## Title

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# Assessment of Two Water and Wastewater Price Sources and Their Applicability in Determining Trends for Planning and Conservation

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# Executive Summary

Water conservation and appliance efficiency standards programs in the United States encounter challenges in assessing their economic impacts due to the limited availability of representative water and wastewater price data. In this report, we review water and sewage price and price trend data from two established sources: the Water and Sewerage Consumer Price Index from the U.S. Bureau of Labor Statistics and water and wastewater rate survey data from Raftelis/American Water Works Association (AWWA). By leveraging historical Raftelis/AWWA data, we develop an empirical approach to (1) interpolate the data by establishing regional trends that capture the pace of price increases as transparently and consistently as possible, and (2) extrapolate prices for future years for the purpose of quantifying water cost savings resulting from policy decisions. Additionally, our prediction models offer a means to verify data consistency when new rate survey data from Raftelis/AWWA become available.

# 1. INTRODUCTION

Increasingly prevalent drought conditions in areas of the United States have created a pressing need for reducing water demand. Postponing capital expenditures for expanding or upgrading water and wastewater infrastructure also requires decreasing consumer water demand. To reduce water demand and forestall utility infrastructure upgrades, the Energy Policy Act of 1992 (EPACT) mandated minimum water efficiency standards for plumbing products. In addition to mandatory standards, voluntary labels provide even higher water savings potentials for utilities and consumers. To quantify the monetary benefits of standards for consumers, EPACT mandated that the U.S. Department of Energy (DOE) conduct life-cycle cost analyses of water-using products. Separately, the U.S. Environmental Protection Agency's (EPA) voluntary WaterSense labeling program estimates consumer savings from the water efficiency of both indoor and outdoor residential and commercial products.

Accurately estimating current and future monetary savings from water conservation and appliance efficiency programs requires developing robust trends for energy and water prices. Each year, the U.S. Energy Information Administration (EIA) publishes data on electricity, natural gas, liquid petroleum gas (LPG), and fuel oil through the Monthly Energy Review (EIA 2021a); Natural Gas Navigator (EIA 2021b); and State Energy Consumption, Price, and Expenditure Estimates for LPG and oil for residential, commercial, and industrial sectors (EIA 2021c). The EIA also develops price trends for each fuel type (EIA 2023). Sources for electricity billing data include the Edison Electric Institute Typical Bills and Average Rates report (2022). However, no price, consumption, or trend-related water data are published at the same level of granularity as for energy. Due to the large number of public and private water and wastewater systems nationwide, obtaining nationally representative and robust data and trends remains a persistent challenge for policy researchers.

In addition to the need for national data, regional cost-benefit analyses are critical in informing policy decisions because water consumption and availability differ widely by region, affecting water and wastewater prices (DeOreo et al. 2011; Romero and Dukes 2013; Schein et al. 2019; Pierce et al. 2020). Also, water price projections must be disaggregated geographically when evaluating equity issues in water planning (Schein et al. 2019; Chen et al. 2021). The lack of nationally or regionally representative water and wastewater price data hinders evaluation of water conservation programs' impacts.

Several recent research efforts have explored ways to fill the data gaps. Lee et al. (2020) analyzed rate trends to better plan future water rates to support water distribution system sustainability. Some models that evaluate program impacts combine historical Raftelis/American Water Works Association (AWWA) data with the Water and Sewerage Consumer Price Index (CPI) trend from the U.S. Bureau of Labor Statistics (BLS) to project water and wastewater rates (Schein et al. 2019).

This paper consults both sources to develop water and sewage price trends: Raftelis/AWWA water and wastewater rate surveys and the Water and Sewerage CPI. We attempt to construct reliable regional water and wastewater rates from each Raftelis/AWWA survey based on key factors such as utility rates, sample size, service population, and geographic coverage. We then use the chained analysis method described in Stratton et al. (2017) to estimate changes in water and wastewater rates between Raftelis/AWWA biennial surveys. We fit those results to a regression model to detect potential anomalies when new data become available, as well as to project future rates. We also rely on the CPI trend in water and sewerage rates to track national year-to-year rate changes and to compare with the national trend derived from the Raftelis/AWWA survey. This approach improves the quality of water and wastewater price inputs policymakers can utilize when evaluating water conservation and efficiency program savings.

# 2. DATA OVERVIEW

Multiple parameters are needed to determine representative water and wastewater prices for calculating consumers' financial benefits from reducing water use. The parameters fall into two major categories: utility service information (service population, numbers of residential and non-residential accounts) and utility price information (rate structures, connection charges, rates by volume, peak rates, and seasonal charges).

Utilities report the components of water and wastewater rates in various ways. Most utilities charge different rates for different types of customers and meter sizes. Generally, non-residential (commercial and industrial) customers pay less for each unit of water volume than do residential customers. However, the former use larger meter sizes to accommodate the greater volumes of water used, and fixed charges increase as meter sizes increase. The diameter of non-residential meters can range from 25.4 mm (1 inch) to greater than 254 mm (10 inches). Residential meter sizes generally are 15.875 to 25.4 mm (5/8 to 1 inch). In addition to customer categories and meter sizes, there may be base (non-volumetric) and volumetric charges. Some utilities have seasonal, distance, and/or elevation rates, as well as rates by levels of usage. Estimating average retail water prices for each Census region and the nation necessitates weighting volumetric water prices according to such customer characteristics.

For the past three decades, organizations have published water rates by usage volumes, customer types, and/or inflation effects. Until 1999, AWWA published financial and revenue information on its member utilities via AWWA Water:\Stats[1], including location and non-volumetric charges by customer type; water rates by customer type, usage volume, and meter size; service population by size and type; and rate structure, including seasonal and peak rates (Water Research Foundation, n.d.). Until 2001, Black & Veatch published water rates of utilities nationwide. In 2001, they reduced their scope to encompass only the 50 largest cities in the country and presented high-level summaries of water price trends and major issues facing water utilities. The data used for those analyses are not public (Black & Veatch 2019). Although several researchers recently investigated water affordability for low-income households (Teodoro and Saywitz 2020; Zhang et al. 2022), data underlying those analyses

[1] https://www.waterrf.org/research/projects/awwa-waterstats

were not published. Several online tools are designed to help utilities assess and compare the affordability of their residential water/wastewater rates and structure based on regional consumers' socioeconomic characteristics (University of North Carolina [UNC] Environmental Finance Center [EFC] 2020; Patterson and Doyle 2021). Those tools, however, rely on rates retrieved from utility websites, which usually are limited to only recent years and require an estimate of consumption level and housing type information. Given the variable utility rate structures found throughout the country, and the different frequencies of website updates, it is difficult to calculate average rates consistently and to obtain historical data to establish a trend.

For this analysis, we use sources that provide multiple years of publicly available and close-to-nationally representative data. The two sources used in this analysis are described in detail below.

## 2.1 Raftelis/AWWA survey data

Since 1993, Raftelis Financial Consultants, Inc., has published a biennial water rate survey. In 2002, they started partnering with the AWWA to co-publish the surveys. Service populations of the utilities covered by the Raftelis/AWWA surveys have ranged from fewer than 500 consumers to more than 9 million. The data are organized by utility size (small, medium, and large) based on population served. Information collected includes system characteristics and data gathered during prior AWWA surveys (non-volumetric charges by customer type; water rates by customer type, usage volume, and meter size; service population by size and type; and rate structures including seasonal and peak rates).

Through 2016, data collection was standardized by considering four meter sizes (15.875, 50.8, 101.6, and 203.2 mm [5/8 inch plus 2, 4, and 8 inch]) and five volumetric divisions for residential consumers using 15.875 mm (5/8-inch) meters. This method enables calculating bills for each usage level based on tariffs. In 2018, however, survey data covered only the first three levels of residential volumetric rates. The 2020 survey collected five volumetric rate levels, but published only the three categories identified in the 2018 survey.

## 2.2 Water and sewerage Consumer Price Index

The BLS determines the CPI as the "average change over time in the prices paid by urban consumers for a market basket of consumer goods and services" (U.S. BLS, CPI n.d.). This market basket contains more than 240 items divided into eight groups. The CPI includes sales and excise taxes levied on consumer goods and services (U.S. BLS, CPI FAQ n.d.). The CPI category relevant to this article is Urban Consumers Water and Sewerage (series ID: CUSR0000SEHG01), which has greatly exceeded the overall CPI since the early 1980s (series ID: CUSR0000SA0), increasing even faster starting in the early 2000s. (see Fig. 1). Based on CPI values indexed to 100 in 1983, the Water and Sewerage CPI approached 600 in 2020, while the overall CPI was 260 (Beecher, 2021).

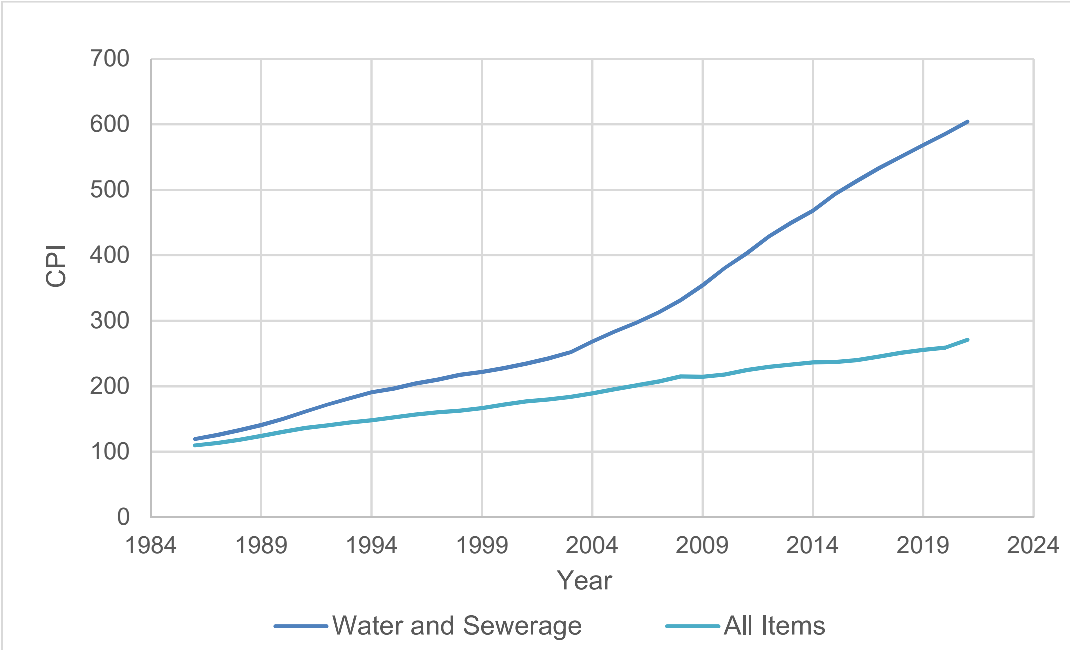


**Figure 1. CPI all-items time series compared to Urban Consumers Water and Sewerage time series (base period 1982–1984 = 100) based on U.S. BLS.**

### 2.2.1 Water and Sewerage CPI methodology

The CPI is determined via a series of related samples. First, BLS selects a sample of geographic areas. Next selected are a sample of outlets, or establishments, at which residents of those areas make purchases (taken from the Consumer Expenditure Survey); a sample of retail goods and services bought by area residents (from the Commodities and Services Survey); and a sample of residential housing units (from the CPI Housing Survey). Collected transaction prices are then weighted by consumer expenditures.

The CPI employs multistage probability sampling within outlets to collect price data. This procedure, termed disaggregation, enables resource-efficient and objective probability sampling. The approach involves (1) identifying the items BLS defines as "entry-level items" (ELIs) sold by the outlet, (2) grouping large numbers of items by common characteristics (e.g., size, brand), (3) designating a selection probability for each group proportional to the sales of the items in each group, and (4) employing a random-number table to select one group (U.S. BLS 2018). After all the items in the selected group are identified, this process is repeated until a unique item is chosen. After data are collected, 7,776 item-area indexes are calculated, including water and sewerage services in each of 32 index areas (J. Church, personal communication, 2022. For goods and services having a low level of consumer substitution, such as water and sewerage, the calculation relies on a Laspeyres formula: a weighted average of price relatives where estimated quantities of items purchased during the sample period are implicit in the expenditures used as weights (U.S. BLS 2018).

Although BLS is integrating alternative data collection procedures for some items, it employs the disaggregation technique for the Water and Sewerage CPI. Most of the outlets selected are water utilities providing both water and sewer services, not apparently separable. When an outlet has different rate schedules for customers living in different areas of their territory, BLS first must determine that territory. Percentages for disaggregation are preferentially based on shares of revenue from separately billed residential customers; if such data are unavailable, BLS uses the number of residential customers or the population of the area served. After a rate structure or territory is chosen, the service to be priced is disaggregated for a particular rate basis (e.g., consumption, lot size) or a combination thereof (e.g., a flat charge and a volumetric charge based on metered consumption) (Church, personal communication, 2022).

The CPI is designed to capture what the ‘average’ or ‘representative’ consumer pays for goods and services. To develop a unique price, BLS data collectors employ some combination of the price-determining characteristics listed in Appendix A. For a single outlet, for example, a data collector might randomly select a quote for sewer service with quarterly billing and a metered inside-city rate structure based on a percent of water usage. BLS does not apparently publish examples of such data collected for any utility. For outlets charging a flat charge, BLS directs data collectors to disaggregate among three typical single-family residences as specified by the survey respondent. For outlets employing a metered rate, the data collector determines ranges of volumetric consumption by residential households and obtains past-year residential revenue data for each range, or the number of customers whose consumption falls into each range. If those data are unavailable, data collectors must disaggregate among the ranges using equal probability. After a range is chosen, dollar volume sales, (if available) or equal probability form the basis of disaggregating to a specific consumption volume.

### 2.2.2 Frequency of data collection

The Consumer Expenditure Survey sample is refreshed every four years for new outlets in the sampled geographic areas. For most items (including water and sewerage), the survey rotates through the total sample of outlets in those four years, during which price collectors are sent to new outlets every quarter (Church, personal communication, 2022).

### 2.2.3 Geographic coverage

The Water and Sewerage CPI is calculated for the nation. Every decade or two, BLS revises the CPI geographic areas sampled based on the decennial U.S. Census, striving to construct a sample that “accurately reflects the current population distribution and other demographic factors” (U.S. BLS, CPI FAQ n.d.). From 1998 to 2018, the geographic sample included 87 primary sampling units (PSUs) in urban areas (Cage 1996). Starting in 2018 the sample was revised to encompass 75 PSUs consolidated into 32 index areas (U.S. Environmental Protection Agency 2010; Paben et al. 2016).

Table 1 displays the percentages of CPI samples in each Census region before and after the 2018 revision. Appendix B breaks down Census population estimates by region biennially from 2000 to 2020. During the period from 2000 to 2020, regional percentages of the national CPI sample diverged from Census population estimates most strongly in the Northeast and South, with the former overrepresented and the latter underrepresented in the CPI sample. These percentages are calculated from percent of index population per sampling unit using Appendix

2 from Cage (1996) and the appendix from Paben et al. (2018).

**Table 1. Percentages of each Census region in the two most recent geographic revisions of the CPI samples.**

| Years | Northeast (%) | Midwest (%) | South (%) | West (%) |
|---|---|---|---|---|
| 1998–2017 | 22.0 | 23.0 | 32.3 | 22.7 |
| 2018 onward | 18.8 | 20.9 | 36.2 | 24.2 |

### 2.2.4 Demographics

The CPI has two target populations: all urban consumers (CPI-U) and urban wage earners and clerical workers (CPI-W). Only the former is used for the Water and Sewerage CPI. The CPI-U population, which comprises about 93% of the U.S. population, encompasses all urban households in Core-Based Statistical Areas and urban locales having at least 10,000 inhabitants (U.S. BLS, CPI Design n.d.). The CPI-U generally excludes residents of rural areas, farms, religious communities, military bases, and institutions. Also, the Water and Sewerage CPI encompasses only separately billed residential units, excluding non-residential units and multifamily residences sharing a meter (rather than being billed separately) (Church, personal communication, 2022).

Whereas BLS selects outlets to form a representative sample, it does not disclose specific data sources or information needed to discern the sample mix of small, medium, and large water utilities or the breakdown between publicly and privately owned utilities. The “concentration rating” for water and sewerage recently was determined to be low, meaning that less than 33% of the CPI sample lies in the top 10 establishments, or outlets, where data are collected. Index quality issues (related to response rate and difficulty collecting price quotes, among others) for water and sewerage are rated as “low” (Konny et al. 2019).

### 2.2.5 Sample size

The national CPI sample size ranges from 600 to 700 quotes for water and sewerage (Church, personal communication, 2022), with 624 quotes in the sample as of August 2018 (Konny et al. 2019). How many utilities the sample includes is unknown because the number of price quotes at each reflects the total expenditures occurring there (i.e., larger utilities may be sampled more than once for separate price quotes) (U.S. BLS 2018).

## 2.3 Summary of available data parameters

Besides Raftelis/AWWA and CPI data, utility webpages sometimes offer water price data. Utility webpages typically contain current rate sheets; however, rate information is inconsistent because of different water supply landscapes and local objectives and policies. Such diversity makes it difficult to manually aggregate and analyze such data at a larger geographic scale. Table 2 shows generalized parameters necessary for calculating water rates and water trends and their availability across data sources.

The parameters necessary to weight the tariffs or the rates to appropriately aggregate utility level water rates and rate trends to the regional level—such as utility service population, numbers of residential accounts and non-residential accounts, peak rates, and seasonal charges—are usually not available from utility web pages. The Water and Sewerage CPI provides changes from the prior reporting year but is not disaggregated by sector or by region, nor are other types of utility parameter available. Raftelis/AWWA surveys provide the inputs listed in Table 2, which enable the calculation of regional average rates as well as changes relative to the prior reporting year.

**Table 2. Available parameters across data sources**

<table>
<tr><th>Data Parameter</th><th>Raftelis/ AWWA</th><th>Utility Web Pages</th><th>BLS's Water and Sewerage CPI</th></tr>
<tr><td>Number of sample utilities</td><td rowspan="9">Yes</td><td>N/A</td><td rowspan="9">No</td></tr>
<tr><td>Service population</td><td rowspan="2">No</td></tr>
<tr><td>Ratio of residential accounts to non-residential accounts</td></tr>
<tr><td>Connection charge</td><td rowspan="2">Yes</td></tr>
<tr><td>Cost by volume consumed for residential accounts</td></tr>
<tr><td>Cost by volume consumed for non-residential accounts</td><td rowspan="4">Inconsistent</td></tr>
<tr><td>Peak rates</td></tr>
<tr><td>Seasonal charges</td></tr>
<tr><td>Rate structures</td></tr>
<tr><td>Change from previous reporting year</td><td>Calculated</td><td>Yes</td><td>Yes</td></tr>
</table>

Considering the scarcity of data sources for nationally and regionally representative water and wastewater prices, this paper proposes a means to evaluate price data and future trends at the national and regional level. Given its extensive price index series, CPI represents the most suitable data source for estimating past or future prices for years in which rate data are unavailable. However, the CPI data sample and processing approach are not publicly available, and thus cannot be disaggregated to the regional level. If a large utility-level historical dataset were available, such as Raftelis/AWWA, it would enable identification of various regional water and wastewater price trends.

# 3. METHODOLOGY

Because a water bill is a function of water consumption, water and wastewater prices also should be a function of consumption. Without data on utility-level sales volumes, annual total revenues, or consumer billing, it is impossible to develop a robust estimate of regional average consumption per household for each Raftelis/AWWA survey year. Additionally, most residential tariffs adopt a structure of block rates (a constant price for water consumption within certain bounds). However, the consumption cutoffs for rate blocks differ by utility and evolve over time, which are unavailable from the survey. Considering these data challenges, this section describes our approach to determine the annual rate based on Raftelis/AWWA data and a chained analysis to construct water and wastewater rate indexes.

Notably, the two most recent Raftelis/AWWA surveys published only three volumetric rate levels instead of the usual five; therefore, average residential water rates were lower than if all five levels had been included and were inconsistent with prior rate estimates. Lacking a distribution of or average consumption data, we assumed a flat consumption structure to estimate average utility-level water and wastewater rates, in which all five volumetric levels have the same proportion of consumers. We then perform a regression analysis to predict future rates. Through these analyses, we aim to (1) observe historical CPI price changes relative to Raftelis/AWWA data, and (2) highlight any inconsistencies between rate changes obtained from the latest survey and utility-published data, which might indicate inconsistencies introduced during data collection and processing.

## 3.1 Processing Raftelis/AWWA data

The Raftelis/AWWA data employed in this analysis are utility-level water and wastewater rates, reported biennially for each of the five tiers in the block rate structure from 2000 to 2020, excluding the 2018 data, which omitted two tiers in the rate structure. For the 2020 Raftelis/AWWA surveys, the 195 water utilities and 140 wastewater utilities water utilities sampled served approximately 19% of the U.S. population. Given the sparse available data, our approach accounts for the complete rate structure by assigning equal weights to the different rate tiers. The by-tier[2] rates were converted to the same unit ($/1,000 cubic feet or 28.3168 $m^3$), and the average rate for each utility was estimated by assuming the same proportion of consumers fell into each of the five volumetric rate levels. This is the same approach BLS follows in the absence of consumption data. We also accept the hypothesis that the change in average rate is affected equally by the rate changes of the five tiers.

Note that most water tariffs/bills also include a periodic fixed charge unrelated to consumption. For evaluating water and energy conservation programs, the fixed charge is the same in both the policy case and the base case, so while it is included in our analysis, does not affect the cost savings from lowered water consumption.

After establishing average utility-level prices, we weighted those by the number of residential accounts served by the utility to estimate an average rate per state. Non-residential accounts were excluded. Next, we considered the state population in the survey year to aggregate state average rates into Census regional averages. To calculate the national average rate, we weighted the Census regional average rates by regional populations. We relied primarily on the utility service population to estimate the state-level average rates, but also incorporated state and Census region population data as weights to recognize the regional differences in water rates and to reduce the chance of a concentration of utility responses in one state being overrepresented in the final rate calculation. All rates were converted to 2020$ using the

[2] Consumption tier categories at (1) below 500 cf; (2) between 501-1000 cf, (3) between 1001-1500 cf; and (4) above 1500 cf

associated year's gross domestic product (GDP) deflator.[3]

## 3.2 Constructing rate indexes

We used a chained analysis to construct water and wastewater rate indexes. A chained analysis (also known as a paired analysis) enables a determination of rate changes if the same set of utilities participated in two consecutive surveys. Our chained analysis includes intermittently sampled utilities, which would be dropped from a cohort analysis (individuals classified in groups sharing the same characteristics, over time, and observes changes in behavior or characteristics) that requires a uniform sample throughout the analysis period. This method limits the sample bias between consecutive surveys, while preserving the largest possible sample size.

Based on the chained analysis, the percentage changes in water and wastewater rates between consecutive Raftelis/AWWA surveys can be transformed into a set of price indexes. Using the water price in 2000 to represent the base year, set to 100, relative rate changes can be calculated to show the evolution of rates from 2000 to 2020. The Water and Sewerage CPI (U.S. BLS, CPI-U) is also normalized to 2000, and the relative changes during the analysis period (2000–2020) can be observed and compared with Raftelis/AWWA trends.

## 3.3 Regression to predict future rates

The water and wastewater rate indexes resulting from the chained analysis enabled us to develop a regression model that can estimate future rates for the nation and by Census region. The reliability of the regression depends on the utility sample size and the variability in rates within the Census region.

For this study, our limited data required developing a simple regression model using only the year variable as the regressor. Potential drivers of rate index changes may include costs of service such as power, infrastructure improvements, equipment purchase and maintenance, labor, pandemic impacts, climate change effects, and variations in government funding. Potential motivations for changing rate structures include promoting water conservation, increasing revenue stability, maintaining affordability, or enhancing system flexibility in response to drought conditions. Most of those factors would increase utility operating costs. Because those causal and sometimes confounding factors cannot be quantified without substantial data, and can rarely be looped into the same predictive model without facing the issue of overfitting, we grouped factors that affect a utility's volumetric level rate and rate structure as a constant effect linked to the continuous variable: the year. This choice enables a simplified approach to project future rates, as opposed to trying to project causal factor-based regressors for future years.

A 95% confidence interval was identified based on our regression model and the observed variability. By comparing the model's predicted rate with a new observed rate (reported by a

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[3] U.S. Bureau of Economic Analysis national income and product accounts: Implicit price deflators for Gross Domestic Product (Available at: https://www.bea.gov/itable/national-gdp-and-personal-income)

new survey), one can assess how consistent the new data are with the historical trend. If the new data point drops from the 95% confidence interval around the predicted value, then reasonable doubt exists regarding the accuracy of the new data. Further analysis can be conducted to understand causes for the differences, including errors in data reporting or input and changes in sample size.

In this analysis, we used 2000–2016 Raftelis/AWWA water and wastewater rates as input to train a simple linear regression model by Census region. The 2020 data were used to evaluate the data quality and the model's predictive capacity. This approach presupposes that future rates will follow a roughly linear trend from past rates; it does not account for runaway inflation or reassessment of rates in the wake of occurrences affecting water supply and/or delivery such as droughts, floods, or water contamination.

# 4. RESULTS

Our results encompass water and wastewater rates for the nation and by region. We also developed a regression to predict future rates.

## 4.1 Raftelis/AWWA data by region—water rates

Table 3 details the relative changes in water rates obtained from the chained analysis for the nation, as well as for each Census region and California. Although California results are included in the West census region, we also present them separately for the following reasons: (1) the savings potential for California is distinct from other states due to its particularly high water rates and severe drought, and (2) it can serve as a test to see if state-specific rates are reliable and to evaluate the representativeness of the data.

**Table 3. Percentage changes in water rates by Census region, nationally, and in California through chained analysis**

| Survey Year | Midwest | South | Northeast | West | Nation | Calif. |
|---|---|---|---|---|---|---|
| *2000–2002* | 6% (26) | 3% (41) | 5% (11) | 6% (24) | 5% (102) | 10% (7) |
| *2002–2004* | 1% (21) | 1% (36) | 13% (10) | 0% (21) | 3% (88) | -3% (6) |
| *2004–2006* | 4% (32) | 1% (63) | 8% (18) | 0% (43) | 3% (156) | 0% (13) |
| *2006–2008* | 14% (21) | 10% (56) | 10% (12) | 17% (32) | 12% (121) | 24% (12) |
| *2008–2010* | 17% (33) | 15% (82) | 21% (11) | 16% (48) | 16% (174) | 21% (23) |
| *2010–2012* | 14% (35) | 7% (91) | 12% (13) | 11% (55) | 10% (194) | 10% (26) |
| *2012–2014* | 9% (35) | 5% (87) | 8% (10) | 3% (55) | 6% (187) | 5% (22) |
| *2014–2016* | 5% (37) | 7% (62) | 2% (12) | 14% (48) | 7% (149) | 20% (23) |
| *2016–2020* | 21% (10) | 16% (32) | 7% (5) | 10% (16) | 14% (63) | -9% (6) |

Note: Sample size is given in parentheses.

To obtain the average value by Census region, the percentage change per utility was weighted by the relative fraction of residential service accounts. Therefore, for a given Census region, if the utility sample size is small, or all the utilities identified (included in two consecutive surveys) have small service populations, then the Census estimated average may be biased.

When looking at the survey-to-survey rate changes by Census region between 2000 and 2016, most changes are positive, in line with research that finds water rates generally increase through time (Beecher 2010; Black & Veatch 2017; Circle of Blue n.d.). In most regions, relatively large rate increases were recorded between 2008 and 2010. Significantly smaller sample sizes were available to the 2016 to 2020 paired analysis, and California exhibits an unusual rate decrease of 9% during this period based on the sample size of only six utilities.

## 4.2 Wastewater rates by region

Relative changes in wastewater rates obtained from the chained analysis are detailed in Table 4. The water and wastewater utilities surveyed each year are not necessarily from the same communities, especially for the Northeast and California, which constrains the analysis of combined water and wastewater charges. Similar to water rates, most changes in wastewater rates are positive, confirming an increasing trend through time. Most regions experienced significant wastewater rate increases between 2008 and 2010, except for the South, for which large increases were recorded between 2014 and 2016.

**Table 4. Percentage changes in wastewater rates by Census region, nationally, and in California through chained analysis**

| Survey Year | Midwest | South | Northeast | West | Nation | Calif. |
|---|---|---|---|---|---|---|
| *2000 to 2002* | 0% (24) | 4% (42) | 6% (6) | 16% (22) | 6% (94) | 44% (3) |
| *2002 to 2004* | 26% (9) | 7% (33) | 42% (6) | -1% (15) | 16% (63) | -4% (2) |
| *2004 to 2006* | 10% (16) | 3% (50) | 1% (9) | -2% (26) | 3% (101) | -5% (8) |
| *2006 to 2008* | 22% (15) | 8% (50) | 10% (9) | 16% (19) | 13% (93) | 14% (8) |
| *2008 to 2010* | 20% (19) | 13% (73) | 20% (7) | 22% (26) | 18% (125) | 28% (10) |
| *2010 to 2012* | 17% (20) | 9% (75) | 10% (7) | 7% (34) | 10% (136) | 3% (11) |
| *2012 to 2014* | 11% (23) | 11% (56) | -4% (6) | 2% (33) | 6% (118) | 0% (9) |
| *2014 to 2016* | 7% (13) | 35% (55) | 1% (6) | 13% (23) | 18% (97) | 2% (6) |
| *2016 to 2020* | 6% (6) | 13% (27) | 5% (1) | 0% (8) | 7% (42) | 0% (2) |

Note: Sample size is given in parenthesis

## 4.3 Rate indexes

We developed rate indexes to illustrate rate changes by Census region. Similar to the CPI and GDP, the water and wastewater rate indexes use 2000 as the base year (an index value equal to 100). Trends reflect only the relative changes within a region and cannot be compared between regions. They also do not indicate the amplitude of the change because they were developed via normalized base-year rates.

Fig. 2 and Fig. 3 show the water and wastewater rate indexes, respectively, allowing a direct comparison of all survey year data for the samples available within a region. Of the regional water rate index curves shown in Fig. 2, the Northeast leads in relative increases until 2016. For wastewater, rates increase more quickly in the Midwest than in other Census regions.

Because of its high base-year rate, the West shows a steadier relative increase for both water and wastewater rates. The California water rate trend is not as smooth as the other trends, perhaps reflecting its small sample size.

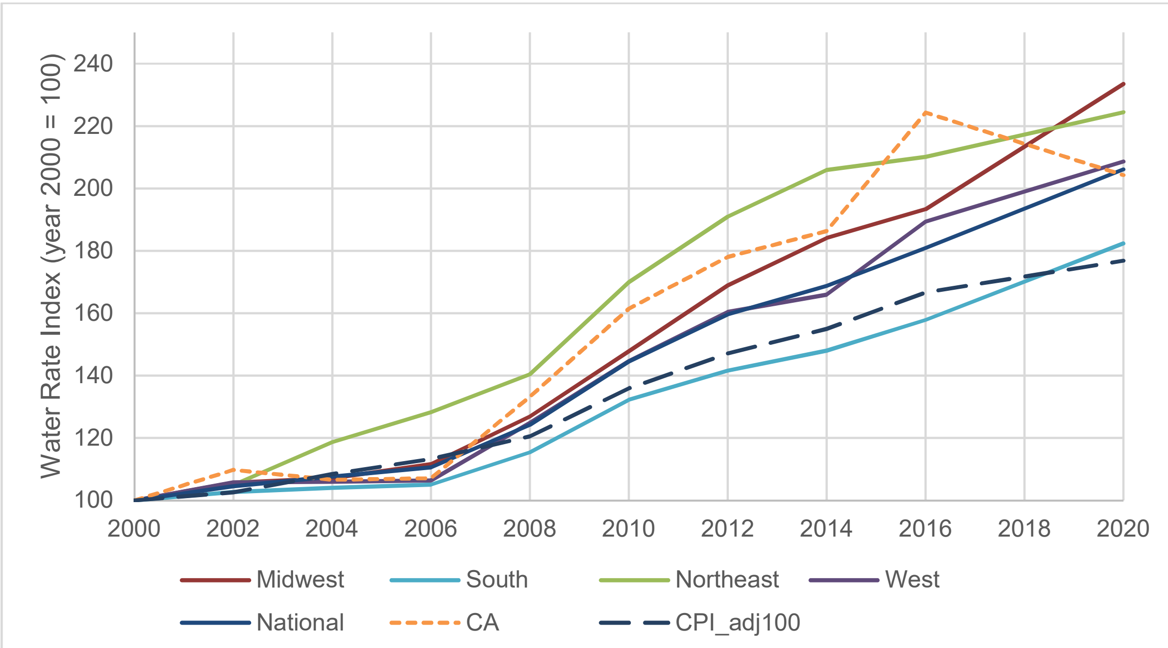


**Figure 2. Water rate index developed for the four Census regions, California, the nation, and the CPI.**

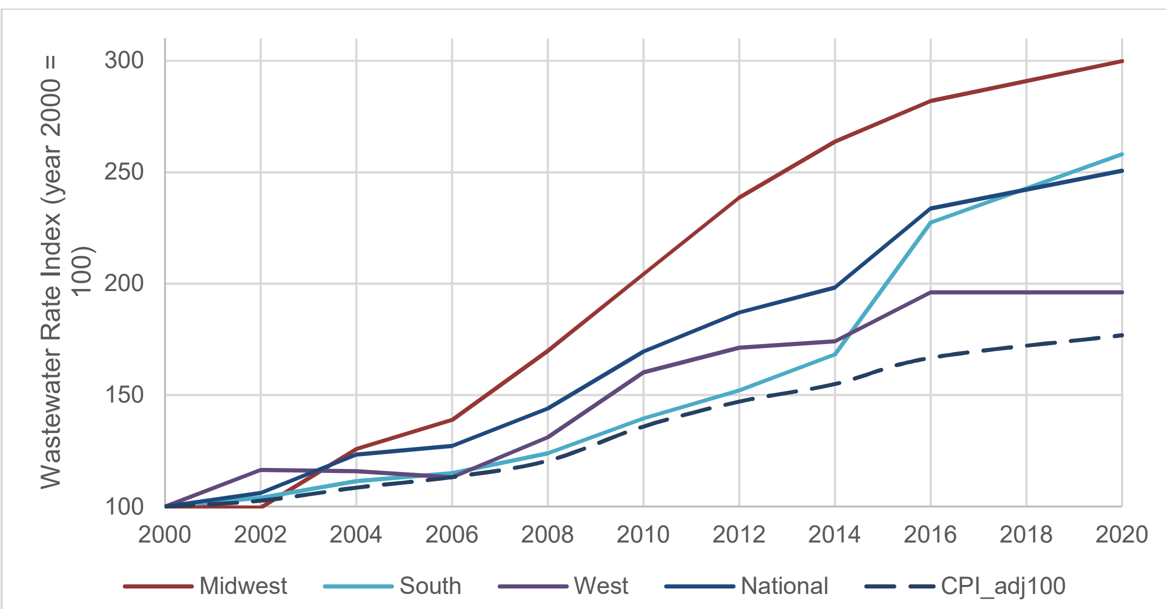


**Figure 3. Wastewater rate index developed for three Census regions, the nation, and the CPI.**

Although the BLS Water and Sewerage CPI generally exhibits an increasing trend, it indicates a lower rate increase (a flatter slope) than does the Raftelis/AWWA national trend for residential consumers, indicating that rates are rising more quickly than the Water and Sewerage CPI trend indicates. This difference could be attributed to how the Water and Sewerage CPI weighted the utility rates, whether the consumer consumption level was taken into account, and the different fixed charges included. Other factors may involve the sample construction and selection, as the CPI data were designed to be nationally representative, but not of rural areas. Finally, other causal factors may come into play as individual price quotes used by CPI may include credits and discounts as well as applicable taxes, which were not accounted for in the Raftelis data.

## 4.4 Predicting future rates

This study aims to assess the pace of change in the Raftelis/AWWA data by introducing a regression tool that compiles all available historical data to establish regional rate trends. A regional regression model can be trained to project future prices based on historical rate data. The pace of change observed in the historical data, combined with a selected confidence level, can predict future rates. Using our chained analysis, new survey data can be compared with predicted values within their associated confidence intervals to assess the new value given the trend established by historical data.

Using the historical rate trends, a linear regression was constructed for each Census region. As explained above, causal indicators were excluded from this model to avoid potential overfitting. Based on history, water and wastewater rates should exhibit an increasing trend. Although the trend may reflect data error due to the lack of a causal factor, the obtained results are consistent with the a priori expectations. The goodness-of-fit (R2) values for each regression model are shown in Table 5. Because all the adjusted R2 values are at or above 0.9, we are confident in the fitting and predictive capacity of the regional models.

**Table 5. Evaluation of goodness-of-fit water rate models for Census regions and California**

| Model | Midwest | Northeast | South | West | Calif. |
|---|---|---|---|---|---|
| *Water: $R^2$* | 0.94 | 0.97 | 0.93 | 0.92 | 0.91 |
| *Water: Adjusted $R^2$* | 0.93 | 0.97 | 0.92 | 0.91 | 0.90 |
| *Wastewater: $R^2$* | 0.98 | NA | 0.83 | 0.93 | NA |
| *Wastewater: Adjusted $R^2$* | 0.97 | NA | 0.80 | 0.92 | NA |

Fig. 4 and Fig. 5 show the predicted regional water and wastewater rate indexes for 2020 with a 95% confidence interval based on the historical data (2000–2016). Using the chained analysis results shown in Tables 3 and Table 4, we calculated the 2020 observed water and wastewater rate indexes (plotted in green). For both the Northeast (Fig. 4, panel a) and California (Fig. 4, panel e), observed rates are lower than the lower bound of the confidence intervals provided by the prediction models. California displayed an unexpected decreasing trend between 2016 and 2020 based on very few overlapping utilities (Table 3). Considering this result, we have reasonable doubt that 2020 Raftelis/AWWA data for California are inconsistent with the national pace of change. Investigating the raw data for California utilities in the 2016–2020 paired analysis, we noticed discrepancies in two of the volumetric rates for two of the six utilities. We consulted the web-published rates for those two utilities, which confirmed our assessment. In consultation with a Raftelis/AWWA analyst, we corrected two per-tier rates (Craley, personal communication, 2022). A new 2020 water rate index was calculated within the confidence interval obtained via historical training data (see the blue point in Fig. 4, panel e).

Given the limited number of paired comparisons for wastewater rates, Fig. 5 excludes Northeast and California results. Because the Midwest 2020 index is outside the predicted confidence interval and the Midwest and West both have limited wastewater utility samples for 2020 (see Table 4), the comparisons are inconclusive.

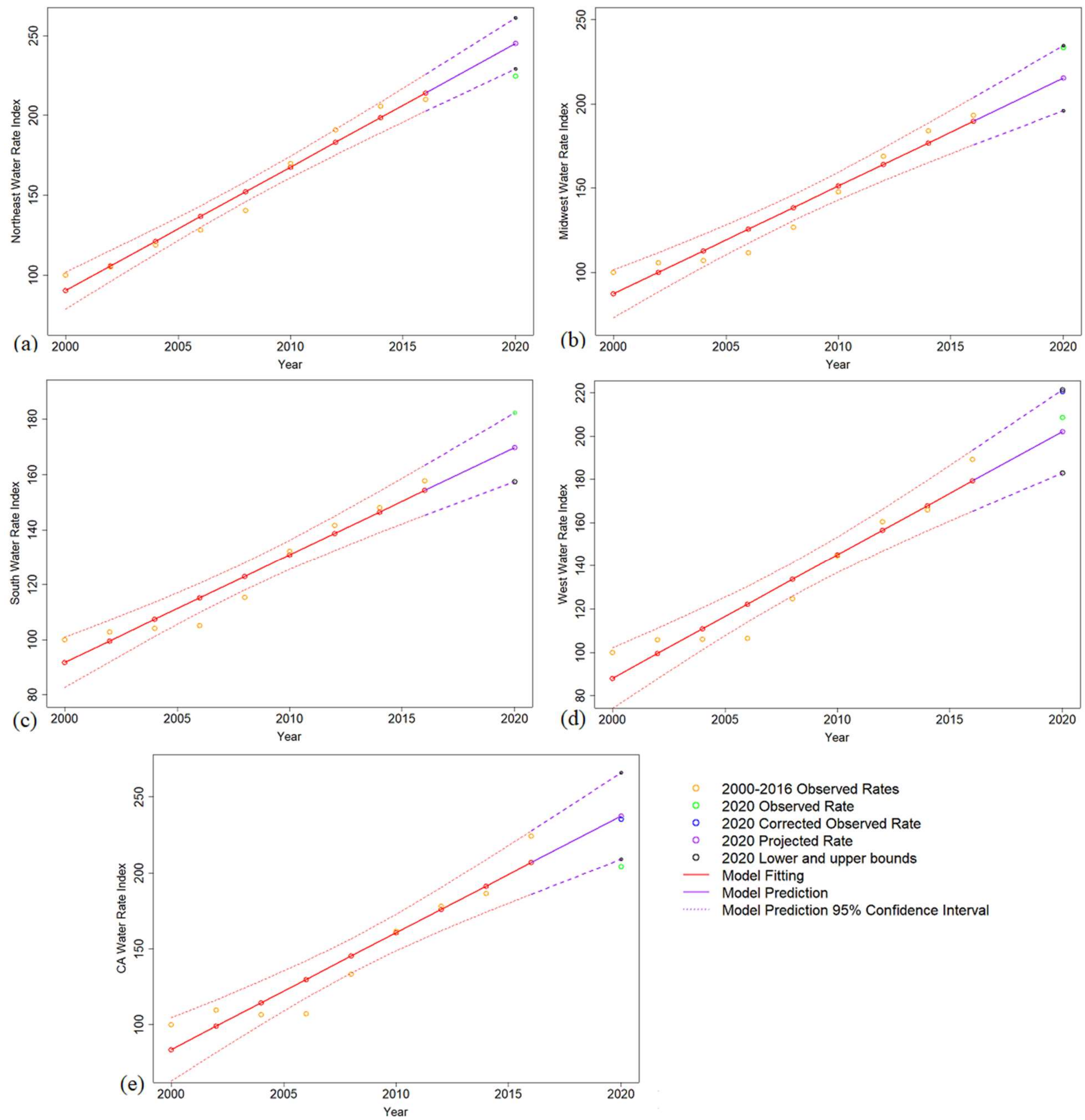

**Figure 4. Comparison of observed and predicted 2020 average water rates based on a linear regression trained by 2000–2016 Raftelis/AWWA survey data; panel a: Northeast, panel b: Midwest, panel c: South, panel d: West, panel e: California.**

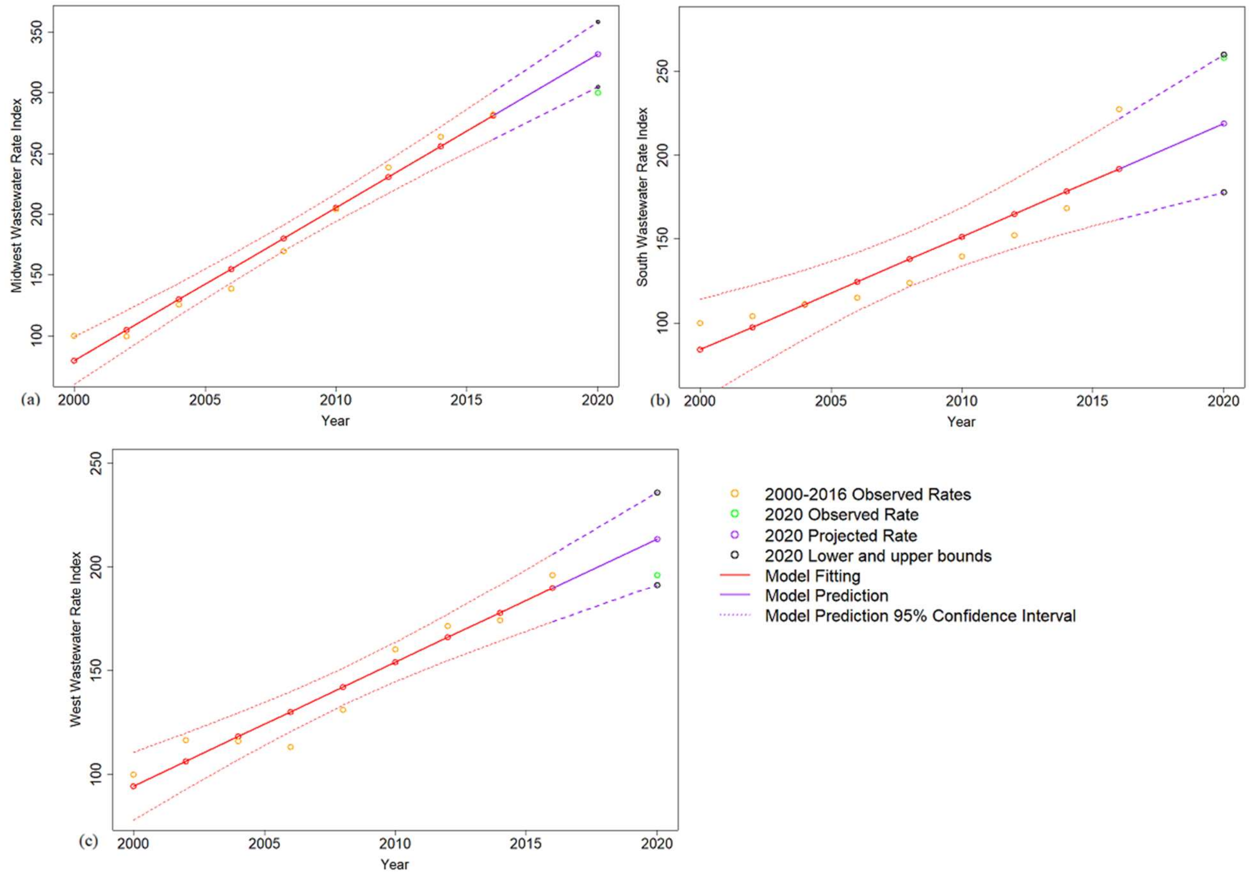


**Figure 5. Comparison of observed and predicted 2020 average wastewater rates based on a linear regression trained by 2000–2016 Raftelis/AWWA survey data; panel a: Midwest, panel b: South, panel c: West.**

It is important to acknowledge the constraints to using chained analysis to develop regression modeling, which include the following.

- Limited sample sizes for the paired comparison, in the case where the two surveys covered utilities having very different profiles (or few utilities appear in both surveys).
- Utilities have different service populations, and some states have no utilities, so that one utility's rate change represented more than 20% of the change in a Census region.
- The approach may not catch data errors if the observed rate falls within the confidence interval.
- Historical data may incorporate errors, affecting the prediction model.
- Reviewing raw data files for all utilities for all years would be labor-intensive. Most utilities do not make detailed rate data publicly available; therefore, only obvious data entry errors are easily identified.

# 5. DISCUSSION

Accurate estimates of national water and wastewater rates are essential for utilities and governmental agencies in their efforts to quantify monetary savings of conservation and efficiency programs. Indeed, both the U.S. DOE's Appliance and Equipment Standards Program and the U.S. EPA's WaterSense program employ these data in analytical models. Moreover, the availability of price data is particularly critical for cost-benefit analyses targeting a population subgroup with specific geographic or socioeconomic characteristics relative to equity considerations. As such, current sources from Raftelis/AWWA and BLS are vital in establishing price trends and improving program accounting, despite survey sample changes. However, given the myriad challenges ahead in continuing to supply reliable, clean, sufficient, and affordable drinking water, efforts to not only extend—but improve upon—current data sources for water and wastewater prices are critical in facilitating more robust assessments of program impacts.

Following analysis of Raftelis/AWWA data, we suggest that our analysis provides a more transparent methodology that can easily be updated across the time to capture utility-level rate changes. The regional-level estimates enable accounting for regional water and wastewater rate changes in order to more accurately quantify regional water savings achieved by energy conservation programs.

Our approach provides advancement in improving the quantity and quality of data available to analysts and that our regressions developed through chained analysis improve the ability to analyze current and future trends in water and wastewater rates. However, much work remains to be done. Some limitations on obtaining adequate robust data concern the differences between the two most accessible data sources (Raftelis/AWWA and the BLS) since both use different methodologies to develop their time series in terms of sample development, representation, and other factors.

First, a simple, randomized sample of the nearly 50,000 water utilities in the United States would need to include at least 382 utilities. (This accounts for a 95% confidence level and 5% margin of error. Stratifying the sample by region and utility type and size would introduce more complexity.) The Water and Sewerage CPI sample contains 600 to 700 quotes for water or sewerage service, representing hundreds of utilities. The BLS rotates through outlets every four years during the decade(s) between geographic sample revisions. Thus, the utilities having the largest service population in an area are sampled at four-year intervals. Raftelis/AWWA samples are generally smaller, ranging from 176 (in 2000) to 318 water utilities (in 2014). For each survey, Raftelis/AWWA relies on utilities voluntarily responding, with the number of overlapping utilities year-to-year ranging from 63 to 194.

Second, CPI data are nationally representative of urban areas given a time lag. The CPI sampling intervals mean that regional data were lower than Census population estimates in the South while overrepresenting the Northeast. Because no individual utility data are publicly available from the CPI, no regional variation can be explored. In addition, we know nothing about the sampled outlets in terms of size (small, medium, or large) or other characteristics. Also, CPI omits most multifamily residences, because BLS's definition of residential water and sewerage services encompasses only separately billed residential units. Given that multi-family units comprise over 25 percent of residential housing, this omission may be significant (Kiefer, et al. 2018).

Third, other causal factors may contribute to identifying different trends in the two data sources. CPI does not weight usage across rate tiers by gathering data on the percent of customers within each tier; instead, it uses multistage probability sampling to represent the price an average consumer pays for water and sewerage. In the absence of consumption data, usage by tier is disaggregated based on equal probability. It is unclear, however, how many CPI samples lack consumption data. Also, individual price quotes making up the CPI include credits, discounts, and applicable taxes. On the other hand, Raftelis/AWWA rates do not specify whether they account for credit, discount, or taxes on water and wastewater prices and do not report actual water consumption. The Methodology section describes how we dealt with the lack of consumption, revenue, and sales data to produce the best average national rate possible.

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2022 Winter report available at:
https://netforum.eei.org/eweb/DynamicPage.aspx?Action=Add&ObjectKeyFrom=1A83491A-9853-4C87-86A4-F7D95601C2E2&WebCode=ProdDetailAdd&DoNotSave=yes&ParentObject=CentralizedOrderEntry&ParentDataObject=Invoice%20Detail&ivd_formkey=69202792-63d7-4ba2-bf4e-a0da41270555&ivd_cst_key=00000000-0000-0000-0000-000000000000&ivd_prc_prd_key=CFDE0E20-CDBD-4FAF-B1B6-3CAAC6AE0327

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# Appendix A.

Price-determining characteristics for the Bureau of Labor Statistics' individual water and sewerage price quotes.

| Price-determining characteristics | Response options | Notes |
|---|---|---|
| Service priced | Water service<br>Sewer service<br>Water and sewer service | |
| Effective date of water rate schedule | | |
| Effective date of sewer rate schedule | | |
| Rate structure | Year-round<br>Seasonal (specify season) | |
| Consumption/billing period | Monthly<br>Bi-monthly<br>Quarterly<br>Triannual<br>Semi-annual<br>Annual<br>Other | |
| Territory | Single-rate structure<br>Inside city rate structure<br>Outside city rate structure<br>Other territory | |
| Tax jurisdiction | | |
| Basis of water charge | Flat rate per housing unit<br>Flat rate per unit based on house and/or lot size<br>Flat rate per type/number of receptacles<br>Metered rate | Complete if service includes water |
| Basis of sewer charge | Flat rate per housing unit<br>Flat rate per unit based on house and/or lot size<br>Flat rate per type/number of receptacles<br>Metered rate<br>Metered rate based on percent of water usage, %<br>Water charge includes sewer charge | Complete if service includes sewer |
| Flat rate water charge per housing unit | Flat rate water charge per housing unit, $ | Complete if basis of water charge is flat rate per housing unit |
| Flat rate sewer charge per housing unit | Flat rate sewer charge per housing unit, $ | Complete if basis of sewer charge is flat rate per housing unit |
| Flat rate per unit based on house and/or lot size | Lot size/front footage<br>Square footage | Complete if basis of charge is flat rate per |

| | | |
|---|---|---|
| | Number of stories<br>Other units | unit based on house and/or lot size |
| Flat rate per type/number of receptacles | Bath tubs<br>Showers<br>Sinks<br>Flush toilets<br>Washing machines<br>Outside spigots<br>Other receptacles | Complete if basis of charge is type/number of receptacles |
| Metered rate | Metered volume<br>Meter size<br>Base metered water rate schedule (rate blocks) | Complete if basis of charge is metered rate |
| Water charges | Water total flat rate per housing unit, $<br>Water total flat rate per house and/or lot size, $<br>Water total flat rate per type/number of receptacles, $<br>Water total metered charges, $<br>Water service charge, $<br>Water other additional charges, $<br>Water total charge, $ | |
| Sewer charges | Sewer total flat rate per housing unit, $<br>Sewer total flat rate per house and/or lot size, $<br>Sewer total flat rate per type/number of receptacles, $<br>Sewer total metered charges, $<br>Sewer service charge, $<br>Sewer other additional charges, $<br>Sewer total charge, $ | |
| Credits and discounts | Quick payment discount, $<br>Senior citizen discount, $<br>Credit/refund, $<br>Other discount or credit, $<br>Total charge after reductions | For water, sewer, or both |
| Total combined water and sewer charges after reductions | Combined charges after reductions, $ | |
| Taxes | Sales tax rate, %<br>Sales tax amount, $<br>Utility tax rate, %<br>Utility tax amount, $<br>Other tax rate, %<br>Other tax amount, $<br>Total taxes, $ | |
| Other price factors | | |
| Total charges after taxes | Total charges after taxes, $ | |

Note: Thanks to Jonathan Church of the U.S. Bureau of Labor Statistics for providing details on CPI methodology and for reviewing the CPI material in this paper.

# Appendix B.

Census population estimates for each Census region, 2000 to 2020[4]

| Year | Northeast (%) | Midwest (%) | South (%) | West (%) |
|---|---|---|---|---|
| 2000 | 19.0 | 22.9 | 35.6 | 22.5 |
| 2002 | 18.8 | 22.6 | 35.9 | 22.7 |
| 2004 | 18.6 | 22.4 | 36.2 | 22.9 |
| 2006 | 18.3 | 22.1 | 36.6 | 23.0 |
| 2008 | 18.0 | 21.9 | 36.9 | 23.2 |
| 2010 | 17.9 | 21.7 | 37.1 | 23.3 |
| 2012 | 17.8 | 21.5 | 37.4 | 23.4 |
| 2014 | 17.6 | 21.3 | 37.6 | 23.5 |
| 2016 | 17.4 | 21.1 | 37.9 | 23.7 |
| 2018 | 17.2 | 20.9 | 38.1 | 23.8 |
| 2020 | 17.3 (17.6) | 20.8 (21.7) | 38.1 (38.9) | 23.7 (21.9) |

Note: Housing percentages given in parentheses for 2020

[4] Population estimates:
2000 through 2009 data from https://www2.census.gov/programs-surveys/popest/tables/2000-2010/intercensal/state/st-est00int-01.xls (accessed 10 June 2024).
2010 through 2018 data from https://www2.census.gov/programs-surveys/popest/tables/2010-2019/state/totals/nst-est2019-01.xlsx (Accessed 10 June 2024)
2020 https://www.census.gov/data/tables/time-series/demo/popest/2020s-state-total.html (Accessed 10 June 2024)
Household estimates https://www.census.gov/data/tables/time-series/demo/popest/2020s-total-housing-units.html (Accessed 10 June 2024)