Energy & Water
for Local Governments

LEAP

Local Government
Energy Assurance Planning

pti Public Technology Institute

U.S. DEPARTMENT OF ENERGY

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Public Technology Institute

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Local Government Energy Assurance Planning (LEAP)

To find out more about local government energy assurance efforts, we encourage readers to visit www.energyassurance.us. This site, maintained by PTI, is designed to support all local governments, large, medium and small, across the nation that want to learn more about creating energy assurance plans for their communities. Once created, these plans will help ensure that local governments can provide life-saving services during an energy emergency.

Editorial Team

The principal author is Laura Dufresne of the Cadmus Group, Inc. Additional contributors from the Cadmus Group included Victoria Kiechel, Vanessa Leiby and Erin Sweet.

This work was managed by Ronda Mosley, Assistant Executive Director for Research and Government Services, Public Technology Institute.

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Energy and Water for Local Governments

1 Overview and Background

The economy of the United States depends on access to ample quantities of both energy and water to support the agriculture, manufacturing, technology, and service sectors. The uses of energy and water are interdependently linked: water is used for many aspects of energy generation, and energy is required to pump and treat water. Figure 1 shows an example of the energy/water nexus.

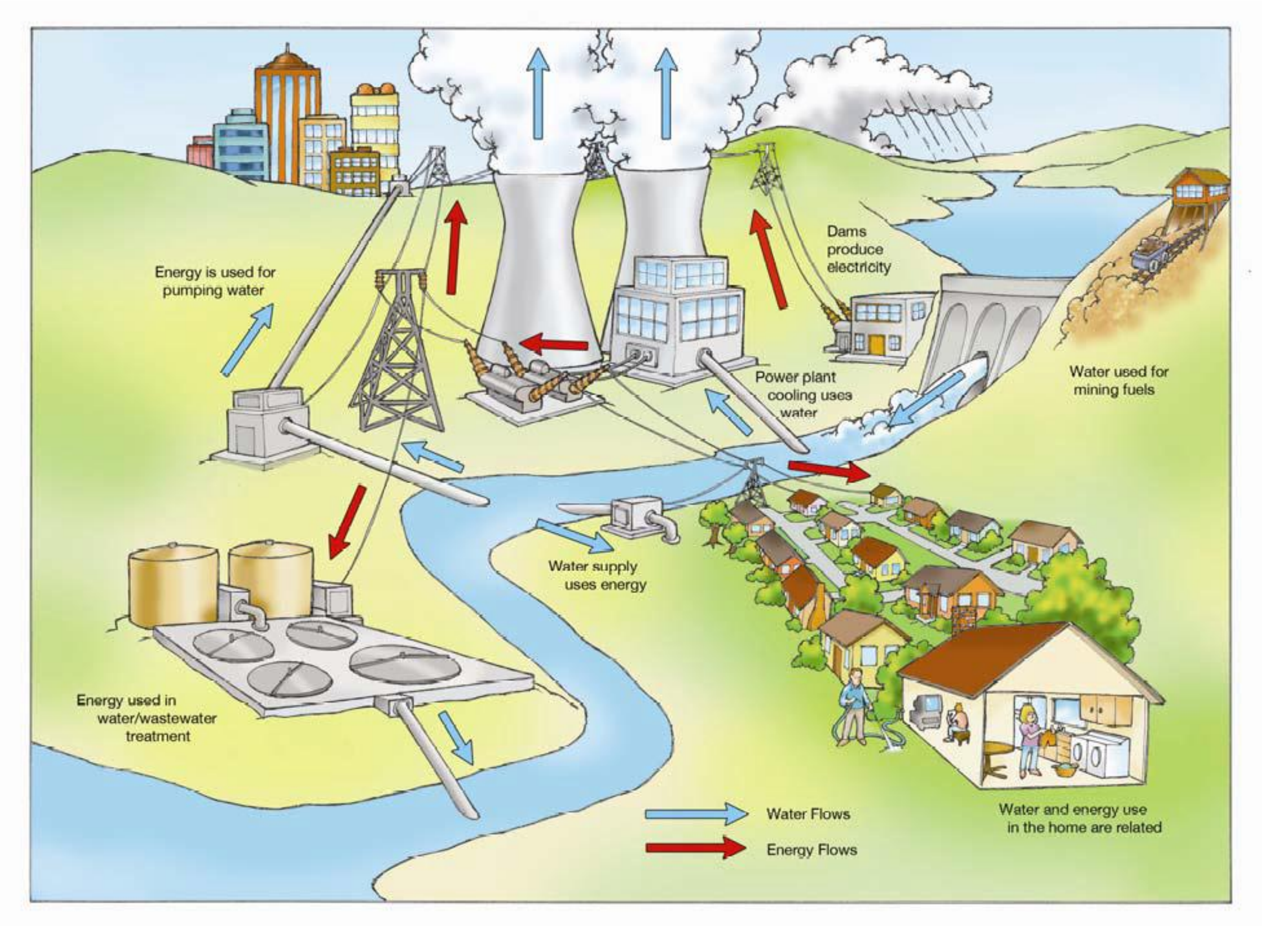

Figure 1: The Energy/Water Nexus
Source: U.S. Department of Energy (DOE). *Energy Demands on Water Resources: Report to Congress on the Interdependency of Energy and Water.* December 2006. http://www.sandia.gov/energy-water/congress_report.htm.

This document serves to help local governments better understand this energy/water nexus, particularly as it affects the local government energy assurance planning process. The remainder of Section 1 examines how water is used in the energy sector and how energy is used by the water sector, and discusses water scarcity issues.

Section 2 identifies ways that local governments can plan for the water needs of the energy sector, and Section 3 follows with recommendations for water and energy efficiency measures for the water sector. Section 4 provides closing remarks.

1.1 Water for Energy

Energy production and processing is dependent on a reliable supply of fresh water. The United States Geological Survey (USGS) estimates that 41 percent of all freshwater withdrawals are used for thermoelectric power generation.[1] Although much of the water withdrawn is used for cooling and then returned to the source, a reliable freshwater source is still a big concern for power plants.[2]

Examples of Water Shortages Limiting Energy Production

- Record drought in Texas could lead to brownouts and keep major firms from expanding due to fears of an unreliable power grid. Although not likely to cause significant power shortfalls in 2012, continued drought through 2013 could have severe impacts on energy generation. http://www.cbsnews.com/8301-505245_162-57356580/texas-senate-mulls-drought-impact-on-power-supply/
- On August 17, 2007, the Tennessee Valley Authority shut down a portion of the Browns Ferry Nuclear Power Plant to maintain water temperature limits in the Tennessee River. http://www.oe.netl.doe.gov/docs/eads/ead081707.pdf
- Also in 2007, Duke Energy had to decrease energy production at two coal plants along the Catawba River because of a lack of cooling water. http://www.ucsusa.org/assets/documents/clean_energy/ew3/ew3-freshwater-use-by-us-power-plants.pdf

Water is used throughout the energy sector, including in resource extraction, refining and processing, electric power generation, storage, and transport.[3] Figure 2 compares water use for different electric power generation technologies. In general, renewable sources of energy such as wind and solar use less water than fossil and nuclear energy, with a few exceptions.

Wet-cooled concentrating solar power (CSP) plants require significant quantities of water to function – as much as 1.24 gallons of water are consumed per kilowatt hour (kWh) generated.[4]

First-generation biofuels[5] have an enormous water footprint, consuming an estimated 130 gallons for every kWh produced. Recent increases in oil prices and a growing desire for energy independence have led to rapid expansion of biofuel production in the United States. Hydropower uses water directly to generate energy but leaves the water in its original source for other uses.

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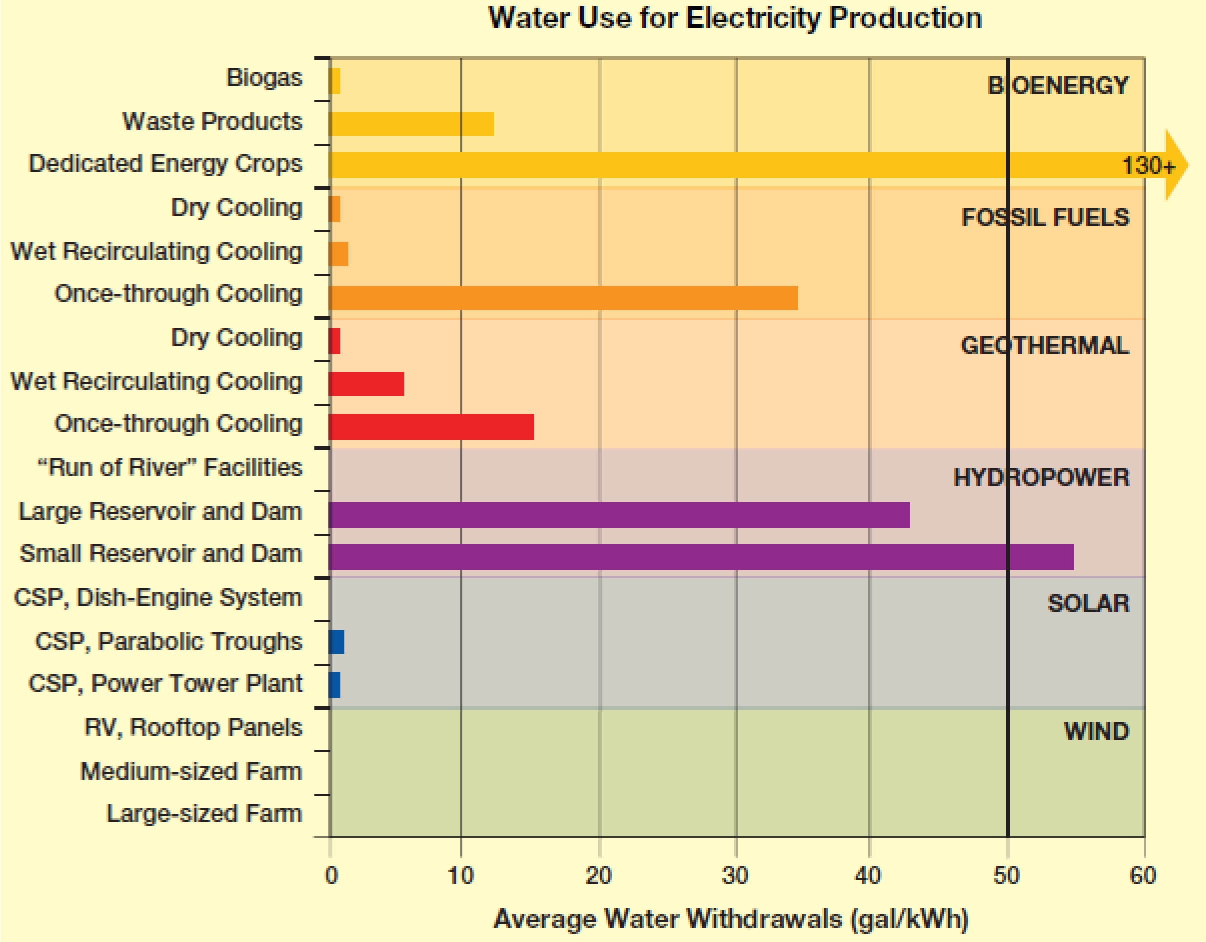
[1] Kenny, Joan; Nancy L. Barber, Susan S. Hutson, Kristin S. Linsey, John K. Lovelace, and Molly A. Maupin. *Estimated Use of Water in the United States in 2005*. USGS. 2009. http://pubs.usgs.gov/circ/1344/pdf/c1344.pdf.

[2] Averyt, K., J. Fisher, A. Huber-Lee, A. Lewis, J. Macknick, N. Madden, J. Rogers, and S. Tellinghuisen. Freshwater Use by U.S. Power Plants: Electricity's Search for a Precious Resource. A report of the Energy and Water in a Warming World initiative. Cambridge, MA: Union of Concerned Scientists. November, 2011. http://www.ucsusa.org/assets/documents/clean_energy/ew3/ew3-freshwater-use-by-us-power-plants.pdf.

[3] U.S. DOE. *Energy Demands on Water Resources: Report to Congress on the Interdependency of Energy and Water*. December 2006. http://www.sandia.gov/energy-water/congress_report.htm.

[4] Burkhardt, John J. III, *et. al*. "Life Cycle Assessment of a Parabolic Trough Concentrating Solar Power Plant and the Impacts of Key Design Alternatives." Environmental Science and Technology. 2011. 45 (6), pp 2457–2464. http://pubs.acs.org/doi/abs/10.1021/es1033266.

[5] First-generation biofuels are made from sugar, starch, vegetable oil, or animal fats using conventional technology http://biofuel.org.uk/first-generation-biofuels.html.



Water requirements are highest for electricity generated from irrigated crop-based biomass, hydroelectric power, and for thermoelectric generation using once-through cooling technology. Note: not all energy crops are irrigated, and regional irrigation differences are great. CSP = concentrating solar power (power towers and parabolic trough plants).

Figure 2: Water Used for Electricity Production in California.
Source: Larson, Dane, *et. al. California's Energy-Water Nexus: Water Use in Electricity Generation*. Southwest Hydrology. September/October 2007. http://www.swhydro.arizona.edu/archive/V6_N5/feature3.pdf

The amount of water used in the cooling process of a power generation plant depends on the type of cooling system. There are three general types:

- **Once-through**: cooling water is withdrawn from a local water source (e.g., a lake or river), passed through the condenser, and returned to the original source. Once-through cooling systems have high water withdrawal, but return all but about 3 percent of water to the water source.

- **Wet recirculating**: uses either a wet tower or cooling pond to dissipate heat from the cooling water to the atmosphere. Water is drawn from a source to replace water losses from evaporation and blowdown. Plants with wet cooling systems withdraw less than 5 percent of the water withdrawn by once-through systems, but most of the water is lost to evaporation.[6]

- **Dry**: uses direct or indirect air cooling process. Direct air-cooled systems do not use water. Although indirect dry cooling systems still use water to condense the turbine exhaust steam, water withdrawal and consumption are minimal with these systems.

Of these, once-through cooling systems at thermoelectric power plants are the biggest freshwater user in the energy sector.

How much water do power plants use?

12 million gallons of water <u>per hour</u> is needed to cool steam turbine exhaust at a 500 MW plant (DOE/NETL. 2011. p 8).

Most thermoelectric power plants use once-through (43 percent) or wet recirculating (56 percent) cooling systems. Less than 1 percent of plants use dry cooling.[7]

Projections suggest that fresh water consumption for electric power generation, using current technologies and approaches, could triple by 2035 relative to 1995 water consumptions.[8] Current policy preferences in the U.S. favoring energy diversification (towards shale gas and its extraction through hydrofracturing, for example) may only increase these water demands.

1.2 Energy for Water

EPA estimates that U.S. water and wastewater services require approximately 100 billion kWh per year.[9] At an average cost of 9.83 cents per kWh[10], the nation spends nearly $10 billion per year on providing safe drinking water and treating wastewater to protect our waterways.

Water and wastewater facilities are often the greatest consumers of electricity in a community, accounting for up to 40 percent of a municipality's total energy bill.[11]

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[6] U.S. DOE. *Energy Demands on Water Resources: Report to Congress on the Interdependency of Energy and Water*. December 2006. http://www.sandia.gov/energy-water/congress_report.htm.

[7] National Energy Technology Laboratory (NETL). *Estimating Freshwater Needs to Meet Future Thermoelectric Generation Requirements: 2011 Update*. September 30, 2011. http://www.netl.doe.gov/energy-analyses/pubs/WaterNeeds2011.pdf.

[8] U.S. DOE. *Energy Demands on Water Resources: Report to Congress on the Interdependency of Energy and Water*. December 2006. http://www.sandia.gov/energy-water/congress_report.htm.

[9] U.S. EPA. *Evaluation of Energy Conservation Measures for Wastewater Treatment Facilities*. EPA 832-R-10-005. September 2010. http://water.epa.gov/scitech/wastetech/upload/Evaluation-of-Energy-Conservation-Measures-for-Wastewater-Treatment-Facilities.pdf.

[10] http://www.eia.gov/electricity/state.

[11] http://www.epa.gov/statelocalclimate/local/topics/energy-efficiency.html.

Energy is required in every step of municipal drinking water services. Figure 3 shows the typical energy breakdown for an urban water supply. The true amount of energy required to treat and convey water in a community is highly variable and depends on many factors.

Source energy depends on the source type (e.g., a surface water source such as a lake or river, or a deep ground water source) and how far it must be pumped to the treatment plant.

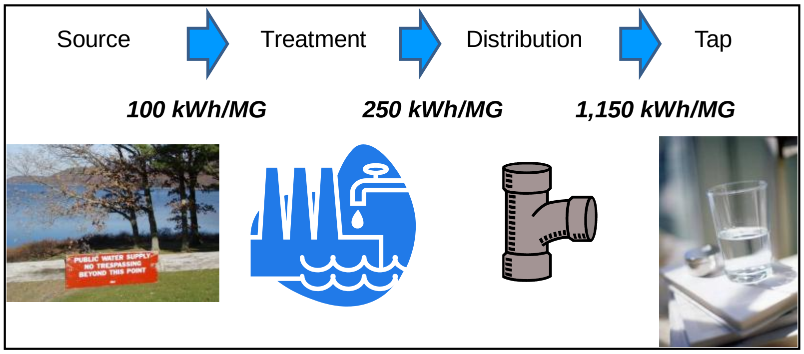

Figure 3: Typical Energy Breakdown for Urban Drinking Water Supply
Note: MG = million gallons
Source: Leiby Vanessa. *Energy Efficiency in the North American Water Supply Industry: Report on Project #4223*. Water Research Foundation Webcast. October 7, 2010.

Treatment energy depends on the treatment technologies used. Conventional treatment to remove particles and disinfect the water is much less energy-intensive than advanced disinfection technologies such as ozone and membrane filtration. The energy used to pump water from the plant to the customers' tap depends on topography and distance, and is typically more than triple the source and treatment energy combined. For drinking water systems that rely on pumps to transport water from the source to the tap, pumping can represent over 95 percent of the electricity used by the entire system.[12]

Outside factors are increasing the amount of energy required for drinking water treatment. Some municipalities in water-scarce areas are desalinating ocean water, which is a highly energy-intensive process. In the drought-stricken southwest, considerable energy is used to pump water from aquifers deep underground. Emerging contaminants in water such as pharmaceuticals and endocrine-disrupting compounds require more energy-intensive technologies to remove.

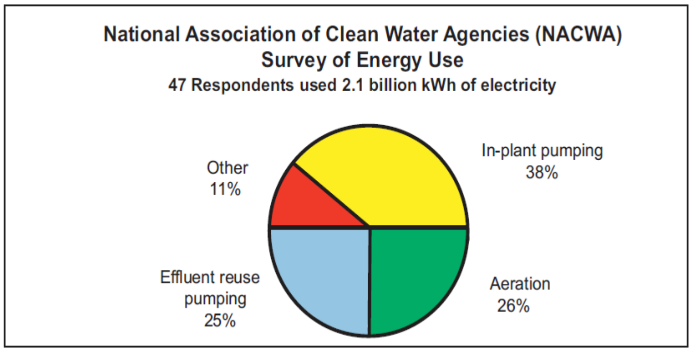

Figure 4: Typical Energy Breakdown for a Large Urban Wastewater Treatment Plant
Source: U.S. EPA. *Ensuring a Sustainable Future: An Energy Management Guidebook for Wastewater and Water Utilities.* January 2008.
http://www.epa.gov/waterinfrastructure/pdfs/guidebook_si_energymanagement.pdf

Similar to drinking water services, collecting and treating wastewater require energy in every step. Pumping and aeration are typically the largest energy users (see Figure 4).

Although many sewers flow by gravity, pumps are often needed to convey wastewater to the treatment plant and send treated water from the plant to the final discharge point.

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[12] Burton, F. L. "Water and Wastewater Industries Characteristics and Energy Management Opportunities." Electric Power Research Institute. Report CR-106941. 1996.

Most wastewater plants use blowers or mechanical mixers to aerate (deliver oxygen) to wastewater to facilitate the breakdown of organic waste.

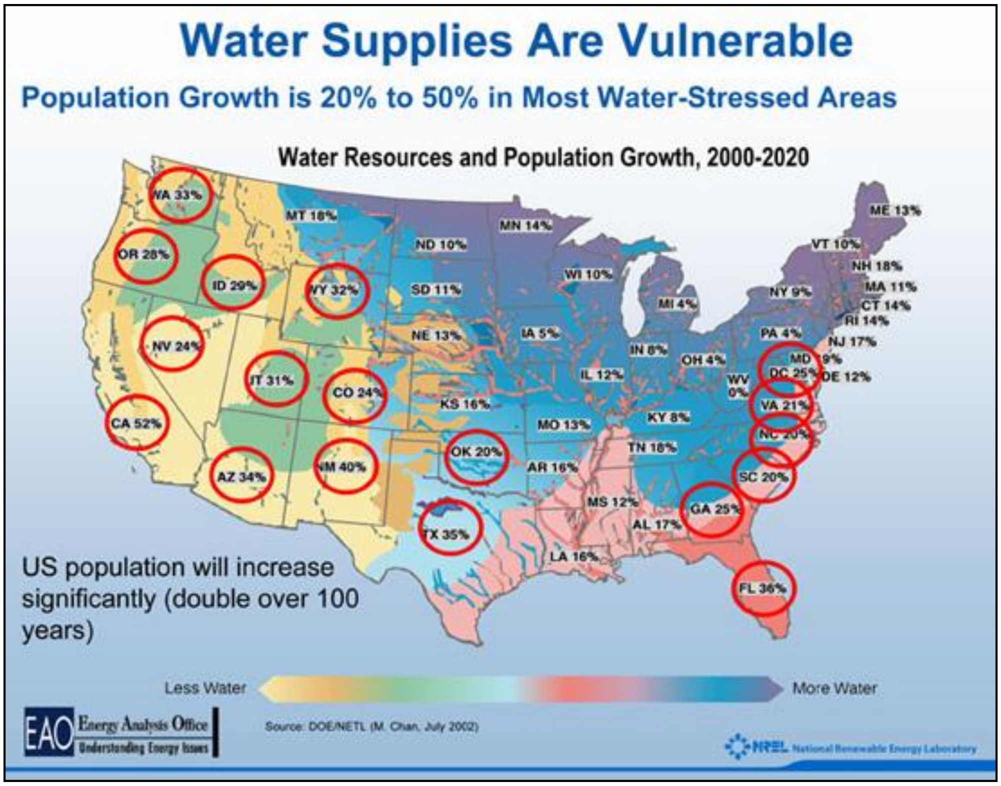
Energy costs in the wastewater industry are also rising due to:[13]

- More stringent treatment requirements, including enhanced nutrient removal and other emerging contaminants that may lead to the use of more energy-intensive technologies.
- Enhanced treatment of solids so that they can be reused as fertilizer or in other applications.
- An aging sanitary sewer system that can cause inflow of storm and ground water through cracks and other openings. Inflow increases wastewater pumping and treatment requirements.

1.3 Water Scarcity Issues

Many areas of the United States are experiencing persistent droughts. A look at the continuously updated U.S. drought monitor[14] shows an alarming increase of severe drought conditions in growing population centers like Texas, the Southeast region, and California.

Droughts may be more severe in the future – Figure 5 shows how population growth is projected to continue increasing in the most water-scarce regions of the country.



Water Supplies Are Vulnerable

Population Growth is 20% to 50% in Most Water-Stressed Areas

Water Resources and Population Growth, 2000-2020

US population will increase significantly (double over 100 years)

Source: DOE/NETL (M. Chan, July 2002)

Figure 5: Comparison of Projected Water Resources and Population Growth
Source: Sandia National Laboratories. "The Energy-Water Connection." http://www.sandia.gov/energy-water/nexus_overview.htm.

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[13] U.S. EPA. *Evaluation of Energy Conservation Measures for Wastewater Treatment Facilities*. EPA 832-R-10-005. September 2010. http://water.epa.gov/scitech/wastetech/upload/Evaluation-of-Energy-Conservation-Measures-for-Wastewater-Treatment-Facilities.pdf.

[14] http://droughtmonitor.unl.edu/.

With increasing water scarcity, local governments may face tough decisions about how to make sure that water supplies can meet consumer demands. To plan for better water supply assurance, or to respond to scarcity, city and county governments can make and mandate policies and management plans that encourage water efficiency. Examples of policies to address water scarcity are provided in the text box below.

How Can Local Governments Encourage Water Efficiency and Protect Water Resources?

Land-use policy. Local governments can regulate land use to encourage water and energy efficiency. By using Smart Growth principles of encouraging higher population density around areas served by shared infrastructure, local governments can minimize unnecessary encroachment on fresh water sources. Local governments can also restrict development on sensitive land areas that are important to water quality, such as wetlands.

Agricultural water-use permits and policy. Regulators can establish local priorities for water use, weigh the social and economic risks of restricting agricultural water-use permits, particularly in times of drought, and establish permit fees proportional to water withdrawals.

Data collection and monitoring. To predict water scarcity, local governments can establish monitoring networks to track human and climate change impacts on ground and surface water sources. Such networks involve establishing stream-flow and water-level monitoring locations and benchmarks, and taking regular measurements. While they require funds to establish and maintain, these networks can save money by making it possible to plan, giving governments the information they need to anticipate needs and wisely direct resources.

Rate structures, surcharges, fees, and incentives. A limited water supply and increased water conveyance and wastewater treatment costs will affect water rates. U.S. households, on average, are paying only 0.55 percent of their income for water and sewer bills.[1] At a minimum, government-run utilities could ensure that rates are set to recover the costs associated with operations. At best, utilities may be able to use rates to help encourage customers to save water. Additionally, imposing emergency surcharges during droughts, providing rebates or incentives for the installation of water-efficient fixtures, and targeting outreach to high-volume water users are all parts of effective water demand management strategies.

Green infrastructure. Local governments and communities are beginning to implement and provide incentives for alternative approaches to managing and reducing storm water runoff. In many urban environments, rainwater is collected from rooftops, streets, parking lots, and other impervious surfaces through rain gutters, curbs, and storm water collection systems. Green infrastructure provides an alternative to this use and treatment cycle by relying on technologies and management approaches that resemble or mimic the natural hydrologic cycle of infiltration, evapotranspiration, and reuse. Green infrastructure includes green roofs, rain gardens, vegetated swales, pocket wetlands, infiltration planters, and porous and permeable pavements. These approaches focus on managing storm water onsite through drainage and capture structures that keep rainwater out of the storm water system.[2]

[1] Congressional Budget Office (CBO). *Future Investment in Drinking Water and Wastewater Infrastructure*. ISMBM 0·16-01243-3. November 2002. http://www.cbo.gov/sites/default/files/cbofiles/ftpdocs/39xx/doc3983/11-18-watersystems.pdf.
[2] American Rivers. *et. al. Managing Wet Weather with Green Infrastructure Action Strategy*. 2008. http://water.epa.gov/infrastructure/greeninfrastructure/upload/gi_action_strategy.pdf.

During water planning processes, local governments should consider reaching out to neighboring local governments, other States, the federal government, local electricity and natural gas service providers, other stakeholders, and citizen representatives.

Collaboration can reduce duplication of effort, resulting in further cost savings. Public outreach and education campaigns can reach wider audiences.

2 Understanding and Planning for the Water Needs of the Energy Sector

2.1 Importance of Partnering with Utilities

As part of energy assurance planning, local governments should already be working with their electricity and natural gas service providers. Local governments may also be able to collaborate with these entities to understand their current and projected water needs, and work collectively to identify opportunities for water savings and alternative water sources. Reducing water use by the energy sector can increase water availability for other uses and may prevent energy production problems caused by water shortages in the future.

2.2 Emerging Water Efficiency and Reuse Strategies for Energy Production

The U.S. DOE and international organizations such as the World Economic Forum and the World Energy Council recognize the need to research and develop water-saving strategies for the energy industry.[15] DOE's Water Energy Technology Team (WETT) is working to identify new technologies to reduce the energy sector's need for fresh water.[16] The California Energy Commission's Public Interest Energy Research Program (PIER) has been investigating replacement options for once-through cooling and plans to eliminate it completely in California by 2021.[17] Other areas of key research include use of non-traditional freshwater sources for energy production and improved data collection methods to monitor and assess water use at power plants.[18]

Freshwater withdrawals can be reduced through the use of non-freshwater sources such as brackish (saline) groundwater and treated (or "reclaimed") wastewater. Arizona, California, Florida, and Texas are among States that use significant quantities of reclaimed wastewater for thermoelectric power generation. See the text box on the next page for examples.

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[15] Sandia National Laboratories. "Energy-Water Nexus Overview." http://www.sandia.gov/energy-water/nexus_overview.htm; World Economic Forum. *Energy for Economic Growth – Energy Vision Update 2012*. 2012. http://www.weforum.org/reports/energy-economic-growth-energy-vision-update-2012; World Energy Council. "Water for Energy." September 2010. http://www.worldenergy.org/publications/2849.asp.

[16] Water Energy Technology Team website http://water-energy.lbl.gov/node/12.

[17] Navigant Consulting. *PIER Advanced Generation Roadmap - Background Paper*. Prepared for the California Energy Commission. CEC-500-209-086. August 2009. http://www.energy.ca.gov/2009publications/CEC-500-2009-086/CEC-500-2009-086-D.PDF.

[18] Pate, R., M. Hightower, C. Cameron, and W. Einfeld. "Overview of Energy-Water Interdependencies and the Emerging Energy Demands on Water Resources." Sandia National Laboratories. SAND 2007-1349C. March 2007. http://www.circleofblue.org/waternews/wp-content/uploads/2010/09/SANDIA-research.pdf.

Examples of Reclaimed Wastewater Use for Public Power

- Salt River Project's K-7 Plant in Tempe, Arizona uses 3.1 million gallons per day (MGD) of reclaimed wastewater for cooling tower make-up water.
- The City of Orlando, Florida's Curtis Stanton Energy Center uses 8 MGD of reclaimed wastewater to cool the plant's boilers.
- The City of Glendale Water & Power's Greyson Plant in California uses 0.3 MGD of reclaimed wastewater for cooling tower makeup.

Source: Blackford, J. P. "Water Efficiency at Public Power Electric Utilities." Presented at the Ground Water Protection Council Annual Forum. September 29, 2010. http://www.gwpc.org/meetings/forum/2010/proceedings/26blackford_JP.pdf.

Energy companies with a focus on water conservation are considering alternative technologies to once-through cooling. Other cooling technologies are not without tradeoffs, however. Although total water demand is significantly less, wet cooling has higher consumptive use of water than once-through cooling, as well as lower plant efficiency, blowdown, and plume and drift issues. Dry cooling has higher capital costs and larger space requirements. New hybrid systems that include both a wet cooling tower and an air-cooled condenser can lower capital costs of dry cooling, reduce water consumption compared to wet cooling systems, and allow for flexible operation. Research into improving dry cooling systems is ongoing.[19]

3 Energy Assurance Measures for the Water Sector

Energy and water efficiency measures at water and wastewater treatment plants are real and practical ways to reduce energy demands at these critical facilities and improve energy assurance. Energy and water efficiency improvements can also help water resources go farther and reduce the need for expensive water and wastewater infrastructure upgrades.

Investments in water and energy efficiency often result in significant cost savings with short payback periods. In many cases, these improvements do not require expensive or extensive capital investments – simply optimizing the performance of a drinking water or wastewater facility can often lead to significant reductions in energy and water consumption.

How can Local Governments Get Involved?

"Local governments can advance the implementation of energy efficiency measures at water and wastewater utilities by constructing practical policy and programmatic structures to support utilities throughout the process. While the onus of implementation rests with utility managers, mayors, local government councils, and local agency personnel are key strategic partners needed to overcome barriers. Local governments may require utilities to determine their baseline energy use to understand energy use patterns. Identification of an energy baseline can lead to an implementation plan, which local governments can help finance."

Source: American Council for an Energy-Efficient Economy (ACEEE). "Water and Wastewater Treatment." Undated. http://aceee.org/sector/local-policy/toolkit/water.

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[19] O'Hagan, Joe and John Maulbetsch. "Water Use for Electricity Generation." Presented at the IEPR Staff Workshop on RD&D of Advance Generation Technologies. August 10, 2009. http://www.energy.ca.gov/2009_energypolicy/documents/2009-08-10_workshop/presentations/04_CEC_OHagan_Advanced_Generation.pdf.

3.1 Systematic Approach to Energy Management

Water and wastewater utilities are realizing that a systematic approach to energy management is the best way to ensure that improvements are sustainable over time and that investments are cost-effective. The U.S. Environmental Protection Agency (EPA) recommends a detailed step-by-step approach for energy management at water and wastewater treatment plants[20] that includes:

- Create an energy sustainability team
- Gather data on energy use
- Benchmark performance
- Conduct an energy audit
- Develop quantifiable energy improvement goals
- Identify energy conservation measures and develop a plan for implementing them
- Implement improvements
- Monitor and measure results
- Communicate successes to employees, management, and the community

3.2 Do More with Less: Water and Energy Conservation and Efficiency

There are many ways local governments can improve energy and water efficiency in their communities. This section touches on key tools and approaches including benchmarking, energy audits, water audits and conservation approaches, peak load shaving, and energy efficient technologies. Local governments can refer to Public Technology Institute's (PTI) *Energy Efficiency and Energy Assurance Planning for Local Governments* for more information.[21]

Benchmarking

Tracking and monitoring changes in energy use are important components of managing energy resources. This may be as simple as monitoring changes in energy bills over time. EPA's ENERGY STAR benchmarking tool, *Portfolio Manager*, can be used by local governments to track energy use and energy costs at water and wastewater facilities.[22] The tool can also compare energy use at wastewater treatment plants with similar plants using the EPA energy performance rating system. Energy use at water treatment facilities can also be tracked using Portfolio Manager; however, these plants cannot receive performance ratings.

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[20] U.S. EPA. *Ensuring a Sustainable Future: An Energy Management Guidebook for Wastewater and Water Utilities*. January 2008. http://www.epa.gov/waterinfrastructure/pdfs/guidebook_si_energymanagement.pdf.

[21] Public Technology Institute (PTI). *Energy Efficiency and Energy Assurance Planning for Local Governments*. Forthcoming in 2012. Will be available at http://www.energyassurance.us.

[22] Portfolio Manager (http://www.energystar.gov/index.cfm?c=evaluate_performance.bus_portfoliomanager) was originally designed to track and assess energy and water consumption across a portfolio of buildings in a secure online environment. Wastewater and water facilities were added in 2007. See http://www.energystar.gov/index.cfm?c=water.wastewater_drinking_water for more information.

Energy Audits

The energy audit is an important step for local governments to understand where, when, and how much energy is being used for water and wastewater services. The goal of an energy audit is for managers to assess the energy use within their facilities, identify the most energy-intensive processes, and develop possible energy conservation measures (ECMs).

There are many levels of audits that can be performed at water systems and wastewater treatment plants. Energy audits can involve onsite power monitoring of individual equipment and processes at a plant, the results of which can be used to prepare detailed cost-benefit analyses of energy conservation alternatives. Audits can also be more simple reviews of existing equipment and energy data to identify savings opportunities. Pumping systems are often an area of focus, particularly for water plants, since pumping can constitute up to 95 percent of their total energy use.[23] Energy audits also often include analysis of lighting and heating, ventilation, and air conditioning (HVAC) systems. Audits can be conducted by water/wastewater treatment plant staff, expert consultants, or energy service contractors (see Section 3.5).

There are numerous resources available to assist in the performance of an energy audit, including State assistance programs, power company assistance programs, and energy audit experts. The California Energy Commission (CEC) has published a free, comprehensive handbook on how to hire an energy auditor.[24] Additional resources include:

- EPA's *Ensuring a Sustainable Future: An Energy Management Guidebook for Wastewater and Water Utilities*, January 2008.[25]
- New York State Energy Research and Development Authority (NYSERDA)'s *Water & Wastewater Energy Management Best Practices Handbook*, March 2010.[26]

Water Audits and Conservation Approaches

Conserving water saves energy – the less water produced by a public water system, the less energy is consumed. Water conservation can also offset future water demands and delay the need to invest in new or expanded drinking water infrastructure. It can likewise enhance emergency preparedness activities related to drought or water system outages.

Water conservation encompasses supply-side and demand-side practices that can lead to reduced water use. On the supply side, activities such as leak detection, metering, and using alternative supplies such as rainwater harvesting, reuse/reclaimed water, and aquifer storage and recovery can reduce potable water use and water loss. For example, local governments can use regulations and incentives to encourage water reuse and rainwater harvesting. Water reuse provides benefits to the water user, to the community water systems for supply and wastewater treatment, and to the environment in the form of reduced energy and infrastructure demands. "Grey water" (wastewater from sinks, showers, and clothes washers) can be reused for such purposes as

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[23] Burton, F. L. "Water and Wastewater Industries Characteristics and Energy Management Opportunities." Electric Power Research Institute. Report CR-106941. 1996.

[24] CEC. "Handbook: How to Hire an Energy Auditor To Identify Energy Efficiency Projects." January 2000. http://www.energy.ca.gov/reports/efficiency_handbooks/400-00-001C.PDF.

[25] http://www.epa.gov/waterinfrastructure/pdfs/guidebook_si_energymanagement.pdf.

[26] www.nyserda.ny.gov/~/media/Files/EERP/Commercial/Sector/Municipalities/best-practice-handbook.ashx.

landscape irrigation, a major end use of water in most office buildings. Grey water systems have been operating successfully for many years and according to EPA, they can meet up to 50 percent of a property's water needs by supplying water for landscaping needs.[27]

On the demand side, water loss audits, leak detection and prevention, implementing water-efficient device incentive programs, installing customer water meters, optimizing irrigation practices, and developing conservation rate structures can significantly reduce water use. Local governments can encourage water conservation by establishing public benchmarks and specific, measurable goals for water use reduction in their own facilities. The Federal government has set a goal of reducing water use in its facilities by 26 percent by 2020, and offers guidance on how to reduce water consumption to meet this goal.[28] Additional web resources that can help local officials in better understanding the many water conservation options include:

The Benefits of Leak Detection and Prevention

Leaks in water distribution systems result in a daily loss of an estimated ***seven billion gallons*** of potable water.[1] These leaks have an associated energy loss because potable water requires energy to treat and distribute. A pilot study conducted by American Water showed that installing acoustic leak detectors reduced water loss more than half, saving an estimated $140,000 in just six months and taking less than two years for the savings to pay for the installation of the detectors.[2]

[1] http://www.asce.org/reportcard/.

[2] American Water. "Innovation & Environmental Stewardship: Review of Significant Water Industry Trends." http://www.amwater.com/files/I&ES%202009%20Review%20of%20Water%20Industry%20Trends.pdf.

- EPA's WaterSense Program[29]
- The WaterReuse Association's "Manual of Practice on How to Develop a Water Reuse Program"[30]
- American Water Works Association (AWWA)'s "Water Loss Control"[31]
- AWWA's Free Water Audit Software[32]

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[27] U.S. EPA, Region 9. "Water Recycling and Reuse: The Environmental Benefits." http://www.epa.gov/region9/water/recycling/.
[28] Federal Emergency Management Program (FEMP). *Domestic Water Conservation Technologies*. October 2002. http://www1.eere.energy.gov/femp/pdfs/22799.pdf.
[29] http://www.epa.gov/watersense/.
[30] WaterReuse Association. "Manual of Practice on How to Develop a Water Reuse Program." 2009. http://www.watereuse.org/product/manual-practice-how-develop-water-reuse-program.
[31] http://www.awwa.org/Resources/WaterLossControl.cfm?ItemNumber=47846&navItemNumber=48155.
[32] http://www.awwa.org/Resources/WaterLossControl.cfm?ItemNumber=48511.

Peak Load Shaving

An important element of energy resiliency and reliability is electric grid stability. While not directly tied to reduced energy use, shifting energy use from peak periods to off-peak periods can reduce costs (through reduction or elimination of peak surcharges in energy bills) and provide higher quality power to energy companies during periods of high usage. Known as "peak shaving," this is the ability to reduce energy use during periods of high demand.

There are two possible approaches to peak shaving; 1) reducing usage through load shedding and 2) reducing demand through addition of on-site generation capacity. Water and wastewater utilities can work with their power companies to determine if operational changes can be made to reduce energy consumption during peak demand periods. As an example, if a utility can pump water during low-demand or off-peak times (generally in the middle of the night), it can often save significantly on energy costs and reduce the strain on the electric grid during times of peak customer usage. Use of on-site generation may include backup electrical generation fueled by an alternative energy source such as wind, solar, hydropower, or geothermal, or by diesel or natural gas. Solar PV, in particular, is well-suited to peak demand reduction, as PV systems produce the most electricity during peak demand periods.

Energy-Efficient Technologies

Many technologies have been successfully used by water and wastewater utilities to improve energy efficiency, reducing total energy use by 30 percent or more. This section describes a few of the most common approaches to reducing total energy use. For more information, including comprehensive lists of energy efficient technologies for water and wastewater services, see:

- EPA's Sustainable Infrastructure information page for water and energy efficiency[33]
- EPA's *Evaluation of Energy Conservation Measures for Wastewater Treatment Facilities*[34]
- Water Research Foundation and NYSERDA's *Energy Efficiency Best Practices for North American Drinking Water Utilities*[35]
- Wisconsin Focus on Energy*'s Water and Wastewater Energy Best Practices Guidebook*[36]

<u>Pumping System Improvements.</u> Pumps are used throughout drinking water and wastewater facilities. They are the largest energy user for water systems and are typically the second largest energy user at wastewater utilities, after aeration. Performing a pumping system evaluation can

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[33] http://water.epa.gov/infrastructure/sustain/waterefficiency.cfm.

[34] EPA. *Evaluation of Energy Conservation Measures for Wastewater Treatment Facilities*. EPA 832-R-10-005 September 2010. http://water.epa.gov/scitech/wastetech/upload/Evaluation-of-Energy-Conservation-Measures-for-Wastewater-Treatment-Facilities.pdf.

[35] Water Research Foundation and NYSERDA. *Energy Efficiency Best Practices for North American Drinking Water Utilities*. December 2011. http://www.waterrf.org/ProjectsReports/PublicReportLibrary/4223.pdf.

[36] Focus on Energy. *Water and Wastewater Energy Best Practices Guidebook*. Prepared by Science Applications International Corporation (SAIC). December 2006. http://www.werf.org/AM/Template.cfm?Section=Home&TEMPLATE=/CM/ContentDisplay.cfm&CONTENTID=10245.

determine if pumps are properly sized for the specific application and if they are working at their optimum setting for highest possible efficiency (i.e., their best efficiency point, or BEP). Pump optimization can be achieved by replacing or augmenting large capacity pumps that operate intermittently with smaller capacity pumps that will operate for longer periods and closer to their BEP.[37] Energy efficiency improvements can be optimized by establishing a regular pump maintenance and efficiency evaluation. DOE has a free software program, the Pumping System Assessment Tool (PSAT), to help local governments evaluate pumping systems.[38] For comprehensive guidance on pump system optimization, see DOE's *Improving Pumping System Performance: A Sourcebook for Industry*.[39]

Improved Motor Efficiency. Motors control the speed of a pump and are directly tied to the efficiency of pumping systems. No motor is 100 percent efficient – they all lose power during operation due to friction and other losses. Minimum efficiency standards for different types of electric motors were originally set by the Energy Policy Act of 1992; the 2007 Energy Act raised efficiency standards to National Electrical Manufacturers Association (NEMA) premium efficiency levels. Local governments should consider replacing older motors with NEMA premium-efficiency motors. The percent savings for this approach is typically modest (4 to 8 percent) except where energy auditors find that existing motors have very low efficiency, are undersized, and/or are underloaded. DOE has developed a number of resources that can be used for planning motor system improvements and identifying the most cost-effective options.[40]

Use of Variable Frequency Drives. Variable frequency drives (VFDs) are electronic controllers that adjust the rotational speed of the motor by controlling the frequency of the electric power supplied to the motor. A single VFD can control multiple motors of the same size. VFDs save energy by continuously matching the motor speed to the energy demands. According to the CEC, the use of VFDs can reduce energy use by as much as 50 percent.[41] Installation of VFDs is one of the easiest energy improvements a facility can implement. Another benefit of installing VFDs is "soft start" of the equipment, which reduces the energy required for start up. A soft start reduces stress applied to the system, thus resulting in less wear and tear on motors, reducing maintenance, and increasing control of processes.

Advanced Control of Aeration at Wastewater Treatment Plants. As noted earlier, the aeration process is often the largest energy user at a wastewater treatment plant. The oxygen required for aeration is variable and often peaks in the morning and evening and dips in the afternoon and middle of the night (following the "diurnal" pattern of household water use). In the past, water treatment plant operators took field measurements once or twice per day to determine dissolved

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[37] U.S. EPA. *Evaluation of Energy Conservation Measures for Wastewater Treatment Facilities*. EPA 832-R-10-005. September 2010. http://water.epa.gov/scitech/wastetech/upload/Evaluation-of-Energy-Conservation-Measures-for-Wastewater-Treatment-Facilities.pdf.

[38] http://www.pumpsystemsmatter.org/content_detail.aspx?id=112.

[39] U.S. DOE Office of Energy Efficiency and Renewable Energy (EERE). *Improving Pump System Performance: A Source Book for Industry*. Second Edition. DOE/GO-102006-2079. May 2006. http://www1.eere.energy.gov/manufacturing/tech_deployment/pdfs/pump.pdf.

[40] For a full list of DOE publications, software tools, and training information, see DOE/EERE's Advanced Manufacturing Office, Motors, Pumps and Fans page at http://www1.eere.energy.gov/industry/bestpractices/motors.html.

[41] CEC. "Variable-Frequency Drive: Use in the Water/Wastewater Treatment Process." http://www.energy.ca.gov/process/pubs/vfds.pdf.

oxygen levels in aeration basins and adjusted controls accordingly. They also applied a safety factor (sometimes a very large safety factor) to make sure that oxygen levels did not drop below the minimum levels requires for the process. This control method wastes a considerable amount of energy. Newer plants are now commonly equipped with automated aeration control systems in which dissolved oxygen probes send signals to process controllers which can then change the amount of air delivered to the treatment basin.

Some plants use a simple strategy of one probe and controller while others use multiple probes and air header control valves for individual basins, saving even more energy. Industry experts estimate the automated aeration process can save a wastewater treatment plant between 10 and 30 percent of total energy costs.[42] For more information on advanced aeration control, see EPA's *Evaluation of Energy Conservation Measures for Wastewater Treatment Facilities*.[43]

3.3 Energy Recovery

Water and wastewater systems aren't just energy users – new technology has made many of them ***energy producers***. Two types of such energy recovery – methane capture and reuse at wastewater treatment plants, and micro-hydro energy recovery in water distribution systems – are discussed below.

Wastewater treatment plants have a major ready source of potential on-site renewable energy generation: wastewater sludge. Sludge that is anaerobically digested (i.e., processed in an oxygen-free environment) produces a biogas rich in methane. This biogas can be used to generate both electricity and useful thermal energy from combined heat and power systems (CHPs), which use a single fuel source to produce both electricity and heating or cooling.

CHP systems use less fuel than conventional systems to provide the same amount of useful energy. While conventional electricity generation is typically 30 to 40 percent efficient, CHP systems can be up to 90 percent efficient.[44]

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[42] U.S. EPA. *Evaluation of Energy Conservation Measures for Wastewater Treatment Facilities*. EPA 832-R-10-005. September 2010. http://water.epa.gov/scitech/wastetech/upload/Evaluation-of-Energy-Conservation-Measures-for-Wastewater-Treatment-Facilities.pdf.

[43] U.S. EPA. *Evaluation of Energy Conservation Measures for Wastewater Treatment Facilities*. EPA 832-R-10-005 September 2010. http://water.epa.gov/scitech/wastetech/upload/Evaluation-of-Energy-Conservation-Measures-for-Wastewater-Treatment-Facilities.pdf.

[44] NAHB Research Center. "Combined Heat and Power Systems for Residential Use." Accessed January 8, 2012. http://www.toolbase.org/Technology-Inventory/Electrical-Electronics/combined-heat-power.

Off the Grid – the Point Loma Wastewater Treatment Plant

The Point Loma Wastewater Treatment Plant near San Diego, California, with a capacity of 240 MGD, has achieved energy self-sufficiency and even sells excess energy in the form of electricity to the grid. The plant uses eight anaerobic digesters to break down organic solids in a process that produces methane which is then collected, cleaned, and piped to an on-site gas utilization facility. The gas is then used to provide space heating and cooling. Methane is also used as fuel for two internal-combustion reciprocating engines that run generators with a total capacity of 4.5 megawatts. The generated electricity runs pumps, lights, and computers. DOE reports that in 2000, "the city of San Diego saved more than $3 million in operational energy costs and was able to sell $1.4 million worth of excess power to the electrical grid."

Source: FEMP. "Fact Sheet: Wastewater Treatment Gas to Energy for Federal Facilities." July 2004. http://www1.eere.energy.gov/femp/pdfs/bamf_wastewater.pdf.

At present, only a fraction of U.S. wastewater treatment plants use biogas as an energy source. FEMP writes: "There are more than 16,000 wastewater treatment plants (WWTPs) in the United States ranging in size from multi-billion-dollar complexes to small, single-community plants. About 3500 of these facilities, mainly the larger ones, employ anaerobic digestion. Since methane is a by-product of digestion, many treatment plants use the gas to supply heat needed to complete the digestion process, but only 2 percent of these plants use the digester gas to produce electricity. Most of these plants could produce power from the gas and still heat their digesters with the waste heat from the generation process."[45]

On the drinking water side, some water systems are capturing stored energy in water distribution systems and turning it in to energy. In regions with highly varying topography, water distribution systems often use pressure-reducing valves to release excess pressure as water flows from a high to a low elevation. Alternatively, some systems are installing in-line turbines to capture and generate electricity from this excess pressure. There are a few barriers to this method – for instance, locations that could be equipped with in-line turbines are often remote and not likely to coincide with locations where the water utility can use the generated power. Grid tie-ins may be necessary to reuse the power, which could require expensive electric lines and regulatory red tape. However, depending on the location and other factors, renewable energy grants or subsidies may be available for an in-line turbine program.[46]

3.4 Renewable Energy Technologies

Due to recent advancements and cost reductions in renewable energy technologies, local governments are increasingly considering them in energy assurance planning. Renewable technologies such as solar photovoltaic (PV) and wind turbines can be installed at water and wastewater facilities to reduce demand on the grid, provide backup power during outages, and provide an alternative power source during peak demand periods. Water facilities may have significant open space available for siting solar PV or wind projects. Power Purchase Agreements (PPAs) allow water systems to purchase electricity from a renewable energy system at a known cost over a 10-20 year contract. These third-party renewable energy systems can

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[45] FEMP. "Fact Sheet: Wastewater Treatment Gas to Energy for Federal Facilities." July 2004. http://www1.eere.energy.gov/femp/pdfs/bamf_wastewater.pdf.

[46] Water Research Foundation and NYSERDA. *Energy Efficiency Best Practices for North American Drinking Water Utilities*. December 2011. http://www.waterrf.org/ProjectsReports/PublicReportLibrary/4223.pdf.

provide protection against volatile electricity prices, making energy budgeting easier for local governments. Solar tank mixers at drinking water facilities are a relatively low-cost renewable energy technology that can benefit public health and offer quick payback. Wastewater facilities may also benefit from water-source heat pumps, which use heat from effluent to provide space heating. For more information on renewable energy technologies and how they can be incorporated into energy assurance plans, see PTI's *Renewable Energy and Energy Assurance Planning for Local Governments*.[47]

New England Wastewater Utility Generates Power with Renewables

The Massachusetts Water Resources Authority's (MWRA) wastewater treatment plant has incorporated wind, solar, and hydroelectric resources into its wastewater treatment processes. The facility currently produces ***22 percent*** of its own energy needs each year. See the MWRA's website for more information: http://www.mwra.state.ma.us/03sewer/html/renewableenergydi.htm.

3.5 Financing Water and Energy Efficiency Improvements

Funding is often seen as a barrier to energy efficiency improvements. But this perception is false: many funding options are available to local governments.

- The Drinking Water State Revolving Fund (DWSRF) and the Clean Water State Revolving Fund (CWSRF), both administered by individual States, offer low-interest loans for water and wastewater system improvements, including energy efficiency projects.[48]

- Many energy companies offer financial incentives including rebates or reduced energy rates for customers that purchase energy efficient equipment or make other energy efficiency improvements.

- In many parts of the U.S., energy performance contracting (EPC) has been used to finance energy efficiency improvements. Performance contracting allows water and wastewater systems to install energy conservation measures without paying for them up front; rather, installation costs are repaid out of guaranteed savings.[49] Examples include energy service provider-based financing and tax exempt lease-purchase agreements.[50]

- The Database of State Incentives for Renewables & Efficiency (DSIRE)[51] is a comprehensive source of information on State, local, utility, and federal incentives and policies that promote renewable energy and energy efficiency. DSIRE is an ongoing

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[47] Public Technology Institute (PTI). *Renewable Energy and Energy Assurance Planning for Local Governments*. 2012. http://www.energyassurance.us/index.php/leap/more_2/126/.

[48] A list of regional and State contacts is available online at http://www.epa.gov/ogwdw/dwsrf/nims/dwagency2.pdf for the DWSRF and http://www.epa.gov/owm/cwfinance/cwsrf/contacts.htm for the CWSRF.

[49] Water Research Foundation and NYSERDA. *Energy Efficiency Best Practices for North American Drinking Water Utilities*. December 2011. http://www.waterrf.org/ProjectsReports/PublicReportLibrary/4223.pdf.

[50] For more information on EPC, see http://www.energystar.gov/ia/partners/spp_res/Introduction_to_Performance_Contracting.pdf.

[51] http://www.dsireusa.org/.

project of the North Carolina Solar Center and the Interstate Renewable Energy Council and is funded by the U.S. DOE.

Local governments and water/wastewater utilities can streamline the energy audit, financing, and implementation steps of an energy management program by hiring an energy services company (ESCO). ESCOs offer a type of performance contract in which the cost of implementing efficiency measures is paid for in whole or part by the energy and water savings guaranteed from the project by the energy performance contractor.

ESCOs may be an attractive option for entities without capital to invest in energy and water conservation measures. Through ESCOs, local governments may be able to conduct comprehensive efficiency upgrades across all municipal facilities without upfront investment while only having to go out to bid once. ESCOs usually develop and manage performance contracts, manage a wide range of tasks, and assume some or most of the technical and performance risk associated with the project.[52]

4 Summary and Conclusions

Because energy production may be vulnerable to water shortages now or in the future, it is important that local governments understand the relationship between water and energy in their communities when they are undertaking energy assurance planning. Energy and water efficiency measures at water and wastewater facilities can significantly reduce energy demands as well as conserve water to ensure that it is available for the many roles it plays within a community.

Local governments can begin by understanding how the energy sector uses water in their communities, and how water and wastewater facilities use energy. Depending on water availability issues, many management and policy tools (incentives, resource allocation, green infrastructure) can be used to protect water resources. Local governments should consider requiring local water and wastewater utilities to benchmark their energy use then follow through with energy audits.

Governments can help with financing energy and water efficiency measures. Implementing improvements is not enough – monitoring and tracking improvements and communicating success can help ensure that energy and water efficiency savings are sustainable for future generations.

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[52] The National Association of Energy Service Companies (NAESCO) offers more information and a list of service providers across the nation at http://www.naesco.org/. See also CEC. "Handbook: How to Hire an Energy Services Company." January 2000. http://www.energy.ca.gov/reports/efficiency_handbooks/400-00-001D.PDF.

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