Economics in Environmental Decision-making:
US Environmental Protection Agency Provides for
Site-Specific Cost-Benefit Analysis in Setting 316(b)
Clean Water Standards

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On 19 May 2014, the US Environmental Protection Agency (EPA) finalized cooling water intake requirements for existing power plants and other industrial facilities under Section 316(b) of the Clean Water Act. These facilities often process millions of gallons of water per day, which leads to fish losses when fish and other aquatic organisms are trapped against intake screens (“impingement”) or pulled into the cooling system (“entrainment”). These final 316(b) standards are the result of a process that has taken almost a decade and has included a major decision by the US Supreme Court allowing the use of cost-benefit analysis.

The final rule provides for substantial flexibility, particularly with regard to potential entrainment requirements. Owners of facilities subject to impingement standards can choose one of seven options for meeting Best Technology Available (BTA) requirements for obtaining a National Pollutant Discharge Elimination System (NPDES) permit. For facilities subject to entrainment standards, permit writers will make site-specific decisions regarding what, if any, additional measures are warranted. Among other information requirements, EPA has required permit writers to develop site-specific cost-benefit analyses of alternative entrainment technologies.

We are encouraged by EPA’s decision to include cost-benefit analysis as an important component of site-specific analyses for setting entrainment standards. Rational decision-making, whether by individuals, private enterprises, or government agencies, requires considering what a given action will yield in benefits compared to what it will cost. With its decision to include cost-benefit analysis as a component of site-specific entrainment decisions, EPA has recognized this important concept. Of course, the role of cost-benefit considerations in individual entrainment permit decisions remains to be seen, as the regulations call for explanations of the basis for BTA determinations to include other factors as well. To be useful to decision makers, the site-specific cost-benefit analyses should be based upon sound methodology and as well as sound engineering, biological and economic information.
The major objective of this paper is to explain the methods and data that environmental economists—working in conjunction with biologists and engineers—have developed to provide sound assessments of the costs and benefits of alternative technologies in individual 316(b) permit cases. This rich history provides a strong foundation for the site-specific cost-benefit analysis called for in the May 2014 regulation.

**Background on Cost Benefit Analysis in EPA Rulemakings and Permit Decisions**

Prior to 2007, EPA and the state agencies that had been delegated to issue NPDES permits compared benefits and costs in deciding what was the BTA for particular sites, with technologies not chosen as BTA if their costs were “wholly disproportionate” to their benefits. In 2004, EPA promulgated rules for existing power plants and industrial facilities (the so-called Phase II rules) in which the criterion for site-specific BTA determinations was to exclude technologies whose costs were “significantly greater” than their benefits.

A 2007 decision by the Court of Appeals for the Second Circuit rejected the comparison of costs and benefits in the determination of BTA. The Court of Appeals found that costs could be considered only in the following conditions: (1) the costs were so high that they could not be “reasonably borne” by industry; or (2) if two technologies achieved the same level of fish protection, the less expensive alternative could be chosen. Otherwise, EPA was required to select the technology that provided the most fish protection, even if it was far more expensive and had few incremental benefits compared to other alternatives.

In April 2009, the US Supreme Court ruled in *Entergy Corporation et al. v. Riverkeeper, Inc.* that the EPA may use cost-benefit analysis in setting standards and issuing permits under Section 316(b) of the Clean Water Act. In the context of its decision, the Court noted the usefulness of cost-benefit analysis in environmental decision making. Thus, the Supreme Court’s ruling was an important victory for economic rationality, or at least the possibility of economic rationality since the Supreme Court held that EPA *may*—not *must*—use cost-benefit analysis.

The EPA’s decision in the May 2014 rule to require permit writers to develop site-specific cost-benefit analysis provides the opportunity to achieve the promise implied by the Supreme Court’s 2009 decision. As noted above, the specific importance of cost-benefit considerations in BTA decisions is unclear. But it is clear that these site-specific cost-benefit analyses should be based on sound methodology and data. Fortunately, careful site-specific cost-benefit analyses of 316(b) alternatives have been done that provide a template for future studies. The remainder of this paper describes the techniques and data used in such cost-benefit analyses.
Overview of Cost-Benefit Analysis for Fish Protection

Cost-benefit analysis is a well-established method of providing information to decision-makers faced with the task of determining whether a project should be undertaken and, if so, at what scale of activity. The approach involves the systematic enumeration of costs and benefits that would accrue to members of society if a particular action were undertaken. The basic rationale for undertaking a social cost-benefit analysis of a particular decision—such as whether to require additional fish-protection technologies at a power plant—is to help put society’s resources to their most valuable uses. In choosing among alternatives, the basic cost-benefit principle is to select the alternative that produces the greatest net benefits (i.e., benefits minus costs).

Figure 1 outlines the general steps in performing a cost-benefit analysis of alternatives to reduce fish losses at a given facility. The steps involve integration of technical, scientific, and economic information. Indeed, we emphasize that sound 316(b) cost-benefit analyses require a collaboration of biologists, engineers, and economists.

Figure 1: General Steps in Cost-Benefit Analysis

Identifying Relevant Technology and Operational Alternatives

Any sound cost-benefit analysis must begin with identification of the alternatives to be evaluated. Most existing power plants and other affected facilities use once-through cooling systems, whereby water is withdrawn from a body of water (e.g., river, lake, or ocean), used to cool the facility, and then discharged back to the water body. Fish losses can result from two general phenomena:
1. Impingement occurs when fish (generally small species or juveniles of larger species) are trapped against intake screens, and some do not survive.

2. Entrainment occurs when eggs or larvae are sucked into the plant’s cooling system, where they may be lost as a result of thermal shock or abrasion.

Entrainment typically makes up a larger fraction of total losses than impingement, although the specific results depend upon the facility and the species.

A range of technologies and operating procedures can reduce impingement and entrainment. One general approach that addresses both impingement and entrainment is to reduce the amount of water taken in by the plant. Converting the plant to closed-cycle cooling—that is, using cooling towers that allow cooling water to be recycled to cool the plant—is generally regarded as the technology achieving the highest level of control—with reductions of 90 percent or more from baseline levels possible—but it also is typically the most costly option. Smaller reductions in flow can be achieved with variable speed pumps that reduce the flow of cooling water during colder weather, when less water is needed, and during periods when fish losses are likely to be greatest (e.g., spawning periods). Scheduling maintenance and refueling outages for periods of high potential fish losses also can provide gains. To specifically address impingement, various types of screens and other devices (e.g., sound and light sources) can reduce mortality.

Many of the alternatives can be operated at various levels; e.g., variable speed pumps can be operated to reduce flows to varying degrees, or used only at certain times. Various combinations of technologies and operational measures also are often feasible.

Economists conducting a cost-benefit analysis work with engineers and fishery biologists to identify a range of technically feasible and realistic alternatives for evaluation, including variations in intensity and combinations of measures, as appropriate. Some technologies might not be technically feasible at a given plant, and these can be eliminated from the cost-benefit analysis.

**Developing Sound Cost Estimates**

Figure 2 summarizes four general categories of costs that are typically relevant to each regulatory alternative. The costs include up-front capital costs for construction and purchase of equipment plus ongoing operation and maintenance ("O&M") costs. These two types of costs generally are estimated in the first instance by engineering firms based on their assessment of the physical requirements for a particular alternative.

In addition to capital and O&M costs, as noted above, some alternatives reduce electricity generated by the plant, and that lost output is valued based on the costs of replacing the generation and capacity. Finally, in some cases, control options also entail some environmental costs, particularly those associated with changes in air emissions. We focus here on the estimation of costs of replacement power and consideration of potential environmental costs.
The Costs of Power Replacement
Lost power output and capacity may be a one-time event resulting from the need to shut down the plant during some portion of the construction period. In addition, net output also may be affected on an ongoing basis by changes in the electricity required by equipment or reductions in gross output associated, for example, with lower cooling water flows that raise operating temperatures and reduce the efficiency of generation. Lost output must be made up by increased generation at other facilities that would not otherwise have been chosen to operate because they have relatively higher marginal operating costs. The types of plants affected by Section 316(b) often provide base load power—i.e., they have low marginal operating costs and hence run as much as possible. The cost of replacement power varies with time of year and time of day, with the highest costs during peak demand periods when even relatively high-cost plants must operate to meet demand. As a result, it is important to specify what time of year a construction outage would be most likely to occur. Often, it is necessary to model the operation of the regional electrical system to predict which types of plants would provide replacement power in future years.

The net cost of replacement power is the difference between the marginal costs of running those other plants more intensively and the savings (if any) from reducing output from the plant affected by the 316(b) regulation. Depending on the nature of the technological alternative, replacement power costs can constitute either a very large or very small fraction of total costs.

Environmental Costs
Air emissions from replacement power are the primary source of environmental costs. If air emissions, such as SO$_2$ and CO$_2$ emissions, are subject to cap-and-trade programs, the market value of the allowances associated with those emissions can provide an estimate of the social costs associated with those emissions. For pollutants not subject to cap-and-trade programs, estimates of marginal damages can be used. There also may be other types of potential external effects, such as aesthetic effects associated with tall cooling towers. For the most part, such effects are very difficult to quantify, but it is important to at least discuss these external effects qualitatively for a complete analysis.
Developing Complete Benefits Estimates

It is important to develop comprehensive estimates of the likely benefits of the various 316(b) technology alternatives. The EPA Guidelines provide a summary of the benefit categories relevant to an assessment of ecological benefits, the broad category relevant to a Section 316(b) analysis. Figure 3, reproduced from the Guidelines, provides a way of organizing the relevant benefit categories based on how they are experienced. The figure divides ecological benefits into two major categories: use benefits and non-use benefits:

- **Use benefits** are those associated with actual use of the resource—such as fishing or various water-related activities. Use benefits can be further subdivided into direct and indirect benefits. Indirect benefits and direct benefits may be classified as market or non-market.

- **Non-use benefits**, in contrast, accrue to individuals who do not use the resource either directly or indirectly, but nonetheless place a value on preventing its impairment.

**Figure 3: Potentially Relevant Benefit Categories**

**Use Benefits from Increased Fish Catches**

The primary benefit from Section 316(b) controls is to reduce fish mortality. The primary “use value” that members of society receive from reduced fish mortality is increased fish catches. In the “direct” benefits category, some species of fish are caught commercially (“market” effect) or recreationally (“non-market” effect). In the “indirect” benefits category, other species are not caught, but rather serve as forage for species that are valued commercially or recreationally; it is important to include the benefits from increased numbers of forage fish in the total benefits.
Figure 4 summarizes the steps involved in valuing increased fish catches. The process starts with estimates of the reductions in fish mortality for a given technology, broken down by species and life stage. For species that are caught commercially or recreationally, the next step is for fisheries biologists to estimate how losses at each life stage translate to “adult-equivalent” fish, accounting for the fact that at each life stage, only a fraction survive to the next stage. Thus, for example, out of hundreds of thousands of eggs, only one may survive to adulthood. These biological calculations are critical to develop sensible benefit estimates, because it is increases in adult-equivalent fish that lead to benefits to commercial and recreational anglers (note that potential “non-use” values associated with fish losses are dealt with separately below). For species that are not caught commercially or recreationally, the usual approach is for biologists to use trophic conversion factors to account for the fact that more forage leads to more potential commercial and recreational fish catch. The final step before valuation is to estimate what fractions of adult-equivalent fish are caught and how that catch is divided between commercial and recreational fisheries.

Figure 4: **Summary of Steps in Calculating Monetized Benefits associated with Reduced Fish Mortality**

For changes in commercial catch, benefits are equal to the increase in producers’ surplus (economic rents to fishermen) plus any increase in consumers’ surplus if prices fall as a result of increased catch. In general, the change in catch due to 316(b) controls is too small (relative to the relevant market) for prices to fall, so the primary question is the extent to which fishermen are better off. Conceptually, this potential gain can be thought of as increased revenues minus increased costs. These costs include the incremental cost of catching more fish. However, because of the well-known “tragedy of the commons,” in many fisheries the ultimate effect of increased catch rates will be an expansion of fishing
effort—both by existing fishermen and by new entrants—that eliminates any increased 
rents to fishermen. In some cases commercial fishing benefits have been adjusted to reflect 
these factors, but it is common to use an "upper bound" estimate based solely on the 
increased revenues received by commercial fishermen, with a qualitative discussion of the 
potential increases in costs.

Valuing increases in recreational catches is more complicated, because there are no directly 
observable market prices for recreational catch. It is clear that recreational fishermen 
value the fishing experience and, indeed, often spend far more on fishing equipment 
and supplies than it would cost to buy the fish in the market. Economists have developed 
various methods for estimating the value that fishermen receive from additional catch and 
how the value changes at different overall catch rates. Methods based on travel costs are 
generally considered the most reliable. Such studies gather data on the characteristics 
(including catch rate) of different fishing destinations and how often fishermen from 
different areas visit each of those destinations. Fishermen implicitly reveal how much 
they value different attributes by their willingness to incur higher travel costs to reach 
destinations with those attributes. Using statistical techniques, the dollar values of these 
attributes (including catch rates) can be estimated.

Many such studies have been conducted by economic researchers in universities and other 
institutions. Cost-benefit studies conducted for individual plants subject to possible Section 
316(b) requirements generally use “benefit transfer” methods to adjust estimates in the 
literature to the case at hand. In its simplest form, benefits transfer consists of identifying 
studies that are relevant in terms of types of locations (e.g., ocean, lakes, or rivers) and 
groups of species and then computing some sort of average value, often supplemented by 
sensitivity analyses using a range of values from the selected studies. More sophisticated 
approaches rely on “meta analysis” statistical techniques that in effect use the results of 
different studies to estimate value functions based on different characteristics of the studies 
and study areas.

For Section 316(b) studies, the key results of those statistical analyses are the measures 
of catch (such as number of fish or pounds caught per day for a given group of species). 
These functions often show that as catch rates rise, the value of catching an additional 
“unit” (e.g., pound of fish) declines; i.e., the marginal value of increasing catch by one 
pound per day is higher if the catch rate is lower, as shown in Figure 5. Typically, the 
estimated values per pound for recreational catches are many times higher than for those 
caught commercially. The benefits analysis must account for fish caught and released as 
well for those harvested.

NERA has developed a sophisticated meta analysis methodology based upon hundreds 
of individual studies, which enables us to evaluate the value of fisheries benefits at an 
individual facility based upon results from a large number of individual studies.
Other Potential Use Benefits

In addition to fishing, EPA has identified a variety of other use benefits that may be relevant in some Section 316(b) cases. Some of these categories are captured by the fishing-related measures. Many of these are in effect subcategories of commercial or recreational fishing—e.g., commercial bait, commercial and recreational shellfishing, and subsistence fishing. Others, such as food chain support, are addressed by an analysis of forage species. EPA also has identified various potential use values that are not addressed by analyses of commercial and recreational fishing. Such benefits include non-fishing activities (such as bird-watching, viewing, or boating). Typically, these other benefits cannot be quantified reliably, but they can be evaluated on a qualitative basis, which is important for completeness. In most cases, they can be shown not to be relevant to the kinds of modest changes in fish populations generally found in Section 316(b) cases.

Non-Use Benefits

Non-use benefits are benefits that are not associated with any direct use by either individuals or society. They are often also referred to as “existence” or “bequest” values. These benefits arise if individuals value the change in an ecological resource without the prospect of using the resource or enjoying the option to use it in the future. The classic example of a non-use value is that many individuals may be willing to pay to preserve the Grand Canyon from being dammed even though they have never visited it and do not expect to do so in the future. Unfortunately, the only way to estimate non-use values is to use “stated preference” or “contingent valuation” methods that involve surveying individuals and eliciting their preferences directly, rather than inferring those values from actual behavior. Such methods are expensive, and it is difficult to ensure that the hypothetical questions of the surveys will elicit true estimates of individuals’ willingness-to-pay to protect environmental resources.
Recognizing these difficulties, in 1993 the National Oceanic and Atmospheric Administration commissioned a “Blue Ribbon Panel” of distinguished economists (including two Nobel Prize winners) to develop a set of criteria under which contingent valuation methods are likely to produce reliable estimates of willingness-to-pay. These guidelines are useful as a set of “best practices” for those attempting to measure non-use values using survey methods.

In practice, it has proven highly difficult to develop a study that elicits useful estimates of non-use benefits for reduced impingement and entrainment. Indeed, EPA has invested significant resources into performing such a study using stated preference methods, and even released preliminary results in June 2012; unfortunately, the EPA survey and associated empirical analysis suffered from numerous methodological problems, and EPA was not able to use the survey results in promulgating its final 316(b) rule for existing facilities in May 2014.

Given the problems with using survey methods to evaluate non-use benefits, it is common to first evaluate non-use benefits qualitatively to determine whether they are likely be significant for the changes in fish populations in a particular Section 316(b) case.

EPA has relied on such criteria in evaluating the potential benefits of Section 316(b) regulatory alternatives. For example, the 2004 Phase II rules recommend that studies consider the “magnitude and character of ecological impacts implied by the results of the impingement and entrainment mortality study and any other relevant information” (69 FR 41648). They suggest considering whether substantial harm is done to one of the following:

- A threatened or endangered species;
- The sustainability of populations of important species of fish, shellfish, or wildlife; or
- The maintenance of community structure and function in a facility’s water body or watershed (69 FR 41648).

Similarly, the academic literature has recognized the need to develop criteria for determining the likely significance of non-use benefits for a given application. For example, in his seminal textbook (published in 2003) on the measurement of environmental and resource values, Freeman notes that while “there is no general method for determining whether a resource will generate important non-use values,” the literature emphasizes two criteria that are most relevant to an assessment of whether non-use values are likely to be important in a given situation:

1. Whether the resource in question is “unique,” or whether there are an abundance of close substitutes.
2. Whether resource losses are irreversible, or whether recovery from the damage is quick and complete.

Working with biologists and site-specific information on impinged and entrained organisms, we have used these various criteria in developing our detailed assessments of the relevance of non-use benefits in individual cases.
Cost-Benefit Comparisons and Uncertainty Analysis

The standard criterion in cost-benefit analysis is to choose the alternative that maximizes net benefits (benefits minus costs). Because benefit and cost streams rarely are constant across time, they must be put in terms of their present values—discounted—before net benefits are computed. The status quo is assumed to have zero net benefits, and all benefits and costs are measured relative to the status quo. Based on the standard cost-benefit criterion, alternatives with costs that exceed benefits are rejected, and if there are multiple alternatives with positive net benefits, then the one with the largest net benefits should be chosen. This requires comparing the incremental benefits and costs of moving to more stringent alternatives. Thus, even if the most stringent alternative has positive net benefits, it should not be chosen if its incremental costs (relative to a less stringent alternative) exceed its incremental benefits.

Of course, the standard cost-benefit criterion assumes that the major categories of costs and benefits have been converted to monetary terms. In practice, the quantification of benefits and costs is rarely complete, and often there is substantial uncertainty about the quantitative estimates. As a result, it is important to conduct both a qualitative assessment of unquantified factors and to provide a quantitative assessment of uncertainties.

Assessment of Unquantified Factors
In evaluating the quantitative results, it is useful to step back and to consider whether costs or benefits that were not quantified are likely to be large enough to reverse tentative conclusions based on the quantified effects. In some cases, it may be clear that quantifying the effect would reinforce the tentative conclusion. For example, if net benefits are positive, taking into account an omitted benefit would increase already positive net benefits. Conversely, if net benefits are negative, then quantifying an omitted cost would make the alternative that much less attractive. In other cases, however, it will be necessary to qualitatively consider the likely magnitude of the unquantified cost or benefit relative to the quantified net benefits.

Uncertainty Analysis
In most cost-benefit analyses there are uncertainties about various elements of the quantitative results. These uncertainties generally come from several sources, including the biological and engineering estimates that provide many of the inputs to the analysis as well as from the economic analysis itself.

At a minimum, it is important to perform sensitivity analyses that vary the values of key parameters over plausible ranges to see their impacts on results. Such analyses are helpful, but have some important limitations: (1) the number of sensitivity analyses can easily become unwieldy, especially if they include varying the values of multiple parameters simultaneously, and (2) it can be hard to interpret the results when some sensitivity analyses point to one conclusion while others point in a different one.
Monte Carlo analysis goes the next step, generating not just a range of possible outcomes, but also a formalized mechanism for estimating the likelihoods of different outcomes. It requires assigning probabilities to alternative assumptions and parameter values. Each trial of a Monte Carlo analysis involves using the computer to sample from each of the probability distributions of parameter values, and then computing the resulting net benefits. Typically, thousands of trials are run, from which a probability distribution of the outcomes is constructed. Figure 6 presents illustrative results for a hypothetical analysis in the form of a cumulative density function for a particular control option. (Similar distributions are generated for alternative control options.) The horizontal axis is net benefits and the vertical axis gives the probability (based on the Monte Carlo runs) that net benefits will be less than or equal to the value on the horizontal axis. In this example, the 50th percentile is about $80 million; i.e., it is equally likely that the value is above or below that amount. In some of the runs there were positive net benefits, but they were relatively few in number; in this illustrative example, there is only about a 4 percent probability that the alternative will yield net benefits greater than zero. Thus, in this example, not only is the most likely estimate of net benefits negative, there is only a small chance that net benefits will be positive.

Figure 6: **Illustrative Cumulative Distribution from a Monte Carlo Analysis**

Concluding Remarks

EPA’s final rule on cooling water intake requirements for existing power plants and other industrial facilities under Section 316(b) of the Clean Water Act directs NPDES permit writers to develop estimates of social costs and benefits as relevant information in deciding on the BTA technology. Economists, engineers, and biologists have developed data and methods to assess the costs and benefits of technology options at facilities covered by this regulation. These cost-benefit studies can help permit writers make sound decisions so that, as a society, we get the “biggest bang for the buck” from dollars spent to improve environmental quality.
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