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Power Plant Cooling and Associated Impacts:
The Need to Modernize U.S. Power Plants and Protect Our Water Resources and Aquatic Ecosystems

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Water withdrawals for thermoelectric power generation were estimated in 2005 to be 201 billion gallons per day—the highest use of any industry. Most of that water is used for cooling. Power plants boil water to produce steam, which is used to spin the turbines that generate electricity. Then, staggering volumes of water are withdrawn from nearby rivers, lakes, and oceans to cool the steam back into water so it can be used to produce more electricity. The three basic types of cooling systems—once-through, closed-cycle, and dry cooling—differ dramatically in their water usage, with once-through cooling being the most water-intensive and environmentally harmful method. The use of once-through cooling systems causes severe environmental impacts, killing billions of fish, degrading aquatic ecosystems, and increasing the temperature of our rivers, lakes, and ocean waters. Power plants utilizing once-through cooling also are subject to increased incidences of shutdowns or curtailments during times of drought and extreme heat. The U.S. Environmental Protection Agency (EPA) is in the process of issuing standards for the use of cooling water at existing U.S. power plants. A clear, consistent national policy is needed to ensure that the U.S. electricity sector is moving toward a cleaner and more water-smart future by replacing antiquated and environmentally destructive once-through cooling systems with modern, less water-intensive technologies.

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POWER PLANTS USE MORE WATER THAN ANY OTHER INDUSTRY

According to the U.S. Geological Survey (USGS), in 2005, water withdrawals for thermoelectric power accounted for 41 percent of total freshwater use, 49 percent of total water use (fresh and saline), and 53 percent of fresh surface water withdrawals for all industry sectors in the United States.[1] With approximately 201 billion gallons of water being used each day in 2005 to produce electricity, thermoelectric power plants have been the largest water users in the country since 1965.[2] Most of the water used in thermoelectric power generation is for cooling and condensing the steam at power plants.

WHY DO POWER PLANTS NEED WATER FOR COOLING?

A thermoelectric plant works by heating water in a boiler until it turns into steam. The steam is then used to spin a turbine, which drives an attached generator, producing electricity. After the steam passes through the turbine-generator, it is sent to a condenser to be cooled or "condensed" back into water. Water used by the condenser to cool the steam is withdrawn from nearby rivers, lakes, and oceans. The condensed water is pumped back to the boiler and converted into steam again so that it can be used to produce more electricity, and the cooling water is generally discharged back to the body of water from which it came. This entire cooling process can wreak havoc on aquatic ecosystems.

UNDERSTANDING COOLING SYSTEMS

There are three basic types of cooling technologies for thermoelectric power plants, along with a hybrid that forms a fourth type.

In **once-through cooling systems**, water is withdrawn from nearby bodies of water, diverted through a condenser where it absorbs heat from the steam, and then discharged back to its original source at higher temperatures. Because once-through cooling systems do not recycle the cooling water, this leads to incredibly high volumes of daily water withdrawals. The water intake structures at power plants with once-through cooling can kill billions of fish annually, and the thermal discharge downstream can also harm aquatic organisms. In addition, the large volume of water required to operate once-through cooling systems makes power plants especially vulnerable in times of drought and extreme heat. Regulations on new power plants prohibit the use of once-through cooling.

In **closed-cycle cooling systems**, instead of being discharged back to its original source, the cooling water goes from the condenser to cooling towers where the heat it has absorbed from the boiler steam dissipates through evaporation. The rest of the cooling water is then recirculated through the condensers. Closed-cycle cooing has become the technology of choice for most power plants since the early 1970s. Compared with once-through cooling systems, closed-cycle cooling generally reduces water withdrawals and the corresponding aquatic impacts by about 95 percent.[3] However, more water is lost through evaporation in closed-cycle cooling systems than in once-through cooling systems; thus the consumptive use of water by these systems is greater.

Dry cooling systems are similar to the typical closed-cycle systems described above, except that the evaporative cooling tower is replaced with dry cooling towers where ambient air is used to cool the steam instead of water. This method uses virtually no water and thus effectively eliminates all fish kills. The tradeoff for these water savings and environmental benefits is a negative impact on efficiency. Because the effectiveness of dry cooling depends on the ambient air temperature and humidity, plant efficiency is higher for plants using wet closed-cycle cooling systems than for plants using dry cooling, especially in hot, arid climates. The average annual loss of output for a plant using a dry cooling system is approximately 2 percent.[4] Capital costs, as well as operation and maintenance costs, for wet cooling systems are also estimated to be lower than for dry cooling systems.[5] Despite these drawbacks, one major advantage of dry cooling systems is that by eliminating the need for cooling water, it offers a new plant much greater flexibility of location, since it will not be dependent on a major body of water.

Hybrid cooling systems combine dry cooling and wet cooling to reduce water use relative to wet systems while improving hot-weather performance relative to dry systems. Hybrids are typically designed to be operated as dry cooling systems during the cooler seasons, supplemented with wet cooling during the hot seasons when dry systems lose their efficiency.

WATER USAGE DIFFERS AMONG THE VARIOUS TYPES OF COOLING SYSTEMS

According to the EPA, the average water use by steam electric power plants across the United States exceeds 200 billion gallons each day.[6] The type of cooling system employed is invariably the greatest determinant of water usage at a steam electric generating unit, in terms of both water withdrawal and water consumption. Even though wet closed-cycle cooling systems *consume* up to 80 percent more water than once-through cooling, they *withdraw* 95 percent less water than once-through cooling systems do.[7,8]

THE EFFECTS OF POWER PLANT COOLING ON AMERICA'S WATERWAYS

Power plants boil water to produce steam, which is used to spin turbines, generating electricity. Oftentimes, staggering volumes of water are withdrawn from nearby lakes, rivers, and oceans to cool the steam back into water so that it can be used to produce more electricity. The three basic types of cooling systems - once-through, closed-cycle, and dry cooling - differ drastically in its water usage, with once-through cooling being the most water-intensive and environmentally harmful method. A clear, consistent national policy is needed to ensure that the U.S. electricity sector is moving toward a cleaner and more water-smart future by replacing outdated and environmentally-destructive once-through cooling systems with modern, less water-intensive technologies.

Power Plant Share of Total Water Use in the U.S.

In 2005, water withdrawals by steam electric power plants accounted for approximately 49 percent of total water use (fresh and saline) in the United States. That is an estimated 201 billion gallons of water per day – nearly three times the daily volume that roars over Niagra Falls!

LARGEST WATER USERS IN THE COUNTRY

MOST OF THAT WATER IS USED FOR COOLING PURPOSES

49% Thermoelectric Power

31% Irrigation

11% Public Supply

4% Industrial

2% Aquaculture

1% Mining

1% Domestic

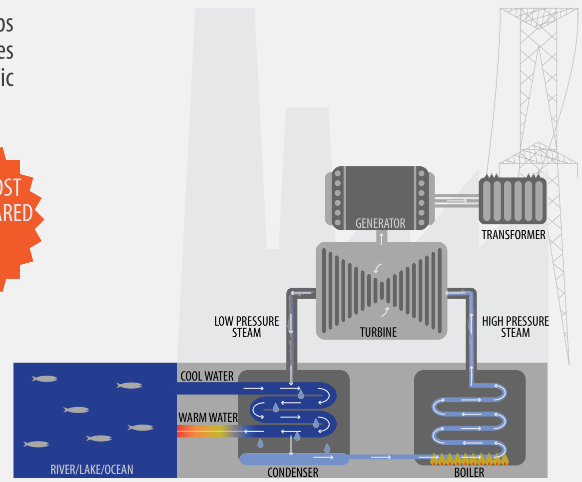
<1% Livestock

Once-Through Cooling is the Most Harmful Cooling Method

Water is withdrawn from nearby bodies of water, diverted through a condenser where it absorbs heat from the steam, and then discharged back to its original source at higher temperatures causing severe environmental impacts, including killing billions of fish, upsetting aquatic ecosystems, and heating up rivers, lakes and ocean waters.

WATER WITHDRAWN*	20,000-50,000 gal/MWh	
FISH KILLED**	100	

USES THE MOST WATER COMPARED TO OTHER SYSTEMS



The water withdrawal requirements for once-through cooling and closed-cycle cooling systems at a conventional coal-fired power plant are, respectively, 20,000–50,000 gallons per megawatt-hour (gal/MWh) of electricity produced, and 500–1,200 gal/MWh.[9] Water consumption rates for once-through and closed-cycle cooling systems are, respectively, 100–317 gal/MWh and 480–1,100 gal/MWh.[10] Both the water withdrawal and consumption requirements for dry cooling systems are 0 gal/MWh.[11]

SECTION 316(b) OF THE CLEAN WATER ACT

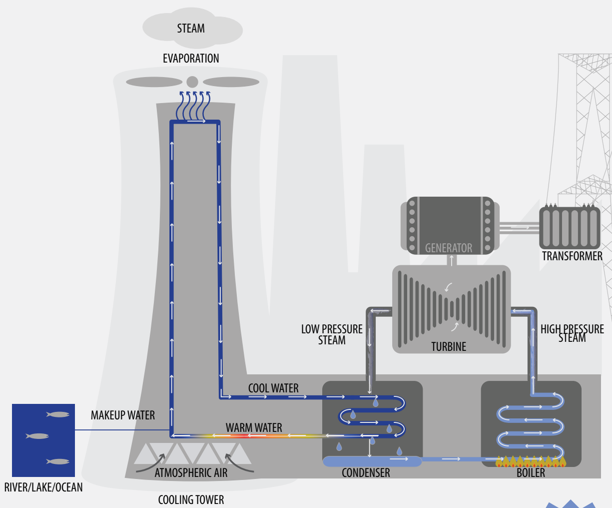
Section 316(b) of the Clean Water Act (CWA) requires that the location, design, construction, and capacity of cooling water intake structures reflect the best technology available (BTA) for minimizing adverse environmental impacts. The withdrawal of cooling water has the potential to cause negative environmental impacts due to impingement (the mortality of or harm to aquatic organisms, primarily fish, on screens that protect the intake system), and through entrainment (the mortality of or harm to smaller organisms, primarily fish eggs and larvae, that pass through those screens and through the plant's entire cooling system). Congress included Section 316(b) in the 1972 CWA, but implementation of Section 316(b) has been stalled for decades.

- In 1977, the EPA's first attempt at Section 316(b) regulations was remanded by the Fourth Circuit due to procedural defects.
- In 1993, a coalition of environmental groups sued the EPA in federal district court to compel re-enactment of the regulations required by Section 316(b).
- In 1995, environmental groups won a consent decree directing the EPA to take final action with respect to Section 316(b) regulations. The agency then developed the regulations in three phases.
- In December 2001, the EPA issued the Phase I rule, which mandates the use of closed-cycle cooling systems at new facilities.

HOW CAN POWER PLANTS BE WATER-SMART?

Replace Once-Through with Closed-Cycle Cooling

Closed-cycle cooling systems recirculate the cooling water through the condensers instead of having the water discharged back to its original water source.

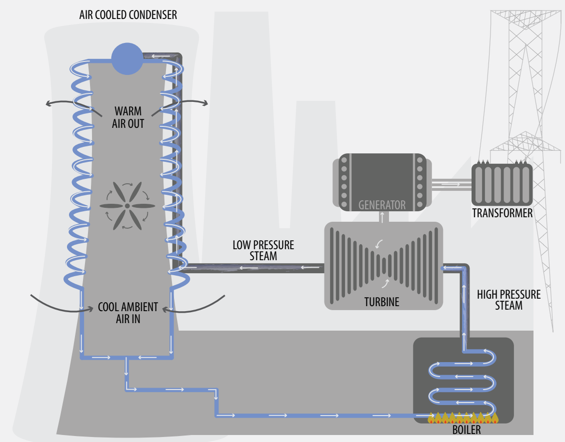


WATER WITHDRAWN*	500-1,200 gal/MWh
FISH KILLED**	5

REDUCES WATER USE AND FISH KILLS BY 95%

Replace Once-Through with Dry Cooling

Dry cooling systems use air from the atmosphere, instead of water, to cool the boiler steam.

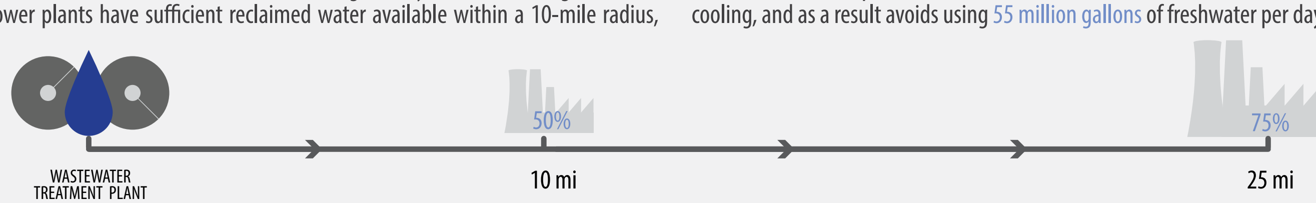


WATER WITHDRAWN*	0 gal/MWh
FISH KILLED**	0

USES ALMOST NO WATER; ELIMINATES FISH KILLS

Use Reclaimed Water for Cooling

Instead of freshwater withdrawals, power plants can use treated municipal wastewater, or reclaimed water, for cooling. Nearly 50% of existing coal-fired power plants have sufficient reclaimed water available within a 10-mile radius, and 75% have sufficient reclaimed water available within a 25-mile radius. The Palo Verde nuclear plant in Arizona uses reclaimed water for its closed-cycle cooling, and as a result avoids using 55 million gallons of freshwater per day.



* Gallons of water required per megawatt-hour of electricity produced
** Relative amounts

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- In July 2004, the agency issued the Phase II rule, covering existing facilities that use at least 50 million gallons per day (MGD) of cooling water.
- Finally, in June 2006, the Phase III rule was issued, covering other existing facilities not covered by the Phase II rule, as well as new offshore and coastal oil and gas extraction facilities that have design intake flow thresholds exceeding 2 MGD.[12]
- In January 2007, the Phase II rule was remanded to the EPA for reconsideration as a result of litigation brought in federal court by Riverkeeper, NRDC, and other environmental groups contending that the rules did not comply with the protective mandates of Section 316(b). The EPA then accepted a voluntary remand of the portion of the Phase III rule dealing with existing facilities, combining it with the Phase II rulemaking.
- On April 20, 2011, the EPA published a draft revision of the Phase II/III Section 316(b) rule, which applies to existing large power plants and manufacturing facilities. The proposed rule intends to regulate existing facilities that withdraw at least 2 MGD of cooling water and use at least 25 percent of that water exclusively for cooling purposes.

The EPA is currently reviewing public comments on the April 2011 proposed rule and is committed via a settlement agreement to issue a final version by Spring 2014.

CLOSED-CYCLE COOLING IS THE BEST TECHNOLOGY AVAILABLE

As mentioned above, Section 316(b) of the CWA requires the EPA to adopt standards for cooling water intake structures based on the BTA for minimizing adverse environmental impacts. Closed-cycle cooling is BTA for cooling water intake structures because it reduces intake flow to the greatest extent and thus is most effective at reducing fish kills. The EPA's own record shows that "numerous" existing facilities have been retrofitted to closed-cycle cooling.[13] The fact that the technology is widely available to existing facilities makes it "available" as that term is used in Section 316(b). The power industry has frequently claimed that requiring closed-cycle cooling for all existing facilities would cause energy shortages and drive up electricity prices. The EPA's own analysis, however, shows that having a national closed-cycle cooling mandate would not have any significant adverse effects on the price or supply of the nation's electricity. At the very most, only 1.5 percent of existing power plants would be retired as a result of compliance costs.[14] Furthermore, the EPA estimates that the average household cost increase would be less than $1.47/month if the agency required all existing power plants to convert to closed-cycle cooling.[15]

Use of closed-cycle cooling provides significant environmental benefits at minimal costs to both the electrical power industry and consumers. The EPA should therefore establish a national, uniform standard for impingement and entrainment mortality based on the performance of closed-cycle cooling systems.

BENEFITS OF CLOSED-CYCLE COOLING OUTWEIGH COSTS BY MORE THAN 3:1

On June 12, 2012, the EPA published a Notice of Data Availability presenting significant new information that was developed since its April 20, 2011, Section 316(b) rule proposal. The additional information resulted from an economic survey of benefits (also known as a "stated preference survey") conducted by the EPA, in which the agency, for the first time, attempted to monetize the benefits of cooling water intake regulations. For many years, the EPA recognized that the benefits of protecting fish, shellfish, and other aquatic organisms from destruction by cooling water intake structures were highly significant. However, in the absence of a stated preference survey, the EPA was unwilling to attach a specific dollar figure to those benefits; as a result, 98 percent of the benefits were routinely "zeroed out" or ignored by the EPA and state agencies. This left the EPA weighing complete costs against drastically incomplete benefits and, more significantly, skewed decision making against environment protection.

Now that the EPA has finally conducted a stated preference study, the benefits of a national, categorical closed-cycle cooling mandate are unequivocal. The EPA's data show not only that the benefits of closed-cycle cooling outweigh the costs by more than 3:1, but also that closed-cycle cooling provides a greater net social benefit ($13 billion at a 3 percent discount rate) than any other option considered by the EPA.[16]

NRDC, along with other environmental groups, submitted comments to the EPA, urging the agency to require a uniform closed-cycle cooling standard in the final rule, as it is the most environmentally protective option and produces the greatest net benefits to society.

ONCE-THROUGH COOLING HAS MANY ADVERSE ENVIRONMENTAL IMPACTS

A power plant with once-through cooling draws hundreds of millions—and for some plants billions—of gallons of water each day from nearby lakes, rivers, or ocean waters. Not only does the withdrawal of cooling water result in a number of adverse environmental impacts on aquatic life, but a reliance on the constant availability of such enormous quantities of cool water leaves plants vulnerable in times of drought and extreme heat.

Power Plants Kill Fish

As water is being drawn into a cooling system, full-grown fish and other aquatic life are smashed and trapped against screens at the opening of an intake structure. This is referred to as impingement. In addition, early-life-stage fish, eggs, and larvae are often sucked into the cooling system, where they are harmed by heat, pressure, mechanical stress, and/or chemicals used to clean the cooling system before being dumped back into a water body. This is referred to as entrainment.

Throughout the country, the toll on fisheries by power plants rivals or even exceeds that of the fishing industry.

- The Salem Nuclear Plant in New Jersey kills an estimated 1.12 million weakfish and 842 million bay anchovies per year—four times more than are caught by commercial fishermen.[17]

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- The 16 California power plants using once-through cooling systems together have the ability to suck in around 14.5 billion gallons of seawater every day. Annually, they kill an estimated 2.4 million fish and 17.5 billion larvae.[18] For the 12 coastal power plants in the Southern California Bight, impingement of recreational fish species accounts for 8 percent to 30 percent of the number of fish caught in the Bight.[19]
- Cumulatively, the five power plants on New York's Hudson River have killed as many as 79 percent of all the fish born in a single species in a single year.[20]
- In 2008, the Bayshore coal power plant in Ohio killed more than 60 million adult fish and more than 2.5 billion fish eggs and larvae.[21] Three of the plant's four units shut down in September 2012, thereby reducing the number of fish kills since then; nevertheless, the EPA admitted that the plant likely impinged and entrained more fish than all of Ohio's other cooling water intakes combined.[22]

Power Plant Water Use Heats Up Rivers and Lakes

Thermoelectric power plants are one of the main causes of thermal pollution, the degradation of water quality by any process that changes ambient water temperature. As water passes through a once-through cooling system, it gets warmer than the source water. Discharging that warmer water to a river or lake can stress and kill fish and other wildlife. The presence of dissolved oxygen in water is critical to the survival and abundance of organisms in aquatic ecosystems. Elevated temperatures typically decrease the level of dissolved oxygen; this is one way in which discharging warmer water back to its original source can harm aquatic life. Moreover, thermal pollution may increase the metabolic rates of aquatic animals, causing these species to consume more food than they normally would in an unchanged environment. Thus, an increased metabolic rate may lead to food shortages, thereby resulting in the migration of organisms to other, more suitable habitats. In addition to forced migration, temperature changes may also cause *immigration* of fish and other aquatic organisms that normally live in warmer waters elsewhere. The latter scenario would lead to greater competition for fewer resources and the more adapted organisms moving in might have an advantage over native organisms that are not used to the warmer temperature. All of these ecological impacts associated with thermal pollution can give rise to significant changes in aquatic biodiversity.

Power Plants are Vulnerable in Times of Drought and Extreme Heat

The high water demands of power plants have adverse consequences not only to the environment but also to the power plants themselves. The colder the cooling water, the more effective the condenser, which in turn allows for more efficient electricity generation. When water is too warm for power plant cooling, it decreases power plants' efficiency, making them less competitive. Power plants suffer from water temperature problems mainly during hot summers or heat waves, when the temperature of intake water is elevated at the same time that plants are running at full capacity to meet peak loads from air conditioning.

Water shortages too can create problems for a power plant's generating capacity. Prolonged drought can drop water levels below a plant's intake pipes. When water is too warm for cooling or simply not available, facilities have to cut back power production or even shut down. For example, in August 2007, the Southeast experienced particularly acute drought conditions. As a result, nuclear and coal-fired power plants in the Tennessee Valley Authority system were forced to curtail operations, and some reactors were even shut down.[23] The problems that drought and extreme heat pose for U.S. power plants are not limited to the Southeast. In August 2012, one of two nuclear reactors at the Millstone Power Station near New London, Connecticut, had to shut down when temperatures in Long Island Sound, the plant's source of cooling water, reached their highest sustained levels since the facility began monitoring in 1971.[24] In July 2012, U.S. nuclear power production hit its lowest seasonal levels in nine years as drought and extreme heat forced plants from Ohio to Vermont to cut back on output.[25]

Although there are times when power plants have to suffer the consequences of their enormous water demands due to periods of extreme heat or drought, at other times power plants prevail in these water/energy conflicts and local ecosystems suffer at their expense. In summer of 2012, the Illinois Environmental Protection Agency granted at least eight coal and nuclear plants special exemptions to discharge water hotter than their permits allow.[26] These "thermal variances" were allowed even though fish died in record numbers across Illinois that summer as a result of the extreme heat and drought.

Climate Change Poses More Risks for Power Plants

Our nation's precious water resources will face even more stress as climate change is projected to make droughts in many regions more severe, thus affecting water availability, and heat waves more frequent, thus affecting water quality by driving up the temperature of lakes, streams, and rivers. These impacts of global warming will create an increased risk of shutdowns at thermoelectric power plants across the country as they are forced to deal with potentially even lower water levels and hotter cooling water.

To further exacerbate the problem, our population—and therefore our demand for energy—continues to grow. This will only increase the conflicts between energy and water in the future.

SMARTER ENERGY CHOICES EXIST TO REDUCE THE WATER IMPACTS OF POWER PLANT COOLING

Trends such as climate change and population growth do not have to continue intensifying water/energy conflicts throughout the nation. By installing better cooling systems, relying more heavily on renewable energy such as wind and solar power, and expanding energy-efficiency efforts, the enormous water use by thermoelectric power plants can be dramatically reduced. Such strategies can help ensure a sustainable energy and water future.

Improve Data and Information on Power Plant Water Use

In order to make water-smart energy choices, obtaining reliable information about this issue is essential. We must know, for example, the volume of water used by thermoelectric power plants, their sources of water, and the resulting impacts.

The U.S. Government Accountability Office (GAO) has pointed specifically to the importance of having reliable information regarding the impacts of thermoelectric power plants on water availability and quality. In a 2009 report, the GAO identified some major gaps in federal data collection with respect to power plants' water use.[27] For example, the USGS collects data on power plant water withdrawals, but a lack of funding has forced the agency to discontinue collecting data on water consumption. In addition, power plant operators across the United States are required to submit their water use information, including withdrawals, consumption, discharge, and some data on water sources, to the U.S. Energy Information Administration (EIA); however, even the most seemingly complete compilations of data contain major shortcomings and inaccuracies. The EIA data gaps, as noted by the GAO, may be partially explained by the fact that several categories of power plants—most significantly the nation's 65 nuclear plants—were exempt from reporting under EIA policy. There is also a lack of oversight, leading many plants either to underreport their withdrawal and/or consumption figures or to flat-out misreport (e.g., giving consumption figures that are greater than withdrawal figures). Furthermore, in 2002, the EIA stopped collecting data on the use of advanced cooling technologies and associated water impacts.[28] The gaps regarding power plants' water use are further exacerbated by the fact that no agency collects data on the use of alternative water sources, such as recycled or reclaimed water, for energy production.

State and federal agencies must work to ensure that power plant operators report their water use both accurately and consistently. The good news is that in 2008, the EIA began to make critical improvements such as getting rid of the nuclear power plant exemption and exercising greater surveillance by verifying numbers that seem suspect. However, there is still room for improvement. The GAO report and more recent findings of the Union of Concerned Scientists highlight the need to further strengthen the EIA's efforts to collect accurate and reliable data on power plants' water use. Such information is critical in making informed decisions about power and water.[29]

Promote Renewable Energy and Invest in Energy Efficiency

Significant water savings and associated environmental benefits can be achieved by shifting to renewable energy and expanding energy efficiency efforts. Replacing conventional fossil fuels with less water-intensive renewable energy sources, such as wind and solar power, will significantly reduce the pressures placed on our nation's water resources by power plants and better protect aquatic ecosystems. For example, wind power uses the force of the wind to spin turbine blades and thus does not require any water for electricity generation or for cooling. Solar technology uses photovoltaic cells to convert sunlight directly into electricity and thus also requires no water.

Another way to reduce the nation's need to build new power plants, and thereby cut back on the water demands of our electricity sector, is to improve the energy efficiencies of our homes, businesses, and industries. Homes and residential buildings can meet energy efficiency goals by, among other things, air-drying dishes and clothes, turning off power strips when electronics are not in use, upgrading to energy-efficient appliances, and installing a programmable thermostat to manage heating and cooling systems and thus lower utility bills. Similarly, business and industrial buildings can take advantage of high-efficiency products and systems in order to reduce their overall energy demands. Investing in energy efficiency strategies will not only help consumers and businesses lower their electricity bills, but will also relieve some of the significant pressure that our electricity sector places on the nation's water resources.

Set Stringent Cooling Technology Requirements

By requiring existing power plants to install closed-cycle cooling rather than allowing them to continue using the antiquated once-through cooling system, power plants can reduce their withdrawals by approximately 95 percent.[30] This, in turn, could lead to at least a 95 percent reduction in the destruction of aquatic life caused by cooling water intake structures. Pursuant to Section 316(b) of the CWA, new facilities are now required to use technology that is equivalent to, or better than, closed-cycle cooling. In certain water-stressed regions, some plant operators have already, out of necessity, converted to closed-cycle cooling technologies. Almost all of the gas-fired power plants and the majority of coal-fired plants built since the mid-1970s use closed-cycle cooling.[31]

Reducing entrainment and impingement does not just help save the lives of fish and other species today. It also can have an exponential benefit in restoring robust populations that currently may be in decline or existing at depressed levels. The EPA must continue to set stringent cooling technology regulations by requiring existing utilities that still employ once-through cooling systems to retrofit to a closed-cycle, dry cooling, or hybrid system.

Use Reclaimed Water for Cooling

While the use of closed-cycle or dry cooling systems can help reduce a power plant's freshwater demands, an additional strategy is to use treated municipal wastewater, or reclaimed water, for cooling. For example, the Palo Verde nuclear plant outside Phoenix, by using reclaimed water for its closed-cycle cooling, avoids withdrawing 55 MGD of freshwater.[32] This amount of water savings is especially beneficial for a water-stressed state like Arizona. In addition to benefiting power plants that are located in water-stressed regions of the United States, using reclaimed water can also make power plants more resilient in times of drought or heat.

Unlike our nation's finite freshwater supplies, treated municipal wastewater is a more reliable water source that is readily available in communities across the United States. A recent study conducted by the U.S. Department of Energy found that nearly 50 percent of existing coal-fired power plants have sufficient reclaimed water available within a 10-mile radius to completely meet their water needs, and 75 percent have sufficient reclaimed water available within a 25-mile radius.[33]

Today, approximately 67 U.S. power plants use reclaimed wastewater for cooling purposes.[34] In addition to cooling, several of these plants also use reclaimed water as process water, such as in air pollution control equipment like scrubbers.[35] Power plants that currently do not use reclaimed water for cooling and process water would be well advised to adopt this practice. Reclaimed water represents a valuable alternative water source that can not only help reduce pressure on our nation's limited freshwater resources—and thereby reduce associated environmental impacts—but also help power plants become less vulnerable in times of water constraints.

ENDNOTES

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2 Ibid. at 42 ("Trends in Water Use, 1950–2005").

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5 *See* U.S. Environmental Protection Agency, *Technical Development Document for the Final Regulations Addressing Cooling Water Intake Structures for New Facilities*, November 2001, Docket No. EPA-821-R-01-036.

6 Kenny et al., at 38.

7 Mielke, Anadon, and Narayanamurti.

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10 Ibid.

11 Ibid.

12 Existing Phase III facilities include manufacturing facilities, electric power producers with a design intake flow of less than 50 MGD, and existing offshore oil and gas extraction facilities. *See* U.S. Environmental Protection Agency, Final Rule, *National Pollutant Discharge Elimination System: Establishing Requirements for Cooling Water Intake Structures at Phase III Facilities,* 71 Fed. Reg. 35006, June 16, 2006, 35008.

13 U.S. Environmental Protection Agency, *National Pollutant Discharge Elimination System—Cooling Water Intake Structures at Existing Facilities and Phase I Facilities: Proposed Rule*, 76 Fed. Reg. 22,174, 22,204, April 20, 2011.

14 *See* U.S. Environmental Protection Agency, *Economic and Benefits Analysis for Proposed 316(b) Existing Facilities Rule*, 2011, Table 6-3.

15 Ibid. at 22,228.

16 In deriving these numbers, noted environmental economist Frank Ackerman of the Stockholm Environment Institute reviewed the EPA's original data and benefits analysis and found two significant errors that greatly skewed the EPA's benefits figures downward. However, even without making the vital corrections noted by Ackerman, the EPA's uncorrected benefits figure for closed-cycle cooling ($7 billion at a 3 percent discount) still exceed the average costs by approximately $1 billion. *See* Comments of NRDC et al. to U.S. EPA, *Notice of Data Availability Related to EPA's Stated Preference Study*, 77 Fed. Reg. 34,927, June 12, 2012 (comments filed July 12, 2012) (Document ID No. EPA-HQ-OW-2008-0667).

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18 California State Water Resources Control Board, *Water Quality Control Policy on the Use of Coastal and Estuarine Waters for Power Plant Cooling Final Substitute Environmental Document*, May 4, 2010, 33-34.

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20 John Boreman and Phillip Goodyear, *Estimates of Entrainment Mortality for Striped Bass and Other Fish Species Inhabiting the Hudson River Estuary*, American Fisheries Society Monograp,1988, Exh. 8.

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22 *See, e.g.*, GRACE Communications et al., *Treading Water: How States Can Minimize the Impact of Power Plants on Aquatic Life*, September 2013, p. 33.

23 National Energy Technology Laboratory, *Impact of Drought on U.S. Steam Electric Power Plant Cooling Water Intakes and Related Water Resource Management Issues*, April 2009, available at http://www.circleofblue.org/waternews/wp-content/uploads/2010/08/Impact-of-Drought-on-Steam-Electric-Power-Plant-Cooling-Water-Intakes.pdf.

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34 J.A. Veil, at 9. After research using the Energy Information Agency's 2009 EIA-860 data and cross-referencing with monthly EIA updates from 2010 and 2011, NRDC identified 14 facilities in addition to those listed by Veil. Also, some plants listed by Veil were proposed but never completed.

35 Ibid. at 28.

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