Washington Internships for Students of Engineering

Water Scarcity and the Nuclear Power Industry

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Foreword

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About the WISE Program

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Introduction

Government subsidies and efforts to expand water infrastructure in the United States have created a situation in which water is extremely undervalued, resulting in inefficient water management and wasteful water use. Groundwater depletion is only now being seriously addressed, as underground water supplies reach critical levels. The American attitude toward water is going to have to change, and this change will likely hurt the nuclear power industry if we are not prepared.

As one of the larger consumers of fresh water, and as the largest short-term user of fresh water, the thermoelectric power industry needs to plan for a future in which water is considered much more valuable, and its use is much more carefully regulated. Nuclear power, with its lower thermal efficiency, will be a particularly vulnerable target for environmentalists criticizing our water use. New approaches to cooling will likely be needed for the next generation of nuclear power, and EPA regulations may even mandate changes to older plants.

By investing now in water-conserving technologies, and by lobbying for more reasonable EPA regulations, the nuclear industry can improve public opinion and save money in the long term.

Water Use and Regulation in the United States

Human civilization is heavily dependent on fresh water, to the extent that one metric for the development level of a nation is the price and availability of potable water on tap.[1] The United States has had a well developed water treatment and distribution system for over a century, and many Americans have come to take water for granted. However, many regions in the U.S. are reaching the peak of sustainable water usage, and some regions are depleting deep groundwater reserves that will take thousands of years to naturally refill.[2] [3] The U.S. must look forward to a future where water is no longer abundant enough to take for granted, and U.S. industries should begin planning now for the water shortages to come.

Water, despite being a fundamental necessity for life, is largely treated as a non-commodity in the United States. Local water utilities generally set tap water prices at a level that barely covers the cost of running and maintaining the infrastructure which transports water to each home. Many public water utilities are unable to recoup their costs based on fees alone, and depend on government support for their continued existence.[4] This system is particular to the United States, where tap water costs make up a lower percentage of the average family budget than anywhere else in the industrialized world. The obvious benefit of lower costs to consumers is counteracted by the hidden problems with this system, particularly the problem of sustainability.

Most water utilities in America charge either a flat volumetric rate, a periodic infrastructure maintenance fee, or a combination of the two. These fees are often applied equally to business, agriculture and home use, resulting in maintenance of large industrial water delivery systems being subsidized by individual homeowners. Furthermore, the total income from these fees if often slightly less than the actual cost of running the system, with the extra money being supplied by the local government. The effect is to make it easy for industry to wastefully consume water, and to level out the average home's water bill, regardless of their actual water use. This subsidization of water is extremely common throughout the United States, and has worked to decrease water awareness. Due to the artificially low prices and constant availability of tap water, little public attention is generally paid to conservation efforts, despite public awareness campaigns by many local governments and despite the gradually sinking groundwater levels in many areas.

There are two basic metrics for measuring water use: consumption and withdrawal. Withdrawal is defined as simply removing water from its natural source, possibly to be returned later, while consumption occurs when water is withdrawn and then somehow prevented from returning to its source. In the power industry, consumption primarily occurs when cooling water is caused to evaporate and released into the atmosphere, removing it from the local environment. Measuring by withdrawal, electric generation is the largest water user in the United States, a fact which is often seen on anti-nuclear propaganda. Measuring by consumption, however, we find that Agriculture alone consumes more than eighty percent of American water, and that electric generation consumes an amount comparable to that used by other industries.[5] Both metrics are required to understand the impact of water-using human activity on the environment, but narrow focus on one metric at the expense of the other can have undesirable, and easily avoided consequences.

Environmental groups focused on the protection of aquatic wildlife have worked to minimize water withdrawal from all natural sources. As water is pumped out of any water body young fish, insects and other aquatic life can either become trapped against the grating protecting the inlet, or else sucked into the machinery and killed; impinged or entrained. Since the natural mortality rates for aquatic life tend to be much higher than the rate at which such life is killed by cooling systems, the environmental impact of open cycle cooling systems has been minor.[6] This has not prevented environmental groups from engaging in protests, legislation and lawsuits against power plants.[7] Nuclear power plants have been an especially large target, both due to the unpopularity of nuclear power among certain groups, and because nuclear power plants require a larger flow of cooling water than conventional power sources due to lower thermal efficiency.

Up until 2001, the EPA has delegated responsibility for permitting power plant cooling structures to the state level, declining to create federal regulations on this issue. While nationwide standards regarding effluent discharge temperature and chemical content were enforced, the exact design of cooling structures was not determined by the federal government. This changed in 2001, when the EPA, facing pressure from environmental groups, implemented Phase I regulations for the Clean Water Act, Section 316(b), setting narrow standards for cooling water withdrawal while ignoring consumption as a measurement of water use.[8] In doing this, the EPA has removed state governments from the decision making process and essentially mandated that all power plants use cooling systems which minimize water withdrawal, often at the cost of increased water consumption. The regulations are currently only applied to new power plants, as a series of lawsuits has so far prevented the EPA from requiring retrofitting of existing structures.[9]

The electric power industry is already a large consumer of water, evaporating an amount roughly equal to that consumed by all other industrial purposes, and half as much as is used for all household consumption, though agricultural water consumption dwarfs all other uses combined.[10] Forcing power plants to increase consumption so as to decrease withdrawal will only exacerbate this problem, and likely lead to more lawsuits and government mandates in the future as water conservation becomes a more important issue.

Many of the more arid states have reached or exceeded the limits of sustainable aquifer use, and must rely on surface water and water imports for all new water needs.[11] [12] This is particularly unfortunate, as deep aquifers are more drought resistant than surface water, and are good natural distribution systems. Furthermore, ground water is often the only water source for farms and outlying towns not connected to the central grid. Surface water access rights are generally dominated by local politics, which can leave independent farmers and other politically powerless groups unable to expand. Furthermore, overconsumption of some aquifers has lead to severe water table depression, greatly increasing the pumping costs for small wells and gradually reducing water access. Ironically, the more arid states such as Nevada are having fewer problems with water table depression than wetter states such as Missouri or Virginia, where ground water is not as carefully regulated and is often taken for granted. Coastal states in particular have been having problems with seawater contamination, as low groundwater levels have allowed salt water to permeate inland, contaminating aquifers and destroying freshwater supplies.[13]

Even states which are active in regulating groundwater consumption have not been willing to treat water as a valuable commodity or increase the price of tap water. In Nevada, it is illegal to water your lawn during certain hours of the day during a drought and "wasting water" is punished as a misdemeanor on the second offence. The governor also has far-reaching power to enforce water conservation during such an emergency.[14] However, despite the obvious importance of water to the state, low water prices have meant that most Nevada citizens only make an effort to conserve water during times of extreme need.

The EPA has been aware of the problem of water overconsumption for some time, and has published several reports and pamphlets aimed at helping local utilities budget for the future and reduce consumption to sustainable levels. One EPA ratesetting guide in particular discusses the problems with the flat fee structure common throughout the US, and recommends a tiered rate structure which charges more for extremely high water use.[15] Despite this federal effort, little progress has been made in reducing water consumption. Many state and local governments have only recently begun to seriously consider the impact of human groundwater use, as water table depression has begun to cause problems such as well dryout and saltwater contamination.

This trend of overconsumption is likely to continue for the near future, as natural water resources are fixed and largely exploited, population is increasing, and public awareness of water issues remains low except during periods of extreme shortage. Increasing water production prices may spur some utilities to increase fees, but water is still seen as more of a public service than a commodity. Unless this changes, tap water will likely continue to be taken for granted.

Conservation programs and more efficient use of existing water resources are part of the solution to this problem, but are less easily implemented and less popular than simple expansion of water resources. Many large cities in California are reaching hundreds of miles to access untapped aquifers in mountain regions, and are paying progressively more for new water capacity. As the costs of water increase, new options become competitive.

The increasing cost of water has opened up new economic opportunities for freshwater production, either from treatment of municipal and factory wastewater, or from desalination of saltwater. Many cultures, including the United States, are innately opposed to drinking processed sewage, regardless of its purity compared to conventional water supplies. Desalination, however, has proven to be a socially acceptable, though expensive, source of potable water[16]. Numerous niche markets exist for desalination, with low grade systems improving the drinkability of brackish groundwater, and small desalination plants providing ultra pure water for specialized uses. Several states facing water shortages have also built desalination plants as auxiliary tap water sources. Florida's Tampa Bay plant is the largest in the United States. It produces ninety five thousand cubic meters of potable water per day, at a predicted average lifetime cost of sixty six cents per cubic meter.[17] Surface water generally only costs a few cents per cubic meter to divert, and groundwater often cost less than ten cents per cubic meter at the source, increasing up to twenty cents per cubic meter for deeper aquifers. Conventional water treatment adds about five cents to this total, but long distance transportation can add much more. Large cities attempting to expand their water sources often pay fifty cents per cubic meter or more for untreated water to be piped in from far off areas.[18] This has allowed desalination, which can be sited near coastal cities, more attractive. Despite the cost to Florida taxpayers, the state is planning to expand their desalination capabilities, as many natural sources have reached the limits of sustainable use and surrounding areas are becoming unwilling to export their water at any price.[19]

The Tampa Bay Plant, as one of the newest, and the largest, of the desalination plants in the United States, represents the lower price limit of desalinated water using the desalination methods common in the U.S. Smaller or older tap water production plants tend to be much more expensive to run. California has several such small, expensive plants which were built after a brief period of increased water awareness during the late 1980's. These plants are no longer operated continuously, but have been mothballed, kept ready to reopen in an emergency.

In countries where energy is cheap and natural fresh water is scarce, desalination has been much more widespread, and has been attempted on a much larger scale. Saudi Arabia has several huge fossil fuel powered desalination plants which supply a large portion of their water needs. The Shoaiba plant, for example, is the largest in the world, producing one hundred and fifty million cubic meters a day, more than the desalination capacity of the entire United States.[20] Projects on this scale may eventually become necessary as fresh water becomes more and more scarce.

Water Use in the Nuclear Power Industry

Ninety percent of electrical power in the United States is produced thermoelectrically, as water is heated into steam and that steam is used to drive turbines connected to electrical generators. These systems, regardless of whether the heat source is coal, oil, gas, concentrated solar heat or nuclear power, require external cooling. By some mechanism, the steam exhaust from the turbines must be condensed back into liquid water, so that it can be returned to the heat source and the cycle continued. This cooling can be accomplished in various ways, but the most efficient methods require large volumes of water to be diverted from external sources. Nuclear plants in particular require more cooling water than comparable coal plants, since nuclear plants tend to operate at lower temperatures, requiring a larger steam flow to produce the same electrical power. While some reactor designs would allow for higher operating temperatures and reduced cooling requirements, all nuclear power plants will require some external cooling.

Water is also used for many internal processes in the current fleet of U.S. power reactors, both as primary coolant, moderator, emergency cooling supply, and for fuel storage. These uses, however, consume far less water than even the most efficient wet cooling designs, and are thus not relevant to this discussion.

The vast majority of thermoelectric power plants, and all current commercial nuclear power plants in the United States, use water as a cooling medium to exchange heat with the outside environment. These wet cooling systems fall into two general types. Open cycle systems take in large volumes of water from a natural source, allow excess heat to enter the water, and then immediately return the water to the environment. Closed-cycle systems use a smaller volume of water, but evaporate much of it, removing the water from the local ecosystem. Both methods have a non-trivial impact on the surrounding environment, but in different ways. Open cycle systems have the largest direct effect on their water supply, as they remove the largest volume of water and return the water at a higher temperature, which can impact local wildlife. However, closed cycle systems, while removing a smaller amount of water, cause most of that water to eventually evaporate, potentially shrinking water supplies. Clearly then, EPA regulations forcing new plants to choose closed cycle systems create a large decrease in water withdrawal, but at the cost of increased consumption.

Despite the lack of evidence that water withdrawal or moderate thermal pollution damages ecosystems, the issue has become a major problem for some power plants. On the Hudson River, the Indian Point nuclear power plant may be forced to shut down its open cycle system due to legal action from environmentalist groups. These groups have succeeded in turning public opinion against the plant, using press materials with titles like "Nuclear Born Killers[21]" to describe the aquatic life destroyed each year by the plant. While the impingement and entrainment of wildlife has not proven to be a major technical problem, either for the plant or for the surrounding environment, it has become a public relations nightmare.

Even closed cycle systems can cause public relations problems, which are likely to increase as water consumption becomes more of an issue. The large amount of water vapor from closed cycle cooling systems can cause a plume of smoky looking fog, which is sometimes considered a public relations problem, either because people do not understand the plume's benign chemical makeup, or because it serves as a reminder of the plants high water use. Plume abatement systems exist which heat the air exiting from such systems, increasing the air's dew point and making the water vapor less visible. These systems do not significantly decrease water consumptions, but do serve as an example of how public perception of water use can impact the nuclear power industry.

Future Water Use in the Nuclear Power Industry

Since the EPA has begun to restrict water withdrawal, open cycle cooling has essentially become illegal for new plants. Lobbying efforts may eventually overturn this regulation, but for now the power industry must turn to more expensive options such as closed cycle cooling, or other cooling methods that do not depend on water as much as current techniques.

The loss of the open cycle option has served to make coastal location less valuable. The lower wildlife density of deep ocean water has long been an attractive feature for coastal power plants, since open cycle cooling systems would become clogged less often and also have reduced environmental impact. As closed cycle wet systems are currently the second most popular option, the shift away from open cycle systems will serve to make freshwater more valuable than salt water for cooling purposes, as salt water is difficult to use in closed cycle systems. The Calvert Cliffs nuclear power plant, for example, is planning to use a small desalination plant to provide fresh cooling water for its proposed third unit.[22] The plants location was originally chosen with the use of open cycle seawater using systems in mind, but has been forced to adopt freshwater using systems, despite the scarcity of fresh water in the immediate environment.

Other coastal plants may face similar problems, especially if older plants are forced to adopt current EPA standards.

Since fresh water is likely to become more expensive, one solution is to use non-potable water instead. Grey water is non-sewage wastewater, such as the water from a storm drain, and is contaminated enough to be unsafe to drink, but is still much more pure and more easily treated than seawater. Nuclear power plants can treat grey for use in closed cycle systems, eliminating the problems of water withdrawal, though this has only been done in one case. Use of grey water, however, can still be environmentally significant. Reuse of grey water causes zero withdrawal, since the water has already been withdrawn, but can increase consumption if the grey water was going to be returned to a natural source. Many cities have begun cleaning their wastewater and pumping it back underground in order to replenish their drained aquifers. For this reason, grey water usage may not be appropriate in the future, as even waste water becomes valuable.

Alternative Cooling Methods

Water is cheaply available almost anywhere in the U.S., has a very high specific heat, evaporates easily in standard atmospheric conditions and is chemically benign. With these advantages, water is not easily replaced as a method of dumping heat into the environment, though alternate technologies do exist.

Direct dry cooling is a well-established method of heat dispersal in which air is blown over the condenser surface to cause convective heat transfer, but dry cooling has rarely been used for thermoelectrical plants since it is generally more expensive than wet cooling methods. These systems tend to be cool less efficiently, and thus need a larger air flow to achieve the same cooling as a wet system, requiring powerful and expensive fans. The higher efficiency of wet systems is due to evaporation. A wet surface will generally cool to the so-called wet-bulb temperature, the average temperature of water vapor leaving the surface. This wet-bulb temperature is significantly lower than the actual air temperature as measured by a dry thermometer, though the difference decreases at high humidity. A dry surface will only cool to the air's ambient temperature, thus requiring higher air flow. This is also problematic, as shifting air temperatures have a large effect on cooling efficiencies. The wet-bulb temperature, and thus the efficiency of wet cooling systems, depends on both air temperature and relative humidity, which tend to be inversely correlated. The wet-bulb temperature is thus less variable than the air temperature. The decreased stability of dry cooling methods as weather conditions shift can cause problems with the generator back pressure, as the exhaust steam is condensed at varying rates.[23] Direct dry cooling is thus used mostly for smaller applications, where this variation is less damaging. Water sprayed onto the dry condenser can quickly improve efficiency and improve stability, but causes maintenance problems unless the system is designed for this use. This water would also be used during the hottest, driest days, when water conservation is most important.

Indirect dry cooling systems use an intermediate loop between the condenser and the environment, decreasing efficiency but increasing the operator's control over the process. This allows for rapid corrections to achieve optimal condensation rates and generator back pressure by simply adjusting the flow in the intermediate loop, making indirect dry cooling more suitable for larger applications.[24] Due to decreased thermal efficiencies, however, the overall cost of these systems is even higher. Indirect dry cooling has another advantage, however, in that the cooling system can be moved further from the generator building. In direct dry cooling, the system must be immediately adjacent to the generator building, due to the difficulty in transporting high temperature exhaust steam without leakage. The secondary loop in indirect dry cooling, however, is at atmospheric pressure, and can easily be stretched away from the main body of the power plant. This allows indirect dry cooling to use natural draft towers, where the natural forces of convection create airflow without using expensive fans. The massive cooling towers used to create the draft needed for dry cooling are expensive, however, compared to similar wet systems.

Another approach is to fit wet closed cycle systems with evaporate capture systems, though this results in only moderate water savings. These systems are currently used for plume abatement, since the foggy white emissions from cooling towers have proven to be a public relations problem. While most plume abatement systems simply heat the air, making the plume less visible, other systems cool the air, causing some of the water vapor to condense as rain and fall back into the tower. These devices have the potential to reduce water consumption for the now mandatory closed cycle systems, and can be cheaply retrofitted onto existing plants. Water conservation has not yet become a large enough issue, however, for these devices to become common in the nuclear industry.

Hybrid systems are another new development, in which indirect dry cooling towers are fitted with wet cooling stages as well. The lower dry stage heats the incoming air, decreasing its relative humidity and making it more useful for wet cooling, which compensates for the increased air temperature. This allows these technologies to work well together in the same structure. The combined system is also more stable, as operators have more options when trying to regulate overall cooling rates. Ideally, these systems would run on dry mode for most of the time, switching on the wet systems only when extra cooling is needed. A simpler version of this concept is to build adjacent wet and dry cooling systems, relying on dry cooling as much as possible, and switching on the wet system when necessary. Other plants hope to have both open and closed cycle systems, with the ability to switch between them as environmental conditions demand, though the EPA does not currently allow this.

As water continues to become more expensive, many thermoelectric power plants may be required to make use of these technologies, adding new water-efficient cooling capacity to take up some of their heat load.

Policy Recommendations

The EPA focus on preserving wildlife has come at the cost of wasting water may prove short sighted, ultimately threatening entire ecosystems. Water-consuming industries must work against narrow-minded environmentalists and fight for legislation which favors water conservation over reduced water withdrawal, calling attention to the proven lack of environmental harm from open cycle systems. However, public opinion is firmly against both nuclear and coal electric power plants when it comes to most environmental issues. This prejudice will likely lead to increasing constraints on water use by all thermoelectric power plants, despite the inexpensive, easily implemented and low consumption option of open cycle cooling.

These constraints, both legal and social, are likely to increase the value of fresh water to the nuclear power industry. This will have several effects, serving to decrease the attractiveness of coastal sites, increase the importance of groundwater availability at plant sites, and spur investment in water-saving cooling systems. These dry or hybrid systems should be considered for all new nuclear power plants, as the long lifespan of nuclear plants makes it more likely that changing regulations will require retrofitting of high-consumption cooling systems.

Nuclear power is unique among large scale producers of electricity in that it creates absolutely no greenhouse gasses during normal operations. Water-consuming cooling practices, however, give anti-nuclear activists an ecological argument against new nuclear plants. Using new cooling practices, we can remove this political vulnerability from our industry and help make the nuclear renaissance a reality.

Appendix: Desalination

Increasing water costs have led to growth in the desalination industry. However, this growth has not yet affected the nuclear industry, except by slightly increasing electricity demand. As desalination becomes used more for drinking water production and less for specialized uses, it is likely that plant sizes will continue to increase. This may offer opportunities for the nuclear power industry, though not unless the United States commits to larger scale projects.

In addition to economic factors such as the cheap price of energy in the Middle East, there are significant technological differences between the Saudi Arabian and Untied States' desalination efforts which have allowed them to successfully make desalination the source of over seventy percent of their fresh water[25]. Saudi Arabia has focused on building large plants, relying on economies of scale and co-production of electric power to bring down costs[26]. Their plants use variations of the distillation method for desalination, where seawater is heated and the surrounding pressure is reduced to instigate boiling. The water vapor is then separated and condensed into fresh water. The United States, on the other hand, has focused on energy efficiency, building small, technologically advanced plants using the reverse osmosis method of desalination, as well as several other more exotic approaches.[27] In the reverse osmosis method, electric pumps force water through a carefully constructed membrane which allows water to pass through it but blocks salt and other contaminants, essentially acting as an extremely fine filter. The electric pumps at these plants are still expensive to run due to the high pressures required, but are less expensive then the heaters in an equivalent distillation plant.

Advances in the last thirty years have greatly improved the performance of the membranes in reverse osmosis plants, and the technology has become cheap enough to be widely popular with isolated resorts, aquariums and other niche markets which need small but reliable sources of high purity water and cannot rely on conventional water supply systems. However, the pumps in a reverse osmosis plant require electricity, whereas the heat source for a distillation plant can come from anywhere. Many of the distillation plants in Saudi Arabia are located alongside thermoelectric power plants, and make use of the waste heat from these plants, which decreases both the cost of the electricity and the cost of the desalinated water. Distillation technology also scales better, becoming less expensive for larger facilities. Reverse osmosis plants also follow economies of scale, but to a lesser extent, as their central components, the membranes, must be replaced on a regular basis, and cannot currently be constructed on a large scale. A large reverse osmosis plant would be composed of many small membranes working in parallel, which is not as efficient as a hypothetical single large membrane. As such, there are doubts that reverse osmosis technology can compete with distillation for large scale plants such as those operating in Saudi Arabia.

Reverse Osmosis is likely to remain the predominant desalination technology in the United States, however, since U.S. companies are more familiar with the technology, and since there are currently no plans in the U.S. for desalination plants large enough to make distillation attractive, though interest in large plants has been slowly increasing.

Appendix: Desalination and the Nuclear Power Industry

Desalination is relevant to the power industry in three ways; as a source of cooling water, as a potential market for waste heat, and as a potential source of cooperative enterprise with water utilities.

As previously described, the EPA requirements mandating closed cycle cooling will create a larger need for fresh water for the nuclear industry, potentially even forcing existing plants to change cooling methods. While desalination is an expensive source of fresh water, this may be the only option for some coastal power plants, such as the nuclear power plant at Calvert Cliffs. Newly produced fresh water can be consumed without environmental complaints, and allows the use of existing wet cooling machinery. This use is likely to remain minor, however, as hybrid cooling methods will become cheaper as the industry expands and the technology is further developed.

Waste heat is not currently traded as a major commodity in the U.S., though increasing energy costs may spur development in “heat recycling.” The waste heat from nuclear power plants, however, tends to be of lower quality than waste heat from other thermoelectric sources, as the heat is contained in a large volume of low temperature coolant, rather than concentrated in a small volume of high temperature coolant. This is due to the low operating temperatures of the reactor designs used for electricity generation today. As such, waste heat is unlikely to become a valuable commodity to the nuclear industry in the near future, as higher quality waste heat from other sources is generally more useful. Future designs for high temperature reactors should be evaluated with at least some consideration paid to the potentially higher value of their waste heat, and should be sited with such uses in mind, particularly if heat recycling becomes more common.

Finally, partnerships between nuclear power and water treatment utilities for co-production of electric power and fresh water may become more likely as both energy and water costs increase. However, the current trend in the United States is toward small, energy efficient desalination plants, which can make only slight use of waste heat, and which are unlikely to partner with the nuclear industry. Larger plants have been proven viable as partners for co-generation of electric power, but represent a much larger and longer term investment. There is not currently the political will in the Untied States for such huge projects, though the political climate is changing. Campaigning by the nuclear industry may gradually increase support for large desalination projects, though such projects are unlikely in the near future.

In fact, most of the desalination plants in the United States are extremely small, and much research is focused on the development of even smaller, low maintenance plants suitable for brackish groundwater treatment in isolated, off the grid areas. Since water supply is handled on a local level, a large portion of the desalination industry has focused on smaller and smaller plants, marketed as expensive but easily implemented auxiliary water sources for towns and small cities facing water shortages. These small plants use the reverse osmosis method of desalination almost exclusively, and those that deviate from the average tend to use experimental techniques such as ion exchange or freezing, not distillation. Large cities have shown interest in higher capacity desalination plants, but this use of desalination is still in the minority. As such, U.S. desalination manufacturers have little experience with the distillation processes used in larger desalination plants, and often do not even have much experience with large scale reverse osmosis. This represents a further barrier toward a partnership between power companies and water treatment plants. Funding research into small scale distillation technology may help prepare the way for nuclear desalination, though it will be difficult to change the current trend toward technologies and methods which are not compatible for electrical cogeneration with nuclear power. As such, nuclear desalination remains a distant, but enticing prospect.

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