Using RiverWare to Enhance Hydropower Modeling in Renewable Generation Integration Studies

Presenter: Mitch Clement

2013 RiverWare User Group Meeting
August 27, 2013

Collaborative Project

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Funding by the Joint Institute for Strategic Energy Analysis through the Innovative Research Analysis Award Program (IRAAP)

Outline

- Overview and Background
  - Renewable generation challenges
  - Role of hydropower
  - NREL's Western Wind and Solar Integration Study
- Methodology
  - PLEXOS power system model
  - Integrating RiverWare with PLEXOS
- Case Study – Columbia River Basin
- Results

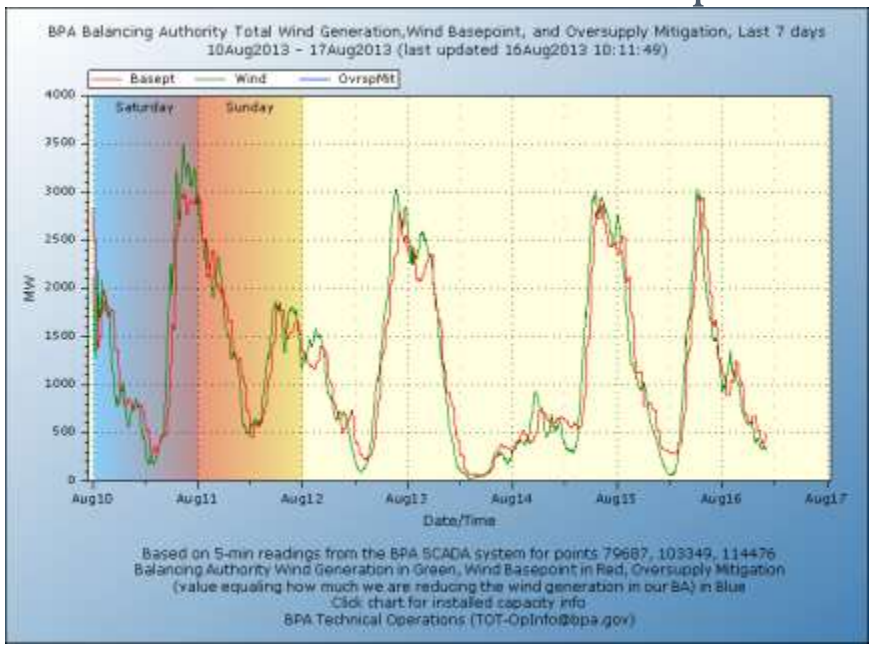
Renewable Energy Generation

- Renewable Portfolio Standards of 15 – 30% by 2025 in western states
- National Renewable Energy Laboratory investigating 20% wind by 2030
- Bonneville Power Administration
  - 4500 MW of wind capacity
  - At times wind generation can make up 70% of total power demand

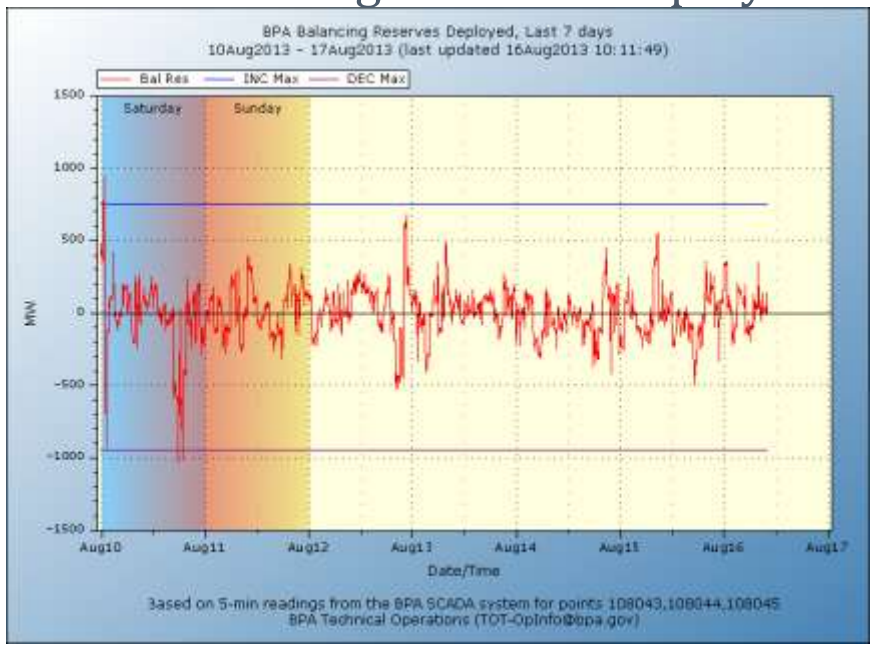
Renewable Generation Challenges

- Increased variability in net load
- Uncertainty in net load forecasting
- Hydropower can provide balancing reserves but limited by non-power objectives, e.g. flood control, environmental flows, water delivery, etc.

BPA Wind Generation Sample



BPA Balancing Reserves Deployed



http://transmission.bpa.gov/Business/Operations/Wind/default.aspx

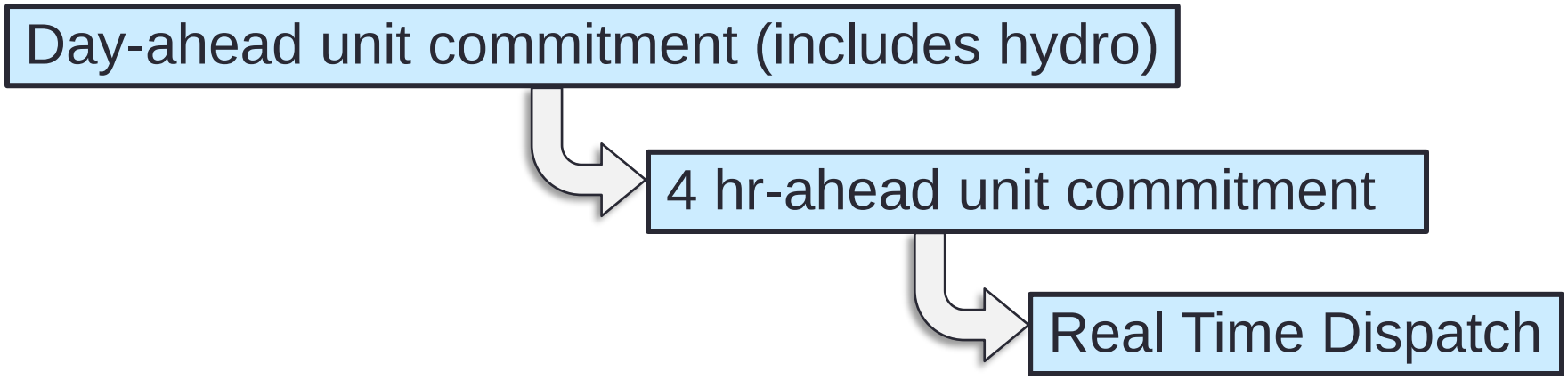
Western Wind and Solar Integration Study - NREL

- Investigates up to 33% renewables in Western Interconnection
- Phase 1 (2010) – Significant reduction in operating costs when utilizing hydro to balance renewables
- Phase 2 (2013) – Increased solar, and evaluates renewables' impact on thermal cycling
- Identified need for improved hydro modeling in integration studies

WWSIS 2 - Modeling

- PLEXOS production cost model

  Models all generating units and major transmission in Western Interconnection at 5-minute resolution



- Hydro Modeling in PLEXOS
  - Matches historic monthly energy (2006) by unit
  - Constrained to historic monthly min/max power
  - No direct modeling of water or water constraints
  - 40% of hydro fixed at historic generation (2006)

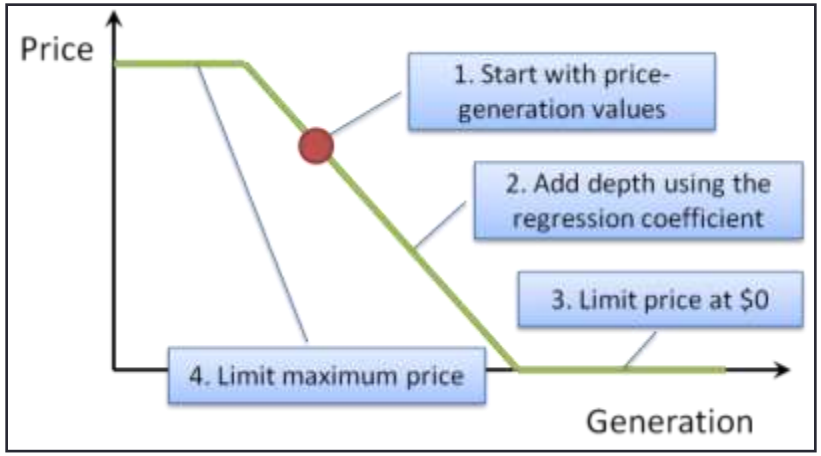
Integrating RiverWare with PLEXOS

Motivation: Combine detailed hydro modeling of RiverWare with detailed power system modeling in PLEXOS to:

- Determine the extent to which electricity production simulation captures the nuances of hydro constraints and the potential for improvement in modeling
- Provide a more realistic representation of hydropower's contribution to the power system for balancing variable renewable generation

Integrating RiverWare with PLEXOS

- Hourly price curves generated from original PLEXOS outputs



- Price curves become inputs to RiverWare using the Calculate Block Economic Value method (thermal object)

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Hydro Block Costs

Value: $/MWh

Scroll 24:00 Apr 16, 2006

	Blk 1 $/MWh	Blk 2 $/MWh	Blk 3 $/MWh	Blk 4 $/MWh	Blk 5 $/MWh
04-16-2006 Sun 24:00	NaN O	NaN O	NaN O	NaN O	NaN O
04-17-2006 Mon 01:00	28.90 I	28.59 I	28.29 I	27.99 I	27.68 I
04-17-2006 Mon 02:00	25.59 I	25.29 I	24.98 I	24.68 I	24.38 I
04-17-2006 Mon 03:00	27.12 I	26.81 I	26.51 I	26.21 I	25.90 I
04-17-2006 Mon 04:00	29.96 I	29.66 I	29.36 I	29.05 I	28.75 I
04-17-2006 Mon 05:00	37.64 I	37.34 I	37.03 I	36.73 I	36.43 I

Show: Description

Integrating RiverWare with PLEXOS

- Run RiverWare Optimization with objective to maximize total economic value of hydropower
  - Optimize over one week
  - Hourly timestep
  - All relevant non-power constraints apply
  - Constrain total RiverWare weekly hydro generation to equal PLEXOS weekly hydro generation

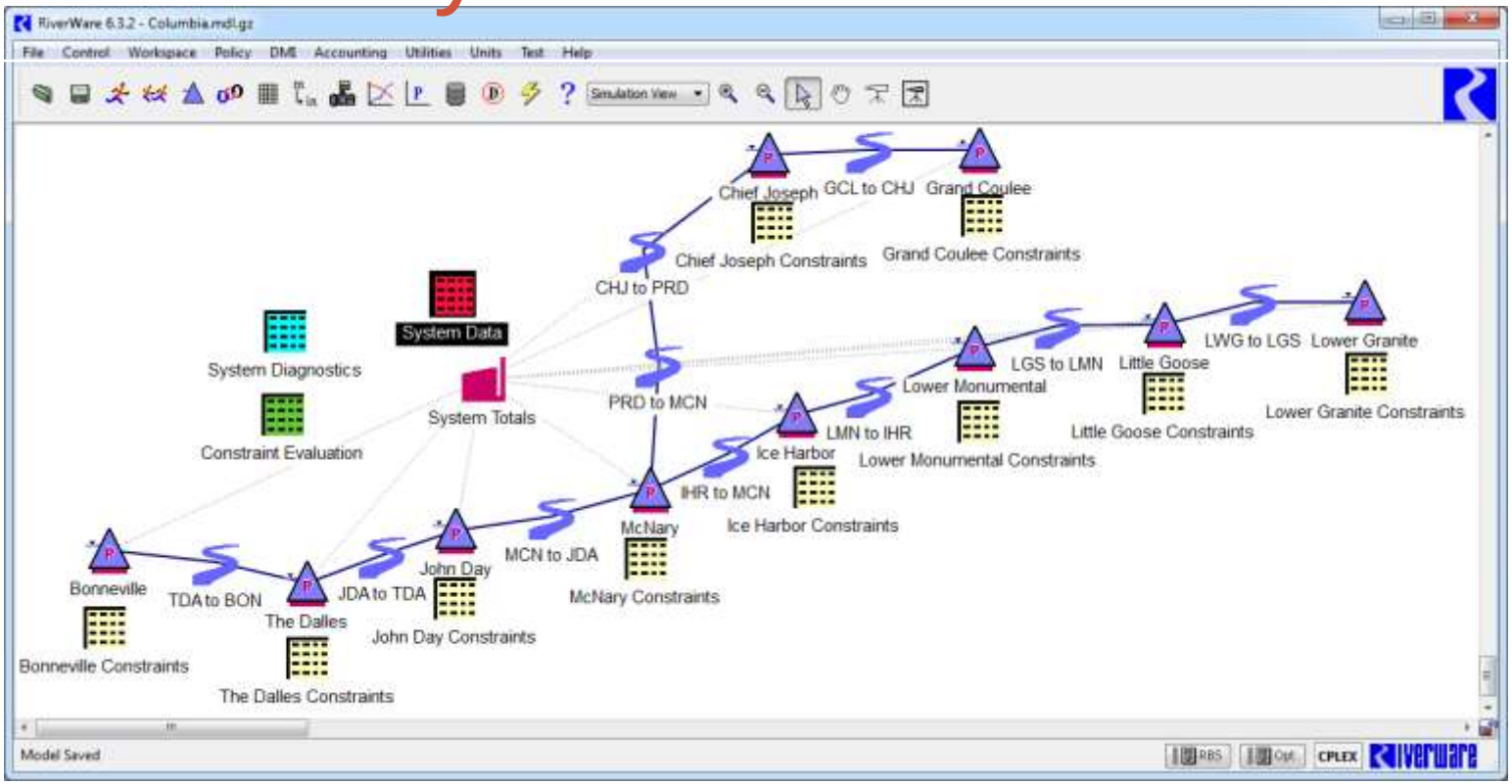
- Return RiverWare hydro generation outputs to PLEXOS and re-run PLEXOS real-time dispatch using RiverWare hydro

Case Study – Columbia River Basin

- RiverWare: FCRPS "Big Ten"
  - Lower Snake and Columbia main stem
  - 19.7 GW capacity
- PLEXOS: Western Interconnection
  - Includes transmission and imports/exports
  - All thermal generation
- Study Week: April 17-23, 2006 (wind and hydrology)
  - High wind variability
  - Moderately high flows
  - Significant non-power constraints, but do not dominate the solution
- Two scenarios from WWSIS 2

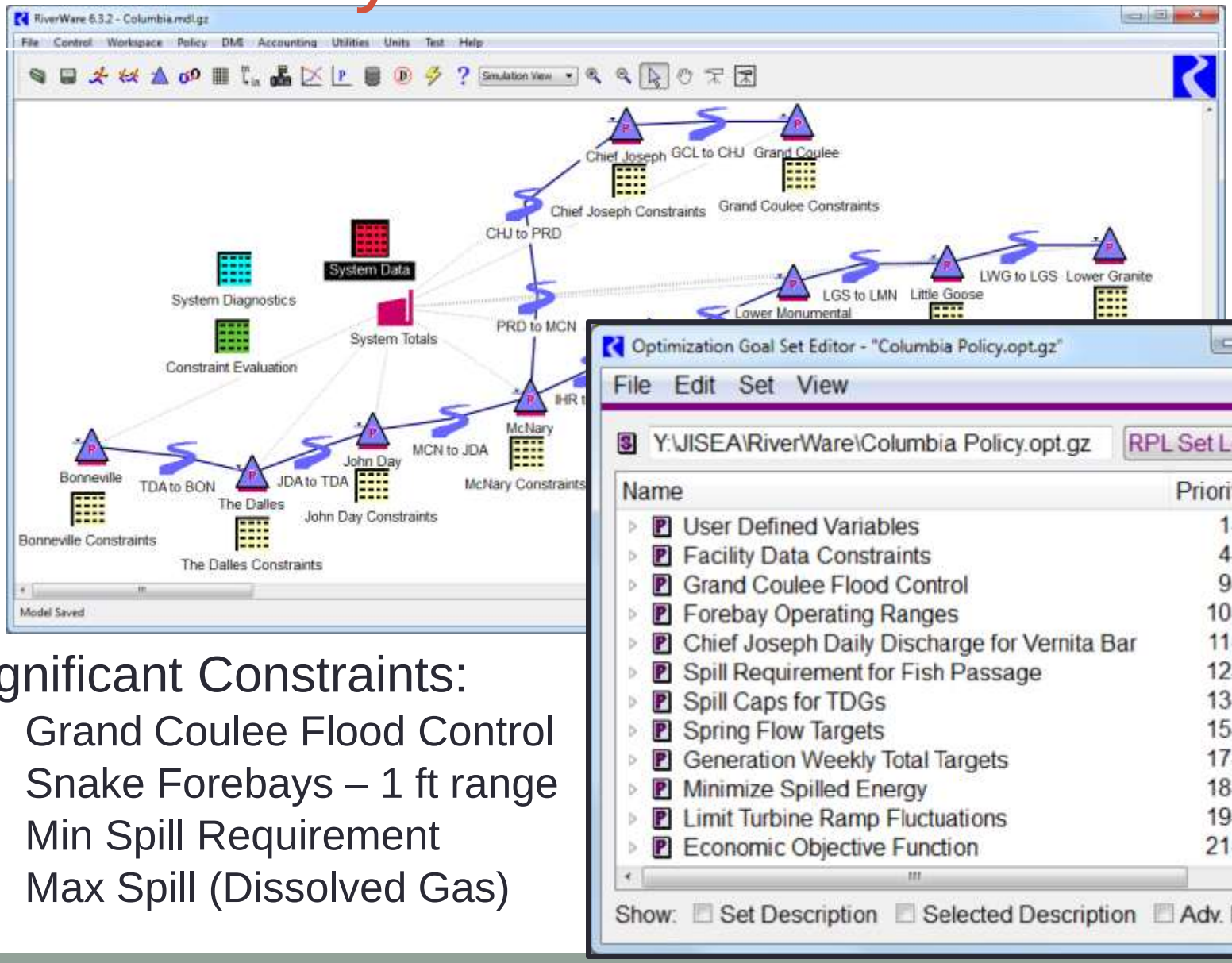
Scenario	Wind	Solar	Total
Business as Usual (BAU)	9.4%	3.6%	13%
HiWind	25%	8%	33%

Case Study – Columbia River Basin



- Reservoir physical data provided by Bonneville Power Administration (BPA)
- Historic Hydrology, April 17-23, 2006
- Non-power policy from FCRPS 2012 Water Management Plan and BPA

Case Study – Columbia River Basin

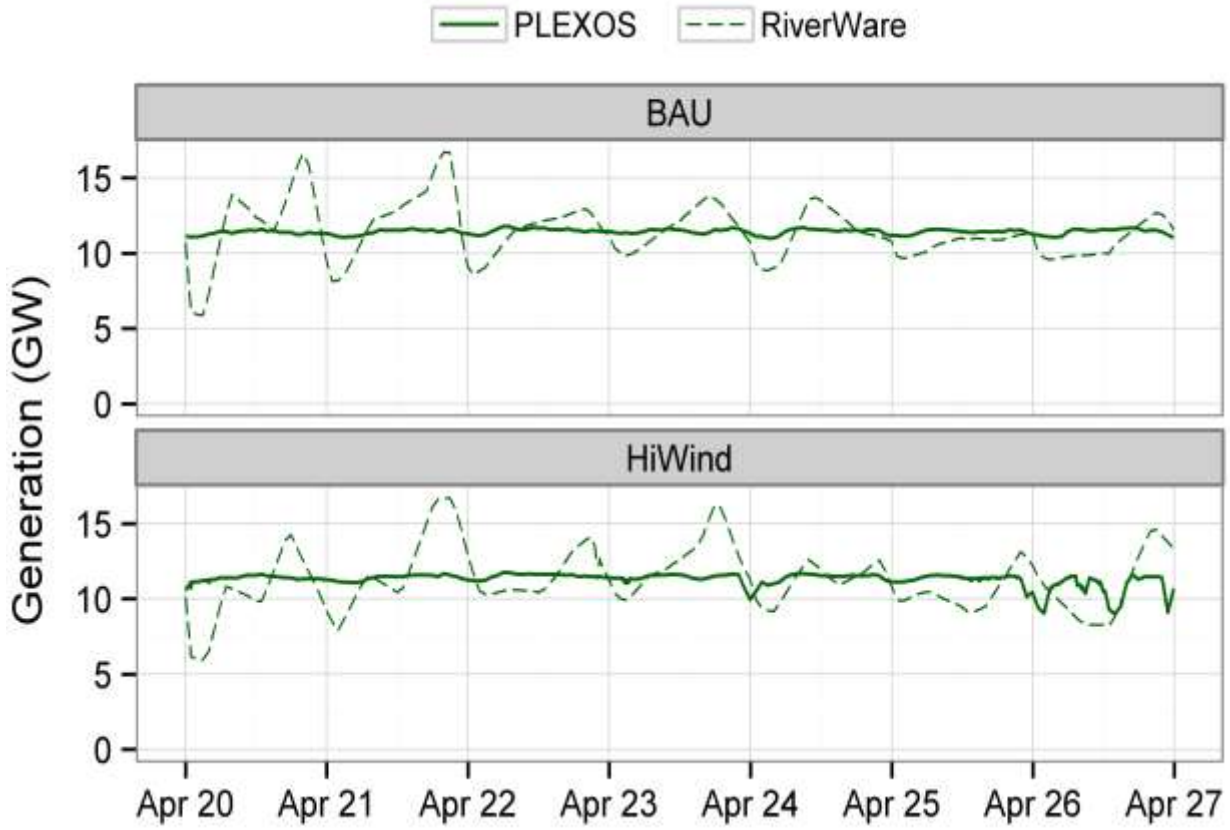


Significant Constraints:

- Grand Coulee Flood Control
- Snake Forebays – 1 ft range
- Min Spill Requirement
- Max Spill (Dissolved Gas)

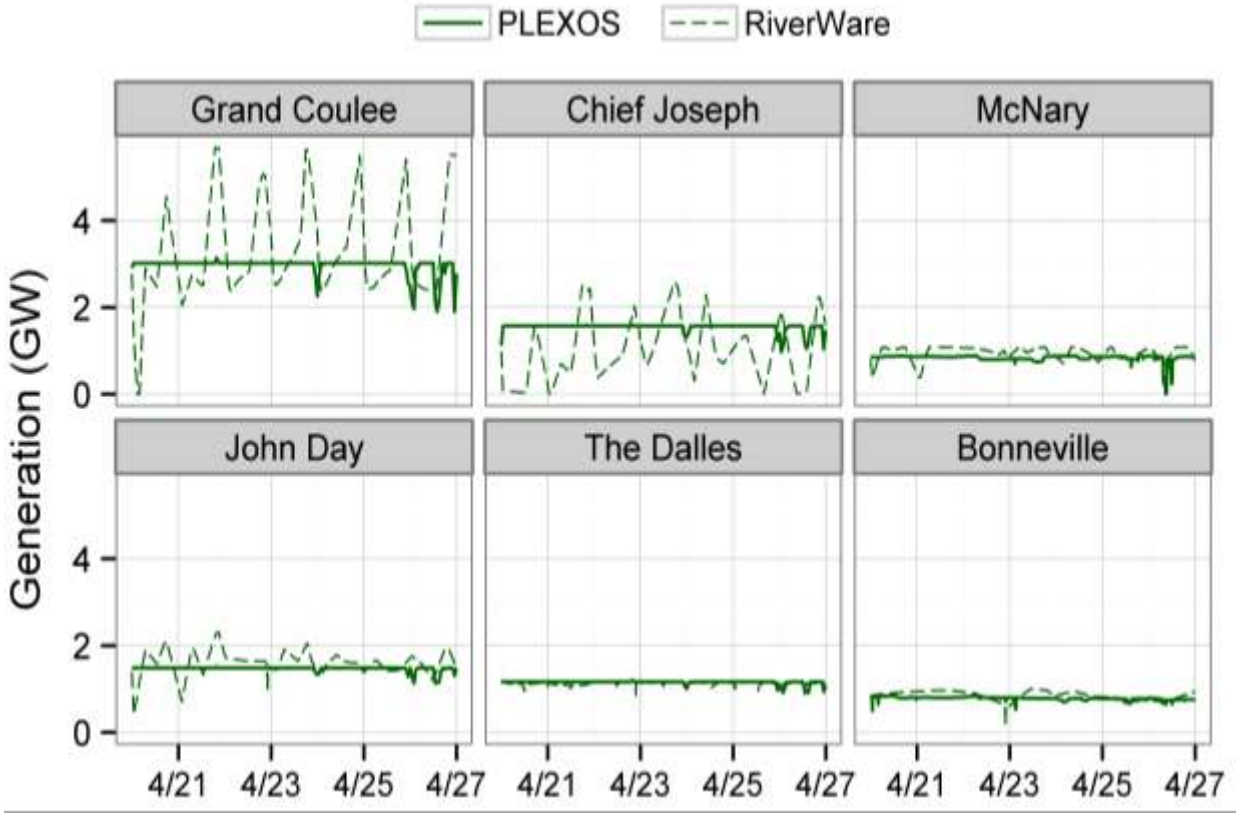
Results – Total Hydro

Total hydro generation by PLEXOS and RiverWare, by scenario



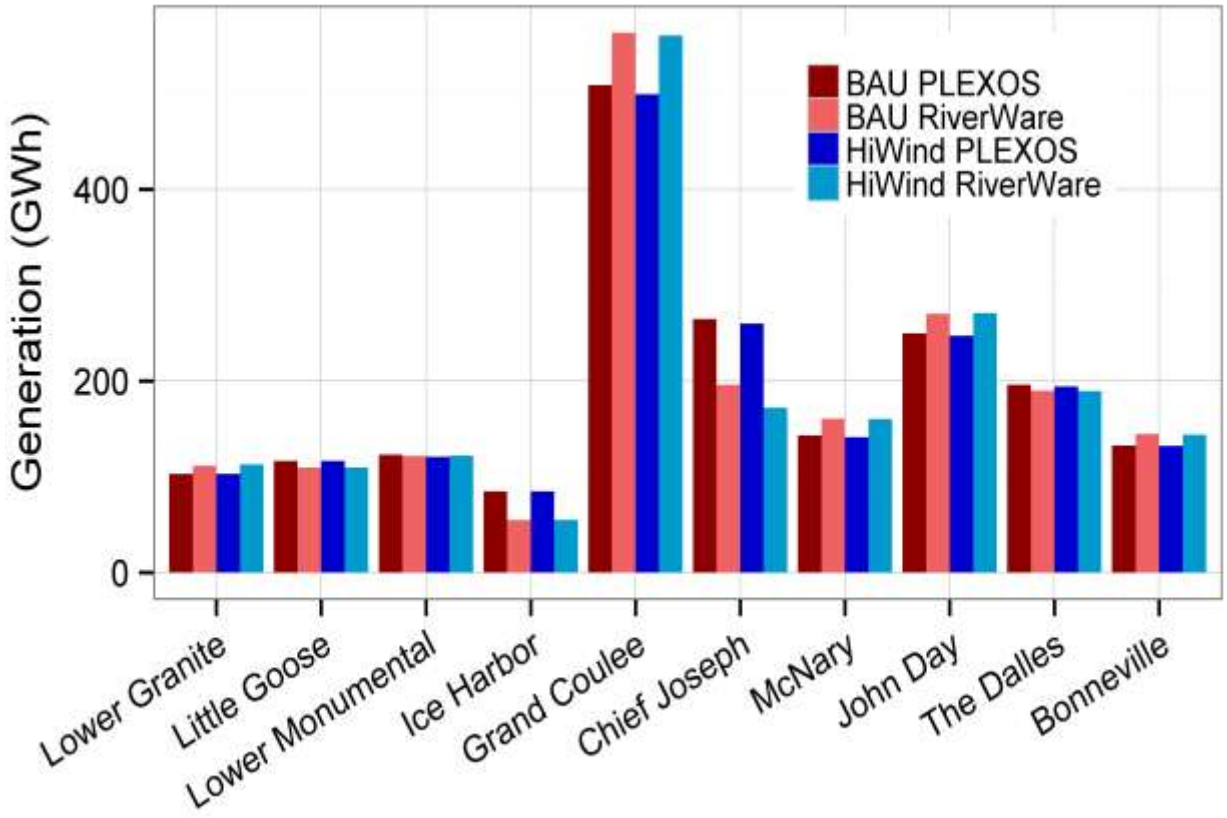
Results – Hydro by Project

Generation by facility – Columbia projects, HiWind scenario



Results – Hydro by Project

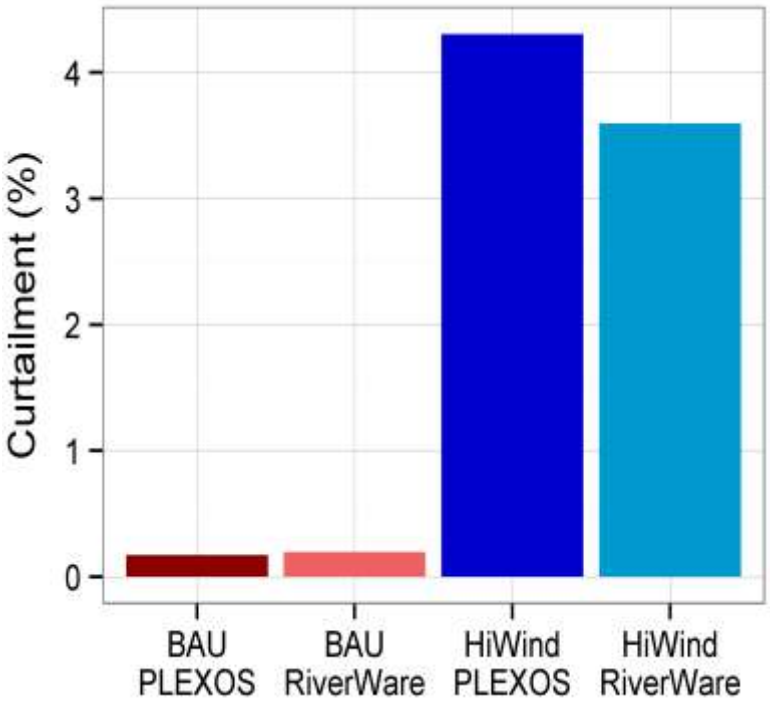
Total energy at each project by scenario



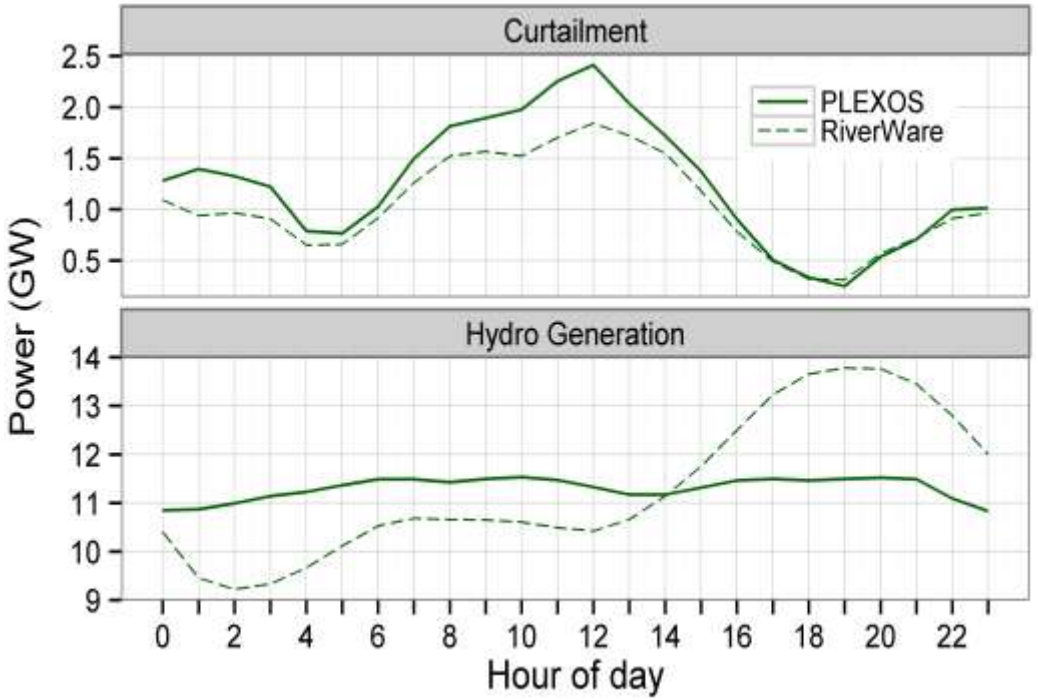
- Largest shift in from Chief Joseph to Grand Coulee
- Combined effect of Grand Coulee flood control and spill limits (TDGs)

Results – Curtailment Reduction

Total Curtailment



Curtailment and Hydro Generation by Hour of Day – HiWind Scenario

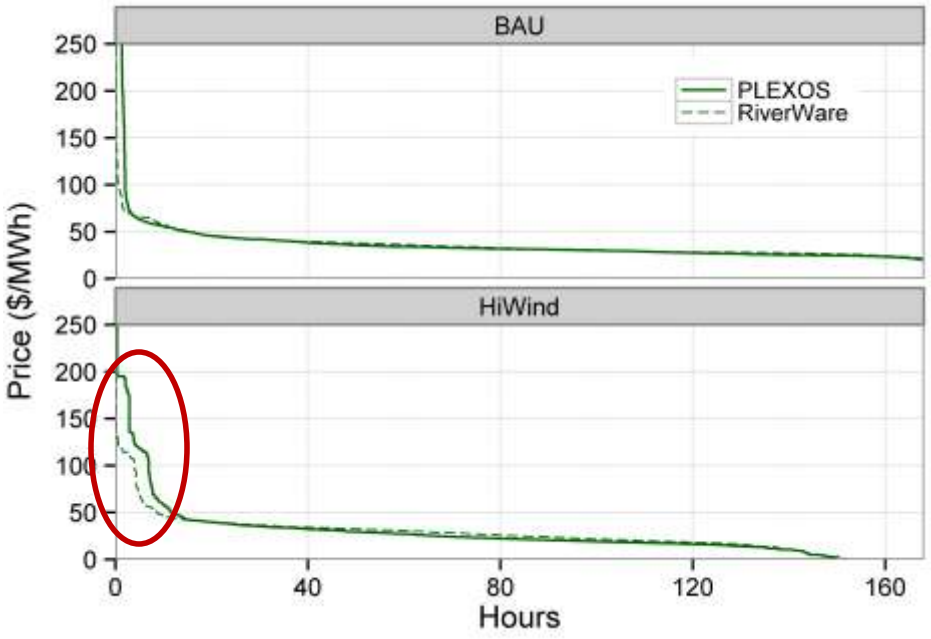


Curtailment reduced by shifting timing of hydro generation

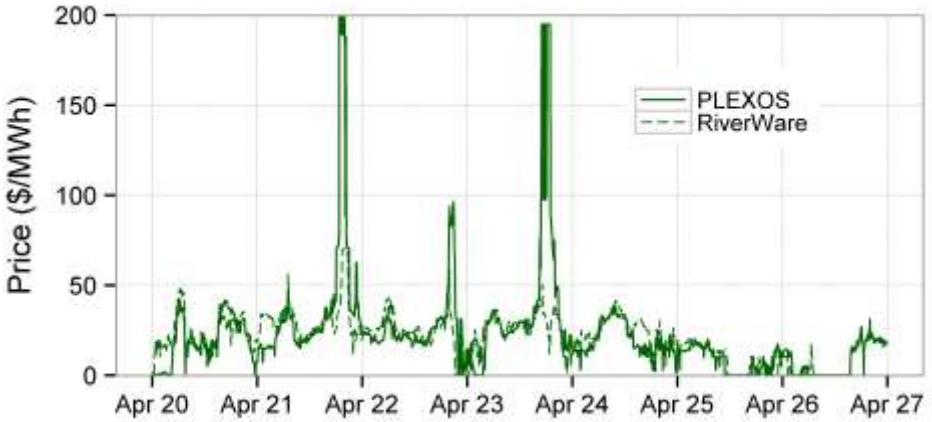
Results – Electricity Prices

- Average marginal prices reduced $2-3/MWh
- Reduction in extreme price "spikes" and total production costs

Interconnection-wide price duration curves



Five-minute price time series for HiWind scenarios



Interconnection-wide total production costs for the study week

Scenario	PLEXOS (million $)	RiverWare (million $)	Reduction (million $, %)
BAU	223.0	218.9	4.17 (1.9%)
HiWind	155.2	154.2	0.98 (0.6%)

Summary

- Coupled RiverWare with a power system production cost model (PLEXOS)
- Modeled two renewable generation scenarios in the Western Interconnection for one week in the spring
- Increased flexibility from the RiverWare hydro model:
  - Reduced production costs in both scenarios
  - Reduced extreme price spikes
  - Reduced renewable generation curtailment by 16% in the HiWind scenario
- Future work will explore the optimization for longer time frames and additional iterations between PLEXOS and RiverWare

Acknowledgements

- Joint Institute for Strategic Energy Analysis (JISEA)
- Bonneville Power Administration (BPA)