Integrating Water Efficiency Standards and Codes into Long-Term Demand Forecasting

Sarah Diringer, Ph.D.,¹ H Cooley,¹ M Heberger,¹ R Phurisamban,¹ K Donnelly,¹ A Turner,² J McKibbin,² M Dickinson³

¹Pacific Institute (Oakland, CA); ²Institute for Sustainable Futures (Sydney, Australia); ³Alliance for Water Efficiency (Chicago, IL)
Project Team and Advisory Committee

Water Research Foundation
Program Manager: Maureen Hodgins
Project Coordinator: Valerie Roundy

Project Advisory Committee
Veronica Blette, U.S. EPA WaterSense Program
David Bracciano, Tampa Bay Water
Ben Dziegielewski, formerly Southern Illinois University
Douglas Frost, City of Phoenix Water Service
Margaret Hunter, American Water
Outline

- Demand Forecasting Overview
- Efficiency Standards and Codes
- Stock Modeling
- Collecting and Incorporating Data
- Characterizing Uncertainty
- Guidance and Recommendations
Accurate demand forecasting is essential.

**Underestimating** future water demand could contribute to water supply shortfalls, temporary increases in water bills, and the imposition of emergency cutbacks.

**Overestimating** demand can lead to costly investment in unneeded infrastructure and water sources, with higher water bills and potential environmental impacts.

Top Left: Hungry Horse Dam, Montana, Dept. of Interior via Wired.com; Top Right: City of Lancaster, Texas; Bottom: Tampa Bay Desalination Plant, Florida, wateronline.com
Forecasts often overestimate demand

Municipal Water Use in the U.S.

Per capita water use in the U.S. is declining, at least partially due to efficiency standards and codes.
Research Objective

WRF Report #4495

Develop guidance to help water planners and managers increase the reliability of their water demand forecasts by accounting for efficiency standards and codes.
# Water-Use Efficiency Standards

<table>
<thead>
<tr>
<th>Category</th>
<th>Units</th>
<th>Federal Standards</th>
<th>WaterSense or ENERGY STAR minimum efficiency</th>
<th>Ultra-high efficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single-flush tank-type toilets</td>
<td>gpf</td>
<td>1.6</td>
<td>1.3</td>
<td>0.79</td>
</tr>
<tr>
<td>Dual-flush tank-type toilets</td>
<td>gpf</td>
<td>1.6</td>
<td>1.6 (full)/1.1 (reduced)</td>
<td>0.95 (full)/0.5 (reduced)</td>
</tr>
<tr>
<td>Commercial toilets (flushometer valve)</td>
<td>gpf</td>
<td>1.6</td>
<td>1.28</td>
<td>1.0</td>
</tr>
<tr>
<td>Showerheads</td>
<td>gpm</td>
<td>2.5</td>
<td>2</td>
<td>0.75</td>
</tr>
<tr>
<td>Bathroom faucets</td>
<td>gpm</td>
<td>2.2</td>
<td>1.5</td>
<td>1.0</td>
</tr>
<tr>
<td>Commercial pre-rinse spray valves</td>
<td>gpm</td>
<td>1.6</td>
<td>1.28</td>
<td>0.65</td>
</tr>
<tr>
<td>Residential clothes washers</td>
<td>IWF</td>
<td>4.7 (front-load)</td>
<td>3.7 (front-load)</td>
<td>2.6</td>
</tr>
<tr>
<td></td>
<td></td>
<td>6.5 (top-load)</td>
<td>4.3 (top-load)</td>
<td></td>
</tr>
<tr>
<td>Commercial clothes washers</td>
<td>IWF</td>
<td>4.1 (front-load)</td>
<td>4.5</td>
<td>3.7</td>
</tr>
<tr>
<td></td>
<td></td>
<td>8.8 (top-load)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Residential dishwashers</td>
<td>gallons per cycle</td>
<td>5.0</td>
<td>3.5</td>
<td>1.95</td>
</tr>
</tbody>
</table>
Demand Forecasting Methods

Four methods for long-term demand forecasting:

(1) **Extrapolation models**: Population x Water Use Factor

(2) **Econometric or regression models**: 
   \[
   \text{Demand} = f(\text{growth, water price, new development, etc.})
   \]

(3) **Comprehensive end use (‘bottom up’) models**: water use projected by end uses individually and then summed.

(4) **Hybrid models**: Extrapolation or econometric models with correction factor for conservation (guesstimate or modeled)
Base Models with Corrections Models

Baseline Econometric or Extrapolation Model with a Correction Factor for Efficiency

Comprehensive End Use Modeling

- Water use projected for each end use as a function of stock, efficiency, and behavior.
- Water use is a function of economic/price impacts, technology, development, and changing efficiency.
- Allows for co-variation between economy and efficiency.
Modeling Water by End Use

End Use Analysis can be used as part of correction factors or comprehensive end use modeling.

\[
\frac{\text{Total Vol}}{\text{Day}} = \left( \frac{\text{# of Homes} \times \frac{\text{# of Homes w/ DW}}{\text{# of Homes}}}{\text{# of Homes w/ DW}} \right) \times \frac{\text{# of DW}}{\text{Use}} \times \frac{\text{Volume}}{\text{DW} \times \text{Day}}
\]

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Stock Model Components

Stock models simulate the turnover of cohorts of devices using replacement distribution and a device lifetime.
Replacement Distributions

Exponential Decay

- Percent of original cohort failing each year
- Exponential Distribution
- 25 year avg life
- Time after installation (yr)

Lognormal Distribution

- Percent of original cohort failing each year
- Lognormal Distribution
- 25 year avg life
- Time after installation (yr)

Diringer et al., forthcoming. WRF Project #4495
Choosing a Replacement Rate

- Water Sector: Australia study showed that lognormal decay best fit the replacement rates of toilets (Snelling 2007)
- Energy Sector: Weibull distributions of replacement rates fit with sales data

The replacement function can dramatically affect the modeled current stock and future conservation savings.
**Impact of Device Lifetime on Models**

<table>
<thead>
<tr>
<th>Device</th>
<th>Range of Device Lifetime</th>
</tr>
</thead>
<tbody>
<tr>
<td>Showerheads</td>
<td>5 – 12 years</td>
</tr>
<tr>
<td>Toilets</td>
<td>20 – 30 years</td>
</tr>
<tr>
<td>Dishwashers</td>
<td>10 – 15.5 years</td>
</tr>
<tr>
<td>Clothes Washers</td>
<td>8 – 20 years</td>
</tr>
</tbody>
</table>

If an analyst forecasts a 20-year average life and the devices last 30 years, that leads to a 17% difference in water usage.

Diringer et al., forthcoming. WRF Project #4495
Example of Stock Modeling

Tampa Bay Water, Demand Management Plan (2013)

Step 1: Separate households by age based on new legislation
  • Pre-1984: 5 gpf toilets
  • 1984–1994: 3.5 gpf
  • 1994–Present: 1.6 gpf

Datasets:
  • Billing and conservation program data
  • Water use data
  • Water Efficiency Program Library (WEPL)
  • Parcel data
  • Market share of WaterSense devices
  • Projected population growth (Moody’s Analytics)
Example of Stock Modeling

Step 2: Run stock model with decay function for each housing group.

Data provided by Tampa Bay Water. (2013). Water Demand Management Plan. Diringer et al., forthcoming. WRF Project #4495
Example of Stock Modeling

Step 3: Determine total stock of toilets in the service area.

Step 4: Multiply stock of toilets by distribution of toilet efficiencies.

Step 5: Adjust per capita water demand by changing average toilet efficiency.

Next Step: (1) Validate model with surveys, in-person assessments, or flow trace analyses. (2) Examine uncertainty in forecast using Monte Carlo or scenario testing.

Data provided by Tampa Bay Water. (2013). Water Demand Management Plan. Diringer et al., forthcoming. WRF Project #4495
# Datasets for Stock Modeling

<table>
<thead>
<tr>
<th>Study Outcomes</th>
<th>Data Collection Method</th>
<th>Residential Water Demand</th>
<th>Total Stock</th>
<th>Efficiency</th>
<th>Behavior</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>REUWS 1999, 2016</strong></td>
<td>End uses of water, single-family homes, <em>Not nationally representative</em></td>
<td>Customer survey, flow monitoring</td>
<td>Average indoor and outdoor residential water demand</td>
<td>Single flush/dual flush toilets, CW, DW, showers, bathtubs</td>
<td>Calculated water efficiency per use</td>
</tr>
<tr>
<td><strong>RECS 2001, 2005, 2009, 2015</strong></td>
<td></td>
<td></td>
<td></td>
<td>DW, CW Presence/Absence</td>
<td>CW: Top Loading vs. Front Loading</td>
</tr>
</tbody>
</table>
Collecting Data

- Surveys for end uses of water
- In-person assessments
- High-resolution flow trace analyses
- Advanced Metering Infrastructure (AMI)

Incorporating Data

Study data be incorporated into models, used to calibrate models, and/or verify model results.

Market share from Australia for toilet, where the orange dots represent census data to calibrate the changing stock.

Characterizing Uncertainty

Multiple scenarios and Monte Carlo simulations can be used to provide a range of predicted future water demand.

(above) Flory, 2013. “Forecasting Water Demand in Seattle.”
(right) Aquacraft, 2015. “Residential Demand Forecasting Model.”
Guidance and Recommendations

1. Improve overall forecasting methods
   • Examine the accuracy of demand forecasts and monitor trends in water use.
   • Incorporate stock models into demand forecasts to capture efficiency improvements resulting from standards and codes.
   • Integrate uncertainty into demand forecasts.

2. Improve stock modeling for demand forecasts
   • Determine current stock and efficiency of devices.
   • Develop realistic device lifetimes and replacement rates.

3. Anticipate the Future
   • Anticipate future standards and codes.
   • Investigate AMI technologies for collecting water data
Acknowledgements

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David Bracciano, Tampa Bay Water
Benedykt Dziegielewski, formerly Southern Illinois University
Douglas Frost, City of Phoenix Water Services Department
Margaret Hunter, Senior Project Manager, American Water

Participating Utilities
City of Austin, TX; Cobb County Water System, GA; East Bay Municipal Utility District, CA; Irvine Ranch Water District, CA; Long Beach Water Department, CA; San Antonio Water System, TX; San Diego County Water Authority, CA; San Francisco Water and Power, CA; Yarra Valley Water, Melbourne, Australia

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Program Manager: Maureen Hodgins
Project Coordinator: Valerie Roundy
Thank You and Contact Info

Sarah Diringer, Ph.D.
Senior Researcher
sdiringer@pacinst.org

Pacific Institute
654 13th St.
Oakland, CA 94612
Phone: (510) 251-1600
www.pacinst.org
info@pacinst.org

Pacific Institute, Oakland Office Staff