Analysis of the Effectiveness of Short-term Demand Forecasting and Recommendations for Improvement (Project 4501)

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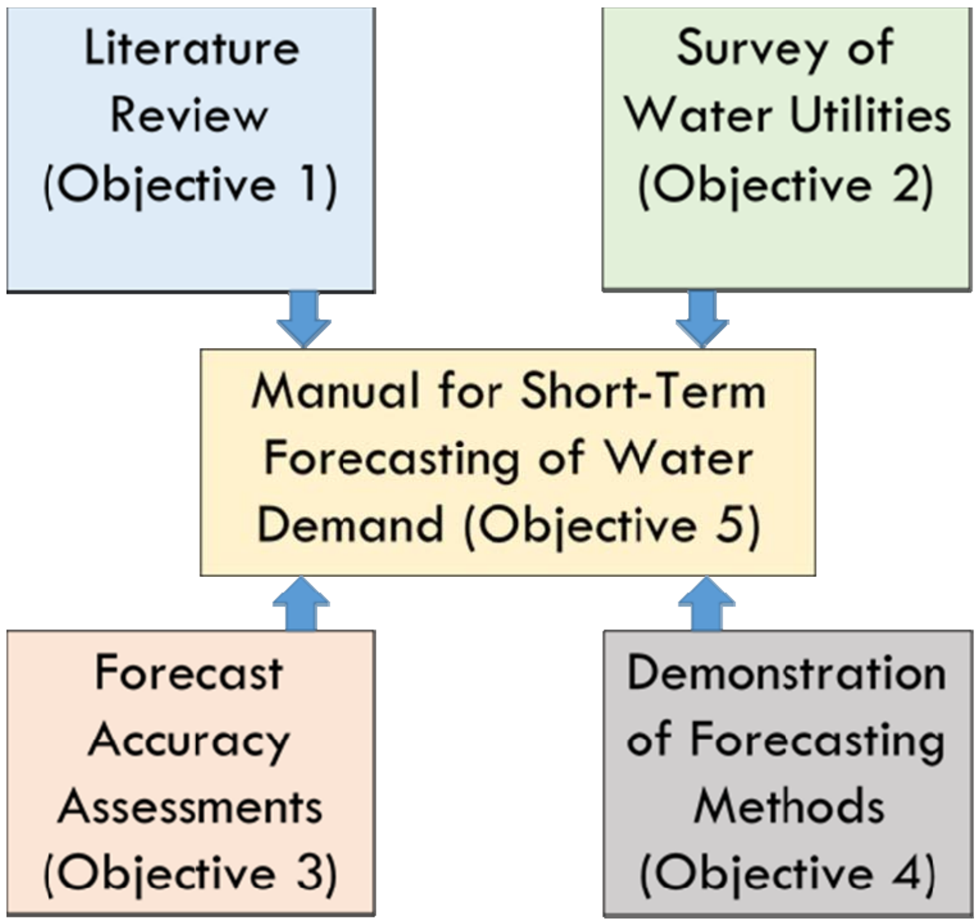
Project 4501 Objectives



Manual for Short-Term Forecasting of Water Demand

Choosing a Forecasting Approach

Implementing a Viable Approach

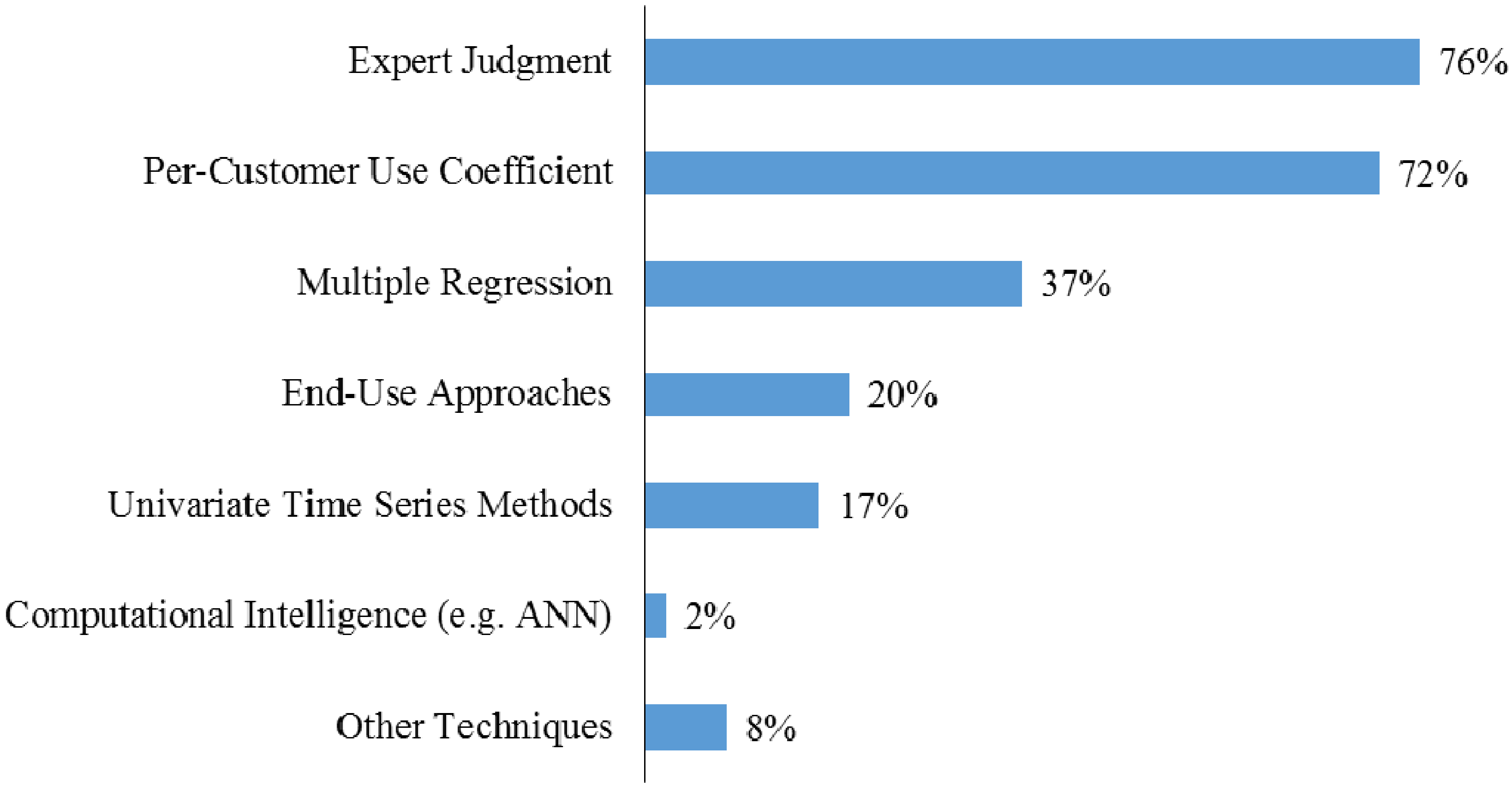
Evaluating the Forecasting Approach

Choosing a Forecasting Approach

Common forecasting techniques

- Expert Judgment
- Per-Unit Use Coefficient
- Multiple Regression Models
- End-Use Models
- Univariate Time Series Methods
- Computational Intelligence Techniques
- Hybrid Approaches

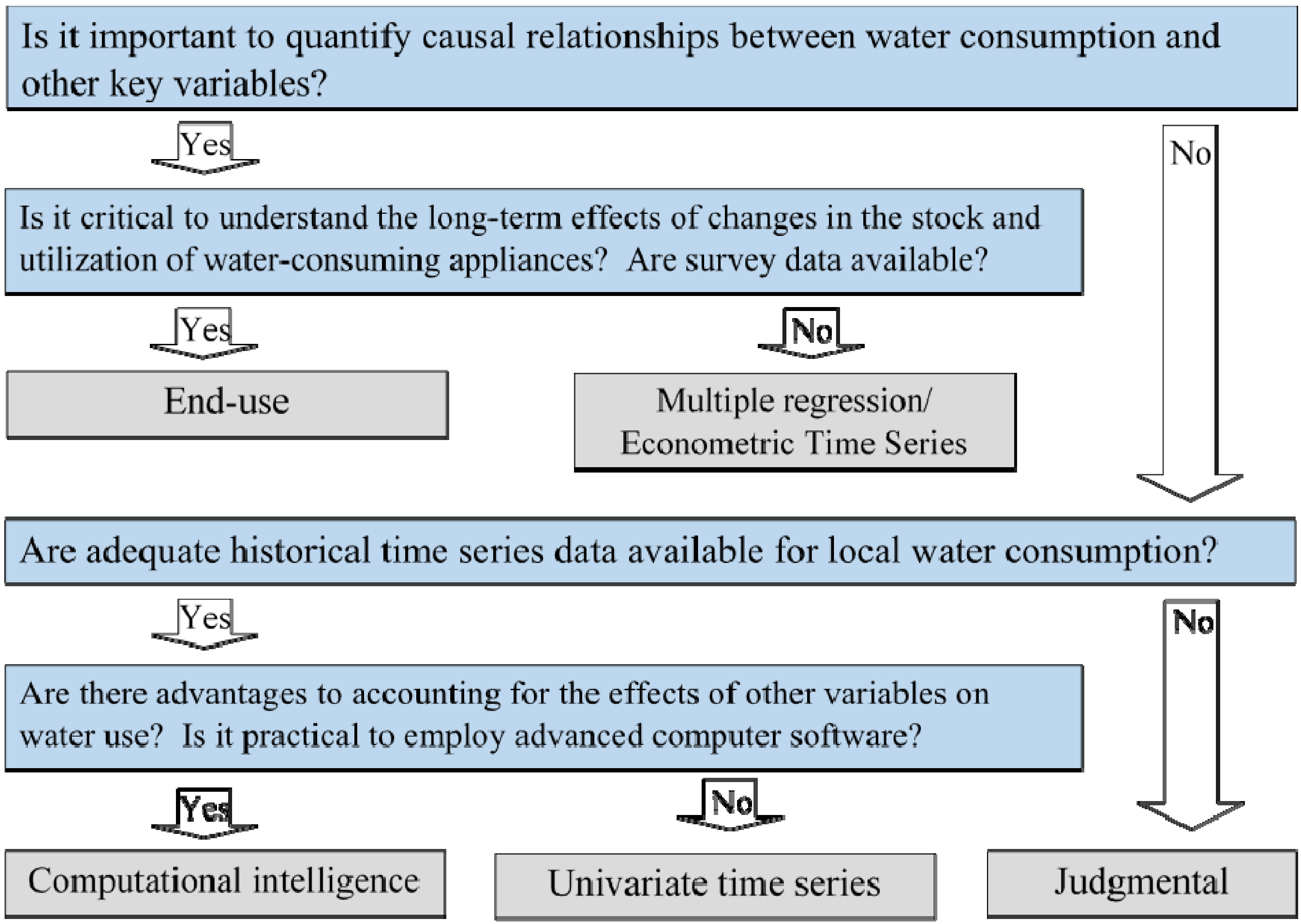
Use of forecasting methodologies by surveyed water utilities



Source: Fullerton, T.F., Jr. and Walke, A.G. [n.d.] *Improving the Accuracy of Short-Term Water Demand Forecasts*. Denver, Colo.: Water Research Foundation, forthcoming.

Factors to consider in choosing a forecasting method

- Accuracy track record for each forecasting approach
- Forecast horizon
- Data availability
- Complexity of the forecasting approach
  - Data, staff, and computational requirements
- Importance to the organization of accurate forecasts
- Organizational goals in forecasting
  - Prediction
  - Analyzing scenarios & alternative policies



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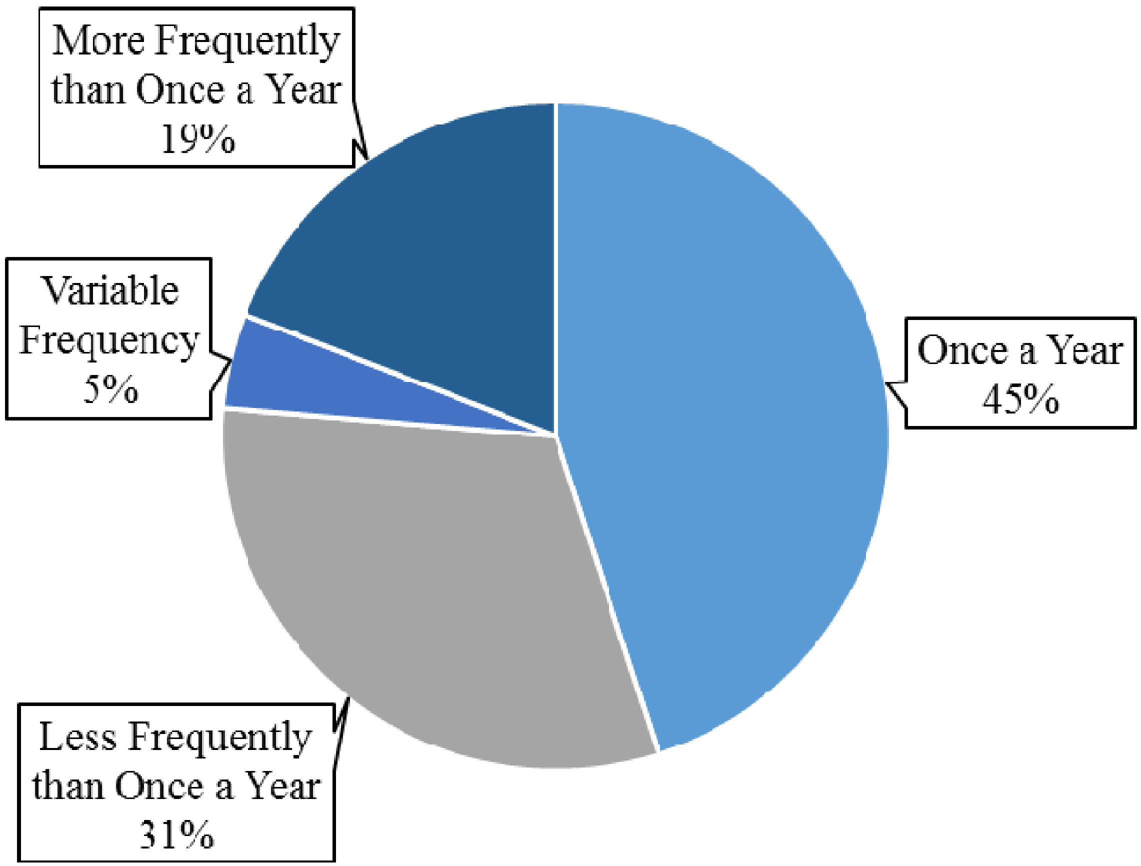
Implementing a Viable Forecasting Approach

Non-methodological factors to consider in developing a forecast

- Sample size
- Data quality issues
  - Measurement of key variables
  - Handling of missing/unreliable data
- Level of aggregation
  - Across customer categories
  - Across geographical areas
  - Customer base & water demand per customer
- Vintage of data used for forecasting

Frequency of forecast re-estimation or updating by water utilities



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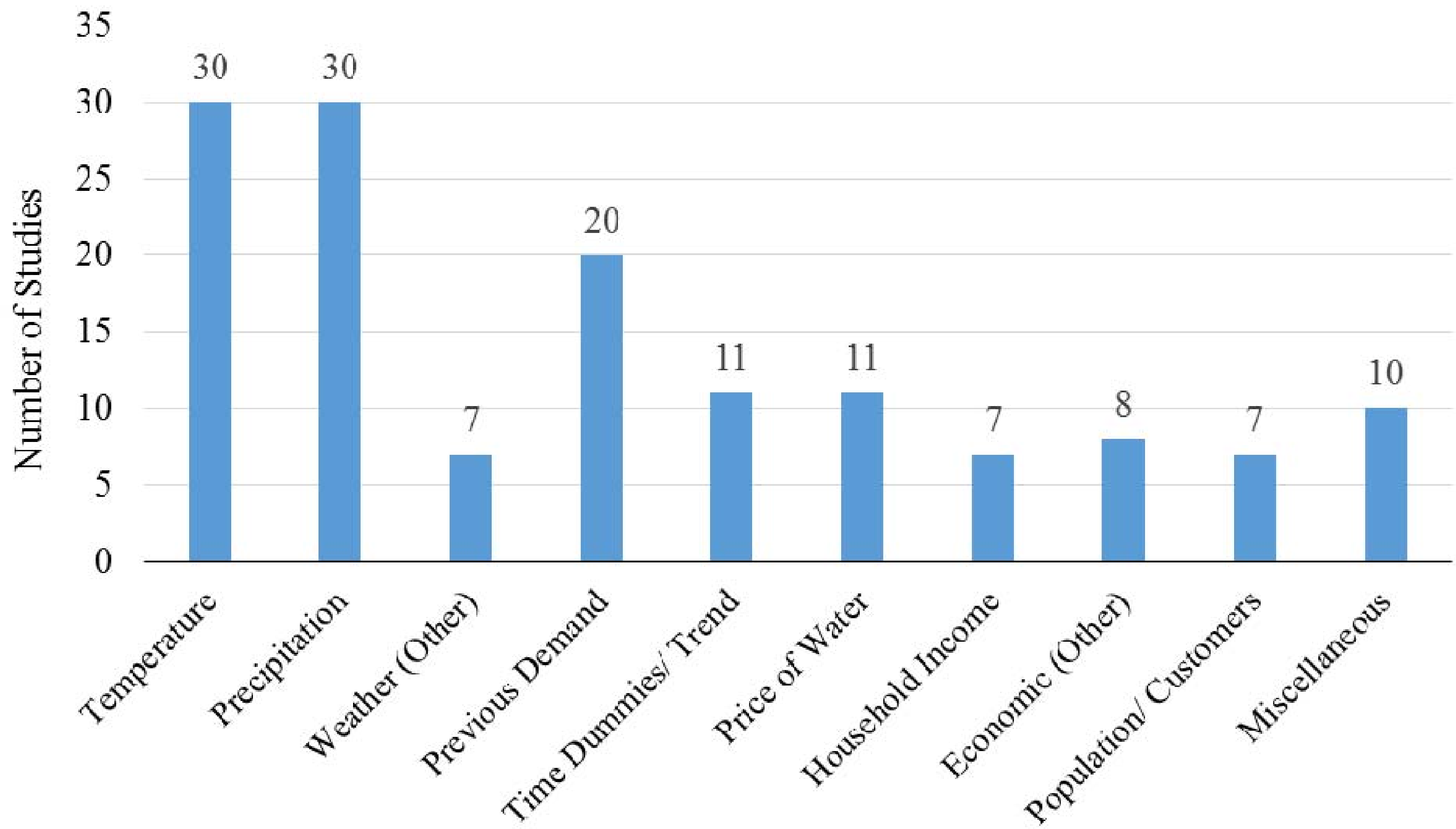
Historical water demand modeling (en route to developing a forecast)

- Water demand is influenced by factors such as:
  - Price of water
  - Weather conditions
  - Economic conditions
  - Other factors (non-price conservation measures, efficiency of water-using devices, etc.)

Variables used in 53 published studies for short-term forecasting



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Linear Transfer Function (LTF) Estimation Methodology:

- Demand is first modeled as a function of lagged values of explanatory variables.

- Any unexplained systematic variation in demand is then modeled using autoregressive (AR) and moving average (MA) parameters.

Estimated LTF Equations for Phoenix: Per-Customer Water Usage

Dependent Variables →	Single-Family Res.	Multi-Family Res.	Non-Residential
Constant	0.188	-0.010	3.067**
Average Price $_{t}$	-2.699*	-15.298*	-39.146**
Cooling Degree Days $_{t-1}$	0.005**	0.037**	0.062**
Days with Rainfall $_{t}$	-0.099*		-1.563**
Econ. Conditions Index $_{t-11}$	0.227*		
Rental Vacancy Rate $_{t-11}$		-1.509*	
Unemployment Rate $_{t-15}$			-6.063*
AR $_{t-1}$	-0.593**		-0.481**
AR $_{t-8}$	-0.342**		
AR $_{t-12}$		-0.354**	
MA $_{t-1}$		-0.981**	
MA $_{t-4}$			-0.581**
R-Squared	0.595	0.691	0.572
F-Statistic	13.482**	23.302**	10.712**

* Probability value <.05; ** Probability value <.01

Source: Fullerton, T.F., Jr. and Walke, A.G. [n.d.] *Improving the Accuracy of Short-Term Water Demand Forecasts*. Denver, Colo.: Water Research Foundation, forthcoming.

Estimated LTF Equations for Phoenix: Number of Water Customers

Dependent Variables →	Single-Family Res.	Multi-Family Res.	Non-Residential
C	46.195	12.891	-20.237
Nonfarm Employment $_{t-11}$	38.122		
Nonfarm Employment $_{t-14}$			7.926*
Multi-Fam. Housing Starts$_{t-15}$		0.064**	
AR $_{t-2}$		-0.549**	
MA $_{t-1}$	-0.512**		
MA $_{t-2}$		0.805**	
R-Squared	0.173	0.323	0.080
F-Statistic	5.978**	7.934**	4.775*

* Probability value <.05; ** Probability value <.01

Source: Fullerton, T.F., Jr. and Walke, A.G. [n.d.] *Improving the Accuracy of Short-Term Water Demand Forecasts*. Denver, Colo.: Water Research Foundation, forthcoming.

Estimated LTF Equations for El Paso: Customer Base & Per-Customer Usage

Dependent Variable →	Per-Customer Usage	Customers
Constant	0.002	345.198**
Average Price $_{t-3}$	-2.899**	
Days over 90°F $_{t}$	0.089**	
Days over 90°F $_{t-1}$	0.131**	
Rainfall $_{t-1}$	-0.396**	
Nonfarm Employment $_{t}$	0.121**	
Nonfarm Employment $_{t-32}$		42.440**
AR $_{t-12}$	-0.295**	0.369**
AR $_{t-18}$		-0.175**
MA $_{t-1}$	-0.706**	-0.299**
MA $_{t-3}$		0.157*
MA $_{t-12}$	-0.265**	
R-Squared	0.702	0.237
F-Statistic	59.808**	10.602**

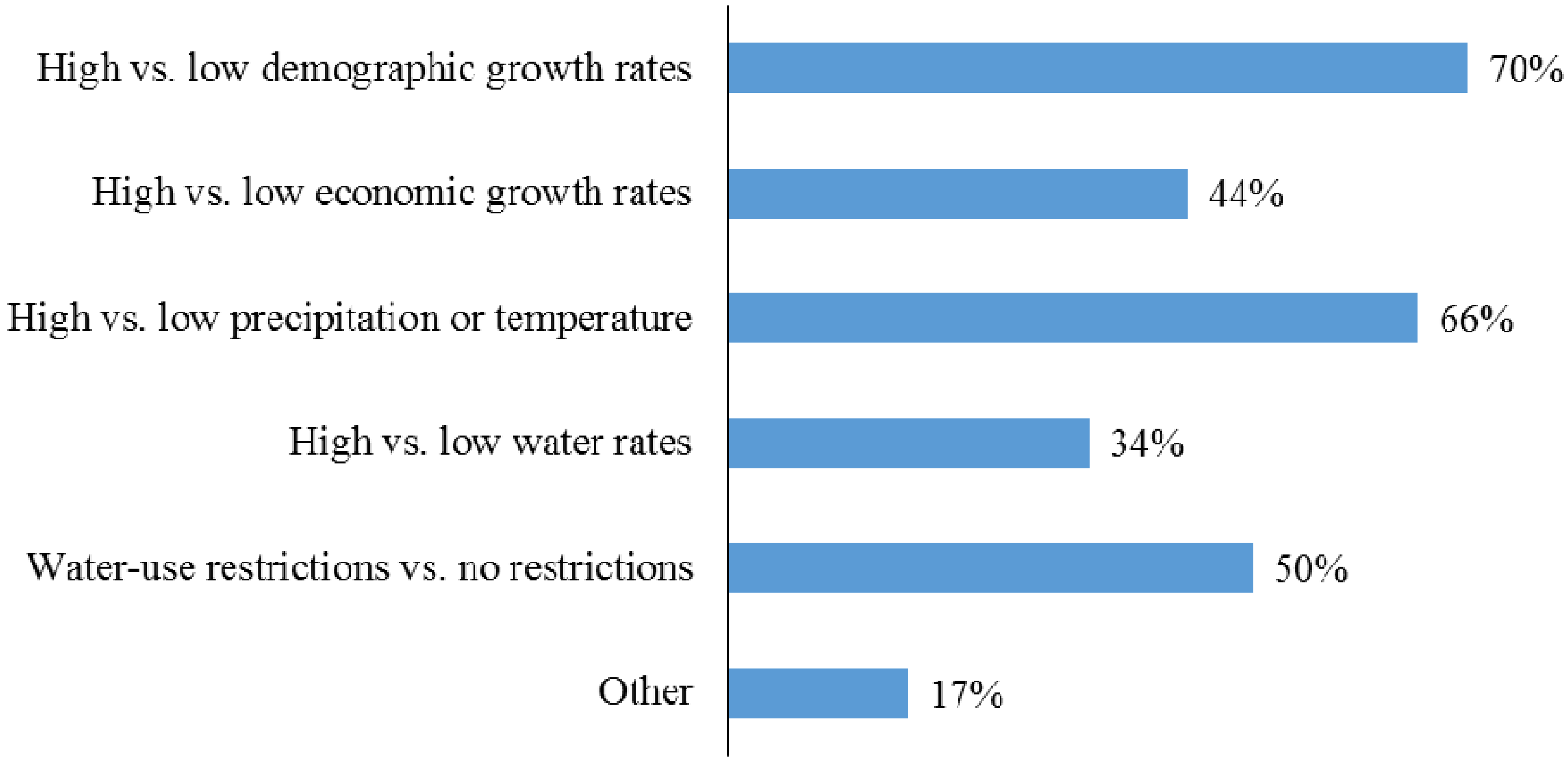
Source: Fullerton, T.F., Jr. and Walke, A.G. [n.d.] *Improving the Accuracy of Short-Term Water Demand Forecasts*. Denver, Colo.: Water Research Foundation, forthcoming.

Scenarios & Counterfactuals

- The coefficient estimates in the preceding tables can be used to develop various alternative scenarios, such as the following:
  - What happens if there is a drought?
  - What happens to demand if rates increase?
  - What rate change would be necessary to achieve a given conservation target?

- A counterfactual is similar but asks what would have occurred in the past if some key factor had been different.

Types of scenarios considered by water utilities



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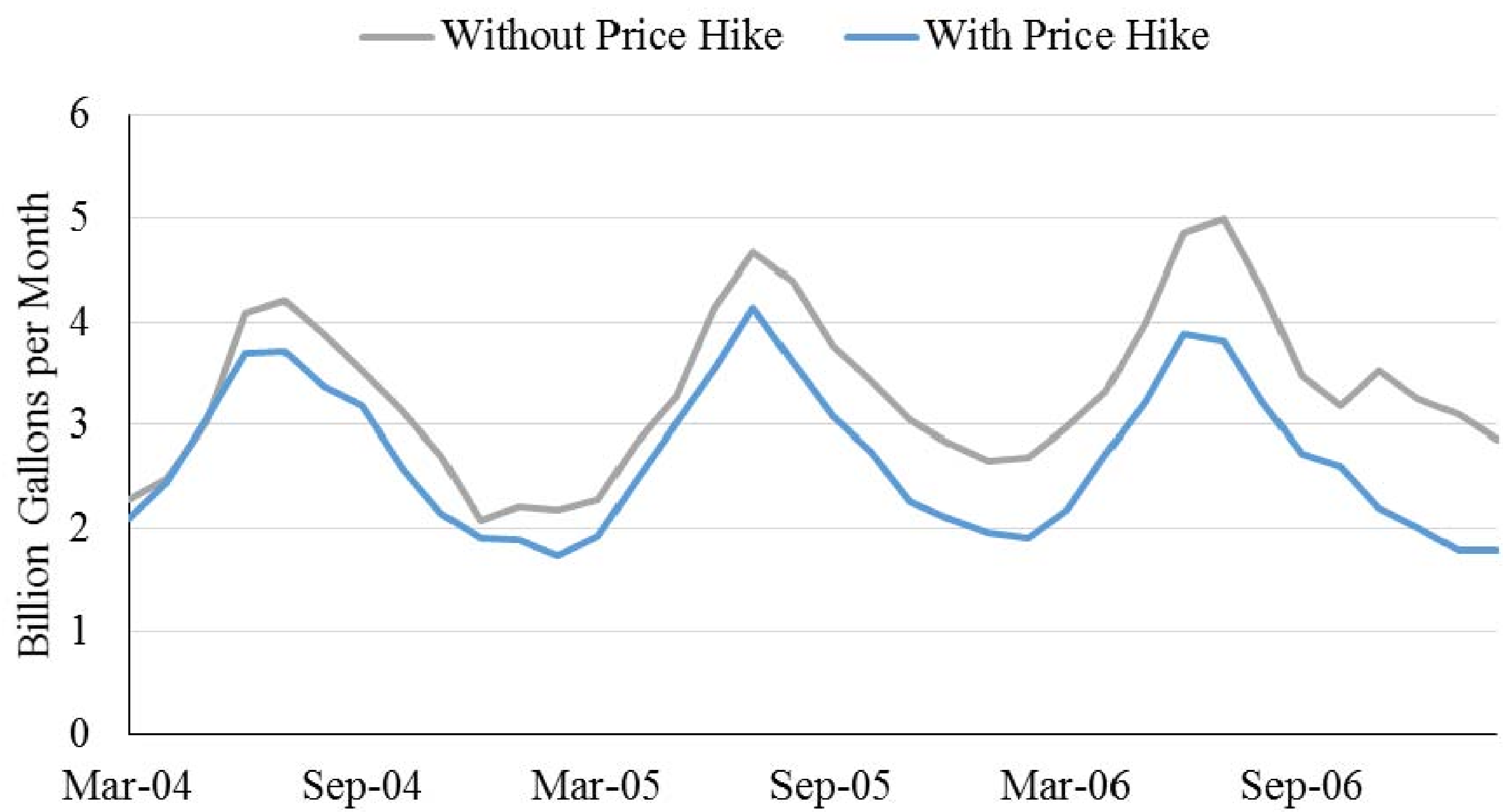
Counterfactual example: What would have happened to demand in El Paso if prices had not increased in 2004?



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Evaluating the Forecasting Approach

Evaluation methodologies used to assess forecast accuracy:

Criteria based on the size of the forecast error:

- Root Mean Squared Error (RMSE)
- Forecast error differential regression test
    - H_0: Both sets of forecasts are equally accurate

Criteria for evaluating directional accuracy:

- Chi-square test
    - H_0: Forecasted and actual events are independent (i.e. forecasts don't provide useful information for predicting the direction of change)

Summary of Accuracy Results for Utility-Generated Forecasts

- Forecasts were collected from 5 utilities, located in Florida, Texas, Arizona, California, and Australia (numbered to protect anonymity).
- Utility forecasts are compared to random walk alternatives to assess relative accuracy.
- Forecasts are disaggregated in different ways (e.g. by step-length, by geography, by customer class)
- For one utility, there were not enough observations to conduct statistical accuracy tests.

Utility Forecast Accuracy Summary: Root Mean Squared Error (RMSE)

#	Horizon (Freq.)	Methodology	Utility % Better
1	2 Weeks (Daily)	Regression with weather and demographic explanatory variables and lagged demand	**71%**
2	1 Week (Weekly)	Regression with weather explanatory variables and lagged demand	**100%**
3	1 Year (Monthly)	Econometric model including price, weather, employment, unemployment rate, and lagged demand	**75%**
4	2 Years (Monthly)	Expert judgment taking into account climatic & economic conditions	**0%**
5	4 Years (Annual)	End-use model based on survey data, and data on demographic trends, prices, and conservation policies	**0%**

Utility Forecast Accuracy Summary: Error Differential Regression Test

#	Horizon (Freq.)	Methodology	% Significantly Better
1	2 Weeks (Daily)	Regression with weather and demographic explanatory variables and lagged demand	**29%**
2	1 Week (Weekly)	Regression with weather explanatory variables and lagged demand	**83%**
3	1 Year (Monthly)	Econometric model including price, weather, employment, unemployment rate, and lagged demand	**50%**
4	2 Years (Monthly)	Expert judgment taking into account climatic & economic conditions	**0%**
5	4 Years (Annual)	End-use model based on survey data, and data on demographic trends, prices, and conservation policies	**NA**

Utility Forecast Accuracy Summary: Chi-Square Test of Independence

#	Horizon (Freq.)	Methodology	% Significant
1	2 Weeks (Daily)	Regression with weather and demographic explanatory variables and lagged demand	**57%**
2	1 Week (Weekly)	Regression with weather explanatory variables and lagged demand	**78%**
3	1 Year (Monthly)	Econometric model including price, weather, employment, unemployment rate, and lagged demand	**75%**
4	2 Years (Monthly)	Expert judgment taking into account climatic & economic conditions	**0%**
5	4 Years (Annual)	End-use model based on survey data, and data on demographic trends, prices, and conservation policies	**NA**

Questions?