

Appendix A – Data Sources and Analysis Methods

Data Sources

Billing Dataset

The Billing Dataset contains monthly total billed water consumption at the utility-level, also separated into residential, commercial, and master meter customer types. This dataset represents approximately 7.3% of the current United States population. Master meter water demand includes “water transfers from a water utility to private companies, neighboring towns, and other water utilities” and was not used in the sector-level analysis. The full dataset of water providers and corresponding water use and demographic variables can be downloaded from the HydroShare open access database (Chinnasamy et al. 2021).

Flume Dataset

The Flume Dataset contains CBSA-aggregated data for: 1) number of installed devices by month; 2) summary statistics for indoor, outdoor and total monthly water demand; 3) summary statistics for fixture-level indoor monthly water demand variables; 4) summary statistics for outdoor/irrigation monthly water demand; and 5) household-level data for irrigation system characteristics, occupancy, and home characteristics. A complete listing of variables used in the analysis is provided in Table A1.

Table A1. Variables Provided in Flume Dataset as Monthly Values for Calendar Years 2022 – 2023, by Core-Based Statistical Area.

Category	Variable	Sub-variable	Scale	Statistic(s)
Household Characteristics	Number of Flume Devices		CBSA	Total
	Number of Households		CBSA	Total
	Number of Events Analyzed		CBSA	Total
	Postal Code		Household	
	Irrigation System Type	Sprinkler System, Garden Hose, Drop, Soaker Hose, None	Household	Sprinkler
	Pool Indicator		Household	Binary Indicator

	Household Size (occupants)		Household	
Household Characteristics	Lot Size (square feet)		Household	
	Estimated Landscape Area (square feet)		Household	Estimated as 40% of Lot Size
Water Use	Daily Water Use	Total	Per Household, Per Capita	Average, Median, Standard Deviation
		Indoor	Per Household, Per Capita	Average, Median, Standard Deviation
		Outdoor	Per Household, Per Capita	Average, Median, Standard Deviation
	Fixture-Level Water Use	Volume	Per Event (except Total)	Average, Median, Total
		Duration (minutes per event)	Per Event	Average, Median
		Flow Rate (gallons per minute)	Per Event	Average, Median
		Number of Events	Per Day (except Total)	Per Household, Per Capita, Total
		Average Water Use (gallons per day)		Per Household, Per Capita
	Irrigation Water Use	Irrigation Rate (gallons per minute)		
		Irrigation Volume (gallons per square foot)		
		Irrigation Frequency (minutes per day)		

Water Loss Dataset

The Water Loss Dataset was compiled from individual utility water loss audit reports and state water loss audit databases obtained from individual state agencies, available upon request. For each water provider, we compiled data reported for each of the variables (where available) listed in Table A2. The summary statistics and geographic coverage of the Water Loss Dataset are discussed in further detail in **Error! Reference source not found..**

Table A2. Listing of Utility Water Loss-Related Variables Used In Analysis.

Variable Name	Description	Units
Public Water System Identification Number	10-digit identification number associated US EPA's with Safe Drinking Water Information System database	n/a
Public Water System Type	Description of water system type, in terms of service area	n/a
Served Population	Estimated average daily population served	each
Served Area	Total land area of water system service area boundary	square meters
Number of Connections	Total number of customer billing connections	each
Distribution and Transmission Mains Length	Total linear length of distribution system transmission and distribution mains, including service lines up to the meter	miles
Operating Pressure	Average annual operating pressure for distribution system	pounds per square inch
Total Water System Input	Annual average volume of treated drinking water input to distribution system	million gallons per day
Real Losses	Average annual volume of water reported as real losses (i.e. physical water lost to leaks and main breaks from tanks, transmission and distribution mains, and services lines)	million gallons per day

Additional Data Sources

We used several additional data sources to inform this analysis, as described in the Methods section of the report. A listing of these additional datasets, as well as the key variables used in the analysis, is provided in Table A3.

Table A3. Description of Additional Datasets and Relevant Variables Used in Analysis.

Data Source	Reference(s)	Geographic Scale	Variables	Notes
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Intercensal Population Totals (2000 – 2010, 2010 – 2020)	(U.S. Census Bureau 2016; 2024c)	Cities and Towns, Census Designated Places, Counties, Core-Based Statistical Areas, States, National	Total Population	
American Community Survey 5-year Estimates (2022)	(U.S. Census Bureau 2023)	Cities and Towns, Census Designated Places, Counties, Core-Based Statistical Areas, States, National	Total Population, Total Housing Units, Occupied Housing Units, Occupancy Type, Household Size	5-year Public Use Microdata Sample
American Housing Survey (2019, 2021, 2023)	(U.S. Census Bureau 2020a; 2020b; 2024b)	Core-Based Statistical Area, National	Number of Buildings, Number of Stories Per Building, Average Household Size Per Unit, Average Lot Size Per Unit	
Economic Census (2002, 2007, 2012, 2017, 2022)	(U.S. Census Bureau 2003; 2008; 2013; 2018; 2024a)	Cities and Towns, Census Designated Places, Counties, Core-Based Statistical Areas,	Employment to Population Ratio, NAICS 3-Digit Code, Number of Employees, Number of Establishments	

		States, National		
NClimDiv Database	(Vose et al. 2014)	National Climate Division	Cooling Degree Days, Heating Degree Days, Precipitation, Maximum Temperate, Minimum Temperature, Average Temperature	Monthly Average Values
Commercial Buildings Energy Consumption Survey (2018)	(U.S. EIA 2022)	Census Division	Total Conditioned Floor Area, Number of Employees, Number of Buildings, Number of Establishments	Summarized by Principal Building Activity and Detailed Principal Building Activity
Plant Hardiness Zone Designations	(USDA et al. 2023)	Zip Code	Plant Hardiness Zone Designation	
Community Water System Boundaries	(U.S. EPA 2024; 2025)	Public Water System	Public Water System Identification Number, Served Population, Number of Connections, Served Area (in square miles)	

Seasonality and Per Capita Demand Analysis

Seasonality and per capita demand cluster assignments for the Residential and CII sectors of each utility in the Billing Dataset are illustrated in Figure A1. In general, seasonality patterns (indicated by color **Error! Reference source not found.**) follow distinct spatial trends in both sectors. Utilities with Low Seasonality patterns were predominantly identified in the eastern half of the United States as well as some water providers in the southwest, while Moderate Seasonality patterns were predominantly located in the southwest and Great Plains regions, and High Seasonality pattern mostly occurring in the Mountain West and Pacific Northwest. Some exceptions to these trends exist in both sectors and could reflect water providers that have taken steps to improve water efficiency within their service area during and/or areas that do not face the same drivers of seasonal water use as surrounding water providers (e.g., weather, cultural/aesthetic preferences, etc.). Patterns of per capita demand cluster assignments follow similar, though less distinct, trends, with predominantly Low and Moderate per capita demand patterns found in the eastern half of the US, and High per capita demand patterns occurring mostly in the Southwest and Mountain West.

Seasonality and GPCD Cluster Assignments for Utilities In Billing Dataset

Residential Sector

Commercial, Industrial, & Institutional Sector

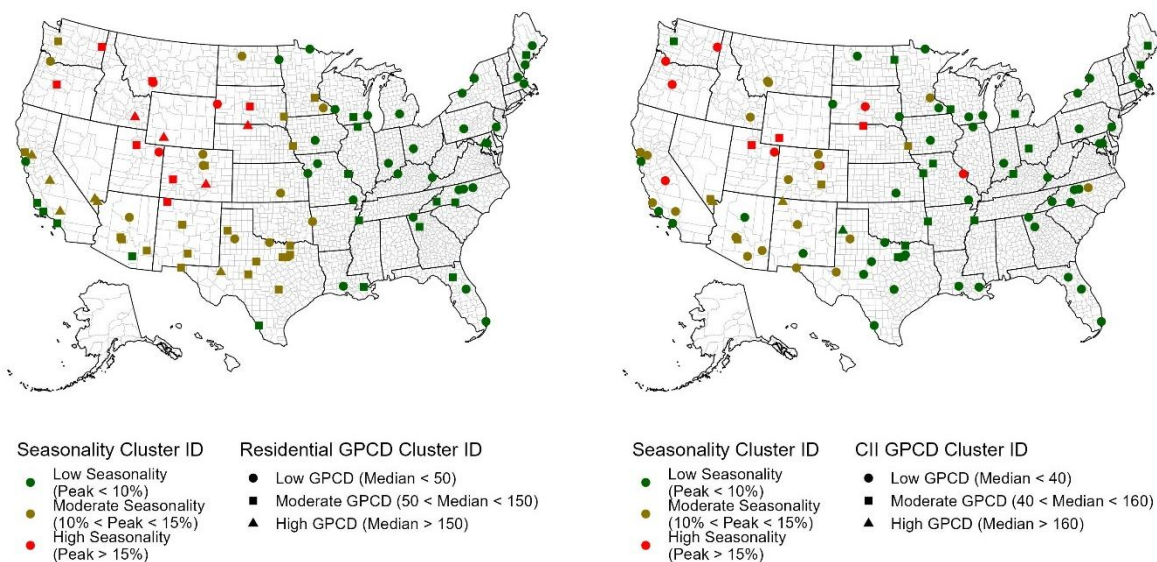


Figure A1. Seasonality and Per Capita Demand Cluster Assignments for Utilities in Billing Dataset, Residential and CII Sectors.

For seasonality, we clustered water providers using the time-series of the mean proportion of monthly water to annual water demand across all years of available data for each utility. For GPCD, we clustered water providers using the average annual GPCD estimated across all years of available data for each utility. We then analyzed the time-series trends in Seasonality and GPCD for each of the three cluster categories over the historical data

period, to evaluate time-dependence of each of the clustering parameters that should be extended to the Baseline year. When accounting for the influence of weather-related variables that also impact monthly water consumption, such as precipitation and temperature, we found no statistically significant time-dependent trends in Seasonality across all three clusters. Therefore, we assume that the Seasonality pattern associated with each cluster extends to the current-day period without change. For GPCD, we similarly accounted for monthly weather-related variables to estimated “weather-normalized” GPCDs for the historical data period and found distinct time-dependent trends in GPCD for each cluster. The “weather-normalized” GPCD represents the hypothetical annual average GPCD for a utility if the weather for that year reflected average values from the historical record. While this approach is suitable for extending water demand trends over a relatively short period, it does not account for changes in water use behavior that could occur due to the impacts of climate change over longer horizons.

The resulting cluster assignments for each parameter were then inspected to ensure that water providers were grouped appropriately and represented distinct Seasonality patterns and GPCD magnitudes. These groupings are illustrated in Figure A2 and Figure A3, showing both the estimated centroid of each cluster and calculated values of the respective clustering parameters for water providers within that cluster. The corresponding monthly average water use, disaggregated by seasonality cluster and GPCD cluster assignments, are also illustrated in Figure A4 and Figure A5 for the Residential and CII sectors respectively. Finally, the results of the Seasonality and GPCD trend analysis are shown in Figure A6 and Figure A7, showing historical cluster-level Seasonality and GPCD as well as projected GPCDs through calendar year 2023, by sector.

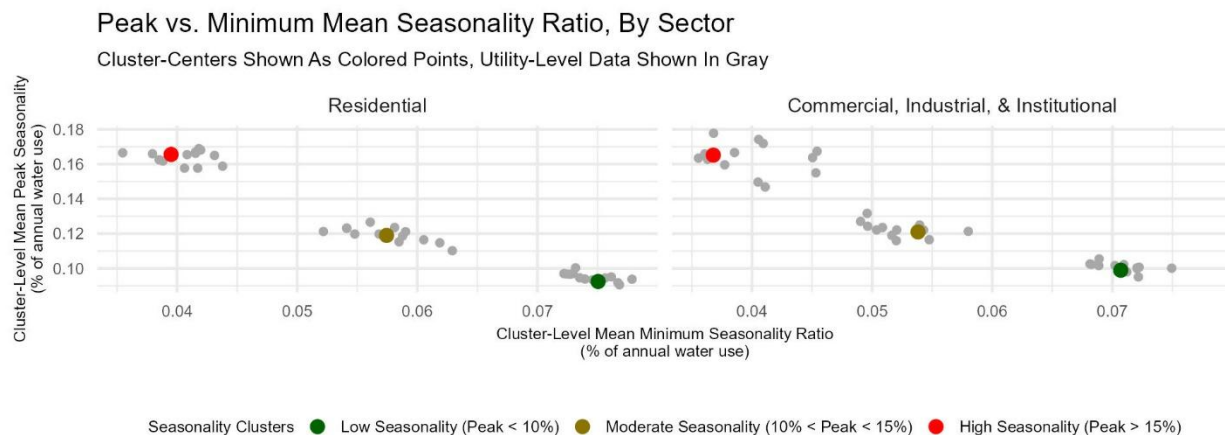


Figure A2. Residential and CII Seasonality Clustering Results Showing Cluster Centers (Colored Points) and Corresponding Utility-Level Data (Gray Points).

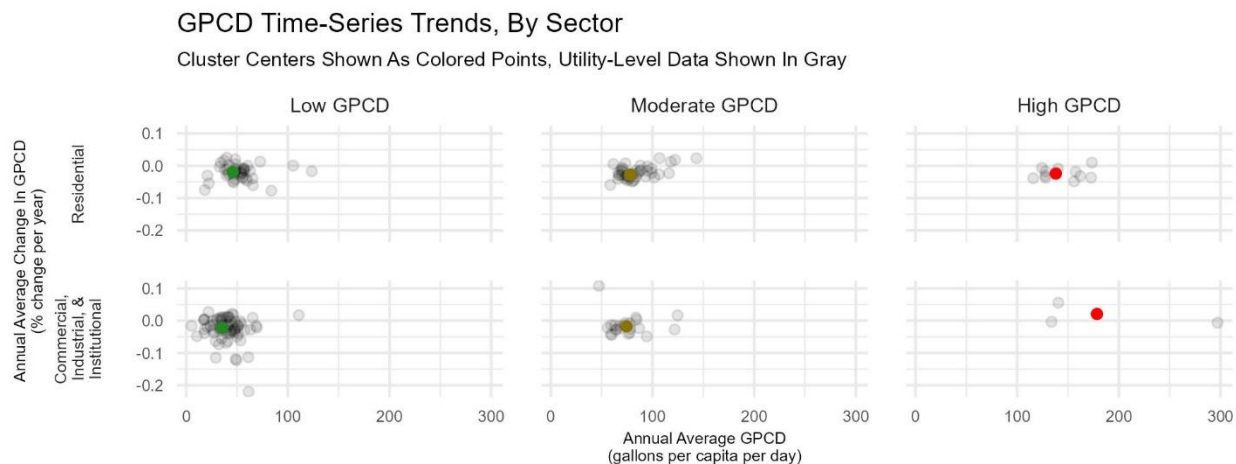


Figure A3. Residential and CII GPCD Clustering Results Showing Cluster Centers (Colored Points) and Corresponding Utility-Level Data (Gray Points).

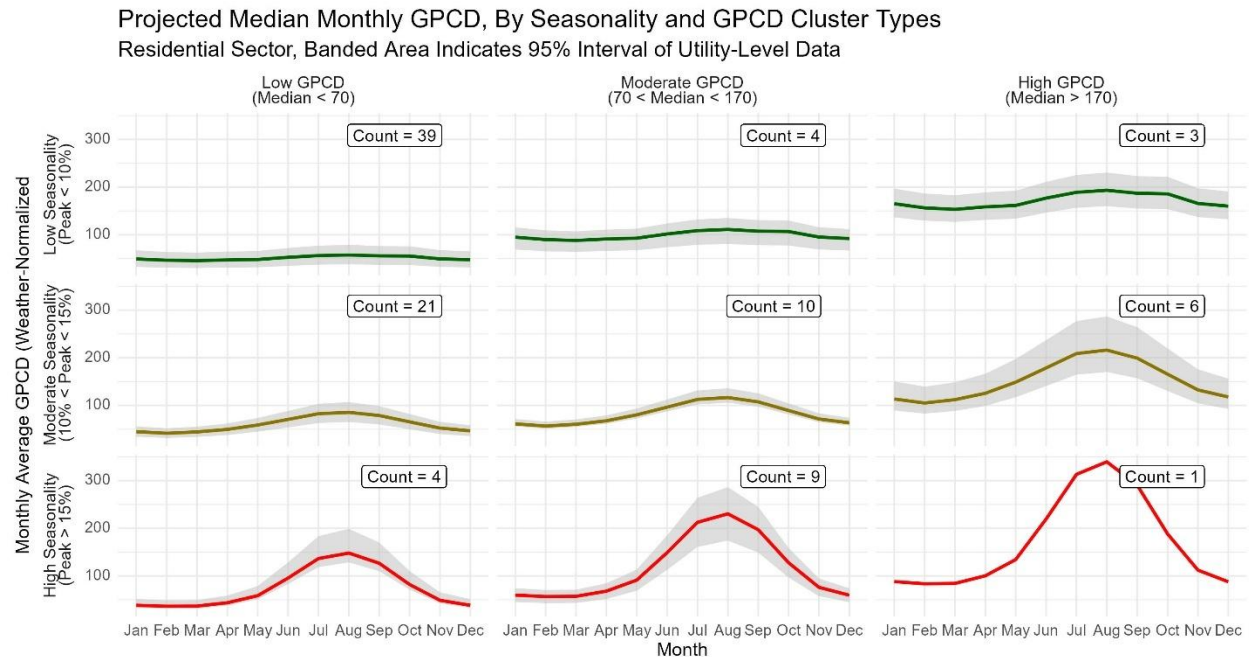


Figure A4. Average Monthly Residential GPCD for Billing Dataset Utilities, By Seasonality Cluster and GPCD Cluster.

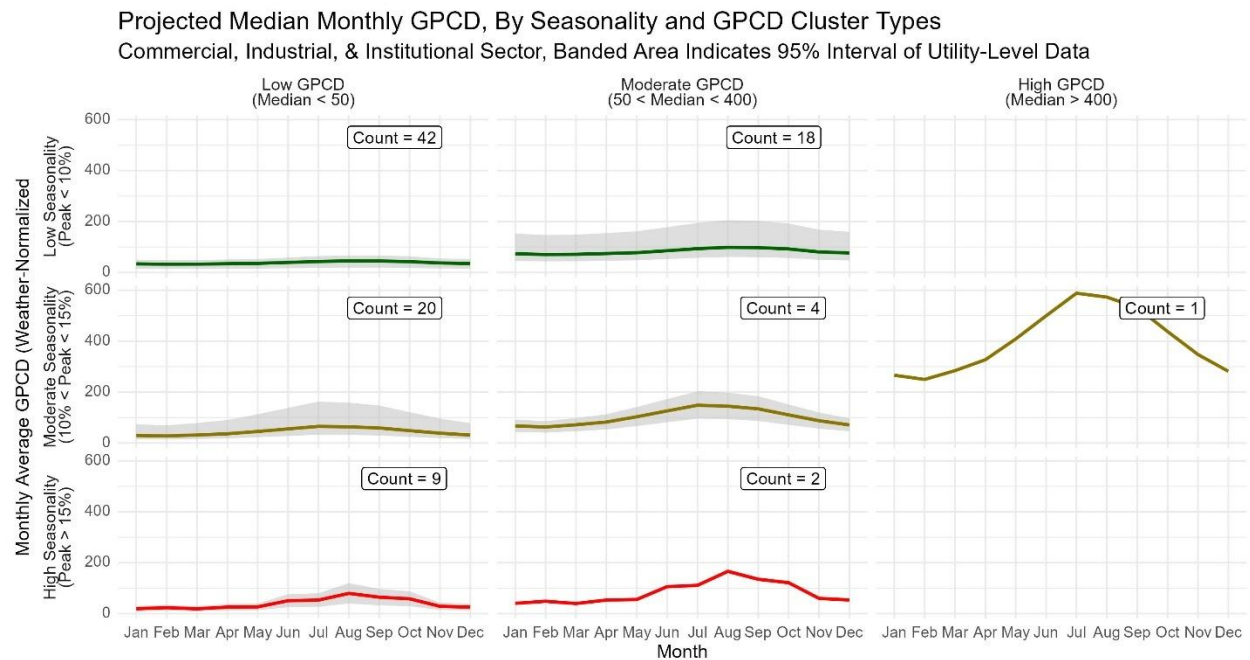


Figure A5. Average Monthly CII GPCD for Billing Dataset Utilities, By Seasonality Cluster and GPCD Cluster.

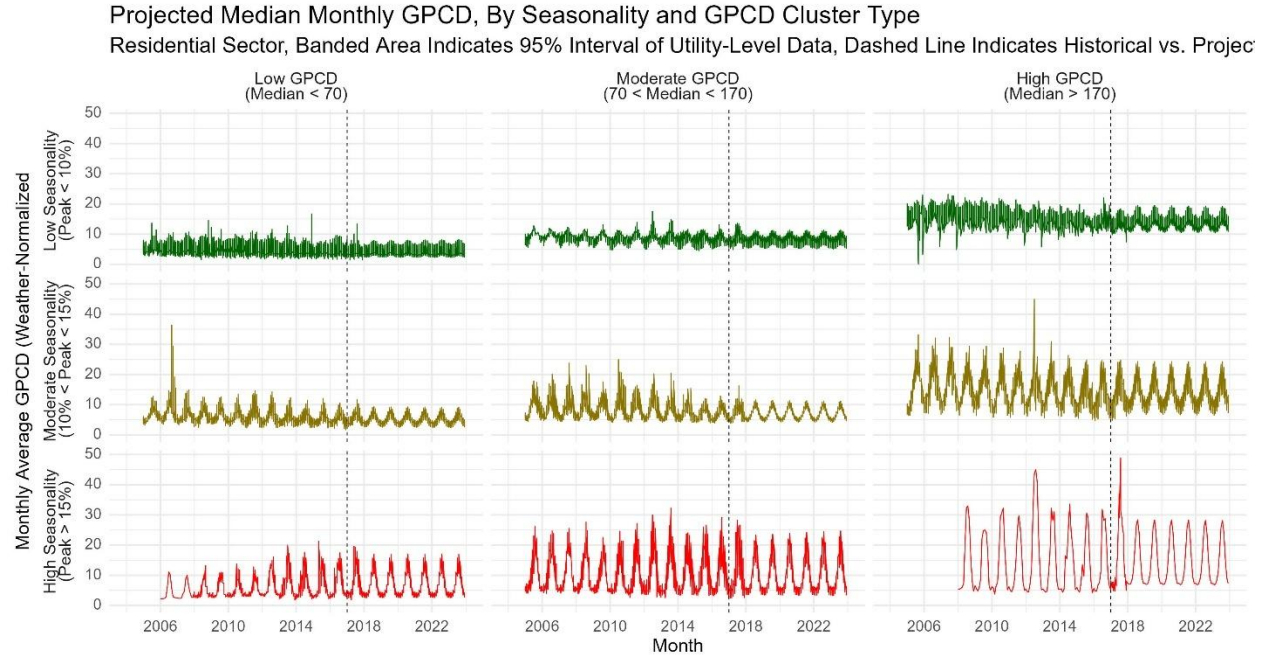


Figure A6. Historical Average (2005 - 2017) and Projected (2018 - 2023) Monthly Residential GPCD for Billing Dataset Utilities, By Seasonality Cluster and GPCD Cluster.

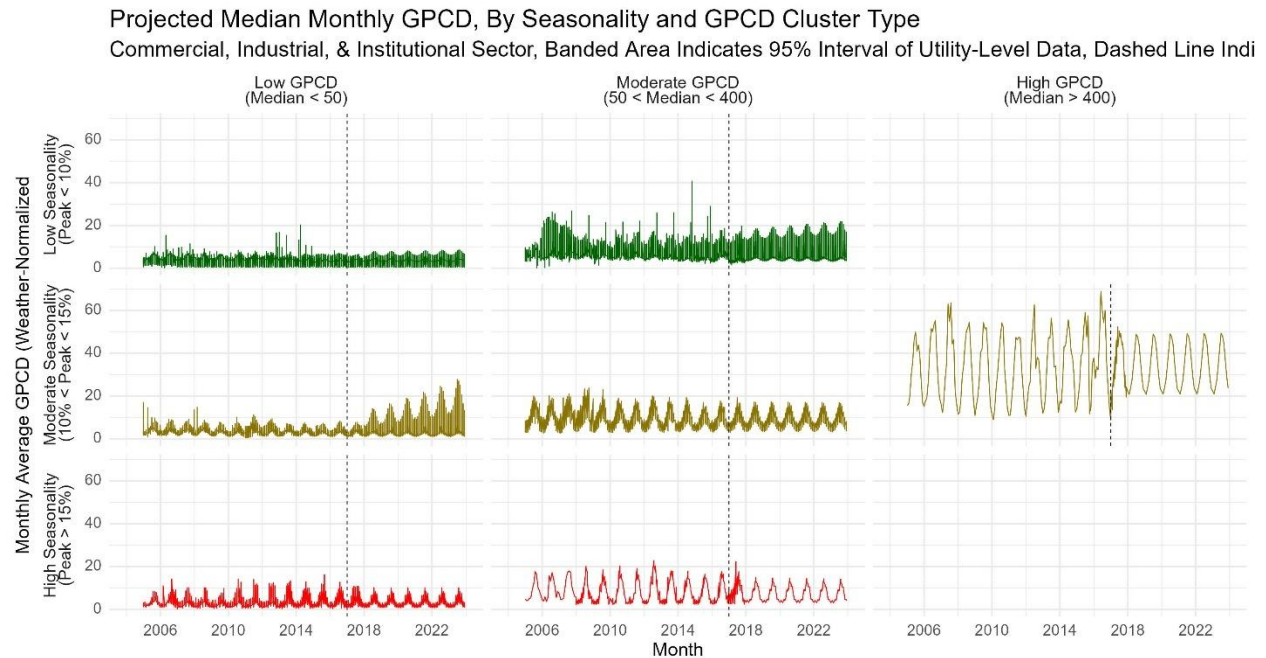


Figure A7. Historical Average (2005 - 2017) and Projected (2018 - 2023) Monthly CII GPCD for Billing Dataset Utilities, By Seasonality Cluster and GPCD Cluster.

For the GPCD analysis, which required monthly data for weather input variables, we assigned each utility to its US Climate Division as defined by the National Oceanic and Atmospheric Administration's National Center for Environmental Information based on location and obtained the corresponding monthly weather input data (Vose et al. 2014).

For GPCD projections, we used the historical average monthly value, over the available period of record, for each weather input variable to represent average weather conditions for projection years and used the average of projected GPCD values for calendar years 2022 and 2023 as the current-day period for this study.

Sector-Specific Analyses

Residential Demand Disaggregation and Seasonal Adjustment

The total water demands in the Residential sector were further disaggregated into indoor and outdoor water demand, as well as to the end use-level for the indoor water demand component. The most common method for disaggregating indoor and outdoor water demand, in the absence of direct data for each component, is to apply the “minimum month” method (MMM). This method assumes that all residential water demand during winter months, typically defined as December through February, is indoor water demand that is relatively consistent throughout the year. Therefore, any surplus water demand beyond this winter month average is considered as outdoor water demand, typically for landscape irrigation. This method is appropriate for areas where winter-time outdoor water demands are almost non-existent but is likely to overestimate the indoor component of water demand in areas landscape irrigation during winter months is more prevalent, such as in southern parts of the United States. The “seasonal adjustment” method (SAM) can be used to account for this geographic trend, by adjusting MMM-derived indoor water use estimates downward using direct data for winter-time outdoor water demands.

For this analysis, we made use of the indoor, outdoor, and total water demand summary statistics from the Flume dataset to compare MMM-derived indoor water demand estimates from the Billing dataset to indoor demands from the Flume datasets for water providers located within one of the CBSAs represented in the Flume dataset. In almost all cases, MMM-derived indoor gpcd estimates were larger than their corresponding Flume dataset indoor gpcd values (Figure A8). To perform the seasonal adjustment for these areas, we calculated the difference in mean monthly indoor water demands between each utility and their corresponding Flume CBSA and re-apportion that difference to outdoor water use across all months. From this process, the largest seasonal adjustments were made to areas classified as “Low” and “Moderate” seasonality, with smaller adjustments observed for “High” seasonality areas and areas where no outdoor water use was reported in the Flume dataset.

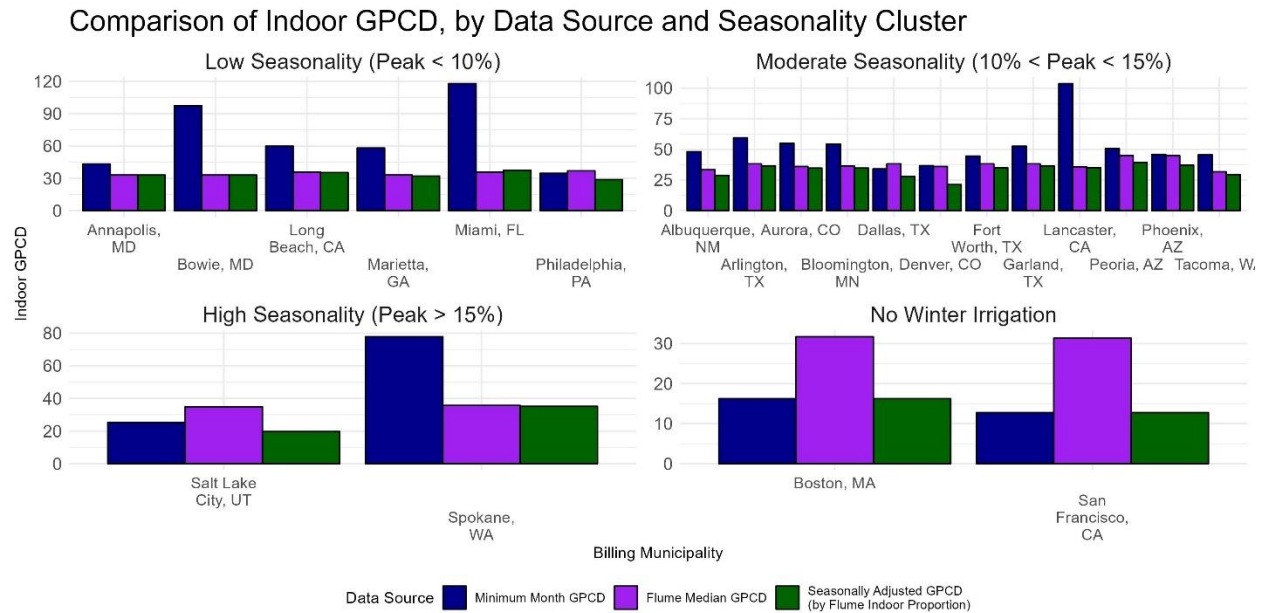


Figure A8. Comparison of Average Monthly Residential Indoor GPCD for Areas Represented by Billing and Flume Dataset, By Estimation Method.

Note: Blue - Minimum Month Method Applied to Billing Dataset-Derived Indoor GPCD, Magenta - Median Flume Dataset-Derived Indoor GPCD, Green - Billing Dataset-Derived Total GPCD Multiplied by Median Proportion of Flume-Derived Indoor Water Use.

CII Subsector Disaggregation

The CII sector has not seen the same level of investigation as the Residential sector, in terms of systematic and comprehensive analyses to understand the primary drivers of water use and types of end-uses represented within non-residential buildings. Instead, CII water efficiency literature has historically focused on building-level audits of water use and utility-level, or sometimes state-level, taxonomies of CII building types for aggregate analysis (Brendle Group 2007; Fedak et al. 2019; Hoffman 2016; 2018; 2019; Kiefer et al. 2015; Morales et al. 2010; 2011). For this study, which required a national-scale approach, we leveraged the existing literature with a dataset of summary statistics of water use intensity (WUI) metrics collected from the ENERGY STAR® Portfolio Manager® tool and developed by the US EPA's WaterSense® program (US EPA 2023). This dataset, referred to as the "WUI dataset" in this report, contains state-level 25th percentile, median, and 75th percentile values for building area-normalized annual water use, in gallons per square foot of conditioned floor area per year, and provides a metric for CII water use using the total floor space dedicated to one of twelve non-residential building categories: College/University, K-12 School, Hospital, Hotel, Office, Medical Office, Fire Station, Retail Store, Non-Refrigerated Warehouse, Multi-Family, Senior Living Community, and Supermarket.

The WUI dataset is a self-selected sample, generally representing CII buildings that are either already taking steps to improve their water use efficiency (or at least better track

water use) or are required to submit water use data as part of a regulatory program such as the City of Boston’s Building Emissions Reporting and Disclosure Ordinance (City of Boston 2023) and the City of Atlanta’s Commercial Buildings Energy Efficiency Ordinance (City of Atlanta 2015). Therefore, we also surveyed the existing literature to develop similar WUI summary statistics of WUI to for comparison. In most cases, the literature-derived median WUI was higher than the median values reported in the WUI dataset, suggesting that the WUI dataset may not be representative of CII buildings at a national-level (Figure A9). To account for this discrepancy, we used the literature-derived WUI values as the starting point for disaggregating the total CII water use estimates developed for this study into subsector-level WUI estimates.

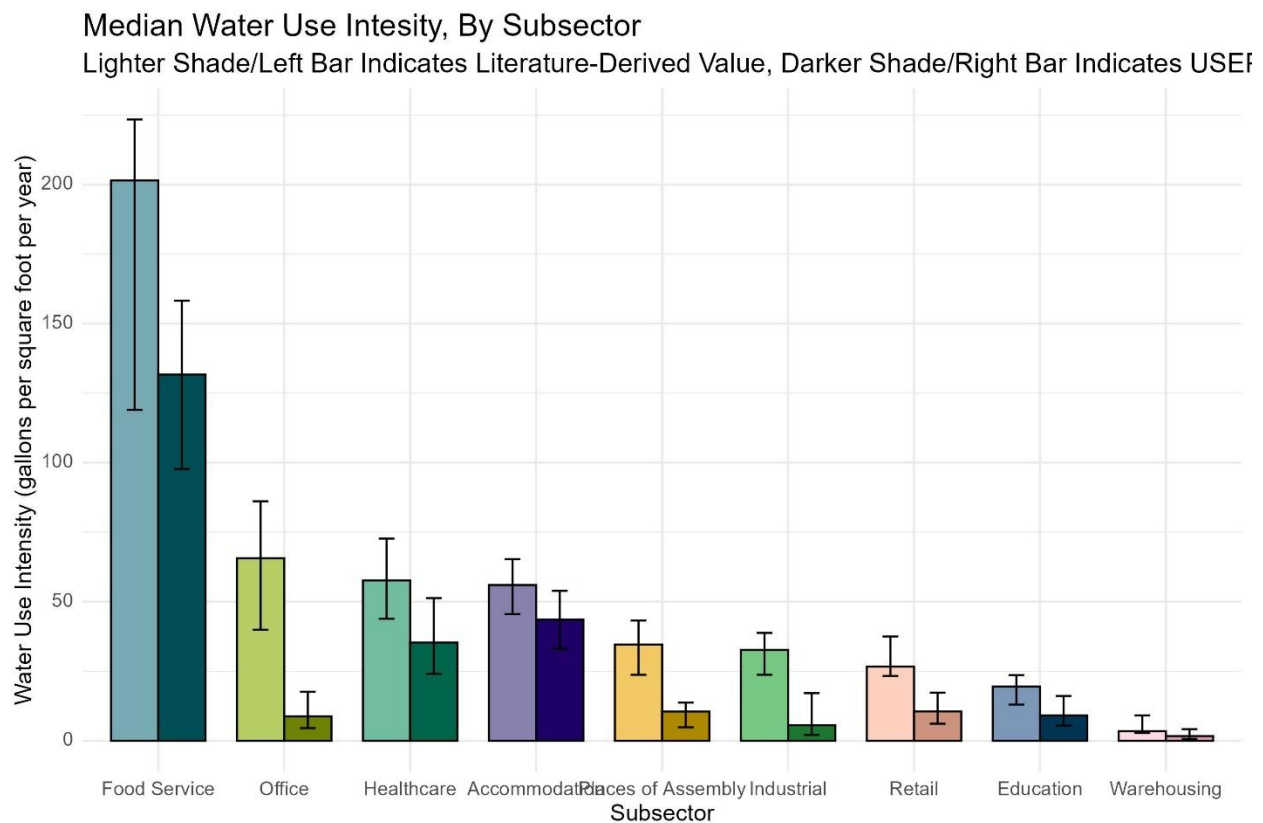


Figure A9. Comparison of Literature-Derived and US EPA-Derived Estimates of Median CII Water Use Intensity, By Subsector.

Note: Bars are grouped and color-coded by CII Subsector, with lighter shade indicated literature-derived values and darker shades indicating US EPA-derived values via ENERGYSTAR Portfolio Manager Tool. Error bars indicate inter-quartile range of values (25th percentile to 75th percentile).

From this starting point, we leveraged multiple datasets which included data for total employment for each of the water providers represented in the Billing Dataset and applied area-normalized estimates of employment occupancy (in employee per 1,000 square feet of conditioned floor area), to develop utility-level WUI estimates for the years represented

in the Billing Dataset, following the process illustrated in Figure A10. We obtained estimates of total employment, categorized by industry type via North American Industry Classification System (NAICS) 3-digit code, from the US Economic Census for years 2002, 2007, 2012, and 2017 (U.S. Census Bureau 2003; 2008; 2013; 2018). For each NAICS code, a numeric designation of industry type with increasing specificity based on the number of digits ranging from 2-8, we assigned a single CII subsector that best captures the types of water use within that industry. We estimated average rates of employment occupancy at the Census Division-scale using reported employment and total conditioned area data collected from the 2018 Commercial Building Energy Consumption Survey (CBECS) conducted by the US Energy Information Administration, which is a national sample survey that collects information on the stock of US commercial buildings categorized by Primary Building Activity (PBA). Each PBA category was also assigned a single CII subsector that best captures the types of water use within that PBA. A complete listing of NAICS 3-digits codes and PBAs used in this analysis and mapped to their respective CII subsectors is available in Table A4.

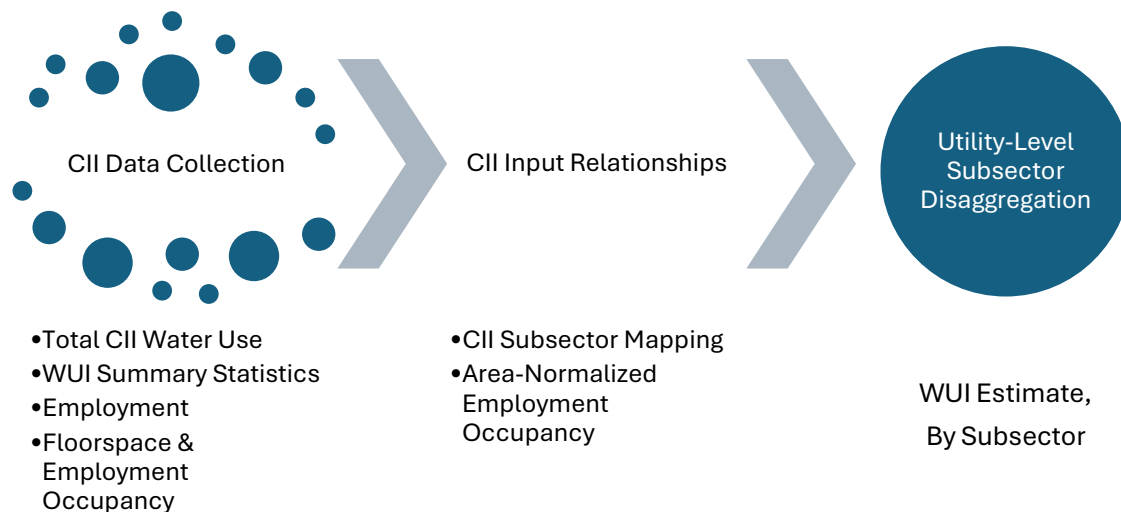


Figure A10. Conceptual Diagram for Disaggregation of Baseline CII Water Use Estimates into Subsectors-Level Estimates.

Using this CII Subsector-NAICS3-CBECS PBA mapping, we also estimated the average ratio of employment occupancy to conditioned floor area and multiplied this ratio by total employment to estimate total conditioned floor area for each CII subsector in each utility's service area. We then apportioned total CII water use for each utility into each CII subsector, assuming subsector-level water use followed the same relative proportion (as a percentage) of subsector-level employment at the utility-level and divided the apportioned annual water use volume by the estimated floor area to develop utility-specific WUI estimates, by CII subsector. As a final adjustment, we then applied a scaling factor to all subsector-level WUIs to ensure that the sum of subsector-level water use estimates matched the total projected current-day water demand for each geography.

Table A4. CII Subsector Assignment Key for NAICS 3-Digit Code, CBECS Principal Building Activity, ENERGYSTAR Portfolio Manager Property Type, and Literature Review-Derived CII Subsectors.

CII Data Source	Subsector Identifier	Subsector Assignment
NAICS 3-Digit Code	111 - Crop Production	Other
NAICS 3-Digit Code	112 - Animal Production	Other
NAICS 3-Digit Code	113 - Forestry and Logging	Other
NAICS 3-Digit Code	114 - Fishing, Hunting and Trapping	Other
NAICS 3-Digit Code	115 - Support Activities for Agriculture and Forestry	Office
NAICS 3-Digit Code	211 - Oil and Gas Extraction	Other
NAICS 3-Digit Code	212 - Mining (except Oil and Gas)	Other
NAICS 3-Digit Code	213 - Support Activities for Mining	Office
NAICS 3-Digit Code	221 - Utilities	Other
NAICS 3-Digit Code	236 - Construction of Buildings	Office
NAICS 3-Digit Code	237 - Heavy and Civil Engineering Construction	Other
NAICS 3-Digit Code	238 - Specialty Trade Contractors	Office
NAICS 3-Digit Code	311 - Food Manufacturing	Industrial
NAICS 3-Digit Code	312 - Beverage and Tobacco Product Manufacturing	Industrial
NAICS 3-Digit Code	313 - Textile Mills	Industrial
NAICS 3-Digit Code	314 - Textile Product Mills	Industrial
NAICS 3-Digit Code	315 - Apparel Manufacturing	Industrial
NAICS 3-Digit Code	316 - Leather and Allied Product Manufacturing	Industrial
NAICS 3-Digit Code	321 - Wood Product Manufacturing	Industrial
NAICS 3-Digit Code	322 - Paper Manufacturing	Industrial
NAICS 3-Digit Code	323 - Printing and Related Support Activities	Office
NAICS 3-Digit Code	324 - Petroleum and Coal Products Manufacturing	Industrial
NAICS 3-Digit Code	325 - Chemical Manufacturing	Industrial
NAICS 3-Digit Code	326 - Plastics and Rubber Products Manufacturing	Industrial
NAICS 3-Digit Code	327 - Nonmetallic Mineral Product Manufacturing	Industrial
NAICS 3-Digit Code	331 - Primary Metal Manufacturing	Industrial
NAICS 3-Digit Code	332 - Fabricated Metal Product Manufacturing	Industrial
NAICS 3-Digit Code	333 - Machinery Manufacturing	Industrial
NAICS 3-Digit Code	334 - Computer and Electronic Product Manufacturing	Industrial
NAICS 3-Digit Code	335 - Electrical Equipment, Appliance, and Component Manufacturing	Industrial
NAICS 3-Digit Code	336 - Transportation Equipment Manufacturing	Industrial

CII Data Source	Subsector Identifier	Subsector Assignment
NAICS 3-Digit Code	337 - Furniture and Related Product Manufacturing	Industrial
NAICS 3-Digit Code	339 - Miscellaneous Manufacturing	Industrial
NAICS 3-Digit Code	423 - Merchant Wholesalers, Durable Goods	Warehousing
NAICS 3-Digit Code	424 - Merchant Wholesalers, Nondurable Goods	Warehousing
NAICS 3-Digit Code	425 - Wholesale Electronic Markets and Agents and Brokers	Warehousing
NAICS 3-Digit Code	441 - Motor Vehicle and Parts Dealers	Retail
NAICS 3-Digit Code	442 - Furniture and Home Furnishings Stores	Retail
NAICS 3-Digit Code	443 - Electronics and Appliance Stores	Retail
NAICS 3-Digit Code	444 - Building Material and Garden Equipment and Supplies Dealers	Retail
NAICS 3-Digit Code	445 - Food and Beverage Stores	Retail
NAICS 3-Digit Code	446 - Health and Personal Care Stores	Retail
NAICS 3-Digit Code	447 - Gasoline Stations	Retail
NAICS 3-Digit Code	448 - Clothing and Clothing Accessories Stores	Retail
NAICS 3-Digit Code	451 - Sporting Goods, Hobby, Book, and Music Stores	Retail
NAICS 3-Digit Code	452 - General Merchandise Stores	Retail
NAICS 3-Digit Code	453 - Miscellaneous Store Retailers	Retail
NAICS 3-Digit Code	454 - Nonstore Retailers	Retail
NAICS 3-Digit Code	481 - Air Transportation	Other
NAICS 3-Digit Code	482 - Rail Transportation	Other
NAICS 3-Digit Code	483 - Water Transportation	Other
NAICS 3-Digit Code	484 - Truck Transportation	Other
NAICS 3-Digit Code	485 - Transit and Ground Passenger Transportation	Other
NAICS 3-Digit Code	486 - Pipeline Transportation	Other
NAICS 3-Digit Code	487 - Scenic and Sightseeing Transportation	Other
NAICS 3-Digit Code	488 - Support Activities for Transportation	Other
NAICS 3-Digit Code	491 - Postal Service	Retail
NAICS 3-Digit Code	492 - Couriers and Messengers	Retail
NAICS 3-Digit Code	493 - Warehousing and Storage	Warehousing
NAICS 3-Digit Code	511 - Publishing Industries (except Internet)	Office
NAICS 3-Digit Code	512 - Motion Picture and Sound Recording Industries	Office
NAICS 3-Digit Code	515 - Broadcasting (except Internet)	Office
NAICS 3-Digit Code	516 - Internet Publishing and Broadcasting	Office
NAICS 3-Digit Code	517 - Telecommunications	Office

CII Data Source	Subsector Identifier	Subsector Assignment
NAICS 3-Digit Code	518 - Internet Service Providers, Web Search Portals, and Data Processing Services	Office
NAICS 3-Digit Code	519 - Other Information Services	Office
NAICS 3-Digit Code	521 - Monetary Authorities - Central Bank	Office
NAICS 3-Digit Code	522 - Credit Intermediation and Related Activities	Office
NAICS 3-Digit Code	523 - Securities, Commodity Contracts, and Other Financial Investments and Related Activities	Office
NAICS 3-Digit Code	524 - Insurance Carriers and Related Activities	Office
NAICS 3-Digit Code	525 - Funds, Trusts, and Other Financial Vehicles	Office
NAICS 3-Digit Code	531 - Real Estate	Office
NAICS 3-Digit Code	532 - Rental and Leasing Services	Office
NAICS 3-Digit Code	533 - Lessors of Nonfinancial Intangible Assets (except Copyrighted Works)	Office
NAICS 3-Digit Code	541 - Professional, Scientific, and Technical Services	Office
NAICS 3-Digit Code	551 - Management of Companies and Enterprises	Office
NAICS 3-Digit Code	561 - Administrative and Support Services	Office
NAICS 3-Digit Code	562 - Waste Management and Remediation Services	Office
NAICS 3-Digit Code	611 - Educational Services	Education
NAICS 3-Digit Code	621 - Ambulatory Health Care Services	Healthcare
NAICS 3-Digit Code	622 - Hospitals	Healthcare
NAICS 3-Digit Code	623 - Nursing and Residential Care Facilities	Healthcare
NAICS 3-Digit Code	624 - Social Assistance	Healthcare
NAICS 3-Digit Code	711 - Performing Arts, Spectator Sports, and Related Industries	Places of Assembly
NAICS 3-Digit Code	712 - Museums, Historical Sites, and Similar Institutions	Places of Assembly
NAICS 3-Digit Code	713 - Amusement, Gambling, and Recreation Industries	Places of Assembly
NAICS 3-Digit Code	721 - Accommodation	Accommodation
NAICS 3-Digit Code	722 - Food Services and Drinking Places	Food Service
NAICS 3-Digit Code	811 - Repair and Maintenance	Retail
NAICS 3-Digit Code	812 - Personal and Laundry Services	Retail
NAICS 3-Digit Code	813 - Religious, Grantmaking, Civic, Professional, and Similar Organizations	Office
NAICS 3-Digit Code	814 - Private Households	Other
NAICS 3-Digit Code	921 - Executive, Legislative, and Other General Government Support	Office
NAICS 3-Digit Code	922 - Justice, Public Order, and Safety Activities	Office

CII Data Source	Subsector Identifier	Subsector Assignment
NAICS 3-Digit Code	923 - Administration of Human Resource Programs	Office
NAICS 3-Digit Code	924 - Administration of Environmental Quality Programs	Office
NAICS 3-Digit Code	925 - Administration of Housing Programs, Urban Planning, and Community Development	Office
NAICS 3-Digit Code	926 - Administration of Economic Programs	Office
NAICS 3-Digit Code	927 - Space Research and Technology	Office
NAICS 3-Digit Code	928 - National Security and International Affairs	Office
CBECS Principal Building Activity	1 - Vacant	Other
CBECS Principal Building Activity	2 - Office	Office
CBECS Principal Building Activity	4 - Laboratory	Office
CBECS Principal Building Activity	5 - Nonrefrigerated warehouse	Warehousing
CBECS Principal Building Activity	6 - Food sales	Retail
CBECS Principal Building Activity	7 - Public order and safety	Office
CBECS Principal Building Activity	8 - Outpatient health care	Healthcare
CBECS Principal Building Activity	11 - Refrigerated warehouse	Warehousing
CBECS Principal Building Activity	12 - Religious worship	Places of Assembly
CBECS Principal Building Activity	13 - Public assembly	Places of Assembly
CBECS Principal Building Activity	14 - Education	Education
CBECS Principal Building Activity	15 - Food service	Food Service
CBECS Principal Building Activity	16 - Inpatient health care	Healthcare
CBECS Principal Building Activity	17 - Nursing	Healthcare
CBECS Principal Building Activity	18 - Lodging	Accommodation
CBECS Principal Building Activity	23 - Strip shopping center	Retail

CII Data Source	Subsector Identifier	Subsector Assignment
CBECS Principal Building Activity	24 - Enclosed mall	Retail
CBECS Principal Building Activity	25 - Retail other than mall	Retail
CBECS Principal Building Activity	26 - Service	Office
CBECS Principal Building Activity	91 - Other	Other
CBECS Principal Building Activity	1 - Vacant	Other
CBECS Principal Building Activity	2 - Administrative/professional office	Office
CBECS Principal Building Activity	3 - Bank/other financial	Office
CBECS Principal Building Activity	4 - Government office	Office
CBECS Principal Building Activity	5 - Medical office (non-diagnostic)	Office
CBECS Principal Building Activity	6 - Mixed-use office	Office
CBECS Principal Building Activity	7 - Other office	Office
CBECS Principal Building Activity	8 - Laboratory	Office
CBECS Principal Building Activity	9 - Distribution/shipping center	Warehousing
CBECS Principal Building Activity	10 - Non-refrigerated warehouse	Warehousing
CBECS Principal Building Activity	11 - Public rental storage units	Warehousing
CBECS Principal Building Activity	12 - Convenience store (w/ or w/out gas station)	Retail
CBECS Principal Building Activity	14 - Grocery store/food market	Retail
CBECS Principal Building Activity	15 - Other food sales	Retail
CBECS Principal Building Activity	16 - Fire station/police station	Office
CBECS Principal Building Activity	17 - Other public order and safety	Office

CII Data Source	Subsector Identifier	Subsector Assignment
CBECS Principal Building Activity	18 - Medical office (diagnostic)	Healthcare
CBECS Principal Building Activity	19 - Clinic/other outpatient health	Healthcare
CBECS Principal Building Activity	20 - Refrigerated warehouse	Warehousing
CBECS Principal Building Activity	21 - Religious worship	Places of Assembly
CBECS Principal Building Activity	22 - Entertainment/culture	Places of Assembly
CBECS Principal Building Activity	23 - Library	Places of Assembly
CBECS Principal Building Activity	24 - Recreation	Places of Assembly
CBECS Principal Building Activity	25 - Social/meeting	Places of Assembly
CBECS Principal Building Activity	26 - Other public assembly	Places of Assembly
CBECS Principal Building Activity	27 - College/university	Education
CBECS Principal Building Activity	28 - Elementary school	Education
CBECS Principal Building Activity	29 - High school	Education
CBECS Principal Building Activity	30 - Preschool/daycare	Education
CBECS Principal Building Activity	31 - Other classroom education	Education
CBECS Principal Building Activity	32 - Fast food	Food Service
CBECS Principal Building Activity	33 - Restaurant/cafeteria	Food Service
CBECS Principal Building Activity	34 - Other food service	Food Service
CBECS Principal Building Activity	35 - Hospital/inpatient health	Healthcare
CBECS Principal Building Activity	36 - Nursing home/assisted living	Healthcare
CBECS Principal Building Activity	37 - Dormitory/fraternity/sorority	Accommodation

CII Data Source	Subsector Identifier	Subsector Assignment
CBECS Principal Building Activity	38 - Hotel/resort	Accommodation
CBECS Principal Building Activity	39 - Motel/inn/bed and breakfast	Accommodation
CBECS Principal Building Activity	40 - Other lodging	Accommodation
CBECS Principal Building Activity	42 - Retail store	Retail
CBECS Principal Building Activity	43 - Other retail	Retail
CBECS Principal Building Activity	44 - Post office/postal center	Retail
CBECS Principal Building Activity	46 - Vehicle service/repair shop	Retail
CBECS Principal Building Activity	47 - Vehicle storage/maintenance	Warehousing
CBECS Principal Building Activity	48 - Other service	Retail
CBECS Principal Building Activity	49 - Other	Other
CBECS Principal Building Activity	50 - Strip shopping mall	Retail
CBECS Principal Building Activity	51 - Enclosed mall	Retail
CBECS Principal Building Activity	52 - Courthouse/probation office	Office
CBECS Principal Building Activity	54 - Middle/junior high school	Education
CBECS Principal Building Activity	55 - Multi-grade school (any K-12)	Education
ENERGYSTAR Property Type	Bank Branch	Office
ENERGYSTAR Property Type	Financial Office	Office
ENERGYSTAR Property Type	Adult Education	Education
ENERGYSTAR Property Type	College/University	Education
ENERGYSTAR Property Type	K-12 School	Education

CII Data Source	Subsector Identifier	Subsector Assignment
ENERGYSTAR Property Type	Other - Education	Education
ENERGYSTAR Property Type	Pre-school/Daycare	Education
ENERGYSTAR Property Type	Vocational School	Education
ENERGYSTAR Property Type	Bar/Nightclub	Food Service
ENERGYSTAR Property Type	Aquarium	Other
ENERGYSTAR Property Type	Fitness Center/Health Club/Gym	Other
ENERGYSTAR Property Type	Swimming Pool	Other
ENERGYSTAR Property Type	Zoo	Other
ENERGYSTAR Property Type	Bowling Alley	Places of Assembly
ENERGYSTAR Property Type	Casino	Places of Assembly
ENERGYSTAR Property Type	Convention Center	Places of Assembly
ENERGYSTAR Property Type	Ice/Curling Rink	Places of Assembly
ENERGYSTAR Property Type	Indoor Arena	Places of Assembly
ENERGYSTAR Property Type	Movie Theater	Places of Assembly
ENERGYSTAR Property Type	Museum	Places of Assembly
ENERGYSTAR Property Type	Other - Entertainment/Public Assembly	Places of Assembly
ENERGYSTAR Property Type	Other - Recreation	Places of Assembly
ENERGYSTAR Property Type	Other - Stadium	Places of Assembly
ENERGYSTAR Property Type	Performing Arts	Places of Assembly
ENERGYSTAR Property Type	Race Track	Places of Assembly

CII Data Source	Subsector Identifier	Subsector Assignment
ENERGYSTAR Property Type	Social/Meeting Hall	Places of Assembly
ENERGYSTAR Property Type	Stadium (Closed)	Places of Assembly
ENERGYSTAR Property Type	Stadium (Open)	Places of Assembly
ENERGYSTAR Property Type	Fast Food Restaurant	Food Service
ENERGYSTAR Property Type	Food Sales	Food Service
ENERGYSTAR Property Type	Food Service	Food Service
ENERGYSTAR Property Type	Other - Restaurant/Bar	Food Service
ENERGYSTAR Property Type	Restaurant	Food Service
ENERGYSTAR Property Type	Supermarket/Grocery Store	Retail
ENERGYSTAR Property Type	Ambulatory Surgical Center	Healthcare
ENERGYSTAR Property Type	Hospital (General Medical & Surgical)	Healthcare
ENERGYSTAR Property Type	Medical Office	Healthcare
ENERGYSTAR Property Type	Other - Specialty Hospital	Healthcare
ENERGYSTAR Property Type	Outpatient Rehabilitation/Physical Therapy	Healthcare
ENERGYSTAR Property Type	Residential Care Facility	Healthcare
ENERGYSTAR Property Type	Senior Living Community	Healthcare
ENERGYSTAR Property Type	Urgent Care/Clinic/Other Outpatient	Healthcare
ENERGYSTAR Property Type	Barracks	Accommodation
ENERGYSTAR Property Type	Hotel	Accommodation
ENERGYSTAR Property Type	Other - Lodging/Residential	Accommodation

CII Data Source	Subsector Identifier	Subsector Assignment
ENERGYSTAR Property Type	Residence Hall/Dormitory	Accommodation
ENERGYSTAR Property Type	Manufacturing/Industrial Plant	Industrial
ENERGYSTAR Property Type	Office	Office
ENERGYSTAR Property Type	Veterinary Office	Office
ENERGYSTAR Property Type	Other	Other
ENERGYSTAR Property Type	Fire Station	Other
ENERGYSTAR Property Type	Prison/Incarceration	Other
ENERGYSTAR Property Type	Other - Public Service	Office
ENERGYSTAR Property Type	Police Station	Office
ENERGYSTAR Property Type	Courthouse	Places of Assembly
ENERGYSTAR Property Type	Library	Places of Assembly
ENERGYSTAR Property Type	Transportation Terminal/Station	Places of Assembly
ENERGYSTAR Property Type	Mailing Center/Post Office	Retail
ENERGYSTAR Property Type	Worship Facility	Places of Assembly
ENERGYSTAR Property Type	Vehicle Dealership	Other
ENERGYSTAR Property Type	Convenience Store with Gas Station	Retail
ENERGYSTAR Property Type	Convenience Store without Gas Station	Retail
ENERGYSTAR Property Type	Enclosed Mall	Retail
ENERGYSTAR Property Type	Lifestyle Center	Retail
ENERGYSTAR Property Type	Other - Retail/Mall	Retail

CII Data Source	Subsector Identifier	Subsector Assignment
ENERGYSTAR Property Type	Retail Store	Retail
ENERGYSTAR Property Type	Strip Mall	Retail
ENERGYSTAR Property Type	Wholesale Club/Supercenter	Retail
ENERGYSTAR Property Type	Other - Services	Other
ENERGYSTAR Property Type	Data Center	Other
ENERGYSTAR Property Type	Laboratory	Other
ENERGYSTAR Property Type	Other - Technology/Science	Other
ENERGYSTAR Property Type	Other - Utility	Other
ENERGYSTAR Property Type	Distribution Center	Warehousing
ENERGYSTAR Property Type	Non-Refrigerated Warehouse	Warehousing
ENERGYSTAR Property Type	Refrigerated Warehouse	Warehousing
ENERGYSTAR Property Type	Self-Storage Facility	Warehousing
Literature Review Subsector	Restaurants	Food Service
Literature Review Subsector	Senior Care Facility	Healthcare
Literature Review Subsector	Hotels	Accommodation
Literature Review Subsector	Hospitals	Healthcare
Literature Review Subsector	Grocery/Supermarkets	Retail
Literature Review Subsector	Medical Office	Healthcare
Literature Review Subsector	Offices	Office
Literature Review Subsector	Banking/Financial	Office

CII Data Source	Subsector Identifier	Subsector Assignment
Literature Review Subsector	Courthouse	Places of Assembly
Literature Review Subsector	K-12 Schools	Education
Literature Review Subsector	Houses of Worship	Places of Assembly
Literature Review Subsector	Retail/Shopping Centers	Retail
Literature Review Subsector	Unrefrigerated Warehouses	Warehousing
Literature Review Subsector	Manufacturing/Industrial	Industrial
Literature Review Subsector	Colleges/Universities	Education
Literature Review Subsector	Residence Halls/Dormitories	Accommodation

Utility Water Losses

Non-revenue water, also known as “water loss” or “utility-side leaks” represents the volume of water that is treated for potable consumption and delivered to a utility’s water distribution system but is not accounted for in metered water use or delivered to an unmetered customer (AWWA 2016). Non-revenue water is typically comprised of three component: 1) Real Losses, or the physical volume of water that enters the distribution system but is lost before reaching a customer due to infrastructure defects and failure; 2) Apparent Losses, or “virtual” volumes of water that represent inaccuracies/errors in meter data acquisition, meter measurements, unbilled consumption, and unauthorized consumption; and 3) Unmetered Authorized Consumption, or water consumption that is sanctioned by a water utility but is not metered or otherwise measured. In general, Real Losses makes up the vast majority of NRW volume and is therefore the focus of this assessment.

Real Losses can occur through leaks and spills in water distribution system infrastructure (utility-side mains, storage tanks & reservoirs, a joints), with causes that can fall within and without directly utility control. Still recent estimates suggest that non-revenue water comprises an average of 14% of the total water produced by water providers across the United States (U.S. EPA 2013), representing a significant category of municipal water use. For this assessment, we collected estimates of real losses reported by water providers to state agencies using the water loss audit evaluation framework developed by the American Water Works Association and published in their M36 – Water Loss Audits and Control Programs manual. These data, referred to as the “Water Loss dataset” in the report, include annual estimates of distribution system input volume, real losses volume, service population and physical characteristics of the water distribution system such as number of service connections, total length of water mains, and average operating pressure. These data were collected by state for years 2019 – 2022 (the most recent vintage of data available at the time of analysis), resulting in a compiled dataset representing over 4,000 water providers across 12 states (Figure A11).

Summary of Utilities Represented in NRW Dataset, County-Level Aggregation
(Dataset Represents 21.9 % of US Population)

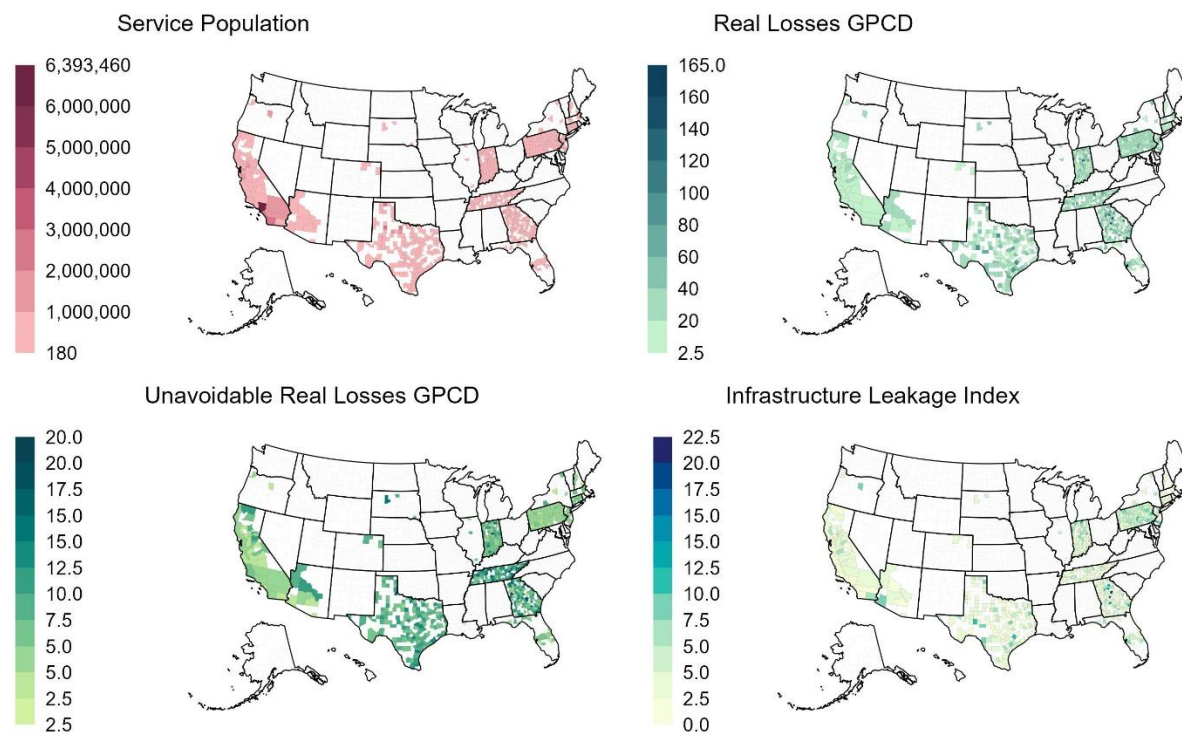


Figure A11. County-Level Summary of Water Loss Dataset Served Population and Real Loss Metrics.

In several cases, individual water audit data were either incomplete or missing one or more variables (water providers with more than two entirely missing variables were not included in this analysis). For these cases, relevant non-revenue water variables were estimated using a simplified geo-imputation process. In this process, we estimated scaling metrics between input variables and calculated average values of these metrics for census-defined geographies ranging from county-level to region-level. Figure A12 shows the relationships between physical system attributes used to develop these scaling metrics (population-connection density and connection-main length density).

Dashed Line Indicates Linear Trend Line Between Variables In Plot
Utility Count = 4,210

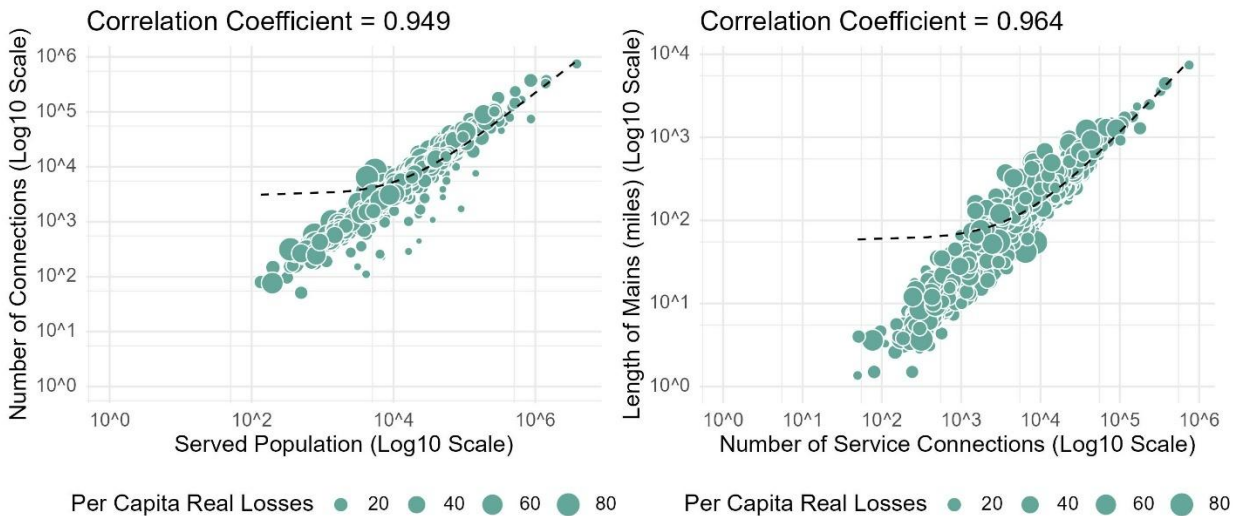


Figure A12. Linear Relationships Between Utility-Level System Characteristics from Water Loss Dataset, Symbolized by Per Capita Real Losses.

For example, for water providers with valid service population data but invalid or missing service connection data, we calculated the average population-connection density for water providers with valid data for both variables and estimate the average population-connection density at the county-level. These county-level estimates were then applied to water providers with incomplete data within the same county, to obtain estimates of the number of service connections where missing. We used a similar approach to estimate total length of mains (using the average service connection-main length density as the scaling metric) and operating pressure (using the direct average operating pressure without scaling). Figure A13 and Figure A14 show the frequency distribution of each NRW variable, separated into observed (via water audit dataset) and estimated (via scaling metric). Of the approximately 4,000 water providers represented by the Water Loss dataset, 27% were complete and were used to geo-impute missing values for the remaining 73%.

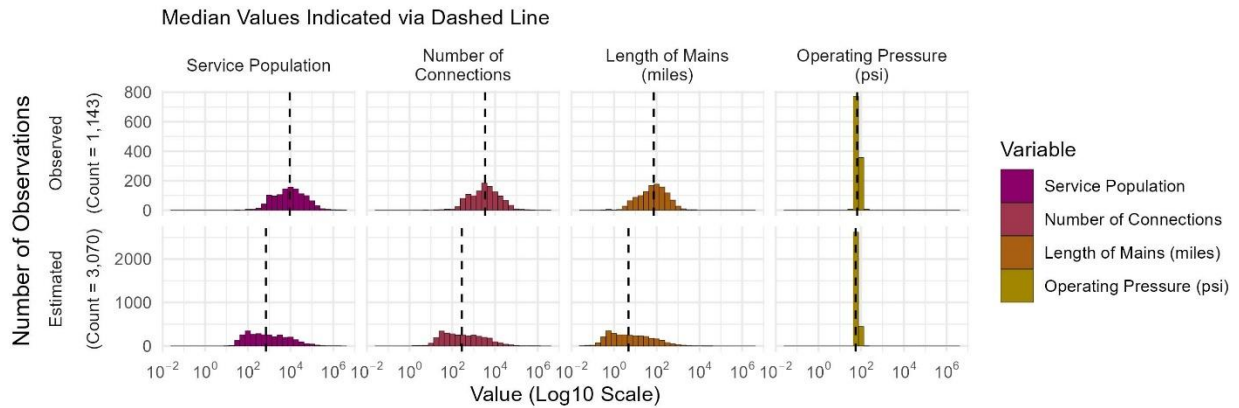


Figure A13. Frequency Distribution of Utility-Level System Characteristics from Water Loss dataset, Disaggregated by Data Source (Observed vs. Estimated).

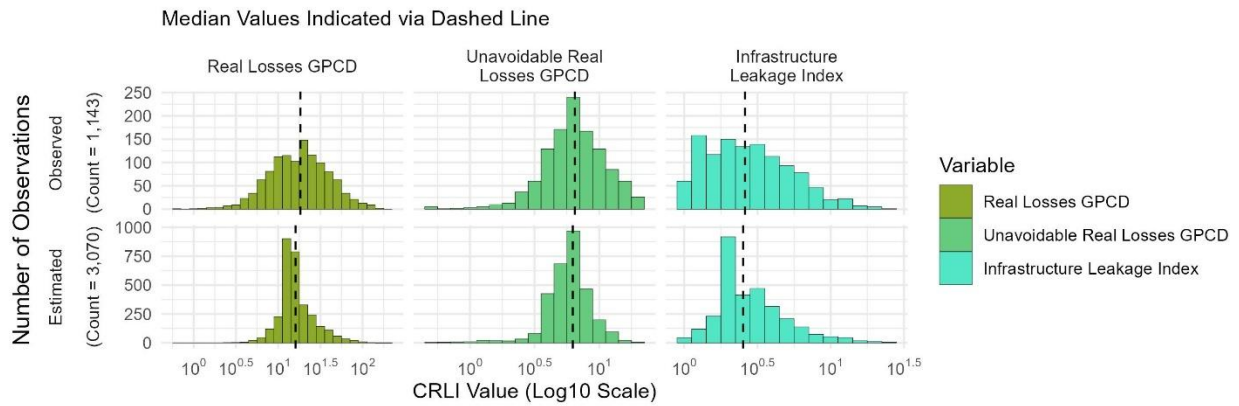


Figure A14. Frequency Distribution of Utility-Level Real Losses Volume Metrics from Water Loss dataset, Disaggregated by Data Source (Observed vs. Estimated).

Using this full (observed and estimated) utility-level dataset, we then calculate the Unavoidable Real Losses (UARL) volume for each utility, which represents the minimum technically achievable volume of Real Losses volume that could be expected of a utility based on its physical characteristics, as shown in Eq. 1 (Lambert et al. 1999). The UARL is an empirically derived equation that acknowledges that it is impossible to eliminate 100% of real losses from a water distribution system and attempts to quantify the minimum expected volume of real losses for a distribution system that can be achieved in the absence of any financial or economic constraints. As shown in Eq. 1, the UARL takes a network component-based approach to marry several performance indicators traditionally used to estimate Real Losses volume for a utility (length of distribution and service mains, number of service connections, and system operating pressure), while providing a single formula that can be applied to a utility of any size and density.

$UARL_{Utility} =$	Eq. 1
$(5.48 * L_{main}) + (0.15 * N) + (7.5 * (N * L_{service}) * OP$	

where,

- $UARL_{Utility}$ is the Unavoidable Real Losses for the Utility, in gallons per day
- L_{main} is the total length of transmission and distribution mains in the Utility service area, in miles
- N is the total number of service connections
- $L_{service}$ is the average length of customer-side service line mains, in miles (assumed as zero for this study)
- OP is the average operating pressure of the utility's distribution system, in pounds per square inch (psi)

The ratio of Current Annual Real Losses (CARL) volume to UARL volume, also known as the Infrastructure Leakage Index (ILI), can be used to assess current levels of real losses for a utility, benchmark against other water providers with similar characteristics, and track improvement in distribution system performance as a utility implements water loss control strategies (Jernigan et al. 2019).

Baseline Water Demand Estimates

The linear regression model specifications, including weather-normalization variables, are provided in Eq. 2 and Eq. 3. Each equation was first applied to the Billing Dataset to estimate regression coefficients, then applied to the constructed monthly time-series for calendar years 2018 to 2023 to project per capita water demands to current day. These per capita demand estimates were then multiplied by current day estimates of the served population for each water provider to calculate a monthly water demand volume by sector.

$Log_{10}(Seasonality\ Ratio)_{Utility} =$	Eq. 2
$\beta_0 + \beta_1 * (Cluster\ ID)_{Utility} * (\beta_{1,2} * Year + \beta_{1,3} * Month)$	

where,

- Seasonality Ratio is the average proportion of monthly water demand to annual water demand across for the Utility, per Year and Month (numeric variable, values between 0 and 1)
- β_0 is the intercept term representing the Seasonality Ratio for the Reference Utility¹
- Cluster ID is the Seasonality Cluster Assignment of the Utility (categorical variable)
 - β_1 is the regression coefficient term for each Cluster ID
- Year is the time-series indicator of the historical data record (numeric variable, as number of years for first year of data for the utility)
 - $\beta_{1,2}$ is the regression coefficient term for the interaction between each Cluster ID and Year
- Month is the categorical indicator for month of the year, as a proxy for seasonality time-series (categorical variable)
 - $\beta_{1,3}$ is the regression coefficient term for the interaction between each Cluster ID and Month

$Log_{10}(GPCD_{norm})_{Utility} =$	Eq. 3
$\beta_0 + \beta_1 * (Cluster\ ID)_{Utility} * (\beta_{1,2} * Log_{10}(Year) + \beta_{1,3} * CDD + \beta_{1,4} * PPT)$	

where,

- $GPCD_{norm}$ is the weather-normalized annual average gpcd of the Utility, per year
- β_0 is the intercept term representing the weather-normalized gpcd in the first year of the data record for the Reference Utility²
- Cluster ID is the Seasonality Cluster Assignment of the Utility (categorical variable)
 - β_1 is the regression coefficient term for each Cluster ID
- Year is the time-series indicator of the historical data record (numeric variable, as number of years for first year of data for the utility)

¹ For Eq. 2, the Reference Utility is the Utility with the lowest average Seasonality Ratio across all months (i.e., the Utility with the least seasonal water use pattern)

² For Eq. 3, the Reference Utility is the Utility with the smallest average annual gpcd across all years

- $\beta_{1,2}$ is the regression coefficient term for the interaction between each Cluster ID and Year
- CDD is the number of cooling-degree-days for month of the year, as a proxy for temperature-related variables (numeric variable)
 - $\beta_{1,2}$ is the regression coefficient term for the interaction between each Cluster ID and CDD
- PPT is the amount of precipitation for month of the year, in inches (numeric variable)
 - $\beta_{1,3}$ is the regression coefficient term for the interaction between each Cluster ID and PPT

References

- AWWA. 2016. *The State of Water Loss Control in Drinking Water Utilities*. White Paper. American Water Works Association.
<https://www.awwa.org/Portals/0/AWWA/ETS/Resources/WLCWhitePaper.pdf?ver=2017-09-11-153507-487>.
- Brendle Group. 2007. *Benchmarking Task Force Collaboration for Industrial, Commercial & Institutional (ICI) Water Conservation*. Report. Colorado WaterWise Council.
https://coloradowaterwise.org/resources/documents/ici_toolkit/docs/brendle%20group%20and%20cww%20ici%20benchmarking%20study.pdf.
- Chinnasamy, Cibi, Mazdak Arabi, Sybil Sharvelle, Travis Warziniack, D. Furth, and Andre Dozier. 2021. "Data for Characterization of Municipal Water Uses in the Contiguous United States." HydroShare, March 8.
<https://doi.org/10.4211/hs.feb5af8990914ce2b28f18b10d65c2a2>.
- City of Atlanta. 2015. "Ordinance 15-0-1101: Commercial Buildings Energy Efficiency Ordinance." <https://atlantabuildingbenchmarking.wordpress.com/wp-content/uploads/2015/05/15-o-1101-atlanta-commercial-energy-efficiency-ordinance.pdf>.
- City of Boston. 2023. "Ordinance Amending City of Boston Code, Ordinances, Chapter VII, Sections 7-2.1 and 7-2.2, Building and Energy Reporting and Disclosure (Berdo)." https://www.boston.gov/sites/default/files/file/2023/12/BERDO%202.0%20Final%20Amended%20Docket%200775_1.pdf.
- Fedak, Rebecca, Derek Hannon, Zach Taylor, and Amy Volckens. 2019. *Developing Water Use Metrics for the Commercial and Institutional Sectors*. No. 4619A. Water Research Foundation. <https://www.waterrf.org/system/files/resource/2022-09/DRPT-4619A.pdf>.
- Hoffman, Bill. 2019. "University Water Use A Study in Benchmarking." Texas Water, Houston, TX, April 5.
- Hoffman, HW. 2016. *Analysis of Five Years of Municipal Water Use Data To Estimate Commercial and Institutional Per Capita Use*. Texas Water Development Board.
https://savetexaswater.org/resources/doc/Hoffman_Analysis_Muni_2016.pdf.
- Hoffman, HW. 2018. *Commercial & Institutional BMP Guidebook*. Guidebook. Texas Water Development Board.
<https://www.twdb.texas.gov/conservation/BMPs/CI/doc/Commercial%20%20Institutional%20BMP%20Guidebook.pdf>.

- Jernigan, Will, George Kunkel, Gary Trachtman, and Alan Wyatt. 2019. *Key Performance Indicators for Non-Revenue Water*. Committee Report. AWWA Water Loss Control Committee Reports. American Water Works Association. <https://www.awwa.org/Portals/0/AWWA/ETS/Resources/WLCKPIReport%202019.pdf?ver=2019-11-20-094638-933>.
- Kiefer, Jack C, Lisa R Krentz, and Benedykt Dziegielewski. 2015. *Methodology for Evaluating Water Use in the Commercial, Institutional, and Industrial Sectors*. No. 4375. Water Research Foundation. <https://www.waterrf.org/system/files/resource/2022-09/4375.pdf>.
- Lambert, A. O., T. G. Brown, M. Takizawa, and D. Weimer. 1999. "A Review of Performance Indicators for Real Losses from Water Supply Systems." *Journal of Water Supply: Research and Technology—AQUA* 48 (6): 227–37. <https://doi.org/10.2166/aqua.1999.0025>.
- Morales, M. A., and J. P. Heaney. 2010. "Estimating Non-Residential Water Use with Publicly Available Databases." *World Environmental and Water Resources Congress 2010*, May 14, 4283–92. [https://doi.org/10.1061/41114\(371\)435](https://doi.org/10.1061/41114(371)435).
- Morales, Miguel A., James P. Heaney, Kenneth R. Friedman, and Jacqueline M. Martin. 2011. "Estimating Commercial, Industrial, and Institutional Water Use on the Basis of Heated Building Area." *Journal AWWA* 103 (6): 84–96. <https://doi.org/10.1002/j.1551-8833.2011.tb11475.x>.
- U.S. Census Bureau. 2003. "2002 Economic Census." 2002 NAICS Sector 00-Multi-Sector Statistics. <https://www2.census.gov/programs-surveys/economic-census/data/2002/sector00/>.
- U.S. Census Bureau. 2008. "2007 Economic Census." 2007 NAICS Sector 00-Multi-Sector Statistics. <https://www2.census.gov/programs-surveys/economic-census/data/2007/sector00/>.
- U.S. Census Bureau. 2013. "2012 Economic Census." 2012 NAICS Sector 00-Multi-Sector Statistics. <https://www2.census.gov/programs-surveys/economic-census/data/2012/sector00/>.
- U.S. Census Bureau. 2016. "Intercensal Datasets: 2000-2010." August. <https://www2.census.gov/programs-surveys/popest/datasets/2000-2010/intercensal/>.
- U.S. Census Bureau. 2018. "2017 Economic Census." 2017 NAICS Sector 00-Multi-Sector Statistics. <https://www2.census.gov/programs-surveys/economic-census/data/2017/sector00/>.

- U.S. Census Bureau. 2020a. “2019 American Housing Survey Metropolitan Public Use File.” Survey. <https://www2.census.gov/programs-surveys/ahs/2019/AHS%202019%20Metropolitan%20PUF%20v1.0%20Flat%20CSV.zip>.
- U.S. Census Bureau. 2020b. “2021 American Housing Survey Metropolitan Public Use File.” Survey. <https://www2.census.gov/programs-surveys/ahs/2021/AHS%202021%20Metropolitan%20PUF%20v1.0%20Flat%20CSV.zip>.
- U.S. Census Bureau. 2023. “2022 American Community Survey 5-Year Estimates.” Nos. B25001, B25002, B25003, B25010, B25032, B25033. September. https://www2.census.gov/programs-surveys/acs/summary_file/2022/table-based-SF/data/5YRData/.
- U.S. Census Bureau. 2024a. “2022 Economic Census.” 2022 NAICS Sector 00-Multi-Sector Statistics. <https://www2.census.gov/programs-surveys/economic-census/data/2022/sector00/>.
- U.S. Census Bureau. 2024b. “2023 American Housing Survey Metropolitan Public Use File.” Survey. <https://www2.census.gov/programs-surveys/ahs/2023/AHS%202023%20Metropolitan%20PUF%20v1.1%20Flat%20CSV.zip>.
- U.S. Census Bureau. 2024c. “Intercensal Datasets: 2010 - 2020.” November. <https://www2.census.gov/programs-surveys/popest/datasets/2010-2020/>.
- U.S. EIA. 2022. “Commercial Buildings Energy Consumption Survey.” Survey. Version 2018. United States Energy Information Administration, September. <https://www.eia.gov/consumption/commercial/data/archive.php>.
- U.S. EPA. 2013. *Water Audits and Water Loss Control For Public Water Systems*. EPA 816-F-13-002. United States Environmental Protection Agency, Office of Water. <https://www.epa.gov/sites/default/files/2015-04/documents/epa816f13002.pdf>.
- U.S. EPA. 2023. “U.S. Water Use Intensity by Property Type.” Technical Reference. United States Environmental Protection Agency, June. https://www.energystar.gov/sites/default/files/tools/National%20WUI%20Technical%20Reference%202023_0719b.pdf.
- U.S. EPA. 2024. *Community Water System Service Areas*. Documentation. EPA/600/X-24/226. United States Environmental Protection Agency, Office of Research and Development Center for Environmental Solutions and Emergency Response.
- U.S. EPA. 2025. “Community Water System Service Area Boundaries.” Shapefile 80c6912ef14f46e480f5afd807767b4b. Version 1.2. EPA Office of Research and

Development Community Water System Service Area Boundaries, February.
<https://www.epa.gov/ground-water-and-drinking-water/community-water-system-service-area-boundaries?tab=resources>.

USDA and PRISM Group. 2023. "2023 USDA Plant Hardiness Zone GIS Datasets." PHZM.
https://prism.oregonstate.edu/projects/plant_hardiness_zones.php.

Vose, Russell S., Scott Applequist, Mike Squires, et al. 2014. "NOAA Monthly U.S. Climate Divisional Database (NClimDiv)." NOAA National Centers for Environmental Information. <https://doi.org/10.7289/V5M32STR>.