THE METROPOLITAN WATER DISTRICT OF SOUTHERN CALIFORNIA

Committee Item
INFORMATION

Finance, Affordability, Asset Management, and Efficiency Committee

6/9/2026 Committee Meeting

6a

Subject

Affordability of Water Services Study in Metropolitan's Service Area

Executive Summary

Attached is the final report and presentation for the "Affordability of Water Services in Southern California" study conducted by the University of California, Riverside (UCR), in partnership with The Metropolitan Water District of Southern California (Metropolitan) and Eastern Municipal Water District (Eastern). Phase 1 of the study focused on Eastern's service area, and the study was later expanded to include Metropolitan's broader service area across Southern California. The study valuated retail water service affordability trends from 2013 through 2024 using retail water agency, demographic, census, and water expenditure data, and also evaluated the potential impacts of Advanced Metering Infrastructure (AMI) on household water use and customer water bills.

Fiscal Impact

There are no fiscal impacts associated with this item.

Applicable Policy

Metropolitan 2026 Legislative Priorities and Principles -Section B 1. Improve water affordability throughout the region, especially for disadvantaged communities, without burdening existing ratepayers.

Related Board Action(s)/Future Action(s)

The item is provided for information only. No board action is requested.

Details and Background

Background

Metropolitan has been tracking water affordability issues for several years following the State's adoption of the Human Right to Water policy. Metropolitan has also supported efforts related to establishing the Safe and Affordable Drinking Water Fund, and affordability continues to be an important topic in regional water policy and planning discussions, including CAMP4Water stakeholder engagement efforts and panel discussions focused on affordability. As a wholesaler and cooperative of member agencies, Metropolitan does not provide retail water or set retail water rates. However, water affordability remains an important objective. Metropolitan works to keep its wholesale rates, charges, and property taxes as low as possible to reduce impacts on member agencies and their retail water customers in the service area.

To support a better understanding of regional retail water affordability trends, Metropolitan partnered with UCR and Eastern on a multi-phase affordability study. The study analyzed affordability trends across approximately 125 retail water agencies within Metropolitan's service area, including affordability challenges within lower-income and disadvantaged communities and the potential impacts of AMI implementation on household water use and customer water bills. Overall, the study found that affordability challenges were generally more pronounced in lower-income and disadvantaged communities, while AMI implementation showed potential to reduce household water use and customer water bills, although results varied across agencies and implementation approaches.

The study authors are Kurt Schwabe and Mehdi Nemati. Dr. Schwabe is a Professor of Environmental Economics and Policy at UCR whose research focuses on water affordability, water conservation, agricultural production, and environmental regulation. Dr. Nemati is an Assistant Professor of Environmental Economics and Policy at UCR whose work focuses on applied econometric methods, big data analysis, and water management policy issues.

Attachment 1 – Affordability of Water Services in Southern California

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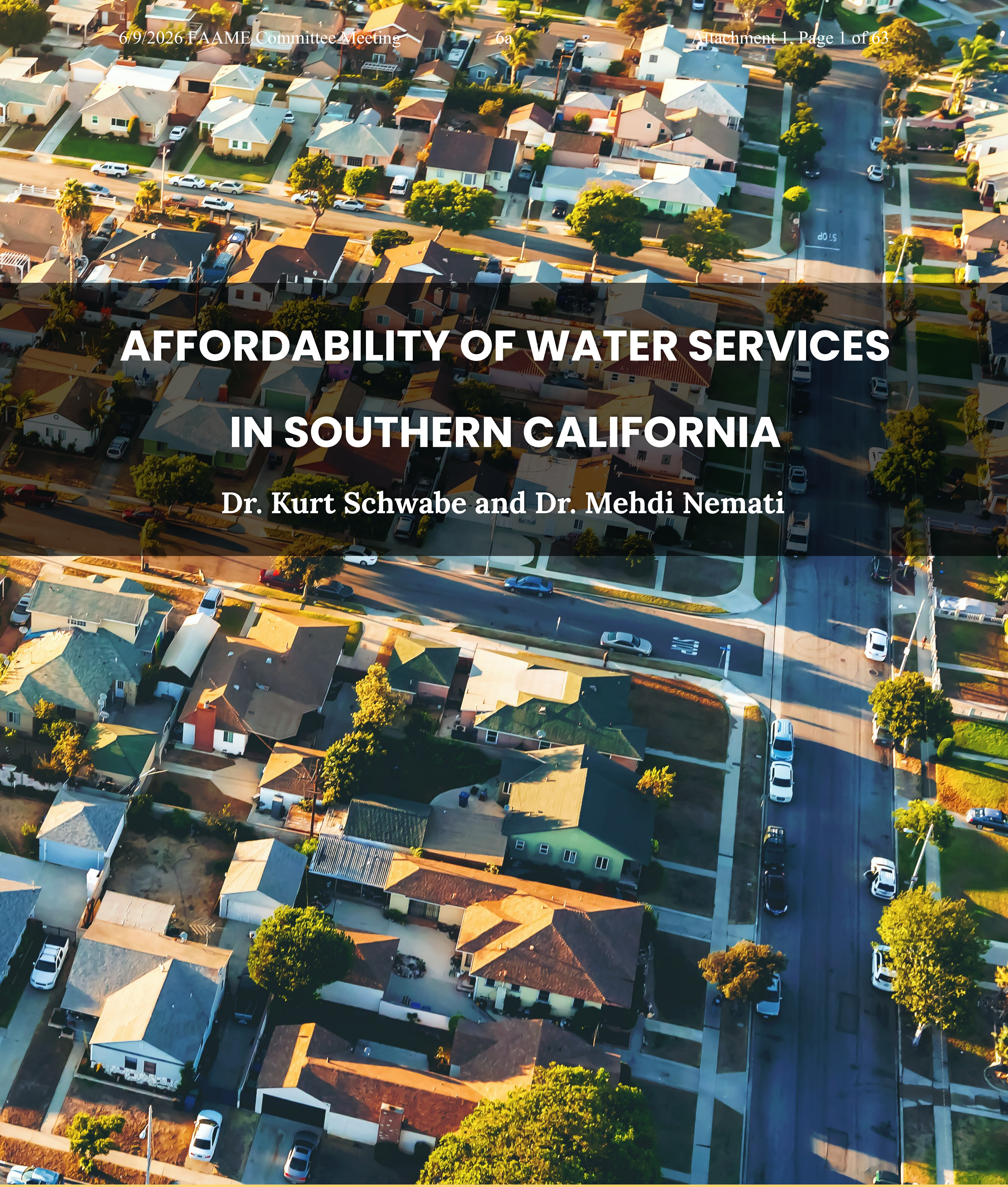

AFFORDABILITY OF WATER SERVICES IN SOUTHERN CALIFORNIA

Dr. Kurt Schwabe and Dr. Mehdi Nemati

UC RIVERSIDE | School of Public Policy

About the Researchers

Kurt Schwabe, M.S., Ph.D.

Dr. Schwabe's research focuses on economic issues associated with water use and water affordability, agricultural production, urban water conservation, ecosystem services, and environmental regulation. His papers have appeared in a wide range of peer-reviewed publications, including Nature Sustainability, Proceedings of the National Academy of Sciences, Journal of Risk and Uncertainty, Land Economics, and the American Journal of Agricultural Economics. He was co-editor of two books on water, titled Drought in Arid and Semi-Arid Regions: A Multi-Disciplinary and Cross-Country Perspective, and The Handbook of Water Economics. Dr. Schwabe received a BA in mathematics and economics at Macalester College in St. Paul, Minnesota, an MS in economics at Duke University, and a Ph.D. in environmental economics at the North Carolina State University. He currently is a Professor of Environmental Economics and Policy in the School of Public Policy at the University of California, Riverside and was a 2023–24 Fulbright Distinguished Chair Fellow of Science, Innovation, and Technology (Australia). Dr. Schwabe is a first-gen college student, and serves as Chair on the Board of Directors for Feeding America of Riverside and San Bernardino counties.

Mehdi Nemati, M.S., Ph.D.

Dr. Mehdi Nemati is an Assistant Professor of Environmental Economics and Policy in the School of Public Policy, University of California, Riverside. With a strong focus on applied econometric methods and big data analysis, Dr. Nemati's policy-oriented research is centered around economic issues associated with water management. He actively collaborates with government agencies and industry leaders in California, and beyond, to tackle pressing water policy challenges. Dr. Nemati earned Ph.D. and MS degrees in agricultural economics from the University of Kentucky. He currently leads the Water Dialogue Lab at UC Riverside.

Acknowledgements

The authors of this report would like to express their gratitude to the Metropolitan Water District of Southern California (MWD) and the Eastern Municipal Water District (EMWD) for their support of this research. We also extend our appreciation to the staff at MWD, and participating agencies, for providing the data used in our analysis. This project also benefited from research assistance provided by Idiana Salam and Kathryn Wren, former Master of Public Policy students at the University of California, Riverside. We also thank the staff of four agencies who worked with us to provide AMI data and descriptions. Finally, we are thankful to the Rachel Strausman for excellent copy-editing. Any errors within are the responsibility of the authors.

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Abbreviations

CCF	Hundreds of Cubic Feet
CPI	Consumer Price Index
GPCD	Gallons Per Capita Per Day
MWD	Metropolitan Water District of Southern California
MHI	Median Household Income
SFR	Single-Family Residential
WER	Water Expenditure Ratio
WSS	Water and Sewer Services

Executive Summary

Many water systems are grappling with aging and deteriorating infrastructure, changing customer bases, regulatory compliance, and climate change—all of which add to the growing costs of providing water services. At the same time, per capita water use has been declining partly because water agencies continue to put significant effort into increasing water use efficiency, particularly in the residential water use sector, with impressive results. In California overall, daily per capita water use declined by 37% between 1990 and 2020, with an especially rapid rate of decline since about 2008. The reduction in water use has been pronounced in Southern California (Lee, Nemati, and Dinar 2021; Lee, Nemati, and Dinar 2022). While increased water efficiency and conservation efforts may help lower customers' water bills, they also can jeopardize the stability of incoming revenues and compel systems to compensate with higher rates. With many agencies changing rates and rate structures as well as adopting new technologies such as Advanced Metering Infrastructure (AMI) as a response to long-term water use targets as well as short-term supply shocks (e.g., the recent drought), there is a general concern over the affordability of water to residential customers, especially lower-income customers.

This research evaluates the affordability of water services to single-family residential (SFR) customers. This research will be built on the previously completed study, titled "*Affordability of Water Services in the Inland Empire-Phase I*," which explored the water affordability for the Eastern Municipal Water District's (EMWD) service area. In the current phase 2 study, we expanded the study area to include member agencies of the Metropolitan Water District of Southern California (MWD) and the customers of those agencies to evaluate how water affordability has changed over time and across MWD's service area, as well as the water savings and household expenditure savings associated with AMI.

The overall objective of this project is to provide the MWD agencies and the water industry in general with a better understanding of the water expenditure ratios for single family residential (SFR) customers over time, with the understanding that such knowledge can identify and/or improve upon the role of regional programs in addressing affordability issues. This is especially important and timely given California's legislative effort—both current and recently vetoed—to address drinking water affordability (Assembly Bills AB 685 and AB 401; and Senate Bill SB 222). To meet these objectives, we have collected relevant data on water use (bill information), and demographic information from the US Census (e.g., income) for a majority of MWD member agencies and their customers (the study area). Specifically, the objectives of this project are:

Objective 1. Using water agency-level data to evaluate the affordability of water services at the district level.

In the process of achieving this objective, our deliverables will include:

1.1. Highlight how residential customers' expenditures on water services have changed from 2013 to 2024;

1.2. Measure the affordability of water services for residential customers over time and across water agencies;

1.3. Identify the affordability of water services in disadvantaged communities defined in CalEnviroScreen by CalEPA (SB 535 Disadvantaged Community);

1.4. Compare residential water expenditures with expenditures on other services (e.g., electricity, transportation, communications, and housing);

1.5. Investigate the relationship between retail water and sewer services (WSS) affordability measures and a variety of factors, including size of agency, rate structure, and housing characteristics (e.g., % rental).

To meet Objective 1, we developed household water expenditure data for each water provider in our dataset, with particular attention on agency-specific expenditures for 6 cubic hundred feet (CCF)[1] of water, or approximately 55 gallons per capita per day (gpcd) for an average household. Our dataset will include water service providers (wholesale and retail agencies) within the MWD service area. We have collected data on rate structures and levels from 2013–2024 for these agencies. In addition, we compiled income and other demographic information using the US Census data in the study agencies, and SB 535 Disadvantaged Communities data compiled from CalEnviroScreen, which CalEPA develops.

Objective 2. Using household-level data from a subsample of retailer agencies within MWD's service area, we investigated the role of AMI to address the following questions:

2.1. What is the impact on water consumption of replacing old meters with AMI-enabled meters?

2.2. What is the impact on water bills of replacing old meters with AMI-enabled meters?

[1] One CCF is equal to approximately 748 gallons and is a common billing unit.

2.3. Is there variation in this impact across agencies, and what might explain such heterogeneity?

To carry out Objective 2, it was essential to obtain household-level data for several agencies across a number of years. In collaboration with MWD and EMWD, we identified four agencies and collected/organized data measuring water use, household information, sewer cost (if applicable), total water cost, and AMI adoption.

Overall Findings: Water Services Affordability

The main findings associated with our analysis of water services affordability based on the sample of 125 retail agencies within MWD's service area include:

Residential water expenditures for 6 CCFs of water have, on average, increased between 2013 to 2024, but at a rate lower than inflation. After adjusting for inflation, the average amount households spent for 6 CCFs of water rose by approximately $10/month over the entire period (in real 2020$), or at an annual rate of approximately 1.71%. Income, as measured by median household income (MHI), increased by approximately 1.1% annually over the same time period, while the average annual inflation rate was slightly over 2.7%.

With water expenditures slightly outpacing median household income, on average, from 2013 to 2024, the Water Expenditure Ratio (WER) rose modestly across agencies in the MWDs service area. From 2013 to 2024, the WER increased from 0.74% to 0.76%, or around 0.24% annually, on average. The minor increase in WERs, which is a measure of water affordability, is consistent with the change in water expenditures for 6 CCFs slightly outpacing the change in income over that period. Notably, the WER ratio was significantly below California's State Water Resources Control Board (SWRCB) water affordability threshold of 1.5% of median household income (MHI) for 6 CCFs of water. Indeed, the number of agencies out of the 125 we analyzed with average annual WER above the state threshold ranges from a high of five (2024) to a low of one (2019). The share of households with WERs above 1.5% decreased over this period from slightly greater than 5.4% (~812,000 households) to approximately 4.4% (~550,000 households) annually. Of course, the prices and expenditures on other essential goods and services rose over this period as well, which the analysis does not consider.

For lower-income households, which we assume are represented by the 20th percentile income level at the census tract level, annual average WERs across the study area increased

slightly over time—from approximately 2.84 in 2013 to 2.95 in 2024—which is above the state threshold of 1.5. When using a 20th percentile measure of income to calculate the WER, the number of agencies with an average annual WER above the state threshold varied from 74 in 2020 to 84 in 2015. Agencies that were above the threshold had, on average, higher water expenditures for 6 CCFs ($51.57 vs $38.27) and lower income ($6,504 vs $10,962) on a monthly basis relative to those agencies with average WERs below the threshold.

In considering water affordability within communities that meet the state's criteria for Disadvantaged Community Status, WERs within DACs were approximately 53 to 78% higher than WERS in non-DACs, although significantly below the state's 1.5% threshold, on average. In only two of the twelve years analyzed were the expenditures on 6 CCFs of water for communities with DAC status higher than those in communities without DAC status (2013 and 2024); else they were slightly less (on average, less than $3 per month difference). Income in communities with DAC status was significantly lower than income in communities without DAC status, which gave rise to WERS being higher annually in communities with DAC status from 2013 through 2024. Overall, for communities with DAC status the WER, on average, reached a high of 1.02% in 2013 and a low of 0.84% in 2022 and 2023. The total number of households within communities with DAC status that were likely above the state's affordability threshold has generally decreased from 2013 through 2024 (from approximately 300,000 in 2013 down to nearly 203,000 in 2024).

Agency-related factors such as budget-based rates, providing wastewater services, and serving larger populations tend to associated with lower WERs. Relative to volumetric-based or tier-based water rates, agencies that use budget-based water rates tend to be associated with lower WERs, on average. Agencies that provide both water and wastewater services and serve larger populations also tend to be associated with lower WERs, perhaps due to economies of scale and scope that allow them to lower their average costs. Finally, agencies that have a higher share of rental properties within their boundaries tend to be associated with higher WERs, which would be expected if rental properties were associated with lower overall incomes on average. Development of water rates is a complex process dependent on a multitude of factors, and thus these associations are suggestive and not necessarily causal.

Overall Findings: AMI and Water Consumption/Bills

The main findings associated with the four agencies we studied that have implemented AMI to varying degrees over the past decade include:

> ***Water use by single-family residential customers in agencies that have implemented AMI has decreased from between 1.3 to 11.1%.*** There is significant variability in the outcomes of agencies installing AMI meters in residential communities, likely due to the differences in how AMI has been implemented and the stage of implementation across agencies. In some cases, the information is still centralized by the agency and provided to customers based on specific criteria related to household-specific anomalies in water use (e.g., water running constantly for over 24 hours). In another case, there were mandated (initially) opt-in requirements for a digital platform, either through a web interface or a mobile application.
>
> ***Average monthly water bills by single-family customers in agencies that have implemented AMI have decreased between $0.82/month and $31.05/month on average.*** Mirroring changes in water use, water bills for customers in agencies that have adopted AMI have seen a statistically significant and negative decrease, although only minimally for three out of the four agencies evaluated. Again, the level of reduction is likely tied to the degree of customer engagement with the new meters and the stage of implementation by the agency in customer engagement.
>
> ***While AMI adoption shows promise as a tool available to water agencies to help customers reduce water use and lower their water bills, the degree to which savings are realized will depend significantly on the level of implementation by the agencies and the degree of engagement with and by customers.*** The degree to which AMI ends up helping customers reduce water use and water bills in any appreciable manner will depend on a wide array of factors, including baseline and unintended leaks, incentives by customers to reduce leaks, the costs to and willingness of customers—including time costs—to engage with agency platforms to understand and respond to leak and water use patterns, including anomalies.

Introduction

Many water systems are grappling with aging and deteriorating infrastructure, changing customer bases, regulatory compliance, and climate change—all of which add to the growing costs of providing water services. At the same time, per capita water use has been declining, partly because water agencies continue to put significant effort into increasing water use efficiency, particularly in the residential water use sector, with impressive results. In California overall, daily per capita water use declined by 37% between 1990 and 2020, with an especially rapid rate of decline since about 2008. The reduction in water use has been pronounced in Southern California (Lee, Nemati, and Dinar 2021; Lee, Nemati, and Dinar 2022). While increased water efficiency and conservation efforts may help lower customers' water bills, they also can jeopardize the stability of incoming revenues and compel systems to compensate with higher rates. With many agencies changing rates and rate structures, as well as adopting new technologies such as Advanced Metering Infrastructure (AMI) as a response to both long-term water use targets as well as short-term supply shocks (e.g., the recent drought), there is a general concern over the affordability of water to residential customers, especially lower-income customers.

This research evaluates the affordability of water services to single-family residential (SFR) customers. This research will be built on the previously completed study, titled "Affordability of Water Services in the Inland Empire-Phase I," which explored the water affordability for the Eastern Municipal Water District's (EMWD) service area. In the current phase 2 study, we expanded the study area to include member agencies of the Metropolitan Water District of Southern California (MWD) and their customers to evaluate how water affordability has changed over time and across MWD's service area as well as what are the water savings and household expenditure savings associated with AMI.

The overall objective of this project is to provide the MWD agencies and the water industry in general with a better understanding of the water expenditure ratios for SFR customers over time, with the understanding that such knowledge can identify and/or improve upon the role of regional programs in addressing affordability issues. This is especially important and timely given California's legislative effort—both current and recently vetoed—to address drinking water affordability (Assembly Bills AB 685 and AB 401; and Senate Bill SB 222). To meet these objectives, we have collected relevant data on water use and water bills from a survey of water agencies (e.g., websites, emails, phone calls, water plans) and demographic information from the US Census (e.g., income) for a majority of MWD member agencies and their customers (the study area).

Part 1: Analysis of Water Affordability at the Retail Level

1.1: Introduction

In this section, we focus on agency-level data to better understand how retail water affordability within the MWD service area varies across the region over time and in comparison to California State-defined affordability criteria. While there are a number of affordability criteria identified by the state and in the literature on water affordability (Nemati and Schwabe 2022; Cardoso and Wichman 2022; Mack and Wrase 2017; Goddard, Ray, and Balazs 2021; Teodoro 2018, 2019; Patterson, Bryson, and Doyle 2023),[2] for the purpose of this report, we focus primarily on the water affordability ratio, although referred to here as a *Water Expenditure Ratio*, WER, defined in general terms as:

$$Water\ Expenditure\ Ratio_{at} = \frac{Water\ Expenditures_{at}}{Income_{at}}$$

where "a" represents agency and "t" represents time, or year. Given this is a district-level analysis, and with a focus on the level of water for indoor use, we fix the level of water at 6 CCF, or about 55 gallons per capita per day (gpcd), for an average household. As such, the numerator is calculated by including all the costs a customer in district "a" would pay for 6 CCFs of water, including fixed costs and charges. Since this is a district-level analysis, water expenditures for 6 CCF will vary across retail water agencies but not within an agency.

Income in our analysis will be represented by a number of different measures. The most widely used measure is median household income, MHI. For our analysis, MHI will be the average MHI across census tracts within an agency's boundaries. Alternatively, and to better represent affordability to lower-income households, we also evaluate WERs using the average 20th percentile income level across census tracts within a district. This is calculated using population-weighted income categories within each census tract. Finally, we consider the MHI within districts designated as Disadvantaged Communities (DAC).

Analyzing water affordability over time and across retail agencies is especially important and timely given California's legislative effort—both current and recently vetoed—to address drinking water affordability (Assembly Bills AB 685 and AB 401; and former Senate Bill SB 222). The benefit of developing water affordability measures throughout MWD member retail agencies

[2] For a summary of the major water affordability measures, see SWRCB, SAFER report https://www.waterboards.ca.gov/drinking_water/certlic/drinkingwater/documents/needs/2024/2024-needs-assessment.pdf and dashboard https://www.waterboards.ca.gov/drinking_water/certlic/drinkingwater/saferdashboard.html

in Southern California is that such information can be used to inform policymakers about the magnitude of water affordability challenges within their region, as well as how these challenges vary across the region and over time.

1.2 Data

There are 221 retail water agencies within MWD's service area (Figure 1-1).[3] Focusing on these retail water agencies, we collected data for this study through an extensive survey of water agencies on their residential water prices, pricing structures, and billing cycles from 2013 to 2024. The survey was conducted through a combination of an extensive review of the agencies' websites (e.g., relevant financial information, water plans), follow-up emails, and phone interviews. The final dataset includes 125 retail water agencies in the MWD service area. Notably, these 125 retail water agencies serve roughly 5,165,095 households in Southern California, or approximately 87% of the total number of households served by the retail water agencies in the MWD service area.[4]

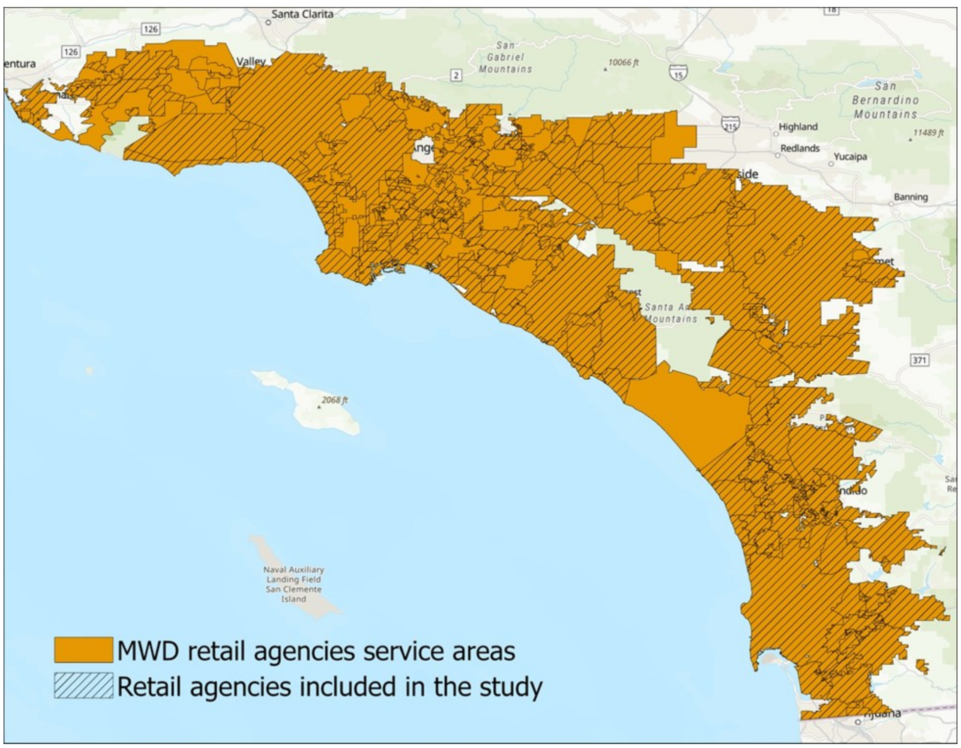

Figure 1-1. Water retail agencies in the MWD service area.[5]

[3] MWD is a wholesale water agency that sells water to retail water agencies as well as other wholesale agencies who then sell water to their own retail water agencies. For our analysis, the approximately 221 retail water agencies include MWD's retail agencies as well as the retail agencies of the MWD's wholesale water agencies within the region.

[4] For the remaining agencies that aren't included in this analysis, we were not able to gather information on their water prices over the time period of the analysis. Most of the retailers that were not included are smaller entities, including some universities. Also, since multiple communities may be served by a single water agency, there may be more communities than the 221 identified here.

Next, we merged these datasets with other data sources from the California Department of Water Resources (DWR) and the State Water Resources Control Board (SWRCB) on water agency characteristics (e.g., ownership type and agency service area population) and service area boundaries. In terms of ownership, of the 125 agencies in our dataset, 107 are under local government ownership, while 18 are privately owned. In addition, we compiled income and other demographic information using the US Census data in the study agencies. We also accessed data from the SB 535 Disadvantaged Communities data compiled from CalEnviroScreen, which CalEPA develops. As indicated in Figure 1-2, there is significant variation in annual median household income (MHI) levels at the census tract level. This also translates to agency-level variations in the MHI, in which the weighted MHI in 2023 ranges from $20,805 to $257,468.

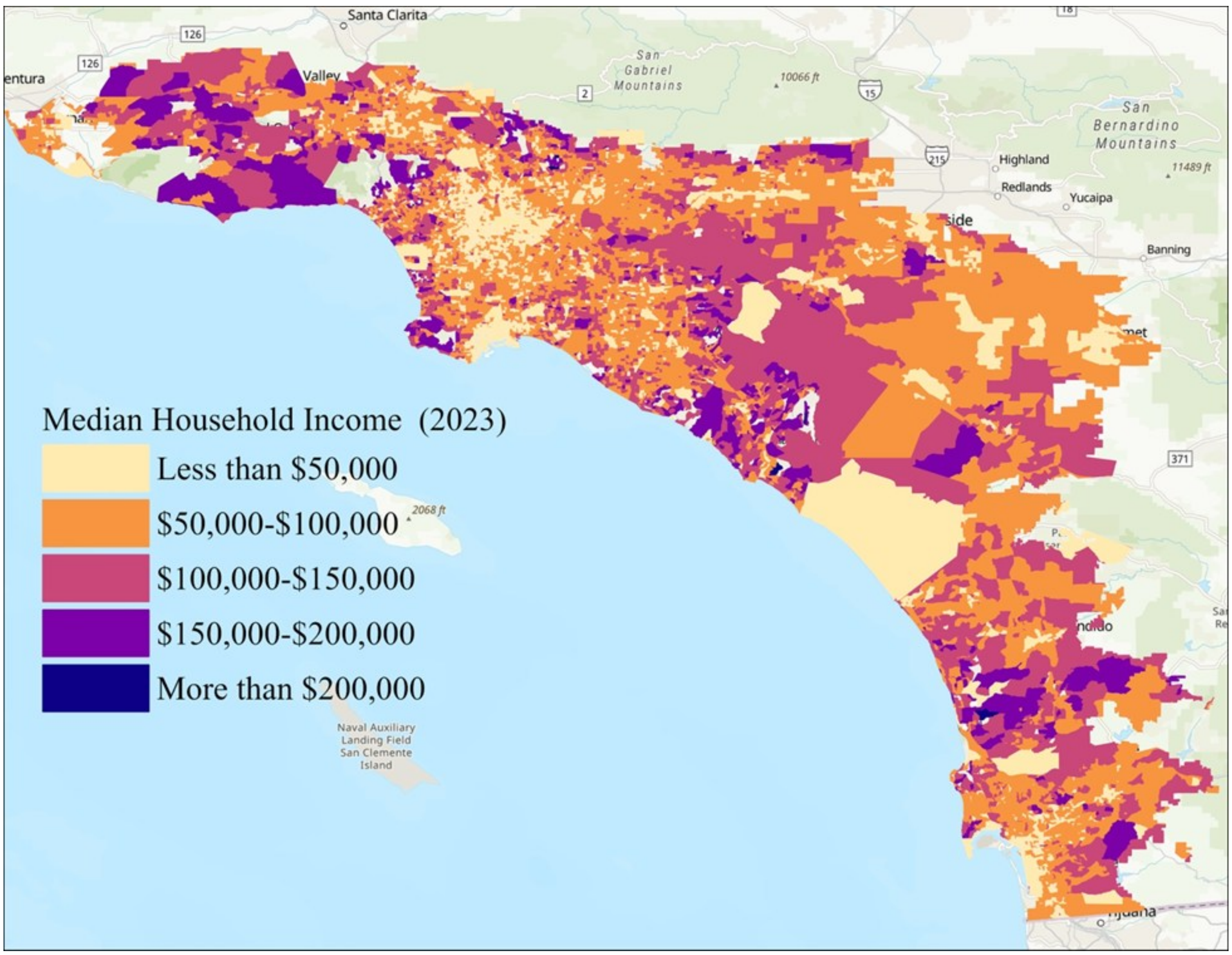

Figure 1-2. Median Household Income (MHI) in 2023 at the census tract level

[5] The large orange area along the coast and below the Santa Ana Mountains is the Pendleton Military Base.

1.3 Water Expenditure and Affordability Trends

With the data described above, we evaluate changes in water affordability by combining measures of the expenditures households would make for particular types of water services with the income available for such services. To evaluate changes in water expenditures for a particular level of water use across retail agencies within MWD's service area over time, we first adjust all costs/expenditures to similar units. As such, all costs are adjusted for inflation to 2024 dollars.[6] With the focus of Part 1 of this report on water affordability, our analyses target the costs (household expenditures) for 6 CCF per month which is nearly equivalent to approximately 55 gpcd for the average family size in California, and similar to recent efficiency standards set in California State law (California Department of Water Resources and State Water Resources Control Board, 2018).[7]

Table 1-1. Summary statistics (2024 dollars) - 6 CCF

Year	Water Expenditure ($/6 CCF)	MHI ($/month)	WER	Inflation rate (%)
2013	45.43	7,585	0.74	-
2014	42.61	7,529	0.69	1.62
2015	42.76	7,595	0.69	0.12
2016	45.28	7,743	0.72	1.26
2017	46.43	7,929	0.71	2.13
2018	46.52	8,138	0.70	2.44
2019	48.75	8,382	0.70	1.81
2020	49.97	8,586	0.70	1.23
2021	50.02	8,701	0.69	4.70
2022	48.16	8,789	0.65	8.00
2023	48.96	8,857	0.65	4.12
2024[9]	54.75	8,600	0.76	2.95

Note: WER is calculated as the average WER across all census tracts in our sample of agencies (125) across MWD's service area.

[6] Unless otherwise noted, all dollars will be normalized to $2024 using the U.S. BLS Consumer Price Index for All Urban Consumers—CPI-U (available at https://data.bls.gov/pdq/SurveyOutputServlet)
[7] Efficiency standards decreased from 55 to 47 gpcd in January 2025 and will decrease further to 42 gpcd in 2030.
[8] The Consumer Price Index (CPI) for the Los Angeles area from 2013 to 2024 was obtained from the U.S. Bureau of Labor Statistics (BLS). The annual CPI values are as follows: 232.957 (2013), 236.736 (2014), 237.017 (2015), 240.007 (2016), 245.120 (2017), 251.107 (2018), 255.657 (2019), 258.811 (2020), 270.970 (2021), 292.655 (2022), 304.702 (2023), and 313.680 (2024).
[9] Income data from the census was not available for 2024 at the time of this report; thus 2023 data was used.

Table 1-1 also lists the average median household income (MHI) per month for households within the retail areas associated with MWD's service area over time. As shown, income has increased, on average, from 2013 to 2024 by 1.1% annually. The last column illustrates how the Water Expenditure Ratio (WER—which is calculated as the water expenditures for 6 CCFs divided by the median household income as measured within a census tract) has changed over time across MWD's service area.[10] In 2013, the WER was 0.74, while in 2024, the average WER across retail agencies was 0.76, representing a slight increase of 0.24% annually.

Of course, water rates differ across water agencies due to a variety of factors, including but not limited to the size of the agency, access to alternative water sources, water quality challenges, and water pricing structure. Figure 1-3 illustrates how the WER varies across agencies and time. The box height illustrates the 25th and 75th percentiles for the WER across retail agencies, while the thick line in the middle represents the median value (50th percentile). The lines above and below the boxes represent the 95th percentiles. The red line identifies the state's threshold level of 1.5 for the water affordability ratio associated with water expenditures for 6 CCFs. Agencies that have WER's above the state's threshold are identified by dots. Figure 1-3 suggests that the average WER across retail agencies hasn't varied significantly over the past decade. Importantly, when this agency-specific average WER is calculated with income represented by the median household income (MHI), few agencies have WERs above the state's threshold of 1.5. As shown, out of the 125 agencies we evaluated, the number of agencies whose WER exceeded the state's threshold ranged from a high of five in 2024 to one in 2019.

While Figure 1-3 illustrates—at the retail agency level—that the number of agencies above the state's affordability threshold is relatively small, these are averages across census tracts within each retail agency. In calculating the WER for any particular agency, the numerator of the WER will not change annually across census tracts. Yet, the denominator will, since it is measured as the median within a census tract. As such, significantly more census tracts are above the 1.5 threshold than agencies. Whether a census tract is above the 1.5 threshold will depend on both the water expenditures that appear in the numerator of the WER equation (and which depend on an agency's water rates and pricing structure) as well as census-tract level representation for income.

[10] The WER in these tables is the average across census tracts, not agencies; thus, it is influenced more heavily by agencies with more census tracts.

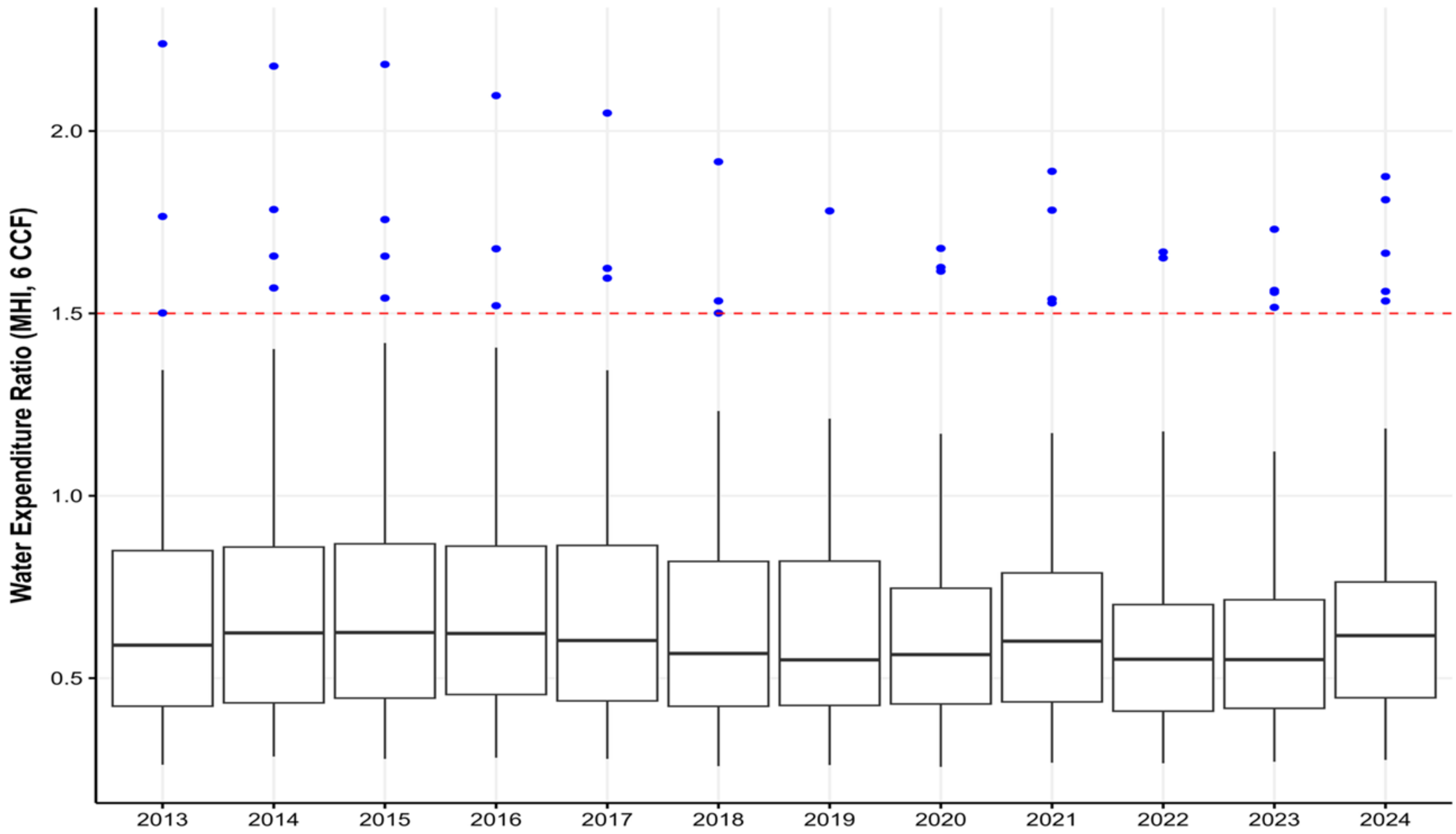

Figure 1-3. Water Expenditure Ratio (6 CCF) over time across retail agencies in the MWD service area (2013–2024).

Notes: The thick black line represents the median value, with the upper and lower edges of the box representing the 75th and 25th percentiles, respectively; lines above and below the box represent the 95th percentile values. The red dashed line indicates the 1.5% threshold (water board). The number of agencies with WER above 1.5% is 3, 4, 4, 3, 3, 3, 1, 3, 4, 2, 4, and 5 from 2013 to 2024, respectively.

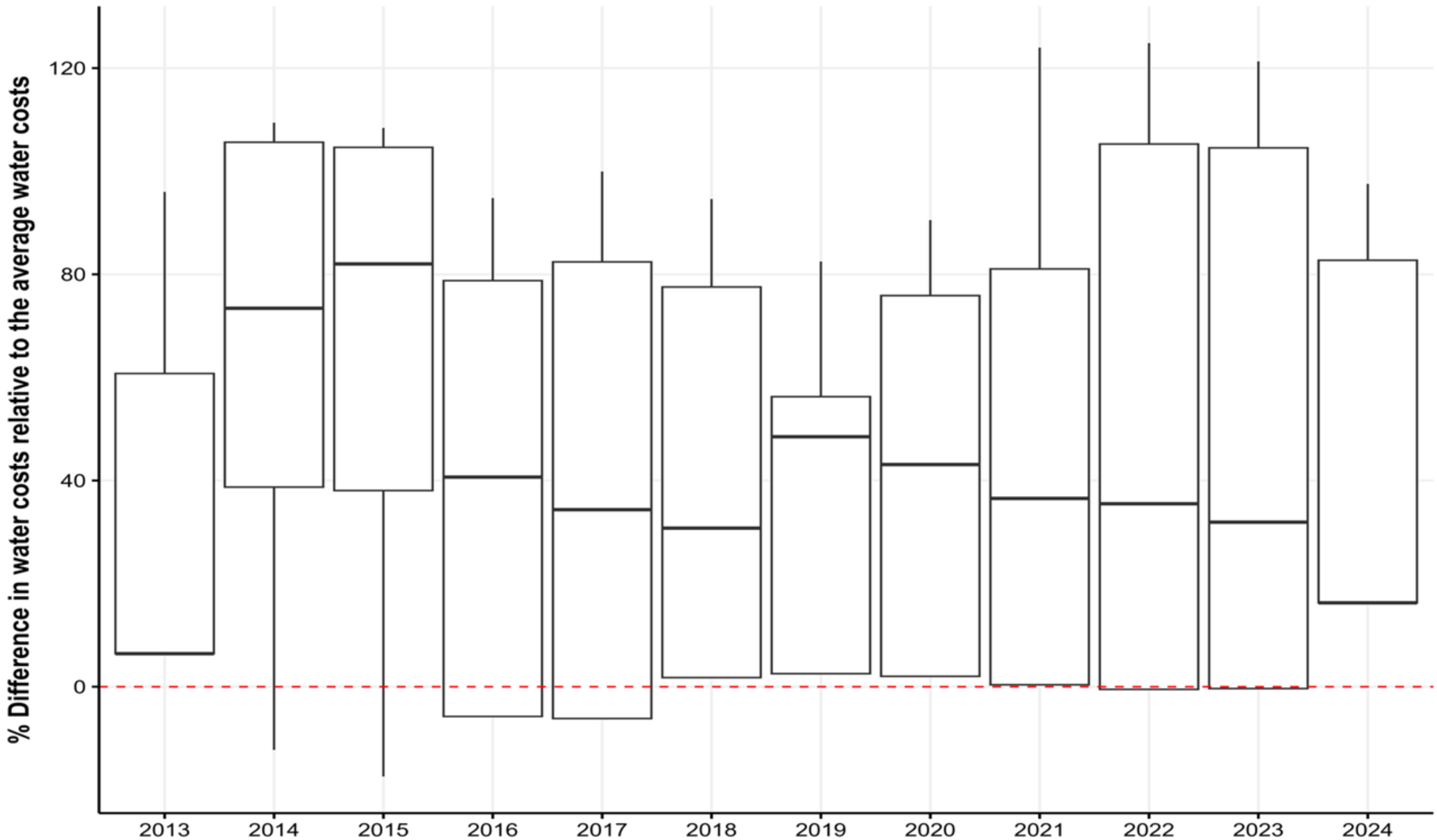

Figure 1-4. Percentage difference in water costs relative to the average water costs for the census tracts with WER above 1.5%.

Notes: Thick black line represents median value, with the upper and lower edges of the box representing the 75th and 25th percentiles, respectively; lines above and below the box represent the 95th percentile values. On average, the water cost for 6 ccf is $50.84 for agencies below the 1.5% threshold and $88.41 for those above it.

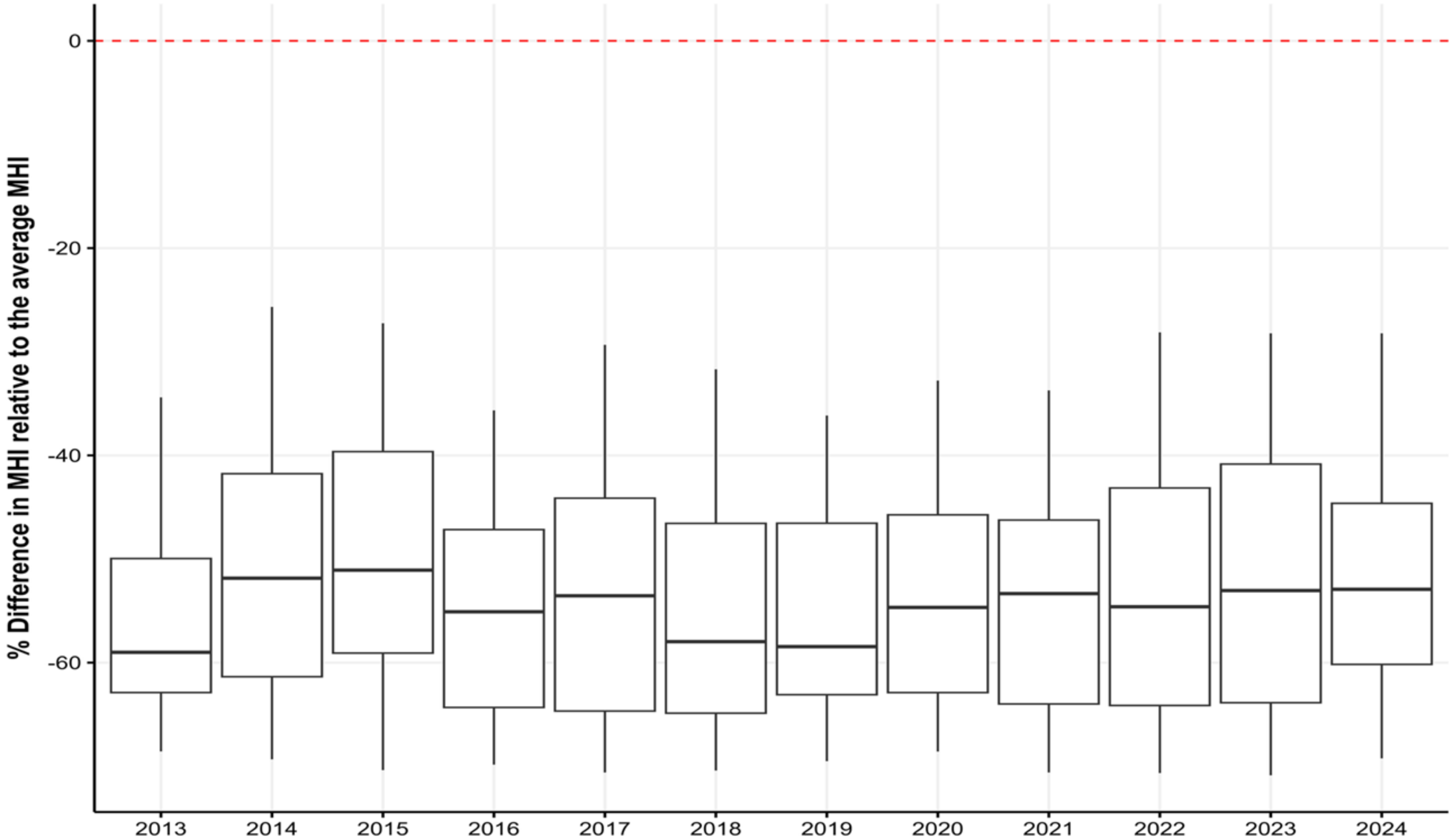

Figure 1-5. Percentage difference in MHI relative to the average MHI for the census tracts with WER above 1.5%.

Notes: Thick black line represents median value, with the upper and lower edges of the box representing the 75th and 25th percentiles, respectively; lines above and below the box represent the 95th percentile values.. On average, the MHI is $9,289 for agencies below the 1.5% threshold and $5,152 for those above it.

Figures 1-4 and 1-5 illustrate how census tracts with WERs above the 1.5 threshold differ from census tracts with WERs below the 1.5 threshold. With respect to water expenditures, Figure 1 -4 illustrates that water expenditures for census tracts with WERs above the 1.5 threshold range from around 6% higher (2013) to over 80% higher (2015), on average, relative to census tracts with WERs below the 1.5 threshold. On average, the water expenditures for six ccf are $50.84 for agencies below the 1.5% threshold and $88.41 for agencies above it. With respect to income, Figure 1-5 shows that the monthly MHI for census tracts with WERs above the 1.5 threshold ranges between 51 and 59% lower, on average, relative to census tracts with WERs below the 1.5 threshold. The MHI is $9,289 for agencies below the 1.5% threshold and $5,152 for those above it, on average.

1.4 Affordability of Water Services for Lower Income Communities

To better represent water affordability challenges for lower-income households, the 20th percentile income is used to calculate the Water Affordability Ratio (WAR) rather than the Median Household Income (MHI).[11] Table 1-2 presents the average water expenditures, 20th percentile income, and WER across the 125 MWD retail agencies we evaluated. As expected, the 20th percentile income is significantly lower in Table 1-2 than in Table 1-1, and consequently, the WERs are higher, ranging from a low of 2.47 in 2022 to a high of 2.95 in 2024. When using the 20th percentile income level by census tract, the average WER within the region exceeds the state's 1.5 threshold for each year from 2013 to 2024.

Figure 1-6 illustrates how WERs vary across agencies and time when income is represented by the 20th percentile within each census tract. Again, the box height illustrates the 25th and 75th percentiles for the WER across retail agencies, while the thick line in the middle represents the median value (50th percentile). The lines above and below the boxes represent the 95th percentiles. The red line identifies the state's threshold level of 1.5 for the water affordability ratio associated with water expenditures for 6 CCFs. Agencies that have WERs above the state's threshold are identified by dots. Similar to Figure 1-3, the average WER across retail agencies hasn't varied significantly over the past decade, with a slight decrease in the average WER up through 2023, where as 2024 experienced a slight increase. A significant difference with what is shown in Figure 1-3 is the number of agencies whose WERs are above the state

[11] Using the 20th percentile, or lowest quintile, income has become a common approach to represent income for lower income households (Teodoro 2019). A unique element to the approach taken here to estimate the 20th percentile income is to weight each income-category by its respective population (midpoint of population range) for each census tract. This differs from many studies that calculate the 20th percentile income with the 20th percentile of the median household income values for each census tract. The approach we take is a more accurate representation of the 20th percentile income.

threshold when it is calculated using the 20th percentile income rather than the MHI. As shown, out of the 125 agencies we evaluated, the number of agencies with an average WER above 1.5% ranged from 74 in 2019 to 84 in 2015.

Table 1-2. Summary statistics (2024 dollars) - 6 CCF 20th percentile income[12]

Year	Water Expenditure (6 CCF)	MHI ($/month)	WER
2013	45.43	2,347	2.84
2014	42.61	2,311	2.63
2015	42.76	2,324	2.62
2016	45.28	2,382	2.73
2017	46.43	2,441	2.70
2018	46.52	2,522	2.62
2019	48.75	2,607	2.63
2020	49.97	2,675	2.65
2021	50.02	2,714	2.58
2022	48.16	2,712	2.47
2023	48.96	2,729	2.50
2024[9]	54.75	2,649	2.95

Figures 1-7 and 1-8 replicate Figure 1-4 and 1-5, yet using the 20th percentile income to calculate the WER rather than the MHI, and highlight how the expenditures and income for those census tracts above the 1.5 threshold differ from those below the threshold. With respect to water expenditures, Figure 1-7 suggests that water expenditures for census tracts with WERs above the 1.5 threshold (and using a 20th percentile income value) are higher, on average, than those with WERs below the 1.5 threshold. On average, the water expenditures for 6 CCF are $38.27 for agencies below the 1.5% threshold, and $51.57 for those above it. With respect to income, Figure 1-8 shows that the 20th percentile income in census tracts with WERs above the 1.5 threshold is lower, on average, relative to census tracts with WERs below the 1.5 threshold. The 20th percentile income, on average, is $10,962 for agencies below the 1.5% threshold and

[12] It may be surprising that the WER in Table 1-2 has not significantly changed over time, which suggests that—on average—retail water has become more affordability if the only metric used is the WER. It should be emphasized that the estimates provided here are in real dollars, both for income and water expenditures, and thus provide a more accurate picture of real purchasing power after controlling for inflation. Second, these expenditures are for water expenditures based on 6 CCFs. As such, for retail water agencies who use a tiered water pricing structure, the increase in water costs they pass onto customers may appear—in some fraction-in the upper pricing tiers and thus may not show up in the expenditures on 6 CCFs. Finally, these are averages across retail member agencies and thus do not reflect potential variability across the agencies.

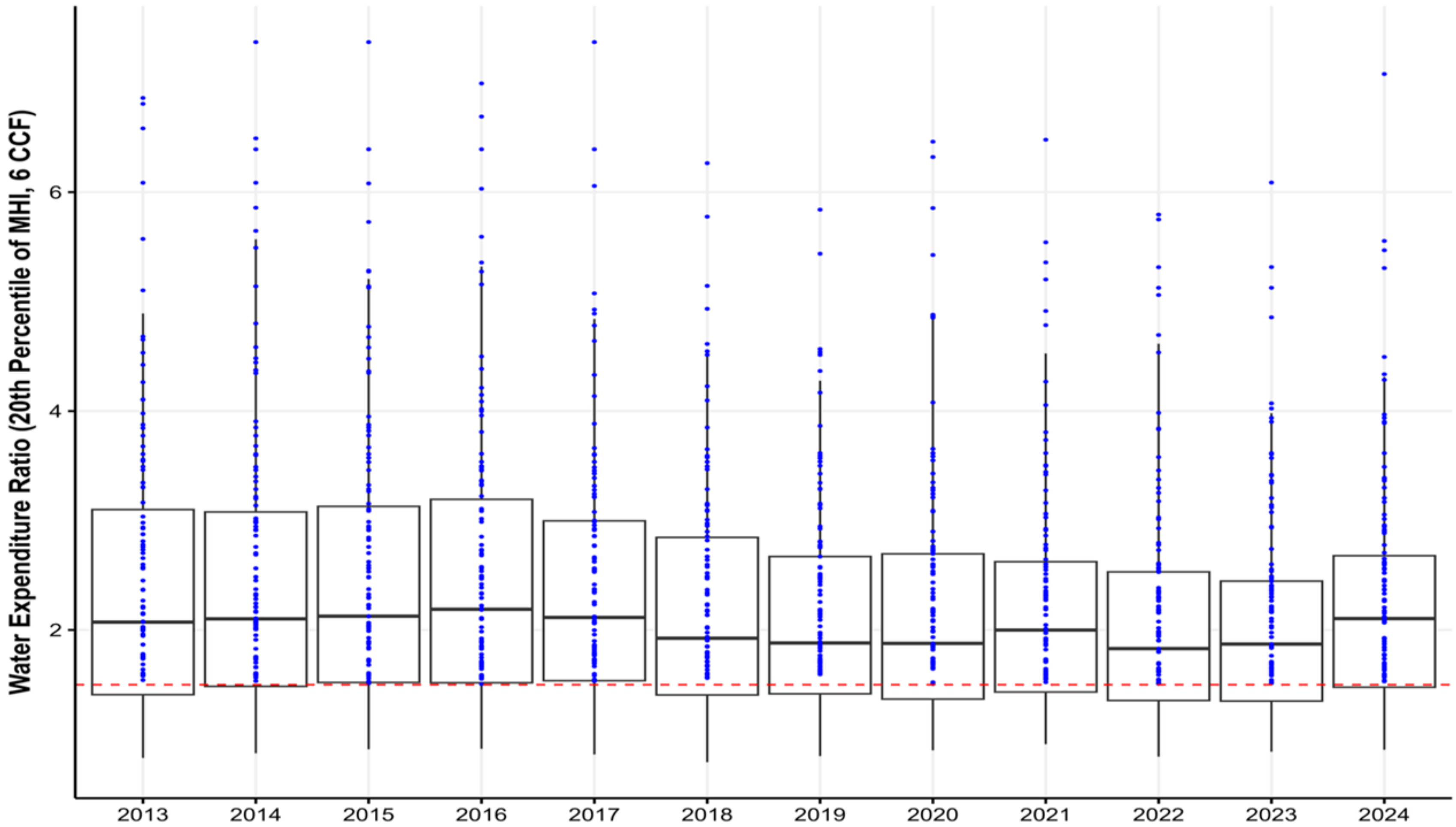

Figure 1-6. Water Expenditure Ratio (6 CCF) at the 20th percentile of MHI over time across retail agencies in MWD service area (2013–2024).

Notes: The Thick black line represents the median value, with the upper and lower edges of the box representing the 75th and 25th percentiles, respectively; lines above and below the box represent the 95th percentile values. The red dashed line indicates the 1.5% threshold (Water board). The number of agencies with WER 20th above 1.5% are 79, 82, 84, 83, 83, 77, 74, 75, 81, 74,75, and 82 from 2013 to 2024, respectively.

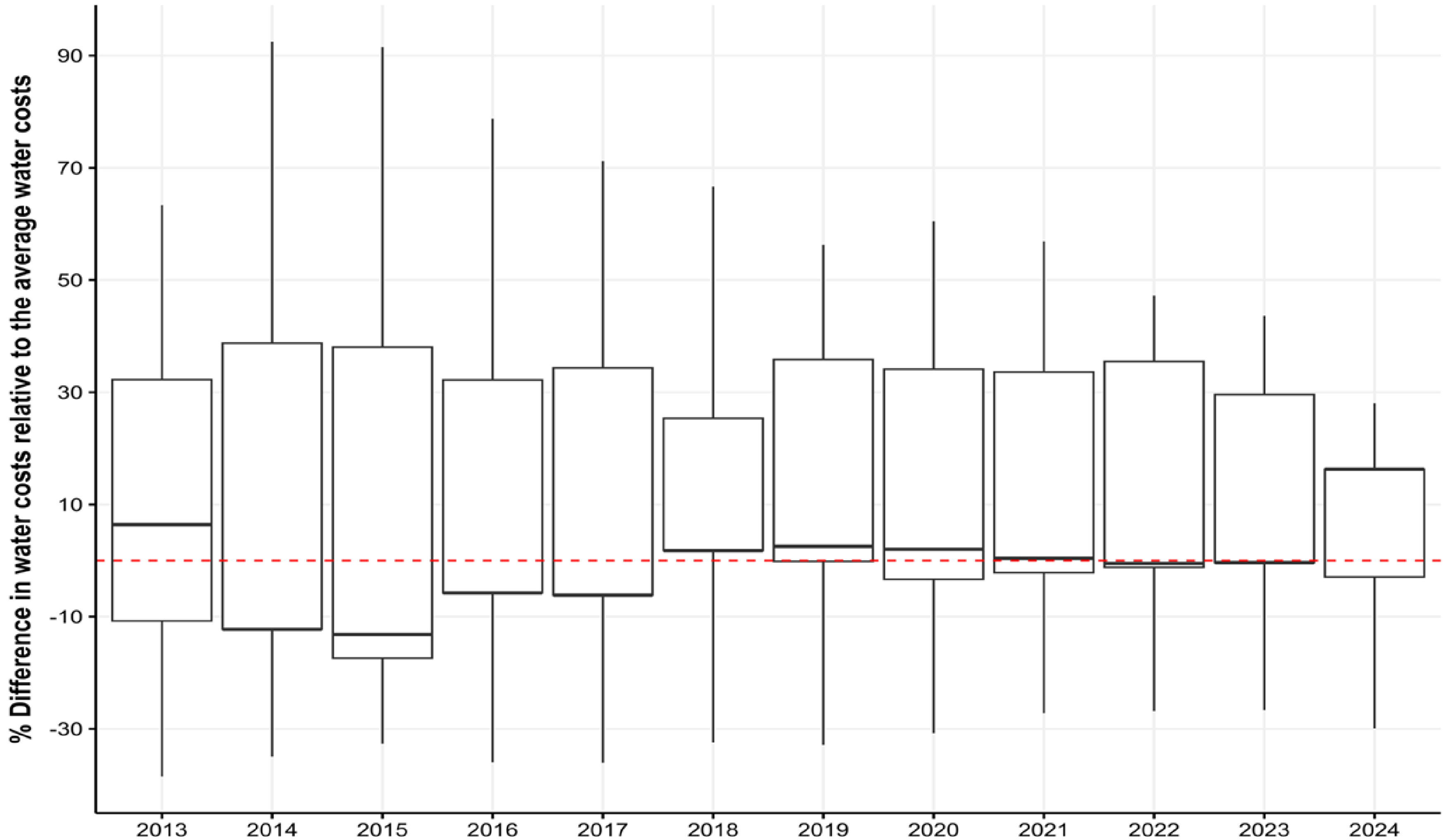

Figure 1-7. The percentage difference in water costs relative to the average water costs for the census tracts with WER 20th is above 1.5%.

Notes: The thick black line represents the median value, with the upper and lower edges of the box representing the 75th and 25th percentiles, respectively; lines above and below the box represent the 95th percentile values. On average, the water cost for six ccf is $38.27 for agencies below the 1.5% threshold and $51.57 for those above it.

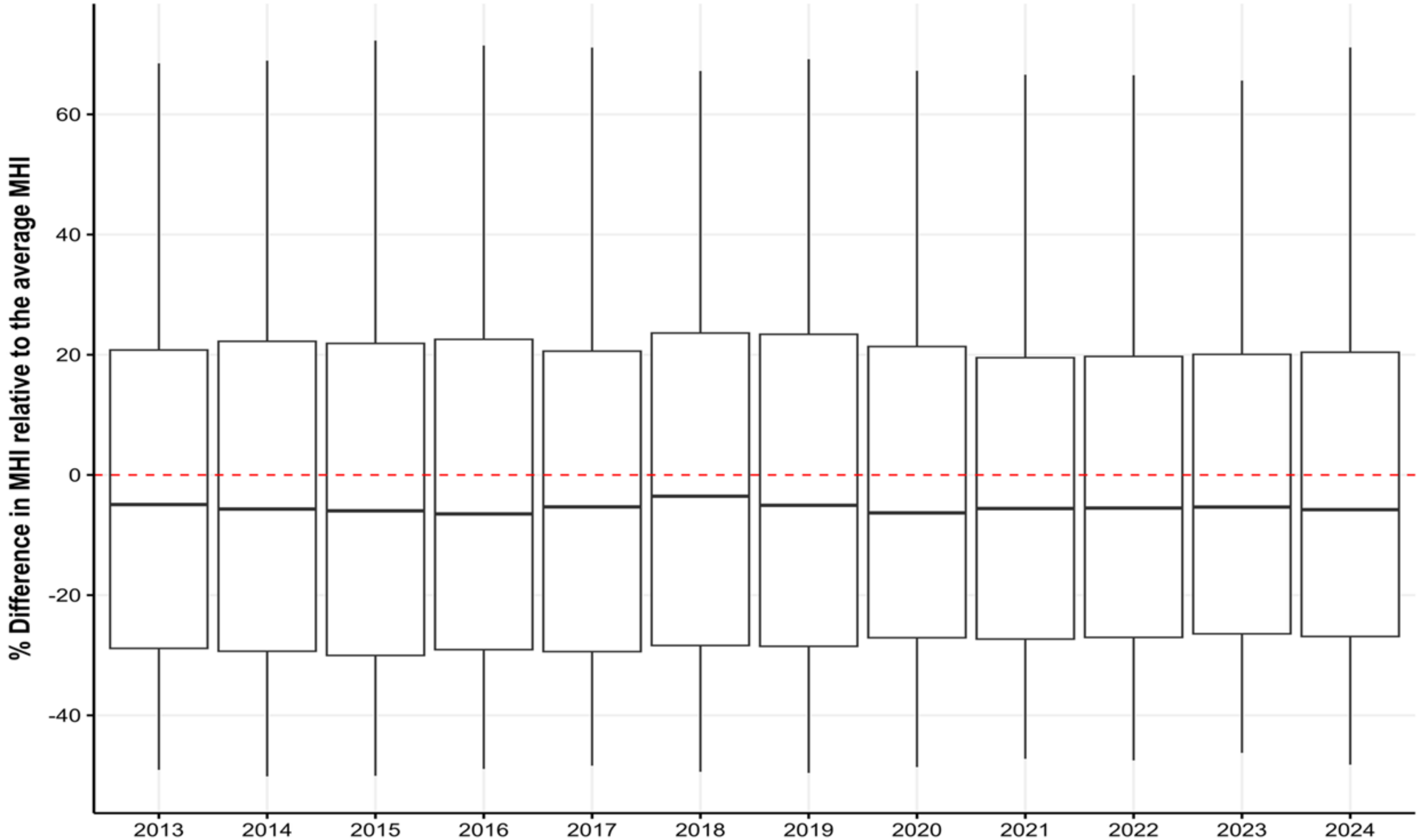

Figure 1-8. Percentage difference in MHI relative to the average MHI for the census tracts with WER 20th above 1.5%.

Notes: The thick black line represents the median value, with the upper and lower edges of the box representing the 75th and 25th percentiles, respectively; lines above and below the box represent the 95th percentile values. On average, the MHI is $10,962 for agencies below the 1.5% threshold and $6,504 for those above it.

1.5 Number of Households in the Study Area Facing Water Affordability Challenges

While the number of agencies with average WERs above the 1.5% threshold is low when representing income by census tract MHI, and given that income within census tracts varies from the MHI, it is helpful to understand how many households may be above the 1.5% threshold. Using population estimates within specific income ranges from the U.S. Census, Table 2-3 presents the total number of households that would be above the state's 1.5 affordability threshold from 2013 to 2024.[13] The total number of households over this period who might confront WERs above the 1.5% threshold varies from an annual low of approximately 550,025 in 2022 to a high of 845,104 in 2015. The share of the total households whose WER is above the 1.5% threshold has generally declined from nearly 5.57% in 2015 to 4.40% in 2024.

Table 1-3. Estimated total number of households & share of households with WER > 1.5%.

Year	Total number of Households with WER>1.5%	Share from total households served
2013	812,097	5.42
2014	839,415	5.57
2015	845,104	5.57
2016	810,257	5.38
2017	776,086	5.10
2018	733,180	4.79
2019	707,891	4.60
2020	548,213	4.51
2021	557,291	4.51
2022	550,025	4.42
2023	550,293	4.40
2024	550,293	4.40

1.6 Affordability of Water Services within Disadvantaged Communities

In this section, we evaluate how water affordability, as measured by the water expenditure ratio (WER), differs within communities that meet the state's criteria for Disadvantaged Community (DAC) status. To identify DACs, we utilize the CalEnviroScreen tool developed by the California Office of Environmental Health Hazard Assessment (OEHHA). Criteria listed by the

[13] In estimating the number of households, we include total households within a census tract, and thus do not constrain our analysis here to only households in single-family residential housing units. While renters in multi-family or high density housing may not confront a direct water bill from property owners, it's likely that the cost of water to the property owner is capitalized into the rental rate.

state that determine DAC status must be based on "…geographic, socioeconomic, public health, and environmental hazard criteria" (OEHHA, 2025).[14]

Table 1-4 presents summary statistics for DAC communities relative to non-DAC communities from 2013 through 2024 for the categories for water expenditures, MHI, and two measures of the WER—one using the MHI and one using the 20th percentile income (WER 20th). As shown, water expenditures are lower for DAC census tracts. Income differences measured by census-tract MHI, alternatively, were significantly different across these two populations. Income within those communities listed as DAC ranged from slightly above $3,000 to around $4,500 less than their non-DAC counterparts from 2013 through 2024.

As expected, then, given how WERs are calculated, the WER for DAC areas—when using MHI as the measure of income—were higher than non-DAC areas. The average WER values in DACs ranged from 0.84 to 1.05 over the years, which were significantly less than the state threshold of 1.5. When the 20th percentile income estimate is used, though, the average WER for DAC areas for each year was significantly above the state threshold of 1.5, ranging from a high in 2024 of 4.37 to a low of 3.53 in 2023.

Table 1-4. Summary statistics (2024 dollars) 6 CCF, by SB535 Disadvantaged Community Status

Year	Water Expenditure		MHI ($/month)		WER		WER 20th	
	DAC	Non-DAC	DAC	Non-DAC	DAC	Non-DAC	DAC	Non-DAC
2013	45.99	45.15	4,905	8,918	1.05	0.59	4.28	2.12
2014	40.84	43.50	4,826	8,879	0.93	0.58	3.76	2.07
2015	40.15	44.06	4,859	8,959	0.91	0.58	3.72	2.08
2016	44.31	45.77	4,961	9,153	0.99	0.58	4.05	2.06
2017	45.15	47.08	5,143	9,340	0.96	0.59	3.94	2.07
2018	46.15	46.70	5,318	9,573	0.95	0.56	3.88	1.98
2019	48.11	49.08	5,552	9,819	0.95	0.58	3.83	2.03
2020	49.53	50.21	5,764	10,061	0.94	0.58	3.81	2.04
2021	49.29	50.39	5,901	10,152	0.91	0.57	3.65	2.02
2022	46.77	48.87	6,036	10,218	0.84	0.55	3.49	1.93
2023	47.32	49.81	6,168	10,245	0.84	0.55	3.53	1.96
2024	55.68	54.27	5,989	9,948	1.03	0.62	4.37	2.21

[14] OEHHA (2025). Accessed on June 17th, 2025 (https://oehha.ca.gov/calenviroscreen/sb535).

Figure 1-9 presents Box-Whisker plots of annual WERs for each census tract—rather than agency—categorized by whether the census tract is designated with DAC and non-DAC status, in the MWD service area. Census tracks with WERs above the 1.5 state threshold are designated by a dot. As shown, census tracts with DAC status are shown to have higher WERs than census tracts without DAC status. While the median WER for census tracts with DAC status is less than 1.0 for each year from 2013 to 2024 and trending downward through 2023, there are a significant number of census tracts with WERs above 1.5 as evidenced by the dots above the dashed horizontal line representing the state threshold.

While the previous table and figure highlight how WERs are systematically different depending on DAC, as well as how WERs vary over time, agencies differ with respect to the number of households and population they serve. In developing programs that may address water affordability, either directly through income transfers or cost adjustments, or indirectly through, say, programs that increase water use efficiency and reduce expenditures on water, it is helpful to understand the number of households that confront potential burdening. Table 1-5 provides an estimate of the number of households in DAC and non-DAC communities that are above the state's threshold, along with their share of the overall population (of households). As shown, the number of households within water agencies with DAC status with WERs greater than 1.5 reached a high in 2015 of slightly over 313,984 households—or 7.63% share of overall households—yet decreased to 203,310 households—or an approximate 5.65% share—in 2023 and 2024.[15]

[13] As mentioned previously, in estimating the number of households, we include total households within a census tract, and thus do not constrain our analysis here to only households in single-family residential housing units. While renters in multifamily or high density housing may not confront a direct water bill from property owners, it is likely that the cost of water to the property owner is capitalized into the rental rate.

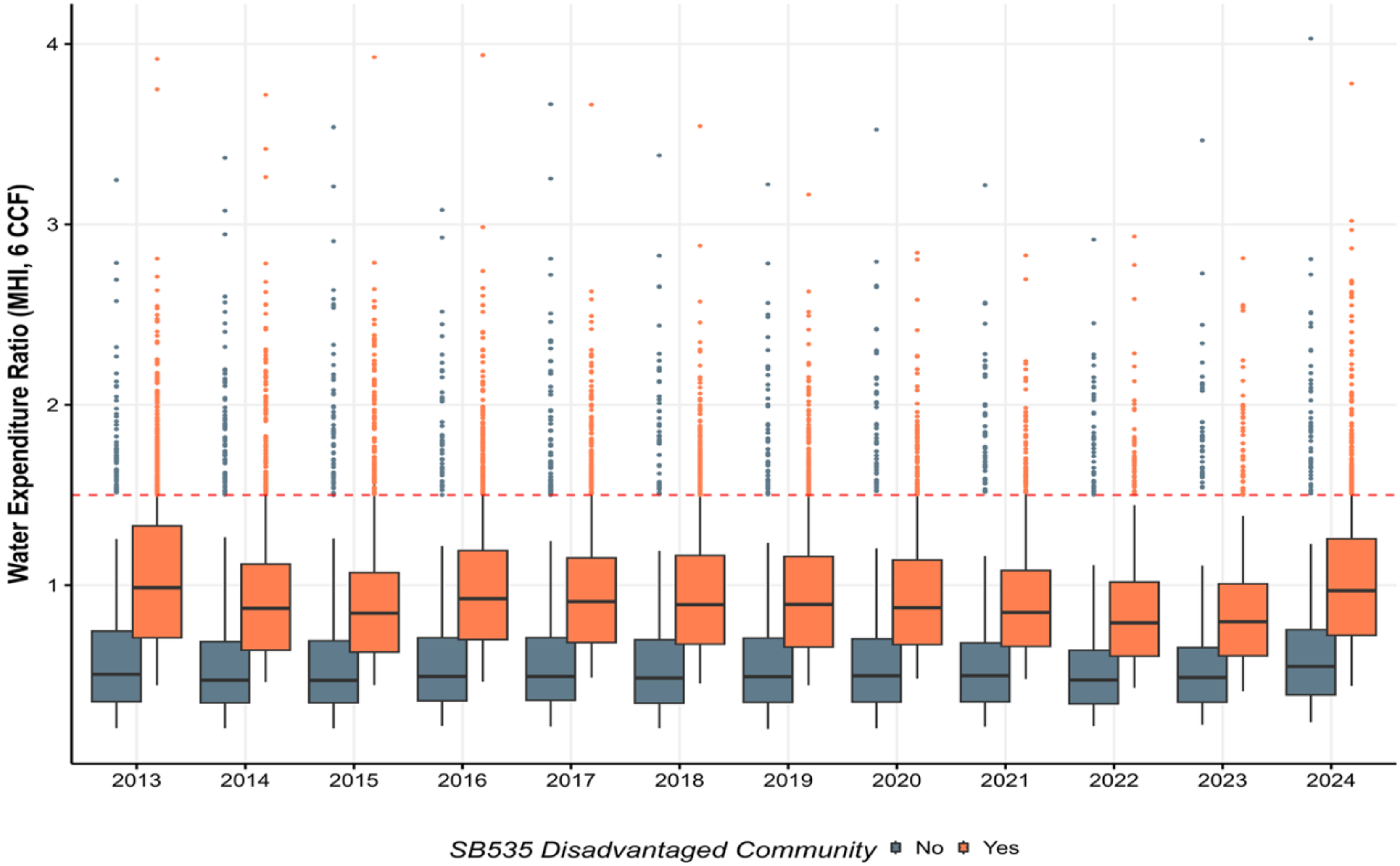

Figure 1-9. Water Expenditure Ratio (6 CCF) across census tracts in MWD service area (2013–2024) by DAC status.

Note: The thick black line represents the median value, with the upper and lower edges of the box representing the 75th and 25th percentiles, respectively; lines above and below the box represent the 95th percentile values. Dots indicate census tracts above the state's 1.5 threshold.

Table 1-5. Estimated total number of households with WER above 1.5% by SB535 Disadvantaged Community status

Year	Total number of Households with WER>1.5%		Percent of Households with WER>1.5%	
	DAC	Non-DAC	DAC	Non-DAC
2013	300,499	511,598	7.45	4.67
2014	307,627	531,788	7.54	4.84
2015	313,984	531,119	7.63	4.80
2016	307,107	503,150	7.43	4.61
2017	290,303	485,783	6.94	4.40
2018	274,319	458,860	6.49	4.15
2019	262,965	444,925	6.18	4.00
2020	214,763	333,450	6.06	3.87
2021	208,276	349,015	5.84	3.97
2022	205,180	344,845	5.71	3.90
2023	203,310	346,983	5.65	3.90
2024	203,310	346,983	5.65	3.90

1.7 Comparing Water Expenditure With Expenditures on Other Services

While examining the expenditures households confront for basic or essential water needs can help water agencies and the state understand whether there are significant affordability issues that require more attention, water is one of several essential services households need. Other services include food, housing, transportation, health care, education, entertainment, and energy, to name a few. To get an idea of how the expenditures on water compared to expenditures on other essential services, we used data from the US Bureau of Labor Statistics Consumer Expenditure Survey (BLS CES) to calculate several expenditure ratios for other essential services.

[16] Education expenditures include tuition, fees, textbooks, supplies, and equipment for public and private nursery schools, elementary and high schools, colleges and universities, and other schools. For more details see https://www.bls.gov/cex/csxgloss.htm

[17] Entertainment expenditures include fees and admissions for television, radio, sound equipment, pets, toys, hobbies, playground equipment, and other entertainment equipment and services such as indoor exercise equipment, bicycles, trailers, and electronic video games. For more details see https://www.bls.gov/cex/csxgloss.htm

Table 1-6 provides information on the expenditure ratios for food, housing, transportation, health care, education,[16] entertainment,[17] natural gas, electricity, and telephone services based on the BLS CES from 2013 to 2020, which is the most recent year of the survey.[18] We should emphasize that the closest "region" to MWD's service area for which data on food, housing, transportation, health care, education, and entertainment were available is the Los Angeles Metropolitan Statistical Area (MSA), which includes LA, Orange, Riverside, and San Bernardino counties. For natural gas, electricity, and telephone services, the closest or most representative region for this granularity of data was the "West" region, which is composed of Alaska, Arizona, California, Guam, Hawaii, Idaho, Nevada, Oregon, and Washington.

As expected, we see that housing comprises the largest fraction of overall income (before taxes) with an average expenditure percentage of 30.57% from 2014 to 2020, followed by transportation and food expenditure percentage of 12.47% and 10.74%, respectively. Health care is the service that accounts for the next highest fraction of income expenditures at slightly below 5% of income, followed by entertainment at 3.46%, education at 2.28%, telephone services at 1.73%, and electricity at 1.55%. Finally, natural gas comprises approximately 0.43% of annual household income. Since the expenditures listed in the BLS CES are actual expenditures and not necessarily based on essential or basic needs, it seems more reasonable to use the overall WER we estimate for comparison purposes. As such, overall water expenditures in MWD's service area from our analysis is less than the fraction of income spent on electricity or water and other public services in western United States and territories, on average. We see that water expenditures comprise a significantly smaller proportion of income than expenditures on telephone services, and expenditures on health care, transportation, food, and housing.[19]

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[16] Education expenditures include tuition, fees, textbooks, supplies, and equipment for public and private nursery schools, elementary and high schools, colleges and universities, and other schools. For more details see https://www.bls.gov/cex/csxgloss.htm

[17] Entertainment expenditures include fees and admissions for television, radio, sound equipment, pets, toys, hobbies, playground equipment, and other entertainment equipment and services such as indoor exercise equipment, bicycles, trailers, and electronic video games. For more details see https://www.bls.gov/cex/csxgloss.htm

[18] This table provides estimates from 2014 to 2020. Note that the expenditure ratios presented in this table are based on actual expenditures from surveys of the populations within their respective regions. As such, they are not necessarily representative of the expenditures associated with basic needs, which is what our WER represents.

[19] Our calculations do not account for differences in tax burdens across different income or geographic groups, nor differences in social program allowances that might contribute to income. These factors will affect the denominator in ratios of affordability.

Table 1-6. Comparing essential needs cost as a percentage of income before taxes[20]

Panel (A): Los Angeles Metropolitan Statistical Area (MSA)

Year	Food	Housing	Transportation	Health care	Education	Entertainment
2013-14	10.53	31.11	12.03	4.60	2.32	3.51
2014-15	10.00	30.20	12.20	5.00	2.19	3.35
2015-16	10.37	30.36	13.13	4.96	2.03	3.46
2016-17	11.41	31.82	12.74	5.17	2.65	3.61
2017-18	13.17	35.71	13.61	5.71	3.43	4.19
2018-19	10.19	27.37	12.17	4.62	2.06	3.22
2019-20	9.49	27.42	11.43	4.64	1.27	2.89
2020-21*	13.2	36.7	17.00	6.2	2.2	4.2
2021-22*	13.2	36.7	17.00	6.2	2.2	4.2
2022-23	13.6	36.6	16.5	6.2	2.1	3.9

Panel (B): West Region

Year	Natural gas	Electricity	Telephone services	Water & other public services
2013-14	0.54	1.75	1.87	0.97
2014-15	0.47	1.63	1.79	0.93
2015-16	0.39	1.47	1.70	0.88
2016-17	0.40	1.48	1.70	0.90
2017-18	0.41	1.57	1.73	0.96
2018-19	0.41	1.5	1.68	0.92
2019-20	0.41	1.46	1.61	0.92
2020-21*	0.40	1.53	1.60	0.93
2021-22*	0.40	1.53	1.60	0.93
2022-23	0.42	1.57	1.58	0.96

*The data in this release were averaged over a 2-year period, 2021 and 2022.

1.8 An Investigation of Factors Possibly Affecting Water Affordability

We now turn our attention to investigating the role different factors may play in impacting water affordability, factors that may or may not present themselves as possible tools that can be used by agencies in efforts to address water affordability challenges. While all public retail water agencies in California are subject to Proposition 218, which limits water agencies from imposing rates that exceed the costs of providing retail water service, agencies have wide

[20] Source: Consumer Expenditure Survey, US Bureau of Labor Statistics, US Census Bureau's ACS. Income for LA and West is based on the US Bureau of Labor Statistic's Consumer Expenditure Survey (CE). Note: Percentages associated with these categories do not comprise all the income categories and thus do not sum to 100.

latitude with respect to what sort of pricing structure to implement. Such structures may include a single rate volumetric structure in which the unit cost of water that households confront is the same regardless of quantity used, to a tiered or increasing block rate in which the unit cost of water rises as more water is used in a step-like (or block-like) manner. While these are two of the most popular rate structures in California, a third relatively prominent rate structure, especially in Southern California, is the budget-based increasing block rate pricing structure. This latter pricing structure is similar to the tiered rate in that water rates rise as households use more water, yet differs in that each household gets an individualized "budget" (or block) that differs based on household characteristics (e.g., household size, size of landscaped area, evapotranspiration within the area). Regardless of the structure used, the individual rates may not exceed the cost of providing the service to the property or class of customer.

Table 1-7 and Figure 1-10 provide summaries over time of the number of agencies in our sample of retail water agencies within MWD's service area that use one of the three designated pricing structures, alongside the average WER associated with those agencies. As shown, the most prevalent pricing structure is the tiered water rate, followed by the volumetric rate, and then the budget-based rate. In general, the average WERs for volumetric and tiered rate structures are significantly higher than the WERs for budget-based rates. Given that a volumetric rate will charge the same unit price for 6 CCFs versus 13 CCFs, it may seem reasonable that the WER is higher for this pricing structure relative to a pricing structure that can allow lower prices for initial units of water and higher prices thereafter, which both the tiered and budget-based rates allow. The fact that there is such a significant difference between the tiered and budget-based rates highlights the fact that the costs, including average costs, agencies confront in providing water to customers is impacted by a wide variety of factors, including the types of water sources they have access to, water quality challenges, and the ability to spread agency fixed costs—which often comprise the bulk of total agency costs—across a larger customer base.

While Table 1-7 and Figure 1-10 suggest some association among different pricing structures and WERs, the degree to which different pricing structures may lead to higher or lower WERs requires a much more sophisticated analysis that controls for other potential confounding factors that may be correlated with both pricing structure and WERs. To help better identify if there is perhaps a stronger association between pricing structure and WER, as well as determine other factors that may impact WERs, we incorporate a multivariate econometric modeling approach. Our objective is to investigate whether statistical relationships exist among WER and characteristics of a retail water agency. The usefulness of this approach is that by evaluating other factors that might impact WERs alongside the pricing structure, we can isolate the effects of each factor on WERs from one another.

Table 1-7. Number of water agencies with various rate structures and average WER at the MHI by rate structure

	Budget		Tier		Volumetric	
Year	# of agencies	Mean WER	# of agencies	Mean WER	# of agencies	Mean WER
2013	12	0.50	83	0.77	30	0.70
2014	12	0.51	83	0.71	30	0.71
2015	12	0.53	83	0.70	30	0.73
2016	14	0.50	77	0.74	34	0.73
2017	13	0.47	78	0.74	34	0.71
2018	13	0.41	78	0.73	34	0.67
2019	13	0.40	78	0.75	34	0.65
2020	13	0.41	77	0.75	35	0.59
2021	15	0.41	76	0.74	34	0.58
2022	15	0.44	77	0.70	33	0.51
2023	15	0.42	77	0.70	33	0.54
2024	15	0.46	77	0.83	33	0.60

*Assuming 6 CCFs of water. Income is represented by MHI.

The modeling approach we employ is referred to as a Fixed-Effects Ordinary Least Squares (OLS-FE) model. This approach is one of the most well-accepted multivariate econometric approaches employed by social scientists to help identify causation—from a statistical perspective—between factors hypothesized to have an association. The benefit of using a "fixed-effects" model is that it allows for the modeler to control for both observable (and modeled) factors as well as unobservable time-invariant factors (Wooldridge 2013).

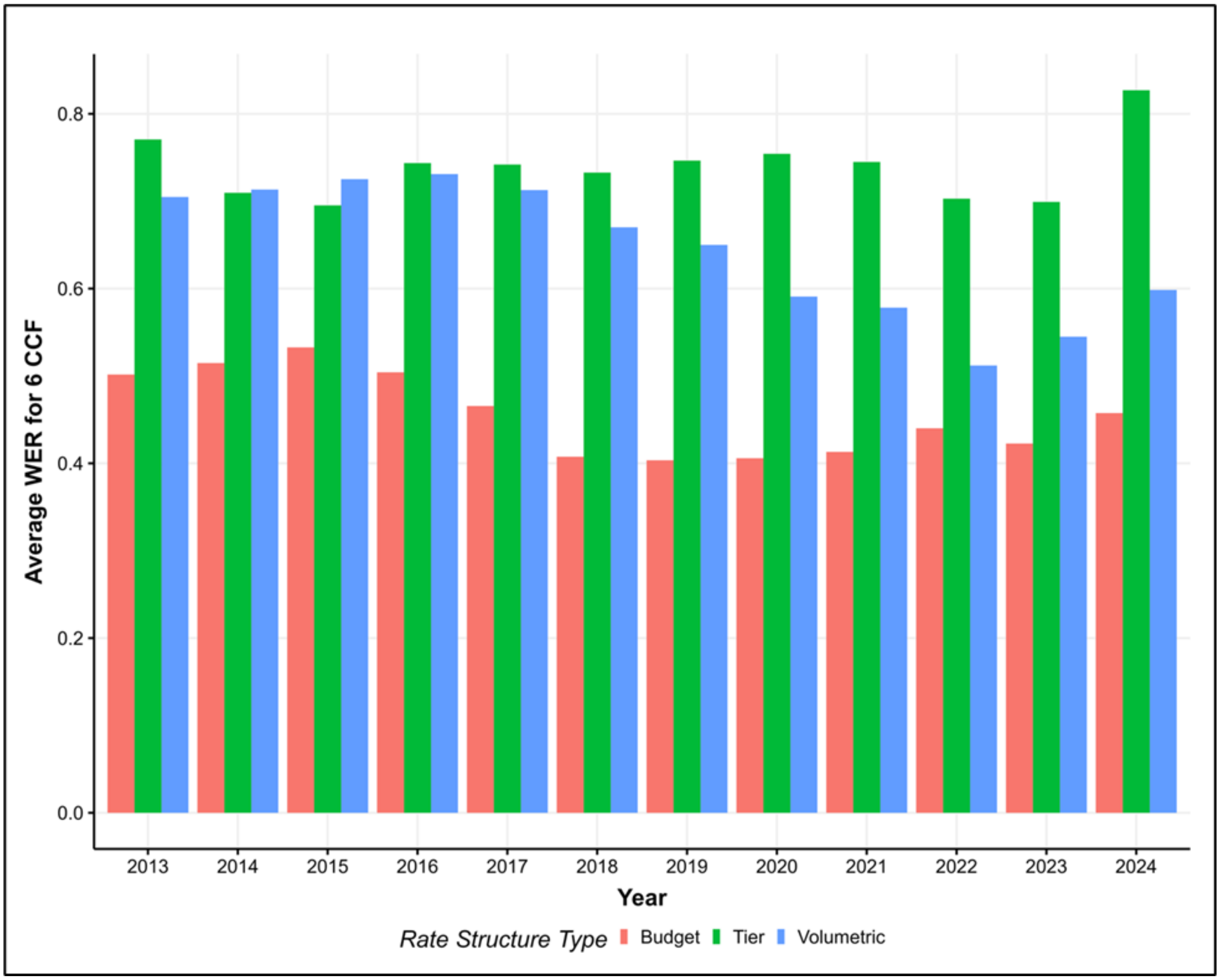

Figure 1-10. Average Water Expenditure Ratio (6 CCF) in MWD service area (2013–2024) by rate structure.

*Note: Assuming 6 CCFs of water. Income is represented by MHI.

Table 1-8 summarizes the key variables used in the regression analysis. A majority of water systems in the sample use tiered rate structures (62%), followed by volumetric (26%), and budget-based rates (12%). Most systems (82%) provide both water and wastewater services, while 18% are water-only providers. On average, systems employ more than two tiers or rate blocks. Rental households make up about 21% of the households served. In terms of system size, 77% of the agencies serve populations greater than 100,000, 22% serve between 10,001 and 100,000 residents, and only 1% serve fewer than 10,000 residents.

Table 1-8. Summary of the variables used in the regression analysis

	Mean
Rate Structure	
Budget-Based (%)	12
Tier (%)	62
Volumetric (%)	26
Water and Wastewater Provider (%)	82
Water only Provider (%)	18
Number of Rate Blocks	1.85
Rental (%)	20.67
Agency Households Served	
<=10,000 (%)	0.85
10,001-100,000 (%)	22.17
>100,000 (%)	76.93

Table 1-9 provides the results of our OLS-FE model. While four different specifications are provided, specification (column) 5 is our preferred specification. Note that all variables are statistically significant at the 1% level. Table 1-9 suggests that relative to a budget-based rate structure (which is the default structure in our model), both tiered and volumetric rates are associated with higher WERs. Water providers that also provide wastewater treatment services are associated with lower WERs. For those agencies that use tiered or budget-based water rates, the more "blocks" or "tiers" the agencies offer, the lower the WERs for 6 CCFs of water. Water providers in areas where there's a greater percentage of renters tend to have higher WERs, a result that is likely proxying for lower-income residents (represented by higher percentages of renters). In considering population served, which likely proxies for the size of the agency, results suggest that relative to the default size of 10,000 customers or less, water providers with greater than 10,000 customers have lower WERs, on average. This result would be consistent with water agencies that confront lower average costs of production, given they are better able to spread their fixed costs over a larger base.

Table 1-9. Association between various factors and WER

	(1)	(3)	(4)	(5)
Rate Structure (base: Budget)				
Tier	0.283***	0.361***	0.226***	0.230***
	(0.004)	(0.005)	(0.004)	(0.004)
Volumetric	0.189***	0.184***	0.112***	0.088***
	(0.005)	(0.005)	(0.005)	(0.005)
Wastewater		-0.022***	-0.051***	-0.055***
		(0.004)	(0.004)	(0.004)
# Rate Blocks		-0.038***	-0.019***	-0.022***
		(0.001)	(0.001)	(0.001)
Percent Rental			0.008***	0.008***
			(0.0001)	(0.0001)
Population Served (base: <=10,000)				
10,001-100,000				-0.401***
				(0.012)
>100,000				-0.435***
				(0.012)
Observations	99,895	99,895	99,895	99,895
Year FEs	Yes	Yes	Yes	Yes

Note: *** $p<0.01$

Part 2: Impact of Advanced Metering Infrastructure (AMI) on Water Use and Affordability

2.1 Introduction and Methods

As water agencies confront long-term conservation goals and short-term supply shocks (e.g., droughts), they are adopting alternative approaches to increase conservation and water use efficiency. A relatively new technology being adopted by some agencies is Advanced Metering Infrastructure (AMI). AMI technology enables near real-time monitoring of household water usage, and has the capacity to provide real-time information to households on usage. This part of the report seeks to examine one key outcome of AMI adoption: its effect on water consumption and, as a result, on water bills and the affordability of water bills.

Accurate and timely monitoring of water use, enabled by modern meters that provide the ability to provide real-time feedback to customers, has been in use in California for more than a decade. The information provided by such meters can help agencies and customers improve water use efficiency. Despite this, there is a lack of research providing evidence on how AMI affects water consumption. This is an unfortunate gap in the literature, especially given that investing in such infrastructure can be expensive for water agencies operating under budget constraints. Also, research in behavioral economics shows that people often do not make optimal decisions regarding water use due to limited information about consumption levels and unclear pricing. In other words, households may lack clear information about how much water they consume or what it costs, making them less likely to conserve or invest in water-saving technologies. AMI systems offer a way for agencies to communicate more frequently and effectively with customers, potentially encouraging conservation and efficient water use.

This report investigates the effects of AMI on residential water use by addressing three core questions: (i) What is the impact on water consumption of replacing old meters with AMI-enabled meters? (ii) What is the impact on water bills of replacing old meters with AMI-enabled meters? (iii) Is there variation in this impact across agencies, and what might explain such heterogeneity?

To explore these questions, we examine a large-scale AMI implementation program across four agencies of the Metropolitan Water District of Southern California. For confidentiality concerns, we use generic names to reference the four agencies, A, B, C, and D.[21] These agencies differ in both the timing of their AMI rollouts and the manner in which they communicated real-time information to households including, for example, how and when they notified customers of potential leaks. The variation both within and across agencies in the implementation and communication strategies offers a valuable opportunity to estimate and compare the effects of AMI on water consumption.

Of course—and it is important to emphasize—each agency was at a different stage of implementing AMI and, in particular, customer engagement; thus, differences in outcomes are largely explained by differences in the stage of implementation of AMI with respect to customer integration. In addition, each agency had previous systems in place to varying degrees, in which the agency may have communicated leaks to customers prior to the installation of AMI. That said, considering the different outcomes based on different stages of implementation offers us a natural experiment that provides insight into the potential mechanisms driving those outcomes, particularly with respect to the role of customer engagement, communication practices, and underlying behavioral responses that would be associated with the implementation of AMI.

In terms of our methods, our approach mirrors that of Daminato et al. (2021), who evaluated a similar program in the Canary Islands. From a methodological perspective, we use a combination of event study and difference-in-differences (DID) techniques to isolate the causal impacts of AMI. These methods allow us to estimate changes in water use before and after meter installation, while controlling household characteristics and broader economic trends. We apply a fixed-effects regression framework controlling for household, time, and neighborhood-level influences. This approach allows for the inclusion of other potentially confounding factors that we, in effect, can control or account for (or net out). Such controls include household-level controls so we're not comparing, for example, a small home to a large one, and month and year controls to account for seasonal effects and trends, such as droughts. We also control for neighborhood effects at the census tract level to ensure we're comparing similar communities in terms of income, housing, and climate.[22]

[21] We use the generic term "agency" to also represent cities who may retail water from MWD. While we contacted nearly 3 dozen agencies that have been using AMI, only four were willing to provide the requisite household-level data for evaluation.

[22] The manner in which we control for household level and community level effects is referred to as a fixed-effects approach that control for time-invariant factors. As such, household-level or community-level factors that vary over the period of our analysis are not controlled for.

2.2 Main Results: Agency A

We use data from the population of single-family residential customers within the service area of Agency A. The dataset is a panel comprising 123,265 households, observed over the period from 2011 to 2021, with a total of about 15 million billing records. Figure 2-1 shows the number of single-family residential households where AMI was installed each month between 2009 and 2022. AMI installations remained relatively low through the early 2010s, but began increasing noticeably around 2014. The most significant surge occurred between 2015 and 2018, with a sharp peak in early 2018, when over 3,000 households were connected in a single month.

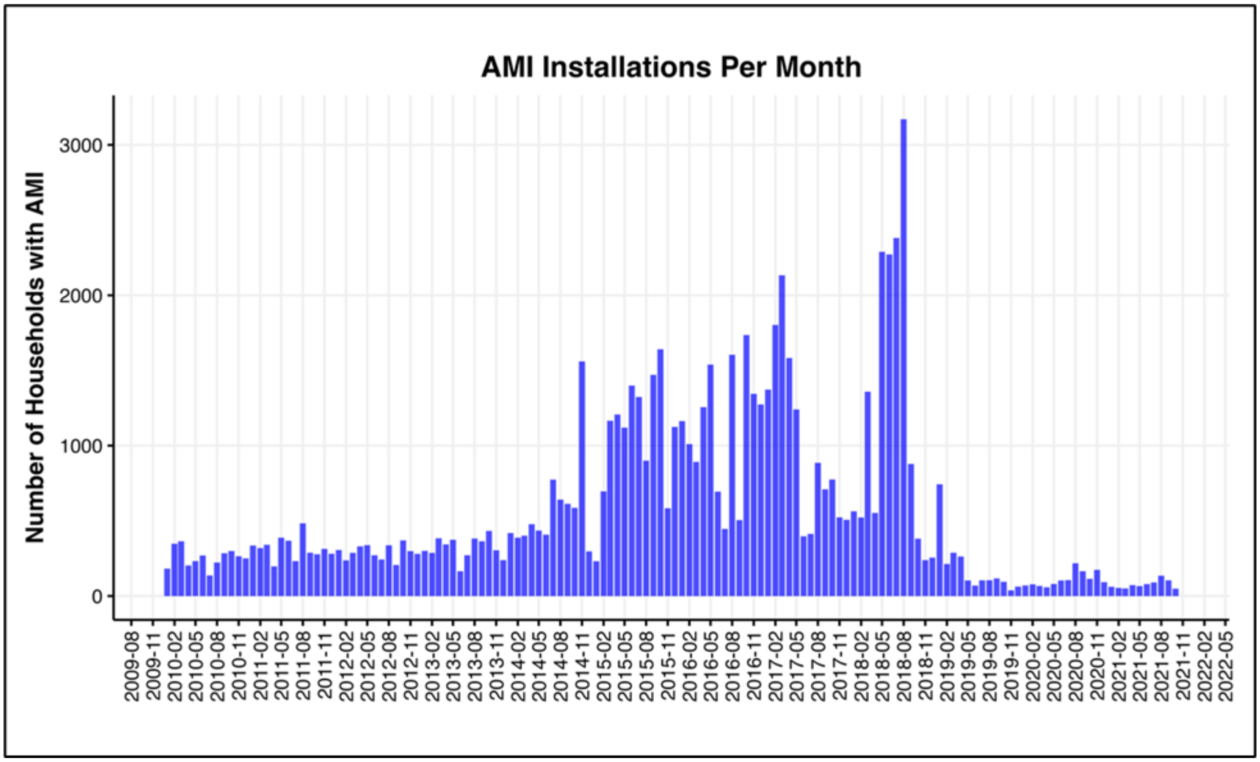

Figure 2-1. Monthly number of Agency A households with AMI (2009–2022)

Figure 2-2 presents the cumulative percentage of households with AMI over time. The curve steadily increases from practically no households using AMI in 2009 to nearly 65% of the households using AMI by 2022. The steepest climb occurs between 2015 and 2018, aligning with the peak adoption phase noted in Figure 2-1. As these figures illustrate, the majority of AMI deployment was completed within that three-year period.

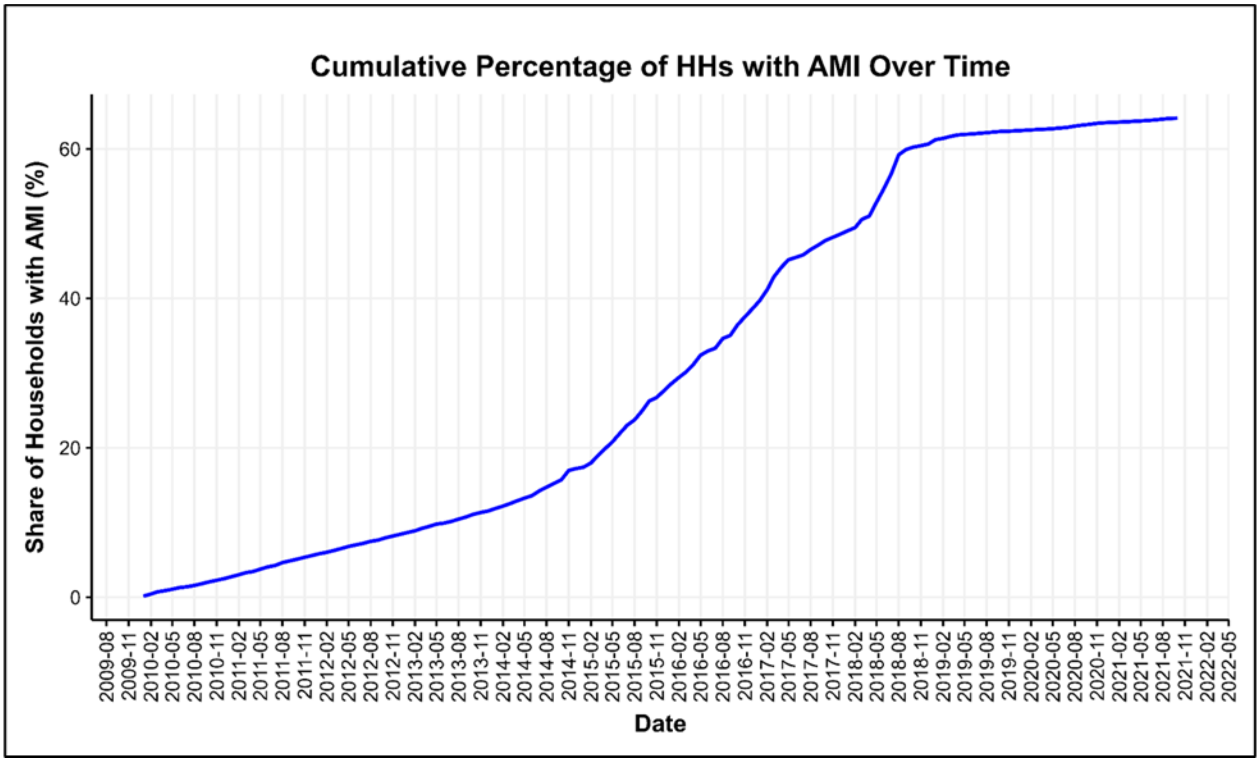

Figure 2-2. Cumulative share of Agency A households with AMI installed (2009–2022)

Graphical Evidence

To begin assessing the effect of AMI adoption on household water use, we divide the sample into two groups: households that had AMI installed at any point during the study period (Treated Group), and households that did not (Comparison Group). We create a binary indicator variable equal to 1 for household-months in which AMI is in place, and 0 otherwise. This distinction allows us to compare the water use behavior between AMI and non-AMI households over time. Figure 2-3 below shows the unadjusted monthly average water use (measured in CCF per month) for both groups between 2011 and early 2021. No additional statistical controls (such as household fixed effects, seasonal effects, or economic variables) are applied in this figure.

As indicated in Figure 2-3, both groups display clear seasonal variation, with higher water use during summer months and lower use in the winter. Starting around 2015, which aligns with the broader AMI rollout seen in Figures 2-1 and 2-2, a notable divergence in average water use appears. The red line (AMI installed) begins to track consistently below the blue line (non-installed), particularly during the high-demand summer months. The graph suggests that AMI-installed households tend to use less water on average than those without AMI. This could be indicative of behavioral changes spurred by AMI features, such as access to real-time consumption data, leak notifications, or greater awareness through increased billing accuracy.

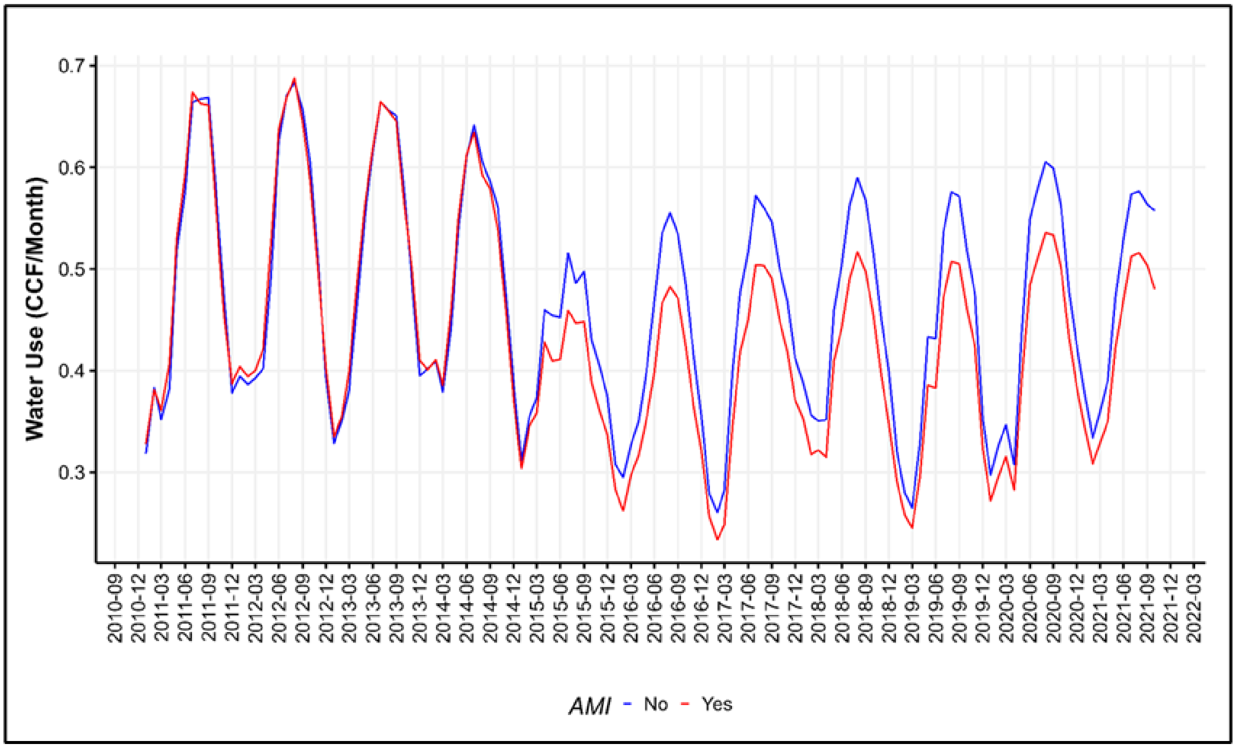

Figure 2-3. Average monthly water use by AMI installation status (2011–2021)

Note that while the figure provides suggestive evidence of an AMI impact, it's important to recognize that AMI installation was not random. Households that received AMI may differ in systematic ways (e.g., size, income, location) from those that did not receive AMI.[23] Hence, this raw comparison could be confounded by other unobserved factors. To isolate the causal effect of AMI on water use, we complement this graphical analysis with statistical methods, including fixed-effects regression and difference-in-differences estimation, which control for household -specific and time-varying influences.

Statistical Evidence

To estimate the effect of AMI installation on household water use and monthly bills, we apply a difference-in-differences approach using data from 2011 to 2021. This method allows us to isolate the causal impact of AMI installation while controlling for both time-invariant household characteristics and broader time trends. The results of our analysis in terms of estimates are presented in Table 2-1. The number (estimate) -0.013 means that after getting an AMI meter, households used 1.3% less water per month, on average, relative to similar households that did not have an AMI meter. The second number, -0.82, tells us that monthly water bills went down by about one dollar (82 cents), on average, after AMI was installed relative to, again, similar

[23] During this period California was in a severe drought for which agencies were initially asked (voluntary) and then required (mandated) to reduce water use by the State Water Resouces Control Board.

households that did not have AMI installed.[24] This impact on bills might come from AMI helping catch leaks earlier or a better understanding of usage. These effects are statistically significant, meaning the differences are unlikely to be due to chance.

Table 2-1. Estimated impact of AMI installation on monthly water use & water bills (Agency A)

	Log Water Use (1)	Water Bill ($) (2)
AMI Installation	-0.013***	-0.820***
	(0.0004)	(0.027)
Observations	14,314,621	14,314,621
R^2	0.545	0.348

Note: *p**p***p<0.01

Notes: We use household, month, year, and census tract fixed effects in all the regressions above.

2.3 Main Results: Agency B

Agency B provided monthly billing information for more than 47,000 accounts, comprising approximately five million billing records for its service area from January 2011 to December 2022. The residential billing records include total water usage, water tier-based rates, water service charges, sewer service charges, and other charges (e.g., water supply reliability capital monthly charge, sewer system capital projects monthly charges). The billing records also included both landscape and household size that the district has on record, as well as billing start and end dates and customer location (latitude and longitude). In addition, Agency B provided us with data on AMI installations over time at the household level. Figure 2-4 shows the number of single-family residential households that had AMI installed each month between 2015 and 2023. We observed that approximately 1,589 accounts with AMI installed during the first pilot program in 2015, while the remaining single-family accounts in the district mostly had AMI installed in 2017.

As shown in Figure 2-5, there was minimal installation prior to 2017, with a small initial increase corresponding to the pilot rollout in 2015, which involved approximately 1,589 households. However, the most significant jump occurred between mid-2017 and early 2018, when the remaining majority of single-family households were equipped with AMI. This rapid

[24] The reason the first estimate is in percentage terms and the second estimate in $ terms is that the dependent variable in our water use analysis is transformed by taking its natural logarithm (i.e., water use), which means that the estimates are in percentage terms (or elasticities). Alternatively, for the water bill specification, the dependent variable is not transformed. Interpretation of log transformed estimates follow convention (Kennedy 1998).

installation phase reflects the district-wide implementation of AMI, following the conclusion of the initial pilot phase and the program's expansion. Since 2018 the share of households with AMI has remained nearly constant at or near 100%.

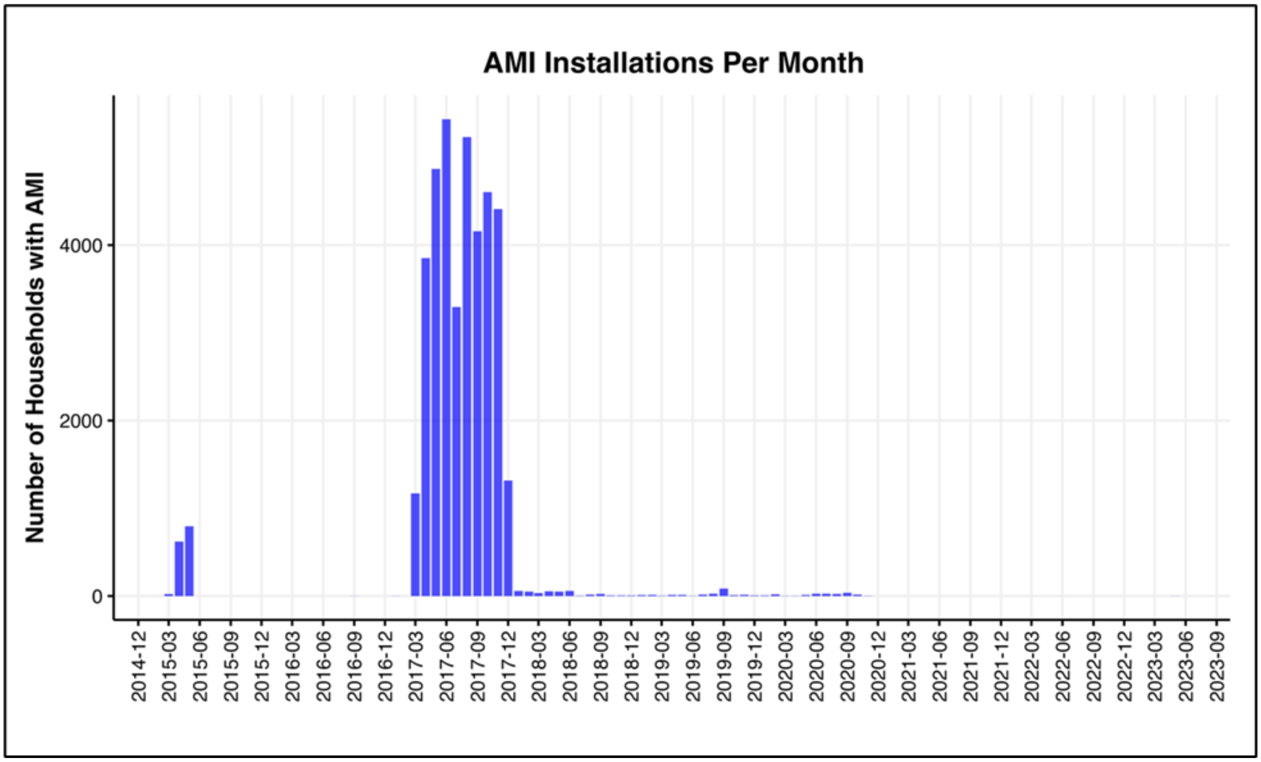

Figure 2-4. Monthly number of households in Agency B with AMI installed (2015–2023)

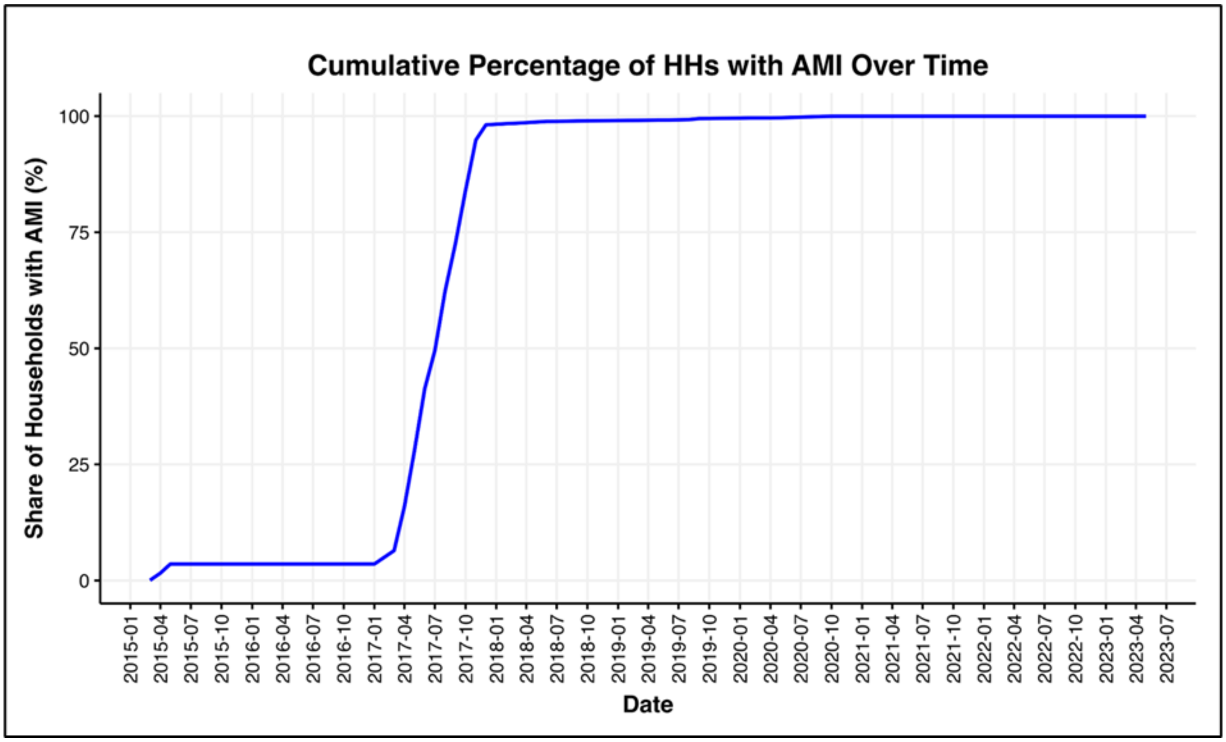

Figure 2-5. Cumulative share of Agency B households with AMI installed (2015–2023)

Graphical Evidence

Given the installation pattern of AMI in Agency B, using households that had AMI installed in 2017 as the treated group is not suitable for a difference-in-differences approach, because it requires observing both treated and comparison groups before and after the policy intervention. As shown, by 2017, nearly 100% of the sample had already had AMI installed, meaning there is a lack of post-treatment observations for any valid comparison group.

To address this challenge, we restrict the analysis to the period from 2011 to 2017 and define the treated group as the set of households that participated in the initial pilot program in 2015. The remaining households, which did not have AMI installed until 2017, serve as the comparison group. This strategy ensures that we observe both groups during pre- and post-treatment periods, allowing us to credibly estimate the impact of AMI using the difference-in-differences framework.

Next, using the data from 2011–2017, we divide the sample into two groups: households that had AMI installed at any point during 2015 (treated group), and households that did not have AMI installed (comparison group) during 2015. We create a binary indicator variable equal to 1 for household-months in which AMI is in place, and zero otherwise. This distinction allows us to compare the water use behavior between AMI and non-AMI households over time.

Figure 2-6 compares average monthly water use (in CCF) between households that had AMI infrastructure as part of the 2015 pilot program (red line), and those that did not during that time (blue line). The vertical green dashed line indicates the timing of the AMI rollout in early 2015. As expected, both groups exhibit strong seasonal patterns, with higher water consumption in summer months. Also note that this period also was associated with the mandated water conservations requirements placed on water agencies by the SWRCB.

As evidenced in Figure 2-6, water use by the households that ended up with AMI in 2015 was lower than those that did not have it installed in 2015 prior to 2015. Following the installation of AMI in 2015, we observe a noticeable and persistent decrease in water use among both the treated households (red line) and comparison group (blue line), which would be consistent with reduced water use in response to the drought mandate and the actions, including messaging, that agencies introduced to their respective ratepayers. While there was a decrease in overall water use for all households, there's also an apparent further decrease in relatives terms associated with the treated group relative to the comparison group throughout 2015 and 2016. This pattern is consistent with the hypothesis that AMI may lead to improved water conservation. However, as mentioned, prior to installation the treated group consistently used less water than the comparison group. This pre-treatment difference suggests potential selection bias. Specifically, AMI pilot participants may have differed systematically from the rest of the population in ways unrelated to AMI itself (e.g., household size, conservation awareness, property characteristics). In such circumstances, it would be inaccurate to attribute the installation of AMI as the reason for the reduction in water use starting in 2015.

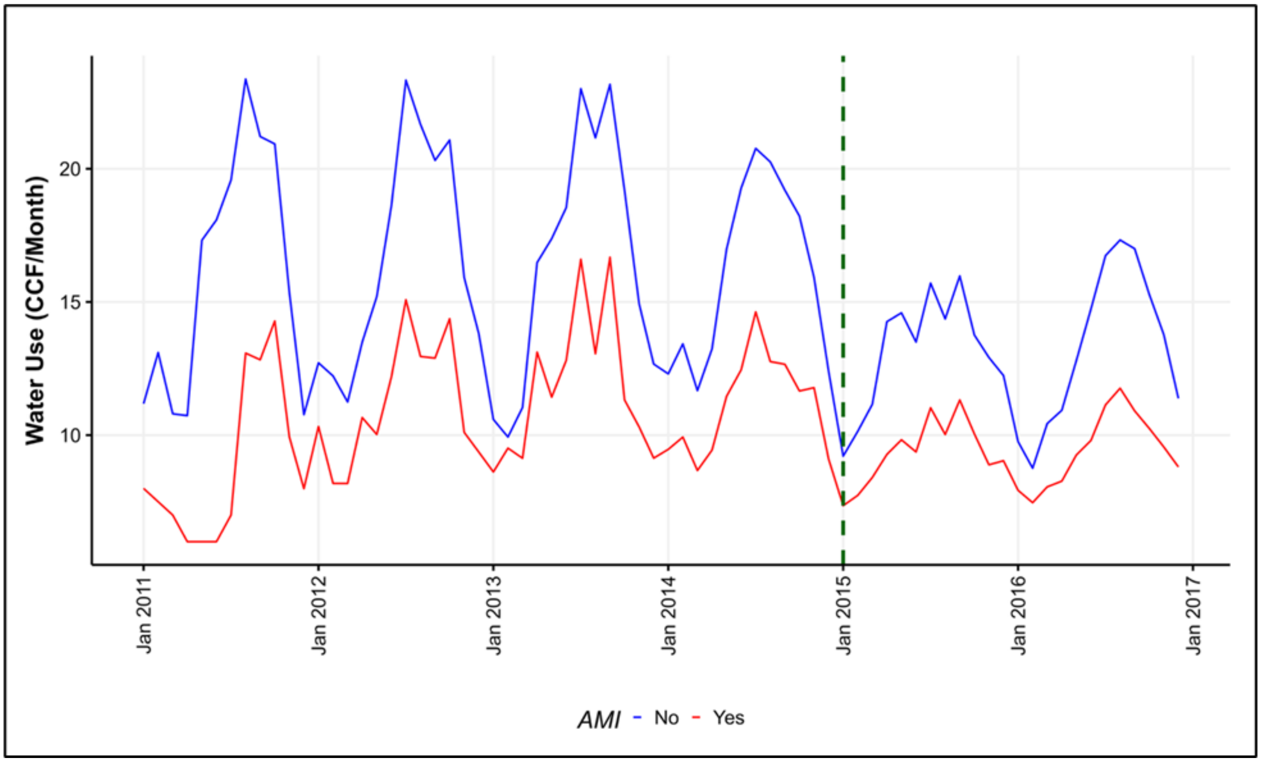

Figure 2-6. Average monthly water use by AMI installation status (2011–2017)

We further test the differences across these two groups using the housing characteristics dataset. Information on the spatial location of each household, comprehensive records, and granular data on all houses within Agency B's service area were obtained from the county assessor. This dataset provided extensive information about each property, including house assessed value, street addresses, parcel boundaries, square footage, year built, number of rooms, number of bathrooms, number of stories, and additional amenities such as the presence of a pool.

Table 2-2 presents a comparison of average household characteristics between the AMI (treated) and non-AMI (comparison) groups, revealing notable differences between the two. On average, non-AMI households have significantly higher property values ($328,593) compared to AMI households ($151,362), and their homes also are nearly twice as large in size (2,028 sqft vs. 1,016 sqft). Non-AMI homes have more bedrooms (3.38 vs. 2.06), more bathrooms (1.95 vs. 1.02), and more stories (1.48 vs. 0.94), suggesting generally larger and potentially more water-intensive households. Additionally, 20% of non-AMI homes have pools, compared to just 3% in the AMI group. These descriptive differences highlight that the AMI pilot group consists of smaller, lower-value homes with fewer amenities. As such, attributing differences in water use between these two groups due to AMI installation is problematic, since they are different types of households based on these observable characteristics.

Table 2-2. Comparison of household characteristics: AMI vs. Non-AMI groups

	AMI	Not- AMI
Average Home Value ($)	151,362	328,593
Average Home Size (square feet)	1,016	2,028
Average Home Age	46	71
Average number of bedrooms	2.06	3.38
Average number of bathrooms	1.02	1.95
Average number of stories	0.94	1.48
Average Share with Pool (%)	3	20

To address the substantial differences in baseline characteristics between AMI and non-AMI households, and develop a comparison that lends itself to isolating the effects of AMI on water use, we perform matching on key covariates, such as home value, square footage, number of bedrooms and bathrooms, presence of a pool, and other structural attributes. This ensures that the comparison between treated and control groups is based on households with similar observable features, helping to reduce selection bias.

Figure 2-7 shows the standardized mean differences for each covariate before (red) and after (blue) matching. Prior to matching, many covariates exhibit large imbalances (i.e., there are observable differences between the control and treated groups), as indicated by the red dots being far from the vertical dashed zero line. After matching (using a subset of the control group that is more similar to the treated group), the blue dots are all clustered closely around zero, showing that the distributions of covariates between the treated and newly identified control group are now well aligned. This demonstrates that the matching procedure is effective in balancing observed characteristics, increasing the credibility of subsequent causal estimates of AMI's impact on water use.

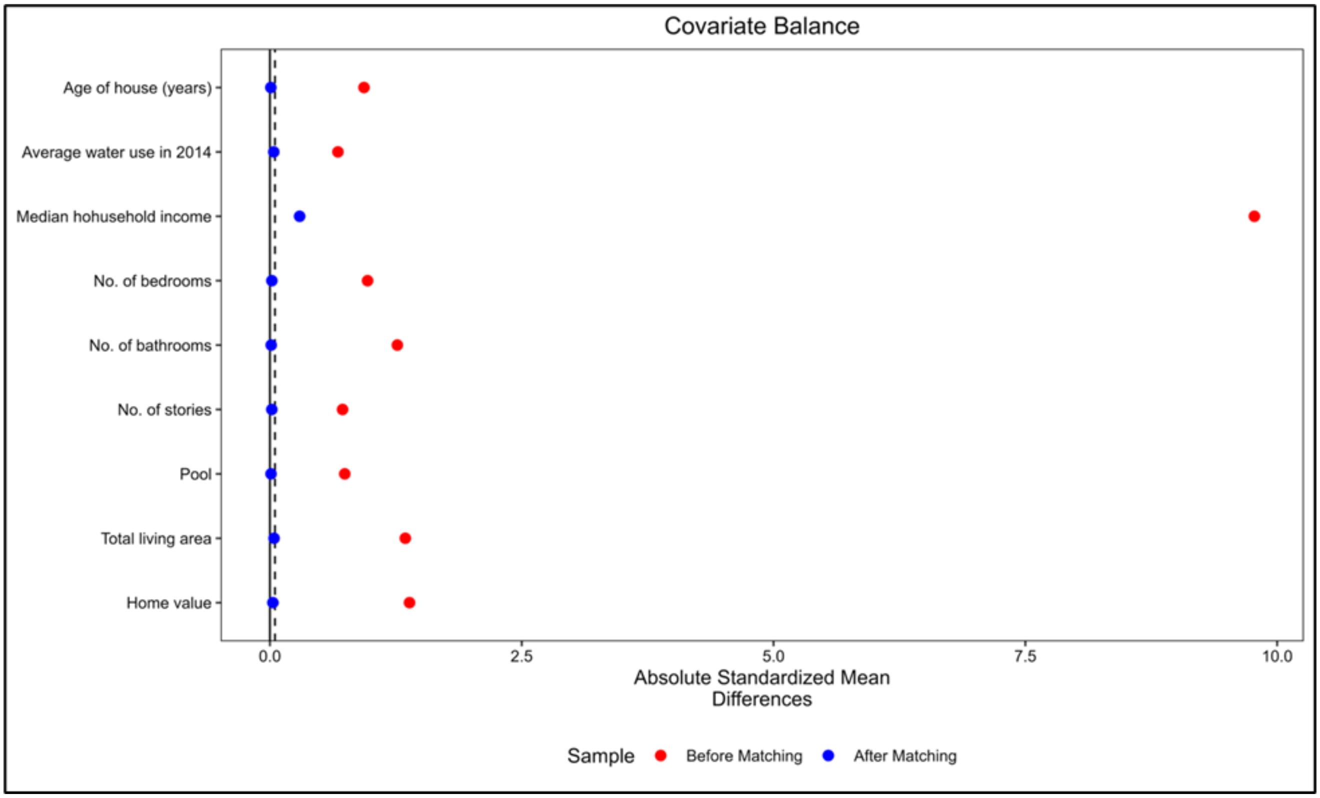

Figure 2-7. Standardized mean differences before and after matching: Balancing covariates between AMI and Non-AMI groups

Figure 2-8 shows average monthly water use (in CCF) for households that had AMI installed in the 2015 pilot (red line) and a matched control group (blue line). Both groups exhibit similar seasonal patterns, with higher use in summer and lower use in winter. Unlike the unmatched sample in Figure 2-6, the matched groups have comparable water use levels. No clear difference in average consumption is seen, suggesting that the effect of AMI is not apparent without adjusting for other factors. To accurately assess its impact, we employ a difference-in-differences method, controlling for household and time-specific effects, as explained below.

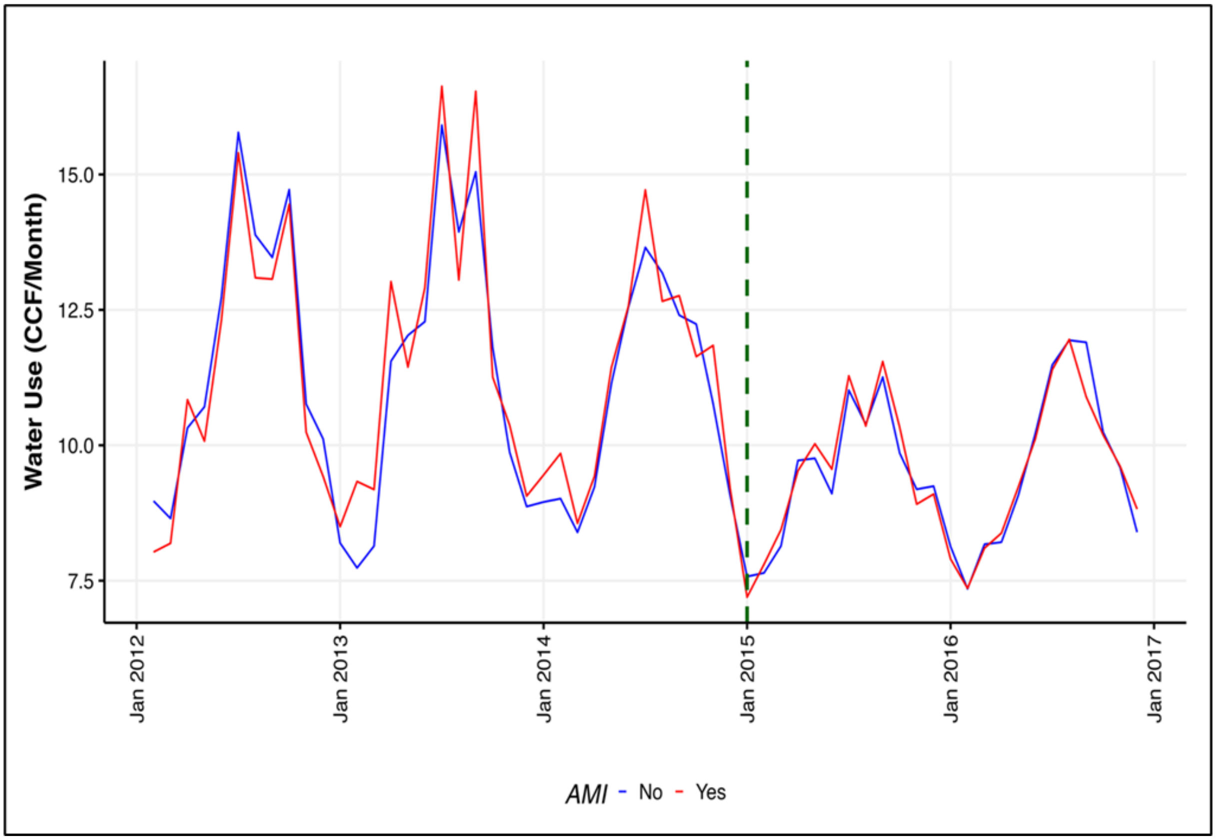

Figure 2-8. Average monthly water use by AMI installation status (2011–2017) matched sample

Statistical Evidence

To estimate the effect of AMI installation on household water use and monthly bills, we apply a difference-in-differences approach using a restricted sample from 2011 to 2017. Importantly, this analysis is conducted after performing matching on observable household characteristics to ensure comparability between treated (AMI) and control (non-AMI) groups. This method allows us to isolate the causal impact of AMI installation while controlling for both time-invariant household characteristics and broader time trends.

Table 2-3 presents the main estimation results. Column (1) shows that AMI installation is associated with an 11.1% reduction in monthly water use, as indicated by the negative and statistically significant coefficient on the log of water use. Column (2) shows a substantial and significant reduction of $31.05 in the average monthly water bill following AMI installation.[25] Both results are statistically significant at the 1% level. All regressions include household, month, year, and census tract fixed effects.

[25] The reason the first estimate is in percentage terms and the second estimate in $ terms is that the dependent variable in our water use analysis is transformed by taking its natural logarithm (i.e., water use), which means that the estimates are in percentage terms. Alternatively, for the water bill specification, the dependent variable is not transformed. Interpretation of log transformed estimates follow convention (Kennedy 1998).

Table 2-3. Estimated impact of AMI installation on monthly water use and water bills (Agency B)

	Log Water Use	Water Bill ($)
	(1)	(2)
AMI Installation	-0.111***	-31.047***
	(0.033)	(1.421)
Observations	125,434	125,434
R^2	0.652	0.681

*Note:*p**p***p<0.01

Notes: We use household, month, year, and census tract fixed effects in all the regressions above.

2.4 Main Results: Agency C

We use data from the population of single-family residential customers within the service area of Agency C. The dataset is a panel comprising about 16,000 households, observed over the period from 2013 to 2024. Figure 2-9 shows the number of single-family residential households in the Agency C that had AMI installed each month between 2020 and 2024. The chart reveals a significant surge in installation at the very beginning of the rollout period, with a peak of over 6,000 AMI installations in April 2020 alone. After that, installations sharply decline and remain relatively low and sporadic from 2021 through 2024. Overall, the figure shows that while the AMI deployment began with a strong initial push, it transitioned into a slower, steady implementation phase in later years.[26]

[26] Prior to the installation of AMI, Agency C was using AMR. AMR Leak letters started being sent out to customers around 2013.

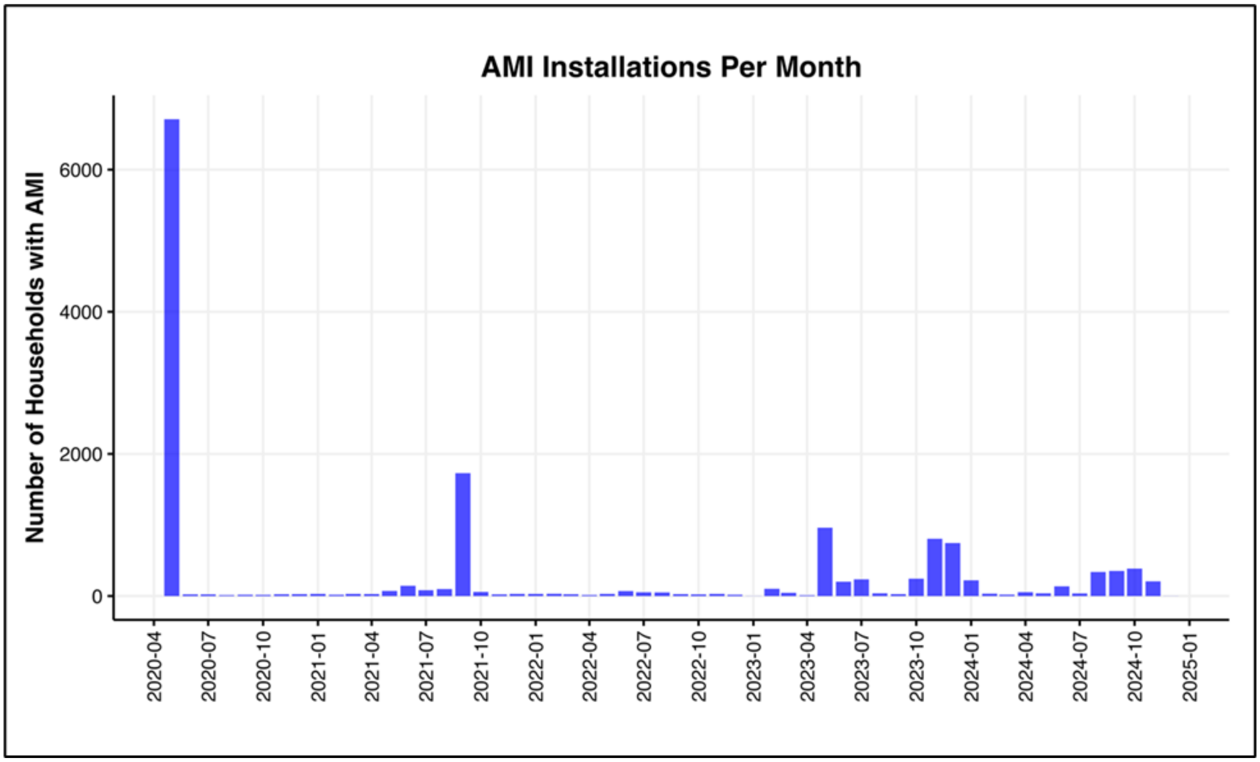

Figure 2-9. Monthly number of Agency C households with AMI installed (2020–2024)

Figure 2-10 presents the cumulative percentage of households with AMI over time. Initially, the installation rate is slow and relatively flat through early 2021, remaining around 42–45%. A sharp increase occurs around mid-2021, raising the cumulative installation rate to nearly 60%. After that, growth is steady but modest until mid-2023, when another major wave of installations pushes the installation rate from about 60% to over 80% within a few months. A final upward trend appears in late 2024, bringing cumulative AMI installation to just above 90%.

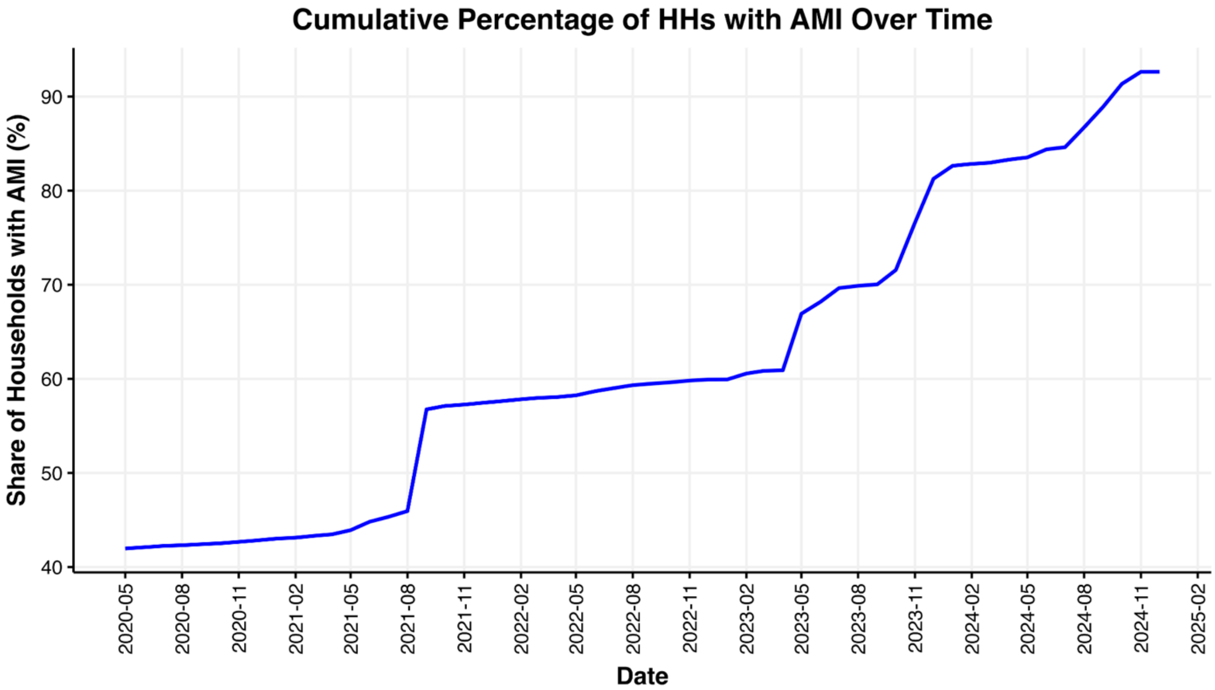

Figure 2-10. Cumulative share of Agency C households with AMI installed (2009–2022

Graphical Evidence

To begin assessing the effect of AMI installation on household water use, we divide the sample into two groups: households that had AMI installed at any point during the study period (treated group), and households that did not (comparison group). We create a binary indicator variable equal to 1 for household-months in which AMI is in place, and 0 otherwise. This distinction allows us to compare the water use behavior between AMI and non-AMI households over time.

Figure 2-11 shows the unadjusted monthly average water use (measured in CCF per month) for both groups between 2013 and early 2024. No additional statistical controls (such as household fixed effects, seasonal effects, or economic variables) are applied in this figure. As shown, both groups display clear seasonal variation, with higher water use during summer months and lower use in the winter. Because of the continuous nature of AMI installation across households throughout the period of analysis, it is difficult to identify an impact of AMI installation on water use without a more systematic and structured approach.

As such, in an attempt to isolate the causal effect of AMI on water use, we complement the graphical analysis with statistical methods, including fixed-effects regression, and difference-in-differences estimation, which control for household-specific and time-varying influences.

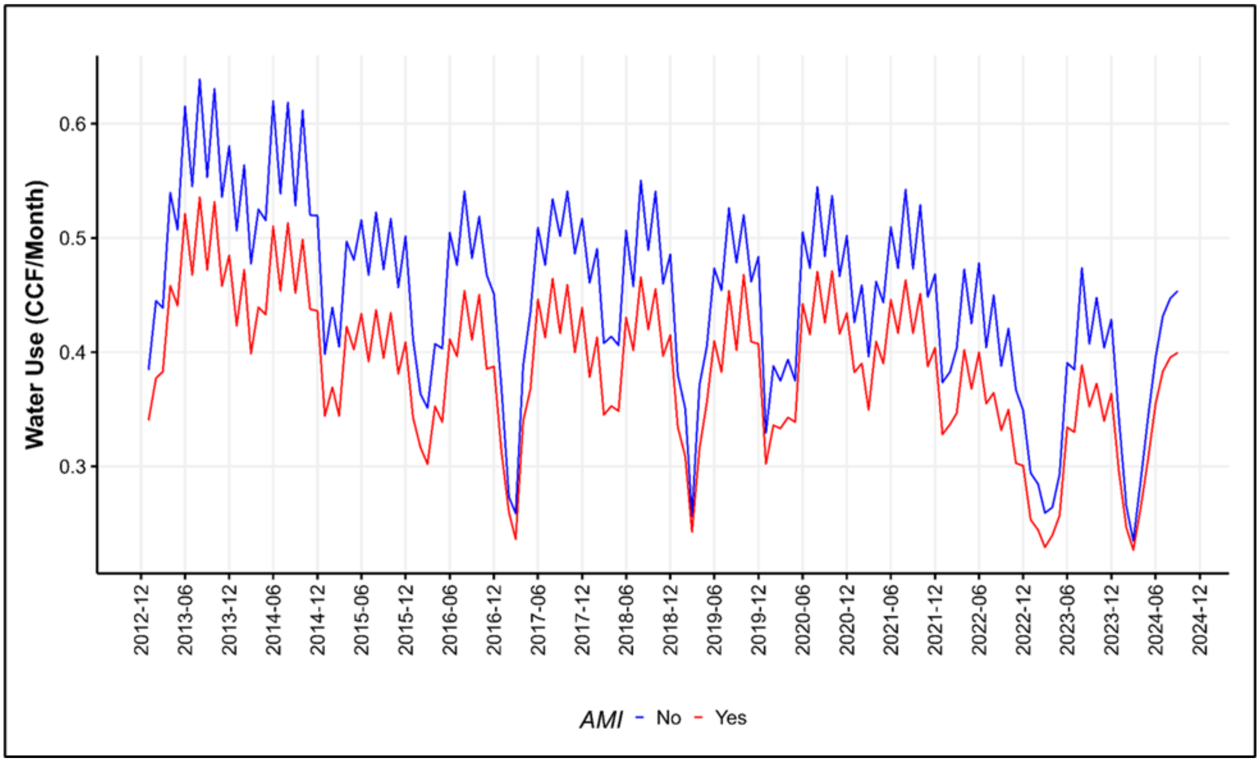

Figure 2-11. Average monthly water use by AMI installation status (2013–2024)

Statistical Evidence

To estimate the effect of AMI installation on household water use and monthly bills, we apply a difference-in-differences approach using data from 2013 to 2024. This method allows us to isolate the causal impact of AMI installation while controlling for both time-invariant household characteristics and broader time trends.

The results of our estimates are presented in Table 2-4. The number (estimate) -0.023 means that after getting an AMI meter, households used 2.3% less water per month, on average. The second number, -0.134, tells us that monthly water bills went down by about 13 cents, on average, after AMI was installed.[27] These effects are statistically significant, meaning they're unlikely to be due to chance.

[27] As mentioned previously, the reason the first estimate is in percentage terms and the second estimate in $ terms is that the dependent variable in our water use analysis is transformed by taking its natural logarithm (i.e., water use), which means that the estimates are in percentage terms. Alternatively, for the water bill specification, the dependent variable is not transformed. Interpretation of log transformed estimates follow convention (Kennedy 1998).

Table 2-4.Estimated impact of AMI installation on monthly water use and water bills (Agency C)

	Log Water Use	Water Bill ($)
	(1)	(2)
AMI Installation	-0.023***	-0.134***
	(0.002)	(0.213)
Observations	942,547	942,547
R^2	0.705	0.633

Note: *p**p***p<0.01

Notes: We use household, month, year, and census tract fixed effects in all the regressions above.

2.5 Main Results: Agency D

We use data from the population of single-family residential customers within the service area of Agency D. The dataset is a panel comprising approximately 35,000 households, observed over the period from 2012 to 2023. Figure 2-12 shows the number of single-family residential households in Agency D that had AMI installed each month between 2017 and 2022. The data reveal a highly uneven installation pattern, with multiple distinct surges in deployment. The largest spike occurs around mid-2018, with over 1,500 households having AMI installed in a single month. Other notable peaks appear in early 2019 and again in early 2020 and 2021.

Figure 2-13 presents the cumulative percentage of households with AMI over time. Initially, AMI installation is minimal, with the share of households under 5% through most of 2016. A clear upward trend begins around early 2017, with installation steadily climbing year over year. The most rapid period of increase occurs between 2017 and 2020, during which the share of AMI-equipped households rises from roughly 10% to nearly 40%. After 2020, the rate of growth slows, with the cumulative share leveling off slightly above 40% by early 2023.

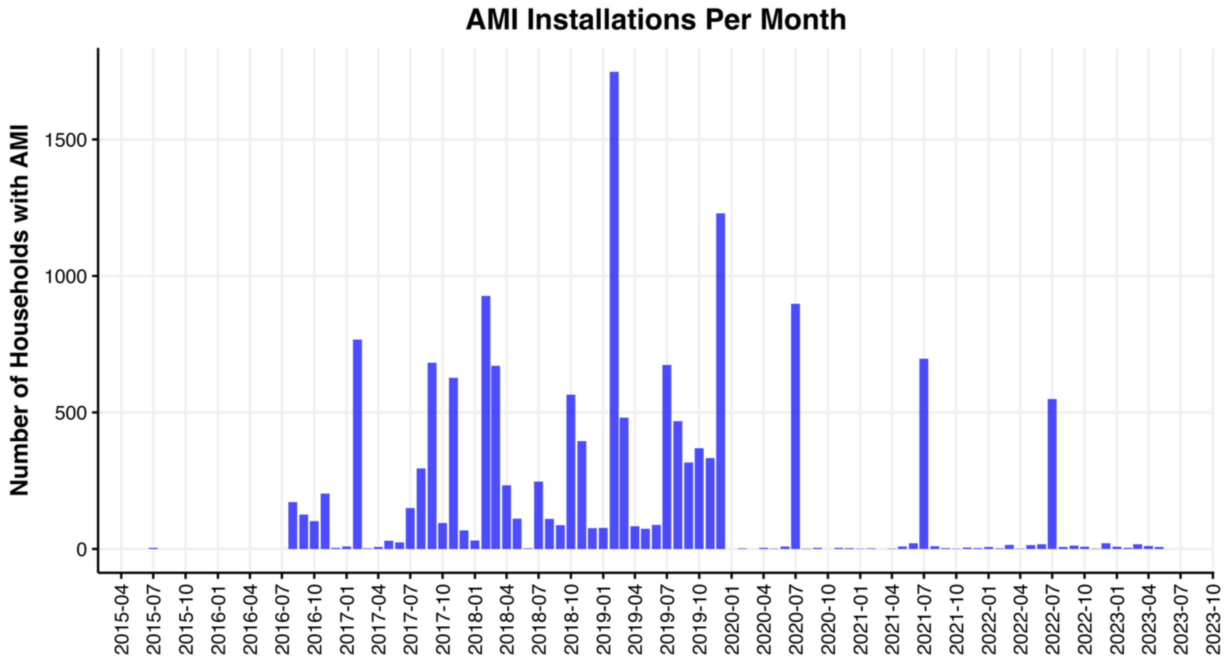

Figure 2-12. Monthly number of Agency D households with AMI installed (2009–2022)

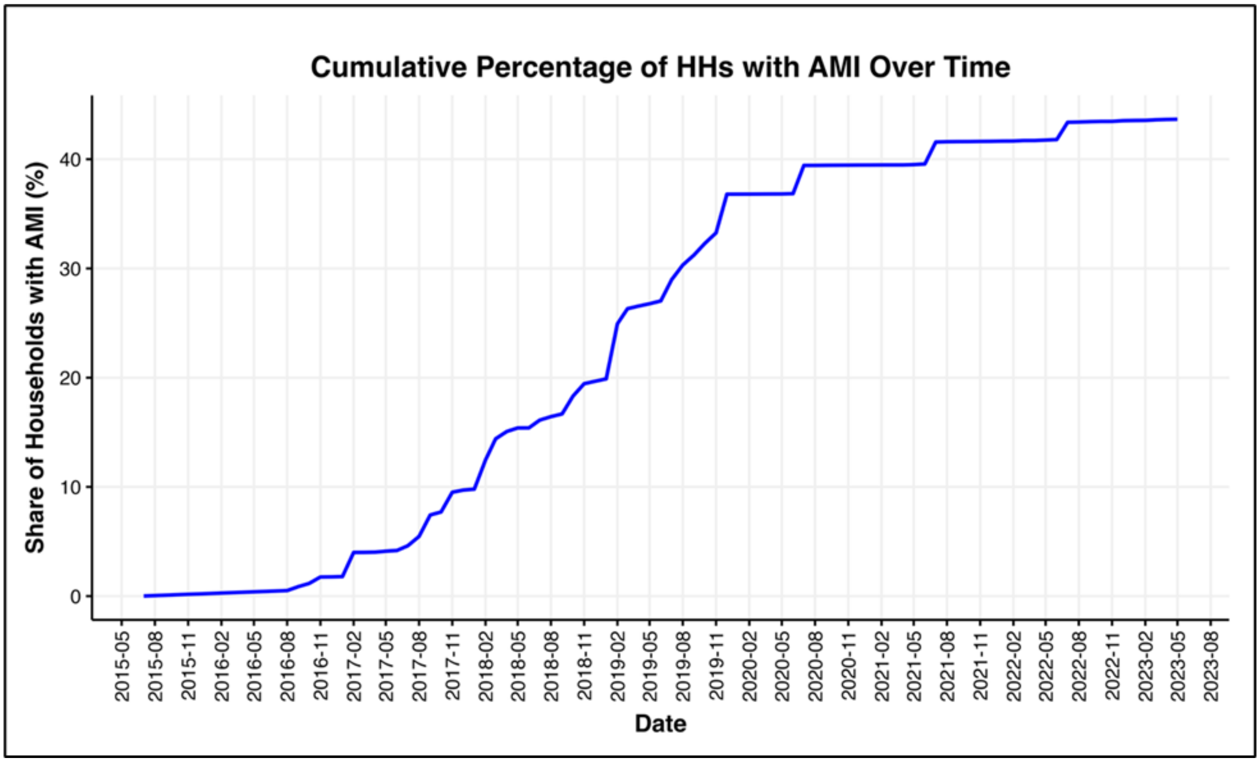

Figure 2-13. Cumulative share of Agency D households with AMI installed (2009–2022)

Graphical Evidence

To begin assessing the effect of AMI installation on household water use, we divide the sample into two groups: households with AMI installed at any point during the study period (treated group), and households that did not have AMI installed (comparison group). We create a binary indicator variable equal to 1 for household-months in which AMI is in place, and zero otherwise. This distinction allows us to compare the water use behavior between AMI and non-AMI households over time. Figure 2-14 shows the unadjusted monthly average water use (measured in CCF per month) for both groups between 2017 and early 2023. No additional statistical controls (such as household fixed effects, seasonal effects, or economic variables) are applied in this figure.

As indicated in Figure 2-14, both groups display clear seasonal variation, with higher water use during summer months and lower use in the winter. We also observe no clear difference in average water consumption between households with AMI installed and those without AMI, based on raw comparisons. This suggests that any potential impact of AMI may not be easily detected without accounting for other influencing factors. Therefore, to formally assess the effect of AMI installation on household water use and bills, we employ a difference-in-differences approach. This method allows us to isolate the causal impact of AMI by comparing changes in outcomes over time between treated and comparison groups, while controlling for unobserved, time-invariant household characteristics and broader temporal trends.

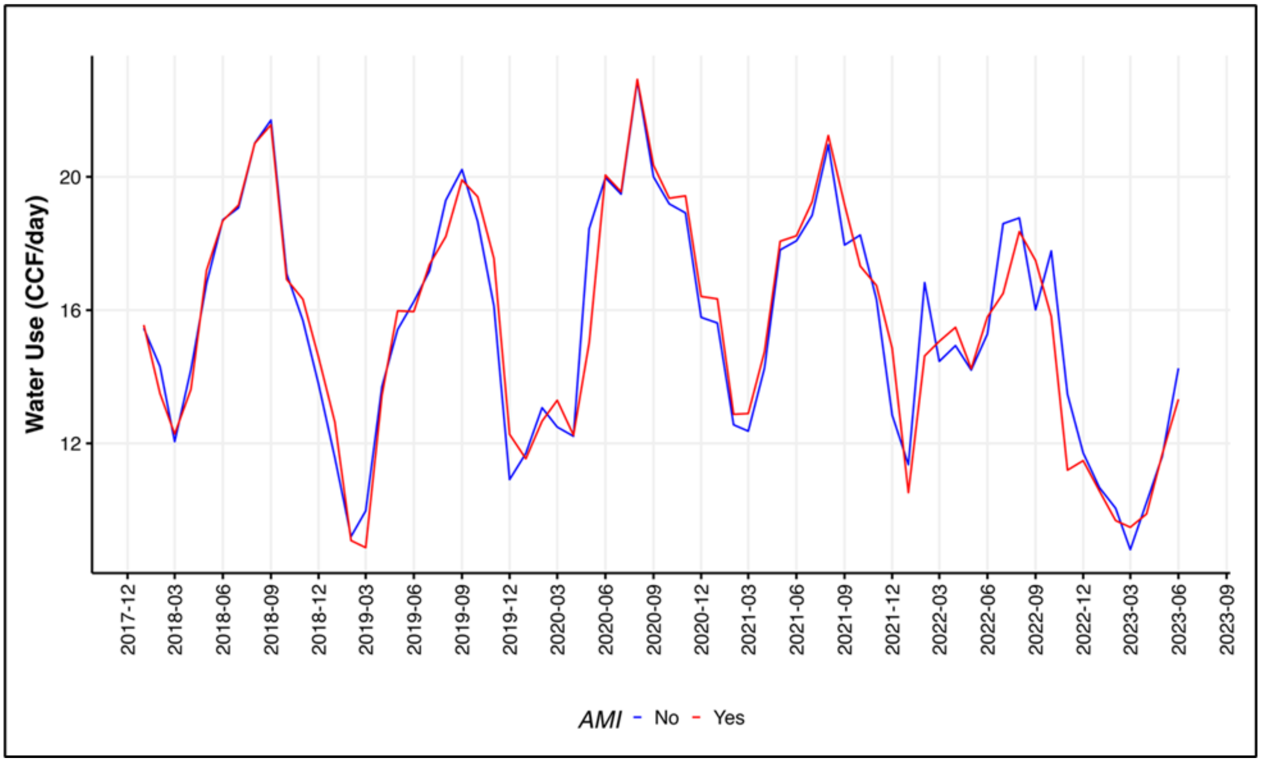

Figure 2-14. Average monthly water use by AMI installation status (2011–2021)

Statistical Evidence

To estimate the effect of AMI installation on household water use and monthly bills, we apply a difference-in-differences approach using data from 2012 to 2023. This method allows us to isolate the causal impact of AMI installation while controlling for both time-invariant household characteristics and broader time trends. The results of our estimates are presented in Table 2-5.

The number -0.016 means that after getting an AMI meter, households used 1.6% less water per month, on average. The second number, -0.697, indicates that monthly water bills decreased by approximately one dollar, on average, after AMI was installed.[28] This impact on bills might come from AMI helping catch leaks earlier, or better understanding their usage. These effects are statistically significant, meaning they're unlikely to be due to chance.

Table 2-5. Estimated impact of AMI installation on monthly water use and water bills (Agency D)

	Log Water Use (1)	Water Bill ($) (2)
AMI Installation	-0.016***	-0.697***
	(0.001)	(0.067)
Observations	2,883,124	2,883,124
R^2	0.618	0.563

Note: *p**p***p<0.01

Notes: We use household, month, year, and census tract fixed effects in all the regressions above.

2.6 Summary of the Findings

Table 2-6 summarizes the estimated effects of AMI installation on monthly water use and household bills across the four water agencies included in the study. The results indicate that the impact of AMI varies substantially across different agencies. The most pronounced effect is observed in Agency B, in which AMI installation is associated with an 11.1% reduction in water use and a $31.05 drop in monthly bills. The other three agencies—A, C, and D—show more modest but consistent reductions in water consumption, ranging from 1.3% to 2.3%, and small

[28] The reason the first estimate is in percentage terms and the second estimate in $ terms is that the dependent variable in our water use analysis is transformed by taking its natural logarithm (i.e., water use), which means that the estimates are in percentage terms. Alternatively, for the water bill specification, the dependent variable is not transformed. Interpretation of log transformed estimates follow convention (Kennedy 1998).

decreases in bills between $0.13 and $0.82. These differences may reflect variations in rollout timing, customer engagement, or baseline water use that influence AMI effectiveness. Overall, the findings support the conclusion that AMI has the potential to reduce both consumption and costs, though the magnitude of impact depends on the agency and implementation details.

Table 2-6. Summary of estimated impact of AMI installation on monthly water use & water bills

	Log Water Use	Water Bill ($)
	(1)	(2)
Agency A	1.3%	0.82
Agency B	11.1%	31.05
Agency C	2.3%	0.13
Agency D	1.6%	0.70

Regarding customer engagement, Agency B implemented a proactive approach along two different pathways. First, an initial requirement for customers to be part of their low-income rate assistance program was to be registered into the AMI portal, although that requirement was removed in 2021. Second, if customers register for online bill pay they are automatically registered into the AMI portal. Through this system, customers can set up alerts for water usage or estimated billed amounts enabling a timely response to potential water leaks. In contrast, Agency A and Agency C offered similar engagement tools, but enrollment was voluntary, and the systems were only actively promoted or functional in recent years, limiting their reach and potential impact.[29] Agency D, on the other hand, relied on a more traditional method. It initially used paper-based bill inserts to inform customers about potential leaks or unusually high usage.[30] These differences in engagement strategies may help explain the variation in AMI impact observed across the agencies.

[29] Prior to implementing AMI systems, some agencies were using AMRs and were messaging customer related to leaks. In some cases, AMR Leak Letters were sent out to customers based on leak codes.
[30] Since then Agency D uses texts and emails as well to communicate with customers.

Summary and Concluding Remarks

The purpose of this project was to analyze how water affordability for single-family residential (SFR) customers has varied over time and across retail water agencies within Metropolitan Water District's service area, as well as to investigate the degree to which installation of AMI has led to any appreciable change in water use and water expenditures for SFR households. The affordability analysis is based on a sample of 125 retail agencies within MWD's service area, covering approximately 87% of the service area population and over 5.1 million households. The AMI findings are drawn from four agencies that have implemented this technology to varying degrees.

Regarding water affordability, residential water expenditures for 6 CCFs (hundred cubic feet) generally increased between 2013 and 2024, but at a rate lower than both inflation but slightly faster than median household income (MHI). Specifically, average monthly spending rose by slightly over $10 in real 2020 dollars, or approximately 1.71% annually, while MHI increased by 1.1% annually and the average annual inflation rate was over 2.74%. Consequently, the Water Expenditure Ratio (WER)—a measure of affordability—slightly increased on average from about 0.74% to 0.76% across agencies, or around 0.24% annually. This average WER was significantly below one affordability measure, the California's State Water Resources Control Board (SWRCB) affordability threshold of 1.5%. However, for lower-income households—and using the 20th percentile income at the census tract to indicate lower income—annual average WERs increased from 2.84% to 2.95% over the period of analysis, a slight increase yet consistently above the state threshold of 1.5%. Agencies serving these populations typically had higher water expenditures and lower incomes than agencies below these thresholds.

For communities that have received Disadvantaged Community status (DACs), WERs were 53% to 78% higher than in non-DACs primarily due to significantly lower incomes within DACs, although these WERs were still generally below the state's 1.5% threshold. Agency-related factors, such as budget-based rates, providing both water and wastewater services, and serving larger populations were associated with lower WERs. Agencies that have implemented budget-based rates may have the flexibility to offer lower-cost water to customers at a lower unit rate that would cover some or much of the 6 CCFs that we evaluate here, especially relative to a uniform price associated with a volumetric rate. [31] Larger populations are likely associated with larger agencies that are able to spread their fixed costs—which often comprise the bulk of

[31] Of course, water rates are influenced by many factors and thus a more indepth analysis would be need to fully analyze the relationship between rate structures and water costs and develop more concreate conclusions regarding causation vs correlation.

overall agency costs—over a larger population thereby lowering their average costs of delivering 6 CCFs per household. There also may be some shared resources for agencies that offer both water and wastewater services that lower the overall average costs of supplying water to customers. Conversely, a higher share of rental properties within an agency's boundaries was linked to higher WERs, likely due to lower average incomes among renters.

For AMI and water consumption/bills, findings from the four agencies that implemented AMI show a negative and statistically significant, albeit varied, relationship between AMI implementation and water use. Water use by single-family residential customers decreased between 1.3% and 11.1%, on average, and average monthly water bills also decreased for these customers, ranging from $0.82 per month up to $31.05 permonth in savings. The variability in these outcomes is attributed to differences in how AMI has been implemented and the stage of implementation across agencies. For example, some agencies centralize information for customers based on water-use anomalies, while another have opted for mandated digital platform engagement. The degree to which savings are realized is significantly dependent on the level of agency implementation and the extent of customer engagement with the new meters and agency platforms. While AMI is considered a promising tool for reducing water use and bills, its effectiveness hinges on various factors, including baseline leaks, customer incentives, and their willingness, time commitment, and incentives to engage with the provided information and tools.

We also note that in our discussions with water agency staff regarding AMI, there were other benefits associated with AMI, and that further analysis of the role it might play may be insightful. For instance, beyond the four agencies that provided data, staff from other agencies highlighted the cost savings associated with not having to manually read meters, savings that would be associated with labor and transportation costs. Of course, there are likely labor and technology costs with automation as well that would need to be figured into this. Additionally, potentially more accurate reading and thus revenue collection also was highlighted as being a benefit related to AMI technology versus older meters. Finally, while on average we find that the savings are varied and, in three of the four cases, somewhat limited, there could be more significant and important adjustments to customers on the margin that such leak detection and access to real-time water use might provide.[32]

[32] This might be particular important for customers who confront a tiered rate system and thus minor changes in water use might lead to more significant changes in water expenditures if they are observed to drop to a lower tier and lower price.

References

Cardoso, Diego S, and Casey J Wichman. 2022. "Water affordability in the united states." *Water Resources Research* 58 (12):e2022WR032206.

Daminato, Claudio, Eugenio Diaz Fariña, Massimo Filippini, and Noemi Padrón. 2021. The Impact of Smart Meters on Residential Water Consumption: Evidence from a Natural Experiment in the Canary Islands. *Resource and Energy Economics*. 64. 101221. 10.1016/j.reseneeco.2021.101221.

Goddard, Jessica J, Isha Ray, and Carolina Balazs. 2021. "Water affordability and human right to water implications in California." *PloS one* 16 (1):e0245237.

Lee, Juhee , Mehdi Nemati, and Ariel Dinar. 2021. "How has residential per capita water consumption in California changed between 1994–2019?" ARE *Update* 24 (5):5-8.

Lee, Juhee, Mehdi Nemati, and Ariel Dinar. 2022. "Historical trends of residential water use in California: Effects of droughts and conservation policies." *Applied Economic Perspectives and Policy* 44 (1):511-530.

Mack, Elizabeth A, and Sarah Wrase. 2017. "A burgeoning crisis? A nationwide assessment of the geography of water affordability in the United States." *PloS one* 12 (1):e0169488.

Nemati, Mehdi, and Kurt Schwabe. 2022. "Re-examining the water affordability: A comparison of alternative measures." JAWRA *Journal of the American Water Resources Association*.

Patterson, Lauren A, Sophia A Bryson, and Martin W Doyle. 2023. "Affordability of household water services across the United States." *PLOS Water* 2 (5):e0000123.

Teodoro, Manuel P. 2018. "Measuring household affordability for water and sewer utilities." *Journal-American Water Works Association* 110 (1):13-24.

Teodoro, Manuel P. 2019. "Water and sewer affordability in the United States." AWWA *Water Science* 1 (2):e1129.

Wooldridge, Jeffrey M. 2013. "Introductory econometrics: A modern approach 5th edition." *Mason, OH: South-Western*.