



Less Water, More Risk

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Exploring national and local
water use patterns in the U.S.

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EXECUTIVE SUMMARY


Frequently overlooked and taken for granted, water is not just vital for life; it also provides an economic foundation for millions of businesses, farms, manufacturers, and households that depend on a reliable supply each day. This foundational role puts considerable pressure on water utilities, which must maintain safe, efficient infrastructure and ensure that water is affordable for end users. Yet, in many areas across the United States, local leaders and residents do not consistently understand how much water they use or how their water demands connect to industrial change, population growth, and environmental stability.

This report provides a comprehensive comparison of metropolitan and nonmetropolitan water use patterns to help fill this information gap. It not only highlights the scale and complexity of how users in different areas depend on water, but also points to difficulties these users—and providers—face managing this scarce resource in an economically efficient and equitable way, alongside a growing list of physical infrastructure and natural environment concerns. It does so by analyzing water use data from the U.S. Geological Survey from more than 50 years to find that:

A. Nearly 355 billion gallons of water are used each day in the United States, a total that has

declined in recent years across a variety of categories. 90 percent of the country's water withdrawals are concentrated in three categories of use—thermoelectric power, irrigation, and public supply—reaffirming water's importance to a number of different industries and households nationally. Over the past few decades, however, water use has fallen by 42 billion gallons each day, in large part because of greater efficiency among these users.

B. More than 221 billion gallons of water are used each day in metro areas, accounting for 63 percent of the U.S. total, but users in these areas tend to be more efficient than those in other parts of the country. As the centers of U.S.



population and economic output, metro areas use the most water, including 80 percent of industrial use and 83 percent of public supply use. Just 25 of these metros, including New York, Chicago, and Washington, D.C., use 90 billion gallons of water per day, a quarter of the U.S. total. Nonetheless, users in these metros are much more efficient in their total water use (840 gallons per capita per day) than nonmetros (2,810 gallons per capita each day).

C. From 1985 to 2010, water use in metro areas fell by 39 billion gallons each day, which drove almost 90 percent of the national decline during this period. As U.S. water use declined in recent decades, users in metro areas led the charge, particularly in the 100 largest metro areas, which reduced their use by 30 billion gallons a day. Aggregate use declined in nearly all major categories except public supply. Increasing public demand in many metro areas is challenging utilities to provide reliable, affordable water to a growing customer base.

D. Several factors—including higher levels of energy and agricultural production, shares of developed land, and population densities—have a significant effect on water use within metro areas and nonmetro areas. When considering total water use, areas that generate more electricity, produce more crops, house more people, and contain more development tend to use

more water, including many parts of California's Central Valley. On the other hand, areas with higher population densities, shares of multi-unit housing, and compact forms of development tend to use less total water and residential water. Other characteristics, including housing values and certain resident demographics, also have significant effects.

While the U.S. is using less water and achieving greater water efficiency as a whole, many users, including power plants and agricultural producers, still require large amounts of water in specific areas, and utilities may be hard-pressed to implement infrastructure improvements in a timely, affordable fashion. In other words, traditional ways of managing scarce water resources are no longer sufficient to achieve long-term, dependable service and fiscal certainty. At a time when consumer demands are evolving, climate concerns are intensifying, and the need for greater technological innovation is growing, utilities and other local, state, and federal leaders must have a clearer assessment of the major environmental and economic risks at hand. By quantifying how water use is changing across different regions, this report creates a new starting point for these leaders to build on, where they can more consistently weigh risks to craft more efficient and equitable water infrastructure strategies.

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01 INTRODUCTION

The United States faces a wide range of water infrastructure challenges, from aging pipes and outdated sewer systems to polluted waterways and degraded floodplains. The enormous variety of water infrastructure in need of repair and investment—with costs totaling up to \$655 billion over the next 20 years—can be difficult to track at times, especially since many of these systems are out of sight and out of mind.¹ At the same time, the country is confronting a rising number of climate concerns and other physical pressures at these outmoded facilities, which face even more urgency and uncertainty after the U.S. withdrawal from the Paris Climate Agreement. Meanwhile, finding the skilled workers to carry out any improvements remains a significant impediment.²

These challenges are growing in frequency and intensity, often with significant environmental and economic ramifications.³ Flint, Mich., is perhaps the most notable example in recent years, as many of its lower-income residents continue to grapple with water quality concerns stemming from its lead-tainted water system. Moreover, communities across California are slowly emerging from one of the most severe droughts in history, which has pressured households, businesses, and other agricultural producers to conserve water in ways never previously imagined. Many regions, from New York and New Jersey to Illinois and Indiana, are simply struggling to keep up with maintenance for their older water systems, as they operate under increasingly tight budgets and cope with water main breaks and other failures.



Given the magnitude of the country's water infrastructure challenges, federal leaders are expressing heightened interest in new interventions. Both the Trump administration and Congress are considering options aimed at jump-starting water infrastructure investment on a national scale. However, a one-size-fits-all approach—based on the needs of only a few places or the U.S. as a whole—fails to capture the remarkable regional variety in water infrastructure governance, financing, design, and management across the country.

Instead, relying on more customized strategies that reflect state and local water needs can help define and ultimately deliver solutions to the country's crumbling water infrastructure. Whether fixing leaking pipes, replacing lead service lines, or protecting vulnerable streams, localities stand at the front line of these challenges. Yet, addressing such challenges is difficult, as places struggle to quantify their needs, coordinate action, and assemble the plans and financial resources necessary to pursue different projects.⁴

This report aims to more consistently identify, measure, and assess infrastructure's connection to broader economic priorities at a subnational level, by exploring how water is used at a metropolitan scale. Through several key metrics—including total water use and per capita water use—it provides a new starting point for metro and nonmetro leaders to consider while balancing water efficiency and equity considerations.

Depending on how water is used in a particular area, water utilities and other public- and private-sector leaders can face specific challenges—and risks—striving for improved environmental outcomes and meeting economic demands.

When using water, industries look to optimize productivity and reduce waste, which is central to an efficient regional economy; likewise, utilities try to ensure that water is accessible and affordable to all users, which is central to an equitable regional economy. Steps toward greater efficiency are crucial, especially from an environmental standpoint, but leaders must also closely track how their water demands are changing in light of broader economic concerns, including equity. In this way, water is a vital natural resource to sustain life, ensure public health, and support a variety of other goals, but it is also an essential input to drive economic growth and opportunity.⁵ Infrastructure is the key conduit to achieve this objective, yet it faces unique pressures in individual markets.

By examining how individuals and industries in metropolitan areas use water each day—from ordinary household uses to large-scale energy and agricultural uses—this report uncovers how these uses place specific demands on infrastructure, including declining levels of water use in many places that may be stressing utility finances. The report begins by defining and articulating the major types of infrastructure responsible for supplying water to different users and how these systems vary widely in their physical scope and investment needs. It then analyzes how water use varies in metro areas and nonmetro areas across the country, both in recent years and over the past few decades, to show how changing demands are prompting leaders to consider new management strategies. The report concludes with a discussion of what federal, state, and local leaders can do to support more efficient and equitable water infrastructure decisions in years to come.

02 BACKGROUND

The following sections describe how the U.S. manages water and offer additional background on infrastructure's complex role to serve different economic users throughout the country. The first section defines water infrastructure and what water use specifically entails in this report. Outlining the major challenges facing these facilities is the focus of the next section, including the need for greater investment despite the widespread fragmentation and difficulty coordinating action among utilities and other regional stakeholders. The last section discusses how these infrastructure concerns relate to a range of different economic users nationally, who may not always be able to clearly see how their water demands influence long-term infrastructure decisions. Together, these sections provide a foundation to better understand the patterns in metropolitan water use explored later in this report and ultimately inform what policymakers

and practitioners need to consider when defining more efficient, equitable management strategies.

What is water infrastructure?

Water infrastructure spans several different manmade and natural systems that supply, treat, and conserve one of the most fundamental resources to communities and the environment.⁶ These systems range from traditional gray infrastructure, such as pipes, pumps, and centralized treatment plants, to green infrastructure, such as rain gardens, bioswales, and other related natural assets that tend to be more decentralized.⁷ In addition, rivers, lakes, ponds, wetlands, and subsurface aquifers are critical components of water infrastructure, as well as large manmade structures, such as aqueducts and levees.



This report focuses primarily on patterns of water use at a metropolitan scale, which tend to relate more directly to infrastructure that supplies and distributes water. As described more extensively in the report's methodology section, "water use" broadly refers to any water withdrawn from the environment for a particular purpose, including residential, commercial, and industrial uses.⁸ Anything from watering residential lawns to supplying water for office buildings to cooling power plant turbines is included.⁹ In short, water is withdrawn from the ground and surface water sources, both freshwater and saline water, which is then transported, treated, and distributed through various infrastructure facilities to the end user.¹⁰ As such, water use covers withdrawals in which water is diverted from a source but returned, generally in an altered state (such as power plant cooling), as well as consumptive water use in which water is removed and not necessarily returned to the source (such as water absorbed by plants or incorporated into industrial products).¹¹

Water infrastructure, in turn, refers to all the transmission lines, treatment plants, storage facilities, distribution mains, and related assets required to move water from surface or groundwater sources, purify it to meet certain health standards, and provide it to users.¹² The physical extent of these infrastructure systems is massive, including 1.2 million miles of water supply mains, almost 26 times the length of the U.S. interstate highway network.¹³

What challenges does water infrastructure face?

The tremendous level of fragmentation across the country's water infrastructure network means that metro leaders must confront a wide assortment of challenges all at once—in terms of governance, physical repairs, and financial concerns—which are not easy to track or address.

The U.S. relies on a number of federal, state, and

local bodies to govern its water infrastructure, as illustrated in Box D later in this report. While many of these bodies coordinate with one another to oversee regulations, guide investments, and manage various infrastructure programs, plans, and projects, they also have a tendency to operate in silos.¹⁴ Localities, in particular, often bear most of the responsibility of operating and maintaining the country's water infrastructure, which can lead to struggles collaborating and developing plans across individual water systems.

Indeed, water infrastructure oversight is highly fractured. In total, more than 52,000 community water systems exist across the country—defined by the U.S. Environmental Protection Agency (EPA) as systems that supply water to the same population year-round.¹⁵ Since these systems vary in scope and geographic reach, metro areas can have dozens, if not hundreds, of these systems stretching across their political boundaries and watersheds, with some systems serving only a few people and others serving hundreds of thousands of residents or other types of customers.¹⁶ Still, of the nearly 300 million people served by community water systems nationally, a little over 400 systems (less than 1 percent of the country's total number of community water systems) serve almost 140 million people (46 percent of the population).

In addition to different system sizes and functions, utility ownership varies from place to place, leading to different governance frameworks. Nearly 90 percent of the country's population is served by water systems that are publicly owned by municipalities, counties, local regional authorities, and governmental districts, which include utilities such as DC Water and Denver Water.¹⁷ However, the remaining 10 percent of the population is served by privately owned water systems, controlled by individuals or companies.¹⁸ These include thousands of smaller systems (mobile home parks, for example) as well as bigger systems owned by large companies such as American Water.¹⁹ Other types of arrangements,

including public-private partnerships (PPPs), are also gaining interest depending on a particular system's needs.²⁰

Likewise, the specific source of water used can complicate how leaders in metro and nonmetro areas manage increasingly scarce or depleted supplies. Nearly 77 percent of all water withdrawals nationally come from surface water sources such as rivers, lakes, and reservoirs, but the remaining 23 percent come from groundwater sources, including aquifers.²¹ While concerns over water quality and quantity may be more apparent in surface water sources, water is constantly moving above and below the Earth's surface as part of the hydrologic cycle, which demands a more integrated look at surface water and groundwater issues together.²² For instance,

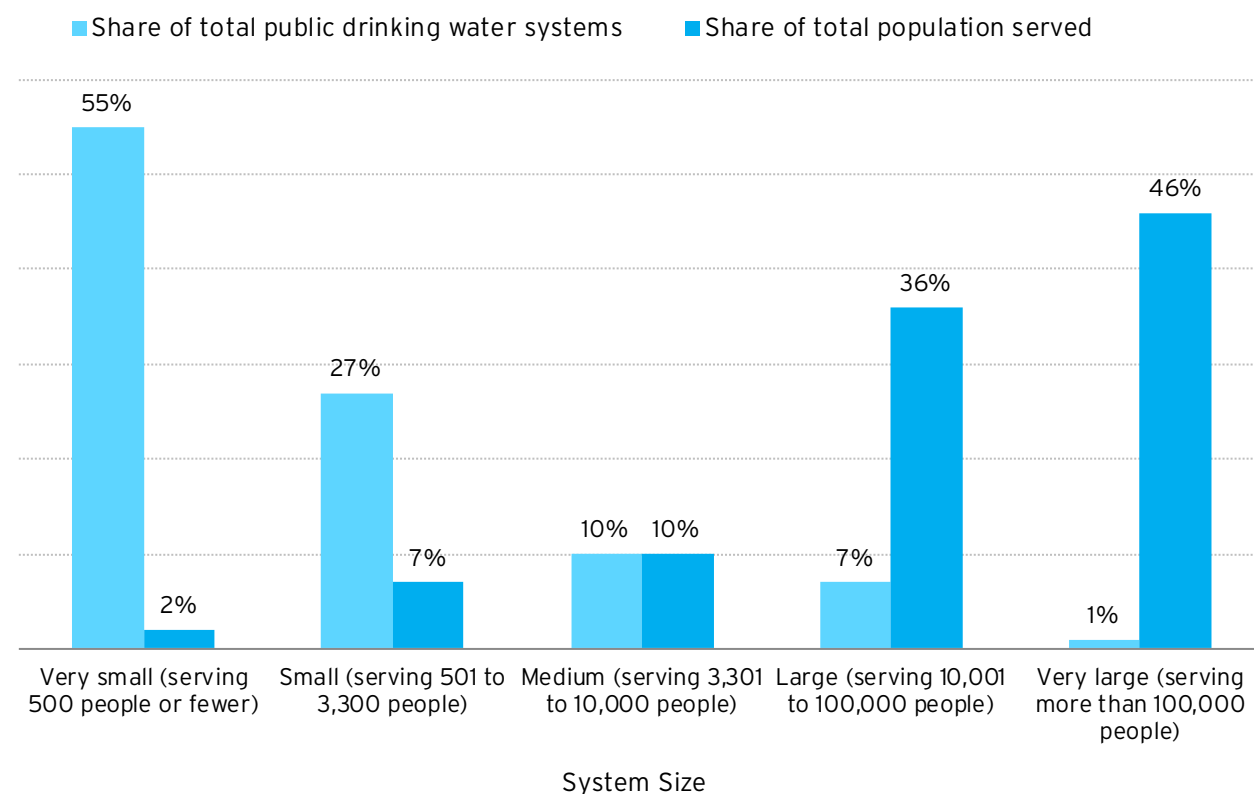
ensuring that ongoing agricultural and urban development does not overuse or contaminate groundwater resources is a key challenge for many regions. Steps toward additional water reuse—including wastewater recycling—are useful to consider in this way. Still, addressing larger surface water and groundwater issues together is challenging given the need to coordinate action among multiple stakeholders, often across jurisdictional and state lines.²³

Beyond governance, the physical challenges are becoming more extreme as well; the pipes, plants, and other systems moving and treating water are near a breaking point in many regions. Years of deferred maintenance, inadequate funding, and other emerging challenges—including increases in population, urban development, and severe

FIGURE 1

Water infrastructure oversight is highly fractured, with more than 52,000 community water systems across the United States

U.S. water infrastructure, by system size and population served



Source: Brookings analysis of Environmental Protection Agency data

droughts and floods—have left systems struggling to provide clean, efficient, and equitable service.

According to EPA water needs surveys, up to \$655 billion in infrastructure investments will be needed over the next 20 years, most of which would be due to replacing and refurbishing deteriorating transmission and distribution facilities.²⁴ This total surges even higher when considering climate change impacts.²⁵ Since many of these systems were built in the late 19th century through the mid-20th century, they are reaching the end of their useful life span.²⁶ Leaking pipes waste 2.1 trillion gallons of water each year, which includes treated water lost before even reaching end users.²⁷ At the same time, more than 2,000 water systems across all 50 states need to replace miles upon miles of lead pipes with excessive levels of contamination.²⁸ Additionally, 240,000 water main breaks occur each year in the U.S., costing \$2.6 billion annually.²⁹

The various physical needs do not fully illustrate the immense financial difficulties faced by individual utilities and regional leaders striving to manage water in more cost-effective, sustainable ways.³⁰ These difficulties are particularly important to consider in achieving more economically efficient and equitable outcomes.

When it comes to **efficiency**, short-term construction projects focused on additional capacity remain important in some areas, but most of the country is in an era of repair and replacement, where service improvements and other upgrades are critical to spell long-term gains.³¹ Yet, states and localities—the major players responsible for these repairs—are operating under limited budgets and may not have the flexibility or capacity to consider new alternatives, take on more debt, or use other financial tools, including new types of bonds.³² Instead, some utilities are delaying projects or may choose lower-cost solutions, rather than investing in innovative engineering approaches and newer technologies.³³ Box B later in this

report provides additional context to understand these challenges.

When it comes to **equity**, numerous utilities are struggling to address their most pressing projects and neighborhood-specific concerns, including water affordability. As highlighted in Box A, many regions are experiencing changes in the amount of water used, which is leading to unpredictable revenue streams for utilities that have traditionally relied on volumetric charges based on steady levels of demand.³⁴ Consequently, regions are realizing gains in water sustainability in many cases, but they are paying for infrastructure projects and making up for their revenue shortfalls by raising water rates up to 50 percent, which tends to hurt low-income households the most.³⁵ Amid these customer-facing affordability concerns, utilities are also struggling to recruit workers. The significant gap in hiring, training, and retaining skilled workers to manage systems is a pressing concern for utilities balancing multiple tasks.³⁶

Combined, these issues pose several risks to the country's water infrastructure, which cities, states, and their federal partners must address

“ In general, utilities face two competing stresses: increasing costs to maintain and update deteriorating infrastructure, along with an expanding customer base that cannot afford rising utility bills. ”

Box A: The water equity challenge

As users in metro and nonmetro areas alter their long-standing patterns of water use—traditionally defined by continued growth—utilities are facing new pressures to manage water. Surrounded by aging infrastructure, they must come up with more financial resources than ever to pay for repairs and manage the costs of service. Yet, they are dealing with greater uncertainty forecasting water demands, as many users are curbing their demand and becoming more efficient. The result: water rates are rising to maintain durable levels of revenue, but not all users can easily absorb these costs, leading to several equity concerns.

In general, utilities face two competing stresses: increasing costs to maintain and update deteriorating infrastructure, along with an expanding customer base that cannot afford rising utility bills. These come on top of several other pressing issues, such as regulatory compliance, public outreach, and increasing resiliency. As consumers fail to make payments or forgo services, other customers' bills climb to cover the deficit, spawning a vicious feedback cycle.³⁷ Historically, utilities have reasonably juggled the two goals of revenue stability and equity, but continued gains in water efficiency and conservation have put many utilities in a tough position.³⁸ Household water bills, for instance, now have the potential to triple in some areas, simply to maintain minimum levels of service.³⁹ The struggle to balance efficiency and affordability, all while earning enough revenue to cover infrastructure needs, has resulted in a "conservation conundrum."⁴⁰

In this way, utilities are finding it increasingly difficult to provide reliable, affordable water,

especially for certain households.⁴¹ Low-income residential users are particularly sensitive to hikes in water prices because of the nature of the resource; water is an essential household commodity, and aside from curbing wasteful practices, demand remains relatively fixed. Increasing prices places a disparate burden on poor households, who cannot adjust the amount of water used for basic needs, whereas wealthier households fail to recognize the price signal and curb their excess consumption.⁴² Small households of one or two members are especially vulnerable to rising water bills.⁴³ While water utilities continue to evaluate what rates are affordable for their customers, these efforts remain a work in progress, next to other infrastructure needs and regulatory concerns.

Meanwhile, federal affordability guidelines have attracted criticism from analysts who note that the challenge is likely larger than estimated. For example, when defining affordability for households, utilities normally follow the EPA's "affordability criteria," placing the standard at 4.5 percent of median household income for combined water and wastewater bills, which can overlook lower-income households.⁴⁴ Using this marker, census data suggest that these services are "unaffordable" for 23 million households,⁴⁵ and conservative estimates of rising rates suggest that the proportion of households with unaffordable bills could grow from 12 percent to nearly 36 percent in the next five years.⁴⁶ These increases come even as the cost of the average monthly combined water, wastewater, and stormwater bill in the U.S. has increased more than 41 percent since 2010.⁴⁷

The extent of the investment and affordability crisis is extensive. Cities such as Austin, Texas; Charlotte, N.C.; Chicago; San Francisco; and Tucson, Ariz., have all experienced water rate hikes of over 50 percent in the past five years, and some studies have predicted that water rates could quadruple over the next two decades.⁴⁸ This crisis is particularly apparent in Detroit,

where a declining urban population has left fewer customers to pay for water.⁴⁹ To continue providing affordable water service for a range of customers, utilities must closely monitor how their water demands are changing and consider new revenue streams beyond increasing volumetric rates. Otherwise, the water equity challenge figures to become even worse.

alongside other competing demands. Developing a more comprehensive, forward-looking approach to improve these interlocking systems of water infrastructure is not easy, but it is crucial to provide efficient, equitable service to millions of users nationwide.

Who are water's major users?

The sizable geographic extent of the country's water infrastructure underscores water's importance to a variety of users and the economy. From farms in Nebraska to factories in Indiana to apartments in New York, water is an indispensable resource used to grow crops, manufacture products, fulfill household needs, and even generate electricity. As measured by the U.S. Geological Survey (USGS), the United States withdraws nearly 355 billion gallons of water each day across all uses.⁵⁰

Based on USGS definitions, this report investigates water use across five major categories: thermoelectric power, irrigation, public supply, industrial, and other.⁵¹

Generating electricity tends to require the most water, particularly for **thermoelectric power** plants, which rely on fuels such as coal and natural gas to heat water and produce steam, which drives a turbine and creates power.⁵² The primary demand for water in thermoelectric power plants, though, is for cooling water, which helps re-condense steam into water before the cycle is repeated.⁵³ Over time, these plants have

transitioned from inefficient "once-through" cooling systems to more efficient "closed-loop" cooling systems, which recirculate and reuse water.⁵⁴ Still, there is more room for innovation in many regions, as researchers, planners, and other practitioners are exploring through a field of work that covers the "water-energy nexus."⁵⁵

Agriculture and horticulture also depend on extensive amounts of water, especially for **irrigation** when harvesting crops or supporting other types of vegetation.⁵⁶ Agricultural states with dry climates such as California and Texas tend to use more water for irrigation, increasingly from groundwater sources.⁵⁷ Ongoing drought conditions and water scarcity concerns, though, have prompted reassessments in irrigation and groundwater management, including advancements in irrigation methods, such as sprinkler irrigation, microirrigation, and surface systems.⁵⁸

Beyond those industry-centric categories, water utilities manage and provide **public supply** water to all types of communities across the country, where residential customers account for most of these water deliveries.⁵⁹ On average, American families use more than 300 gallons of water per day at home, 70 percent of which tends to take place indoors and 30 percent outdoors.⁶⁰ As a result, utilities often face immense pressure to keep up with consumer demands, maintain assets, and provide clean, reliable service.⁶¹ While doing so, they also act as major economic anchors in their communities. Public utilities

invest \$23 billion each year, contribute \$52 billion in economic output, and employ 289,000 workers annually.⁶²

In addition, direct **industrial** water use is critical for a variety of economic activities, including manufacturing. Commodities such as food and beverages, paper, and chemicals are among the major goods that depend on relatively large amounts of water, particularly in bigger manufacturing establishments.⁶³ Even the production of simple goods such as T-shirts can require 700 or more gallons of water each, from creating materials to diluting waste.⁶⁴ Consequently, exploring ways to improve efficiencies in these processes is a priority for many industries and researchers.

Finally, multiple **other** categories individually withdraw smaller amounts of water but further underscore water's economic significance nationally. Water for livestock, aquaculture, mining, and self-supplied residential uses are captured here. Livestock withdrawals involve

watering, feeding, and conducting dairy operations but do not necessarily capture the full "water footprint" of meat production, which is often closely tied to other agricultural activities.⁶⁵ Aquaculture involves the controlled harvesting and cultivating of fish and other aquatic organisms. Mining activities include quarrying and fracking, which have environmental and regulatory implications.⁶⁶ Self-supplied residential use generally involves private water sources, such as wells, which tend to be concentrated in rural areas.⁶⁷

When viewed together, the categories described in this section highlight water's diverse economic role nationally. Strengthening this role, however, requires an infrastructure network that can deliver water reliably, efficiently, and equitably. To support this network, metro and nonmetro leaders must have a more consistent and comprehensive sense of how their shifting water uses can influence steps toward greater innovation, revenue stability, and coordinated planning efforts.

Major categories of water use⁶⁸

Thermoelectric power uses water to generate electricity from steam-driven turbine generators and for subsequent cooling processes.

Irrigation involves the controlled application of water for agricultural and horticultural purposes not satisfied by rainfall alone, including the use of systems to supply water to crops and other types of vegetation in golf courses, parks, and nurseries.

Public supply involves withdrawals by public and private water suppliers that provide water to at least 25 people or have a minimum of 15 connections, including residential, commercial, and industrial customers.

Industrial refers to water used as part of industrial and manufacturing activities, including fabrication, processing, and washing. Water in this category can be supplied by utilities, but only self-supplied withdrawals (that is, establishments that withdraw their own water) are examined separately in this report because of data limitations.

Other refers to a miscellaneous collection of smaller water uses, including livestock and aquaculture operations as well as mining activities.

03 DATA AND METHODS

This report investigates patterns in U.S. water use by examining data from the USGS National Water-Use Science Project. The USGS provides the most comprehensive water use data set that is publicly available nationally, with estimates produced every five years from 1950 to 2010.⁶⁹ Estimates are available for individual states and the U.S. as a whole since 1950; however, county-level estimates also became available beginning in 1985, which allow for metropolitan and nonmetropolitan area aggregations.⁷⁰

As noted earlier, this report follows USGS terminology and categories of analysis, described more extensively in the box at the end of this section. It focuses on water use—any water withdrawn from the environment for a particular purpose—across five categories: thermoelectric power, irrigation, public supply, industrial, and other. It does not exclusively or separately focus

on consumptive water use, nor does it track levels of water reuse. While the USGS employs several different units of analysis to measure water use, including flow rates and land area, this report concentrates more exclusively on the amount of water used, or volume, which is expressed in the number of gallons used per day. This report does not separately examine trends in the sourcing of water (that is, groundwater versus surface water) or the quality of water used (freshwater versus saline water).

In addition, the report examines water use per capita—both total and residential⁷¹—to get a clearer sense of the relative amount of water used each day by individuals across different metropolitan areas. Per capita measures also provide insights into how efficient these uses can be over time; however, note that per capita changes may also result from different USGS estimation methods.



Although the USGS covers an extensive range of geographies and categories in estimating national water use over time, the most current data available from 2010, which do not capture the ever-evolving set of climate concerns, management strategies, and other changes that have taken place in the past few years.⁷² With that said, this report analyzes water use across a host of different categories where consistency exists over time.⁷³ It not only outlines broader national trends from 1950 to 2010, but also explores subnational trends from 1985 to 2010. In particular, it examines patterns among metropolitan areas—defined as the country’s 381 metropolitan statistical areas (MSAs) according to the Office of Management and Budget (OMB)—while also considering patterns in nonmetropolitan areas outside these MSAs. For added detail, the report looks into water use patterns within the 100 most populated metro

areas. When measuring changes over time, this report classifies MSAs and related counties based on the most recent OMB definitions.

Lastly, the report examines subnational water use in terms of several variables of interest to better understand some of the underlying factors behind regional variation. Specifically, it uses an ordinary least squares (OLS) multiple regression to investigate the association between these variables and county-level water use. It uses two OLS models to do so; one model explores total water use in relation to several industrial, environmental, and spatial variables, while the other model explores residential water use in relation to several household and demographic variables. The models are based on a single year of data from 2010. Further information on these models is in Appendix A.

Key terms⁷⁴

Water use: The total amount of water withdrawn from the environment for a particular purpose, including for a host of residential, commercial, and industrial uses. It does not exclusively or separately focus on consumptive uses. An all-encompassing term, it spans withdrawals, deliveries, and self-supplied water. It is measured in the number of gallons used each day.

Water use per capita: The amount of water used, divided by population. This report considers both “total water use per capita” (total water use divided by population) and “residential water use per capita” (residential water use divided by population) to help gauge how efficiently water is used across different parts of the country. It is measured in the number of gallons used each day per individual.

Withdrawals: Water removed from the ground or diverted from a surface-water source for use. Withdrawals can involve deliveries to the end user or be self-supplied. They are measured in the number of gallons used each day.

Deliveries of water: The amount of water that is withdrawn and ultimately delivered from a public supplier to end users, which may include conveyance losses. They are measured in the number of gallons used each day.

Self-supplied water: The amount of water that is withdrawn by a user—via a well or other source—rather than being obtained from a public supplier. It is measured in the number of gallons used each day.

Consumption: The portion of withdrawn water that is evaporated, transpired, or incorporated into a product or plant, and not necessarily returned to the original source for immediate use. This report does not analyze consumptive water use separately.⁷⁵

Metropolitan water use: The amount of water used in a metropolitan statistical area (MSA), as defined by the Office of Management and Budget (OMB). These include the 100 largest (or most populated) MSAs and 281 smaller MSAs. This term can refer to total metro water use, in addition to metro water use across other individual categories (irrigation, residential, etc.). It is measured in the number of gallons used each day.

Nonmetropolitan water use: The amount of water used in areas outside MSAs. These include rural areas and smaller micropolitan statistical areas. Similar to metro water use, nonmetro water use is analyzed in total terms and across other individual categories. It is measured in the number of gallons used each day. “residential water use per capita” (residential water use divided by population) to help gauge how efficiently water is used across different parts of the country. It is measured in the number of gallons used each day per individual.

04 FINDINGS

A. ***Nearly 355 billion gallons of water are used each day in the United States, a total that has declined in recent years across a variety of categories.***

Water represents not only a basic service to sustain life, but also an essential input to drive economic activity. The U.S. uses nearly 355 billion gallons of water each day. The two largest categories of water use—thermoelectric power (161 billion gallons) and irrigation (115 billion gallons)—together account for almost 78 percent of this national total. Public supply use comes next at 42 billion gallons, or 12 percent, which includes deliveries to most of the country's residential customers. The remaining 10 percent is split among industrial water use (16 billion gallons) and a miscellaneous assortment of other uses (20 billion gallons), including mining, livestock, aquaculture, and self-supplied-residential water use.

Despite the enormous amount of water used across the country, the U.S. experienced an overall decline in these levels over the past few decades. From 1985 to 2010, water use fell by 42 billion gallons each day—from 397 billion gallons to 355 billion gallons, an 11 percent decline. From 2000 to 2010, this pattern accelerated, with a 14 percent reduction. Although the U.S. is using nearly twice the amount of water than it did each day in 1950—355 billion gallons compared with 180 billion—this increase has been more uneven compared with the country's steady climbs in population and rapid jumps in economic output in the same period. For instance, population more than doubled, while real gross domestic product (GDP) nearly septupled.

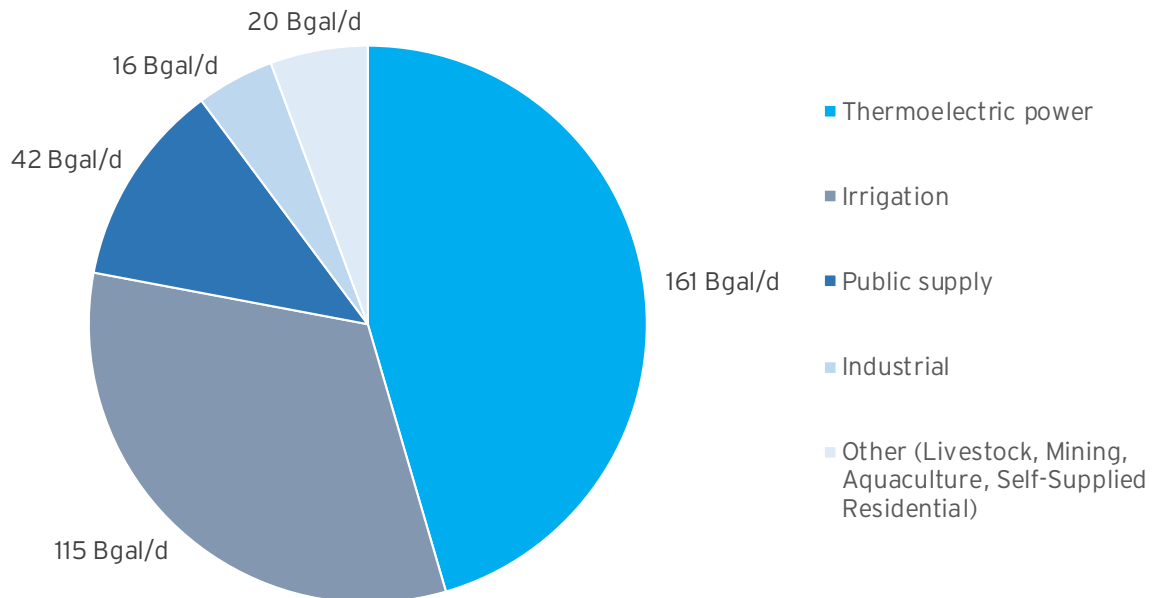
Declines in water use appear across several major categories, as shown in Figure 4. From 1985 to 2000, withdrawals for thermoelectric power and irrigation fell by 26 billion gallons and 20 billion gallons each day, respectively, equal to about a



FIGURE 2

Nationally, thermoelectric power and agriculture account for most water use

U.S. water use, by category, 2010 (billions of gallons each day)

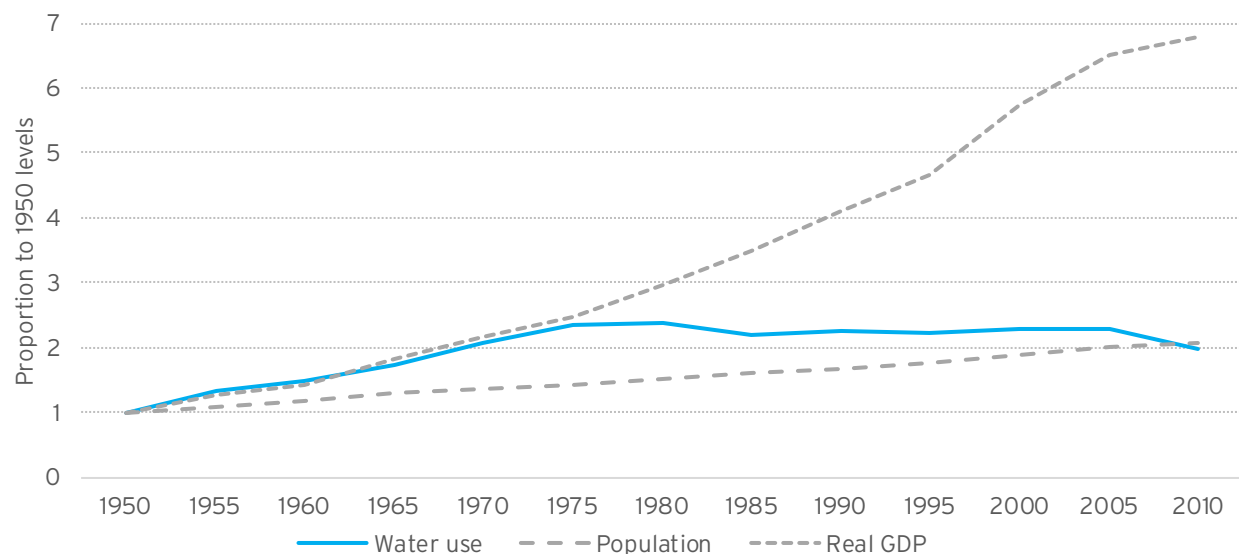


Source: Brookings analysis of USGS data

FIGURE 3

Water use is up since 1950, but it has not risen in lockstep with population and economic growth and has started to decline in recent decades

Changes in U.S. water use, population, and real GDP, relative to 1950 levels

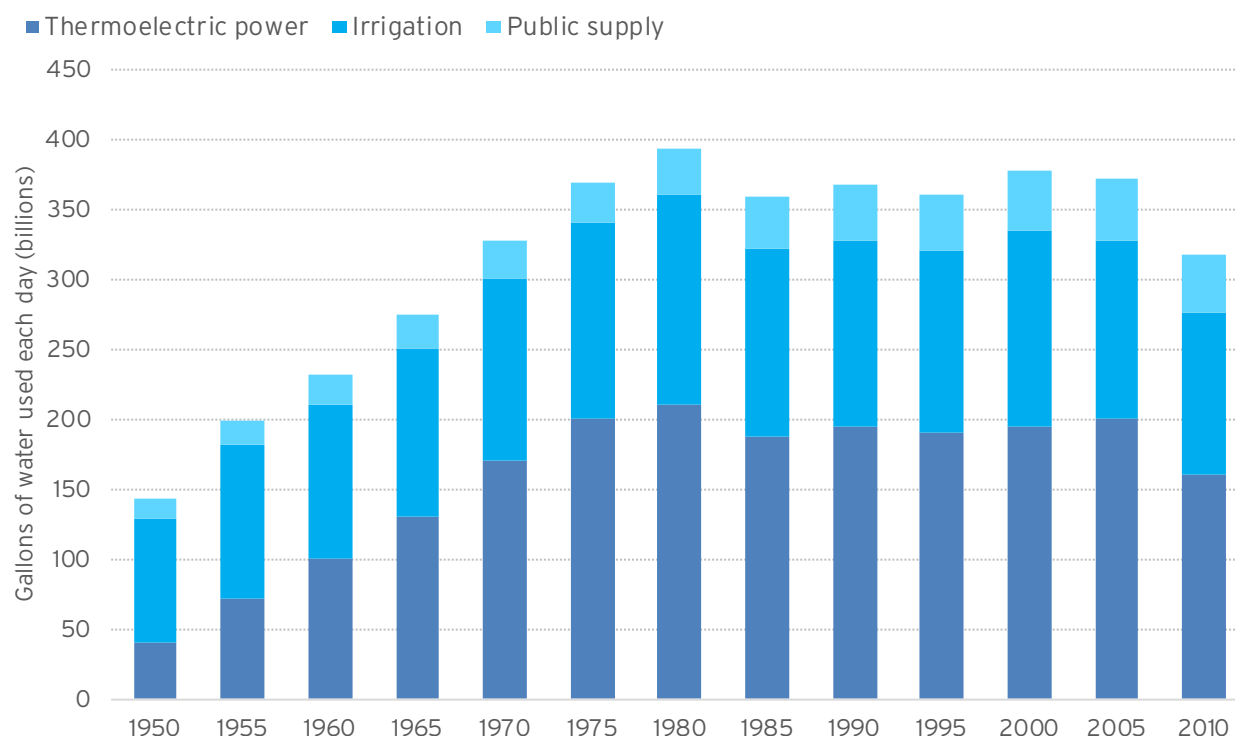


Source: Brookings analysis of USGS (Water Use), Census (Population), and BEA (Real GDP) data

FIGURE 4

Water use rose until the 1980s when declines occurred in several major categories

Changes in U.S. water use, by selected major categories, 1950 to 2010



Source: Brookings analysis of USGS data

14 percent reduction in water use. From 2000 to 2010, the same two categories declined 17 percent, driving most of the overall declines at a national level. On the other hand, public supply withdrawals represent the only major category that generally had aggregate increases in water use, likely tied to the nation's growing population. Since 1950, public supply withdrawals tripled—from 14 billion gallons each day to 42 billion—and since 1985, they surged by more than 5 billion gallons each day, a 15 percent increase. However, public supply use tailed off slightly from 2005 to 2010, declining 5 percent despite continued U.S. population growth.

Although public supply withdrawals—including deliveries to residences—grew in importance over the past few decades, the nation became much more efficient in its water use, especially on a per capita basis. From 1985 to 2010, U.S. population increased by 29 percent, but total water use

declined by 11 percent; in turn, total water use per capita fell from 1,640 gallons each day to 1,130. A closer look at how residences adjusted their use reveals a similar trend. Since 1985, residential water use per capita fell from 101 gallons a day to 88, potentially reflecting how many households adopted conservation measures and used more efficient appliances and other technologies.⁷⁶ Still, additional steps to improve water efficiency remain a key concern for utilities and other leaders. Box B outlines the various environmental and technological factors involved in solving this challenge.

- B. ***More than 221 billion gallons of water are used each day in metro areas, accounting for 63 percent of the U.S. total, but users in these areas tend to be more efficient than those in other parts of the country.***

Box B: Water disruptions and innovations

While the U.S. already contends with a number of barriers to make more efficient and equitable infrastructure decisions, a variety of environmental pressures and technological changes add even more urgency to this challenge.

The threat of climate change poses severe risks for water utilities and users alike.⁷⁷ The rising uncertainty associated with floods, droughts, and related climate concerns are altering the ways in which places manage and use water, including the need to adopt long-term planning strategies rather than reacting with short-term fixes.⁷⁸ These concerns are not isolated to one region, either. While extreme drought conditions in the West continue to dominate national headlines, water shortages have also occurred in places like New York City and Philadelphia in recent years.⁷⁹ Over the next decade, 40 of 50 states will experience water shortages to some degree.⁸⁰ In addition, the population continues to surge in many drought-stricken and flood-prone areas nationally.⁸¹

To boost resilience and provide greater economic certainty, leaders in many places are creating new plans and forming new collaborations, but doing so is not always easy. From green infrastructure investments⁸² to water resilience programs,⁸³ these efforts often mark a departure from previous ways of designing and delivering projects. In California and other water-scarce regions, new conservation strategies such as water use restrictions on urban customers and incentives for water reuse and recycling are now online.⁸⁴ Conservation programs will continue to become the norm, as precipitation patterns, temperatures, and

other climatic factors affect the availability of water.⁸⁵ Other methods will play a role as well, including new pricing schemes, which may not be easy to implement quickly depending on particular system needs.⁸⁶

Utilities and industries are also emphasizing water efficiency technologies to respond to these stresses. These include better leak detection, pipe condition assessment, and pressure management. Some areas are also looking into water reuse and desalination. For metros grappling with long-term water supply concerns, such as San Diego, recycling treated wastewater rather than discharging it into coastal waters could significantly augment available water sources.⁸⁷ At least 32 states have regulations in place to allow forms of reuse, including Florida, California, Texas, and Arizona.⁸⁸ Likewise, seawater and brackish water can be treated to remove dissolved salts and other substances to become potable through desalination, although concerns exist over cost and energy use.⁸⁹

For the most part, however, the development of and investment in new water technologies remain lackluster.⁹⁰ Budget constraints and a lack of political urgency have restrained capital expenditure on research and development on water infrastructure. Water technologies are at a competitive disadvantage in an already difficult venture capital market because of few groundbreaking discoveries, problems integrating into existing systems, and an inability to scale up effectively.⁹¹ As Figure 5 shows, the number of water and wastewater patents issued nationally has lagged compared with several other clean tech categories since 2001, averaging under

2 percent annual growth over this span.⁹² The same proves true for venture capital (VC) investment; water and wastewater VC investment fell by \$100 million from 2011 to 2016, alongside other precipitous declines in energy efficiency.⁹³

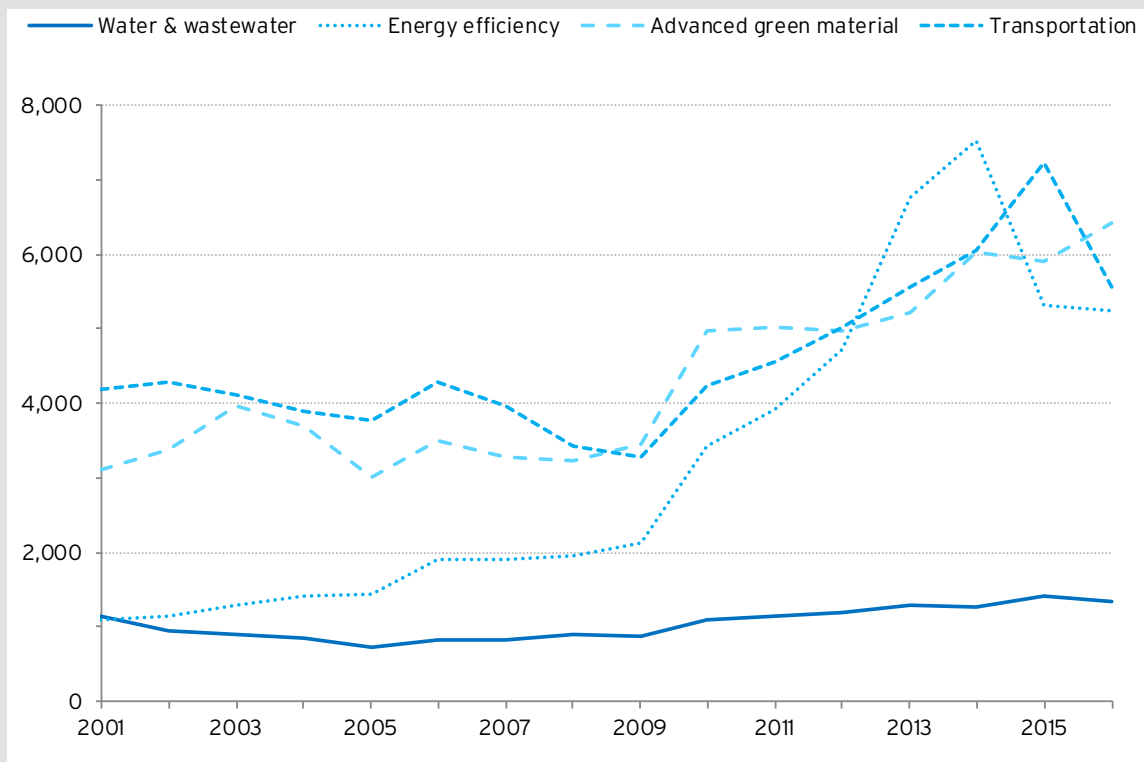
Perhaps more importantly, even though supporting environmentally resilient and technologically efficient infrastructure systems is increasing in importance, many utilities and other leaders nationally are

struggling to implement upgrades. While the inability to pay for these improvements and the lack of clear regulatory frameworks to encourage them represent two major impediments, some water users and providers may not even know where to start, geographically or otherwise.⁹⁴ With a better understanding of infrastructure needs and a clearer identification of economic priorities, though, metro areas can forge water management strategies that are more responsive to innovation.

FIGURE 5

The number of water and wastewater patents issued nationally has lagged compared with several other clean tech categories since 2001

Number of cleantech patents issued in the U.S., across selected categories, 2001 to 2016



Source: Brookings analysis of IP Checkups' Cleantech PatentEdge database

National water use patterns broadly depict how households, businesses, and other economic actors depend on water each day. Yet, these patterns do not reveal how different places across the U.S. can vary widely in their water needs or how efficiently they use water. Examining how metro areas and nonmetro areas vary in their patterns of water use offers a clearer view into the unique infrastructure pressures that different areas face and the importance of considering trends from a more regional perspective.

As the centers of U.S. population (85 percent) and economic activity (88 percent of GDP), metro areas also account for most of the country's water use (63 percent).⁹⁵ The 221 billion gallons of water used each day in metro areas include the bulk of the country's withdrawals: from

thermoelectric power (76 percent) to industrial (80 percent) to public supply (83 percent). Not surprisingly, the only categories in which users in metro areas do not account for the majority of water use are irrigation (41 percent) and other (mining, livestock, aquaculture, and self-supplied) uses at 37 percent.

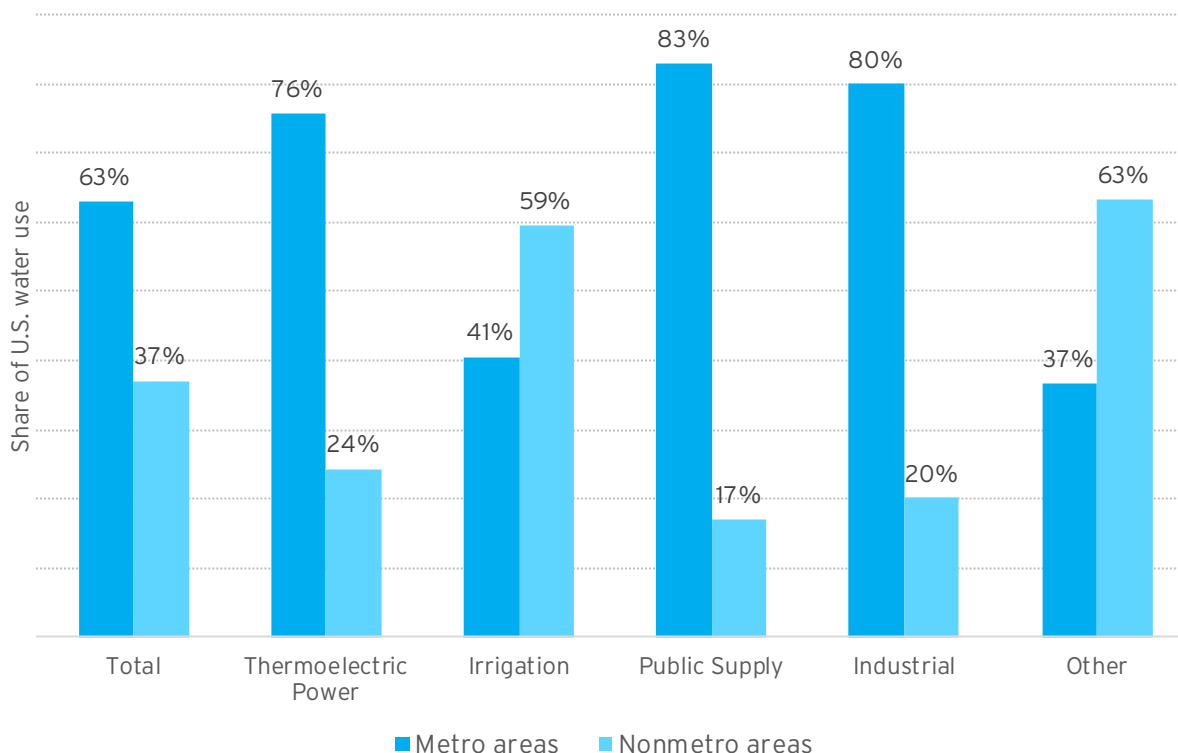
While metro areas and nonmetro areas play considerably different roles, there are also fundamental differences within each of these two geographies.

First, users in the most populated metro areas tend to have the greatest impact on national water use. As shown in Table 1, users in the 100 largest metro areas depend on almost 136 billion gallons of water each day, which accounts for

FIGURE 6

As the centers of U.S. population and economic activity, metro areas also account for most of the country's water use across several categories

Metro and nonmetro shares of U.S. water use, by category, 2010



Source: Brookings analysis of USGS data

62 percent of the all-metro total and 39 percent of the U.S. total. They also exceed the entire nonmetro total (130 billion gallons each day). Their public supply withdrawals (27 billion gallons per day) rank among the highest nationally, responsible for nearly two-thirds of the U.S. total. Their withdrawals for thermoelectric power (77 billion gallons a day) and industrial uses (8 billion gallons a day) are quite sizable as well, each making up about half of the U.S. totals in these two categories.

Second, users in metro and nonmetro areas depend on water in different ways. As Figure 7 illustrates, more than half of total water use (54 percent) in metro areas—almost 120 billion gallons each day—goes toward thermoelectric power, versus 30 percent in nonmetro areas. Withdrawals for irrigation are sizable in metro areas (21 percent), but they are especially important in nonmetro areas (53 percent). In addition, the higher populations in metro areas mean that public supply water use plays a bigger role (16 percent) than it does in nonmetro areas (5

percent). As a result, improvements in irrigation technology are likely to make a bigger difference in aggregate terms in nonmetro areas, while efforts to improve household water efficiency are likely to spell bigger gains in metro areas. Energy efficiency is paramount, regardless of geography.

Third, per capita water use differs markedly between metro and nonmetro areas. Water use in metro areas totals 840 gallons per capita each day, less than one-third the per capita rate of 2,810 gallons in nonmetro areas. The difference is even starker when compared with the 100 largest metro areas, which have a total water use per capita of 670 gallons each day. It is important to note, however, that much of this total variation is heavily influenced by the lopsided irrigation withdrawals in nonmetro areas. For example, in terms of residential water use per capita, metro and nonmetro areas are both near the national average of 89 gallons each day. In other words, while large energy and agricultural users can lead to enormous differences in total water use per capita at a metro scale, most households

TABLE 1

Individuals and industries in the 100 largest metro areas tend to use the most water overall

Water use totals, by geography and category, 2010 (billions of gallons each day)

Geography	Total	Thermoelectric power	Irrigation	Public supply	Industrial	Other
All metro areas	221.2	119.9	46.7	34.3	12.7	7.5
Top 100 metro areas	135.6	7	19.1	26.7	8.1	4.3
Small metro areas	85.6	42.6	27.6	7.6	4.6	3.2
All nonmetro areas	130.2	38.5	68.6	7.0	3.2	12.9
Micro areas	59.6	20.7	27.9	3.5	1.6	5.9
Rural areas*	70.6	17.8	40.7	3.5	1.6	7.0
U.S. total**	351.4	158.5	115.3	41.4	15.9	20.3

Source: Brookings analysis of USGS data

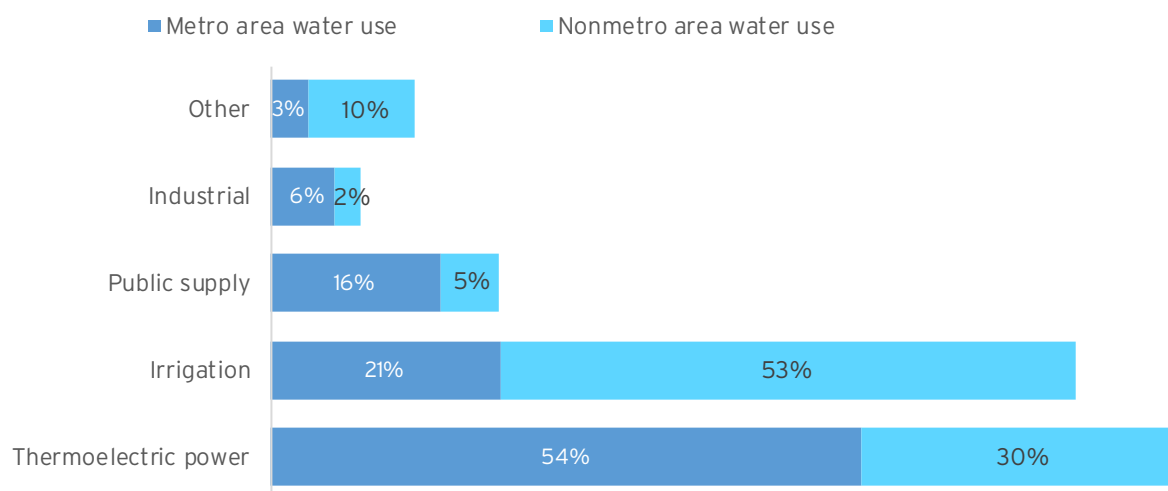
*Rural areas refer to counties not contained in a metropolitan statistical area or micropolitan area

**Aggregated U.S. totals shown here may deviate from other reported USGS totals due to rounding

FIGURE 7

Metro and nonmetro users depend on water differently, with thermoelectric power and public supply playing an enormous role in more urban geographies

Water use shares within metro areas and nonmetro areas, by category, 2010



Source: Brookings analysis of USGS data

are using water in similar amounts nationally and residential water use per capita is more consistent.

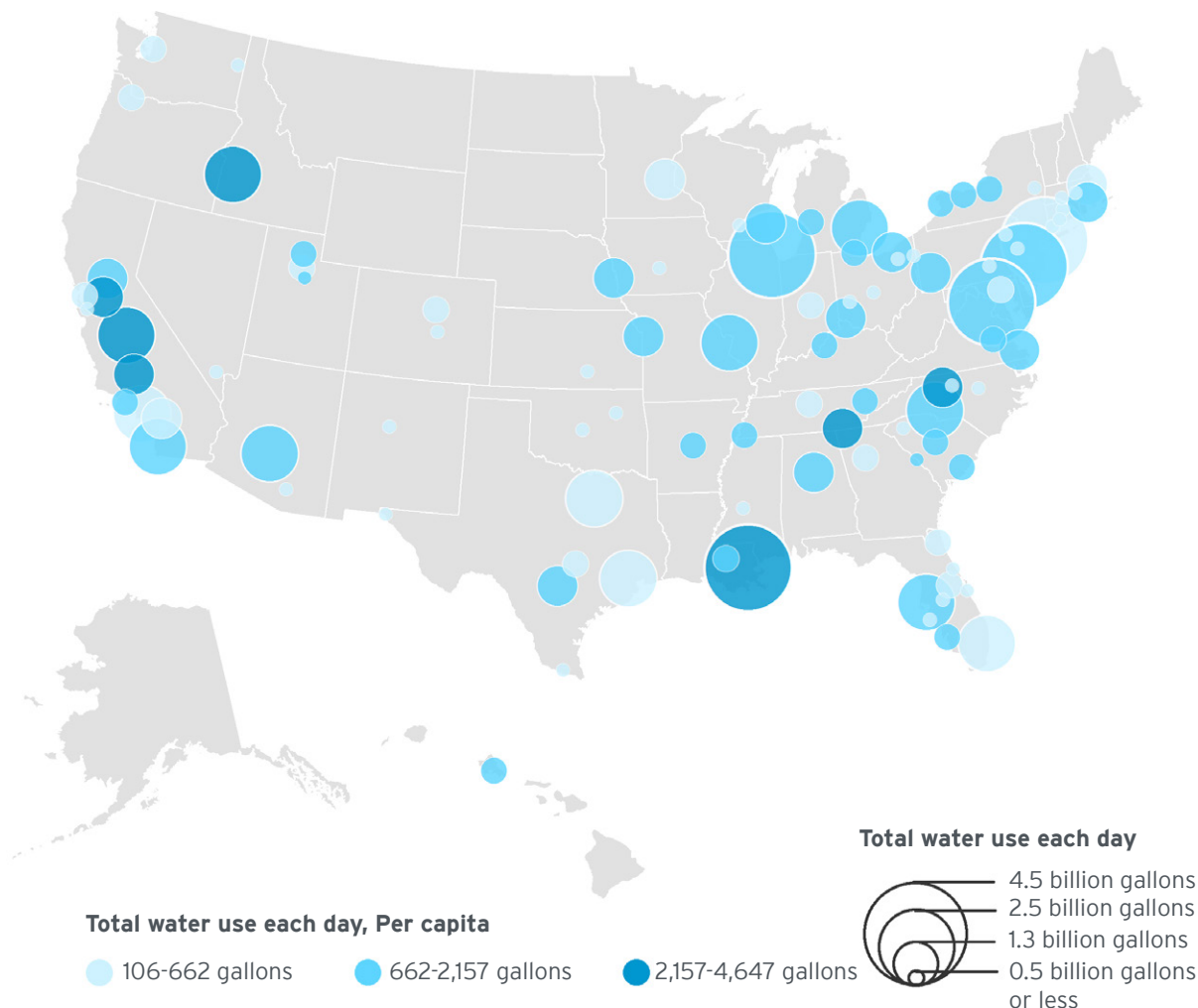
Together, these differences in metro and nonmetro water use come into greater focus when comparing specific places across the country. For instance, as shown in Figure 8, users in the biggest metro areas such as Chicago, New York, and Washington, D.C., depend on the most water; the 25 metro areas with the most water use nationally depend on more than 90 billion gallons each day, equal to a quarter of the U.S. total. In many of these metro areas, withdrawals for thermoelectric power and public supply are especially significant, including in places such as Charlotte, N.C.; Tampa, Fla.; and St. Louis, where these two categories alone account for more than 95 percent of their total water use.⁹⁶ Agriculturally focused metros such as Fresno and Stockton, Calif., stand out along the relative measure given their widespread irrigation activities.

Although users in metro areas depend on sizable amounts of water, they are generally more efficient than users in nonmetro areas, primarily because of their less water-intensive economic activities. From New Haven, Conn., to Colorado Springs, Colo., users in many of the country's largest metro areas not only use under 200 gallons of total water per capita each day, but also use under 75 gallons of residential water per capita each day—which are both well under the national averages. However, there are several exceptions, namely in places with higher withdrawals for thermoelectric power and irrigation relative to their population. This is the case in metro areas such as Chattanooga, Tenn., and New Orleans, where large thermoelectric power withdrawals take place and total water use per capita exceeds 3,750 gallons each day.⁹⁷ The range of water uses across metro areas and nonmetro areas, in turn, requires targeted management strategies to realize additional gains in efficiency.

FIGURE 8

Total water use and per capita use vary widely across the 100 largest metro areas, where the most populated markets tend to use the most water overall

Water use in the 100 largest metro areas, Total and per capita, 2010



Source: Brookings analysis of USGS data

C. From 1985 to 2010, total water use in metro areas fell by 39 billion gallons each day, which drove almost 90 percent of the national decline during this period.

Over the past few decades, water use in metro and nonmetro areas reflected larger national trends, where many industries and other users reduced their withdrawals. However, the pace at which these declines occurred varied widely from place to place. For example, while total water use

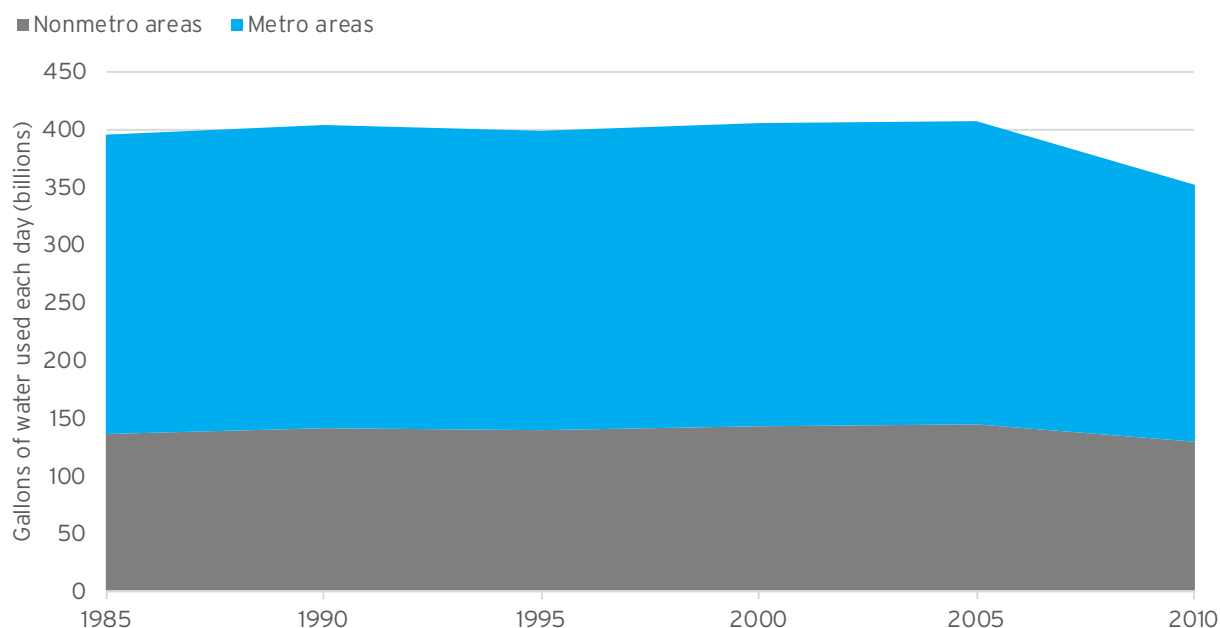
in the country as a whole fell by 42 billion gallons each day (11 percent) from 1985 to 2010, metro areas experienced a decline of 39 billion gallons per day (15 percent), to 221 billion. Nonmetro areas, on the other hand, reduced their water use by only about 3 percent.⁹⁸ Many of these declines took place over the past five to 10 years, largely driven by metro areas as shown in Figure 9.

Users in the 100 largest metro areas generated the largest aggregate decreases. From 1985 to 2010, they reduced their total water withdrawals

FIGURE 9

For 1985 to 2010, metro areas saw their water use decline by 15 percent, compared to just 3 percent in nonmetro areas

Changes in metro, nonmetro, and U.S. total water use, 1985 to 2010



Source: Brookings analysis of USGS data

Note: Aggregated U.S. totals shown here may deviate from other reported USGS totals, due to rounding and suppressions.

by 30 billion gallons each day to 136 billion gallons—an 18 percent decline. Consequently, they were responsible for more than 71 percent of the total national decline over this period—30 billion gallons out of 42 billion—despite continuing to account for only about 40 percent of all U.S. water use. In other words, these large metro areas are playing an outsized role in reducing the country's total water use.

Since 1985, metro and nonmetro areas experienced declines across all types of water categories, with one notable exception: public supply. As Figure 10 shows, metro and nonmetro withdrawals for thermoelectric power and irrigation fell about 15 percent, in the same direction as national trends. Industrial withdrawals dropped nearly 40 percent—a precipitous decline perhaps indicative of more advanced technologies being used in manufacturing processes, among other changes.

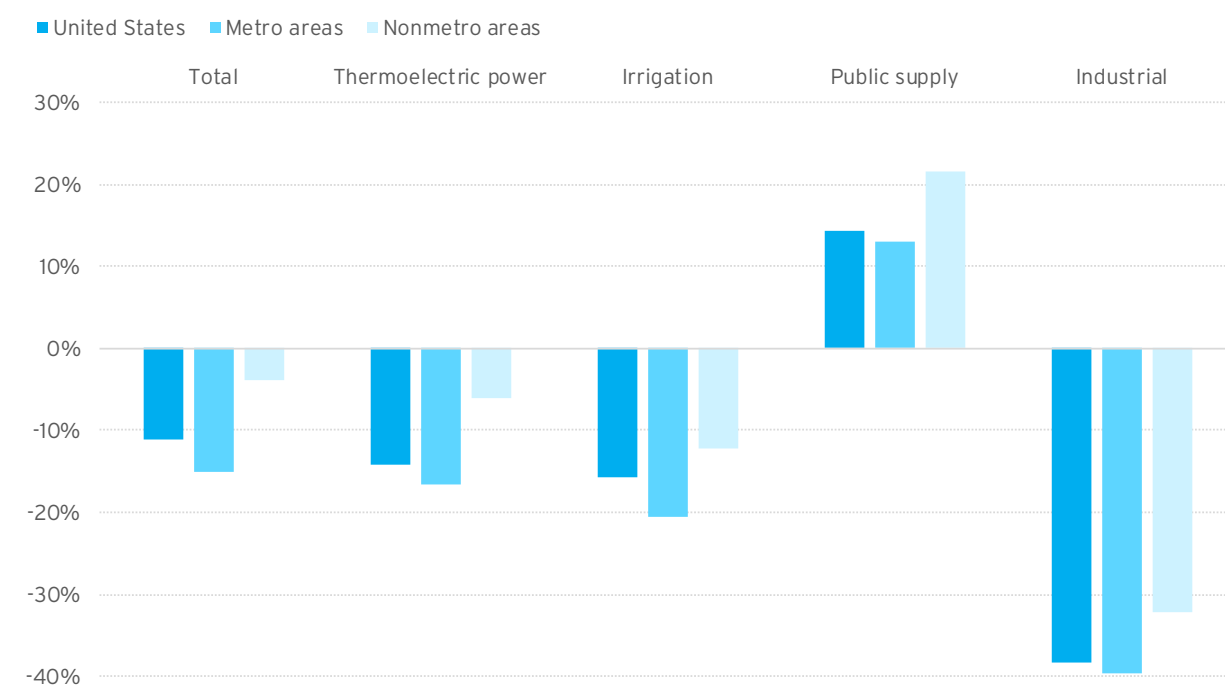
As the country's population grows, though, public supply withdrawals are rising in both metro and nonmetro areas, up to 22 percent since 1985. More recently, since 2005, public supply withdrawals nationally declined slightly, but population gains in many places are still stressing utilities to provide efficient and equitable water to a growing customer base.

As users in metro areas and nonmetro areas depend on less water, they are also becoming more efficient. From 1985 to 2010, water use per capita in metro areas declined 480 gallons each day (36 percent) from 1,320 gallons to 840, while nonmetro areas had a slightly smaller reduction of 420 gallons per day (13 percent), from 3,230 gallons to 2,810. The implementation of new technologies likely influenced these numbers, particularly in thermoelectric power plants and various agricultural industries. In terms of

FIGURE 10

Since 1985, metro and nonmetro areas experienced declines across all types of water categories, with one notable exception: Public supply

Percent change in metro, nonmetro, and U.S. water use, by category, 1985 to 2010



Source: Brookings analysis of USGS data

Note: "Other" water withdrawals are not included due to category changes over time.

residential water use per capita, metro areas fell 14 gallons each day to 88 gallons, while nonmetro areas declined 8 gallons a day, to 86. The use of new appliances and other behavioral changes potentially played a role at a household level.

Certain metro and nonmetro areas, of course, are driving these trends. Since most declines occurred from 2005 to 2010, these recent water use patterns offer clearer insight into the types of economic shifts taking place in specific markets—and what those shifts might mean for their infrastructure.⁹⁹

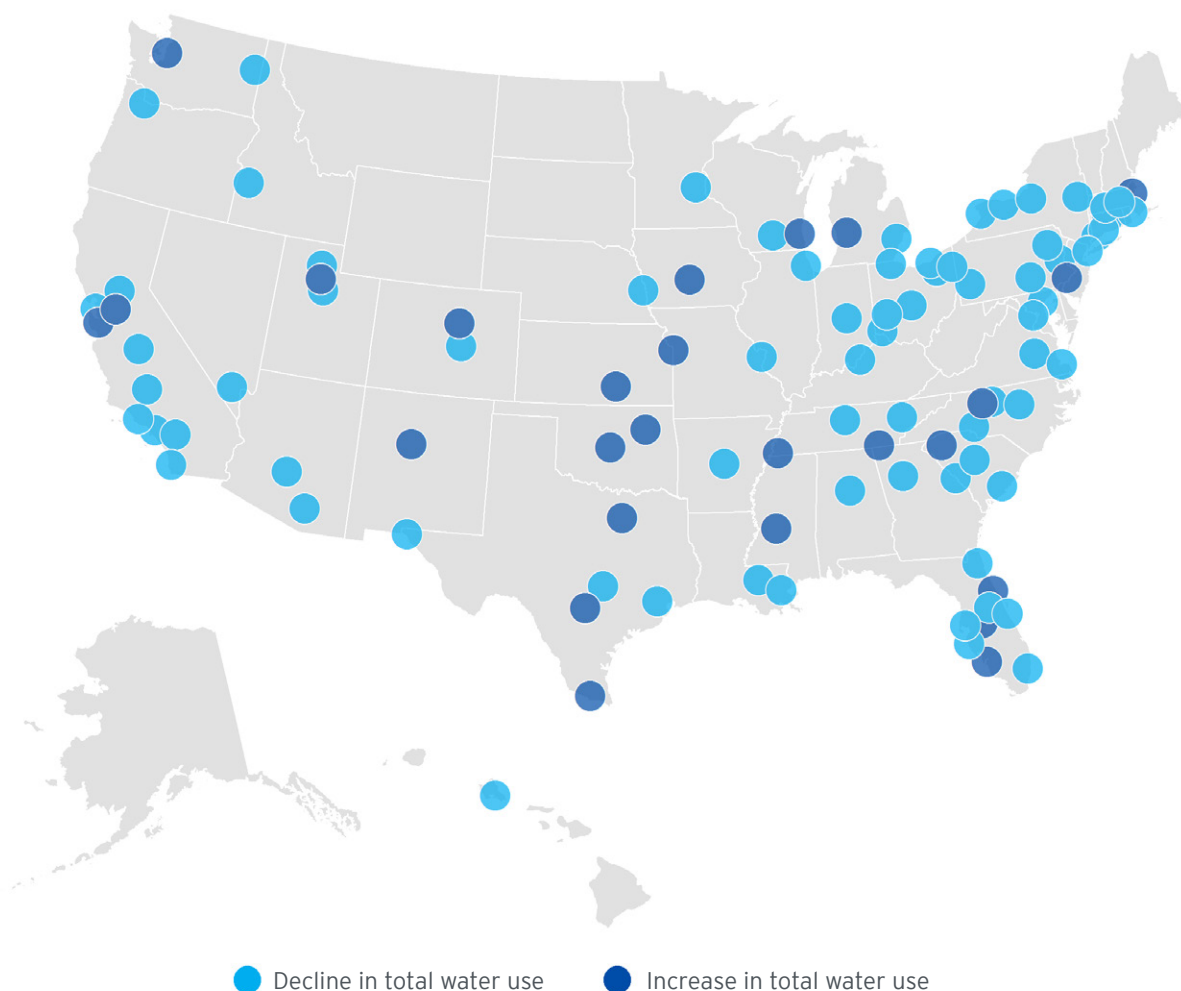
Figure 11 displays how some of these trends have played out among different metro areas. In total, users in 74 of the 100 largest metro areas reduced their water use from 2005 to 2010, using 293 million gallons less each day on average.

Led by bigger markets such as New York, Miami, and San Diego, many of the declines resulted from falling thermoelectric power withdrawals of up to 1 billion gallons per day.¹⁰⁰ Among the exceptions are metro areas with faster-growing populations such as Seattle and Denver, although steps toward less water use are starting to take hold in many of these places as well.¹⁰¹ Beyond declines in total water use, one of the bigger and more consistent patterns taking place in most metro areas has been improved water efficiency. Total water use per capita fell in 81 of the 100 largest metro areas over these five years, while residential water use per capita fell in 65 of these metro areas, anywhere from Syracuse, N.Y., to San Antonio, Texas. In many ways, these metro-specific changes reflect national trends, but they also point to questions over what factors are leading to such regional variation.

FIGURE 11

Most declines in U.S. water use have occurred since 2005, including reductions across 74 of the 100 largest metro areas

Changes in total water use among the 100 largest metro areas, 2005 to 2010



Source: Brookings analysis of USGS data

- D. ***Several factors—including higher levels of energy and agricultural production, shares of developed land, and population densities—have a significant effect on water use within metro and nonmetro areas.***

Understanding why users in some places—including particular cities and neighborhoods—depend on more water than others has attracted

considerable attention from academics and practitioners. Typically, through household surveys and other methods, research has pointed to several economic, environmental, and demographic factors potentially explaining this variation (Box C). Yet, it can be difficult to draw any definitive conclusions given the relatively narrow geographic scope of many of these studies, the lack of consistent data, and the complicated set of concerns managing water

across different regions, which may not always be easy to quantify.¹⁰²

This analysis attempts to build on previous studies to better understand what variables might have a positive (or negative) effect on water use within metro areas and nonmetro areas, specifically at a county level. It does so

by developing two regression models—for total water use and for residential water use—to assess certain variables of interest while controlling for other factors. As regions look to better manage their scarce water resources and accelerate infrastructure investments in support of a more efficient and equitable economy, it is crucial that they examine a broad set of users—not just

Box C: What factors tend to affect water use?

Water use at national, state, and local levels varies for a host of reasons, attracting interest from policymakers, planners, and researchers. Typically, analyses focused on specific categories of use, such as residential or industrial, to more precisely define the set of factors that may affect a particular geography.¹⁰³ Demographic and housing unit characteristics, for instance, are frequently linked to variations in residential use, while an assortment of technological and environmental characteristics are often examined in relation to broader water use patterns. Based on this work, researchers point to several common variables that tend to significantly affect water use.

A number of economic and environmental factors are generally associated with total water use in a given locality. The **types of industries present**, particularly large energy and agricultural operations, can result in a greater need for water as an input to drive production.¹⁰⁴ Likewise, the level of **urban development** and the specific type of **population distribution (or density)** in a region can influence water demand.¹⁰⁵ Certain climatological conditions can also play a role. Lower levels of **precipitation**, for instance, can increase watering needs for farms, businesses, and households while placing more pressure on water utilities to deliver water, even during times of drought.¹⁰⁶ Similarly, higher **temperatures** increase the

need for plant watering and other outdoor uses.¹⁰⁷ Finally, climate change is predicted to intensify **evapotranspiration** of water used for landscape maintenance and agricultural irrigation, heightening water demand.¹⁰⁸

Residential water use, while affected by many of those same factors, can also vary depending on demographic and housing characteristics.¹⁰⁹ Not surprisingly, having a higher **population** and more residents in each household often requires a city to have more water to function each day.¹¹⁰ **Features of the housing units** themselves can also require more water, including whether there are fewer compact, multiunit structures and more expensive single-unit homes, which may have more rooms and involve significant outdoor use.¹¹¹ Questions over the age of these structures, including the lack of efficient **technologies** and appliances, are another consideration.¹¹² Several operational factors controlled by water utilities, including **prices** and **conservation programs**, can weigh heavily on how much water residents use.¹¹³ Certain demographic factors, including the **income, age, and race** of residents, have been shown to influence water use as well.¹¹⁴ While higher-income households tend to be less sensitive to price fluctuations and use more water than lower-income households (via swimming pools, etc.), this may not always be the case; recent analyses in Los Angeles have borne out these trends,¹¹⁵ but

a study in Milwaukee found less affluent neighborhoods using more water instead.¹¹⁶

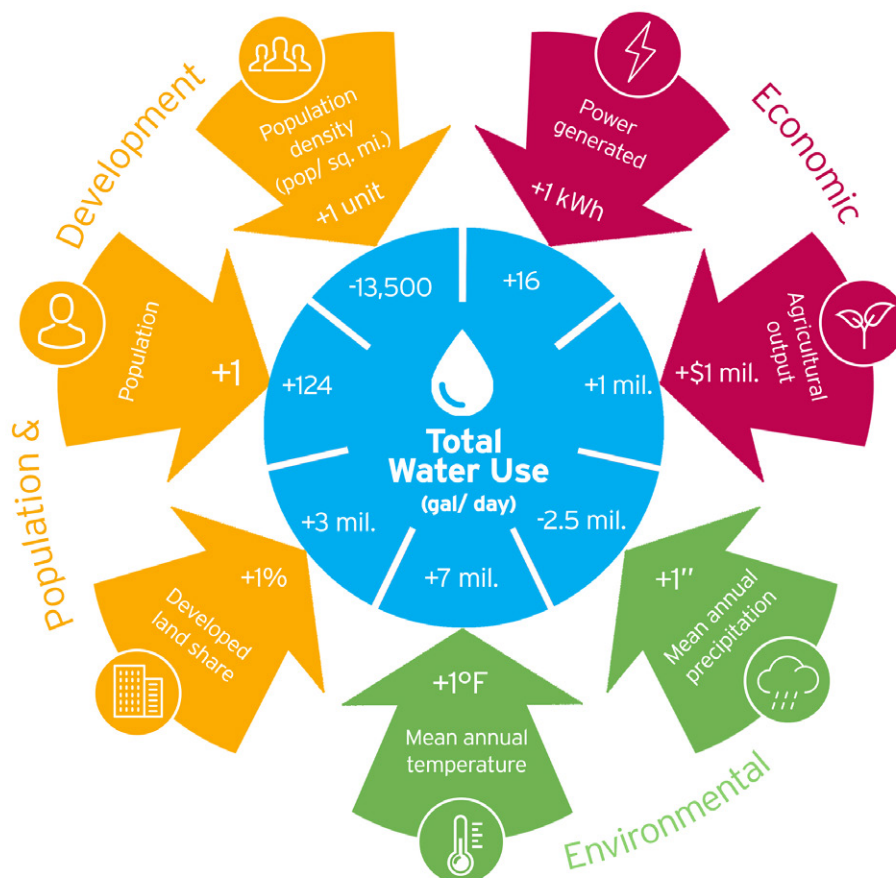
Together, those variables help explain why water use differs nationally, but they also point to the need for improved data and methods to peel back more layers at a geographically detailed level. For instance, the need for more reliable and affordable water is of utmost importance to cities and

utilities, and several new studies are helping better define the scale of this challenge from place to place. While that research is setting new benchmarks, though, it can still be a challenge to develop precise metrics and establish clear methodological parameters.¹¹⁷ It is important to bear these caveats in mind for any ongoing work in this space, especially as interest continues to increase in measuring subnational water needs.

FIGURE 12

Several environmental, economic, and developmental factors play a role in how much water different places use across the U.S.

Variables with a significant effect on total water use each day at the county level, 2010



Source: Brookings analysis of data from USGS (water use), Moody's Analytics (GDP), EIA (net electricity generation), Census (population and density), and Vanderbilt Institute for Energy and Environment (land cover, temperature, and precipitation).

bigger, productive industries but also smaller, more vulnerable households. While the primary dependent variable, water use, is drawn from the most recent 2010 data from the USGS, the analysis looks into several explanatory variables—including housing unit characteristics and demographic information—from the U.S. Census and other sources. Additional background on the design of these models and the specific data used are available in Appendix A.

The model for total water use estimates that several economic, environmental, and population/

development variables have a significant effect on county-level withdrawals. Figure 12 summarizes the estimated effects across the seven variables analyzed.

In line with previous studies, certain types of industrial activity—namely, energy and agricultural production—have a positive effect on total water use. In particular, an increase of 1 kilowatt-hour (kWh) of electricity generated each day is associated with more than 16 additional gallons of total water use per day, while an additional \$1 million in agricultural output is associated with

TABLE 2

Areas with higher levels of energy and agricultural output, warmer and drier climates, and more development tend to use more water overall

Top ten counties for total water use each day, with selected economic and environmental variables, 2010

County	Total water use	Net electricity generation, per day	Agricultural GDP	Mean annual temperature	Annual precipitation	Population	Population density	Share of developed land
	million gallons/day	kWh	\$US million	°F	inches		Pop./sq. mi.	
Calvert County, Md.	3,265	38,340	14	57.3	42.7	88,737	416	14.4%
Los Angeles County, Calif.	3,064	46,114	537	59.4	20.0	9,818,605	2,420	31.5%
San Diego County, Calif.	2,818	20,221	884	59.5	23.2	3,095,313	736	16.4%
Fresno County, Calif.	2,813	11,993	1,910	55.8	21.4	930,450	156	3.8%
Mecklenburg County, N.C.	2,805	49,378	30	60.1	36.7	919,628	1,756	61.6%
York County, Pa.	2,641	82,153	109	53.7	44.7	434,972	481	16.9%
Tulare County, Calif.	2,600	695	1,541	53.1	18.5	442,179	92	2.2%
San Luis Obispo County, Calif.	2,579	50,825	334	55.6	23.1	269,637	82	3.2%
Oconee County, S.C.	2,538	55,692	27	59.6	47.7	74,273	119	6.9%
St. Charles Parish, La.	2,476	19,773	35	67.7	46.7	52,780	189	7.0%
Average across all counties sampled	151	5,009	50	54.2	33.0	127,536	236	6.6%

Source: Brookings analysis of data from USGS (water use), Moody's Analytics (GDP), EIA (net electricity generation), Census (population and density), and Vanderbilt Institute for Energy and Environment (land cover, temperature, and precipitation).

Note: Other counties with higher water use totals are excluded due to a lack of data for some variables.

nearly 1 million gallons of total water use each day.¹¹⁸ Higher temperatures and lower amounts of precipitation are also linked to greater total water use; 1 extra degree in mean annual temperature is associated with more than 7 million additional gallons of total water use each day, while having 1 inch less in annual precipitation is associated with almost 2.5 million additional gallons of total water use each day. Warmer, semi-arid places in

California's Central Valley, such as Fresno, stand out in this way, as shown in Table 2.

Interestingly, the distribution of a county's population and the level of its physical development are among the other major variables estimated to have a significant effect on total water use. Overall, each additional person is associated with 124 more gallons of total water

TABLE 3

Areas with bigger populations and higher housing values tend to use more residential water, but other housing characteristics can play a role too

Top ten counties for residential water use each day, with selected housing, demographic, and environmental variables, 2010

County	Residential water use	Population	Population density	Average household size	Mean annual temperature	Annual precipitation	Share of multi-unit housing	Median value, All housing units
	million gallons/day		Pop./sq. mi.		°F	inches		
Los Angeles County, Calif.	968	9,818,605	2,420	3.0	59.4	20.0	42.2%	\$429,500
Maricopa County, Ariz.	617	3,817,117	415	2.7	70.6	10.7	25.7%	\$180,800
Cook County, Ill.	416	5,194,675	5,495	2.6	51.5	33.9	54.1%	\$244,400
Harris County, TX	342	4,092,459	2,402	2.8	68.4	38.3	36.2%	\$132,500
Riverside County, Calif.	342	2,189,641	304	3.1	65.1	9.9	16.5%	\$227,900
Orange County, Calif.	330	3,010,232	3,808	3.0	60.1	20.1	33.6%	\$528,200
San Diego County, Calif.	297	3,095,313	736	2.8	59.5	23.2	35.7%	\$407,000
San Bernardino County, Calif.	261	2,035,210	102	3.3	63.1	10.2	19.4%	\$221,700
Clark County, Nev.	251	1,951,269	247	2.7	62.5	6.6	33.4%	\$170,100
Dallas County, TX	232	2,368,139	2,718	2.7	65.7	29.7	38.9%	\$129,300
Average across all counties sampled	29	326,309	805	2.6	55.9	36.8	29.4%	\$233,754

Source: Brookings analysis of data from USGS (water use), Census (population, density, and housing), and Vanderbilt Institute for Energy and Environment (temperature, and precipitation).

Note: Other counties with higher water use totals are excluded due to a lack of data for some variables.

use per day—in line with total per capita estimates explored earlier in this report. The more physical development covering a county's land area—including asphalt, concrete, and buildings—also tends to lead to more water use; specifically, a 1 percent increase in the share of developed land is associated with more than 3 million additional gallons of total water use each day.¹¹⁹ Crucially, however, counties with a greater concentration of population and more compact development tend to use *less* water. For example, an increase in a county's population density by one unit is associated with 13,500 fewer gallons of total water use each day. As a result, a smarter, compact mix of land uses is likely to require less water—and potentially result in greater efficiencies—than more sprawling development patterns.

For residential water use, the second model finds that several housing and demographic variables are estimated to have a significant effect on county-level withdrawals. Population is the single most important variable; each additional person is associated with 99 more gallons of residential water use per day—comparable to but slightly higher than the 88 gallons per capita shown earlier in this report. Moreover, if the number of people living in each household increases, more water is also often needed; an increase of one person in the average household size across a county is associated with 3 million or more gallons of residential water use each day. Similar to the first model looking at total water use, higher temperatures and lower levels of precipitation are also associated with increased residential water use. Table 3 lists the counties with the highest levels of residential water use, many of which tend to share these characteristics, such as San Diego and Riverside, Calif.

The specific type of housing can also have a significant effect on residential water use. For instance, a 1 percent increase in the share of multiunit housing is associated with 185,000 fewer gallons of residential water use each day. In other words, the presence of apartments and other structures beyond detached or attached single-unit housing tends to result in lower levels of water use, paralleling the first model's finding on higher population density. However, as the values of all housing units increase, the opposite occurs; a \$1 increase in the median value of a county's housing units is associated with 35 additional gallons of residential water use. Of course, several other housing characteristics can be playing a role as well—including the age of these units, the presence of more efficient appliances, and variations in outdoor space—and exploring these details in greater depth is an area ripe for additional analysis.

Indeed, the same proves true for examining particular demographic variables. The second model explores how age, education, and race are related to residential water use, but the results are less clear. While controlling for other factors, counties with an older, more educated population tend to have lower levels of residential water use, as do counties with a higher minority share of population. At the same time, gauging the effects of household incomes and water prices remains complicated.¹²⁰ As researchers continue to refine available data sources and develop more consistent methods to compare water use at a subnational level, it will be useful to reassess these and other variables of interest to investigate potential implications for household equity.

05 IMPLICATIONS & RECOMMENDATIONS

Nationally, water use patterns underscore the variety of industries, households, and infrastructure assets that are foundational to U.S. economic growth, environmental sustainability, and other long-term goals. Yet, supporting these economic actors and strengthening these assets remains a challenge, especially when many federal policymakers rely on strategies that tend to paint in broad strokes and do not offer much clarity on where (or how) any investments should take place. Meanwhile, state and local leaders may focus more on projects specific to individual water systems, failing to address broader regional needs and economic challenges.

However, by taking a closer look at metro and nonmetro water use patterns, one enormous challenge becomes clear: the dual stress that

leaders in many metro areas face achieving greater economic efficiencies while promoting economic equity. Declining levels of water use hold promise for a more sustainable future, but utilities and other users must still grapple with aging, inefficient infrastructure, which requires an influx of new investment and results in a growing cost burden.

As a result, leaders in many places must address pressing infrastructure concerns at a time when less water—and unpredictable water demand—is leading to more financial and economic risk. Steps toward greater water efficiency are crucially important from an environmental standpoint, but these leaders must closely monitor and manage these shifts with a broader set of economic concerns in mind.



Defining the specific location and scale of this challenge can easily elude policymakers, but several trends emerge from this report that highlight the importance of viewing water management from a more regional perspective.

At a basic level, metro areas matter when it comes to national water use. They make up nearly two-thirds of all water withdrawals each day. Furthermore, as the U.S. sees a decline in water use, metro areas play an even more significant role; of the 42 billion-gallon reduction in water use each day since 1985, metro areas have been responsible for 39 billion gallons, or more than 90 percent of the national decline. The 100 largest metro areas are especially important, accounting for 71 percent of the decline by themselves. In short, these populated, urbanized markets have figured prominently in recent developments concerning U.S. water use and will likely continue to do so in years to come. Managing the country's future water infrastructure needs is not an exclusive urban or rural phenomenon, but it demands attention from the biggest users, many of which concentrate in metro areas.

“ Leaders in many places must address pressing infrastructure concerns at a time when less water—and unpredictable water demand—is leading to more financial and economic risk.

Specific categories of water use can also vary across different metro and nonmetro areas, pointing to the need for additional flexibility in how larger federal and state policies approach infrastructure challenges. While water represents a major input for many industries and businesses, particularly those focused on thermoelectric power and irrigation, water use can vary widely across different localities. Public supply water use—which includes most of the country's residential use—is concentrated in more populated metro areas, where it is one of the only categories nationally that *increased* in withdrawals from 1985 to 2010. Targeting water infrastructure plans based on these category-specific patterns can help leaders in metros, nonmetros, and the country as a whole respond more precisely and consistently to ongoing needs in support of additional efficiencies.

Water use is on the decline nationally, but there are clear gaps in efficiency in different parts of the country.¹²¹ This is especially important to consider as metro economies and populations continue to grow, placing enormous pressure on specific utilities and other users to conserve scarce water resources. As industrial patterns change and new technologies emerge, metro areas are leading the way, particularly when it comes to total water use per capita, in which they tend to be much more efficient (840 gallons per capita each day) than nonmetro areas (2,810 gallons). Striving for additional efficiency gains in thermoelectric power and irrigation is critical in this way.

On the other hand, for metro areas experiencing continued increases in public supply water use—or facing unpredictable demands in general—gains in residential water efficiency should remain a top priority. The bigger challenge in doing so, though, concerns the ability of utilities to implement new technologies and other infrastructure improvements affordably when they may be generating less revenue from their overall volumetric rates and are passing along costs to the most vulnerable households through

increased rates. While industries and individuals are striving to use less water and promoting greater sustainability, these actions can also hurt the ability of utilities to invest in infrastructure. Therefore, new ways of planning and paying for future improvements are key.

Finally, several economic, environmental, and demographic factors influence variations in metro and nonmetro water use, revealing some of the major levers available to policymakers and planners to better manage water. Industrial activities, including energy and agriculture,

remain two of the primary drivers behind total water use nationally and should warrant continued attention from metro and nonmetro areas alike; technological upgrades and other alternative water management practices are key in this way.¹²² In addition, the inextricable link among temperatures, precipitation, and water use will require more resilient solutions as the climate fluctuates.¹²³

Perhaps most crucially, the scale and type of development taking place in communities can have a profound effect on water use. Places with

Box D: Understanding water infrastructure governance

When thinking about potential strategies to address the country's water infrastructure challenges, it is crucial to consider the vast array of federal, state, and local players involved. Administrative and programmatic functions, such as monitoring water quality, managing assets, or providing technical guidance, are often split across multiple layers of government, making it difficult to craft integrated and comprehensive infrastructure strategies.¹²⁴

The federal government embodies these concerns. With responsibilities divided among various agencies and several other executive and congressional staffs, the federal role is expansive in terms of infrastructure oversight, regulatory action, and policy direction. EPA is the most notable agency in this respect, responsible for enforcing provisions of the Clean Water Act and Safe Drinking Water Act—the two major laws protecting American water resources and public water supplies—and for overseeing numerous environmental programs and technical assistance efforts.¹²⁵ The

departments of Energy (DOE), Agriculture (USDA), and Interior (DOI) are among the other federal agencies that manage standards and programs in support of water efficiency, sustainability, and investment. Likewise, Congress maintains control over the appropriations process for different programs and crafts supporting legislation, such as the Water Resources Development Act, via several committees.¹²⁶ Finally, the White House, including such bodies as the Council on Environmental Quality (CEQ), exerts influence over policies and plans.¹²⁷

Despite the federal government's sizable role overseeing water regulations, operating related programs, and setting certain strategic priorities, its importance for infrastructure investment is quite limited by comparison. Unlike states and localities that are bearing most of the financial burden, the federal government accounts for just 4 percent of total public spending on water infrastructure (or about \$4.3 billion out of \$109 billion), a share that has held fairly steady in recent years.¹²⁸ EPA is the primary

agency responsible for channeling federal spending on water by capitalizing state-led water loan programs, or state revolving funds (SRFs), for clean water and drinking water projects, which amount to about \$2.5 billion annually.¹²⁹ While the SRFs have helped finance thousands of water projects nationally since their inception decades ago, the demand for additional support remains high.¹³⁰ The Water Infrastructure Finance and Innovation Act (WIFIA) pilot program aims to complement the SRF programs and help support larger projects, although concerns

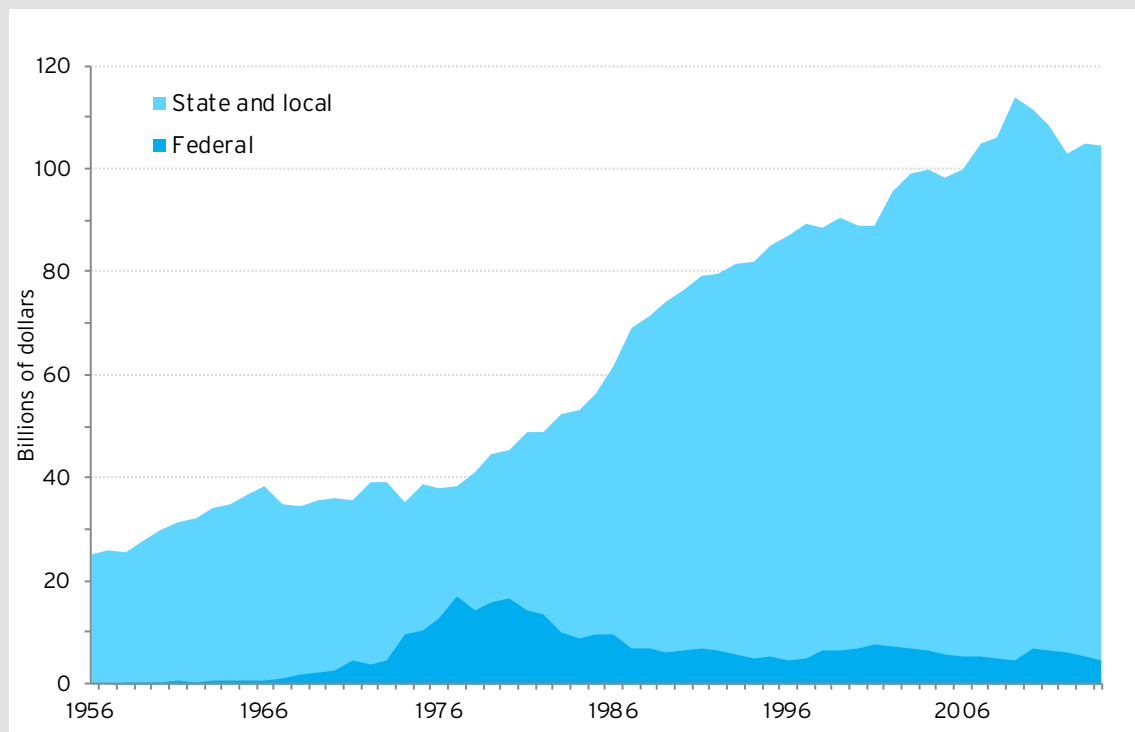
linger on eligibility requirements and implementation.¹³¹ Other agencies, including USDA, help administer grant and loan programs directly to communities, many of which may struggle to receive assistance from the SRFs.¹³²

State governments also execute water investment and regulatory oversight. Since physical, financial, and legal issues can vary widely across states, the specific types of agencies and institutions can operate differently, especially when managing

FIGURE 13

Compared to the federal government, states and localities are responsible for an increasing share of public spending on water infrastructure

Real spending on water infrastructure by federal, state, and local governments, 1956 to 2014



Source: Brookings analysis of Congressional Budget Office data.

Note: Water infrastructure spending is for water supply and wastewater treatment only, excluding water resources.

water rights and allocating water among users.¹³³ Moreover, since many watersheds do not conform to political boundaries, several states use cross-state partnerships to manage their shared water resources.¹³⁴ In general, though, states depend on overarching environmental departments that coordinate water plans and other programmatic activities within their borders, which frequently act as a bridge between federal agencies and localities in managing water quality, quantity, and compliance.¹³⁵ In addition to monitoring and enforcing water regulations—a challenging task in itself—these state-level bodies also help oversee SRF programs to provide loans and other subsidies for local infrastructure improvements. Finally, states’ public utility commissions oversee local water service decisions, including adjustments to service areas and rates.¹³⁶

Beyond federal and state support, governing water locally—in a city or county, or across an entire metropolitan area—requires perhaps the most vigilant action each day. Unlike the electric utility industry, which operates on an interconnected grid, water systems are disjointed and subject to localized control and ownership.¹³⁷ With dozens of separate utilities often situated in a given locality, a

lack of coordination can lead to operating inefficiencies and limited economies of scale to provide reliable, affordable service to consumers.¹³⁸ Likewise, the dizzying number of projects to carry out puts pressure on utilities to develop comprehensive plans, create detailed metrics, and secure financial resources—despite high levels of debt and other political challenges in many cases.¹³⁹ Doing so, of course, also ideally hinges on involvement from all types of local stakeholders, including mayoral leadership, economic development agencies, and private partners such as developers, farmers, and other businesses, which may be resistant to change. In short, the local governance challenge is not easy.

As a whole, these federal, state, and local governance structures result in a complex, ever-shifting puzzle of responsibilities. This should not be too surprising given the variety of water infrastructure needs across the country, but it creates several barriers to driving more efficient and equitable decisions. Leaders at all levels of government need to work actively with one another to take greater shared ownership of the challenges at hand and devise crosscutting solutions.

higher population densities, shares of multiunit housing, and compact development patterns tend to have lower levels of total and residential water use. Exploring these results in greater depth, alongside other relevant indicators such as water prices, represent clear next steps for places looking to encourage more efficient and equitable outcomes.

These trends reaffirm that there are no one-size-fits-all solutions to the country’s water infrastructure challenges. Defining water use more clearly in terms of metro area concerns provides a more consistent barometer to compare different places and weigh different needs. Ultimately, coordinated efforts at local, state, and federal levels are essential to respond to such needs.

Local strategies: Implementing new plans, financial tools, and technological innovations

Leaders in metro and nonmetro areas—including utilities and other large water users—are well-positioned to tackle their water infrastructure challenges head-on. Since they are often directly involved in overseeing water use, they can more closely track resource limitations, operational demands, and other hurdles to water management. Furthermore, they can engage in peer-to-peer learning and share best practices. The bigger challenge, though, is uniting action among different local actors and creating more holistic management strategies, which not only respond to short-term maintenance needs, but also emphasize long-term fixes and economic priorities.¹⁴⁰

As a starting point, developing more comprehensive water plans can encourage greater collaboration and strategic action.

Integrated water resources management, which involves coordinated water planning in light of different land use, economic, and environmental considerations, is helping cities and entire regions bring groups together in support of more efficient and equitable outcomes.¹⁴¹ Integrated water planning efforts, of course, remain difficult to execute in reality among several different agencies and are not a catch-all solution for the water infrastructure issues that metro areas face nationally.¹⁴² The consideration of water supply and distribution needs alongside other expansive wastewater and stormwater concerns is not always clear-cut and may not uniformly translate into the same economic vision (or outcomes) desired in different markets.¹⁴³

However, these efforts, including “One Water” planning, are helping utilities, industries, and other local leaders work more closely together to define their water priorities—from diversifying water supplies to forging new partnerships to supporting more affordable water access.¹⁴⁴

A One Water approach also encourages local leaders to focus on a broader mix of green and gray infrastructure projects, including a variety of centralized and decentralized facilities that are geared toward regulatory compliance and more sustainable water management.¹⁴⁵ The One Water LA plan, for instance, is helping Los Angeles and prompting neighboring jurisdictions to consider alternative ways to manage scarce water supplies in support of regional economic growth and affordability.¹⁴⁶

When developing or enhancing their water infrastructure plans, metro leaders should ideally view them in terms of the particular users served, including the larger built environment. As this report has shown, households and businesses use less water when located in markets with smarter, denser development patterns. Previous studies have pointed to the same trends, including the need to accommodate future population and economic growth in ways that minimize water use, distribution costs, and ongoing capital and operational expenses.¹⁴⁷ In addition to encouraging a mix of land uses in close proximity to essential services—such as water—some localities are implementing novel planning tools in support of more efficient and sustainable use. For example, Santa Fe, N.M., is among 13 communities nationally that have created water neutrality ordinances, which require developers to adopt conservation measures based on the amount of water demanded by a particular project.¹⁴⁸ San Antonio is among several areas that have also viewed future water needs in terms of development and population changes.¹⁴⁹

If designed well, these planning measures can support more a resilient built environment. Water availability and reliability are critical issues that remain at the top of many utilities’ priority lists, and are likely to become even more significant as temperatures and precipitation levels fluctuate rapidly in years to come.¹⁵⁰ Many areas, from New York to New Orleans, are already addressing these issues by crafting new adaptation strategies

and exploring ways to safeguard sensitive water resources.¹⁵¹ Places such as Boston, moreover, are striving toward efficient energy upgrades via building codes, which is decreasing water use and increasing transparency on new metrics.¹⁵² A variety of civic and philanthropic partners are also proving instrumental in these efforts, helping coordinate water management plans across different urban watersheds and localities.¹⁵³ When it comes to reducing levels of urban irrigation, even golf courses and their managers have a role to play.¹⁵⁴

Planning for future water needs at a larger regional scale, though, does not simply end with improved efficiency and sustainability; ensuring that all users have equitable and affordable access is key. And once again, compact development is a major way to support more cost-effective service: the closer households are to needed public water supplies—and the smaller the lot size—the lower the water bills tend to be than for larger, more dispersed households.¹⁵⁵ Planners need to carefully weigh the type of development and infrastructure improvements taking place across an entire region. Tucson, for instance, is implementing a targeted low-income rainwater harvesting program—designed to support the creation of rainwater collection systems in higher poverty areas—that provides more sustainable, affordable water to the most vulnerable household users.¹⁵⁶ As residential water bills surge in many markets and outpace inflation, utilities and other local leaders need to consider all tools at their disposal, which should relate directly to how they plan their communities.

In much the same way, beyond planning, metro leaders must also confront a complicated and long-standing barrier to efficient and equitable water use: how to pay for infrastructure maintenance and upgrades. Utilities, in particular, are facing a crunch to provide reliable, affordable water, often for a growing customer base as this report has illustrated. With almost a

75 percent decline in federal spending on water since the late 1970s, this also means they have to cobble together most of the financial resources by themselves—and from their customers.¹⁵⁷ Ultimately, utilities and the users they serve must bear a heavier cost burden. Yet, several new tools and best practices that are emerging nationally offer a clearer path forward.

The creation of more robust water asset management plans and the development of new revenue streams are two of the major types of efforts underway, which both hold promise for improved regional water management and addressing the cost of service. First, with a more thorough accounting of their assets, utilities can more accurately determine the entire life cycle of different infrastructure facilities and set priorities for certain improvements—steps that can help respond to increased demand for services and promote more sustainable water use.¹⁵⁸ Second, by exploring new ways to generate revenue and ultimately creating a more resilient business model, utilities are seeking a more flexible way to respond to changing water demands with greater

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As residential water bills surge in many markets and outpace inflation, utilities and other local leaders need to consider all tools at their disposal, which should relate directly to how they plan their communities.

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certainty.¹⁵⁹ Utilities in North Carolina, Georgia, and Texas have been engaged in these efforts.¹⁶⁰

Localities are also experimenting with different financial tools and arrangements to support long-term upgrades—from DC Water’s green century bonds to San Francisco’s certified water climate bonds, the first of their kind.¹⁶¹ Providing incentives for water reuse and other novel water management practices should also be front and center in these discussions.

The need for new local funding and financing tools is also closely intertwined with issues concerning water access and affordability. Users in metro and nonmetro areas are reducing their water withdrawals—while these places are seeing gains in population and economic output. In short, this means that many utilities are facing the dual stress of generating less revenue from volumetric rates—because less water is being used—but they are having to reach more customers, who can often have unpredictable demands. This has caused water rates to spike in many places nationally and led to serious questions over the “price” of water and how much users can affordably pay.¹⁶²

Fortunately, new financial models are emerging to address these efficiency and equity concerns together. While utilities tend to rely on volumetric charges to generate revenue, they are also turning more toward fixed fees—such as connection charges—to provide revenue stability regardless of the levels of water used. For example, Austin Water is among the utilities experimenting with new types of consumption-based fixed rates that aim to reduce peak water demand, avoid revenue volatility, and ultimately limit the need for costly repairs.¹⁶³ In addition, several localities are creating (or strengthening) customer assistance programs, which offer useful models to consider in alleviating this cost burden. Philadelphia, for instance, recently unveiled a tiered assistance program that links water bills more closely to income considerations,¹⁶⁴ while residents in

Detroit and surrounding jurisdictions are seeing more relief through regionwide assistance programs.¹⁶⁵ Still, recent surveys indicate that up to three-quarters of utilities nationally lack any type of customer pricing assistance program, which leaves many households struggling to pay for water.¹⁶⁶

In addition to exploring new plans and financial tools, metro leaders should emphasize technological innovation to drive additional efficiencies. Reducing water withdrawals for thermoelectric power and irrigation are especially important in this way, but utilities and other local leaders should seek to incorporate more efficient technologies across all categories of water use. The key is stimulating the widespread investment in and use of these new technologies. By doing so, regions may spend more money today, but they can save more money tomorrow through reduced infrastructure costs (and lower customer bills). Although many efforts are already underway in different industries and households across the country, the relative lag in water technology investment and implementation signals that there is still a need for improvements.

When it comes to energy, leaders in metro and nonmetro areas should build from ongoing successes. Upgrades in energy generation technology, including closed-loop cooling systems, have helped power plants of all types reduce their water demands and resulted in a cleaner, more sustainable environment.¹⁶⁷ Planners should become more familiar with the water needs of local energy facilities and more consistently track how these needs vary depending on the availability of local water supplies; in some regions, for instance, water-intensive coal and biofuel plants may be sustainable in the short run, but shifts toward less-intensive solar and wind power facilities should be seriously considered.¹⁶⁸ Several municipal and investor-owned utilities are trying to further encourage improvements, not only through better tracking but also through expanded energy efficiency financing programs.

The Northwest Energy Efficiency Alliance is one such cross-regional effort aimed at building capacity in this direction, uniting action among several small utilities.¹⁶⁹

Likewise, in the agricultural sector, there is the potential for more efficient irrigation that integrates improved on-farm water management practices with advanced application systems, especially since more than half of irrigated cropland acreage nationwide is still supported by traditional inefficient methods.¹⁷⁰ However, several regions, including many of the most water-intensive areas in California's Central Valley, are deploying new technologies, data platforms, and management strategies to address their water scarcity.¹⁷¹ Providing sales tax exemptions and rebates for more efficient equipment, supporting certain property tax benefits, and considering other subsidies are among the steps that policymakers are taking to encourage greater local innovation.¹⁷² Continued collaboration and joint efforts between utilities and farmers will be key to replicating these solutions.

Industries, utilities, and households should also remain a big part of water innovation at a local level. By incorporating new technologies, altering processes, and better quantifying their water footprint (that is, how much water is used to make particular products), small and large manufacturers alike should continue exploring ways to achieve efficiency gains. Food and beverage companies, for instance, have tried to limit and reuse the amount of water they require in their operations, with some taking water neutrality pledges to fully return water into the environment.¹⁷³ Milwaukee, for instance, has become a hub for water industry research with more than 200 water technology businesses in the region.¹⁷⁴ The economic importance of achieving greater efficiencies should not be underestimated; in neighboring Michigan, one in five jobs are water-dependent, inextricably linked to the Great Lakes through manufacturing and other sectors.¹⁷⁵

The amount of energy and waste that water utilities themselves must also limit is extraordinary, which several regions are already addressing through better leak detection, water reuse, and other new treatment processes. For example, the Southern Nevada Water Authority is among several systems that have implemented direct and indirect water reuse processes;¹⁷⁶ DC Water's Blue Plains Advanced Wastewater Treatment Plant has reused biosolids and recycled other nutrients to reduce electricity consumption;¹⁷⁷ and the San Diego County Water Authority has pioneered various "pure water" improvements and explored desalination as way to more efficiently use scarce water resources.¹⁷⁸ Lastly, households should also be active in these efforts; local incentives to install low-flow toilets, showers, and washers can make a difference, as can other outdoor water use improvements.¹⁷⁹ Utilities are helping household users pursue these efficiencies via rebate programs, bill credits, and other incentives.

State and federal strategies: Building financial capacity, boosting collaboration, and providing policy direction on innovation

The range of local issues and actors involved in managing water infrastructure demands targeted solutions for effective implementation. However, metro and nonmetro areas must still contend with a highly fragmented set of water challenges and cannot address these issues alone; state and federal leaders should help utilities, industries, and households across the country achieve greater financial and technical capacity to unlock new solutions. At the same time, establishing a clearer policy framework to guide these efforts is essential, including steps toward greater technological innovation. State and federal leaders are admittedly in a challenging position themselves—having to balance multiple other regulatory and budgetary responsibilities—but they should seek iterative, actionable ways to accelerate water infrastructure improvements in the months and years to come.

First, as with all types of infrastructure nationally, these state and federal efforts must address sticky questions on how to pay for future improvements. Although the water funding gap is significant and more overall investment would help utilities, in particular, operate with greater certainty, this does not mean that state and federal leaders should swing for the fences.¹⁸⁰ Instead, state and federal leaders should pursue a combination of short-term and long-term strategies, based on a reasonable expectation to get certain projects done.¹⁸¹ At a state level, for instance, ballot measures can help introduce new revenue streams and build political support for targeted water investment.¹⁸² Supporting low-cost loans and other grant opportunities has gained traction in states such as New York and Pennsylvania, where governors have emphasized the need to invest in a broad range of water projects to support regional sustainability and economic growth.¹⁸³

At the federal level, an infusion of new funding for SRFs would provide a stronger channel for additional state and local investment,¹⁸⁴ but offering greater financial flexibility via a strengthened Water Infrastructure Finance and Innovation Act (WIFIA) program would also offer a clearer outlet to pursue a variety of different projects.¹⁸⁵

“State and federal leaders should pursue a combination of short-term and long-term strategies, based on a reasonable expectation to get certain projects done.”

EPA and USDA are among the multiple federal agencies that should be involved in supporting additional financial and technical capacity among different localities, building on past efforts to improve asset management among smaller utilities.¹⁸⁶ Maintaining the tax-exempt status of municipal bonds,¹⁸⁷ encouraging the wider use of private activity bonds, and exploring the potential for PPPs should also be considered. However, as the Trump administration and Congress increasingly emphasize the role of private and institutional investors in infrastructure, federal leaders will need to weigh these relatively new collaborations carefully; integrating water into investment portfolios is not a straightforward process, which should ideally examine broader public benefits, including sustainability.¹⁸⁸

Finally, federal and state leaders must be sure to connect these broader financial considerations with more specific affordability guidelines. As this report has shown, metro and nonmetro areas must not only address their water management needs and related infrastructure gaps, but also weigh them in light of particular needs among users, including households that may struggle to pay their water bills. EPA's affordability guidelines—which focus on water rates as a share of median household income—are often lacking in this respect and should capture a greater variety of income groups and regional concerns. While federal policymakers are having more conversations on this matter, states are starting to take action; California is creating the nation's first statewide water affordability program, intended to help low-income ratepayers achieve greater cost savings and equitable access.¹⁸⁹ States should also consider revising potential legal barriers to forming local customer assistance programs, allowing utilities to more easily navigate what can be a byzantine set of regulations to design and fund such programs.¹⁹⁰

Alongside discussions on water finance, state and federal leaders should also develop more comprehensive plans and collaborations in support of regional infrastructure upgrades.

Many states have long adopted such an approach—including the development of multistate collaborations focused on water management across political boundaries—and should continue to foster stronger partnerships. States along the Colorado and Delaware rivers, for instance, have engaged in extensive river basin management agreements, which at times have been contentious but are crucial in addressing water supply issues across multiple regions.¹⁹¹

Federally, on the other hand, cross-agency collaborations and planning efforts remain a work in progress and must continue to pick up momentum. Nascent initiatives, such as the Urban Waters Federal Partnership, have helped increase coordination among different agencies to accelerate infrastructure improvements in economically distressed regions nationwide and offer a useful model to consider.¹⁹² Likewise, EPA's Water Infrastructure and Resiliency Finance Center¹⁹³ and WaterCARE (Community Assistance for Resiliency and Excellence) initiative¹⁹⁴ have helped build greater technical capacity for regions interested in pursuing innovative financial tools and defining clearer economic development strategies. Congressional proposals focused on integrated water planning also hold promise in boosting regional capacity and should be monitored closely.¹⁹⁵

While considering these new approaches, state and federal leaders must also recognize that improving regional water management involves a constantly moving target; as population and

climate concerns continue to intensify, water needs will fluctuate widely and require an eye toward greater technological innovation.

In light of federal uncertainty in this space following the Paris Climate Agreement withdrawal by the Trump administration, states are in an especially strategic position to encourage innovations across metro and nonmetro areas. Following the precedent set in the clean energy sector, for instance, states should adjust inconsistent regulations, enact new performance standards, and consider other public benefit charges—via state-led innovation offices—to support more widespread technological innovation and adoption.¹⁹⁶ Western states with the most pressing water scarcity issues, such as California, Arizona, and Texas, could serve as a test bed for these efforts, while considering other market-driven management strategies.¹⁹⁷

With that said, the federal role should not be easily dismissed. For example, federal agencies such as DOE and EPA should coordinate on innovation-led programs in support of greater water efficiency, including the continued development of best management practices¹⁹⁸ and efforts within the Innovations for Existing Plants Program.¹⁹⁹ Continuing to support EPA's WaterSense program is also enormously important to expand the market for water-efficient products and appliances.²⁰⁰ Having a more reliable baseline of water use data and other metrics will be crucial in any future federal efforts and should remain a top priority as well. USGS, the National Oceanic and Atmospheric Administration, and several other agencies have started to collaborate more on this front, especially for projects focused on resilience, but they should further expand these platforms.²⁰¹

06 CONCLUSION

While water infrastructure needs are gaining greater attention nationally, this report demonstrates the tremendous regional variety in these challenges throughout the country. By exploring how water use varies across metro and nonmetro areas, it provides a more comprehensive and consistent way to gauge water demands and infrastructure considerations from place to place, which helps fill a long-standing analytical gap among researchers and practitioners. Taking such an approach is crucial to supporting more environmentally sustainable outcomes and driving more economically efficient and equitable solutions.

With nearly 355 billion gallons of water used each day, the U.S. depends on a wide assortment of

aging and brittle water infrastructure facilities. Millions of businesses, households, and other users rely on a steady supply of water to carry out their economic activities, particularly those focused on energy production and irrigation. Yet, for the most part, water use is on the decline, falling by 42 billion gallons each day, or 11 percent, since 1985. Despite continued gains in population and economic output, the U.S. is generally becoming more efficient in its water use, minus certain pressures facing public supply use. As a result, many water utilities are facing the dual stress of receiving less overall revenue while having to provide reliable and equitable service to a growing customer base; in turn, water bills are rising to unaffordable levels to help cover needed infrastructure improvements.



In other words, as many places use less water and face more unpredictable water demands, utilities and other regional leaders are confronting greater financial and economic risks when addressing their infrastructure needs.

These national trends play out in different ways at a metropolitan scale and emphasize the need to develop more targeted infrastructure strategies. Above all, these strategies need to move beyond anecdotal urban and rural comparisons, and look instead toward the sizable role played by metro areas and nonmetro areas alike. In particular, metro areas such as New York and Chicago are the major centers of the country's water use. Collectively, users in metro areas withdraw more than 221 billion gallons of water each day, or 63 percent of the U.S. total. Metro areas are also the primary sites for many of the utility concerns just described; they are responsible for 83 percent of public supply use and have had the greatest reductions in total water use since 1985 (39 billion gallons a day). While metro gains in efficiency are helping the U.S. achieve greater economic productivity and environmental sustainability, utilities and other water users still have to cope with enormous infrastructure costs

and affordability concerns. A range of economic, environmental, and demographic factors help explain how these variations are playing out at a subnational level, where climate concerns, sprawling development patterns, and certain household characteristics are important to bear in mind.

Ultimately, with a better understanding of their water use patterns, leaders in metro areas and nonmetro areas can more clearly weigh their infrastructure demands and begin to plot out more specific next steps on how to address them. Local leaders can consult this new body of information—alongside other metrics—to implement new plans, financial tools, and technological innovations in support of more efficient and equitable water use. At the same time, federal and state leaders can help bolster the financial capacity of metro areas as they undertake these efforts, while encouraging greater collaboration and providing a clearer policy direction for innovation. Designing and deploying these strategies will take time and not necessarily come easily, but they offer a clearer direction for the U.S. as whole to address its substantial and fragmented water infrastructure challenges.

APPENDIX A

Note: Additional background on water use data sources, categorizations, and other methods is available in the report's methodology section.

Overview

This report investigates patterns in U.S. water use by examining data from the U.S. Geological Survey's (USGS) National Water-Use Science Project. The USGS provides the most comprehensive water use data set that is publicly available nationally, including estimates at the county level. To get a better sense of how metro areas and nonmetro areas use water nationally, the report not only examines patterns in total water use, but also explores patterns among different categories of water use, including power plants, farms, manufacturers, and households.

At the same time, this report provides additional clarity on the types of factors that might explain this regional variation. As described in Box C in the report, developing a consistent way to gauge differences across the entire country—in a statistically reliable and geographically granular manner—is challenging because of data limitations. For this reason, many previous studies are considerably narrower in geographic scope, typically relying on survey data for a given class of water users, such as households in a particular city or state. However, this report uses available county-level USGS estimates alongside several other economic, environmental, and demographic variables to provide a more comprehensive look into subnational water use via a regression analysis.

Data sources

This report takes advantage of several data sources to carry out this regression analysis. For consistency, all data are for 2010 unless otherwise noted. The primary variable analyzed—water use at a county level—is drawn from USGS estimates for 2010, the most current year of data available.

Additional housing, population, and demographic information come from the U.S. Census Bureau's American Community Survey (ACS) and decennial census. When it comes to measuring industrial output, the report uses electricity generation data from the U.S. Energy Information Administration (EIA) and agricultural production data from Moody's Analytics. Certain environmental data—including land cover characteristics, temperature, and precipitation—were collected with help from the Vanderbilt Institute for Energy and Environment.²⁰² Finally, the report considers water pricing information based on survey data from the American Water Works Association and Raftelis Financial Consultants; however, the report did not ultimately use these data in final regressions because of limitations in geographic coverage.

Models

To examine regional variation across a broad range of water users, this report relies on two different ordinary least squares (OLS) multiple regressions. In particular, it investigates the association among several variables on (1) total water use each day at the county level and (2)

residential water use each day at the county level.²⁰³ The first OLS model—focusing on total water use (in millions of gallons each day) as the main dependent variable—is based on the following formula:²⁰⁴

$$Y_c = \beta_0 + \beta_1 X_{1,c} + \dots + \beta_p X_{p,c}$$

Where c designates the county and p designates the seven independent variables.

The seven independent variables are: net electricity generation, measured in kilowatt-hours each day; agricultural gross domestic product (GDP), measured in millions of dollars annually;²⁰⁵ total precipitation, measured in inches annually; annual mean temperature, measured in degrees Fahrenheit; share of developed land;²⁰⁵ population; and population density, measured in population per square mile.

The results of this regression, plus four alternative models, are shown in Table A1. All told in Model 5—the preferred model—six variables were found to have significance at the 1 percent level, and a seventh variable was significant at the 5 percent level. Overall, this model explains about half of the variation in total water use each day for 1,882 counties that had data for all fields. As previous research has shown, a wide range of other variables not included in this model could also be having an explanatory effect, but improved data are crucial to measuring these effects.

The second OLS model—focusing on residential water use (in millions of gallons each day) as

the main dependent variable—is based on the following formula:

$$Y_c = \beta_0 + \beta_1 X_{1,c} + \dots + \beta_p X_{p,c}$$

Where c designates the county and p designates the 10 independent variables.

The 10 independent variables are: population; population density, measured in population per square mile; average household size; total precipitation, measured in inches annually; annual mean temperature, measured in degrees Fahrenheit; share of multiunit housing;²⁰⁶ median value of housing, measured in dollars; median age of the population; share of population over age 25 with a bachelor's degree or higher; and minority share of the population.²⁰⁷

The results of this regression, plus three alternative models, are shown in Table A2. All told in Model 4—the preferred model—seven variables were found to have significance at the 1 percent level, one variable was significant at the 5 percent level, one was significant at the 10 percent level, and one was not found to be significant. Overall, this model explains up to 93 percent of the variation in residential water use each day for 768 counties that had data for all fields. Similar to total water use, examining variable effects on residential water use remains an imperfect exercise, particularly when it comes to analyzing certain demographic variables. Ongoing research is needed to examine these variables in greater depth, in addition to exploring pricing, income, and other relevant factors.

TABLE A1

Regression of variables on millions of gallons of total water use per day at the county level, 2010

Variables	Model 1	Model 2	Model 3	Model 4	Model 5
Net electricity generation (kWh) per day	0.000016***	0.000015***	0.000015***	0.000014***	0.000013***
Agricultural GDP (millions of \$), annual	-0.000001	-0.000001	-0.000001	-0.000001	-0.000001
Total annual precipitation (inches)		1.017041***	0.951703***	0.942286***	0.856982***
Annual mean temperature (°F)		-0.071829	-0.072534	-0.071262	-0.071887
Share of developed land			-1.918588**	-2.452811***	-2.426300***
Population			-0.830752	-0.81865	-0.811171
Population density (Pop./sq. mi.)			10.388496***	7.507829***	6.821442***
Constant	20.682168	1.705649	-553.202806***	-369.702464***	-323.197847**
Observations	1,901	1,882	1,882	1,882	1,882

Note: Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Source: Brookings analysis of data from USGS (water use), Moody's Analytics (GDP), EIA (net electricity generation), U.S. Census (population and density), and Vanderbilt Institute for Energy and Environment (land cover, temperature, and precipitation).

TABLE A2

Regression of variables on millions of gallons of residential water use per day at the county level, 2010

Variables	Model 1	Model 2	Model 3	Model 4
Population	0.000099*** -0.000001	0.000098*** -0.000001	0.000099*** -0.000001	0.000099*** -0.000001
Population density (Pop./sq. mi.)	-0.001083***	-0.001026***	-0.000855***	-0.000957***
Average household size	-0.000176 12.114177***	-0.000173 6.707883**	-0.000206 3.048609	-0.000213
Total annual precipitation (inches)	-2.643193	-2.786934 -0.259180***	-3.034604 -0.280084***	-0.250103***
Annual mean temperature (°F)		-0.051682 0.236855***	-0.052671 0.257492***	-0.051806 0.303404***
Share of multiunit housing		-0.07954	-0.082355 -19.226163***	-0.088869 -18.489667**
Median value of housing (\$)			-6.852551 0.000013*	-7.342035 0.000035***
Median age of population			-0.000007	-0.000009 -0.483011***
Share of population over age 25 with a bachelor's degree or higher				-0.155831 -24.743776***
Minority share of population				-8.119377 -8.405533*
Constant	-33.210883*** -6.716076	-23.011045*** -7.995419	-12.888269 -8.748121	-4.983765 13.658527* -7.857838
Observations	768	768	768	768

Note: Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Source: Brookings analysis of data from USGS (water use), U.S. Census (population, density, housing, and demographics), and Vanderbilt Institute for Energy and Environment (temperature and precipitation).

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etc.), this OLS model uses state fixed effects.

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206 The share of developed land is based on all types of constructed materials covering a given land area per USGS definitions, including residential, commercial, industrial, and transportation facilities.

207 The share of multiunit housing is based on all units that are not single unit-attached or single unit-detached housing.

208 The minority share of the population refers to all races other than white, as categorized by the U.S. Census.

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