2022 SUMMARY REPORT: REPRESENTING CLIMATE CHANGE IMPACTS IN WATER DEMAND MODELING

The Water Utility Climate Alliance (WUCA) was formed in 2007 to provide leadership and collaboration on climate change issues affecting U.S. water agencies. WUCA members include 12 of the nation's largest water providers, which supply drinking water for more than 50 million people across the U.S.

WUCA conducted an informal water demand assessment in 2022 to learn more about how its member agencies address and model projected climate change impacts on future water demands. As detailed below, demand impacts include higher evapotranspiration rates, increased evaporation demand for cooling, longer growing seasons, increased conservation program implementation and population shifts.

WUCA met with member agency demand forecasting staff as part of an information-gathering process and issued a survey. Participating agencies shared information on how their utility models long-term demands (10-50 years) and incorporates climate change impacts into water demand projections.

Key Findings

- 67% of WUCA agencies are either modeling climate change or updating their demand model to do so.
- Many utilities develop multiple demand scenarios and plan water supply options that support a range of future conditions.

Current & Anticipated Impacts of Climate Change on Water Demands

From extreme flood events that damage facilities to unprecedented droughts that reduce the reliability of water supplies, water utilities face a multitude of climate change impacts. As described below, climate change impacts have significant potential to influence water demands.

Higher Evapotranspiration Rates. Rising air temperatures will increase evapotranspiration rates and, consequently, irrigation demand requirements for vegetation, including landscape maintenance and agricultural production.

Increased Evaporation Demand for Cooling. Evaporative cooling systems will work harder and longer to achieve target comfort settings for more days each year and during heat extremes.

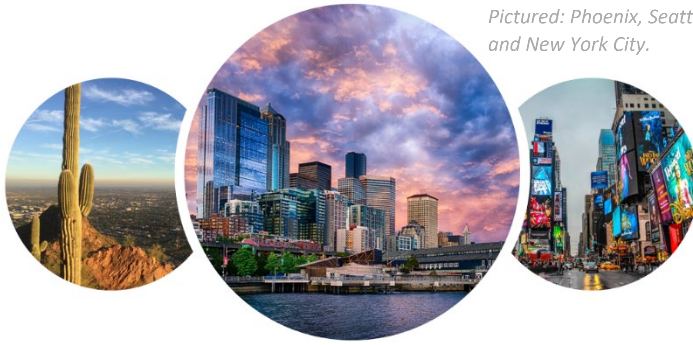
Longer Growing Seasons. Shoulder seasons will stay warmer longer, lengthening the growing season and increasing irrigation water use.

Change In Landscapes: Customers are responding to warming by replacing water intensive grasses with climate appropriate landscapes with the help of conservation programs.

Population Shifts: Population shifts are expected as climate change makes some areas of the country less hospitable due to rising seas, more frequent and intense storms, wildfires and other factors.

While some demand changes can be quantified—such as those associated with evapotranspiration, evaporation and shifting growing seasons—others are difficult to predict because they are based on behavioral changes that can materialize in unpredictable ways.

- Many utilities are experiencing declines in per capita water demands (GPCD). These declines are related to the 2008-2010 economic recession, conservation, changing land use patterns and other factors[i]. Differences between projected demands (the expectation that climate change will increase demands) and actual demands (declining demands, in some cases) present a challenge in climate change planning.



Pictured: Phoenix, Seattle and New York City.

Although WUCA member agencies represent communities with diverse demand characteristics, the most common demand drivers are population, price, climate/weather, land use/agriculture and economic variables.

- WUCA utilities generally use two modeling approaches: end-use modeling and explanatory econometric modeling.[ii] The end-use modeling approach categorizes use types (for example, laundry, dishwasher/kitchen, restroom, etc.) and makes assumptions about use rates for each. The explanatory econometric modeling approach correlates water demands to different socioeconomic and climate variables to explain trends. As detailed at the bottom of this page, each approach has benefits and drawbacks.

- Some utilities rely on consultants to develop their demand model but are building internal capacity so that staff can maintain, update and run models (Portland Water Bureau, San Diego County Water Authority and Austin Water). Other utilities primarily rely on staff to develop, update and run their models (Southern Nevada Water Authority, Denver Water, and Metropolitan Water District of Southern California).

- While having numerous variables in the model can allow agencies to test demand sensitivity to different variables, most of WUCA's member agencies prefer simplicity. Some utilities are moving away from the more complex econometric demand models and are working with consultants to simplify their models for staff use and maintenance.

- Although WUCA member agencies represent communities with diverse demand characteristics, the most common demand drivers are population, price, climate/weather, land use/agriculture and economic variables. However, specific demand variables vary depending on if the utility models different sectors (such as single-family residential and multi-family residential, commercial, industrial and agriculture). For instance, there is negligible farming in Southern Nevada. As such, agricultural acreage is not a variable in Southern Nevada Water Authority's (SNWA) model.

Comparing Water Demand Models – Some utilities prefer one over the other, but selection depends on each utility's unique needs and expertise.

PROS & CONS

END-USE MODEL

Pros:

- Easy to modify assumptions to accommodate scenario planning.
- Can explicitly apply anticipated changes due to behavior change.

Cons:

- Relies on many assumptions that may not be grounded in locally collected data.
- May not be able to tell users about the most important drivers (requires knowledge from outside of the model).

EXPLANATORY ECONOMETRIC MODEL

Pros:

- Relies on local water use data – fewer assumptions.
- Can model price elasticity of demand and identifies key demand drivers.
- Allows users to conduct sensitivity tests to see how different climate futures might impact demand if climate variables are inputs.
- Does not explicitly account for behavior change.

Cons:

- Requires that climate variables be explicitly included as explanatory variables in model if user wants to test alternative climate scenarios.
- Explanatory model is generally not a forecast model, i.e., does not model effects on demand that differ from historical trends in economy or market conditions.

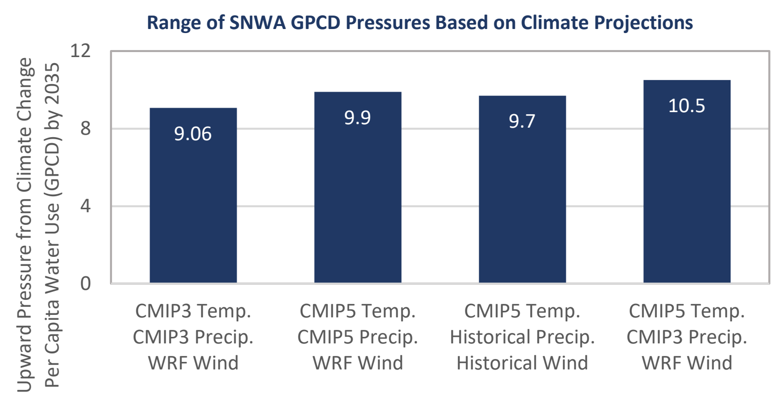
Q & A

In the context of scenario and adaptive planning, how do utilities develop demand modeling tools that are informative to these processes?

- Most agencies ensure their demand models use climate variables (temperature, precipitation and wind speed) as inputs for climate change. That way, the baseline model can use long-term climatology to compare alternative scenarios using different climate projections (Tampa Bay Water).

- Denver Water was an early adopter of “multiple scenario” planning. The agency’s last plan explored four futures, with the primary drivers being climate, growth and development patterns. The agency has found scenario planning useful in representing lower-demand futures. This information is insightful as most—if not all—WUCA utilities have declining per capita water use; some also have declining total water demand.

- Like Denver Water, the SNWA conducts scenario planning to address uncertainty and bracket the range of anticipated future water resource needs. SNWA planning scenarios consider variable supply and demand conditions that include assumptions about population growth, conservation achievements and Colorado River hydrology. The SNWA also considers the impact of climate change on demand (total and per capita water use) to inform conservation and water resource planning processes.



The SNWA reviews updated climate projections and considers a range of possible outcomes to inform planning processes.

- Other agencies identify primary demand drivers and apply different weights to drivers with a climate change component. For example, to address concerns about demands associated with climate migrants, Seattle Public Utilities (SPU) adjusts the weight on population to represent climate migration. This approach allows SPU to modify weighting from one plan to the next.

- Austin Water (AW) and Metropolitan Water District of Southern California (MWD) use an “adaptive pathways” approach. These agencies develop a portfolio of supply options and test the portfolio’s robustness against many scenarios. Agencies pivot to a new pathway when certain variables or “signposts” pass predetermined thresholds.

MWD Example: Signposts for Monitoring

Demographics

- Growth Rates
- Housing Type Trends
- Employment
- Areas of Growth
- Density Trends

Bay-Delta

- Environmental Impacts
- New & Improved Facilities
- Ecosystem Restoration
- Operations

Local Supplies

- Groundwater Adjudications
- Regulations
- Reduced Yields
- Water Quality Impacts
- New Projects/Timing

Climate Change

- Precipitation Trends
- Global Modeling Results
- Temperature Trends
- Downscaling Improvement

Q & A

How can utilities develop the capacity to do this work internally—who relies on consultants to perform demand modeling, who does it internally and who uses a mix of the two?

Some WUCA utilities develop their demand models in-house, while others use consultants. Notably, some utilities rely on more than one demand model. To this end, a single utility could maintain and run some demand models internally while seeking consultant support for others.

- The San Diego County Water Authority (SDCWA) has historically used consultants to develop several of its forecasting models (such as, the long-range econometric demand model and agricultural water use forecast model) and is evaluating development of internal capacity to maintain and run the various models.
- Denver Water uses consultants when a high level of sensitivity is warranted; otherwise, the agency relies on internal staff.
- The Portland Water Bureau (PWB) had an in-house model. The agency is actively working with a consultant to develop and refine a new model that is more user-friendly for internal use. The model will run different scenarios that feed into PWB's adaptive supply planning process.

What are the merits of including many variables in demand models? Does it make it harder to tease out the main drivers of demand? And, if you had to build a simplified demand model for your system, what two or three variables would be most important for your agency to include?

- The San Francisco Public Utilities Commission (SFPUC) found that using a bottom-up (end-use) model was disadvantageous because they wanted to incorporate demand elasticity into their model. After using the end-use model for ten years, the agency moved to an econometric model that helps them better understand the most important demand drivers. For SFPUC, the key variables are price, land use and median income. The agency has not yet incorporated climate change into its demand model.
- Other agencies indicated that preferences related to variables depend on which sector is being modeled. For example, the single-family and multi-family residential, population, weather and price are key drivers. For SDCWA, when estimating future agricultural demands, irrigated acreage is a significant variable.
- The Philadelphia Water Department (PWD) only includes variables that are statistically significant within the bounds of uncertainty. For them, population and historical demand trends are key variables.
- The SNWA and other demand analysts noted that 'simple is better.' Keeping the model as simple as possible while still being able to have the best fit line that can represent demands is most desirable.

Simplicity

Benjamin Obi Tayo, Ph.D., is a physicist, data scientist and writer. As paraphrased below, he offers three reasons why a simple model is preferred over a complex model:[iii]

- **Prevents Overfitting.** A dataset with too many features can sometimes lead to overfitting, capturing both real and random effects.
- **Interpretability.** An over-complex model with too many features can be hard to interpret, especially when features correlate with each other. It can also be more challenging to communicate results to key stakeholders.
- **Computational Efficiency.** A model trained on fewer data variables is computationally efficient, requiring less computational time for algorithm execution.

While WUCAs state simpler models tend to be better, this does not mean the members are making the case for one type of model over another. Every utility determines the right level of complexity for their own needs.

Next Steps

WUCA participants would like to continue focused learning sessions on water demand modeling, and we plan to continue calls in 2023. Additionally, some utilities are interested in exchanging information on how to project the impact of conservation programs on demands. Others would like to explore how demand modeling efforts used in U.S. Bureau of Reclamation Secure Water Act reports relate to wholesale and retail water demand forecasts.[iv]

Capturing impacts on demand from Non-Revenue Water is more of a concern for our northeast utility members than changing demands due to drought and climate change. For instance, PWD is interested in learning how to model Non-Revenue Water, which is system water loss from leakage and pipe breaks, generally due to aging water systems. Other topics for exploration include ways utilities can capture water system changes like water main replacement frequencies and more efficient fixtures for indoor water use.

References:

[i] Types of conservation and other factors mentioned here could include, fixture efficiency, efficient watering and changing types of landscapes, drought, and water scarcity messages.

[ii] An Econometric model uses the application of statistical and mathematical theories in economics to establish relationships between the variable of consideration and other variables that are known to affect it, called “explanatory variables.” The model is used for testing hypotheses and can, in some situations, be used to forecast future trends.

[iii] Simplicity vs Complexity in Machine Learning — Finding the Right Balance. Benjamin Obi Tayo Ph.D., https://towardsdatascience.com/simplicity-vs-complexity-in-machine-learning-finding-the-right-balance-c9000d1726fb Accessed 9.29.2022

[iv] 2021 SECURE Water Act Report to Congress. U.S. Bureau of Reclamation. https://www.usbr.gov/climate/secure/ Accessed 9.29.2022