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U.S. DEPARTMENT OF ENERGY

Load Forecasting in Electric Utility Integrated Resource Planning

Webinar – November 21st, 2016

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Electricity Markets and Policy Group

Background

- **Integrated resource planning** (IRP) used by ~30 U.S. states.
  - Regulatory tool to determine **least-cost / managed risk** supply and demand-side resources that meet **future obligations** to customers.
  - IRPs are developed periodically and include a **host of information** about assumptions, methods, and strategies to deal with uncertainty.
- There is little to no empirical research on the **outcome of the planning process**.

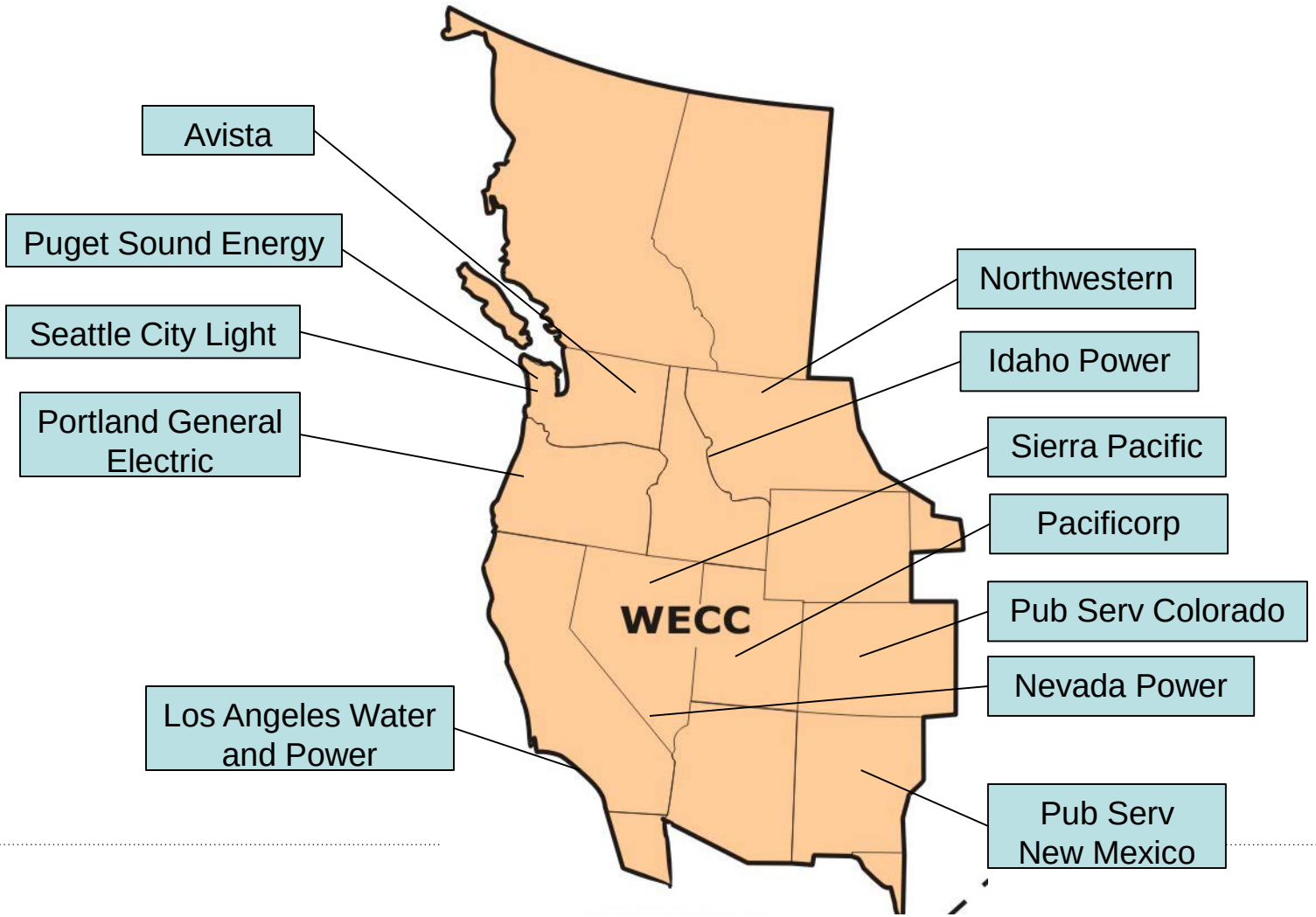
Research design

- We split our research on ***inputs* and *outcomes.***
- Long term **load forecasts** are a cornerstone of IRP.
- This presentation:
  - How did load forecasts **perform** for plans developed in the early 2000s?
  - How did forecasts and their techniques **evolve**?
  - What **load forecast sensitivities** were analyzed and how?
  - How does load **correlate** to resource expansion?
- Our follow-up paper:
- How does **planning compare to procurement** and what explains any potential differences?

Previous research

- Three lines of related research
  - "**Best practices**" by comparing LSEs among themselves (Schwitzer 1991, Mitchell 1992, Aspen/E3 2008, Wilson and Biewald 2013)
  - "**Normative practices**" by criticizing methods against theoretical benchmarks (Hirst 1990-1991-1994)
  - **Very little quantitative** work on demand forecast accuracy and from the mid-1980s (Willis and Northcote Green 1984, Mitchell 1986)

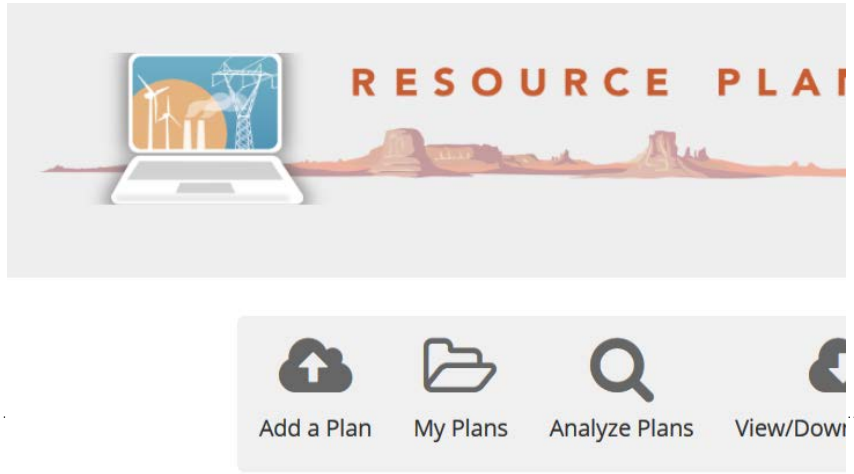
Sample of LSEs and IRPs



LSE short name	LSE name	First Plan Year	Recent Plan Year	Reference
Avista	Avista Corporation	2005	2013	(Avista, 2013, 2005)
COPSC*	Public Service Company of Colorado (Xcel Energy)	2003	2011	(COPSC, 2011, 2004)
Idaho	Idaho Power Company	2006	2013	(Idaho, 2013, 2006)
LADWP	Los Angeles Department of Water and Power	2006	2012	(LADWP, 2012, 2006)
NVPower	Nevada Power Company	2006	2012	(NVPower, 2012, 2006)
NW	NorthWestern Corp. dba NorthWestern Energy	2004	2013	(NW, 2013, 2004)
PacifiCorp	PacifiCorp	2004	2015	(PacifiCorp, 2015, 2005)
PGE	Portland General Electric Company	2007	2013	(PGE, 2014, 2007)
PNM	Public Service Company of New Mexico	2007	2011	(PNM, 2011, 2007)
PugetSound*	Puget Sound Energy, Inc.	2005	2013	(PugetSound, 2013, 2005)
Seattle*	Seattle City Light	2006	2012	(Seattle, 2012, 2006)
SierraPacific*	Sierra Pacific Power Company	2004	2013	(SierraPacific, 2013, 2004)

Methods and data

- We study older (2003-2007) and recent (2012-2015) plans for a given utility.
- Data:
  - Load forecast assumptions; resource expansion collected from IRP in the Resource Planning Portal (http:\\resourceplanning.lbl.gov) from **older plans**.



- Actual energy and peak demand load; actual incremental procurement from **Ventyx** and **recent plans**.

Modeling approaches

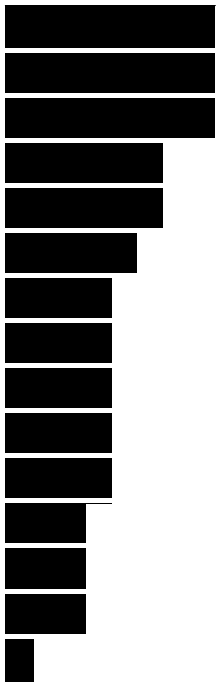
	Time series regression (AR*, MA**)	Cross-section regression	Engineering model	SAE
Avista		RC		
COPSC				RC
Idaho				RC
LADWP		RC		
NVPower	RC	RC		
NW	C	R		
PacifiCorp				
PGE				
PNM			RC	
PugetSound		RC		
Seattle		RC		
SierraPacific				

*AR: Auto-regressive; **MA: Moving Average

R: Residential; C: Commercial

Load forecast methodologies

Variable	Avista	COPSC	Idaho	LADWP	NVPower	NW	PacifiCorp	PGE	PNM	PugetSound	Seattle	SierraPacific
Historical sales												
Cooling degree days												
Heating degree days												
Population growth												
Electricity price/tariffs												
Employment												
Household size												
Number of customers												
Energy intensity trends												
Appliance saturation												
Time dummies (day,month,season,year)												
Housing stock												
Household income												
Gross product (national/regional)												
Air conditioning usage												
Model complexity												



Coding

- Low complexity
- Medium complexity
- High complexity
- Residential
- Commercial/Industrial
- All

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Changes in load forecast methodologies

LSE	Older IRP Year	Recent IRP Year	Variables/Analytical Analysis Framework	Variables/Analytical Techniques	Variables/Analytical Key Data Sources	*Overall Change*
NV Power	2006	2012				
Sierra Pacific	2004	2013				
Avista	2005	2013				
LADWP	2006	2012				
PNM	2007	2011				
Seattle	2006	2012				
Puget Sound	2005	2013				
PGE	2007	2013				
NW	2004	2013				
Idaho	2006	2013				
Pacificorp	2004	2015				
COPSC	2004	2011				

Legend:

- *Little or no change*
- *Some change*
- *Significant change*

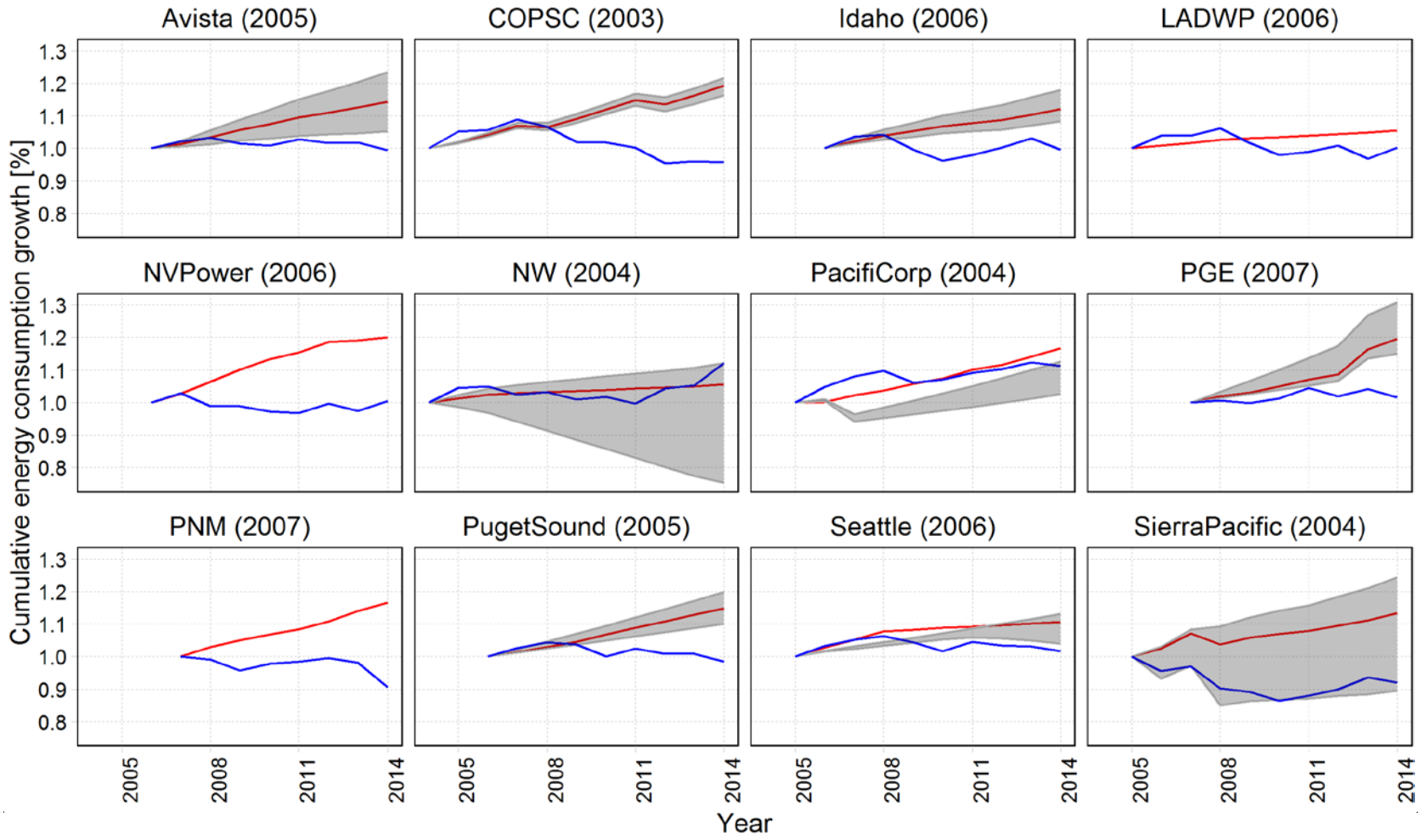
Cumulative energy consumption error

LSE	Sum of errors (1) [TWh]	Sum of actual load (2) [TWh]	Proportional Error (1)/(2)
PGE	29.1	151.3	19%
Avista	14.7	85.4	17%
NVPower	26.0	199.0	13%
SierraPacific	10.6	89.4	12%
Idaho	13.5	138.4	10%
PNM	5.6	85.2	7%
COPSC	21.4	365.1	6%
LADWP	13.0	236.5	6%
PacifiCorp	33.4	580.6	6%
Seattle	5.2	100.5	5%
PugetSound	2.1	206.2	1%
NW	-1.3	68.5	-2%

Cumulative energy consumption error: Insights.

- LSEs with higher share of industrial load had less accuracy in this period. This suggests that a different planning strategy should be used with these customers, particularly in the way sensitivities are designed and run and risk is assessed for them.
- LSEs that are larger or have more diversified load tend to have reduced error.
- We find that more complex models may have very small marginal benefits to performance.

Energy consumption forecast error and sensitivities



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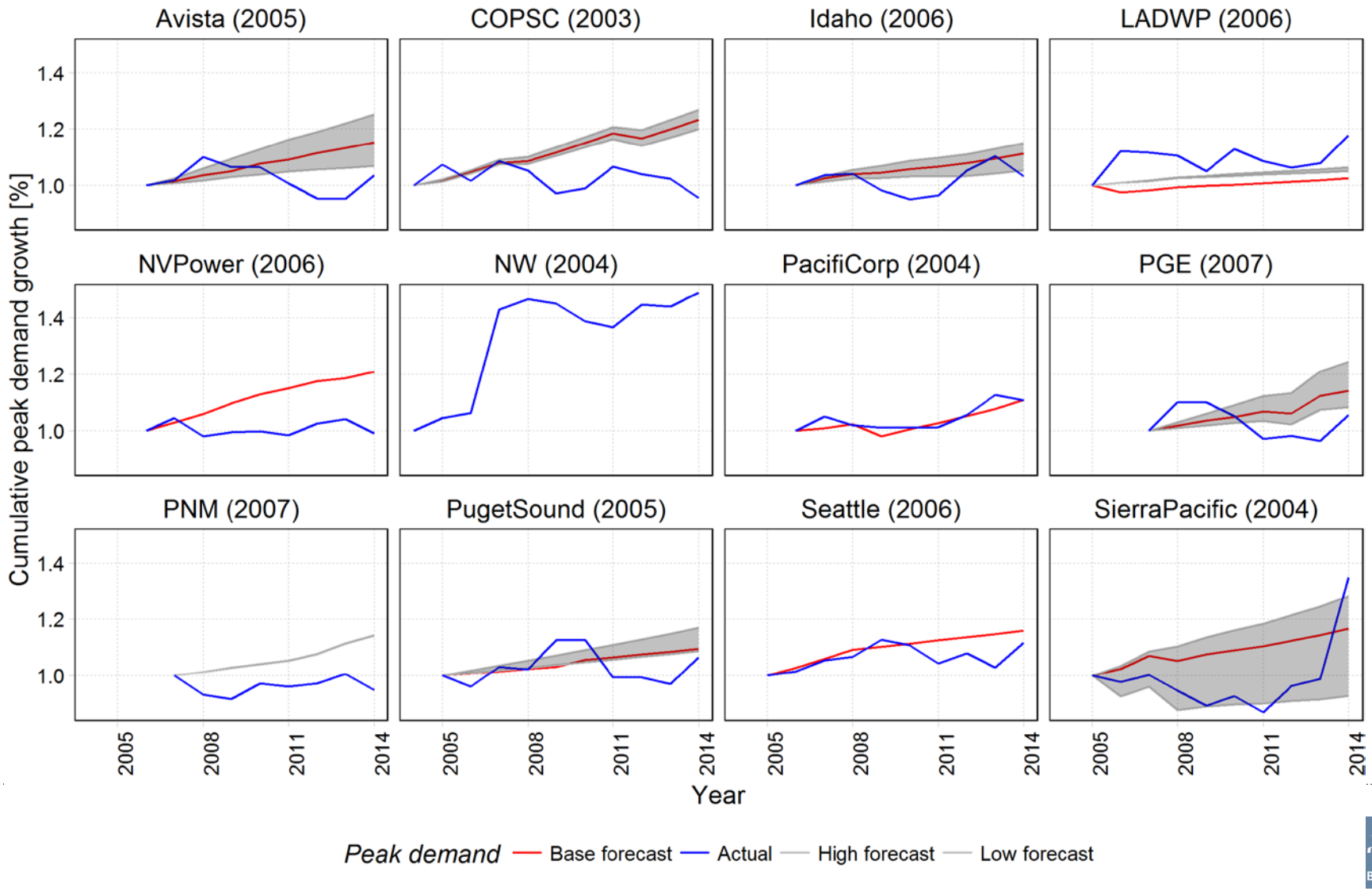
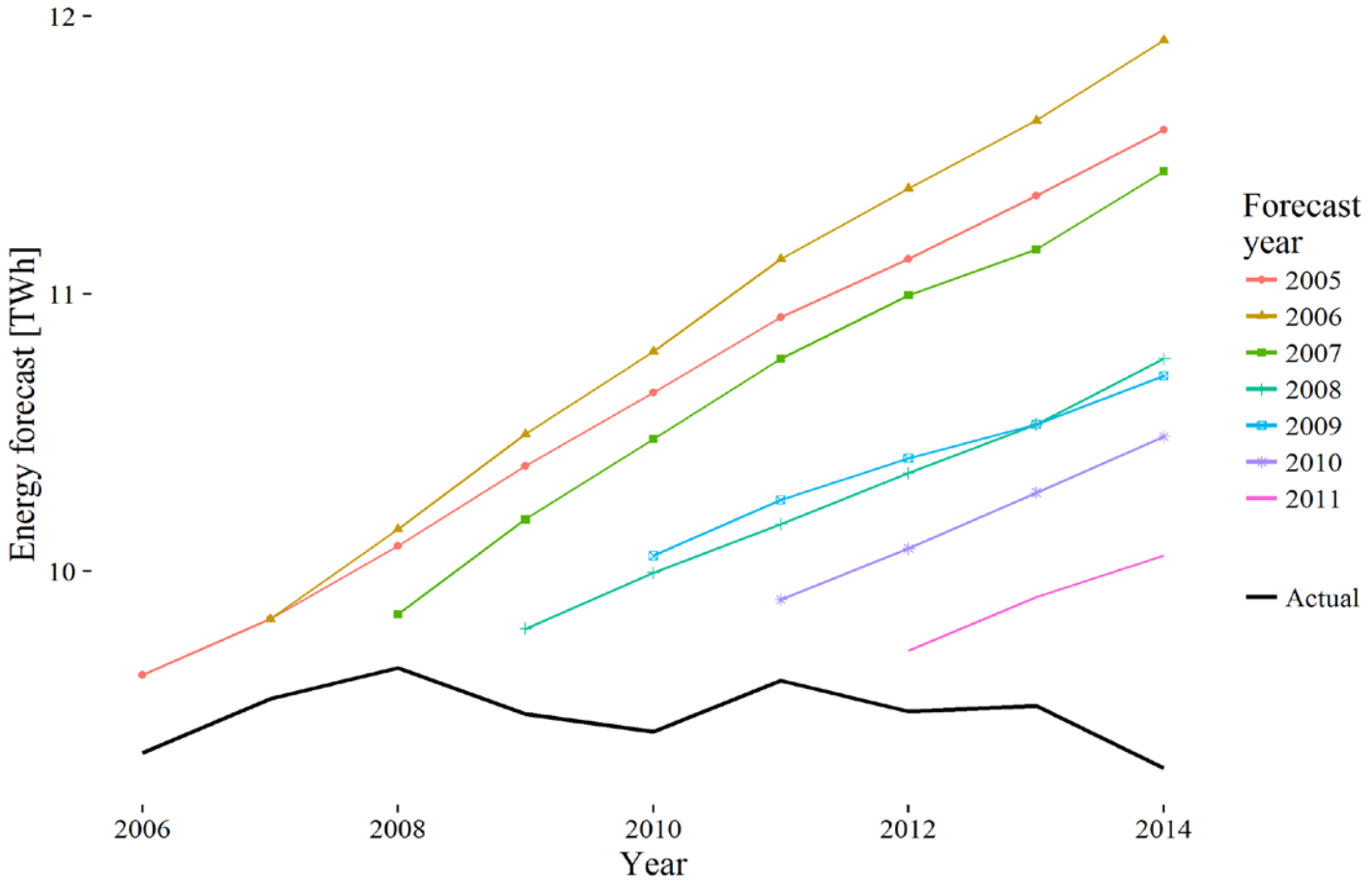
Peak demand error and sensitivities



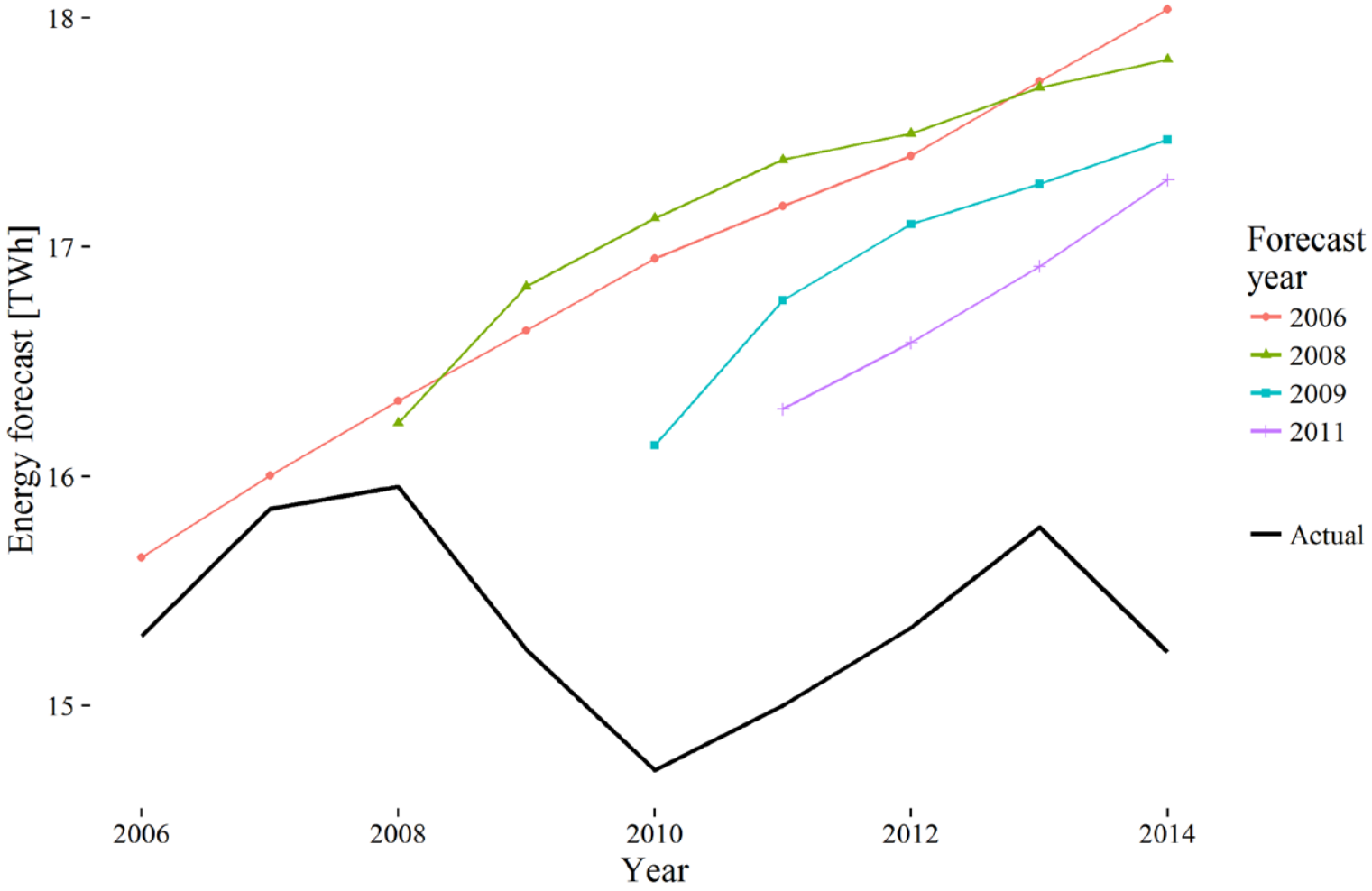
Load forecast sensitivities

- Designed to (i) **test a preferred portfolio** or (ii) offer **alternative** plans.
- Most LSEs migrated from earlier **scenario-based** to more recent **stochastic** analysis.
- The effect of **load changes** in revenue requirement is much larger than the differences between portfolios.
- General absence of **methods/strategies to respond** to alternative load growth.
  - Two strategies for adaptation: resource flexibility and market transactions.

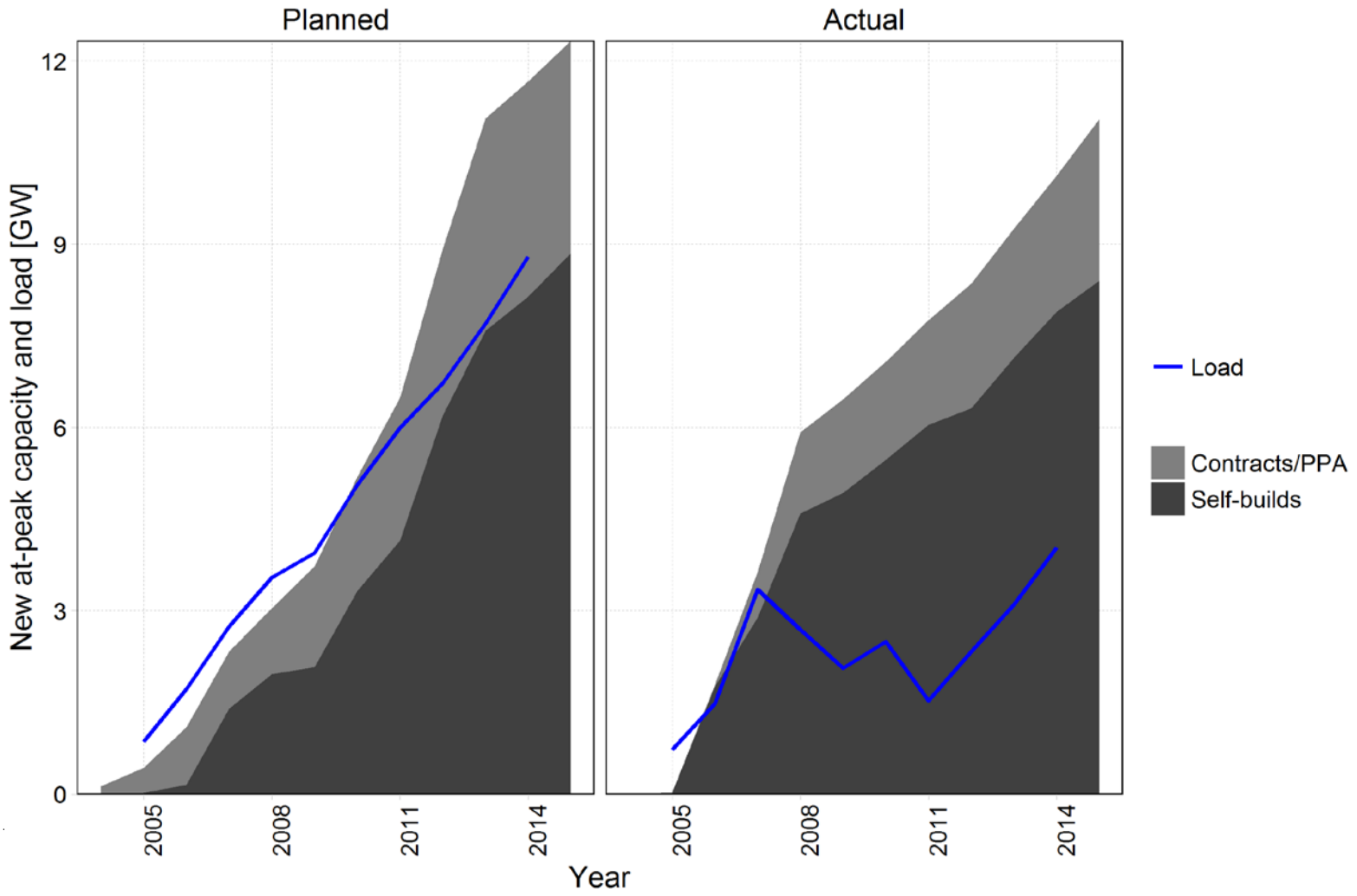
Subsequent IRP forecast evolution - Avista



Subsequent IRP forecast evolution - Idaho



Load-Resource relationship



Conclusions

- **Sustained over-estimation** of load in older and subsequent IRPs.
- There may **be small marginal benefits to model complexity** in terms of improved performance.
- Lack of **actionable strategy component** to respond to alternative load growth scenarios.
- Aggregate (12 LSEs) **procurement followed planning**, but actual **load was significantly smaller than forecast**.
- Load forecast **techniques present little to no change** in time, making our analysis applicable to current planning efforts.

Contacts/Acknowledgments

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