RESILIENCE STRATEGIES FOR DROUGHT

CENTER FOR CLIMATE AND ENERGY SOLUTIONS

Across the United States, the risk of drought is expected to grow due to reduced precipitation and higher temperatures caused by climate change. Drought's far-reaching impacts can ripple through communities, regions, watersheds, economies and ecosystems. This fact sheet overviews strategies for areas with a projected increase in drought conditions to become more resilient. It concludes with a community case study that has used a number of these strategies, and a list of tools to help communities evaluate the costs and benefits of resilience strategies.

CHANGING CONDITIONS

Drought is defined as a trend away from the a precipitation norm toward persistent reduced precipitation, causing a reduction in water supplies. The United States has experienced drought driven by natural variation in seasonal or annual precipitation in the past, but in recent years the U.S. has suffered a number of significant droughts. It is difficult to attribute these events to climate change, but human-induced climate change combined with natural variations can affect the severity of a drought event. Climate change could cause the warmer temperatures and seasonal shifts that contribute to more intense droughts. U.S. population growth and 20th century water supply projects have simultaneously increased demand for water from both residential and agricultural uses, adding to water stress.[1]

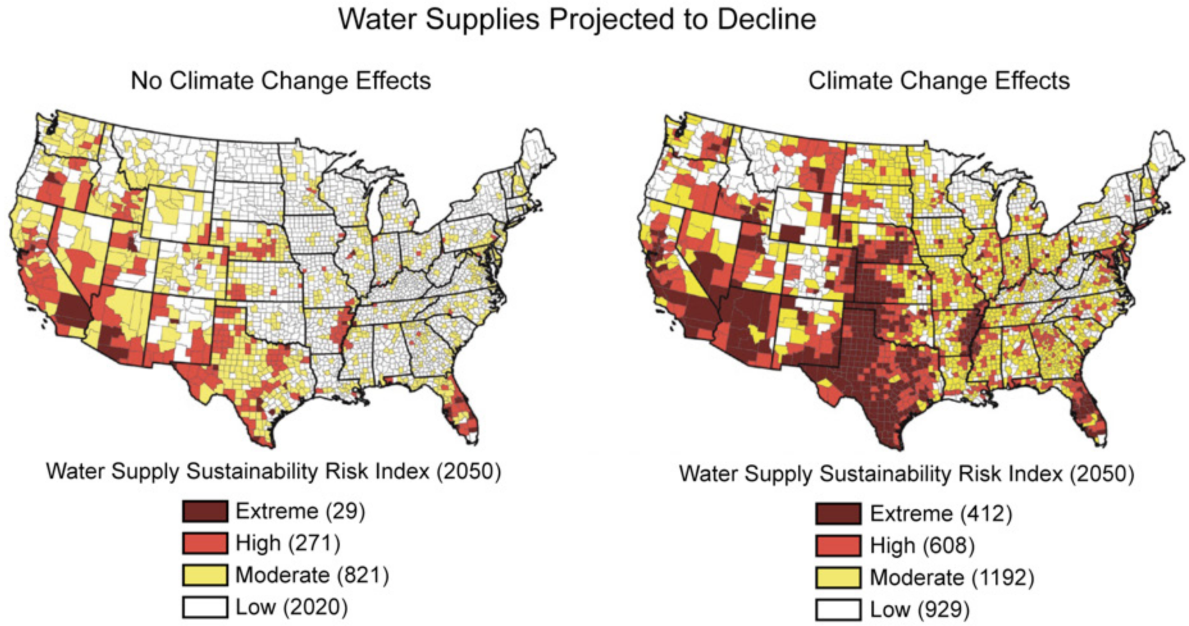
Projected climate impacts include significant reductions in precipitation in the southwest, and higher future temperatures that will likely contribute to greater frequency and intensity of drought. Among scientists who study this issue, there is medium confidence that soils will be drier in the future, even in regions with projected increases in average total precipitation.[2] In addition, seasonal changes in precipitation could cause longer and more uncertain timing of dry seasons.[3]

Warmer future climates are very likely to reduce snowfall accumulations, causing earlier spring runoff that will disrupt many Western watersheds, also contributing to drought risk.[4] In the highest emissions scenarios, projections show several western U.S. snowpacks disappearing by 2100, which could result in chronic drought in affected areas.[5]

Droughts can have far-reaching impacts including degraded water quality, low river flows with ecological implications, saltwater intrusion in tidal river areas and land subsidence.[6] If the past decade is any indication, the cost of drought in the U.S. will continue to grow. In 2015, severe drought caused $2.7 billion in economic losses in California alone.[7] Drought directly affects agriculture, the landscaping industry, and even hardware retailers. Agricultural losses due to drought conditions resulted in $787.2 million in losses for Georgia in 2007. In addition, recreational activities are impacted, including hunting, fishing, skiing and snowmobiling—all of which can significantly impact local economies.[8] Drought can also cause costly structural damage as drying soil shifts, damaging foundations and underground infrastructure. A 2011 drought in Texas caused over 700 water main breaks per day in Houston and severely damaged home foundations (with repairs typically ranging from $15,000 to $20,000 per home).[9]

Communities across the country should be evaluating their current risk of drought and how it could be

Figure 1: Effect of Climate Change on Water Supplies



Climate Change is projected to reduce water supplies mostly in the southwestern, central and southeastern regions of the United States. Today 10 percent of counties are at high or extreme risk of water shortages, and in 2050 that proportion of at-risk counties will grow to 32 percent. Projections assume an increase in greenhouse gas emissions through 2050 and a slow decline after.

Data: National Climate Assessment, 2014

affected by climate change. This fact sheet overviews a number of strategies that can help address this risk and highlights their associated co-benefits (social, economic and environmental benefits beyond the intended resilience outcomes). Estimates of costs are included, where available, though project costs will depend on local climate projections, material prices, and other factors. Identifying co-benefits can create additional opportunities for financing, help align resilience efforts with existing priorities and increases the political viability of these resilience actions. The monetization of each benefit summarized in this fact sheet will be most helpful in prioritizing strategies for closer study in your community.

WATER CONSERVATION AND PUBLIC EDUCATION

Communities in drought-prone regions generally have extensive water conservation efforts underway, serving as models for areas now facing the prospect of increased drought conditions in the future. Water conservation is often spearheaded by water utilities or local nonprofits, and carried out by local governments, individuals and businesses. This section overviews some key technologies and equipment available to help reduce water use on an individual level and the policy strategies that can encourage or require widespread implementation.

The U.S. Environmental Protection Agency (EPA) developed the WaterSense label to show that any product with the label is at least 20 percent more efficient without sacrificing performance.[10] Since 1989, eight states have set water efficiency standards for all faucets, toilets and shower heads installed statewide and California has mandated new efficiency standards that are more stringent than WaterSense.[11]

Outdoor water conservation can reduce the annual summer peak in water demand when water supplies are often the most stressed. About one third of nation-wide residential water use is devoted to landscape irrigation.[12] Steps that individuals can take to reduce outdoor water consumption include:

- Use native plants or choose plants that need less water.
- Practice xeriscaping, a comprehensive landscaping approach for water conservation that combines planning and design to create landscapes that need less water and retain more water onsite.
- Group plants according to water needs and then water according to each groupings' specific needs.
- Maintain healthy soils with mulching to minimize runoff and retain water.
- Minimize turf areas, or choose grasses that require less water.
- Avoid watering during the heat of the day.
- Use efficient irrigation systems that reduce leakage and water demand. An automated system offers irrigation controller technology that uses local weather data to inform when to irrigate and can be controlled by smartphone apps. Look for the WaterSense label (which is also applied to outdoor water components).
- Capture runoff from rooftops with rain barrels or cisterns (rainwater harvesting). Capturing rainwater for outdoor uses reduces the demand on drinking water and avoids the energy (and associated greenhouse gas emissions) needed to treat it.[13]

Synthetic grass can also replace water-intensive lawns and is being employed in California and other states. Synthetic grass reduces water consumption, but does not offer the co-benefits of natural vegetation like infiltrating rainwater, and retains and emits more heat than natural landscapes.

In partnership with local water suppliers, communities can and have enacted policies to encourage, or require public and commercial adoption of these conservation practices. Policy options can range from incentives for water efficient appliances, to water pricing systems that penalize large users (e.g., block water pricing that increases with use rather than decreases), to strict mandates that limit water use. Engaging residents about an area's vulnerability to drought and the importance of individual conservation measures is a key element of successful water conservation initiatives.

CITY PLANNING

Drought as well as other climate impacts, should be considered throughout local government planning processes. Planning decisions affect future water consumption by influencing the size of homes and yards. A Utah study found that households on 0.2-acre lots used half the water of those on 0.5 acre-lots.[14] A study in Ipswich, Massachusetts, compared residential water use in two future land use scenarios: traditional suburban development and smart growth with higher residential densities. Higher-density growth yielded a 5 percent reduction in water use over time without any additional conservation programs.[15]

CODES AND ORDINANCES

Communities can encourage or require individual water conservation through plumbing codes and conservation ordinances. An ordinance can require property owners to replace inefficient fixtures and repair plumbing leaks. Outdoor water conservation ordinances can require water-efficient irrigation devices or define maximum water allowances based on square footage of the landscape and the climate of the region. California provides towns with a Model Water Efficient Landscape Ordinance that includes guidance on what size landscapes to include in ordinances, recommends limiting high water-use plantings to only 25 percent of residential landscapes, and sets maximum applied water allowances. It also sets out requirements for irrigation systems requirements, soil health and permeability.[16]

WATER PRICING

Pricing water and services to accurately reflect the cost of providing water and wastewater services can help water-users be more conscious of their use and incentivize conservation. Conservation pricing can be designed and implemented to reduce water consumption, reduce impacts on utility revenue, reward customers for choosing water-efficient appliances, target inefficient uses of water, delay costly water supply expansion projects and avoid financial hardships on low-income customers.[17] Elements and price structures that utilities can employ to encourage conservation, include:

- Water meters at all single family and multifamily dwellings
- Increasing block rates use tiered per-unit pricing that increases with water usage
- Water surcharges are a higher rate for excessive

water use, as defined by a water utility.

- Seasonal rates change based on weather conditions and the corresponding demand for water.[18]

There are a number of considerations that go into choosing conservation pricing structures such as the size of the water system, and how rate increases might affect low-income customers in a community. A literature review of how rate increases affect consumption found that a 10 percent rate increase corresponded with a 5 percent average reduction in consumption.[19]

RETROFIT AND LANDSCAPE REBATES

Communities can offer rebates on low-flow or water-conserving indoor fixtures, or offer the fixtures directly to residents for a low price or free. Rebates can also fund the conversion from turf to low-water use landscaping based on the amount of lawn removed, installation of water efficient irrigation, or other local conservation considerations. The San Diego County Water Authority set up a turf replacement incentive program in 2012 to prompt the replacement of more than 1 million square feet of water-intensive turf grass with low-water-use landscaping. The utility also offers classes on installing low-water landscapes, plant fairs that offer discounts on low-water-use plants and an online home water-use calculator.[20]

LEAK DETECTION AND REPAIR

A regular leak detection survey or audit of water distribution systems and repair of leaks can conserve water before it reaches a faucet. Every day, nearly 6 billion gallons of treated drinking water is lost, wasting the equivalent of an estimated 14 to 18 percent of daily water use.[21] Cities and water utilities have access to new technologies to aid with leak detection and repair including smart meters to detect leaks in residential water connections, water sensors that can send the utility alerts about low water pressure, and probes to ease water main inspections. Individuals can also be empowered to perform water audits with kits to help measure water use and leaks, or a nonprofit or utility can offer free audits to individuals.

The Massachusetts Water Resource Authority (MWRA) requires its member communities to carry out leak detection. Communities can also initiate a survey.[22] The MWRA's leak detection and repair programs are primarily credited with a 20 percent drop in water use over five years in its service area.[23] Birmingham Alabama's water audit in 2011 revealed more than 2.8 billion gallons of water loss with a value of $962,914 in 2011. The audit identified nearly 14 miles of pipe that needed immediate replacement.[24]

PUBLIC EDUCATION AND OUTREACH

Water conservation programs require education and outreach to the public which can be carried out by local governments, utilities, or in partnership with local non-profits. The Alliance for Water Efficiency lists the key goals of any education program as informing and educating the public about: reasons water conservation is necessary; benefits of conserving water; liabilities of not conserving water and; actions needed to achieve water conservation goals. Some utilities reported reduced water usage by over 20 percent after public education campaigns. It is important to note that behavior change may not be permanent, and to ensure long-term change, education should accompany other water conservation strategies like those described above.[25]

COSTS

For individual users, low-flow fixtures can have higher upfront costs compared to traditional fixtures, but many are comparably priced. A low-flow toilet, for example, can cost about $100 more than a traditional toilet, but depending on water rates, users can recoup the costs in a few years.[26] Low-flow faucets and showerheads are generally priced comparably with traditional fixtures.[27]

The cost of installing drought-tolerant landscape is higher upfront, but needs less maintenance than non-drought-tolerant landscaping, which may struggle in areas with drought conditions. The estimated replacement cost of traditional landscaping with drought-tolerant landscaping can range from $1.50 to $2.50 per square foot.[28] Synthetic turf lawns cost an estimated $5 to $20 per square foot, but can be eligible for rebates, and yield significant water savings.[29] These cost ranges are only estimates and depend on many variables including plant choice, hardscape (fixed landscape infrastructure like fencing and stonework), and labor costs.

The costs to a community or utility for developing incentive programs vary based on population, but the

Inland Empire Utilities Agency in California did a 2005 cost-benefit analysis of its conservation programs and found, across all programs, an average return of $1.52 for every dollar spent, with the toilet rebate program (costing about $38,000 for 630 units) and toilet exchange program (costing about $109,120 for 1760 units) returning about $2.40 for every dollar spent.[30] Rebates for landscape conversion to drought-tolerant landscape were found to be less cost-effective at the community level. In Orange County for instance, turf removal rebates had a greater cost per acre foot of water conserved than other water conservation strategies.[31]

The cost of leak detection varies based on system and geographic location. The Massachusetts Water Resources Authority (MWRA) offers leak detection contracts to communities for about $145 per mile of water main to be inspected.[32] A three-year leak detection survey in Decatur, Illinois, a city of 79,000 people with a 528-mile water distribution water, cost $80,000. The repair of the identified leaks cost $70,000 with an return of $5 in savings for every dollar invested. The leak detection and repair program identified water losses amounting to $944,000 and the city was able to prioritize easy repairs on fire hydrants and water service leaks right away.[33]

Outreach campaigns to explain water conservation to water-users varies broadly in cost. The estimated budget for outreach required to carry out and explain water conservation policies or campaigns is between $10,000 and $50,000 for a basic print campaign depending on agency size.[34]

BENEFITS

Water and electricity bill savings

Water conservation provides considerable savings to individuals. The EPA estimates that replacing bathroom faucets with WaterSense-labeled models alone can save a family $240 in water and electricity costs (mostly from water heating) over the faucet's lifetime. Replacing showerheads with water efficient models can reduce an average family's water consumption by 2,700 gallons per year, and reduce electricity costs by $70 per year. In total, the average family spends more than $1,000 per year on water, but can save more than $380 from installing WaterSense fixtures.[35] WaterSense smart sprinklers can save the average home more than 8,000 gallons per year, with the potential to save $435 million in water costs each year, nationally.[36]

Water conservation also helps communities and states save on energy costs. The California Energy Commission documented that 19 percent of the state's electric energy load is used to pump, treat, and distribute drinking water and collect and treat wastewater.[37] In 2015, the governor of California mandated a 25 percent reduction from 2013 levels in water consumption, resulting in savings of 524 billion gallons of water from June 2015 to May 2016, energy savings of 1830 GWh, and avoided greenhouse gas emissions of 521,000 metric tons of carbon dioxide equivalents (the equivalent of taking 111,000 cars off the road for a year).[38]

Water affordability

Water conservation campaigns and policies can be structured to help low-income households or areas be able to afford water. Portland, Oregon, transitioned to consumption-based billing in 1993, but developed programs for low-income customers. Programs included discounted bills, water audits, and toilet rebates.[39] Water conservation campaigns can also lower the municipal costs, especially if new construction of water infrastructure is avoided, and pass on savings to rate payers, as has been observed in Tucson[40] and Gilbert, Arizona,[41] (described in the Implementation Examples).

Less Landscape Maintenance

A public demonstration drought-tolerant garden in Santa Monica showed that sustainable landscapes use less than a fifth of the water of traditional landscaping, and require about a third of the maintenance of a traditional garden.[42] Another study found that xeriscaping can provide an estimated 36 cents per square foot savings annually due to decreased maintenance costs. Synthetic lawns or xeriscaping also can reduce costs of watering, fertilizer, and a hired gardener or lawn mower.

Ecological Benefits

Plants that are native to arid areas can lower maintence costs and provide ecological benefits as well. They are typcially better suited to native soils, needing less fertilization to reduce harmful run-off, are less susceptible to pests reducing pesticide application, and can provide habitat for local wildlife.

Reducing water demand can also augment streamflow, restore wetlands, or enhance water quality.

Avoided water diversion allows waterways to support environmental benefits like water quality, flood control, and species habitat and recreational benefits, including fishing, boating, and swimming. Low stream flows can also reduce or eliminate recreational opportunities like rafting and fishing, which is a significant part of the American West's economy. The Colorado River alone is estimated to support a $26.4 billion recreation industry, and this value is closely tied to instream flows that depend on water conservation and reuse.[43] Within cities, conservation can leave more water for urban green spaces, which offer health and economic benefits like lowering temperatures and avoiding heat illness or stress.[44]

Flexible implementation

Water efficiency programs can be deployed in stages, with immediate benefits when compared with large infrastructure projects. Investments targeted to lower-income areas can help areas where infrastructure or appliances are older and less efficient. In the early 1990s, the City of Los Angeles used community-based-organization deployments for deploying low-flush toilets. This created employment opportunities in the areas with the highest unemployment rates.[45] Conservation programs like watering restrictions can be adjusted when drought conditions have passed, or when water supplies are restored.

IMPLEMENTATION EXAMPLES

- **Albuquerque, New Mexico,** implemented a Water Conservation Landscaping and Water Waste Ordinance in 1995 that bans turf installation for new commercial developments. The city also offers a rebate of $1 per square foot, and $1.50 per square foot on steep slopes, for turf removal and replacement with native vegetation. This effort along with the city's Long-Range Water Conservation Strategy helped Albuquerque reduce its per-capita water usage from 250 gallons per person, per day in 1995 to 148 gallons per person per day in 2011.[46]
- In **Gilbert, Arizona**, water conservation initiatives from 2001 through 2016 helped customers avoid the costs of acquiring, delivering and treating additional water supplies for a growing population. The fees for a new customer to connect to the water system in 2015 are 45 percent lower than if per capita demand had not been reduced. Water rates and wastewater rates are also 5.8 percent lower than if there had been no water conservation.[47]
- **Boston** reduced consumption from 125.5 billion gallons in 1980 to 70.9 billion gallons in 2009, a 43 percent reduction. The city spent $40 million to improve water efficiency but avoided $500 million in costs for upgrading the system. This was accomplished through repair of leaks, requiring low-flow toilets in new construction and retrofitting homes with efficient plumbing fixtures.[48]
- **Tampa, Florida,** addressed its dependence on drought-sensitive open water sources (which provided 75 percent of the city's drinking water) through a variety of measures. Starting in 1989, the water department modified the plumbing code to require water-efficient plumbing fixtures in new and renovated construction, and began distributing water conservation kits to homeowners. The city's per capita water use from 1989 to 2001 decreased by 26 percent.[49]

REGIONAL WATER CONSERVATION

URBAN-RURAL PARTNERSHIP

The U.S. Geological Survey estimates that irrigated agriculture accounted for 38 percent of U.S. freshwater withdrawals in 2010, and agriculture accounts for about 80 to 90 percent of U.S. consumptive water use.[50] This demand for water presents opportunities for towns and cities to engage with agricultural producers and rural water users to enact watershed-wide conservation incentives and policies. Agricultural water consumption can be reduced through soil moisture monitoring, managing soil capacity to retain more water, conservation tillage, efficient irrigation and crops that are better able to withstand water stress and withdraw water from the soil.[51]

In an urban-rural partnership, cities work with agricultural water users to reduce consumption on farms, freeing up water supply for urban use while reducing water-related costs of farming, and farmers' vulnerability to water shortages and drought.

Urban-rural partnerships can be cost-effective water supply strategies for cities and farms,[52] and are most successful when tangible water quality improvements are identified that also improve farm operations, improve soil quality, and create regulatory certainty for municipalities and producers.[53]

WATERSHED COORDINATION

It is critical to manage for drought resilience at the watershed level, despite the local nature of water suppliers and management agencies. Watersheds cross local and state boundaries creating a need for inter-basin cooperation. Watershed-scale management can be scoped to provide a number of other benefits like enhancing fisheries, expanding surface and groundwater storage, improving habitats and water conservation.

COSTS

There is little data available about the cost of implementing an urban-rural partnership or basin-wide conservation efforts. In the San Diego case, detailed below, the cost, per cubic meter, of water conserved through agriculture to urban water transfers, was $0.57, while the comparative costs for other water recycling and storage methods were higher (only local stormwater capture and urban water conservation were a lower price).[54]

BENEFITS

Avoided Costs

Similar to the benefits that result from water conservation, watershed and urban-rural partnerships to address water shortages can help communities avoid the costs associated with building alternative water supply systems.

Ecological Benefits

Agricultural conservation allows water conservation to occur upstream of cities, limiting the water lost in transit to urban areas. Agricultural water diversions can harm fish and wildlife, so agricultural conservation can benefit ecological health and ecosystem services in addition to enhancing recreational opportunities in waterways.[55] Watershed-scale drought planning can also benefit aquatic species and include habitat restoration goals.

Agricultural Benefits

Water conservation in agriculture can increase yields and improve crop quality. Water efficiency improves the reliability of a farmer's existing water supplies and reduces vulnerability to drought. Farmers can use income from water transfers to fund purchase of irrigation technology, and for complex irrigation management like irrigation scheduling or applying less water to plants in more drought-tolerant growth stages. On-farm and water-district-level water efficiency could result in agricultural water savings of 4.3 million acre-feet per year in California, and 0.4 million acre-feet of those water savings could be made available to other uses.[56]

Watershed drought coordination can also benefit farms. In the Blackfoot River watershed in Montana, individual irrigators and streams suffered in droughts. In 2000, water users developed the Blackfoot River Drought Response Plan to improve the health of the river during normal periods and provide certainty for irrigators during droughts by determining drought indicators that trigger water conservation.

IMPLEMENTATION EXAMPLES

- **San Diego** developed an urban-rural water conservation partnership in which the city compensates farmers in surrounding areas for implementing agricultural water conservation measures. Some growers implemented conservation measures that resulted in a 55% reduction in agricultural use within 3 years. Agricultural and residential water conservation efforts helped San Diego maintain the same city-wide water use in 2010 as in 1995 despite a growth in population by over 400,000.[57]
- **Colorado** and other western states are employing "alternative transfer methods" which generally allow agricultural producers to maintain ownership of their water rights. The Arkansas Valley Super Ditch in Colorado began a pilot project phase in 2015 allowing temporary water transfers. Irrigators lease water to cities in 3 out of every 10 years and receive payment for leased water. Farmers reduce consumptive water use by planting non-irrigated crops in their crop rotation or fallowing fields.[58]
- Water users in the **Yakima Basin, Washington** launched the Yakima Basin Integrated Water

Resource Management Plan to bring together more than two dozen stakeholders and develop an integrated management approach for the Yakima River which provides water to towns, supports $4 billion in agricultural production,[59] fisheries, a river ecosystem, and is important to the culture and economy of Native American tribes. The plan includes restoration elements to help fish populations, make structural and operational changes to existing facilities, create surface water and groundwater storage, protect habitat and the watershed, enhance water conservation and establish a market-based water bank to reallocate water, including during periods of drought. The overall cost of implementing the plan over decades is estimated to cost between $3.2 and $5 billion.[60]

ALTERNATIVE WATER SUPPLY

When reducing demand is not enough, communities can consider additional sources of water. By diversifying water supply and identifying alternative water sources for emergencies, communities can improve their resilience to drought. This can include approaches like building piplines to existing water supplies, enlarging or adding reservoirs to increase storage, drilling or acquiring groundwater wells, and establishing emergency interconnections with nearby water or power utilities. This paper will focus on less traditional strategies that can address increasing drought conditions. Water reuse and desalination have been included in some cities' drought or water management plans for the coming decades and are being implemented in select cities.

WATER REUSE

Water reuse or recyling is the use of highly treated wastewater, called reclaimed water, for potable or nonpotable purposes. Communities are implementing inexpensive water reuse programs that serve specific outdoor facilities such as golf courses or parks or more advanced systems like agricultural use, creation of wetlands and industrial reuse like in cooling towers. Some communities are treating wastewater for potable uses, or are considering the option for future scenarios of drought or increased water demand. California already reuses an estimated 13 percent of wastewater generated, with additional potential for reusing 1.2 to 1.8 million acre-feet per year.[61]

This can also be carried out on-site, to reduce the consumption of treated drinking water and the amount of wastewater that needs treatment. On-site systems separate graywater (any wastewater not from toilets and sometimes kitchen sinks and dishwashers) from blackwater (water that could carry sewage) and treats the gray water for reuse.[62]

DESALINATION

Desalination refers to the process of removing dissolved solids, mostly salts and other minerals, from water. The process is most often used to convert seawater or brackish groundwater to potable water, but can also be applied to treat wastewater in reclamation and reuse projects. Desalination plants are being constructed around the U.S., with 117 municipal desalination plants built between 2000 and 2010. Florida has the most municipal desalination plants with 148 as of 2013.[63]

COSTS

The costs of installing non-potable reuse facilities vary based on the size of the facilities and the intended use of the water. A National Academies of Sciences report found that the capital costs (construction of plants, pipelines, well fields and engineered natural systems) for water reclamation and reuse varies from $1.14 to $18.75 per thousand gallons (kgal) capacity. Costs of operations and maintenance were between $0.05 and $1.18 per kgal per year (averaging $0.69 per kgal). Potable reuse projects generally have higher capital costs, ranging from $3.90 to $31 per annual kgal capacity and from $0.31 to $2.38 per kgal capacity (averaging $0.95 per kgal) for operations and maintenance, but this can vary. A Denver analysis of future water supply options found that potable water reuse was cheaper than expanding the existing nonpotable system throughout the city.[64]

Desalination is often the most expensive drought strategy. One-third to one-half of the operating cost is spent on electricity to run the desalination systems, and this can make the price unpredictable. Desalination plants should rely on low carbon energy sources like nuclear or renewable energy to avoid additional greenhouse gas emissions. In November 2012, San Diego County Water Authority approved the purchase of desalinated water from the Carlsbad desalination facility costing about $1,600 per acre-foot.[65] Desalination can also have negative impacts, including the disposal of byproducts created during the deslination process. Careful management and disposal can avoid contamination of other estuaries and wetlands near facilities.[66]

BENEFITS

Water reclamation and recycling has many of the same benefits as water conservation by reducing demand on natural surface water sources. These include ensuring affordable water for customers, avoiding water diversion, avoiding aquifer stress and depletion, decreasing discharge of wastewater into sensitive water bodies and the additional possible benefit of using recycled water to enhance wetlands or riparian habitats.

Energy Savings and Avoided Costs

On-site water recycling can produce benefits related to avoided investment in water infrastructure to transfer water to the site and wastewater from the site. In Los Angeles, water recycling offered energy savings over pumping water from the Los Angeles Basin, also contributing to improved air quality.[67] Desalination facilities can also help communities save money on transporting water. In El Paso, Texas, the cost of importing fresh water was about $6 or $7 per thousand gallons versus between $4 and $5 per thousand gallons to desalinate.[68]

IMPLEMENTATION EXAMPLES

- **El Paso, Texas,** has the world's largest inland desalination plant, which allows the city to access brakish groundwater resources. The plant can produce up to 27.5 million gallons of fresh water each day. Desalination doubles as a comprehensive water treatment technology, removing other pollutants in the process. The wells for the plant are strategically placed to slow or prevent brakish water intrusion in freshwater wells.[69]
- **Phoenix** reuses nearly 100 percent of its wastewater, and Arizona Public Service Company's Palo Verde Nuclear Power Plant is cooled by reused water.[70]

EMERGENCY PLANNING FOR DROUGHT

Communities can develop drought plans to prepare the community (including citizens, local government and industry) to address drough conditions. Drought planning can be included in a local hazard mitigation planning process[71] or through local, regional or statewide water management planning, water shortage contingency planning, in a separate climate resilience plan, or other city documents. Drought planning typically includes:

- Designating a drought task force or planning team
- Drought monitoring
- Adopting a local definition of drought and different alert levels that trigger phasing in and out of local, state, federal responses to drought
- Provisions for communicating with a drought planning team, groups or agencies with interests related to drought and the public
- A vulnerability assessment to analyze past impacts and causes of continued vulnerability
- Specific planning about how to help the public understand regional water supply vulnerability to drought, and how individual choices and actions can reduce water consumption
- Communication planning for during the drought with coordination between involved entities
- Identification of other resilience strategies to be implemented.[72]

Drought risk should be communicated to the community before the start of a drought. Outreach programs can explain water conservation, the drought plans in place, and how residents and businesses will be expected to respond in drought conditions through mass, targeted and daily communication. Use of electronic messaging and social media platforms can also extend and better target messages. Communications can leverage past outreach from water utilities as well.[73] There is little data on the costs of developing an emergency drought plan so this paper will next discuss the benefits.

BENEFITS

Behavior Change

In the process of developing drought planning documents, early engagement can build support for municipal drought mitigation and also understanding of regional water stress. Alerting residents to challenges with drought can also create a collective consciousness and concern about the issue, contributing to more effective conservation outreach. For instance, during California's drought in 2015, Sacramento-area residents reported water wasters 5-10 times more frequently than the rest of the state and cut water use by 35 percent.[74]

IMPLEMENTATION EXAMPLES

- **Arizona's** Department of Water Resources requires annual water use reports and system plans from drinking water providers in the state. System water plans must include a water supply plan, water conservation plan and drought preparedness plan.
- **Tucson, Arizona,** developed a Drought Preparedness Plan in 2005. It provides water efficiency incentives and recycles wastewater for irrigation. Tuscon spends $3 million a year on conservation education programs.[75]
- **Las Vegas** responded to a 10-year drought by adopting an Emergency Action Plan establishing drought management measures and water use restrictions. Part of this plan was to implement an outreach campaign that through presentations, community meetings and media reports helped reduce water use by 26 percent.[76]

CASE STUDY: SAN ANTONIO

Most communities facing some form of drought threat need to take a multi-faceted approach and implement a combination of the strategies outlined above. San Antonio provides a model for developing a comprehensive suite of strategies to improve resilience to drought. San Antonio's population has grown by 80 percent in the last 30 years, but water demand has only grown by 20 percent. San Antonio achieved these reductions in consumption through a number of initiatives.

The San Antonio Water System (SAWS) utility required and incentivized retrofits for residential and commercial water conservation. Rebates were offered for water-saving improvements like irrigation systems, and custom rebates created incentive for businesses to upgrade equipment. Rebate programs resulted in the replacement of over 250,000 traditional toilets and urinals with low-flow models.[77]

The utility and city also supported outdoor conservation. Residents are encouraged to use native, drought-tolerant plants. SAWS offers incentives to eliminate unnecessary spray irrigation, convert to drip irrigation and establish drought tolerant landscape. Over 2 million square feet of water-intensive grass has been replaced with low water-use plants or permeable patios through the WaterSaver Landscape Coupon program. These water conservation incentives were paired with a tiered rate structure to discourage water waste.[78] The utility also offered services to customers like water-saver irrigation consultants, which reduced household usage by 84 million gallons per year, and repairing leaks at no cost for low-income customers.

The utility's work complemented city initiatives like its 2010 Sustainable Buildings Ordinance to increase energy efficiency as well as water efficiency in buildings.[79] The city has also passed a small addition to the sales tax to purchase conservation easements to protect sensitive land over the recharge zones for the city's aquifer. San Antonio has the nation's largest direct recycled water system, with infrastructure capacity to deliver up to 35,000 acre-feet per year of treated recycled water through more than 130 miles of pipeline to commercial and industrial customers, golf courses and parks.[80] San Antonio also has an aquifer storage and recovery facility that stores enough water to supply the city for four months[81] and has invested in a brackish desalination plant that can produce 12 million gallons of water per day.[82]

Incentives and ordinances are supported by education through years of media campaigns, educational events and home conservation consultations. SAWS seeks to engage 100,000 citizens per year through face-to-face conservation education by partnering with community organizations.[83]

The city conducted an analysis, comparing the costs avoided by conservation programs to the capital costs of operations and maintenance of new water supplies, potable water delivery, and wastewater treatment, without conservation, from 2010 to 2060. The study found that for every dollar invested in conservation, the utility saved $4 on the capital costs, operation and maintenance of new water supplies.[84] In 2011, San Antonio's conservation efforts saved 120,000 acre-feet of water, or $84 million in just one summer.

Looking to the future, SAWS is exploring additional drought resilience projects like direct potable reuse of treated wastewater, stormwater management to enhance aquifer water levels, and expanding its brakish water desalination plant. San Antonio's short term plans include continued encouragement of water conservation to reduce total planned per capita consumption in an average year from 124 gallons per capita per day in 2017 to 112 gallons per capita in 2025. The utility has set an even more aggressive conservation goal of 88 gallons per capita per day in 2070.[85]

KEY INSIGHTS

This paper draws examples mostly from the west where droughts are natural, historic, occurrences, but communities are now facing more severe and longer periods of drought, and in different regions. These communities that have been conscious of drought and water-use for decades, if not centuries, serve as models for other communities. Most of the communities mentioned in the paper are employing multiple strategies, with San Antonio providing a prime example of developing multi-pronged plans to encourage individual conservation, recycle water, and find additional storage and sources for times of drought. Using multiple strategies helps a community be more resilient to changing climate conditions.

Water conservation is the most cost-effective strategy for reducing water consumption and becoming more resilient to potential climate impacts that incease draught conditions. Desalination is the most expensive drought strategy, but costs may come down as the technology is improved, becoming more competitive because of the high cost of water transport. Water conservation or reusing wastewater provide numerous co-benefits including instream-flow habitat, reduced energy consumption and cost of water pumping and treating, and reduced cost of updating water storage options. Strategies with these co-benefits can improve city resilience to other climate impacts like drought and flooding.

Table 1 (on the following page) shows that each strategy offers benefits and costs. Considering which benefits are most in-line with other community priorities, and which combination of strategies may yield them, helps to prioritize local resilience activity.

TOOLS

Several tools are available to support decision making around adoption of resilience strategies to drought.

AQUEDUCT (WORLD RESOURCES INSTITUTE)

This series of mapping tools help companies, investors, government and other users understand where and how water risks and opportunities are emerging worldwide. Maps look at flood imapcts, as well as river basins' exposure to water stress, interannual variability, seasonal variability, flood occurrence and drought.

http://www.wri.org/our-work/project/aqueduct

CLIMATE RESILIENCE EVALUATION AND AWARENESS TOOL (CREAT) CLIMATE SCENARIOS PROJECTION MAP (EPA)

Users can look at projections for precipitation (as well as other climate impacts) in hot and dry, central, and warm and wet scenarios in the years 2035 and 2060.

https://epa.maps.arcgis.com/apps/MapSeries/index.html?appid=3805293158d54846a29f750d63c6890e

CONSERVATION TRACKING TOOL (ALLIANCE FOR WATER EFFICIENCY)

The Tracking Tool is an excel-based model that can evaluate water savings, costs, and benefits of conservation programs for a specific water utility. Information entered into the tracking tool provides a standardized methodology for water savings and benefit-cost accounting including a library of pre-defined conservation activities users can use to build conservation programs. The tool is available for free to Alliance for Water Efficiency members.

http://www.allianceforwaterefficiency.org/Tracking-Tool.aspx

CREATING RESILIENT WATER UTILITIES CASE STUDY AND INFORMATION EXCHANGE (EPA)

A set of maps that provide links to brief stories of planning efforts being conducted by water utilities in the United States to build resilience to natural hazards and other water management challenges. The utilities have shared experiences and lessons learned to assist other

Table 1: Co-Benefits of Resilience Strategies for Drought

	BENEFITS									
	AVOIDED INDIVIDUAL COSTS	AVOIDED COMMUNITY COSTS	AFFORDABILITY	LESS LANDSCAPE MAINTENANCE	ENERGY SAVINGS	ECOLOGICAL	SOCIAL AND HEALTH	ADAPTABLE IMPLEMENTATION	AGRICULTURAL	INCREASED AWARENESS
Indoor Conservation	●	●	●		▲	▲	▲	●		▲
Outdoor Conservation	●	●	●		▲	▲	▲	●		▲
City Planning	▲	▲	▲	▲	▲	▲	▲			
Conservation Ordinances	●	▲	▲	▲	●	▲				▲
Water Pricing	▲	●	▲		▲	▲	▲	●		▲
Landscape Rebates	●	▲	●	▲	▲	●	▲	●		▲
Plumbing Retrofit Rebates	●	▲	●		▲	▲	▲	●		▲
Community Leak Detection and Repair	▲	●	▲		▲	▲	▲	●	▲	
Public Education	▲	▲	▲	▲	▲	▲	●	●		●
Water Reuse/Recycling	▲	▲	▲		▲	▲	▲			
Desalination		▲				▲				
Urban-Rural Partnerships	▲	●	▲		●	●		●	▲	
Watershed Management	▲	▲	▲		▲	●	▲		▲	
Emergency Planning		▲					●			●

The benefits of the strategies overviewed in the factsheet are summarized above, with green dots indicating a benefit that could be expected from each of the strategies. The yellow triangles indicate benefits and costs that could apply in certain areas or circumstances, especially if the strategy was designed or implemented to that purpose. When weighing different strategies for use in a community, consider the greatest local vulnerabilities, which benefits would address them and choose strategies that offer these benefits. Be aware of gaps in benefits offered by the strategies prioritized.

water sector utilities that are currently developing their own plans or responding to recent events.

https://epa.maps.arcgis.com/apps/MapSeries/index.html?appid=03d35ca84b5944f8b3ab59bf3a981462

NATIONAL DROUGHT MITIGATION CENTER

The NDMC at the University of Nebraska-Lincoln helps people and institutions develop and implement measures to reduce vulnerability to drought. Resources include monitoring tools, planning tools, and information about current and historic drought conditions.

http://drought.unl.edu/

NATIONAL INTEGRATED DROUGHT INFORMATION SYSTEM (NOAA)

This tool coordinates and integrates drought research building on existing federal, tribal, state, and local partnerships. NIDIS's website is a portal into data, maps and tools that can be used to inform drought planning. For example, the Soil Moisture Map displays interactive soil moisture and soil temperature data. Users can select the location, whether they'd like temperature or moisture data, and at what depth the data should be from (between 2 inches and 40 inches).

www.drought.gov

WATERSENSE CALCULATOR (EPA)

The calculator allows users to estimate how much water, energy and money can be saved with WaterSense labeled products in a home or apartment building.

https://www.epa.gov/watersense/watersense-calculator

WATERSENSE REBATE FINDER (EPA)

Users can search for money-saving rebates in their area. The site categorizes the types of rebates, elligible building types, and the states where the rebate is available.

https://www.epa.gov/watersense/rebate-finder

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