NATIONAL ENERGY TECHNOLOGY LABORATORY

Institutional Impediments to Using Alternative Water Sources in Thermoelectric Power Plants

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Notation

The following is a list of the acronyms and abbreviations (including units of measure) used in this report.

Acronyms and Abbreviations

ARR	aquifer recharge and recovery
CDFG	California Department of Fish and Game
CEC	California Energy Commission
DEP	Department of Environmental Protection
DOE	U.S. Department of Energy
DRBC	Delaware River Basin Commission
EPA	U.S. Environmental Protection Agency
EPOC	emerging pollutant of concern
MCL	maximum contaminant level
MFL	maximum flow or level
NEPA	National Environmental Policy Act
NETL	National Energy Technology Laboratory
NPDES	National Pollutant Discharge Elimination System
PM	particulate matter
R&D	research and development
SWP	State Water Project
SWRCB	State Water Resources Control Board
SWUCA	southern water use caution area
TDS	total dissolved solids
TMDL	total maximum daily load
THM	trihalomethane
WQBEL	water quality–based effluent limit
WWTP	wastewater treatment plant

Units of Measure

mgd	millions of gallons per day
MW	megawatt(s)
ppm	parts per million

Summary

This report was funded by the U.S. Department of Energy's (DOE's) National Energy Technology Laboratory (NETL) Existing Plants Research Program, which has an energy-water research effort that focuses on water use at power plants. This study complements the Existing Plants Research Program's overall research effort by evaluating water issues that could impact power plants.

Obtaining adequate water supplies for cooling and other operations at a reasonable cost is a key factor in siting new and maintaining existing thermoelectric power plant operations. One way to reduce freshwater consumption is to use alternative water sources such as reclaimed (or recycled) water, mine pool water, and other nontraditional sources. The use of these alternative sources can pose institutional challenges that can cause schedule delays, increase costs, or even require plants to abandon their plans to use alternative sources.

This report identifies and describes a variety of institutional challenges experienced by power plant owners and operators across the country, and for many of these challenges it identifies potential mitigating approaches. The information comes from publically available sources and from conversations with power plant owners/operators familiar with using alternative sources.

Institutional challenges identified in this investigation include, but are not limited to, the following:

- Institutional actions and decisions that are beyond the control of the power plant. Such actions can include changes in local administrative policies that can affect the use of reclaimed water, inaccurate growth projections regarding the amount of water that will be available when needed, and agency workloads and other priorities that can cause delays in the permitting and approval processes.

- Developing, cultivating, and maintaining institutional relationships with the purveyor(s) of the alternative water source, typically a municipal wastewater treatment plant (WWTP), and with the local political organizations that can influence decisions regarding the use of the alternative source. Often a plan to use reclaimed water will work only if local politics and power plant goals converge. Even then, lengthy negotiations are often needed for the plans to come to fruition.

- Regulatory requirements for planning and developing associated infrastructure such as pipelines, storage facilities, and back-up supplies that can require numerous approvals, permits, and public participation, all of which can create delays and increased costs.

- Permitting requirements that may be difficult to meet, such as load-based discharge limits for wastewater or air emissions limitations for particulate matter (which will be in the mist of cooling towers that use reclaimed water high in dissolved solids).

- Finding discharge options for cooling tower blowdown of reclaimed water that are acceptable to permitting authorities. Constituents in this wastewater can limit options for discharge. For example, discharge to rivers requires National Pollutant Discharge Elimination System (NPDES) permits whose limits may be difficult to meet, and underground injection can be limited because many potential injection sites have already been claimed for disposal of produced waters from oil and gas wells or waters associated with gas shale extraction.

- Potential liabilities associated with using alternative sources. A power plant can be liable for damages associated with leaks from reclaimed water conveyance systems or storage areas, or with mine water that has been contaminated by unscrupulous drillers that is subsequently discharged by the power plant.

- Community concerns that include, but are not limited to, increased saltwater drift on farmers' fields; the possibility that the reclaimed water will contaminate local drinking water aquifers; determining the "best" use of WWTP effluent; and potential health concerns associated with emissions from the cooling towers that use recycled water.

- Interveners that raise public concerns about the potential for emissions of emerging pollutants of concern to cause health or environmental problems.

Mitigating solutions range from proactive communications with the local communities (which can be implemented by the power plants) to technical solutions, such as developing means to reduce the concentrations of total dissolved solids (TDS) and other contaminants in cooling water to maintain plant efficiency and while meeting discharge limits. These kinds of solutions may be appropriate for DOE research and development (R&D) funding.

1 INTRODUCTION

This report was funded by the U.S. Department of Energy's (DOE's) National Energy Technology Laboratory's (NETL's) Existing Plants Research Program, which has an energy-water research effort that focuses on water use at power plants. This study complements the Existing Plants Program's overall research effort by evaluating water issues that could impact power plants.

Obtaining adequate water supplies for cooling and other operations at a reasonable cost is a key factor in siting new and maintaining existing thermoelectric power plant operations. The use of alternative water sources (also referred to as nontraditional sources and including sources such as reclaimed water, mine pool water, stormwater, produced water from oil and gas drilling, and ash pond water) to substitute for freshwater in power plants has been and continues to be investigated from technology and cost perspectives. However, there are also potential institutional impediments to using alternative water sources that have not been addressed in a comprehensive manner.

NETL (2009) provides an overview of many research and development activities it has supported regarding the use of nontraditional waters for power plant operations, and the reader is referred to this document for findings regarding the use of reclaimed (also referred to as recycled) water, produced waters from oil and gas wells, and mine pool waters in power plant applications. Further details on using secondary treated municipal wastewater, passively treated abandoned mine drainage, and effluent from ash sedimentation ponds for use as makeup water in recirculating cooling water systems is available from Vidic and Dzombak (2009). Veil (2007) provides data on the volumes of reclaimed water used by more than 50 power plants in 16 different states, and EPA (2004) contains information on federal and state regulations associated with the use of reclaimed water. This report builds on the information developed in these and other documents, and the information from these documents will generally not be repeated here.

The most commonly used alternative water source for power plant operations is reclaimed water. Reclaimed water is generally considered to be treated municipal wastewater, but it can be any wastewater, which, as a result of treatment, is suitable for nonpotable uses. Reclaimed water is available to most power plants in quantities sufficient to meet cooling water needs, its constituents are generally known, and it is often subject to a variety of state or regional regulatory requirements to ensure quality. Other sources suffer from various competitive disadvantages. For example, many mine pool waters are acidic and have high concentrations of dissolved solids, and the costs to reduce these concentrations to levels that would satisfy discharge limitations are high. In addition, it is has been difficult to identify mines with "good" water that are close enough to power plants to justify the transportation costs. A recent study of water vulnerabilities for existing coal-fired power plants showed that of 347 vulnerable plants, about 14% were located near coal mines (Elcock 2010). Produced waters from oil and gas wells and enhanced coalbed methane recovery activities also have high concentrations of chlorides and dissolved solids. In addition, the collection and transportation of produced waters to the power plants is generally not cost-effective. Ash pond waters could be treated to necessary levels, but the volumes are typically not sufficient to replace a significant portion of a power plant's cooling water needs (Vidic and Dzombak 2009). Because reclaimed water is currently the dominant alternative water source for power plant cooling and there is more information on institutional barriers associated with its use, the focus of this report is on institutional challenges to using reclaimed water.

The findings presented in this study are based on information from the literature and the World Wide Web, permit applications and assessments, newspaper and magazine articles, publicly available communications between power plant operators and regulatory agencies, agency findings regarding applications to use reclaimed water, public comments and responses, and discussions with power plant owners and operators that have used, or considered using, alternative sources. The results are intended to help power plant developers and operators prepare for and, where possible, overcome institutional barriers in a cost-effective manner, and to help NETL identify and direct further research and development efforts to minimize the use of freshwater in thermoelectric power plants.

The rest of the report contains three chapters. Chapter 2 describes the approach used in this study; Chapter 3 identifies issues to be considered when evaluating the use of reclaimed water and the institutional challenges that stem from these issues; and Chapter 4 provides conclusions and recommendations.

2 APPROACH

Economic challenges (which can be quantified) and technical challenges (which can be framed as engineering, physical, or chemistry problems) to using alternative sources are often reported in the technical literature. Institutional challenges, about which less seems to be written, tend to be more subjective and less definitive. For example, some regulations can provide incentives to using alternative sources, and some can be impediments. Public opinions against the use of freshwater can result in support for alternative sources, but it can also result in support for air cooling and opposition to alternative sources. The needs of a municipal wastewater treatment plant (WWTP) can be in tandem with those of a power plant when the WWTP needs to discharge large volumes of treated water and the plant needs a source for that water, for example. However, competition from other users for that reclaimed water may sometimes limit the amount of water available, causing the power plant to seek other sources or pay more for the reclaimed water. Each situation is unique, and the conditions regarding use of alternative sources depend on a variety of factors that can include water quality, logistics, water rights, public perception, and local regulatory environments, among others. In many cases, the motivation for using an alternative source is not necessarily to reduce freshwater consumption. For example, sometimes alternative sources are simply less expensive than freshwater alternatives, sometimes the salinity of the local freshwater (particularly, for example, in some parts of Florida) is higher than that of the reclaimed water, and sometimes there are simply no economically viable alternatives. Nonetheless, the lessons regarding institutional impediments in these cases still apply in cases where the motivation is to reduce the use of freshwater.

To capture as much information as possible on institutional barriers, given the uniqueness of each situation and the subjectivity associated with various institutional challenges, the approach used to identify potential institutional impediments in this study combines traditional literature reviews and Internet searches with non-peer-reviewed information that is often not contained in scholarly articles. The approach consisted of the following steps:

1. Identify the use of alternative water sources at specific power plants by reviewing existing reports and searching the Internet.
2. Collect and review additional information on the power plants so identified for examples of institutional challenges.
3. Attempt to contact staff at or associated with (e.g., attorneys, contractors) identified power plants to explore institutional concerns.
4. Conduct telephone interviews with the staff identified in step 3 to discuss institutional impediments at the plants with which they were familiar and to solicit contact information for other operators that may use or have considered using alternative water sources.
5. Supplement information obtained in the above steps with that from regulatory agencies and academic institutions to provide further insight.
6. Compile and digest the collected information.
7. Review issues that are often considered, or should be considered, when evaluating the use of alternative water sources, and identify institutional challenges.
8. Prepare report of findings based on the amalgam of information collected.

To protect the confidentiality of the information obtained, the names of the individuals that were contacted and of specific power plants are not included in the report of findings except in cases where the reported information is publicly available.

3 IMPLEMENTATION ISSUES AND INSTITUTIONAL CHALLENGES

An understanding of the kinds of issues to be considered when contemplating the use of alternative water sources can provide a foundation for identifying institutional barriers. The following sections summarize several considerations and highlight areas to be addressed from an institutional perspective. They include water quality, water quantity, logistics, costs, water rights, policies and regulations, and community concerns.

3.1 Quality of Water

The quality of an alternative water source has important institutional implications for both the water that enters the power plant and the wastewater that leaves it.

3.1.1 Quality of Incoming Water

Reclaimed water typically contains higher concentrations of certain constituents, such as total dissolved solids (TDS), than freshwater. In some parts of California, for example, the TDS concentration in reclaimed water is 750 parts per million (ppm), while the TDS concentration in freshwater is 450 ppm. There are no federal standards that dictate the quality of effluent from WWTPs, and the regulations in states with reclaimed water quality requirements vary. As a consequence, the effluent coming from the WWTP to the power plant must be tested to determine what, if any, additional treatment will be required. Additional treatment will depend on the needs of the power plant and the level of treatment (e.g., secondary, tertiary) conducted at the WWTP.

> *Onsite treatment may be required.* Reclaimed water often requires additional treatment, and sometimes a power plant may need to permit, build, operate, and maintain an onsite WWTP. Such actions trigger a number of institutional challenges that include obtaining additional permits beyond those needed for a power plant that used freshwater, assuring the public that water sources will be protected, and training and hiring a large, skilled staff to operate the treatment plant. (WWTP operations are completely different from power plant operations, so new staff will need to be hired, managed, and retained.) To obtain the quality of water needed for operations at the Palo Verde facility near Phoenix, Arizona (the largest nuclear power plant in the country and the only one to use reclaimed water), an onsite treatment plant had to be built. The treatment plant is so large that the facility is sometimes referred to as a treatment plant with a power plant attached to it. The state of Arizona is considering adopting a licensing procedure that would require reclaimed water treatment operators to demonstrate a minimum level of skill and knowledge. Such requirements could help facilitate the hiring of minimally qualified WWTP staff, but they could also instill an additional layer of bureaucracy that could cause delays and increase costs.
>
> *Quality can vary.* Even long-term testing and data cannot ensure that the quality of the reclaimed water will be consistent. For example, if a WWTP treats water from one or more industries that discharge large amounts of a particular constituent on an infrequent basis, the

constituents of these discharges may not show up in the treatment plant's monitoring data. Nonetheless, these infrequent high concentrations (e.g., phosphates) can cause problems at the power plant (e.g., fouling). These problems can eventually be solved by additional treatment, but without sufficient data, it may take a long time to determine that additional treatment is needed. Questions can then surface as to who pays for the additional treatment. The contract between the WWTP and the power plant will generally specify the required water quality parameters of the effluent, but if these parameters are expressed in terms of annual averages, then short-term fluctuations may not be covered. As one power plant manager noted, "You can never have too much water quality data."

Mine pool water quality issues. For mine pool waters, significant variations in water quality can be related to the rock formations that contain the water.

In one case, a power plant that was planning to use mine pool water learned, after testing the incoming water, that the TDS levels were too high and that there would not be enough good-quality mine water to meet the needs of the 700-MW power plant.

The Limerick power plant in eastern Pennsylvania, on the other hand, uses good-quality water from a coal mine about 75 miles upstream. The mine water is transported via the Susquehanna River: it enters the river from the mine's outfall and is removed downstream at the power plant's intake. To protect water users between these two points, the power plant is required to monitor water quality levels at various points along the river; if the limits are exceeded, the regulatory authority can require the water transport to cease.

3.1.2 Quality of Wastewater

High concentrations of constituents in the wastewater leaving the power plant can limit the disposal options for that water or can trigger additional costs or permitting requirements. Options for wastewater disposal and the institutional concerns associated with them include the following:

Return the wastewater to WWTP for treatment and disposal. At least one plant in California returns its wastewater to the same WWTP that provides the (tertiary-treated) reclaimed water to the power plant. The wastewater, which is collected after about four cycles of concentration, is transported via a brine return line back to a holding pond at the WWTP, where it is blended with the effluent from the rest of the plant and is eventually discharged to the ocean. (A cycle of concentration is a measure of the degree to which dissolved solids are concentrated in the circulating water.) Constituents in the power plant's returned wastewater cannot exceed certain specified levels. Although returning the plant's wastewater to the WWTP is a common approach, many WWTPs will not accept the returned wastewater if the TDS levels are too high. This often means that if the power plant wants to return the wastewater, it must operate using fewer cycles of concentration than is efficient. For example, the TDS concentration increases to about 4,000 ppm after about 10 cycles of concentration when using freshwater, but when using reclaimed water, the concentration reaches 4,000 ppm after only four cycles of concentration. Additional investment at the

WWTP would allow the facility to handle the higher concentrations of dissolved solids, but the WWTPs often do not want to pay the costs that would be required to perform the additional treatment. Institutional arrangements with the WWTP are critical to the successful use of reclaimed water.

Install a discharge treatment system at the power plant. Such a system would remove the TDS and salts from the wastewater, which would then be hauled away as a solid. However, this may not be cost-effective. It is much more efficient for a WWTP to install additional treatment than for a power plant to build and operate treatment facilities. However, because it would require additional permitting and increased costs, the WWTP may not be willing to do this. Again, institutional arrangements with the WWTP can influence the feasibility of using reclaimed water.

Evaporation ponds. Power plants using evaporation ponds for disposal in very dry areas can operate at high cycles of concentration and increased efficiency, because the effluent is not discharged. Concentration levels would be limited to prevent corrosion or scaling in the cooling tower, but not to meet discharge limits. However, not all geographies are suitable for building evaporation ponds. Evaporation ponds have significant space, maintenance, and regulatory requirements (e.g., liners, monitoring) and must undergo a permitting process that generally includes public participation, which can lead to delays.

Discharge to a stream. If a power plant is located on a stream this may be an option, but obtaining a permit may be difficult, particularly if the stream has total maximum daily load (TMDL) limits or if the plant's NPDES permit has water quality–based effluent limits (WQBELs) that would not allow water with these high concentrations to be discharged (see Section 3.7.2.2). Similarly, if the reclaimed water contains nutrients that are concentrated and then discharged, they may be subject to load- or concentration-based limits, and the power plant may not want to provide additional treatment to remove them.

Discharge to the ocean. If the WWTP will not take back the wastewater, it might be possible to discharge to the ocean. However, in some states such discharges are not allowed, even if the salinity of the wastewater is less than that of the ocean, because of other constituents in the wastewater.

Underground injection. Underground injection requires a discharge permit, and these can be difficult to obtain in certain parts of the country. In parts of the Northeast, for example, there is insufficient porosity in the subsurface, and discharge permits are increasingly being used for disposal of fracking water used in the drilling of gas in the Marcellus shale.

3.1.3 Liability Concerns

The quality of the alternative water source also has liability implications, as exemplified in the following three situations:

Leaks from the infrastructure. Often, when purveying reclaimed water to a power plant, a municipality will own and operate the infrastructure (e.g., treatment plant, storage areas, pipelines to convey the water), but sometimes, to make a deal between a municipality providing the water and the power plant that is using the water work, the power plant will build and then own and or operate this infrastructure. As an owner/operator, the power plant is liable for any leaks within the system that could result in damage to human health or to ecological resources.

Unknown constituents. WWTPs treat the effluent they release to certain required levels, which are generally specified by the state within which they operate. However, not all constituents have limits. It is possible that during the cooling process and its cycles of concentration, some of these constituents could become concentrated to the point where they could pose concerns when they are released. Even though the power plant did not add these constituents to the wastewater (and possibly was unaware that they were in the wastewater, in any concentration) it could—depending on who is determined to “own” the pollutants—become liable for damages or permit exceedences caused by their discharge.

Illegal operations. When using mine pool water, the power plant can be at the receiving end of actions by unscrupulous operators over which the power plant has no knowledge or control. For example, there are charges pending against certain Marcellus shale operators who allegedly dumped wastewater into local mine pools to avoid disposal costs and permits. These mine pools can be quite large (3–10 square miles), and they are relatively easy to penetrate. If the power plant uses water that has become contaminated because of illegal actions by unknown entities and then discharges it, the power plant may be responsible and liable for permit exceedences or potential damages.

3.1.4 Air Emissions

The constituents of reclaimed water can become constituents of the emissions leaving the cooling tower. While most of the dissolved solids in the reclaimed water will be concentrated in the cooling tower blowdown, some will be released to the air. Examples of specific air emissions issues and their institutional implications are highlighted below.

PM-10 nonattainment. The quantity of dissolved solids, which are released to the air as particulate matter (PM) from the cooling tower, is added to the quantity of PM that is released from the combustion stack, thereby increasing the total PM emitted from the plant. If a power plant is located in a federal nonattainment area for PM-10 (an area that does not meet the national primary or secondary ambient air quality standard for PM that is 10 microns or less), it must demonstrate that it has offset these emissions by reducing an equivalent amount from another source before it can emit any PM-10. This is often accomplished by purchasing “emission reduction credits”—if they are available. If available, they can be costly—up to $600,000 or more per pound in some parts of California (Howard 2010). If they are not available, the permit cannot be issued. This is the situation in Southern California: About10 years ago, the state of California established an Emission Reduction Credit Bank. Credits generated by this program were made available to certain essential public services (including certain power plants) that needed to add capacity. In 2007, a group of environmental organizations filed a legal challenge against the use of these credits by power plants, and in 2008, the courts ruled in favor of the plaintiffs. As a result, the Southern California Air Quality Management District suspended operation of its internal bank of emission reduction credits. The state legislature eventually lifted the suspension, but that suspension is scheduled to sunset in 2012 (Schwartz 2011).

Farmers' fields. High TDS concentrations can also increase salt drift and affect farmers' fields, resulting in concerns from the local population.

Sulfates in mine water. Sulfates, which are often concentrated in mine water, can be released as aerosols in the mist from the cooling towers, thereby increasing total sulfur emissions from the plant. The difficulty in obtaining an air permit for a power plant in West Virginia that had planned to use an alternative water source with high sulfur levels was a factor in the ultimate decision for that plant to change its plans from using the alternative source to using freshwater from the local river (Kasey 2008).

Emerging pollutants of concern. Reclaimed water may also contain pharmaceuticals, personal care products, caffeine, and other substances for which regulators have not established limits for releases to water and air. That these "emerging pollutants of concern" (EPOCs) can be emitted to the air from cooling towers is a concern that many environmental and activist groups are using to oppose the use of reclaimed water in power plants. This issue is discussed further in Section 3.8.

3.2 Quantity of Water

Water is becoming increasingly hard to find, and it is often the most critical constraint faced by power plant developers. Indeed, some plants are on hold until adequate and acceptable water sources can be secured:

- One representative said that of four fossil fuel plants in the company's permitting process, two will use air-cooling technology and two are located in the east where rainfall averages 80 inches per year and water is not a critical issue.
- A power plant site in Florida that is designed to accommodate two additional units is not adding those units because sufficient water supplies for operating them cannot be identified at the present time.
- A power plant in Florida uses seawater for cooling, but it needs groundwater for certain pollution-control devices. The plant was granted a temporary groundwater allotment of roughly 3 million gallons per day (mgd), but the regulatory agency has mandated that alternatives be identified. One option under consideration is desalination, which is a very expensive option, but it is being considered because there are few if any other viable alternatives.

Large quantities. The quantity of water needed for cooling purposes at power plants is significant—on the order of 5 to 7 mgd—with large, multi-unit sites using up to 90 mgd. For some plants, the quantity of reclaimed water simply may not be available. Some municipalities may not produce enough effluent, and in some areas there is insufficient feedstock (untreated water), so that even additional treatment capacity would not provide additional water.

At the Hines Energy Complex, in Polk County, Florida, a variety of alternative water sources are being used, and more are being investigated to help the facility meet its 32-mgd demand. The facility, which consists of four separate power blocks, is built on an old phosphate strip mine within the southern water use caution area (SWUCA). Florida regulations prohibit the use of groundwater in the SWUCA. The complex thus uses a closed-loop cooling pond designed for zero discharge; essentially all the water used for cooling purposes at the plant is withdrawn from and returned to the pond. In addition, the facility has tapped a variety of alternative sources, some of which are subject to one or more institutional challenges. The sources used for the first two power blocks (which use a combined total of 7.9 mgd) are as follows (Hines 2003):

- Reclaimed effluent from the City of Bartow (1.86 mgd). The Bartow treated effluent pipeline is a cooperative funding project between the Peace River Basin Board and the utility. Obtaining water from the city's WWTP is generally viewed favorably by environmental agencies and citizens, but the state of Florida requires high levels of treatment for cooling tower drift.

- Stormwater runoff collected from the plant island (0.67 mgd).

- Direct precipitation to the cooling pond (2.87 mgd—normal average).

- Water cropping (up to 4.87 mgd). Water cropping is the capture and temporary storage of precipitation on a site and the subsequent transfer of that water to the facility to make up for evaporative losses. Water cropping initiatives require approvals from several agencies, and although water cropping is encouraged by the regulatory agencies, approvals are not guaranteed.

In growing areas, large quantities of feedstock may be available, but the infrastructure to treat that water to standards needed by power plants (e.g., tertiary in California), may not be in place, and WWTPs are expensive to build ($10–30 million). A power plant typically requires a 4-year planning horizon, and future WWTP capacity cannot be reserved. The power plant can get a "will serve" letter, which declares the intent of the WWTP to provide water to the power plant, but there is no guarantee that the water will be there when it is ultimately needed.

Shortages of reclaimed water can occur for several reasons. In some areas, effluent availability is estimated on the basis of projected economic growth. If there is a recession, growth, and hence the associated wastewater generated, will be lower than projected. If the feedstock water does not flow to the WWTP, the WWTP cannot produce the effluent that would be used by the power plant.

Shortages can also occur unexpectedly during the life of the contract between the WWTP and the power plant. For example, during the initial negotiations between the municipality and the power plant, the municipality may have more than enough supply for the power plant, but over time, as the municipality finds other users for that water, the supply to the power plant may become less assured. Additional unforeseen demands can also occur. In Florida, for example, the amount of freshwater supplies was reduced as a result of saltwater intrusion into some wells, and therefore the demand for reclaimed water has increased.

Growth upstream of the WWTP can also temporarily reduce supplies. In growing areas, cities build satellite treatment plants, and a new treatment plant built upstream of the WWTP that is delivering water to the power plant can reduce the amount of effluent coming to the power plant.

3.2.1 Competition

Reclaimed water is increasingly being viewed as a resource. Several years ago, because of permitting and other requirements, disposal of wastewater effluent was difficult and expensive. In some parts of the country, this is still the case, but in many areas, users now compete for reclaimed water as they have competed in the past for freshwater. In some areas, there is a concern that there may not be enough for local users, and some communities oppose “outsiders” wanting to use their water in the future.

Competitive uses. Competitive uses for reclaimed water include fish and wildlife habitat protection, wetlands restoration, golf courses, and other private uses. Fish and wildlife agencies can negotiate minimum discharge requirements with municipal WWTPs. For example, the California Department of Fish and Game (CDFG) executed a memorandum of understanding with a local wastewater reclamation authority requiring the authority to supply specified minimum amounts of effluent for fish and wildlife. These diverted amounts mean less reclaimed water is available for power plant use. In addition, the public can exert pressure on agencies to use reclaimed water for restoration efforts. Advocates in Florida argue against the use of reclaimed water for power plants, saying that the water should be used instead for restoring the Everglades. At least one power plant planned to use untreated raw water as a backup supply in case the WWTP could not provide needed reclaimed water. During the public comment process (required as part of the approval process), the argument was made that the raw water that would be used by the power plant as occasional backup should instead be used to produce much-needed drinking water.

Competition impacts on contract renewals. Contracts between the WWTP and the power plant sometimes must be renegotiated, for example if the quantity of water delivered is not sufficient to meet the plant’s needs, or if the original contract is expiring. Often, the terms of the renegotiated contract are not as favorable to the power plant as the original terms. The recent renegotiation of the contract for Palo Verde illustrates how the terms can change; in this case, the contract had to be renegotiated because the life of the plant was being extended beyond the expiration date of the initial contract between the power plant and the WWTP. Competition for the water produced by the WWTP had increased over time, and the power plant needed a secure water supply for the remaining life of the plant. The new contract provides less water at a higher cost, and it required 18 months to negotiate. One of the many challenges of developing the contract was that all five municipalities and all seven owners of the power plant had to agree to the terms of the contract. According to the original agreement, signed in 1973, the five supplying municipalities would provide about up to 34 billion gallons of treated effluent per year to the power plant at a rate of about $30 per acre-foot with no escalation in price. Until that time, the treated effluent was discharged into the river, and even though the river was dry most of the time, the effluent had to meet stringent discharge standards. That Palo Verde would take up to 34 billion gallons of this wastewater per year was very advantageous for the municipalities, who essentially asked, "You are going to pay for this water?" Under the new 40-year contract, the municipalities will provide up to 26 billion gallon per year at a tiered price that begins at $53 per acre-foot and increases over time, to about $300 per acre-foot in 2026. Thereafter, price adjustments will be tied to water- and power-related indices that are part of the Consumer Price Index (Murelio 2010). In addition, the agreement requires the power plant to pay $30 million up front in four annual installments of $7.5 million beginning in 2010. These rates are the final, negotiated rates; the rates proposed by the municipalities at the beginning of the renegotiation were much higher.

3.2.2 Consistent Flow

In addition to needing large quantities of water, power plants need water on a continuous basis. In other words, there must be a constant flow of water from the WWTP to the power plant. This can be an issue with respect to reclaimed water, because the amount of effluent produced at a WWTP decreases at night and increases during the day, so that even if the WWTP provides enough water on an annual or monthly basis, that water may not be adequate for power plant operations that need a constant flow throughout the day. The flow of WWTP effluent can also vary over longer time periods, and it is subject to interruptions (e.g., from upsets, leaks, or breakdowns that can slow or halt the water flow for undetermined time periods). Generally, a WWTP will do its best to provide the amount of water stated in the contract between the WWTP and the power plant—not only because of the contract, but also because of the revenue it generates and the concern over what to do with the water if it is not taken by the power plant. Even with a contract in place, the power plant has little leverage over the WWTP in the event of reduced water flow, because contracts typically contain *force majeure* clauses. If a WWTP or other source cannot deliver the amount and rate needed by the power plant, the power plant must build storage, have a backup supply, or be prepared to shed load or shut down.

3.2.3 Backup

Because of the potential for short- and long-term water deficiencies, power plants often develop backup supplies, and some jurisdictions require backup supplies as a condition of the operating permit. Not only must the alternative water go through the regulatory process and obtain permits, but so must the backup source, and sometimes the development and approval process for the backup source and the associated institutional challenges can be as involved as those required for the alternative source. The following example illustrates this point:

> The Palomar Energy Project is a nominal 550-MW combined cycle power plant in a part of California where precipitation averages about 10–11 inches per year. The project includes two combustion turbine generators, a steam turbine generator, two heat recovery steam generators, and a wet-cooling tower. The following information comes from the final

California Energy Commission (CEC) Staff Assessment for the Palomar project application (CEC 2003). (The CEC has overall permitting authority for power plant development in California, including permitting for reclaimed water use.) The Palomar project proposed using about 3.6 mgd of tertiary-treated reclaimed water supplied by the City of Escondido for process water and wet cooling. With planned upgrades, the WWTP would produce 9 mgd of tertiary-treated reclaimed water. The power plant would have 530,000 gallons of raw (not reclaimed) water—sufficient to cover a four-hour supply interruption at maximum plant load. No other backup source was proposed. If an outage at the WWTP lasted longer than the emergency supply of the onsite raw water tank, the power plant would either shut down or would operate only those generation facilities that do not require cooling water (i.e., the combustion turbine generators). The CEC approved the license for the plant in August 2003. The information in the remainder of this paragraph comes from a subsequent CEC staff analysis of soil and water resources for the power plant (Ellis 2006). During construction and commissioning in 2004 and 2005, the WWTP experienced extended multiple-day outages of recycled water production. The water shortages were described as anomalies, and the city began developing an emergency backup raw-water supply for its recycled water system to help ensure the reliability of recycled water deliveries to current and future customers, including Palomar. As a consequence, Palomar requested that the CEC allow a modification to the power plant's license that would allow for the use of this raw water backup supply for power plant cooling when activated by the city. This modification would change the source of the power plant's water from reclaimed water (which meets the definition of recycled water) to a combination of reclaimed water and raw water (which would run counter to California's policy that recycled water has higher priority for use over raw water at power plants—see Section 3.7). CEC staff found that although limited use of raw water by the power plant would not impact local water supplies, significant environmental impacts to fish and water quality in the San Francisco Bay-Delta and Colorado River ecosystems do result from exports of raw water to meet demands in the San Diego region and other areas. To prevent the use of raw water at the power plant from potentially contributing to these cumulative impacts, CEC recommended offsetting all raw water use with a per-acre-foot mitigation fee, paid to San Diego area water conservation programs. In addition, it recommended that the power plant provide reports detailing the duration of outages and quantities of water. It also limited the use of raw water to no more than 7 consecutive days or 20 days in a calendar year. During the approval process, there were considerable delays resulting from an intervener who contended that dry cooling should be used rather than wet cooling.

Sometimes, a power plant will build (or contract to have built) a backup supply source. These backup supplies must be accepted (by the public), and approved and permitted by the state and local agencies. Required permits can include building permits, wetlands permits, National Pollutant Discharge Elimination System (NPDES) permits, and others. In addition, because backup water will also need to be discharged, the discharge options must be appropriate for both the reclaimed water and the backup water. This may generate additional challenges because the chemical characteristics of the two sources may be quite different. Examples of backup systems and some of the institutional challenges associated with their development are highlighted below.

- *Storage reservoir*. Building a storage reservoir requires a permit and a large amount of land. The regulatory authorities will likely require that the reservoir be lined and that monitoring wells be established around it. A second reservoir may also be required to store the water in the event that there is a failure at the original reservoir.

- *Aquifer recharge*. Aquifer recharge provides a way to store water in an aquifer for later use. Recent tests on such uses near a power plant in Florida have indicated that the formation rock in the aquifer may cause arsenic to leach from the injected water, potentially triggering a violation of water quality standards (see Section 3.7.2.2).

- *Backup freshwater wells*. In some locations, freshwater backup wells can be used, but there are often stringent limits placed on their use. One Florida plant that uses reclaimed water has backup wells, but such wells can only be used as a last resort, and there is an absolute limit on the amount that can be withdrawn. If the limit is exceeded, the plant must shed load.

- *Radial collector wells.* A radial collector well is a shallow well with long lengths of well screens projected horizontally near the base of the aquifer formation; it functions in a manner similar to that of directional drilling techniques for oil and gas. Radial collector wells have been used in the Midwest in large river systems for drinking water. A power plant in Florida has proposed using radial collector wells to provide backup water from the aquifer under Biscayne Bay; interveners have mounted a major challenge to the use of these wells, saying that the wells would extract much-needed freshwater that has higher and better uses than power plant cooling (Darrow and Zemanski 2010).

3.2.3 Too Much Water

The reverse of having too little water is having too much. This can occur if the contract between the WWTP and the power plant requires the power plant to accept a certain amount of reclaimed water per unit time, regardless of conditions at the power plant. If the power plant with such a contract needs to shut down (for example for maintenance), or reduce power production for any reason, it must continue to accept the volumes for which it has contracted. In such cases, the question of what to do with the excess water can be problematic. If the power plant’s storage capacity is not sufficient, then an alternative disposal means must be used, which would likely require an NPDES permit. If the plant has an NPDES permit, that permit may not allow for the discharge of the additional constituents that may be in the WWTP effluent.

3.3 Logistics

Logistics issues for using alternative water sources can be much more involved than those for using freshwater, which are fairly straightforward and generally similar from plant to plant. When using alternative sources, the situation for each plant is different. Water may need to come from multiple sources with different water chemistries and perhaps from different basins; negotiations must occur between the water purveyor(s) and the power plant (which often involves multiple plant owners); backup supplies need to be identified; the logistics for water treatment, conveyance, storage, and discharge must be worked out; relationships among the different political entities must be established and nurtured; and permits, which often involve public input, must be obtained. The logistics required to coordinate the varied pieces can become quite complex. The following examples illustrate the types of logistics that must be addressed when using reclaimed water:

> *Infrastructure development.* At a minimum, in most cases, the infrastructure to deliver the water from the WWTP to the power plant needs to be built, and often the power plant is involved—either in the actual development or, more likely, in paying for it. An NPDES permit may be required for the pipelines—if there is a leak, the discharge must be permitted. In addition, when testing for pipeline integrity and conducting leak tests, the pipe must be emptied of the water, and that water must go somewhere—such as through an NPDES-permitted discharge point. If the power plant owns and or operates the pipelines, it will be responsible for obtaining the NPDES permit. Whether the power plant or the WWTP builds the infrastructure, the power plant will likely need to contend with institutional challenges that include time, cost, and permitting requirements.
>
> *Planning and negotiation.* The Limerick nuclear generating station in Montgomery County, Pennsylvania, uses mine pool water that is released from an NPDES-permitted discharge at a coal mine about 75 miles upstream of the power plant and withdrawn at the plant's intake for cooling. The mine pool water is naturally high in alkalinity, which improves the buffering capacity of the receiving stream, and no additional treatment is required at the power plant beyond that required for any other water used at the plant. In this case, the river serves as the conveyance pipeline, so no additional infrastructure is needed. The system has worked well since 2004, when the Delaware River Basin Commission (DRBC) (the local regulatory authority) granted approval to conduct a demonstration project involving supplementing the flow of the Schuylkill River by pumping water from the Wadesville Mine Pool into the headwaters of the Schuylkill River. It should be noted that when the power plant began searching for alternative water sources, it found that only mine waters were capable of reliably supplying the sizeable quantities of water required (Normandeau Associates and URS Corporation 2011). The project was designed to augment the flow of the Schuylkill River during the low-flow season. Increased use of the Schuylkill River water for consumptive cooling would allow a corresponding reduction in the amount of water diverted for the same purpose from the Delaware River, thereby expanding the source water options available to the power plant and reducing the costs associated with conveying water from the Delaware River. (The Delaware River conveyance system requires a complex system of pipes, pumps, reservoirs, natural creek flows, and underground piping to bring water to the plant.) One of the conditions that must be met for using the mine pool water is a comprehensive monthly sampling protocol that tests several water quality parameters. (Over the 8-year monitoring period, the data for all parameters has remained in an expected range of variably [Normandeau Associates and URS Corporation 2011]).

Although the technical and economic aspects of using the mine water were fairly simple, the institutional aspects included a significant amount of planning and negotiation, and "the pumping plan was a source of great controversy for years, and in fact it took several decades before the water removal began" (Fallik 2003). It should be noted that one of the "deal sweeteners" that facilitated the DRBC's granting of the demonstration project in 2004 was the agreement that the parent company would establish a Schuylkill River Restoration fund, the purpose of which was to provide financial resources to water-quality improvement projects within the Schuylkill Basin. So far, the power plant has contributed nearly $1 million to the fund. In addition, although the plant has been using the mine water for 8 years, final approvals to do so have not been received, and the process continues to operate as a demonstration. The situation has been described as "one foot on the river and one foot on the dock." When the demonstration project was last renewed in 2010, the DRBC indicated that the project was not receiving final approval but was being renewed in part because of a continued heavy workload at the DRBC (the DRBC is also responsible for developing regulations and reviewing applications related to natural gas drilling projects in the Marcellus Shale formation), and a high level of public interest warranting a separate public hearing, which the DRBC needs time to develop and complete.

Convergent goals. Often a plan to use reclaimed water will only work if local politics and power plant goals are aligned and the interests converge. Even then, significant negotiation is required for the pieces of the puzzle to come together. One example of a successful convergence of interests occurred at a California power plant seeking to use reclaimed water from a municipality that was generating more effluent than it had disposal capacity for. To improve the quality of the water, thereby making it attractive for more users and freeing up some disposal capacity, the city obtained a loan from the state to install tertiary treatment. The tertiary-treated water was then used by the power plant to meet its cooling needs.

3.4 Costs

Although the per unit cost of recycled water is often (but not always) significantly less than that of freshwater, the capital costs required to build WWTPs and associated infrastructure such as pipelines and backup systems are high, and either directly or indirectly, the power plant usually pays for these capital costs, often in addition to fees for the water. Power plant owners are financially conservative. Costs for plant expenditures often need to be recovered from the rate payers, and owner/operators must be able to justify those expenditures. This can present an institutional challenge that is not generally a factor for plants using low-cost freshwater. Nonetheless, as water supply and demand parameters change, owners are becoming more amenable to using reclaimed water. For example, power plants in drought-prone areas may have to shed load if freshwater levels drop below intake levels. Plants may also have to shed load or shut down if the freshwater source levels drop below an established regulatory minimum flow or level (MFL). In addition, communities that are becoming more water conscious often oppose the construction of new power plants that use large quantities of freshwater that they believe can be put to better uses.

3.5 Water Rights and Transfers

Water rights as they pertain to reclaimed water are of particular concern in the West. The information in this paragraph comes primarily from Bell and Taylor (2008). The predominant method for allocating water resources in the West is the doctrine of prior appropriation. Prior appropriation generally requires that a water user show (1) intent to apply water to beneficial use; (2) a diversion to convey water from the stream to the place of use; and (3) timely and beneficial use of the water. The system is often referred to as "first in time, first in right." Water rights can be taxed, regulated, or taken by eminent domain, and they can be terminated if they are abandoned or forfeited. Senior water rights holders will have their rights satisfied before junior rights holders. A junior rights holder may consist substantially or entirely of return flow from a senior rights holder. If the senior holder reuses or sells or diverts the water that was previously returned to the stream for downstream use, then a junior holder may be unable to exercise his water rights.

As highlighted below, the laws regarding rights to wastewater effluent vary from state to state:

- In general, but not always, the owner of a WWTP that produces effluent is considered to have first rights to its use. The Arizona Supreme Court's decision in *Arizona Public Service Co. v. Long* embodies this idea:

  > No appropriator can compel any other appropriator to continue the waste of water which benefits the former. If the senior appropriator, through scientific and technical advances, can utilize his water so that none is wasted, no other appropriator can complain. The junior appropriator, using waste water, "takes his chance" on continued flow. To hold otherwise and require the Cities to continue to discharge effluent would deprive the Cities of their ability to dispose of effluent in the most economically and environmentally sound manner.

- In Utah, a public agency owning a water right may reuse the water if the reuse is consistent with the underlying water right, the right is a municipal water right, and the public agency receives approval from the state engineer for the reuse.

- In Washington, facilities may reclaim water only if downstream rights are not impaired, or compensation or mitigation for the impairment is agreed to by the holder of the impaired right.

The Washington position is obviously more restrictive than the position taken by Arizona and Utah, and it provides greater protection to downstream appropriators that have relied on a facility's discharge of effluent into surface waters. As states and municipalities continue to develop and implement water reuse programs, the degree of legal control over effluent that is granted to WWTPs may affect the ability of power plants and other users to use effluent in their systems.

Water transfers. Sometimes a power plant that decides to use an alternative water source is in one watershed or basin, and the alternative water source is in a different watershed or basin. Moving water from one basin to another is often controversial and frequently contentious. Communities that have water generally oppose transfers of that water from their basins to others. This is particularly true for freshwater, but it is also the case for alternative waters. Actual policies and regulations vary from state to state; some states disallow such transfers outright. Some states' regulations allow for transfers, but typically require that the transfer be approved, and because the approval process generally involves public participation, such approvals can be difficult to obtain due to the significant opposition against interbasin transfers.

3.6 Locational Differences

Attitudes, geography, regulations, and other factors that can affect the decision to use reclaimed water vary from region to region. For example, in the states of California and Florida, the use of reclaimed water is encouraged, and people accept it—particularly for industrial use. However, in some parts of the country that do not yet suffer from significant water supply problems, such as New England, using reclaimed water in this part of the country is often viewed as something new and "scary." Physical characteristics of a location, such as weather, geography, distance to alternative water sources, quality of the receiving water, and other physical characteristics will affect decisions regarding the use of nontraditional waters. In addition, regulations that can limit or preclude the use of reclaimed water and vary by region can include zero liquid discharge requirements and total maximum daily loads.

3.7 Policy and Regulatory Environment

There are no federal laws or regulations that address the use of reclaimed water, but state and local policies on reclaimed water can have major impacts on the decision to use reclaimed water. A key impediment to using alternative water sources, particularly reclaimed water used by power plants, is the lack of state policy or law that incentivizes its use. Incentives are needed to overcome challenges; reclaimed water is often more costly, needs to be transported, often requires further treatment, can entail changes to power plant operations, and so on. Without sufficient incentives, unless the power plant is in an area with limited freshwater supplies, it will be unlikely to invest the resources needed to pursue the use of reclaimed water. Incentives can range from advocating the use of recycled water to requiring its consideration as part of the permitting process to requiring its use unless it can be demonstrated that doing so is technically or economically infeasible.

The states with the two most incentivizing policies/statutes are California and Florida. On the basis of data collected in 2007, of 57 plants identified as using alternative water sources, more than half were located in these two states (30% in Florida and 23% in California) (Veil 2007). Between 2004 and 2009, the CEC had approved or was in the process of reviewing an additional 15 power plants that were planning to use reclaimed water (GAO 2009).

Summarized below are salient points of California and Florida policies/laws that provide incentives for using alternative water at power plants.

California. In 1975, the California State Water Resources Control Board (SWRCB)—the state's designated water pollution control agency—established a policy that the use of fresh inland waters for power plant cooling would only be approved when the use of other water supply sources or other methods of cooling would be environmentally undesirable or economically unsound. The Water Quality Control Policy on the Use and Disposal of Inland Waters Used for Power Plant Cooling (SWRCB Resolution 75-58) requires that power plant cooling water should, in order of priority, come from wastewater being discharged to the ocean, ocean water, brackish water from natural sources or irrigation return flow, inland waste waters of low total dissolved solids, and other inland waters. The policy defines inland waters as all waters within the territorial limits of California exclusive of the waters of the Pacific Ocean outside of enclosed bays, estuaries, and coastal lagoons, and fresh inland waters as those inland waters that are suitable for use as a source of domestic, municipal, or agricultural water supply and that provide habitat for fish and wildlife.

Specific requirements regarding the quality of reclaimed water required for cooling purposes are contained in Title 22 of the California Code of Regulations, and water that meets the requirements for cooling water use is often referred to as “Title 22 water.” The policy also addresses cooling water discharge prohibitions. For example, discharge of blowdown to land disposal sites is prohibited except to salt sinks or to lined facilities, and discharges from once-through inland facilities is prohibited unless the existing water quality is maintained.

Florida. While California’s water reclamation requirements evolved from water-supply shortages, Florida’s requirements initially stemmed from the need to limit surface water discharge. Thus, Florida promoted reuse as a solution to water-quality issues arising from the need to limit polluted discharges. The Florida legislature has since established the encouragement and promotion of reuse of reclaimed water and water conservation as formal state objectives. Florida law establishes a mandatory reuse program and requires its water management programs to direct the reuse of reclaimed water as an integral part of water conservation and wastewater management programs. Reuse is compulsory in Water Resource Caution Areas (areas where water supply problems are critical). Florida law also provides regulations for the quality of water that can be used for various purposes, including cooling.

Examples of other states’ policies regarding the use of alternative sources include the following:

- Texas has a friendly approval process for using alternative sources, but there are no requirements for using alternative sources.

- Georgia has a Water Conservation Implementation Plan, which is a voluntary request to encourage industry to use water-conserving technologies including alternative sources.

- Pennsylvania has a policy that encourages the use of mine water as a source for cooling purposes in the generation of electricity.

3.7.1 Interpretation and Enforcement of Policies and Laws

Regardless of a state’s policies and regulations regarding reclaimed water, the degree to which those policies are followed and laws are enforced can vary over time and by location. These variations can affect the ease or difficulty encountered in using alternative water sources.

Similarly, while a policy may encourage the use of reclaimed water, actual permitting aspects can pose challenges and barriers to its actual use. In addition, the level of enforcement can vary. Some of these interpretation and enforcement issues are described below.

Political agendas can change. Administrative policies, political agendas, and agency staff can change over time, so something that was favored by one administration could lose favor in the next. A project that was encouraged to use mine water and was moving toward that goal in one administration had to change its water source to river water, in part because the climate of the following administration was not as favorable to the plant as the previous one. Uncertainties that result from such shifts can make investors nervous, and as a result, can make obtaining necessary funding more difficult.

That administrative policies change can also work in favor of a project's facilitated use of reclaimed water. In Fairfax County, Virginia, for example, a WWTP had suffered capacity problems for a long time, and had developed a plan to reduce those problems by selling some of the effluent to a local power plant. The power plant was not averse to changing from freshwater to reclaimed water, because under its current contract, it simply passed along its water costs to the county. When the contract came up for renewal however, the county indicated that the power plant would have to pay at least a portion of the water costs and that the reclaimed water costs would be less than the freshwater costs. The public was generally in favor of the change to use reclaimed water, so the remaining issue was obtaining the funding to build the necessary infrastructure, which was primarily a pipeline to convey the effluent to the power plant. Until funding became available, however, the change to reclaimed water could not occur. A change in the Administration brought along the American Recovery and Reinvestment Act, which provided stimulus funding for "shovel ready" projects. The county immediately applied, and eventually the project was funded. There was no significant public opposition, and the major difficulty has been meeting the strict construction schedule.

Subjectivity. Florida policy is to use the lowest quality water for the use that is economically and technically feasible. The interpretation of "economically and technically feasible" is subjective and depends on the water management district in which the plant is located. (Florida is divided into water management districts, which grant groundwater and freshwater permits for beneficial use from streams and rivers.) The degree to which a water management district enforces "economically and technically feasible" can depend on local water conditions. Districts with less water are generally stricter in their interpretations than districts with more water. For example, districts in the central part of the state project that to maintain aquifer levels, they will be unable to allocate additional water after 2013. These districts could be more likely to find that certain technologies (e.g., desalination) are economically feasible, whereas districts with more abundant supplies may agree that such technologies are not economically feasible.
Local agency restrictions. Proposals to use reclaimed water can be stalled or even denied by local agencies. Local health departments have expressed concerns about possible comingling of reclaimed water with freshwater. A fire department expressed concern that any firefighters on site would be fighting fires with reclaimed water. These types of concerns can usually be addressed by good communication and community outreach.

However, some restrictions can be more challenging. The following example describes a local agency denial of a reclaimed water application and the repercussions of that denial:

The project developers of an 830-MW natural gas-fired combined-cycle facility in San Bernardino County, California, were well aware of the scarcity of water in that part of the state and cognizant of the state's policy regarding the use of reclaimed water over raw water. As such, they determined that the use of reclaimed water from a WWTP located about 2.5 miles from the project site was the best source of cooling water for the plant. The local governments were not opposed to the power plant's use of reclaimed water, because of the revenues it would generate. However, the CDFG expressed concern that the diversion of WWTP effluent would reduce surface flows of the Mojave River, which supports fish populations and riparian vegetation (even though surface flows of the Mohave River within the project area typically occur only during heavy rainstorms) (CEC 1999). Thus, to ensure that there would be no negative ecological impacts, the CEC agreed to prohibit the use of WWTP effluent for power plant operations, and hence the power plant developers had to develop an alternative plan. Because the project was located in the Mohave River Basin, where water supplies are fully allocated and tightly regulated, the power plant developers were required to import water to meet all of the project's water demands. This meant obtaining numerous permits, addressing comments by interveners, and cooperating and negotiating with the local water supplier, the city, and the Mojave Water Agency—a local water contractor with access to water from the State Water Project (SWP). (The SWP conveys raw water from northern to southern California, where it is distributed to reservoirs and urban and agricultural water suppliers; SWP water is not potable.)

The approach to which all parties eventually agreed (and which required 3 years to arrange) was the following: The primary water supply would be surface water from the SWP purchased from the Mohave Water Agency. (The Mohave Water Agency had procured more water from the SWP than it could use and was therefore willing to transfer its rights to a portion of that water to the power plant in exchange for needed revenues.) Because SWP deliveries are routinely suspended for a few days each year for canal maintenance, and could be suspended for longer periods during severe drought, the primary supply is interruptible. Accordingly, the CEC required that a backup supply be obtained. This was accomplished by the power plant's establishing a groundwater bank wherein surface water from the SWP is imported and injected into the local aquifer to be used on an as-needed basis. The amount of water to be injected was determined to be equal to a 3-year supply plus a 1,000-acre-foot environmental reserve. In addition, the injected water could not exceed specified limits for TDS and trihalomethanes (THM), meaning that the power plant had to construct a pre-injection ultrafiltration water treatment process to remove THM precursors from the SWP water prior to injection. The participants agreed that the bank could be established in 5 years.

The power plant was successfully built in accordance with this plan. However, during operations, it was determined that the quality of the SWP water as found during the original testing was higher than what was delivered during operations. Thus, the injection operations for the groundwater bank were significantly limited because the THM and

TDS concentrations in the injection water exceeded water quality limits for extended periods of time. As a result, the power plant operators have had to seek a modification to the banking schedule and to add an ultraviolet system to disinfect the raw SWP water. Both the power plant and the CEC agreed (after the fact) that the period of record used to calculate the mean TDS concentrations was too short and that the initial analysis failed to recognize the extreme annual variability of TDS concentrations in the raw water supply (Bond 2006). In addition to the water quality being lower than originally projected, the water quantity from the SWP was also lower than projected, meaning that fewer than 10 years after start of operations, the power plant is now seeking to modify the certification to allow the plant to use recycled water—in much the same way as it had originally proposed. The CEC analysis agreed with the proposed modification, in part because, since power plant certification in 2000, the local area has grown, generating additional wastewater that can now satisfy the earlier CDFG concerns regarding insufficient water going to the Mohave River. However, the CEC staff assessment also stated, "The project owner currently has no commitment for supply and delivery of recycled waste water, a use permit, or the water quality characterization necessary to design the project changes, and as a result, the staff has insufficient information to analyze project impacts and identify which laws, ordinances, regulations, and standards will be required for project compliance" (Weaver 2009). The resolution of this issue will likely involve additional studies, permitting requirements, and discussions with interveners, all of which can be expected to require additional time and other resources. The CEC Web site (http://www.energy.ca.gov/sitingcases/highdesert/index.html) contains numerous memos, analyses, and other reports that illustrate the institutional challenges associated with using (or not using) reclaimed water.

3.7.2 Regulatory Requirements

Regulatory requirements that can affect the use of alternative water sources include National Environmental Policy Act (NEPA) reviews, water and air permits, and regulations that facilitate the use of alternative sources.

3.7.2.1 NEPA

NEPA requires that all major federal actions significantly affecting the quality of the environment undergo an assessment of environmental impacts. In addition, many states have environmental regulations similar to NEPA. For example, California's Environmental Quality Act provides that those undertaking government projects and private projects that involve government participation, financing, or approval must first file an environmental impact report. The environmental impact report must identify potential, significant environmental effects of the proposed project, as well as alternatives to the proposed project and ways to mitigate or avoid the potential environmental effects. As illustrated by the following example, these requirements can impede the use of recycled water for power plant cooling. A California power plant planning to use reclaimed water from the local WWTP had developed the plan and negotiated with the WWTP and the city—both of which favored the use of reclaimed water at the plant. A local engineer who believed that dry cooling was preferable to wet cooling then filed a lawsuit under the California Environmental Quality Act requiring that the environmental impact report consider the use of dry cooling as one of the alternatives to using reclaimed water. The additional technical and economic analyses required to show that reclaimed water was preferable from an environmental perspective, including calculations and analyses about costs, energy penalties for dry cooling, noise, visual impacts, and tradeoffs, caused significant delays in project implementation as well as additional costs.

3.7.2.2 Permitting

The use of alternative water may require permits or permit provisions that may not be needed by plants using freshwater. Examples of the types of permits that may need to be obtained or modified include the following:

NPDES permits

A power plant using reclaimed water may need an NPDES permit if it plans to discharge wastewater from the plant to a river or stream, build a reservoir to hold water, or maintain a conveyance pipeline. In addition, the use of alternative water sources could cause violations of some existing permits. The following concerns regarding NPDES permits for discharging reclaimed water can be considered institutional challenges:

- *Numeric nutrient criteria.* On November 14, 2010, the U.S. Environmental Protection Agency (EPA) issued a rule that sets numeric limits, or criteria, on the amount of nutrient pollution allowed in lakes, rivers, streams, and springs in the state of Florida. This rule could limit the use of reclaimed water in the state. As explained by Choi (2010), this is because sometimes (e.g., during plant shutdown or during wet weather events), a power plant using reclaimed water would need to discharge excess reclaimed water. Because the newly issued criteria are concentration-based, the power plant would be in jeopardy of violating the criteria, even if the discharge events are limited. To avoid such violations, the power plant would need to construct expensive treatment or a zero liquid discharge system, which would force the power plant to seriously reconsider the use of reclaimed water.

- *Maximum contaminant levels (MCLs).* MCLs are contaminant-specific, concentration-based standards set by the EPA to protect drinking water quality. It is possible that MCLs for arsenic, and perhaps other contaminants, can be exceeded during a process known as aquifer recharge and recovery (ARR) that is used to generate alternative water sources. With ARR, water is injected or recharged into an aquifer for later recovery and use. An ARR demonstration project is underway at the Hines Energy Complex in Florida, in which a combination of stormwater, treated effluent, and blowdown is treated onsite to potable standards via wetland and sand filtration, after which the water is injected into the Floridan aquifer via an onsite recharge well field. The owners/operators of the Hines complex are partnering with the Southwest Florida Water Management District and the Florida Institute of Phosphate Research to assess the effectiveness and viability of the concept. A variation of this approach addresses water balancing challenges that occur in

Florida as the wet season produces more water than can be used, while during droughts, water supplies can be insufficient. The technique diverts water from a river during high flow periods, pumps it into existing created wetlands for treatment to remove solids and other pollutants, and allows it to flow into partially filled clay settling areas at a former phosphate mine site for storage. The water is then treated to potable standards and recharged to the Floridan aquifer. The approach provides additional storage of river water that would otherwise be discharged to the ocean or for surface water collected during the wet seasons that exceeds the capacity of water cropping reservoirs.

Other variations of the approach all involve injecting excess water into an aquifer for later use. Florida law allows for the removal for later use of 85% of the amount that is so injected, thereby providing a net increase to the water in the aquifer and an incentive to use the practice. According to Arthur et al. (2000), 30 ARR facilities have been constructed in Florida and many more have been proposed. Recent research into the geochemical interactions between injected surface water, native ground water, and the aquifer rocks has indicated that at two sites in southwest Florida, the concentrations of arsenic in the recovered water were up to five times greater than the concentration in the injected water and in the native groundwater. The MCL for arsenic is 10 ppb, and maximum observed concentrations of arsenic at the sites approached 50 ppb (Arthur et al. 2000). The hypothesized reason for this is that the introduction of surface water into the typically reduced Floridan aquifer system leads to oxidation and dissolution of finely disseminated arsenic-bearing pyrite and/or organic material. Maximum observed concentrations of arsenic in limestone samples taken near two of these ARR wells was 4 ppm. A representative of the Florida Department of Environmental Protection (DEP) indicated that if monitoring wells at the Hines ARR testing site indicated an exceedence of the arsenic MCL, all injection activity would have to cease (Drango 2011). This regulatory barrier could be reduced if the EPA would consider a "zone of discharge" concept under its Underground Injection Control Program, whereby the MCL would be met at some distance from the injection zone, rather than at the point of injection. This approach (i.e., measuring compliance at the permittees' property line or 100 feet down gradient from the edge of the point of discharge) is currently used in Florida's industrial wastewater discharge-to-groundwater regulations (Drango 2011).

- *TMDLs.* A TMDL is the maximum amount of a pollutant that a specific water body can receive and still safely meet water quality standards. As required by the Clean Water Act, states and other jurisdictions develop TMDLs for impaired waters (waters that are too polluted or otherwise degraded to meet the water quality standards) in their jurisdictions. There is a concern that because TMDLs are load based and not concentration based, the discharge of any amount of additional pollutant, regardless of its concentration or infrequency, may violate a permit or mean that a new permit would be required.

- *WQBELs.* Federal regulations require effluent limitations for all pollutants that are or may be discharged at levels that have a reasonable potential to exceed a water quality criterion. When considering the reasonable potential to exceed such criteria, regulatory authorities consider several factors including variability of the pollutant in the effluent and the sensitivity of species to toxicity testing. The use of reclaimed water in recirculating cycle cooling systems, the blowdown from which is often discharged to a river or stream, will likely result in the addition of new WQBELs into NPDES permits. It may be difficult for power plants that use reclaimed water to meet these new limits for constituents such as copper, cadmium, chromium, and mercury, which become concentrated in the blowdown.

- *Mine pool water—treatment triggers a permit requirement.* If a power plant owner/operator removes the water from an abandoned mine pool and treats it to remove iron and metals and raise the pH to acceptable levels for use in the power plant, there is a chance that additional treatment requirements will be triggered. Once the water is treated, it must have an NPDES permit before it can be released to a river or stream. It is possible that during the permitting process, the regulators will require, as a condition of the permit, that the power plant also treat the water to remove other contaminants such as sulfate, sodium, and chloride (which are often present in mine water). This would be an additional burden on the power plant and could serve as a barrier to using mine pool water.

Air Permits

As noted previously, air permitting requirements can pose challenges to the use of alternative water sources (see Section 3.1.4 for air permitting issues regarding sulfates in mine pool water and PM-10 in reclaimed water).

Sometimes permitting issues can pose a challenge for the municipality that operates the WWTP, for example in situations where the power plant returns its wastewater to the WWTP. The chemistry of the water returned from the power plant is different than that of the effluent that was sent to the power plant originally, because the constituents (e.g., salts, phosphates) in the wastewater are much more concentrated than in the original effluent water. For the municipality to discharge this water it may need to provide additional treatment or undergo a permit modification.

3.2.7.3 Regulations that Can Facilitate the Use of Alternative Sources

One regulation that facilitates the use of alternative water sources is the ability to add water at one location along a river and withdraw it downstream. This type of regulation may be unique to the DRBC—a U.S. government agency created in 1961 by an interstate compact, among the states of Pennsylvania, Delaware, New Jersey, and New York, intended to bring the Delaware River under collective control, and to ensure fair usage by the states. Among other things, the DRBC is responsible for all allocations of water within the basin. The DRBC regulation that allows for water placed in a river upstream by a user to be taken out downstream by the same user enabled the Limerick power plant in Pennsylvania to use mine pool water for cooling (see Section 3.3 for details on Limerick's use of this regulation).

3.8 Community Concerns, Public Perceptions and Interveners

Public opposition can take many forms, all of which can present challenges to the use of alternative water sources. Sometimes, these challenges can be overcome through proactive outreach, contributions to local environmental causes, or lengthy legal battles. But sometimes interveners or public opposition will require that a plant change or abandon its reclaimed water use plans. Opposition sources can range from "well-funded NIMBY groups" that raise concerns in the local community via the press and other media to dedicated individuals willing to invest time and energy toward pursuit of a particular objective. Often, interveners are well-versed in their subject matter, and the interactions among the project sponsor, regulator, and intervener can be protracted. For example, the implementation schedule for a new power plant in California that was planning to use reclaimed water was delayed for several months, during which time technical and legal experts prepared voluminous documentation in response to the well-researched and presented claims of an intervener that opposed wet cooling, regardless of the water source, and instead argued that the plant should use an air-cooled system.

Interveners are often opposed to the construction of a power plant itself, and will "latch on" to a specific water reuse issue as leverage to oppose a plant. Sometimes, unions will use an issue such as reclaimed water use to oppose the construction of a new plant until the owner/operator concedes to use union labor.

Public concerns regarding a plant's use of an alternative water sources can vary depending on location. An important factor appears to be the public's familiarity with the concept. Thus, in areas where reclaimed water has been used for years and is "a way of life," acceptance is often easier than in areas where water supplies are not generally a major concern and the practice is viewed with skepticism.

Interveners and the public have levied a variety of specific charges against the use of reclaimed water at power plants. A particularly thorny challenge pertains to EPOCs. EPOCs, also referred to as microconstituents, are chemicals and other substances whose presence in water or air releases is currently not regulated, but which may nonetheless be harmful to human health or the environment. In recent years, many of these substances, such as pharmaceuticals, personal care products, and steroids, have been detected in municipal wastewaters. As such, they have raised concerns, because many of them are designed to cause physiological effects and could affect nontarget organisms (Gardinali et al. 2008). The relatively recent concern regarding this class of contaminants stems in large part from significant advances in analytical technology that allow detection of compounds at concentrations in water that were not previously possible. Further, even if low levels of these contaminants are not a risk to public health, the knowledge that these contaminants exist at any level raises concerns for many in the public. While there are regulations that set acceptable levels of certain pollutants that can remain in wastewater after secondary (and tertiary) treatment, there are no comparable regulations for EPOCs. Because no regulations limit the releases of these constituents, they are not monitored and can easily pass through secondary and subsequent treatments. This issue has gained traction at several power plants attempting to use reclaimed water; the following two examples illustrate the concern.

- *Nuclear plant in Florida.* Interveners at the Turkey Point nuclear facility in Florida have repeatedly raised this issue: "FPL will cycle large amounts of partially treated sewage through Turkey Point's cooling towers. The public can't know what diseases or endocrine disruptors or cancer agents will come out of these towers and drift into our communities" (Darrow and Zemanski 2010). However, the reclaimed water undergoes ultraviolet treatment once it reaches the facility, and although consultants have concluded that EPOCs are not an issue, the burden of proof is on the power plant to show that there are no issues; proving a negative is difficult when there are no regulations to use as benchmarks. Public concern over this issue is contributing to permitting challenges for the plant.

- *Biomass plant in Massachusetts.* EPOCs led to the abandonment of plans to use reclaimed water at a to-be-developed 50-MW biomass plant in Massachusetts. In this case, the motivation to use reclaimed water was to "do the right thing." (In Massachusetts, where water resources are relatively abundant, neither discharge issues nor water supply are viewed with the same urgency as they are in other parts of the country.) The plan was to build a pipeline from the WWTP (which was about 5 miles from the power plant site), provide additional onsite treatment, and use the treated reclaimed water for cooling. The plant owners were prepared to pay not only for the pipeline construction, but also $520,000 per year for the water, which would otherwise be discharged, without further treatment, to the river. However, public perception regarding EPOCs eventually caused the power plant developers to change their plans and use dry cooling instead. The state DEP had recently issued reclaimed water rules that set limits for several common contaminants such as nitrogen and some metals, but not for pharmaceuticals, caffeine, and other EPOCs. The zoning board and other local agencies approved the project and its use of reclaimed water. But a local opposition group raised concerns about respiratory issues resulting from emissions of EPOCs from the cooling tower (and the stack). Because the WWTP does not test for pollutants for which there are no regulatory limits, the group argued that no one could know what would be in the air that came from the cooling towers. The DEP then expressed concern that because there were no DEP or EPA standards that could be used to support its decision, it could not support the project against an appeal. As a consequence, the project developers abandoned the plan for using reclaimed water.

In both of these cases, it is possible, and perhaps likely, that the interveners were using the reclaimed water/EPOCs issue as a means for gaining public support against the power plants, per se. In one case, a large nuclear facility was being planned near the Everglades and Biscayne Bay, and in the other a biomass plant was being planned in an area where the environmental groups advocate wind and solar projects.

Another issue sometimes raised by interveners is the risk of Legionnaires' disease resulting from cooling towers at plants that use reclaimed water. Legionnaires' disease is a type of pneumonia caused by a freshwater bacterium known as legionella. There does not appear to be any evidence that Legionnaires' disease is or would be more likely to occur in cooling towers that use reclaimed water than in those that use freshwater. In any case, many governmental agencies, cooling tower manufacturers, and industrial trade organizations have developed design and maintenance guidelines for preventing or controlling the growth of Legionella in cooling towers.

Examples of other charges posed by interveners and the public regarding the use of reclaimed water include the following:

- Emissions of ammonia (as a product of the chlorine that is used for disinfection) will cause odors in the area of the plant.
- Other health impacts will result from air emissions in the area surrounding the plant.
- A breakdown or upset at the WWTP will reduce the flow of needed water to the power plant.
- Workers at the power plant will be drinking reclaimed water.
- The storage pond may leak and contaminate local aquifers.
- The community's reclaimed water supply should not be used by a power plant, because such use will result in precious water either being evaporated or discharged as wastewater.
- Reclaimed water should be used for wetlands restoration and other environmental purposes and not wasted by power plants.
- Dry cooling should be used rather than wet cooling, because it uses less water.
- The rates the power plant pays should not be lower than the rates paid by other local users.

All of these issues represent challenges that must be addressed before reclaimed water can be used.

4 CONCLUSIONS AND RECOMMENDATIONS

As freshwater supplies in many parts of the country become less secure and as wastewater discharge limits at treatment plants become more strict, the interest in, if not the necessity for, using alternative water sources at thermoelectric power plants increases. However, a variety of institutional challenges can limit the use of such water sources. Some of the institutional challenges, such as permit limits on releases of TDS and other constituents can be resolved by using technical or other engineering solutions that generally translate into increased costs and are ultimately viewed as a part of doing business; these institutional impediments cause delays and increased costs, but they can often eventually be resolved.

Sometimes, however, an institutional impediment is so intractable that a power plant desirous of using an alternative water source, may, despite hard work and investment, be forced to abandon its plans to use a particular alternative source. One institutional challenge that has thwarted the use of reclaimed water at power plants is public opposition to potential environmental releases of EPOCs. The issue is particularly vexing because without regulations regarding their release, it is not possible to prove that the concern is not valid.

The significance of a given impediment will vary depending on the location and other characteristics of the specific power plant. Each situation is unique. The same owner operator with the same plant design in one part of the country may find it much easier to use reclaimed water than in another part of the country. This is in part because, lacking federal rules pertaining to the use of reclaimed water, states and local jurisdictions develop their own rules that reflect their own situations (e.g., water supply) and goals (e.g., minimize discharges). In addition, public attitudes regarding the use of reclaimed water vary—in states where reclaimed water is routinely used, the public may be more accepting than in areas where freshwater supplies are more abundant. Factors such as the necessity for the WWTP to find ways to minimize its discharges will also affect the ability of a power plant to use reclaimed water. Municipalities with WWTPs that cannot discharge all of the effluent they produce are growing and are expecting more wastewater to treat, and those in areas where discharge permits are difficult to obtain will likely welcome the opportunity to sell their effluent to a power plant. However, this situation is not universal. Some WWTPs do not produce the effluent in the quantities needed by power plants, and they may be in communities whose public believes the effluent should be used for higher and better uses. If these WWTPs are in states that do not have policies that promote the use of reclaimed water, it will be more difficult for a power plant to overcome these barriers. A power plant considering using reclaimed water should be prepared to confront one or more institutional impediments. At the same time, there is often a convergence of needs and objectives that makes the use of reclaimed water easier than securing a freshwater supply source.

During this investigation, numerous specific impediments have been identified, and in many cases, options for addressing them have been also been identified. All of the impediments have occurred at one or more power plants, and all of the recommendations have been suggested by power plant owners/operators. Because each case is unique, not all recommendations can be expected to successfully address all situations. Nonetheless, they may provide options to consider when confronted with institutional impediments. Table 4-1 summarizes many of these impediments and possible recommendations for mitigating them.

TABLE 4-1 Institutional Challenges to and Possible Mitigating Approaches for Using Reclaimed Water

Potential Institutional Challenge	Possible Recommendations for Addressing Challenge
Delays in obtaining final approval for an innovative alternative water use	Operate as "demonstration" project and renew on annual basis
Difficulty in gaining local approvals	Draw support by making financial or other contributions to local environment or other causes
Over time, increased demands for recycled water from the municipality (or other purveyor) or reduced feedstock can put water supply of power plant at risk, resulting in higher prices for the power plant or reduced supplies	Try to anticipate potential competitive uses and prices and include as many contingencies as possible in contract: • Make agreement subject to life of power plant, rather than fixed number of years • Ensure for adequate water supplies (e.g., if another WWTP is built upstream that diminishes the flow temporarily) • Contract for monthly amounts, not annual, to minimize impacts of variable flows • Be willing to compromise for the long term • Support R&D for freshwater-reducing technologies such as desalination
Interveners can try to stop the alternative use project	Conduct outreach, including technical presentations
Permitting requirements that limit use of freshwater backup	Consider seeking multiple backup sources
Liability for contamination due to leaks from pipelines, reservoirs, etc., owned/operated by the utility	Consider transferring ownership and operating and maintenance responsibilities to the municipality
Coordination with multiple agencies and municipalities, some of which may not favor use of reclaimed water for power plants	• Consider providing incentives to municipalities • Prepare for long, possibly contentious negotiations
Permitting agency may deny use of reclaimed water for power plant cooling (on the basis that there are better uses for the water)	Develop creative alternatives that include combinations of innovative approaches such as transferring water rights, contributing to aquifer recharge, aquifer banking, etc.
Regulations are subject to interpretation and can be based on the political thinking of the time	Consider timing of request with respect to policies and goals of current administration
Unforeseen, nontechnical events can occur	Be prepared for delays and schedule interruptions
Quality of water from alternative sources may vary over time; sometimes it may not meet the parameters needed by the power plant	• Support development of improved, low-cost monitoring technologies for testing effluent • Be prepared to renegotiate contract or install additional treatment
Inability to obtain air quality permit because plant is located in a nonattainment area	Check status of nonattainment and availability of credits
Community skepticism regarding the safety and quality of their water sources (e.g., concerned about potential leaks of effluent from pipelines, storage areas)	• Foster good, clear communications from the very start of the process • Establish and use a Citizens' Advisory Board • Be proactive with influential people in the

Potential Institutional Challenge	Possible Recommendations for Addressing Challenge
Public concerns about potential negative impacts that could affect their health	community and listen to their concerns
Need to hire, train, manage, and maintain workforce to manage onsite water treatment	Consider having the municipal WWTP provide additional treatment when necessary
TDS concentrations in blowdown exceed many discharge limits unless cycles of concentration are reduced	Develop wet-cooling technologies that avoid concentration of TDS and other constituents in blowdown or technologies to lower concentrations prior to release
Increased pressure by interveners and regulatory agencies to used air cooling rather than reclaimed water in wet-cooling technologies	• Develop more efficient air-cooling technologies • Conduct a lifecycle analysis that compares environmental impacts and resources used for air-cooling and wet-cooling technologies to support (or refute) claims regarding environmental impact
Existing and proposed environmental regulations can limit the use of alternative water sources	Provide comments and other input to the regulatory process on regulations that could affect the use of alternative sources

Many of the solutions to institutional impediments involve long-term, costly approaches that often require attorneys and engineers. As a result, small power plants that lack the resources of the larger utilities may be at a disadvantage, because they cannot devote the time or financial resources needed to overcome these institutional challenges. At the same time, while the large utilities may have the resources, they often must convince their owners that investing those resources in overcoming these impediments to use reclaimed water is a good decision for the rate payers or shareholders.

Recommendations

Many of the recommendations suggested for mitigation would appropriately be used by power plant developers and operators. Some recommendations, however, are candidates for DOE action. Such recommendations are of two types: (1) providing input to the regulatory process that could address permitting challenges; and (2) supporting R&D for technical improvements to reduce the resource requirements for meeting environmental requirements. Suggested examples for each type include the following:

Input to the regulatory process. The EPA's regulatory process incorporates formal notice and comment procedures, during which time the EPA accepts comments from the public on proposed regulations. State regulatory processes also generally provide for such input. DOE can take a proactive approach to addressing barriers posed by environmental rules by tracking proposed regulations that could affect reclaimed water use and then providing comments to the regulatory agency explaining why and how such proposals could be modified to minimize their impact on the use of reclaimed water. For example, the recently enacted criteria for nutrient limits in Florida may be followed by similar criteria or other contaminants and in other states. Similarly, DOE could follow the development of TMDLs that could impact reclaimed water use. In addition to providing written comments, DOE can also work directly with the EPA as it develops these regulations. Through receiving evidence for how the regulations can impact the use of reclaimed water, the EPA may be willing to make allowances or other changes that will allow for the use of reclaimed water while still protecting the environment.

R&D for technical improvements. As noted, institutional challenges are often mitigated by using technical solutions, such as increased treatment to reduce the concentrations of contaminants such as TDS that can limit disposal options. These technical solutions are expensive, and if not cost-effective, they may not be used at all. DOE could help increase the use of alternative water sources by supporting R&D for cost-effective technical solutions. Examples of such R&D activities include the following:

- *Technologies to reduce the concentration of TDS in cooling tower blowdown*. With reduced TDS concentrations, the cycles of concentration could be increased while simultaneously ensuring that wastewater from the power plant meets discharge limits imposed by various regulations.

- *Technologies to reduce emissions of particulate matter from cooling towers*. In nonattainment areas, power plants cannot release particulates unless they receive offsets from other sources, which can be difficult to obtain.

- *Efficient air-cooling technologies*. Many regulators and members of the public believe that because air-cooling technologies use less water, they are preferable to wet-cooling technologies that use reclaimed water. However, air-cooling technologies are frequently not used because they are not efficient in locations where ambient air and/or wet-bulb temperatures are high, they suffer from significant energy penalties, and they are costly to operate. Additional R&D aimed at developing more effective and efficient air-cooling technologies would help address this concern. At a minimum, an examination of the types of air-cooling technologies use in other countries could provide a starting point for further R&D. A related research activity that would address the concern about relative benefits of air-cooled vs. wet-cooled technologies would be to conduct a lifecycle analysis that would compare overall resource use and environmental impacts of air-cooling technologies with wet-cooling technologies. While air-cooling technologies clearly use less water, a study of all resources used and environmental impacts for both wet- and dry-cooling technologies could help identify appropriate location-specific approaches.

- *Improved monitoring techniques*. Current monitoring techniques and protocols allow many constituents in wastewater effluent to escape detection. The eventual detection of these constituents can require expensive equipment repair to the power plant's cooling system, additional treatment capacity (at the power plant or the WWTP), or other solutions that may involve institutional challenges (e.g., negotiations, permitting requirements) that consume time and other resources. DOE's direct involvement with or support for efforts aimed at mitigating monitoring deficiencies can help reduce these impacts. Similarly, the ability to detect EPOCs in the effluent (and subsequent testing of those constituents), will provide data that can be used to support or refute the claims that these constituents can cause harm to human health or the environment.

- *Desalination*. With increased competition for reclaimed water, power plants seeking to reduce freshwater consumption are looking more closely at desalination—a technology historically deemed expensive and energy intensive. DOE support of R&D into desalination techniques that use less energy will not only help provide another cost-effective means for reducing freshwater consumption at power plants, but can also facilitate and speed the use of desalination for other water users.

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