# A HOLISTIC LOOK AT MINIMIZING ADVERSE ENVIRONMENTAL IMPACT UNDER SECTION 316(b) OF THE CLEAN WATER ACT

**(Abbreviated Title - "Holistic Look at Minimizing AEI")**

**John A. Veil,[1,*] Markus G. Puder,[1] Debra J. Littleton,[2] and Nancy Johnson[2]**

[1] Argonne National Laboratory, 955 L'Enfant Plaza, SW, Suite 6000, Washington, DC 20024;

[2] U.S. Department of Energy, Office of Fossil Energy, 1000 Independence Avenue, Washington, DC 20585.

* Corresponding author

*Email addresses:* John Veil - jveil@anl.gov; Markus Puder - puder@anl.gov; Debra Littleton - debra.littleton@hq.doe.gov; Nancy Johnson - nancy.johnson@hq.doe.gov

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**Abstract**

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 for minimizing adverse environmental impact." As the U.S. Environmental Protection Agency (EPA) develops new regulations to implement section 316(b), much of the debate has centered on adverse impingement and entrainment impacts of cooling water intake structures. Depending on the specific location and intake layout, once-through cooling systems withdrawing many millions gallons per day can, to a varying degree, harm fish and other aquatic organisms in the water bodies from which the cooling water is withdrawn . On the basis of this argument, opponents of once-through cooling systems have encouraged EPA to require wet cooling tower

or dry cooling tower systems as the best technology available, without considering site-specific conditions.

However, within the context of the broader scope of the CWA's mandate, this focus seems too narrow. Therefore, this paper examines the phrase "minimizing adverse environmental impact" in a holistic light. Emphasis is placed on the analysis of the terms "minimizing" and "environmental." "Minimizing" does not equal "eliminating." Technologies may be available to minimize adverse environmental impacts without totally eliminating such impacts. The other key word, "environmental," was chosen by Congress in lieu of other more narrowly focused terms like "impingement and entrainment," "water quality," or "aquatic life." In this light, best technology available for cooling water intake structures must minimize the entire suite of environmental impacts – as opposed to just those associated with impingement and entrainment. Wet and dry cooling tower systems work well to minimize entrainment and impingement, but they introduce other equally important impacts because they impose an energy penalty on the power output of the generating unit. The energy penalty results from a reduction in plant operating efficiency and increased internal power consumption. As a consequence of the energy penalty, to achieve the same net output, power companies must generate additional electricity, leading to additional environmental impacts associated with extraction and processing of the fuel, air emissions from burning the fuel, and additional evaporation of fresh water supplies during the cooling process. Wet towers also require the use of toxic biocides that are subsequently discharged or disposed.

**Synopsis**

According to section 316(b) of the Clean Water Act, cooling water intake structures must reflect the best technology available for minimizing adverse environmental impact. Technologies such as wet and dry cooling towers are effective at reducing the effects of impingement and entrainment, but they may introduce other adverse environmental impacts. This paper analyzes the terms "minimizing" and "environmental" in the context of major policy decisions regarding cooling water intakes.

## Introduction

The U.S. Environmental Protection Agency's (EPA's) rationale for proposing rigorous new facility intake structure requirements was based on the Agency's desire to minimize the number of aquatic organisms that are impinged (trapped on an intake structure during cooling water withdrawal) or entrained (carried by the cooling water flow through the entire cooling system). While these are real environmental impacts, some stakeholders in the regulatory process have viewed these impacts as the only basis for decision making. Some of the technologies that have been proposed to date (wet cooling towers) and others that have been supported by the environmental community (dry cooling towers) are extremely effective at minimizing impingement and entrainment impacts, but their use introduces other types of adverse environmental impacts. This paper discusses a broader, more holistic point of view that evaluates all types of environmental impacts – impingement, entrainment, and several others – to determine the overall adverse environmental impact.

Much of the discussion contained in the following sections is gleaned from the years of active debate surrounding the section 316(b) issue. Some of the points have been raised previously by the authors, while others have been taken from the extensive public record that has been presented to EPA through several public meetings and during open comments periods.

## Power Plant Cooling Systems

In 1999, more than 60% of the utility power generating capacity in the United States (382,270 MW) utilized the steam electric process.[1] At nuclear and fossil-fuel power plants, electricity is produced by heating purified water to create high-pressure steam. The steam is expanded in turbines, which drive the generators that produce electricity. After leaving the turbines, the steam passes through a condenser that has multiple tubes and a large surface area. A large volume of cool water circulates through the tubes, absorbing heat from the steam. As the steam cools and condenses, the temperature of the cooling water rises.

Most power plants use either once-through cooling or closed-cycle cooling. Once-through cooling systems withdraw large volumes of water, typically in the range of tens of millions to billions of gallons per day, from a river, lake, estuary, or ocean. The water is pumped through the condenser and finally returned to the same or a nearby water body. Closed-cycle cooling systems receive their cooling water from and return it to a cooling tower and basin, cooling pond, or cooling lake rather than to a natural surface water body. Because evaporation and planned cooling tower blowdown removes cooling water from the evaporative system, regular additions of "makeup" cooling water are needed. Makeup volumes are much lower than daily once-through volumes, and may range from hundreds of thousands to millions of gallons per day.

The most commonly used type of closed-cycle cooling systems employs wet cooling towers, where water rejects heat to the atmosphere through evaporation and sensible heat transfer to the ambient air flowing through the tower. The air flow through the tower is maintained by fans (mechanical draft) or by convective currents created by the shape of the tower (natural draft).

Some stakeholders have advocated the dry cooling tower as being preferable because it requires even less makeup water than a wet tower. Although few dry towers have been installed in power-plant-sized applications (capacity of several hundred MW) to date, the most likely type for use in a retrofitted system would be an indirect dry tower. This type of system circulates hot water from the condenser to numerous finned tubes that are cooled by large diameter fans. The cooled water is then returned to the condenser to repeat the cycle. The heat is lost to the atmosphere only by sensible heat transfer. The system does not rely on evaporation. An automobile radiator is a type of indirect dry cooling system, although it operates on a much smaller scale than a power-plant-sized system.

Another type of dry cooling system, the direct dry cooling tower, is not practical for retrofitting at power-plant-sized units because it requires significantly larger ductwork to move air. Most existing power plants do not have adequate space available for the additional ductwork. The system uses a finned tube heat exchanger as a direct air-cooled condenser. The steam is condensed inside finned tubes; whereas the indirect dry system condenses steam in a conventional condenser and then circulates the hot condenser effluent to the tower. The heat of condensation is transferred directly to the surrounding atmosphere by using large fans to blow ambient air over the tubes.

## Legal and Regulatory Considerations

Section 316(b) of the Clean Water Act

Steam electric power plants and other industries that withdraw cooling water from surface water bodies (e.g., pulp and paper, iron and steel, chemical, manufacturing, petroleum refineries, offshore oil and gas production) must comply with the terms of section 316(b) of the Clean Water Act (CWA) enacted by Congress in 1972:

> "Any standard established pursuant to section 301 or section 306 of this Act and applicable to a point source shall require that the location, design, construction, and capacity of cooling water intake structures reflect the best technology available for minimizing adverse environmental impact."

This single statutory sentence has spawned numerous biological studies and technological and operational plant modifications. The cost of these actions has been very high.

Implementation of Section 316(b)

In 1976, the EPA promulgated final section 316(b) regulations (April 26, 1976; 41 FR 17387). However, those regulations were successfully challenged by a group of 58 utilities [*Appalachian Power Co. v. Train*, 10 ERC 1965 (4th Cir. 1977)]. In 1979, EPA formally withdrew its section 316(b) regulations (June 1979; 44 FR 32956). As a consequence of the vacuum created by the absence of federal regulations, states adopted their own cooling water intake regulations implementing the section 316(b) requirements. The broad statutory language facilitated widely differing interpretations by the states. Some adopted comprehensive programs, others imposed less rigorous requirements, and others never developed any formal regulations.

In the mid-1990s, a coalition of environmental groups, headed by the Hudson Riverkeeper, filed suit against EPA over failure to repromulgate section 316(b) regulations [*Cronin, et al. v. Reilly*, 93 Civ. 0314 (AGS)]. On October 10, 1995, the U.S. District Court, Southern District of New York, entered a Consent Decree between the parties, directing EPA to regulate cooling water intake structures. Under the Consent Decree, EPA agreed to propose regulations by June 1999 and promulgate a final rule by 2001. The Consent Decree was modified on November 21, 2000, to: (a) finalize new facility regulations by November 9, 2001; (b) propose existing source utility and non-utility power producer regulations by February 28, 2002, and issue final regulations by August 28, 2003; and (c) propose regulations by June 15, 2003, and issue final regulations by December 15, 2004, for other existing facilities not covered in (b) above.

EPA's New Facility Proposal

EPA proposed section 316(b) regulations for new sources on August 10, 2000 (65 FR 49060). Under this proposed rule, most new facilities would have to install closed-cycle cooling systems (nearly all of these would use cooling towers). During public meetings and in written comments, the environmental community and several states have supported the use of dry cooling as the appropriate technology for addressing adverse environmental impacts. The final outcome of the new source rule is still pending.

EPA's Upcoming Rules for Existing Facilities

EPA is in the process of developing cooling water intake regulations for existing utility and non-utility power generating facilities but has not yet revealed any details of its proposed rule. There is a potential that at least some of the requirements in the proposal for new sources may be carried over to the rule for existing facilities. About 44% of the U.S. steam electric power plants employ once-through cooling systems.[2] If the final existing facility rule requires many or all of these plants to install dry- or wet-cooling tower systems there could be serious impacts on electricity costs and availability. Moreover, such a decision could trigger other significant secondary environmental impacts beyond impingement and entrainment. These other impacts are discussed in detail below.

Legislative History

The language of section 316(b) is quite short and easily subject to much interpretation. Legislative history may prove to be a powerful tool for ascertaining the Congressional intent behind section 316(b). Legislative history consists of all legislative events that transpired throughout the process of enacting or defeating proposed legislation. The documentation generally includes the bill, the drafts and the preceding mark-up documents, the testimony at hearings, the reports or studies commissioned by the legislature, the chronology of voting, the floor debates, and the message of the executive accompanying the signature or veto of the bill.

Little legislative history exists with respect to section 316(b). The language appeared suddenly, without any further explanation, in the Federal Water Pollution Control Act (the law that was modified in 1972 to become the CWA) Conference Report under the heading "Regulation of Thermal Discharges" in "Title III–Standards and Enforcement." The Conference Report provided no additional commentary but merely included the language that was to become law. Neither the Senate nor House bill had included intake structure language like the section 316(b) language added by the conference committee. In fact, the Senate bill, S. 2770, did not even contain a specific provision governing thermal discharges;[3] whereas the House bill, H.R. 11896, had provided the following language relating to thermal discharges:

> "...The regulations shall require any person proposing to make such a discharge to consider all alternative methods for controlling such a discharge, including, but not limited to (1) utilization of available water bodies or cooling devices, including once-through cooling, mixing zones, cooling ponds, spray ponds, evaporative or non-evaporative cooling towers, (2) dilution of heated waters with cooler waters, and (3) an alteration of the outlet configuration. In evaluating such alternative methods of control consideration shall be given to (1) their relative engineering and technical feasibility, (2) their relative social and economic costs and benefits, (3) their relative impact on the environment, considering not only water quality but also air quality, land use, and effective utilization and conservation of natural resources, and (4) methods of minimizing adverse effects

and maximizing beneficial effects of such discharges."[4]

Section 316(b) has never been amended. Although, over the years, reform bills were periodically introduced, no legislation has been passed. Thus, the minimalist language of 316(b) remains as initially enacted.

**Interpretation of Section 316(b) Language**

The following sections discuss and analyze two statutory terms that are central to section 316(b) – "minimizing" and "adverse environmental impact".

Minimizing

"Minimize" and the related terms "minimum" and "minimal" are used throughout the CWA and its implementing regulations but are never defined. In the absence of a formal statutory or regulatory definition, two approaches can be used for ascertaining the meaning of the term. Consulting a dictionary provides a sense of the common usage of the word. This approach is often used by courts to ascertain the plain meaning of terms. "Minimize" is defined in one dictionary as "to reduce to the smallest possible amount, extent, size, or degree."[5] Another dictionary defines the term as "to reduce or keep to a minimum", and defines "minimum" as "the least quantity assignable, admissible, or possible."[6] Neither definition implies complete elimination.

A second approach involves searching for the context and usage of the term in existing laws and regulations. The phrase "at a minimum" is commonly used in the CWA regulations and implies that the expected value for the parameter in question is a defined value greater than zero. Another example can be found on page 28869 of EPA's recent Notice of Data Availability for the section 316(b) regulations (May 25, 2001; 66 FR 28853). The relevant text states that: "EPA would not define these technologies [closed-cycle cooling and extremely low approach velocities] as BTA for 'minimizing' adverse environmental impact but instead determine that they avoid adverse environmental impact altogether." In this example, EPA emphasizes the difference between a technology that minimizes impacts and one that avoids or eliminates impacts entirely.

The concept of minimizing entails making a value judgment relative to the smallest amount of effect that is possible or acceptable. At each installation that falls under the purview of section 316(b), it is necessary for accuracy and optimal decision-making to make a site-specific evaluation of the relevant factors that may contribute to adverse environmental impact.

During the past few years, EPA has evaluated various types of technologies that can effectively reduce impingement and entrainment impacts (e.g., wedge wire screens, fine-mesh traveling screens with a fish return system, Gunderbooms). The degree of impact reduction achieved by these technologies varies at different locations, but in some instances they may perform well enough to be construed as effectively minimizing adverse environmental impacts.

During EPA's section 316(b) public meetings, some stakeholders have expressed their opinion that the threshold for minimization should be "one dead fish equals adverse environmental impact." The evidence presented in the previous paragraphs demonstrates that the loss of one fish does not equate to adverse environmental impact.

Adverse Environmental Impact

"Adverse" connotes undesirable attributes. In the context of section 316(b), adverse has been interpreted as relating to the quantities of a water or air pollutant, the extent of biological harm through impingement or entrainment, or the amount of water lost through evaporation, among other circumstances. Adverse is not an absolute but a subjective term that should be assessed in relationship to the entire system or universe under review. For example, does the addition of 5 kg/day of nitrogen to a water body cause an effect that could be considered an adverse impact? If the water body is a small pond or slow-flowing stream, the nitrogen addition would likely cause an undesirable adverse effect. If the nitrogen enters a large river or an estuary with a total nutrient budget of thousands of kilograms of nitrogen, the consequences (if any) would be small and not observable. No adverse impacts would be expected in this latter case. Another example involves entrainment loss of fish larvae. In a small water body that hosts limited populations of important species, the entrainment of 1,000 larvae might have a critical adverse impact. However, in a large water body with extensive populations of species, the loss of 1,000 larvae would be insignificant to the species population, the food chain, and the overall ecosystem. In this light, the entrainment would not pose an adverse impact.

The other relevant word in section 316(b) is "environmental." In a regulatory context, the term encompasses a wide range of attributes of the natural world, including, among others, air, water, land, noise, and their relationship to one another. In the section 316(b) debates of recent years, EPA has interpreted "environment" to mean direct effects on aquatic organisms (i.e., impingement and entrainment). These are very real impacts that are attributable to water intakes. However, the CWA mandates are not well served by this narrow focus. In fact, a whole suite of environmental impacts is associated with any type of cooling water intake or cooling water system. For each intake or system, the relative importance of each type of impact will vary. For a comprehensive impact determination, the evaluator must consider the composite and cumulative impacts, along with any benefit offered by a particular cooling water intake system. The following sections discuss important environmental impacts and describe their relative weight for once-through cooling systems, wet cooling tower systems, and indirect dry cooling tower systems.

**Types of Adverse Environmental Impacts**

<u>Impingement and Entrainment</u>

As a general rule, as more water is withdrawn from a surface water body, the higher the number of aquatic organisms that are impinged on the intake structure and entrained through the cooling water system. Following this assumption, a cooling system that reduces the volume of water withdrawn will concomitantly reduce the number of organisms injured or killed by impingement and entrainment. This relationship is not linear (e.g., 10 times less flow does not necessarily result in 10 times less impingement and entrainment) and must be evaluated on a site-specific basis. Moreover, not all impinged and entrained organisms are killed or otherwise removed from the ecosystem. Nevertheless, the adverse impact associated with impingement and entrainment will be reduced when less cooling water is withdrawn. The highest impact in this category is associated with once-through cooling systems. Power plant once-through cooling systems typically withdraw in the range of tens of millions to billions of gallons per day. The volume of makeup water required for wet cooling towers is many times less than that used in once-through systems. The percent reduction varies but generally falls in the range of 1 to more than 10% of the once-through flow volume. Dry towers use even less cooling water than wet cooling towers. Cooling systems that rely on moving large volumes of air by fans (mechanical-draft wet towers and dry towers) may create their own form of impingement and entrainment. Insects and birds may be drawn into the intake plumes of large fans. Larger organisms can be trapped on the exterior of the fans or their intake coverings (like insects caught on automobile radiators). Smaller organisms can be pulled through the moving fan and injured or killed. The authors are not aware of any published literature quantifying this impact, but the parallels to aquatic impingement and entrainment are obvious. Potentially, large batteries of fans may inflict harm to local populations of endangered insects or birds or important pollinator species. To place this in perspective, a dry tower installed to cool a power plant-sized unit might have banks of fans covering several acres. For example, a dry tower system at a 40-MW geothermal power plant near Reno, Nevada employs 240 fans covering a large surface area. Photographs of that facility are available at http://home.nvbell.net/sbgeo/steamboat.html.

Energy Penalty

Steam condensers are designed to produce a vacuum at the outlet end of the turbine, thereby increasing the efficiency of the system. The temperature of the cooling water exiting the condenser affects the performance of the turbine – the cooler the temperature, the better the performance. As cooling water temperatures decrease, a higher level of vacuum can be produced and additional energy can be extracted. On an annual average, once-through cooling water has a lower temperature than recirculated water from a cooling tower. As a result of switching a once-through cooling system to a cooling tower, less energy can be generated by the power plant from the same amount of fuel. In addition, cooling towers use more electricity for pumps and fans than does a once-through system. The net output of a plant that has converted its cooling system from once-through to a cooling tower will be reduced through both of these mechanisms. This reduction in energy output is known as the "energy penalty."

As stated in a 1992 report funded by the U.S. Department of Energy (DOE), the majority of literature values for the energy penalty associated with retrofitting fossil-fueled plants using once-through cooling with wet cooling towers were clustered in a band between 1.5% to 2.5%.[6] This means that a plant now equipped with a wet tower will produce 1.5% to 2.5% less electricity on an annual average than previously with a once-through system, while burning the same amount of fuel. Results for nuclear power plants showed greater variability, ranging between 1% and 5.8%. The data points were not as clearly clustered in a narrow range when compared with the data for the fossil plants. The authors of that report selected a range of 2% to 3% for the decrease in net electrical power that could be experienced if existing nuclear power plants retrofit from once-through to wet cooling.[7]

A report being prepared by the DOE, the National Energy Technology Laboratory (NETL), and the Argonne National Laboratory [as of the submittal deadline for this paper, a working draft of the energy penalty analysis was undergoing review for publication later this year] calculates the energy penalties resulting from converting plants using once-through cooling to wet towers and to dry towers.[8] In that draft analysis, the energy penalties are estimated for the hottest time of the summer months when electricity demand would also be at its peak by modeling hypothetical 400-MW coal-fired plants in five regions of the country with an ASPEN simulator model. The preliminary results indicate that conversion of a plant to a wet tower could cause energy penalties ranging from 2.8% to 4.0%. Conversion to an indirect dry tower, where possible, could cause energy penalties ranging from 8.9% to 14.1% under conservative design assumptions, and 12.7% to almost 18% under a more realistic set of design assumptions.

The implications of the energy penalty are quite important from an environmental standpoint. In order to make up lost energy, additional fuel would have to be burned at the affected plants, at other plants within the power grid, or at completely new units that would have to be constructed. In addition, extraction and combustion of the additional fuel would cause several new adverse environmental impacts.

*Fuel:* In most situations, the most probable type of generating unit used to make up the lost energy would be a fossil-fueled unit. The process of extracting fossil fuels impacts water and air, solid waste generation, and land use. The process of moving the incremental fuel to the power plants consumes additional fuel for pumps or engines in transportation equipment.

*Air Emissions:* As fossil fuels are combusted, they give off a range of undesirable air emissions. The pollutants of concern include sulfur dioxide, nitrogen oxides, mercury, particulate matter, and carbon dioxide. It has been estimated that a plant converting from a once-through cooling system to a wet cooling tower increases its carbon dioxide emissions by 22 tons/year per megawatt for oil and gas and by 58 tons/year per megawatt for coal.[9] The DOE/NETL/Argonne report[8] will also include estimates of annual energy penalties and air emission.

Water Quality

Discharges of once-through cooling water and cooling tower blowdown to surface waters are subject to the conditions of National Pollutant Discharges Elimination System (NPDES) permits. Once-through cooling water may contain chlorine used as a biocide, but otherwise is unlikely to contain toxic chemicals added by either the generating or the cooling processes. A wide range of toxic chemicals, including biocides (chlorine and other, more toxic chemicals), corrosion inhibitors, and scaling inhibitors, may be added to cooling towers.[10] Portions of the recirculating water in wet cooling tower systems are blown down periodically. These blowdown effluents contain some of the toxic chemicals that had been added to the towers. Dry towers will also have blowdown effluents, but the volume will be lower than in the case for wet towers.

Heated discharges of once-through cooling water can have positive or negative effects. In temperate climates, warm discharges during the winter can enhance and sustain fish populations. At many locations, however, excessive heat can be damaging. Removal or addition of heat can yield different impacts on aquatic communities, depending on site-specific circumstances.

Water Quantity and Consumption

The first type of water quantity impact to be considered is related to availability of sufficient water for the cooling needs without causing adverse impacts on the water body and its other uses. Historically, power plants were sited near large bodies of water that could supply large volumes of once-through cooling water. As the use of wet cooling towers increased, new plants were also sited in locations where smaller volumes of water were available. Plants with dry towers need very little water and can be sited in a wide range of locations. Plants cannot be sited on water bodies where cooling water withdrawal could reduce the water level in the water body to a point where significant habitat is lost or water quality conditions become undesirable. Plants using once-through cooling systems withdraw large volumes of water, although they return nearly all of that water to the water body at the same or a nearby location. Plants using cooling towers must also consider water availability, particularly if they are situated on a water body that is too small to support a withdrawal of several million gallons per day of makeup water that is not returned to the water body.

The second type of water quantity impact relates to evaporation. Many fresh water bodies face heavy demands on their water. Any cooling system use that removes fresh water from those systems will need to compete with other existing and future uses. Plants with once-through cooling systems do not directly evaporate water. Virtually all water used for cooling is returned to the surface water body. However, the returned water is warm and will raise the temperature of the receiving water body to an extent that may increase the rate of natural evaporation from the surface of the water body.

In contrast, wet cooling tower systems intentionally evaporate water as an intrinsic part of the cooling process. The authors are not aware of any literature studies that estimate the difference between surface evaporation due to once-through cooling water discharges and direct evaporation in wet towers. Intuitively, the cooling towers would be expected to consume more water. One study estimates that when plants are converted from once-through cooling to cooling towers, an additional 15 gallons per minute of fresh water would be evaporated for each converted megawatt of generating capacity. This estimate assumes a conservative energy penalty of just 1%.[8] For a higher percentage energy penalty, the impacts would be proportionally higher.

Dry cooling towers do not rely on evaporation for cooling. Therefore, the evaporative losses associated with dry towers are very low.

Solid Waste

Debris, trash, and other waterborne solids are captured by the bar racks at cooling water intakes. The volume of solids corresponds to the volume of water that is passed through the intake structure. Therefore, once-through systems are likely to generate a larger volume of solid waste than closed-cycle systems. Wet towers accumulate sludge in the bottom of the towers that must be removed periodically. Dry towers collect some amount of airborne debris (e.g., leaves, paper) on their intake screens. The relatively small solid waste volumes attributable to all three types of systems are unlikely to cause adverse environmental impacts.

Noise

Noise emissions are recognized as adverse environmental impacts on workers, nearby residents, and wildlife. Like many other major industrial facilities, power plants can be noisy. Once-through cooling systems do not add appreciably to the overall background noise at power plants. However, mechanical-draft wet towers use banks of fans that do contribute to plant noise levels, particularly in the vicinity of the towers themselves. Because of the large surface area needed to house the towers (up to several acres) and the large number of fans, dry towers are likely to be noisier than the other types of cooling systems.

Land Use/Habitat

It is difficult to assess what type of cooling system is likely to have the greatest adverse impact on land use. Once-through systems need larger capacity intake structures that typically are built in the water body or on the shoreline. Some surface water intakes require pipes that extend meters to kilometers offshore. Shore-side facilities for once-through systems are smaller than those for closed-cycle systems, however. The banks of towers, pumps, and piping used by closed-cycle systems may occupy significant land space.

Plants that convert from once-through systems to closed-cycle systems will consume more fuel. The process of extracting the fuel can disrupt terrestrial or aquatic habitats. An indirect land use/habitat consideration was previously mentioned in the energy penalty section.

Plumes/Air Circulation

Once-through systems do not generate any significant plumes of water vapor, nor do they influence local air circulation. Wet towers can release visual plumes. In remote locations, these effects may be merely aesthetic, but plants located in urban areas, near major highways, or in the flight paths of airports could create adverse impacts. These impacts, though real, may not be fall under the purview of "environmental impacts," depending on how broadly the term "environmental" is defined by a decision-making body. Such effects may be more correctly interpreted as safety impacts.

As a result of the large amount of air that must be moved through dry cooling systems, large banks of fans may affect local air circulation patterns. The authors are not aware of any research on this issue, but potentially this could affect windborne seed distribution and could establish small microclimates around the power plants. It is not known whether these impacts would be adverse, positive, or neutral.

**Discussion**

The language of section 316(b) is brief, leaving appreciable room for alternative interpretations. The authors believe that a holistic approach to section 316(b) leads to the most rational interpretation. The preceding paragraphs suggest that the language of section 316(b) directs regulatory decision makers to consider a wide range of adverse environmental impacts. Moreover, the decision makers should evaluate how to minimize those impacts in the context of the physical and environmental setting of the power plant and the nearby water bodies. This evaluation should consider the cumulative impacts of all facilities, pollutant inputs, and natural processes operating in the water body.

The types of adverse impacts and the authors' qualitative assessment of their relative magnitude (high, moderate, low, or none) for each type of cooling system are summarized in Table 1. These rankings are not absolute and will vary somewhat depending on site-specific factors, but Table 1 provides a useful consolidated presentation of the multiple types of impacts and reflects the discussion in the preceding sections. The authors believe that decision makers should comprehensively evaluate all the factors listed in Table 1. Because this evaluation is qualitative, the different types of impacts summarized in Table 1 should not necessarily be given the same weight. For example, impingement and entrainment impacts are probably of greater significance than noise, plume, or air circulation impacts.

**Conclusions**

Congress added section 316(b) to the CWA to ensure that cooling water intakes did not cause unnecessary adverse environmental impacts on water bodies. Impingement and entrainment are important processes that can adversely impact aquatic ecosystems. However, decisions on cooling water intakes and systems made solely on the basis of minimizing or eliminating impingement and entrainment do not meet the CWA's comprehensive mandate, nor do they necessarily provide the best environmental protection. A holistic approach to section 316(b) allows for a more thorough and comprehensive evaluation of the suite of potential adverse environmental impacts associated with a cooling water intake structure. It also allows for a comprehensive evaluation of whether a plant's environmental setting is being adversely impacted by a cooling water intake structure.

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**References**

1. *Inventory of Electric Utility Power Plants in the United States 1999*, DOE/EIA-0095(99)/1, U.S. Department of Energy, Energy Information Administration (September 2000).

2. *Environmental Directory of US Powerplants,* Edison Electric Institute, Washington, D.C. (1996).

3. Federal Water Pollution Control Act Amendments of 1972, Conference Report to Accompany S. 2270, S. Conf. Rep. No. 92-1236, 92nd Congr., 2nd Sess., at 137 (September 28, 1972).

4. H.R. 11896, Rep. No. 92-911, 92nd Congr., 2nd Sess., at § 316(b) (November 19, 1971/March 1972).

5. *The American Heritage© Dictionary of the English Language*, Fourth edition, Houghton Mifflin Company (2000).

6. *Collegiate® Dictionary*, Merriam-Webster Online, http://www.m-w.com/.

7. Veil, J.A., J.C. VanKuiken, S. Folga, and J.L. Gillette, "Impact on the Steam Electric Power Industry of Deleting Section 316(a) of the Clean Water Act: Energy and Environmental Impacts," Argonne National Laboratory Report ANL/EAIS-5 (January 1993).

8. Unpublished analyses generated by the U.S. Department of Energy - Office of Fossil Energy, National Energy Technology Laboratory, and Argonne National Laboratory during May and June 2001. The analyses are part of a working draft of the report "Energy Penalty Analysis of Proposed Cooling Water Intake Structure Requirements on Existing Coal-Fired Power Plants," that is expected to be released in late 2001.

9. Carter, D., unpublished memorandum from Carter, U.S. Department of Energy, to James

Gardner, Edison Electric Institute (September 27, 1991).

10. Veil, J.A., J.K. Rice, and M.E.S. Raivel, “Biocide Usage in Cooling Towers in the Electric Power and Petroleum Refining Industries,” prepared for DOE Office of Fossil Energy (September 1997); also published by DOE- National Petroleum Technology Office as DOE/BC/W-31-109-ENG-38-3, DE98000455 (November 1997).

Table 1 - Summary of Types of Adverse Environmental Impacts Associated with Cooling Systems

| Type of Adverse Environmental Impact | Anticipated Magnitude of Impact (High [H], Moderate [M], Low [L], or None [N]) | | |
|---|---|---|---|
| | Once-Through Cooling | Wet Cooling Tower | Dry Cooling Tower |
| Impingement | H | L | L |
| Entrainment | H | L | L |
| Energy Penalty | N | M to H | H |
| Additional Air Emissions | N | M to H | H |
| Additional Fuel Usage | N | M to H | H |
| Water Quality | Heat + or –<br>Biocides - L to M | Biocides - M to H | Biocides - L |
| Water Consumption | L | M | M to H |
| Solid Wastes | L | L | L |
| Noise | L | M | M to H |
| Land Use/Habitat | Aquatic - M to H<br>terrestrial - L | Aquatic - L<br>terrestrial - L to M | Aquatic - L<br>terrestrial - M to H |
| Plumes | N | M to H | N |
| Air Circulation | N | L | Unknown, but potentially M to H |

Note: Not all types of environmental impacts should be assigned the same weight.