Wounded Waters

The Hidden Side of Power Plant Pollution

CLEAN AIR TASK FORCE

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The Clean Air Task Force *is a nonprofit organization dedicated to restoring clean air and healthy environments through scientific research, public education and legal advocacy.*

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Executive summary

Power plants are widely recognized as major sources of air pollutants that damage human health and the environment. Less well recognized is the damage they cause to water, both as large users and polluters. These damages are the hidden dimension of power generation pollution. Lifting the veil off this problem is essential to both restoring and wisely using many of our nation's waters.

The electricity generation industry **withdraws** about 15 percent of the total freshwater flow in United States ***each year*** – more than half as much as the contents of Lake Erie, **consumes** nearly half as much freshwater as all U.S. commercial and residential users combined, and **discharges** hundreds of billions of gallons of heated and treated waters back into US water bodies each day.

The environmental effects of these water withdrawals and discharges are substantial and include:

- Entrainment and impingement of fish and shellfish species from cooling water intakes, with resultant damage to fish populations and economic fishing losses.
- Alteration of water levels and flows in ways that can be damaging to plant and animal communities.
- Discharge of water at temperatures as high as 60 degrees hotter than the water body from which it came – threatening aquatic ecosystems which cannot sustain such a temperature shock
- Discharge of toxic chemicals used not only to keep cooling water usable but also to support boiler operation and as part of waste treatment.
- The cumulative damage from intake and discharge from multiple plants along a river, coastal area or other important waters is poorly understood but can be causing considerably more damage than would occur from any single plant.

In addition, the demand for water by the electric utility sector increasingly competes with demands for other ecologic and economic needs. This competition is occurring throughout the U.S., including in regions considered to be water rich.

Fortunately, there are technologies that can avoid or minimize impacts and reduce water use.


JENNY HAGER

- Dry-cooling avoids significant water intake.
- Closed-cycle cooling reduces water use more than standard once-through cooling practices.
- Technological and process options exist to reduce or eliminate harmful plant discharges.

In 2002, EPA decided not to require dry cooling for all new plants, but to allow a case-by-case determination. In early 2004, EPA will decide what technologies need to be applied to existing plants. For this upcoming decision, we call on the federal EPA to require, at a minimum, closed-cycle re-circulating systems, and we advocate for the assessment of the cost/benefit of retrofitting with dry cooling systems as part of the permitting process.

We also call for a review and revision of the National Pollutant Discharge Elimination System (NPDES) program to insure that all chemical and thermal discharges meet the criteria of biological acceptability and that discharges are permitted, monitored and reported in a timely manner. Further, on water bodies with multiple power plants, we advocate for an evaluation of the cumulative impacts from water withdrawals and discharges.

Water and Power Plants: A Case of Scarcity

Water is becoming increasingly valuable for a multitude of uses. Power plant demands for water directly conflict with demands of a growing population. Periods of drought in the past few years in areas generally considered to be water rich have raised concerns across a broad spectrum of parties – regulators, utilities, environmental interests, citizen groups – about both the adequacy of water supply for electricity production and the impact of power plant operations on water quality.

As a result, communities are now reassessing how to best use this vital resource. Fortunately, there are many practical opportunities to significantly reduce both water use and water quality impacts from power generation.

This report examines the close relationship between power generation and water, including water use effects on competing uses, water quality and power system reliability. The report sets out an action agenda that, if implemented, can minimize the impacts from water used for power generation and positions us to ensure power system reliability, conserve scarce water resources, and protect lakes, rivers, streams and groundwater from the impacts caused by unnecessary withdrawals and discharges.

These issues are of critical importance, now, because:

- The number of proposed new power plants, when combined with the already high water usage figures for existing power plants, will have adverse impacts on the quality and quantity of U.S. waters, absent new approaches to power plant cooling.
- Increasing demand for energy, combined with recent periods of drought throughout much of the country, means that public attention is now directed towards the limits of local and regional water resources and how they should best be shared.
- The U.S. EPA is currently in the process of finalizing nationally applicable regulations for cooling water intake structures at power plants. Strong federal regulations would be a positive step forward toward significantly reducing power plant water use.

In sum, the time is ripe for a more comprehensive understanding of the full relationship between power generation and water use.

In 2002, electric generating plants in the US (fossil and nuclear) withdrew nearly 225 billion gallons of water per day.[1] This is the equivalent of over 250 million acre-feet or over 310 cubic kilometers (km) each year. For comparison, the volume of Lake Erie is 484 cubic km.

Water "withdrawn" refers to water removed from lakes, streams, groundwater and/or oceans. Depending on the cooling technology, water is either consumed or discharged after use back into the local surface or groundwater system, where it is available for subsequent use downstream. Nearly 80 percent of the water used by power plants in the U.S. comes from fresh surface waters (mostly rivers), less than five percent comes from groundwater, and eight percent comes from ocean waters. The balance comes from a range of small freshwater and municipal wastewater sources.[2] The power sector is a close second to agriculture in terms of fresh water withdrawals (39 percent compared to 41 percent of U.S total of freshwater withdrawals.) [3] Freshwater consumption from the power sector (water that is not discharged back into receiving waters after use) accounts for 3.3 percent of the nation's total freshwater use, which is slightly less than half the amount of water consumed by the country's residential and commercial users.

Water use by cooling systems

The primary use of water at steam generating power plants is for condensing steam, i.e., cooling steam back to water. Water is also used to make up the high-pressure steam for rotating turbines to generate electricity, purge boilers, wash stacks and provide water for employee use. Different cooling systems have distinctly different water needs.

Once-through cooling

As the name implies, once-through cooling uses water only once as it passes through a condenser to absorb heat. Intermittently, chlorine is added to control microbes that corrode the piping and diminish the cooling capacity. This heated, treated water is then discharged downstream from the intake into a receiving water body (usually, but not always, the original water source). While there is little water consumption with once-through systems, there are severe impacts to aquatic life as a result of water intake (entrainment and impingement) and water discharge (increased water temperatures and added chlorine). Once-through cooling is currently the most common technology in use nationwide, representing about 52 percent of generation.[4] *(See Figure 2)*

Re-circulating (closed-cycle) systems

Closed-cycle, or re-circulating, systems are the most common cooling system in states with limited water supplies. Re-circulating systems, by recycling water, reduce water withdrawals by 90 percent or more compared to once-through cooling systems. In a typical closed-cycle system, steam comes out of the turbine into a shell and tube condenser. Cold water is run through the tubes of the condenser; the cooling water heats up as the steam condenses back to water. The cooling water reaches the top of a cooling tower where some of it evaporates, forming a plume of steam above the towers. Most of the water does not escape as steam but dribbles back down through material that supports heat transfer, where it is cooled by 20-25°F and returned to the condenser. Cooling ponds and spray facilities are also used to augment water-cooling and reuse.

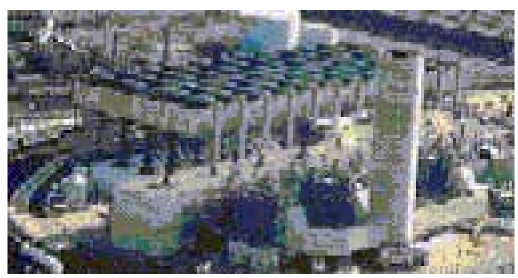
While re-circulating systems withdraw much less water than once-through systems, they consume a much greater portion – about 60-80 percent – of the withdrawn water.[5] The water also requires more chemical treatment because the fresh water used by the cooling systems contains naturally-occurring salts and solids, which can accumulate in the cooling equipment as water evaporates. To reduce deposits and prevent corrosion , at regular intervals some water is discharged (termed cooling tower blowdown), and fresh water is added that has been treated with chlorine and other chemicals (biocides) to control corrosion, mineral build up and microbes. The cooling tower blowdown water, which contains the residues of the chemicals used for water treatment, is discharged into receiving waters or designated wastewater collection ponds. *(See Figure 3)*

The U.S.EPA has recently issued rules requiring that the location, design, construction and capacity of cooling water intake structures at new power plants reflect the best technology available to minimize adverse environmental impact and protect fish, shellfish and other forms of aquatic life from being killed or injured. By this ruling, EPA has estimated that over the next several decades at least 90 percent of new power plant cooling systems will use closed-cycle technology.[6]

Dry cooling

A very small percentage of plants in the country – about one percent – use dry cooling technology, in which air, not water, cools the steam that drives the turbines. The most common type of dry cooling system in use in the U.S – direct-acting – works like an automobile radiator. The steam in the tubes is cooled by air blown over the outside of the tubes. The water demands from dry cooling are extremely low. There are no evaporative losses, and water consumption is limited to boiler requirements, including routine cleaning and maintenance.
(See Figure 4)

Although the market penetration of dry cooling is low, the technology has been in commercial use worldwide since the mid 1900s. Sixty-nine percent of proposed new capacity in Massachusetts includes provisions for dry cooling. Cogen Technologies' 640 MW plant in Linden NJ uses dry cooling and is one of the most efficient plants in the U.S. The 330 MW, coal-fired Wyodak Generating Station in Gillette, Wyoming was the first large power plant to install dry cooling technology in the U.S., in 1977. At that time, it had become clear that local rivers and groundwater could not otherwise support the cooling demands of the plant.



Cogen Tech Plant, Linden NJ

Multiple factors influence consumption and withdrawals

Power plant water use varies by location, fuel type and technology. To date, close-looped systems dominate in Washington, Oregon, Idaho, Nevada, Arizona, New Mexico, Colorado, Oklahoma, Utah and South Dakota. Once-through systems are more common in the remaining states.

Fuel and generation technology are major variables as well. As seen in Figure 1, steam electric generating plants have the highest water demand per KWh of electricity produced. Combined cycled gas plants, by contrast, produce more energy per unit of fuel, and this increased efficiency means reduced cooling requirements and therefore a lower demand for cool-ing water. This is in part because combined cycle gas plants get about two-thirds of their power from the gas turbine, which generates energy without using any steam.

Since the 1970s, there has been a trend toward constructing power plants that are more efficient and also cleaner consumers of water. For instance, combined cycle natural gas plants are projected to represent the largest growth in capacity over the next 20 years.[7] In addition to using between 40-60 percent less water per megawatt of power generated, their condensers rely on non-copper metals that cause less environmental damage.[8]

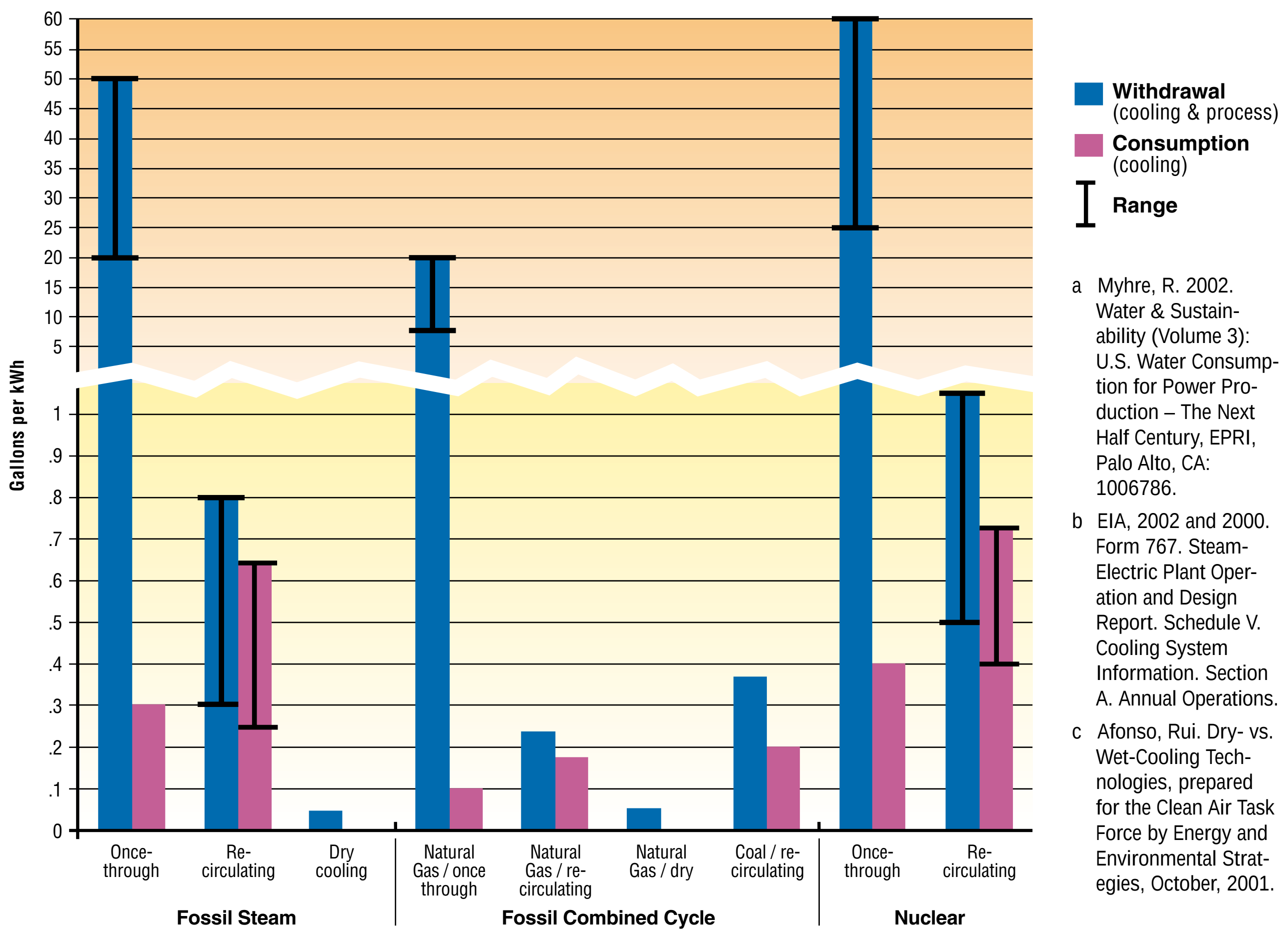
Despite this good news, plant retirement and turnover is not common. Many older, less water efficient generating units are still in operation today and are likely to continue in operation. The U.S. EPA has recently issued a controversial set of air rules related to the New Source Review program[9] that would make it even less likely that many older plants will be retired in the near future.

Non-cooling uses of water

During the process of electricity generation, impurities build up, not only in the cooling system, as previously described, but also in the boiler. To maintain quality, the water is periodically purged from the boiler and replaced with clean water. Purged water, termed boiler blowdown

Figure 1 –

Cooling Water Withdrawal and Consumption, by fuel and technology in gal/kWh[a, b, c]



a Myhre, R. 2002. Water & Sustainability (Volume 3): U.S. Water Consumption for Power Production – The Next Half Century, EPRI, Palo Alto, CA: 1006786.

b EIA, 2002 and 2000. Form 767. Steam-Electric Plant Operation and Design Report. Schedule V. Cooling System Information. Section A. Annual Operations.

c Afonso, Rui. Dry- vs. Wet-Cooling Technologies, prepared for the Clean Air Task Force by Energy and Environmental Strategies, October, 2001.

(not to be confused with cooling water blowdown), is usually alkaline and contains both the chemical additives used to control mineral buildup and corrosion, as well as trace amounts of copper, iron and nickel that leach from boiler parts.

Other sources of water discharge from the plant include the wastewater from cleaning the boiler and other metal parts, which results in pollutants such as iron, copper, nickel, zinc, chromium and magnesium. Water from non-cooling sources is discharged to either a public wastewater treatment facility or the plant's onsite wastewater treatment facility, from which the treated wastewater is subsequently discharged to a receiving water body.

At the fossil-fuel fired plant site, there are also other sources of water discharge not directly resulting from the actual combustion process. These include: coal pile runoff that forms when rain water or snow melt comes into contact with coal storage piles (this runoff is usually acidic and can contain high concentrations of copper, zinc, magnesium, aluminum, chloride, iron, sodium and sulfate); area storm sewers and leachate collection systems; and pyrite transport water generated from coal cleaning (containing suspended solids, sulfate, and metals found in coal). A small amount of water also often is with-drawn to support operation of air emissions controls.[10] Finally, the combustion solid waste stream, a mixture of fly ash, bottom ash, boiler slag and sludge from emissions control devices, typically is drenched with water and placed in ponds where the solids settle out. The wastewater remaining after this process is discharged, often untreated, into receiving waters. This wastewater can contain high concentrations of arsenic, cadmium, chromium, lead, selenium, sulfates and boron.

Figures 2, 3 and 4 illustrate how a "typical" fossil-fuel fired steam electric generating plant uses water under the three cooling regimes. While there are number of points throughout the generating and waste handling process where inputs of water are needed, the largest demand is for cooling (except in the case of dry cooling).

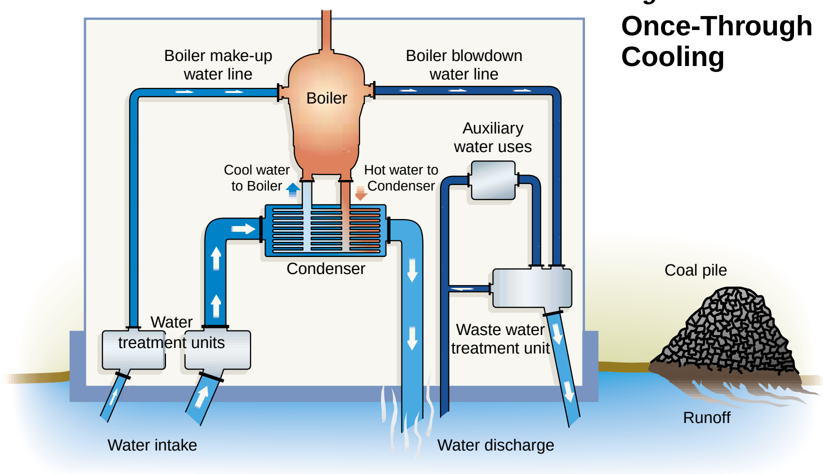


Figure 2 –
Once-Through Cooling

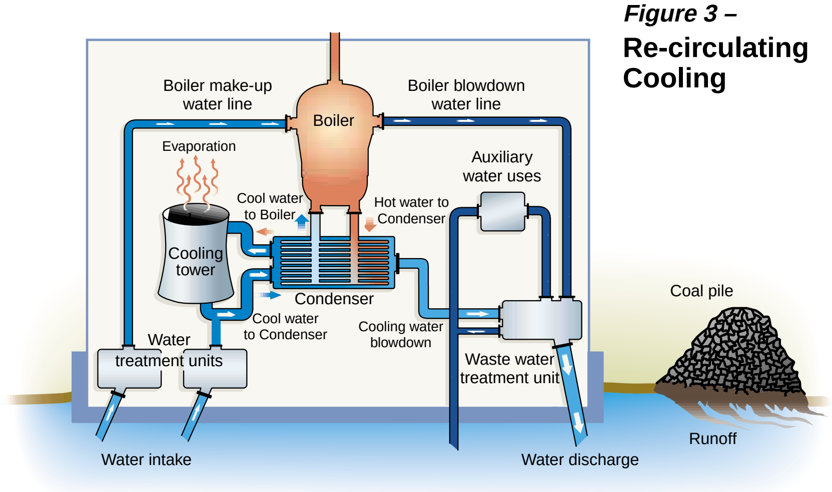


Figure 3 –
Re-circulating Cooling

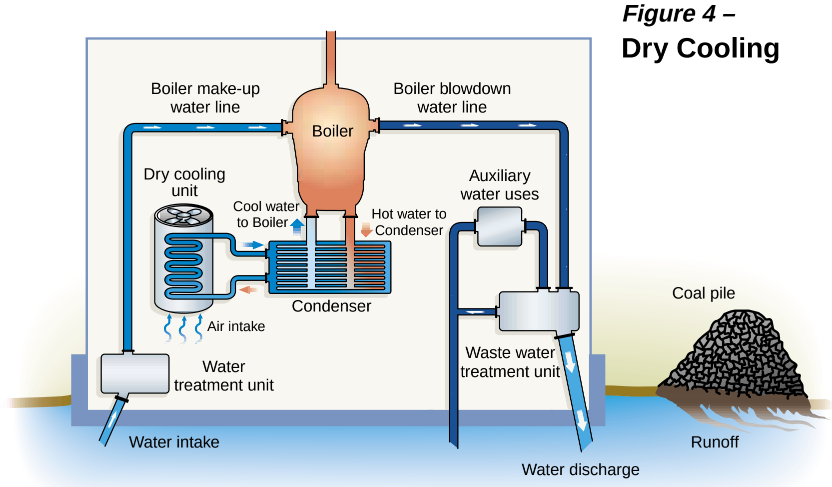


Figure 4 –
Dry Cooling

PAUL MIRTO / WWW.MIRTOART.COM

Common environmental impacts from water withdrawals and discharges

Both withdrawals and discharges from power plants cause disruptions to the hydrology of water systems. Timing, temperature, intensity/magnitude and location of the withdrawal and the discharge can all have negative impacts on water bodies.

At the intake

Water is brought into the plant through cooling water intake structures. To prevent entry of debris, the water is drawn through screens. Fish, larvae and other organisms are often killed as they are trapped against screens (impingement). Organisms small enough to pass through the screens can be swept up in the water flow where they are subject to mechanical, thermal and/or toxic stress (entrainment). Impingement and entrainment account for substantial losses of fish and seriously reduce opportunities for both recreational and commercial anglers.[11]

Recent evaluations have identified many water-body specific entrainment and impingement impacts, a sample of which is described below.

- Studies of entrainment during the 1980s at five power plants on the Hudson River in New York (Indian Point, Bowline, Roseton, Lovett and Danskammer) predicted year-class reductions (the percent fish kill of a given age class) of up to 79 percent, depending on fish species. An updated analysis completed in 2000 of entrainment at three of these plants predicted year-class reductions of up to 20 percent for striped bass, 25 percent for bay anchovy and 43 percent for Atlantic tom cod.[12]
- Impingement losses in the Delaware Estuary Watershed have been calculated at over 9.6 million age one equivalents fish per year (loss of 332,000 pounds of fishery yield). Entrainment-related losses came to nearly 616 million average equivalents of fish (loss of 16 million pounds of yield). Recreational fishing loss from combined impingement and entrainment losses are calculated at $5 million/year.[13]
- As a result of the cooling intake system at the Crystal River Power Plant (units 1, 2, and 3 – coal and nuclear), in Florida, 23 tons of fish and shellfish of recreational, commercial or forage value are lost each year. The greatest impact of the power station is on the highest trophic levels where the top predators – gulf flounder and stingray – have either disappeared or changed their feeding pattern.[14]
- In the Tampa Bay Watershed, economic loss from Big Bend, PL Bartow, FJ Gannon and Hookers Point plants range from $146,800-$162,200 for impingement and $17.2 - $18.1 million for entrainment. Combined recreational fisheries losses are estimated at $2.4 million/year.[15]
- The U.S. EPA evaluated entrainment and impingement impacts at nine facilities along a 500-mile stretch of the Ohio River. Extrapolating these results to 20 additional facilities, impingement losses came to approximately 11.6 million fish age 1 equivalents (15,500 lbs lost fishery) annually, and entrainment losses totaled approximately 24.5 million fish age 1 equivalents (40,000 lbs lost fishery) annually. Recreational-related losses were calculated at approximately $8.1 million/year.[16]
- About 20 miles downstream of Cincinnati on the Ohio River at the Miami Fort Power Plant, the combined average impingement and entrainment is about 1.8 million age one equivalent fish per year (298,027 impinged and 1,519,679 entrained).[17]

At the point of discharge

- ***Temperature***

Discharged cooling water is almost always higher in temperature than intake waters, making electric utilities the largest thermal discharger in the U.S.[18] Large temperature differences between intake and discharge waters (temperature deltas) can contribute to destruction of vegetation, increased algae growth, oxygen depletion and strain the temperature range tolerance of organisms.[19] Impacts can be multiple and widespread, affecting numerous species, at numerous life cycle stages. In some cases, plants and animals will simply not be able to survive in or adapt to the higher temperatures; warmer temperatures can send the wrong temperature signal to species, thus allowing life stages to get out of sync with normal cycles. In other cases, species that can handle (and thrive in) the warmer waters move into the warm-water plume and then become susceptible to the “cold shocks” that occur during periodic plant shutdowns.

Fish are not only affected by the spikes of high temperature, they also are impacted by the chronic and cumulative stress of fluctuations in temperature. Unfortunately, there is only a poor understanding of the cumulative nature and subsequent response of organisms to thermal stress,[20] in part because effects from thermal discharges are site-specific and dependent on characteristics of the receiving water body, volume and temperature of the discharge water, plant operation schedule and type of cooling system in use. In general, shallower waters that turn over more slowly have a harder time absorbing the thermal impact.

Because of the variable sensitivity of local ecosystems, there is no absolute value for an acceptable thermal discharge.[21] Some thermal discharges, however, are remarkably high. Of the data collected in 2002 by Energy Information Agency (EIA) that **included** temperature intake and discharge data points, over 150 once-through units (many plants have more than one unit) had summer or winter discharges with water temperature deltas in peak load months over 25°F, and 72 units had both summer and winter discharges exceeding 25°F. The actual number of units with high temperature deltas is likely to be even higher, since temperature data is frequently not provided to the EIA. Note that there are also large temperature differentials with re-circulating plants, however, the volume of water – and thus the extent of the thermal plume – is smaller. Figure 5 gives units in 21 states with summer and winter temperature deltas exceeding 25°F.

Figure 5 –

Units with summer and winter discharge water deltas exceeding 25°F[22]

Plant name (unit)	State	Affected Waterbody	Winter delta (°F)	Summer delta (°F)
J.E. Corrette (2)	MT	Yellowstone River	63	32
JM Stuart (1, 2 ,3)	OH	Ohio River	58	36
Harding Street (10)	IN	West Fork of the White R.	58	32
Cane Run (4)	KY	Ohio River	55	26
Brunner Island	PA	Susquehanna River	55	26
Baxter Wilson (1)	MS	Mississippi River	52	42
Bremo Bluff (4)	VA	James River	48	45
AES Somerset (1)	NY	Lake Ontario	48	35
J H Campbell (3)	MI	Lake Michigan	48	26
New Madrid (1)	MO	Mississippi River	47	31
Leland Olds (2)	ND	Missouri River	46	38
Edgewater (3, 4)	WI	Lake Michigan	44	29
Riverside (6, 7)	MN	Mississippi River	43	26
West Springfield (3)	MA	Connecticut River	36	31
George Neal North (1)	IA	Missouri River	34	29
William Wyman (3, 4)	ME	Casco Bay	34	27
Albright (1)	WV	Cheat River	34	26
Humbolt Bay (2)	CA	Humbolt Bay	33	28
Joppa Steam (5, 6)	IL	Ohio River	29	27
Valley (2)	TX	Valley Lake	28	28
Marshall (1)	NC	Lake Norman	27	28

What is a biologically acceptable temperature range?

Operating licenses typically include provisions to protect aquatic resources from thermal impacts. While some licenses list a specific temperature delta that cannot be exceeded, the Federal Clean Water Act includes a provision that allows for waiving thermal standards as long as a balanced population of fish, shellfish and wildlife can be demonstrated in the water body where the discharge occurs.[23]

Thus in many states, power plants receive a variance to temperature discharge requirements. For instance, many power plants on the Ohio River received cooling water discharges variances in the 1970s. While permit renewals have been handled differently by different Ohio River states, automatic renewals since the 1970s are commonplace.[24]

The concept of "demonstrated" balance has been widely interpreted. There are concerns about the criteria (or lack thereof) used to determine biological acceptability and the ease with which some states automatically renew the variance without re-evaluation. Unfortunately, acceptability is commonly defined to mean that aquatic organisms are not absent for the entire year. So even if discharges have dramatically altered populations and their life cycles, as long as there is evidence that some fish are present, some of the time, high discharge temperatures can be deemed acceptable.

- ***Chlorine, anti-fouling, anti-microbial and water conditioning agents***

Cooling water is treated with chlorine to limit the growth of mineral and microbial deposits that reduce the heat transfer efficiency, and re-circulating cooling water is treated with chlorine and biocides to improve heat transfer. But the same mechanisms that make chlorine and biocides effective in killing nuisance organisms make them effective in killing non-target organisms as well. This means that both will have an impact on a range of both desirable and undesirable species. Chlorine and its by-products are present in the discharge water plume and can be toxic to aquatic life, even at low concentrations.[25] High water temperatures can magnify the damaging impacts of chlorine.[26]

Chlorine and biocide discharges are subject to federal and state water quality standards. In the case of chlorine, engineers have predicted that the presence of chlorine byproducts in drinking water supplies – notably trihalomethanes – may result in even stricter limitations on the use of chlorine in cooling systems.[27] In the case of biocides, EPA keeps a database of biocides used in cooling structures throughout the country, but delegates approval decision to states. This has resulted in uneven and inconsistent application and enforcement of standards by state.[28]

- ***Non-cooling water discharges***

Common chemicals found in discharge waters are copper, iron and nickel that can leach from water condenser piping and end up in discharge waters, sometimes at toxic levels.[29]

Waters discharged from waste treatment have been shown to have high concentrations of arsenic, cadmium, chromium, lead, selenium, sulfates and boron.[30]

Intakes and discharges receiving regulatory attention

- For the first time in 20 years, the New York State Department of Environmental Conservation reviewed discharge permits renewals for three plants located adjacent to the Hudson River – Indian Point, Bowline Point and Roseton. These plants have used once-through cooling, withdrawing 1.69 trillion gallons annually and discharging heated water back into the Hudson River. [35] They are responsible for billions of annual deaths of aquatic species (fish, eggs and larvae). A draft permit released in November 2003 for the Indian Point plant identified closed-cycle cooling as the best available technology to minimize the impact of Indian Point.[36,37]
- The Brayton Point Generating Station in Somerset, MA converted a unit from a closed-cycle, re-circulating system to a once-through cooling water system in July 1984. The temperature increases from thermal discharges and impingement and entrainment losses as a result of the modification caused an 87 percent reduction in finfish abundance in Mt. Hope Bay.[38] In October 2003, EPA issued a permit requiring the annual heat discharge to the estuary be reduced by 96 percent, and water withdrawal from the Bay be reduced by approximately 94 percent.[39]

- Following disposal of coal combustion wastes in Pines, Indiana (northwest Indiana), water from at least 40 residential wells and one business well became contaminated and undrinkable with levels of manganese, arsenic, lead, boron and/or molybdenum far exceeding drinking water standards.[40] In addition, surface waters in a creek draining the landfill area were found to be polluted with boron and molybdenum from the landfill.[41] On January 28, 2003, the U.S. EPA signed an Emergency Removal Action order under Superfund, requiring parties responsible for dumping coal ash to provide emergency public water to one third of the town. Since the action was signed, tests from at least ten additional wells have found elevated boron levels. One well measured eight times the concentration of boron considered acceptable by the U.S. EPA.[42]

Changes in water levels and flows

Alteration in natural patterns of water levels and flows can occur as a result of both water intake and discharge, and these impacts often go unnoticed. Water levels and flows in lakes and rivers have a natural variability that varies both year-to-year and within a year. Plants and animals have adapted to these fluctuations and, in turn, this natural variability is critical to ecosystem health.[43] Withdrawals and discharges can alter this natural variability in different ways (e.g., withdrawing water during drought periods, discharging it during high flow) at different times of the year, in ways that can be damaging to plants and animals. Unfortunately, few regulations address impacts to water levels and flows. Without attention to this issues and clear standards that power plants (and other water users) must meet regarding water withdrawals and return flow, there can be serious consequences to ecosystem health.

Cumulative impacts

The issue of cumulative impact on water bodies goes beyond the question of thermal impact and expands to how the full range of impacts from power plant withdrawals and discharges might be affecting a single water body. The absence of a systematic evaluation means that large-scale impacts are likely going unnoticed.

When "zero" doesn't always mean zero discharge

Power plants that maintain and use water within their boundaries are often called "zero-discharge" facilities, based on the assumption that no post-generation water leaves the property. But "zero discharge" can be a misnomer. Public Service Company of New Mexico (PNM) claims the San Juan Generating Station in Fruitland is a "zero-discharge" facility. But that claim is being challenged by local residents who contend that waste from the mining operation and power plant have moved beyond the company's property lines and deposited large amounts of dissolved solids, including high concentrations of sulfates, into a nearby arroyo system, thereby contaminating local groundwater and sediments.[44, 45] The contaminated water is blamed for livestock deaths. One area rancher claims to have lost more than 1,000 sheep following exposure to the contaminated water downstream of the plant.[46] A lawsuit currently seeks reparations based on these claims.

Tributylin (TBT), banned in ship-bottom paints but registered for use in cooling towers

TBT represents what is probably the most toxic biocide used in cooling towers today.

It very toxic in aquatic environments and both persistent and bioaccumulative. As a first order impact, its use diminishes invertebrate populations. This impact on invertebrates moves up the food chain in two ways: 1) less food for predator species, like salmon, and 2) accumulation of TBT in fish where affected invertebrates are part of the food chain. There is evidence that fish show adverse effects at very low concentrations, including masculinization of feminine fish.[31] While TBT has a short lifetime in water, it persists and continues to have an impact for a much longer time in sediments.[32] The recognition of its harmful effects has prompted bans in ship paint for some vessels. While most of the attention is focused on banning its use in paints and fishing gear, TBT prohibitions for cooling are much less common, [33]and TBTs continue to be registered for use in cooling towers.[34]

Evaporation and settling pond waters can leak into groundwater and/or create toxic hazards for wildlife

Ponds that do not leak can also cause serious damage to migrating birds as they stop over at these highly contaminated waters. Problems include destroyed insulation and buoyancy – which can lead to hypothermia and drowning – and mortality from sodium toxicity or avian botulism as a result of ingesting the water high in contaminants and salts.[47]

Elevated selenium in ponds, either from combustion wastes or concentrated from naturally-occurring high levels as is found in western states, has been shown to cause adverse effects on bird health and reproduction.[48]

Sodium concentrations in evaporation ponds at the Jim Bridger Plant in Wyoming exceeded the toxicity threshold for aquatic birds, according to a U.S. Fish & Wildlife Service study.[49] To alleviate the conflict, the Bridger Plant installed a bird-deterrent – a non-lethal "bird-hazing" project[50] – designed to discourage any wildlife (mainly waterfowl) from entering the evaporation ponds.[51]

Even relatively clean water that is discharged from plants in dry areas can pick up salts and sulfates found in dry streambeds, thus resulting in high levels of sulfates and sediments in rivers and streams.

Water competition and water use conflicts

Water availability is emerging as an important issue not only in the southwestern U.S., where there has been rapid growth in electric power generation and limited options for ground and surface water sources, but also in areas usually considered water rich, such as the northeastern U.S.[55] According to EIA, 355 gigawatts of new generation capacity will be built between 2000 and 2020 to accommodate demand and retiring facilities.[56] If the majority of these new plants generate electricity using fossil fuels and also use closed-loop cooling technology, the additional water consumption demand could be as much as 2.39 billion gallons per day.[57]

Water availability is playing a growing role in permitting decisions, as the demand for water by the electric utility sector increasingly competes with demands from other sectors of the economy.[58] As water resources become more valuable, and as water has become better understood as a critical component in sustaining complex biotic systems, permitting authorities have begun to deny permits or condition them based on potential impacts to water resources. There are also concerns over less obvious impacts, too. Scientists have begun to better understand how the withdrawal of water from underground aquifers can lower water tables enough to cause subsidence of the overlying land;[59] reduce surface water flow; and dewater wetlands and streams, and private and public wells. And some fear that an over-commitment of water resources for power generation will close out future options for other economic opportunities.[60]

A recent assessment conducted for the Southern States Energy Board, a consortium of 16 states,[61] examined whether and how water availability has been considered in decisions to build merchant power plants in the South. The South has been one of the fastest growing regions of the country. Since the 2000 census, nine of the 10 fastest growing counties have been in the South: three in Texas, three in Georgia and one each in Virginia, Kentucky and Florida.[62] Between 1960 and 2040, regional water use and population will have more than doubled, placing increasing pressure on a water sources.[63] This is a region where groundwater consumption is outstripping recharge capacity and where surface water is subject to periods of drought. [64] Dry years in the 2000 and 2001 resulted in drought conditions throughout much of the region in 2002.

Due to rapidly growing demand and competition in electric markets, the number of proposed plants saw a rapid increase beginning in the mid-1990s. Since January

Water quality damage begins upstream...

The Case of the Big Sandy River

Water quality issues do not begin at the power plant. In October, 2000, water and sludge broke through the bottom of a mountaintop coal impoundment in Martin County Kentucky, spilling 300 million gallons of coal sludge into Coldwater and Wolf Creeks, and the Big Sandy River. Fish populations were hard hit, and lawns were buried under seven feet of sludge.[52] In December, 2003, a Virginia mine impoundment overflowed, spilling thousands of gallons of liquid coal waste into the headwaters of the Big Sandy River.[53]

Of the 635 coal waste lagoons located nationwide, about 240 have been constructed in areas (atop abandoned underground mines) that carry a risk of collapsing.[54]

1, 1996 roughly 500 merchant power plants have been proposed for the region; some have been built or are under development, while others have been postponed or canceled.

A preliminary report to the Southern States Energy Board identified varying levels of water concerns, understanding and regulatory authority.[65]

Florida – County officials, citizens' groups and regulatory agencies have expressed water shortage concerns about three projects: two in Lake County and one in Levy County.

Georgia – Regulators, local governments and citizens groups have voiced concerns about power plants competing with municipalities and general residential consumption demand for the public water supply.

Kentucky – A report assessing the effects of merchant power plants on state water resources concluded the task could not be completed since data on withdrawals did not exist. This lack of data has made state regulators realize that more information is needed to better assess the effects of new and proposed projects on water supply.

Louisiana – Policy makers and citizens group alike see new merchant facilities as a serious threat to water resources. The Legislature recently created a ground water commission, which for the first time gave State oversight to groundwater withdrawals. Local citizen opposition to increased demands placed on the Sparta aquifer apparently influenced the cancellation of Duke Energy's proposed project near Ruston.

Mississippi – Citizen groups have frequently voiced concerns about proposed power plants' impact on water supply, particularly groundwater. These concerns, however, do not appear to have had any impact on permitting.

North Carolina – The North Carolina Water Resources Research Institute has observed that since merchant power plants have not been required to provide information about water use, regulators are seriously limited in terms of their ability to assess how power plants will affect water resources.

South Carolina – Water shortage concerns have exerted an influence on the siting process and are believed to be the primary factor in the Public Service Commission's denial of a Cogentrix Inc.'s project in Greenville County. State regulators, county officials and citizens have all expressed concerns about the potential impacts of new and proposed merchant projects on water supply. These concerns have led to delays in application reviews.

Tennessee – Citizen groups cite high water consumption demands as the grounds for opposition to at least three projects: Dominion Energy's Ashland City and Centerville projects and the CME North America project in Columbia. Regulators in the Department of Environmental Control have indicated a preference in siting plants near sources of high water volume (i.e. Mississippi and Tennessee Rivers).[66]

Texas – Supply concerns voiced by citizens groups influenced the decision that required Entergy's project in Harrison County to change their water supply from Caddo Lake to treated wastewater.

Virginia – Water supply availability has been an issue in specific proposals, with concerns being raised by state regulators, local governments and citizen groups.

In addition to the issues found in the Energy Board report, there are mounting concerns about water supply in a number of southern states and in particular in Georgia and Florida, where development pressure remains high, and consumptive uses are growing. Water managers in Polk County Florida are at the center of a debate looking at how to support power generation, without having wells dry up.[67] The seriousness of Florida's water crisis is demonstrated by the expensive measures being pursued to increase the State's water supply, including the construction of desalinization plants in the Tampa Bay area. In February 2002, in response to drought conditions, a Georgia state judge reduced the amount of water Georgia Power could draw from the Chattahoochee River to cool new gas-fired units.[68] How water should be shared is at the heart of a decade long dispute between Alabama, Florida and Georgia.[69] Alabama and Florida argue that Georgia should be required to participate in a regional sharing plan with them.

Water supply concerns also have played a role in permitting decisions in other parts of the country:

- In August 2002, two proposed plants in Idaho – Cogentrix Energy Inc.'s 800-megawatt natural-gas-fired plant and Newport Northwest's 1,300-megawatt natural gas plant – were denied permits because of the projected impact on the Spokane-Rathdrum Prairie aquifer.[70] Based on this conflict, Idaho and Washington have embarked on a collaborative, comprehensive study of the aquifer and how and where water withdrawals impact the Spokane River.[71]

- Water considerations played an important role in the Arizona Corporation Commission's (ACC) decision to deny permits for the Big Sandy Power Plant, a 720-megawatt, gas-fired facility proposed for construction near Wikieup, Arizona and the Toltec Power Plant, a 1,800-MW gas-fired facility proposed for construction near Eloy, Arizona.[72]
- In response to recent increases in the number of proposals for new power plant construction, in the spring of 2003 the New Mexico Legislature considered enacting, for the first time, regulations requiring review of the cooling water efficiency of plants exceeding 50 MW.[73] The bill would require an analysis of water use by all new power plants and consideration of dry cooling.[74]
- The Washington State Energy Facility Evaluation Council recommended support for the Sumas 2 plant in northwestern Washington, one mile from the border with British Columbia. Following the December 2002 decision, Canada's National Energy Board decided to conduct an environmental assessment, including looking at the possible impact of the plant on the aquifer that moves from Canada to the United States.[75]
- In November 2003, the Wisconsin Public Service Commission approved the largest power plant project (615 MW) in state history, While the U.S. EPA and others contended the units should be treated as a "new" facility and therefore subject to EPA's requirement to use a closed-cycle cooling system, the Commission sided with WI Energies' position, that the coal-fired facility was an expansion of the Elm Road power station and therefore could use once-through cooling (under federal rules). In advocating that use of once-through cooling violated provisions of the Clean Water Act requiring use of Best Technology Available, opponents projected that the withdrawal of 3.2 billion additional gallons of Lake Michigan water every day would kill tens of millions of aquatic organisms through impingement and entrainment each year and cause damaging thermal impacts.[76] A lawsuit challenging the decision has been filed.

Veil, Argonne National Laboratory

Problems with Clean Water Act compliance

Across the country, state and federal agencies responsible for water quality are understaffed and often have difficulty reaching decisions that adequately protect water systems. Clear guidance is needed through federal and state regulation to address power plant water use.

Decisions about water withdrawals and plant siting permits are handled differently by different states, and fall within the jurisdiction of local, regional and state planning and regulatory agencies. Power plant water discharges are regulated largely at the state level, whereas rules for water allocation and use are grounded on state and local law.

Water discharges are regulated under the National Pollutant Discharge Elimination System (NPDES) program of the Clean Water Act (CWA). Most states have been delegated the authority to implement and enforce the CWA. In a few states, implementation authority lies with the U.S. EPA. State and local water quality regulatory agencies determine allowable temperature discharges.[77]

Little attention has been paid to the cumulative impacts of water intakes and discharge on a single water body, especially in cases when a particular water body comes under the jurisdiction of regulatory authorities in more than one state. The Ohio River Valley Water Sanitation Commission (ORSANCO) has initiated a protocol to address the problems of inconsistent regulatory decision making in states bordering the Ohio River.

The EPA has identified 53 chemicals as pollutants of concern in the wastewater discharged from steam electric plants.[78] A great deal of autonomy is granted to state regulators to choose additional biological and chemical parameters and/or decide which portion of the waste stream must comply with discharge limits. For instance, NPDES permits rarely set requirements for metals found in combustion wastes water, despite the fact that elevated discharges of arsenic, selenium, cadmium, chromium, lead, sulfates and boron are common.[79] Some NPDES permits require monitoring of these metals, but offer no discharge limits, even in cases where discharges from a facility at levels exceed concentration levels that have been identified as safe. More typically requirements for combustion waste waters only cover total suspended solids, oil and grease. Examples like this illustrate why the NPDES permitting process is not providing full protection from power plant discharges.

Serious concerns have been raised about problems that arise when so much authority lies in the hands of states without clear federal requirements.[80]

- **Lack of predictability.** This makes planning difficult for industry and leaves regulatory agencies uncertain as to what requirements are appropriate.
- **Lack of guidance.** Without clear national requirements, states often lack authority to pursue efforts to best protect ecological resources.

Other issues with state authority include:

- **Permit backlogs.** EPA has identified backlogs of NPDES permits as a nationwide problem and has set a goal to reduce backlogged permits to 10 percent, from a current national, industry-wide average of 17.3 percent.[81]
- **Compliance and enforcement problems.** In an analysis conducted on violations, compliance and enforcement of air, water and solid waste laws in the power plant sector, US EPA found that over 10 percent of the CWA violations were considered to be of "significant non-compliance."[82]

Notably, clearing the backlog of permits should not be an end in itself. Backlogs must be resolved inside a regulatory system that results in real, on-the-ground protection of the nation's waters.

In addition, working with the data submitted to the EIA also shows a lot of missing and clearly incorrect data (i.e. in a number of cases the outlet temperature is shown as lower than the inlet temperature).

- Find out more about local permitting decisions by visiting **www.rivernetwork.org**
- Find out more about proposed changes to the Clean Water Act at **www.cwn.org**

Drought and power production

During periods of drought, which now occur with marked regularity throughout many regions of the country and occurred in many regions of the country in the early 2000s, there are intense periods of water scarcity and competition between uses. Drought can produce several impacts that significantly reduce electric power generation based on site-specific engineering and hydrologic conditions. First, scarcity of local water resources can constrain or curtail power production at fossil power plants for reasons related to cooling system design and operation. Additionally, scarcity due to drought has direct impacts on surface cooling water source levels, which can fall below intake structures. Furthermore, drought conditions are often accompanied by periods of high ambient air temperatures, over extended time periods, which raise the temperature of receiving waters so that permitted temperatures of cooling system discharge waters are exceeded by the operation of the plant. Finally, areas that rely on hydropower are served a double whammy by the occurrence of drought conditions. When there is less water, less hydropower can be generated which in turn results in a larger demand on the steam plants, which at the same time are contending with the more limited water supply. [83]

Cooling systems that use lake water are designed assuming that the lake surface will be within a narrow range of normal elevation. However, under drought conditions, lake levels can (and do) fall below this range and cause plant shutdowns, for all the reasons set forth above. Similarly, drought-induced reductions in river flows can impact water intake and simultaneously reduce the ability of streams to assimilate heat loading from cooling system discharges. Assessments of several Texas power plants by University of Texas researchers has confirmed that the drought conditions that have occurred in Texas since 1900 would reduce or curtail power generation at plants in operation today.[84]

Drought conditions also intensify existing conflicts between all water users – power plants, domestic well owners, municipal water suppliers, farmers, wildlife advocates and recreational interests.

While drought clearly threatens power system reliability, opportunities do exist to modify existing fossil plants and to design new fossil plants to avoid or minimize drought-related reliability concerns. In most cases where drought could reduce power generation, dry cooling systems could be installed to allow unconstrained generation. While such plant modifications would alleviate drought susceptibility, they do require substantial time and investment.[85]

However, despite broad-based understanding of the issue, and the availability of solutions, drought impacts on unit operation are not typically assessed in the power plant permitting process at the state level. Furthermore, no systematic evaluation is known to have been conducted on the general susceptibility of power generation to drought. Assessing the impacts of drought or low-water flow conditions would be similar to flood planning, a federal requirement for all development in floodplain areas.

Technologies exist to conserve water and reduce impacts

Dry cooling technologies currently available reduce water demand and, as a result, minimize many of the water-related impacts associated with power production. The low intake requirements of dry cooling systems allow for more flexibility in plant siting since the facilities can meet their relatively minor water requirements using a variety of sources, including treated sewage effluent discharges. This, in turn, frees facilities from having to locate next to ecologically-sensitive waters.

Worldwide, there are more than 600 power plants using a dry cooling technology, in hot and cold climates alike. One of the largest systems is located at a 1,200 MW gas-fired combined cycle plant in Saudi Arabia, where ambient air temperatures can reach 122°F. In the U.S., dry cooling systems are used in over 50 operating plants, representing about 6,000 MW of installed capacity, and market penetration growing.[86]

While exact cost estimates vary, dry cooled plants are more expensive to build and operate than are wet cooled plants. Dry cooling at combined cycle plants would be expected to raise consumer electricity rates by 30.4 to 33.5 cents per month for the average household.[87]

In between wet and dry cooling are hybrid designs and modifications to existing systems. Dry cooling systems can be fitted with water nozzles to be used in the hottest weather, when air-drying is less efficient.[88] Other hybrid systems rely on wet cooling when there are adequate supplies of water and dry cooling during a dry season or drought year.[89]

In addition, there are systems where the water is recycled and essentially distilled off, leaving a solid cake of salts. The water, which is fairly pure, is reused. The resulting solid discharges can be disposed of in regulated landfills. This can virtually eliminate the discharge issue associated with cooling towers.[90]

Technologies also exist to handle waste from power plants in a manner that protects ground and surface waters through lined and covered impoundments, leachate collection and even use of fully closed tanks where water is treated before discharge.

The U.S. Department of Energy (DOE) also predicts that the electricity generating industry will be under increased pressure to minimize water use in the future.[91] In recognition of this, the DOE has funded three efforts to test and evaluate processes to reduce water consumption.

Moving ahead

Reducing the water intake demands of existing and new power plants requires policy changes at the national, state and local levels. Action at all levels is also necessary to reduce the impacts of power production on downstream water quality. Citizens can become much more involved in advocating for these policies, especially when plants undergo siting and permitting reviews.

Remove the veil from this hidden problem

Effective action will likely require building a solid foundation of public awareness as to how large the footprint of power generation is on our water resources. This "hidden" problem must be communicated effectively to key policy makers, affected interests (i.e. fisherman)) as well as the general public. Optimal success with the actions listed below will be facilitated once this foundation of public awareness is solid and deep.

- **Step One —**
  Characterize the damage to local waters
  Communicating the magnitude of power plant water damage will require producing a sound assessment of such damage in a watershed, river basin, coastal estuary or other important water system. As part of this evaluation, advocates should look at the cumulative and multiple impacts from thermal and chemical discharges that occur on a single water body. It may be possible to carry out such assessments with the help of academic institutions or public agencies, or it may be necessary for advocates to commission and/or produce such assessments themselves.
- **Step Two —**
  Develop a public outreach plan
  Once relevant water damage problems have been characterized, they need to be communicated to a wide audience. This communication might begin by identifying key public policy makers who could influence the necessary clean up or excessive water use, key constituencies – like sports fisherman – who could be expected to support actions that protect water quality and quantity, and also the general public. Once critical targets have been identified, a plan to efficiently reach these targets – through meetings, media work, contacting decision makers – should be prepared.

- **Step Three** —
  Implement the outreach plan
  As the plan is implemented, relevant knowledge gained in the outreach process should be fed back into ongoing outreach plan revisions.

Specific advocacy opportunities

The long-term target is to restore waters currently or prospectively damaged by power generation to pre-damage conditions (wherever possible) by reducing power generation water consumption and pollutant discharges to zero. Steps that can be taken now to reduce power plant damages to waters and thus make progress towards the long-term target are:

- ***For existing plants*** *– Citizens can…*
  Call on the federal EPA, and state permitting authorities, to require, at a minimum, that existing plants with once- through cooling be retrofitted with closed-cycle systems, and ideally that all existing plants upgrade to dry cooling systems over some reasonable period of time.
- ***For new plants*** *– Citizens can…*
  Advocate for dry cooling systems to be installed at all fossil-fuel fired combustion steam and combined cycle plants, as part of federal and state permitting processes.
- ***For all plants*** *– Citizens can…*
  - Seek an assessment of potential power system reliability problems that could result from local and region-wide drought conditions.
  - Advocate for implementation of corrective action based on this assessment to prepare for drought, including modification of cooling water systems.
  - Become informed about and advocate for appropriate controls over power generation water withdrawal from underground sources so as to avoid potential problems ranging form aquifer depletion to local land surface subsidence problems.
  - Advocate for power generation water withdrawals from surface sources in ways that minimize the impacts to fish.
  - Advocate for assessments that evaluate the impact of water withdrawals and discharges on water levels and flows.
- ***Water quality*** *– Citizens can…*
  - Advocate for the revision of existing power plant NPDES permits, at the time the permits are periodically renewed and subject to public comment, so as to include all toxic substances likely to be found in all discharges. Access to information about existing power plant NPDES permits, permit monitoring , etc. can be found at *www.rivernetwork.org* and *www.cwn.org*
  - Support effluent trading schemes that clearly result in an overall benefit to the quality of receiving water.
  - Advocate for appropriate restrictions on discharge of toxic substances and requirements for adequate discharge monitoring to ensure that NPDES permit limits are met.
  - Advocate for the required use of the safest processes possible to reduce corrosion, fouling and microbial growth in cooling systems and include any toxic substances used in revised NPDES water discharge permits.
  - Advocate for improved combustion waste management – for example the use of state of the art practices, including impermeable combustion waste impoundment liners and covers, groundwater monitoring, and leachate collection, treatment and clean up, to improve local ground and surface water quality conditions.
  - Raise local awareness of cooling water and waste treatment impoundment contamination and advocate for corrective action to avoid contamination of off-site areas.

Restoring an economic balance

Taking action to require existing and new power plants to reduce their use of and impacts on waters to minimal levels – which can be done with existing, affordable technology – will internalize the significant damages to our waters. By doing so, the price of such plants and the power they produce will increase to reflect the costs of clean up, which will in turn make competing power generation sources that do not damage our waters – like wind power or ultra-clean fossil power with dry cooling – more competitive. This will help restore the economic balance between dirty and clean power sources and will facilitate ultimate conversion of our current fleet of dirty power plants to much more sustainable power technologies.

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