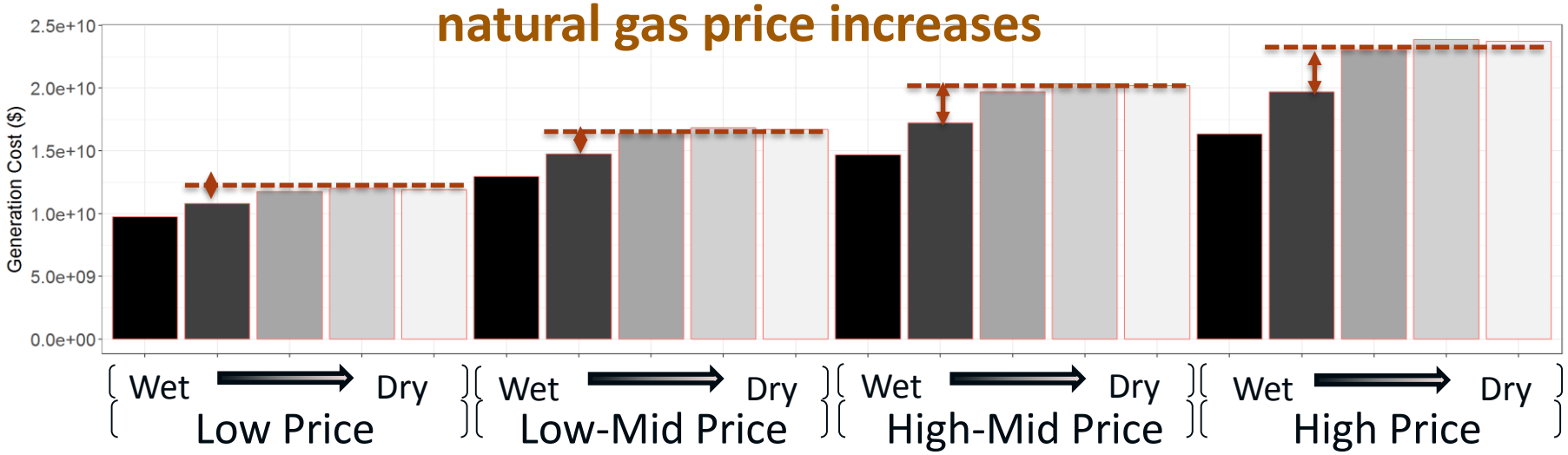
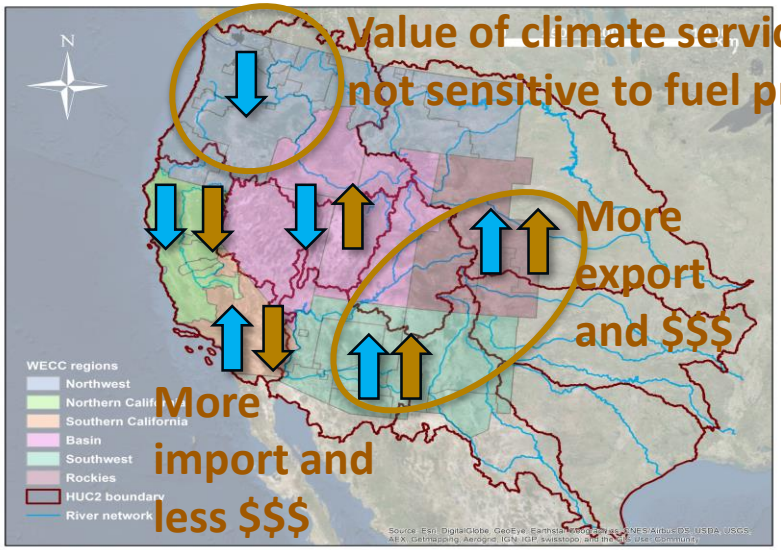
Upper value of dry conditions forecast increases as natural gas price increases





Value of climate information has regional responses to fuel prices.

Conclusions and directions for valuing climate services for hydropower industry

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- Challenges:
  - How do probabilistic forecast influence the information sent to bidders and utility operations planners, and what is associated the net revenue?
  - How do changes in regional power systems (renewable integration, batteries, market) affect the requested hydropower services?

- Future directions:
  - New data-driven Hydropower Value Project
  - Improve representation of water operations in production cost models

$[\text{services, \$}]_{\text{market region}}$

$[\text{operations, cost and maintenance}]_{\text{utility}}$

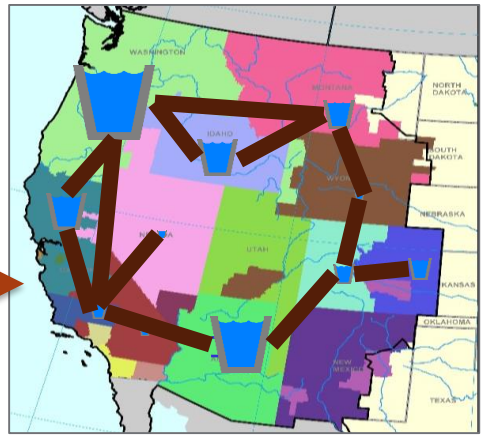
$[\text{services, hydropower operations}]_{\text{plant}}$

$[\text{revenues, hydropower operations}]_{\text{plant?}}$

Modeling needs in representing hydro in power system models

Δ forecast → Δ hydro operations → Δ revenues → value

River operations are not represented



Thank you

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Office of Science – BER – Integrated Multi Scale Multi Sector Modeling, PRIMA, RIAM
Office of Energy Efficiency and Renewable Energies – Hydropower Value Consortium, WUOT
Office of Energy Policy and System Analysis – US-EU water energy modeling challenge
Office of Electricity – grant to support WECC in designing climate change scenario
PNNL Lab directed research and development

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